Graph Neural Networks for RICH Reconstruction

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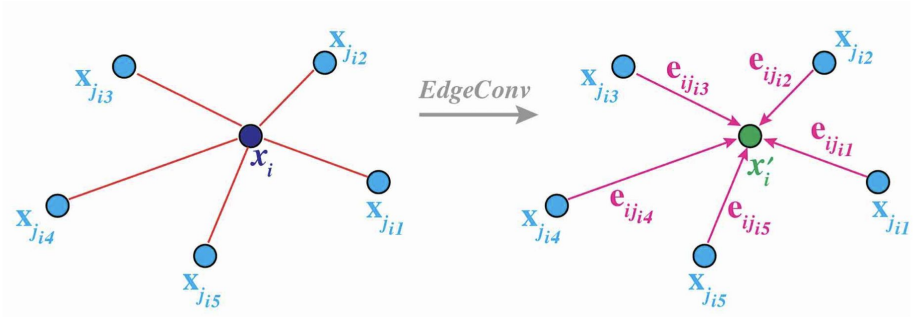
Graph Neural Networks (GNN)

- GNN - neural network architecture which acts via convolutions over a graph
- Graph:
  - Set of nodes with edges between nodes
  - Each node has individual features, e.g. timing, position
- Convolutions carried out between nodes create trainable parameters which update node features, connections
- GNNs very successful in pattern recognition tasks, HEP applications



Example: dynamic feature and edge updating with ParticleNet (arXiv:1902.08570) and EdgeConv layer (figure from ParticleNet: Jet Tagging via Particle Clouds, 3rd IML Machine Learning Workshop Workshop)

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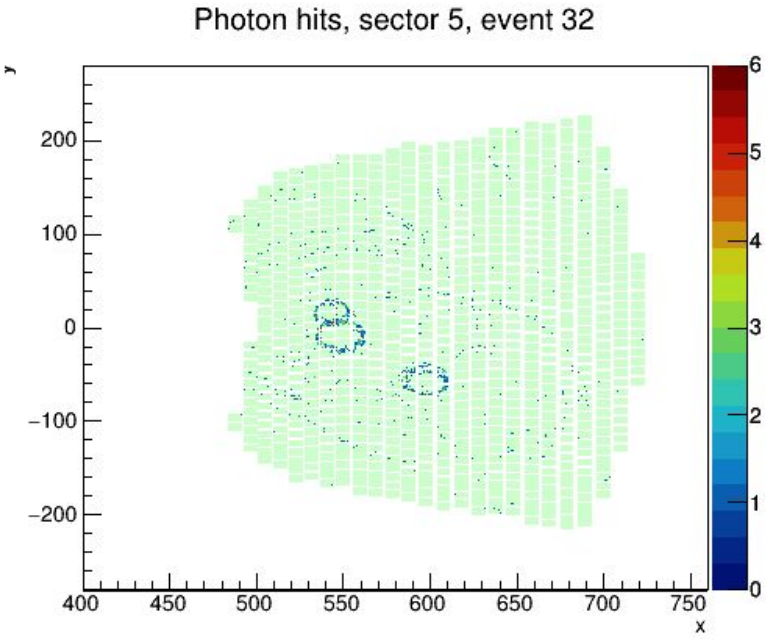
Possible GNN for RICH reconstruction

- Hits in rich detector + track projection onto electronics plane could be treated as nodes in a graph
  - Features including spatial position on PMT plane, timing information, etc.
- Edges between each hit and projected track, and between nearest neighbors or with connection between all nodes
  - Possibly better at untangling events with many tracks



Hits in simulated ePIC dRICH event, from C. Dilks

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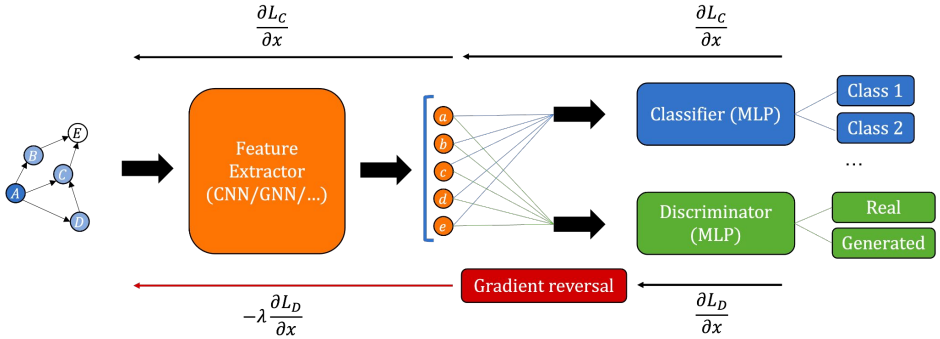
PDF and additions to neural network for PID

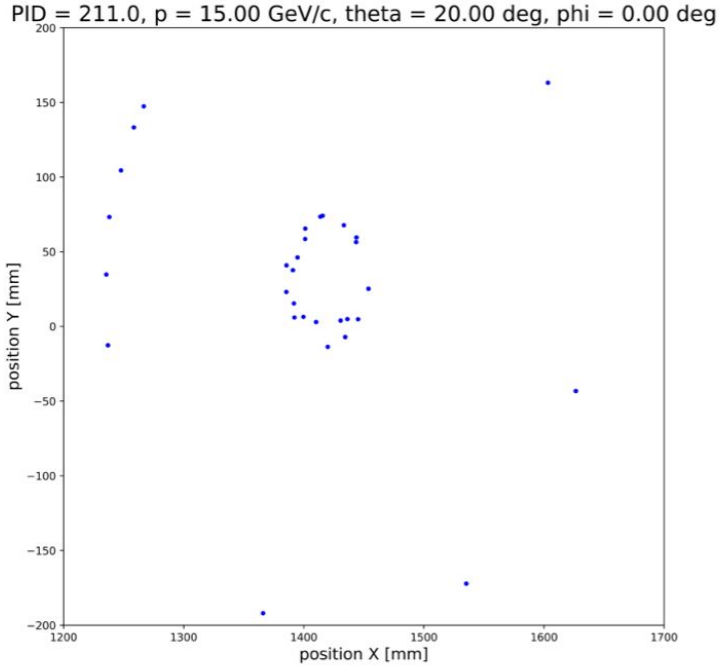
- Modern ML techniques allow construction of PDF output from neural network to allow for full ML classifier
  - Error quantification of network
  - Examples: normalizing flows, Bayesian networks
- Techniques like domain adversarial training can improve MC-data agreement for NN classifier



Domain adversarial network structure

Efforts so far on GNN for RICH

- Applied GNNs on AI4EIC dRICH hackathon dataset
  - Dataset in medium momentum range, where both radiators may produce cherenkov radiation
  - Used fully connected graphs (only spatial hit information) and graph attention convolution layers
  - With simple implementation and no optimization, and in the presence of noise, achieved ~90% test accuracy
- Efforts started in our group to add test GNN reconstruction to modular EPIC reconstruction software



From 2022 AI4EIC Workshop hackathon

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