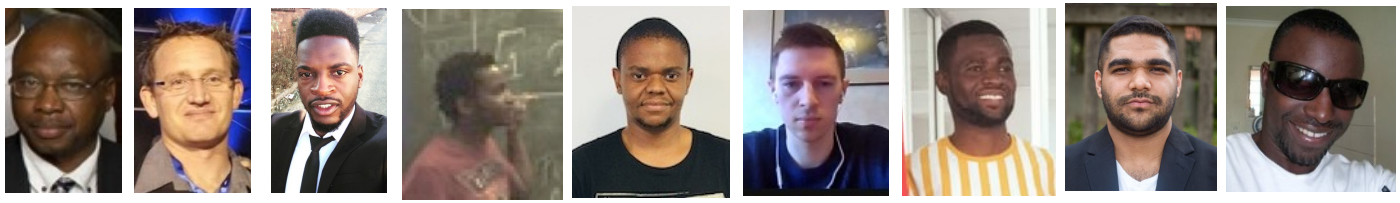
The UJ–ATLAS and Associated Innovation Group + UNISA + UWC

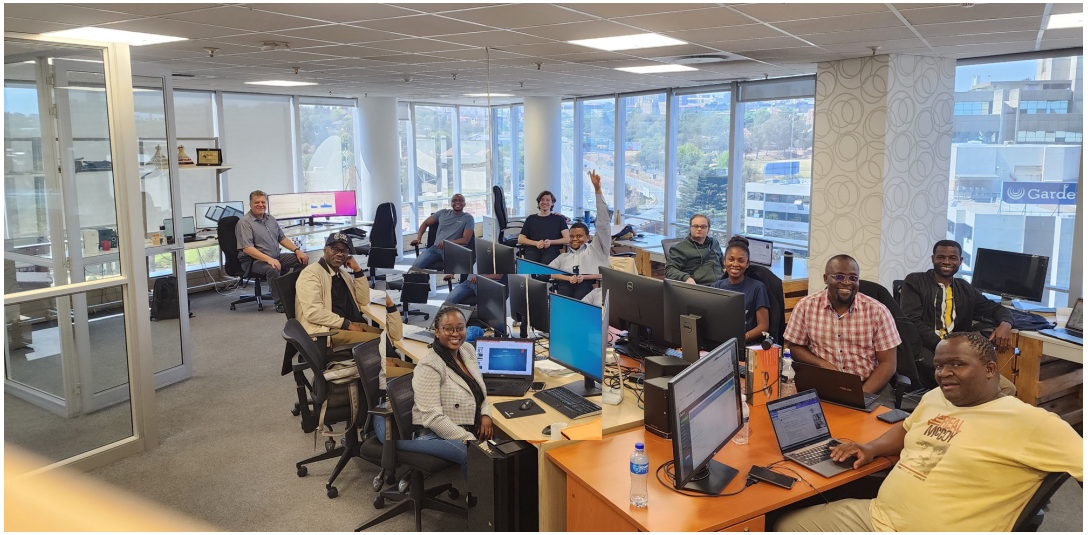
- **Staff**
  - Simon Connell (Prof)
  - Muaaz Bhamjee (Sn Lect)
  - Nicolin Govender (Prof)
  - Loan Truong (Lecturer, Visiting Prof)
  - Mpho Gololo (Sn Lect)
- **Post Docs**
  - Bongani Maqabuka
  - Emmanuel Igumbor
  - Hasina Ralijaona
- **Students**
  - PhD: Phineas Ntsoele
  - PhD: Thendo Nemakhavhani
  - PhD: Matthew Connell
  - MSc: Xola Mapekula
  - MSc: Mr Mitchell Phiri
  - MSc: Gideon Bentum
  - MSc Chris Lee
  - Doomnull Unwuchola
  - MSc Abdool Sattar Cassim
  - Brenton Munhungewarwa
- **Associate sub-institute**
  - Lerothodi Leeuw (Prof UWC)
  - Pedro Mafa (Dr UNISA)
  - Mantile Lekala (Prof UNISA)
- **Necsa Associates**
  - Dr Graham Daniels, Dr Dazmen Mavunda, Eric Chi
- **Research Associates**
  - Dr Martin Cook (SRA UJ),
  - Dr Sergio Ballestrero (SRA UJ)
  - Tim Brooks (SRA UJ)

+ many colleagues from ATLAS Prof Kétévi Assamagan BNL



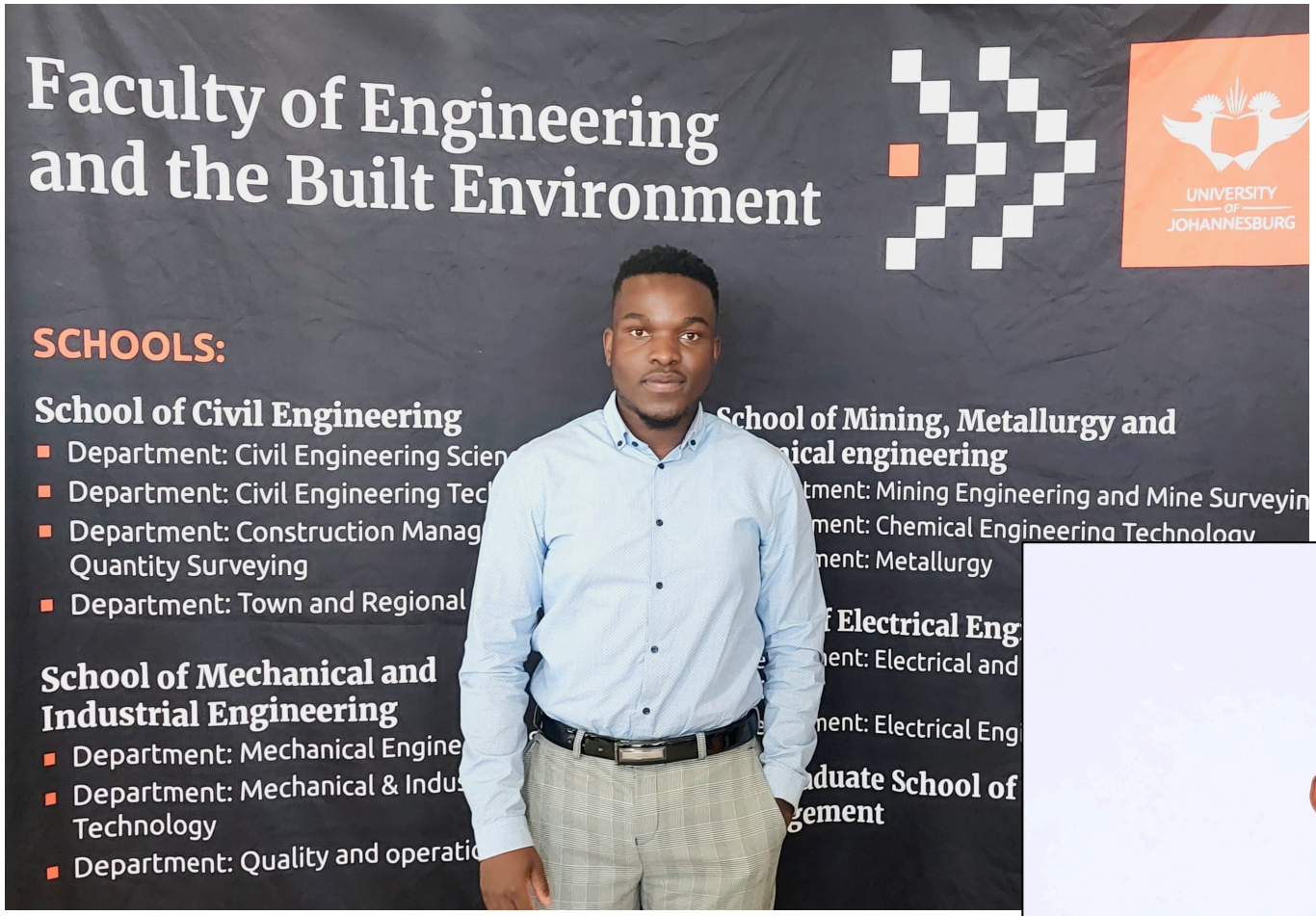
ATLAS Innovation

Local Labs and Presentations



UJ @ CERN: Fibre Optic Lab

UJ @ CERN: New High Throughput Electronics and Analysis



ATLAS Analyses

Analysis in the exotics Higgs decay sector for Beyond SM physics,

ANA-HDBS-2018-55, **H → XX → 4l, X can be Z_d or a**
Completed for Run 2

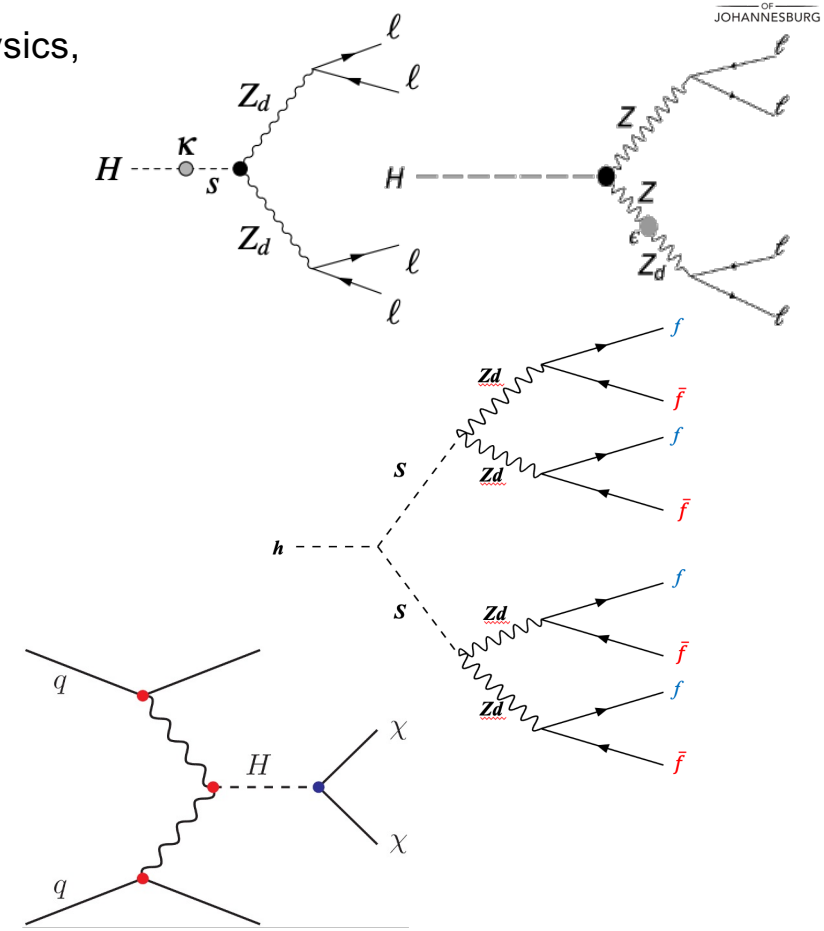
ANA-HDBS-2021-13, **S → XX → 4l**
2D search has a dark Higgs
Run 2 paper submitted, awaiting referee response.

ANA-HDBS-2024-06, **S/H → XX/XZ → 4l analysis**
This analysis aims to continue into Run 3, includes MET
Matthew Connell, Xola Mapekula analysis contacts

ANA-HDBS-2021-30, **S->Z_dZ_d-> lljj / llvv**
Run 2 / 3

ANA-HIGG-2021-05, **VBF H → invisible analysis**

CP eγ analysis
Combined Performance of ATLAS detector
using Full Geant4 and Fast Monte Carlo Simulations.



ATLAS Analyses

H/S → XX/ZX → ZX analysis

Motivation

- Clean 4l final state to investigate HAHM decays
- X can be Z_d or a

Analysis

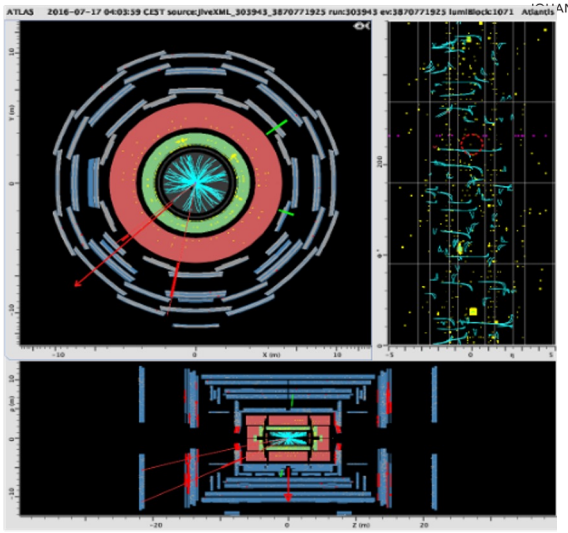
- Run 2: Higgs to 4l decays via: ZZ_d, Za and Z_dZ_d
- Run 2: AS to 4l decays via Z_dZ_d
- Run 3: extension of both Run 2 analyses to Run 3
- H→ZZ framework from previous Z_dZ_d analyses

New techniques

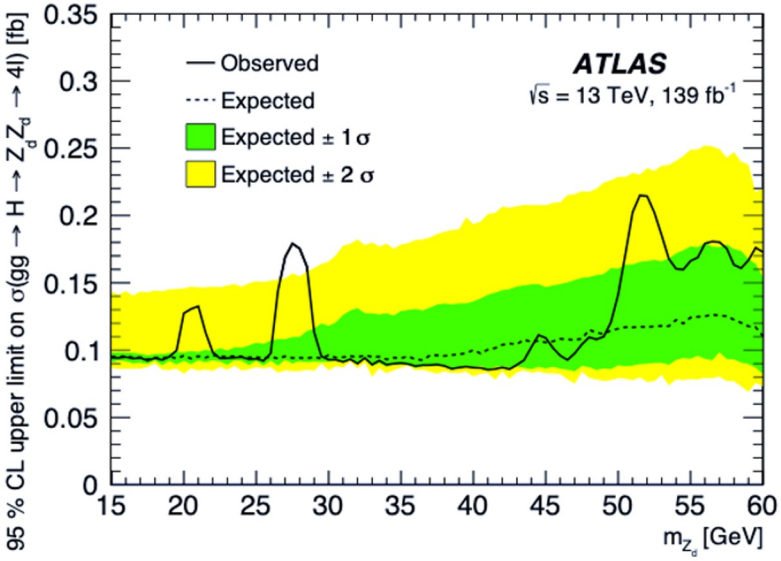
- Z_dZ_d pairing algorithm
  - Framework for Run 2 Analyses
  - Matt + Xola analysis contacts for Run 3
- Binning in MET
- Planned MVA for background discrimination

Status

- HM: published
- AS: in peer review
- HM+AS Run 3: Requesting MC



Event display above) and cross-section (below) for H→ZdZd→4l



ATLAS Analyses

2l2v Analysis

Motivation

- Follow up to $S \rightarrow Z_d Z_d \rightarrow 4l$ Run 2 analysis
- Consider Z_d decays to dark fermions, extension to 2l2v channel

Analysis

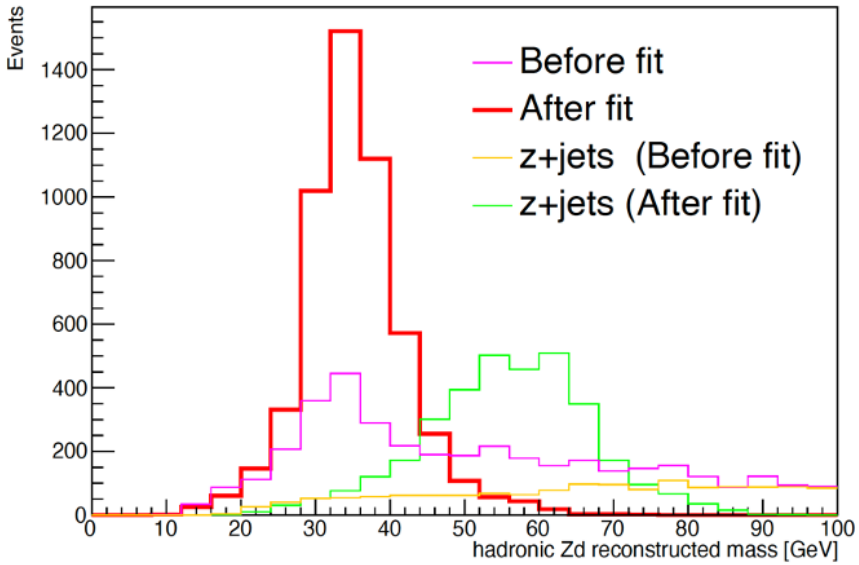
- **Signatures:** dileptons, jets
- **Dominant backgrounds:** Z+ jets (including low mass), ggZZ/WW, ttbar, WZ
- Using $H \rightarrow ZZ$ framework

New techniques

- MET related variables are replaced with parametrised Neural Net (NN), to reduce background
- Adversarial NN used to reduce bias to any parameter space.
- Likelihood function includs events with ≥ 2 jets not from Z_d compatible with di-lepton invariant mass: mjj ≠ mll)
- NN for to distinguish signal from background.

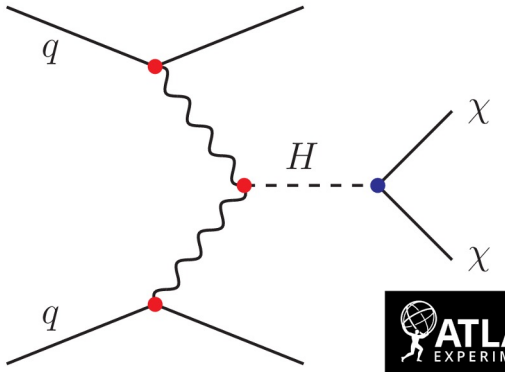
Status

- Applying FSR recovery from $H \rightarrow 4l$ to reduce background
- Full framework running on Release 22
- MC20 + MC23 samples produced.



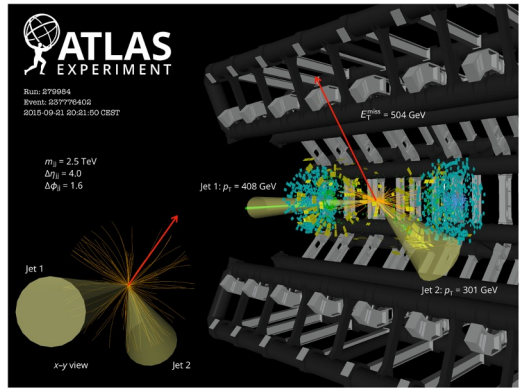
$$L = \max_{(j1,j2)} \max_{(E1,E2)} [\mathrm{Gaus}(m_{jj}(E1,E2) - m_{ll} \mid 0,5) \times \mathrm{Gaus}(E1 \mid E_{j1}, \sqrt{E_{j1}}) \times \mathrm{Gaus}(E2 \mid E_{j2}, \sqrt{E_{j2}})]$$

ATLAS Analyses



Motivation

- Exploit Higgs decays to objects not detected by ATLAS (i.e. invisible)
- Not sensitive to SM H→invisible processes (H→ZZ→4v has BR~0.1%)
- Mainly sensitive to BSM physics, e.g. Higgs portal Dark Matter, for mass > ½mH
- Also search for VBF+MET+y and H→ yy_d analyses (y_d : dark photon), input to global Higgs combination

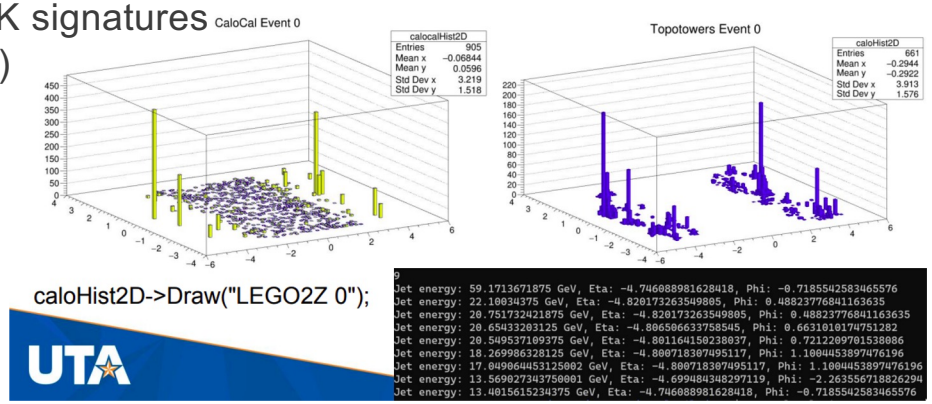


- **Signatures**: di-jets with large η-separation & large invariant mass, large MET
- **Main backgrounds**: W/Z + jets, multi-jets

New techniques

- Multivariate Analysis (MVA):
  - Deep learning convolutional NN (CNN) used on low level objects
  - Discriminates QCD-strong processes against VBF-EWK signatures
- New multijet estimate, limit-setting framework (using pyhf)
- New interpretations with dark matter mass > 1/2 mH
- MVA optimization, limit setting

Low level jet's object



Status

- Full framework running on Release 22
- MC20 + MC23 samples produced.
- MVA Studies and multijet estimate being conducted

The search for DM @ ATLAS

Motivation

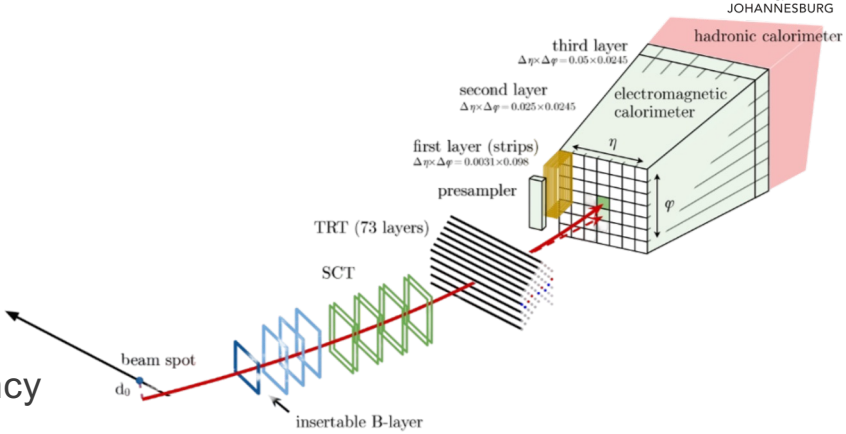
- Geant4 full simulation is computationally expensive
- Economise for showers and modelling ATLAS geometry
- AF3 is a new efficient simulation method:
  - Detector response to particles is parameterised.
  - Uses simplified geometry

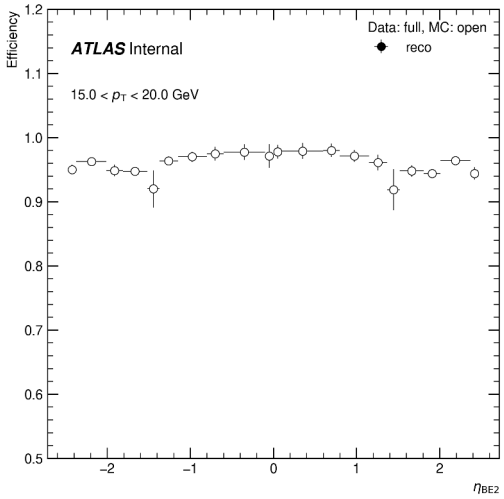
Analysis of feasibility

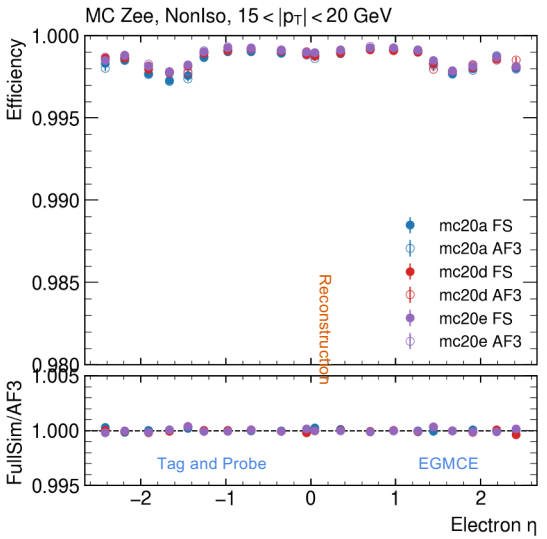
- Compare electron identification (ID) & reconstruction efficiency
  - Tag and Probe framework:
  - EGMCE algorithm:
    - counts electrons from decays and computes scale factors
- Results:
  - AF3 viable alternative to Full Simulation
  - EGMCE > Tag and Probe in efficiency (e^- counting method)
- AF3 electron reconstruction and ID efficiency studies

Status

- Measuring scale factors with Tag and Probe for reference
- Modifying EGMCE framework to match Tag and Probec

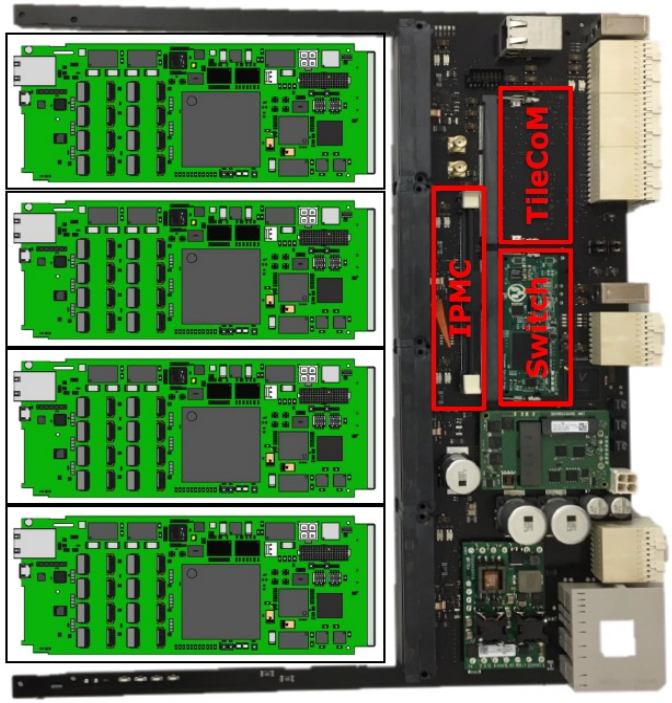


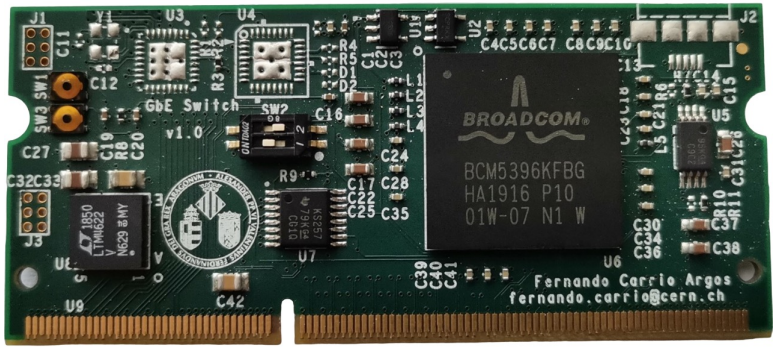




TileCal PPr project overview

- Contributing 24% of the Tile PPr
  - Production of boards in S.A.
  - Current focus on the TileCoM and Tile GbE Switch
- Current work and procurement
  - OPC UA server firmware and software development
  - Procurement of FPGAs
  - Integration of TileCoM with Tile-PPr boards

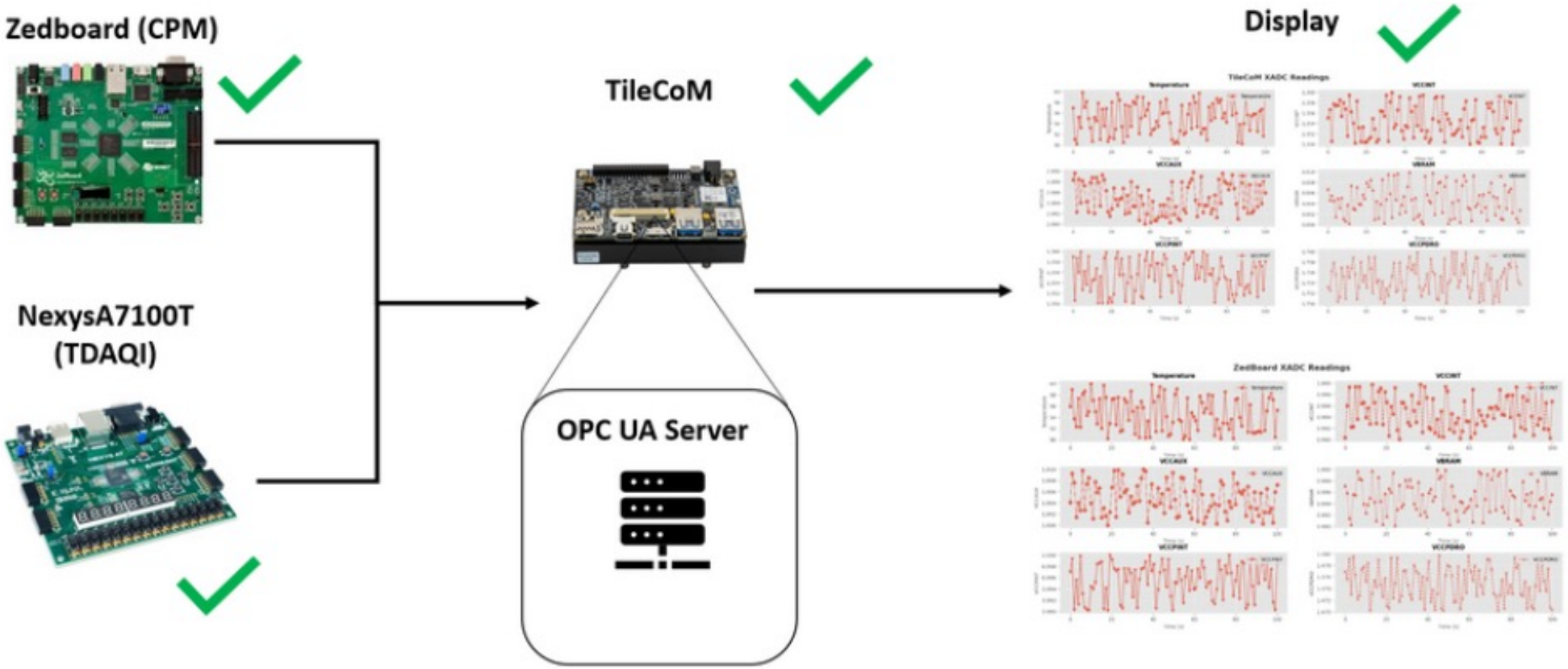




Tile GbE Switch

TileCoM

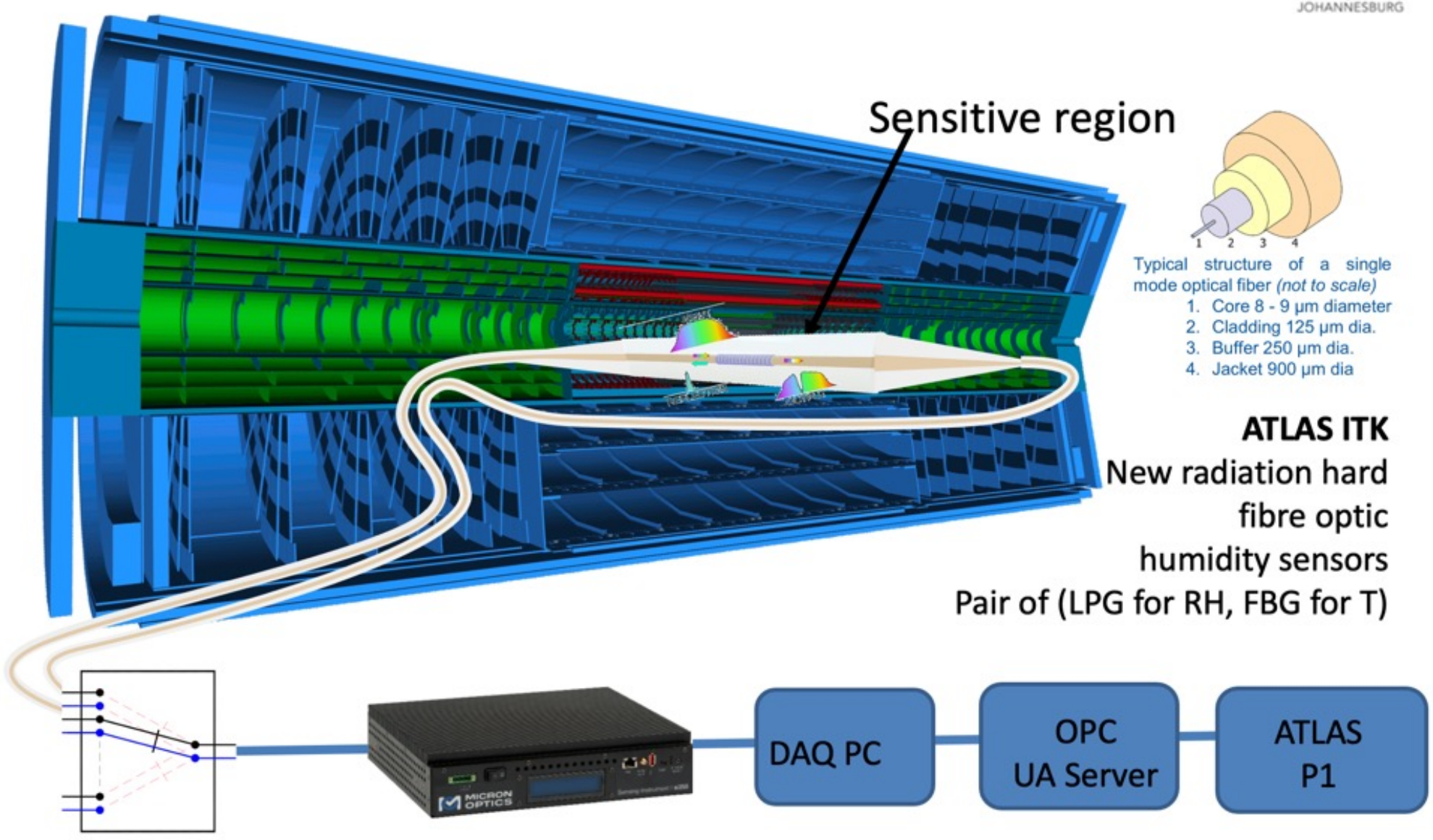
Status of the firmware/software with TileCal PPr intergation



Procurement status and project future plans

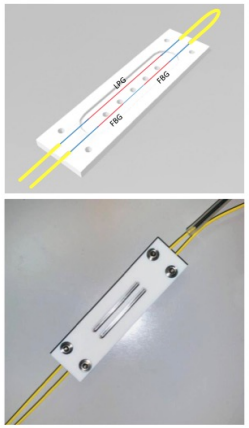
- Procurement for the TileCoM and CPM FPGAs
  - Ongoing process to approve a deviation of R6.3 Million deviation for these FPGAs
  - Manufacturing of TileCoM PCBs to commence immediately after FPGA procurement
- Future plans
  - Test station of the complete integration tests of TilePPr modules in SA
  - PCB validation and integration tests to be done before shipping manufactured PCBs to CERN
  - Develop lab at UJ

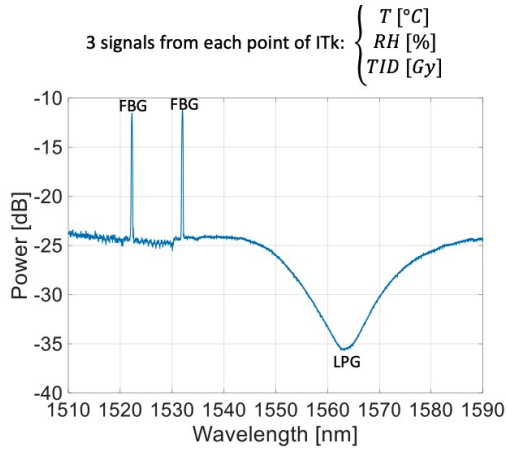
Fibre Optic Sensors in ATLAS … Keep ATLAS dry !



Fibre Optic Sensors in ATLAS … Keep ATLAS dry !

- ❖ Keep ATLAS dry .. No commercially available sensor
- ❖ Monitor humidity and temperature to protect ITk.
- ❖ Harsh radiation environment
- R&D + I for grating, functional coating, readout, algorithm,
- ❖ QA/QC and production, continue R&D, DCS Monitoring
- ❖ FDR approved, PRR just held
- ❖ Conducted pre-approval purchase of 25% sensor components
- ❖ Development of OPC-UA server code



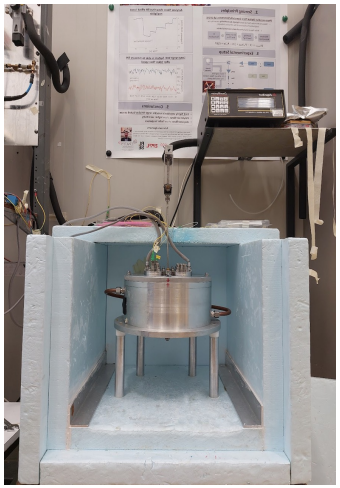


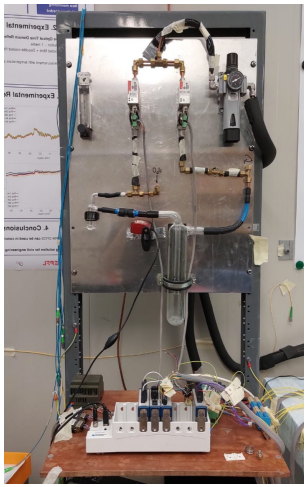
Research and Development – First of a Kind, pre-commercial solution

Innovations in sectors

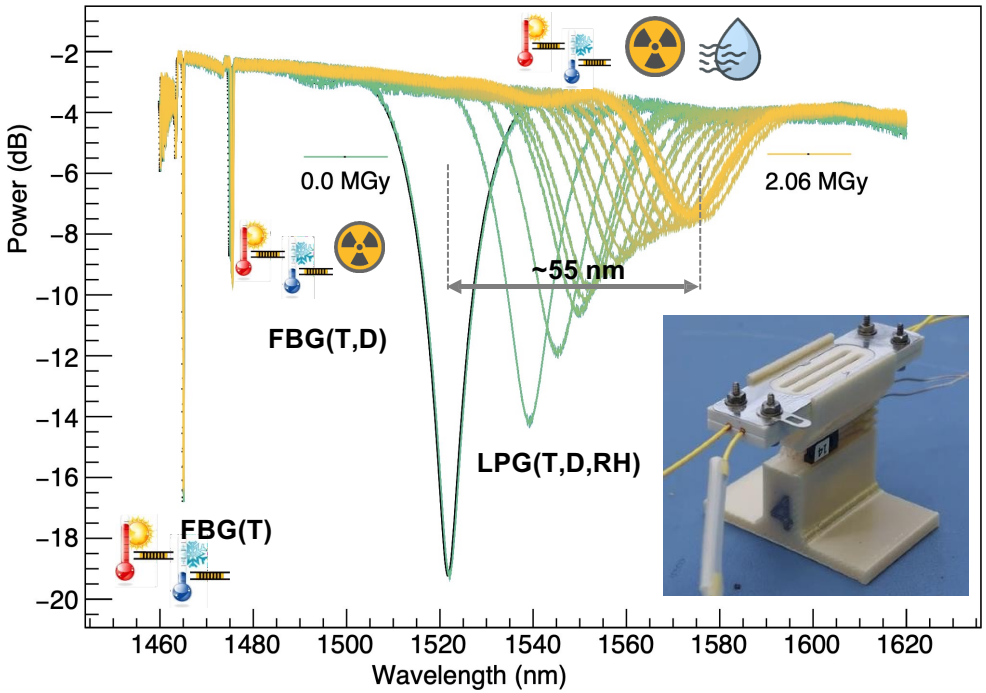
- Energy
- Water
- Food
- Medicine

- Sensor calibration with environmental chamber



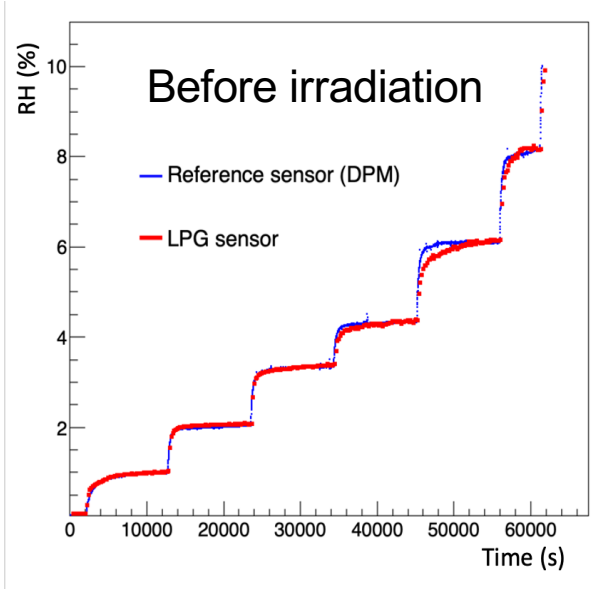


Irradiation tests: p, n, γ to effective 2 MGy ~ ten years of exposure



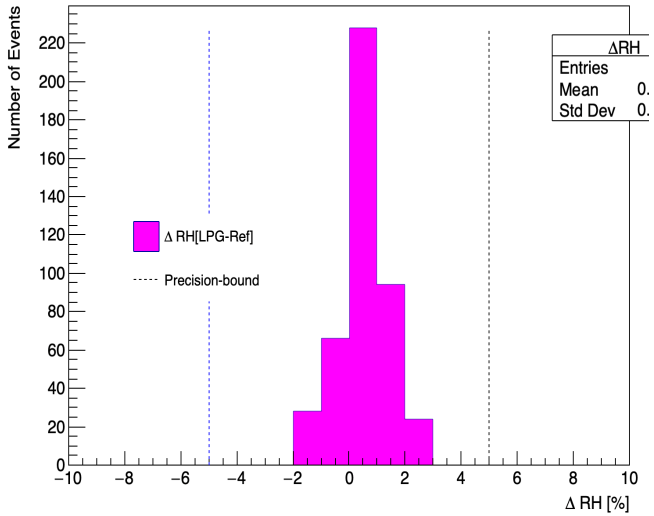
Fibre Optic Sensors in ATLAS … Keep ATLAS dry !

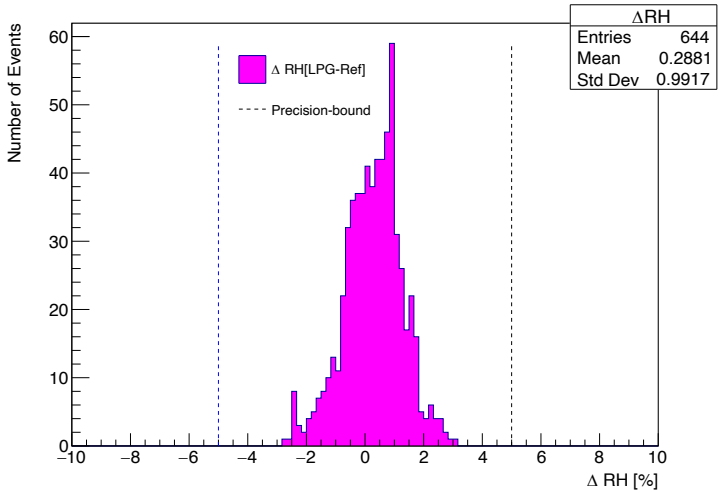
Agreement between FOS readout & HIH sensor



After irradiation

- Sensors were calibrated after irradiation
- Agreement between FOS and HIH sensors





Continuum Fluid Dynamics → CFD : model the ITk fluid system

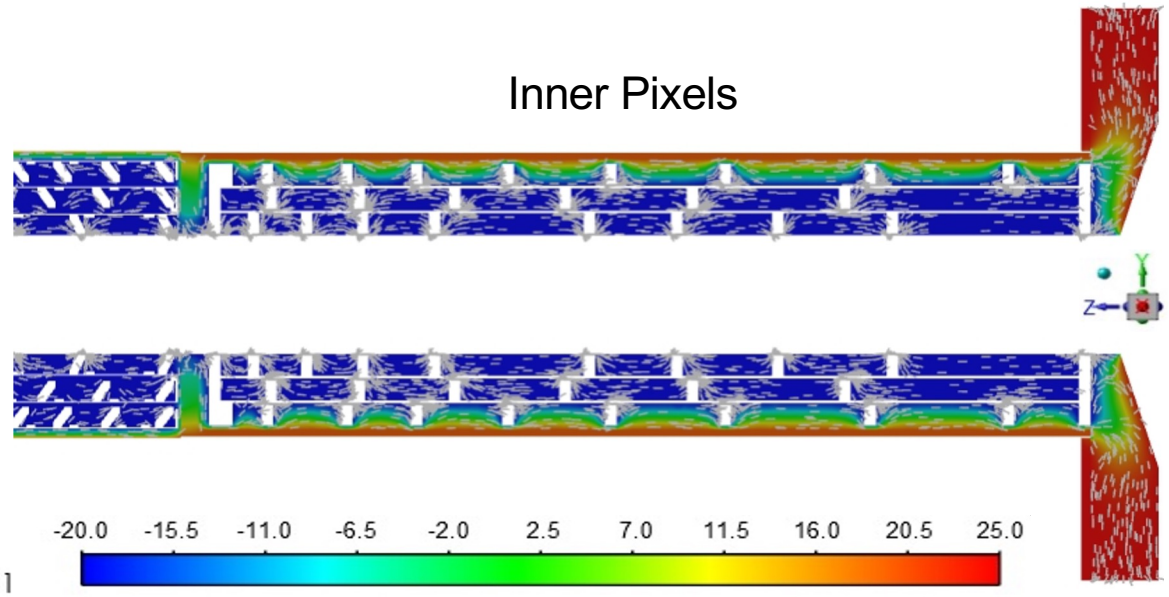
Continuum Fluid Dynamics (CFD)

- **Initially for sensor placement**

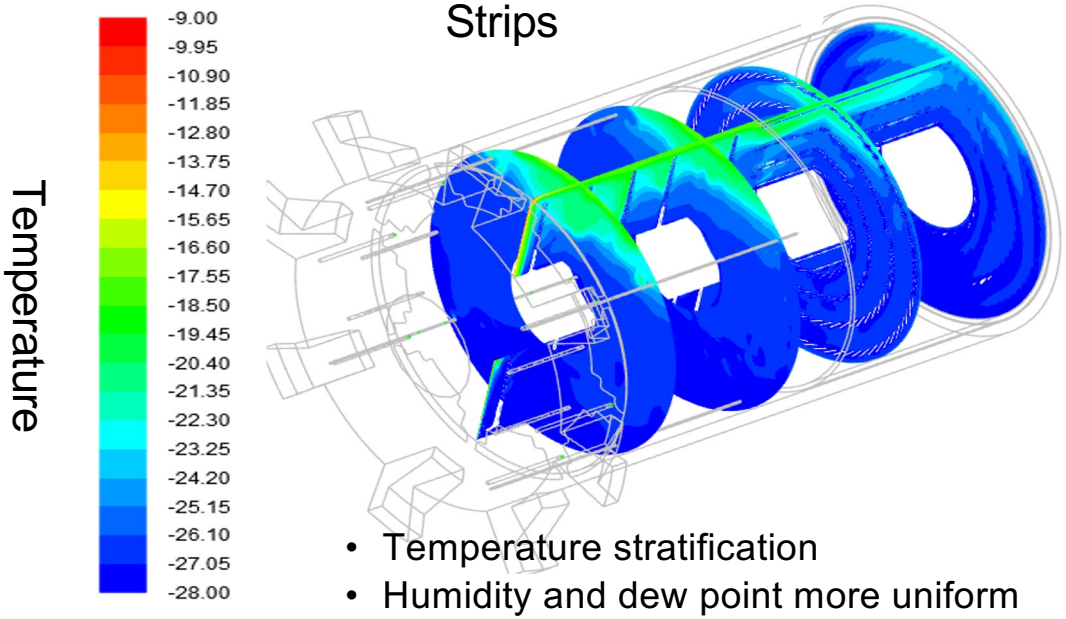
Now

- **Fluid flow,**
- **Thermals,**
- **Leaks,**
- **Bake-out**

Inner Pixels



Strips



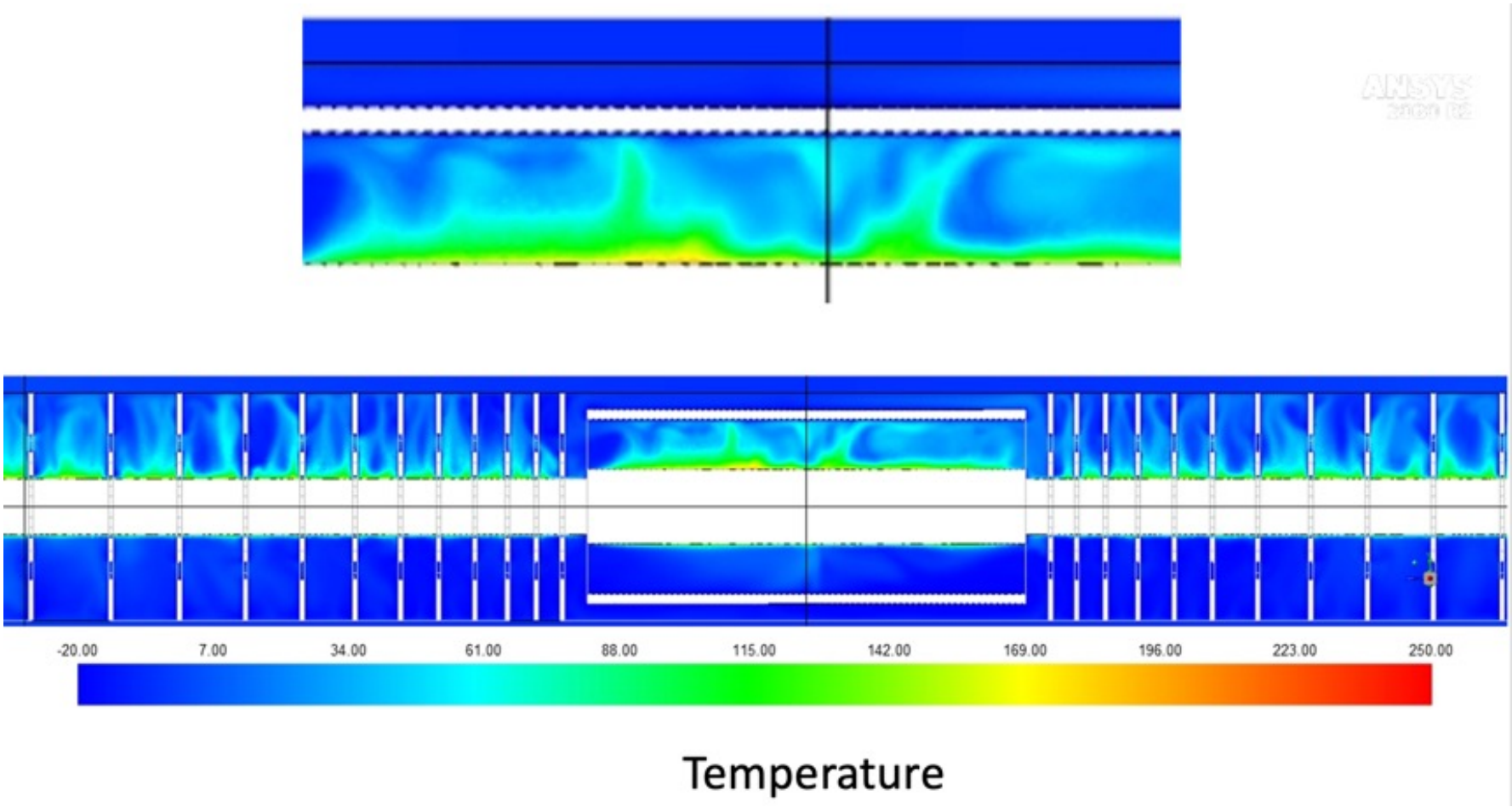
- Temperature stratification
- Humidity and dew point more uniform

Temperature distribution is uniform throughout most of the volume due to cooling effect of detector discs. Boundary condition at layer 4 may change.

Continuum Fluid Dynamics → CFD : model the ITk fluid system

Simulate fluid flow, thermals, drying out, vapour leaks, sensor placement, performance
Example from ITk Inner Pixels volume ……

In this example … bake-out conditions for Inner Pixels.



Tech transfer: Local FOS Lab

FOS Lab
Environment chambers

Weiss WT3 WK3 180/40

Temperature range from -40C to 1000C.
Humidity range as appropriate for Temperature

Envirotronics Chamber EV240LN2-X with Star28-X

Temperature range from -70C to 40C. Humidity range as appropriate for Temperature. Mechanical agitation

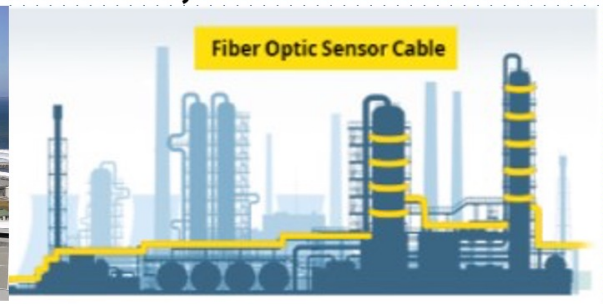
UNIVERSITY OF JOHANNESBURG

Applied Nuclear Science Innovation and Commercialization

Fiber Optic Sensors for Remote Sensing in Nuclear Reactors
radiation hard, multi-sensor, 4IR

Eskom

Koeberg Nuclear Power Station



UNIVERSITY OF JOHANNESBURG

- UJ DMES Research Team
- UJ Tech Transfer Office
- UJInvnt

New IP in progress

Developing novel 4IR capable smart sensors: first of a kind, in-core, real-time & online, radiation resistant optic fibers – to perform high spatial resolution measurements for physical parameters e.g., **dose**, **water level**, etc.

A joint MoA with Necsa for R&D, also preferred service provider to ESKOM. Funding of R2.2 M from ESKOM and R1.1 M from UJ

Eskom

necsa
We're in your world

Tech transfer: MinPET - Now acquiring R100M for the CDR

Accelerators, Detectors, High-throughput electronics, Big Data, Simulation (Geant4), Data quantitative visualization (ROOT), High Performance Computing, AI

MINPET DIAMONDS | SORTED

4IR Technology to "see" diamond enclosed in kimberlite. Other related technologies in medicine, mining, waste, homeland security

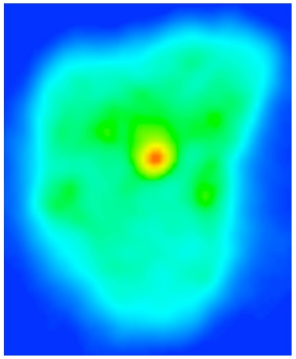
National Science and Technology Forum (NSTF)
2022 - Innovation Award: Corporate Organization

2 Patents Granted in 2022
Innovation beyond MinPET

- **XRT on Steriods**: Method of Multiple Source and Detector Gamma Ray Tomographic Radiography
- **Poly-PET**: Materials Analysis Method and System

95mm kimberlite

0.91 ct



UJ DMES Research Team
UJInvnt
UJ Tech Transfer Office

GEM DIAMONDS

UJ takes leadership in Innovation and Commercialization

Begins de-risking spend with work packages for the International Technology Partners and building the UJ Research Team

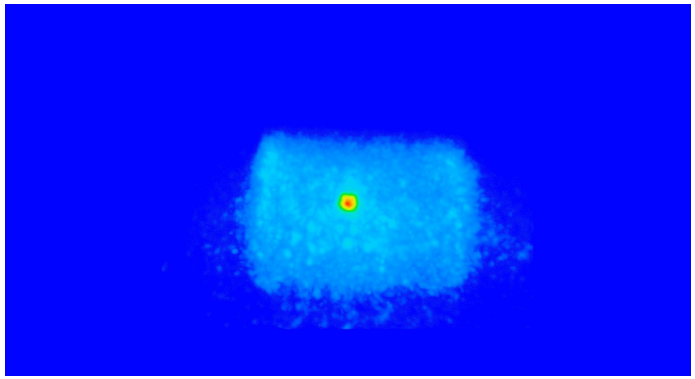
research instruments

NeT instruments

COSYLAB

STARK

Tech transfer: MinPET – Finding diamond in Rock



Accelerator Activation

irradiation hopper produce PET isotopes

AI, ML, Classification

Big Data processing

Novel PET Detection System

30 MINUTE HOLD HOPPER

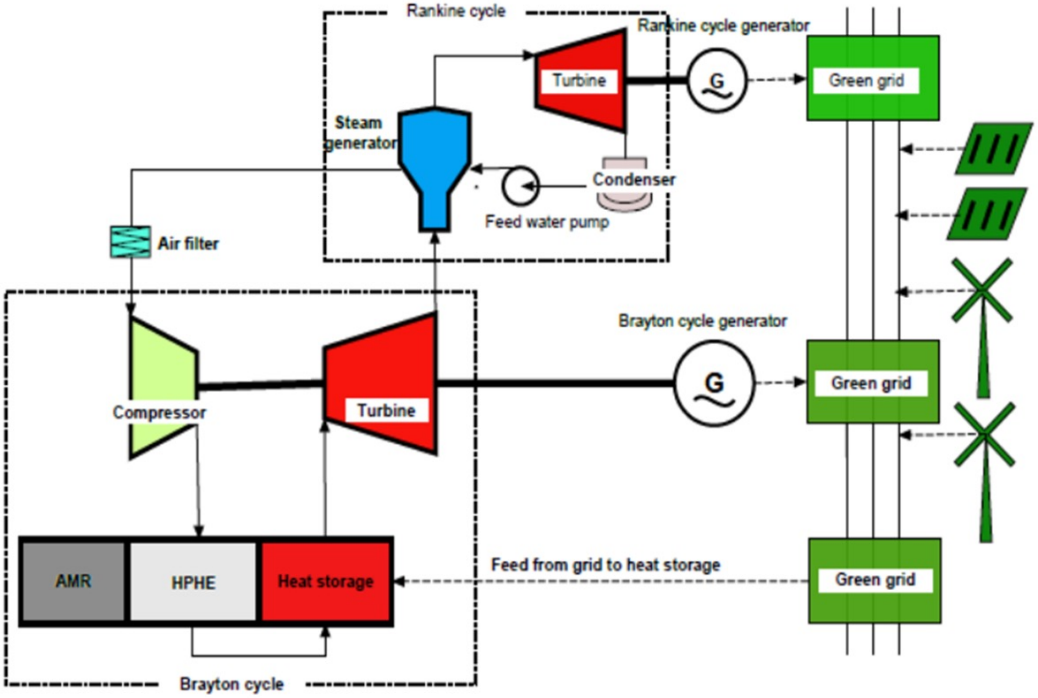
hold hopper ~30 min ^{11}C dominates

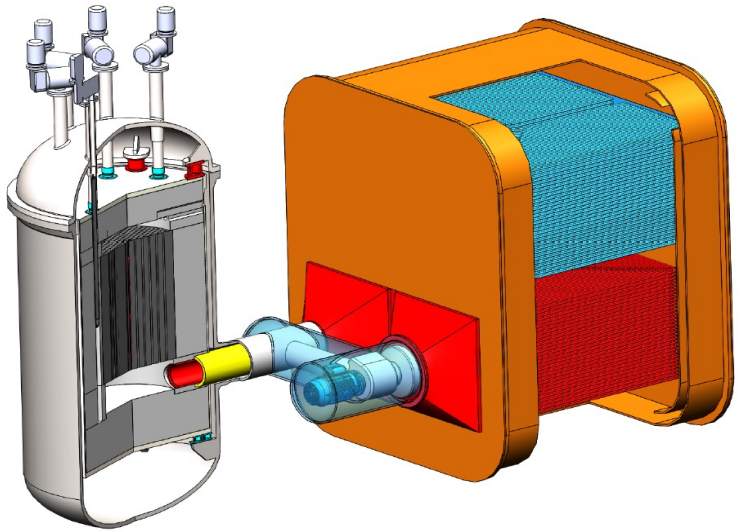
planar PET array

ejection system

Tech transfer: CFD 1 – Micro Reactor Nuclear Battery

The Nuclear battery.
SAIEE Webinar https://youtu.be/gY1hNVaW8IQ 16/2/2023
Support renewables
UP initial design, Prof Johan Slabber
UJ working on Passive Heat Exchange Optimisation





CFD for the natural convection of the Heat Pipe Heat Exchanger (HPHE) coupled to the Advanced Micro Reactor (AMR)

Tech transfer: CFD 2 – Public health

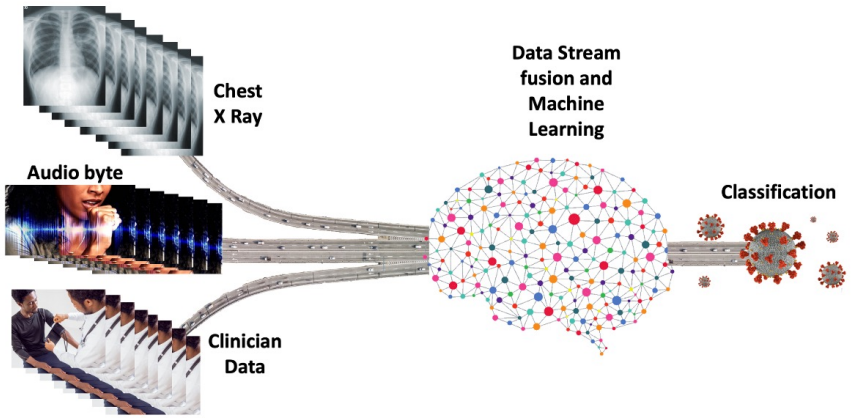
Some of our projects ….. ML and CFD inspoired by COVID, continuing interdisciplinary resewarch

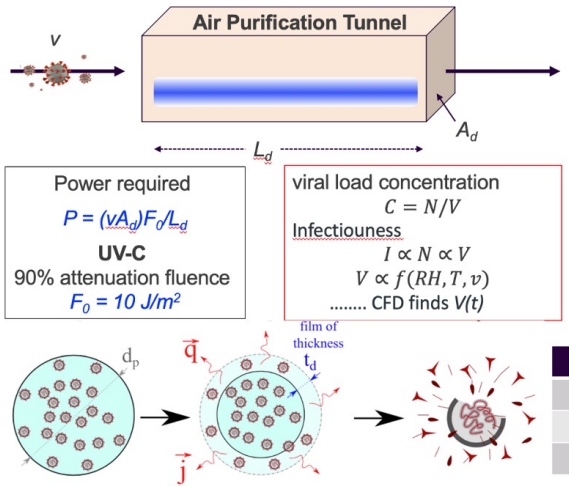
ELSEVIER

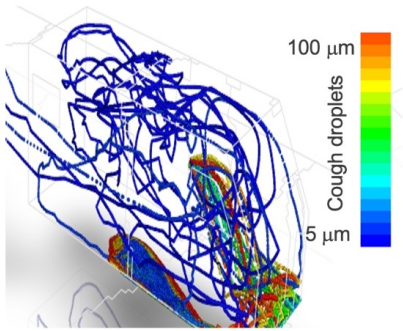
Computers & Fluids
Volume 275, 15 May 2024, 106242

Infectiousness model of expelled droplets exposed to ultraviolet germicidal irradiation coupled with evaporation

Mbolahasina Ralijaona [a], Emmanuel Igumbor [a], Muaaz Bhamjee [a 1], Kennedy Otwombe [b c], Firdaus Nabeemeeah [c], Minja Milovanovich [c], Neil Martinson [c], Pedro Mafa [d], Lerothodi Leeuw [e], Simon Connell [a]



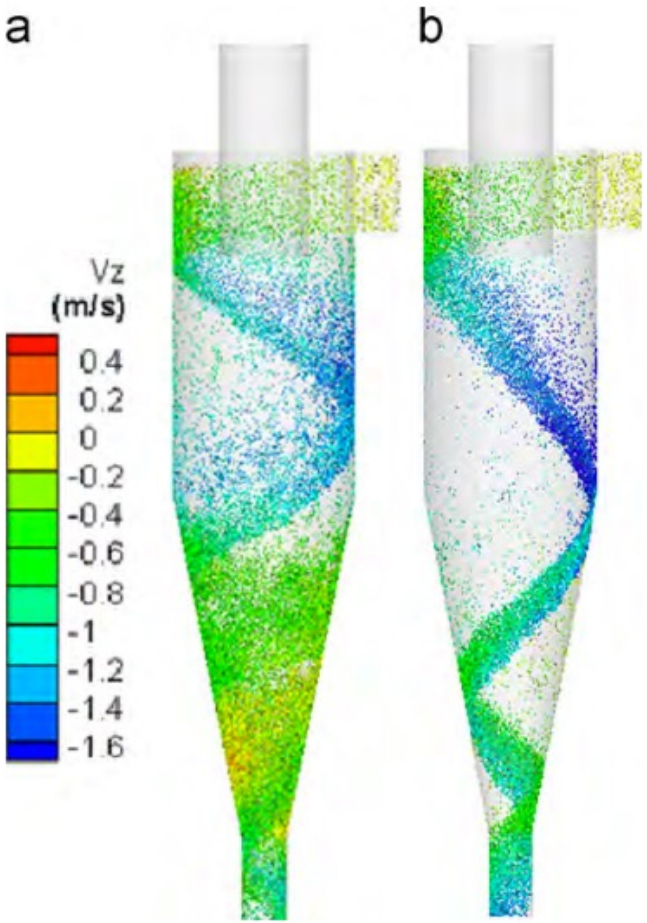




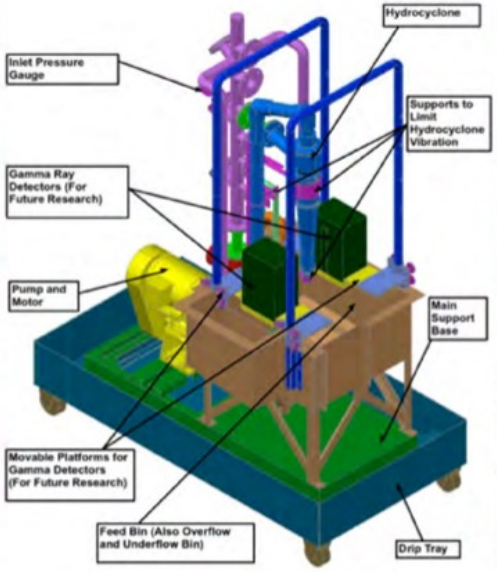
UV-C (nm)	Pathogen	F_0 (J/m²)
222	H1B1	15
254	MHV	6.6
254	RNA-DNA viruses	3 - 12

CFD 3 – Multotec – UJ and Hydrocyclones

CFD simulation of a hydrocyclone for mineral slurry separation
First CFD sim to attain the air-core
Benchmark CFD with PEPT → Rapid digital prototyping for design improvement



MULTOTEC



UNIVERSITY OF JOHANNESBURG

Applied Nuclear Science – Ubuntu for Reactors

Criticality, burn, decay, poisoning, etc

GEANT4 A SIMULATION TOOLKIT

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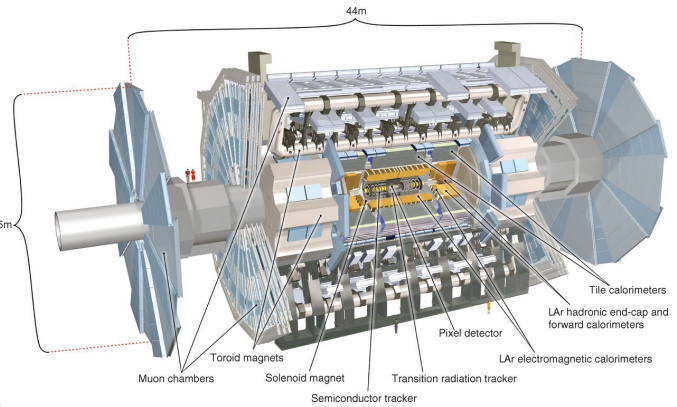

Towards a Monte Carlo simulation of a pebble bed type high temperature gas cooled reactor using Geant4

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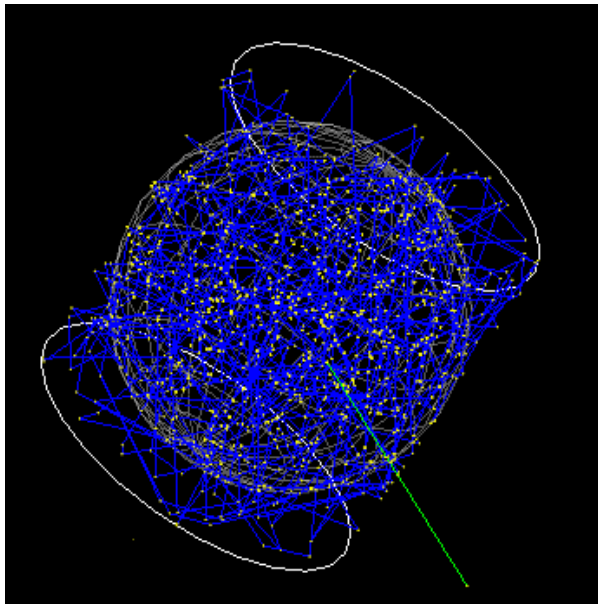

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ABSTRACT

This paper introduces the stochastic Monte Carlo (MC) modelling of a nuclear reactor core using the Geant4 framework. The simulation is exercised in the context of a High Temperature Gas Cooled Reactor (HTGCR) that uses helium (a noble gas) as a coolant and graphite as a neutron moderator. The study presents the results from the implementation of basic neutronics, scalability, geometrical discretisation for studying the spatial variation of physical parameters, time slicing and adaptation of Geant4 for correct intra-slice persistence, a scheme of integration with thermal hydraulics by workflow scheduling, validation of the thermal macroscopic cross-section behaviour, the process of fission, burn, decay, and differential energy depositions for the various physics processes, validation of the Xenon effects on the neutronics, criticality and core follow over multiple time steps.

Future Plans

Analysis

1. Continue with current analysis in the short term
2. **Major review**: Loan Truong to visit BNL to study the future direction with Ketevi and other colleagues
3. Mpho Gololo to initiate analysis in BSM physics with a new student
4. Excellence and calibre outputs

Innovation

1. MinPET, MediPET, PolyPET, PEPT
2. FOS + AI in Energy Sector – Nuclear Power Reactors (Necsa and ESKOM)
3. FOS + AI Water Sector (FibreSight and State)
4. FOS + AI in Food Sector (FibreSight and CEI collaboration)
5. AI in Medicine – 6 current projects

Intellectual Property

1. Knowledge Transfer + Ideation
2. Inteum Disclosures (5 new possible patents disclosed: several preparing filing)
3. Patents (Chronicle of 11 Patents on file and in grant)

Training

1. Academic excellence
2. Entrepreneurialism
3. Business development

Commercialisation

1. Spin-outs, SMEs
2. Competitive Industry
3. Wealth generation