The Daya Bay Experiment

Kam-Biu Luk
(UC Berkeley & LBNL)

for
The Daya Bay Collaboration

P5 Review, Fermilab, April 18, 2006

θ_{13}: The Last Unknown Neutrino Mixing Angle

U_{MNSP} Matrix

Maki, Nakagawa, Sakata, Pontecorvo

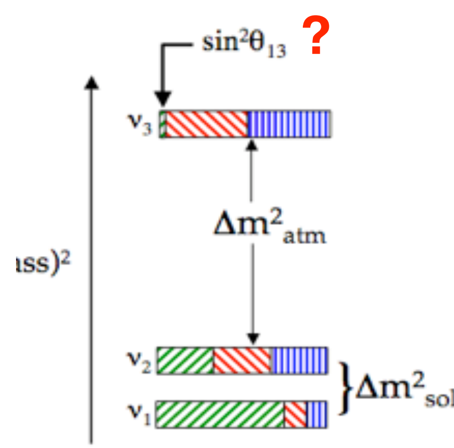
$$U = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} = \begin{pmatrix} 0.8 & 0.5 & U_{e3} \\ 0.4 & 0.6 & 0.7 \\ 0.4 & 0.6 & 0.7 \end{pmatrix} \; ?$$

$$= \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix}}_{\text{atmospheric, accelerator}} \times \underbrace{\begin{pmatrix} \cos\theta_{13} & 0 & e^{-i\delta_{CP}}\sin\theta_{13} \\ 0 & 1 & 0 \\ -e^{i\delta_{CP}}\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix}}_{\text{reactor, accelerator}} \times \underbrace{\begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}}_{\text{SNO, solar SK, KamLAND}} \times \underbrace{\begin{pmatrix} 1 & 0 & 0 \\ 0 & e^{i\alpha/2} & 0 \\ 0 & 0 & e^{i\alpha/2+i\beta} \end{pmatrix}}_{0\nu\beta\beta}$$

atmospheric, accelerator	reactor, accelerator	SNO, solar SK, KamLAND	$0\nu\beta\beta$
θ_{23} = ~ 45°	θ_{13} = ?	θ_{12} ~ 32°	

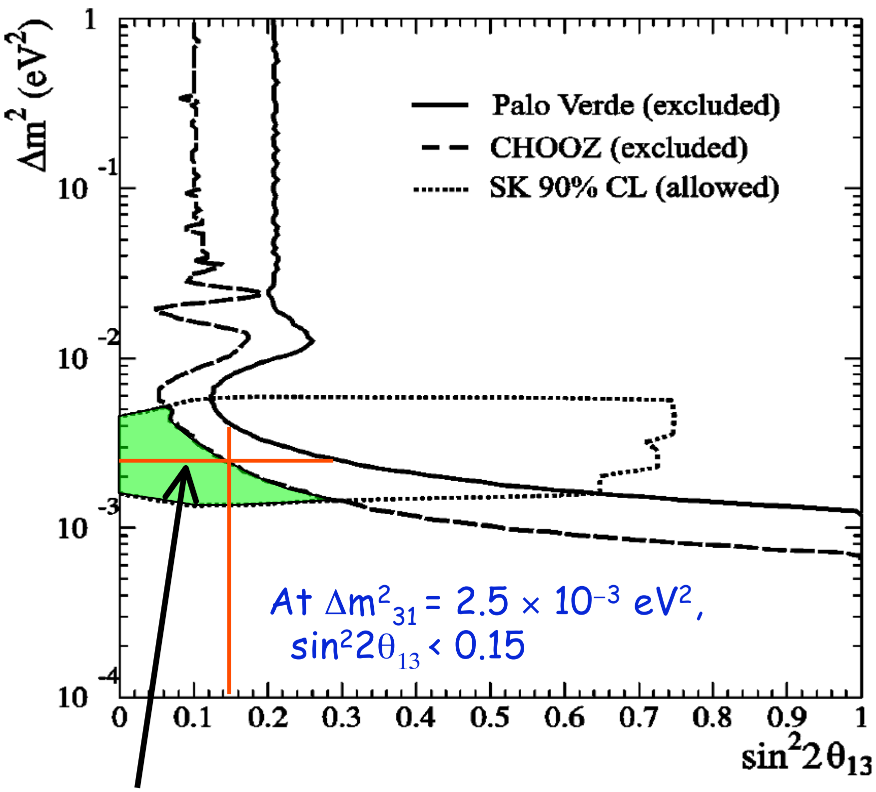
- What is ν_e fraction of ν_3?
- U_{e3} is the gateway to CP violation in neutrino sector:

$$P(\nu_\mu \rightarrow \nu_e) - P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e) \propto \sin(2\theta_{12})\sin(2\theta_{23})\cos^2(\theta_{13})\sin(2\theta_{13})\sin\delta$$



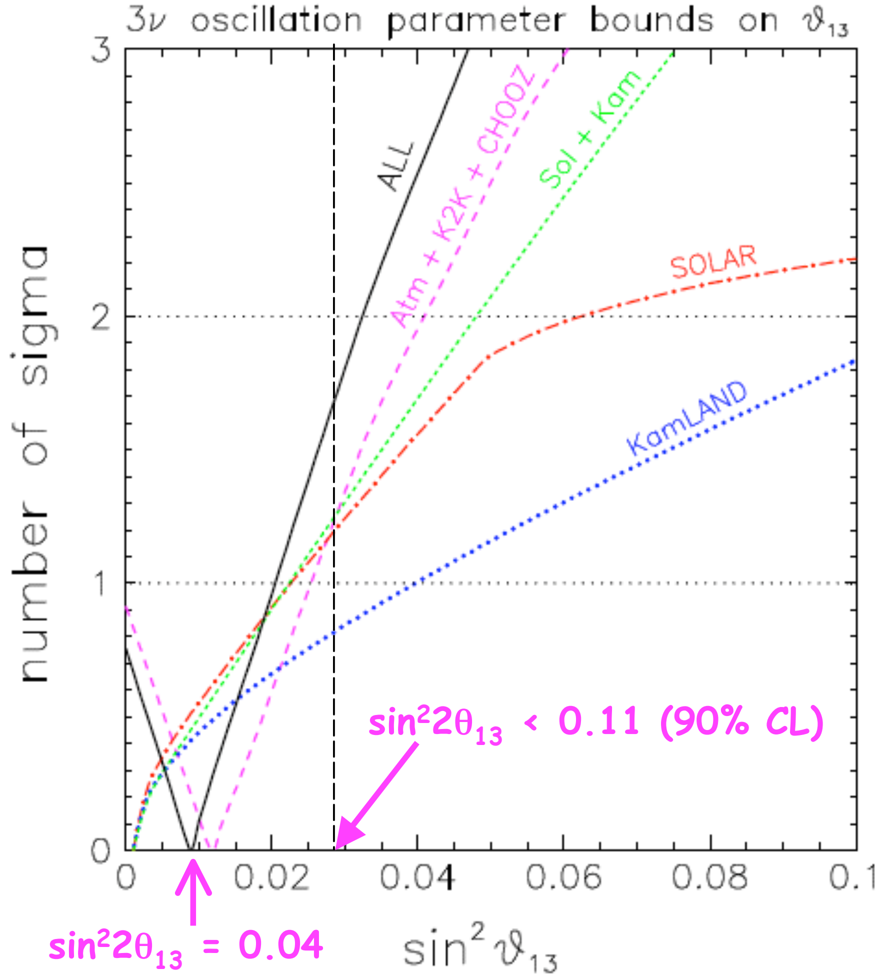
Current Knowledge of θ_{13}

Direct search



allowed region

Global fit



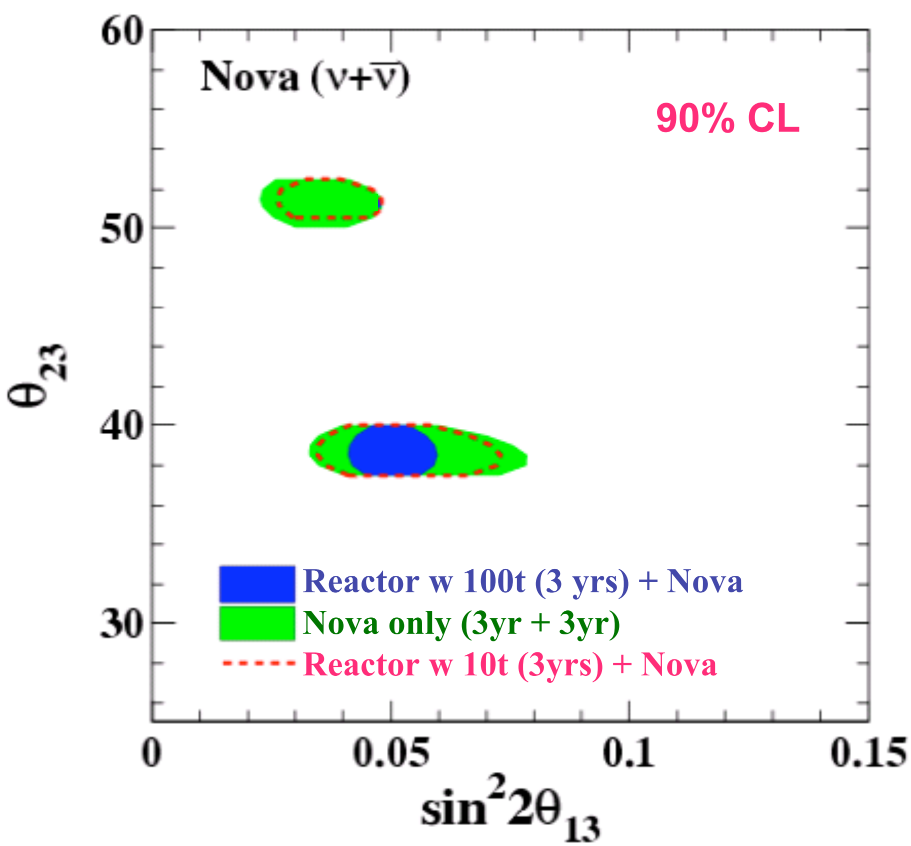
Best fit value of $\Delta m^2_{32} = 2.4 \times 10^{-3}$ eV^2

Fogli etal., hep-ph/0506083

Synergy of Reactor and Accelerator Experiments

- **Neutrino Scientific Assessment Group:**

the reactor determination of $\sin^2 2\theta_{13}$ helps disentangle the combination of parameters measured by an accelerator ν_e appearance experiment by eliminating some of the ambiguities. A reactor experiment is therefore valuable regardless of its timing with respect to an accelerator experiment.



(Example: $\sin^2 2\theta_{23} = 0.95 \pm 0.01$)

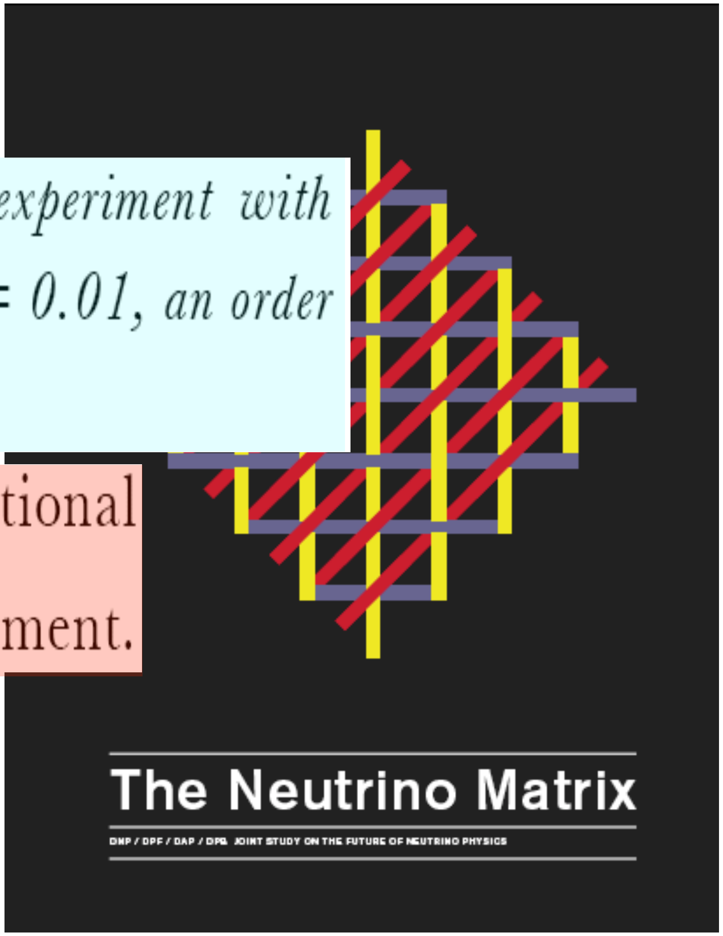
McConnel & Shaevitz, hep-ex/0409028

Recommendations

- **APS Neutrino Study Group:**

  - *An expeditiously deployed multidetector reactor experiment with sensitivity to $\bar{\nu}_e$ disappearance down to $\sin^2 2\theta_{13} = 0.01$, an order of magnitude below present limits.*

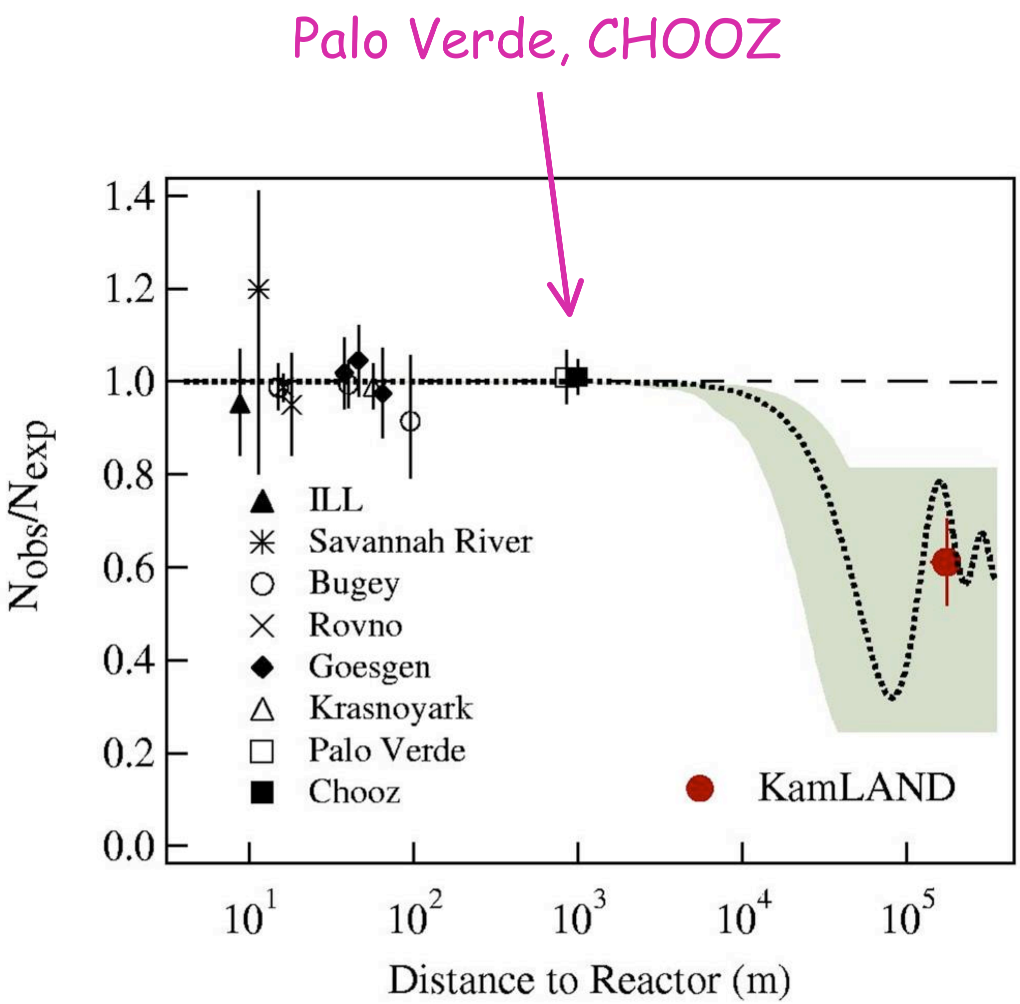
  Our recommendations encourage international cooperation, in order to leverage U.S. investment.



- **Neutrino Scientific Assessment Group:**

  The United States should mount one multi-detector reactor experiment sensitive to $\bar{\nu}_e$ disappearance down to $\sin^2 2\theta_{13} \sim 0.01$.

Limitations of Past and Current Reactor Neutrino Experiments



Typical precision is 3-6% due to

- limited statistics
- reactor-related systematic errors:
  - energy spectrum of $\bar{\nu}_e$ (~2%)
  - time variation of fuel composition (~1%)
- detector-related systematic error (1-2%)
- background-related error (1-2%)

How To Reach A Precision of 0.01 ?

- Powerful nuclear plant
- Larger detectors
- "Identical" detectors
- Near and far detectors to minimize reactor-related errors
- Optimize baseline for best sensitivity and smaller residual reactor-related errors
- Interchange near and far detectors – cancel detector systematic errors
- Sufficient overburden/shielding to reduce background
- Comprehensive calibration/monitoring of detectors

Daya Bay: Goals And Approach

- **Utilize the Daya Bay nuclear power facilities to:**
  - determine $\sin^2 2\theta_{13}$ with a sensitivity of 0.01
  - constrain Δm^2_{31}
- **Adopt horizontal-access-tunnel scheme:**
  - mature and relatively inexpensive technology
  - **flexible** in choosing **overburden** and changing **baseline**
  - relatively easy and cheap to add experimental halls
  - easy access to underground experimental facilities
  - easy to move detectors between different locations with **good environmental control**.
- **Employ three-zone antineutrino detectors.**

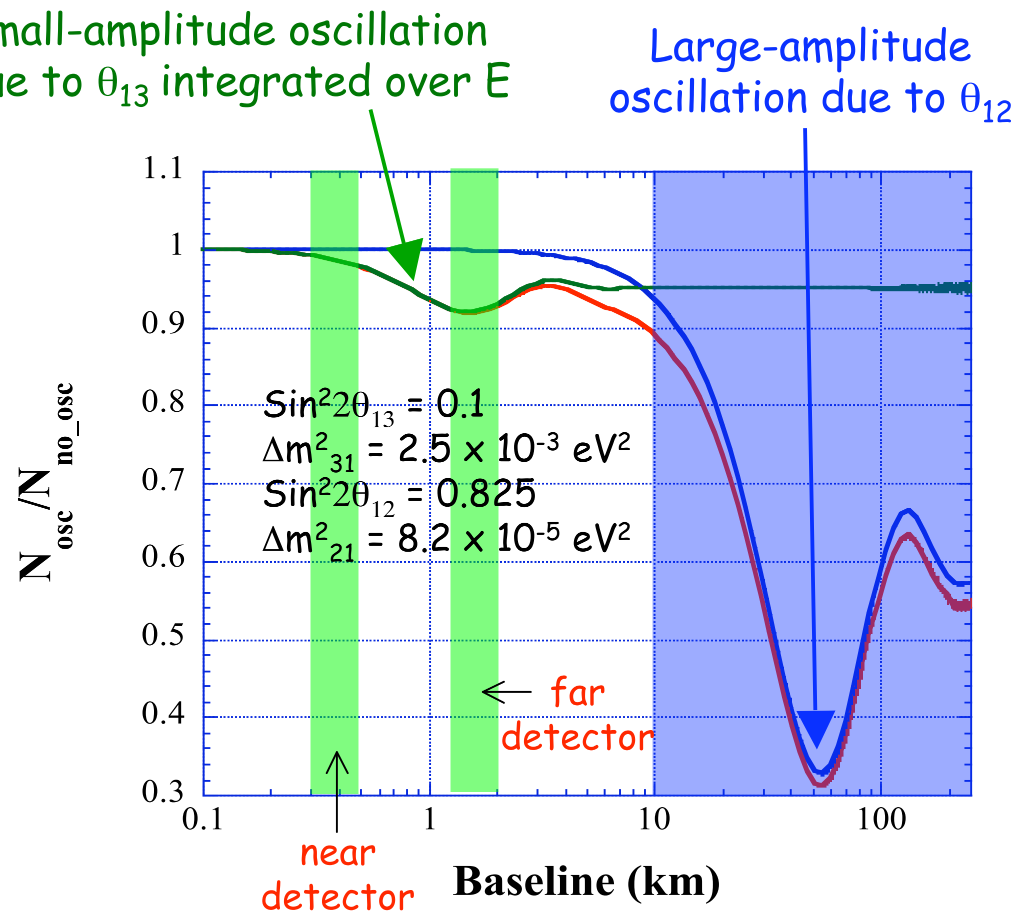
Where To Place The Detectors ?

- Since reactor $\bar{\nu}_e$ are low-energy, it is a disappearance experiment:

$$P(\bar{\nu}_e \to \bar{\nu}_e) \approx 1 - \sin^2 2\theta_{13} \sin^2\left(\frac{\Delta m^2_{31} L}{4E}\right) - \cos^4\theta_{13} \sin^2 2\theta_{12} \sin^2\left(\frac{\Delta m^2_{21} L}{4E}\right)$$

- Place near detector(s) close to reactor(s) to measure raw flux and spectrum of $\bar{\nu}_e$, reducing reactor-related systematic

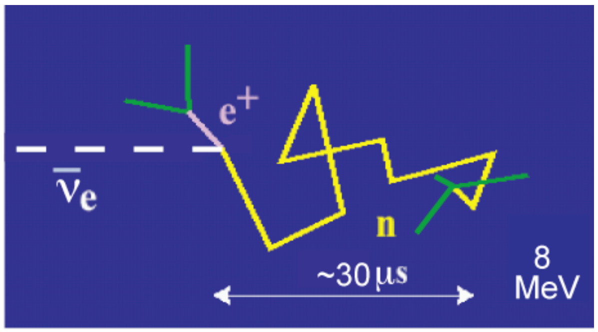
- Position a far detector near the first oscillation maximum to get the highest sensitivity, and also be less affected by θ_{12}



Detecting Low-energy $\bar{\nu}_e$

- The reaction is the inverse β-decay in 0.1% Gd-doped liquid scintillator:

$$\bar{\nu}_e + p \rightarrow e^+ + n \quad \text{(prompt)}$$



0.3b $\rightarrow + p \rightarrow D + \gamma(2.2\ \text{MeV})$ (delayed)

50,000b $\rightarrow + Gd \rightarrow Gd^*$

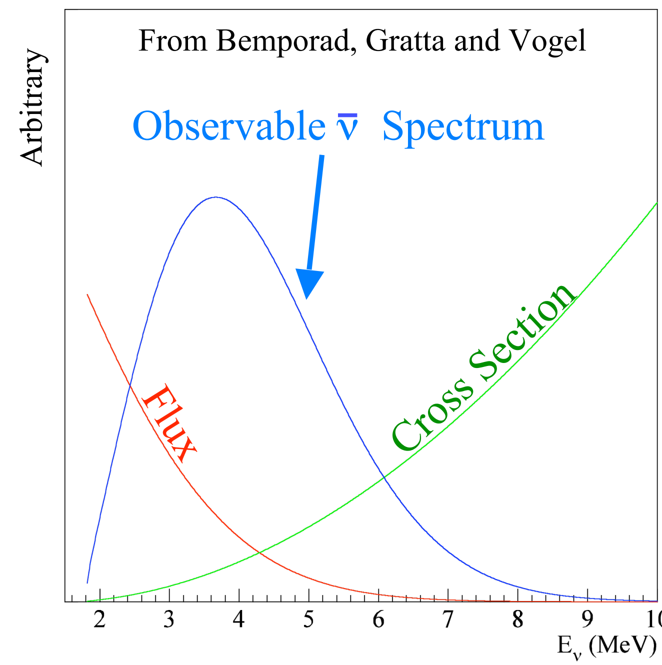
$\rightarrow Gd + \gamma\text{'s}(8\ \text{MeV})$ (delayed)

- Time- and energy-tagged signal is a good tool to suppress background events.

- Energy of $\bar{\nu}_e$ is given by:

$$E_{\bar{\nu}} \approx T_{e+} + T_n + (m_n - m_p) + m_{e+} \approx T_{e+} + 1.8\ \text{MeV}$$

10-40 keV



The Daya Bay Collaboration: China-Russia-U.S.

20 institutions, 89 collaborators

X. Guo, N. Wang, R. Wang
Beijing Normal University, Beijing

L. Hou, B. Xing, Z. Zhou
China Institute of Atomic Energy, Beijing

M.C. Chu, W.K. Ngai
Chinese University of Hong Kong, Hong Kong

J. Cao, H. Chen, J. Fu, J. Li, X. Li, Y. Lu, Y. Ma, X. Meng, R. Wang, Y. Wang, Z. Wang, Z. Xing, C. Yang, Z. Yao, J. Zhang, Z. Zhang, H. Zhuang, M. Guan, J. Liu, H. Lu, Y. Sun, Z. Wang, L. Wen, L. Zhan, W. Zhong
Institute of High Energy Physics, Beijing

X. Li, Y. Xu, S. Jiang
Nankai University, Tianjin

Y. Chen, H. Niu, L. Niu
Shenzhen University, Shenzhen

S. Chen, G. Gong, B. Shao, M. Zhong, H. Gong, L. Liang, T. Xue
Tsinghua University, Beijing

K.S. Cheng, J.K.C. Leung, C.S.J. Pun, T. Kwok, R.H.M. Tsang, H.H.C. Wong
University of Hong Kong, Hong Kong

Z. Li, C. Zhou
Zhongshan University, Guangzhou

Yu. Gornushkin, R. Leitner, I. Nemchenok, A. Olchevski
Joint Institute of Nuclear Research, Dubna, Russia

V.N. Vyrodov
Kurchatov Institute, Moscow, Russia

B.Y. Hsiung
National Taiwan University, Taipei

M. Bishai, M. Diwan, D. Jaffe, J. Frank, R.L. Hahn, S. Kettell, L. Littenberg, K. Li, B. Viren, M. Yeh
Brookhaven National Laboratory, Upton, New York, U.S.

R.D. McKeown, C. Mauger, C. Jillings
California Institute of Technology, Pasadena, California, U.S.

K. Whisnant, B.L. Young
Iowa State University, Ames, Iowa, U.S.

W.R. Edwards, K. Heeger, K.B. Luk
University of California and Lawrence Berkeley National Laboratory, Berkeley, California, U.S.

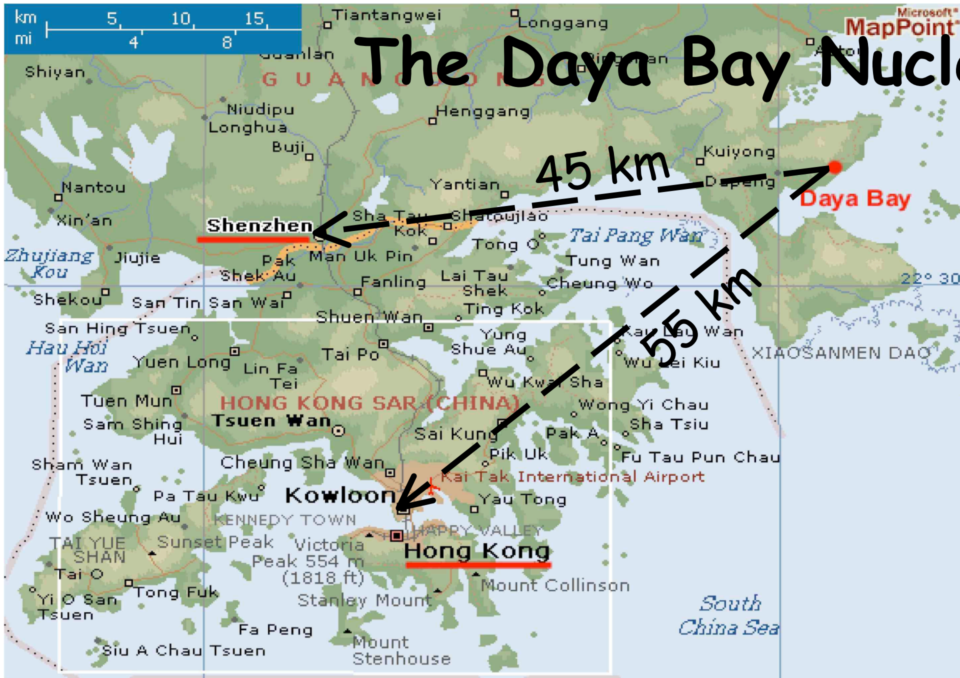
V. Ghazikhanian, H.Z. Huang, S. Trentalange, C. Whitten Jr.
University of California, Los Angeles, California, U.S.

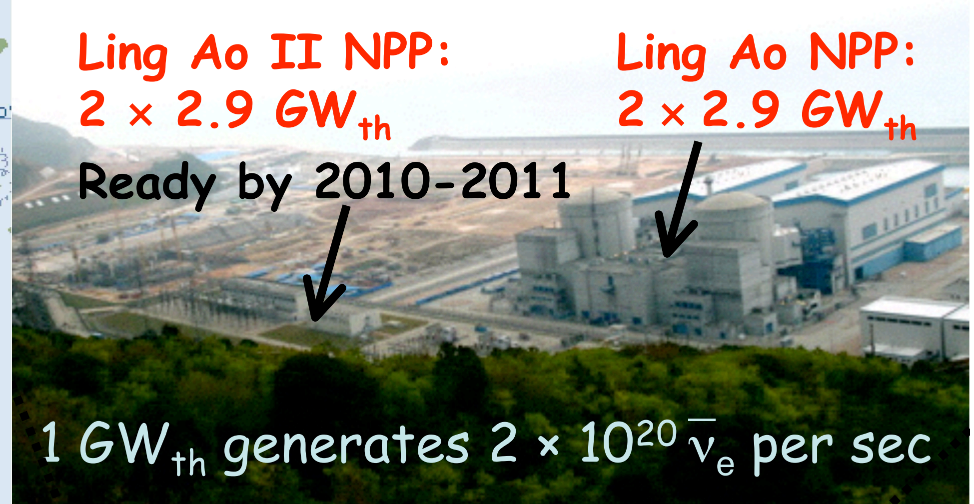
M. Ispiryan, K. Lau, B.W. Mayes, L. Pinsky, G. Xu, L. Lebanowski
University of Houston, Houston, Texas, U.S.

J.C. Peng
University of Illinois, Urbana-Champaign, Illinois, U.S.

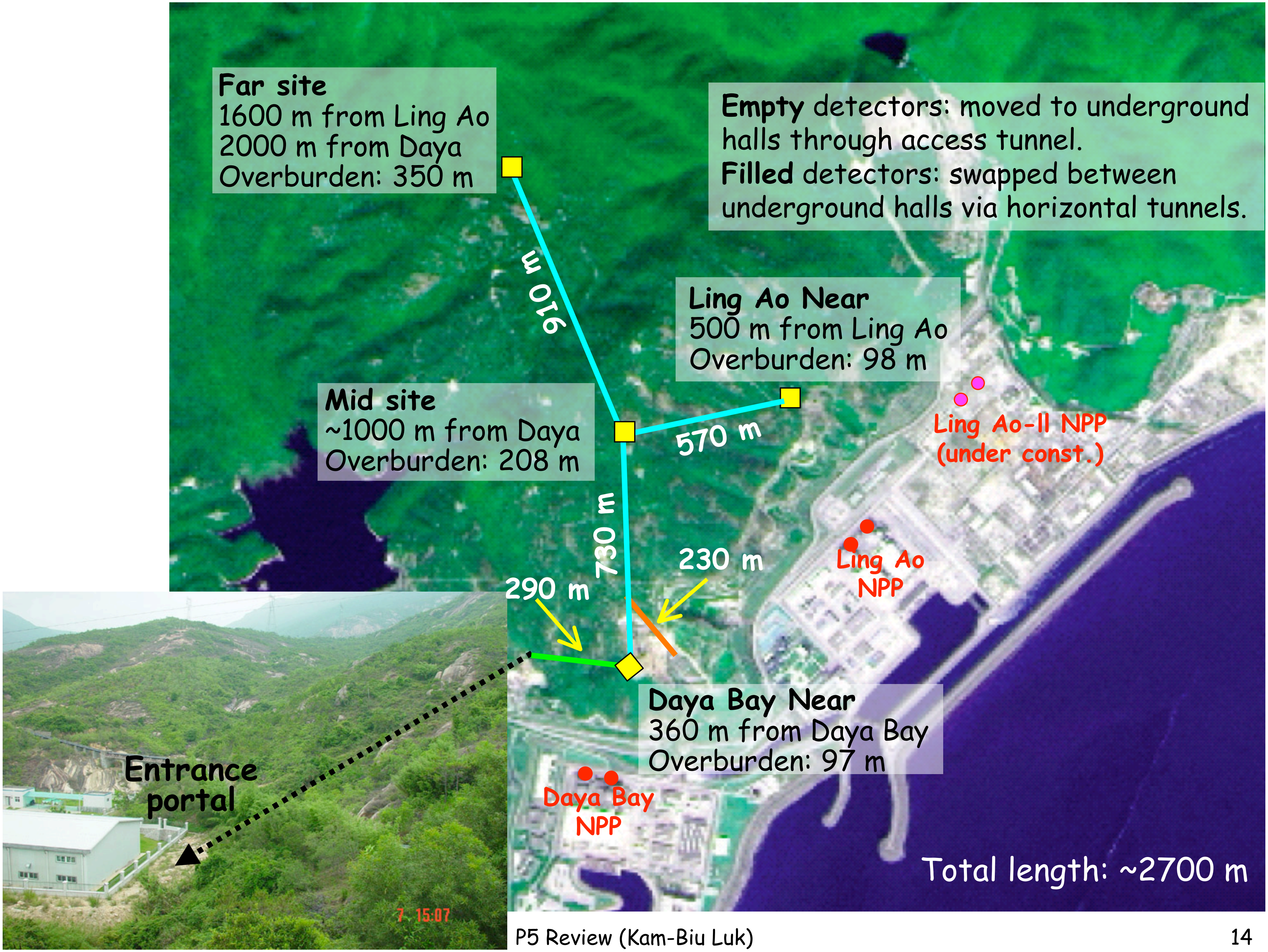

Daya Bay Collaboration Meeting
IHEP,Beijing,Feb.13-15,2006

The Daya Bay Nuclear Power Facilities



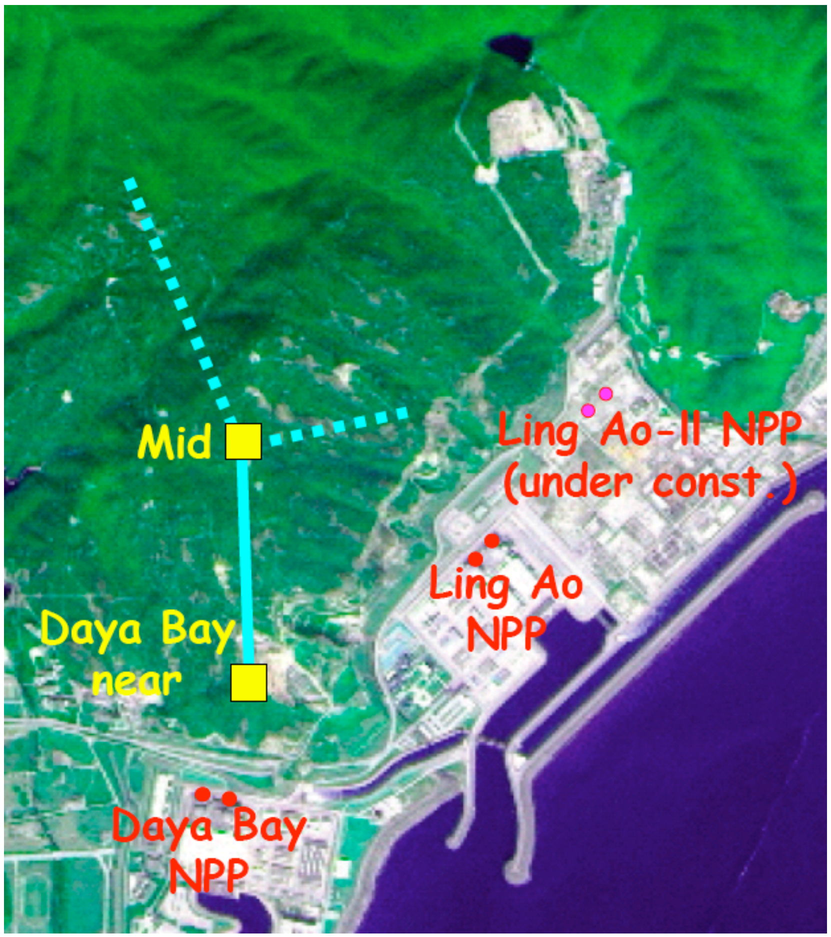


- 12th most powerful in the world (11.6 GW)
- Top five most powerful by 2011 (17.4 GW)
- Adjacent to mountain, easy to construct tunnels to reach underground labs with sufficient overburden to suppress cosmic rays


Far site
1600 m from Ling Ao
2000 m from Daya
Overburden: 350 m
Empty detectors: moved to underground halls through access tunnel.
Filled detectors: swapped between underground halls via horizontal tunnels.
910 m
Ling Ao Near
500 m from Ling Ao
Overburden: 98 m
Mid site
~1000 m from Daya
Overburden: 208 m
570 m
Ling Ao-II NPP
(under const.)
730 m
230 m
290 m
Ling Ao
NPP
Daya Bay Near
360 m from Daya Bay
Overburden: 97 m
Entrance
portal
Daya Bay
NPP
Total length: ~2700 m

A Versatile Site

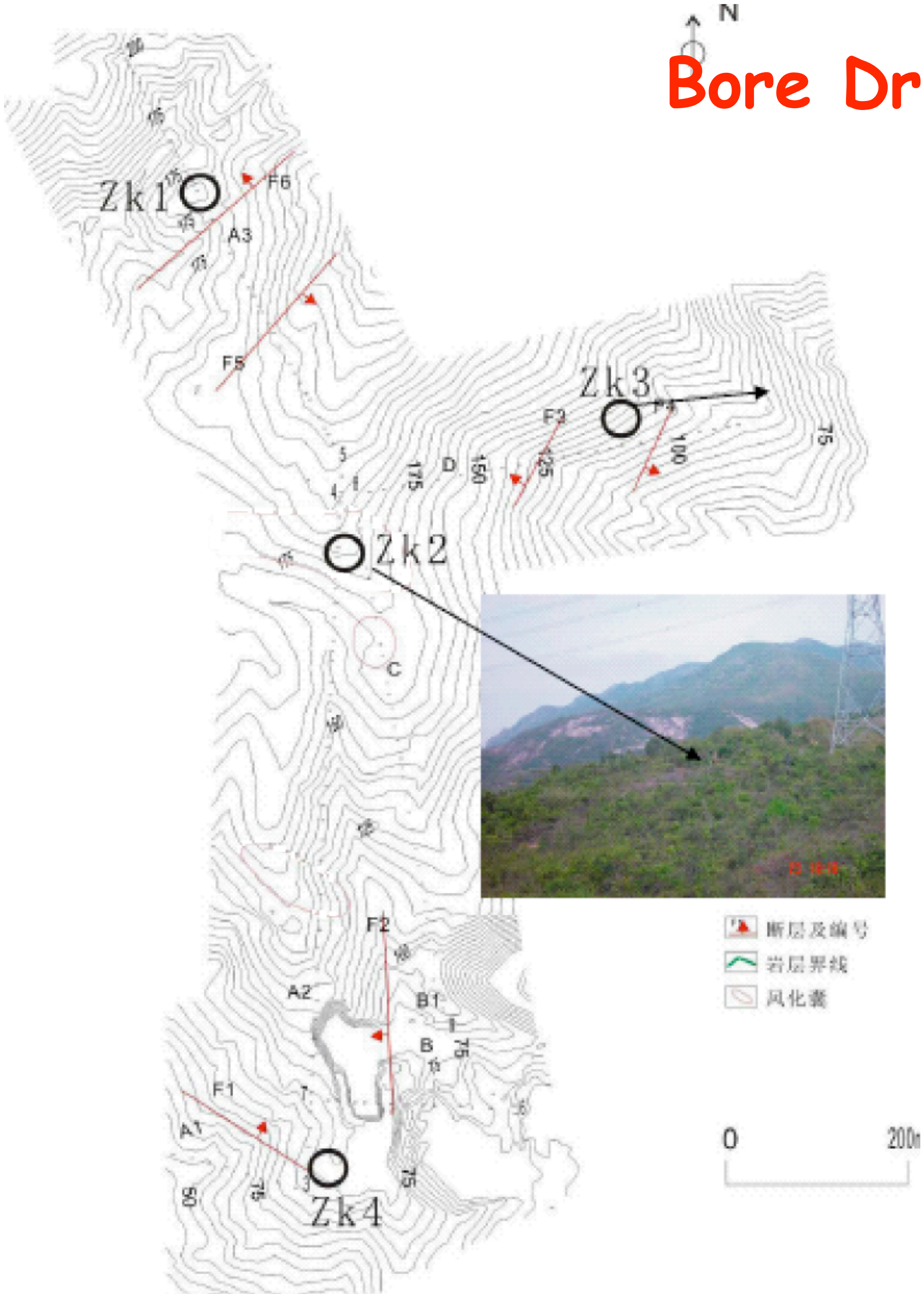
- **Rapid deployment:**
  - Daya Bay near site + mid site
  - 0.7% reactor systematic error



- **Full operation:**
  - (A) Two near sites + Far site
  - (B) Mid site + Far site
  - (C) Two near sites + Mid site + Far site

Internal checks, each with different systematic

Bore Drilling



Location	Drill Depth (m)
ZK1	211
ZK2	210
Zk3	127
Zk4	133

Bore Samples

Zk2 (depth: ~180 m)

Zk4 (depth: 133 m)

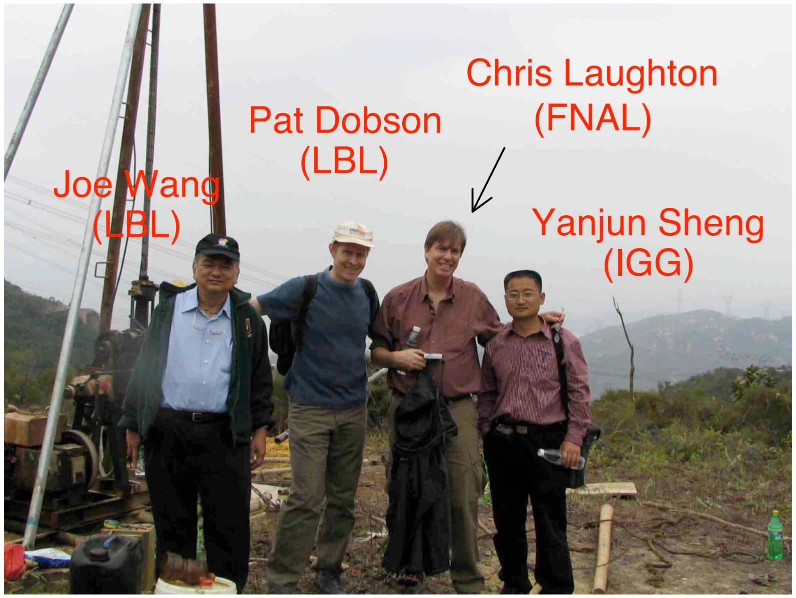
Zk1 (depth: 210 m)

Zk3 (depth: ~64 m)

Findings of Geotechnical Survey

- No active or large faults
- Rock structure: massive and blocky granite
- Rock: most is slightly weathered or fresh
- Groundwater: low flow at the depth of the tunnel
- Quality of rock mass: stable and hard

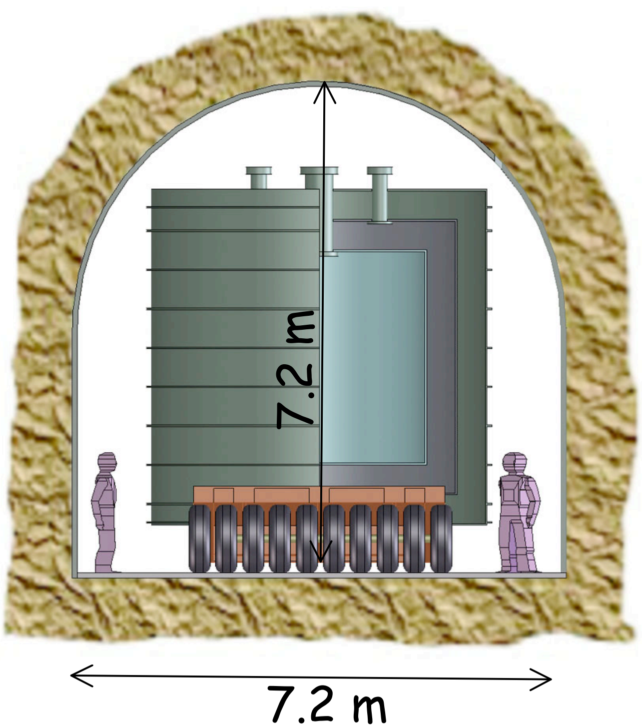
U.S. experts in geology and tunnel construction assist geotechnical survey:



Excellent conditions for tunnel construction

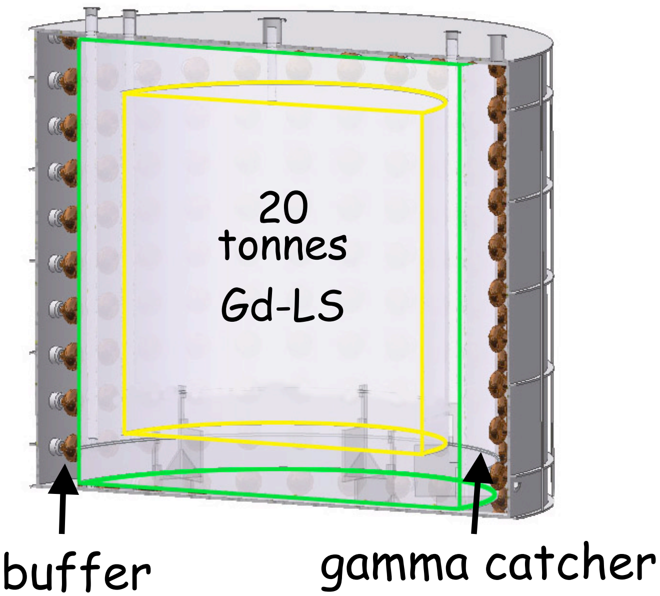
Civil construction

- The total tunnel length is ~3 km
- Preliminary civil construction cost: ~$3K/m
- Time for tunnel construction is <24 months (>5 m/day)
- A similar tunnel exists on the reactor site as a reference



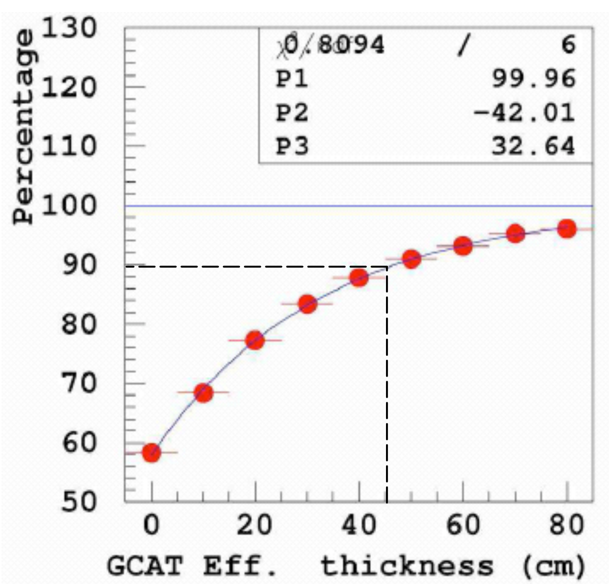
Design of Antineutrino Detectors

- **Three-zone structure:**
  - I. Target: 0.1% Gd-loaded liquid scintillator
  - II. Gamma catcher: liquid scintillator, 45cm
  - III. Buffer shielding: mineral oil, ~45cm



- **Possibly with diffuse reflection at ends. For 200 PMT's around the barrel:**

$$\frac{\sigma}{E} \sim \frac{14\%}{\sqrt{E(\text{MeV})}}, \quad \sigma_{\text{vertex}} = 14\text{cm}$$



Oil buffer thickness

Isotopes (from PMT)	Purity (ppb)	20cm (Hz)	25cm (Hz)	30cm (Hz)	40cm (Hz)
^{238}U(>1MeV)	50	2.7	2.0	1.4	0.8
^{232}Th(>1MeV)	50	1.2	0.9	0.7	0.4
^{40}K(>1MeV)	10	1.8	1.3	0.9	0.5
Total		5.7	4.2	3.0	1.7

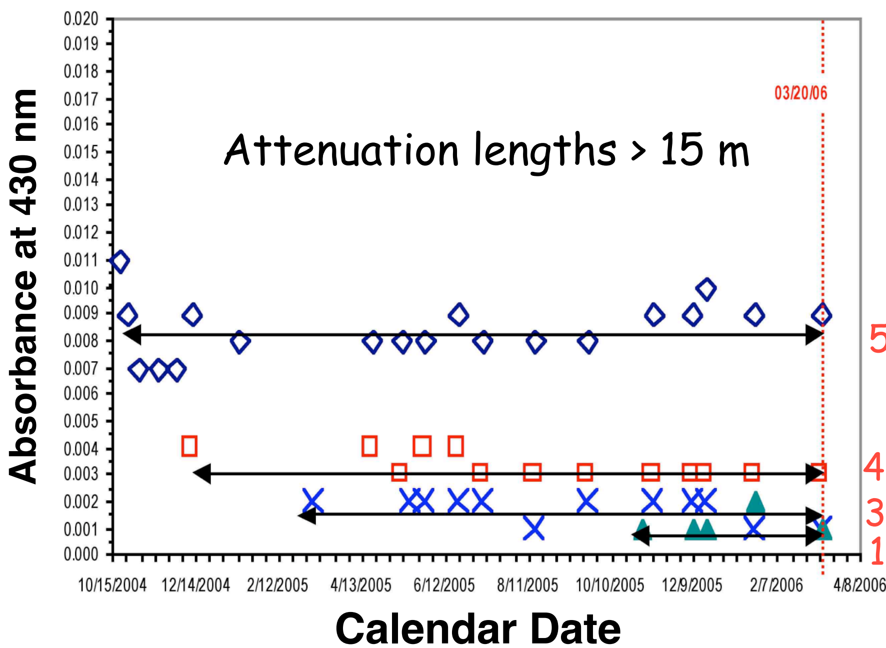
Gd-loaded Liquid Scintillator For Daya Bay

- Require **stable** Gd-loaded liquid scintillator with

  - high light yield
  - long attenuation length

- BNL nuclear chemists with extensive experience in metal-loaded liquid scintillator have prepared several Gd-doped liquid scintillators with ~1% Gd that can be diluted to ~0.1% Gd for Daya Bay:

  - technology of 1% Gd in pseudocumene (PC) and in mixture of PC and dodecane is mature
  - need R&D for 1% Gd in linear alkyl benzene (LAB)

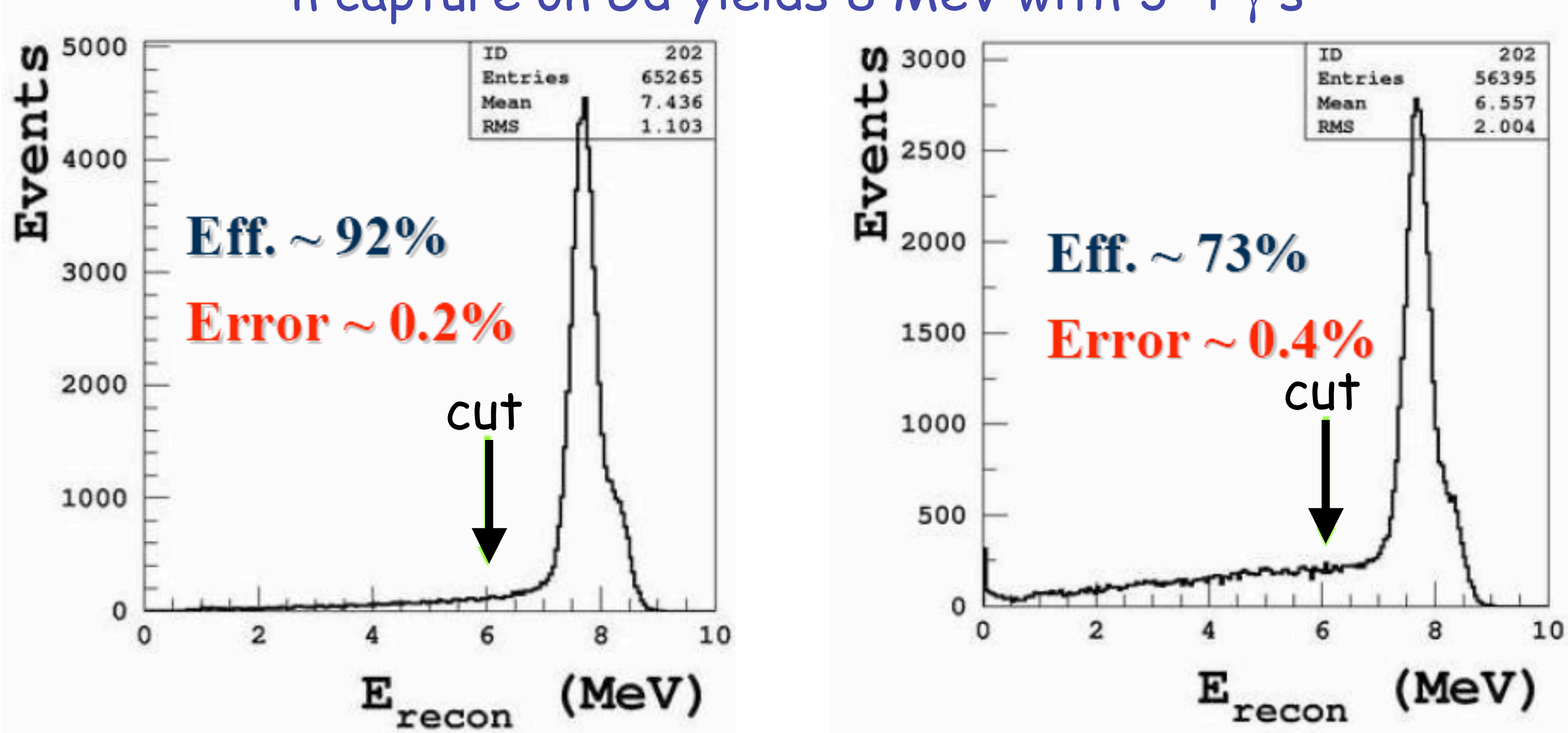


- IHEP has also developed good quality Gd-loaded LS.

Why three zones ?

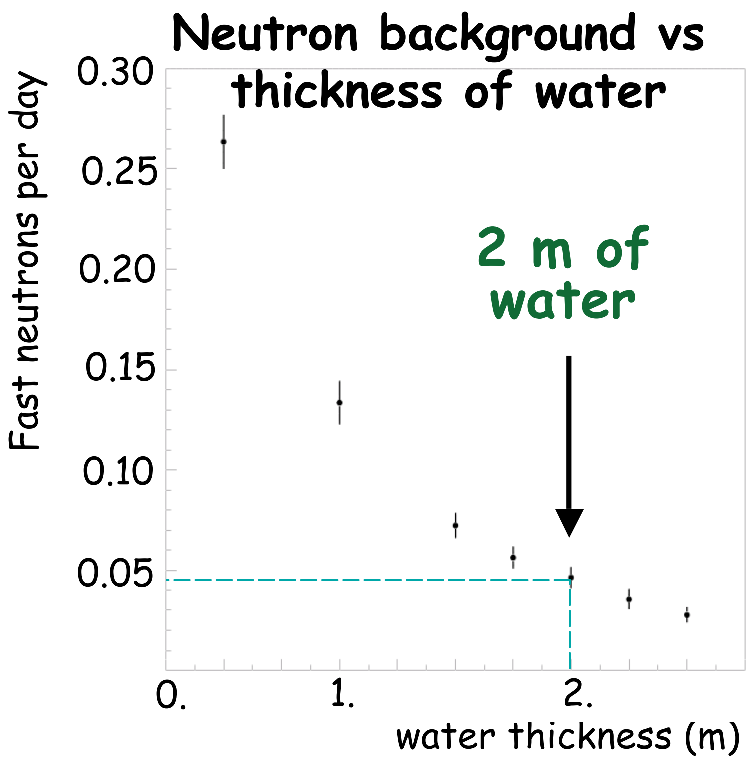
- 3 zones provides increased confidence in systematic error associated with detection efficiency and fiducial volume
- 2 zones implies simpler design/construction, some cost reduction but with increased risk to systematic error

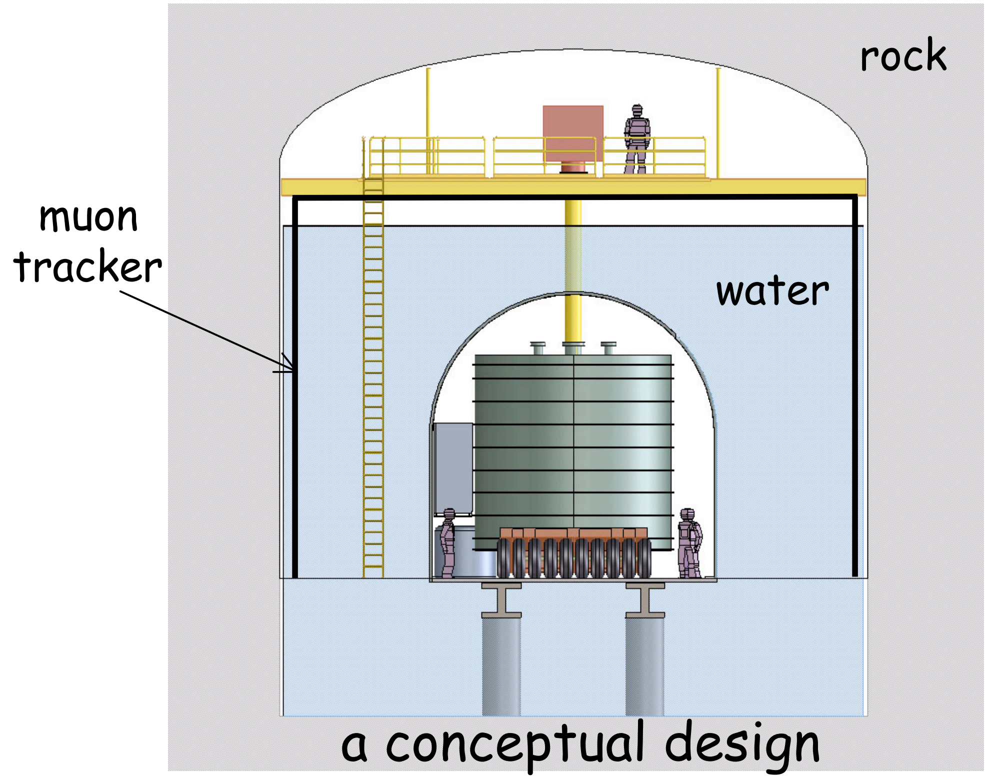
n capture on Gd yields 8 MeV with 3-4 γ's



Can't lower the energy cut due to low-energy γ background

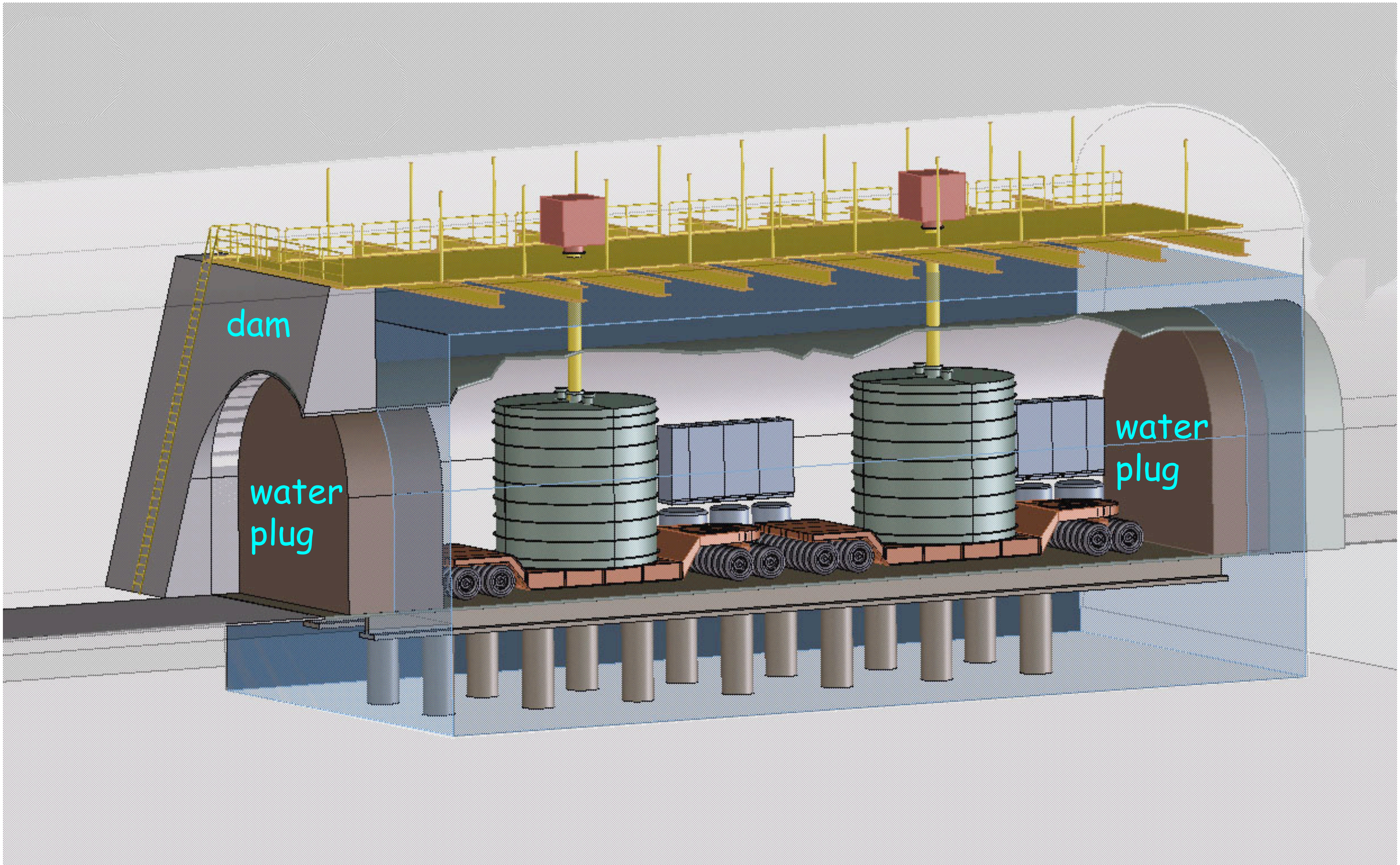
Design of Shield-Muon Veto





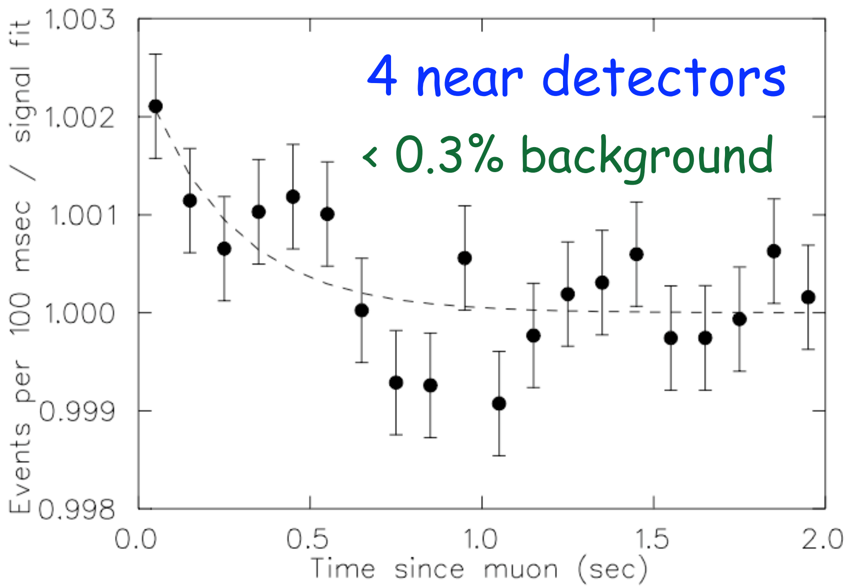
- Detector modules enclosed by 2m of water to shield neutrons produced by cosmic-ray muons and gamma-rays from the surrounding rock
- Water shield also serves as a Cherenkov veto for tagging muons
- Augmented with a muon tracker: scintillator or RPCs
- Combined efficiency of Cherenkov and tracker > 99.5%

Underground Experimental Hall



Background

- **Natural Radioactivity**: PMT glass, Rock, Radon in the air, etc
- **Slow and fast neutrons produced by cosmic muons**
  - Neutrons produced in rock and water shield (99.5% veto efficiency)
- **Muon-induced cosmogenic isotopes: $^{8}He/^{9}Li$ which can β-n decay**
  - Cross section measured at CERN (Hagner et. al.)
  - Can be measured in-situ, even for near detectors with muon rate ~ 10 Hz:



Half-life of ^{9}Li = 0.18s

β-n decay of ^{9}Li mimics signal

Summary of Background

- **Use a modified Palo Verde-Geant3-based MC to model response of detector:**

	Near Site	Far Site
Radioactivity (Hz)	<50	<50
Accidental B/S	<0.05%	<0.05%
Fast neutron B/S	0.14% ± 0.16%	0.08 ± 0.1%
$^{8}He/^{9}Li$ B/S	0.41% ± 0.18%	0.2% ± 0.08%

Further rejection of background may be possible by cutting showering muons.

Systematic Uncertainty

- Main contributions:

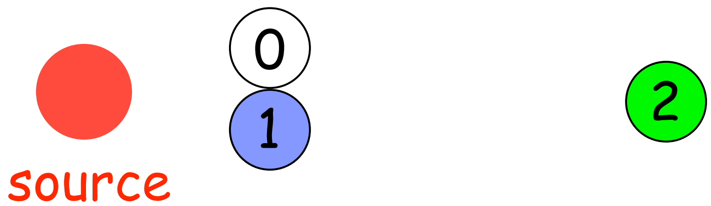
    1. Reactor-related errors
    2. Detector-related errors

- Swapping detectors can reduce detector systematic errors

- Assume background is measured

Detector Swapping

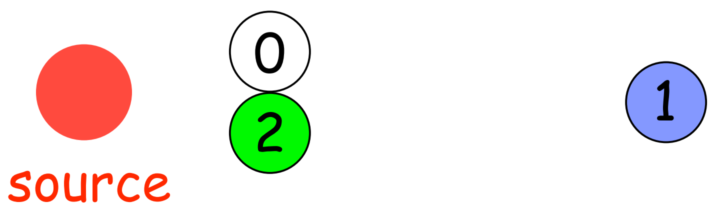
Basic concept:



$$\frac{N_1}{F_2} = \frac{N}{F} \cdot \frac{\varepsilon_1}{\varepsilon_2}$$

N = number of $\bar{\nu}$ at near site
ε_1 = efficiency of detector 1
F = number of $\bar{\nu}$ at far site
ε_2 = efficiency of detector 2

Detector 0 is used to cross check detectors before and after swapping



$$\frac{N_2}{F_1} = \frac{N}{F} \cdot \frac{\varepsilon_2}{\varepsilon_1} = \frac{N}{F}\left(1 + \frac{\delta}{\varepsilon_1}\right)$$

$$\frac{N_1}{F_2} + \frac{N_2}{F_1} \approx 2\frac{N}{F}\left[1 + \frac{1}{2}\left(\frac{\delta}{\varepsilon_1}\right)^2\right] = 2\frac{N}{F}(1+\eta)$$

For example,
ε_1 = 0.8 (KamLAND),
δ = 0.02
$\Rightarrow$ $\eta = 3\times10^{-4}$

Reactor-related Uncertainties of Daya Bay

- The error due to power fluctuations of the reactors is given by:

$$\sigma_{sys} = \sigma_p \sqrt{\sum_r \left(f_F^r - f_N^r\right)^2}$$

- Based on experience of past experiments, uncorrelated error per reactor core $\sigma_p \approx 2\%$ is due to uncertainty in measuring the amount of thermal power produced.

  f^r_F and f^r_N are fractions of the events at the far and near site from reactor r respectively.

# Reactor Cores	Syst. error due to Power Fluctuations	Syst. error due to Core Positions	Total syst. error
4	0.035%	0.08%	0.087%
6	0.097%	0.08%	0.126%

Detector-related Uncertainties

Source of error		CHOOZ	Daya Bay		
		Absolute measurement	Relative measurement		
			Baseline	Goal	w/ Swapping
# protons	H/C ratio	0.8	0.2	0.1	→ 0
	Mass	-	0.2	0.02	→ 0.006
Detector Efficiency	Energy cuts	0.8	0.2	0.05	
	Position cuts	0.32	0.0	0.0	
	Time cuts	0.4	0.1	0.03	
	H/Gd ratio	1.0	0.01	0.01	→ 0
	n multiplicity	0.5	0.05	0.01	
	Trigger	0	0.01	0.01	
	Live time	0	< 0.01	< 0.01	
Total detector-related uncertainty		1.7%	0.36%	0.12%	→ 0.06%

Baseline: currently achievable **relative** uncertainty without R&D
Goal: expected **relative** uncertainty after R&D
Swapping: can reduce **relative** uncertainty further

Summary of Systematic Errors

- Reactor-related systematic errors are:

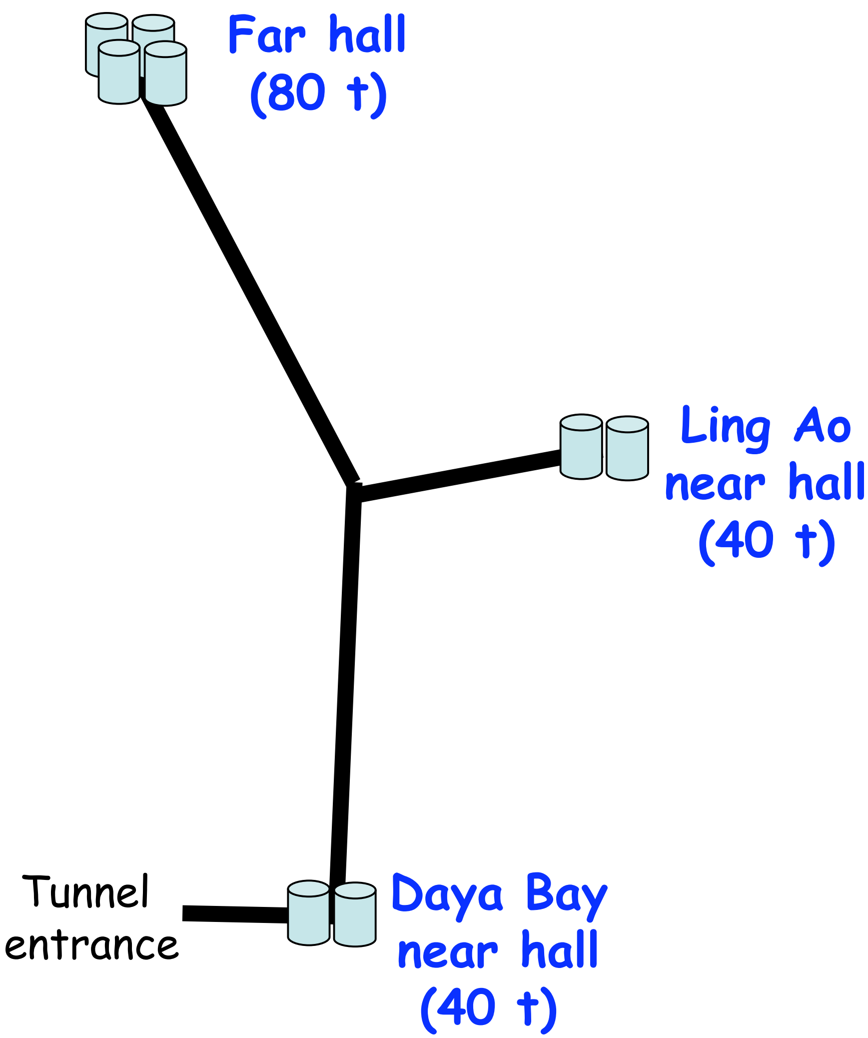
  0.09% (4 cores)
  0.13% (6 cores)

- Relative detector systematic errors are:

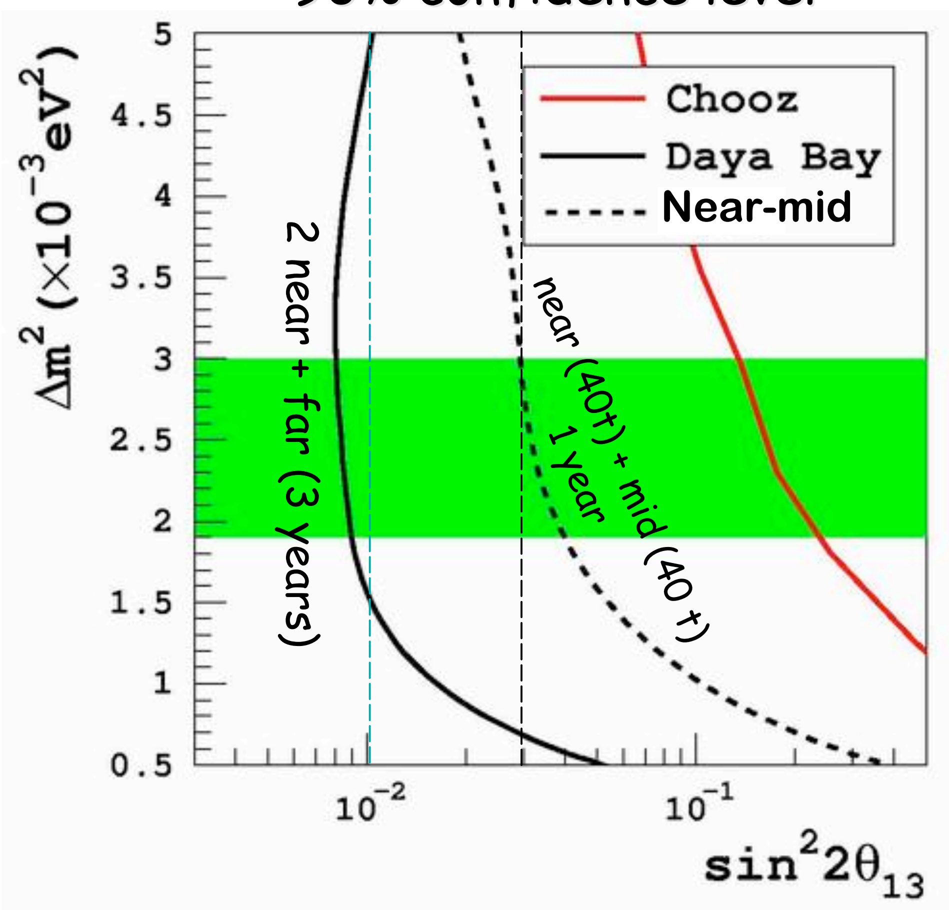
  0.36% (baseline)
  0.12% (goal)
  0.06% (with swapping)

- These are input to sensitivity calculations

Sensitivity of Daya Bay in $\sin^2 2\theta_{13}$



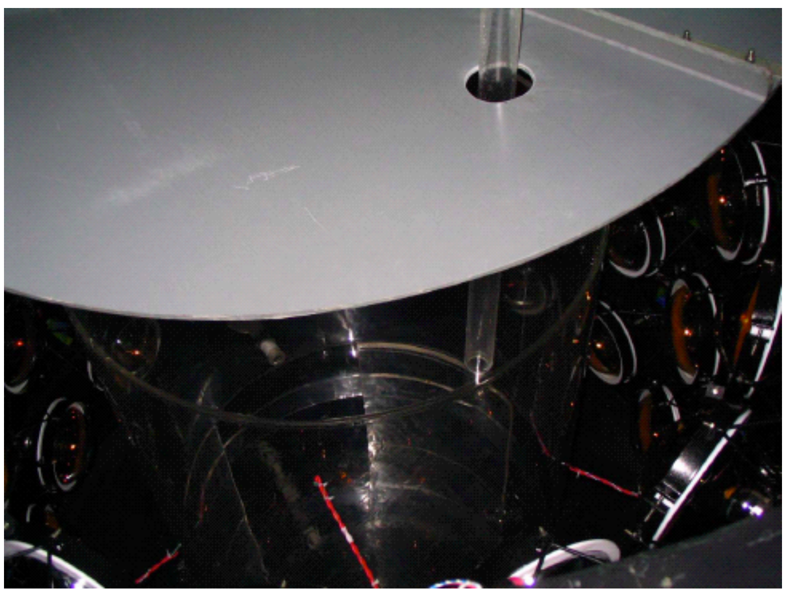
90% confidence level

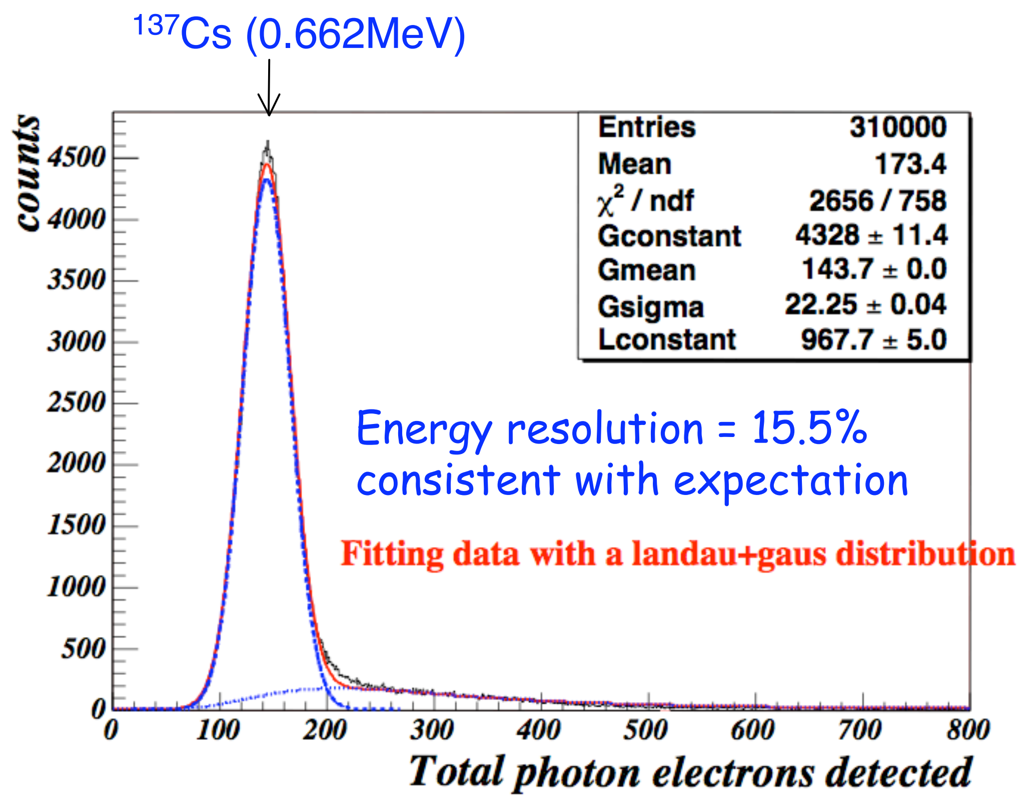


- Use rate and spectral shape
- input relative detector systematic error of 0.2%

Prototype at IHEP

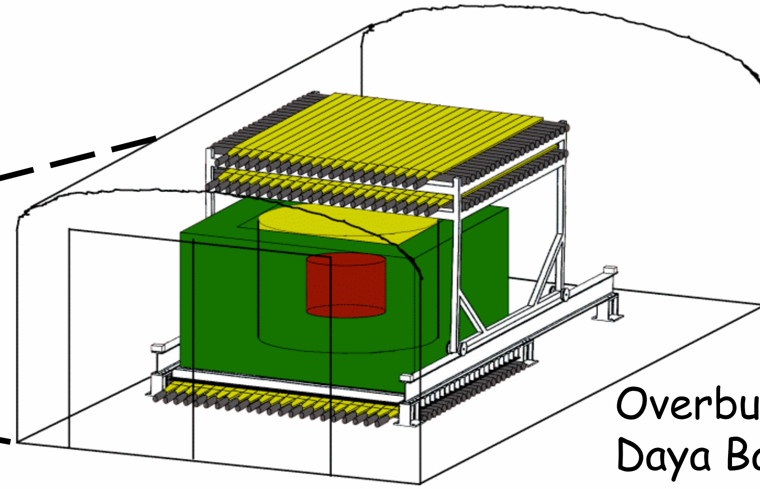
- Built a 2-layer prototype with 0.5 t (Gd-doped) LS enclosed in 5 t of mineral oil, and 40 8″ PMTs to evaluate design issues at IHEP, Beijing





The Aberdeen Tunnel Experiment

- Study cosmic muons & cosmogenic background in Aberdeen Tunnel, Hong Kong.



Overburden ~ Daya Bay sites

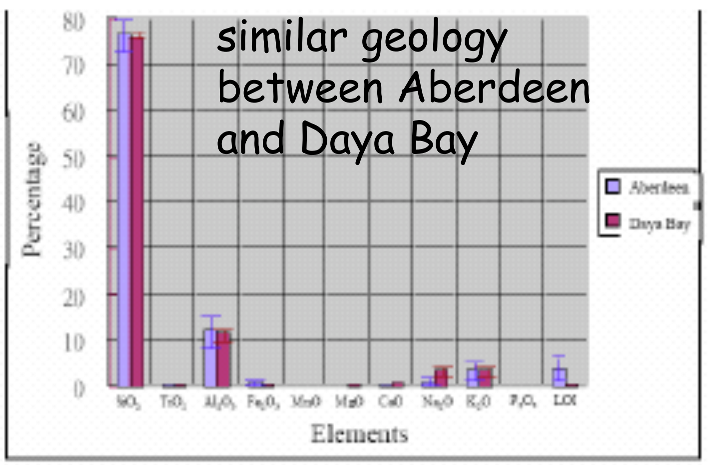


Fig. 1 A comparison of rock compositions at Daya Bay and Aberdeen.

Current Scope & Responsibility List by Country

WBS	Description	Majority Responsibility China	US
1	**Central Detector**	√	
	System design, steel vessels, unloaded LS, mineral oil,	√	
	readout electronics co-design, electronics mfg, safety	√	
	systems, racks, assembly & installation	√	
	Acrylic vessels, PMT's & support structure, Gd loaded LS,		√
	LS purification system, locomotion system, readout		√
	electronics co-design, cables, crates		√
2	**Veto Detector**		√
	System design, muon tracker system, supplemental water		√
	veto PMT's, muon tracker assy & test		√
	Water veto system hardware, compensation coils, readout	√	
	electronics mfg, safety syst, water veto assy & test	√	
3	**Calibration & Monitoring Systems**		√
	Automated deployment system & glove box, laser sources,		√
	monitoring system & system test		√
	Manual calibration sys & glovebox, LED sources, radioactive	√	
	calib. sources, low-background source & matls counting syst	√	

Scope & Responsibility List - Continued

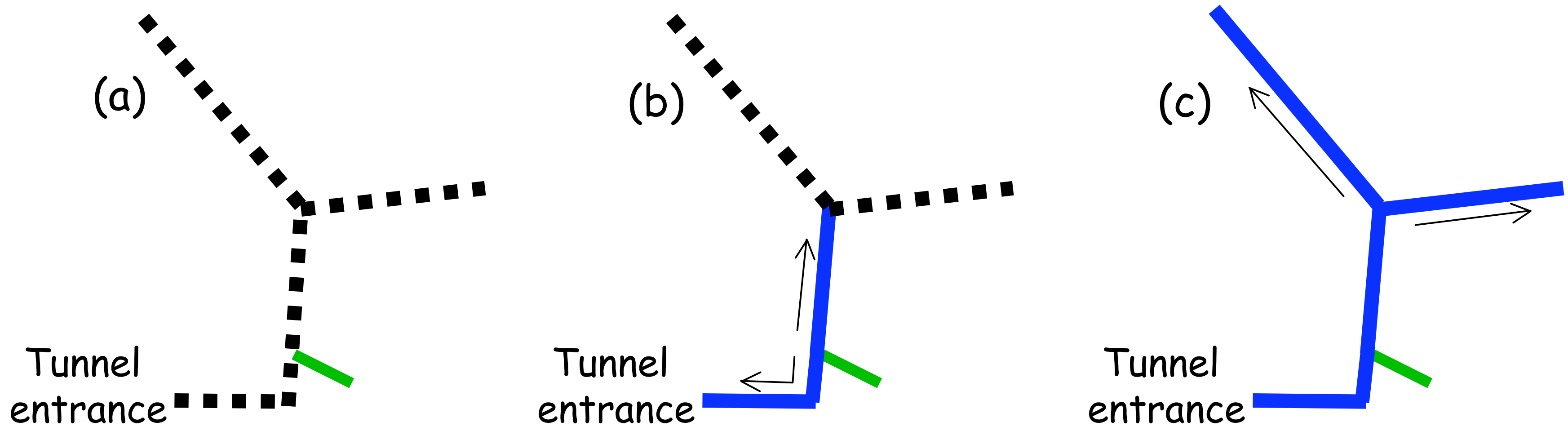
WBS	Description	Majority Responsibility China	US
4	**DAQ, Trigger, Online & Offline Hardware**	√	
	DAQ & trigger board co-design, board manufacture, racks,	√	
	monitoring & controls hardware, some on-line hardware	√	
	DAQ & trigger board co-design, crates, cables, on-line hardware		√
	off-line hardware & data archiving in US, system test platform		√
5	**DAQ, Trigger, Online & Offline Software**	√	√
	Overall software architecture, DAQ & trigger software,	shared	shared
	on-line & off-line software, simulations software	shared	shared
	Monitoring & controls software	√	
6	**Conventional Construction & Equipment**	√	
	Tunnels, entrances, experimental halls, underground utilities,	√	
	safety systems, surface facilities	√	
7	**System Integration**	√	√
8	**Project Management**	√	√

- Russia will contribute to liquid scintillator, calibration, and plastic scintillator
- Taiwan will contribute to the acrylic vessels and trigger electronics
- Hong Kong will contribute to calibration and data storage

Major Items of U.S. Project Scope

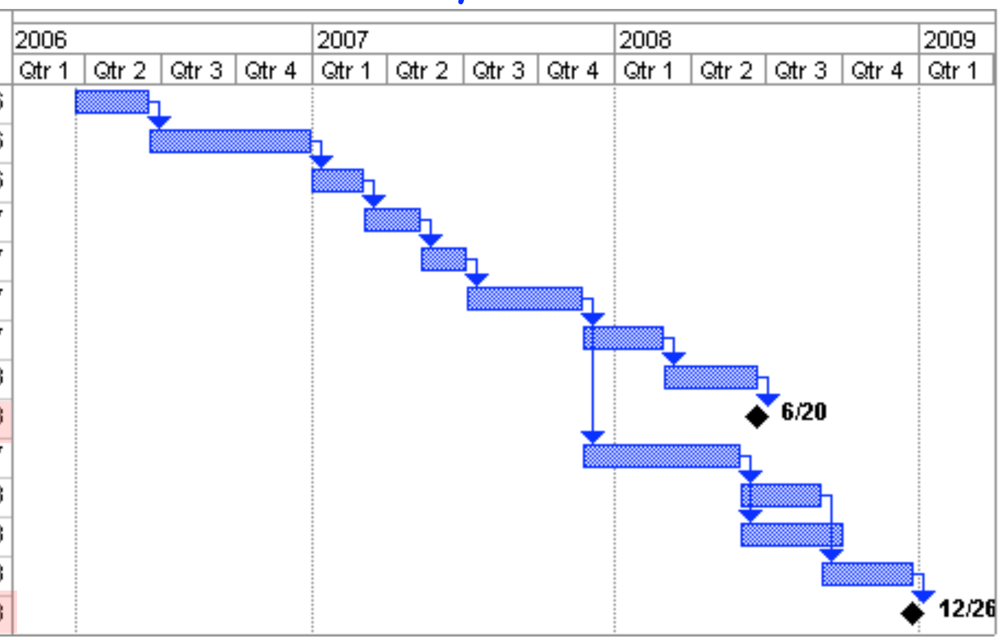
- Muon tracking system (veto system)
- Gd-loaded liquid scintillator
- Calibration systems
- PMT's, base's & control
- Design readout & trigger electronics
- Acrylic vessels (antineutrino detector)
- Other mechanical components
- Detector integration activities
- Project management activities

Prelim. Civil Construction Schedule



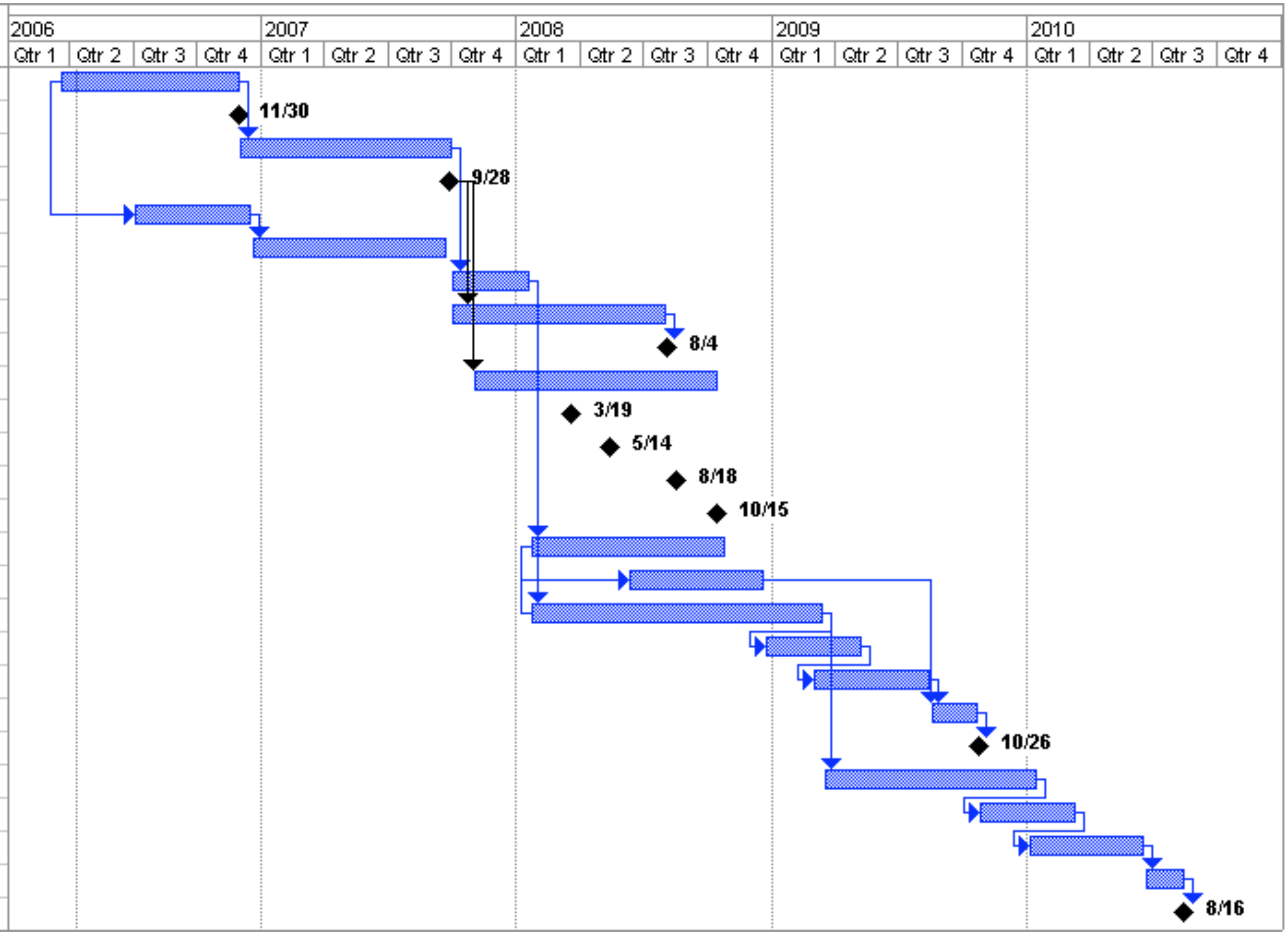
Based on preliminary study of civil construction by BINE in China

ID	Task Name	Duration	Start
1	Establish Prelim Specs for Civil Dsgn	65 days	Fri 3/17/06
2	Civil Design of tunnels & caverns	140 days	Fri 6/16/06
3	Select Civil Construction Firm	45 days	Fri 12/29/06
4	Mobilize Equipment & prep for constr.	50 days	Fri 3/2/07
5	Construct 200m waste removal tunnel	40 days	Fri 5/11/07
6	Tunnel to DayaBay Entr & Mid site (500m ea)	100 days	Fri 7/6/07
7	Construct D-B Near Hall & Mid Hall in Parallel	70 days	Fri 11/23/07
8	Install Utilites in D-B Near & Mid Hall in Parallel	80 days	Fri 2/29/08
9	D-B Near & Mid Halls Complete - Ready for Instal	1 day	Fri 6/20/08
10	Cont. Tunnel to L-A Near (700m) & Far Site (1000m)	135 days	Fri 11/23/07
11	Constuct Ling-Ao Near Hall	70 days	Fri 5/30/08
12	Construct Far Site Hall	90 days	Fri 5/30/08
13	Install Utilites in L-A Near & Far Hall in Parallel	80 days	Fri 9/5/08
14	L-A Near & Far Halls Complete - Ready for Instal.	1 day	Fri 12/26/08



Overall Project Schedule

ID	Task Name
1	Conceptual Dsgn & R&D Activities
2	CD-1 Approval
3	Preliminary Dsgn Activities
4	CD-2 Approval
5	Prototyping
6	System Test 1 (prototype elements)
7	Finalize Detail Dsgn & Prep for Construction
8	Procure, manuf. & ship Gd Loaded LS
9	Deliver Gd Loaded LS to Site
10	Contract & Procure PMT's & Bases (200 per mo)
11	PMT Delivery to China - 1
12	PMT Delivery to China - 2
13	PMT Delivery to China - 3
14	PMT Delivery to China - 4
15	Fab & Assemble Calibration Syst Elements
16	System Test 2 (w/ Prod. Elems while in US)
17	Construct Veto Syst Elem for D-B & Mid Cav
18	Crate & Ship Veto Elements to China -1
19	Assemble Veto Syst Elems in D-B & Mid Caverns
20	System Test 3 (in-situ in D-B & Mid Caverns)
21	Near 1 & Mid Sites Ready to Take Data
22	Construct Veto Syst Elem for Near2 & Far Cav
23	Crate & Ship Veto Elements to China -2
24	Assemble Veto Syst Elems in L-A & Far Caverns
25	System Test 4 (in-situ in L-A & Far Caverns)
26	Near 2 & Far Sites Ready to Take Data



Project Development

- Schedule/activities over next several months:

Determine scale of detector for sizing halls:	now – June
Continue building strong U.S. team - key people:	now – summer
Conceptual design, scale & technology choices:	now – Aug
Firm up U.S. scope, schedule & cost range:	July – Nov
Write CDR, prepare for CD-1 revew:	Aug – Nov

Funding Profile

FY08	U.S. Construction	$10M
FY09		$14M
FY10		$ 8M

CD-1 review in U.S.	November 2006
Begin construction in China	March 2007
CD-2 review in U.S.	September 2007
Begin data collection	January 2010
Measure $\sin^2 2\theta_{13}$ to ≤ 0.01	March 2013

Synergy Between Reactor and Accelerator Experiments

Before 2011: Daya Bay provides basis for early decision on future program beyond NOνA for CP and mass hierarchy

After 2011: Daya Bay will complement NOνA and T2K for resolving θ_{23}, mass hierarchy, and CP phase

Summary

- The Daya Bay nuclear power facility in China and the mountainous topology in the vicinity offer an excellent opportunity for carrying out a reactor neutrino program using horizontal tunnels.
- The Daya Bay experiment has excellent potential to reach a sensitivity of ≤ 0.01 for $\sin^2 2\theta_{13}$.
- The Daya Bay Collaboration continues to grow. International working groups with U.S.-China co-leadership have been established.
- Will complete preliminary design of detectors and detailed design of tunnels and underground facilities in 2006.
- Plan to start with the Fast Deployment scheme in 2009, and begin full operation in 2010.