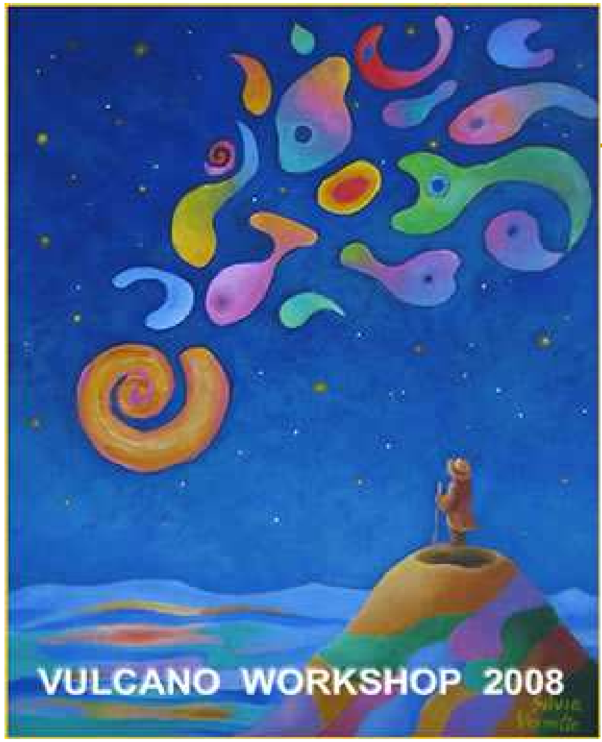
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Double-Chooz Neutrino Experiment



Carmen Palomares
Ciemat (Spain)
For Double-Chooz Collaboration

Neutrino Oscillation

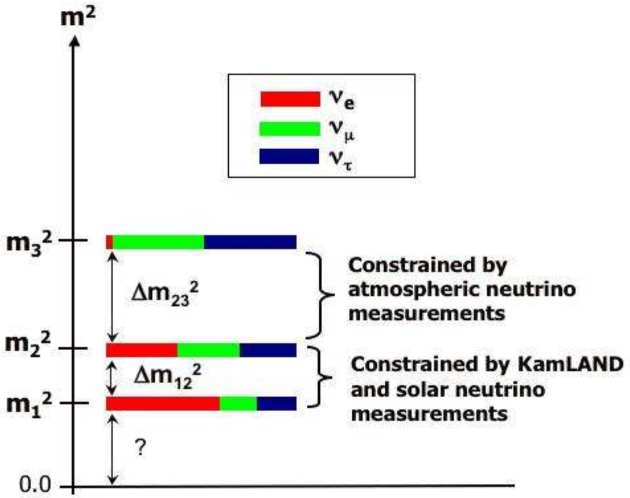
From $\nu_\mu \to \nu_\tau$
Atmospheric ν_μ

From nuclear reactor experiments

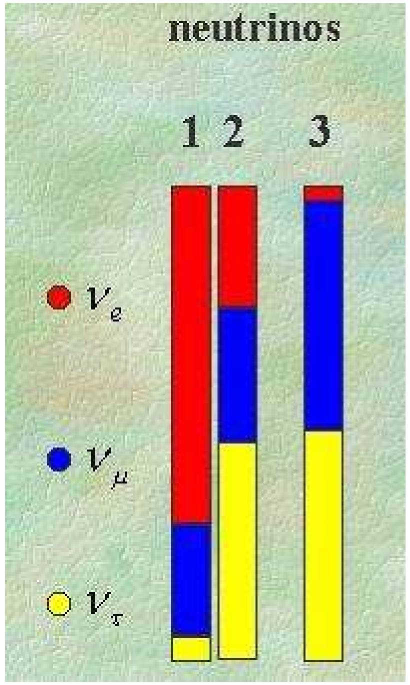
From $\nu_e \to \nu_x$
Solar ν_e

$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = \begin{pmatrix}1 & 0 & 0\\ 0 & c_{23} & s_{23}\\ 0 & -s_{23} & c_{23}\end{pmatrix}\begin{pmatrix}c_{13} & 0 & s_{13}e^{-i\delta}\\ 0 & 1 & 0\\ -s_{13}e^{-i\delta} & 0 & c_{13}\end{pmatrix}\begin{pmatrix}c_{12} & s_{12} & 0\\ -s_{12} & c_{12} & 0\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$$

where $s_{ij} = \sin\theta_{ij}$ $c_{ij} = \cos\theta_{ij}$



3 mixing angles
1 complex phase
2 mass differences



Current knowledge

SK+K2K+MINOS

$$\theta_{23} = 43.3^{+4.3}_{-3.8}$$

$$|\Delta m^2_{13}| = 2.6 \pm 0.2 \times 10^{-3} eV^2$$

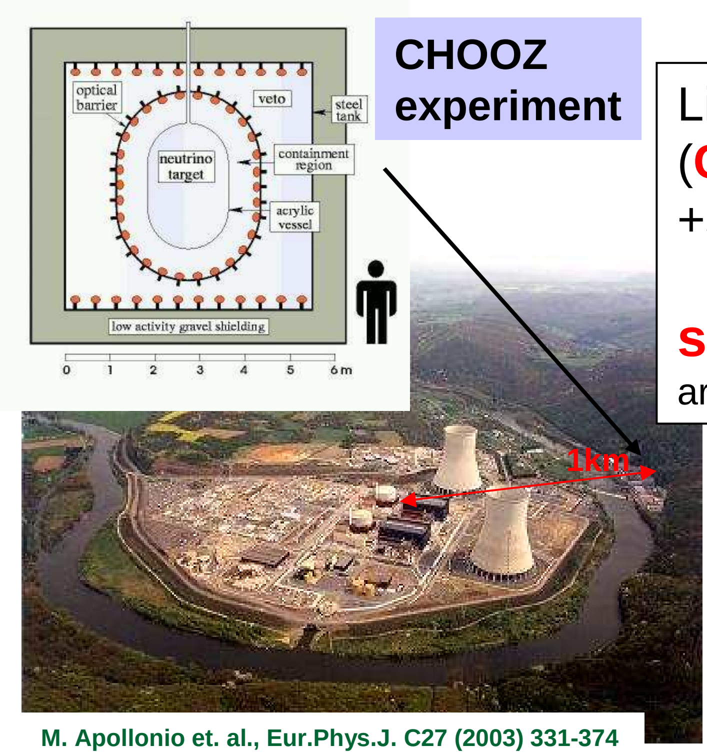
Solar+KamLAND

$$\theta_{12} = 33.7 \pm 1.3$$

$$\Delta m^2_{12} = 7.9^{+0.27}_{-0.28} \times 10^{-5} eV^2$$

@1σ arXiv:0704.1800

CHOOZ experiment

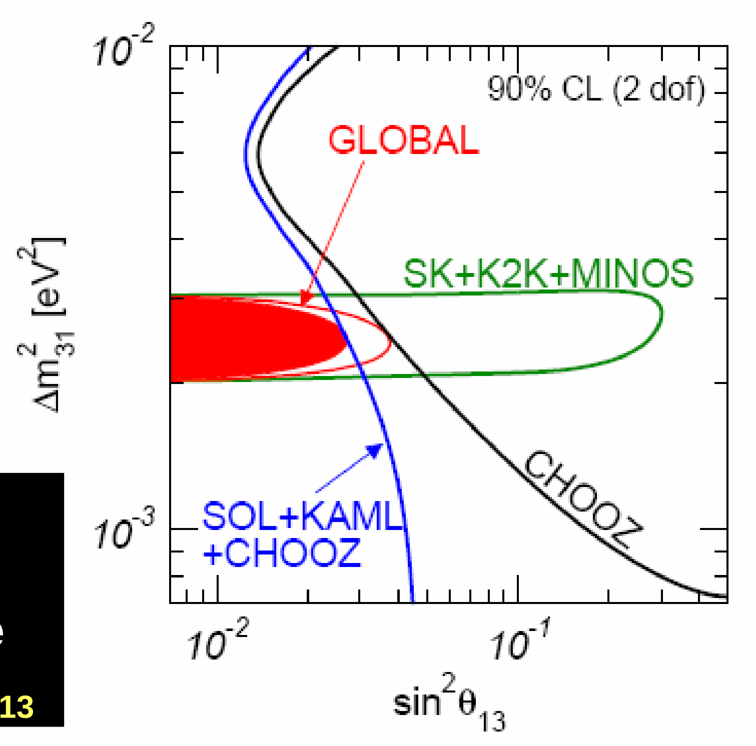


M. Apollonio et. al., Eur.Phys.J. C27 (2003) 331-374

Limit at 90% CL:
(**CHOOZ**+atm+LBL +solar+KamLAND)

$\sin^2 2\theta_{13} < 0.11$
arXiv:0710.5027

The main goal of upcoming experiments is the determination of θ_{13}



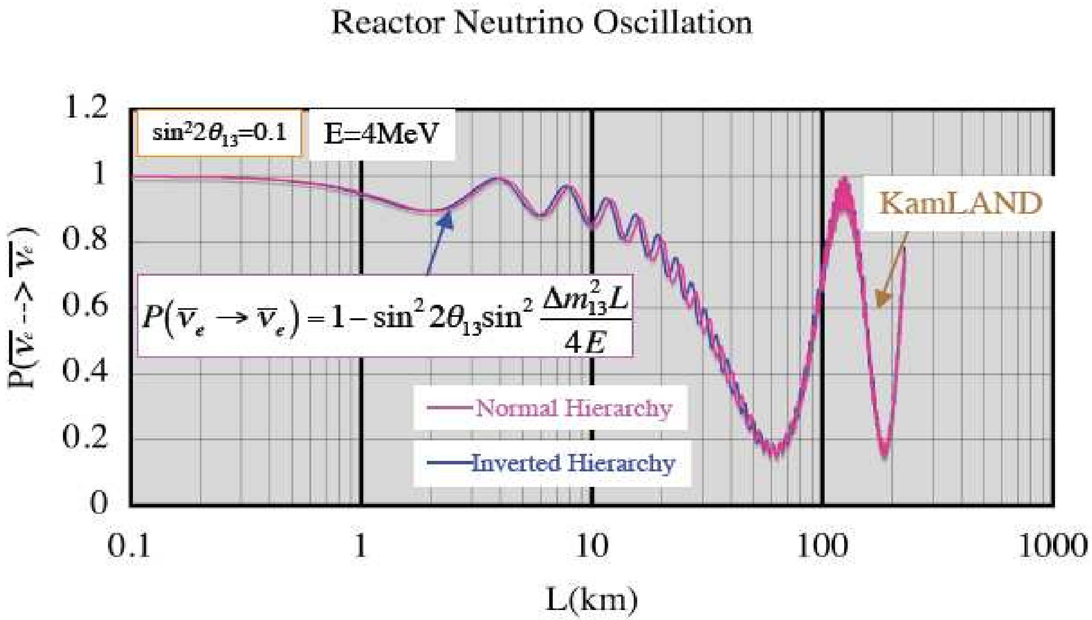
Θ_{13} at nuclear reactors experiments

$\bar{\nu}_e$ disappearance searches

$P(\bar{\nu}_e \rightarrow \bar{\nu}_e)$ Independent of δ-CP, weak dependence on Δm_{12}

Matter effects negligible due to the small distances and the ν energy O(MeV)

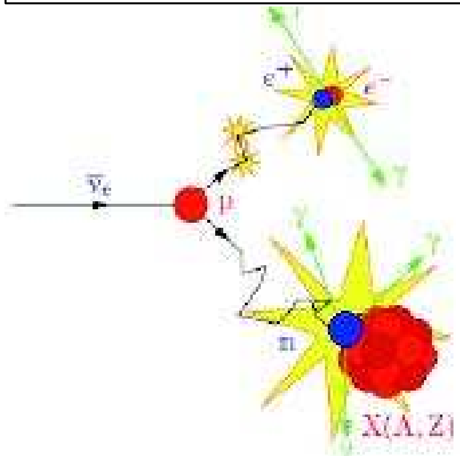
- Unambiguous measurement of Θ_{13} complementary to beams
- The only limitation comes from statistical and systematic errors
- These experiments must be carried out on a short time scale to provide an input for future beams

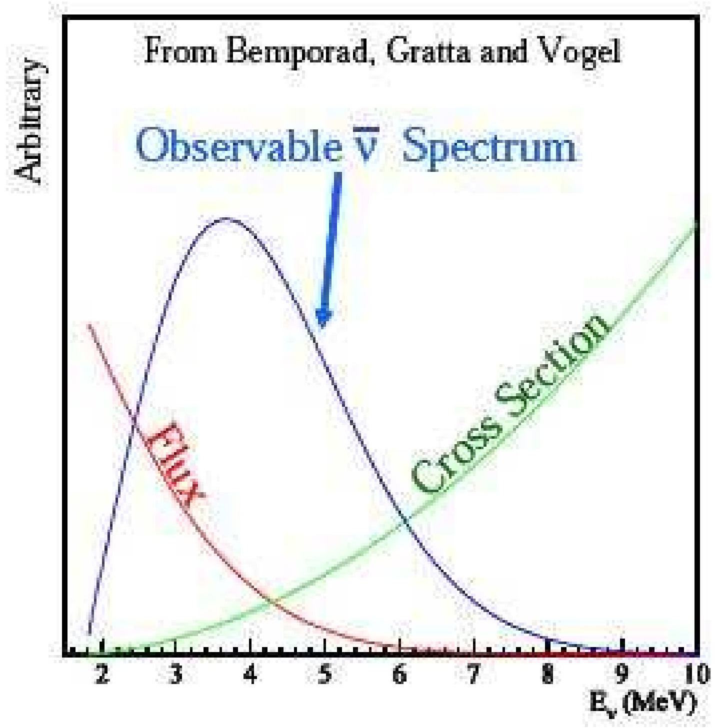


Neutrino detection at nuclear reactor experiments

Detection by inverse β-decay

$$\overline{\nu}_e + p \rightarrow e^+ + n$$





Signature Delayed coincidence of:

Prompt **e^+** annihilation $E_{e+} = E_\nu-(M_n-M_p)$

Photons from **n** capture on H E_γ= 2 MeV

on dedicated nuclei (Gd) E_γ = 8 MeV

Backgrounds

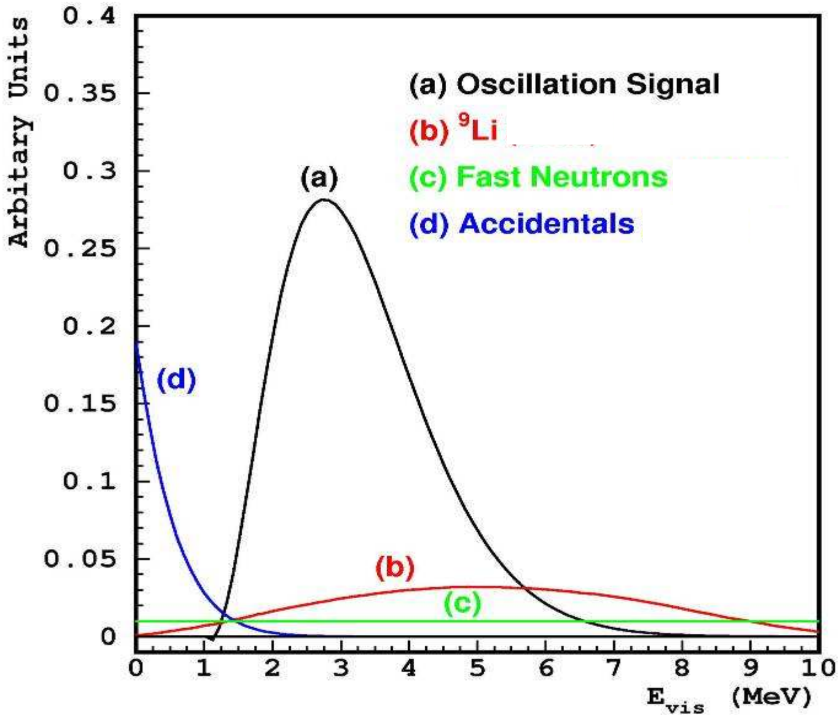
Accidental:

- e+-like signal: radioactivity from materials and surrounding rock.
- n signal: n from cosmic μ spallation, thermalized and captured on Gd.

  Or another radioactivity event

Correlated:

- fast n (by cosmic μ) recoil on p (low energy) and captured on Gd
- long-lived (^{9}Li, ^{8}He) β-decaying isotopes induced by μ

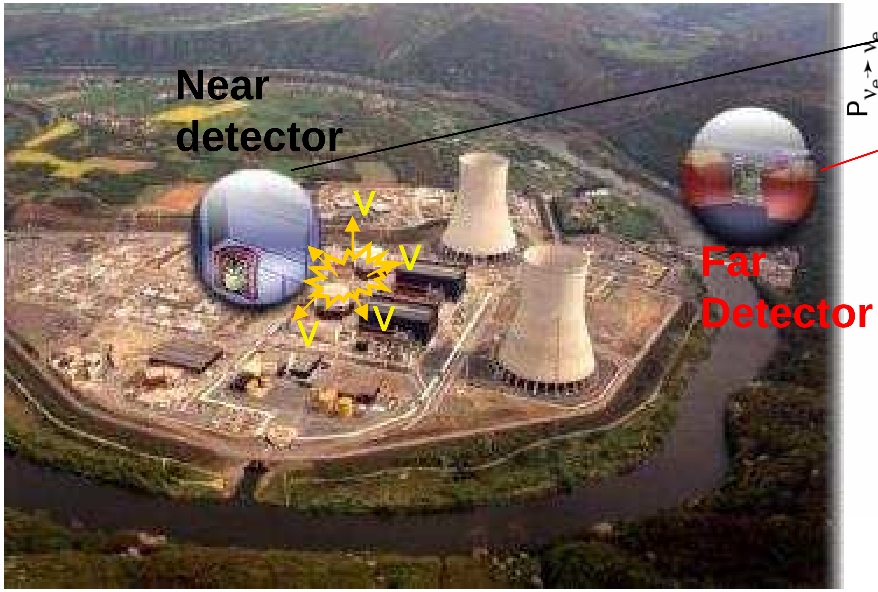


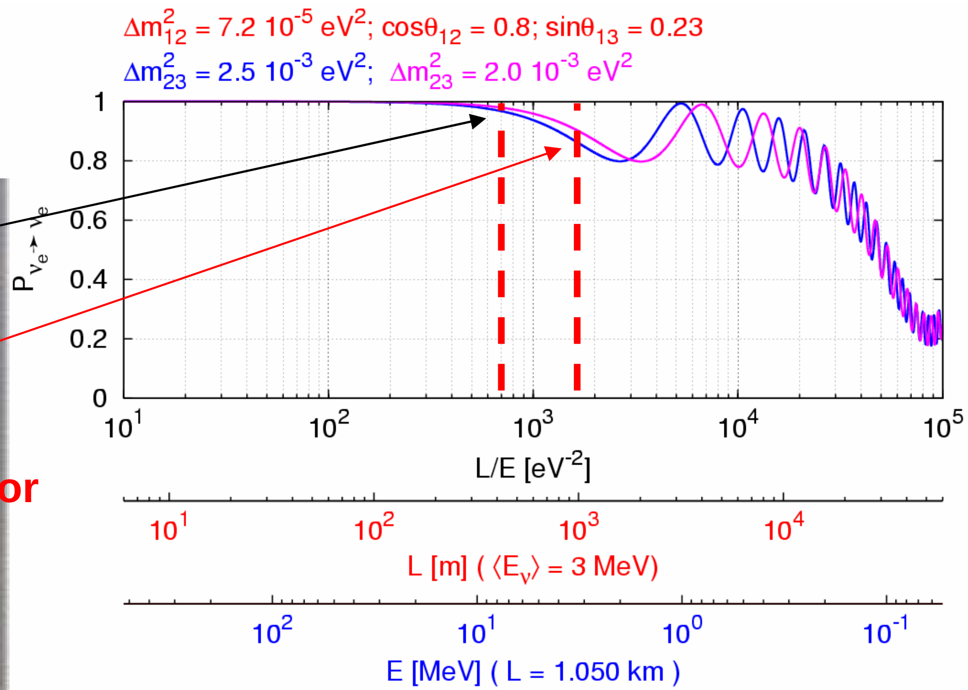
Double Chooz Concept

To look for non-zero values of Θ_{13}

Beyond the previous systematic limitations:

1. **Two detectors** to reduce uncertainties to the reactor flux
2. **Identical detectors** to reduce errors due to detector acceptance





Improving CHOOZ

CHOOZ: $R = N_{meas}/N_{exp} = 1.01 \pm 2.8\%\ (stat) \pm 2.7\%\ (sys)$

Statistical error

	CHOOZ	Double Chooz
Target volume	5.55 m3	10.3 m3
Data taking period	Few months	3-5 years
Event rate	2700	Chooz-far 40000/3y Chooz-near > 1 106/3y
Statistical error	2.8%	0.5%

Systematic errors

	CHOOZ	Double Chooz
Reactor uncertainties	2.1%	----
Number of protons	0.8%	0.2%
Detector Efficiency	1.5%	0.5%

- Improve detector design and knowledge
- Large S/B detector design (shielding and radiopurity materials) and increasing overburden

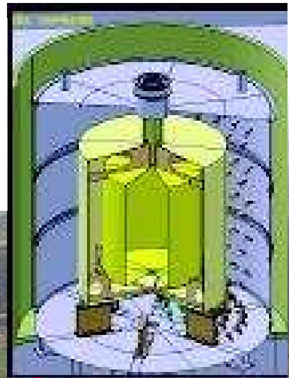
The Double Chooz Collaboration

Spokesman: Hervé de Kerret (APC)

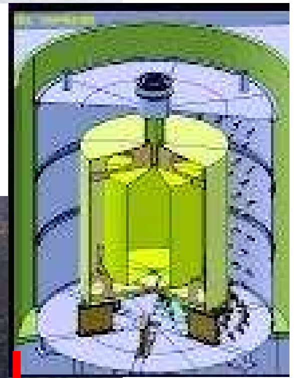
- **France: APC Paris, CEA/Dapnia Saclay, Subatech Nantes, Strasburg**
- **Germany: Aachen, MPIK Heidelberg, TU München, EKU Tübingen, Hamburg**
- **Spain: CIEMAT Madrid**
- **UK: Sussex**
- **Japan: HIT, Kobe, MUE, Niigata, TGU, TIT, TMU, Tohoku**
- **Russia: RAS, RRC Kurchatov Institute**
- **USA: Alabama, ANL, Chicago, Columbia, Drexel, Illinois, Kansas, LLNL, LSU, Notre Dame, Sandia, Tennessee, UCD**
- **Brazil: CBPF, UNICAMP**

The Chooz site:

Near lab
400 m
115 m.w.e.

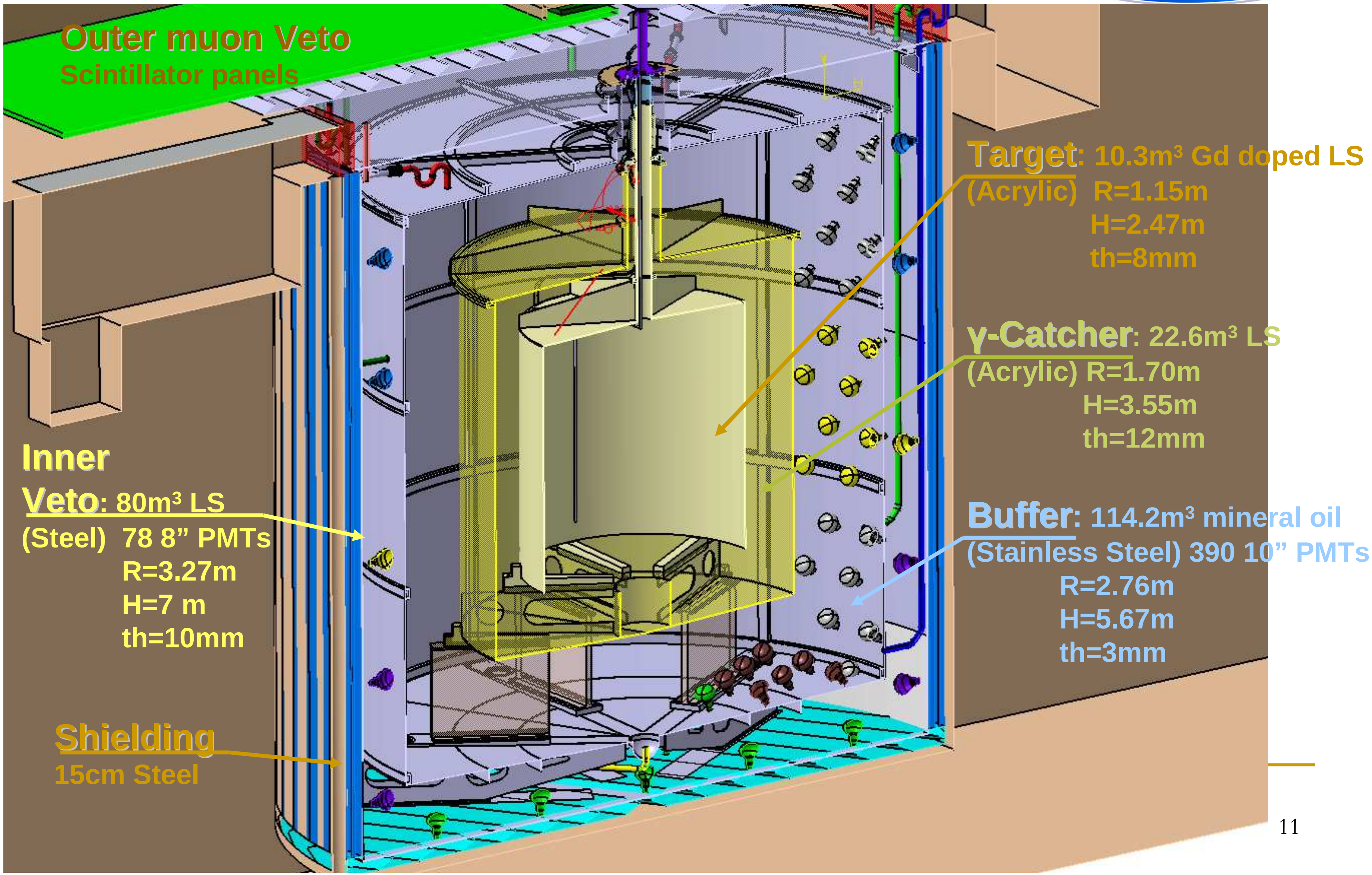


Far lab
1050 m
300 m.w.e.



Chooz-B reactors
8.4 GWth
Placed in the Ardennes
(France)

The Detector(s)



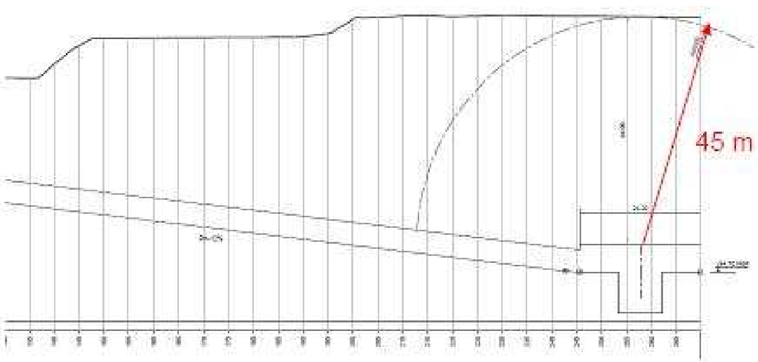
Current Status

- Current Activity: Far Detector Construction and Integration

Civil engineering work completed.
Pit refurbished and access adapted.

Near detector:

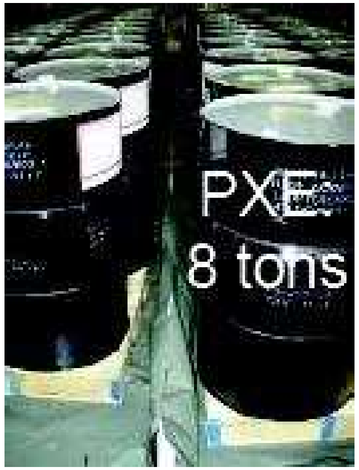
- Location defined
- Preliminary study completed
- Lab ready end of 2009



Current Status

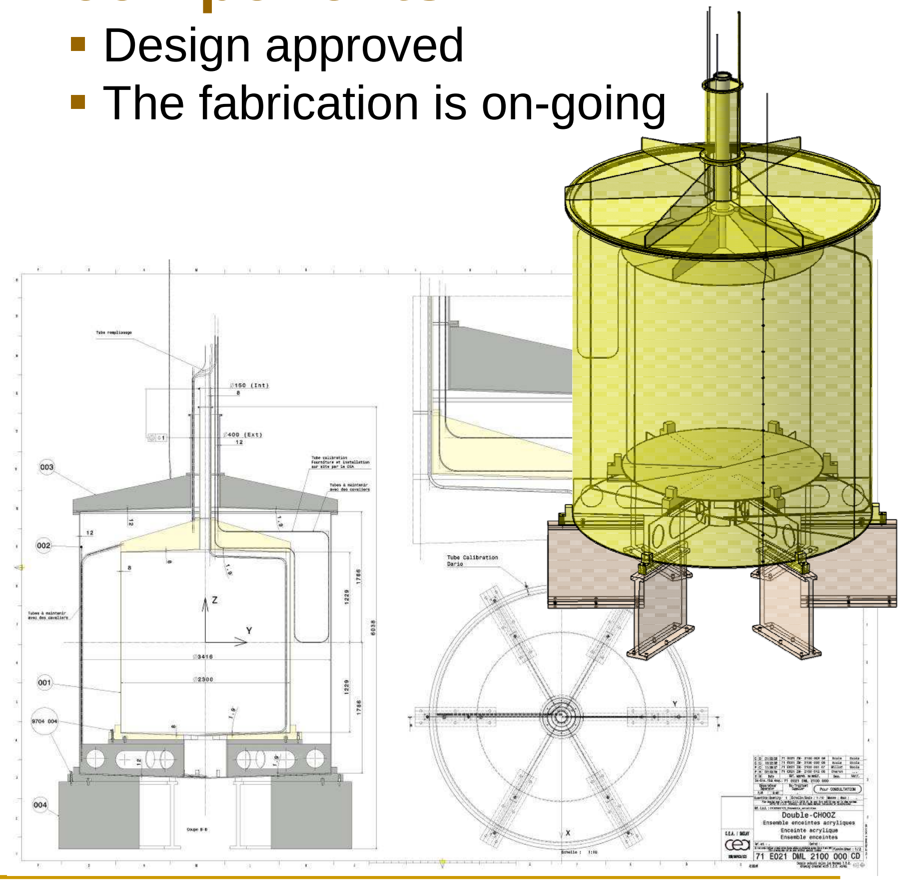
Liquid Scintillator

- Delivery Gd-complex completed
- PXE arrived in MPIK (Heidelberg) tests and purification going on
- Scintillator hall ready, filling up with equipment



Vessels and mechanical components:

- Design approved
- The fabrication is on-going

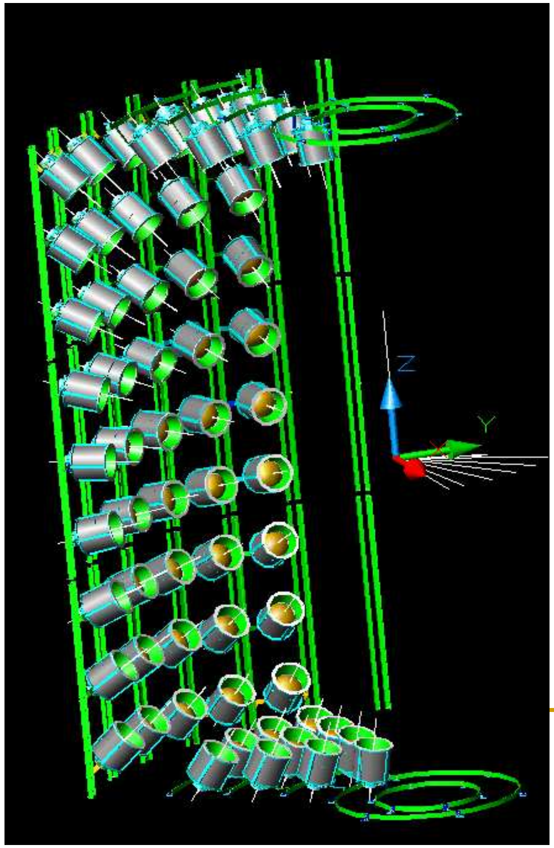


Current Status

PMT 10" Hamamatsu R7081

First 100 PMT batch delivered.
Test benches ready

PMT geometry baseline
390 PMTs/detector

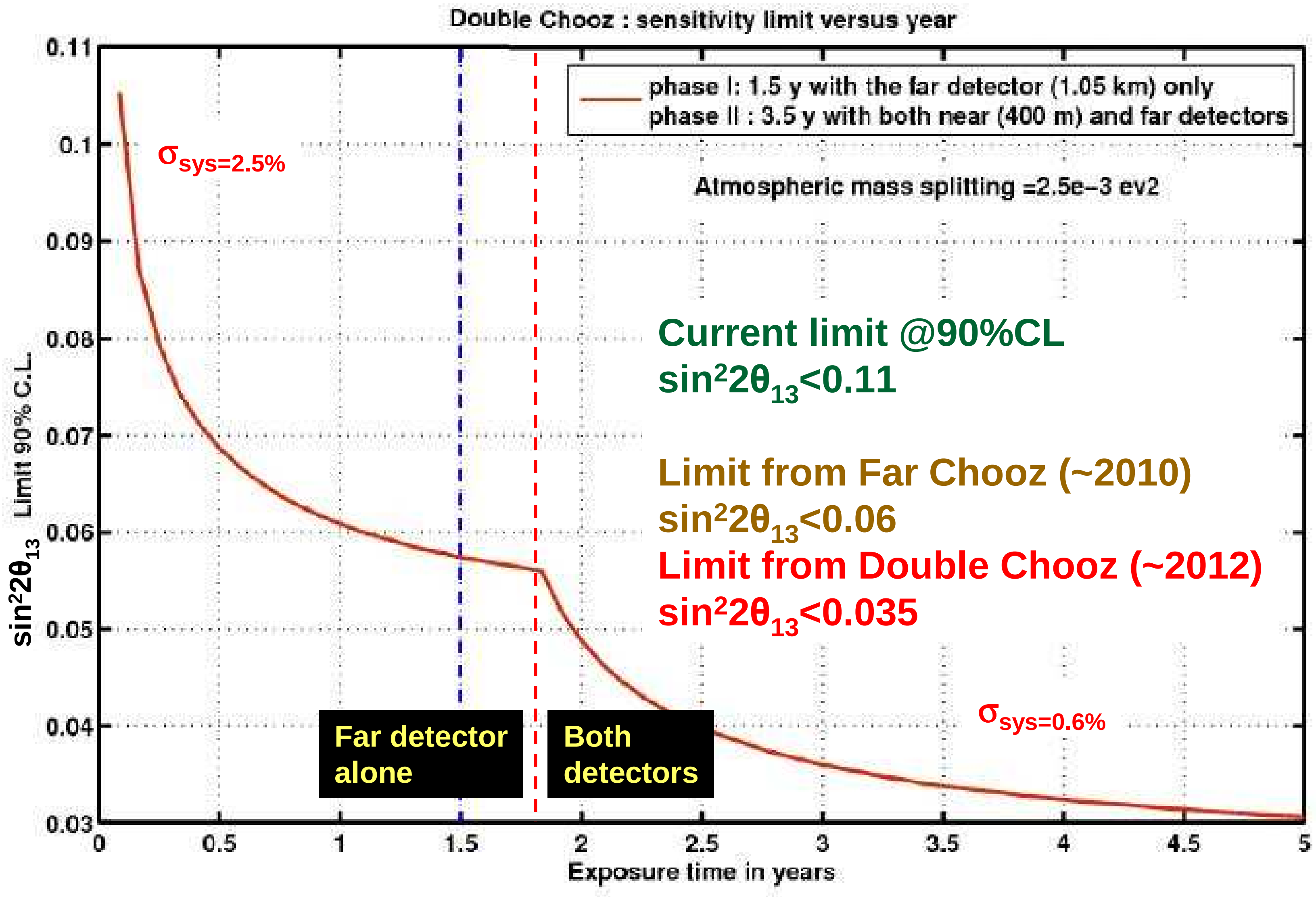


PMT mechanical support
& magnetic shield

Schedule

Far detector assembly	2008–Summer 2009
Far detector commissioning	Summer 2009
Near detector civil work complete	End 2009
Near detector assembly	2010
Near detector start	Beginning 2011

Expected Sensitivity



Current limit @90%CL
$\sin^2 2\theta_{13}<0.11$

Limit from Far Chooz (~2010)
$\sin^2 2\theta_{13}<0.06$

Limit from Double Chooz (~2012)
$\sin^2 2\theta_{13}<0.035$

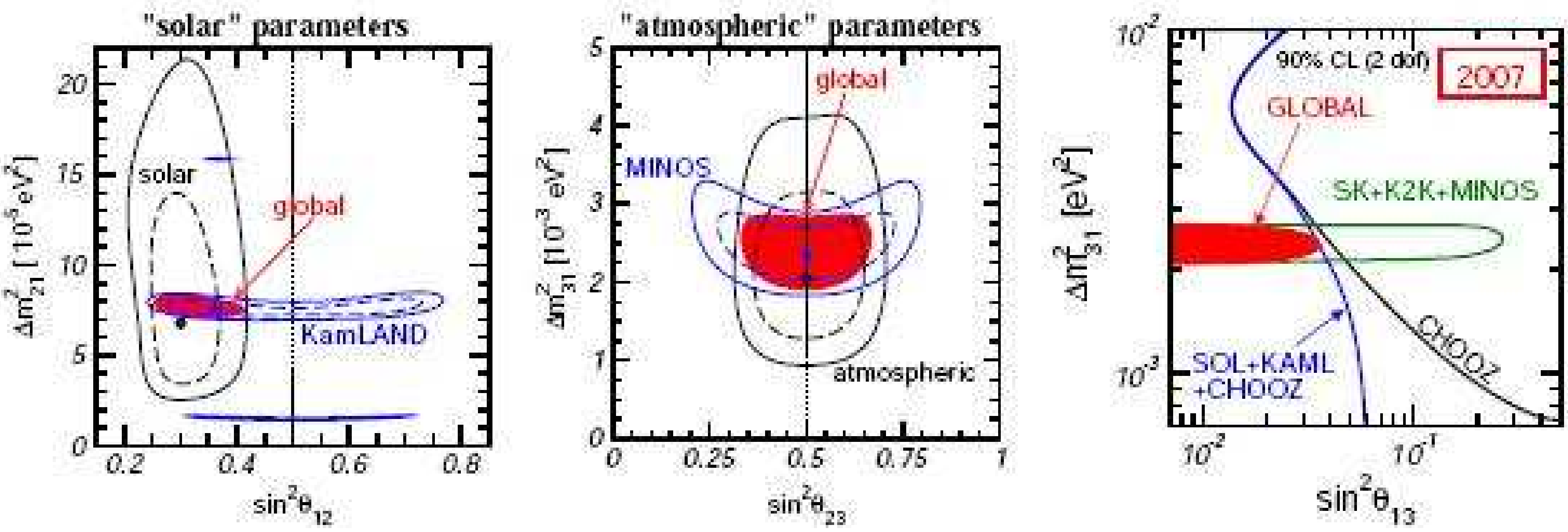
Summary

- **Double Chooz** will be the first of a new generation of neutrino experiments **using identical detectors at different distances** from a reactor to measure Θ_{13}

- We will **measure or set a strong limit in Θ_{13}** within a few years

Backup

Neutrino oscillations: present status



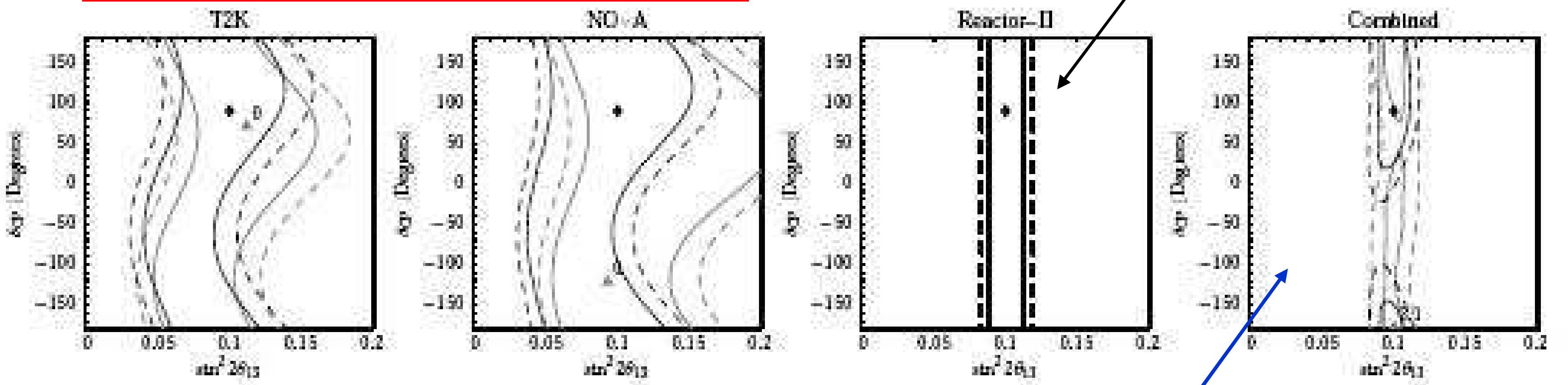
Θ_{13} Determination

$\sin^2 2\theta_{13}$—δ plane for the true values $\sin^2 2\theta_{13}=0.1$ and $\delta=90°$

arXiv:0710.5027

Super beams

Reactor experiment determines $\sin^2 2\theta_{13}$ unambiguosly



—— 90% CL

- - - - - 3σ

♦ Best fit normal hierarchy

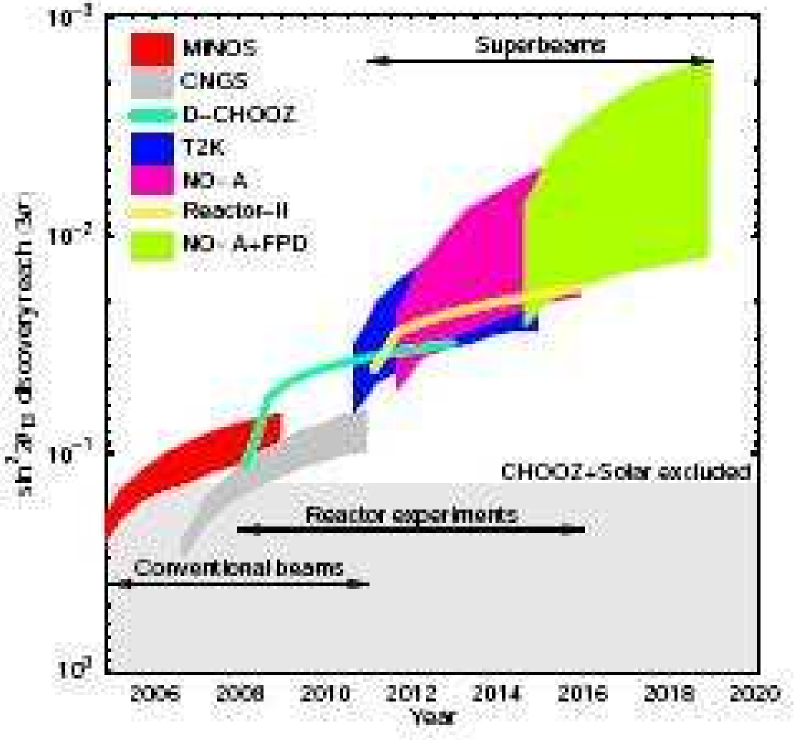
▲ Best fit inverted hierarchy

Combination:

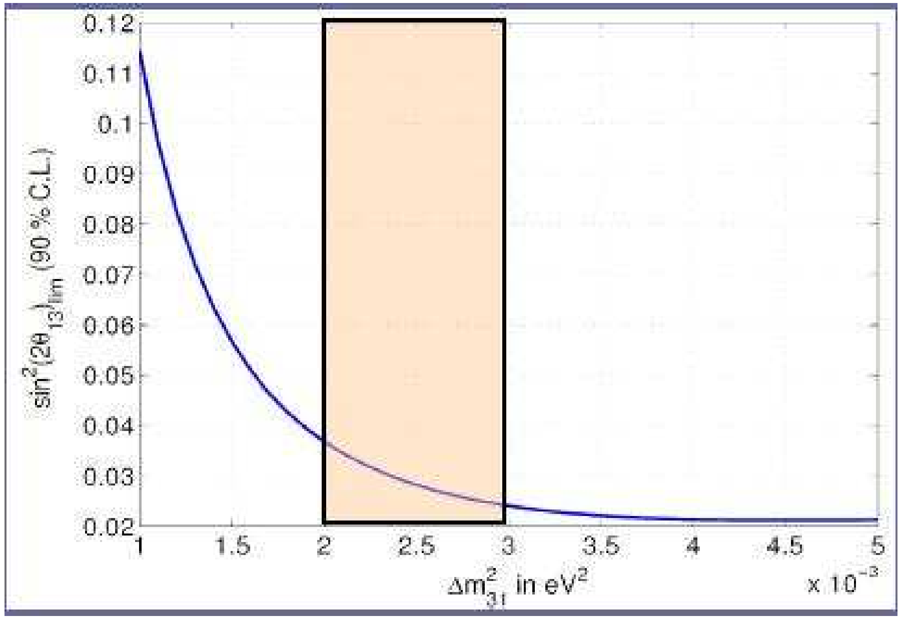
- A relative good determination of θ13
- Some information on δ (corrupted by the ambiguity in the mass hierarchy)
- CP violation cannot be established

Θ_{13} Determination

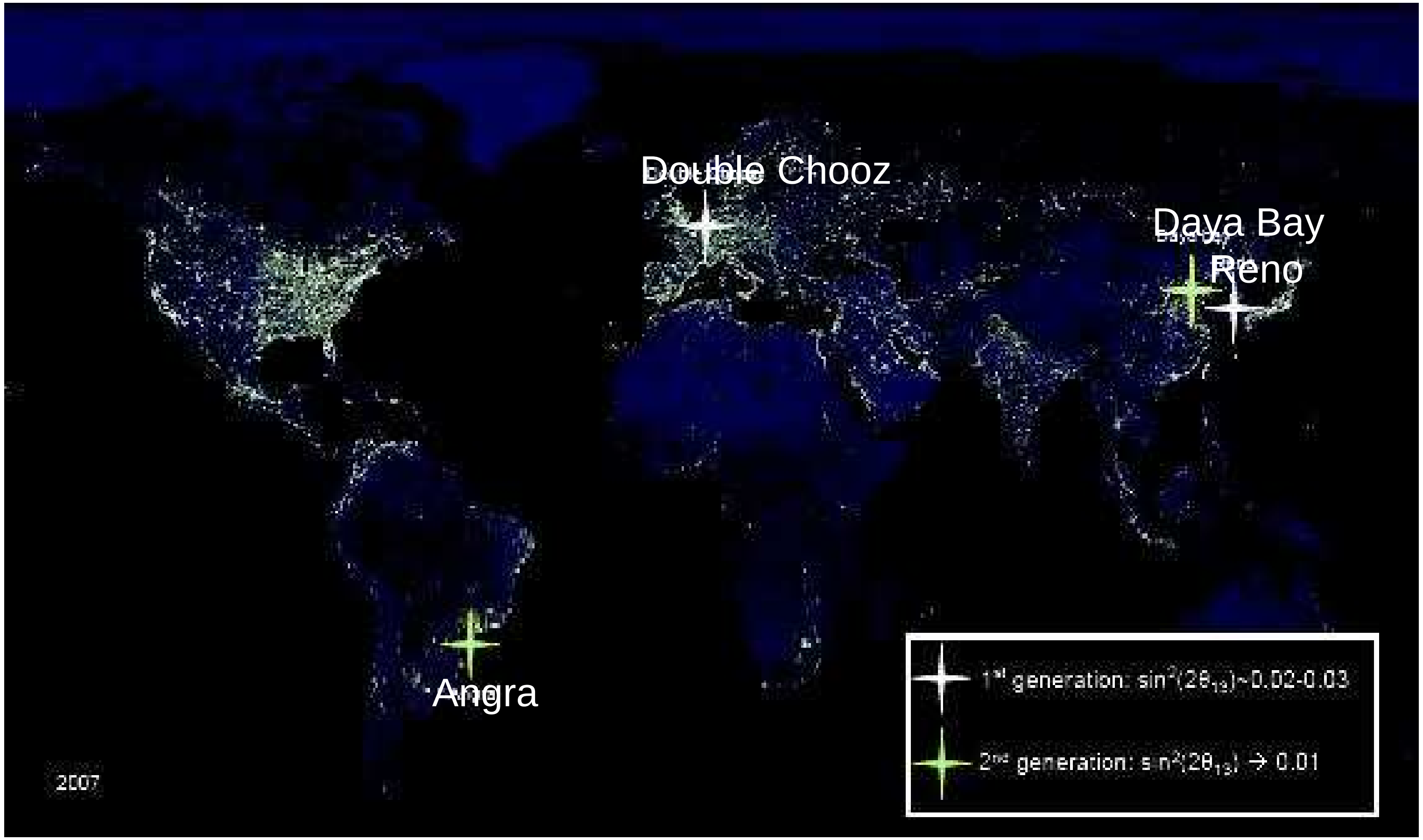
Evolution of the 3σ discovery potential of a non-zero value of θ_{13} of upcoming experiments



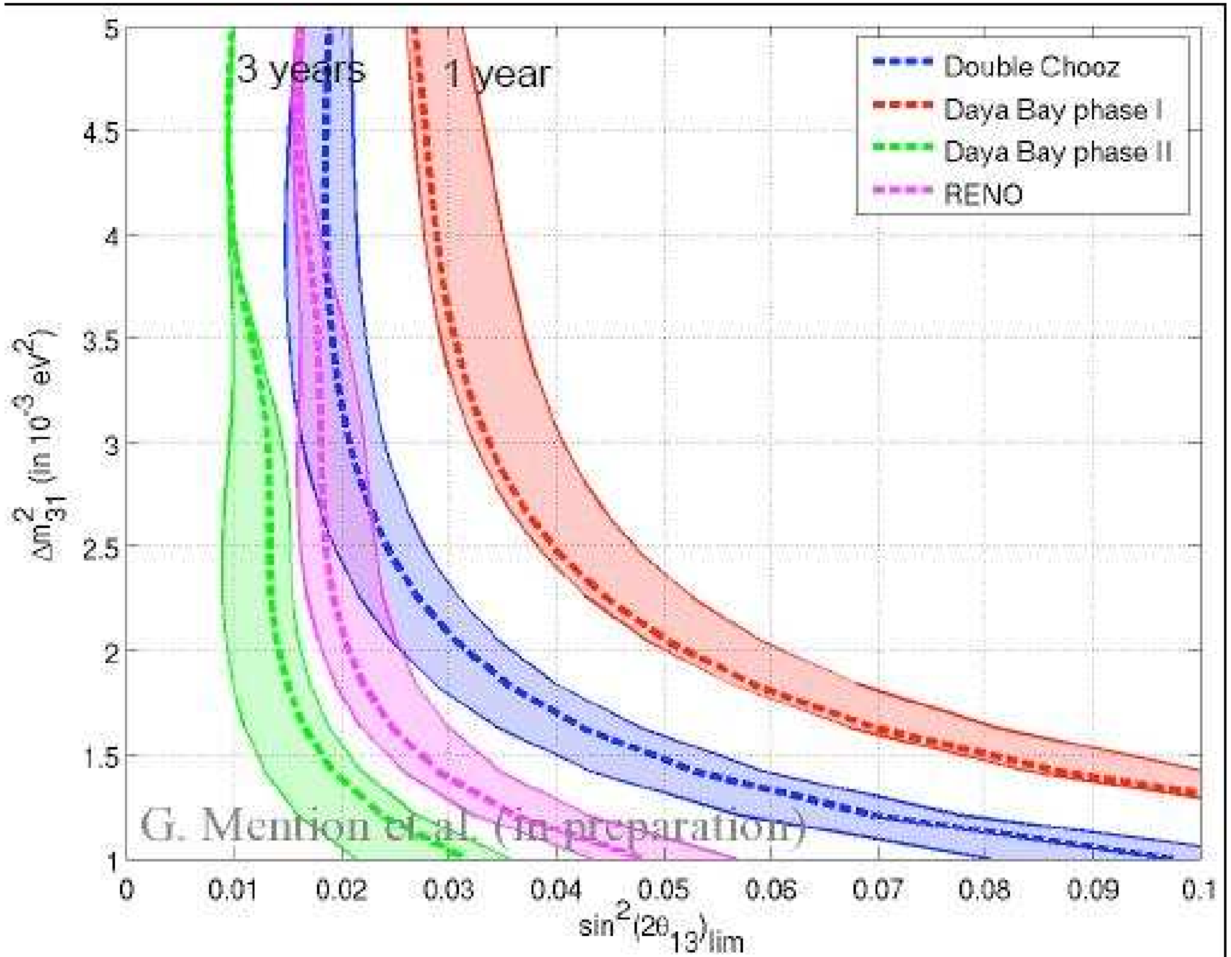
Lowest true value for which $\sin^2 2\theta_{13} = 0$ excluded at $\geq 3\sigma$



Reactor experiments proposals



Reactor experiments proposals



Double-Chooz: Systematic errors

		Chooz	Double-Chooz	
Reactor-induced	ν flux and σ	1.9 %	<0.1 %	Two "identical" detectors, Low bkg
	Reactor power	0.7 %	<0.1 %	
	Energy per fission	0.6 %	<0.1 %	
Detector - induced	Solid angle	0.3 %	<0.1 %	Distance measured @ 10 cm + monitor core barycenter
	Target Mass	0.3 %	0.2 %	Same weight sensor for both det.
	Density	0.3 %	<0.1 %	Accurate T control (near/far)
	H/C ratio & Gd concentration	1.2 %	<0.2%	Same scintillator batch + Stability
	Spatial effects	1.0 %	<0.1 %	"identical" Target geometry & LS
	Live time	few %	0.25 %	Measured with several methods
Analysis	From 7 to 3 cuts	1.5 %	0.2 - 0.3 %	(see next slide)
	Total	**2.7 %**	**< 0.6 %**	**(Total ~0.45% without contigency ....)**