Icarus T600 for Short Baseline (SBN) at Fermilab

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Anomalies in the neutrino sector

- Neutrino oscillations established a coherent picture with mixing of 3 physical ν_e, ν_μ, ν_τ with small mass differences $\Delta m^2_{31} \sim 2.4 \times 10^{-3}$ eV^2, $\Delta m^2_{21} \sim 8 \times 10^{-5}$ eV^2 and relatively large mixing angles.

- There are however a number of "anomalies" which could hint at an additional sterile 4th neutrino, with non-standard oscillations at small distances with $\Delta m^2_{new} \sim 1$ eV^2, small $\sin^2 2\theta_{new}$:

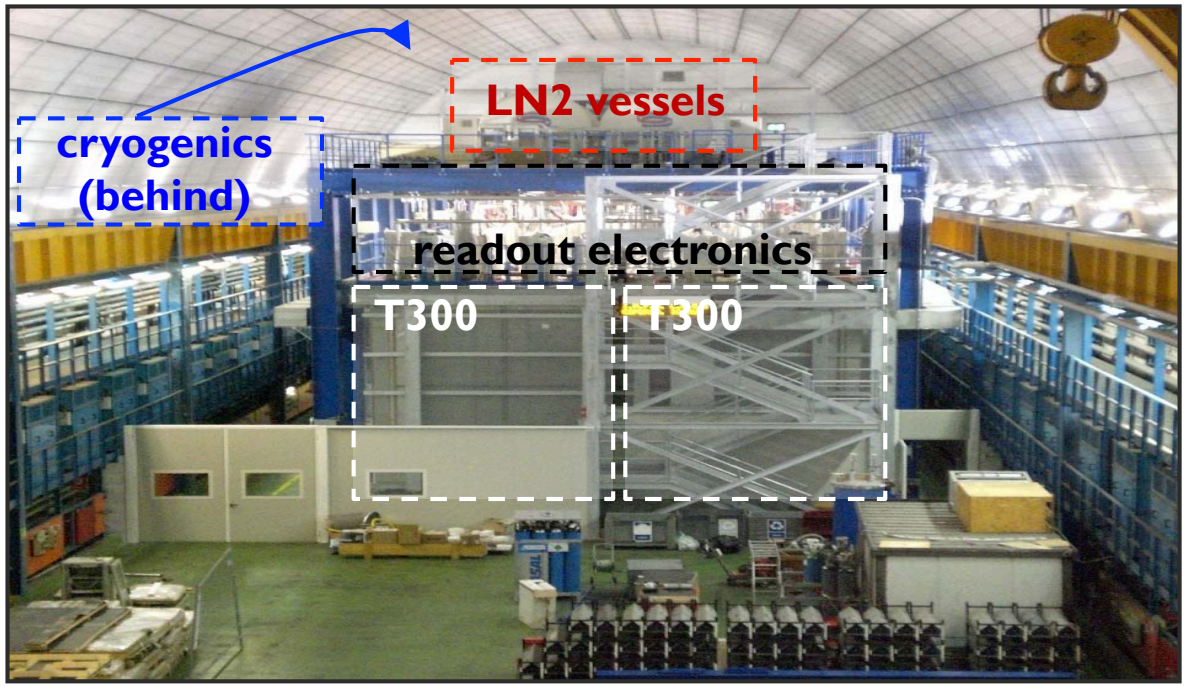
  (1) observation of $\nu_\mu \rightarrow \nu_e$ excess signals from LSND, MiniBooNE at accelerators (LSND effect: 3.8 σ)

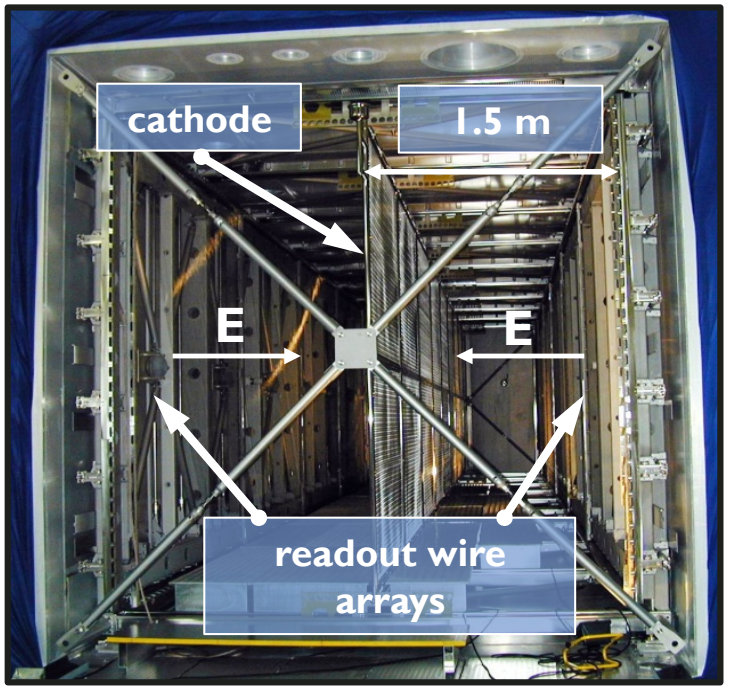
  (2) deficit of anti-ν_e events, detected from near-by nuclear reactors, where the observed to predicted event rate is R=0.938±0.023;

  (3) deficit of anti-ν_e events, from Mega-Curie calibration sources in solar ν_e experiments, with R=0.86±0.05.

- According to Planck measurement and Big Bang cosmology one sterile ν is possible, with m< 0.4 eV.

ICARUS T600 at LNGS





Two identical modules

- 3.6x3.9x19.6 ~275 m^3 each;
- LAr active mass: 476 t;
- Drift length: 1.5 m (1 ms);
- E=0.5 kV/cm, v_{drift}~1.5 mm/μs;
- Sampling time 0.4 μs (sub-mm resolution in drift direction).

Four wire chambers: 2 chambers/ module

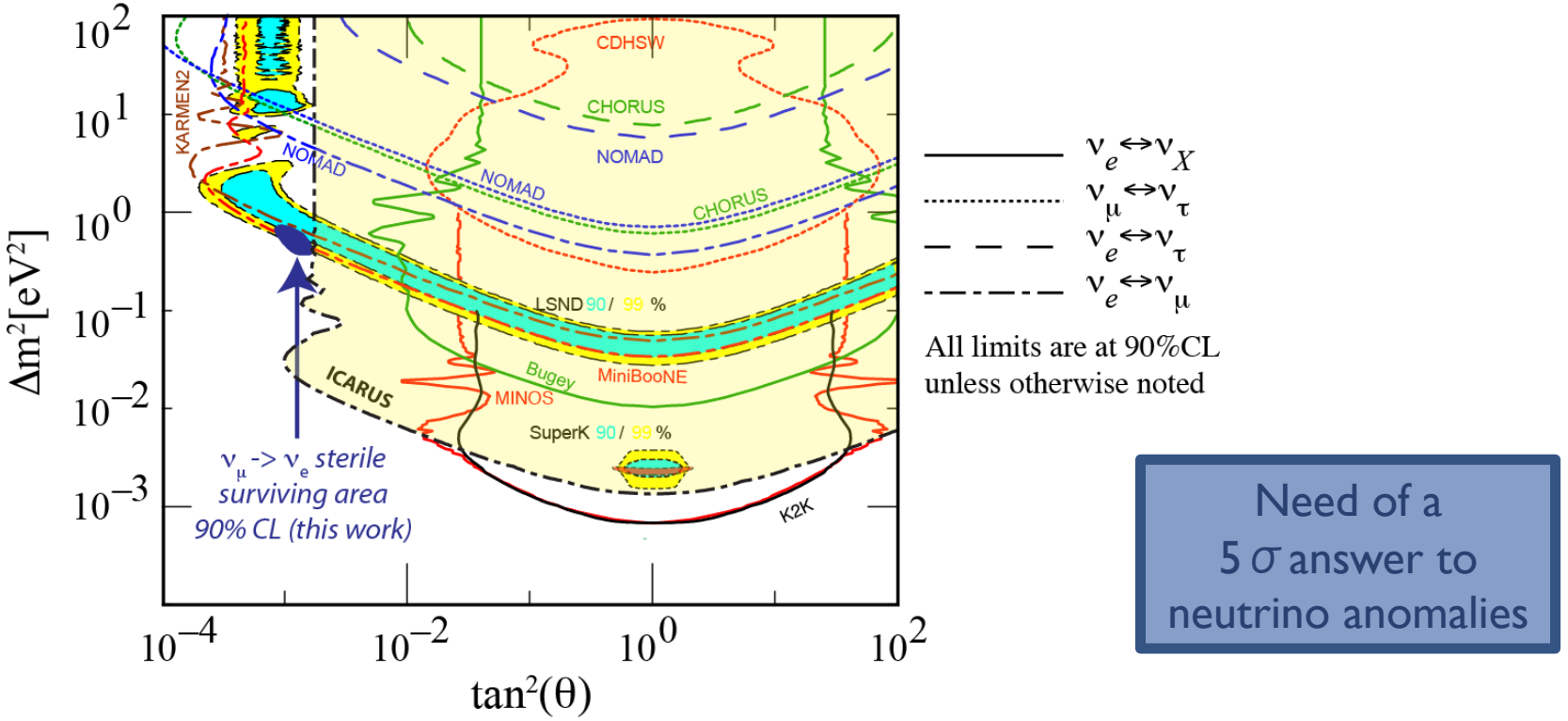
- 2 Induction + 1 Collection readout wire planes per chamber; ~54000 wires, 3 mm pitch and plane spacing, oriented at 0°,±60°.

20+54 8" PMTs for scintillation light detection:

- VUV sensitive (128nm) with TPB wave shifter;
- trigger and t_0 assignation.

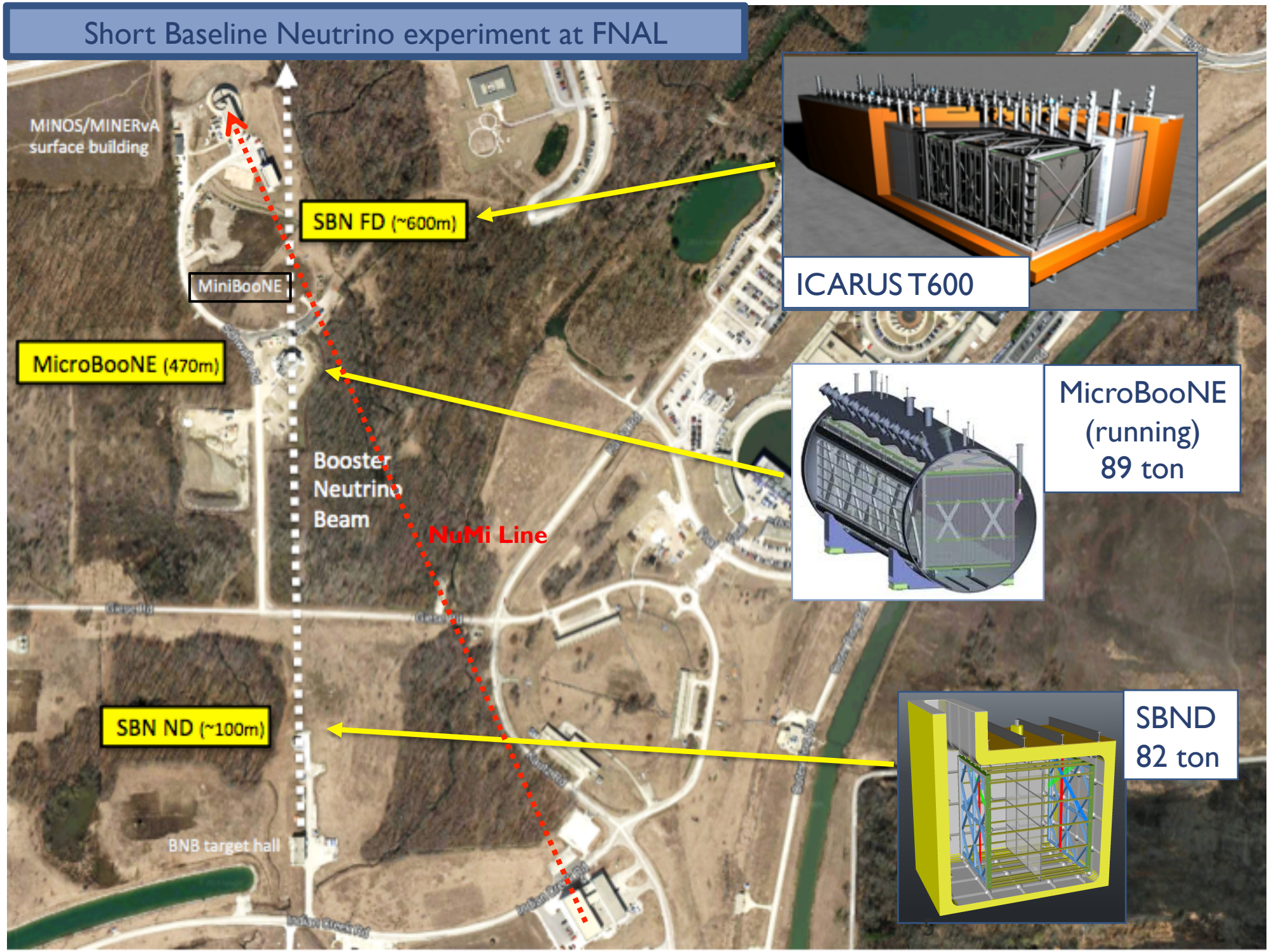
Search for LSND-like anomaly by ICARUS at LNGS

- ICARUS searched for ν_e excess related to LSND-like anomaly on the CNGS ν_μ beam (~ 1% intrinsic ν_e contamination, L/E_ν ~ 36.5 m/MeV).
- Analysis on 7.23 x 10^{19} pot event sample provided the limit on the oscillation probability $P(\nu_\mu \rightarrow \nu_e) \leq 3.85\ (7.60) \times 10^{-3}$ at 90 (99) % C.L.
- ICARUS result indicates a very narrow region of parameter space, $\Delta m^2 \sim 0.5\ eV^2$, $\sin^2 2\theta \sim 0.005$, where all experimental results can be accommodated at 90% C.L..



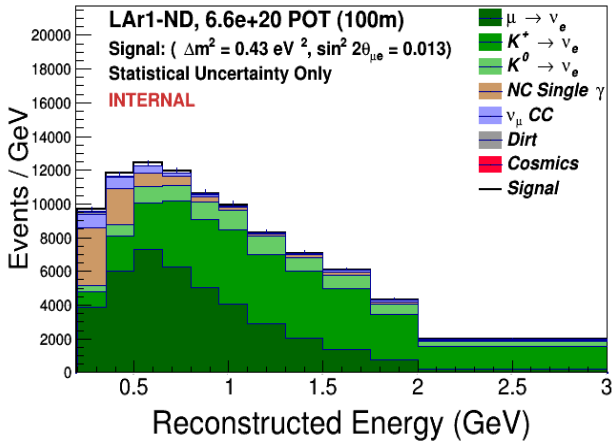
Need of a
5 σ answer to
neutrino anomalies

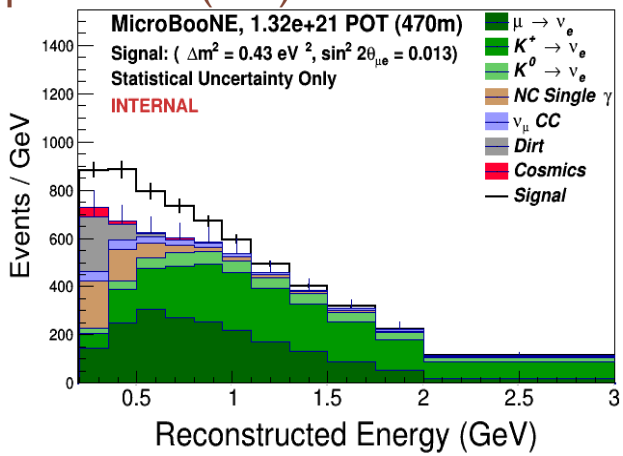
Short Baseline Neutrino experiment at FNAL

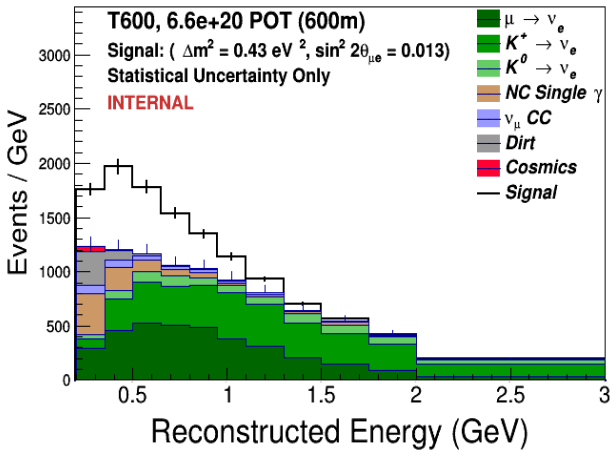


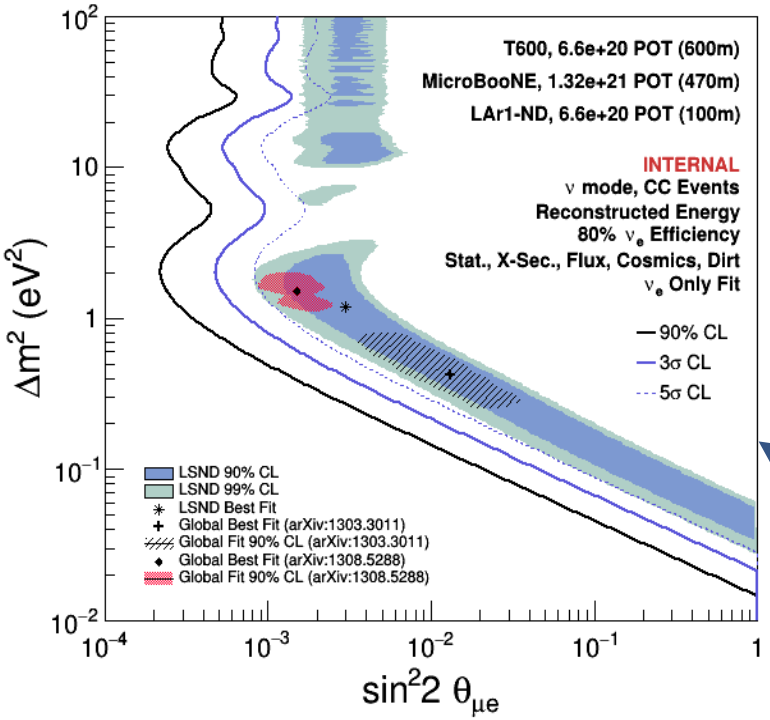
$\nu_\mu \rightarrow \nu_e$ appearence sensitivity

Example for $\sin^2(2\theta)=0.013$ and $\Delta m^2=0.43$ eV^2





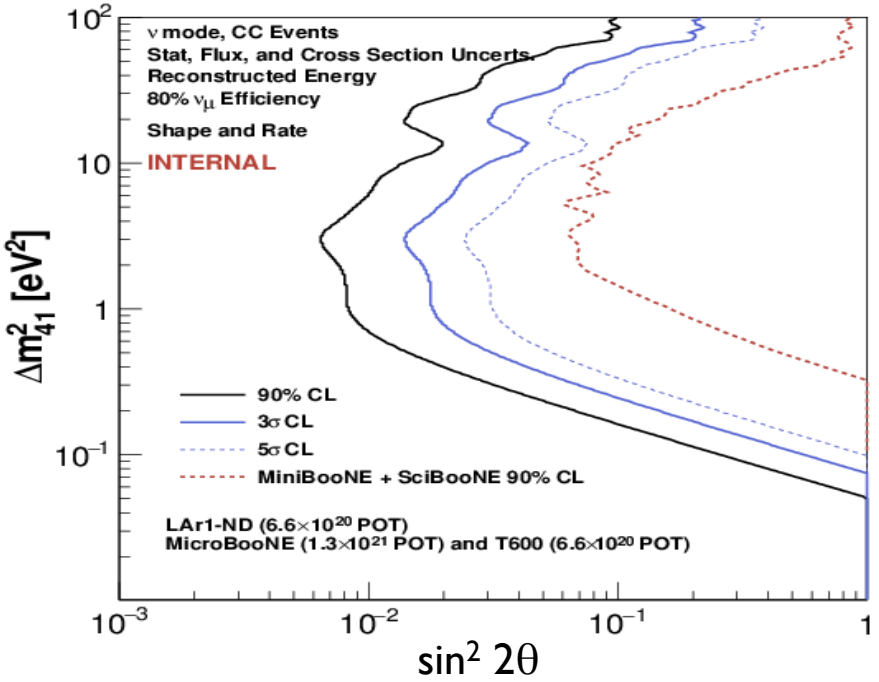




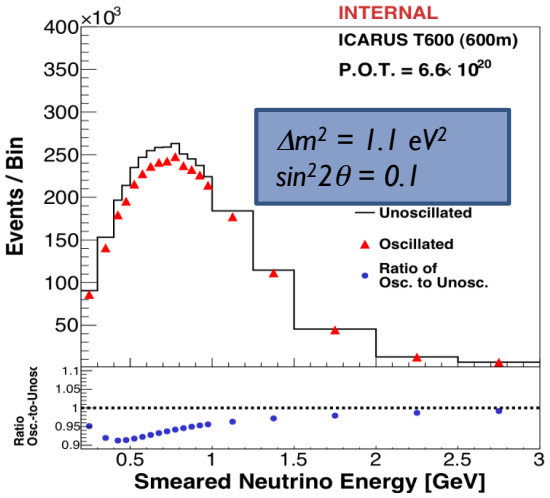
In absence of oscillations, the spectra should be copies of each other (only small correction due to the dimension of ν source)

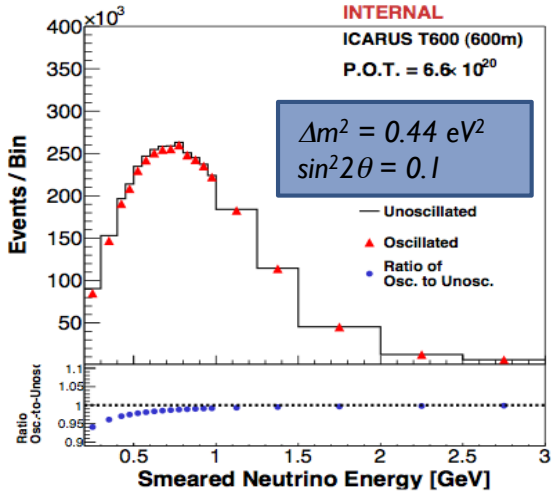
Expected exposure sensitivity of $\nu_\mu \rightarrow \nu_e$ oscillations for 3 years - 6.6 10^{20} pot BNB positive focusing (6 years for MicroBooNE):
LSND 99% C.L. region is covered at ~5σ level

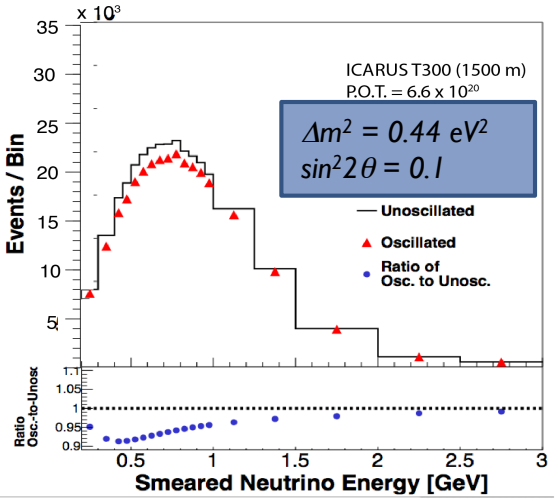
ν_μ disappearence sensitivity



- High event rates/ correlations between 3 LAr-TPCs will allow extending sensitivity by one order of magnitude beyond present limits.
- However for $\Delta m^2 < 0.5$ eV^2, disappearance at 600 m will be limited at lowest ν energy bins 0.2-0.4 GeV.
- In order to amplify the effect, at a later stage one ICARUS T300 module could be moved to 1500 m distance (to be decided).

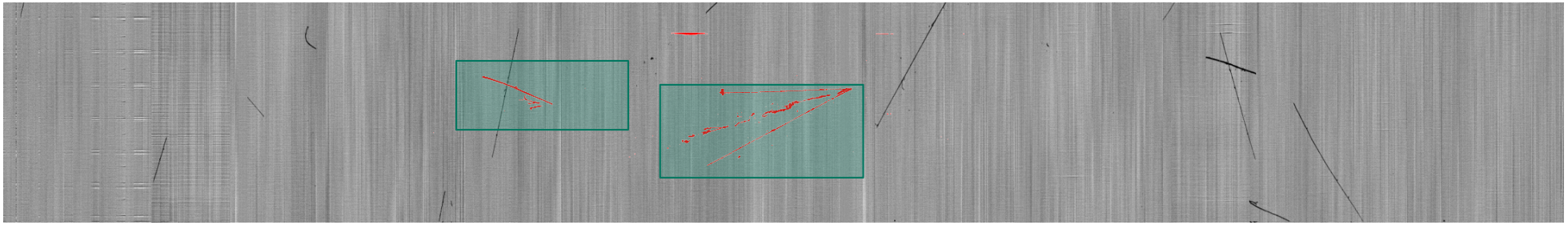






ICARUS T600 at shallow depths

- At shallow depth ~12 uncorrelated cosmic rays will occur in T600 during 1 ms drift window readout at each triggering event.
- This represents a new problem compared to underground operation at LNGS: the reconstruction of the true position of each track requires precisely associating to each element of TPC image the occurrence time with respect to trigger time.



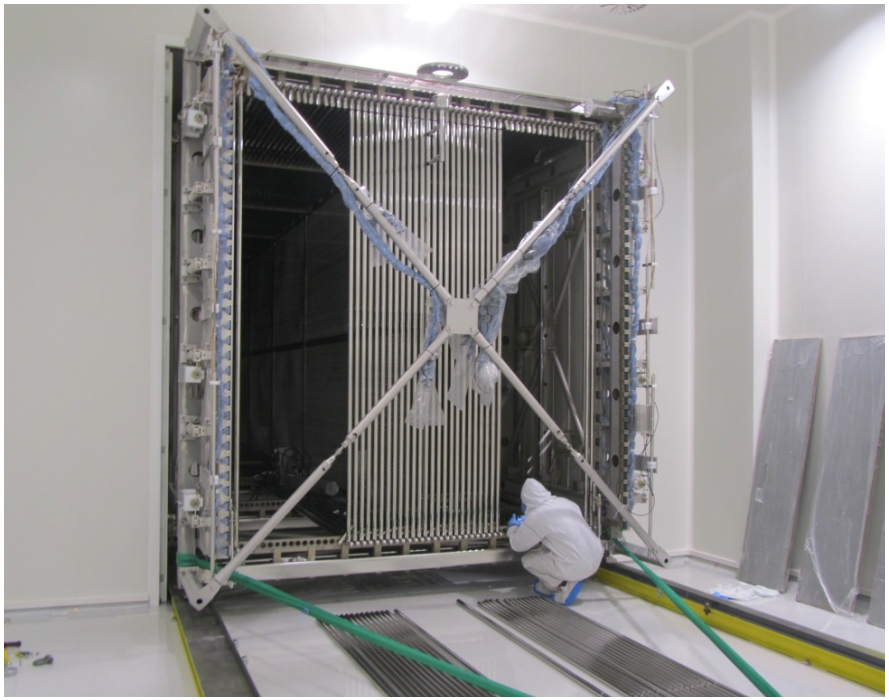
Cosmic rays + low energy CNGS beam events

- The γ's associated with cosmic μ's represent a serious background for the ν_e appearance search: electrons generated in LAr via Compton scattering / pair production can mimic a ν_e CC genuine signal.
- A 4π Cosmic Rays Tagger (total surface ~ 1200 m^2) of plastic scintillators around the LAr active volume will unambiguously identify all cosmic ray entering the detector, with time and position information to be combined with the light / charge reconstructed image.

WA 104 program: overhauling of T600

The T600 was moved to CERN in Dec. 2014 and is being upgraded, by introducing technology developments while maintaining the already achieved performance (WA104 program):

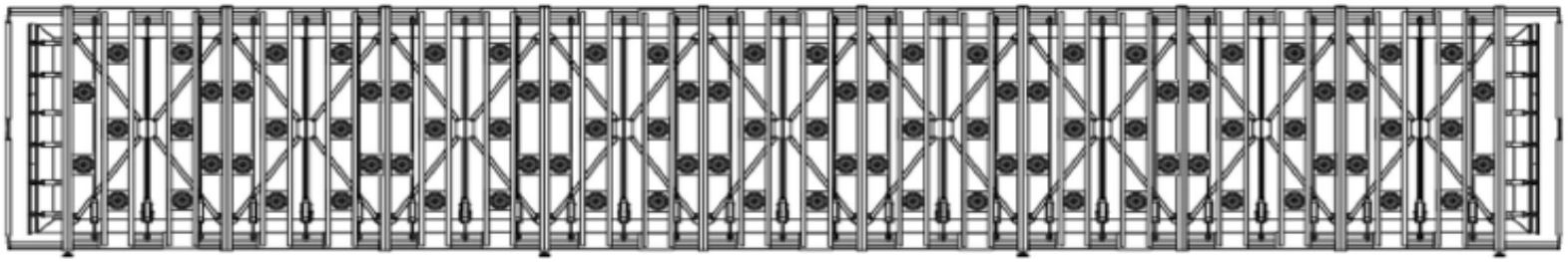
- new cold vessels and purely passive insulation;
- refurbishing of the cryogenic and purification equipment;
- existing cathode panels flattened, to provide improved planarity (factor 5-10);
- new faster, higher-performance read-out electronics;
- upgrade of the light collection system.



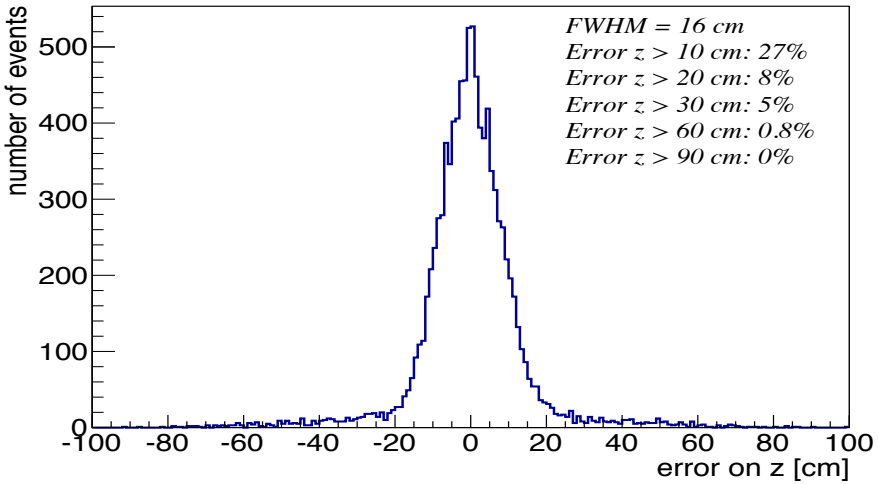
The CRT and reconstruction tools are items common to all the three SBN detectors

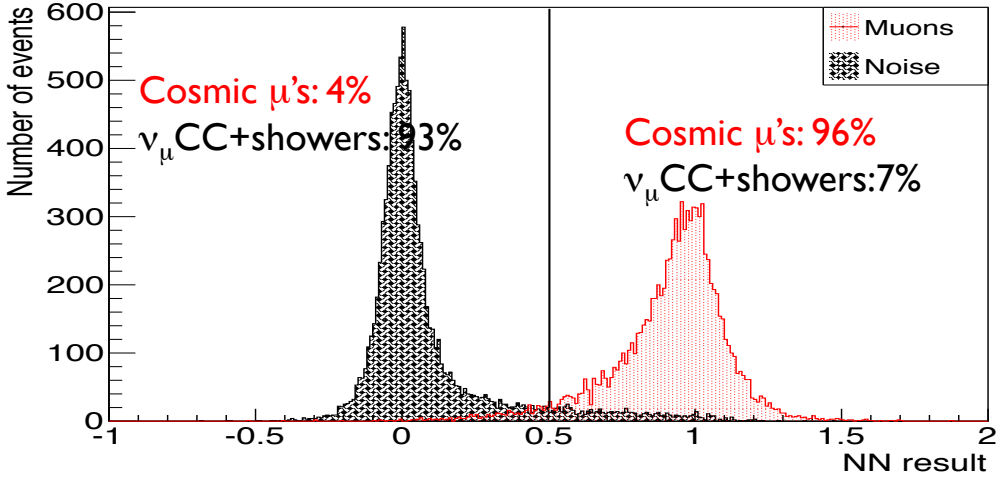
The WA104 program is regulated by a Memorandum of Understanding between CERN and INFN. The detector is expected to be transferred to FNAL before end 2016 for installation, commissioning and start of data taking (end 2017).

New light collection system



- 90 8" diameter Hamamatsu R5912 PMTs for each TPC (5% wire area coverage – 15 phe/MeV collected).
- Localization of events with error < 30 cm along beam direction, to assign the right t_0 at each events. Capability to distinguish between incoming cosmic rays and internal ν induced events.
- Time resolution ~ 1 ns to exploit the BNB bunched structure.





Conclusion

- The ICARUS detector has successfully operated for three years at the LNGS, providing multiple results on neutrino physics and LAr-TPC technology.

- A study of exotic oscillations, mediated by sterile ν was carried on with the CNGS ν_μ beam, to test the so-called "LSND effect", to no positive outcome.

- To confirm/exclude the sterile neutrino hypothesis, the ICARUS detector will take part in the dedicated FNAL Short Baseline Neutrino program, consisting of three LAr-TPC detectors (T600, MicroBooNE, SBND) aiming at the search for non-standard oscillations.

- Such experiment will allow fully covering the parameter space for the $\nu_\mu \rightarrow \nu_e$ appearance and ν_μ disappearance channels.

- The T600 detector is now undergoing a major technological overhaul at CERN and is expected to be deployed at FNAL by the end of 2016 for installation, commissioning and start of data taking with n beam by the end of 2017.

Thanks !