Daya Bay Neutrino Experiment: Goal, Progress and Schedule

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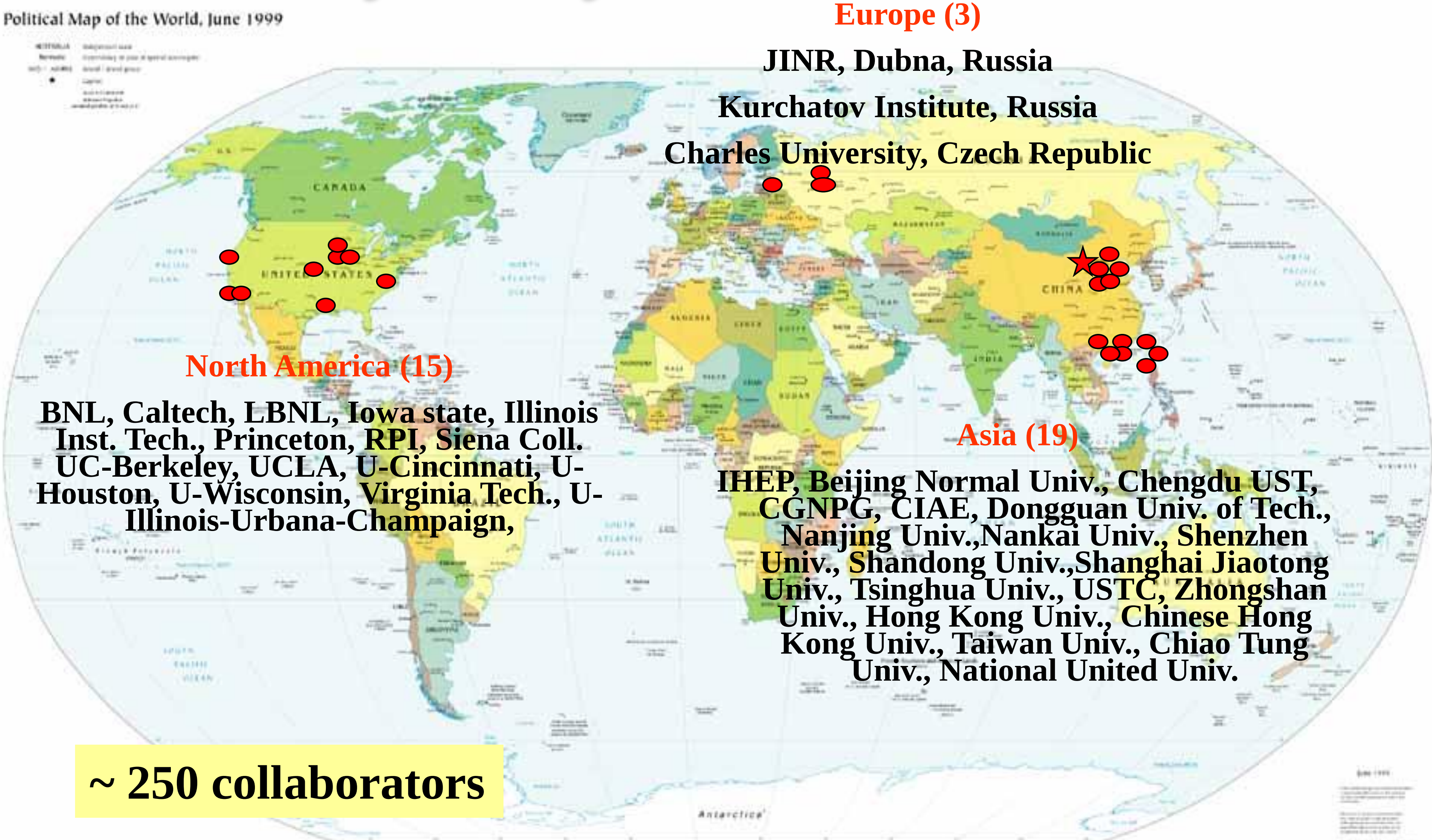
(on behalf of the Daya Bay Collaboration)

DPF meeting at Brown University

Aug. 9, 2011

Daya Bay collaboration



Europe (3)

JINR, Dubna, Russia

Kurchatov Institute, Russia

Charles University, Czech Republic

North America (15)

BNL, Caltech, LBNL, Iowa state, Illinois Inst. Tech., Princeton, RPI, Siena Coll. UC-Berkeley, UCLA, U-Cincinnati, U-Houston, U-Wisconsin, Virginia Tech., U-Illinois-Urbana-Champaign,

Asia (19)

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

~ 250 collaborators

Neutrino Mixing and θ_{13}

❖ Based on an assumption of three generations, a 3x3 neutrino mixing matrix was proposed – PMNS.

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

1. The SM has no prediction power on the values of these mixing angles and the CPV phase. It relies on experimental input.
2. θ_{13} is the last unobserved mixing angle.
3. Provide knowledge of the basic assumptions:
   - The unitarity of PMNS matrix
   - Three generations of neutrinos
4. A critical input for other researches, for example:
   - Search for leptonic CP violation
   - Determine the neutrino mass hierarchy
   - Understand the 'effective' neutrino Majorana mass limit

Measurement Method

- Detection of anti-electron-neutrino

$$\bar{\nu}_e + p \rightarrow e^+ + n$$

Prompt: e+ annihilation Delay: neutron capture

Neutrino events: coincidence in time and energy

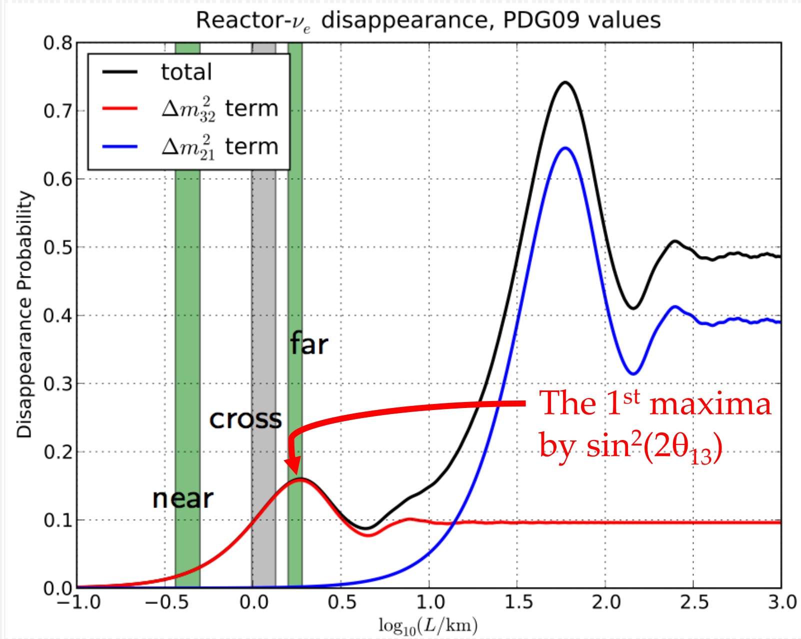
0.3b $\rightarrow + p \rightarrow D + \gamma\,(2.2\ MeV)$ *(delayed)* 180μs

50kb $\rightarrow + Gd \rightarrow Gd^* \rightarrow Gd + \gamma\text{'s}\ (8\ MeV)$ *(delayed)* 28μs 0.1%Gd

- Extraction of θ_{13}

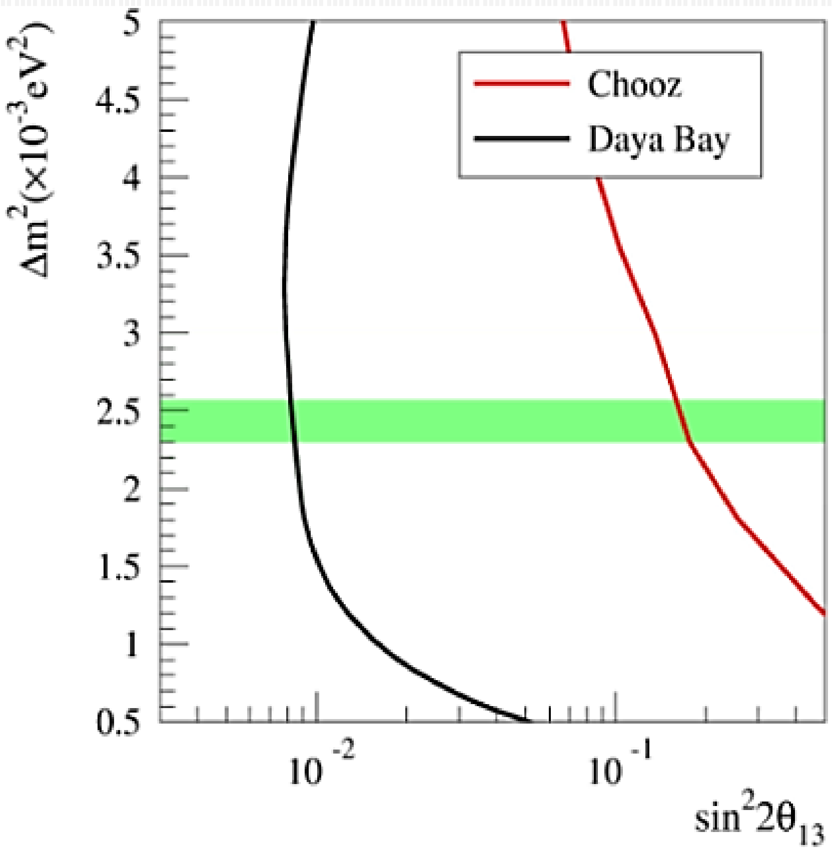
Far/Near IBD events ratio:

$$\frac{N_f}{N_n} = \left(\frac{N_{p,f}}{N_{p,n}}\right)\left(\frac{L_n}{L_f}\right)^2\left(\frac{\epsilon_f}{\epsilon_n}\right)\left[\frac{P_{sur}(E,L_f)}{P_{sur}(E,L_n)}\right]$$



Measure $\sin^2 2\theta_{13}$ to the precision 0.01

❖ We plan to measure $\sin^2 2\theta_{13}$ to the precision 0.01 at 90% CL in three years.



- Far-near Inverse-Beta-Decay (IBD) events ratio:

$$\frac{N_f}{N_n} = \left(\frac{N_{p,f}}{N_{p,n}}\right)\left(\frac{L_n}{L_f}\right)^2\left(\frac{\epsilon_f}{\epsilon_n}\right)\left[\frac{P_{sur}(E,L_f)}{P_{sur}(E,L_n)}\right]$$

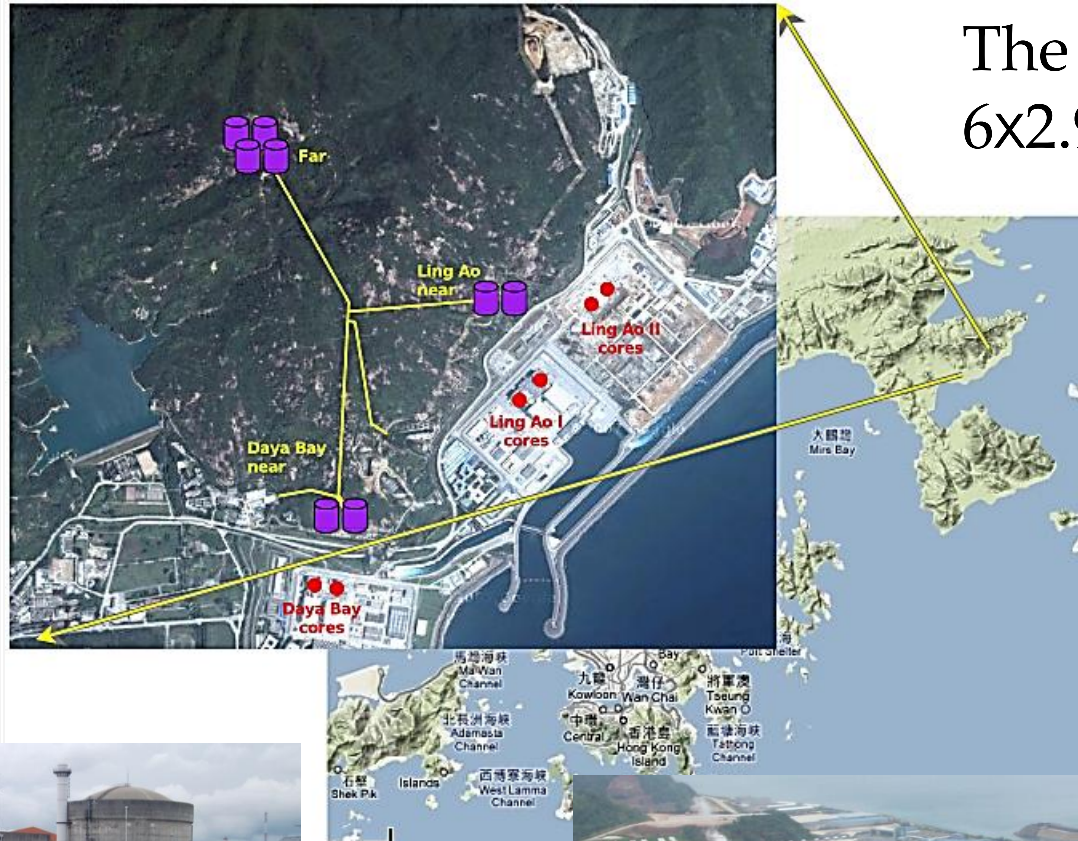
A few key factors:

1. Near-Far error cancelation
2. Optimized baseline
3. High reactor power
4. Overburden and muon veto
5. High target mass
6. Identical Antineutrino detector
7. Detector swapping

- Details about sensitivity and design can be found in arXiv:hep-ex/0701029

Nuclear Power Plant

The total power
$6 \times 2.9\ GW_{th}$.



Daya Bay cores

Ling Ao II cores Turned on recently

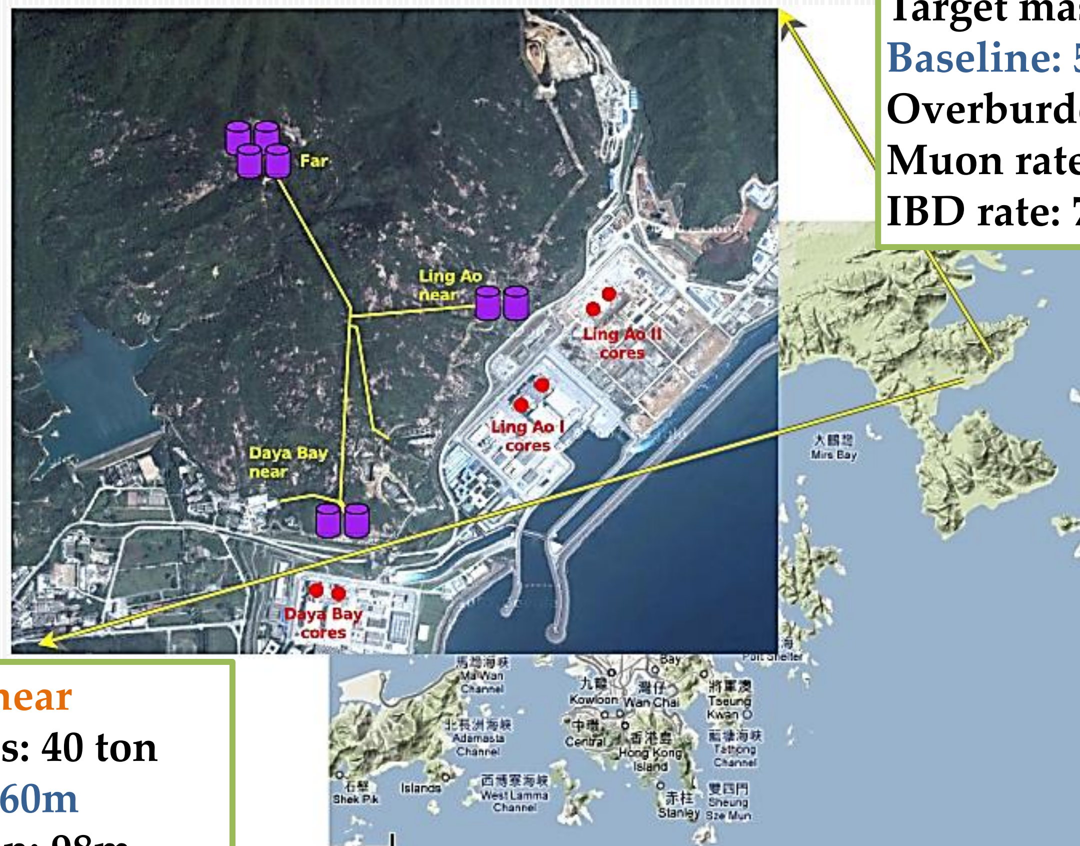
Ling Ao I cores

Daya Bay 13

BROOKHAVEN NATIONAL LABORATORY

Three Experimental Sites

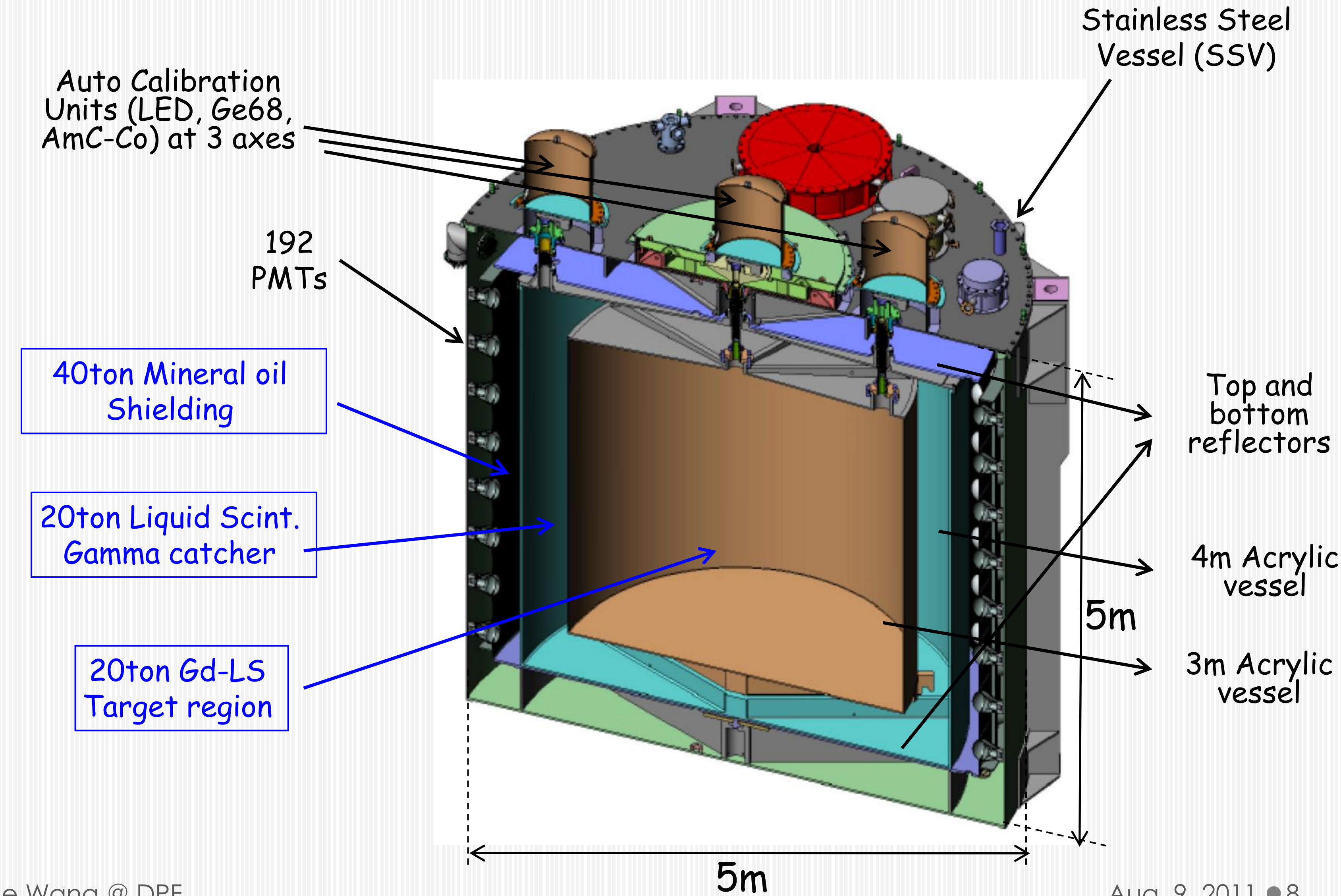
Far
Target mass: 80 ton
1600m to LA, 1900m to DYB
Overburden: 350m
Muon rate: 0.04Hz/m^2
IBD rate: 90/day



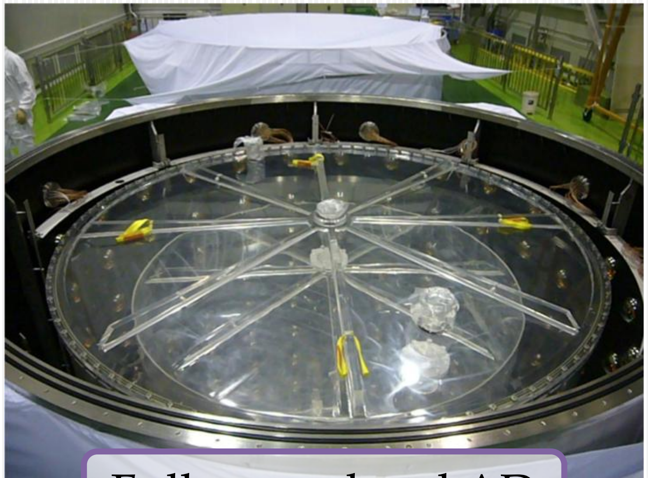
Ling Ao near
Target mass: 40 ton
Baseline: 500m
Overburden: 112m
Muon rate: 0.73Hz/m^2
IBD rate: 740/day

Daya Bay near
Target mass: 40 ton
Baseline: 360m
Overburden: 98m
Muon rate: 1.2Hz/m^2
IBD rate: 840/day

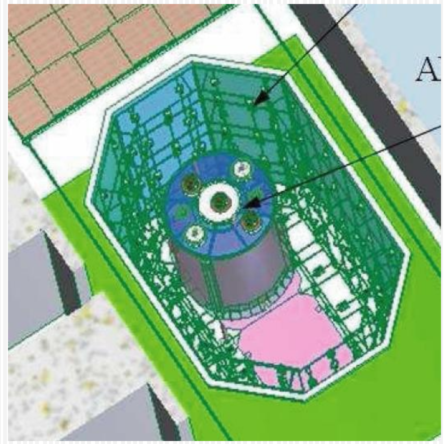
Antineutrino Detector (AD)

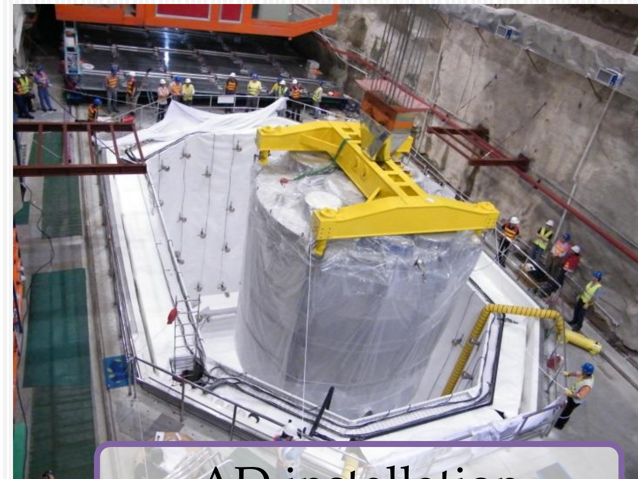


Antineutrino Detector Construction



Fully populated AD

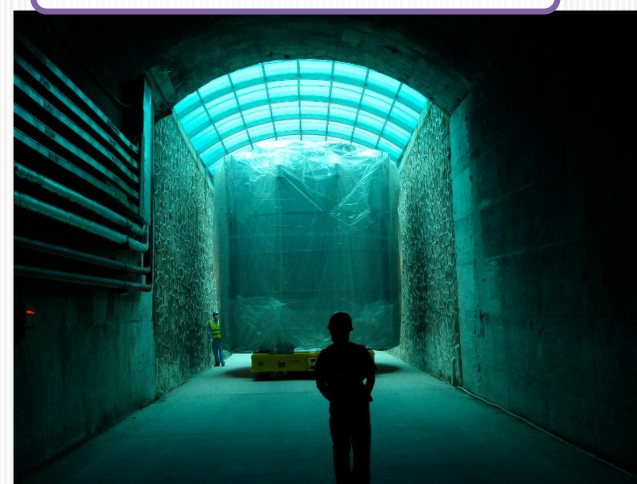




AD installation

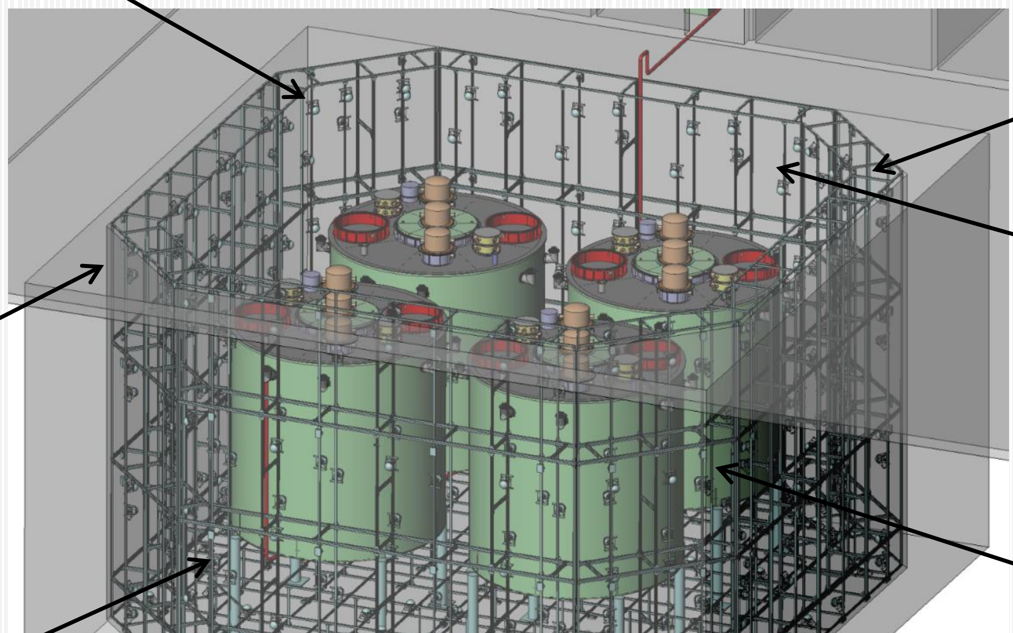
Instruments on lid
(calibration unit, etc.)

Image of inside an AD



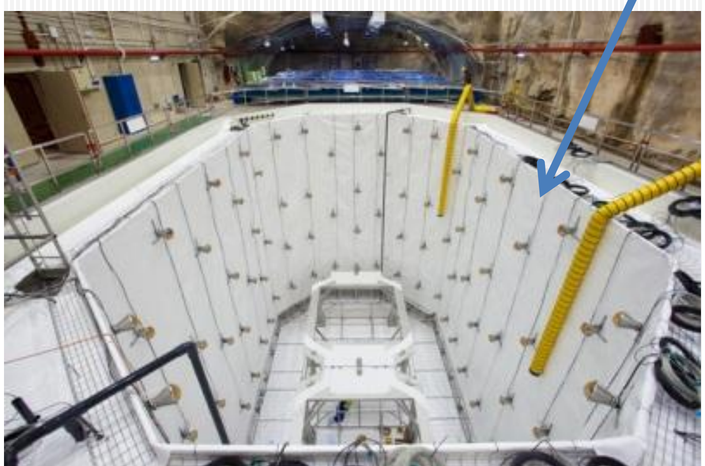
AD1 moved to hall 1

Muon Veto


PMT
Outter water shield
Inner water shield separated by reflective tyvek sheet
RPC modules above water surface
two (four) ADs
Pure water

Finished DayaBay near hall water pool

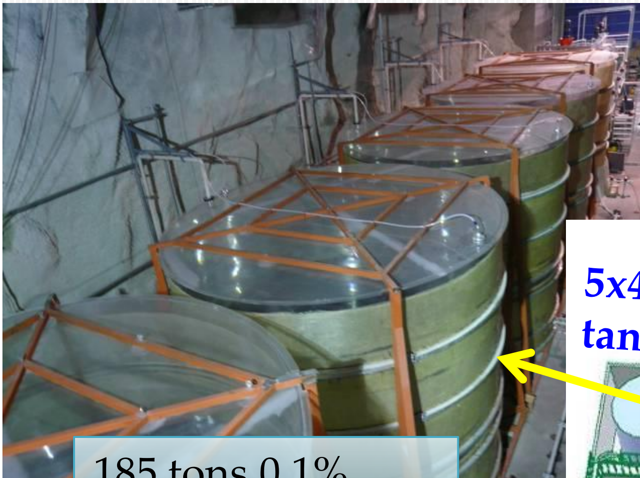
Hall 1 RPCs are all installed and gas is flowing.



Hall 1 construction is complete.

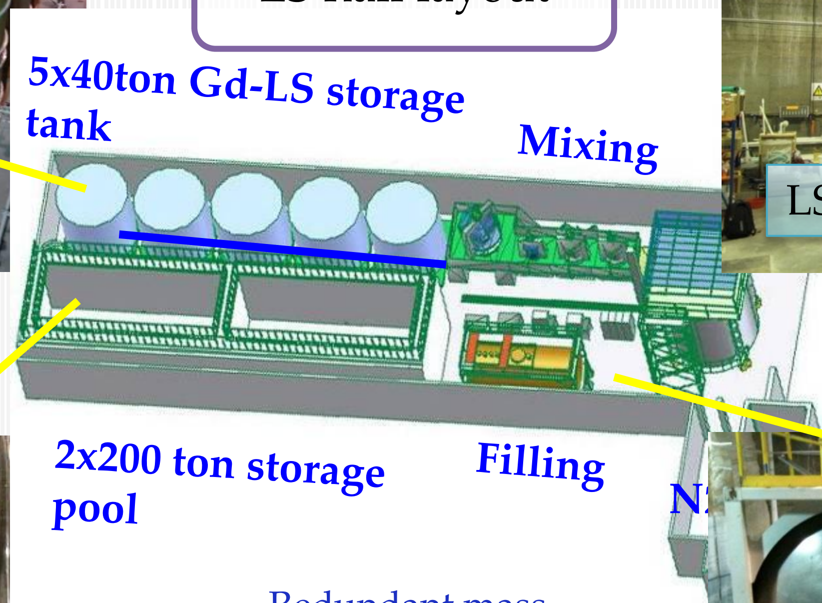
Redundancy: two water cerenkov detectors

Liquid scintillator

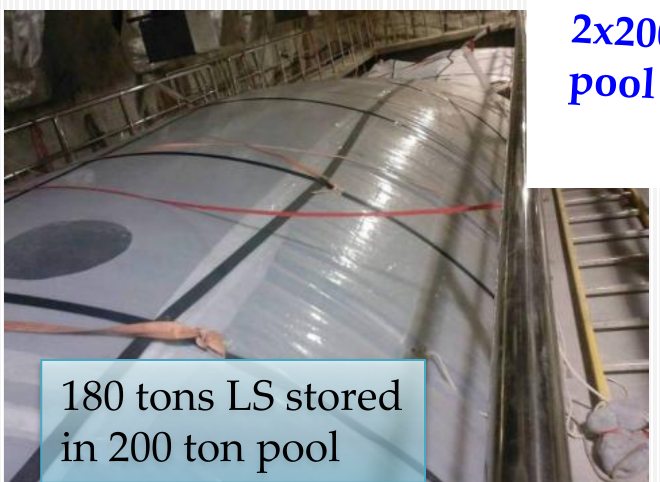


185 tons 0.1% GdLS stored in 5 40-ton tanks

LS hall layout



LS hall in March



180 tons LS stored in 200 ton pool

Redundant mass measurement systems:

1. 20ton ISO tank
2. Coriolis mass flowmeters

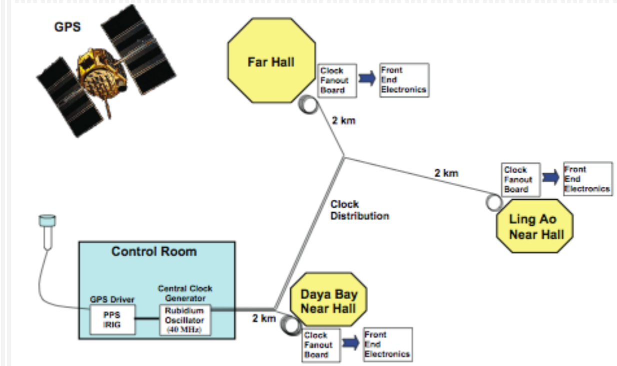
Uncertainty: 4kg of 20t

Filling system

Electronics

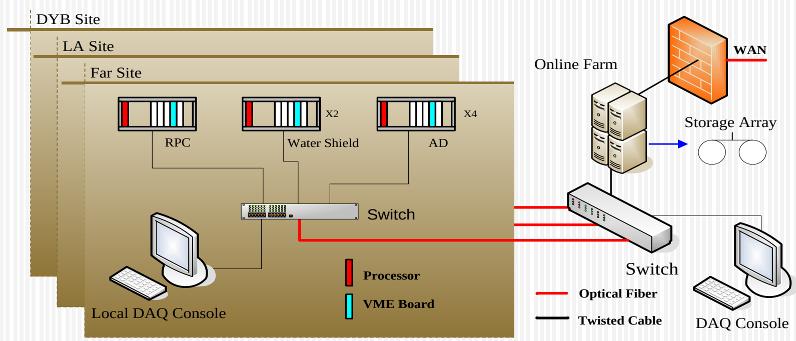
PMT Front End Electronics
1.5625 ns TDC
300 ns ADC shaping

Hall 1 electronics room



GPS synchronized clock

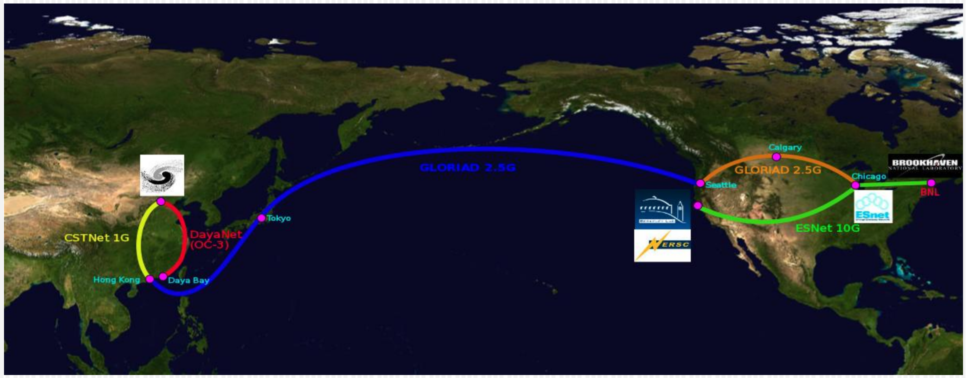
RPC Electronics

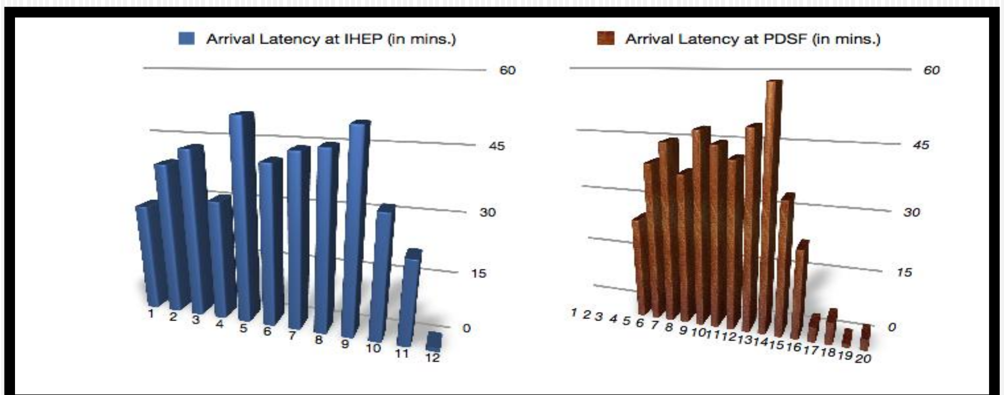


DAQ system
Flexible multi-detector configuration
Fully remote control

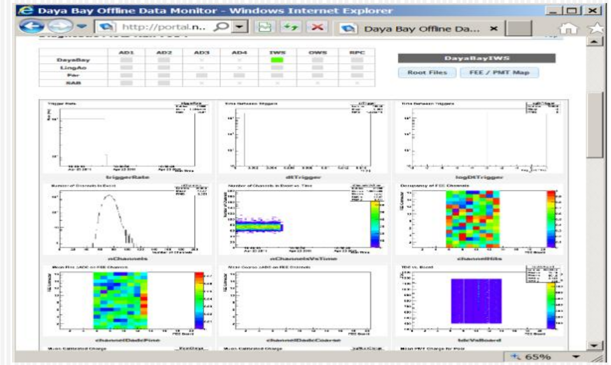
Trigger system
Multiplicity, energy
cross trigger, etc.

Data transfer, data quality monitor

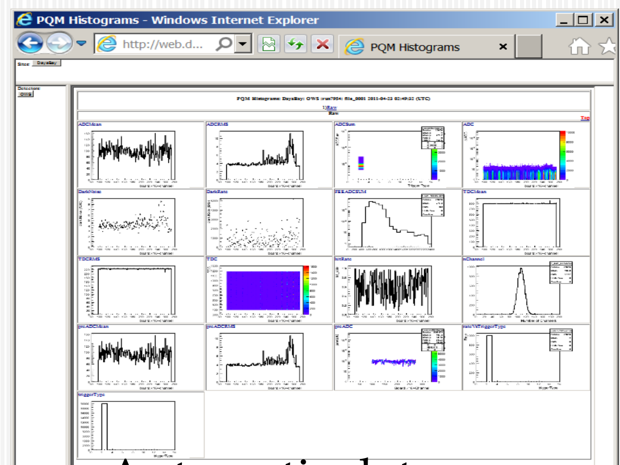




Measured data delivery times are ~14 minutes from Daya Bay to US Tier 1 at LBNL/NERSC.

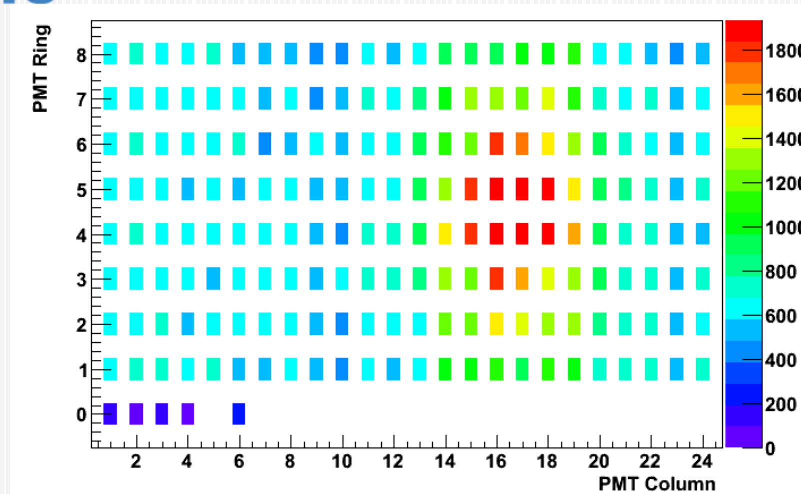


Automatic detector performance monitor

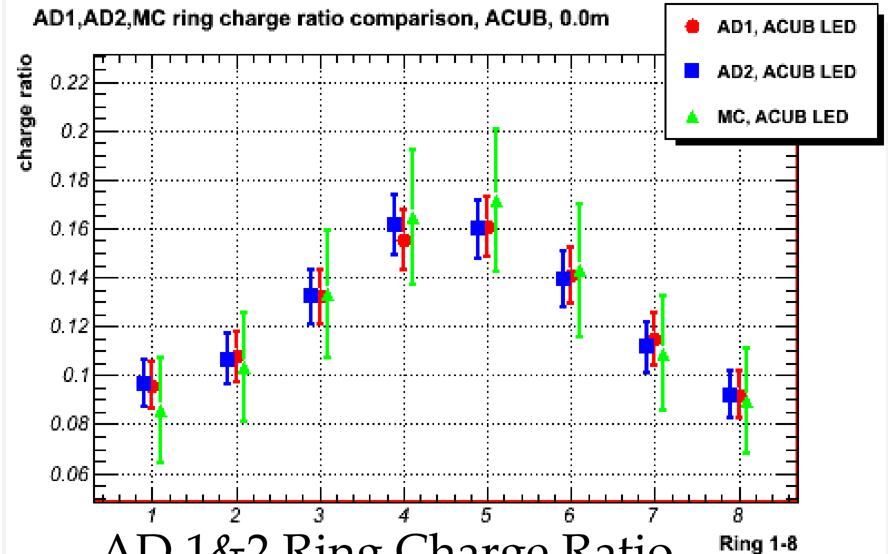


Automatic data quality monitor

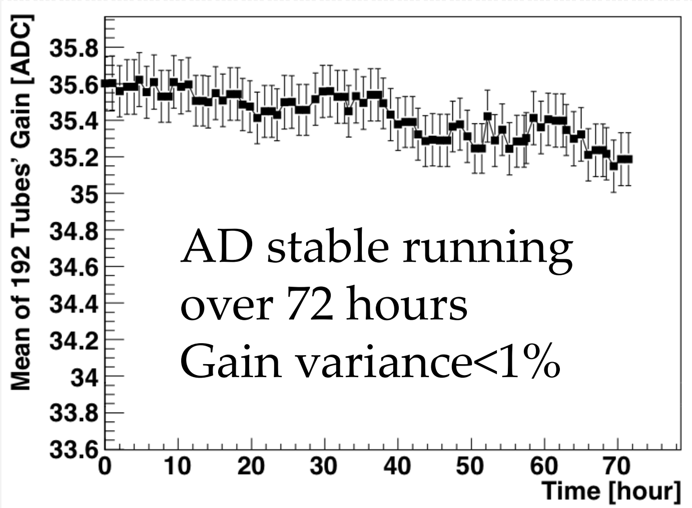
AD 1&2 Dry Run Status



Example 192-PMT charge distribution for one off-center LED source run (ACUB)

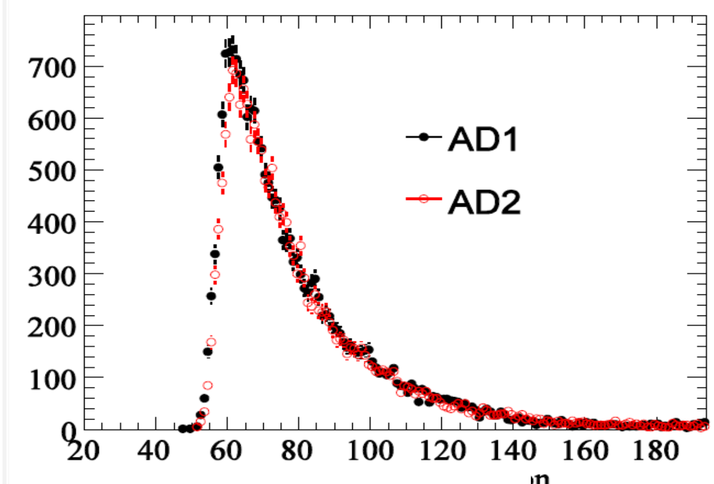


AD 1&2 Ring Charge Ratio Comparison (ACUB z=0)



AD stable running over 72 hours
Gain variance<1%

72 hours PMT gain monitor

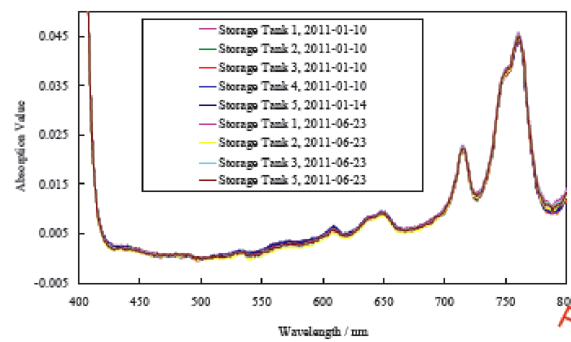


Multiplicity Dist. (Cosmic muons …)

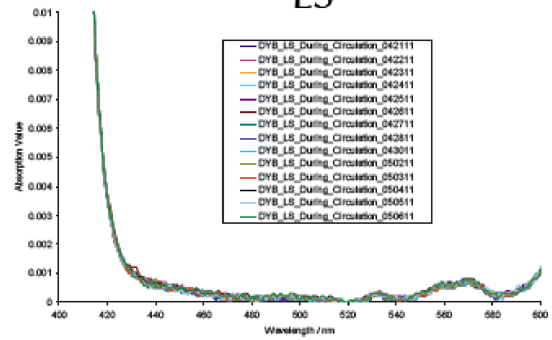
LS, GdLS Properties

❖ The liquid properties have been stable so far

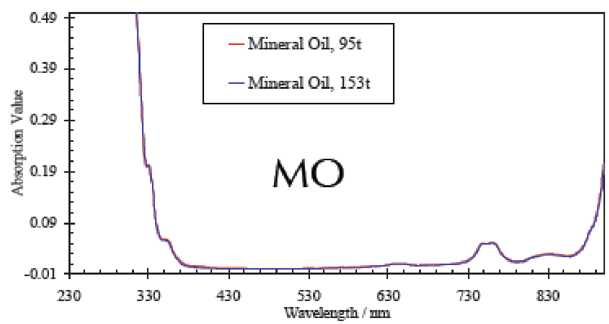
Gd-LS



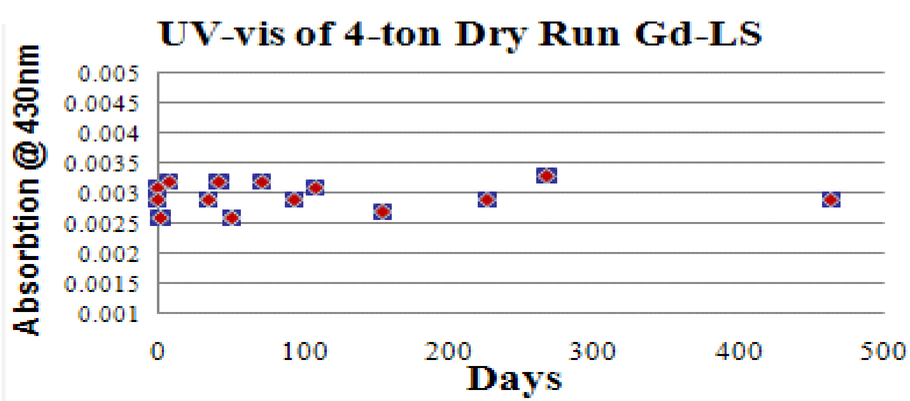
LS



Preliminary



Absorption monitoring before and after AD 1&2 filling.



Summary and outlook

- To achieve the challenging goal of measuring $\sin^2 2\theta_{13}$ to the precision 0.01, great efforts were put into the design and construction of the Daya Bay Neutrino Experiment. All these key concepts now are being turned from blueprint to reality.
- AD 1&2 dry run and filling indicate a good status.
- Schedule:
  1. Begin data taking with two ADs in the Daya Bay Hall in the summer of 2011
  2. Begin data taking with all eight ADs in three halls in the summer of 2012 to reach $\sin^2 2\theta_{13}$ of 0.01 or better

Thank you.