Neutrino Energy Reconstruction in NOvA
Andrew Sutton (atcsutton@gmail.com)
for the NOvA Collaboration
53rd Fermilab Users Meeting

The NOvA Experiment
- Long-baseline neutrino oscillation experiment utilizing the Fermilab NuMI beam
- Observing $\nu_\mu$ appearance and $\bar{\nu}_\mu$ disappearance

- Two functionally identical segmented liquid scintillator calorimeters
  - Low-Z material (mineral oil, PVC)
  - 6X cell depth ~ 1 radiation length
- Utilize both track length and calorimetric information to estimate neutrino energies
- More precise fits by utilizing spectrum shape. Requires good energy resolution

Particle Identification (PID)
- Convolutional Visual Network (CVN)
  - Event maps are input to a convolutional neural network
  - Convolve the event maps with various filters to extract features
  - Identify event and particle types based on event topology

- Combine with traditional BDTs to reject cosmics and identify muons

$\nu_\mu$ Energy Estimation
- Muon energy:
  - Spline fit to track length
  - Energy resolution ~ 3%
- Hadronic energy:
  - Sum calorimetric energy of hits not associated with muon track accounting for possible overlap
  - Spline fit to calorimetric energy
  - Energy resolution ~ 26%
- Yields an overall neutrino energy resolution of ~ 9%

$\nu_e$ Energy Estimation
- Simulated flux is peaked at about 2 GeV
- Re-weight events to a flat flux to avoid bias

$E_\nu = A \cdot E_{EM} + B \cdot E_{Had} + C \cdot E_{EM}^2 + D \cdot E_{Had}^2$
- EM (e, $\gamma$, $\pi^0$, etc) and hadronic (p, $\pi^\pm$, etc) particles have different detector responses
- Use CVN-PID to separate particle types

$\nu_\mu$ Energy - In Development
- Relying only on the track and remaining calorimetric energy may miss important information
- Recurrent neural networks (RNNs) can utilize more information and expand to a variable number of particles

Sequential inputs
Sequential outputs

$\nu_e$ Energy - In Development
- Feed event images into a CVN with a linear regression applied to the output layer to estimate event energy

- Minimizes dependency on “classical” reconstruction
- Shows better performance