Using deep learning techniques on hardware accelerators for particle identification studies on NP04

CERN openlab Technical Workshop

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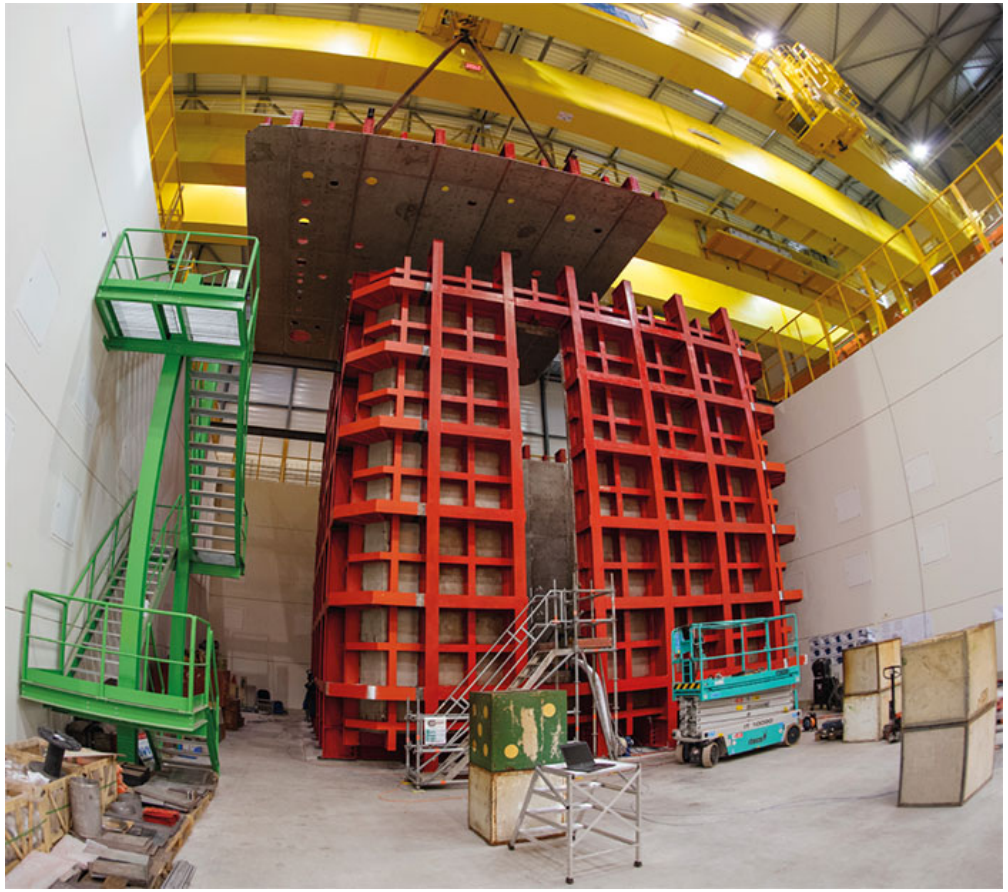
9 March 2021

WHAT IS NP04?

The protoDUNE Single Phase (NP04) experiment

- Prototype of a Single-Phase Liquid Argon TPC for DUNE
- 0.77 kt LAr: largest monolithic single-phase LArTPC detector [1]
- Goals:
  - Prototype the **production and installation** procedures
  - **Validate the design** from the perspective of basic detector performance
  - **Calibrate the response** of the detector to different particle species
  - Demonstrate the **long-term operational** stability of the detector

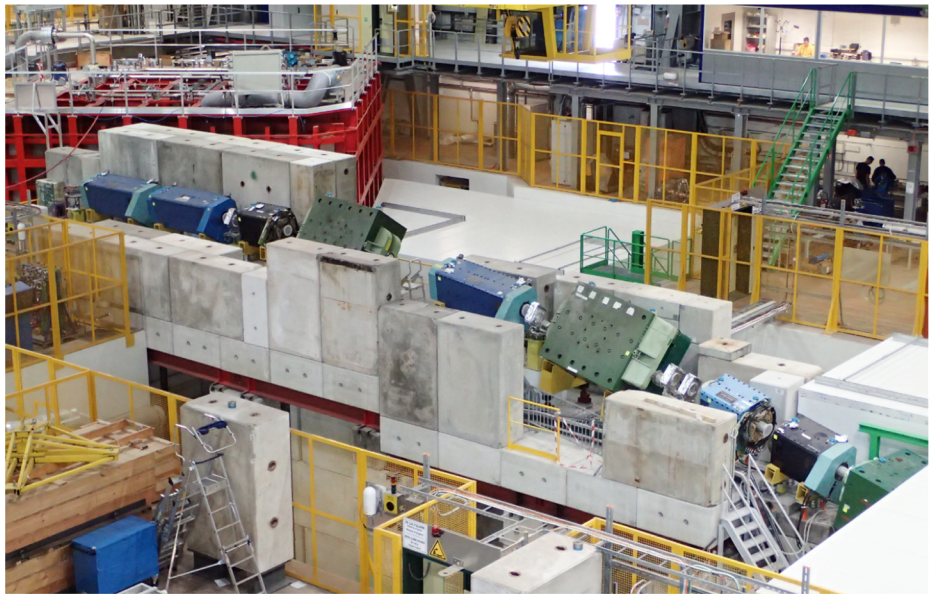


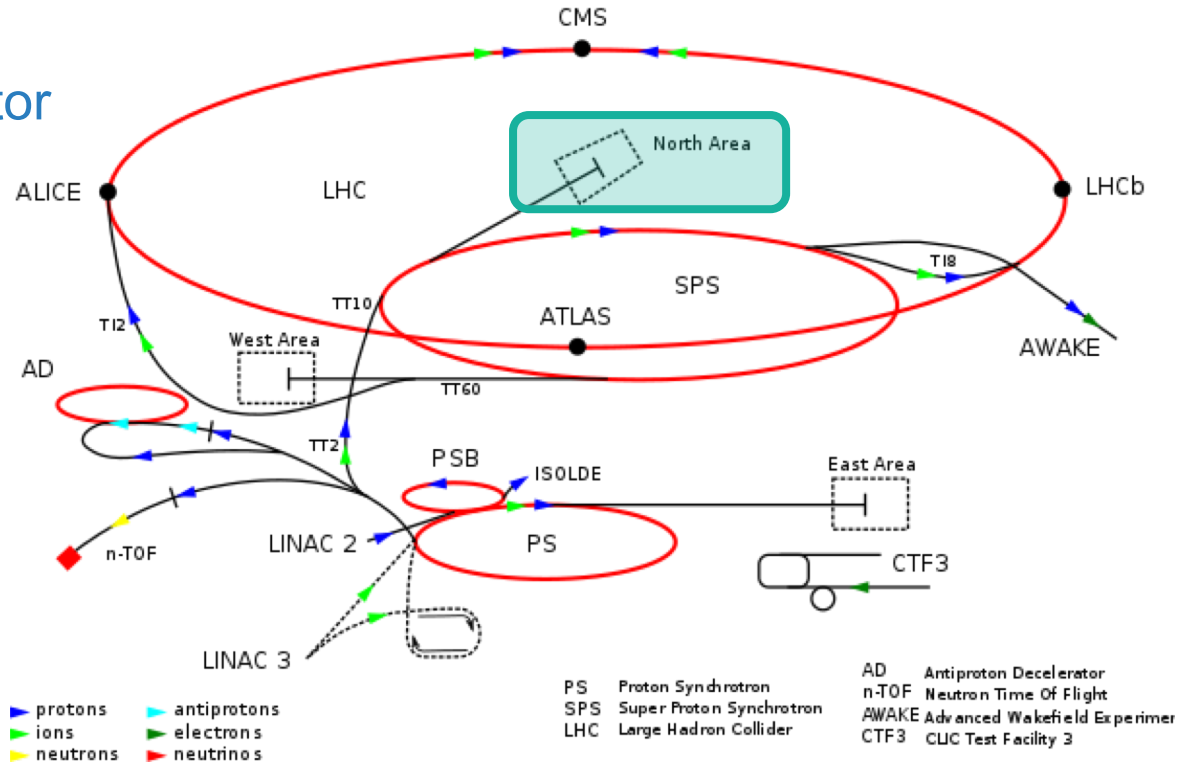
[1] Cavanna, F., R. Rameika, and C. Touramanis. *Single-phase ProtoDUNE, the Prototype of a Single-Phase Liquid Argon TPC for DUNE at the CERN Neutrino Platform*. No. CERN-SPSC-2017-028. 2017.

WHAT IS NP04?

The protoDUNE Single Phase (NP04) experiment

- Located in CERN Test Beam area EHN1
- Tertiary beam of the CERN SPS accelerator

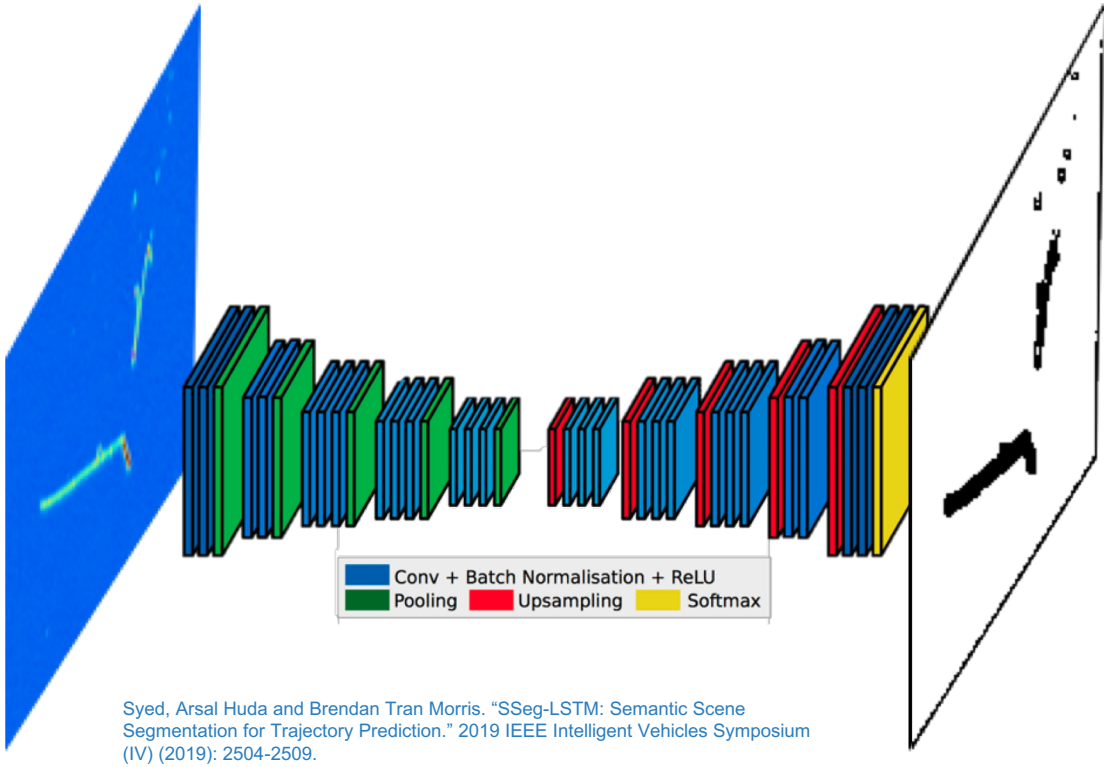




ROI SEARCHES

Data selection and trigger generation

- Focus on identifying areas of interest where there is activity on the detector.
- Fully Convolutional Networks to do image segmentation (UNets).
- Input: raw signals.
- Goal: checking the raw signals to get information from the waveforms.
  - Locate where there are hits!



Syed, Arsal Huda and Brendan Tran Morris. “SSeg-LSTM: Semantic Scene Segmentation for Trajectory Prediction.” 2019 IEEE Intelligent Vehicles Symposium (IV) (2019): 2504-2509.

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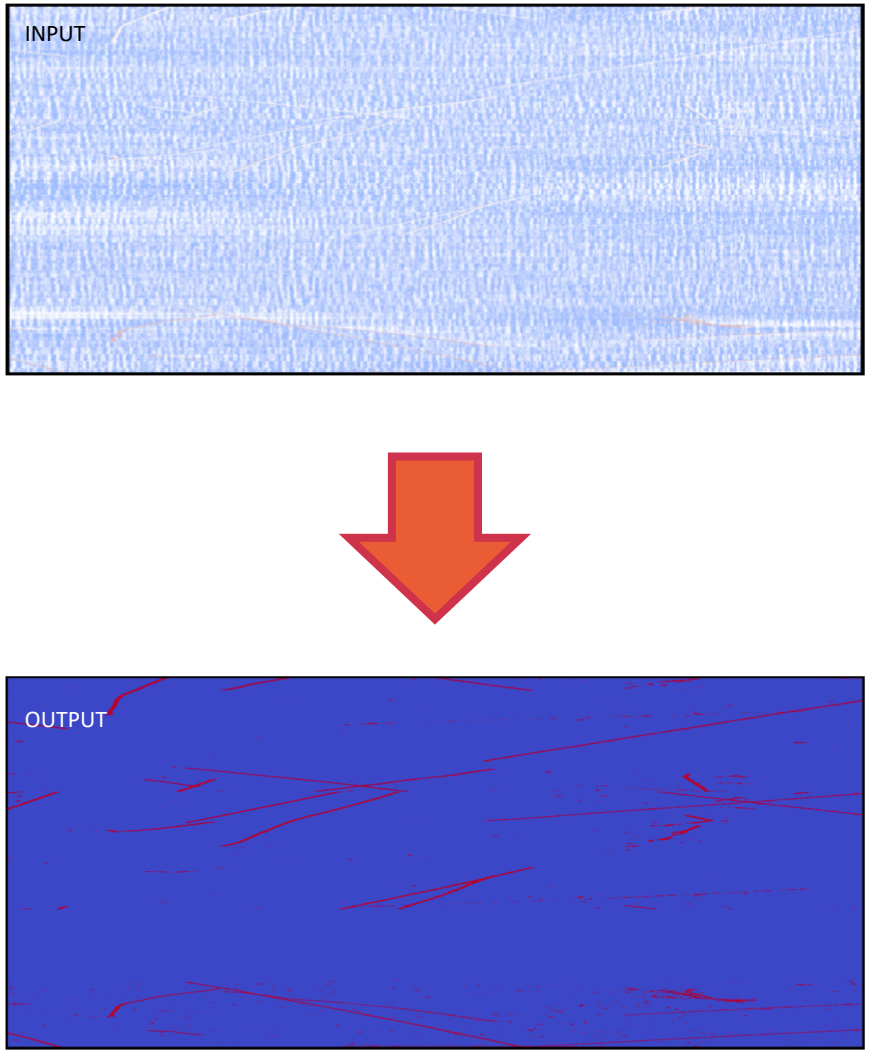
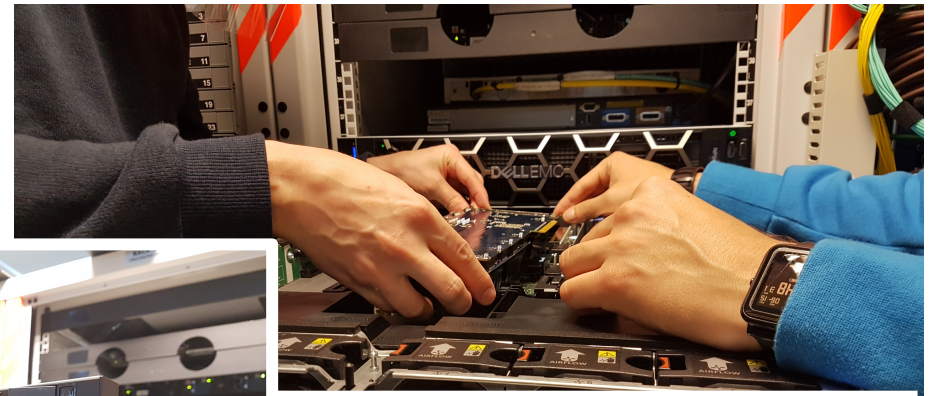
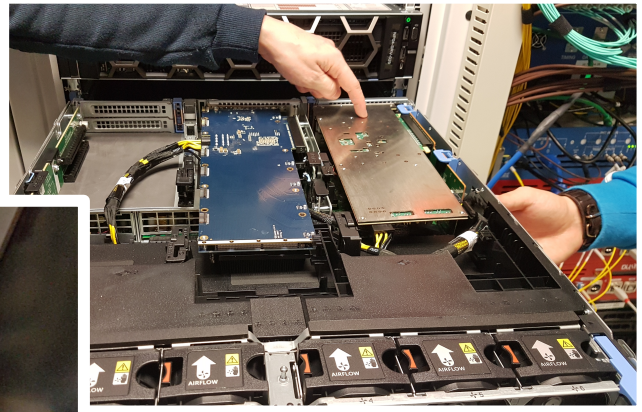


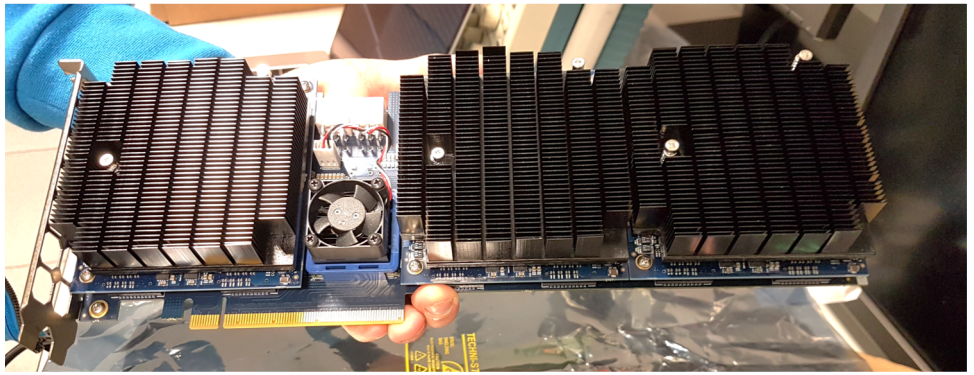
TEST ON NP04

Setup on the detector readout chain to analyse real time data

- 3x AC511 on an EX-700 backplane
- Dual setup using FELIX as readout system
- Communication between the two board was achieved
- We faced some technical difficulties
- Ran in the last runs of NP04 at nominal
- We didn't have enough time to finish the test





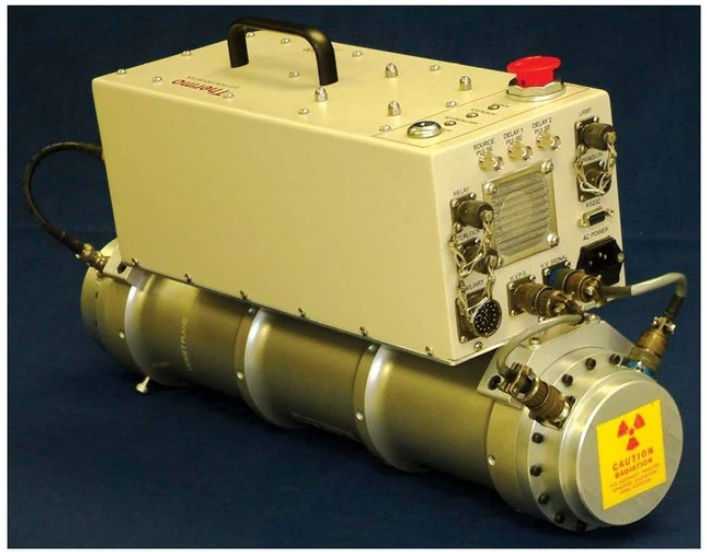


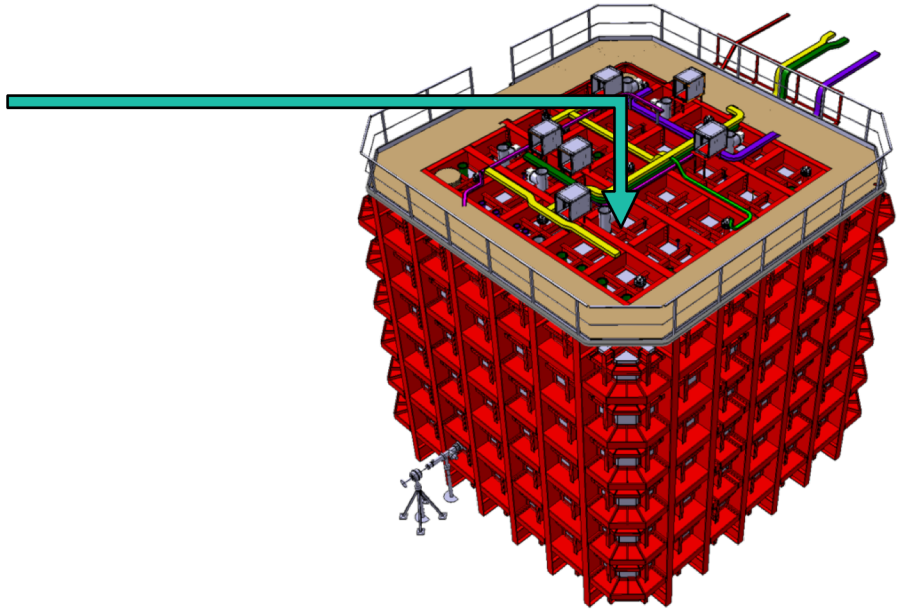
LOW ENERGY DEPOSITIONS

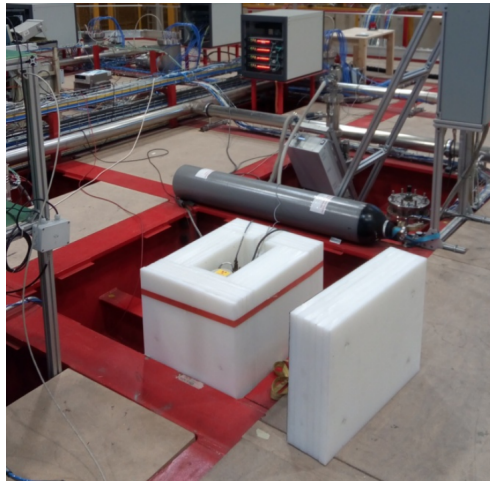
After the test on NP04 some runs with a neutron generator were taken

- Supernovae burst
- Solar neutrinos

→ Localized low energy depositions (MeV range) → is the network able to detect?







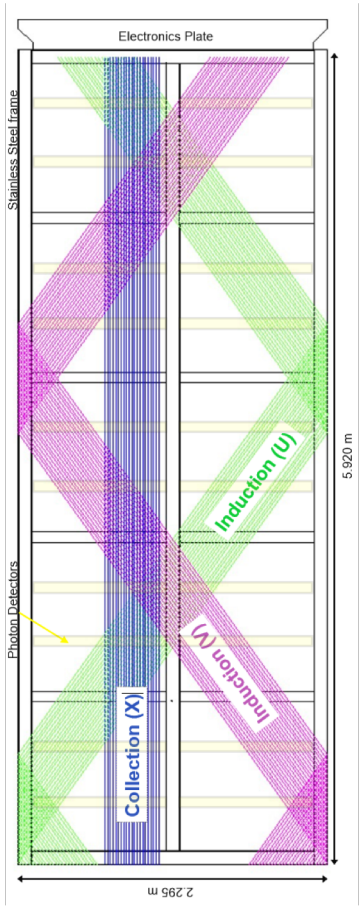
Neutrons in LAr are captured and release **6.1 MeV** via a gamma cascade → Perfect test!

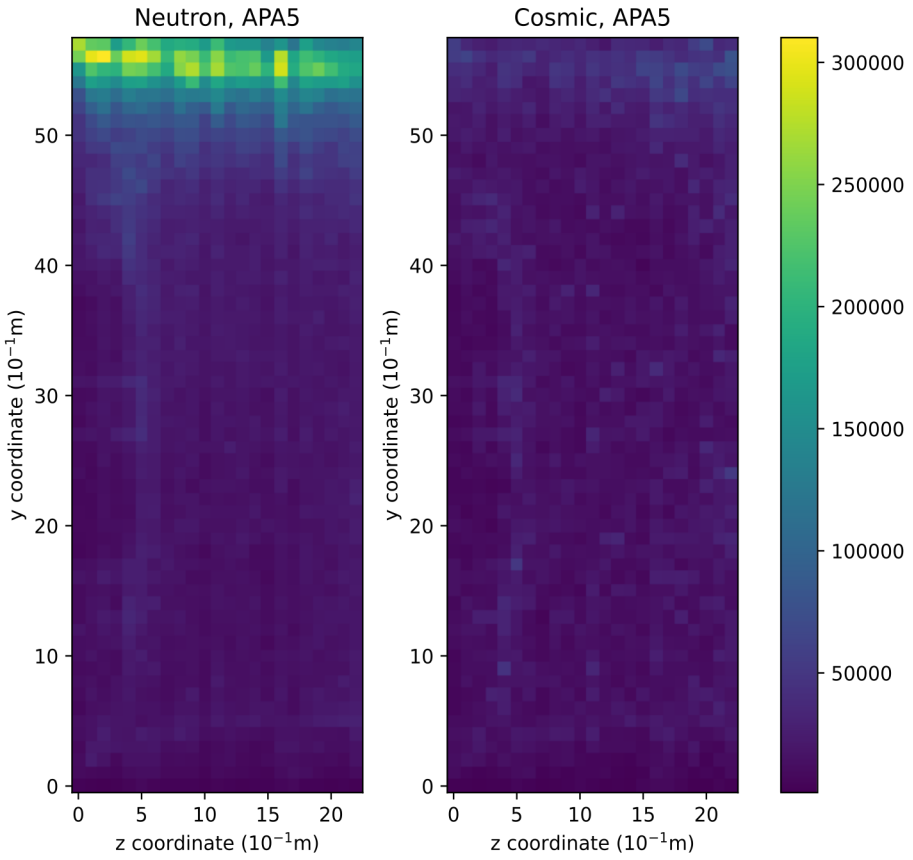
Two datasets:
- Equal number of events
- One with generator **on**
- One with generator **off**

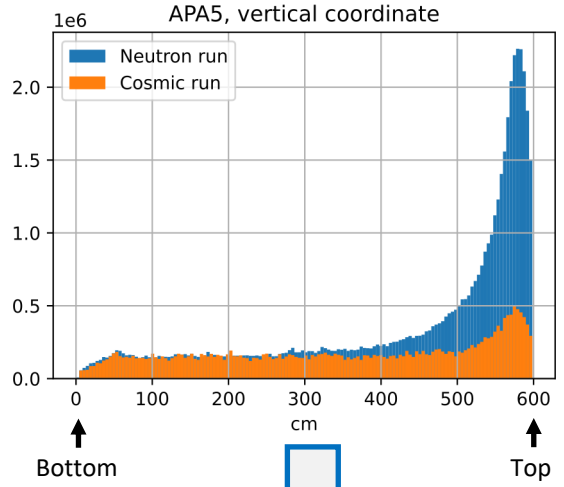
LOW ENERGY DEPOSITIONS

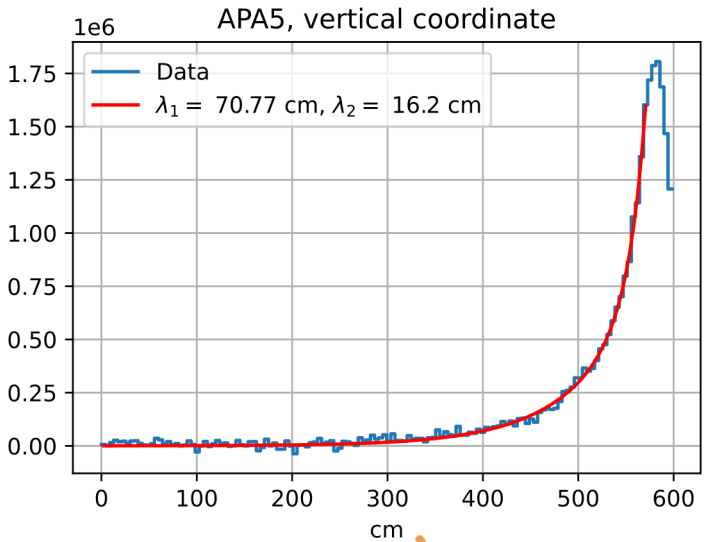
Gamma mean free path → ~ 14 cm

Neutron mean free path → ~ 80 cm





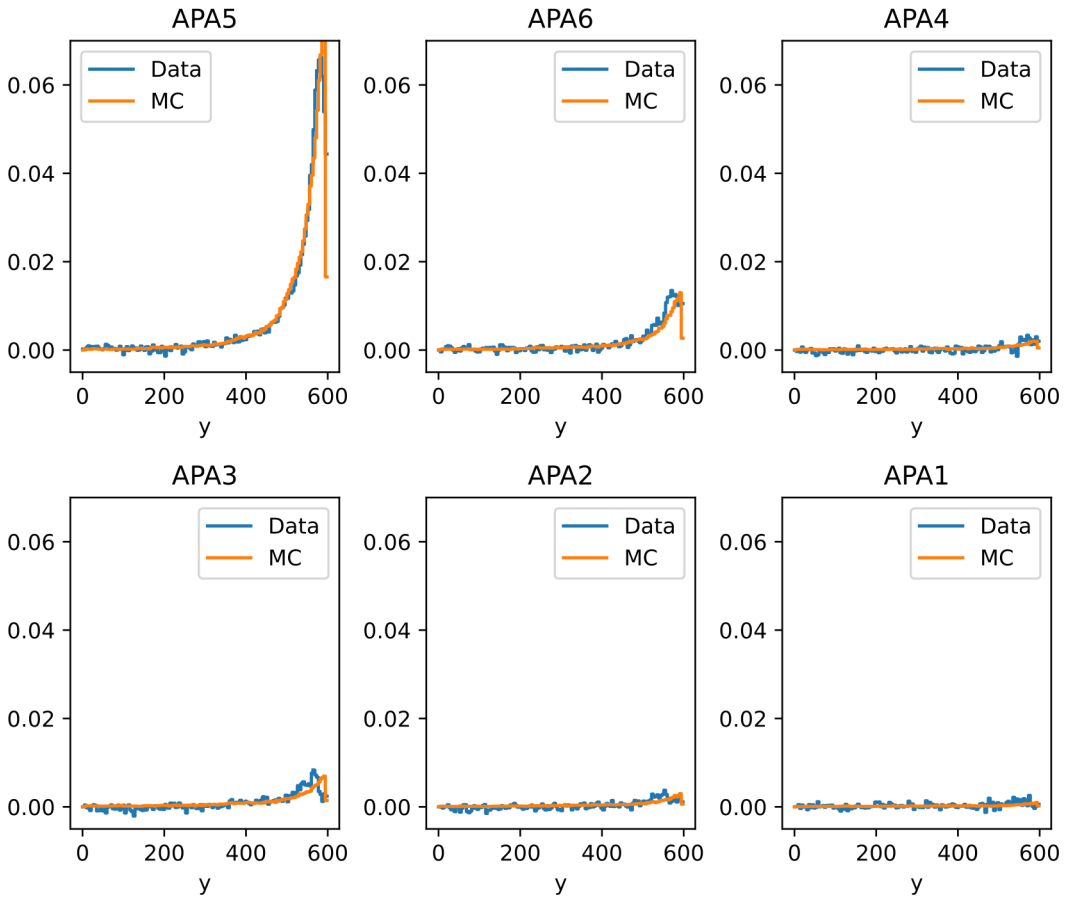


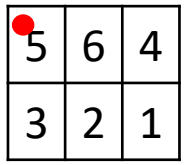


MONTE CARLO COMPARISON

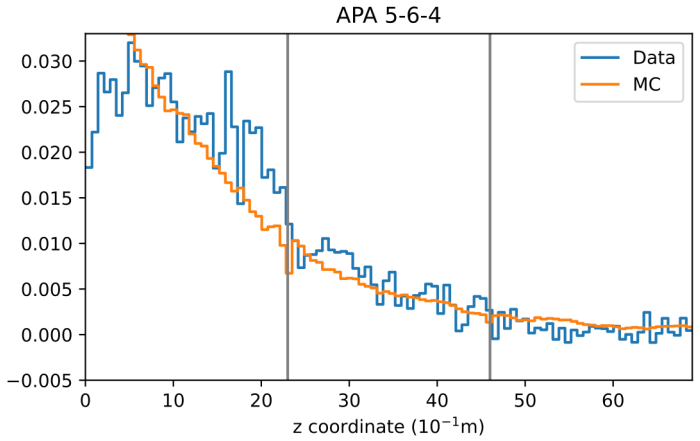
Full ProtoDUNE geometry plus the neutron gun performed with FLUKA

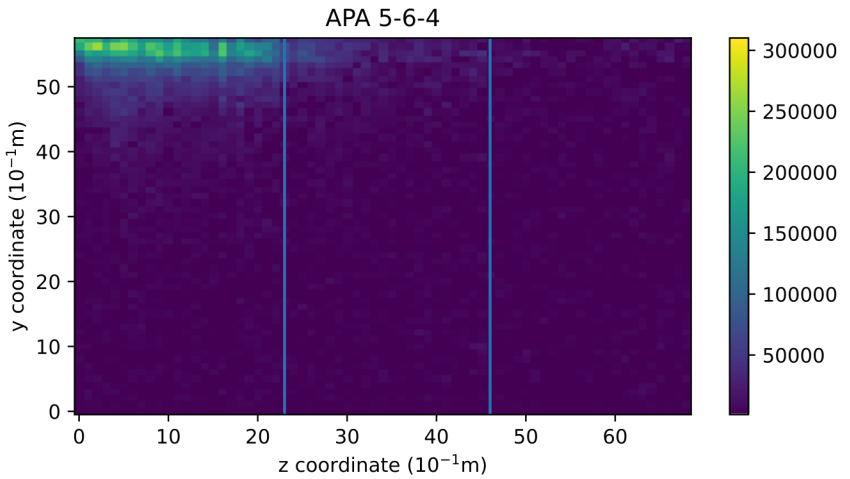
Vertical coordinate





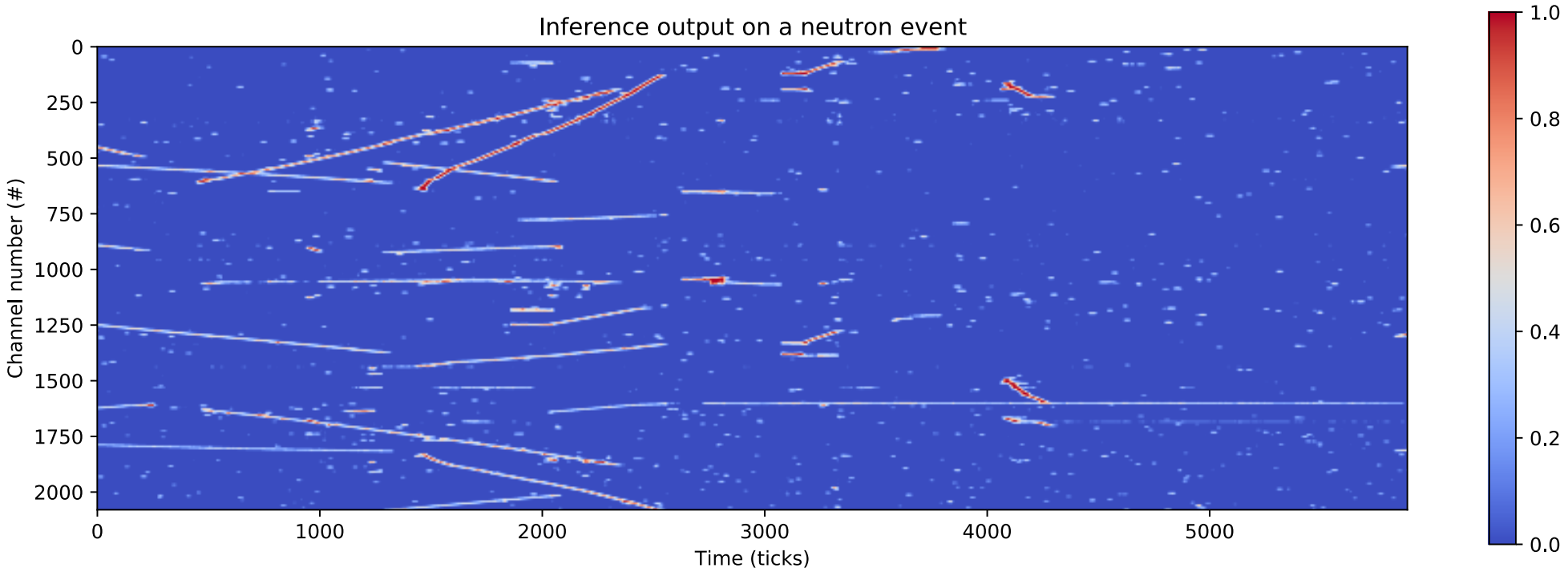
Transversal coordinate





DEALING WITH SPARSE DATA

How can we profit from the sparsity of our data?

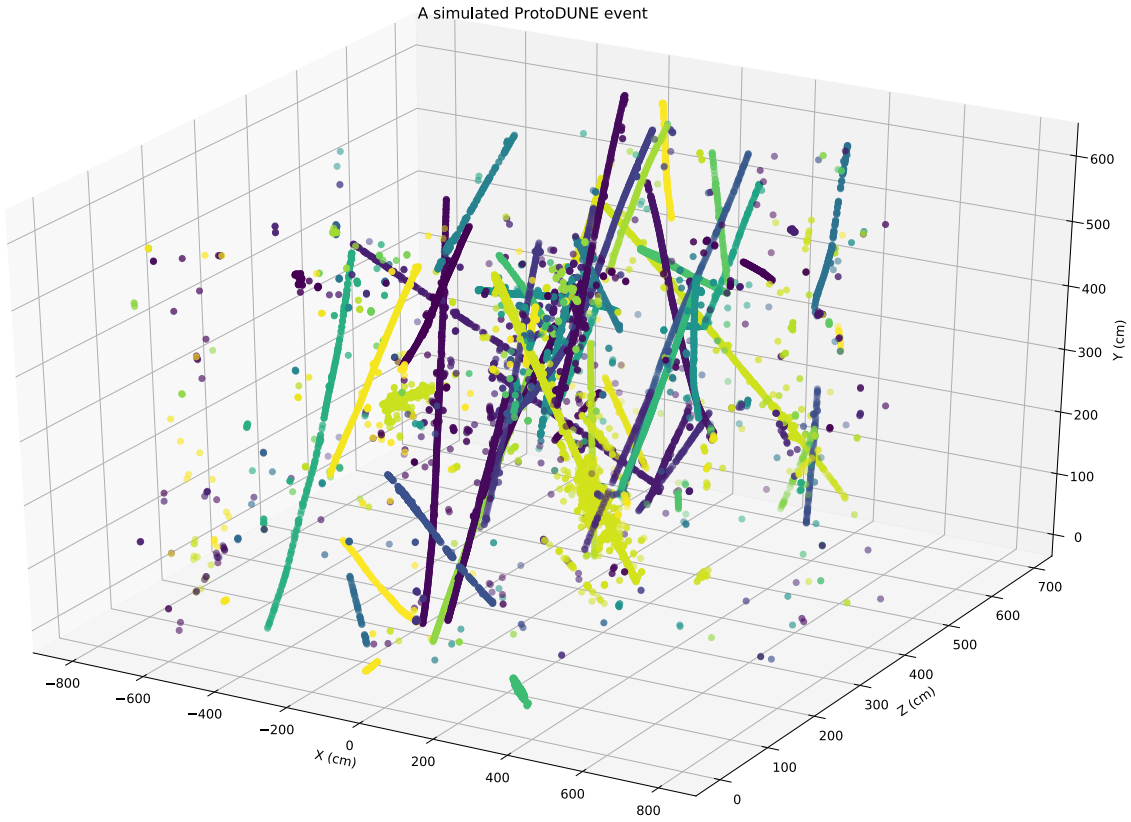


Only 1.79% of the image is signal.

DEALING WITH SPARSE DATA

How can we profit from the sparsity of our data?

- Instance segmentation allow us to identify all the hits that belongs to the same particle
- Graph Neutral Networks (GNN) are a commonly used approach to do it
- Constructing graphs is not currently supported on the Inference Engine (IE)
- We are working with Micron to develop a solution that allow us to explore those networks



SUMMARY

That's all folks!

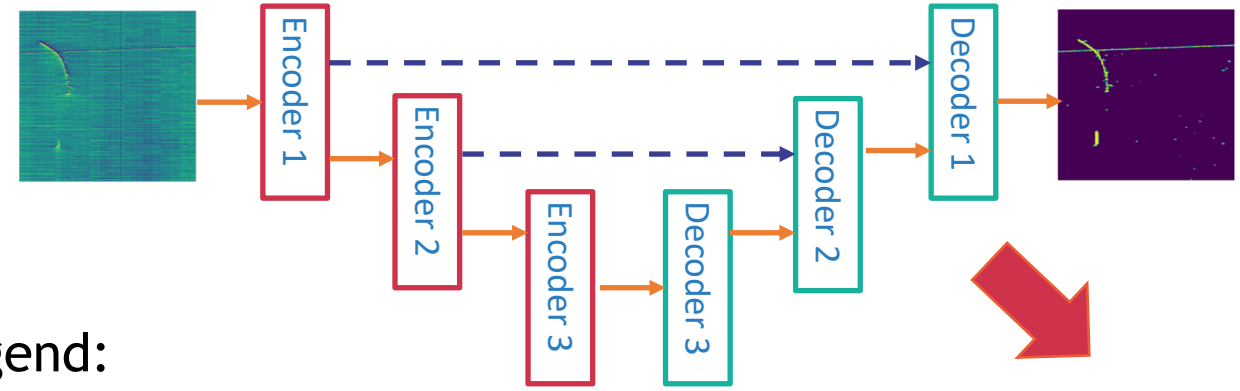
- We trained a network able to identify regions of interest (hits) using data from the Single-Phase ProtoDUNE (NP04)
- We tested it using the Micron DLA solutions in NP04. We would need more detector time to fully test it
- We proved that the network is able to identify low energy events (~6.1MeV) with really good results
- We are exploring different solutions to cluster hits generated by the same particle

THANK YOU!

BACKUPS

Training on ProtoDUNE data

Neural Network adapted from LinkNet [1]

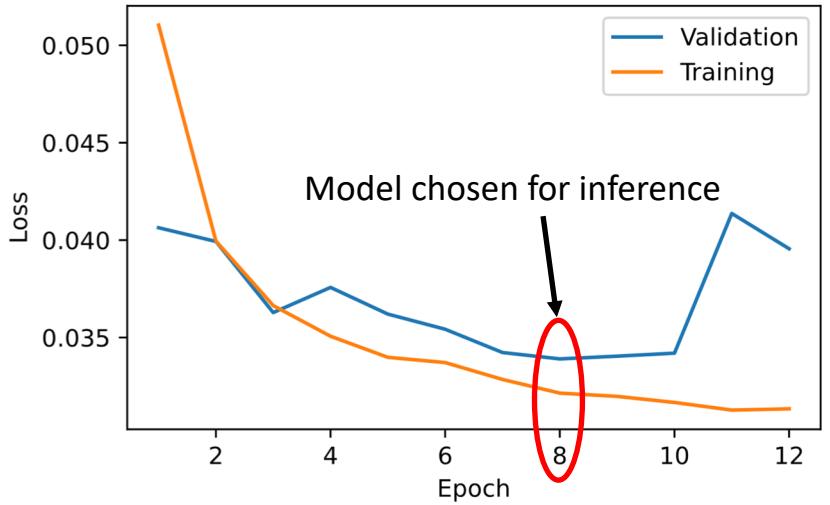


Legend:

- Encoder — convolutional residual block
- Decoder — transposed convolution
- main data flow
- skipped connection for loss convergence

	LinkNet	TinyLinkNet
Weights	11'863'562	182'353
One pass (MB)	2'169	379
GFLOPs	36.9	1.1

Trained on mixture of MC and real data with unbalanced Binary Cross Entropy loss:



- **BCE loss**: cost function to minimize during training
- **Epoch**: training iteration

Results on real data:
- Signal lost ~ 1%
- Unnecessary data ~0.5 %

[1]: LinkNet: Exploiting encoder representations for efficient semantic segmentation, 2017 IEEE Visual Communications and Image Processing