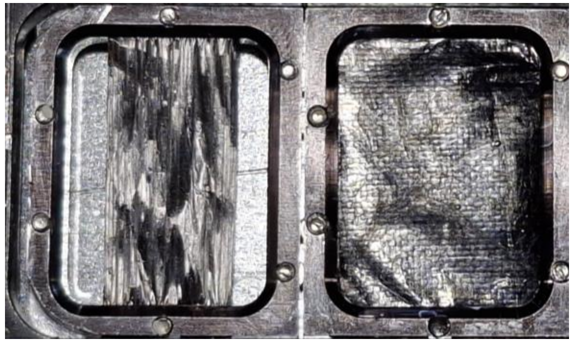
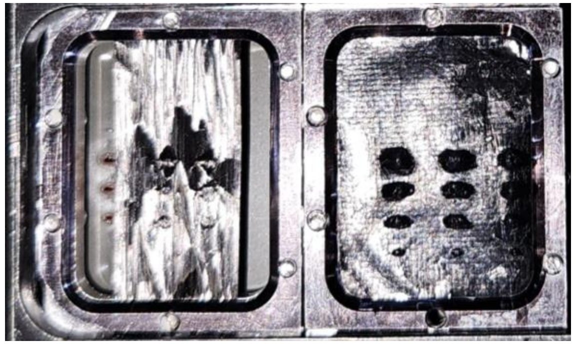
Evaluation of Novel Materials for Beam Diagnostics

- **In this PhD thesis:**
  - Test novel materials that can be used in beam profile monitors
  - Understand the limits of commonly used materials and investigate new possibilities
  - 440 GeV/c proton beam (delivered in ~8 μs)

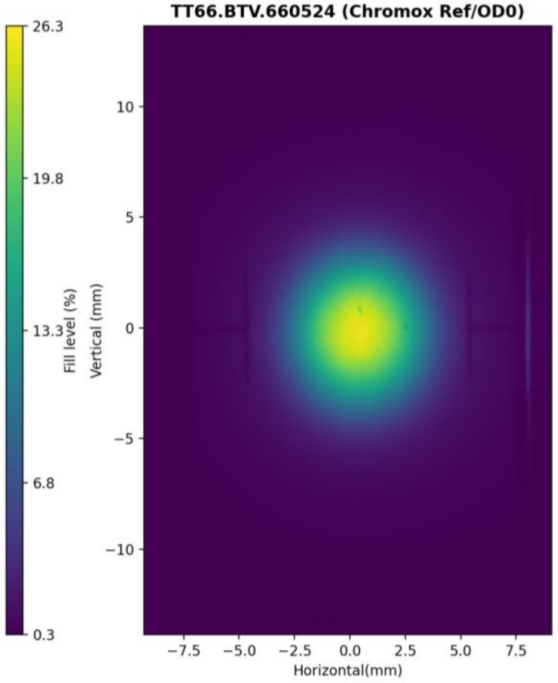


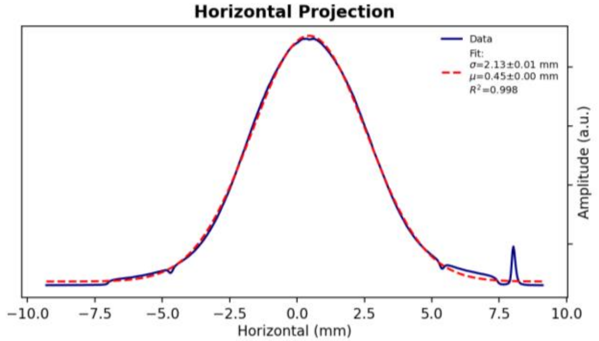
Pre-irradiation

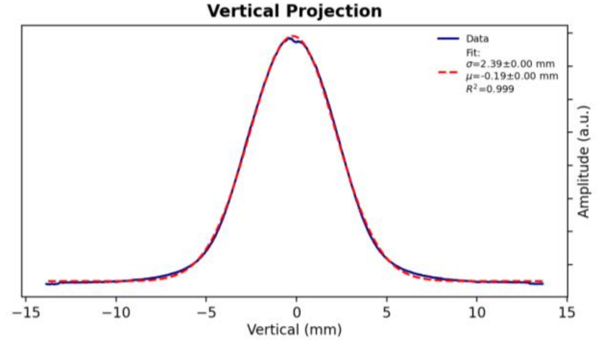


Post-irradiation

Beam profile Monitor





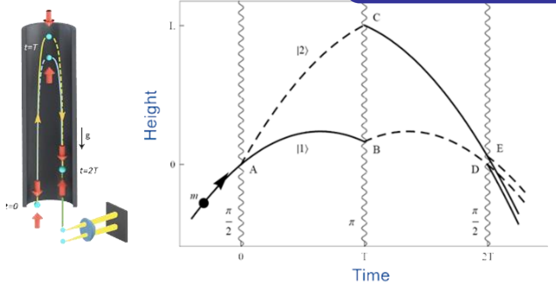


Atom Interferometry: The MAGIS and AION experiments

Chetan Parmar

Supervised by: **Dr Jonathan Tinsley**
Prof. Jonathon Coleman

MAGIS-100

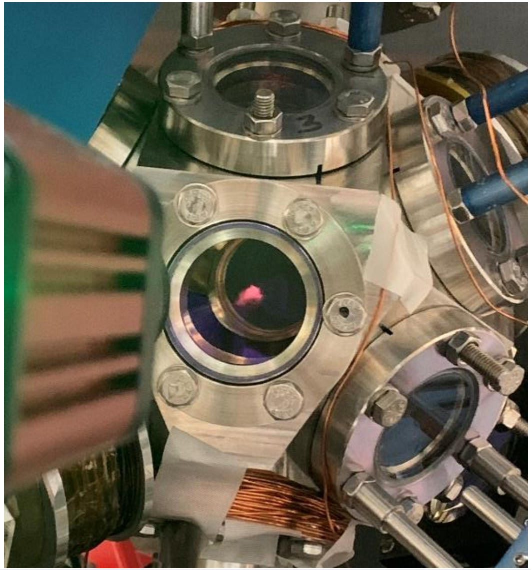


The MAGIS-100 detector will be a 100-meter baseline atom interferometer hosted at Fermilab (FNAL) in the USA.

- Proposed sensitivity to mid-band gravitational waves (30 mHz to 3 Hz) – not covered by laser interferometers
- Searches for Ultra-Light dark matter (ULDM), ‘fifth forces’.
- Tests of gravity, standard model, and quantum mechanics
- Longest vertical atom interferometer in the world

Current work

- Work on 1-meter interferometer at Liverpool (pictured), recent advancements include:
    - A working frequency chirping system to keep Raman laser beams on resonance as atoms fall
    - Various improvements to control code and DAQ: 5-fold increase in shot frequency
- Bayesian likelihood estimator & signal simulator for ULDM detection in MAGIS-100



Future work

- Vertical launching of atoms in the Liverpool interferometer
- Exploring space-based atom interferometry at RAL Space
- Commissioning of MAGIS-100 detector upon construction in 2027

UNIVERSITY OF LIVERPOOL MAGIS-100 LIV.INNO

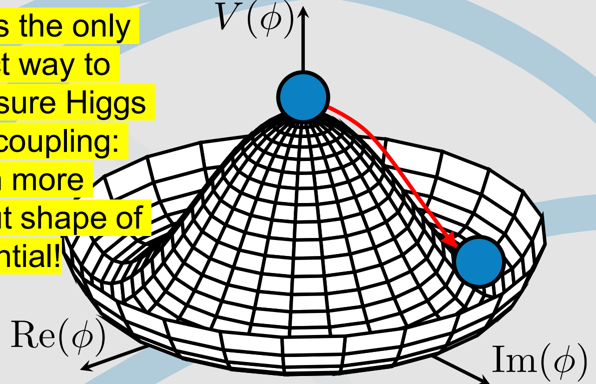
HH → bbττ at ATLAS and Validating New Tau ID Performance

Supervisors: Prof. Carl Gwilliam, Dr. Jordy Degens, Prof. Monica D'Onofrio

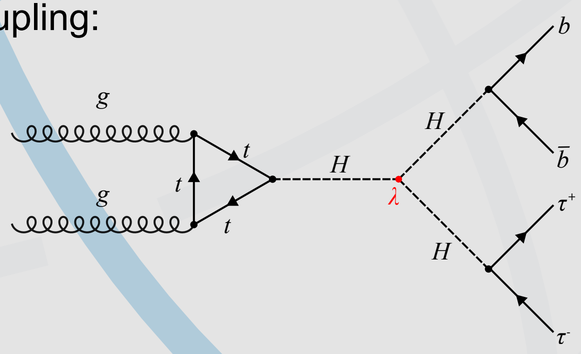
HH→bbττ Analysis *(PhD Topic)*

Study of *HH* is integral for learning more about important questions of origins of universe and its potential fate!

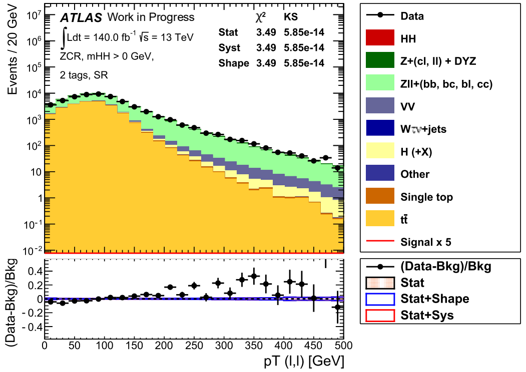
HH is the only direct way to measure Higgs self-coupling: learn more about shape of potential!



HH → bbττ is the most sensitive to the *HH* cross-section for measuring self-coupling:

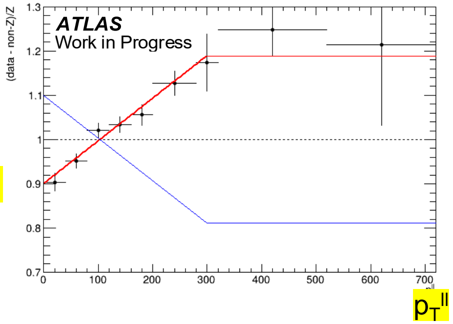


Z→ττ+bb is one of our major backgrounds but is not well modelled.



Use p_T^{ll} variable to reweight Z+HF background:

Data/MC matching improves when reweight is applied for most variables!



This work will go into a run-2 + partial run-3 paper aiming for late summer.

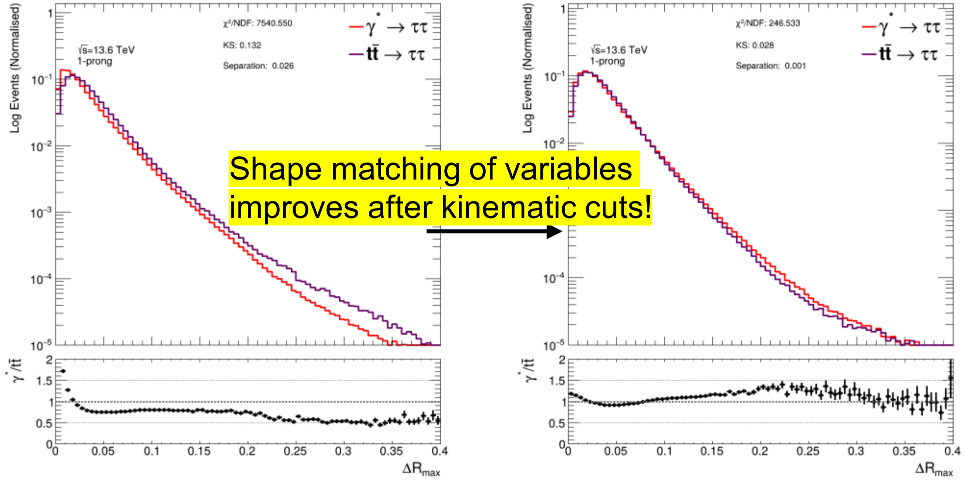
I will work on the full run-3 (332 fb^{-1}) analysis after. 😊

GNTau Performance Evaluation *(Qualification Project)*

- New Tau ID that uses graph neural network (GNN): currently only trained only on specific tau samples
- Investigating how this looks for other tau sample final states (such as those with b-jets like in bbττ) and various generator parameters

Done for:

- Informing which variables should/should not be used for training GNN
- Potentially develop MC Dependent calibrations/systematics



Shape matching of variables improves after kinematic cuts!

Maximum dR Between Associated Track and Tau Axis

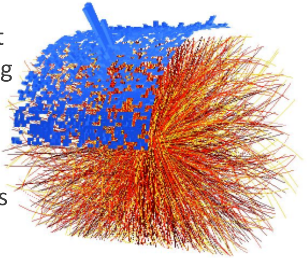
Lennox Wood **University of Liverpool Annual HEP Meeting 2026** **21st May**

Mastering jet reconstruction in heavy-ion collisions

Nicola Wilson
Supervisors: Dr. Jaime Norman, Prof. Marielle Chartier, Prof. Peter Jacobs, Dr. Alexander Schmah

UNIVERSITY OF LIVERPOOL
GSI Helmholtzzentrum für Schwerionenforschung
ALICE

Problem

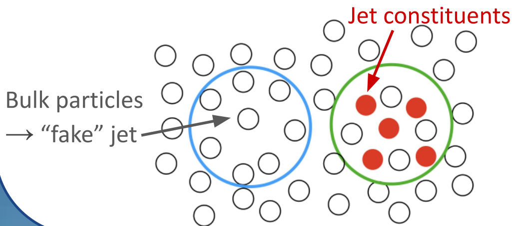


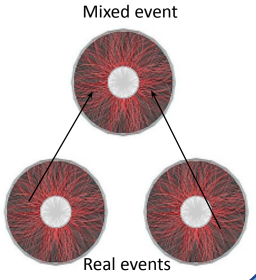
- **A L**arge **I**on **C**ollider **E**xperiment (**ALICE**) at LHC: designed to study strongly interacting matter and quark-gluon plasma (**QGP**)
- Medium-induced jet quenching effects used to constrain properties of the QGP
- Large uncorrelated background challenges jet reconstruction & smears true jet momentum

→ **Background correction methods needed!**

Solution: Novel Event Mixing

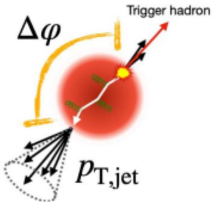
- Remove background in heavy-ion collisions statistically using **Mixed Events** (MEs)
- Create MEs such that all tracks are completely uncorrelated
  → Each track stems from a different real event (SE)
  → No true jets within MEs!

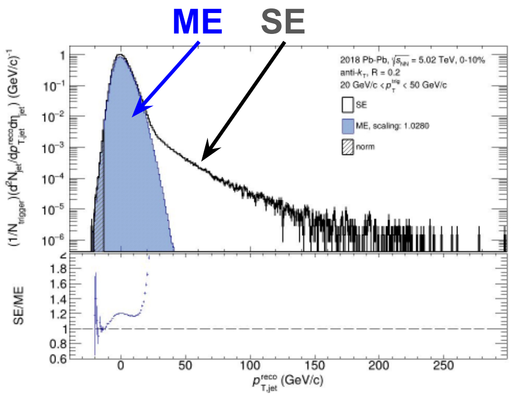


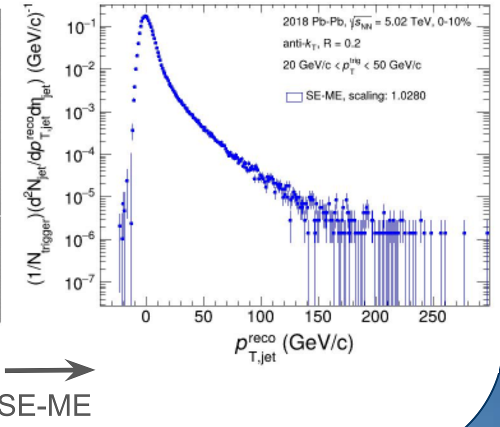


Jet Analysis

- Charged jets recoiling from high p_T trigger hadron (**h+jets**): Measure QGP-induced jet-energy loss and deflection
- Same analysis performed on SE and ME population
  → ME subtracted from SE to obtain signal distribution







Outlook

- Novel event mixing approach enables unique measurements of jet-medium interactions

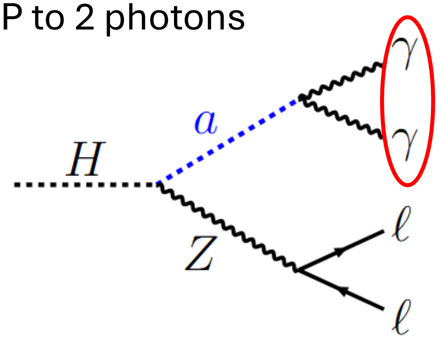
UNIVERSITY OF LIVERPOOL

Search for long-lived axion-like particles

Supervisors: Monica D'Onofrio, John Anders, Nikolaos Rompotis

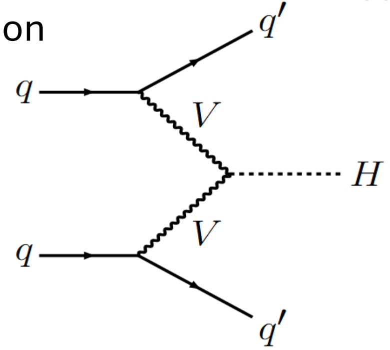
ATLAS EXPERIMENT

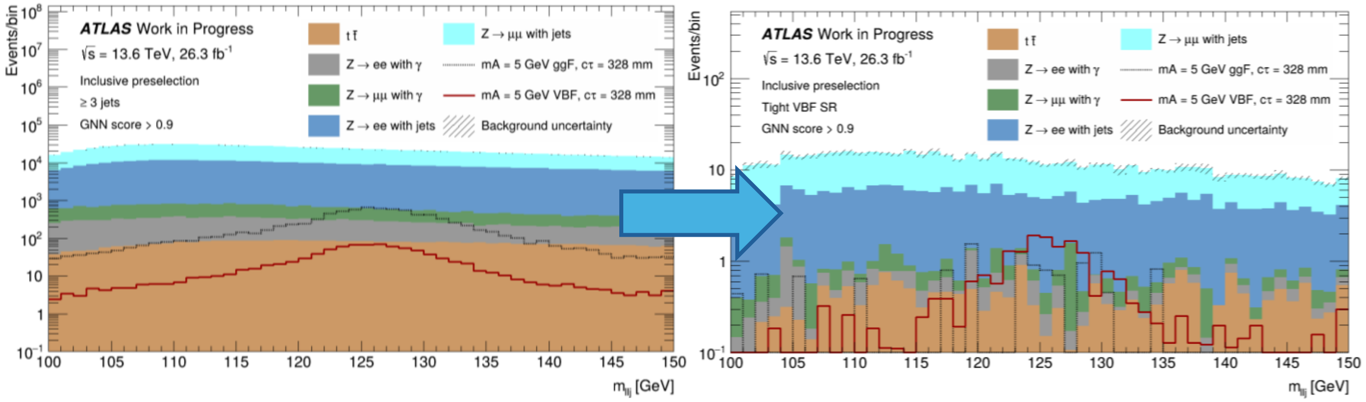
Looking for a **Higgs boson decaying to Z + a**, with the Z decaying to 2 leptons, and the ALP to 2 photons



Event Selection

Defining a **Signal region** for the **VBF** production of the Higgs boson





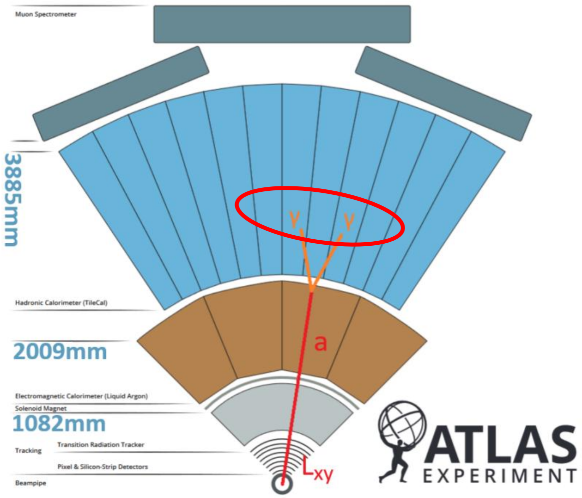
After preselection

After VBF Signal Region

(Simulated VBF signal shown in red)

There are many different motivations for BSM physics, and exotic Higgs decays is one of the most promising channels.

The **ALP will be long-lived**, so the **photons will be displaced** within the ATLAS detector – often in the hadronic calorimeter

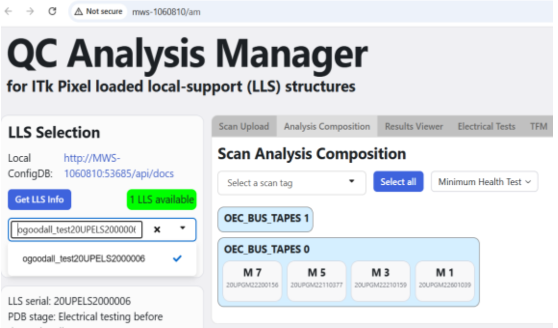


Future work

- Further optimising the VBF signal region definition
- Verifying the agreement between data and background simulations in control regions
- Performing significance calculations and cutflows for the group documentation

ATLAS Qualification Task

Creating a container and UI to implement quality control tests for modules used in the **ATLAS ITk upgrade**



mws-1060810/am

QC Analysis Manager

for ITk Pixel loaded local-support (LLS) structures

LLS Selection

Local ConfigDB: http://MWS-1060810:53685/api/docs

1 LLS available

ogoodall_test20UPELS200000

ogoodall_test20UPELS2000006

Scan Analysis Composition

Select a scan tag

Minimum Health Test

OEC_BUS_TAPES 1

OEC_BUS_TAPES 0

M 7	M 5	M 3	M 1
20UPGM22200156	20UPGM22110377	20UPGM22210159	20UPGM22601039

LLS serial: 20UPELS2000006
PDB stage: Electrical testing before

Oliver Goodall

Liverpool HEP Annual Meeting 2026

21/5/2026

Liquid Argon Detectors:
Optical Readout & Glass-THGEM Development

Heriques Frandini Gatti | Supervisor: Dr. Kostas Mavrokoridis.

Background

Academic Background:

- Bachelor's Degree in Science and Technology - UFABC
- Bachelor's Degree in Physics - UFABC
- Master's Degree in Physics - UNIFAL

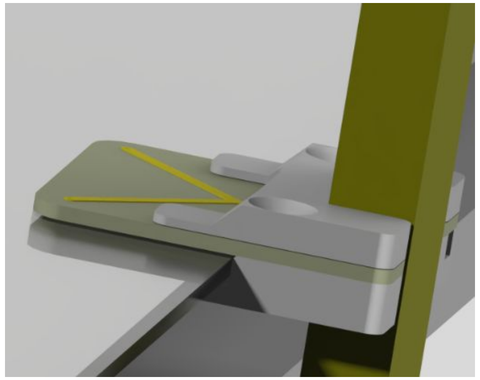
Experience:

- Cryogenics and Vacuum designs and applications
- Scientific Applied Instrumentation
- Photon Detection System in TPCs

Current Work

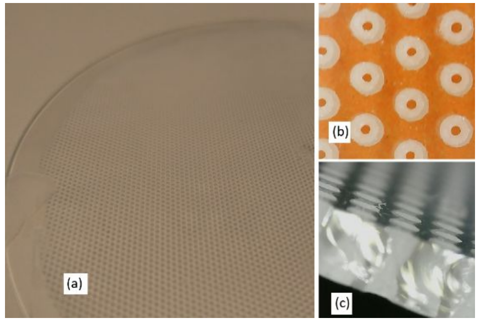
ARIADNE Upgrades:

- Novel cryogenic piston pump.
- THGEM new connectors.
- Capacitive level meters.



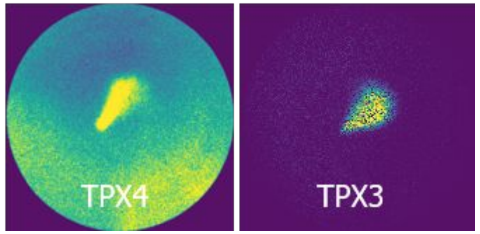
Glass-THGEM Facility:

- Photolithography work space.
- Micro-sandblasting protocols.



Timepix4 Sensor Evaluation:

- Integrated Timepix4 into the demonstrator to leverage its timing and space resolution.



Future Work

Data Analysis:

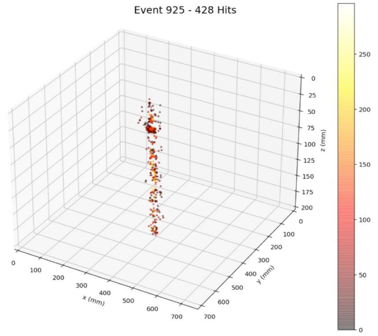
- Finalize comparative performance data analysis between Timepix4 and Timepix3 camera runs.

Prototype Characterization:

- Initiate comprehensive gain testing, stability tracking, and discharge mapping on home fabricated Glass-THGEMs.

Continue Upgrades :

- Keep the hardware upgrades on ARIADNE detector.



Muon Capture at the Mu2e Experiment

Sean Isaac

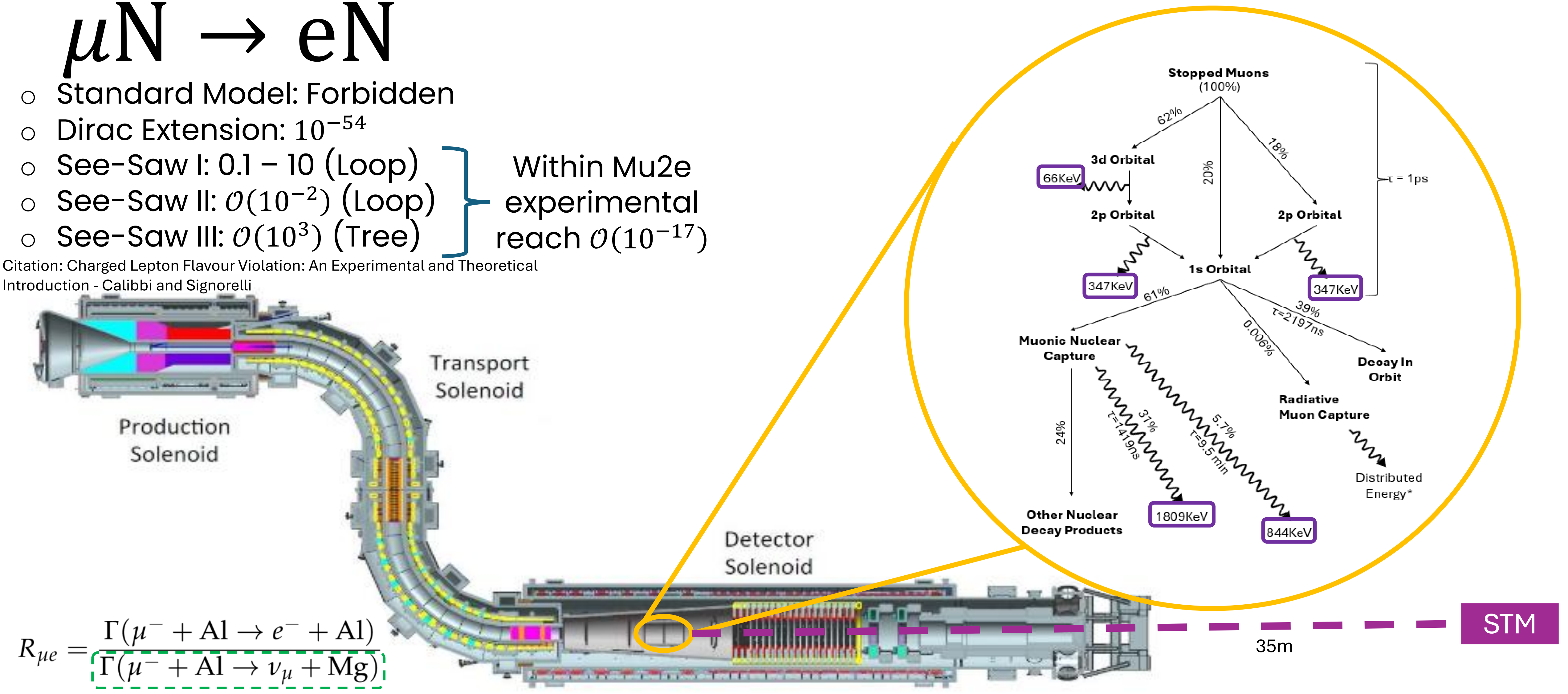
Supervisor: Joe Price

$$\mu N \rightarrow eN$$

- Standard Model: Forbidden
- Dirac Extension: 10^{-54}
- See-Saw I: 0.1 – 10 (Loop)
- See-Saw II: $\mathcal{O}(10^{-2})$ (Loop)
- See-Saw III: $\mathcal{O}(10^{3})$ (Tree)

Within Mu2e experimental reach $\mathcal{O}(10^{-17})$

Citation: Charged Lepton Flavour Violation: An Experimental and Theoretical Introduction - Calibbi and Signorelli



$$R_{\mu e} = \frac{\Gamma(\mu^- + \mathrm{Al} \rightarrow e^- + \mathrm{Al})}{\boxed{\Gamma(\mu^- + \mathrm{Al} \rightarrow \nu_\mu + \mathrm{Mg})}}$$

Rate of Muon Capture

Aluminium Target

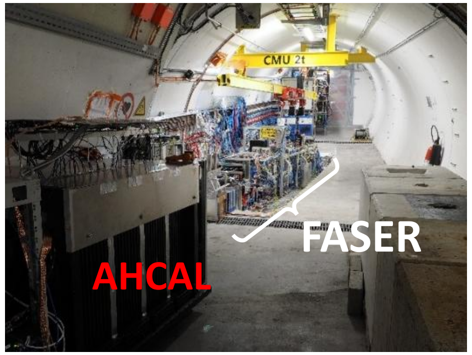
Mu2e Image credit: https://users.hep.manchester.ac.uk/u/markl/muons/mu2e/index.shtml

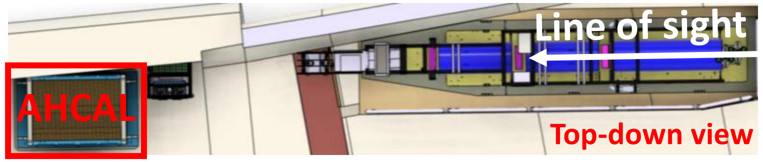
Run 4 FASER Upgrade and LHCb Scintillating Fibre Tracker

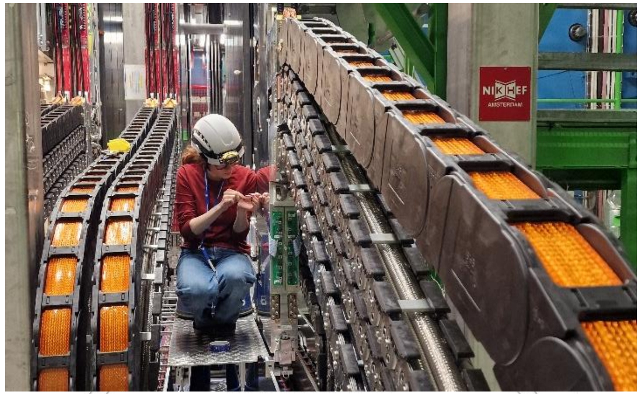
- Annabelle Marie Parry (CERN doctoral student).
- Supervisors: Dr Sune Jakobsen (CERN), Prof Monica D'Onofrio (Liverpool), and Dr Karol Hennessy (Liverpool).

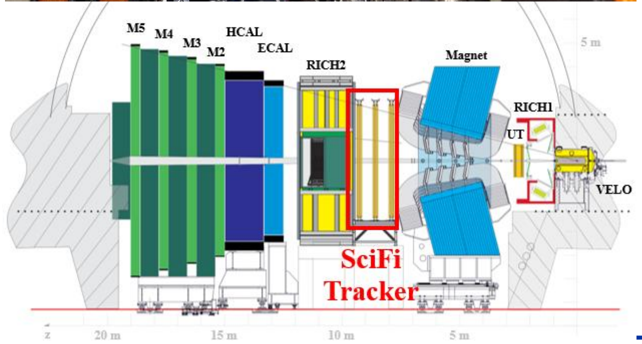
Work with FASER:

- The focus is on a foreseen upgrade during LS3 with a new subdetector.
  - Two prototype calorimeters were installed during the 2025/26 YETS to test a proposal for an off-axis electronic neutrino detector.
  - Currently working the prototype veto scintillators and low voltage for one of the prototypes: the Analogue Hadronic Calorimeter (AHCAL).









Work with LHCb Scintillator Fibre Tracker (SciFi):

- SciFi is the downstream tracker of LHCb.
  - Provides high precision tracking and momentum measurements as part of the tracking system of LHCb for b-physics studies.
  - Has several key services to enable the detector to take data.
    - SiPM cooling, Dry gas, Vacuum, Condensation Prevention system, front end electronics cooling.
- The focus is on the re-optimisation of the services for changes in detector conditions for Run 4 to compensate for the increased luminosity.
- Also currently working on scintillating fibre R&D.

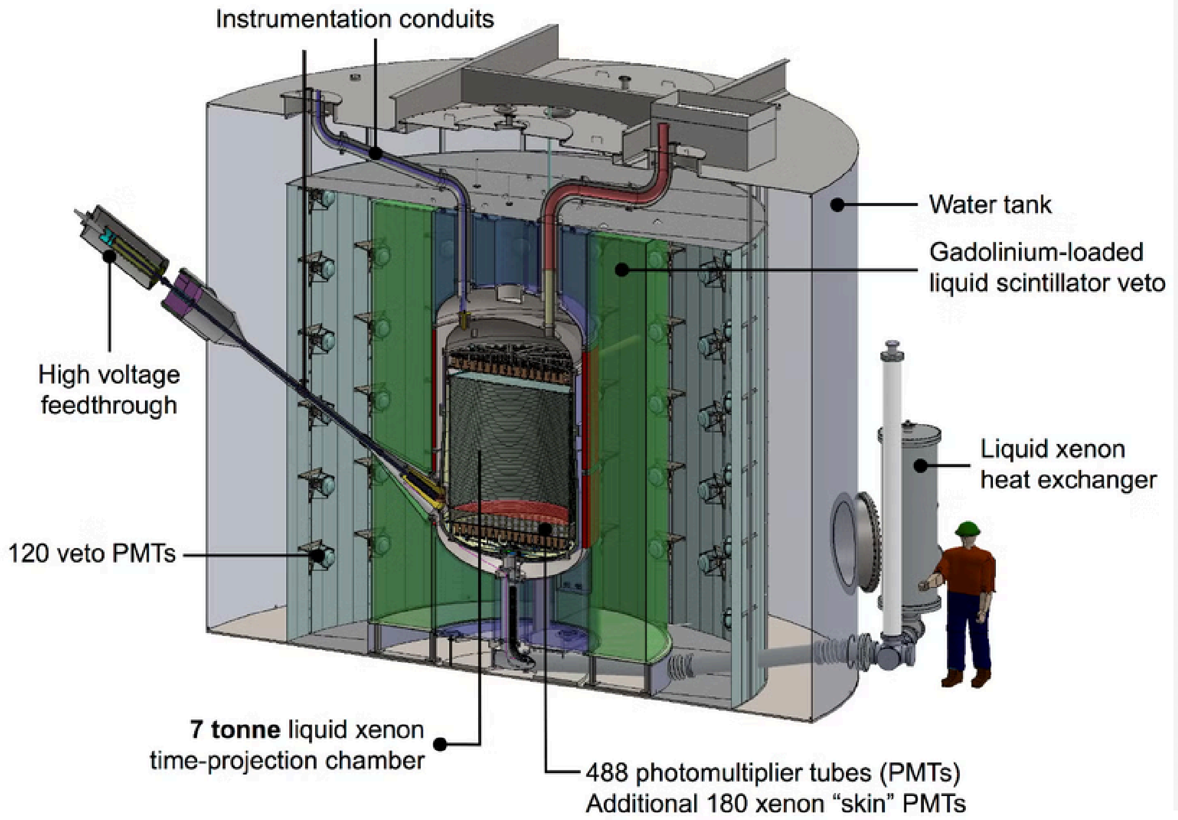
LZ and XLZD | Dark Matter Direct Detection

The LZ Experiment

Dual phase liquid Xe time projection chamber (TPC) for dark matter direct detection searches.

Recent Results:

- 4.5 σ significance on coherent elastic neutrino-nucleus scattering (CEvNS) from B^8 solar neutrinos. (Dec 2025)
- Spin-independent cosmic ray-boosted dark matter (CRDM) - nucleon cross section constrained to $3.9 \times 10^{-33} cm^2$ at 90% confidence level for sub-GeV/c^2 masses. (May 2026)

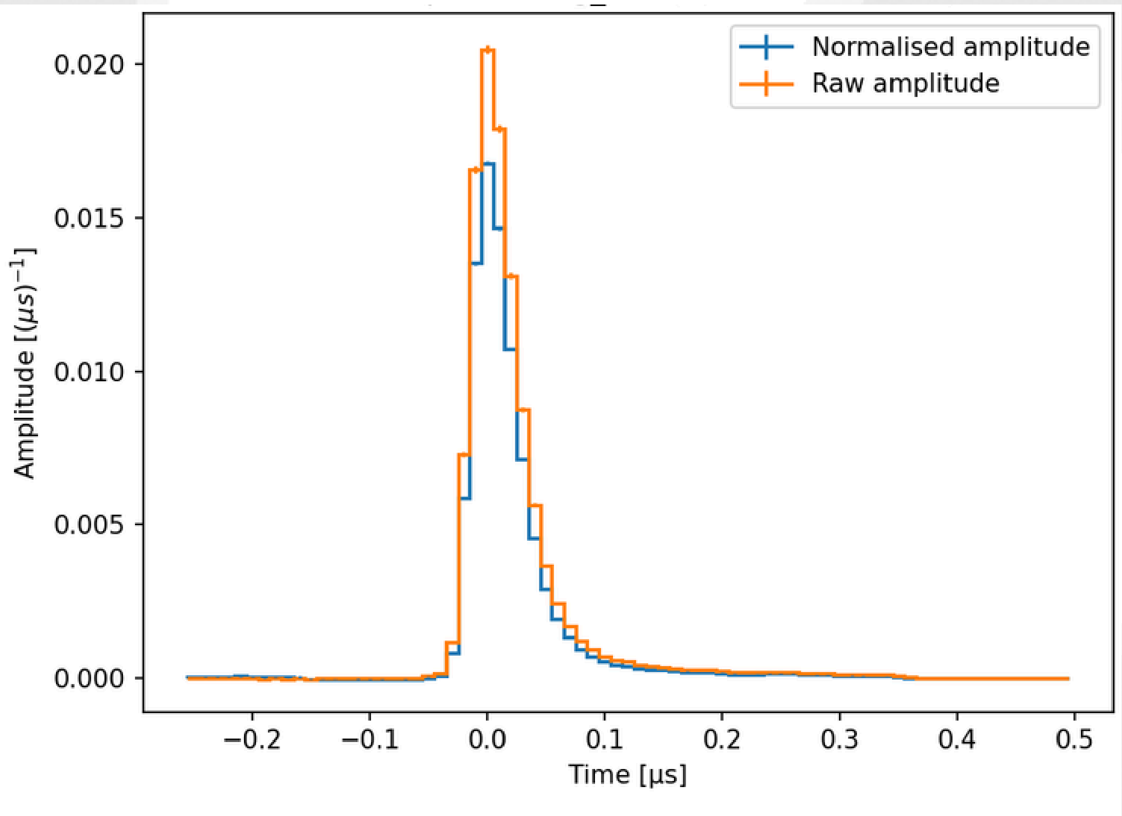


Single Photon Template

Aim: Creation and verification of photon template for photon counting.

Motivation: Improving energy resolution in OD and TPC

Waveforms aligned using iterative fast Fourier transforms.



Currently comparing simulated and WIMP search data templates to validate LZs simulated detector response.

Future aim: To verify simulated single photon template and to use neural network ML to count single photons in data.

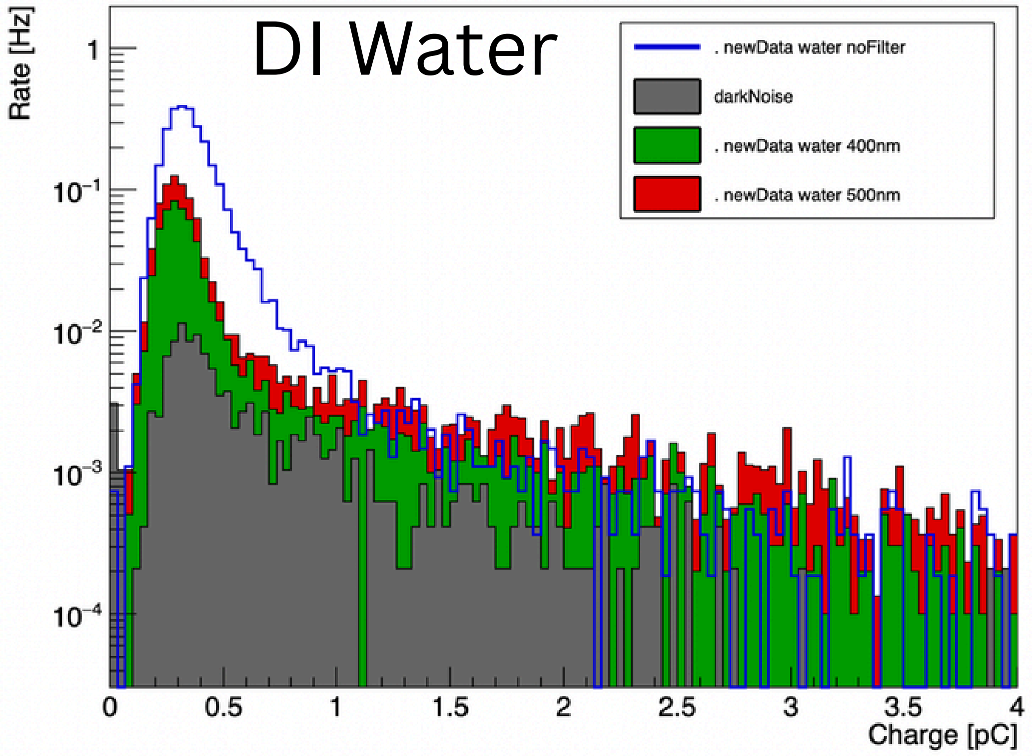
XLZD Testbench

Liverpool XLZD group uses a AmBe neutron source to investigate different media for use in XLZD's outer detector (OD).

Recent test: The addition of 4-Methylumbelliferone (4-MU) to a Gd-water OD.

Motivation: Enhance the light yield of Gd-water by shifting the Cherenkov photons wavelength to the visible spectrum.

My contribution: Calculating charge and rate from waveforms and verifying the total rate overtime of various data sets, ensuring data quality.



Bethan Twigg

Supervisors: Sergey Burdin, Ewan Fraser & Sean Hughes

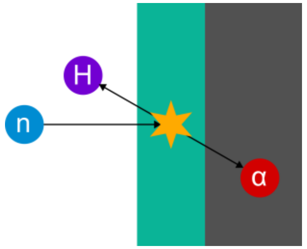
Optimising Silicon Detectors for Thermal Neutron Detection with ^{6}Li

Brandon Crowley

Supervisors: Dr. Jon Taylor, Prof. Sergey Burdin

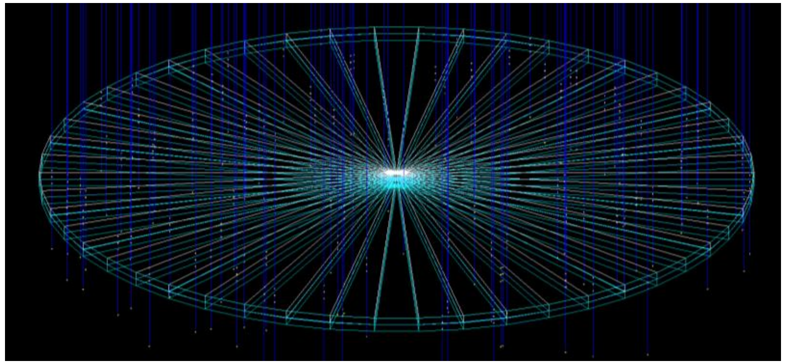
Overview:

- Thermal neutron detection with silicon, using a ^{6}Li converter
- Reaction: $^6\mathrm{Li} + n \rightarrow \alpha + {}^3\mathrm{H}$. Ions detected by silicon; exploit this to detect neutrons
- Detector must be optimised to maximise its efficiency



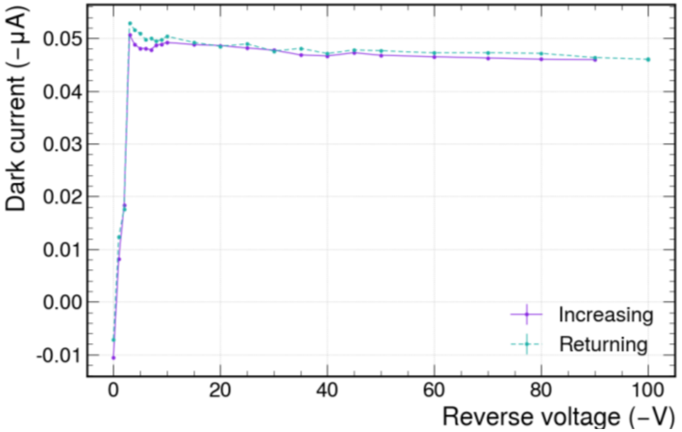
Simulating detectors in Geant4:

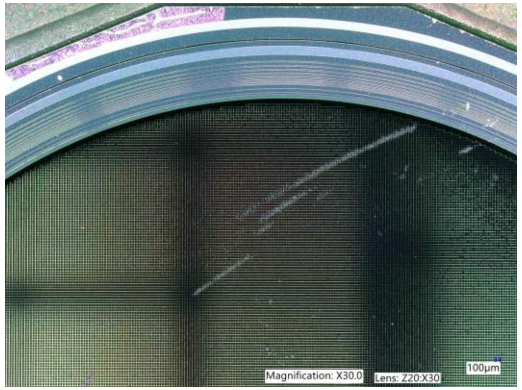
- Fire neutrons at coated silicon
- Use simulations to optimise the detector geometry, and test segmented geometries



Testing detectors in the lab:

- I-V characteristics
- Radiation testing/calibration
- Coating diodes and testing them with neutrons



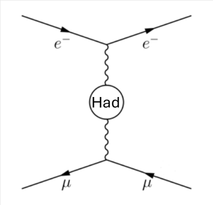


Beam Energy Measurement at the MUonE experiment

Tom Lenane | University of Liverpool

MUonE Goal:

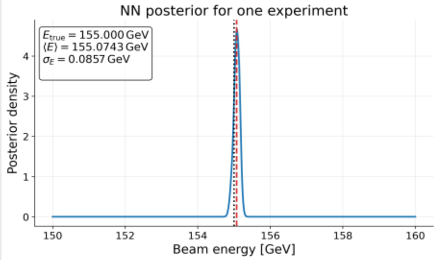
- Measure HVP contribution to a_μ.
- Aims to resolve tension between theoretical values of muon g-2.
- Uses elastic scattering of 160GeV muons off atomic electrons.

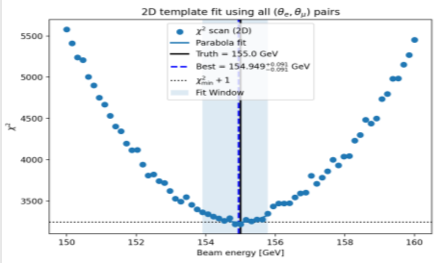


Beam Energy Measurement:

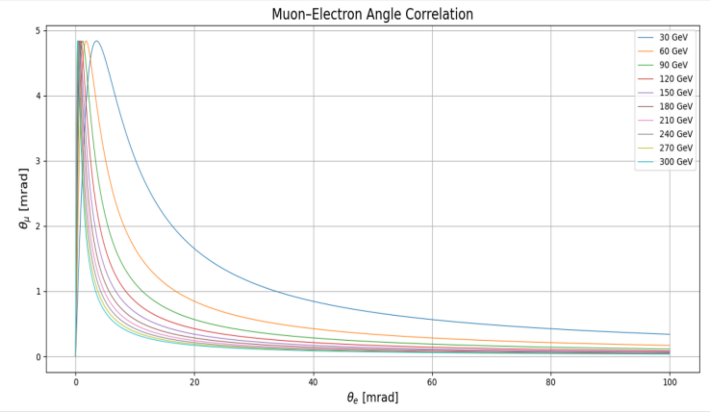
- Target precision: ~5MeV.
- Built toy MC to study beam energy reconstruction.
- Using template fits and developing a NN method.
- Also applying methods to real data with elastic event selection cuts.

Beam energy extraction

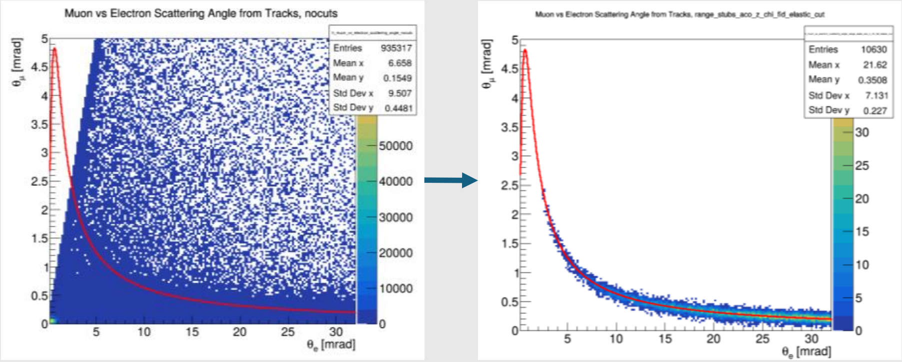

NN posterior for one experiment


2D template fit using all (θ_e, θ_μ) pairs

Kinematic Energy Dependence


Muon-Electron Angle Correlation

Elastic Event Selection


Muon vs Electron Scattering Angle from Tracks, nocuts

Muon vs Electron Scattering Angle from Tracks, range_stubs_aco_z_chi_fid_elastic_cut

Future Work

- Improve NN precision.
- Add more realistic beam profile into toy MC.
- Investigate new methods.
- Luminosity study.

GENIE’s Hadronization Model Comparisons to HERMES Data

Qianying Yu Supervisors: Prof. Costas Andreopoulos, Dr. Marco Roda, Dr. Julia Tene Vidal

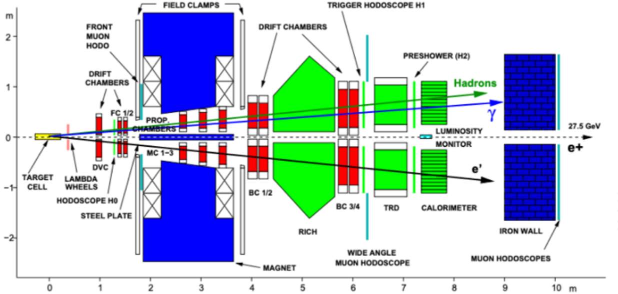
UNIVERSITY OF
LIVERPOOL

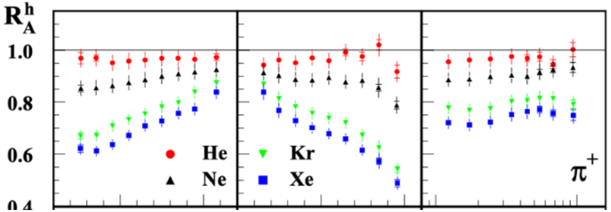
GENIE

A Monte Carlo event generator for neutrino and lepton-nucleus interactions — the standard simulation tool for **T2K, NOvA, DUNE** and other major neutrino experiments.

HERMES Experiment

27.6 GeV e^+/e^- beam at DESY | SIDIS measurements on deuterium, helium, neon, krypton, and xenon targets data collected from 1997 - 2005

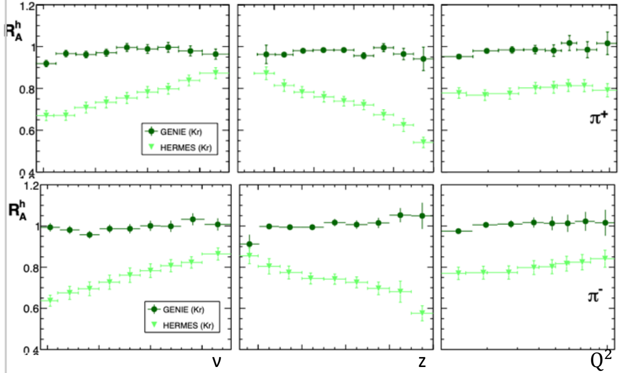




Hadronization in Nuclear Matter

After a quark is struck, it fragments into observable hadrons — this is **hadronization**. Inside a heavy nucleus, those hadrons can be **absorbed** before escaping — fewer hadrons come out compared to a simple deuterium target.

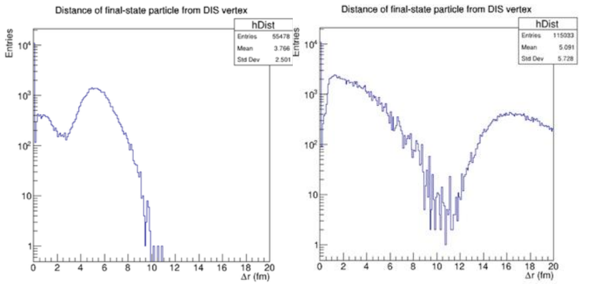
Current GENIE Comparisons to HERMES data



The GENIE results currently show a flat nuclear attenuation and not obvious kinematic dependence. R increases with ν (longer formation length → less absorption), decreases with z (more hadronic absorption), and rises weakly with Q^2 (partonic energy loss).

This Work

Comparing **GENIE** predictions for **hadron attenuation** in nuclear DIS to HERMES data, to quantify and understand the gap in GENIE’s nuclear model.



Both D and Kr show vertex distributions extending far beyond their respective nuclear radii, with the same average of ~5.3 vertices/event — confirming that the displaced vertices arise from Lund string fragmentation。

Goal

Key question: What are the time scales and mechanisms of hadronization inside nuclear matter?

Tune GENIE’s nuclear model to reproduce HERMES data across targets and hadron species — providing a validated model for current and future neutrino experiments.

Muon g-2 at J-PARC and MUonE

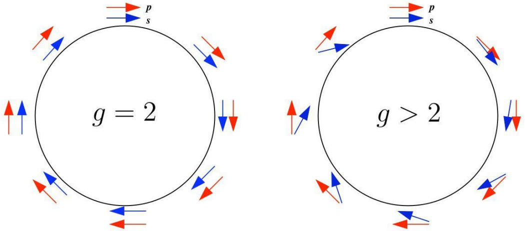
Shreya Pipraiya

Supervisors: Graziano Venanzoni, Jonathan Tinsley

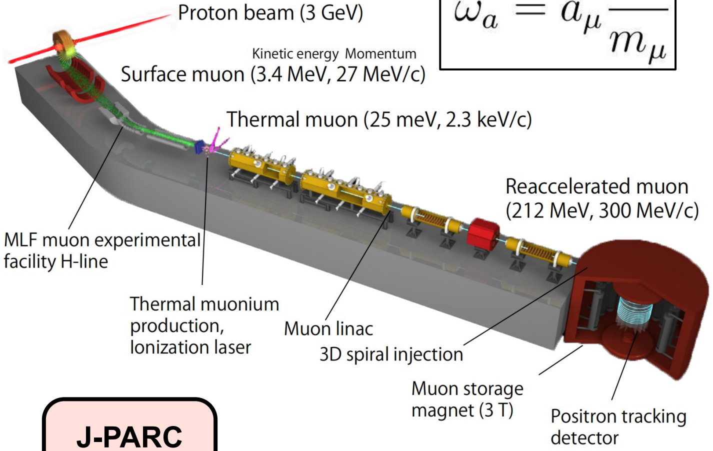
J-PARC facility uses a novel ultra-cold low emittance muon beamline to measure the g-2.

Store polarized μ⁺ in a ring with a uniform dipole magnetic field.

If $g_\mu \neq 2$, muon spin precesses around the direction of the magnetic field.



$$\boxed{\omega_a = a_\mu \frac{eB}{m_\mu}}$$

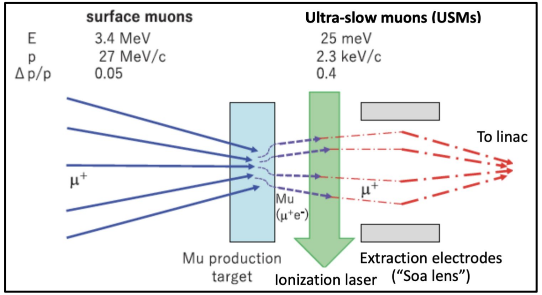


J-PARC

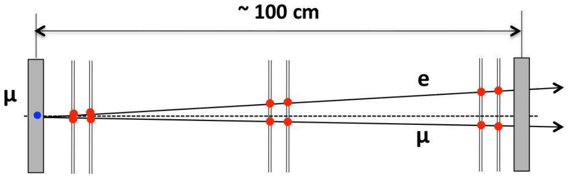
Muons are stopped in a silica aerogel target to form muonium atoms (μ⁺e⁻) with a lifetime ~2 μs lifetime.

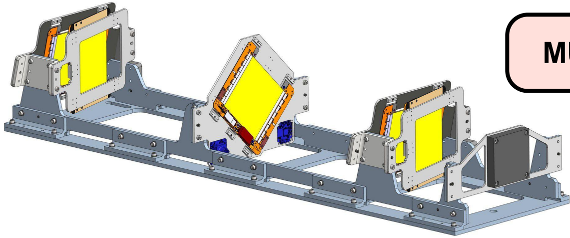
Lasers are then used to polarise and ionize the Muonium to separate the electrons from muonium to produce polarised ultra-slow (cold) muons.

This produces a well focused and non-dispersive beam which then goes to the LINAC.



$$\boxed{a_\mu^{\mathrm{SM}} = a_\mu^{\mathrm{QED}} + a_\mu^{\mathrm{EW}} + a_\mu^{\mathrm{HAD}}}$$





MUonE

Machine Learning Method in JUNO

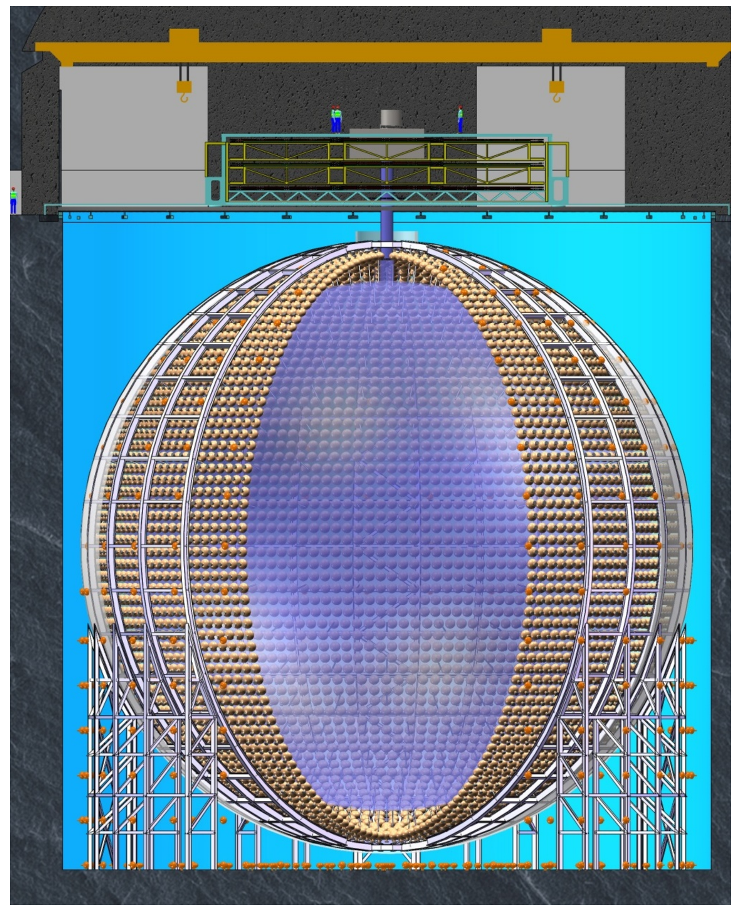
Atmospheric Neutrino Reconstruction

Zekun Yang | *Supervisors:* ***Prof. Costas Andreopoulos*** *& Prof. Xianguo Lu (University of Warwick)*

JUNO

The **J**iangmen **U**nderground **N**eutrino **O**bservatory is the largest liquid scintillator detector with 78% PMT coverage, aiming to:

- Determine the neutrino mass ordering (NMO);
- Improve the precision of neutrino oscillation parameters, etc.



Why Atmospheric Neutrino

Reactor neutrinos are the main sensitivity source of NMO via oscillation in vacuum while atmospheric neutrinos can provide sensitivity to NMO via oscillation with matter effect.

The measure of atmospheric neutrino oscillations has great potential to enhance JUNO's NMO sensitivity.

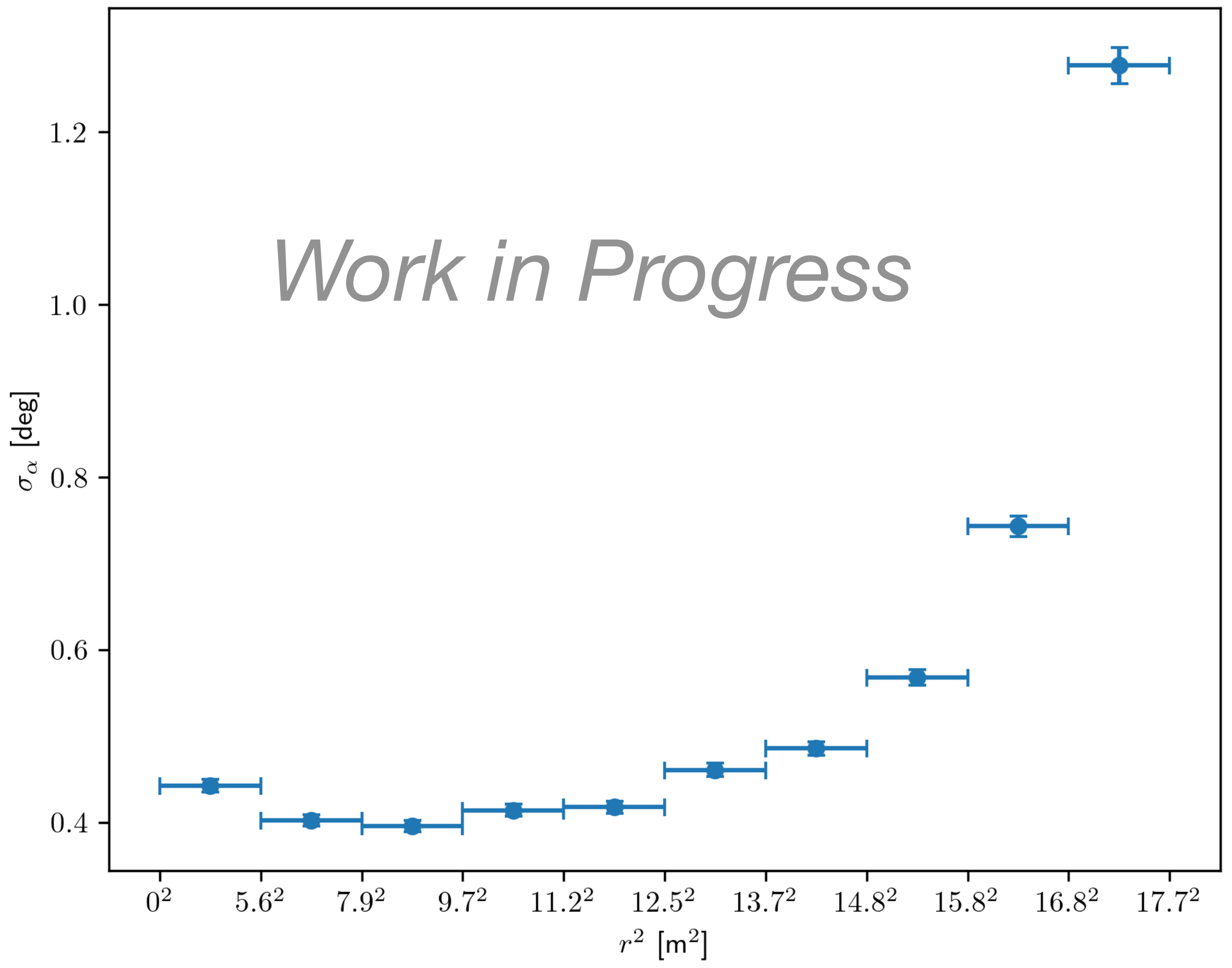
Current Work

Muon direction reconstruction：

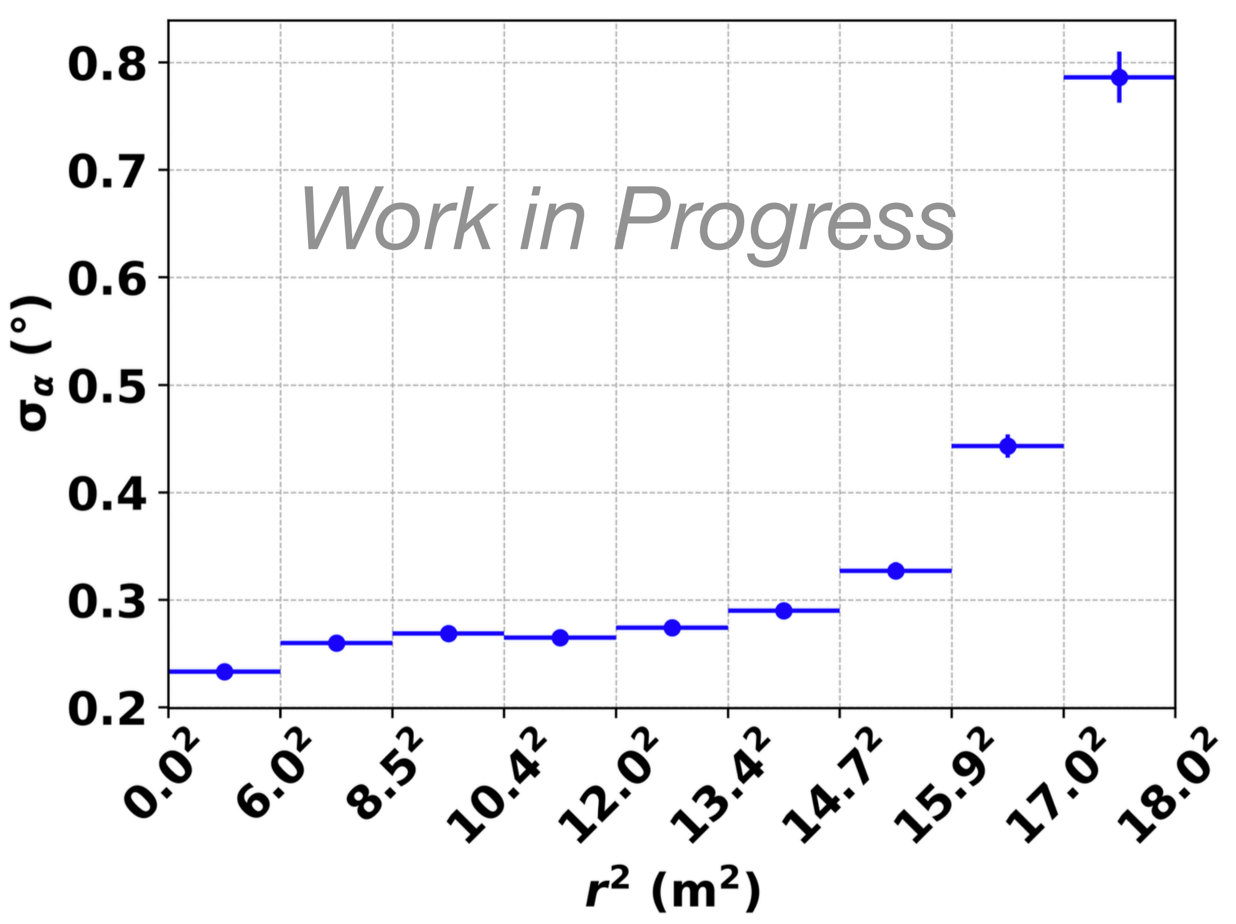
- Secondary leptons, like muons, carry the directional information θ of the incident neutrino. $P = f(L/E) = f(\theta/E)$

Sparse 3D Convolution:

- GPU-economic and fast;
- Showing great potential compared with other ML method.



Sparse 3D model



GNN model for reference