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Book of Abstracts

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R&D status for an innovative crystal calorimeter for the future Muon Collider

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The Crilin calorimeter is a semi-homogeneous calorimeter based on Lead Fluoride (PbF2) Crystals readout by surface-mount UV-extended Silicon Photomultipliers (SiPMs). It is a proposed solution for the electromagnetic calorimeter of the future Muon Collider. A high granularity is required in order to distinguish signal particles from the background and to solve the substructures necessary for jet identification. Time of arrival measurements in the calorimeter could play an important role, since very large occupancy due to beam-induced backgrounds is expected, and the timing could be used to identify energy depositions compatible with the expected muon-muon interaction time. The calorimeter energy resolution is also fundamental to measure the kinematic properties of jets. Moreover, the calorimeter should also operate in a very harsh radiation environment: 1 Mrad/year total ionizing dose (TID) and a 10^14 neutron 1MeV/cm^2/year equivalent neutrons fluence. Our radiation hardness studies on crystals and SiPMs, have demonstrated we can work in this environment both for dose and neutron fluences.
A dedicated test beam, on single cell prototype (Proto-0), has been performed at CERN H2 in August 2022 with an electron energy of 120 GeV: a timing resolution better than 50 ps has been achieved for energy deposits greater than 1 GeV.
In order to validate the design choices, the proposal is to build a larger prototype, called Proto-1. The design has been optimized with the simulation studies starting from dimensions of 0.7 R⊠ and 8.5 X0 (~ 0.3⊠). This size comes from a compromise of an acceptable containment of 100 GeV electrons and cost constraints. Results will be extrapolated to the optimum length of the Muon Collider calorimeter of the order of 20 X0.
The proposal is to build Proto-1 with two layers of 3 × 3 PbF2 crystals, each read out with UV-extended SiPMs (Hamamatsu S14160-3010 PS SMD sensors) as already done in Proto-0. These new SiPMs were already tested with an ultra-fast blue laser (400 nm, 100 ps) and the new electronics front-end (FEE) that showed a dynamic range from 0 to 2 V, a rise time of ~ 2 ns with full signal in ~ 70 ns and a time resolution less than 50 ps even at a charge as low as 100 pC (~ 250 Np.e.). The proto-1 operational temperature will be 0/−10◦C and the performance will be validated in a dedicated test beam. Specifically, our goals are: 1) perform a complete operational test of the prototype, including operation with cooling; 2) obtain data for a complete analysis of digitized signals from the detector for electrons and minimum-ionizing particles; 3) test the cluster reconstruction capability and measure the time resolution; 4) measure longitudinal and transverse shower profile and compare with results obtained in simulation.
Details about the prototype mechanics and electronics will be shown; Proto-1 will be tested in a dedicated test beam at Cern before the end of 2023.

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Resistive Charge-Readouts: Towards the Next Generation of Dual-Phase LArT-TPCs

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The development of new materials with tunable surface and/or bulk resistivity paved the way to explore new resistive-MPGD technologies for application in cryogenic systems. We will present new results obtained with two novel technologies targeting operation in liquid argon DP-TPCs: the cryogenic Resistive WELL (RWELL) and the cryogenic Resistive Plate WELL (RPWELL). The RWELL and RPWELL consist of a single-sided THGEM electrode coupled to a readout anode either through an insulating sheet coated with a thin resistive layer (DLC) or through a Fe2O3-YSZ ceramic plate, respectively. The advantages of these technologies relative to non-resistive detector configurations are demonstrated and their performance is compared in terms of maximal achievable gain, pulse shape, and discharge probability. Scaled-up versions of such detectors could become a technology of choice in DP-TPC-based applications requiring cost-effective solutions for large area coverage at moderate spatial and energy resolution.

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New scintillation strip design for the DANSS detector upgrade

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DANSS detector at Kalininskaya nuclear power plant demonstrates excellent performance in antineutrino detection. Counting rates of up to 5000 events per day made it possible to record more than 6.5 million antineutrino events in 6 years of remarkably stable operation. The data sample is extremely clean and features the signal to background ratio in excess of 50. Yet only moderate energy resolution of 34% at 1 MeV limits the sensitivity of the experiment for the sterile neutrino searches. The upgrade of the detector is aimed at more than twice better energy resolution of 12% at 1 MeV. Besides that the sensitive volume is planned to be increased by 70% inside the same shielded space on the lifting platform, leading to almost twice higher the counting rate. New scintillation strips feature much better uniformity of the light collection. Readout from both strip edges provides information on the longitudinal event coordinate. The talk will address the details and the status of the upgrade together with the latest results of beam tests. The expected influence of the improvements on the sensitivity to the sterile neutrino will also be discussed.

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Ultimate precision of a tracking system in future high energy experiments

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One of the top goals of a high energy experiment is to perform precision tests on the Standard Model and probe new physics beyond the Standard Model. Therefore, it is essential to precisely measure the momenta and impact parameters of charged tracks. Because of the rapid advancement of technology, excellent tracking systems could be built. The most accurate silicon pixel tracker is approaching the spatial resolution of micron-level and a material budget of sub-permille-level. As a result, the trade-off between spatial resolution and material budget becomes critical. Analytical calculation and fast simulation are used to examine the maximum accuracy of a tracking system with restricted resolution and material budget. These conclusions could be beneficial for future experiments.

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Glass Scintillator HCAL at future e+e− Higgs factory

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The future e+e− Higgs factory, whose main goal is to achieve a precise measurement of mass and properties of the Higgs boson, is the main development trend of the next-generation large collider. A big challenge for this goal is to fulfill an unprecedented jet energy resolution, and the scheme selection of hadronic calorimeter (HCAL) is one of the most important factors. Scintillation materials can convert high-energy rays into visible light. Generally, solid scintillator can be divided into crystal scintillator, plastic scintillator, glass scintillator and ceramic scintillator. Compared with crystal scintillator, the glass scintillator has many advantages, such as a simple preparation process, low cost and continuously adjustable components. Therefore, glass scintillator has long been conceived for application in the nuclear detection such as hadronic calorimeter. Given the deficiency of the crystal and the plastic scintillator, a new concept, Glass Scintillator Hadronic Calorimeter for CEPC (GS-HCAL), was proposed. In 2021, the researchers in the Institute of High Energy Physics (IHEP) have set up the Large Area Glass Scintillator Collaboration (GS group) to study the new glass scintillator with high density and high light yield. Currently, a series of high density and high light yield scintillation glasses have been successfully developed. The GSHCAL conceptual design with preliminary detector optimization by simulation has been done. The physics potential and the R&D of the GSHCAL will be presented in this paper.

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The R&D of the MCP based PMTs for High Energy Physics Detectors

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The Micro-Channel Plate (MCP) is a specially crafted microporous plate with millions of independent channels, which have secondary electron emission capability. The MCP could be used as the electronic multiplier amplifier in the PMTs. There are two types of MCP Photomultiplier tube (MCP-PMT), large-area electrostatic focusing PMTs (LPMT) and small size proximity focusing PMTs (FPMT) respectively. The LPMT always used in the large scalar neutrino detector for it's large area efficiency photocathode. The small size FPMT is widely used in high energy physics for its fast time response, strong anti-interference ability. The MCP-PMT Collaboration Group in China has successfully research and developed the LPMT for JUNO in 2017, and plan to research a new type of FPMT with multi-anode readout (4X4, 8X8). The FPMT prototypes have been produced with 50 ps time resolution, and also the 8X8 readout anode for the position resolution. We will introduce some design of the FPMTs for the time measurement, and the performance of the several different prototypes with different readout channels.

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Scintillation Detector for Muon Imaging System

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Muon scattering tomography has a broad application prospects in homeland security, nuclear reactor and waste imaging, etc. Scintillation detector is a very competitive solution due to its stability and robustness in harsh environment. However, it's a challenge to develop such detectors with both high spatial resolution and large detection area, especially with a limited budget.

We have built 15cm×15cm×1cm prototype detectors with 1cm pitch, composed of scintillators with groove curved on surface, wavelength shift(WLS) fibers and SiPMs. Detectors adopt quadrangular prism, triangular prism and slab structure respectively. Results show that 1-dimensional spatial resolution of these detectors are 3.3 mm, 1.7mm, 6.4mm respectively, proving that triangular prism structure can improve resolution significantly.

A GEANT4 program has been developed to simulate the detector's reaction to incident muons, and to correct systematic deviation of the detector. Simulations give an uncorrected resolution of triangular detector $\sigma = 1.5$mm, which is close to experimental result. After precise correction, the spatial resolution can reach up to 1mm within the limited 1cm pitch.

Large detection area is necessary for muon imaging in several situations, thus a detector with 45cm×45cm area is under construction. The upgraded detector adopts a new layout and electronic system that designed for reducing readout channels.

Two WLS fibers are placed in one prism slat to reduce false trigger of SiPM, meanwhile, four fibers from different slats make up a cluster and are connected with a 3mm×3mm SiPM so that signals can be encoded and read out by fewer channels. Except from the electrical considerations, the new layout also improve photon collection efficiency and spatial resolution. Several properties of the detector will be tested and reported, e.g. spatial resolution, acceptance, detection efficiency.

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CRYO-PoF: Cryogenic power over fiber for fundamental and applied physics at Milano-Bicocca

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The power over fiber (PoF) technology delivers electrical power by sending laser light through an optical fiber to a photovoltaic power converter, in order to power sensors or electrical devices.
This solution offers several advantages: removal of noise induced by power lines, robustness in a hostile environment, spark free operation when electric fields are present and no interference with electromagnetic fields.
This technology is at the basis of the CRYO-PoF project: an R&D funded by the Italian Insitute for Nuclear Research (INFN) in Milano-Bicocca (Italy).
This project is inspired by the needs of the DUNE Vertical Drift detector, where the VUV light of liquid argon must be collected at the cathode, i.e. on a surface whose voltage exceeds 300 kV.
We aim to develop a cryogenic system, which is solely based on optoelectronic devices and a single laser input line, to power both the Photon Detection devices and its electronic amplifier.
In this talk we will presents the results obtained during test campaign performed in Milano- Bicocca with emphasis on performance and potential application in the field of applied physics.

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Gd-PMMA: a novel neutron tagging technology for low background detectors

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Low background detectors, such as those used in direct dark matter searches, require high-efficient neutron veto to reject nuclear recoil backgrounds. Gadolinium-doped polymethyl methacrylate (Gd-PMMA) has emerged as a promising solid neutron tagging material, with high hydrogen content for moderating neutrons and gadolinium content for capturing thermal neutrons and exploiting subsequent emission of high-energy gamma rays. This talk introduces a novel Gd-PMMA material based on a complex compound called gadolinium methacrylate, which will be used in the DarkSide-20k experiment, a direct dark matter search experiment with liquid argon.
The Gd-PMMA will serve as both a neutron tagging material and the main structural material of the dual-phase argon Time Projection Chamber (TPC) in the DarkSide-20k detector. This design allows for the Gd-PMMA to be located as close as possible to the detector's active volume to tag any possible neutrons from intrinsic backgrounds. With liquid argon buffers on both sides of the Gd-PMMA, gamma rays released during neutron capture can be effectively detected. To maximize neutron veto efficiency, a ~1% gadolinium mass fraction with 15 cm thick Gd-PMMA surrounding the TPC's active volume is required. Radiopurity control of this material is also being studied to ensure its suitability for use in low-background experiments.

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Development of FARICH technique for the Super Charm-Tau Factory project

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The Super Charm-Tau (SCT) Factory project is a future electron-positron colliding beam experiment with unprecedented high luminosity $10^{35}\text{cm}^{-2}\text{s}^{-1}$ at the interaction energy range from 3 to 7 GeV. The physics program of the experiment is aimed to search the phenomena beyond the standard model and its precise calibration in this energy range. The main features of the SCT Factory project are presented. To perform the broad physics program at the ultimately high beam intensity the high performance universal detector is proposed. One of the proposed detector subsystems is the PID system based on Focusing Aerogel RICH (FARICH) technique. The proposed FARICH scheme combined with abilities of tracking system will provide the excellent π/K-separation for the whole operation momentum range and μ/π-separation up to momentum of 1.5 GeV/c. The idea of FARICH detector based on dual aerogel radiator (focusing aerogel tile with maximal refractive index 1.05 and high optical density aerogel with refractive index of 1.12) is described. Results of GEANT4 simulation and beam test results are in good agreement. PID capabilities of this approach is demonstrated with help of numerical simulation. In 2023 two multilayer focusing aerogel samples with overal sizes $230\times230\times35$ mm were produced in Novosibirsk for the first time all over the world. The results of the first beam tests of these aerogel samples and comparison with simulation are presented. Conceptual design and some technical issues of the PID system based on FARICH technique are discussed as well.

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The Future Circular Collider Project and its Physics Programme

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The talk will provide a brief description of the proposed Future Circular Collider (FCC) project and its physics program. According to the latest update of the European Strategy for Particle Physics, the first stage of the project will be the construction of an approximately 90 km circular tunnel, instrumented with an e+e- collider based on established technologies. This would allow for an extensive physics program, realized at center-of-mass energies spanning the range from the Z resonance up to a t-tbar threshold. Such a machine, called FCC-ee, would provide a clean experimental environment, producing high luminosity for precision measurements of the Higgs boson, W and Z bosons, and the top-quark. Precision searches will test the consistency of the Standard Model and push the sensitivity to new physics at high scales. Direct searches for new particles, including dark matter, are also feasible.
The tunnel can then be reused for a proton-proton collider (FCC-pp), collecting data in the range of 100 TeV. Such a machine would offer a vast program of measurements of the Standard Model observables and a huge potential of direct searches for new particles.
During the talk, both the aspects of the accelerator and physics program of the FCC project will be presented, paying special attention to the e+e- stage

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FCC detector concepts

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The Future Circular Colliders (FCC) project is centered on the construction of a large, 91 km in circumference, circular tunnel located around the Geneva area. The project foresees two distinct phases of operation. In the first one, denominated FCC-ee, the tunnel will house an electron positron collider. FCC-ee will be operated at several center-of-mass energies, ranging from the Z peak to the WW production threshold, to the Higgs boson production peak (~ 250 GeV), and then to just above the ttbar production threshold (~365 GeV). FCC-ee promises exceptionally high luminosities, beyond 10^{36} cm^{-2}s^{-1} at the Z peak and will allow to explore with unprecedented precision the electroweak sector while also producing a sample of more than a million Higgs boson events in very clean experimental conditions. In a second phase, denominated FCC-hh, the tunnel will instead house a proton-proton collider with the aim of producing the highest possible collision energies, up to more than 100 TeV in the center-of-mass.
Such a challenging project calls for extremely high-performance detectors being able to study all the many channels of interesting physics that both FCC-ee and will FCC-hh will unravel. Especially for FCC-ee there are already three different detector concepts that are being studied and that will be presented. FCC-ee will in fact have four interaction points that could house each a different detector. There is a significant detector R&D program that has started since a few years in order to optimize and improve the detector concepts for the best possible exploitation of FCC-ee. Many different technologies, going beyond the state-of-the-art in the field, are being investigated for the various subdetector components. The final detectors will likely be a mix and match of the currently investigated technologies.
FCC-hh is farther in the future and presents extremely challenging experimental conditions, nevertheless a possible detector concept has been devised and will also be presented.

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Data acquisition system of the TPC/MPD detector for the NICA project

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The data acquisition system (DAQ) is consisting of 95232 registration channels in total containing 1488 Front-End Cards (FEC) grouped into 24 groups of 62 pcs. in each. Each FEC has an individual full-duplex few-gigabit communication channel with Readout and Control Unit (RCU). Each RCU manages each FEC within the group of size of 1/24 of full TPC, collects data with subsequent transmission via a high-speed optical channel into the Local Data Concentrator (LDC) computer. Every 4 optical channels are connected to a LDC computer via a Data Concentrator Unit (DCU) card installed. Each of the 6 DCU controls four RCUs, receives data from them and stores it into the LDC's memory via the PCIe interface. LDC computers are docking point of the TPC DAQ with the MPD DAQ.
The DAQ was designed for operating with raw TPC event of size of 37 MB containing information up to 2000 tracks from central heavy ion collision and trigger rate of up to 7 kHz in zero suppression mode.
The report presents the overall structure of the system, realized functionality of its main parts and result of the DAQ prototype testing.

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Light Detection System for the DUNE Near Detector

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The Deep Underground Neutrino Experiment (DUNE) is an international long-baseline accelerator neutrino experiment hosted in the US. DUNE is currently under construction and will consist of two neutrino detectors: the Near Detector at Fermilab and the Far Detector in the Sanford Underground Research Facility, 1300 km downstream of the beam source. The Near Detector (ND) will sample the beam near the source and, like the Far Detector, will feature liquid argon (LAr) Time Projection Chamber (TPC) technology to resolve neutrino interactions in detail. These interactions produce scintillation light in the TPC volume which is registered by the Light Detection System (LDS). The LDS provides fast light information with a good spatial resolution that is essential to overcoming the high event pile-up expected in this TPC. It is based on dielectric light traps and a silicon photomultiplier readout. Two light detection approaches are employed in the ND-LAr TPC – ArCLight and Light Collection Module (LCM). Four prototypes of ND-LAr TPC were tested with cosmic rays at the University of Bern. The performance of the LDS is presented using the test results from the Bern data.

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Nonlinear optical spectroscopy for studying carrier transport and recombination in scintillators for fast radiation detectors

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The current demand for materials with fast scintillation response for radiation detectors in both major application fields, future high-luminosity high energy physics experiments and medical imaging with better spatial resolution, require the characterization of processes in scintillators in picosecond domain. In particular, excitation transfer becomes important for fast scintillation response.
In this work, we adopted nonlinear optical spectroscopy to study the processes limiting the rate of excitation transfer in activated scintillators, especially in those with multicomponent crystalline matrix where the transfer might be affected by carrier trapping due to the potential fluctuations caused by compositional disorder. Transient optical absorption technique in pump and probe configuration was exploited to monitor the time evolution of nonequilibrium carrier density. Selective excitation using tuneable-wavelength pulses and measuring a wide spectrum of transient absorption (TA) at variable delay after short pulse excitation enabled the identification of the type of nonequilibrium carriers responsible for TA and revealing the peculiarities of excitation transfer. Time-resolved photoluminescence was also exploited.
Our study was focused on two families of prospective Ce-doped scintillators: lutetium yttrium oxyorthosilicates (LYSO:Ce) and gadolinium aluminium gallium garnets (GAGG:Ce). The comparison of the TA response rise time with the coincidence time resolution, which is a conventional parameter measured under gamma excitation, showed that the delay in the front of the TA response due to the population of the lowest (emitting) excited level of Ce3+ after excitation of the ion to higher excited levels reflects the electron transfer that is affected by electron trapping. The influence of aliovalent codoping on the luminescence response time was studied in LYSO:Ce,Ca and GAGG:Ce,Mg with different codoping level. It is shown that the codoping results in faster luminescence response due to elimination of trapping centers and enhances the luminescence decay rate due to introduction of quenching centers. A trade-off between luminescence efficiency and decay time is considered.

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A SiPM-based optical readout system for the EIC dual-radiator RICH

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Silicon photomultipliers (SiPM) are the baseline photodetector technology for the dual-radiator Ring-Imaging Cherenkov (dRICH) detector of the ePIC experiment at the future Electron-Ion Collider (EIC). SiPM optical readout offers a large set of advantages being cheap devices, highly efficient and insensitive to the high magnetic field (~ 1.5 T) at the expected location of the sensors in the experiment. On the other hand, SiPM are not radiation tolerant and despite the integrated radiation level is expected to be moderate (< 10^{11} 1-MeV n_{eq}/cm^2) it should be tested whether single-photon counting capabilities and the increase in Dark Count Rate (DCR) can be kept under control over the years. Several options are available to maintain the DCR to an acceptable rate (below ~100 kHz/mm^2), namely by reducing the SiPM operating temperature and by recovering the radiation damage with high-temperature annealing cycles. Moreover, by utilising high-precision TDC electronics and selecting bunch crossing information, the use of timing information can effectively reduce background due to DCR.

In this talk we present the current status of the research and the results on studies performed on significant samples of commercial and prototype SiPM sensors. The devices have undergone proton irradiation in two campaigns in 2021 and 2022. The first campaign aimed at studying the device performance with increasing NIEL doses up to 10^{11} 1-MeV n_{eq}/cm^2 delivered at once to different sensor subsets and after long high-temperature annealing cycles to recover the radiation damage. The

second campaign aimed at studying the reproducibility of the performance in repeated irradiation-annealing cycles, where the sensors have undergone high-temperature annealing cycles to recover the radiation damage. During the second campaign it was also explored the use of Joule annealing as a potential way to perform high-temperature annealing in-situ. In October 2022 the sensors were mounted inside the dRICH detector prototype and successfully tested with particle beams at the CERN PS accelerator.

The results reported here, obtained in laboratory with SiPM characterisation measurements and in test-beam measurements, are based on the first 32-channel prototypes of the ALCOR chip and on a complete readout system. ALCOR is an ASIC chip that offers both single photon counting and Time-over-Threshold modes with a time resolution of 50 ps and an event rate capability of up to 5 MHz per channel, originally designed for reading out silicon photomultipliers at low temperatures.

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Progress in the production of aerogel radiators for the RICH detectors in Novosibirsk

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Modern projects require large format aerogel radiators. In 2022-2023, several unique aerogel tile were produced in Novosibirsk. Aerogel blocks larger than 200 by 200 mm in lateral size and 40, 50 mm thickness with a refractive index of 1.03 or 1.05 were fabricated. Also in 2023, for the first time in the world, samples of a multilayer focusing aerogel with dimensions of 230x230x35 mm were made. Their parameters were investigated on the test benches and with relativistic electron beams. The results of these tests are presented.

C3 / **25**

TEMPUS: a Timepix4-based readout system for photon science

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A readout system for the Timepix4 timestamping pixel ASIC, TEMPUS, is being developed for photon science experiments. Compared to current systems, this will have higher time resolution (in the ns regime for silicon sensors and X-ray applications) and much higher event rate capability (around Mhit/mm2/s), requiring development of high-data-rate board designs and firmware. Moreover, when working in the photon counting mode, higher frame rates than currently available systems will be achievable (40kfps). The first image from a single chip has been obtained using a radioactive source.

Also multi-chip modules are under development with the idea of covering large areas while reducing gaps between sensors. In this context, TSV technology (fully supported by the ASIC) is expected to be used.

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Study of the radiation aging of materials with using of beam of the fast neutrons at BINP SB RAS

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The BINP SB RAS, in collaboration with Novosibirsk State University,has upgraded facility for boron-neutron capture therapy for the possibility of radiation tests on beam of fast neutrons with the integral flux up to 10^14 neq/cm2.

In 2022 the experiment on the study of the radiation aging of optical fibers for the laser calibration system of electromagnetic calorimeter CMS (CERN, Switzerland) was carried out. The uniqueness of this radiation tests in contrast to irradiation in reactor is the precise control of the level of the accumulated dose with continuous measuring of degradation fiber transparency.

It has been demonstrated for the first time that at the BINP SB RAS it is possible to operate with such doses using of neutron beam. It could be in further used for the wide range of radiation test tasks, related with the development of facilities for HEP.

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Segmented scintillator neutrino detector SuperFGD for T2K experiment

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The long baseline T2K neutrino experiment in Japan obtained a first indication of CP violation in neutrino oscillations. To obtain better sensitivity, T2K will accumulate more statistics with a higher intensity beam and the upgraded near detector ND280 which allows us to reduce systematic uncertainties in oscillation measurements. The upgraded detector will have the full polar angle coverage for muons produced in neutrino charged current interactions, a low threshold for proton detection and will be able to measure neutrons using time-of-flight due to a good timing performance. Thanks to these new capabilities, the energy spectra of muon neutrinos and antineutrinos will be measured with an unprecedented level of accuracy. A 3D highly granular scintillator detector called SuperFGD with a mass of about 2 tons is being constructed at J-PARC now. It consists of about two millions of small optically-isolated plastic scintillator cubes with a 1 cm side. Each cube is read out in the three orthogonal directions with wave-length shifting (WLS) fibers coupled to micro pixel photon counters (MPPC). All cubes are assembled in a light protected box with about 60000 holes for WLS fibers. An LED calibration system with Light Guide Plates is used for calibration and control for

WLS/MPPC readout. SuperFGD Front End Board electronics based on CITIROC chips is developed and tested. On-surface SuperFGD will be provided with cosmic muons and the installation into the ND280 magnet is expected in September 2023 to take the neutrino beam in the Fall of 2023. In this talk, the results of the tests, obtained parameters and current status of SuperFGD will be reported. The unique features of SuperFGD physics program will be also described.

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The simulation of DIRC detector at the Electron-ion collider in China

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The Electron-ion collider in China (EicC) is a proposed future electron-ion collider with a high luminosity above 2.0 × 10e33 cm−2·s−1 and center-of-mass energy ranging from 15 to 20 GeV. To meet its PID requirement in the barrel region, a focusing DIRC detector is proposed, which consists of fused silica radiators, MCP-PMT photosensor array, and fast-timing readout electronics. In order to study and optimize its performance, we conducted a GEANT4 simulation including various optical transmission and focus systems, readout electronics, and image reconstruction algorithm. The simulation results demonstrate a high angular resolution of ~ 1mrad and time resolution <100ps, achieving the 3σ Pion/Kaon separation in the momentum range of 1~6GeV/c.

F1 / **29**

Event reconstruction for reactor anti-neutrinos in JUNO

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Jiangmen Underground Neutrino Observatory (JUNO), located in the southern part of China, will be the world's largest liquid scintillator (LS) detector upon completion. Equipped with 20 kton LS, 17612 20-inch PMTs and 25600 3-inch PMTs in the central detector, the primary goal of JUNO is to determine the neutrino mass ordering by precisely measuring the oscillation energy spectrum of anti-neutrinos from reactors. One of the main challenges for JUNO is the demanding unprecedented energy and vertex resolution. This talk will present some recent highlights on PMT waveform reconstruction, vertex and energy reconstruction for reactor anti-neutrinos in JUNO. Both traditional methods and novel ones based on Machine-Learning will be covered, which in principle could also be applied to other LS detectors.

A1 / **30**

The MoEDAL Dedicated Search Detector for LHC's Run-3

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The MoEDAL detector, deployed at IP8 in 2010, was the LHC's first dedicated search experiment. It is a largely passive detector utilizing a 70 sqm arrangement of Nuclear Track detectors and a unique trapping detector array of mass ~ 1tonne. An active detector array of Timepix2 pixel devices monitors the radiation field near MoEDAL. MoEDAL is designed to detect highly ionizing avatars of BSM physics without requiring a restrictive trigger. For Run-3 the MoEDAL detector was redeployed with a much-enhanced detector efficiency and a new Timepix3 detector array that will now be used to measure the luminosity and search for new physics. Additionally, the detectors at IP8 will receive a factor of roughly five times greater instantaneous luminosity during Run-3 than at Run-2.

A1 / 31

The MAPP-1 Detector at LHC's Run-3

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The MAPP-1 (MoEDAL Apparatus for Penetrating Particles) detector, currently being installed in the UA83 tunnel some 100m from IP8, was approved by CERN for installation on the LHC ring or Run-3 operation in December 2021. The purpose of the MAPP-1 detector is to extend the reach of the MoEDAL experiment to include sensitivity to Feebly Ionizing Particles such as milli-charged particles. MAPP-1 combined with MoEDAL trapping detectors also has an unprecedented sensitivity to extremely long-lived massive charged particles. Additionally, MAPP-1 has some sensitivity to very long-lived neutral particles.

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The MAPP-2 Detector for HL-LHC

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The MAPP-2 detector is a large instrumented tunnel decay volume adjacent to IP8 with a volume of 1200m3. The detector utilizes large area scintillator panels with x-y WLS fibres readout by SiPMs arranged in a "Russian Doll configuration to measure the vertices of very Long-Lived Particles (LLPs)emanating from IP8. The sensitivity of MAPP-2 is complementary to other planned LLP detectors and the existing LHC general-purpose detectors. The plans for deploying the MAPP-2 detector at the High Luminosity LHC (HL-LHC) have been endorsed by the LHCC.

A1 / 33

The MoEDAL- MAPP Facility for the LHC Program

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The MoEDAL detector, deployed at IP8 in 2010, was the LHC's first dedicated search experiment. MoEDAL is designed to detect Highly Ionizing Particle avatars of BSM physics without requiring a

restrictive trigger. MoEDAL's MAPP-1 (MoEDAL Apparatus for Penetrating Particles) is currently being installed in UA83 adjacent to IP8 on the LHC ring MAPP-1's purpose is to extend the reach of the MoEDAL experiment to include sensitivity to Feebly Ionizing Particles (FIPs) such as milli-charged particles. MAPP-1 combined with MoEDAL trapping detectors also has an unprecedented sensitivity to extremely long-lived massive charged particles. Additionally, MAPP-1 has some sensitivity to very long-lived neutral particles. The LHCC has also endorsed MoEDAL's NoI to install the MAPP-2 detector for data taking at the High Luminosity LHC. MAPP-2 will greatly extend MoEDAL-MAPP's reach in the search for LLPs. The reach of MAPP-2 is complementary to other planned LLP detectors and the existing LHC general-purpose detectors. In this talk, the MoEDAL-MAPP project for the LHC that includes competitive sensitivity to HIP, FIPs and LLPs, without relying on hardware triggers, will be described.

C2 / **35**

Strategy for Precise Calibration in JUNO

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A 20 kton liquid scintillator (LS) detector was designed in the Jiangmen Underground Neutrino Observatory (JUNO) for multiple physics purposes. In order to determine the neutrino mass ordering, JUNO needs an excellent energy resolution of $3\% / \sqrt{E}$(MeV) and an accuracy of the energy scale at 1% level or better. On one hand, a comprehensive calibration system is designed, deploying multiple radioactive sources in various locations inside/outside of the central detector (CD), including Auto Calibration Unit (ACU), Cable Loop System (CLS), Guide Tube Calibration System (GTCS), and Remotely Operated Vehicle (ROV). On the other hand, the strategy of the JUNO calibration system has been developed and optimized based on Monte Carlo simulation results. Following this calibration strategy, we expect to achieve an accurate and comprehensive understanding of the energy resolution, energy non-linearity and non-uniformity responses of the JUNO detector. In this talk, the details of the JUNO calibration system design and calibration strategy will be presented.

C2 / **36**

Status of the liquid scintillator for JUNO

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The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose experiment designed to elucidate fundamental neutrino properties, study neutrinos with astrophysical or terrestrial origins, and search for rare processes beyond the Standard Model of particle physics. Its central detector is a 20 kton liquid scintillator (LS) located 650 m underground in Guangdong, China. To achieve its physics goals, the JUNO LS must have high transparency and ultra-low radiation background. To purify the LS, five plants were designed: alumina filtration, distillation, mixing, water extraction, and steam stripping. In addition, two corollary plants were designed to supply ultra-pure water and high purity nitrogen for the liquid scintillator purification system. Currently, the construction of the seven plants is almost completed, and the commissioning of the plants is underway.

F3 / **37**

Cryogenic Silicon-based photosensors: the Photon Detection Units for dark matter detection in DarkSide-20k

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DarkSide-20k (DS-20k) is the next stage of the DarkSide program and will be a new generation experiment involving a global collaboration from all the current argon-based detectors. The experiment is designed as a 20-tonne fiducial mass dual phase liquid argon time projection chamber (LAr-TPC) filled with low radioactivity argon and instrumented with SiPM-based cryogenic photosensors. The detector will be housed underground at the INFN Gran Sasso National Laboratory (LNGS) and is expected to be free of any instrumental background for an exposure of 100 tonne×year.
The DarkSide collaboration started a dedicated development and customization of SiPM technology for its specific needs resulting in the design, production, and assembly of large surface modules of 20×20 cm2 readout as 4 DAQ channels, named Photo Detection Unit (PDU) for the DS-20k experiment. PDUs will be mass-produced in the following years to integrate both the two optical planes for the TPC (~21 m2 total SiPM surface) and the photosensors for the veto system (~5 m2) of DarkSide-20k detector.
To this purpose a dedicated facility has been built at INFN Naples Cryogenic Laboratory with the aim of characterize the PDUs. The main characteristics of the first Photon Detection Unit prototype have been measured in liquid nitrogen. The PDU was tested for varying overvoltage values and different readout configurations by measuring the main photosensor parameters for each of them. The results of the tests will be reported, and the study of the performances will be discussed.

E2 / **38**

The Quality Assurance test setup for DUNE SiPMs characterization

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The Deep Underground Neutrino Experiment (DUNE) is an upcoming neutrino physics experiment that will answer some of the most compelling questions in particle physics and cosmology. DUNE comprises a high-intensity neutrino source located at Fermilab, a massive far detector (FD) situated 1.5 km underground at the Sanford Underground Research Facility (SURF) in South Dakota, and a composite near detector (ND) installed just downstream of the neutrino source.
The DUNE FD exploits silicon photomultipliers (SiPMs) to detect scintillation photons produced by the interaction of charged particles in a liquid Argon time projection chamber (LArTPC). The FD is composed of four modules, each with a fiducial mass of 10 kt. The first module (HD-FD) is a LArTPC with electrons drifting horizontally toward modular Anode wire-Plane Assembly (APA), inside where the Photon Detection System (PDS) is located.
The SiPMs are photosensors consisting of a matrix of single-photon avalanche diodes (SPAD) operating in the Geiger-Mueller region. Their high sensitivity and dynamic range, as well as the possibility to fill large surfaces with high-granularity sensors, makes them an ideal choice for the DUNE FD photodetection system.
An international consortium of research groups is currently engaged in systematic quality assurance tests of all the sensors that will be installed in the HD-FD to control their specifications. A custom setup, CACTUS (Cryogenic Apparatus for Continuous Tests Upon SiPMs), has been developed at Ferrara and Bologna Universities-INFN sites to automatically perform the tests for a large number of sensors in parallel. This system can characterize up to 120 SiPM simultaneously both testing their mechanical and thermal resistance, and measuring the current-voltage curve for each sensor

at room and cryogenic temperatures. These data allow to extrapolate the quenching resistor (R_q) and the breakdown voltage (V_bd), the key operating parameters of the SiPMs. Furthermore, the CACTUS test facility allows to perform dark noise assessment through a custom-made fixed threshold amplifier-discriminator system.
The CACTUS system will operate in the next years in 5 laboratories (in Bologna, Ferrara, Granada, Milano Bicocca and Prague) allowing the test of at least 120 sensor per day per site with the aim of quality assurance and determine the sensors operating voltage of the whole DUNE HD-FD productions. Preliminary results of the measurements already performed on ~4000 sensors for ProtoDUNE2-HD and in progress on the first batches of more than 25000 sensors for the DUNE HD-FD will be presented.

G1 / **39**

Cryogenic SiPMs for the DUNE experiment

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DUNE is the most ambitious long-baseline experiment under construction in the US for the study of neutrino oscillation and astroparticle physics. The DUNE far detector will employ the Liquid Argon TPC technology, enhanced by a powerful Photon Detection System that records the 128 nm scintillation light emitted by argon. The basic devices of this system are custom SIPMs.
A dedicated development program has been performed over the last three years by the DUNE PDS Consortium together with Hamamatsu Photonics (HPK) and Fondazione Bruno Kessler (FBK).
The technology employed by Hamamatsu benefits from a low terminal capacitance and a new type of metallic resistance with a tuneable thermal coefficient and an high quenching resistance system to suppress large-amplitude afterpulses. This allows for careful tuning of the signal shape and recovery time at 87 K to match the dynamic range needed in DUNE.
Similarly, FBK employed a well-established technology (NUV-HD-CRYO) as the backbone for the customized SiPMs, using enlarged tranches to reduce cross talk.
The tests were performed in several labs in Europe and the US and investigated both performance and cryo-reliability. The results include the complete characterization of the sensors (Dark Count Rate, correlated noise, photon detection efficiency, etc.) and the most relevant phenomena that drive the detector behaviour at cryogenic temperature (thermal behaviour, signal bandwidth evolution, scaling of DCR, etc.).

A4 / **40**

ATLAS MDT AMT Simulations for LHC Run3 and HL-LHC

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The Large Hadron Collider (LHC) started Run 3 operation in 2022, and the peak instantaneous luminosity will reach 2.3x1034 cm-2s-1 and the average number of collisions per bunch crossing is expected to be around 60 in 2023. The ATLAS Monitored Drift Tube (MDT) chambers are the main component of the precision tracking system in the ATLAS muon spectrometer. It is important to understand any potential issues with the MDT Front-End (FE) readout electronics for an expected Level 1 (L1) trigger rate of 98 kHz and a complex dead time of over 4% for RUN3 operations. We use raw data collected in 2022 to emulate the expected hit rates in MDT chambers and perform a realistic simulation on the ATLAS Muon TDC (AMT) chip with the current configuration. We study the AMT chip performances by analyzing the trigger/L1/readout buffer occupancies and hit-loss fractions under different luminosities with L1 rate of 100 kHz by using the Modelsim software. The hit-loss fraction of the hottest MDT chamber (BIL3C05) is lower than 0.1% due to FE readout, even at a luminosity of 2.98 x1034 cm-2s-1 with a complex dead time of 5% and a L1 rate of 100 kHz, indicating that AMT can operate under Run 3 conditions without problems. The MDT trigger and readout electronics will be replaced for triggerless readout during High-Luminosity LHC (HL-LHC) operation. We also simulate the AMT behavior in the trigger-less mode up to 7x1034 cm-2s-1 and propose possible AMT configurations in case some FE electronics could not be replaced during the pre-HL-LHC shutdown.

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FELIX Phase II, the ATLAS readout system for LHC Run 4

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The FELIX system has been introduced as a readout system for ATLAS in LHC Run 3, for a subset of the ATLAS subdetectors. An evolved version of FELIX, dubbed Phase II, will be deployed in Run 4 (2029 – 2032) and will serve all ATLAS subdetectors.
The FELIX Phase II system will be comprised of about 300 servers, each equipped with custom PCIe FELIX cards and a 400 GbE network interface. The system will receive detector data at the rate of 1 MHz for a total throughput of 4.6 TB/s.
The new FELIX PCIe card for Run 4, called FLX-182, is equipped with a Xilinx Versal Prime VM1802 FGPA/SoC, a PCIe Gen4x16 interface, four optical links to relay Timing, Trigger and Control information, and 24 optical links that operate up to 25 Gb/s to interact with the front-end electronics.
The FLX-182 runs FELIX firmware which has been redesigned and upgraded to deal with the higher data and trigger rates, as well as newly added communication protocols for the subdetectors in ATLAS. The firmware design has passed a preliminary design review in January 2022. The primary goals of the FELIX firmware are to decode and transfer the data from the front-ends into the host server memory and to receive and distribute precise timing, trigger and control information.
The software running on the FELIX server will also be upgraded to deal with the increased data and trigger rates.

A1 / 42

FASER Detector and First Physics Results

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FASER is an experiment dedicated to searching for light, extremely weakly-interacting particles that are produced in the very forward direction of high-energy pp collisions at CERN's Large Hadron Collider (LHC). The detector is placed 480 m downstream of the ATLAS interaction point, aligned with the beam collisions axis, and consists of both active electronic components intended to search for BSM physics and a passive tungsten emulsion target intended for neutrino physics. This talk will focus on giving an overview of the FASER detector and will also present our first physics results using a dataset collected at center-of-mass energy $\sqrt{s} = 13.6$ TeV in 2022 during LHC Run 3, where we were the first to directly observe neutrino interactions at a particle collider experiment and also probed previously unconstrained phase space of the dark photon with couplings 10^{-5}–10^{-4} and masses ~10 MeV - 100 MeV.

A3 / **43**

Design and Implementation of the TDAQ System for the JUNO-TAO Detector

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The Taishan Antineutrino Observatory (TAO or JUNO-TAO) will be deployed next to a core of the Taishan Nuclear Power Plant to measure the reactor neutrino spectrum precisely as a reference spectrum for JUNO. TAO also aims to measure the fine structures for the first time and to test the nuclear database used in the summation calculation of the spectrum. The ultra-high energy resolution of TAO is realized via an almost full coverage of its target volume, 2.8 ton gadolinium-doped liquid scintillator, with about 10 m^2 of cutting-edge silicon photomultipliers (SiPMs) with an high photon detection efficiency. However, this will bring high data rate due to the dark count of SiPMs. The TDAQ system, designed as a pure digital system, will process the high input data rates of O(100 Gbps) from the TAO detector by executing trigger algorithms on FPGA and compression strategies on CPU. Finally, it will suppress the data storage bandwidth to less than 100 Mbps which is limited by TAO onsite network. In this talk, the detailed design and implementation of TAO TDAQ system will be presented.

A2 / **44**

The KM3NeT underwater neutrino telescope: status and future perspective

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The KM3NeT collaboration started to build a multi-km3 neutrino telescope in the Mediterranean Sea. The telescope is composed of the ARCA detector, optimised for searches for high-energy neutrino sources in the Universe and it is under construction at the Capo Passero site, Italy, 80 km offshore at a depth of 3500 m; and the ORCA detector, near Toulon, France, 40 km offshore at a depth of 2500 m, aimed at the determination of the mass hierarchy of neutrinos. The basic detection element of the KM3NeT detector is the Digital Optical Module. The module is a pressure resistant glass sphere, containing 31 photo-multipliers tubes. Eighteen modules are arranged in the Detection Unit, a vertical string anchored on the sea floor. The Detection Units are deployed on the seabed to form a three- dimensional array of optical modules to detect Cherenkov light produced by neutrino-induced particles. In this contribution, an overview of the latest results and the future perspectives for the KM3NeT telescopes to detect the high energy neutrino sources in the Universe with the ARCA telescope and to determine the properties of the elusive neutrino particles with ORCA detector are presented.

D5 / **45**

Status of the FOOT experiment and first measurements of 16O fragmentation cross sections on C target

Author: The FOOT collaboration[None]

The study of nuclear fragmentation plays a central role in many important applications: from the study of Particle Therapy up to radiation protection for space missions.

In Particle Therapy, nuclear interactions of the beam with the patient's body causes fragmentation of both the projectile and target nuclei.
In treatments with protons, target fragmentation generates short range secondary particles along the beam path, that may deposit a non-negligible dose especially in the entry channel. On the other hand, in treatments with heavy ions, such as C or other potential ions of interest, like He or O, the main concern is long range fragments produced by projectile fragmentation, that release the dose in the healthy tissues downstream of the tumor volume.
Fragmentation processes need to be carefully taken into account when planning a treatment, in order to keep the dose accuracy within the recommended 3% of tolerance level.
The assessment of the impact that these processes have on the released dose is currently very limited from the lack of experimental data, especially for the relevant fragmentation cross sections. For this reason, treatment plans are not yet able to include the fragmentation contribution to the dose map with the required accuracy.
The FOOT (FragmentatiOn Of Target) collaboration designed an experiment to fill this gap in experimental data, aiming the measurement of the differential cross sections of interest. In this contribution, an overview of the FOOT experiment, including the present detector design and the expected performances will be discussed. In addition the measurement of the elemental fragmentation cross sections for a 16O beam of 400 MeV/u kinetic energy interacting with a graphite target using a partial setup composed of the FOOT scintillator detectors for the time of flight (TOF) and energy loss (ΔE) measurements together with a drift chamber, used as beam monitor, will be shown.

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The drift chamber project for the Super Charm-Tau Factory detector

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The Budker Institute of Nuclear Physics is actively developing the Super Charm-Tau Factory (SCTF) project, which is a mega-science class facility that will be used to study the decays of rare c-quarks and tau-leptons in Sarov, Russia. A new drift chamber to the SCTF detector is proposed consisting of 41 layers of hexagonal cells with an average radius of 7 mm in the He/C3H8 gas mixture. The tasks of the tracking system are to provide efficient reconstruction of charged particles, to determine their momentum and to identify their type by measuring ionization energy losses. To obtain more isotropic isochrones inside the cells a wire structure optimization algorithm was performed. A momentum resolution was simulated, for pions with an energy of 1 GeV it is equal to 0.35%.

The spatial resolution was measured at various gas amplifications on a drift chamber small prototype consisting of 7 hexagonal cells. The average spatial resolution is less than 100 mkm.

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Development of Hit Finding Algorithms for the DUNE Experiment Using SiMD Parallel Processing

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The DUNE experiment will start operating at the end of this decade, with the objective of measuring in detail neutrino oscillations, and other rare physics processes. Four far detectors modules (17 kt each) will be installed at SURF, in South Dakota, about 1.5 km underground. The data selection system of one DUNE far detector module's Time Projection Chamber (TPC) relies on the real-time processing of approximately half a million channels sampled at 2 MHz. Data for each channel are analyzed to identify activity incompatible with noise (hit finding). The hits are then clustered and processed further to form a trigger decision. The aim of the DUNE data selection system is to reduce the data volume produced by the detector electronics by four orders of magnitude. In this paper, after the description of the application design, we present the implementation and tuning of multiple software-based hit finding algorithms. The high rate of incoming data (~20 GB/s per host) is sustained through the employment of SiMD parallel processing, using algorithm implementations based on the AVX2 instruction set. We show the obtained performance comparing it across multiple CPU hardware platforms and conclude by illustrating live results from recent tests at a setup using prototype detector components.

F4 / **48**

Development and prototype of a new luminometer for the ATLAS experiment during Run 3 and Run 4 of the LHC

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The Beam Monitor for ATLAS detector (BMA) is an additional luminosity monitor for the ATLAS experiment, targeting the luminosity determination in Run 4 of the Large Hadron Collider (LHC). The detector is composed of small square pads with about 1mm per side of Low Gain Avalanche Detector (LGAD) silicon sensors, intended to be placed in the ATLAS detector forward shielding at about 16m from the interaction point.
The detector is innovative in several aspects: It does not need an external cooling system, and its readout preamplifiers are meant to be placed at about 25m distance from the sensors, in an area in which the radiation levels for the electronics can be neglected. Moreover, the tiny acceptance of the small pads is supposed to minimize systematic effects in the luminosity determination due to pile-up of several interactions in a single or consecutive proton-bunch crossings.
A two-channels prototype of the detector has been installed already for Run 3 of the LHC and recorded data in the year 2022. A modified version is set up for data-taking in the current year 2023.
The talk will present the technical details of the project regarding the sensors, their cooling, and the readout system. A short summary of the performances obtained during the detector operation periods so far will be given in addition.

D5 / **49**

Positron Emission Tomography with Pixelized Liquid Argon Detectors

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There have been significant advances in the use of Liquid Argon Time Projection Chambers (LArTPCs) for the study of neutrinos in recent years. The low-energy particle identification capabilities and scalability of LArTPCs with pixelated charge readout systems could provide enhanced performance in detecting the Compton scattering of photons used in medical imaging techniques such as Positron Emission Tomography (PET). This presentation will describe investigations of the optimization of LArTPCs for the detection of photons with energies corresponding to those used in PET scans, which already suggest the potential for significant improvement over traditional PET devices based on scintillation crystals. The details of a simulation that includes both charge and light collection in a pixel-based LArTPC will be described, as will the status of efforts to measure the performance of a prototype device using radioactive sources. Finally, preliminary plans for a larger-scale PET LArTPC device will be discussed.

F1 / 50

JUNO's potential for GeV events

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The Jiangmen Underground Neutrino Observatory (JUNO) is a next-generation 20 kton liquid scintillator detector under construction in southern China. It is designed to determine the neutrino mass ordering via the measurement of reactor neutrino oscillation. In addition, it has the potential for various other topics including atmospheric neutrinos, cosmic muons, etc., in the GeV energy region. Liquid scintillator detectors such as JUNO have good energy resolution and low threshold, but traditionally have relatively limited capabilities in tracking and directionality measurements. In this talk, I present the development of a novel reconstruction method which greatly expands JUNO's capability for GeV events. This method combines PMT waveform analysis and machine learning techniques, and can be used to reconstruct multiple quantities such as directionality, energy, vertex, and track. Preliminary performance results with MC simulation are presented. The method is applicable to other liquid scintillator detectors as well, which makes liquid scintillator detectors good candidates for future physics measurements in the GeV energy region.

D1 / 51

ALICE ITS3: how to integrate a large dimension MAPS sensor in a bent configuration detector

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The ALICE collaboration foresees the replacement of the three innermost layers of the present inner tracking system (ITS2), during the LHC long shutdown 3, with a completely new system, called ITS3. The expected performance will improve the pointing resolution of the tracking, particularly at low transverse momentum, hence significantly extending the heavy flavour physics program of the experiment.

The full detector consists of two half-barrels, each containing three sensors, of the size up to ~26 cm x ~10 cm, bent in a half-cylindrical shape, spaced by 6 mm in a concentrical configuration, covering a pseudo rapidity acceptance up to ±2.5 (layer 0). The development of a wafer size MAPS sensor is based on 65 nm technology, using the stitching technique to allow for a sensor size exceeding the technologies reticle size. A sensor thickness of less than 50 um and the usage of extremely light support structures based on carbon foam and air cooling allow reducing the material budget per layer to the order of 0.05% X/X_0 in the detector active area. Replacement of the beam pipe allows placing the first detector layer only 1.8 cm far from the interaction point.

The contribution will describe the global detector integration concept, focusing on: the sensor bending procedure at different thicknesses to the target radii, the electrical interconnection techniques via wire-bonding and the choice of the best carbon foam, in terms of material density and thermal dissipation properties, as light mechanical supporting structures. Details on the electrical characteristics and mechanical integration of the flexible circuits designed to provide power and communication with sensors will be discussed, as well as findings from the study of the cooling by air at the expected dissipated power. Moreover, results on the effects of the bending on already available 180 nm sensors (ALPIDE), both in laboratory and in particle beams, and on new 65 nm prototype sensor structure, will be exposed. Finally, the outcome of the assembly of the first working large-scale sensor detector prototype, called super-ALPIDE, will be reported.

B2 / **52**

Development of wavelength-shifting plate light collector for Outer Detector of Hyper-Kamiokande

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Hyper-Kamiokande (HK) is a next generation underground water Cherenkov detector to be built in Japan for neutrino oscillation studies, proton decay searches, and neutrino astrophysics. An Outer Detector (OD) will provide information to identify interactions originating from particles outside the inner detector of HK and to veto background events. The baseline configuration of OD includes a few thousand photosensitive units. Each unit consists of a 3-inch PMT with a wavelength shifting (WLS) plate mounted around it to collect Cherenkov light, reemit it and concentrate on the PMT. The plates doped with different fluors were tested in air and water using a set of UV LED light sources with different wavelengths. The photon detection efficiency of wavelength shifting fluors, side reflectors, optical coupling between a PMT and a plate were studied. Presented results include comparative performance of WLS plates, absolute photodetection efficiencies, parameters of attenuation and light collection efficiency, optimization of chemical composition of WLS dopants.

E1 / **53**

ALICE Inner Tracking System upgrade: characterization of first chips fabricated in 65 nm CMOS technology

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The Inner Tracking System of ALICE (A Large Ion Collider Experiment) will undergo a major upgrade during the next Long Shutdown of LHC aimed at enhancing the tracking capability. In particular, the three innermost sectors of the current vertex tracker will be replaced by truly cylindrical layers produced by using curved (wafer-scale) silicon sensors thinner than 50 µm, based on monolithic active pixel structures realised in a 65 nm CMOS process. The innermost layer will be placed at only 18 mm of radial distance from the interaction point guaranteeing at the same time a material budget as low as 0.05% of a radiation length X0.

The R&D on the sensor ASICs involves a series of submissions in silicon and the first one (named MLR1: Multi-Layer per Reticle 1) was completed at the end of 2020. MLR1 provided several test structures containing transistors, memories and small matrices of pixels with integration of front-end electronics inside the sensitive area of the pixels; these devices have been used to qualify the technology in terms of performance and radiation hardness. In particular, to evaluate the charged particle detection performance, this first submission includes 3 variants of pixel matrices: analog pixel test structure (APTS, 4x4 pixels of 10, 15, 20 and 25 µm pitch, with analog readout); digital pixel test structure (DPTS, 32x32 pixels of 15 µm pitch, with digital in-pixel discrimination and digital readout); CE65 (64x32 pixels of 15 µm pitch, test structures with rolling shutter analog readout).

This contribution will provide an overview of these test structures, describing the results of characterisations performed with radioactive sources and beam tests in order to choose the best pixel pitch and sensor configuration, optimising timing, charge collection efficiency and stability after radiation damage. The obtained results show a satisfactory behaviour as 100% efficiency for charged particles in the range of GeVs and timing of few ns, giving the direction for the next submission (ER1: Engineering Run 1) directed to large, stitched sensor chips.

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Design and Implementation of the DAQ System for the HEPS-BPIX 6M Detector

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The High Energy Photon Source (HEPS) is a 4th generation synchrotron radiation light source of ultrahigh brightness that is currently under construction in China. HEPS-BPIX 6M is a dedicated silicon pixel detector under development that will be used in HEPS. The detector hosts about 6 million pixels which will be assembled with 40 modules, covering a large effective detection area of about 28.8 x 40.5 cm2. The readout chip supports dual threshold readout and achieves maximum frame rate up to 1 kHz. The characteristics of the detector leads to high readout data bandwidth, which brings challenges for the data acquisition. Based on the detector's specifications, a distributed DAQ system has been designed to achieve high-throughput data readout, high-performance data processing and real-time data storage. Meanwhile, friendly user interface has been provided for configuration, run control, real-time monitoring and so on. The detailed design, implementation and performance tests will be presented in this talk.

D1 / 55

The ATLAS HL-LHC Upgrade Program

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While the on-going Run-3 data-taking campaign will provide twice the integrated proton-proton luminosity currently available at the LHC, most of the data expected for the full LHC physics program will only be delivered during the HL-LHC phase. For this, the LHC will undergo an ambitious upgrade program to be able to deliver an instantaneous luminosity of 7.5×10^{34} cm^{-2} s^{-1}, allowing the collection of more than 3 ab^{-1} of data at $\sqrt{s}$ =13.6 (14) TeV. This unprecedented data sample will allow ATLAS to perform several precision measurements to constrain the Standard Model Theory (SM) in yet unexplored phase-spaces, in particular in the Higgs sector, a phase-space only accessible at the LHC. To benefit from such a rich data-sample it is fundamental to upgrade the detector to cope with the challenging experimental conditions that include huge levels of radiation and pile-up events. The ATLAS upgrade comprises a completely new all-silicon tracker with extended rapidity coverage that will replace the current inner tracker detector; a redesigned trigger and data acquisition system for the calorimeters and muon systems allowing the implementation
of a free-running readout system. Finally, a new subsystem called High Granularity Timing Detector, will aid the track-vertex association in the forward region by incorporating timing information into the reconstructed tracks. A final ingredient, relevant to almost all measurements, is a precise determination of the delivered luminosity with systematic uncertainties below the percent level. This challenging task will be achieved by collecting the information from several detector systems using different and complementary techniques.
This presentation will describe the ongoing ATLAS detector upgrade status and the main results obtained with the prototypes, giving a synthetic, yet global, view of the whole upgrade project.

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Diamond XBPM Detector System for the HEPS(High Energy Photon Source ,China)

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High Energy Photon Source (HEPS) is a high-performance and high-energy synchrotron radiation light source with a beam energy of 6GeV and an ultra-low emittance of better than 0.06nm.rad. HEPS will be the first high-energy synchrotron radiation light source in China. It will make many contributions to the development of science and technology in China. This light source can provide essential support for the breakthroughs in technological and industrial innovation. In the mean time, HEPS provides a state-of-the-art and multi-disciplinary experimental platform for basic science researchers.
The XBPM detector based on a single crystal diamond is used to detect the position of the X-ray beam, to provide accurate position feedback information for optical control system. The dynamic range of the detector is from nA to mA in the linear range and the position resolution ranges from microns to tens of nanometers. The diamond sensor is 50μm thick to ensure the samll absorption. The electronic system includes a weak current transfer and the data acquisition.The sampling rate is from 4MHz to 1Hz and the signal noise is processed by digital filtering algorithm inside the FPGA. The XBPM system will installed in the HEPS beamlines in 2024.

A2 / **57**

JUNO underground facility

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The Jiangmen Underground Neutrino Observatory (JUNO), with 53 km baseline from a set of nuclear reactors under construction, and featuring an overburden of more than 700 meters, will aim at measuring the neutrino mass hierarchy, as well as many other quantities of utmost importance in neutrino and astroparticle physics. The underground experimental hall, in which JUNO detector installed and characterized by a width of 50 meters., was excavated underneath granite mountain as well as facility halls and tunnels.
The kick-off of the civil construction was on January 10, 2015 and finished at end of 2021. This poster shows layout of underground facility and conditions provided for experiment.

A2 / **58**

Status of the JUNO-TAO Detector

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The Taishan Antineutrino Observatory (TAO or JUNO-TAO) is a satellite experiment of the Jiangmen Underground Neutrino Observatory (JUNO). By adopting 10 m^2 Silicon Photomultipliers (SiPMs) with 50% photon detection efficiency (PDE) and 94% coverage, and 2.8 ton gadolinium-doped liquid scintillator (GdLS) with 4500 photoelectrons per MeV effective light yield, TAO detector will reach

2%/√E when running at -50℃ low temperature. The high energy resolution of TAO offers good potential to precisely measure the reactor antineutrino spectrum providing reference for JUNO, and a new benchmark for nuclear database. TAO could also measure isotopic neutrino spectrum and monitor the reactor. In this talk, the status of detector design and construction, liquid scintillator, SiPM mass testing, muon veto, calibration, and 1:1 prototype will be presented.

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Integration Tests with 2S Module Prototypes for the Phase-2 Upgrade of the CMS Outer Tracker

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The CMS experiment will be upgraded until 2028 to deal with the increased luminosity of the HL-LHC. During this Phase-2 Upgrade, the CMS Outer Tracker will be equipped with modules each assembled with two silicon sensors. These are placed on mechanical structures in form of ladders in the central barrel of the Outer Tracker or disks in the endcap region.

During the prototyping phase the modules are initially investigated individually to evaluate their performance. Next steps are integration tests performed with the purpose to test the module functionality on the final detector structures. Investigations focus on the cooling performance as well as on electrical performance of a group of modules on the supporting structures.

This contribution summarizes integration tests with the Outer Tracker module prototypes. The main focus will be on a cooled ladder integration test performed at CERN and a full ladder integration test at Institut Pluridisciplinaire Hubert Curien (Strasbourg).

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HEPS-BPIX40: the upgrade of the hybrid pixel detector for the High Energy Photon Source

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HEPS-BPIX40 is a new hybrid pixel detector specifically designed for the High Energy Photon Source, which is currently under construction in Beijing, China. It is a full upgrade from both the chip and detector module of its former version, BPIX20. The pixel chip comprises a matrix of 128 x 96 pixels, with each pixel measuring 140 μm x 140 μm. The pixel circuit operates in the single photon counting mode with dual thresholds, featuring programmable gains for different beam energies and deadtimeless readout. The counting depth for each threshold is designed to be 14 bits, and the frame rate was tested to be 2 kHz when operating in continuous readout mode. The chip was designed using CMOS 130 nm technology and fabricated by 12-inch wafers, with a yield of 97% tested by a dedicated probe card. Assembled by 2 x 6 chips, a detector module covers an area of 3.7 cm x 8.1 cm. The periphery circuit of the chip was optimized along its height, allowing the assembly gap between multiple modules to be as small as 3 mm, even with conventional wire-bonding processes. All chips of the module were bump bonded by the CuSn process with high yield. The noise after packaging was tested to be about 112e-, and the equalized non-uniformity was found to be 123e-. The full system will consist of 40 modules to implement a detector with approximately six million pixels. This paper presents a detailed design and test results of the detector.

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Future ASICs for calorimetry at OMEGA

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Calorimeters have recently evolved to provide much more granularity in order to better identify particles inside showers and improve the energy resolution, in particular for jets. "Imaging calorimetry" has been studied in detail by the CALICE collaboration since the mid 2000s and more recently chosen by the CMS experiment to equip its endcap calorimeter. Imaging calorimetry increases by one or two orders of magnitude the number of channels and requires readout electronics embedded onto the detectors. Also recently, timing information with a few tens of picoseconds accuracy has been added to the energy measurements and provides valuable supplementary information. All these improvements have been made possible by high performance readout ASICs, handling the large calorimeter dynamic range with high speed low noise performance while operating at low power (~20 mW/ch). In the future, the granularity will continue to increase, requiring even lower power operation. This will be achieved by further progress on the analog front-end and also advanced on-chip data processing.
OMEGA laboratory has been developing the SKIROC/SPIROC/HARDROC ASIC family for the CALICE readout and more recently HGCROC for CMS HGCAL, which is now undergoing its final tests before fabrication for the HL LHC. Their design and performance will be recalled and the architectural choices and prototypes in design for the future experiments (EIC, ILC, FCC…) will be presented.

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TPC Development for the ILD Detector at ILC (On behalf of the LCTPC Collaboration)

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A large, worldwide community of physicists is working to realize an exceptional physics program of energy-frontier, electron-positron collisions with the International Linear Collider (ILC) and other collider projects (summarized and evaluated in https://arXiv.org/abs/2208.06030).
The International Large Detector (ILD) is one of the proposed detector concepts at the next electron-positron linear collider (ILC). The ILD tracking system consists of a Si vertex detector, forward tracking disks, and a large volume Time Projection Chamber (TPC), all embedded in a 3.5 T solenoidal field. The TPC is designed to provide up to 220 three dimensional points for continuous tracking with a single-hit resolution better than 100 μm in rφ, and about 1 mm in z. An extensive research and development program for a TPC has been carried out within the framework of the LCTPC collaboration. A Large Prototype TPC in a 1 T magnetic field, which allows to accommodate up to seven identical Micropattern Gaseous Detector (MPGD) readout modules of the near-final proposed TPC-design, has been built as a demonstrator at the 5 GeV electron test-beam at DESY. Three MPGD concepts are being developed for the TPC: Gas Electron Multiplier, Micromegas and Pixel, also known as GridPix (MicroMegas integrated on a Timepix chip). Successful test beam campaigns with the different technologies have been carried out during the last decade. Fundamental parameters such as transverse and longitudinal spatial resolution and drift velocity have been measured. In parallel, a new gating device based on large-aperture GEMs has been successfully developed. Recent R&D also led to a design of a Micromegas module with monolithic cooling plate in 3D printing and 2-phase CO2 cooling. In this talk, we will review the track reconstruction performance results and summarize the next steps towards the TPC construction for the ILD detector. The TPC with pad (pixel) readout electronics is designed to have about 10e6 pads (10e9 pixels) per endcap for continuous tracking and

a momentum resolution of delta(1/pT) ~ 1x10e-4/GeV (TPC only) (delta(1/pT)~0.8x10e-4}/GeV (60% coverage, TPC only)), and the dE/dx resolution is ~5 % (~4 %). The momentum resolution including all tracking subdetectors is 2x10e-5/GeV.

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PFA reconstruction for the transverse crystal bar ECAL in the future lepton colliders

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Future electron-positron colliders require precise energy resolution of jets to measure the Standard Model particles and explore new physics. A novel electromagnetic calorimeter (ECAL) with transverse crystal bars has been proposed for the future electron-positron collider experiments, offering high intrinsic energy resolution, 3D granularity required by the Particle Flow Approach (PFA) and O(10) fewer readout channels. The main challenges of this new design are the ambiguity problem for multiple simultaneously injected particles from the perpendicular arrangement of crystal bars and the overlap between showers from larger Moliere radius of the crystal.

In this report we will present a new PFA with several sub-algorithms to address above issues, and prove the feasibility of this ECAL design. The ambiguity problem is solved by multiple optimized pattern recognition approaches, and the overlapping showers are addressed by an energy splitting module. The global performance is preliminary investigated within the Circular Electron Positron Collider (CEPC) environment. The results indicate that the proposed ECAL design, combined with the self-designed PFA approach, offers a promising solution for future collider experiments. It improves the energy resolution and is compatible with the PFA idea. This can be a new option to the future collider experiment technology.

G2 / **64**

High spatial resolution of Time Projection Chamber R&D at high luminosity Tera-Z on CEPC

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The Circular Electron Positron Collider (CEPC) was been proposed as a Higgs and high luminosity Z factory in last few years. The detector conceptual design of a updated detector consists of a tracking system, which is a high precision (about 100μm) spatial resolution Time Projection Chamber (TPC) detector as the main track device in very large 3D volume. The tracking system required the high precision performance requirements, but without power-pulsing not likely as the International Linear Collider (ILC), which leads to additional constraints on detector specifications, especially for the case of the machine operating at the high luminosity Z pole (Tera Z). TPC detection technology requires longitudinal time resolution of about 100ns and the physics goals require Particle Identification Detection (PID) resolution of very good separation power with cluster counting to be considered. A number of critical issues are still remaining regarding the TPC research. The simulation and PID

resolution show TPC technology potential to extend Tera Z at the future e+e- collider.
In this talk, I will present the feasibility and status of high precision TPC as the main track detector for e+e collider. The traditional pad readout is designed about 1mm x 6mm and the pixelated readout is designed about 55μm x 5μm or bigger size. Compared with the pad readout, the pixelated readout option will obtain the better spatial resolution of single electrons, the very high detection efficiency in excellent tracking and good dE/dx performance. A smaller prototype TPC has been developed with a drift length of 500 mm, gaseous chamber, 20000V field-cage, the low power consumption FEE electronics and DAQ have been commissioned and some studies have been finished. Some updated experimental results including the spatial resolution, the gas gain, the laser track reconstruction and dE/dx will be reported. The track performance results and summarize the next steps of the pad/pixelated TPC technology for e+e- collider will presented in this talk.

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MCP-Based Detectors for Diagnostics of Circulating Beams in the NICA Accelerating Complex

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A promising diagnostic system for circulating beams based on microchannel plates (MCP) is presented in the framework of implementation of the NICA project. The profile monitors developed, manufactured and tested in Nuclotron and Booster provide measurements in a range of intensities of single-charged ions from 10^3 to 10^8 which is not covered by other existing measurement equipment. The experimental data on space-time characteristics of beams from single-charged to heavily stripped ions are presented. The loading and time characteristics, as well as the advantages and disadvantages of MCP-based detectors are discussed. Another application of MCP-based detectors is a measurement of small-angle scattering in the SPD experiment at the NICA collider. The advantages of such detectors are precise determination of the interaction vertex and sub-nanosecond time resolution. Both were experimentally demonstrated.

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Investigation of Neutron Radiation Damage in 4H-SiC PiN Diodes

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Silicon Carbide (SiC) is a wide-bandgap semiconductor that has recently become a topic of intensified interest in the HEP instrumentation community due to the availability of high-quality wafers from the power electronics industry. SiC features multiple advantageous material properties over silicon. It is insensitive to visible light, hypothesized to be more radiation hard, and has much lower

leakage currents, even after irradiation. Especially for future high-luminosity experiments, the radiation hardness is an essential parameter. One of the most important metrics associated with radiation hardness is the charge collection efficiency (CCE), which typically decreases with irradiation due to the formation of traps and defects. A thorough understanding of these traps and defects is crucial for estimating the performance of a detector over its lifetime and can open to the door to techniques such as defect engineering.
We present the current status of characterization and simulations for 50 µm thick 4H SiC PiN diodes together with radiation hardness studies. The characterization work includes the determination of material parameters of 4H-SiC (ionization energy and Fano factor) and comparisons to TCAD and Monte-Carlo simulations. Recently, significantly increased signals (with respect to unirradiated samples) were reported for neutron-irradiated SiC diodes in forward bias using UV-TPA-TCT, hinting at charge multiplication. We re-investigate neutron irradiated 4H-SiC PiN diodes (fluences between 5×10^{14} and 1×10^{16} cm^{-2} 1 MeV neutron equivalent n_{eq}) which have been previously characterized using UV-TCT and alpha spectroscopic measurements. The CCE and transient waveforms were measured in forward and reverse bias using alpha and UV-TCT measurements. Furthermore, I-V and C-V measurements for forward as well as reverse bias voltages of up to 3kV were performed to serve as additional input in understanding observed radiation damage. For samples irradiated to 5×10^{14} and 5×10^{14} n_{eq} cm^{-2}, the CCE in the forward direction grows exponentially, surpassing 100% and coinciding with an increase in the leakage current. At the highest irradiation fluence, no exponential behavior was observed. However, the CCE in the forward direction was found to be larger than for reverse bias. For this fluence, the leakage current remained below 1 nA.

E4 / **67**

Status and prospects of the low radioactivity Argon for dark matter searches

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A major global effort is currently underway to obtain radiopure argon for DarkSide-20k (DS-20k), the first large-scale detector of the Global Argon Dark Matter Collaboration (GADMC). The Urania project aims to extract underground argon (UAr) from CO2 wells in the USA at a production rate of approximately 300 kg/day. Additional chemical purification of the UAr will be necessary before it can be used in the DS-20k LAr-TPC. The Aria project will purify the UAr using a cryogenic distillation column (Seruci-I), located in Sardinia, Italy. To assess the radiopurity of the UAr in terms of Ar-39, the GADMC is building the DArTinArDM experiment at the LSC laboratory in Spain. The DArT chamber (~1 liter) containing underground Argon will be placed in the center of the ~1-ton atmospheric argon ArDM detector, which acts as an active veto for gammas from the detector materials and surrounding rock. DArT is designed to measure the Ar-39 contamination in the UAr with a sensitivity better than 1 mBq/kg, ensuring the radiopurity level of the different UAr batches necessary for DS-20k.
In this talk, I will provide an overview of the status and prospects of the UAr projects for DarkSide-20k.

H1 / **68**

System Design and Prototyping for the CMS Level-1 Trigger at the High-Luminosity LHC

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The High-Luminosity LHC will open an unprecedented window on the weak-scale nature of the universe, providing high-precision measurements of the standard model as well as searches for new physics beyond the standard model. Such precision measurements and searches require information-rich datasets with a statistical power that matches the high-luminosity provided by the Phase-2 upgrade of the LHC. Efficiently collecting those datasets will be a challenging task, given the harsh environment of 200 proton-proton interactions per LHC bunch crossing. For this purpose, the trigger and data acquisition system of the Compact Muon Solenoid (CMS) experiment will be entirely replaced. Novel design choices have been explored, including ATCA prototyping platforms with SoC controllers and newly available interconnect technologies with serial optical links with data rates up to 28 Gb/s. Trigger data analysis will be performed through sophisticated algorithms, including widespread use of Machine Learning, in large FPGAs, such as the Xilinx Ultrascale family. The system will process over 60 Tb/s of detector data with an event rate of 750 kHz. The system design and prototyping are described and examples of trigger algorithms reviewed.

B1 / **69**

The phase-1 upgrade of the ATLAS level-1 calorimeter trigger

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The ATLAS level-1 calorimeter trigger is a custom-built hardware system that identifies events containing calorimeter-based physics objects, including electrons, photons, taus, jets, and missing transverse energy. In Run 3, L1Calo has been upgraded to process higher granularity input data. The new trigger, currently running in parallel with the legacy system, comprises several FPGA-based feature extractor modules, which process the new digital information from the calorimeters and execute more sophisticated trigger algorithms. The design of the system will be presented along with an analysis of the improved performance of the upgrade in the increasingly challenging Run-3 LHC pile-up environment.

C1 / **70**

The new readout system for the Alice Zero Degree Calorimeters in LHC Run 3

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The Zero Degree Calorimeters (ZDC) were designed to provide the measurement of the event geometry and luminosity in heavy-ion operation.

In order to exploit the potential offered by the LHC increased luminosity in Run 3 the ZDC upgraded its readout system to be able to acquire all collisions in self-triggered mode without dead time.
The purpose of the upgrade was to enable the detector to cope with the increased event rate, while preserving its time and charge resolution performance.
The ZDC operating conditions in Run 3 Pb-Pb collisions are extremely challenging due to the presence of ElectroMagnetic Dissociation processes (EMD).
When running in self-triggered mode the ZDC system will need to sustain a readout rate of ~ 2.5 MHz for the channels of the most exposed calorimeters that compares to the foreseen hadronic rate of 50 kHz sustained by the other detectors.
The previous electronics, based on Charge-to-Digital Converters (QDCs), with a fixed dead time of ~ 10 us, and on readout through VME bus, could not cope with such a high rate.
Moreover, a crucial aspect of the ZDC operation in Run 3 is acquiring the events with a reduced bunch spacing of 50 ns (lower than the length of the signal of ~ 60 ns) in the presence of a large signal dynamics (from a single neutron to ~ 60 neutrons).
The new acquisition chain is based on a commercial 12 bit digitizer with a sampling rate of about 1 GSps, assembled on an FPGA Mezzanine Card.
The signals produced by the ZDC channels are digitized, and samples are processed through an FPGA that, thanks to a custom trigger algorithm, flags for readout the relevant portion of the waveform and extracts information such as timing, baseline average estimation and luminosity.
The architecture of the new readout system, the auto trigger strategy, the firmware structure and the ZDC performance during the 2022 Pb-Pb collisions are presented.

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The upgrade of the CMS Muon System for the LHC Phase 2

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During the Phase 2, the Large Hadron Collider (LHC) will increase the instantaneous luminosity to 5-7.5 x 10^34 cm-2 s-1, representing a new challenge for the Muon System of the CMS detector. To cope with the new data-taking conditions and to improve the present tracking and triggering capabilities, the muon system will undergo specific upgrades targeting both the electronics and detectors. The upgrade of the electronics will involve all legacy systems, based on Drift Tubes (DT) and Resistive Plate Chambers (RPC), in the barrel region, and Cathode Strip Chambers (CSC) and RPC in the endcap region. In order to restore the Muon System redundancy in the high eta region and further extend the coverage up to |η| ~2.8, new stations based on triple Gas Electron Multiplier (GEM) and Improved RPC (iRPC) will be installed. During the second long shutdown LS2 (2019-2021), the first GEM station and few GEM and iRPC demo-chambers were installed. Moreover, some prototypes of the new On Board electronics for DT(OBDT) were installed in the CMS slice-test demonstrators. In this presentation, we report the status of the Muon Upgrade project, including the performance results of the already installed systems with the Run-3 data. The status of the production and validation tests of the new detectors that will be installed before LS3 and of the new electronics boards to be installed during LS3 will be also reported.

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The Upgrade of the Level-1 Muon Trigger at the CMS experiment for the High-Luminosity LHC era

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We present an innovative upgrade to the CMS Level-1 Muon trigger for the High Luminosity LHC (HL-LHC) era. The upgrade includes a new, modular, ATCA, time-multiplexed, platform that hosts large FPGAs and can run a variety of muon reconstruction algorithms, including Machine Learning based ones. The system also takes advantage of the availability of tracks at the Level-1 from the CMS track trigger upgrade project. We will describe the full system, the algorithms that are expected to run in it and their performance in the challenging conditions of the HL-LHC

D5 / **73**

Status of low-pressure Time Projection Chamber for ion identification in Accelerator Mass Spectrometry

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The Accelerator Mass Spectrometry technique makes it possible to measure rare long-lived isotopes such as 10Be, 14C, 26Al, 129I. The content of these isotopes can be at the level of 10^{-15} of the total element content. The Accelerator Mass Spectrometer developed by Budker Institute of Nuclear Physics (BINP AMS) successfully measures the concentration of 14C relative 12C. However, there is a problem of separating the 10B isobaric background from 10Be. Beryllium-10 is used to date geological objects on a time scale from 1 thousand years to 10 million years.
To solve this problem we have proposed a new technique for ion identification based on measuring both ion track ranges and ion energies in a low-pressure Time-Projection Chamber (TPC) with Gas Electron Multiplier (GEM) readout. We have developed the TPC with a dedicated thin silicon nitride window for an efficient passage of ions. To begin with, the characteristic of the low-pressure TPC were studied in isobutane at a pressure of 50 torr using alpha particle sources.
In this work, we set up the low-pressure TPC on BINP AMS facility and successfully measured track ranges and energies of ions from samples containing 14C. At the next stage, we are going to carry out measurements with samples containing 10Be. However, using the obtained results and SRIM simulation we have already shown that the isobaric boron and beryllium ions can be separated by more than 10 sigma. This technique is proposed to be applied in AMS for dating geological objects, namely for geochronology of Cenozoic era.

D4 / **74**

Design and performance of one Shashlyk calorimeter for the SoLID project at Jefferson Lab

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SoLID (Solenoidal Large Intensity Device) is a large acceptance spectrometer which can handle very high luminosity, being planned at Jefferson Lab, USA. The Shashlyk-type sampling detector will be used for the electromagnetic calorimeter for SoLID. Several modules of Shashlyk electromagnetic calorimeter have been built in our laboratory to study the structure and the performance. The machining process for several essential materials will be introduced in this talk. One testing system with cosmic ray muon is setup based on flash ADC to study the performance of the module, including the light yield and timing. The effect of the mirror on fiber end, package and coating of the module will be study. One on-line calibration scheme of the calorimeter is discussed. One supermodule is assembled with seven modules, the combined test of multi-module with inclined incident muon also will be presented.

B4 / **76**

Longevity Studies of the CMS Muon System for HL-LHC

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During the upcoming years of the High Luminosity Large Hadron Collider (HL-LHC) program, the CMS Muon spectrometer will face challenging conditions. The existing detectors, which consist of Drift Tubes (DT), Resistive Plate Chambers (RPC), and Cathode Strip Chambers (CSC), as well as recently installed Gas Electron Multiplier (GEM) stations, will need to sustain an instantaneous luminosity of up to $5 - 7 \cdot 10^{34}$ $\mathrm{cm}^{-2}\mathrm{s}^{-1}$, resulting in increased pile-up, and about 10 times the expected LHC integrated luminosity. To cope with the high rate environment and maintain good performance, additional GEM stations and improved RPC (iRPC) detectors will be installed in the innermost region of the forward muon spectrometer. The CMS muon system upgrade program includes, together with the substitution of the on-detector and backend electronics of the existing detectors, accelerated irradiation studies performed at the CERN Gamma Irradiation Facility (GIF++) or with specific X-ray sources, in order to certify the detector performance for 10 years of operation under the harsh HL-LHC conditions. Furthermore, since RPCs and CSCs use gases with a global warming potential (GWP), ongoing efforts are being made to find new eco-friendly gas mixtures, as part of the CERN-wide program to phase out fluorinated greenhouse gases. This report presents the status of the CMS Muon system longevity studies, along with actions taken to reduce detector aging and minimize greenhouse gas consumption.

B3 / **77**

ASHIPH Cherenkov counters in the KEDR experiment

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The particle identification system ASHIPH (Aerogel, SHifter, PHotomultiplier) has been working in the KEDR experiment at VEPP-4M e^+e^--collider (Budker INP, Novosibirsk) since 2014. The system consists of 160 aerogel cherenkov counters arranged in two layers and covers 96% of the solid angle. The volume of aerogel is 1000 liters, its refractive index is 1.05. For the photon detection we use the Micro Channel Plate (MCP) PMTs. π/K separation in the momentum range from 0.95 to 1.45 GeV/c is better than 4σ. The status of the system is presented. The long-term stability of aerogel counters in the KEDR experiment is shown. A review of the use of ASHIPH system for perform physical analysis in the KEDR experiment is presented, such as measurements of the masses of neutral and charge D-mesons and measurement the branching fractions of J/ψ meson decays to the final states $p\bar{p}$, $2(\pi^+\pi^-)\pi^0$, $K^+K^-\pi^+\pi^-\pi^0$, $2(\pi^+\pi^-)$ and $K^+K^-\pi^+\pi^-$.

C5 / **78**

Spin Physics Detector at the NICA accelerator complex

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The Spin Physics Detector (SPD) is designed as a universal 4π detector with advanced tracking and particle identification for studying the spin structure of the proton and deuteron and other spin-related phenomena. The detector will be installed at one of the two beam intersection points of the NICA collider, which is currently at the final stage of construction at JINR. A luminosity of 10^{32} $cm^{-2}s^{-1}$ can be achieved in collisions of pp beams at the maximum interaction energy of 27 GeV. Both longitudinal and transverse beam polarizations will be available. The SPD detector will be equipped with silicone vertex and straw-tube detectors for tracking, time-of-flight and Cherenkov systems for particle identification, an electromagnetic calorimeter, and a range system for muon identification. A solenoidal magnetic field of 1 T will be provided by a superconductive magnet. The presentation will give an overview of the evolving detector design. The commissioning of the detector is divided into two stages. The data taking of the first stage is planned for the end of this decade.

G1 / **79**

Significant performance recovery of SiPMs' irradiation damage with in-situ current annealing

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We have developed a technique that utilizes the forward current to heat and anneal SiPMs to mitigate the effects of radiation damage in high-radiation environments. We conducted an experimental study on the radiation damage and recovery of SiPMs. SiPMs from three different manufacturers (SengL, Hamamatsu, and Beijing Normal University) were examined. Unlike the conventional method of using low current for prolonged periods, our approach yields a substantial annealing effect in a shorter duration of tens to hundreds of seconds using higher current (about 0.8 A). A magnitude reduction of 1-2 orders in the dark current of all SiPMs was observed post-annealing. When the irradiated SiPMs were subjected to temperature sensitivity testing from -30℃ to 20℃, it was noticed that in-situ current annealing corrected the decreased sensitivity of SiPMs to temperature and enhanced the energy resolution of SiPMs, which restored the peak position of SiPMs to nearly 80% of their pre-irradiation levels. In conclusion, our outcomes demonstrate considerable enhancement of SiPM properties following in-situ current annealing. Therefore, our short-duration but higher-ampere in-situ annealing provides a practical and effective method to improve the radiation resistance of SiPMs in space and collider experiments.

A2 / **80**

Low radioactivity and Multi- disciplinarily Underground Laboratory of Modane (LSM)

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The Modane Underground Laboratory (LSM) is located 1700 m (4800 m.w.e) below Fréjus peak (Alpes chain) mountain in the middle of the Fréjus tunnel between France/Italy. The LSM is a multi-disciplinary platform for the experiments requiring low radioactivity environment. Several experiments in Particle and Astroparticle Physics, low-level of High Purity of Germanium gamma ray spectrometry, biology and home land security hosted in the LSM. It's equipped by Anti-Radon facility where all of the detectors are under Radon depleted Air. We will present the LSM structure and briefly reviewed of all experiments are installed in.

C5 / **81**

The Silicon Vertex Detector of the Belle II Experiment

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In June 2022 the data taking of the Belle II experiment was stopped for the Long Shutdown 1 (LS1), which is primarily required to install a new two-layer DEPFET detector (PXD) and upgrade components of the accelerator. The whole silicon tracker (VXD) will be extracted from Belle II, then the outer four-layer double-sided strip detector (SVD) is split into its two halves to allow access for the PXD installation. Then a new VXD commissioning phase will begin such that it will be ready to take data by the end of 2023. We describe the challenges and status of this VXD upgrade.
In addition, we report on the performance of the SVD, which has been operated since 2019. The high hit efficiency and the large signal-to-noise are monitored via online data-quality plots.
The good cluster-position resolution is estimated using the unbiased residual with respect to the track, resulting in reasonable agreement with the expectations. A novel procedure to group SVD hits event-by-event, based on their time, has been developed. Using the grouping information during reconstruction allows to significantly reduce the fake rate while preserving the tracking efficiency.
So far, in the layer closest to the I.P., the SVD average occupancy has been less 0.5%, which is well below the estimated limit for acceptable tracking performance. As the luminosity increases, higher machine backgrounds are expected and the excellent hit-time information in SVD can be exploited for background rejection. We have developed a method that uses the SVD hit-time to estimate the collision time (event-T0) with similar precision to the estimate based on the drift chamber. The execution time needed to compute SVD event-T0 is three orders of magnitude smaller, allowing a faster online reconstruction that is crucial in a high luminosity regime. Furthermore, the front-end chip (APV25) is operated in "multi-peak" mode, which reads six samples. To reduce background occupancy, trigger dead-time and data size, a 3/6-mixed acquisition mode, based on the timing precision of the trigger, has been successfully tested in physics runs.
Finally, concerning the radiation damage, the SVD dose is estimated by the correlation of the SVD occupancy with the dose measured by the diamonds of the monitoring and beam-abort system. Although the sensor current and the strip noise have shown a moderate increase due to radiation, we expect the detector performance will not be seriously degraded during the lifespan of the detector.

E1 / **82**

The ATLAS ITk Strip End-of-Substructure Card - From design to production

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The building blocks of the ATLAS Strip Tracker for HL-LHC are modules that host silicon sensors and front-end electronics. The modules are mounted on carbon-fiber substructures hosting up to 14 modules per side. An End-of-Substructure (EoS) card on each substructure side connects up to 28 differential data lines at 640 Mbit/s to lpGBT and VL+ ASICs that provide data serialization and 10 GBit/s optical data transmission to the off-detector systems respectively. A dedicated, magnetic-field resistant DC-DC converter provides both 1.2 and 2.5 V to the EoS using the rad-hard bPol ASICS from CERN. Overall almost 2000 EoS card need to be manufactured.
The EoS card recently went into production and we report on our first experience during production and integration. Additionally we report results from recent quality assurance tests as well as lessons learned throughout the project from design to production.

F3 / 83

Development of an active Transverse Energy Filter (aTEF) with angular-dependent electron detection for background reduction at the KATRIN experiment

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The KATRIN experiment aims at the direct measurement of the neutrino mass scale via precision endpoint spectroscopy of tritium β-decay. The current upper limit on the neutrino mass set by KATRIN is 0.8 eV/c² (90% C.L.) (Nature Physics 18, 160–166 (2022)). Despite advances in background reduction, the elevated background level prohibits to achieve its target sensitivity of 0.2 eV/c² (90% C.L.).
Our investigations showed that the special nature of the background allows in principle differentiating background (small pitch angles) from β-decay electrons (large pitch angles). Therefore, one option to reduce the background is by implementing an "active Transverse Energy Filter" (aTEF, Eur. Phys. J. C 82, 922 (2022)), which discriminates electrons at the detector based on their pitch angle. First aTEF prototypes fabricated at the University of Münster show the expected angular-selective electron detection.
This contribution presents the concept of an active Transverse Energy Filter, its fabrication process and the performance of current prototypes in a test setup. It furthermore gives an outlook on the potential for background reduction and the related sensitivity improvement from an implementation of an aTEF at KATRIN.
This work is supported by BMBF under contract number 05A20PMA and Deutsche Forschungsgemeinschaft DFG (Research Training Group GRK 2149) in Germany.

D1 / 84

ATLAS ITk Pixel Detector Overview

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In the high-luminosity era of the Large Hadron Collider, the instantaneous luminosity is expected to reach unprecedented values, resulting in up to 200 proton-proton interactions in a typical bunch crossing. To cope with the resulting increase in occupancy, bandwidth and radiation damage, the ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk). The innermost part of the ITk will consist of a pixel detector, with an active area of about 13 m2. To deal with the changing requirements in terms of radiation hardness, power dissipation and production yield, several silicon sensor technologies will be employed in the five barrel and endcap layers. Prototype modules assembled with RD53A readout chips have been built to evaluate their production rate. Irradiation campaigns were done to evaluate their thermal and electrical performance before and after irradiation. A new powering scheme – serial – will be employed in the ITk pixel detector, helping to reduce the material budget of the detector as well as power dissipation. This contribution presents the status of the ITk-pixel project focusing on the lessons learned and the biggest challenges towards production, from mechanics structures to sensors, and it will summarize the latest results on closest-to-real demonstrators built using module, electric and cooling services prototypes.

A3 / **85**

Development of the interaction trigger system for study of nucleus – nucleus collisions at BM@N/NICA experiment

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The fixed-target experiment "Baryonic Matter at Nuclotron" (BM@N) is aimed to study characteristics of hot and dense nuclear matter produced in nucleus – nucleus collisions at beam energies of 2 – 4 A GeV. The developed trigger system is an important part of the experiment and allows fast and effective selection of nucleus – nucleus interactions in a target. It includes several subsystems such as beam and multiplicity detectors, fast electronics, trigger unit with programmable logic, graphical user interface and special software for monitoring beam conditions, detector/trigger operation and communication with DAQ. The trigger system was implemented and evaluated in the recent BM@N experimental run with a Xe ion beam and a CsI target. The description of the system is presented with emphasis on its performance in the run.

A2 / **86**

Construction of the JUNO Detector

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The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose experiment with a 20 kton liquid scintillator (LS) detector of unprecedented 3% energy resolution (at 1 MeV) at 700 meter underground (1800 m.w.e.). The liquid scintillator target is contained in an acrylic sphere with a diameter of 35.4 meter, which is supported by a stainless steel latticed shell structure outside. There are about 18,000 20-inch photomultiplier tubes (PMTs) and 25,000 3-inch PMTs facing inwards and installed at the inner surface of stainless steel structure with extremely high photon coverage. The detector is located in a water pool which mitigates the natural radioactivity from the surrounding rocks. The onsite installation of the JUNO detector, which is expected to face enormous challenges

and difficulties due to the huge size and high requirement, started in early 2022 after completing the civil construction. The stainless steel structure had been almost finished except the bottom area, which is also served as the transportation path during the acrylic vessel construction, and 120,000 sets of special bolts were used during assembly. Right after the construction of stainless steel structure, the onsite installation of the acrylic vessel started from top to bottom, which requires 263 huge acrylic panels to be bulk-polymerized layer by layer. The PMTs installation follows the acrylic sphere construction. The detector will be filled 20 kton LS in the acrylic vessel and 3.5 kton ultra-pure water in the water pool next year. This talk will focus on the construction status of the JUNO detector, and some key points during stainless steel and acrylic structure installation.

D1 / **87**

The ALICE Inner Tracking System Upgrade

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The ALICE experiment at CERN is developing an upgrade of the three innermost layers of the Inner Tracking System (ITS3) vertexing detector, to be installed during the Long Shutdown 3 of the LHC (2026-28)[1]. It will consist of three truly cylindrical sensors wrapped around the beam pipe, a concept that is enabled by the flexible nature of silicon when thinned down to less than 50 µm[2]. The three layers will be installed at a distance of 30, 24, and 18 mm from the interaction point, respectively — so close that a thinner beam pipe will also be installed. Full tracker half-layers will be covered by single wafer-scale CMOS monolithic active pixel bent detectors measuring up to 10×26 cm^2 in size, manufactured in a commercial 65 nm technology developed by Tower Partners Semiconductor Co. (TPSCo). In order to build detector elements larger than the reticle size, a process called stitching is used to join detector elements to build sensors up to 300 mm in length in a single wafer. Mechanical support is provided by carbon foam spacers, dramatically reducing the material budget in the region close to the interaction point from the current $0.35\%\ X/X_0$ down to $0.05\%\ X/X_0$ per layer. The new technology also provides improved power efficiency below 20 mW/cm^2, only requiring the use of forced air for cooling.

At the core of the development, the R&D process of the sensor ASIC poses an entire new set of challenges mainly revolving around designing and validating the first wafer-scale silicon detector for high-energy physics. To this purpose, a submission named Engineering Run 1 has been delivered in April 2023 that includes a large stitched detector prototype named Monolithic Stitched Sensor (MOSS). MOSS is the first full-size stitched sensor demonstrator designed to validate manufacturing yield and feasibility of power and signal transmission. A custom readout system has been developed to test the MOSS in all of its features and evaluate its functional yield at a high level of granularity down to each single one of its 7 million pixels. This was a challenge in itself, given the nearly 3000 connections needed to operate it and the expertise required to handle, bond, and mechanically support such a huge and delicate sensor in a variety of use cases such as lab testing or test beams. This contribution will provide an overview of the detector, the MOSS prototype, and its test system, including the early results of its characterization.

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The ATLAS ITk Strip Detector for the Phase-II LHC Upgrade

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The ATLAS ITk Strip Detector for the Phase-II LHC Upgrade
ATLAS-ITK Strip Collaboration

The inner detector of the present ATLAS experiment has been designed and developed to function in the environment of the present Large Hadron Collider (LHC). At the ATLAS Phase-II Upgrade, the particle densities and radiation levels will exceed current levels by a factor of ten. The instantaneous luminosity is expected to reach unprecedented values, resulting in up to 200 proton-proton interactions in a typical bunch crossing. The new detectors must be faster and they need to be more highly segmented. The sensors used also need to be far more resistant to radiation, and they require much greater power delivery to the front-end systems. At the same time, they cannot introduce excess material which could undermine tracking performance. For those reasons, the inner tracker of the ATLAS detector was redesigned and will be rebuilt completely.

The ATLAS Upgrade Inner Tracker (ITk) consists of several layers of silicon particle detectors. The innermost layers will be composed of silicon pixel sensors, and the outer layers will consist of silicon microstrip sensors. This contribution focuses on the strip region of the ITk. The central part of the strip tracker (barrel) will be composed of rectangular short (~ 2.5 cm) and long (~5 cm) strip sensors. The forward regions of the strip tracker (end-caps) consist of six disks per side, with trapezoidal shaped sensors of various lengths and strip pitches. After the completion of final design reviews in key areas, such as Sensors, Modules, Front-End electronics, and ASICs, a large scale prototyping program has been completed in all areas successfully. We present an overview of the Strip System and highlight the final design choices of sensors, module designs and ASICs. We will summarise results achieved during prototyping and the current status of pre-production and production on various detector components, with an emphasis on QA and QC procedures.

H5 / 89

Doped cryogenic crystals for fundamental physics researches

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The electron electric dipole moment (e-EDM) is a model-independent probe of parity and time-reversal violation at energies beyond the ones that can be reached in particle colliders. The PHYDES project is an R&D experiment funded by CSN V of INFN aimed to test innovative approaches for e-EDM studies. In particular, the proposed idea is to use diatomic polar molecules, where e-EDM effects are amplified because of the large internal molecular field, embedded into cryogenic matrices made of unreactive elements. In such solids, a diatomic molecule substitutes an atom of the host matrix leading to a density of the host molecules as large as 10^{18} cm^{-3}.

The main goal of the PHYDES R&D program would be to embed Barium Fluoride (BaF) molecules in a solid matrix of para-Hydrogen (p-H2), to study their alignment with an external electric field and to verify the assumption that BaF molecules are all polarized in p-H2 matrix.

The set-up we are developing to grow cryogenic crystal of around 1 cm^3 doped with about 100 ppm of BaF, consists of five different modules. In the first one the BaF molecues are produced, ionized, accelerated and focused into the Wien Filter chamber which is necessary for mass selection. Then the molecular beam will be neutralized and cooled in order to prepare the BaF for the insertion in cryogenic crystal. In parallel we are developing an opportune system for para-Hydrogen production and storage. Finally the last chamber is the condensation chamber where p-H2 and BaF are mixed together in order to form a solid crystal through the matrix isolation technique.

The presentation will focus on the experimental results obtained untill now.

D1 / **90**

Prototype validation for the CMS Inner Tracker Phase-2 upgrade

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The **Inner Tracker** of the **CMS experiment** will be replaced during the Phase-2 upgrade in order to maintain nominal performance under the harsh conditions of HL-LHC. The main factors defining the new detector design are:
- radiation dose: 1 MeV neutron equivalent fluence of up to 2.3 x 10^16 neq/cm^2 and a total ionizing dose (TID) of up to 12 MGy (1.2 Grad);
- projected hit rates of up to 3 GHz/cm^2;
- pile-up of 140-200 collisions per bunch crossing.

The core components of the Inner Tracker making it compatible with these conditions are pixel sensors with smaller thickness and finer pitch, as well as a new readout chip with improved radiation hardness.

This contribution will give an overview of the **Phase-2 upgrade of the CMS pixel tracker**, focusing on the ongoing testing and validation of module prototypes in preparation for large-scale production. This includes wafer-level testing of readout chips, laboratory characterisation of assembled module prototypes and testing their performance with charged-particle beams.

B2 / **91**

The 3-inch PMT system and its progress at JUNO

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About 25 thousand 3-inch PMTs (SPMTs) were designed to install in JUNO detector between the gaps of about 18 thousand 20-inch PMTs (LPMTs) to enhance the detector performance, such as improving energy resolution and nonlinearity, extend JUNO physics like supernova neutrino detection and so on. Currently, all the parts of SPMT system, such as SPMTs, cables, electronics and under water boxes have already been mass produced and delivered to the JUNO site. They are being installed in the JUNO underground detector. The SPMT system and the installation progress will be presented in this talk.

B2 / **92**

The Water Cherenkov Detector of JUNO

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The Jiangmen Underground Neutrino Observatory (JUNO) is a large liquid scintillator detector being built for neutrino detection. The detector will be built in a laboratory at 700-m underground for cosmic muon-induced background reduction. The 20 kton of liquid scintillator target is in an acrylic sphere surrounded by 17612 20-inch large PMTs that compose the central detector. A 34 kton ultrapure water pool surrounds the central detector, and 2400 20-inch PMT is installed as a Water Cherenkov detector for cosmic muon detection and background reduction. On top of the water pool was a top tracker detector for muon tracking for Li9/He8 background study. The water pool's wall inner surface and the stainless steel's outer surface are covered with Tyvek reflectors to increase light collection efficiency. A water system is used for water purification and circulation to maintain high water quality for better detector performance. A set of radon removal equipment will be integrated with the water system to reduce the radon-induced background in water, with anticipation of radon concentration in water reduced to 10mBq/m^3.The main goal of JUNO is for neutrino mass ordering determination; it is also a multi-purpose experiment, such as supernova neutrino, atmospheric neutrino, solar neutrino, and nuclear decay, being also detected in addition to reactor neutrino detection. The cosmic muon detection efficiency of the water Cherenkov detector is >99%, and the cosmic muon-induced fast neutron background can also be controlled to ~0.1/day level. This presentation will cover the design and status of the Water Cherenkov detector of JUNO.

G4 / **93**

JUNO's R&D Program for Neutrinoless Double Beta Decay

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It is extremely important for future neutrinoless double-beta ($0\nu\beta\beta$) decay experiments to reach a sensitivity to effective Majorana neutrino mass $|m_{\beta\beta}|$~meV. At this level, the determination of neutrinos' Majorana nature, absolute masses and the constraints on one of two Majorana CP phases are possible, which will provide profound insights into understanding the neutrino mass origin and the observed matter-antimatter asymmetry in our Universe. The Jiangmen Underground Neutrino Observatory (JUNO), which has the largest liquid scintillator (LS) detector with extremely low background and excellent energy resolution, will be online soon. JUNO has great potential to be upgraded to search for $0\nu\beta\beta$ and to reach a sensitivity of $|m_{\beta\beta}|$~meV after its primary mission on the determination of neutrino mass ordering and the precision measurements of oscillation parameters is accomplished. The dedicated R&D program focused on the LS doping with a suitable $0\nu\beta\beta$-decaying isotope and the purification, as well as on the development of advanced techniques for background rejection, are being carried out in the past and forthcoming years. If successful, JUNO could be ready to begin searching for $0\nu\beta\beta$ decays at the turn of the next decade. This talk will report the up-to-date R&D progresses on Tellurium-doped LS development and the studies on the cosmogenic backgrounds on Tellurium.

C4 / **94**

Wavelength shift fiber enhancing PMT for the water Cherenkov detector prototype at very high energy Gamma-ray observatory

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The Southern Wide-field Gamma-ray Observatory (SWGO) is the proposal for a new ground-based gamma-ray observatory in the Southern Hemisphere, and an array of water-Cherenkov detectors (WCD) will be used to monitor the very-high-energies gamma-ray emission from the southern sky. In this report, we propose one fiber-PMT, small size photomultiplier tube (PMT) coupling with wavelength shift fiber bunch to enhance light collection efficiency, to be used as photosensor for these WCDs. This is a cost effective approach with respect to a large area PMT currently used in WCD. One WCD prototype has been built in our laboratory with this fiber-PMT, XP3960 PMT and Kuraray Y11 fiber bunch the structure of this fiber-PMT photosensor and the WCD will be introduced. The light yield and time resolution of this fiber-PMT WCD prototype has tested with cosmic ray muon, the single particle peak is clear visible with charge resolution 19% and time resolution less than 4 ns. The uniformity of this WCD is also tested with cosmic ray muon by changing the trigger prober position and direction. The simulation based on GEANT4 also is developed to optimize the performance of this detector, including the effect of detector area, water depth and fiber length. The optimized WCD design demonstrates the potential for improved performance while reducing costs and simplifying installation and maintenance processes.

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The performance of atmospheric neutrino identification in JUNO

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The Jiangmen Underground Neutrino Observatory (JUNO) with a 20 kton liquid scintillator (LS) detector is a multi-purpose underground experiment. The neutrino mass ordering (NMO) in JUNO can be determined by measuring atmospheric neutrinos with the matter effect (MSW) and measuring the spectrum modification of reactor anti-neutrinos induced by oscillations with $\Delta M_{31}{}^{2}$, respectively. The two independent methods are complementary, and the joint analysis can greatly increase the NMO sensitivity. Considering the signal efficiency and purity, flavor identification is crucial to the NMO sensitivity of atmospheric neutrino. Based on the high detection efficiency of a LS detector for neutrons and Michel electrons compared with other detector like a water Cerenkov detector, we can make full use of these particle's distribution information for particle identification (PID), particularly for the identification of neutrinos and anti-neutrinos. The features extracted from the waveforms of the photomultiplier tubes are also used. The preliminary PID strategy and results of the atmospheric neutrino based on multiple machine learning methods will be presented in this contribution.

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Radiation Hard Pixel Sensors for the Phase 2 Upgrade of the CMS Inner Tracker

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The Inner Tracker (IT) of the Compact Muon Solenoid (CMS) experiment of the Large Hadron Collider at CERN will be upgraded for the High-Luminosity LHC (HL-LHC). In the ultimate running scenario, the expected integrated luminosity at the end of the HL-LHC running phase is 4000 fb^{-1}, corresponding to a 1 MeV neutron equivalent fluence of 3.5×10^{16} cm^{-2} and a total ionizing dose (TID) of 19 MGy at the innermost layer of the IT. All the layers of the IT (except for the innermost barrel layer) will be equipped with planar n^{+}-p pixel sensors with an active thickness of 150 µm and pixel sizes of 25 µm x 100 µm. The innermost barrel layer will feature 3D silicon sensors owing to their excellent radiation hardness and lower power consumption; and it is foreseen to be exchanged at least once during HL-LHC operation. Planar and 3D prototype sensors from different producers and with a variety of pixel cell designs were bump bonded to the demonstrator readout chip (RD53A) and to the CMS prototype chip (CROC), both implemented in 65 nm CMOS technology. In this presentation, we report on an extensive qualification campaign performed over the last four years in the laboratory and at the CERN and DESY test beam facilities. The sensor-chip assemblies were tested before and after proton irradiation up to end-of-lifetime fluences of 2×10^{16}. Measurements of the hit efficiency, spatial resolution, crosstalk, and noise studies are presented. For all parameters investigated, the results meet or exceed the specifications by CMS. Based on the results of these measurements and on tracking and thermal simulations, sensor designs were chosen for the IT Upgrade and CMS has started to prepare for the production phase of pixel sensors and modules. The main lessons learned on the path to the choice of a radiation hard sensor will be summarized.

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Status of the 20-inch PMTs for the JUNO experiment

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The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose neutrino experiment with a 20 kton Liquid Scintillator central detector. The primary goal of JUNO is determination of the neutrino mass ordering by measuring the reactor antineutrinos. There are 20012 20-inch PMTs for JUNO, 17612 for the central detector and 2400 for the outer water-Cherenkov detector. To achieve the unprecedent energy resolution of 3% at 1MeV, the 20-inch PMTs will have high detection efficiency (>27%), high optical coverage (>75%), and high reliability (failure rate < 0.5% in the first 6 years) when running in the water up to 44 m in depth. Testing and Instrumentation of these PMTs have been working for several years, now installation of the PMTs for JUNO has started. In this talk, a summary of the results of PMT testing, waterproof potting and implosion protection will be presented, with a focus on the status of PMT installation and the in-situ test at JUNO.

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Advancing RPC Detectors with Alternative Eco-Friendly Gas Mixtures and Recuperation systems

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Resistive Plate Chamber (RPC) detectors, employed in the muon systems of CERN LHC experiments, are operated with gas mixtures containing C2H2F4 (R-134a) and SF6, both greenhouse gases (GHGs) with a high global warming potential (GWP). Among strategies developed by CERN Gas Team to

reduce GHG emissions, one branch is focused on studying alternative gas mixtures and one on recuperating gases from gas mixtures used in the detectors. Firstly, R-1234ze is investigated as a potential replacement for R-134a, with additional tests exploring the necessity of a fourth gas to maintain the same working point range as R-134a based gas mixture. The performance of RPCs with R-1234ze was evaluated at different gamma rates in the presence of a muon beam at the CERN GIF++ facility by measuring efficiency, streamer probability, induced charge, cluster size, and time resolution. Secondly, adding CO2 to the standard gas mixture is studied as a mid-term solution to reduce R-134a usage and decrease CO2-equivalent emissions by 15-20%. These gas mixtures were characterized using muon beams and gamma background at the GIF++ facility, and an aging test is planned with the collaboration of EP-DT Gas team, ATLAS, and CMS RPC teams. This mid-term solution is particularly relevant to the ATLAS RPC system, as its leak rate disallows the use of a recuperation system. The third strategy involves the development of an R-134a recuperation system for the standard gas mixture, with a prototype tested in 2020-2021 and a production version under operation at CMS. This recuperation system separates and recuperates R-134a from the standard gas mixture with an efficiency of approximately 80%, allowing the recovered gas to be reused and injected into the system.

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Early Performance of the Scintillating Fibre Tracker for the LHCb Upgrade

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LHCb has undergone a major upgrade during LHC LS2 (2019-2022) to cope with increased instantaneous luminosities and a 40 MHz read-out with a full software-based trigger and real-time analysis to improve on many world-best physics measurements. A light and homogeneous tracking detector based on plastic scintillating fibres has been installed downstream of the LHCb dipole magnet.
The Scintillating Fibre (SciFi) tracker covers an area of 340 m2 by using more than 10,000 km of blue emitting scintillating fibre with 250 µm diameter, enabling a spatial resolution of better than 80 µm for charged particles and a hit efficency better than 99%. Six-layer fibre mats of 2.4 m length are assembled to form individual detector modules (0.5 m x 4.8 m) consisting of eight fibre mats each. Linear arrays of Silicon Photomultipliers cooled to -40 ℃ are placed at the fibre ends. The readout of 524k channels occurs through custom-designed front-end electronics with fast 10 ns shaping, dual integrators, and a 3-comparator flash ADC to digitise the signals. An FPGA clusters the signals over threshold and outputs a barycentre to the 40 MHz DAQ farm with a total bandwidth of over 20 Tbits/sec.
At the time of the conference, the commissioning will be complete with measurements of the early performance of the detector in 2022 and 2023. The presentation will include the first results of the SciFi detector performance as well as results from SiPM irradiations studies.

A3 / **100**

Front-End Rdma Over Converged Ethernet, real-time firmware simulation

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Several physics experiments are moving (or are evaluating the possibility to move) towards new acquisition models. The tendency is to leave the hardware trigger system in favour of a complete or partial acquisition of the front-end data paired with a powerful online software event discrimination. Hardware trigger systems usually have to deal with a tight latency budget due to the narrow readout buffering. To reduce the selection inefficiencies resulting from the adoption of not optimal trigger algorithms due to the limited time budget and online computing resources, the main trigger schema is going to be revisited. The traditional first trigger level is going to be replaced by a hardware pre-processing of the data stream followed by a software online selection [1,2,3].
In a DAQ system a large fraction of CPU resources is engaged in networking rather than in data processing. The common network stacks that take care of network traffic usually manipulate data through several copies performing expensive operations. Thus, when the CPU is asked to handle networking, the main drawbacks are throughput reduction and latency increase due to the overhead added to the data transmission process. Networking with zero-copy can be achieved by adding a RDMA layer to the network stack and making dedicated hardware take care of the burden of the stack handling.
The main goal of the RDMA implementation in the detector front-end electronics is to move up the adoption of clever networking protocols to the data producer. Therefore, it is the front-end electronics that could take care of initiating the RDMA transfer towards the computing farm. In such a way it is possible to eliminate the point-to-point connection between the front-end and the back-end leaving the freedom of switching dynamically the routing to the computing nodes according to their processing availability. By appropriately choosing the network protocol for RDMA it is also possible to obtain a two-fold benefit. The possibility of adopting commodity hardware makes the DAQ system reduce reliance on custom hardware and it exploits all the advantages of a mature technology. In this way, the DAQ system gains in scalability and easiness of maintainability.
RoCE is the natural choice as it is the only industry-standard Ethernet-based RDMA solution with a multi-vendor ecosystem. In this work the main firmware block needed for the realisation of the RoCE endpoint has been implemented and verified. A real-time firmware simulation of the RoCE network stack has been developed where real network packets are exchanged between free-running Systemverilog code and the host machine via a TUN/TAP device which emulates a connection with a physical device (FPGA). The second part is devoted to show the verification process of the modified RoCE stack using the tools developed so far such as the novel simulation framework. The lightweight RoCE will be a stripped down version of the already verified firmware allowing the deployment on FPGAs with a low resource pool possible target devices could be rad-hard FPGAs used in front-end detector boards.
[1] LHCb Collaboration, LHCb Trigger and Online Upgrade Technical Design Report, CERN-LHCC-2014-016, LHCB-TDR-016
[2] CMS Collaboration, The Phase-2 Upgrade of the CMS Data Acquisition and High Level Trigger Technical Design Report, CERN-LHCC-2021-007, CMS-TDR-022
[3] Ryu, FELIX: The new detector readout system for the ATLAS experiment, JINST Volume 898, 2017

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The LHCb VELO detector: design, operation and first results

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The LHCb experiment has been upgraded during the second long shutdown of the Large Hadron Collider at CERN, and the new detector is currently operating at the LHC. The Vertex Locator (VELO) is the detector surrounding the interaction region of the LHCb experiment, responsible of reconstructing the proton-proton collision (primary vertices) as well as the decay vertices of long-lived particles (secondary vertices).
The VELO is composed by 52 modules with hybrid pixel detector technology, operating at just 5.1 mm from the beams. The sensors consist of 200 μm thick n-on-p planar silicon sensors, read out via 3 VeloPix ASICs.
The sensors are attached to a 500 μm thick silicon plate, which embeds 19 micro-channels for the circulation of the CO_2 evaporative cooling.
The VELO operates in an extreme environment, which poses significant challenges to its operation. During the lifetime of the detector, the sensors are foreseen to accumulate an integrated fluence of up to 8×10^{15} 1MeV $\mathrm{n_{eq}cm^{-2}}$, roughly equivalent to a dose of 400 MRad. Moreover, due to the geometry of the detector, the sensors will face a highly non-uniform irradiation, with fluences in the hottest regions expected to vary by a factor 400 within the same sensor.
The highest occupancy ASICs foresee a maximum pixel hit rate of 900 Mhit/s and an output data rate exceeding 15 Gbit/s. The design, operation and early results obtained during the first year of commissioning will be presented.

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Transient Studies using a Technology Computer-Aided Design and Allpix Squared combination approach

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The goal of the TANGERINE project is to develop the next generation of monolithic silicon pixel detectors using a 65 nm CMOS imaging process, which offers a higher logic density and overall lower power consumption compared to previously used processes. A combination of Technology Computer-Aided Design (TCAD) and Monte Carlo (MC) simulations are used to understand the physical processes within the sensing element and thus the overall performance of the pixel detector. The response of the sensors can then be tested in laboratory and test beam facilities and compared to our simulation results.

Transient simulations allow for studying the response of the sensor over time, such as the signal produced after a charged particle passes through the sensor. The study of these signals is important to understand the magnitude and timing of the response from the sensors and improve upon them. While TCAD simulations are accurate, the time required to produce a single pulse is large compared to the here used approach. The combination of MC and TCAD simulations reduces the simulation time and thus allows for studies that are not possible with an TCAD alone approach such as Landau fluctuations or secondary particle production. In this approach, electrostatic fields from TCAD are imported into the Allpix Squared framework, a simulation framework for semiconductor radiation detectors, and through the use of the Shockley-Ramo Theorem, the pulses induced from charges moving through the sensor are calculated.

In this contribution, the advantages of this approach and the resulting pulses obtained from the MC and TCAD simulations used as validation between the two methods, preliminary time resolution studies obtained at the DESY-II Test Beam facility, and a comparison with simulations will be presented.

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Energy response function and calibration of the FOOT calorimeter.

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The FOOT experiment aims at measuring the differential cross sections for the production of secondary fragments in interactions between light ions (C, O) and hydrogen-enriched targets, with beam energies of up to 400 MeV/u, a topic relevant for the optimization of particle therapy treatments, which can only be addressed in inverse kinematics [1]. By extending the energy range up to 800 MeV/u, the experiment will also collect valuable data for understanding fragmentation processes relevant for the design of spacecraft shielding [2].

The experiment, whose construction is almost completed, aims at identifying heavy fragments by measuring their momentum, kinetic energy, and time of flight with high resolution: 5%, 2% and <100 ps respectively. The kinetic energy will be measured with a calorimeter detector made of 320 BGO crystals coupled to SiPM photodetectors, covering a dynamic range from tens of MeVs to about 10 GeV.

Data takings, aiming at measuring the response function for different ions and at optimizing crystal intercalibration, have been conducted at HIT (Heidelberg, Germany), and at CNAO (Pavia, Italy), using 12 modules of 3x3 crystals each. The energy response between 50 and 430 MeV/u is consistent with a modified Birks function for all the ions, although the parameters depend on Z. The parameters dependency on Z has been measured, allowing to reconstruct the fragment energy. The integrated system resolution is, as expected, well below 2% over the 100-300 MeV/u range.

1. *Battistoni G, Toppi M, Patera V and The FOOT Collaboration (2021) Measuring the Impact of Nuclear Interaction in Particle Therapy and in Radio Protection in Space: the FOOT Experiment. Front. Phys. 8:568242. doi: 10.3389/fphy.2020.568242*

2. *M. Durante and F. Cucinotta, "Physical basis of radiation protection in space travel," Rev. Mod. Phys., vol. 83, no. 4, p. 1245, 2011.*

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NEWS-G: Detection of low mass WIMPs with Spherical Proportional Counters

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NEWS-G is an experiment searching for dark matter using the Spherical Proportional Counter (SPC) technique. Such detectors can operate significant mass of target, of order of kgs with meter size spheres, while keeping single ionization electron detection sensitivity. They can be filled with gaseous targets of low atomic mass such as hydrogen, helium, and neon, giving sensitivity to low mass WIMPs down to O(0.1GeV). Using multiple taget gases, the detector can characterise unexpected backgrounds and systematic effects.
The talk will cover principle of operations of the SPC and a description of the 140cm diameter detector and compact shielding, installed in the SNOLAB underground facility. The latest WIMP limits

obtained with a temporary shield at the underground laboratory of Modane (LSM, France) with methane as target gases will be presented. Preliminary results from the full detector at SNOLAB with additional gas mixtures will also be shown.
The talk will also introduce projects to improve the SPC performance, and expand their reach to coherent elastic neutrino-nucleus scattering (CEvNS).
Another contribution to this conference describes calibration of the ionisation yield from nuclear recoils using smaller SPCs.

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Operational Experience and Performance with the ATLAS Pixel detector at the Large Hadron Collider at CERN

Author: Collaboration ATLAS[None]

The tracking performance of the ATLAS detector relies critically on its 4-layer Pixel Detector. As the closest detector component to the interaction point, this detector is subjected to a significant amount of radiation over its lifetime. At the start of the LHC proton-proton collision RUN3 in 2022, the innermost layer IBL, consisting of planar and 3D pixel sensors, had received an integrated fluence of approximately Φ = 1 × 10**15
1 MeV neq/cm2.
The ATLAS collaboration is continually evaluating the impact of radiation on the Pixel Detector..
In this talk the key status and performance metrics of the ATLAS Pixel Detector are
summarised, and the operational experience and requirements to ensure optimum data quality and data taking efficiency will be described, with special emphasis to radiation damage experience. A quantitative analysis of charge collection, dE/dX, occupancy reduction with integrated luminosity, under-depletion effects, effects of annealing will be presented and discussed, as well as the operational issues and mitigation techniques adopted for the LHC Run3.

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Including radiation damage effects in ATLAS MonteCarlo simulations: status and perspectives

Author: Collaboration ATLAS[None]

Signal reduction is the most important radiation damage effect on performance of silicon tracking detectors in ATLAS. Adjusting sensor bias voltage and detection threshold can help in mitigating the effects but it
is important to have simulated data that reproduce the evolution of performance with the accumulation of luminosity, hence fluence.

ATLAS collaboration developed and implemented an algorithm that reproduces signal loss and changes in Lorentz angle due to radiation damage. This algorithm is now the default for Run3
simulated events. In this talk the algorithm will be briefly presented and results
compared to first Run3 collision data.

For the high-luminosity phase of LHC (HL-LHC) a faster algorithm is necessary since the increase of collision, event, track and hit rate imposes stringent constraints on the computing resources that can be allocated for this purpose.
The philosophy of the new algorithm will be presented and the strategy on how to implement it and the needed ingredients will be discussed.

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Studies on wide dynamic-range SiPMs with high pixel densities

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The future Circular Electron-Positron Collider (CEPC), as one of future large-scale scientific facilities for high energy lepton collider experiments, aims to accurately measure the Higgs boson, electroweak physics and the top quark. A highly granular crystal electromagnetic calorimeter is proposed within the CEPC 4th detector concept to achieve an excellent EM energy resolution of less than 3%. It is design by a homogenous calorimeter instrumented with crystal scintillator bars as the active material, and silicon photomultipliers (SiPMs) are selected as the major photosensor candidate. To cover a large energy range of a crystal detector unit (typically on the order of magnitude from 100keV to 10GeV) would lead to a stringent requirement on the SiPM dynamic range. Two promising SiPM candidates (from NDL and HPK) with a sensitive area of $3 \times 3\ mm^2$ and 6 micron and 10 micron pixel pitches respectively, have been identified for detailed studies. A dedicated test-stand has been developed to address the challenge of response calibration for the wide dynamic-range SiPMs in a typical range from single photon to the order of 100k photons.
Meanwhile, a Monte Carlo simulation model has been developed for a deeper understanding and comparisons with experimental measurements. The SiPM simulation model includes SiPM's characteristics e.g. Photon Detection Efficiency (PDE), inter-pixel optical crosstalk, after-pulse and pixel recovery time, etc.
In this contribution, the dedicated setup for characterizations of the SiPM dynamic range will be firstly presented, followed by the experimental measurements of SiPMs with high pixel densities and comparisons with the simulation predictions. To the best knowledge of the authors, these results of dynamic range measurements may be the first ones for the NDL-SiPM equipped with ~250k pixels (with the pixel pitch of 6 micron).

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The operational experience and performance of the ATLAS SCT during Run-2 and LS2, and the first impression from Run3 operations

Author: Collaboration ATLAS[None]

The ATLAS SemiConductor Tracker (SCT) restarted operations in LHC Run-3. The SCT successfully operated in LHC Run-2 (2015-2018) which came with high instantaneous luminosity and pileup conditions that were far in excess of what the SCT was originally designed tomeet. The first significant effects of radiation damage in the SCT were alsoobserved during Run-2. The operation condition of SCT from LHC Run-3 isexpected to be the same as those in Run-2. This talk will summarise the operational experience, challenges and performance of the SCT during Run-2 and LS2, and the first impression from Run3 operations. Also the observation and prospect of the radiation damage on SCT silicon strip sensors will be presented.

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CERN beamtests of CALICE scintillator-based calorimeter prototypes

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Various technological options of high granularity calorimetry are being explored and developed within the CALICE collaboration for future collider experiments. Two CALICE technological prototypes of scintillator-based calorimeter have been developed to address major challenges of system integration and to demonstrate the mass assembly capability for a final detector which typically requires one to ten million readout channels. An electromagnetic calorimetry (namely CALICE ScW-ECAL) prototype, with scintillator strips ($45 \times 5 \times 2\ \mathrm{mm}^3$) interleaved with copper-tungsten absorber was successfully constructed in 2020, which consists of 32 sampling layers with around 6700 readout channels in total and measures ($60 \times 60 \times 40\ \mathrm{cm}^3$ in dimensions and 250 kg in weight. The construction of a sampling hadronic prototype (namely CALICE CEPC-AHCAL) with 40 longitudinal layers of scintillator tiles ($40 \times 40 \times 3\ \mathrm{mm}^3$) and iron plates was completed in 2022. The AHCAL prototype is equipped with totally 12960 readout channels and measures around 1 cubic meter in dimension and roughly 5 tons in weight. Both two prototypes are based on silicon photomultiplier (SiPM) readout and each scintillator strip/tile is directly coupled with a SiPM individually (i.e. the "SiPM-on-Tile" design developed within the CALICE collaboration).

A successful beamtest campaign was performed in late 2022 at the CERN SPS H8 beamline for the ScW-ECAL and AHCAL prototypes with high-energy beam particles in the momentum range of 10-160 GeV and decent statistics of data samples was collected, which enable detector performance evaluation, detailed studies of shower profiles in the 3D space and time domain, Geant4 simulation validation as well as particle-flow studies.

This contribution will present the highlights of the prototype developments. Results of the detector performance from beamtest data analysis and studies of electromagnetic and hadronic shower properties will be followed. As further beamtests of these two prototypes at CERN PS and SPS are foreseen to happen in April and May, 2023, preliminary results of these new beamtest campaigns could also be expected.

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Development of a novel high granularity crystal electromagnetic calorimeter

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Motivated by the physics programs that aim at precision measurements of the Higgs, W and Z bosons, as well as the top quark, future lepton colliders (e.g. the Circular Electron Positron Collider, or CEPC) require an excellent calorimetry system to achieve the unprecedented jet energy resolution. The CEPC team has proposed a new detector concept named "the 4th detector concept". A major motivation is to significantly improve the Boson Mass Resolution (BMR) of better than 3% compared to 4%, which corresponds to the performance of the baseline detector proposed in the CEPC Conceptual Design Report (CEPC CDR). As a key sub-detector of "the CEPC 4th detector concept", the novel high granularity crystal electromagnetic calorimeter (ECAL) is designed to achieve an excellent jet reconstruction and an optimal EM energy resolution of $2-3\ \%/\sqrt{E(GeV)}$ with the homogeneous structure and excellent three-dimensional spatial and temporal resolutions.

Extensive R&D efforts have been carried out to assess the potential and requirements of the crystal ECAL with dedicated Geant4 full simulation, ranging from the ECAL detector units to the full

sub-detector system. Hardware activities, which focus on characterizing crystals and silicon photomultipliers (SiPMs), have been conducted to provide solid inputs for simulation validation. The physics performance evaluation studies are ongoing with particle-flow algorithm "Arbor", which is being optimized for the crystal ECAL as well as the general "4th detector concept". Meanwhile, small-scale crystal modules are currently under development for beam tests to evaluate the performance of electromagnetic showers and to address critical issues at the system-level.

This contribution will introduce the crystal ECAL design and optimizations, the latest progress on the performance evaluation, crystal-SiPM measurements and simulation validation. Preliminary beamtest results could also be expected.

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Electronics design and testing of the CMS Fast Beam Condition Monitor for HL-LHC

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The high-luminosity upgrade of the LHC (HL-LHC) brings unprecedented requirements for precision bunch-by-bunch online luminosity measurement and beam-induced background monitoring with 1 second time granularity, creating the need for new high-precision instrumentation at CMS. A key component of the CMS Beam Radiation Instrumentation and Luminosity system is a stand-alone luminometer, the Fast Beam Condition Monitor (FBCM), which is fully independent from the CMS central trigger and data acquisition services and able to operate at all times with an asynchronous readout. FBCM utilizes a dedicated front-end ASIC to amplify the signals from CO2-cooled silicon-pad sensors with a few nanoseconds timing resolution also enabling the measurement of beam-induced background. Front-end (FE) electronics are subject to high radiation conditions with an expected 1 MeV neutron equivalent fluence of about 2.5e15 at the sensor location, thus all components are radiation hardened: sensors, ASICs, high-speed optical transceivers and voltage regulators. FBCM uses a modular design with two half-disks of twelve modules at each end of CMS, with 4 service modules placed around the disk edge at a radius of reduced radiation fluence. The electronics system design adapts several components from the CMS Tracker for power, control and read out functionalities. The dedicated FBCM ASIC contains 6 channels with 600e- ENC and adjustable shaping time to optimize the noise with regards to sensor leakage current. Each channel outputs a single binary high-speed asynchronous signal carrying the Time-of-Arrival and Time-over-Threshold information. The chip output signal is sent via a radiation-hard gigabit transceiver and an optical link to the back-end electronics for analysis. The ASIC has slow control for internal testability features,

calibration and configuration registers access. A dedicated test system is designed for the FBCM FE electronics, it provides a modular and flexible setup for all testing needs throughout the project stages: initial ASIC validation test, irradiated sensor and ASIC tests and system level testing with the full read-out chain. The paper reports on the design, readout architecture and testing program for the FBCM electronics.

G2 / 113

Development of highly granular hadronic calorimetry with glass scintillator tiles

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Future electron-positron colliders (e.g. the Circular Electron Positron Colllider, namely CEPC) impose stringent requirements on the energy resolutions of hadron and jets for the precision physic programs of the Higgs, Z, W bosons and the top quark. To address the challenges, one of the state-of-art calorimetry options is high-granularity calorimetry based on the particle flow algorithms (PFA). The CEPC team has proposed a new detector concept named "the 4th detector concept". A major motivation is to significantly improve the Boson Mass Resolution (BMR) of better than 3% compared to 4%, which corresponds to the performance of the baseline detector proposed in the CEPC Conceptual Design Report (CEPC CDR).
As a key sub-detector in "the CEPC 4th detector concept", a new design of highly granular sampling hadronic calorimetry (HCAL) has been proposed, which consists of sensitive layers with glass scintillator tiles and absorber plates. A major motivations is to significantly improve the hadronic energy resolution with a higher energy sampling fraction and a significantly lower energy threshold, which in turn requires the merits of high density and high light yield for the glass scintillator materials. A simulation model with Geant4 has been developed for the design optimizations of the glass scintillator HCAL and quantitative hadronic performance with single hadrons. Furthermore, physics potentials of the PFA performance have also been evaluated in the CEPC full detector simulation. Highlights of the expected hadronic performance and hardware developments will be presented in this contribution. Future beamtest preparations of a few glass scintillator tiles are currently ongoing and preliminary results could be expected as well.

C5 / 114

Beam tracker system for the BM@N/NICA experiment

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A new beam tracker system for BM@N experiment was developed and implemented in the recent experimental run with Xe beam. The tracker consists of three double sided silicon detectors, which determine beam ion trajectory in each event. Design parameters of the system are driven by the requirements of the experiment: ability to operate in beams of light and heavy ions, to cover relatively large transverse width of the beam profile, and to measure with sufficient accuracy the beam ion position and impact angle at the target. Each detector has 61x61 mm^2 active area, 128 strips on each of the p+ and n+ sides (450 μm pitch), with orthogonal orientation of strips. The detectors are 175 μm thick, placed in vacuum, and positioned 1 m apart from each other along the beam

direction. The front-end electronics of the detectors is developed based on ASIC VATA64HDR16.2 (IDEAS, Norway) with large dynamic range (-20 pC / +50 pC). The read-out electronics is placed outside of vacuum and is not subject to radiation damage. The detailed characteristics of the beam tracker detectors and front-end electronics are presented, as well as operational performance of the system in the experiment with Xe beam.

H1 / **115**

The ATLAS Level-1 Topological Processor: Phase-I upgrade and Phase-II adaptation

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The instantaneous luminosity of the LHC in Run 3 is increased up to 3x10^34 cm^-2s^-1, bringing the need for the upgrade of the ATLAS detector, including the trigger system.

The new Phase-I L1Topo system, which replaces its Phase-0 predecessor, processes data from the jet, electromagnetic, and global Feature Extractors and the upgraded Muon to Central Trigger Processor Interface to perform topological and multiplicity triggers. The L1Topo system consists of three modules, each hosting two processor FPGAs (Xilinx Ultrascale+ 9P). High-speed optical transceiver modules are used for the modules' real-time data path to support data transmission at speeds up to 11.2 Gb/s per link.

The L1Topo firmware is composed of a large number of sort/select, decision, and multiplicity algorithms, that are automatically assembled and configured based on the provided trigger menu.

The fully synchronous, very low latency, parallel implementation of the Phase-I Topological firmware is inadequate for the new Phase-II operational environment, where a significantly higher latency budget with a substantially tighter resource budget is available. Therefore, all the developed algorithms, including the automatic menu-based firmware assembly functionality, are being adapted for use within the Global Trigger System, coming into play after the Phase-II upgrade of the ATLAS detector.

A detailed overview of the Phase-I L1Topo hardware and firmware will be provided. Phase-II related firmware adaptations will also be discussed.

B4 / **116**

Long-term Performance Studies of Resistive Plate Chambers with Environmentally Friendly HFO/CO2 Gas Mixtures at the GIF++ Facility

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The development and evaluation of environmentally sustainable gas mixtures for Resistive Plate Chambers (RPCs) have become increasingly important due to the high Global Warming Potential (GWP) associated with the currently mostly used gases, C2H2F4 and SF6. The ECOGAS collaboration, which includes ATLAS, CMS, ALICE, LHCb/SHiP, and the CERN EP-DT group, is dedicated to investigating the long-term performance of RPC detectors under irradiation using eco-friendly

HFO/CO2-based gas mixtures. These long-term tests conducted at the GIF++ facility complement existing research on alternative gas mixtures aimed at reducing greenhouse gas emissions. The experimental setup and the tools utilized to monitor the system are designed to study the impact of HFO/CO2 gas mixtures on RPC performance over extended periods and high integrated charge. This abstract presents the latest results from test beams and aging test and it discusses future plans for continued evaluation of environmentally friendly gas mixtures in the context of RPC detectors.

C3 / **117**

Powering SiPMs and front-end electronics in HEP detectors: the ALDO2 ASIC

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SiPMs (also known as MPPCs) are becoming widely used in HEP experiments thanks to their excellent photon counting performance, compactness, and immunity to magnetic fields.
Powering these devices, apparently simpler than high-voltage photosensors, still poses several challenges due to the dependence of their performance on bias voltage and the significant increase of leakage current after radiation damage.
To help integrate SiPMs in HEP detectors, we designed the ALDO2 ASIC, a rad-hard, multi-function, adjustable, low dropout linear regulator in onsemi I3T80 0.35 μm HV CMOS technology.
ALDO2 allows for precise and stable regulation of the bias voltage of SiPM arrays, as well as its adjustment using an external DAC.
By providing a mirrored copy of the output current, the chip enables on-detector I-V curve characterization and fine-tuning of the SiPMs' working points as radiation damage accumulates.
The chip also features auxiliary low-dropout linear regulators to filter and stabilize the supply voltage of the front-end chips, making it a complete power management solution for SiPM-based readout systems in HEP detectors, like the CMS Barrel Timing Layer (BTL) and the High-granularity Calorimeter (HGCAL).
In this contribution, we present a general overview of the chip and the powering scheme adopted, together with selected measurements and radiation hardness qualification of samples from the final production.

E2 / **118**

Testing of back-end card(BEC) for JUNO experiment

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Jiangmen Underground Neutrino Observatory (JUNO) is a neutrino experiment currently under construction in China. Its main goal is to determine the mass hierarchy of neutrinos, and it will do this by detecting the antineutrinos produced by nuclear reactors using a large liquid scintillator (LS) volume. The JUNO detector will be instrumented with around 20,000 large photomultiplier tubes(20-inch), and the JUNO electronics readout system is composed of two parts: (i) the underwater front-end electronics system and (ii) the back-end electronics system.
The back-end card(BEC) is a critical component of the JUNO experiment's back-end electronics system, as it links approximately 7,000 underwater electronics boxes to the trigger system. Each BEC is comprised of a base board, 6 mezzanine cards and 1 TTIM (Trigger/Timing interface Mezzanine) module, located inside a mechanical box. A total of 180 boxes have been produced and installed at

the JUNO site. This presentation will focus on the testing of the BECs, which include both self-tests and combined tests.

B2 / 119

Production line and quality assurance of mPMT photosensors for WCTE.

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The Water Cherenkov Test Experiment (WCTE) is a CERN experiment that aims to test several technologies and techniques related to water Cherenkov detectors. It will consist of approximately 120 multi-PMT photosensors placed in a water tank (~3.8 m diameter, ~3.6 m height, total water mass ~41 tonnes). Each multi-PMT consists of nineteen 3" PMTs and the associated front-end electronics enclosed in a water-tight pressure vessel. A similar system will be used in the Intermediate Water Cherenkov Detector (IWCD) and, with some modifications, in the far detector of the Hyper-Kamiokande experiment.

This talk briefly covers the production process of the multi-PMT system along with the adopted procedures for the assembly and quality assurance control and tools. Also, we will present the methods used to evaluate the performance of the electronics and optical parameters of the multi-PMTs. Finally, the quality assurance data collected from a sample module will be discussed.

D2 / 120

SoLAr detector small scale prototype

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The LArTPC technology, in the last decade has witnessed several novelties, preparing the stage for the next generation of large scale long baseline neutrino experiments such as DUNE.
The SoLAr detector concept aims to extend the sensitivities of such detectors to the MeV energy range, and expands their physics reach to precision measurement of solar and supernovae neutrinos. The core concept is centered around an integrated charge-light readout plane, consisting of pixel pads for charge collection and VUV SiPMs for direct detection of LAr scintillation light. The main challenges are to achieve low energy thresholds with an excellent energy resolution and successfully perform background rejection using pulse shape discrimination.
A staged prototyping program is planned to demonstrate the technology viability of the detector concept step by step. In October 2022, a small scale SoLAr prototype was constructed and tested in LAr at Bern University. Here we present the results from the first prototype run with cosmics muons and discuss the roadmap to a ton scale demonstrator at Boulby Underground Laboratory.

A5 / 121

Innovative hybrid photodetector based on the Timepix4 ASIC as pixelated anode

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An innovative single-photon detector based on a vacuum tube with transmission photocathode, a microchannel plate and the Timepix4 CMOS ASIC [[1]] as read-out anode is presented. This photodetector will allow to detect up to 1 billion photons per second over an area of 7 cm^2, allowing to simultaneously achieve a position resolution of $5-10$ μm and a timing resolution better than 100 ps. The detector is based on about 230 thousand channels with analog and digital front-end electronics. The ASIC features a data-driven architecture producing up to 160 Gb/s that are handled by FPGA-based external electronics with flexible design, used as well as control board. These performances will enable significant advances in particle physics, life sciences, quantum optics or other emerging fields where the detection of single photons with excellent timing and position resolutions are simultaneously required.

Recent timing resolution measurements of the Timepix4 ASIC will be presented, obtained using a 100 μm thick n-on-p Si sensor illuminated by an infrared pulsed picosecond laser. The measured timing resolution shows a non-negligible dependence on the Voltage-Control-Oscillator frequency, requiring a frequency mapping and calibration over the whole matrix. A timing resolution of about 60 ps for the Time-to-Digital Converter itself has been measured, and of 110 ps when also considering the contributions from signal generation in the silicon sensor and the electronics front-end.

E4 / 122

Progress on a novel coextruded high-voltage feedthrough concept for DarkSide-20k

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As noble liquid time projection chambers get larger, so does the high voltage (HV) requirements required to maintain strong electric drift fields. HV feedthrough (FT) designs become increasingly complex given limitations imposed by cryogenic temperatures, HV, and cryostat geometry. In this talk, progress on a novel HV FT using a coextruded multi-layered coaxial cable is presented for DarkSide-20k, emphasizing design considerations implemented to the unique, fully-plastic cable construction.

DarkSide-20k is a 49.7 ton active volume dual-phase underground argon time projection chamber (TPC) that will perform the search for dark matter reaching the sensitivity 4.9e10-48cm2 with for 90% C.L. exclusion for a 1TeV/c2 over a 10yr run.

G3 / 123

The CMS ECAL upgrade for precision timing measurements at the High-Luminosity LHC

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The High Luminosity upgrade of the LHC (HL-LHC) at CERN will provide unprecedented instantaneous and integrated luminosities of around 5 x 10^34 cm-2 s-1 and 3000/fb, respectively. An average of 140 to 200 collisions per bunch-crossing (pileup) is expected. In the barrel region of the Compact Muon Solenoid (CMS) electromagnetic calorimeter (ECAL), the lead tungstate crystals and avalanche photodiodes (APDs) will continue to perform well, while the entire readout and trigger electronics will be replaced.

A dual gain trans-impedance amplifier and an ASIC providing two 160 MHz ADC channels, gain selection, and data compression will be installed. The noise increase in the APDs, due to radiation-induced dark current, will be mitigated by reducing the ECAL operating temperature. The trigger primitive formation will be moved off-detector and performed by powerful and flexible FPGA processors.

The upgraded ECAL will greatly improve on the time resolution for photons and electrons with energies above 10 GeV. Together with the introduction of a new timing detector designed to perform measurements with a resolution of a few tens of picoseconds for minimum ionizing particles, the CMS detector will be able to precisely reconstruct the primary interaction vertex even with 140-200 pileup interactions per event.

The design of the full ECAL barrel readout chain and the status of the individual component R&D will be presented and results from recent test beam campaigns at the CERN SPS, using electron beams with energies of up to 250 GeV, will be summarised. In particular, we will present measurements of the energy and timing resolution performance of the latest HL-LHC ECAL readout electronics prototypes.

C1 / 124

Achieving the optimal calibration and performance of the CMS Electromagnetic Calorimeter in LHC Runs 2 and 3

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Many physics analyses using the Compact Muon Solenoid (CMS) detector at the LHC require accurate, high resolution electron and photon energy measurements. Excellent energy resolution is crucial for studies of Higgs boson decays with electromagnetic particles in the final state, as well as searches for very high mass resonances decaying to energetic photons or electrons. The CMS electromagnetic calorimeter (ECAL) is a fundamental component of these analyses, and its energy resolution is crucial for the Higgs boson mass measurement. It also provides a measurement of the electromagnetic component of jets, and contributes to the measurement of calorimeter energy sums, both of which are important for a wide range of CMS physics analyses.

The energy and timing response of the ECAL has been precisely calibrated exploiting the full Run 2 (2015-18) dataset, and has been used for the legacy reprocessing of these data. A dedicated calibration of each detector channel has been performed. This talk will summarize the calibration techniques,

the improved ECAL performance that has been achieved, and will describe how this impacts on the sensitivity of the Higgs mass measurement in the H->ZZ->4l and H->gg channels.

The calibration plans that are being developed to maintain the optimum ECAL performance during LHC Run 3 (2022-25) will also be discussed, and results from the first year of operation in 2022 will be shown. A new system has been developed to automatically execute the calibration workflows during data taking in Run 3. This new development aims to reduce the time needed to provide the best possible performance for physics analyses by one order of magnitude, and the status, plans, and operational experience with this system will be described.

B5 / 125

Deep learning techniques for energy clustering in the CMS electromagnetic calorimeter

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The reconstruction of electrons and photons in the Compact Muon Solenoid (CMS) detector depends on topological clustering of the energy deposited by an incident particle in different crystals of the electromagnetic calorimeter (ECAL). These clusters are formed by aggregating neighbouring crystals according to the expected topology of an electromagnetic shower in the ECAL.

The presence of upstream material causes electrons and photons to start showering before reaching the ECAL. This effect, combined with the 3.8T CMS magnetic field, leads to energy being spread in several clusters around the primary one. It is essential to recover the energy contained in these satellite clusters to achieve the best possible energy resolution. Historically, satellite clusters have been associated to the primary cluster using a purely topological algorithm which does not attempt to remove spurious energy deposits from additional pileup interactions (PU). The performance of this algorithm is expected to degrade during LHC Run 3 (2022+) because of the larger average PU levels and the increasing levels of noise due to the ageing of the ECAL detector.

New methods are being investigated that exploit state-of-the-art deep learning architectures like Graph Neural Networks (GNN) and self-attention algorithms. These more sophisticated models improve the energy collection and are more resilient to PU and noise. This talk will cover the challenges of training the models and the opportunities offered by the deep learning techniques.

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Precision Timing at High-Luminosity LHC with the CMS MIP Timing Detector

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The MIP Timing Detector (MTD) is a new sub-detector planned for the Compact Muon Solenoid (CMS) experiment at CERN, aimed at maintaining the excellent particle identification and reconstruction efficiency of the CMS detector during the High-Luminosity LHC (HL- LHC) era. The MTD will provide new and unique capabilities to CMS by measuring the time-of-arrival of minimum ionizing particles with a resolution of 30 - 40 ps at the beginning of HL-LHC operation. The information provided by the MTD will help disentangle ~200 nearly simultaneous pileup interactions occurring in each bunch crossing at LHC by enabling the use of 4D reconstruction algorithms. The MTD will be composed of an endcap timing layer (ETL), instrumented with low-gain avalanche diodes, as well as a barrel timing layer (BTL), based on LYSO:Ce crystals coupled to SiPMs. In this talk we present an overview of the MTD design, describe the latest progress towards prototyping and production, and show test beam results demonstrating the achieved target time resolution.

C2 / 127

Testing of the 20-inch PMTs for the JUNO experiment

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The JUNO detector, a 20 kt liquid-scintillator detector currently under construction, is aimed at measuring the neutrino mass ordering as its primary physics goal. An excellent energy resolution of at least 3 % at 1 MeV is required. To achieve this energy resolution, stringent requirements are applied to all the PMTs. Up to now, more than 20,000 20-inch PMTs have been accepted after a detailed test started from 2017 to 2021. During the test, detailed parameters of all PMTs were measured. Currently, the installation of JUNO is going on including PMTs, and a functionality test is scheduled during the installation. This poster presents the test results from the acceptance test and the current in-situ test, covering the PDE, DCR, TTS, charge resolution, etc.

C3 / 128

TID effects study on the monitoring system of the RD53 chip

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The High-Luminosity LHC upgrade aims to increase the instantaneous luminosity of the LHC machine to a nominal value of 5×10^{34} $cm^{-2}s^{-1}$. During the Long Shutdown 3 (2026-2028), ATLAS and CMS silicon tracking systems will be entirely replaced and the main design goals include the capability to deal with high hit and data rates, the increase in granularity, and improved radiation tolerance to cope with fluences of up to 2×10^{16} n_{eq}/cm^2 and a Total Ionizing Dose (TID) of up to 1 Grad.

The RD53 collaboration has been working since 2014 on the development of pixel chips for the future CMS and ATLAS upgrades. This work has recently led to the development and submission of the ATLAS RD53 production chip (ITkPixV2) which is using the 65 nm CMOS process and containing 153600 pixels of 50 $\mu m \times 50$ μm.

Several TID test campaigns with Xray sources were already done on the full-size pre-production chip under low temperature (same conditions as for the inner detector) and have shown that the chip continues to work correctly up to 1 Grad. However, these tests have shown that some analog voltage and current values can shift by about 8%. It is therefore important to monitor the different sensitive voltages and currents in the chip in order to measure the variation and possibly adjust them if necessary.

The monitoring system implemented in the RD53 front-end chip is based on a 12-bit ADC associated with a multi-channel multiplexer. It allows the digitization of different sensitive parameters in the chip, particularly the voltages issued from the on-chip temperature sensors required for the off-line temperature calculation. The dependence of the ADC reference voltage (V_{refADC}) on the total ionizing dose results in a high drift of the temperature measured through the ADC, making the measurement unacceptable.

A new temperature measurement approach not dependent on the V_{refADC} shift is proposed. It provides more precise temperature measurement even at high radiation levels. Based on this, a correction method for the V_{refADC} value is foreseen to be applied regularly during the operation of the pixel detector to increase the accuracy for the digitization of voltages or currents in the RD53 chip.

The purpose of this presentation is to give a general overview of the RD53 chip architecture, in particular the monitoring system implemented inside the chip. Next, the TID test results for the monitoring bloc are presented to show that the shift of the V_{refADC} due to the TID has the most significant impact on the measurement accuracy and results in an unacceptable loss of accuracy for temperature measurement. Afterwards, the new temperature measurement approach that does not use the V_{refADC} value is presented to show that better accuracy can be achieved. Finally, the method to be followed to ensure more accurate voltages and currents monitoring despite dose effects on the ADC reference voltage is shown and discussed.

G4 / 129

LEGEND: Background-free hunt for the neutrinoless double-beta decay

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The discovery that neutrinos are Majorana fermions would have profound implications for particle physics and cosmology. The Majorana character of neutrinos would make neutrinoless double-beta ($0\nu\beta\beta$) decay, a matter-creating process without the balancing emission of antimatter, possible. The LEGEND Collaboration pursues a phased, ^{76}Ge-based double-beta decay experimental program. The first phase, LEGEND-200, deploys up to 200 kg of germanium detectors enriched in ^{76}Ge. A background index of $2 \cdot 10^{-4}$ counts/(keV kg yr) will be achieved. With that background index, when integrated over the exposure, less than one background event in the region around the expected peak position of the $0\nu\beta\beta$ decay will be accumulated. It constitutes a quasi-background-free operation of LEGEND-200, enabling a potential discovery of the $0\nu\beta\beta$ decay at a half-life of at least 10^{27} years. The second phase, LEGEND-1000, will deploy 1000 kg of enriched germanium and reach a discovery potential above 10^{28} years. This talk will portray how LEGEND utilizes high-purity materials, novel sub-detector systems, and sophisticated analysis tools to obtain a quasi-background-free energy spectrum. Furthermore, first results from the currently ongoing data-taking period of LEGEND-200 are presented.

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ATLAS Tile Calorimeter Temperature Data Analysis on a Continuous Basis

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This paper compares the historical temperature data of the ATLAS Tile Calorimeter (TileCal) drawers, extracted from the Detector Control System (DCS). ATLAS TileCal is an experimental tool used in particle physics for measuring the energy of particles. The TileCal DCS continuously monitors all the hardware and infrastructure for each subsystem. The Tile-in-One (TiO) tool is used to visualize and analyze this temperature study. The TiO is a collection of small, independent web tools called plugins. Plugins assess the quality of data and conditions for ATLAS TileCal. A change in temperature inside the drawers alters the photomultiplier tube (PMT) gain, resulting in readout electronics that give null results or data with lots of errors. Implying that those results may not be used for physics data. The TileCal drawers are water-cooled using a circuit below atmospheric pressure to prevent leaks, maintain stable temperatures, maintain constant PMT gain, and finally, maintain the stability of the electronics. A comparative analysis is done to determine the development of the leaks or improvements achieved in the cooling system and the stable values of the temperature in the drawers. The work aims to continuously study the variation of temperature in the module over a short period of time using the TiO platform and display it to a user in a friendly and intuitive manner using contemporary web technologies. The DCS provides temperature data through a dedicated interface called the DCS Data Viewer (DDV). The TiO temperature plugin is being developed by having the proper scripts that will easily query TileCal DCS using the DDV server. Currently, the temperature data is extracted and subsequently transformed into a form suitable for the visualizing library. The plots can be interacted with using the visualization tool. The biggest focus is on having the temperature plugin be stable and be able to display the status of the whole detector to be able to detect temperature problems at an early stage.

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Detector challenges of the strong-field QED experiment LUXE at the European XFEL

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The LUXE experiment aims at studying high-field QED in electron-laser and photon-laser interactions, with the 16.5 GeV electron beam of the European XFEL and a laser beam with power of up to 350 TW. The experiment will measure the spectra of electrons, positrons and photons in expected ranges of 10^{-3} to 10^{9} per 1 Hz bunch crossing, depending on the laser power and focus. These measurements have to be performed in the presence of low-energy high radiation-background. To meet these challenges, for high-rate electron and photon fluxes, the experiment will use Cherenkov radiation detectors, scintillator screens, sapphire sensors, as well as lead-glass monitors for backscattering off the beam-dump. A four-layer silicon-pixel tracker and a compact electromagnetic tungsten calorimeter will be used to measure the positron spectra. The layout of the experiment and the expected performance under the harsh radiation conditions will be presented. Particular attention will be devoted to the sapphire sensors gamma beam profiler (GBP) which should provide a 5 um precise Compton-scattered gammas beam profile width, which in turn, will allow a 5% determination of the absolute laser field intensity experienced by the electron beam. This performances is quite challenging, given the high irradiation dose experienced by the GBP (about 1 MGy/year). The use of sapphire sensors in high energy physics experiments is quite novel, and details will be given on the R&D performed until now to assess their performances in the harsh environment of the LUXE experiment.
The experiment has received stage 1 critical approval (CD1) from the DESY management and is about to publish its technical design report (TDR). It is expected to start running in 2025/26.

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Simulating monolithic active pixel sensors: A technology-independent approach using generic doping profiles

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The optimisation of the charge collection behaviour in the sensitive region of CMOS sensors with nonlinear electric fields requires precise simulations, and this can be achieved by a combination of finite-element electrostatic field simulations and Monte Carlo methods. Monolithic active pixel sensors (MAPS) produced using commercial CMOS imaging processes are attractive in a particle physics context, as they allow for a reduced material budget and reduction of production complexity and cost compared to hybrid sensors. The use of commercial processes enables relatively cheap large-scale production of sensors, but it also means that precise information of the doping concentrations and manufacturing process may not be publicly available. Exact predictions of sensor behaviour are thus difficult to make, as the detailed electric field configuration in the sensitive material is highly dependent on the extent and concentration of different doping regions in the silicon.
This talk aims to demonstrate that by making basic assumptions and performing simulations based on the fundamental principles of silicon detectors and using generic doping profiles, performance parameters of MAPS can be inferred and compared for different sensor geometries. A procedure for this will be described in detail, along with example results. The described procedure utilises Sentaurus TCAD and Allpix Squared, and serves as a toolbox for performing sensor response simulations without detailed knowledge of the sensor doping concentrations and manufacturing process.

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Loading of ATLAS ITk pixel module on multi flavour local supports

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For the HL-LHC upgrade the current ATLAS Inner Detector is replaced by an all-silicon system. The pixel detector will consist of three different subsystems with different mechanical support structures, resulting in an actively instrumented area of about $13m^2$. The Outer Barrel is made of longerons and inclined half-rings, the Outer Endcaps is made of half-rings and the Inner System consists of staves and rings. Prototypes of all flavours of support structures were loaded with pixel modules based on the RD53A readout chip. The different loading techniques, used in the different loading sites for the different support structures, are illustrated and discussed. The techniques range from being based on high precision positioned jig tools to multi-functional pick-and-place head on a robotic gantry.
After the successful loading, the performance of these first large scale detector prototype structure have been carefully evaluated ensuring also the electrical functionality of the modules after the loading process in a larger system.
The overview gives emphasis on the loading techniques of the pixel modules on the local support as well as their subsequent performance qualification.

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ARIADNE+: Large Scale Demonstration of Fast Optical Readout for Dual Phase LArTPCs at the CERN Neutrino Platform

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Optical readout of large scale dual-phase liquid Argon TPCs is an attractive and cost effective alternative to charge readout. Following the successful demonstration of 3D optical readout with the ARIADNE 1-ton detector, the ARIADNE+ experiment was deployed using the protoDUNE "cold box" at the CERN neutrino platform imaging a much larger active region of 2mx2m. ARIADNE+ uses 4 Timepix3 cameras imaging the S2 light produced by 16 novel, patented, glass THGEMs. ARIADNE+ takes advantage of the raw Timepix3 data coming natively 3D and zero suppressed with a 1.6 ns timing resolution. Three of the four THGEM quadrants were visible readout with the fourth featuring a VUV light image intensifier, thus removing the need for wavelength shifting altogether. Cosmic muon events were recorded successfully at stable conditions providing the first demonstration for its use in kton scale experiments such as DUNE.

In my talk I will be discussing in detail the innovative ideas that make ARIADNE+ unique and the benefits that come with these technologies. These include, but are not limited to, TPX3Cams, PEN wavelength shifting, a chemically etched stainless steel extraction grid, Invar support structure and a new way to manufacture glass THGEMs. Future plans and a road map towards an even larger demonstration using the ProtoDUNE cryostat itself for a dedicated dual phase optical run will also be discussed.

A4 / 135

Machine learning based reconstruction techniques for CMS HG-CAL

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Nearly all physics analyses at CMS rely on precise reconstruction of particles from their signatures in the experiment's calorimeters. This requires both assignment of energy deposits to particles and recovery of various properties across the detector. These tasks have traditionally been performed by classical algorithms and BDT regressions, both of which rely on human-engineered high level quantities. However, bypassing human feature engineering and instead training deep learning algorithms on low-level signals has the potential to further recover lost information and improve the overall reconstruction. We have therefore developed novel algorithms for particle reconstruction based on graph neural networks, which allow us to represent the energy deposits recorded in the calorimeter directly in our models. In this presentation we will show the performance of our GNN architecture applied to energy reconstruction in test beam data for the CMS High-Granularity Calorimeter (HGCAL), planned for operation in the HL-LHC, which have shown an unprecedented improvement in the energy resolution of single hadrons compared to traditional rules based methods. Furthermore, we will discuss the new particle flow algorithm designed for HGCAL to do end-to-end particle reconstruction which uses graph architectures to build 3D particle showers.

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Design and prototyping of large-scale flex circuits for the ATLAS ITk Pixel detector

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The tight space constraints of the ATLAS ITk Pixel system motivate the design of large-scale flex circuits for carrying low-voltage power, high-voltage sensor bias, and command/data transmission. These circuits extend over long distances in the barrel or large areas in the endcap rings, and they pose unique design challenges. We report on the design and prototyping of large-scale flex circuits for the ATLAS ITk Pixel system, with a focus on technical issues encountered and lessons learned.

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System tests of the ATLAS ITk planar and 3D pixel modules

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A new all-silicon Inner Tracker (ITk) has been designed for the ATLAS experiment at the HL-LHC. As part of this, a new pixel detector consisting of a total area of approximately 12m2, will be constructed with planar and 3D pixel modules, mounted onto ring and stave shaped low mass carbon-fibre fibre support structures. The data will be transmitted optically to the off-detector readout system. To save material in the servicing cables, serial powering is employed for the supply voltage of the readout ASICs. Together, these structures are arranged on larger structures to provide tracking up to a pseudo rapidity of 4.0. In order to validate the design of this new tracker, large scale prototyping programmes are being carried out by all subsystems. A series of system tests has been performed, with some of these prototypes, to assess the performance of modules arranged into serial power chains mounted on to realistic mechanical structures. In this report, the prototype loaded local supports and test infrastructure is described. The key results of the tests are presented

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Straw Tracker of the future Spin Physics Detector at NICA collider

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The Spin Physics Detector (SPD) at the NICA collider at JINR is being developed to measure the nucleon spin structure. Polarized proton and deuteron beams will collide at the centre-of-mass energy up to 27 GeV in the proton-proton collision mode, with instantaneous luminosity up to 1e32 Hz/cm2. Tracks of charged particles will be measured in the magnetic field of a superconducting magnet with straw-based tracking system. Besides of the track coordinate measurements, the tracker will be used

as a part of the particle identification system (PID). The barrel part of the tracker will be made of thin-wall straw tubes produced with ultrasonic welding of a metallized PET foil. The straws have 1 cm diameter and will be assembled in self-supporting octants made of 31 double-layers, resulting in total in ~25 000 readout channels. The tracker should have a good spatial resolution and provide measurements of the particle ionization losses serving the PID. This implies a challenging requirement to the tracker readout electronics. In this talk we present several possible concepts of the readout electronics together with simulation of the straw response compared to the test beam measurements.

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Missing data reconstruction using Machine Learning techniques in the gaseous TPC PandaX-III experiment

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The PandaX-III experiment aims to detect the Neutrinoless Double-beta decay (NLDBD), a hypothetical process where only two electrons are emitted from the atomic nucleus. Since the Q-value of the decay is divided only between charged particles, the electron sum energy spectrum of the NLDBD would show a single peak at the Q-value point. While only a few isotopes undergo double-beta decay with the emission of two anti-neutrinos, Xe-136 was chosen for the experiment due to its high natural abundance and suitability for use in gaseous TPC detectors. However, the Q-value for Xe-136 (~2.5MeV) can be contaminated by background radiation, which needs to be distinguished from the signal.
The PandaX-III experiment uses a Time Projection Chamber (TPC) detector filled with 10 bar gaseous Xe-136 and a readout plane consisting of 52 Thermal-bonded Micromegas modules (TBMM) 1, each with readout pixels connected in channels. There are 128 readout channels per module: 64 per X and Y directions. Therefore, XZ and YZ projections of the initial decay event track represent the detector output. It stores not only the amplitudes of the signal deposited by ionized particles inside the gas but also the topology of the event. Thus, such data configuration is beneficial for background discrimination from the signal [2]. In NLDBD searches, the experiment requires excellent energy resolution to discriminate signals from the background, and the PandaX-III experiment design aims to achieve better than 3% at 2.5 MeV. However, in the real-world experiment, readout channels may be disconnected due to physical damage, the appearance of sparks, high dark currents, and other factors, resulting in losses in energy measurement and track reconstruction. In addition, the signal gain may be inhomogeneous on the Micromegas modules, further degrading the energy reconstruction. To improve the measurement quality, registered data should be corrected for missing channels and inhomogeneities.
In this project, Machine Learning techniques have been implemented to predict the total energy of events detected by TBMM modules that have missing channels. Additionally, event classification was studied to differentiate between NLDBD events and background events based on their topology. To conduct the analysis, Monte-Carlo simulations were performed using REST software based on the Geant4 and ROOT libraries. Multiple Neural Network (NN) architectures were tested to find the most optimal configuration that yields the best predictions. The results indicate an improvement in the detection efficiency of an NLDBD signal when NN is applied to correct missing energy compared to direct signal detection with missing energies. Finally, discrimination of the background using NN demonstrates noticeable results, helping select events that require reconstruction due to detector flaws. Such a technique shows excellent potential in implementation in Micromegas-based experiments. After having presented the experiment and the status of the MM readout, the methodology of the ML studies will be described along with the corresponding results.

References
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TIGER ASIC as a candidate front end electronics solution for future Straw Trackers

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A custom Application Specific Integrated Circuit (ASIC) TIGER (Turin Integrated Gem Electronics for Readout) is capable of simultaneous precise measurements of both the charge and time characteristics of signals in gaseous detectors. Flexibility of TIGER operation parameters makes it attractive to be evaluated as a front-end electronics solution for Straw-based Trackers of future High Energy and Neutrino Physics experiments.

We present first performance measurements done with Straw drift tubes operated with the TIGER-based readout. The results obtained with the SPS muon beam at CERN allows us to explore the advantages and limitations of the TIGER readout option for Straw tubes. An overview of possible further development is presented.

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Development of charge-based calibration systems for LAr-TPCs in the DUNE Experiment

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Large liquid argon time projection chambers (LAr-TPCs) are playing an increasingly important role in neutrino physics, with several past and present accelerator neutrino experiments choosing this technology for their designs. The upcoming DUNE experiment will supersede all its predecessors both in size and physics reach. The calibration of the DUNE detector will be an essential component of its capability to reach the required performance and precision. In the past experiments, natural sources have been extensively used, but for DUNE these present limitations, since natural radioactivity from Ar-39 is of low energy, and the rate of cosmic ray muons is low when the detectors are placed deep underground. Since several decades, argon gas TPCs have been calibrated with ionizing laser beams, and more recently the technique has been further developed for use in liquid TPCs. Other recent ideas include the use of external neutron generators creating pulses that propagate into the detector. This talk will outline the methods employed for the calibration of DUNE, as well as a description of the planned systems and their goals, including the plans for the upcoming runs of ProtoDUNE, the large scale prototypes deployed at CERN that will be running later this year.

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Gas Quality Monitor for gaseous detectors

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Reliable operation of gaseous coordinate detectors in modern High Energy Physics experiments requires precise and stable composition of the working gas mixture. Independent monitoring of the gas quality is vital for many detector systems.

We propose independent gas quality monitoring system based on a straw tube module equipped with a configurable high voltage supply, readout electronics and RaspberryPi-based lightweight Data Acquisition System. The module can be connected to a supply or return lines of the monitored gas system. Straw response to a 55Fe X-ray source is amplified, digitized and recorded. The peak position of the signal amplitude spectra is proportional to the straw gas gain which in turn depends on the gas quality, pressure and temperature.

Careful calibration of pressure and temperature dependence allows to obtain high sensitivity to the changes of the gas composition. The results achieved with Ar/CO2/CF4 gas mixtures are presented.

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Sterile Neutrino Dark Matter Searches with the KATRIN Experiment

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Sterile neutrinos are a natural extension of the Standard Model of particle physics. If their mass is in the keV range, they are a viable dark matter candidate. One way to search for sterile neutrinos in a laboratory-based experiment is via tritium beta decay. A sterile neutrino with a mass up to 18.6 keV would manifest itself in the decay spectrum as a kink-like distortion. The objective of the TRISTAN project is to extend the Karlsruhe Tritium Neutrino Experiment (KATRIN) with a novel multi-pixel silicon drift detector and readout system to search for a keV-scale sterile neutrino signal. This talk will give an overview on the current status of the project.

This work is supported by BMBF (05A17PM3, 05A17PX3, 05A17VK2, 05A17WO3), KSETA, the Max Planck society, and the Helmholtz Association. Moreover, this project has received funding from the European Research Council (ERC) under the European Union Horizon 2020 research and innovation program (grant agreement no. 852845).

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The Baksan Large Neutrino Telescope Project

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A large-volume liquid scintillator neutrino detector is proposed to develop at the Baksan Neutrino Observatory of Institute for Nuclear Research of the Russian Academy of Sciences in the North Caucasus. The detector will be located at the depth of 4700 m.w.e. (meter of water equivalent). A target mass of the detector will be 10 kt. This multipurpose detector is being developed to study primarily natural neutrino and antineutrino fluxes namely fluxes of solar neutrinos, geoneutrinos and neutrinos from other astrophysical sources. The project is aimed to have a record energy resolution which along with its location at the large depth and relatively far distance from operating nuclear reactors will allow reaching a record sensitivity to the natural neutrino and antineutrino fluxes. The project, if implemented, would be a successor of the Borexino experiment and other European projects like LENA. We report in the paper the present status of the project and describe some selective results of the project first stage - the detector prototype with 0.5 t liquid scintillator. Results of R&D for the project second stage with 5 t liquid scintillator are presented. Further perspectives of the project including 100 t prototype are discussed too.

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Novel pixel sensors for the Inner Tracker upgrade of the ATLAS experiment

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The High Luminosity upgrade of the Large Hadron Collider at CERN, the HL-LHC, is expected to provide up to 200 proton-proton interaction per bunch crossing delivering about 4000 fb^{-1} of data over 10 years.
To operate in such a harsh particle environment the present inner detector of ATLAS experiment will be replaced by a completely new Inner Tracker (ITk). The pixel detector, which is the innermost part of the ITk, will have to face an extremely large particle multiplicity and a consequent huge radiation fluence up to $2\times10^{16}\mathrm{n}_{eq}/\mathrm{cm}^2$. The pixel modules are therefore designed with a fine granularity employing pixel cells of 25×100 μm^2 in the innermost barrel layer and 50×50 μm^2 pixel cells in the remaining four layers and in the rings. Moreover, the pixel detector will be built with different sensor technologies depending on the distance from the proton interaction point and the consequent radiation levels expected.
Thin n-in-p planar sensors with 150 μm and 100 μm thick active substrates will instrument the outermost pixel layers and the second innermost layer, respectively; 3D silicon sensors produced with a single side process will instead instrument the innermost layer due to their superior radiation hardness.
The production of all sensor types for ITk is about to start, and the first pre-production sensors and modules have been already delivered and evaluated by the ATLAS Collaboration.
In this contribution we will present the performance of the different 3D and planar pre-production sensors as well as the result of the first modules assembled with the latest revision of the final readout chip, the ITkPix. Particular focus will be given to the evaluation of the radiation hardness of these sensors which have been irradiated up to the doses expected at the HL-LHC.

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Calibration system of EAS Cherenkov arrays using commercial drone helicopter

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EAS Cherenkov arrays are a powerful instrument for studies of primary cosmic rays in a wide range of energy. In this approach the Earth's atmosphere is used as a calorimeter providing EAS Cherenkov arrays high energy resolution. Another advantage of the method is its high time resolution which results in a good angular resolution. Usually EAS Cherenkov array is a sparsely instrumented array with a distance of 100 m (or more) between individual Cherenkov photon detectors (optical stations/modules) covering hundreds of square meters or a few thousands of square kilometers. So, to calibrate such arrays is not simple task. We developed a calibration system of EAS Cherenkov arrays based on a single fast light source on board of remotely controlled commercial drone helicopter. The light source is based on a single high power blue InGaN LED driven by avalanche transistors driver. The light source provides light pulses with 2-3 ns (FWHM) width and 1010-1011 photons per pulse. Preliminary results of test flights of the calibration system are presented. Preliminary results of calibration measurements of Cherenkov arrays of the TAIGA experiment using described calibration system are presented too.

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Quenching factor measurements for the NEWS-G experiment

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The NEWS-G experiment is a dark matter experiment based on gaseous detectors, located at SNO lab. The experiment aims to detect WIMPs by measuring nuclear recoils in noble gases using a spherical proportional counter (SPC) detector, which offers high sensitivity due to its unprecedented low energy threshold. Accurate measurement of the recoil energy requires knowledge of the quenching factor (QF), which quantifies the reduction of ionization due to nuclear recoils compared to electromagnetic interactions. We have already conducted quenching factor (QF) measurements at TUNL using a mixture of Ne + CH4 gas at 2 bar. As part of our future plans, we intend to measure the QF using various gas mixtures and different detector parameters. To facilitate these in-beam QF measurements, we recently carried out a tabletop experiment at Queen's University to study SPC detector characteristics for different detector parameters. Plan for another campaign at TUNL for QF measurement is ongoing and a possibility of conducting such an experiment at UdeM is also underway.

In this talk, the highlights of the tabletop experiment will be presented. In addition, the past measurement, current status, and the future plans of the NEWS-G collaboration in measuring QF with SPC will be summarized.

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A project to develop a few kt GAGG(Ce) scintillator detector for low energy neutrino studies at the Baksan Neutrino Observatory

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We present a project to develop Gallium containing scintillator detector for low energy neutrino studies. GAGG(Ce) is a relatively new highly efficient fast inorganic scintillator. Recently the scintillator was propsed (P. Huber, 2022) as neutrino detector to test the well known and still not yet

resolved Gallium anomaly. Following this idea we evaluate GAGG(Ce) scintillator as a possible material for low energy neutrino detection, not only to test Gallium anomaly but also as neutrinoless double beta-decay detector. The latter point will demand enrichment by 160Gd isotope. The first very preliminary R&D studies looks very promissing. Possibilities of using other Gallium containing scintillators for low energy neutrino studies are discussed too.

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Development of Muon Tomography for the Geometry Validation of the CMS High Granularity Calorimeter

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The high granularity calorimeter (HGCAL) of CMS is planned to operate during the high luminosity operation of the LHC, replacing the existing electromagnetic and hadronic calorimeters at the endcap section. It will enable a detailed investigation of vector boson fusion processes and Lorentz-boosted topologies in forward regions. An extensive validation of the hardware and software components of this state-of-the-art calorimeter is currently in progress.

In this presentation we describe some of the interesting and complex details that need to be included in a high quality simulation of the calorimeter. We have developed a muon tomography technique that is found to be very useful for identifying any problems after changes are made as well as for testing the correctness of the geometry. We discuss how this technique is used to figure out energy loss discrepancies with partial-wafer silicon sensors, incorrect rotation of full and partial-wafer silicon sensors, and validation of GEANT hit positions in the HGCAL scintillator tiles.

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Neutrinoless double beta decay search with the AMoRE-II experiment

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Neutrinoless double beta decay search is a powerful tool to clarify the nature of neutrino as a Dirac or Majorana-type particle and probe the unknown neutrino mass.
Observing this decay means the lepton number violating process, which will help us understand the baryon asymmetric universe with the leptogenesis scenario.
The AMoRE collaboration has been searching for neutrinoless double beta decay of 100Mo with cryogenic calorimeters using scintillating molybdate crystals and MMC (metallic magnetic calorimeter) sensors. AMoRE-pilot and AMoRE-I phases of the experiment demonstrated the competitive potential for the search and the experiment is rapidly moving toward the AMoRE-II phase, which will exploit 100 kg of 100Mo isotopes ultimately. The AMoRE-II detector will consist of hundreds of cryogenic calorimeters and surrounding muon veto detectors made up of an array of plastic scintillators and water cherenkov detector. The material for the detector system has been carefully chosen and radiation shielding structure has been optimized to reach the background level of 10^-4 cnts/kg/keV/year around the region of the interest for the signal search. The new experiment will be built in Yemilab, the new underground laboratory located 1000 meter below Yemi mountain in Gangwon province, South Korea, which allows the large space and utilities for the experiment with

significantly improved sensitivity. The recent result of AMoRE-I new limit and the overall status of the AMoRE-II experiment will be presented in the conference.

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The high-performance DIRC detector for ePIC Detector at the future Electron-Ion Collider

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The next frontier project of nuclear physics in the United States will be the Electron-Ion Collider (EIC), planned to be built in the Brookhaven National Laboratory (BNL). Excellent particle identification (PID) is one of the key requirements for the EIC central detector. Identification of the hadrons in the final state is critical to study how different quark flavors contribute to nucleon properties. A detector using the Detection of Internally Reflected Cherenkov light (DIRC) principle, with a radial size of only 7-8 cm, was selected to meet these requirements. The high-performance DIRC (hpDIRC) detector is being developed through multiple R&D programs. It will extend the momentum coverage well beyond the state-of-the-art 3 standard deviations or more separation of π/K up to at least 6 GeV/c, p/K up to 10 GeV/c, and low momentum e/π. Key components of the hpDIRC detector are a 3-layer compound lens and small pixel-size photosensors. This contribution will present major developments in the DIRC R&D programs, with a focus on developing and validating the radiation hard 3-layer lens, investigating the reuse of BaBar DIRC bars, and the hpDIRC full system prototype program with Cosmic Ray Telescope at Stony Brook.

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Tracking-detector design for a multi-TeV Muon Collider

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A multi-TeV **Muon Collider** is a promising candidate for the next energy-frontier facility, combining in a single machine usually competing features, such as high energy reach, clean final states, and small environmental footprint. In particular, a collider with the centre-of-mass energy of 10 TeV is the long-term target of the ongoing design study, while lower intermediate energies are also considered. Featuring much smaller size and lower energy consumption its discovery potential would be comparable to that of the FCC-hh with its 100 TeV centre-of-mass energy.

One of the biggest technical challenges at a Muon Collider experiment is designing a detector capable of delivering high physics performance under the extremely intense beam-induced background (BIB) that originates from the muon decays along the collider ring. It is particularly challenging in the tracking detector, where hit density can reach 1000 hits/cm^2 close to the interaction region at the total ionising dose of ~1 Mrad/year. It is therefore necessary to design the tracking detector such that effective mitigation of background can be achieved to make full event reconstruction feasible.

This contribution presents the latest results from a full-simulation study on the optimal design of a Muon Collider tracking detector. It includes the nominal performance figures obtained from simulations together with the most promising BIB-mitigation strategies, and an overview of promising technologies compatible with this detector design.

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Development of CMOS Pixel Sensor prototypes for the CEPC vertex detector

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The proposed Circular Electron Positron Collider (CEPC) imposes new challenges for the vertex detector in terms of material budget, spatial resolution, readout speed, and power consumption. The TaichuPix chip is a dedicated CMOS Pixel Sensor that is being developed for the first 6-layer silicon vertex detector prototype of the CEPC vertex detector R&D. The TaichuPix chip need to provide a spatial resolution better than 5 μm, and a radiation tolerance higher than 1 MRad. The TaichuPix development is based on a fast in-pixel readout combined with a hit-driven architecture, which would be beneficial for the high hit rate. Over the last years of R&D, several prototypes have been designed to optimize in-pixel circuit and readout architecture, and to verify radiation hardness. Two small-scale demonstrator chips (25 mm^2) capable of achieving a hit rate up to 36 MHz/cm^2, were developed in a 180 nm CMOS process. Two different in-pixel digital readout designs, benefiting from the FE-I3 and ALPIDE approaches, have been implemented to achieve a fast readout. The readout of the pixel array is based on a proposed "column-drain" architecture. The positive results of the small-scale prototypes led to a submission of the first full-scale (2.6 cm × 1.6 cm) TaichuPix prototype in 2022. These prototypes were firstly characterized with electrical and radioactive sources in laboratory. The full-scale sensor chip was further characterized at the DESY test beam facility. The design details of TaichuPix prototypes and a summary of the results obtained are given.

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Module development for the ATLAS ITk Pixel Detector

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Abstract:
In HL-LHC operation the instantaneous luminosity will reach unprecedented values, resulting in about 200 proton-proton interactions in a typical bunch crossing. The current ATLAS Inner Detector will be replaced by an all-silicon system, the Inner Tracker (ITk). The innermost part of ITk will consist of a state-of-the-art pixel detector.
Several different silicon sensor technologies will be employed in the five barrel and endcap layers.
Based on first modules assembled using the RD53A prototype readout chip, numerous issues are studied, and solutions found. These included production issues like bump bonding of large area, thin modules, as well as layout issues like optimization of the bandwidth and sharing of links between multiple chips and modules. The talk will present results of many of these studies, which directly impacted the construction and assembly of pre-production modules using the first production version of the readout chip ITkPixV1. The status of the ITk preproduction pixel module will be presented.
Summary:
In this work the latest results with the latest pre-production ITkpix pixel module will be presented.

In the ITk pixel system there are 5 pixel layers and there will be different module flavours depending on their distance with respect to the interaction point:
• In L2-4 there will be quad modules with 150 um thick planar sensors.
• In L1 there will be quad modules with 100 um thick planar sensors.
• In L0 (the innermost layer) three different flavours of triplet modules will be used with different pixel sizes and hybrid shapes all on 150 um active thick substrates but:
o 50 x50 um2 pixel size in the endcaps (rings)
o 25 x 100 um2 pixel sizes in the barrel (staves)
The reasons for the election of the different technologies will be justified. The different assembly procedures and challenges found on the module prototyping phase will be described.
About 15,000-pixel modules will be built for the Inner Tracker. The module assembly requires very high precision and custom designed tooling that can provide extreme accuracy. Design aspects of the components and tooling will be discussed.
The module deign is validated for bump delamination caused by thermal stress due to the wide operational temperature range of -45 and +40℃. Results from the design validation will be presented.
All the modules have to undergo an exhaustive quality control protocol based on metrology and electrical functionality. These tests ensure that the whole detector will fit without problems within the tight ATLAS volume available, perform electrically within a serial power chain within the tight powering envelope and with the required pixel analogue and digital performance.
Final QC test of each module will include a thermal cycling in a wide range of temperatures between -45 and +40℃ in order to estimate reliability of the modules. All electrical parts of the pixel modules need to be carefully tested and the modules which did not meet the required specifications will be rejected during production. A description of the QC procedure and the most recent test results will be presented, including the results of basic and advanced pixel module tests.

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163Ho implantation in TES-based micro-calorimeters for the HOLMES experiment.

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The HOLMES experiment aims to directly measure the ν mass studying the 163Ho electron capture decay spectrum, developing arrays of TES-based micro-calorimeters implanted with O(102 Bq/detector) ^{163}Ho atoms.
The ^{163}Ho embedding inside detectors is a crucial step of the experiment. Because ^{163}Ho is produced by neutron irradiation of a ^{162}Er sample, the source must be separated from a lot of contaminants. A chemical process removes every species other than Ho, but it is not sufficient to remove all background sources: in particular, ^{166m}Ho beta decay can produce fake signal in the region of interest. For this reason a dedicated implantation / beam analysis system has been set up and commissioned in Genoa's laboratory. It is designed to achieve more than 5σ separation @163/166 a.m.u. simultaneously allowing an efficient Ho atoms embedding in the absorbers. The machine performances in terms of achievable current, beam profile and mass separation have been studied with Monte-Carlo simulations and evaluated by means of calibration runs using Cu, Mo, Au and 165Ho beams. In this work, the commissioning of the machine and the production of the first set of low activity (O(1Bq/detector)) implanted TES will be described.

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Timing and synchronisation of the DUNE far detector

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The Deep Underground Neutrino Experiment (DUNE) will be composed of two neutrino detectors positioned in an intense neutrino beam, originating at the Fermi National Accelerator Laboratory (FNAL). The near detector (ND) will be located at FNAL, and will characterise the neutrino beam. The far detector (FD) will be 1300 km from FNAL, and 1.5 km underground. The FD is segmented into four liquid argon time projection chamber (LArTPC) modules, each with a mass of 17kt. The DUNE timing system (DTS) will distribute a phase-aligned clock and synchronised timestamps to all FD electronics. Alongside clock and timestamps, the DTS will be able to distribute fast fixed-latency messages, allowing synchronised operations across the large DUNE FD, e.g. calibration laser firing. The system is expected to achieve sub-ns timestamp synchronisation within a FD module. High reliability through system redundancy in a hot-swap configuration is a fundamental feature of the system's architecture. The built-in redundancy will help minimise downtime, and allow cross-checking of synchronisation. An overview of the DTS hardware, firmware, software, and system level functionality is given, as well as summary of the DTS prototype operations at the ProtoDUNE detectors hosted at the European Organization for Nuclear Research (CERN).

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The T2K Near Detector upgrade

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Neutrino oscillation physics has now entered the precision era. In parallel with needing larger detectors to collect more data, future experiments further require a significant reduction of systematic uncertainties with respect to what is currently available. In the neutrino oscillation measurements from the T2K experiment, the systematic uncertainties related to neutrino interaction cross sections are currently dominant. To reduce this uncertainty, a significantly improved understanding of neutrino-nucleus interactions is required. In particular, it is crucial to better characterise the nuclear effects which can alter the final state topology and kinematics of neutrino interactions in such a way which can bias neutrino energy reconstruction and therefore bias measurements of neutrino oscillations.

The upgraded ND280 detector will consist of a totally active Super-Fine-Grained-Detector (Super-FGD) composed of 2 million 1 cm^3 scintillator cubes with three 2D readouts, two High Angle TPC (HA-TPC) instrumented with resistive MicroMegas modules, and six TOF planes. It will directly confront our knowledge of neutrino interactions thanks to its full polar angle acceptance and a much lower proton tracking threshold. Furthermore, neutron tagging capabilities, in addition to precision timing information, will allow the upgraded detector to estimate neutron kinematics from neutrino interactions. Such improvements permit access to a much larger kinematic phase space which correspondingly allows techniques such as the analysis of transverse kinematic imbalances, to offer remarkable constraints of the pertinent nuclear physics for T2K analyses.

New reconstruction algorithms are being developed to fully benefit from the improved capabilities of the Super-FGD and of the HA-TPC and will be described in this talk together with the expected performances of the ND280 upgrade.

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Overview of the ATLAS High-Granularity Timing Detector: project status and results

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The increase of the particle flux (pile-up) at the HL-LHC with instantaneous luminosities up to L ⊠ 7.5 × 1034 cm−2s−1 will have a severe impact on the ATLAS detector reconstruction and trigger performance. The end-cap and forward region where the liquid Argon calorimeter has coarser granularity and the inner tracker has poorer momentum resolution will be particularly affected. A High Granularity Timing Detector (HGTD) will be installed in front of the LAr end-cap calorimeters for pile-up mitigation and luminosity measurement.
The HGTD is a novel detector introduced to augment the new all-silicon Inner Tracker in the pseudorapidity range from 2.4 to 4.0, adding the capability to measure charged-particle trajectories in time as well as space. Two silicon-sensor double-sided layers will provide precision timing information for minimum-ionising particles with a resolution as good as 30 ps per track in order to assign each particle to the correct vertex. Readout cells have a size of 1.3 mm × 1.3 mm, leading to a highly granular detector with 3.7 million channels. Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides enough gain to reach the large signal over noise ratio needed.
The requirements and overall specifications of the HGTD will be presented as well as the technical design and the project status. The R&D effort carried out to study the sensors, the readout ASIC, and the other components, supported by laboratory and test beam results, will also be presented.

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Chips for calibration of the ATLAS LAr calorimeter

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The LHC upgrade at CERN implies an increase in the dynamic range for the electromagnetic liquid argon (Lar) calorimeter of the ATLAS detector, a change in the power supply system and an increase of the luminosity and thus of radiation effects on detectors. This requires completely redoing the Lar calibration system. The new system should provide a 16-bit range current (from 625 nA to 320 mA) with 1‰ accuracy while being radiation tolerant. The former operating principle is used: a very precise DC current is stored in an inductor when this current is switched off it generates a precise pulse injected in the readout electronics. This is achieved by two different chips: the first one, in TSMC 130nm technology, provides the 16-bit current DAC as well as the calibration management system (I2C slow control and commands to obtain pulses); the second chip, in XFAB 180nm technology, embeds four high-frequency switches (1GHz) to generate the fast pulses for calibration. This talk will present these two chips in details and give measurement results as well as irradiation test results for both technologies.

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ATLAS LAr Calorimeter Commissioning for LHC Run-3

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To cope with the increase of the LHC instantaneous luminosity, new trigger readout electronics were installed on the ATLAS Liquid Argon Calorimeters.

On the detector, 124 new electronic boards digitise at high speed 10 times more signals than the legacy system. Downstream, large FPGAs are processing up to 20 Tbps of data to compute the deposited energies. Moreover, a new control and monitoring infrastructure has been developed.

This contribution will present the challenges of the commissioning, the first steps in operation, and the milestones still to be completed towards the full operation of both the legacy and the new trigger readout paths for the LHC Run-3.

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Development of the ATLAS Liquid Argon Calorimeter Readout Electronics for the HL-LHC

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A new era of hadron collisions will start around 2029 with the High-Luminosity LHC which will allow to collect ten times more data than what has been collected during 10 years of operation at LHC. This will be achieved by higher instantaneous luminosity at the price of a higher number of collisions per bunch crossing.

In order to withstand the high expected radiation doses and the harsher data taking conditions, the ATLAS Liquid Argon Calorimeter readout electronics will be upgraded.

The electronic readout chain is composed of four main components.
1: New front-end boards will allow to amplify, shape and digitise the calorimeter's ionisation signal on two gains over a dynamic range of 16 bits and 11 bit precision. Low noise below Minimum Ionising Particle (MIP), i.e. below 120 nA for 45 ns peaking time, and maximum non-linearity of two per mille is required. Custom preamplifiers and shapers are being developed to meet these requirements using 65 nm and 130 nm CMOS technologies. They shall be stable under irradiation until 1.4kGy (TID) and 4.1x10^13 new/cm^2 (NIEL). Two concurrent preamp-shaper ASICs were developed and, "ALFE", the best one has been chosen. The test results of the latest version of this ASIC will be presented. "COLUTA", a new ADC chip is also being designed. A production test setup is being prepared and integration tests of the different components (including lpGBT links developed by CERN) on a 32-channels front-end board are ongoing, and results of this integration will be shown.
2: New calibration boards will allow the precise calibration of all 182468 channels of the calorimeter over a 16 bits dynamic range. A non-linearity of one per mille and non-uniformity between channels of 0.25% with a pulse rise time smaller than 1ns shall be achieved. In addition, the custom calibration ASICs shall be stable under irradiation with same levels as preamp-shaper and ADC chips. The HV SOI CMOS XFAB 180nm technology is used for the pulser ASIC, "CLAROC", while the TSMC 130 nm technology is used for the DAC part, "LADOC". The latest versions of those 2 ASICs which recently passed the production readiness review (PDR) with their respective performances will be presented.
3: New ATCA compliant signal processing boards ("LASP") will receive the detector data at 40 MHz where FPGAs connected through lpGBT high-speed links will perform energy and time reconstruction. In total, the off-detector electronics receive 345 Tbps of data via 33000

links at 10 Gbps. For the first time, online machine learning techniques are considered to be used in these FPGAs. A subset of the original data is sent with low latency to the hardware trigger system, while the full data are buffered until the reception of trigger accept signals. The latest development status of the board as well as the firmware will be shown.
4: A new timing and control system, "LATS", will synchronise with the aforementioned components. Its current design status will also be shown.

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Machine Learning for Real-Time Processing of ATLAS Liquid Argon Calorimeter Signals with FPGAs

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The Phase-II Upgrade of the LHC will increase its instantaneous luminosity by a factor of 7 leading to the High Luminosity LHC (HL-LHC).
At the HL-LHC, the number of proton-proton collisions in one bunch crossing (called pileup) increases significantly, putting more stringent requirements on the LHC detectors electronics and real-time data processing capabilities.

The ATLAS Liquid Argon (LAr) calorimeter measures the energy of particles produced in LHC collisions. This calorimeter also feeds the ATLAS trigger to identify interesting events. In order to enhance the ATLAS detector physics discovery potential, in the blurred environment created by the pileup, an excellent resolution of the deposited energy and an accurate detection of the deposited time is crucial.

The computation of the deposited energy is performed in real-time using dedicated data acquisition electronic boards based on FPGAs. FPGAs are chosen for their capacity to treat large amount of data with very low latency. The computation of the deposited energy is currently done using optimal filtering algorithms that assume a nominal pulse shape of the electronic signal. These filter algorithms are adapted to the ideal situation with very limited pileup and no overlap of the electronic pulses in the detector. However, with the increased luminosity and pileup, the performance of the optimal filter algorithms decreases significantly and no further extension nor tuning of these algorithms could recover the lost performance.

The off-detector electronic boards for the Phase-II Upgrade of the LAr calorimeter will use the next high-end generation of INTEL FPGAs with increased processing power and memory. This is a unique opportunity to develop the necessary tools, enabling the use of more complex algorithms on these boards. We developed several neural networks (NNs) with significant performance improvements with respect to the optimal filtering algorithms. The main challenge is to efficiently implement these NNs into the dedicated data acquisition electronics. Special effort was dedicated to minimising the needed computational power while optimising the NNs architectures.

Five NN algorithms based on CNN, RNN, and LSTM architectures will be presented. The improvement of the energy resolution and the accuracy of the deposited time compared to the legacy filter algorithms, especially for overlapping pulses, will be discussed. The implementation of these networks in firmware will be shown. Two implementation categories in VHDL and Quartus HLS code are considered. The implementation results on Stratix 10 INTEL FPGAs, including the resource usage, latency, and operation frequency will be reported. Approximations in the firmware implementations, including the use of fixed-point precision arithmetic and lookup tables for activation functions, will be discussed. Implementations including time multiplexing to reduce resource usage will be presented.
We will show that two of these NNs implementations are viable solutions that fit the stringent data processing requirements on the latency (O(100ns)) and bandwidth (O(1Tb/s) per FPGA) needed for the ATLAS detector operation.

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Present and future of tracking and vertexing in CMS

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Accurate reconstruction of charged particle trajectories and measurement of their parameters (tracking) is one of the major challenges of the CMS experiment. A precise and efficient tracking is one of the critical components of the CMS physics program as it impacts the ability to reconstruct the physics objects needed to understand proton-proton collisions at the LHC. In this work, we describe the evolution of tracking and vertexing algorithms in CMS, both at the high-level trigger and for the offline reconstruction. Results will include how the adoption of heterogeneous architectures enables novel tracking approaches targeting both the LHC Run 3 and HL-LHC data-taking periods.

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Optimization of the Efficiency of the DUNE FD1 and FD2 photon detection system.

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DUNE is a long-baseline accelerator experiment in construction at Fermilab and SURF (South Dakota) aiming to probe CP violation in the neutrino sector and to identify the neutrino mass hierarchy.
The DUNE physics reach on the observation of supernova neutrino bursts and proton decay is remarkably enhanced by the DUNE Photon Detection System (PDS) and strictly related to the Photon Detection Efficiency (PDE) of its fundamental unit, which is based on a light concentration technology named X-Arapuca.

In this contribution, we will present the latest results achieved in the framework of DUNE PDS Consortium activities on the optimization of the PDE of the X-Arapuca device, to reach and surpass the baseline value of 3%, allowing to target the FD1 physics reach. This thanks to the new engineering of the relevant components embedded in the XA device i.e. the Dichroic Filters and the secondary downshifting (WLS) lightguide slab. The latter is now the baseline product for both Dune FD1 and FD2 modules: thanks to the manufacturing process, it shows high performances at low cost and can be shaped in slabs sizing one square meter or more. This will allow to cover the large surfaces required for DUNE.
Accurate PDE measurements and simulations of the X-Arapuca cells will be presented, showing

how the new WLS material in synergy with improved SiPMs-to-WLS coupling and light trapping of the WLS device, enhances the PDE up to 3% and greater. The cryo-reliability, cryo-aging tests and radiopurity assessment of the WLS material will be also presented.
This material may found application in any project aiming to enhance the down conversion and collection of NUV light, as in SBND, SOLAR, LEGEND-200, LEGEND-1000.

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Understanding the temperature dependence of SiPM characteristics

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The prototype detector of the ICAL experiment at the India-based Neutrino Observatory, the mini-ICAL
is in operation at the IICHEP, Madurai. A Cosmic Muon Veto detector (CMVD) around the mini-ICAL is
being commissioned using extruded plastic scintillators with embedded WLS fibers. The SiPM is used
as a photo-transducer and that will be calibrated using an ultrafast LED driver. Other than the basic efficiency and gain study for the CMVD as a function of overvoltage (V_{ov}), an experimental setup was
designed to characterise the SiPMs in a temperature controlled environment. The readout electronics involves trans-impedance amplifiers of combined gain 1.24 mV/μA and a digital storage oscilloscope for the data collection without much distortion of SiPM signal. Various characteristics of the Hamamatsu SiPM
(S13360-2050VE), e.g. signal shape, optically correlated and uncorrelated noise, recovery time etc were studied as a function of V_{ov}, number of photoelectrons and the ambient temperature. This paper will cover the details of those results.

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Expected Performance of cosmic muon veto detector at IICHEP, Madurai, India

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The purpose of the cosmic muon veto (CMV) detector is to investigate the feasibility of constructing a large-scale neutrino experiment at shallow depths. An extruded plastic scintillator (EPS)-based active veto system for cosmic ray muons is being built around the existing miniICAL detector, which is a scaled-down version of the proposed ICAL detector, at the transit campus of India-based Neutrino Observatory in Madurai.

Individual detector consists of extruded plastic scintillator (EPS) ($\sim\ 500cm \times 5cm \times 1cm$) consisting of two WLS fibres to collect scintillation photons and four silicon-photomultipliers (SiPMs) as photo-transducers. Eight such detectors are grouped to form a module, called a tile, which is placed adjacent to other tiles to cover the entire mini-ICAL detector. To achieve high efficiency and cover the dead space, up to four of these layers are stacked, to form veto-wall. The CMV detector comprises four walls, one on top, three on the sides, making it an active veto system that covers the miniICAL detector. The performance of scintillators, WLS fibres, SiPM readout systems, and muon reconstruction in the miniICAL have been well established. Using these developments, this work examines the feasibility of building such a large veto system around the miniICAL detector using the GEANT4 toolkit. The efficiency of the CMV is estimated using reconstructed muon tracks in the RPC stack with sufficient hits and good fit quality. The performance of the CMV detector is tested with and without a magnetic field using the muon reconstruction algorithm and extrapolating the same to the veto detector.

The goal is to achieve a veto efficiency $> 99.99\%$ and a false-positive rate of less than 10^{-5}. By achieving this high level of veto efficiency, the neutrino experiment can be conducted at a much shallower depth (just 100m) than what would normally be required (1.3km). The detailed performance of the hardware components and expected performance of the CMVD around the miniICAL will be discussed in this presentation.

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Demonstration of the 25 ps single-photon time resolution of an RPC-based gaseous photodetector

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Photosensitive gaseous detectors with a simple photoelectron multiplication mechanism of a resistive plate chamber are expected to have both a large photo coverage and an excellent time resolution and to be low-cost. To demonstrate the time resolution, we built a prototype detector with a LaB6 photocathode. We successfully detected single-photon signals. We performed a waveform fitting to precisely measure the timing of the signals, and measured the time resolution to be 25 ±0.2 ps at the gain of 3.3×10^6.
We also studied the photon feedback event that is additional avalanches caused by UV photons from the primary avalanche. Because the photon feedback doubles or triples the output charge, it was clearly seen in the charge distribution of the signals. We extracted the probability of the photon feedback by fitting the charge distribution. Using this result, we determined the photon feedback probability to be 0.3 under assumption of a Poisson model. Photon feedback probability can be larger with a photocathode that has a better quantum efficiency, and it can be a major challenge in practical application of the gaseous photodetectors.
In this presentation, we will discuss the details of the above measurements and prospects of the future R&D of this photodetector.

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Cosmic Muon Momentum Spectra at Madurai

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The INO-ICAL collaboration has built a prototype detector called mini-ICAL at IICHEP, Madurai, India, as part of their research and development efforts. This module serves to investigate detector performance, and engineering challenges in constructing large-scale magnets and magnetic field measurement systems, and to test ICAL electronics in the presence of a magnetic field. Additionally, mini-ICAL is being used to measure charge-dependent cosmic muon flux at the earth's surface and also to study the feasibility of a cosmic muon veto for a shallow-depth neutrino experiment. Mini-ICAL is a magnetised detector, composed of 11 layers of iron plates (measuring $4\,m \times 4\,m \times 0.056\,m$) with 45 mm gaps between each layer. Resistive plate chambers ($2\,m \times 2\,m$) with $30\,mm$ strip width are placed between each iron layer to track cosmic ray muons. The iron is magnetised to a maximum field of $1.5\,T$ by applying a current of $900\,A$. A Kalman filter-based track fitting algorithm is used to reconstruct muon tracks. The simulation includes CORSIKA event generator, Geant4 toolkits for the detector geometry and muon interactions as well as detector noise and inefficiency, which eventually used in the unfolding technique to obtain muon spectrum at the earth's surface from the observed distributions. This talk presents the results of the momentum spectrum of cosmic muons obtained from mini-ICAL and compares them with the extensive air shower (EAS) simulation results in the range of $\sim$1 to 3 GeV/c

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The Phase-II Upgrade of the ATLAS Hadronic Tile Calorimeter for the High Luminosity LHC

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Abstract. The Tile Calorimeter (TileCal) is a sampling hadronic calorimeter covering the central region of the ATLAS experiment, with steel as absorber and plastic scintillators as active medium. The High-Luminosity phase of LHC, delivering five times the LHC nominal instantaneous luminosity, is expected to begin in 2029. TileCal will require new electronics to meet the requirements of a 1 MHz trigger, higher ambient radiation, and to ensure better performance under high pile-up conditions. Both the on- and off-detector TileCal electronics will be replaced during the shutdown of 2026-2028. PMT signals from every TileCal cell will be digitized and sent directly to the back-end electronics, where the signals are reconstructed, stored, and sent to the first level of trigger at a rate of 40 MHz. This will provide better precision of the calorimeter signals used by the trigger system and will allow the development of more complex trigger algorithms. The modular front-end electronics feature radiation- tolerant commercial off-the-shelf components and redundant design to minimize single points of failure. The timing, control and communication interface with the off-detector electronics is implemented with modern Field Programmable Gate Arrays (FPGAs) and high speed fibre optic links running up to 9.6 Gb/s. The TileCal upgrade program has included extensive RD and test beam studies. A Demonstrator module with reverse compatibility with the existing system was inserted in ATLAS in August 2019 for testing in actual detector conditions. The ongoing developments for on- and off-detector systems, together with expected performance characteristics and results of test-beam campaigns with the electronics prototypes will be discussed.

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The use of Machine learning to improve quality control for the ATLAS Phase-II Upgrade LVPS bricks at CERN

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Abstract. The Tile Calorimeter (TileCal), a sampling hadronic calorimeter covering the central region of the ATLAS experiment, will require new electronics to meet the requirements of the High-Luminosity LHC (HL-LHC). This talk will demonstrate how deep neural networks can improve quality control of the new Low Voltage Power Supply (LVPS) boards in the contest of the ATLAS Phase-II Upgrade program for HL-LHC. Deep Neural Networks (DNNs) as a machine learning algorithm is used to analyze complex data from the LVPS Boards. The first initial testing done on the boards determined their reliability and performance. A total of eleven tests with a binary metric of PASS/FAIL make up the initial test station. The measurements are stored in a database and the multi-dimensional data is explored and then analyzed by a DNN algorithm. The DNN model classifies the data and produces significant insights with predictions about the quality of the LVPS boards. These forecasts will help the Quality Control of the upgraded TileCal LVPS. Pre-production and production of the LVPS boards will commence this year generating more data than before.

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Long-term stability uncertainty of luminosity measurements of the ATLAS detector in Run 3 during the 2022 data-taking period

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Abstract. Precise measurements of luminosity play a crucial role in the ATLAS physics programme at the LHC, in particular for cross section measurements, where it can be one of the largest systematic uncertainties. The Tile Calorimeter of the ATLAS experiment plays an important role in these measurements due to its luminosity measurements being independent of pileup. The comparison of LUCID luminosity measurements in different detector operating conditions to those obtained by the Tile Calorimeter and the Inner detector is used to measure and study the dominant systematic uncertainty associated with the LUCID luminosity measurements. There are several factors affecting luminosity measurements, these include the aging of photomultiplier tubes and aging of scintillating tiles. The long-term stability studies are performed to evaluate time-dependent factors that affect the long-term stability of the uncertainties associated with the luminosity measurements.

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Extracting and Analyzing Data from Detector Control System to investigate the behavior of High Voltage Power Supplies at the ATLAS Experiment

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Abstract. The TileCal is the hadronic calorimeter found in the central region of the ATLAS. It is a sampling calorimeter made of steel tiles as the absorber material and scintillating tiles as the active medium. The light produced as the particle crosses the scintillator tiles is transmitted by the wavelength-shifting fibres. The PMT converts the light into an analog signal and transfers it to the next stage of the signal chain. The TileCal DCS's main responsibility is to ensure the safe operation of the detector. This project aims to develop a plugin that will extract and analyze offline data for continuous analyses of the behavior of the PMT High Voltage (HV) supply in order to detect unstable channels during data taking period. The data is provided by the dedicated Detector Control System (DCS) Data Visualization tool (DDV) through convenient API and then visualized using an interactive JavaScript plotting library. The plugin will be integrated into the Tile-in-One (TiO) platform that combines all TileCal offline data quality tools.

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Long term aging studies of the new PMTs for the HL-LHC ATLAS hadronic calorimeter upgrade

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Abstract. TileCal, the central hadronic calorimeter of the ATLAS experiment at the Large Hadron Collider (LHC), is readout by about 10,000 photomultipliers (PMTs). Earlier studies of performance showed a degradation in PMT response as a function of the integrated anode charge. At the end of the High-Luminosity LHC (HL-LHC) program, the expected integrated charge for PMTs reading out the most exposed cells is 600 C. A model of the evolution of the PMT response as a function of the integrated charge, based on the measurement response during the Run 2, was built. The projected loss at the end of the HL-LHC is 25% for 8% of the total TileCal PMTs. These PMTs will be replaced with a newer version, in order to keep the global detector performance at an optimal level. A local test setup is being used in the Pisa laboratory to study the long term response of the new PMT model considered for replacement in the TileCal readout of most exposed calorimeter cells. Furthermore, the performance of the new is compared to the old PMT model, the current version used to readout TileCal cells. For the first time this new PMT model has been tested after integrating more than 800 C of anode charge. Preliminary results obtained from data collected in the Pisa laboratory over a period exceeding one year are shown in this presentation. We started a study aimed to understand the response degradation of the PMTs in order to disentangle the effect of loss of quantum efficiency and change in gain.

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The CMS tracker performance in Run3

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The inner tracker of CMS is the largest silicon tracker ever built with 1856 pixel and 15148 strip detector modules that provide accurate track reconstruction. To achieve high precision in measurements of the momenta of charged particles, corrections for the position, rotation and curvature of these modules must be found; such a procedure is known as tracker alignment. Magnet cycles, temperature variations and ageing of modules cause significant time variations that affect the track reconstruction and therefore necessitate continuous alignment throughout the operation of the LHC machine. Special challenges must be addressed in the Run 3 data-taking period as the high instantaneous luminosity and the newly installed layer 1 of the barrel pixel lead to fast changes in the irradiation of modules.

In this presentation, the performance of tracker alignment on Run 3 data will be presented, highlighting new features developed for the Run 3 data taking period. The impact of the tracker alignment on physics performance will also be reviewed.

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3DΠ: A Novel Total-Body PET Scanner Using Xenon-Doped Liquid Argon Scintillator with SiPM-based Photosensors

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The 3DΠ scanner is a Total-Body (TB), Time Of Flight (TOF), Positron Emission Tomography (PET) imaging device that utilizes silicon photomultiplier-based technology and a Xenon-doped Liquid Argon (LAr) scintillator. The scanner has an axial field-of-view (AFOV) of 200 cm and consists of 9 double-sided concentric rings of SiPM panels. The addition of Xenon doping to the LAr scintillator suppresses the long-lifetime component of the scintillation light, allowing for higher data rates and potentially higher patient doses, if needed for a specific application. This is due to the faster de-excitation process in the LAr-Xenon mixture, which allows for direct energy transfer and emission of Xenon light, compared to traditional fluorescence processes involving wavelength shifters (WLS). Moreover, studies have shown that lowering the operating temperature of SiPMs to match the temperature of LAr significantly reduces the dark count rate within the SiPM.

The 3DΠ scanner project is a medical imaging application of the ongoing research and development efforts of the DarkSide collaboration, which is focused on direct dark matter particle searches using LAr targets. The 3DΠ monte carlo simulation package has been derived from the DarkSide simulation package, which is based on the Geant4 toolkit. The main objective of our study was to evaluate the performance of the 3DΠ scanner using established NEMA NU 2–2018 standards for spatial resolution, sensitivity, image quality, count rate performance, and timing resolution.

The sensitivity of the 3DΠ scanner was measured to be 564.02 kcps/MBq at the center of the scanner. The noise-equivalent count rates (NECRs) were found to be 1.5 Mcps at a concentration of 5.3 kBq/mL, and increased to 3 Mcps at a concentration of 21.2 kBq/mL. The TOF resolution was measured as 160 ps. These preliminary results indicate that the system performance of the 3DΠ scanner is comparable to, if not better than, other commercial scanners.

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Position Measurement in single-gap RPCs using Timing-Difference from Two Ends of Pickup Strips in Differential Configuration

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This work explores a technique for extracting the position of particle along the direction of a pickup strip, in a large area single-gap Resistive Plate Chamber (RPC), by measuring the timing-difference from the two ends of the strip. Using precise time-difference measurement, the position can be obtained more precisely than the conventional x-y strip readout with the same number of electronics channels. This technique was reported in the case of multigap RPCs (MRPCs) in 1 with timing difference resolution of 18 ps corresponding to position resolution of 1.7 mm, with sensitivity of 104ps/cm. The sensitivity is defined as the ratio of the change in mean of timing-difference to the change in position where the particle crosses the gas gap. Sensitivity is just twice the inverse of propagation speed in the transmission line formed by the pickup strips. In 1, the readout strips on either side of the MRPC are kept in parallel, and the signals from both ends of the strip are read differentially to minimise noise. It is expected that this method would work on single-gap RPCs also as the signal will be induced to both sides of a strip simultaneously. The intrinsic fluctuations of timing of the device is common to both ends of the strip and gets cancelled out when the timing-difference is taken (pulse height effect may bias the time measurements). However, MRPCs which are operated at higher electric fields produce a sharper rising signal than the single-gap RPCs, so the position resolution may not be as good for single-gap RPCs as in the case of MRPCs. A similar method has been tested on single-gap RPCs in [2] achieving a position resolution of 10.69 mm (timing difference resolution of 150 ps), but this was done using single-ended signals with pickup strips mounted only on one side of the RPC. Single-ended readout will limit the timing-difference resolution as compared to differential readout. A similar method has been tested in the development of the Improved RPCs (iRPCs) in CMS [3] with a resolution of 16mm (160 ps timing-difference resolution), and in [4] with a resolution of 5mm. This work will present the development of readout electronics for differential readout of RPCs and the measurement of the timing-difference resolution and sensitivity of the RPC using a cosmic muon telescope.

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Q. Li et al 2021 JINST 16 P10036 https://iopscience.iop.org/article/10.1088/1748-0221/16/10/P10036

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The CUPID double beta decay experiment

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Neutrinoless double-beta decay ($0\nu\beta\beta$) is a key process to address some of the major outstanding issues in particle physics, such as the lepton number conservation and the Majorana nature of the neutrino. Several efforts have taken place in the last decades in order to reach higher and higher sensitivity on its half-life. The next-generation of experiments aims at covering the Inverted-Ordering region of the neutrino mass spectrum, with sensitivities on the half-lives greater than 10^{27} years. Among the exploited techniques, low-temperature calorimetry has proved to be a very promising one, and will keep its leading role in the future thanks to the CUPID experiment. CUPID (CUORE Upgrade with Particle IDentification) will search for the neutrinoless double-beta decay of ^{100}Mo and will exploit the existing cryogenic infrastructure as well as the gained experience of CUORE, at the Laboratori Nazionali del Gran Sasso in Italy. Thanks to ~1600 scintillating Li_2MoO_4 crystals, enriched in ^{100}Mo, coupled to ~1700 light detectors CUPID will have a simultaneous readout of heat and light that will allow for particle identification, and thus a powerful alpha background rejection. Numerous studies and R&D projects are currently ongoing in a coordinated effort aimed at finalizing the design of the CUPID detector and at assessing its performance and physics reach.
In our talk, we will present the current status of CUPID and outline the forthcoming steps towards the construction of the experiment.

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Laser-driven secondary photon emission of SiPMs

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The recent R&D for underground low-energy particle physics experiments involve SiPMs extensively as the prime photo-detectors due to their ability to enhance the sensitivity of rare particle events. Along with their advantages of having low operating voltages, high PDE, and excellent single-photon resolution, they cause secondary photon emissions which are responsible for at least three processes: (i) internal cross-talk (ii) external cross-talk and (iii) optically-induced afterpulsing. While the internal crosstalk and afterpulsing involves photon transport within the SiPM, the external cross-talk photons escape from the surface of one SPAD and potentially: (i) reflect back into the SiPM at the surface coating interface and trigger avalanches in neighbouring SPADs, (ii) transmit through the SiPM surface coating. External crosstalk can be a significant background in future multi-ton detectors such as DarkSide-20k and nEXO that will cover large surface areas with SiPMs which can trigger each other in the vicinity. This may reduce the accuracy of photo-electron resolution for high photo-electron events, leading to a degradation in the position and energy reconstruction. To quantify the systematic effects which deteriorate the overall performance of such detectors, a study on SiPM secondary photon emission was conducted. It determined the absolute secondary photon yield equal to the number of photons emitted per charge carrier (γ/e^-) using a spectroscopy setup at TRIUMF, Canada. The setup comprises an Olympus IX83 microscope with light filters and a Princeton Instruments spectrometer. The SiPM is triggered by 405 nm laser that stimulates the emission of secondary photons from the SiPM. These photons pass through the long pass filter of the microscope to finally be detected by the spectrometer. We have characterised FBK VUV-HD3, HPK-VUV4, and the FBK NUV-HD Cryo SiPMs at 163 K and 87 K (for FBK NUV-HD Cryo) to mimic the SiPM performance at liquid Xenon and liquid Argon temperatures. In this talk, I will summarise the data analysis used to quantify the secondary photon yield at these temperatures. I will also present a model of the SPADs which allows us to estimate the photon yield for an impact on the sensitivity of large-area detectors.

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South African contribution status of the Tile Calorimeter Phase-II upgrade off-detector electronics

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Four important experiments for the High Luminosity Large Hadron Collider (HL-LHC) are currently being upgraded to accommodate an increase in luminosity. These four key experiments include ATLAS (A Toroidal LHC ApparatuS), which has been improved to study a broad range of physics. The central hadronic calorimeter is the Tile Calorimeter (TileCal), which is part of the ATLAS detector. The readout electronics system of the ATLAS TileCal must be completely redesigned to accommodate the increased radiation levels and data bandwidth for the HL-LHC. South Africa is contributing 24 % to the Tile Phase-II upgrade off-detector electronics. The contribution involves the firmware and software design; and production of Tile GbE Switch and TileCoM. This paper presents the status of the South African contribution towards the TileCal Phase-II upgrade off-detector electronics.

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Waveform calibration of the SND electromagnetic calorimeter

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The Spherical Neutral Detector (SND) is intended for the study electron-positron annihilation processes operating at VEPP-2000 e+e- collider, which is located at Novosibirsk, Russia. The main part of the SND detector is a three-layer electromagnetic calorimeter (EMC).
The EMC is equipped with spectrometric channel, which provides measurement of the calorimeter signal arrival time and amplitude with 1 ns and 250 keV resolutions, respectively. It's necessary for providing reliable detection of low-speed anti-neutrons, which are produced in $e^+e^- \to n\overline{n}$ reaction near threshold.
The algorithm of determination of signal parameters (time, amplitude) is based on invariability of the signal waveform. The waveform calibration procedure using generator signals and Bhabha scattering events is presented here.

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Latest results from the CUORE experiment

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The Cryogenic Underground Observatory for Rare Events (CUORE)
is the first bolometric experiment searching for 0νββ decay
that has successfully reached the one-tonne mass scale.
The detector, located at the LNGS in Italy, consists of an array of 988 TeO2 crystals arranged in a compact cylindrical structure of 19 towers.
CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and has been collecting data continuosly since 2019, reaching a TeO2 exposure of 2 tonne-year in spring 2023.
This is the largest amount of data ever acquired with a solid state cryogenic detector, which allows for further improvement in the CUORE sensitivity to 0νββ decay in 130Te.
In this talk, we will present the new CUORE data release, based on the full available statistics and on new, significant enhancements of the data processing chain and high-level analysis.

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X-ARAPUCA as photon detection system of SBND

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The SBND (Short Baseline Near Detector) is the near detector of the short baseline neutrino program (SBN) at Fermilab. SBND, is located at 110m from the neutrino beam and will collect an impressive statistic of neutrino-argon interactions. SBND will also serve as test bed for new technologies for LAr-TPCs. In particular SBND implements different and complementary solutions for the detection of LAr scintillation light. LAr light is emitted in a narrow 10 nm band centered around 127 nm, in the Vacuum Ultra-Violet and the shape of the signal is the sum of two exponential decays with very different characteristic times (6 ns and 1,500 ns). Scintillation light can be used to perform calorimetric measurements of the deposited energy, T0 determination of the neutrino interaction and particle discrimination through pulse shape studies.
The Photon Detection System is a combination of traditional, large area (8") photomultipliers and X-ARAPUCAs, a novel detector which is the baseline choice of the Deep Underground Neutrino Experiment.
The PDS will collect not only the direct VUV LAr light, but also the visible one, shifted by the layer of Tetra-Phenyl Butadiene (TPB – emission wavelength around 430nm) deposited on reflective foils installed on the cathode of the TPC. This will allow to test a new version of X-ARAPUCA which is sensitive to visible light, and SBND is the only experiment which will operate this version of X-ARAPUCA.

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Innovative media for the purification of liquid argon from nitrogen contaminations

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Liquid argon (Large) is used as active media in several neutrino and dark matter experiments (DUNE, SBND, Microboone, Icarus, DarkSide, DEAP, …). Ionization particles in liquid argon produce free charges and scintillation photons. Both signals are used to perform calorimetric measurements, particle identification and three dimensional reconstruction. LAr scintillation light can be quenched and absorbed by the presence of nitrogen contaminations. In neutrino detectors electronegative contaminants, like oxygen and water, are continuously filtered, while nitrogen is not. This can lead to a reduction of the scintillation signal in case of air leaks in the detector. Dark matter experiments typically filter nitrogen in gas phase at room temperature.
A new innovative media for the purification of argon from nitrogen in liquid phase will be presented.
The innovative molecular sieve is the zeolites Li-FAU. Purification tests have been performed using the Liquid Argon (LAr) Purification Cryostat (PuLArC) at IFGW/Unicamp. Previous studies performed with nitrogen gas at T=89 K, revealed a strong interaction of nitrogen with the lithium cations present in the zeolite LiX. The tests performed in PuLArC have unequivocally shown that the Li-FAU adsorbent is capable of capturing N2 recirculating argon in liquid phase. The Li-FAU was able to reduce a N2 contamination of 20-50 ppm (part per million) to 0.1-1.0 ppm in 1-2 hours of circulation time. The test was repeated several times. These results invoke further investigations in larger scale LAr cryostats at Fermilab and CERN in order to support the possible use of Li-FAU molecular sieve, in replacement of Molecular Sieve 4A, in LBNF-DUNE and other LAr experiments.

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SND@LHC: a detector for neutrino physics at the LHC

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SND@LHC is a compact and stand-alone experiment that performed the first collider neutrino observation at the LHC.
The detector, located 480 m from the ATLAS interaction point, is composed of a target region, followed downstream by a hadronic calorimeter and a muon identification system.
The target region is instrumented with five walls of emulsion cloud chambers, each followed by a scintillating fiber (SciFi) tracker plane, whose function is to assign a timestamp to the reconstructed neutrino events and measure the energy of electromagnetic showers.
Both the scintillating fiber layers and the multichannel SiPM arrays of the SciFi modules were originally developed for the LHCb SciFi tracker and are here also exploited to perform timing and calorimetric measurements for the first time.
The read-out electronics, based on the TOFPET2 ASIC, has been therefore optimised to meet the stringent time resolution requirements and to allow the measurement of signal amplitudes from the photo-detectors.
After an overview of the SND@LHC detector, the talk will focus on the SciFi tracker, the read-out electronics, and the characterisation of their performance, particularly in terms of time resolution and energy measurement.

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Development of a SiPM-based Water-Cherenkov Detector for High-Energy Particle and Astrophysics Experiments

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A new photodetection device that uses Silicon Photomultipliers and a Cherenkov photon trap system will be presented, which was named C-Arapuca. We describe the construction of a tank containing 550 liters of ultra-pure water, where C-Arapuca and a photomultiplier tube were installed. Cherenkov photons produced by cosmic ray muons are trapped through the use of a dichroic filter on the optical window and an internal plate that performs wavelength shifting and guides photons to Silicon Photomultipliers. We present a comparison of the performance of C-Arapuca with the photomultiplier tube in detecting cosmic ray muons. Our results suggest that C-Arapuca could be a viable option for future Water-Cherenkov Detector designs and upgrades, providing a reliable solution for particle detection in high-energy physics and astrophysics experiments.

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Detector physics and event reconstruction at the MicroBooNE experiment.

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The MicroBooNE experiment is a Liquid Argon Time Projection Chamber (LArTPC) placed on-axis to the Booster Neutrino Beam (BNB) at Fermilab. MicroBooNE ran its physics and R&D runs from 2015 through 2021. Its primary physics goal is to contribute to addressing the elusive short-baseline MiniBooNE low energy excess. MicroBooNE records and utilizes both the ionization charge and scintillation light produced inside the TPC to select and reconstruct its events. To properly address the physics goals, it is crucial to properly understand how the detector evolves over time and perform continuous calibrations. This means performing state of the art measurement of detector physics quantities such as electron lifetime, diffusion, as monitoring and calibrating the light yield. This talk will go over what MicroBooNE has learned and measured throughout its nearly continuous 7 years of running regarding detector physics measurements. Analysis of MicroBooNE performance over time will be beneficial to the next many years long running Short-Baseline Neutrino (SBN) and DUNE programs to properly understand the important detector physics measurements in LArTPCs. Finally, we will present recent developments in LArTPC analysis that demonstrate O(ns) neutrino interaction timing and MeV-scale physics reach employing both charge and scintillation signatures.

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Performance of a prototype gaseous TPC with optical readout for rare events studies

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A gaseous Time Projection Chamber (TPC) with optical readout is proposed in the CYGNO project as an innovative technique to study rare events such as DM particle or solar neutrino interactions. 3D particle tracks can be reconstructed in the TPC volume, filled with He:CF4 at atmospheric pressure. The amplification stage exploits a stack of three Gas Electron Multipliers (GEM) stack where the ionisation charge is multiplied; photons are produced in the multiplication process which are in turn read out by sCMOS sensors and PMTs. The sCMOS camera guarantees a high readout granularity, a high sensitivity, and a low noise level. PMTs are used as well to measure the drift time of ionisation electrons to obtain the coordinate perpendicular to the camera plane. This technique allows the measurement of the particle energy with a O(KeV) threshold and, also, to have a sensibility to the direction of the events. This last characteristic is very relevant, especially for background discrimination.

A 50 L prototype (LIME) is the last and largest prototype built. It was operated at the Frascati National Laboratories (LNF) and was then moved underground at the Gran Sasso National Laboratories (LNGS) where it is still under test exploiting different shielding configuration to carefully measure internal and external backgrounds and to test reconstruction capability in realistic conditions.

Results on the measured performance of LIME overground using several radioactive sources will be presented, as well as the studies on the long-term stability and performances of the prototype both over and underground. The comparison of a Monte Carlo simulation of the detector response with measured data will be shown. Moreover, current R&D activities with the aim of optimizing the design of the O(1) m3 demonstrator to be hosted in Hall F of LNGS will be discussed.

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SpecMAT, the active target for nuclear transfer reactions studies at ISOLDE, CERN

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SpecMAT is an active target developed for studying the shell evolution in exotic isotopes and observing the fundamental aspects of the nuclear structure far from stability via transfer reactions carried in inverse kinematics. The active target, which is a novel modification of a time projection chamber, can acquire three-dimensional tracks of light reaction products and work in coincidence with the scintillation array sensitive to gamma-rays emitted by the heavy reaction products. The SpecMAT is currently at its final developmental stage undergoing characterisation measurements at ISOLDE, CERN. During the most recent characterisation, SpecMAT was installed in the ISOLDE Solenoidal Spectrometer, which generated a magnetic field of 2.5 T. This characterisation was performed offline using a standard alpha source. In this measurement spiral tracks of alpha particles were successfully observed in the time projection chamber of the detector. Gamma rays emitted in the decay chain of 241Am were detected in coincidence with the particle tracks by the scintillation array. With this characterisation, we demonstrated that all detector components could operate in the strong magnetic field and are ready for future online experiments.
In this talk, recent Geant4 simulations of transfer reactions that can be studied with SpecMAT also will be presented. Using the newly developed simulation toolkit, SpecMATscint, we demonstrated the feasibility of studying the shell evolution in the chain of neutron-rich copper isotopes via a (d,3He) transfer reaction.

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Trigger and data acquisition systems for SABRE South

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The SABRE (Sodium-iodide with Active Background REjection) South experiment, located at the Stawell Underground Physics Laboratory (SUPL) in Australia, aims to measure an annual modulation in dark-matter interactions using ultra-high-purity NaI(Tl) crystals. In partnership with the SABRE North effort at the Gran Sasso National Laboratory (LNGS), SABRE South is designed to disentangle any seasonal or site-related effects from the dark matter-like modulated signal observed by DAMA/LIBRA in the Northern Hemisphere.
SABRE South is instrumented with 7 ultra-high-purity NaI(Tl) crystals surrounded by a liquid scintillator veto, and covered by 8 plastic scintillator muon detectors. Each NaI(Tl) crystal and muon detector is coupled to 2 photomultiplier tubes (PMTs) and a further 18 PMTs are used to detect interactions in the liquid scintillator giving a combined total of 48 channels. The data acquisition system for SABRE South utilises a number of CAEN digitisers to acquire waveform data for each of these PMTs. The trigger system is built upon a CAEN logic unit using custom FPGA logic which is extensively simulated and also tested in hardware to ensure long term reliability.
This talk will cover the design and status of the SABRE South trigger and data acquisition systems.

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Crystal detector backgrounds of the SABRE South experiment

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The SABRE (Sodium iodide with Active Background REjection) experiment aims to detect an annual rate modulation from dark matter interactions in ultra-high purity NaI(Tl) crystals in order to provide a model independent test of the signal observed by DAMA/LIBRA. It is made up of two separate detectors; SABRE South located at the Stawell Underground Physics Laboratory (SUPL), in regional Victoria, Australia, and SABRE North at the Laboratori Nazionali del Gran Sasso (LNGS). SABRE South is designed to disentangle seasonal or site-related effects from the dark matter-like modulated signal.
The experiment can host seven NaI(Tl) crystals, each instrumented with two R11065 PhotoMultiplier Tubes (PMTs) which are encapsulated in cylindrical copper enclosures flushed with nitrogen. These are surrounded by an active scintillator medium which provides both passive and active shielding, additionally outside this is further passive shielding to block external radiation.
To achieve the highest sensitivity possible, SABRE is working to produce NaI(Tl) crystals with extremely low background in the (1-6) keVee energy region. In this low energy region radioactive contaminants dominate the signals produced in the crystals but also noise introduced by the photomultipliers and readout system can become dominant at lower energies. Significant work has been undertaken to understand and mitigate the background processes that take into account radiation from detector materials, from both intrinsic and cosmogenic activated processes, and to understand the performance of the crystal system.
This talk will report on the results on the characterisation of and dedicated studies on understanding and reducing noise associated with the SABRE South crystal PMTs and their electronics. The results of a detailed simulation of the expected background due to radioactive contamination of the detector will also be shown.

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Electron transport measurements in liquid xenon with Xenoscope, a large-scale DARWIN demonstrator

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There is a compelling physics case for a large, xenon-based underground detector devoted to dark matter and other rare-event searches. A two-phase time projection chamber as inner detector allows for a good energy resolution, a three-dimensional position determination of the interaction site and particle discrimination. To study challenges related to the construction and operation of a multi-tonne scale detector, we have designed and constructed a vertical, full-scale demonstrator for the DARWIN experiment at the University of Zurich. Here we present first results from a several-months run with 343 kg of xenon and electron drift lifetime and transport measurements with a 53 cm tall purity monitor immersed in the cryogenic liquid. After 88 days of continuous purification, the electron lifetime reached a value of 664(23) microseconds. We measured the drift velocity of electrons for electric fields in the range (25–75) V/cm, and found values consistent with previous measurements. We also calculated the longitudinal diffusion constant of the electron cloud in the same field range, and compared with previous data, as well as with predictions from an empirical model.

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Pixelised Resistive Micromegas for Tracking Detectors in Future Particle Physics Experiments

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In this contribution, we present a development of resistive Micromegas (MM) technology to reach stable and efficient operation up to particle fluxes of 10 MHz/cm2. This can be achieved with a pixelized detector using readout pads of a few mm2 area, significantly reducing the occupancy of the readout elements. In the most recent prototypes (exploiting double DLC layer), the resistive layer is continuous and uniform and the charge is evacuated through many dot-connections, several mm apart. An overview of the measured performance in terms of gain, rate capability and recent results on time, efficiency, and spatial resolution from test-beam campaigns is reported for the latest small area prototypes. Different gas-mixtures have been tested and compared, as well.
Moving towards a larger scale, a new detector with an active area of 400 cm2 has been built, implementing a double layer of DLC foils with a surface resistivity around 30 MOhm/square. Results will be reported following laboratory and test beam measurements.

A5 / 196

A square PMT module with 256 channels of <100 ps timing accuracy

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Photek have developed a square microchannel plate (MCP) PMT using 6 µm pore MCPs to achieve superior timing, compared to the previous generation which used 15 µm pores. The native anode pattern is 64x64, but for this module the pattern is ganged to a 16x16 design using an epoxy bonded PCB giving an anode size of 3.3×3.3 mm2 in a 53×53 mm2 active area. The electronic front-end is the TOFPET2d ASIC from Petsys Electronics, a combined amplifier / discriminator / TDC with 30 ps time bins and capable of 480 kHz per channel count rate, with sufficient dynamic range to allow for the gain variation inherent in large area MCP-PMTs. Communications is through gigabit ethernet. The outer envelope of the combined PMT and electronic front-end package allows for close packing on 4 sides with outer dimensions of 60×62 mm giving a 76% fill factor. We present results showing the uniformity of detection efficiency, single photon timing accuracy and count rate capability. We will show simulations of the recoil electrons seen in the timing data, and cross-talk data from a new 32x32 readout format.

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Using NLP for Hardware Quality Control by predicting Alert Signals from Particle Accelerator Detectors

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Abstract.
Particle physics data consists of patterns in measurements that can be separated into hot topics and more mundane data. This approach is analogous to looking for keywords or topics in huge text data by separating more specific words and phrases from the generalities of text through the application of NLP. This will be done using DCS alarm data. The NLP models that were constructed or fine-tuned for text classification included SVM, BERT- base-cased, RoBERTa-base, as well as stacked LSTM and bi-LSTM. This was done on Google Colab using Pytorch and Python libraries, and the hyperparameters were optimised using the WandB platform, in which an extensive Baye's optimisation search was performed. The idea is to use the best-performing models i.e., BERT or RoBERTa and train them by fine-tuning their hyperparameters in order to classify the alarms, as well as predict future alarm signals, and then follow the same procedure for an LSTM model and compare the results. The inputs would contain information about the date and time the alarm was received, the physical variable involved, the type of error as well as the particular system, component or sub- component affected. Since this data provides information about the detector components as well as the abnormal values of the physical variables of their constituent parts during a hardware malfunction, as well as the length of time that is taken until the issue is resolved, this data can be used as a correlator for the status of other sub-detector components during a hardware malfunction of another component. Moreover, the predictive power of this algorithm could avoid fatal errors in the functioning of the hardware and electronic systems especially during testing periods and upgrades and allow for faster and more effective management and advancement of the hardware and electronic systems towards greater technological capabilities.

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The X-rays detector system of the FAMU Experiment for the measurement of the muon transfer rate to carbon

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The study of the properties of the proton is based on spectroscopy measurements. The FAMU experiment aims to meaure the Zemach radius of the proton through exotic atoms. In particular the hyperfine splitting (HFS) of the energy ground levels of the muonic hydrogen (μp) is directly related to the Zemach radius. In presence of a gas mixture, muons are transferred from μp to heavier gas with energy-dependent rate resulting also in a higher rate of X-rays. An efficient and fast detector system is required for such a precise measurement. The experiment is based on LaBr3(Ce) fast timing X-rays detectors read by PMTs.
Performances of the detector system had been analyzed in order to obtain the measurement of the muon transfer rate to carbon and they are presented here.

F2 / 200

Challenges and concepts for a multi-TeV Muon Collider experiment

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Muon colliders provide a unique route to deliver high energy collisions that enable discovery searches and precision measurements to extend our understanding of the fundamental laws of physics. All this at a single circular collider and on a feasible timescale, as reviewed in the frame of the European Roadmap for Accelerator R&D and during the U.S. Snowmass process. The recently formed International Muon Collider Collaboration,
hosted at CERN, targets the design of a muon collider facility with a center of mass energy of 10 TeV or higher, which seem feasible and
sustainable with technologies that can be made available in the near future. Currently a 3 TeV stage is considered viable as a post HL-LHC facility.
The main challenges are to produce bright muon beams, while facing the drawback arising from the short muon lifetime at rest. The detector design,
the choice of the technologies, and reconstruction algorithms are heavily influenced by the beam-induced background (BIB). A dedicated design
of the machine detector interface is required to mitigate an unprecedented amount of secondary and tertiary decay products of muons beams at the interaction point. From an initial detector concept and full simulation studies of data reconstruction performance and physics projections
at 1.5 and 3 TeV, we outline next steps in the development of a multi-purpose detector for a muon collider with center-of-mass energies up to 10 TeV.
The status of the experiment design, future plans for R&D and synergies will be discussed.

C3 / 201

HKROC: a modern integrated front-end ASIC to readout photomultiplier tubes for Cherenkov-based experiments

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The HKROC ASIC was originally designed to readout the photomultiplier tubes for the Hyper-Kamiokande experiment. HKROC is an auto-triggered very versatile and innovative ASIC capable of readout a large number of channels while meeting very stringent requirements in terms of noise, time & charge resolution while sustaining very high hit-rate and low-power consumption.
Each HKROC channel features a low-noise preamplifier and shapers, a 10-bit successive approximation Analog-to-Digital Converter (SAR-ADC) for the charge measurement (up to 2500 pC) and a Time-to-Digital Converter (TDC) for the Time-of-Arrival (ToA) measurement with 25 ps binning. The key feature of HKROC is its "waveform digitization" capability: it dynamically opens acquisition windows for internal digitization. It enables new possibilities in terms of pulse-shape analysis and double pulse triggering with a low dead time (down to 10 ns), while preserving a very low power consumption compared to standard flash-ADC. Moreover, HKROC is equiped with an adaptive readout which allows to cope with very high rate events such as close supernovae (Betelgeuse…) for neutrino based experiment.
The presentation will describe the ASIC architecture and the experimental results of the second HKROC prototype received in December 2022.

H3 / 203

The Use of a Burn-In Station for stress-testing and reliability studies in particle physics instrumentation

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Abstract. Electronics, in general, experience a high mortality rate in the first few months of their use - this is especially true for particle physics instrumentation, where electronic components are subjected to high temperatures, constant loads, and radiation. This environment necessitates the development of a process to test the performance and reliability of the electronics to mitigate the risk of early-life failures. A burn-in station is a sophisticated testing station which emulates the high-stress environment the electronics would experience, in order to artificially age them; data can be collected on the input and output currents and voltages and temperatures, which can be graphed to find behaviour trends. The test station, and the data collected from running it, can then be used for reliability studies on the instrumentation and to create a predictive model as a preemptive warning system to alert technicians in advance if a component is likely to fail.

C1 / **204**

ATLAS New Small Wheel Performance Studies with First Data of LHC Run3

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After successfully completing Phase I upgrades during LHC Long Shutdown 2, the ATLAS detector is back in operation with several upgrades implemented. The most important and challenging upgrade is in the Muon Spectrometer, where the two inner forward muon stations have been replaced with the New Small Wheels (NSW) system featuring two entirely new detector technologies: small strip Thin Gap Chambers (sTGC) and the resistive Micromegas (MM).
After massive construction, testing and installation work in ATLAS, the two NSW endcaps are now fully operational in the experiment participating in the muon spectrometer tracking system and muon trigger system. At the same time completing the phase of commissioning of this completely new system. A huge effort has gone into the operation of the new data acquisition system, as well as the implementation of a new processing chain within the muon software framework.
The new detectors are fully integrated into the software. Tracking is performed with full consideration of the absolute alignment of each individual detector module by the ATLAS Muon Spectrometer optical alignment system. All the deviations from the nominal geometry of all the constituent elements of each sTGC and MM module are accounted for through the modeling of the real chamber geometry reconstructed from the information of the construction databases.
After an overview of the software implementation and the strategies adopted for the simulations and reconstruction, the studies on the performance of the NSW system from the 2022 and from the first months of 2023 RUN3 data taking will be reported.

A3 / **205**

The trigger and calo DAQ of the HEPD-02 on CSES-02 satellite

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The High Energy Particle Detector (HEPD-02) onboard the second China Seismo-Electromagnetic Satellite (CSES)-02 is designed to measure cosmic rays, i.e., electrons and protons, along with light nuclei, in the energy range between a few MeV and a few hundreds of MeV. This high-precision

instrument is composed by different subdetectors: a tracking system, a trigger system, a calorimeter made by a tower of plastic scintillators and an array of LYSO crystals, and a veto system.
The data acquisition of trigger, calo, and veto is performed by a single electronic board which relies on two Weeroc Citiroc ASICs. This board issues and manages the trigger signals for the whole apparatus and optimizes the acquisition of signals with different timing characteristics, such as those coming from plastic scintillators and LYSO.
Since particle fluxes span several orders of magnitude along the orbit of CSES-02, the trigger generation system must be extremely adaptable, and the data acquisition must guarantee the measurement of energy spectra with a high duty cycle.
The HEPD-02 trigger system features concurrent trigger configurations and prescaling capability to adjust the data acquisition scheme depending on the orbital zone and on the presence of impulsive events. Each trigger pattern is optimized to meet scientific requirements about the field of view and the nature of particles impinging in the detector, with prescaling settings suitably adjusted.
While still monitoring particle bursts, trigger configurations dedicated to gamma rays will be tracked on a time basis of 5 milliseconds, to measure photon fluxes in the MeV-tens of MeV energy range and provide sensitivity for rare events, such as Gamma Ray Bursts (GRB).
This contribution describes the design criteria and the architectural choices for the use in space. The performance of the trigger system, including results from laboratory and beam tests performed on the flight model of the HEPD-02, is also presented.

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An innovative particle detector onboard the CSES-02 satellite

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The China Seismo-Electromagnetic Satellite (CSES) mission develops through a constellation of satellites, devoted to the study of the near-Earth environment, including electromagnetic fields, ionospheric plasma and particle populations. Each satellite - flying on a quasi-polar Sun-synchronous low-Earth orbit - is a multi-channel space observatory and hosts several instruments onboard.

One of its scientific instruments is the High Energy Particle Detector (HEPD), a sophisticated apparatus designed to identify and measure energy and arrival direction of cosmic particles in the MeV energy window, thus being a perfect detector for Space Weather purposes. This high-precision instrument is composed by several subdetectors: a tracker, a trigger system, a calorimeter made by a tower of plastic scintillators and an array of LYSO crystals and a veto system.
The first High Energy Particle Detector (HEPD-01) has been working since 2018 onboard the CSES-01 satellite.

HEPD-02 – subject of this contribution - presents important improvements with respect to its predecessor: it is the first instrument carrying a CMOS pixel tracker in space, designed to reach a 5 micron resolution; the LYSO crystals are the largest ever used in space; the new trigger system, providing trigger pre-scaling and concurrent trigger configurations, allows to adapt the data acquisition scheme depending on the orbital zone and on the presence of impulsive events. HEPD-02 will be hosted on the second satellite of the CSES mission, scheduled to fly at the beginning of 2024.

In this contribution I will focus on the design choices and the new technologies used for HEPD-02, and mention the test campaign for the instrument space qualification and calibration.

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The Power System of GEM-Muon Sub-Detector for CMS Phase-II upgrade

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In preparation for the High Luminosity LHC phase, the Compact Muon Solenoid (CMS) experiment is working on its (Phase-2) upgrade. The Gas Electron Multiplier (GEM) detectors are one of the technologies involved in this upgrade. The GEM systems consist of 3 stations. GE1/1 was installed and is taking data since the beginning of Run3; GE2/1 and ME0 will be installed during the next Year End Technical Stop (YETS) and the Long Shutdown 3 (LS3). The GEM stations utilize different modules manufactured by CAEN for the High-Voltage (HV) and Low Voltage (LV) power systems (PS). The HV-PS is used to generate the electric field needed for the multiplication of electrons inside of the GEM foils while the LV-PS is crucial for the GEM ON/OFF detector electronics. Some hardware modifications are applied to CAEN HV-boards to meet the HV-PS requirements for ME0. We benefit from different features of CAEN modules to build a LV power system for the 3 stations of GEM detectors that minimizes the space needed in both the service and the experimental caverns of CMS, the power consumption, and the financial budget. All these modules have to be tested and validated before installation in the CMS caverns. In this talk the configuration, the design and mapping of HV and LV power systems for the GEM Phase-II upgrade will be presented.

D4 / **208**

Implementation of large imaging calorimeters

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The next generation of collider detectors will make full use of Particle Flow algorithms, requiring high precision tracking and full imaging calorimeters. The latter, thanks to granularity improvements by 2 to 3 orders of magnitude compared to existing devices, have been developed during the past 15 years by the CALICE collaboration and are now reaching maturity. The state-of-the-art and the remaining challenges will be presented for all investigated readout types: silicon diode and scintillator for a electromagnetic calorimeter, gaseous with semi-digital readout as well as scintillator with SiPM readout for a hadronic one. We will describe the commissioning, including beam test results, of large scale technological prototypes and the raw performances such as energy resolution, linearity and studies exploiting the distinct features of granular calorimeters regarding pattern recognition. Note that, at the time of conference new results obtained in recent (2021/22) beam tests with a technological prototype of a highly granular silicon tungsten electromagnetic calorimeter standalone and combined with the CALICE analogue hadron calorimeter (SiPM on Tile) will be available. The setup did comprise around 37500 (15500+22000) readout cells. Beyond the mentioned prototypes, the design of experiments addressing the requirements and potential of imaging calorimetry will be discussed. In addition, less established but promising techniques for dedicated devices inverse APD or segmented crystal calorimeters will also be highlighted. In the last year also first results with high resolution timing devices have been obtained. The integration of these devices in the CALICE prototypes is one of the major goals in the coming years.

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Exploring the structure of hadronic showers and the hadronic energy reconstruction with highly granular calorimeters

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Prototypes of electromagnetic and hadronic imaging calorimeters developed and operated by the CALICE collaboration provide an unprecedented wealth of highly granular data of hadronic showers for a variety of active sensor elements and different absorber materials. In this presentation, we discuss detailed measurements of the spatial and the time structure of hadronic showers to characterise the different stages of hadronic cascades in the calorimeters, which are then confronted with GEANT4-based simulations using different hadronic physics models. These studies also extend to the two different absorber materials, steel and tungsten, used in the prototypes. The high granularity of the detectors is exploited in the reconstruction of hadronic energy, both in individual detectors and combined electromagnetic and hadronic systems, making use of software compensation and semi-digital energy reconstruction. The results include new simulation studies that predict the reliable operation of granular calorimeters. Further we show how granularity and the application of multivariate analysis algorithms enable the separation of close-by particles. We will report on the performance of these reconstruction techniques for different electromagnetic and hadronic calorimeters, with silicon, scintillator and gaseous active elements. Granular calorimeters are also an ideal testing ground for the application of machine learning techniques. We will outline how these techniques are applied to CALICE data and in the CALICE simulation framework.

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IISMA developments towards modern highly granular calorimeters

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Institute of Scintillation Materials, Kharkiv, Ukraine has been a member of CMS collaborators for more than 20 years, is also a technically associated member of the LHCb experiment, takes part as a partner in other projects and communities in high energy physics experiments
The Institute is a manufacturer and supplier of scintillators for different experiments. Active take part in the development of materials for detectors for industrial and high energy physics experiments.
Most of the research work of the institute is devoted to the development of radiation-resistant materials based on organic and inorganic scintillation materials. Optical materials for the detector: reflector, optical contact, absorber.
Work is underway to develop and create technologies for obtaining scintillators for modern highly granular calorimeters.
We take part in R&D project aims to study the concept of a next-generation calorimeter, in analogy

with the Shashlik technology, for possible application in FCC e+e- experiments. Potential it provide extremely fine sampling of the electromagnetic shower and for this reason a very good photon energy resolution is expected (~2%/√E) with respect to conventional Shashlik detectors.

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Scintillating sampling ECAL technology for the LHCb PicoCal

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The aim of the LHCb Upgrade II is to operate at a luminosity of 1.5 x 10^{34} cm^{-2} s^{-1} to collect a data set of 300 fb^{-1}. The required substantial modifications of the current LHCb electromagnetic calorimeter due to high radiation doses in the central region and increased particle densities are referred to as PicoCal. A consolidation of the ECAL already during LS3 will reduce the occupancy and mitigate substantial ageing effects in the central region after Run 3.

Several scintillating sampling ECAL technologies are currently being investigated in an ongoing R&D campaign: Spaghetti Calorimeter (SpaCal) with garnet scintillating crystals and tungsten absorber, SpaCal with scintillating plastic fibres and tungsten or lead absorber, and Shashlik with polystyrene tiles, lead absorber and fast WLS fibres.

Timing capabilities with tens of picoseconds precision for neutral electromagnetic particles and increased granularity with denser absorber in the central region are needed for pile-up mitigation. Time resolutions of better than 20 ps at high energy were observed in test beam measurements of prototype SpaCal and Shashlik modules. Energy resolutions with sampling contributions of about 10%/sqrt(E) in line with the requirements were observed. The presentation will also cover results from detailed simulations to optimise the design and physics performance of the PicoCal.

G2 / **212**

Drift chamber with cluster counting techniques for CEPC

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The Circular Electron Positron Collider (CEPC) is designed to operate at center-of-mass energies of 240 GeV as a Higgs factory, as well as at the Z-pole and the WW production threshold for electroweak precision measurements and study of flavor physics. A good identification of charged kaons is essential for the flavor physics and benefits the determination of jet flavor and jet charge. To achieve these physics goals, a design of tracking system combining a silicon tracker and a drift chamber is proposed. The silicon tracker provides excellent spatial resolution and granularity to cope with track separation in dense jets. The drift chamber could provide excellent particle identification (PID) performance with cluster counting technique. The cluster counting, which measures the number of primary ionizations (dN/dx) instead of the energy loss (dE/dx) along the particle trajectory in a gaseous detector, represents the most promising breakthrough in PID. The Poissonian nature of the dN/dx offers a more statistically significant way of ionization measurement, which makes the dN/dx potentially has a resolution two times better than the dE/dx.
In this presentation, detailed PID study of the CEPC drift chamber will be discussed. Simulations

from the ideal model to a more realistic one have been carried out. The ideal model, which only simulates the ionization process without considering the detector response, shows promising PID performance for dN/dx over dE/dx. The realistic model, which includes the detector and electronics responses as well as the reconstruction algorithm, is used to optimize the drift chamber design and to provide the PID performance. A preliminary CEPC drift chamber design is proposed. The PID performance in terms of the kaon and pion separation power with one meter track for 20 GeV/c momentum can reach 2σ level, which satisfies the preliminary physics requirements of CEPC.

F4 / 213

Online Luminosity Monitor at Belle II

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We describe a system used for online measurements of luminosity, utilizing elastic e^+e^- Bhabha scattering and two-photon annihilation processes reconstructed with the Belle II electromagnetic calorimeter. The Belle II experiment at the SuperKEKB asymmetric-energy e^+e^- collider is designed to achieve a luminosity of 6×10^{35} cm^{-2}s^{-1}. With the designed parameters of SuperKEKB, the statistical accuracy of the instantaneous luminosity measurement provided by the Online Luminosity Monitor is expected to be better than 1% within one second. The overall systematic uncertainty is estimated to be at the level of 1.7%. Comparison with a dedicated offline analysis and results on the long-term stability of the monitor's performance are also presented.

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New Ideas on ILC Detector Technologies & Sustainability Studies for Linear Colliders

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Among all "Higgs Factories", the international Linear Collider project (ILC) with a first stage at 250 GeV, followed by an upgrade to higher energy, is by far the most advanced in terms of technology, maturity, cost, and preparations in international cooperation. A global design and R&D effort for baseline detector concepts, ILC and SiD, allowed drawing up the main specifications for the detector performance. Intentionally, ILD and SiD concept groups did not make specific choices and keep various options for technologies open to realize the individual sub-detectors. This has an advantage that the technologies can be further matured until specific choices will be made once the project is approved. Several promising new ideas for improved sensors and detector systems that can be integrated into ILD and SiD will be discussed in this talk. Recent developments are ongoing to adapt elements of ILD concept that might need to be changed, should ILD operates at other circular Higgs Factory colliders.

This talk will also highlight the challenges and necessary technological advances for detector optimization, further R&D work on critical accelerator technologies within the ILC International Technology Network (ITN), and address sustainability aspects for future Linear Collider facilities.

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Results from the first science run of the XENONnT expertiment

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The XENON project is a multi-stage research program that aims to identify the true nature of dark matter using two-phase liquid xenon time projection chambers of increasing size and sensitivity. The current phase, XENONnT, is operating at the Laboratori Nazionali del Gran Sasso in Italy. Designed to be a rapid upgrade of its predecessor XENON1T, XENONnT is expected to improve sensitivity to weakly interacting massive particles (WIMPs) by more than an order of magnitude. To accomplish this, XENONnT features new technology and infrastructure enabling it to achieve an unprecedented target purity and background level. The first science run (SR0) was performed from May to December 2021. Results from dark matter searches and other beyond the standard model processes will be shown as well as the main hardware upgrades of the experiment.

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European Innovation Council (EIC) : support of breakthrough technologies and disruptive innovation

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The European Innovation Council (EIC) has been established under Horizon Europe as Europe's flagship innovation programme to identify, develop and scale up breakthrough technologies and game changing innovations. With its budget of €10.1 billion for the period 2021-2027 it focuses mainly on high-risk innovation throughout the lifecycle from early stage research, to proof of concept, technology transfer, and the financing and scale up of start-ups and SMEs. A majority of the funding is awarded through 'open' calls with no pre-defined thematic priorities. This enables support for any technologies and innovations that cut across scientific, technological, sectoral and application fields or represent novel combinations. This is complemented by a 'challenge' driven approach informed by the work of EIC Programme Managers. The programme has three main instruments such as Pathfinder (supporting research and development on high-risk emerging technologies), Transition (pushing ideas from lab to business) and Accelerator (supporting start-ups' development and scaling up incl. through the EIC Fund providing investments from seed to early growth). The support from the EIC goes beyond funding. All beneficiaries receive access to tailor-made Business Acceleration Services. This facilitates connections and support that can help scale-up EIC-supported companies and enable researchers to take the first steps towards commercialising their results.

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The DESY Innovation Ecosystem - from Basic Research to Deep-Tech Business

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I will give an overview of the different measures DESY is taking to foster innovation and technology transfer. This is happening on four different levels. First DESY is systematically scouting for promising technologies and ideas for exploitation within the research teams. Second is that DESY is inviting the industry to cooperate with its scientists and use the scientific infrastructure within its innovation processes. The third field is to encourage our scientist to go into business themselves and found companies with their technological developments and last but not least there is a set of infrastructure projects pr

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Max Planck Innovation: Patents, Licensing, and Startups – A Comprehensive Service for Max Planck Scientists

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Max Planck Innovation (MI) is responsible for technology transfer from the research institutes of the Max Planck Society.

The Max Planck Society (MPG) operates as Germany's most successful organization in basic research and is world renowned for its cutting-edge research. In many cases this cutting-edge research also forms the basis for innovative products and services that are implemented through licensing and spin-off companies.

Thus we perform an important task: the transfer of basic research results into products, which contribute to the economic and social progress.

MI has been providing a link between science and business since 1970. Max Planck Innovation advises and supports Max Planck scientists in assessing the potential of an invention and applying for patents. It also markets patents, technologies and know how to industry and is on hand to help new entrepreneurs set up their business who convert the research results from the Max Planck Society into products and services.

Two start-ups are briefly presented as examples of successful technology transfer (licensing and company foundation) in the MPG: Ultrafast Innovations GmbH (www.ultrafast-innovations.com) and terraplasma GmbH (www.terraplasma.com).

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Technology Transfer in particle physics research institutes: the case of the National Institute of Nuclear Physics (INFN)

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Large experiments, designed and built to answer questions of fundamental physics, have a very high level of frontier technology. One of the challenges we face today, alongside that of advancing knowledge, is to take these technologies out of the research field so that the advantage for society also translates into the country's competitive growth.

Building successful projects does not follow a linear path and involves multiple players with different skills. Researchers are an active part of the process, but the system is increasingly organizing itself towards the creation of dedicated structures that take care of the many steps necessary to bring research products closer to the market: the Technology Transfer model INFN is based on the close synergy between the National Committee for Technology Transfer (NTTC), which has the task of identifying strategies for enhancing knowledge and making the tools available to develop it, and the Technology Transfer Office (TTO), which provides expertise on patenting procedures, definition and protection of intellectual property, support for the creation of academic spin-offs and relationships with companies. In each INFN structure there is also a network of local representatives coordinated directly by the NTTC who promote the scouting of new technologies and proposals coming from the network of researchers.
Over the past few years, the joint and coordinated work of the TT's various structures has facilitated a significant increase in collaborative research initiatives conducted with companies, protection and exploitation of intellectual property, and support of spin-off creation. INFN's most successful stories will be presented.

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ATTRACT, an European Funded project to foster the transition from the lab to the market

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In 2018, the European Commission (EC)'s Horizon 2020 Programme funded ATTRACT phase 1, which supported 170 breakthrough technology concepts in the domain of detection and imaging technologies across Europe. The projects were each granted €100,000 in seed funding to create a proof-of-concept. ATTRACT co-innovation approach seeks to act as a bridge between two communities – research and industry – with apparently different motivations and goals for undertaking research and development and innovation (R&D&I). The ATTRACT Consortium uses public funding to lower the intrinsic risk that breakthrough technology bears as it moves along technology readiness levels (TRLs) and reaches private investment and the market. Lowering risk is achieved in two phases:
- Risk absorption (ATTRACT phase 1): ~TRLs 1 to 4.
- Risk reduction (ATTRACT phase 2): ~TRLs 4 to 7.
After reaching a stage around TRL 7, breakthrough technologies – thanks to public funding – will have been sufficiently de-risked to become more attractive to private funders. At this point, ATTRACT phase 2 will be completed, and private investment will help to commercialize new products and services for society. The ATTRACT project is now in its Phase 2. In this talk, some of the lessons learnt will be analyzed which might prove insightful for understanding the process of managing R&D&I Innovation Ecosystems

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KT at CERN: opportunities and challenges

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After a general introduction of KT at CERN, its activities and some examples, the talk will cover the main opportunities for CERN KT partners and the main challenges associated to the sometimes tortuous path from research to commercialization and societal impact.

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Knowledge & Technology Transfer with Industry in EU projects

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Future projects in particle and nuclear physics typically have a large scale in terms of complexity, size, technological requirements and associated costs. These projects therefore cannot be realised like earlier experiments in the field, where most of the equipments were designed, tested , built, and installed by academic researchers. For future projects cooperation with industry will be essential from the early stages of a project in order to achieve success. This calls for co-creation and co-development between Academia and Industry for a rather extensive period in the lifetime of these projects. European funded projects are very important to pursue the necessary R&D in close collaboration with Industry.
Examples of co-creation and co-development between Academia and Industry in various EU projects will be showcased during this session.

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Knowledge Exchange through Collaborations with Industry Partners: A Perspective from a University Group

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The detectors in experimental physics are typically custom made devices developed by the research groups who later use them for their experiments.The production of such detectors requires industrial processes.While the physicists and engineers designing the detectors need to have a good understanding of the details of the technologies offered by industry,the industry partners have to understand our specifications and potentially adapt their processes to our needs. Open collaborations with industry partners are therefore essential for the field of instrumentation for experimental physics. Using specific examples, we will showcase what knowledge exchange is in this context and how it boost technology advancements.

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Random Power, from single photon sensitive detectors to random bit generation: an entrepreneurial endeavor

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Random Power is a project, now turned into a start-up company, aimed to develop a platform of devices for random bit stream generation. The history of the company will be presented, from the idea flashing while working on single photon sensitive devices to awareness of the market potential,

promotion through start-up competition and funding. The latter will be critically analysed, with a focus on the interaction with Venture Capital firms and the role of public funding.

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The DEPFET based all-silicon module for the Belle II Pixel Detector PXD: construction, assembly and installation

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Belle II located at the SuperKEKB collider at KEK, Japan, started data taking in March 2019 and is currently in the 1st long shutdown (LS1) after reaching the peak luminosity of 4.7e34 /cm2.s and collected about 430 fb-1 of data. Crucial to the Belle II detector is the Pixel Sub-Detector (PXD), which provides precise vertexing capabilities in a challenging radiation environment. LS1 opens the opportunity to replace the 1st de-scoped version of PXD (PXD1) with the fully completed arrangement of DEPFET modules forming PXD2.

This presentation focuses on the concept and assembly of the unique DEPFET based all-silicon modules for PXD1 and PXD2, discussing the performance of PXD1 and transition from PXD1 to PXD2. PXD2 passed the commissioning phase and is at the time of writing being installed in the interaction region of Belle II.

We will describe in detail our experience during the construction and assembly of the modules. The presented technology allows the currently most light-weight pixel detector in operation. The material is just about 0.2% of a radiation length including all structures needed for interconnection, support, and thermal management. This is only possible with the unique approach where all readout ASICs and interconnects are integrated on a micro-machined and self-supporting piece of silicon with the ultra-thin active DEPFET pixel sensor as integral part of the module.

We will conclude with the application of this module concept for other experiments like direct electron detectors and the outlook to integration of micro-channels into the supporting silicon.

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The performance of the liquid krypton calorimeter of the KEDR experiment

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The performance of the 30 tons liquid krypton calorimeter of the KEDR experiment during successful operation in 2004–2022 at the VEPP-4M e+e- collider will be presented. A brief introduction to the design, cryogenic system, readout electronics, and trigger will be given. The stability and of all aspects of the calorimeter operation will be discussed. The physical performance of the calorimeter (energy, spatial resolutions and etc.) obtained in the experiments is presented in detail.

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Low Gain Avalanche Detectors for the ATLAS High Granularity Timing Detector: laboratory and test beam campaigns

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The High Granularity Timing Detector (HGTD) is designed for the mitigation of pile-up effects in the ATLAS forward region and for bunch per bunch luminosity measurements. HGTD, based on Low Gain Avalanche Detector (LGAD) technology and covering the pseudorapidity region between 2.4 and 4.0, will provide high precision timing information to distinguish between collisions occurring close in space but well-separated in time. Apart from being radiation resistant, LGAD sensors should deliver 30 ps time resolution per track for a minimum-ionising particle (35 ps per hit) at the start of lifetime, increasing to 50 ps per track (70 ps per hit) at the end of HL-LHC operation. Each readout cell has a transverse size of 1.3×1.3 mm2 leading to a highly granular detector with about 3 millions of readout electronics channels. A dedicated ASIC for the HGTD detector, ALTIROC, is being developed in several phases producing prototype versions of 2×2, 5×5 and 15×15 channels. HGTD modules are hybrids of the LGAD and ALTIROC connected through flip-chip bump bonding process.Several test beam campaigns have been conducted at DESY and CERN SPS H6 beamline in 2022. The performance of irradiated Carbon-enriched LGAD sensors from different vendors has been studied.This talk covers the promising results in terms of collected charge, time resolution and hit efficiency of LGADs. A time resolution of < 70 ps is observed in most cases for highly irradiated sensors (2.5e15 neq/cm^2), while integrating timing information to the EUDET system allows for a surface resolution of less than 50 µm. First module prototypes of 15×15 arrays with a pad size of 1.3×1.3 mm2 for the HGTD project have been tested from different manufacturers. Their performance with charged particle beams before irradiation is evaluated. A summary of the results from LGAD-only and hybrids will be presented.

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Photon Detection System in the far detector module of the DUNE experiment

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The Deep Underground Neutrino Experiment (DUNE) is a long baseline neutrino experiment for neutrino science and Beyond the Standard Model physics, aiming to resolve the neutrino mass hierarchy and measure CP-violation phase. DUNE will also have sensitivity to detect neutrinos from supernovae.

The experiment will make use of four far detector (FD) modules, 1300 km away from the beam line, installed 1.5 km deep underground. The FD modules will consist of Liquid Argon Time Projection Chambers with 17 kt of liquid argon each, the largest ever attempted.

Photon detection systems (PDS) are integrated in the liquid-argon neutrino detectors and are used to provide the timing information for an event, which is necessary for reconstructing the drift coordinates of ionizing particle tracks and can be effectively used for other purposes including triggering events, background rejection, and calorimetric energy estimation.

The PDS of the first FD module consists of light collector modules placed in the inactive space between the innermost wire planes of the TPC anode. The light collectors, the so-called X-ARAPUCAs, consist of cells acting as light trap and capturing wavelength-shifted photons inside boxes with highly reflective internal surfaces where they are guided to Silicon Photomultipliers by wavelength-shifting bars.

The first FD module will use X-ARAPUCAs based rectangular Photon Detection unit (Supercell) having dimensions 209×12×2 cm3. The 48 SiPMs on each X-ARAPUCA supercell are ganged together, and the signals are collected by FE electronics, mounted on the supercell. The second FD module

will be equipped with Vertical Drift system, in which charge is drifted vertically toward the charge readout planes. In this case, a new design for X-ARAPUCA, called Megacell has been implemented in which the detector has square dimensions 600×600×8 mm3. In the present work the results in term of photon detection efficiency performances for X-ARAPUCA Supercell design and the test ongoing for the X-ARAPUCA Vertical Drift modules are reported.

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Introduction

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Message from the Director General of the DSI

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Message from the Deputy CEO of the National Research Foundation

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Message from the Director of iThemba LABS

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From CERN to Sesame, the role of global laboratories for science

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From Science to society, view from the IUPAP

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CERN, the international laboratory for particle physics

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Science Diplomacy, a South African view

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Panel Discussion

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The Square Kilometer Array

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NaI experiments

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Technological developments for the CMS HL-LHC Detector Upgrade

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Advances in instrumentation at iThemba LABS

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MicroPattern Gaseous Detectors

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Implementation of Detector R&D Roadmap in Europe (DRD collaborations @CERN)

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Recent development in the field of inorganic scintillator for radiation detectors

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Applications of CMOS Technology at the ALICE Experiment

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Liquid Scintillator Detectors

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Noble Liquid Experiments

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Axion Detection

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Knowledge and Technology Transfer

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Closing Remarks

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Superconducting Technology for Future Colliders and Detectors

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Water Cherenkov Detectors for Neutrinos

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Axion Detection: Techniques, Experiments and Instrumentation

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Axions are a hypothetical elementary particle originally proposed as a result of the Peccei-Quinn solution to the Strong CP problem. With the right masses, axions are a compelling dark matter candidate and have been the subject of growing interest in recent years among the international dark matter detection community.

Generally, axion dark matter is very light – on the order of micro-eV in mass (give or take a few orders of magnitude) meaning that detection techniques look radically different from common WIMP detectors. Axions are theorized to have several couplings to the standard model, the most probed of which is the axion-photon coupling. There are various axion dark matter detection experiments around the world which seek to exploit this coupling, by converting axions into photons and vice-versa.

We will discuss some of the common axion detection techniques, with a focus on axion haloscopes, and give an overview of some of specific experiments in the field such as ADMX and ORGAN. We will look at the current state of the art in axion detection and discuss the future of the field with a focus on instrumentation and detector technology.

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A BURN-IN APPARATUS FOR THE ATLAS TILE CALORIMETER PHASE-II UPGRADE TRANSFORMER COUPLED BUCK CONVERTERS

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Abstract
The upgrade of the ATLAS hadronic Tile-calorimeter (TileCal) Low Voltage Power Supply (LVPS) is a part of the preparation for the High-luminosity LHC project. This talk serves to provide a detailed overview of the development of a Burn-in test station for an upgraded LVPS component known as a Brick. These Bricks are radiation hard transformer-coupled buck converters that function to step-down bulk 200 V Direct Current (DC) power to the 10 V DC required by the on-detector electronics. To ensure the high reliability of the Bricks, once installed within the TileCal, a burn-in test station has been designed and built. The burn-in station functions to implement a burn-in procedure on eight Bricks simultaneously. This procedure subjects the Bricks to suboptimal operating conditions that function to accelerate their ageing as well as to stimulate failure mechanisms. This results in elements of the Brick that would fail prematurely within TileCal failing within the burn-in station or to experience performance degradation that can be detected by follow-up testing effectively screening out the non-performative sub-population. The burn-in station is of a fully custom design in both its hardware and software. The development of the test station will be explored in detail, the preliminary burn-in procedure to be employed will be provided, the preliminary and final commissioning of the test station will be presented culminating in an outlook of the project

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Design and Prototype Testing of the Homogeneous Crystal Calorimeter for STCF

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The Super Tau-Charm Facility (STCF) is the next generation high luminosity e^+e^- collider focusing on the tau-charm physics. STCF will achieve a luminosity of over $0.5 \times 10^{35} cm^{-2} s^{-1}$ at 4 GeV, resulting in a high event rate and a high beam background for the detector system. The background count rate of over 1 MHz per module places new demands on the electromagnetic calorimeter (EMC): maintaining good energy and position resolution under severe pileup conditions. Meanwhile, the development of event timing and particle identification capability is also an important aspect of calorimeter R&D, where a time resolution of better than hundreds of picoseconds is expected.

This talk summarizes the simulation and optimization of the calorimeter system, the prototype fabrication and the test results on the prototype are summarized. The STCF EMC is based on a fast pure CsI crystal and is read out by avalanche photodiodes (APD). By considering the effect of crystal and electronics response, as well as the pileup condition, a complete chain of simulation and reconstruction is implemented in the Offline Software of Super Tau-Charm Facility (OSCAR). The architecture and module geometry of EMC are designed by optimizing the physical performance under OSCAR. Based on the module design, a novel wavelength shifter (WLS)-enhanced prototype is fabricated, which features fast time response and good signal-to-noise ratio at a reasonable cost. The comprehensive test results on the prototype, especially on the radiation hardness of the prototype, the uniformity of the light collection and the cosmic ray-timing performance of the prototype, are also presented.

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Cosmic Ray Muography: Selected Case Studies

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This review systematically explores the rapidly advancing field of cosmic ray muography, a non-invasive imaging technique that utilizes high-energy cosmic ray muons from the atmosphere. These elusive particles can penetrate diverse materials, offering insights into the interiors of geological formations, archaeological sites, nuclear waste storage, and more. This paper examines various studies that employed muography in various imaging applications and scenarios, revealing its challenges, current stage of development, and room for future improvement for each respective paper.