The ICARUS T600 detector and the search for sterile neutrinos

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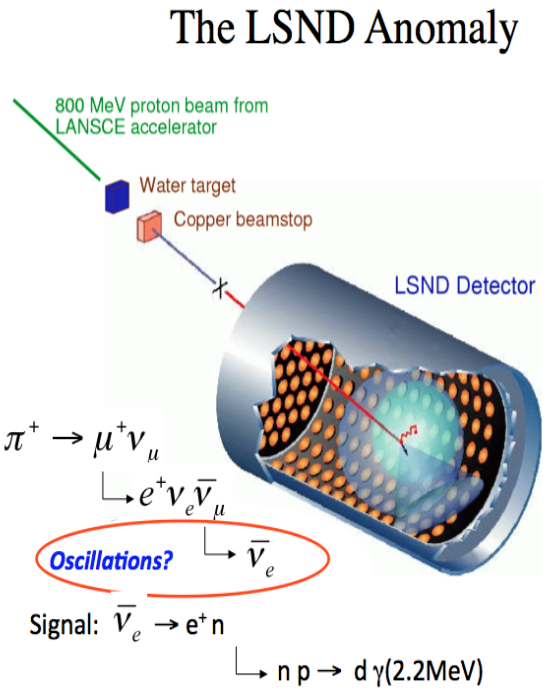
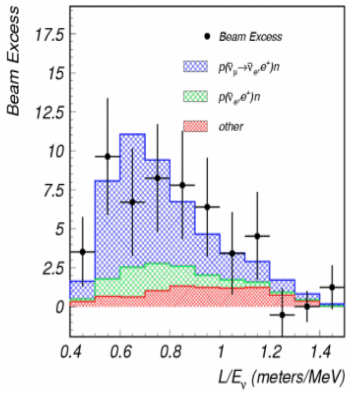
Neutrino related anomalies ?

Neutrinos are the most abundant massive particles in Universe but their basic properties are still largely unknown: neutrinos are the main experimental portal for novel physics beyond the Standard Model

- For several decades, many anomalies beyond an ordinary 3-flavour mixing picture have been collected in the neutrino sector, suggesting some additional new related physics:
  - *anti-νe appearance: anti-nm accelerator LSND experiment where anti-νe -> e^+ + n with neutron captured by a proton, n + p into d + γ.*
  - *Evidence also of anomalous (anti-) νe disappearance for example in reactor experiments.*





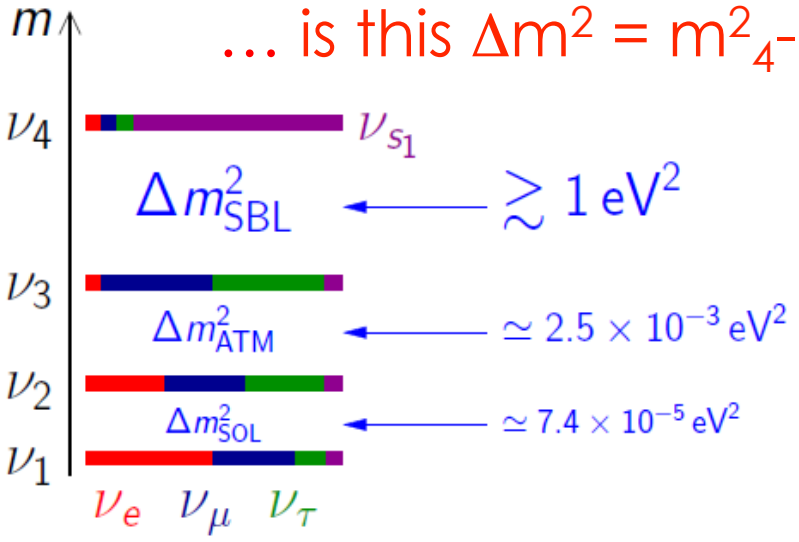
Saw an excess of $\bar{\nu}_e$: 87.9 ± 22.4 ± 6.0 events.

With an oscillation probability of (0.264 ± 0.067 ± 0.045)%.

3.8 σ evidence for oscillation.

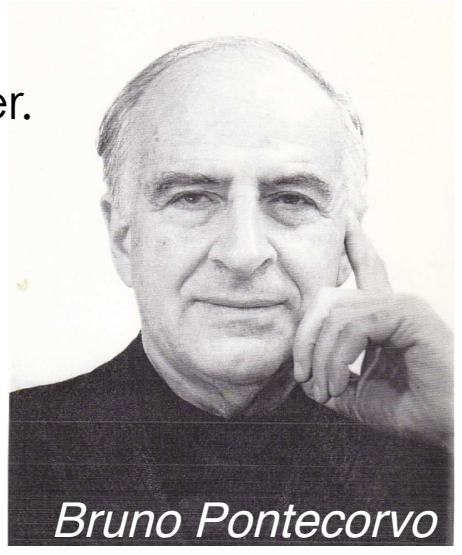
Sterile neutrinos?

These experiments highlight oscillations with a $\Delta m^2 \sim O(1\ eV^2)$, incompatible with the well studied oscillation related to solar and atmospheric ν ($\Delta m_{12}^2 \sim 7.4 \times 10^{-5}\ eV^2$ and $\Delta m_{23}^2 \sim 2.5 \times 10^{-3}\ eV^2$).



- Sterile neutrinos are an hypothetical type of neutrinos that do no interact via any of the fundamental interactions of the Standard Model except gravity. The name was conied in 1957 by B. Pontecorvo.

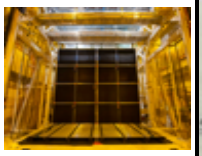
- If they are heavy enough, they may also contribute to dark matter.
- Sterile neutrino may mix with ordinary neutrinos, so if they exist, it is necessary to extend the "standard neutrino model" based on 3 neutrinos at least to a minimal 3+1 model
- Since they would not interact with matter, they are extremely difficult to detect and they can be recognized only "indirectly": **anomalous appearance/disappearance ν oscillation signals**

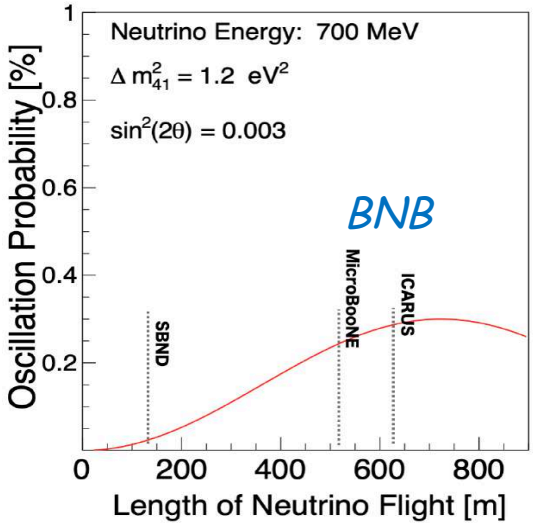

Bruno Pontecorvo

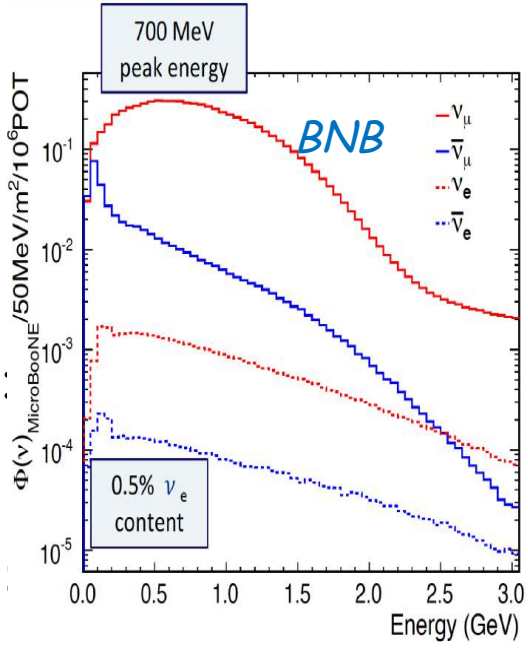
Short Baseline Neutrino SBN at FNAL: a definitive answer to sterile νs?

ICARUS
600m baseline
470t active volume
data taking

SBND
110 m baseline
112t active volume
under completion



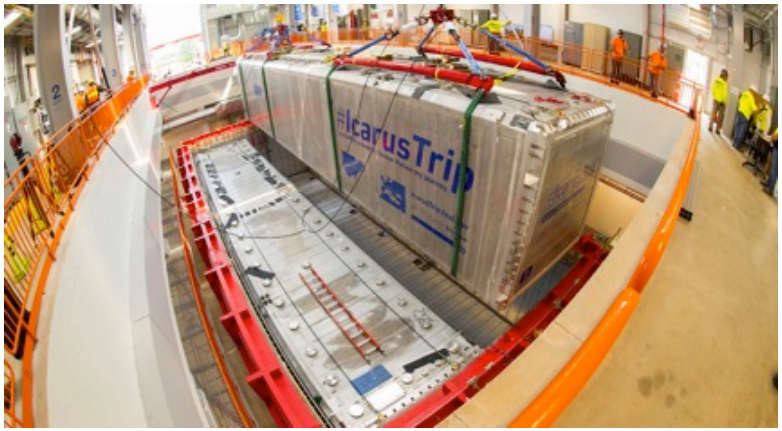




- ICARUS and SBND LAr-TPC's installed at 600 and 110 m from Booster target, searching for sterile-ν oscillations both in appearance and disappearance channels.
- Furthermore, high-statistics ν-Ar cross-sections measurements and event identification/reconstruction studies in view of DUNE:
  - ~10^6 events/y in SBND <1 GeV from Booster
  - ~10^5 events/y in ICARUS >1 GeV from NuMI beam (700 m, 60 off-axis from target).

The ICARUS LAr-TPC ν detector

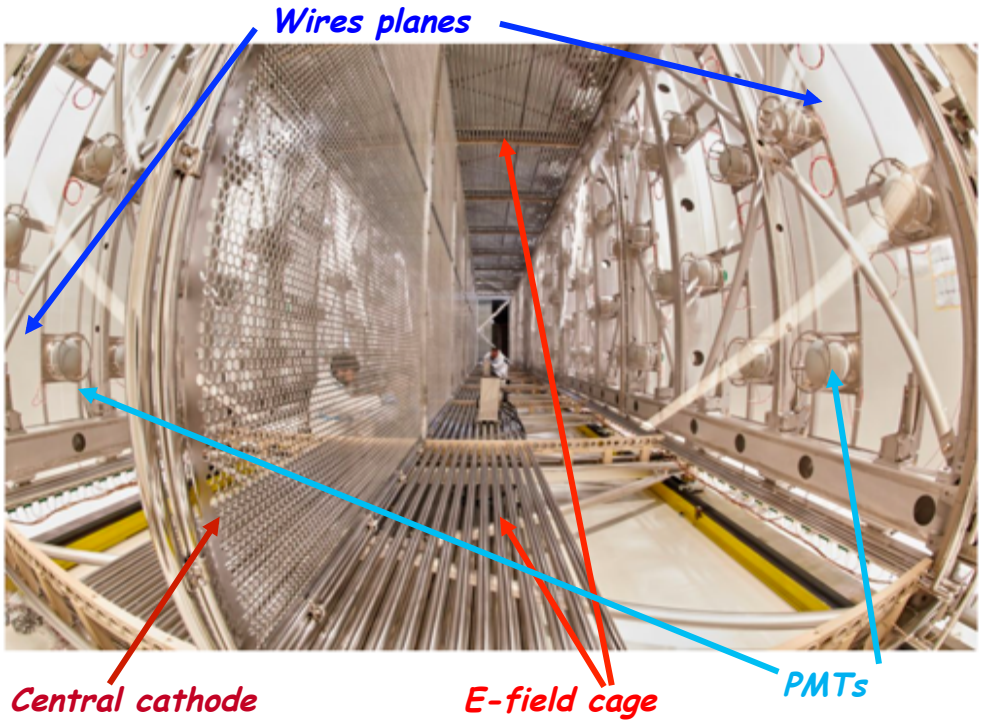
- Liquid Argon Imaging technology LAr-TPC, an ''electronic bubble chamber'' identifying unambiguously each ionizing track in complex neutrino events, was proposed by C. Rubbia [CERN-EP/77-08] as an alternative to Cherenkov detectors.



Long R&D by INFN/CERN culminated in the first large scale experiment ICARUS-T600, 0.76 kt ultra-pure LAr-TPC at G. Sasso underground lab:

… paving the way for Long-Baseline experiments

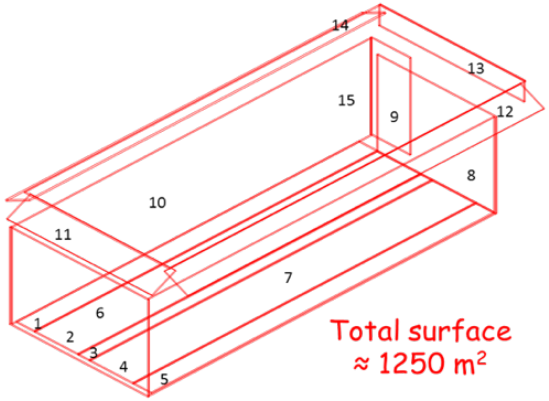
- ICARUS-T600 overhauling in 2014-18 in view of shallow depth operation at Fermilab:
  - 2 modules, 2 TPCs per module with central cathode (1.5 m drift, E_D= 0.5 kV/cm);
  - 3 readout wire planes per TPC, 54000 wires at 0, ± 600, 3 mm pitch, in total;
  - 360 PMTs, TPB coated detecting scintill. light produced by particles in LAr



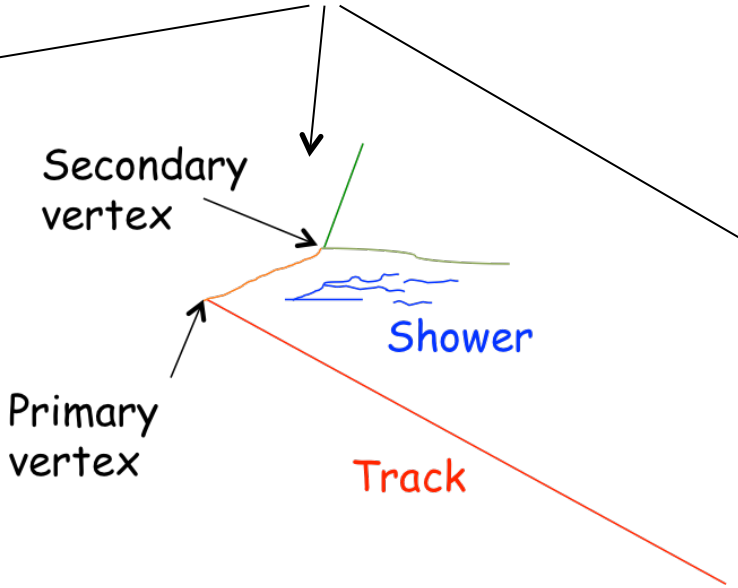
A new experimental challenge: a LAr-TPC on surface

ICARUS at FNAL is facing a challenging experimental condition, requiring the recognition of O(10^6) n interactions amongst 11 KHz of cosmic rays.

- A 3 m concrete overburden will remove contribution from charged hadrons/γ's.
- Automatic tools for the selection of the neutrino interactions and for the rejection of the backgrounds, in particular associated to cosmic particles, are mandatory and should use all the available information



Cosmic Ray Tagging System surrounding the T600 allow to reject incoming cosmic particles

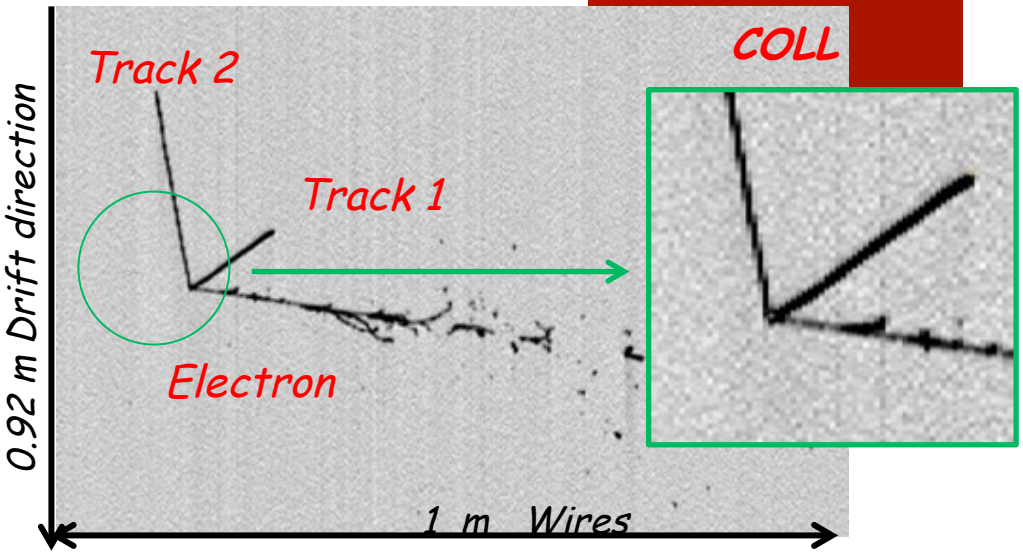


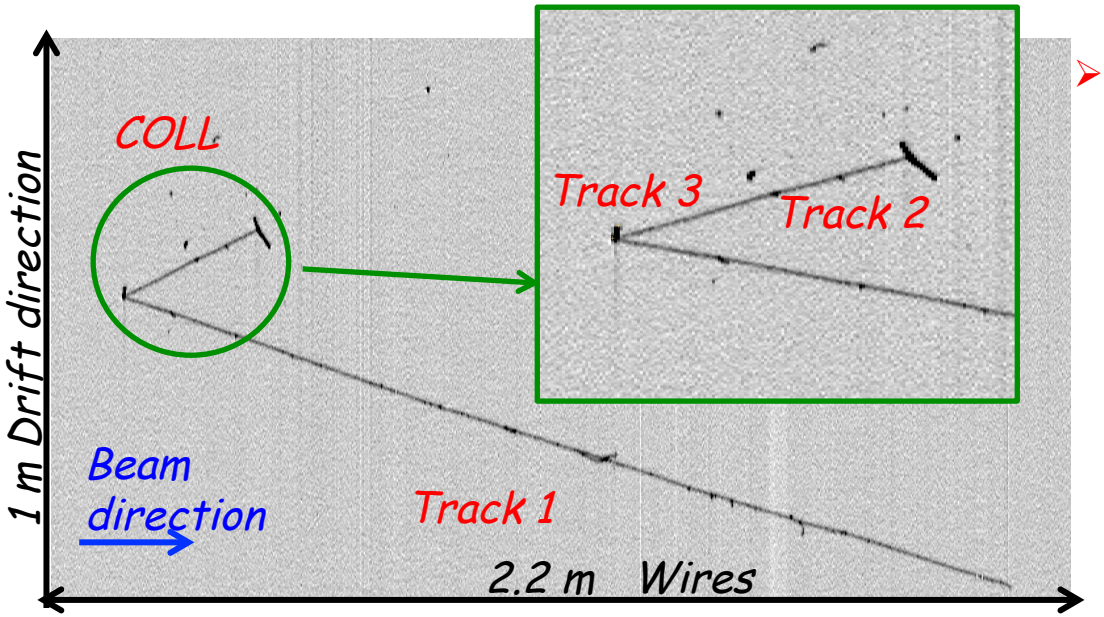
The study of the wire signals allow to recognize and reconstruct the neutrinos in the TPCs

360 PMTs provides the t_0 time of each particle with a time resolution ~ ns and the ν event localization

Neutrino events in ICARUS

- νe CC event from NuMI fully contained in active LAr, E_{dep}~830 MeV:
  - ✓ The electron, E_{DEP}~570 MeV is downward going; Track 1: upward going, stopping proton candidate, L = 23.7 cm; Track 2: stopping proton, L = 33.4 cm.



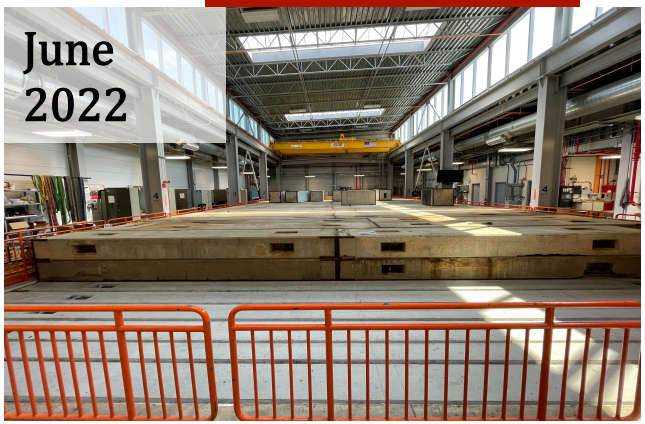


- νμ CC event from BNB fully contained with three tracks at the vertex:
  - ✓Track 1 is a downward going muon, L= 6.4 m; Track 2 is downward going proton interacting in the detector and producing two short protons; Track 3 is an upward going proton L=3.4 cm

The first ICARUS physics runs

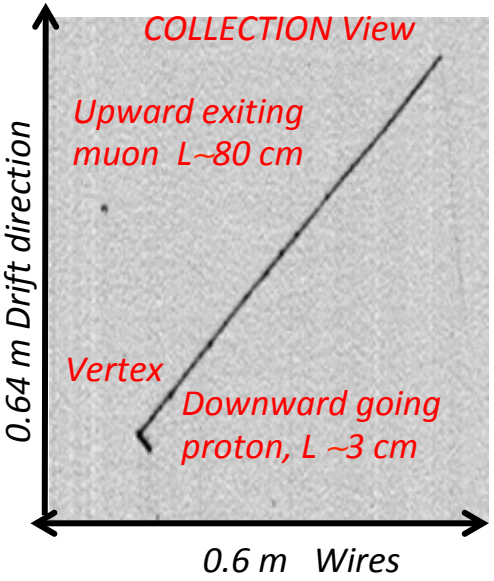
Start of TPC/PMT operation

Completion of CRT installation

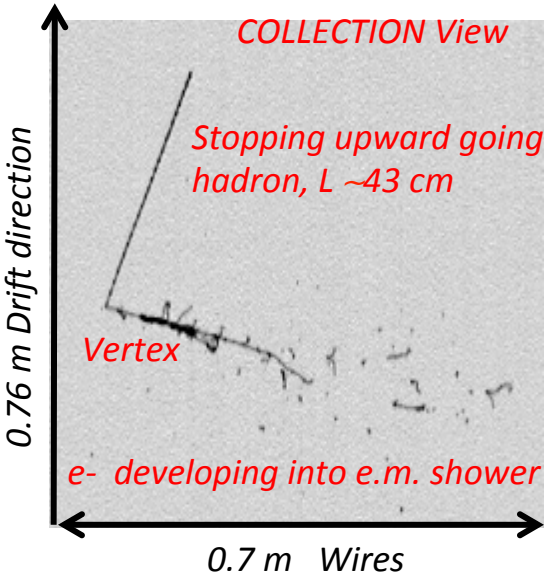


Completion of overburden installation

BNB CCQE $\nu\mu$ candidate, E_{DEP} ~200 MeV



Contained NuMI CCQE νe candidate, E_{DEP} ~ 800 MeV



June 7th '22: overburden installed over the CRT: cosmics' rate reduced by ~2

ICARUS started June 9th 2022 operating in physics mode. Data acquisition largely successful for both BNB/NuMI:

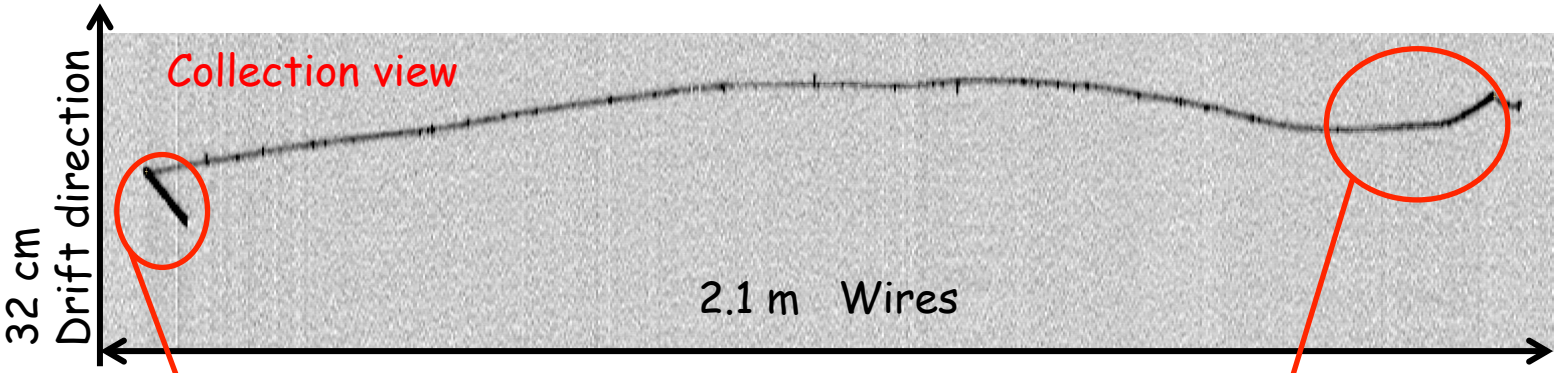
- *Run 1 :June - July 2022, POT collected: ~6.8 10^{19} for NuMI and ~4.1 10^{19} for BNB with ~93% efficiency.*
- *Run 2 :December 2022 - July 2023, POT collected: ~2.8 10^{20} for NuMI and ~2.1 10^{20} for BNB with >95% efficiency.*

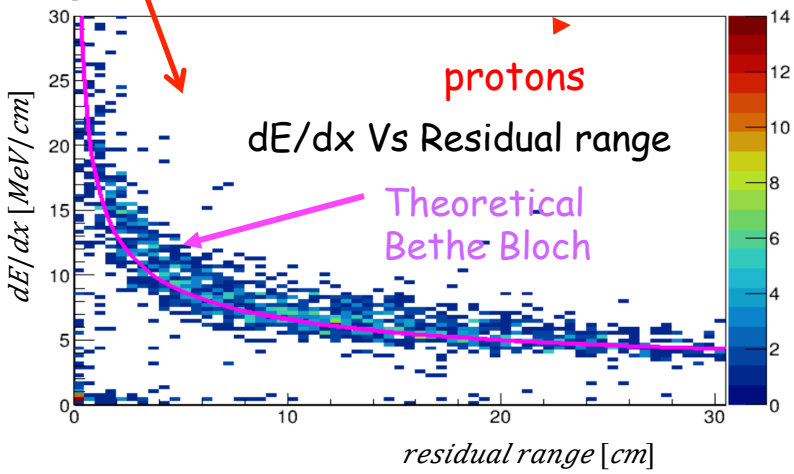
Ongoing activities in Padova

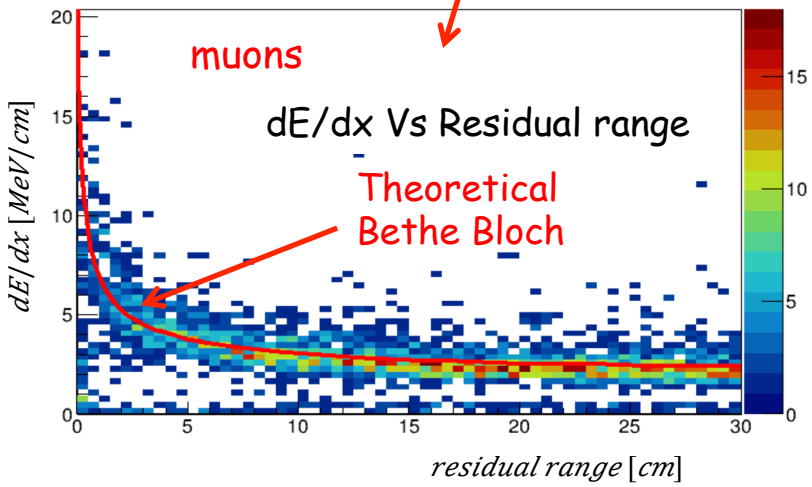
The ICARUS Padova group is deeply involved in many activities fundamental for the experiment:

- **TPC reconstruction and calibration**

Studies for a precise identification and reconstruction of the neutrino interaction vertex and off all the particles produced in the interaction





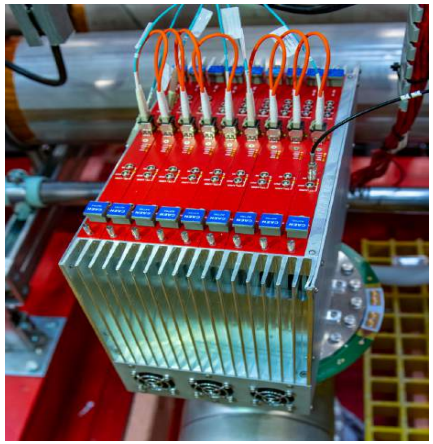


Calibration of the TPC wire signals and studies on the detector effects

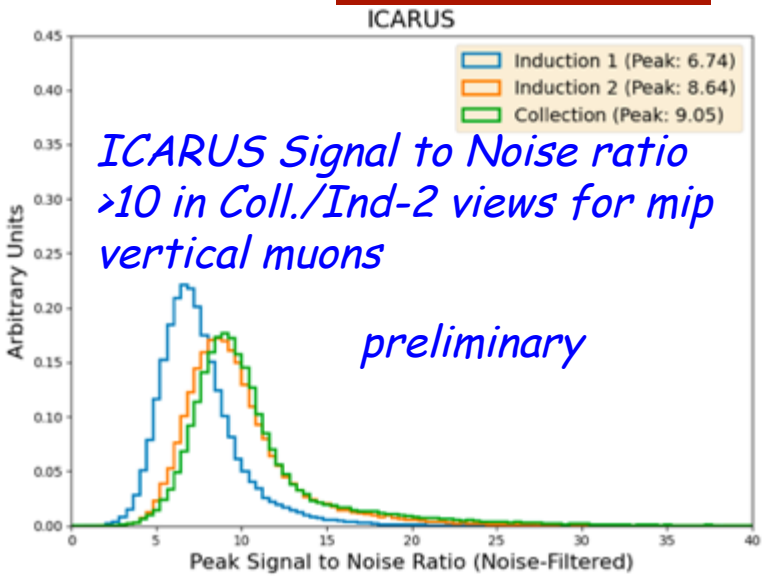
In Padova:
L. Stanco (TPC reconstruction Working Group convener),
F. Varanini
(Calibration Working group convener)

Ongoing activities in Padova - 2

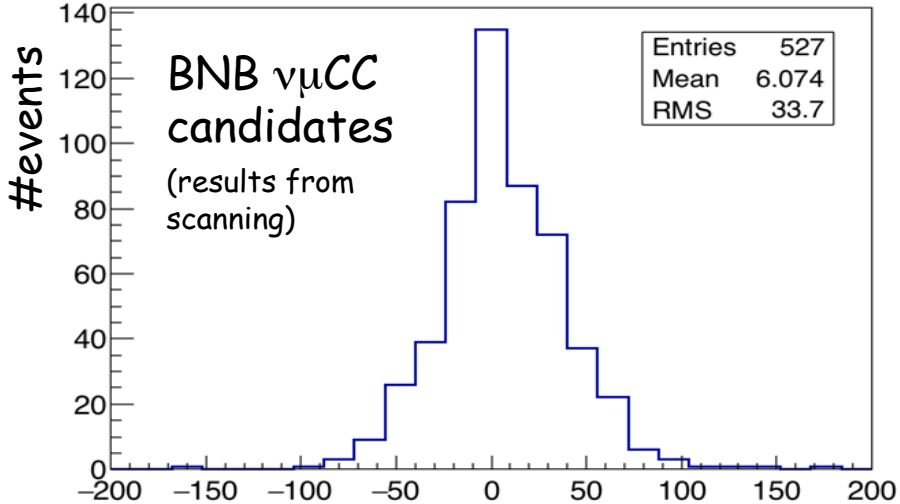
- TPC read-out electronics: installation, maintenance and studies of the performance for the T600 detector at FNAL and developments for future LAr-TPC detectors (DUNE)

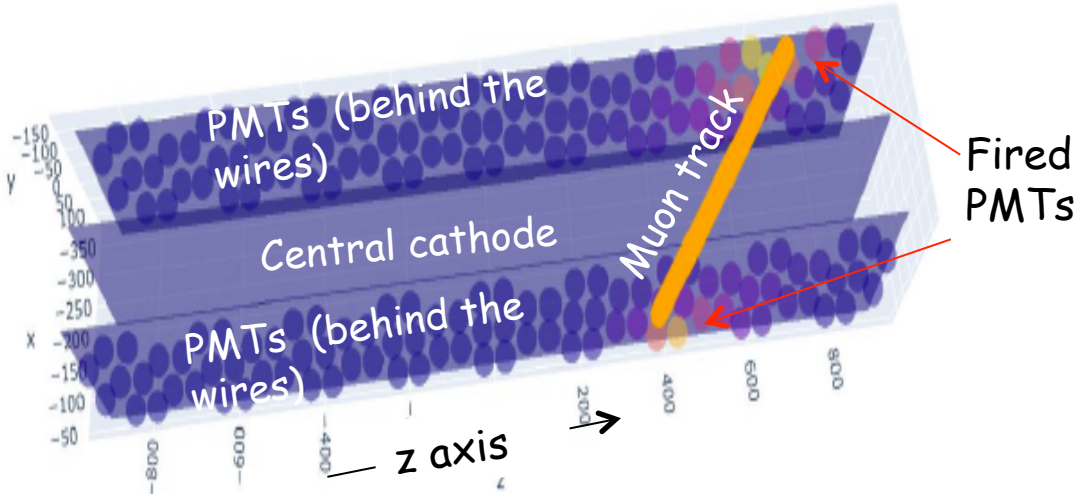


10 liter mini-crate on a feed-through hosting 9 boards (576 wires)



- PMT Light simulation and reconstruction and its exploitation for the ν identification



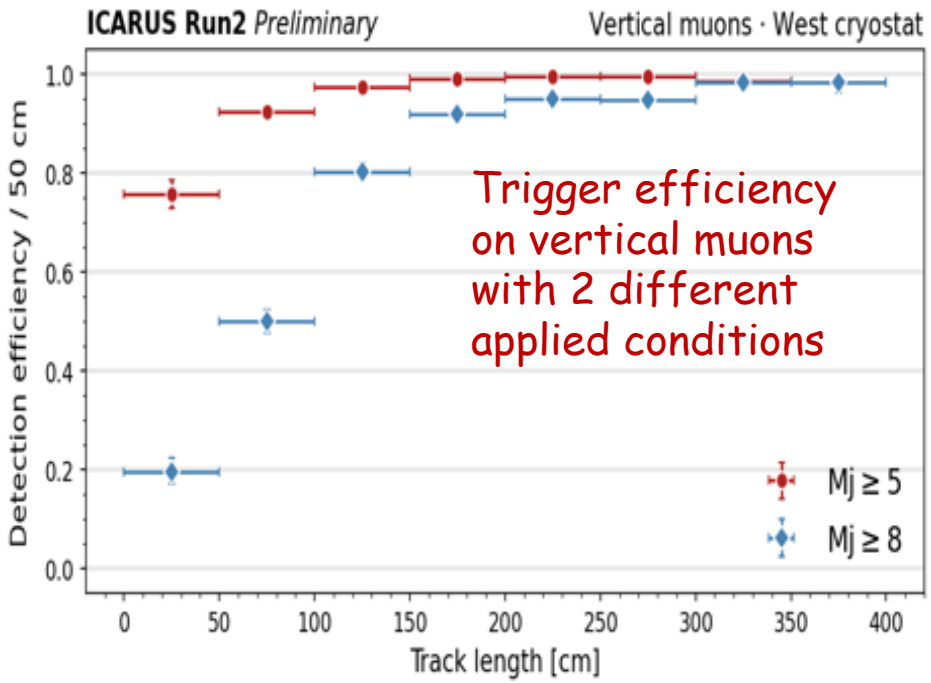


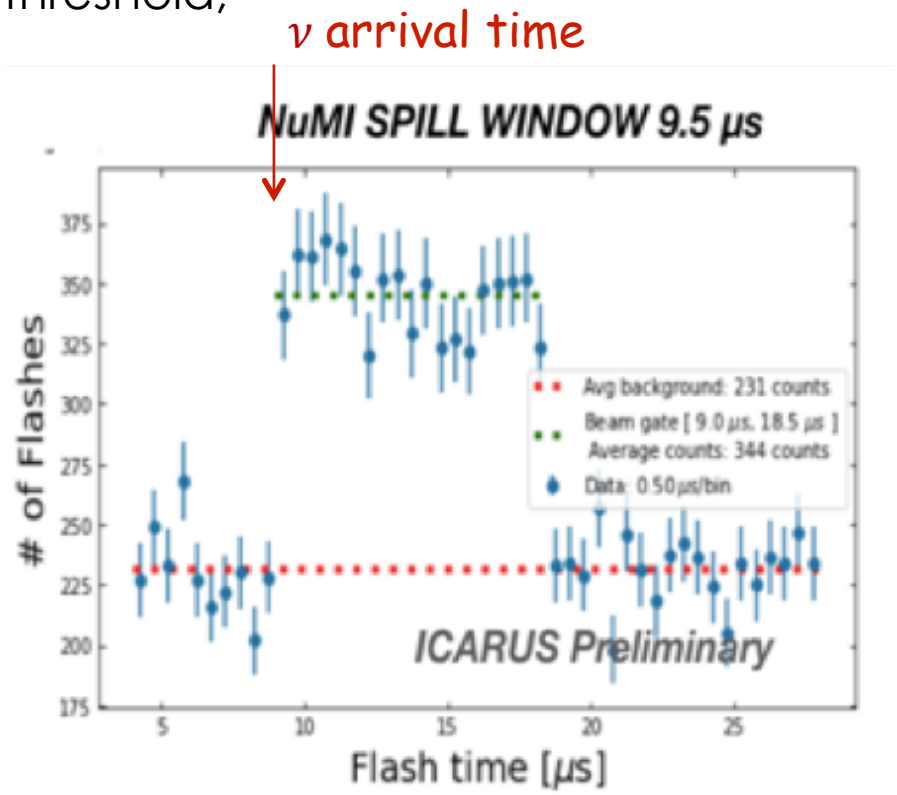
Ongoing activities in Padova - 3

- Trigger system development and performance evaluation

ICARUS trigger relies on the PMT light signals in coincidence with beam spills:

- Mj >= 5 fired PMT pairs requested inside one of 5 staggered longitudinal slices (6 m long) of a cryostat, 13 phe PMT threshold;

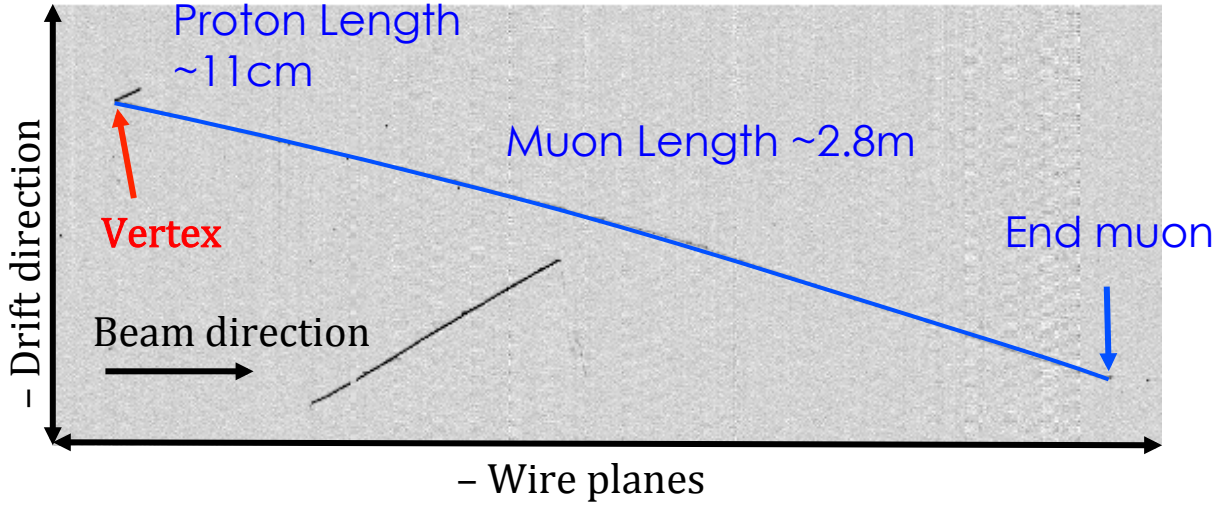




In Padova: A. Guglielmi – Trigger Working Group convener

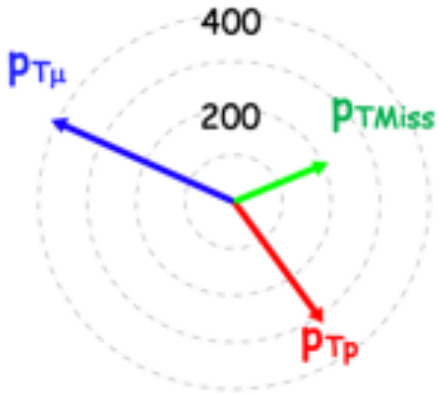
Ongoing activities in Padova - 4

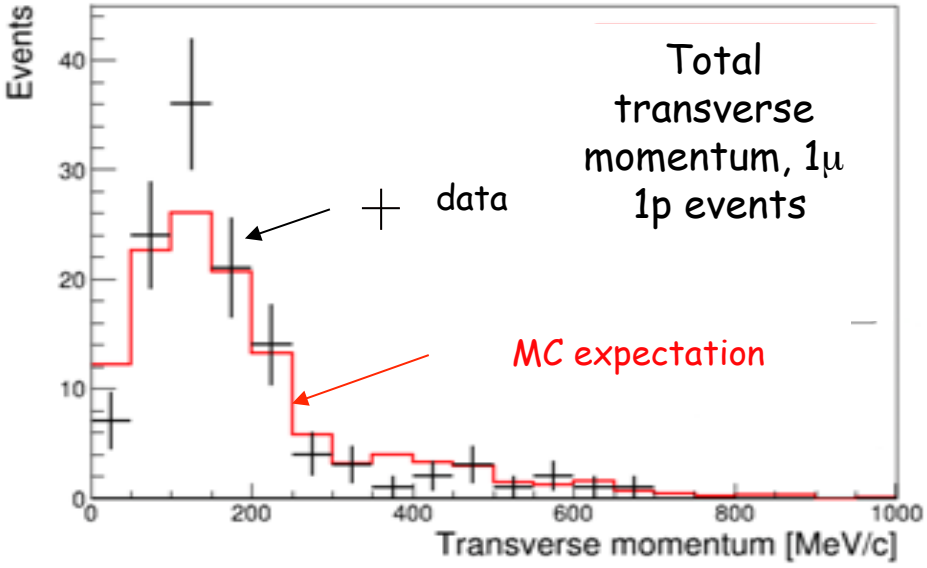
- Neutrino identification and reconstruction



Ongoing studies in particular for the BNB neutrino interactions fully contained in the active volume, with a clear muon track and a single proton track at the primary vertex

1.8 m Wire direction





In Padova:
C. Farnese (Neutrino identification Working Group convener),
D. Gibin (Analysis coordinator)


77 cm
Join
Us!
32 cm
77 cm

Contacts

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