The Daya Bay Reactor Neutrino Experiment

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Daya Bay θ13

BROOKHAVEN NATIONAL LABORATORY

Measuring θ_{13} at a Reactor

Neutrino mixing:

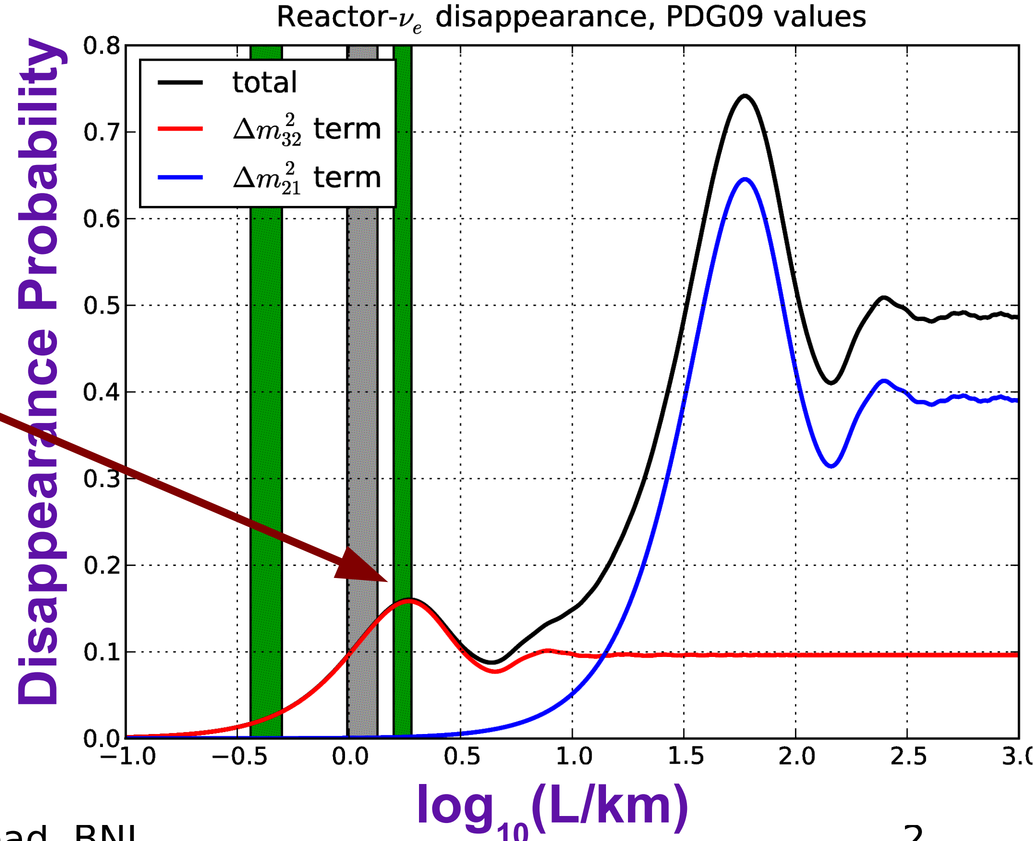
$$S_{jk} = \sin\theta_{jk} \quad C_{jk} = \cos\theta_{jk}$$

$$U_{MNSP} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & C_{23} & S_{23} \\ 0 & -S_{23} & C_{23} \end{pmatrix} \begin{pmatrix} C_{13} & 0 & S_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -S_{13}e^{i\delta} & 0 & C_{13} \end{pmatrix} \begin{pmatrix} C_{12} & S_{12} & 0 \\ -S_{12} & C_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

known: θ_{23} & θ_{12}, mass differences $|\Delta m_{32}^2|$ & Δm_{21}^2; unknown: θ_{13} and δ (CP-violating)

Look for disappearance of reactor $\overline{\nu_e}$ over a baseline of ~2 km where the probability is dominated by $\sin^2 2\theta_{13}$

$$P_{dis} \approx \sin^2 2\theta_{13} \sin^2(1.27 \Delta m_{32}^2 L/E) + C_{13}^4 \sin^2 2\theta_{12} \sin^2(1.27 \Delta m_{21}^2 L/E)$$



Keys to a Precise Measurement

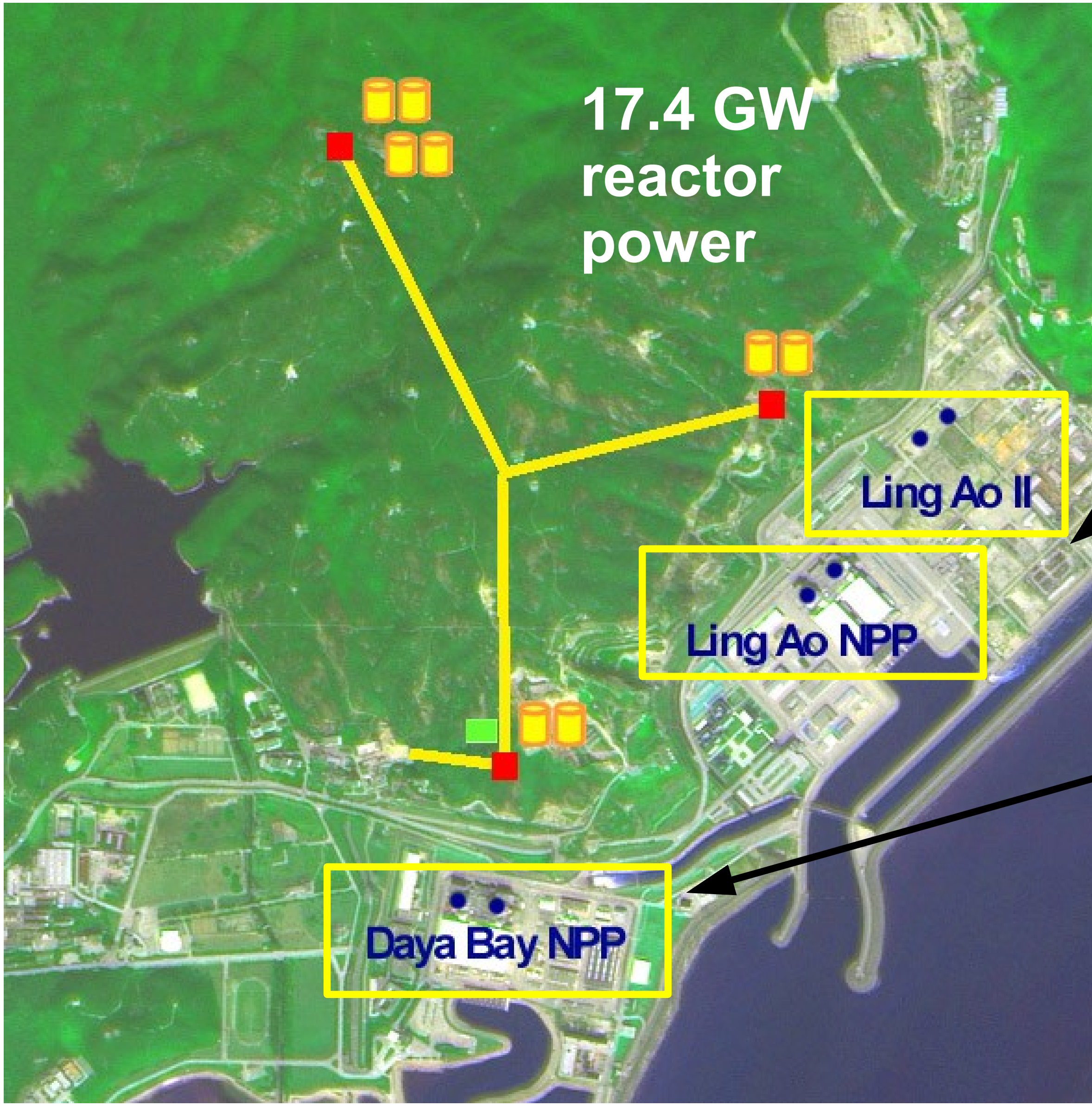
high statistics

identical near and far detectors
(systematic uncertainties from flux and cross sections cancel)

control of detector-related systematic uncertainties

background suppression

The Daya Bay Site



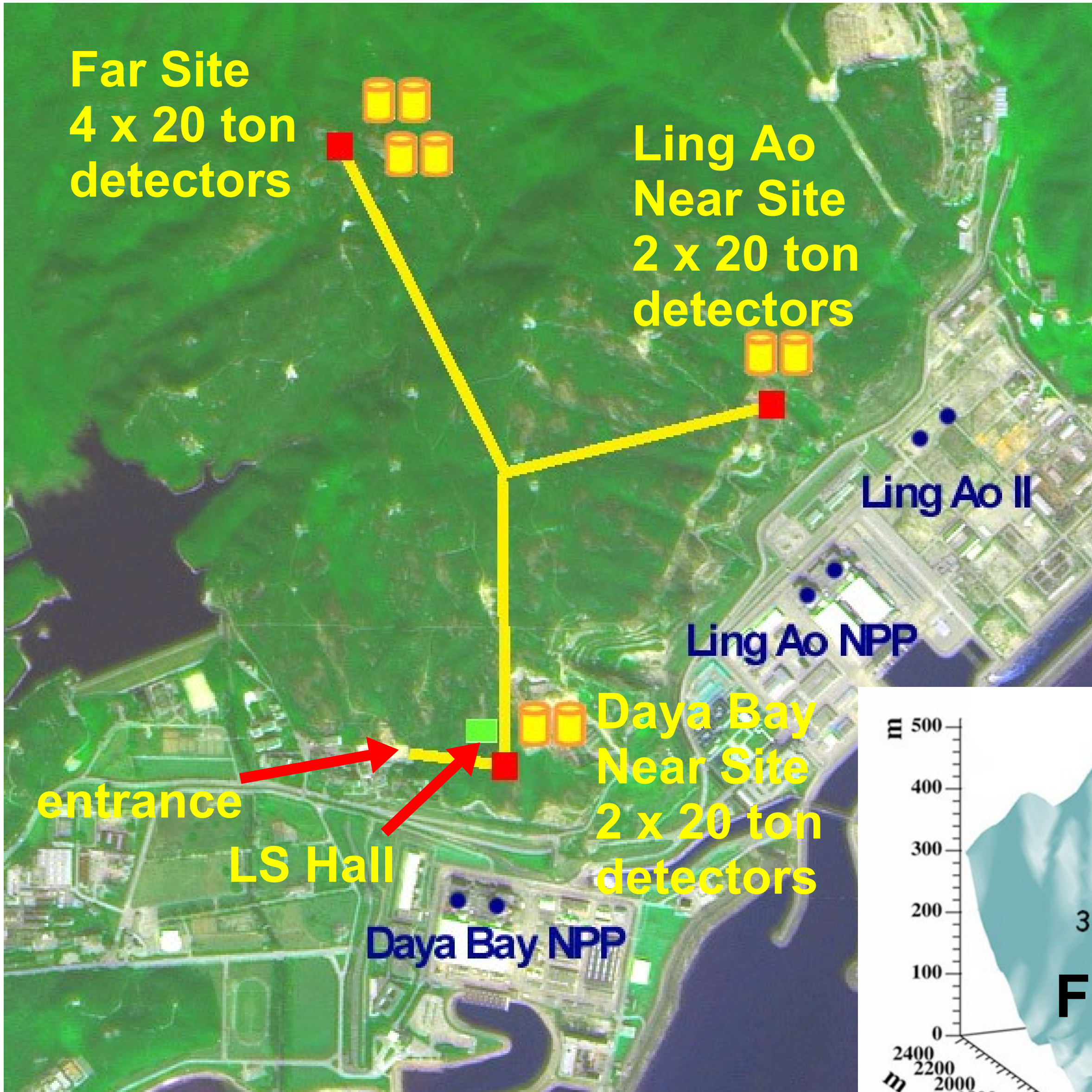
nuclear power complex located in China ~55 km from Hong Kong

Ling Ao
- 2 x 2.9 GW cores
- 2 more 2.9 GW cores by 2011

Daya Bay
2 x 2.9 GW cores

~2e20 $\overline{\nu_e}$/s per GW

The Daya Bay Site



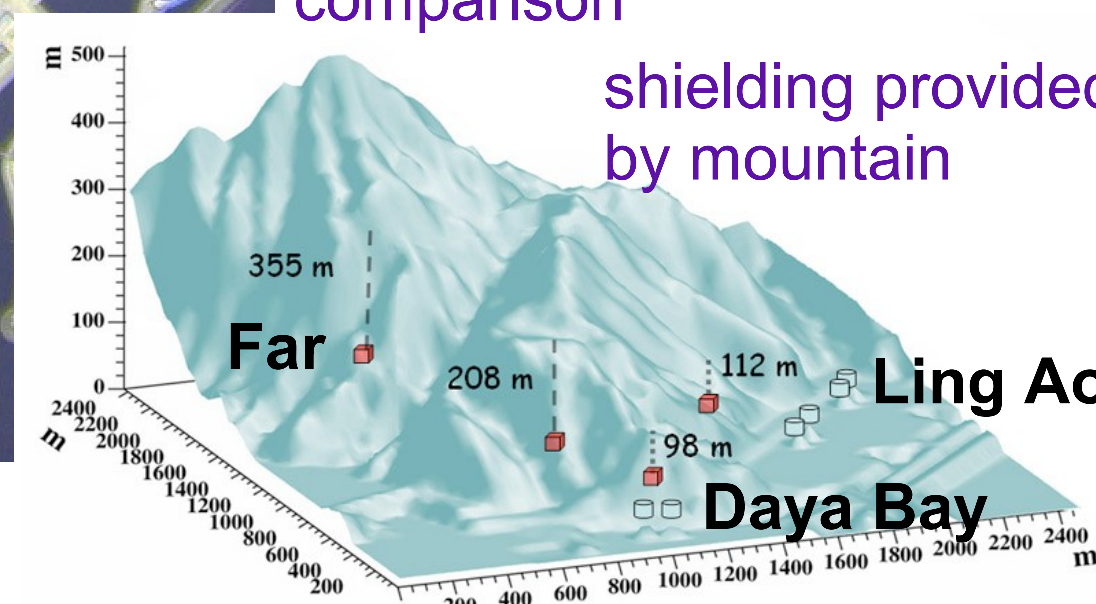
2 near detector sites

Far site:
1985 m from Daya Bay cores
1615 m from Ling Ao cores

movable detectors

more than one detector at each site allows side-by-side comparison

shielding provided by mountain



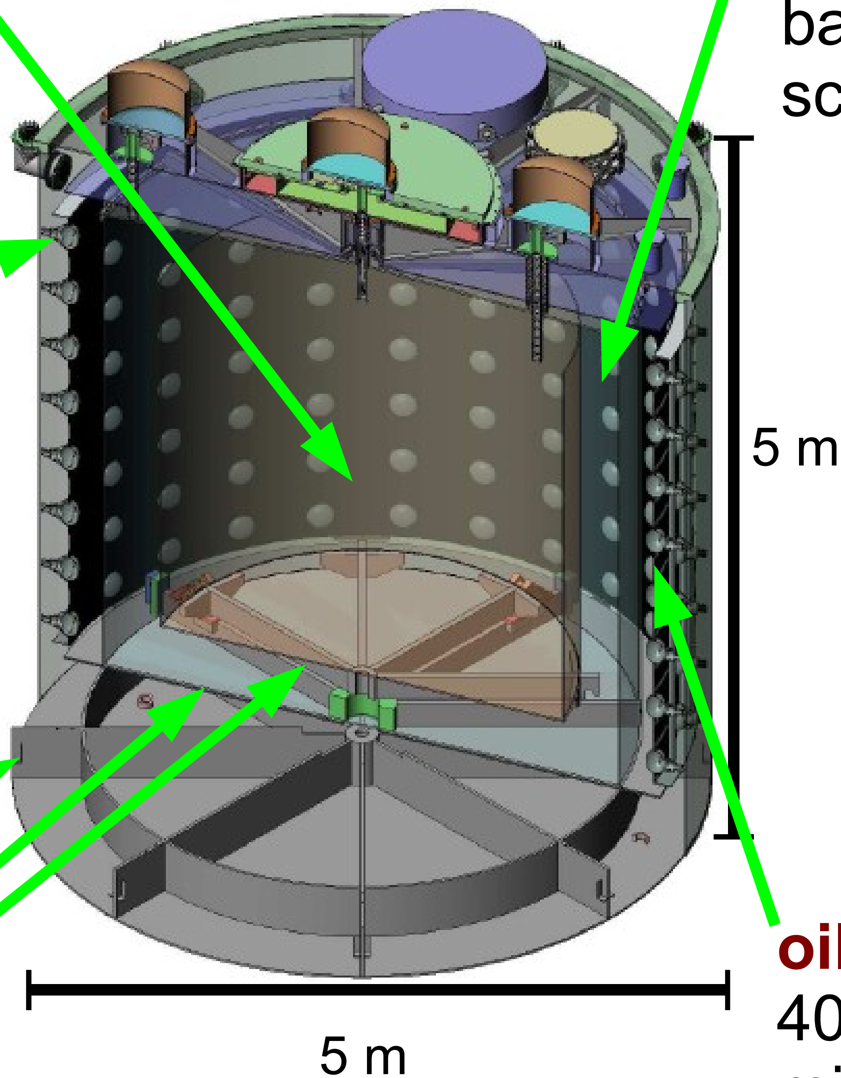
Antineutrino Detectors

Target region:
20 tons Gd-loaded (0.1%) LAB-based liquid scintillator

PMTs:
192 8-inch PMTs around the tank, reflectors on top and bottom

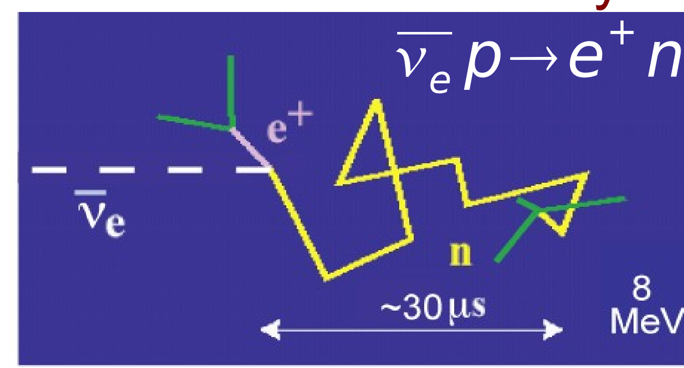
Steel tank

Acrylic vessels



γ-catcher:
20 tons LAB-based liquid scintillator

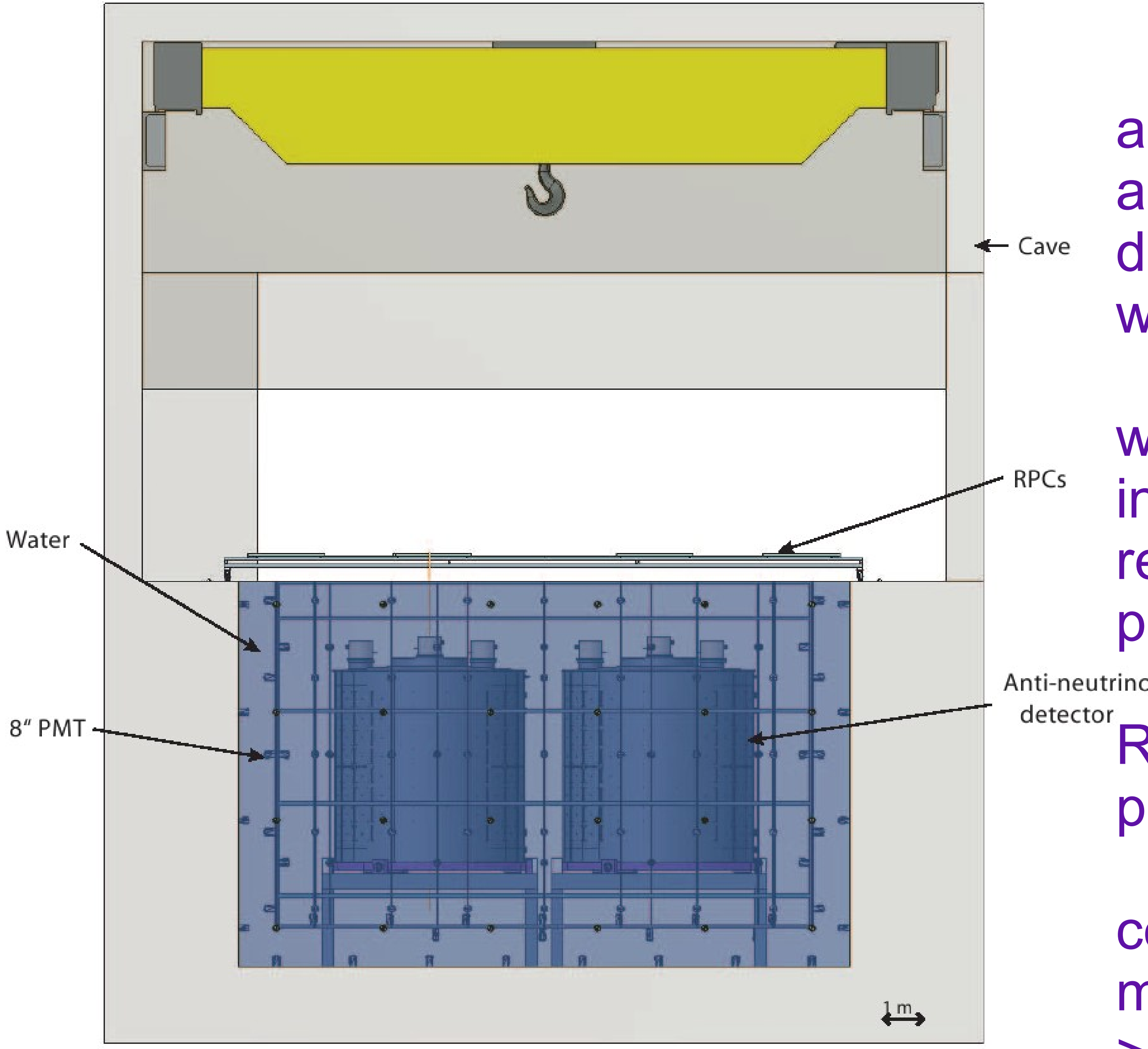
Inverse Beta Decay



signal is coincidence between prompt positron energy and delayed neutron capture

oil buffer:
40 tons mineral oil

Muon Veto System



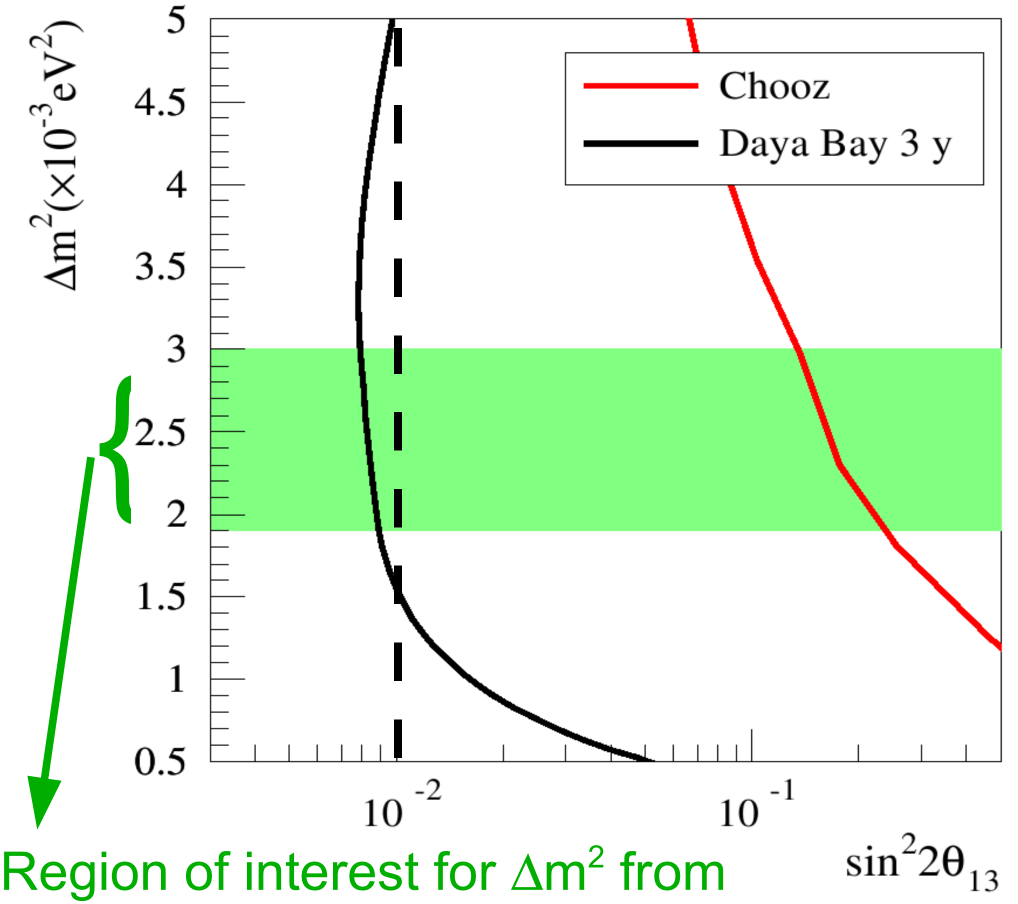
a 2.5 m active water shield around the antineutrino detectors instrumented with 8-inch PMTs

water shield divided into inner region and outer region separated by Tyvek partitions

RPCs on top of the water pool

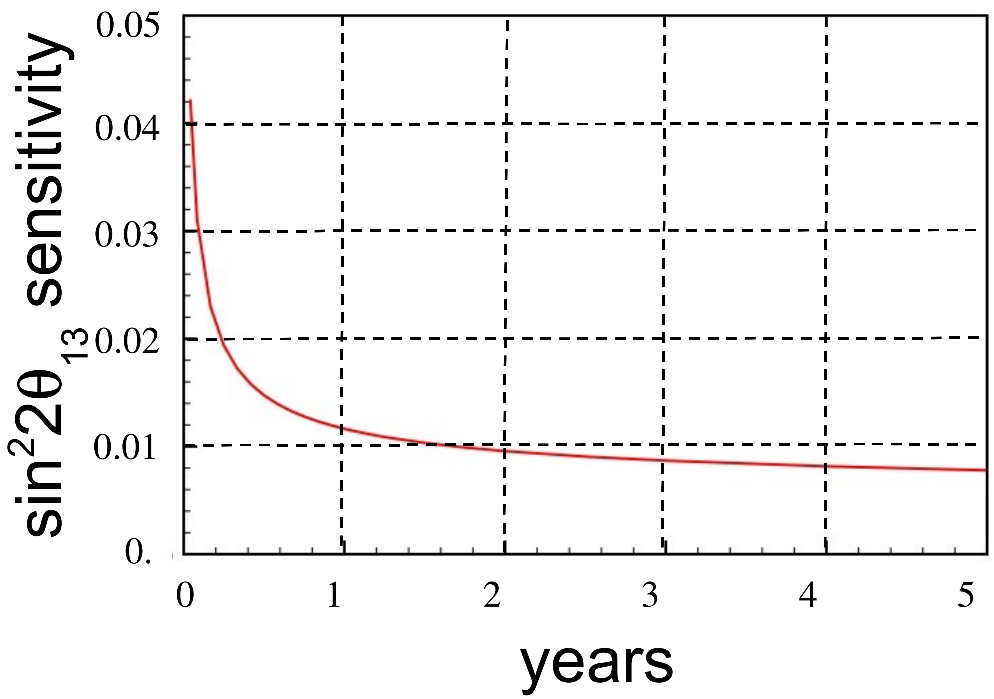
combined system has muon tagging efficiency of >99.5%

Sensitivity



Region of interest for Δm^2 from atmospheric ν experiments

Daya Bay's sensitivity: $\sin^2 2\theta_{13} < 0.01$ in 3 years of running (90% C.L.)



Source	Uncertainty
Detector	0.38% (baseline) 0.18% (goal)
Reactor	0.13%
Signal Statistics	0.2%

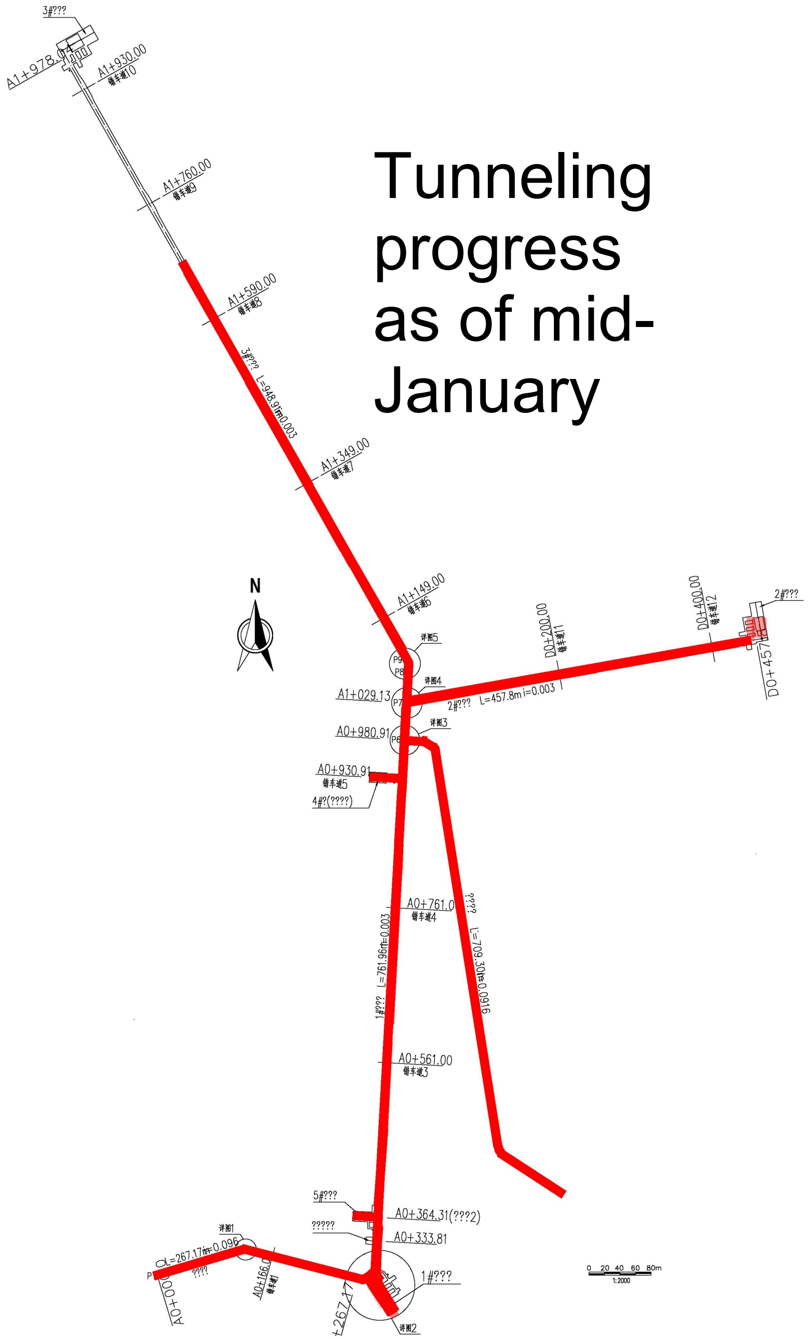
Status


surface assembly building
2009/02/18


tunnel entrance

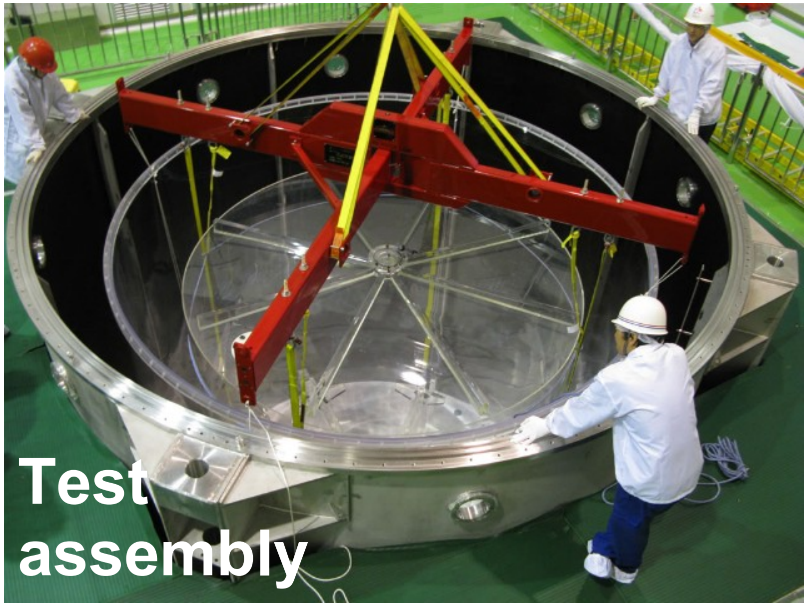

control room
2009/02/18

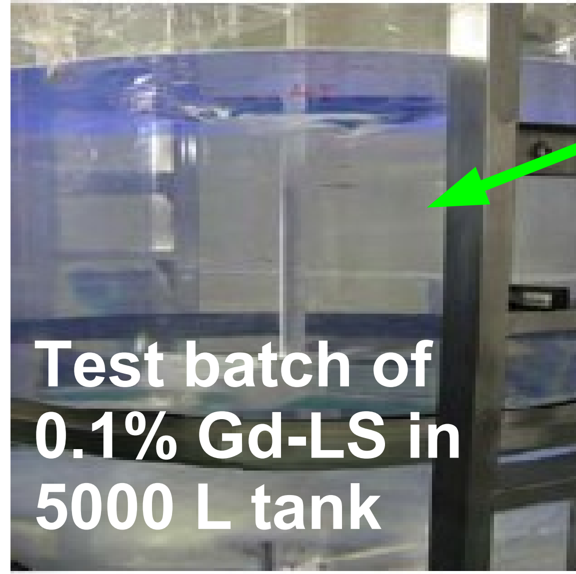
Status



Tunneling progress as of mid-January

Status



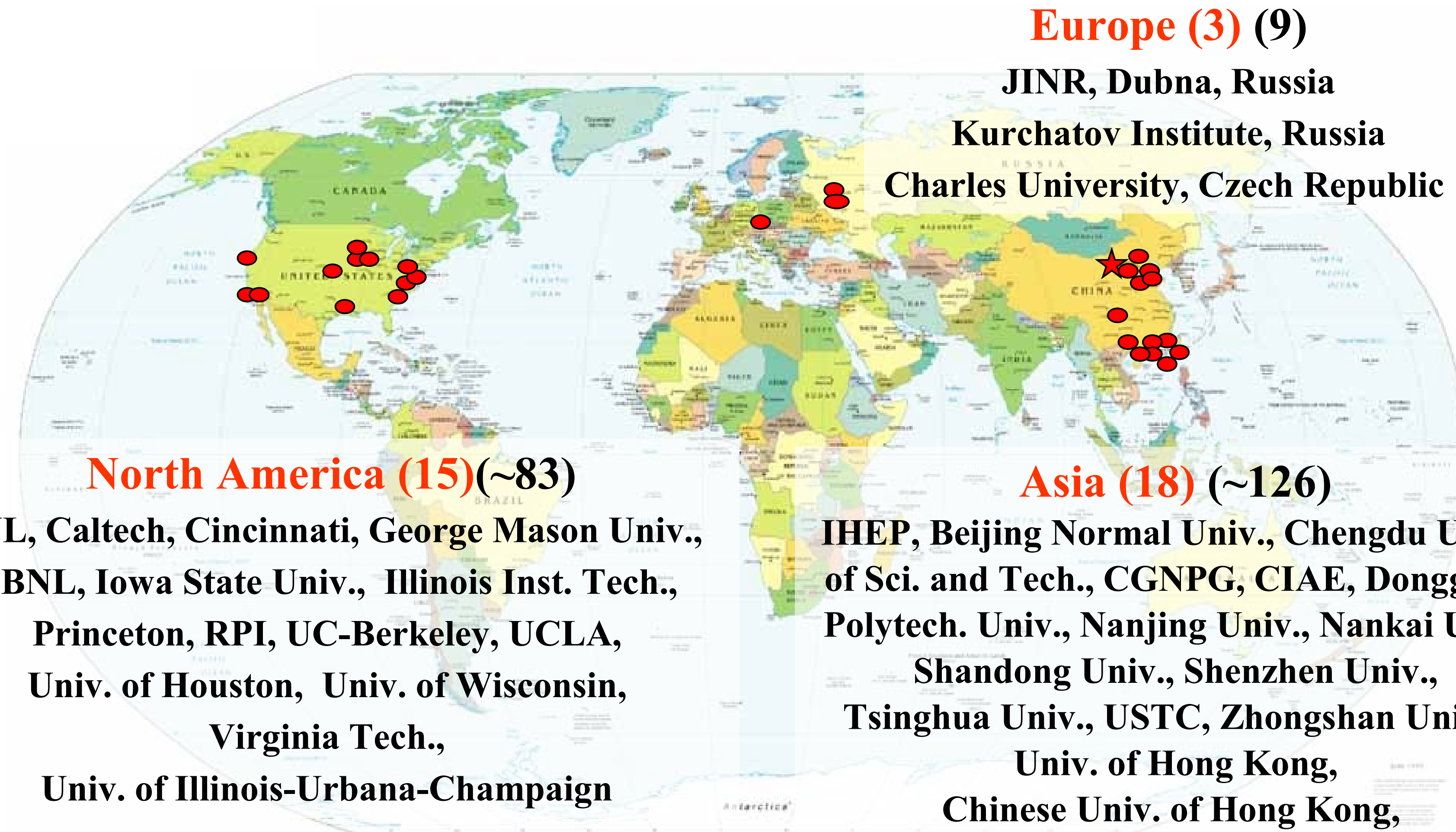


Test batch of Gd-LS has been studied for almost one year now!

Project Schedule

October 2007: Ground breaking
August 2008: CD 3 reviews completed
2010: Daya Bay Near Hall ready for data
2011: Far Hall ready for data

The Daya Bay Collaboration



Europe (3) (9)

JINR, Dubna, Russia
Kurchatov Institute, Russia
Charles University, Czech Republic

North America (15)(~83)

BNL, Caltech, Cincinnati, George Mason Univ., LBNL, Iowa State Univ., Illinois Inst. Tech., Princeton, RPI, UC-Berkeley, UCLA, Univ. of Houston, Univ. of Wisconsin, Virginia Tech., Univ. of Illinois-Urbana-Champaign

Asia (18) (~126)

IHEP, Beijing Normal Univ., Chengdu Univ. of Sci. and Tech., CGNPG, CIAE, Dongguan Polytech. Univ., Nanjing Univ., Nankai Univ., Shandong Univ., Shenzhen Univ., Tsinghua Univ., USTC, Zhongshan Univ., Univ. of Hong Kong, Chinese Univ. of Hong Kong, National Taiwan Univ., National Chiao Tung Univ., National United Univ.

> 200 collaborators

Backup Slides

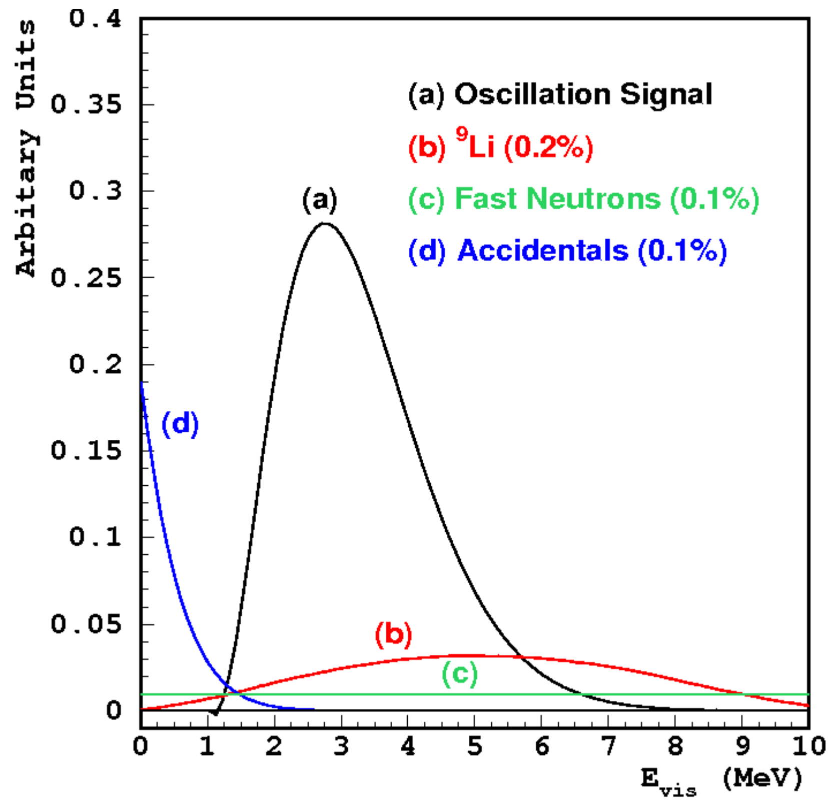
Backgrounds

	DYB site	LA site	far site
Antineutrino rate (/day/module)	840	740	90
Natural radiation (Hz)	<50	<50	<50
Single neutron (/day/module)	18	12	1.5
β-emission isotopes (/day/module)	210	141	14.6
Accidental/Signal	<0.2%	<0.2%	<0.1%
Fast neutron/Signal	0.1%	0.1%	0.1%
$^{8}He^{9}Li$/Signal	0.3%	0.2%	0.2%

1) **$^{9}Li/^{8}He$ isotopes** – have significant beta-neutron decay branching fractions

2) **Fast neutrons** – recoil proton gives prompt signal followed by neutron capture

3) **Accidentals** – coincidence of neutron capture with natural radioactivity in the detector



Systematic Uncertainties

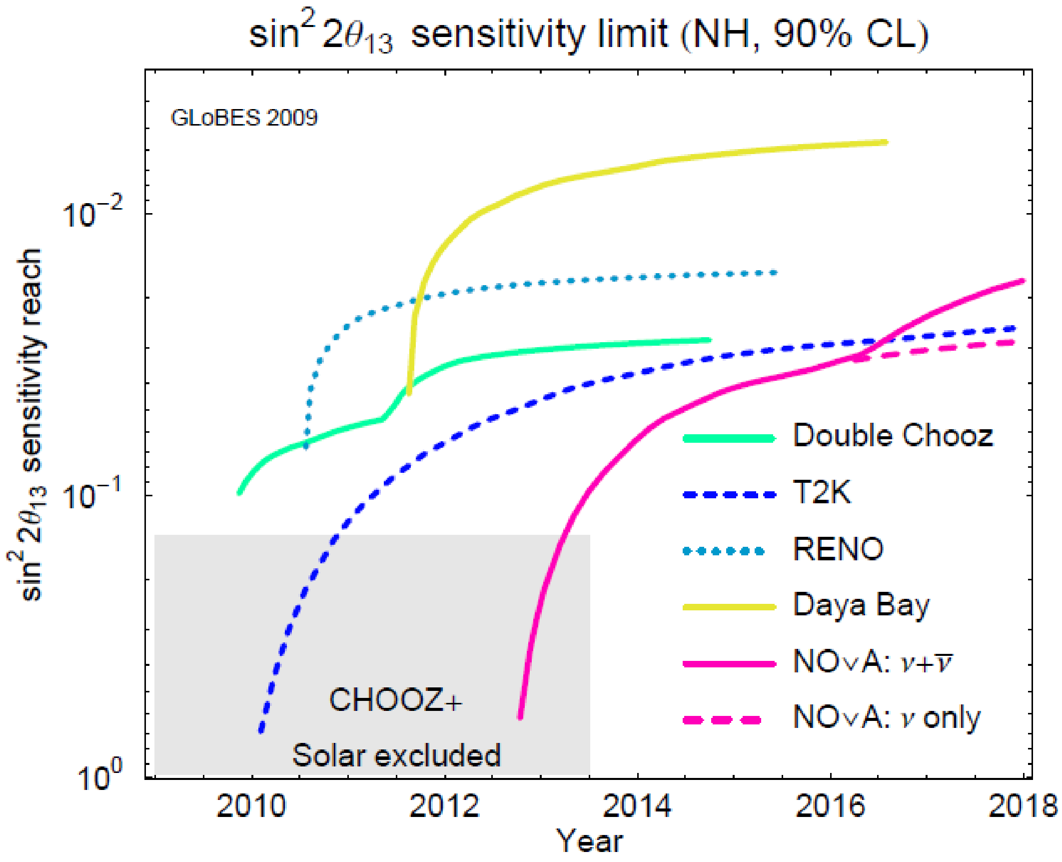
Detector-related uncertainty

Source of uncertainty		Chooz (*absolute*)	Daya Bay (*relative*)		
			Baseline	Goal	Goal w/Swapping
# protons		0.8	0.3	0.1	0.006
Detector Efficiency	Energy cuts	0.8	0.2	0.1	0.1
	Position cuts	0.32	0.0	0.0	0.0
	Time cuts	0.4	0.1	0.03	0.03
	H/Gd ratio	1.0	0.1	0.1	0.0
	n multiplicity	0.5	0.05	0.05	0.05
	Trigger	0	0.01	0.01	0.01
	Live time	0	<0.01	<0.01	<0.01
Total detector-related uncertainty		1.7%	0.38%	0.18%	0.12%

assumptions for systematics in sensitivity calculation

	uncertainty
reactor-related correlated	2%
reactor-related per core	2%
spectrum shape	2%
detector-related correlated	2%
detector-related per module	0.38%
accidental background	100%
fast neutron background	100%
He/Li background	0.3%
bin to bin	0.3%

Global Sensitivity Comparison



arXiv:0907.1896