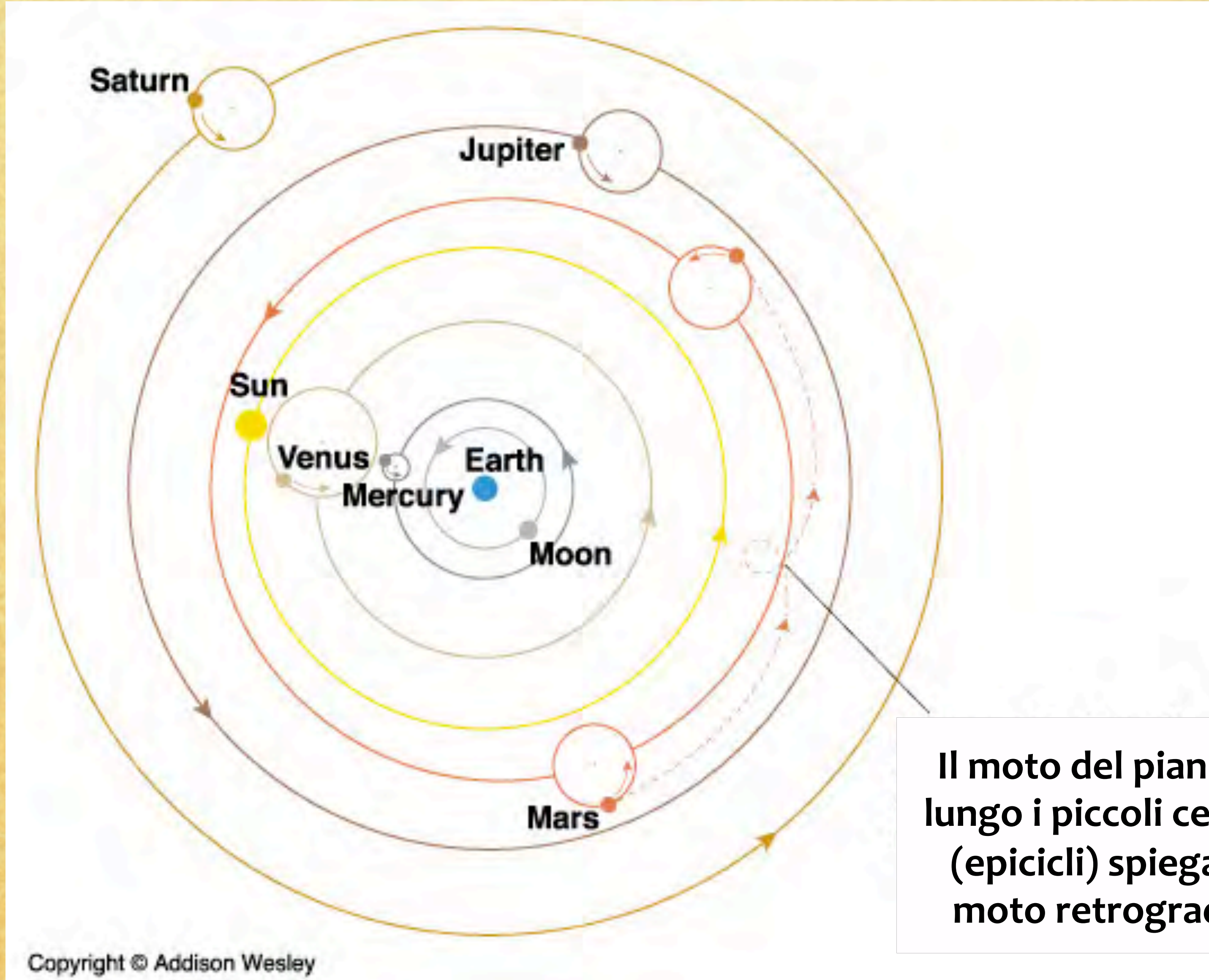
Neutrino Telescopes 2011 Highlights

M.Laveder **CSN2 @ Frascati - 11 aprile 2011**

Il cannocchiale di Galileo sembra infrangere le incorruttibili sfere e rimuovere l'orizzonte

Il nuovo cannocchiale !

La soluzione Tolemaica



Il moto del pianeta lungo i piccoli cerchi (epicicli) spiega il moto retrogrado

Unknowns:

θ_{13}, δ_{CP}, sign(Δm^2), m_ν , Majorana ν, ...and a deeper understanding of flavor!

[Minos] [T2K] [NOvA]
[Opera] [SN ν]
[Icarus] [New detectors, new facilities, new beams]

[DChooz]
[DayaBay]
[RENO]

[Melchiorri]

[Iachello]
[Gomez-C.]
[CUORE]
[GERDA]
[KL-Zen]

[Dark Matter]
[Astro sources]

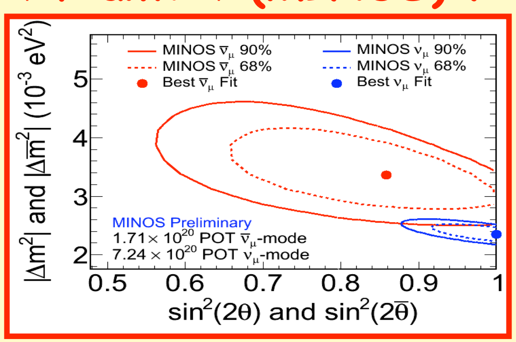
[King]
[Di Bari]

[Paradisi]
[MEG]

Some "mismatches:"

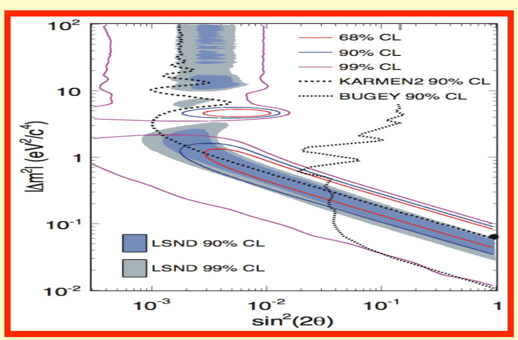
[Corwin] [Maltoni]

ν / anti-ν (MINOS) ?



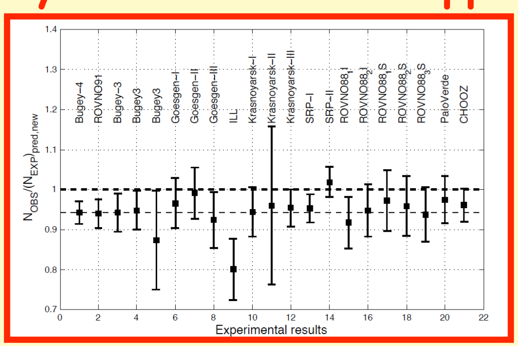
[Mills] [Rubbia] [Giunti] [Lasserre]

LSND/MiniBooNE ?



ν_S?

very SBL reactor disapp.?



The rich NEUTEL 2011 program (talks and posters) reflects an evolving field, open to surprises and challenges, both within and …

…beyond the standard 3ν framework

But that's a land with no boundaries…

So, let me discuss just two examples of possible **surprises** and **challenges** in ν non-oscillation and oscillation physics

Results from Super-Kamiokande

Jeffrey Wilkes
University of Washington
For the Super-K collaboration*

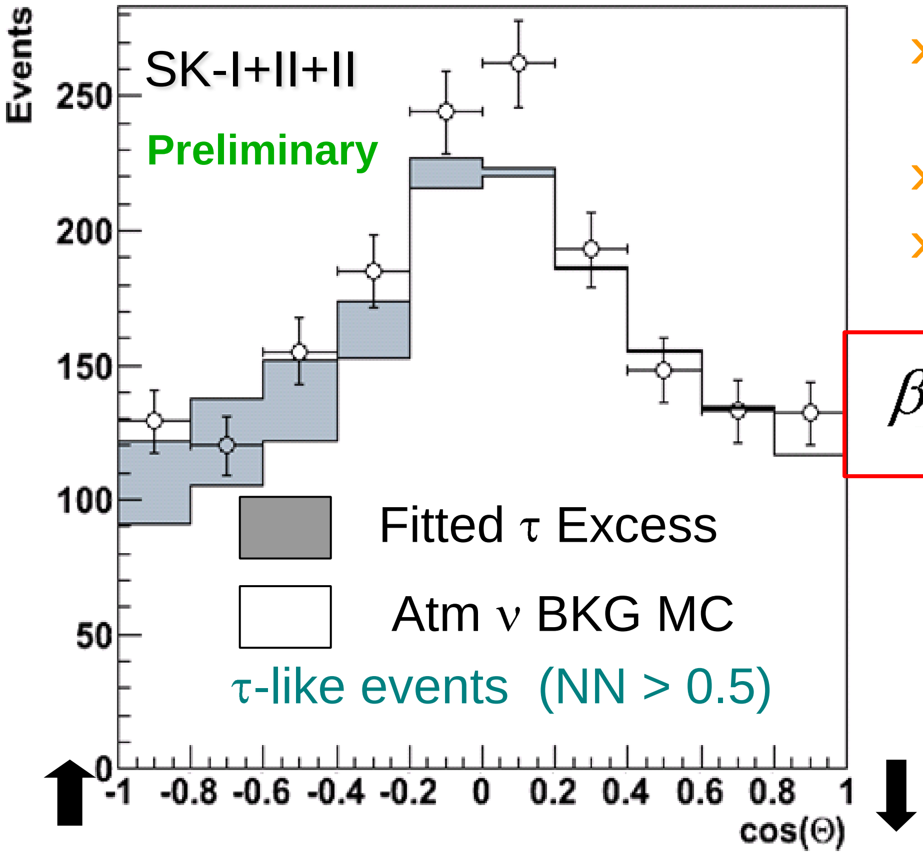
15-Mar-2011, Neutel11

* Thanks to many colleagues for slides; errors are all mine

Fit Results

If no τ appearance , $\beta = 0$

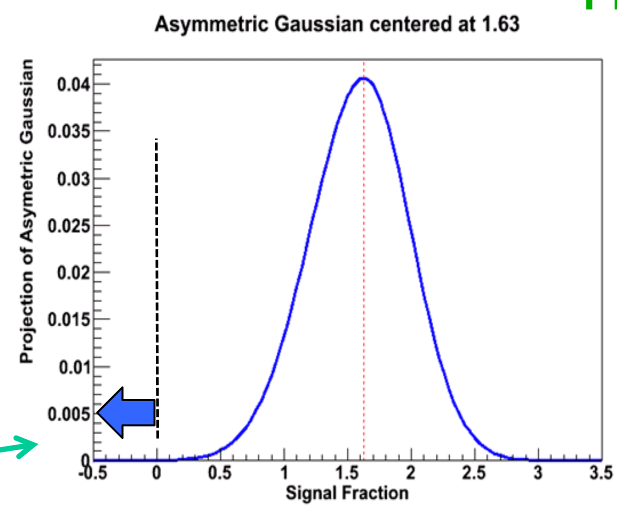
$$Data = \alpha(\gamma) \times bkg + \beta(\gamma) \times signal$$



- Tau signal clearly appears in upward-going region
- DIS fits to +1 σ
- τ normalization fit is 1.63 × expectation

$$\beta = 1.63 \pm 0.35_{(stat)} \,{}^{+0.10}_{-0.08}\,(sys)\,{}^{+0.02}_{-0.22}\,(3\,flav)$$

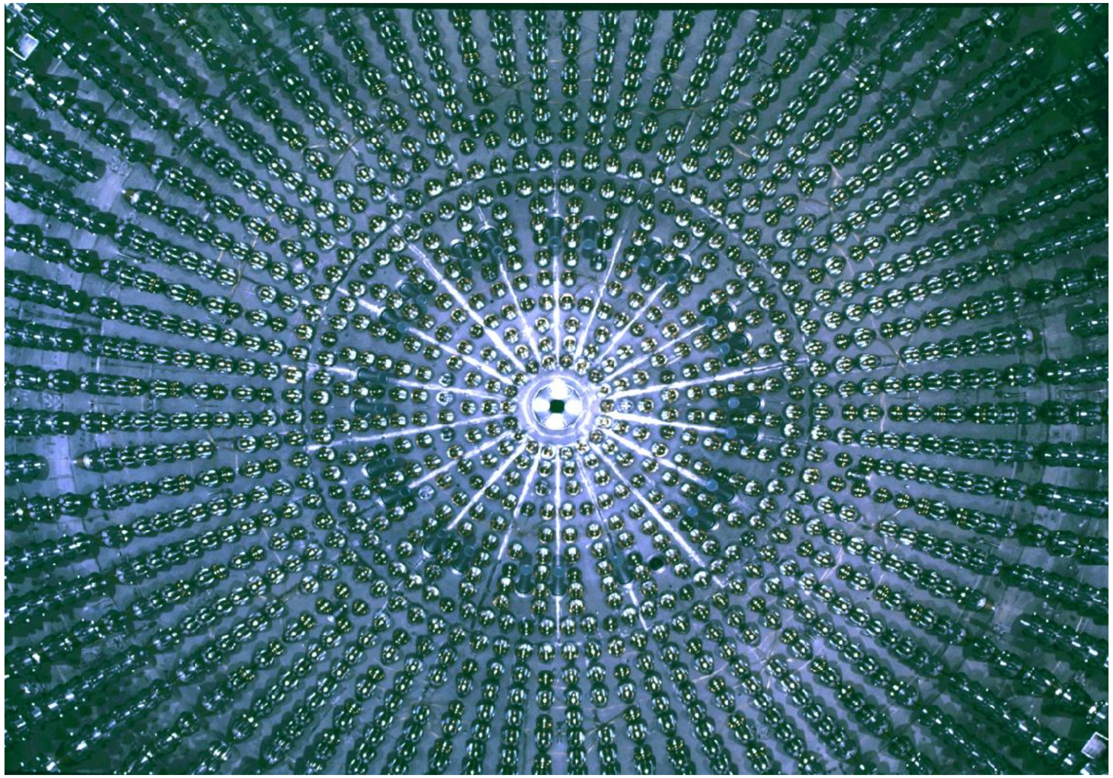
Preliminary



(This corresponds to 213.6 τ Events)
Measure of significance: Area under asymmetric Gaussian centered at β=1.63, for $\beta < 0$ (= no τ appearance)

SK data are ***inconsistent*** with ***no*** τ appearance at 3.8σ

Neutrino Physics with the Borexino experiment



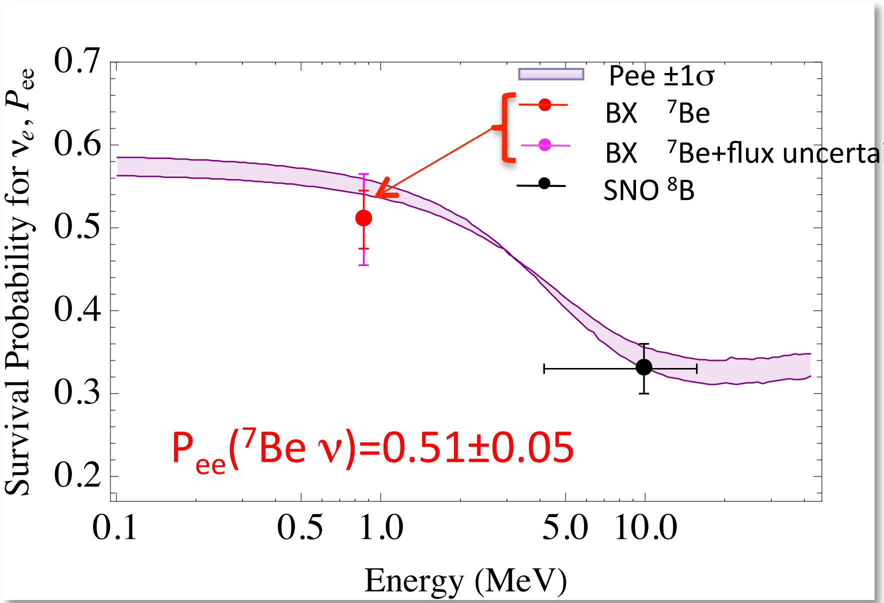
Emanuela Meroni
On behalf of the Borexino Collaboration

Hypothesis	Expected rate (cpd/100t)
No oscillation +High Metallicity	74±4
No oscillation + Low Metallicity	67±4
Oscillation MSW + High Metallicity	48±4
Oscillation MSW + Low Metallicity	44±4

BX measurement confirms oscillations but cannot discriminate between High and Low metallicity

46.0 ± 1.5 (stat) ± 1.3 (sys)

Survival probability for solar neutrinos



The day night preliminary result

- The ^{7}Be flux is obtained from the separated full fit of the day and night spectra

- Preliminary (and conservative) result: $$A_{DN} = 2\frac{\Phi_n - \Phi_d}{\Phi_n + \Phi_d} = 0.007 \pm 0.073(stat)$$

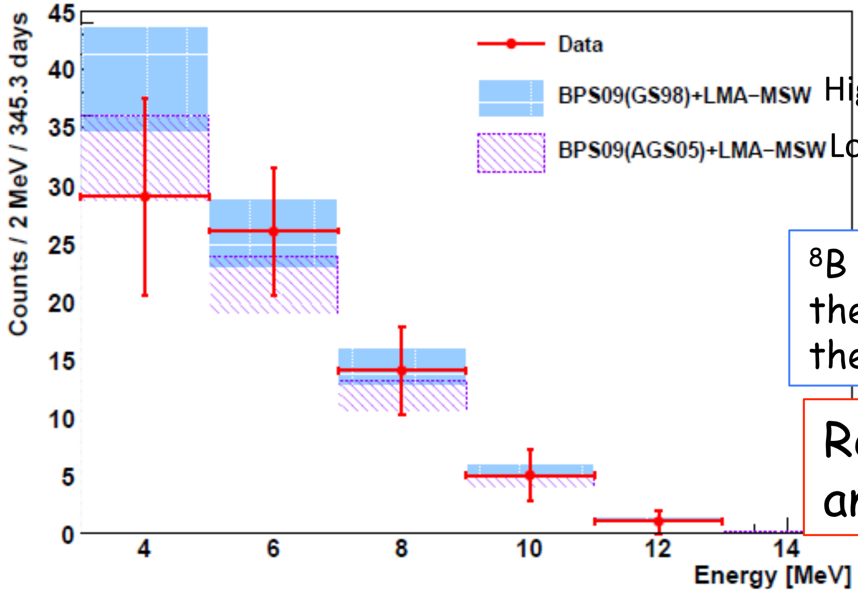
➢ A_{DN} is well consistent with zero: further confirmation of the LMA!

- Unique measurement for solar ^{7}Be neutrinos

- Result not sensitive to many systematic effect influencing the ^{7}Be absolute measurement

⇨ More refined analysis is in progress aiming to reduce the error

^{8}B ν with 3 MeV energy threshold in Borexino



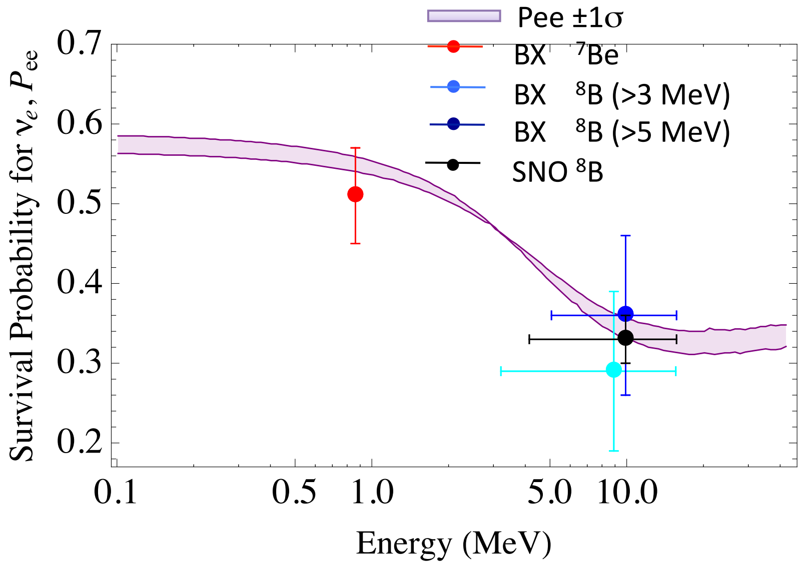
High metallicity

Low metallicity

^{8}B solar neutrinos: electron recoil spectrum after the background subtraction and comparison with the models

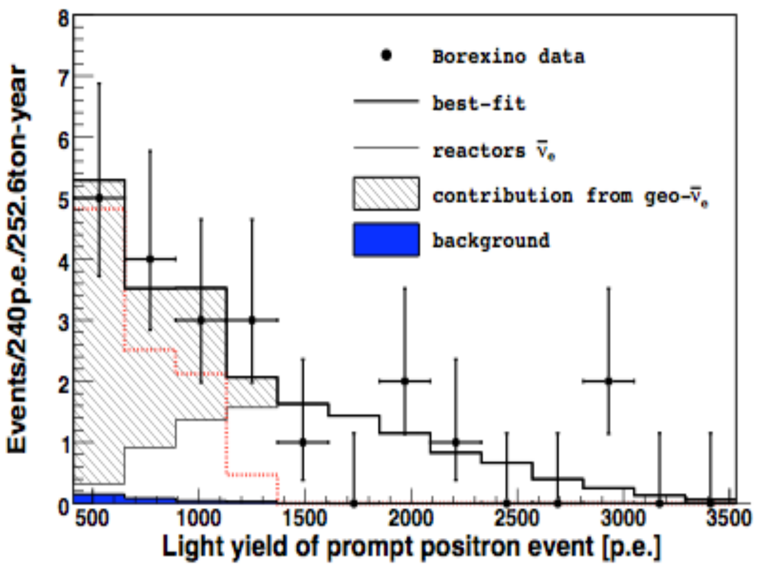
Results in agreement with LMA-MSW and solar models

Probing for the first time with the same experiment the Pee in the vacuum regime (^{7}Be neutrinos) and in the matter-enhanced regime (^{8}B neutrinos);



GeoNeutrino Results:

- 21 candidates selected
- exposure= 483 live days (252.6 ton-year after all cuts) December 07 – December 09



- Extract signal with an unbinned maximum likelihood fit using reference MonteCarlo shapes for both geo-neutrinos and reactor neutrinos, since small statistics;
- just the result is plot in a binned spectrum;
- result of the fit: amplitudes of the geo and reactor anti-ν spectra;

68.3 % 99.7%

$$N_{geo} = 9.9^{+4.1}_{-3.4}{}^{+14.6}_{-8.2}$$

68.3 % 99.7%

$$N_{react} = 10.7^{+4.3}_{-3.4}{}^{+15.8}_{-8.0}$$

- the first clear observation of geoneutrinos at 4.2σ ;
- the rate is measured with 40% precision;
- confirmation/exclusion of geological models limited by the statistics;
- confirmation of oscillations (reactor antinu) at 1000 km @ 2.9σ;
- georeactor in the Earth core with > 3 TW rejected at 95% C.L.;

March 15, 2011

XIV International Workshop on “Neutrino Telescopes”

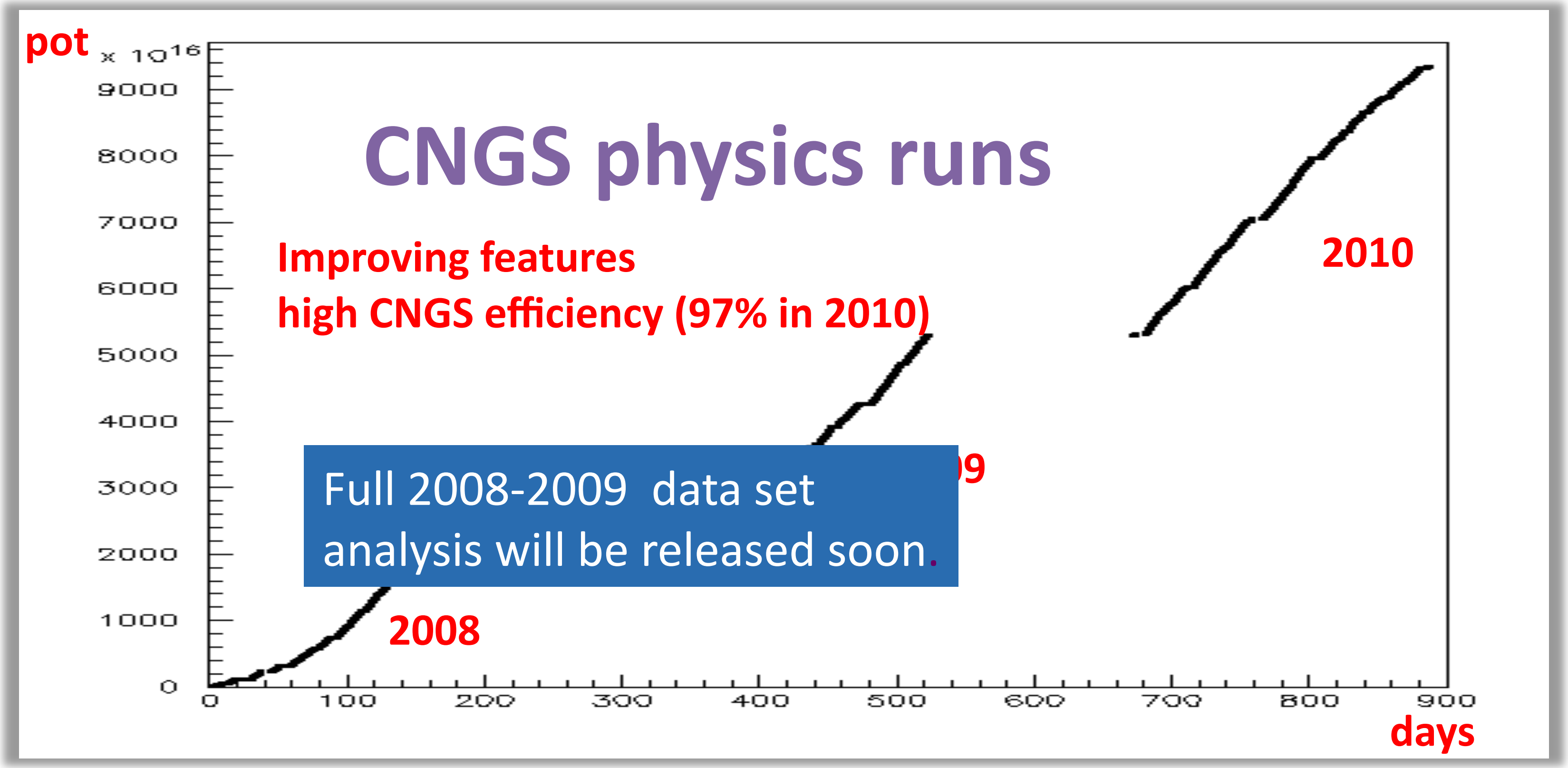
OPERA

- The OPERA experiment
  - The physics case
  - Detector description
- Experimental results
  - Oscillation physics
    - → First ν_τ candidate event — Physics Letters B 691 (2010) 138
    - → $\nu_\mu \leftrightarrow \nu_e$??
  - Non-Oscillation physics
    - → Atmospheric muon charge ratio — EPJC 67 (2010) 25
    - → Atmospheric neutrinos??

Summary & Outlook

L Patrizii on behalf of the OPERA Collaboration

INFN - Bologna



year	beam days	protons on target	SPS eff.	events in the bricks
2008	123	1.78×10^{19}	61%	1698
2009	155	3.52×10^{19}	70%	3693
2010	187	4.04×10^{19}	81%	4248
TOTAL	465	**9.34×10^{19}**	<71%>	**9639**

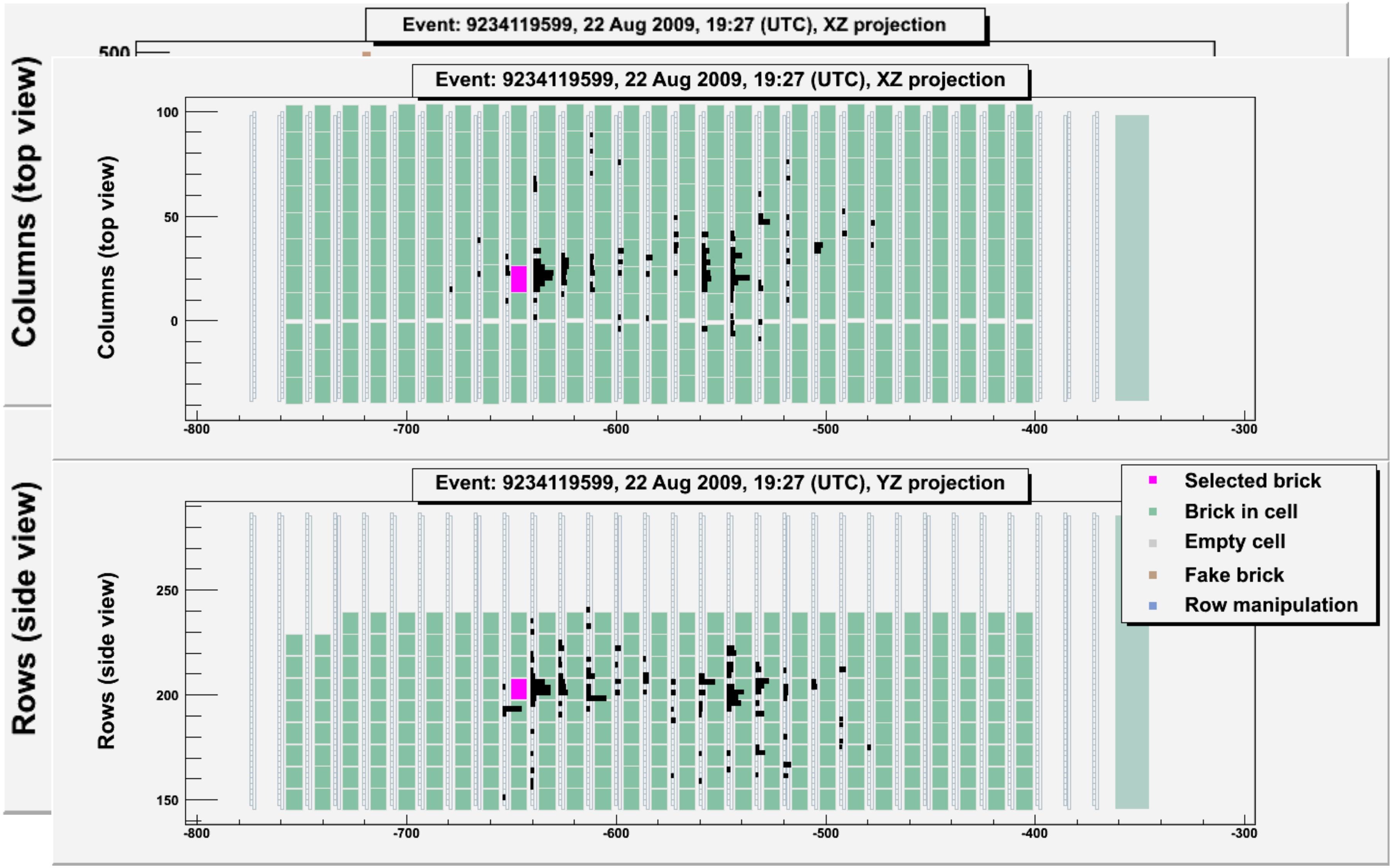
2.1 nominal CNGS years

NB. In what follows results refer to data released in physics publications **1088 (187 NC)** **1.85×10^{19} p.o.t. , 35% of 2008-'09 statistics, 20% of the total)**

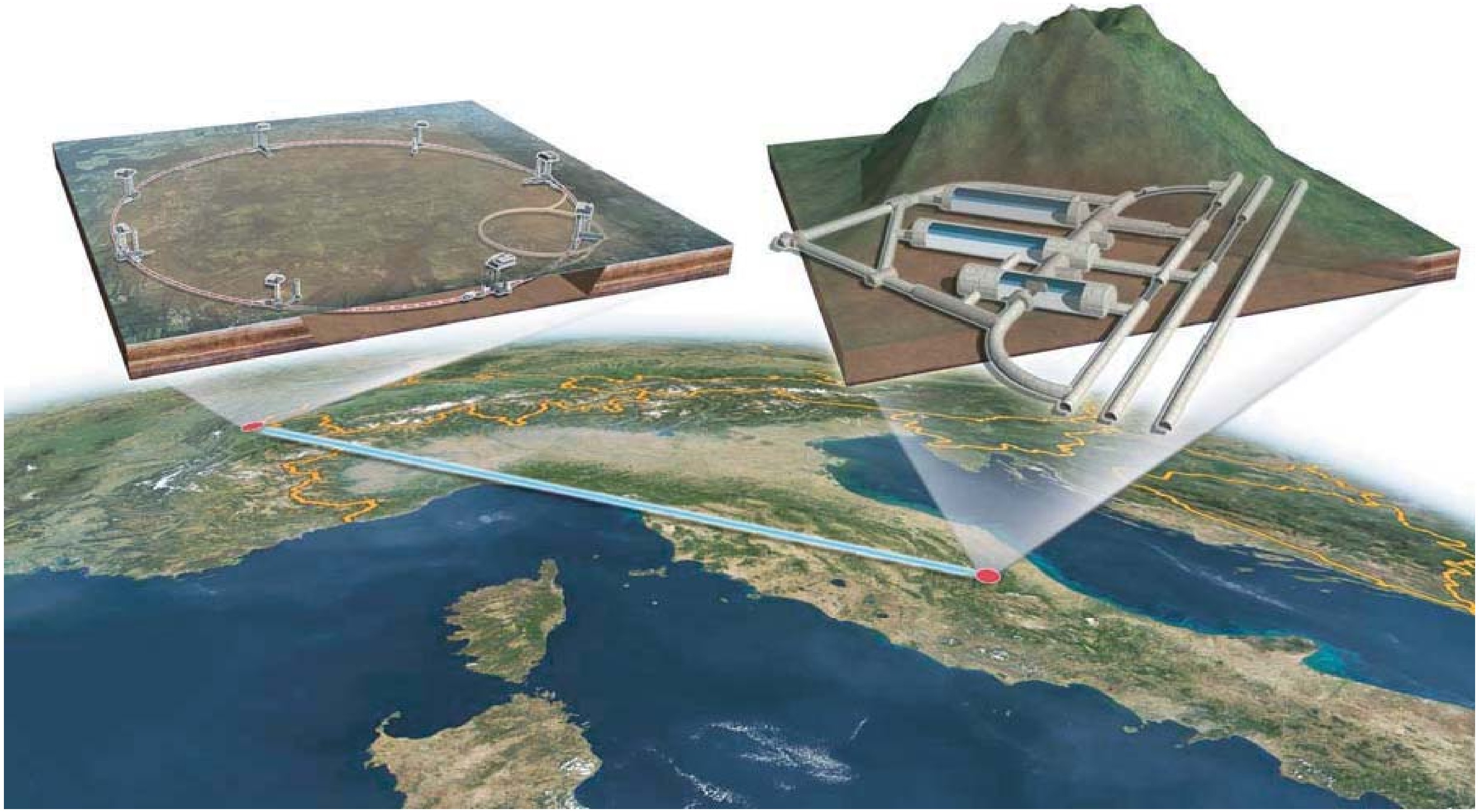
With that limited statistics, for $\Delta m^2_{23} = 2.5 \times 10^{-3}$ eV^2 and full mixing OPERA expected ~ 0.5 ν_τ events

The first ν_τ candidate event

Phys. Lett. B 691 (2010) 138



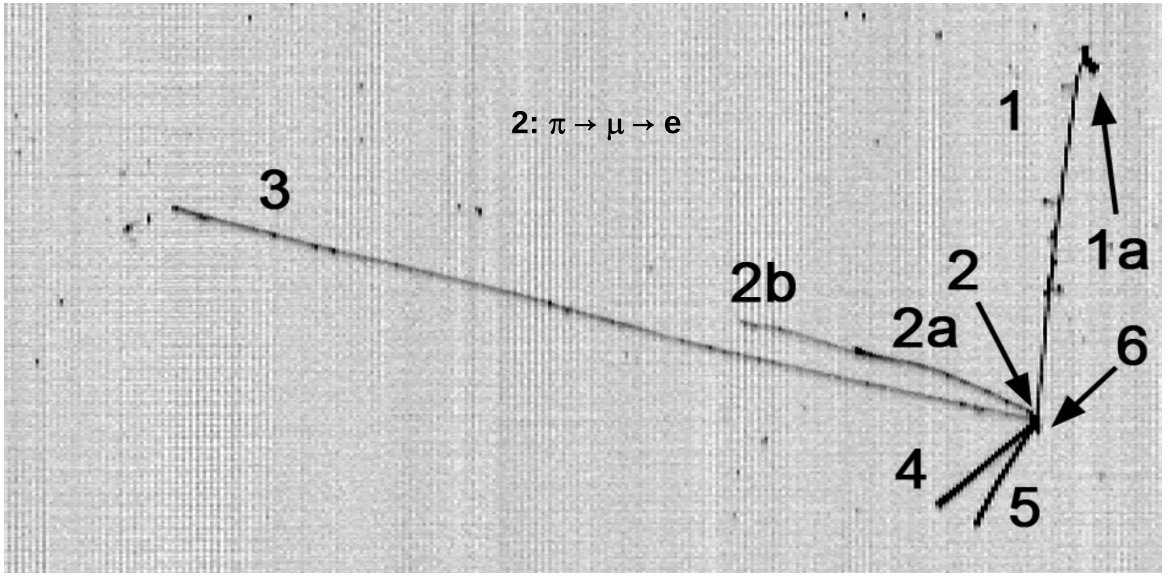
ICARUS and Status of Liquid Argon Technology

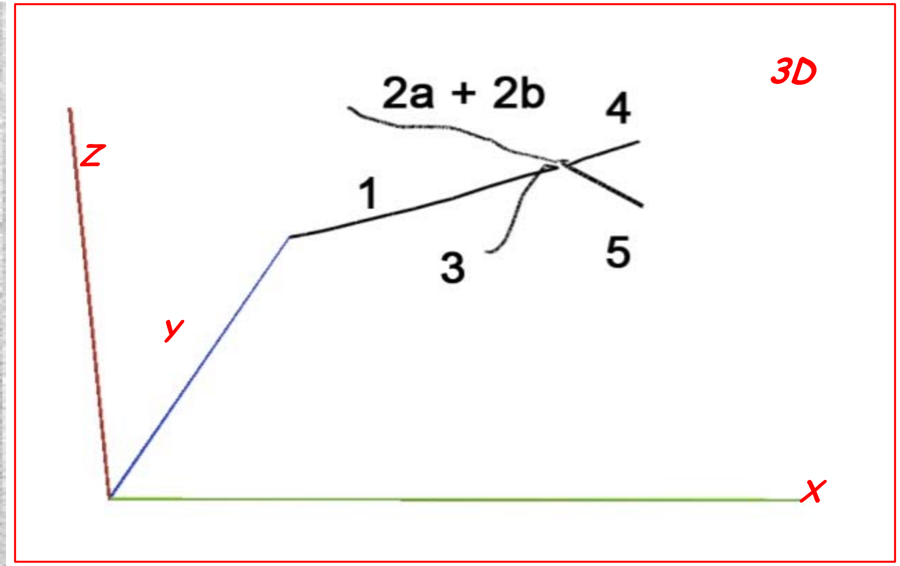


F. Pietropaolo (INFN-PD)
for the ICARUS Collaboration

Venezia, 15-03-2011

Run 9392 Event 106





Track	E_k [MeV]	Range [cm]
1 (prob. π, decays in flight)	136.1	55.77
2 (π)	26	3.3
2a (μ)	79.1	17.8
2b (e)	24.1	10.4
3 (μ)	231.6	99.1
4 (p)	168	19.2
5 (p)	152	16.3
6 (?) (merged with vtx)		2.9

- Total deposited energy: 887 MeV
- Total reconstructed momentum: 929 MeV/c at about 35° away from the CNGS beam direction

Preliminary results of first CNGS 2010 run

- Analyzed sample: 1494 CNGS triggers, i.e. $4.54 \cdot 10^{18}$ pot = 78 % out of whole sample. Classified by visual scanning into fiducial volume of 434 t.
- Number of collected interactions compared with number of interactions predicted ((2.6 ν CC + 0.86 ν NC) 10^{-17}/pot), in the whole energy range up to 100 GeV, corrected by fiducial volume and DAQ dead-time.

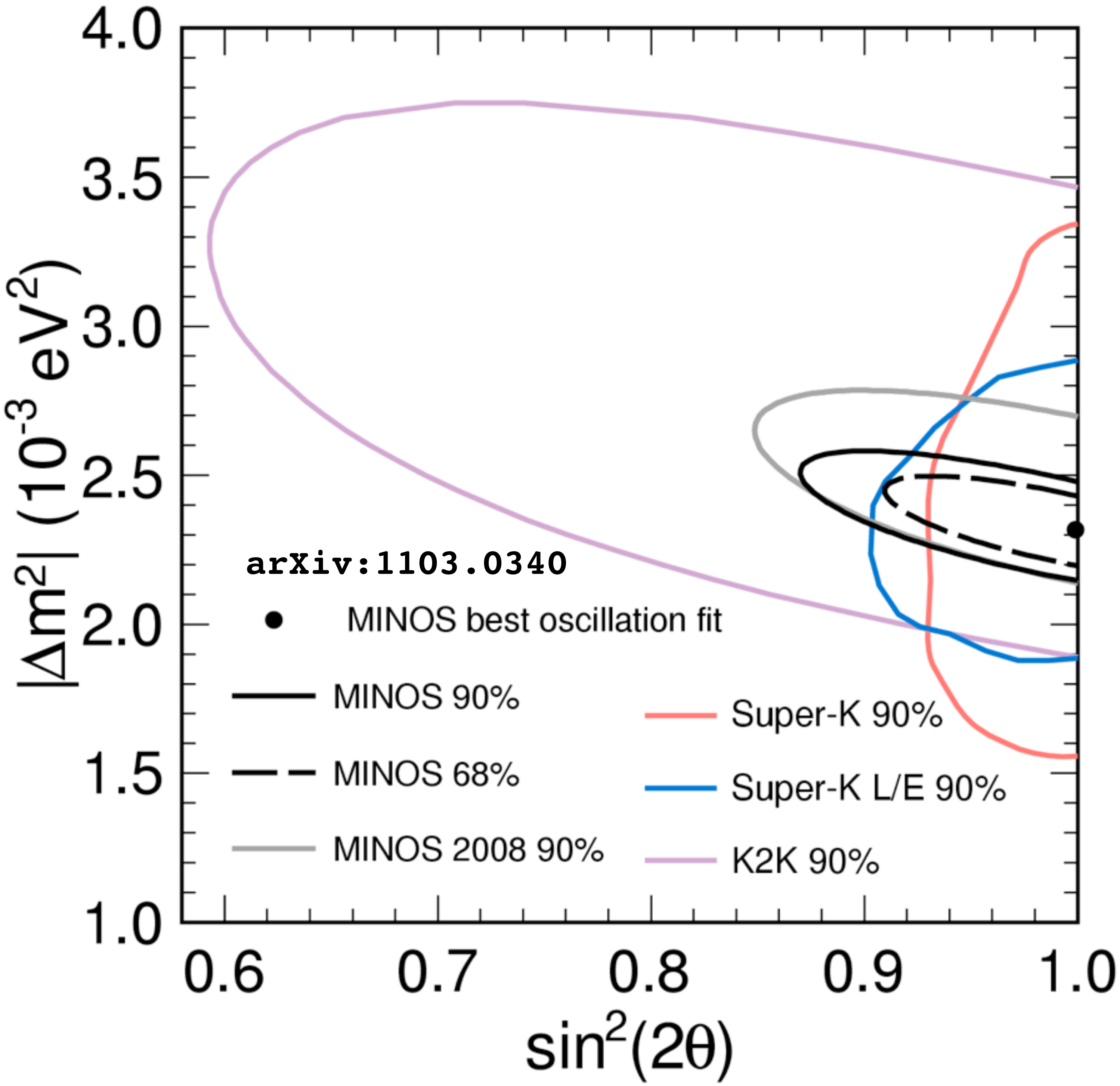
Event type	Collected	Expected
ν_μ CC	94	98
ν NC	32	31
ν XC *	6	-
Total	132	129

* Events at edges, with μ track too short to be visually recognized: further analysis needed.

On overall statistics in agreement with expectations.

MINOS

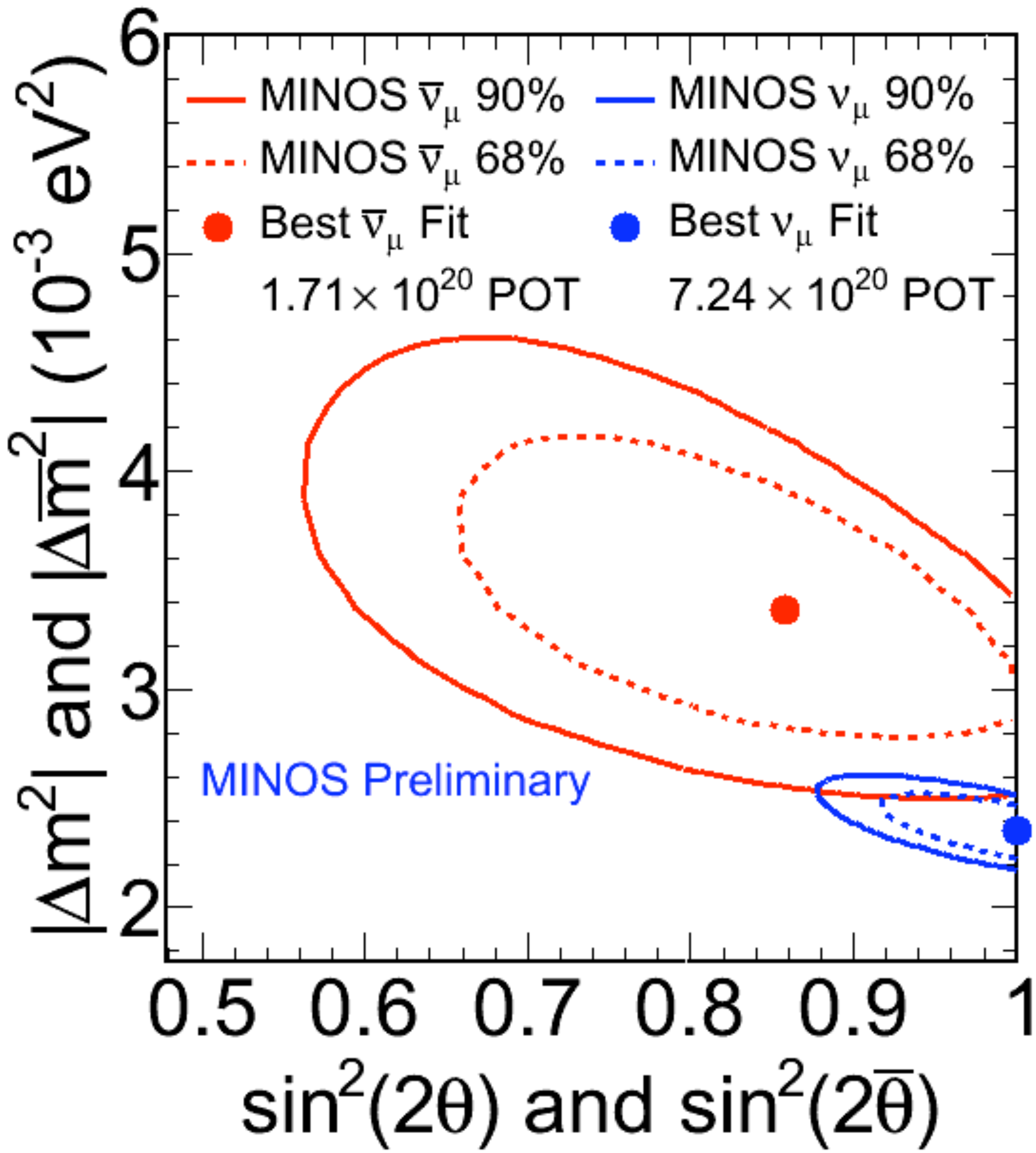
Luke A. Corwin, for MINOS Collaboration
Indiana University
XIV International Workshop On Neutrino Telescopes
2011 March 15



$$|\Delta m^2| = 2.32^{+0.12}_{-0.08} \times 10^{-3} \mathrm{eV}^2$$

$$\sin^2(2\theta) > 0.90 (90\%\ C.L.)$$

- Pure decoherence disfavored at 9σ
- Pure decay at 7σ
- World's most precise $|\Delta m^2|$ measurement
- Included Samples
  - Fiducial Events
  - Events outside fiducial volume
  - Muons from neutrino events in rock



- Interesting Tension (2.3σ difference)
- Plan to have at least double current data set by this Summer.
  - Data taking interrupted by target failure on Feb. 26
  - Plan to have new target in April

Results from the MiniBooNE Experiment

Geoffrey Mills

Los Alamos National Laboratory

For the MiniBooNE Collaboration

NeuTel2011

Venezia, Italia

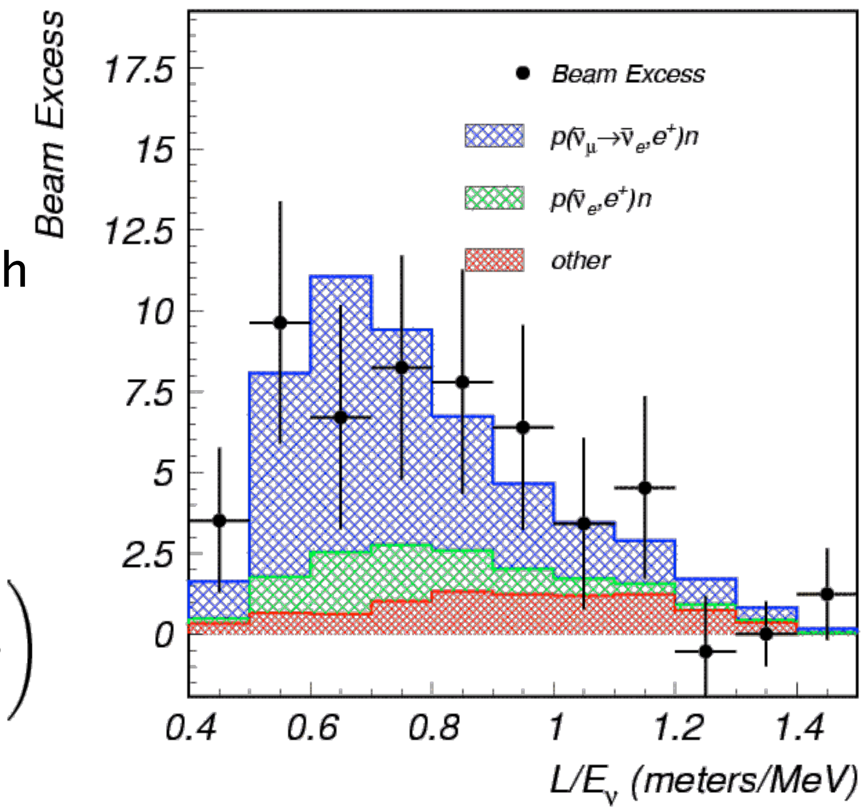
Motivation....

Excess Events from LSND still remain:

- LSND found an excess of $\overline{\nu}_e$ in $\overline{\nu}_\mu$ beam
- Signature: Cerenkov light from e^+ with delayed n-capture (2.2 MeV)
- Excess: 87.9 ± 22.4 ± 6.0 (3.8s)
- *The data was analysed under a two neutrino mixing hypothesis**

$$P(\overline{\nu}_\mu \to \overline{\nu}_e) = \sin^2(2\theta)\sin^2\left(\frac{1.27\, L\, \Delta m^2}{E}\right)$$

$$= 0.245 \pm 0.067 \pm 0.045\ \%$$

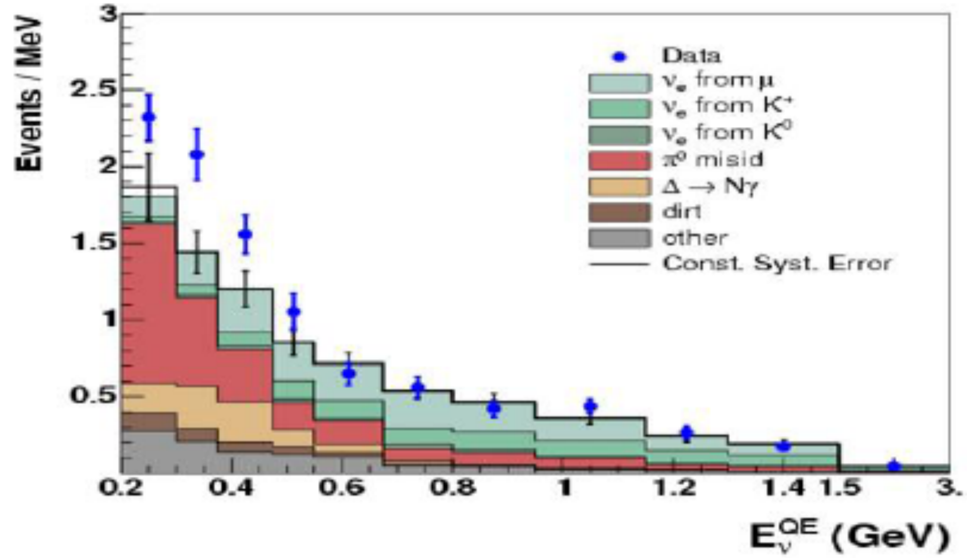


KARMEN at a distance of 17 meters saw no evidence for oscillations →low Δm^2

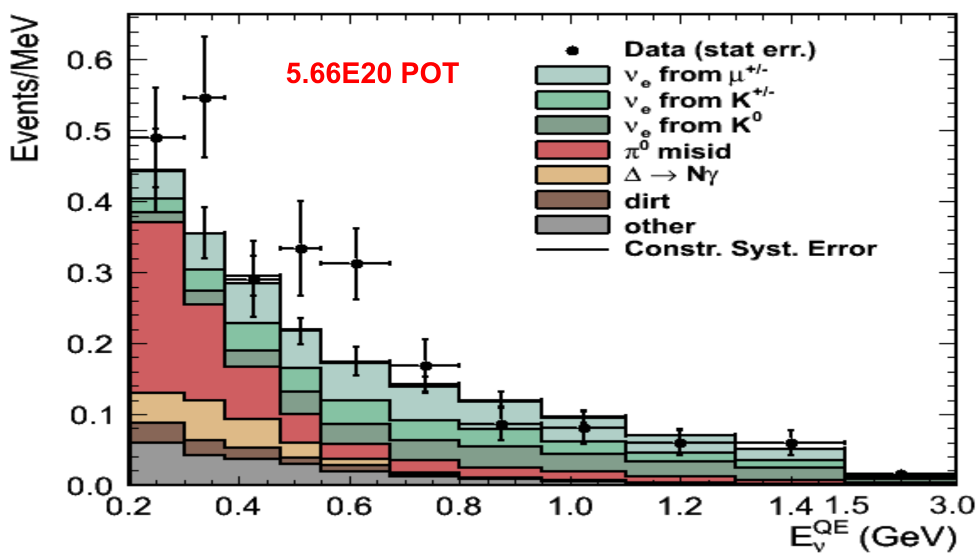
*3 active + ≥2 sterile vs needed to fit all appearance and disappearance

MiniBooNE ν_e and $\bar{\nu}_e$ Data

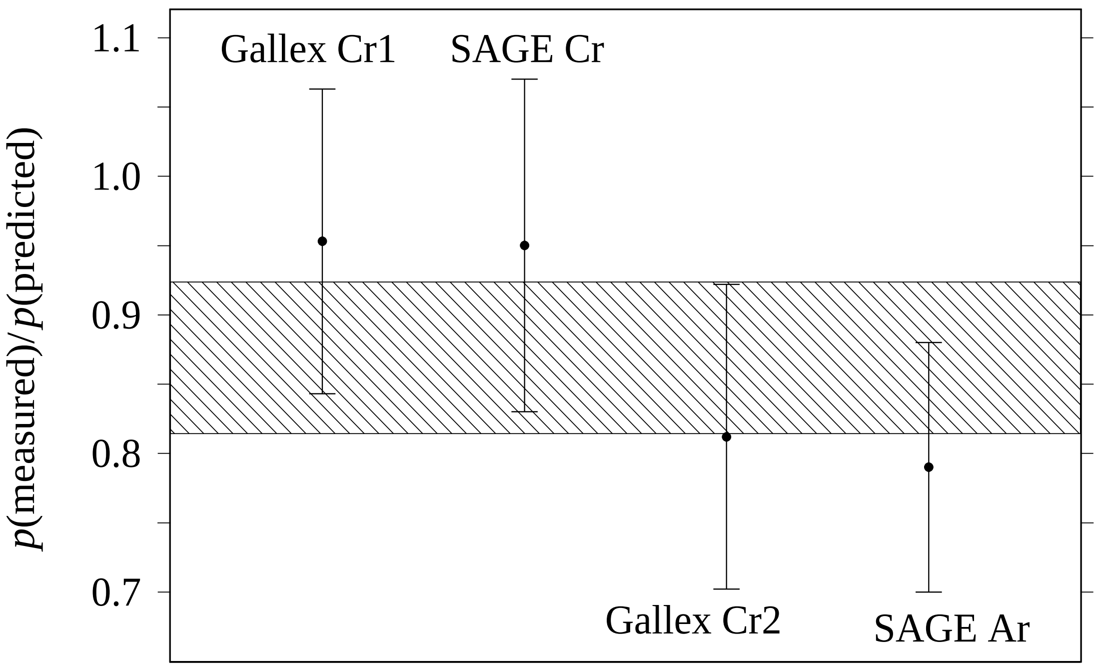
ν Mode



$\bar{\nu}$ Mode



ν_e Disappearance in Gallium radioactive source experiments



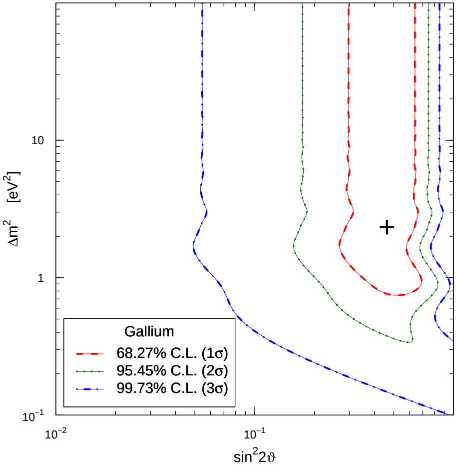
$R \equiv$ wheighted average value of the ratio of measured and predicted ^{71}Ge production rates (p) :

$$R \equiv \frac{\mathrm{p(measured)}}{\mathrm{p(predicted)}} = 0.87 \pm 0.05$$

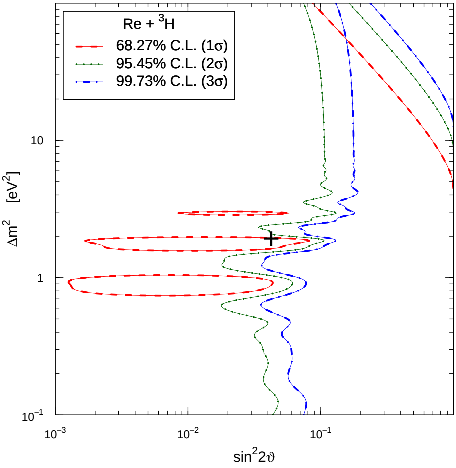
arXiv:0901.2200[nucl-ex]

Ga radioactive source exp. results may be interpreted as an indication of the disappearance of ν_e due to active-sterile oscillations!

hep-ph/0610352 Carlo Giunti & ML



[Giunti, Laveder, arXiv:1006.3244]



[Giunti, Laveder, PRD 82 (2010) 053005, arXiv:1005.4599]

$\Delta m^2_{SBL} \gtrsim 1\,eV^2$ is OK, but $\sin^2 2\vartheta_\nu > \sin^2 2\vartheta_{\bar\nu}$

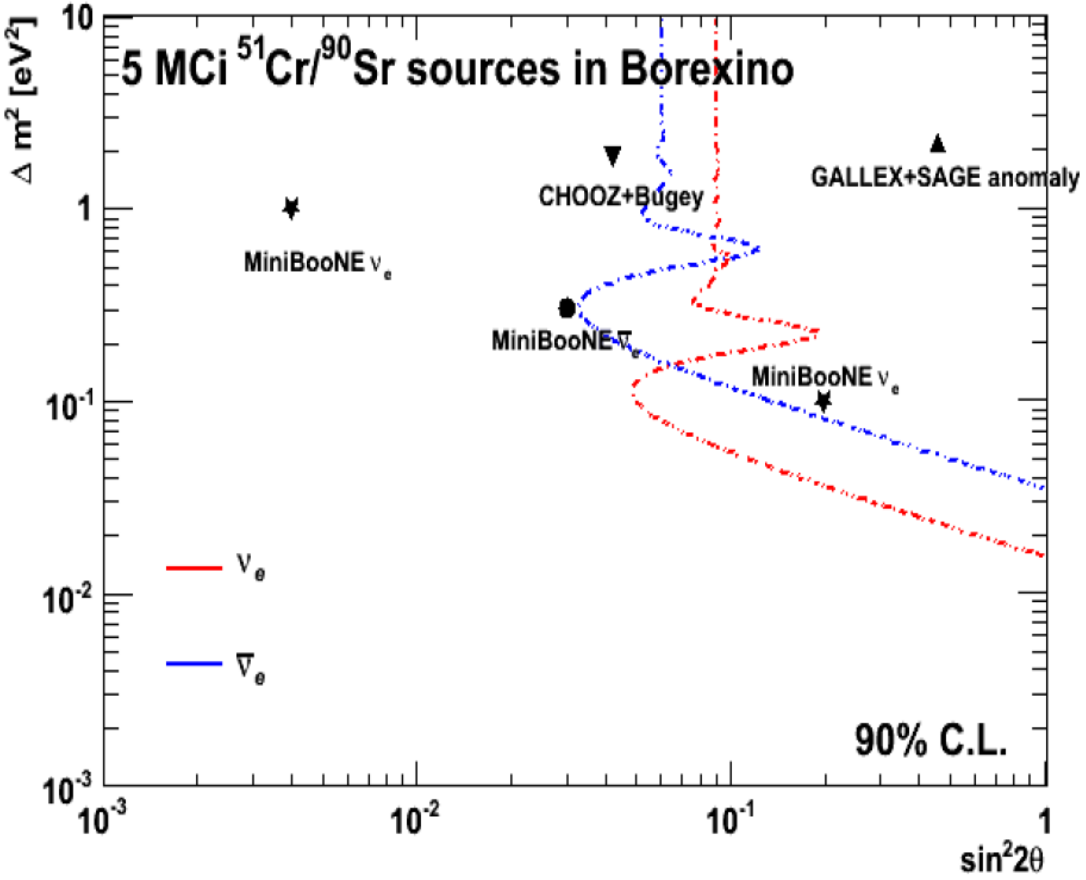
Parameter Goodness of Fit = 0.2%

CPT violation? [Giunti, Laveder, PRD 82 (2010) 113009, arXiv:1008.4750]

Borexino test exp

▶ Borexino:

[Ianni, Montanino, Scioscia, EPJC 8 (1999) 609, arXiv:hep-ex/9901012]



[A. Ianni, Private Communication]

Two-zone Ga source experiment

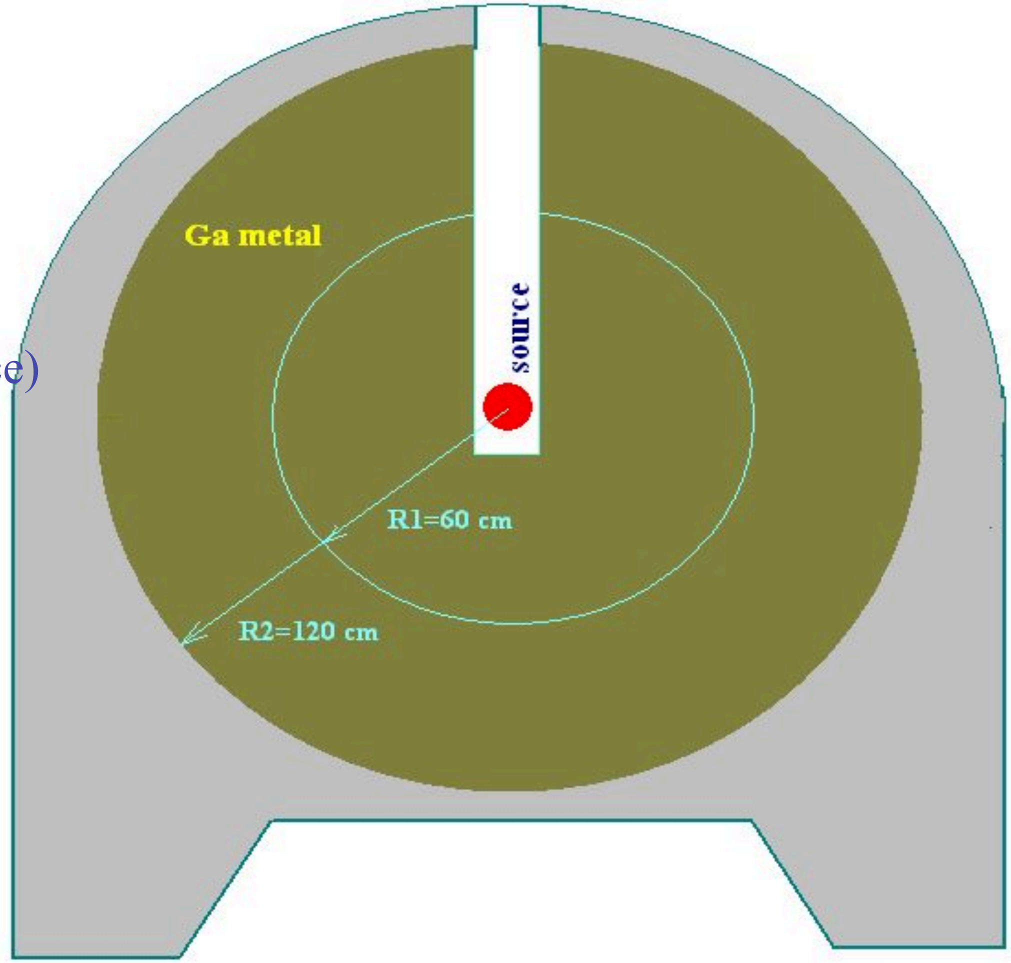
To get additional information in source experiment we separate the SAGE Ga target (50 tons) on two independent spherical zones.

It gives:

dependence on distance of source (test of ν_e disappearance)

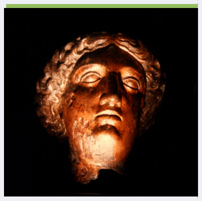
additional possibilities for statistical analysis

For two zones of target with thickness 60 cm each, the total uncertainty for each zone will be 5-5.5%, and statistical error of combined result will be about 3%



MINERνA

Prospects and Status



NEUTEL 2011

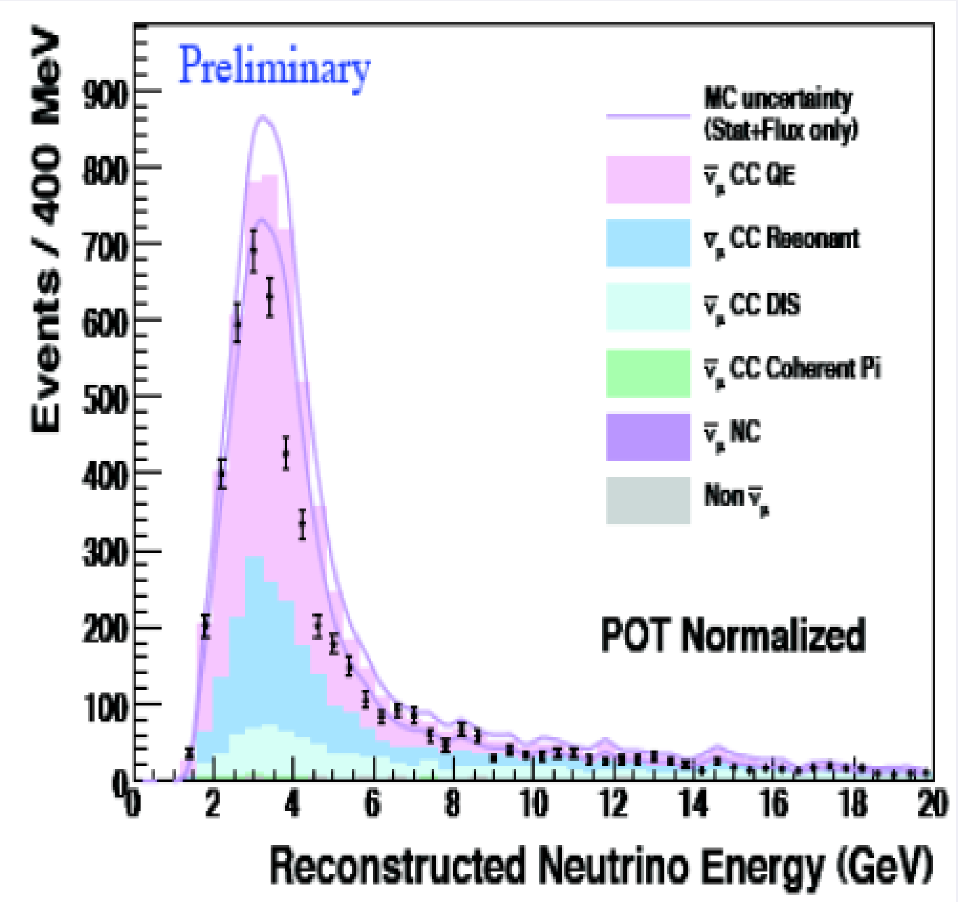
XIV International Workshop on Neutrino Telescopes

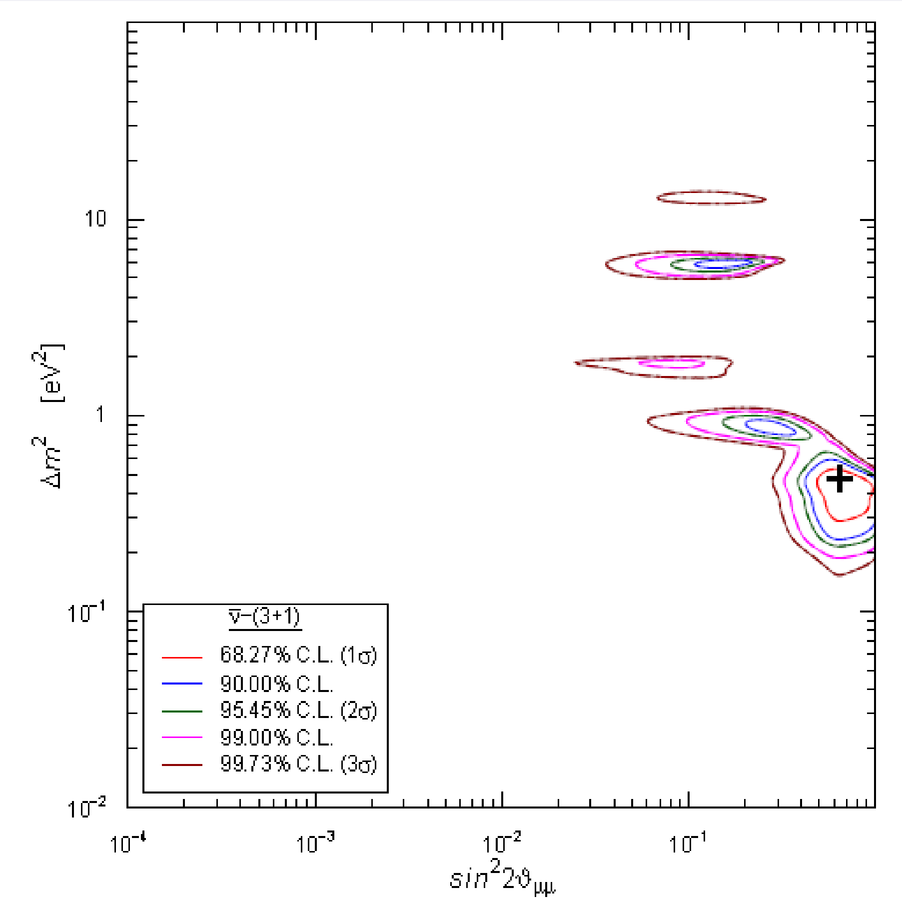
15 - 18 March 2011

Venice, Italy

Vittorio Paolone
University of Pittsburgh
(Representing the MINERνA collaboration)

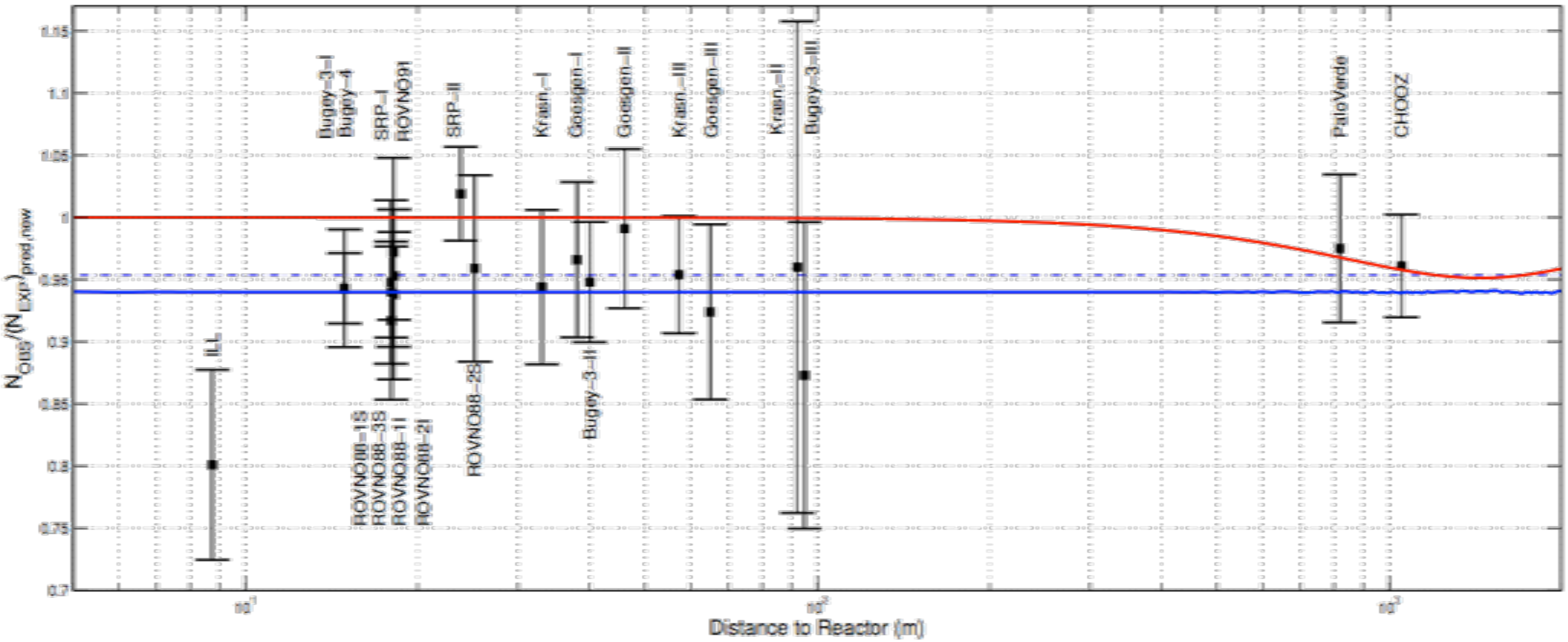
Minerva anomaly - new





C.Giunti & ML PRD 83 (2011) 053006

The Reactor Antineutrino Anomaly and implications

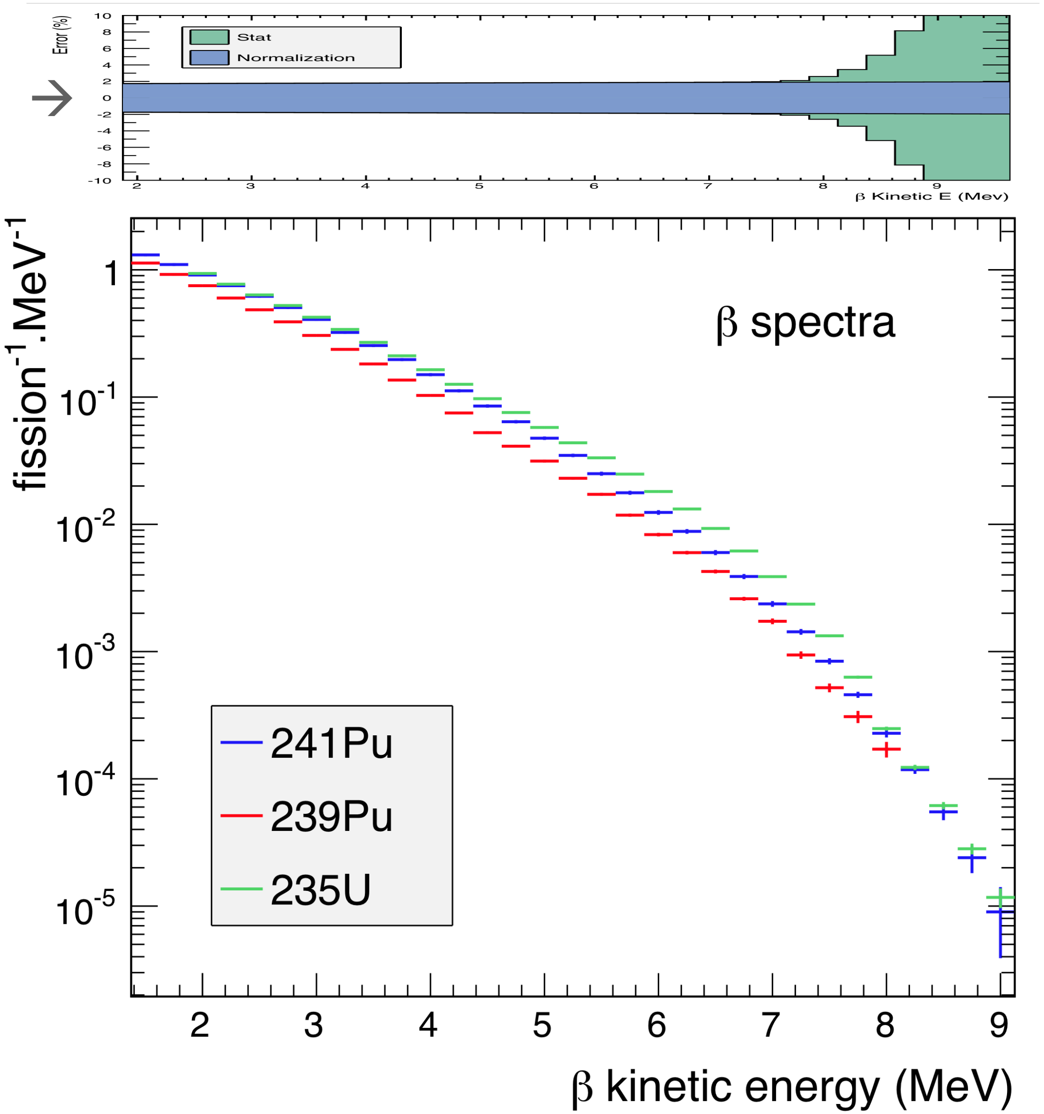


Th. Lasserre (CEA-Saclay, Irfu SPP & APC)

The ILL electron Data Anchorage

Unique reference to be met by any other measurement or calculation

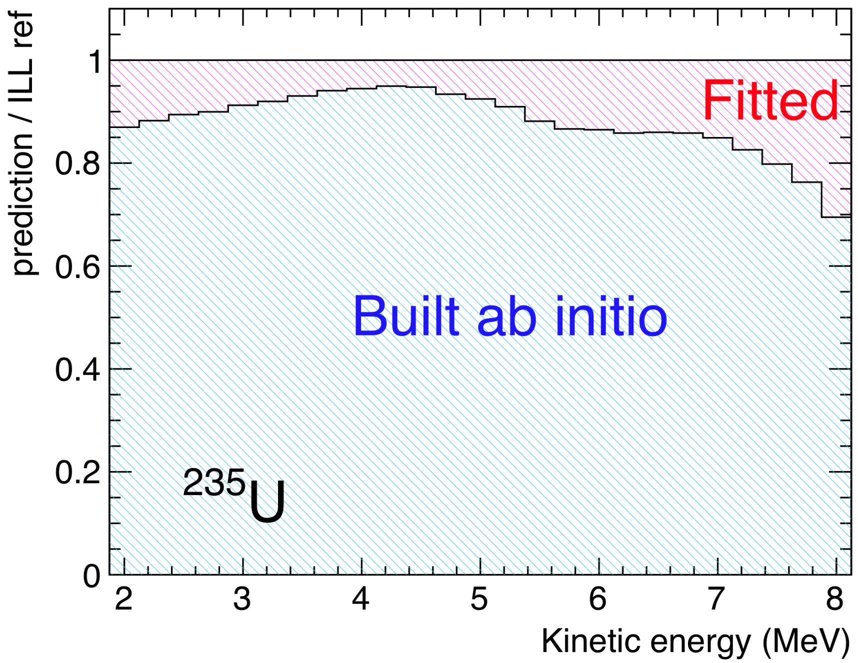
uncertainty →

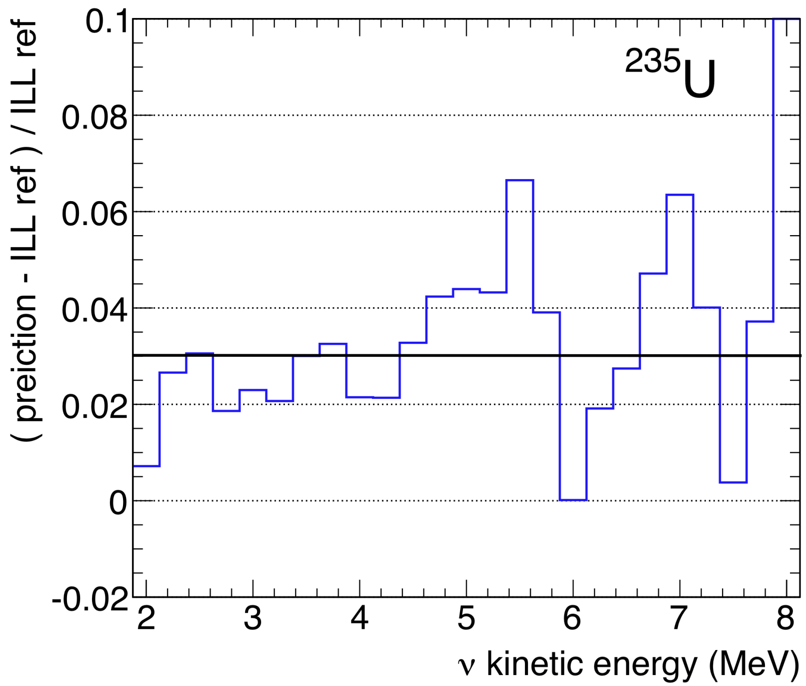


- Accurate e$^-$ measurements @ ILL' (1980-89):
  - High resolution magn. spectrometer
  - Intense and pure thermal n spectrum from the core
  - Extensive use of reference internal conversion electron lines → Normalization (1.8%)

The New Mixed Conversion Approach

1. **SAME** ILL e- data Anchorage
2. Ab-Initio: “true” distribution of β-branches reproduces >90% of ILL e- data.
3. Old-procedure: five effective anchorage-branches to the remaining 10%.





- **+3% normalization shift with respect to old ν spectrum**
- **Similar result for all isotopes (^{235}U, ^{239}Pu, ^{241}Pu)**
- **Stringent Test Performed – Origin of the bias identified**

19 Experimental Results Revisited (L<100m)

Technology — Baseline

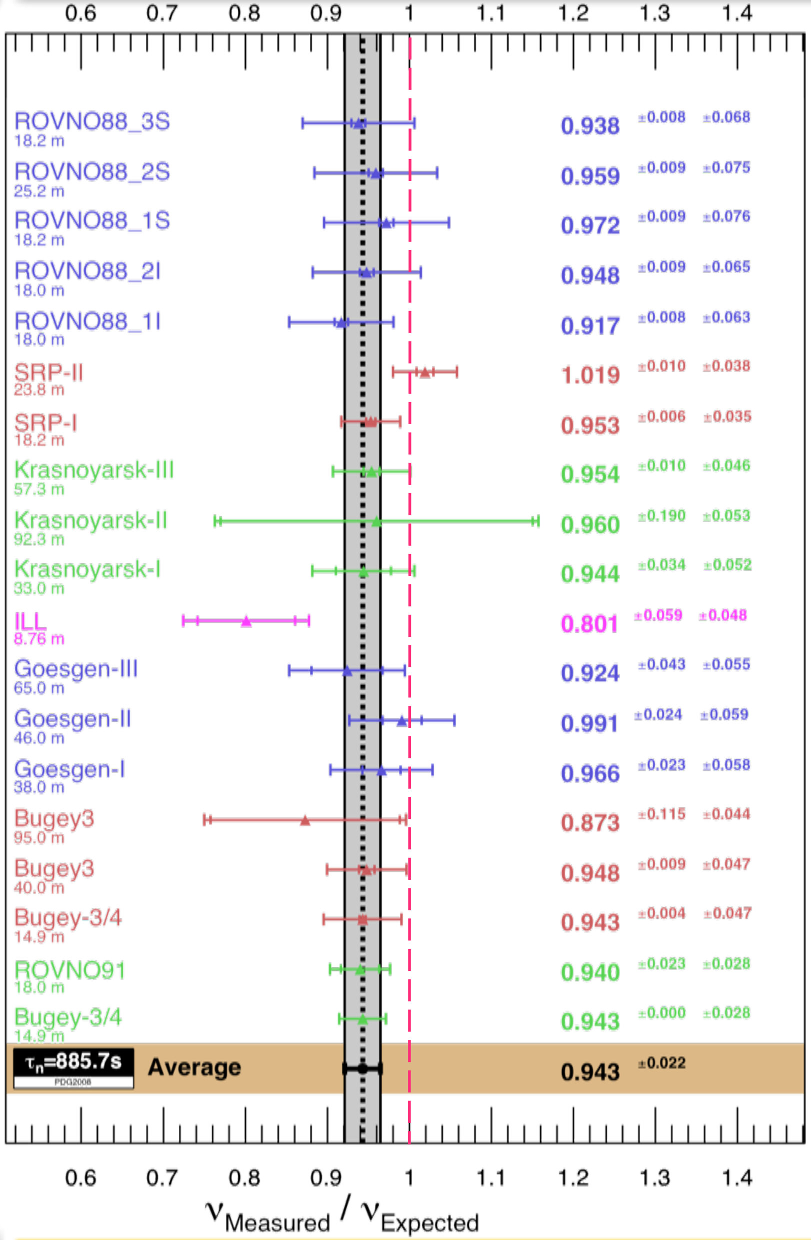
#	result	techno	τ_n (s)	^{235}U	^{239}Pu	^{238}U	^{241}Pu	old	new	err(%)	corr(%)	L(m)
1	Bugey-4	^{3}He+H$_2$0	888.7	0.538	0.328	0.078	0.056	0.987	0.943	3.0	3.0	15
2	ROVNO91	^{3}He+H$_2$0	888.6	0.614	0.274	0.074	0.038	0.985	0.940	3.9	3.0	18
3	Bugey-3-I	^{6}Li-LS	889	0.538	0.328	0.078	0.056	0.988	0.943	5.0	5.0	15
4	Bugey-3-II	Li-LS	889	0.538	0.328	0.078	0.056	0.994	0.948	5.1	5.0	40
5	Bugey-3-III	Li-LS	889	0.538	0.328	0.078	0.056	0.915	0.873	14.1	5.0	95
6	Goesgen-I	^{3}He+LS	897	0.6198	0.274	0.074	0.042	1.018	0.966	6.5	6.0	38
7	Goesgen-II	^{3}He+LS	897	0.584	0.298	0.068	0.050	1.045	0.991	6.5	6.0	45
8	Goesgen-II	^{3}He+LS	897	0.543	0.329	0.070	0.058	0.975	0.924	7.6	6.0	65
9	ILL	^{3}He+LS	889	$\simeq$1	<0.01	<0.01	<0.01	0.832	0.801	9.5	6.0	9
10	Krasn. I	^{3}He+PE	899	$\simeq$1	<0.01	<0.01	<0.01	1.013	0.944	5.1	4.1	33
11	Krasn. II	^{3}He+PE	899	$\simeq$1	<0.01	<0.01	<0.01	1.031	0.960	20.3	4.1	92
12	Krasn. II	^{3}He+PE	899	$\simeq$1	<0.01	<0.01	<0.01	0.989	0.954	4.1	4.1	57
13	SRP I	Gd-LS	887	$\simeq$1	<0.01	<0.01	<0.01	0.987	0.953	3.7	3.7	18
14	SRP II	Gd-LS	887	$\simeq$1	<0.01	<0.01	<0.01	1.055	1.019	3.8	3.7	24
15	ROVNO88-1I	^{3}He+PE	898.8	0.607	0.277	0.074	0.042	0.969	0.917	6.9	6.9	18
16	ROVNO88-2I	^{3}He+PE	898.8	0.603	0.276	0.076	0.045	1.001	0.948	6.9	6.9	18
17	ROVNO88-1S	Gd-LS	898.8	0.606	0.277	0.074	0.043	1.026	0.972	7.8	7.8	18
18	ROVNO88-2S	Gd-LS	898.8	0.557	0.313	0.076	0.054	1.013	0.959	7.8	7.8	25
19	ROVNO88-3S	Gd-LS	898.8	0.606	0.274	0.074	0.046	0.990	0.938	7.2	7.2	18

19 Experimental Results Revisited (L<100m)

OBSERVED/PREDICTED ratios: OLD & NEW (this work)

#	result	techno	τ_n (s)	^{235}U	^{239}Pu	^{238}U	^{241}Pu	old	new	err(%)	corr(%)	L(m)
1	Bugey-4	$^3He+H_20$	888.7	0.538	0.328	0.078	0.056	0.987	0.943	3.0	3.0	15
2	ROVNO91	$^3He+H_20$	888.6	0.614	0.274	0.074	0.038	0.985	0.940	3.9	3.0	18
3	Bugey-3-I	^{6}Li-LS	889	0.538	0.328	0.078	0.056	0.988	0.943	5.0	5.0	15
4	Bugey-3-II	Li-LS	889	0.538	0.328	0.078	0.056	0.994	0.948	5.1	5.0	40
5	Bugey-3-III	Li-LS	889	0.538	0.328	0.078	0.056	0.915	0.873	14.1	5.0	95
6	Goesgen-I	^{3}He+LS	897	0.6198	0.274	0.074	0.042	1.018	0.966	6.5	6.0	38
7	Goesgen-II	^{3}He+LS	897	0.584	0.298	0.068	0.050	1.045	0.991	6.5	6.0	45
8	Goesgen-II	^{3}He+LS	897	0.543	0.329	0.070	0.058	0.975	0.924	7.6	6.0	65
9	ILL	^{3}He+LS	889	$\simeq$1	<0.01	<0.01	<0.01	0.832	0.801	9.5	6.0	9
10	Krasn. I	^{3}He+PE	899	$\simeq$1	<0.01	<0.01	<0.01	1.013	0.944	5.1	4.1	33
11	Krasn. II	^{3}He+PE	899	$\simeq$1	<0.01	<0.01	<0.01	1.031	0.960	20.3	4.1	92
12	Krasn. II	^{3}He+PE	899	$\simeq$1	<0.01	<0.01	<0.01	0.989	0.954	4.1	4.1	57
13	SRP I	Gd-LS	887	$\simeq$1	<0.01	<0.01	<0.01	0.987	0.953	3.7	3.7	18
14	SRP II	Gd-LS	887	$\simeq$1	<0.01	<0.01	<0.01	1.055	1.019	3.8	3.7	24
15	ROVNO88-1I	^{3}He+PE	898.8	0.607	0.277	0.074	0.042	0.969	0.917	6.9	6.9	18
16	ROVNO88-2I	^{3}He+PE	898.8	0.603	0.276	0.076	0.045	1.001	0.948	6.9	6.9	18
17	ROVNO88-1S	Gd-LS	898.8	0.606	0.277	0.074	0.043	1.026	0.972	7.8	7.8	18
18	ROVNO88-2S	Gd-LS	898.8	0.557	0.313	0.076	0.054	1.013	0.959	7.8	7.8	25
19	ROVNO88-3S	Gd-LS	898.8	0.606	0.274	0.074	0.046	0.990	0.938	7.2	7.2	18

The reactor antineutrino anomaly

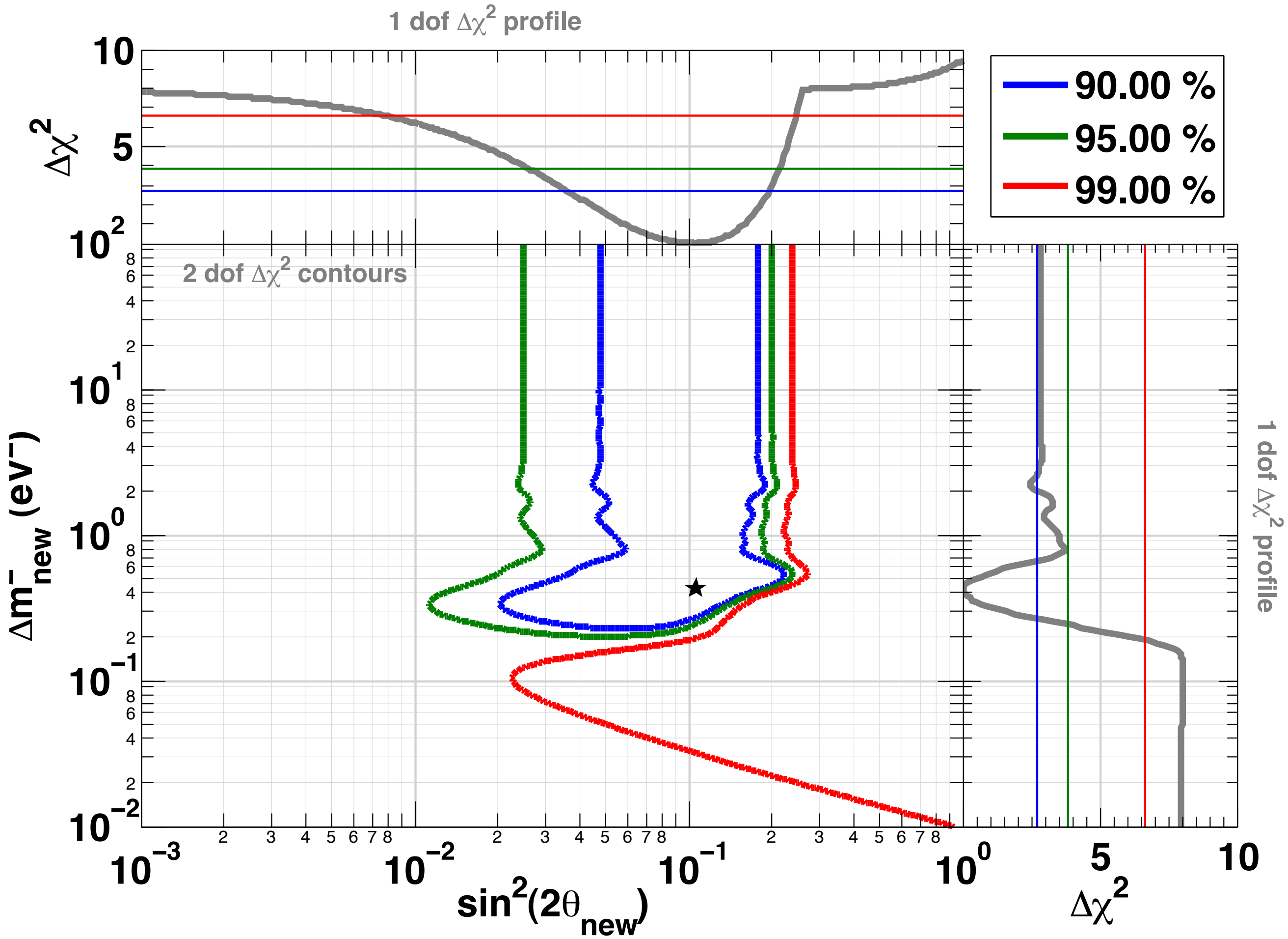


$$\chi^2 = \left(r - \vec{R}\right)^T W^{-1} \left(r - \vec{R}\right)$$

- **Best fit : μ = 0.943**
- **Uncertainty : 0.023**
- χ^2 = 19.6/19
- Deviation from unity
  - Naïve Gaussian : 99.3% C.L.
  - Toy MC: 98.6% C.L. (10^6 trials)
- No hidden covariance
  - 18% of Toy MC have χ^2_{min}<19.6

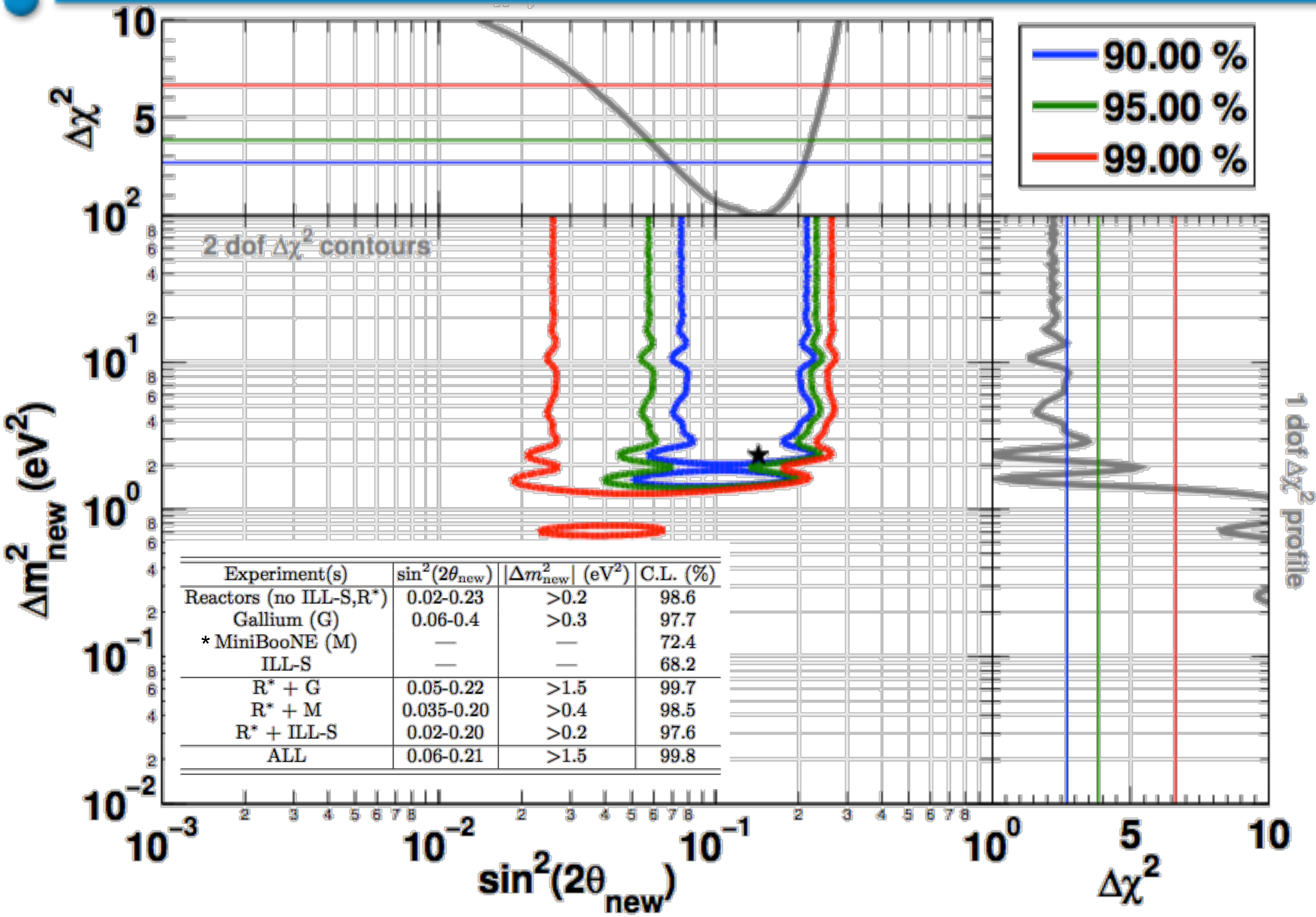
The 4th neutrino hypothesis

- Combine all rate measurements, no spectral-shape information
- Fit to anti-ν_e disappearance hypothesis



- Absence of oscillations disfavored at 98.6% C.L.

Putting it all together: reactor rates + shape + Gallium + (MB)



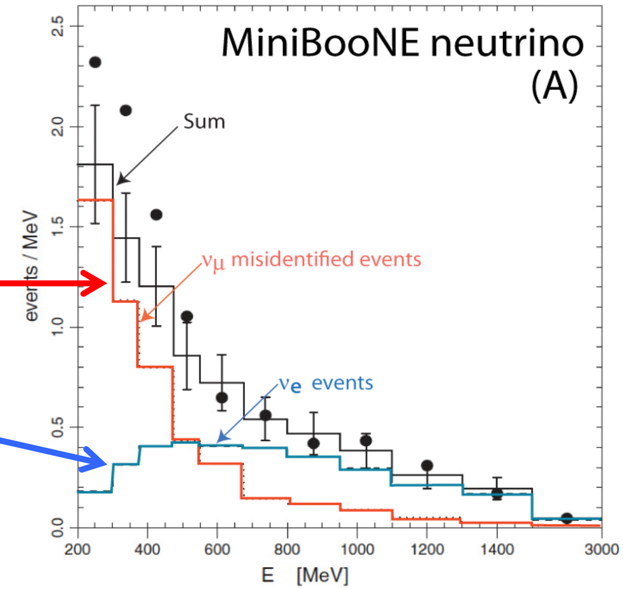
Experiment(s)	$\sin^2(2\theta_{new})$	$\lvert\Delta m^2_{new}\rvert$ (eV^2)	C.L. (%)
Reactors (no ILL-S,R*)	0.02-0.23	>0.2	98.6
Gallium (G)	0.06-0.4	>0.3	97.7
* MiniBooNE (M)	—	—	72.4
ILL-S	—	—	68.2
R* + G	0.05-0.22	>1.5	99.7
R* + M	0.035-0.20	>0.4	98.5
R* + ILL-S	0.02-0.20	>0.2	97.6
ALL	0.06-0.21	>1.5	99.8

The no-oscillation hypothesis is disfavored at 99.8% CL

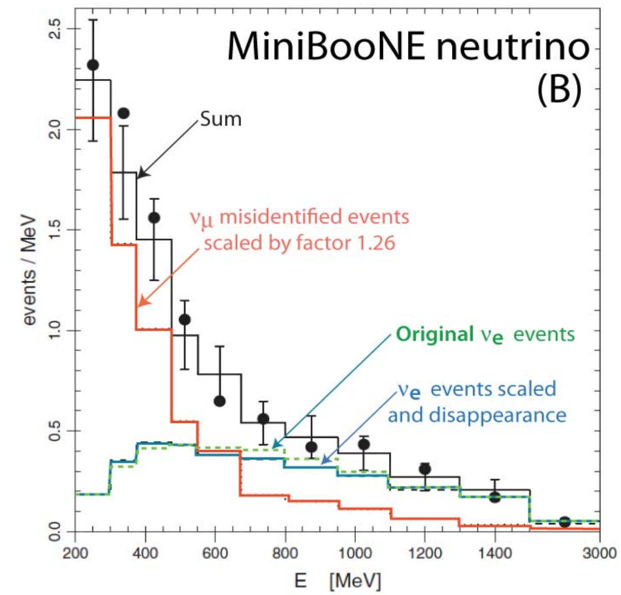
* Miniboone re-analysis of : C. Giunti, M. Laveder, Phys. Rev. D82 (2010) 053005

The neutrino run

- (A) electron-like neutrino data. Comparison between the data (black dots) and the calculated distributions due to misidentified ν_μ events (red) and genuine ν_e events (blue). The sum is indicated in black. One notices an anomaly at low energies, which is incompatible with LNSD predictions.

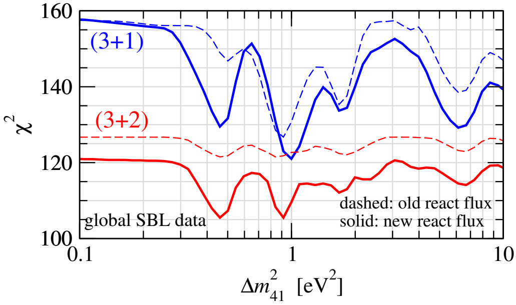


- (B) according to Giunti & Laveder scaling of the events is applied with a factor 1.26, within the permitted uncertainty of F = 1.24 ±0.21 and gives an acceptable fit to the data. The ν_e with and without scaling and disappearance are also shown.



3+2 global fit

Δm^2_{41}	$\lvert U_{e4}\rvert$	$\lvert U_{\mu 4}\rvert$	Δm^2_{51}	$\lvert U_{e5}\rvert$	$\lvert U_{\mu 5}\rvert$	δ/π	χ^2/dof
0.47	0.131	0.170	0.93	0.135	0.142	1.62	105.9/130



- $\Delta\chi^2$ (old vs new fluxes) $= 15.5$
- $\Delta\chi^2$ (3+1 vs 3+2) $= 14.1$ (99.3% CL, 4 dof)

Intermezzo sulla fisica di Majorana

Natura del neutrino

Nuovo Cimento **14** (1937) 171-184

TEORIA SIMMETRICA DELL'ELETTRONE E DEL POSITRONE

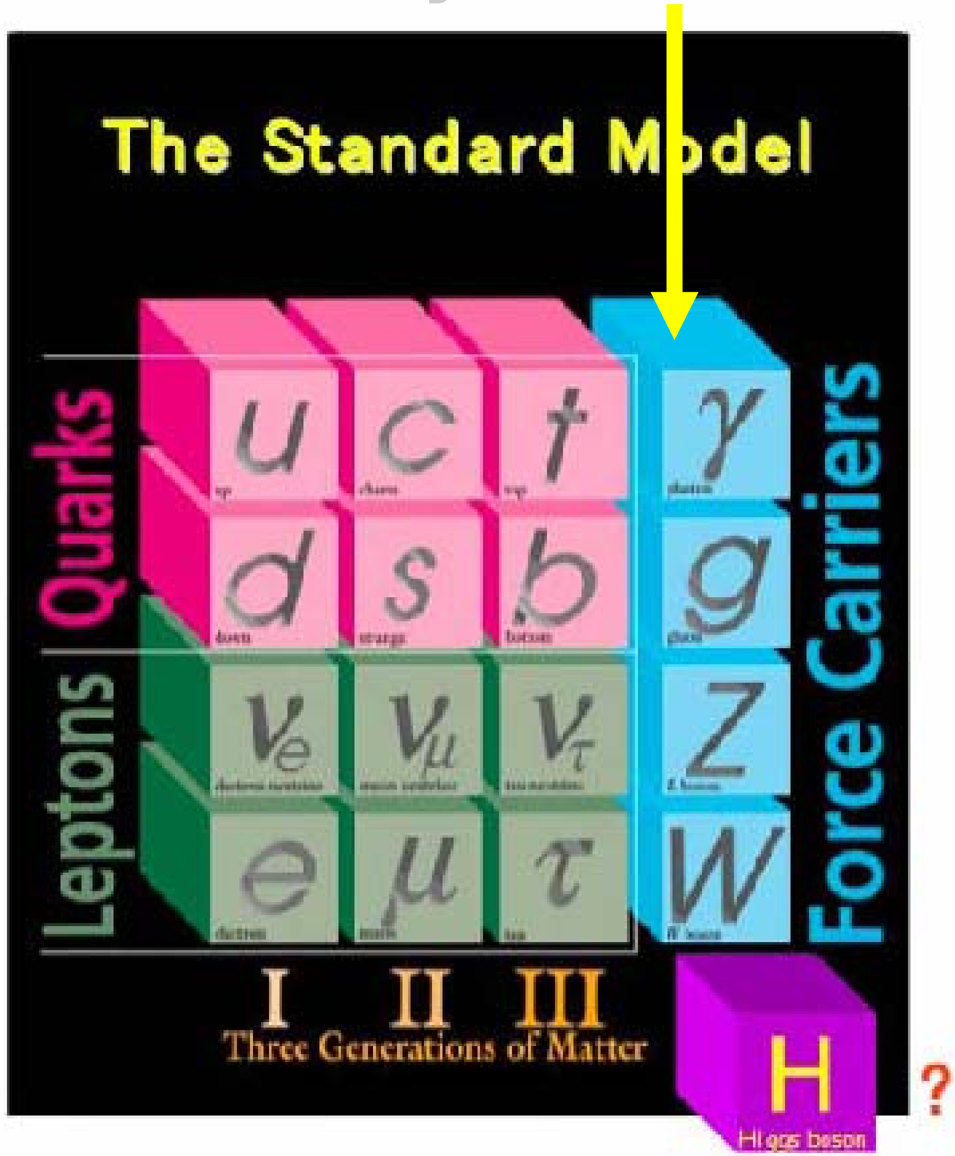
Nota di Ettore Majorana

Sunto. - *Si dimostra la possibilità di pervenire a una piena simmetrizzazione formale della teoria quantistica dell'elettrone e del positrone facendo uso di un nuovo processo di quantizzazione. Il significato delle equazioni di* Dirac *ne risulta alquanto modificato e non vi è più luogo a parlare di stati di energia negativa; nè a presumere per ogni altro tipo di particelle, particolarmente neutre, l'esistenza di «antiparticelle» corrispondenti ai «vuoti» di energia negativa.*

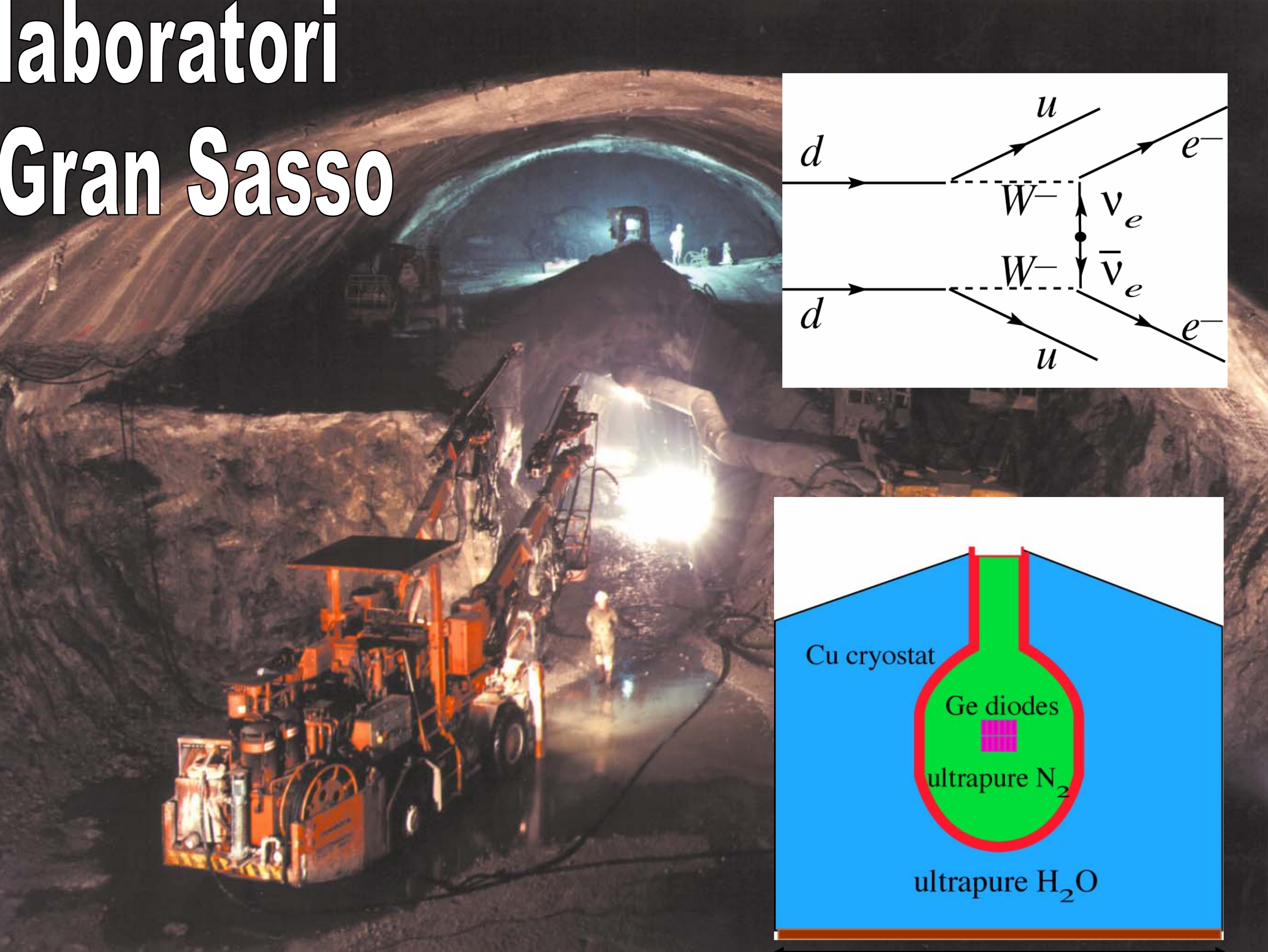
We show that it is possible to achieve complete formal symmetrization in the electron and positron quantum theory by means of a new quantization process. The meaning of Dirac equations is somewhat modified and it is no more necessary to speak of negative-energy states; nor to assume, for any other type of particles, especially neutral ones, the existence of antiparticles, corresponding to the "holes" of negative energy.

Majorana Neutrino

Gravity
?



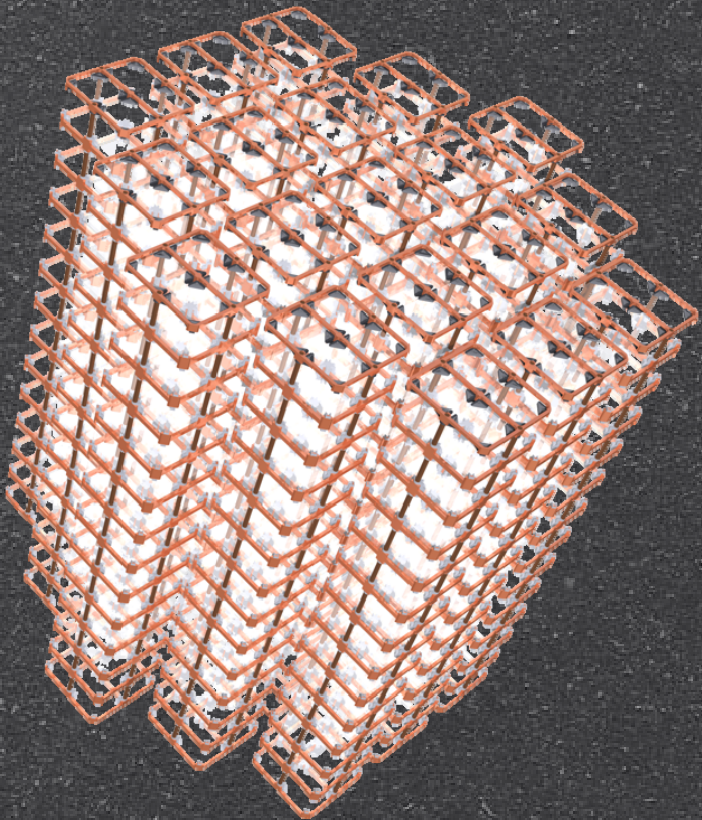
laboratori Gran Sasso



XIV International Workshop on "Neutrino Telescopes"

Venice, March 15-18, 2011

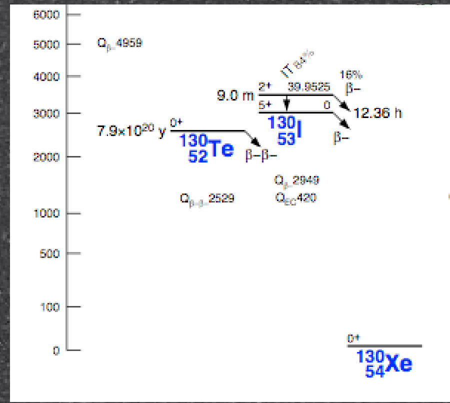
CUORICINO, CUORE-0 AND CUORE: AN UPDATE



C. Brofferio, University of Milano Bicocca
on behalf of the CUORE Collaboration

CUORICINO: 0νDBD RESULT

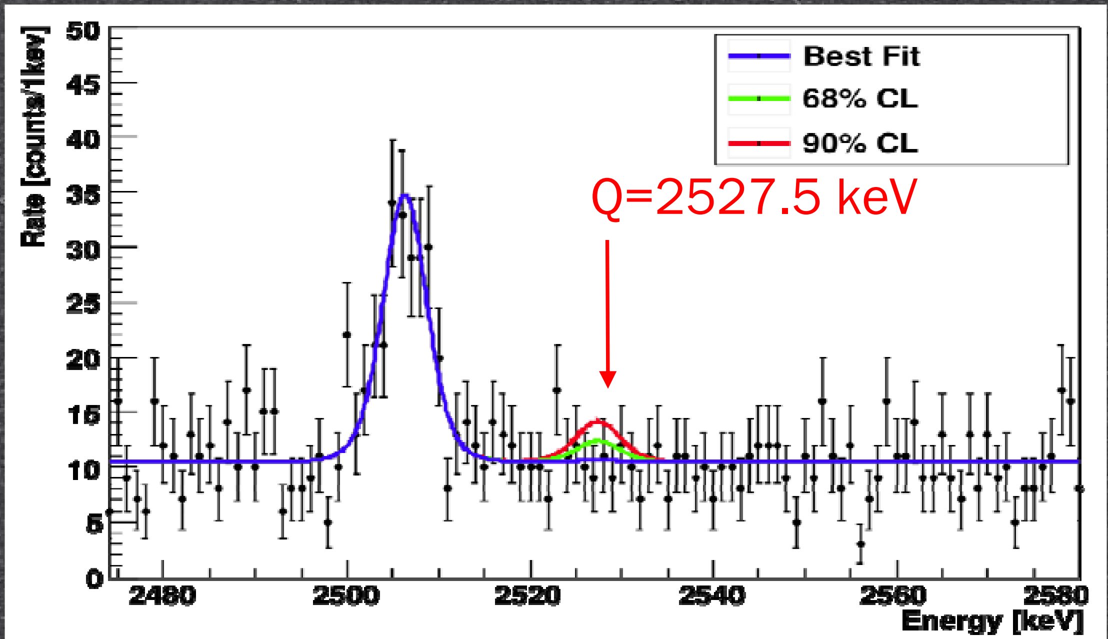
Astropart. Phys. (2011), doi:10.1016/j.astropartphys.2011.02.002



TOTAL: **19.6 kg · yr** ^{130}Te exposure

collected in 2 runs (2003-2004, 2004-2008)

(II Run, Big Crystals alone: 15.8 kg · y)



NME bibliography:

1 Šimkovic et al., PRC 77 (2008) 045503
2 Civitarese et al., JoP:Conference series 173 (2009) 012012
3 Menéndez et al., NPA 818 (2009) 139
4 Barea and Iachello, PRC 79 (2009) 044301

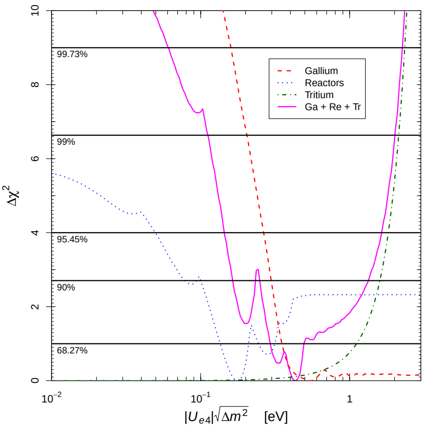
Background Big Crystals, II run: 0.153 ± 0.006 counts/keV/kg/y

Lower limit, half-life: $T_{1/2}^{0\nu}$ (^{130}Te) > 2.8 × 10^{24} y (90% C.L.)

Upper limit, Majorana mass: m_{ν_e} < 0.3 - 0.7 eV

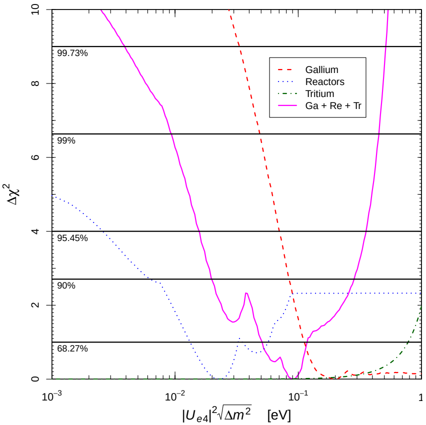
Implications of Gallium and Reactor Anomalies

β Decay



$$m_\beta^2 = \sum_k |U_{ek}|^2 m_k^2$$

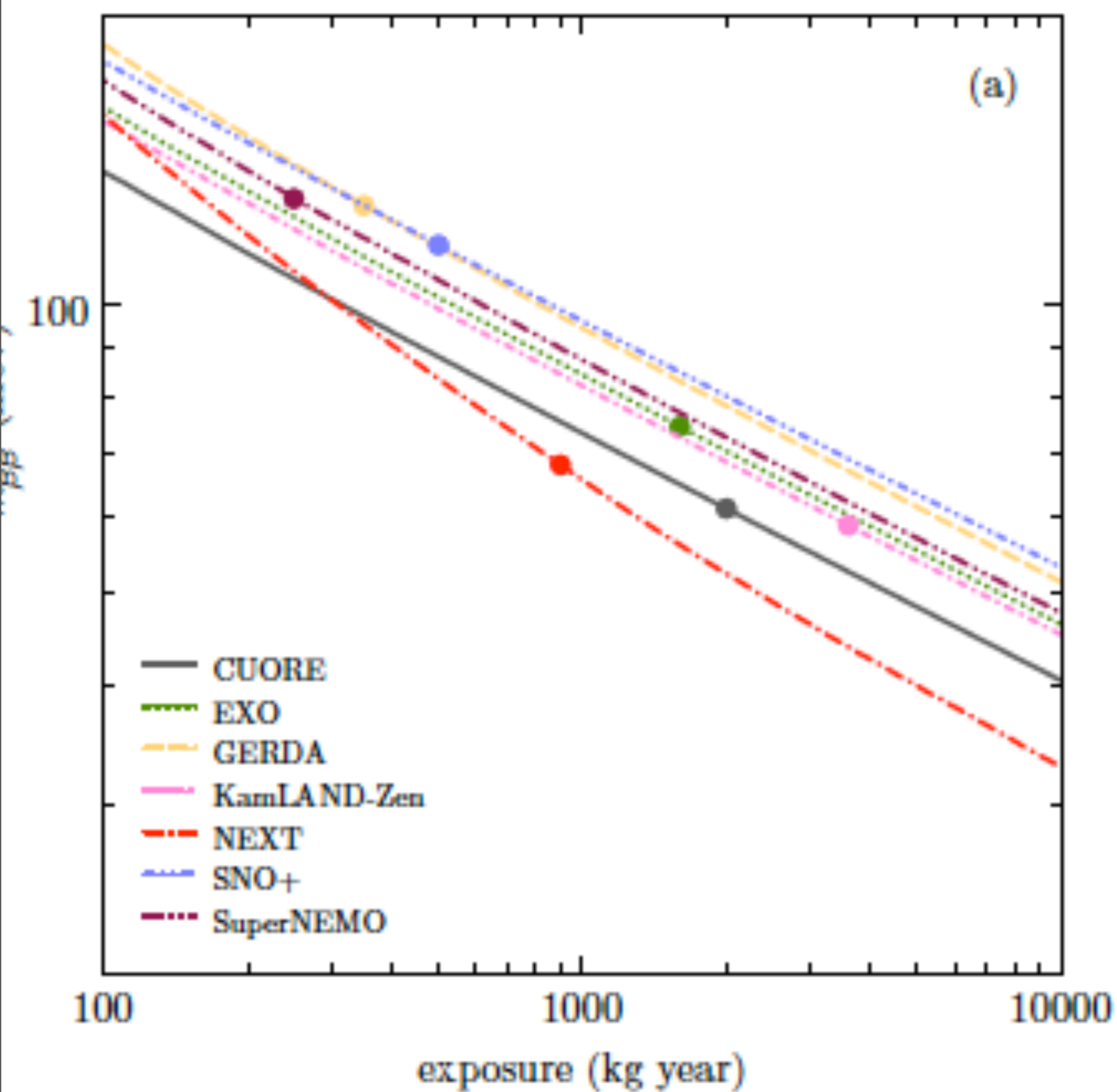
$(\beta\beta)_{0\nu}$ Decay



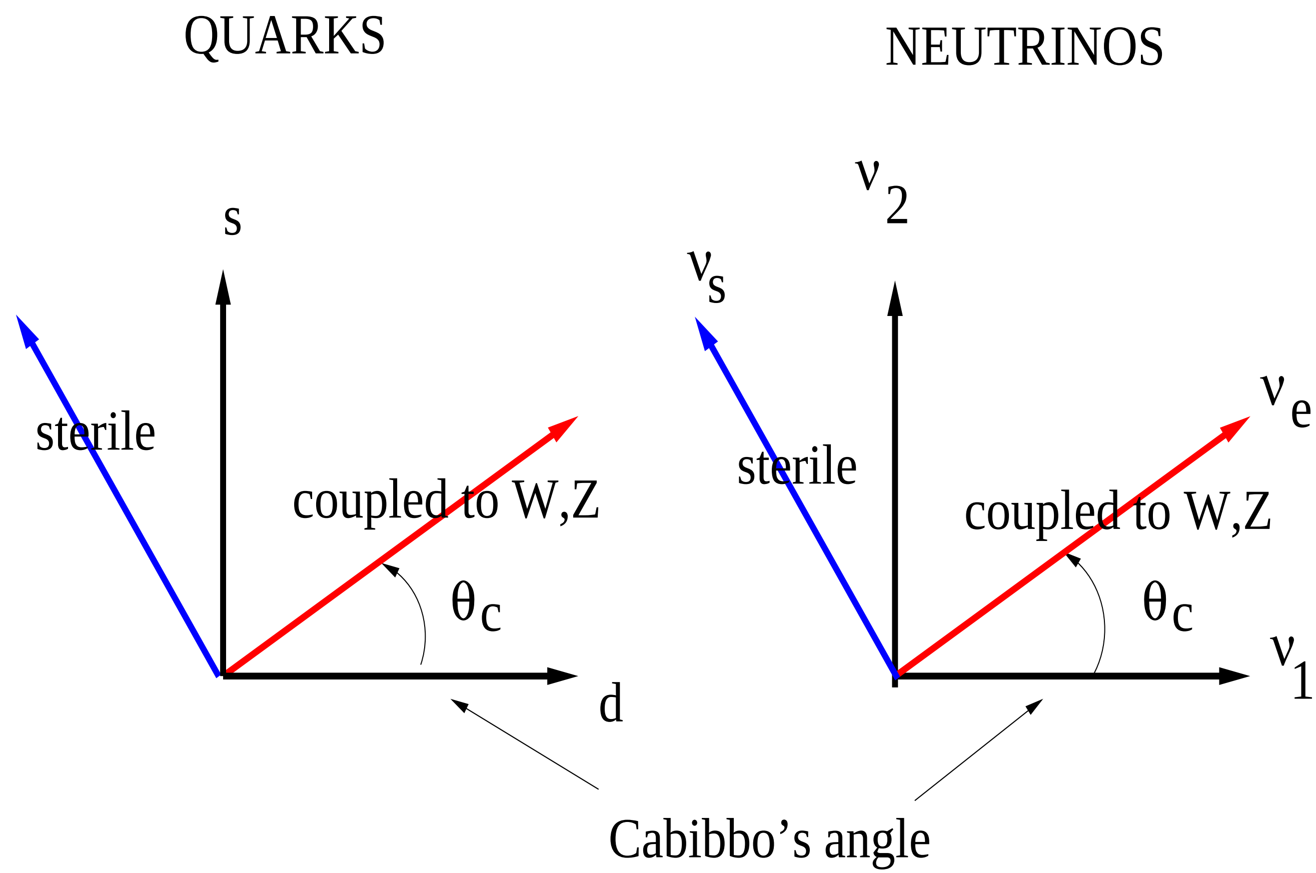
$$m_{\beta\beta} = \left| \sum_k U_{ek}^2 \, m_k \right|$$

[Giunti, Laveder, In Preparation]

Sensitivity of proposals



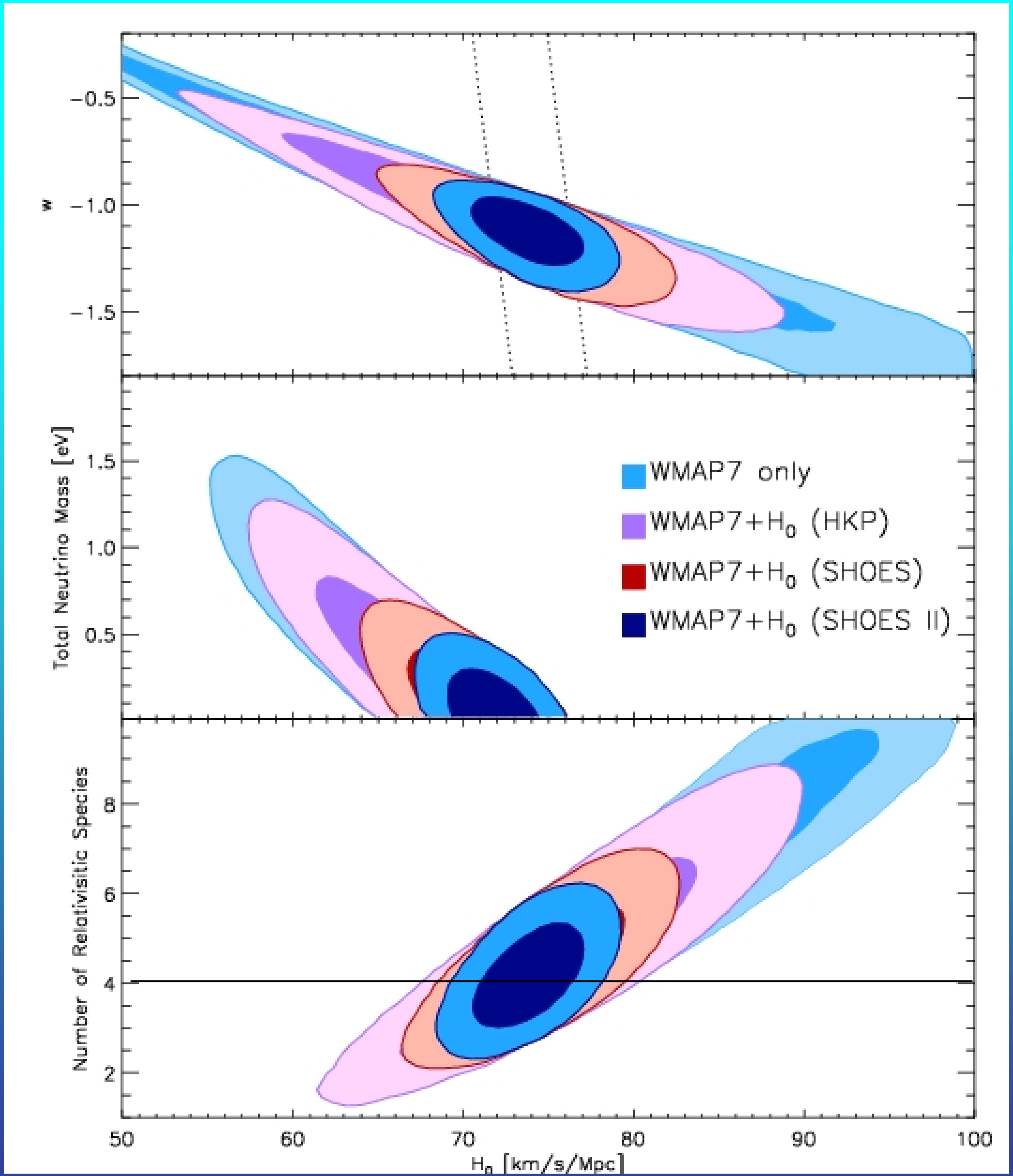
- Does not take into account "t0"
- Uses "conservative" background model (that can be more conservative for some experiments than for others)
- Uses central values for PMRs
- (should we use rather lower and upper limits of PMR?).
- Dots mean (10 years x mass)



COMPLEMENTARITY relation :

$$\theta_{12} \sim 32^o \qquad \theta_{es} \sim 13^o \qquad \theta_{12} + \theta_{es} = 45^o$$

A.G. Riess et al. astro-ph 1103.2976



... if they are roses they'll flower...

... A BRIGHT FUTURE for Majorana ν physics !!!

A proposed search for Sterile Neutrinos with the ICARUS detector at the CERN-PS

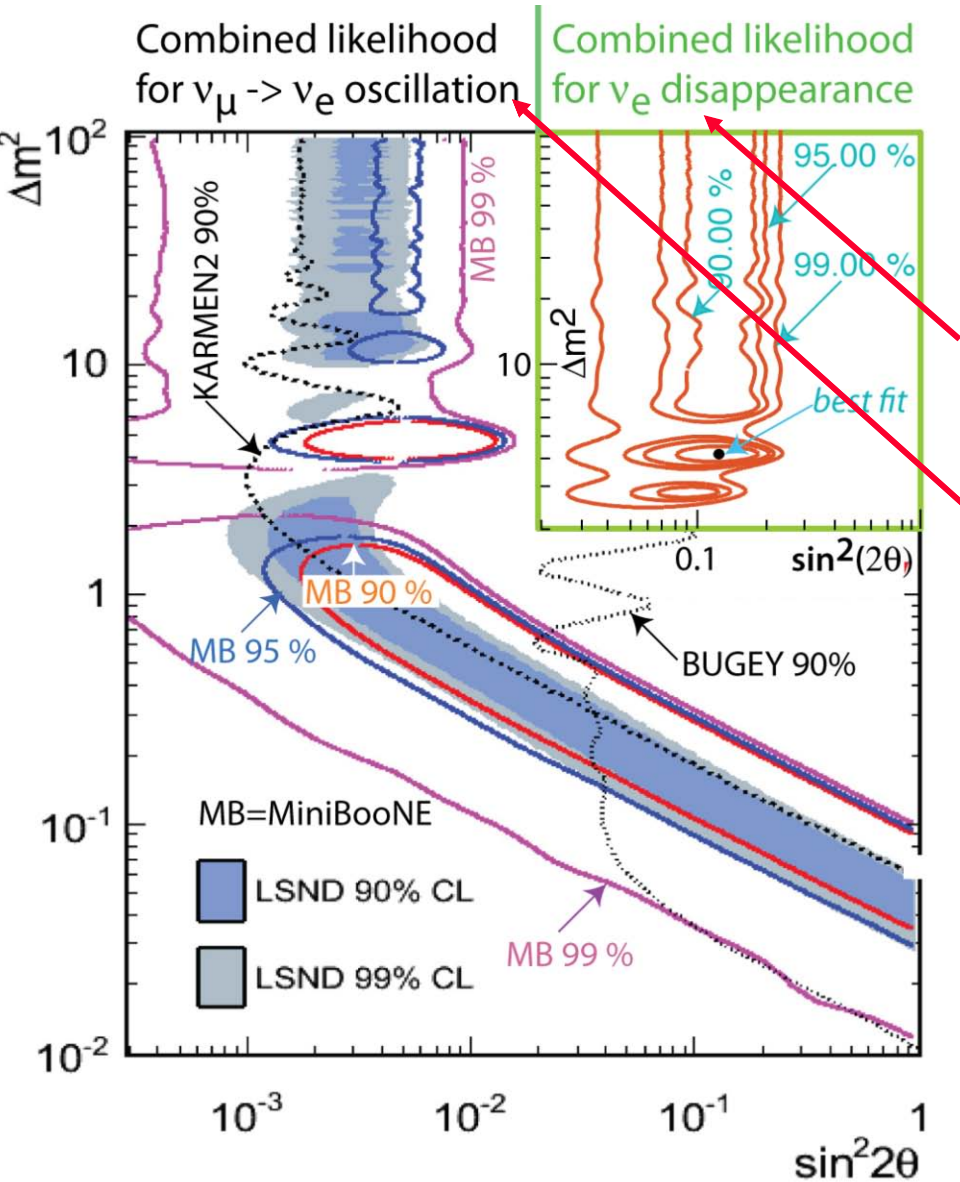
Carlo Rubbia

INFN/LNGS, Assergi, Italy

and

CERN, Geneva, Switzerland

An unified approach ?



Allowed regions in the plane for combined results:

the νe disappearance rate (right)

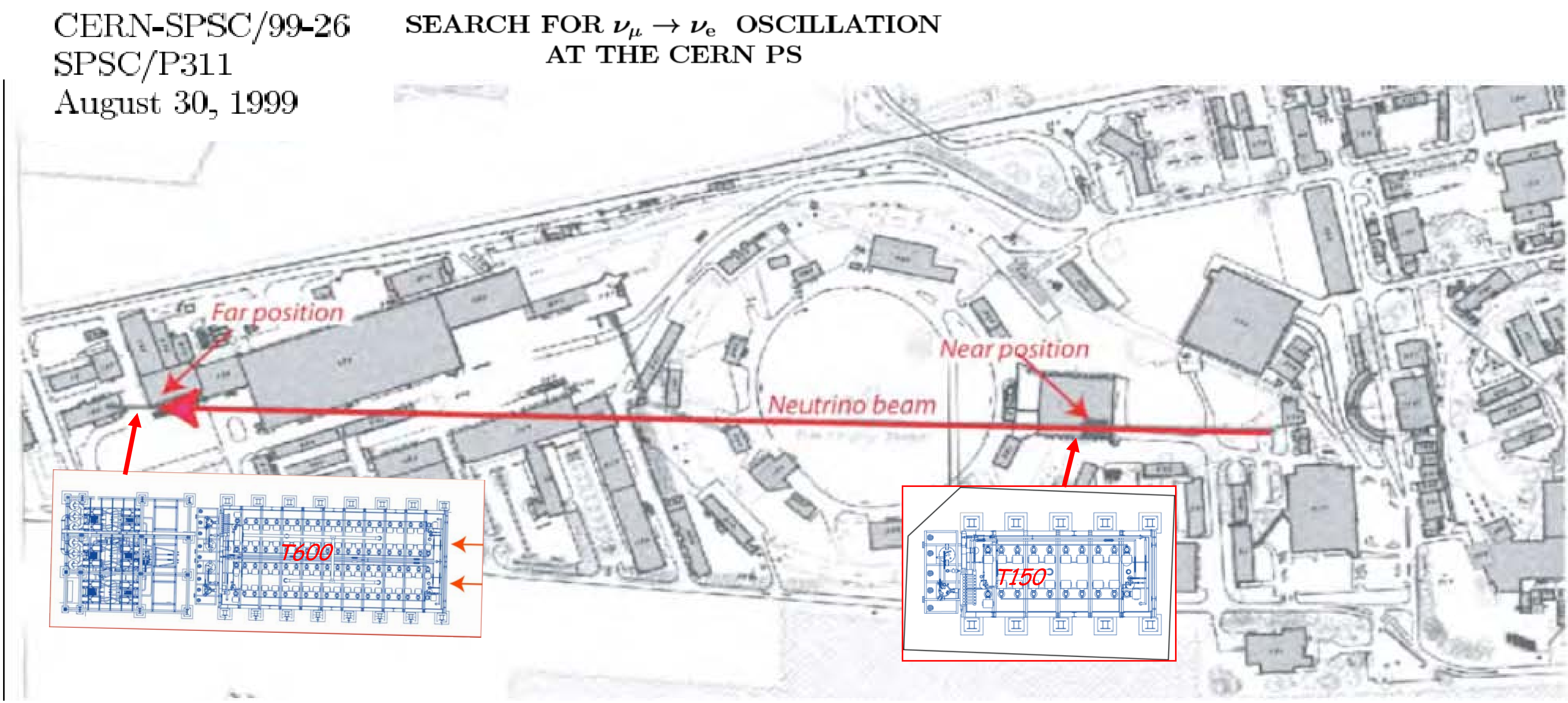
the LSND /MiniBooNE anti-νe anomaly (left).

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.

Basic features of the proposed experiment

- Our proposed experiment, collecting a large amount of data both with neutrino and antineutrino focussing, 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 ν–μ signal, so far unknown.
  - Accurate comparison between neutrino and antineutrino related oscillatory anomalies
- 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.

Two detectors at the CERN-PS neutrino beam



Two positions are foreseen for the detection of the neutrinos

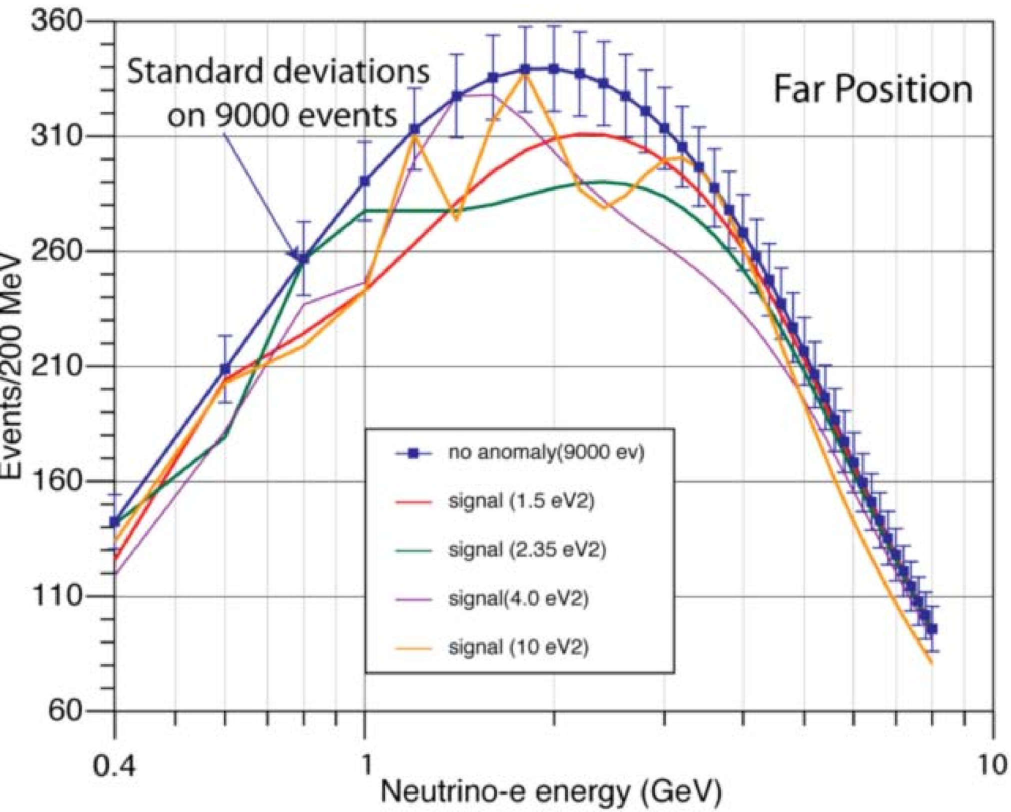
The far (T600) location at 850 m from the target: L/E ~ 1 km/GeV;

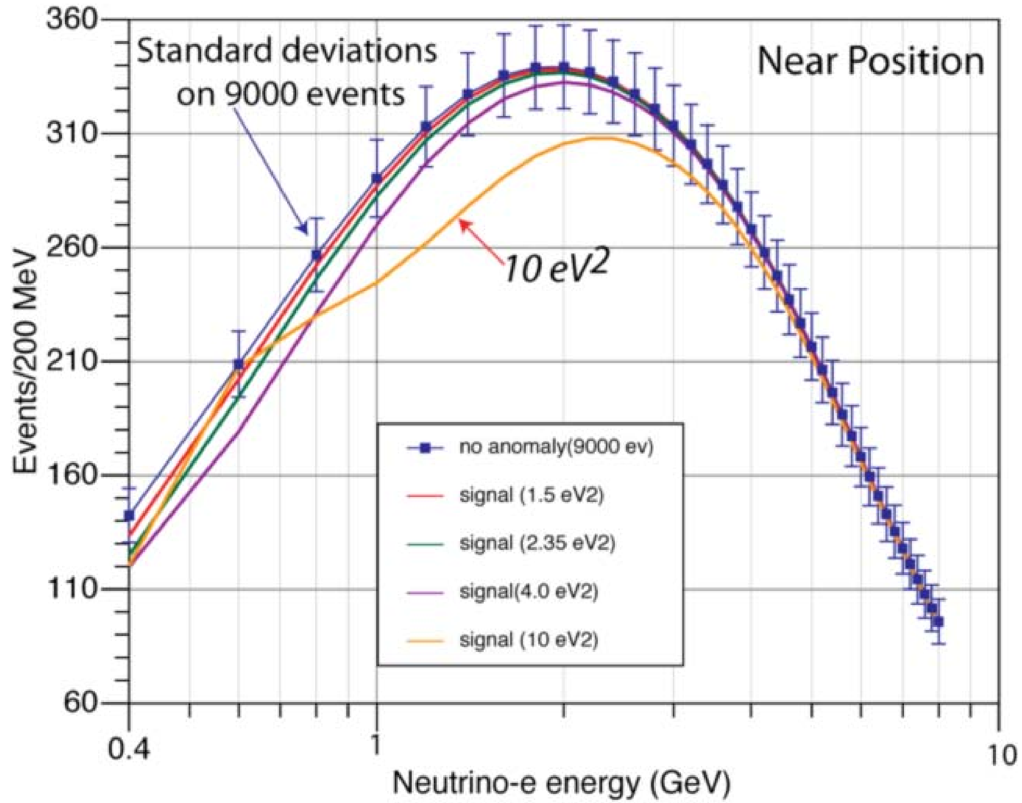
The new location at a distance of 127 m from the target: L/E 0.15 km/GeV

A new experiment at the CERN-PS

- The present proposal at the CERN-PS is based on the search for spectral differences of electron like specific signatures *in two identical detectors but at two different neutrino distances*, at the "Far" and the "Near" locations, respectively at 850 m and 127 m away from the source.
- The "Far" detector is the ICARUS T600, now perfectly operational in the underground Hall B of the LNGS in a neutrino beam from the CERN-SPS, collecting data as CNGS2 experiment. The T600 detector is the largest liquid Argon TPC ever built, with a size of about 600 t of imaging mass.
- The "Near" detector has to be constructed anew and it is as far as possible identical to the T600 but with a mass of 150 t, namely a clone of a single T300 half-module with the length reduced by a factor 2.

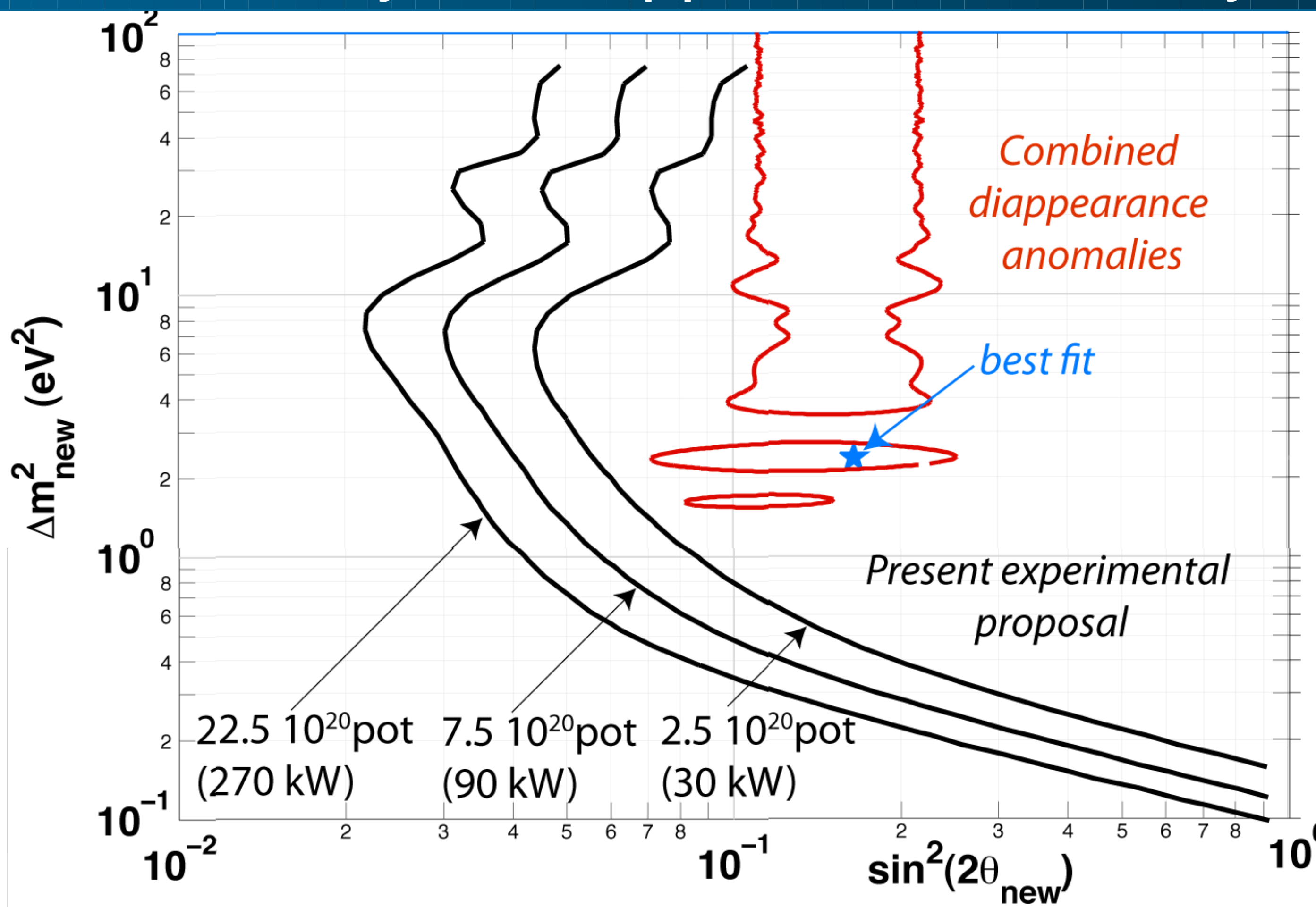
Sensitivity to νe (and νμ) disappearance signals





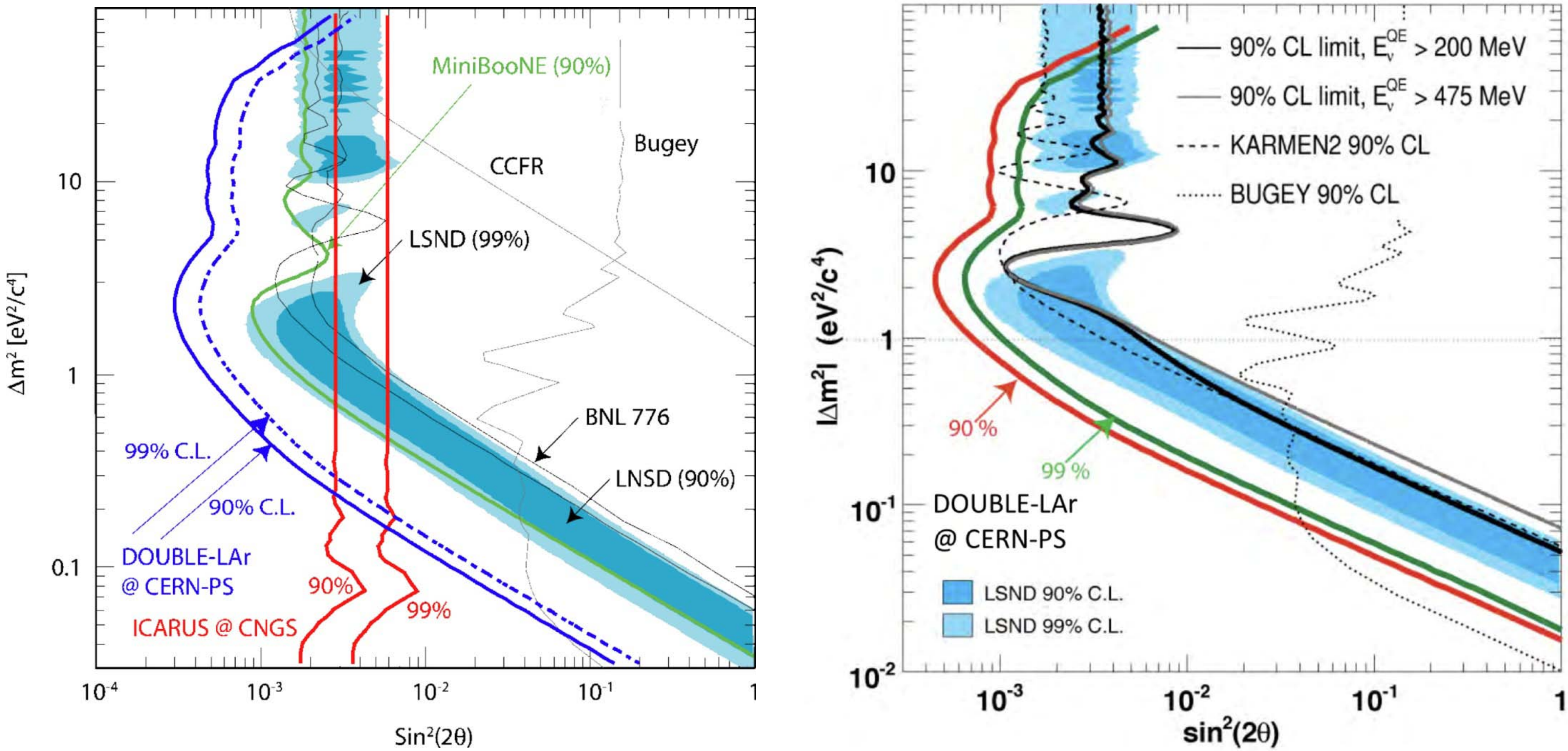
The energy distributions of the electron neutrino events is shown in (a) and (b)respectively for the "Far" and "Near" and a number of possible values in the region of $\Delta m^2 > 1eV^2$ and $sin^2(2\theta) \approx 0.16$.
If confirmed without any doubt such a large mass difference will have an important role in the explanation of the existence of the Dark Mass in the Universe.

Sensitivity to disappearance anomaly



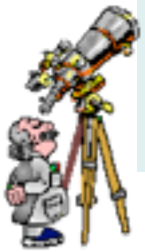
- Sensitivities (90% CL) in the $\sin^2(2\theta_{new})$ vs. Δm^2_{new} for an integrated intensity of (a) at the 30 kWatt beam intensity of the previous CERN/PS experiments, (b) the newly planned 90 kWatt neutrino beam and (c) a 270 kWatt curve. They are compared (in red) with the "anomalies" of the reactor + Gallex and Sage experiments. A 1% overall and 3% bin-to-bin systematic uncertainty is included (for 100 MeV bins).

Comparing sensitivities *(arXiv:0909.0355)*



Expected sensitivity for the proposed experiment exposed at the CERN-PS neutrino beam (left) for 2.5 10^{20} pot and twice as much for anti-neutrino (right) . The LSND allowed region is fully explored both for neutrinos. The expectations from one year of at LNGS are also shown.

Possibilities for future ν beams at CERN



I. Efthymiopoulos - CERN

Many thanks to: M. Dracos, R. Garoby, E. Gschwendtner,, A. Guglielmi, K. Long, F. Pietropaolo, A. Rubbia, R. Steerenberg, E. Wildner

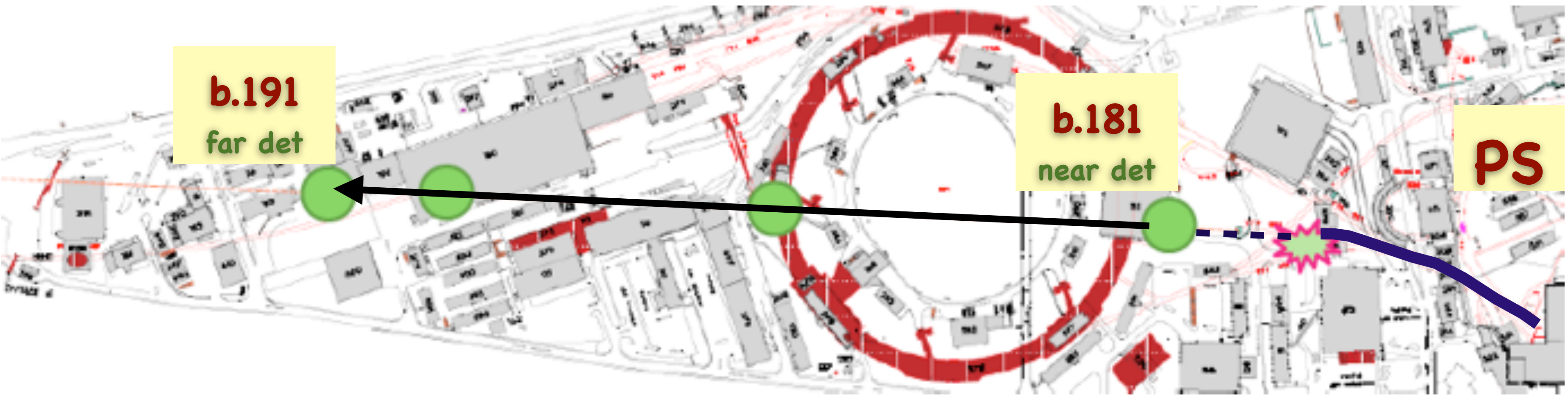
XIV International Workshop on "Neutrino Telescopes"
Venice - March 17, 2011

PS – Short Baseline ν-beam

- A search for anomalous neutrino $\nu_\mu \rightarrow \nu_e$ oscillations at the CERN PS with LAr-TPC detectors

☞ *Talk from C. Rubbia*

C. Rubbia et al



- Beam line originally operated in early 80's for PS169, PS181, PS180(BEBC) experiments
- PS beam possibilities (180, 85% efficiency) :
  - $6.13\ 10^{19} \div 2.02\ 10^{20}$ from zero to max impact to PS users

	Old neutrino facility		New neutrino facility		
	PS dedicated Feb-Mar 1983	PS parallel 1983 - 1984	PS dedicated	PS parasitic	PS ultimate[2]
Proton Momentum	19.2 GeV/c	19.2 GeV/c	20 GeV/c	20 GeV/c	26 GeV/c
Protons/pulse	1.25×10^{13}	1.2×10^{13}	3×10^{13}	2.6×10^{13}	4×10^{13}
Max. rep. rate	1.2 s	14.4 s	1.2 s	1.2 s	1.2
Beam energy	38 kJ	38 kJ	96 kJ	84 kJ	166 kJ
Average beam power	32 kW	2.5 kW	80 kW	70 W	140 kW

Courtesy: R. Steerenberg – CERN

First Neutrino Oscillation Results from the T2K Experiment

André Rubbia (ETH Zurich)
for the T2K Collaboration

XIV International Workshop on Neutrino Telescopes
Venice, March 15-18th 2011

Message from KEK

Japan experienced very severe earthquake on March 11th 2011 at 14:46 JST. J-PARC facility suffered damages for some extent. There are no reports of casualties and all staff, graduate students, and foreign visitors have been located and as of evening Sunday March 13th all T2K members have been evacuated from Tokai area.

Fortunately enough, the Tsunami tidal wave did not hit J-PARC. We will start the investigation of the facilities. We will update the announcement as we learn the detail of the entire damage.

Our present priority is to restore life-supporting infrastructure such as electricity, water supply and gas at J-PARC. It may take some time, but we promise the full recovery of the J-PARC accelerator and T2K experiment in the near future.

I thank you for the messages of solidarity and sympathy.

Director of the Institute of Particle and Nuclear Studies, KEK
Koichiro Nishikawa

Spokesperson of the T2K experiment
Takashi Kobayashi

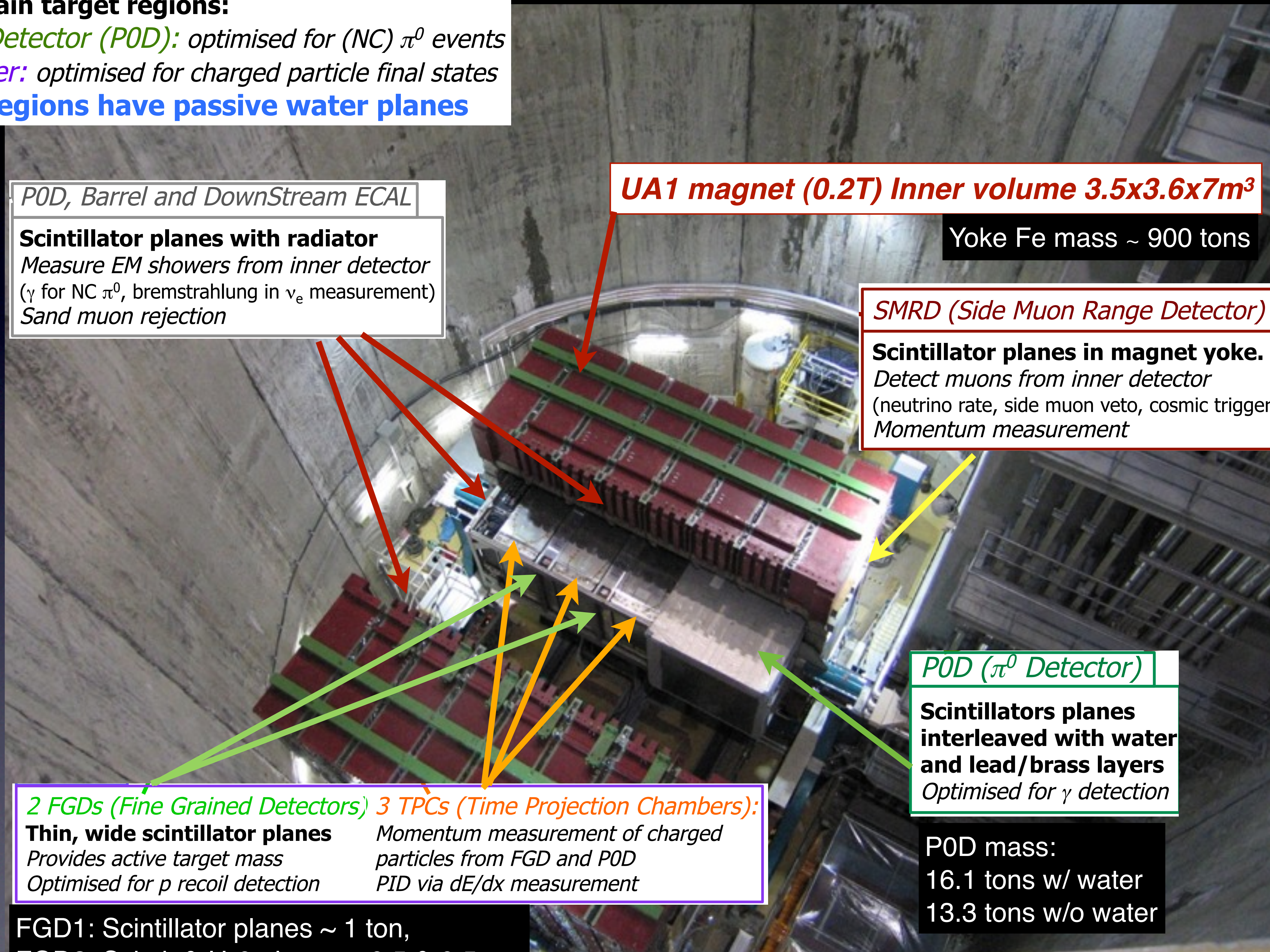
J-PARC Facility (KEK/JAEA)

Bird's eye photo in January of 2008

ND280 off-axis detector overview

Two main target regions:
- *Pi-0 Detector (P0D): optimised for (NC) π^0 events*
- *Tracker: optimised for charged particle final states*

Both regions have passive water planes



P0D, Barrel and DownStream ECAL

Scintillator planes with radiator
Measure EM showers from inner detector
(γ for NC π^0, bremstrahlung in ν_e measurement)
Sand muon rejection

UA1 magnet (0.2T) Inner volume 3.5x3.6x7m^3

Yoke Fe mass ~ 900 tons

SMRD (Side Muon Range Detector)

Scintillator planes in magnet yoke.
Detect muons from inner detector
(neutrino rate, side muon veto, cosmic trigger)
Momentum measurement

P0D (π^0 Detector)

Scintillators planes interleaved with water and lead/brass layers
Optimised for γ detection

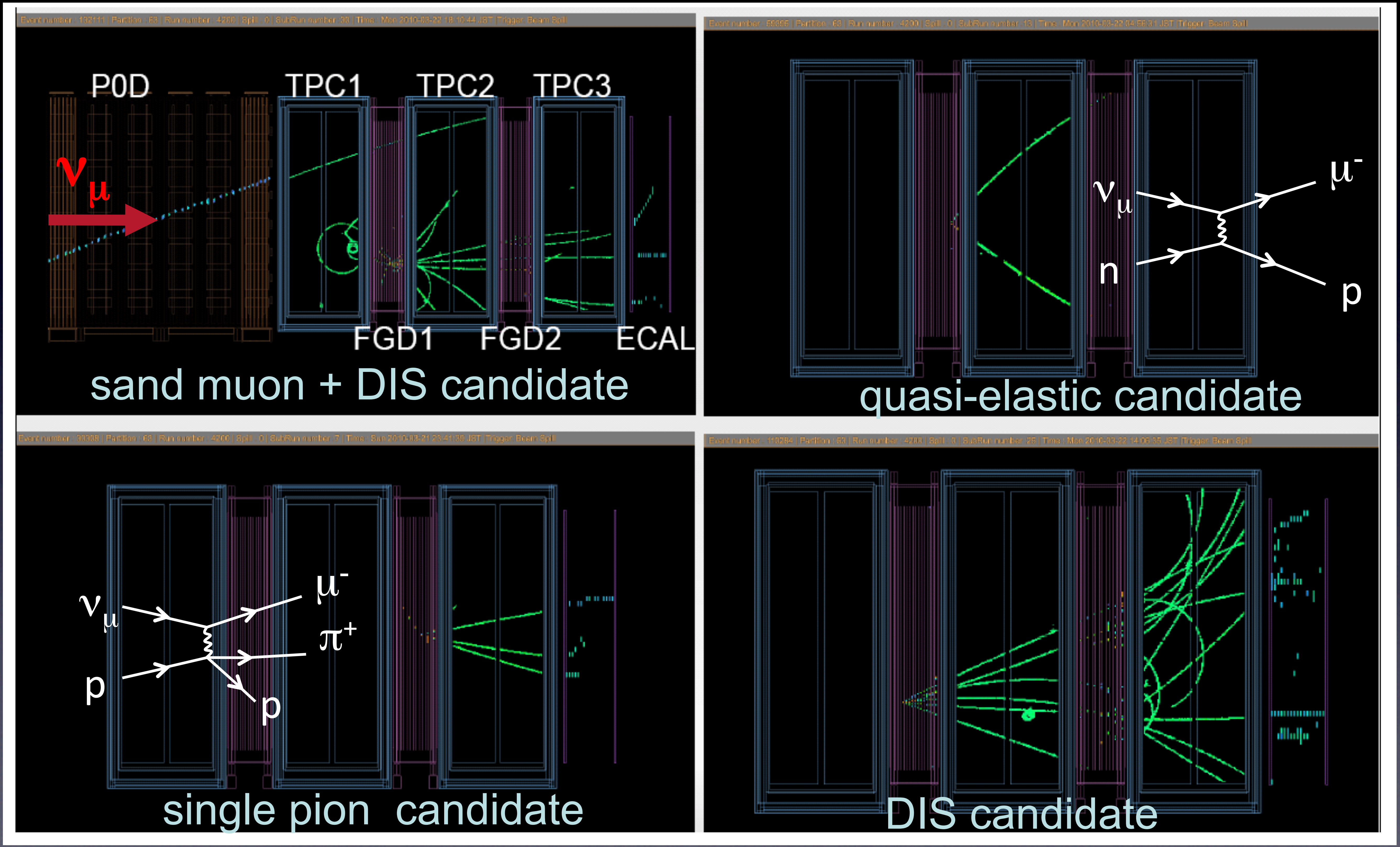
P0D mass:
16.1 tons w/ water
13.3 tons w/o water

2 FGDs (Fine Grained Detectors)
Thin, wide scintillator planes
Provides active target mass
Optimised for p recoil detection

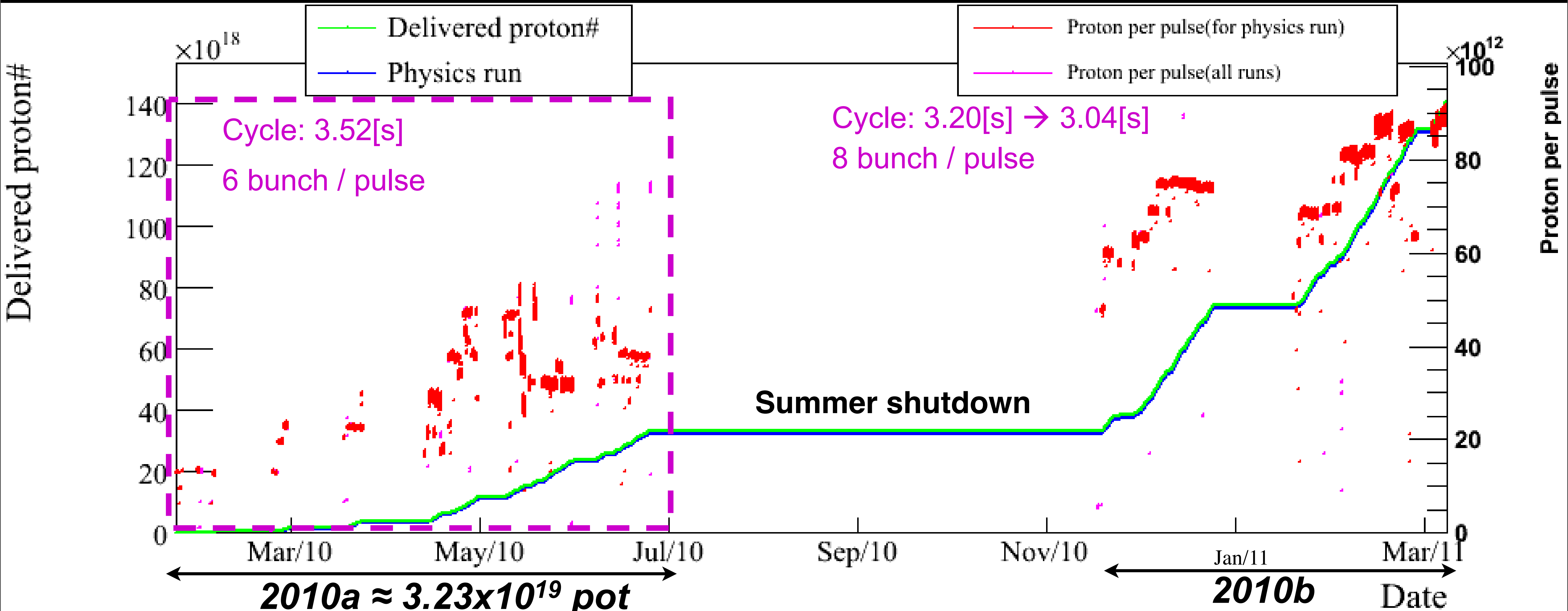
3 TPCs (Time Projection Chambers):
Momentum measurement of charged particles from FGD and P0D
PID via dE/dx measurement

FGD1: Scintillator planes ~ 1 ton,
FGD2: Scinti. & H_20 planes ~ 0.5 & 0.5 ton

ND280 off-axis event gallery



MR protons# delivered



Run 2010a (Jan-Jun 2010)

- 6 bunches/spill, cycle: 3.52 sec
- **3.23×10^{19} p.o.t** for T2K analysis
- 50kW stable beam operation (trials at 100 kW)
- Super-K live time >99%

Run 2010b (Nov 2010-??? 2011)

- 8 bunches/spill, **9×10^{13} ppp**
- cycle: 3.52 sec → **3.04 sec**
- 135kW → **145 kW beam power**
- **1.45×10^{20} p.o.t** accumulated so far
- MR intensity limited by losses

ν_μ disappearance analysis

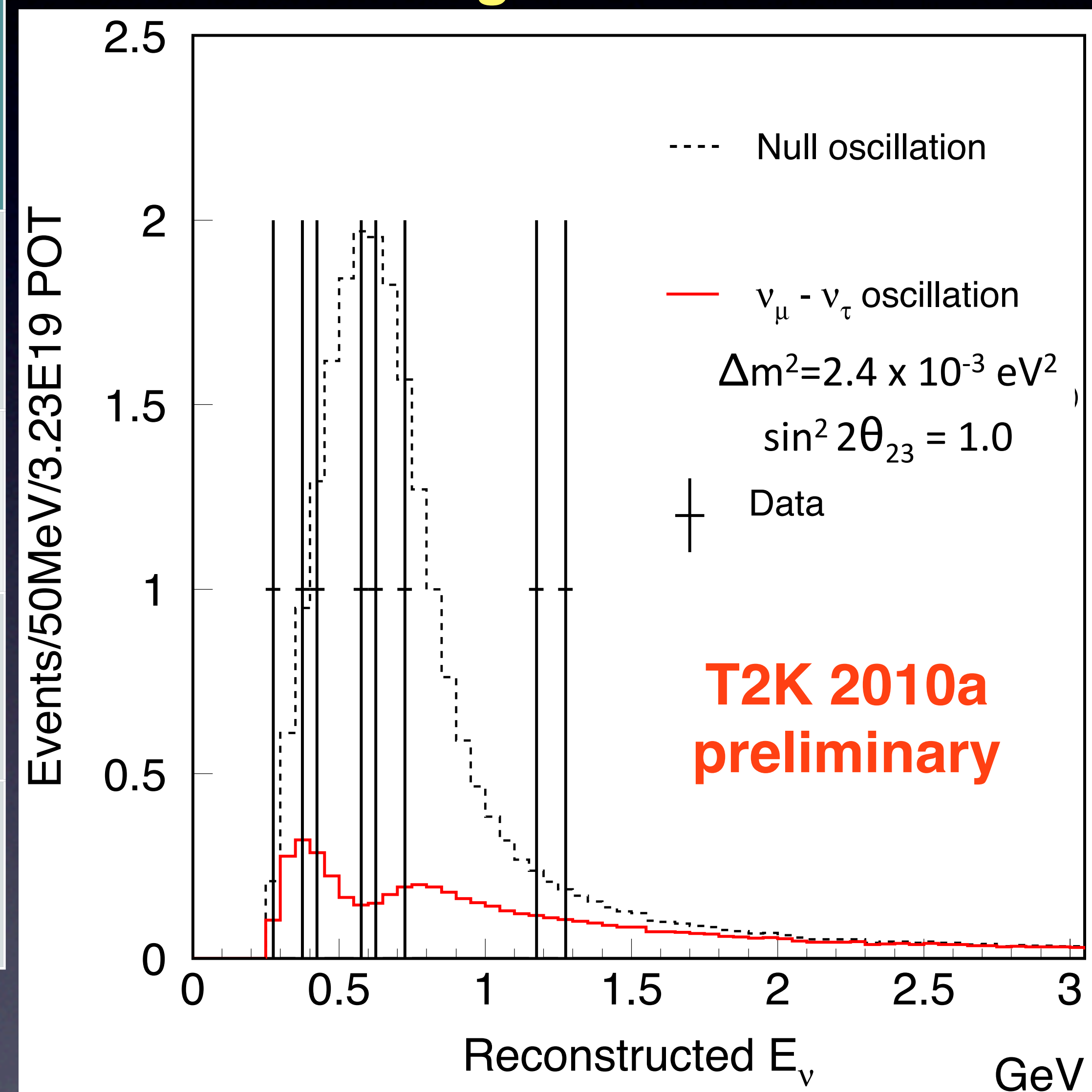
T2K

Event selection for muon disappearance measurement

T2K-SK events	Data	MC		Acc.BG (12μs window)
		No oscillation	W/ oscillation	
Fully-Contained	**33**	54.5	24.6	0.0094
Fiducial Volume, E_{vis} > 30MeV	**23**	36.8	16.7	0.0011
Single-ring μ-like P_μ>200MeV/c	**8**	24.5±3.9	7.1±1.3	-
+ number decay-e <=1 & Erec<10 GeV	**8**	22.8±3.2	6.3±1.0	-

$\Delta m^2=2.4 \times 10^{-3}$ eV^2 and $\sin^2 2\theta_{23} = 1.0$

Reconstructed energy assuming QE kinematics



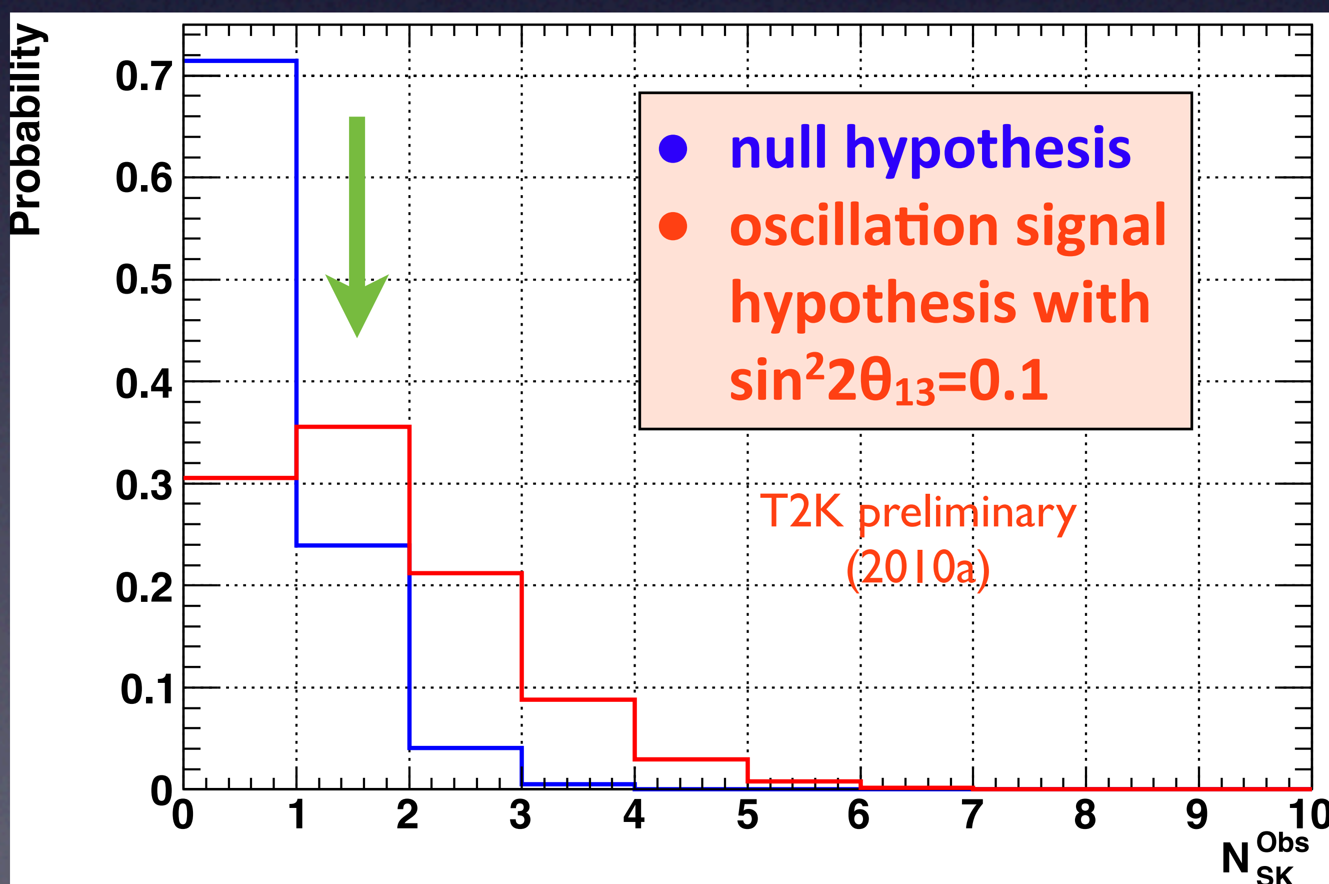
- Consistent with oscillation parameters measured by MINOS / SK / K2K
- Parameter fitting underway – T2K plans to release result in the near future

Expected #SK events

Source	Estimated number
Beam ν_μ (CC+NC)	0.13
Beam $\bar{\nu}_\mu$ (CC+NC)	0.01
Beam ν_e (CC)	0.16
Total background	**0.30 ± 0.07 (syst.)**
Total sig.+background	**1.20 ± 0.23 (syst.)**

- #events normalized to p.o.t. and corrected for ND280 ν_μ CC measured normalization
- Assumed oscillation parameters for signal:

$\Delta m^2_{23}=2.4\cdot10^{-3}eV^2$
$\sin^2 2\theta_{23}=1.0$
$\sin^2 2\theta_{13}=0.1$
$\delta_{CP} = 0$



T2K preliminary (2010a)

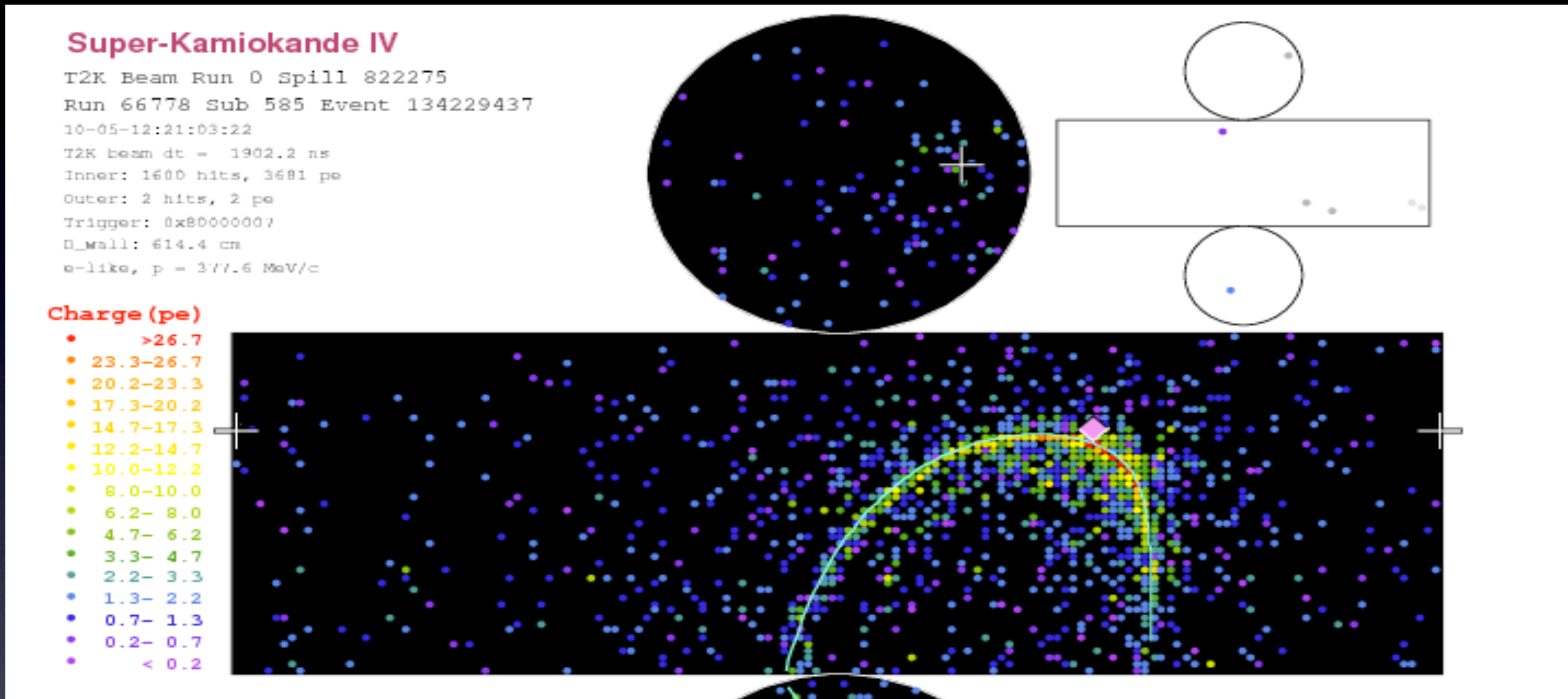
~29% probability to observe >=1 event when expected average = 0.3 event

1 data candidate!

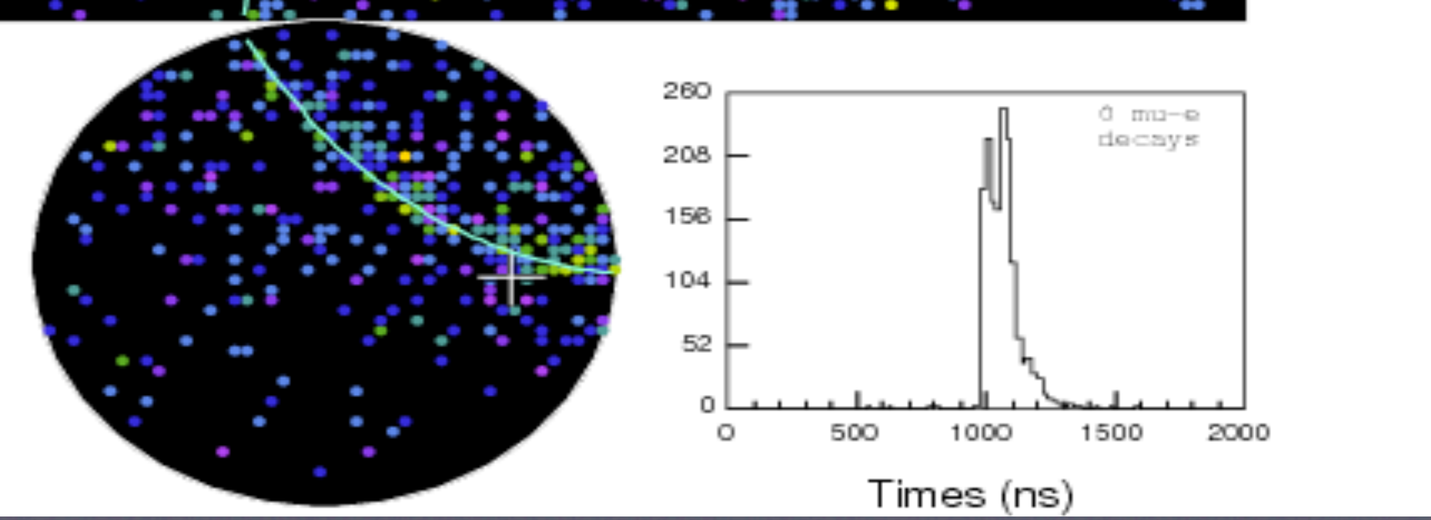
$N_{SK}^{obs} = 1$

T2K ν_e CC signal candidate (2010a)

Signal candidate event passing all cuts



Item	Event	T2K cut
Date (JST)	2010 May 12th 21:3:22	
Ring, PID	1-Ring electron-like	OK
Momentum	378 MeV	>100
N_{dcy}	0	0
$\cos(\theta_{\nu e})$	0.55 (57 degree)	N/A
$Mass$	0.13 MeV	<105
E_{rec}	496 MeV	<1250



T2K appearance upper limit results

Two independent statistical procedures

T2K preliminary (2010a)

Assuming $\Delta m^2_{23}=2.4\cdot10^{-3}eV^2$ and $\sin^2 2\theta_{23}=1.0$, $\delta_{CP} = 0$:

(A) Feldman-Cousins

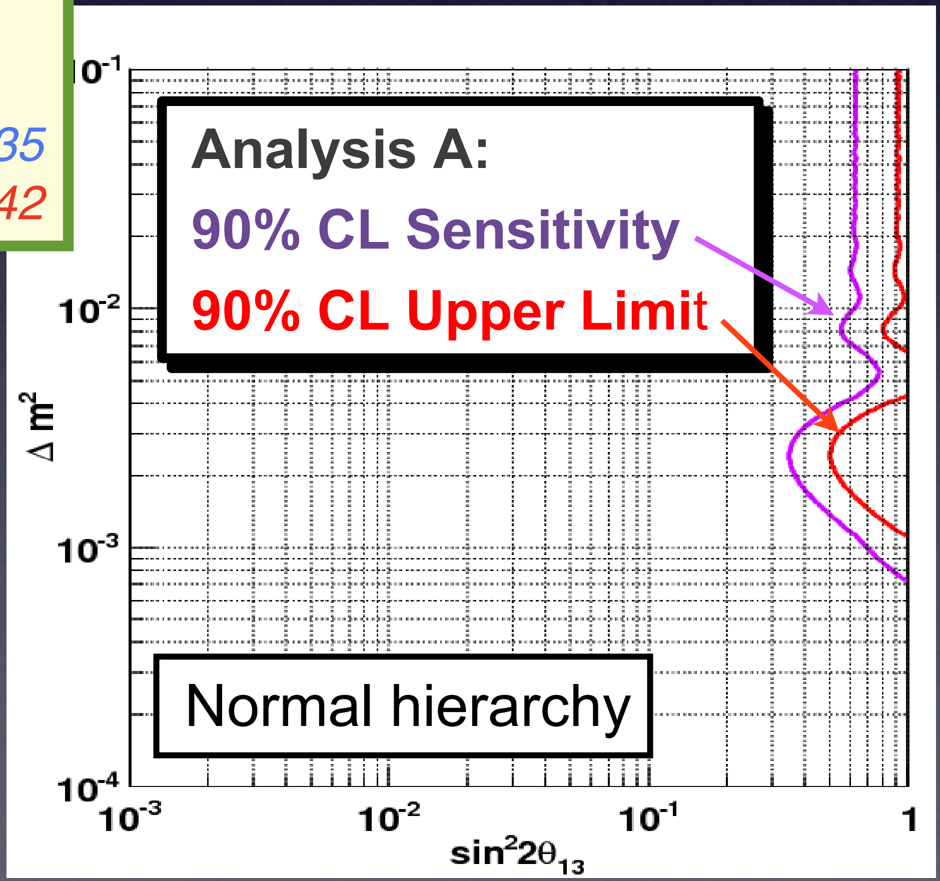
Normal Hierarchy : $\sin^2(2\theta_{13}) < 0.50$ *(90%C.L.)*
Inverted Hierarchy : $\sin^2(2\theta_{13}) < 0.59$ *(90%C.L.)*

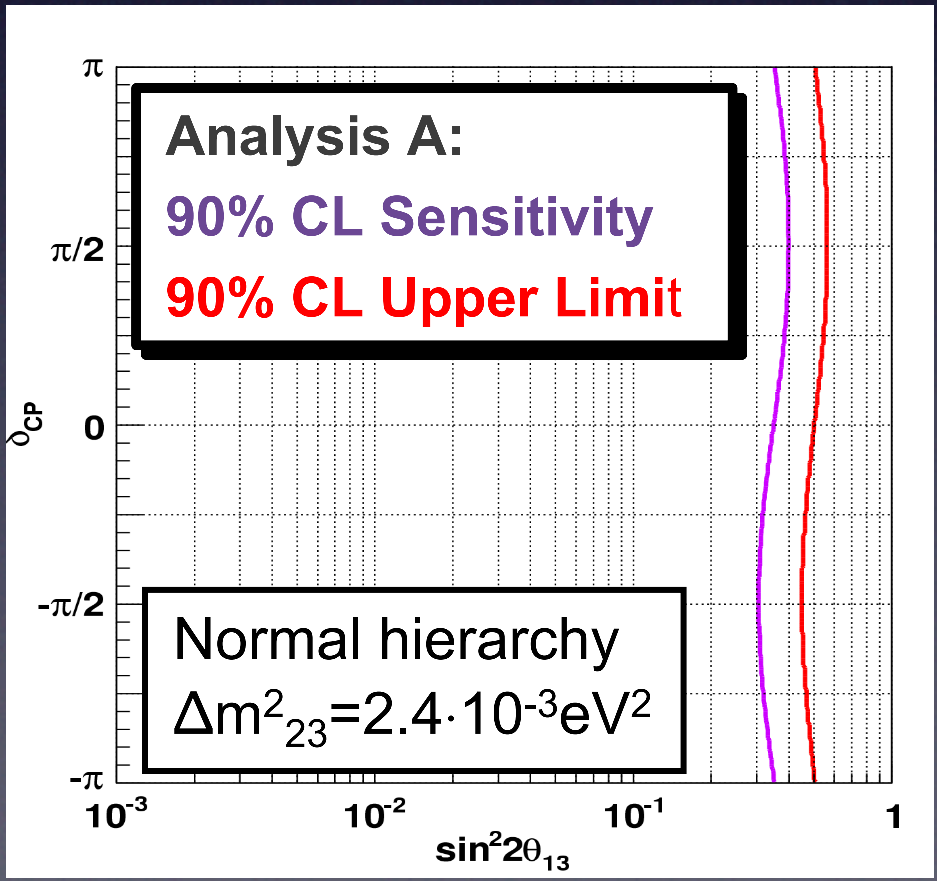
(B) Classical one-sided

Normal Hierarchy : $\sin^2(2\theta_{13}) < 0.44$ *(90%C.L.)*
Inverted Hierarchy : $\sin^2(2\theta_{13}) < 0.53$ *(90%C.L.)*

T2K 2010a 90%C.L. sensitivity (Analysis A):
Normal Hierarchy : $\sin^2(2\theta_{13}) < 0.35$
Inverted Hierarchy : $\sin^2(2\theta_{13}) < 0.42$

- More collected data on tape
- Analyses underway





As a last speaker, on behalf of all partecipants I would like to most warmly thank the Organisers of this Conference

I am sorry that this is my first NeuTel without the charming presence of Milla Baldo Ceolin who has always been the Queen of the place

So I extend our best greetings to Milla and our warmest wishes of a prompt recovery

EPILOGUE

Three (ν) gondolas are safe in the harbor…
…but that's not what they are made for.
New gondolas might join, and all lead us
towards new (physics) horizons

Thank you for your attention