High precision measurement of θ_{13}:

Progress of Daya Bay reactor antineutrino experiment

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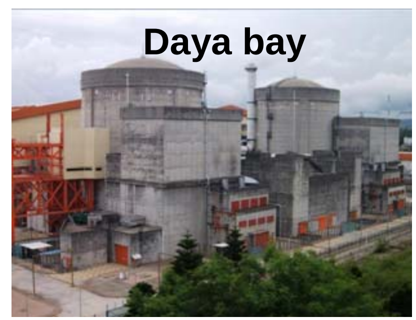
On behalf of Daya Bay collaboration

NuFact'11, 1st~6th, Aug., Geneva

Daya Bay, China

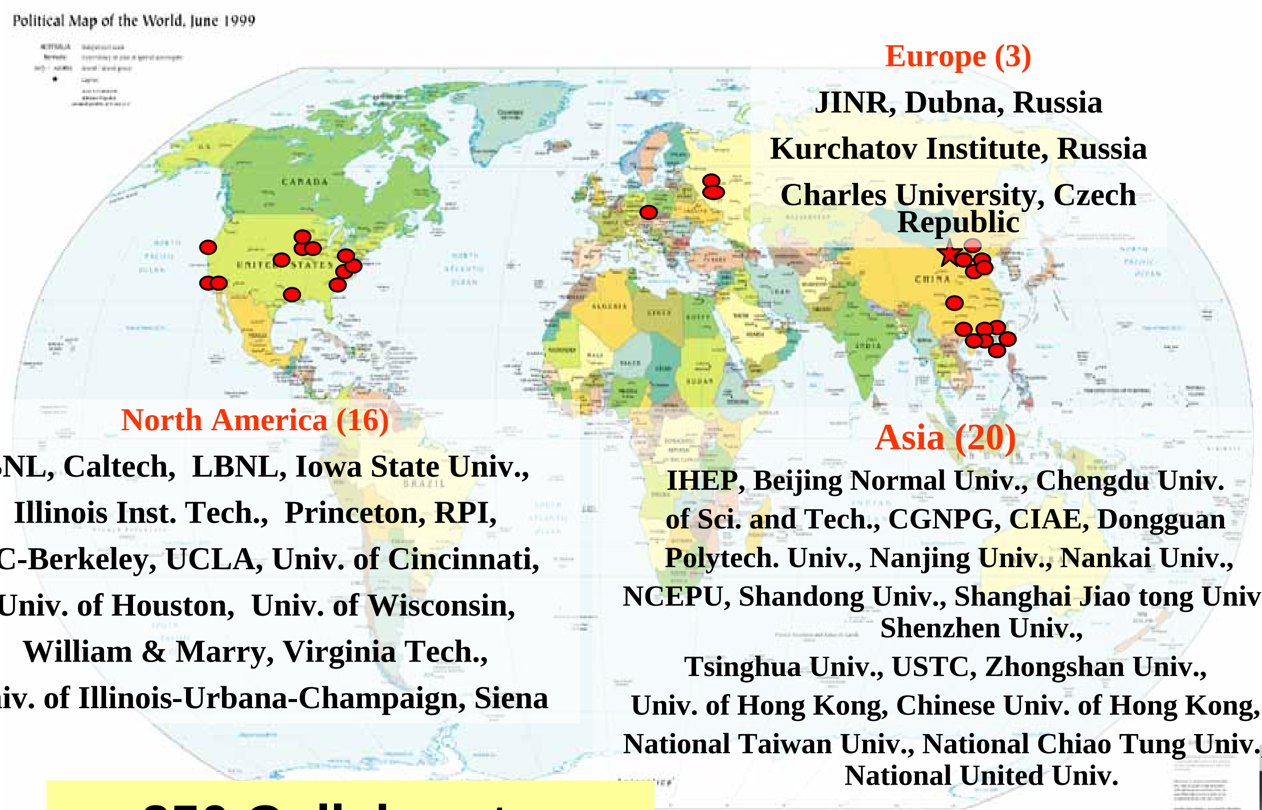
Southern China



- Very powerful nuclear power complex:
  - Daya Bay: 2 X 2.9GW
  - Ling Ao I: 2 X 2.9GW
  - Ling Ao II: 2 X 2.9GW (will be online 2011)

~17.4GW

The Daya Bay collaboration



Europe (3)

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

North America (16)

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

Asia (20)

IHEP, Beijing Normal Univ., Chengdu Univ. of Sci. and Tech., CGNPG, CIAE, Dongguan Polytech. Univ., Nanjing Univ., Nankai Univ., NCEPU, Shandong Univ., Shanghai Jiao tong 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.

~250 Collaborators

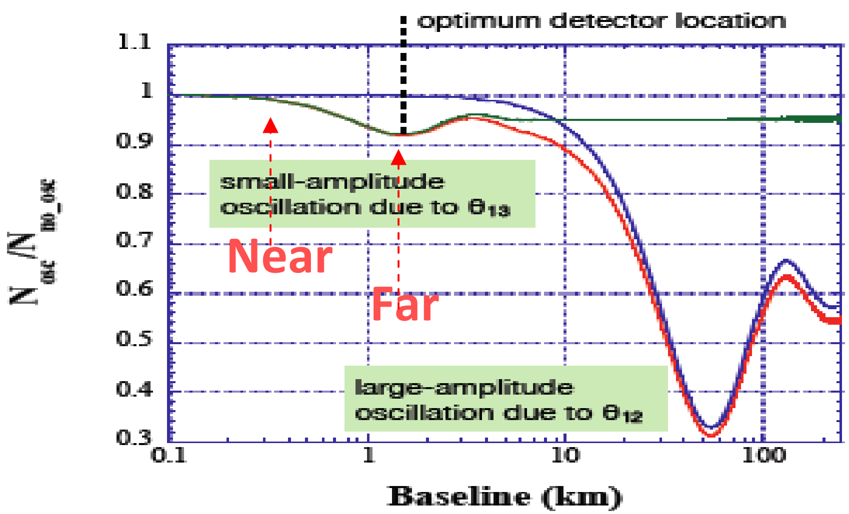
Outline

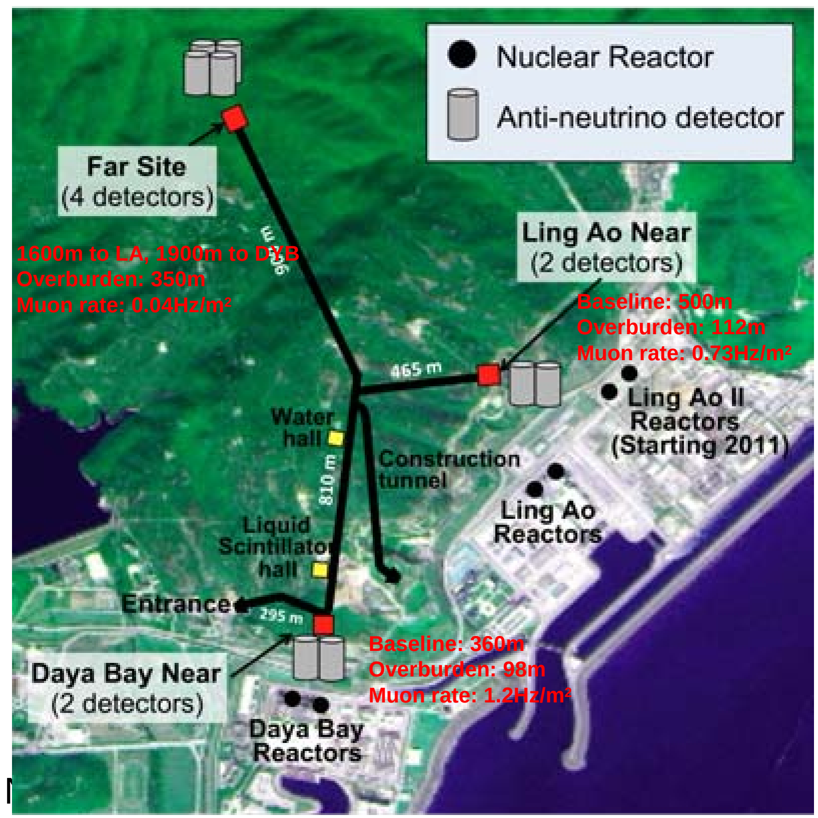
- Goal
- Daya Bay detectors
- Assembly & Installation & Test
- Current status & Schedule

Goals

- Daya Bay's goal:
  - Precision measurement of θ_{13} (if it's large)
  - Best sensitivity to θ_{13} (if it's small)

Reactor neutrinos:
✓ Clean signal
✓ No CP violation
✓ Negligible matter effects
✓ Free neutrinos!





Systematic uncertainties

- **Few key factors for systematic uncertainties control:**
  - Near-Far measurement
  - Identical Antineutrino detectors
  - Overburden
  - Active/passive multi Muon veto
  - Detector swapping (optional)

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%

arXiv:hep-ex/0701029v1 CDR

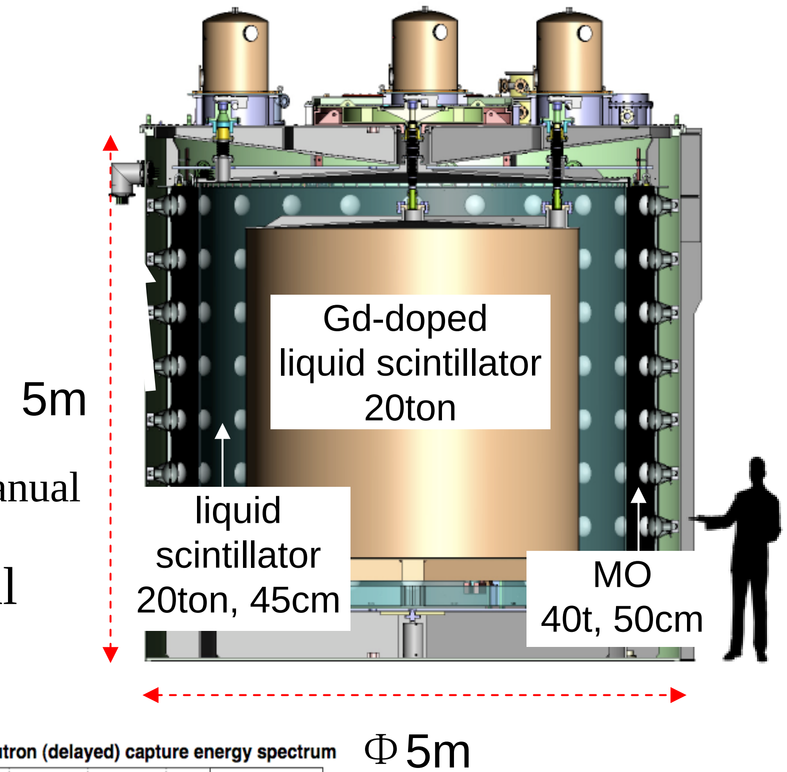
Expt.	Thermal Power (GW)	Target mass Near/Far (tons)	Baseline Near/Far (Km)	Overburden Near/Far (m.w.e)	Signal rates Near/Far (per day)	Sensitivity to $\sin^2 2\theta_{13}$ 90% C.L. 3years
Double Chooz	4.25×2 8.5	8.2/8.2	*0.4/1.05*	*120/300*	*400/50*	*0.03*
RENO	2.73×6 16.4	16/16	*0.29/1.38*	*120/440*	*1280/114*	*0.02*
Daya Bay	2.9×6 17.4	40,40/80	*0.36, 0.48 /1.99, 1.62*	*255, 290/910*	*840, 740 /90*	*0.008*

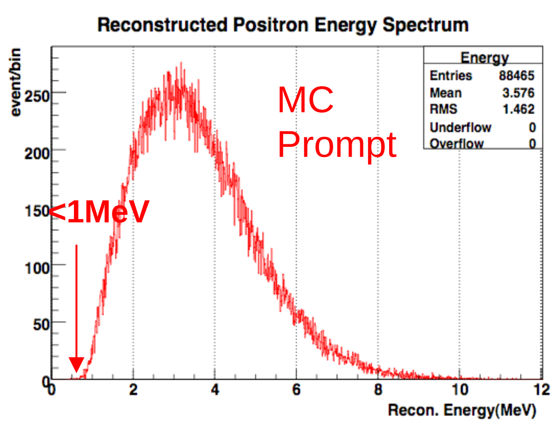
Daya Bay, NuFact'11

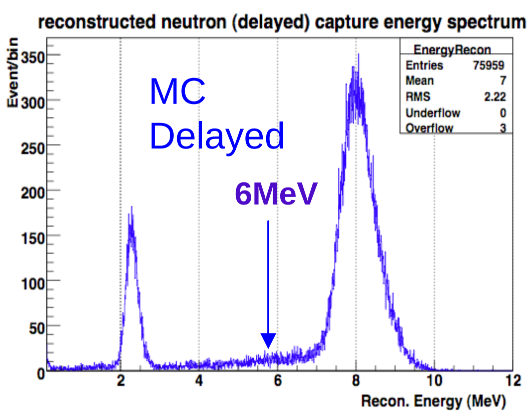
Numbers from A. Cabrera (DC) and K. K. Joo (RENO)'s talks in NEUTRINO 2010

Antineutrino Detector (AD)

- 8 "identical", 3-zone detectors in 3 experimental halls
  - 20t GdLS, 20t LS, 40t MO, separated by Acrylic Vessels
  - 192 8" PMTs in 8 rings, top and bottom reflectors
  - Precise target mass control
  - Low background
  - Low charge threshold
  - High precise calibration: auto scan and manual calibration
- No position reconstruction, no fiducial cut needed



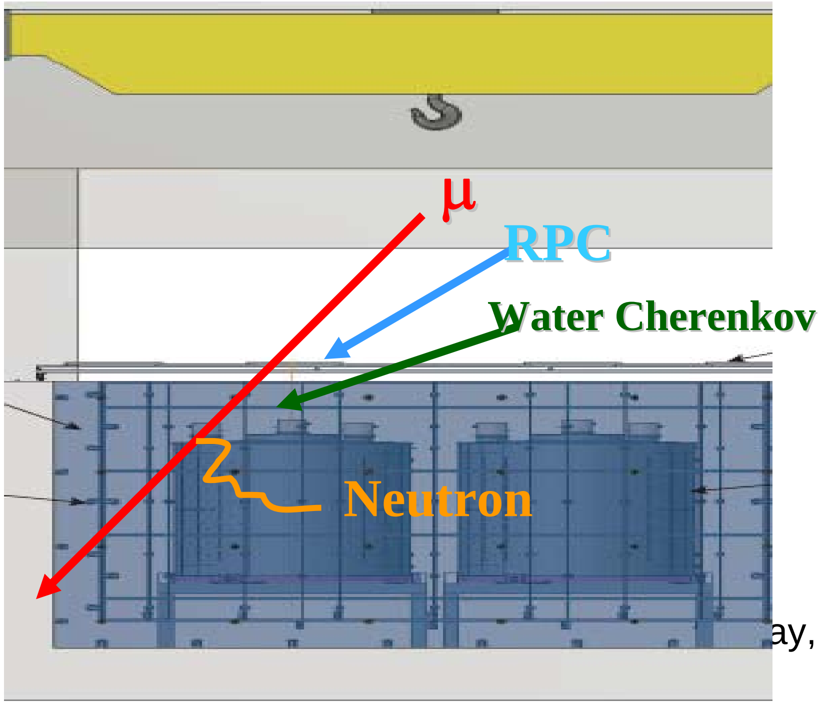




Neutron capture time on 0.1% GdLS ~28us

Muon veto detectors

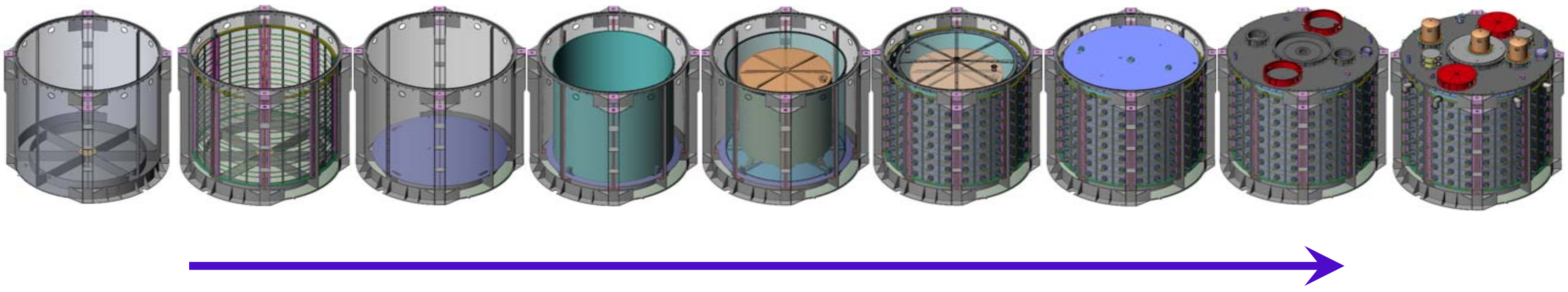
- Multi Muon Veto detectors:
  - Active and passive Muon detectors
  - Two layers water Cherenkov detector
  - RPC detector on top
- Redundant veto system = highly efficient Muon rejection
  - ε > (99.5 +/- 0.25)%



- Water Cherenkov
  - Passive shielding against radioactivity and neutron at least ~2.5m,
  - Two layers optically separated by Tyvek
- RPC on top
  - 4 layers: X or Y strip direction of each layer
  - Independent Muon tagging
  - Retractable roof above pool

AD assembly

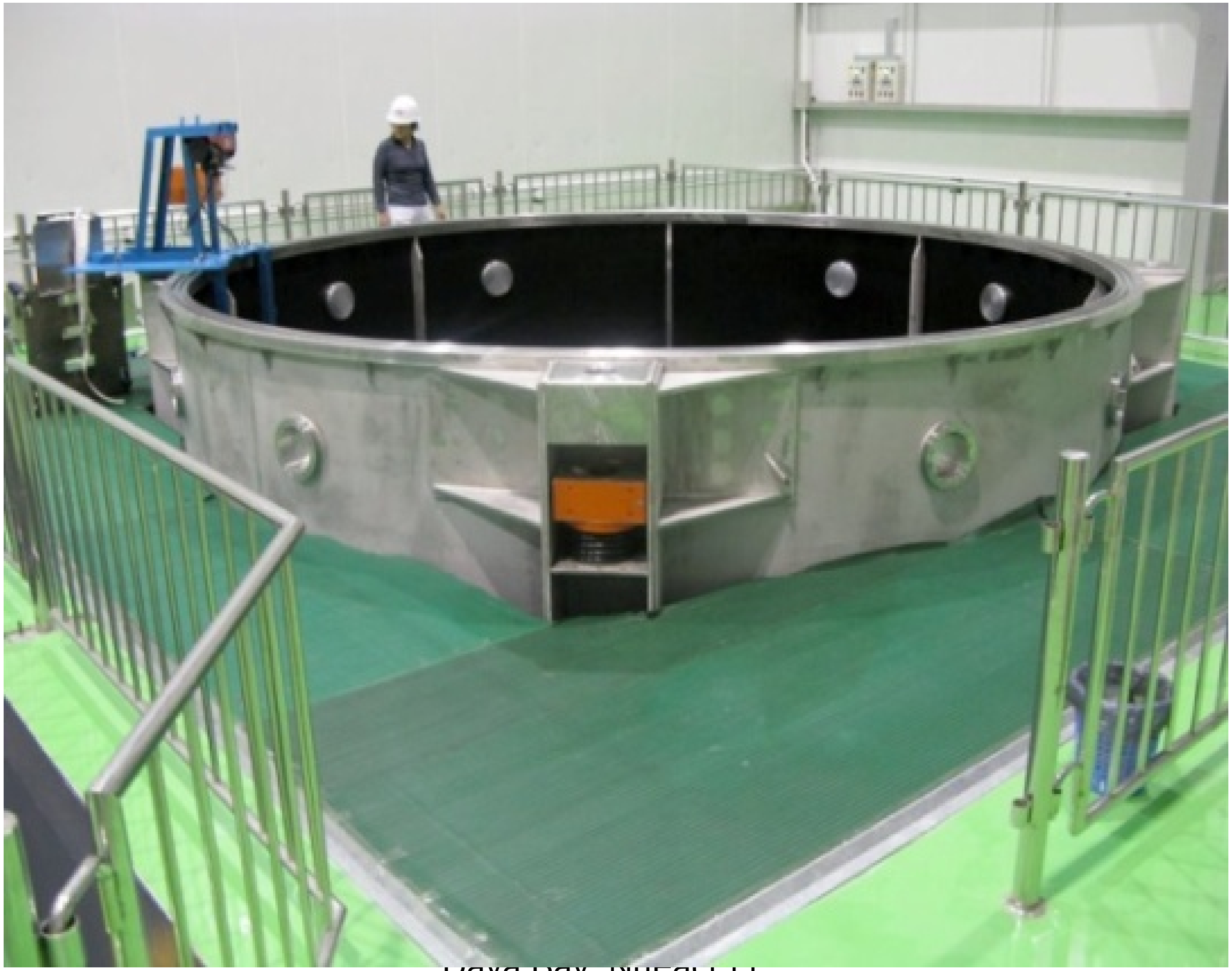
- The assembly of 2 pairs of ADs has been finished at **S**urface **A**ssembly **B**uilding (SAB) of Daya Bay; the 3rd pair is being assembled.
  - Installation in Clean room
  - Leakage check for all the flanges
  - Hardware test after installation: Dry run (results show later)



Move SSV

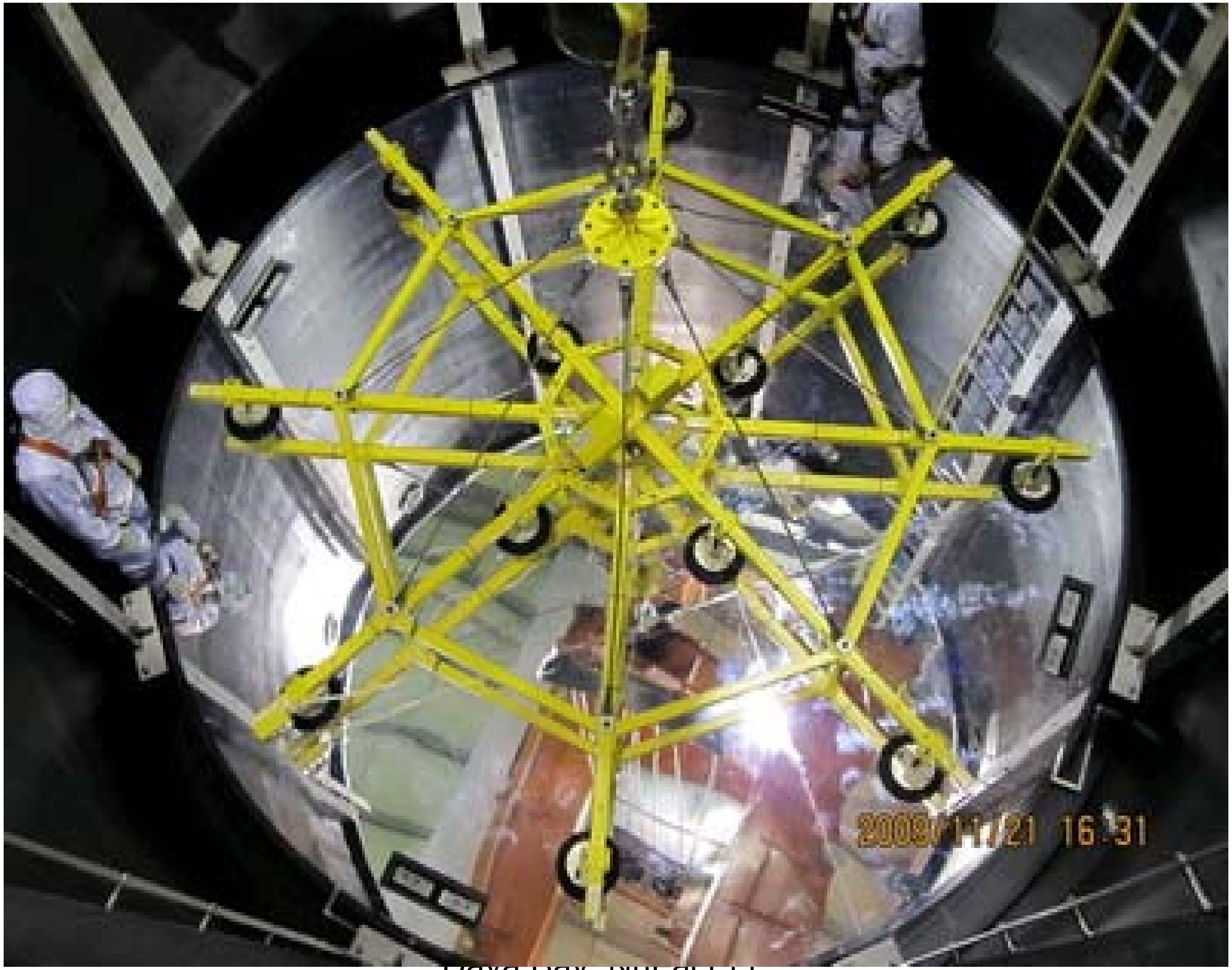
(Stainless Steel Vessel, Φ5m)

SSV sits in pit



Clean SSV inside

Insert bottom reflector

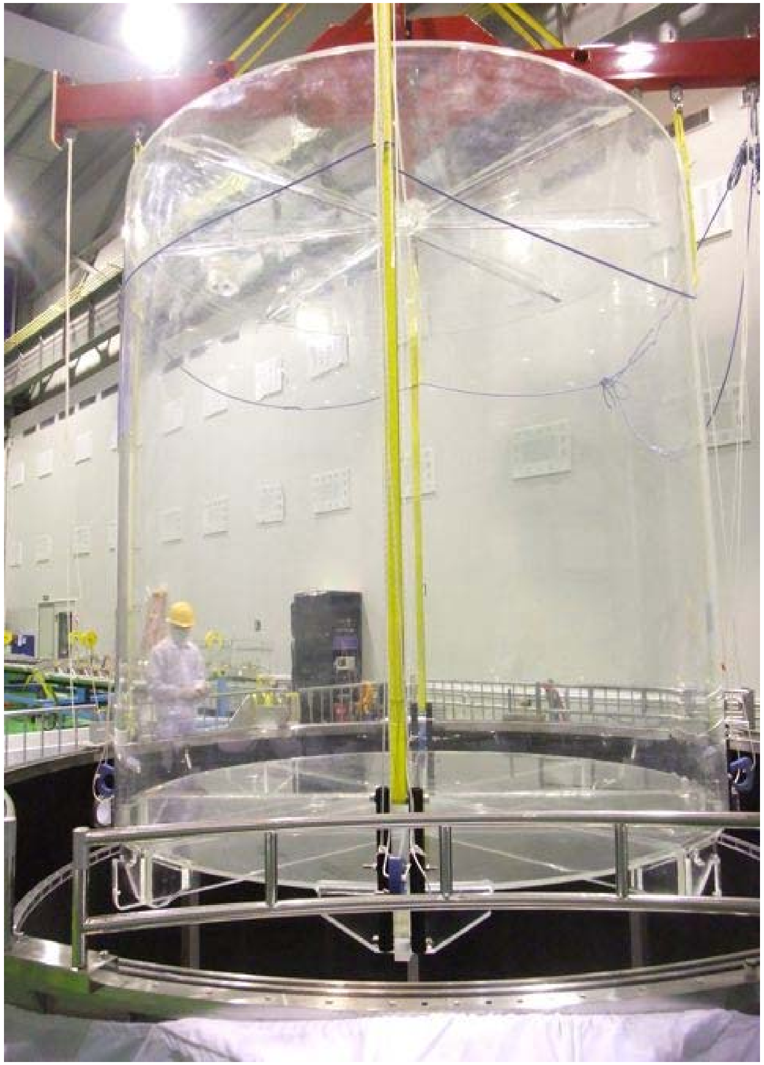


Insert outer AV

(Acrylic Vessel, Φ4m)

Insert inner AV

(Φ3m)

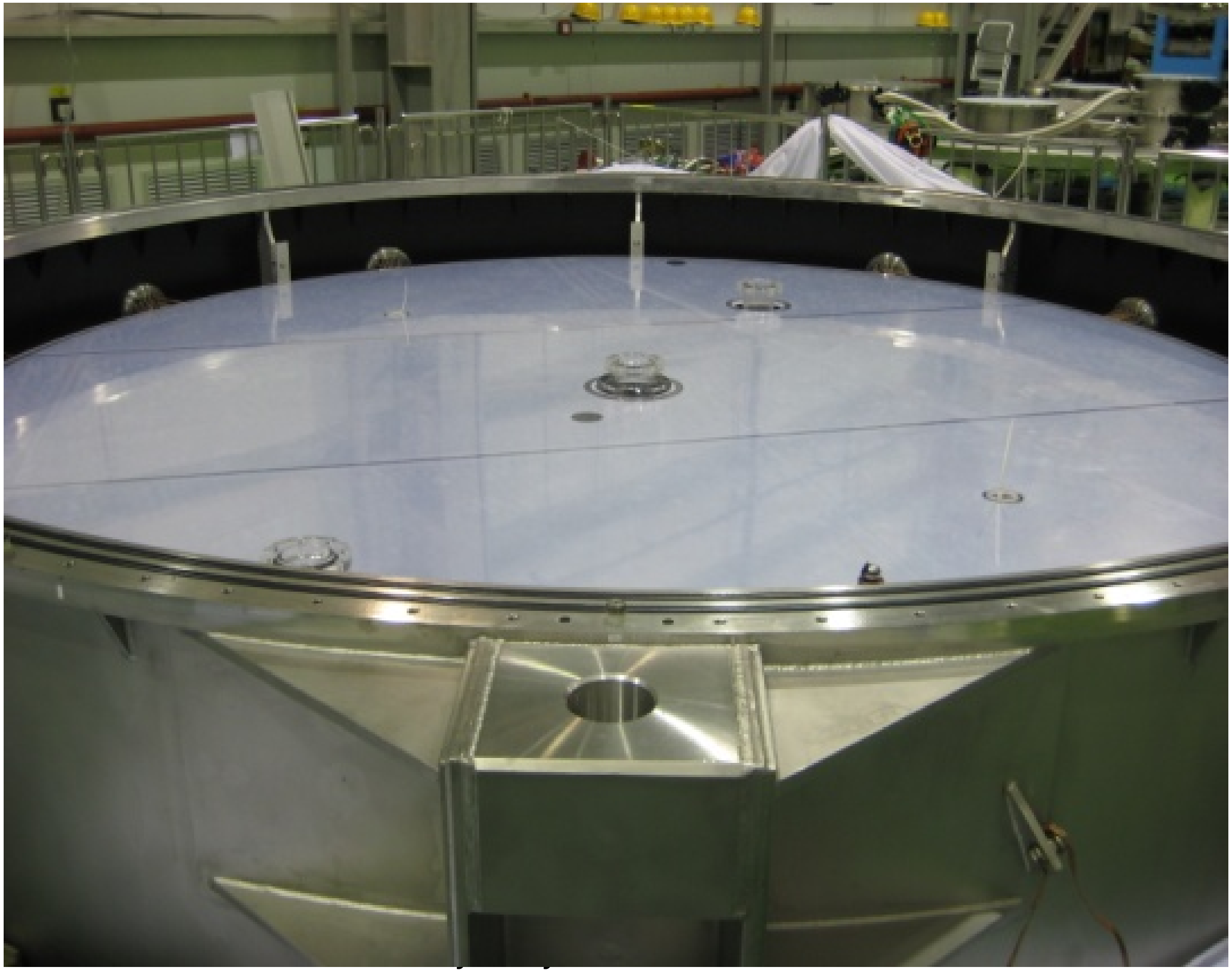


Close outer AV lid

Lift PMT ladder

(Photo Multiplicity Tube)

Install top reflector



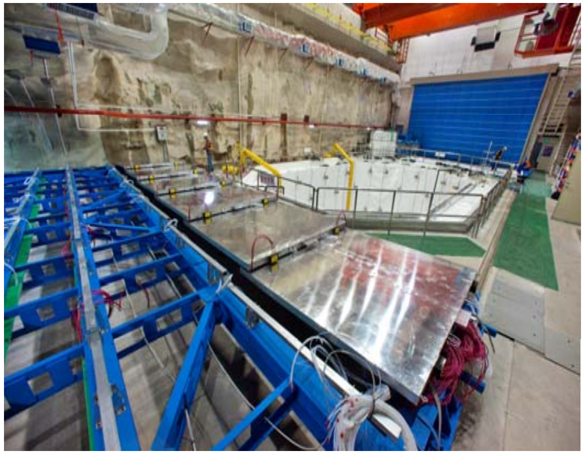
Close SSV lid

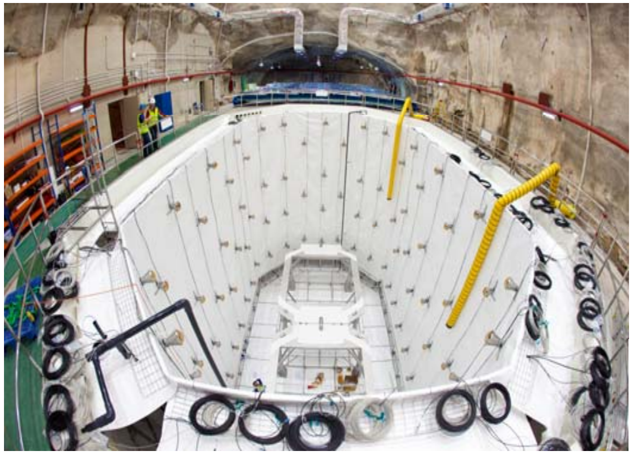
Install ACUs

(Auto Calibration Unit)

Daya Bay near Hall Installation

RPC

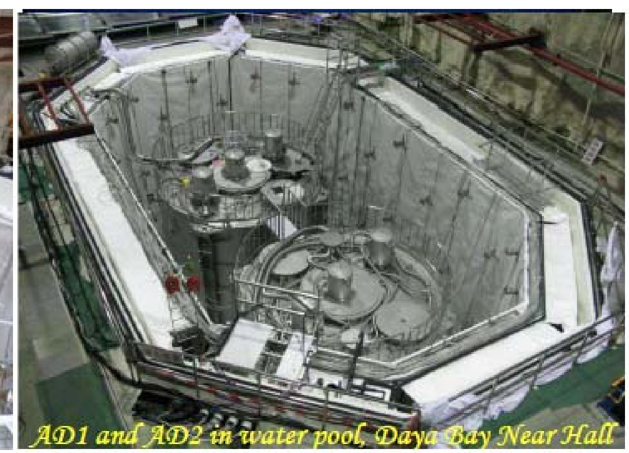




Water pool

Daya Bay near hall

- 1st pair of ADs has been put into the pool
  - Doing final installation
  - Water filling



AD#1

AD#2

Online / slow control system ready Daya Bay near hall

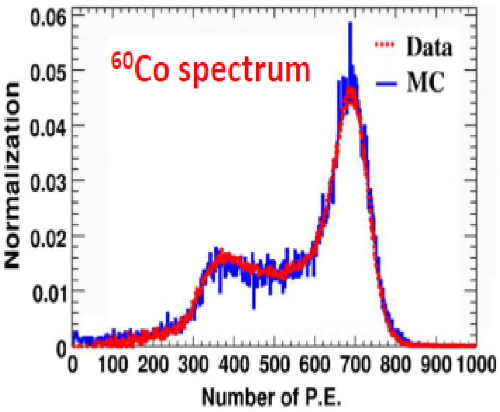
- Online system ready
  - GPS clock system: uniform clock and time stamp for all the subsystems
  - Master trigger board for cross trigger (MTB)
  - Local trigger board for event trigger (LTB)
  - Front End Electronics (FEE): precise charge and relative hit time measurements
  - RPC electronics
  - DAQ
- Slow control working

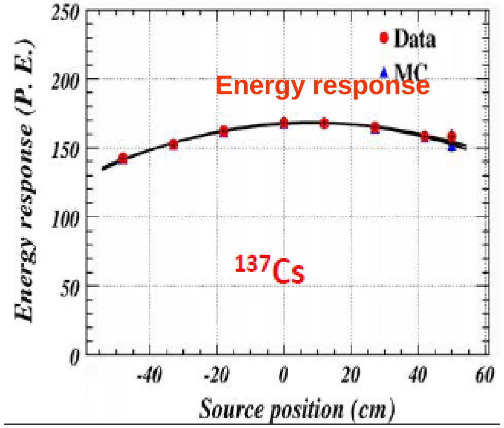
Installed electronics for Daya Bay near hall

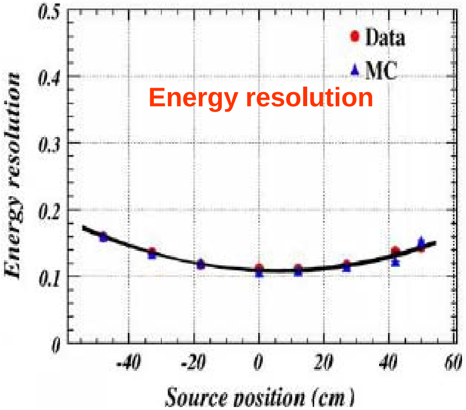
AD Prototype (Beijing)

- **2005. Jan ~ 2008. Sept.**
  - Validate detector design principle
  - Geant4 simulation
  - GdLS study: Long term stability
  - Effects of reflectors
  - Reconstruction algorithm
  - Gamma and neutron response: PuC tagged neutron
  - Electronics development / system commissioning

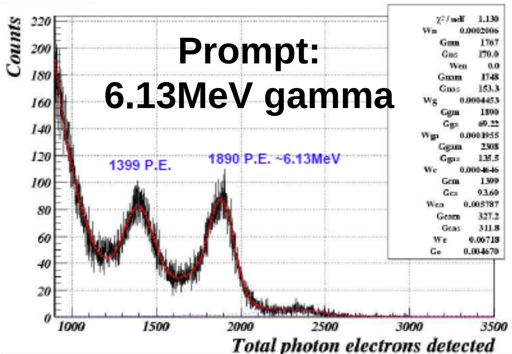
Data comparison with MC

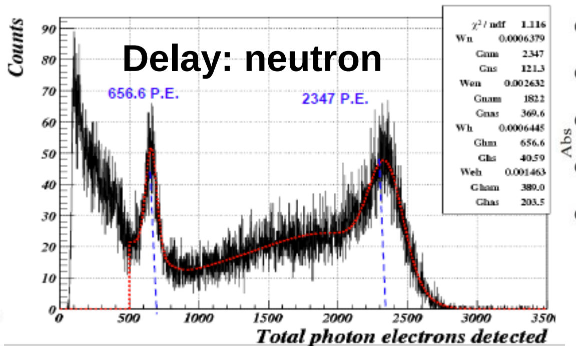


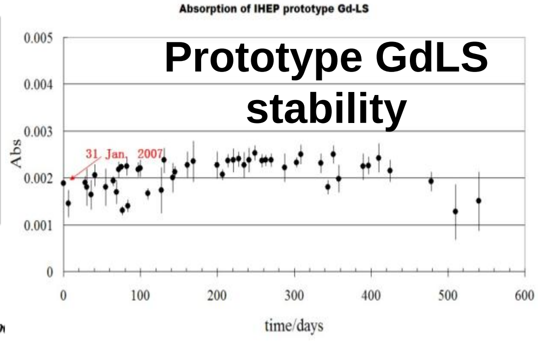




Plutonium-Carbon neutron source

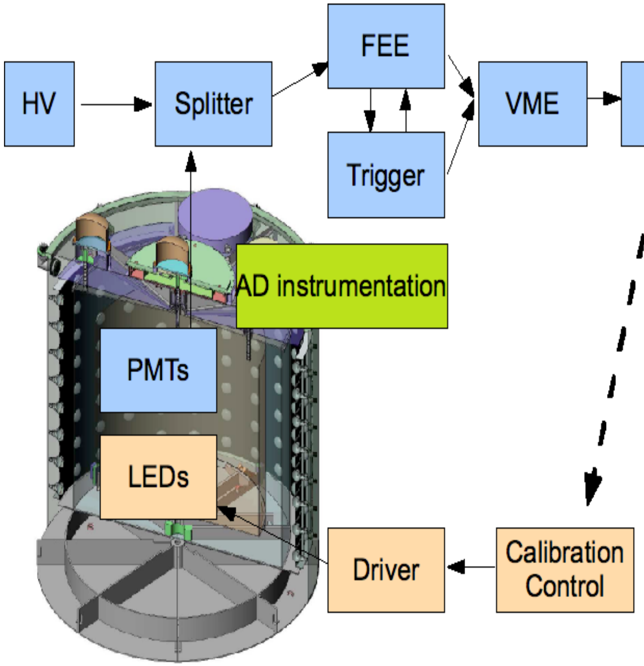


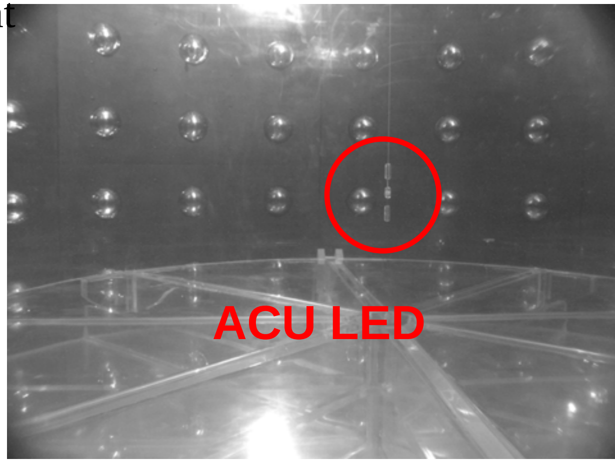


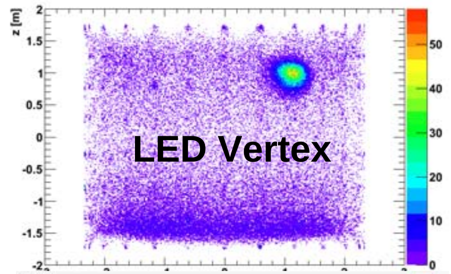


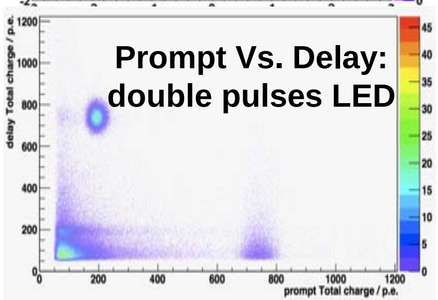
AD Dry run (Daya Bay)

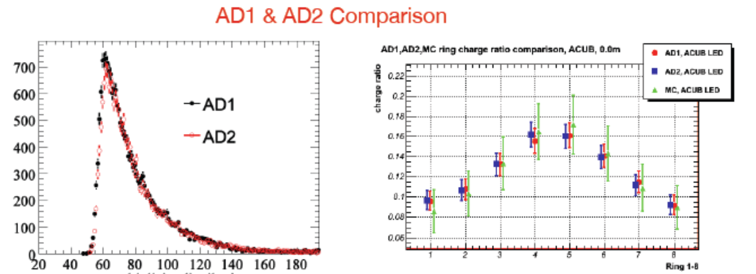
- All the subsystems test for Antineutrino Detector except liquid scintillator
- Goals:
  - Check hardware status for installation
  - System commissioning/debug, software/analysis development
  - Detector/Auto Calibration Units test
  - Detector identical study: differ <1%, and consistent with MC

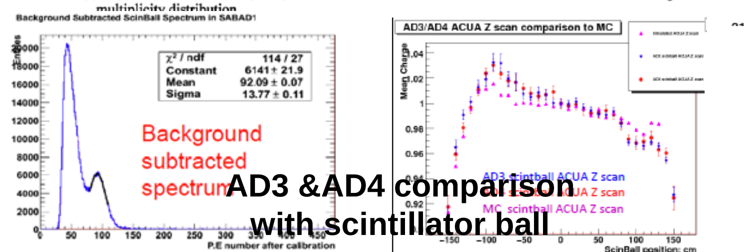






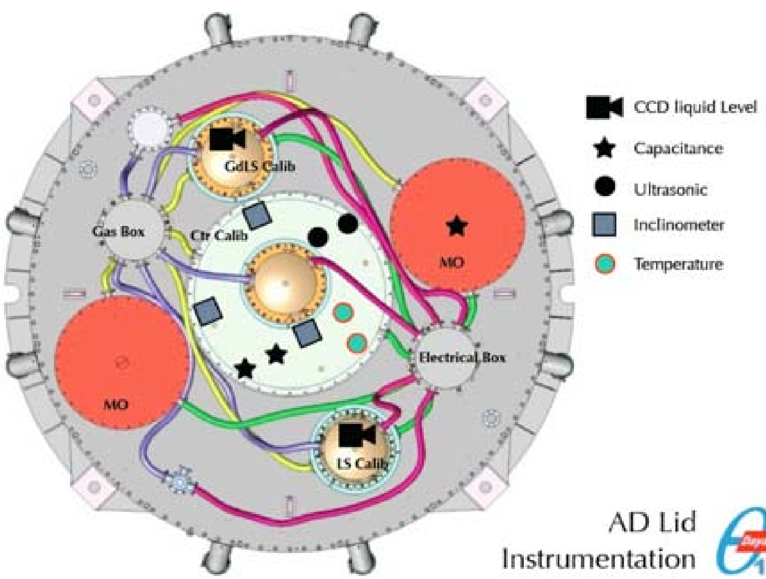




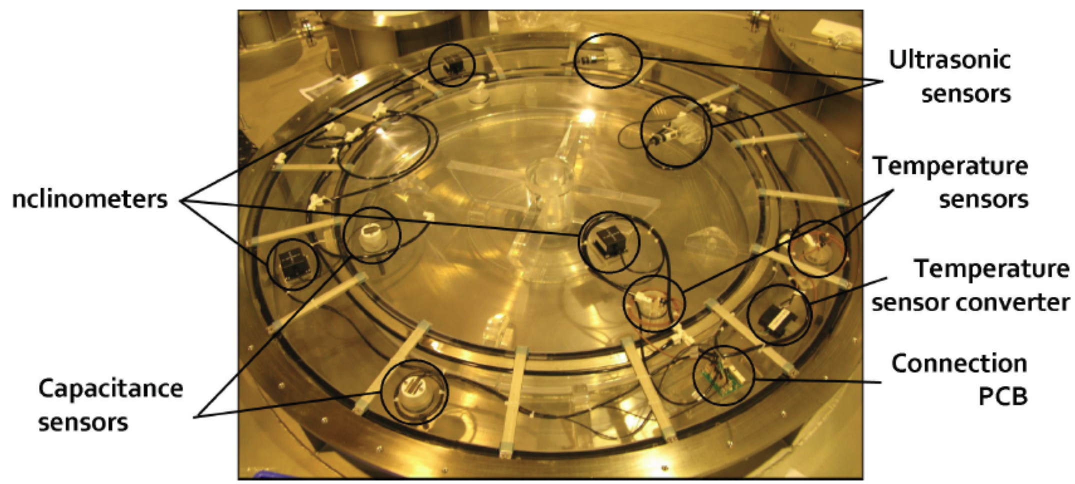


AD sensors

- To monitor:
  - Detector status, precise target mass
- The sensors:
  - 4 mineral oil temperature sensors at different depth
  - 2 Cameras for vision check after lid final closed
  - Lid sensors for temperature, tilt level, and liquid level of GdLS and LS by ultrasonic, capacitance, CCD etc



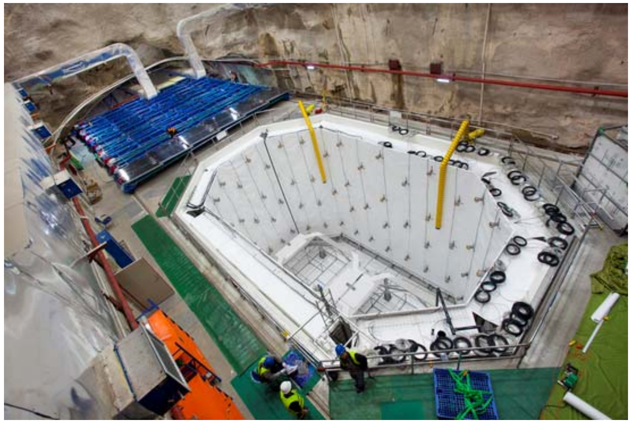
AD Lid Instrumentation

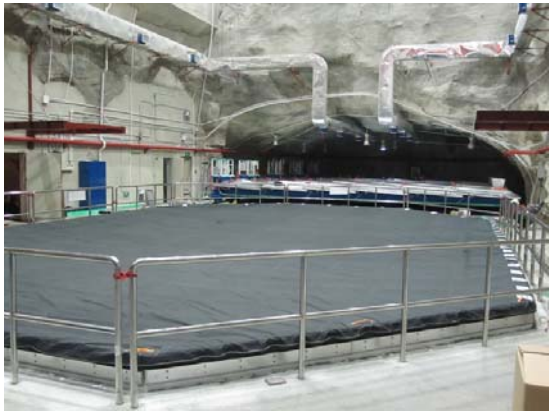


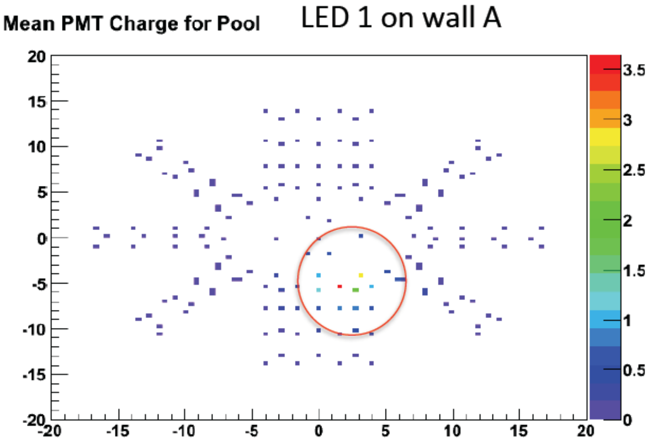
Installed sensors in central overflow tank

Dry water pool test (Daya Bay near hall)

- Goals:
  - Check the hard ware status
  - LED calibration system
  - Cover light tightness
  - Basic detector performances

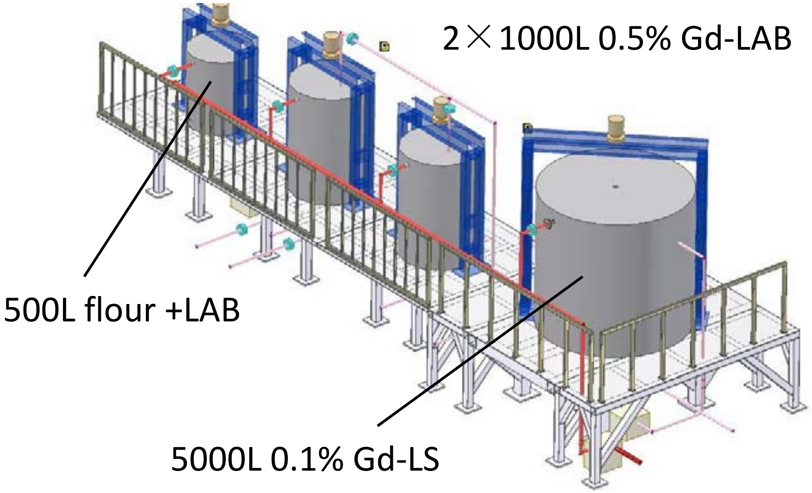


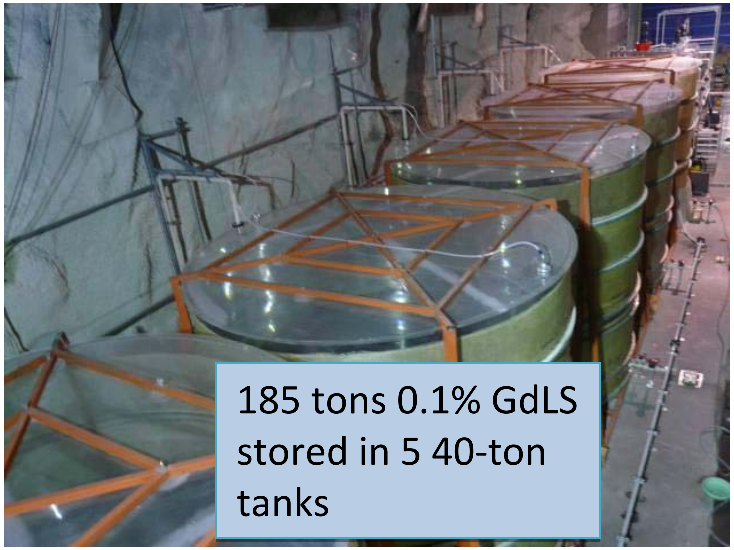




GdLS/LS production

- All the Gd-LS and LS for the experiment have been mixed and stored

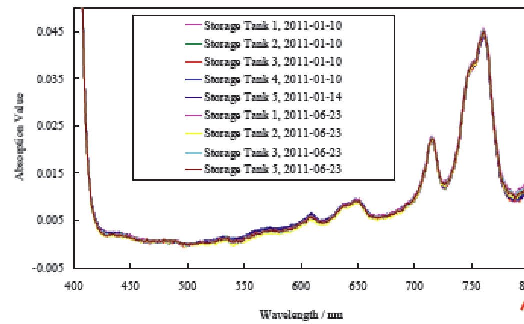




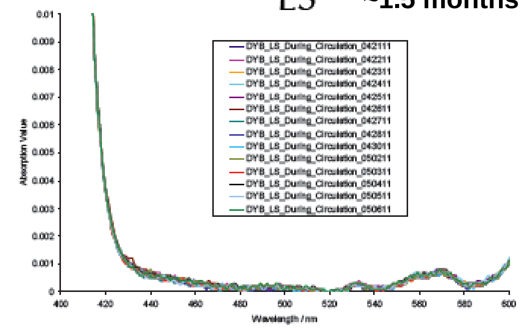
GdLS/LS properties

❖ The liquid properties have been stable so far

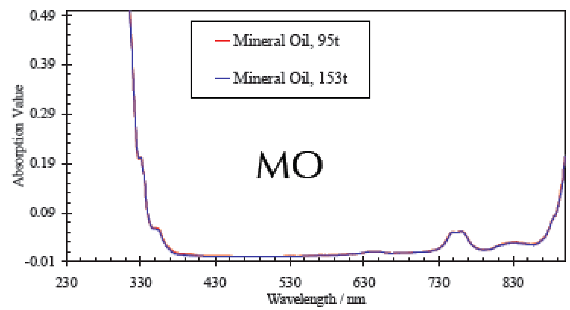
Gd-LS ~5 months



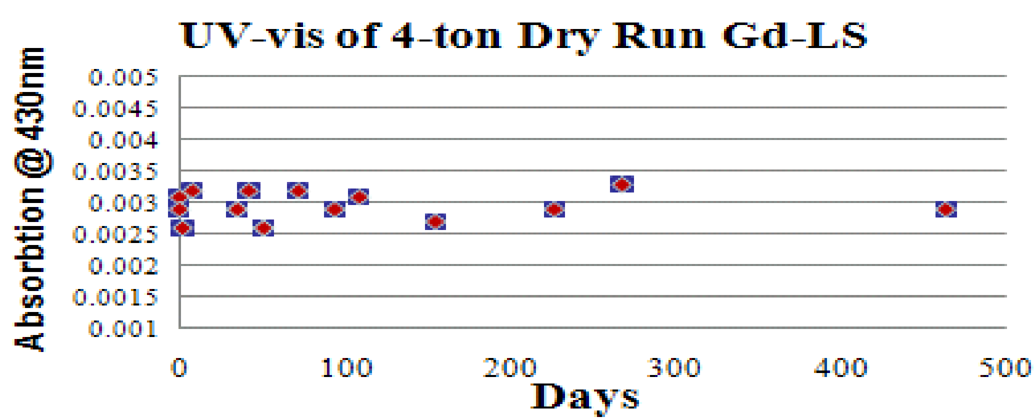
LS ~1.5 months



Preliminary



Absorption monitoring

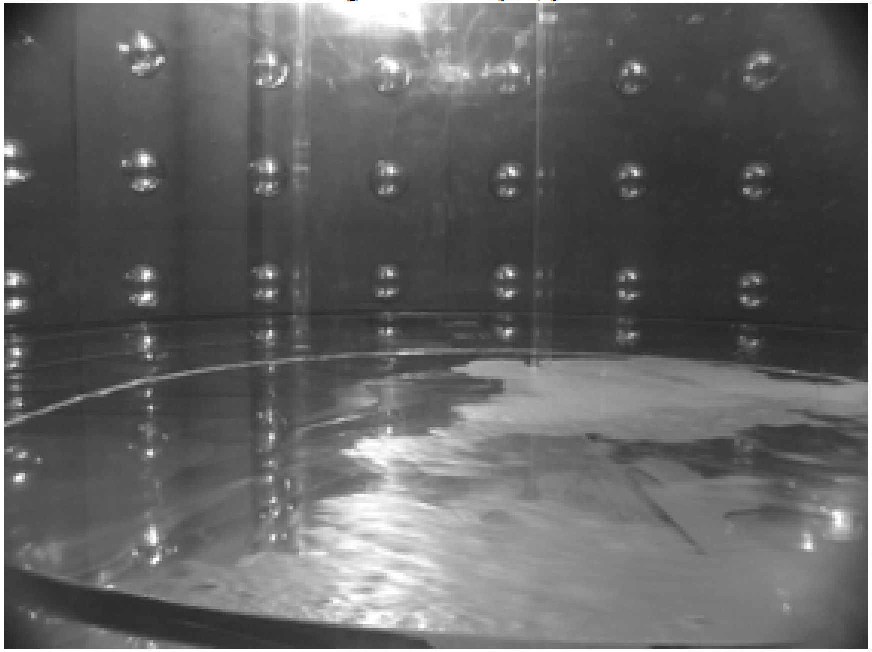


GdLS/LS filling

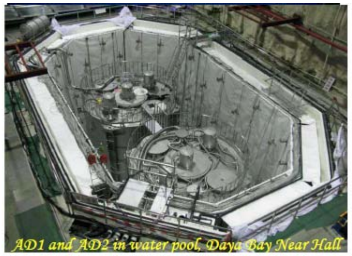
- 1st pair of ADs has been filled till now, preparing for 2nd pair
  - Auto liquid level control
  - Precise target mass control

Coriolis mass flowmeters < 0.1%

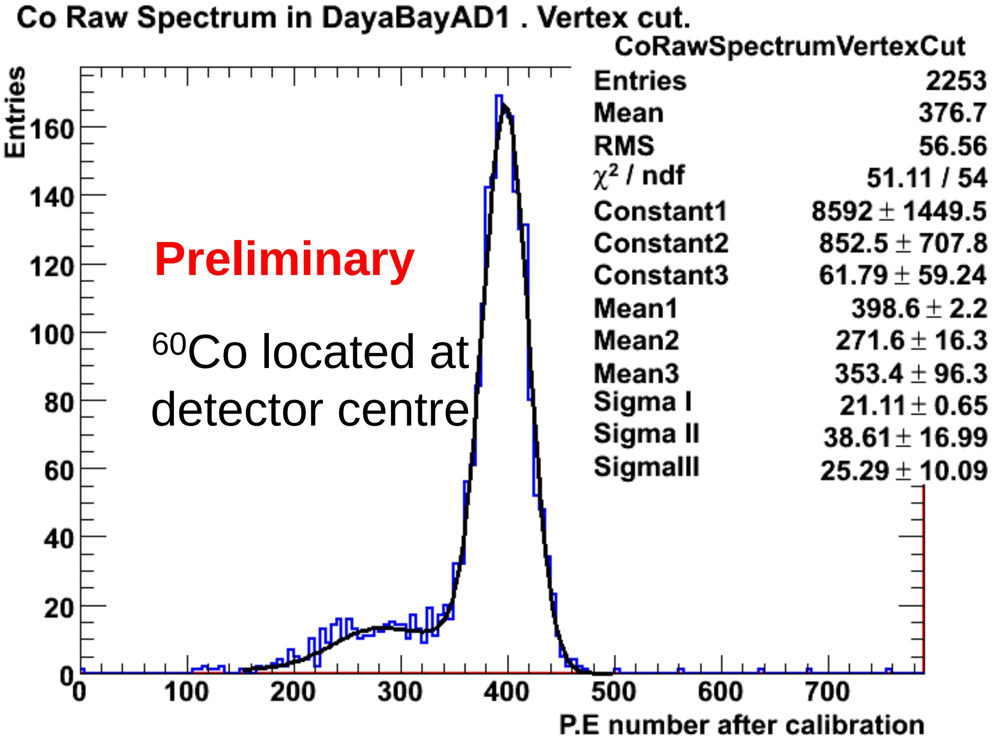
load cell accuracy < 0.02%



Response of filled AD



- After the installation of filled AD#1 to Daya Bay near hall without water in pool, a short test was taken to check the detector response;
- The plot shows the measured charge spectrum with ^{60}Co located at detector centre;
- All the systems working properly: detector, scintillator, online, slow control, and offline analysis



Schedule

Daya Bay near hall

Water filling now

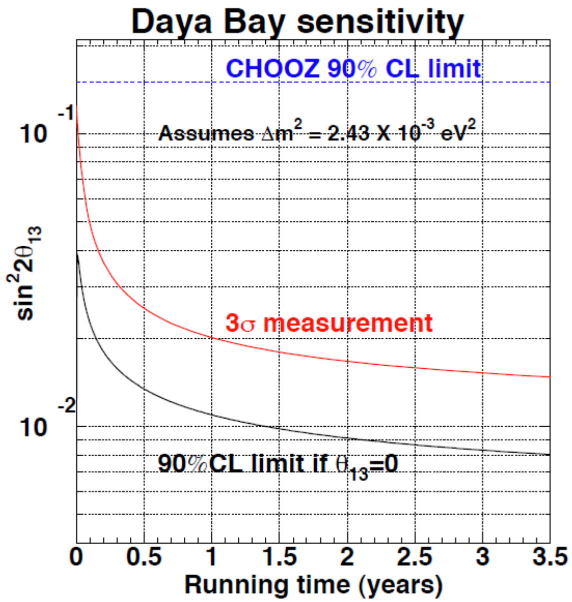
Ling Ao near hall

Muon pool Tyvek and PMTs being installed

Far hall

Completing facilities installation

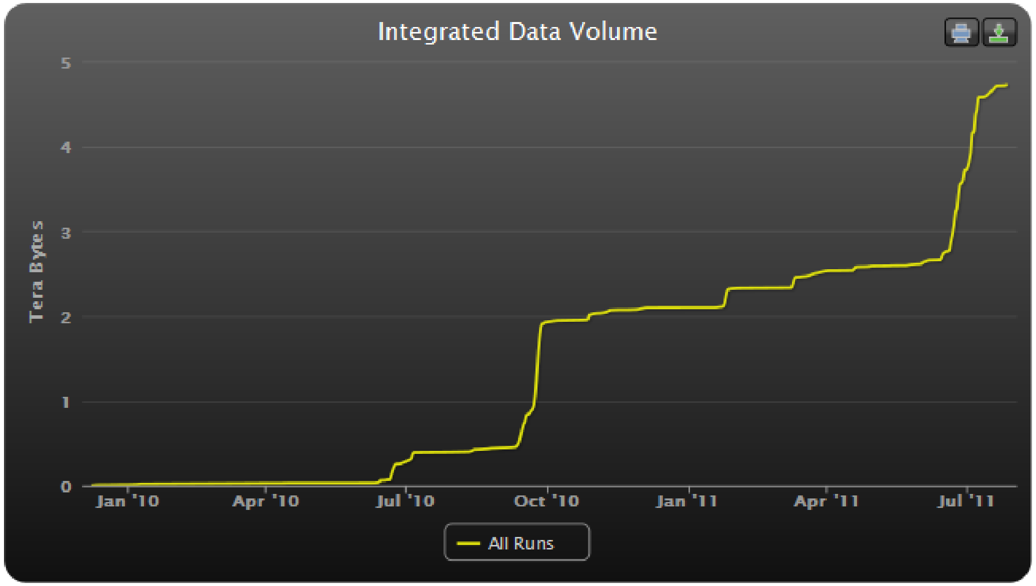
- Smooth progress: Daya Bay near hall
  - 1st filled pair of ADs fully completed
  - Muon system installation completed.
  - Water pool filling now.
  - Physics data ready this summer;
- Fall 2012:
  - All near/far halls physics ready



Summary

- Daya Bay experiment can measure the mixing angle θ_{13} to a great precision: $\sin^2 2\theta_{13} < 0.01$ @ 90% C.L.
- Smooth progresses are going on for civil, detector assembly, filling, detector installation, test/commissioning;

Exciting time as rapidly increasing of test run/commissioning data!



Thanks