A GRAPH NEURAL NETWORK FOR RECONSTRUCTION OF LArTPC DETECTOR DATA

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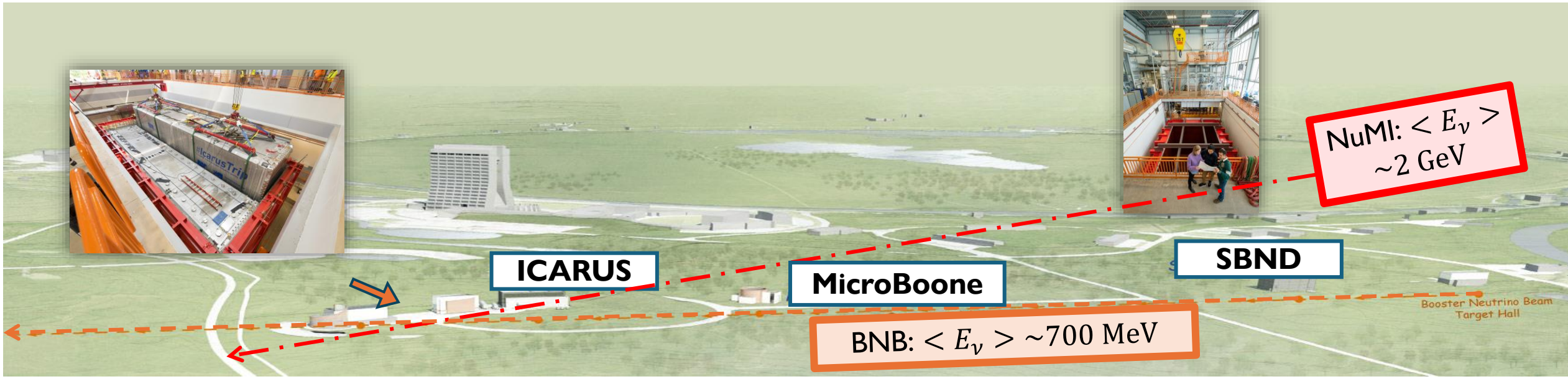
Fermilab

THE SBN PROGRAM



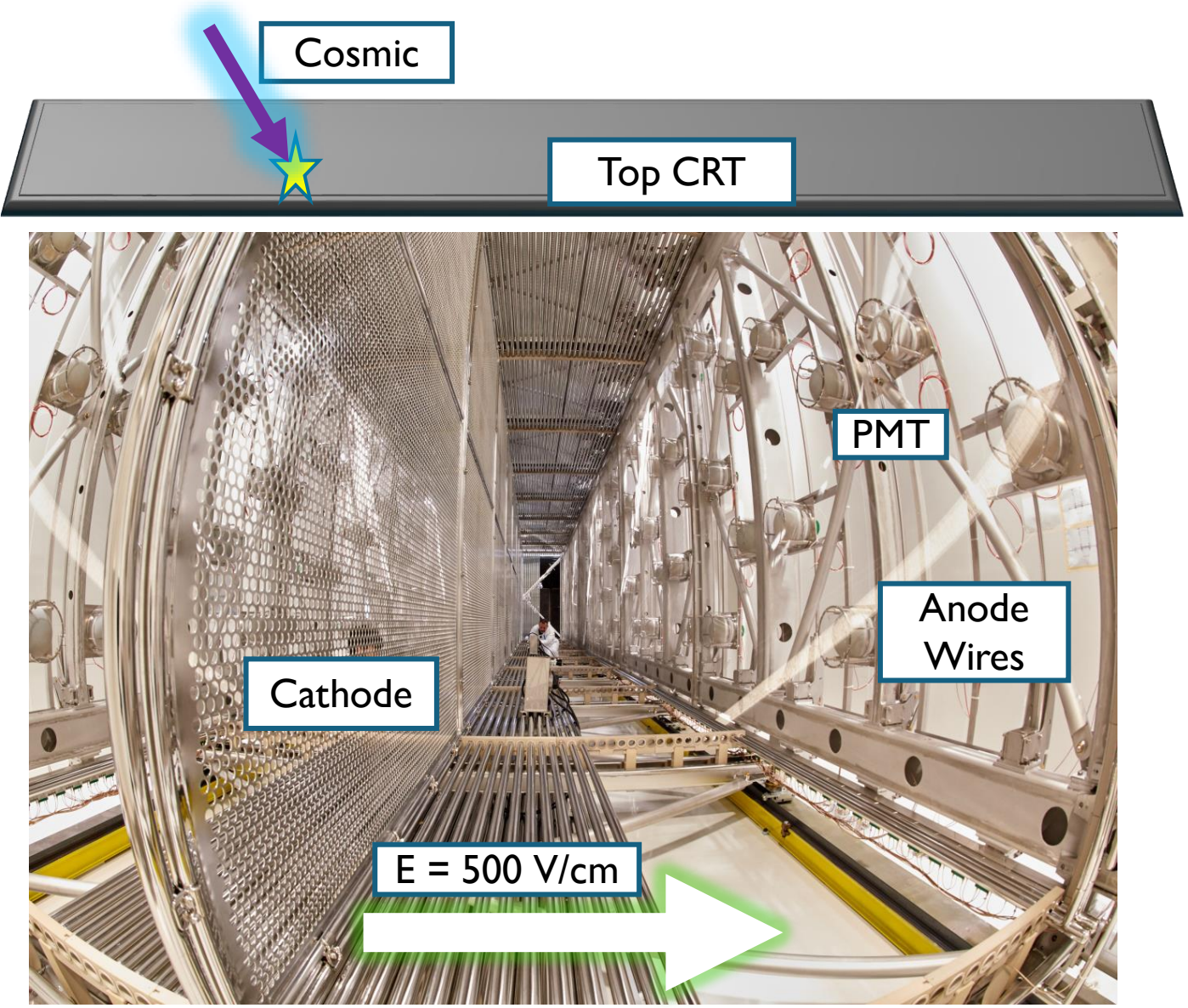
Sterile neutrinos are a possible explanation of the observed anomalies that challenge the standard 3-ν oscillation scenario (Reactor Neutrino, Gallium, LSND and MiniBooNE Low-Energy Excess)

Physics Goals:

- Confirm or rule out sterile neutrinos in the eV scale.
  - -Measure ν_e appearance and ν_μ disappearance rates on the Booster Neutrino Beam (BNB).
  - - ν_e (dis)appearance on NuMI beam.

Near/Far detector joint program reduces systematic uncertantities and increases the sensitivity on the oscillation measurements.

THE FAR DETECTOR: ICARUS



ICARUS has two $3.6 \times 3.9 \times 19.9\ m^3$ cryostats, filled with 760 t of LAr, located at shallow depth 600 meters from the BNB source.

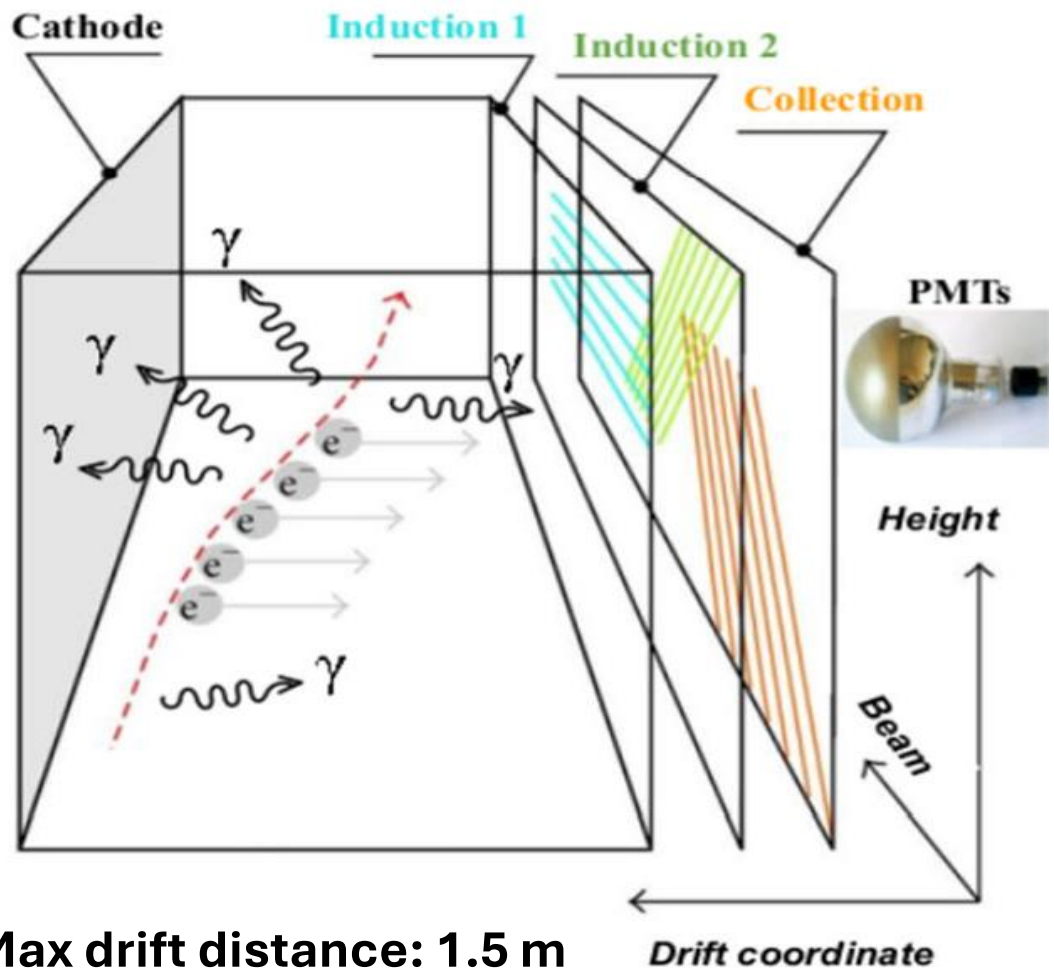
Three subsystems:

- **Time Projection Chamber (TPC)**
  3 readout planes at $0°, \pm 60^{\circ}$ wr.t. the horizontal.

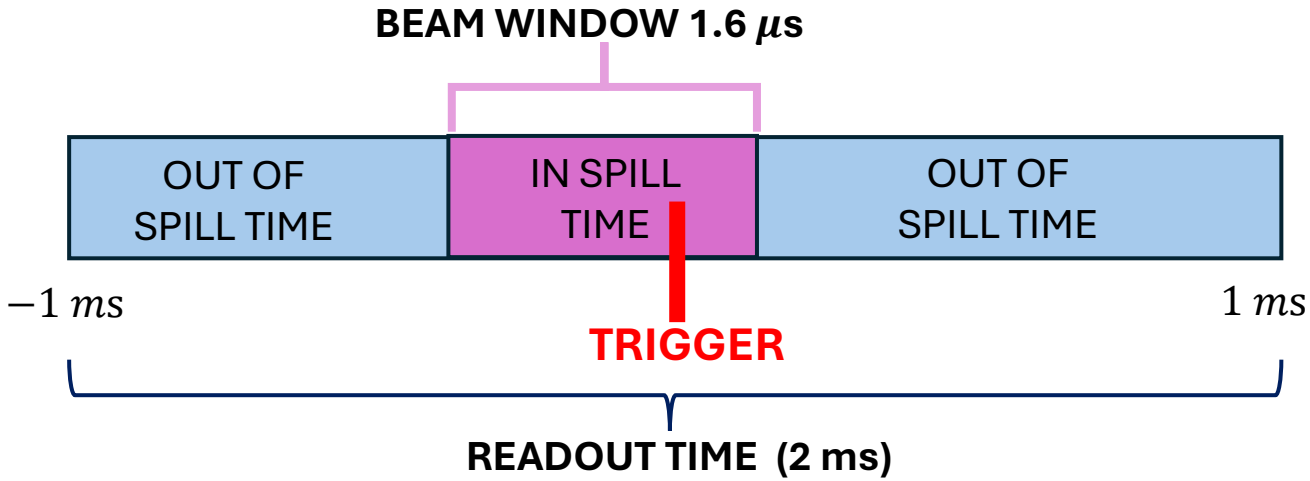
- **PhotoMultiplier system (PMT)**
  360x 8" PMTs, $\sim 1\ ns$ time resolution

- **Cosmic Ray Tagger (CRT)**
  Top, Side and Bottom scintillator bars
  time resolution ~ 1 ns
  spatial resolution ~ 1 cm

TIME PROJECTION CHAMBER



Max drift distance: 1.5 m
Max drift time: 0.96 ms



- Each cryostat contains 2 TPC systems divided by the cathode with independent coordinates
- Induction 1 wires are split at z=0 on both TPC.

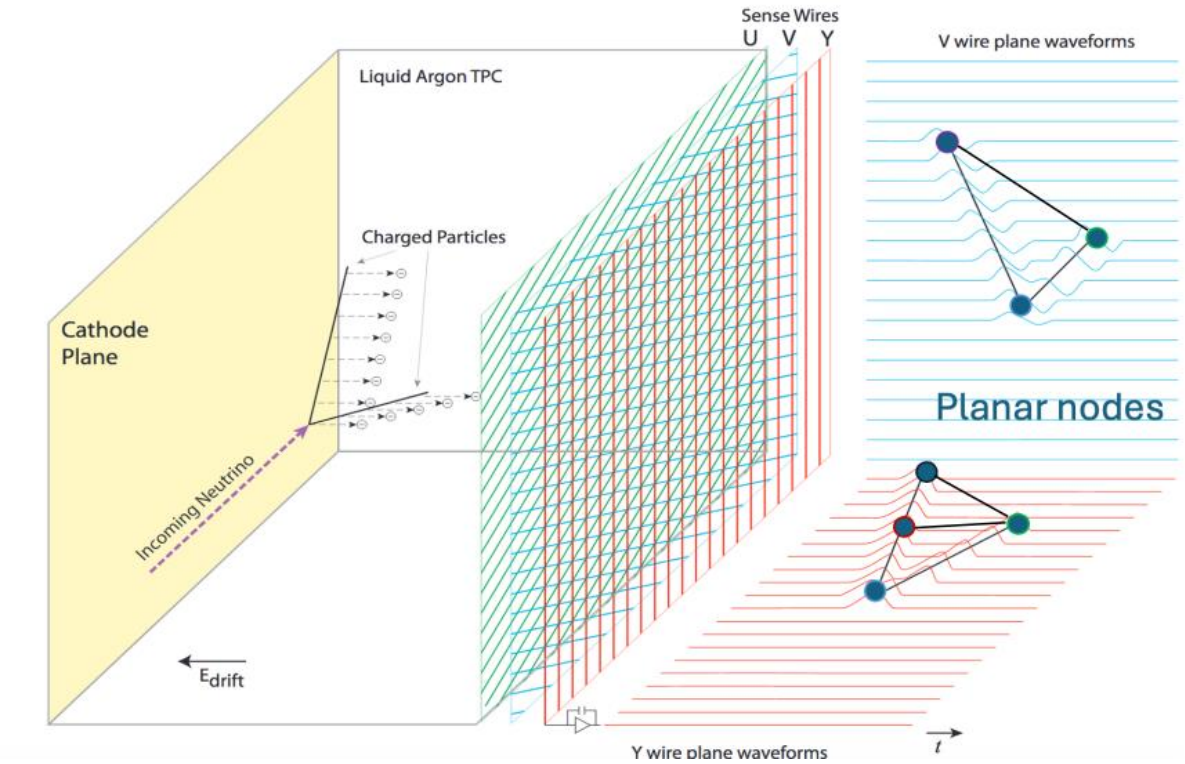
→ The reconstruction algorithm collects deposited charges on each wire and clusters them, forming 3D hits.

NuGraph

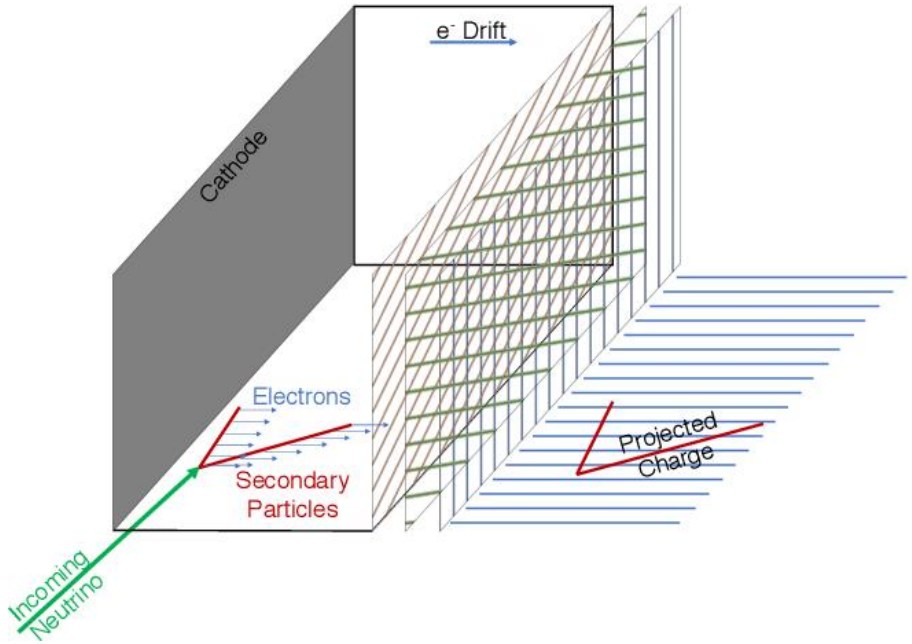
- Nugraph is a Graph Neural Network that takes the hits on each wire and determines the type of particle that originated them.

- The principal inputs are:
  - WireID
  -Peak time
  - charge integral
  -RMS

- Tested on MicroBooNE data and now planned on ICARUS

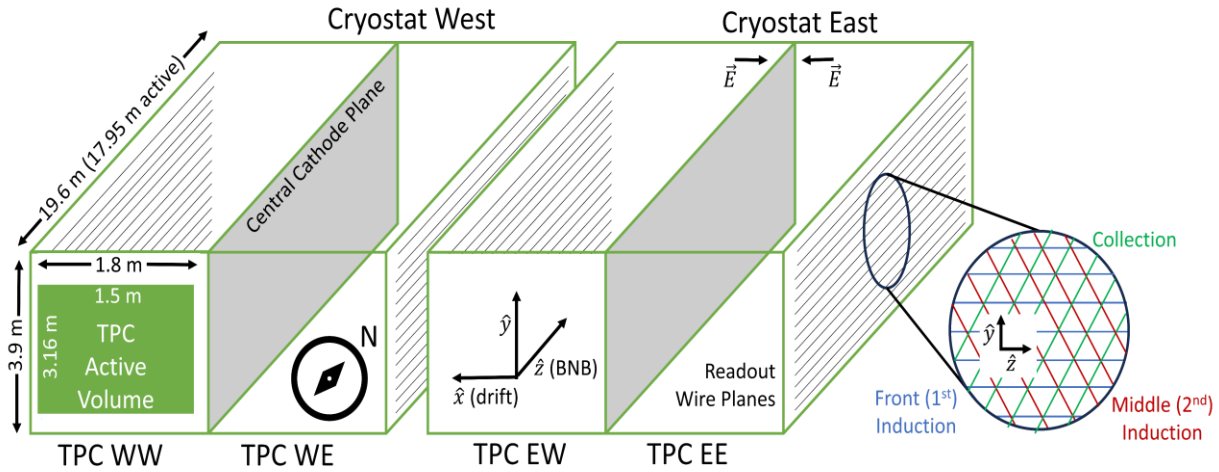


MicroBooNE VS ICARUS



MicroBooNE is a monolithic LArTPC with one cryostat and one readout plane

The collection plane of MicroBooNE is vertical while the other 2 are at $\pm 60°$ with respect to it



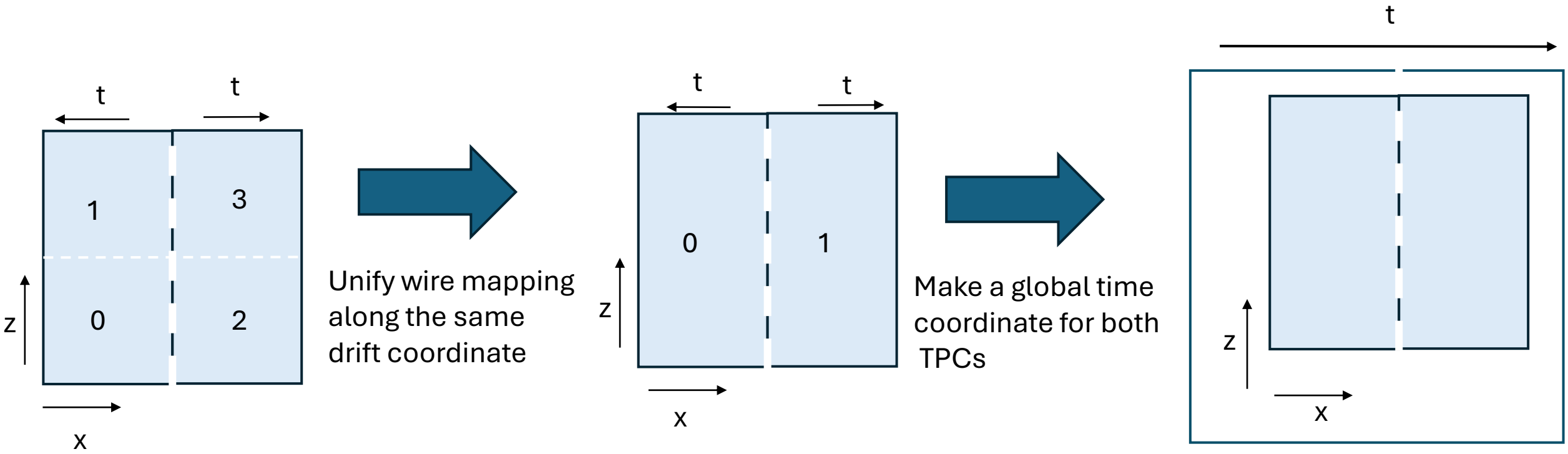
Each cryostat of ICARUS contains two TPC with independent readout systems

The 1st induction plane of ICARUS is horizontal* while the other 2 are at $\pm 60°$ with respect to it

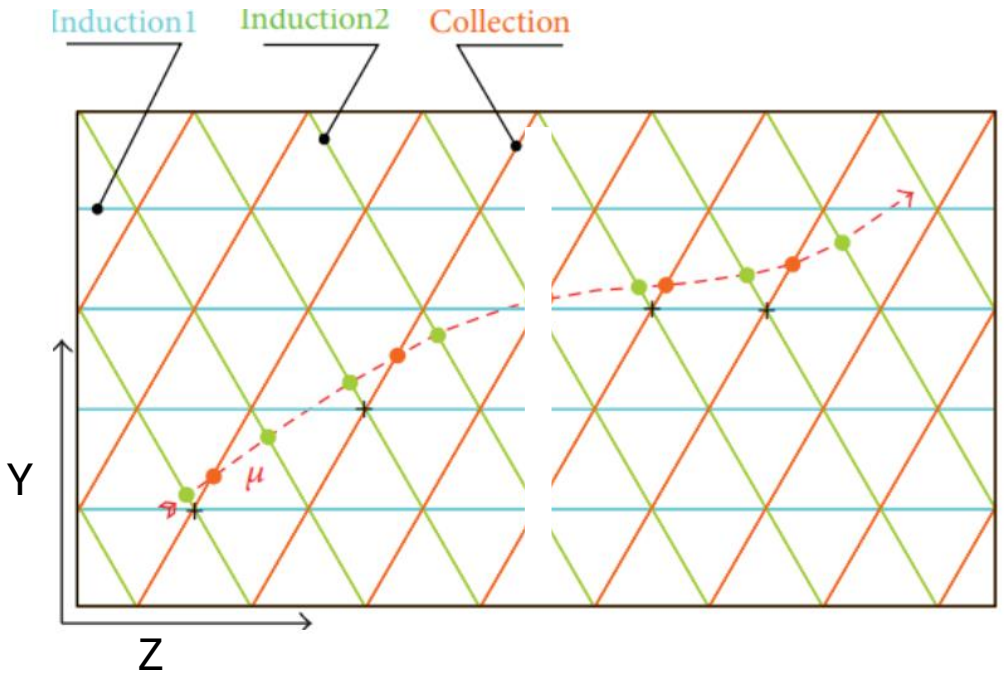
*The horizontal wires are split and create another 2 logical TPC units

ADAPTING THE DATASET

To train NuGraph in ICARUS data is necessary to map the 4 logical TPCs of ICARUS into 1.



WIRE MAPPING

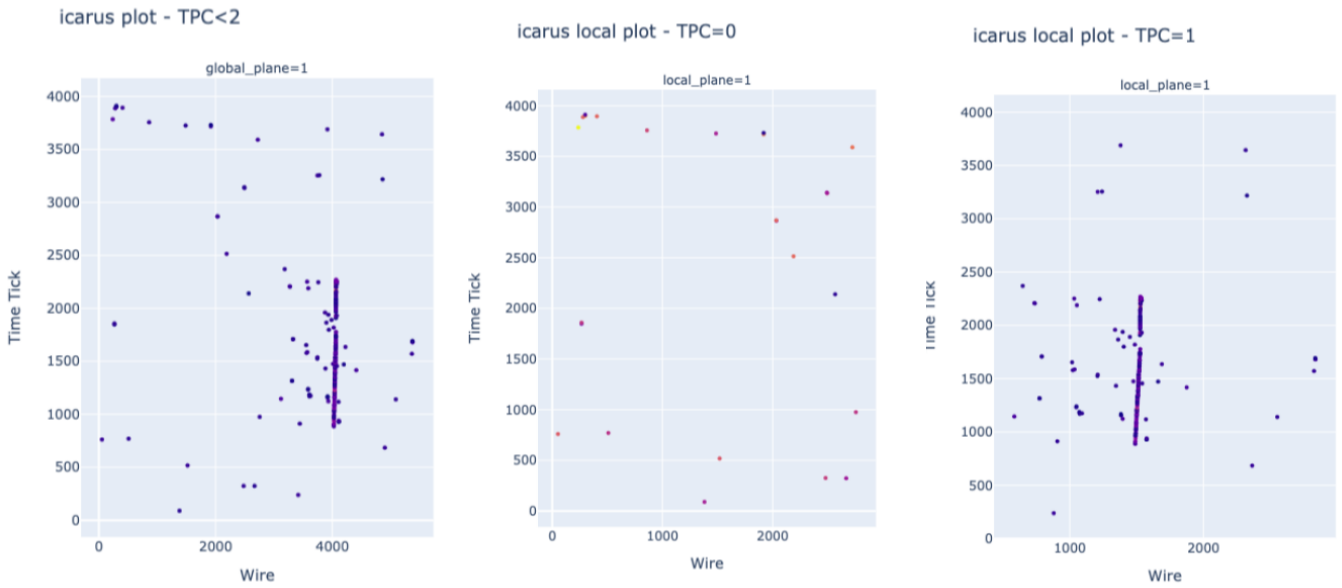


- Induction1 wires keep the same ID on contiguous TPC systems
- Induction2 and collection wires are logically stitched as the last wires of one TPC are connected to the first of the contiguous one.

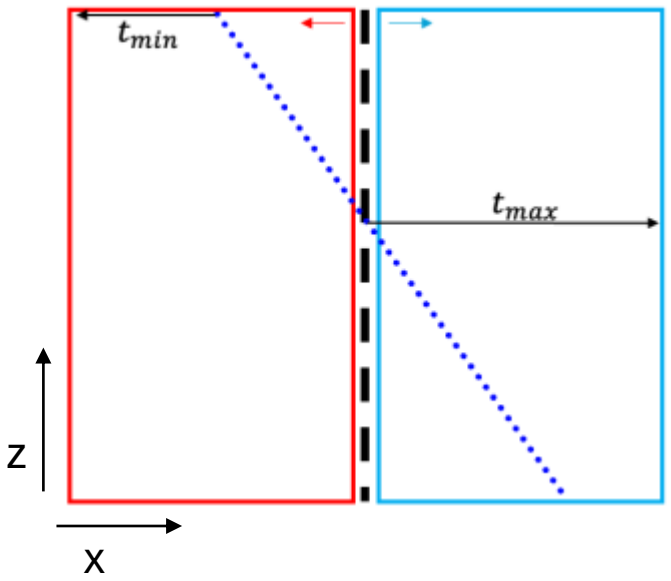
The mapping of the wire labels in planes 1 and 2 is:

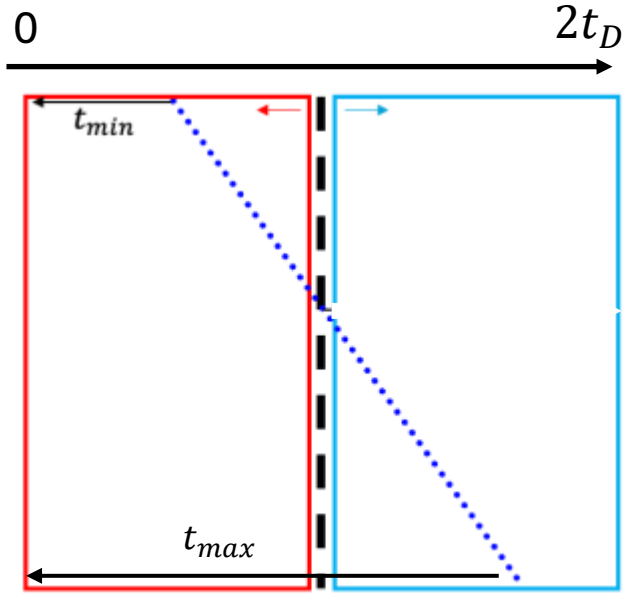
$$WireID \rightarrow WireID + 2536$$

As the wire 2536 of the TPC 0 is stitched with the wire 0 of TPC 1 and so on. Same with TPCs 2 and 3.



TIME MAPPING

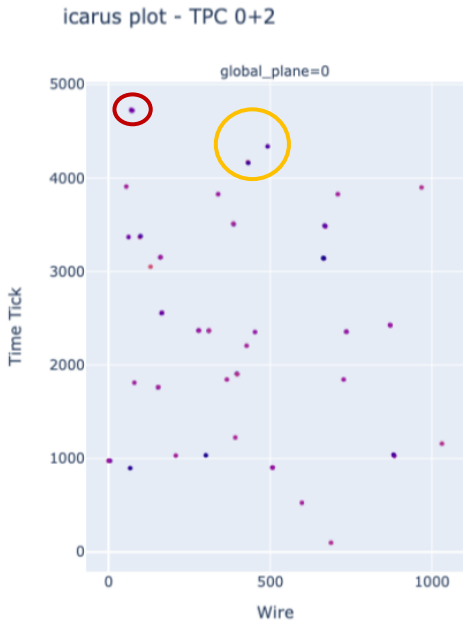


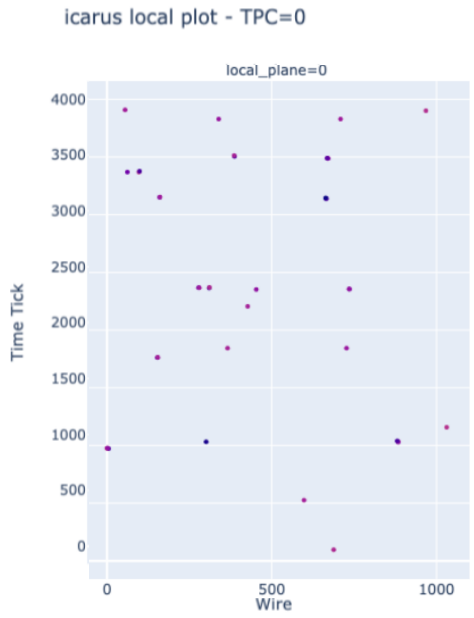


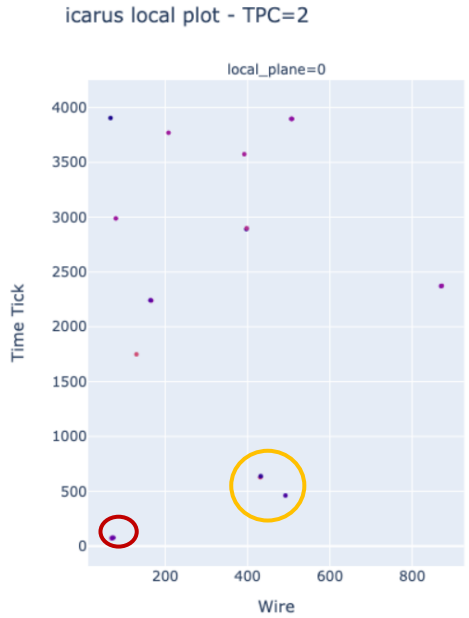
The 0 is set in one TPC plane while at the other the time translation is:

$$t_{hit} \rightarrow \frac{2 * t_D}{0.4} - t_{hit}$$

- Each TPC reconstructs time independently taking the drift distance from the cathode.
- A global timing is set by taking one TPC as reference and scaling the time value to the other TPC

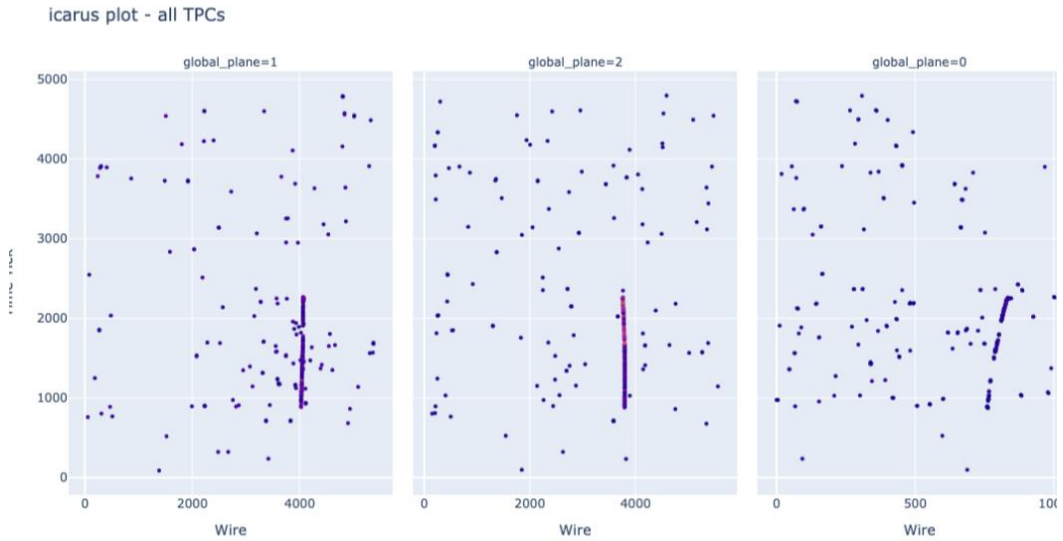






NEXT STEPS

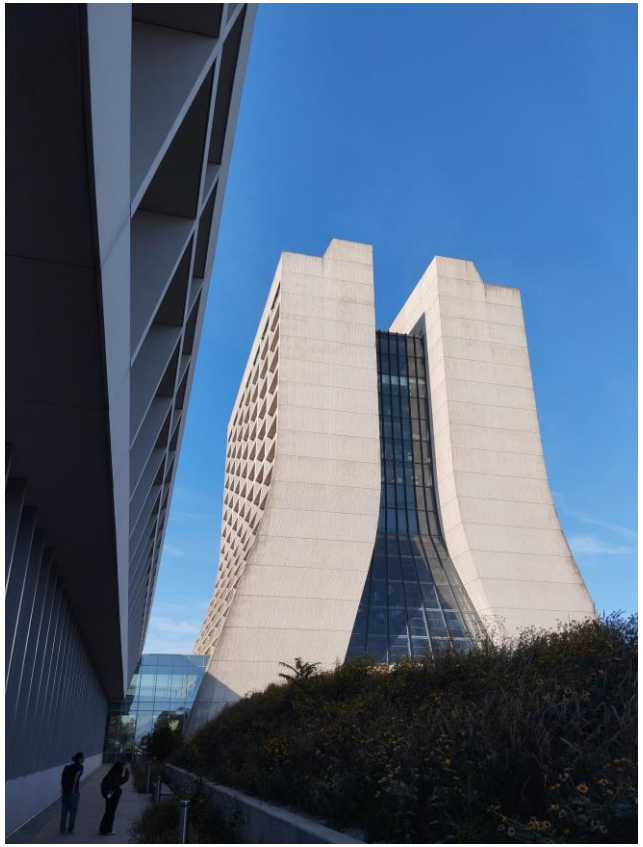
- A mapping of the 4 TPCs into one has been performed for each cryostat of ICARUS



- At a reconstruction level MicrooBooNE stores one neutrino even per slice, while ICARUS stores multiple events in the same object:
  - next step is to choose the event inside an ICARUS slice that would represent the neutrino interaction. This Will be done by means of the light-charge Barycenter distance

- Once the dataset is fully adapted Nugraph Will be trained on an ICARUS monte carlo sample

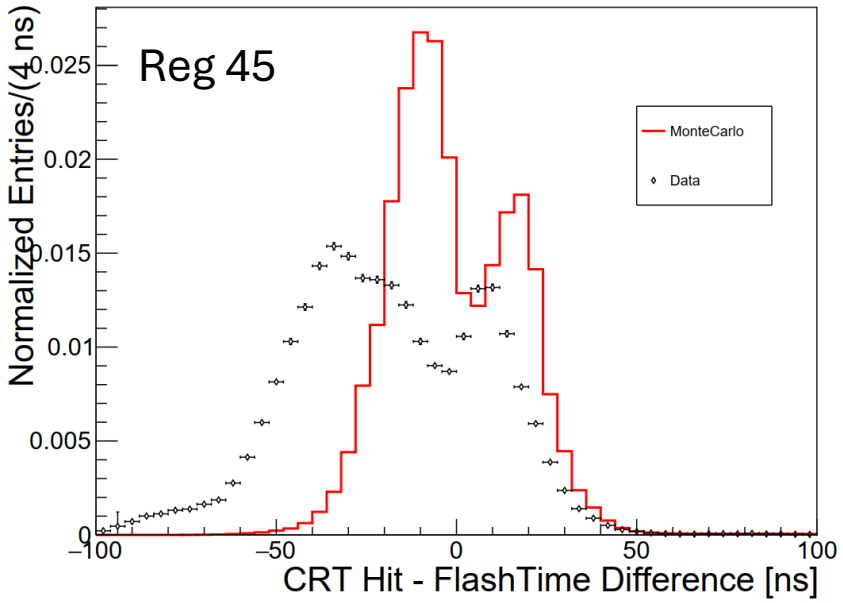
- Extra features may be added to increase the performance of the network (this will be check with the results of the training)

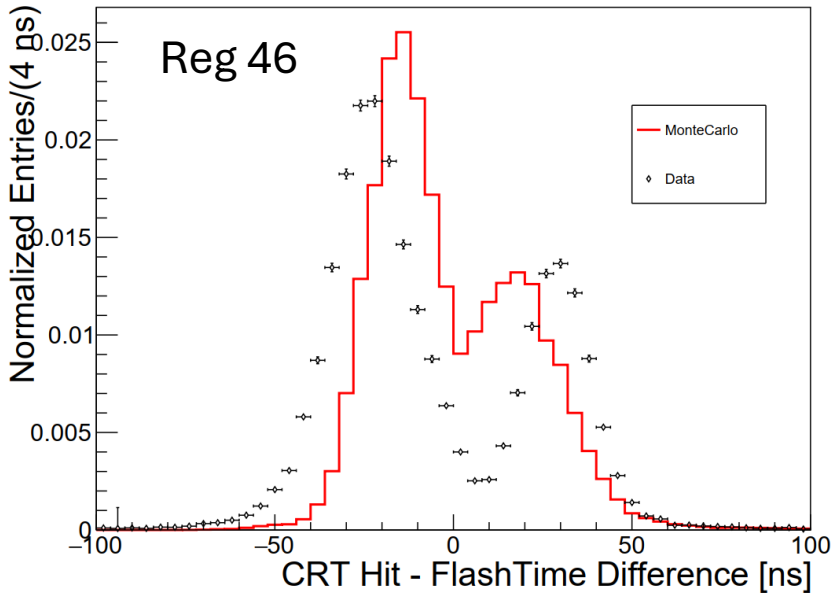


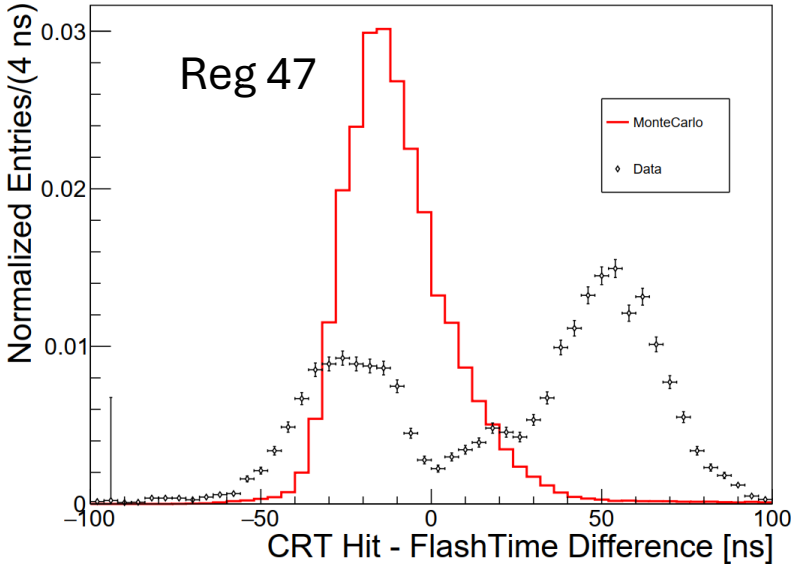
THANK YOU

APPENDIX: ICARUS SIDE CRT TIME DELAY

During my thesis work some discrepancias between the Montecarlo simulation and the data for the time difference between the optical flashes and the CRT system were found for the side system.





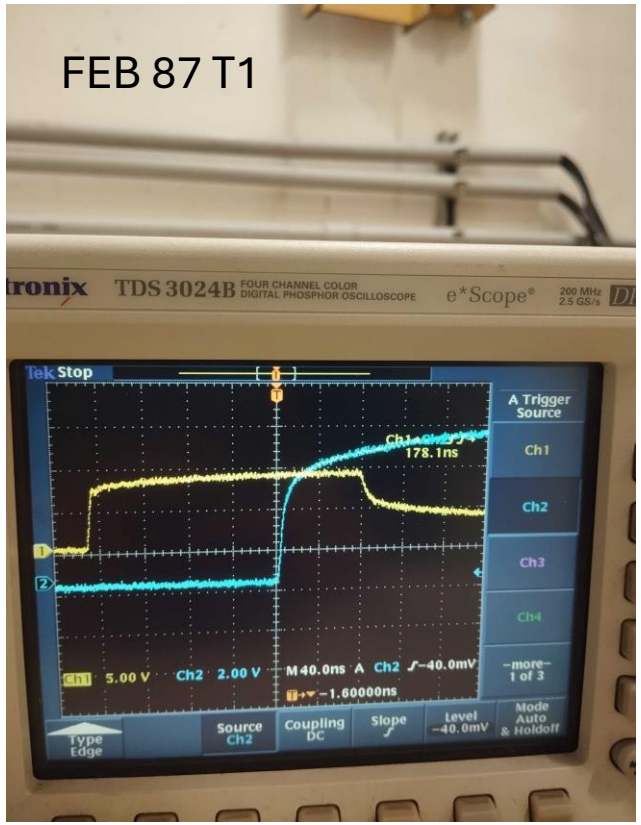


APPENDIX: ICARUS SIDE CRT TIME DELAY

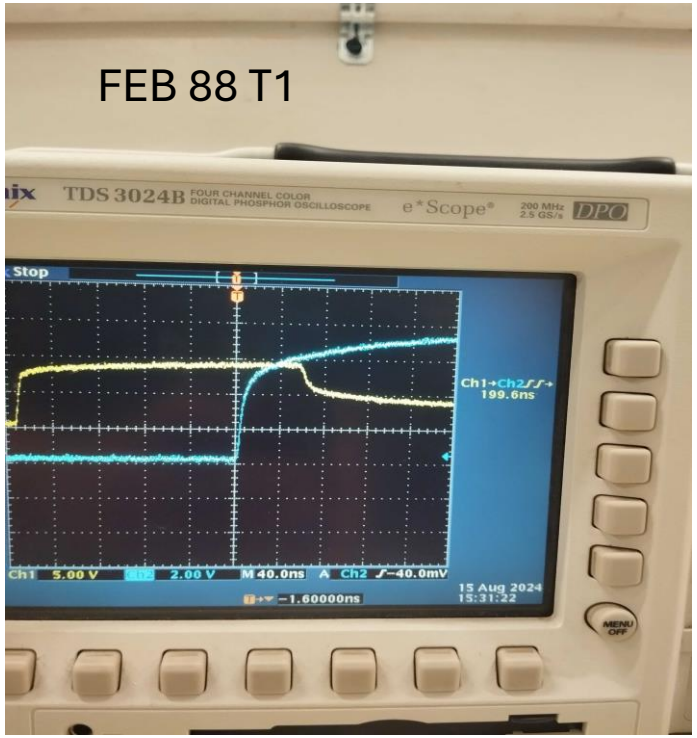
A measurement the delay time on each FEB signal with respect to the global trigger signal.

Reg 45
FEBS: 86-103

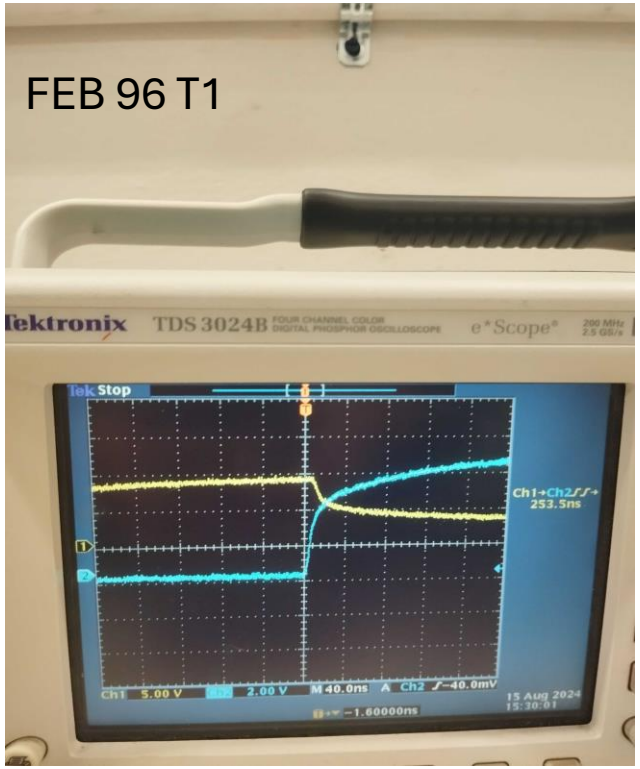
FEB 87 T1



FEB 88 T1



FEB 96 T1



NEXT STEPS

- Finishing the measurements on the side FEBs (halfway through).

- The quantification of the time delay on the side FEBs will be added to the CRT .fcl and is expected to improve the reconstruction on the data coming from the CRT.

- A spreadsheet with the information regarding the T0 and T1 signals on each FEB is being written.