The status of the Double CHOOZ experiment.

Sergey Sukhotin – RRC “Kurchatov Institute”

on behalf of Double CHOOZ collaboration.

Neutrino oscillations

$(\nu_e, \nu_\mu, \nu_\tau)^T = U\,(\nu_1, \nu_2, \nu_3)^T$

U=matrice PMSN : 3 angles, 1 CP phase (+2 mass differences)

atmospheric ν | leptonic ~~CP~~ phase δ | solar ν

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

Super-K+K2K+MINOS $P(\nu_\mu \to \nu_\mu)$

Solar+KAMLAND $P(\nu_e \to \nu_x)$

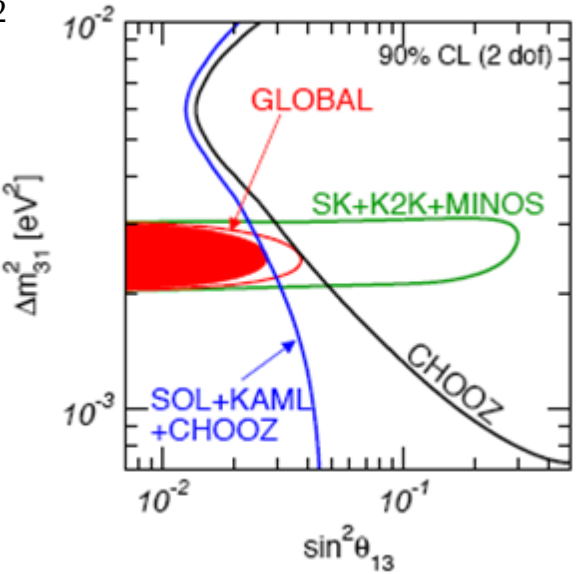
CHOOZ
$\sin^2(2\theta_{13})<0.2$

$\Theta_{23} = (45.0^{+4.0}_{-3.4})^\circ$

$\Delta m^2_{23} = (2.40 \pm 0.12) \times 10^{-3} eV^2$

$\Theta_{12} = (33.5^{+1.3}_{-1.0})^\circ$

$\Delta m^2_{12} = (7.65^{+0.23}_{-0.20}) \times 10^{-5} eV^2$



arXiv
0808.2016

The future quest for θ_{13}

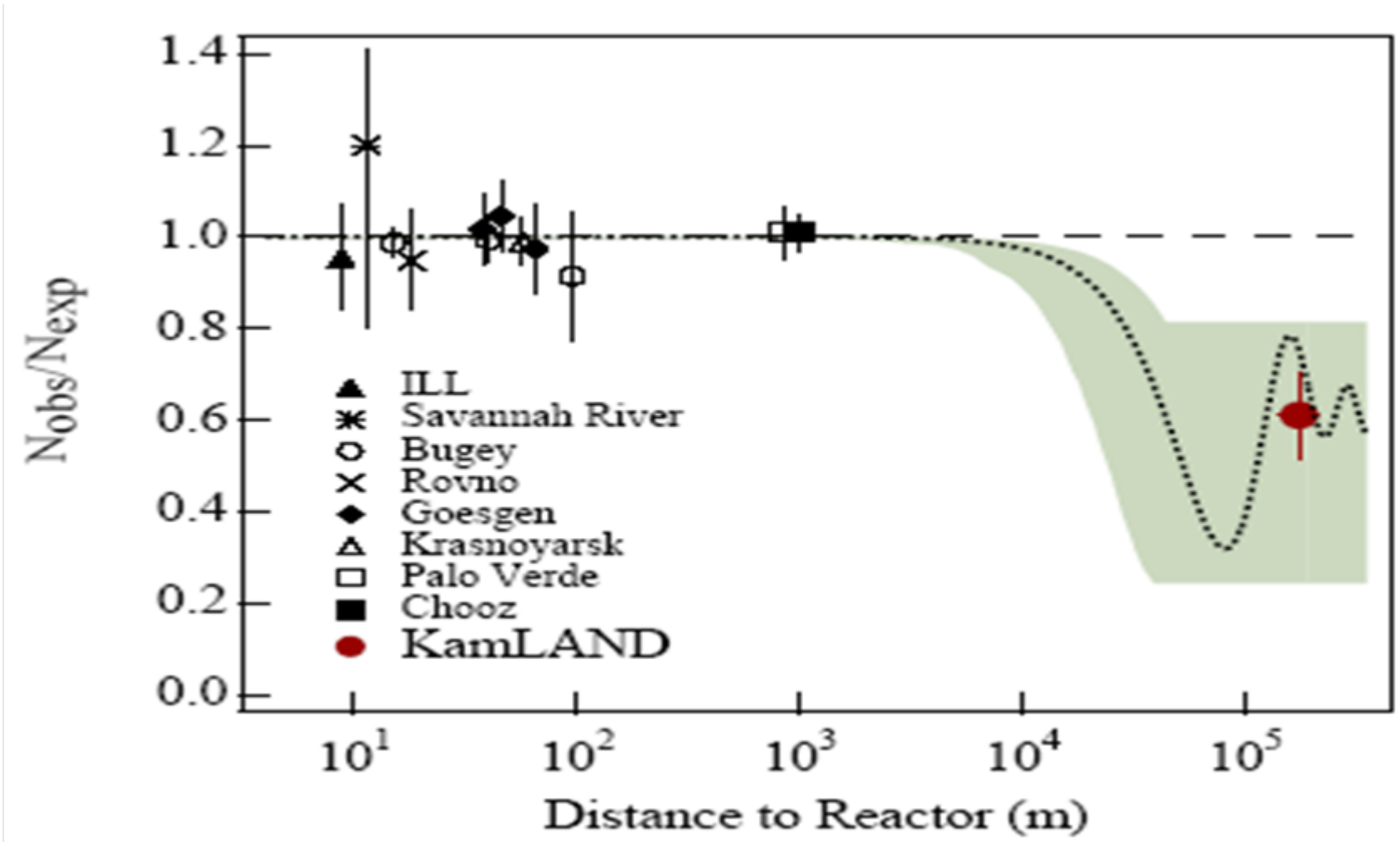
Accelerators | Reactors

parameter	Ref. [1] best fit$\pm 1\sigma$	Ref. [1] 3σ interval	Ref. [2] (MINOS updated) best fit$\pm 1\sigma$	Ref. [2] (MINOS updated) 3σ interval
$\Delta m^2_{21}\,[10^{-5}\mathrm{eV}^2]$	$7.65^{+0.23}_{-0.20}$	7.05–8.34	$7.67^{+0.22}_{-0.21}$	7.07–8.34
$\Delta m^2_{31}\,[10^{-3}\mathrm{eV}^2]$	$\pm 2.40^{+0.12}_{-0.11}$	$\pm$(2.07–2.75)	-2.39 ± 0.12 $+2.49 \pm 0.12$	$-$(2.02–2.79) $+$(2.13–2.88)
$\sin^2\theta_{12}$	$0.304^{+0.022}_{-0.016}$	0.25–0.37	$0.321^{+0.023}_{-0.022}$	0.26–0.40
$\sin^2\theta_{23}$	$0.50^{+0.07}_{-0.06}$	0.36–0.67	$0.47^{+0.07}_{-0.06}$	0.33–0.64
$\sin^2\theta_{13}$	$0.01^{+0.016}_{-0.011}$	≤ 0.056	0.003 ± 0.015	≤ 0.049

Ref.[1] – T.Schwetz, M.Tortola and J.W.F.Valle, New J.Phys. 10(2008) [arXiv:0808.2016]

Ref.[2] – M.C.Gonzalez-Garcia and M.Maltoni, Phys.Rept. 460 (2008) [arXiv:0704.1800]

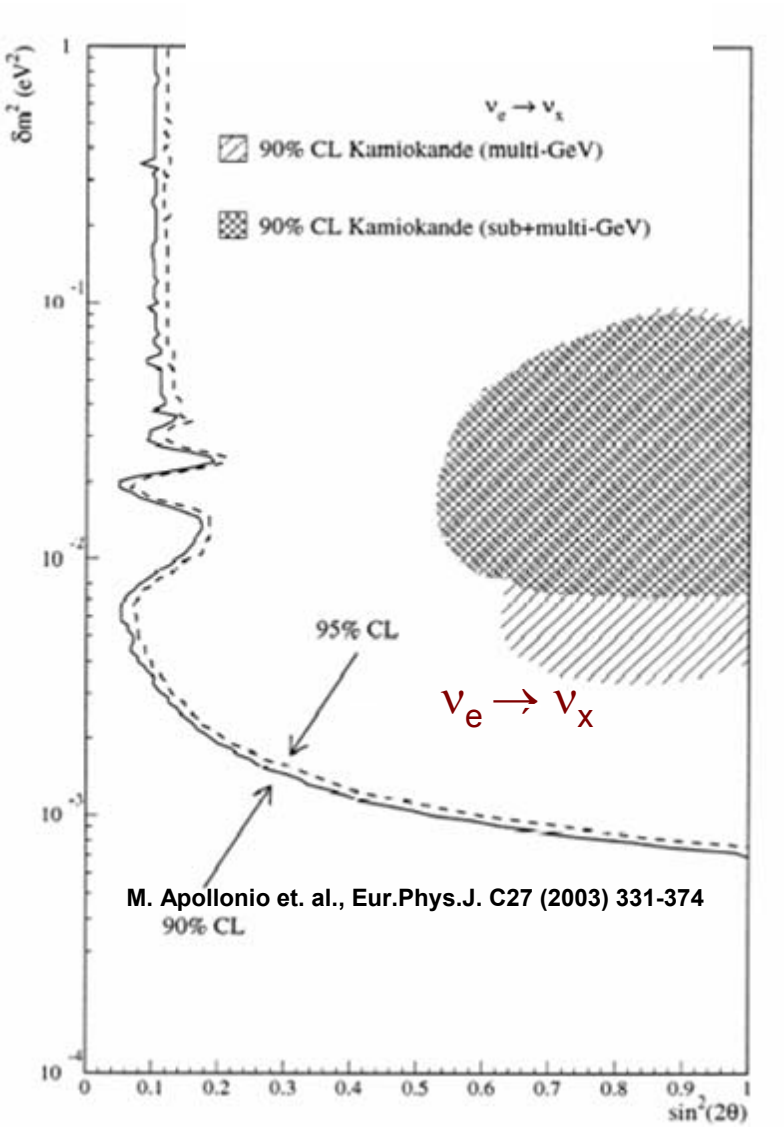
50 years of the neutrino experiments at nuclear reactors.

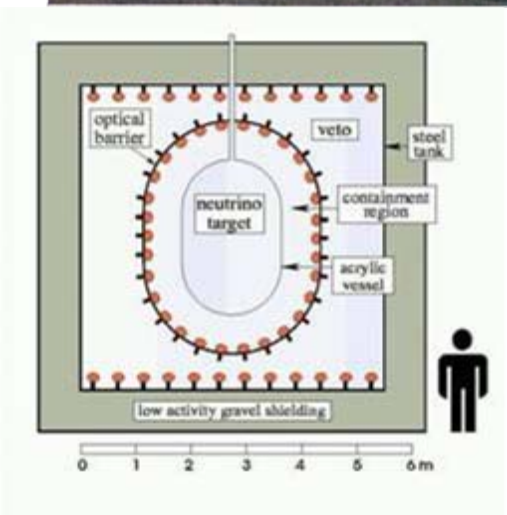


Chooz experiment (1995-1998)

R = 1.01 ± 2.8% (stat.) ± 2.7% (syst.) $\bar{\nu}_e \rightarrow \bar{\nu}_e$

Disappearance experiment
P=8.4GW. L=1.05 km. M=5 t @300 m.w.e.





@$\Delta m^2_{13} = 2*10^{-3}$ eV^2

$\sin^2(2\theta_{13}) < 0.2$

(90% C.L)

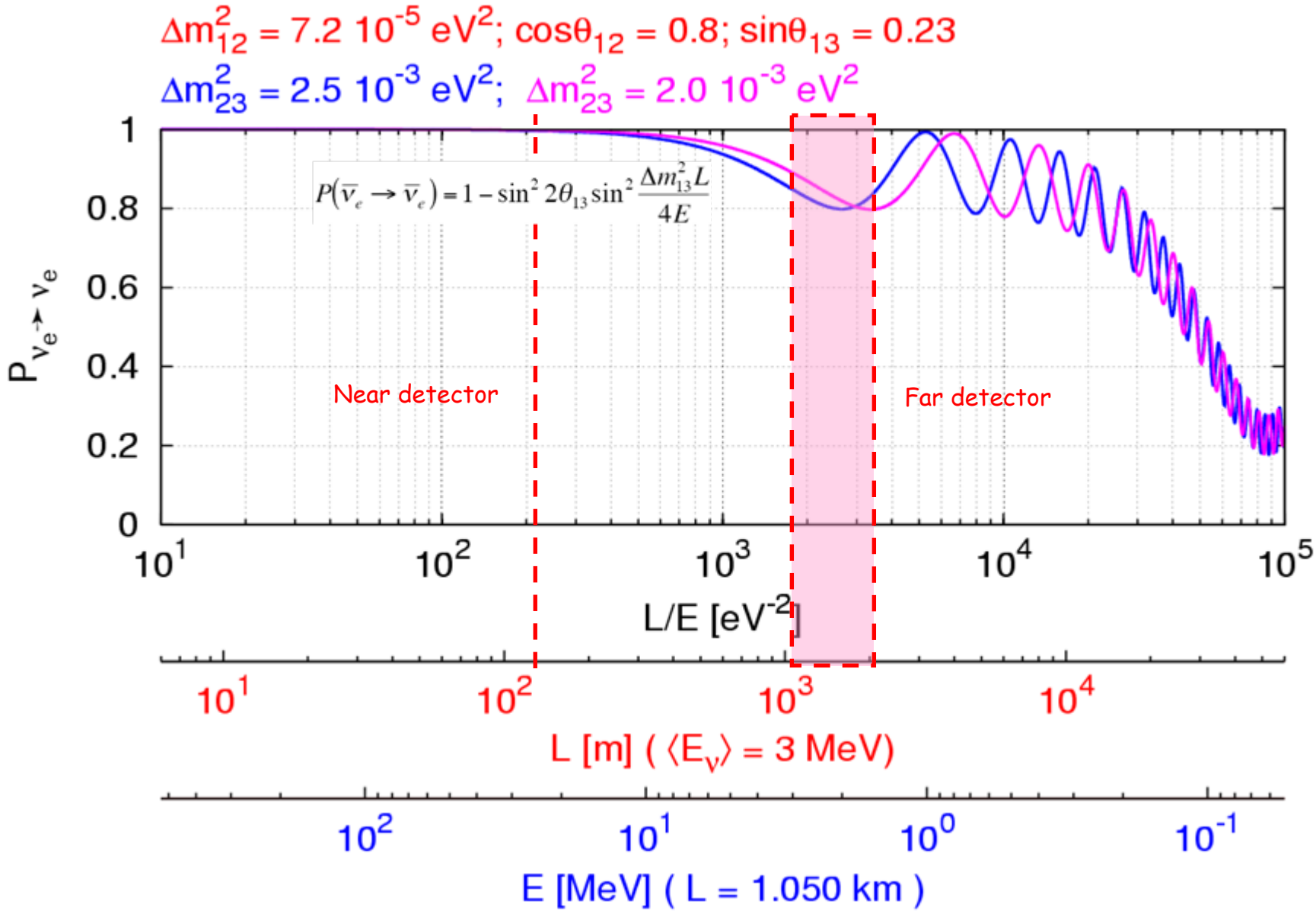
New concept of the reactor experiment:
how to improve the results of CHOOZ

L.A.Mikaelyan and V.VSinev arXiv:hep-ex/9908047v1 11-Aug-1999
Talk given at the International Conference on Non-Accelerator New Physics, NANP-99, Dubna, (28/06-03/07)-1999.

The White Paper «A new reactor neutrino experiment to measure θ_{13}»
hep-ex/0402041 (2002)

Double CHOOZ Proposal hep-ex/0606025 v2 20-June-2006

Two identical detectors



From CHOOZ to DoubleCHOOZ

R = N(meas.) / N(expect.) = 1.01 ± 2.8% (stat) ± 2.7% (syst)

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 60000/3y
Statistical error	2.8%	0.5%

Systematic error

	CHOOZ	Double Chooz
Reactor uncertainties ν flux and reactor power	2.1%	----
Number of protons	0.8%	0.2%
Detector Efficiency	1.5%	0.5%

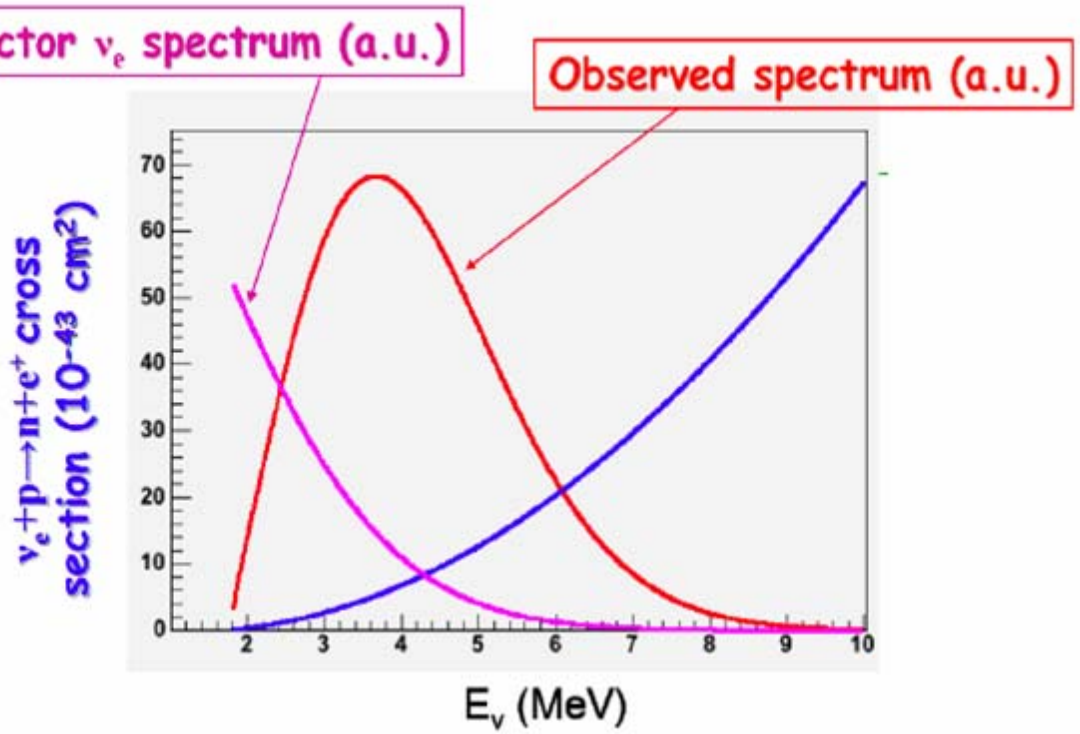
ν_e detection at reactor experiments

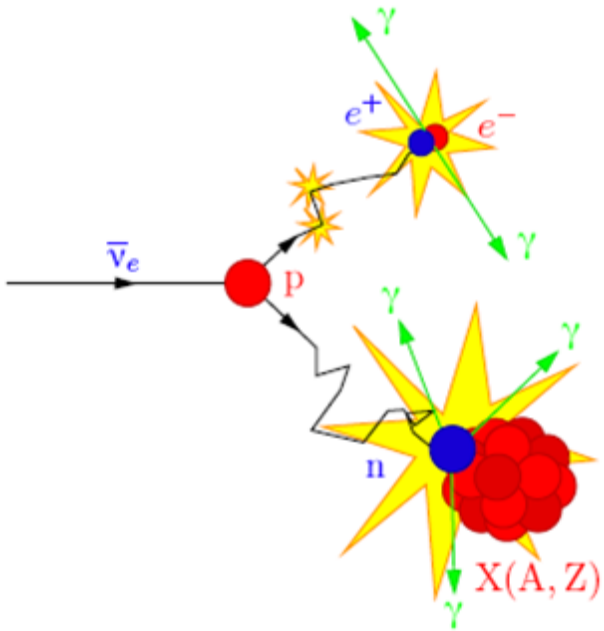
P=8GW $\Rightarrow N_\nu \sim 10^{21} s^{-1}$ on all solid angle

Detection by "inverse beta"

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

$E_{thr.} = 1{,}8$ MeV



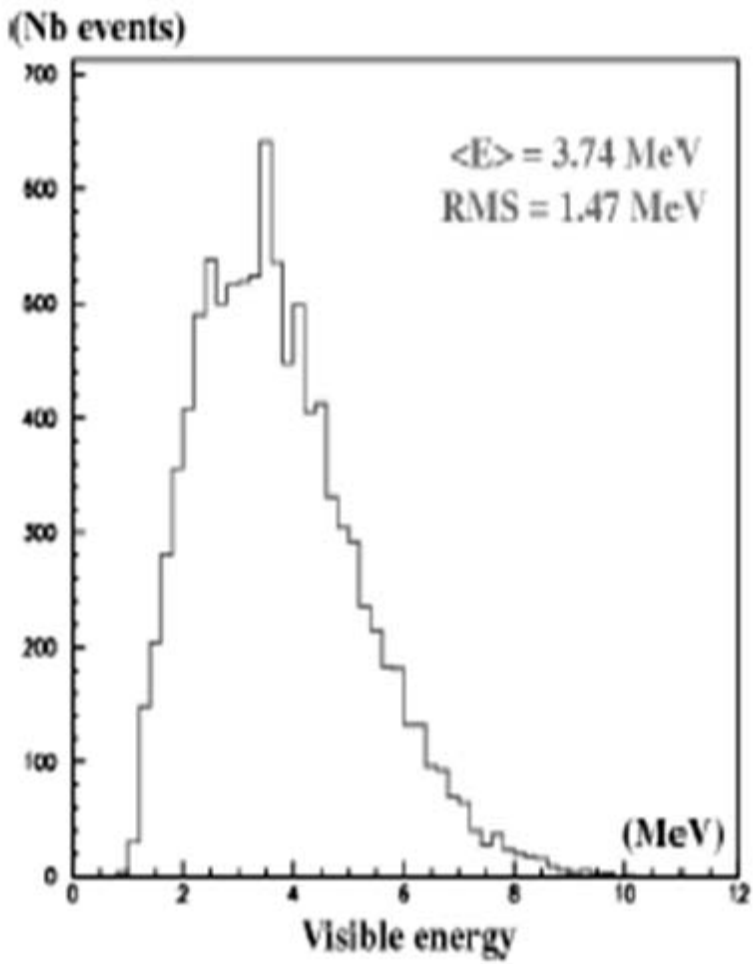


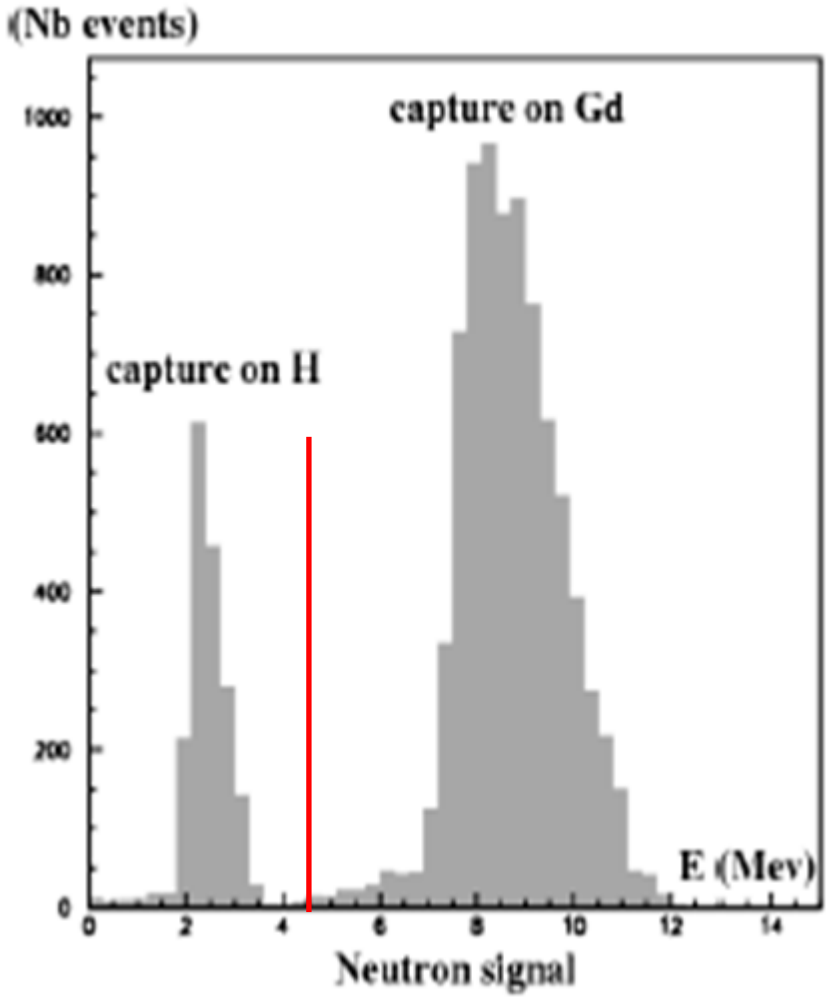
Prompt photons from **e^+** and two annihilation gammas (2 * 511 keV)

$E_{vis} = E_\nu - 0.78$ MeV + $O(E_e/m_n)$

Delayed photons from **n** capture on dedicated nuclei (Gd)

$\Delta t \sim 30\ \mu s$ <E> ~ 8 MeV

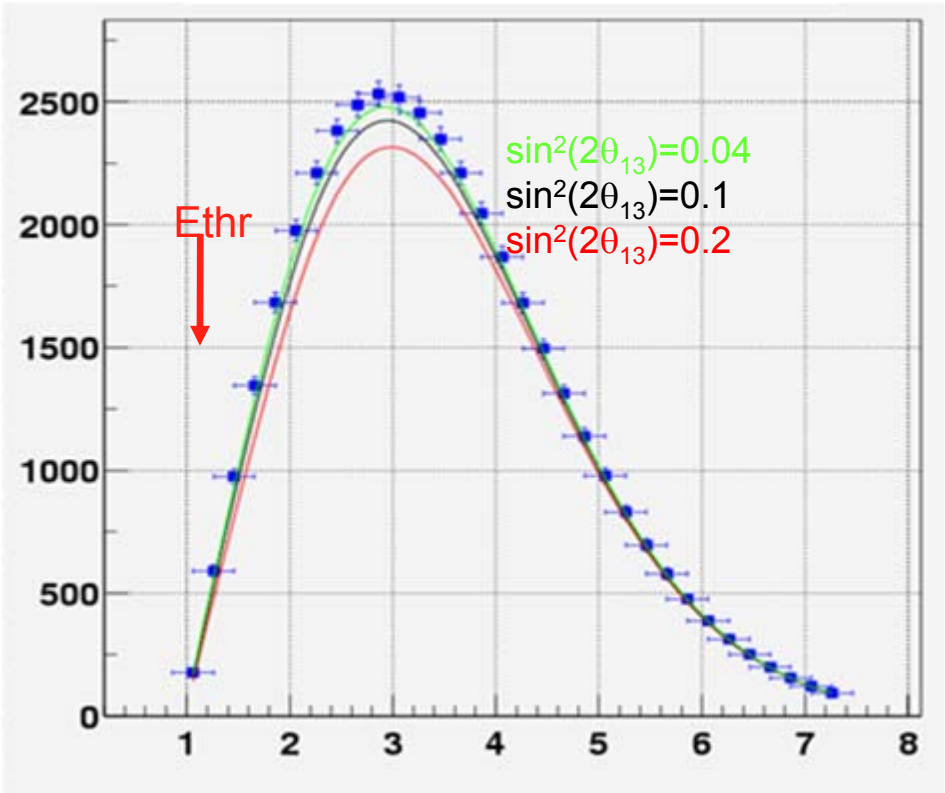




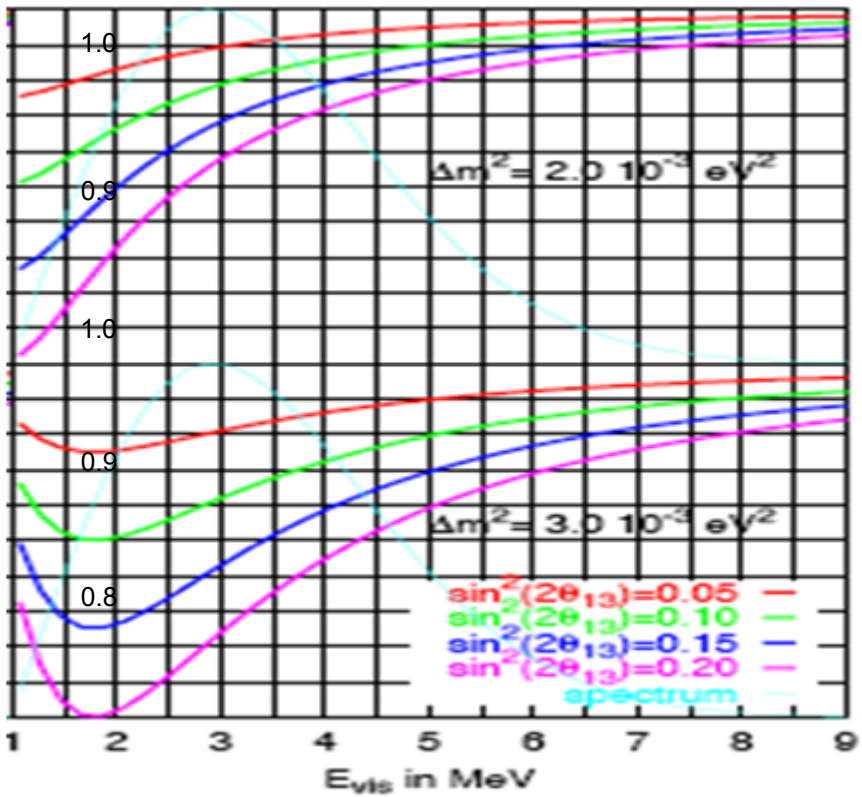
Positron and neutron spectra

θ_{13} at reactors: a new experimental concept

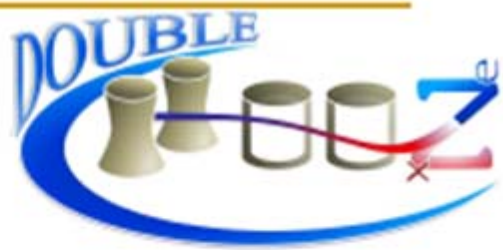
Two independent sets of information:
Normalisation + Spectrum distortion



Ratio Obs/Th



Backgrounds



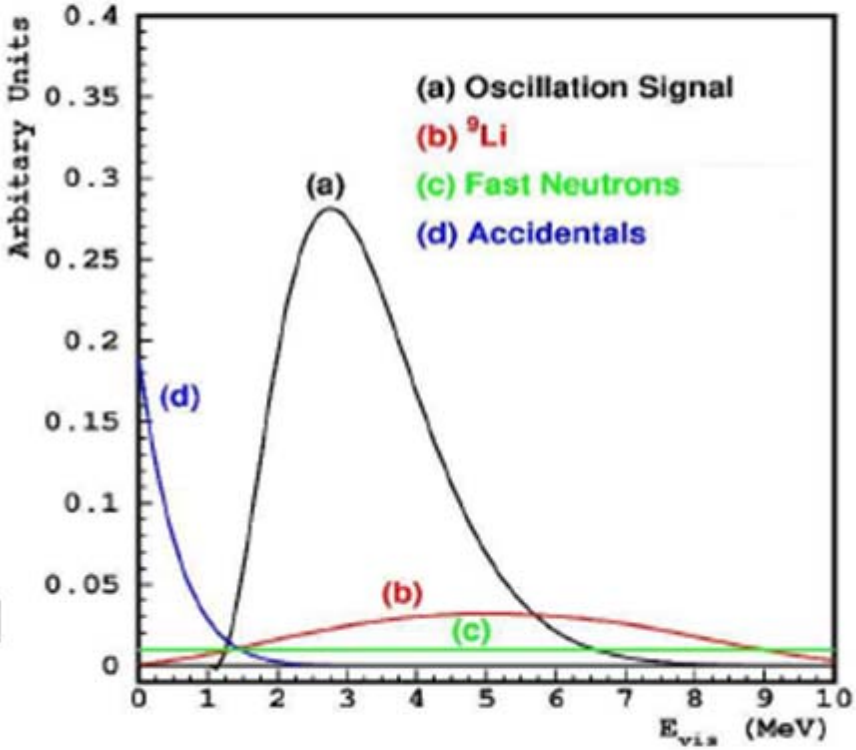
Accidental:

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

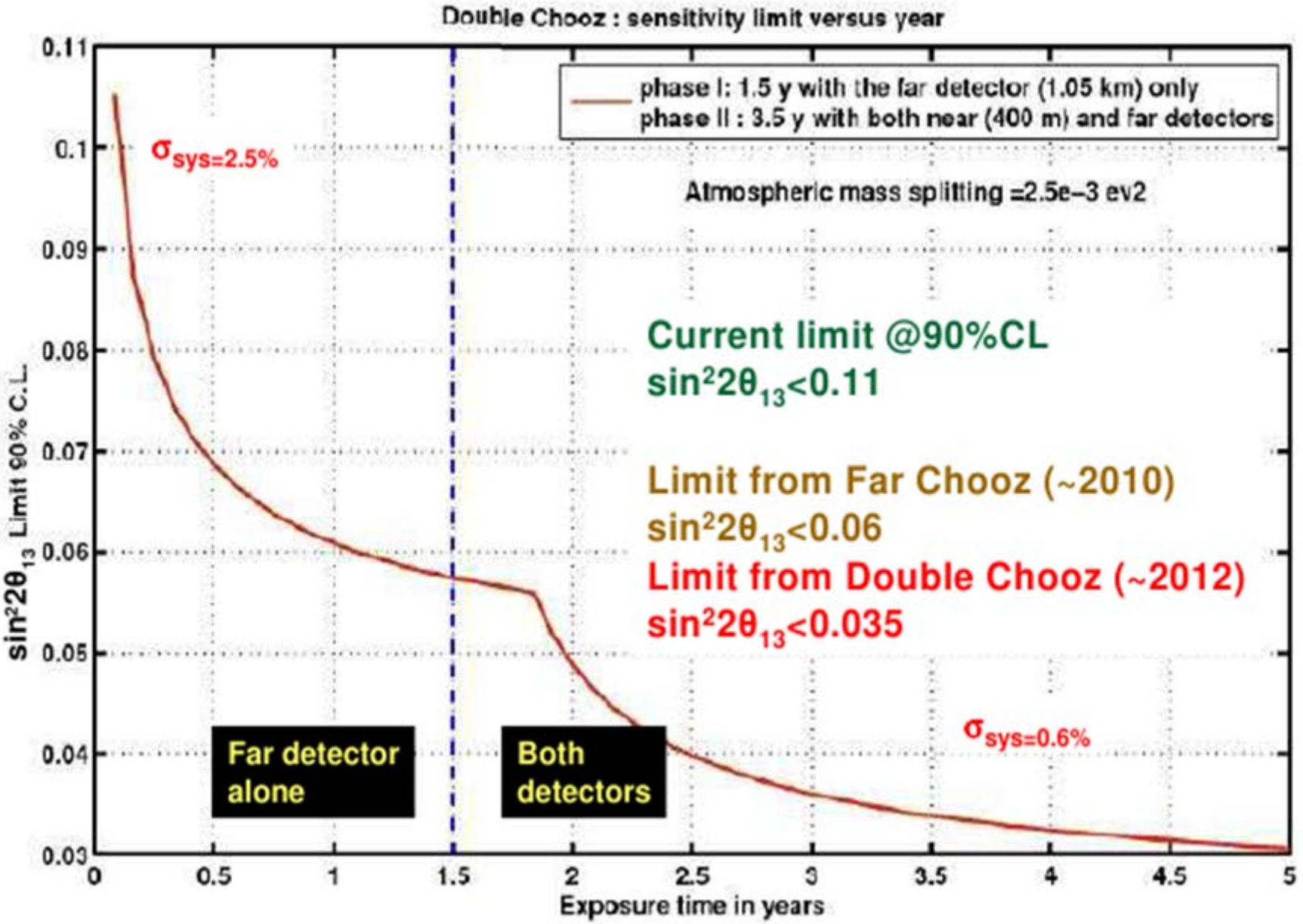
  Or another radioactivity event

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



DoubleCHOOZ Sensitivity



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

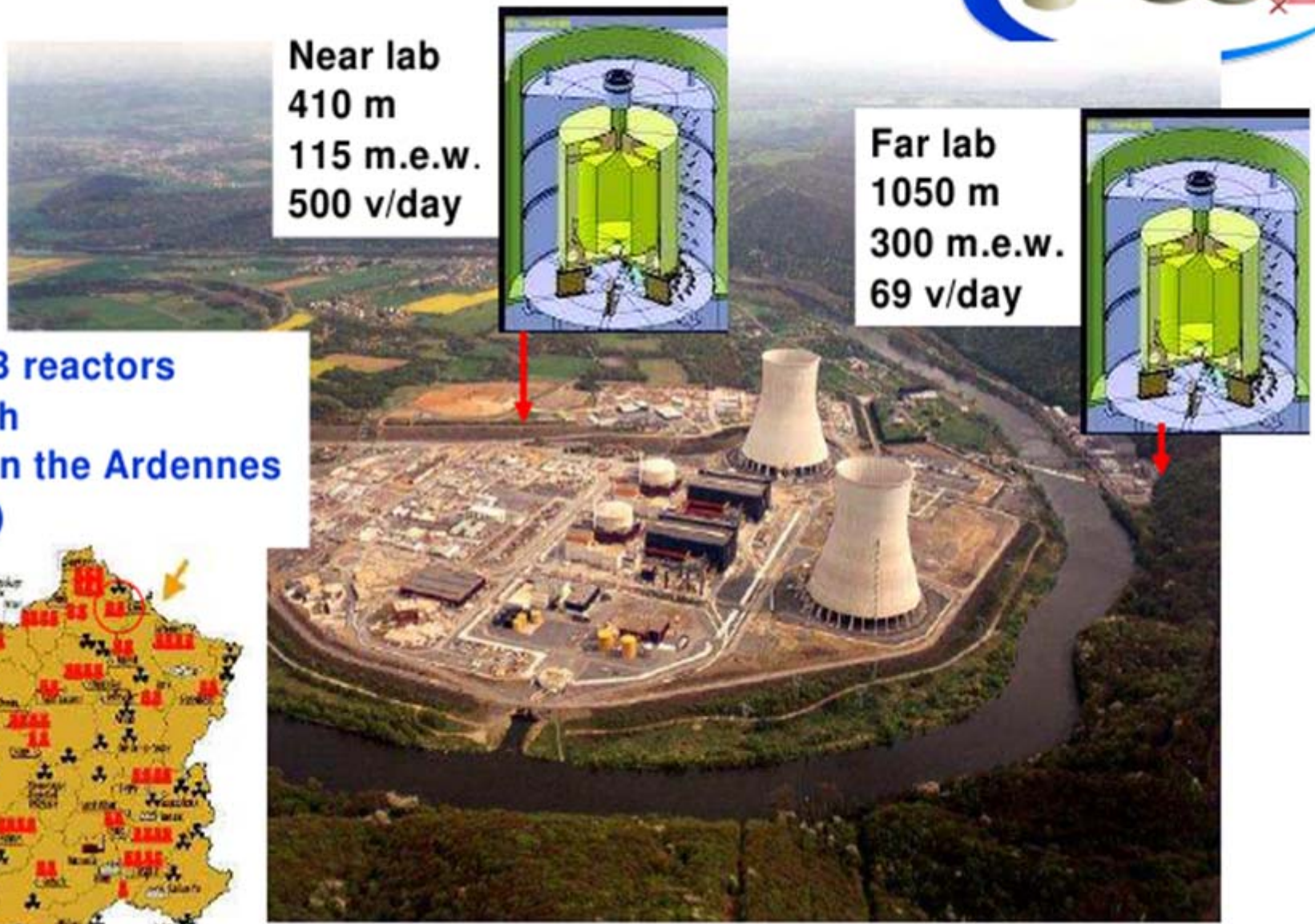
Japan: HIT, Kobe, Niigata, TGU, TIT, TMU, Tohoku

Russia: RAS, RRC Kurchatov Institute

USA: Alabama, ANL, Chicago, Columbia, Drexel, Illinois, Kansas, LLNL, LSU, Notre Dame, Sandia, Tennessee, UCD

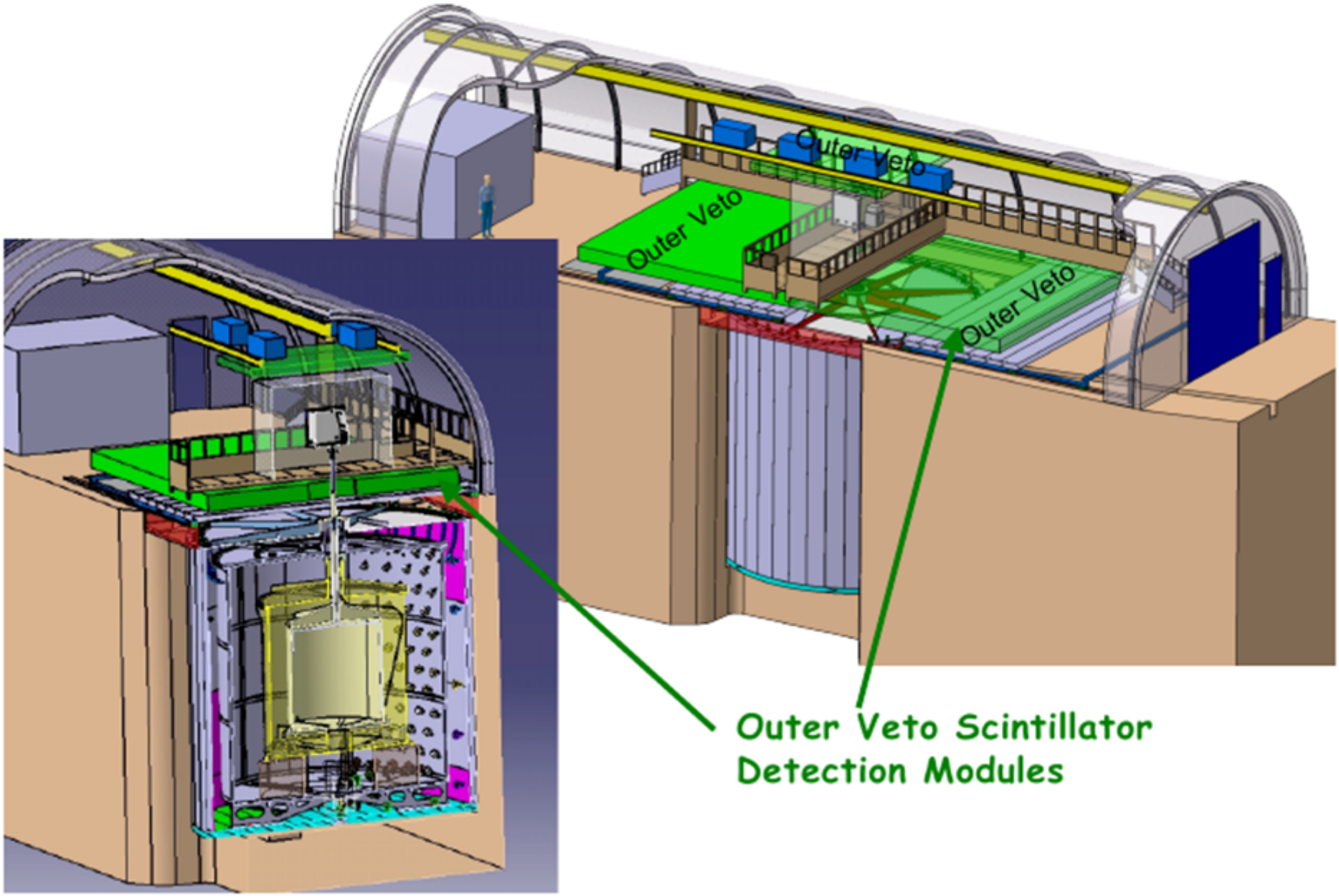
Brazil: CBPF, UNICAMP

The Chooz site:

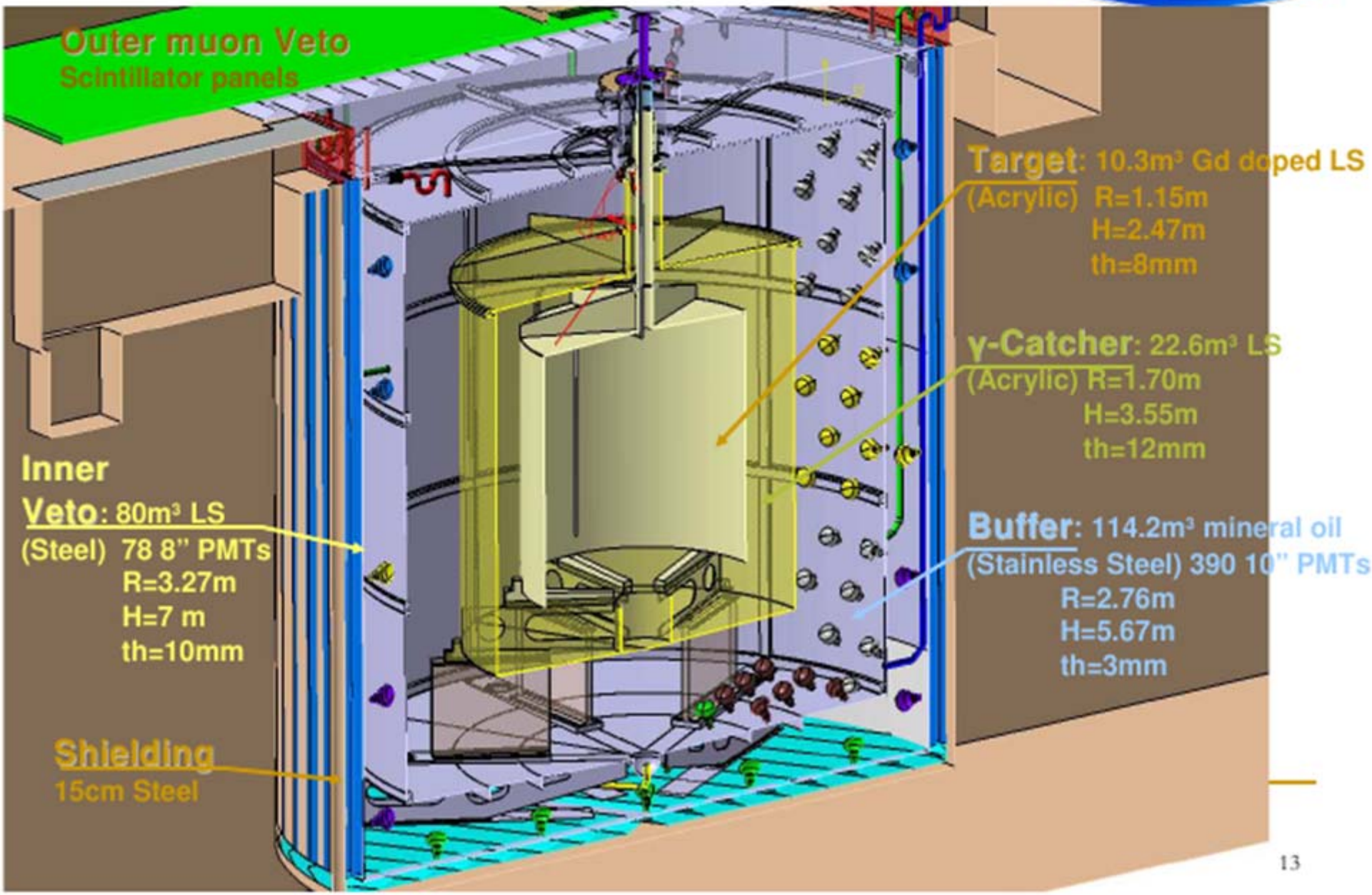


Chooz-B reactors
8.4 GWth
Placed in the Ardennes
(France)

Outer Veto Layout



The Detector(s)



Far Detector Construction

After refurbishment of the pit, the detector construction started in the second half of 2008.

Far Detector Construction

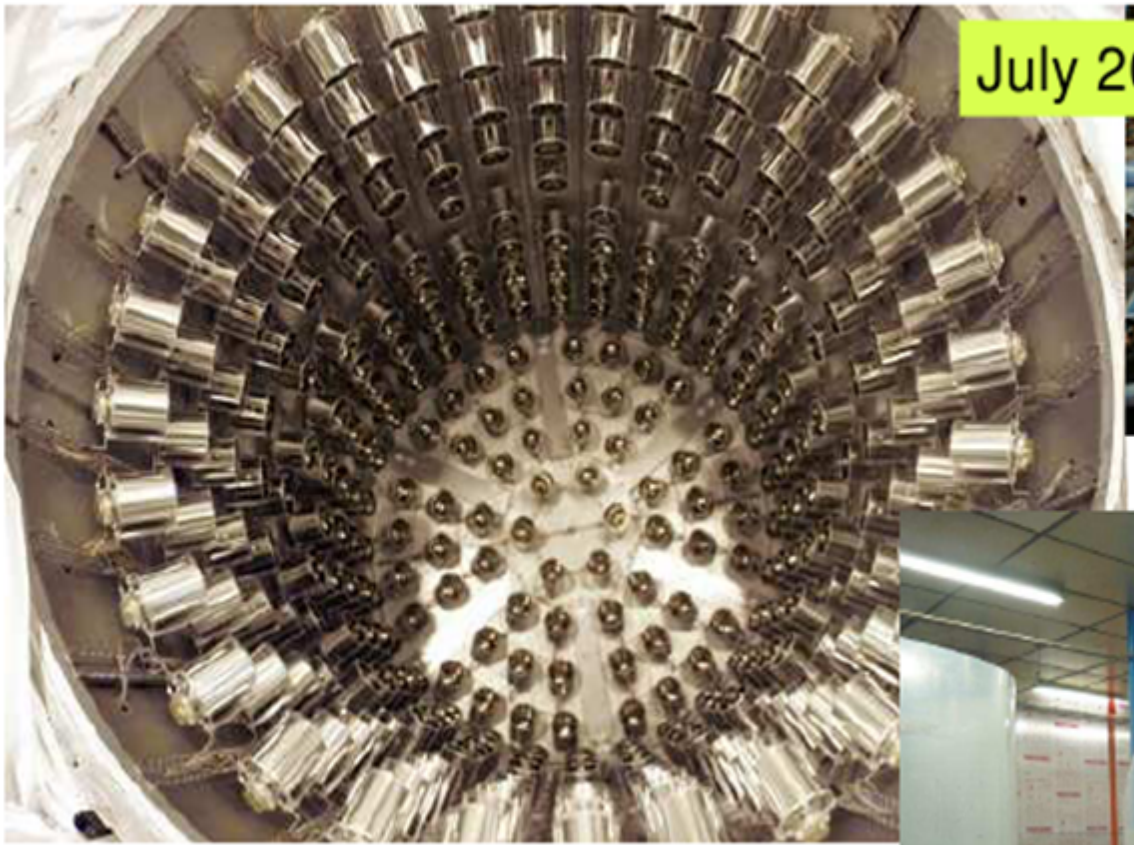
February 2009

Inner Veto PMTs
Installation completed

Far Detector Construction

PMT Installation

Current Status



July 2009

PMT Installation completed
Acrylic vessels ready to be assembled on site


30-July-2009

Schedule

- Far detector construction will be completed at the end of 2009.
- Filling and comissioning — begining of 2010.
- Outer veto will be installed in April 2010.
- From April 2010 one of the reactors will be off during 4 months (there will be a chance to get some weeks with both reactors OFF).
- Near Lab. construction will be started at 2010.
- Start of data taking with both detectors - 2011.
- After 3 years → $\sin^2(2\Theta_{13})<0.035$ ($\Theta_{13}<5°$) at 90% C.L.

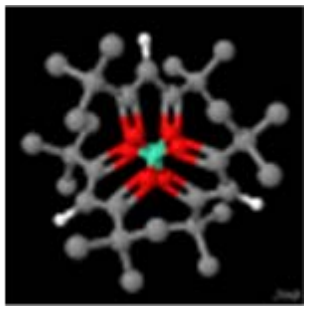
Backup slides

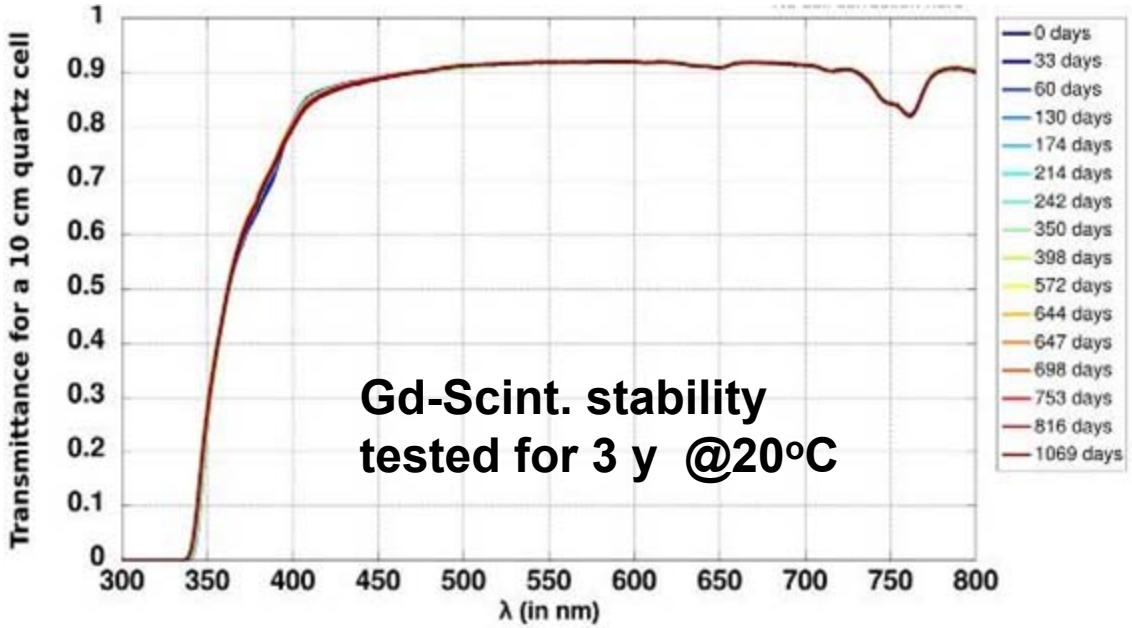
Liquids

- **New DC Development:**

-**Solvent:** 20% PXE ($C_{16}H_{18}$) + 80% Dodecane ($C_{12}H_{24}$) + PPO/Bis-MSB.

-**1 g/l Gd(dpm)$_3$** tris-(2,6-tetramethyl-3,5-heptanedione) Gd(III)



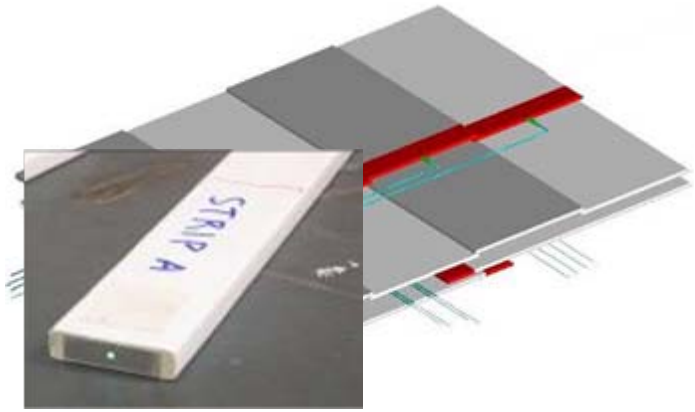


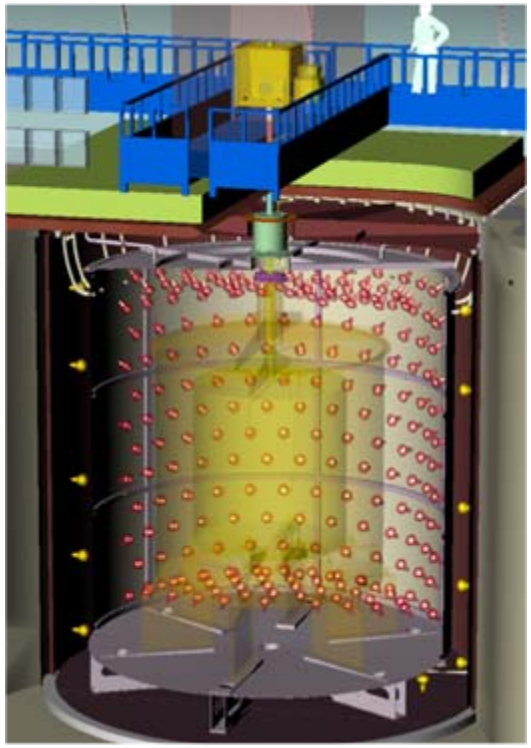
- **A SINGLE Batch LS for both detectors**
- **Target Solvant delivered**
- **GC Solvant: 4 % PXE – 46% Dod. - 50% Oil**
- **100 Kg Gd compound delivered**
- **Buffer Oil Ordered**

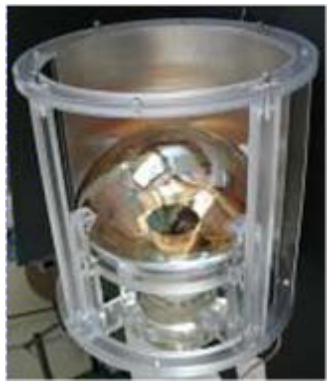
3 iso-tanks ready for transportation, storage & filling

MPIK new building for LS storage, mixing and purification

Detector Parts





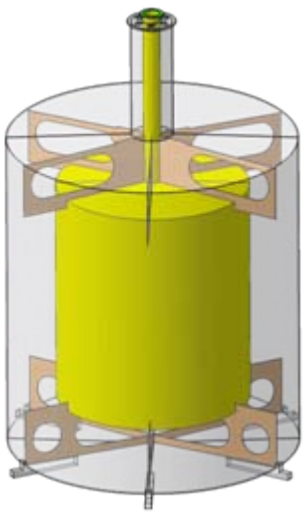


▪ **10“ Hamamatsu tubes x 390**

→ ~15 % coverage of inner det.

- Goal σ(E)/E~7 % @ 1 MeV

▪ **Outer veto:** Panels of strips of coextruded plastic scintillator with wavelength shifting fiber.



▪ **Acrylic vessels:**

-Target : 8 mm, γ catcher : 12 mm

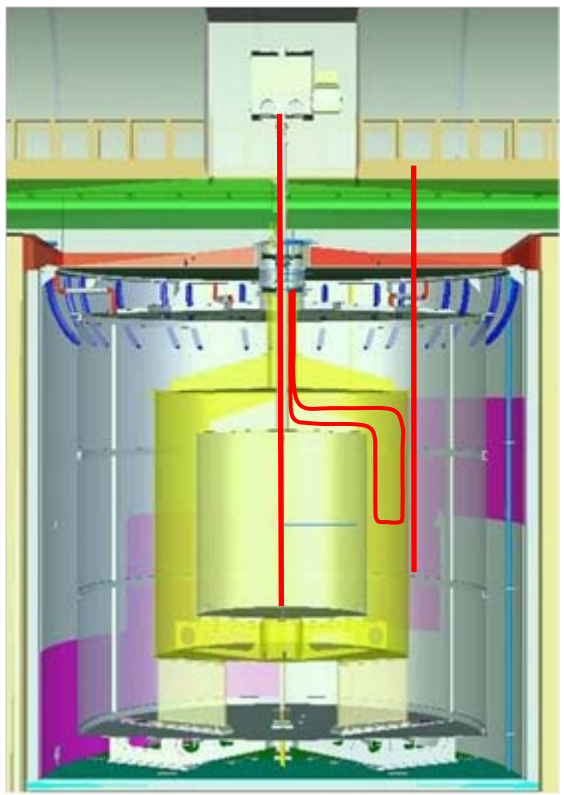
▪ **Buffer vessel:**

- 3mm stainless steel

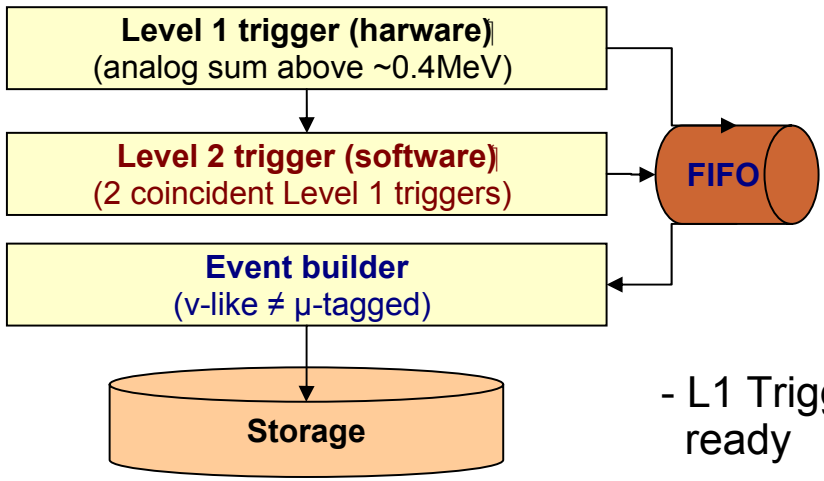
Detector Signal

▪Calibration:

- Target fish-line & articulated arm
- γ-catcher and buffer guide tubes
- Embedded LEDs

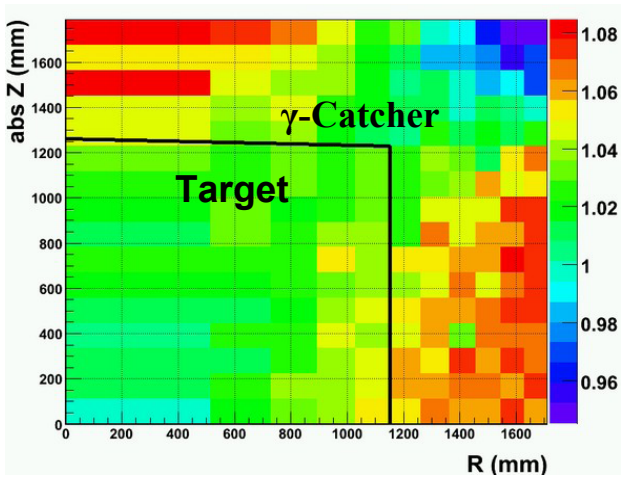


▪Electronics & DAQ

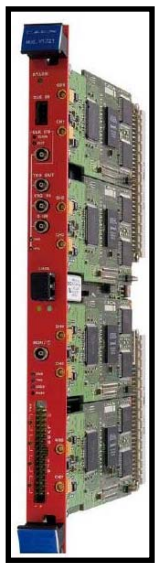


- L1 Trigger board ready

▪ Simulation



-F-ADC CAEN V1721 (500MHz & 8-bits) Being ordered



-Detailed geom and optics
-Detector uniformity

Site in French Ardennes