The Daya Bay Reactor Antineutrino Experiment

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1) Why Daya Bay?
2) Status/BNL involvement

The Last Mixing Angle: θ_{13}

U_{MNSP} Matrix
Maki, Nakagawa, Sakata, Pontecorvo

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

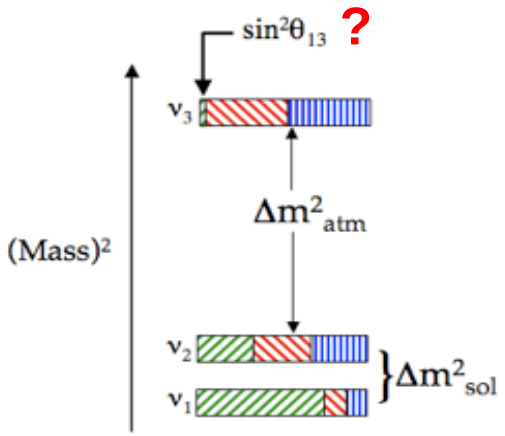
$$= \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \times \begin{pmatrix} \cos\theta_{13} & 0 & e^{-i\delta_{CP}}\sin\theta_{13} \\ 0 & 1 & 0 \\ -e^{i\delta_{CP}}\sin\theta_{13} & 0 & \cos\theta_{13} \end{pmatrix} \times \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} 1 & 0 & 0 \\ 0 & e^{i\alpha/2} & 0 \\ 0 & 0 & e^{i\alpha/2+i\beta} \end{pmatrix}$$

atmospheric, K2K, MINOS | reactor and accelerator MINOS, Double Chooz Daya Bay | SNO, solar SK, KamLAND | $0\nu\beta\beta$

θ_{23}~45° θ_{13}<12° θ_{12}~32°

Motivations to measure θ_{13}

- **Key to leptonic CP violation.**
- **How to extend the SM?**
  - **What is ν_e fraction of ν_3?**
  - **Is there μ–τ symmetry in mixing?**

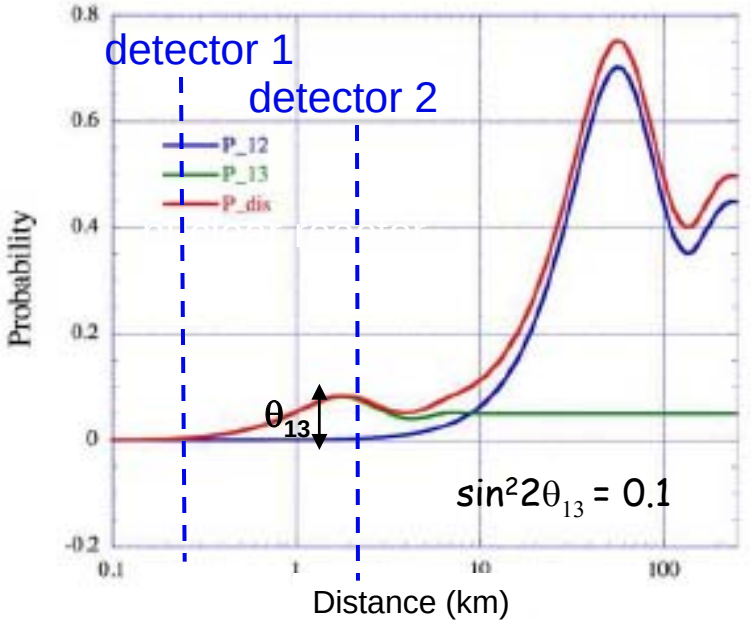


Measuring $\sin^2 2\theta_{13}$ with Reactor Antineutrinos

ν_e disappearance probability

$$P_{ee} \approx \sin^2 2\theta_{13} \sin^2\left(\frac{\Delta m_{31}^2 L}{4E_\nu}\right) - \cos^4\theta_{13} \sin^2 2\theta_{12} \sin^2\left(\frac{\Delta m_{21}^2 L}{4E_\nu}\right)$$

- No dependence on δ_{CP} or matter effects
- Cost effective
- Rapid deployment

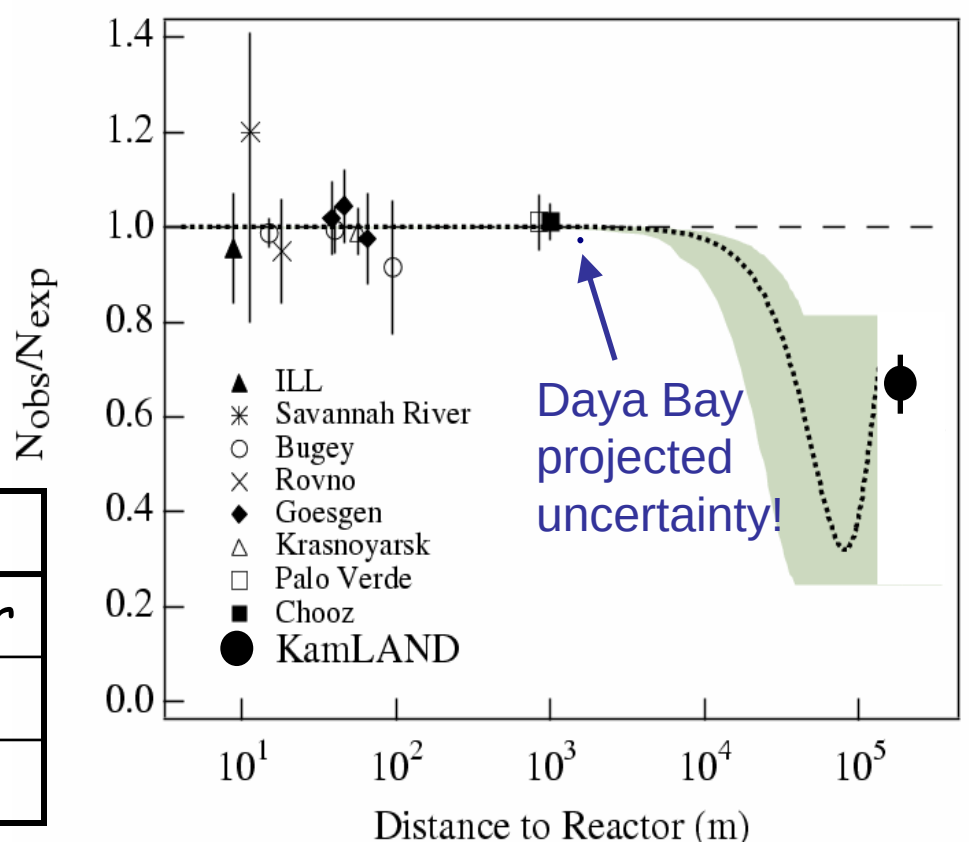


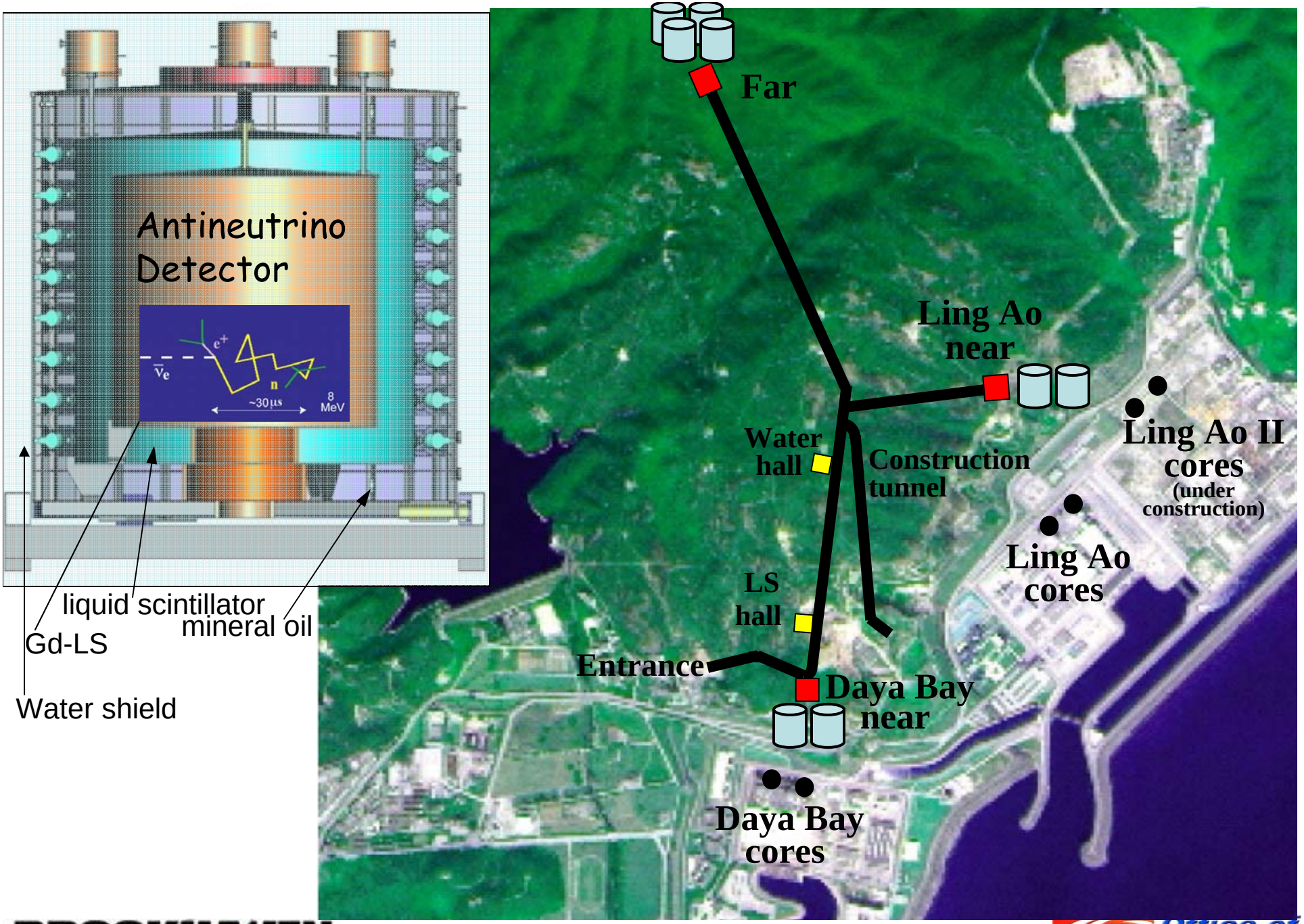
Daya Bay Strategy for θ_{13}

Limit on θ_{13} from Chooz

$\sin^2 2\theta_{13} < 0.17$ ($\Delta m^2_{31} = 2.5 \times 10^{-3}$ eV^2)

	Chooz	Daya Bay
events	3000/335d	230k/3yr
Mass	5 ton	80 ton
Sys. Err	2.7%	0.2%



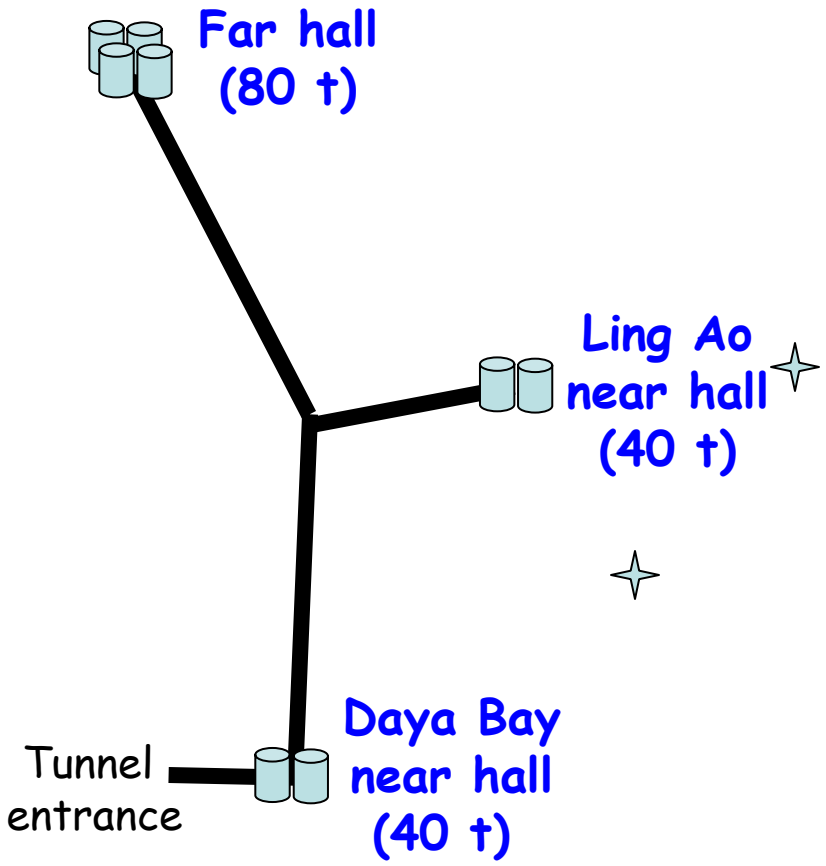

Antineutrino Detector
e+
$\bar{\nu}_e$
n
~30μs
8 MeV
liquid scintillator
Gd-LS
mineral oil
Water shield
Far
Ling Ao near
Ling Ao II cores (under construction)
Water hall
Construction tunnel
Ling Ao cores
LS hall
Entrance
Daya Bay near
Daya Bay cores

Daya Bay @ BNL

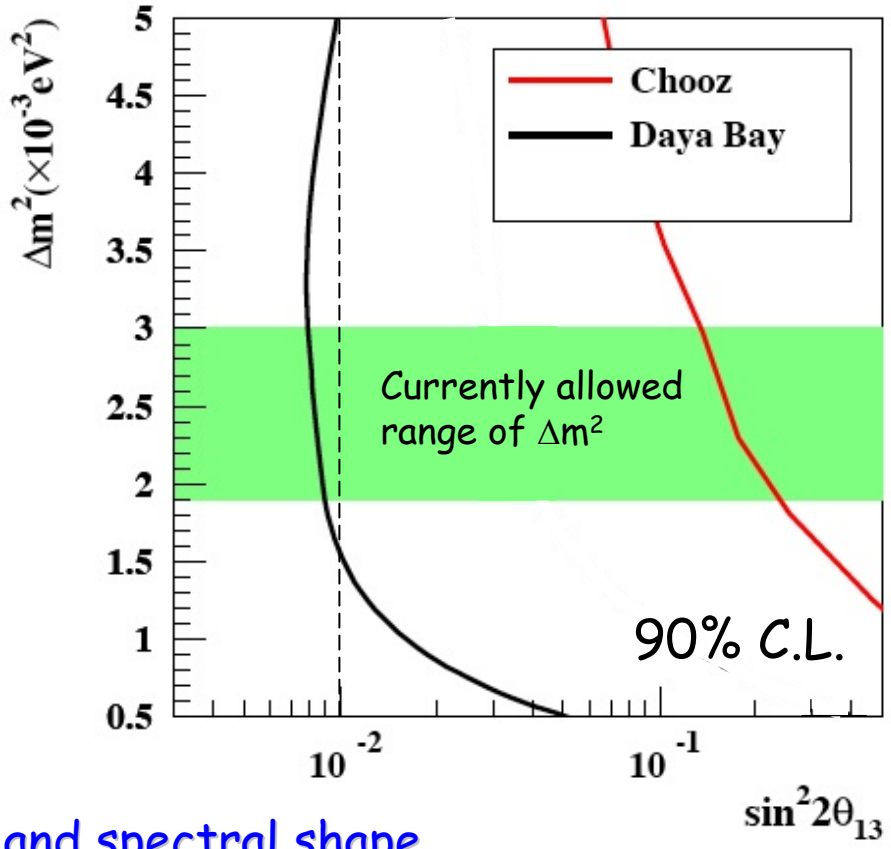
- The Physics is compelling! and a critical step to ~~CP~~
- Measuring Beyond the Standard Model parameters — now!
- Diversity for Physics Department: complementary to LHC
- BNL has a rich tradition in ν physics: in both Physics and Chemistry departments (2 Nobel Prizes)
- Good match to the existing Physics Department effort on MINOS and future long-baseline experiment to measure CP violation in the neutrino sector.
- Priority with DOE - HEP

Sensitivity

$\sin^2 2\theta_{13} < 0.01$ (90% CL) over allowed Δm^2



3-year run with 80 t at far site



- Rate and spectral shape
- Relative detector systematic error of 0.2%

Daya Bay Status

- APS multi-divisional study recommends reactor experiment (2004)
- CD-0: 11/2005
- BNL formally joins collaboration 2/2006
- NuSAG endorses DB goal and DB expt. as one option 2/2006
- PAC endorses BNL involvement 3/23/2006
- Successful DOE Physics Review 10/16/2006
- P5 Roadmap: Recommends Daya Bay 10/2006
- CD-1: 9/28/2007 ⟸ *today*
- Start of Civil construction 10/2007 (groundbreaking 10/13)
- CD-2/3a baseline review 1/8/2008 at BNL
- CD-3b construction start Spring 2008
- CD-4b start of full operations fall 2010

Summary

- The measurement of θ_{13} at Daya Bay is a key part of the US HEP program
- This measurement is important in its own right and for future experiments to search for CP violation in neutrinos

  $\rightarrow$ All sites ready to take data in 2010.
- BNL is the largest US group on Daya Bay (2nd overall after IHEP)
- Important part of the overall BNL neutrino plan (along with MINOS and Long Baseline/DUSEL)