

Rare events detection in DUNE with Deep Learning techniques: application to ProtoDUNE

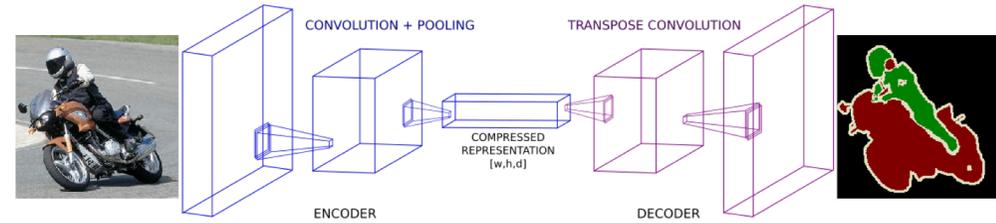
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Semantic Segmentation and Deep Learning approach

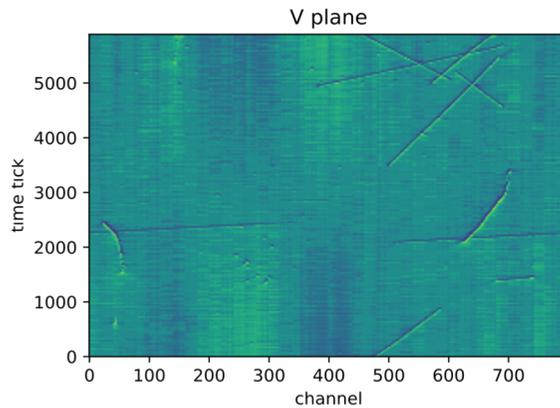
Pixel-wise classification



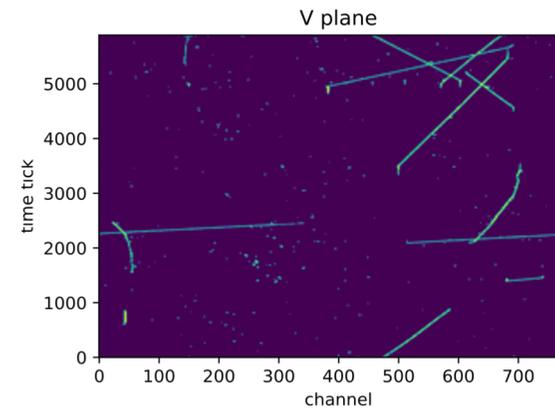
Neural network approach



LArTPC data is well suited for semantic segmentation



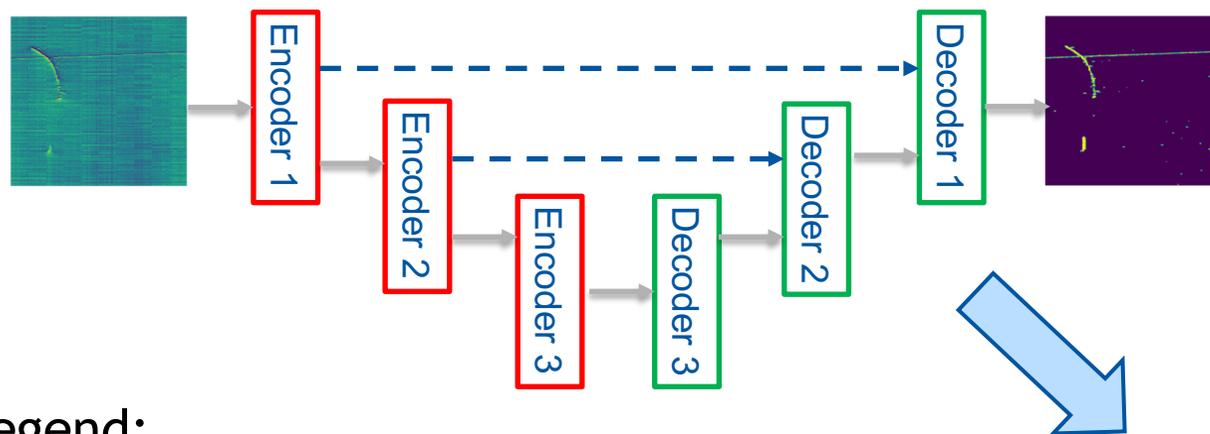
Reconstruction
chain



Noise can be
discarded,
signal kept

Training on ProtoDUNE data

Neural Network adapted from LinkNet [1]

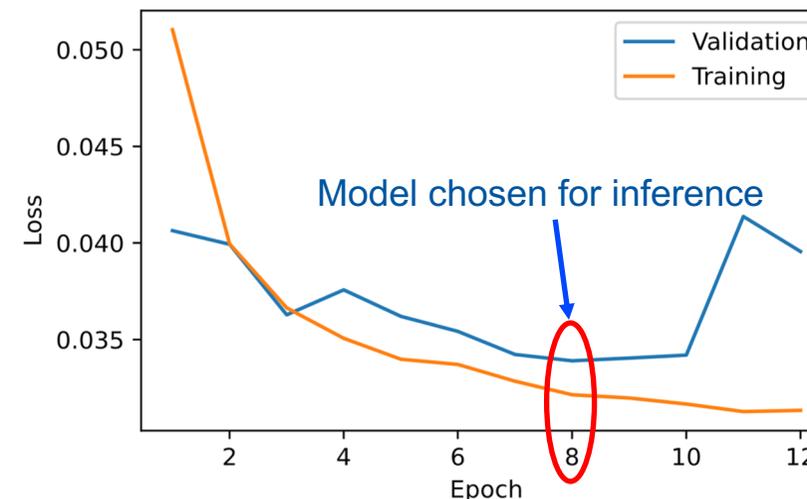


Legend:

- 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

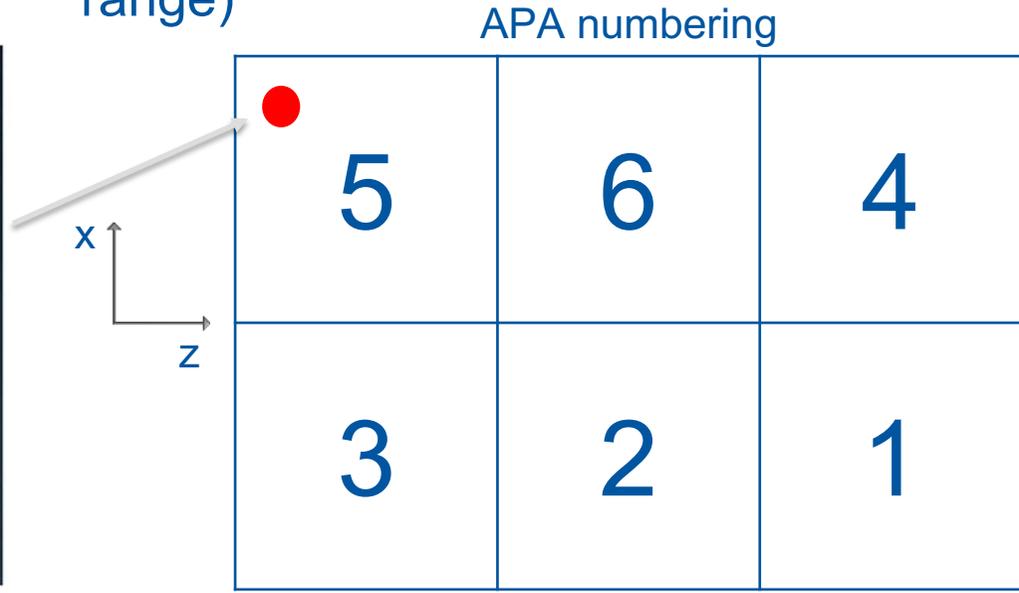
Results on real data:

- Signal lost ~ 1%
- Unnecessary data ~0.5 %

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

Low energy depositions

- Supernovae burst
 - Solar neutrinos
- Localized low energy depositions (MeV range) → is the network able to detect?

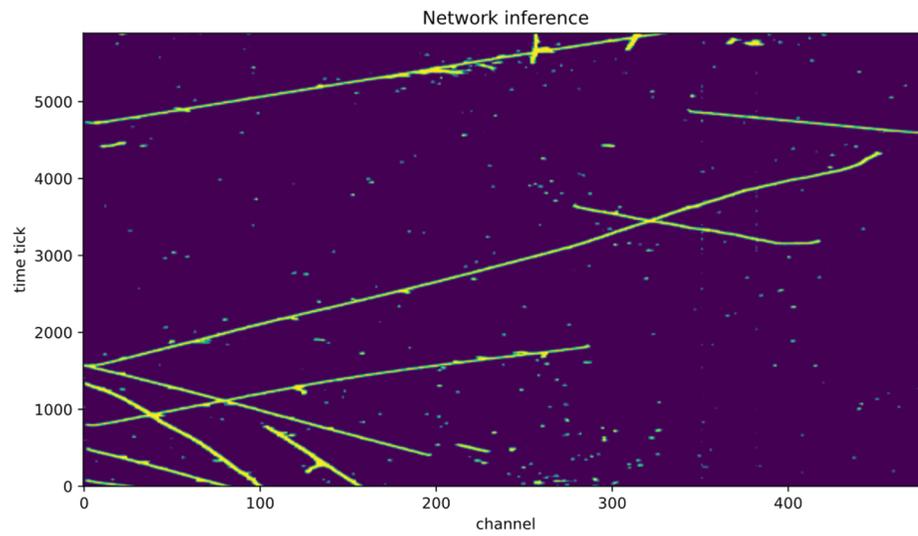


Neutrons in LAr are captured and release **6.1 MeV** via a gamma cascade → Perfect test!

Two datasets:

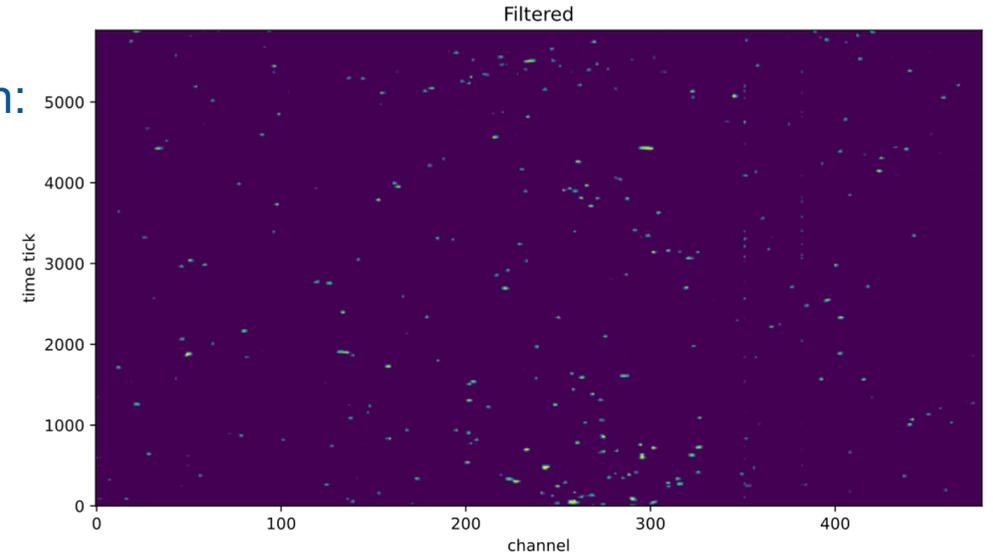
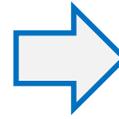
- Equal number of events
- One with generator **on**
- One with generator **off**

Hits selection

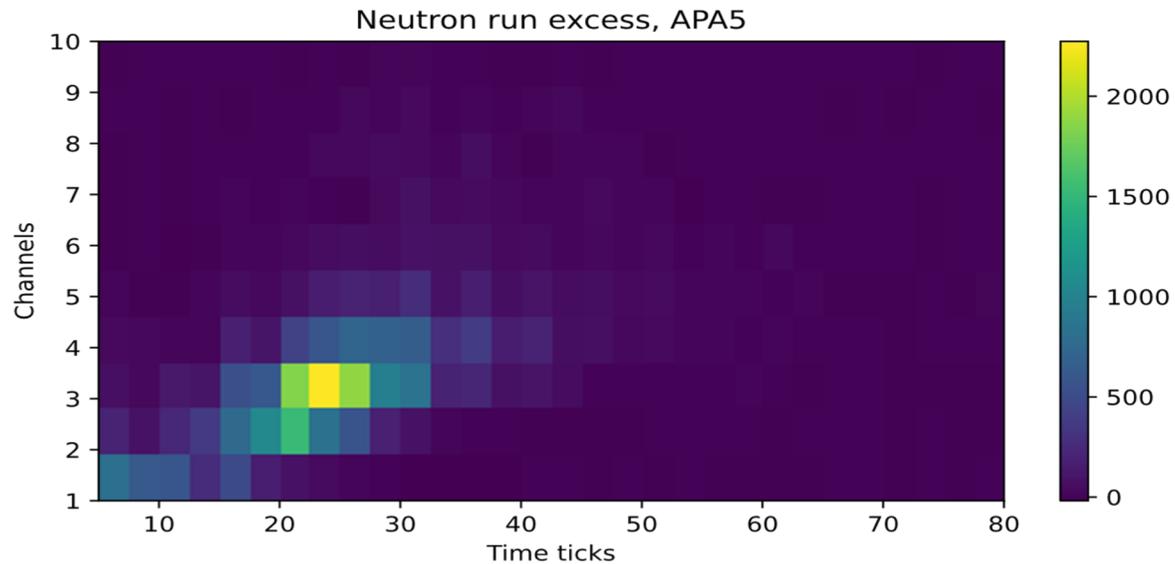


Cut tracks longer than:

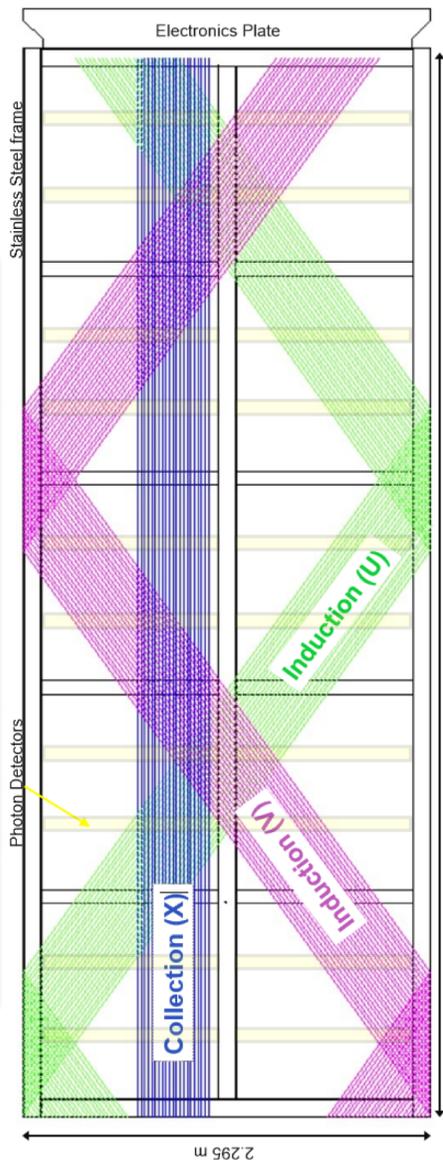
- 10 channels
- 80 time ticks



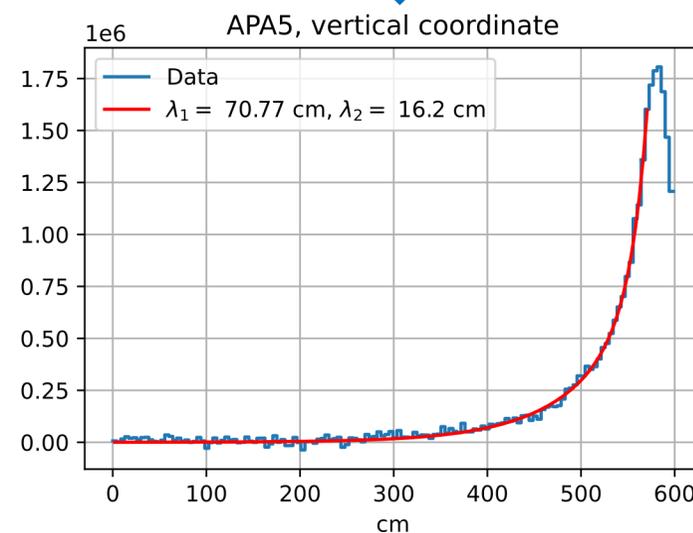
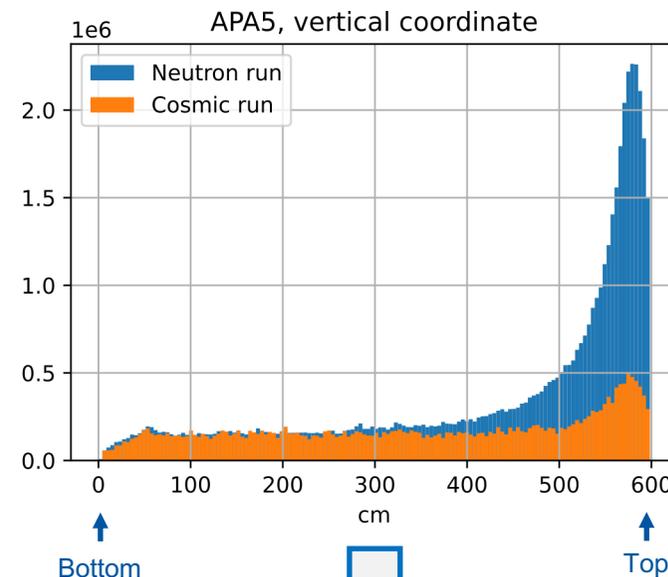
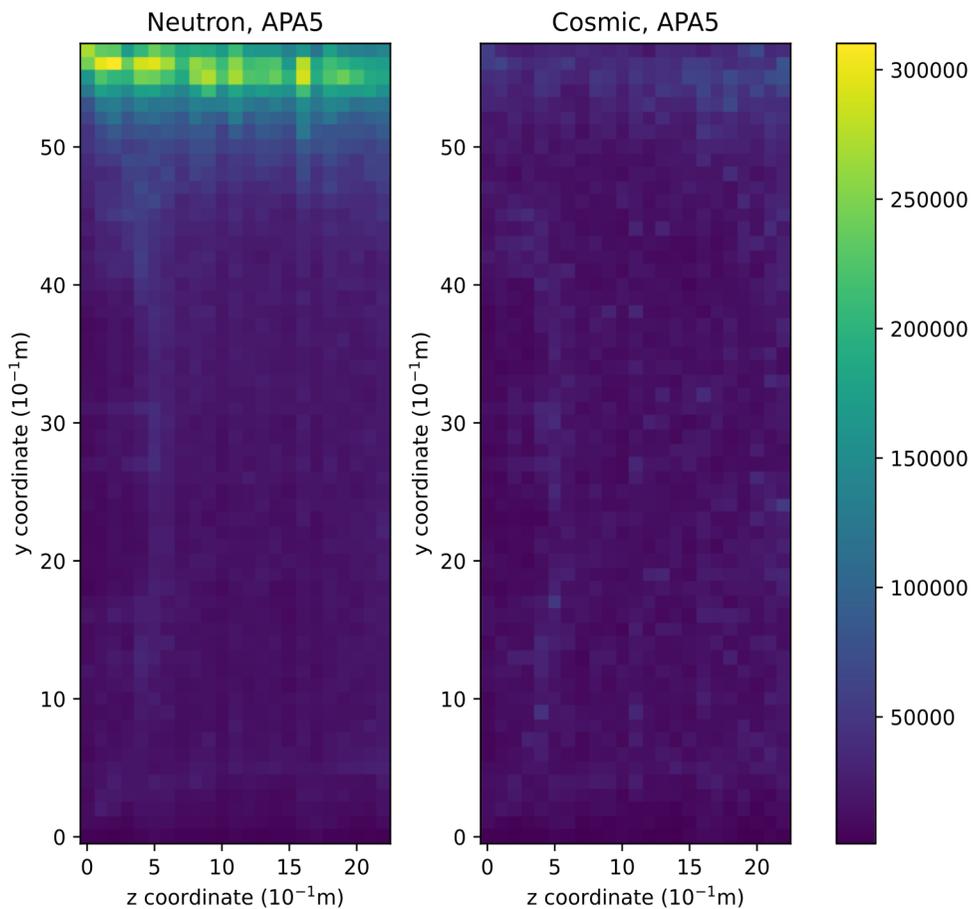
Result: neutron vs cosmic runs



Spatial localization



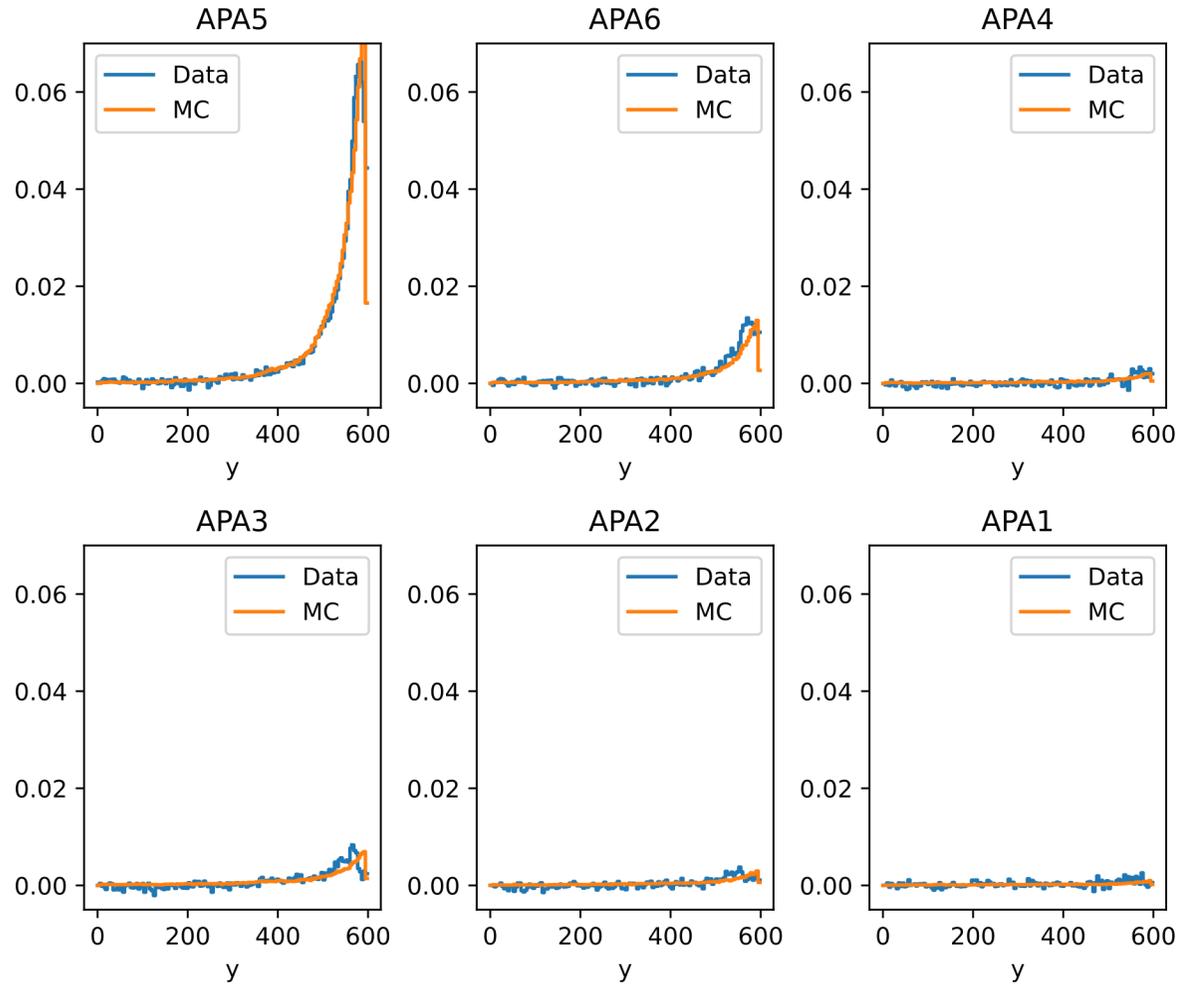
Gamma mean free path $\rightarrow \sim 14$ cm
Neutron mean free path $\rightarrow \sim 80$ cm



Monte Carlo comparison

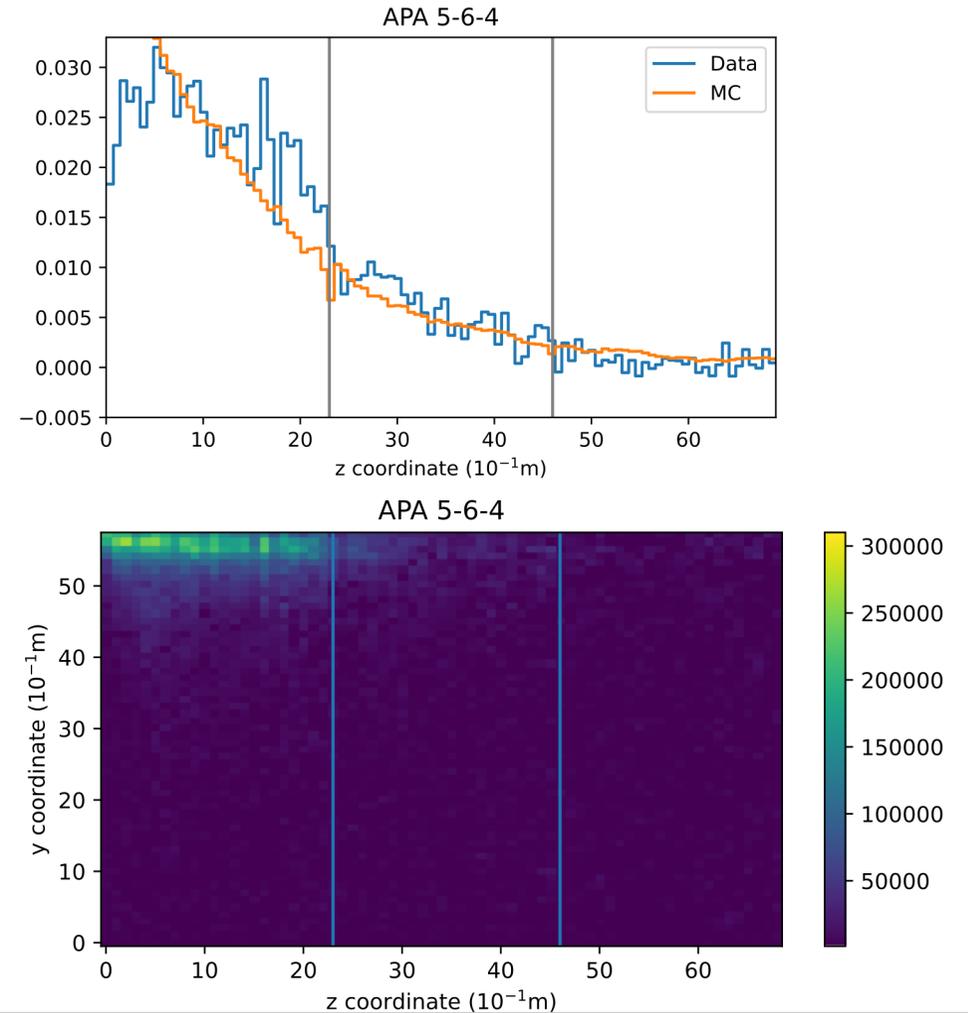
Full ProtoDUNE geometry plus the neutron gun performed with FLUKA

Vertical coordinate



5	6	4
3	2	1

Transversal coordinate



Conclusions

In order to perform the rare events studies DUNE data:

- We developed and adapted a semantic segmentation neural network to the DUNE requirements
- We trained it using MC and ProtoDUNE real data.
- We tested in a situation that resembles the DUNE's low energy events and we obtained very promising results
- The network is able to find neutron low energy interactions: it will be a powerful tool for the DUNE experiment.

Future developments:

- An implementation in hardware (FPGA or ASIC) for online application
- A subsequent network can be trained to perform a pre classification of the event