DOUBLE CHOOZ: STATUS REPORT

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GDR Neutrino - 29th October 2009 - Strasbourg

INTRODUCTION

- Double Chooz is a reactor neutrino experiment.
- The goal is a measurement of the θ_{13} mixing angle (or a limit on its value) using two identical detectors

MOTIVATIONS

- The discovery of a non-zero value of θ_{13} will open the way for CP violation searches in leptonic sector.
- Reactor oscillation experiments aim to the observation of $\overline{\nu}_e \rightarrow \overline{\nu}_e$ transition according to the oscillation probability:

$$P(\overline{\nu}_e \rightarrow \overline{\nu}_e) \cong 1 - \sin^2(2\theta_{13})\sin^2\left(\frac{\Delta m_{23}^2 L}{4E}\right)$$

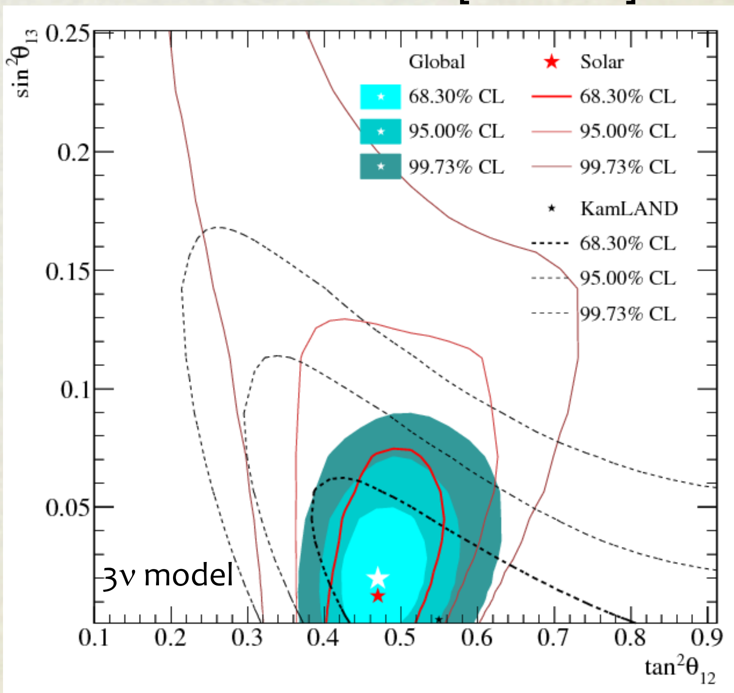
- The advantages of this measurement with respect to long baseline oscillation experiments is a ***clean measurement*** of θ_{13} since:

  1. It is a disappearance experiment, therefore insensitive to the value of the δ-CP phase.
  2. It has a short baseline (order of 1 km) and it is therefore insensitive to matter effects.
  3. The dependence on Δm^2_{21} is very weak : $O(\Delta m^2_{21}/\Delta m^2_{31})$.

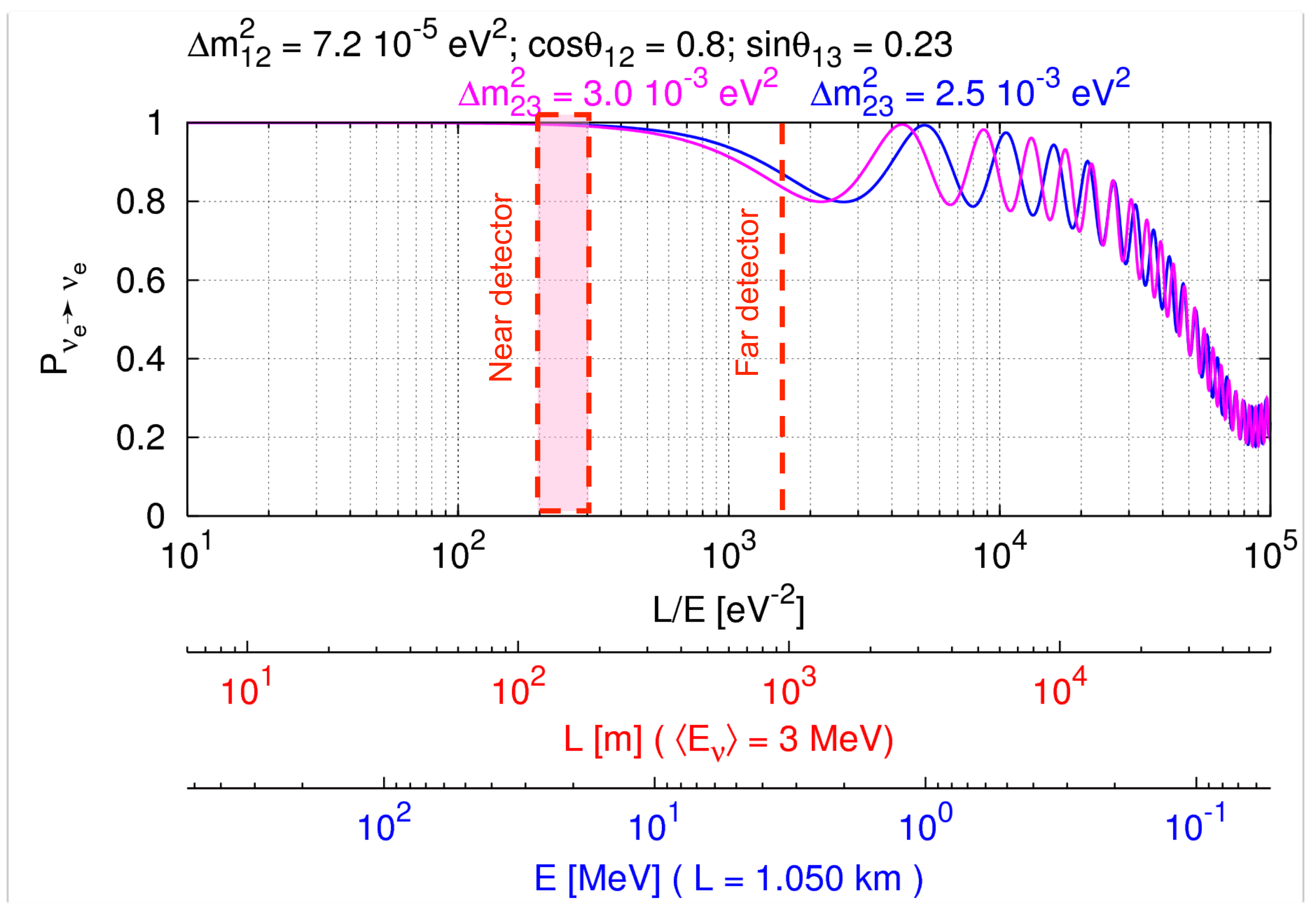
- Reactor neutrino experiments have lower (about one order of magnitude) discovery capabilities with respect to next generation long baseline experiments, however they have a short timescale.
- Moreover there are *hints* that favours *large values* of $\sin^2(2\theta_{13})$:

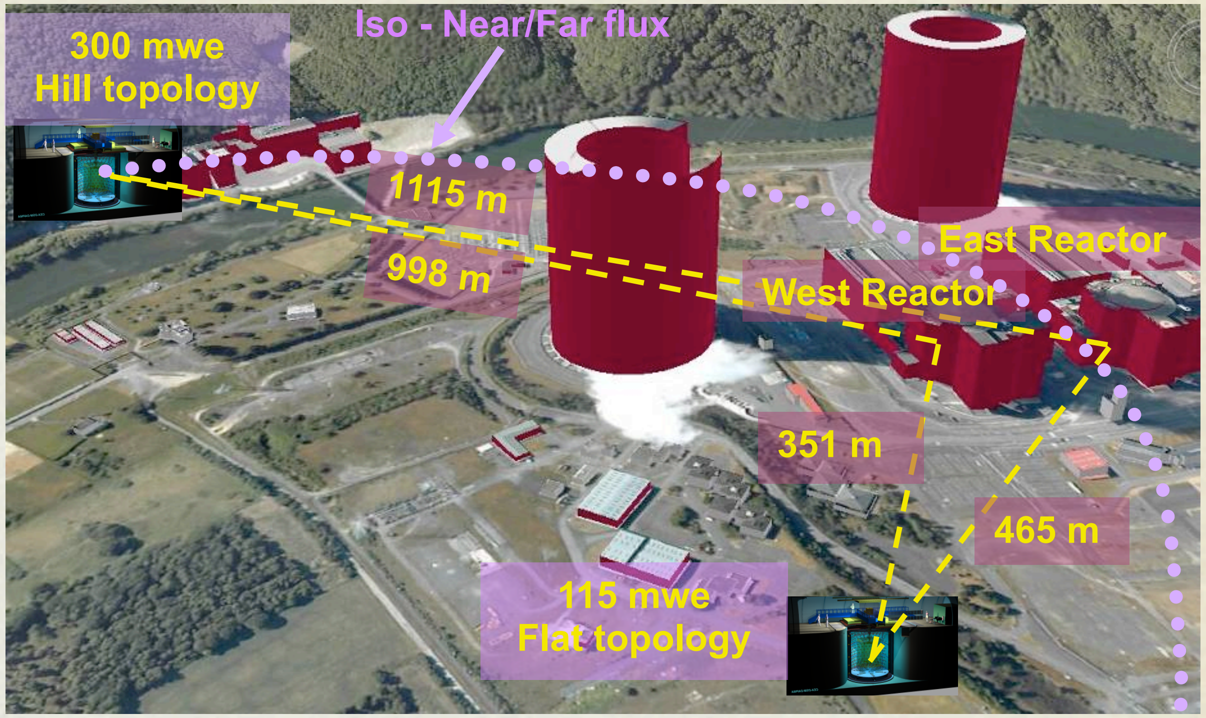
  $\sin^2(2\theta_{13}) = 2.00\ (+2.09\ -1.63) \times 10^{-2}$

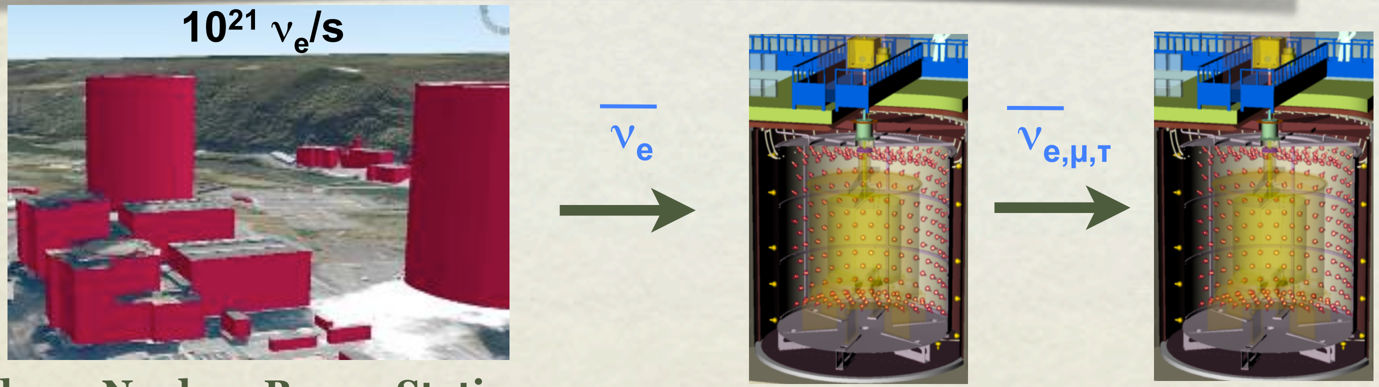
arXiv:0910.2984 [nucl-ex]



EXPERIMENTAL CONCEPT





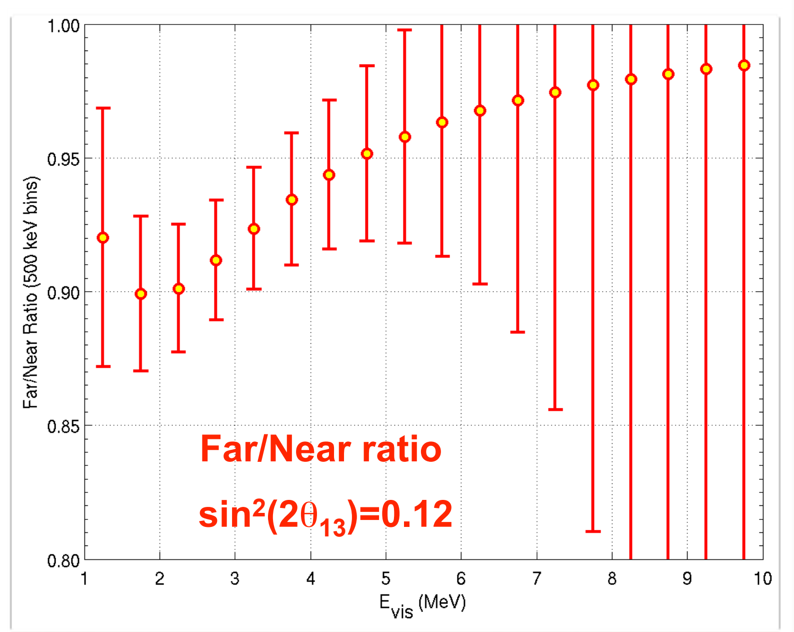


Chooz Nuclear Power Station
2 cores of 4.27 GW_{th} each

Ardellier et. al, hep-ex/0405032

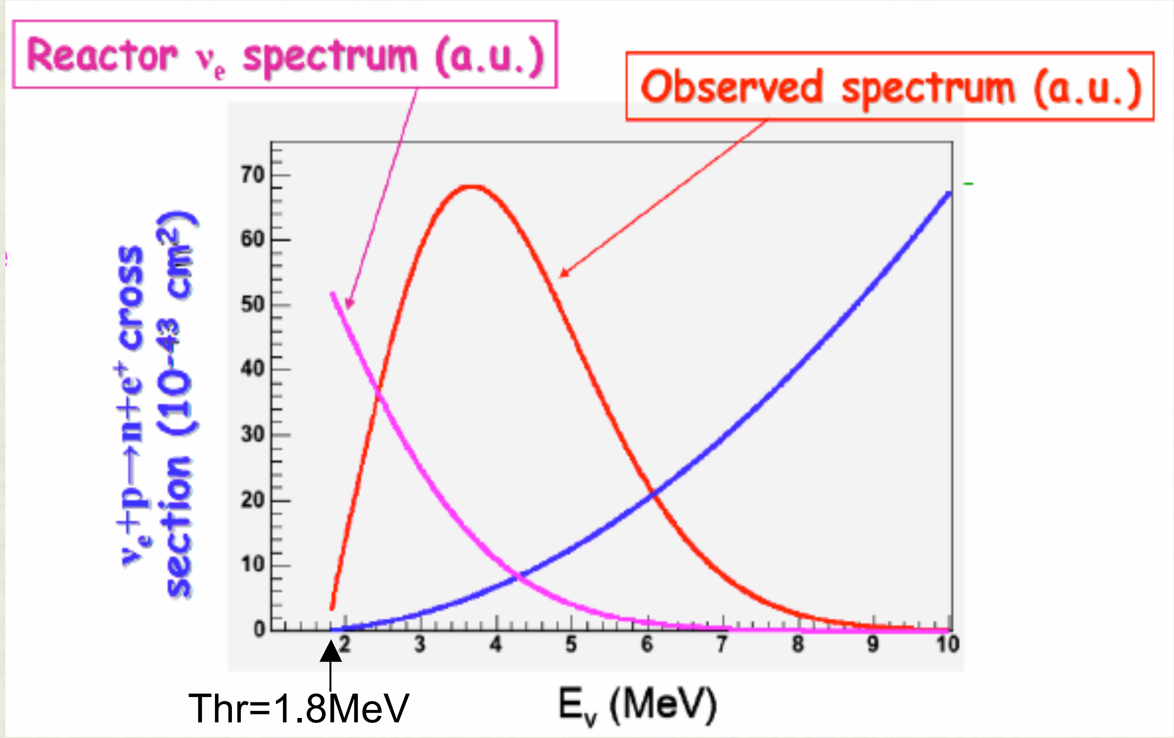
Near detector
400 m

Far detector
1050 m

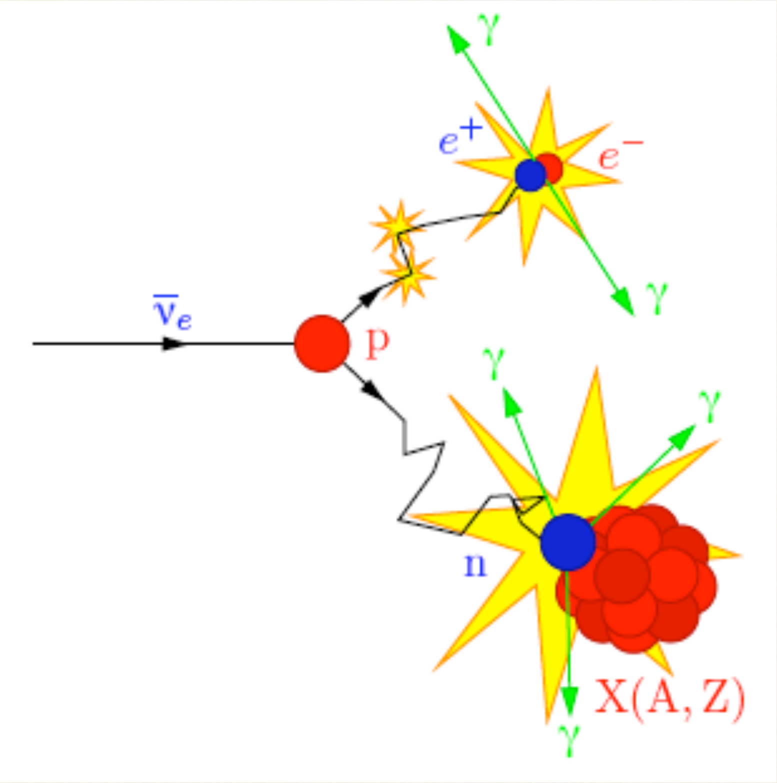


NEUTRINO DETECTION

- Neutrinos are emitted isotropically at a "known" rate: 8 GW power → 10^{21} neutrinos s^{-1}



- The energy spectra is a convolution of flux and cross section (threshold at 1.8 MeV).
- The expected rate at Double Chooz is:
  - 70 events per day at far detector.
  - 500 events per day at near detector.



- Neutrinos are observed via Inverse Beta Decay (IBD): $\overline{\nu}_e$ + p → e^+ + n
- The signal signature is given by:

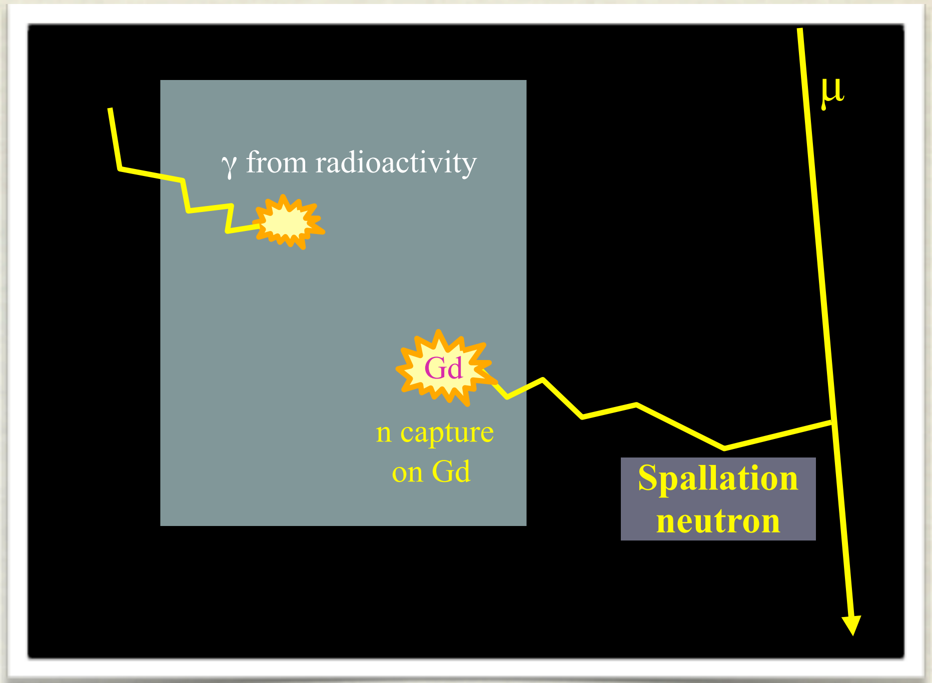
1. Prompt photons from **e^+** annihilation (1-8 MeV).
2. Delayed photons from **n** capture on Gadolinium (8 MeV).
3. Time (Δt ~30μs) and space (< 1m) correlation.

BACKGROUND

- There are two different types of background: accidental and correlated.

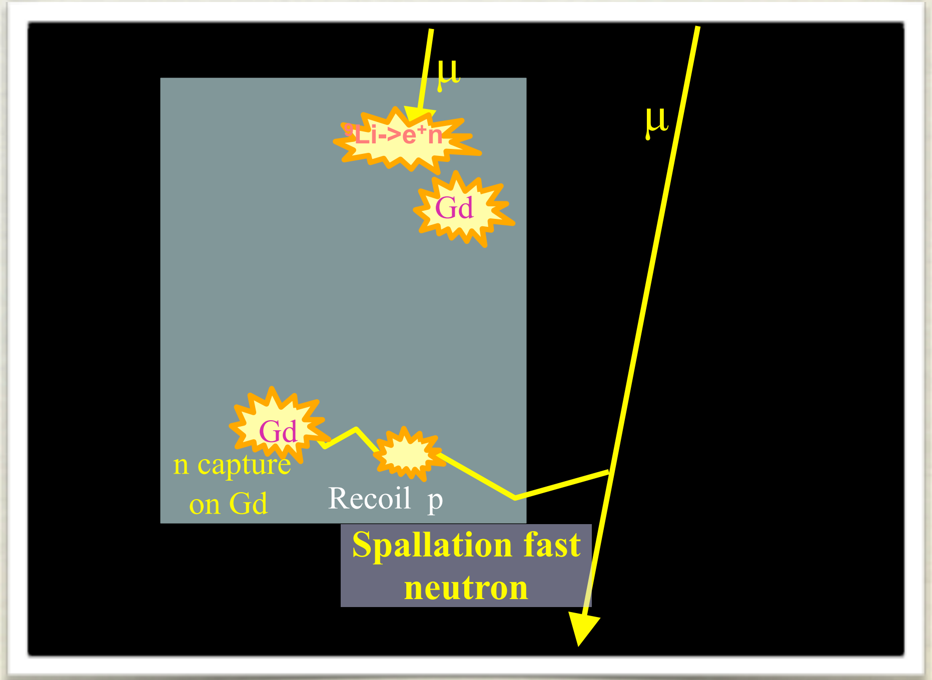
Accidental BG

- e^+-like signal: radioactivity from materials, PMTs, surrounding rock (^{208}Tl).
- n signal: n from cosmic μ spallation, thermalised in detector and captured on Gd or γ mimicking n.
- The expected rate at Double Chooz is:
  - 2 events per day at far detector.
  - 11 events per day at near detector.



Correlated BG

- Fast n (by cosmic μ) recoil on p (low energy) and captured on Gd.
- Long-lived (^{9}Li, ^{8}He) β+n-decaying isotopes induced by μ.
- The expected rate at Double Chooz is:
  - 1.6 events per day at far detector.
  - 5.2 events per day at near detector.



HOW TO IMPROVE CHOOZ LIMIT?

- The Chooz experiment did not observe any oscillation and set a limit on $\sin^2(2\theta_{13})$ of 0.1.
- How can we improve the experiment sensitivity to reach the final goal of 0.03 on the limit on $\sin^2(2\theta_{13})$?

Best Sensitivity @CHOOZ: R = 1.01 ± 2.8%(stat)±2.7%(syst)

- **Statistics**: Larger detector volume and longer exposure.

	CHOOZ	Double Chooz
Target volume	5.55 m^3	10.3 m^3
Target composition	6.77 10^{28} H/m^3	6.55 10^{28} H/m^3
Data taking period	Few months	3-5 years
Event rate	2700	Far: 40000 / Near: 500000 (3 y)
Statistical error	2.8%	0.5%

- **Systematics**: Two detectors concept.

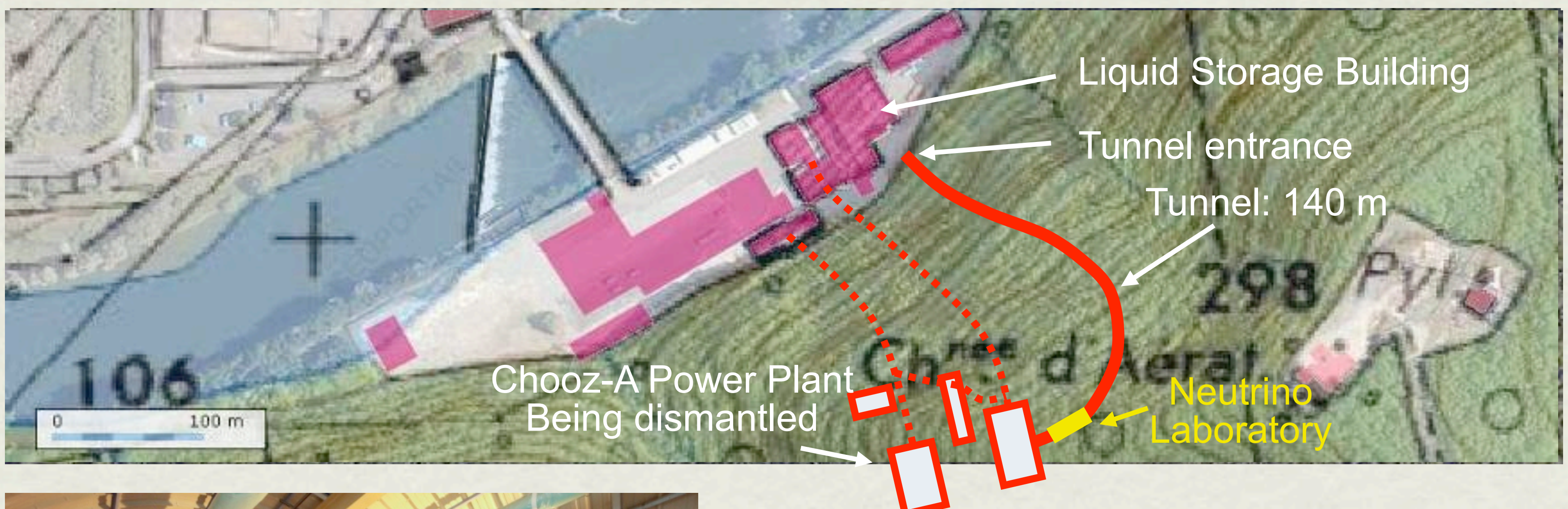
  Improved detector design (lower threshold, higher e^+ and n efficiencies, calibration system).

  Reduced background (shielding and radiopurity).

	Chooz	Double-Chooz
Reactor cross section	1.9 %	—
Number of protons	0.8 %	0.2 %
Detector efficiency	1.5 %	0.5 %
Reactor power	0.7 %	—
Energy per fission	0.6 %	—

FAR LAB STATUS

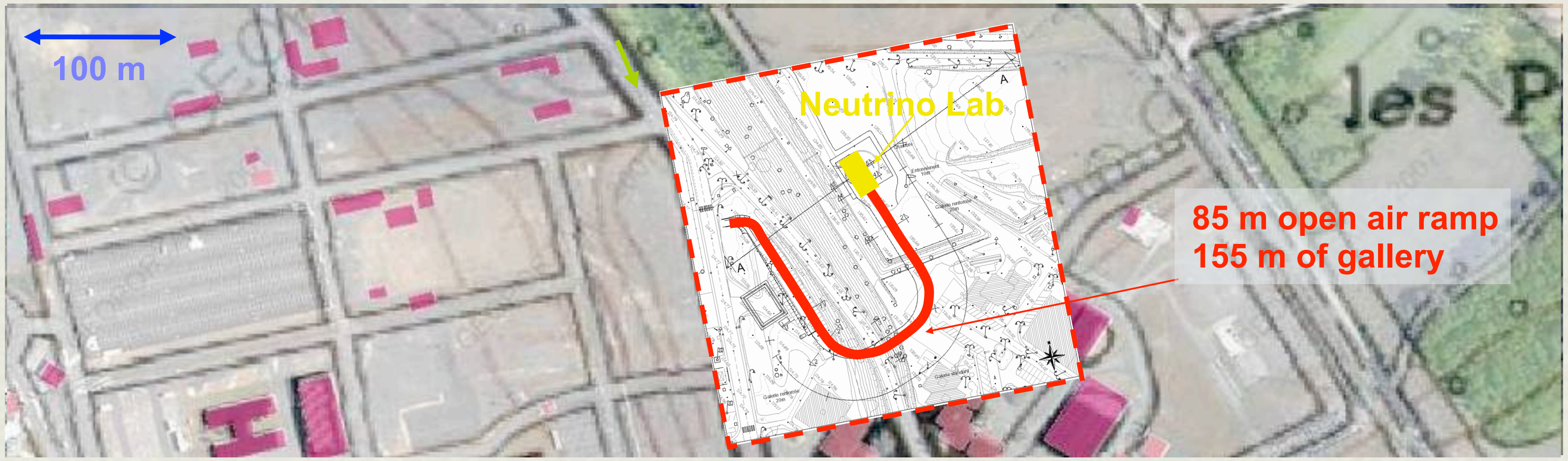
- The laboratory is the site of the CHOOZ experiment.
- Integration of the detector is ongoing.
- Liquid storage building is ready and liquid delivery is expected in November/December.



Some numbers:
1 km baseline (15 000 y^{-1})
300 m.w.e. (hill topology)
μ-rate: ~20 Hz @IV
μ-flux: ~0.4 Hz m^{-2} @ detector level
ISO 6 Clean Room

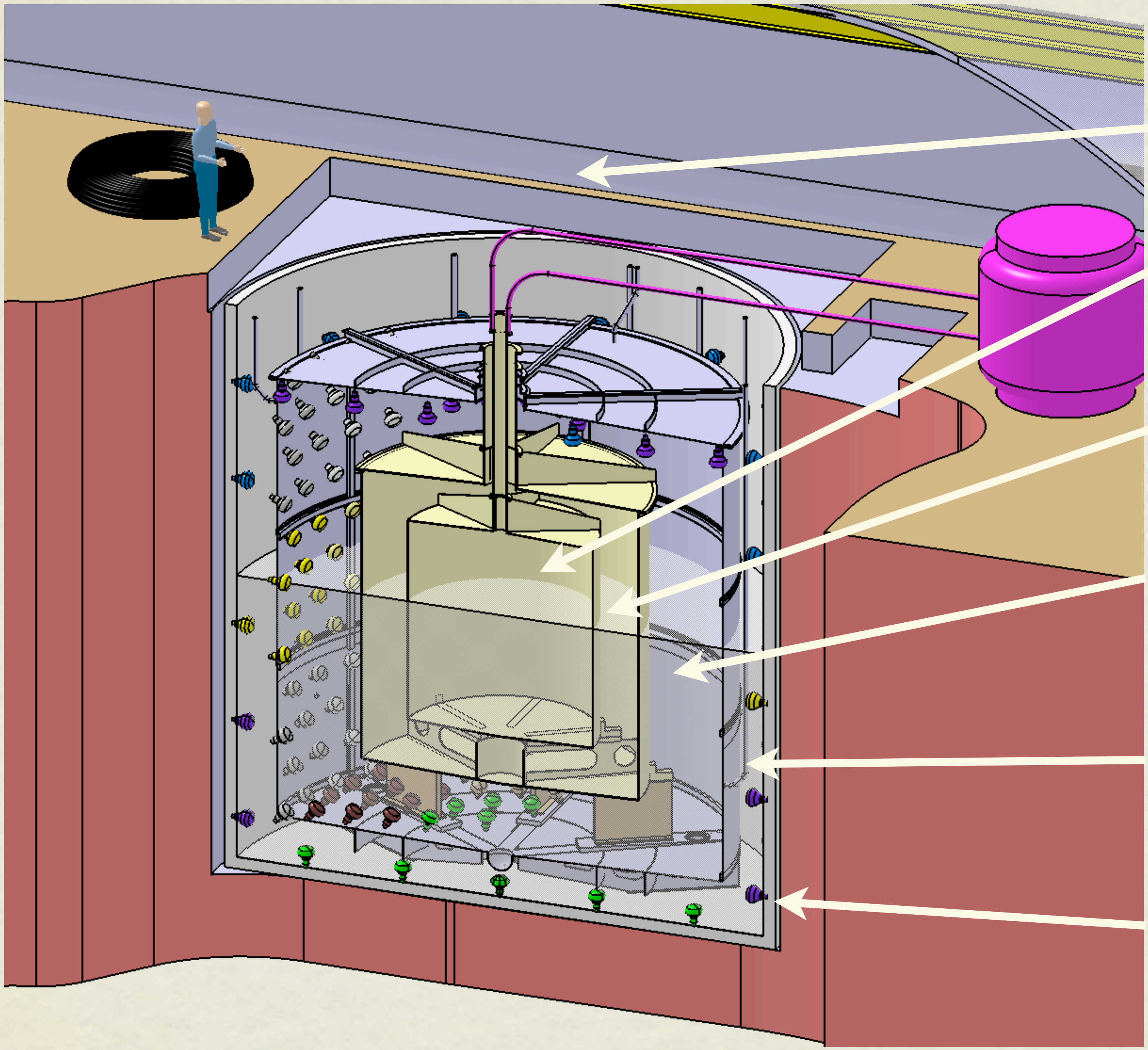
NEAR LAB STATUS

- The near laboratory is fully founded (7 partners)
- The site engineering study is completed.
- The construction is expected between July 2010 and July 2011.



Some numbers:
400 m from nuclear cores (150 000 y^{-1})
A 155 m tunnel to access the new lab
115 m.w.e (almost flat topology)
μ-rate: ~250 Hz @IV
μ-flux: ~5 Hz m^{-2} @ detector level

DETECTOR DESIGN



Outer Veto: plastic scintillator strips (400 mm)

ν-Target: 10.3 m^3 scintillator doped with 0,1g/l of Gd compound in an acryclic vessel (8 mm)

γ-Catcher: 22,3 m^3 scintillator in an acrylic vessel (12 mm)

Buffer: 110 m^3 of mineral oil in a stainless steel vessel (3 mm) viewed by 390 PMTs (10 inches)

Inner Veto: 90m^3 of scintillator in a steel vessel (10 mm) equipped with 78 PMTs (8 inches)

Shielding: about 250t steel shielding (150 mm)

INSTALLATION STATUS

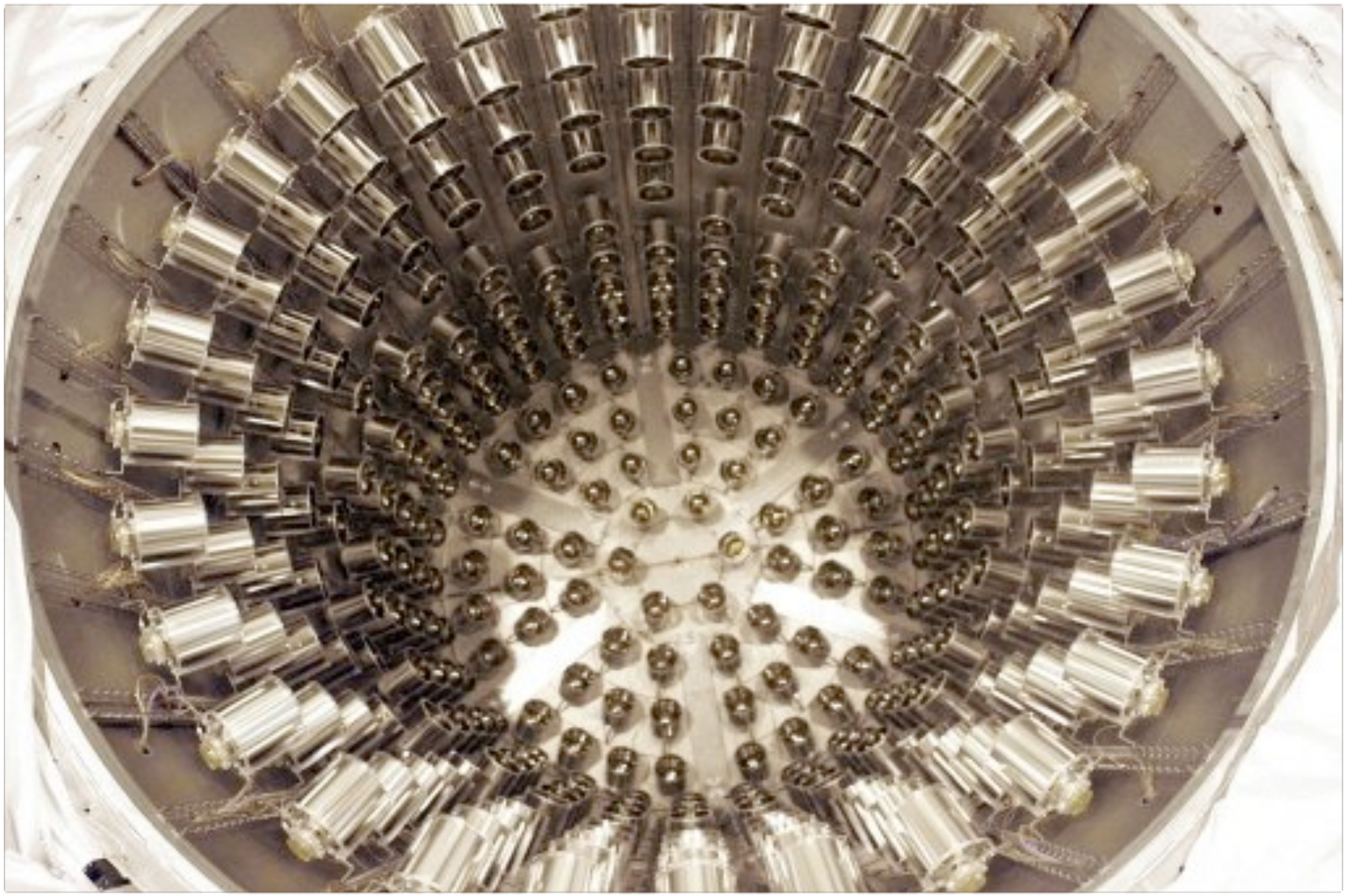
250 ton Steel shielding ✓

INSTALLATION STATUS

Inner Veto PMT installation ✓

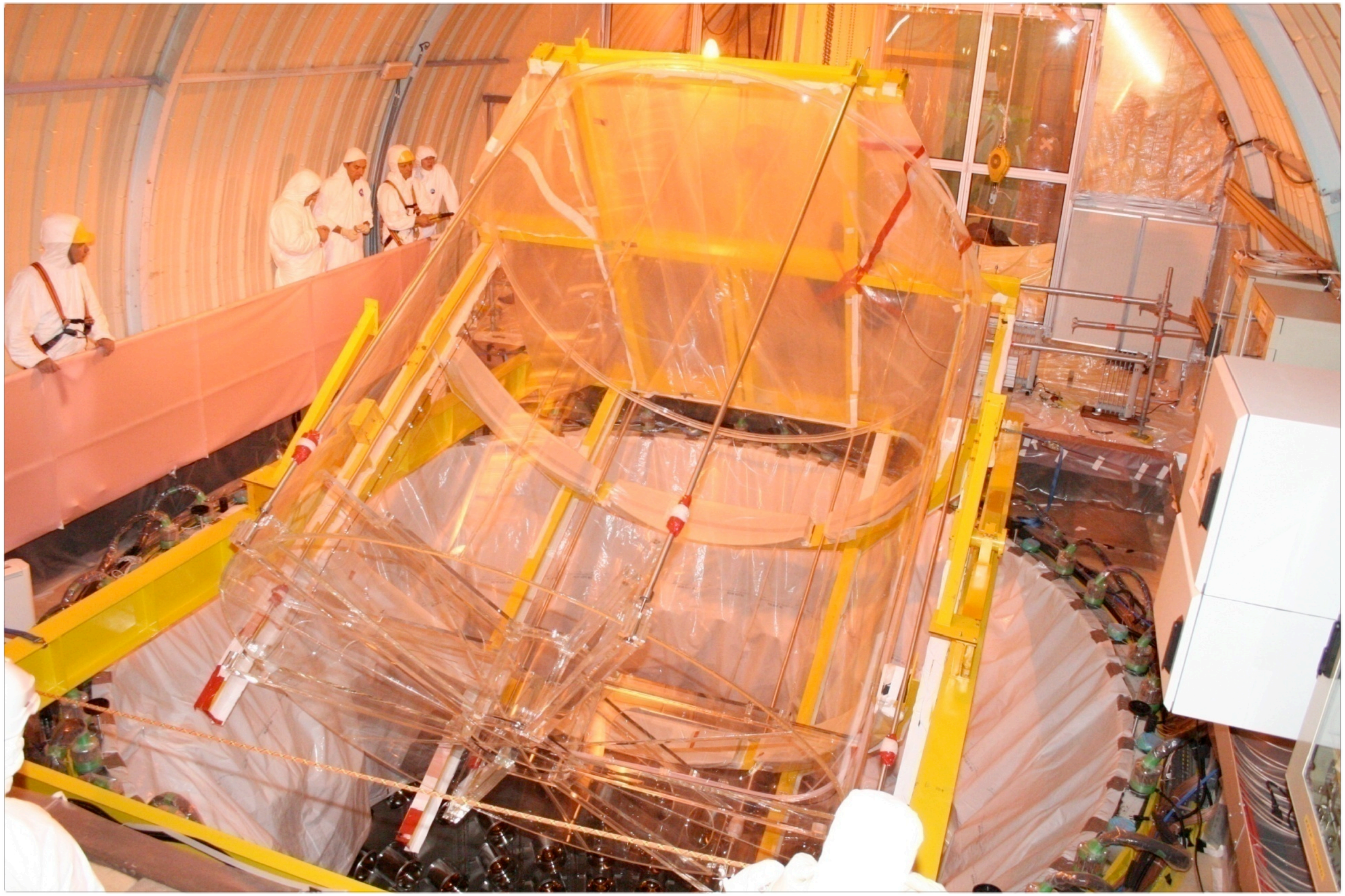
INSTALLATION STATUS

Buffer PMT installation ✓



INSTALLATION STATUS

Gamma catcher and target installation ✓



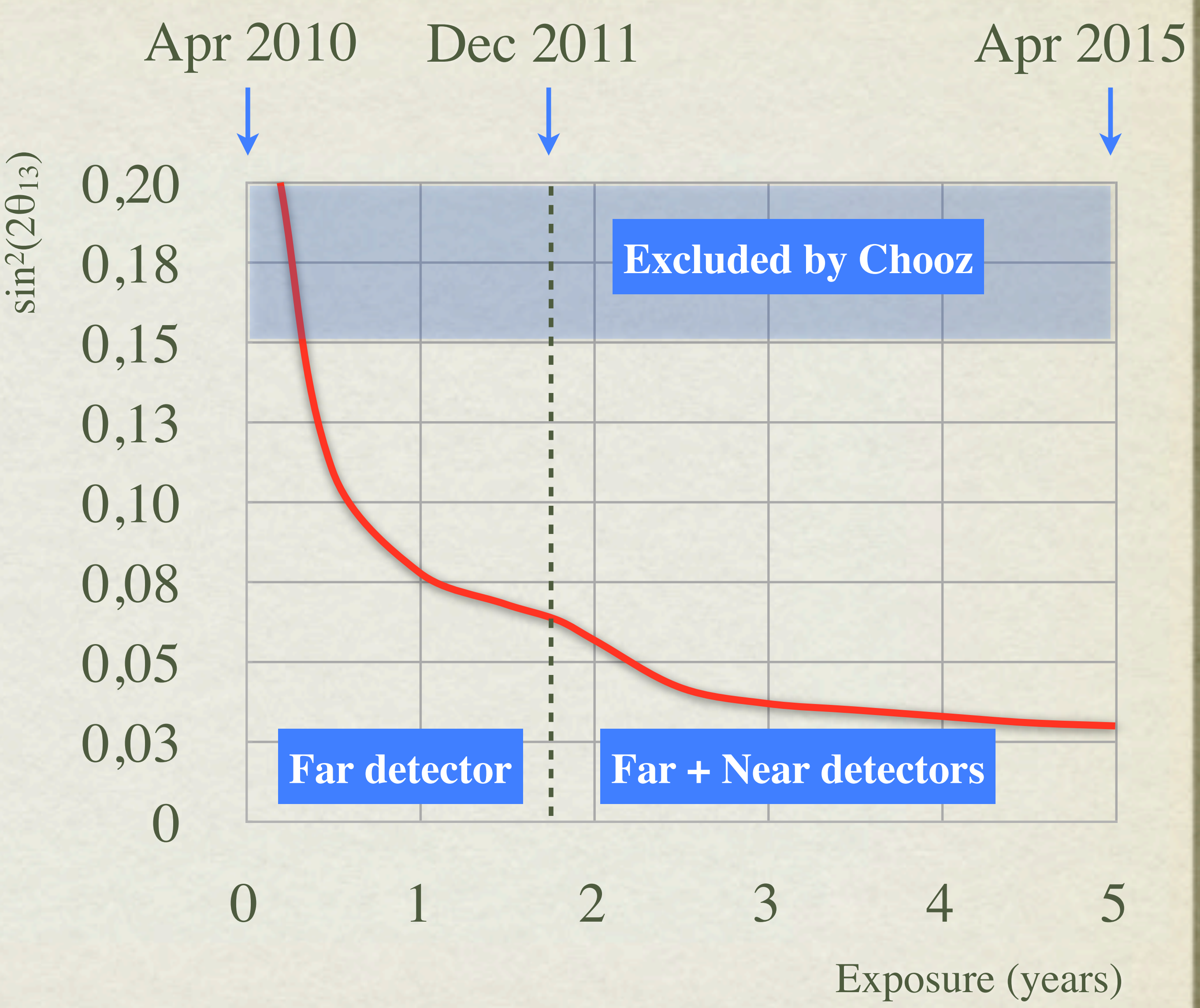
INSTALLATION STATUS

To do ✕

- Buffer and Inner veto lid PMT installation (December 2009).
- Electronics and DAQ installation (January 2010).
- Detector filling (April 2010).
- Outer veto assembling (June 2010)
- Data taking is foreseen to start at the end of April 2010

TIMELINE AND SENSITIVITY

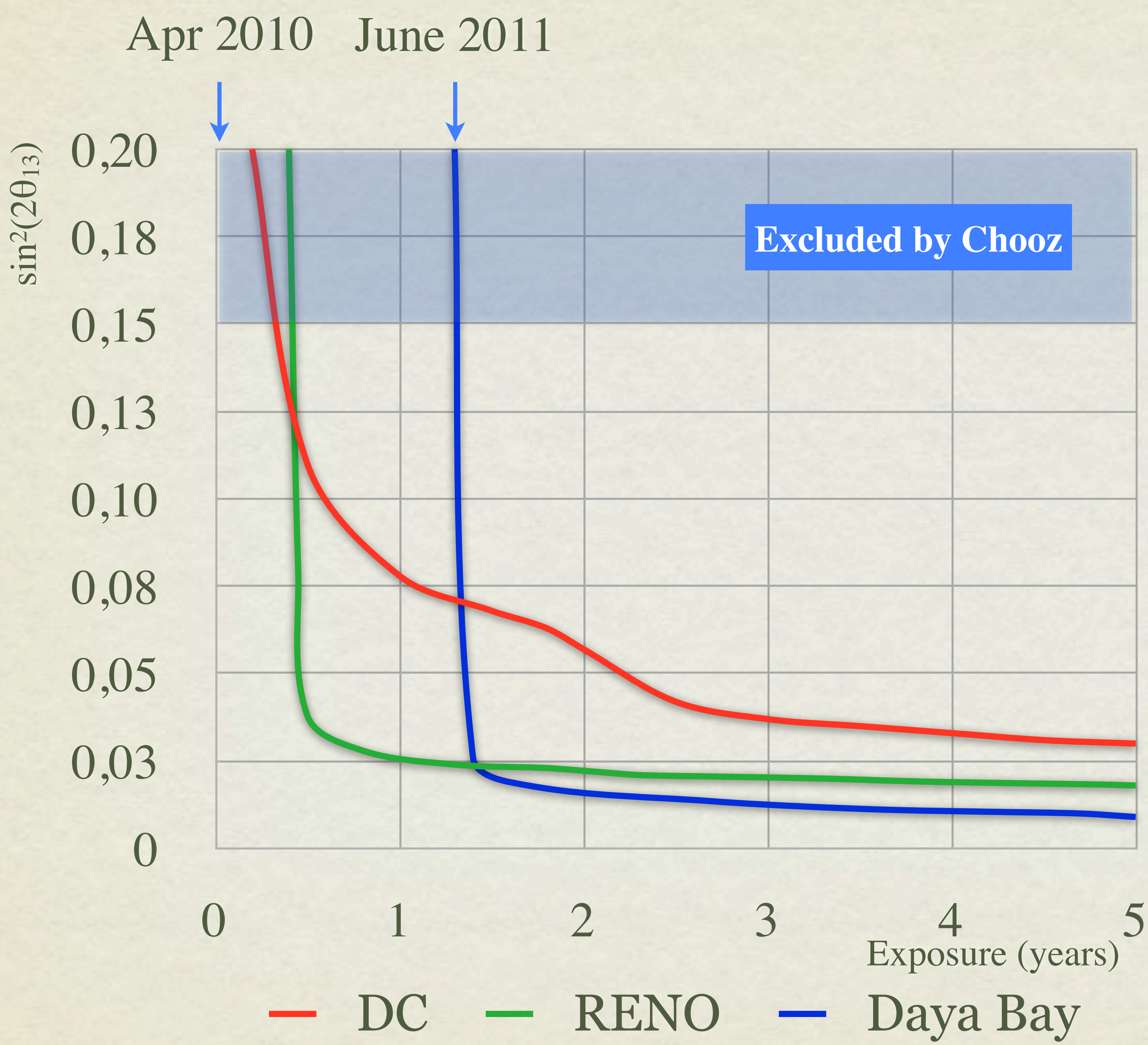
- Limit calculated for Δm^2_{atm} = 2.5 x 10^{-3} eV^2 (20% uncertainty).
- Efficiencies have been included.
- 1% 'bin-bin' uncorrelated error on background subtraction.
- Systematics for 1 detectors has been taken equal to Chooz experiment: σ_{sys} = 2.7%.
- Systematics for 2 detectors has been assumed σ_{sys} = 0.6%.



For 3 years of data taking with 2 detectors we obtain (if no-oscillation is seen):

$\sin^2(2\theta_{13})<0.032$ at 90% C.L.

COMPARISON



- DC is late with respect to the original proposal: people often asks "is it still worth it?" The answer is **yes** since:

1. In case a signal is seen an independent measurement is very important.
2. Although RENO and Daya Bay have managed so far to respect theirs schedule, delays are always round the corner and not just for DC experiment.
3. The use of many reactor, on the long term reduces the systematics and increases the statistics. However, a full understanding of the detector response and evaluation of the errors is more complicated and might take longer than expected.

THE END