Current status of Double Chooz experiment (Far detector construction)

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DBD09 Hawaii

Double Chooz experiment

Precise measurement of θ_{13} by detecting anti e neutrinos from Chooz reactor.

Neutrino oscillation

$(\nu_e,\nu_\mu,\nu_\tau)^T = U\,(\nu_1,\nu_2,\nu_3)^T$ U = matrix PMNS : **3 angles, 1 complex phase**

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

atmospheric ν | leptonic CP phase δ | solar ν

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

$$P(\nu_\alpha \to \nu_\beta) = \delta_{\alpha\beta} - 4\sum_{i>j}\mathrm{Re}(U^*_{\alpha i}U_{\beta i}U_{\alpha j}U^*_{\beta j})\sin^2\Phi_{ij} \mp 2\sum_{i>j}\mathrm{Im}(U^*_{\alpha i}U_{\beta i}U_{\alpha j}U^*_{\beta j})\sin 2\Phi_{ij}$$

$\Phi_{ij} = \dfrac{\Delta m^2_{ij}L}{4E} \quad \Delta m^2_{ij} = m^2_j - m^2_i$ **2 mass differences**

Neutrino oscillation parameter : $\theta_{12},\theta_{23},\theta_{13},\Delta m^2_{12},\Delta m^2_{23},\Delta m^2_{13},\delta$

Measured parameters

SK, K2K, MINOS

$sin^2 2\theta_{23} \sim 1$

$\left|\Delta m^2_{23}\right| = 2.5\times10^{-3}eV^2$

Solar+KamLAND

$sin^2 2\theta_{12} \sim 0.85$

$\Delta m^2_{12} = 7.9\times10^{-5}eV^2$

Unknown parameters

$\left|\Delta m^2_{13}\right| \sim 2.5\times10^{-3}eV^2$

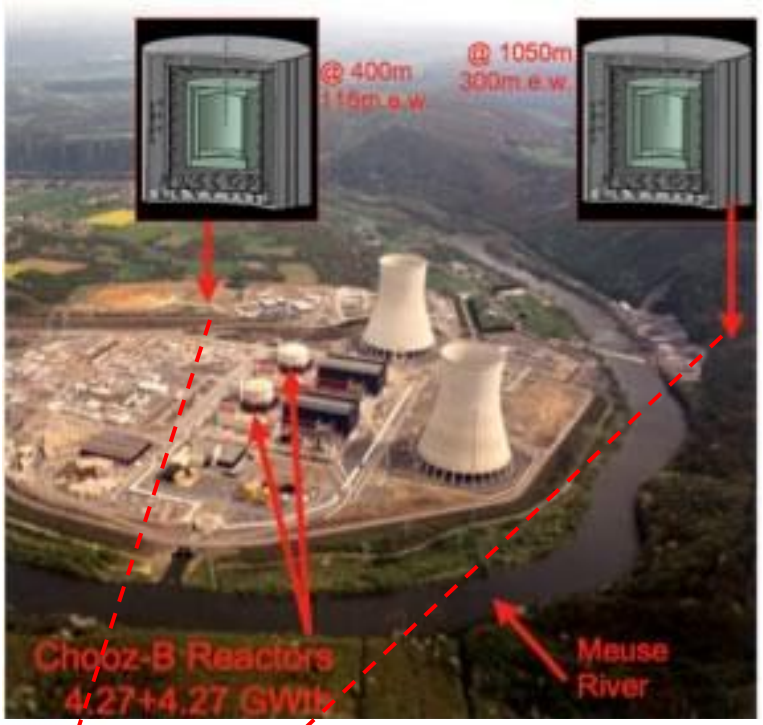
$sin^2 2\theta_{13} = ?(<0.15@CHOOZ)$

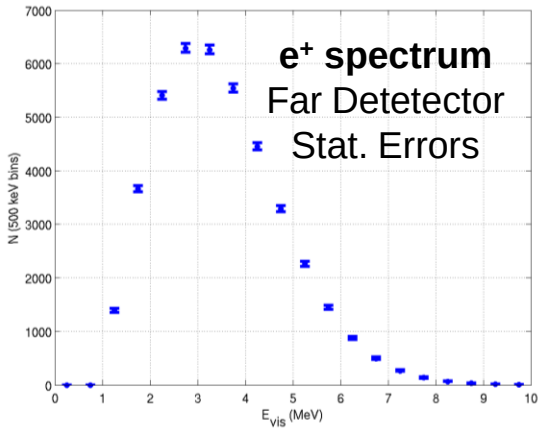
$\delta = ?$

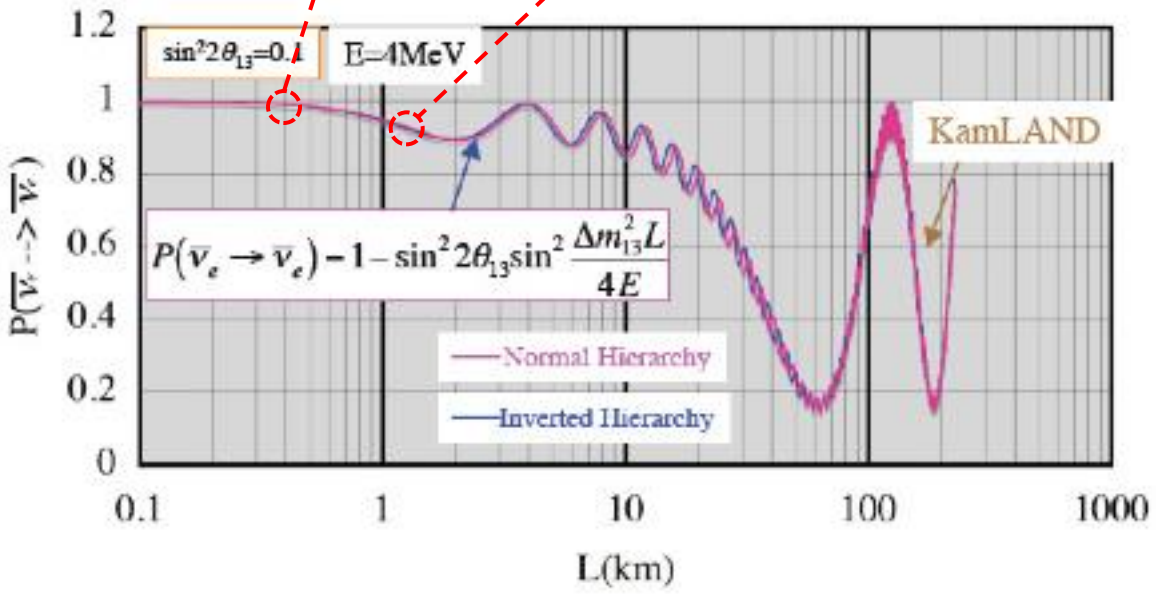
Double Chooz experiment

Chooz reactor

Near a border of France and Belgium.



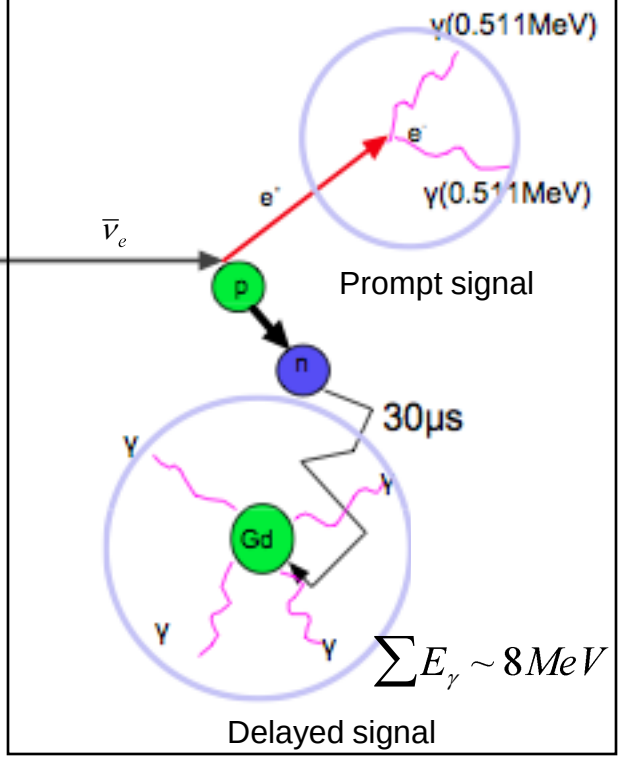




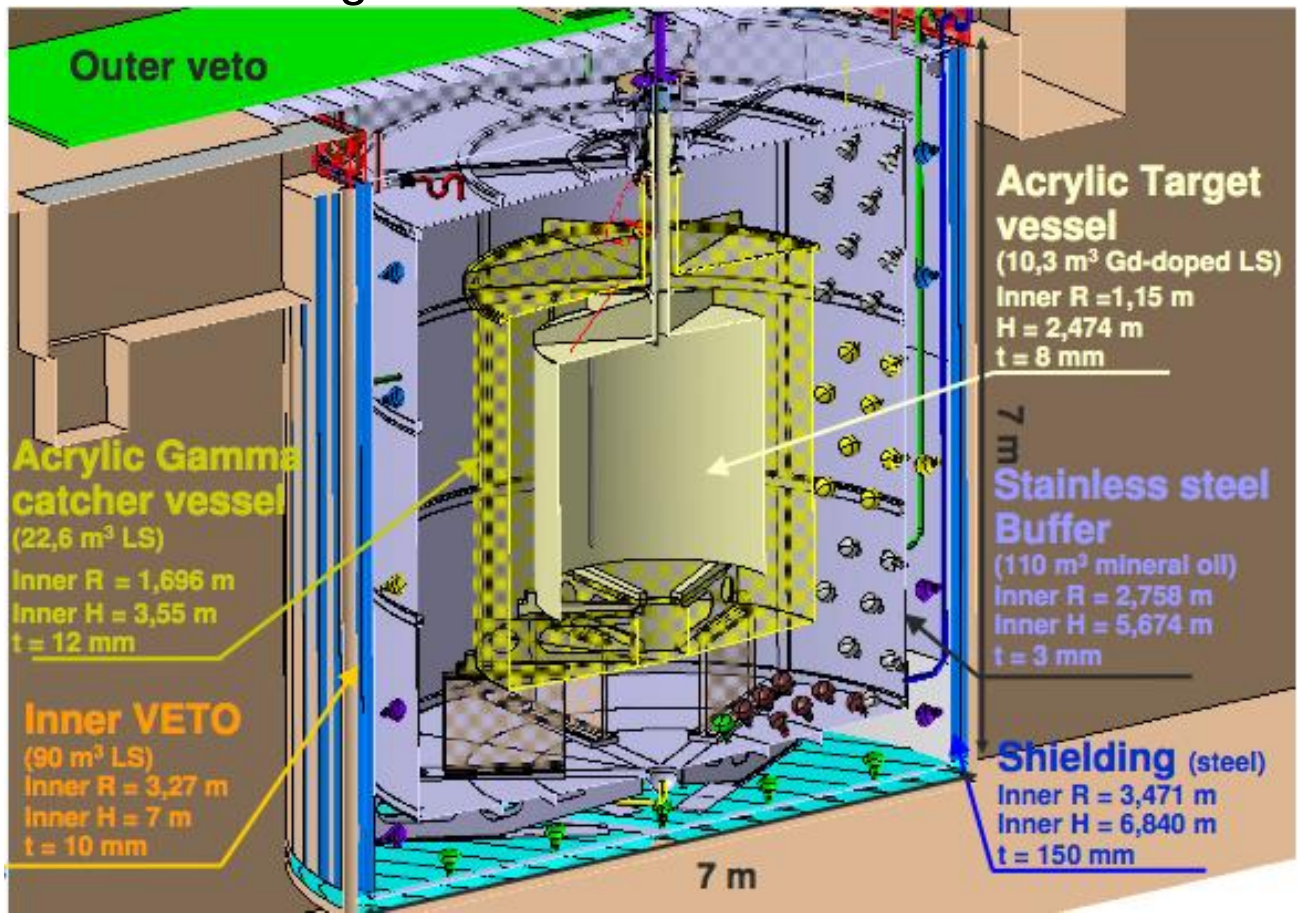
Detection method and detector design

Detection method

Delayed coincidence
(Inverse β decay reaction)



Detector design



Inner detector : Neutrino target(0.1w%Gd-LS, 10.3m^3) + Gamma catcher(LS, 22.6m^3)

- Target PMT : 390 10” PMTs (Photocathode coverage ~13%)

Achievable sensitivity of $\sin^2 2\theta_{13}$

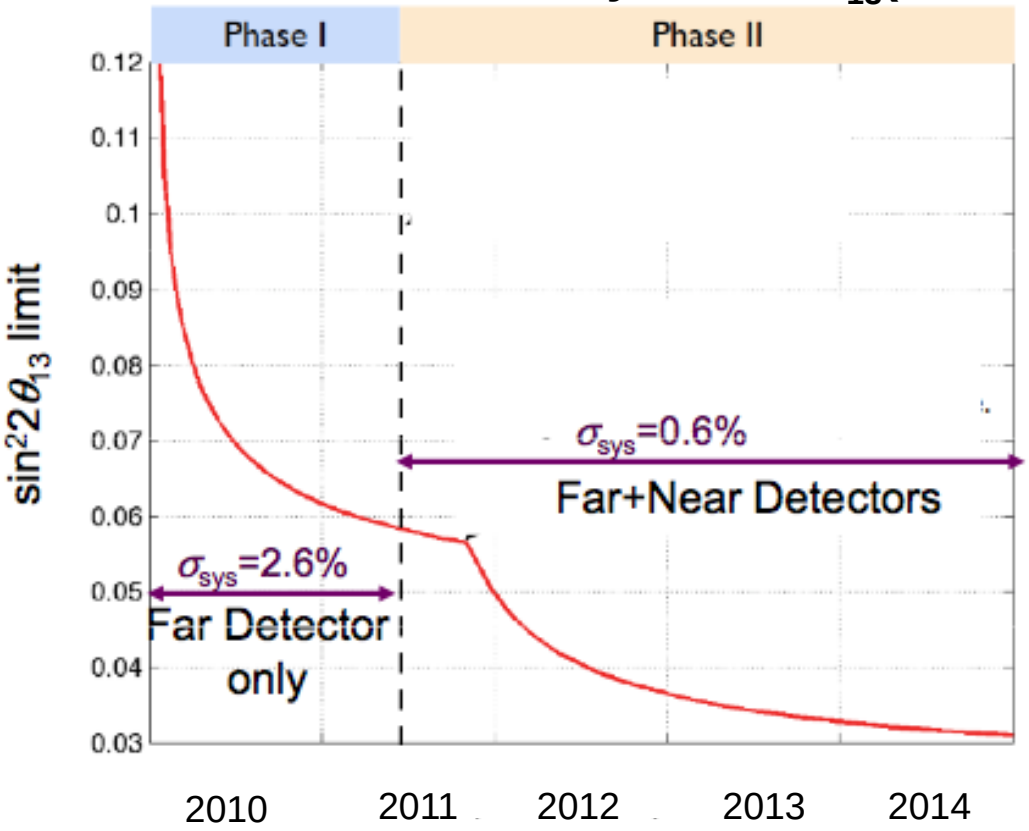
Improvement of error

Systematic error	Chooz	Dobule Chooz
Reactor Cross section	1.9%	-
Number of protons	0.8%	0.2%
Detection efficiency	1.5%	0.5%
Reactor power	0.7%	-
Energy per fiission	0.6%	-
Total systematic error	2.7%	<0.6%
Statistical error	2.8%	<0.5%

※Near/Far error cancellation
※2 layer inner detector
→ improve systematic error

※Stable Gd-LS → improve statistical error

Achievable sensitivity of $\sin^2 2\theta_{13}$(90%CL)



CHOOZ: 1.01 ±2.8%(stat)±2.7%(syst)
: $\sin^2 2\theta_{13} < 0.15$(0.12@global)

↓

5 times better than current limit
(5 year measurement)

Double Chooz collaboration

Spokesman: Hervé de Kerret (APC)

France: APC Paris, CEA/Dapnia Saclay, Subatech Nantes, Strasbourg

Germany: Aachen, MPIK Heidelberg, TU München, EKU Tübingen, Hamburg

Spain: CIEMAT Madrid

UK: Univ. 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

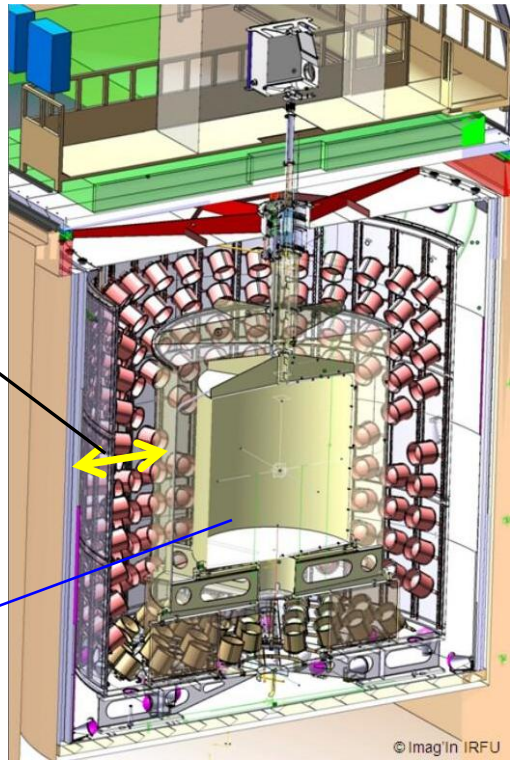
Brazil: CBPF, UNICAMP

Contribution of DC-Japan

- Buffer PMT (for main target volume)
  - Development of very-low-BG 10-inch PMT
  - Development of PMT test system and the test.
  - installation and commissioning
  - Development of HV system
  - Development of PMT calibration software
- Online data-acquisition
  - Data quality monitoring and histogram viewer
  - Run control and message logging software
- Offline software developments
  - MC and reconstruction software
  - Calibration interfaces to offline and database
  - Japanese analysis cluster

Current status of Far detector construction (on going)

Material	Status of installation
Steel shield	Complete
Inner veto tank	Complete
Inner veto PMT (8” 78PMTs)	Complete
Buffer tank	Complete
Buffer tank PMT(10” 390PMTs)	Complete (except for lid part)
Gamma catcher and target vessels	Now on going



Japanese group is in charge of main works for Buffer tank PMT.
(development, installation, calibration and HV system)

The PMT installation was almost finished in this July.
(Japanese group supervised the PMT installation.)

Hot topic

The PMT installation is main topic in this talk (see next slides)

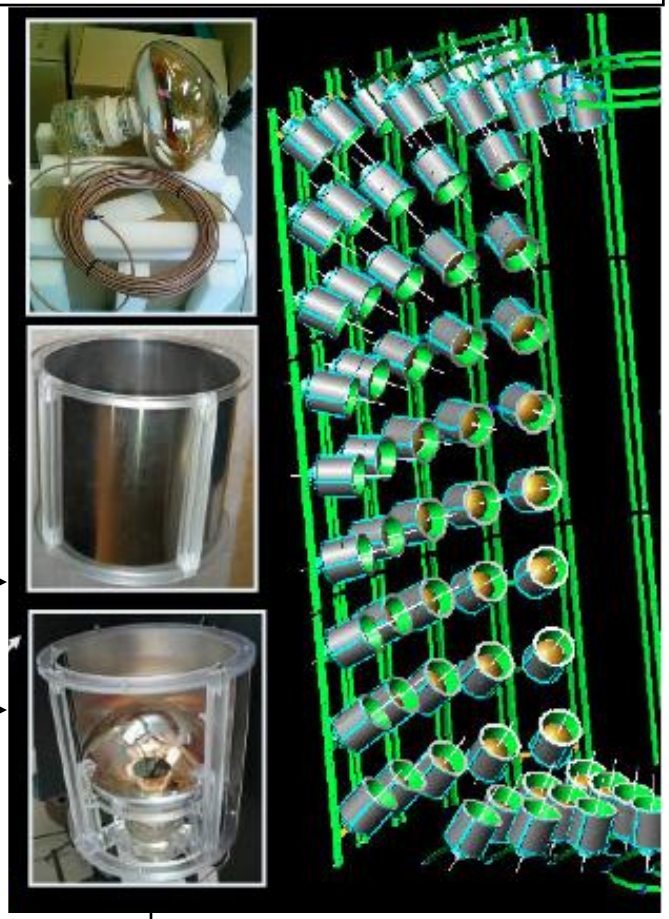
Flow until the PMT installation

Buy 400PMTs(HAMAMATSU R7081MOD-ASSY)
Evaluation test of the PMTs (at JAPAN and MPIK, 200PMTs each)

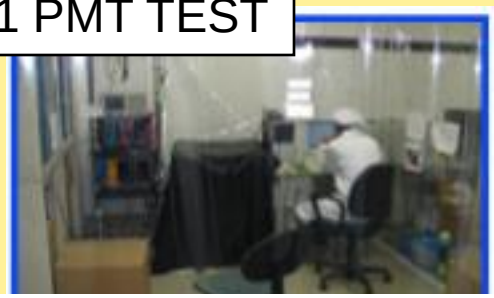
Transport
to TIT(Japan)
Evaluation test by Japanese system

Transport
to MPIK

Assembly + Cleaning @MPIK



1 PMT TEST



Evaluation test
by MPIK system

Gain,TTS,DC,QE,P/V

Transport to MPIK(Germany)

8 PMTs TEST

Transport to Chooz

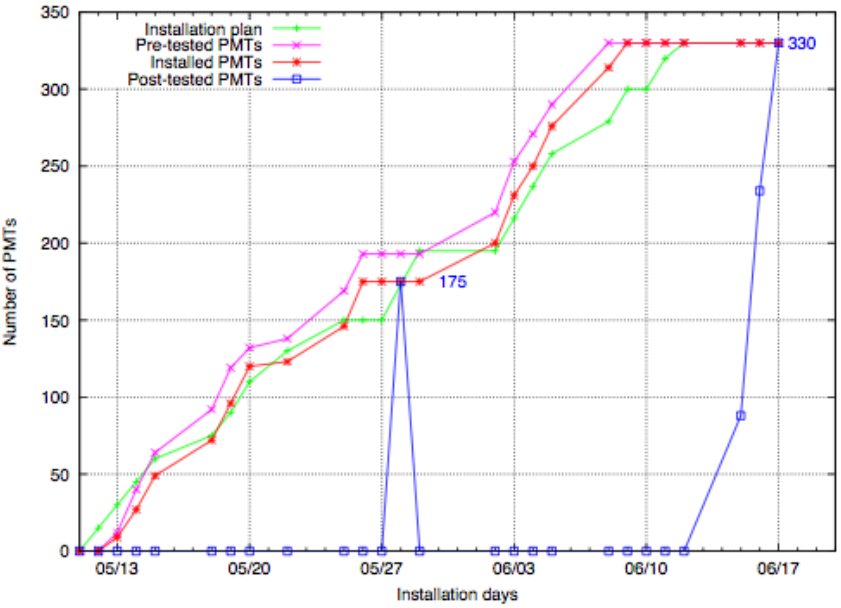
Installation
(see Next slides)

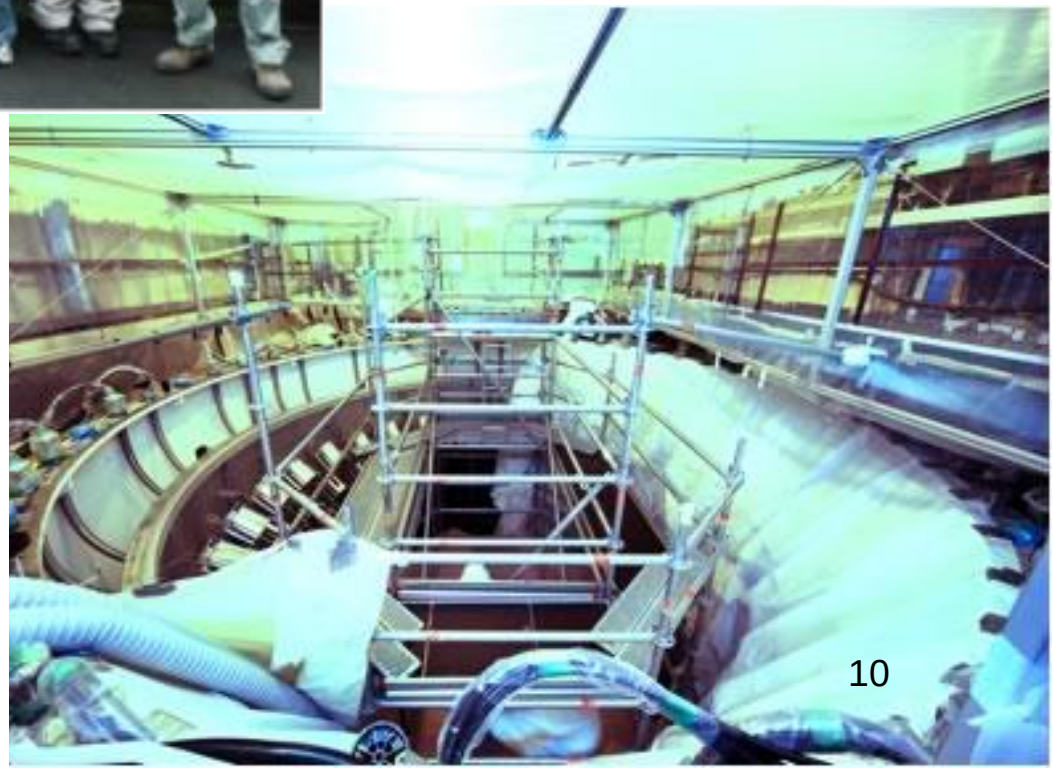
PMT installation-team

Person in charge

Collaborators from various countries joined in the installation.

PMT installation is complete on schedule.



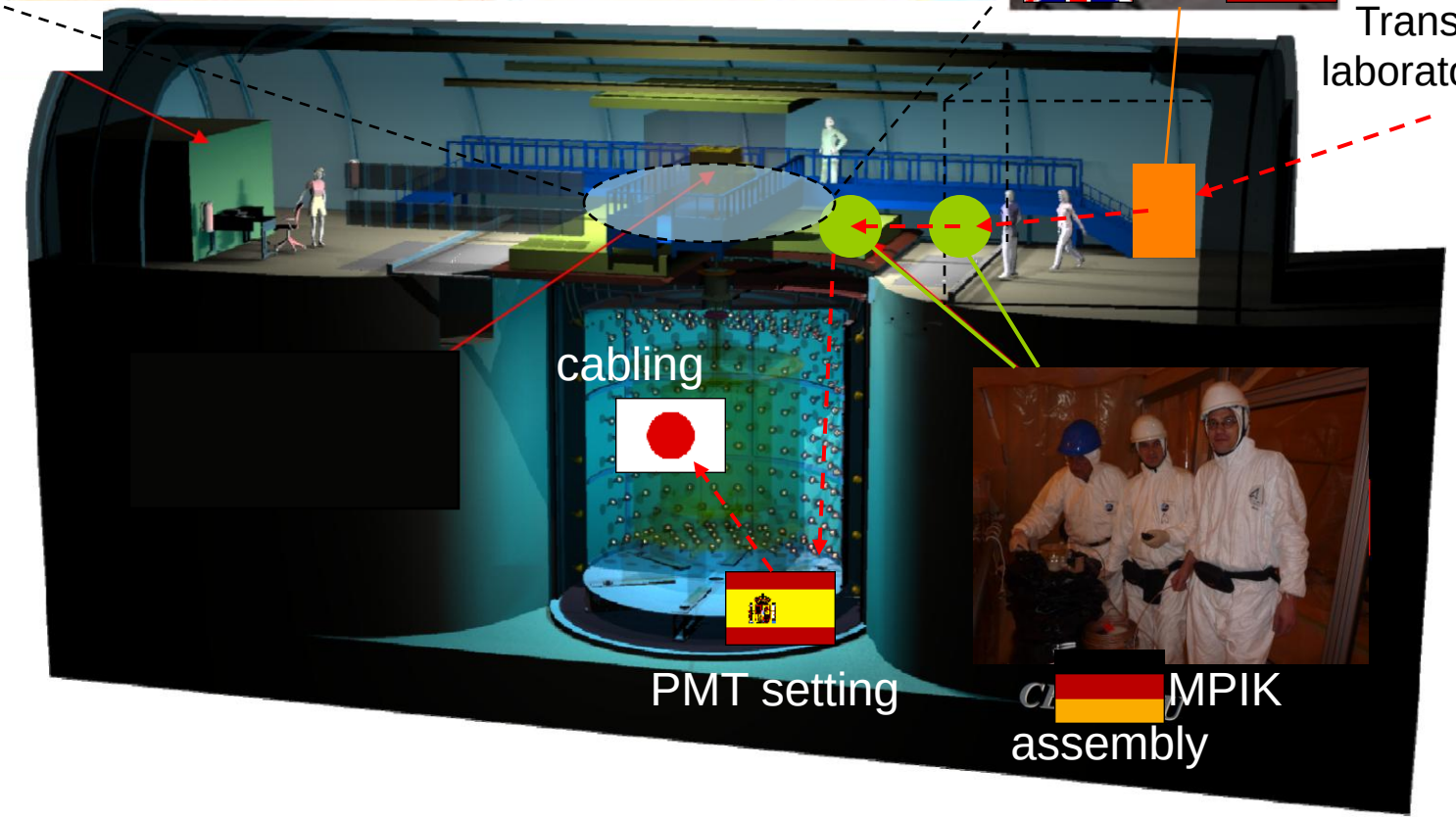


PMT installation flow

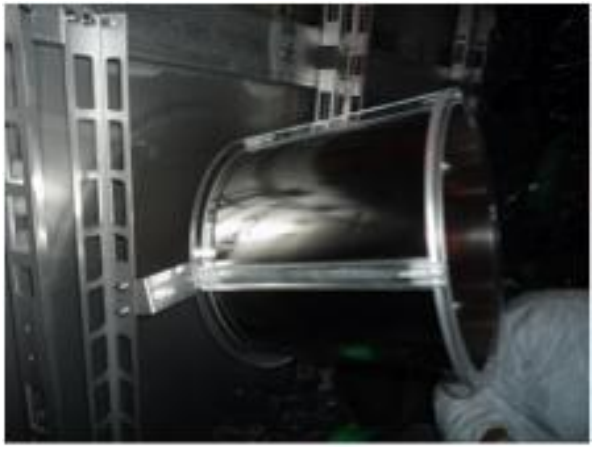
PMT had been stored on ground level.

↓

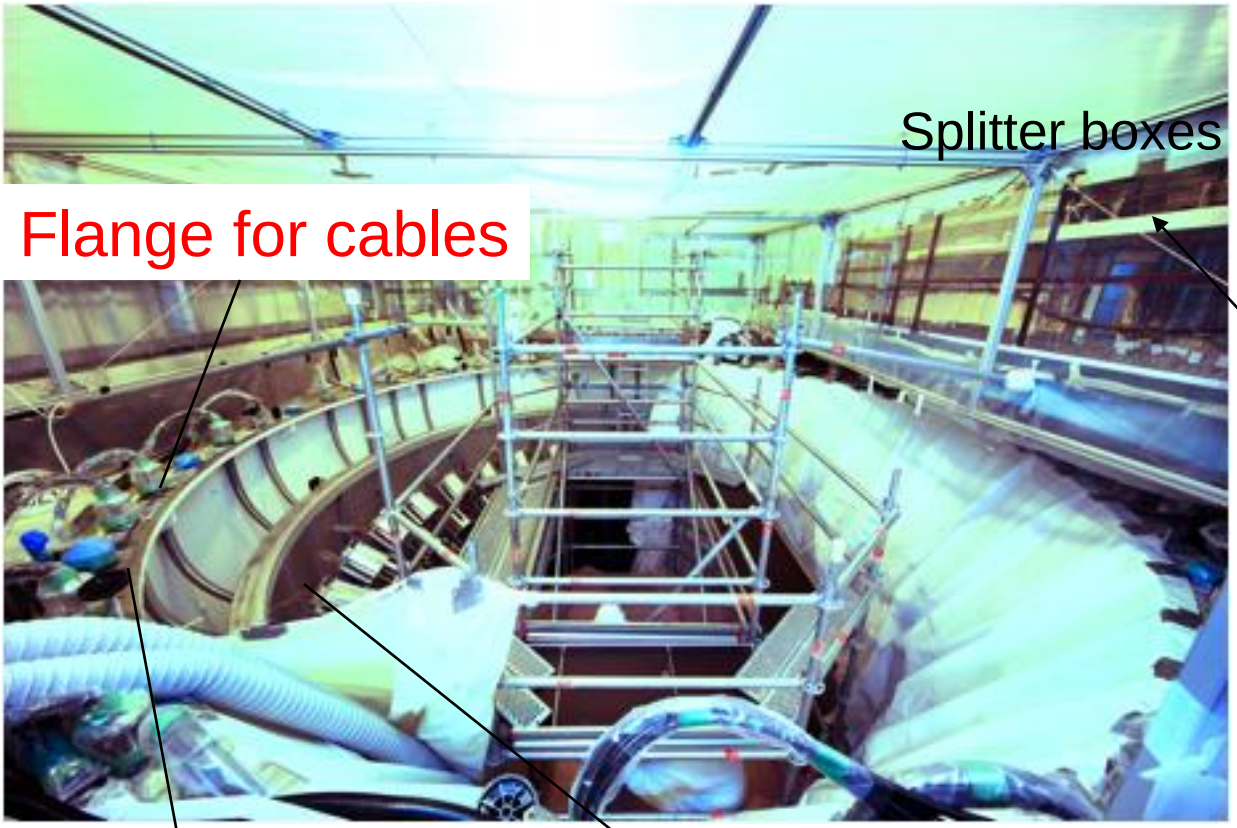
Transport PMTs inside a laboratory through a gallery.

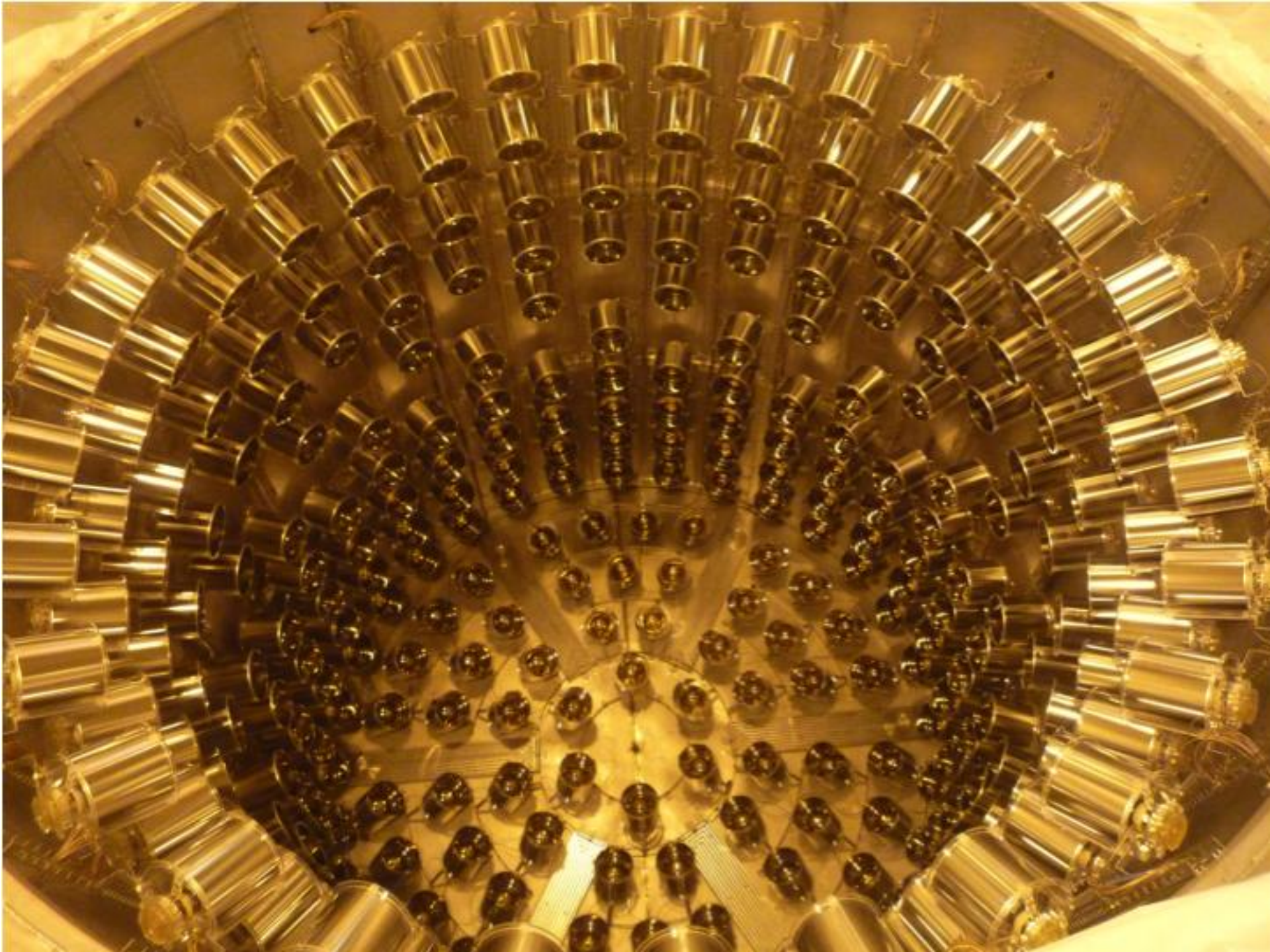


PMT installation and cabling



Cable routing in the pit (JPN)





Far detector construction (now)

An acrylic vessel for a gamma catcher was installed by Saclay in this September!

Now on Installation of an acrylic vessel for target (10.2009)

Future plan

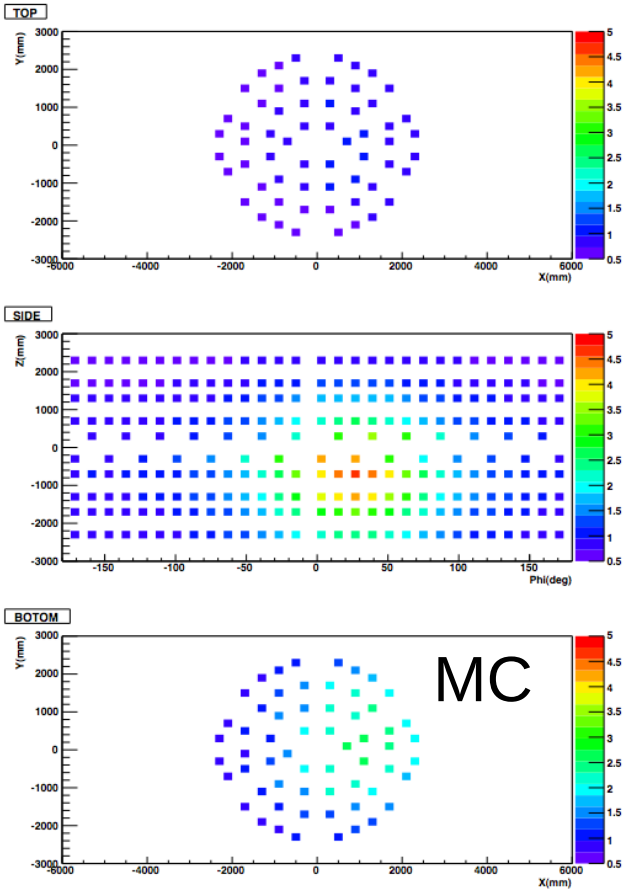
Far detector construction

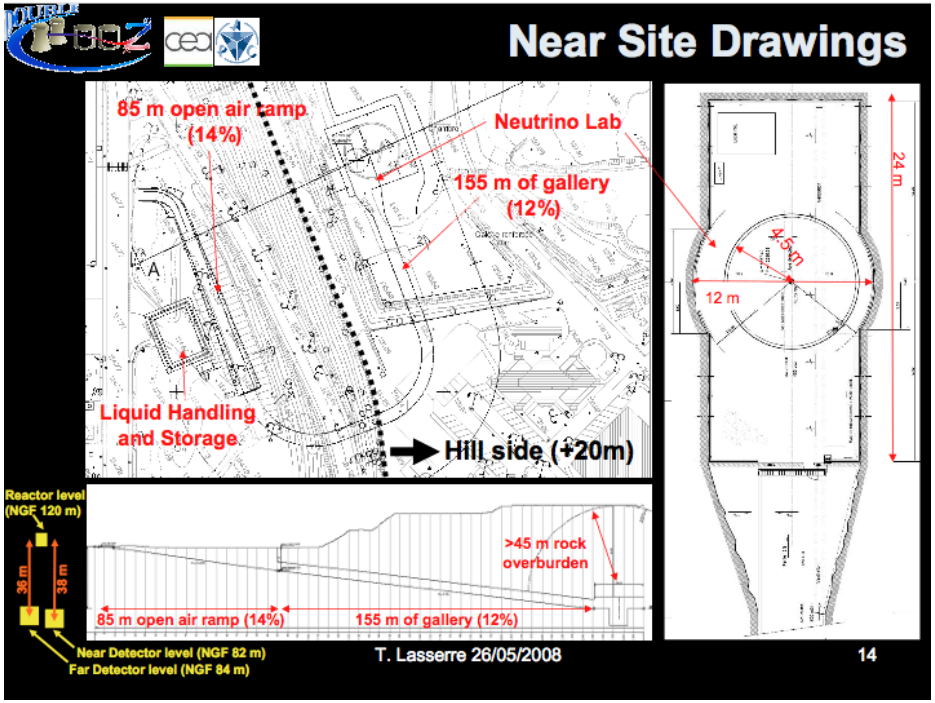
2009.10 lid PMT installation

12~ electronics installation

2010.2~3 LS filling

4 data taking starts!





Near detector construction

We start to construct the Near detector in 2010.
Data taking with both detector starts in 2011.

Summary

- Double Chooz is a reactor neutrino oscillation experiment to measure directly neutrino mixing angle θ_{13}.
- PMTs for the far detector were almost installed.
- An acrylic vessel for target layer will be installed in this month.
- Now the construction of the far detector is in full swing, and we will see the first neutrino data in April, 2010.

End

Cleanliness (All)

- The tunnel was cleaned every week and a clean floor protected the entrance to the laboratory
- The access to the pit was protected by the path in several clean areas
- Workers dressed in Tyvek suits + clean safety shoes + gloves
- Working areas vacuumed everyday and some cleaning periods reserved during PMT installation

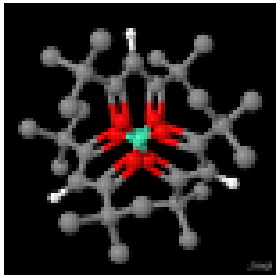


Liquids

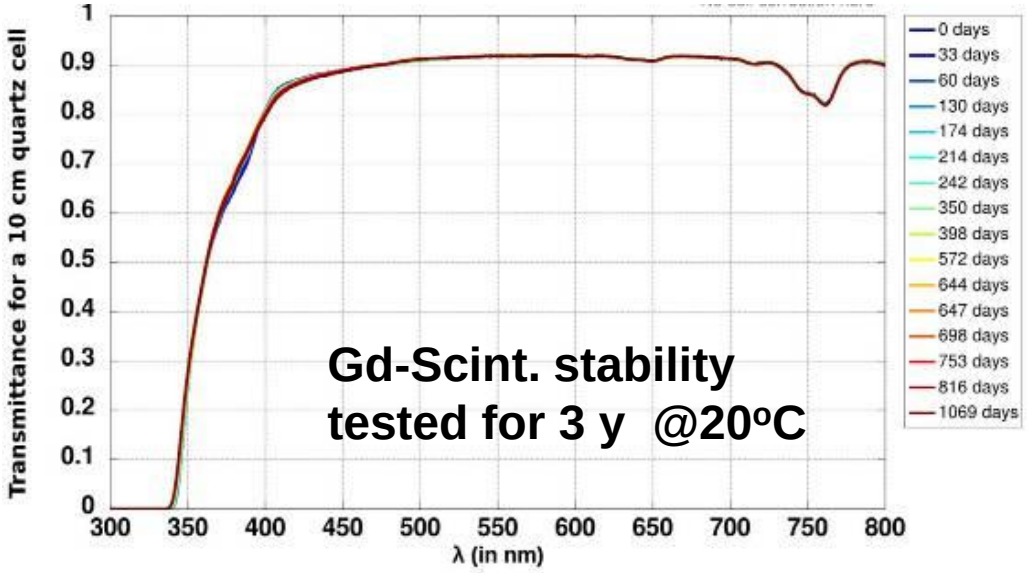
- **New DC Development:**

-**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)

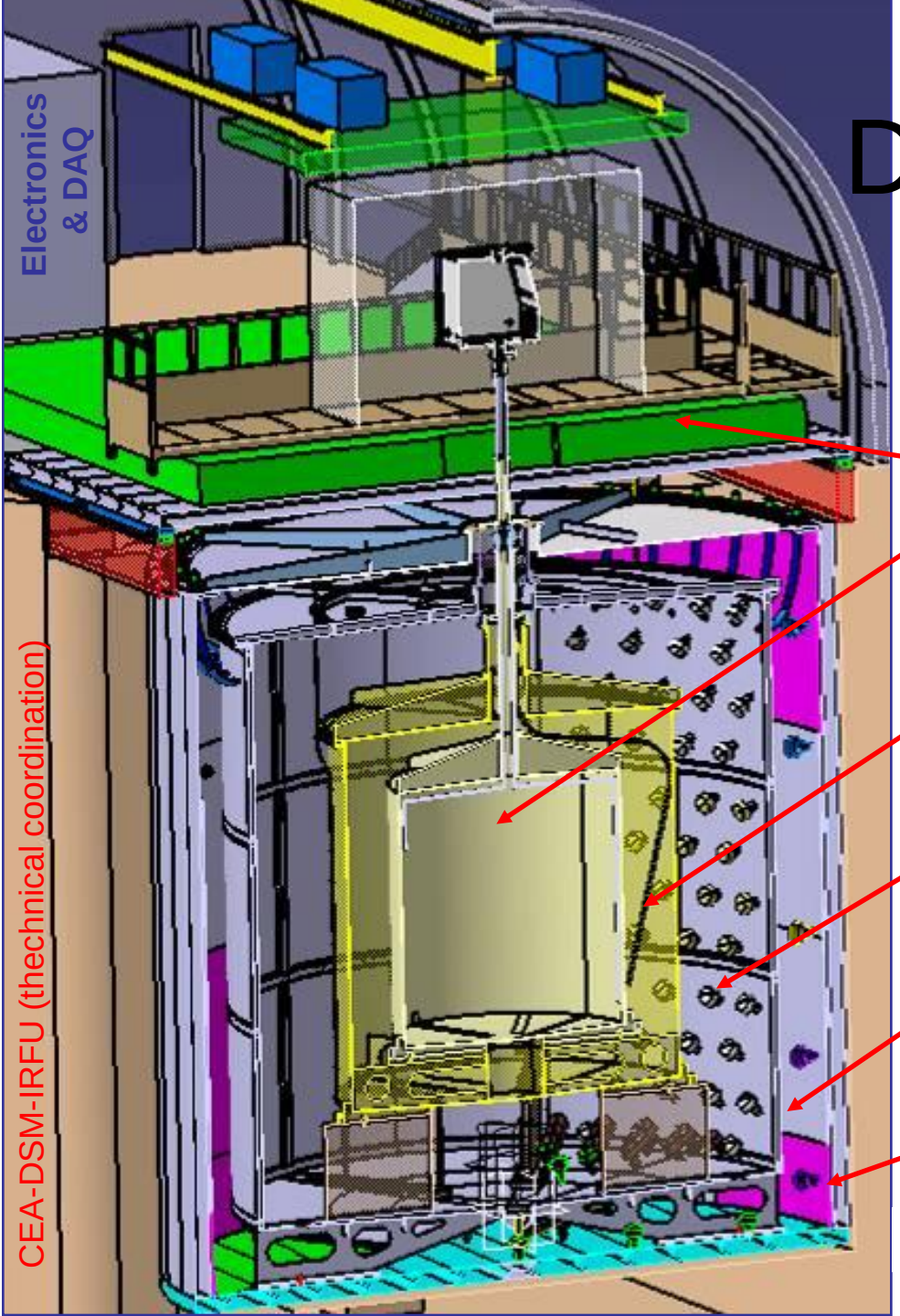
Attenuation length>10m



3 iso-tanks ready for transportation, storage & filling



- **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**



Detector Design

Detector Design

New 4-region large detector concept from Double Chooz Collab. (2003)

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

Inner Veto: 90m^3 of scintillator in a steel vessel equipped with 78 PMTs

Veto Vessel (10mm) & **Steel Shielding**

(4 liquid densities adjusted at 0,800⌖0,005)

Measuring θ_{13}: ν-reactors vs super-beams

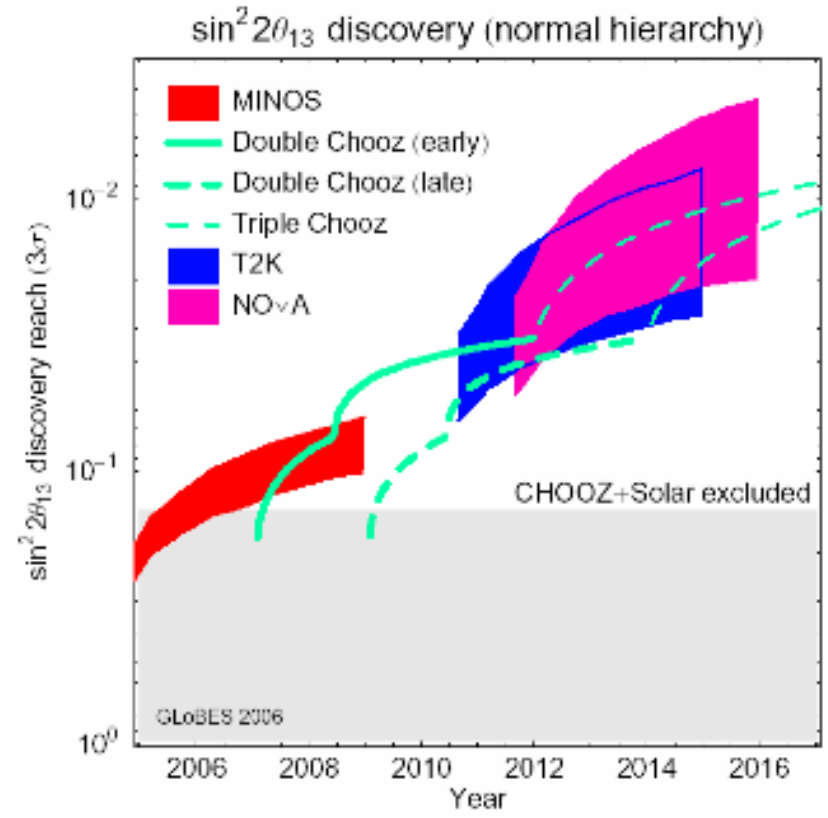
- **Accelerator experiments**: appearance experiments
  - $P(\nu_\mu \rightarrow \nu_e)$ depends on $\sin^2(2\theta_{13})$, $\sin^2(\theta_{23})$, $\text{sign}(\Delta m^2_{31})$, δ_{CP} phase
    - Parameter degeneracies and correlations
    - Matter effects sensitive
- **Reactor ν experiments** are unique for:
  - Unambiguous determination of θ_{13}
    - no dependence on δ_{CP}
    - no dependence on mass hierarchy
    - weak dependence on Δm^2_{12}

    } No parameter degeneracies, No matter effects
  - Resolve θ_{23} degeneracy combined with accelerator experiments
- **Reactor advantages with respect to accelerators**:
  - Pure θ_{13}
  - Pure ν_e, no flavor contamination
  - ν flux known at few%
  - Smaller detectors (cheaper)

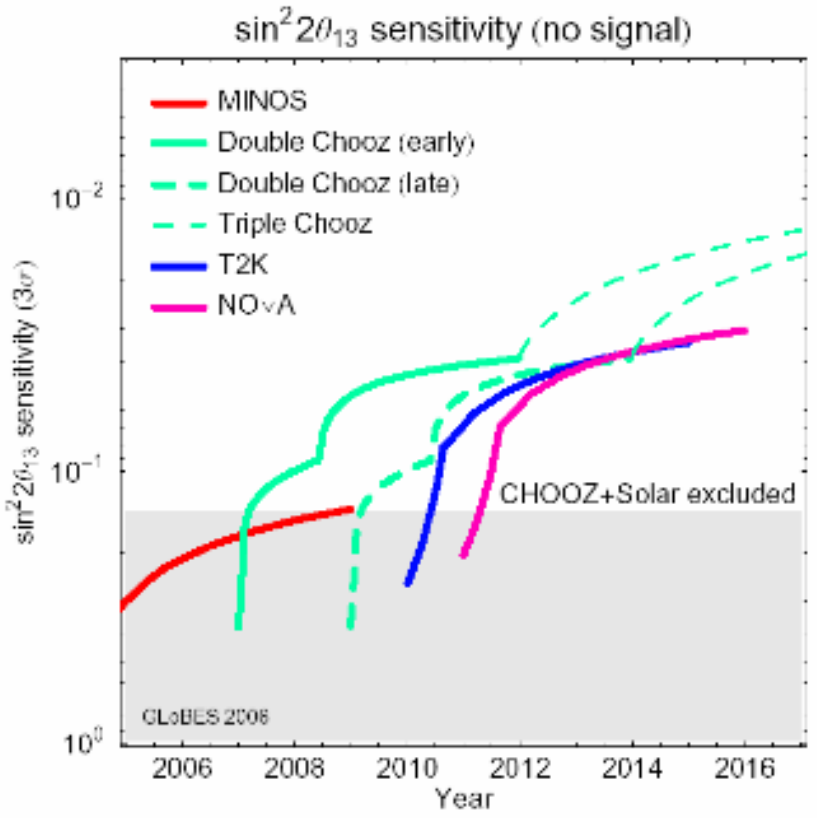
Both type of experiments provide independent and complementary information

Complementarity with super-beams

3σ discovery potential



3σ sensitivity (no signal)



hep-ph/0601266

Background

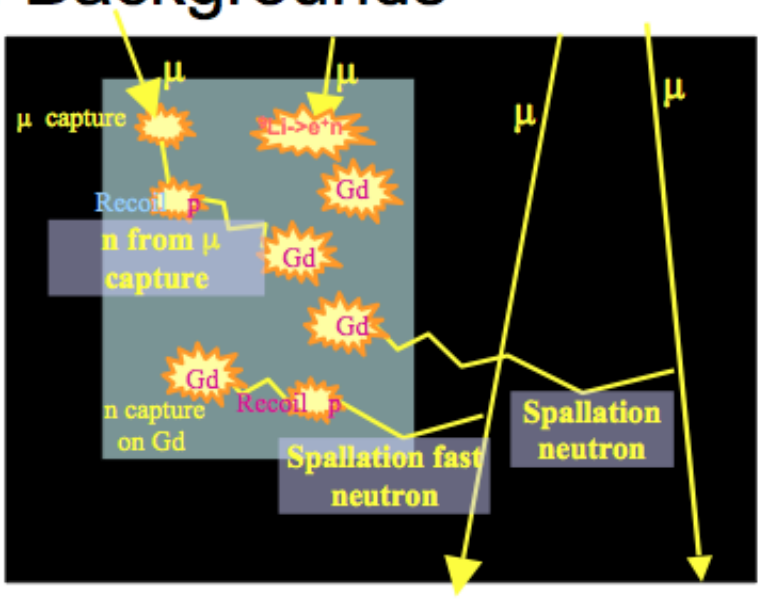
θ_{13} at reactors : Backgrounds

Accidental bkg:

- e^+-like signal: radioactivity from materials, PMTs, surrounding rock (^{208}Tl). (Rate=R_e)
- n signal: n from cosmic μ spallation, thermalised in detector and captured on Gd (R_n);
  γ mimicking n

➡ Accidental coincidence

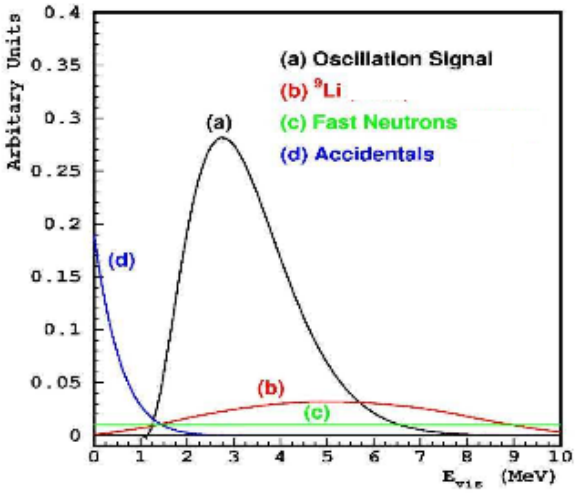
Rate = R_e x R_n x Δt



Correlated bkg:

➡ 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



Expected S/N>50

Background studies

Signal/Bkg >50

Detector	Site		Background				
			Accidental			Correlated	
			Materials	PMTs	Fast n	μ-Capture	^{9}Li
CHOOZ		Rate (d^{-1})	—	—	—	—	0.6 ± 0.4
(24 ν/d)		Rate (d^{-1})	0.42 ± 0.05		$1.01 \pm 0.04(stat) \pm 0.1(sys)$		
	Far	bkg/ν	1.6%			4%	
		Systematics	0.2%			0.4%	
Double Chooz		Rate (d^{-1})	0.5 ± 0.3	1.5 ± 0.8	0.2 ± 0.2	< 0.1	1.4 ± 0.5
(69 ν/d)	Far	bkg/ν	0.7%	2.2%	0.2%	<0.1%	1.4%
		Systematics	<0.1%	<0.1%	0.2%	<0.1%	0.7%
Double Chooz		Rate (d^{-1})	5 ± 3	17 ± 9	1.3 ± 1.3	0.4	9 ± 5
(1012 ν/d)	Near	bkg/ν	0.5%	1.7%	0.13%	<0.1%	1%
		Systematics	<0.1%	<0.1%	0.2%	<0.1%	0.2%

estimates with "old" near detector location
= conservative
(with new location: $N_\nu/2$, $N_\mu/3$)

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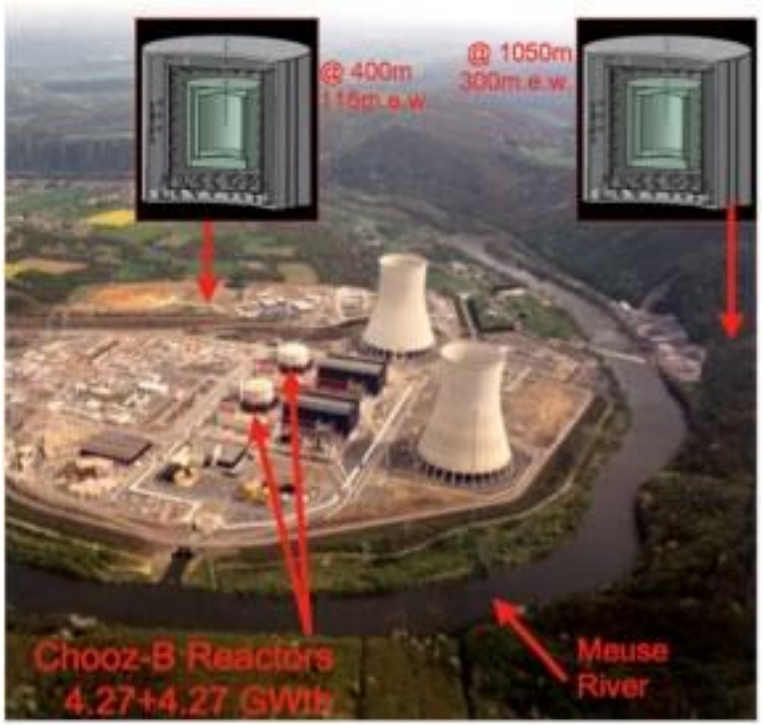
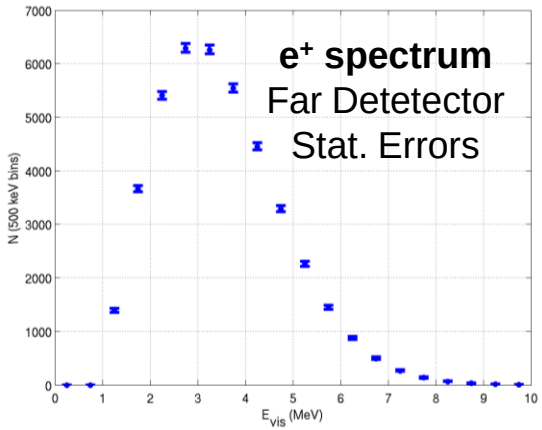
Double Chooz experiment

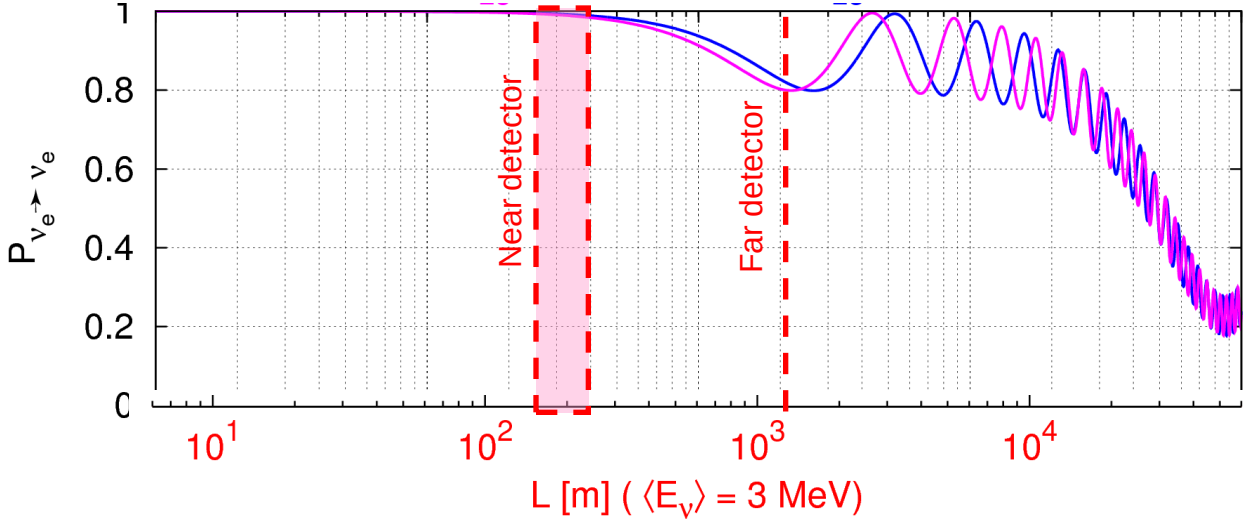
Chooz reactor

Near a border of France and Belgium.





$P(\nu_e \rightarrow \nu_e) = 1 - \sin^2(2\theta_{13}) \sin^2(\Delta m^2_{31} L/4E))$



Neutrino oscillations at nuclear reactors

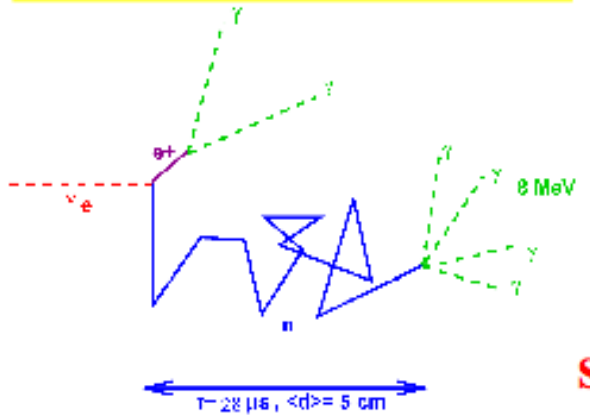
$\bar{\nu}_e$ disappearance searches

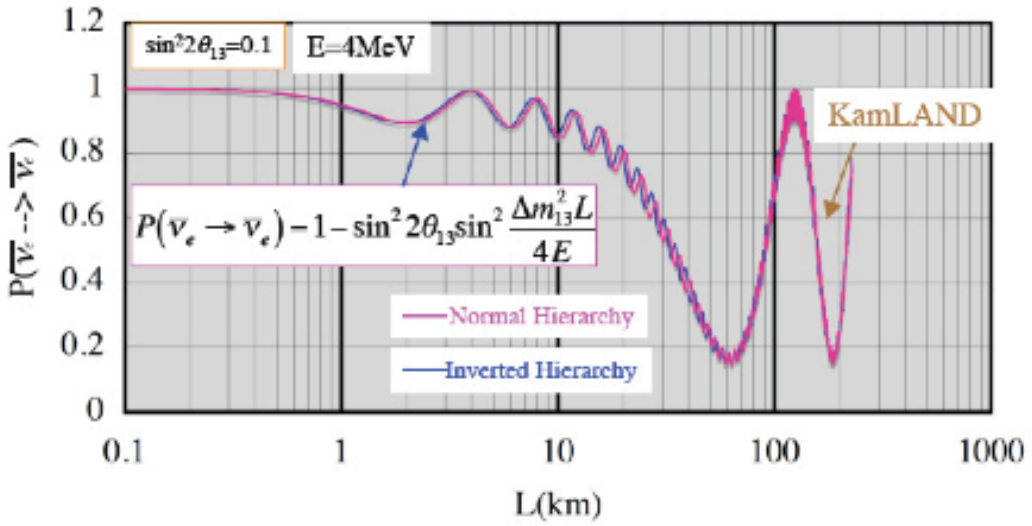
$$P_{ee} \approx 1 - \sin^2 2\theta_{13} \sin^2\left(\frac{\Delta m_{13}^2 L}{4E_\nu}\right) - \cos^4\theta_{13} \sin^2 2\theta_{12} \sin^2\left(\frac{\Delta m_{21}^2 L}{4E_\nu}\right)$$

Reactor Neutrino Oscillation

$\bar{\nu}_e$ detection: inverse beta decay

$$\bar{\nu}_e + p \rightarrow n + e^+$$
$$n + Gd \rightarrow 8\,\text{MeV}\,\gamma$$





Small deficit (= $\sin^2 2\theta_{13}$) ➲ high precision is necessary

Pre test
～Before installation～

- PMT設置作業直前の確認テスト
- PMT1本ずつ1×10^7Gain の得られるHV値を印加し約10分間放置
- 検査項目

- Dark count rate(1/4 SPE Threshold)
  ノイズ測定
- SPE ADC value
  SPE Spectrum の取得
  Random triggerでpedestalの取得

- 光源は使用せずDark noiseでのデータ取得

Post test
～After installation～

- 検出器へのPMT設置後の確認テスト

- 検出器上部をブラックシートで覆い、全ての照明を落として8本ずつPMTからのデータ取得を行う。
- テスト前日に全PMTへ電圧を印加し一晩放置。
- Pre testと同様Dark count rate,
  SPE ADC valueを取得。
- HV, Splitter boxも本実験で
  使用するもので行った。

Summary

~PMT testing~

- 3本のPMTを初期high Dark rateにより除外
- 1本のPMTをSPE resolution により除外
- 1本のPMTを不安定 Dark rateにより除外

~その他~

- 2本のPMTをInstallation中の事故により除外
- 2本のPMTがJapan testにより除外

→計9本(3%)のPMTを実験での使用から除外

- 5つのHVモジュールをCAENへ返送

~今後~

- 10月15日以降からLid用PMT設置作業の開始