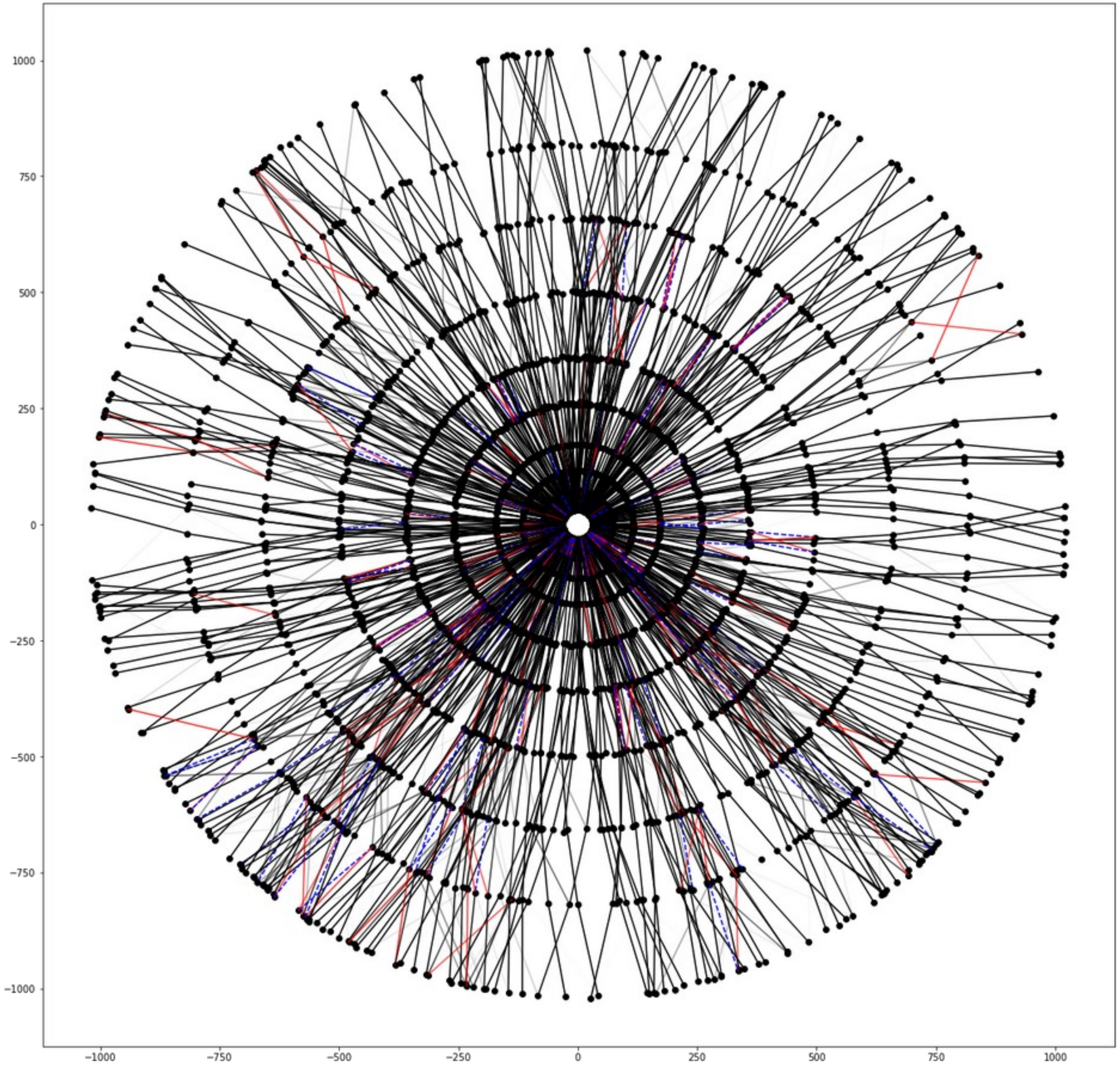
Reconstruction of particle tracks using Deep Neural Networks



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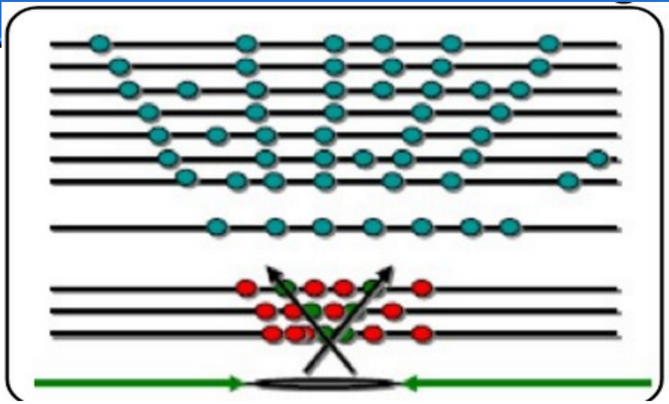
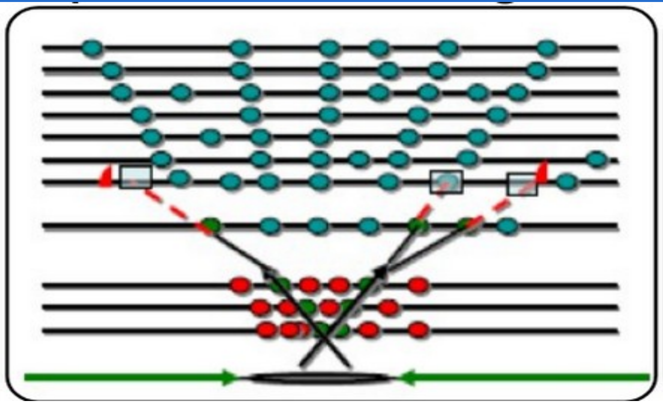
11 July 2022

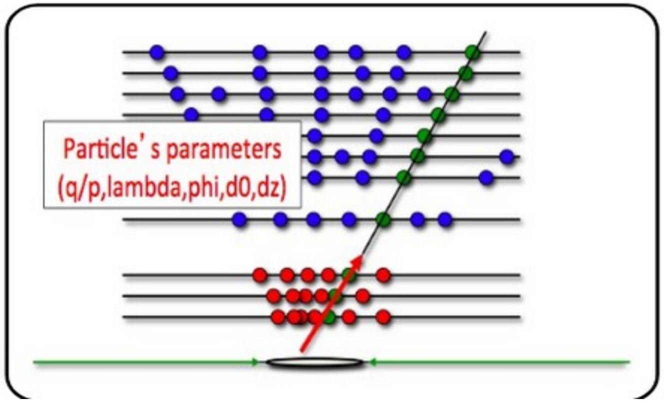
Track reconstruction



Seeding



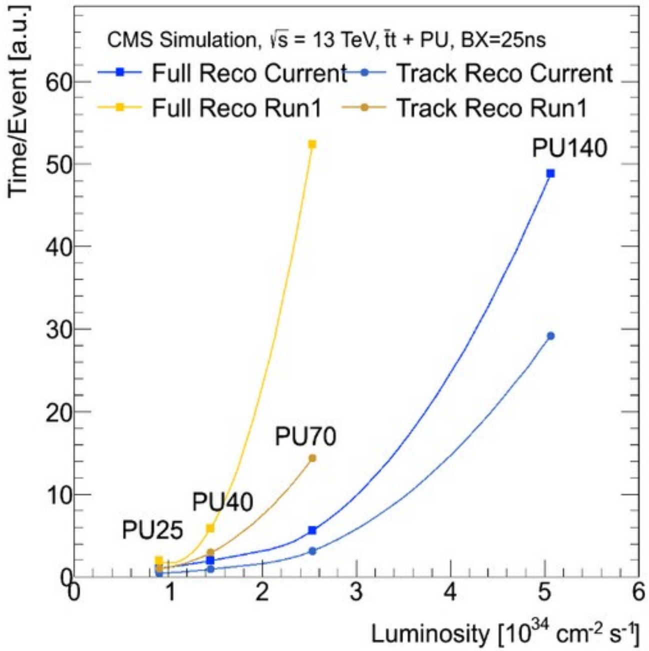
Track Building



Track Fitting

Usually this method works fine, is robust and efficient!

- **Problem:**
  - The time needed to process one event grows quickly (worse than quadratic) with luminosity (number of collisions).
  - Huge part of CPU consumption by the track finding.

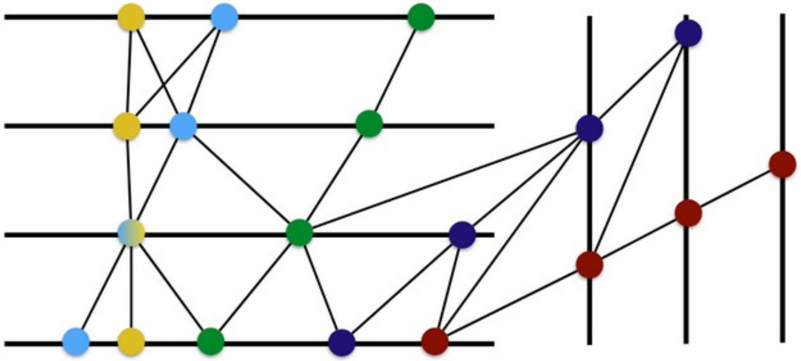


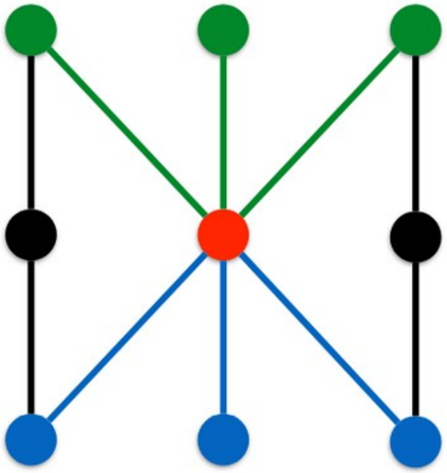
Solution: use Neural Network!

Graph Neural Network

Structure our data as a graph of connected hits

- What kinds of models can we apply to this representation?
- Traditional architectures clearly don't work
- but there's a growing sub-field of ML called Geometric (Graph) Deep Learning





Two main components operate on the graph locally:

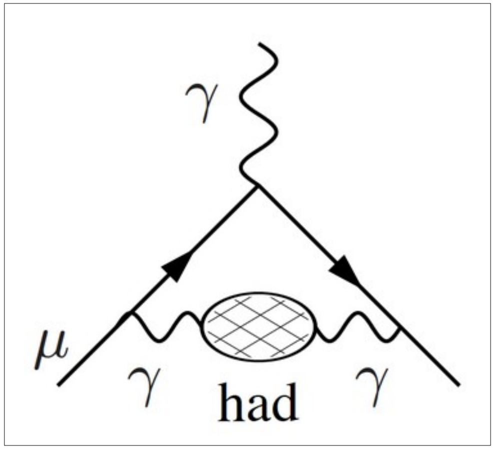
- Edge network uses the node features to compute edge weights
- Node network aggregates forward and backward node features with the edge weights and updates node features

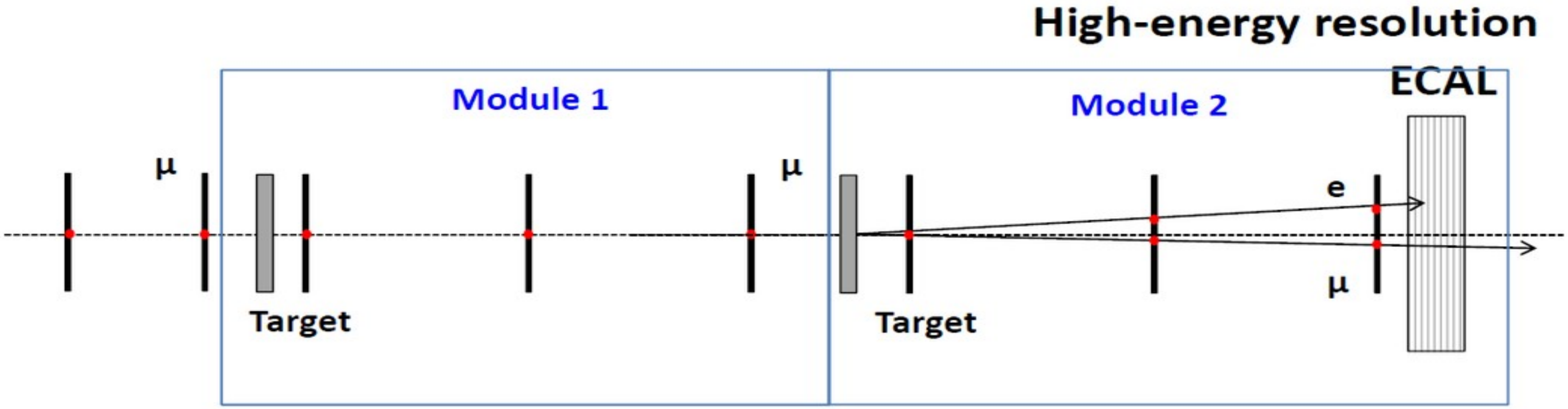
Task – GNN for MuonE experiment

- MuonE – future CERN experiment dedicated to measure a hadronic correction to the anomalous muon magnetic moment.

- **TASK: apply GNN to the simulated test beam data:**
  - No magnetic field – straight tracks
  - Few detector layers
  - Layers detecting X and Y position with so called stereo layers rotated by 45 degrees

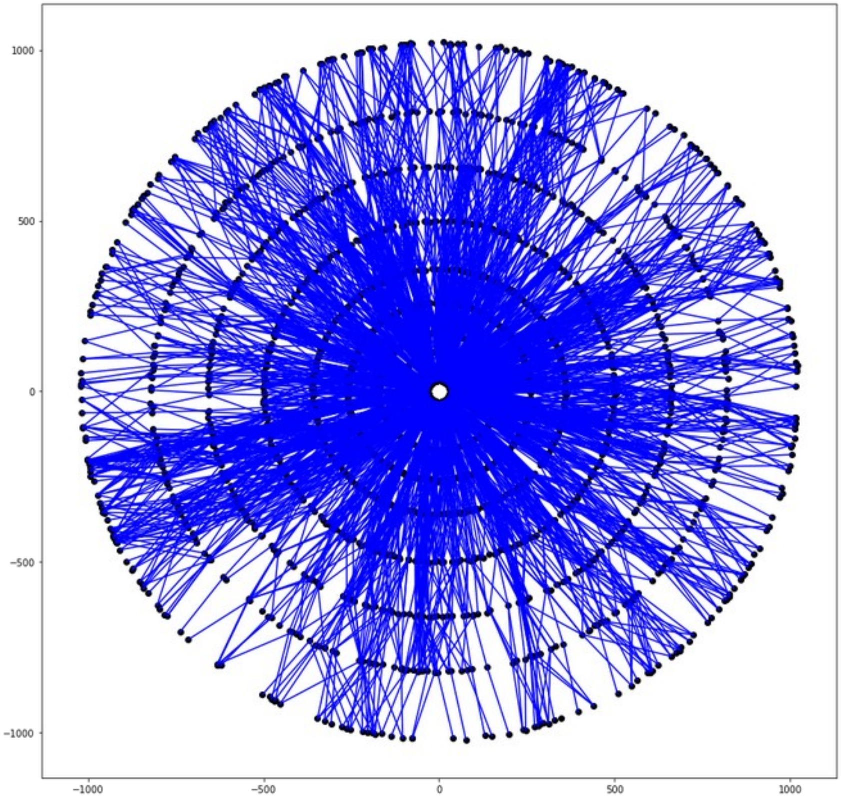
hadronic vacuum polarization





Information about Graph Neural Networks

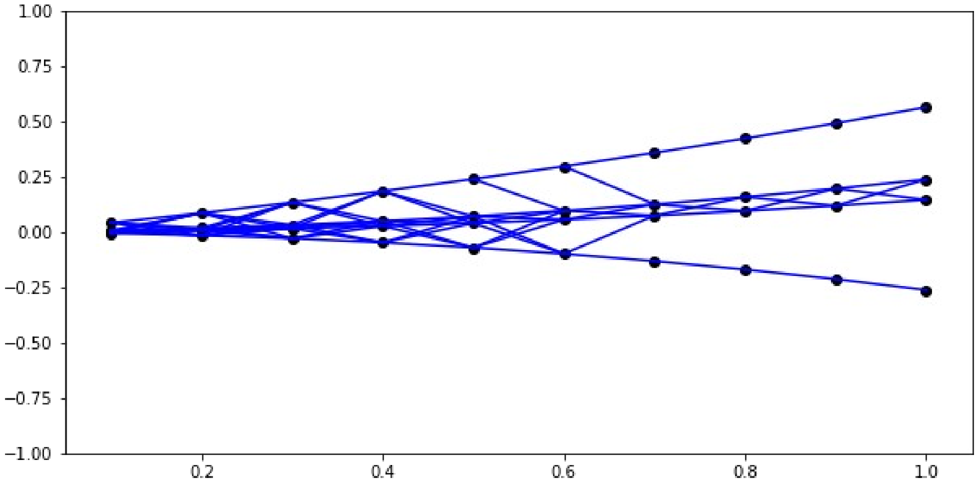
- Great page: http://geometricdeeplearning.com/
- Nice lecture: https://ucbrise.github.io/cs294-ai-sys-sp19/assets/lectures/lec03/gnn.pdf
- Presentation about GNN tracking:
- https://indico.cern.ch/event/658267/contributions/2881175/

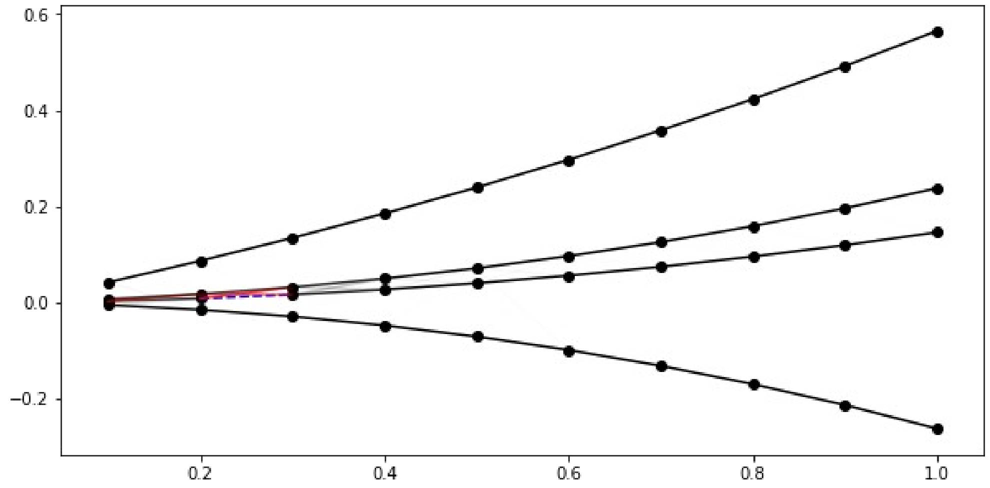


See the code of a toy example on github

- It is pretty compact:
- https://github.com/marcinwolter/Tracking_student2022/blob/master/GNN_Tutorial_Colab.ipynb
- Plus input data: https://drive.google.com/open?id=1NNZadxZcrxkm0NJv3CgeNGwBnsnByioV

And you can run it on Google Colab: https://colab.research.google.com





Repository

- There is a starting repository for you:

  https://github.com/marcinwolter/Tracking_student2022

- It contains:
  - GNN_Tutorial_Colab.ipynb - tutorial code for GNN tracking

    Data for GNN_Tutorial_Colab: https://drive.google.com/drive/folders/1NNZadxZcrxkm0NJv3CgeNGwBnsnByioV?usp=sharing
  - GNN_MuonE_v1.ipynb - starting code I have prepared for students in 2020

    Data: https://drive.google.com/drive/folders/1PpdNJHw9KYpY6kczmeGsFLRfaeCq65gK?usp=sharing
  - GNN_MuonE_v1_Robust_mc-recon_comparison.ipynb - program for tracking in 2D created by students in 2020

Your task

- Read the tutorials (we can do it together)
- Read the presentation of summer students from 2022:
  - https://github.com/marcinwolter/Tracking_student2020/blob/master/PPSS_Presentation.pdf
  - Try to understand the code GNN_MuonE_v1.ipynb
  - Think how to make pattern recognition
- Students in 2020 created the code working in 2D doing:
  - Pattern recognition using GNN
  - Robust fit to the hits to find the track parameters

Your task

- There are so called stereo layers tilted by 45 deg – they allow reconstruction in 3D
- Think, whether we can do reconstruction using three types of layers at once:
  - X layers
  - Y layers
  - Stereo layers