Classification of neutrino-induced particles and characterisation of showers at DUNE

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I. Introduction

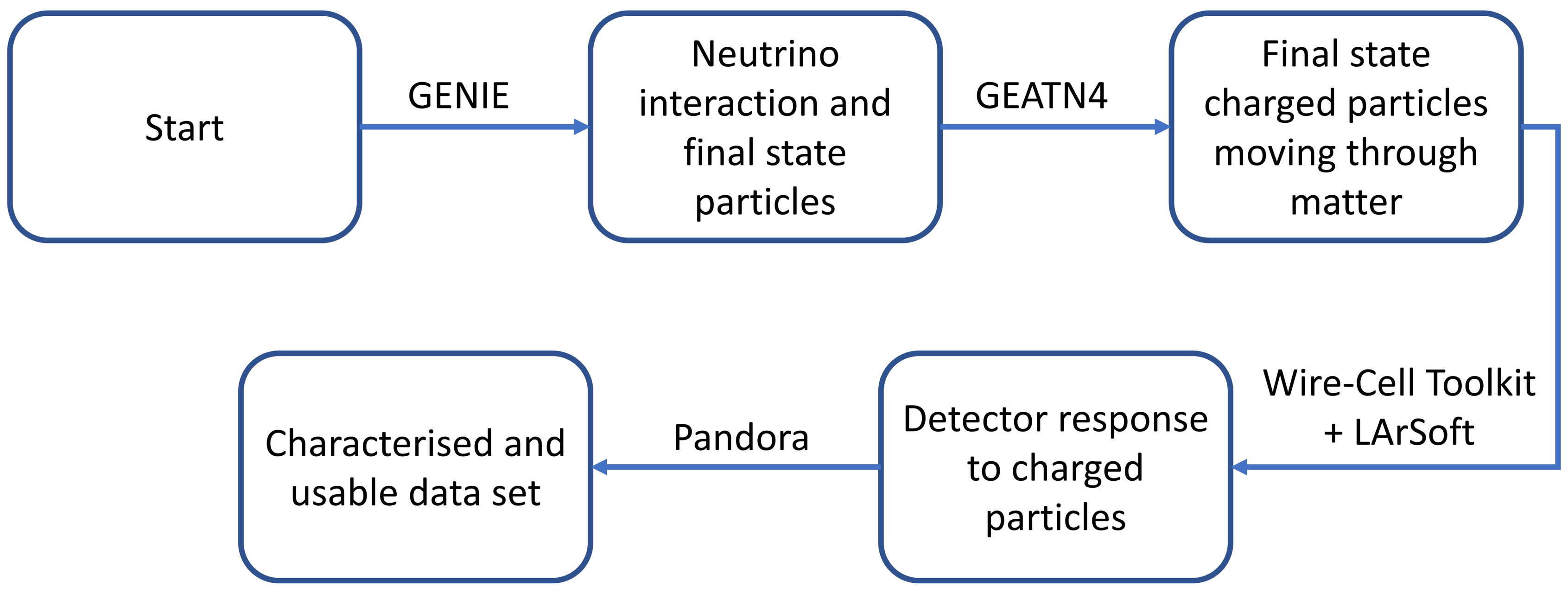
The Deep Underground Neutrino Experiment (DUNE) (1) has created a need for new approaches in the characterisation of neutrino interaction final state particles and this poster presents details on how this has been tackled. This poster contains:

- A description of model data used and interaction topologies.
- Variables used to separate final state particles.
- The effectiveness of particle characterisation.

II. Data Generation and Usage

The data generation process follows a series of steps:

- GENIE (2) is used for generation and simulation of neutrino interactions.
- GEANT4 (3) is used for the simulation of charged particles moving through matter. This is used to simulate how the final state particles of a neutrino interaction propagate through a Liquid Argon Time Projection Chamber.
- A combination of Wire-Cell Toolkit (4) and Liquid Argon Software (LArSoft) (5) are used with the data from GEANT4 to simulate a detector response.
- The detector response is processed by Pandora (6), a pattern recognition software which collects the detector signal into Particle Flow Objects (PFOs) which correspond to topologies induced by certain particles.



III. Event Topologies

The final state particles fall into one of two topologies: shower or track. In Figure 1 the proton and electron represent typical track and shower topologies respectively. Figure 2 shows a shower induced by a photon, which differs from the electron by the gap between the beginning of the shower and the neutrino interaction vertex. Separating between the electron and photon showers poses a difficulty in characterisation of final state particles.

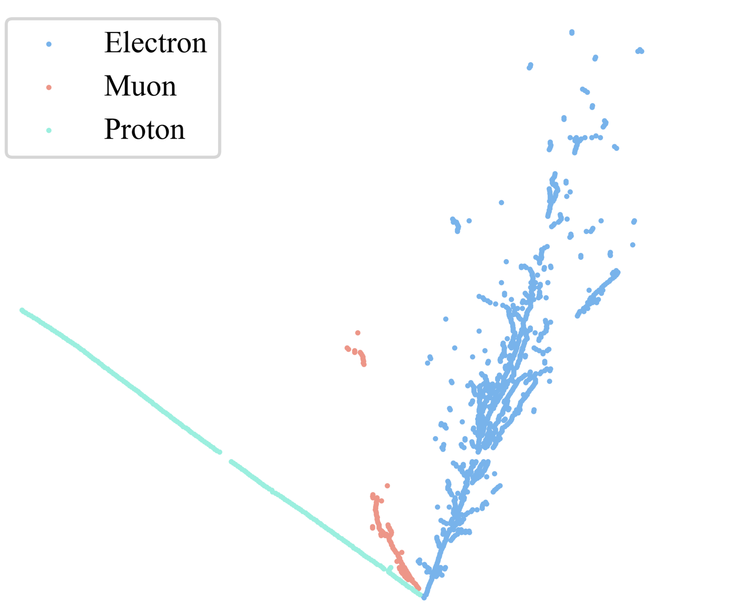


Fig. 1: A diagram of a typical event. The electron shows a typical shower topology. The proton shows a typical track topology. The muon demonstrates the issue when a particle has no clear topology.

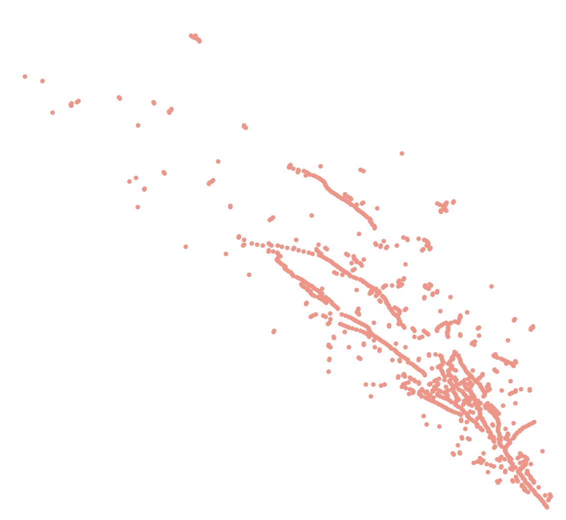


Fig. 2: A diagram of a typical photon PFO. The black point on the plot represents the neutrino interaction vertex.

IV. Separation Variables

Three variables were used for track and shower separation:

- The ratio of energy deposited by a PFO in the final 25% of its travel and the total energy deposited, see Figure 3.
- The sum of the line integral between hits in a PFO normalised by the number of hits.
- The distribution of angles between neighbouring hits in a PFO.

Three variables were used for photon and electron separation:

- The separation between the neutrino interaction vertex and PFO vertex.
- The rate of change of energy deposition in the first 5cm of the PFO, see Figure 4.
- The fraction of total energy deposited in the first 5cm of the PFO.

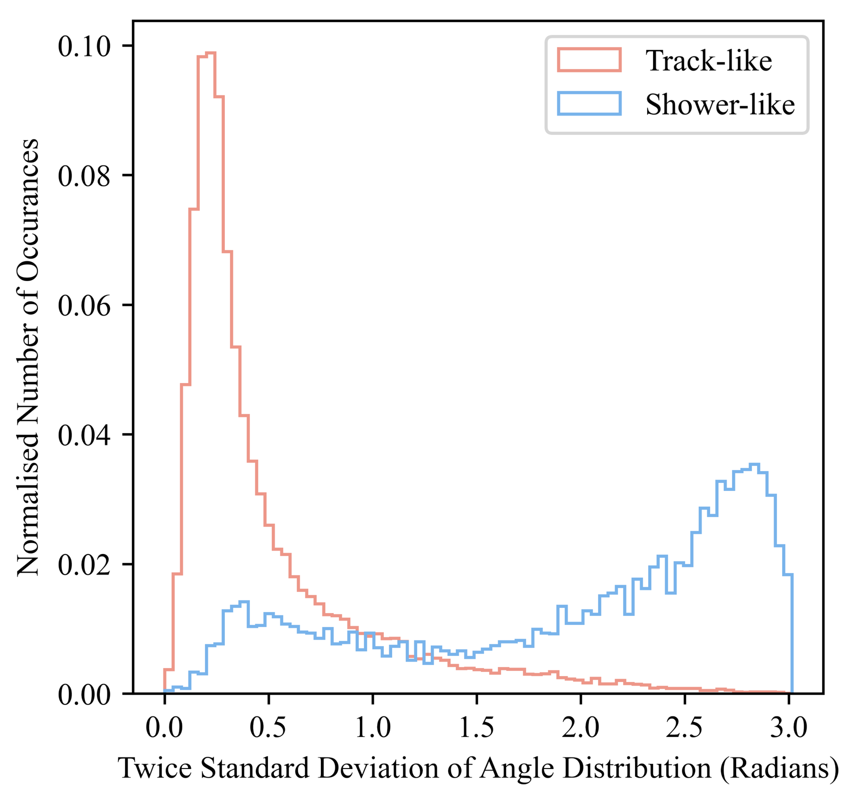


Fig. 3: Plot of the angular distribution variable for showers and tracks.

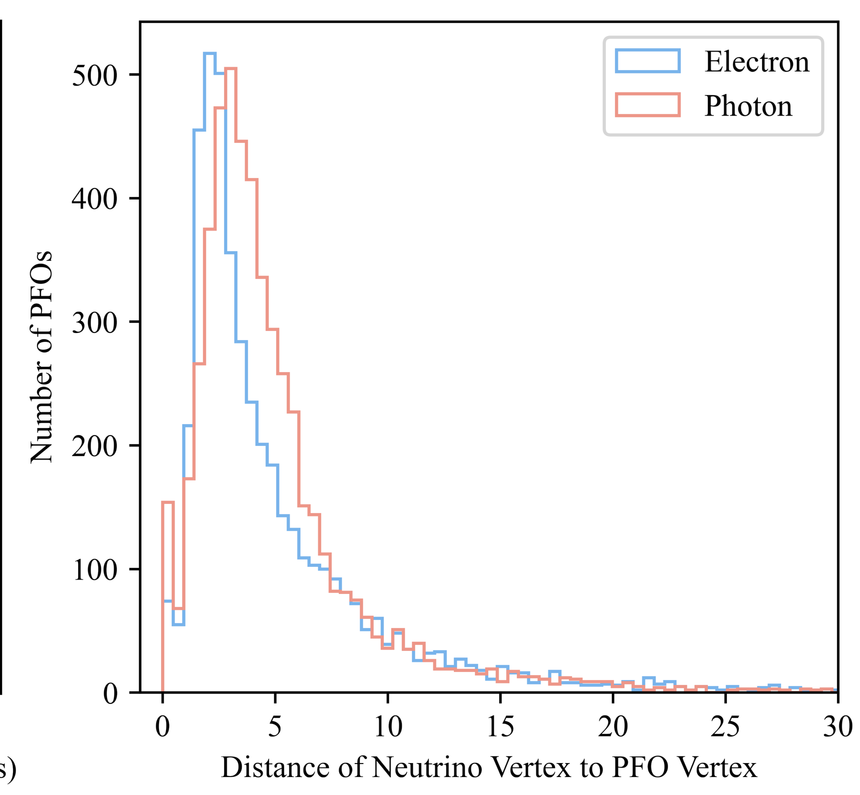


Fig. 4: Plot of the rate of energy deposition variable for electrons and photons.

V. Event Separation

Two boosted decision trees (BDTs) where used in combination with the separation variables in order to characterise showers and tracks, and to characterise electrons and photons resulting from a neutrino interaction as seen in Figures 5 and 6.

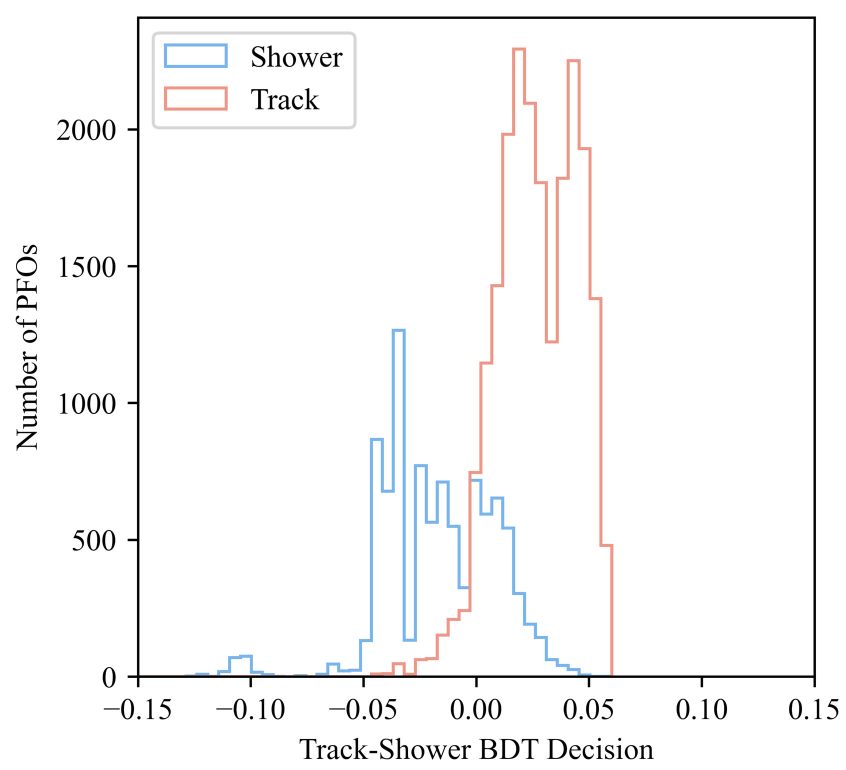


Fig. 5: Plot of the BDT decision function for track and shower PFOs.

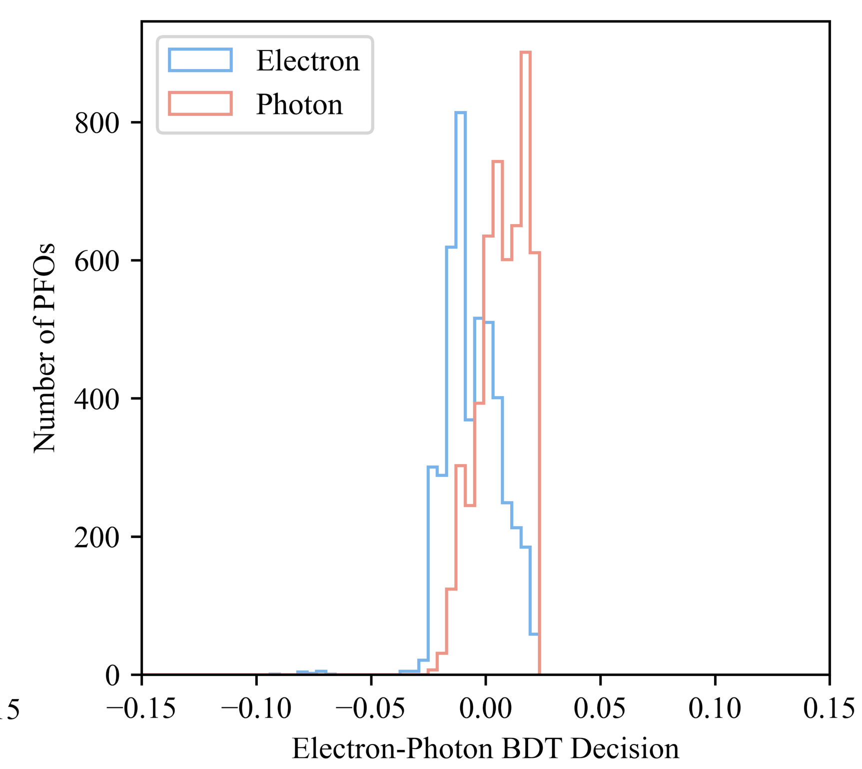


Fig. 6: Plot of BDT decision function for electron and photon PFOs.

The overall effectiveness of differentiating between showers and tracks was 87.2$\pm$0.2% while between electrons and photons it was 70.1$\pm$0.5%. With such an efficiency the variables used have been shown to be a valid method of final state particle characterisation.

VI. Future Work

- Test the effectiveness of the separation variables by re-generating the data set with the detector wire currents distorted by a large uncertainty value.
- After successful separation of showers and tracks, and electrons and photons, determine whether events are neutral or charged current interactions to investigate Charge-Parity violation.

References

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