दिल्ली विश्वविद्यालय
University of Delhi

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Particle Track Reconstruction Using Deep Neural Networks.

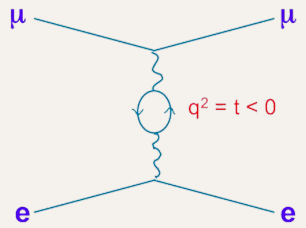
Particle Physics Summer Student Programme, 29 July 2022

Priyanshu Gupta
Clarisse Prat
Supervisor: Dr. Marcin Wolter

THE HENRYK NIEWODNICZAŃSKI
INSTITUTE OF NUCLEAR PHYSICS
POLISH ACADEMY OF SCIENCES

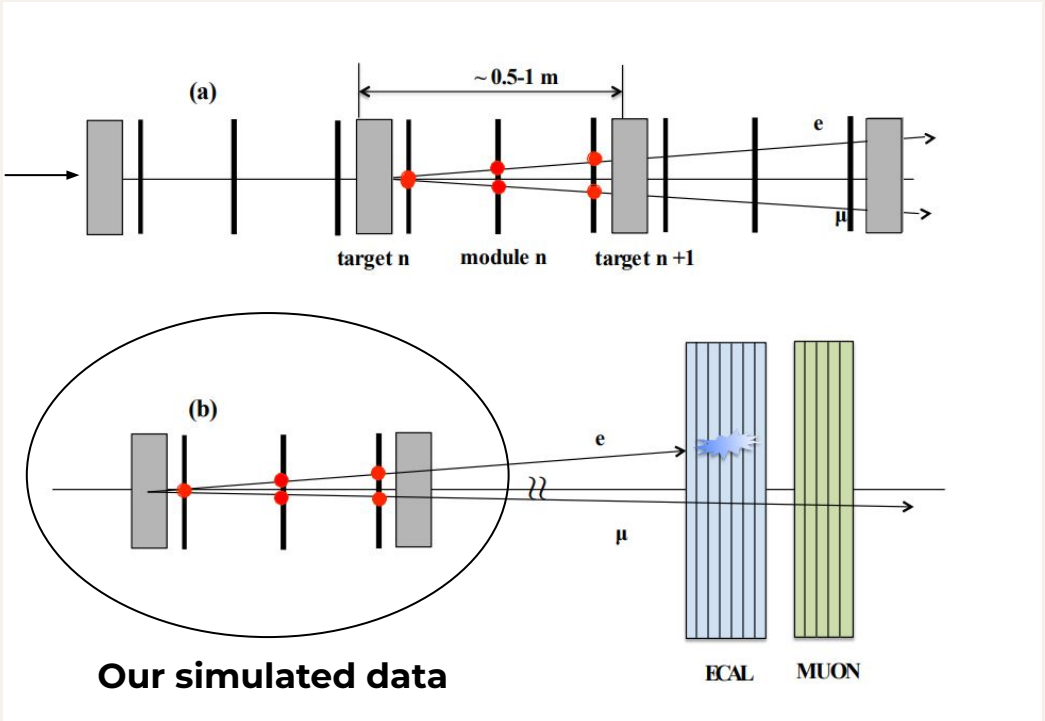
The MuonE Experiment

- Proposed experiment dedicated to measure hadronic correction to the anomalous muon magnetic moment.
- Look at the elastic scattering of high-energy muons on atomic electrons in a low-Z target.
- Layers of detectors:
  - X, Y and stereo layers that are rotated by 45 degrees are used to determine the hit points and trajectory of the flying particles.
- Working on **simulated test beam data**
  - Monte Carlo simulated tracks.
  - No applied magnetic field, so particle tracks are straight.

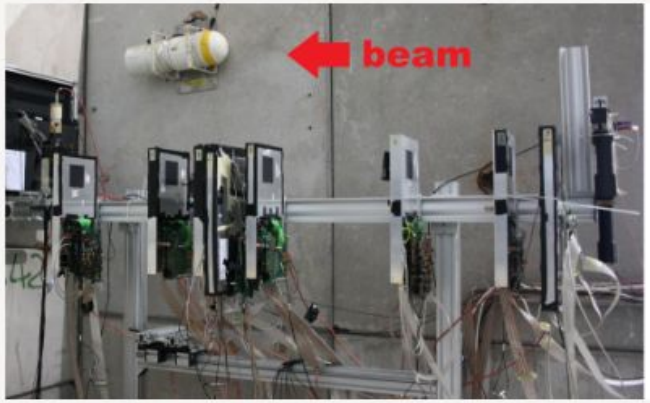


Experimental Set-Up

M2 μ beam
150 GeV/c



Letter of Intent: The MUonE Project



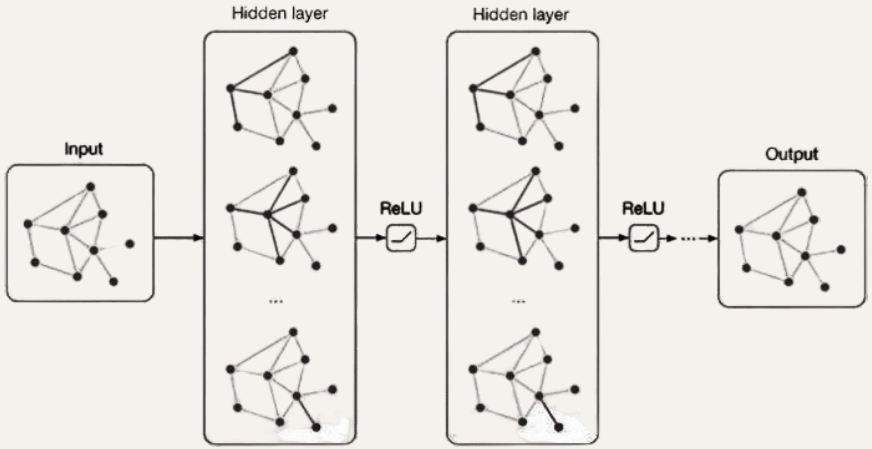
The MUonE 2018 run setup

Graph Neural Networks

- Data is structured as a graph of connected hits.
- Two main components operate on the graph locally:
  - Edge networks use the node features to compute weight edges.
  - Node network aggregates forward and backward node features with the edge weights and update node features.
- Using the **hit positions** as nodes (input).
- Output is the graph with edges, connecting the hit points.
  - Each edge has a weight, denoting the probability that it belongs to the particle track.

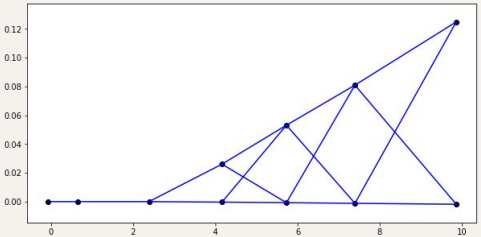
Why GNNs?

- Building track reconstruction method alternative to the standard pattern recognition methods.
- Increasing luminosity at the LHC means more data from experiments.
- Time taken for track reconstruction for each event increases dramatically.
- **Need to speed up pattern recognition.**
- **Ideally:**
  - Input all hit points with no distinction between X, Y and stereo layers
  - Output is in 3D regardless of 2D (x-z and y-z) inputs

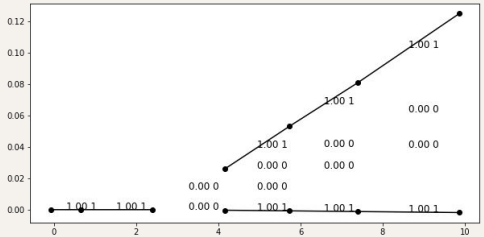


2D Particle Tracking Using GNNs

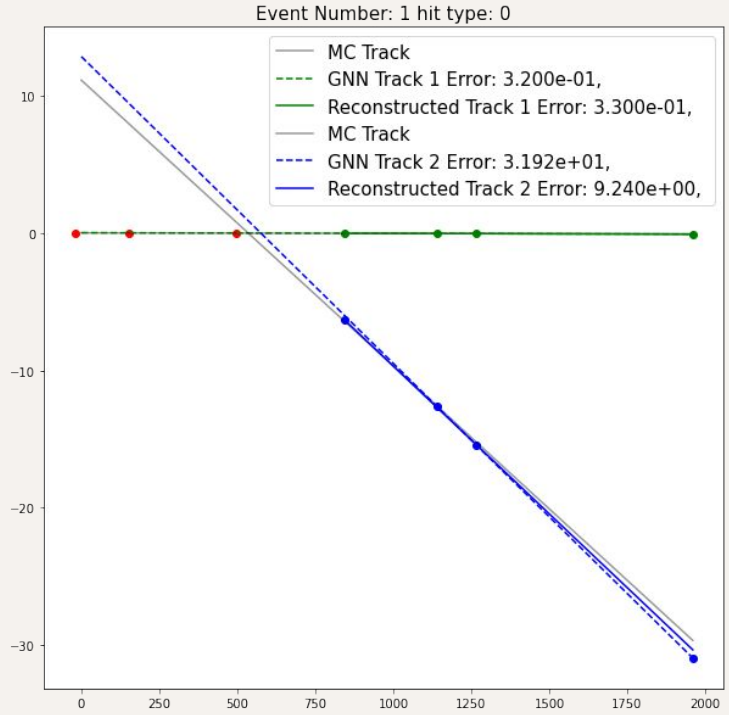
- Connecting all possible edges in the x-z and y-z planes
- The edges are validated by the GNN: they are assigned a probability that they form a track.
- From this we can reconstruct the particle track and compare it to the robust fit and the Monte-Carlo simulated track



All possible edges between hits

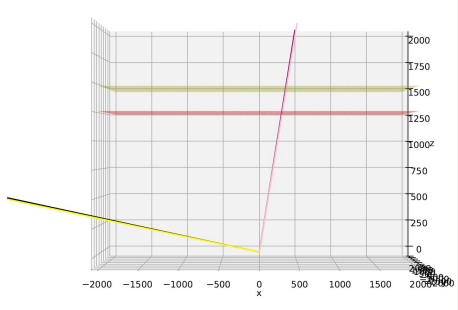


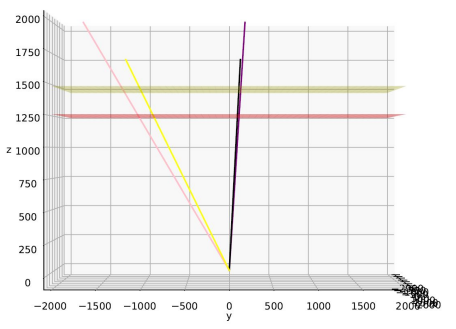
Edges selected by GNN

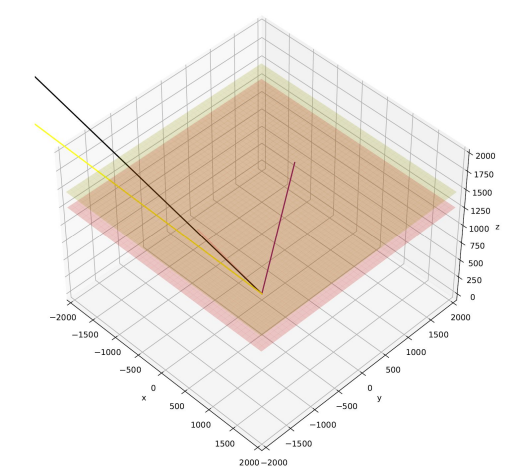


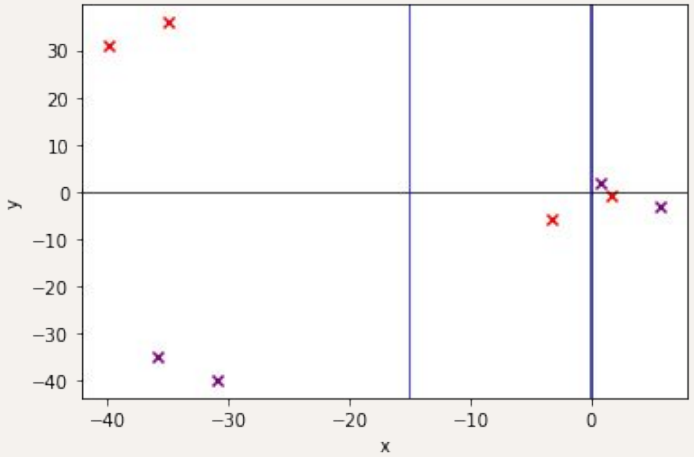
3D Reconstruction

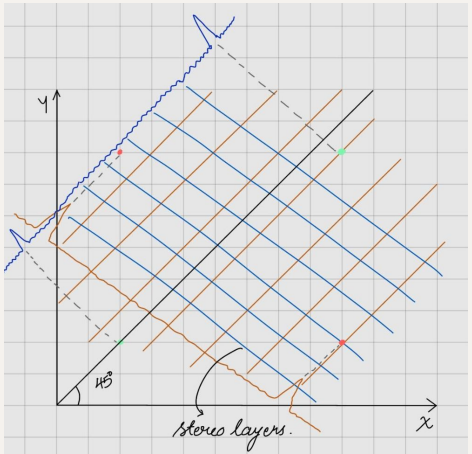
Main issue: ambiguity in the reconstruction
There are 2 combinations of possible reconstructed particle tracks.
Use the stereo layers to perform the selection.









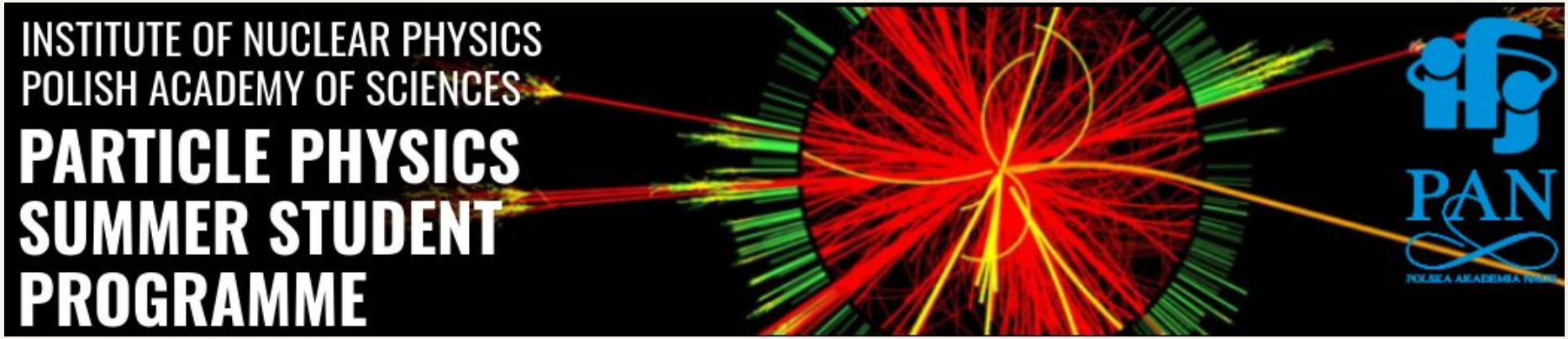


Conclusion

- Neural networks works very well for the 2D track reconstruction.
- Expect accurate results in 3D reconstruction.
- Due to time constraints and certain positive tests we could not fix the issue with the track selection, so we were unsuccessful in the final 3D reconstruction.

Next Steps?

- Make the track selection and reconstruct the tracks for the muon and the electron, and compare this to the Monte Carlo and Neural Network tracks
- **Better way: simply input the hit points and let the machine do the work.**
  - **Machine doesn't care about the hitpoints, but rather the weight of the edges connecting the hit points**
  - **Let the GNN do the track finding in 3D using stereo layers as well. Would it manage?**



We are really grateful to Dr. Marcin Wolter for his support and guidance throughout our project. We would also like to thank the organisers and all the participants for this amazing experience!

Questions?