Some Results on NuGraph Tau Neutrino Identification

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Motivation

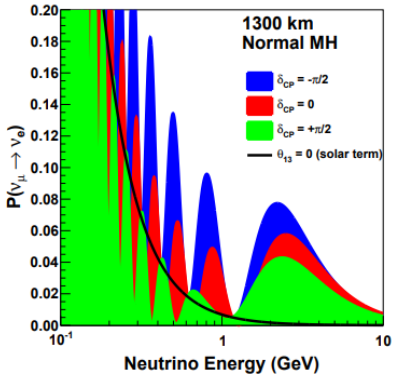
The DUNE far detector is at a baselin of 1300km, this puts the first oscillatio maximum at about 2.5 GeV and the second at just under 1 GeV.

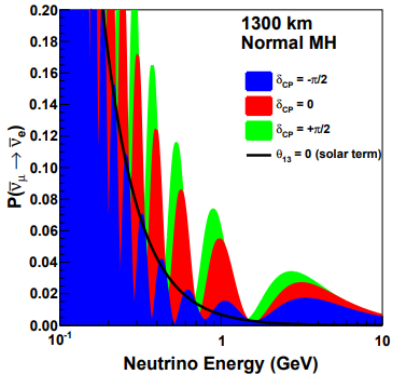
The DUNE beam has been optimized so that the largest flux is around this first oscillation maximum.

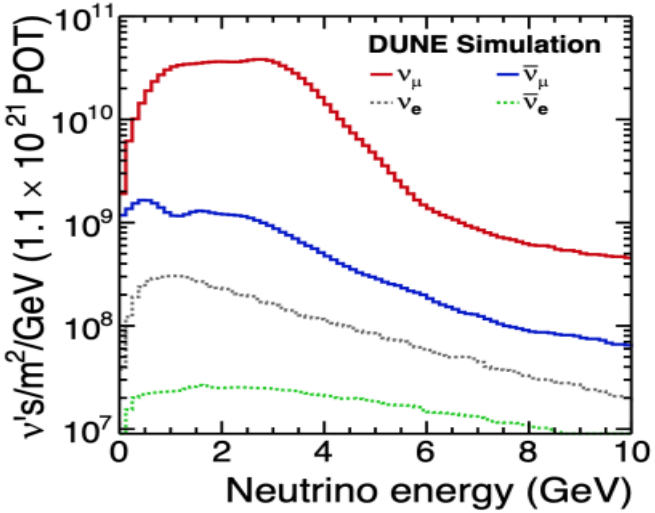
This is useful for us because almost all of the muons disappear here but almost none oscillate to electron neutrinos.

The natural assumption is that they are oscillating into tau neutrinos.

Could also be more physics (sterile neutrinos non unitarity ect).

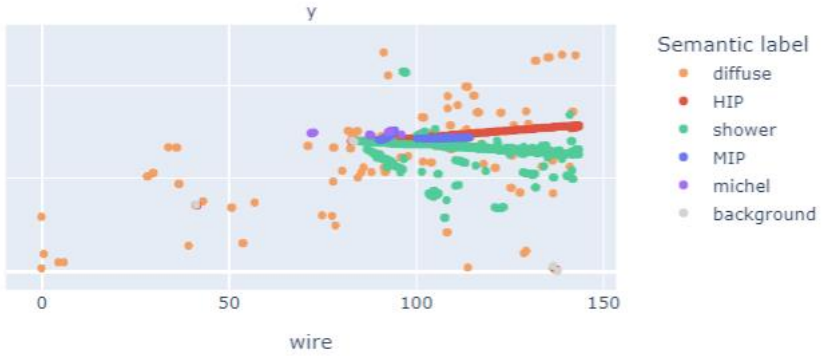


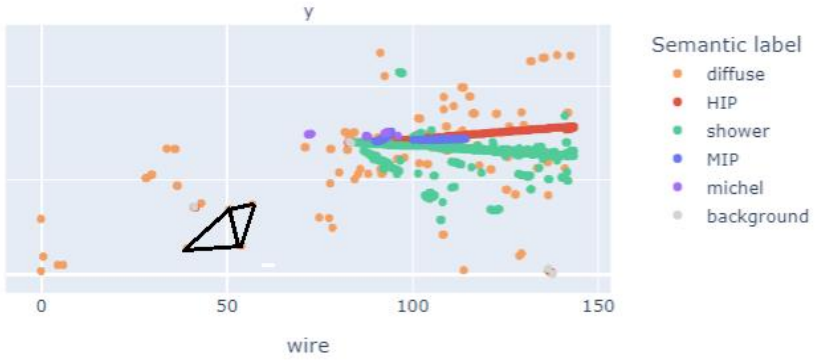




NuGraph

- The NuGraph neural network is a graph neural network that was developed by the exatrkx collaboration which adapted a similar network that was used for identifying jets in collider experiments.
- The neural network uses a simple architecture first there is a categorical embedding layer then a message passing nexus layer and finally a attentional aggregation decoder layer.
- The message passing layer allows context to be shared between hits (allowing for example to differentiate between electrons that are part of a shower and primary electrons).
- We have also added DUNE specific features to the network (the TPC id and drift direction).





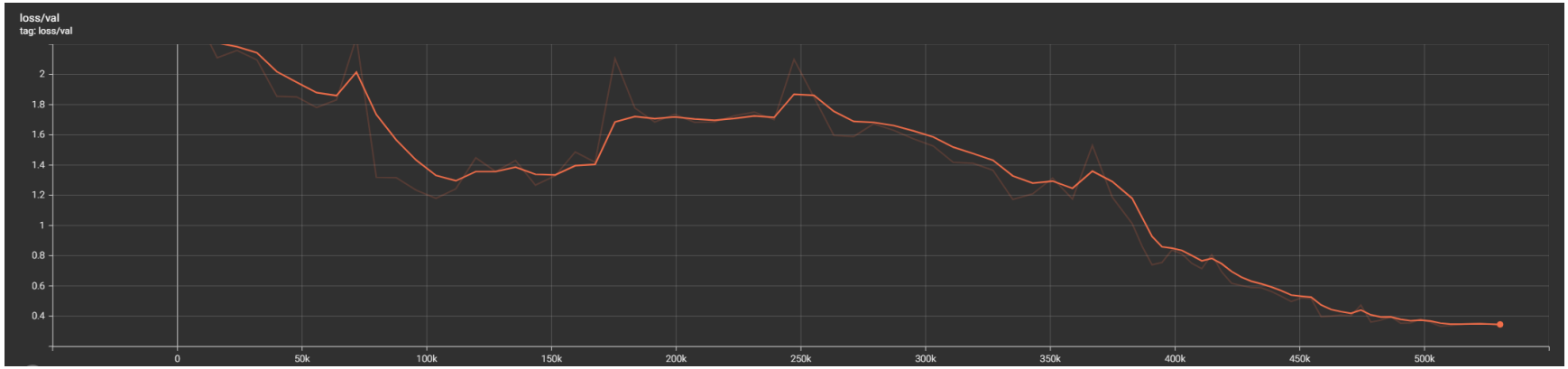
Our Sample

- So we have made our own MC sample initially this was 600k events muons with 200k each flavour swapped to tau neutrinos and electron neutrinos.
- We have now archived these and stored them on tape because we are making a bigger sample which rather than just being flavour swapped will be split evenly between cc_nue cc_numu cc_nutau and nc events based on our testing this will improve the training.
- We also are doing this on the cedar cluster because we have the most resources there for this.
- For purposes of analysis approval it might be good to have these on Fermilab computers somewhere (I don't really use them).
- I was previously told NOT to upload them there but I don't really know what do for this.
- All of our samples were made in the same way with the usual DUNEsw v09_77_00d00 the only changes from the standard fcl files were to add the full EM truth record for the showers.

NuGraph Training

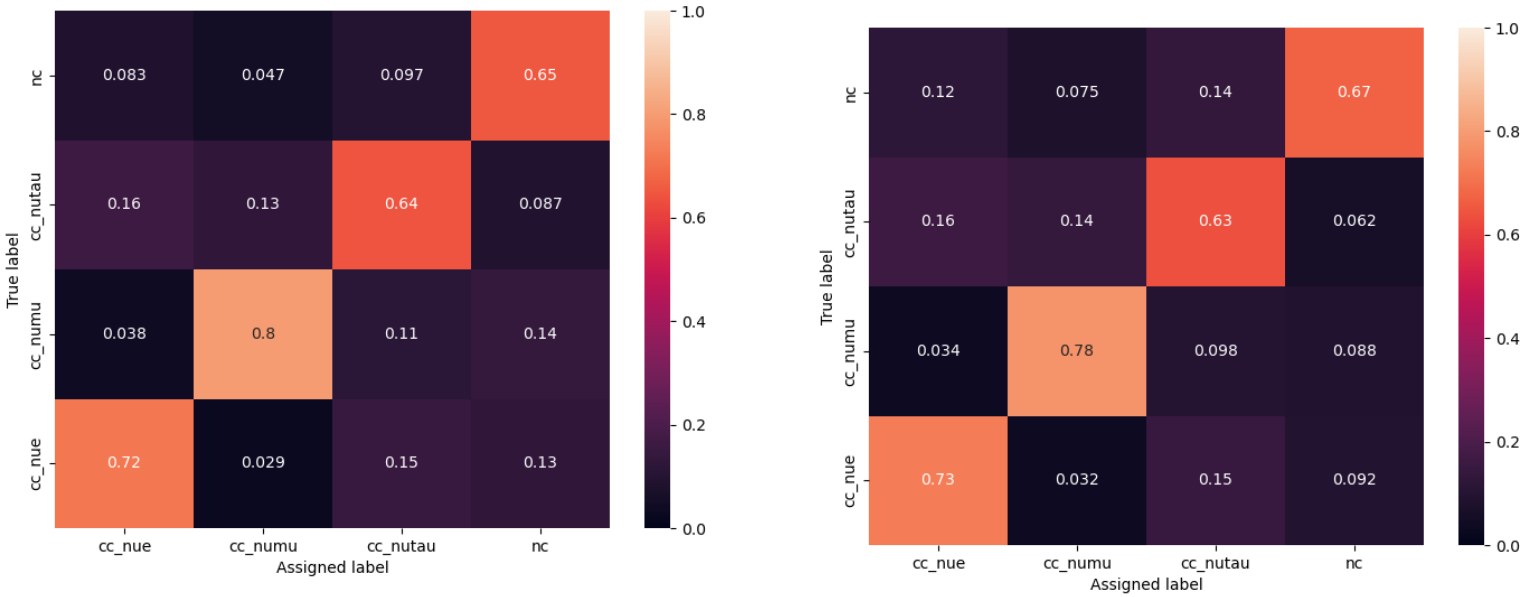
- We have generated 600k events in total 200k from muon neutrinos 200k from tau neutrinos and 200k from electron neutrinos.
- Because we were naïve and using the standard fcl files we had only about 30k charged current tau events total.
- Reduced the total to ~120k events about 1/6 of the initial sample to have roughly 30k of each of the four type of interactions.
- This vastly improved the training despite the reduced amount of data for training
- Going forward we have learned from this and have made a new sample that has the interaction type selected at the GENIE level so there are 250k now of each type for the four interaction types for a total of 1M events.
- We are currently processing these into graphs to prepare them for training but this is taking some time so we are doing a preliminary analysis with the training we have already done.

Training Performance



The training occurred over one month and got stuck for a bit but then got significantly better.

Confusion Matricies



Left: Confusion matrix for the precision. Right: Confusion matrix for the recall.

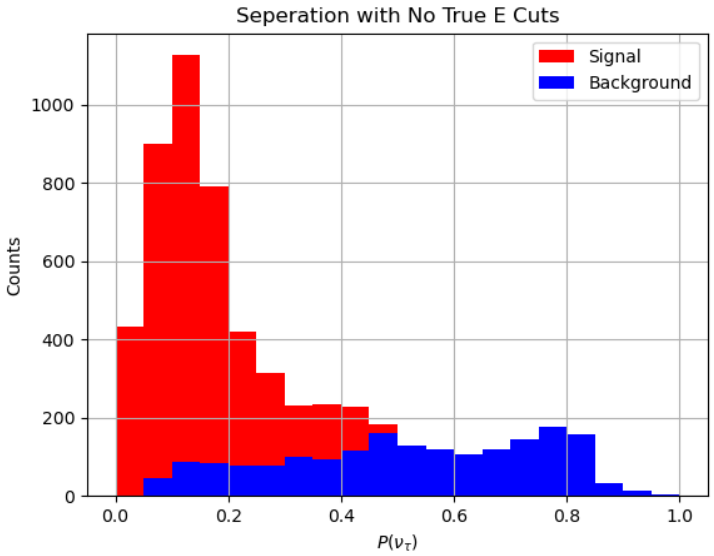
- Overall performance is good but can be better with more samples which is why we have made more samples.

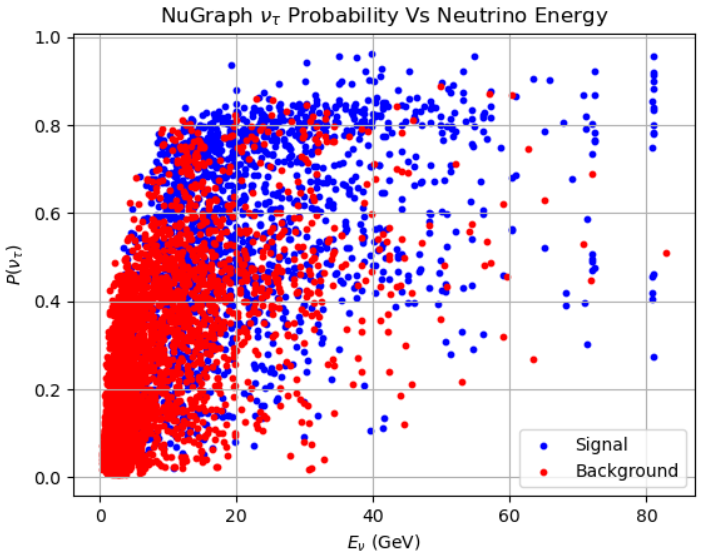
Preliminary Analysis

- We used the NuGraph network to classify the events in the validation sample as a mock data sample to get some preliminary results.
- The train/test/validation sample is selected randomly from the sample in a proportion of 90%/5%/5%.
- Thus our validation sample has roughly 6k events evenly distributed between the four interaction types.
- This represents obviously a very high event rate for the tau neutrino interactions and so we can normalize the event rates to more them more realistic for the DUNE far detector.

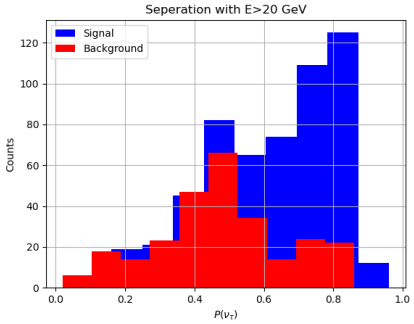
Our Results

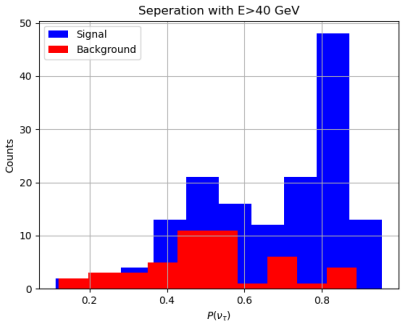
Separation with all of the validation sample and the probabilities as a function of energy

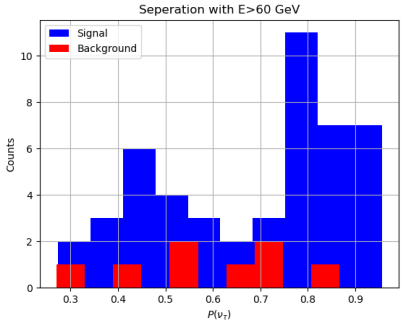




Separations with True Energy Cuts

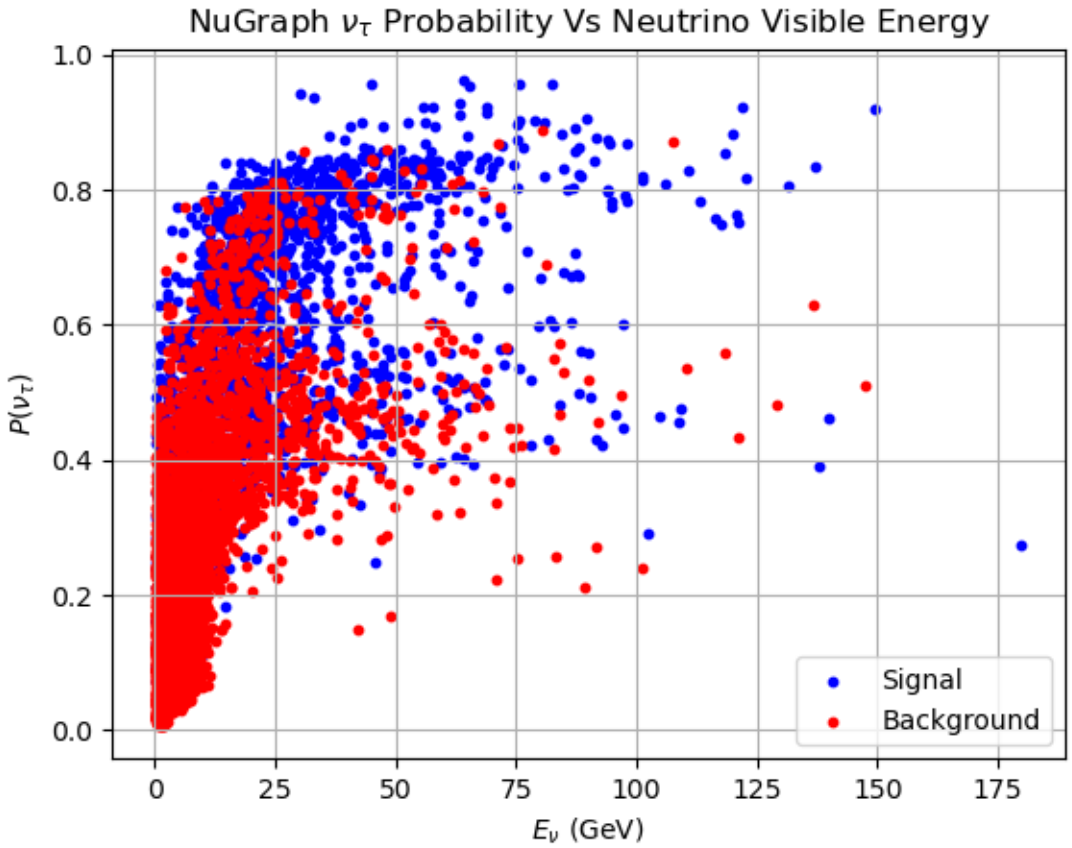






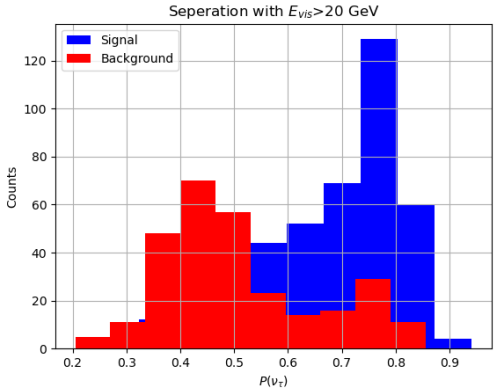
- As we make energy cuts the performance of the classifier gets worse.
- Most likely because there are fewer high energy events for the classifier to learn from.

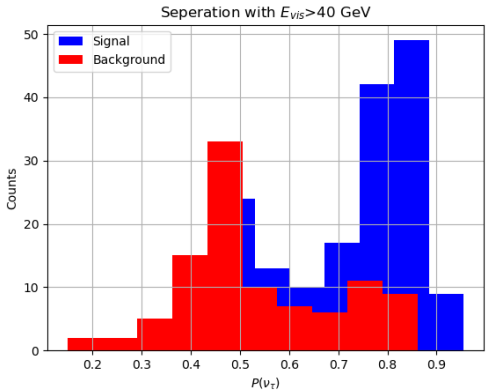
“Visible” Energy (Wrong)

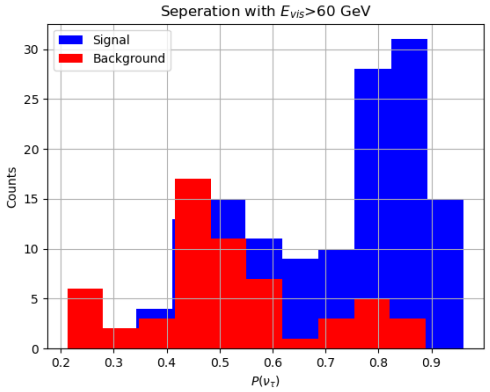


- We can do the same thing with the visible energy.
- Trend is much the same as in the true energy case.
- Note that the scale on the x-axis is wrong because I am multiple counting some energy deposits but I am fixing this now.

Separation with Visible Energy Cuts







- Very similar story when we look at the distribution as a function of the total energy in the hits (this is an actual variable that NuGraph has access to)
- This to me confirms that it is the lack of high energy events that causes the classifier to get worse at higher energies.

Thanks for Your Attention!