中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

NG2013, Takayama, JAPAN

Update of Daya Bay II

Jiangmen anti-neutrino observation spectrometer

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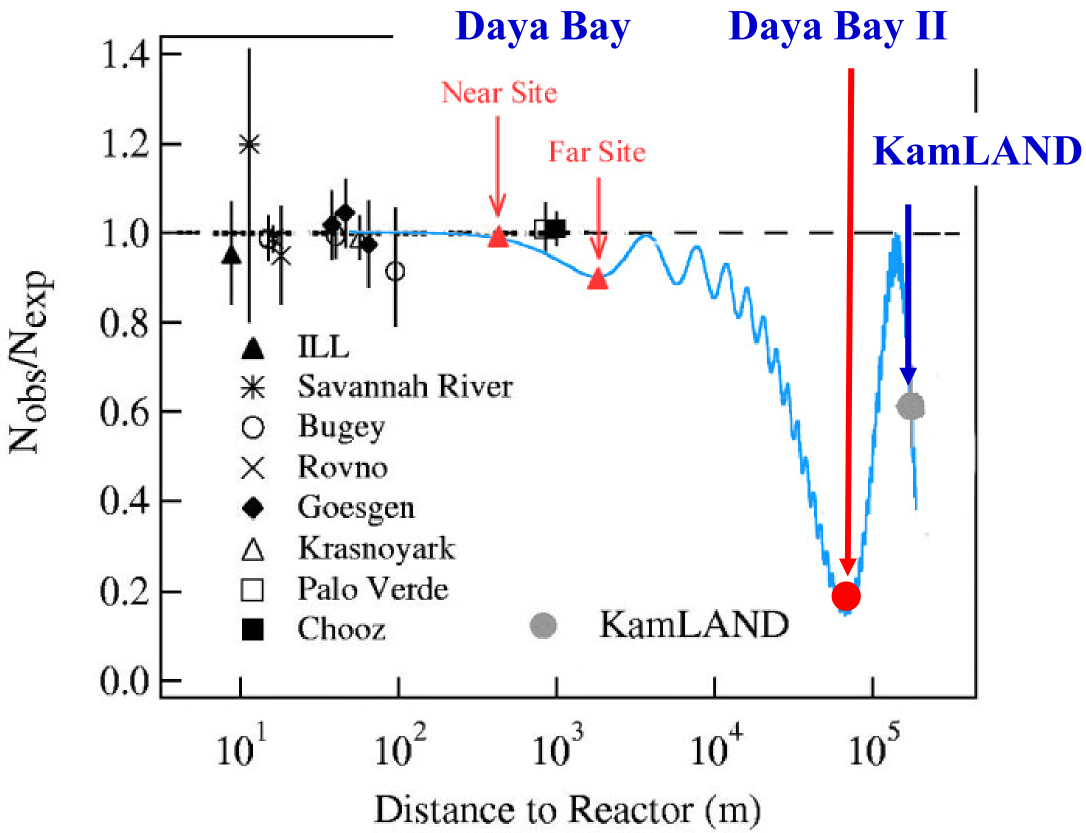
Overview

- Daya Bay-II
- Design of detectors
- Signals and backgrounds
- Site survey & civil
- Neutrino Geosciences with Daya Bay-II
- Schedule

Daya Bay-II Experiment

DYB-II has been approved in China in Feb. 2013

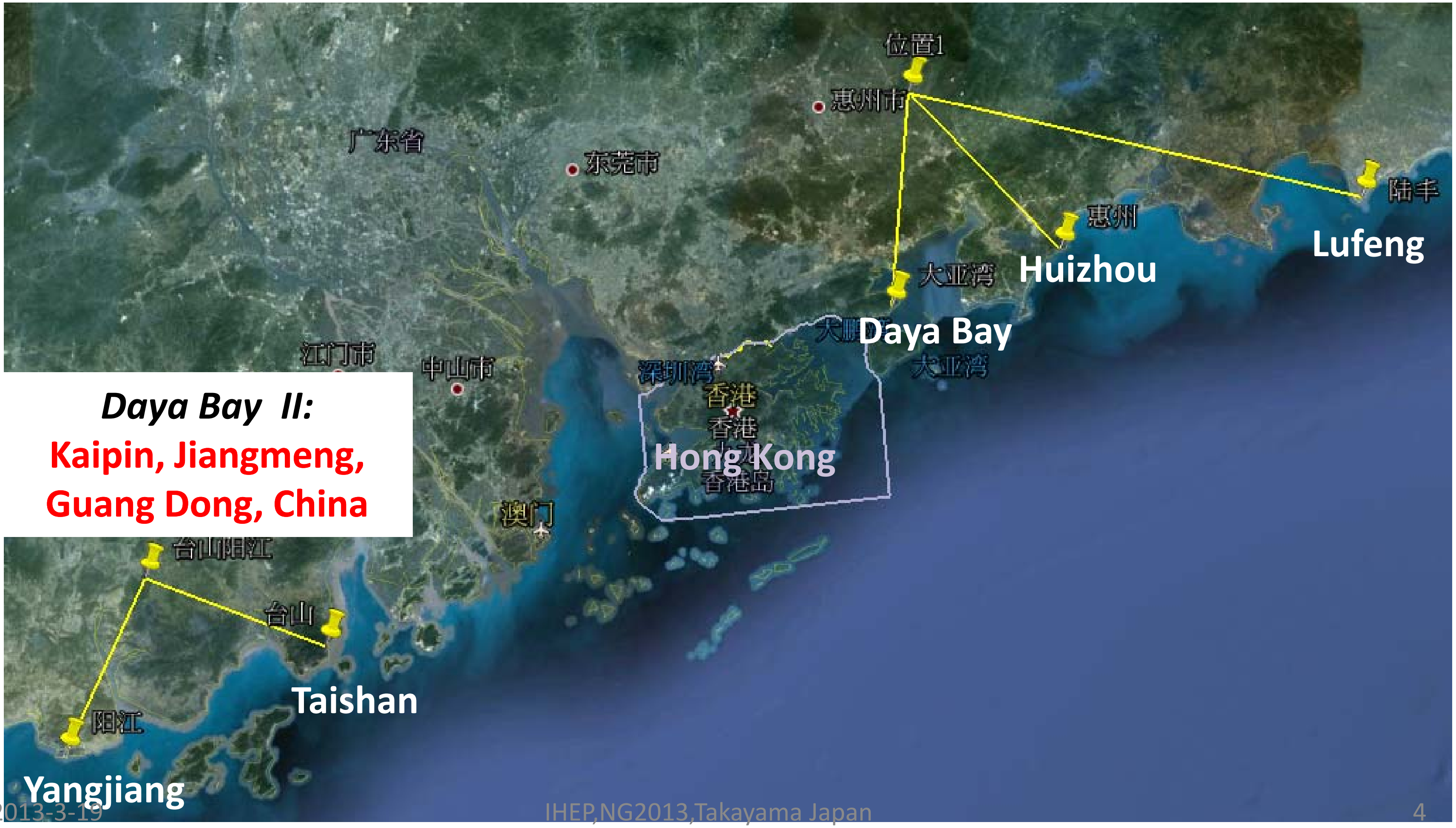
Equivalent to CD1 of US DOE



- **20 kton LS detector**
- **2-3 % /√E resolution**
- **Rich physics**
  - ⇨ **Mass hierarchy**
  - ⇨ **Precision measurement of 4 oscillation parameters to <1%**
  - ⇨ **Supernovae neutrino**
  - ⇨ **Geoneutrino**
  - ⇨ **Sterile neutrino**
  - ⇨ **Atmospheric neutrinos**
  - ⇨ **Exotic searches**

The reactors and sites

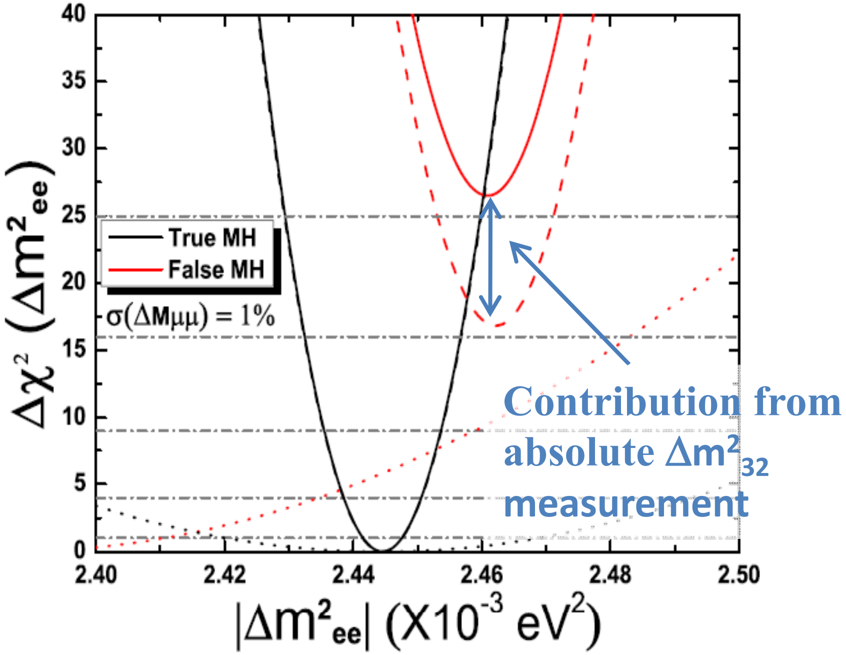
	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW (~2017)	18.4 GW(~2014,?)



Daya Bay II:
Kaipin, Jiangmeng,
Guang Dong, China

Sensitivity

Taking into account Δm^2_{32} from T2K and Nova in the future:



	Current	DYB 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%

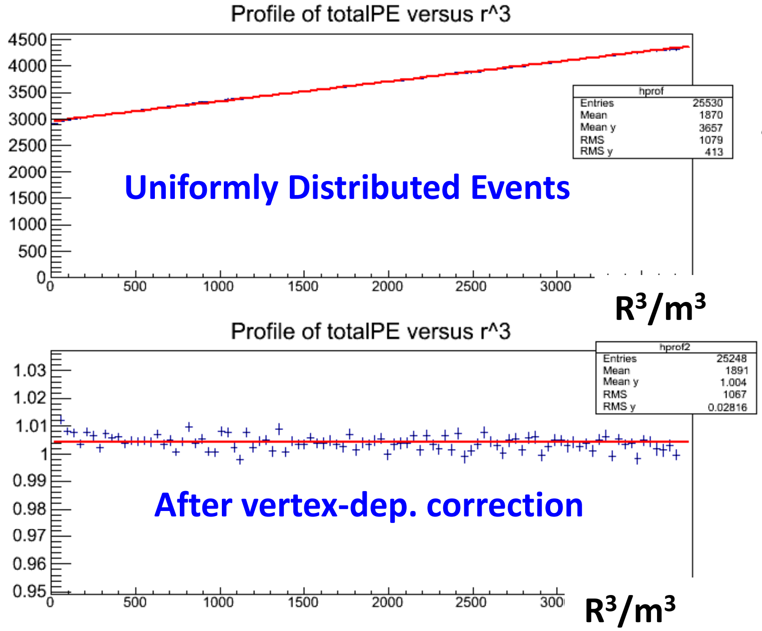
If Δm^2_{32} at 1% precision, mass hierarchy could be determined to ~5σ in 6 years. (core distribution and energy non-linearity may degrade it a little.

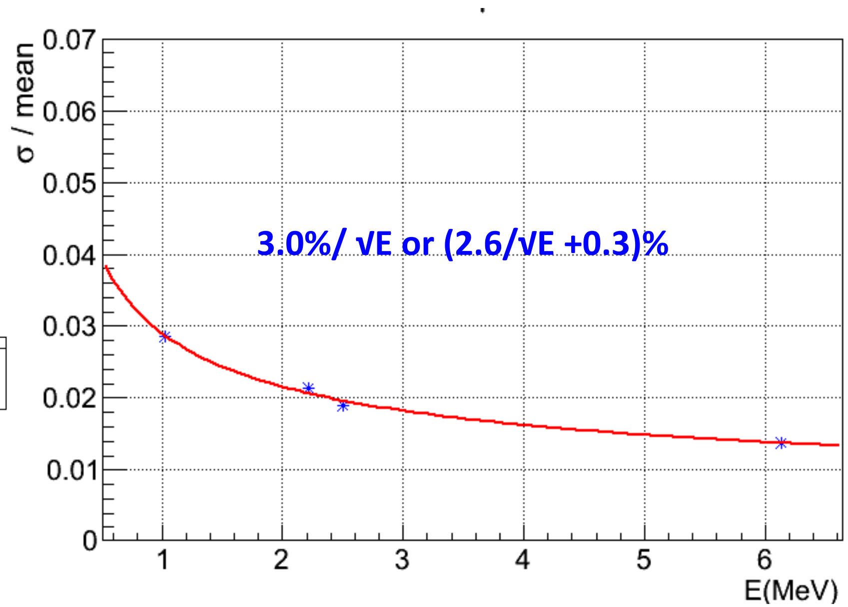
Will be more precise than CKM matrix elements !

Probing the unitarity of UPMNS to ~1% level

Challenges

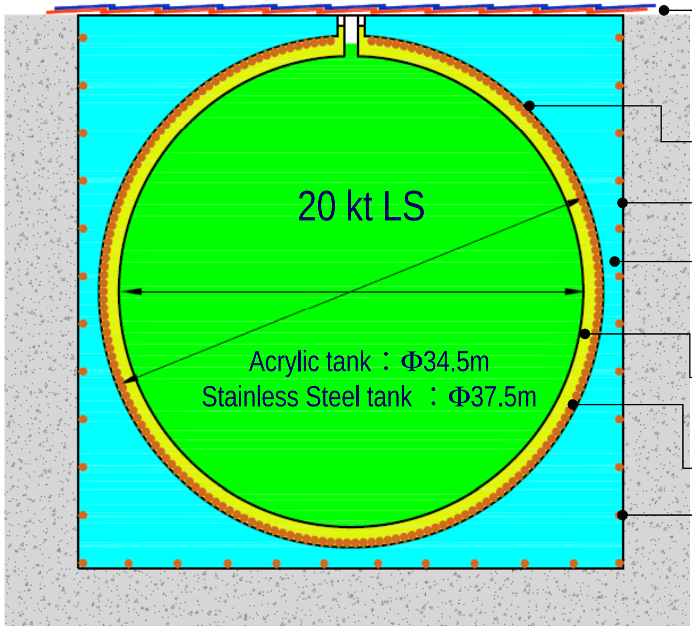
	KamLAND	Daya Bay II
LS mass	~1 kt	~20 kt
Energy Resolution	~6%/√E	~3%/√E
Light yield	~250 p.e./MeV	~1200 p.e./MeV





DYBII previous simulation based on DYB with the consideration of DYBII Geometry, photocathode coverage, upgraded PMT efficiency, better LS attenuation length, upgraded light yield;

The plan: a large LS detector



- Largest detector options：
  - No steel tank, only acrylic one
  - Steel tank +
    - Acrylic box/wall
    - Balloon
    - Nothing
- High efficiency PMTs

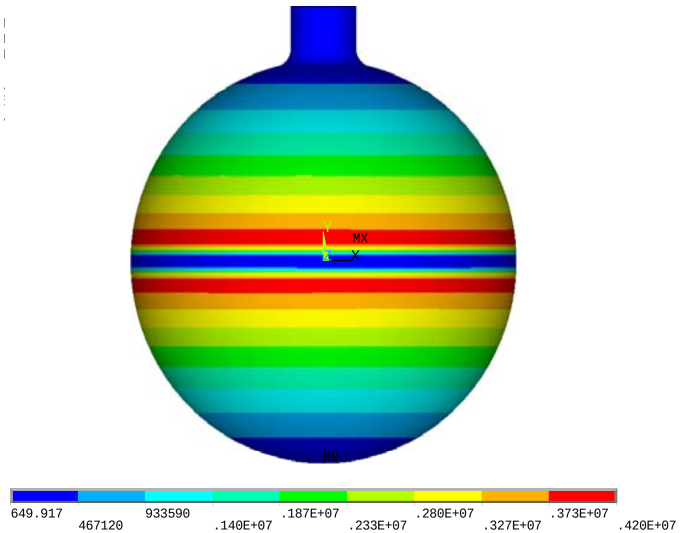
- LS volume: × 20
- Light(PE) × 5
- Background control

- Option 1: no steel tank
- No more interference
- “Easy” for PMT holding
- Water buffer ➔ cheap
- Difficulties:
  - **Larger pressure difference**
  - **Production**

◆ Stress calculation shows that it is a 5cm thick acrylic is feasible but in really…

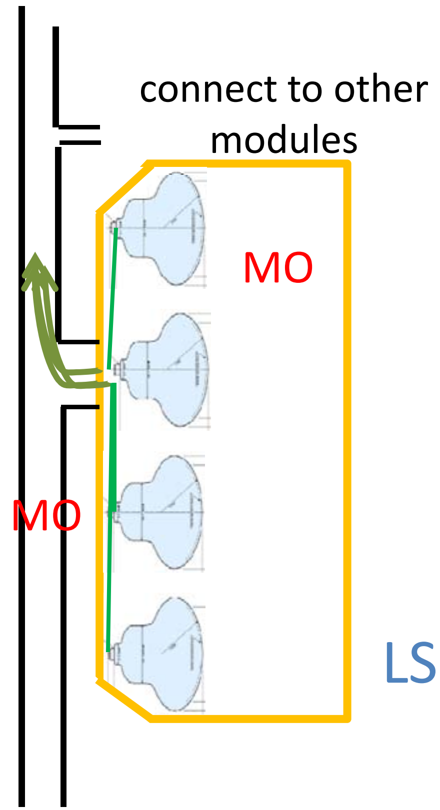
◆ SNO 1kt (ø12m): a 10-person team for two years

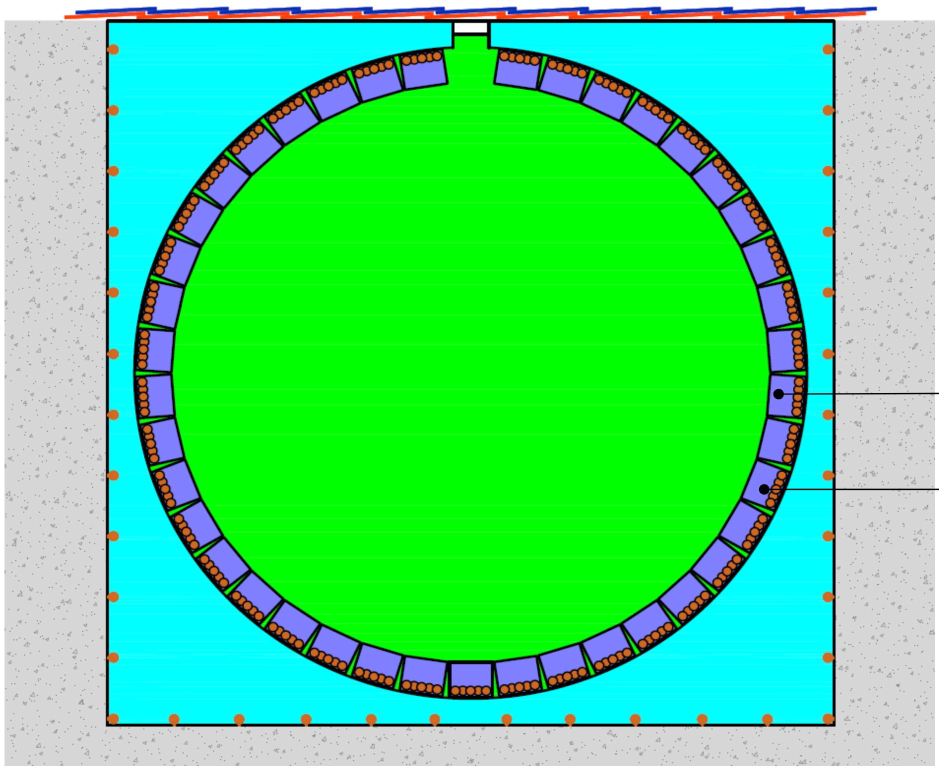
◆ 20kt (ø37.5m): ???

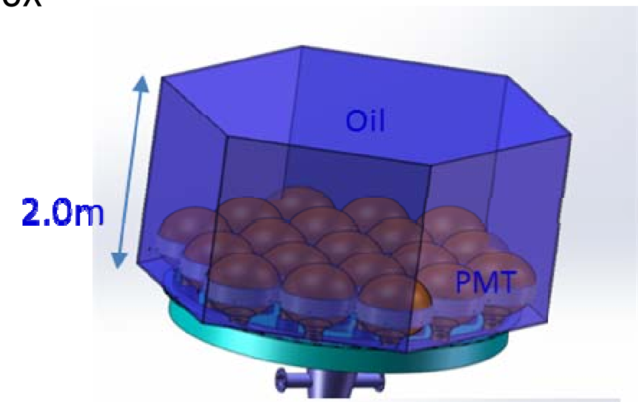


Option 2: Acrylic box

- Mineral Oil in the optical modules.
- Pipe for filling MO and cabling
- Concerns
  - **Leakage through cables**

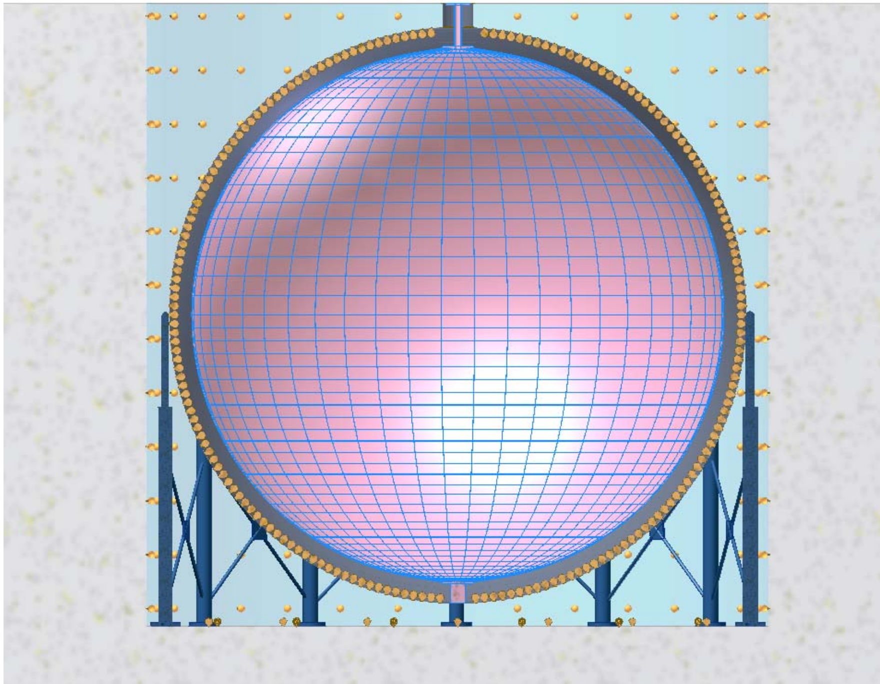






Option 3： Balloon

- “Cheap” for construction & quick for installation
- Experience from Borexino (0.5kt) & KamLAND (1kt)
- Need to consider film materials(mechanics, transparency, compatibility, welding technique, radon permeability, …) , cleanness, leak check, deployment, backup plan if fails, …

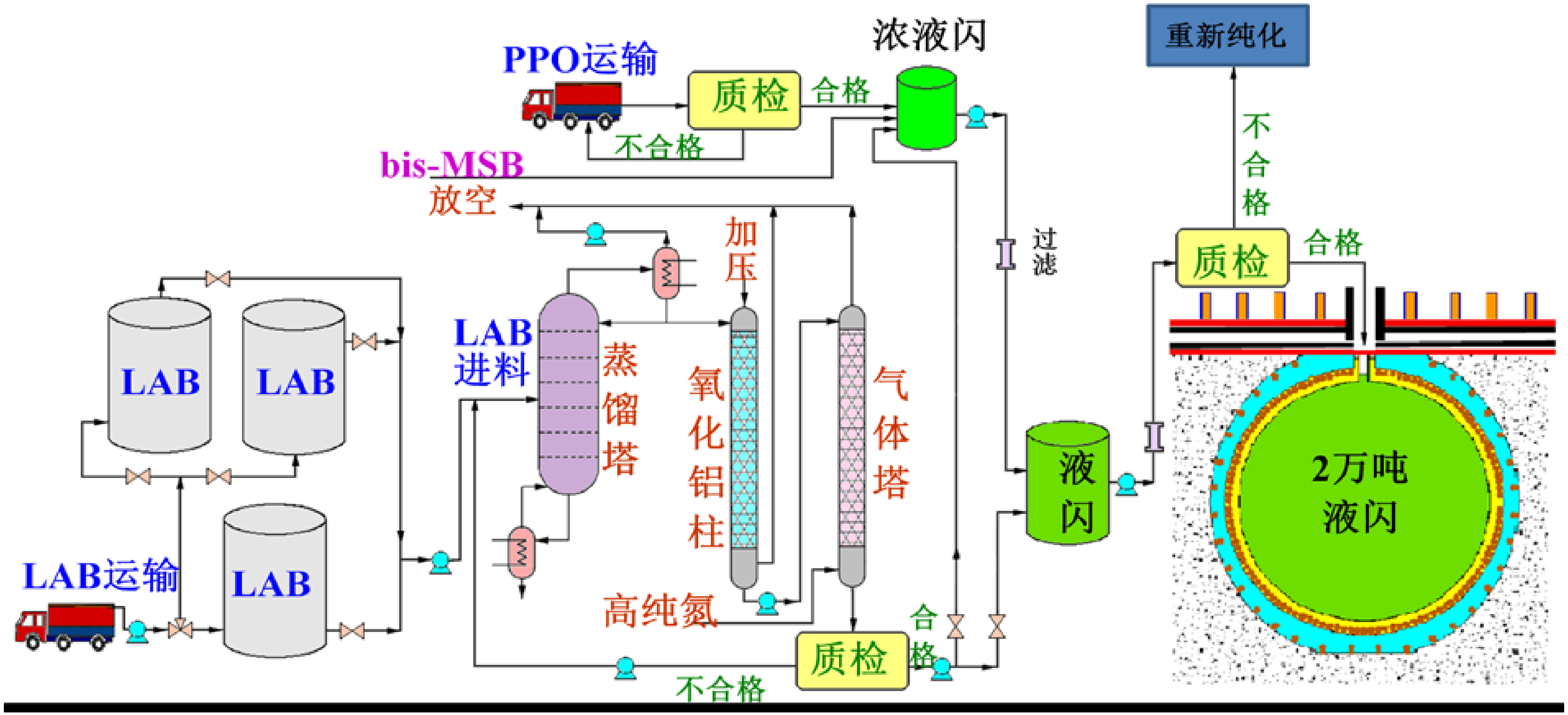


Future plan

- Prototyping： one or all of the following：
  - **Φ2m acrylic ball**
  - **Φ2m steel ball**
  - **Φ35m balloon**
  - **Acrylic box**

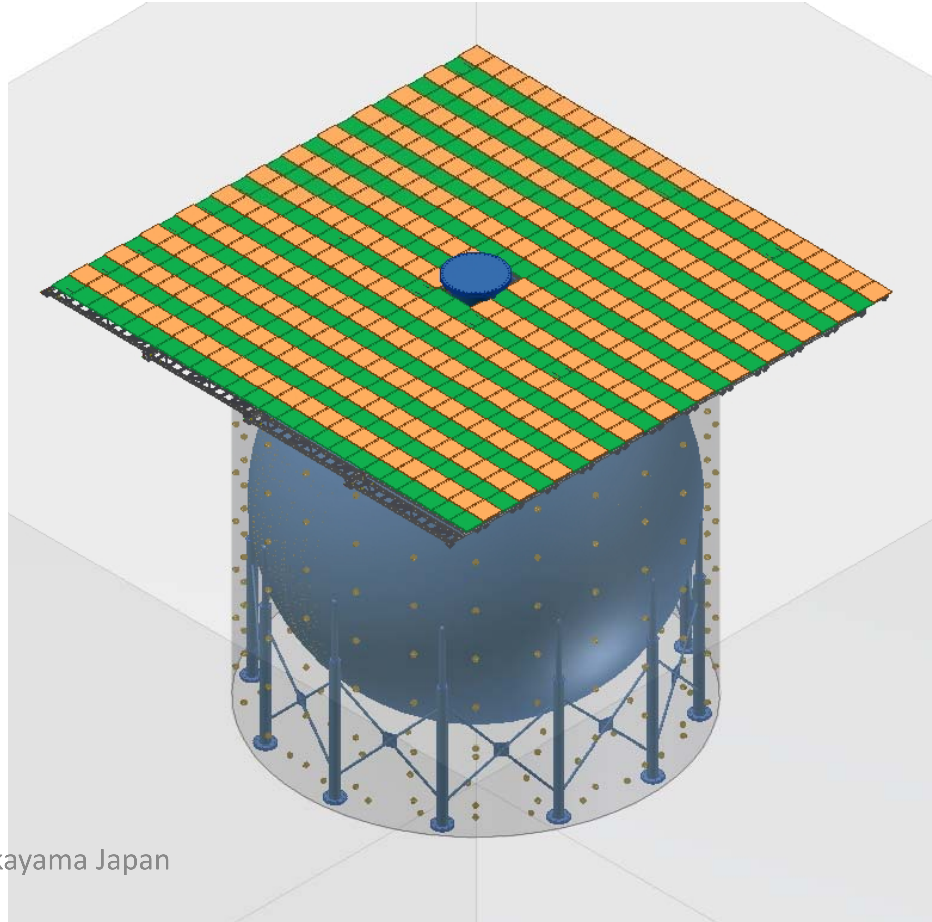
◆ **To understand the following：**
  - **Design and manufacturing technologies**
  - **Assembly and installation issues**
  - **Background suppression capabilities**

LS handling on site



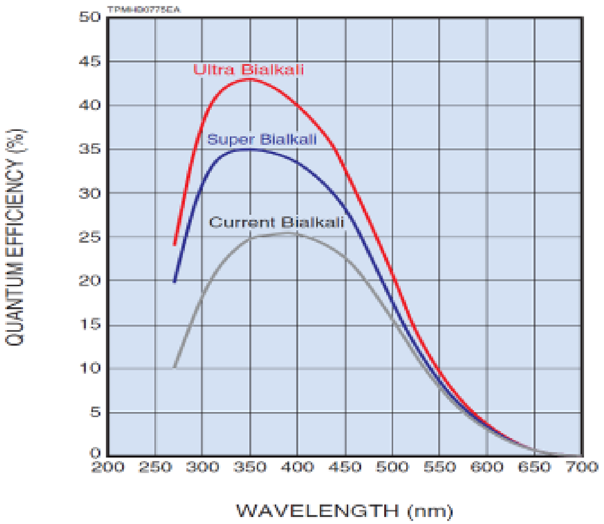
VETO

- Water
  - **A MC simulation show that ~ 2m water, 1500 20" PMT is good enough**
- Top VETO
  - **Do we really need it ?**
  - **To what spec ?**
  - **Options:**
    - **RPC**
    - **Plastic scintillator**
    - **Liquid scintillator**

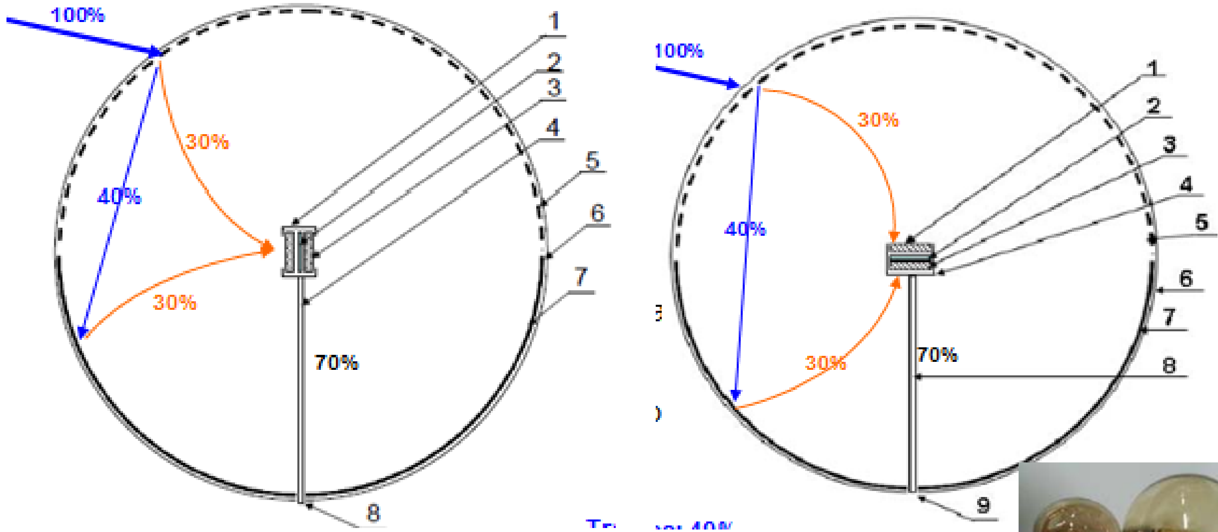


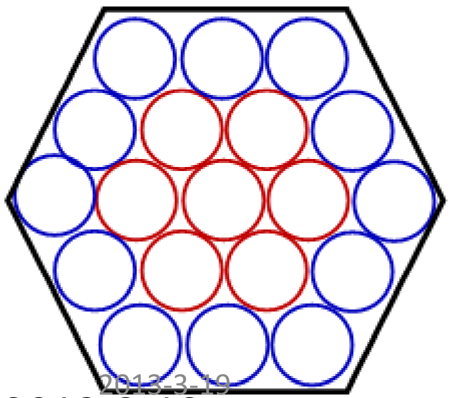
More Photoelectrons-- PMT

SBA photocatode

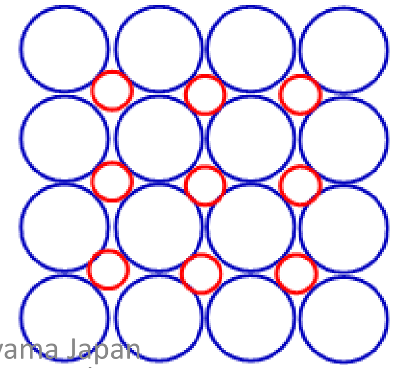


New type of PMT: MCP-PMT





No clearance:
coverage 86.5%
1cm clearance:
coverage: 83%



20" + 8" PMT
8" PMT for better timing(vertex)

2013-3-19
IHEP,NG2013,Takayama Japan

IBD Signal

- Signal:

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

Estimated IBD rate: ~40/day

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

- 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
    - Em ~ 211 GeV, Rm ~ 3.8 Hz
  - Single rates from LS and PMT are 5Hz, respectively
  - Good Muon tracking
  - Similar Muon efficiency as DYB

Per module	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

Singles

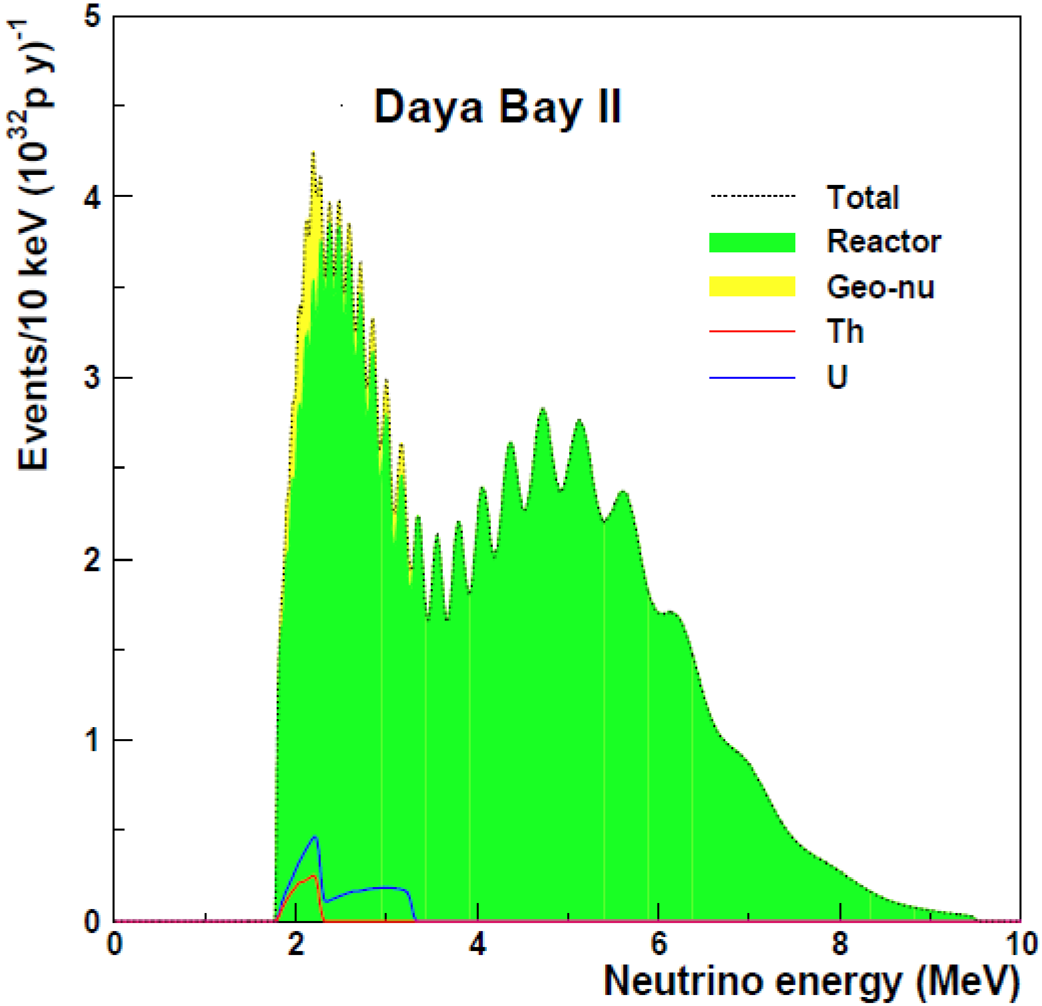
Backgrounds

Event Type	Raw rate	Reduction
Radioactivity	~5Hz (PMTs) ~5Hz (LS)	Use low radioactivity PMTs, and buffer; LS purification
Cosmogenic isotopes (delayed)	~550/day	→ ~320/day (tighter delayed energy cut, e.g, 2.0MeV< E_d<2.45MeV)
Spallation neutron	~1.6Hz	→ 7/day (2ms muon veto)
Accidentals	~1000/day	→ ~4/day (prompt-delayed distance $R_{p\text{-}d}$ < 2m) → ~2/day (tighter delayed energy cut, e.g, 2.0MeV< E_d<2.45MeV)
Fast neutron	~0.15/day	
$^9Li/^8He$	~122/day	→ ~60/day (2s Shower muon veto) → ~0.3/day (distance to muon track $R_{d2\mu}$ < 5m and 2s veto, will lead to 8.4% dead volume)

Estimated anti-neutrino signal rate: ~40/day

Geoneutrinos@DYBII

- 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



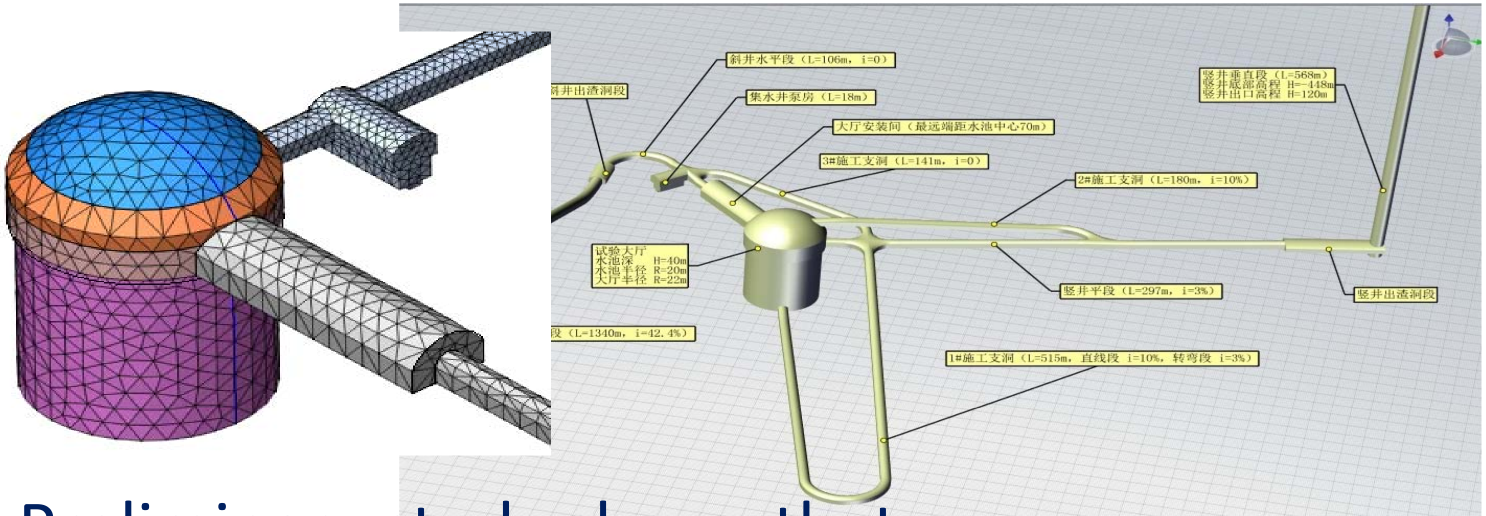
From Stephen Dye

Sites

- Kaiping: a tourist site with no industry
  - Famous for its architecture: mixture of east & west

Experiment hall

- Experimental hall selected:
  - **In granite**
  - **Mountain height: ~270 m**
- Preliminary geological survey completed:
  - **Review held on Dec. 17, 2012**
  - **No show-stoppers**
- Detailed geological survey started at the beginning of March.
- Contacts with local government established, good support.



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

Overall Schedule

2013
Complete conceptual design, complete civil design, & bidding

2014
Start civil construction, complete prototyping (PMT & detector)

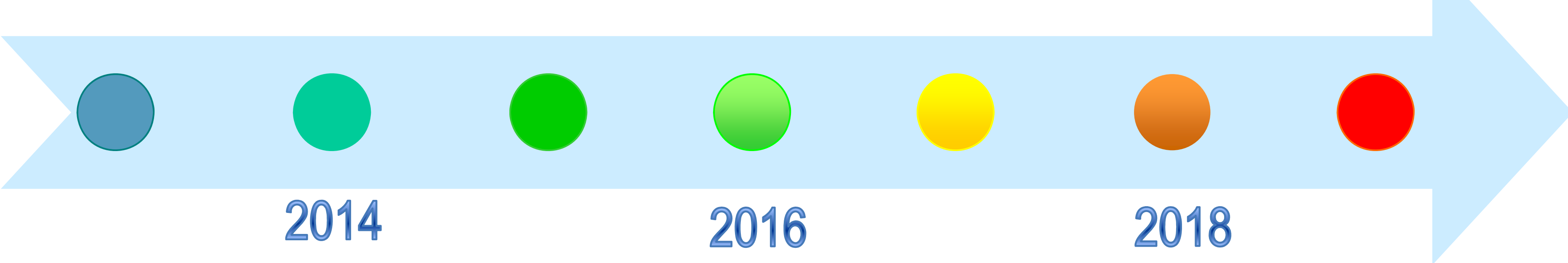
2015
PMT production line manufacturing

2016
Start PMT production, start detector production or bidding

2017
Complete civil construction, start detector construction & assembly

2018
Start LS production

2019
Complete detector assembly & installation, & LS filling



Summary

- "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 started
- Detector design and civil design has been started
- Need more collaborators, more support from the community and funding agencies

Thanks

ありがとう

谢谢

Backup

Variation： acrylic wall

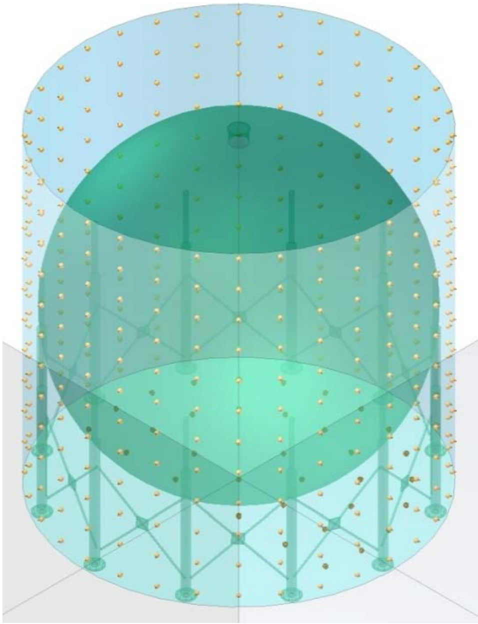
- Mature technology
- Quick installation
- Good for PMT explosion protection
- But
  - **Light loss， 5% ?**
  - **Compatibility， Sealing， 。。**

Airport

Zhujiang City Building
Ball conference : 39 m

Expo 2010, Shanghai
Sunshine Valley

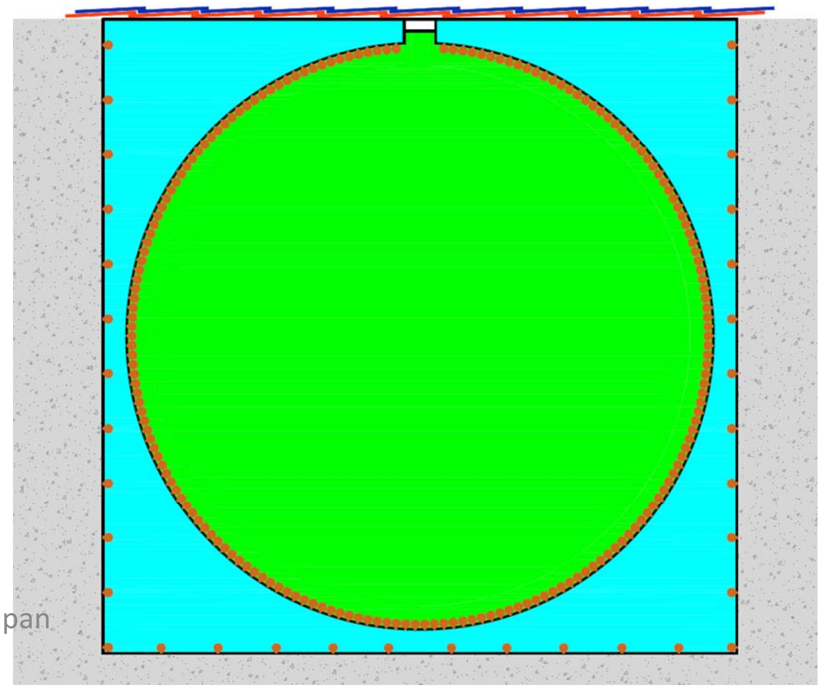
Option 4: Steel tank only



- No problem for construction
- A fall back plan of the balloon option
- But
  - **PMT protection**
  - **Trigger rate by backgrounds**
  - **Resolution affected by backgrounds**

If the PMT glass is the same as Daya Bay, radioactivity will be 44 Bq/PMT, or 3.3 MHz in total

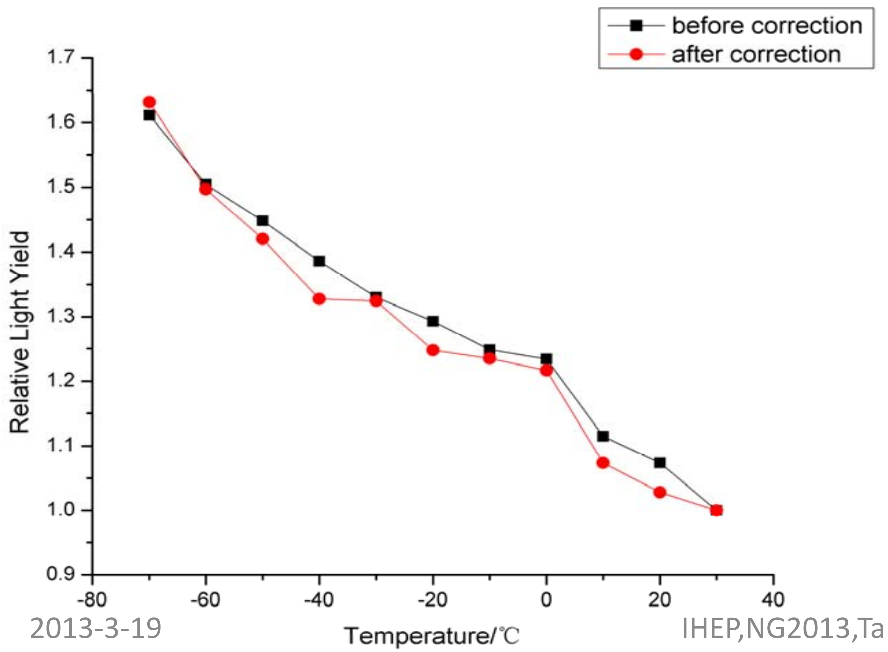
If better glass is used, it may be reduced to 1 MHz

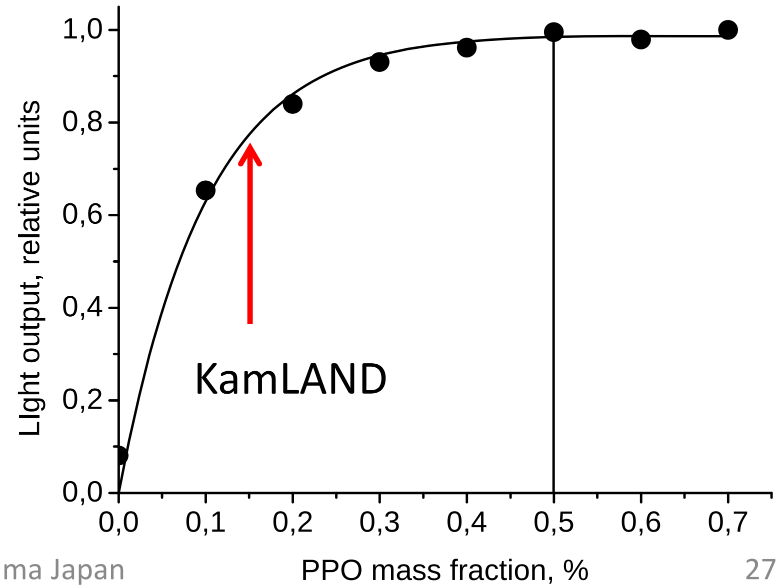


More Photoelectrons-- LS

- 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

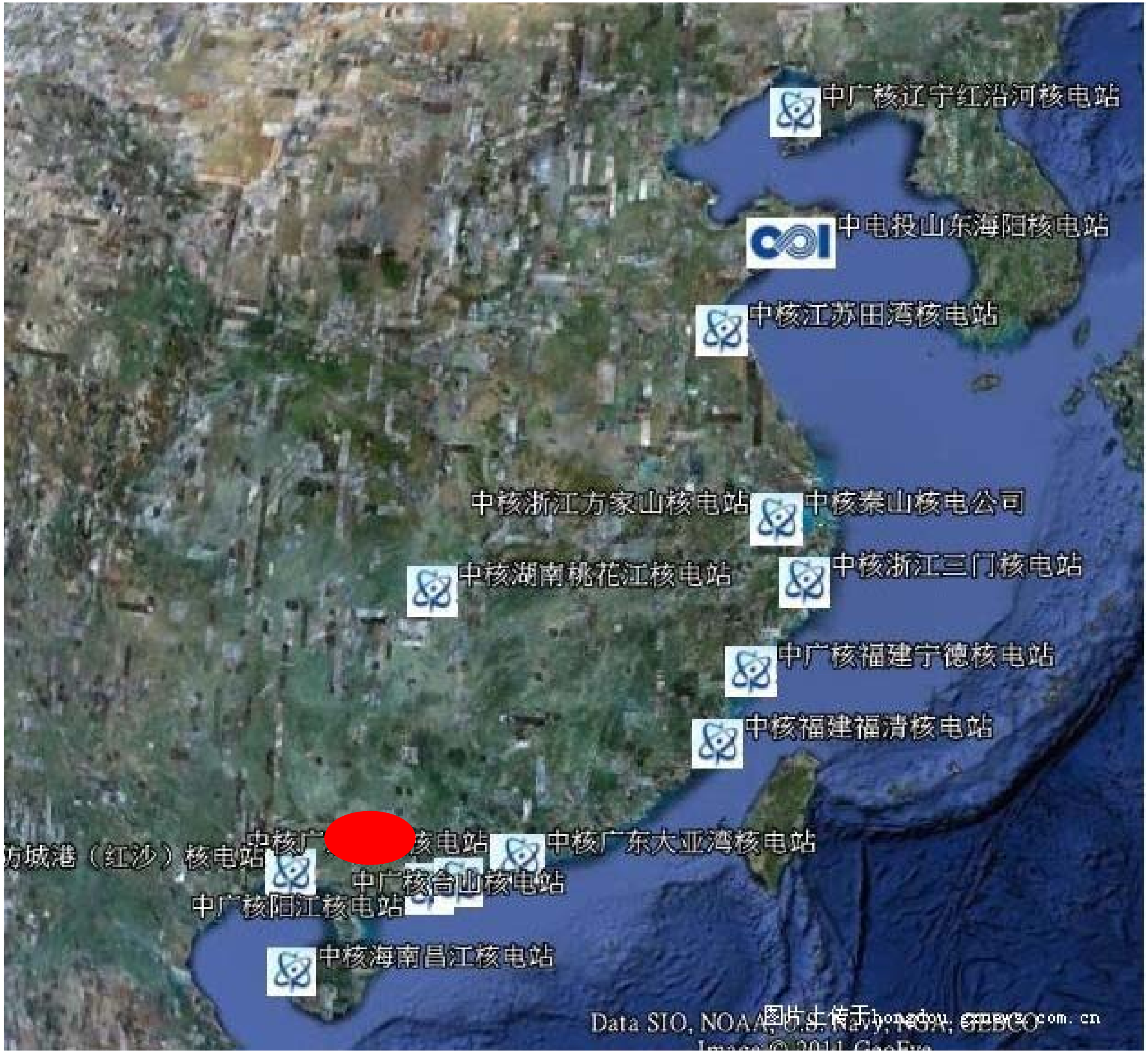




Calibration, Electronics, trigger, DAQ…

- Of course we need it
- Daya Bay or KamLAND type ?
- Sub-marine type ?
- Need more ideas and R&D

- Probably we need FADC at 1GHz sampling rate for pattern recognition, more information for event reconstruction, better event quality, …
- Complicated trigger schemes should be available
- Supernova is an additional burden
- A challenge to DAQ if FADC is used
- A new software scheme for neutrino experiments ?
- No real work yet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