Next generation reactor neutrino experiment

Yifang Wang
Institute of High Energy Physics

Paris，April 29, 2013

Neutrino Oscillation

- **If the neutrino mass eigenstate is different from that of the weak interaction, neutrinos can oscillate: from one type to another during the flight:**

$\nu_e \longrightarrow \nu_\mu \longrightarrow \nu_e \longrightarrow \nu_\mu \longrightarrow$

Oscillation probability:

$$P(\nu_e \to \nu_\mu) = \sin^2(2\theta)\,\sin^2(1.27\Delta m^2 L/E)$$

Oscillation amplitude (θ)

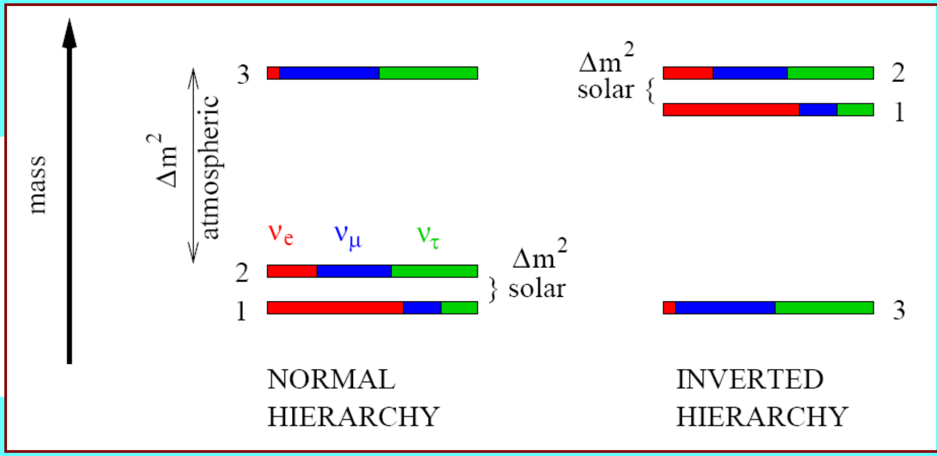
Oscillation frequency (Δm^2)

Neutrino oscillation is a great method to probe the neutrino mass
Neutrino oscillation is the central issue of neutrino studies

Neutrino Oscillation with 3 Generations

PMNS mixing matrix:

$$\begin{pmatrix} \nu_e \\ \nu_\mu \\ \nu_\tau \end{pmatrix} = \begin{pmatrix} V_{e1} & V_{e2} & V_{e3} \\ V_{\mu 1} & V_{\mu 2} & V_{\mu 3} \\ V_{\tau 1} & V_{\tau 2} & V_{\tau 3} \end{pmatrix} \begin{pmatrix} \nu_1 \\ \nu_2 \\ \nu_3 \end{pmatrix}$$



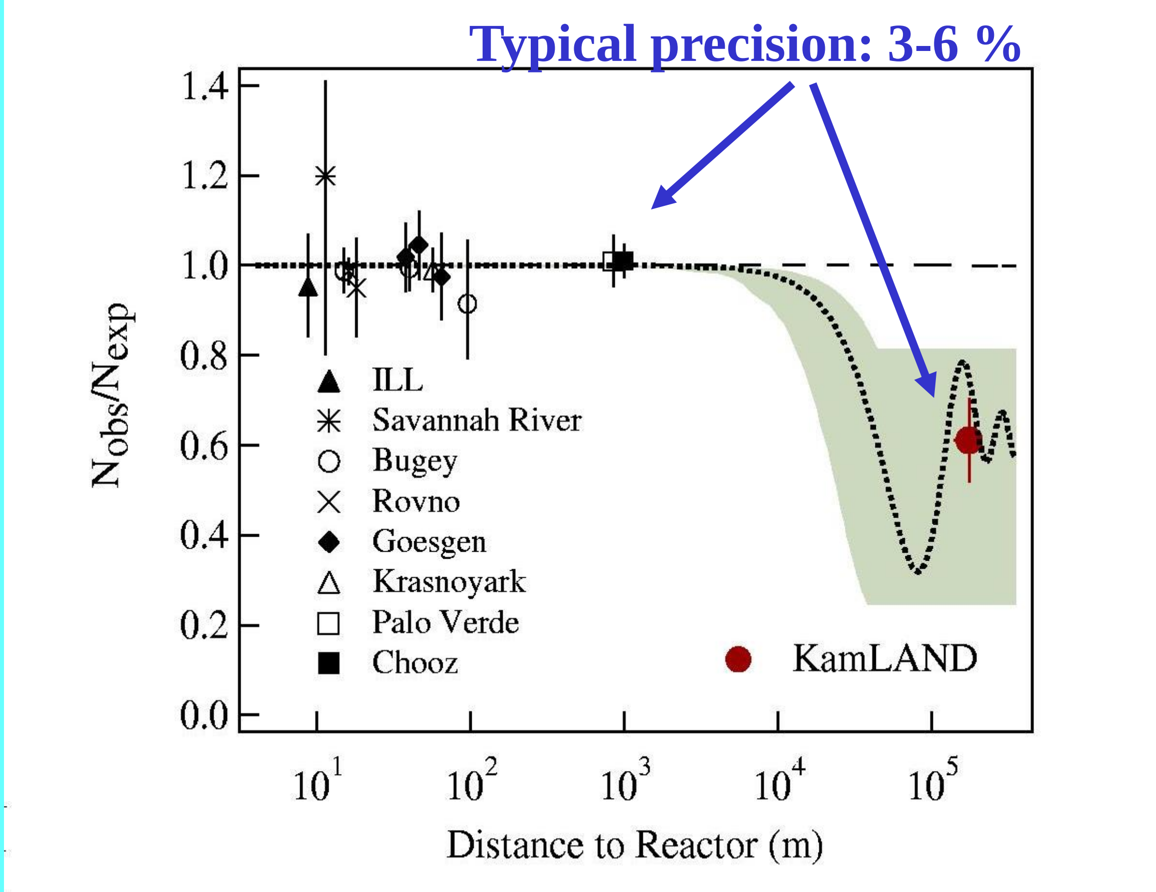
Atmospheric — CP phase & θ_{13} — Solar — Majorana phase

$$V = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13} \\ 0 & e^{-i\delta} & 0 \\ -s_{13} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} e^{i\rho} & 0 & 0 \\ 0 & e^{i\sigma} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

- **Known parameters:** θ_{23}, θ_{12}, $|\Delta M^2_{23}|$, ΔM^2_{12},
- **Recent progress:** θ_{13} **(by reactors)**
- **Unknown parameters: mass hierarchy(ΔM^2_{23}), phases δ, ρ, σ**

Successful Reactor neutrino Experiments

- Confirmed solar neutrino oscillation and precisely determined θ_{12}, ΔM^2_{12}
- Discovered non-zero θ_{13}
- May determine the mass hierarchy



Precision:

- Reactor power: ~1%
- ν spectrum: ~0.3%
- Fission rate: ~ 2%

- Backgrounds: ~1-3%

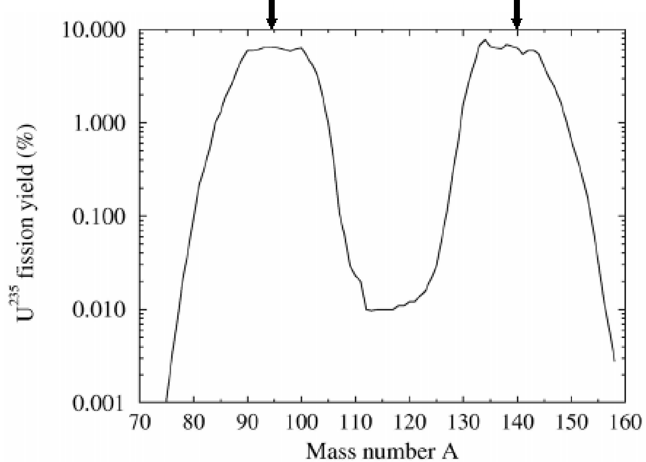
- Target mass: ~1-2%
- Efficiency: ~2-3%

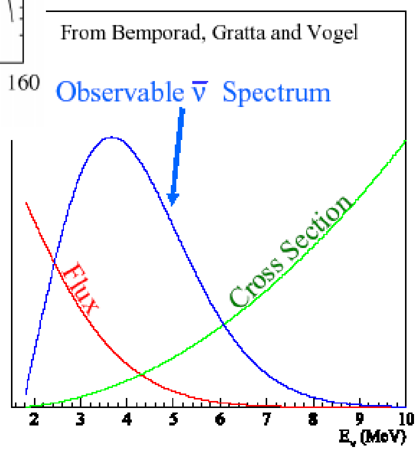
Experiments with neutrinos from reactors

- **Huge production yield:**
  $6\times 10^{20}\ \bar{\nu}$ /s @ 3 GW

$$^{235}_{92}U + n \rightarrow X_1 + X_2 + 2n$$

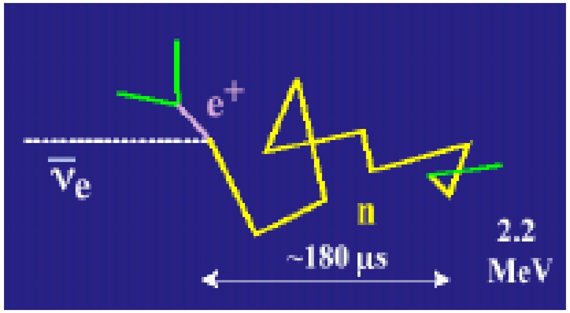
$$^{94}_{40}Zr \qquad ^{140}_{58}Ce$$





- **Powerful background rejection capability:**

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



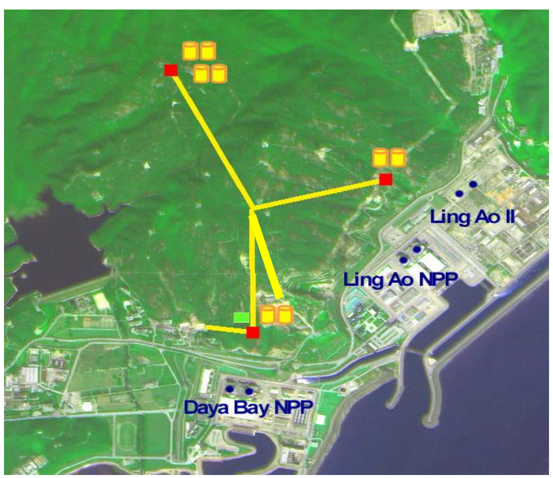
Neutrino energy:

$$E_{\bar{\nu}} \cong T_{e^+} + \underbrace{T_n}_{} + (M_n - M_p) + m_{e^+}$$

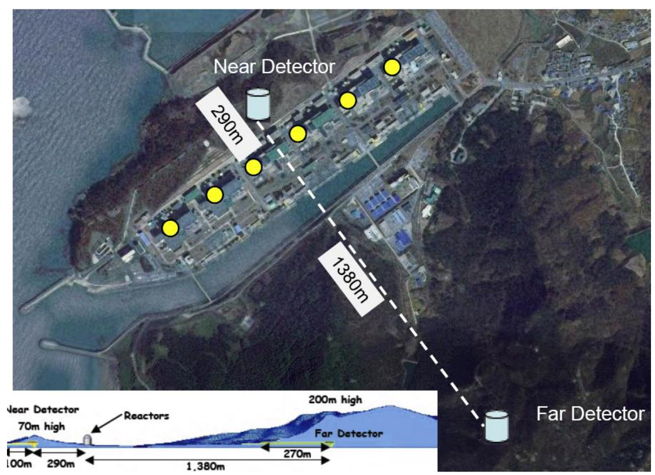
10-40 keV *1.8 MeV:* **Threshold**

Three on-going experiments for θ_{13}

Experiment	Power (GW)	Baseline(m) Near/Far	Target mass (t) Near/Far	Overburden (MWE) Near/Far	Sensitivity (90%CL)
Double Chooz	8.5	400/1050	8.2/8.2	120/300	~ 0.03
Daya Bay	17.4	470/576/1650	40//40/80	250/265/860	~ 0.008
Reno	16.5	409/1444	16/16	120/450	~ 0.02



Daya Bay

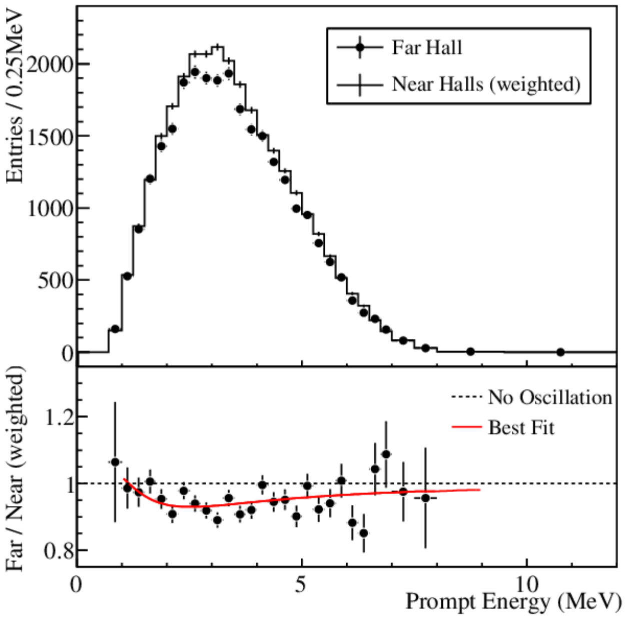


Reno

Double Chooz

θ_{13} is determined in 2012

Daya Bay

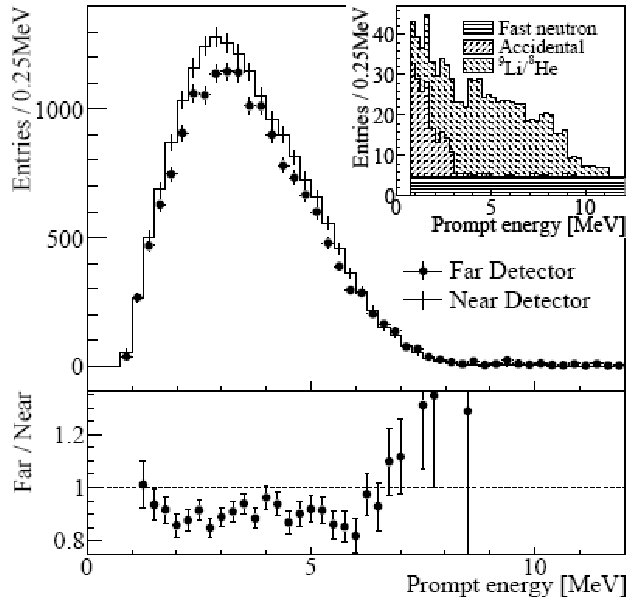


R=0.944 ± 0.007 ± 0.003

$Sin^2 2\theta_{13}$=0.089±0.010±0.005
7.7 σ for non-zero θ_{13}

F.P. An et al., Phys. Rev. Lett. 108, (2012) 171803
F.P. An et al., Chin. Phys.C 37(2013) 011001

Reno

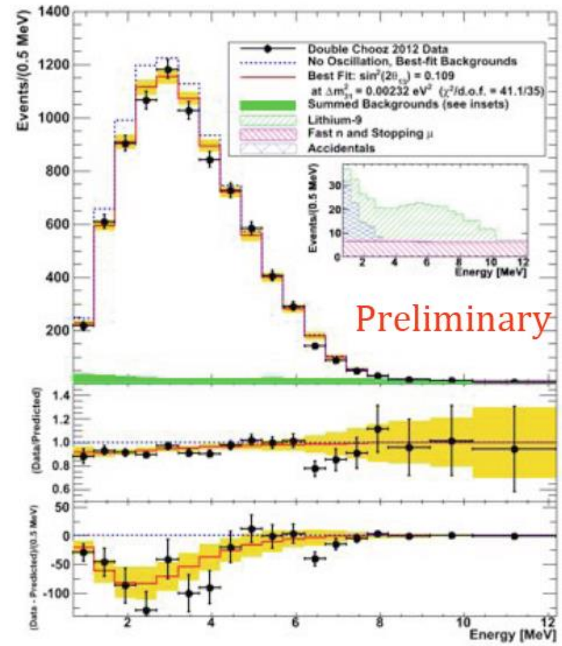


R= 0.920±0.009±0.014

$Sin^2 2\theta_{13}$=0.113±0.013±0.019
4. 9σ for non-zero θ_{13}

J.K. Ahn et al., Phys.Rev.Lett. 108 (2012) 191802

Double Chooz

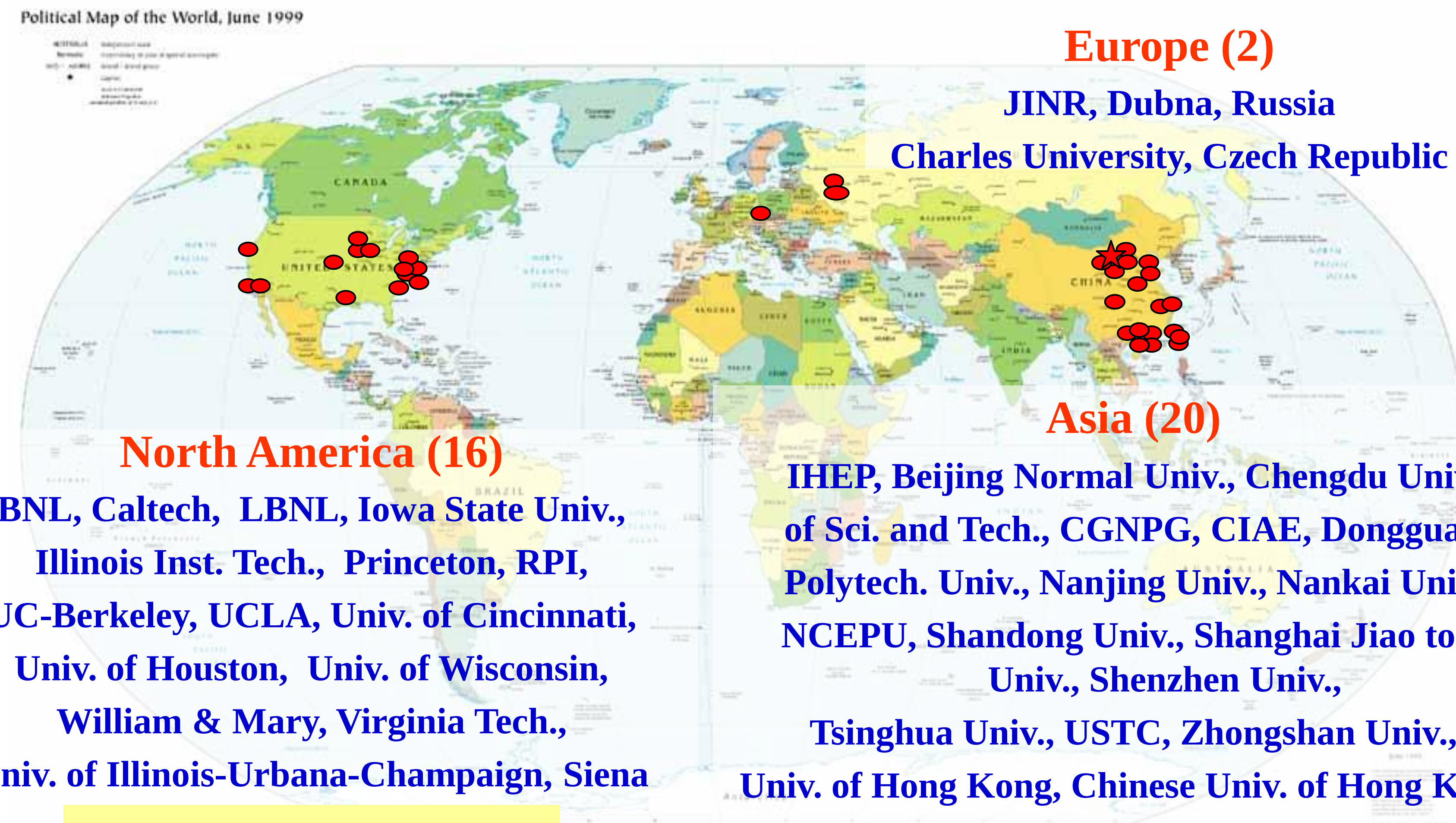


$Sin^2 2\theta_{13}$=0.170±0.035±0.040

$Sin^2 2\theta_{13}$=0.109±0.030±0.025
3.1 σ for non-zero θ_{13}

Y. Abe et la., Phys.Rev. D86 (2012) 052008

The Daya Bay Collaboration



Europe (2)

JINR, Dubna, 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 & Mary, Virginia Tech., Univ. of Illinois-Urbana-Champaign, Siena

~250 Collaborators

Asia (20)

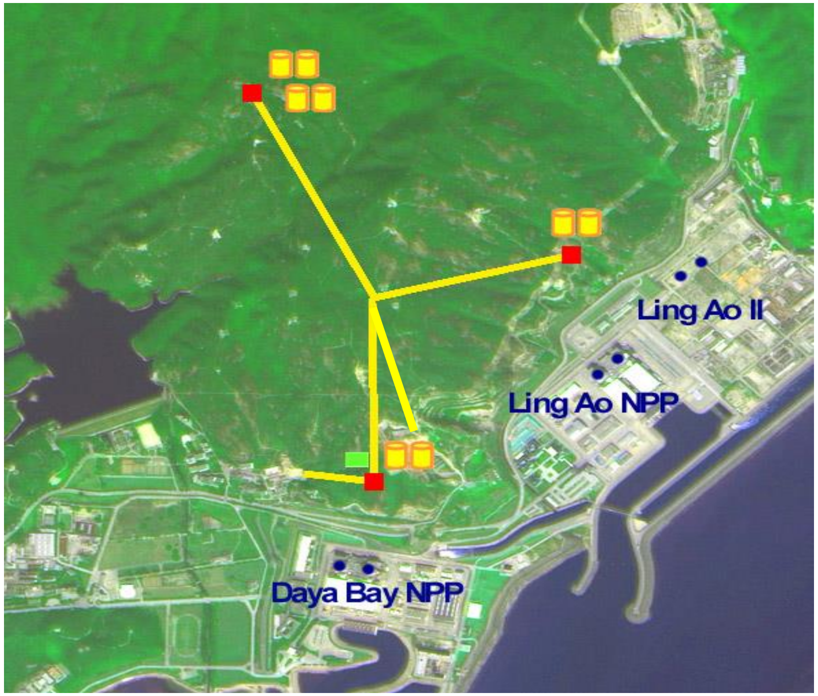
IHEP, Beijing Normal Univ., Chengdu Univ. of Sci. and Tech., CGNPG, CIAE, Dongguan Polytech. Univ., Nanjing Univ., Nankai Univ., NCEPU, Shandong Univ., Shanghai Jiao tong Univ., Shenzhen Univ., Tsinghua Univ., USTC, Zhongshan Univ., Univ. of Hong Kong, Chinese Univ. of Hong Kong, National Taiwan Univ., National Chiao Tung Univ., National United Univ.

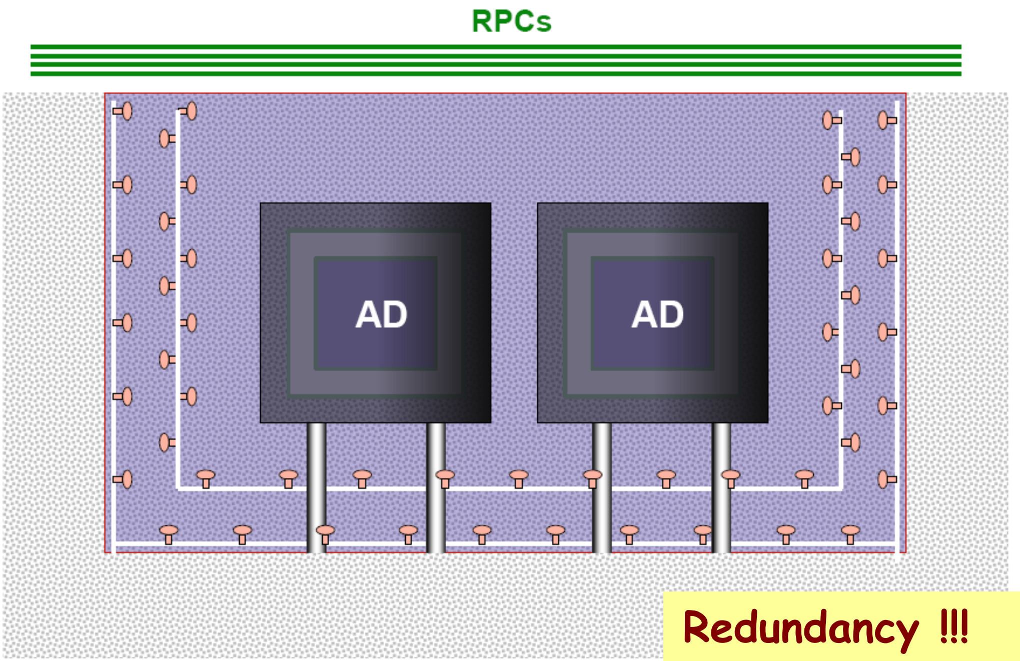
Timeline of the Experiment

- **Aug. 2003: Experimental plan and the detector design is proposed**
- **2006: Project approved in China, and afterwards in other countries**
- **Oct. 2007: Civil construction started**
- **Dec.2010: All the blasting for the tunnel and underground hall completed**
- **2008-2011: Detector construction, assembly and installation**
- **Aug. 2011: Near detector data taking started**
- **Dec. 2011: Far detector data taking started ➔ full detector data taking**

Opening ceremony： Oct. 2007

Daya Bay Experiment: Layout





Redundancy !!!

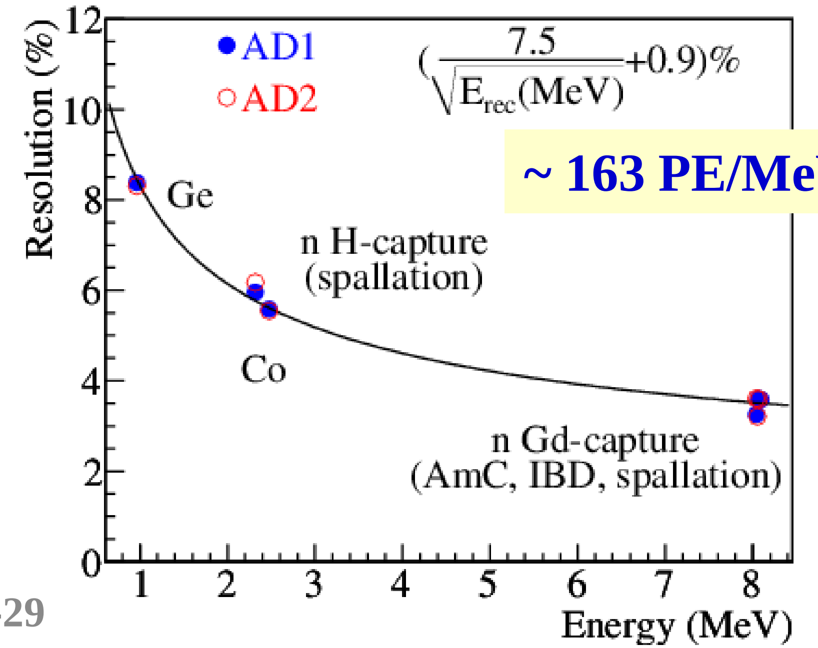
- Relative measurement to cancel Corr. Syst. Err.
  - ⇨ 2 near sites, 1 far site
- Multiple AD modules at each site to reduce Uncorr. Syst. Err.
  - ⇨ Far: 4 modules， near: 2 modules

Cross check; Reduce errors by 1/√N

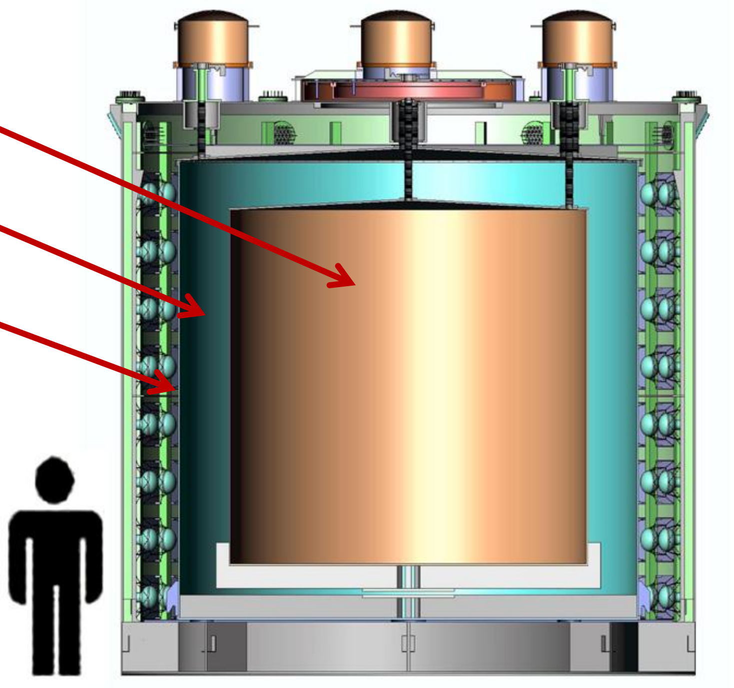
- Multiple muon detectors to reduce veto eff. uncertainties
  - ⇨ Water Cherenkov： 2 layers
  - ⇨ RPC： 4 layers at the top + telescopes

Anti-neutrino Detector (AD)

- **Three zones modular structure:**
  - **I. target: Gd-loaded scintillator**
  - **II. γ-catcher: normal scintillator**
  - **III. buffer shielding: oil**
- **192 8" PMTs/module**
- **Two optical reflectors at the top and the bottom, Photocathode coverage increased from 5.6% to 12%**



~ 163 PE/MeV

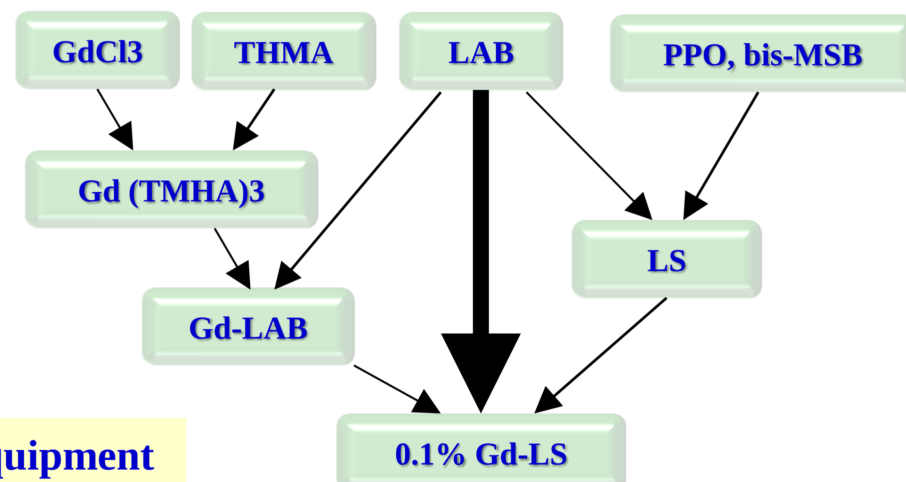


Target: 20 t, 1.6m
γ-catcher: 20t, 45cm
Buffer: 40t, 45cm
Total weight: ~110 t

Gd-Loaded Liquid Scintillator

- **Issue: transparency, aging, …**

Groups	Solvent	Complexant for Gd compound	Quantity(t)
Chooz	IPB	alcohol	5
Palo Verde	PC+MO	EHA	12
Double Chooz	PXE+dodecane	Beta-Dikotonates	8
Reno	LAB	THMA	40
Daya Bay	LAB	THMA	185



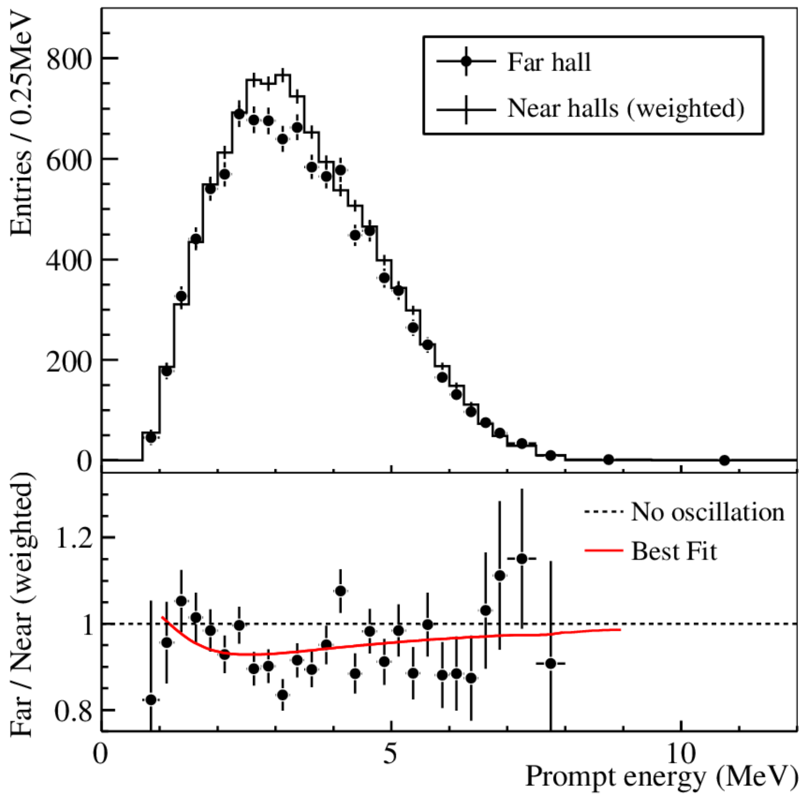
Gd-LS production Equipment and the process by Daya Bay

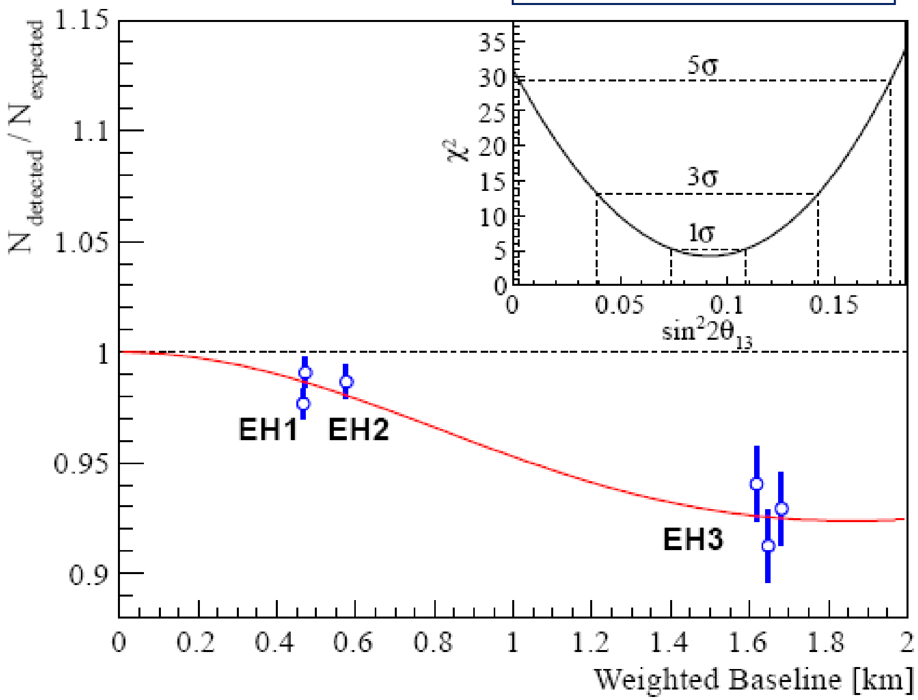
A New Type of Oscillation Discovered

- **Observation of electron anti-neutrino disappearance:**

R = 0.940 ±0.011 (stat) ±0.004 (syst)

announced on Mar. 8, 2012





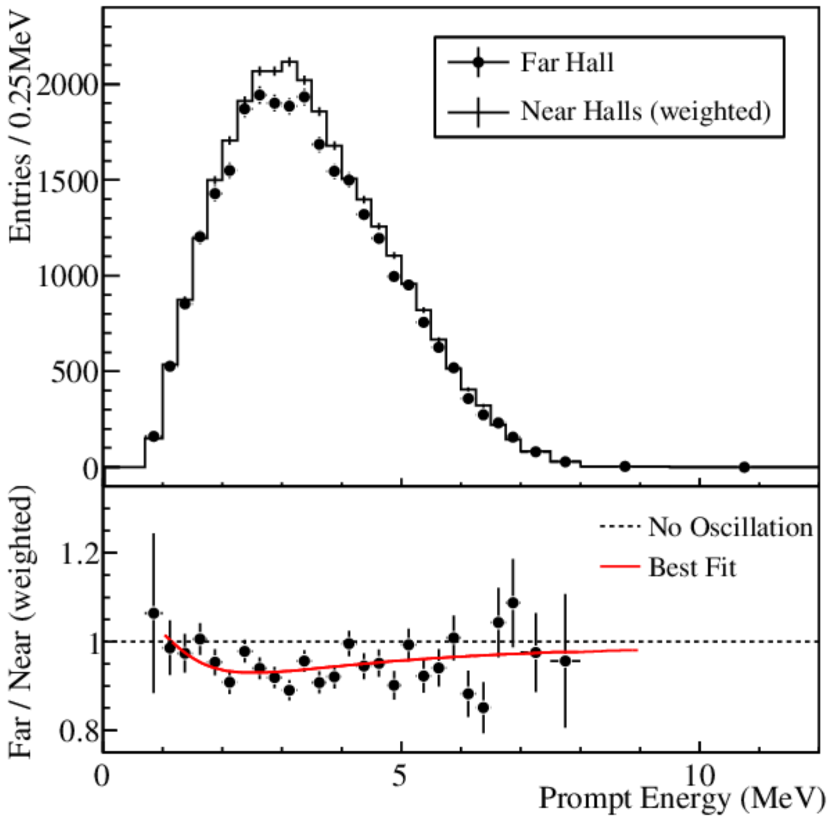
$\sin^2 2\theta_{13} = 0.092 \pm 0.016(\text{stat}) \pm 0.005(\text{syst})$

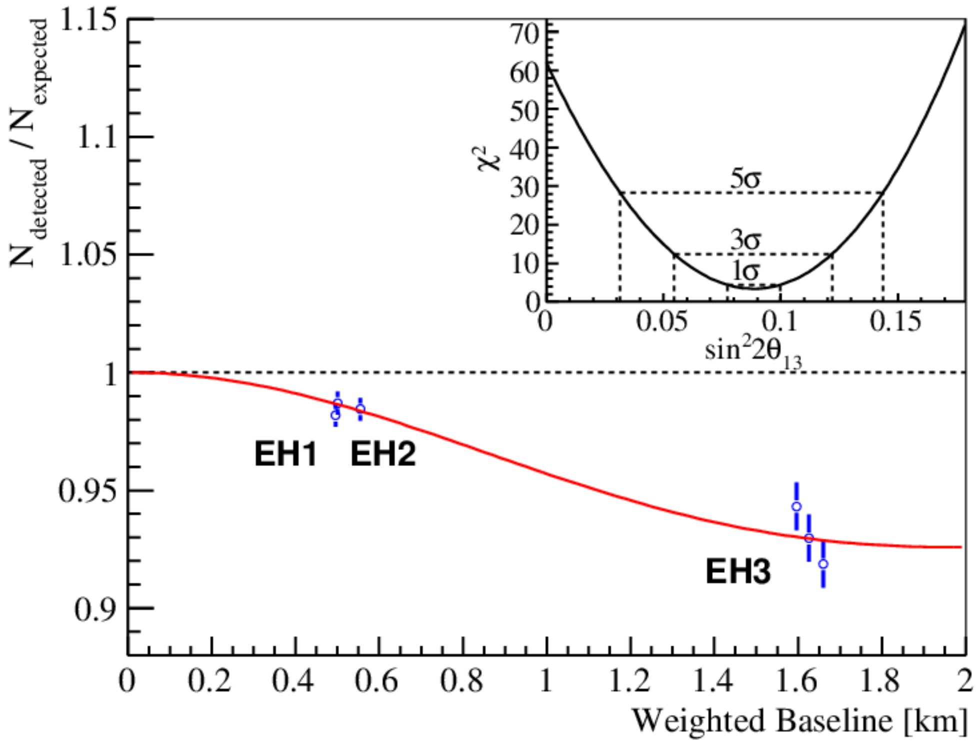
$\chi^2/NDF = 4.26/4$, 5.2 σ for non-zero θ_{13}

F.P. An et al., NIM. A 685(2012)78

F.P. An et al., Phys. Rev. Lett. 108, (2012) 171803

Updated results





F.P. An et al., Chin. Phys.C 37(2013) 011001

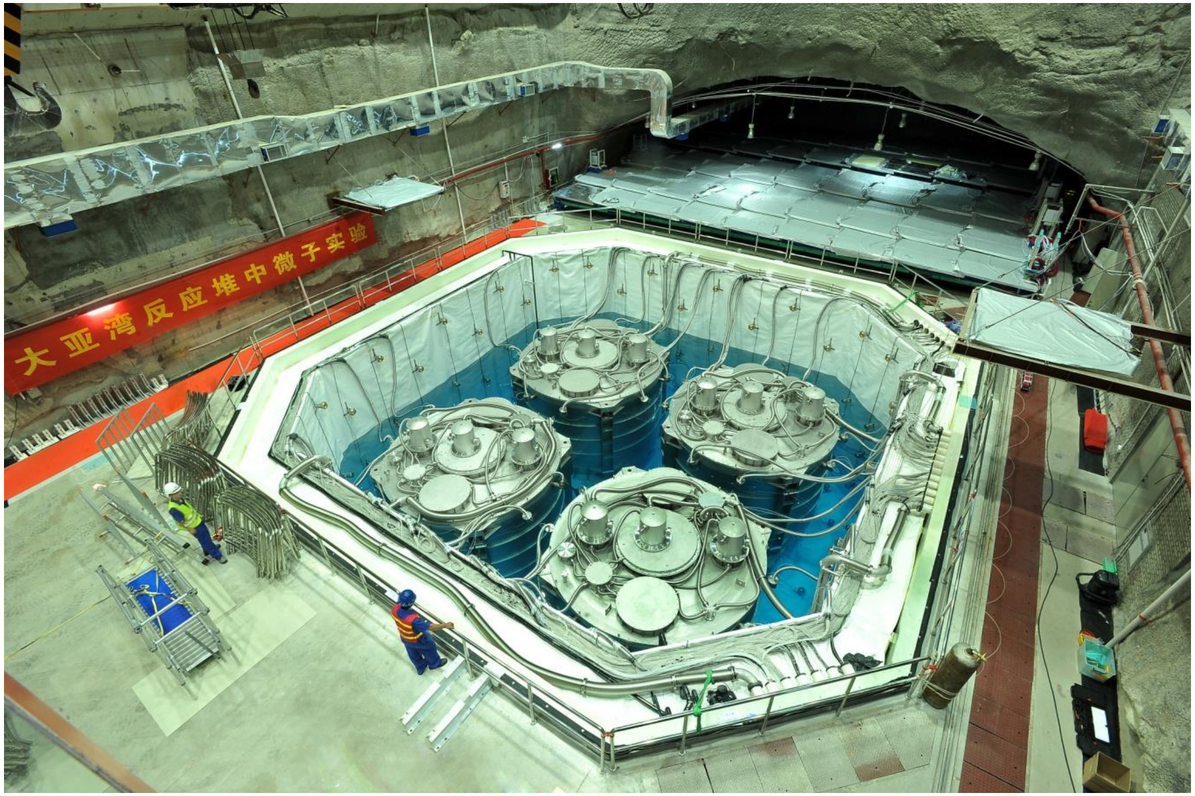
R = 0.944 ±0.007 (stat) ±0.003 (syst)

$\sin^2 2\theta_{13} = 0.089 \pm 0.010(\text{stat}) \pm 0.005(\text{syst})$

χ^2/NDF = 3.4/4, 7.7 σ for non-zero θ_{13}

Current status and future plan

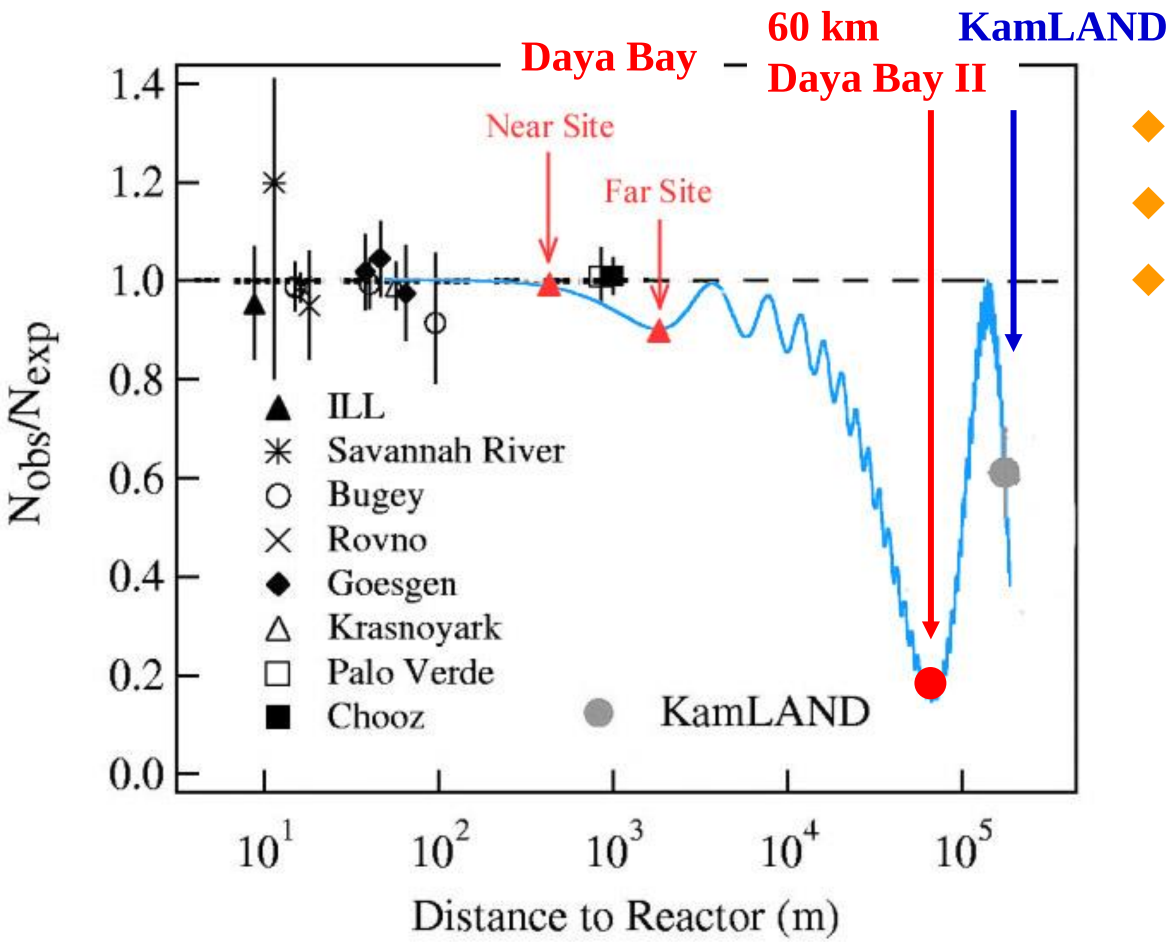
- Summer（2012） maintenance completed
- Two new AD modules installed
- Data taking resumed in Oct.
- Precision results in three years, $\Delta(\sin^2 2\theta_{13}) \sim 4\%$



What is next after θ_{13} ?

- Neutrino oscillation
  - ⇨ What is the neutrino mass hierarchy ?
  - ⇨ Are there CPV in neutrinos ?
  - ⇨ Is the neutrino mixing angle θ_{23} maximized ?
  - ⇨ Is the neutrino mixing matrix unitary ?
- What are the absolute mass of neutrinos ?
- Are neutrinos their anti-particles ?
- Are there sterile neutrinos ?
- Are there fourth generation neutrinos ?
- How to detect relic neutrinos ?

Idea of the Daya Bay-II Experiment

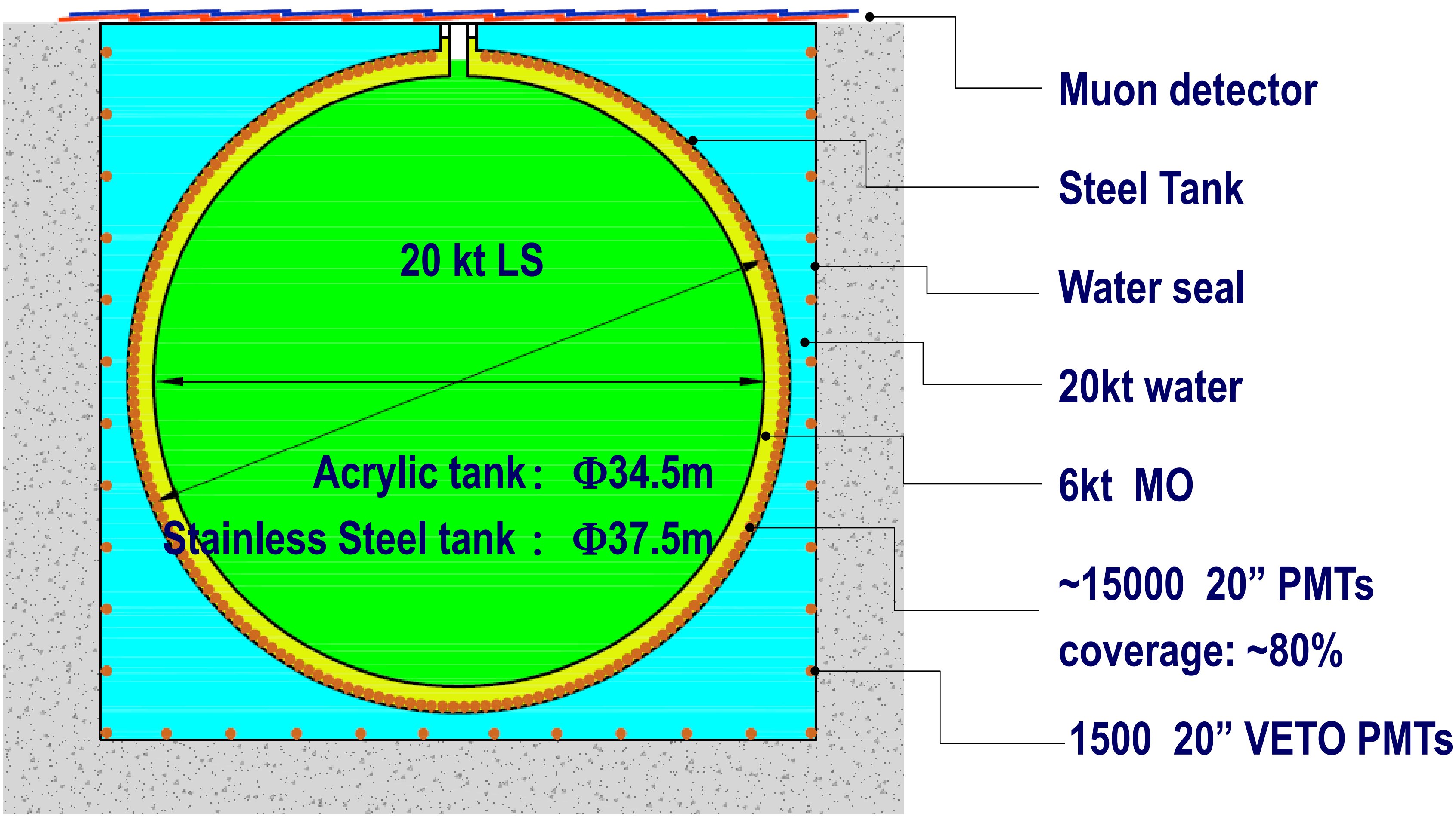


- 20 kton LS detector
- 3% energy resolution
- Rich physics possibilities
  - ⇨ Mass hierarchy
  - ⇨ Precision measurement of 4 mixing parameters
  - ⇨ Supernovae neutrinos
  - ⇨ Geoneutrinos
  - ⇨ Sterile neutrinos
  - ⇨ Atmospheric neutrinos
  - ⇨ Exotic searches

Talk by Y.F. Wang at ICFA seminar 2008, Neutel 2011; by J. Cao at Nutel 2009, NuTurn 2012 ;
Paper by L. Zhan, Y.F. Wang, J. Cao, L.J. Wen, PRD78:111103,2008; PRD79:073007,2009

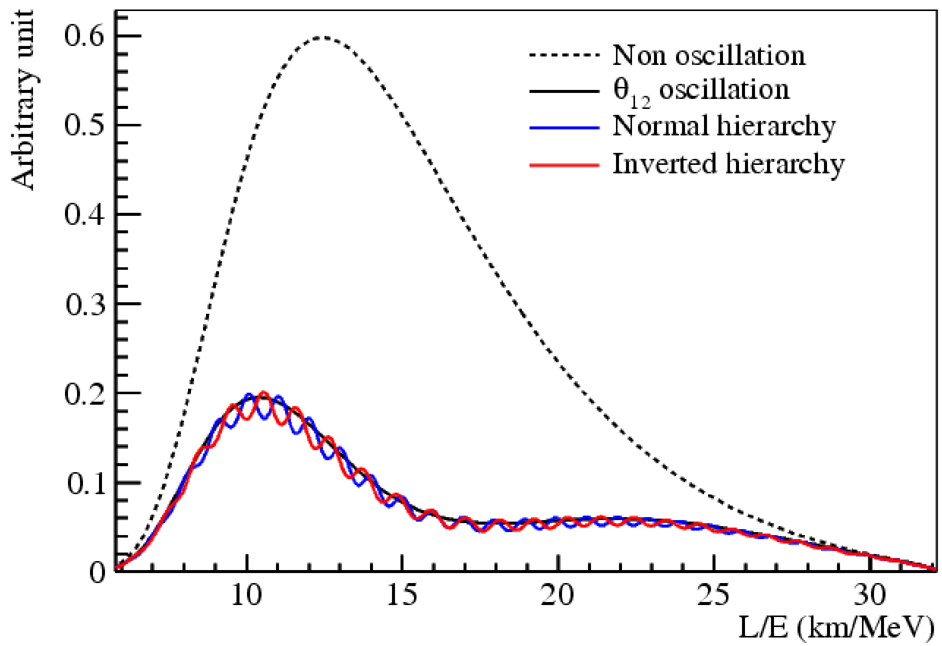
The plan: a large LS detector

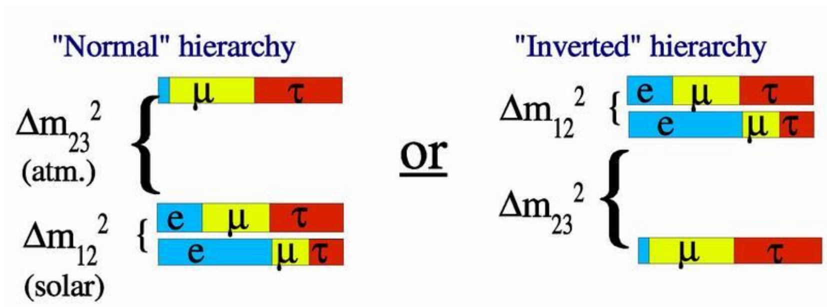
- LS volume: × 20 ➔ for more mass & statistics
- light(PE) × 5 ➔ for resolution



Principle

40 neutrinos/day



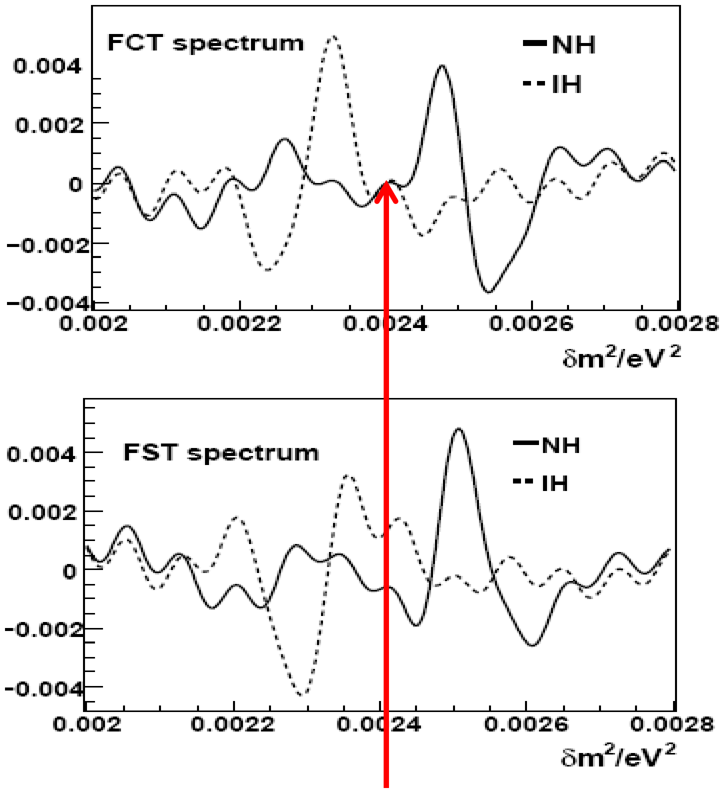


$$
\begin{aligned}
P_{ee}(L/E) &= 1 - P_{21} - P_{31} - P_{32} \\
P_{21} &= \cos^4(\theta_{13})\sin^2(2\theta_{12})\sin^2(\Delta_{21}) \\
P_{31} &= \cos^2(\theta_{12})\sin^2(2\theta_{13})\sin^2(\Delta_{31}) \\
P_{32} &= \sin^2(\theta_{12})\sin^2(2\theta_{13})\sin^2(\Delta_{32})
\end{aligned}
$$

- **Precision energy spectrum measurement: Looking for interference between P_{31} and P_{32} → relative measurement**

Mass hierarchy：sensitivity

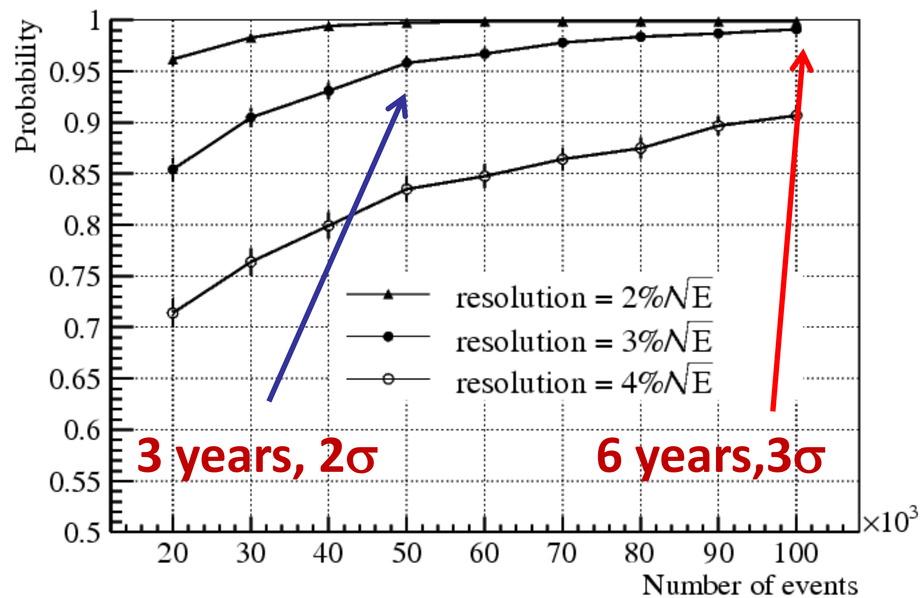
- **Thanks to a large θ_{13}**



ΔM^2_{23}

$$\begin{aligned} \Delta m^2_{31} &= \Delta m^2_{32} + \Delta m^2_{21} \\ \text{NH}: \ |\Delta m^2_{31}| &= |\Delta m^2_{32}| + |\Delta m^2_{21}| \\ \text{IH}: \ |\Delta m^2_{31}| &= |\Delta m^2_{32}| - |\Delta m^2_{21}| \end{aligned}$$

Fourier transformation:



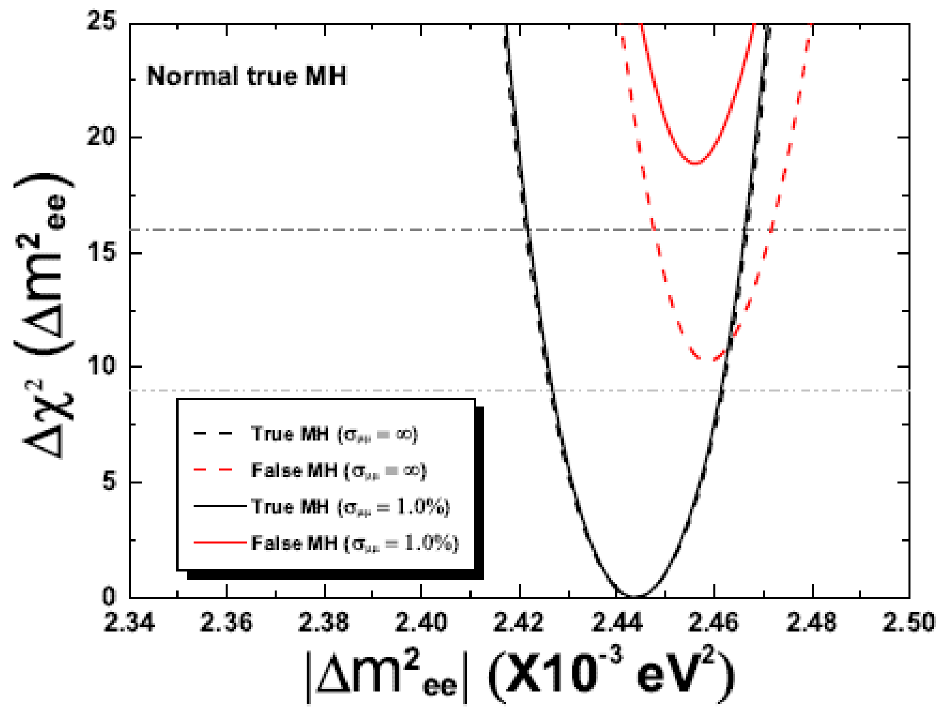
Detector size: 20kt
Energy resolution: 3%/√E
Thermal power: 36 GW
Baseline 58 km

L. Zhan, Y.F. Wang, et al., PRD78:111103,2008; PRD79:073007,2009

Taking into account $\Delta M^2_{\mu\mu}$

For 6 years data taking:

- **Ideally, relative measurement can reach 4σ. With the help of $\Delta m^2_{\mu\mu}$, Sensitivity can reach 5σ**
- **Due to reactor core distributions, detector non-linearity uncertainties, etc., relative measurement can reach 3σ. With the help of $\Delta m^2_{\mu\mu}$, Sensitivity can reach 4σ**



arXiv:1303.6733

A χ^2 method by taking into account $\Delta M^2_{\mu\mu}$ from T2K and Nova in the future

Precision measurement of mixing parameters

- **Fundamental to the Standard Model and beyond**
- **Probing the unitarity of U_{PMNS} to ~1% level !**
  - ⇨ Uncertainty from other oscillation parameters and systematic errors, mainly energy scale, are included

	Current	Daya Bay II
Δm^2_{12}	3%	0.6%
Δm^2_{23}	5%	0.6%
$\sin^2\theta_{12}$	6%	0.7%
$\sin^2\theta_{23}$	20%	N/A
$\sin^2\theta_{13}$	14% ➔ 4%	~ 15%

Will be more precise than CKM matrix elements !

Supernova neutrinos

- Less than 20 events observed so far
- Assumptions:
  - Distance: 10 kpc (our Galaxy center)
  - Energy: 3×10^{53} erg
  - L_ν the same for all types
  - Tem. & energy $T(\underline{\nu}_e) = 3.5$ MeV, $\langle E(\underline{\nu}_e)\rangle = 11$ MeV

    $T(\nu_e) = 5$ MeV, $\langle E(\nu_e)\rangle = 16$ MeV

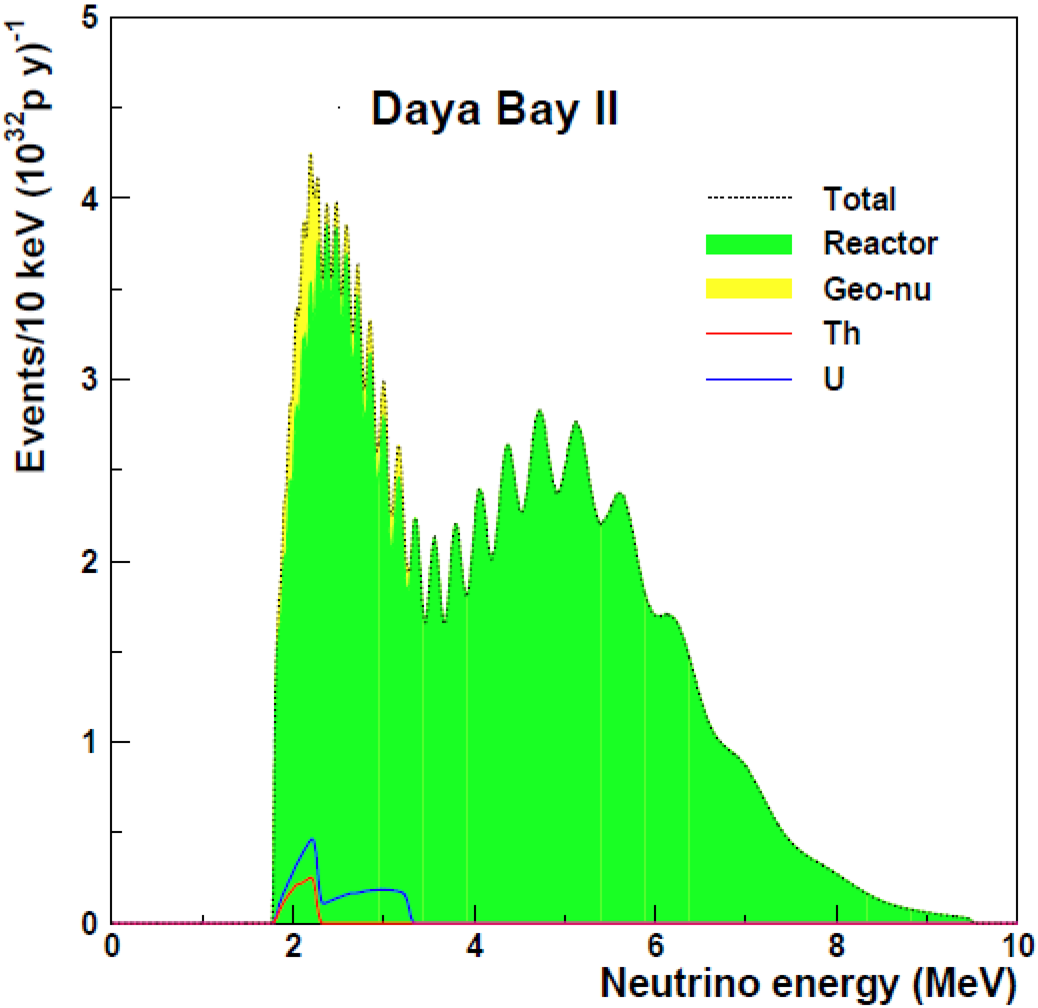
    $T(\nu_x) = 8$ MeV, $\langle E(\nu_x)\rangle = 25$ MeV
- Many types of events:
  - $\bar{\nu}_e + p \rightarrow n + e^+$, ~ 3000 correlated events
  - $\bar{\nu}_e + {}^{12}C \rightarrow {}^{12}B^* + e^+$, ~ 10-100 correlated events
  - $\nu_e + {}^{12}C \rightarrow {}^{12}N^* + e^-$, ~ 10-100 correlated events
  - $\nu_x + {}^{12}C \rightarrow \nu_x + {}^{12}C^*$, ~ 600 correlated events
  - $\nu_x + p \rightarrow \nu_x + p$, single events
  - $\nu_e + e^- \rightarrow \nu_e + e^-$, single events
  - $\nu_x + e^- \rightarrow \nu_x + e^-$, single events

Water Cerenkov detectors can not see these correlated events

Energy spectra & fluxes of all types of neutrinos

Geoneutrinos

- Current results:
  - KamLAND:
    40.0±10.5±11.5 TNU
  - Borexino:
    64±25±2 TNU
- Desire to reach an error of 3 TNU: statistically dominant
- Daya Bay II: >×10 statistics, but difficult on systematics
- Background to reactor neutrinos



From Stephen Dye

Challenges

- Large detector: >10 kt LS
- Energy resolution: < 3%/√E ➔ 1200 p.e./MeV

	KamLAND	Daya Bay II
LS mass	~1 kt	20 kt
Energy Resolution	6%/√E	3%/√E
Light yield	250 p.e./MeV	1200 p.e./MeV

More photons, how and how many ?

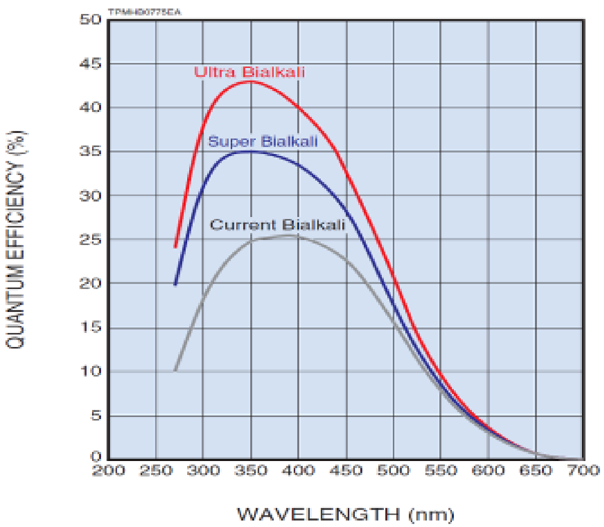
- **Highly transparent LS:**
  - ⇨ **Attenuation length/D: 15m/16m → 30m/34m ×0.9**
- **High light yield LS:**
  - ⇨ **KamLAND: 1.5g/l PPO → 5g/l PPO**
  - **Light Yield: 30%→ 45%; × 1.5**
- **Photocathode coverage :**
  - ⇨ **KamLAND: 34% → ~ 80% × 2.3**
- **High QE "PMT":**
  - ⇨ **20" SBA PMT QE: 25% → 35% × 1.4**
  - **or New PMT QE: 25% → 40% × 1.6**
  - **Both: 25% → 50% × 2.0**

4.3 – 5.0 → (3.0 – 2.5)% /√E

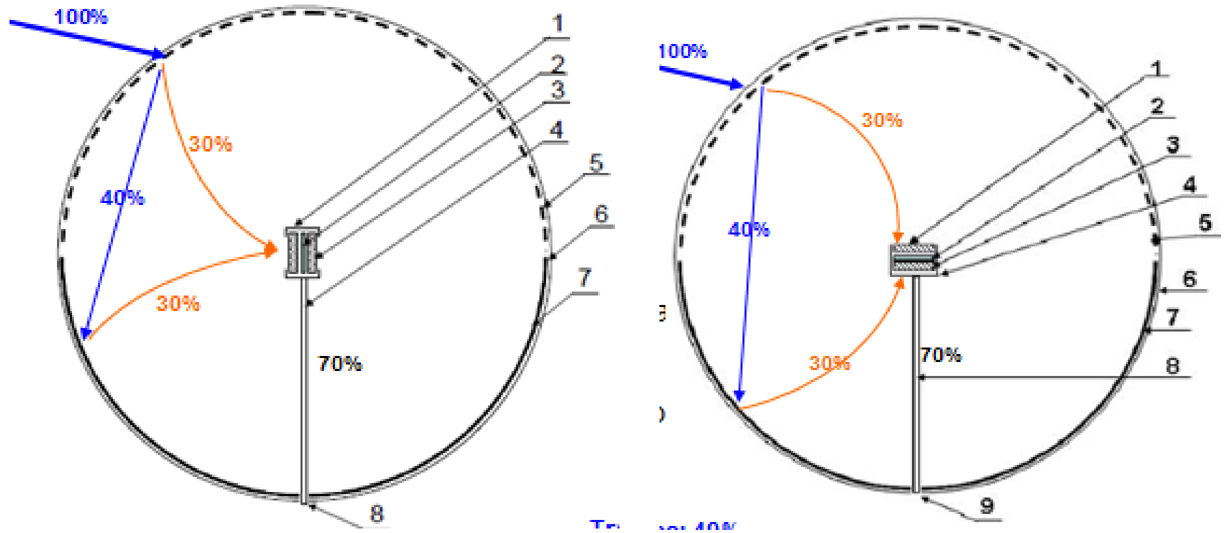
Other contributions: 0.5% constant term & 0.5% neutron recoil uncertainty

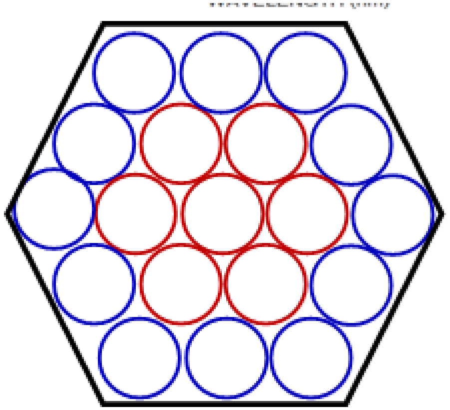
More Photoelectrons-- PMT

SBA photocatode



New type of PMT: MCP-PMT



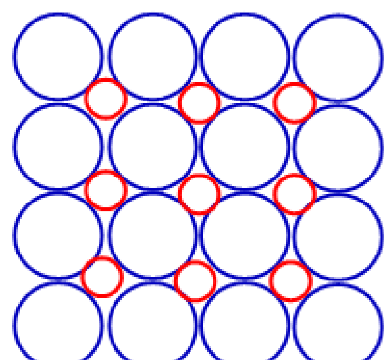


No clearance:

coverage 86.5%

1cm clearance:

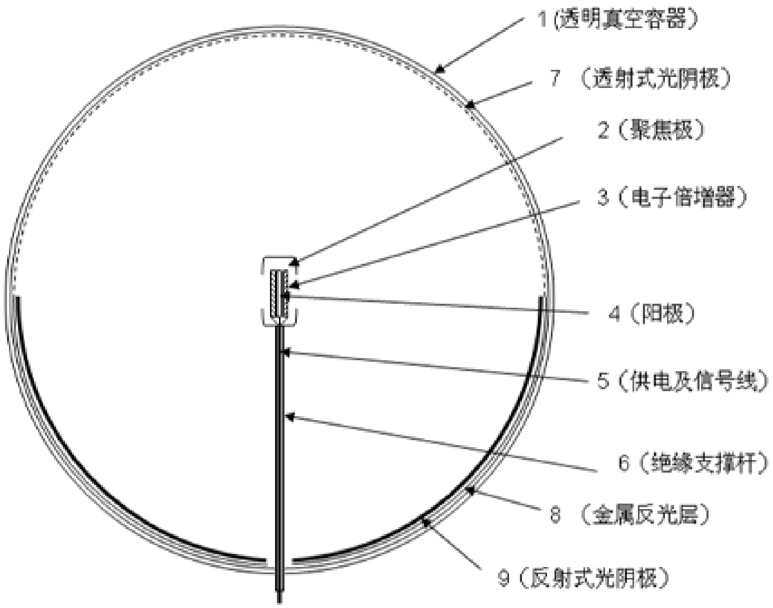
coverage: 83%

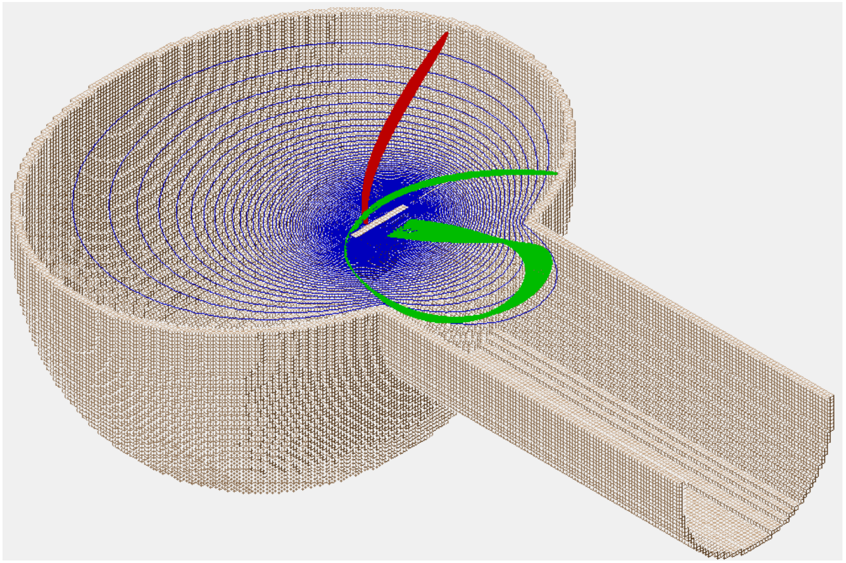


20" + 8" PMT

8" PMT for better timing(vertex)

A new type of PMT: higher photon detection eff.





- Top: transmitted photocathode
- Bottom: reflective photocathode

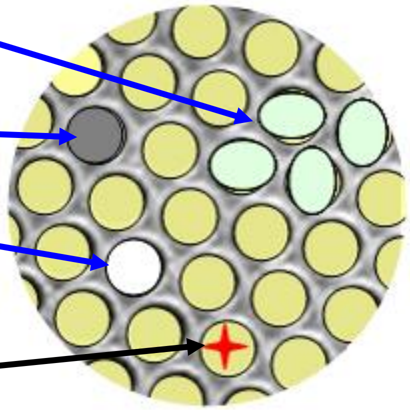
  additional QE: ~ 80%*40%
- MCP to replace Dynodes ➔ no blocking of photons

~ ×2 improvement

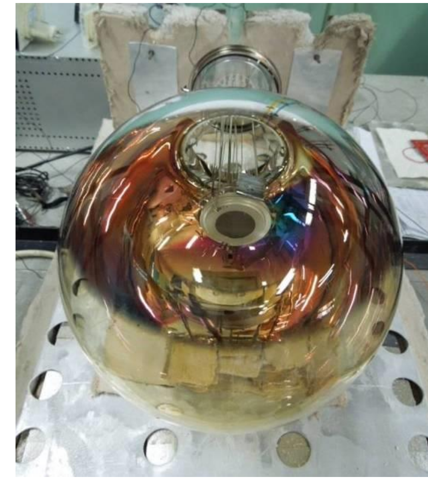
Low cost MCP by accepting the following:

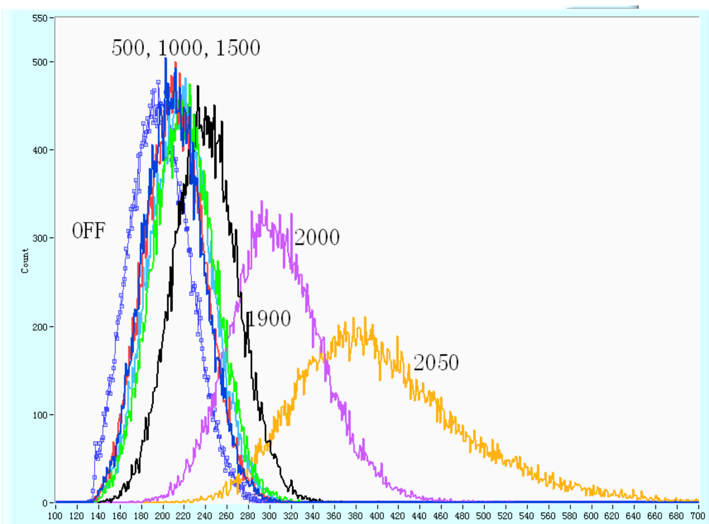
1. asymmetric surface;
2. Blind channels;
3. Non-uniform gains

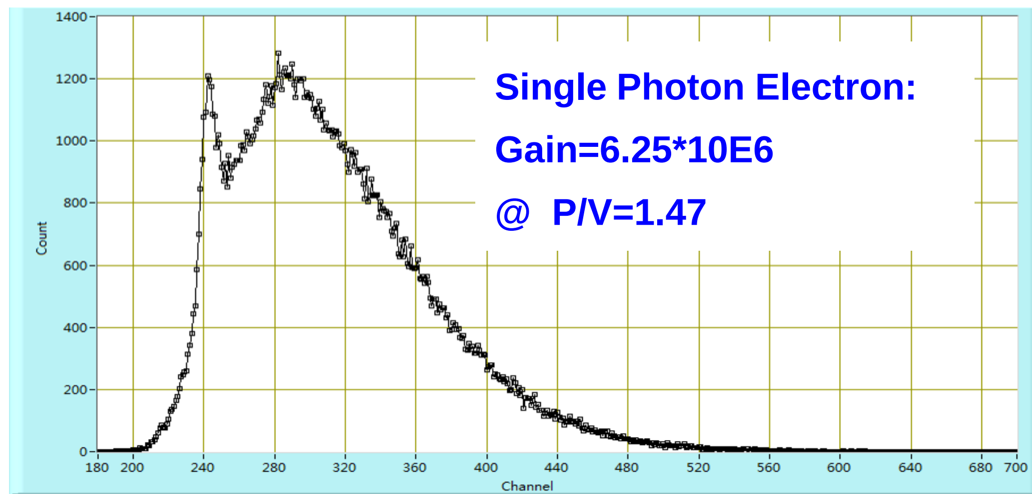
4. Flashing channels



Prototypes





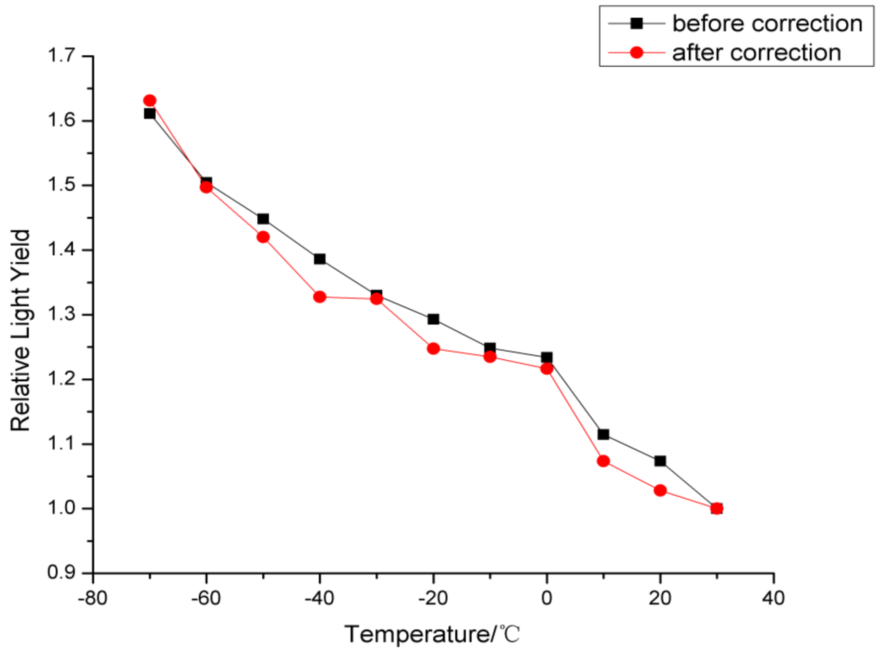


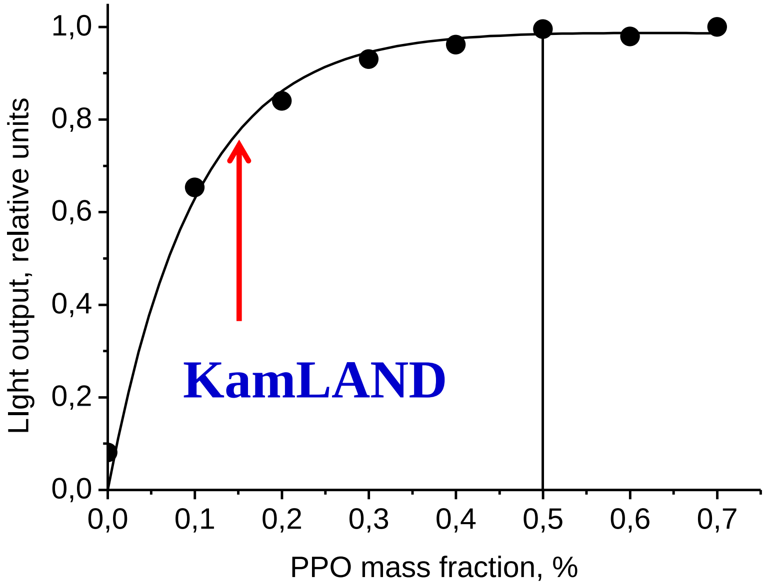
中国科学院高能物理研究所 Institute of High Energy Physics Chinese Academy of Sciences
北方夜视技术股份有限公司 NORTH NIGHT VISION TECHNOLOGY CO.,LTD
中国科学院西安光学精密机械研究所 XIAN INSTITUTE OF OPTICS AND PRECISION MECHANICS OF CAS
海南展创光电技术有限公司 HZC PHOTONICS
中核（北京）核仪器厂 CNNC Beijing Nuclear Instrument Factory

More Photoelectrons-- LS

- **Longer attenuation length**
  - ⇨ Improve raw materials (using Dodecane instead of MO for LAB production）
  - ⇨ Improve the production process
  - ⇨ Purification
- **Higher light yield**
  - ⇨ Lower temperature
  - ⇨ fluor concentration optimization

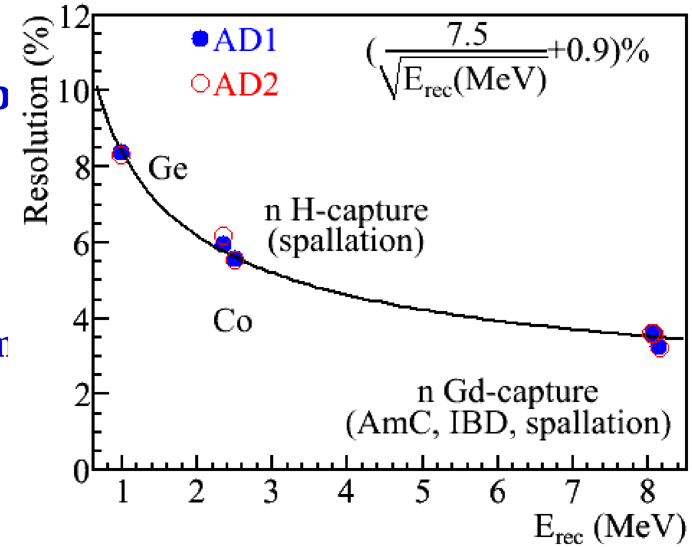
Linear Alky Benzene	Atte. Length @ 430 nm
RAW	14.2 m
Vacuum distillation	19.5 m
SiO_2 coloum	18.6 m
Al_2O_3 coloum	22.3 m

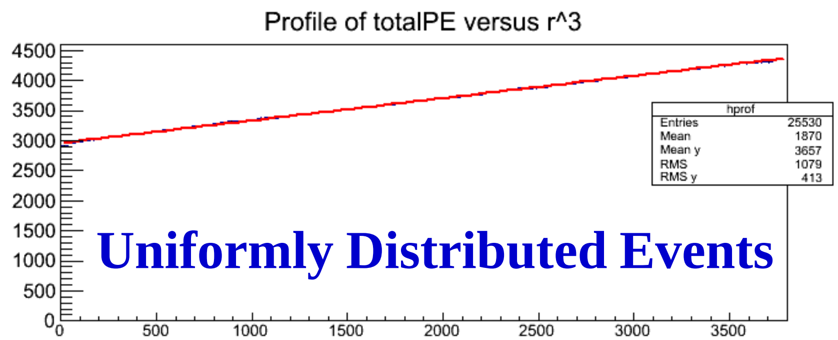


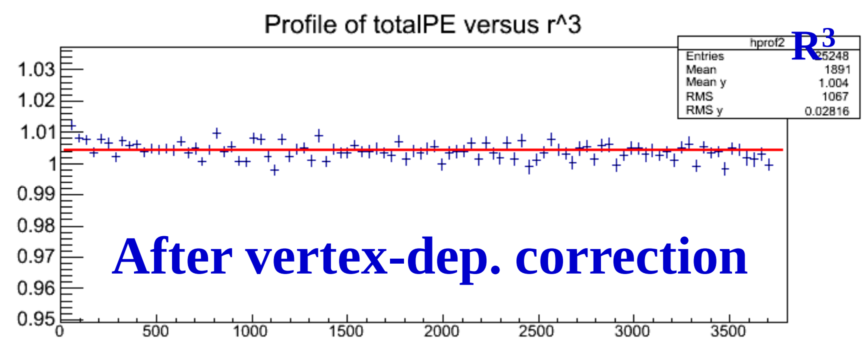


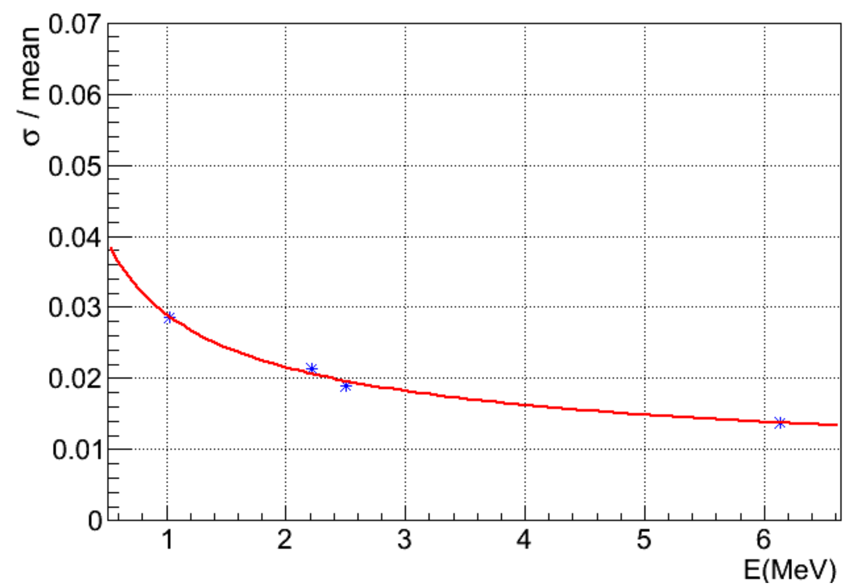
MC example: Energy Resolution

- DYBII MC, based on DYB MC (tuned to data), excep
  - DYBII Geometry and 80% photocathode coverage
  - SBA PMT: maxQE from 25% -> 35%
  - Lower detector temperature to 4 degree (+13% light)
  - LS attenuation length (1m-tube measurement@430nm
    - ✓ from 15m = absoption 24m + Raylay scattering 40 m
    - ✓ to 20 m = absorption 40 m + Raylay scattering 40m









$3.0\%/\sqrt{E}$, or $(2.6/\sqrt{E} + 0.3)\%$

IBD Signal

- **Signal:**

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

Estimated IBD rate: ~40/day

$$n + p \rightarrow d + \gamma\ (2.2\ \text{MeV}) \qquad \tau \sim 200\ \mu s$$

- **LS without Gd-loading for**
  - Better attenuation length ➔ resolution
  - Lower irreducible accidental backgrounds from LS, important for a larger detector:
    - ✓ With Gd: ~ 10^{-12} g/g
    - ✓ Without Gd: ~ 10^{-16} g/g
  - Less risk
- **Longer capture time & lower energy the capture signal ➔ more accidental backgrounds**

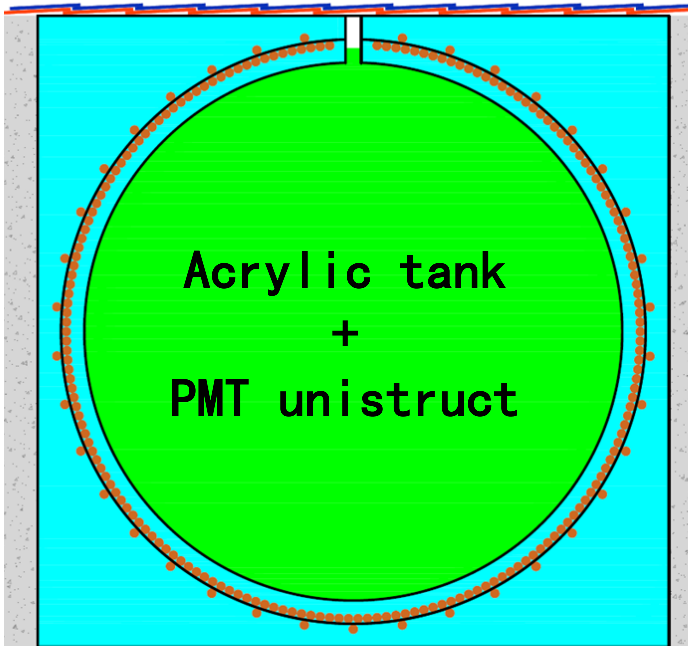
Backgrounds Summary

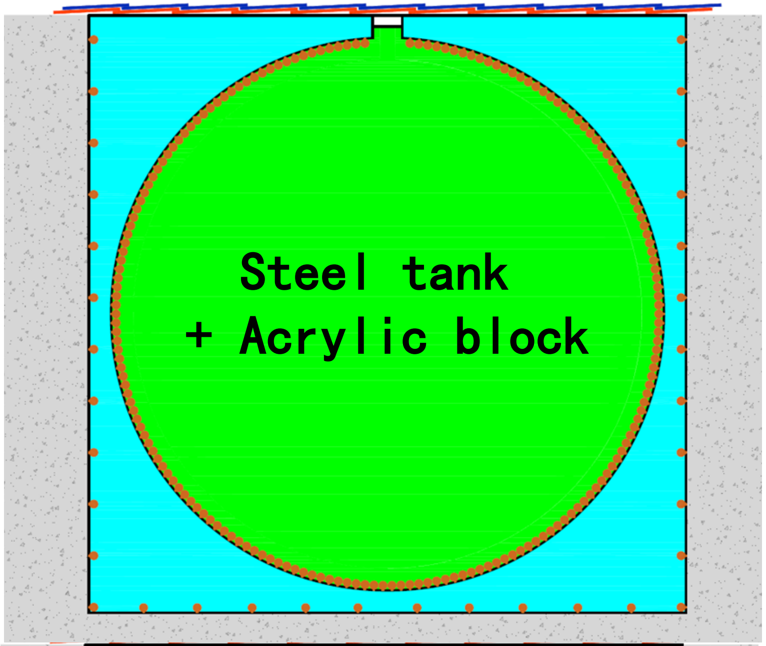
- **Assumptions**
  - Overburden is 700m
    - ✓ E_μ ~ 211 GeV, R_μ ~ 3.8 Hz
  - Single rates from LS and PMT are 5Hz, respectively
  - Good muon tracking
  - Similar muon efficiency as DYB

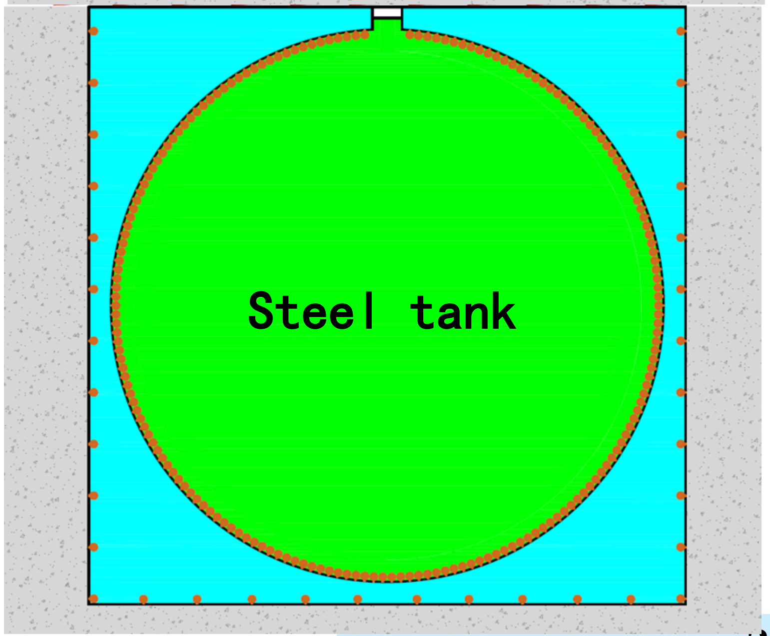
	Daya Bay	Daya Bay II
Mass (ton)	20	20,000
E_μ (GeV)	~57	~211
L_μ (m)	~1.3	~ 23
R_μ (Hz)	~21	~3.8
$R_{singles}$ (Hz)	~50	~10

	B/S @ DYB EH1	B/S @ DYB II	Techniques used for DYB II detector
Accidentals	~1.4%	~10%	Low PMT radioactivity; LS purification; prompt-delayed distance cut
Fast neutron	~0.1%	~0.4%	High muon detection efficiency (similar as DYB)
$^{9}Li/^{8}He$	~0.4%	~0.8%	Muon tracking; If good track, distance to muon track cut (<5m) and veto 2s; If shower muon, full volume veto 2s

Detector design: different options





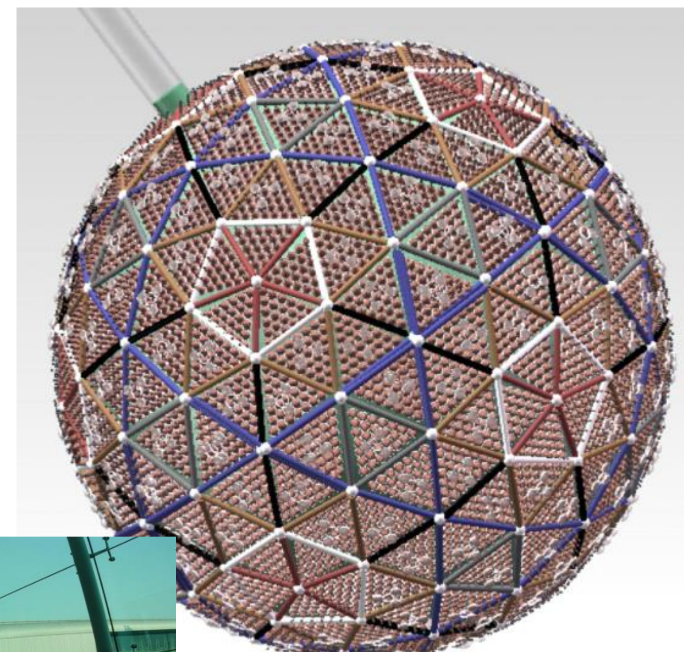


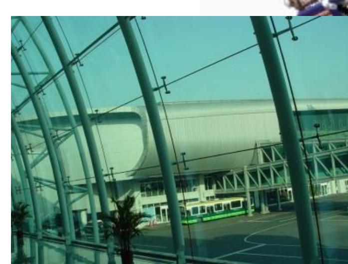
Example 1: Acrylic tank

- **Unistruct for PMT mounting ➔ Same structure for Central Detector and VETO**
- **Oil buffer ➔ Water buffer ➔ Cheap**
- **Technology from construction industry**

15% density difference leads to a maximum pressure of ~6m in air ➔ A normal aquarium

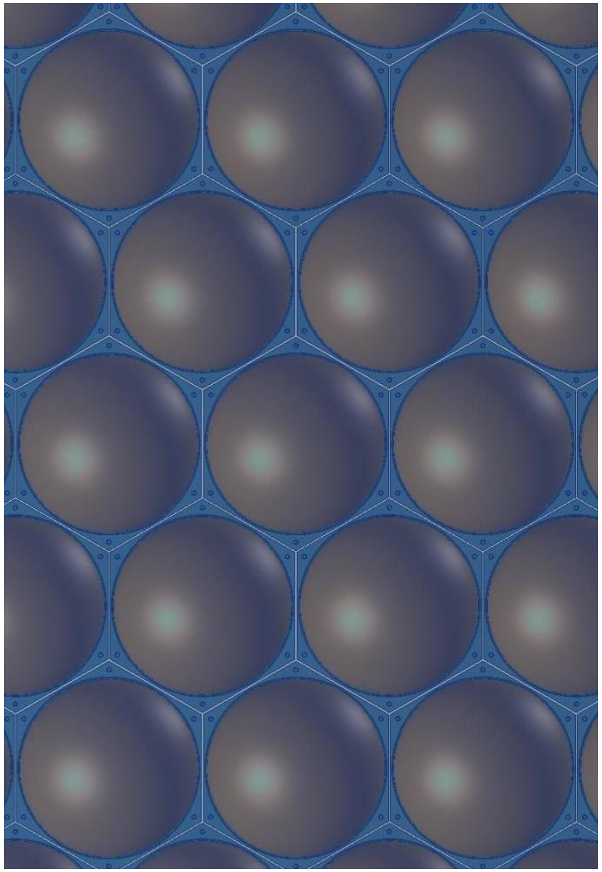
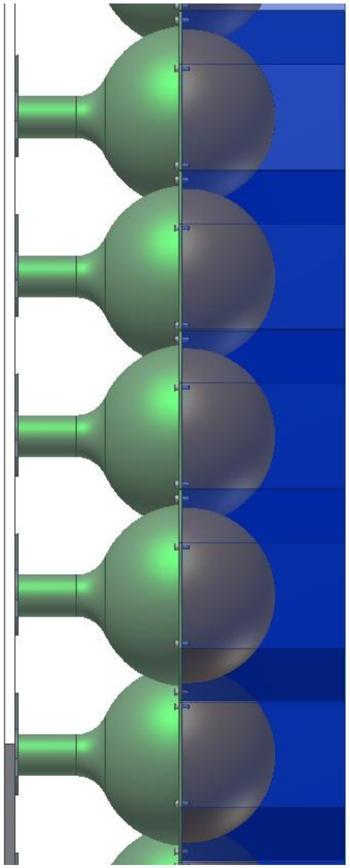
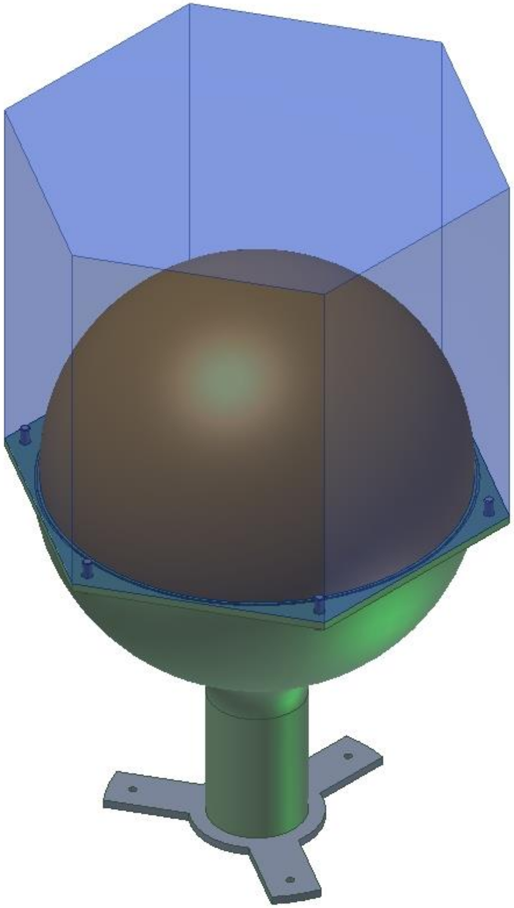
Zhujiang City Building
Ball conference : 39 m





Example 2: Acrylic block

- Individually mounted
- Technically easy but may loose light

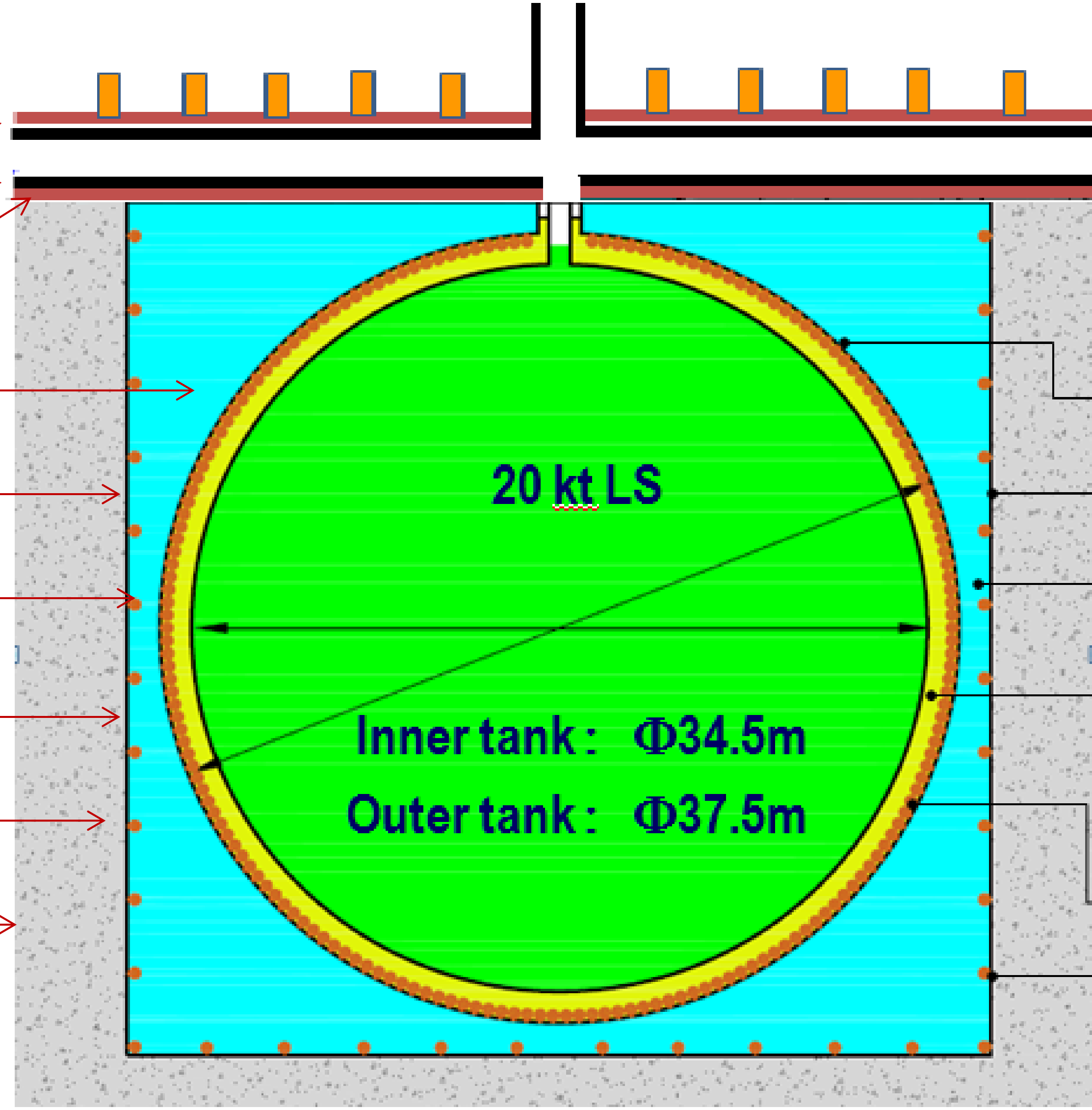




R & D Plan

- Nail down to two options at maximum
- Build prototypes to understand
  - Design and manufacturing technologies
  - Assembly and installation issues
  - Background suppression capabilities
- Final decision: end of next year
- Engineering design: 2015

VETO detectors

- Top tracker
- Top tracker support
- Water
- Tyvek
- PMT & support
- Water pool seal
- Water pool temp. shield
- Earth mag. field shield



Other systems

- Readout & trigger:
  - FADC for PMT ?
- DAQ & slow control
- Offline software & computing
- Calibration system
  - Sub-marine
  - 4π – robes
  - Others ?

New site：Kaiping county, Jiangmen city

	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	running	planned	approved	Construction	construction
power/GW	17.4	17.4	17.4	17.4	18.4

Kaping county, Jiangmen city
广东省江门市开平市金鸡镇、赤水镇一带

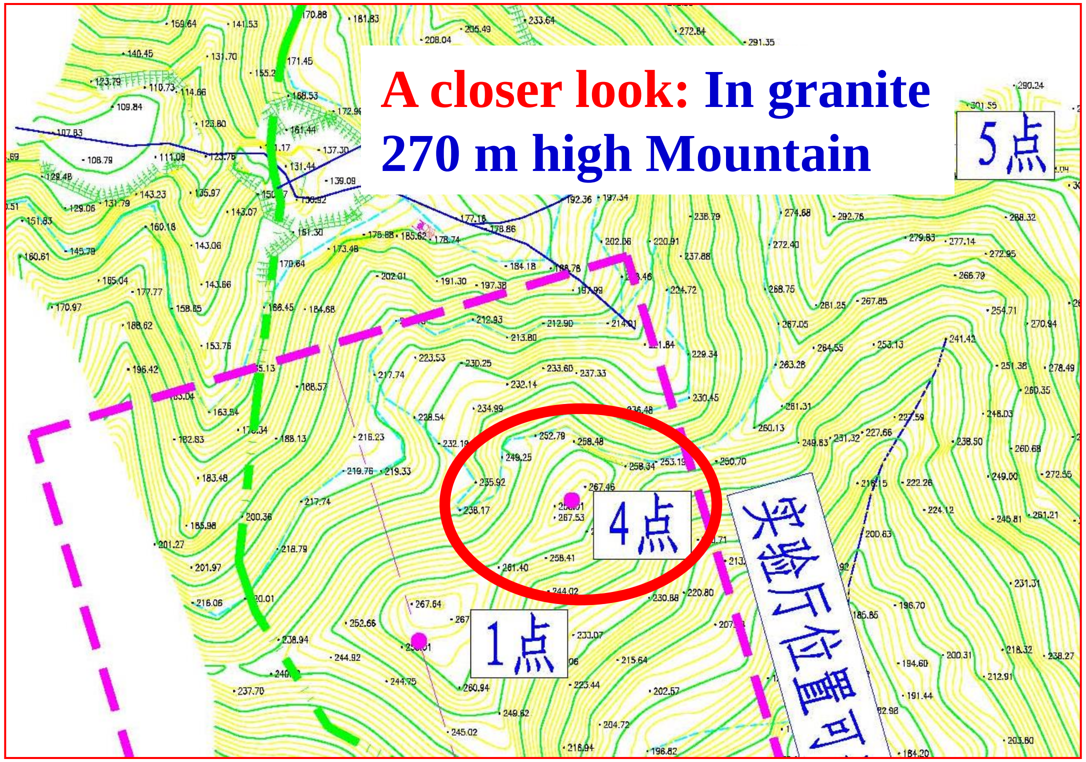
Kaiping: a tourist site with no industry

- **Famous for its architecture: mixture of east & west**



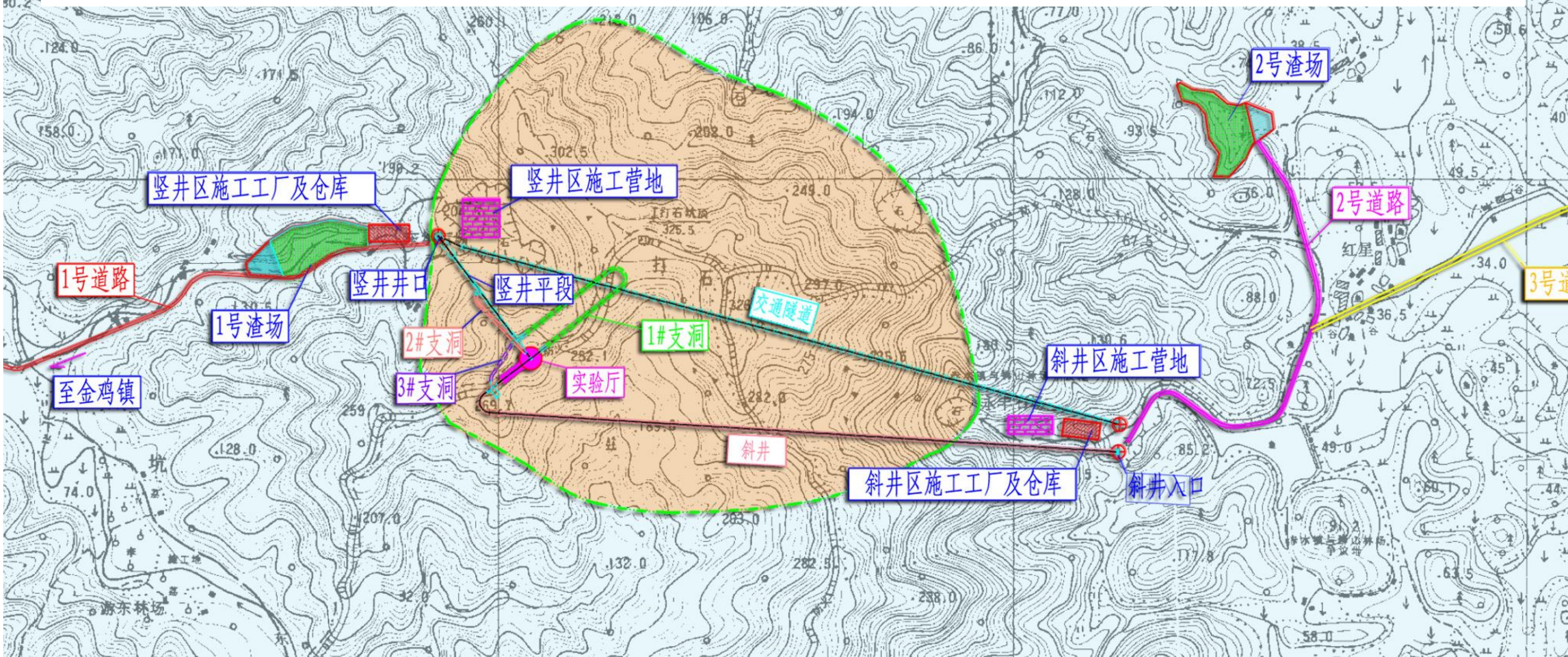

Site selection

- Experimental hall selected
- Preliminary geological survey:
  - ⇨ Review held on Dec. 17, 2012
  - ⇨ No show-stoppers
- Detailed geological survey started this month

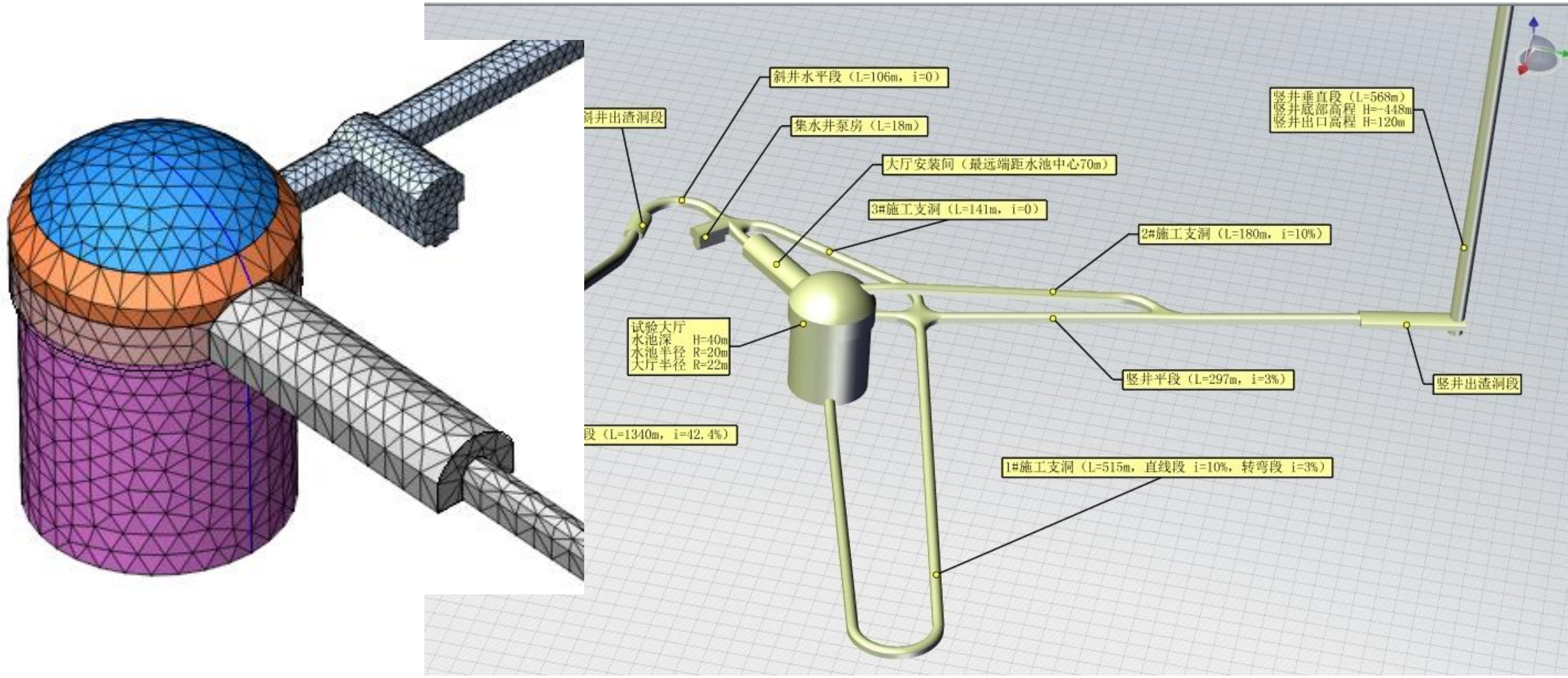


Construction plans

- **Two options considered**
  - ⇨ Rails(40%, 1100m) + vertical shaft(600m)
  - ⇨ Rails(40%, 1100m) + horizontal tunnel(6600m)
- **Conceptual design completed. Review held on Dec.17, 2012.**
  - ⇨ Rails+vertical shaft is chosen for cost and schedule reasons
  - ⇨ No show-stoppers



Experimental hall



- Preliminary study shows that:
  - Stability of the hall is not a problem
  - Total time needed for the civil construction is 3 years

Brief schedule

- **Civil preparation：2013-2014**
- **Civil construction：2014-2017**
- **Detector R&D：2013-2016**
- **Detector component production：2016-2017**
- **PMT production：2016-2019**
- **Detector assembly & installation：2018-2019**
- **Filling & data taking：2020**

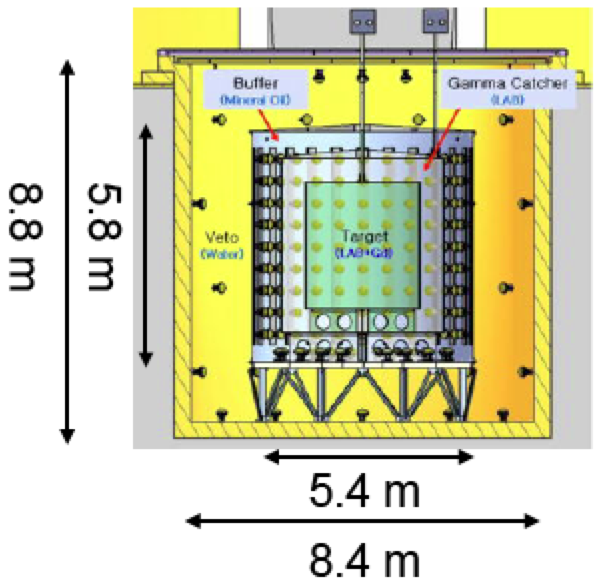
Project Status

- **Progress since last summer:**
  - **Great support from CAS: "special fund for advancement"**
  - **Passed a number of reviews:**
    - ✓ **Sep. 28**
    - ✓ **Oct. 9**
    - ✓ **Dec. 18**
    - ✓ **Jan. 7. (equivalent to CD1): Approved on Feb.1**
  - **Funding(2013-2014) review:**
    - ✓ **Mar.19**
    - ✓ **Apr. 25**
- **Collaboration:**
  - **First get-together meeting in Jan.**
  - **Next meeting in July 8-9 at IHEP**
  - **Interests from US, Russia, Czeck, Italy, Germany, France and Japan, mainly members of DYB, Borexino, LENA, Double Chooz,…**
  - **Plan: establish the collaboration by the end of the year**

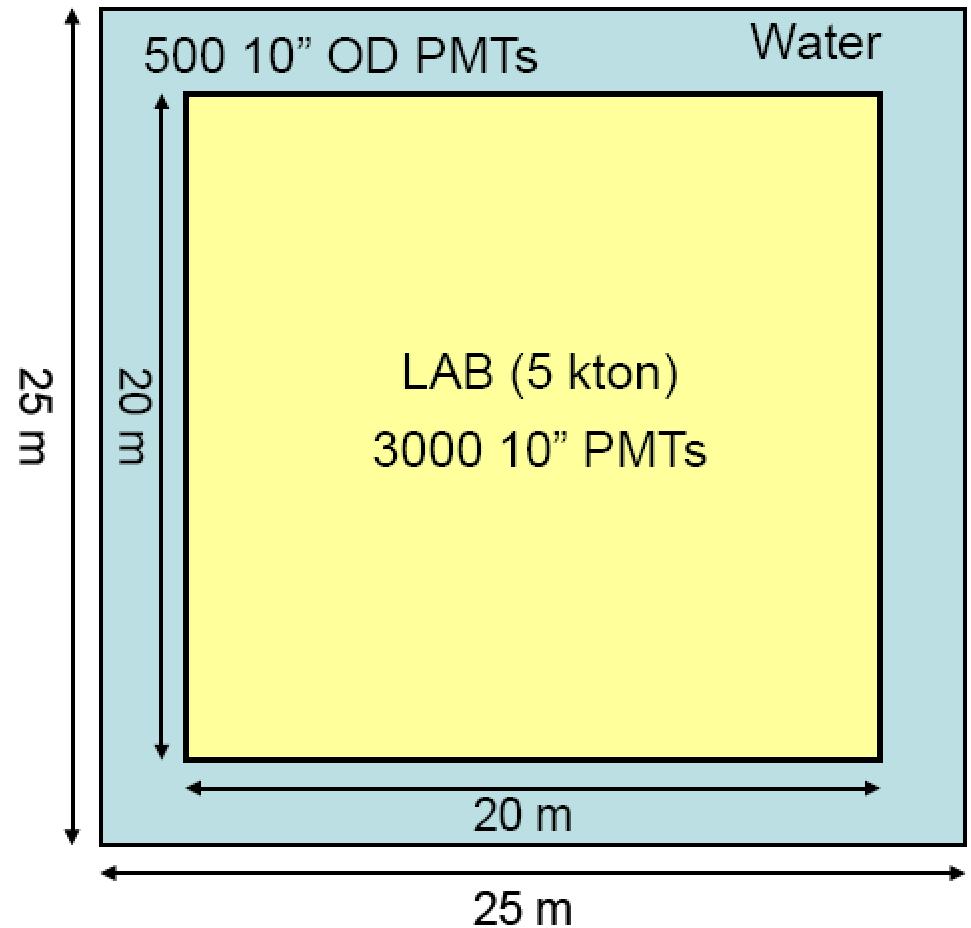
RENO-50

- 5000 tons ultra-low-radioactivity Liquid Scintillation Detector

RENO



RENO-50



S.B. Kim, talk at Neutrino 2012

Physics with RENO-50

- Precise measurement of θ_{12}

$$\frac{\delta \sin^2\theta_{12}}{\sin^2\theta_{12}} \sim 1.0\%(1\sigma)$$ in a year $\leftarrow$ current accuracy : 5.4%

- Determination of mass hierarchy Δm^2_{13}

- Neutrino burst from a Supernova in our Galaxy :

  ~1500 events (@8 kpc)

- Geo-neutrinos : ~ 300 geo-neutrinos for 5 years

- Solar neutrinos : with ultra low radioacitivity

- Reactor physics : non-proliferation

- Detection of T2K beam : ~120 events/year

- Test of non-standard physics : sterile/mass varying neutrinos

Summary

- Reactor neutrino experiments are very successful
- "Daya Bay II" is a project with a very rich and interesting physics program
- Although challenging, initial study shows that it is not impossible
- A few R&D efforts already started, more will come
- Detector design and civil design has been started
- Good support from the local government & the Chinese funding agencies

Welcome collaborators