A deep neural network to direct the Pandora multi-algorithm LArTPC event reconstruction

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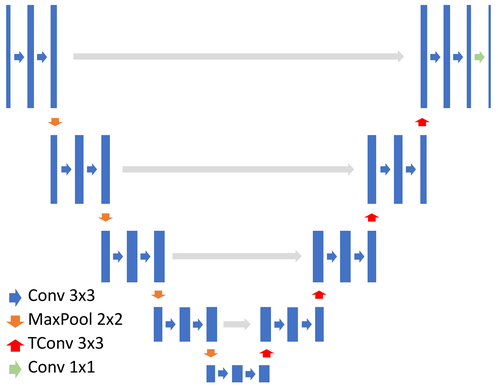
Combining **deep learning** and algorithmic pattern recognition for **LArTPC** event reconstruction.

ARCHITECTURE AND TRAINING

- N = 18,000 DUNE FD 1x2x6 events
  - 70:30 training : validation
  - Need 1-to-1 hit-pixel correspondence
  - 256^2 pixel tile for each 128^2 cm^2 region
  - Empty tiles discarded
- U-Net architecture [arXiv:1505.04597] used to classify each hit

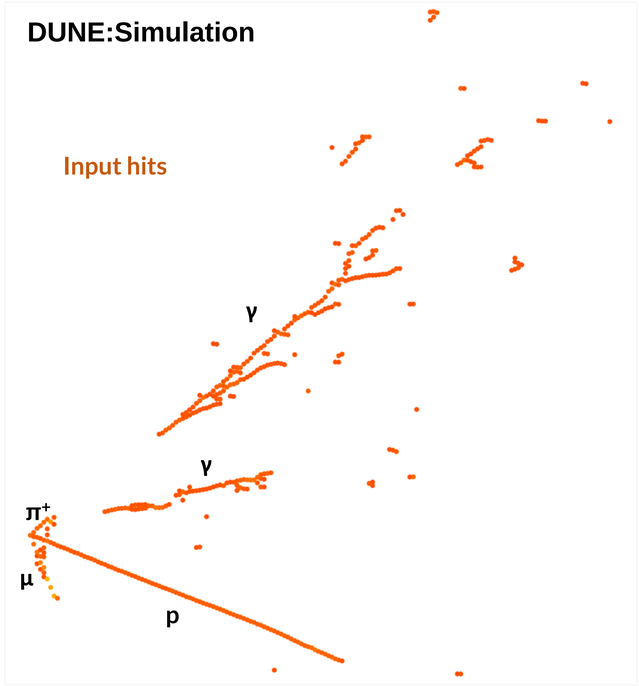


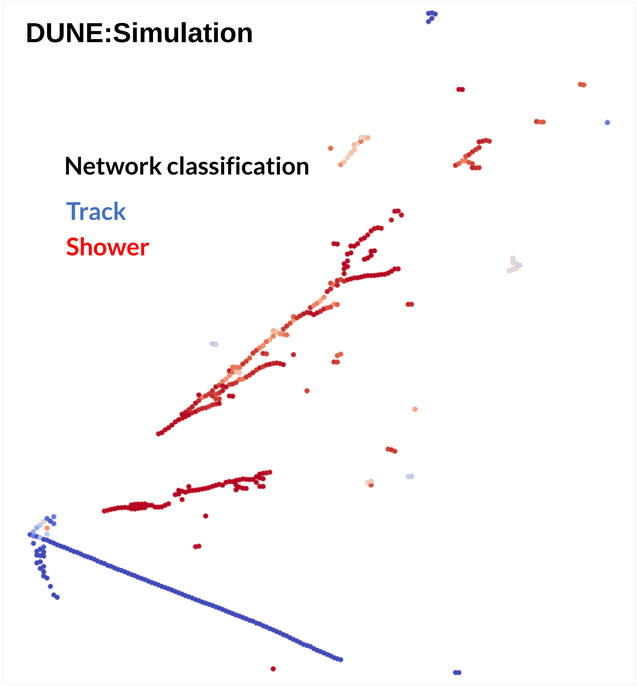
  - Batches of 96 images passed to down-sampling branch
  - Down- and up-sampling blocks are convolutional/batch normalization pairs separated by ReLU activation
  - Max pooling down-samples output from blocks in down-sampling branch, while convolutional filter count doubles
  - Stride two transpose convolution up-samples input to blocks in up-sampling branch, while convolutional filter count halves
  - Skip connections concatenate intermediate outputs from down-sampling with inputs to up-sampling, augmenting information
  - A final convolution is performed to produce per-hit prediction for each class
- Ground truth
  - Tracks : μ, k, π, p and nuclei
  - Showers : e, γ
- Loss function
  - Categorical cross-entropy
  - -log(softmax(x))

INTRODUCTION AND MOTIVATIONS

Liquid argon time projection chambers allow neutrino interactions to be studied at millimeter resolution using signals from drifting electrons produced by charged particles ionizing the liquid argon as they traverse the chamber.

Fully exploiting these high-resolution images is a significant reconstruction challenge. The goal of reconstruction is to produce high-level physics outputs, such as interaction hierarchies, particle identification and energy, given low-level inputs from the detector. Topologies are complex and diverse, so a single clustering approach is unlikely to work. **Multiple techniques** can build up events gradually. This work performs hit-level track/shower discrimination and explores the **combination of algorithmic and machine learning** approaches in Pandora to generate a hierarchy of track-like and shower-like particles.





~2 GeV CC Deep Inelastic Scattering interaction in DUNE FD

CLASSIFICATION RESULTS

True\Net	Track	Shower
Track	92.1%	18.4%
Shower	7.9%	81.6%
Σ	100%	100%

Table 1: Confusion matrix normalized with respect to network classification

Learn more about Pandora
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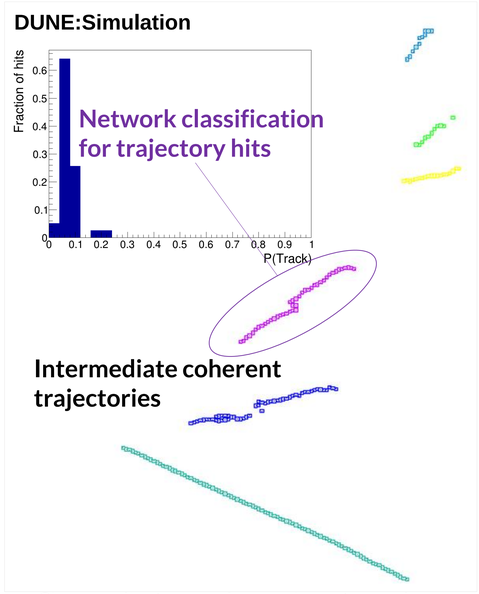
WARWICK

AUGMENTING ALGORITHMS

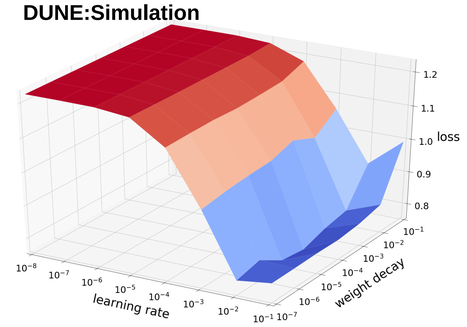
- Early Pandora algorithms identify coherent track-like trajectories
- True tracks should be protected from later shower-building algorithms



- Shower-like topologies can have track-like spines
- Network can identify shower-like hits in trajectories and tag them accordingly

HYPERPARAMETER OPTIMISATION

- Optimal hyperparameters can improve network convergence.
- High learning rates are attainable in early training



DEEP UNDERGROUND NEUTRINO EXPERIMENT