STATUS AND PLANS OF ICARUS

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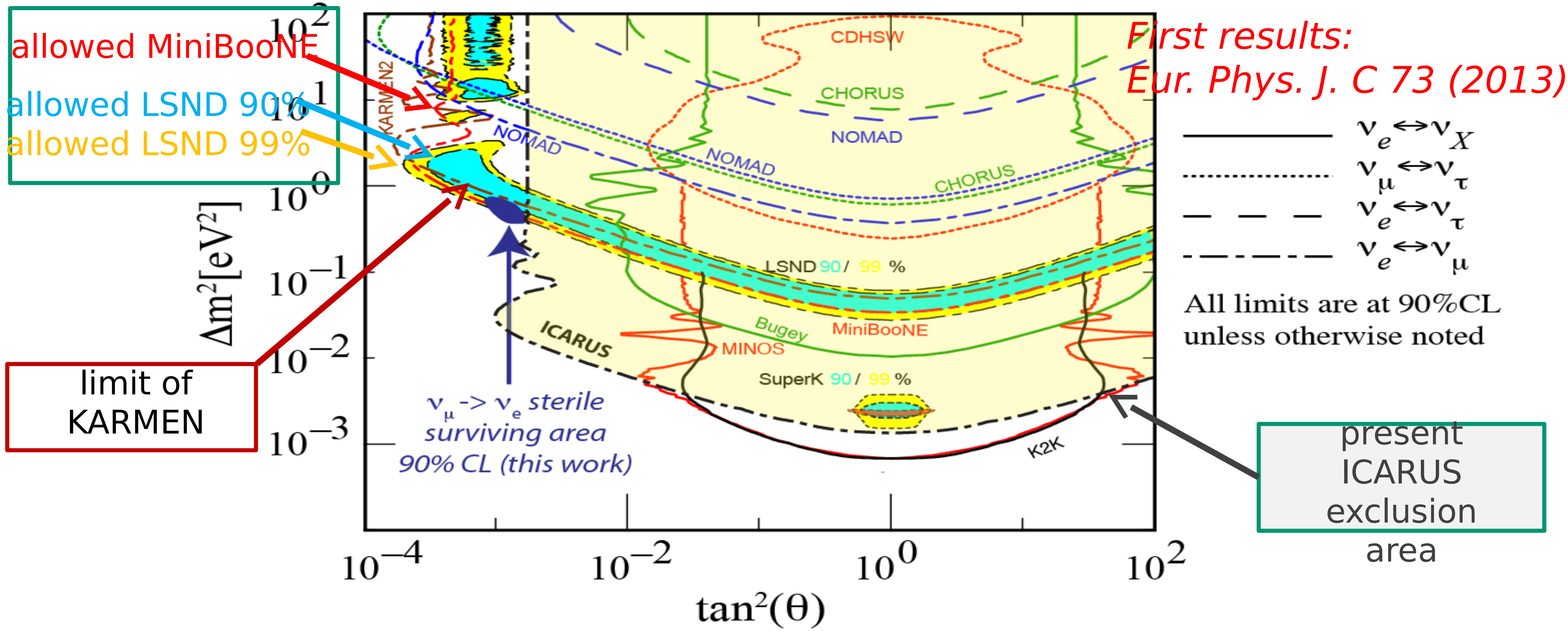
- Neutrino oscillations, for which evidence has emerged only in the past two decades, are one of the most important recent discoveries in particle physics. This covers two distinct and complementary main lines:

a) A new era of discovery in long-baseline experimental neutrino physics, including the opportunity to test for CP-violation in the neutrino sector. Testing CP-violation among the neutrinos is an important step in determining if leptogenesis is the explanation for the matter/antimatter asymmetry that may exist in the universe. This is a long range program needing developments over decades and giga-dollar expense.

b) There are existing experimental anomalies at short-baselines that may be hinting at exciting new physics, including the possibility of additional low-mass sterile neutrino states. Definitive evidence for sterile neutrinos would be a revolutionary discovery, with implications for particle physics as well as cosmology. A neutrino of 1 eV mass will necessarily be a leading component of the dark mass in the universe. These experiments which involve neutrino beams, reactors and mega curie sources have generated a multitude of shorter term and much cheaper programs.

- Proposals to address these hints from reactor, accelerator, and source experiments are in the planning stages or underway worldwide.
- In the next four years planning of CERN, so far no significant financial support has been granted for neutrino related activities. Therefore the very many neutrino researches of CERN memberstates in general and of INFN in particular will have to be adressed to bilateral collaboration activities with US and Japanese programs were neutrino beams continue to exist.
- Future accelerator based experiments will be either based on Water (Japan) or Liquid Argon (ICARUS and more recently US). Water Cherenkov detectors are not able to distinguish electrons from single photons. An important advantage of the LArTPC is the ability to separate them by sampling the energy deposition before the buildup of an electromagnetic shower.
- Liquid argon time project chamber detectors (LArTPCs) are particularly attractive for use in neutrino physics because of their exceptional capabilities in tracking, particle identification and calorimetric energy reconstruction. At the detector boundary, planes of closely spaced sense wires (wire pitch in the 3-mm range) are used to collect the free electrons.

LSND-like exclusion from the ICARUS experiment

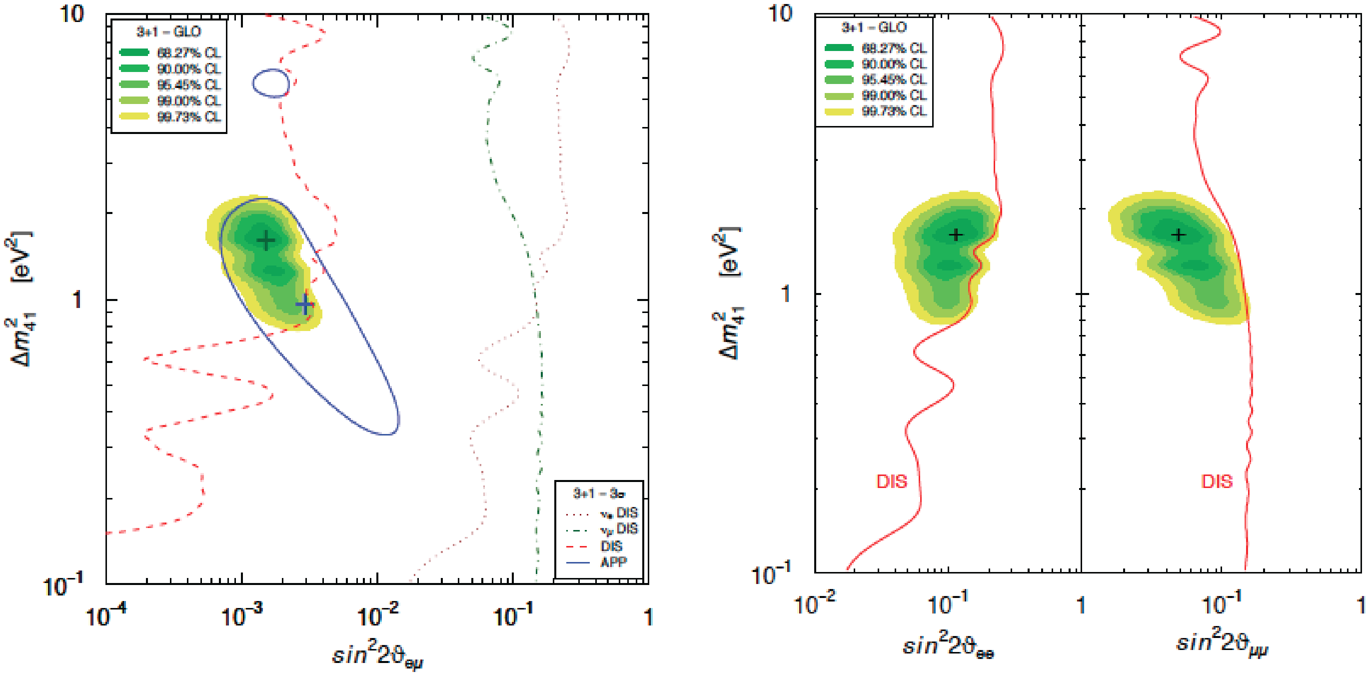


First results: Eur. Phys. J. C 73 (2013)

ICARUS result strongly limits the window of parameters for *a possible* LSND anomaly to a very narrow region *(Δm2 ≈ 0.5 eV2 and sin22θ ≈ 0.005)* where there is an overall agreement (90% CL) *of*

- the present ICARUS limit
- the limits of KARMEN
- the positive signals of LSND and MiniBooNE

Giunti, Laveder et al.,arXiv:1308.5288

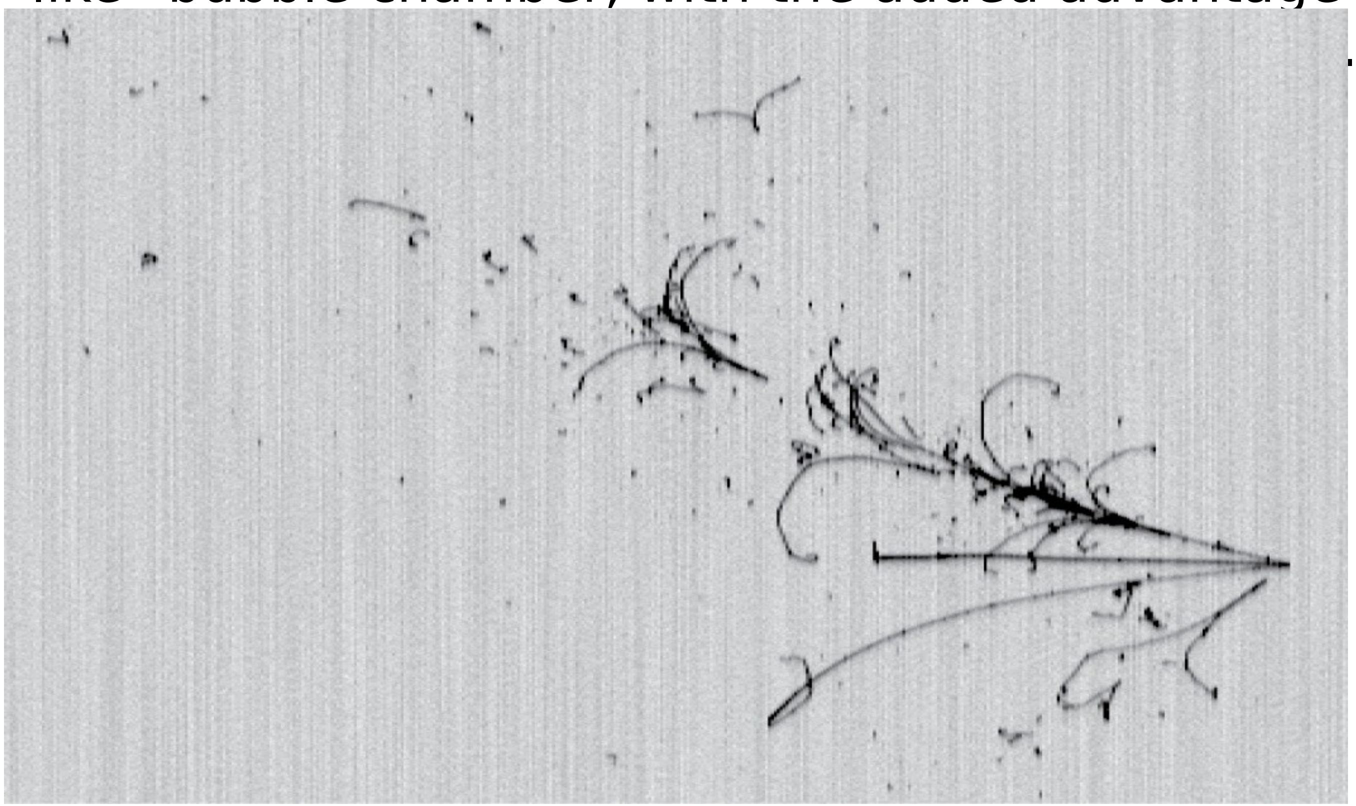


ICARUS contribution is relevant in excluding most of the area.

- Global fits of sin2θμe (appearance) & sin2θee and sin2θμμ (disappearance) with corresponding Δm241: a well defined common region 0.82<Δm241<2.19 eV2 within expectations of relevant cosmological measurements.
- The crucial indication in favor of short-baseline appearance is still the initial LSND result. MiniBooNE experiment has been inconclusive: new and better experiments are needed to search for the presence of these signals

- With a total LAr volume of 720 ton, the ICARUS detector has a unique role since it is presently the largest operational LAr-TPC and it will remain so for several years to come. It represents the status of the art and it marks a milestone in the practical realization of any future larger scale LAr detector.
- The T600 detector was moved to the Hall B of the Gran Sasso underground National Laboratory (LNGS) of Istituto Nazionale di Fisica Nucleare (INFN) in 2008 and made operational solving successfully the new, demanding problems associated with the underground operation of a large detector in association with the neutrino beam coming from CERN.
- From October 2010 to December 2012, the T600 was exposed to the CNGS beam, collecting neutrino data corresponding to 8.6 x 1019 protons on target with an efficiency exceeding 93%. Data were also collected with cosmic rays to study the detector capability for atmospheric neutrinos and proton decay.
- From the technological point of view, the T600 run was a complete success, featuring a smooth operation, high live time, high reliability. A total of about 3000 CNGS neutrino events have been collected and are being actively analysed. Several papers have been already published

- The introduction of an appropriate magnetic field to the LAr-TPC permits to further contribute to the progress of LAr technology, allowing the unambiguous determination of the sign and momentum of the secondary charged particles and a greatly improved visibility of the e.m. showers.
- It provides an even closer visual similarity to the one of a "Gargamelle like" bubble chamber, with the added advantage of an accurate .



Example of a 4 GeV e-neutrino event, with a negative electron, $\pi 0$, $\pi +$ and proton in the final state

- A proposal for a dual baseline experiment has been initially presented at CERN as early as 2009, followed by a number of documents to the SPS-C.
- Our proposed experiment, collecting a large amount of data both with neutrino and antineutrino focussing, should be able to give a likely definitive answer to the 4 following queries:
  - the LSND/+MiniBooNe both antineutrino and neutrino $\nu\mu \rightarrow \nu e$ oscillation anomalies;
  - The Gallex + Reactor oscillatory disappearance of the initial $\nu - e$ signal, both for neutrino and antineutrinos
  - an oscillatory disappearance maybe present in the $\nu - \mu$ signal, so far unknown.
  - Accurate comparison between neutrino and antineutrino related oscillatory anomalies, maybe due to CPT violation.
- In absence of these “anomalies”, the signals of the detectors should be a precise copy of each other for all experimental signatures and without any need of Monte Carlo comparisons.
- The beam at CERN represents by far the best alternative for such searches.

- The CERN SPS-C has recommended the experiment on Jan 15th, 2013.
- An initial project is starting at CERN, with the aim to provide an effective platform for future neutrino activities at CERN and/or outside CERN
- The proposal SPSC-P-347 ICARUS-NESSIE *"has been conditionally approved"* for the ICARUS group on October 1, 2013 with CERN code WA104 following the Research Board of August 28. *Conditionally* implies that at this moment in time the construction of a short baseline neutrino beam is not granted and the focus is mainly on detector technology development and qualification in test (charged) beams.
- A MOU between CERN and the participating institutions (INFN) is under preparation, with the installation of the ICARUS detectors in the "Gargamelle Hall" of the West Area. The duration of this program is of about two years.
- However we strongly believe that the exclusive utilization of charged particle beams will be vastly insufficient at the level of development & complexity of our present LAr-TPC program.
- *The direct and continued access to a neutrino beam either at CERN or alternatively to FNAL is necessary. A proposal is under preparation for FNAL, although the CERN beam has substantial advantages.*

Conclusions

- The recent, major success of ICARUS-CNGS2 experiment has conclusively demonstrated that LAr-TPC is *a leading technology for future short/long baseline accelerator driven neutrino physics. Neutrino beams at CERN could however have been the best choice.*
- On a longer time scale, INFN has just concluded an important cooperation agreement toward a joint experiment with US-LBNE collaboration, involving the long term realization of a truly large mass, LAr-TPC detector for a search of CP violation in the lepton sector, proton decay and other topics. *This without any doubt will be a leading future experimental programme in the accelerator* ν*-physics world-wide.*
  - ICARUS' intention is to proceed towards the joint realization of a larger underground LAr detector in the LBNE neutrino beamline:
  - We agree to collaborate and coordinate R&D in the development of large LAr detectors for neutrino physics. The previous experience with "MODULAR" will be of value.
  - We agree to collaborate and coordinate on development of software.
  - We are interested to investigate the potential use of ICARUS