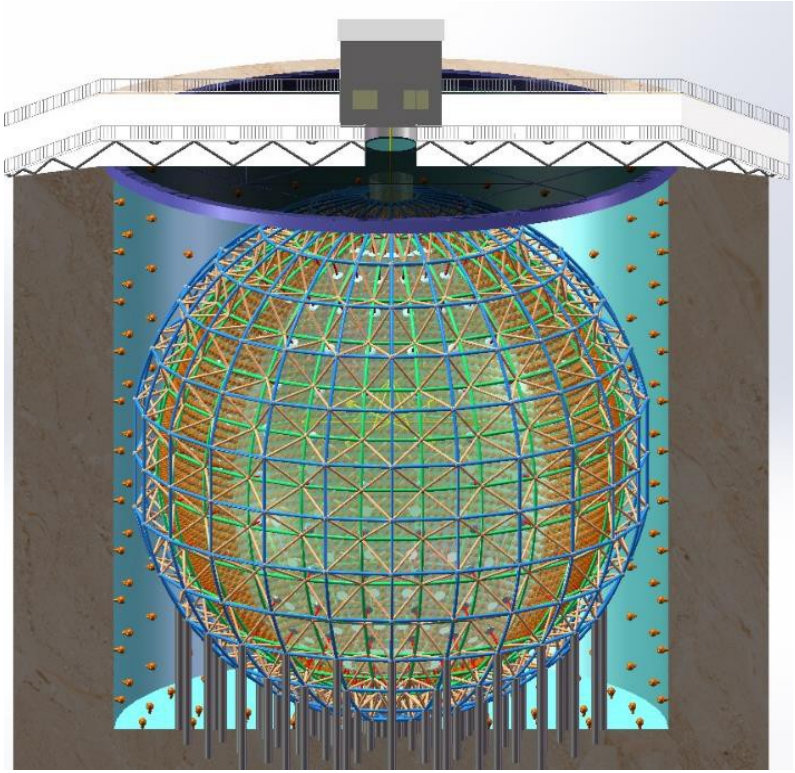
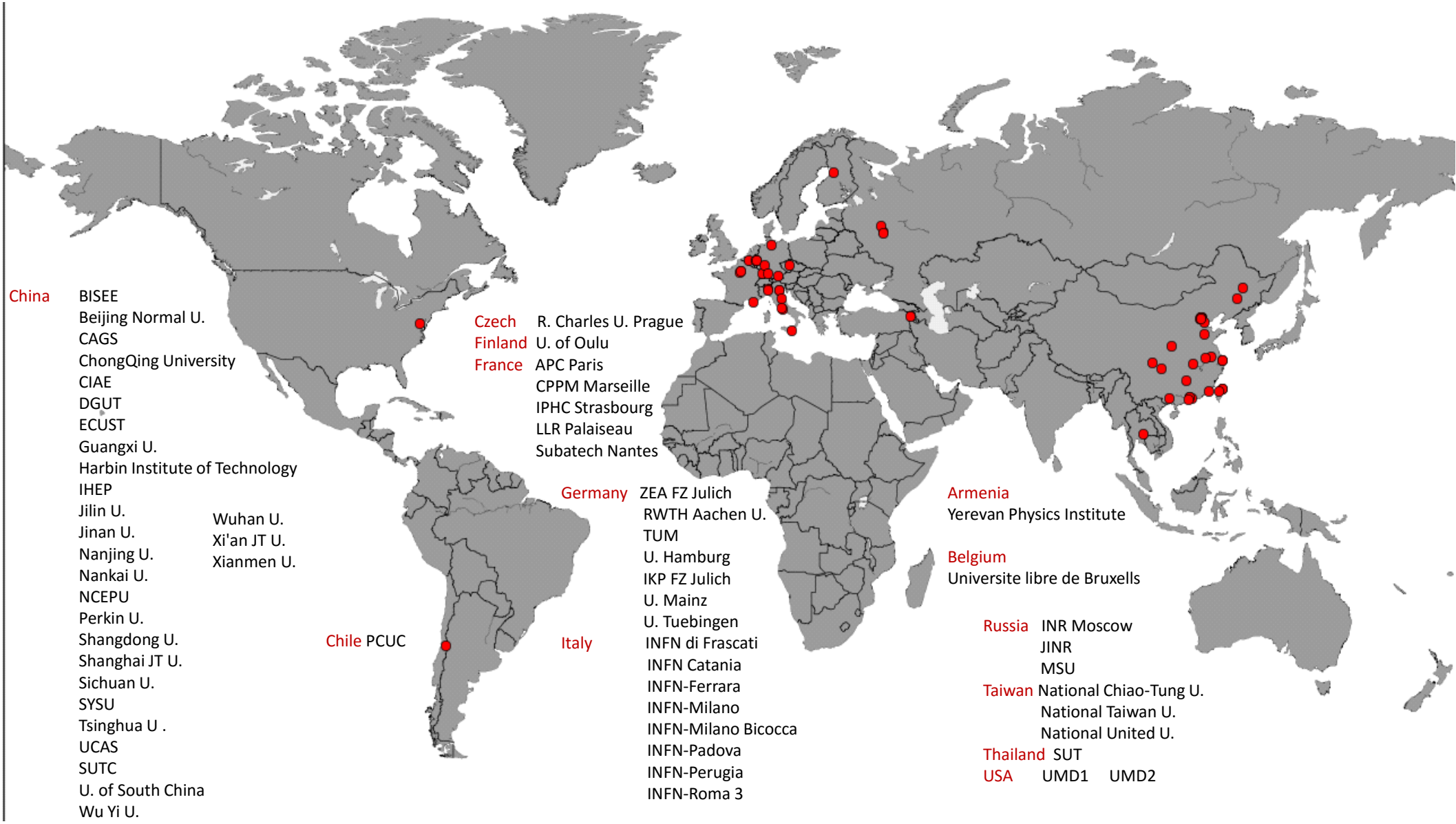
Physics prospects and status of JUNO

Jian Tang
(On behalf of the JUNO collaboration)

NuFact2016, Quy Nhon, Vietnam
2016.08.23



JUNO Collaboration



China BISEE
Beijing Normal U.
CAGS
ChongQing University
CIAE
DGUT
ECUST
Guangxi U.
Harbin Institute of Technology
IHEP
Jilin U.
Jinan U.
Nanjing U.
Nankai U.
NCEPU
Perkin U.
Shangdong U.
Shanghai JT U.
Sichuan U.
SYSU
Tsinghua U .
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Xi'an JT U.
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Taiwan National Chiao-Tung U.
National Taiwan U.
National United U.

Thailand SUT

USA UMD1 UMD2

International Collaborations with 64 institutions and ~450 members until June in 2016

JUNO Collaboration

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- JUNO Physics prospects
- Status of JUNO
  - Central Detector
  - Liquid Scintillator
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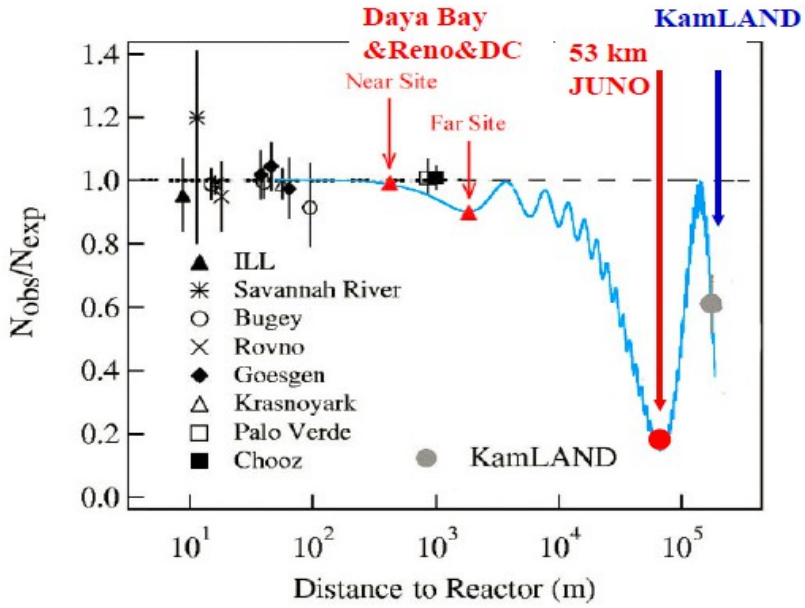
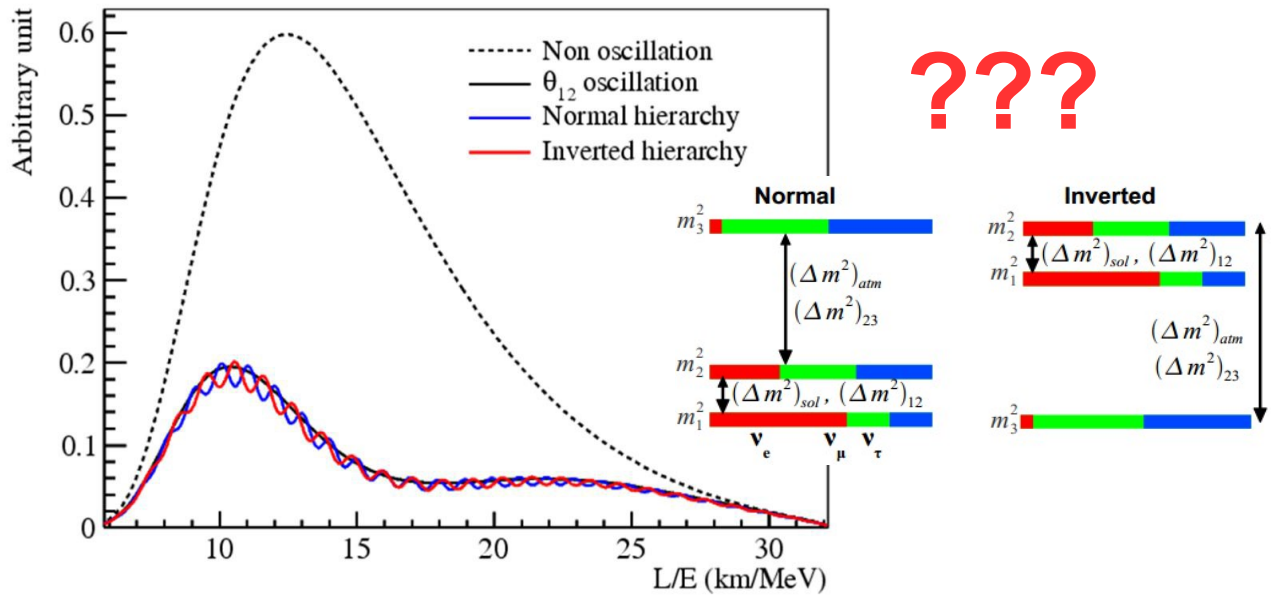
Jiangmen Underground Neutrino Observatory (JUNO)

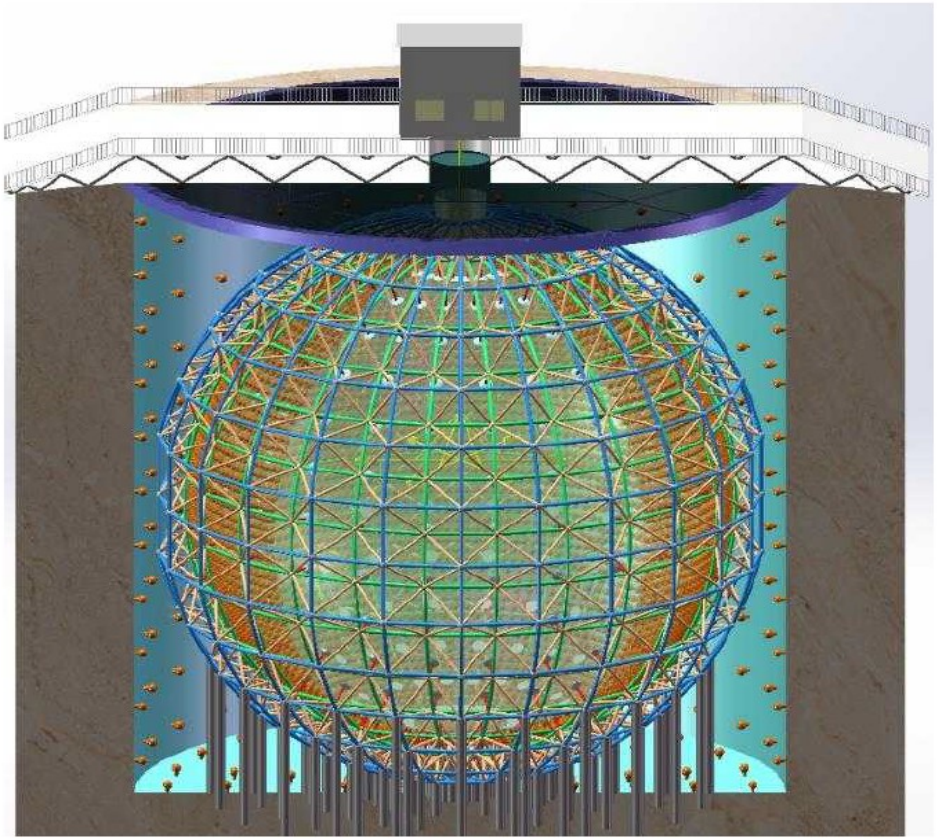
Cores	YJ-C1	YJ-C2	YJ-C3	YJ-C4	YJ-C5	YJ-C6
Power (GW)	2.9	2.9	2.9	2.9	2.9	2.9
Baseline (km)	52.75	52.84	52.42	52.51	52.12	52.21
Cores	TS-C1	TS-C2	TS-C3	TS-C4	DYB	HZ
Power (GW)	4.6	4.6	4.6	4.6	17.4	17.4
Baseline (km)	52.76	52.63	52.32	52.20	215	265





Rich Physics Programs

- JUNO has been approved in Feb. 2013. ~ 300 M$.
- A multiple-purpose neutrino experiment



- 20 kton LS detector
- 3% energy resolution
- 700 m underground
- Rich physics possibilities
- Reactor neutrino
  - ⇨ for Mass hierarchy and precision measurement of oscillation parameters
  - ⇨ Supernovae neutrino
  - ⇨ Geoneutrino
  - ⇨ Solar neutrino
  - ⇨ Atmospheric neutrino
  - ⇨ Exotic searches including proton decay, dark matter

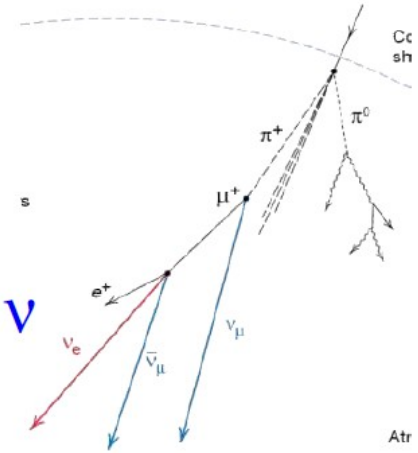
Neutrino Physics with JUNO, J. Phys. G 43, 030401 (2016)

JUNO Event Rates
after selection

Supernova ν
5-7k in 10s for 10kpc

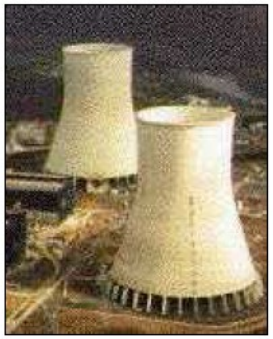
Solar ν
(10s-1000s)/day

Atmospheric ν
several/day



700 m

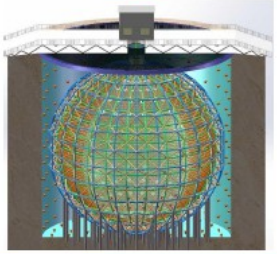
Cosmic muons
~ 250k/day



36 GW, 53 km

reactor ν, 60/day
Bkg: 3.8/day

20k ton
LS



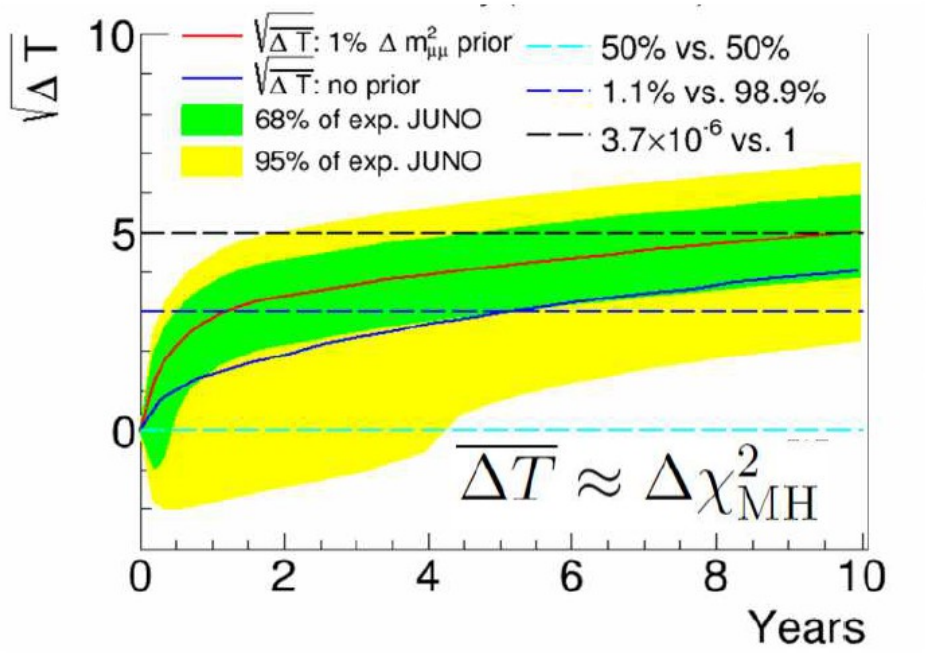
0.003 Hz/m²
215 GeV
10% multiple-muon

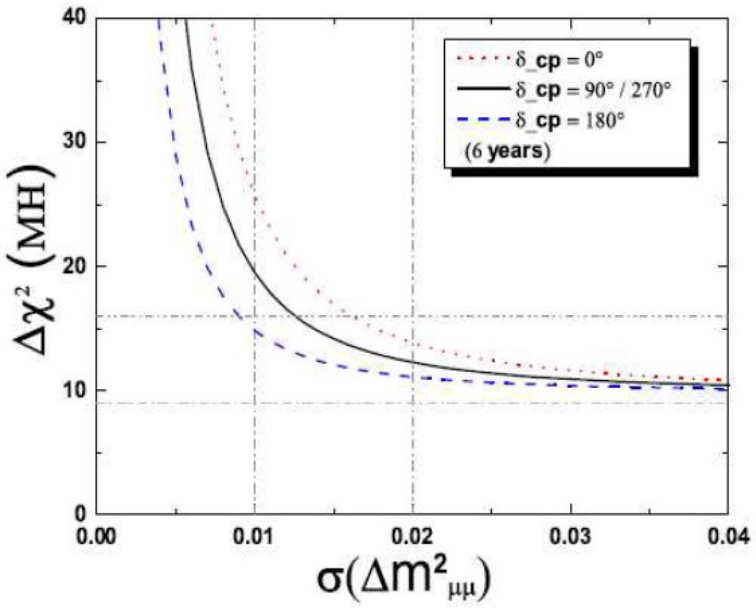
Geo-neutrinos
1.1/day

JUNO Sensitivity on MH

PRD 88, 013008 (2013)	Relative Meas.	w/ absolute Δm^2
Statistics only	4σ	5σ
Realistic case	3σ	4σ

***JUNO* MH sensitivity with 6 years' data:**





	Ideal	Core distr.	DYB & HZ	Shape	B/S (stat.)	B/S (shape)	$\lvert\Delta m^2_{\mu\mu}\rvert$
Size	52.5 km	Real	Real	1%	6.3%	0.4%	1%
$\Delta\chi^2_{\mathrm{MH}}$	16	- 3	-1.7	- 1	- 0.6	- 0.1	+ (4-12)

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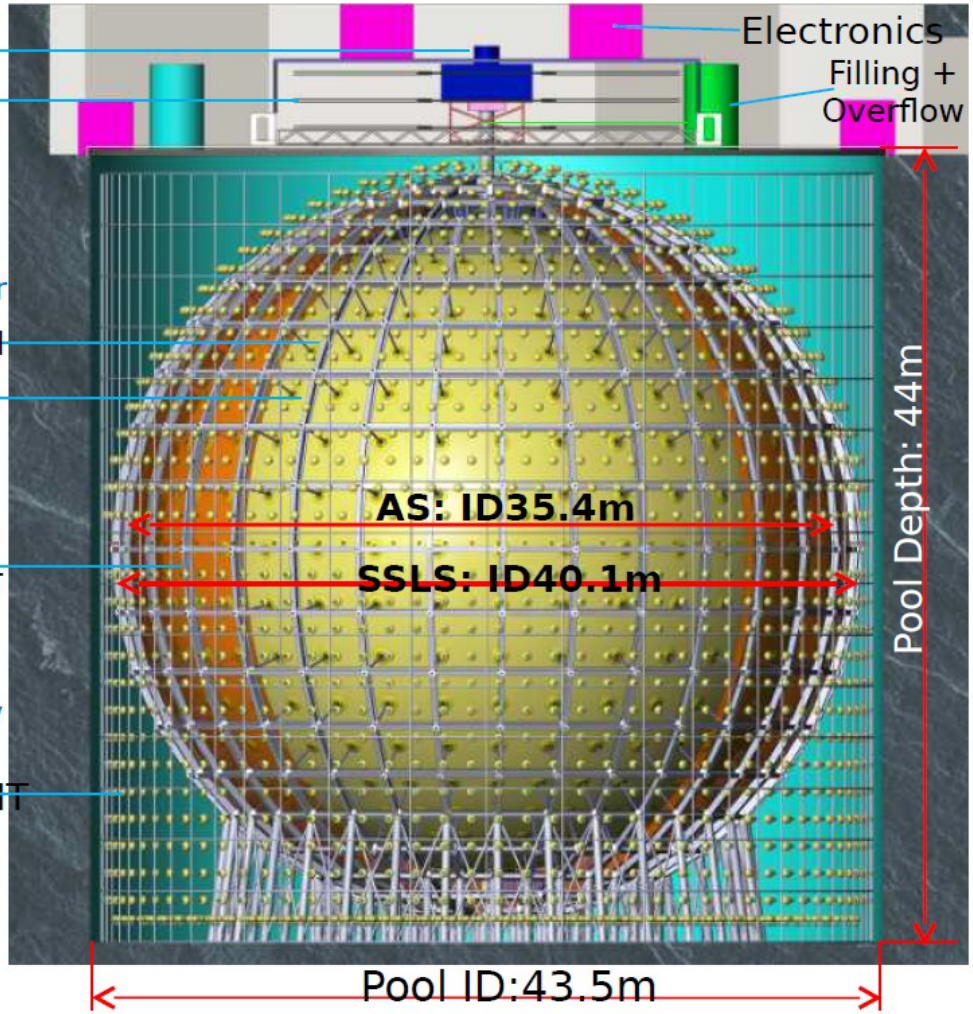
JUNO detector



AS: Acrylic sphere; SSLS: stainless steel latticed shell

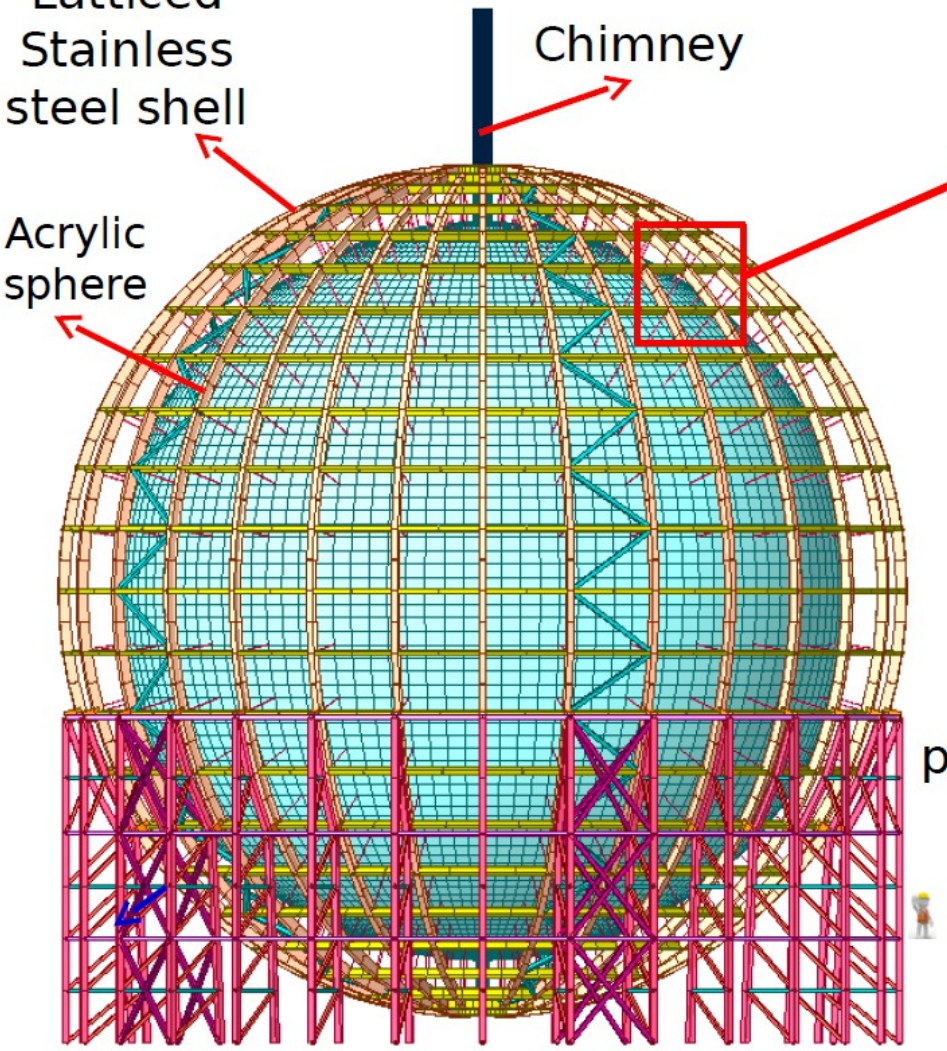
A multi-purpose neutrino observatory

- **Largest LS detector: ~20kt@Φ35.4m**
- **Energy resolution: <3%@1MeV under ≥1200p.e./MeV with high QE 20" PMTs coverage**
- **1GHz sampling waveform readout electronics for better energy understanding and more possibilities**
- **Double calorimetry both for low/high energy and cross checking**

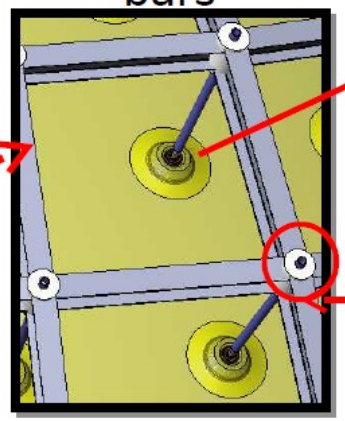
Acrylic Option: sphere + stainless steel latticed shell

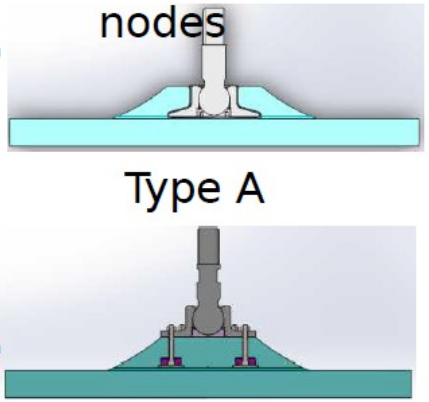
Most of the key designs determined

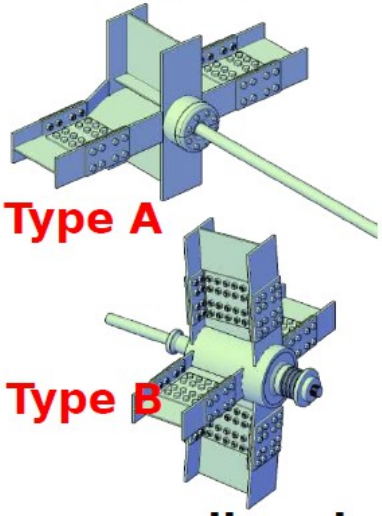
CD Structure design



Acrylic sphere supported by stainless steel shell

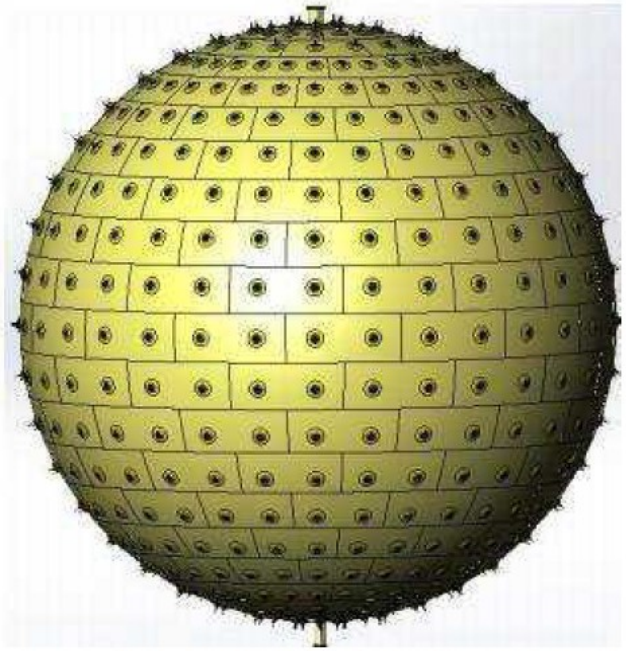




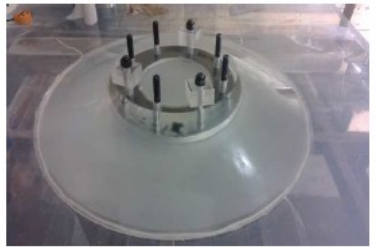


- **Shaping 120mm acrylic sphere plate**
- **Build the biggest acrylic sphere**
- **Tolerance both for weight and buoyancy under different conditions**
- **Low background control**
- **Transparency and less shadowing**
- **Installation and filling**

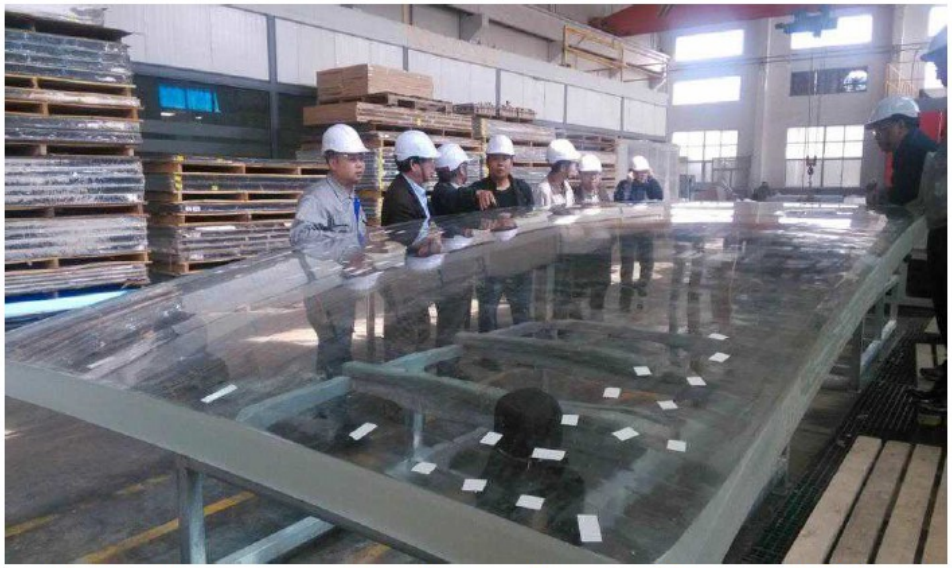
Acrylic sphere R&D



Acrylic divided into 200+panels

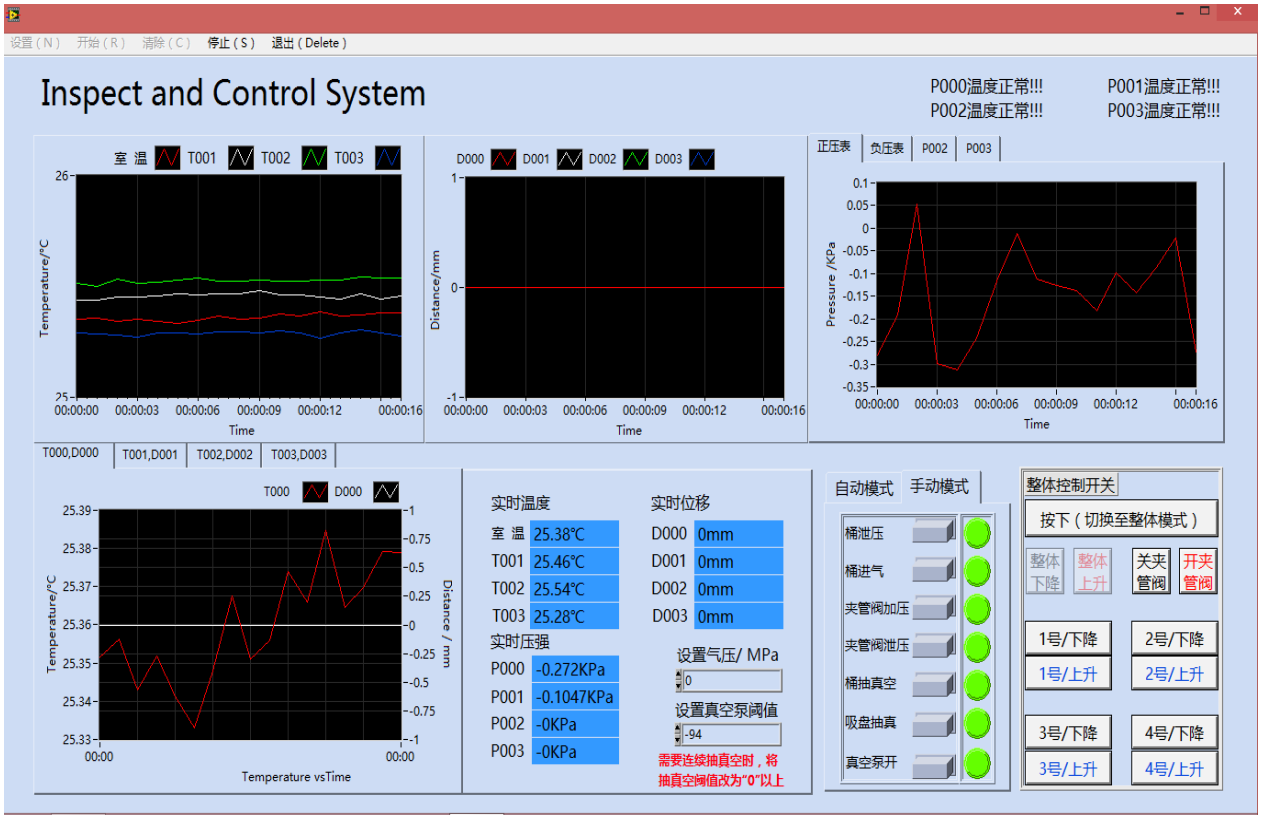


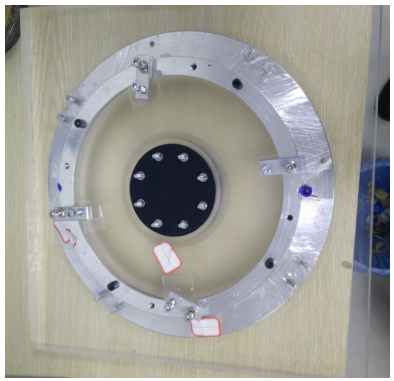
The problems of shrinkage and shape variation were resolved.
Three companies had good practices.

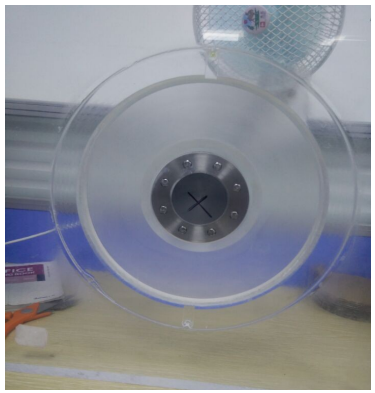


Forming panel size: 3m x 8m x120mm

A bonding machine for CD construction by SYSU







- **Air-tight tests to control radio-purity**
- **Automatic glue injection with ultra-pure Nitrogen**
- **On-line monitor to keep the consistency**
- **Multiple bonding in parallel to increase efficiency**
- **Warning system to avoid dangerous polymerization**

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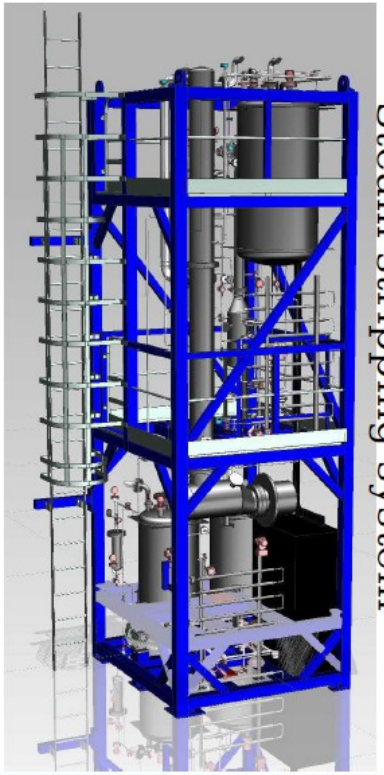
LS Pilot plant

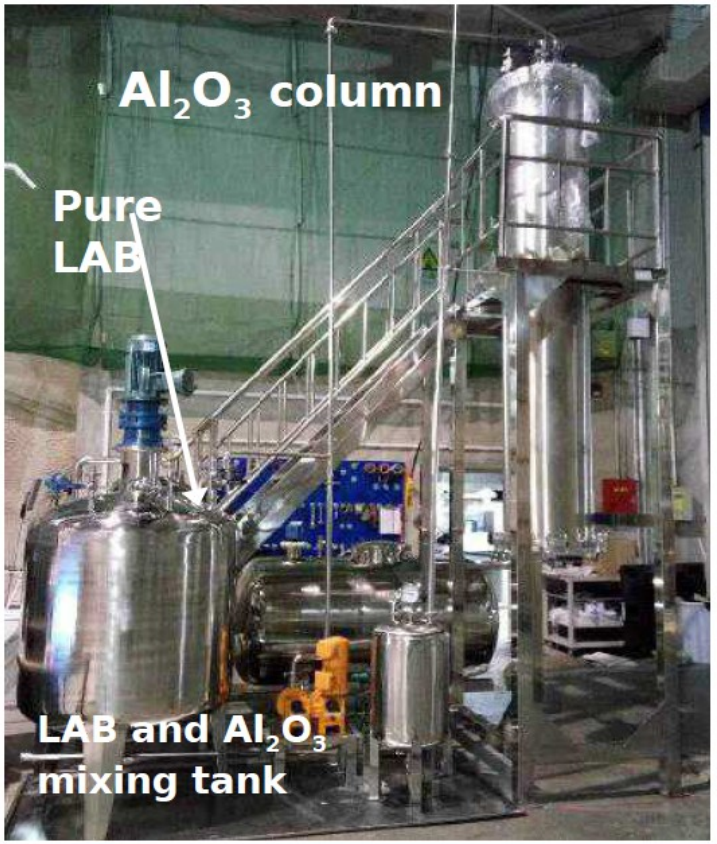
- Purify 20 ton LAB to test the overall design of purification system at Daya Bay. Plan to replace the target LS in one detector.
- Quantify the effectivities of subsystems
  - ⇨ Optical : >20m A.L @430nm
  - ⇨ Radio-purity: < 10^{-15} g/g (U, Th)
- Determine the choice of sub-systems
  - ⇨ Al_2O_3, distillation, gas striping, water extraction

Distillation and steam stripping

Installed at Daya Bay



Al_2O_3 column pilot plant installed in Daya Bay LS hall



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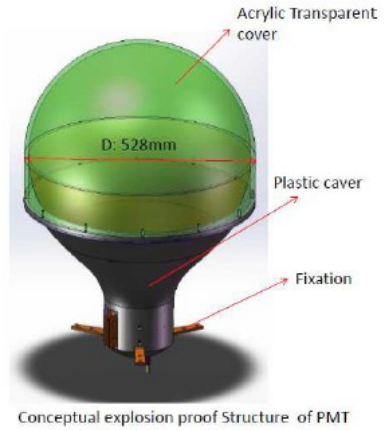
PMT coverage



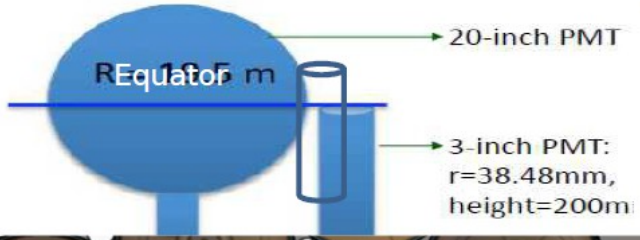
Conceptual explosion proof Structure of PMT

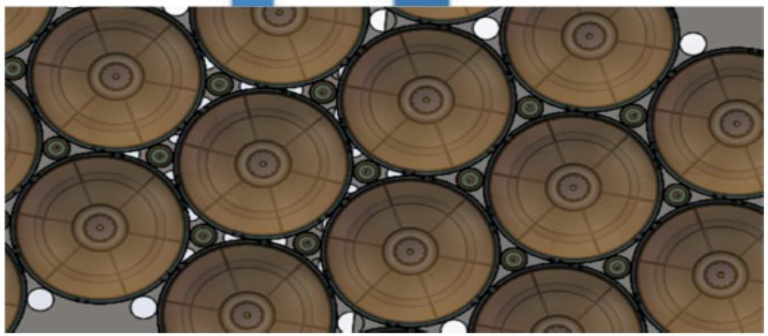
20” PMTs with structure
Installation with few mm gap

Single PMT in layers

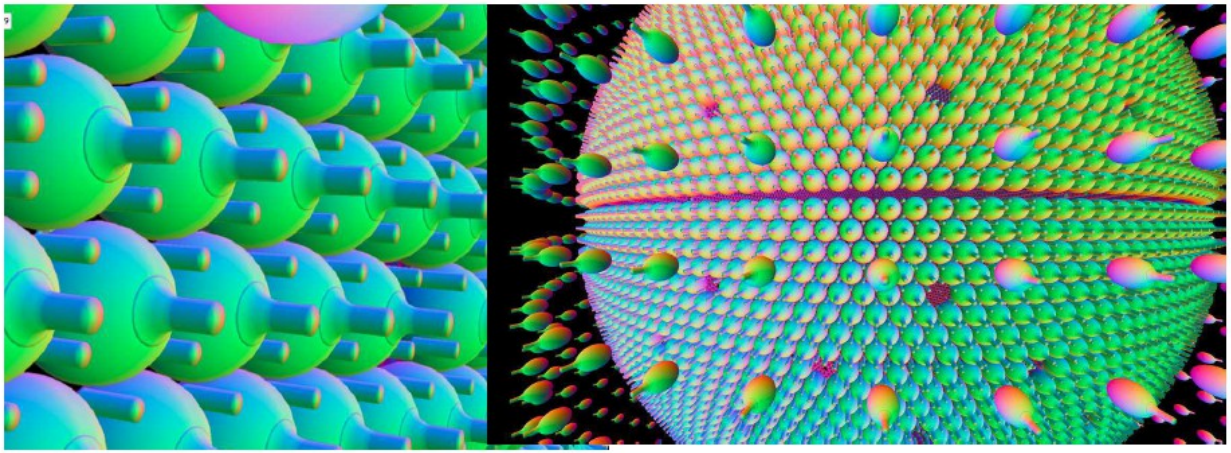
PMT No. : ~17000
PMT coverage: ~75%

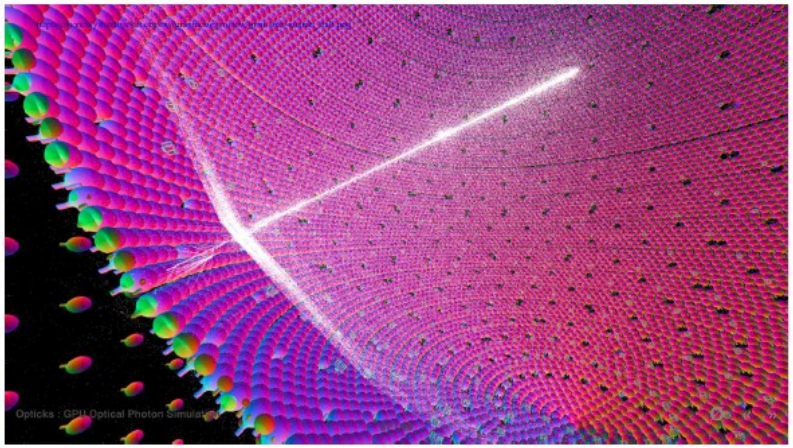
Double calorimetry



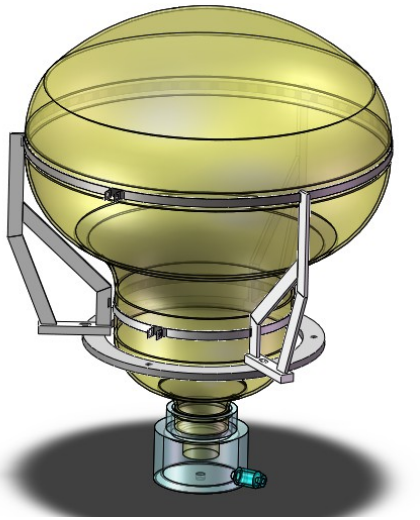


Targeted the largest light level ever detected in LSD ~1200 pe/MeV
(Daya Bay 160 pe/MeV -Borexino 500 pe/MeV –KamLAND 250 pe/MeV)



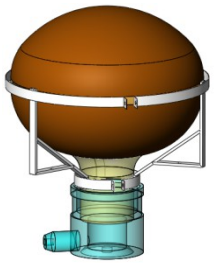


Development of PMTs for JUNO



H

M



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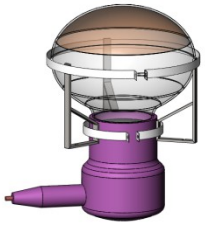

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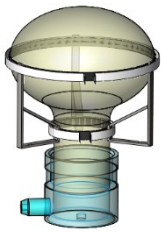

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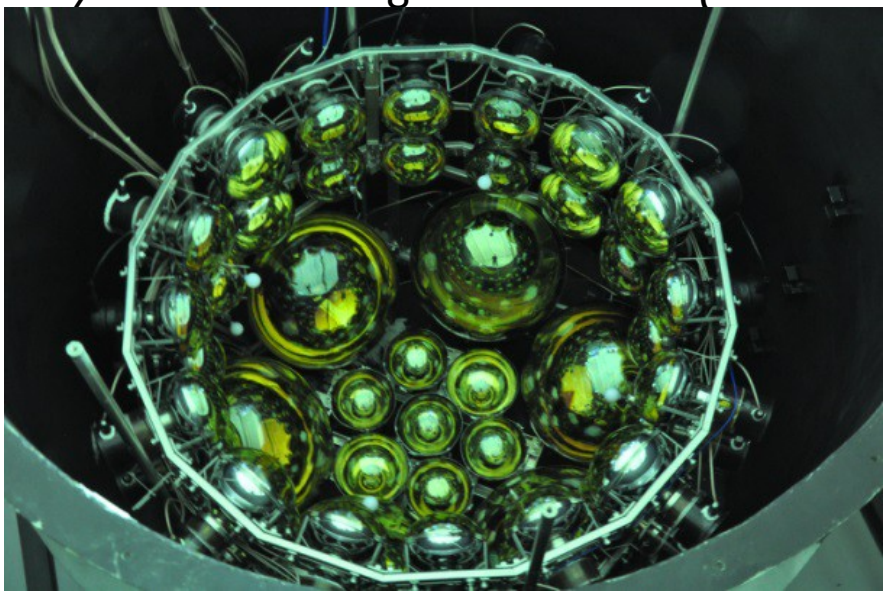
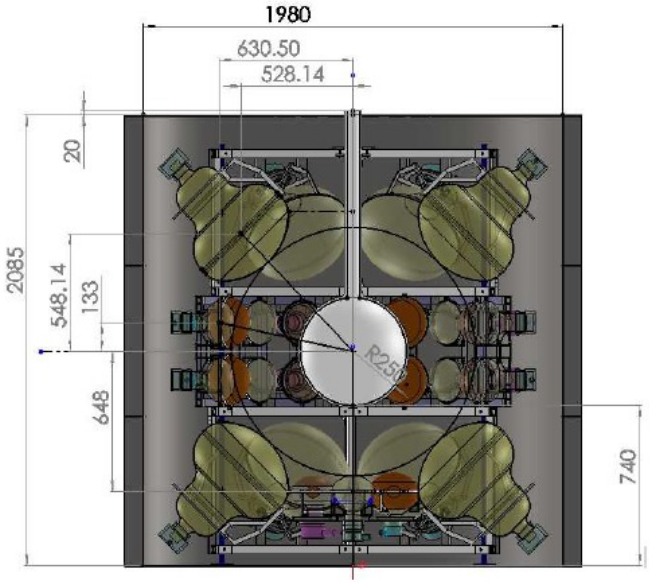
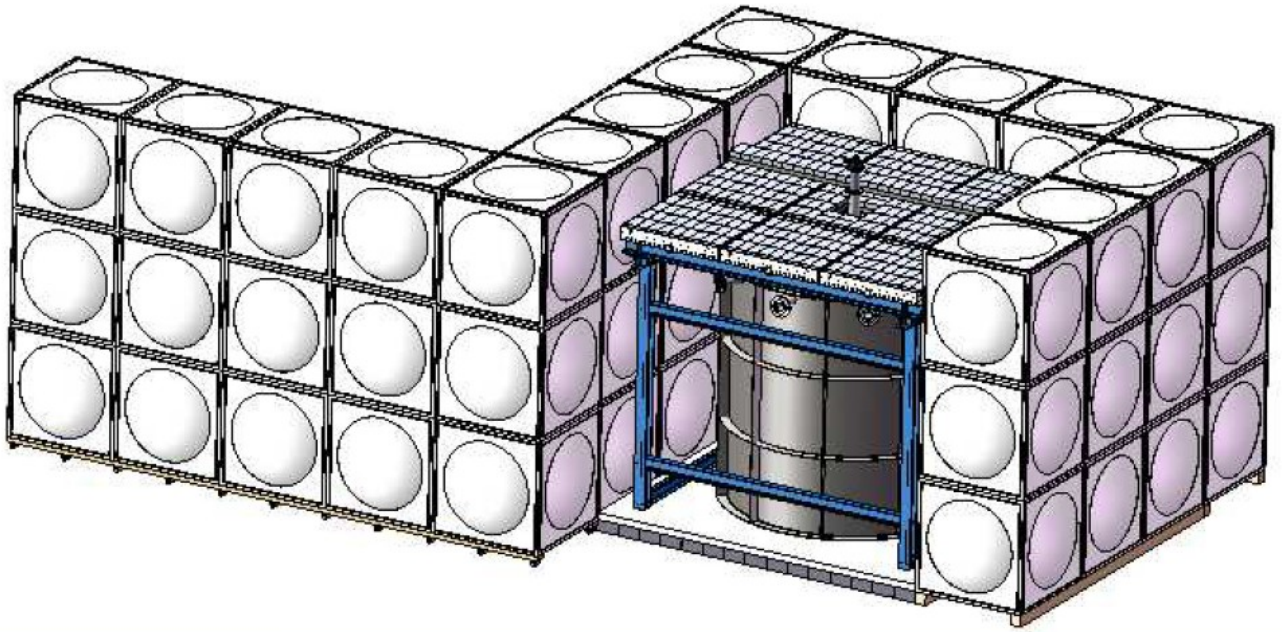


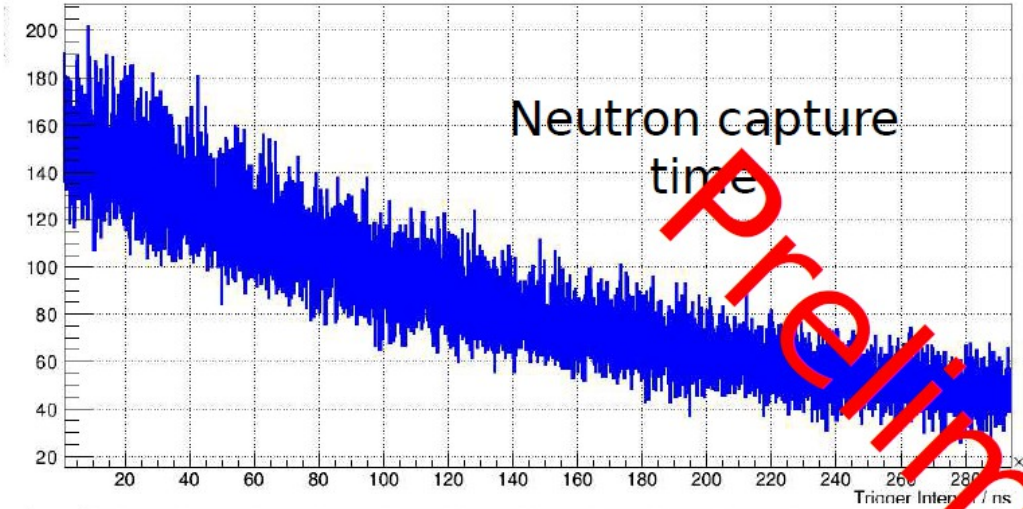
JUNO Detector Prototype

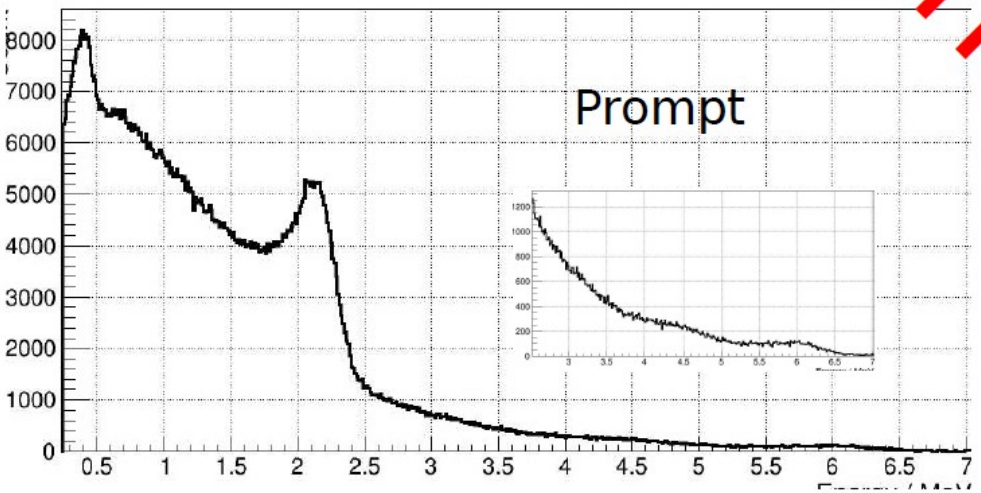
- Goal: Study/Comparison of PMTs' performances in a real LS detector
  - MCP-PMT 8"+20", Hainan Zhanchuang (HZC) 9", Hamamatsu 8"+20"
- Bench test to cross check company parameters, Bench test to prepare for PMT mass testing, JUNO Prototype detector for more experience on:
  - New PMT testing
  - Large PMT mounting
  - Large PMT installation
  - Water proof PMT potting
  - PMT performance in LS detector
  - Calibration testing

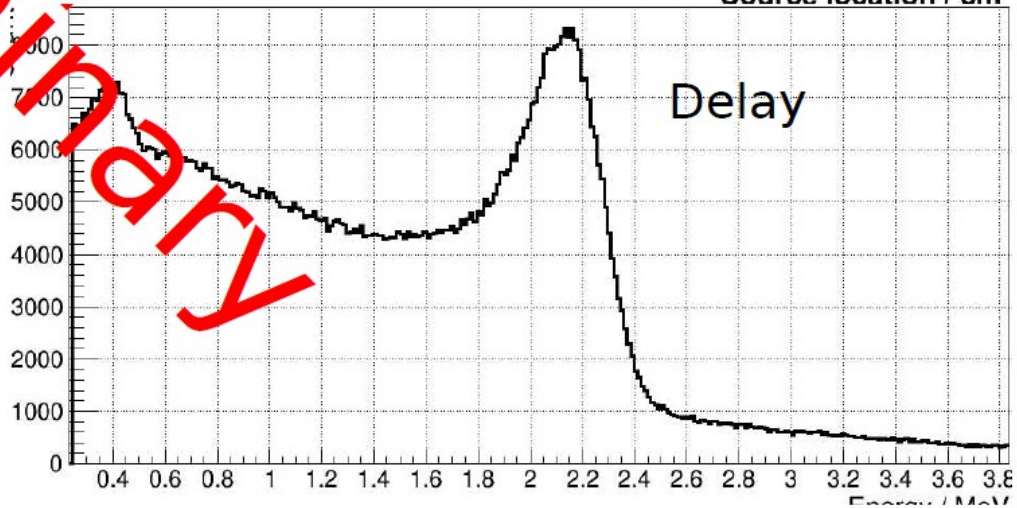




PuC neutron source loaded in JUNO prototype







Preliminary

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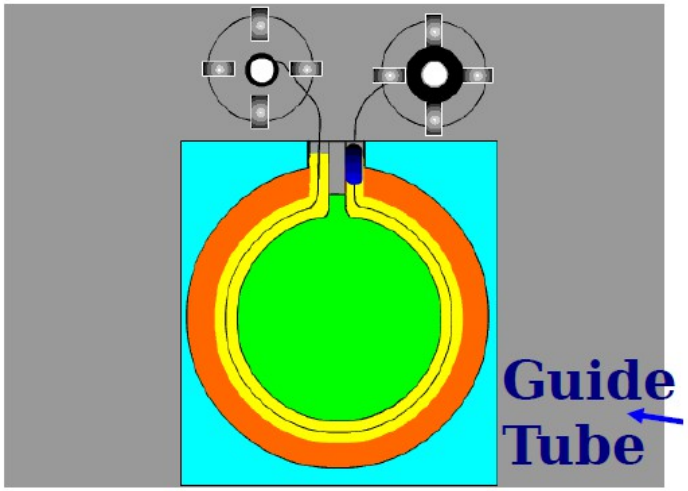
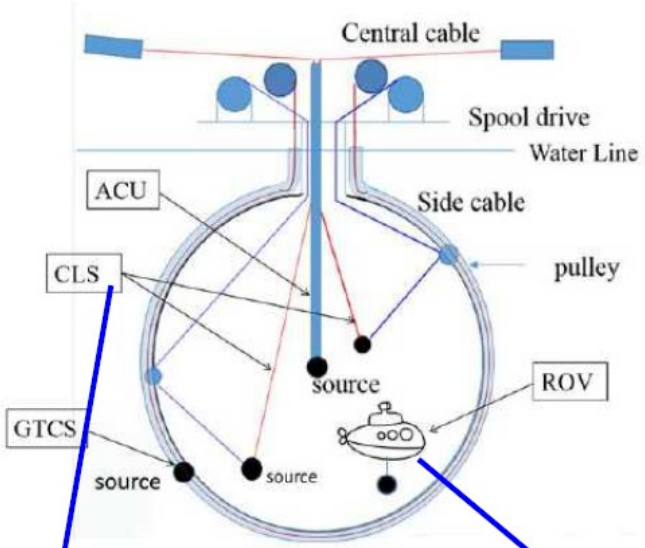
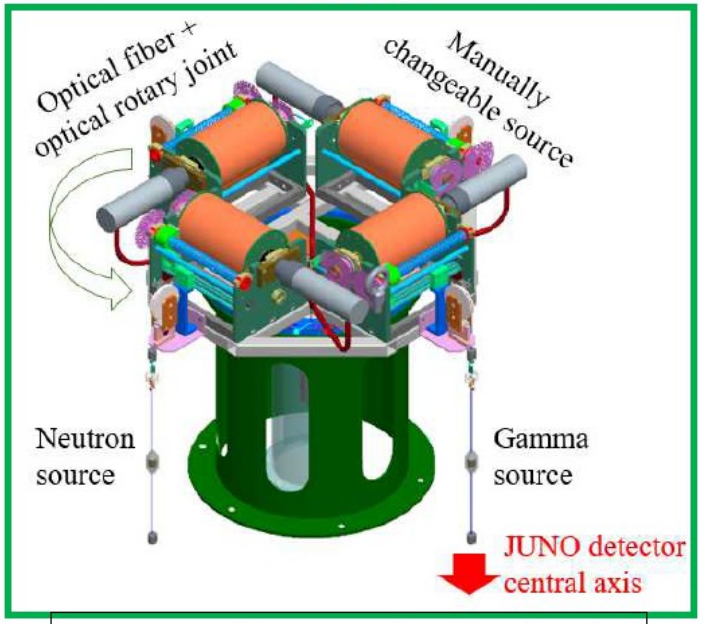
Calibration System



Boundary scan

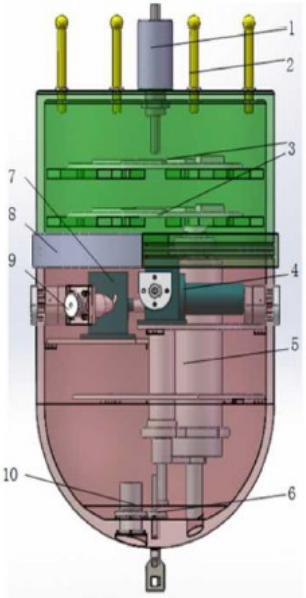


ACU



Scan of central axis (1D)

Scan of vertical plane (2D)



ROV:3D scan

Schedule

ITEMs	Start
CD & water poll equipment installation	2018
PMT potting and testing	2018
CD & VETO PMT installation	2019
AD & VETO water filling	2019
LS filling	2019
Run	2020

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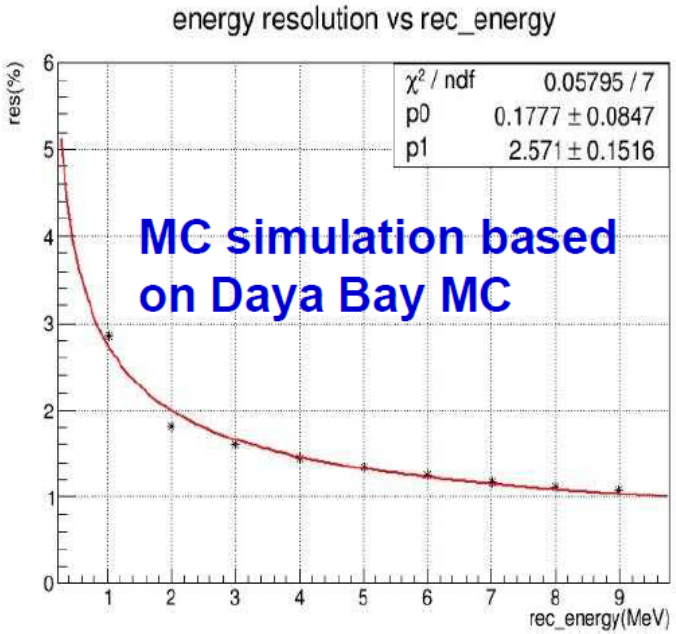
Summary

- **JUNO is a fully funded project and progresses in the fast track.**
- **JUNO central detector designed, matched with simulation for response, background, reconstruction, etc.**
- **PMTs selected and R&D of PMT instrumentation going on**
- **LS Pilot plant is ready to be scaled up for JUNO.**
- **Calibration system just passed the preliminary design review.**
- **Prototype testing for PMT, potting, LS, electronics, analysis etc. going well.**
- **Welcome to joining our efforts in JUNO.**

Thank you for your attention.

Challenges



- 77% photocathode coverage
- PMT peak QE: 35%
- Attenuation length of 20 m
- abs. 60 m + Rayl. scatt. 30m

- **Two Challenges:**
  - ⇨ How good is the energy resolution
  - ⇨ How well we know the reactor spectrum
- **Model prediction (2-10%) + energy nonlinearity (1-3%) from LS and electronics/readout**
- **Two approaches to mitigate the spectrum uncertainties**
  - ⇨ Direct measurement of the spectrum to 1% by SBL reactor exp.
  - ⇨ Constraint from Daya Bay measurements, independent of models, similar LS and similar electronics ~ 1%

	KamLAND	BOREXINO	JUNO
LS mass	1 kt	0.5 kt	20 kt
Energy Resolution	6%/√E	5%/√E	3%/√E
Light yield	250 p.e./MeV	511 p.e./MeV	1200 p.e./MeV