Segmentation Neural Networks for Particle Identification in ProtoDUNE

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ProtoDUNE-SP Detector

The ProtoDUNE single-phase (SP) detector is the prototype of the DUNE far detector SP technology built with full scale components at the CERN neutrino platform. With a total liquid argon mass of 0.77 kt it is the world largest Liquid Argon Time Projection Chamber (LArTPC) built to date. The TPC consist of a central Cathode Plane Assembly (CPA) held at 180kV that is flanked by 6 Anode Plane Assemblies (APAs) at a distance of 3.6m. Each APA is 6 m long x 2.5m wide and contains a set of three planes of sense wires (tow collection planes and one induction plane) oriented at different angles.

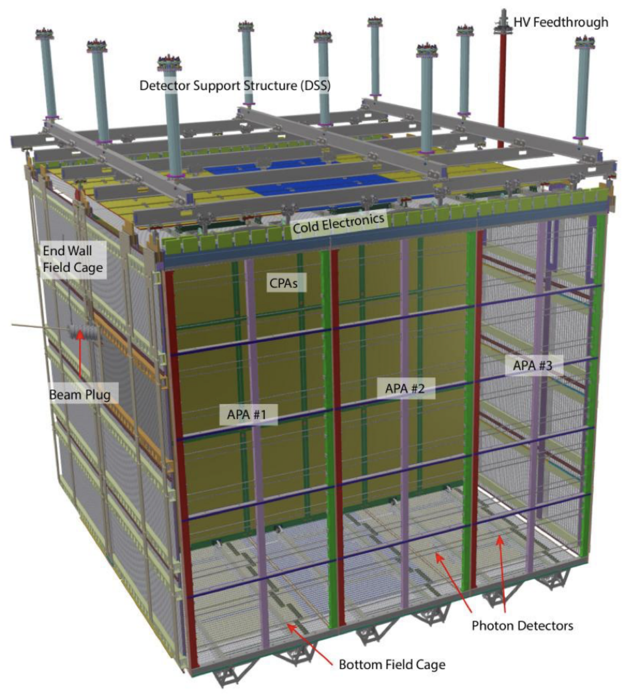


Fig. 1: Illustration od the ProtoDUNE-SP detector

Semantic Segmentation

We apply sparse CNNs for semantic segmentation at a pixel level using simulated event displays in two and three dimensions in the ProtoDUNE (LArTPC) detector. We use a hybrid network of two popular architectures that are U-Net and ResNet. U-Net is an auto-encoder made of two parts where the first part applies a series of convolution blocks that reduces the size of the feature maps and learns important properties of the image at different scales. The second part applies a series of up-sampling operations and convolutions to recover the original resolution of the image. Based on ResNet architecture, we allow residual skip connections that speed learning.

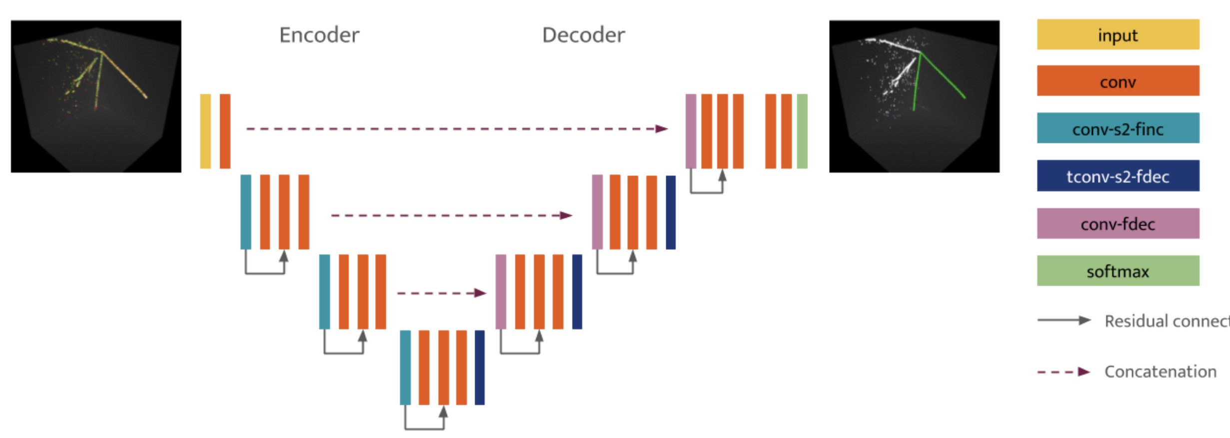


Fig. 2: Illustration of the UResNet architecture, figure from [1]

Ground Truth

The performance of any machine learning model is limited by the quality of the definition of the ground truth. In this case the ground truth is a tensor that holds the true information of the different types of particles present in each pixel (or voxel for the 3D case) of an event display.

In order to define the ground truth, we use the information from the underlying simulation such as the PDG code of the particles, the track ID, the process name and the amount of energy deposited by each particle per pixel (or voxel). The different particle classes used in our training are: Mouns, pions, heavily ionizing particles (such as protons, kaons and nuclei), Michel electrons, electromagnetic showers, and diffuse electromagnetic activity. Then we record the fraction of energy deposited by each type of particle per pixel.

Results

We trained a sparse CNN for particle identification using a set of 70.000 3D reconstructed samples that we split into 95% and 5% for train and test respectively. We calculated the accuracy of each particle class and we summarized those results in a confusion matrix. Moreover, we tested the capability of the neural network to correctly separate pions and protons.

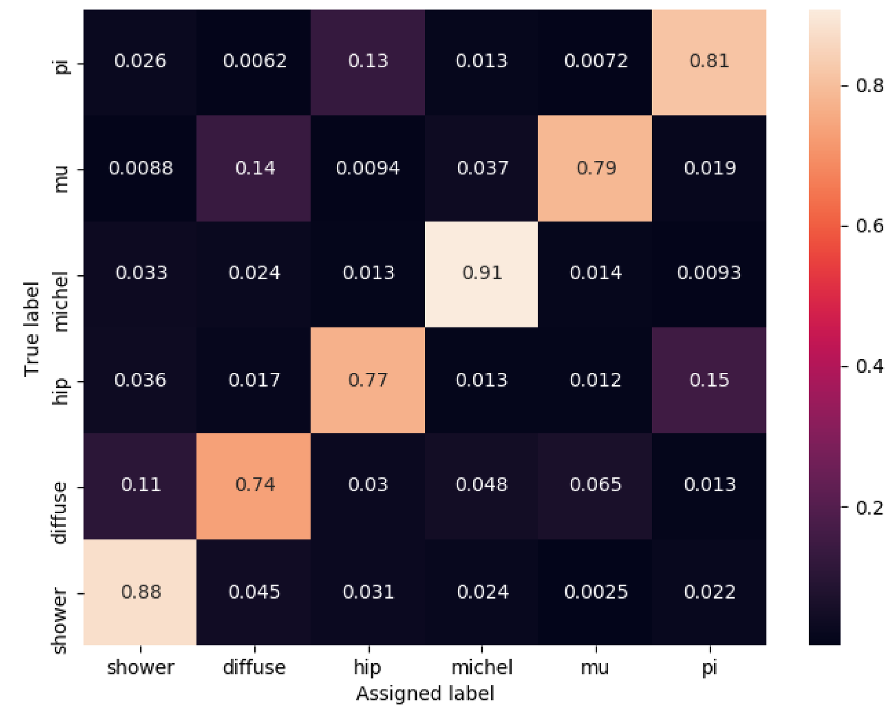
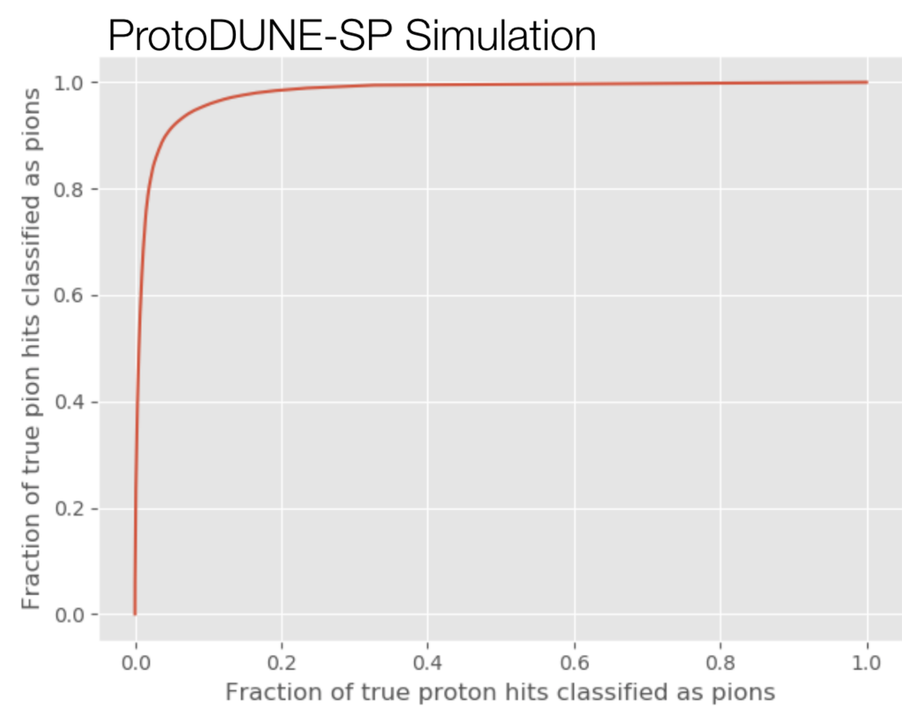


Fig. 3: Confusion Matrix.



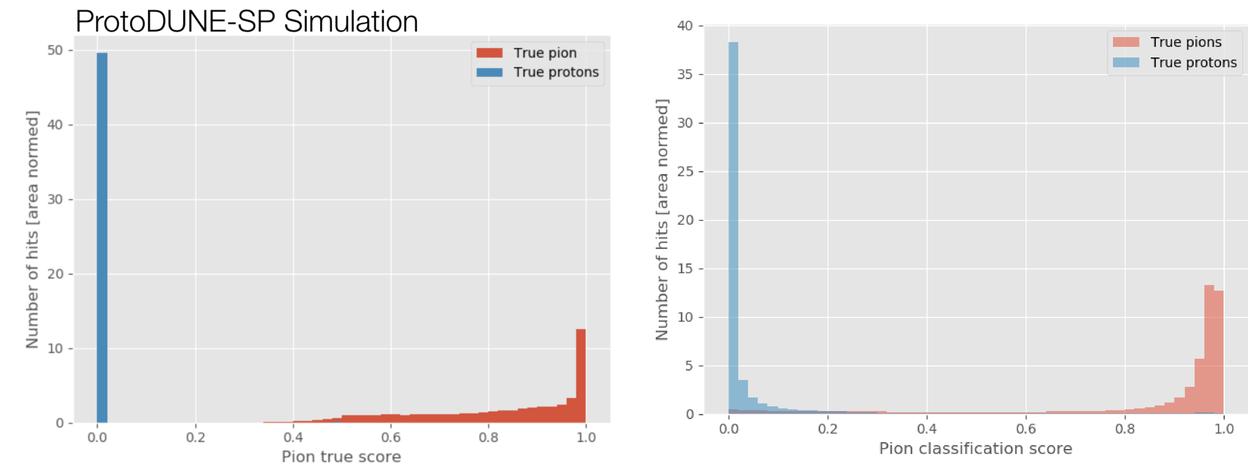


Fig. 5: True and classified scores for pion and proton separation.

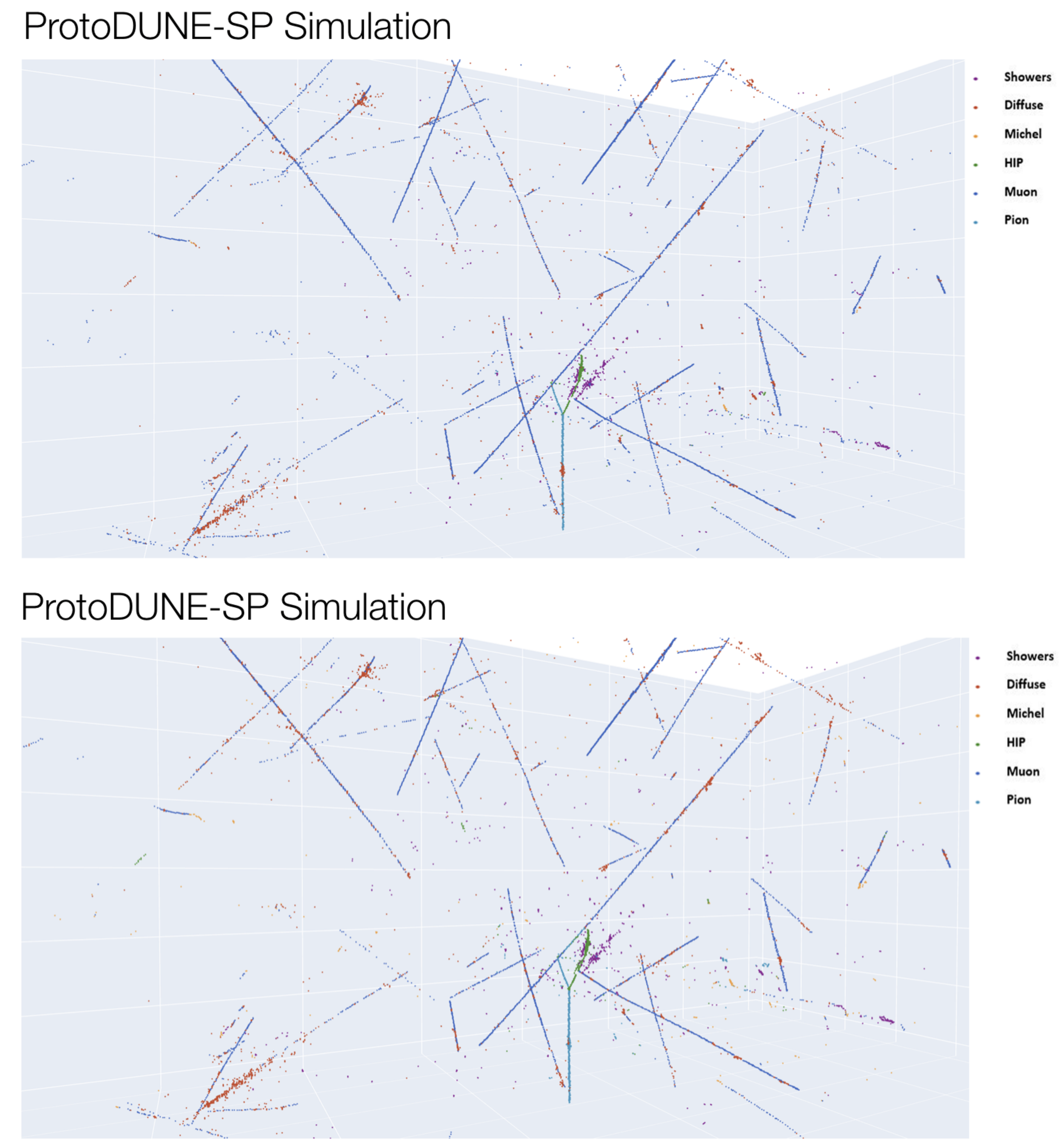


Fig. 6: The figure in the top represents the true labels. The figure in the bottom shows the classified labels

Status and Future Plans

- These results show a very good performance of the network for the task of semantic segmentation at a pixel level, they also show that pions can be well separated from protons.
- We plan to train the network using single particles dataset.
- Test the capability of the network to separate electrons and photons as well as muons and pions.

References

[1] Laura Domine and Kazuhiro Terao. "Scalable Deep Convolutional Neural Networks for Sparse, Locally Dense Liquid Argon Time Projection Camber Data". In: *arXiv:1903.05663* (2019).