



JUNO Central Detector and PMT system

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(IHEP, Beijing)

On behalf of JUNO collaboration

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ICHEP 2016, Aug. 3-10, Chicago

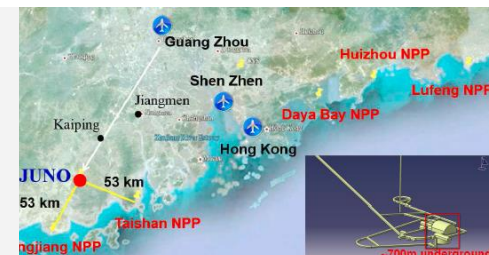


中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



**38th INTERNATIONAL CONFERENCE
ON HIGH ENERGY PHYSICS**

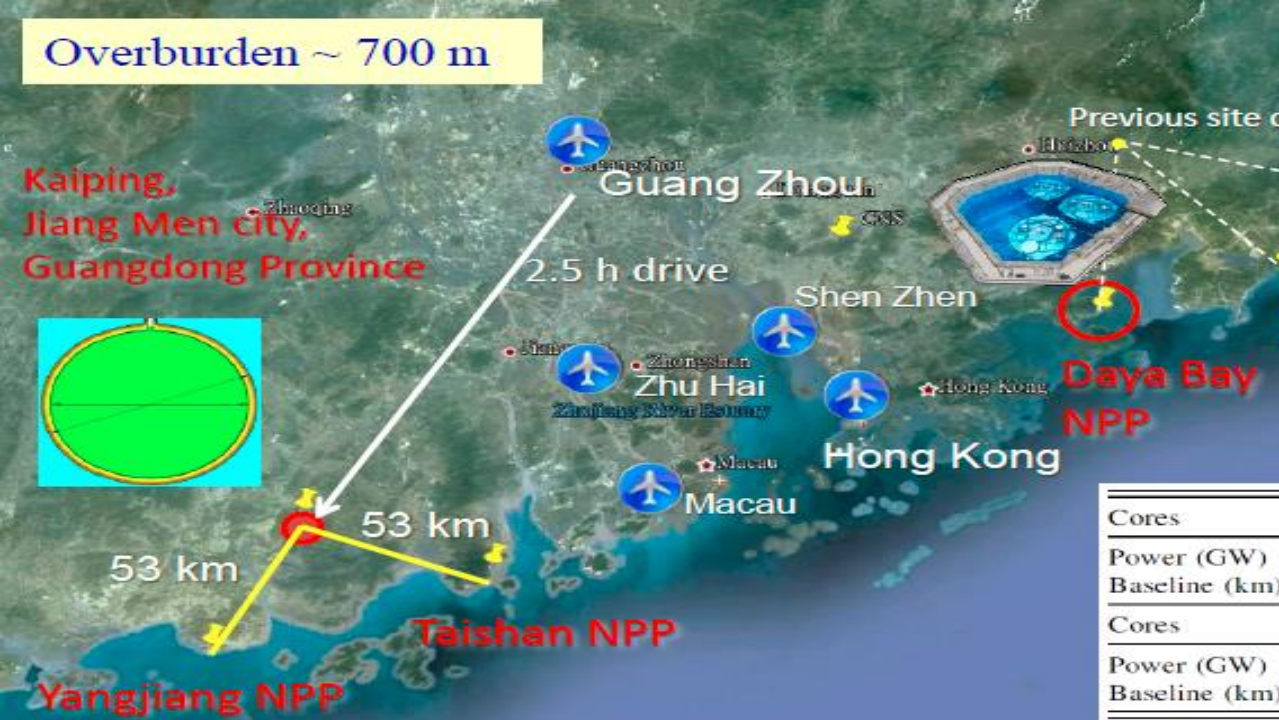
AUGUST 3 - 10, 2016
CHICAGO



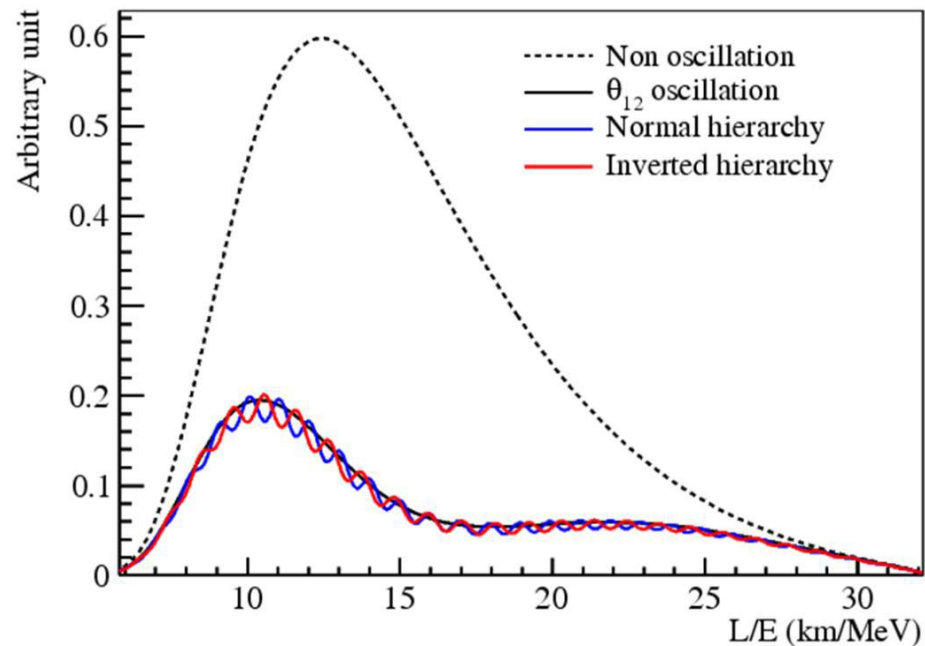
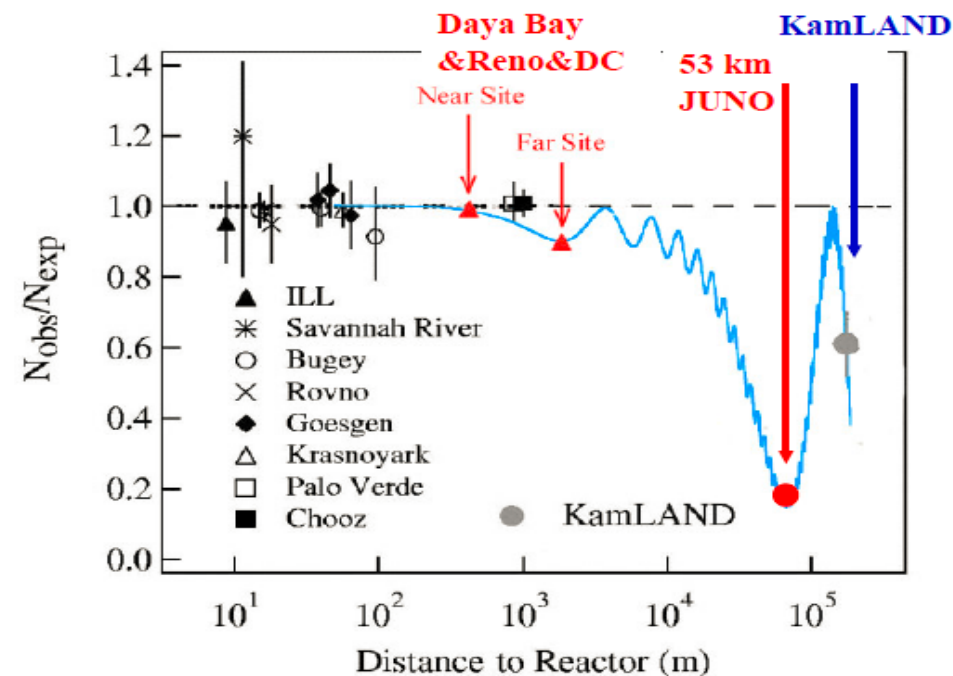
Overburden ~ 700 m

Outline

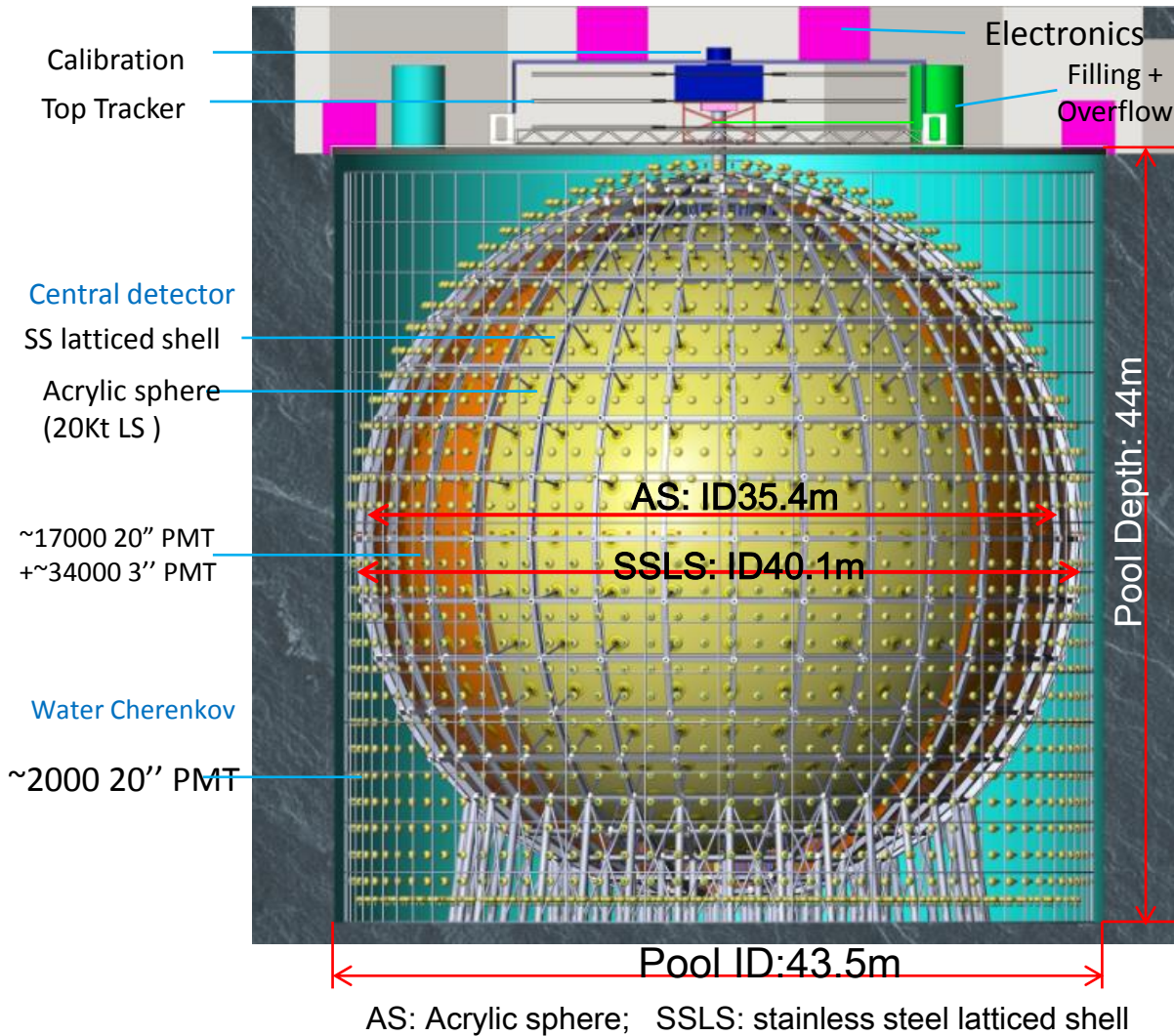
- Central Detector
- PMT system
- Prototyping



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



JUNO detector



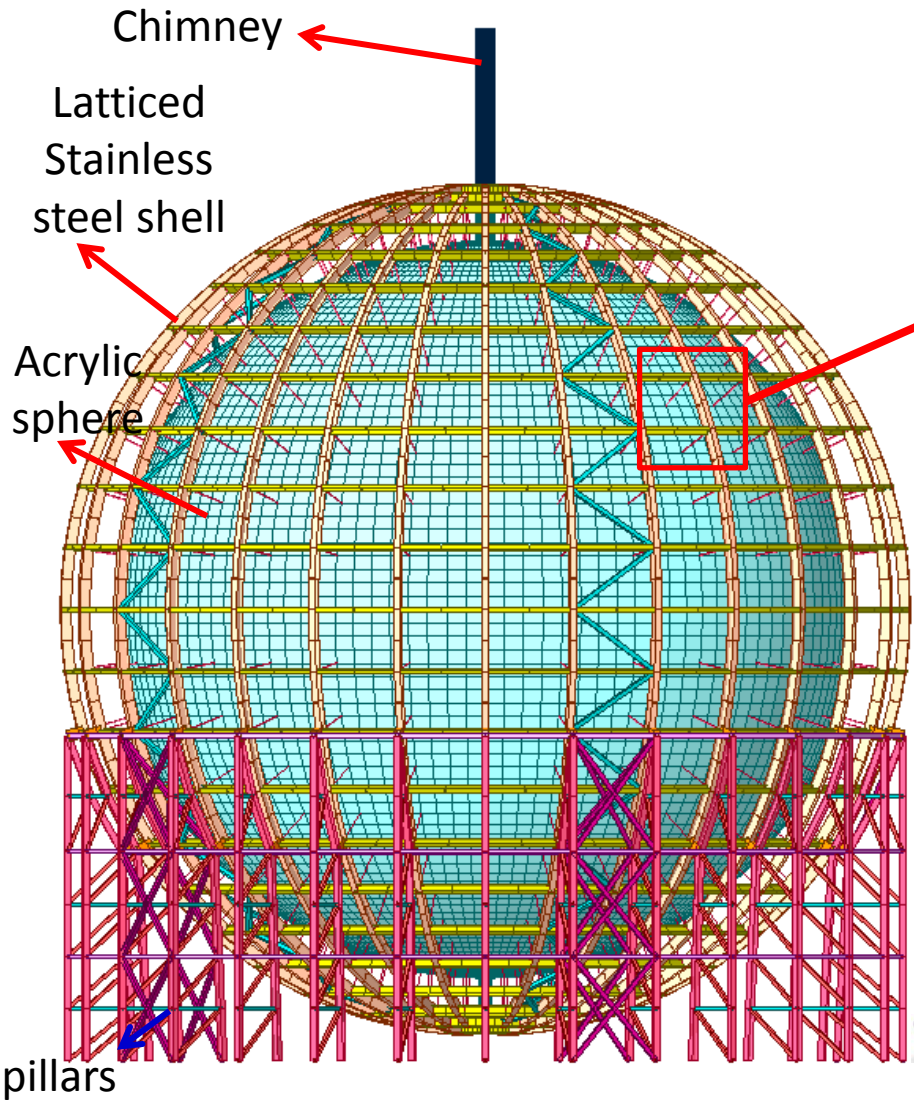
A multi-purpose neutrino observatory

- Largest LS detector: ~20kt@ Φ 35.4m
- Energy resolution: <3%@1MeV under ≥ 1200 p.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

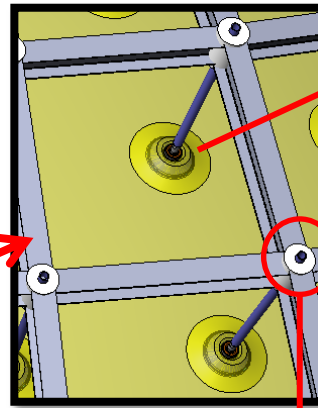
Most of the key designs determined

CD Structure design



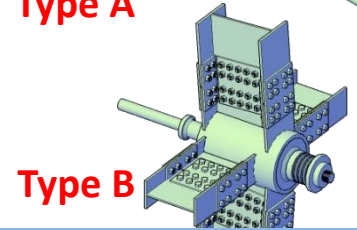
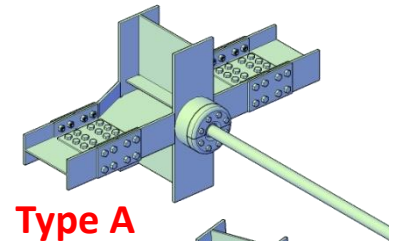
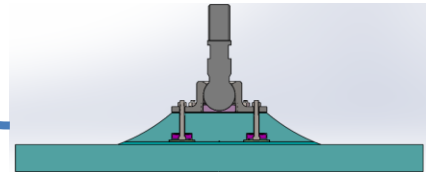
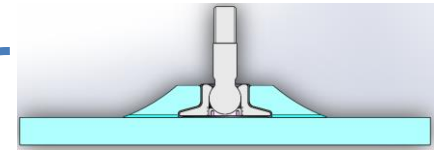
Acrylic sphere supported by stainless steel shell

Connection bars



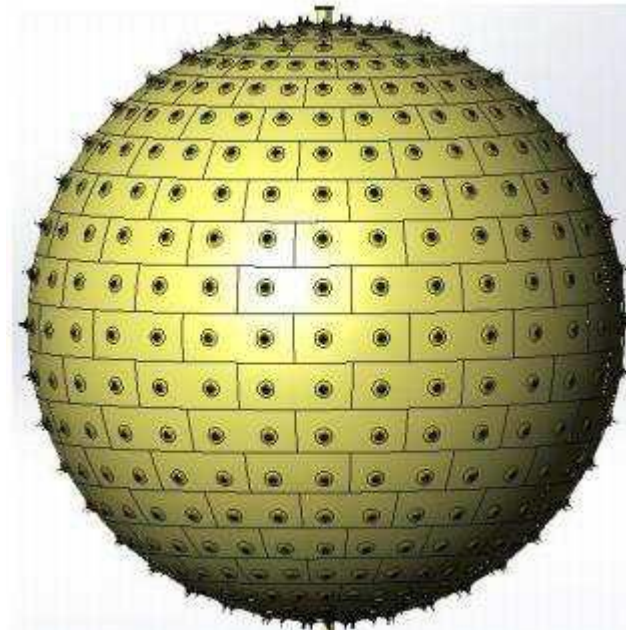
Shell node

Acrylic nodes

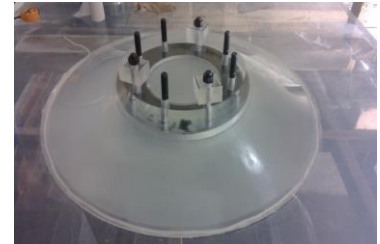
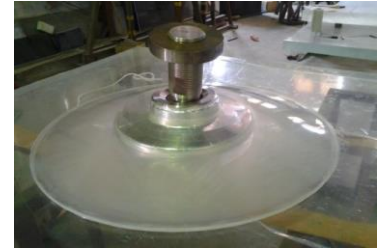


- Shaping 120mm acrylic sphere plate
- Makeup the biggest acrylic sphere
- Tolerance both for Weight and buoyance under different conditions
- Low background control
- Transparency and less shadowing
- Installation and filling

Acrylic sphere R&D



Acrylic divided into 200+panels



Three companies had good practices.

The problems of shrinkage and shape variation were resolved.

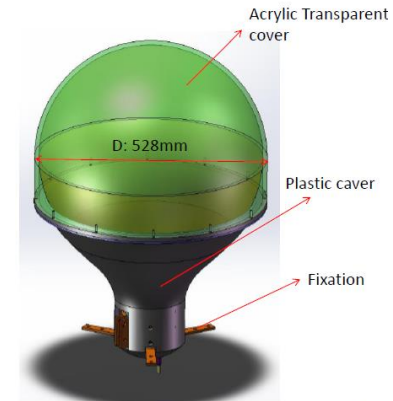
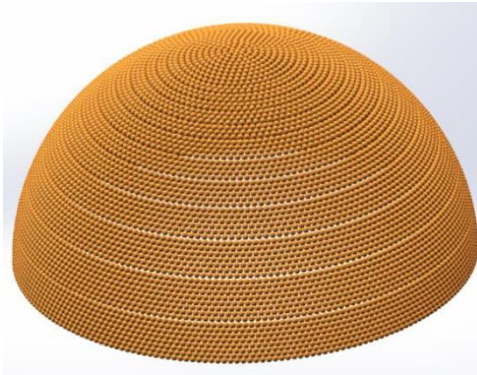


Forming panel size: 3m x 8m x120mm



PMT coverage

Single PMT in layers

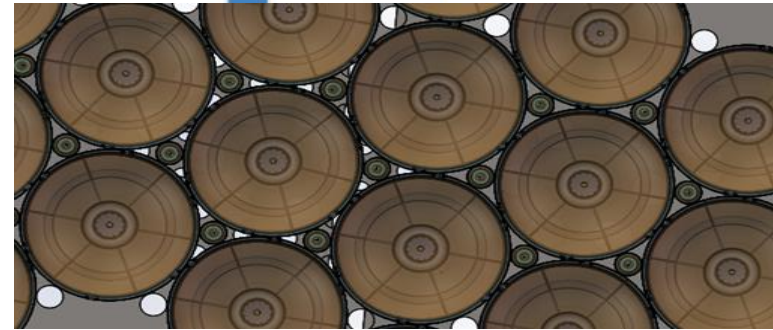
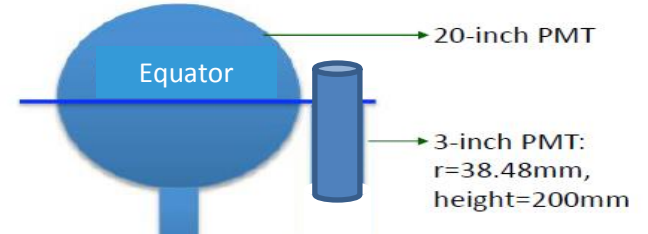


Conceptual explosion proof Structure of PMT

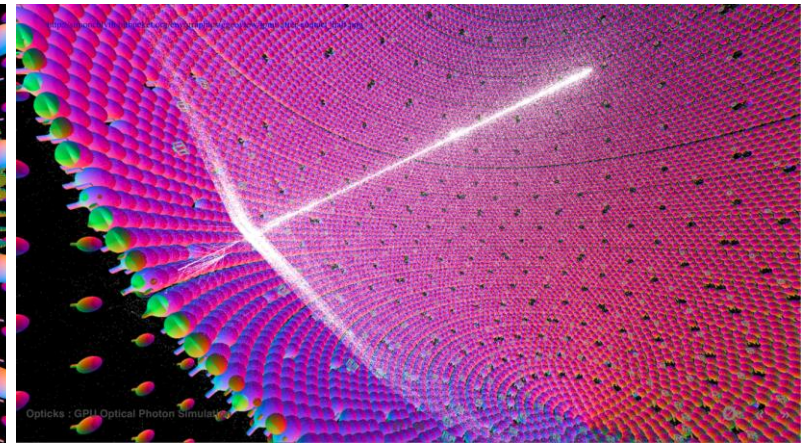
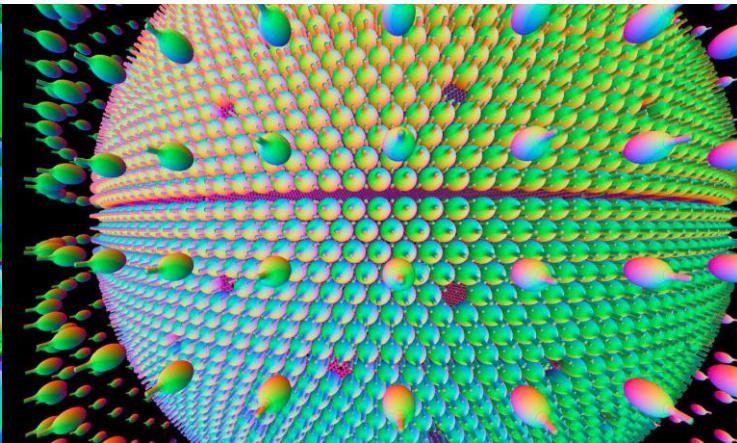
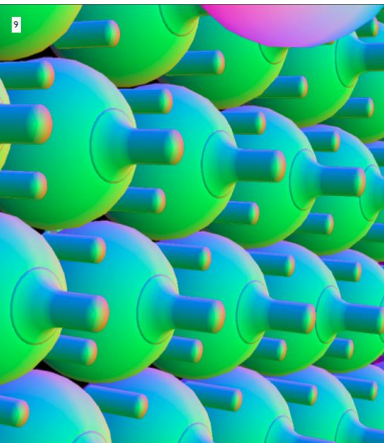
20" PMTs with structure
Installation with few mm gap

PMT No. : ~17,000
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)



PMT system

Challenging: (~15,000 NNVT MCP-PMT 20", ~5,000 Hamamatsu 20", ~34,000 3" tubes)

PMT water proof potting with electronics in and heat out

Implosion protection under 40 meters water

PMT installation under limited workspace

High reliability

Parameters of 20-inch PMT

List of the Parameters	Minimum requirement
Detection efficiency @420nm (QE * CE)	27% in average, all >24%
TTS of SPE (FWHM)	<12 ns
Rise time and fall time	<8ns, < 16ns
Gain	10 ⁷
Non-linearity @10 ⁷ gain	<10% (0-1000pe)
Dark rate @ 0.25 SPE, 10 ⁷ gain	<50kHz
non-uniformity of QE	<15%
Operating High voltage @10 ⁷ gain	<3000 V
P/V ratio of SPE	>2.5
Pre-pulse ratio (80ns time windows) and after-pulse ratio (20μs time windows)	<5%, <5%
Spectral response range (nm)	300-650
Geomagnetic field sensitivity (@450mG)	SPE variation < 20%; TTS variation < 15%
Long-term stability	Gain variation < 5% for 1 week, and <10% for 1 year ; Anode current variation < 1% /°C



MCP 20"
(NNVT)

Several options

- MELZ (RU)
- HZC (CH)
- ETL (UK)
- Hamamatsu(JP)

R12860
(Hamamatsu)



Photograph of MCP-PMT

MCP 20" (NNVT)

Microchannel Plate Photomultiplier Tube (MCP-PMT)

Description	
Window material	Borosilicate glass
Photocathode	Sb-K-Cs
Multiplier structure	Microchannel plate

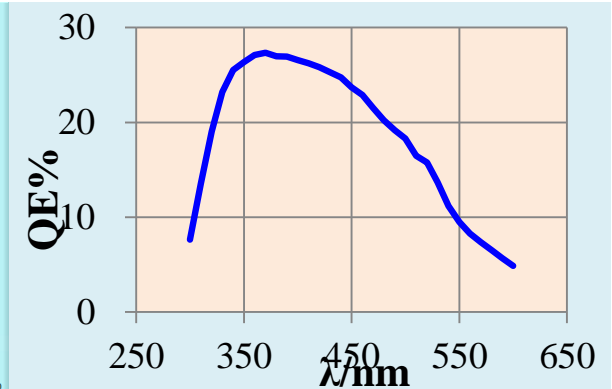
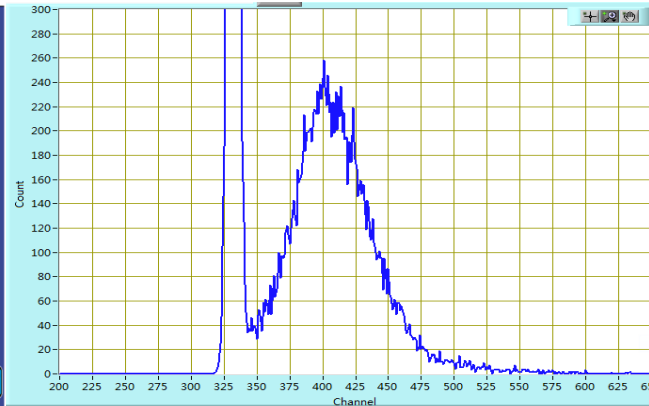
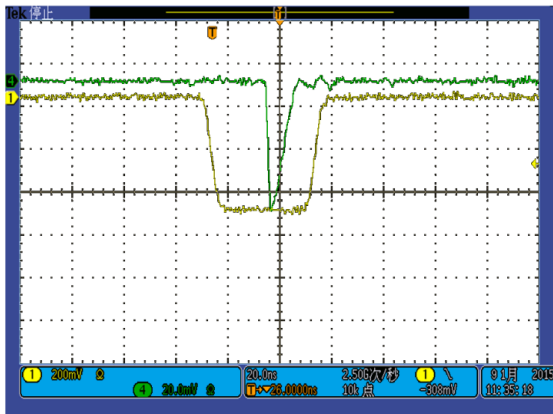
Application

- High Energy Physics
- Neutrino Physics
- Single Photon Detection

Features

- Large Photocathode Area
- Fast Time Response
- Less Dark Count
- Good Linearity

Type	8"	20"
	Typ.	Typ.
Photocathode characteristics		
Spectral Range(nm)	300-650	300-650
Maximum sensitivity at (nm)	380	380
Sensitivity		
Luminous($\mu\text{A}/\text{lm}$)	70	60
QE at 420nm(%)	26	26
Supply Voltage(V)	-1700	-1600
Gain		
Anode Dark Current(nA)	1×10^7	1×10^7
Background Noise(cps)	100	150
Single Electron Spectrum	5 K	30 K
Energy Resolution(%)	60	40
Peak to Valley Ratio	2.5	3.5
Anode Pulse		
Rise Time(ns)	1.7	1.7
Duration at half height(ns)	8.8	8.8



NORTH NIGHT VISION TECHNOLOGY Co., LTD (NNVT)

Address: No.2, Campion Street, Integrity Avenue, Jiangning Development Zone, Nanjing, Jiangsu, China

Zip Code: 211106

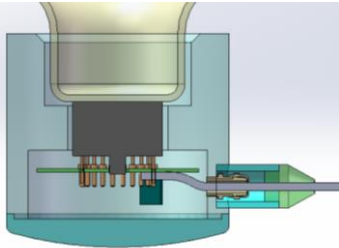
Tel:+86-25-86988112

Fax:+86-25-86988115

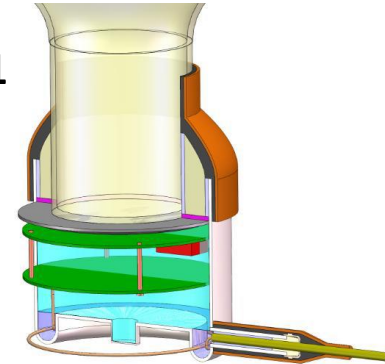
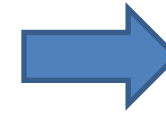
Website: www.nvt.com.cn E-mail: nj@nvt.com.cn

PMT water proof potting

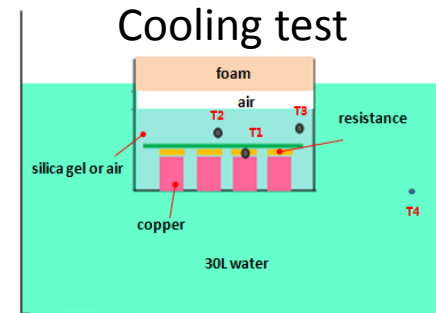
Pressure test



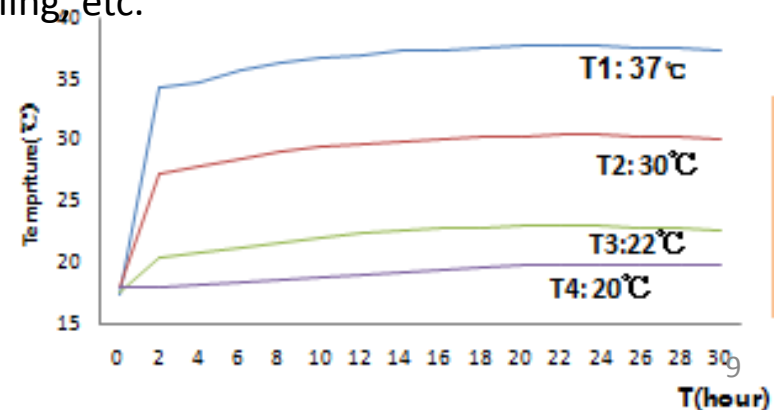
Scheme 1



- 1st **TESTED**: water proof potting only with PMT+HV divider + single cable for IHEP JUNO prototype detector
 - working well in the prototype detector in ~6monthes, Checked with signal quality
- 2nd **R&D** with front end electronics
 - Challenging: Heat from electronics
- Investing/testing materials, heat distribution
 - waterproof putty, bonding sealants, RTV , cooling, etc.



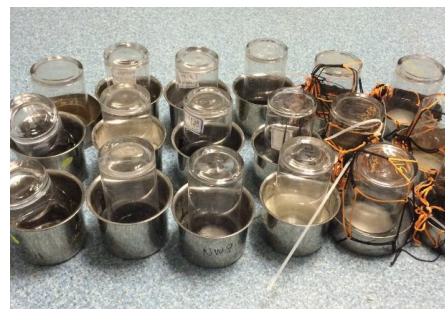
2) Silica gel (1.0W/K·m) + copper



Putty



Sealants



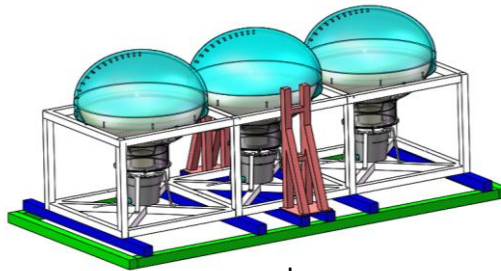
PMT implosion Protection

- To protect the PMTs from chained implosion by any accidents or defect tubes:
 - Strong enough to protect the PMTs
 - Good transparency for light
 - Limited dimension by coverage and cost.
 - Compatible with pure water
 - Low radioactivity
- The new designed structure is working well in pressed water test.

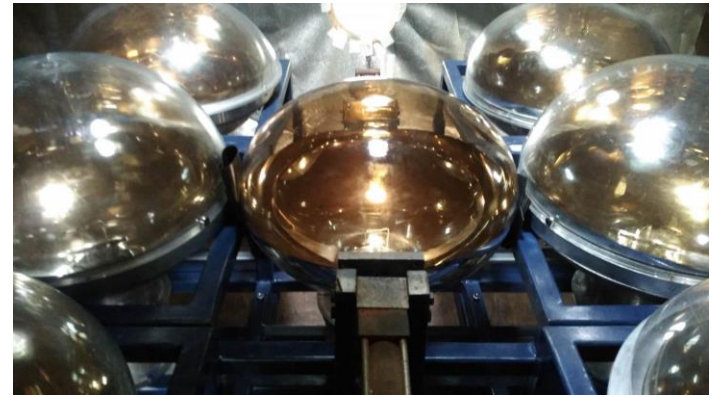
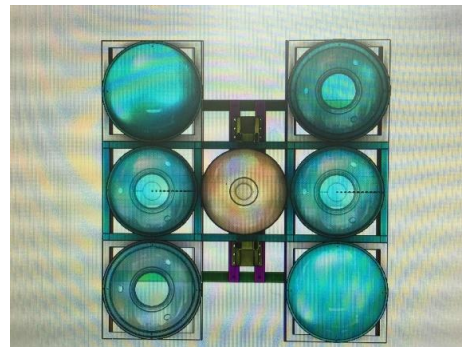
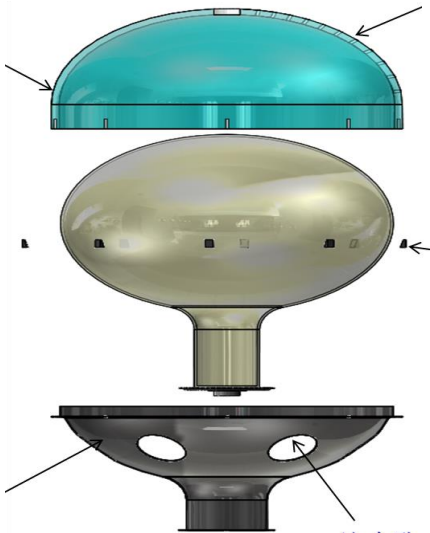
Different production technology



1st test 2016



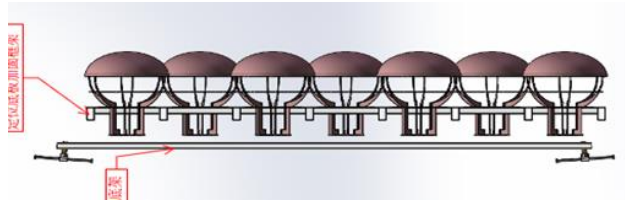
2nd test 2016



PMT Installation

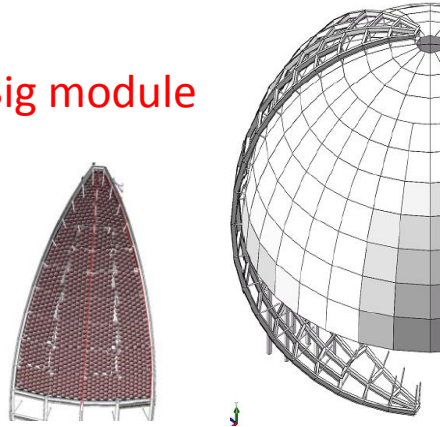
- PMT installation of JUNO is challenging:
 - Limited workspace, Too many channels, Radioactivity, Tight schedule
- Install options:
 - under discussion with designer, companies for all the possibilities, "Dry" and "Wet"
- PMT module:
 - Install PMTs in module

Baseline: Double plates + Clamp

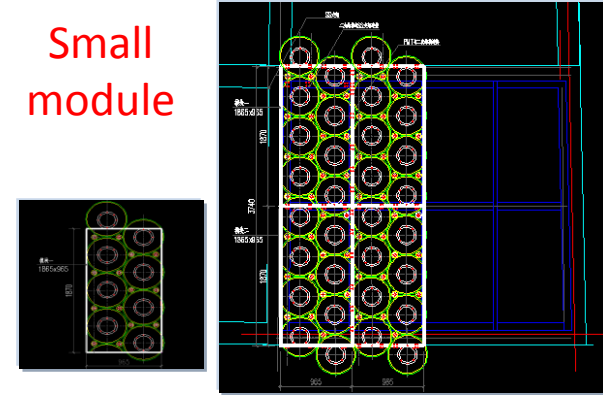


Just as example

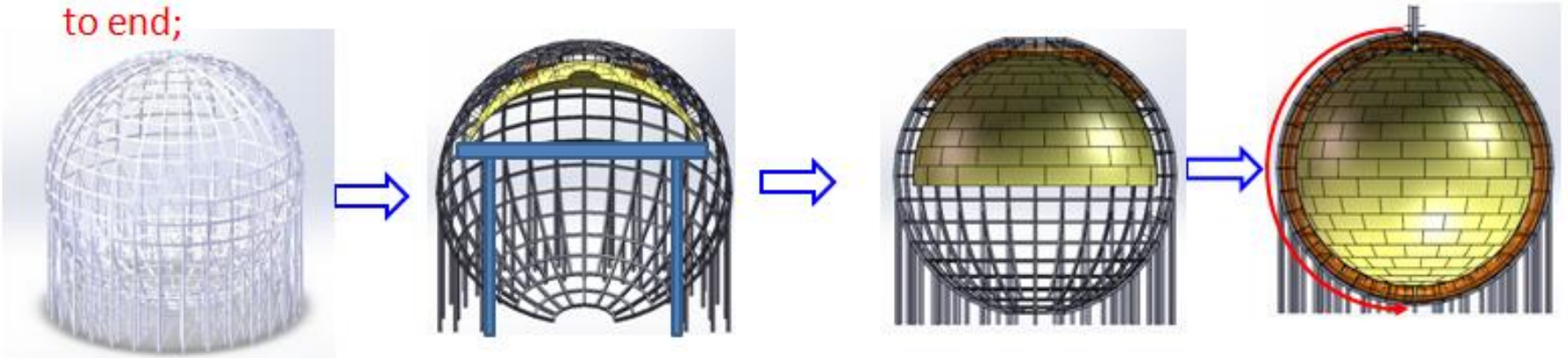
Big module



Small module



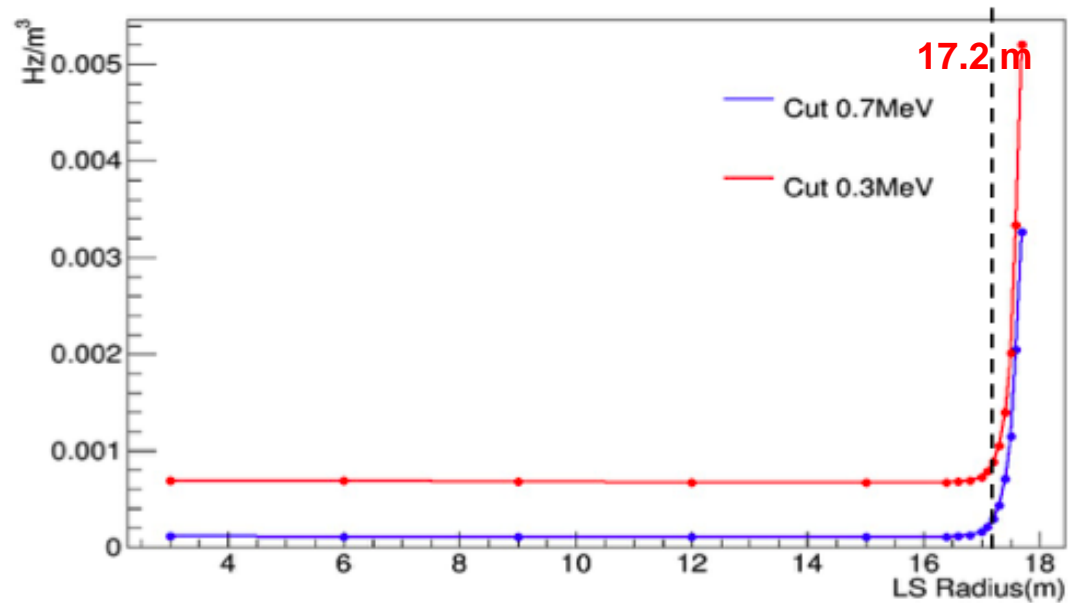
Scheme 4. Partial alternation: SS truss → Some circles Acrylic Ball → One circle PMT → Cycling to end;



Singles rate from MC Simulation

Including the contribution from: U238, Th232, K40, Pb210(Rn222), Ar39, Kr 85, Co60

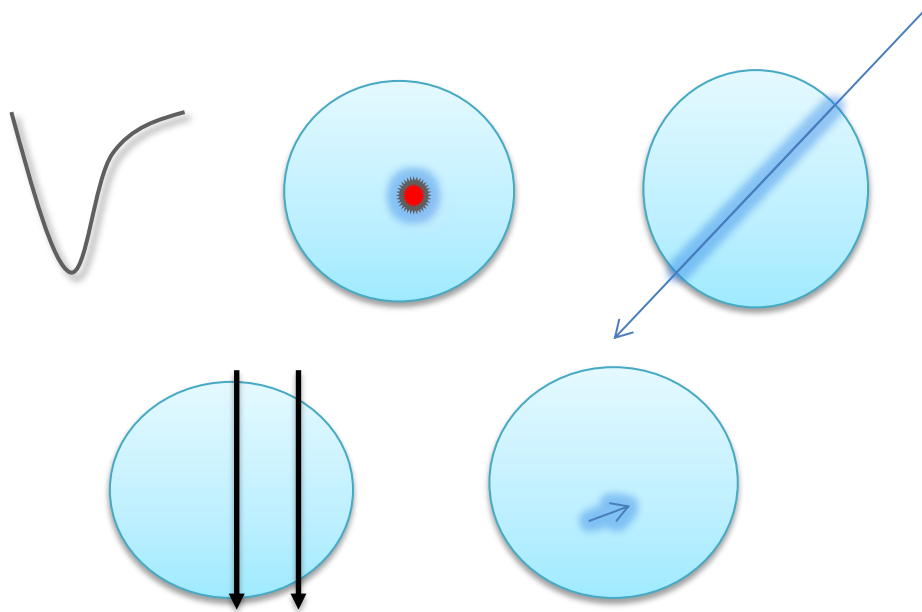
Rock with 3.2m water	Singles@0.7MeV/Hz
<17.7m	7.4
<17.2m	1.0



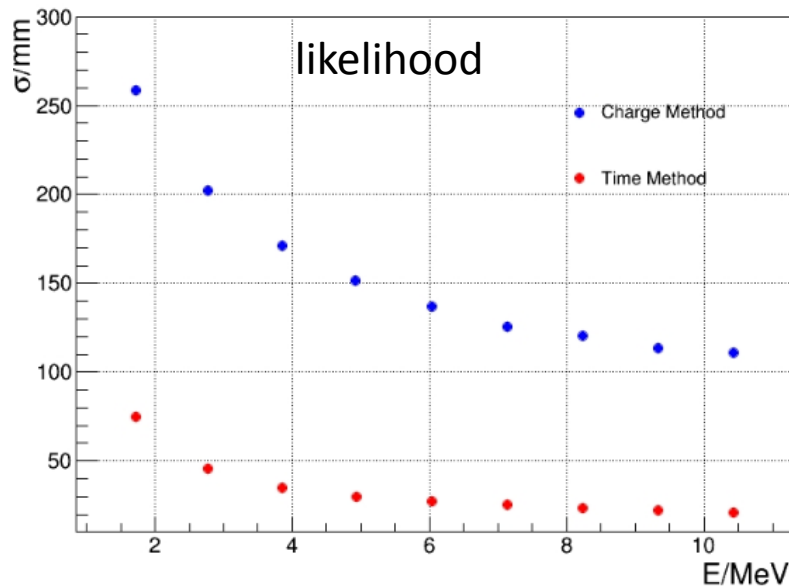
LS R (m) (Cut 0.7MeV)	PMT (Hz)	Acrylic (Hz) (10ppt)	Strut (steel) (Hz)	Fastener (Cu) (Hz)	SUM (Hz)	LS (Hz)
<17.7	2.43	69.23	0.89	0.82	73.37	2.39
<17.6	1.91	41.27	0.66	0.55	44.38	2.35
<17.5	1.03	21.82	0.28	0.32	23.45	2.31
<17.4	0.75	12.23	0.22	0.19	13.39	2.27
<17.3	0.39	6.47	0.13	0.12	7.10	2.24
<17.2	0.33	3.61	0.083	0.087	4.10	2.20
<17.1	0.23	1.96	0.060	0.060	2.31	2.16
<17.0	0.15	0.97	0.009	0.031	1.16	2.12

Reconstruction

- PMT reconstruction
 - Charge and timing
 - Pulse Shape Discrimination
- Point-like source reconstruction
 - Energy and vertex
- Tracking at high energy
 - Direction and track length
- Tracking at low energy
 - Direction



Z resolution for different energy



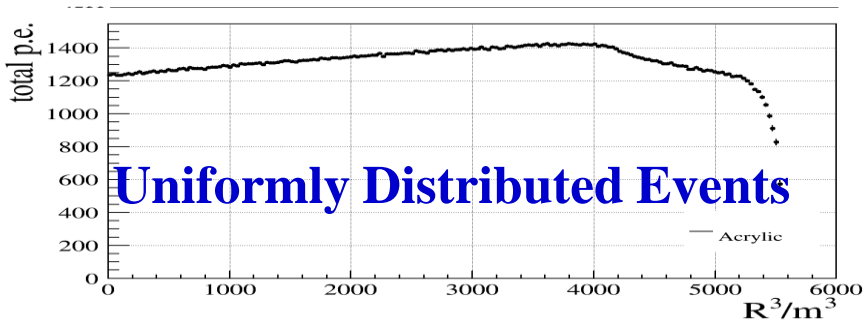
Point like:

- <10cm@1MeV when PMT time resolution better than 4ns;
- <35cm@1MeV for charge only;

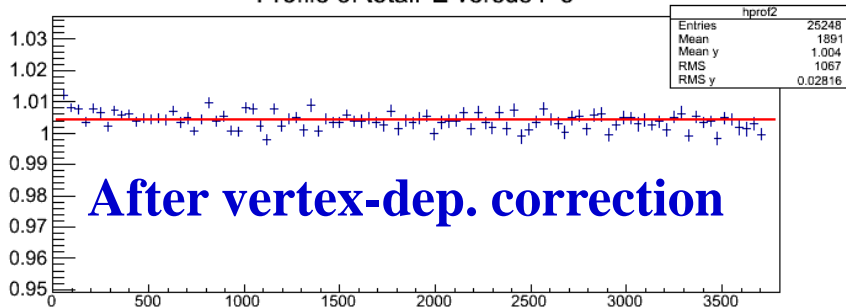
Energy response

- With the designed geometry, parameters, the detector will reach better than 3%@1MeV energy resolution
- While the total internal reflection at large radius, reconstruction algorithm still need improvement

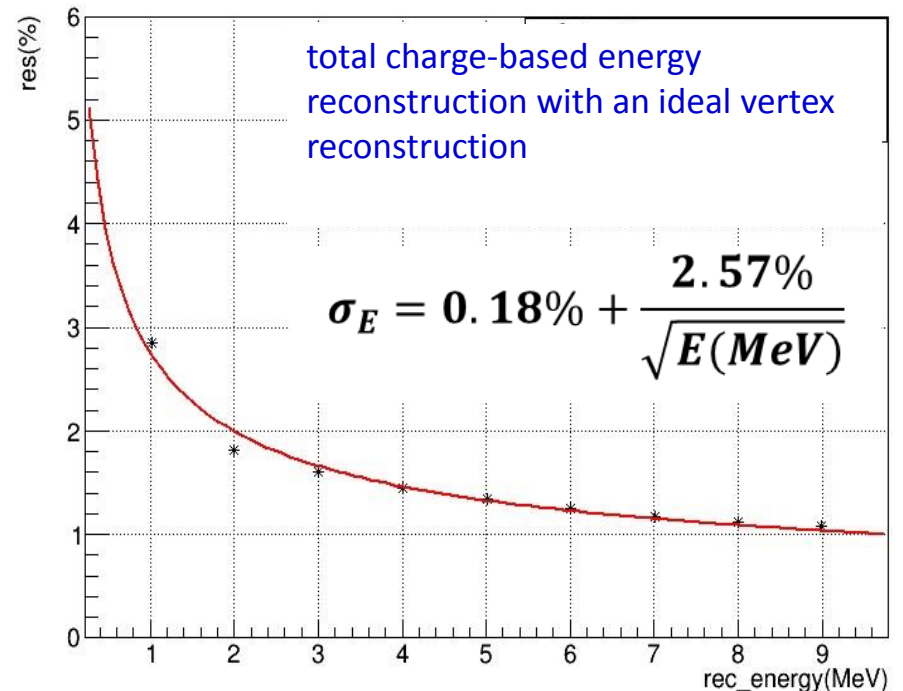
Profile of totalPE versus r^3



Profile of totalPE versus r^3

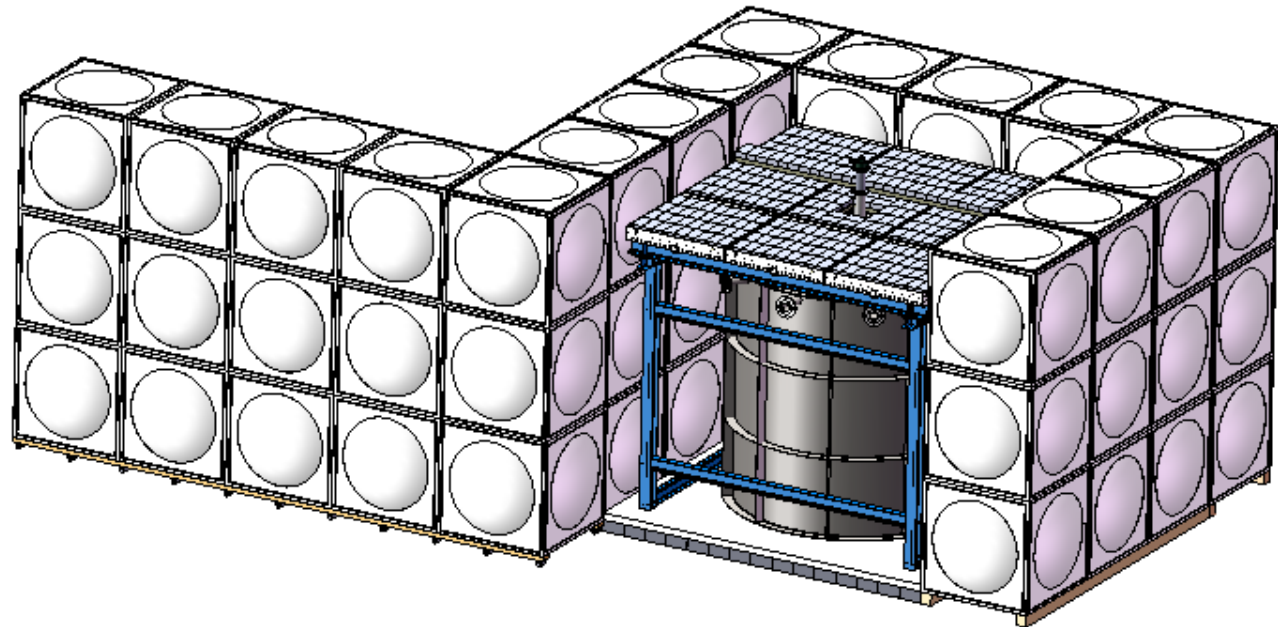
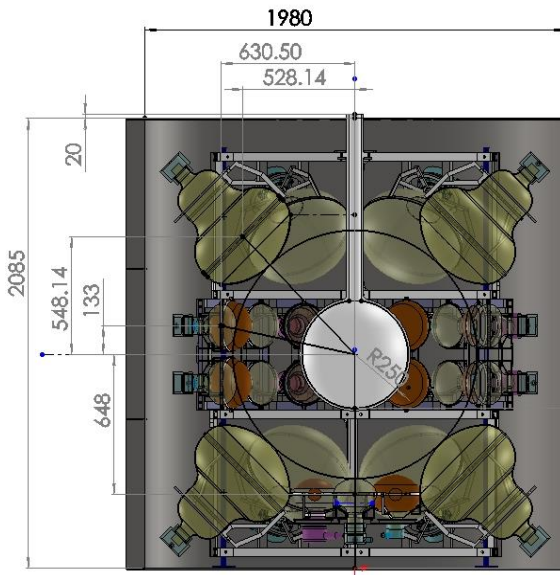


energy resolution vs rec_energy

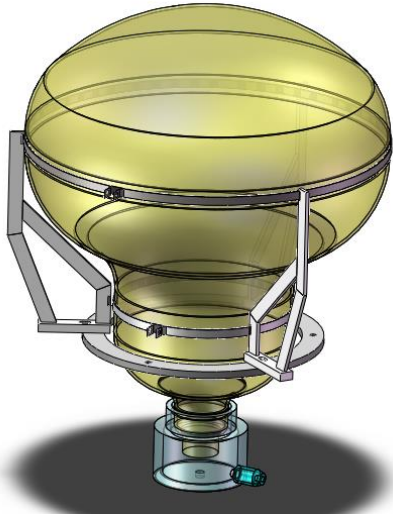


JUNO Detector Prototype

- 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 i



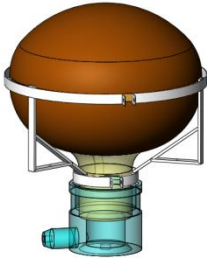
PMTs



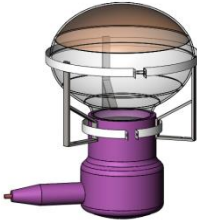
H 20"



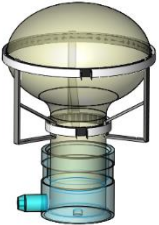
MCP 20"



HZC 9"



H 8"



MCP 8"



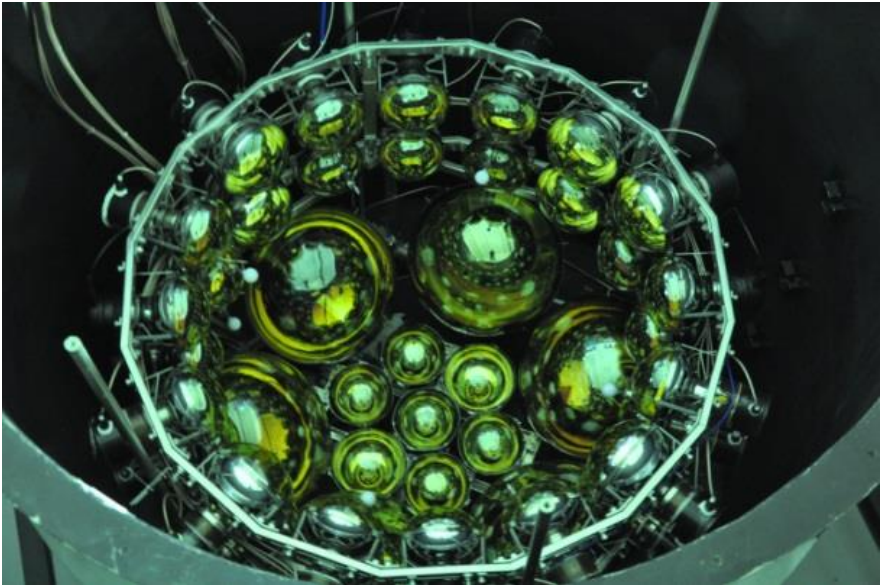
Dynode-PMT- 20"

MCP-PMT- 20"

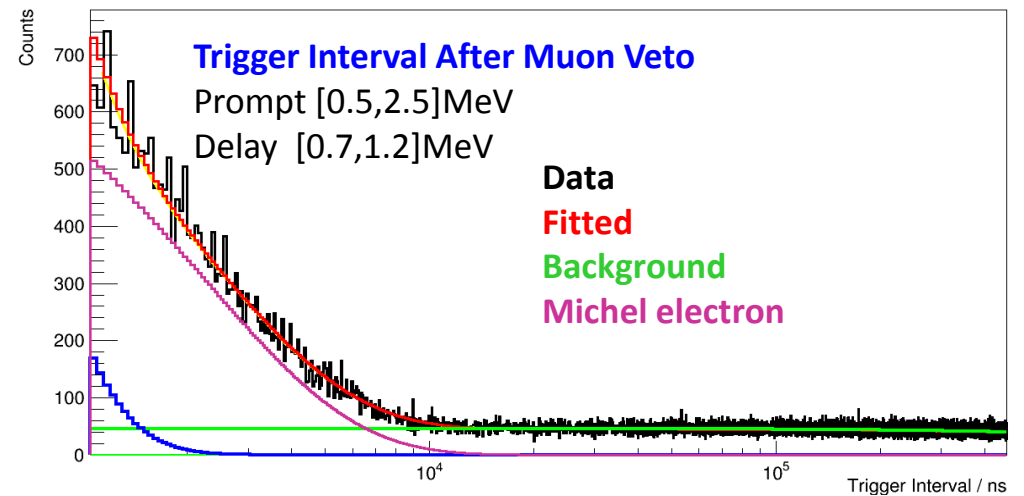
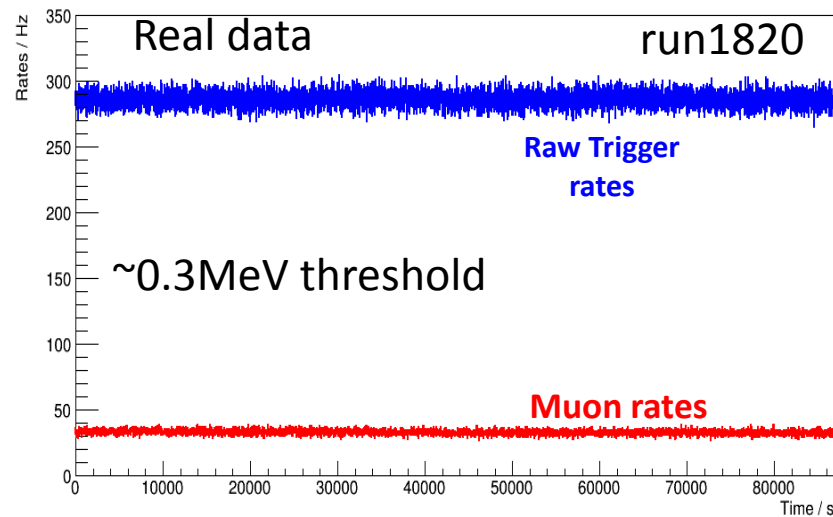
MCP-PMT- 8"

Dynode-PMT- 9"

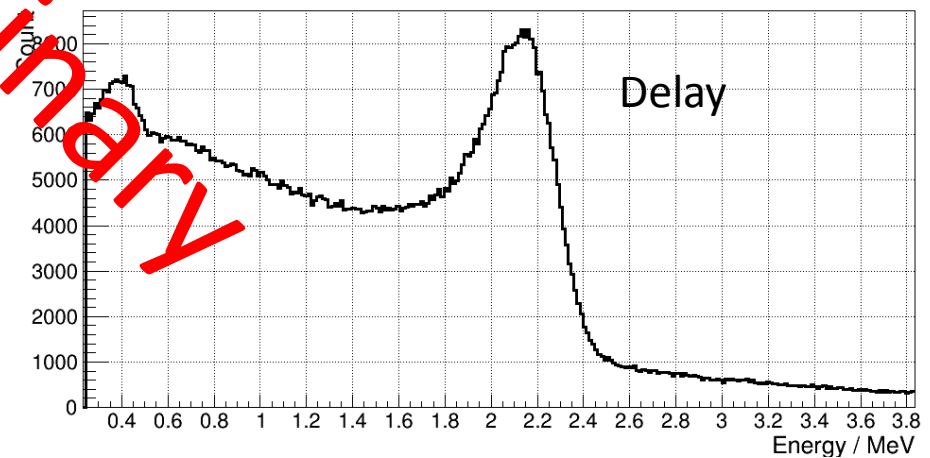
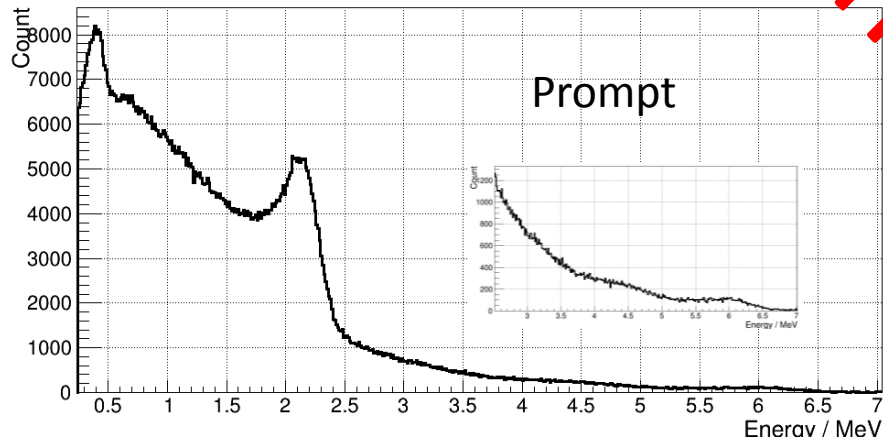
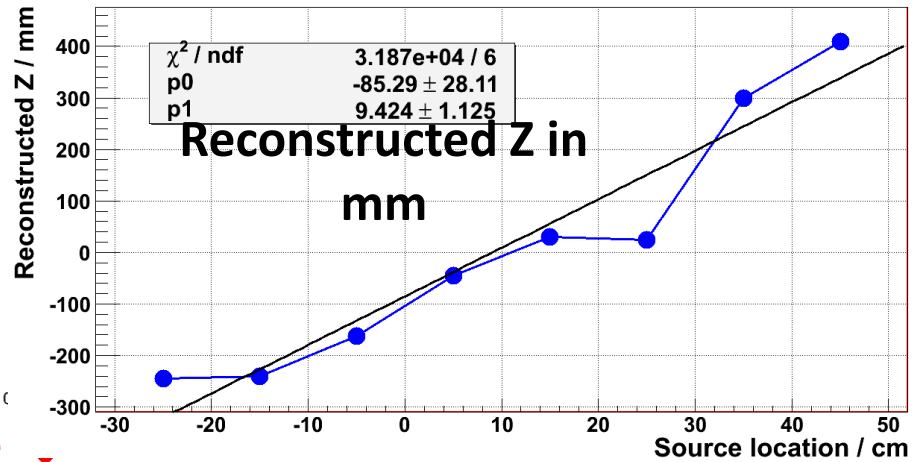
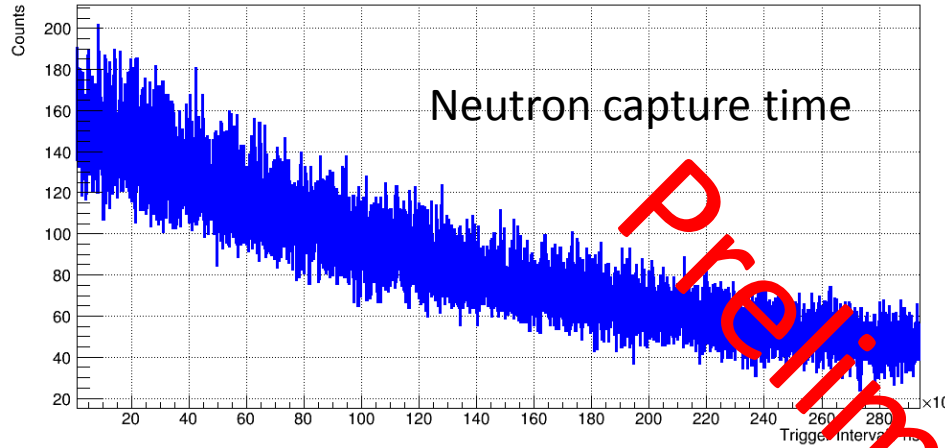
Dynode-PMT- 8"



Data taking



PuC neutron source



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

Summary

- JUNO central detector Principle designed, calculated by simulation for response, background, reconstruction, etc.
- PMT system R&D going on
- Prototype testing for PMT, potting, LS, electronics, analysis etc. going well.



JUNO Collaboration

July, 2016

Country	Institute	Country	Institute
China	Xiamen University	China	NUDT
Armenia	Yerevan Physics Institute	Czech	Charles U.
Belgium	Universite libre de Bruxelles	Finland	University of Oulu
Brazil	PUC	France	APC Paris
Brazil	UEL	France	CPPM Marseille
Chile	PCUC	France	IPHC Strasbourg
Chile	BISEE	France	LLR Palaiseau
China	Beijing Normal U.	France	Subatech Nantes
China	CAGS	Germany	Forschungszentrum Jülich
China	ChongQing University	Germany	RWTH Aachen U.
China	CIAE	Germany	TUM
China	DGUT	Germany	U. Hamburg
China	ECUST	Germany	IKP FZI Jülich
China	Guangxi U.	Germany	U. Mainz
China	Harbin Institute of Technology	Germany	U. Tuebingen
China	IHEP	Italy	INFN Catania
China	Jilin U.	Italy	INFN di Frascati
China	Jinan U.	Italy	INFN-Ferrara
China	Nanjing U.	Italy	INFN-Milano
China	Nankai U.	Italy	INFN-Milano Bicocca
China	NCEPU	Italy	INFN-Padova
China	Pekin U.	Italy	INFN-Perugia
China	Shandong U.	Italy	INFN-Roma 3
China	Shanghai JT U.	Pakistan	PINSTECH
China	IMP-CAS	Russia	INR Moscow
China	SYSU	Russia	JINR
China	Tsinghua U.	Russia	MSU
China	UCAS	Taiwan	National Chiao-Tung U.
China	USTC	Taiwan	National Taiwan U.
China	U. of South China	Taiwan	National United U.
China	Wu Yi U.	Thailand	SUT
China	Wuhan U.	USA	UMD1
China	Xi'an JT U.	USA	UMD2 Beijing, July 2016

= **66 members**
+ 8 Observers

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8. Institute of Electronics and Computer Science, (Riga, Latvia)

***Thanks for your
attention!***