Daya Bay Physics

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Outline

The goal of the Daya Bay Reactor Antineutrino Experiment

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The mini-dry run

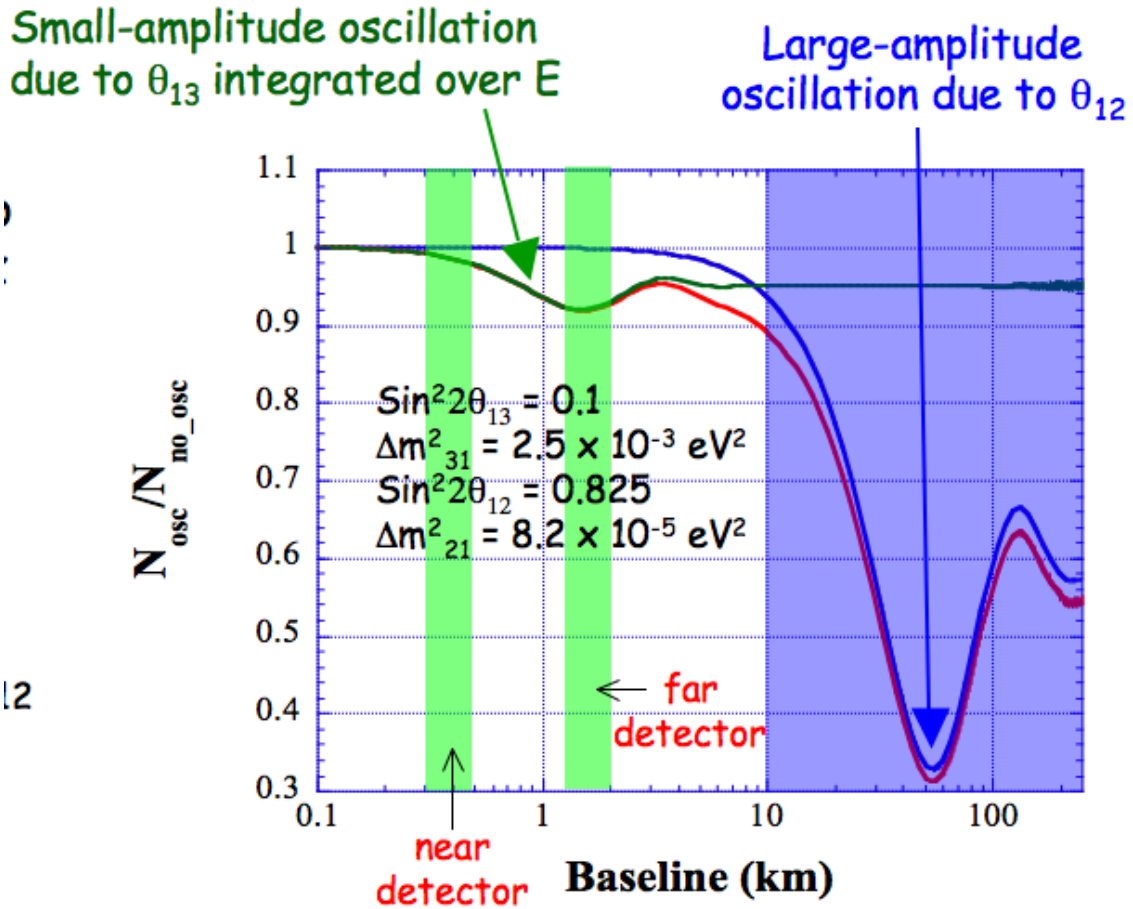
Goals and plans for dry run and near site running

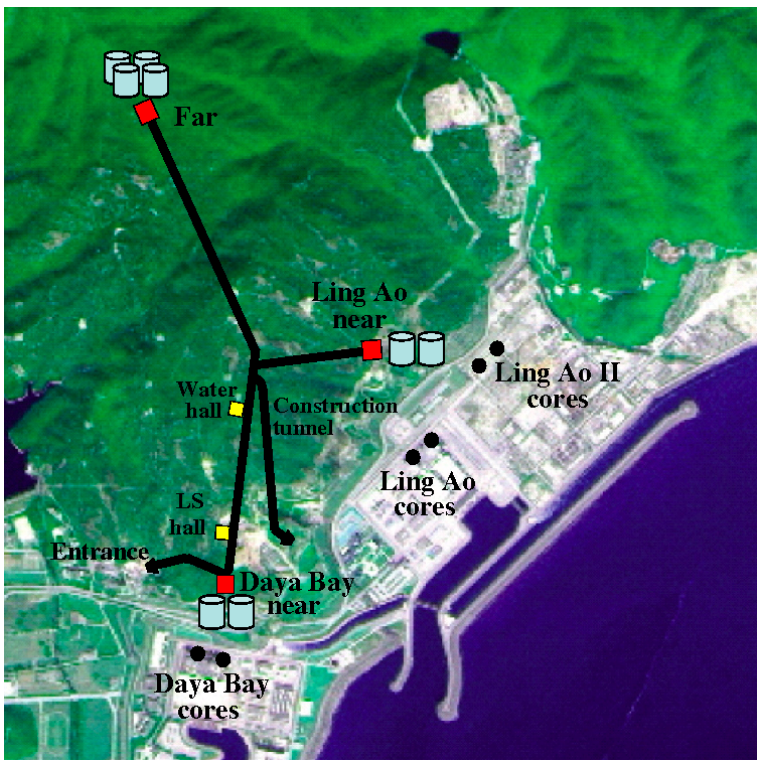
Summary

The goal of the Daya Bay Reactor Antineutrino Experiment

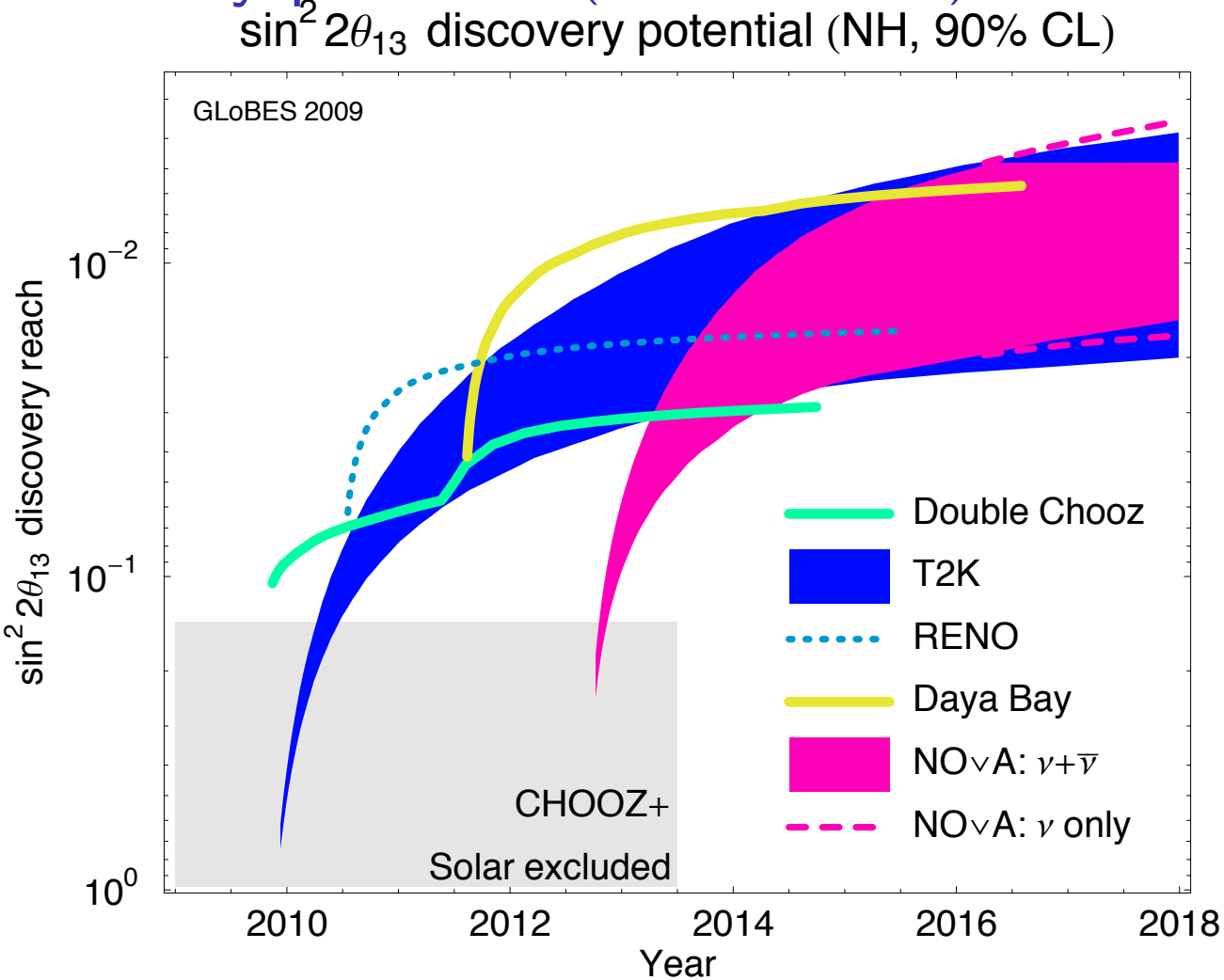
Daya Bay has a design sensitivity of $\sin^2 2\theta_{13} < 0.01$ at 90% CL after three years of running based on the disappearance of reactor $\bar{\nu}_e$.

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





$\sin^2 2\theta_{13}$ discovery potential (arXiv:0907.1896)



The $\sin^2 2\theta_{13}$ discovery potential (*i.e.*, the smallest value of $\sin^2 2\theta_{13}$ that can be distinguished from zero at 90% CL) of reactor and accelerator experiments as a function of time assuming the Normal Heirarchy (NH). The band width shows the uncertainty due to $\delta_{\rm CP}$. The accelerator experiments have less sensitivity for the Inverted Heirarchy.

BNL personnel and responsibilities

BNL Daya Bay Project responsibilities described in S.Kettell's presentation.

BNL contributions to Daya Bay physics:

- Software: Jaffe[1], Viren[1], Wang[2], Whitehead[2], Zhang[3]
- Detector commissioning: Viren[1], Wang[2], Whitehead[2]
- Simulation: Jaffe[1], Viren[1], Wang[2], Whitehead[2], Zhang[3]
- Analysis: Jaffe[1], Kettell[1], Littenberg[1], Viren[1], Wang[2], Whitehead[2]

[1] permanent physicist staff
[2] postdoc
[3] postdoc. Departed 10/2009.

BNL Daya Bay accomplishments(1)

- Software
  1. Offline software framework: Development, implementation, maintenance (Viren)
  2. Data model development and implementation (Viren, Wang)
  3. File I/O development, implementation, maintenance (Viren)
  4. Design, development, implementation and maintenance of "Fifteen" simulation package. Provides realistic sim. of all expected effects (Viren, Wang, Jaffe)
  5. Transient data management (Wang)
  6. Data production processing (Jaffe, Viren)
  7. Centralized storage of auxillary data for analysis (Jaffe)
  8. Event display (Wang)
- Detector commissioning
  1. Offline group representative for dry run (Wang)
  2. Mini-dry run analysis:
     - 2.1 Features of front-end electronics (Wang)
     - 2.2 Timestamp validation and assessment (Wang)
     - 2.3 Trigger assessment (Wang)
     - 2.4 File transfer validation (Viren)
  3. Remote experimental control proposal (Jaffe, Viren)

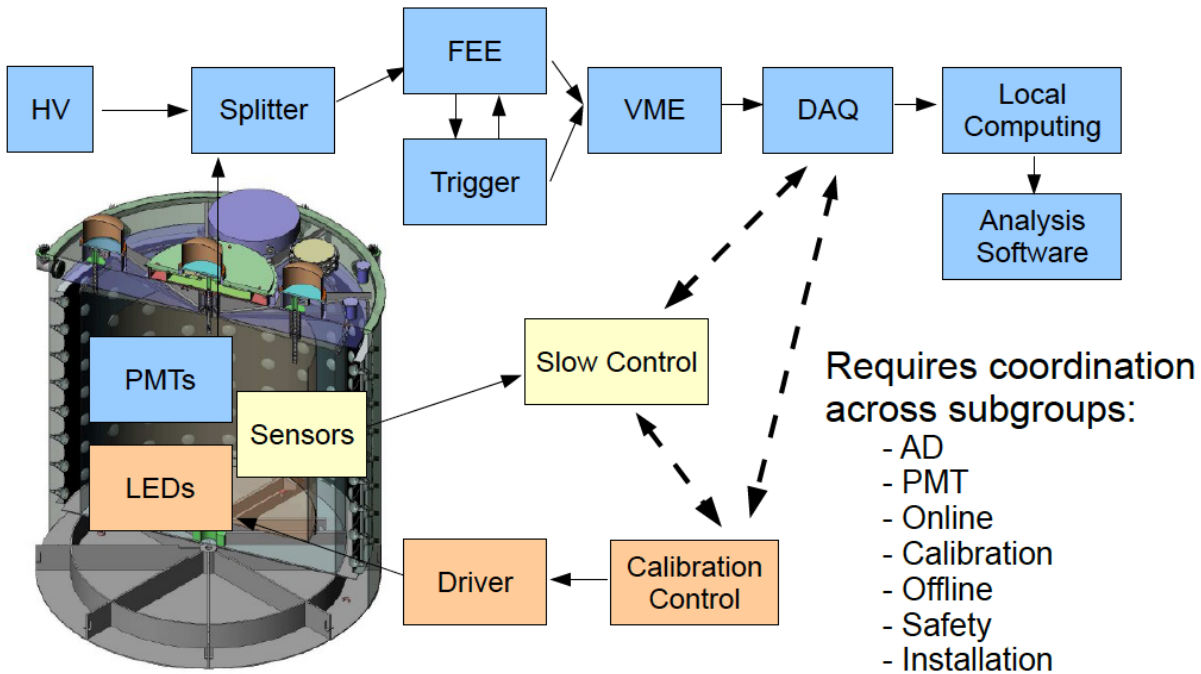
BNL Daya Bay accomplishments(2)

- Simulation
  1. Simulation, optimization and design of water pools (Zhang)
  2. NNDC-data-driven radioactive decay kinematics generator (Viren)
  3. Fast simulation of muons and cosmogenic background (Wang)
  4. Muon simulation in AD (Jaffe, Wang, Zhang)
  5. PMT model (Viren)
  6. Modeling of liquid scintillator optical properties (Whitehead)
  7. Validation of simulation (Whitehead, Zhang)
- Analysis
  1. Chair of Analysis Coordination Committee (Jaffe)
  2. Convenor of weekly simulation/analysis phone meeting (Jaffe)
  3. Long-term analysis plans (Jaffe, Kettell, Viren)
  4. Mock Data Challenge coordination (Jaffe)
  5. $\sin^2 2\theta_{13}$ sensitvity evaluation (Whitehead)
  6. Cosmogenic background study (Zhang)
  7. Enumeration of non-θ_{13} analyses (Jaffe)
  8. Evaluation of effects of AD radial reflector (Whitehead)

Research milestones for Daya Bay

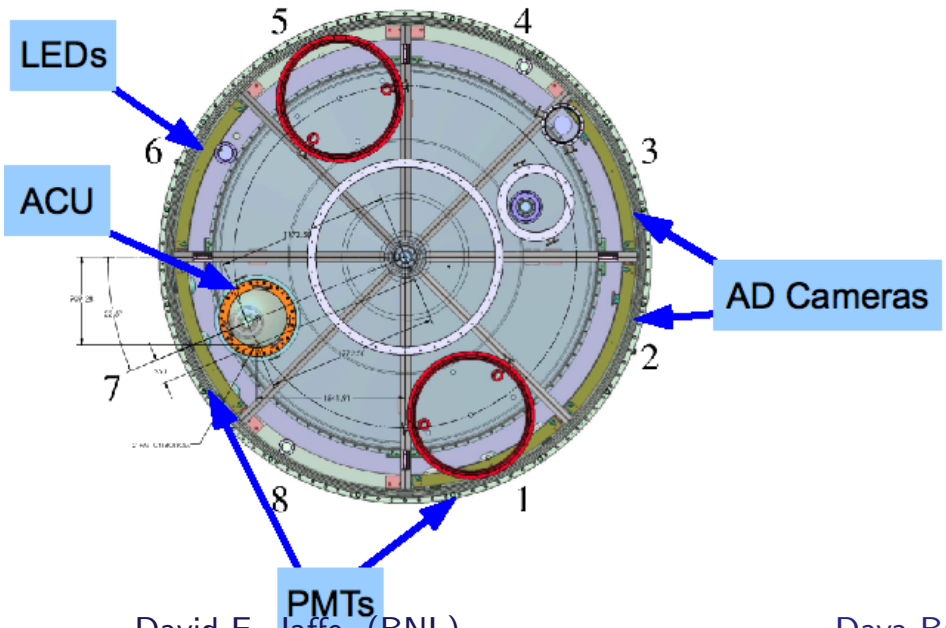
1. Mini-dry run — Dec 2009 - Jan 2010
2. AD#1 Dry Run — July 2010
3. Daya Bay near site ready for data — Spring 2011
4. Far site ready for data — Fall 2012

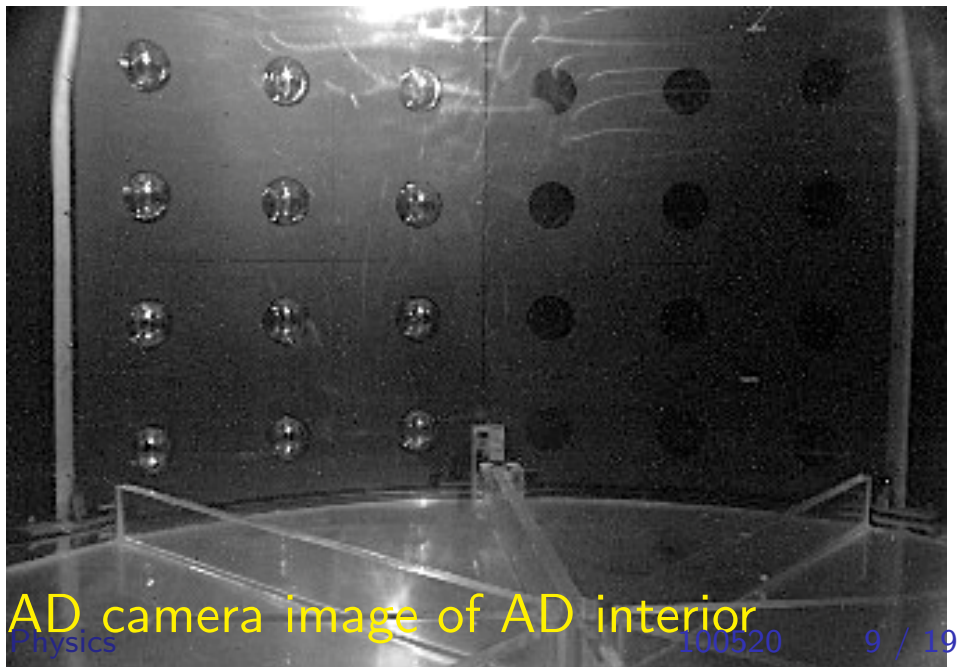
The "Dry Run" comprises a full system test with a fully instrumented Anti-neutrino Detector (AD) as assembled in the Surface Assembly Building (SAB) prior to liquid filling.



The mini-dry run

- We took advantage of an opportunity in the schedule to stage a "mini" dry run 21 Dec 2009 to 12 Jan 2010 on a partially instrumented AD.
- PMT data from light from calibration LEDs and cosmic muons traversing the acrylic vessel and reflector were taken and analyzed.
- The electronics, DAQ, calibration, offline analysis and automated raw data transfer to IHEP and LBNL were tested.
- A subset of the raw data was copied to BNL.

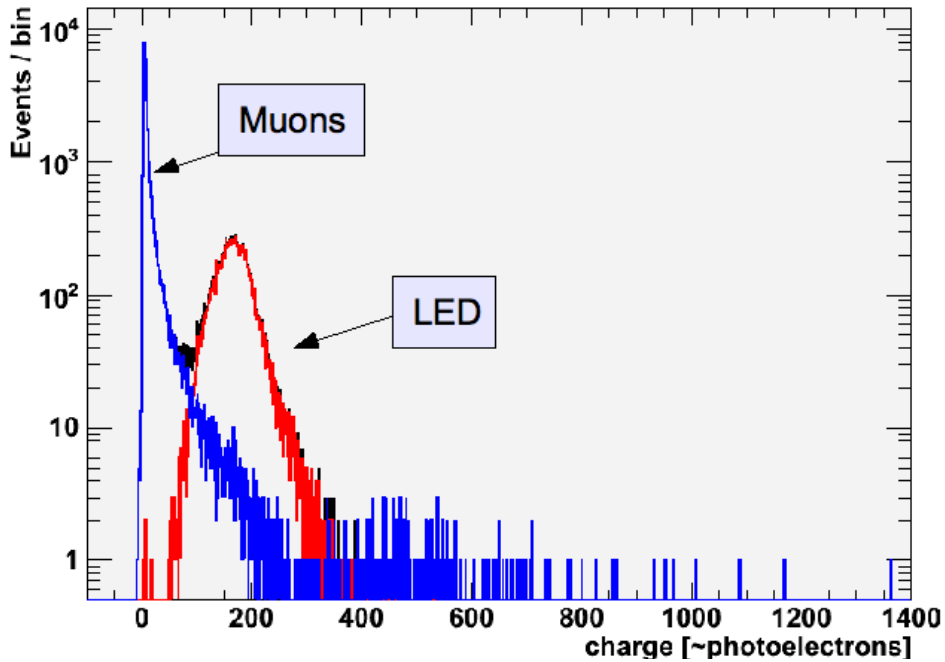


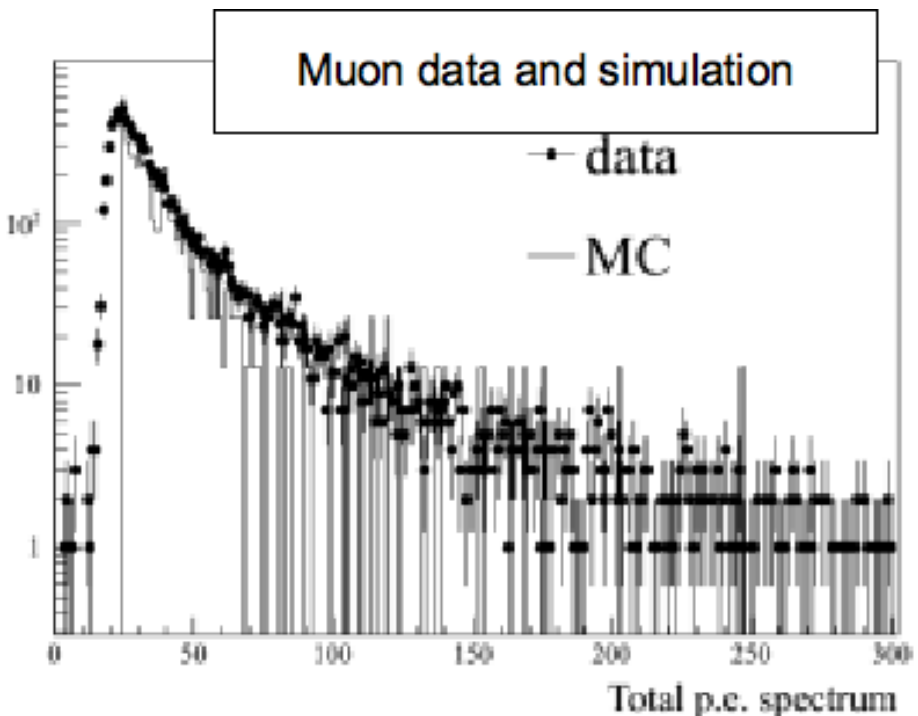


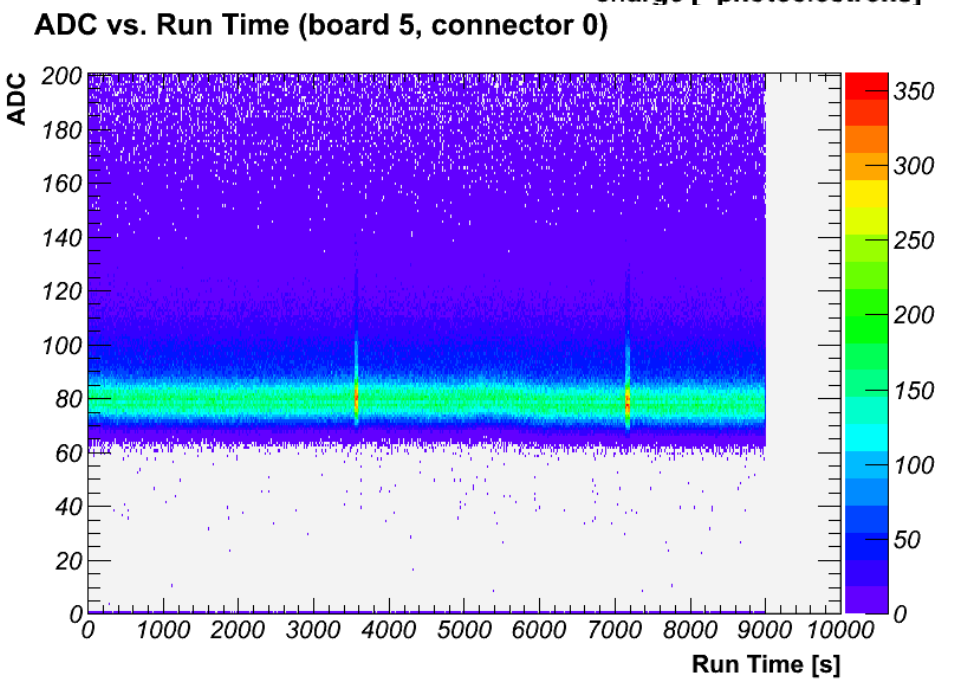
AD camera image of AD interior

Results of mini-dry run

- AD performance verified
- Can discriminate LED and muons
- Low-level PMT, electronics, DAQ, trigger, online and offline features revealed





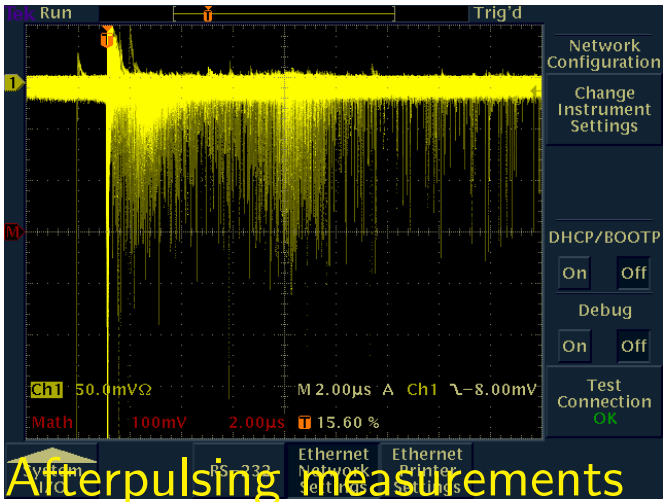


Preparation for Dry Run in July 2010

- We are using a staged approach and testing items as ready. Z.Wang compared the FEE/DAQ response with waveform analysis for PMT.

Apparatus:

- PMT in dark box
- Calibration LEDs
- Front-end electronics (FEE)
- DAQ system
- Digital oscilloscope



Afterpulsing measurements

- Develop analysis algorithms on mini-dry run data and simulated data (Wang, Viren, Jaffe)
- Assess overall readiness of full production chain from PMT to permanent storage at BNL (Viren, Wang, Jaffe)
- AD#1 and #2 commissioning and analysis (Wang, Viren, Whitehead, Jaffe)

Storage and analysis of Daya Bay data at BNL

Goal	Store and analyze 1/10-reduced data set in the RHIC Atlas Computing Facility. Provide user resource for Daya Bay collaborators at universities. Half of current users are non-BNL collaborators.
Status	Currently in use for MC production and analysis
Completion	25% (now), 100% (Mar11)

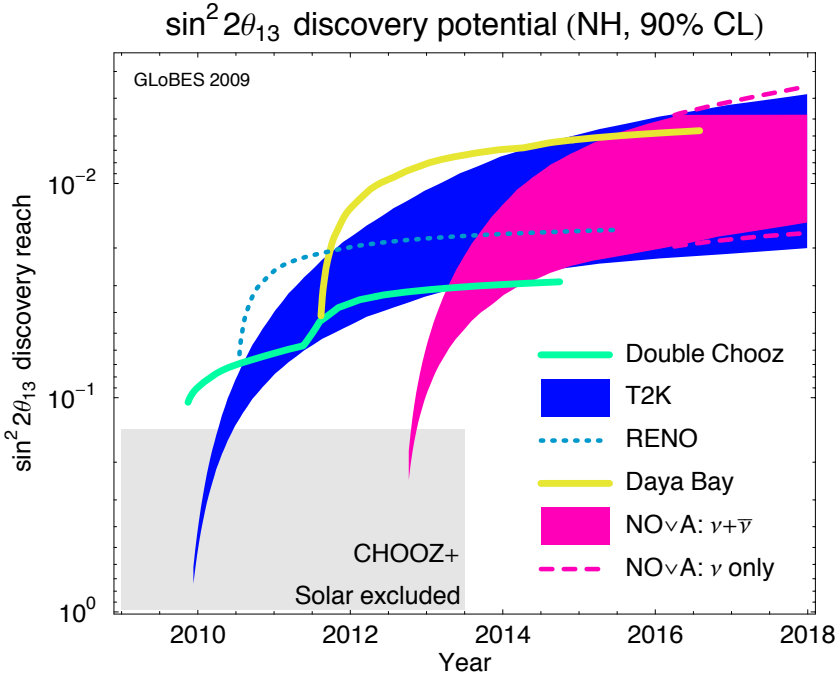
Daya Bay near site run: Spring 2011

- The near site run provides an opportunity to test the majority of the assumptions behind our sensitivity predictions.
- The primary goals of initial operations at the Daya Bay near site are
  1. a fully calibrated muon system and
  2. fully calibrated AD pair,
  3. followed by verification of muon and AD performance,
  4. an extensive study and verification of systematic uncertainties, and
  5. validation of reactor flux information from the power plant.
- The Daya Bay near site run will be preceded by a full analysis of simulated near site data corresponding to at least $\sim$3 months of near site data.

In addition to the muon installation responsibilities, BNL personnel are preparing the simulation of the near site data as well as the analysis software to verify the performance of the muon and AD systems.

Summary

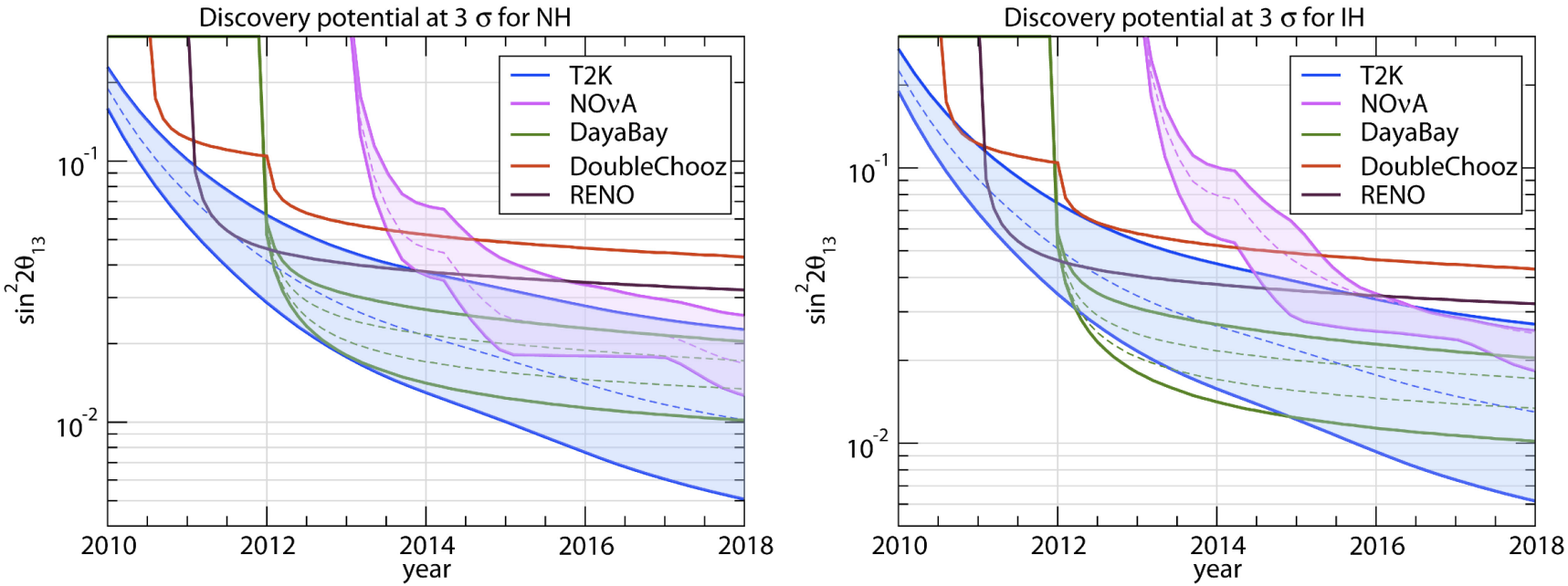
- BNL has made, and continues to make, critical contributions to Daya Bay physics simulation, offline software, and data analysis.
- We have a leadership role in preparations and in developing goals for the dry run and near-site run commissioning and analysis.
- We are ramping up our on-site presence to ensure the success of the dry run and near-site commissioning.



BNL personnel have a leading role in forming and implementing Daya Bay's long-term analysis plan to promptly exploit the world's best $\sin^2 2\theta_{13}$ measurement potential.

Additional slides

Comparison of $\sin^2 2\theta_{13}$ 3σ discovery potential



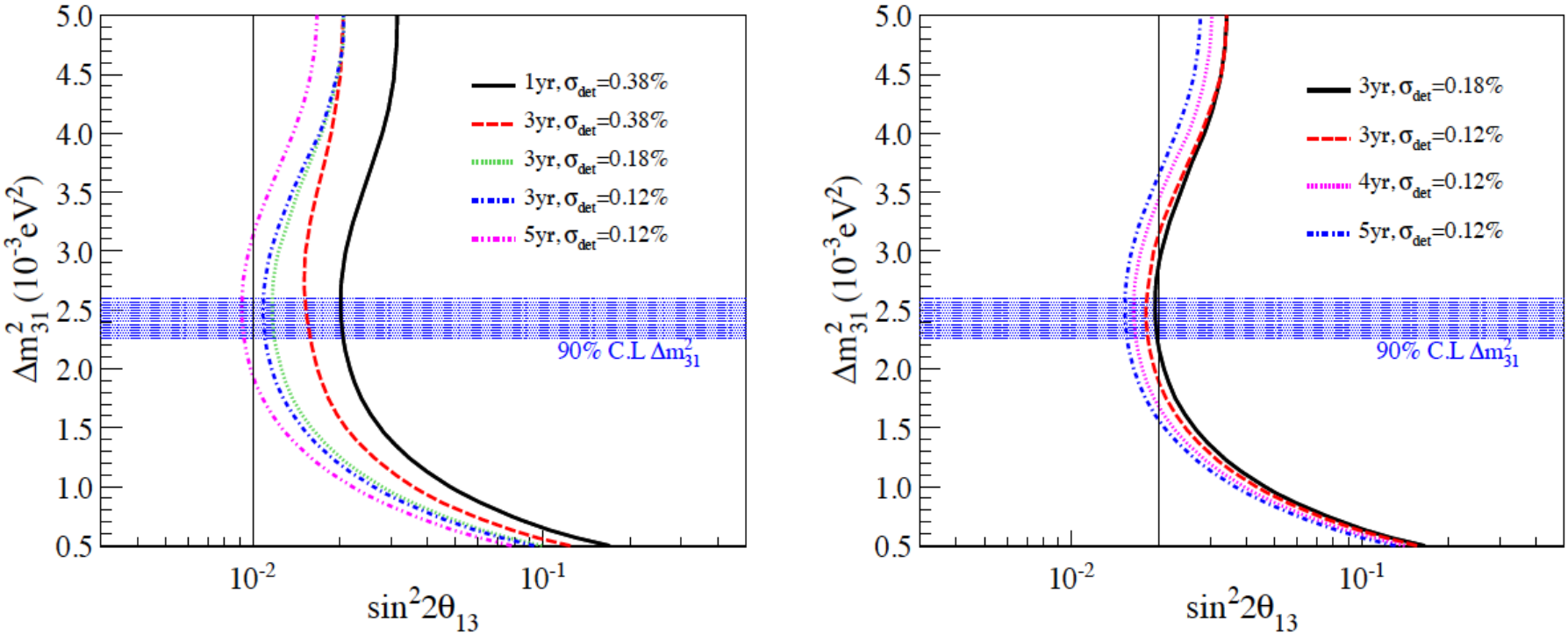
Smallest value of $\sin^2 2\theta_{13}$ that can be distinguished from zero at 3σ as a function of time.

Bands for T2K, NOvA reflect unknown $\delta_{\rm CP}$ value; dashed curve has $\delta_{\rm CP} = 0$.

Four Daya Bay curves correspond to 0.6% correlated uncertainty between modules, 0.38% correlated, 0.38% uncorrelated, 0.18% uncorrelated.

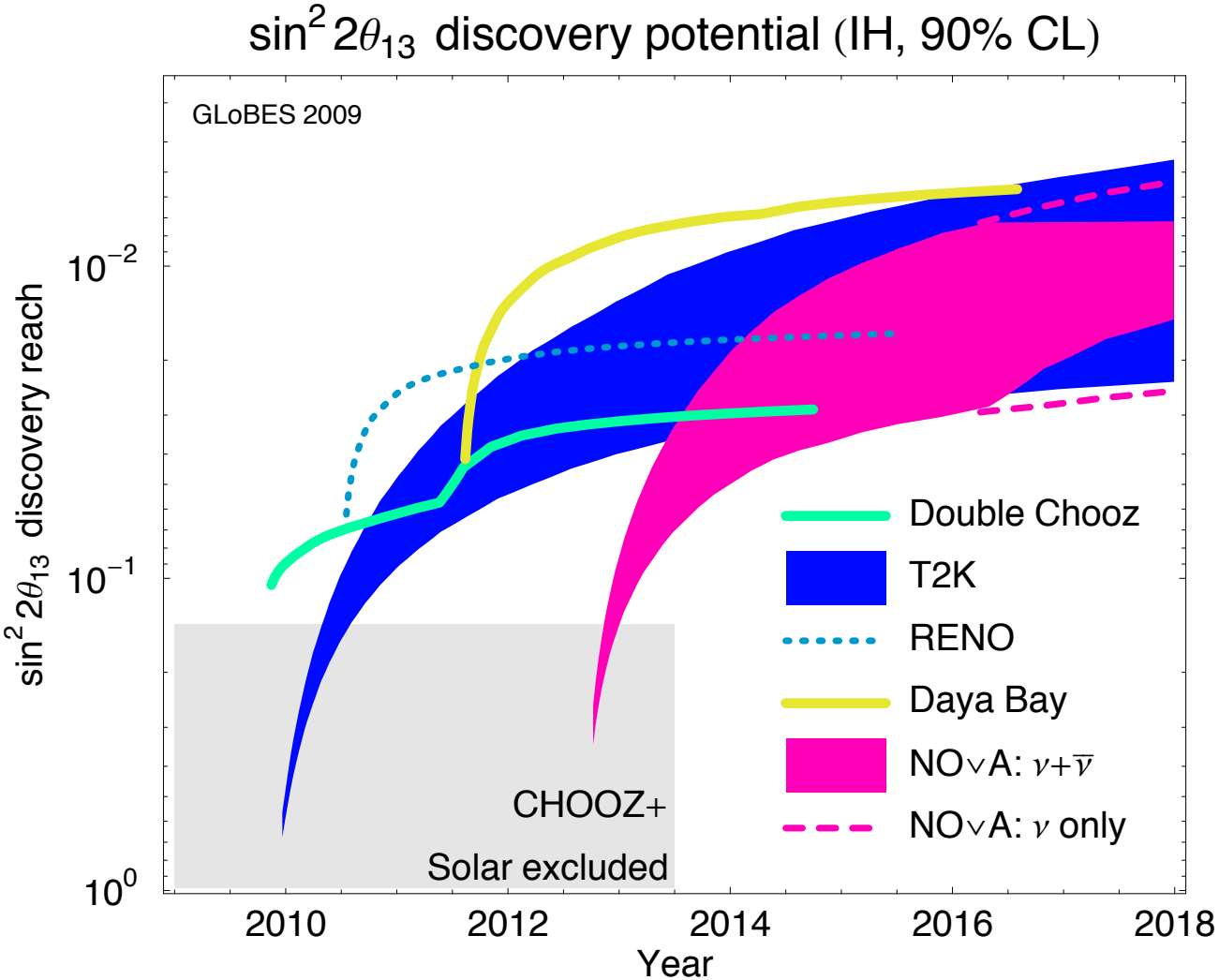
Mezzotto & Schwetz, arXiv:1003.5800

Daya Bay $\sin^2 2\theta_{13}$ discovery potential



Daya Bay $\sin^2 2\theta_{13}$ discovery reach at **3σ(left)** and **5σ(right)** for running times up to 5 years and different detector systematic uncertainties ($\sigma_{\rm det} = 0.38, 0.18, 0.12\%$ = baseline, goal, with swap). (From internal DYB-doc-3930)

$\sin^2 2\theta_{13}$ Discovery potential Inverted Heirarchy
(arXiv:0907.1896)



Conference talks:

- Whitehead: APS Feb 2010, APS May 2009, NuFact July 2008
- Zhang: Gordon Conf. July 2009, DNP 2008
- Jaffe: DBD09 Oct 2009, Miami2008 Dec 2008
- Viren: NDM09, Aug 2009
- Kettell: WIN09, Sept 2009