

DoubleLAr

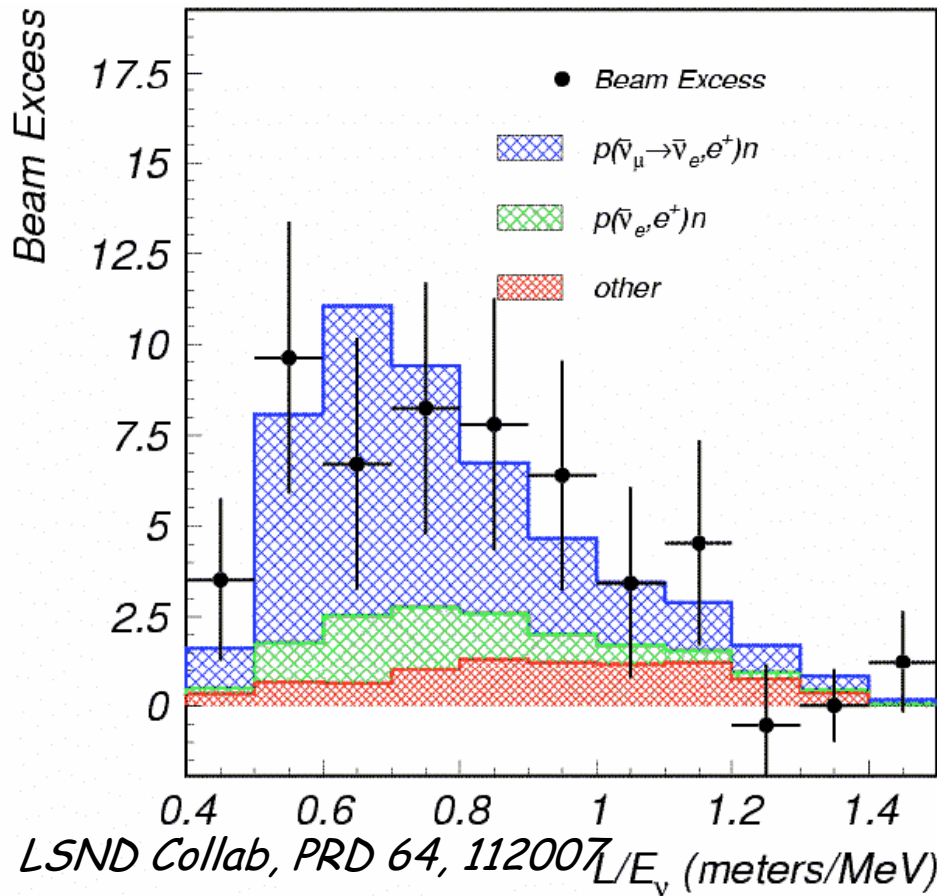
Sterile Neutrinos with the CERN PS

E. Calligarich, S. Centro, A. Guglielmi, D. Gibin, F. Pietropaolo, C. Rubbia and P. Sala

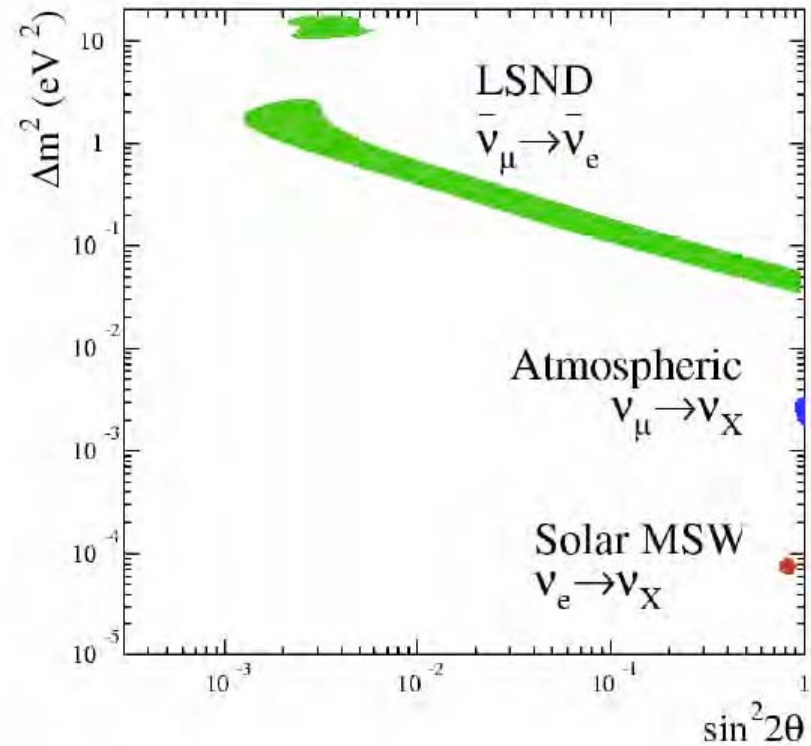
INFN Pavia, University and INFN Padova, CERN,
INFN LNGS, INFN Milano

LSND results : anti- ν oscillations ?

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



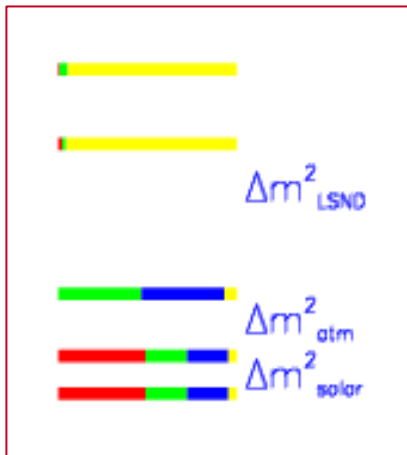
$$P_{osc} = \sin^2 2\theta \sin^2(1.27 \Delta m^2 L/E)$$



■ 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
Quantum Decoherence
Lorentz Violation***

Barger, Marfatia, & Whisnant (PLB576(2003)303)

***Extra Dimensions
Sterile Neutrino Decay***

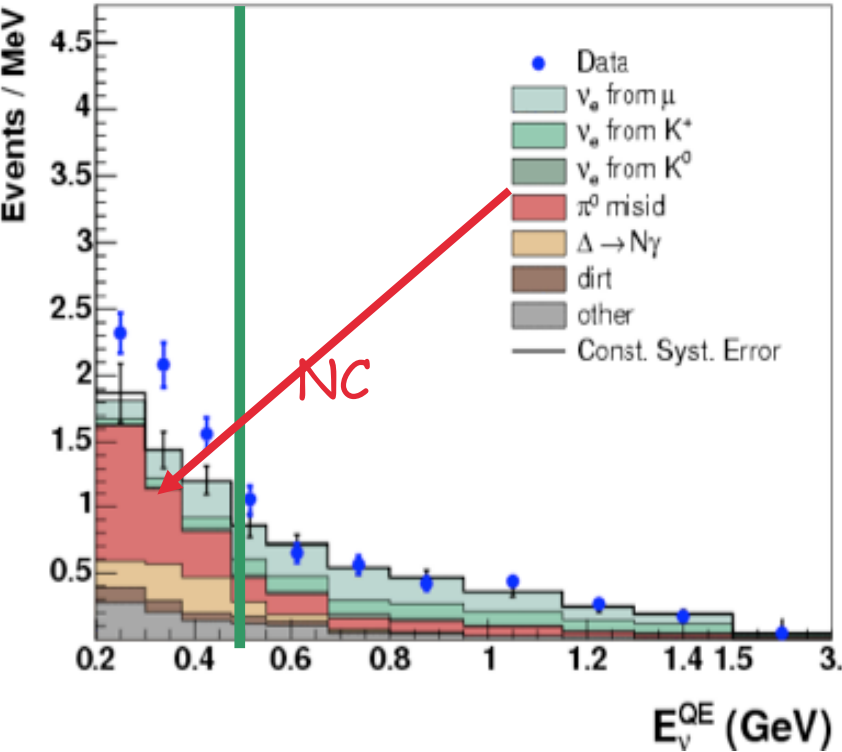
Barenboim & Mavromatos (PRD70(2004)093015)
Kostelecky & Mewes (PRD70(2004)076002)
Katori, Kostelecky, Tayloe (hep-ph/0606154)
Pas, Pakvasa, & Weiler (PRD72(2005)095017)
Palomares-Ruiz, Pascoli, & Schwetz (JHEP509(2005)48)

And so on....

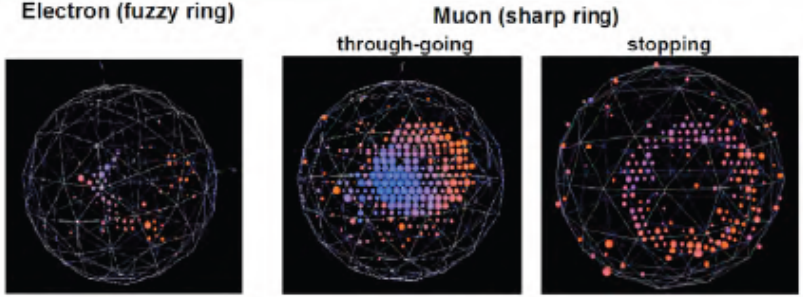
MiniBoone

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

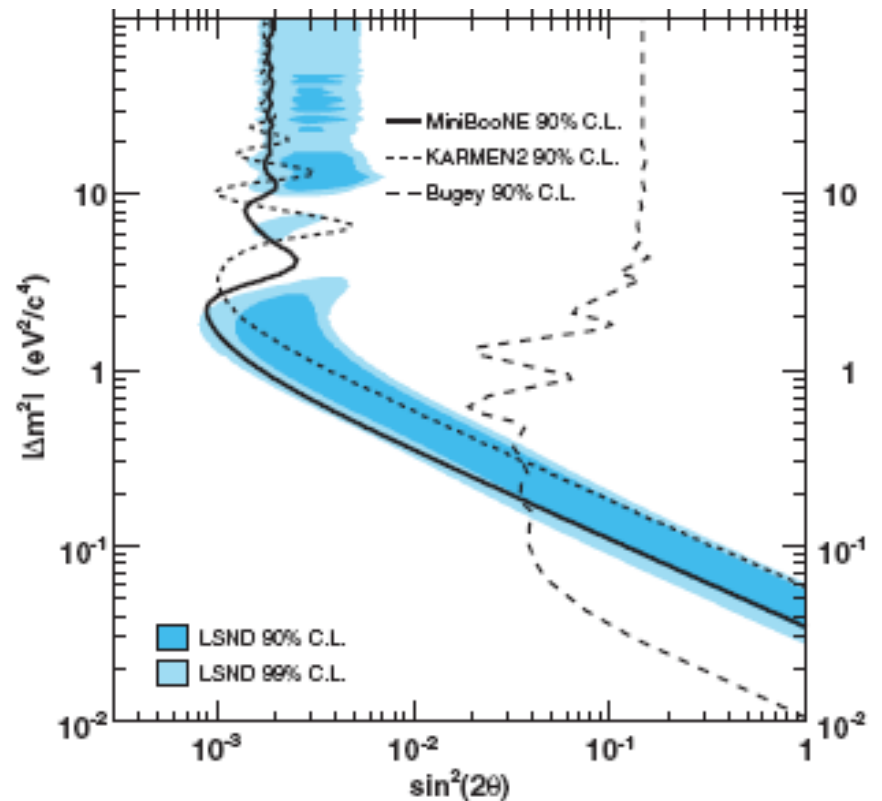
ν mode $6.6e20$ POT 450t fiducial

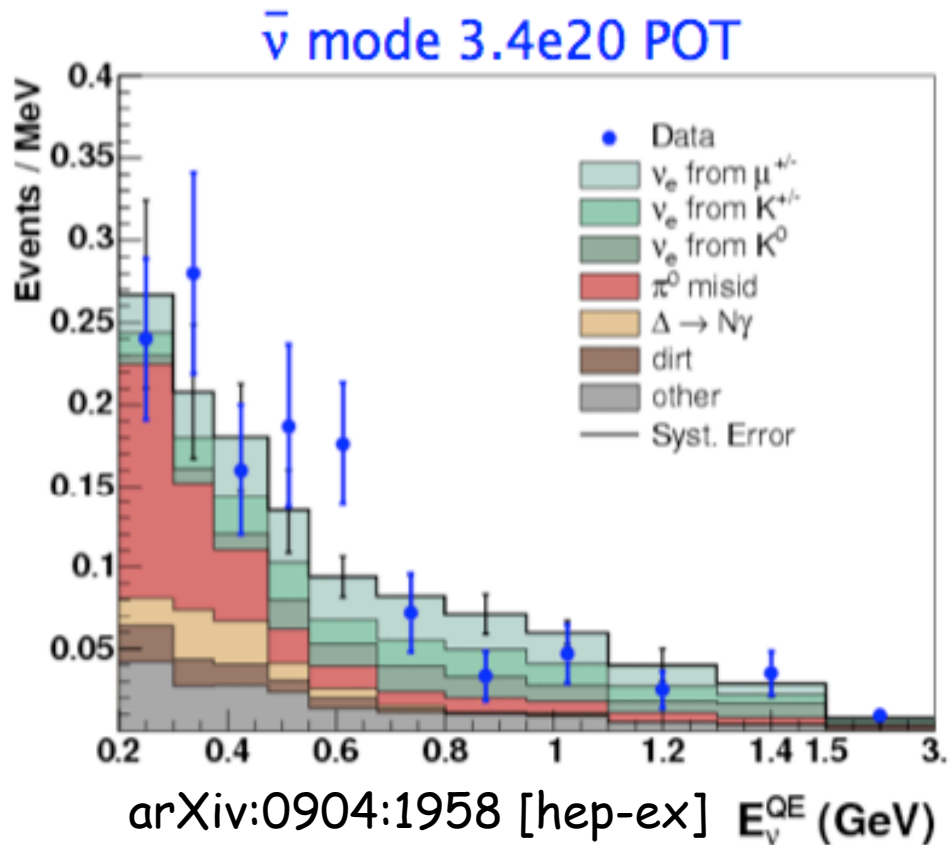


$E < 475$ MeV: low energy
excess persists
(3σ 200-475 MeV)
expected: 415.2 ± 43.4
excess : $128.8 \pm 20.4 \pm 38.3$



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



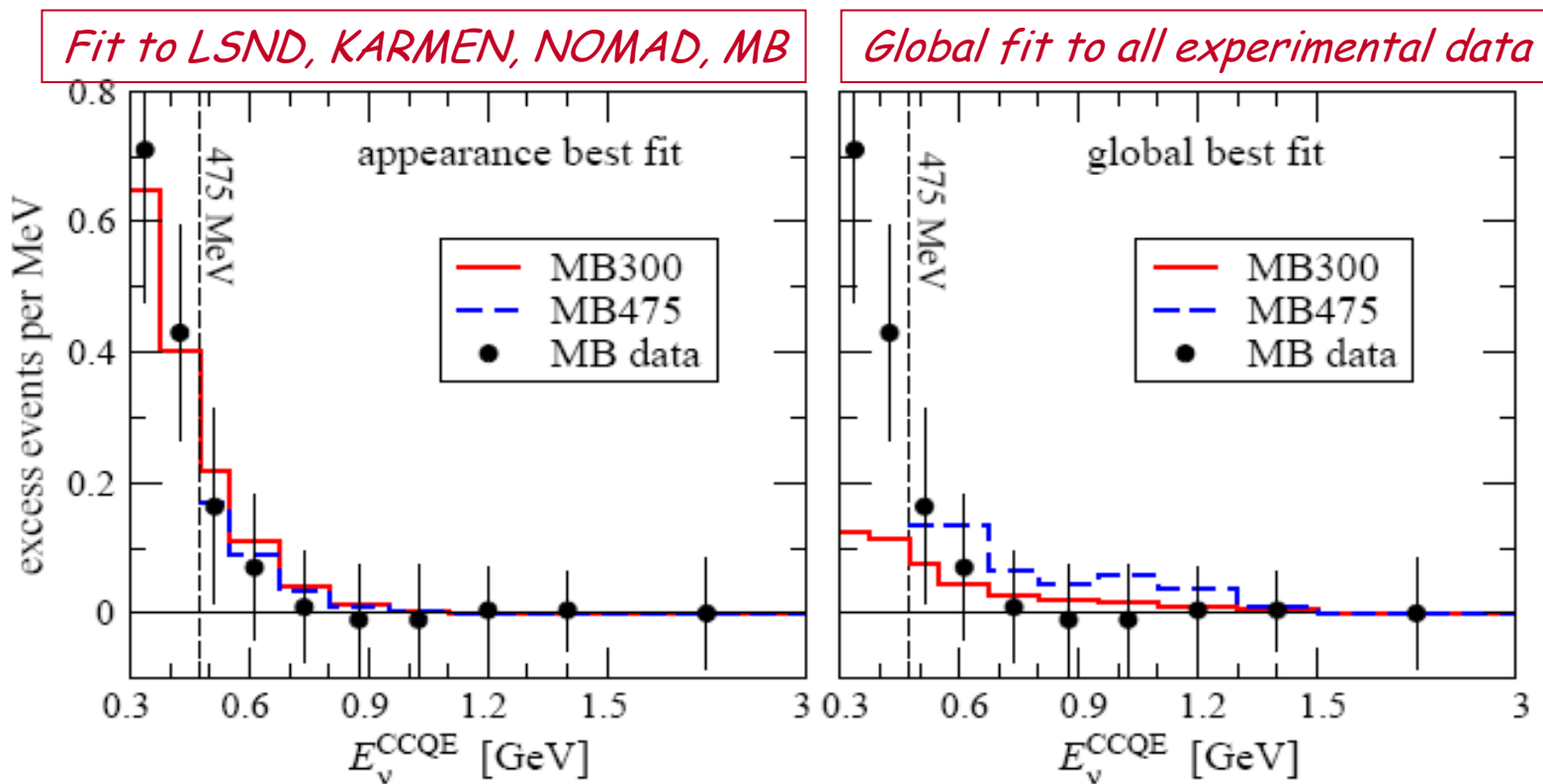


Anti-neutrino run:
 only $3.4 \cdot 10^{20}$ pot
 no low energy excess
 no statement on LSND yet

LSND is still alive and well.

A model with 5 neutrinos?

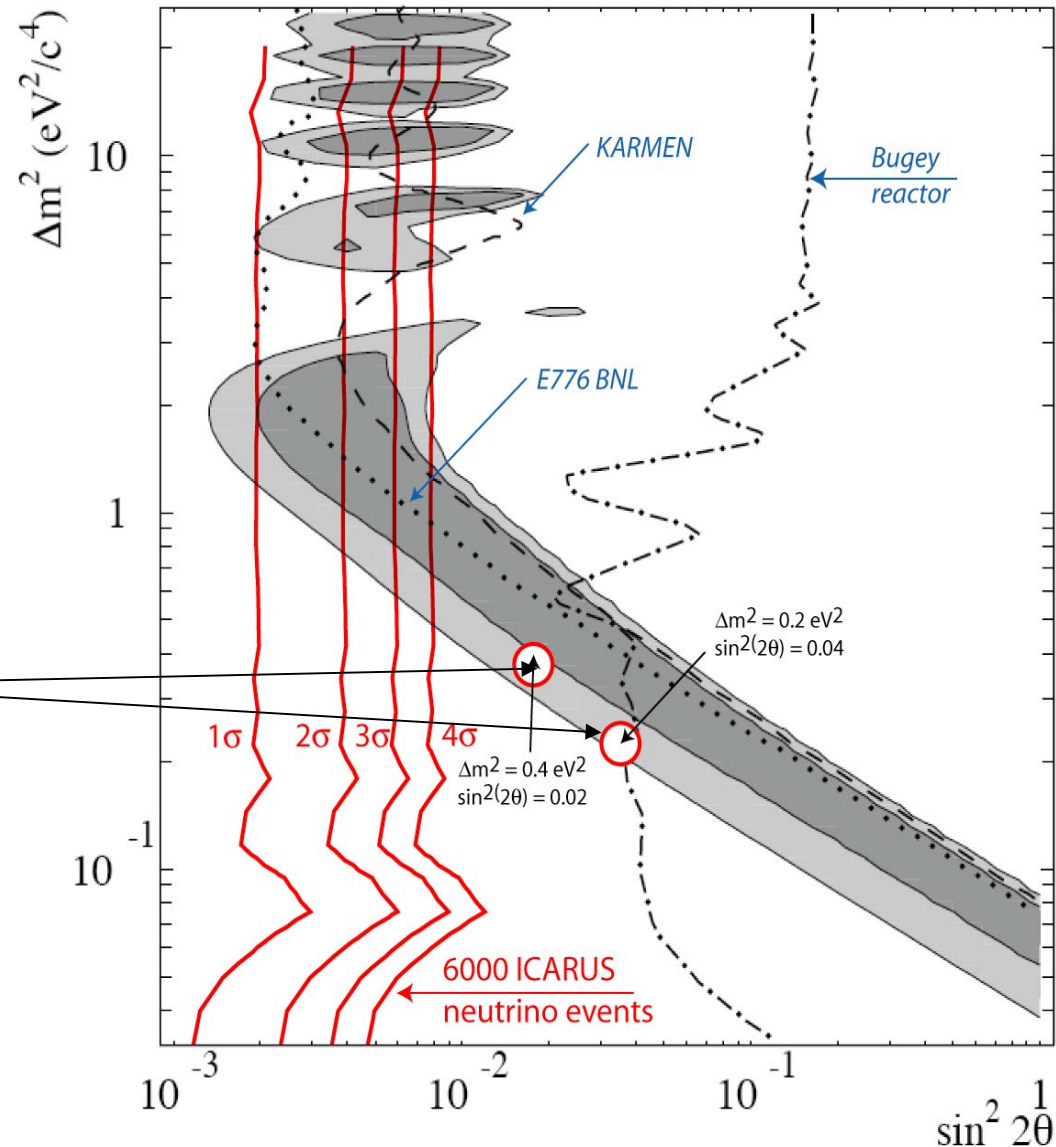
- ❖ In models with more than one sterile ν (see i.e. Maltoni and Schwetz, Phys. Rev. D 76, 093005 (2007)) MiniBooNE results are in perfect agreement with the LSND appearance evidence.
- ❖ However, if all other disappearance data are taken into account (3+2) oscillations are no longer in full agreement.



MB still takes data, other experiments are coming

ICARUS T600 at CNGS

- Sensitivity region for 6000 raw CNGS neutrino events. The potential signal is above the background generated by the intrinsic ν_e beam contamination, in the deep inelastic interval **10-30 GeV**.
- The Δm^2 distribution extends widely beyond the LNSD and MiniBoone regions.
- Two indicated points are reference values of MiniBoone proposal
- Smaller $\sin^2(2\theta)$ are not explored.
- **An additional LAr experiment at PS is proposed for ν and $\bar{\nu}$**

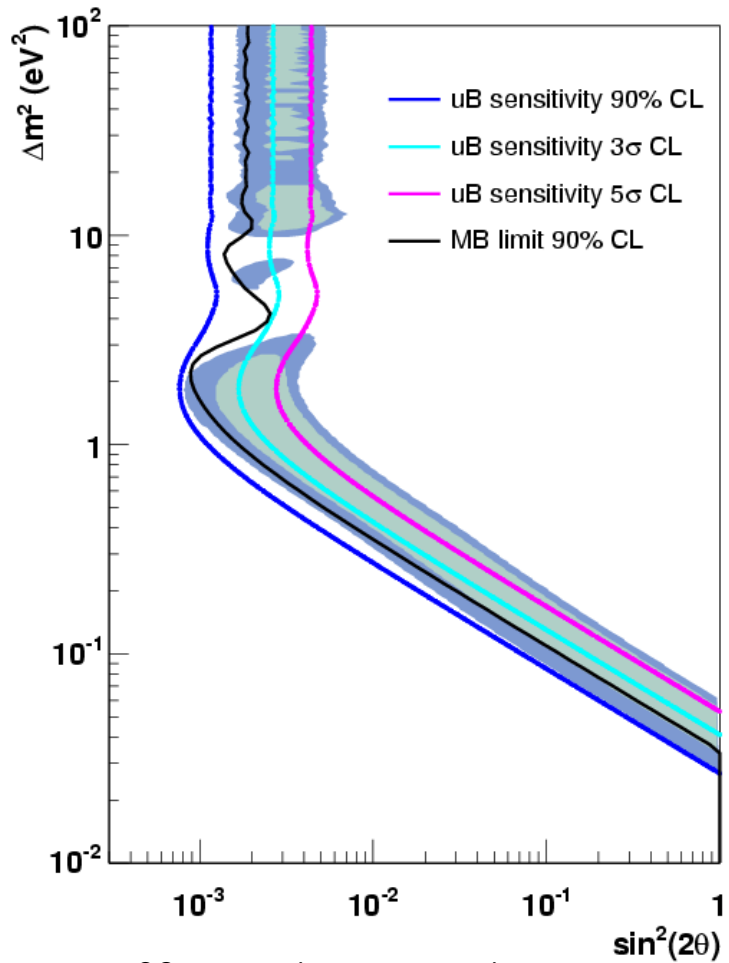


Proposal: MicroBooNE

● The LNSD search is continuing at FNAL:

- MicroBooNE is a new LArTPC detector to be placed on the Booster ν beam
- designed to advance LAr R&D in the US in collaboration with ICARUS and
- to determine whether the **MiniBooNE low-energy excess** is due to electrons or photons.
- A **70-ton** fiducial volume detector, located near MiniBooNE.
- Might start data-taking in **2012**

Are 70 tons without near detector enough?

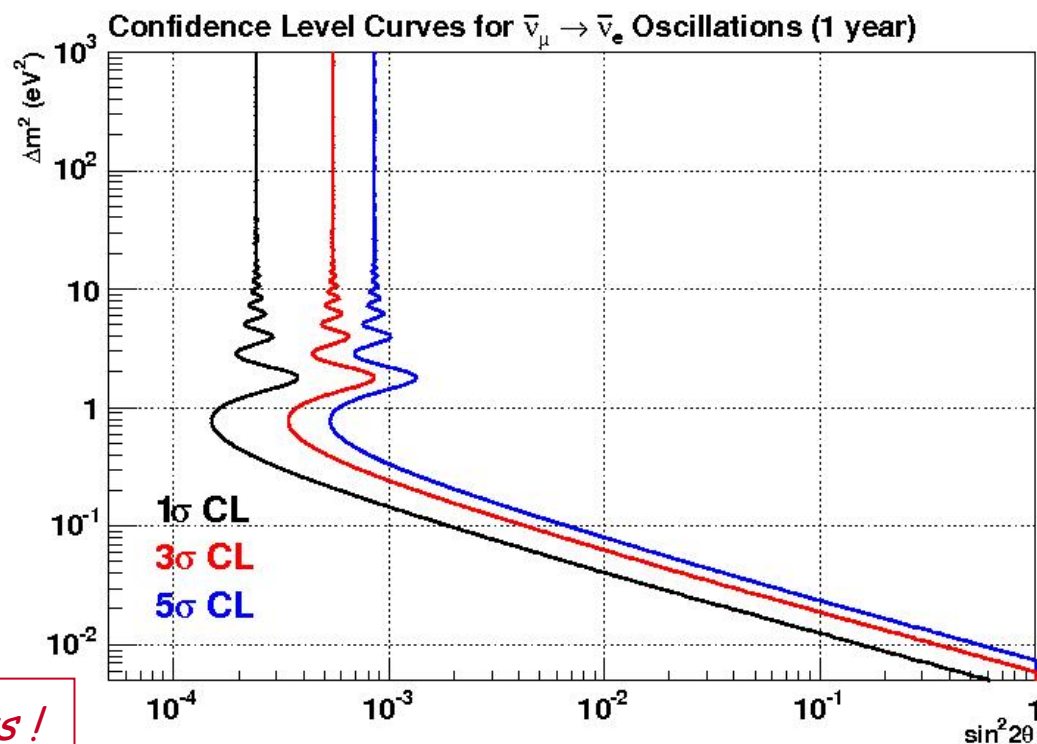


MicroBooNE sensitivity, 6 10²⁰ pot (3 years)

Proposal: OscSNS at ORNL

- A new experiment with pions at rest, similar to LSND but with a higher intensity spallation source (1.4 MW) planned at SNS
- A "MiniBooNE-like" detector (800 t) with higher PMT coverage at a distance of ~ 60 m from the SNS beam stop at ORNL.

Appearance Search, 1 y exposure		
Channel	Backg	Signal
$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$	79 ± 24	253 ± 3
$\nu_\mu \rightarrow \nu_e$	16 ± 0.22	6 ± 0.3



LSND result was based on 87.9 events!

DoubleLAr

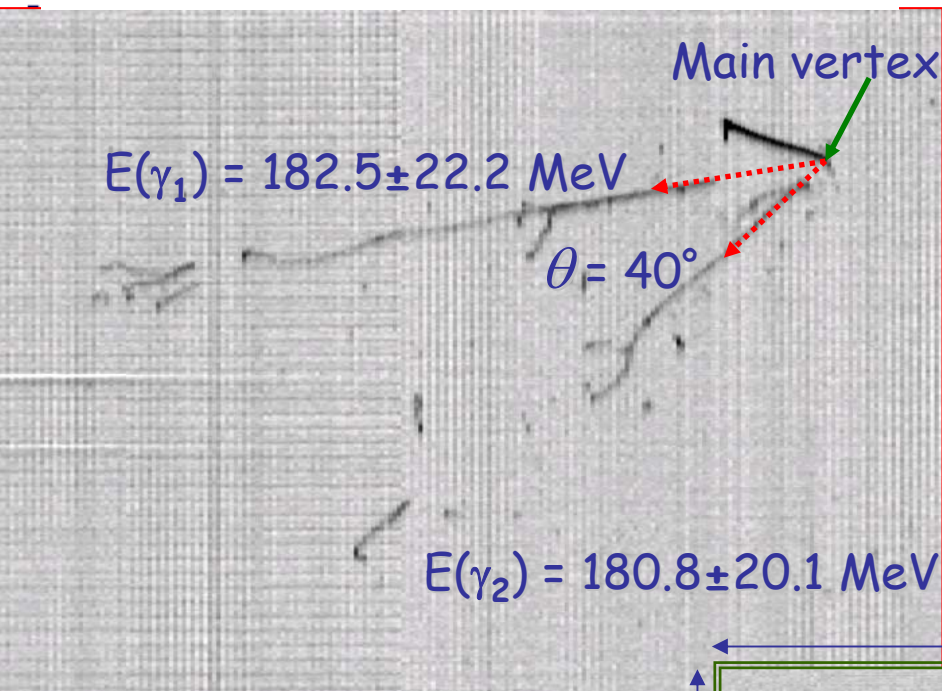
A definitive determination of
the sterile neutrino anomaly puzzle
with LAr at the CERN-PS ?

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

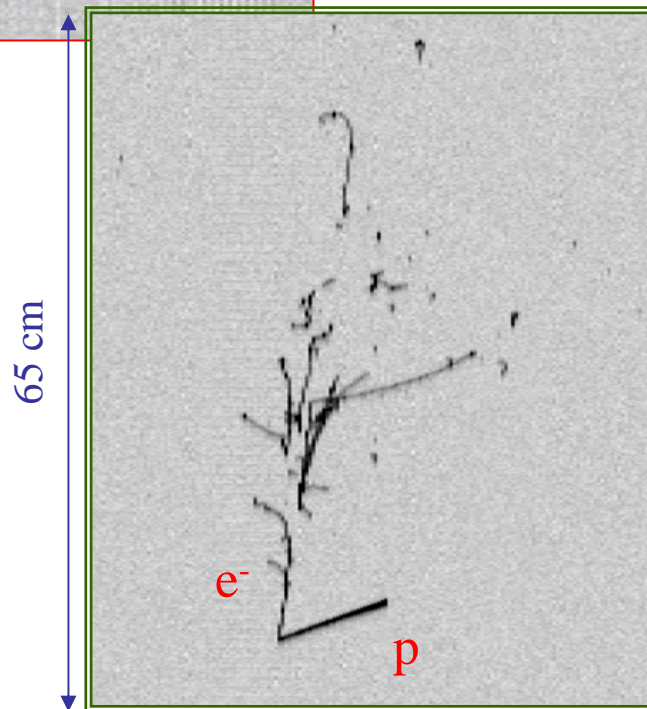
A starting project, **open to collaboration**,
first contacts in italy showed interest from
INFN/ Univ. Padova, Pavia, Genova, Milano, Milano-2, LNGS, CERN

π^0 in T300 (Pavia 2001 data)

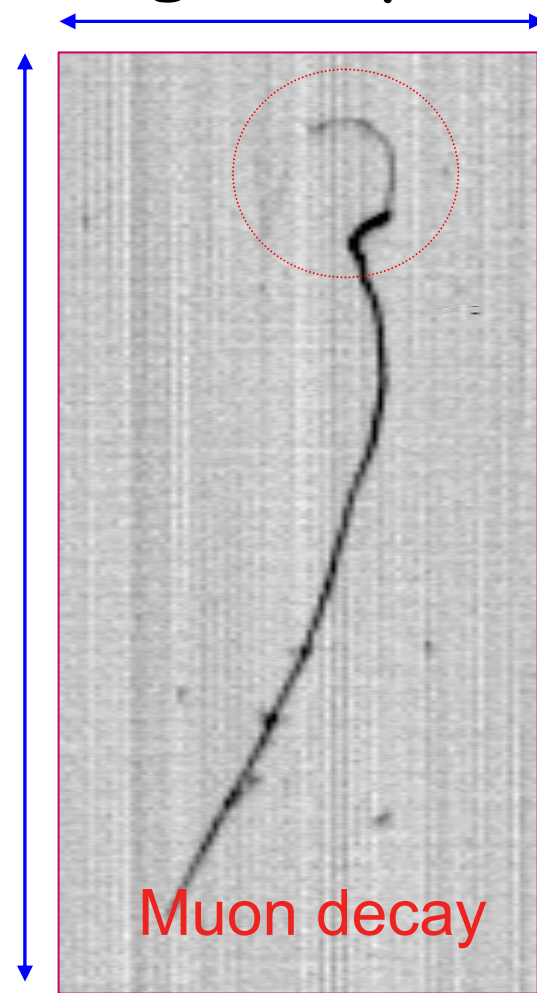


LAr event gallery

ν_e QE CC simulated event



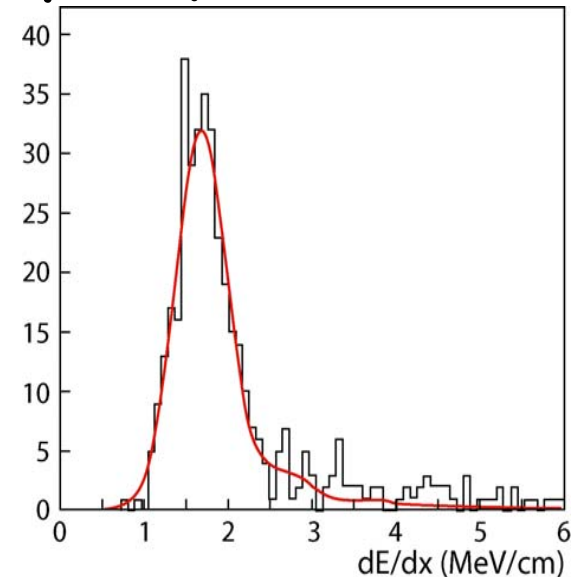
50 cm



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



RESOLUTIONS

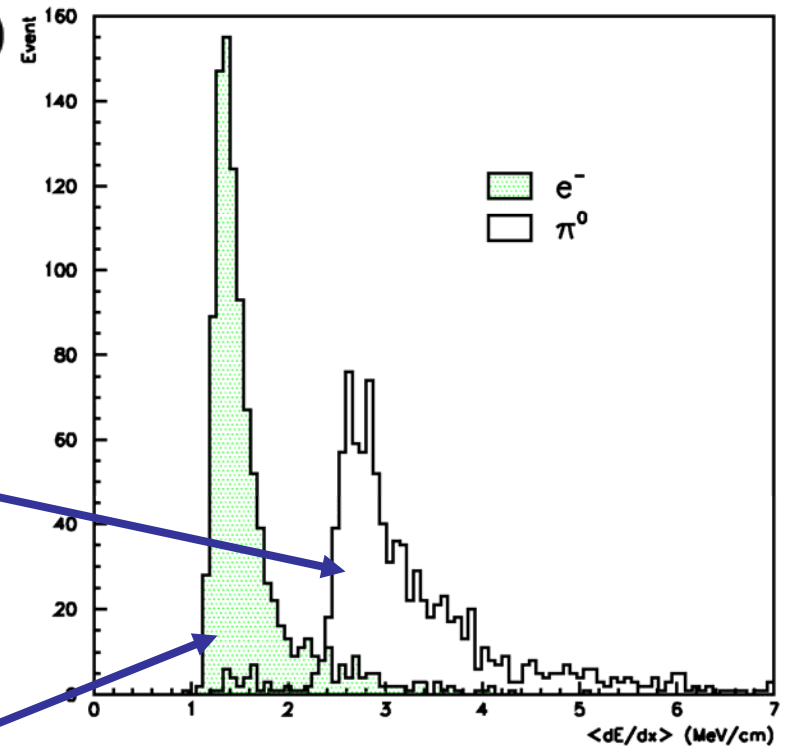
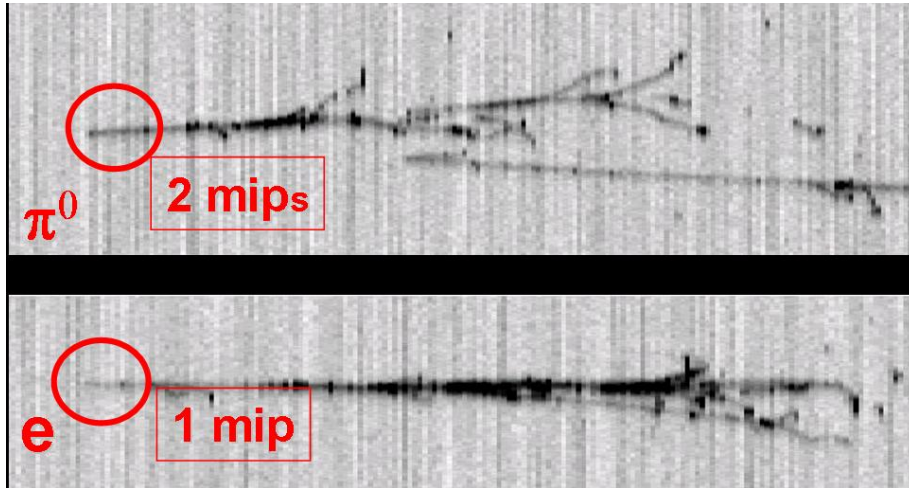
Low energy electrons: $\sigma(E)/E = 11\% / \sqrt{E(\text{MeV})} + 2\%$

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

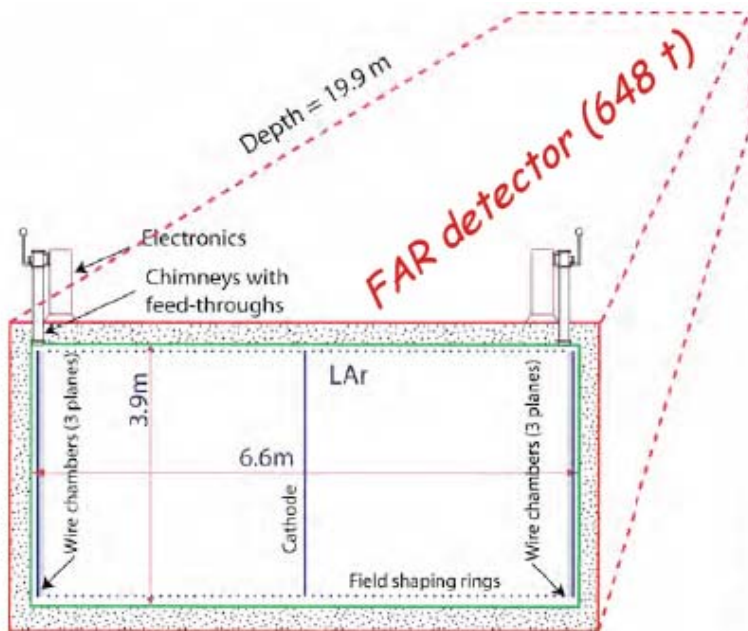
Hadron shower (pure LAr): $\sigma(E)/E \approx 30\% / \sqrt{E(\text{GeV})}$

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%



The DoubleLAr detectors

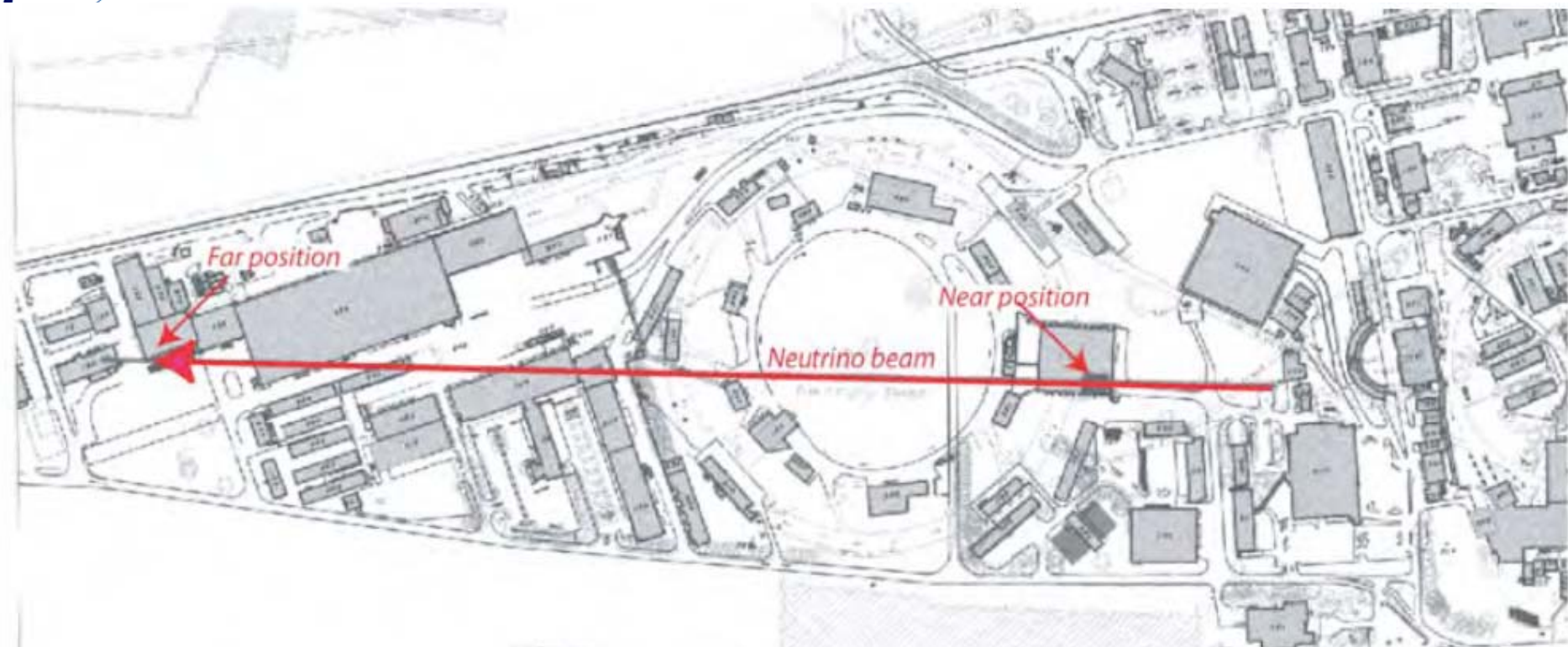


Re-use the ICARUS experience

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

- Wire chambers with 3 readout planes, 6mm pitch
- Maximum drift length < 4 m
- Far detector: 500 tons sensitive
- Near detector: same technology, 10 ton fiducial

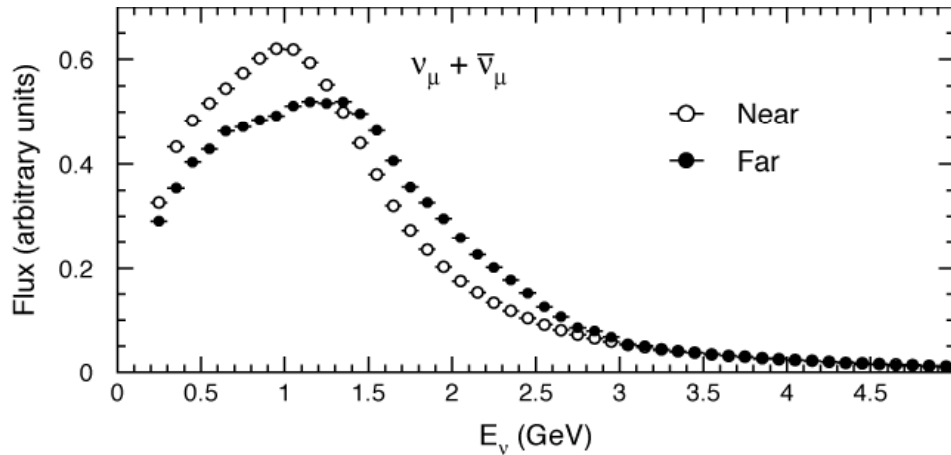
The PS neutrino beam



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

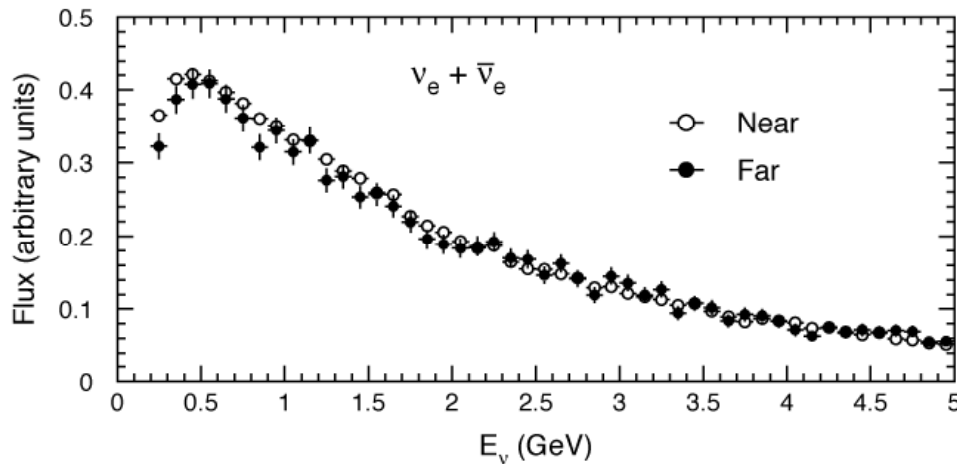
Two positions are foreseen for the detection of the neutrinos
The **far** (main) location at 850 m from the target;
The **near** location at a distance of 127 m from the target.

Neutrino beam



Expected neutrino spectra at the near and far locations

Starting point:
the 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

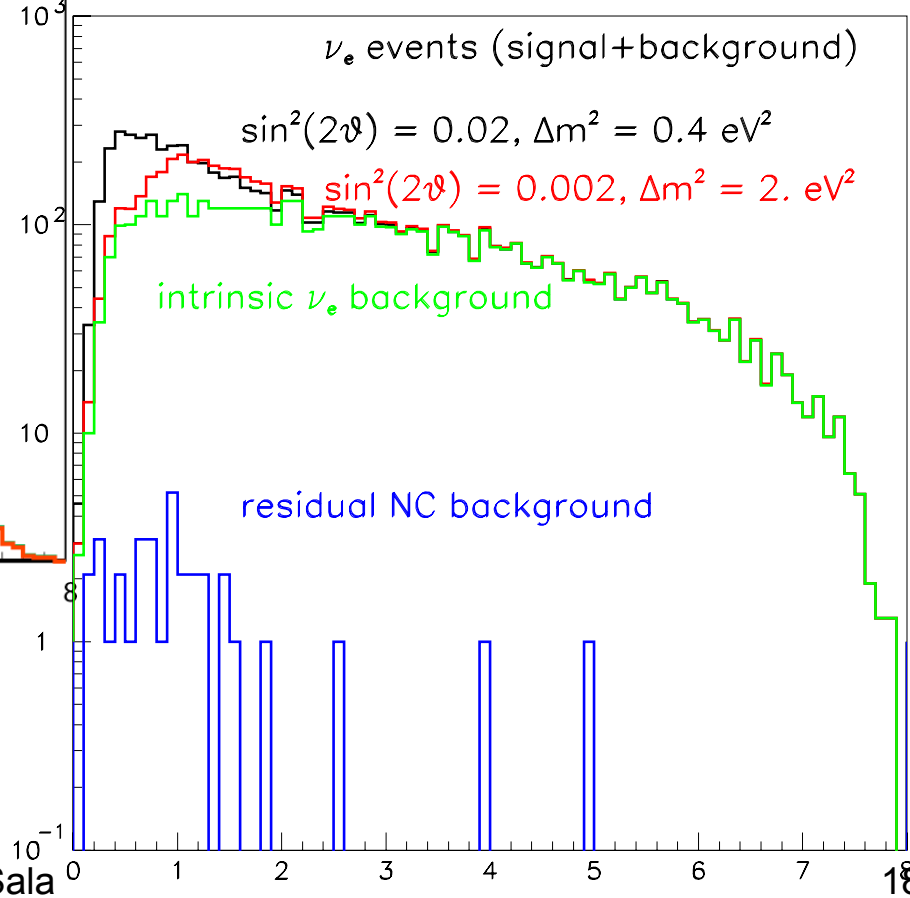
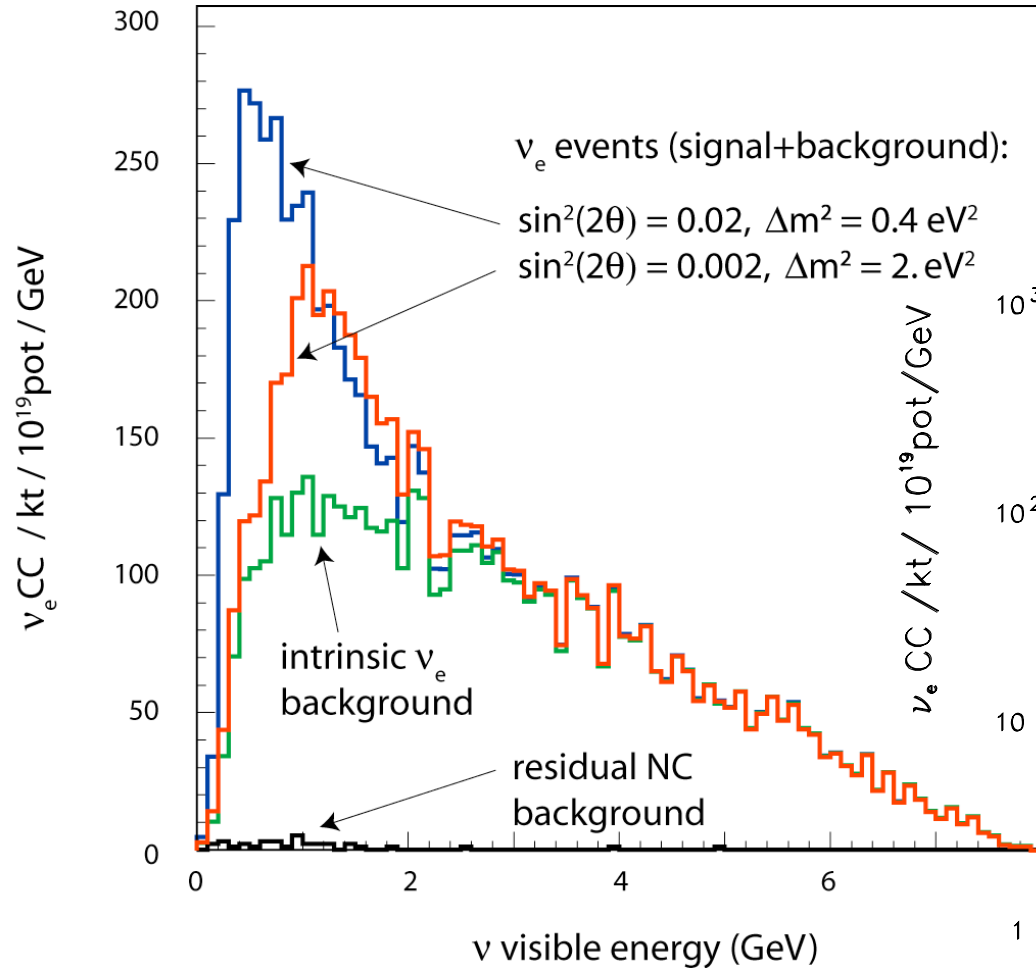
Assuming 2 years run for a total of $2.5 \cdot 10^{20}$ pot

	FAR	NEAR
Integrated protons on target	$2.5 \cdot 10^{20}$	
Fiducial mass	500 t	10 t
Distance from target, m	850	127
ν_μ interactions	1.2×10^6	1.2×10^6
QE ν_μ interactions	4.5×10^5	4.4×10^5
Events/burst	0.17	0.17
Intrinsic ν_e from beam	9000	8000
Intrinsic ν_e from beam ($E_\nu < 3$ GeV)	3900	3600
ν_e oscillations: $\Delta m^2 = 2. \text{ eV}^2$; $\sin^2 2\theta = 0.002$	1194	70
ν_e oscillations: $\Delta m^2 = 0.4 \text{ eV}^2$; $\sin^2 2\theta = 0.02$	2083	156

	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

Expected spectra

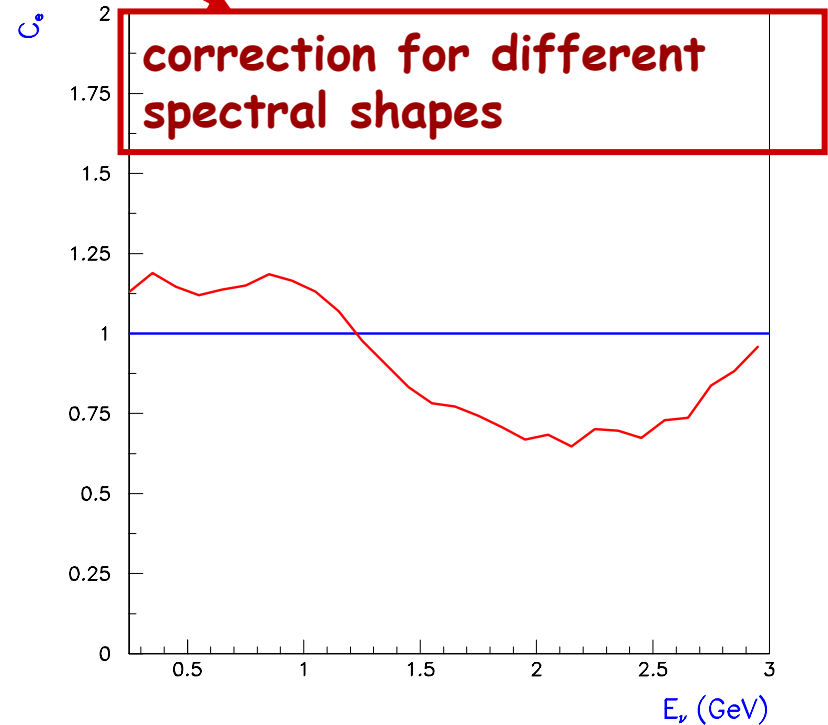
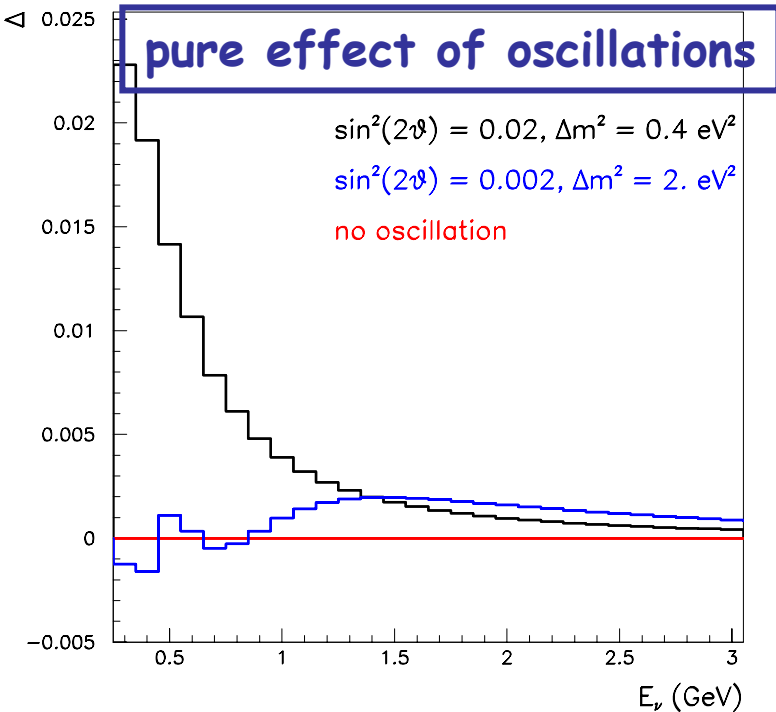
Visible energy
in the FAR detector
of DoubleLAR
 ν_e -like events
full simulation



log scale →

Far-Near analysis

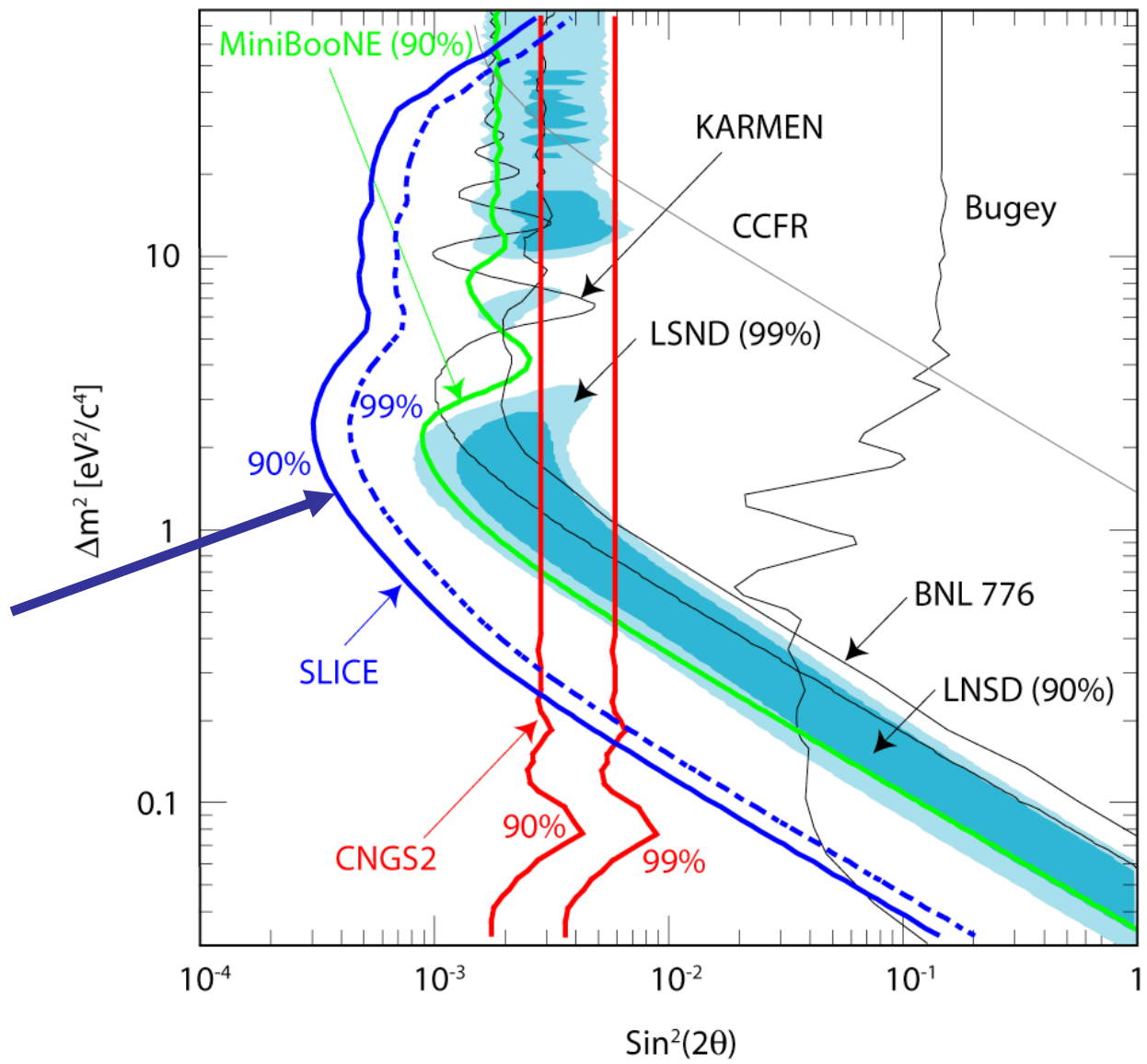
$$\Delta_e = \left(\frac{N_e}{N_\mu} \right)^{far} - C_e \left(\frac{N_e}{N_\mu} \right)^{near}$$



In absence of neutrino oscillations, after C_e correction, ratios cancel, $\Delta_e=0$
 No neutrino and/or nuclear cross sections and no detector related effects.

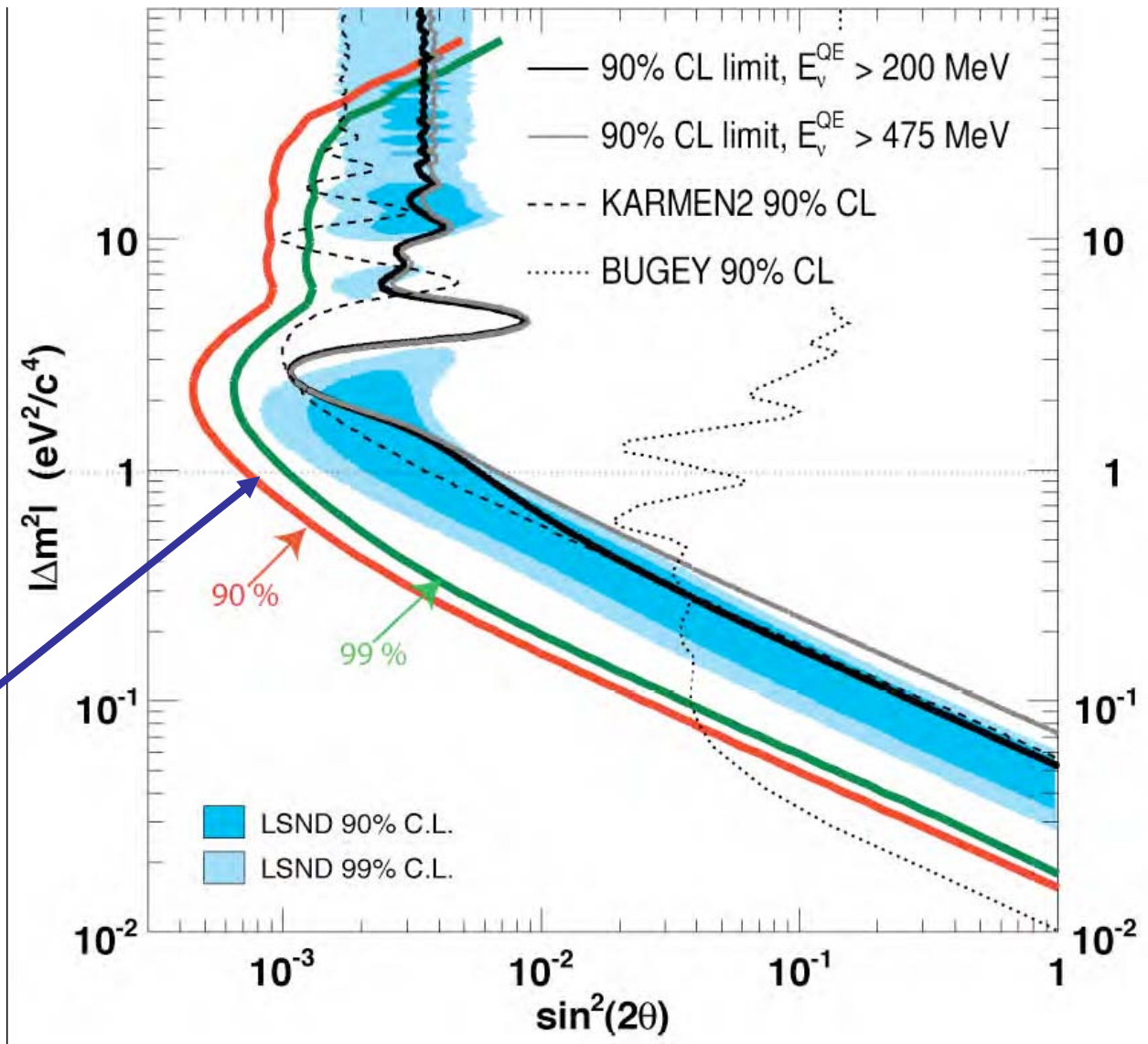
Expected sensitivity

DoubleLAr,
2 years
neutrino run
 $2.5 \cdot 10^{20}$ pot



Expected sensitivity

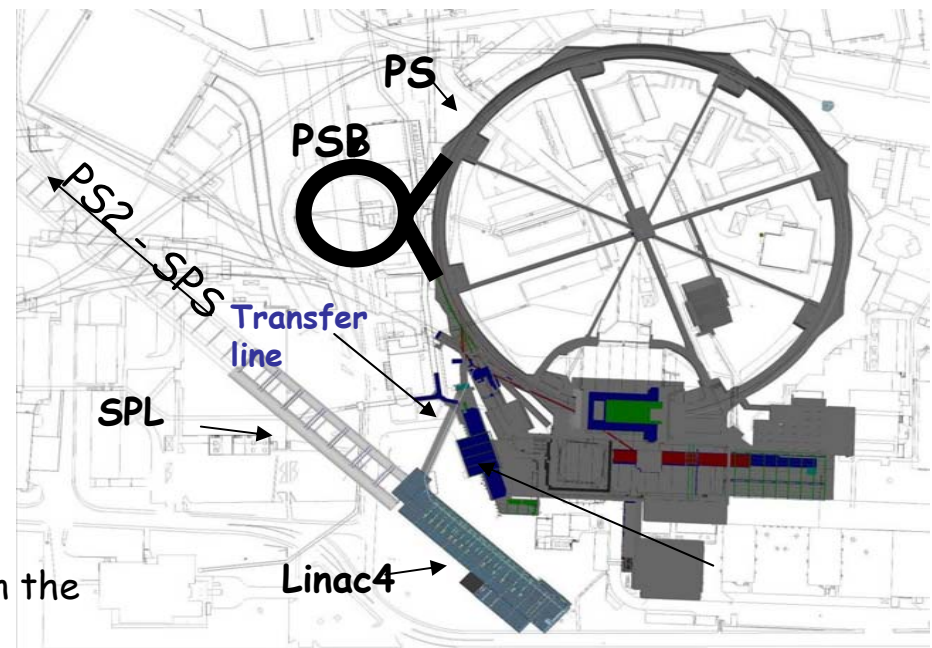
DoubleLAr,
2 years
anti-neutrino run
 $2.5 \cdot 10^{20}$ pot



Next Steps

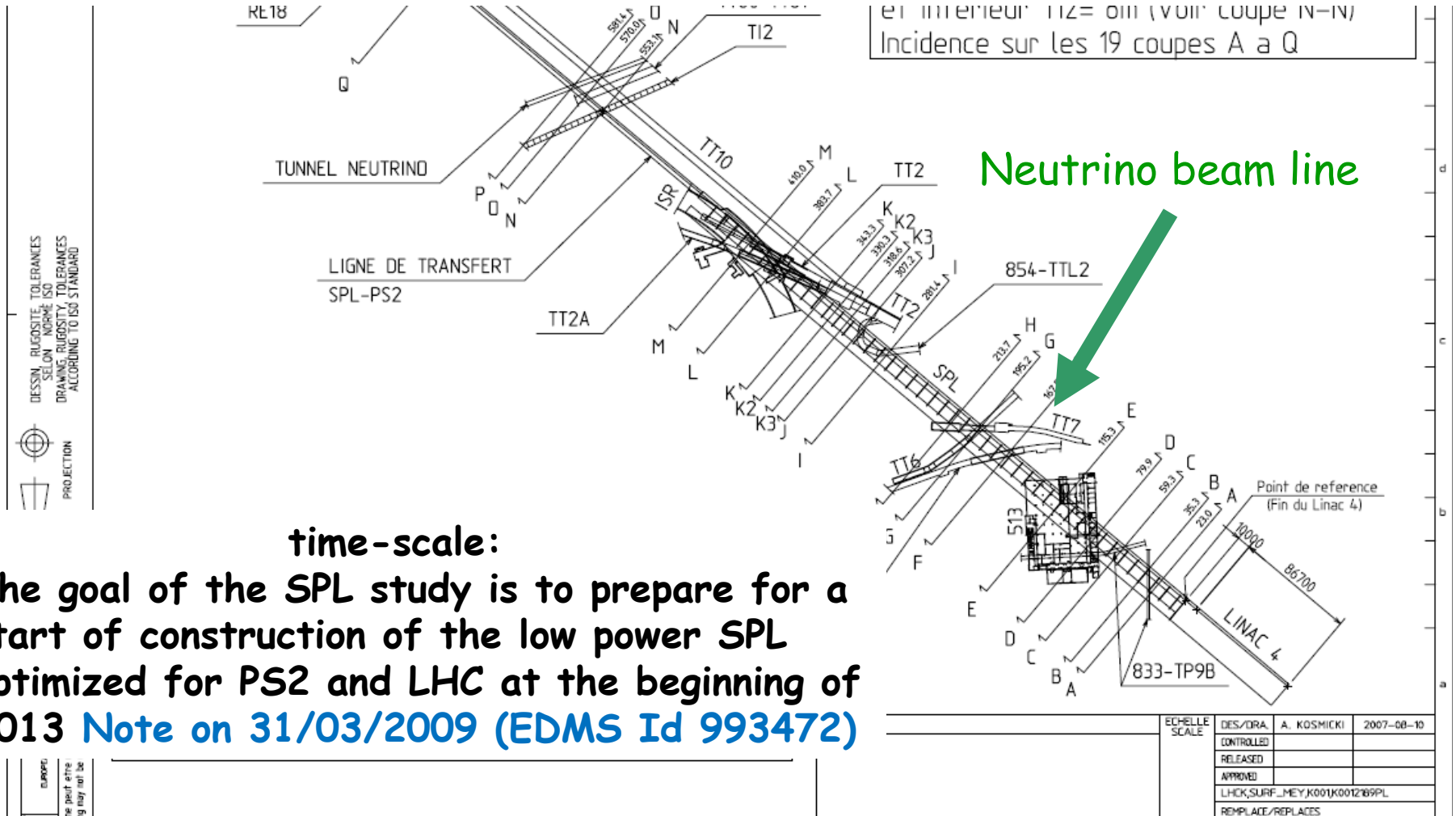
- Target/horn optimization: present work based on old BEBC beam line, possible gain from better technologies/experience (WANF, CNGS)
- Proton line to TT7 : no problem foreseen
- TT7 now used as storage area, solutions needed for removal and relocation of material
- Calculations will be performed to investigate whether there is an interference with the installation of the new SPL accelerator, and in case to devise shielding/coordination solutions

(LP-SPL: Low Power-Superconducting Proton Linac (4 GeV), will be part of the next injection chain at CERN)

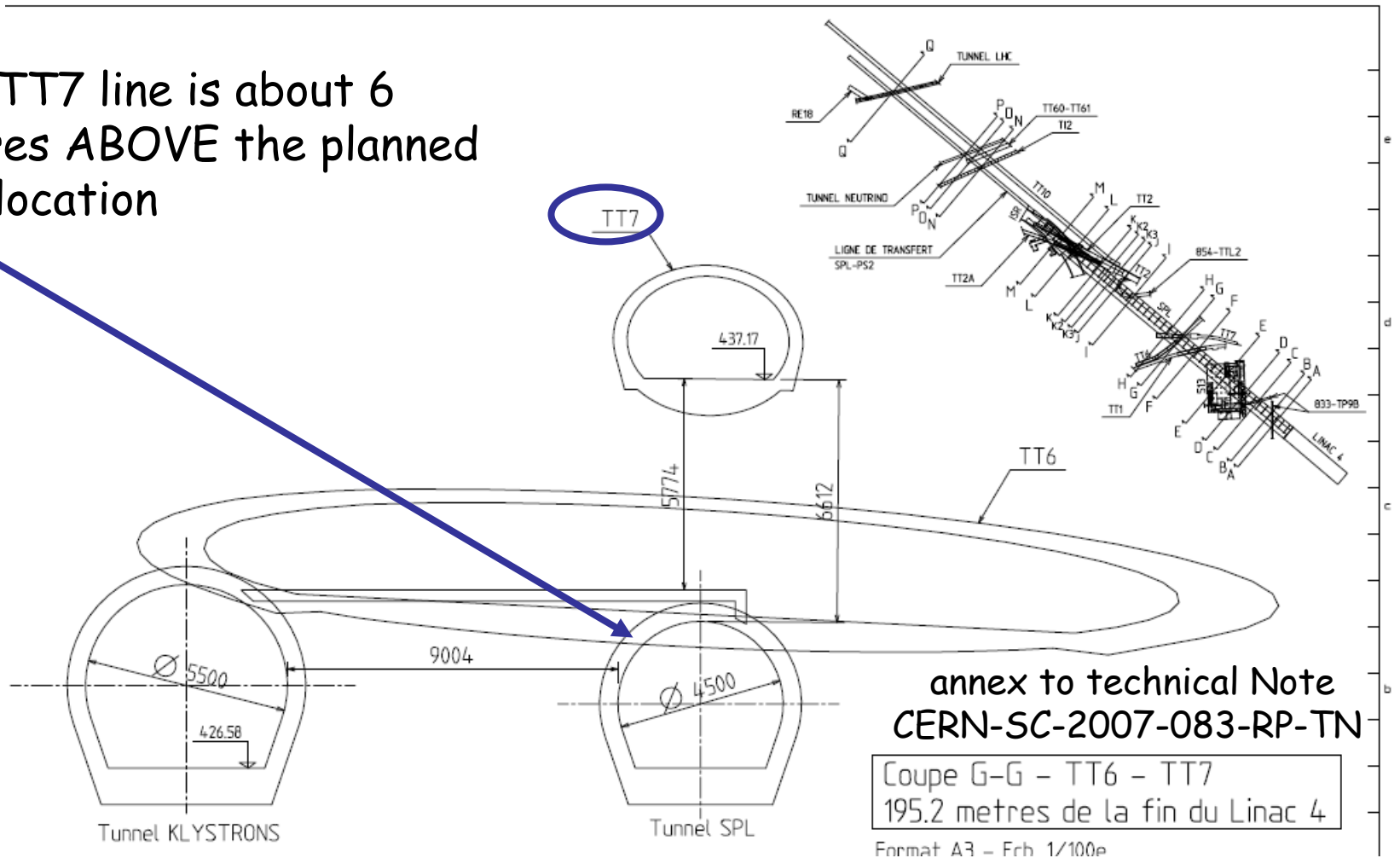


drawing from M.Vretenar , New Opportunities in the Physics Landscape at CERN, 11-13 May 2009

Integration with new CERN accelerators: SPL



The TT7 line is about 6 metres ABOVE the planned SPL location



The remaining issue is radiological: are 6 metres of earth enough to shield the SPL installation site when the neutrino beam is on? Under study. If not, **shielding and/or coordination** are viable solutions

end

DoubleLAr : a search for sterile neutrinos at CERN PS

OUTLINE

- The case is still open: from LSND to MINIBoone
- New proposals
- The DoubleLAR LOI