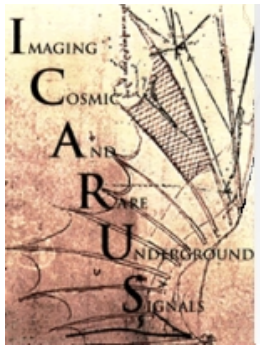

Imaging Cosmic And Rare Underground Signals

Istituto Nazionale
di Fisica Nucleare
Sezione Pavia

ICARUS T600 experiment: latest results and perspectives

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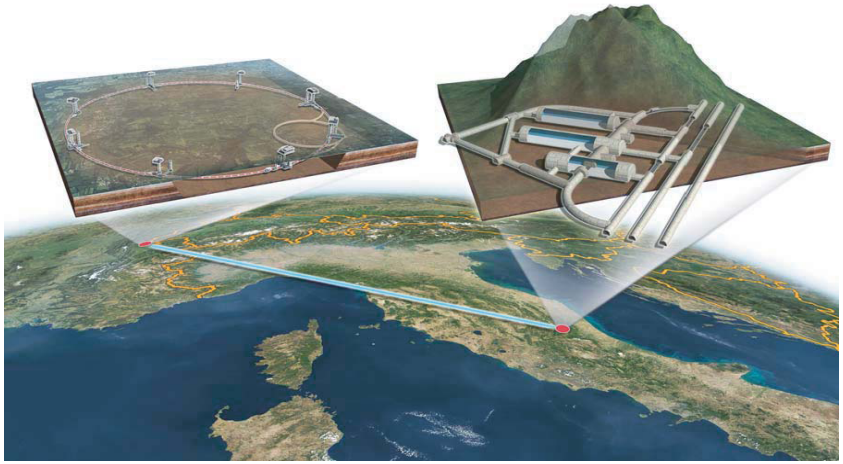
NBIA Ph.D School: Neutrinos underground & in the heavens

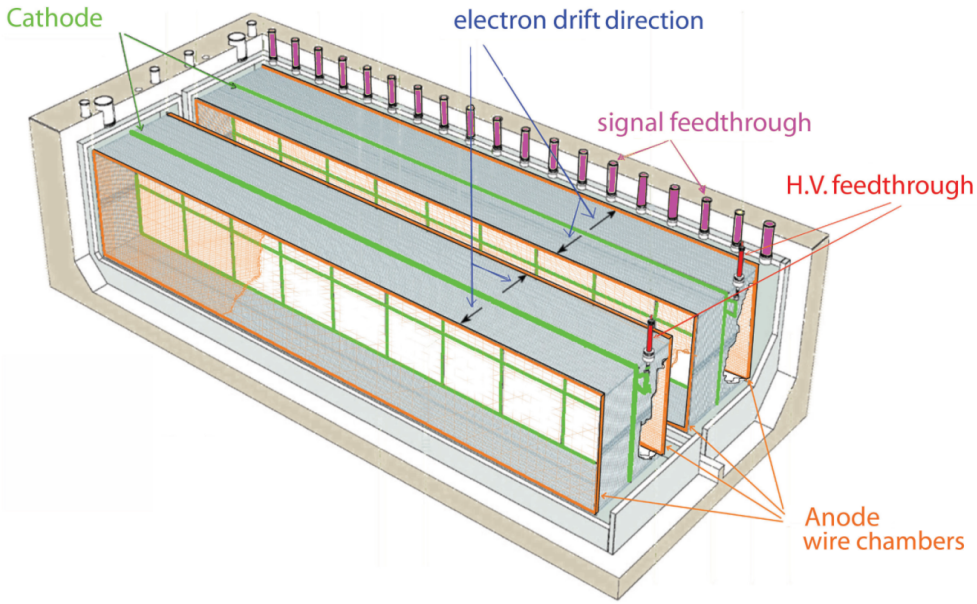
ICARUS T600 at LNGS

- The ICARUS T600 detector is placed in the Hall B of Laboratori Nazionali del Gran Sasso (LNGS).
- It has been exposed to CNGS (Cern Neutrino to Gran Sasso) beam from 2010 to 2012.
- After the shutdown of the beam, data were taken with cosmic rays.
- ICARUS T600 is under decommissioning.

▪ The CNGS facility delivered an almost pure ν_μ beam in 10 - 30 GeV E_ν range (beam associated ν_e~1%) at a distance L=732 km from detector.



Detector overview

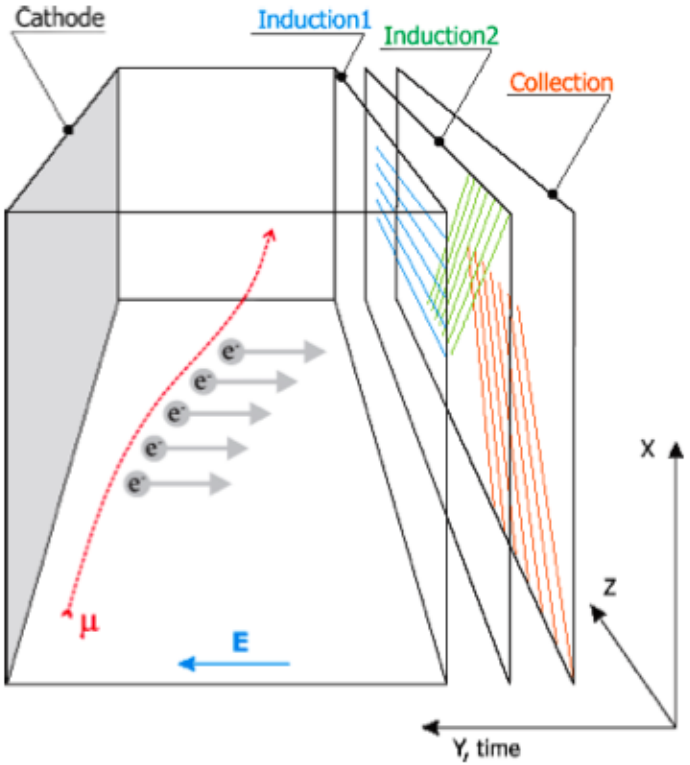


- Two identical modules
  - 3.6 x 3.9 x 19.6 ≈ 275 m^3 each
  - Liquid Ar active mass : ≈ 476 t
  - Drift length = 1.5 m (1ms)
  - drift velocity = 1.55 $mm/\mu s$
  - HV = -75 kV E = 0.5 kV/cm

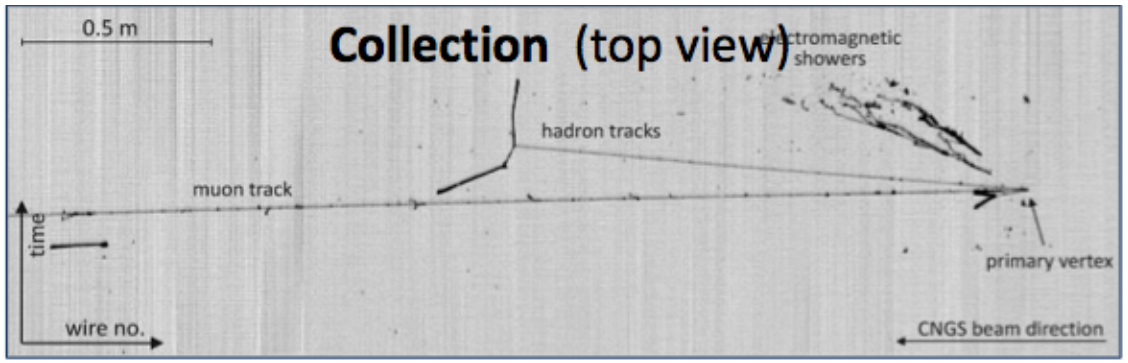
- 4 wire chambers:
  - 2 chambers per module
  - 3 readout wire planes per chamber, wires at 0,±60° w.r.t. the horizont
  - ≈ 54000 wire, 3 mm pitch, 3 mm plane spacing
- 20+54 PMTs , 8" Ø, for scintillation light detection:
  - VUV sensitive (128 nm) with wavelenght shifter (TPB)

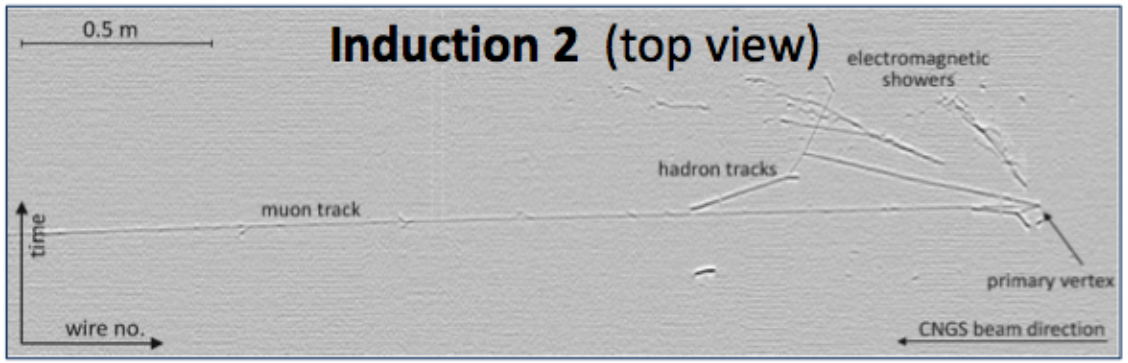
ICARUS detection tecnique

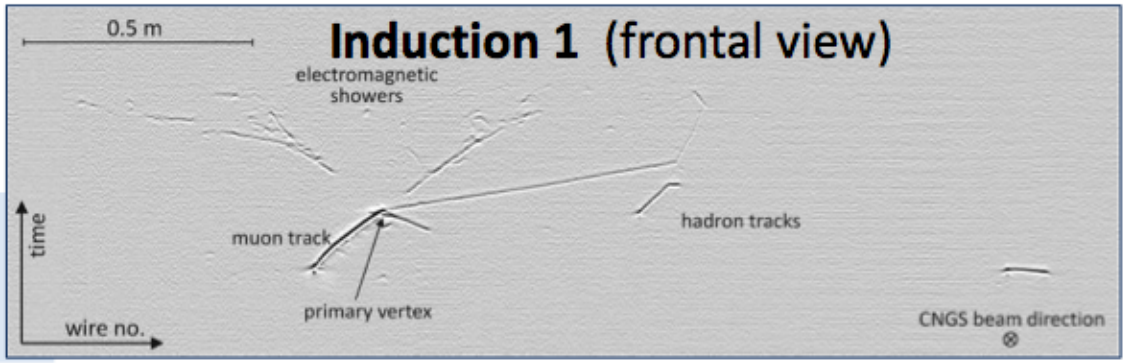
- 2D projection for each of 3 wire planes per TPC (drift time vs. wire number)
- 3D spatial reconstruction from stereoscopic 2D projections
- charge measurement from Collection plane signals



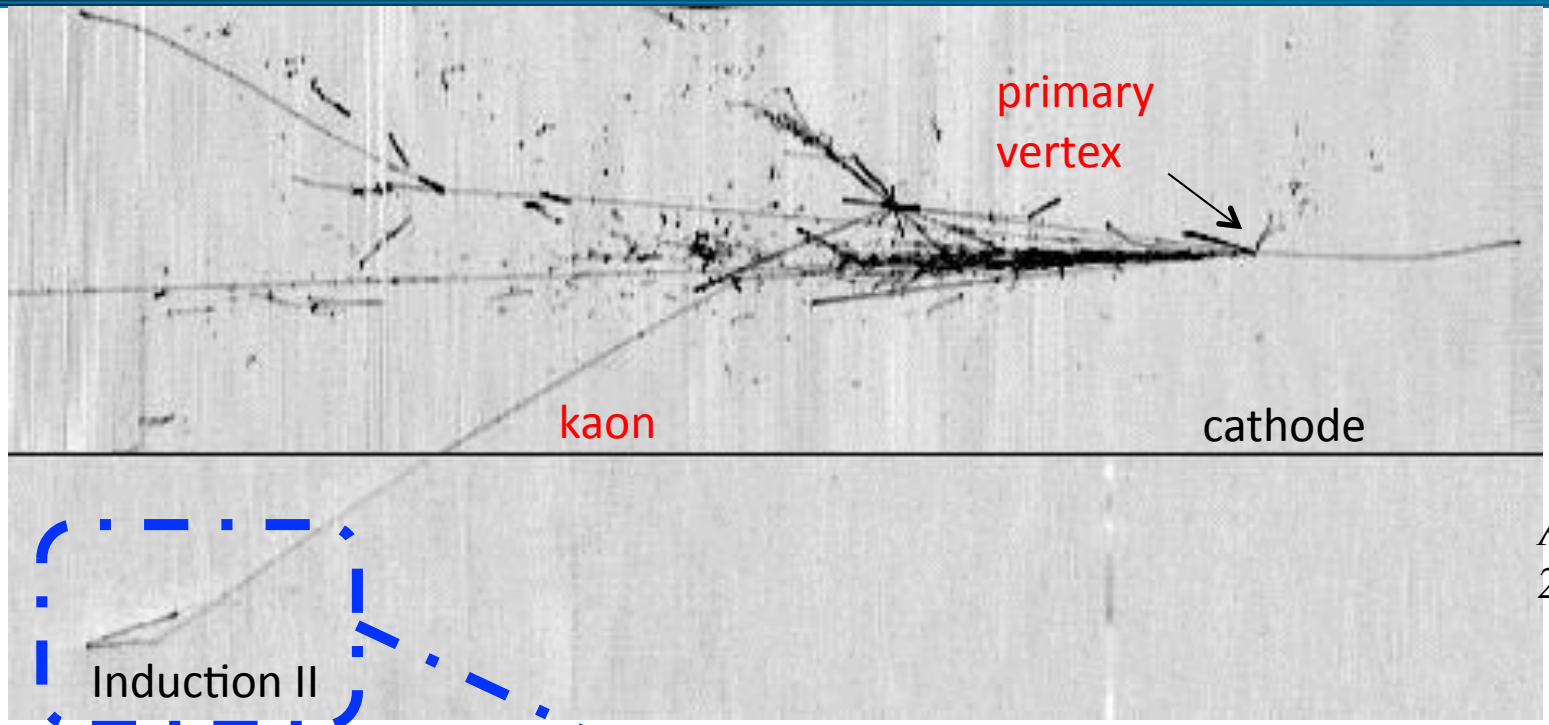
CNGS ν_μ charge current interaction, one of TPC's shown







3D reconstruction



CNGS
beam

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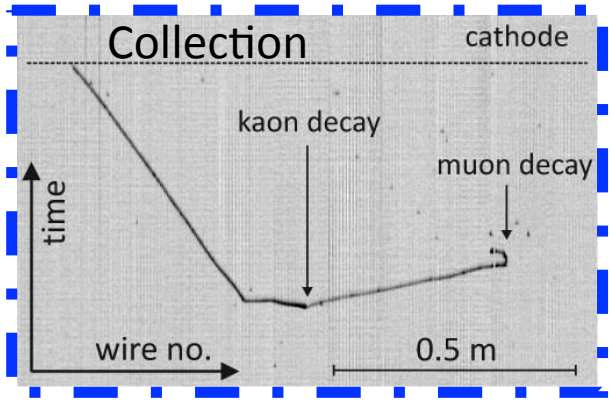
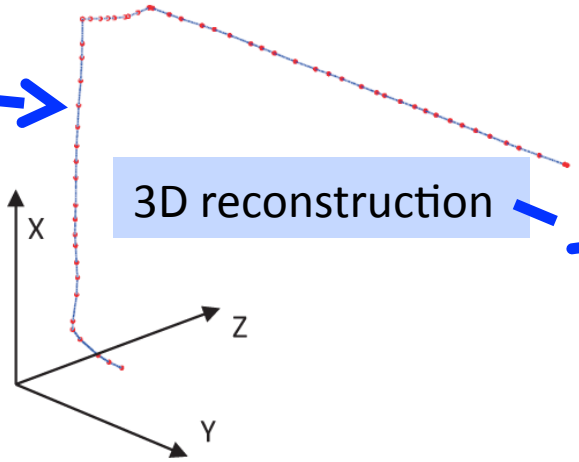
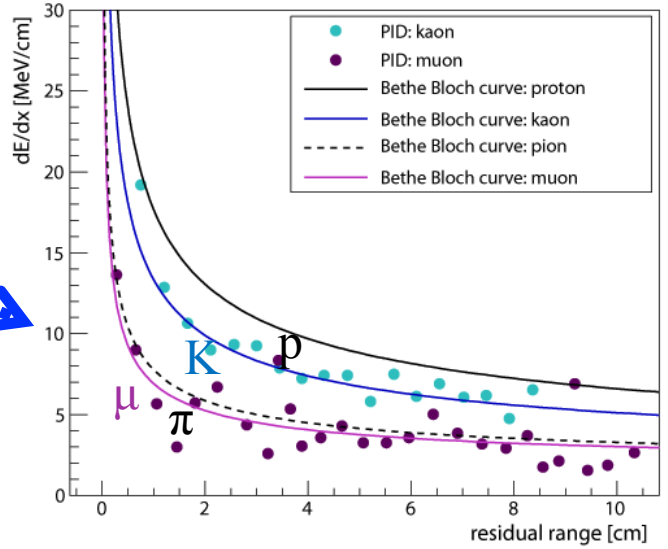
Induction II



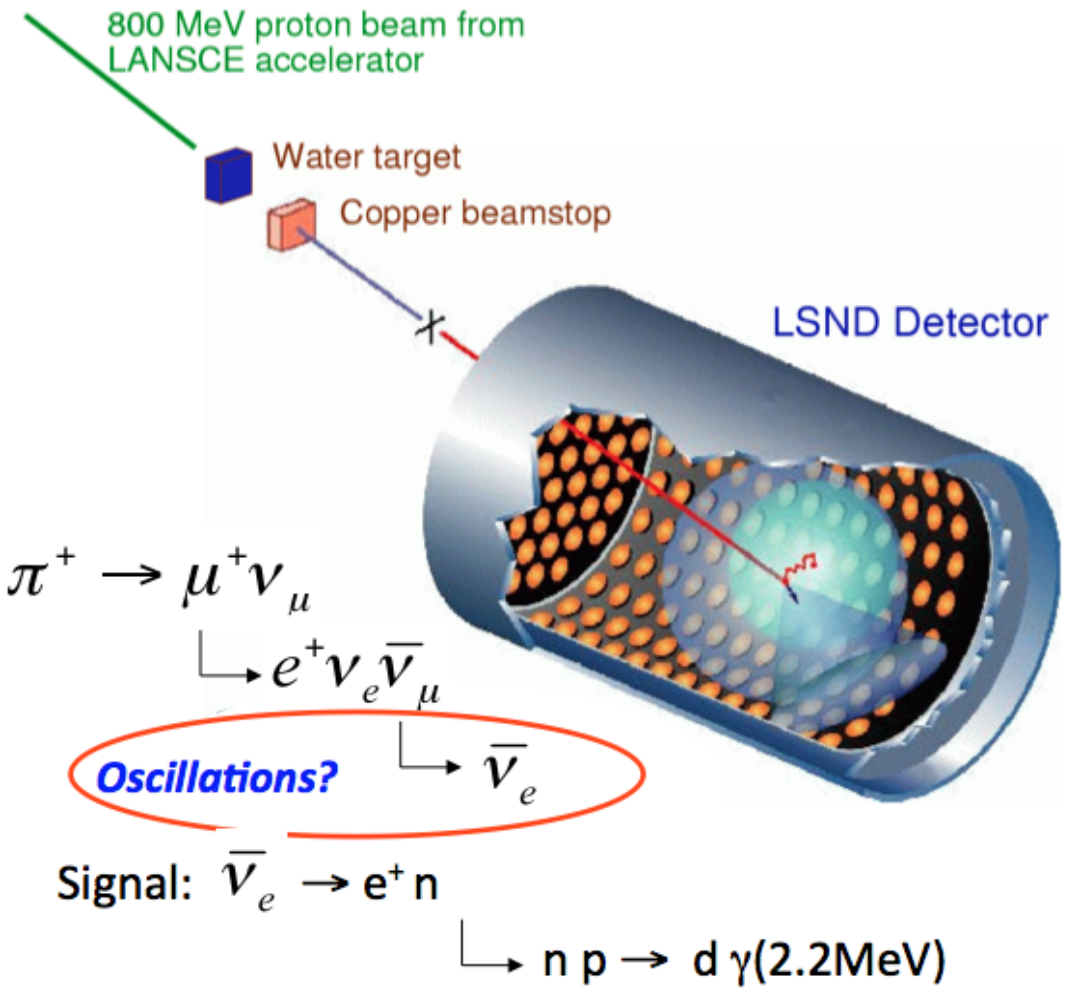


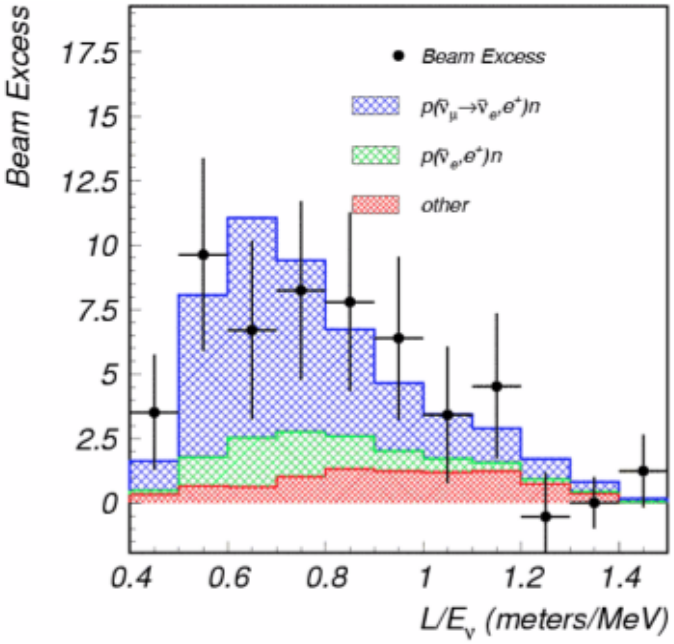
3D reconstruction



PID based on dE/dx

The LNSD Anomaly (some unexplained ν_μ->ν_e events)





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)%.

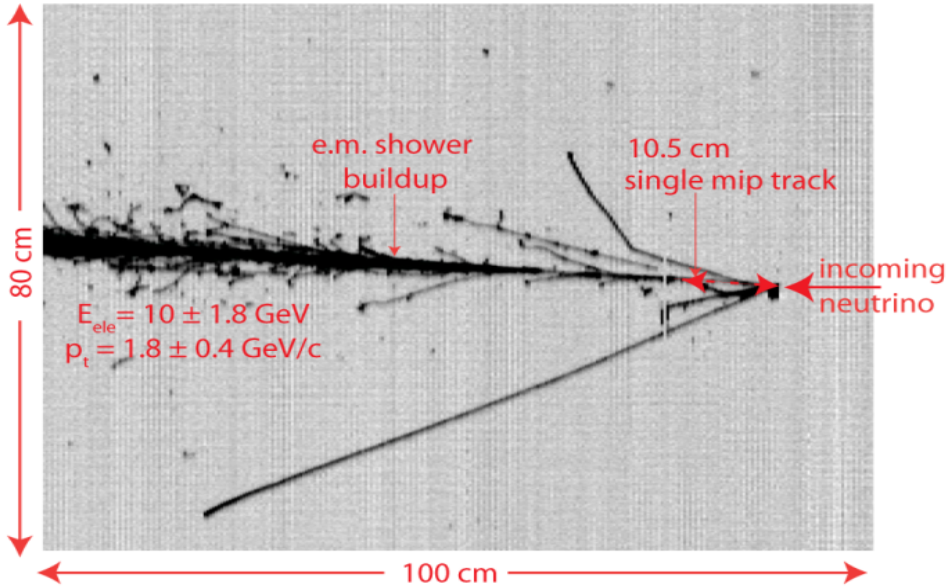
3.8 σ evidence for oscillation.

LSND anomaly search at ICARUS

ICARUS made a search for this effect with CNGS ν_μ beam, although with a different L/E :

L/E ≈ 36.5 m/MeV in ICARUS

L/E ≈ 1 m/MeV at LSND .



Searching for a ν_e events in the CNGS beam:

- ν_e CC event candidates, with vertex inside fiducial volume, are visually selected;
- electron efficiency has been studied with events from a MC reproducing in every detail the signals from wire planes ;
- the expected number of electron events, taking into account the detection efficiency: 7.9 ± 1.0 (syst. only);
- 6 ν_e events have been identified in a sample of 2450 ν interactions, where the single electron shower is opposite to hadronic component in the transverse plane.

ICARUS result on LSND anomaly

Weighting for the efficiency, ICARUS limits on the number of events due to LSND anomaly are:

5.2 (90 % C.L.)
10.3 (99 % C.L.) .

These provide the limits on the oscillation probability:

$$\mathbf{P(\nu_\mu \rightarrow \nu_e) \leq 3.85 \times 10^{-3}\ (90\ \%\ C.L.)}$$
$$\mathbf{P(\nu_\mu \rightarrow \nu_e) \leq 7.60 \times 10^{-3}\ (99\ \%\ C.L.)}$$

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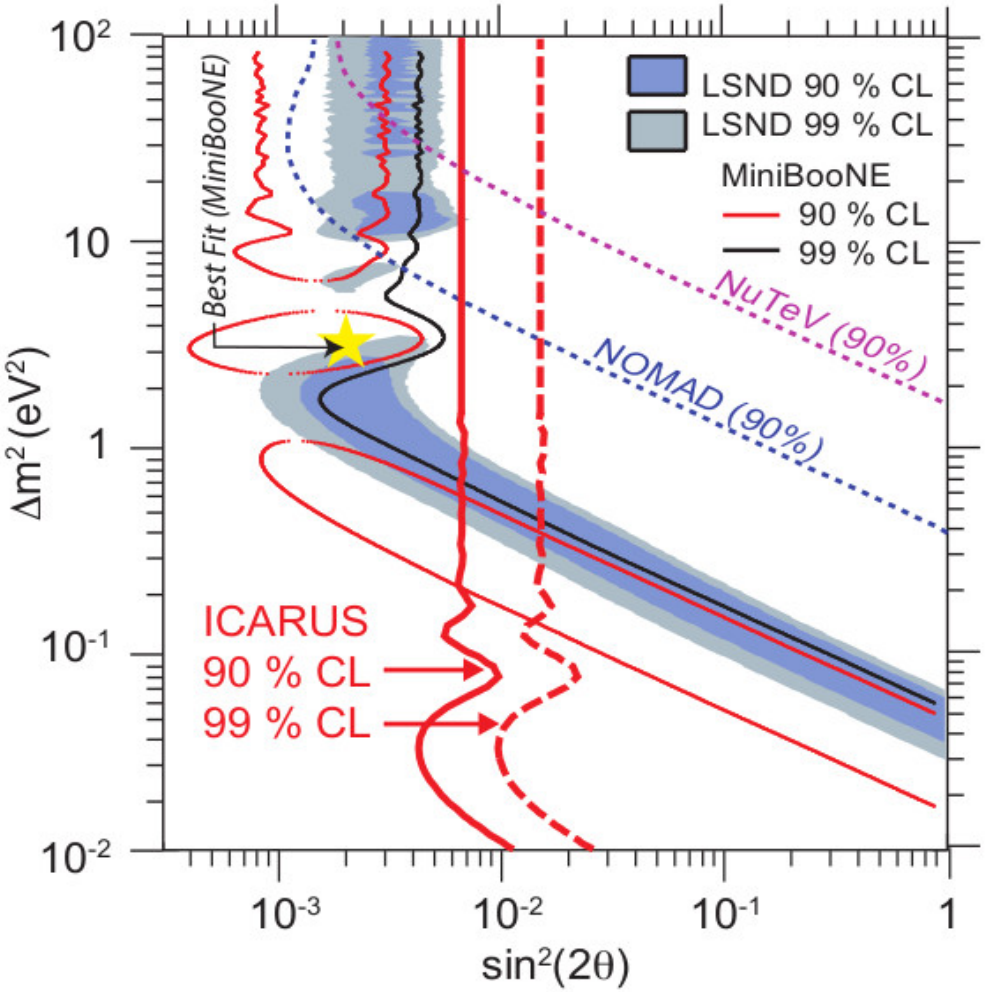


ICARUS result strongly limits the window of parameters for the LSND anomaly to a very narrow region ($\Delta m^2 \approx 0.5$ eV^2 and $\sin^2 2\theta \approx 0.005$) for which there is an overall agreement (90% CL) with other experiments (KARMEN, MiniBooNE and LSND).

Future perspectives

- To clarify the existence of a sterile neutrino state, a new phase of the ICARUS experiment is foreseen, with the optimal L/E value.

- This new phase foresees the addition of a magnetic field to perform charged particle identification and momentum measurement.

- In the hypothesis of magnetizing the active volume, it is necessary to determine automatically if the incoming particle is a neutrino or an anti-neutrino.

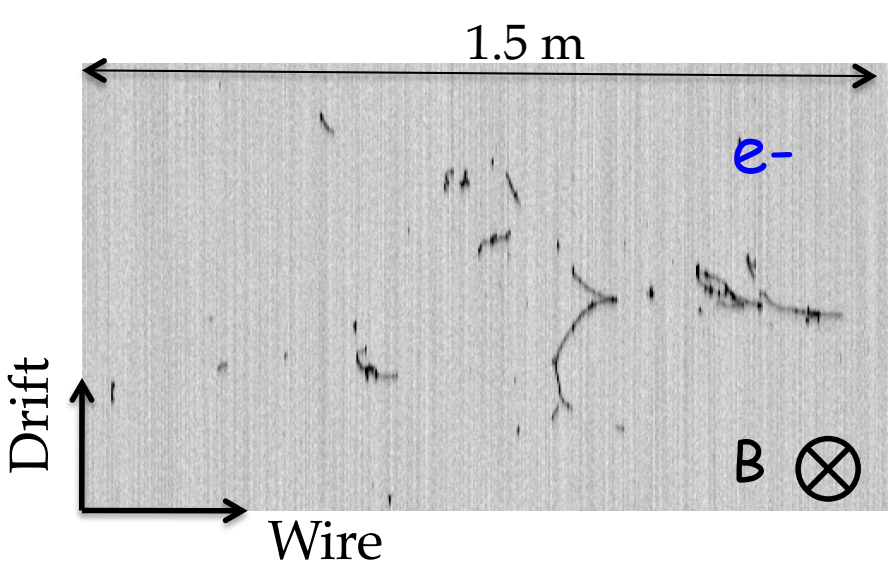
- In this framework, a dedicated algorithm is under development to automatically distinguish electrons from positrons produced in neutrino charged current interactions.

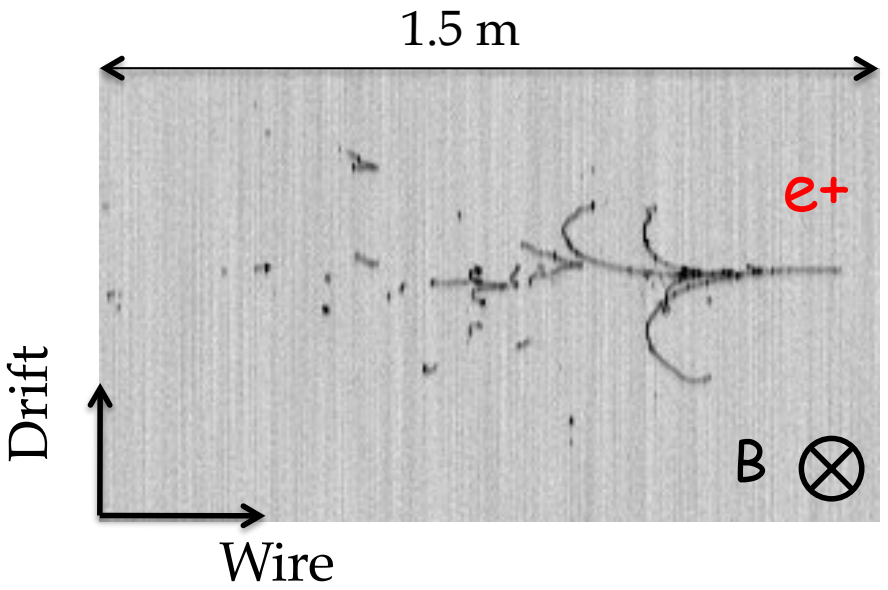
e+/e- Monte Carlo sample

In order to test this algorithm, a Monte Carlo simulation has been carried on, with a 1 T magnetic field, perpendicular to the drift and beam directions, present in the active volume.

A total sample of 2000 events, equally divided between e+ and e-, is produced with the Fluka package.

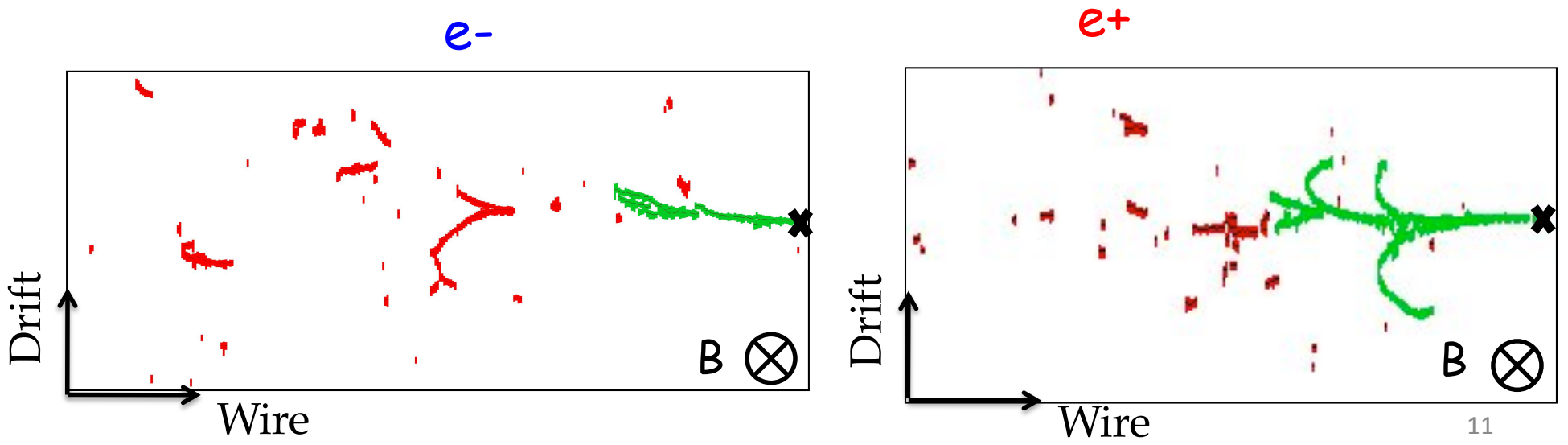
Electronic neutrinos and anti-neutrinos, with a fixed energy of 500 MeV, are generated and made to interact within the detector .





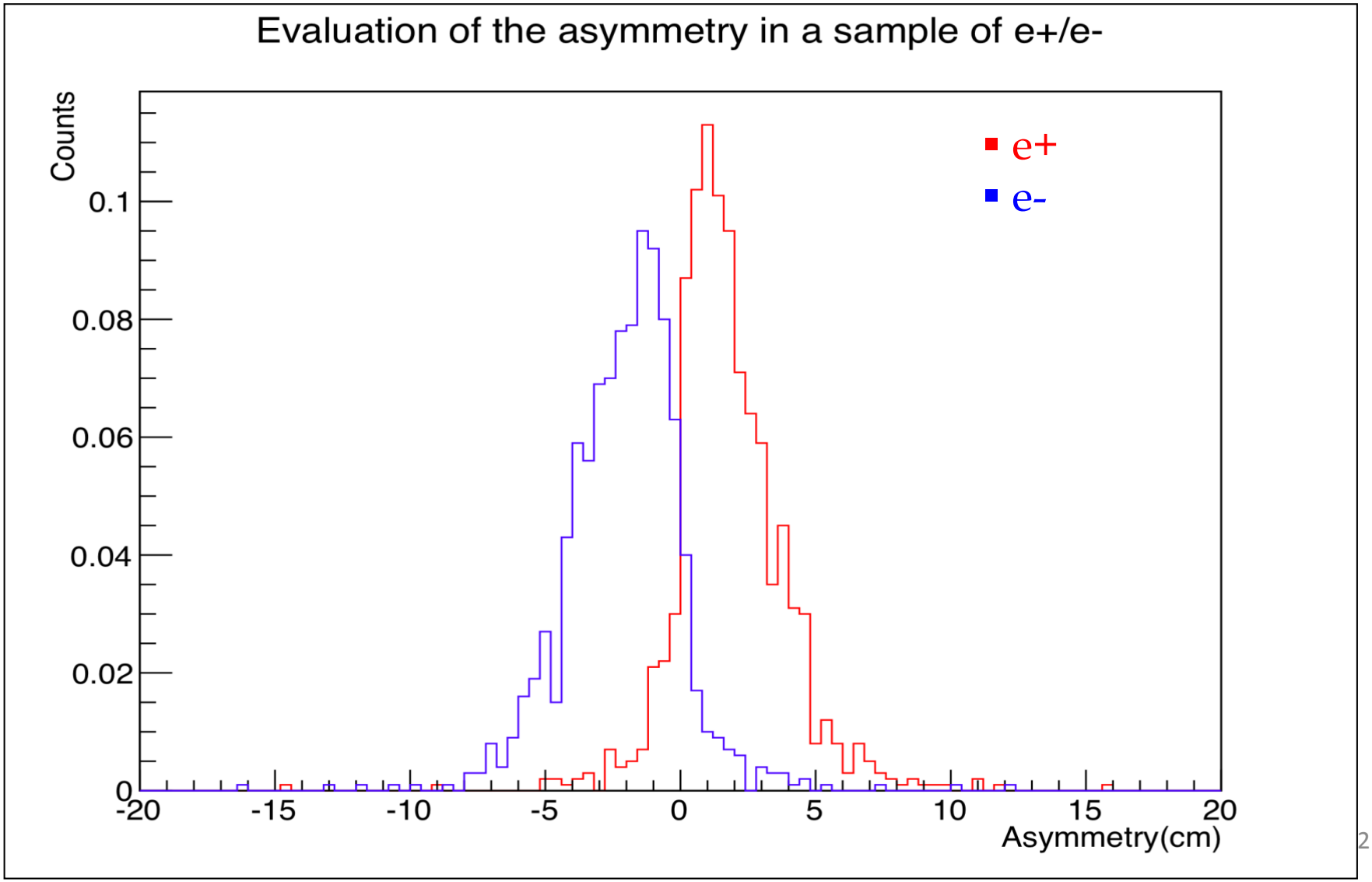
Procedure step by step

1) The information on the primary vertex position, included in the simulation, is retrieved (the primary vertexes are the black crosses in the images below).
2) The cluster containing the primary vertex is selected (green hits) considering only neighbouring hits, due to the requirement of having particles coming from the original one.
3) A portion of the lepton track, free of interactions, is selected (the so called clean track). The sequence of hits of the clean track is then modeled with a straight line.



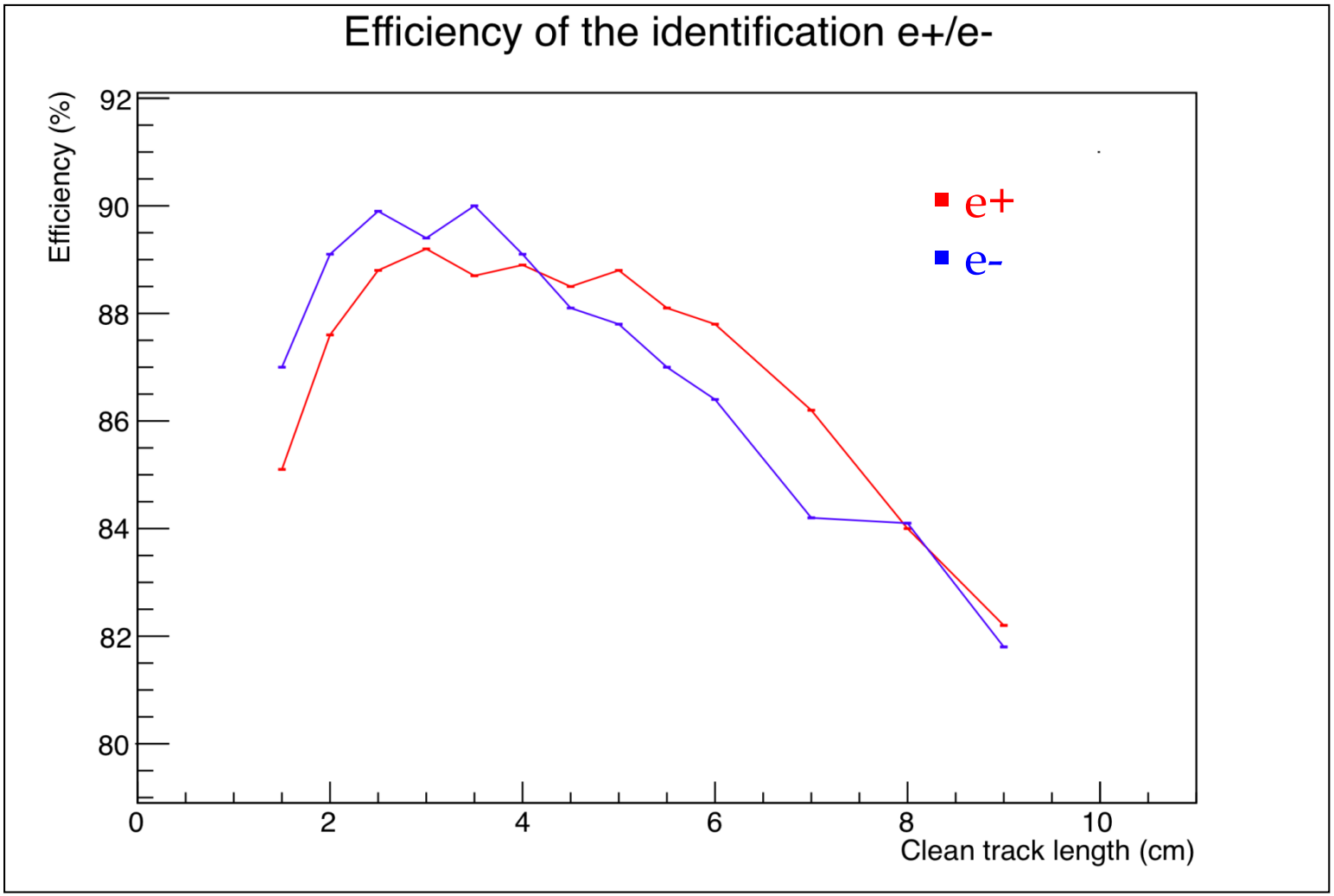
Results

4) **Asymmetry**: oriented distance between hits (in the selected cluster) actual position and its projection on the modeled straight line.



Results

Evaluating the recognition efficiency of these two classes of particles, it can be possible to choose an optimal value for the first track length.
Optimal lengh -> 2.5 ÷ 3.5 cm



Conclusions

• ICARUS T600 detector has successfully concluded the operation at LNGS, demonstrating that LAr-TPC is a leading technology for future short/long baseline accelerator-driven neutrino physics.

• The accurate analysis of the CNGS events and the identification of 6 ν_e events provide no evidence of oscillation into sterile neutrinos in ICARUS L/E value. The global fit of all data limits the window of parameters for a possible LSND anomaly to a very narrow region around $\Delta m^2 \approx 0.5$ eV^2.

• To better investigate the presence of a sterile neutrino state, the ICARUS collaboration proposes a new phase of the experiment.

• In the hypothesis of magnetizing the active volume of the ICARUS T600 detector, a new algorithm that permits to automatically distinguish between electrons and positrons is being developed. Using a Monte Carlo simulation, the asymmetry parameter of the track is identified as a good parameter to separate these two classes of particles.


Thank you !