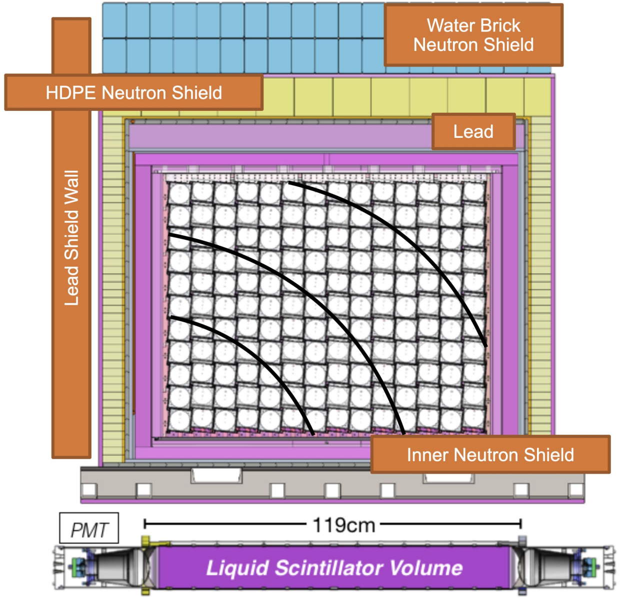
Machine Learning Analysis of PROSPECT Data

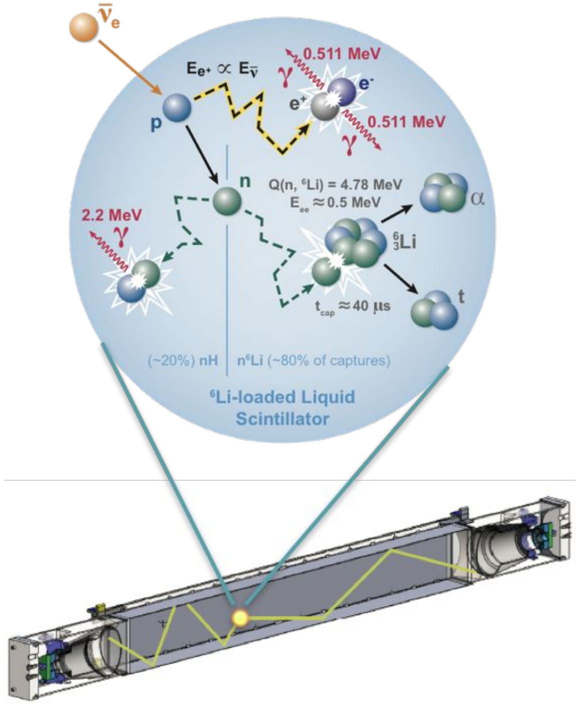
Blaine Heffron

On behalf of the PROSPECT collaboration

PROSPECT Overview

PROSPECT took data at ORNL's High Flux Isotope Reactor from 2018-2019. It is a highly enriched uranium reactor with a compact core





14 x 11 array of 6Li doped liquid scintillator for detecting inverse beta decay from reactor antineutrinos (6m from compact highly enriched uranium reactor core)

Machine Learning Activities

- Particle identification using sparse convolutional neural networks
- Single ended event reconstruction
- Antineutrino energy and position reconstruction with deep networks

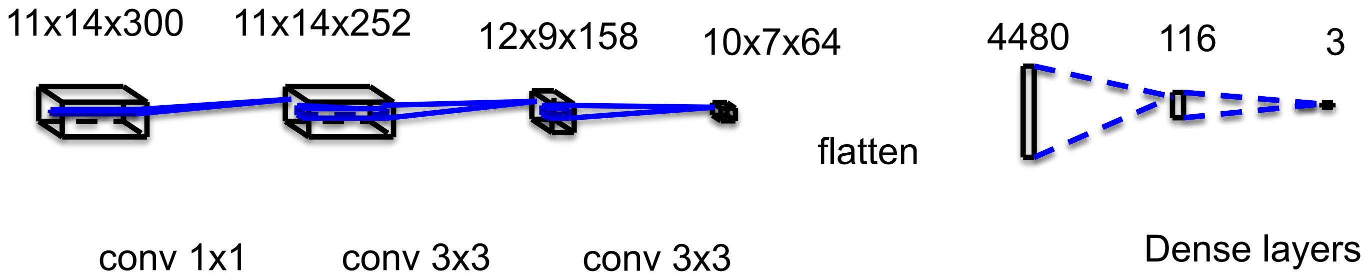
Convolutional neural networks with PROSPECT data

Convolutions are nxn windows consisting of trainable weights that move over the 14x11 segments of the detector

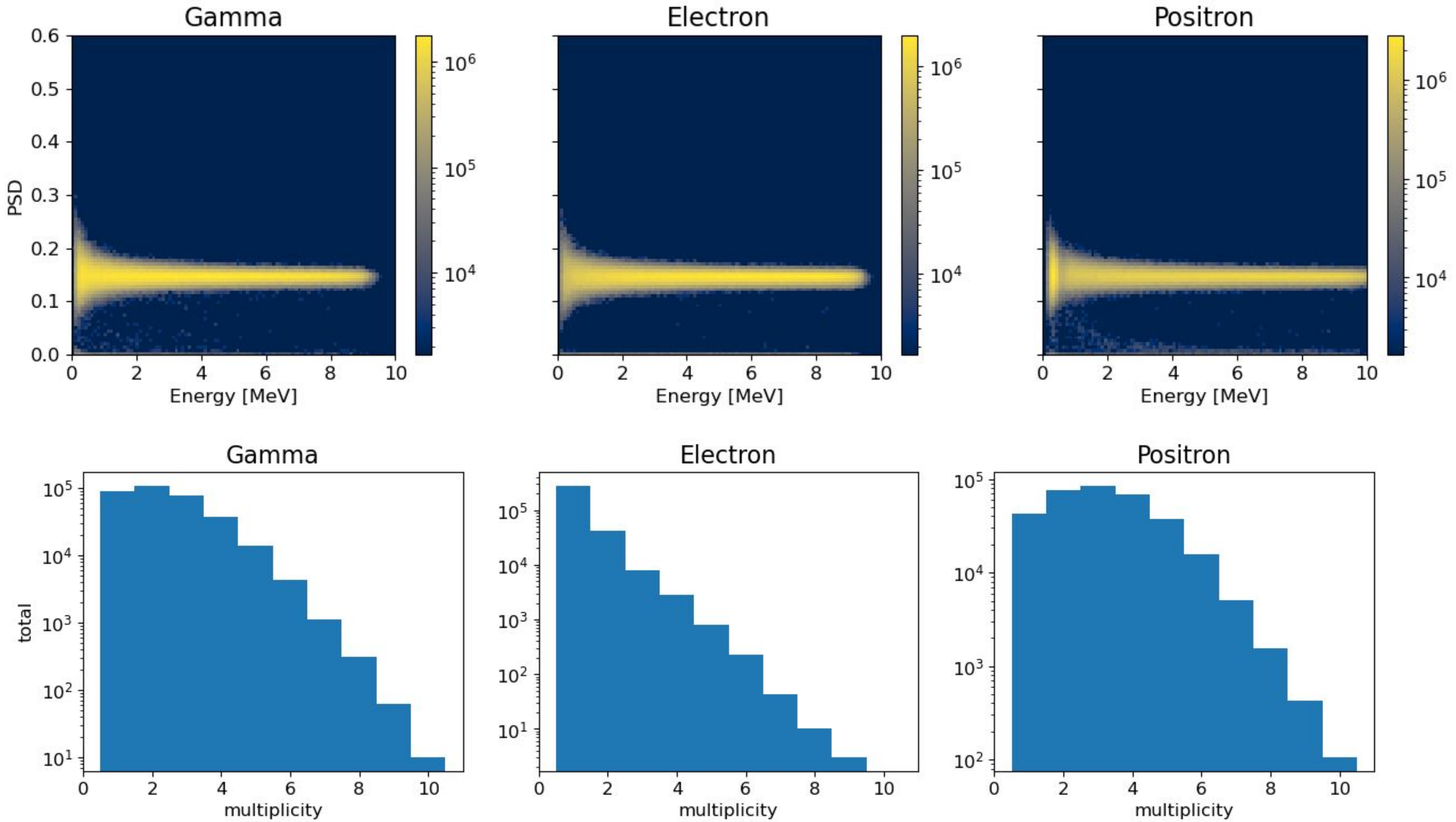
Each weight is multiplied with the physics quantities at each segment and summed together to form a transformed output

The final stage consists of “fully connected” layers used to transform the outputs into a classifier

2 models - one with calibrated physics quantities (energy, timing, position, pulse shape), one with full waveform

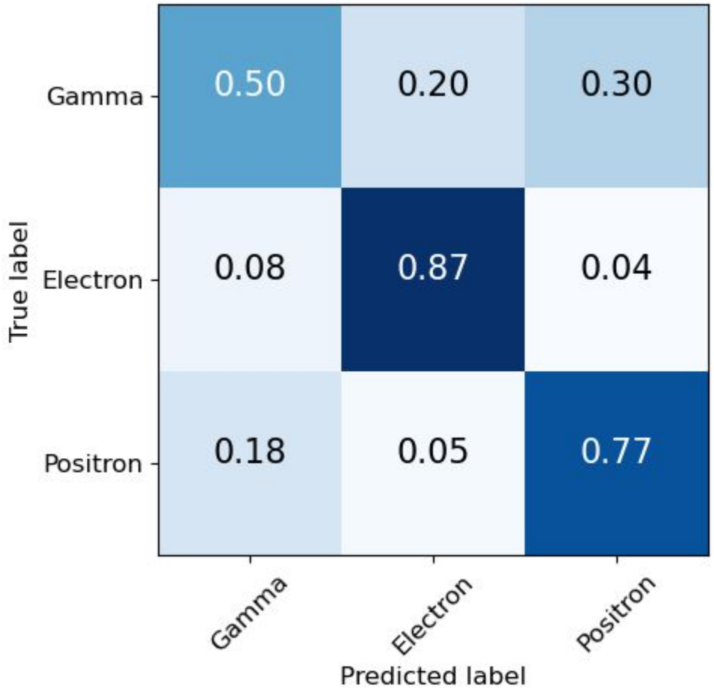


CNNs for Positron Identification - Test dataset (simulation)

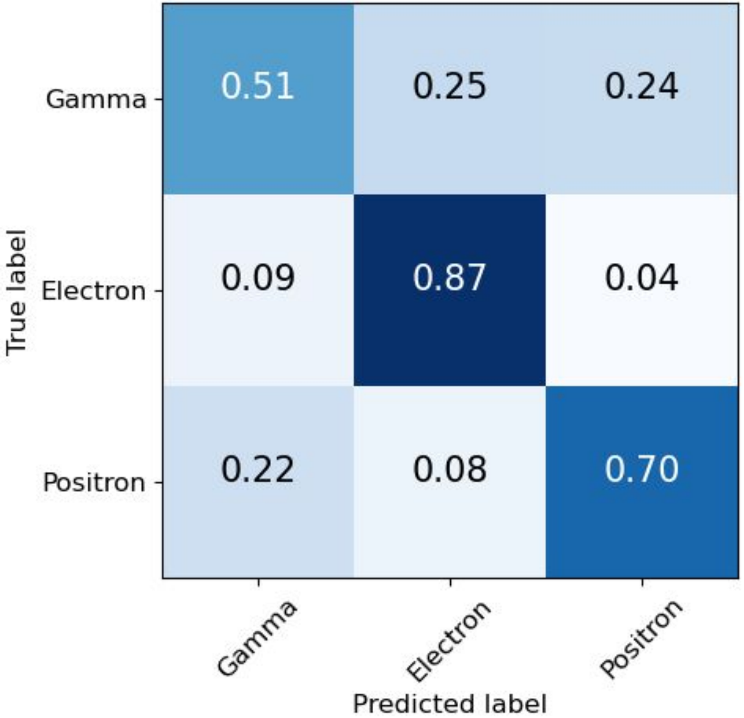


CNNs for Positron ID results (simulated data)

Waveform model

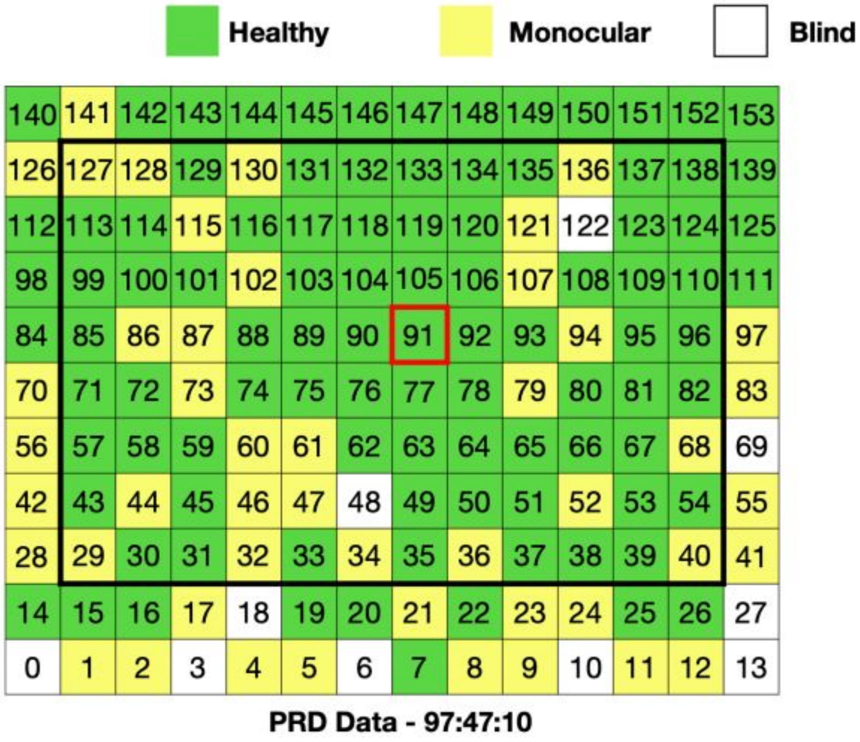


Calibrated Physics Quantities model



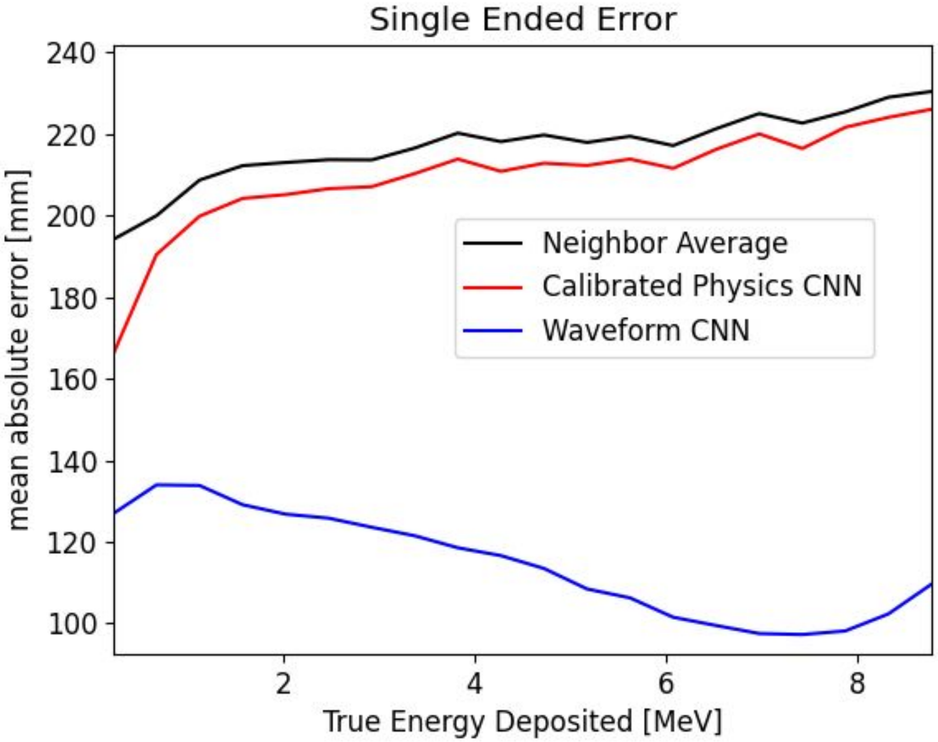
CNNs for single ended Z position reconstruction

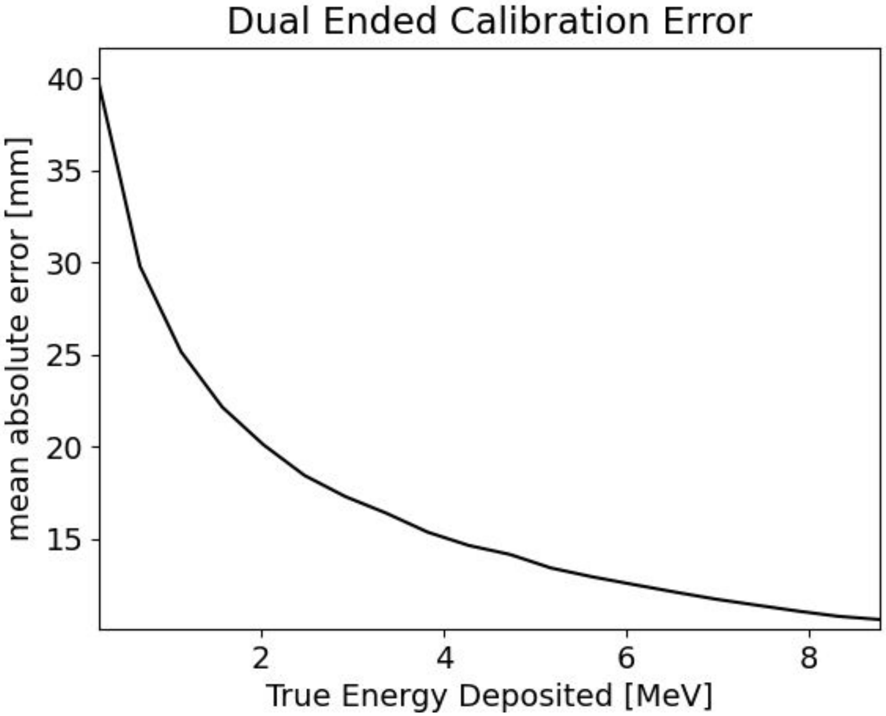
- Dataset is gamma, electron, and positron simulations (0-9 MeV, randomly distributed throughout detector volume)
- Neural network is only trained on Single Ended segment predictions
- Network consists of series of pointwise (kernel size = 1) and 3x3 convolutions with padding set to 1 to obtain z predictions for each cell
- Train weights by minimizing the single ended z position error based on simulation true z position



PhysRevD 103 (2021) 032001

Z position reconstruction results



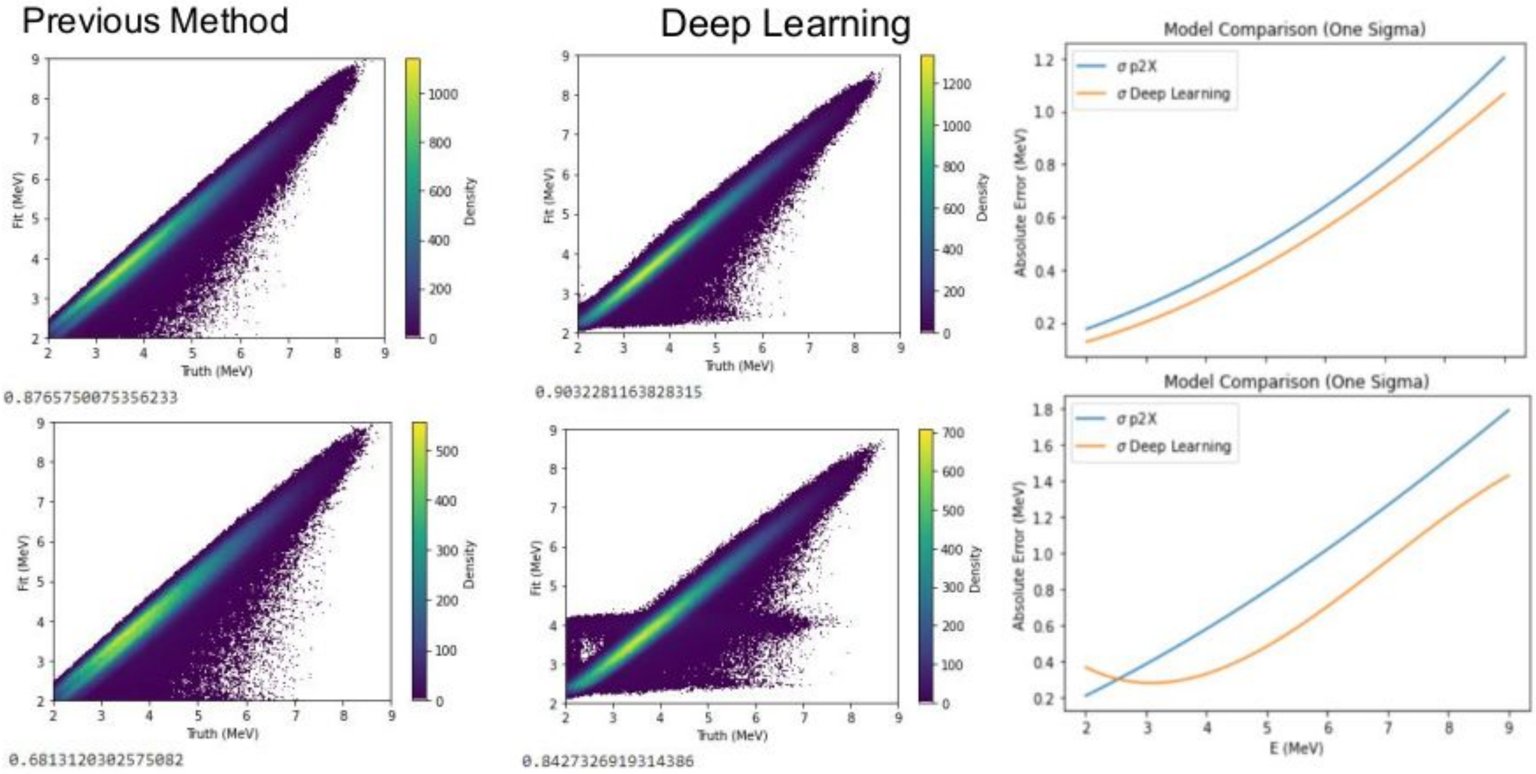


Simulated IBD Energy Reconstruction (work in progress)

Idealized Detector

rsquared

Fiducialized and Dead PMTS (PRD cuts)



- R-squared scores show an outperformance of fully connected neural net over traditional maximum likelihood estimate with **large gap** in performance for ‘non-ideal’ detector (except very low energies)
- Thin band artifact in middle bottom plot is not correlated with energy spectrum (shows up in both training with uniform or reactor spectrum) -likely related to dead neurons associated with poor events.

John Koblanski UH Manoa

Summary

- Neural network is able to distinguish between positron and gamma events; work is ongoing to apply this to current IBD selection
- There is some evidence that we can extract more information from the detector pulses for the purposes of particle identification and single ended position reconstruction
- Preliminary results from IBD energy reconstruction using neural networks is promising
- Work is ongoing to apply the models to real data

Thanks!

https://prospect.yale.edu/