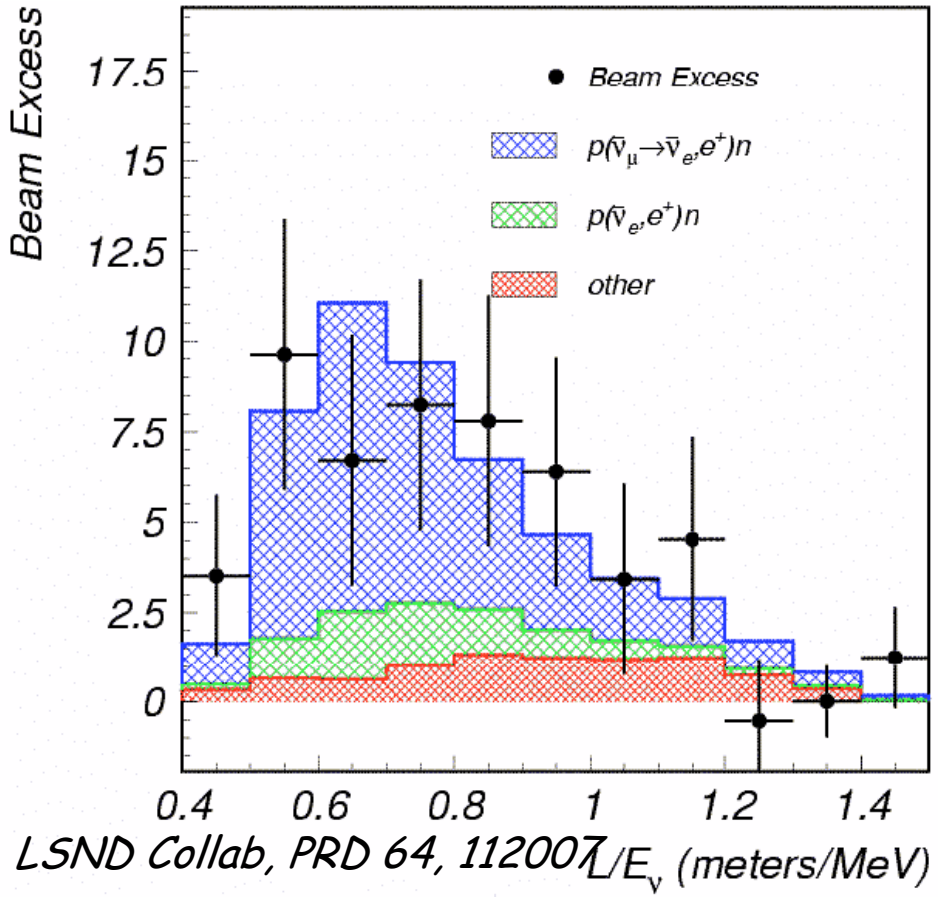
A new search for anomalous neutrino oscillations at the CERN PS

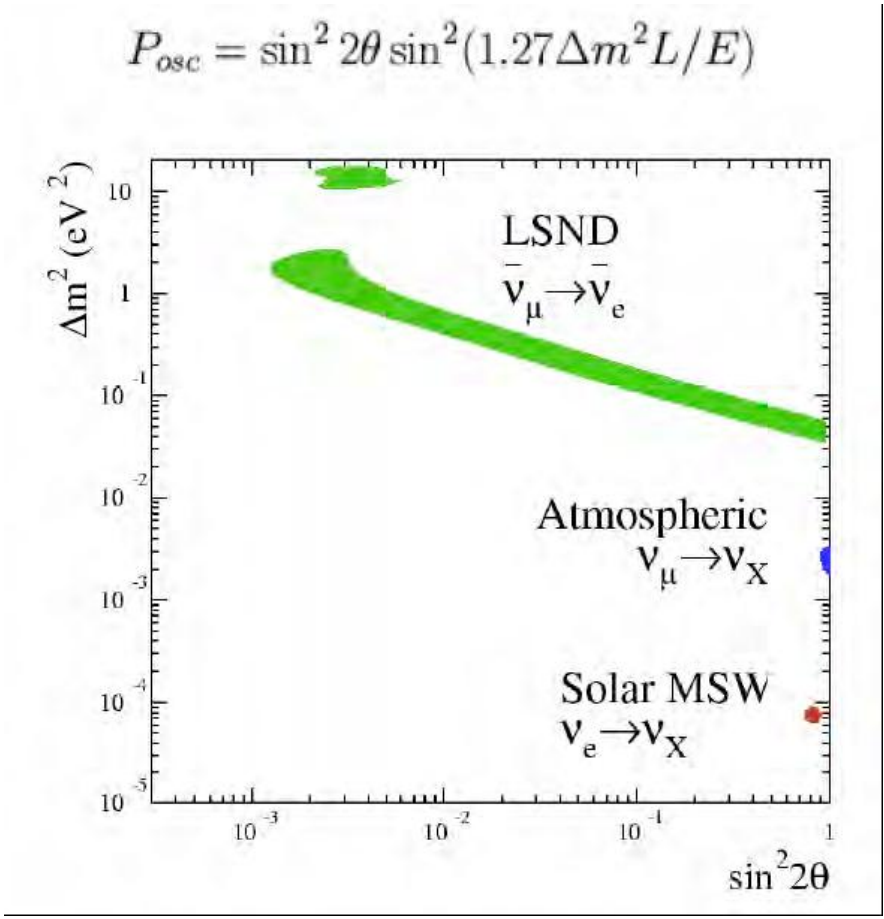
C. Rubbia & C.

arXiv:0909.0355

LSND results : anti-ν oscillations ?

LSND has observed an excess of $\bar{\nu}_e$ events in a $\bar{\nu}_\mu$ beam,
87.9 ± 22.4 ± 6.0 ⇒ 3.8 σ

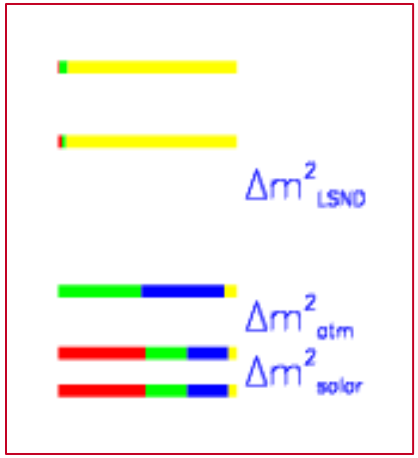




- 3 oscillation signals, if confirmed, require new physics beyond the SM

Many theoretical hypothesis

3+2 Sterile Neutrinos Sorel, Conrad, & Shaevitz (PRD70(2004)073004)



← Additional, sterile neutrinos ?

← Standard neutrinos

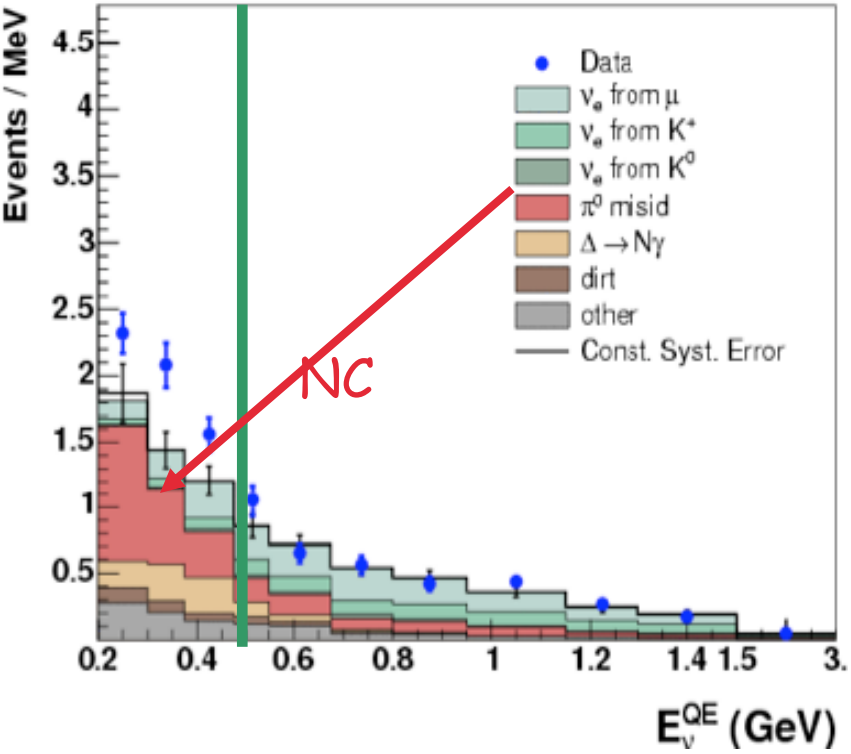
MaVaNs & 3+1 Sterile Neutrino	Hung (hep-ph/0010126) Kaplan, Nelson, & Weiner (PRL93(2004)091801
CPT Violation & 3+1 Sterile Neutrino	Barger, Marfatia, & Whisnant (PLB576(2003)303)
Quantum Decoherence	Barenboim & Mavromatos (PRD70(2004)093015)
Lorentz Violation	Kostelecky & Mewes (PRD70(2004)076002) Katori, Kostelecky, Tayloe (hep-ph/0606154)
Extra Dimensions	Pas, Pakvasa, & Weiler (PRD72(2005)095017)
Sterile Neutrino Decay	Palomares-Ruiz, Pascoli, & Schwetz (JHEP509(2005)48)

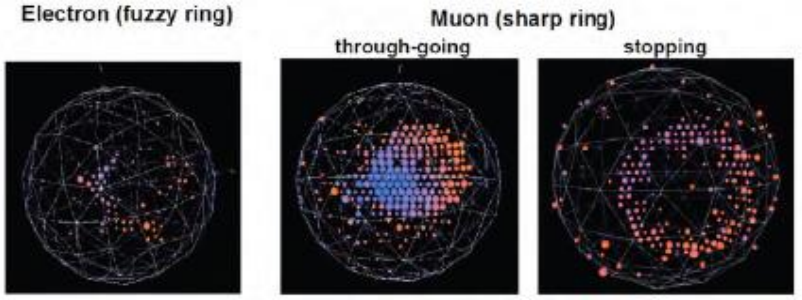
And so on....

MiniBoone

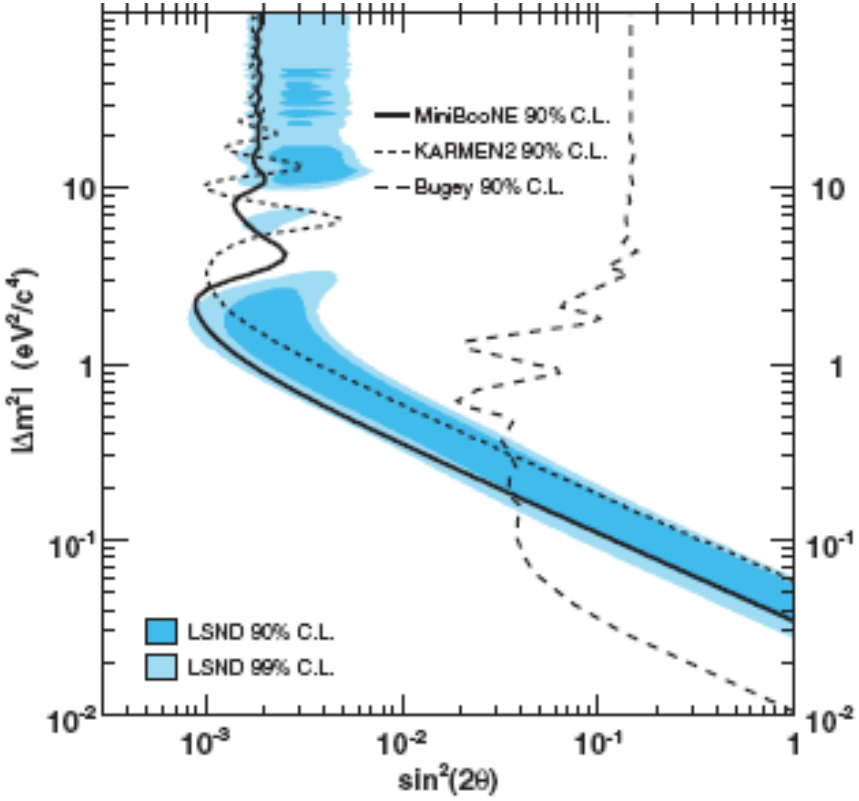
re-analysis of ν mode PRL 102, 101802 (2009)

ν mode 6.6e20 POT 450t fiducial





E > 475 MeV:
expected: 385.9 ± 35.7
observed: 408



E< 475 MeV: low energy excess persists
(3σ 200-475 MeV)
expected: 415.2 ± 43.4
excess : 128.8 ± 20.4 ± 38.3

MiniBoone: Preliminary $\bar{\nu}$ Data with 4.863 10^{20} POT

W.C. Louis & G.B. Mills, FNAL PAC, November 13, 2009

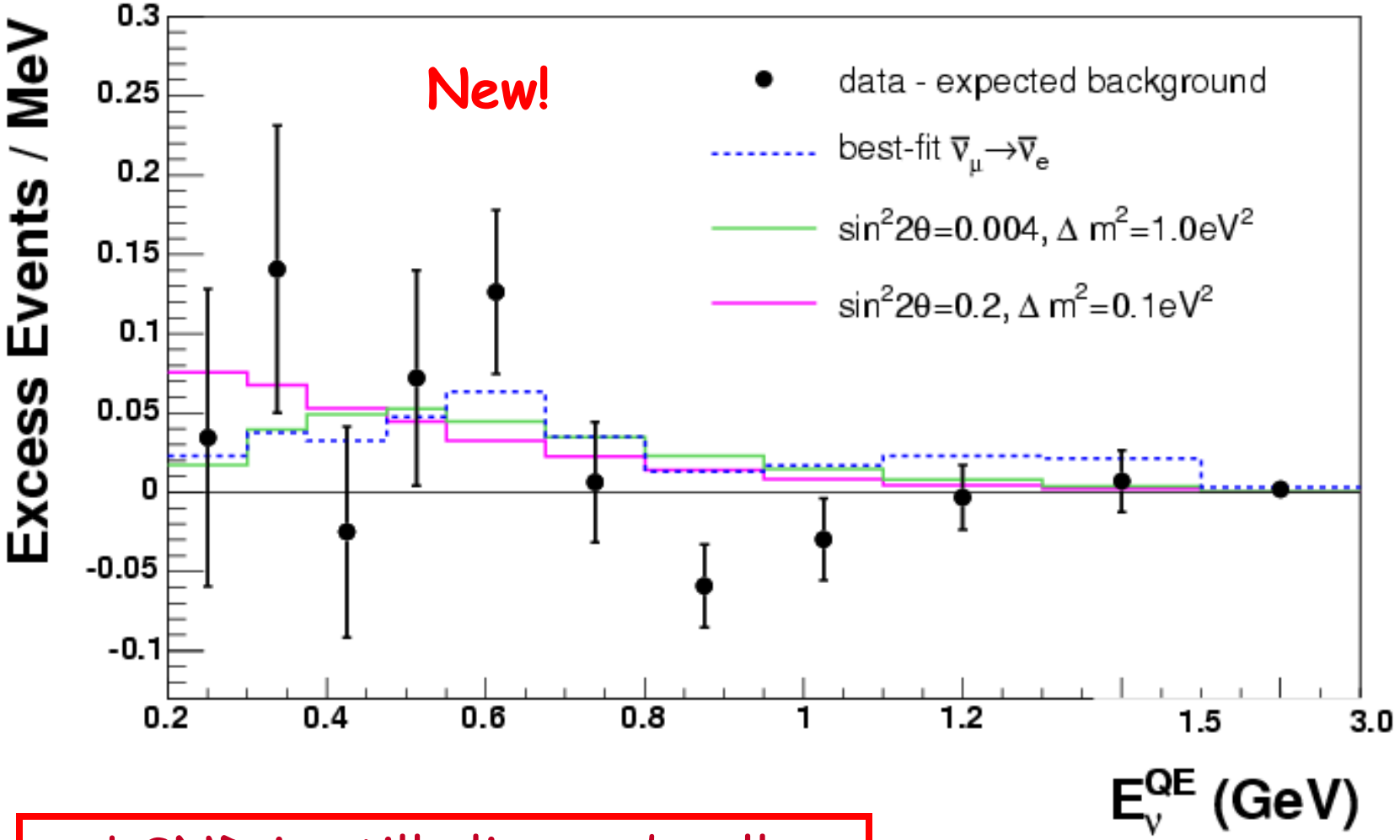
	E_ν>200 MeV	E_ν>475 MeV
Data Events	225	126
Bkgd Events	201.6	114.1
Excess Events	23.4+-22.6	11.9+-16.4
Excess at b.f.	41.6+-23.4 (1.78σ)	32.2+-16.8 (1.92σ)
LSND Expect.	~29.7	~21.8
χ^2_{null}	32.3/18 DF (2%)	27.5/15 DF (2%)
χ^2_{bf}	21.8/16 DF (15%)	18.4/13 DF
Δm^2_{bf}	4.42 eV^2	4.64 eV^2
$\sin^2 2\theta_{bf}$	0.0058	0.0058

Event excess has increased with new data. Additional data will double #POT and determine whether this excess is real.

MiniBooNE $\bar{\nu}_e$ appearance data are inconclusive at present but are consistent so far with LSND

Excess from 200-475 MeV = 11.4 ± 9.4 ± 11.2 events

Preliminary for 4.863E20 POT (~50% increase in POT!)



LSND is still alive and well.

Coming/ proposed experiments

- A Letter of Intent to Build a MiniBooNE Near Detector: BooNE (W.C. Louis & G.B. Mills, FNAL PAC, November 13) : New Detector or Moving MiniBooNE
- MicroBooNE at FNAL: a new LArTPC detector to be placed on the Booster ν beam to study the MiniBooNE low-energy excess. 70-ton fiducial volume, Might start data-taking in 2012
- OscSNS at ORNL. A new experiment with pions at rest, similar to LSND but with a higher intensity spallation source (1.4 MW). A "MiniBooNE-like" detector (800 t) at a distance of ~60 m from the SNS beam stop
- ICARUS T600 at LNGS: events in the deep inelastic region 10-30GeV. High sensitivity at small Δm^2

A definitive determination of the sterile neutrino anomaly puzzle with LAr at the CERN-PS ?

LOI

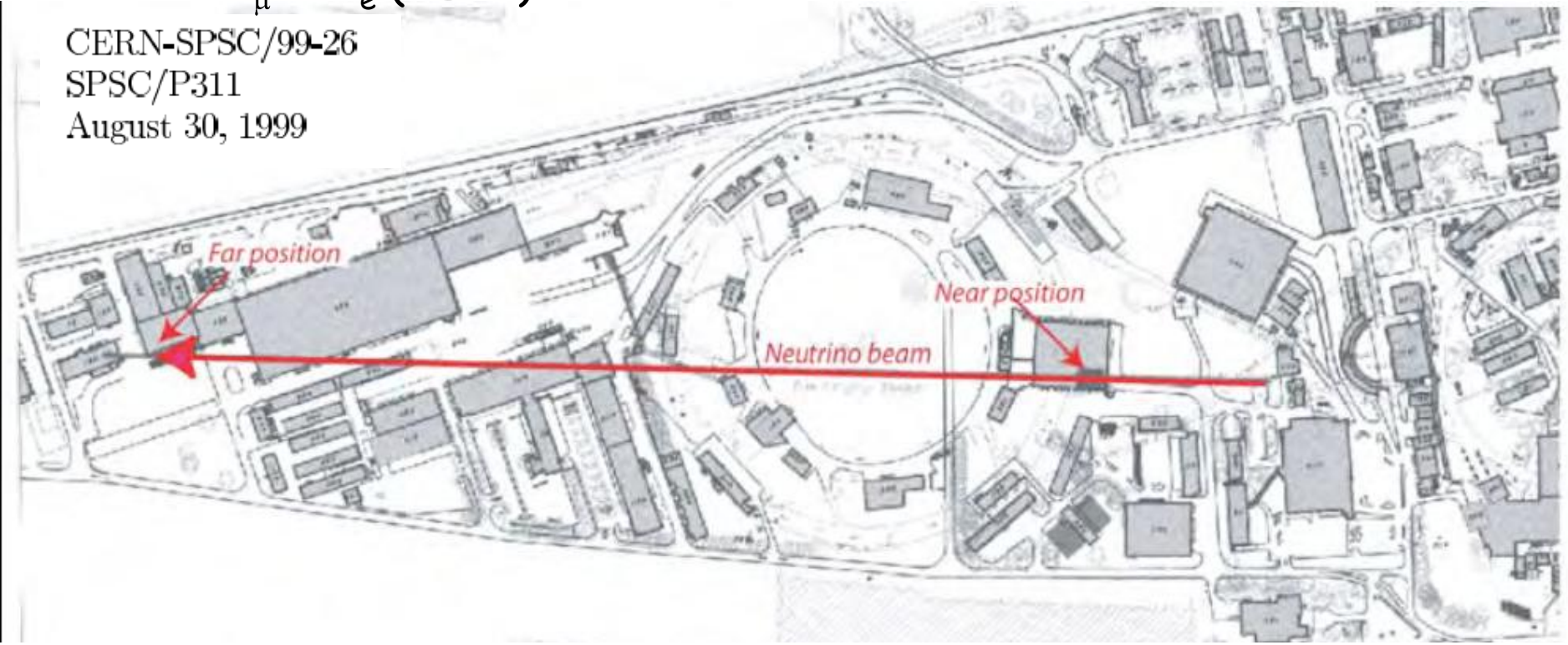
- LAr TPCs at the CERN PS
- FAR and NEAR detectors to reduce systematics due to beam, MonteCarlo and ν-cross-section knowledge
- The ICARUS technology to
  - reject NC backgrounds
  - include non-QE events in the analysis

A starting project, open to collaboration,
first contacts in italy showed interest from
INFN/ Univ. Padova, Pavia, Genova, Milano, Milano-2, LNGS, CERN

Two detectors at the PS neutrino beam

PS-180 $\nu_\mu \rightarrow \nu_e$ (BEBC)

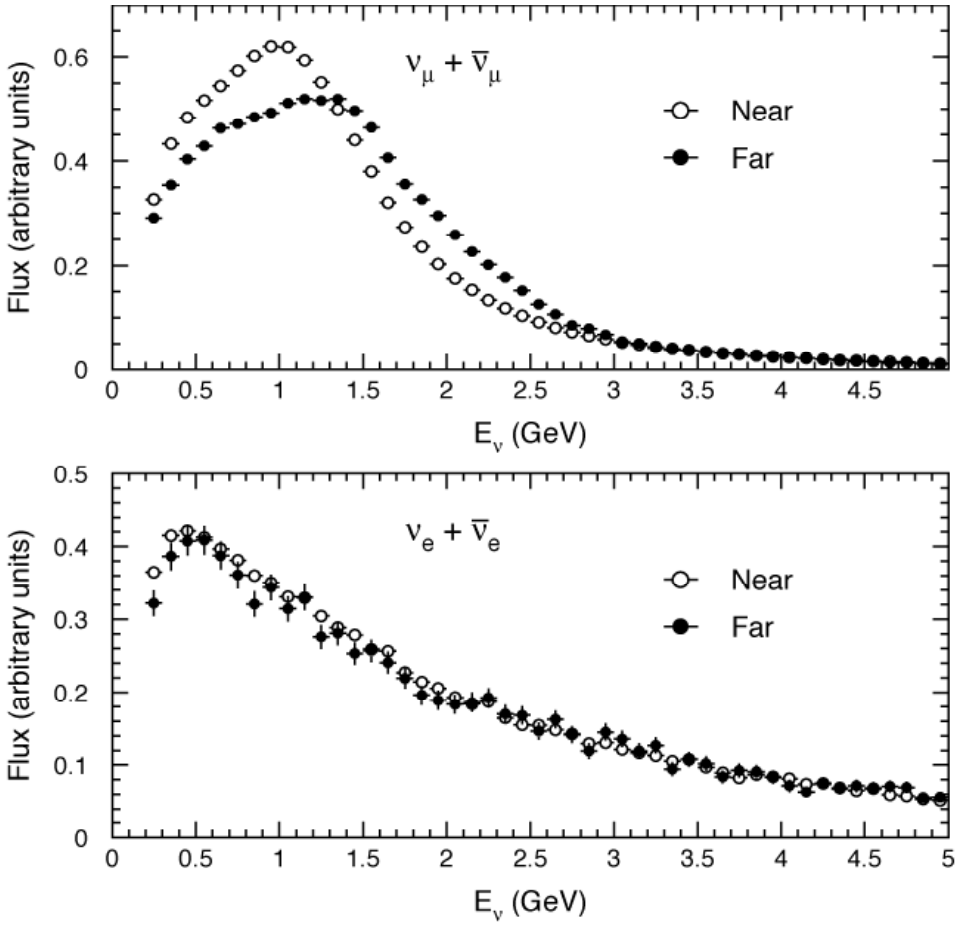
CERN-SPSC/99-26
SPSC/P311
August 30, 1999



- The PS proton beam at 19.2 GeV/c is extracted via TT2, TT1 and TT7.
- The magnetic horn is designed to focus particles of momentum≈2GeV/c.
- The decay tunnel is about 50 m long, followed by an iron beam stopper

Two positions are foreseen for the detection of the neutrinos
The far (main) location at 850 m from the target;
The near location at a distance of 127 m from the target.

Neutrino beam



Expected neutrino spectra at the near and far locations

Starting point: PS-180 exp and I216 /P311 proposal

CERN-SPSC/99-26
SPSC/P311
August 30, 1999

SEARCH FOR $\nu_\mu \rightarrow \nu_e$ OSCILLATION AT THE CERN PS

refurbish the old line used by BEBC

Event rates

Assuming 2 years run for a total of 2.5 10^{20} pot

Fiducial mass	**500 t**	**150 t**
Distance from target	**850 m**	**127 m**
ν_μ interactions	**1.2 x 10^6**	**18 x 10^6**
QE ν_μ interactions	**4.5 x 10^5**	**66 x 10^5**
Events/rst	**0.17**	**2.5**
Intrinsic ν_e from beam	**9000**	**120000**
Intrinsic ν_e from beam (E_ν < 3 GeV)	**3900**	**54000**
ν_e oscillations: Δm^2 = 2. eV^2; $\sin^2 2\theta$ = 0.002	**1194**	**1050**
ν_e oscillations: Δm^2 = 0.4 eV^2; $\sin^2 2\theta$ = 0.02	**2083**	**2340**

	background	osc. evts prob= 0.0026
LSND	30	88 $\bar{\nu}$
MiniBOONE E>475	386	163 ν
MicroBOONE	31	54 ν 3y
oscSNS	79	253 $\bar{\nu}$ 1y

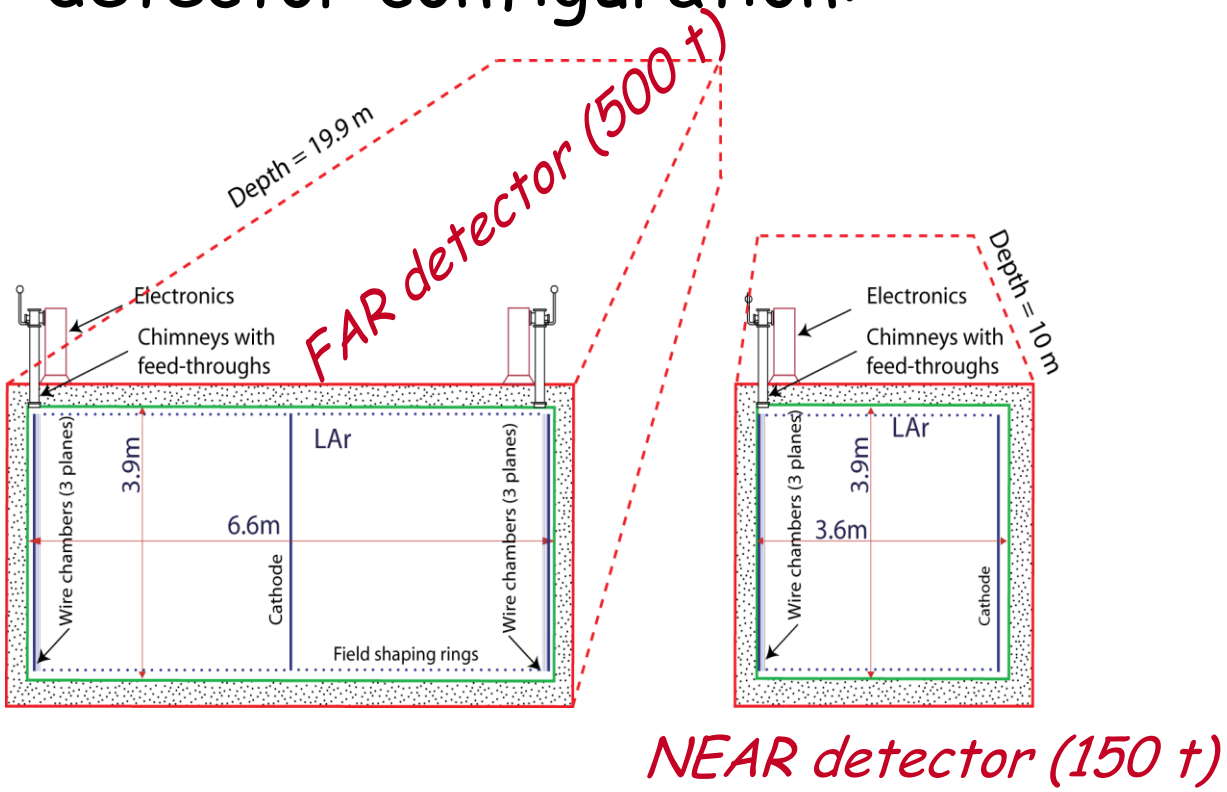
Nu-beam design

- Quoted event rates are from te old BEBC beam. Re-design of beam optics/ monitoring/shielding to be started soon profiting of our past experience
- Simulation of WANF :excellent comparison with NOMAD data
- Simulation of CNGS: from engineering to neutrino event rates (see *An updated Monte Carlo calculation of the CNGS neutrino beam* CERN-AB-Note-2006-038 , EDMS No. 745389)
- Simulation of CNGS-2 for the Modular project
- Simulation of events in LAr for ICARUS
- New neutrino event generator for FLUKA

➢ All tools are there for target/ horn/ shielding/ neutrino production/ neutrino detection.

A twin LAr detector configuration:

- A far detector with roughly the T600 total mass
- inner volume NEAR: 3.6 x 3.9 x 8 m^3
- Wire chambers with 3 readout planes at 0°, ±6HV = -180 kV @ 0.5 kV/cm



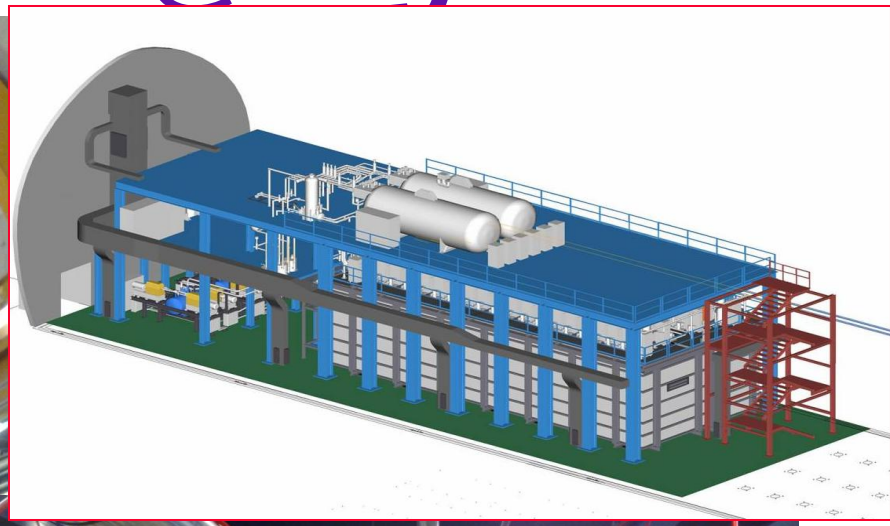
ArXiv: 0909.0355

- Set-up simplified with respect to ICARUS
- Cheaper, cryogenic vessel with ≈ 1 m thick perlite walls
- Wire chamber mechanics, purification system and readout electronics "cloned" from the ICARUS set-up
- Very quick construction schedule.

A practical strategy

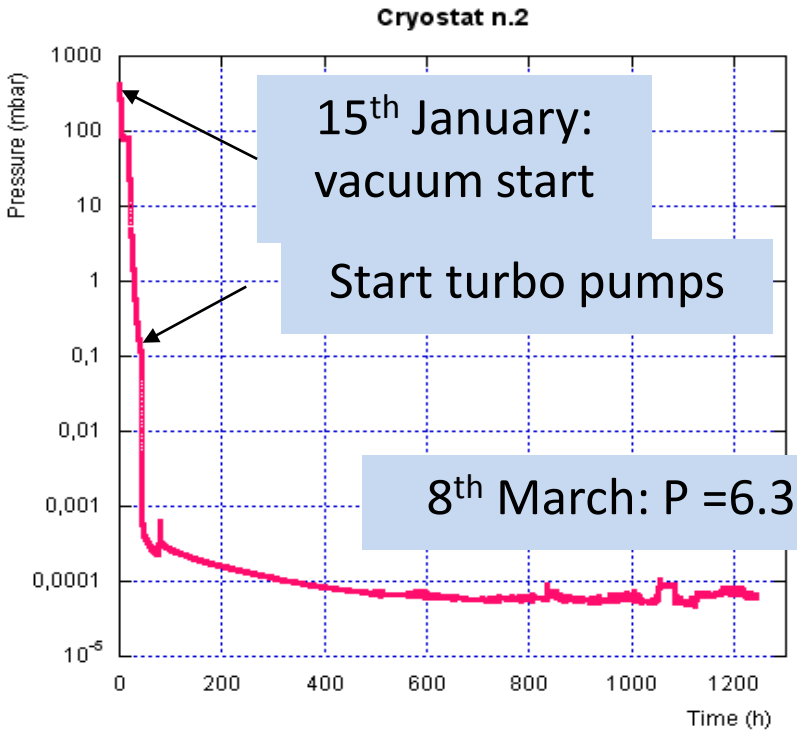
- ICARUS T600 will start taking data in 2010 May exposed at the CNGS neutrino beam, studying also cosmic neutrinos and searching for p-decay with a COMPLETELY NEW TECHNIQUE w.r.t. Water Cherenkov.
- The ICARUS-T600 detector could be available in 3 years from now if:
  - the CNGS programme has been fulfilled, and
  - the ICARUS physics programme at LNGS has been covered
- ICARUS-T600 fits perfectly as the Far Detector in the BEBC Hall
- The detector is ``by design'' transportable: all the mechanical structure including wire chambers; cryogenics; purifiers and electronics.
- The insulation vessel, site dependent, can be reengineered in situ.
- The effort could be concentrated on the construction of the near detector, which could be the play-ground for additional R&D toward larger masses.

ICARUS-T600 @ Ings



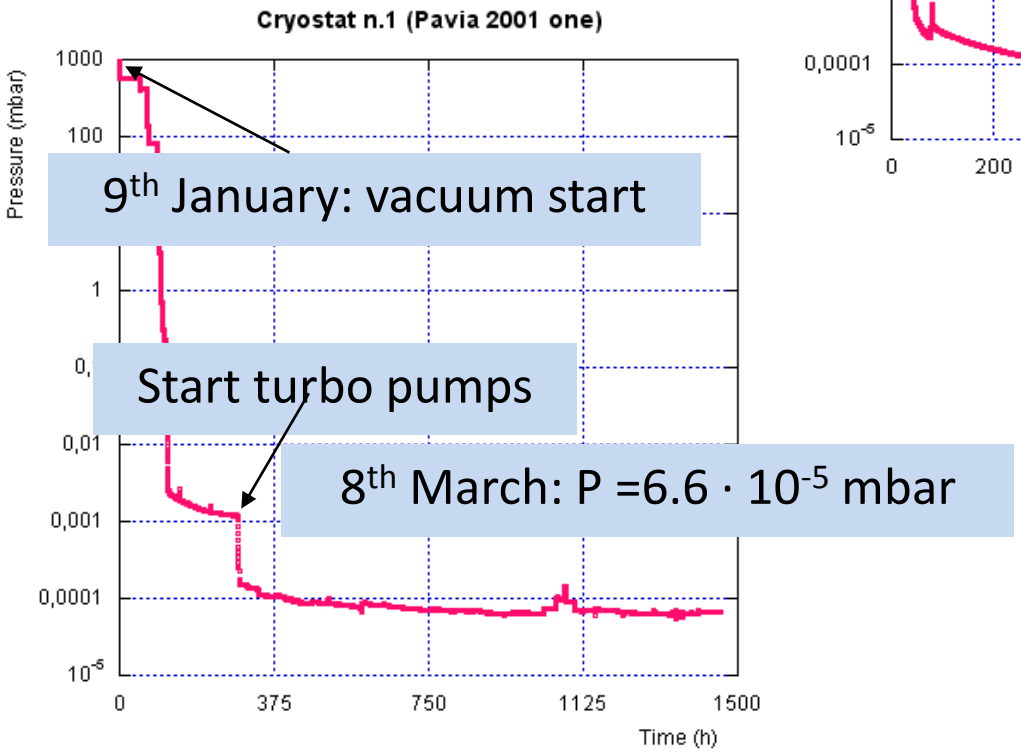
T600 status:vacuum test successful

Cryostat 2 ⇒



Cryostat 1

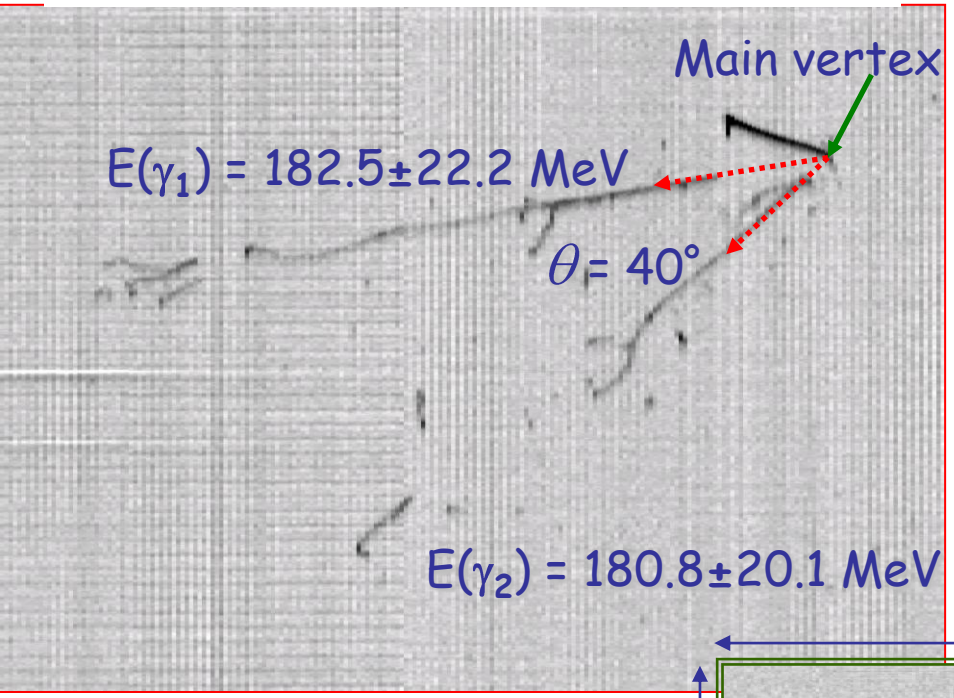
⇓

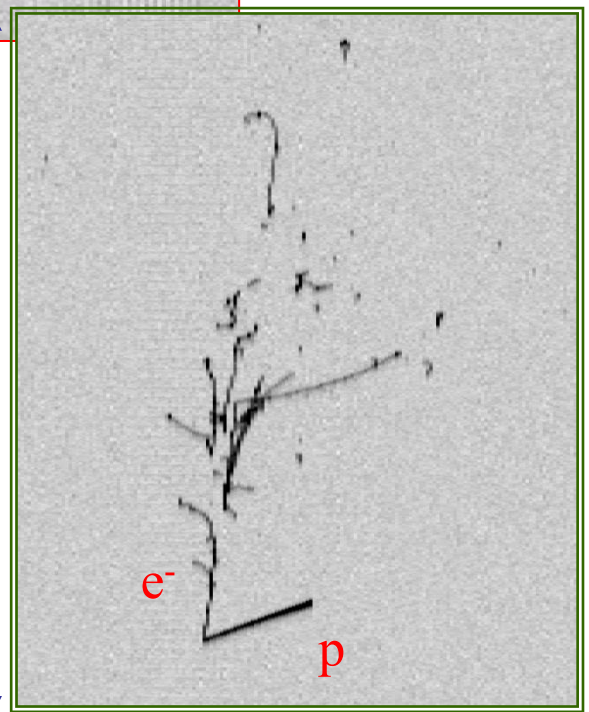


Cooling and filling phase starting this week
Operational in May

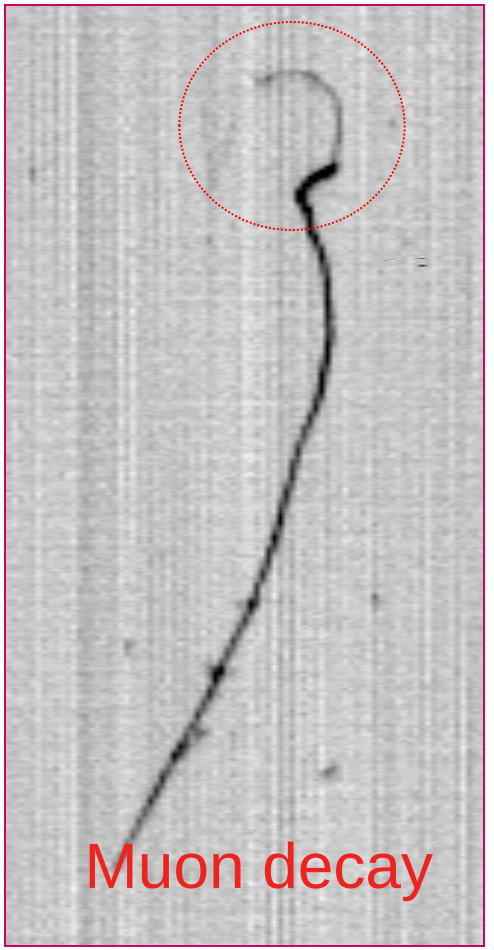
LAr event gallery

π^0 in T300 (Pavia 2001 data)





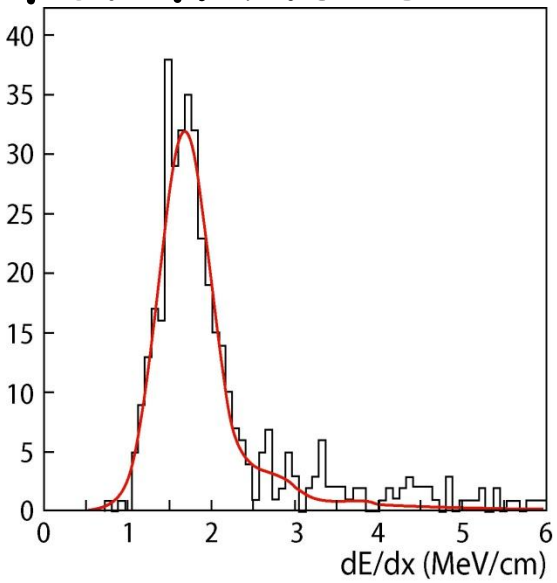
ν_e QE CC simulated event



Run 960, Event 4 Collection Left
(Pavia 2001 data)

summary of LAr TPC performances

- Tracking device
  - Precise event topology
  - Momentum via multiple scattering
- Measurement of local energy deposition dE/dx
  - e / γ separation (2%X_0 sampling)
  - Particle ID by means of dE/dx vs range
- Total energy reconstruction of the events from charge integration
  - Full sampling, homogeneous calorimeter with excellent accuracy for contained events



dE/dx distribution along a single muon track

RESOLUTIONS

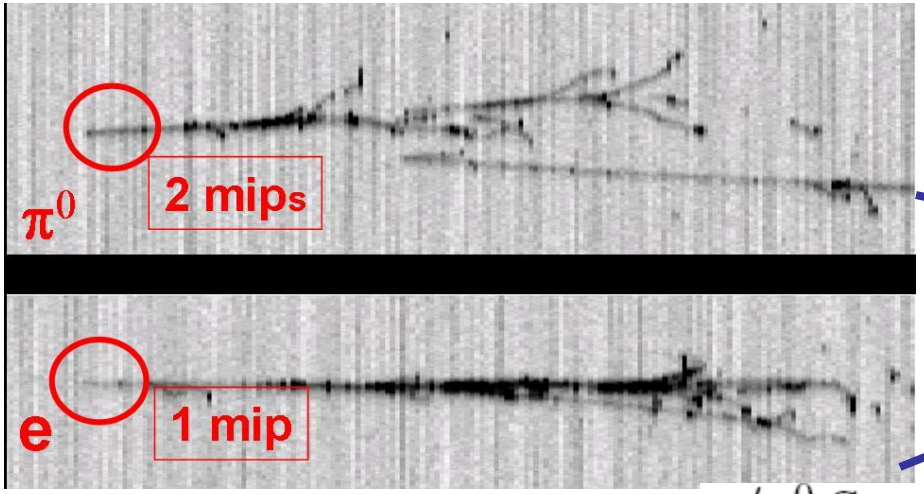
Low energy electrons: $\sigma(E)/E = 11\% / \sqrt{E(MeV)} + 2\%$

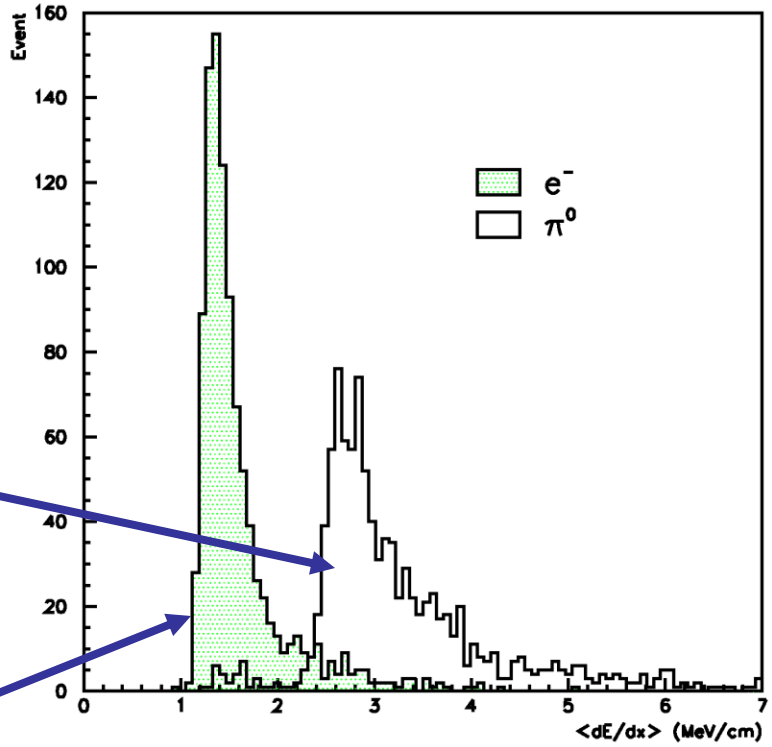
Electromagn. showers: $\sigma(E)/E = 3\% / \sqrt{E(GeV)}$

Hadron shower (pure LAr): $\sigma(E)/E \approx 30\% / \sqrt{E(GeV)}$

NC rejection in LAr

- NC in LAr suppressed by:
  - topology (γ conversion from vertex)
  - reconstruction of π^0 mass
  - electron/photon separation (dE/dx)
- Electron identification eff. = 90 %
- Residual misidentification < 0.1%





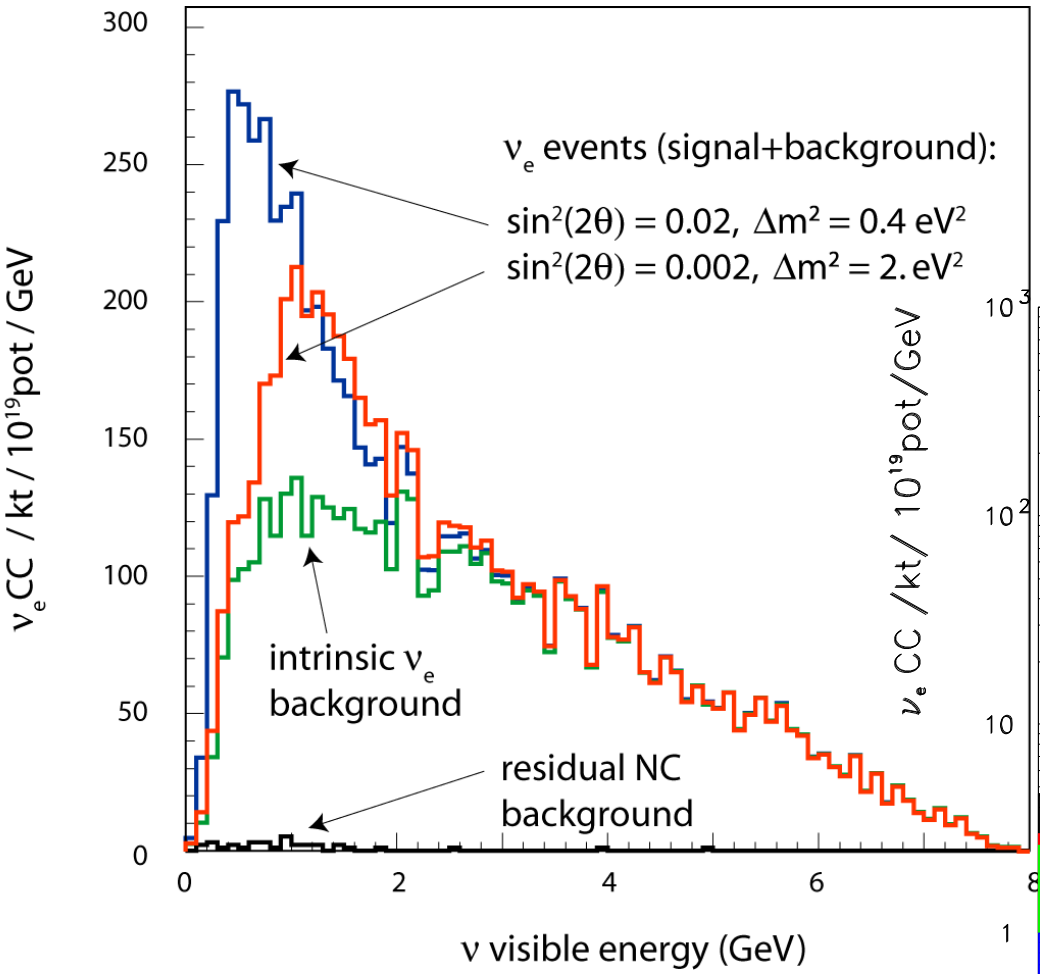
e/π^0 Separation in ICARUS Liquid Argon Time Projection Chamber

ICARUS-TM/03-05
August 12st, 2003

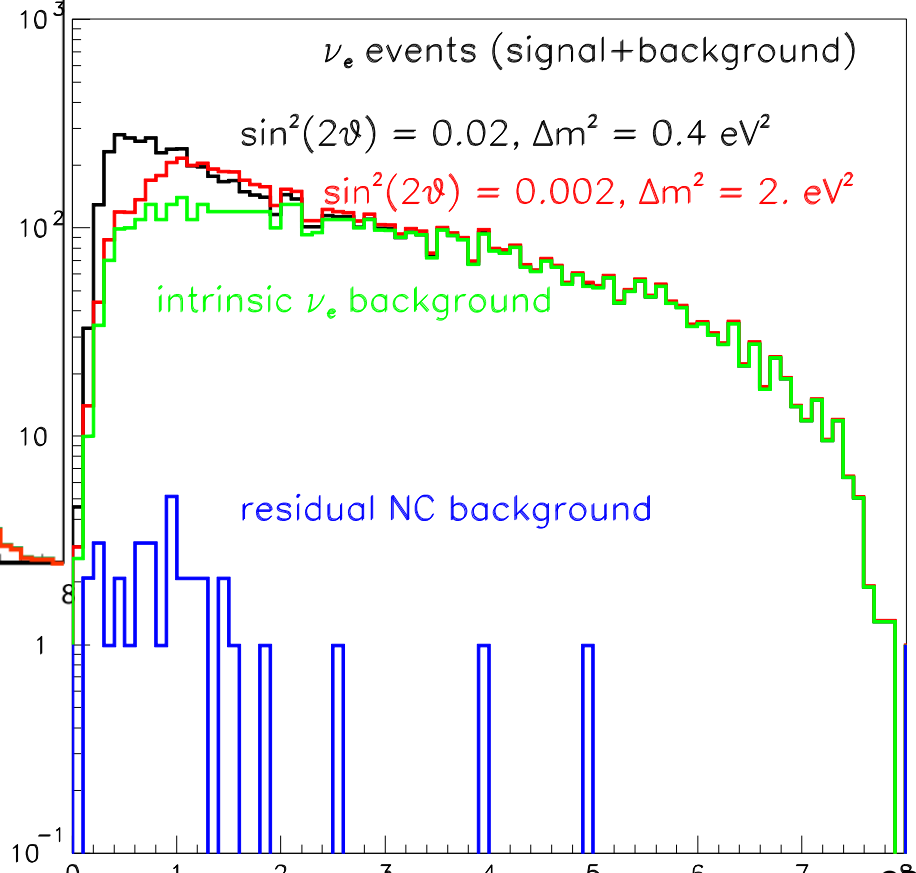
Y. Ge, P. Sala, A. Rubbia

Expected spectra

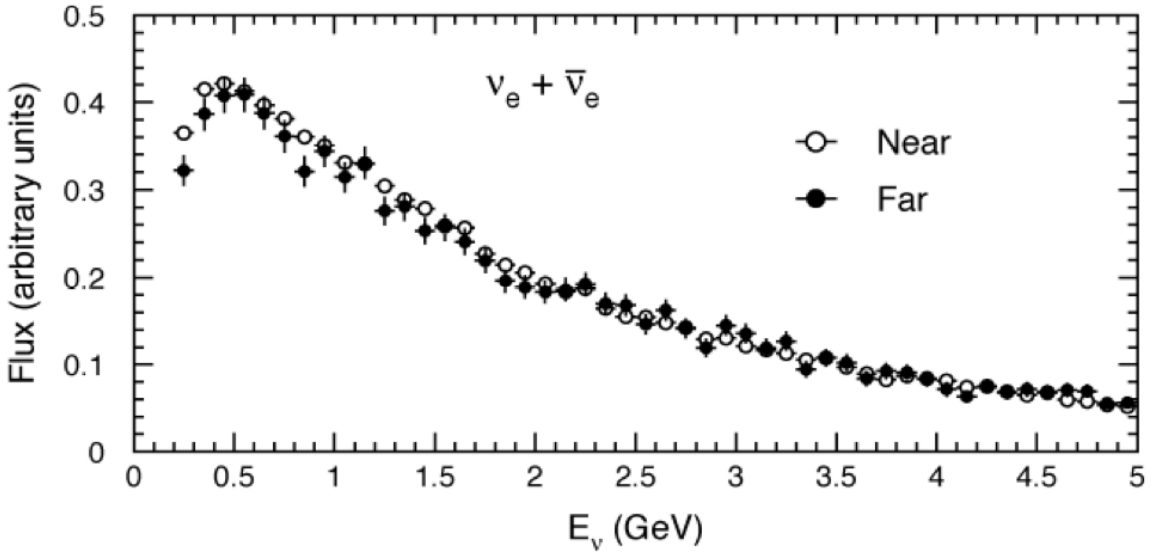
Visible energy in the FAR detector ν_e-like events full simulation



log scale→



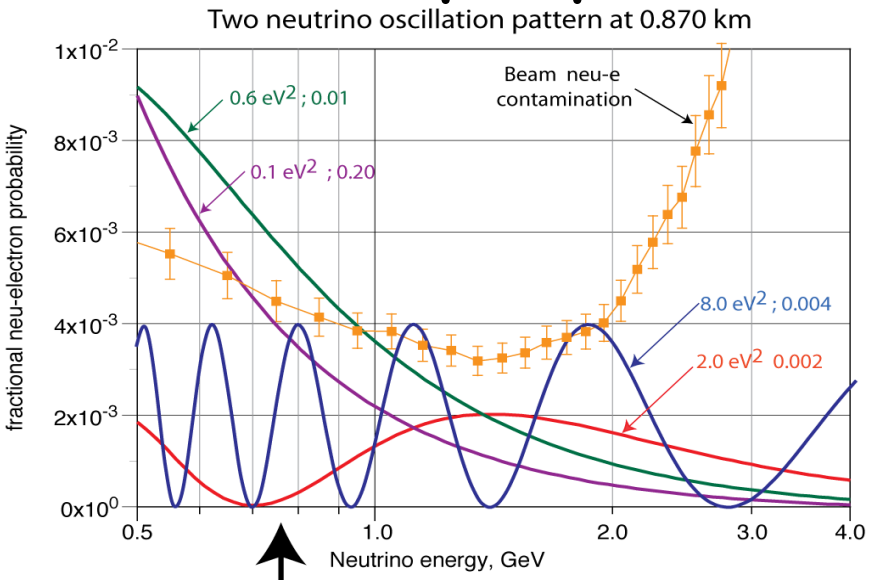
- The present proposal is a search for spectral differences of electron like specific signatures in *two identical detectors* but at two different neutrino decay distances.
- *In absence of oscillations*, apart some beam related small spatial corrections, the two spectra are a precise copy of each other, independently of the specific experimental event signatures and without any Monte Carlo comparison.

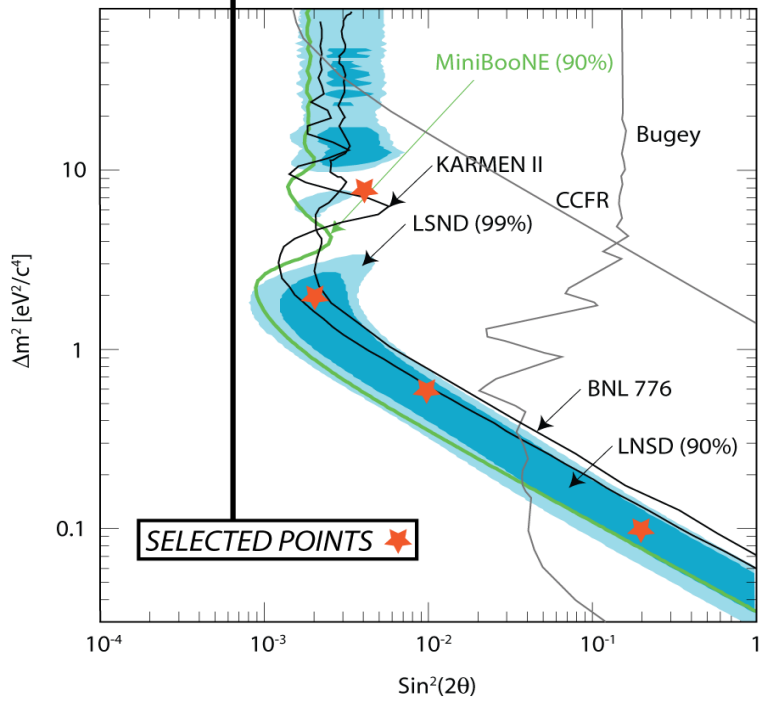


- Therefore an exact, observed proportionality between the two νe spectra implies directly the absence of neutrino oscillations over the measured interval of L/E.

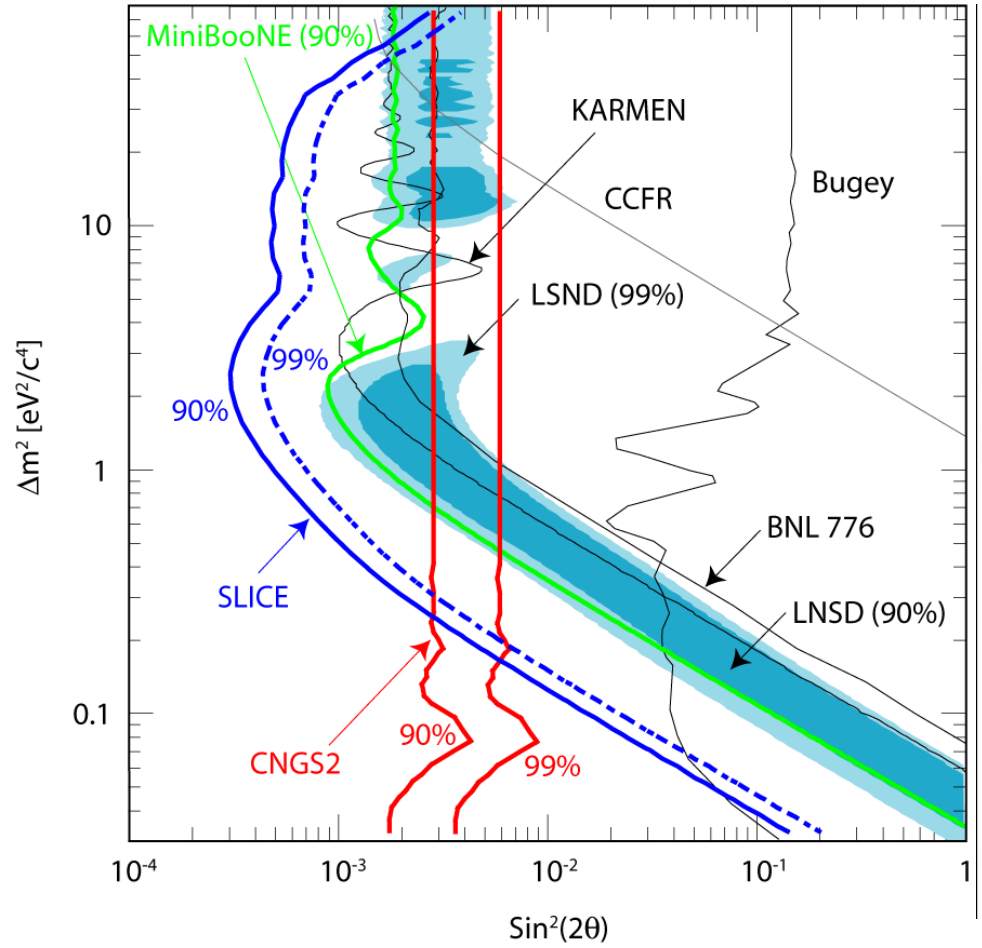
New features of the CERN proposal

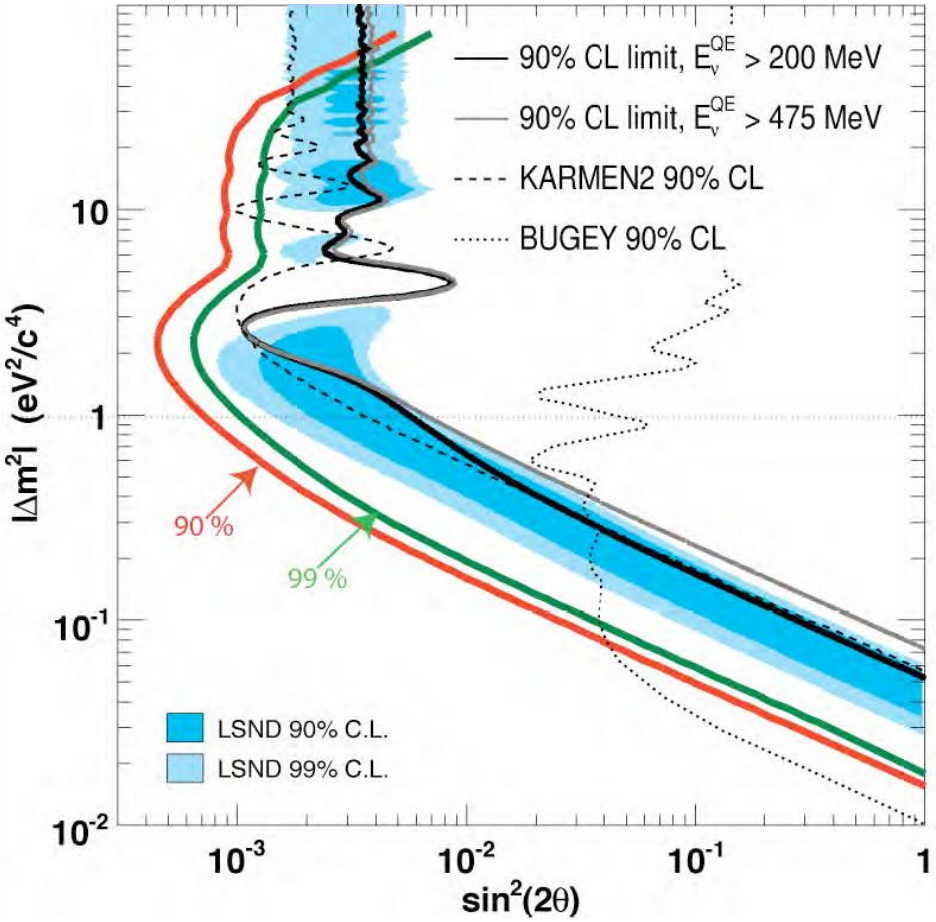
- It appears that the present proposal, unlike LNSD and MiniBooNE, can determine both the mass difference and the value of the mixing angle.
- Different patterns are possible depending on the values in the (Δm^2 – $\sin^2 2\theta$) plane.
- The magnitude of the LNSD expected oscillatory behaviour, for the moment completely unknown, would be well above the backgrounds, also considering the very high statistical impact and the high resolution of the experimental measurement.





Comparing sensitivities





Expected sensitivity for the proposed experiment exposed at the CERN-PS neutrino beam (left) and anti-neutrino (right) for 2.5 10^{20} pot. The LSND allowed region is fully explored. In the neutrino case, the expectations from CNGS2/ICARUS T600 at LNGS are also shown.

- A definitive determination of the sterile neutrino anomaly puzzle is at reach with a twin Lar-TPC exposed at the CERN-PS.
- The ICARUS-T600 detector could be available in 3 years from now: it fits perfectly as the Far Detector in the BEBC Hall.
- The effort could be concentrated on the construction of the near detector, which could be the play-ground for additional R&D toward larger masses.

⇨ **Open to a wide collaboration**

end