Reconstruction of particle tracks using Deep Neural Networks

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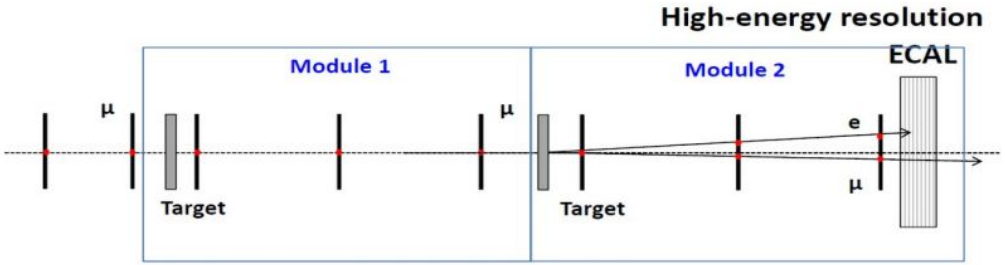
MuonE experiment

MuonE

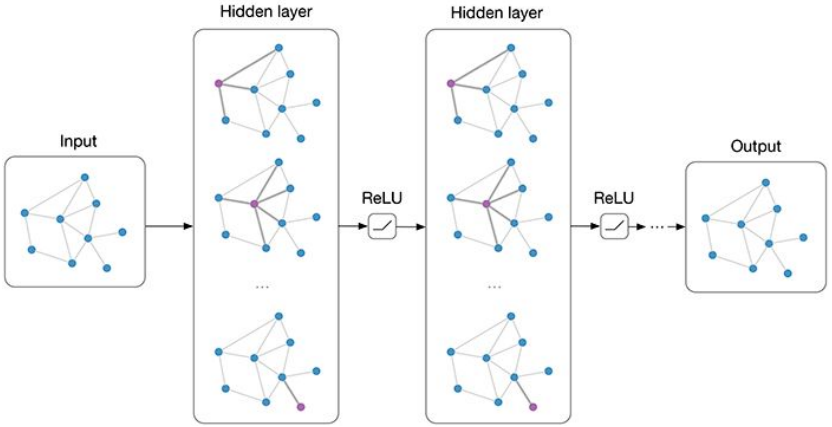
- Future CERN experiment - planned to be built in 2021-2022
- Dedicated to measure hadronic correction to the anomalous muon magnetic moment.
- We are working on the **simulated test beam data**
- No magnetic field applied, tracks of particles are **straight lines**
- **Layers of detectors,** determining position of a flying particle - X, Y layers and stereo layers rotated by 45 degrees



GNN - Graph Neural Network

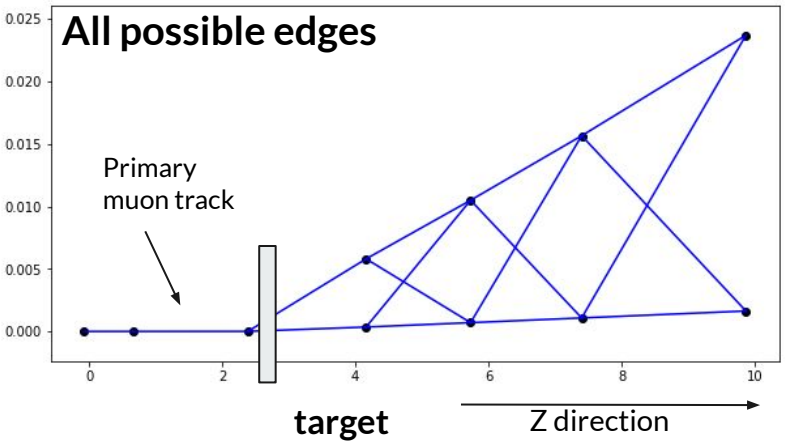
We used the code of HEPTrkX group, which applied GNN to track reconstruction. We have modified their code:
https://github.com/HEPTrkX/heptrkx-gnn-tracking

- **Motivation to use** - building track reconstruction method alternative to the standard pattern recognition methods
- **Input data** - graph, instead of vectors or matrices. In our case, hit positions - nodes.
- **Output data** - graph with edges, connecting the hit points. Each edge has a weight, denoting the probability that it belongs to the particle track

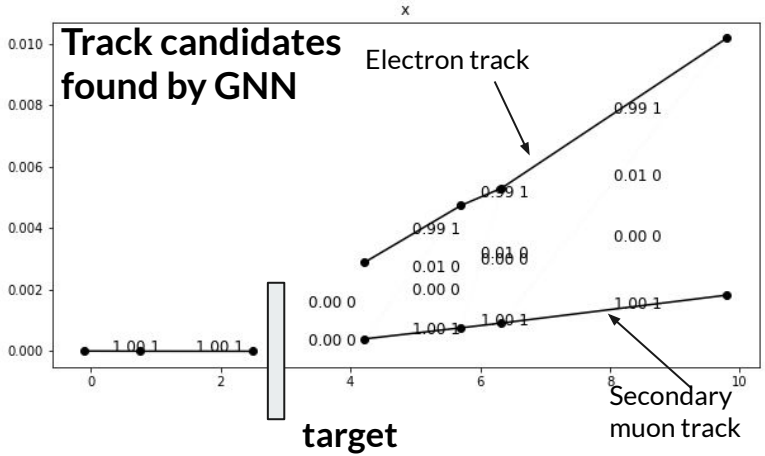


GNN applied to MuonE track recognition

- At the moment, we can reconstruct 2D tracks (XZ and YZ)
- First we find all potential edges connecting the hits
- Then the edges are validated by GNN; they get probabilities that they form a track

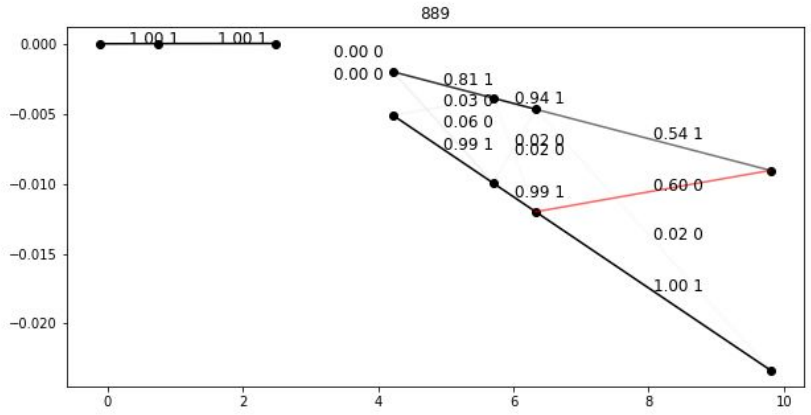


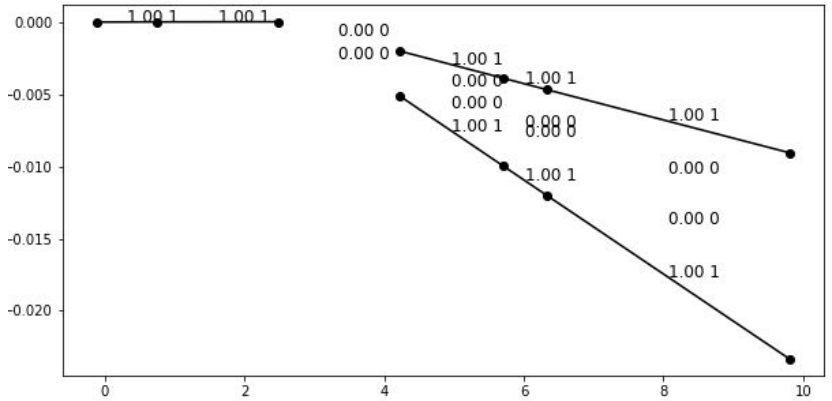
Edges with high probabilities - marked as black



Tuning GNN parameters

- Potential problems - simulating tracks that are not real
- Changing parameters:
  - Numbers of layers of Edge Neural Network and Node Neural Network
  - Number of iterations of weights updates per epoch
- This last parameter turned out to be the most significant
- Maximum edge classification accuracy that was obtained is 99.9%

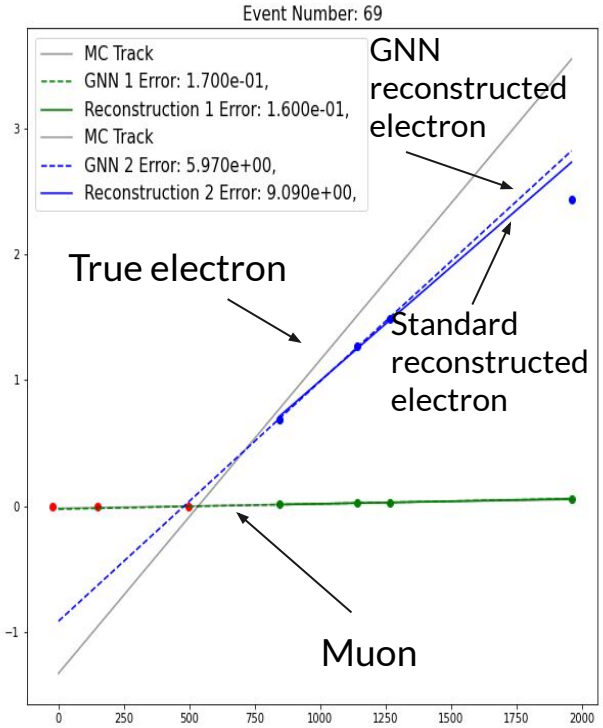


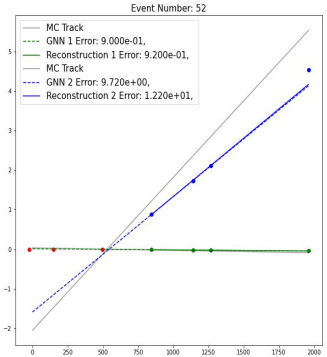


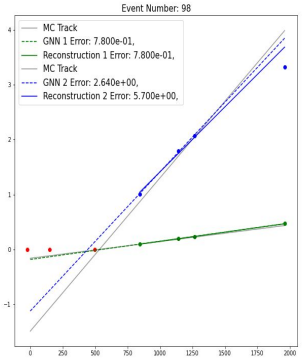
Fitting the particle tracks

Particle track is determined by **linear fit to the hits** found by GNN

- **Robust fit algorithm -** extension of standard linear regression. Allows to drop one outlying point
- Comparison between real tracks (Monte Carlo tracks) and those reconstructed by us
- Tracks are also compared to those obtained using standard MuonE reconstruction

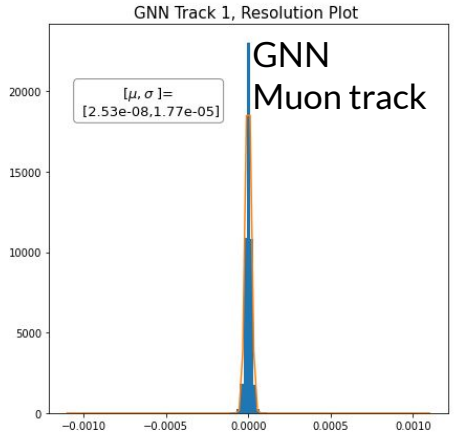


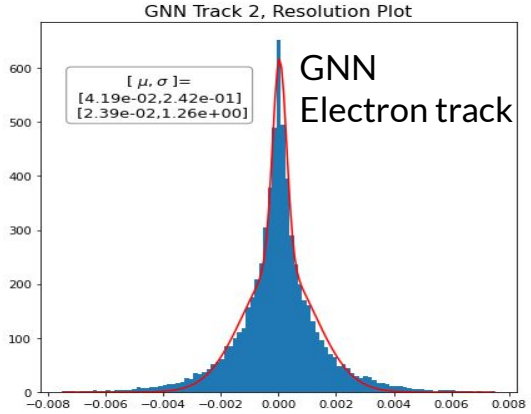




Results: Slope resolution (reconstructed - true)

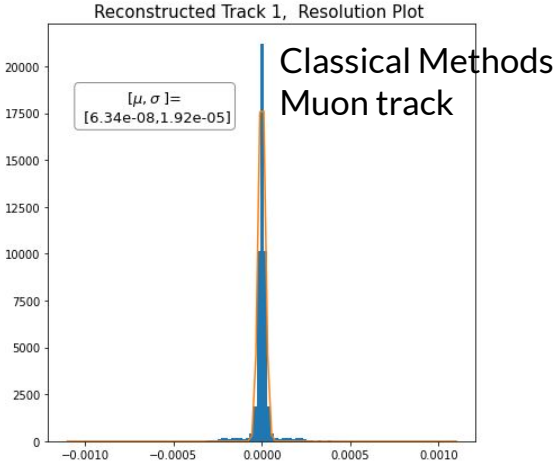
Number / Percentage of successful reconstructions:
24970 / %99.951965

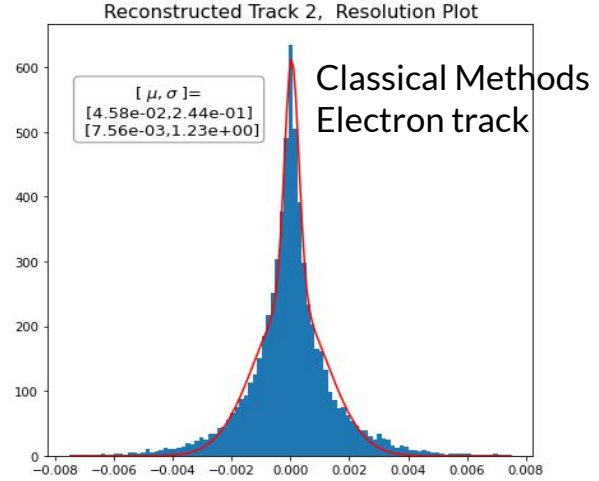




Number / Percentage of successful reconstructions:
24777 / %99.179409

Number / Percentage of successful reconstructions:
24978 / %99.983988





Number / Percentage of successful reconstructions:
24077 / %96.377392

Our code:
https://github.com/marcinwolter/Tracking_student2020

Conclusions

- We managed to implement GNN to reconstruct particle tracks based on hit positions
- We obtained the reconstruction efficiency and resolution comparable to the classical methods (and for the scattered electron track even slightly better)
- We therefore introduced alternative working method for track reconstruction in the MuonE experiment

- Future development of the project - reconstruction of the tracks in 3D

Supplementary