1^{st} Year student presentations

LUX-ZEPLIN Direct Dark Matter Detection

Tea Hall

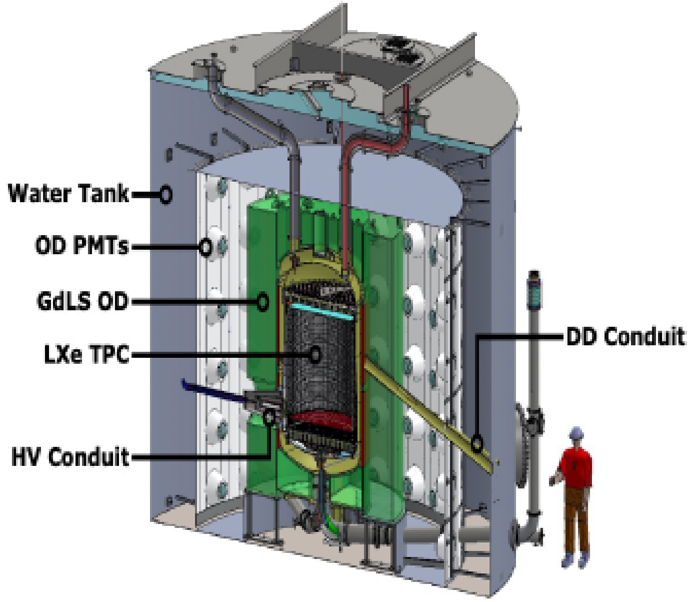
Supervised by Prof. Sergey Burdin & Dr. Ewan Fraser

Current Contributions:

- Developing position reconstruction for the GdLS Outer Detector (OD).
- SR3 neutron veto efficiency code consolidation.

Future Work:

- Continue developing OD position sensitivity (LRFs, MLP and CNNs).
- Neutron veto efficiency.
- LTA at SLAC (CA, USA), calibration campaign at SURF (SD, USA).



LZ Detector Schematic

Development of OD Position Reconstruction

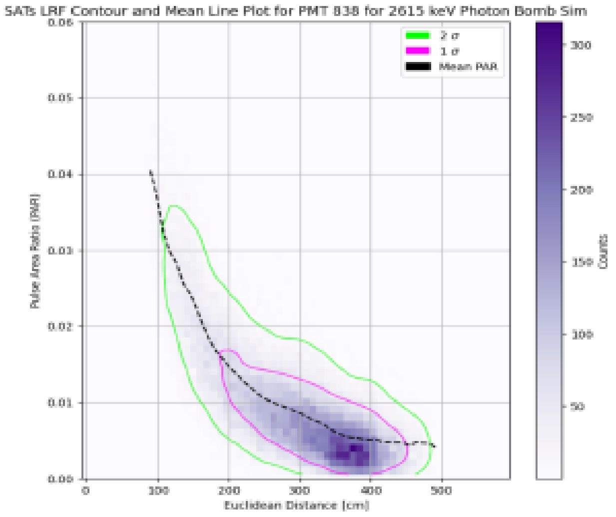
Motivation:

- Currently a CoG method is used, events are being mis-reconstructed outside of the OD.
- Equip the neutron veto with position sensitivity.
- Understand light collection efficiencies and energy resolutions in different OD regions.

I am investigating two methods, **light response functions (LRF)** and **machine learning (ML).**

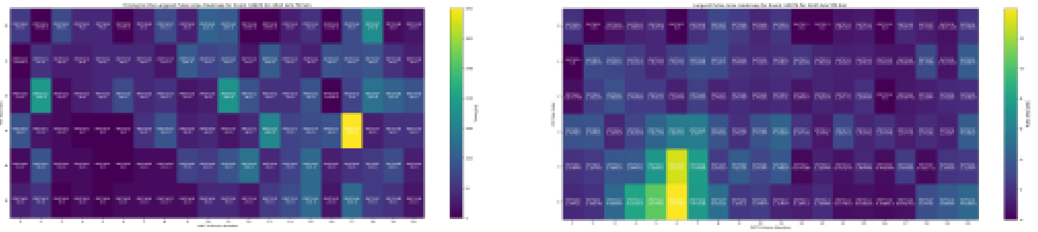
Light Response Functions

- An LRF defines a PMT's response to scintillation light, as a function of an event's distance from said PMT.
- TPC uses S2 light in LRFs for (X,Y) event position recon → I'm trying to replicate this approach for the OD.

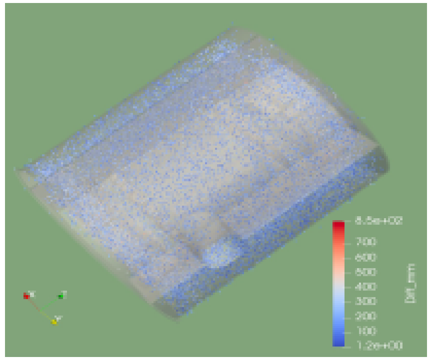


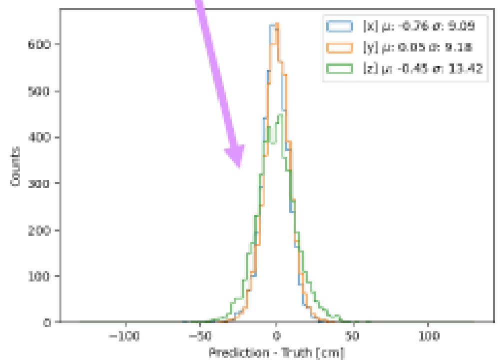
Machine Learning

- Multi-layer perceptron, trained on largest pulse areas per PMT and their timing values from 2615keV photon bomb simulations.



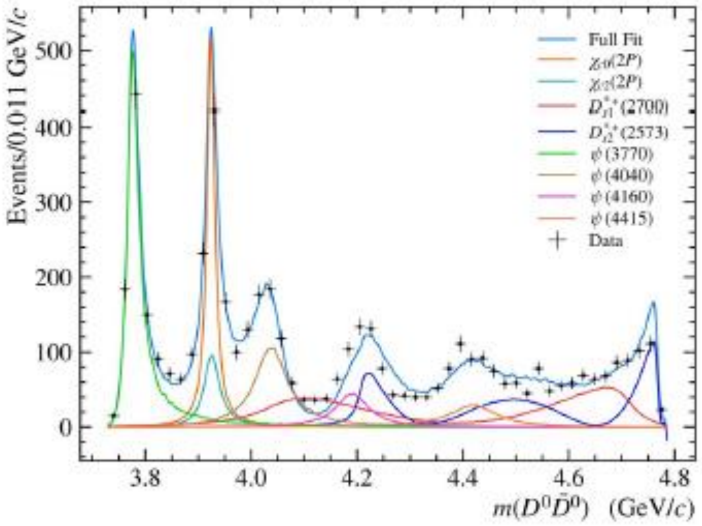
- MLP outputs 3 nodes: (X,Y,Z) positions.
- Model is used to predict the (X,Y,Z) positions of events within the OD, which is then used to obtain the (X,Y,Z) resolution.

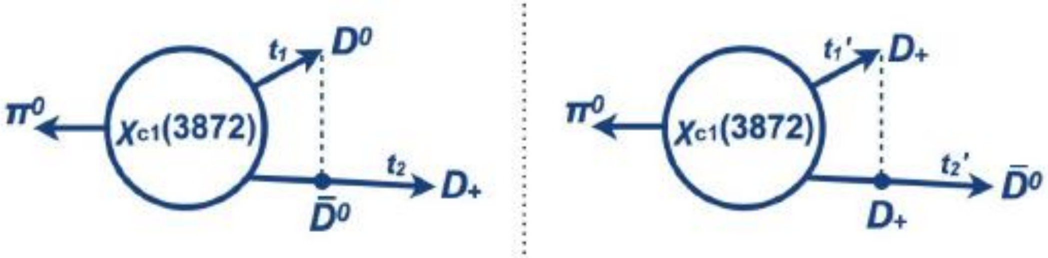




Coherent $D^0 \overline{D}^0$ Pairs at LHCb

- Work so far:
  - Monte-Carlo study on correlated charm in Dalitz plot analyses
  - Some resonances suppressed, other enhanced ⇒ Simplified amplitude model
- Plans for the future:
  - Separate out $C = +1$ correlated $D^0 \overline{D}^0$ from prompt charmonia decays
    - Instrumental in measuring T violation in the charm system
    - Additional input into D decay phases – major source of uncertainty in CKM angle γ





arXiv: 2102.07729

Tracking Performance and Searches for Hidden Sectors at FASER

Sinead Eley

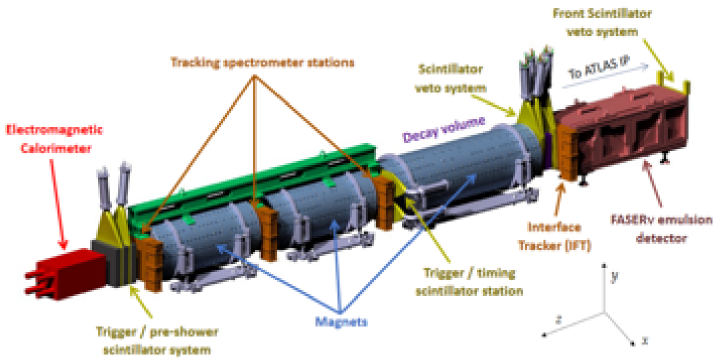
Supervisors: Dr. Carl Gwilliam & Prof. Monica D'Onofrio

UNIVERSITY OF LIVERPOOL

LIV.INNO

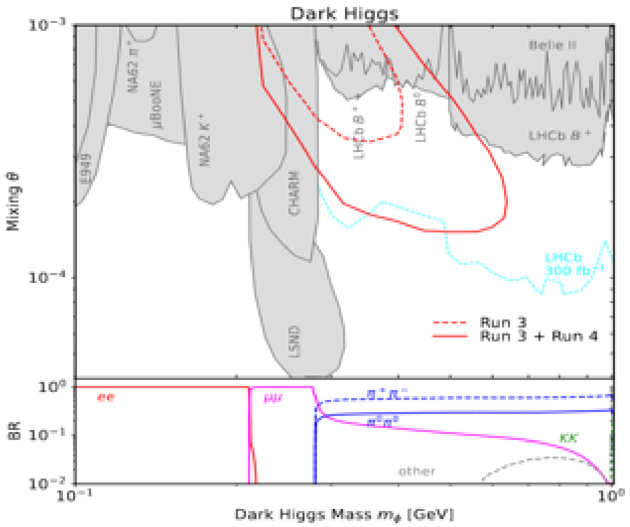
FASER

- ForwArd Search ExpeRiment (FASER)
- Located 480m far-forward from ATLAS interaction point (IP) @ LHC
- Purpose built detector searching for hidden sectors



Long Term

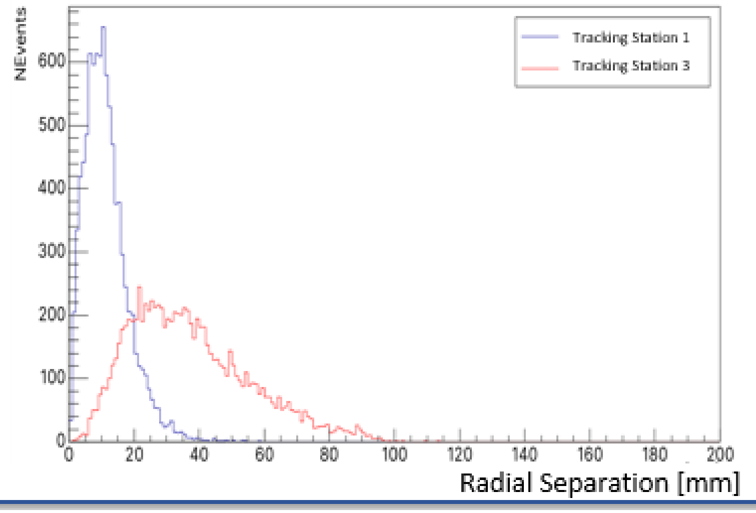
- Thesis on searches for dark photons and dark higgs boson
  - Utilise entire FASER run 3 dataset
  - Focusing on tracking

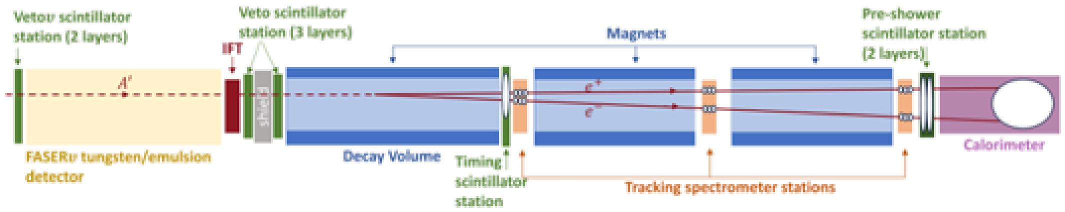


Current Work

- Dark Higgs and Dark Photon both decay to charged particles
  - Both rely on tracking close-by particles
- Initial work focuses on track performance
  - Currently working with Dark Photon (A') MC samples
- Operations:
  - Taking on shifts as a remote monitoring shifter

$A' \to e^+e^-\ m0.1\ \epsilon 1e^{-5}$:Radial Separation between e+ and e-

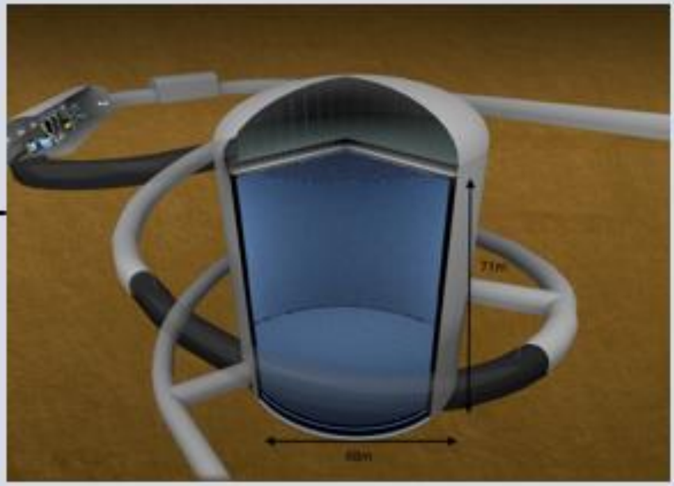




A' Decay Signature in FASER

Unik Limbu
Supervisors: Prof. Neil McCauley and Dr. Sam Jenkins

Project: Neutrino oscillation at T2K and Hyper Kamiokande and development of the Hyper Kamiokande light injection calibration system

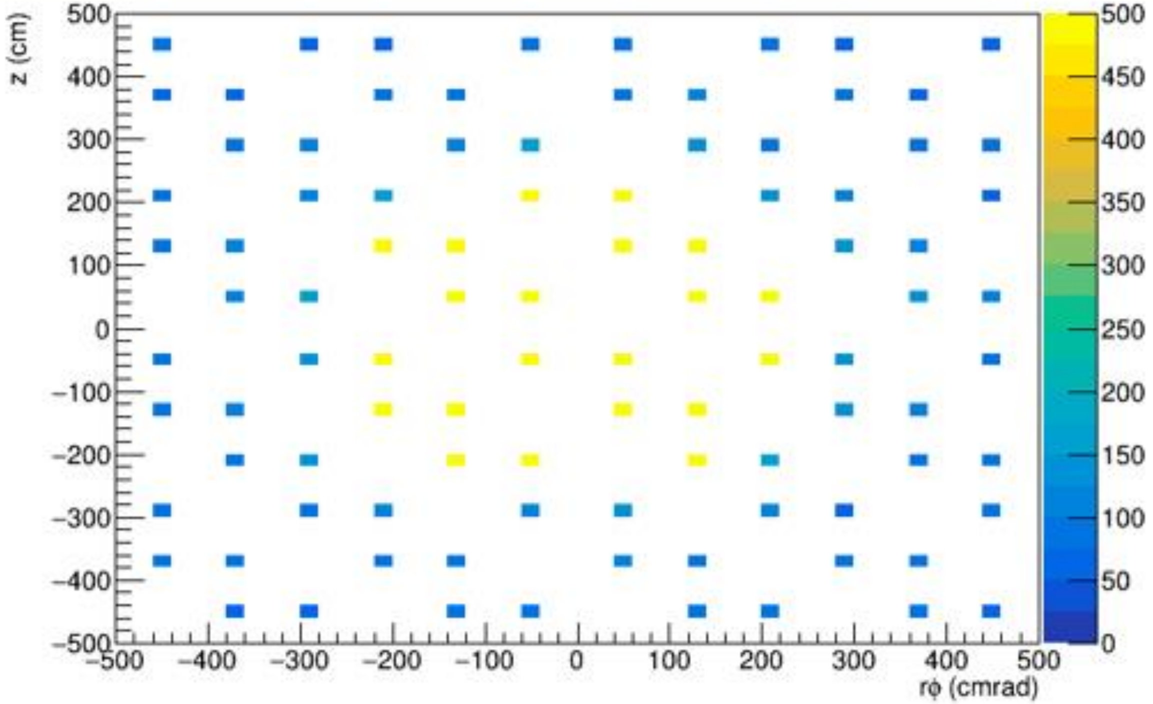


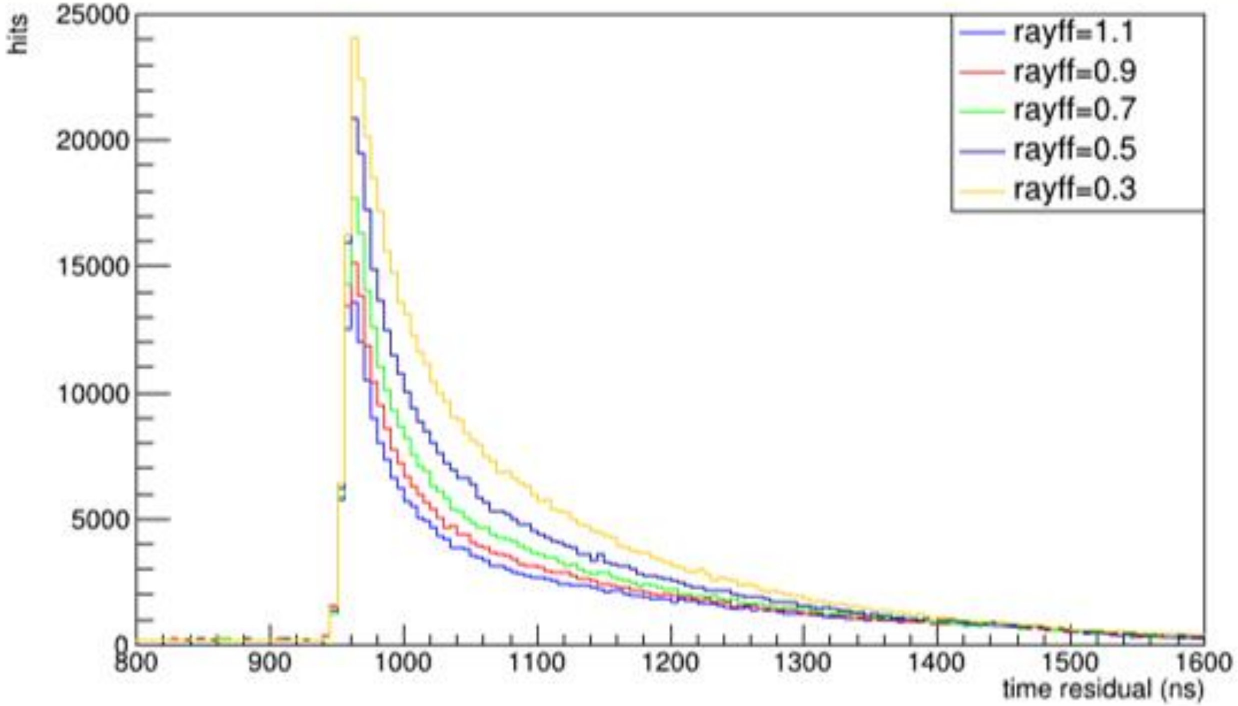
Current work:

- Light injection (LI) system for the Hyper-K detector
- Investigating for water parameters such as the Rayleigh scattering and absorption

Future work:

- LI board R&D
- Bottom-up analysis for detector systematics



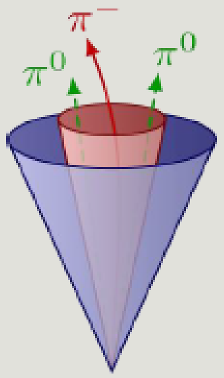


Leptoquarks and Tau Reconstruction

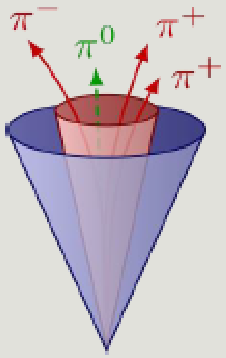
Supervisors: Prof Andrew Mehta (P), Prof Monica D'Onofrio (S) and Dr Nikolaos Rompotis

Task for ATLAS Authorship:

- Working on classification of Taus.
- Tau leptons decay hadronically (BR: 65%).
- Challenges due to secondary vertex and short lifetime in the Inner detector.
- Tau decays produce at least one neutrino.

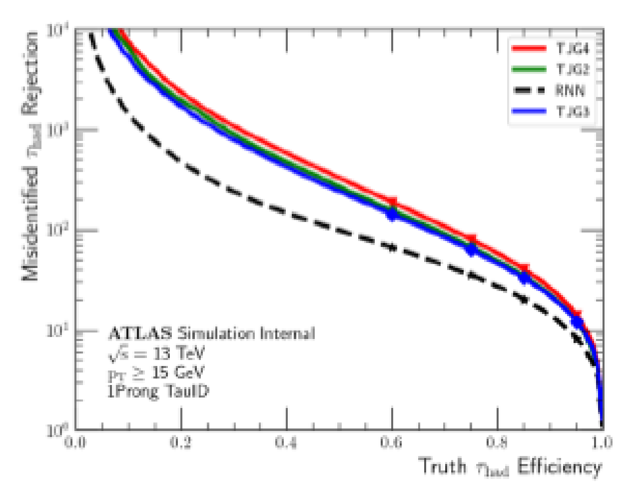


1-prong

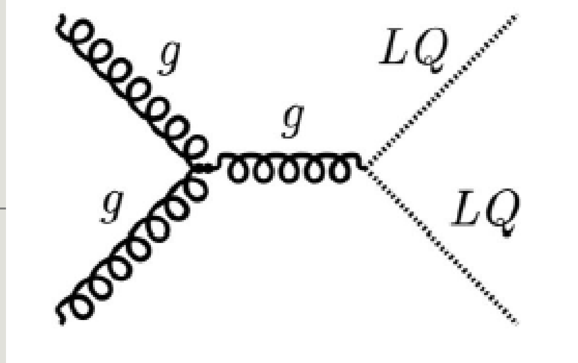


3-prong

- Liverpool group working on TauJetGraph, a Graph Neural Network (GNN) to supersede the current Recurrent Neural Network (RNN) and the DeepSet Neural Network (DSNN).
- Aim to combine Tau ID and Decay Mode Classification



Courtesy of Joe Carmignani



Source -arXiv:2010.02098

My work so far:

- Experimenting with the code and understanding application to physics analyses.
- Understanding the input variables for the training.
- Working on analysis of the discriminating power of isolation tracks.

Future work:

- Training and evaluating the performance of the TauJetGraph GNN and comparing to other models.
- Performing a validation on data once implemented in official software.
- Start the LQ analysis into pair produced LQ's in the bτ bτ, bτ bv and bv bv channel.
- Aim to extend current limits with more data, higher centre mass energy and better b-tagging and tau id performance.

Mehul Gunvant Depala

Quantum Computing for Neutrino Scattering

Marina Maneyro, Year 1 PhD student, University of Liverpool

Introduction

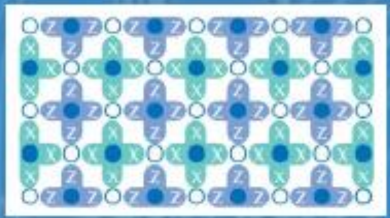
- BSc and MSc in Physics at the University of the Republic, Uruguay
- Dissertation Topic: QCD Phenomenology, Diffractive proton–proton scattering at the LHC

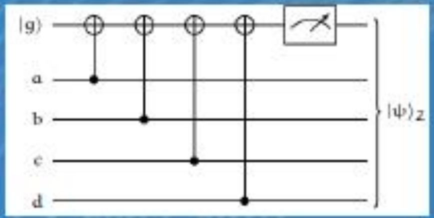
PhD project overview

- Can quantum computing help address particle physics simulation needs?
- Focus on interactions neutrino–Nucleon, applications for Monte Carlo generators and near–term experiments

So far

- Review of qubit–based computing, error correction
- Bosonic quantum computing (QHO)
- Algorithm implementations





Outlook

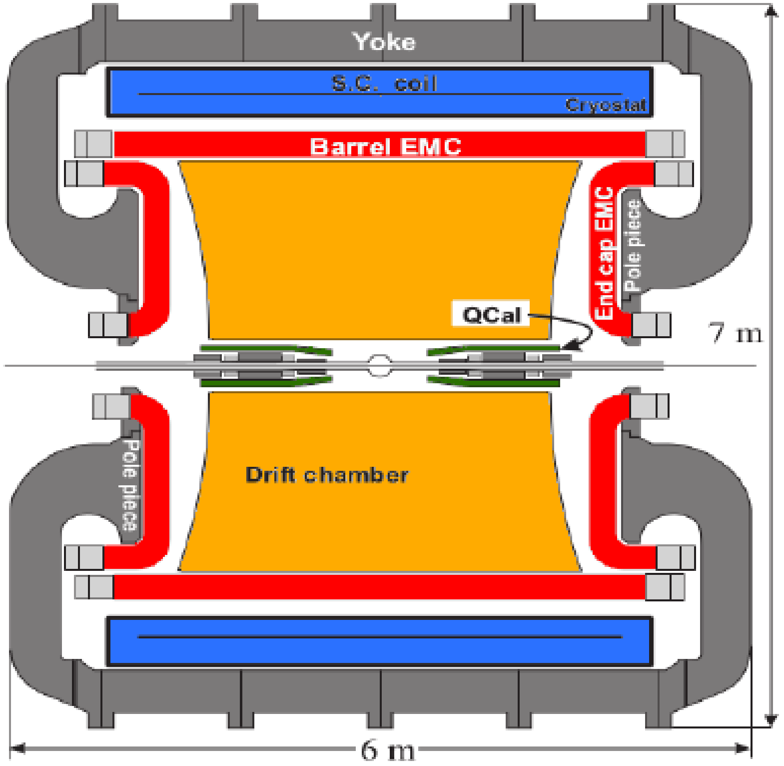
- Simulations for HEP with qudits
- Viability in current hardware
- Error mitigation

Project: *Hadronic data analysis and the determination of the hadronic vacuum polarization contribution to the muon anomalous magnetic moment*

KLOE Experiment

Supervisors: Graziano Venanzoni, Thomas Teubner and Paolo Beltrame

KLOE Detector



Alka Kumari

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- *Determine the missing quantities and other quantities from the Drift Chamber and Electromagnetic Calorimeter using data and various Monte Carlo simulations used in the analysis*
- *Produced the Monte Carlo Root files for KLOE-2 data with different streams*
- *Currently working on 2002 data to reproduce the Luminosity results*

Luminosity

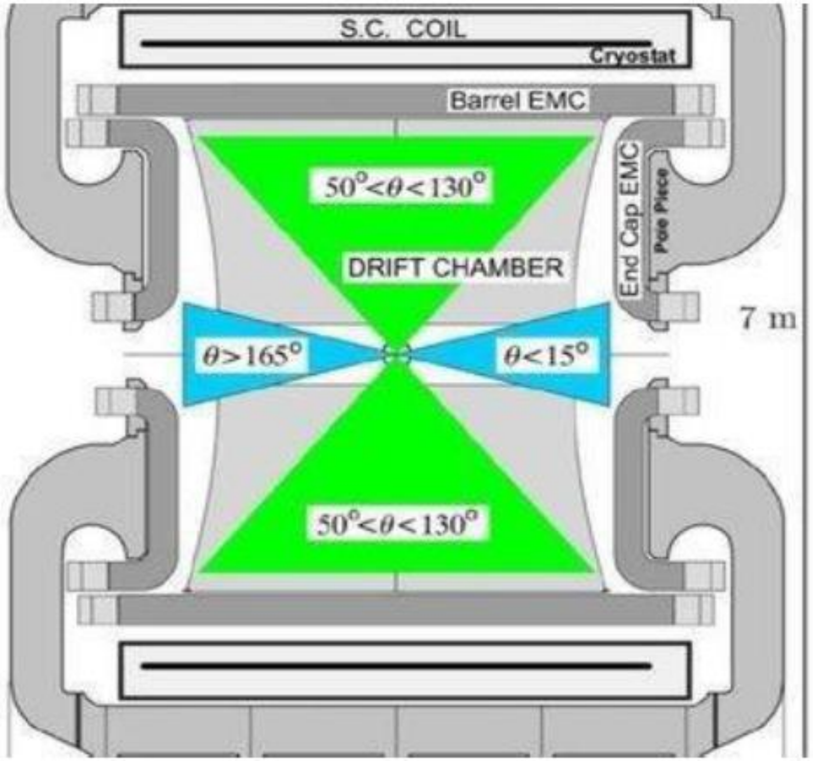
For an accurate measurement of the cross section of an e +e − annihilation process, precise knowledge of the collider luminosity is required.

$$\int \mathcal{L}\,\mathrm{dt} = \frac{N_{\mathrm{obs}} - N_{\mathrm{bkg}}}{\sigma_{\mathrm{eff}}} \;.$$

"Future Task: Luminosity determination with Kinematic Cuts:

Analysis cuts to select e+e- -> e+e- (Bhabha) events

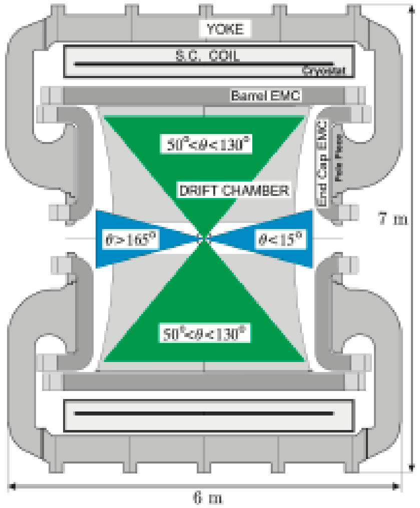
- *Cut on Cluster Polar Angle & Accolinearity*
- *Require the 2 selected Tracks to have opposite Charge*
- *Calculate the spatial difference for 2 selected tracks*
- *For both tracks the momentum cut greater than or equal to 400 Mev*



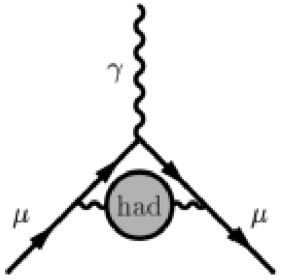
Schematic view of the KLOE Detector

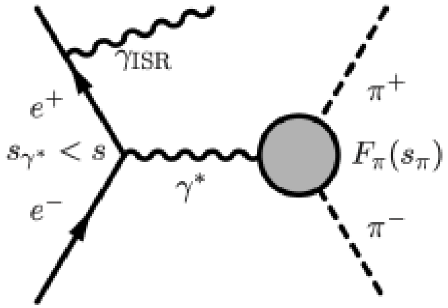
Determination of the hadronic contribution to the anomalous magnetic moment of the muon with the KLOE detector

Supervised by:
Graziano Venanzoni
Paolo Beltrame
Fedor Ignatov



Relating HVP contribution to cross section of $\pi\pi\gamma$ and $\mu\mu\gamma$





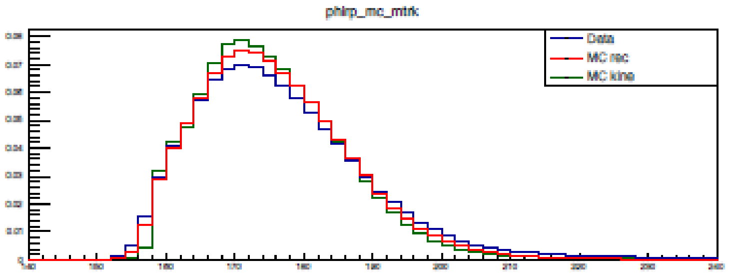
$$\sigma_{\pi\pi(\gamma)} = \sigma_{\mu\mu(\gamma)}\frac{d\sigma_{\pi\pi\gamma}/ds'}{d\sigma_{\mu\mu\gamma}/ds'} = \frac{4\pi\alpha^2}{3s'}(1+2m_\mu^2/s')\beta_\mu\frac{d\sigma_{\pi\pi\gamma}/ds'}{d\sigma_{\mu\mu\gamma}/ds'}$$

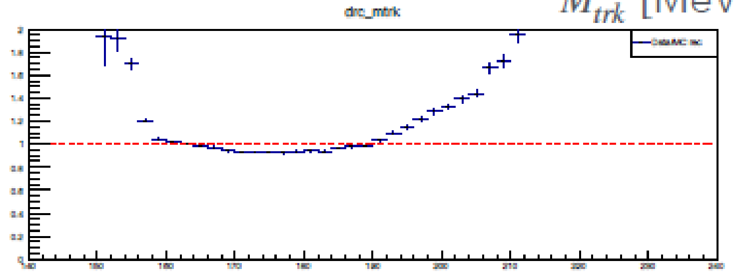
$$a_\mu^{\mathrm{HVP,LO}} = \frac{\alpha^2}{3\pi^2}\int_{M_\pi^2}^{\infty}\frac{K(s)}{s}R(s)ds$$

$$R(s) = \frac{\sigma^0(e^+e^- \to \mathrm{hadrons}(+\gamma))}{\sigma_{\mathrm{pt}}}$$

Current research work:

1. Implementation of blinding on software level
2. Detector tuning and data vs Monte Carlo studies





Niels Vestergaard 23/5-2024 1st year Ph.D student

UNIVERSITY OF LIVERPOOL

LEVERHULME TRUST

MUonE experiment

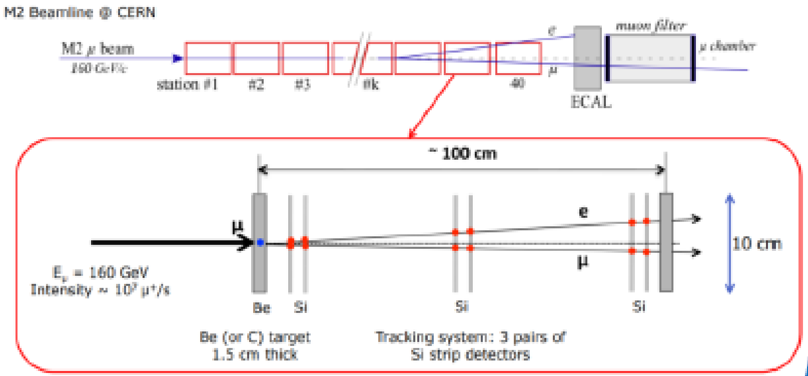
UNIVERSITY OF LIVERPOOL

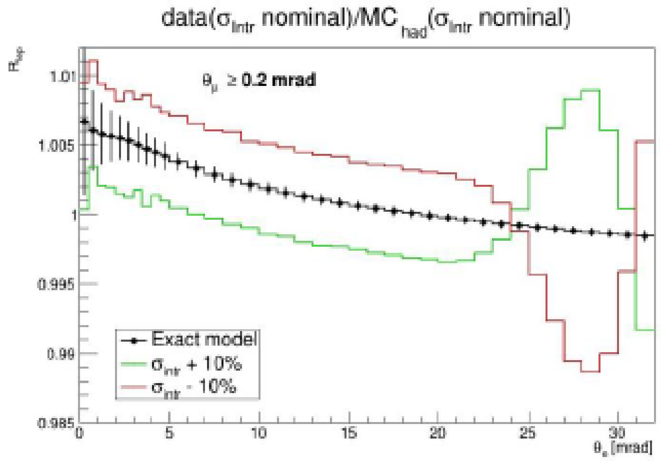
Student: Clément Devanne, Supervisors: Dr G. Venanzoni, Dr R. Pilato

LEVERHULME TRUST

MUonE in a nutshell

MUonE aims to provide an independent measurement of the contribution from hadronic vacuum polarization at leading order to the muon's anomalous magnetic moment using the scattered angles in a muon-electron elastic interaction.



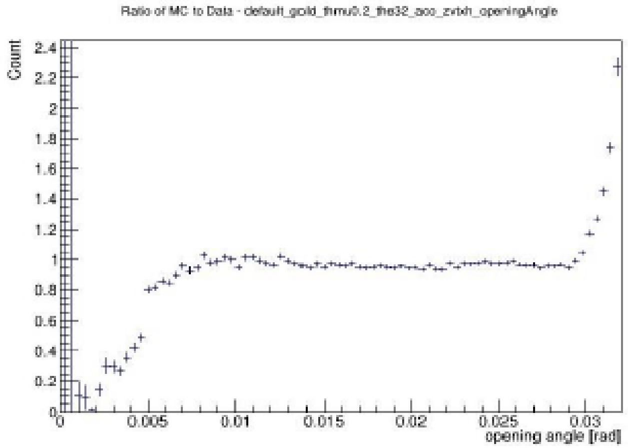


Systematic uncertaities

Carried out simulations to study how sources of systematic uncertainties impact the precision of measurements, such as intrinsic angular resolution, muon beam energy, and multiple Coulomb scattering.

Data – MC comparison

Studied the ratio of data from a test run made during the summers of 2023 to the Monte Carlo event from the FairMUonE simulation



Giorgia Cacciola

Supervisor: Prof Graziano Venanzoni

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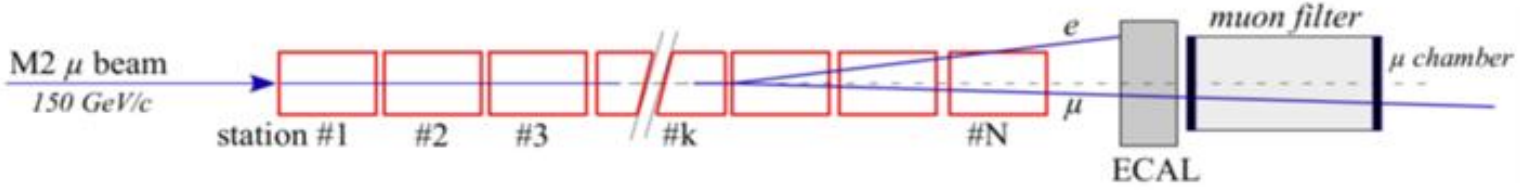
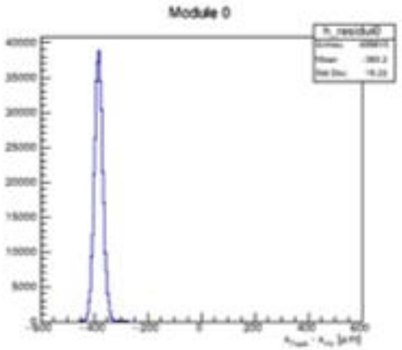
The aim of the MUonE experiment is to measure a_{μ}^{HLO} independently of other experiments by using accurate measurements of $\mu - e$ elastic scattering on a low z target.

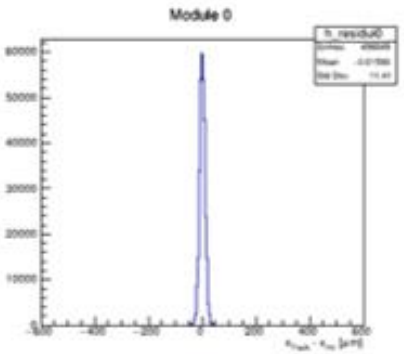


Alignment:

Recently completed some alignment studies and comparisons of alignment parameters at different points in a run.



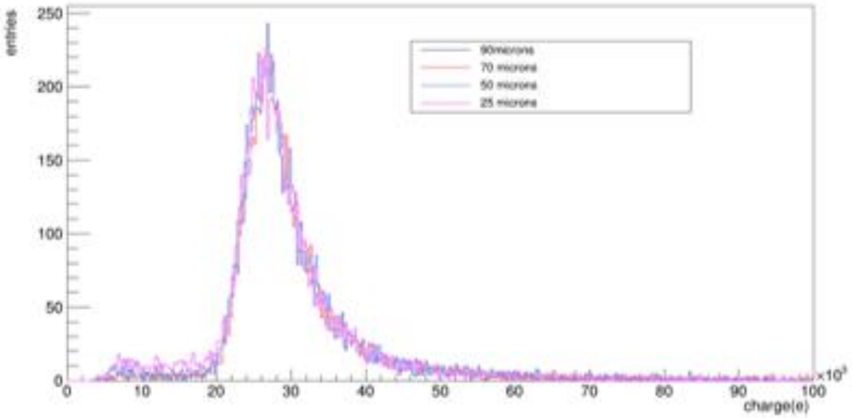
before alignment



after alignment

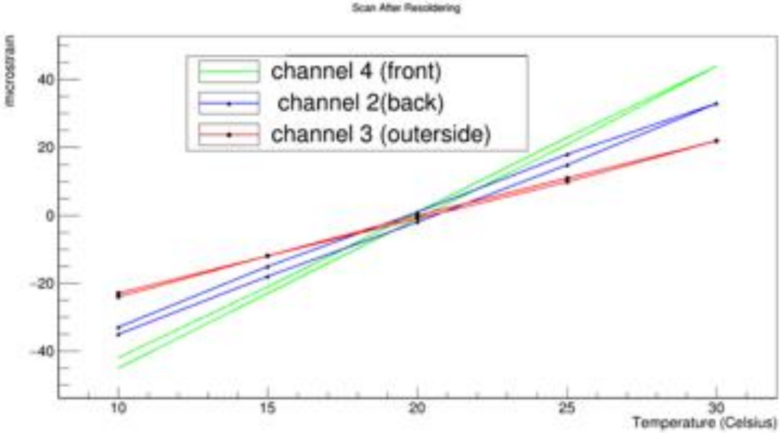
Simulations:

Carried out simulations to study the optimal pitch and thickness for a future silicon strip sensor to be used in MUonE.



Hardware:

Currently testing different types of carbon fibre to be able to replace Invar for the MUonE detector support structure.



Quantum Computing For Neutrino Scattering

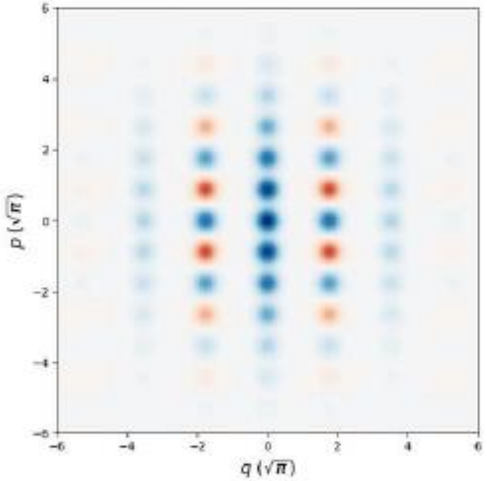
Sam Godwood

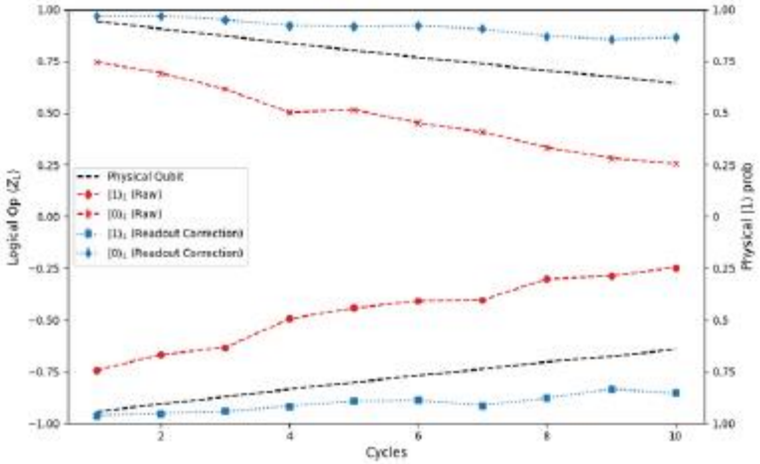
Supervisors: Prof. Costas Andreopoulos, Dr. Gabriel Perdue and Dr. Doğa Murat Kürkçüoğlu

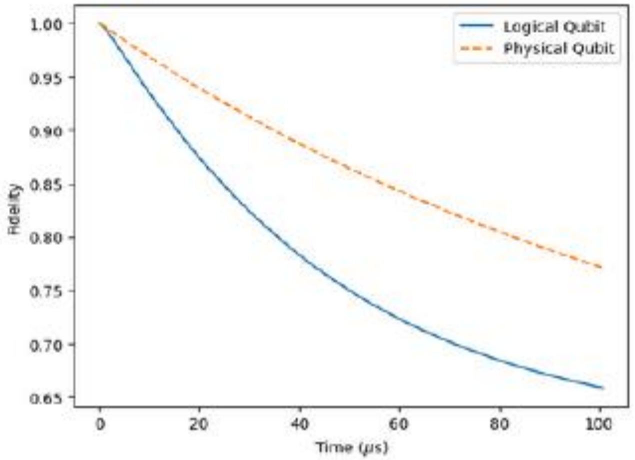
- Current Quantum hardware is noisy and unreliable
- Fault Tolerant Quantum Computers will require Quantum Error Correction (QEC)

Work So Far:

- Gaining an understanding of QEC and quantum noise
- Simulated performance of simple QEC codes under realistic quantum noise
- Understanding Quantum Computing with continuous variables with SQMS High-Q SRF Cavity
- Reproduced results of experimental implementations of more sophisticated QEC codes (arXiv:1912.09410)







Future Work:

- Further research into continuous variable error correction with hardware at SQMS (planned LTA at Fermilab)
- Explore hybrid error correction approaches combining continuous and discrete variable QEC codes