

Kruger 2026: Discovery Physics at the LHC



Report of Contributions

Contribution ID: 1

Type: **Oral**

Asymptotic Grand Unified models

We present the idea of asymptotic grand unification, where the gauge couplings run to a unique fixed point at high energy, thanks to the presence of a compact extra dimension and to a specific choice group structure and multiplet content. We introduce a minimal model based on a $SU(5)$ gauge theory but also discuss $SO(10)$ and other generalisations, giving also few results on the expected phenomenology.

Primary author: DEANDREA, Aldo (IPNL - University Lyon 1)

Co-authors: Prof. CORNELL, Alan (University of Johannesburg); Dr KHOJALI, Mohammed Omer (Univ. Lyon 1); CACCIAPAGLIA, Giacomo (IPN Lyon)

Presenter: DEANDREA, Aldo (IPNL - University Lyon 1)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 2

Type: **Oral**

Searching for New Physics with Unconventional CMS Data Streams and Machine Learning

Scouting and cosmic-ray data extend CMS sensitivity into regions the standard trigger and analysis pipeline cannot reach. Scouting streams have enabled a growing suite of searches for physics beyond the Standard Model; we highlight recent results and new directions that pair them with modern machine-learning methods to expose signatures conventional approaches would miss. The cosmic stream in particular remains largely untapped, offering significant potential for beyond-the-Standard-Model searches that, freed from the energy scale of LHC collisions, could reach regions inaccessible to conventional collider analyses.

Primary author: VAMI, Tamas Almos (Wigner RCP)

Presenter: VAMI, Tamas Almos (Wigner RCP)

Session Classification: Parallel - BSM

Track Classification: BSM and Flavour

Contribution ID: 3

Type: **Oral**

Phenomenological Viability of the Five-Dimensional MSSM at Two Loops

In this talk we shall go through the derivation of the two-loop renormalisation group equations of the five-dimensional MSSM and demonstrate that the power-law mechanism responsible for generating a realistic Higgs mass remains perturbatively consistent once higher-order corrections, KK-resummed contributions, and electroweak precision constraints are taken into account.

Primary author: Prof. CORNELL, Alan (University of Johannesburg)

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Presenter: Prof. CORNELL, Alan (University of Johannesburg)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 4

Type: **Oral**

Dark Matter in an $SU(2)_D$ Gauged Hidden Sector

In this talk, we extend the electroweak gauge group of the Standard Model by introducing extra gauge factors, $SU(2)_L \times SU(2)_H \times U(1)_1 \times U(1)_2$. We analyze theoretical consistency, Higgs constraints, electroweak precision tests, and dark matter relic density and direct detection bounds. Our results show that the model can accommodate viable dark matter scenarios while remaining compatible with current collider and astrophysical limits.

Primary authors: DEANDREA, Aldo (IPNL - University Lyon 1); Prof. AHRICHE, Amine (University of Sharjah); Dr KHOJALI, Mohammed Omer (Univ. Lyon 1); Prof. NASRI, Salah (UAE University); Dr BAOUCHE, Nabil (University of Jijel)

Presenter: Dr KHOJALI, Mohammed Omer (Univ. Lyon 1)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 5

Type: **Oral**

The strong coupling constant from lepton collider observables

In this talk, I will briefly review the current status of the world average of the strong coupling constant, as reported by the Particle Data Group. I will then focus on determinations from event shapes and jet rates measured at lepton colliders, highlighting the key outstanding challenges in these measurements and recent developments aimed at resolving them.

Primary author: Prof. ZANDERIGHI, Giulia (Max Planck Institute for Physics)

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Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 6

Type: **Oral**

Improved Regge Kinematics and All-Path-Length Corrections to Momentum Broadening in the Quark–Gluon Plasma

We present a detailed study of transverse momentum broadening for high-energy partons traversing the quark–gluon plasma (QGP), extending the Gyulassy–Levai–Vitev (GLV) formalism to include both all-path-length (APL) corrections and improved sub-Regge kinematics. The standard GLV framework relies on the large separation distance and large formation time approximations, which are well justified in large nuclei but may break down in small collision systems, such as high-multiplicity pp and p/dA collisions, where characteristic path lengths and coherence scales become comparable. Working to first order in the opacity expansion, we derive analytic expressions for the transverse momentum broadening distribution and the corresponding momentum transport coefficient, $\hat{q}$, while systematically relaxing these approximations. Relaxing the large separation distance approximation gives rise to the APL correction, while the sub-Regge and combined sub-Regge-APL corrections are obtained using an improved set of Regge kinematics that extends beyond the strict Regge limit. We find that these corrections can significantly modify both the transverse momentum broadening distribution and the corresponding momentum transport coefficient, $\hat{q}$, particularly in small collision systems, providing a more controlled theoretical framework for describing jet–medium interactions beyond the standard GLV approximations and highlighting the importance of finite path-length and sub-Regge effects in precision studies of jet quenching.

Primary author: VAN DEN BERG, Dario (University of the Witwatersrand)

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Presenter: VAN DEN BERG, Dario (University of the Witwatersrand)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 7

Type: **Oral**

Opportunities in Flavour Physics

I will present a status report on flavour physics, highlighting those observables that are relevant to the search for new physics. Furthermore, I will discuss new opportunities for flavor physics with a Future Circular Collider (FCCee). Finally, I will address some precision observables, for example the inclusive penguin decays, explain calculations to order in $1/m_b$ and α_s^1 using soft collinear effective theory, especially refactorisation techniques, and outline their potential in the new physics search.

Primary author: HURTH, Tobias

Presenter: HURTH, Tobias

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 8

Type: **Oral**

Investigating Magnetic Field Dynamics in the Quark-Gluon Plasma

Relativistic heavy-ion collisions at the Large Hadron Collider (LHC) produce a deconfined quark-gluon plasma (QGP) under extreme temperatures, energy densities, and electromagnetic fields. Understanding the influence of these fields on the evolution of the QGP remains an important challenge in heavy-ion physics. This work presents a theoretical and computational model based on the relativistic conservation laws of energy, momentum, and baryon number to describe the space-time evolution of the QGP produced in Pb+Pb collisions at a nucleon-nucleon centre-of-mass energy of 5.02 TeV. The model establishes investigations of magnetic-field dynamics through relativistic magnetohydrodynamics, providing a platform for studying the interplay between the QGP evolution and electromagnetic fields in Heavy-Ion Collisions.

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Presenter: SEABI, Magdeline (Nelson Mandela University)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 9

Type: **Oral**

Breaking of color coherence in LHC cross sections: Curses and blessings

In recent years, it has been understood that collinear factorization and QCD color coherence are violated at hadron colliders in higher orders of perturbation theory. In this talk, I will review the physical origin of these phenomena, their implications (such as super-leading logarithms and coherence-violating logarithms), and the role they play with regards to PDF factorization, which is the basis for most calculations of hadron collider observables.

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Presenter: NEUBERT, Matthias (Johannes Gutenberg University Mainz)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 10

Type: **Oral**

B $\rightarrow$ K+a decays in QCD factorization and revised bounds on ALP couplings

Rare flavor-changing processes such as B $\rightarrow$ Ka decay offer sensitive probes of axion-like particles (ALPs) for masses below a few GeV. We study this process in the framework of QCD factorization and ALP effective theory, in which the ALP couples to the Standard Model fermions through shift-invariant derivative interactions. In contrast to previous studies, where flavor violation arises solely from flavor-changing ALP couplings, we also include the contributions proportional to flavor-conserving ALP couplings, in which the flavor change is mediated by the weak interactions of the Standard Model. Based on this analysis, we derive model-independent bounds on both flavor-changing and flavor-conserving ALP couplings at low energies. Then we consider the UV scenario of a “minimally flavor-violating ALP”, which features flavor-universal ALP–fermion couplings at very high energies, and evaluate the resulting constraints on the UV couplings.

Primary author: NEUBERT, Matthias (Johannes Gutenberg University Mainz)

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Session Classification: Parallel - BSM

Track Classification: BSM and Flavour

Contribution ID: 11

Type: **Oral**

Dilepton Probes of Hot QCD Matter

Authors: Adrian William Romero Jorge, Taesoo Song, Gaia Ingrosso, Jiaxing Zhao, Elena Bratkovskaya

Dileptons are penetrating electromagnetic probes of strongly interacting matter and provide direct access to thermal radiation emitted throughout the evolution of relativistic nuclear collisions. We investigate dilepton production from SIS to LHC energies within the off-shell Parton–Hadron–String Dynamics (PHSD) transport approach, which consistently describes the dynamical evolution and interactions of partonic and hadronic degrees of freedom.

The partonic sector of PHSD is based on the Dynamical QuasiParticle Model (DQPM), whose temperature- and baryon-density-dependent quasiparticle properties are constrained by lattice-QCD thermodynamics. At low and intermediate collision energies, we additionally explore dilepton radiation for different realizations of the QCD equation of state, including a crossover and a scenario with a critical end point and first-order phase transition.

PHSD calculations of dilepton invariant-mass spectra in p+p, p+A, light-ion, and heavy-ion collisions are compared with available HADES, STAR, and ALICE measurements and provide an overall good description of the data. We present the excitation function of thermal QGP dilepton radiation and study its competition with correlated heavy-flavor decays. In central Au+Au collisions, the QGP contribution exceeds correlated charm dileptons below $\sqrt{s_{NN}} \simeq 25\text{--}30\text{ GeV}$, whereas toward RHIC and LHC energies heavy-flavor decays become increasingly important in the intermediate-mass region.

We further investigate transverse-mass spectra and inverse-slope parameters T_{eff} , including recent O+O collisions, and discuss the origin of the large effective slopes observed by STAR. Toward LHC energies, we find an increasing contribution of partonic radiation also in small systems, including proton–proton collisions. Our results demonstrate that dileptons provide a sensitive probe of thermal QGP radiation and its space–time evolution over a broad range of collision energies.

Primary author: BRATKOVSKAYA, Elena (ITP, FIAS, Uni. Frankfurt)

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Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 12

Type: **Oral**

The ATLAS Trigger System

The ATLAS experiment in the LHC Run 3 uses a two-level trigger system to select events of interest to reduce the 40 MHz bunch crossing rate to a recorded rate of up to 3 kHz of fully-built physics events. The trigger system is composed of a hardware based Level-1 trigger and a software based High Level Trigger. The selection of events by the High Level Trigger is based on a wide variety of reconstructed objects, including leptons, photons, jets, b-jets, missing transverse energy, and B-hadrons in order to cover the full range of the ATLAS physics programme.

We will present an overview of improvements in the reconstruction, calibration, and performance of the different trigger objects, as well as computational performance of the High Level Trigger system.

Primary author: Dr HILLIER, Stephen (University of Birmingham)

Presenter: Dr HILLIER, Stephen (University of Birmingham)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 13

Type: **Oral**

The upgrade of the ATLAS Trigger and Data Acquisition system for the High Luminosity LHC

The ATLAS experiment at CERN is constructing upgraded system for the “High Luminosity LHC”, with collisions due to start in 2030. In order to deliver an order of magnitude more data than previous LHC runs, 14 TeV protons will collide with an instantaneous luminosity of up to 7.5×10^{34} cm⁻²s⁻¹, resulting in much higher pileup and data rates than the current experiment was designed to handle. While this is essential to realise the physics programme, it presents a huge challenge for the detector, trigger, data acquisition and computing.

The design of the TDAQ upgrade comprises: a hardware-based low-latency real-time Trigger operating at 40 MHz, Data Acquisition which combines custom readout with commodity hardware and networking to deal with 4.6 TB/s input, and an Event Filter running at 1 MHz which combines offline-like algorithms on a large commodity compute service with the potential to be augmented by commercial accelerators. Offline-style clustering and jet-finding in FPGAs, and accelerated track reconstruction are designed to combat pileup in the Trigger and Event Filter respectively.

This contribution will report recent progress on the design, technology and construction of the system. The physics motivation and expected performance will be shown for key physics processes.

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Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 14

Type: **Oral**

Sensitivity of jet observables to event-by-event medium fluctuations

Hard probes have historically been central in the study of the fluid of quarks and gluons produced in the collisions of relativistic heavy ions. Objects such as the highly collimated sprays of particles known as jets are produced at very early times in the collision and, therefore, experience the entire evolution of the system. In this work, we explore different jet observables and how they are modified by the medium using the JEWEL (Jet Evolution With Energy Loss) event generator. We compare the results obtained from a simplified smooth medium to those emerging from a realistic hydrodynamically evolving plasma obtained with the software Trajectum. We show that jet substructure observables tend to not be as sensitive to the event-by-event fluctuations of the medium as, for example, the azimuthal anisotropy of high $p_{\perp}$ particles. We also explore the same observables across different system sizes and conclude that, in small systems, the medium fluctuations are more likely to leave signatures on the jet structure.

Primary authors: LE ROUX, Chiara (Wits University); Dr KOLBE, Isobel (University of the Witwatersrand); NIJS, Govert (CERN); MASHAO, Martha (University of the Witwatersrand)

Presenter: LE ROUX, Chiara (Wits University)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 15

Type: **Oral**

Large initial state anisotropies in small systems with a new Glauber model

In this work, we developed a new Glauber model based on the nucleon-nucleon cross sections calculated within the KMR/SHRiMPS model as implemented in the SHERPA event generator. These cross sections arise from a well-motivated phenomenological calculation from which a non-trivial impact parameter emerges naturally, without any ad-hoc assumptions. In Eur. Phys. J. C 86, 63 (2026), it was shown that this characteristic of the cross section is responsible for the appearance of large anisotropies in the spacial distribution of participating nucleons in p+Pb collisions compared to other commonly used models. Now we extend this model to A+A collisions and explore its consequences on the anisotropies and number of participating nucleons across different system configurations.

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Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 16

Type: **Invited Talk**

Probing jet quenching in OO collisions with ALICE

The ALICE experiment investigates the properties of the quark–gluon plasma (QGP) created in ultrarelativistic heavy-ion collisions. Two of the most prominent signatures of QGP formation are the collective hydrodynamic expansion of the produced medium and the energy loss of high-energy partons traversing the medium, known as jet quenching. Measurements performed in high-multiplicity p–Pb and pp collisions have revealed flow-like signatures but have not provided unambiguous evidence for jet quenching. This raises important questions about the relationship between system size and the onset of QGP effects.

The recent light-ion collision runs at the LHC provide a unique opportunity to bridge the gap between p–Pb and Pb–Pb collisions and to investigate how QGP signatures evolve with system size. This contribution presents the first ALICE measurements of inclusive π^0 production in OO and p–O collisions, as well as inclusive jet production and hadron–jet correlations in OO collisions. The inclusive observables exhibit a suppression consistent with partonic energy loss in the produced medium, while no significant modification is observed in hadron–jet correlations within the current experimental precision. The different sensitivities of these observables will be discussed.

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Presenter: KRIZEK, Filip (Nuclear Physics Institute of the Czech Academy of Sciences)

Session Classification: Plenary

Track Classification: Heavy Ions and Nuclear

Contribution ID: 17

Type: **Poster**

Diamond-Coated Fibre Bragg Grating Sensors for Radiation-Hard Environmental Monitoring in High-Energy Physics

Fibre-optic sensors (FOS) are attractive for environmental monitoring in high-energy physics (HEP) experiments due to their small size, multiplexing capability, immunity to electromagnetic interference, and potential radiation tolerance. However, the development of radiation-hard fibre sensors capable of monitoring parameters such as humidity remains challenging for future detector environments. This work investigates diamond-coated fibre Bragg gratings (FBGs) as a potential platform for radiation-tolerant humidity sensing, motivated by the exceptional radiation hardness, chemical stability, and surface sensitivity of diamond.

Boron-doped FBGs were functionalised with nanodiamond coatings using a dip-coating approach, with the coating process investigated as a function of deposition cycles. The coated sensors were characterised alongside bare boron-doped FBGs and conventional polymer-coated FBG humidity sensors under controlled relative-humidity cycling. Preliminary measurements show that the nanodiamond-coated FBG exhibits a repeatable humidity-dependent change predominantly in reflected optical power, while comparatively little change is observed in Bragg wavelength or spectral width. This behaviour differs from the wavelength response of polymer-coated FBGs, where humidity-induced swelling produces strain transfer to the fibre. The observed optical-power response of the diamond-coated sensor suggests that the sensing mechanism may instead originate from humidity-dependent interactions at the diamond-coated fibre surface and associated changes in optical attenuation.

The response during increasing and decreasing humidity cycles is further investigated to assess sensitivity, reversibility, hysteresis, and adsorption/desorption behaviour. Scanning electron microscopy is used to correlate coating morphology and nanodiamond coverage with the optical response. The study forms part of a broader programme investigating radiation effects and radiation-hardening strategies for fibre-optic sensors intended for particle-detector environments. Future irradiation studies will determine whether diamond functionalisation can provide a viable route towards robust, radiation-tolerant environmental sensors for HEP detector systems.

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Presenter: CASSIM, Abdool Sattar (University of Johannesburg)

Session Classification: Poster

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 18

Type: Oral

AI-Enabled Radiation Dose Prediction Using Proton-Irradiated Fibre Bragg Grating Sensors

Radiation monitoring is critical for evaluating the performance and lifetime of detector components in high-energy physics (HEP) experiments. Fibre Bragg grating (FBG) sensors are particularly attractive for such environments due to their small size, electromagnetic immunity, multiplexing capability, and potential radiation tolerance. Beyond conventional temperature and strain monitoring, radiation-induced changes in the optical response of FBGs may provide information on the radiation exposure experienced by the sensor.

This work investigates the use of artificial intelligence and machine-learning (AI/ML) techniques to predict radiation dose from experimental proton-irradiation data obtained from FBG sensors. The evolution of the FBG reflection spectrum during proton irradiation is characterised using multiple optical parameters, including Bragg wavelength, reflected peak power, full width at half maximum, and integrated spectral intensity. These parameters are used as input features for machine-learning regression models trained to establish relationships between the measured optical response and accumulated radiation dose.

The performance of different regression approaches is evaluated using appropriate prediction metrics, while feature-importance analysis is used to determine which spectral characteristics provide the greatest sensitivity to radiation exposure. Particular consideration is given to the coupled and potentially nonlinear evolution of the FBG spectral parameters with increasing dose, as well as the influence of environmental variables that may introduce competing changes in the measured optical response.

The proposed approach demonstrates how experimental proton-irradiation data can be combined with data-driven modelling to investigate FBGs as intelligent radiation-sensing elements. The methodology could ultimately enable fibre-optic sensor networks to provide both conventional environmental monitoring and distributed estimation of accumulated radiation exposure within particle detectors and other high-radiation environments.

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Presenter: CASSIM, Abdool Sattar (University of Johannesburg)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 19

Type: Oral

Proton Irradiation Response of a Radiation-Hard Femtosecond Fibre Bragg Grating

Reliable temperature sensing in intense radiation fields remains an important instrumentation challenge across high-energy physics (HEP), accelerator facilities and nuclear systems. In these environments, radiation may not only produce an instantaneous perturbation to an optical sensor, but also alter its underlying calibration and therefore its ability to provide reliable measurements after prolonged exposure. This work investigates both effects through the in-situ proton irradiation and pre- and post-irradiation characterisation of a radiation-hard femtosecond-written iXblue fibre Bragg grating (FBG).

Prior to irradiation, the FBG underwent controlled temperature calibration to establish its initial wavelength-temperature relationship and spectral characteristics. The sensor was subsequently exposed to the 24 GeV/c proton beam at the CERN Proton Synchrotron IRRAD facility, while its reflected spectrum was continuously interrogated throughout the irradiation. This enabled the evolution of the Bragg wavelength and spectral characteristics to be followed directly as radiation exposure accumulated, providing insight into the dynamic response of the grating under beam rather than relying exclusively on measurements performed before and after exposure.

Following irradiation, the temperature calibration was repeated under comparable conditions. Comparison of the pre- and post-irradiation response was used to distinguish radiation-induced offsets and spectral modifications from changes in temperature sensitivity. This distinction is particularly important for practical radiation instrumentation: an accumulated wavelength offset may potentially be corrected through recalibration, whereas a significant change in sensitivity or degradation of the grating response directly affects its suitability as a quantitative sensor.

The combination of real-time irradiation measurements with post-exposure metrological verification provides a framework for assessing whether femtosecond FBGs can remain functional sensing elements after high-dose particle exposure. Although performed using high-energy protons relevant to accelerator and particle-detector environments, the methodology has broader relevance to radiation-tolerant temperature and structural monitoring in nuclear facilities, irradiation beam-lines and other extreme radiation environments. The results contribute towards the development and qualification of fibre-optic instrumentation capable of providing remote, multiplexed sensing where conventional electrical sensors may be constrained by radiation exposure, electromagnetic interference or accessibility.

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Presenter: CASSIM, Abdool Sattar (University of Johannesburg)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 20

Type: **Poster**

From Particle Detectors to Aircraft: Technology Transfer of Fibre Bragg Grating Sensors for Wing Structural Monitoring

Technologies developed for high-energy physics (HEP) experiments frequently operate under demanding constraints on sensor size, reliability, cabling, electromagnetic compatibility and remote accessibility. These requirements have driven the development of fibre-optic sensor (FOS) systems for environmental monitoring within the ATLAS experiment at CERN. Many of the same characteristics are desirable in aerospace structural monitoring, where large numbers of sensing points must be integrated into lightweight structures without significantly increasing mass or wiring complexity. This work investigates the transfer of fibre Bragg grating (FBG) sensing techniques from particle-detector instrumentation towards structural monitoring of aircraft wings.

An array of FBG sensors is applied at selected locations along an aircraft wing structure to measure strain under controlled mechanical loading. Changes in Bragg wavelength are converted to local strain using experimentally determined sensor calibrations, allowing the spatial strain distribution across the structure to be reconstructed as the applied loading is varied. Particular attention is given to sensor placement, strain transfer between the wing structure and optical fibre, temperature compensation and the multiplexing of multiple FBG sensing points along a common optical fibre.

The measured strain response is used to investigate wing bending and deformation and to identify regions experiencing increased structural loading. The multiplexed architecture enables several locations to be interrogated through a single optical fibre, demonstrating a pathway towards lightweight sensor networks capable of continuously monitoring large aerospace structures. Such measurements can ultimately contribute to structural health monitoring through the identification of abnormal strain distributions, load histories and changes in structural behaviour.

The study demonstrates a technology-transfer pathway between HEP instrumentation and aerospace engineering. Fibre-sensing expertise developed for monitoring inaccessible and challenging regions of particle detectors can be adapted to aircraft structures, where low sensor mass, reduced cabling, electromagnetic immunity and multi-point sensing are similarly advantageous. The work highlights the broader potential for technologies originating in fundamental physics experiments to contribute to intelligent structural monitoring and condition-based maintenance in aerospace systems.

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Presenter: CASSIM, Abdool Sattar (University of Johannesburg)

Session Classification: Poster

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 21

Type: Oral

A quality assurance and calibration procedure for fiber optic sensors in high energy physics applications

The Inner Detector of the ATLAS experiment will be completely replaced by the Inner Tracker (ITk) in preparation for the High-Luminosity upgrade of the Large Hadron Collider (LHC) at CERN in Geneva, Switzerland. The ITk will target an operational dew point of $-60\text{ }^{\circ}\text{C}$, requiring precise environmental monitoring to ensure reliable detector performance. With normal operation at $-20\text{ }^{\circ}\text{C}$, and fault conditions potentially leading to local temperatures as low as $-55\text{ }^{\circ}\text{C}$, the monitoring system must protect the detector and prevent condensation on sensitive electronics through accurate temperature and humidity measurements—a critical challenge in high-radiation and high-electromagnetic-field environments.

This paper details the mechanical design, calibration framework, and quality-assurance protocols for radiation-tolerant fibre-optic sensor (FOS) packages developed for this purpose. Each integrated FOS package combines a radiation-hard fibre Bragg grating (FBG) for temperature measurement, a radiation-sensitive FBG for temperature and radiation measurement, and a long-period grating (LPG) sensitive to humidity, temperature, and radiation. A novel ultra-low-thermal-expansion Neoceram package body houses the sensors, while a custom PCB provides electrical conductivity between the mounting bolts for EMI/ESD protection. Structural integrity was validated through thermal cycling between $-30\text{ }^{\circ}\text{C}$ and $70\text{ }^{\circ}\text{C}$ to ensure robustness under extreme operational conditions.

A data-driven calibration procedure addresses the high-accuracy requirements of the ITk using a climatic chamber equipped with precision humidity control and a chiller. A PID-controlled system automates data collection across temperatures from $-20\text{ }^{\circ}\text{C}$ to $25\text{ }^{\circ}\text{C}$ and relative humidity from 0% to 100% RH. FOS outputs are calibrated against electronic reference sensors, while a dedicated algorithm decouples radiation and temperature effects from the LPG humidity response. Rigorous QA/QC protocols ensure measurement reproducibility through an established procedure designed to maintain measurement accuracy within the ITk specifications.

This work establishes a high-reliability framework that combines radiation-tolerant mechanical design with algorithmic calibration and quality-assurance methodologies, providing a comprehensive approach for the deployment of fibre-optic environmental monitoring systems in extreme high-energy physics environments.

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Session Classification: Plenary

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 22

Type: **Oral**

Muon-based measurements and searches with the CMS detector in Run 3 and towards the HL-LHC

The excellent muon reconstruction, identification, and triggering capabilities of the CMS detector play a central role in a broad range of measurements and searches at the LHC. Final states containing one or more muons provide clean experimental signatures, high trigger efficiency, and precise momentum measurements over a wide kinematic range, enabling both precision studies of Standard Model processes and sensitive probes of physics beyond the Standard Model.

This contribution reviews recent CMS results exploiting muon final states, including precision measurements of electroweak and heavy-flavour processes, studies of Higgs boson properties, and searches for new phenomena. Prospects for future measurements and searches at the High-Luminosity LHC are also discussed, highlighting the key role of the upgraded muon detector in extending the discovery reach of the CMS experiment.

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Session Classification: Parallel - H, EW, top

Track Classification: Higgs, Electroweak, Top

Contribution ID: 23

Type: Oral

Path-length dependence of parton energy loss in Pb-Pb and O-O collisions using JEWEL and Trajectum

The path-length dependence of energy loss in the quark-gluon plasma (QGP) has been extensively studied through perturbative quantum chromodynamics (pQCD), where energy is lost through both radiative and collisional processes. Collisional energy loss is expected to scale linearly with the path-length L , while radiative energy loss scales as L^2 , and is known to be the dominant mechanism. Taking a step away from analytical and parametrized energy loss models, JEWEL (Jet Evolution With Energy Loss), a Monte Carlo event generator, simulates jet quenching in heavy-ion collisions by explicitly modeling the full parton shower. JEWEL includes both radiative and collisional processes through medium-induced gluon emissions and computed pQCD calculations. To isolate the path-length dependence of energy loss, a brick medium in JEWEL is employed. The brick medium assumes the QCD medium has uniform temperature and density over a finite time interval. From this approach, the jet and charged hadron nuclear modification factor R_{AA} can be obtained as a function of L . This study is then extended by using a realistic hydrodynamic background from *Trajectum*, which acts as an external medium in JEWEL, providing a medium description for heavy-ion collisions. Preliminary results for the emerging path-length dependence from JEWEL will be presented, by comparing the brick medium and realistic hydrodynamic backgrounds.

Primary authors: MASHAO, Martha (University of the Witwatersrand); Dr KOLBE, Isobel (University of the Witwatersrand)

Presenter: MASHAO, Martha (University of the Witwatersrand)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 24

Type: **Oral**

Non-gaussian matter distribution inside nucleons and its application to small systems.

The initial geometry of a heavy-ion collision is determined by the spatial distribution and fluctuations of the participating nucleons. In small collision systems, such as p+Pb, O+O and Ne+Ne, these spatial distributions can have a pronounced influence on the geometry of the produced matter and its subsequent hydrodynamic evolution. While hydrodynamic models have successfully described a wide range of observables, the description of the initial state remains a significant source of uncertainty, particularly in small collision systems where fluctuations in the spatial structure of the colliding nucleons can strongly influence the subsequent evolution. Most initial-condition models commonly assume a Gaussian nucleon profile; however, the extent to which the shape of this profile affects the initial collision geometry and the resulting final-state observables remains an important question. This motivates the investigation of more flexible nucleon density profiles and their impact on hydrodynamic predictions. In this work, generalised Gaussian initial conditions are investigated within the \textsc{TRAJECTUM} framework using the TRENTTo initial-condition model with nucleon substructure. Constituent hot spots are sampled from a generalised normal distribution characterised by a shape parameter β , which allows the spatial profile of the nucleon substructure to be varied while maintaining a fixed distribution width. The resulting initial conditions are evolved through the pre-hydrodynamic and relativistic hydrodynamic stages before particlisation. The dependence of the initial-state geometry and final-state observables, including anisotropic flow coefficients and mean transverse momentum, on the generalised Gaussian profile is studied for different values of β . Comparisons with conventional Gaussian initial conditions and experimental measurements at LHC energies will be used to assess the sensitivity of these observables to the assumed nucleon shape.

Keywords:

Relativistic heavy-ion collisions; Small collision systems; Generalised Gaussian distribution; Nucleon substructure; TRENTTo; TRAJECTUM; Hydrodynamic modelling

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Co-authors: Prof. MURONGA, Azwinndini (Nelson Mandela University); Dr NIJS, Govert (CERN)

Presenter: Mr MUNYAI, Tendani Oliver (Nelson Mandela University)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 25

Type: **Oral**

Readout Studies of 64-channel SiPM Arrays in Test Beams

We are studying a new readout system for the ATLAS TileCal. The idea is to replace the photo-multiplier tubes by SiPM arrays. This allows us to record the signal of each individual tile. This information can be used for particle flow and would be useful for the ATLAS experiment since CMS is building this highly sophisticated endcap calorimeter. We have constructed a prototype reading out 32 3 mm thick TileCal scintillator tiles. Each tile is read out with two wavelength-shifting fibers that are coupled to a 64-channel SiPM array via an air gap or via optical grease. We first tested the prototype with electrons in a test beam at DESY where the beam was typically perpendicular to the tiles. We measured the relative gain and light yield of each channel. We studied the gain as a function of overvoltage and temperature and determined the breakdown voltage. The light yield for 3 mm tiles lies between two and three photoelectrons. To increase the light yield we also sent the beam through the longest side of the tile (about 22 cm). We further measured the uniformity by sending the beam at different x, y positions. We repeated some measurements with a second SiPM array. To study the response to hadrons we conducted another test beam at the PS at CERN.

Primary author: Prof. EIGEN, Gerald (Uni Goettingen)

Presenter: Prof. EIGEN, Gerald (Uni Goettingen)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 26

Type: **Oral**

3+1D Baryon Transport and Pre-Equilibrium Dynamics in the Fragmentation Region

Monday, 30 November 2026 17:00 (15 minutes)

The next decade of heavy-ion phenomenology will be significantly shaped by the expansion of experimental reach into far forward kinematics. Upcoming detector upgrades, such as the ALICE FoCal programme and STAR forward calorimetry, require robust theoretical baselines to interpret baryon stopping in regions where standard boost-invariant models fail. We present a fully 3+1D classical transport framework for pre-equilibrium baryon number deposition within the Color Glass Condensate framework. The collision is modelled in the target rest frame as an ultra-relativistic saturated gluon sheet sweeping through a static distribution of collisionless classical coloured particles (Wong quarks). Averaging over the McLerran-Venugopalan ensemble yields the saturation-driven transverse momentum kicks imparted to the target degrees of freedom. This formulation provides analytic and semi-analytic solutions for the phase-space distribution, baryon current, and proper baryon density. By extending previous one-dimensional shockwave models to a realistic 3+1D geometry incorporating Woods-Saxon profiles, we explicitly quantify the competition between longitudinal compression and transverse expansion induced by momentum broadening. We derive a closed analytic expression for the transported baryon rapidity distribution, peaking at $y \simeq \frac{1}{2} \ln(Q_s^2/m_q^2)$. These results establish a mathematically controlled initial state baseline for forward-rapidity hydrodynamics, offering testable quantitative predictions for high-density QCD matter

Primary authors: LUSHOZI, Mawande (University of Cape Town); Mr TRUE, Alexander (University of Cape Town)

Presenter: LUSHOZI, Mawande (University of Cape Town)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 27

Type: **Oral**

Collective effects and heavy-flavour muon production in oxygen-oxygen collisions at $\sqrt{s_{\text{NN}}} = 5.36$ TeV with EPOS4

Oxygen--Oxygen (OO) collisions provide an important intermediate system between proton-proton and light-ion collisions, offering a unique opportunity to investigate particle production and collective effects in a relatively light-ion collision system.

In this contribution, OO collisions at $\sqrt{s_{\text{NN}}} = 5.36$ TeV were simulated using the EPOS4[1] event generator. The nuclear modification factor R_{OO} for light-flavour particles and inclusive muons is studied to characterise particle production in OO collisions relative to proton-proton collisions at $\sqrt{s_{\text{NN}}} = 5.36$ TeV. In addition, the elliptic flow coefficient (v_2) of charged particles and inclusive muons has been studied to describe the anisotropic dynamics of the produced systems. Furthermore, the inclusive muon v_2 will emphasise the anisotropy of heavy-flavour muons. The combined study of v_2 and R_{OO} will give complementary information on collective effects and particle production and provide predictions for heavy-flavour observables in light-ion collision systems.

[1]K. Werner, "Revealing a deep connection between factorization and saturation: New insight into modeling high-energy proton-proton and nucleus-nucleus scattering in the EPOS4 framework," Phys. Rev. C 108, 064903 (2023).

Primary author: NAIK, Bharati (University of the Witwatersrand, Johannesburg)

Presenter: NAIK, Bharati (University of the Witwatersrand, Johannesburg)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 28

Type: **Oral**

Model-Robust CNN-Based Event Selection for QGP-Sensitive Heavy-Ion Collisions

Identifying rare events with enhanced sensitivity to deconfined quantum chromodynamics (QCD) matter in high-rate heavy-ion experiments requires fast event-selection methods that are robust against detector effects and theoretical model uncertainties. We present a convolutional neural network (CNN) based approach for event-by-event identification of QGP-sensitive collision patterns using compact multidimensional representations of the reconstructed final state, encoding particle species and momentum-space information.

The classifier is trained and validated using Au+Au collisions at 30 AGeV simulated with the Parton-Hadron-String Dynamics (PHSD) and Ultra-relativistic Quantum Molecular Dynamics (UrQMD) transport approaches. Cross-model tests are performed to determine whether the learned response reflects robust physical correlations rather than generator-specific features. The classifier retains its discriminating power when transferred between the two transport descriptions, which provides evidence for a model-robust, QGP-sensitive event representation. After propagation through the detector of the Compressed Baryonic Matter (CBM) experiment and reconstruction chain, classification accuracy decreases from 95.1% at the generator level to 83.7% after full reconstruction. This demonstrates substantial robustness under realistic experimental conditions. SHAP-based interpretability studies show that strange hadrons and antibaryon-related channels significantly contribute to the network's decision-making process.

These results demonstrate the potential of interpretable, transport-model-robust machine learning for fast event enrichment and physics-driven data reduction in future high-rate heavy-ion experiments.

Primary authors: Prof. KISEL, Ivan (Frankfurt Institute for Advanced Studies, FIAS); Dr BELOUSOV, Artemiy (University of Frankfurt); BRATKOVSKAYA, Elena (ITP, FIAS, Uni. Frankfurt); Dr SOLOVEVA, Olga (GSI Helmholtz Centre for Heavy Ion Research)

Presenter: Prof. KISEL, Ivan (Frankfurt Institute for Advanced Studies, FIAS)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 29

Type: **Poster**

Single-muon production in pp collisions at $\sqrt{s} = 13.6$ TeV with ALICE

Muons produced in W-boson and heavy-flavour (HF) hadron decays provide useful information on particle production in proton-proton (pp) collisions. Both mother particles have large masses and are produced in hard-parton scattering in the initial stages of the collision. W-boson studies can probe light-quark parton distribution functions and serve as a baseline for the study of initial-state nuclear effects. HF measurements in pp collisions help to understand the heavy-quark production mechanisms, fragmentation, hadronisation, and are an important test of perturbative Quantum Chromodynamics. The ALICE detector is uniquely equipped to probe HF and electroweak processes via the single-muon decay channel across both low- and high-transverse momentum probing small Bjorken- x dynamics.

In this contribution, realistic simulations of pp collisions at $\sqrt{s} = 13.6$ TeV are used to determine the two-particle correlations of forward-rapidity ($2.5 < y < 4.0$) single muons from B-hadron decays with charged particles ($|y| < 0.8$) to study the hadronisation mechanism of b quarks. Machine Learning (ML) techniques, specifically neural networks, are used at low p_T ($p_T < 20$ GeV/c) to separate HF semileptonic decay muons ($\text{HF} \rightarrow \mu$) from background candidates. The ML technique is extended to high p_T ($p_T > 20$ GeV/c) to isolate electroweak $W \rightarrow \mu\nu$ signals from HF and $Z \rightarrow \mu^+ \mu^-$ background contributions.

Primary authors: MAKATU, Farelani Tshwaranang (University of the Witwatersrand); MUNOZ, Maya (University of Cape Town); SURIAH, Brenton (University of Cape Town)

Presenters: MAKATU, Farelani Tshwaranang (University of the Witwatersrand); MUNOZ, Maya (University of Cape Town); SURIAH, Brenton (University of Cape Town)

Session Classification: Poster

Track Classification: Higgs, Electroweak, Top

Contribution ID: 30

Type: **Invited Talk**

ATLAS Open data session

ATLAS, together with the Physics Without Frontier Program, would like to organize a full afternoon program of an open-data session to train students or delegates on accessing ATLAS open data and how to use it. This is an Outreach activity of the conference besides the Outreach that will be done at different historically disadvantaged universities before the conference. The trainees once trained can deliver similar activities at other places later, and that could be integrated in teaching and learning in different curricula.

Primary authors: TRUONG, Thi Ngoc Loan (University of Johannesburg); SHAW, kate (The International Centre for Theoretical Physics); Prof. OULD-SAADA, Farid (University of Oslo)

Presenters: SHAW, kate (The International Centre for Theoretical Physics); Prof. OULD-SAADA, Farid (University of Oslo)

Session Classification: Plenary

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 31

Type: **Oral**

Searches for Dark Matter with the ATLAS Experiment at the LHC

Many theoretical models predict that Dark Matter (DM) could interact weakly with the Standard Model (SM), thus be produced at the LHC. Many searches have been conducted by the ATLAS experiment to look for DM candidates in the final states with large missing transverse momentum produced in association with other SM particles (light and heavy quarks, leptons, photons, as well as additional heavy scalar particles). There are also searches where the Higgs portal scenario is considered to probe the DM such as in invisible Higgs decay searches. The results of LHC Run 2 and Run 3 at 13 and 13.6 TeV pp collision data and their combinations will be presented.

Primary author: TRUONG, Thi Ngoc Loan (University of Johannesburg)

Presenter: TRUONG, Thi Ngoc Loan (University of Johannesburg)

Session Classification: Parallel - BSM

Track Classification: BSM and Flavour

Contribution ID: 32

Type: Oral

Dihadron correlations as a probe of partonic energy loss in small and large systems

We present preliminary predictions for the dihadron away-side suppression ratio I_{AA} in $p + A$ and $A + A$ collisions at RHIC and the LHC. Our predictions are made using a perturbative quantum chromodynamics (pQCD)-based energy loss model coupled to event-by-event hydrodynamic evolution of the medium, with short path length corrections to the energy loss. The $p + p$ reference is generated with the Monte Carlo event generator \textsc{Pythia}, providing a vacuum fragmentation baseline against which the medium-modified yields are normalized. While the single-inclusive nuclear modification factor R_{AA} integrates over the full geometry of the collision, dihadron correlations select a biased subset of it. The trigger requirement preferentially surfaces partons produced near the medium boundary, so that the away-side parton traverses a longer and more sharply constrained path length, and the away-side associated yield at $\Delta\phi \approx \pi$ therefore probes both the magnitude of the energy loss and the angular redistribution of the radiated energy. We present the extracted I_{AA} as a function of trigger and associated transverse momentum, and argue that away-side suppression provides an additional test of whether a quark-gluon plasma is formed in small collision systems.

Primary author: VAN DER MERWE, Tiaan (iThemba Labs)

Co-authors: HOROWITZ, Will (University of Cape Town); FARADAY, Coleridge (University of Cape Town)

Presenter: VAN DER MERWE, Tiaan (iThemba Labs)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 33

Type: Oral

Measurement of forward electroweak boson production in Run 3 Pb–Pb collisions at $\sqrt{s_{NN}} = 5.36$ TeV with ALICE

With the increased luminosity of the Run 3 data-taking at the LHC, more precise measurements of the electroweak bosons ($W^\pm/Z^0$) are now possible. Studying the production of the electroweak bosons in heavy-ion collisions is useful for a variety of physics reasons, with the main goal being to study the formation of the Quark Gluon Plasma (QGP). Since electroweak bosons are produced during the initial hard-scattering of the collision and carry no colour charge, they serve as medium-blind probes of initial-state nuclear effects of the collision, such as the nuclear modified parton distribution functions (nPDFs). In addition, the W^+/W^- charge-asymmetry as a function of collision centrality can aid in probing the neutron skin effect of lead nuclei. The ALICE detector includes a muon spectrometer in the forward rapidity region ($2.5 < \eta < 4.0$), which allows for the measurement of electroweak bosons through their leptonic decay channels ($W^\pm \rightarrow \mu^\pm + \nu_\mu$ and $Z^0 \rightarrow \mu^+ \mu^-$). Currently, ALICE is the only experiment at the LHC that has measured electroweak bosons at forward rapidity in Pb–Pb collisions, which can help to constrain the small Bjorken- x region of nPDFs. In this work, the analysis strategy to measure $W^\pm$ bosons in ALICE Run 3 Pb–Pb data at $\sqrt{s_{NN}} = 5.36$ TeV will be explored. Results from Pb–Pb Monte Carlo simulations of the relevant signal and background processes will be presented, as well as a first look at the inclusive experimental yield of high- p_T muons. Improvements to the analysis procedure used in Run 2 for the same measurement will also be suggested, through the investigation of machine-learning methods that can serve as event-by-event triggers and potentially reduce the impact of systematic uncertainties.

Primary author: POTGIETER, Stephan (University of Cape Town)

Co-authors: BUTHELEZI, Zinhle (iThemba LABS, National Research Foundation (ZA)); FORTSCH, Siegfried (iThemba LABS)

Presenter: POTGIETER, Stephan (University of Cape Town)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 34

Type: **Oral**

Expanding the ATLAS TileCal Phase-II Control and Monitoring System and Validation of Tile GbE Switch Electronics for the High-Luminosity LHC

The High-Luminosity Large Hadron Collider (HL-LHC) will significantly increase the instantaneous luminosity of the Large Hadron Collider (LHC), requiring major upgrades to the ATLAS detector electronics to ensure reliable data acquisition, detector control, and long-term operational stability. As part of the ATLAS Tile Calorimeter (TileCal) Phase-II upgrade. This contribution presents two complementary activities supporting the commissioning and operation of the upgraded system. First, an existing control and monitoring framework, previously developed for the TileCal off-detector electronics, is expanded to incorporate the on-detector electronics, providing a unified platform for real-time monitoring, configuration, and diagnostics of the upgraded TileCal readout system. Second, the functionality and performance of the newly manufactured Tile Gigabit Ethernet (GbE) Switch Printed Circuit Board (PCB) and Tile GbE Switch Motherboard PCB are being validated through comprehensive electrical, communication, and system integration tests. The validation program will be carried out at the University of Johannesburg using dedicated test facilities and subsequently at CERN to verify compatibility and performance within the TileCal Phase-II test environment. Together, these developments strengthen the readiness of the upgraded TileCal electronics for HL-LHC operation by improving detector monitoring capabilities and ensuring the reliability of critical readout hardware prior to detector deployment.

Primary author: GIFT DOCTOR GOLOLO, Mpho (University of Johannesburg (ZA))

Presenter: GIFT DOCTOR GOLOLO, Mpho (University of Johannesburg (ZA))

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 35

Type: **Oral**

Quality Control and Validation of LVPS Box Assembly for the ATLAS TileCal Phase-II Upgrade

The Phase-II upgrade of the ATLAS Tile Calorimeter (TileCal) requires a reliable Low Voltage Power Supply (LVPS) system to support stable detector operation during the High-Luminosity LHC era. The LVPS box houses multiple LVPS boards and associated control components that provide regulated low-voltage power to the TileCal front-end electronics. Following assembly at CERN, each LVPS box undergoes a structured quality control and validation process, including post-assembly functionality testing, stability testing, and final verification. Test results, component information, and repairs are recorded in the TileCal database (TileDB), ensuring full traceability throughout the validation process. Boxes that fail at any stage of testing are inspected, repaired, and retested. This contribution presents the quality control procedures used to identify assembly issues and faulty components, ensuring that the LVPS boxes meet the requirements for approval and integration into the upgraded TileCal detector.

Primary author: SANELE, Sanele Scelo

Presenter: SANELE, Sanele Scelo

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 36

Type: **Oral**

Production and Integration Testing of Finger Low Voltage Power Supply Boards

The Phase-II upgrade of the ATLAS Tile Calorimeter (TileCal) for the High-Luminosity Large Hadron Collider (HL-LHC) includes the Low Voltage Box (LVBOX), which provides reliable low voltage power distribution to the front-end electronics while meeting stringent radiation and performance requirements. The production of the finger Low Voltage Power Supply Boards (fLVPSB), manufactured and tested in several places, including South Africa. A comprehensive quality assurance program, including electrical performance metrics, burn-in, and functional testing, was implemented to ensure compliance with ATLAS specifications. Assembly of the LVBOX was completed at CERN, integrating eight and six power fLVPS for the long and extended barrel configurations, respectively. The fully assembled systems were subjected to functional and overnight stability tests to demonstrate reliable operation under nominal conditions. The results demonstrate stable operation, high efficiency, and reliable performance, confirming the system's suitability for HL-LHC conditions. This contribution highlights the contributions towards the ATLAS Phase-II upgrade and the expertise developed in the production and qualification of detector power systems for large-scale particle physics experiments.

Primary author: PHAKATHI, Lungisani (UNIZULU & iThemba Lab)

Presenter: PHAKATHI, Lungisani (UNIZULU & iThemba Lab)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 37

Type: **Oral**

Multiplicity Dependence Study of Heavy-Flavour Muon and J/ψ in pp Collisions Using EPOS4

The multiplicity dependence of heavy-flavour production provides insight into the interplay between soft and hard processes in proton-proton collisions. By studying the relative yield of J/ψ as a function of charged-particle multiplicity, the mechanisms governing quarkonium production in events with different levels of activity can be investigated.

This work uses the EPOS4[1] event generator with and without hydrodynamic evolution to predict the production of muons from charm- and beauty-hadron decays as a function of charged-particle multiplicity in different transverse-momentum regions in pp collisions at $\sqrt{s} = 5.02$ TeV. The study compares the relative J/ψ yield with and without hydrodynamic evolution, as well as observations from the ALICE Collaboration [2]. The comparison provides insight into the role of hydrodynamic evolution in the multiplicity dependence of heavy-flavour and quarkonium production in pp collisions.

REFERENCE

K. Werner, "Revealing a deep connection between factorization and saturation: New insight into modeling high-energy proton-proton and nucleus- nucleus scattering in the EPOS4 framework," Phys. Rev. C 108, 064903 (2023).

The ALICE collaboration., Acharya, S., Adamová, D. et al. Forward rapidity J/ψ production as a function of charged-particle multiplicity in pp collisions at $\sqrt{s} = 5.02$ and 13 TeV. J. High Energ. Phys. 2022, 15 (2022). [https://doi.org/10.1007/JHEP06\(2022\)015](https://doi.org/10.1007/JHEP06(2022)015)

Primary author: MOTHIBI, Matsobane Alex (University of Witwatersands)

Presenter: MOTHIBI, Matsobane Alex (University of Witwatersands)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 38

Type: Oral

Calibration of the ATLAS Tile Calorimeter Gap and Crack Scintillators Using Collision Muons in Run 3

The gap and crack scintillator cells (E1–E4) of the ATLAS Tile Calorimeter provide essential energy measurements in the transition region between the barrel and extended barrels, where accurate calibration is important for maintaining the calorimeter energy scale and overall detector performance. This contribution presents a measurement of the energy response of these cells using isolated muons from $W \rightarrow \mu\nu$ and $Z \rightarrow \mu\mu$ decays in 2022-2026 proton–proton collision data collected at $\sqrt{s} = 13.6$ -TeV, corresponding to the integrated luminosity for LHC Run 3. Data/Monte Carlo energy scale ratios are derived using different ATLAS simulation campaigns. Multiple energy-scale extraction techniques are evaluated, including truncated-mean methods designed to suppress the impact of electronic noise while preserving the muon signal. The response uniformity of individual calorimeter modules in the Extended Barrel A and C is assessed using a median absolute deviation (MAD)-based outlier identification procedure, with anomalous modules characterized and reported separately from the determination of the central calibration constants. The resulting Data/MC energy scale ratios are compared across the different extraction techniques to identify the method that provides the optimal balance between noise suppression and signal retention. Systematic uncertainties associated with the energy-scale extraction are estimated from the variation among the methods.

Primary author: MOSALA, Karabo (University of the Witwatersrand)

Presenter: MOSALA, Karabo (University of the Witwatersrand)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 39

Type: **Invited Talk**

Operation and Performance of the ATLAS Tile Calorimeter Phase-II Demonstrator

The Tile Calorimeter, a central hadronic calorimeter of the ATLAS experiment at the Large Hadron Collider, is undergoing a major upgrade to meet the requirements of the High-Luminosity LHC (HL-LHC). The Phase-II upgrade aims to address the challenges posed by increased trigger rates of up to 1 MHz, higher radiation levels, and enhanced pile-up conditions through a complete redesign of the front-end and readout electronics. As part of an extensive research and development program, a Demonstrator Phase-II Upgrade module was constructed in 2014, featuring the new electronics architecture while preserving backward compatibility with the existing ATLAS Trigger and Data Acquisition system. The module was validated through a series of test beam campaigns at CERN and installed in the ATLAS detector in July 2019 to operate under real experimental conditions. During LHC Run-3 (2022–2026), it has provided valuable operational experience and performance data in a realistic environment. This contribution presents the hardware and software developments of the Demonstrator Phase-II Upgrade module and discusses its operational performance within ATLAS. The latest results demonstrate the viability of the upgraded design and provide essential input for the final implementation of the Tile Calorimeter Phase-II upgrade.

Primary author: SOTTO-MAIOR PERALVA, Bernardo (Rio de Janeiro State University)

Presenter: SOTTO-MAIOR PERALVA, Bernardo (Rio de Janeiro State University)

Session Classification: Plenary

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 40

Type: **Oral**

Upgrade of the ATLAS Tile Calorimeter for the High-Luminosity LHC Era

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 up to 7.5 times the LHC nominal instantaneous luminosity, is expected to begin in 2030. 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 2026-2030. 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 minimise single points of failure. The timing, control and communication interface with the off-detector electronics is implemented with modern Field Programmable Gate Arrays and high speed fibre optic links running up to 9.6 Gb/s. The TileCal upgrade program has included extensive R&D and test beam studies. A Demonstrator module with reverse compatibility with the existing system was inserted in ATLAS in July 2019 for operating 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.

Primary author: SOTTO-MAIOR PERALVA, Bernardo (Rio de Janeiro State University)

Presenter: SOTTO-MAIOR PERALVA, Bernardo (Rio de Janeiro State University)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 41

Type: **Oral**

Performance and calibration of the ATLAS Tile Calorimeter in Run 3

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 scintillators are read-out by the wavelength shifting fibres coupled to the photomultiplier tubes (PMTs). The analogue signals from the PMTs are amplified, shaped, digitized by sampling the signal every 25 ns and stored on detector until a trigger decision is received. The TileCal front-end electronics reads out the signals produced by 9852 channels measuring energies ranging from about 30 MeV to about 2 TeV. Each stage of the signal production from scintillation light to the signal reconstruction is monitored and calibrated. The calorimeter time resolution has been studied with multi-jet events. High-momentum isolated muons have been used to study and validate the electromagnetic scale, while hadronic response has been probed with isolated hadrons. This contribution will present recent performance results, including the calibration, stability, absolute energy scale, uniformity and time resolution.

Primary author: SOTTO-MAIOR PERALVA, Bernardo (Rio de Janeiro State University)

Presenter: SOTTO-MAIOR PERALVA, Bernardo (Rio de Janeiro State University)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 42

Type: **Oral**

Implementation and Validation of a (2+1+1)-Flavour Equation of State in the Heavy-Ion Event Generator *Trajectum*

Trajectum is a relativistic hydrodynamics code, designed to simulate the behaviour of the Quark-Gluon Plasma (QGP) produced during heavy-ion collisions using a hydrodynamic model. Given that the QGP undergoes hadronization as the temperature decreases, a hybrid equation of state (EoS) is required, combining one that is calculated from lattice QCD (LQCD) with one that describes a hadron resonance gas (HRG). In this work, the LQCD EoS calculated in (2+1)-flavours, which includes contributions from the up, down and strange quarks, is exchanged for a (2+1+1)-flavour LQCD EoS which additionally accounts for the charm quark. In addition, the interpolation method is changed from one that uses a ninth-order polynomial parameterized using the LQCD and HRG equations of state, to one that utilizes a connecting function previously employed in studies that incorporate a finite baryonic chemical potential. These changes are implemented into the broader *Trajectum* framework, and observables are generated using the modified code, which are then compared to their unmodified counterparts and observables from experiments to validate the modified event generator.

Primary authors: HARRIS, Liam (University of the Witwatersrand); Dr KOLBE, Isobel (University of the Witwatersrand); NIJS, Govert (CERN)

Presenter: HARRIS, Liam (University of the Witwatersrand)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 43

Type: **Oral**

Jet quenching in the smallest systems: pQCD predictions for R_{AB} and the absence of high- p_T v_2

We present predictions from a perturbative quantum chromodynamics energy loss model that includes small system size corrections and event-by-event hydrodynamic evolution of the medium. The effective strong coupling is constrained by a rigorous statistical analysis of high- p_T suppression data from central heavy-ion collisions at RHIC and LHC.

Extrapolating downwards in system size, we find quantitative agreement with recent Ne + Ne and O + O R_{AA} measurements, and measurable suppression persisting in very light ions down to $^3\text{He} + ^3\text{He}$, where deep inelastic scattering data tightly constrain the nPDF baseline.

Strikingly, the same model predicts $v_2 \approx 0$ at high- p_T for all small systems. We argue this prediction is generic to energy loss models when v_2 is extracted via the standard experimental method of hard-soft correlations, due to a geometric decorrelation between the hard and soft sector participant planes.

Primary authors: HOROWITZ, Will (University of Cape Town); FARADAY, Coleridge (University of Cape Town); Mr BERT, Ben (l'Ecole Polytechnique)

Presenter: HOROWITZ, Will (University of Cape Town)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 44

Type: **Oral**

The Thermal Casimir Effect in Scalar Lattice Field Theory

Motivated by the recent small system collisions at the LHC, we present exact first principles results for the finite-system-size corrections to the thermodynamics of both massless and massive non-interacting scalar field theories. We find corrections of 50-75% to the speed of sound at scales relevant to the quark-gluon plasma produced in heavy-ion collisions. The methods used to derive these results rely on a rigorous formulation of the lattice path integral partition function, with particular focus on ensuring absolute analytical control over every step of the derivation. Finally, we discuss the extension of this rigorous framework toward interacting theories, outlining the path toward computing next-to-leading order (NLO) finite system size corrections in a massive ϕ^4 theory.

Primary author: ROOSENSTEIN, Rens (University of Cape Town)

Co-author: HOROWITZ, William (University of Cape Town)

Presenter: ROOSENSTEIN, Rens (University of Cape Town)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 45

Type: **Oral**

Implications of Realistic Centrality Determination for QGP Formation in Small Systems

Signatures of collective behaviour consistent with a QGP-like medium have been observed in proton–lead (p–Pb) collisions, but jet quenching has not been observed despite theoretical predictions of partonic energy loss. The nuclear modification factor, a common signature of jet quenching, can be affected by biases introduced by multiplicity-based centrality selection.

In p–Pb collisions, multiplicity fluctuations at fixed collision geometry are large, causing multiplicity-based selections to preferentially select events with particular particle-production dynamics at a given collision geometry. This can bias the inferred number of binary nucleon–nucleon collisions for a centrality class used in determining the nuclear modification factor.

Experimentally, Zero Degree Calorimeters provide an alternative centrality estimator based on spectator neutrons near beam rapidity, which is less directly influenced by mid-rapidity particle production. This project investigates ZDC-based centrality selection in theoretical simulations using the heavy-ion collision framework Trajectum by modelling spectator fragmentation with GEMINI and constructing a ZDC signal from the resulting spectator neutrons.

Preliminary results show that the choice of centrality estimator affects the inferred collision geometry and high-pT suppression, with ZDC-based selection currently showing weaker suppression than multiplicity-based selection in most central events. Further analysis will investigate the physical origin of this difference.

Primary author: BROOMHALL, Daniel

Co-authors: FARADAY, Coleridge (University of Cape Town); HOROWITZ, Will (University of Cape Town)

Presenter: BROOMHALL, Daniel

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 46

Type: **Oral**

Initial-state hard-soft correlations and nuclear modification from saturation physics

High-energy particles are suppressed as they traverse the quark-gluon plasma, but the initial-state contribution to this suppression—or lack thereof—in small systems remains largely unconstrained. We use the saturation-physics-based framework IP-Glasma to predict the nuclear modification factor as a function of centrality in p +Pb, O+O, and Pb+Pb collisions due only to initial-state effects. Tuned only to HERA data, the model accurately predicts the self-normalized multiplicity distributions in p +p, p +O, p +Pb, O+O, and Pb+Pb collisions, the centrality-selected nuclear modification factor in p +Pb collisions, and the anomalous suppression observed in very peripheral Pb+Pb collisions. The model captures the centrality dependence of R_{pPb} and the peripheral Pb+Pb suppression through initial-state effects alone, while the minimum-bias R_{AA} in O+O and Pb+Pb collisions is significantly less suppressed than data, in qualitative agreement with a scenario in which the observed suppression requires final-state energy loss. We show that the hard-soft correlations in IP-Glasma arise from fluctuations in the local saturation scale, which simultaneously drive enhanced production of both soft ($p_T < 3$ GeV) and semi-hard (5–20 GeV) particles, giving a first-principles handle on how centrality selection biases high- p_T observables.

Primary authors: FARADAY, Coleridge (University of Cape Town); HOROWITZ, William (University of Cape Town); Dr SCHENKE, Bjoern (Brookhaven National Laboratory)

Presenter: FARADAY, Coleridge (University of Cape Town)

Session Classification: Parallel - HI

Track Classification: Heavy Ions and Nuclear

Contribution ID: 47

Type: **Oral**

Heavy-Hadron Lifetimes from Theory to Experiment

In this talk, I review recent progress in the theoretical description of heavy-hadron lifetimes across different flavor systems, ranging from heavy–light mesons and baryons to doubly heavy hadrons and the B_c meson. I discuss how different mechanisms contribute to lifetime differences among hadrons with the same heavy quark, and how these effects can be quantified using nonperturbative inputs such as NRQCD and lattice QCD.

I will compare theoretical predictions with available experimental measurements and highlight the remaining theoretical uncertainties.

These studies provide a coherent picture of heavy-hadron lifetimes across flavor systems and offer important benchmarks for testing our understanding of heavy quark weak decays and nonperturbative QCD.

Primary author: MELIC, Blazenska (Rudjer Boskovic Institute)

Presenter: MELIC, Blazenska (Rudjer Boskovic Institute)

Session Classification: Parallel - Theory

Track Classification: QCD and Theory Tools

Contribution ID: 48

Type: Oral

Beyond the Standard Model Searches for Dark Vector Bosons: A Comparison of BDT and Parametric Neural Networks

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pdftitle={Beyond the Standard Model Searches for Dark Vector Bosons: A Comparison of BDT and
Parametric Neural Networks},
hidelinks
}

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\noindent{\large\textbf{Beyond the Standard Model Searches for Dark Vector Bosons: A Compari-
son of BDT and Parametric Neural Networks}}

\vspace{0.5em}

The search for exotic Higgs boson decays to pairs of dark vector bosons,  $H \rightarrow Z_d Z_d \rightarrow 4\ell$ , where
each  $Z_d$  decays to a pair of same-flavour opposite-sign leptons, presents a significant multivariate
classification challenge due to the continuous and unknown mass of the dark vector boson  $Z_d$ .
Traditional approaches based on Boosted Decision Trees (BDTs) require separate training at each
signal mass hypothesis, limiting sensitivity interpolation across the mass spectrum and increasing
computational overhead. Parametric Neural Networks (pNNs) offer an alternative by conditioning
the classifier on the signal mass hypothesis as an additional input, enabling a single unified model
to provide optimised discrimination across the full  $Z_d$  mass range. In this work, we present a
systematic comparison of BDT and pNN classifiers for the  $H \rightarrow Z_d Z_d \rightarrow 4\ell$  search using ATLAS
Run 3 proton-proton collision data at  $\sqrt{s} = 13.6$  TeV. We evaluate both approaches in terms of
signal-to-background discrimination, sensitivity as a function of  $Z_d$  mass, computational cost, and
interpolation behaviour between trained mass points  $m_{Z_d} \in [15, 60]$  GeV.

\end{document}

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Primary authors: Ms ZWAKALA, Kgomotso (University of Johannesburg); CONNELL, Simon (University of Johannesburg); MAPEKULA, Xola (CERN); Dr IWASHOKUN, Opeoluwa (University of Johannesburg)

Presenter: Ms ZWAKALA, Kgomotso (University of Johannesburg)

Session Classification: Parallel - BSM

Track Classification: BSM and Flavour

Contribution ID: 49

Type: **Oral**

Investigation of candidate radiation resistant materials with high secondary electron emission yield for Photomultiplier tubes (PMTs) in the readout systems of the ATLAS TileCal.

Photomultiplier tubes (PMTs) play a critical role in the readout systems of the ATLAS TileCal. They rely on dynode materials with high secondary electron emission (SEE) and radiation tolerance. Secondary electron yields correlate with the electrical conductivity of these dynode materials which are usually extremely high band gap insulators. The conductivity in its turn is dramatically affected by radiation induced defects which in high radiation doses cause damaging electronic fatigue. This study investigates the effects of gamma radiation, with doses comparable to the ones in TileCal, on the electrical properties of three candidate dynode materials: CNS, Al_2O_3 and MgO. In addition, secondary electron yield results are shown for pristine and irradiated samples.

Primary authors: MOUANE, Othmane (University of Witwatersrand); Mr LALL, Gaurav (University of the Witwatersrand); SIDERAS-HADDAD, ELIAS (WITS UNIVERSITY); MOLOI, Lehlohonolo (University of Witwatersrand); Mr NKADIMENG, Edward (iThemba LABS); DAVYDOV, Yuri (JINR)

Presenters: Mr LALL, Gaurav (University of the Witwatersrand); SIDERAS-HADDAD, ELIAS (WITS UNIVERSITY)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 50

Type: Oral

Linearity, Resolution, and Simulation Comparison Studies for the CALICE SiW-ECAL Prototype at the 2026 CERN Test Beam

The CALICE Silicon-Tungsten Electromagnetic Calorimeter (SiW-ECAL) is a highly-granular imaging calorimeter prototype developed to validate particle-flow calorimetry techniques for future lepton and hadron collider experiments, using fine transverse and longitudinal segmentation to resolve individual showers within dense jets. We present linearity and energy-resolution studies of the SiW-ECAL prototype using positron beam data recorded during the 2026 CERN test beam campaign across six beam energies (7.5–74-GeV). Energy response is reconstructed using three complementary estimators – hit multiplicity, summed calibrated energy, and tungsten-thickness-weighted energy – with Gaussian fits performed on purified event samples. Event selection is refined using shower-shape variables, including MIP-likeness and the Molière radius, to suppress electronic noise, particle contamination, and shower leakage, and the resulting improvement in resolution is quantified explicitly against the unpurified baseline. The effect of channel-level intercalibration is assessed by comparing reconstructed energies before and after calibration. As part of this work, we identify and correct a methodological limitation in the prior estimate of the transverse beam-spot profile: hits in the first detector layer have already undergone more than one radiation length of tungsten and therefore trace early shower development rather than the incident beam itself. We introduce an alternative estimate based on the reconstructed shower barycentre, compare it against the layer-0-based method, and use the result to inform a matching Geant4-based simulation campaign at the same beam position and energies. Preliminary data-versus-simulation comparisons of linearity and resolution, including a data/MC ratio, are presented, together with an outlook on forthcoming track-reconstruction efficiency studies using newly available tracking software.

Primary authors: PULE, Tshepang; NKADIMENG, Edward (iThemba LABS)

Presenter: PULE, Tshepang

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 51

Type: Oral

MinPET: Knowledge transfer from particle physics to precious stones

MinPET is an intelligent, sensor-based sorting technology to map light element concentrations inside host rock at run-of-mine throughput. This technique can bring large savings in the monetary and environmental cost of diamond mining. Conventional techniques have poor recovery rates due to occlusion of exposed diamonds and encapsulation within kimberlite. This requires scrupulous washing and multiple stages of crushing to liberate diamonds, using large quantities of water and energy.

In contrast, MinPET aims to image carbon concentrations using Positron Emission Tomography. A high power 40 GeV Linac is used to generate a gamma beam optimised to excite the Giant Dipole Resonance. Natural carbon is transmuted via the reaction $^{12}\text{C} \rightarrow (\gamma, n) \rightarrow ^{11}\text{C}$. Background signatures such as ^{15}O and non carbon origin ^{11}C are also produced. The decay of shorter lived PET isotopes is awaited before scanning. Large-area planar PET detector arrays record coincident hits. GPU compute is used to reconstruct activity tomograms at high speed. Machine learning is used to develop classifiers that discriminate diamond-bearing rocks. The latency of this data-acquisition - reconstruction - classification pipeline is critical to ensure mechanical separation of concentrate in a reasonable sized installation.

The project has supported 4 PhD students, 2 MSc students and 5 Honours research projects. Geant4 is used for full-fidelity simulation of material activation and detection. There is international collaboration with engineering companies on accelerator conceptual design and sub-scale detector production and characterisation.

Primary author: BROOKS, Timothy (University of Johannesburg)

Co-authors: CONNELL, Simon (University of Johannesburg); MPAI, Tiego (University of Johannesburg); Mr CONNELL, Nicholas (University of Johannesburg); NCUBE, Prince (University of Johannesburg)

Presenter: BROOKS, Timothy (University of Johannesburg)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 52

Type: **Oral**

Test

Test submission/acceptance

Primary authors: KUMAR, Mukesh (University of the Witwatersrand); Dr WORKU, Dawit; Dr KOLBE, Isobel (University of the Witwatersrand)

Presenter: KUMAR, Mukesh (University of the Witwatersrand)

Session Classification: Parallel - H, EW, top

Track Classification: Higgs, Electroweak, Top

Contribution ID: 53

Type: **Oral**

Electroweak Symmetry Breaking in Scale Invariant Models with Multiple Scalars

Scale invariance provides an interesting framework for understanding the origin of the electroweak scale without introducing explicit dimensionful parameters. In this talk, I will study electroweak symmetry breaking (EWSB) in two scale-invariant extensions of the Standard Model with multiple scalar fields. First, I consider the SM extended by two scalar singlets, both acquiring nonzero vacuum expectation values. Second, I study a model with two scalar doublets and one scalar singlet, leading to a richer scalar sector and mixing structure. For both scenarios, I investigate the conditions for a viable electroweak vacuum and analyze the resulting scalar mass spectrum and couplings. I will also discuss the role of tree-level flat directions and radiative symmetry breaking, together with theoretical constraints such as vacuum stability, perturbativity, and unitarity, as well as relevant phenomenological constraints from collider and precision measurements. The results highlight how different scalar representations and multiplicities affect the mechanism of electroweak symmetry breaking and the phenomenology of scale-invariant models.

Primary author: AHRICHE, Amine (Sharjah U.)

Presenter: AHRICHE, Amine (Sharjah U.)

Session Classification: Parallel - H, EW, top

Track Classification: Higgs, Electroweak, Top

Contribution ID: 54

Type: **Oral**

CMS Muon System Upgrade for the HL-LHC: Status, Progress and Challenges

The CMS Muon system is undergoing a comprehensive upgrade to prepare for the High Luminosity LHC (HL-LHC), ensuring optimal performance under increased particle rates and luminosity. Key upgrades include enhancements to existing detectors and electronics, as well as the addition of new muon stations to expand coverage and improve resolution. The upgrades include enhancements to both the front-end and back-end electronics for the Drift Tubes (DT) and Cathode Strip Chambers (CSC), as well as back-end electronics for the Resistive Plate Chambers (RPC). Additionally, new detectors, such as improved Resistive Plate Chambers (iRPC) and Gas Electron Multipliers (GEM), are being introduced. New on-board DT electronics will enhance resolution and trigger capabilities, while iRPC chambers will improve efficiency at high rates. Additionally, new GEM stations will extend pseudorapidity coverage and boost momentum resolution. Production and installation of these components are planned during upcoming technical stops, ensuring the CMS Muon system is fully equipped to meet the rigorous demands of the HL-LHC. This talk will provide an overview of the current progress, challenges, and test results, illustrating the CMS collaboration's preparation for the next phase of high-energy physics research.

Primary authors: Dr MEYER, Arnd (CERN); Dr BILAL KIANI, Muhammad (University of Torino)

Presenter: Dr BILAL KIANI, Muhammad (University of Torino)

Session Classification: Parallel - Tech, QI

Track Classification: Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 55

Type: Oral

Probing anomalous Higgs couplings at the future μ^+p collider

We investigate Higgs boson pair production at a future high-energy muon–proton (μ^+p) collider through the charged-current vector-boson-fusion process $\mu^+p \rightarrow \bar{\nu}_\mu hh j$. Focusing on the $hh \rightarrow b\bar{b}b\bar{b}$ decay channel, we consider the characteristic final-state topology comprising four b -jets, a forward jet, and missing transverse momentum. The analysis is performed for two beam-energy configurations, $E_\mu = 0.5$ and 1 TeV with $E_p = 7$ TeV, corresponding to centre-of-mass energies of $\sqrt{s} \simeq 3.74$ and 5.29 TeV, respectively. We investigate the contributions of different production amplitudes and their destructive interference, which plays an important role in determining the di-Higgs production rate and its sensitivity to modifications of the Higgs interactions. Within an effective Lagrangian framework, we explore deviations from the Standard Model in the CP-even and CP-odd Higgs interactions involving the hhh , hWW , and $hhWW$ vertices. Using the characteristic kinematic distributions and a dedicated event-selection strategy, we derive projected 95% confidence-level exclusion limits on the anomalous couplings for an integrated luminosity of 1 ab^{-1} . Our results highlight the potential of high-energy μ^+p collisions to probe the Higgs self-coupling and its interactions with electroweak gauge bosons, providing complementary sensitivity to future Higgs-sector measurements

Primary author: LEBOHO, Thapelo Gerry (University of Witwatersrand)

Co-authors: Dr NKADIMENG, Edward Khomotso Nkadimeng (University of Witwatersrand and Ithemba labs); Dr KUMAR, Mukesh (University of the Witwatersrand); Dr SHARMA, Pramod Sharma (Institute of Collider Particle Physics); Prof. MELLADO, Bruce Garcia (Institute for Collider Particle Physics, School of Physics University of Witwatersrand and Institute of High Energy Physics, Chinese Academy of Sciences)

Presenter: LEBOHO, Thapelo Gerry (University of Witwatersrand)

Session Classification: Parallel - H, EW, top

Track Classification: Higgs, Electroweak, Top

Contribution ID: 56

Type: **Invited Talk**

Top and Multi-boson Physics

We will present the latest measurements in multiboson and top-quark physics performed by the ATLAS, CMS, and LHCb experiments at the LHC. These measurements cover a broad range of production processes and provide complementary probes of the Standard Model, testing its predictions across different energy scales and interaction regimes. We will review recent experimental results, highlighting their comparison with theoretical predictions and their implications for our understanding of fundamental interactions. We will also discuss the potential of these measurements to constrain possible extensions of the Standard Model and outline prospects for future studies.

Primary author: BELLAN, Riccardo (Università di Torino and INFN)

Presenter: BELLAN, Riccardo (Università di Torino and INFN)

Session Classification: Plenary

Track Classification: Higgs, Electroweak, Top

Contribution ID: 57

Type: **Invited Talk**

Light ion collisions (soft sector)

For over a decade, the question of whether or not small systems such as $p\text{Pb}$ form a Quark-Gluon Plasma (QGP) has been hotly debated. A central piece of evidence is the presence of anisotropic flow, which can be interpreted as a hydrodynamic response to initial geometry. The problem with this argument is that the initial geometry of $p\text{Pb}$ is poorly understood. Over the past year, data from light ion collisions has injected new life into the discussion. For light ion collisions, the initial geometry is well under control, allowing for precise quantitative model-to-data comparisons. This seems to affirm the statement that small systems are hydrodynamic. In addition, since small systems are more sensitive to the early stages of the collision compared to large systems, we are presented with a unique opportunity to learn more about these poorly understood aspects of ion collisions.

Primary author: NIJS, Govert (Utrecht University)**Presenter:** NIJS, Govert (Utrecht University)**Session Classification:** Plenary**Track Classification:** Heavy Ions and Nuclear

Contribution ID: 58

Type: **Invited Talk**

Theory Developments in Beyond-Standard-Model Physics

Despite the successful structural completion of the Standard Model (SM) of particle physics through the discovery of the Higgs boson, questions remain open that cannot be answered within the SM. Among these, two of the most prominent ones are those for the nature of Dark Matter (DM) and why there is more matter than antimatter in the universe. The answers to these (and also other) open questions require physics beyond the SM (BSM). So far, unfortunately, we do not have any direct sign of new physics. In this situation the role of the Higgs boson becomes extremely important as a door opener to the BSM landscape and as a dissection tool for its analysis. I will highlight in my talk the special role of the Higgs boson within both specific UV-complete models and within more model-independent effective field-theory approaches. I will discuss how it may guide our way in our quest for the model that allows us to describe nature and help us to understand the true picture behind it.

Primary author: MUHLLEITNER, Milada Margarete (Karlsruhe Institute of Technology (KIT))

Presenter: MUHLLEITNER, Milada Margarete (Karlsruhe Institute of Technology (KIT))

Session Classification: Plenary

Track Classification: Higgs, Electroweak, Top

Contribution ID: 59

Type: **Invited Talk**

Jets and Heavy Flavour as QGP Probes: Experimental overview

Monday, 30 November 2026 10:00 (30 minutes)

Jets and Heavy Flavour as QGP Probes: Experimental overview

Jets and heavy-flavour particles are powerful probes of the quark-gluon plasma (QGP) created in heavy-ion collisions at the LHC. Their production rates, angular anisotropies, and internal structure provide insights into parton energy loss, medium-induced modifications of parton showers, heavy-quark transport, and hadronization in strongly interacting matter. This presentation will provide an overview of selected recent results from the ALICE, ATLAS, CMS, and LHCb experiments. Topics include measurements of jet suppression, studies of heavy-flavour-tagged jets, and recent experimental insights into the mass dependence of in-medium radiation, including the first measurement of the charm-quark dead-cone effect in heavy-ion collisions by the CMS Collaboration. Particular attention will be devoted to recent measurements of charm-hadron production and azimuthal anisotropies, which probe the coupling of heavy quarks to the QGP and the role of recombination during hadronization. Overall, these measurements provide complementary constraints on the microscopic dynamics of heavy quarks and jets in the QGP and contribute to the development of a quantitative description of parton interactions in hot QCD matter.

Primary author: KRIZEK, Filip (Nuclear Physics Institute of the Czech Academy of Sciences)**Presenter:** KRIZEK, Filip (Nuclear Physics Institute of the Czech Academy of Sciences)**Session Classification:** Plenary**Track Classification:** Heavy Ions and Nuclear

Contribution ID: 60

Type: **Invited Talk**

Dark Matter: Collider, Direct, and Indirect Searches

Dark matter is one of the greatest mysteries that cannot be explained by the Standard Model. Many new physics models beyond the Standard Model have been proposed to explain dark matter, and various experimental approaches, including direct, indirect, and collider searches, are being pursued. This talk provides an overview of recent dark matter searches, focusing in particular on the multi-pronged search efforts conducted by the ATLAS, CMS, and LHCb experiments.

Primary author: USHIODA, Risa (Tokyo Metropolitan University)

Presenter: USHIODA, Risa (Tokyo Metropolitan University)

Session Classification: Plenary

Track Classification: BSM and Flavour

Contribution ID: 61

Type: **Invited Talk**

Computing and Software for the HL-LHC Era

The High-Luminosity Large Hadron Collider (HL-LHC) promises an unprecedented wealth of data and exciting opportunities for precision measurements and searches for new physics. However, exploiting this physics potential will require overcoming formidable challenges in computing and software. With increasing collision rates, more complex events, and ever-growing demands on simulation and data analysis, the computing resources required by the experiments are expected to grow far beyond what can be accommodated by simply scaling up existing infrastructure.

In this talk, I will provide an overview of the computing and software challenges facing the LHC programme as it prepares for the HL-LHC era, and discuss how the community is responding. From increasingly sophisticated theoretical simulations and more efficient event reconstruction to new computing architectures, modern software technologies, and machine learning, I will highlight some of the developments that will be essential to realising the HL-LHC's scientific potential.

Primary author: GUTSCHOW, Christian (UCL)

Presenter: GUTSCHOW, Christian (UCL)

Session Classification: Plenary

Track Classification: QCD and Theory Tools

Contribution ID: 62

Type: **Invited Talk**

Introduction to Heavy-Ion Physics: Experimental View

Lattice QCD predicts that at sufficiently large energy density a transition to a medium with deconfined quarks and gluons occurs - a Quark-Gluon Plasma is created. The talk gives an introduction to the study of high-density Quantum Chromodynamics using ultrarelativistic heavy-ion and proton beams. The main observables and results are introduced which allow to detect and characterize this Quark-Gluon Plasma. An overview of the findings based on LHC Run 2 data is given and open questions which are addressed with data recorded in the just finished LHC Run 3 are presented. Highlights from Run 3 including the recent light-ion run are showcased in order to give the audience the basis to put the related talks during the conference in a broader context.

Primary author: GROSSE-OETRINGHAUS, Jan Fiete (CERN)

Presenter: GROSSE-OETRINGHAUS, Jan Fiete (CERN)

Session Classification: Plenary

Track Classification: Heavy Ions and Nuclear

Contribution ID: 63

Type: **Invited Talk**

Education, Outreach & Science Communication initiative

The South African scientific collaboration with CERN (SA-CERN), celebrating more than 15 years of partnership, has built a broad footprint of world-class research and financial support for students to participate in the LHC endeavours, as well as outreach via the International Masterclasses. Other public engagement activities in South Africa are highlighted, such as Phenomenal Physics at the University of Cape Town, showcasing live demonstrations to 300 learners, and screenings of the film Particle Fever at the African Institute for Mathematical Sciences (AIMS), followed by a live Q&A with featured CERN physicists connecting online. Beyond South Africa, the HEP community is active across the continent: the biennial African School of Physics (ASP) offers a rich programme of both talks and hands-on sessions, and Masterclasses are organised in countries including Kenya and Morocco. During a science festival in the DRC, a booth introduced CERN and the LHC to 10,000 learners from Kinshasa and surrounding areas. In Kenya, the 2-day Sisters Science Safari engages young women to pursue their passion for STEM, while an educational muon detector, MERCI, was built and demonstrated for the first time during ASP 2026. The presentation will offer insights on how to pursue African HEP public engagement, as well as how to get involved.

Primary author: DAVID, Claire**Presenter:** DAVID, Claire**Session Classification:** Plenary**Track Classification:** Instrumentation, Tech Transfer, and Quantum Information

Contribution ID: 64

Type: **Invited Talk**

Perspectives on the Future of High-Energy Collider Physics

After the discovery of the Higgs boson at the LHC particle physics has entered a new era. With the successful data taking over the past decade, many properties of this particle have been established. Despite this, important questions remain open and call for experimental exploration. The Higgs field itself is linked to deep structural questions of the Standard Model of particle physics such as flavour, naturalness and the stability of the vacuum. In addition, the nature of the dark matter in the universe, the origin of the matter-antimatter asymmetry and of the neutrino masses remain open.

Over the past years, within the European Strategy for Particle Physics process, the future of European particle physics has been debated, and recommendations have been expressed for the Future Circular Collider (FCC) as the next large flagship collider project at CERN.

In this talk the European Strategy process and the rationale behind the recommendations is discussed together with the physics potential of the FCC. In addition, an overview of the current strategic global planning for particle physics, including areas beyond collider physics, is given.

Primary author: Prof. JAKOBS, Karl (University of Freiburg)

Presenter: Prof. JAKOBS, Karl (University of Freiburg)

Session Classification: Plenary

Track Classification: Higgs, Electroweak, Top

Contribution ID: 65

Type: **Invited Talk**

Recent progress in event generators for QCD

This talk will discuss the recent progress in describing perturbative QCD in event generators.

Primary author: VAN BEEKVELD, Melissa (Nikhef)

Presenter: VAN BEEKVELD, Melissa (Nikhef)

Session Classification: Plenary

Track Classification: QCD and Theory Tools

Contribution ID: 66

Type: **Invited Talk**

Light-Ion Collisions at the LHC: Hard Probes and Nuclear Structure

The dedicated 2025 LHC light-ion run delivered p+O, O+O and Ne+Ne datasets, opening a new opportunity to study QCD in collision systems intermediate between proton–nucleus and large heavy-ion collisions. These new data broaden the range of systems available for investigating nuclear structure, initial-state effects and the emergence of final-state medium phenomena.

This talk will review the first results from the 2025 LHC light-ion programme, with emphasis on hard and electroweak probes complementary to the broader jet-quenching programme. Measurements of charged-particle production, electroweak bosons, heavy flavour and quarkonia will be discussed as probes of nuclear parton distribution functions, collision geometry and possible final-state medium effects. Selected jet-related observables will be included where they provide essential context for the emerging picture of parton energy loss.

Particular attention will be given to comparisons between O+O, Ne+Ne, p+Pb and peripheral Pb+Pb collisions, and to what these measurements reveal about the interplay between nuclear structure, initial-state modifications and the onset of QGP-like behaviour in small and intermediate collision systems.

Primary author: BARON, Petr (Charles University IPNP)

Presenter: BARON, Petr (Charles University IPNP)

Session Classification: Plenary

Track Classification: Heavy Ions and Nuclear

Contribution ID: 67

Type: **Invited Talk**

Tech Transfer and SA-CERN

CERN has a new 2026–2030 strategy the next five years framed around: (1) global leadership in accelerator science and technology, (2) cutting-edge scientific research, (3) delivering value for stakeholders, (4) wider societal impact, and (5) organisational excellence. This has value for external User Groups like South Africa beyond participation in frontier level research. There is an additional focus on knowledge transfer, innovation, industry engagement and societal impact which are no longer peripheral activities. They are embedded as the above five strategic pillars alongside the core physics programme. This is well aligned to the new Technology Transfer (TT) Pillar of SA-CERN. This TT Pillar provides an additional funding stream that facilitates TT, Innovation and Commercialisation. In addition, it regularises that funding to the legislation, regulations and procedures to shape a partnership between all funders (Universities, Industry, other State Institutions) in a coherent way, with a view to the ultimate objective of promotion of value and fairly distributed 3rd stream income. This contribution will review the ecosystem, all aspects, and document some of the current TT projects.

Primary author: CONNELL, Simon (University of Johannesburg)

Presenter: CONNELL, Simon (University of Johannesburg)

Session Classification: Plenary

Track Classification: Instrumentation, Tech Transfer, and Quantum Information