A deep-learning based raw waveform region-of-interest finder for the liquid argon time projection chamber (LArTPC)

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FERMILAB-POSTER-20-086-ND-SCD-V

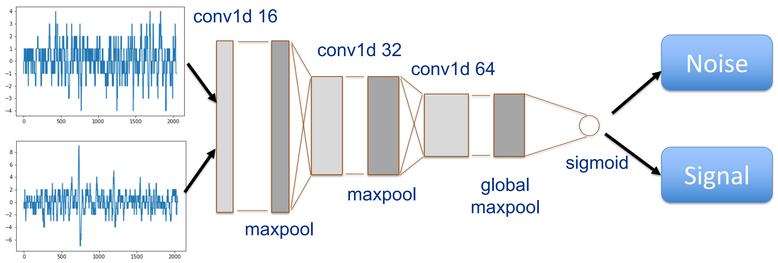
Introduction

- The LArTPC detector offers excellent spatial and energy resolution for the low energy physics.
- Extracting small signals from huge background becomes very challenging for low-energy phenomena.
- ArgoNeuT already shows the ability to reconstruct activity at the MeV scale in a LArTPC [1].
- An application of a 1D-CNN to the task of finding the region-of-interest (ROI) in LArTPC raw waveforms is considered and tested on the ArgoNeuT experiment.
- The 1D-CNN ROI finder shows promise in its ability to extract small signals and can be implemented in early stages of reconstruction as a very effective filter to remove noise. It offers great potential for low-energy physics, such as supernova, solar neutrino interactions, and some new physics scenarios [1-2].

[1] Phys. Rev. D 99 (1),012002 (2019), arXiv: 1810.06502
[2] Phys. Rev. Letters 124, 131801 (2020) arXiv: 1911.07996

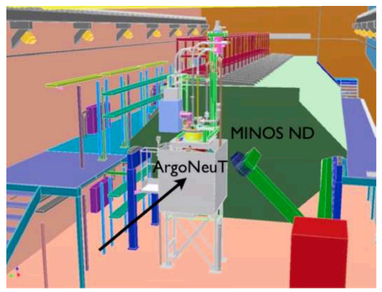
1D - Conventional Neural Network (CNN)

- This effort began by adapting 1D-CNNs used for analyzing cellphone accelerometer data to the analysis of LArTPC waveforms.
- After a successful proof-of-concept demonstration, the initial model was replaced with a more optimal design that was faster, more compact, and more accurate.
- Its capability as a simple classifier of signal vs noise waveforms was further expanded to permit the localization of the signal region within the waveform.



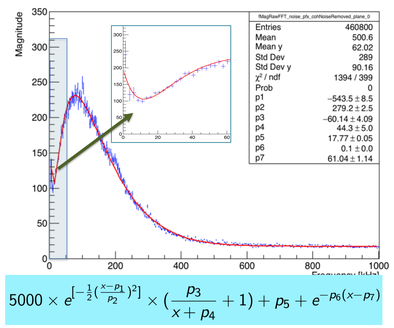
ArgoNeuT LArTPC

- Argon Neutrino Teststand detector located in front of MINOS near detector.
- 40×47×90 cm^3 [vertical, drift, horizontal (beam)].
- 240 induction wires and 240 collection wires; 2048 samples with 198 ns sampling time.
- Data taking in ν/ $\bar{\nu}$ mode in 2009-2010.

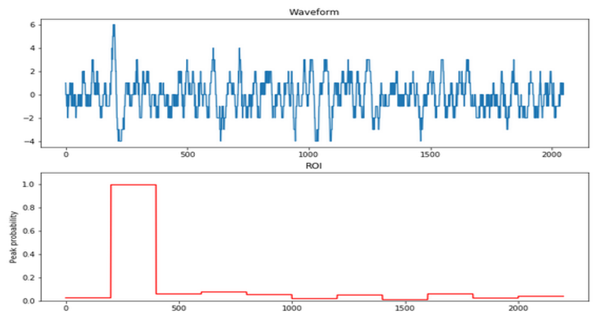


Data Driven Noise Model & Noise Removal

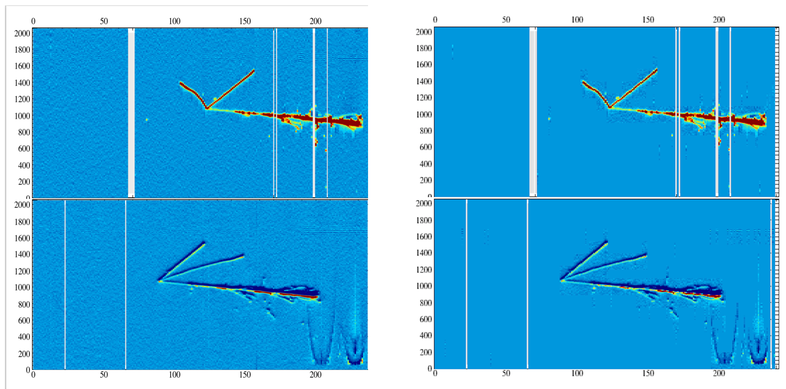
- Coherent noise removal was applied in order to study the data driven noise model.
- Perform an FFT on data noise and fit noise frequency to find noise model that can be used in simulation.



- Coherent noise removal is applied according to wire noise correlation.
- Adaptive baseline subtraction is used to remove noise from electronics and cable readout responses.

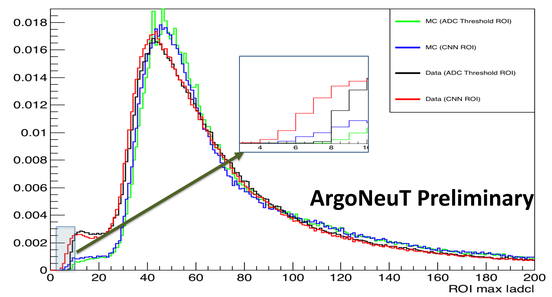


1D-CNN ROI Finder



- Event displays for ArgoNeuT run 806, subrun 1, event 19509: left after noise removal and right from 1D-CNN ROI.

Performance on Data and MC



- Traditional over threshold ROI finder is considered in order to check the performance of 1D-CNN ROI finder.
- 1D-CNN ROI finder shows comparable results and demonstrates better sensitivity for small signals.

Conclusions

- Encouraging results in the application of a 1D-CNN to the task of finding ROI in raw LArTPC waveforms using ArgoNeuT data are shown.
- The 1D-CNN shows a promising ability to extract small signals and offers great potential for low-energy neutrino physics.

This document was prepared by ArgoNeut collaboration using the resources of the Fermi National Accelerator Laboratory (Fermilab), a U.S. Department of Energy, Office of Science, HEP User Facility. Fermilab is managed by Fermi Research Alliance, LLC (FRA), acting under Contract No. DE-AC02-07CH11359.