Neutrino Physics Event reconstruction tools

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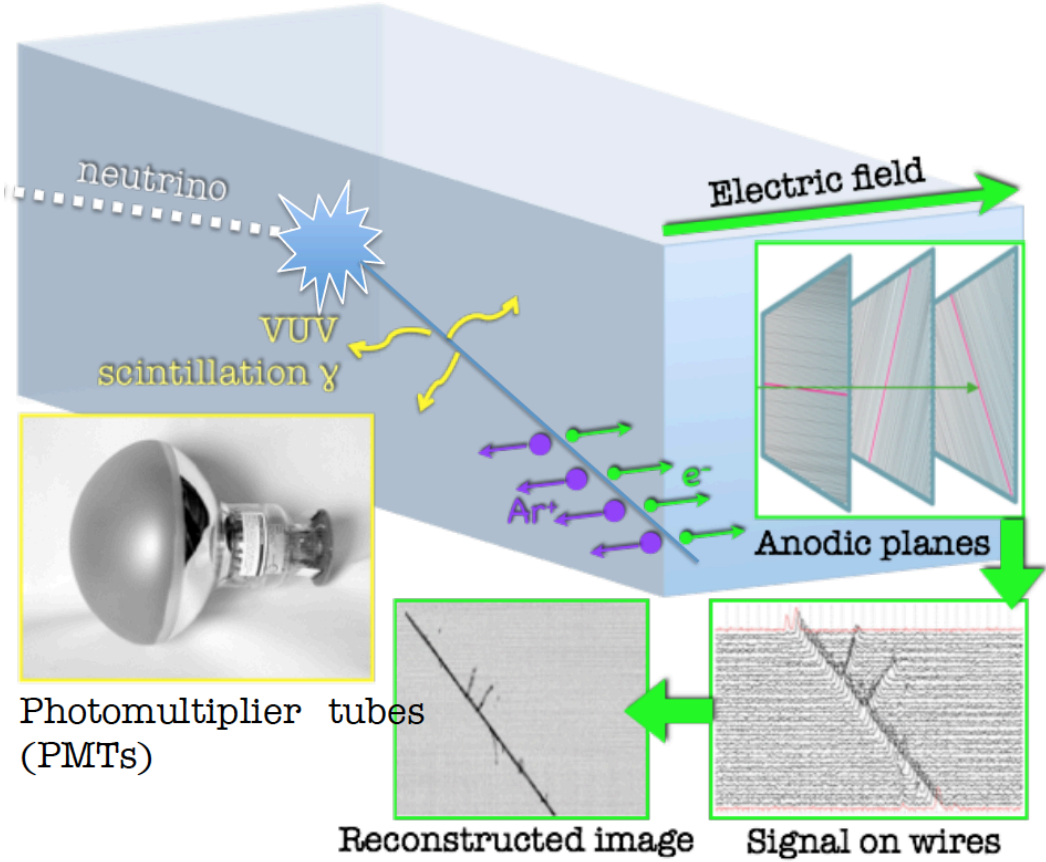
Different tools are needed for the different sub-detectors

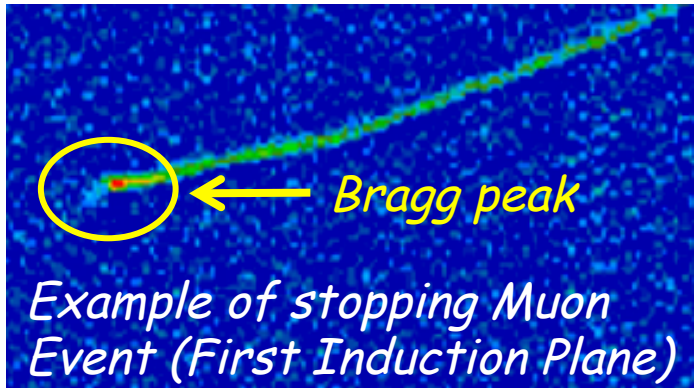
- The liquid argon time projection chamber detector (LAr-TPC) allows to visualize the 3D image of interactions inside the liquid argon (LAr), by properly processing the signals induced by drifting ionization electrons on three planes of anodic sense wires (~54000 wires for ICARUS);
- Relevant additional information (precise timing, fast localization, etc) provided by the scintillation light produced in LAr, requiring to precisely reconstruct the light signals detected by a sophisticated and finely segmented photo detection (PDS) system;
- In addition the cosmic ray tagger (CRT) system encapsulating the TPCs allows to discriminate between the incoming cosmic ray particles from neutrino interactions inside the LAr

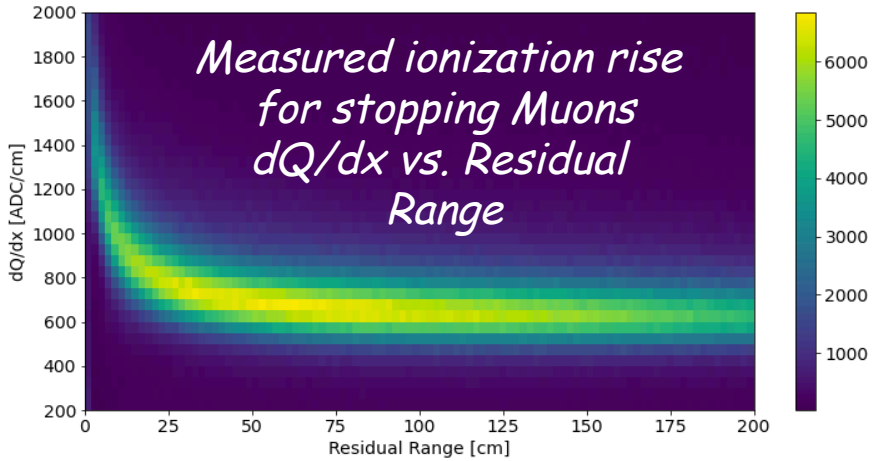


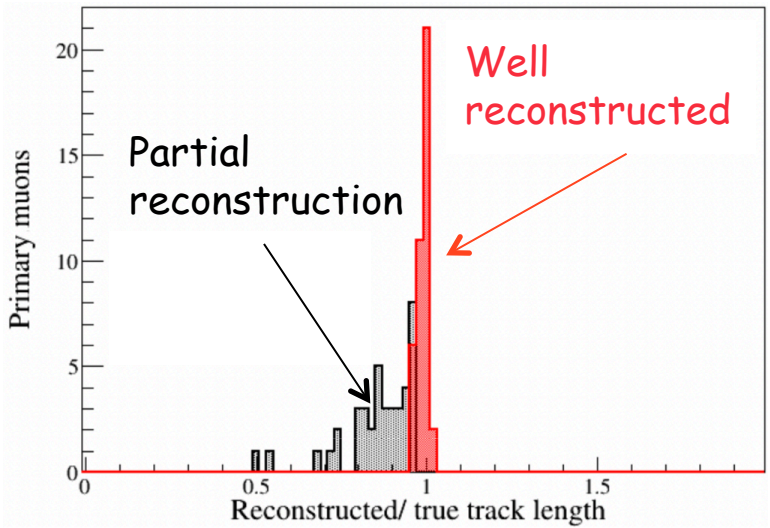
- Reliable and robust reconstruction tools are necessary for all the three sub-detectors.
- Activities have progressed despite the pandemic limitations.

TPC wire signal reconstruction

- TPC wire signals are processed to identify and measure genuine physical signals while rejecting fake contribution from different sources of noise. Identified wire signals are then used by pattern recognition (PANDORA) code to reconstruct the tracks inside the TPC.
- A full calibration chain has been developed, based on the reconstruction of the expected ionization rise of cosmic muons crossing the TPC and stopping in the LAr;



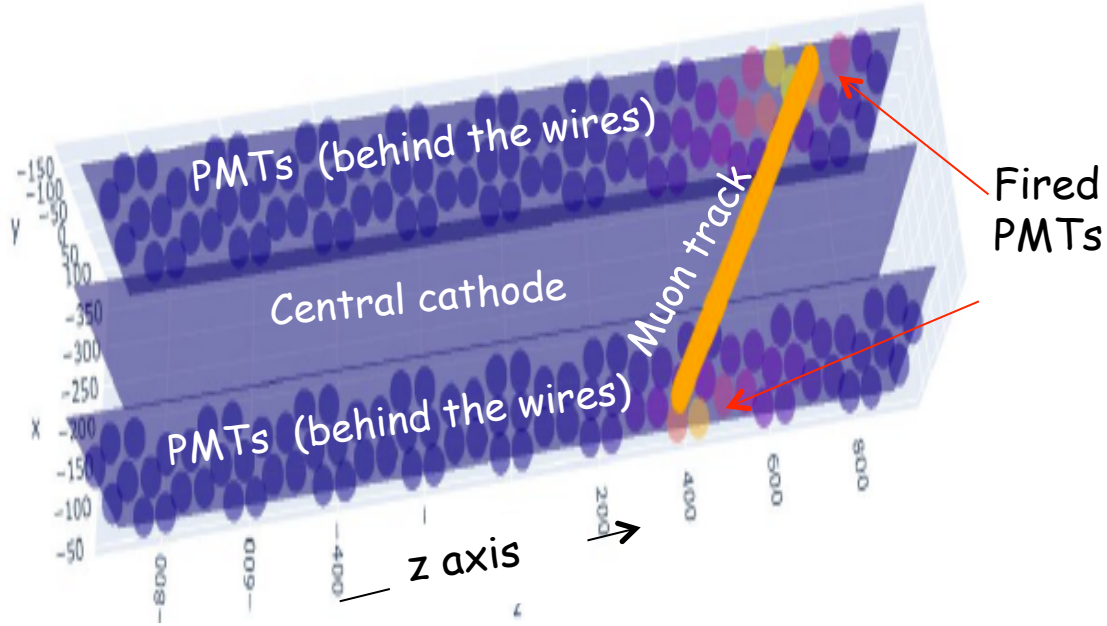


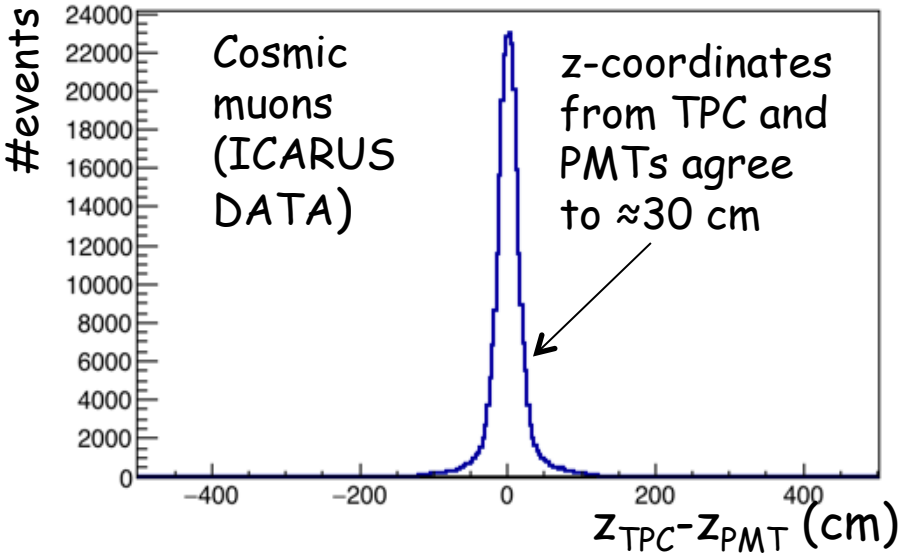


- The performance of the track identification is studied and optimized with realistic simulations;
- Example of completeness of reconstruction for simulated muons produced in neutrino interactions from the beam.

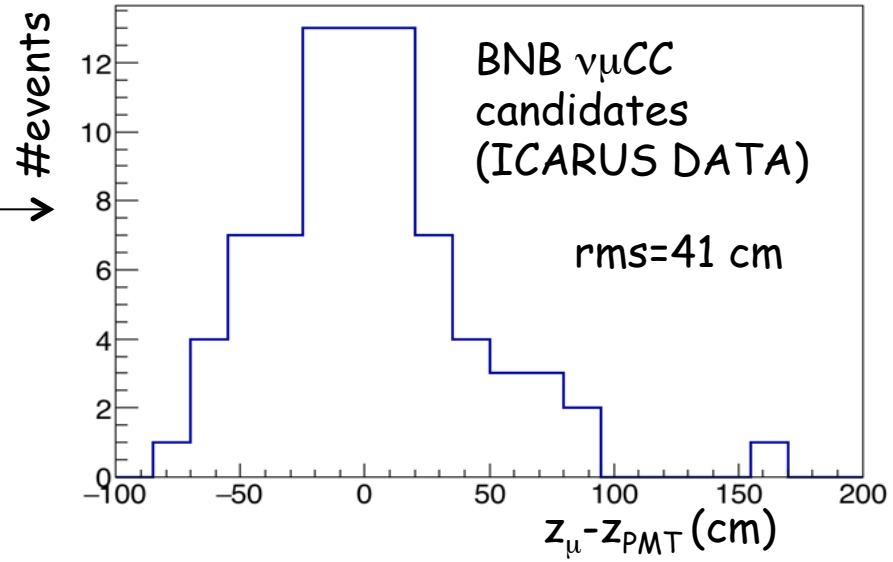
Reconstruction of the light signals

- The image reconstructed inside the TPC can be compared with the associated image reconstructed from the light detected by the photo detection systems (PMTs).

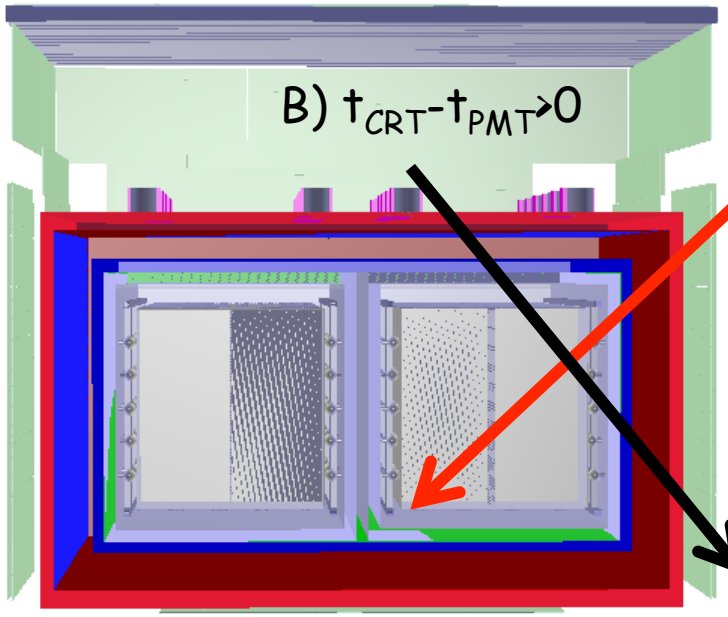


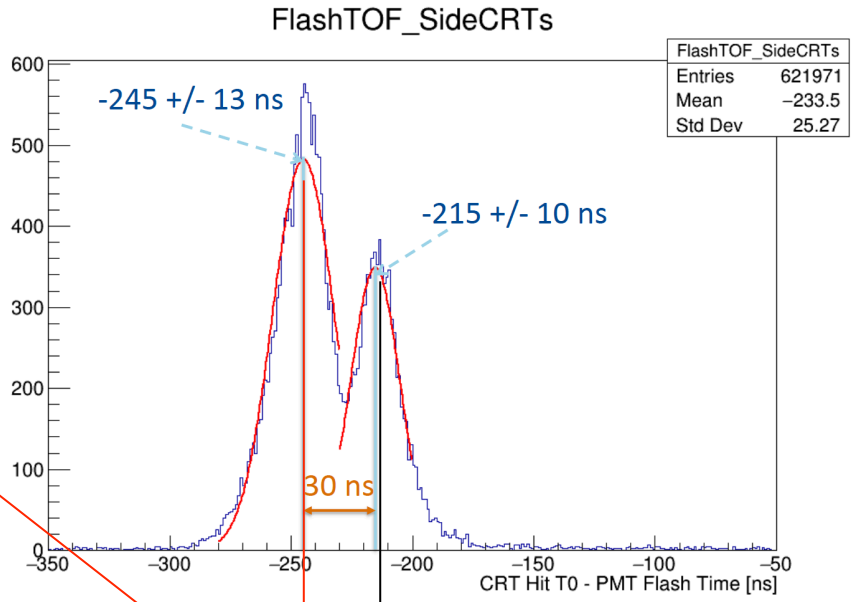


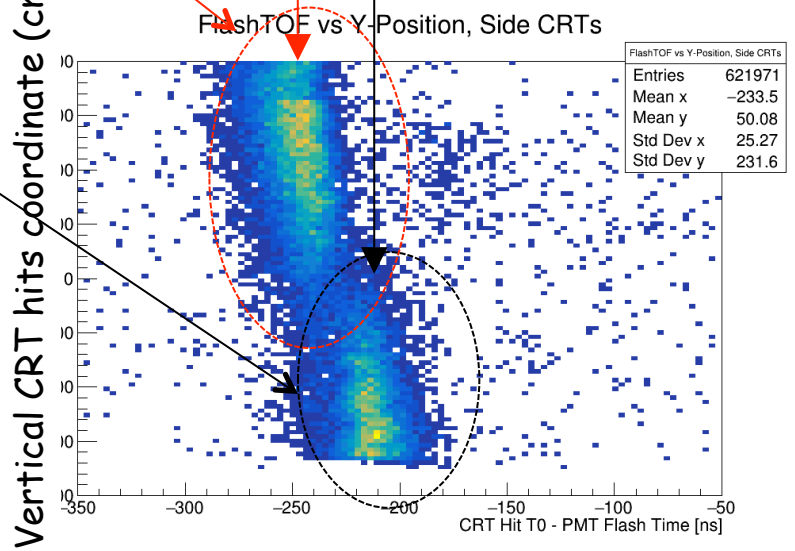
- A similar study has been performed on a set neutrino interactions from the BNB beam identified by scanning: the average z coordinate of the muon z_μ agrees with the light barycenter within ~1 m.



CRT – inner PMT time correlation







- Study performed at the moment with data collected during the commissioning of ICARUS
- The two peaks are due to cosmic tracks entering (A) or exiting (B) through the Side CRT, with 30 ns difference between the two components.
- The individual channel time offset and the global time offset are presently being calibrated.

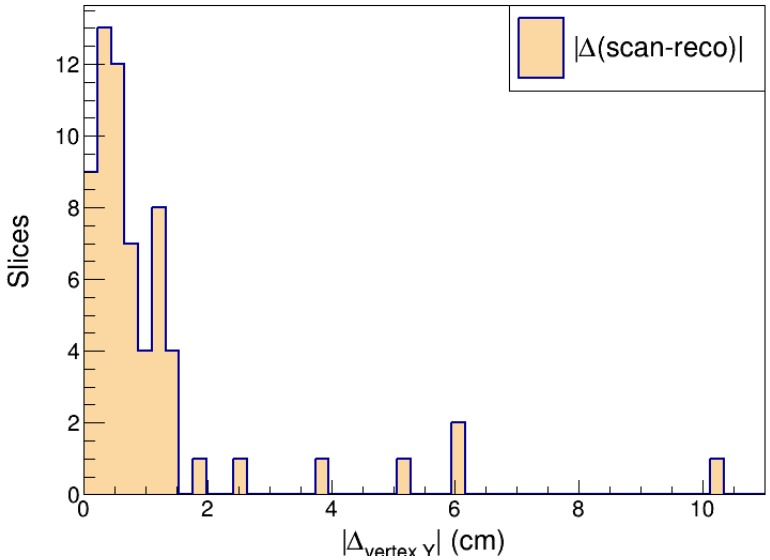
Summary

- Despite the strong limitations imposed by the pandemic, activities have progressed significantly;
- Tools required to reconstruct the events have been prepared in the general shared framework and are presently working on simulations and ICARUS commissioning DATA;
- All the algorithms are being optimized with MC and validated with data;

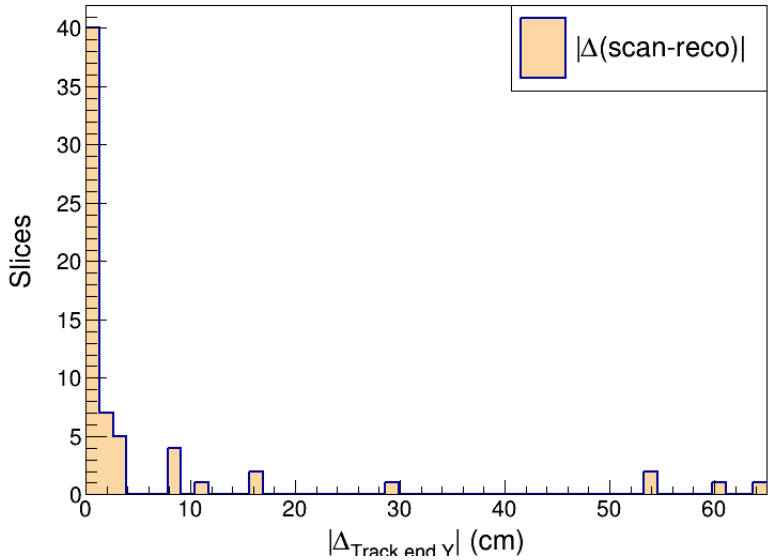
BACKUP

Neutrino event selection

- A full selection of neutrino event reconstruction has been implemented with the presently available tools.
- The events selected and reconstructed with the automatic procedure have been compared with a sample of $\nu\mu$ charged current interactions collected in ICARUS with the BNB beam and then visually identified and manually measured by physicists.
- Encouraging first results for: a) the neutrino vertex correctly identified within ~2 cm and b) the complete reconstruction of the associated muon in the event;



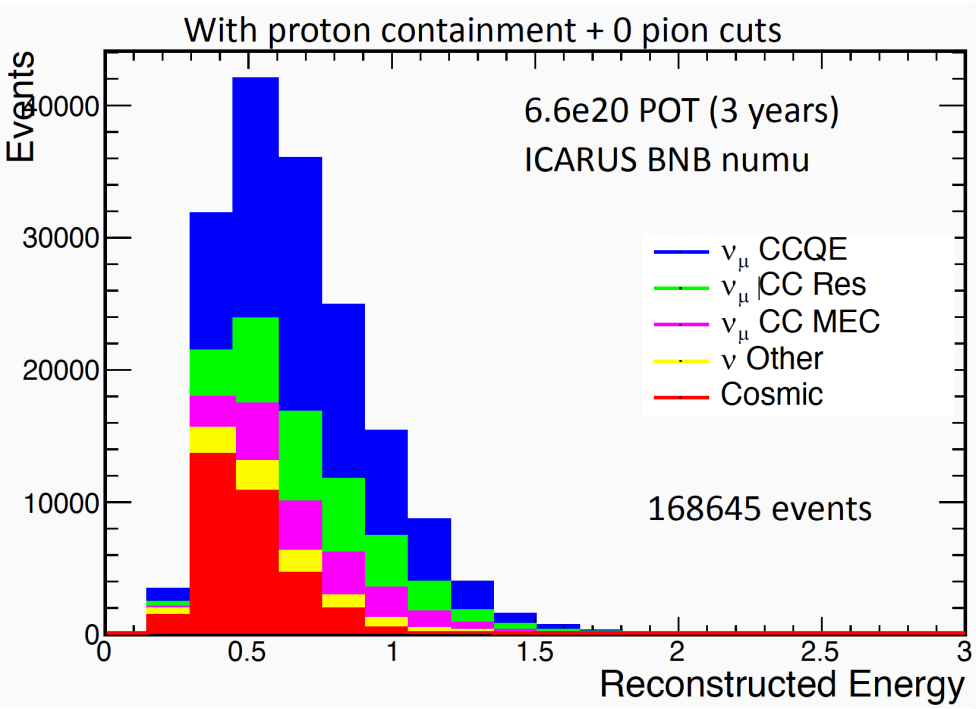
Difference between the automatically reconstructed vertex and the measured one along the vertical axis

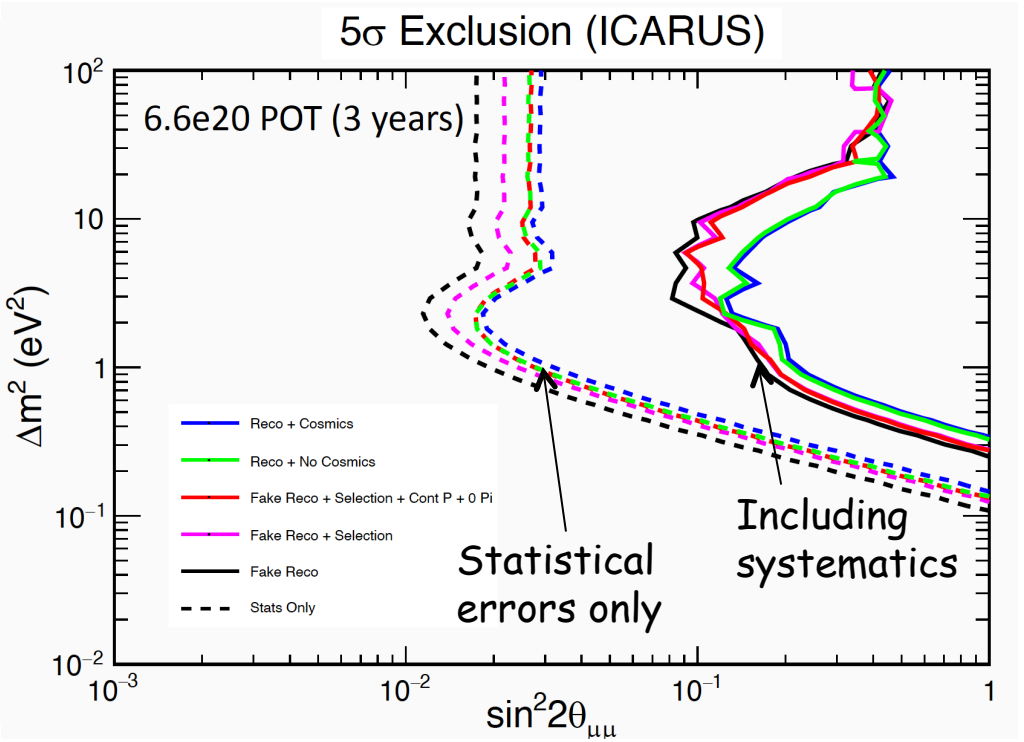


Difference between the automatically reconstructed end of the m track and and the measured one along the longitudinal axis

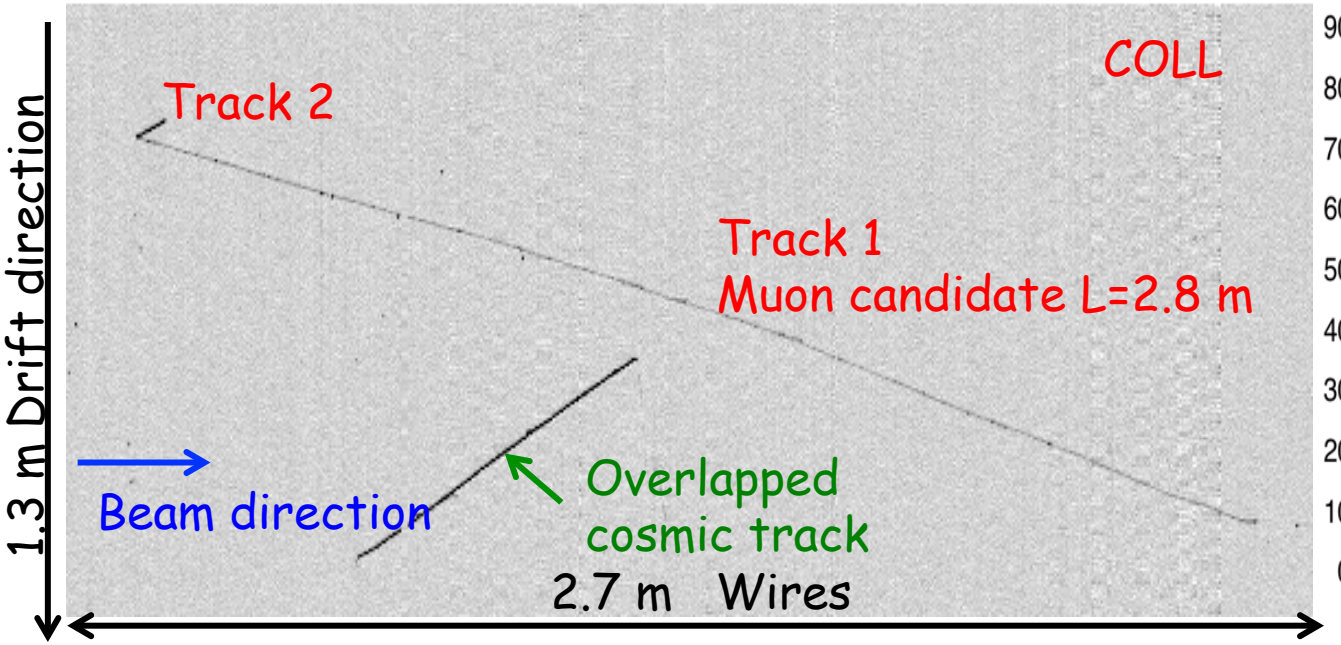
SBN event reconstruction: MC study (ICARUS)

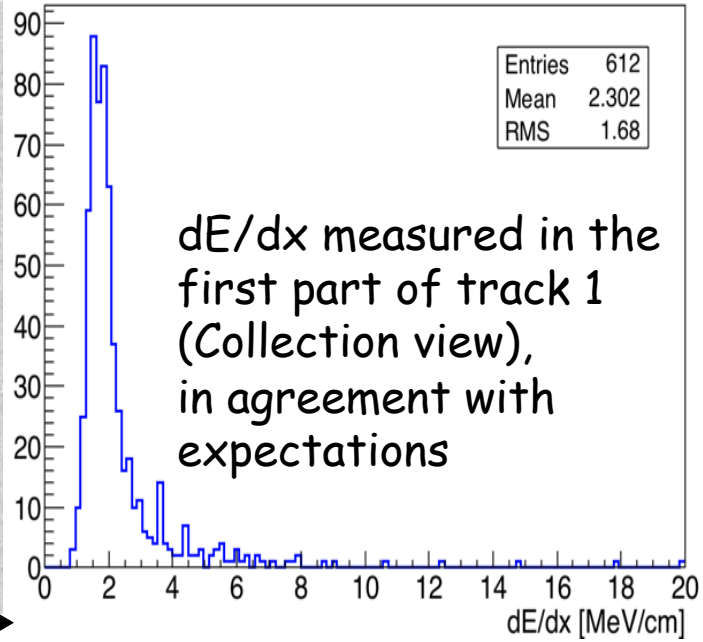
- An exercise to apply fitting methods to fully reconstructed MC events and study variations w.r.t. the fake reconstruction applied so far;
- First end to end application to ICARUS alone $\nu\mu$ disappearance;
- Only events with contained protons and no reconstructed pion;
- $E\nu = E\mu + \Sigma_{Trk} EK_{trk}$ for tracks identified as protons.





An example of νμ CC candidate from BNB beam in ICARUS





- The deposited energy in the interaction is ~ 750 MeV. Two tracks are produced:
  - ✓ Track 1 (muon candidate) is upward going and stopping inside L= 2.8 m E_{DEP}~650 MeV; the dE/dx in the first part is roughly in agreement with the expectation.
  - ✓ Track 2 (proton candidate) is downward going and stopping inside: L= 10.9 cm E_{DEP}~100 MeV, E_K ~120 MeV from range. The angle in 3D between track 1 and track 2 is ~55°