Double Chooz and RENO

θ_{13}

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International Workshop on

Next Nucleon Decay and Neutrino Detectors,

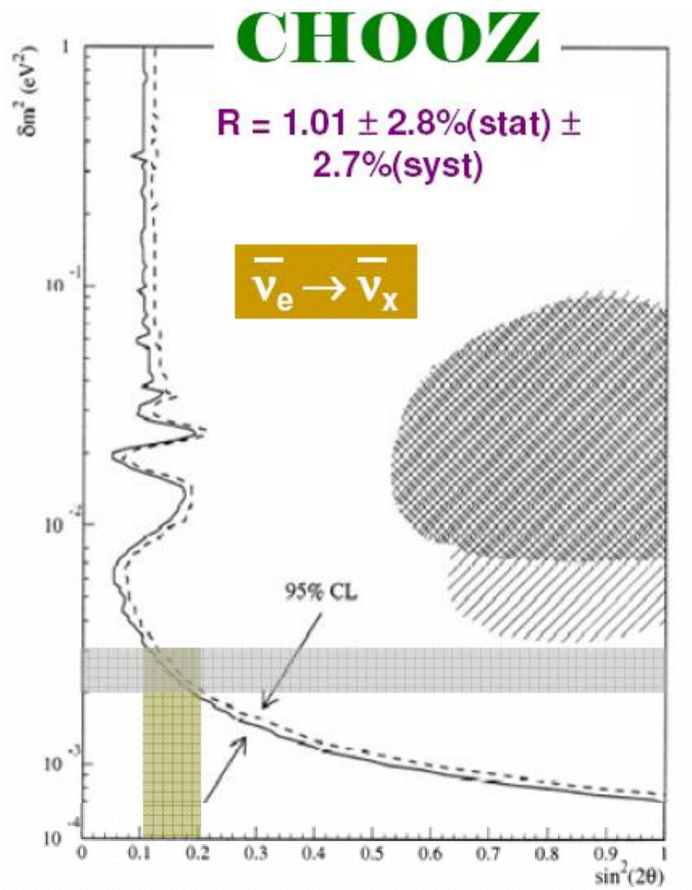
Paris 11-13 September 2008

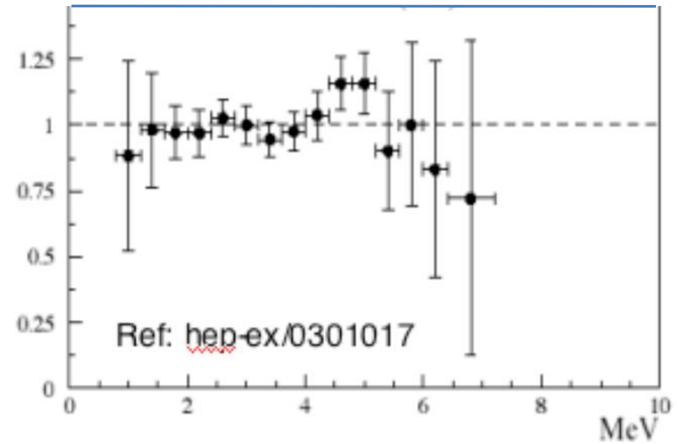
Current knowledge

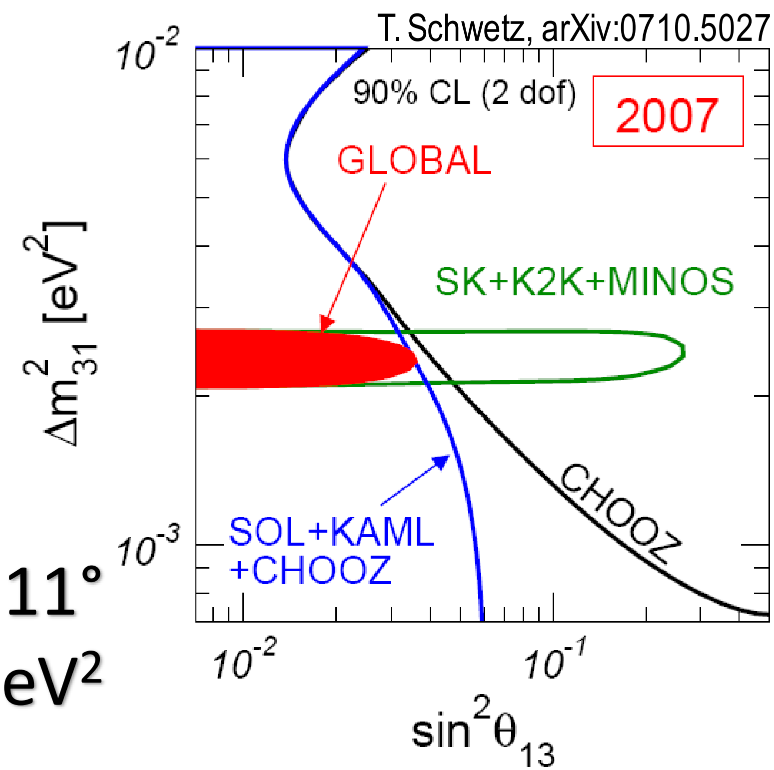
M. Apollonio et al., Eur.Phys.J C27 (2003) 331:

R = 1.01 ± 2.8% (stat) ± 2.7% (syst)

in 1 km distance to reactors





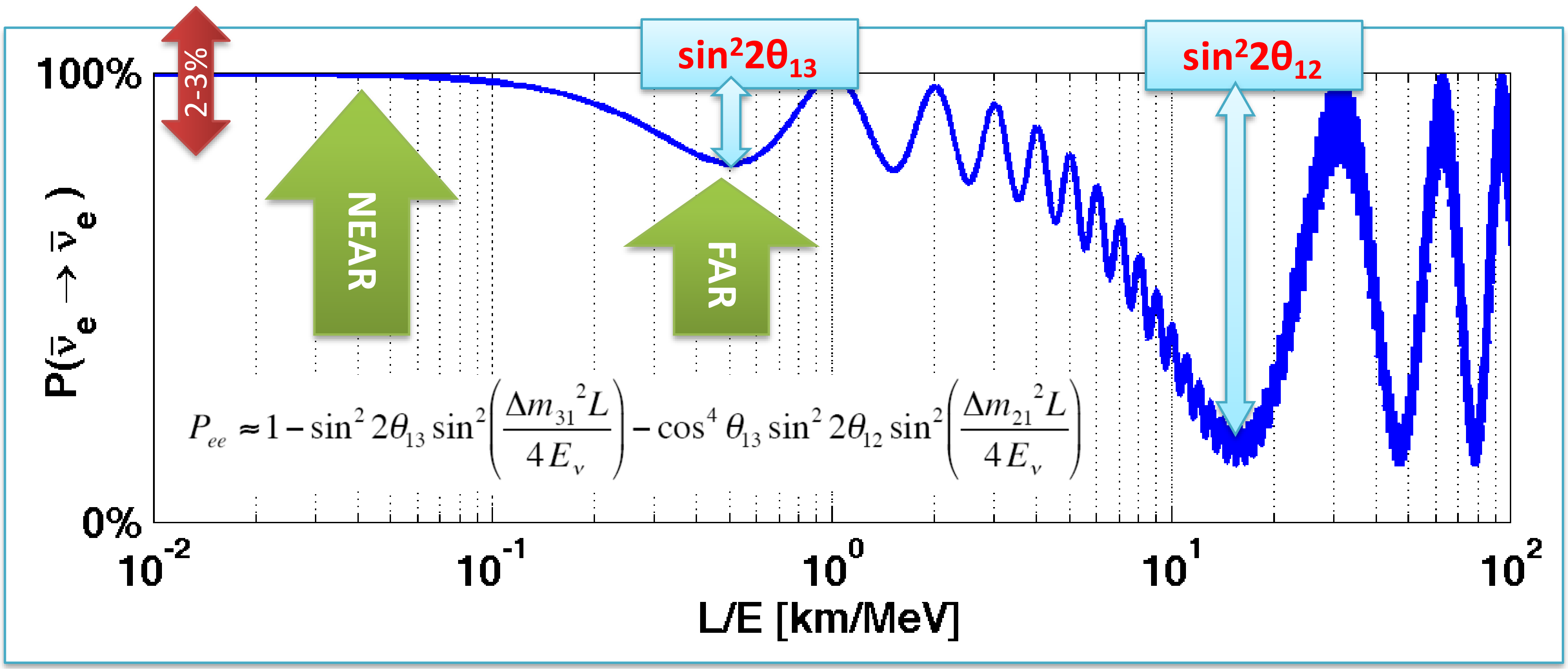


global: $\sin^2(2\theta_{13}) < 0.14$ or $\theta_{13} < 11°$

(90% CL) for $\Delta m^2 = 2.5 \cdot 10^{-3}$ eV²

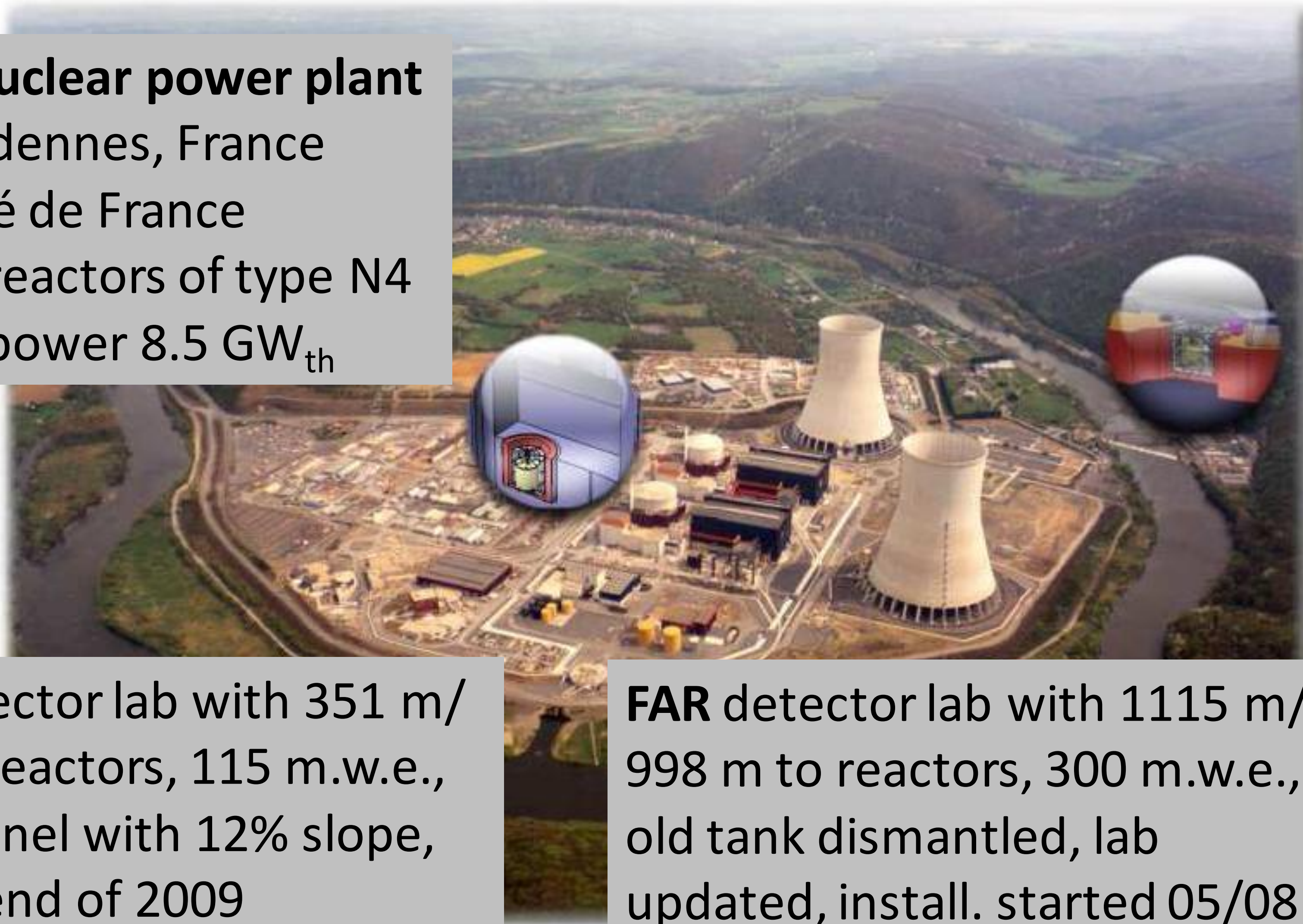
Measuring θ_{13} with reactor neutrinos

- $\bar{\nu}_e$ disappearance experiment with a second, identical detector near to the source to measure the full flux and spectrum
- Uncertainties of reactor power, burnup effects, neutrino spectrum, cross section and detector efficiency (almost) cancel.
- Clean θ_{13} measurement, independent of δ-CP, independent of sgn(Δm^2_{31})
- Complementary to neutrino beams, can break correlations and degeneracies



Double Chooz site

Chooz-B nuclear power plant
- in the Ardennes, France
- Electricité de France
- two PW reactors of type N4
- thermal power 8.5 GW_{th}



NEAR detector lab with 351 m/ 465 m to reactors, 115 m.w.e., access tunnel with 12% slope, available end of 2009

FAR detector lab with 1115 m/ 998 m to reactors, 300 m.w.e., old tank dismantled, lab updated, install. started 05/08

Detector layout

Calibration Glove-Box

Outer Veto
Plastic scintillator strips

10m^3 Target:
LS: 80% oil + 20% PXE + 1 g/l Gd
+ PPO + Bis-MSB in acrylic vessel

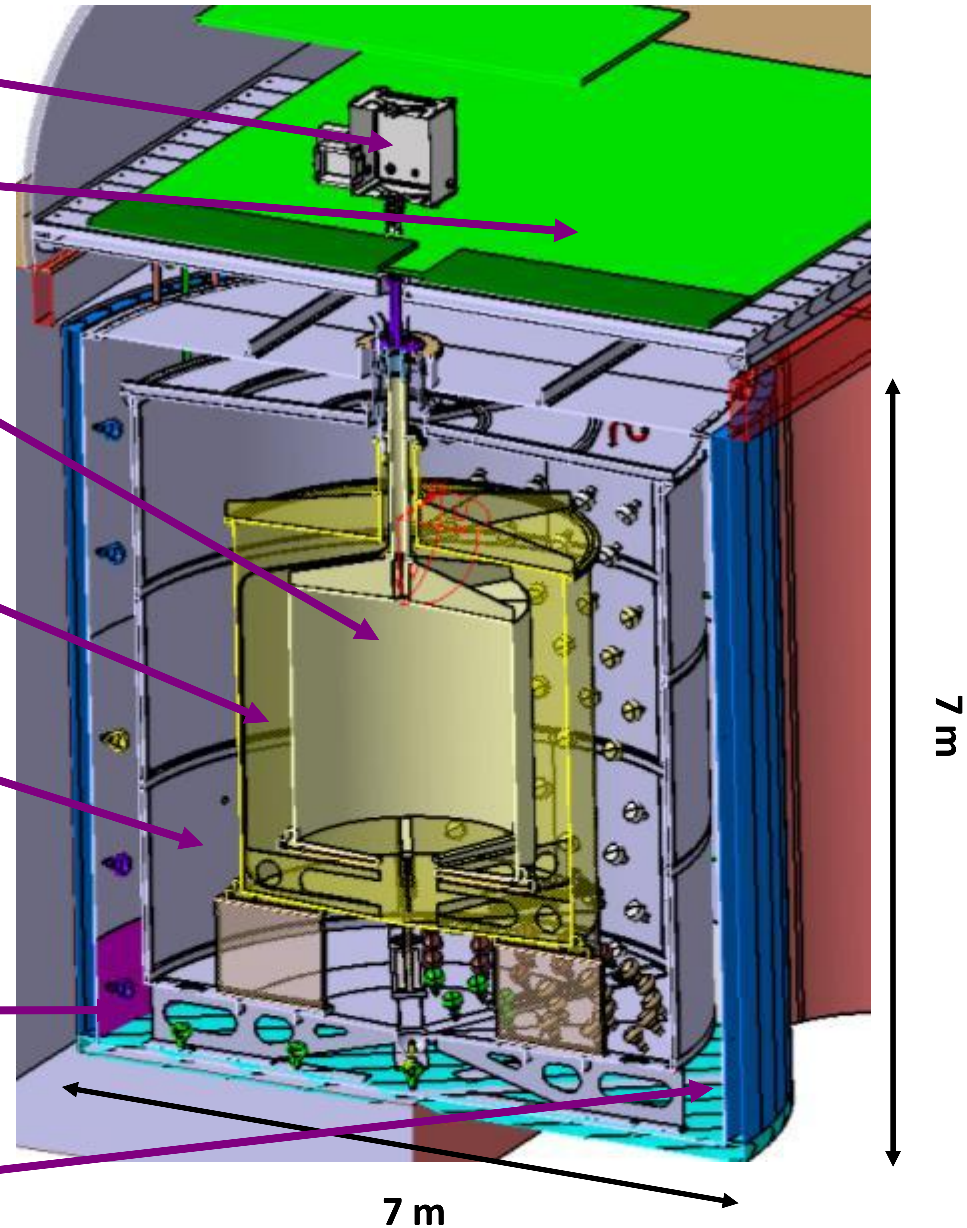
γ Catcher:
LS: 80% oil + 20% PXE
+ PPO + Bis-MSB in acrylic vessel

Non scintillating Buffer:
non-scintillating mineral oil

Buffer vessel with 390 10'' PMTs:
Stainless steel 3 mm

Inner Muon Veto:
Scintillator + 78 8'' PMTs

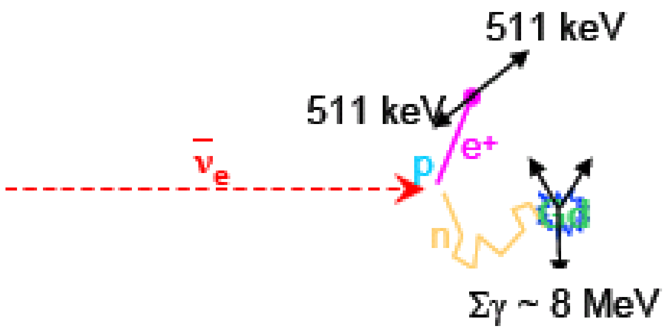
Steel Shielding:
15 cm demagnetized steel



Target density for all liquids: 0,800 g/cm^3

Signal and Background

e^- antineutrino Signature

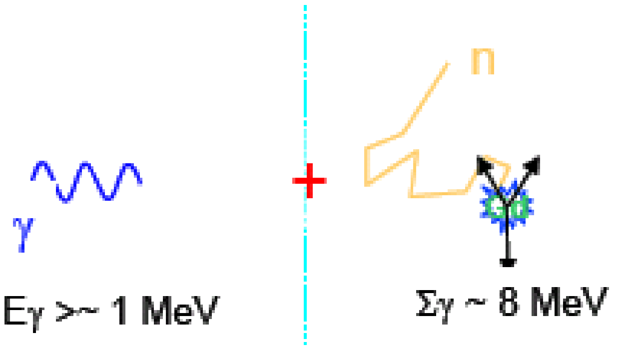


Prompt e^+ (1-8 MeV)   Delayed n Gd-capture (8 MeV)

Time correlation: τ~30 µs   Space correlation: <1 m

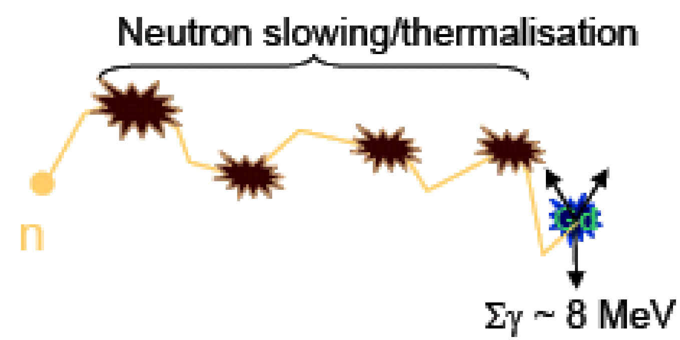
Far: 70 neutrinos d^{-1}
Near 500 neutrinos d^{-1}

Accidental Background



Far: 2 neutrinos d^{-1}
Near 11 neutrinos d^{-1}

Correlated Background



Far: 1.6 neutrinos d^{-1}
Near 5.2 neutrinos d^{-1}

Collaboration

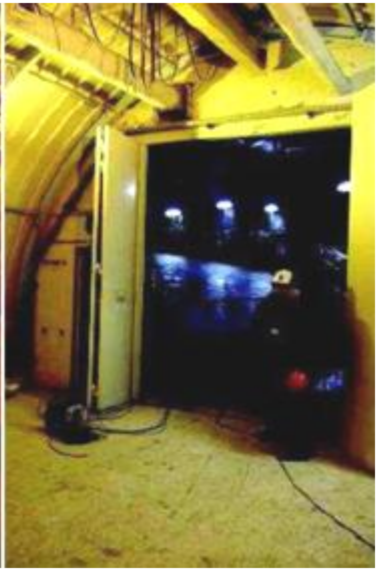
June 2006: Double Chooz proposal:
119 authors from 26 institutions
(hep-ex/0606025)

October 2007: TDR

June 2008

Far detector site status

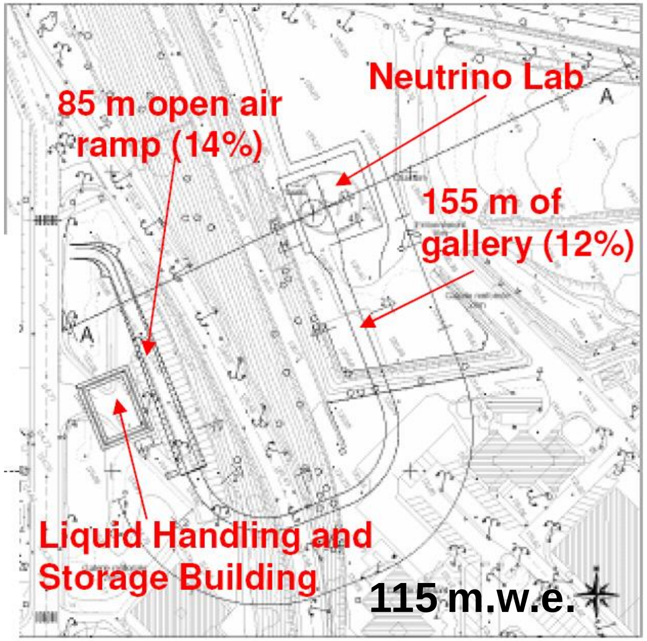
Installation in the Liquid Handling Building has started (6 large storage tanks from TUM)

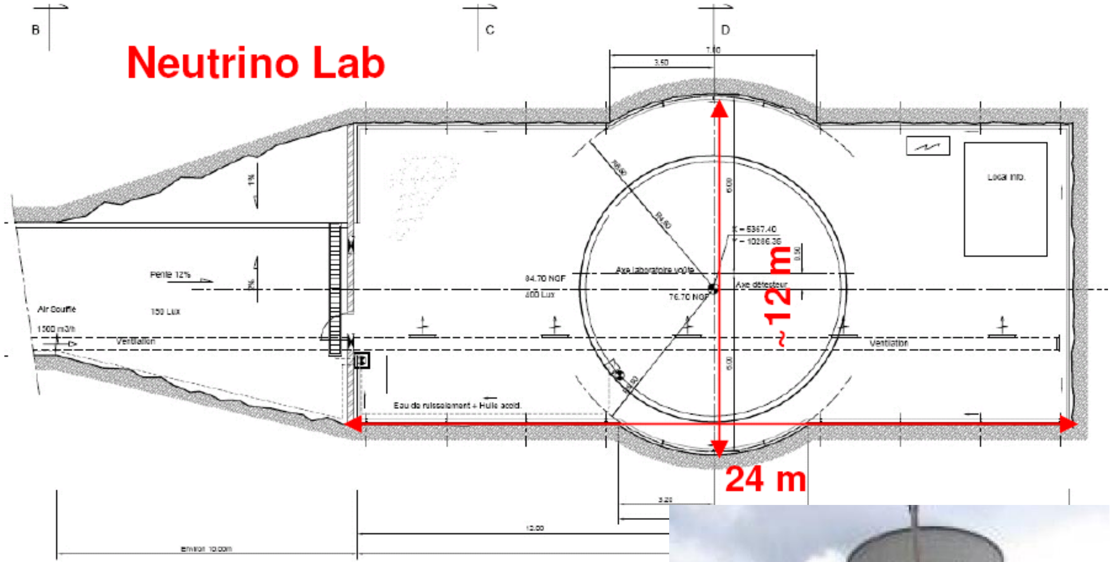


Civil engineering work has been finished (detector pit refurbished, doors enlarged, new ventilation system, safety system).

Shielding steel bars have been mounted in the pit.

Near detector lab





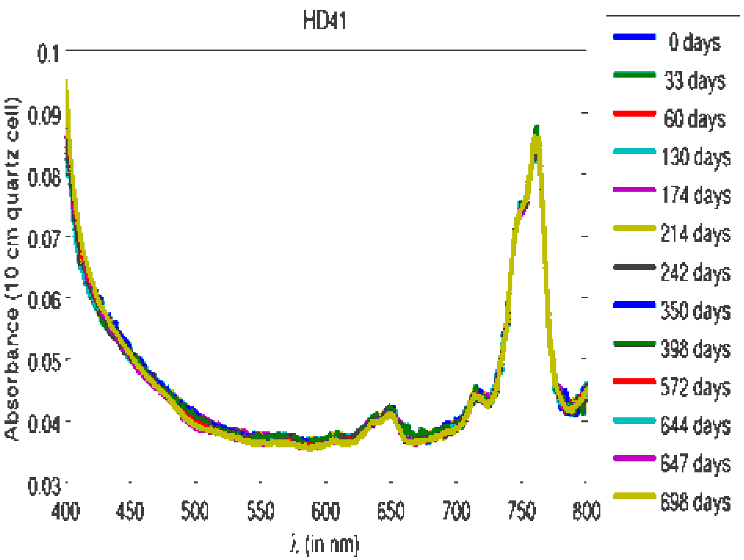
Site has been chosen with >45m overburden, almost flat topology.

Geological site study completed.
Tender process for construction.
Schedule: lab available end of 2009.

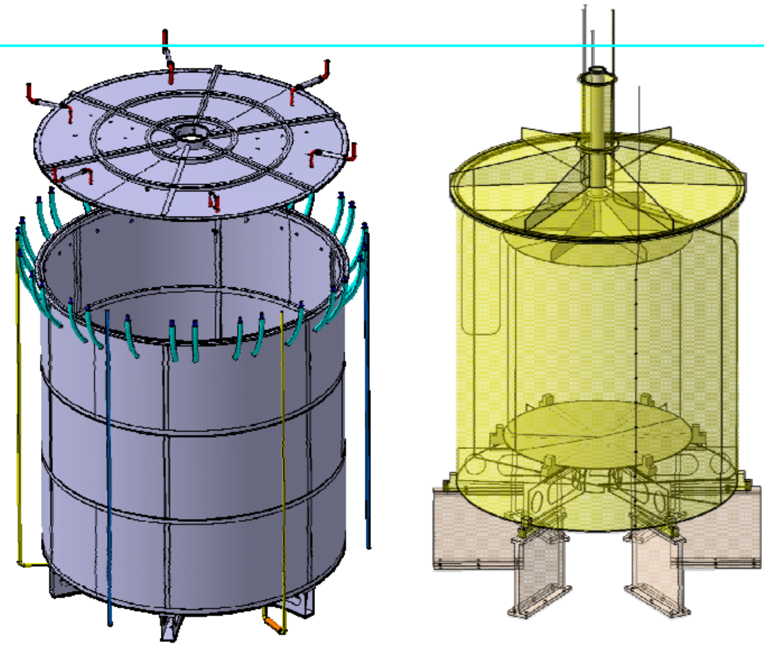
Inner detector components

Scintillators

Target solvent: 20% PXE – 80% Dodecane
PPO / bis-MSB (γ spectroscopy, NAA)
1 g/l Gd loading: developed @MPIK
100 kg $Gd(dpm)_3$ compound delivered



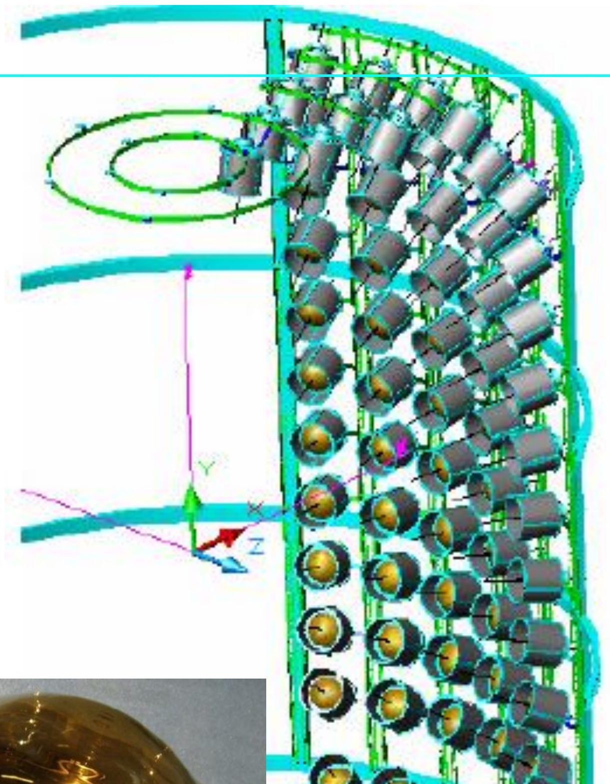
New building at MPIK for production, storage and purification of scintillators



Buffer vessel and acrylics:

Design completed, suitable material has been chosen in discussion with manufacturer, now production.

Photodetection system



15% coverage with 390 10“ PM tubes

Energy resolution goal: 7% @ 1MeV

PMT radiopurity: single rate < 5 Hz/detector

PMTs have been shipped to Japan & Germany for tests and assembly.

390 Hamamatsu R7081 10“ PMTs per detector

μ metal shields

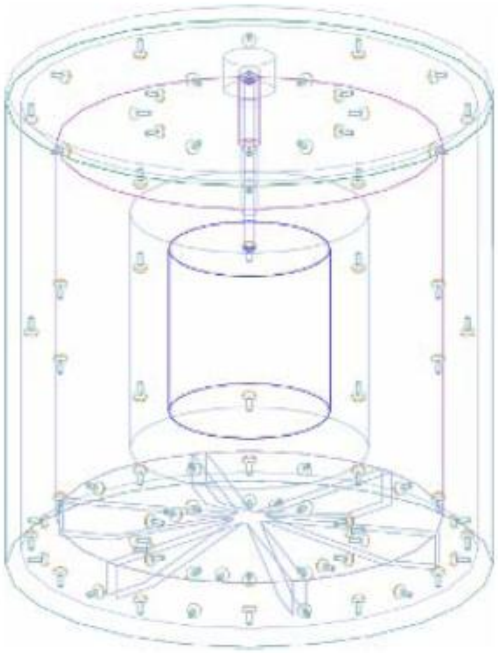
PMT mechanics

HVsplitters

Inner and Outer Muon Veto

Inner Veto

to tag efficiently cosmic ray muons and secondaries



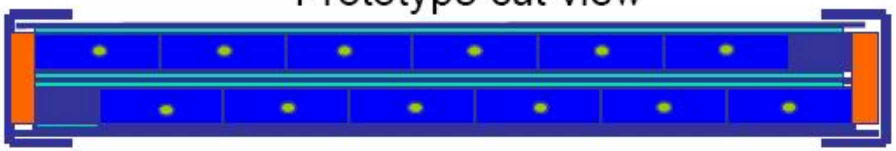
LAB and tetradecane, 50 cm thickness
78 8“ PMTs (encapsulated IMB tubes)
Reflective walls (painted and foil)

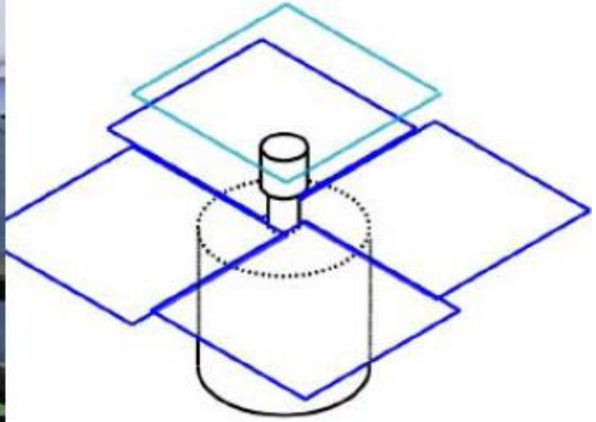
PMTs, almost all parts ready for Chooz

Outer Veto

- Tag “near-miss” μ
- Redundancy for high rejection power

Prototype cut view



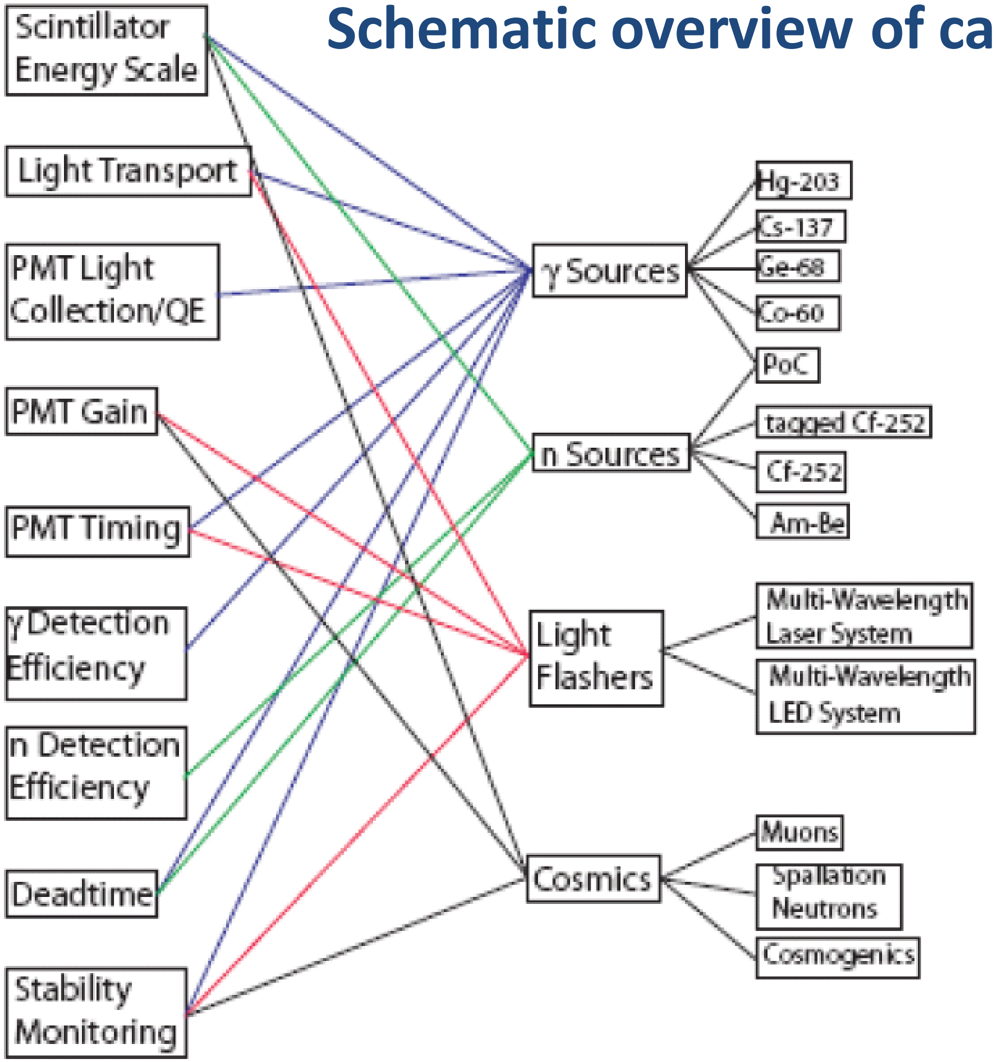


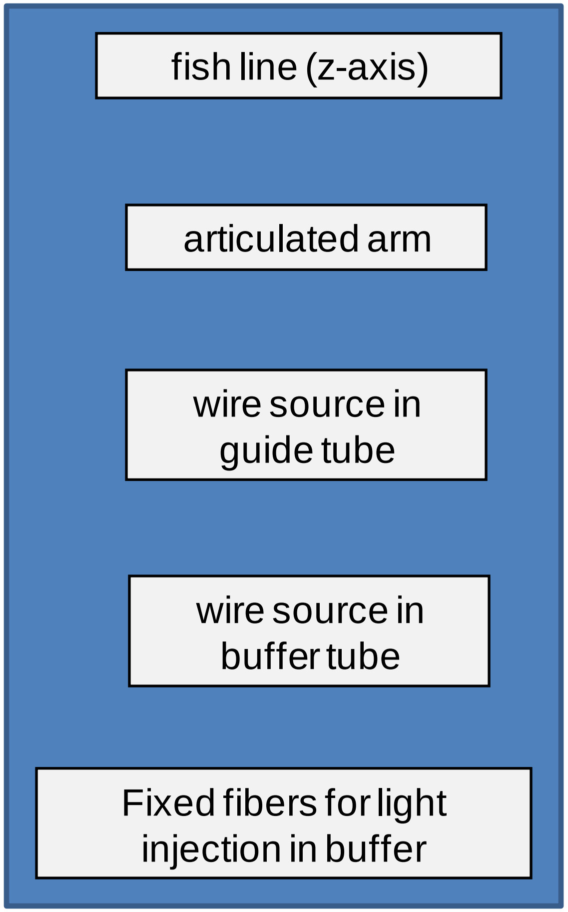
- Panels of strips
- Coextruded scintillator + TiO_2 reflector
- 1.2 mm Ø wavelength-shifting fibre

completed first prototype module

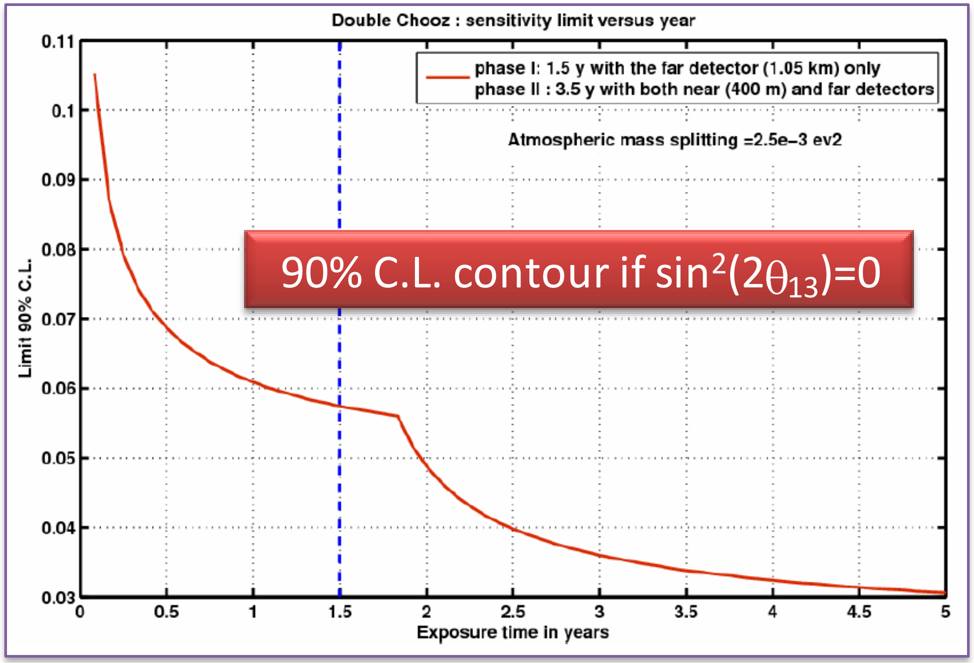
Detector Calibration

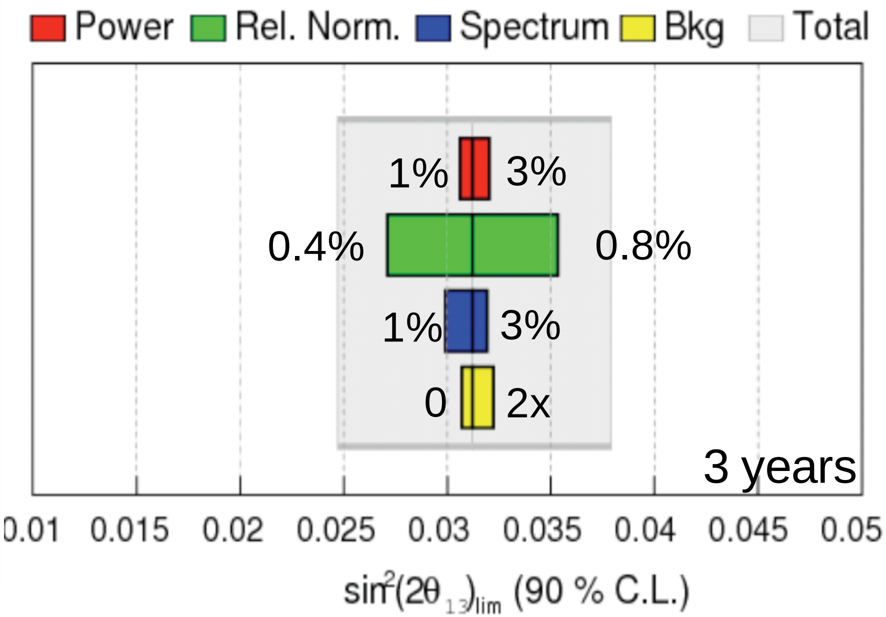
Schematic overview of calibration source deployment



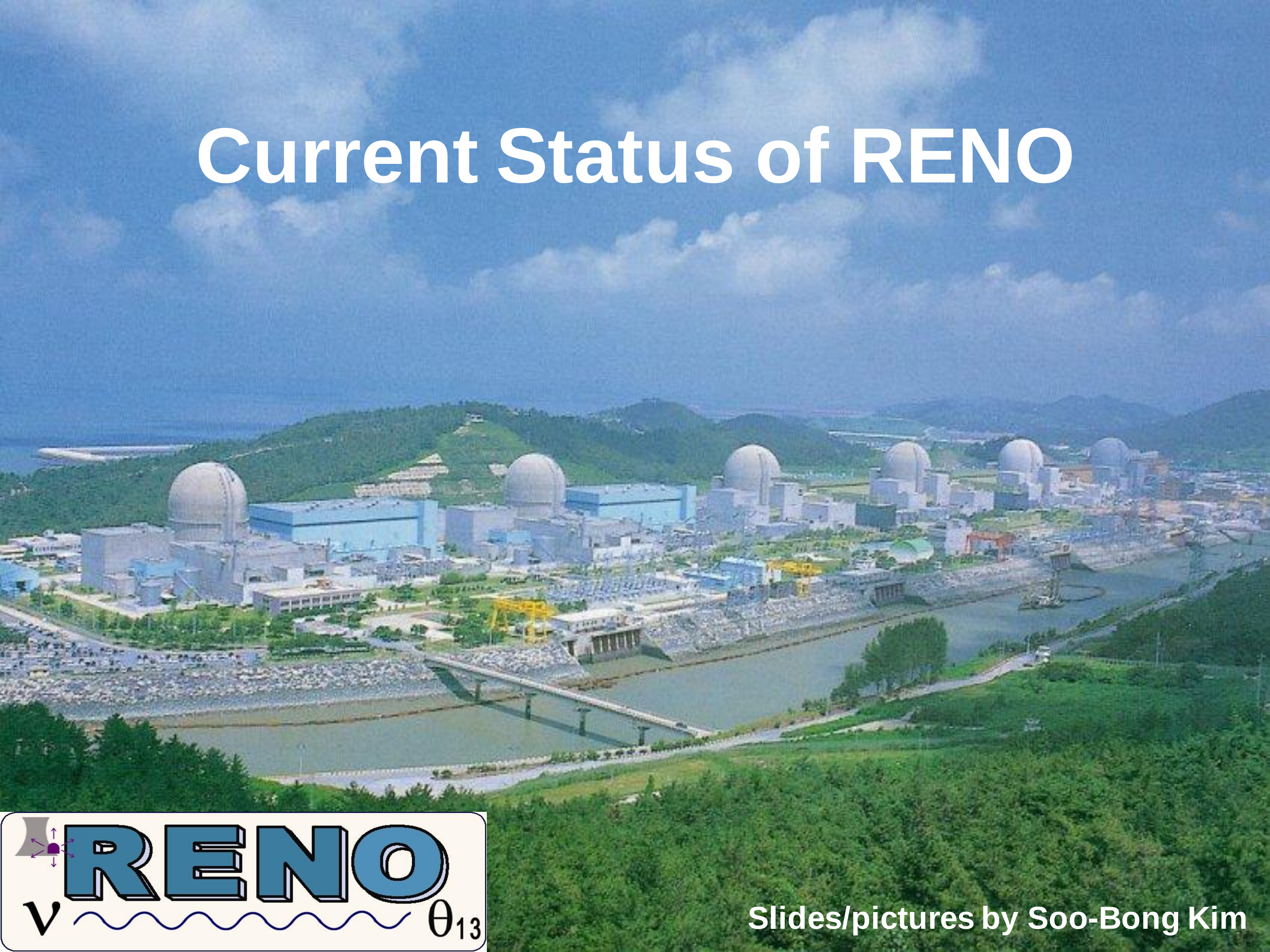


Sensitivity & schedule





- **Double Chooz Far integration Started in May 08**
  - *2008-09* → *Far Detector construction & integration*
  - ***Mid-2009*** → ***Start of phase I : Far 1 km detector alone***
    $\sin^2(2\theta_{13}) < 0.06$ after 1,5 year (90% C.L.) if no-oscil.
  - *2008-10* → *Near Lab Escavation & Near Detector Integration*
  - ***2011*** → ***Start of phase II : Both near and far detectors***
    $\sin^2(2\theta_{13}) < 0.03$ after 3 years (90% C.L.) if no-oscil.


Current Status of RENO
RENO
Slides/pictures by Soo-Bong Kim

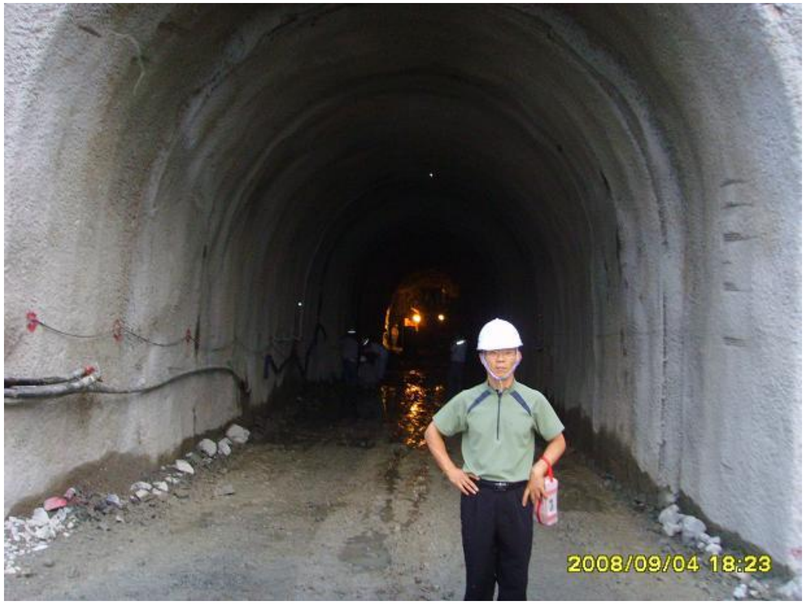
Schematic Setup of RENO at YeongGwang

Summary of Construction Status

- 03~10, 2007 : Geological survey and tunnel design are completed.
- 07~12, 2008 : Tunnel construction
- Hamamatsu 10” PMTs are considered to be purchased. (expect to be delivered from March 2009)
- 09, 2008 : SK new electronics are adopted and electronic modules are delivered.
- 09, 2008 : A mock-up detector (~1/10 in volume) is assembled.
- 10~12, 2008 : Steel/acrylic containers and mechanical structure will be ordered soon.
- Liquid scintillator handling system will be prepared.

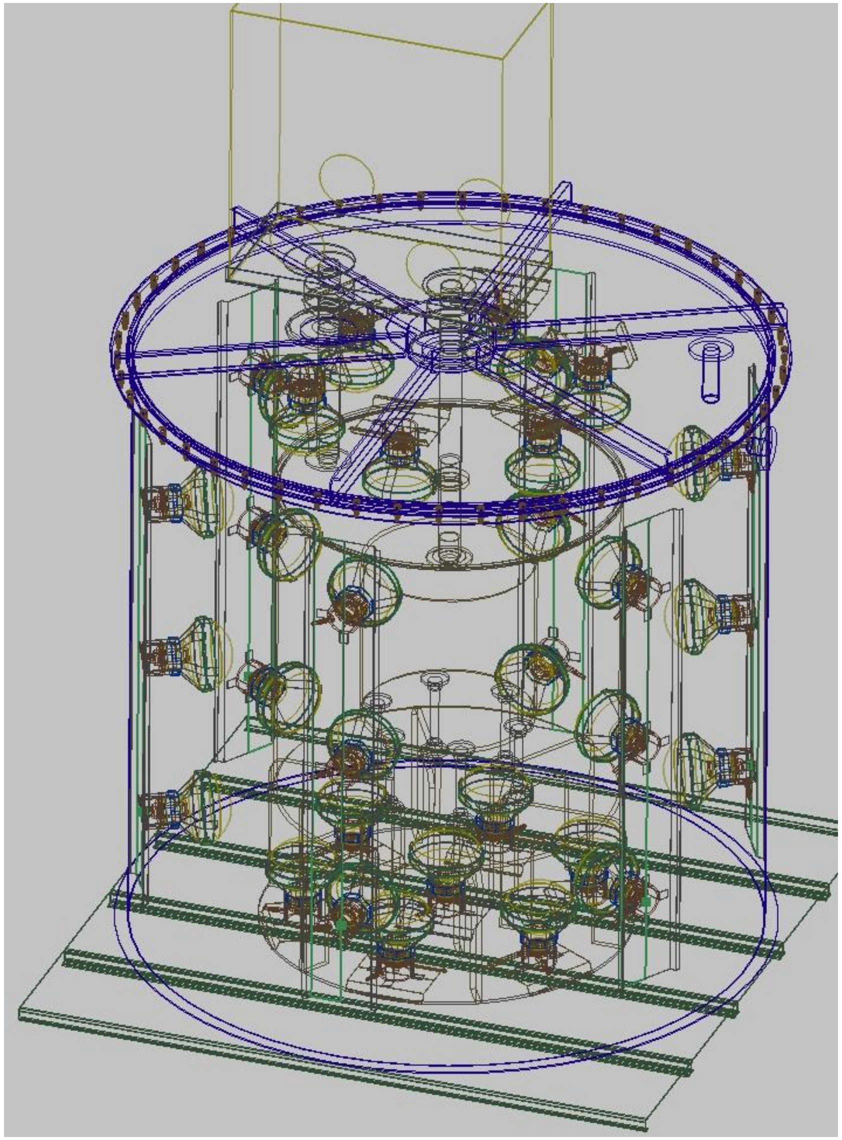
Tunnel Construction

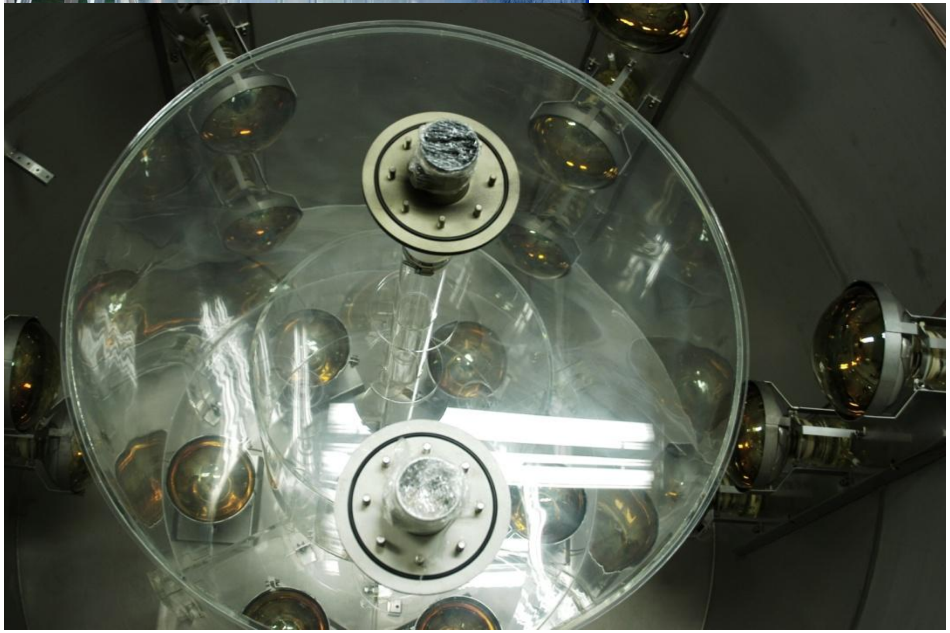
Far detector site



Near detector site

Mockup Detector





Summary of RENO

- RENO is suitable for measuring θ_{13} ($\sin^2(2\theta_{13}) > 0.02$)

- Geological survey and design of access tunnels & detector cavities are completed → Civil construction began in July, 2008.

- RENO is under construction phase.

- Data–taking is expected to start in early 2010.

- International collaborators are being invited.

Conclusions & Outlook

Several experiments aim at being the first of a **new generation of reactor neutrino experiments** using identical detectors at different distances from a reactor **to measure θ_{13}**.

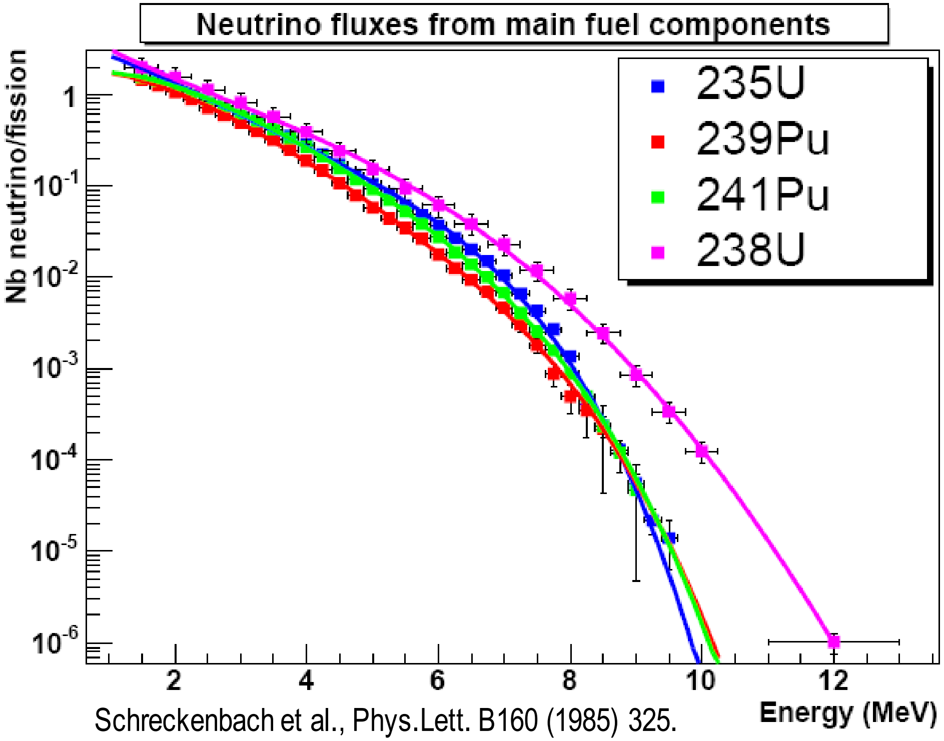
R&D phase is far advanced, **we are in the construction phase**, **with detector installation started** in Chooz in May 2008. Data taking with far detector is scheduled for mid-2009.

Era of precision measurements with reactor neutrinos will improve knowledge on θ_{13}, in a **complementary way to long baseline experiment**.

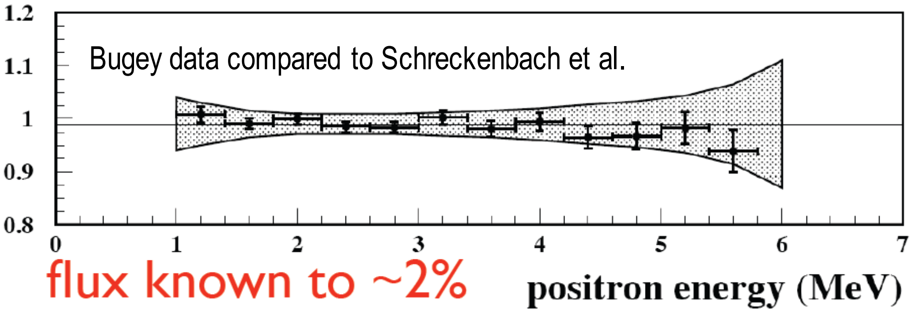
Reactor antineutrinos

Nuclear reactors are a strong, pure source of electron antineutrinos

$\sim 2 \cdot 10^{20} \, \overline{\nu}_e \, (s \cdot GW_{th})^{-1}$



Schreckenbach et al., Phys.Lett. B160 (1985) 325.
Hahn et al., Phys.Lett. B218 (1989) 365.

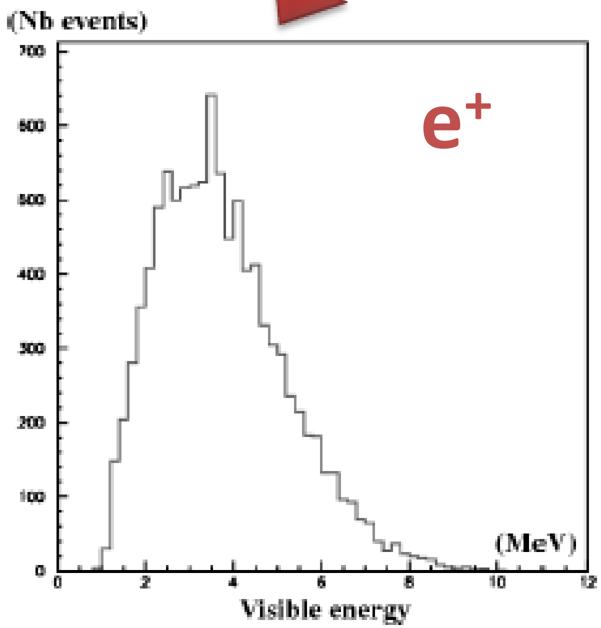


flux known to ~2%

Antineutrino detection

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

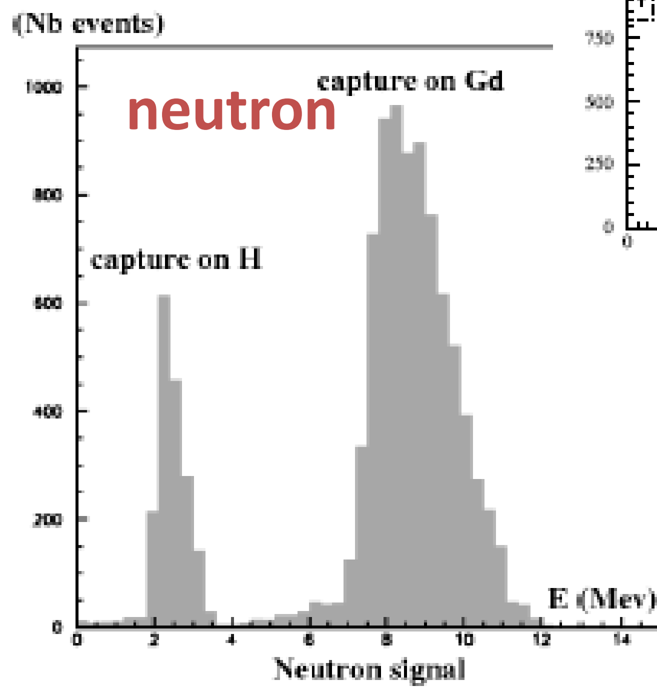
$$n + p \rightarrow d + \gamma \ (2.2\ \text{MeV})$$
$$n + Gd \rightarrow Gd + \gamma\text{'s} \ (8\ \text{MeV})$$

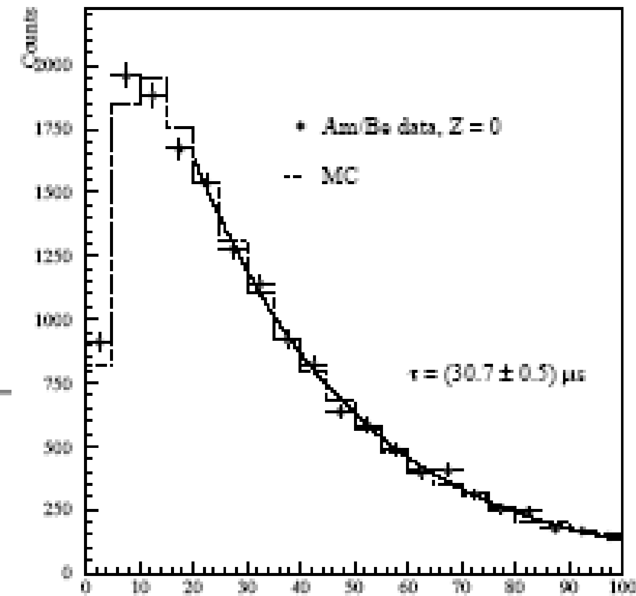


threshold $E_\nu > 1.8$ MeV

$E_\nu \approx E_{vis} + 0.8$ MeV

delayed signal

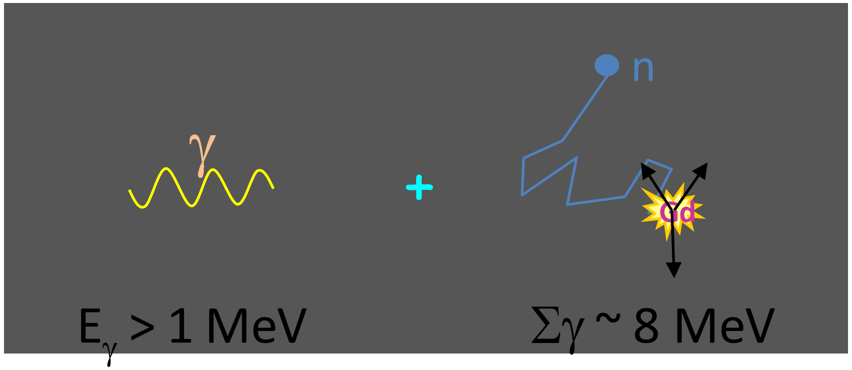




τ =(30.7   0.5)µs
with 0.1% Gd

τ =180µs
for capture on H

Accidental & correlated background

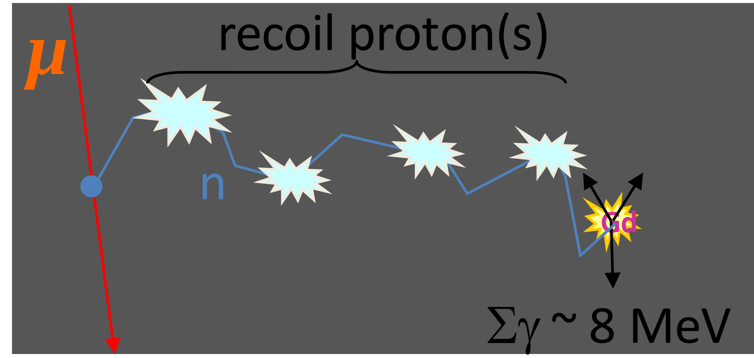


Accidental coincidences between:

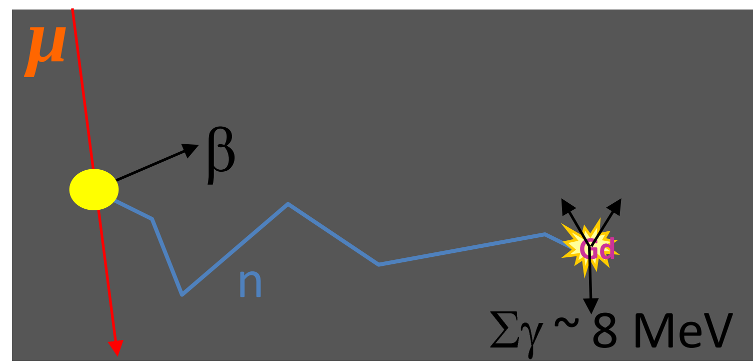
- **e^+-like signal** (radioactivity from materials, PMT, surrounding rock) R_e
- **neutron signal** (induced by cosmic μ, γ's mimicking neutron) R_n

$$R_{acc} = R_e \times R_n \times \Delta t$$

→ reduce gamma background
→ rate & shape of accidental background can be measured ***in situ*** and subtracted from the spectrum

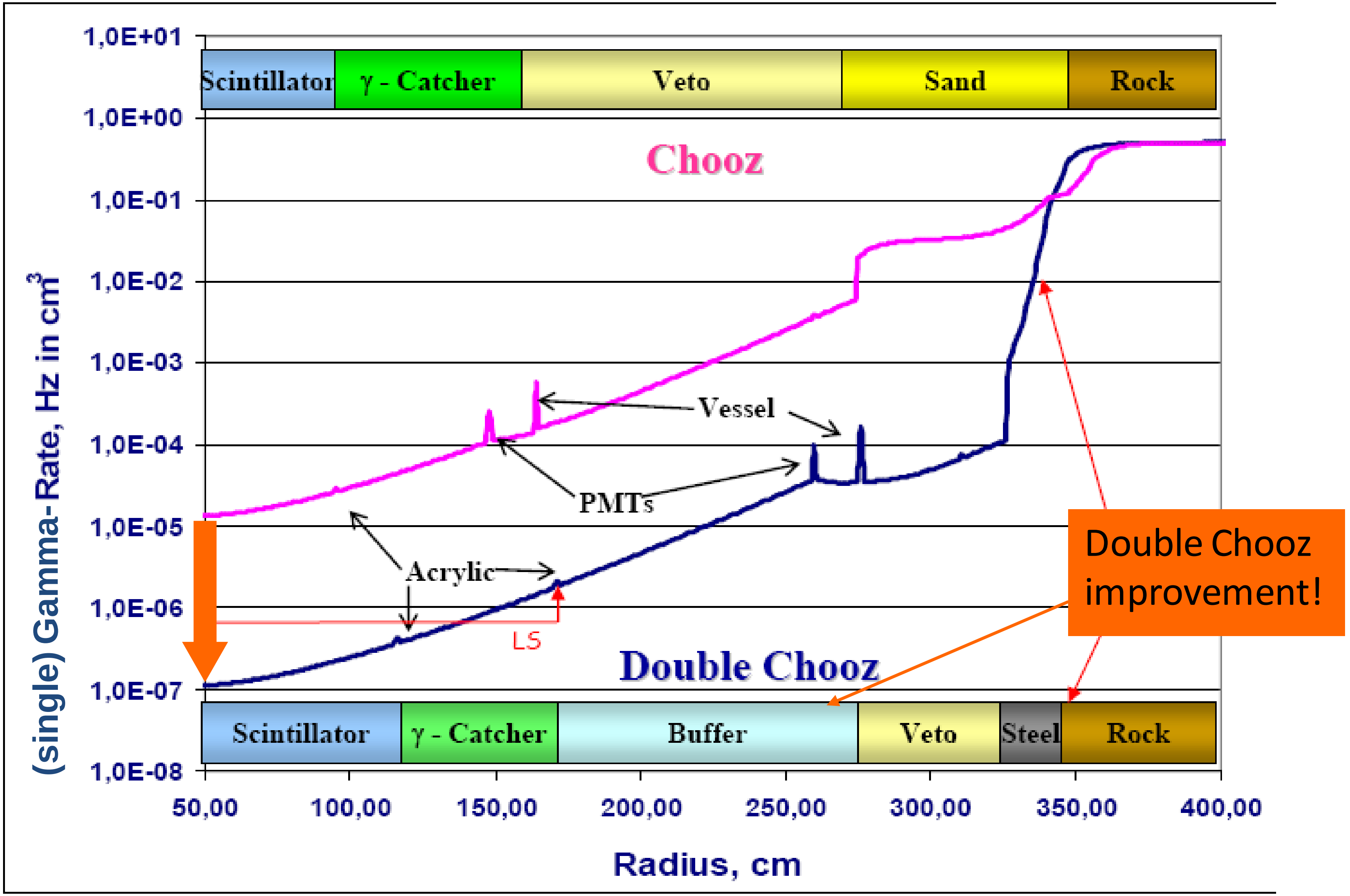


Fast neutrons (induced by cosmic μ) scatter on protons and are captured by Gd.

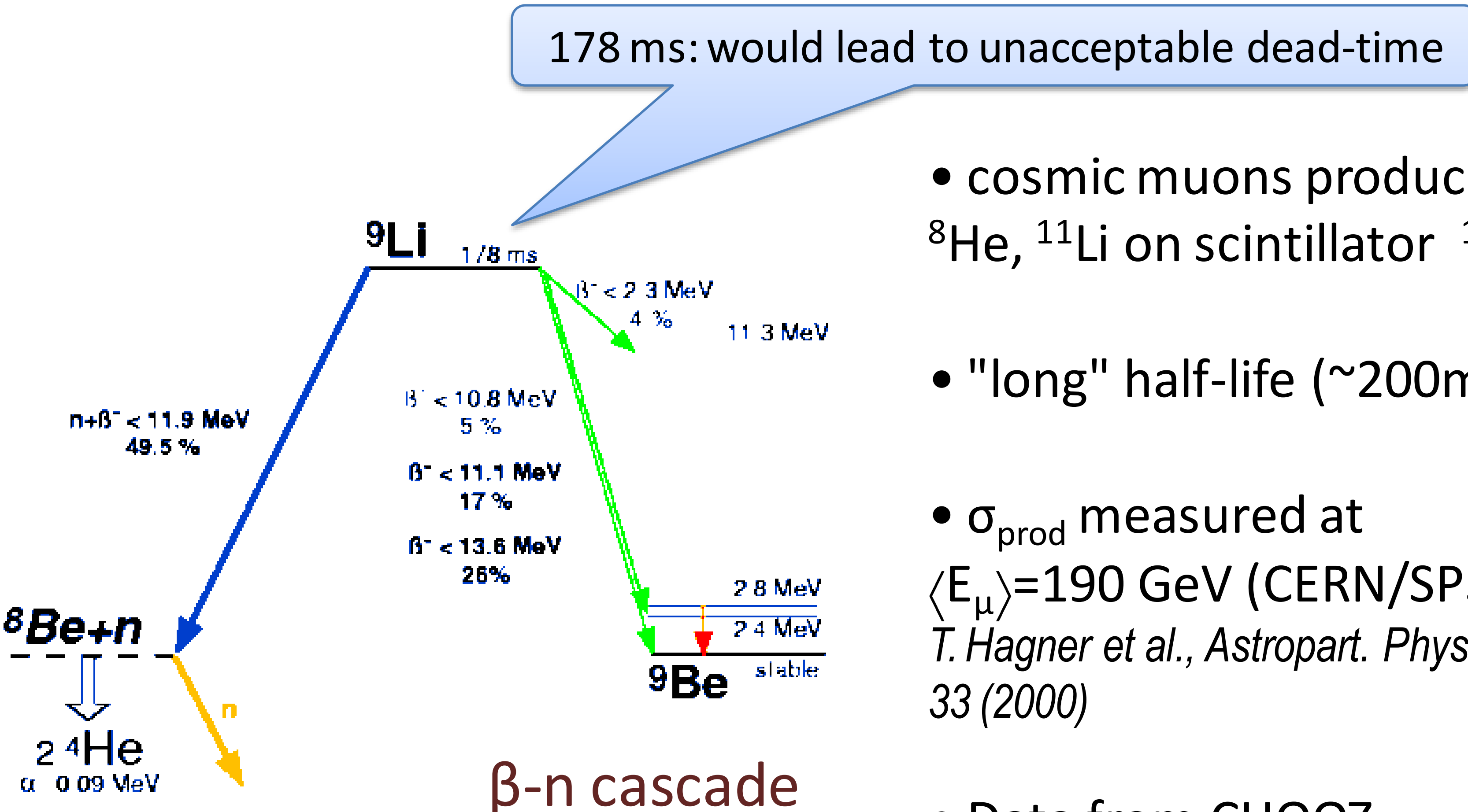


Long-lived isotopes (^9Li, ^8He) with β-n-cascades (induced by cosmic μ).

Gamma background

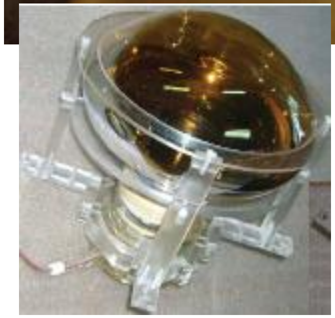


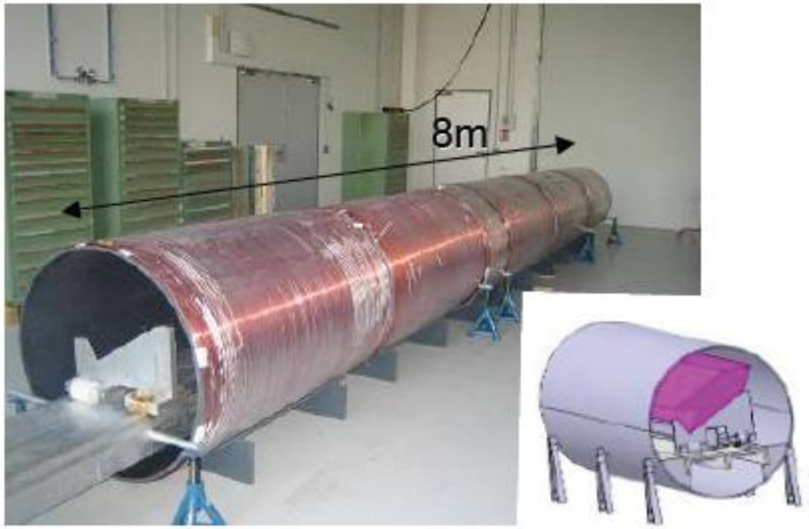
Cosmogenic background: ^{9}Li example



- cosmic muons produce ^{9}Li, ^{8}He, ^{11}Li on scintillator ^{12}C
- "long" half-life (~200ms)
- σ_{prod} measured at $\langle E_{\mu} \rangle$=190 GeV (CERN/SPS)
  T. Hagner et al., Astropart. Phys. 14, 33 (2000)
- Data from CHOOZ, CTF and KamLAND (+ Borexino)

Start of construction





Reactor Experiment for Neutrino Oscillation

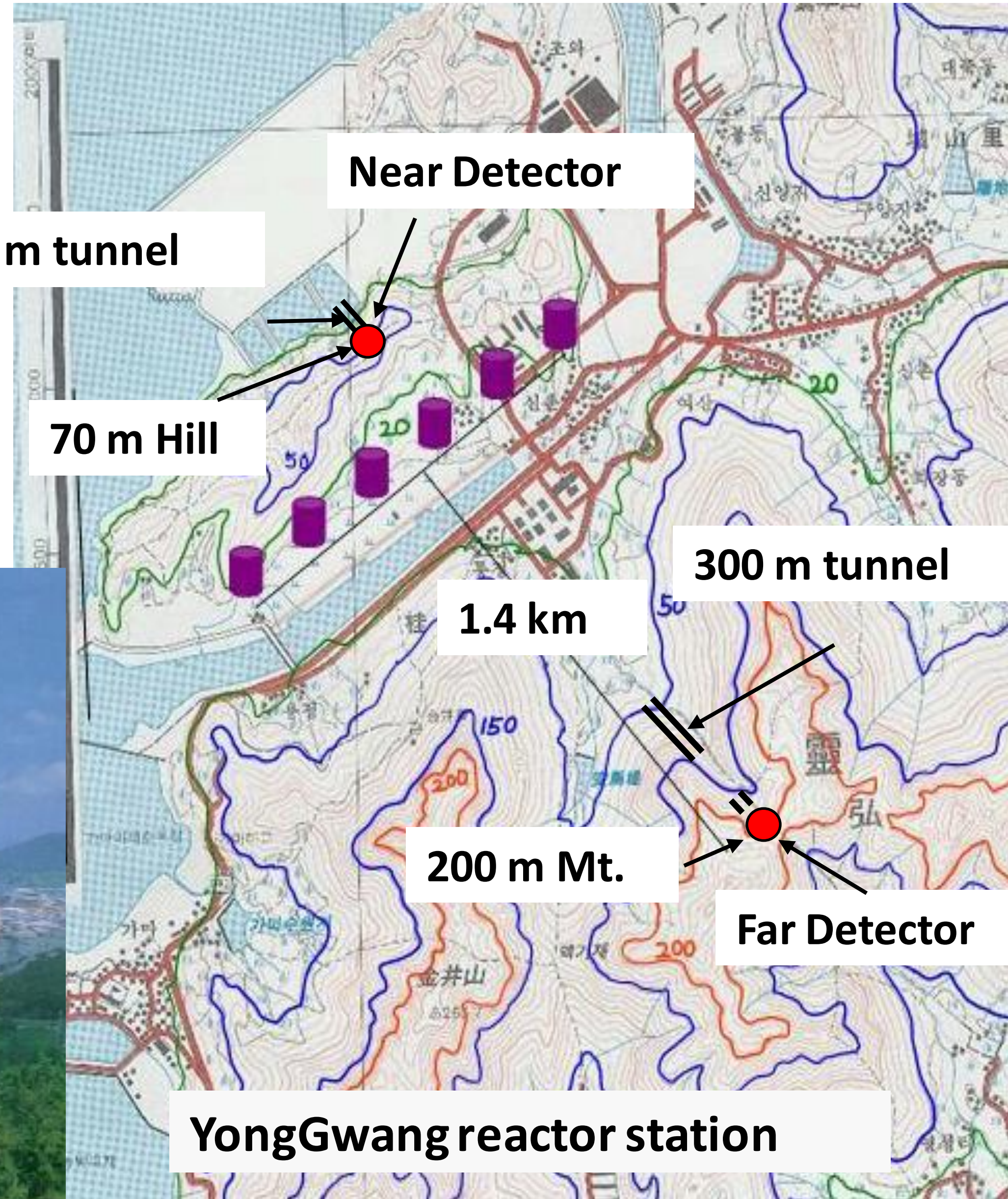
Korean/Russian collaboration

6 reactors with total 17.3 GW_{th}

target mass: 15 tons

Goal:

$\sin^2 2\theta_{13} \sim 0.02$ @ 90% CL in 3 years



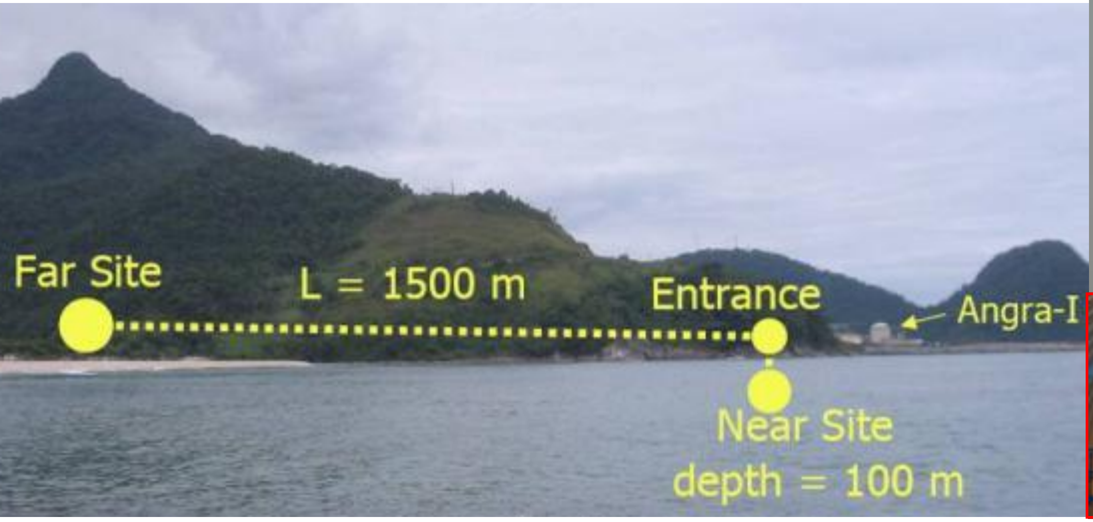
Larger Detectors

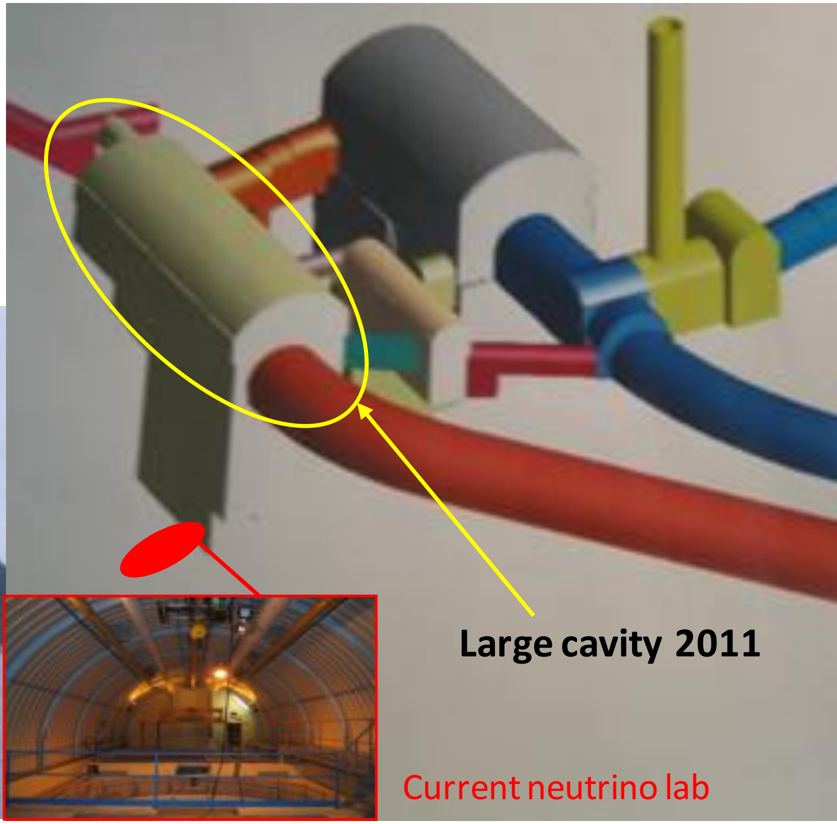
Angra dos Reis, Brazil:

- Goal: $\sin^2 2\theta_{13} \sim 0.006$
- very large target mass (~ 200t)
- 30 researchers from 11 institutions
- very near prototype detector approved by FINEP in March 2007
- participation of the Brazilian group in Double Chooz
- full experiment in Angra around 2013?

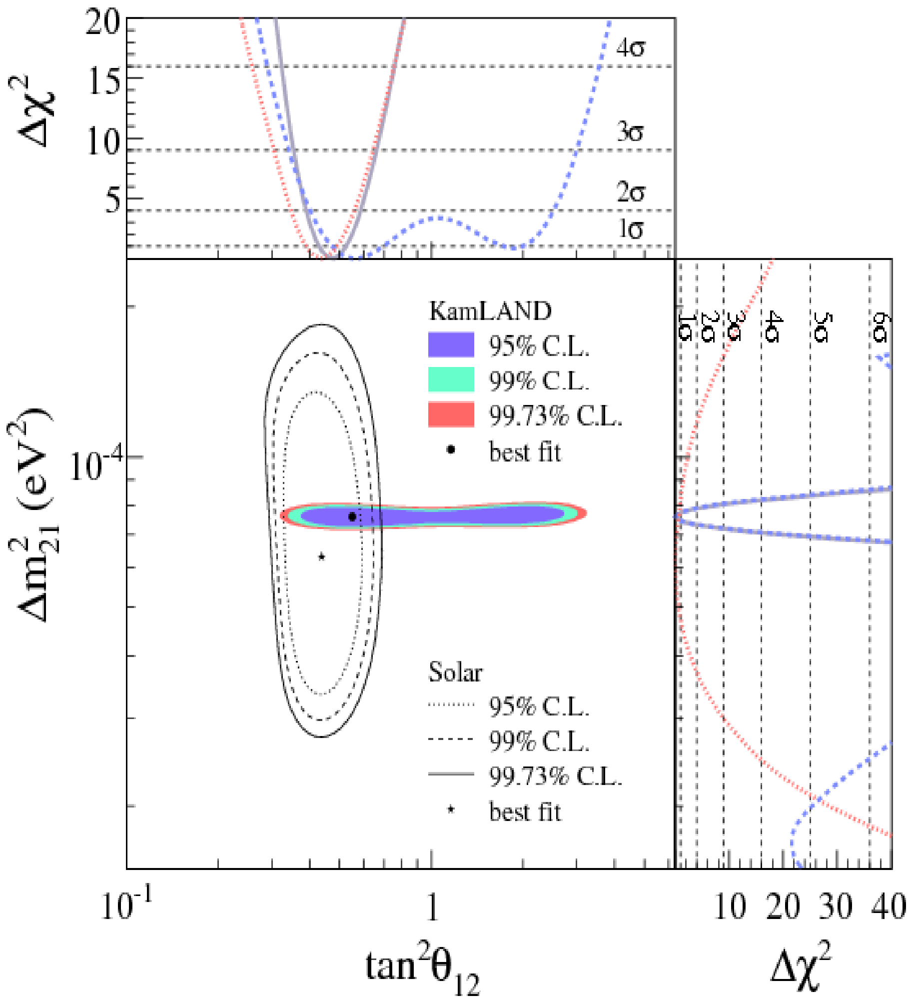
Triple Chooz:

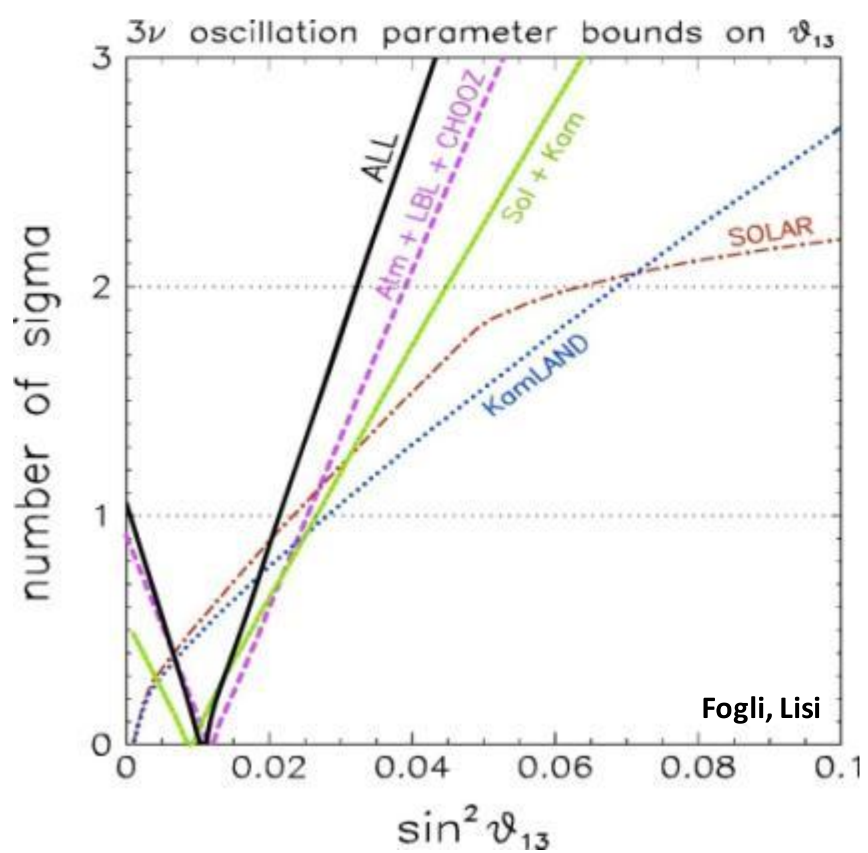
- just an idea yet...
- larger cavity available in 2011
- 200t target (possible to observe spectral distortions)





A small hint for non-zero θ_{13}





slight preference for

$\sin^2\theta_{13} \sim 0.013$

from the combination of solar+reactor 2008 data

2 detectors

Systematics

		Chooz	Double-Chooz	
	Total	**2.7 %**	**< 0.6 %**	
Reactor-induced	ν flux and σ	1.9 %	<0.1 %	two ''identical'' detectors, monitor flux with near det.
	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
	Volume	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 %	<0.1 %	same scintillator + stability of scintillator
	Spatial effects	1.0 %	<0.1 %	''identical'' target geometry & LS
	Live time	few %	0.25 %	measured with several methods
Analysis	From 7 to 2-3 cuts	1.5 %	0.2 - 0.3 %	Low backgr., reduction of accidentals

The detector(s)