Deep Learning For Dune Real-Time Event Processing

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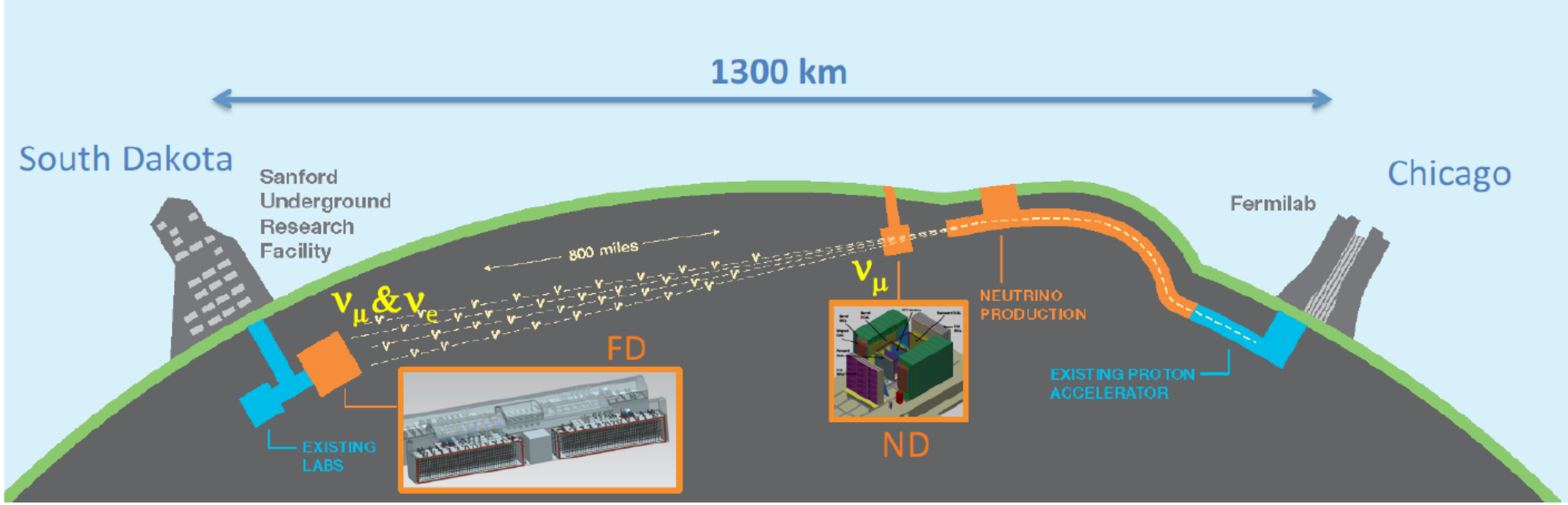
CERN

European Research Council

What is DUNE



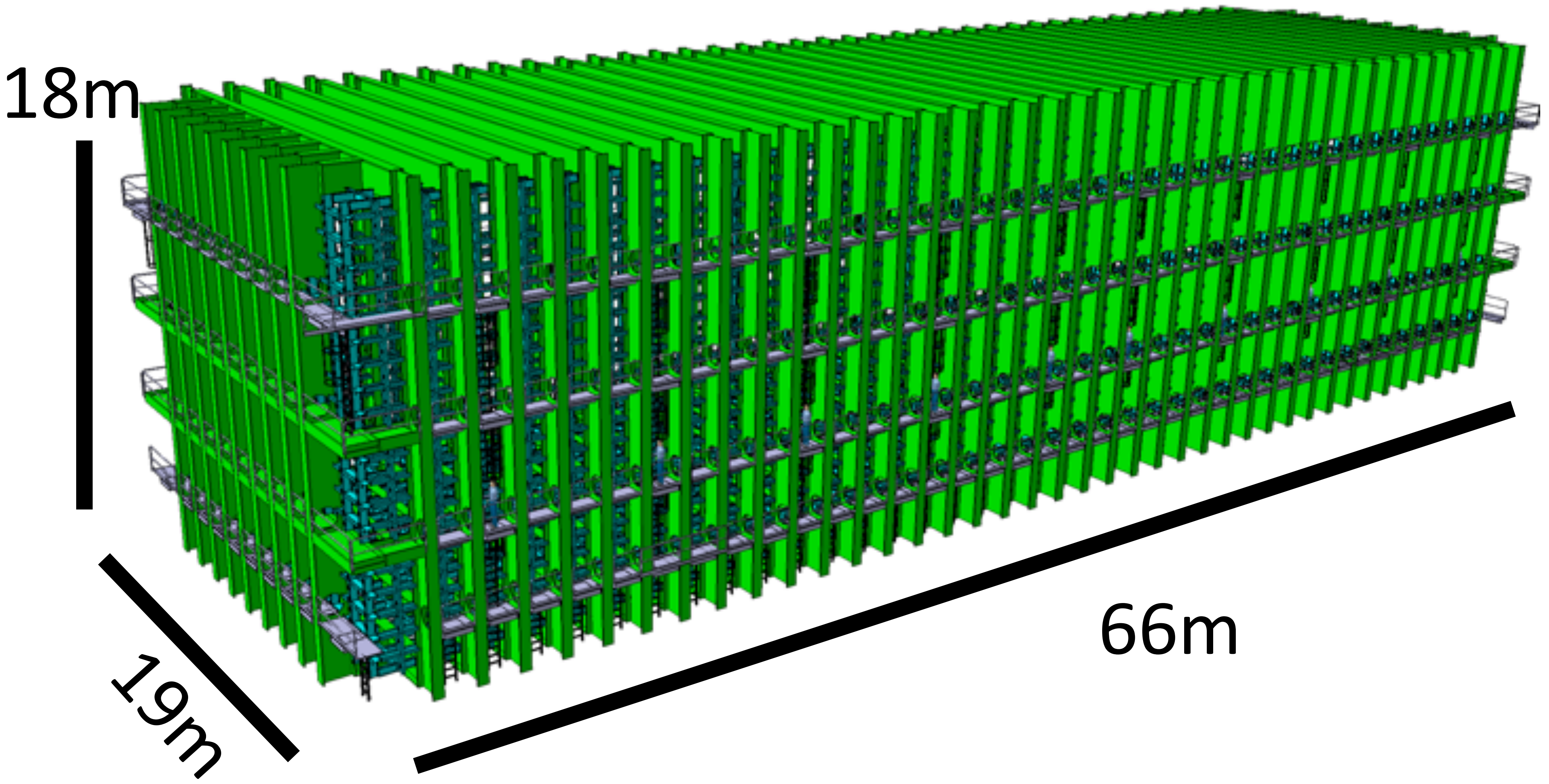
- Big Liquid Argon detector to observe neutrinos produced by FERMILAB and sent to South Dakota

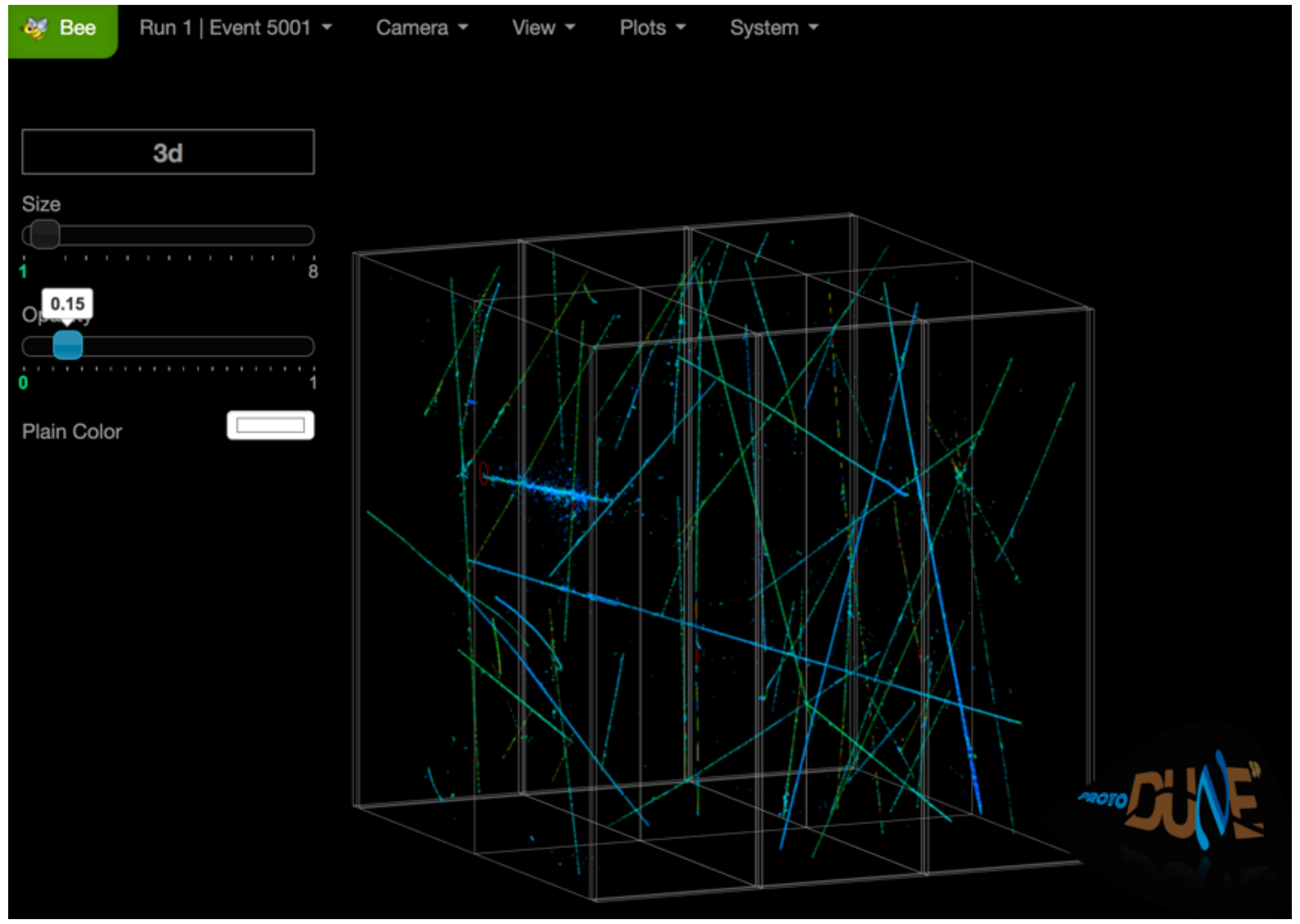
- Designed to precisely measure (anti)neutrino oscillations and measure matter/anti-matter differences

- Sensitivity to rare events, e.g., close-by Supernovae explosion, proton decay

What is DUNE

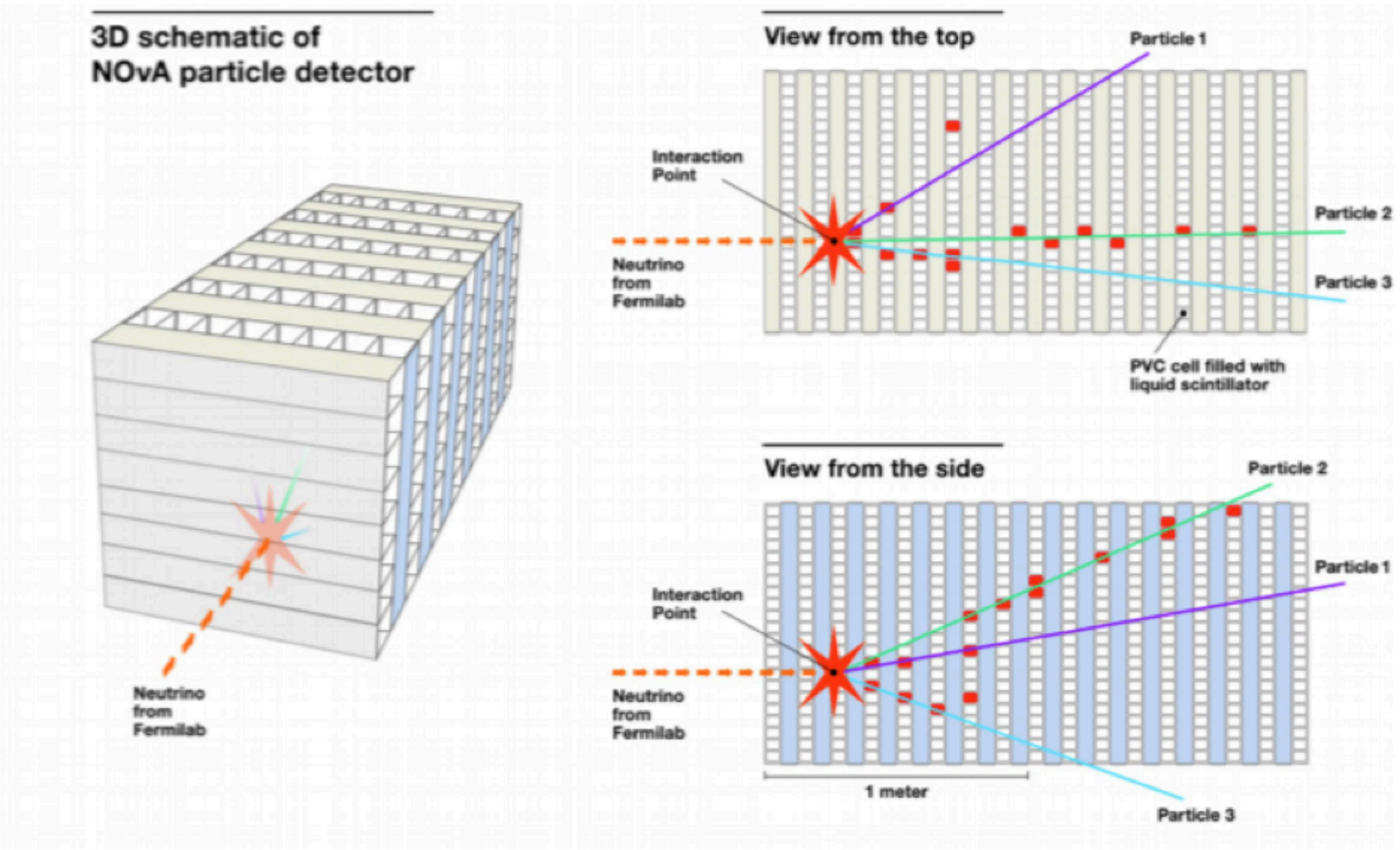
- *1500 m underground*
- *4 modules, each consisting of 10 kton LAr*
- *can observe charged particles produced by neutrinos (or by noise)*
- *Unlike LHC: no vertex interaction point: the interaction can happen anywhere (and anytime, e.g., for supernovae)*
- *Observe XY and XZ 2D views. Needs to reconstruct the 3D image*

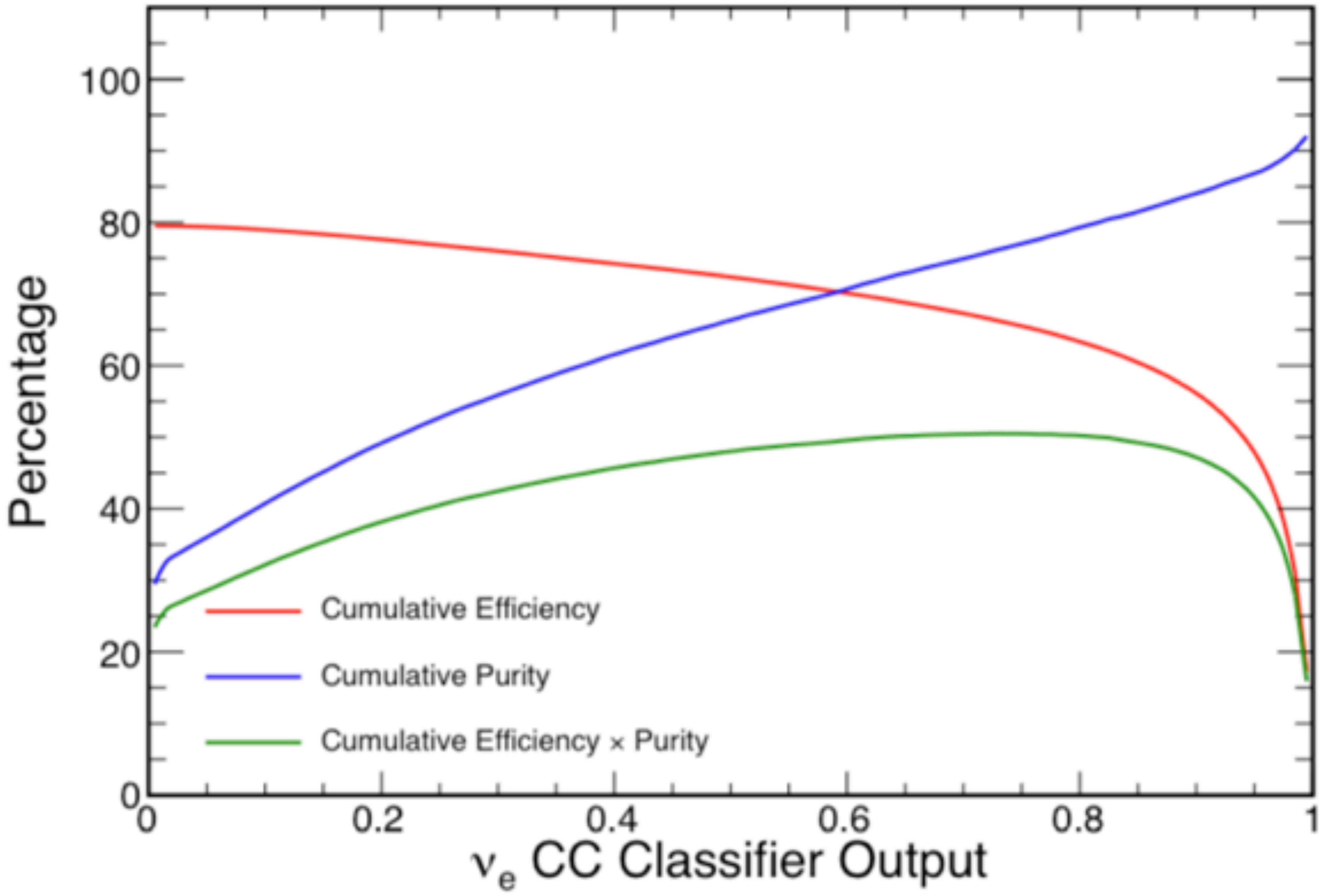




Neutrinos & Deep Learning

- First application of Deep Learning to particle physics was a neutrino reconstruction problem
- Successfully demonstrated power of computing vision techniques for our problems
- Problem scale smaller than what we want to face
- Smaller detector
- NN applied locally to region already identified by classic algorithms
- Such an offline approach is under study for DUNE as well (not the topic of this project)





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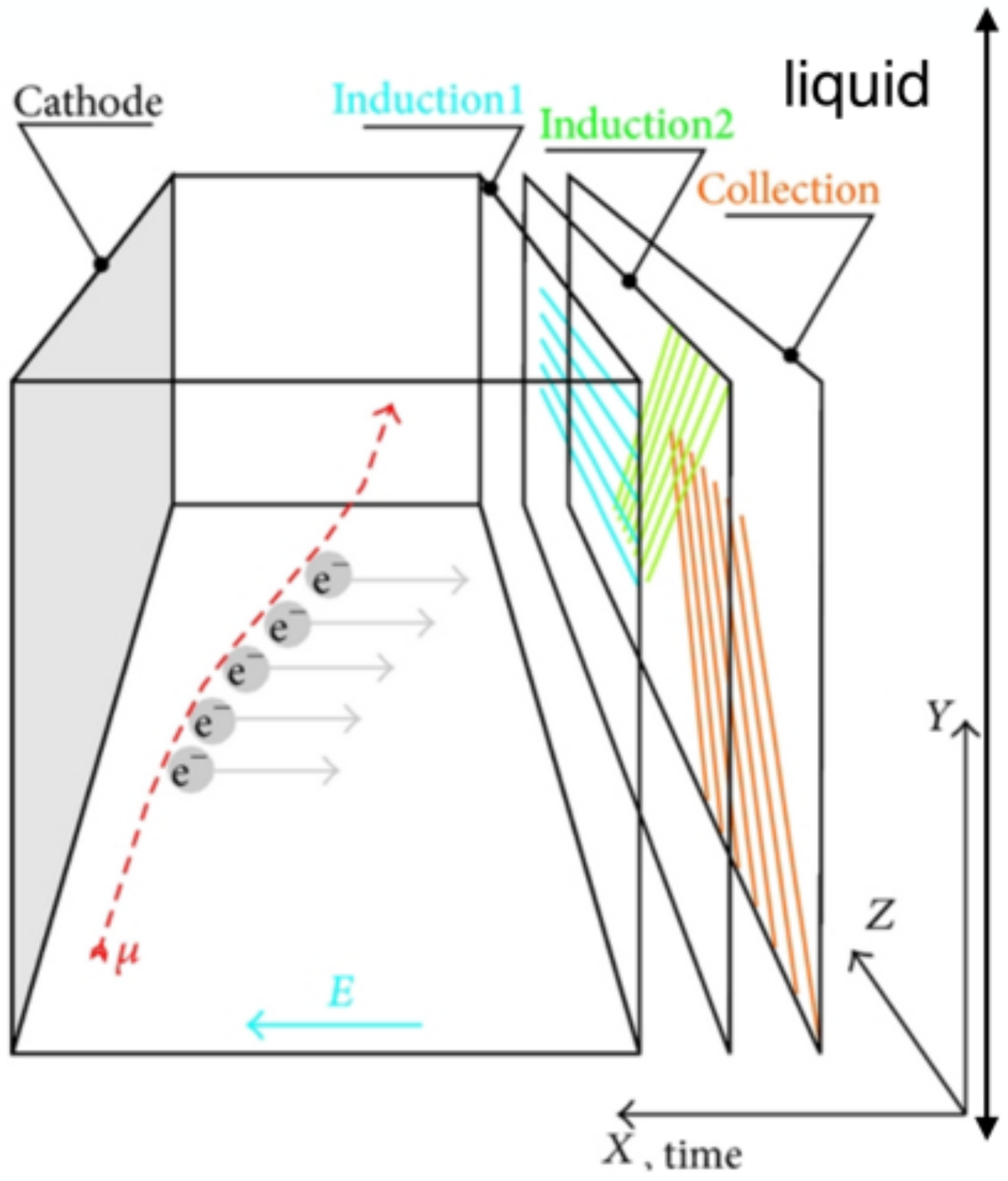
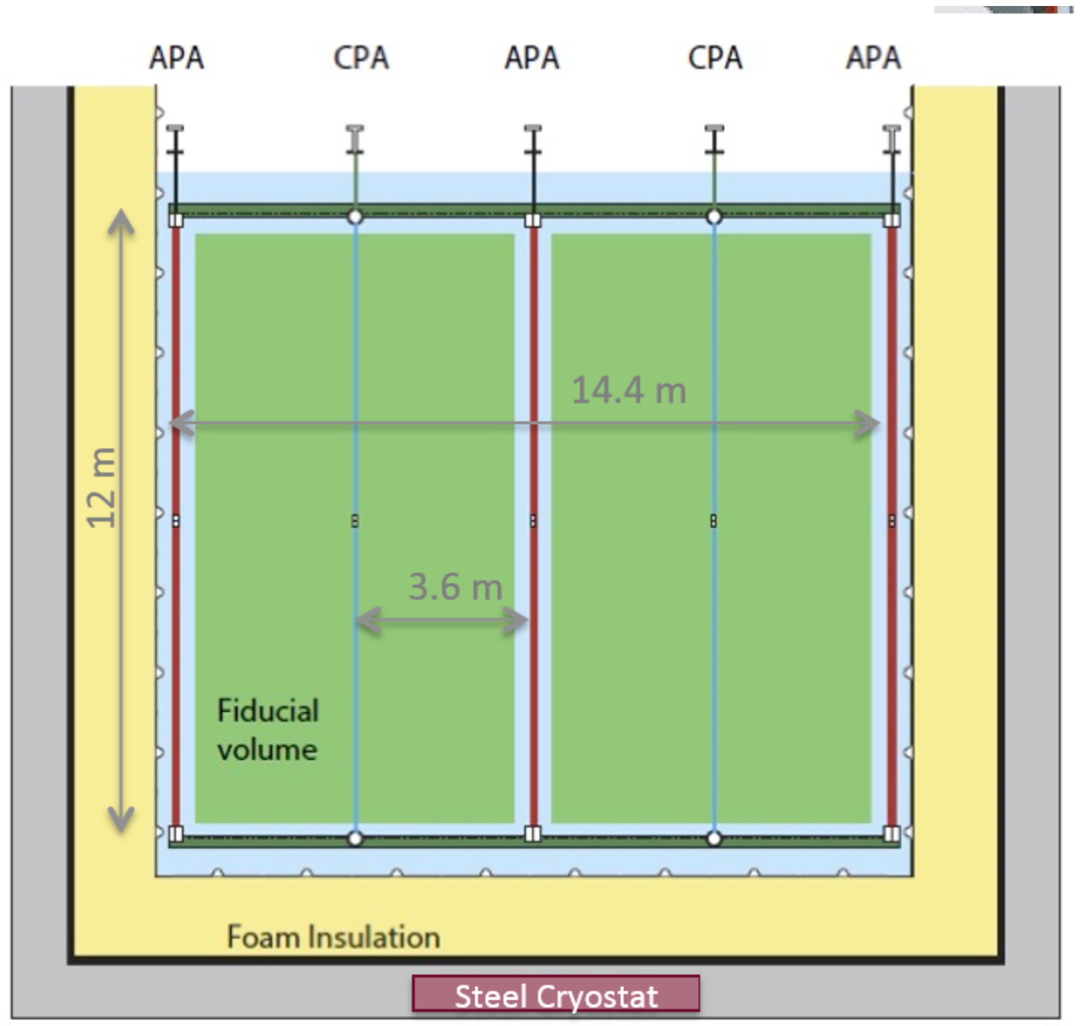
What is Challenging of DUNE

- All problems track down to the fact that neutrinos don't like to interact with other particles. So one needs A BIG DETECTOR and a LOT OF NEUTRINOS to make sure that a decent amount will be seen.
- Due to this
  - Very high data rates (ip to 4.6 TB/s!)
  - Limited bandwidth cannot be handled using large-energy thresholds, since rare events (e.g., supernova neutrinos) come at low energy
  - Real physics events are very rare, and the majority of the readout for each of these rare events is mostly noise.
  - The noise outweighs the real physics in data size by a factor 10^7
  - Internal background events from ^{39}Ar decay : 1 event/second/l
  - Need to filter noise, apply zero-suppression and have region of interest selection to reduce the data rate and allow for trigger-less data taking.





Built on repeated structure

Total : 150 readout planes/module

2560 readout channels/plane

384000 channels/module

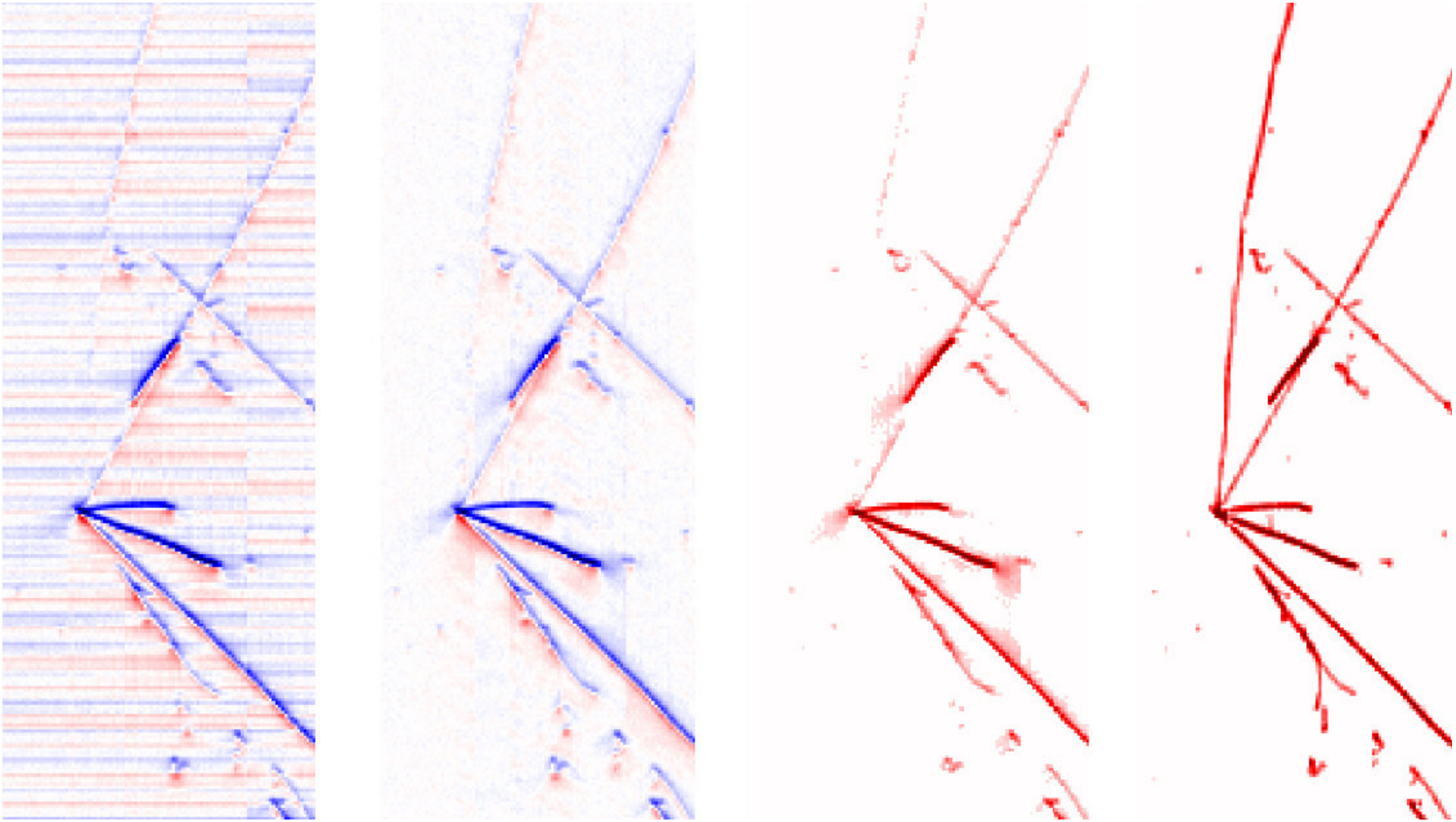
ProtoDUNE

"Small scale" prototype built and operated at CERN

Project Plan

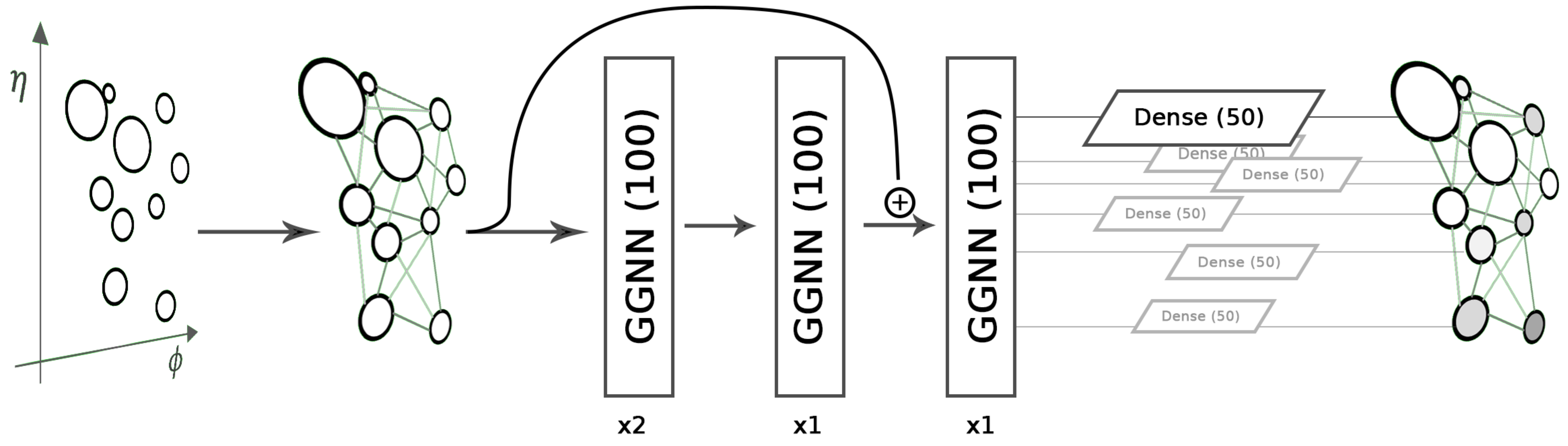
- *This partnership with MICRON aims to integrate deep learning solution in the real-time data acquisition process of the experiment*
- *Two use cases identified:*
  - *Step1: design a local-noise suppression algorithm that could reduce the event size and reduce throughput*
  - *Step2: design a by-module (or global?) event classifier capable of rejecting the obvious background and free some bandwidth*
- *Each step will consists in*
  - *designing the ML model*
  - *integrate it on MICRON hardware*
  - *(eventually) produce a demonstrator on simulation or ProtoDUNE data*

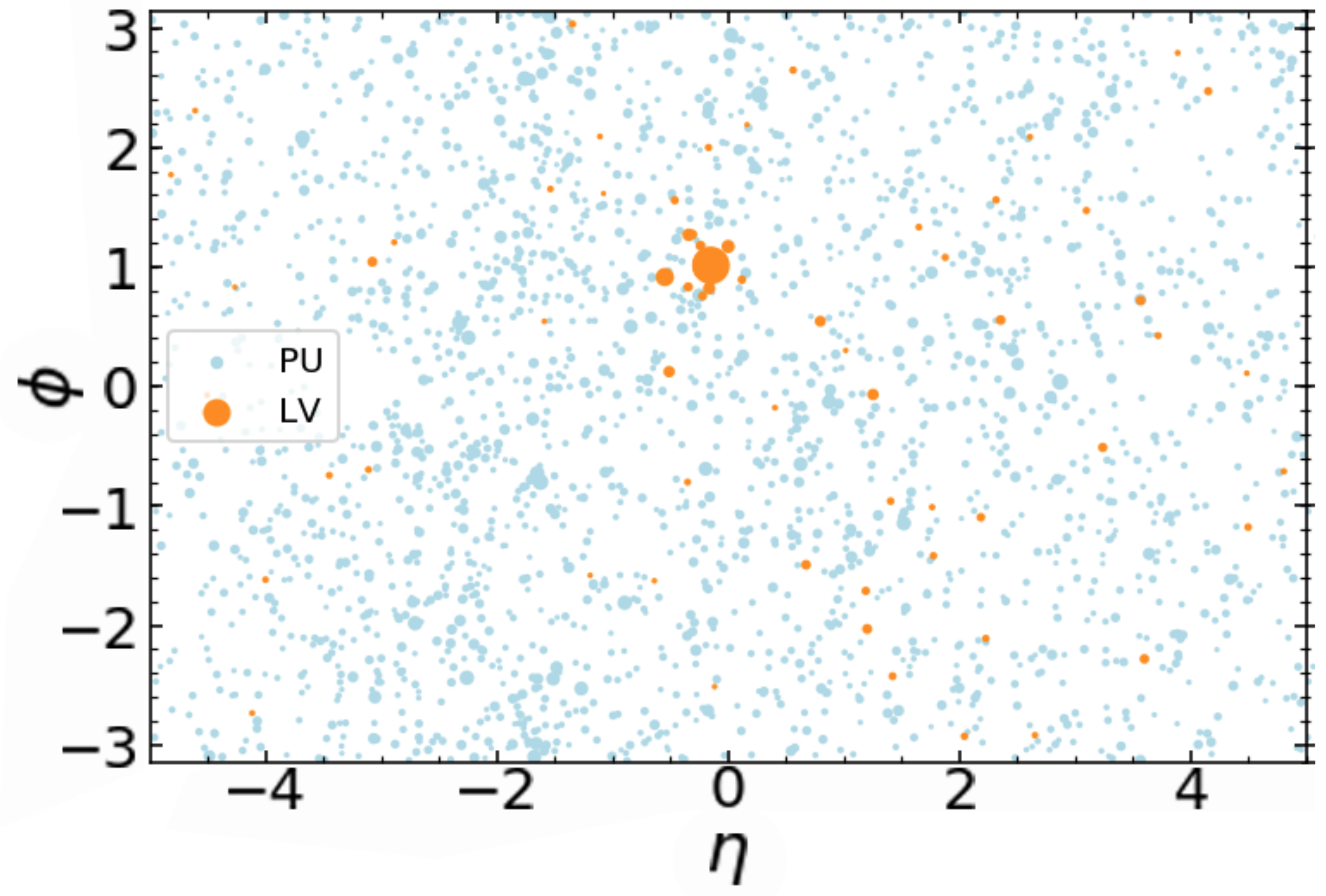
An example: Noise Suppression



Example taken from MicroBooNE (smaller scale neutrino experiment operated @FNAL)

An example: Noise Suppression





- We already solved a similar problem for LHC events (pileup suppression)
  - take a single hit
  - look nearby & build a near-neighbours graph
  - process the graph with Message-passing NN, classifying good vs noise events
- Works very well there, should also work here