NOW 2012

Neutrino Oscillation Workshop

Conca Specchiulla (Otranto, Lecce), 9-16 Septemb 2012

Short-baseline oscillations of high-energy neutrinos

(on the "short term" quest of STERILE neutrinos at CERN)

Luca Stanco (INFN-PD)

September 12, 2012

“Tensions” in the Standard Model between Quark and Lepton sectors:

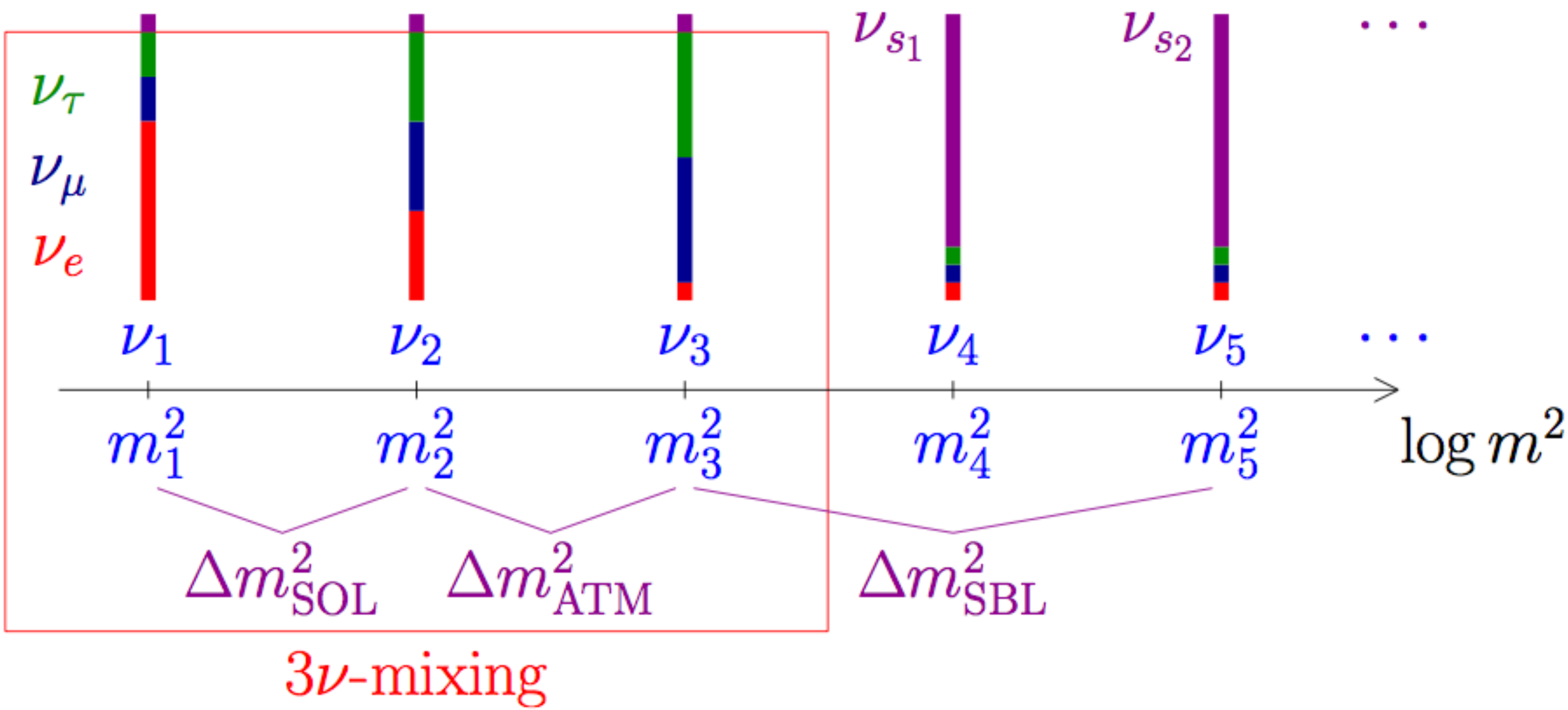
- *No right handed neutrino (in classical SM)*
- *Majorana masses*
- *Very different from quarks: large mixings and tiny masses*
- *Non coherent picture: discrepancies at ≈ 3-4 sigma level, in several measurements*
- *Neutrinos are neutral !*

As Higgs is going to be where expected…

As many open questions stay (e.g. Dark Matter)…

Neutrinos are an excellent place for looking ***Beyond Standard Model***

Beyond Three-Neutrino Mixing



C. Giunti©

Sterile neutrinos

- The possible presence of oscillations into sterile neutrinos was proposed by B. Pontecorvo, *(JETP, 53, 1717, 1967)*, but so far without conclusion.
- "Sterile" means "No Standard Model Interactions"
  (i.e think to anti-ν_R, light neutrinos which can oscillate with "active" neutrinos)
- Smoking Gun: Neutral Current Deficit
- Counterchecked Smoking Gun: NC/CC ratios

- Two distinct classes of anomalies have been analyzed, namely
  - the apparent ***disappearance signal*** in the anti-ν_e events detected from (1) near-by nuclear reactors and (2) the from Mega-Curie k-capture calibration sources in the Gallium experiments to detect solar ν_e
  - observation for ***excess signals*** of anti-ν_e electrons from neutrinos from particle accelerators (LNSD/MiniBooNE)

- At least a fourth non-standard neutrino state can oscillate at small distances, $\Delta m^2_{new} \approx 1\ eV^2$ (➔ **SHORT BASELINE projects)**

QUESTIONS in the present NEUTRINO Scenario

1) Is it worthwhile to investigate further ?

Sure !

- *θ_{13} measured in the "standard scenario"*
- *Missing MH, CP, Majorana/Fermi, masses*
- *What else ?* *coherent picture*

2) Are there Neutrino ANOMALIES or lack of Precise MEASURES/Computations ?

Almost sure

- *"anomalies" from SBL (LSND, MiniBooNE)*
- *"anomalies" from Reactor fluxes*
- *"anomalies" from Gallium*

3) Do we need/want to optimize the World/European searches ?

Critical

- *Where ? and When ? and How ? and What ?*

What is going on ?

1) Standard Scenario

– *θ_{13} is "very large" compared to previous studies*

- *Optimizations on the Facilities not done yet*

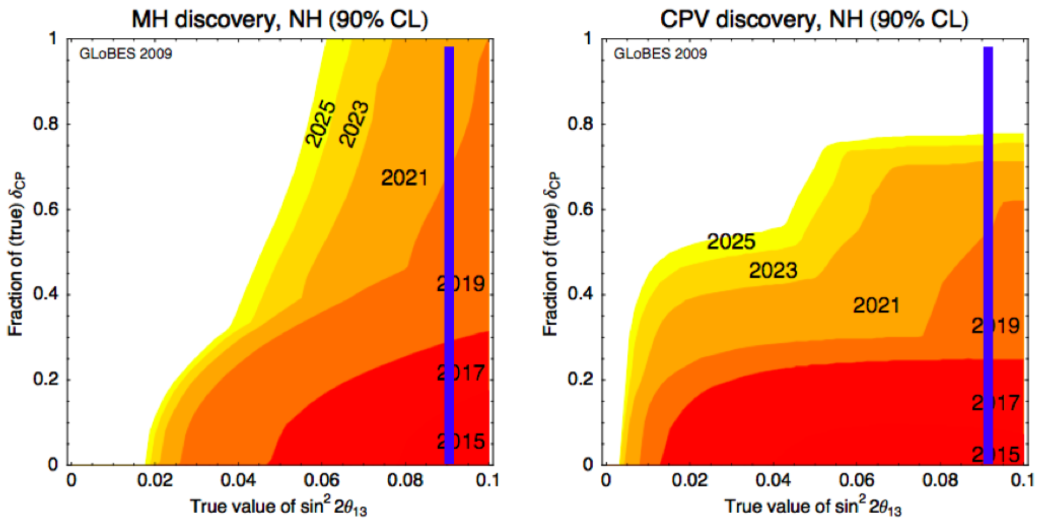
  (even if Phenomenologists result much powerful than Experimentalists believe, Experimentalists are much clever than Phenomenologists believe)

- *"Brute force" (i.e. Mass or Power) is challenging*

MH from T2K+NOνA+PINGU+INO+Reactors+...+fit ?

OLD study

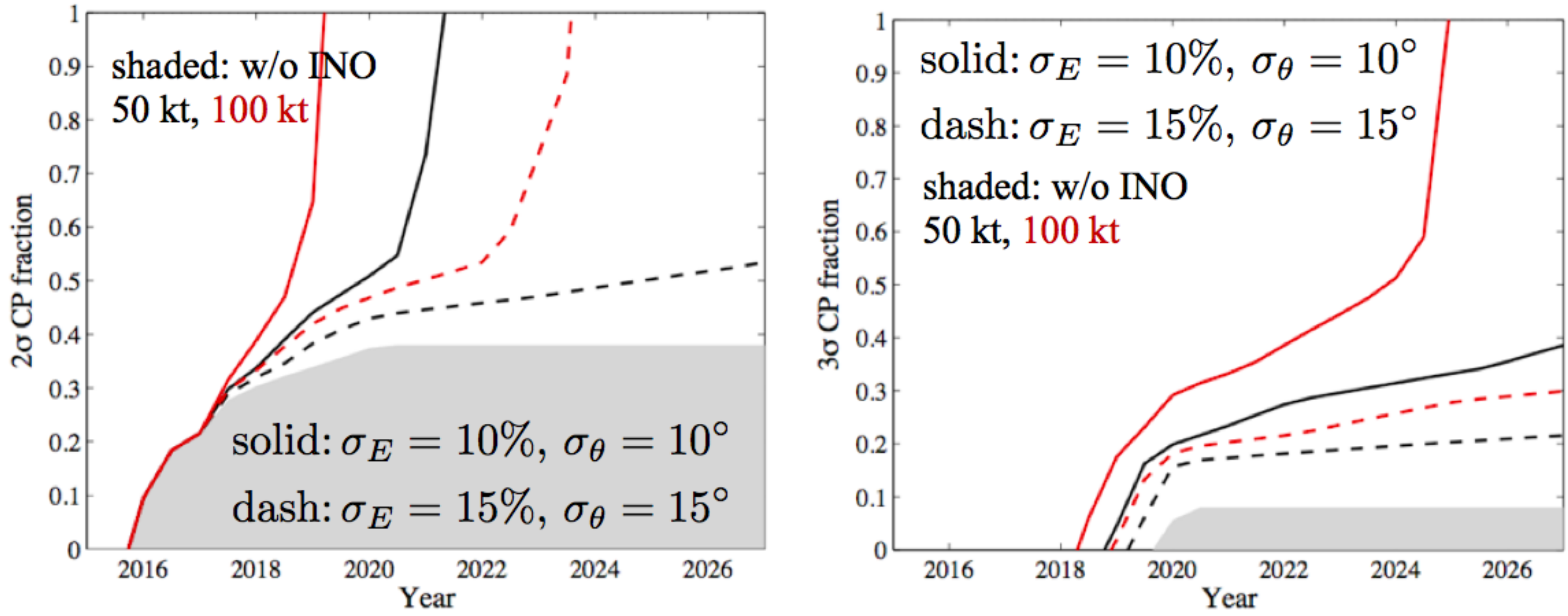
Huber, Lindner, TS, Winter, 0907.1896



What is going on ?

It might be that we have only a 6 years window to wait

100 % !!!



Blennow,TS, 1203.3388

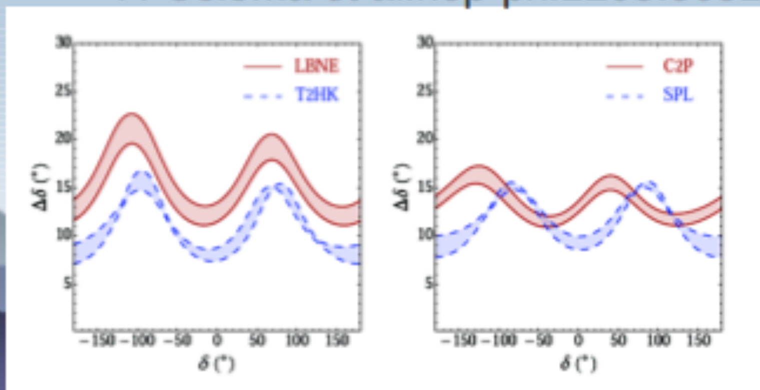
M. Zito©

Long baseline projects

Project	Beam power MW	Fiducial Mass kt	Baseline km	MH	CPV 90%CL, (3σ)	Physics starts	Astrophysical program
LBNO	0.8	20->100	2300	Excellent	71 (44)	2023	Yes
T2HK	0.75	500	295	No	86 (74)*	2023	Yes
LBNE	0.7	10	1300	OK	69 (43)	2022	No
Lund	5	440	365	Some	86 (70)	>2019	Yes
CERN-Canfranc	0.8-4	440	650	Some	80-88(80)	>2020	Yes

P. Coloma et al.hep-ph:1203.5651

*: if mass hierachy is known



T2HK: 4MW, 500 kt
LBNE: 0.8 MW,33 kt
C2P=LBNO : 0.8 MW, 100 kt

co Zito

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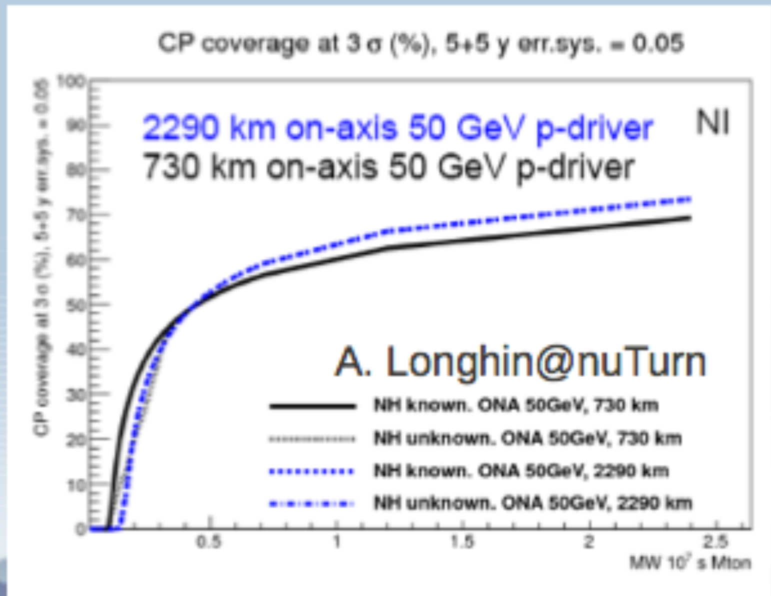
CPV and the baseline issues

- CPV sensitivity is mainly driven by the total exposure (MW Mt year) and by the control of systematic uncertainties
- The baseline has a relatively mild effect
- For ultimate exposure, the sensitivity to the second maximum is at premium



Marco Zito

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Going on and next Future

2) ANOMALIES/Steriles

Radioactive sources
Reactors
Beams

None of these experiments can be considered the definitive one:

*- measure ν and **anti-ν**, **muons** ed **electrons***
- in different sites (≥ 2)
- provide a 5 sigma result

We need a Superior Class Experiment: 3 Kton Fe + 1 Kton LAr

The ultimate 3+1 experiment !

Effective SBL Oscillation Probabilities in 3+1 Schemes

$$P_{\nu_\alpha \to \nu_\beta} = \sin^2 2\vartheta_{\alpha\beta} \sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right) \qquad \sin^2 2\vartheta_{\alpha\beta} = 4|U_{\alpha 4}|^2 |U_{\beta 4}|^2$$

(no CP violation)

$$P_{\nu_\alpha \to \nu_\alpha} = 1 - \sin^2 2\vartheta_{\alpha\alpha} \sin^2\left(\frac{\Delta m^2_{41} L}{4E}\right) \qquad \sin^2 2\vartheta_{\alpha\alpha} = 4|U_{\alpha 4}|^2 \left(1 - |U_{\alpha 4}|^2\right)$$

coupled measurements !!

Perturbation of 3ν Mixing

$$|U_{e4}|^2 \ll 1\,, \quad |U_{\mu 4}|^2 \ll 1\,, \quad |U_{\tau 4}|^2 \ll 1\,, \quad |U_{s4}|^2 \simeq 1$$

$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} & U_{e4} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} & U_{\mu 4} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} & U_{\tau 4} \\ U_{s1} & U_{s2} & U_{s3} & U_{s4} \end{pmatrix}$$

SBL

$$\sin^2 2\vartheta_{\alpha\alpha} \ll 1$$

$$\Downarrow$$

$$|U_{\alpha 4}|^2 \simeq \frac{\sin^2 2\vartheta_{\alpha\alpha}}{4}$$

M. Laveder©

Effective SBL Oscillation Probabilities in 3+2 Schemes

$$\phi_{kj} = \Delta m^2_{kj} L/4E$$

$$\eta = \arg[U^*_{e4} U_{\mu 4} U_{e5} U^*_{\mu 5}]$$

$$P_{\overset{(-)}{\nu}_\mu \to \overset{(-)}{\nu}_e} = 4|U_{e4}|^2 |U_{\mu 4}|^2 \sin^2 \phi_{41} + 4|U_{e5}|^2 |U_{\mu 5}|^2 \sin^2 \phi_{51} + 8|U_{\mu 4} U_{e4} U_{\mu 5} U_{e5}| \sin \phi_{41} \sin \phi_{51} \cos(\phi_{54} \overset{(+)}{-} \eta)$$

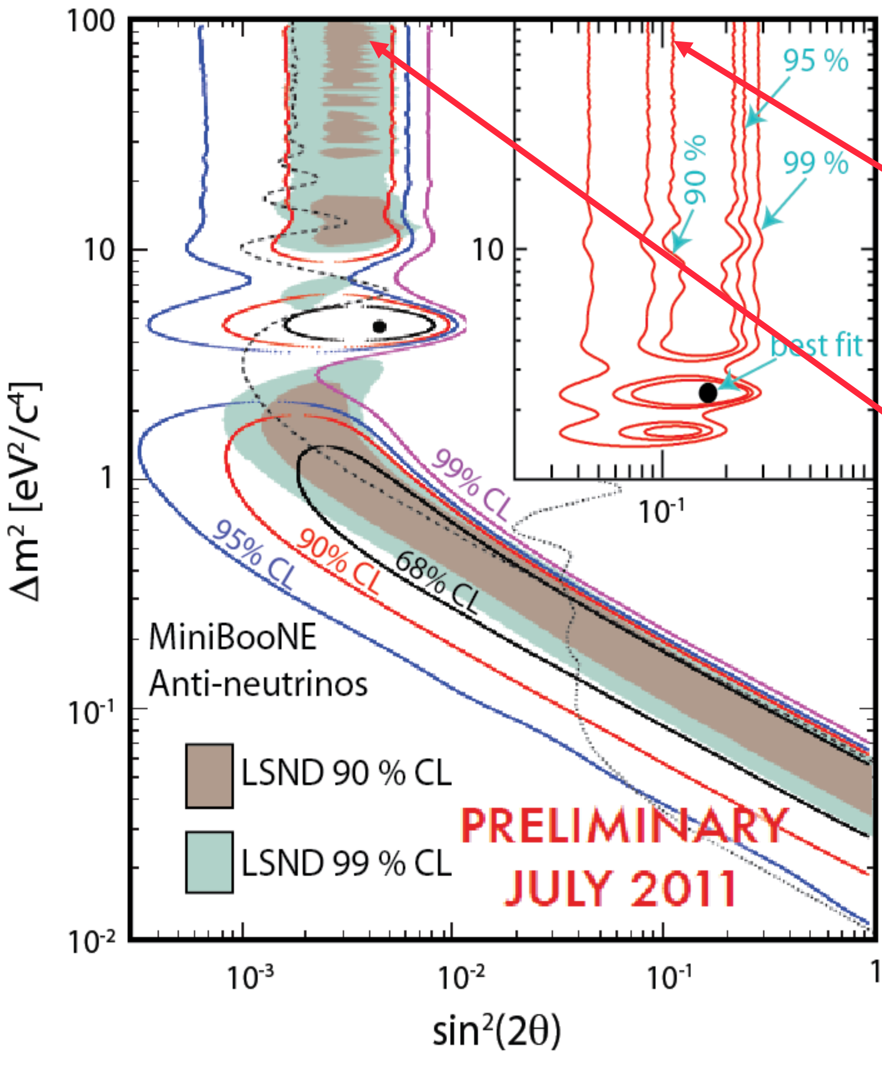
$$P_{\overset{(-)}{\nu}_\alpha \to \overset{(-)}{\nu}_\alpha} = 1 - 4(1 - |U_{\alpha 4}|^2 - |U_{\alpha 5}|^2)(|U_{\alpha 4}|^2 \sin^2 \phi_{41} + |U_{\alpha 5}|^2 \sin^2 \phi_{51}) - 4|U_{\alpha 4}|^2 |U_{\alpha 5}|^2 \sin^2 \phi_{54}$$

- More parameters: 7 *many coupled measurements !!*
- CP violation

[Sorel, Conrad, Shaevitz, PRD 70 (2004) 073004; Maltoni, Schwetz, PRD 76 (2007) 093005; Karagiorgi et al, PRD 80 (2009) 073001; Kopp, Maltoni, Schwetz, PRL 107 (2011) 091801; Giunti, Laveder, PRD 84 (2011) 073008; Donini et al, arXiv:1205.5230]

M. Laveder©

Anomalies: an unified approach ?



Allowed regions in the plane for combined results:

the νe disappearance rate (right) (reactors and Gallium sources)

the LSND /MiniBooNE anti-νe accelerator driven anomaly (left).

While the values of Δm^2_{new} may indeed have a common origin, the different values of $\sin^2(2\theta_{new})$ may reflect within the four neutrino hypothesis the structure of $U_{(4,k)}$ mass matrix, with k = μ and e.

C. Rubbia©

3+1 SBL oscillations

appearance

$$P_{\mu e} = \sin^2 2\theta_{\mu e} \sin^2 \frac{\Delta m^2_{41} L}{4E} \qquad \sin^2 2\theta_{\mu e} = 4|U_{e4}|^2 |U_{\mu 4}|^2$$

disappearance ($\alpha = e, \mu$)

$$P_{\alpha\alpha} = 1 - \sin^2 2\theta_{\alpha\alpha} \sin^2 \frac{\Delta m^2_{41} L}{4E} \qquad \sin^2 2\theta_{\alpha\alpha} = 4|U_{\alpha 4}|^2 (1 - |U_{\alpha 4}|^2)$$

$$\boxed{\sin^2 2\theta_{\mu e} \approx \frac{1}{4} \sin^2 2\theta_{ee} \sin^2 2\theta_{\mu\mu}}$$

$\nu_\mu \to \nu_e$ app. signal requires also signal in both, ν_e and ν_μ disappearance
(appearance mixing angle quadratically suppressed)

T. Schwetz©

Fitting all together?

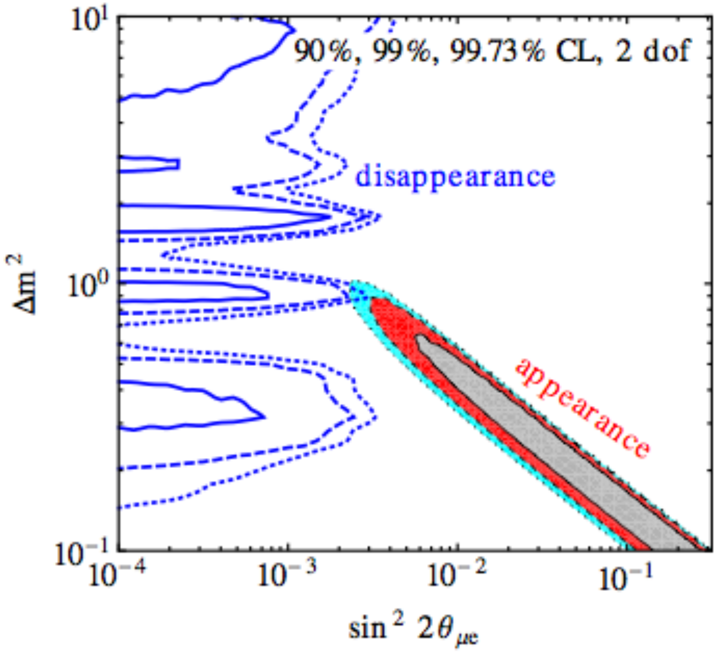
there are three classes of data:

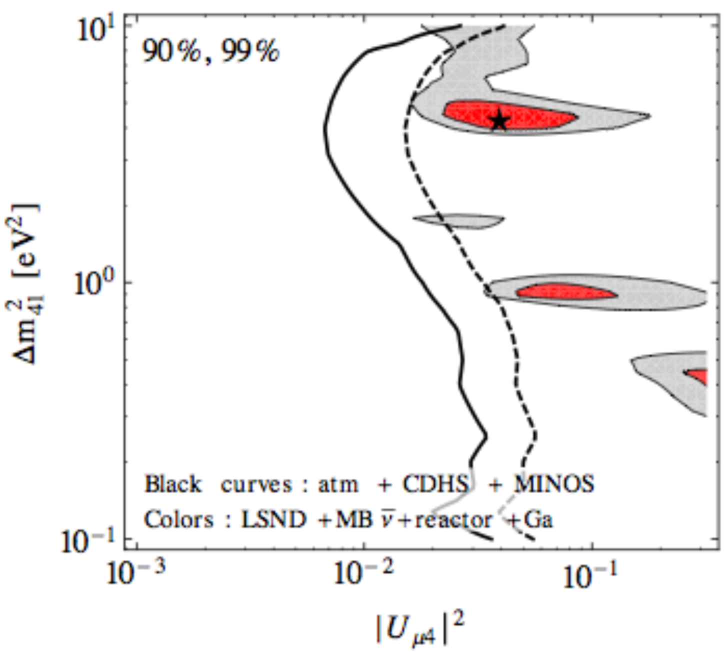
$\nu_e \rightarrow \nu_e$ disappearance $\quad \sin^2 2\theta_{ee}$

$\nu_\mu \rightarrow \nu_\mu$ disappearance $\quad \sin^2 2\theta_{\mu\mu}$

$\nu_\mu \rightarrow \nu_e$ appearance $\quad \sin^2 2\theta_{\mu e}$

$$\boxed{\sin^2 2\theta_{\mu e} \approx \frac{1}{4} \sin^2 2\theta_{ee} \sin^2 2\theta_{\mu\mu}}$$





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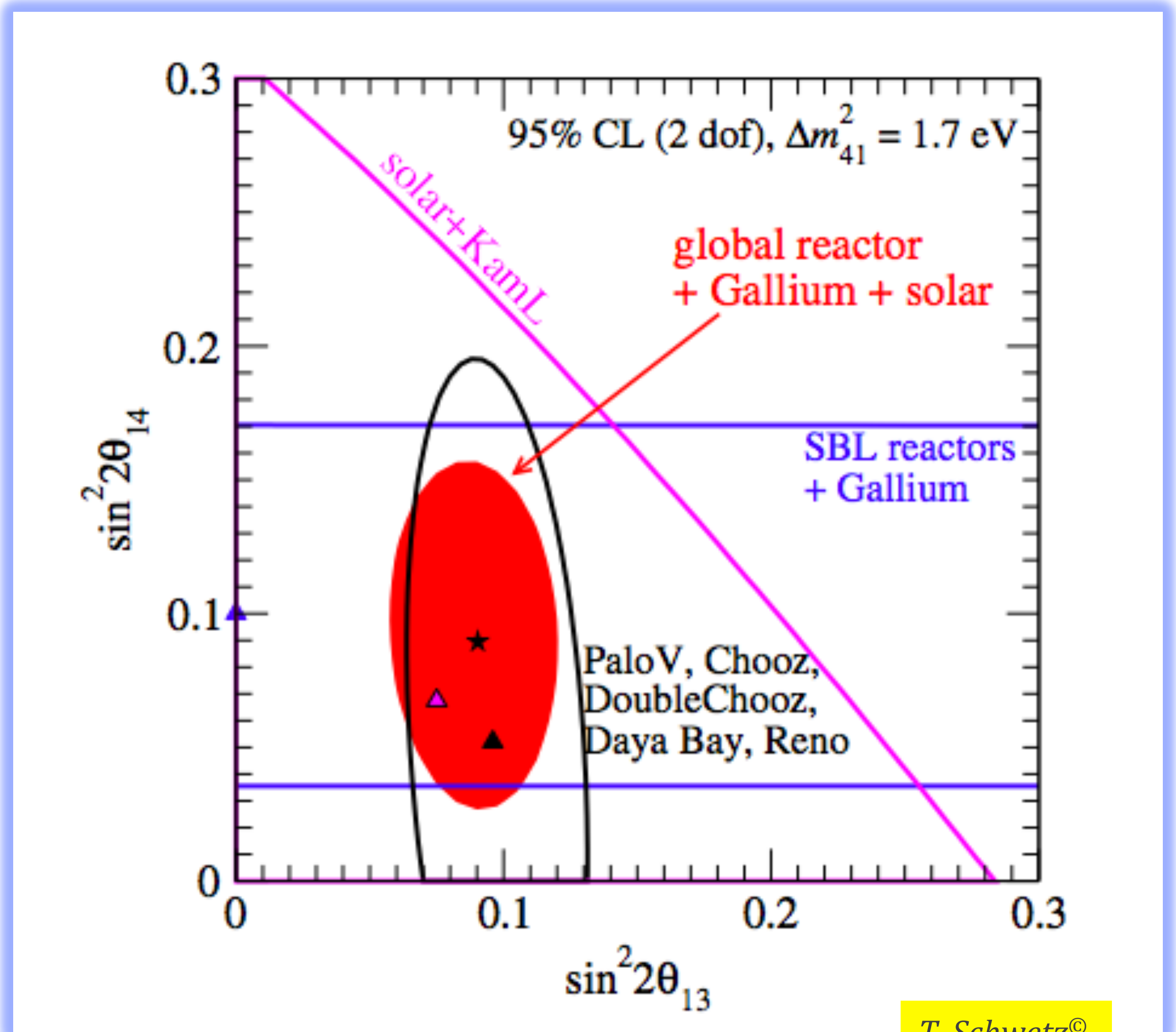
TENSIONS…

TENSIONS also for the 3+2 scheme, due to disappearance bounds, particularly for ν_μ
On top of that, coupling to standard 3-flavour scenario is weak :



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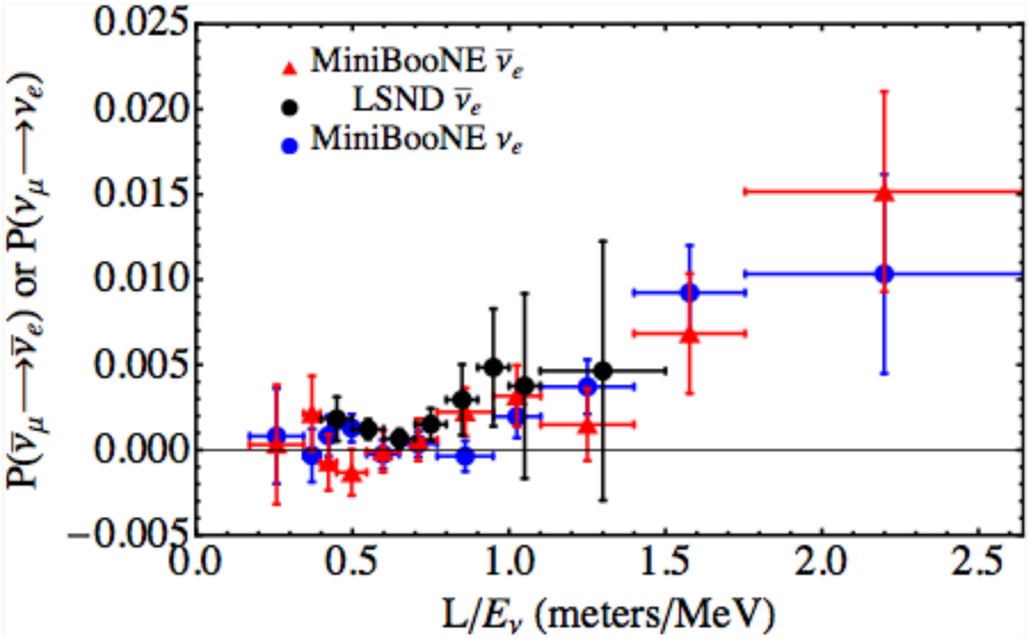
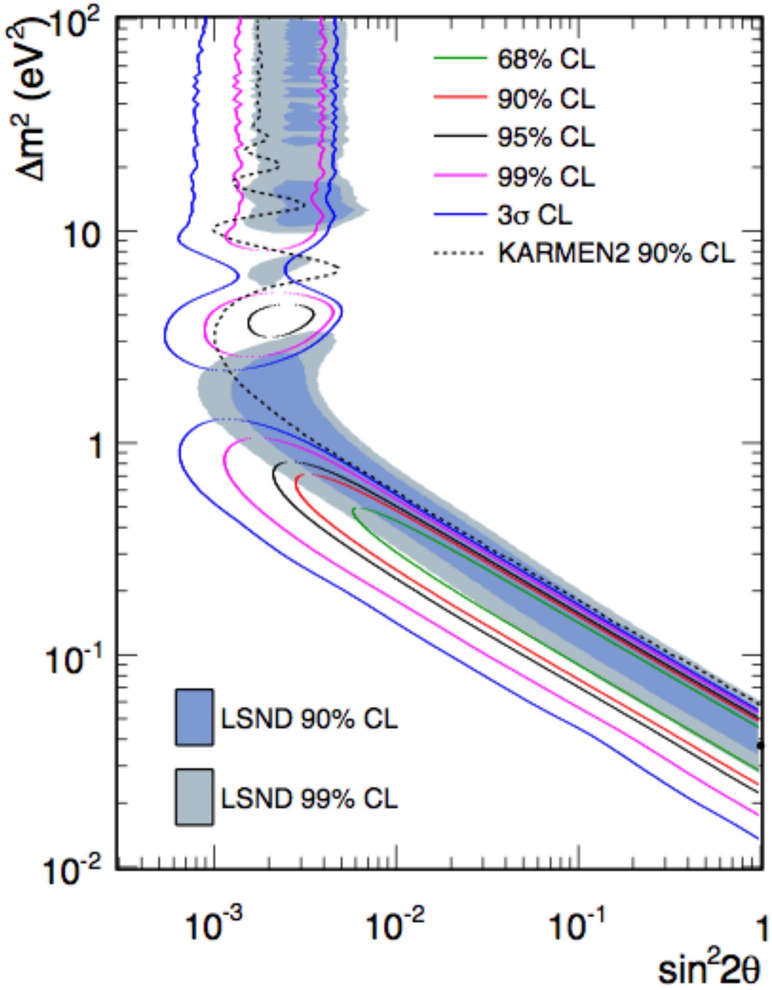
is it a convenient game to play ?

Just after Kyoto 2012, a new 3.8 σ measure.
MiniBooNE just released full data analysis, arXiv:1207.4809





Combined ν and anti-ν modes

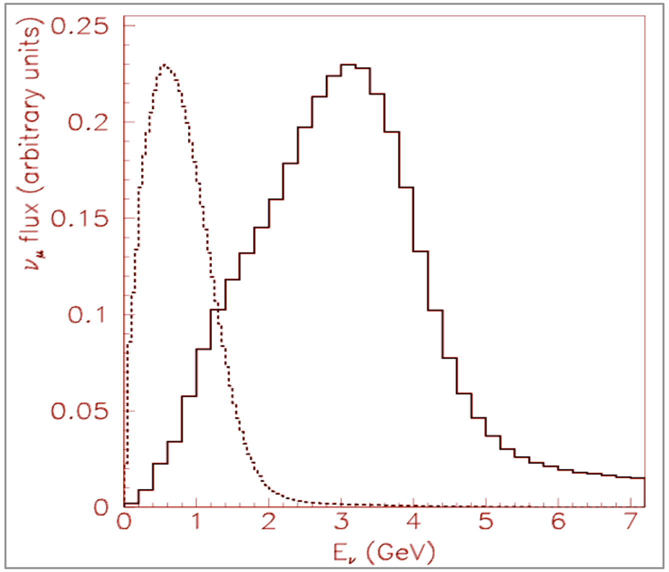
is there something going on here ?
a complicate picture, if any...

it is worth for physics

periculum in mora

FERMILAB (see the talk by Leslie Camilleri this afternoon)

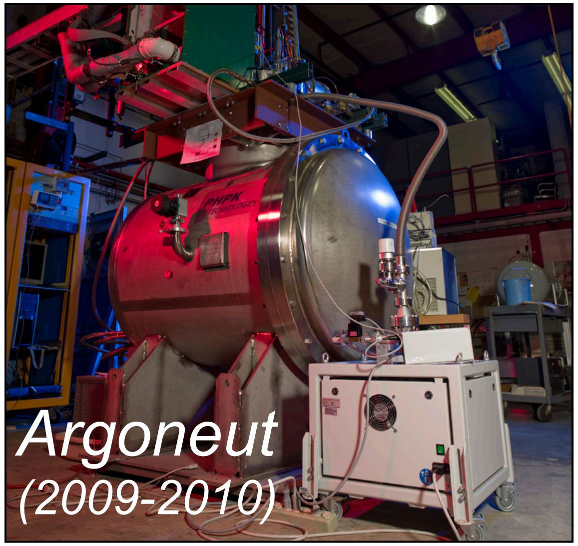
- **NuMI** (Neutrinos at the Main Injector)
  - 120 GeV protons from MI
  - 90 cm graphite target
  - 675 m decay region
- **BNB** (Booster Neutrino Beam)
  - 8 GeV protons from Booster
  - 71 cm beryllium target
  - 50 m decay region



RECENT FNAL SBL EXPERIMENTS

Booster Beam Experiments (+ NuMI Off-Axis)

NuMI Beam Experiments



MicroBooNE

- *Short baseline experiment to explore the origin of the low energy excess reported by MiniBooNE, measure neutrino cross-sections, & develop liquid argon time projection (LArTPC) technology for future facilities.*
- *Will use a 170 ton LArTPC in the Booster Neutrino Beam (E=0.7 GeV) at a distance of L=0.5 km. It also sees the NuMI beam at a wide off-axis angle.*

Data taking expected to start in 2014.

2-3 years run will yield 6×10^{20} POT and 10^5 neutrino events

TABLE 2. Summary of event rates in MicroBooNE's 60 ton volume by the neutrino mode BNB (6E20 POT), 468 m from the target.

production mode	formula	#evt ($\times 10^3$)
CC quasi-elastic	$\nu_\mu + n \rightarrow \mu^- + p$	66
NC elastic	$\nu_\mu + N \rightarrow \nu_\mu + N$	21
CC resonance π^+	$\nu_\mu + N \rightarrow \mu^- + N + \pi^+$	28
CC resonance π°	$\nu_\mu + n \rightarrow \mu^- + p + \pi^\circ$	7
NC resonance π°	$\nu_\mu + N \rightarrow \nu_\mu + N + \pi^\circ$	8
NC resonance $\pi^\pm$	$\nu_\mu + N \rightarrow \nu_\mu + N' + \pi^\pm$	3
CC DIS	$\nu_\mu + N \rightarrow \mu^- + X, W > 2$ GeV	1
NC DIS	$\nu_\mu + N \rightarrow \nu_\mu + X, W > 2$ GeV	0.5
CC coherent π°	$\nu_\mu + A \rightarrow \mu^- + A + \pi^+$	3
NC coherent $\pi^\pm$	$\nu_\mu + A \rightarrow \nu_\mu + A + \pi^\circ$	2
CC Kaon production	$\nu_\mu + N \rightarrow \mu^- + K + X$	~0.1
NC Kaon production	$\nu_\mu + N \rightarrow \nu_\mu + K + X$	<0.1
others		4
total		143

But…

- *Is the LAr mass sufficient ?*
- *Is the CC measurement (in)essential ?*

Where, When, How, What ?

3) Let's do something !

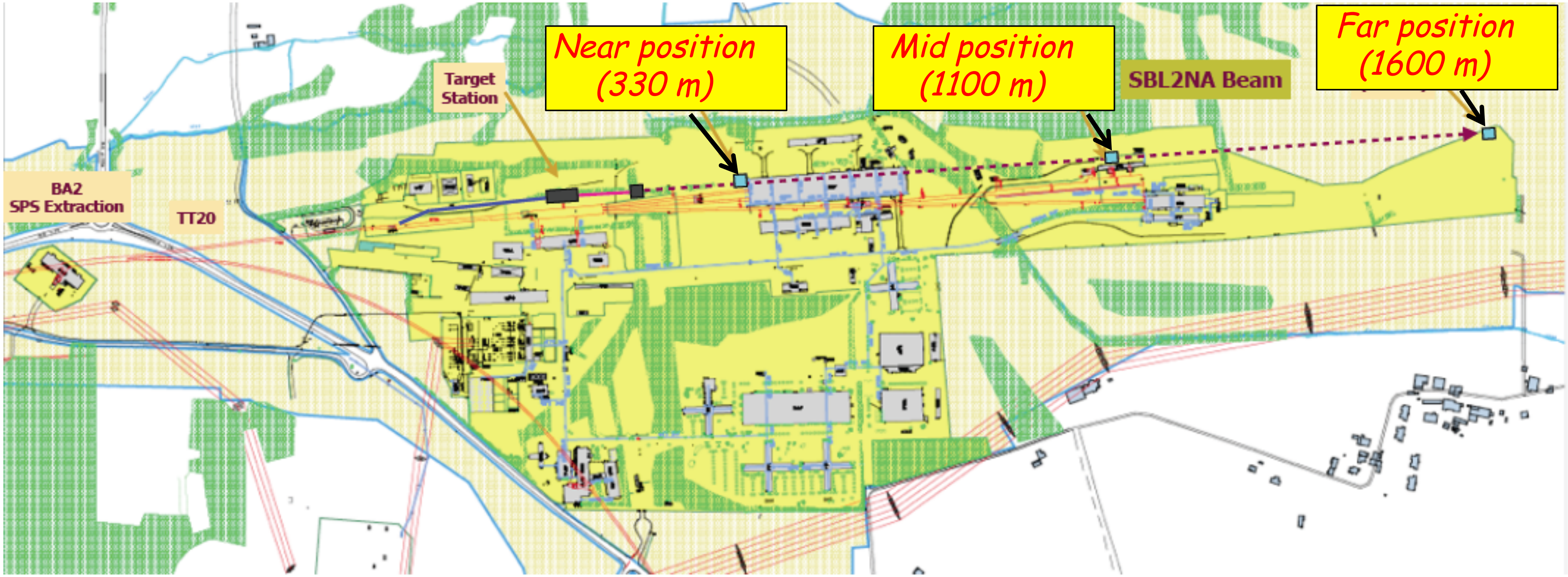
- *CERN, towards ? For the time being decide the place:* ***North Area !***
  create an infrastructure for beams/R&D/multi-experiments

- ***Now !***

- ***Multistep project***
  Begin with SBL

- ***What*** *? (decide on tecnology)*
  we are proposing LAr+Fe

New Neutrino Facility in the CERN North Area

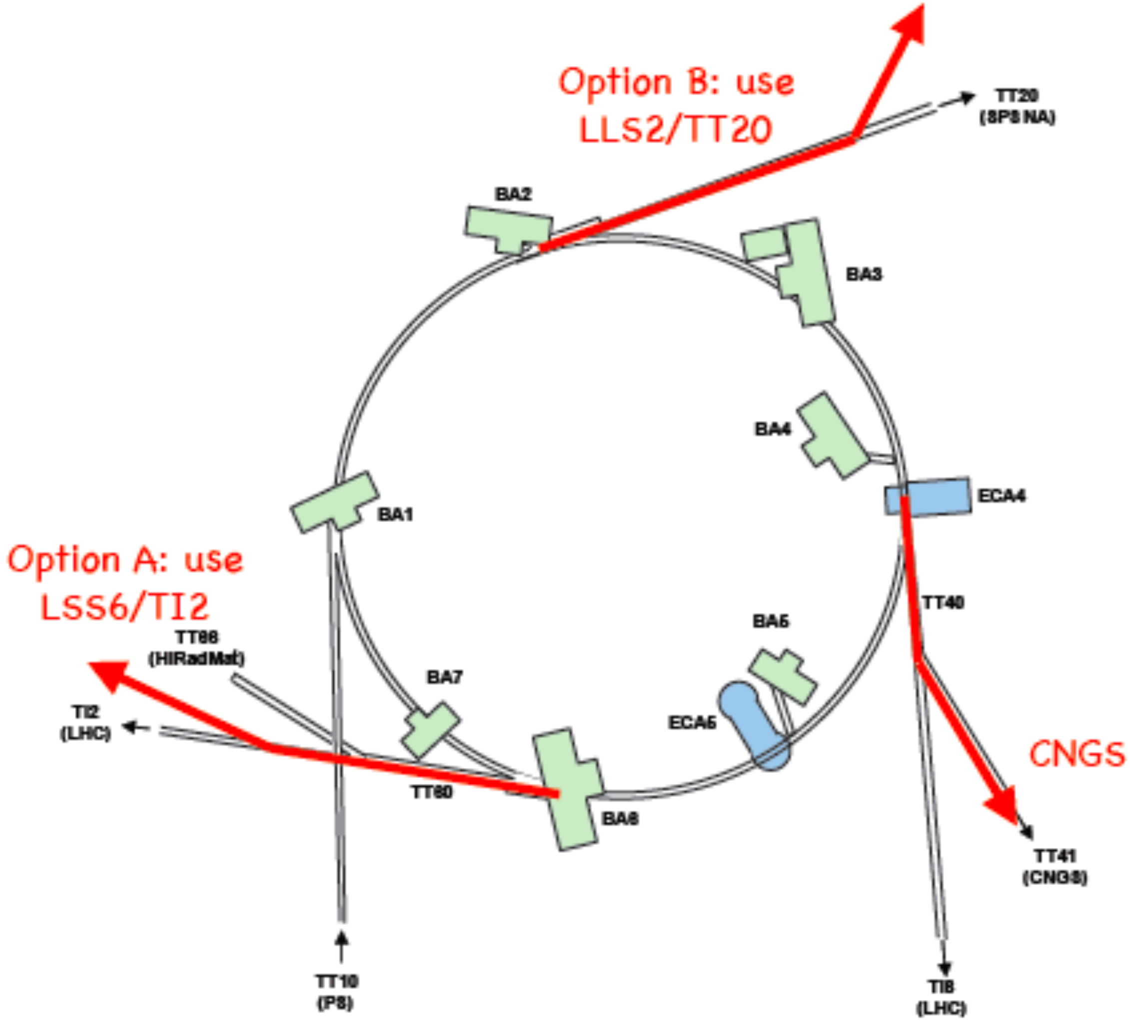


100 GeV primary beam fast extracted from SPS; target station next to TCC2; decay pipe l =100m, ø = 3m; beam dump: 15m of Fe with graphite core, followed by μ stations.
Neutrino beam angle: pointing upwards; at -3m in the far detector ~5mrad slope.

CERN (see the talk by Daniele Gibin this afternoon)

Passed proposals…

- **Option A**: LSS6 extraction, target near BA2
  - LSS6 fast extraction and TT60 beam line exists
  - New switch to direct the proton beam towards North
  - ?!? Long (~1.6km) proton tunnel to bring the beam towards BA2
- **Option B** : LSS2 extraction, target near TCC2
  - ?!? new fast extraction system in LSS2
  - TT20 beam line exists
  - Target area near existing TCC2



Solution: take the best from each option and be ready in 2015 !

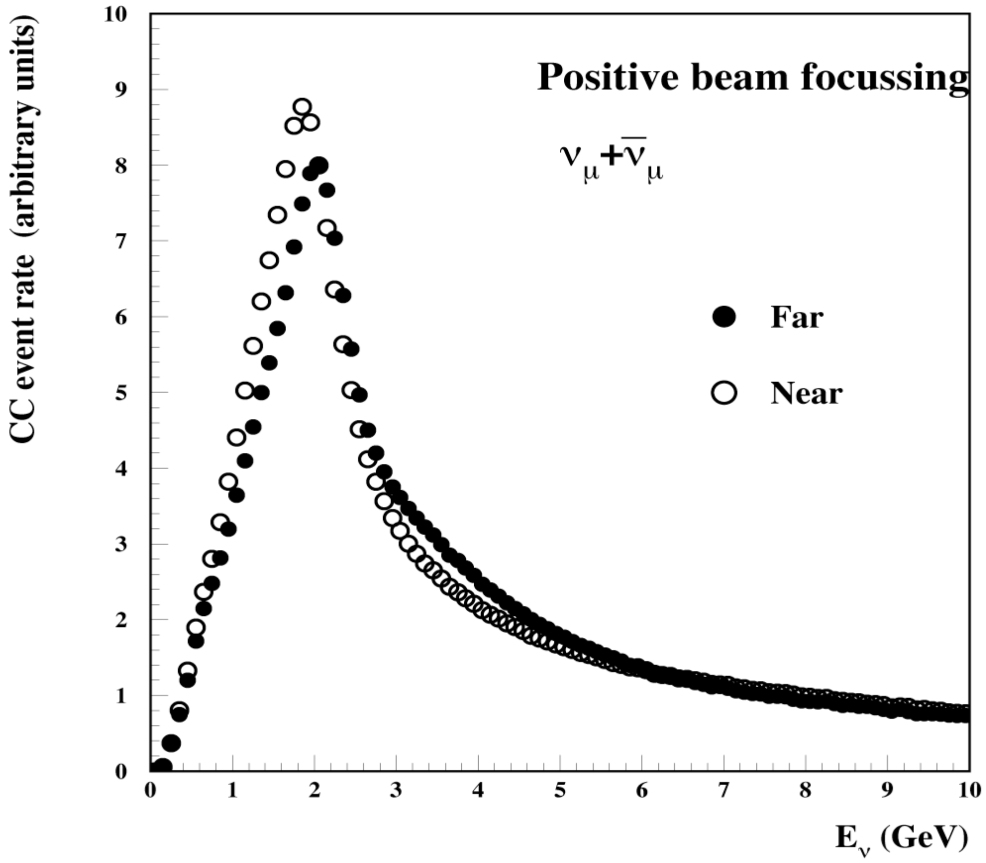
Courtesy : B. Goddard – LLBNO

By Ilias Efthymiopoulus, June 14 2012

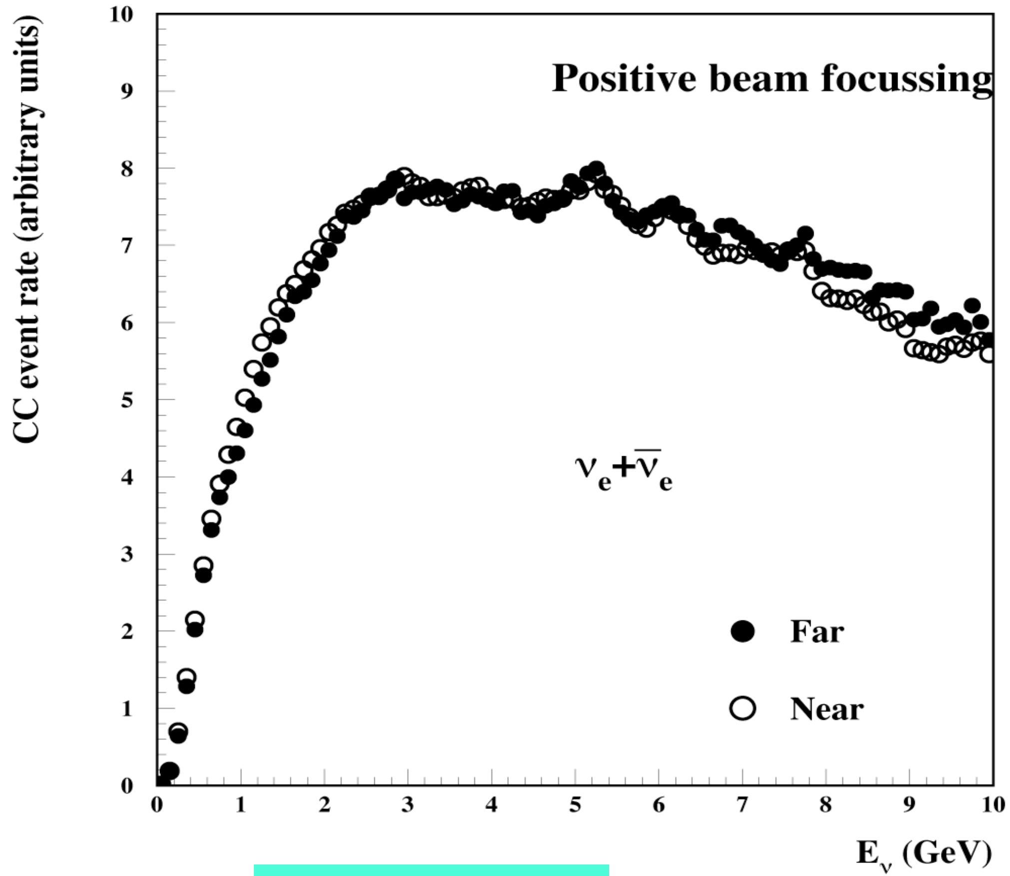
Beam Studies at SPS

- 100 GeV proton, Fast Extraction (10.5 μs), Luminosity as at CNGS (conservative)

On-Axis !!



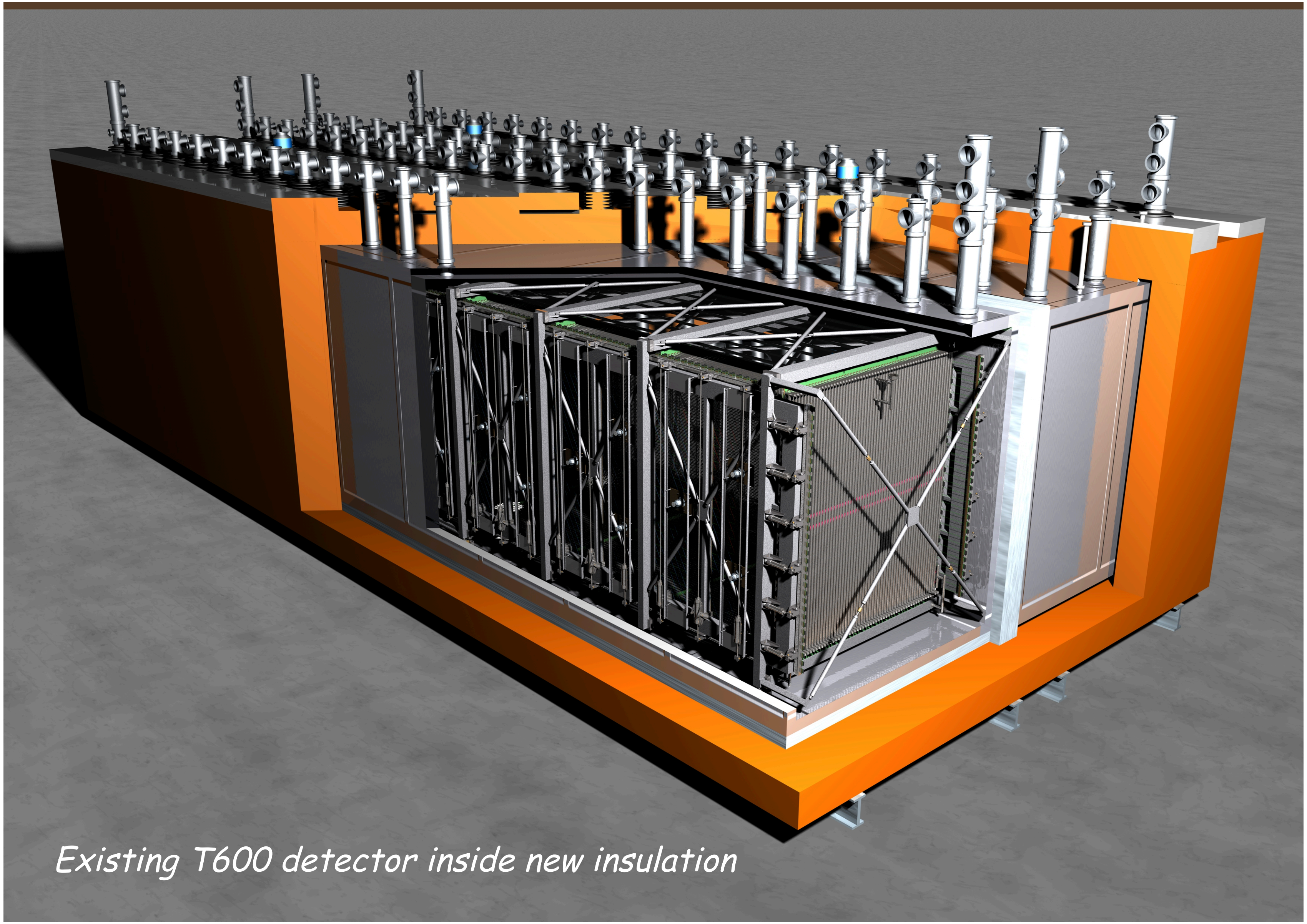
CC muons



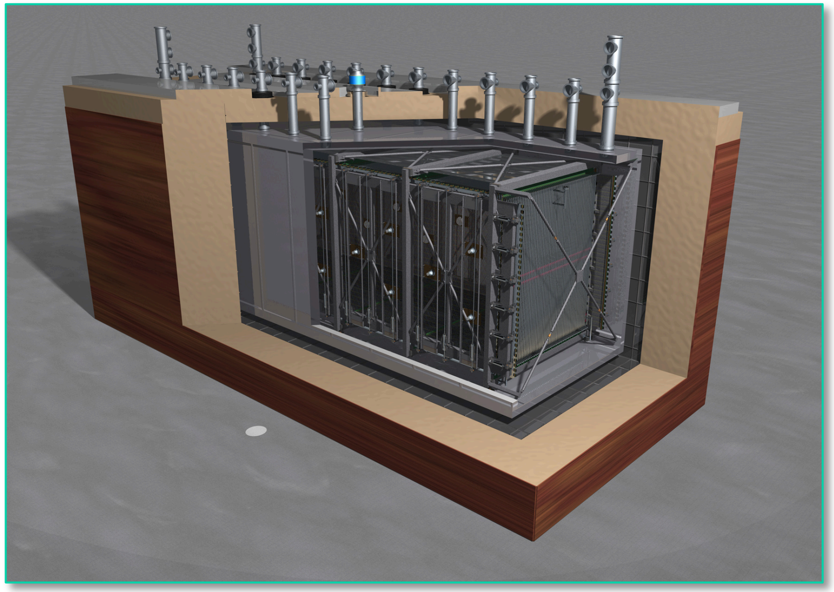
CC electrons

Scenario **defined** for DATA Taking: 2 years of anti-ν followed by 1 year ν

T600 layout in the CERN-SPS

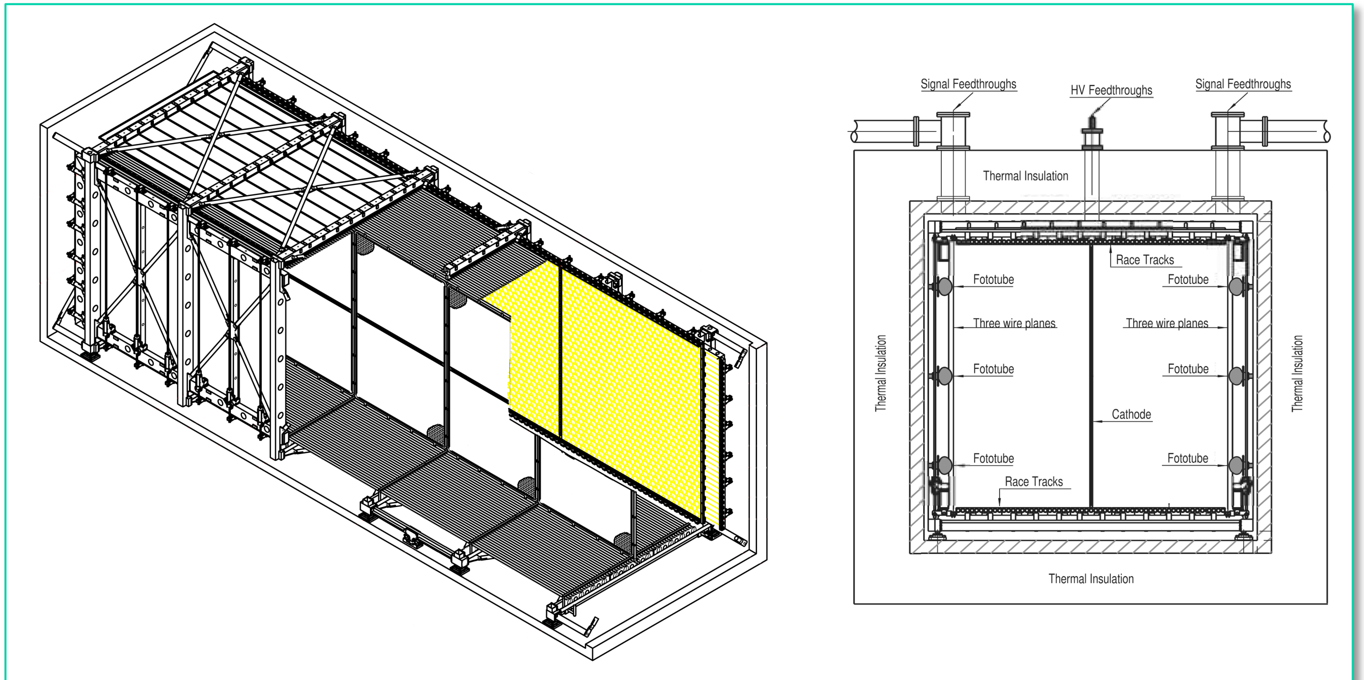


New T150 LAr-TPC



The present design of the T600 is extended to the basic structure of the T150 module. The module contains a high precision, high stability stainless steel structure independent of the container that supports two wire chambers, with three read-out planes each, the field shaping electrodes and one cathode, separating the two 1.5 m drift regions.

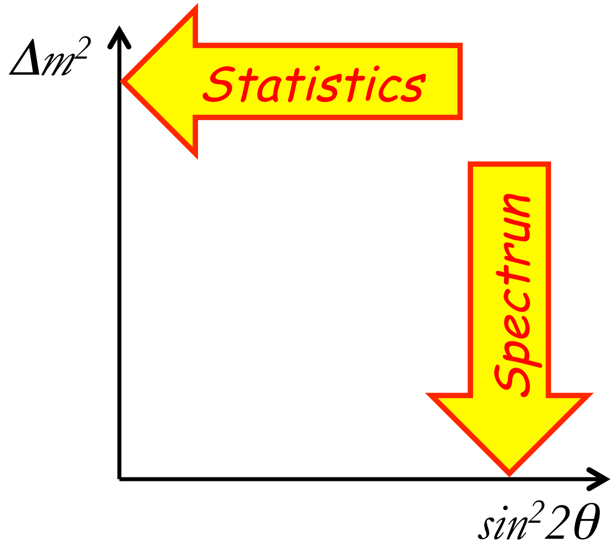
Most of the solutions already successfully adopted for the T600 at LNGS will be used. Existing equipment will be conveniently re-used (wiring tables, cleaning tools, etc.).



NESSiE detector concept

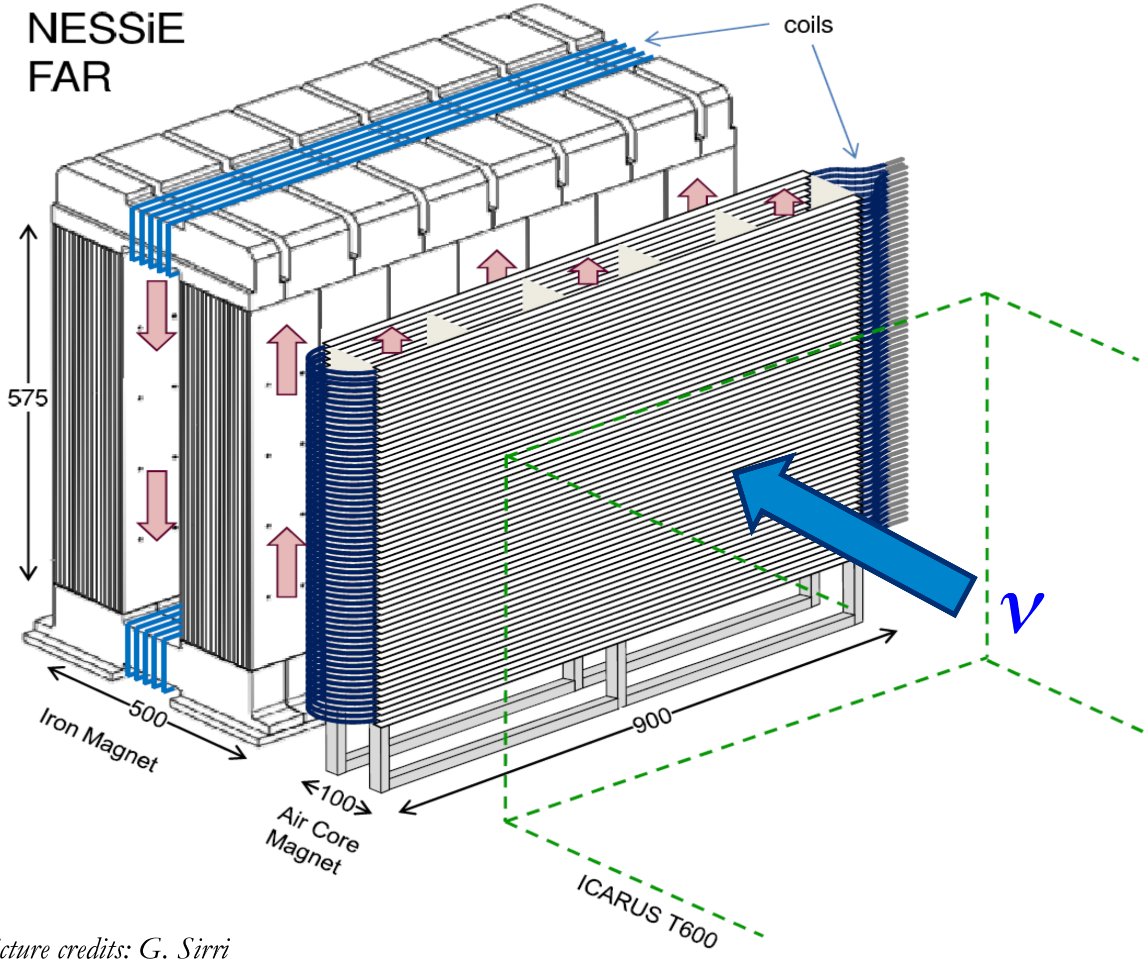
NESSiE (Neutrino Experiment with SpectrometerS in Europe)

- Goal:
  - Allow charge separation and momentum measurement of as many muons as possible escaping from LAr (large statistics ↔ low $\sin^2 2\theta$)
  - Go as low as possible in muon momentum (low momenta ↔ low Δm^2)
  - Possibility to also study (NESSiE) internal events (coarser resolution w.r.t. LAr)

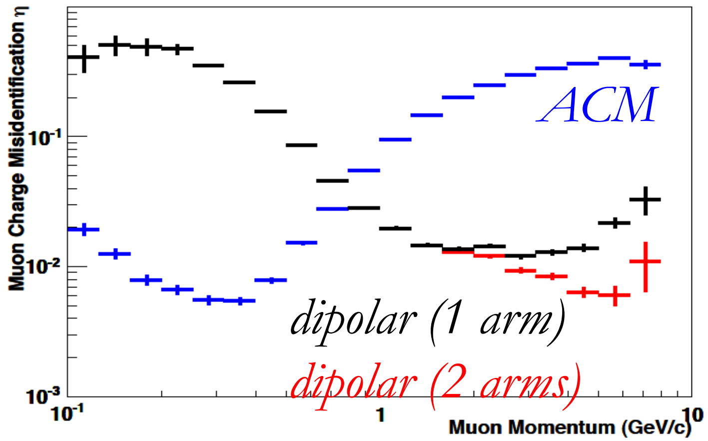


- Solution:
  - Air-core magnets for low momentum muons escaping from LAr ($E_\mu < 0.5$ GeV/c in NESSiE ↔ $\langle E_\nu \rangle < 1$ GeV in LAr)
  - Downstream massive iron dipolar magnets for higher momenta extension

NESSiE Detector configuration (far position)



Picture credits: G. Sirri



Charge mis-reconstruction at few percent level in all dynamical range of interest (full simulation including selection, efficiency and recontruction)

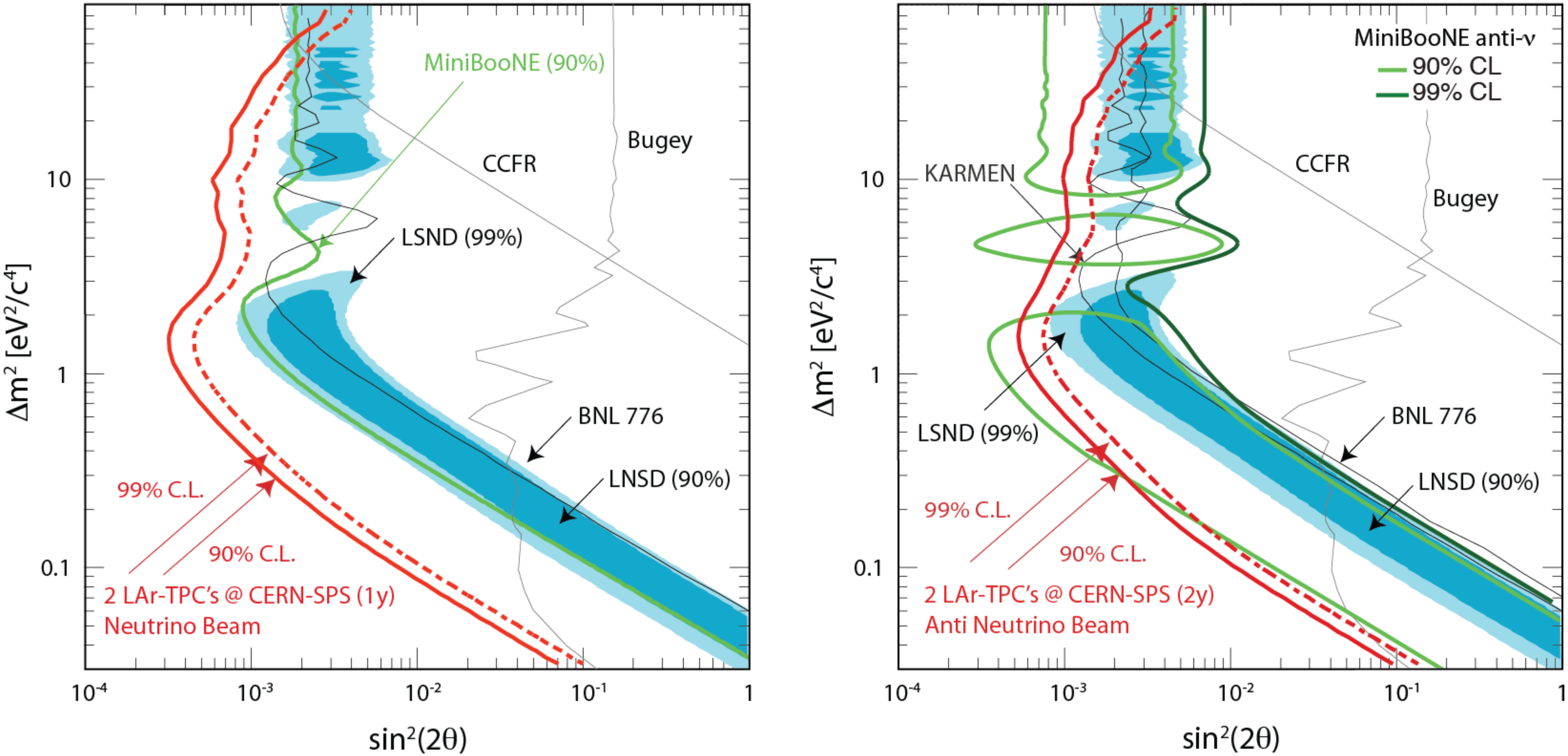
A direct, new approach to sterile oscillations at CERN/SPS

- The direct, unambiguous measurement of an oscillation pattern requires necessarily the (simultaneous) observation at several different distances. It is only in this way that the values of Δm^2 and of $sin^2(2\theta)$ can be separately identified.
- The CERN experiment introduces important new features, *which should allow a definitive clarification of all the present "anomalies"*:
  - L/E oscillation paths lengths to ensure appropriate matching to the Δm^2 window for the expected anomalies.
  - **"Imaging" detector capable to identify unambiguously <u>all</u> reaction channels with a *"Gargamelle class" LAr-TPC***
  - **Magnetic spectrometers to determine muon charge and p**
  - Interchangeable ν and anti-ν focussed beams
  - Very high rates due to large masses, in order to record relevant effects at the % level (>10^6 νμ, ≈10^4 νe)
  - Both initial νe and νμ components cleanly identified.

Basic features of the proposed experiment

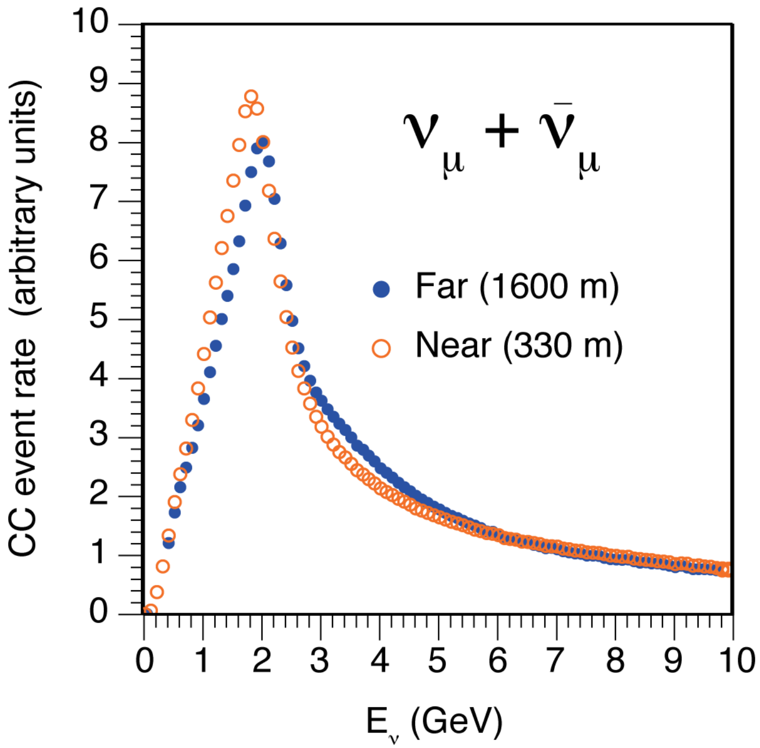
- Our proposed experiment, collecting a large amount of data both with neutrino and antineutrino focussing and muon momentum determination may be able to give a likely definitive answer to the 4 following queries:
  - the LSND/+MiniBooNe both antineutrino and neutrino $\nu\mu \rightarrow \nu e$ oscillation anomalies;
  - The Gallex + Reactor oscillatory disappearance of the initial ν−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.

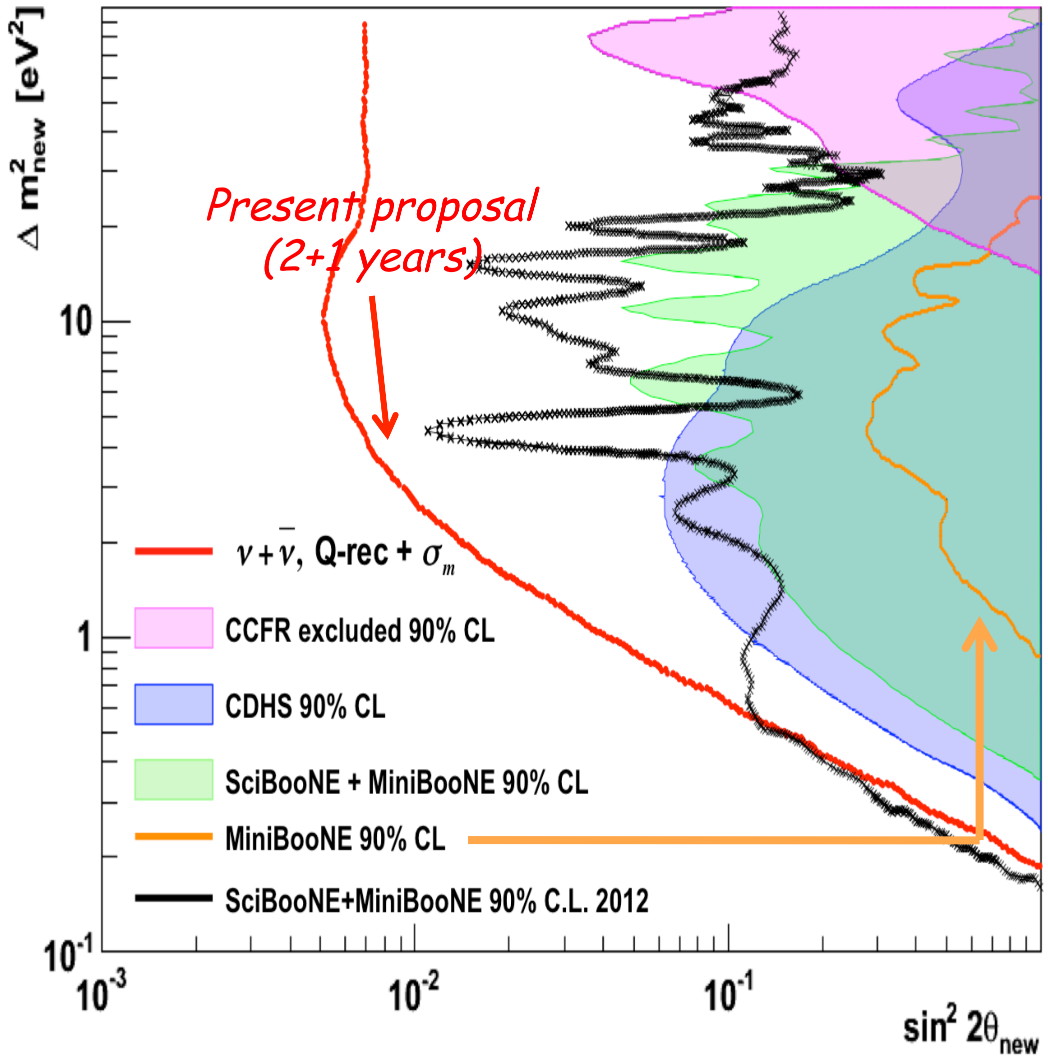
Comparing LSND sensitivities



Expected sensitivity for the proposed experiment: ν_μ beam (left) and anti-ν_μ (right) for 4.5 10^{19} pot (1 year) and 9.0 10^{19} pot (2 years) respectively. LSND allowed region is fully explored in both cases.

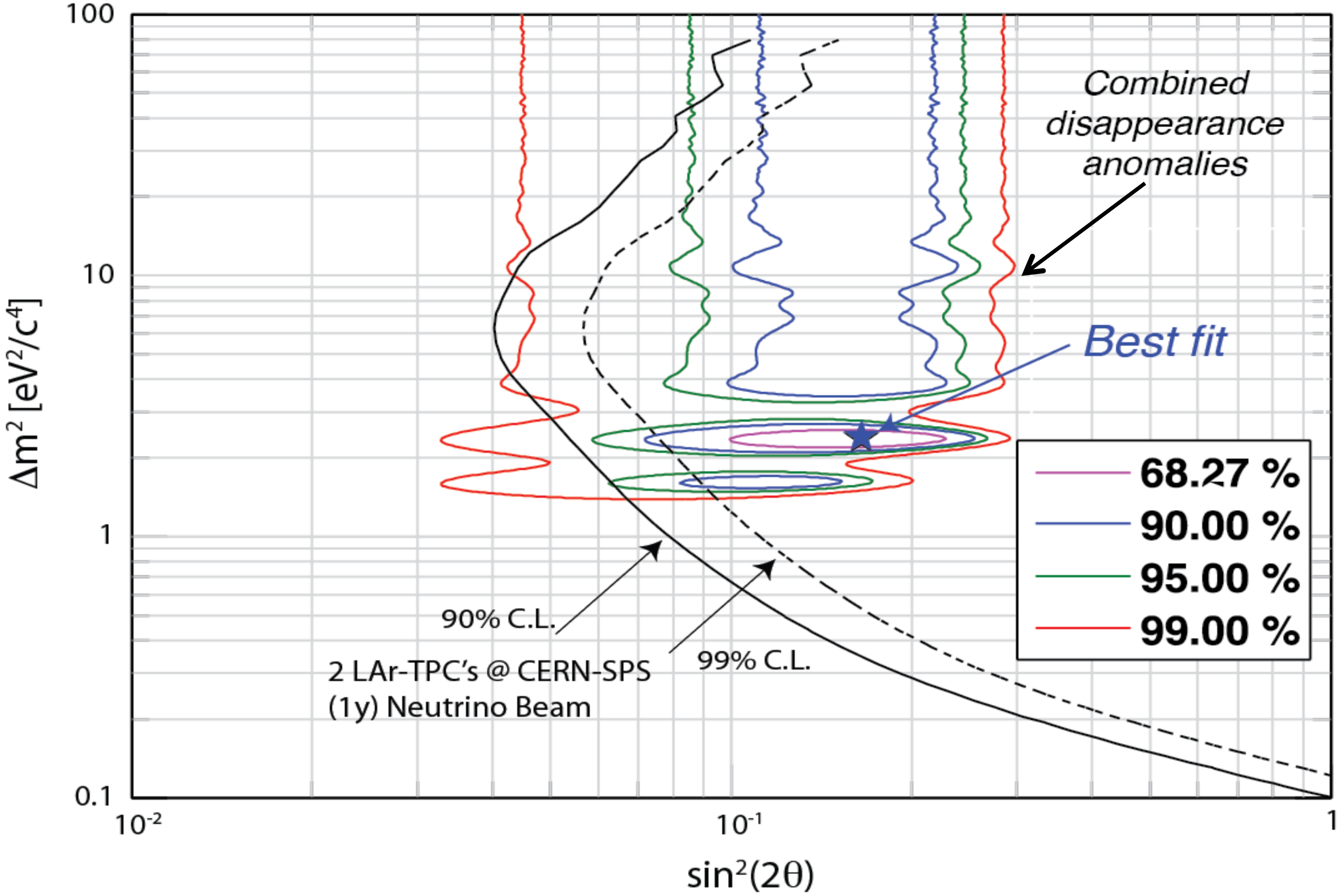
Sensitivity to ν_μ disappearance





90% C.L. sensitivity for 2 years anti-ν + 1 year ν
Exclusion limits :
CCFR, CDHS, SciBooNE + MiniBooNE

Sensitivity to ν_e disappearance anomalies



- *Oscillation sensitivity in $\sin^2(2\theta_{new})$ vs. Δm^2_{new} distribution for CERN-SPS neutrino beam (1 year). A 3% systematic uncertainty on energy spectrum is included. See also combined "anomalies" from reactor neutrino, Gallex and Sage experiments.*

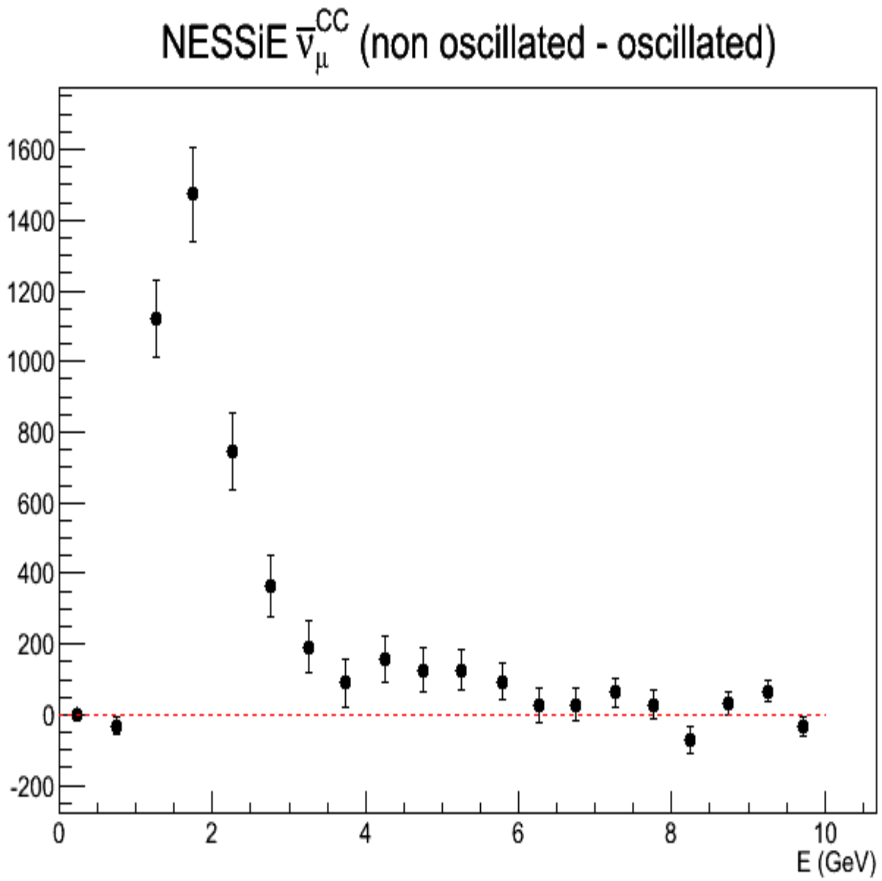
Expected signal for LSND/MiniBooNE anomalies

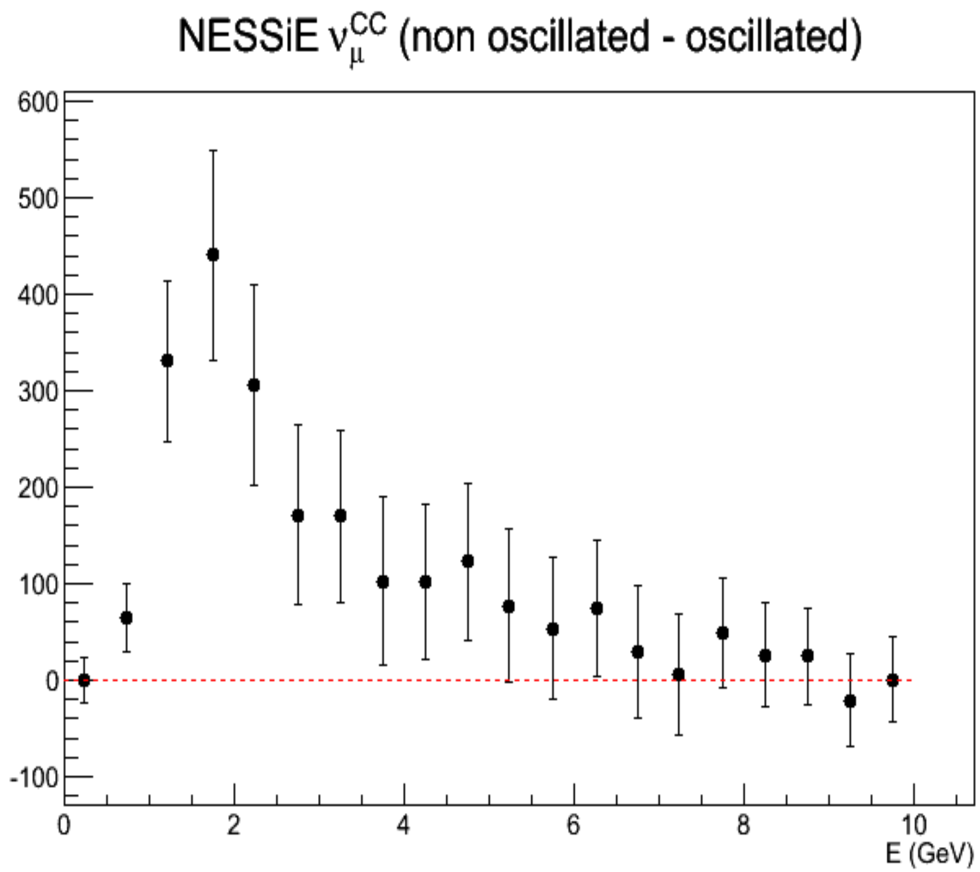
- Event rates for the near and far detectors given for 4.5 10^{19} pot. The oscillated signals are clustered below 3 GeV of visible energy.
- Values for Δm^2 around 2 eV^2 are reported as example

		NEAR (ν–bar)	NEAR(ν)	FAR(ν–bar)	FAR(ν)
produced	$\nu_e + \nu_e$–bar (LAr)	35 K	54 K	4.2 K	6.4 K
	$\nu_\mu + \nu_\mu$–bar (LAr)	2000 K	5250 K	270 K	670 K
	Appear. test point	590	1900	360	910
detected	ν_μ (LAr+NESSiE)	230 K	1200 K	21 K	110 K
	ν_μ (NESSiE)	1150 K	3600 K	94 K	280 K
	ν_μ–bar (Lar+NESSiE)	370 K	56 K	33 K	6.9 K
	ν_μ–bar (NESSiE)	1100 K	300 K	89 K	22 K
	Disappear. test point	1800	4700	1700	5000

NOTE: ν "contamination" in anti-ν negative polarity beam

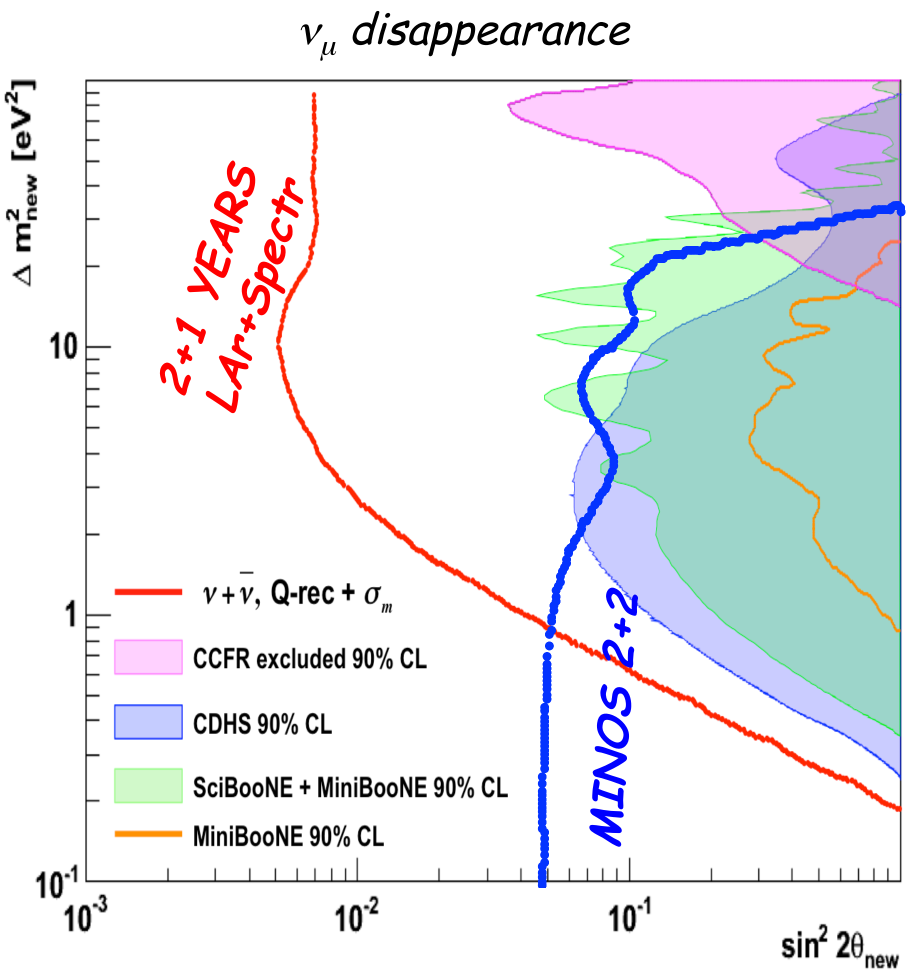
Muon disappearance signal

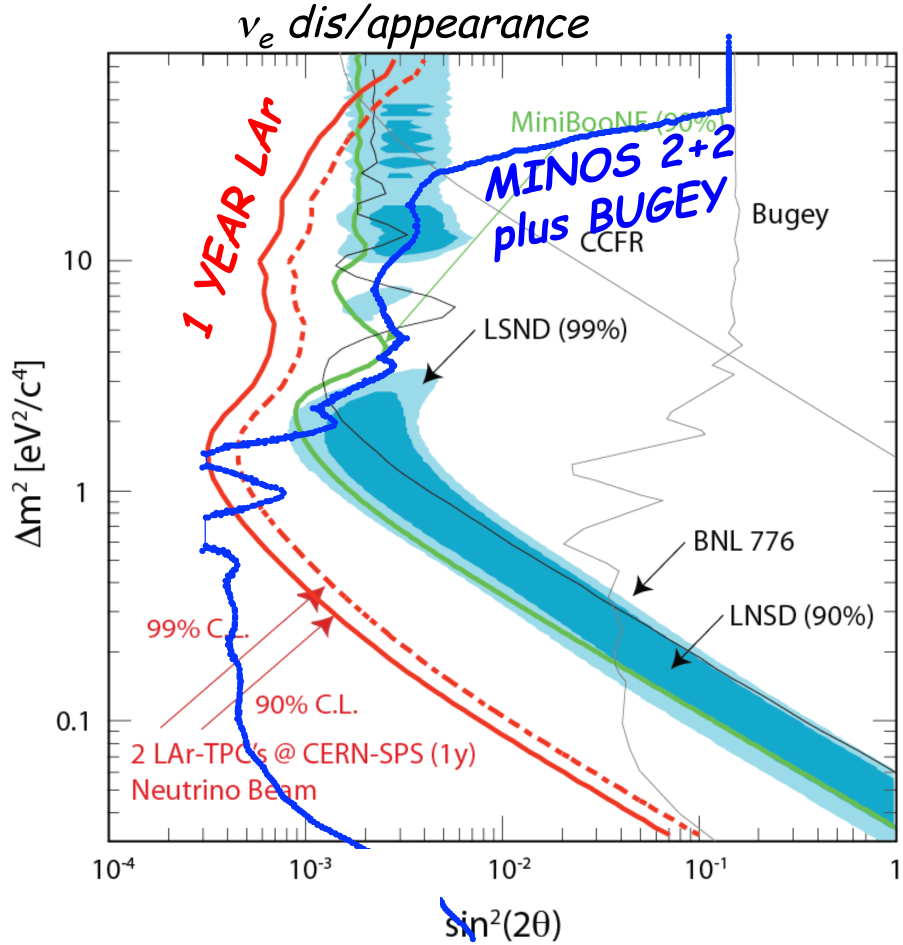




1 year of anti-neutrinos !

Comparison with MINOS+ limits





Time Schedule

Name	Days
Buildings in NA: preparation-erection	356
⊟T600	**833**
Vessels, thermal Isolation: design, orders...	373
Transport frame: design, order, constructio...	349
Working area equipment...	111
T600 decommissiong & disassembly...	106
T600 first vessels delivery...	11
T600 first TPC transport to CERN	6
T600 First module assembly	46
T600 First module tranport in NA	6
T600 thermal isolation erection...	73
T600 second vessels delivery	10
T600 second TPC transport to CERN	9
T600 second module assembly	35
T600 second module tranport in NA	6
T600 plant assembly...	131
T600 final tests, commissioning, filling...	125
⊟T150	**566**
T150 TPC order, construction, delivery	346
T150 vessel delivery	6
T150 cryostat assembly	2[illegible]
T150 thermal isolation erection	[illegible]
T150 transport in NA	[illegible]
T150 plant assembly	[illegible]
T150 final tests, commissioning, filling...	6[illegible]

Months →

Name	Days
⊟NESSIE	**773**
prototype construction	110
Start Tenders for Iron	1
iron production-Lamination	239
Construction Assembling Tools	194
Coils and cooling	196
FAR Iron Magnet - Assembling	261
FAR Commissioning	65
NEAR Iron Magnet - Assembling	218
NEAR Commissioning	43
Air Magnet construction	261
Air Magnet insertion on site	15

≳ 20 M€, All Inclusive !

Conclusive Studies

Oscillation type	Neutrinos	Experiments
θ_{12}	ν_e(solar, reactors)	SNO, SK, Borexino, Kamland
θ_{23}	ν_μ (atmospheric, accelerators)	SK, Minos, T2K
θ_{13}	ν_e(reactors)	Daya Bay, RENO, Double Chooz
θ_{14}	ν_e(reactors, radioactive sources)	SBL Reactors, Gallex, Sage. **This Proposal**
θ_{24}	ν_μ (accelerators)	CDHS, Miniboone. MINOS+ **This Proposal**

Measure at L/E corresponding to Δm^2~1 eV^2

ν_μ **AND** $\bar{\nu}_\mu$

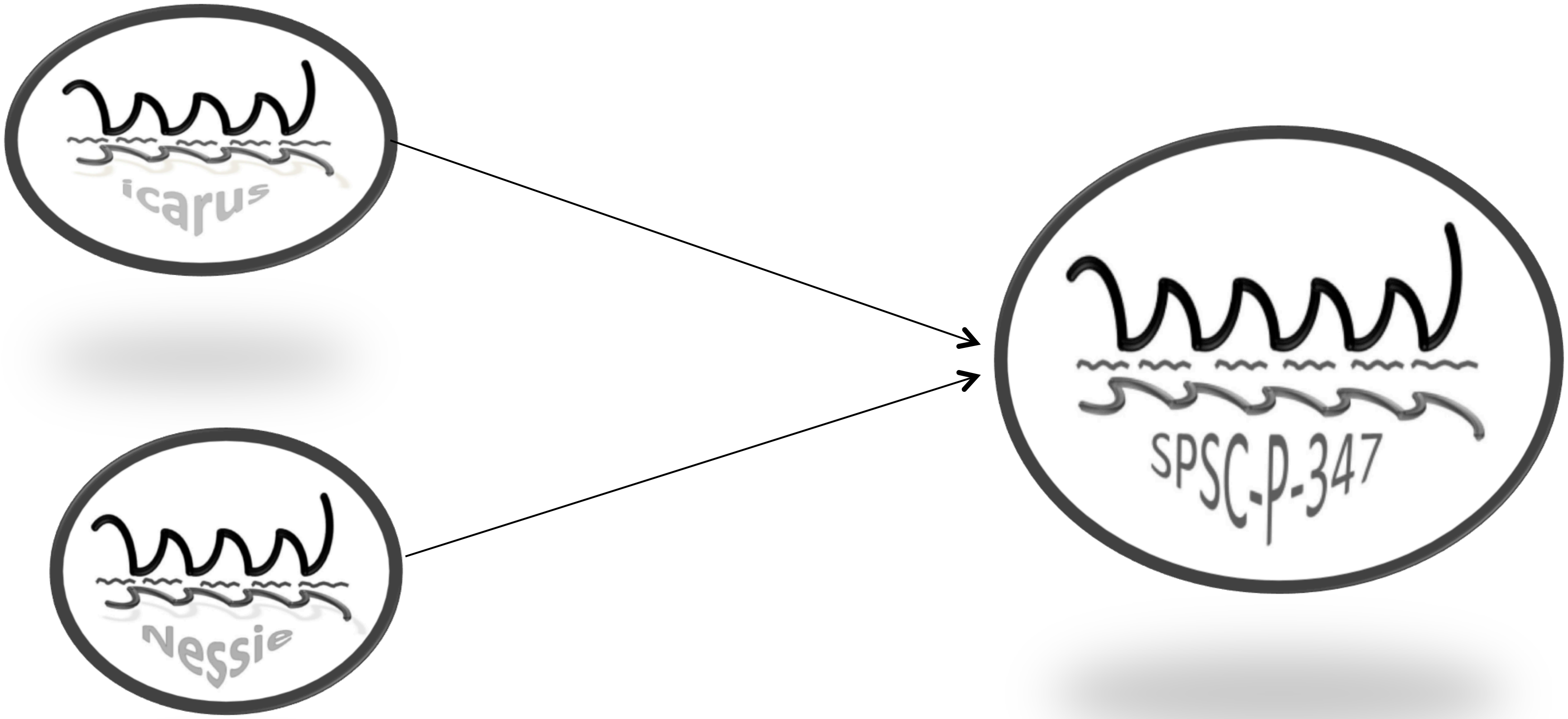
AND with ≥ 2 sites

in Appearance (ν_e)
AND
in Disappearance (ν_μ)

2^3 combs

L.Stanco©

Thank you !



BACKUP slides

Are neutrino a simple “carbon copy” repetition of quarks?

- Over the last several years, neutrinos have been the origin of an impressive number of “Surprises”:
  - Mass differences, once zero “by ignorance”, are important
  - Large mixing oscillations
  - Oscillations due to matter exist, due to neutral currents
- But this isn't all ! Important discoveries may be ahead:
  - CP violation in the lepton sector, following the $\theta_{13} >> 0$ result
  - Majorana or Dirac ν's ?; ν-less β-decay
  - Actual values of ν-masses
  - Right handed neutrinos and see-saw mechanisms
  - Sterile neutrino and other “surprises”
- Of course the astronomical importance of neutrinos in space is immense, so is their role in the cosmic evolution.
- Just a few eV neutrino may be the source of the dark mass.

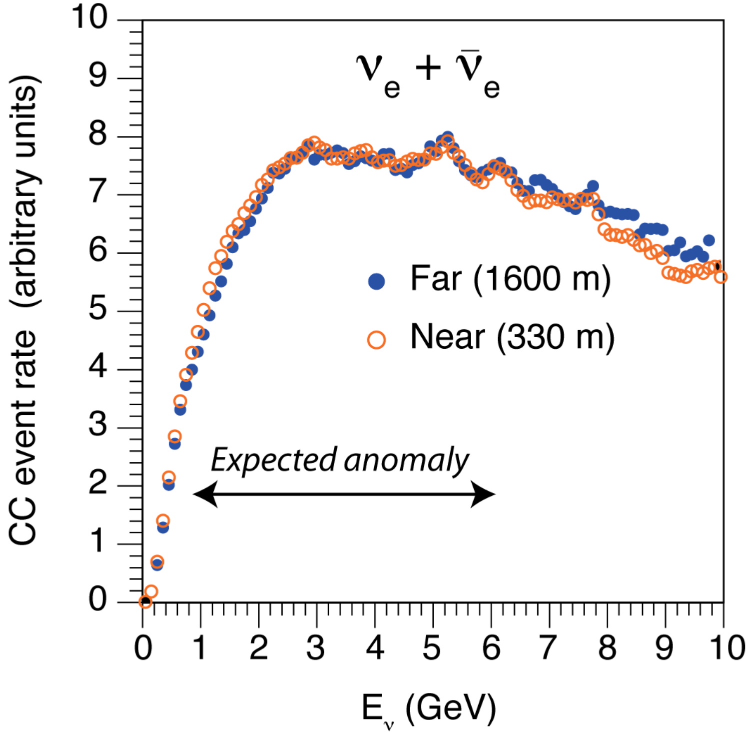
Future sterile neutrino searches elsewhere

- **Radioactive sources** (EC, fission fragments) plus low energy detectors to search for ν_e, anti-ν_e disappearance. Elastic Scattering: Daya Bay, Borexino, SNO+Cr; Charged Current: LENS, Baksan, Ce-LAND, Borexino; Neutral Current: RICOCHET. Most use existing detectors.
- **Reactors.** Several ideas for new reactor experiments. Some, piggy-backing on safe guards measurements are under construction: Nucifer, SCRAAM, Stereo. Need to be very close to reactor core. Small cores advantageous.
- **Stopped π Beams:** (Direct test of LSND anomaly): OscSNS: Improved LSND (Off beam axis, lower duty factor, gadolinium?); LSND-Reloaded: Gd-loaded Super-K plus cyclotron. What if LSND is new physics but not oscillations?
- **Decay in Flight Beams:** MicroBooNE, BooNE, LArLAr, VLENF: the CERN idea of a two-detector experiments is now also considered in order to clarify the MiniBooNE/LSND anomaly.

(visit http://cnp.phys.vt.edu/white_paper/)

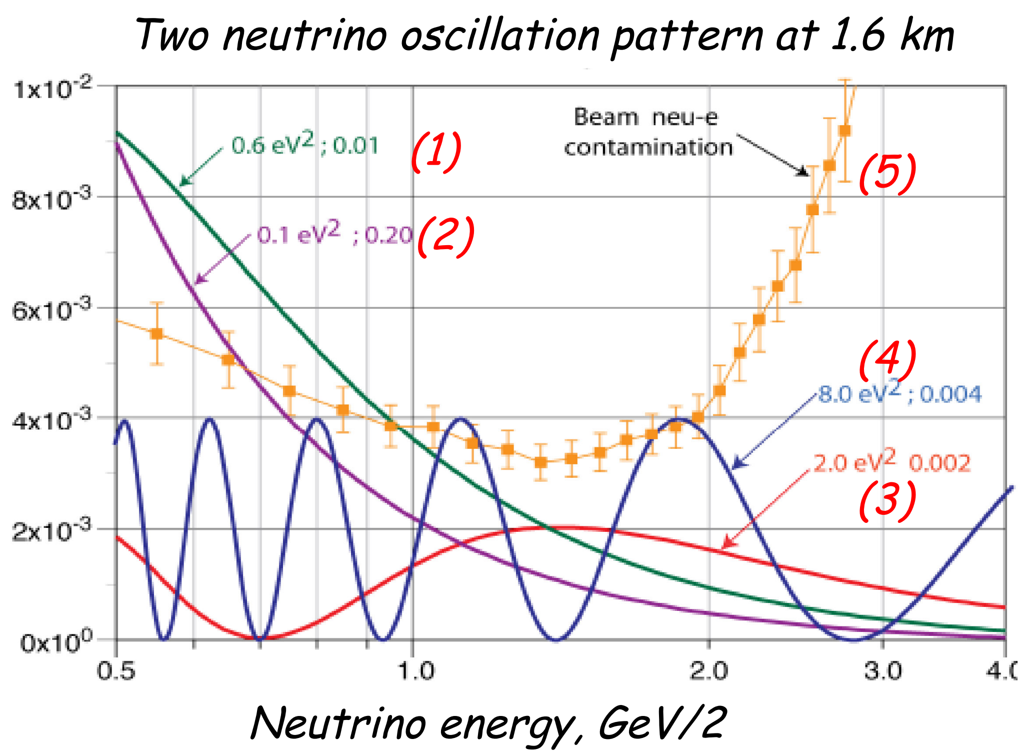
Unique features of the CERN beam

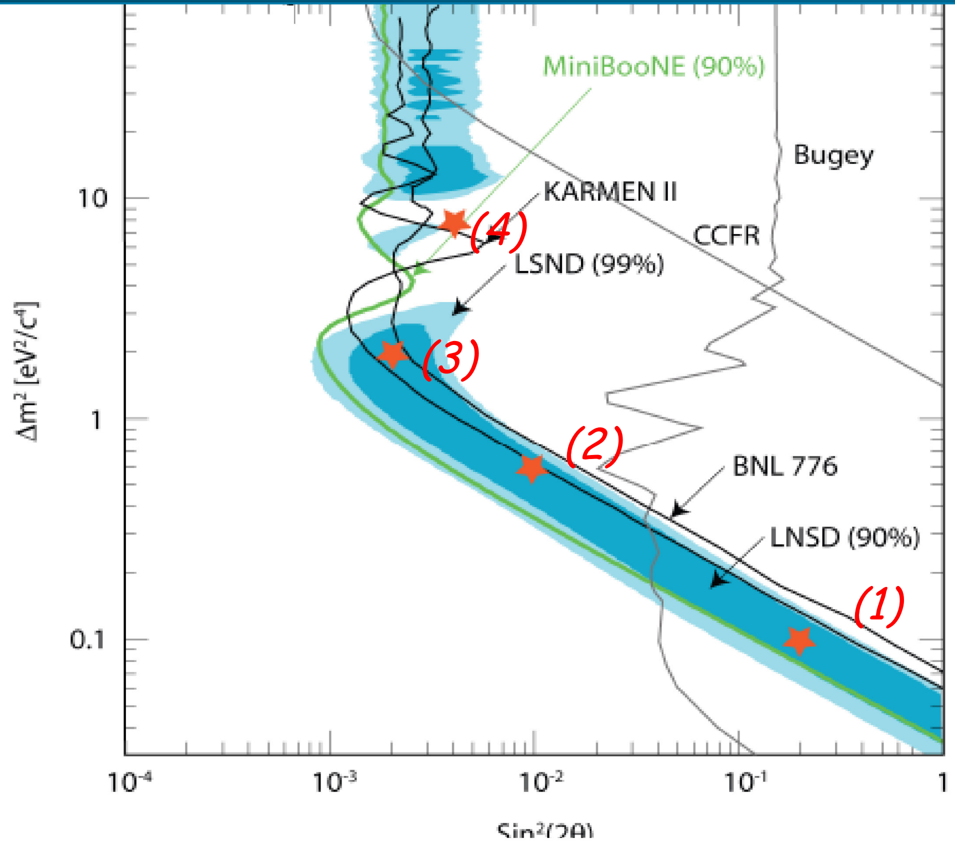
- The present proposal is a search for spectral differences of electron like specific signatures in *two identical detectors* but at two different neutrino decay distances.
- *In absence of oscillations*, apart some beam related small spatial corrections, the two spectra are a precise copy of each other, *independently of the specific experimental event signatures and without any Monte Carlo comparisons*.
- Therefore an exact, observed proportionality between the two ν_e spectra implies directly the absence of neutrino oscillations over the measured interval of L/E.



Precise identity of ν-e events in the near and far positions

LSND direct determination of mass and mixing angle





- The present method, unlike LNSD and MiniBooNE, determines both the mass difference and the value of the mixing angle.
- Very different and clearly distinguishable patterns (1-4) are possible, depending on the values in the (Δm^2 – $\sin^2 2\theta$) plane.
- The intrinsic ν -e background (5) is also shown.