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Gặp gỡ khoa học tại Việt Nam lần thứ 13

Flavour Physics Conference

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Status of JUNO

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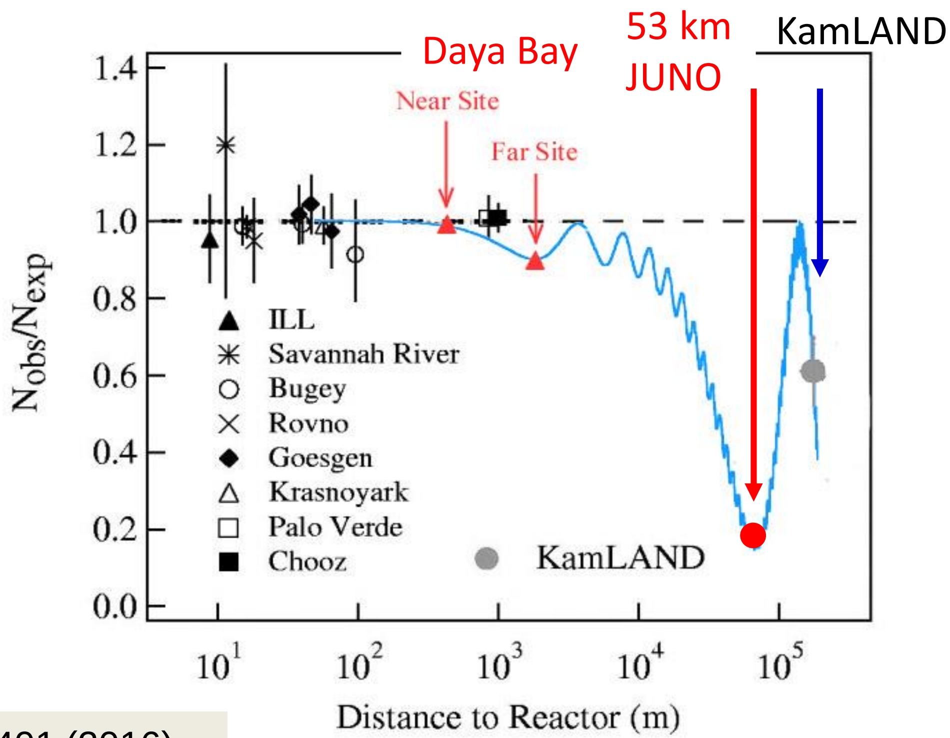
On behalf of the JUNO Collaboration

A multi-purpose neutrino experiment

- **Jiangmen Underground Neutrino Observatory**
- 27-36 GW reactor power, 20 kton LS detector, 3%/√E energy resolution
- Proposed in 2008, approved in 2013

- Rich physics possibilities
  - **Mass hierarchy**
  - **Precision measurement of 3 mixing parameters**
  - Supernovae neutrino
  - Geoneutrino
  - Solar neutrino
  - Atmospheric neutrino
  - Exotic searches including nucleon decay, dark matter

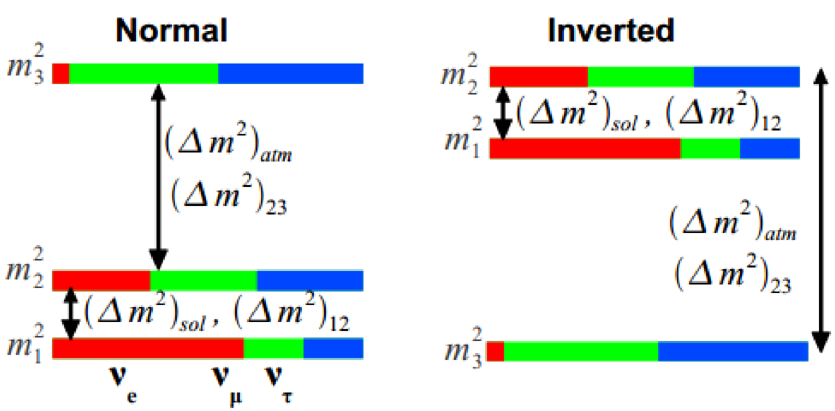


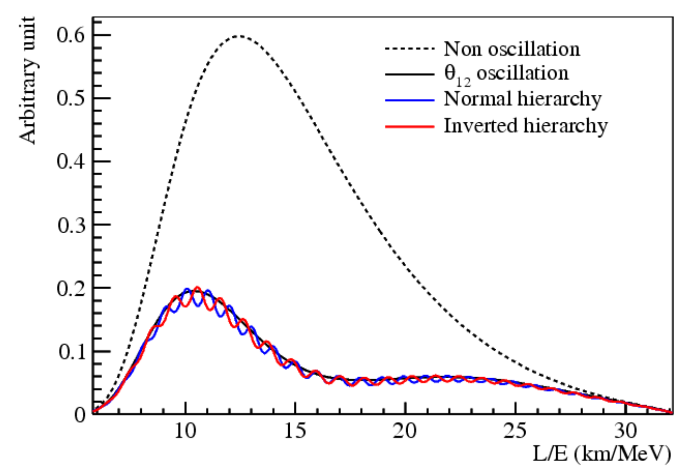
Neutrino Physics with JUNO, J. Phys. G 43, 030401 (2016)

Neutrino Mass Hierarchy

- Large θ_{13} opens a door to neutrino MH and CP violating phase, as the focus of next generation neutrino experiments.
- MH can be determined utilizing
  - Matter effects of accelerator (DUNE, LBNO) and atmospheric (PINGU, HK, INO) neutrinos
  - Oscillation interference effects of reactor neutrinos driven by Δm^2_{32} and Δm^2_{31}

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

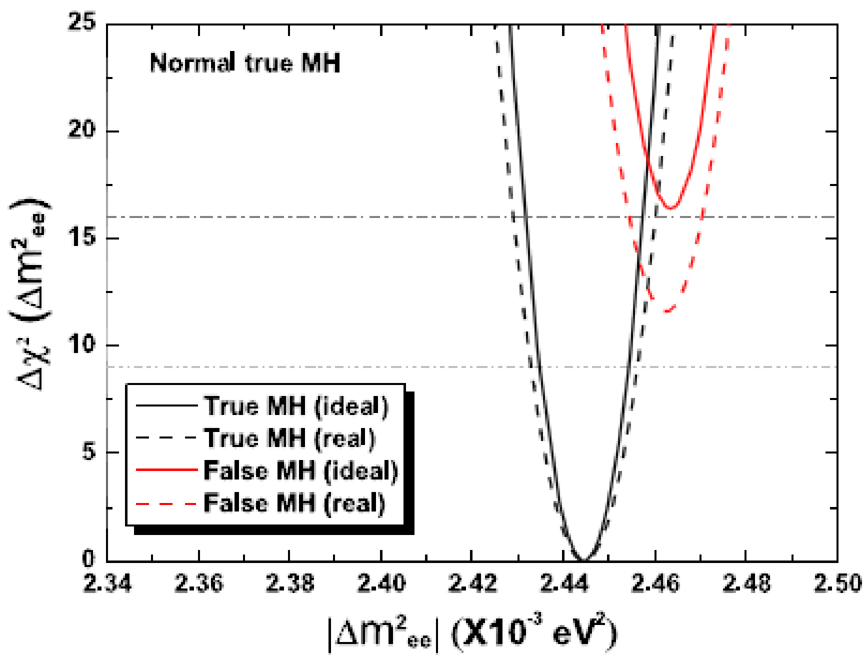




Sensitivity of MH Determination

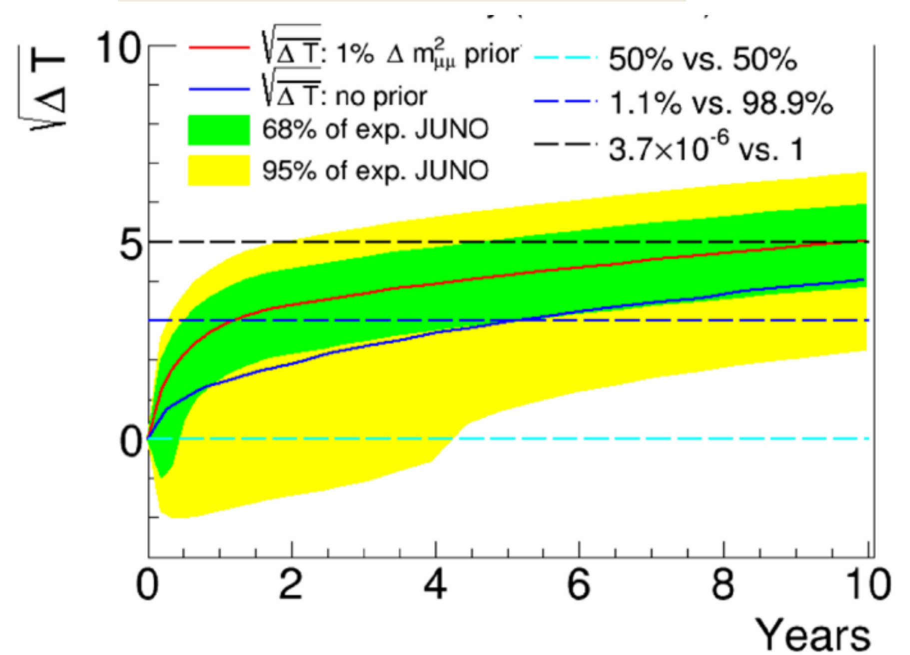
Assume NH as true MH, and fit the spectrum with false and true MH cases respectively, and we get
$\Delta\chi^2 = \chi^2(\text{false}) - \chi^2(\text{true})$

$$\chi^2_{\rm REA} = \sum_{i=1}^{N_{\rm bin}} \frac{\left[M_i - T_i\left(1 + \sum_k \alpha_{ik}\,\epsilon_k\right)\right]^2}{M_i} + \sum_k \frac{\epsilon_k^2}{\sigma_k^2},$$



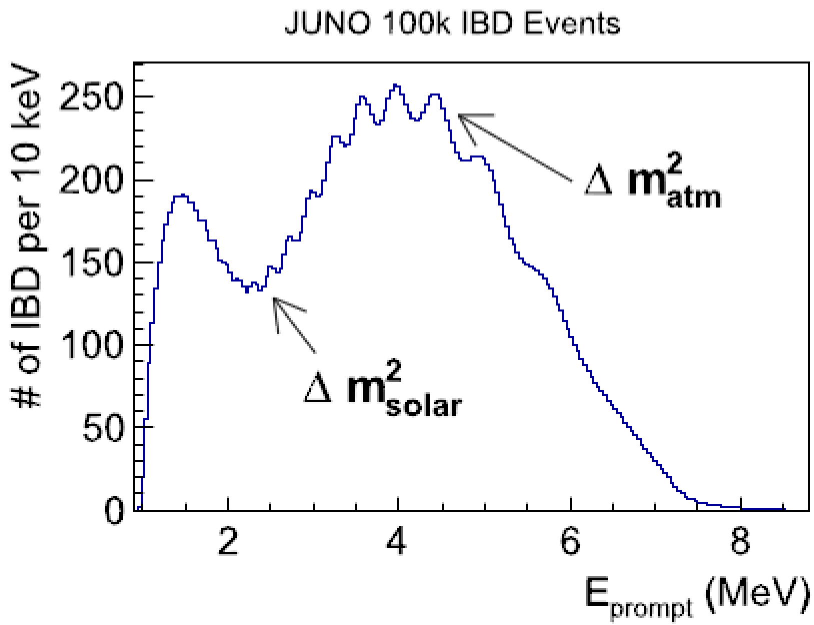
Nominal experimental setup
- Detector size: 20kt
- Energy resolution: 3%/√E
- Thermal power: 36 GW
- Running time: 6 years

Sensitivity vs. running time



Measurement of Oscillation Parameters

- Good energy resolution and proper baseline help to measure the Δm^2_{21} and Δm^2_{32} driven oscillations simultaneously.
- Precisions of three parameters (Δm^2_{21}, Δm^2_{32} and $\sin^2\theta_{12}$) reach sub-percent level, several times improvement compared with current precision.
- Probing the unitarity of U_{PMNS} to ~1% level



	Nominal	+B2B (1%)	+BG	+EL (1%)	+NL (1%)
$\sin^2\theta_{12}$	0.54%	0.60%	0.62%	0.64%	0.67%
Δm^2_{21}	0.24%	0.27%	0.29%	0.44%	0.59%
$\lvert\Delta m^2_{ee}\rvert$	0.27%	0.31%	0.31%	0.35%	0.44%

Other Physics Potentials

- Supernova neutrinos
  - Less than 20 events observed so far
  - Estimated number of neutrino events in JUNO at distance of 10 kpc and typical SN parameters

Channel	Type	Events for different $\langle E_\nu \rangle$ values		
		12 MeV	14 MeV	16 MeV
$\overline{\nu}_e + p \to e^+ + n$	CC	4.3×10^3	5.0×10^3	5.7×10^3
$\nu + p \to \nu + p$	NC	6.0×10^2	1.2×10^3	2.0×10^3
$\nu + e \to \nu + e$	NC	3.6×10^2	3.6×10^2	3.6×10^2
$\nu + {}^{12}\mathrm{C} \to \nu + {}^{12}\mathrm{C}^*$	NC	1.7×10^2	3.2×10^2	5.2×10^2
$\nu_e + {}^{12}\mathrm{C} \to e^- + {}^{12}\mathrm{N}$	CC	4.7×10^1	9.4×10^1	1.6×10^2
$\overline{\nu}_e + {}^{12}\mathrm{C} \to e^+ + {}^{12}\mathrm{B}$	CC	6.0×10^1	1.1×10^2	1.6×10^2

For JUNO:
Good energy resolution, all types of neutrinos

- Geoneutrinos
  - Current results: KamLAND: 164±27 (talk at Neutrino Research and Thermal Evolution of the Earth), Borexino: 23.7±6 (PRD 92 (2015) 031101(R))
  - JUNO, X10 statistics, but huge reactor antineutrino background
- Solar neutrinos, atmosphere neutrinos, nucleon decay, sterile neutrinos

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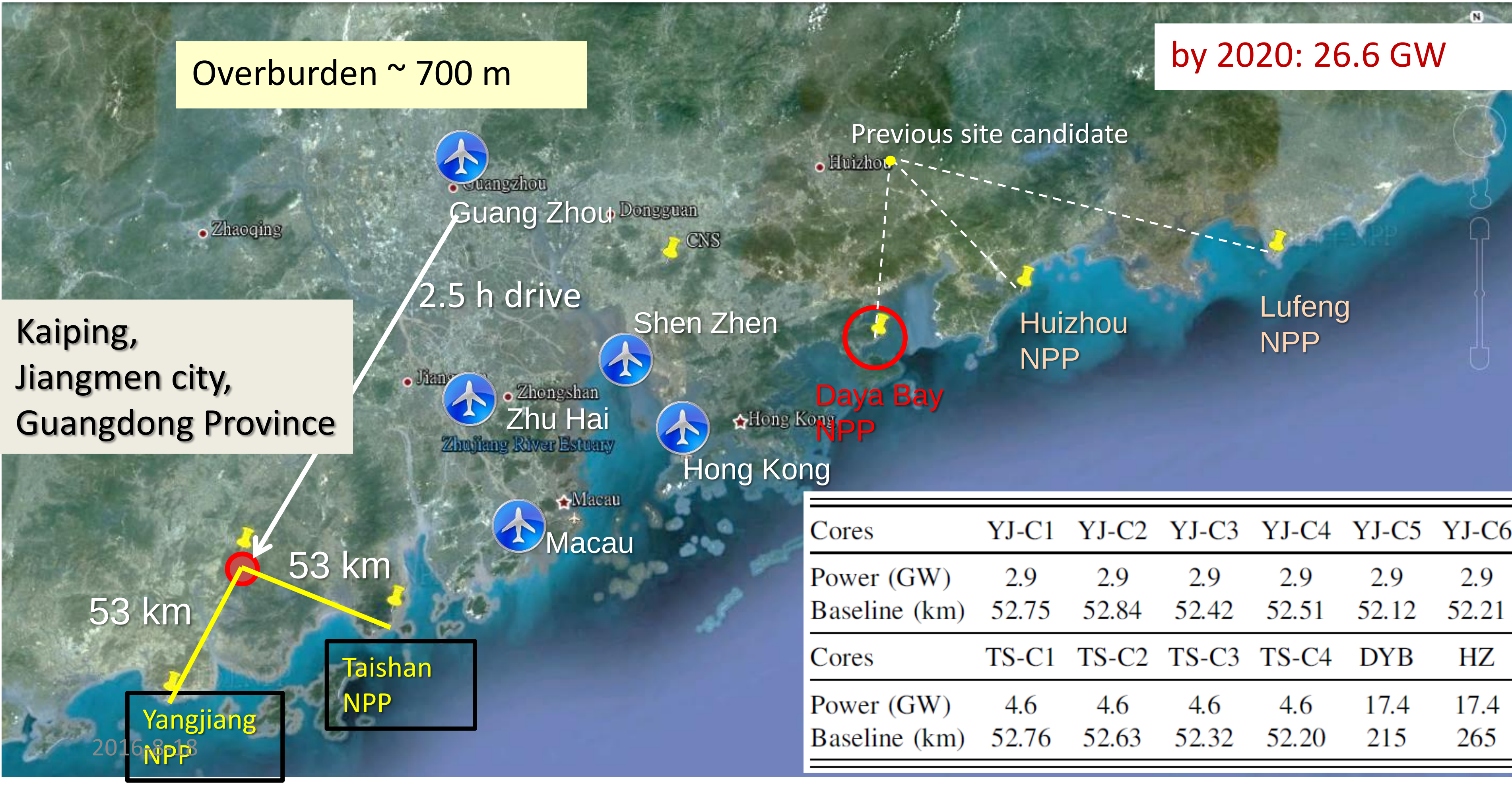
Location of JUNO

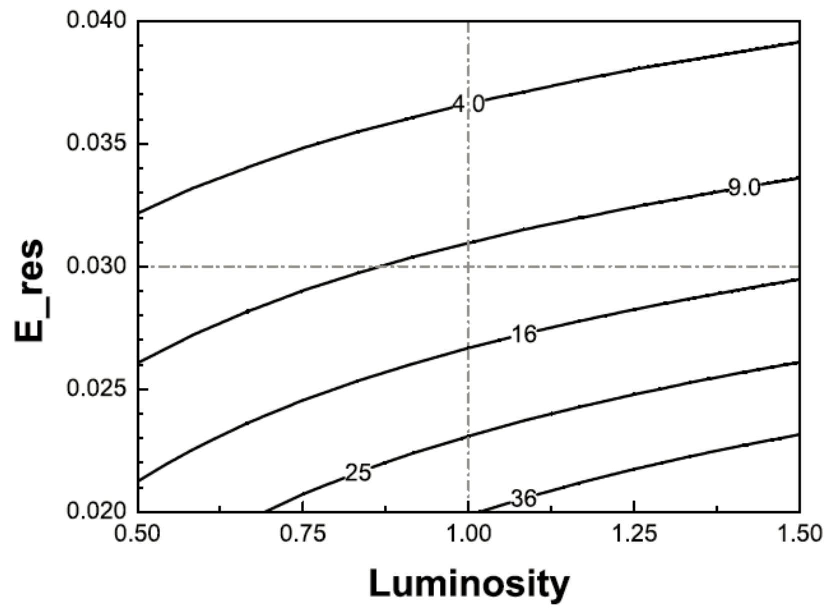
NPP	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	18.4 GW



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

Requirements on JUNO experiment

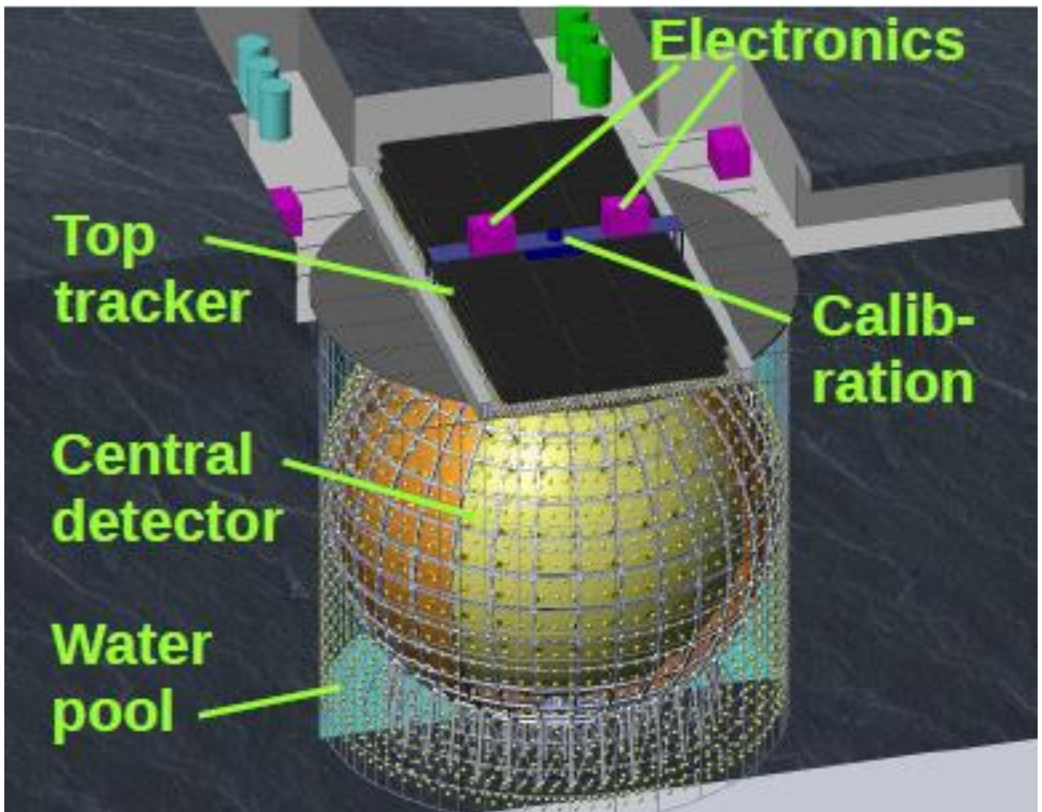
- 20 kton and 6 years data taking ➔ 100000 antineutrino events.
- 3%/√E energy resolution➔ precise measurement of oscillation antineutrino spectrum (~1200 p.e./MeV)



Experiment	Daya Bay	BOREXINO	KamLAND	JUNO
LS mass	20 ton	~300 ton	~1 kton	20 kton
Coverage	~12%	~34%	~34%	~80%
Energy resolution	~7.5%/√E	~5%/√E	~6%/√E	~3%/√E
Light yield	~ 160 p.e. / MeV	~ 500 p.e. / MeV	~ 250 p.e. / MeV	~ 1200 p.e. / MeV

JUNO detector

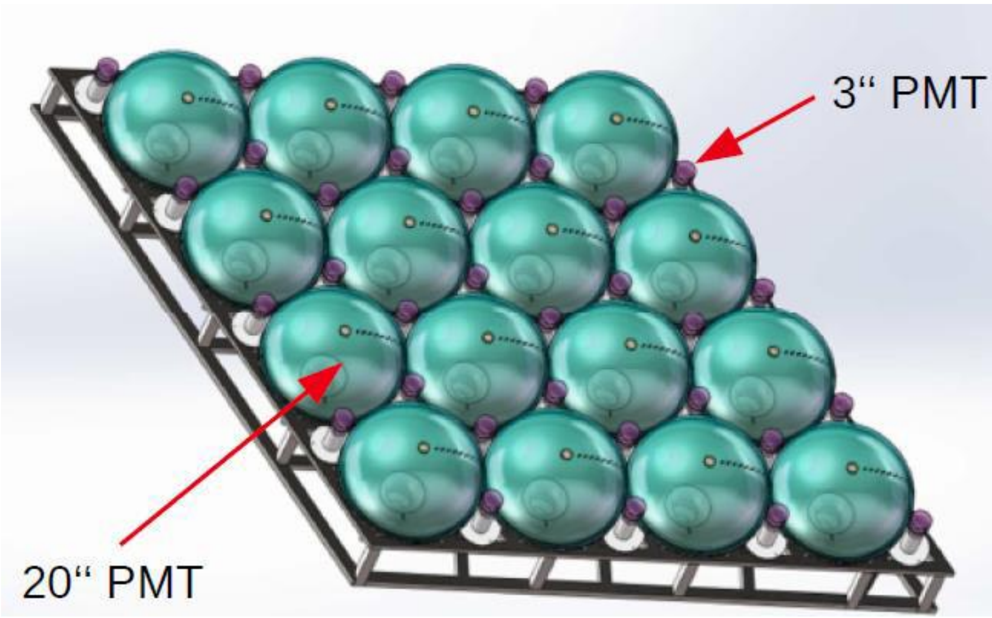
- 20 kton of liquid scintillator in a 35.4 m acrylic sphere
- 18000 20’’ PMT and 25000 3’’ PMT to detect photons with a coverage of ~78%



- Top tracker: plastic scintillator
- Water pool: Cherenkov veto, 44 m deep and 43.5 m high

- Design goals: large target mass with an unprecedented energy resolution (3%/√E)

JUNO PMT systems

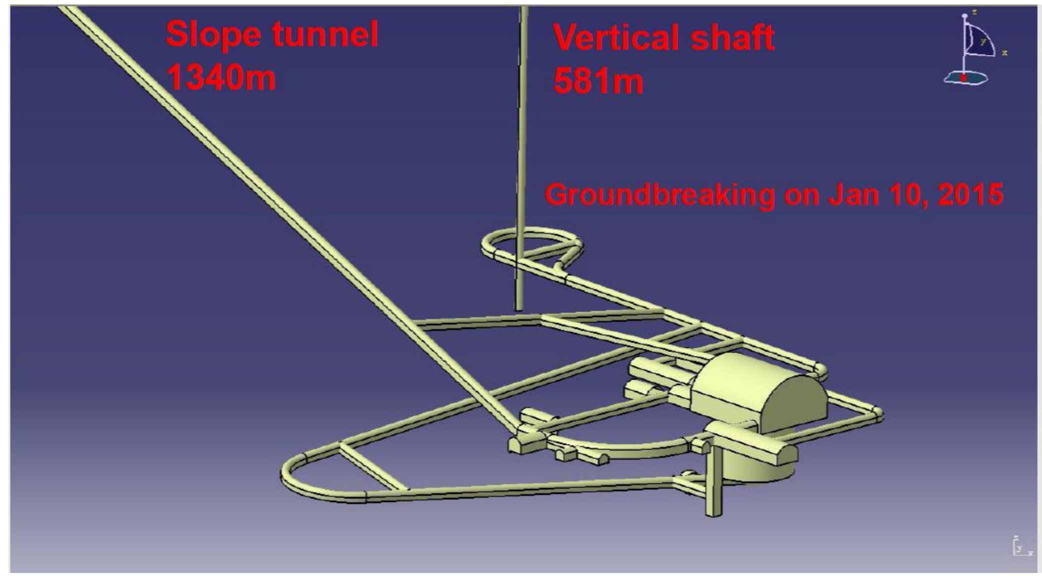


- Design goals: 1200 p.e./MeV
- Requirements
  - High coverage
  - High photon detection efficiency
  - Acceptable dark noise and radioactivity level

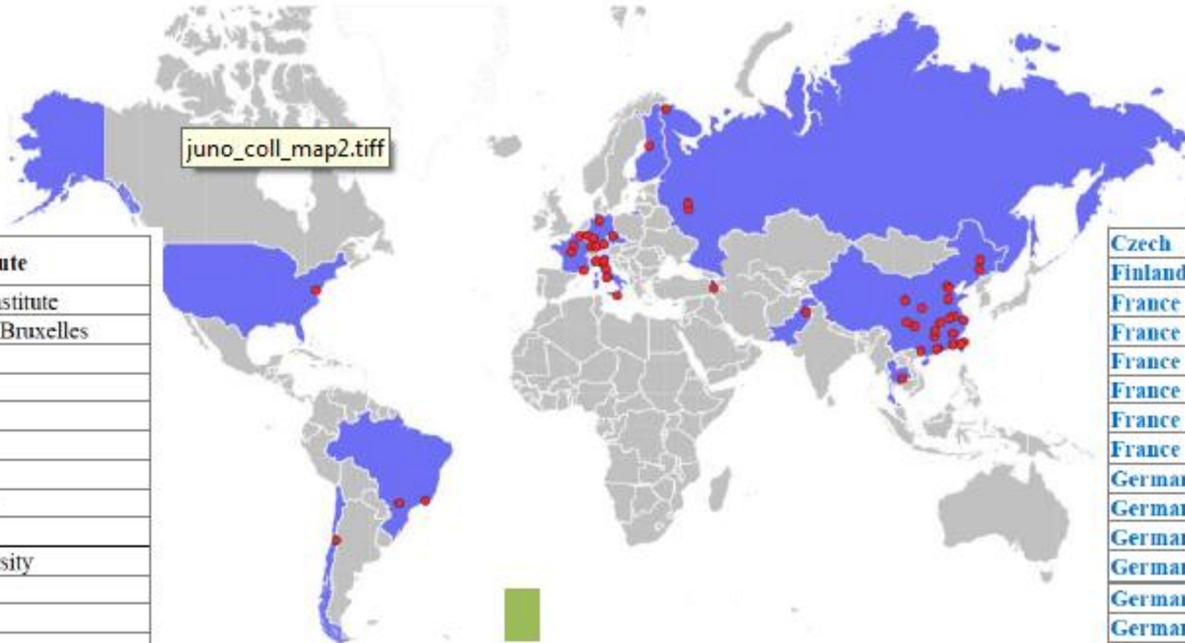
- Double calorimetry PMT systems
  - 18000 20" PMTs: 75% coverage, good energy resolution
  - 25000 3" PMTs: 2.5% coverage, good timing

JUNO civil construction

- Experiment hall overburden: ~700 m (~1900 MWE)
- Vertical shaft and slope tunnel accomplished



JUNO collaboration



Country	Institute
Armenia	Yerevan Physics Institute
Belgium	Universite libre de Bruxelles
Brazil	PUC
Brazil	UEL
Chile	PCUC
Chile	USM
China	BISEE
China	Beijing Normal U.
China	CAGS
China	ChongQing University
China	CIAE
China	DGUT
China	ECUST
China	Guangxi U.
China	Harbin Institute of Technology
China	IHEP
China	Jilin U.
China	Jinan U.
China	Nanjing U.
China	Nankai U.
China	NCEPU
China	Pekin U.
China	Shandong U.
China	Shanghai JT U.
China	IMP-CAS
China	SYSU
China	Tsinghua U.
China	UCAS
China	USTC
China	U. of South China
China	Wu Yi U.
China	Wuhan U.
China	Xi'an JT U.
China	Xiamen University
China	NUDT

Established in July 2014
71 institutions/Universities
571 collaborators

Czech	Charles U.
Finland	University of Oulu
France	APC Paris
France	CENBG Bordeaux
France	CPPM Marseille
France	IPHC Strasbourg
France	LLR Palaiseau
France	Subatech Nantes
Germany	FZJ ZEA2
Germany	RWTH Aachen U.
Germany	TUM
Germany	U. Hamburg
Germany	IKP FZJ
Germany	U. Mainz
Germany	U. Tuebingen
Italy	INFN Catania
Italy	INFN di Frascati
Italy	INFN-Ferrara
Italy	INFN-Milano
Italy	INFN-Milano Bicocca
Italy	INFN-Padova
Italy	INFN-Perugia
Italy	INFN-Roma 3
Pakistan	PINSTECH (PAEC)
Russia	INR Moscow
Russia	JINR
Russia	MSU
Slovakia	FMPICU
Taiwan	National Chiao-Tung U.
Taiwan	National Taiwan U.
Taiwan	National United U.
Thailand	NARIT
Thailand	PPRLCU
Thailand	SUT
USA	UMD1
USA	UMD2

JUNO schedule

2013	2014	2015	2016	2017	2018	2019	2020
Complete conceptual design. Complete civil design and bidding	Start civil construction. Complete prototyping (PMT & detector). International collaboration established	PMT production line manufacturing	Start PMT production. Start detector production or bidding	Complete civil construction. Start detector construction and assembly	Start LS production	Complete detector assembly, installation and LS filling	Start data taking

Summary

- JUNO has rich physics possibilities with the main goals to determine mass hierarchy and precisely measure oscillation parameters.

- JUNO experiment is under construction and is expected to start data taking in 2020.

Thanks!