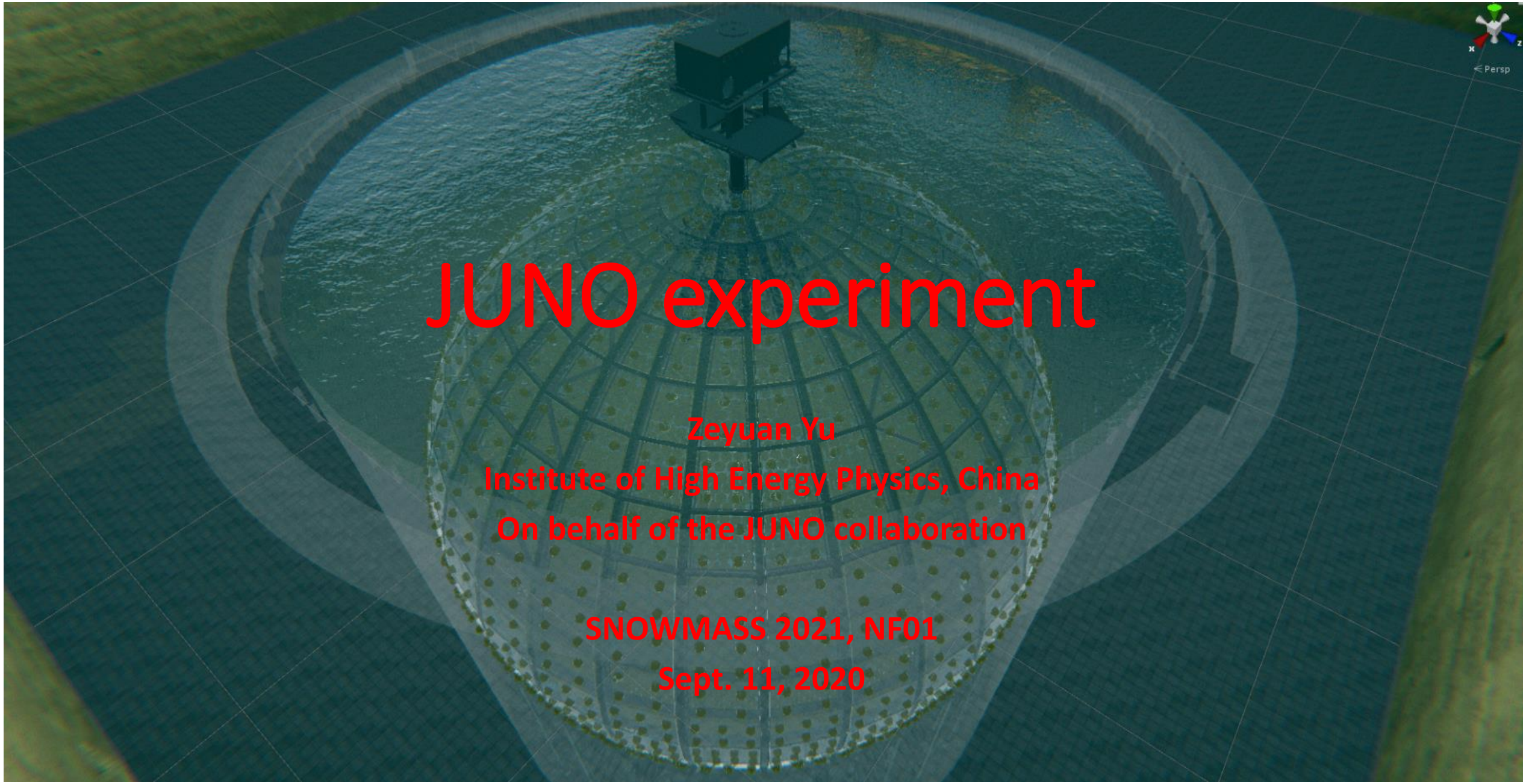


JUNO experiment

Zeyuan Yu
Institute of High Energy Physics, China
On behalf of the JUNO collaboration

SNOWMASS 2021, NF01

Sept. 11, 2020

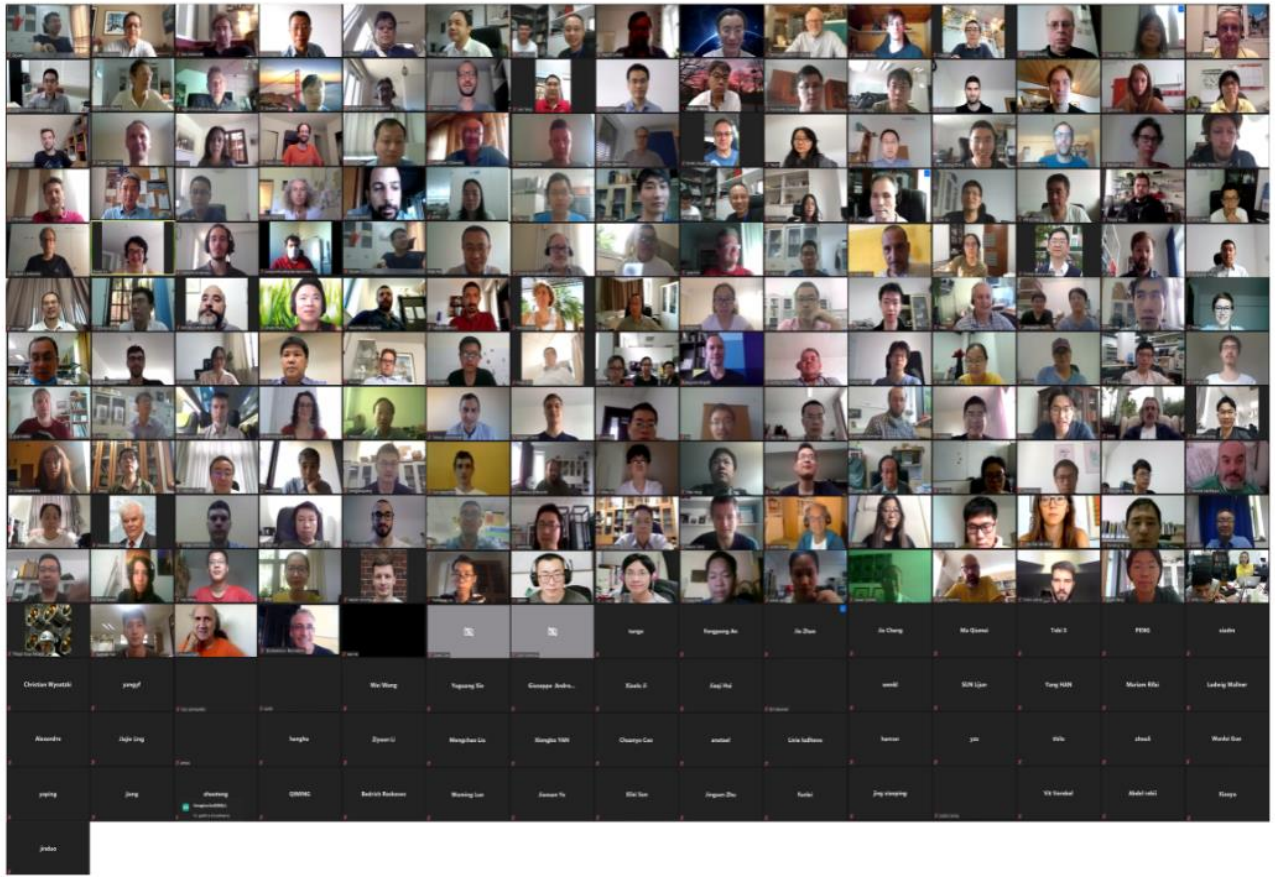
The JUNO collaboration

77 institutes
669 members

Country	Institute	Country	Institute
Armenia	Yerevan Physics Institute	China	IMP-CAS
Belgium	Universite libre de Bruxelles	China	SYSU
Brazil	PUC	China	Tsinghua U.
Brazil	UEL	China	UCAS
Chile	PCUC	China	USTC
Chile	UTFSM	China	U. of South China
China	BISEE	China	Wu Yi U.
China	Beijing Normal U.	China	Wuhan U.
China	CAGS	China	Xi'an JT U.
China	ChongQing University	China	Xiamen University
China	CIAE	China	Zhengzhou U.
China	DGUT	China	NUDT
China	ECUST	China	CUG-Beijing
China	Guangxi U.	China	ECUT-Nanchang City
China	Harbin Institute of Technology	Croatia	UZ/RBI
China	IHEP	Czech	Charles U.
China	Jilin U.	Finland	University of Jyvaskyla
China	Jinan U.	France	LAL Orsay
China	Nanjing U.	France	CENBG Bordeaux
China	Nankai U.	France	CPPM Marseille
China	NCEPU	France	IPHC Strasbourg
China	Pekin U.	France	Subatech Nantes
China	Shandong U.	Germany	FZJ-ZEA
China	Shanghai JT U.	Germany	RWTH Aachen U.
China	IGG-Beijing	Germany	TUM
China	IGG-Wuhan	Germany	U. Hamburg

The 16th JUNO Collaboration Meeting

July 8-10,2020,Online



JUNO LOIs

- JUNO
  - https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF1_NF4_Pedro_Ochoa-034.pdf
- JUNO-TAO
  - https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF9_NF7_Pedro_Ochoa-035.pdf
- JUNO-0νββ
  - https://www.snowmass21.org/docs/files/summaries/NF/SNOWMASS21-NF5_NF10_Pedro_Ochoa-125.pdf

The JUNO site

NPP	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operation	Planned	Planned	Operation	Operation
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	9.2 GW

A multipurpose observatory

Supernova ν's
~10^4 in 10 s
for 10 kpc

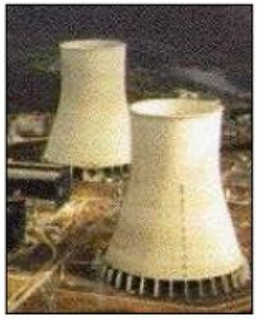
Atmospheric ν's
several/day

Solar ν's
(10-1000)/day

700 m

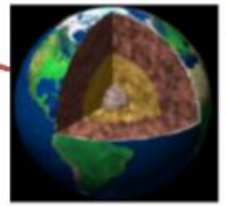
Cosmic muons
~ 250k/day

0.003 Hz/m^2, 215 GeV
10% multiple-muon



36 GWth, 53 km

reactor ν's
~ 80/day

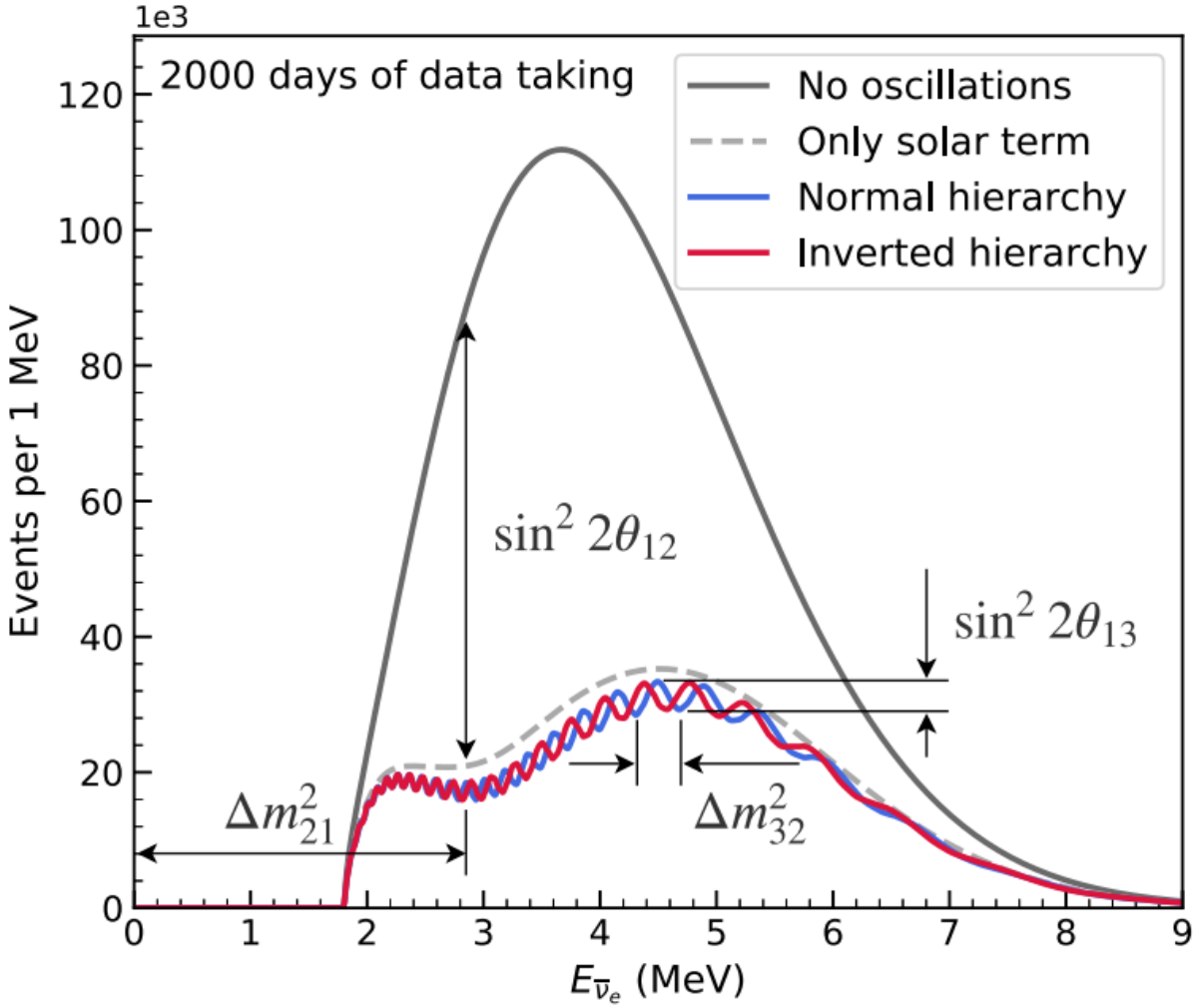


Geo-ν's
1-2/day

From J. Pedro Ochoa-Ricoux's Nufact 2019

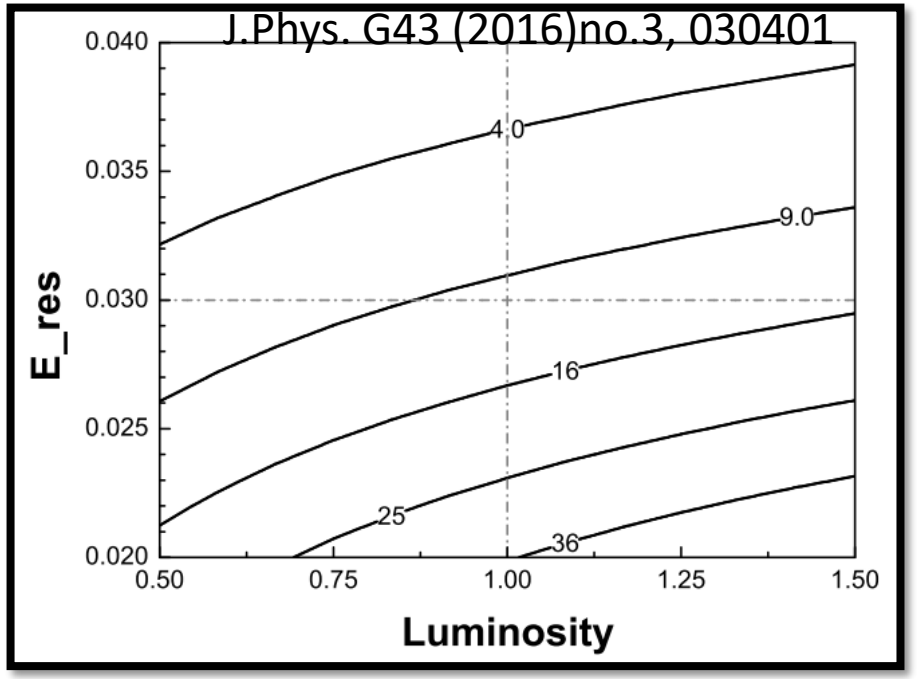
Reactor antineutrino disappearance

- Determine the neutrino mass ordering at ~3σ level with 6 years
  - Independent on δ_{CP} and $\sin^2\theta_{23}$
  - 4σ with constraints from long baseline accelerator experiments
- Significantly better than 1% precision for
  - $\mathrm{Sin}^2 2\theta_{12}$, Δm^2_{21}, and $|\Delta m^2_{32}|$



Neutrino mass ordering

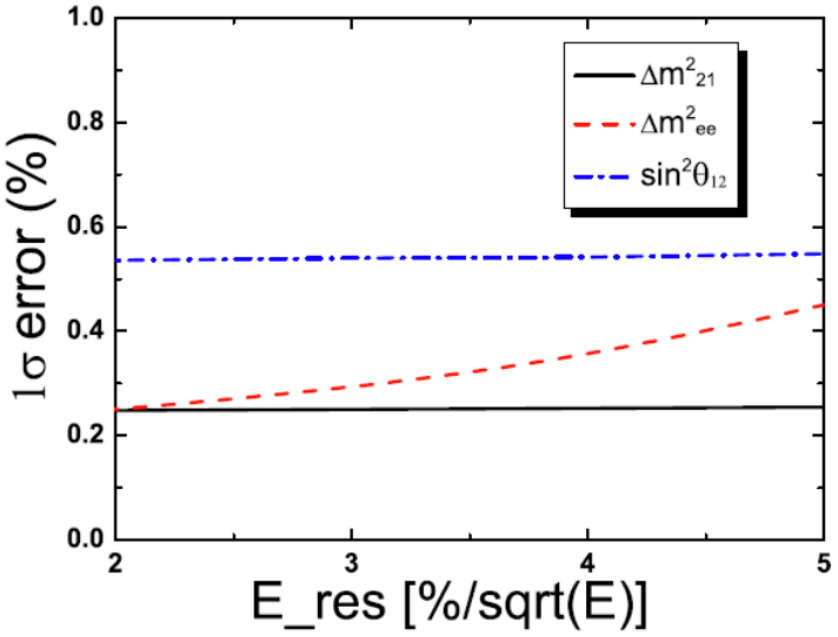
- Critical requirements
  - 3% energy resolution at 1 MeV
    - High light yield, large PMT coverage and efficiency
  - Energy scale uncertainty < 1%
    - Calibration strategy, double calorimetry, etc.
  - Reference spectrum with high energy resolution



	Stat.	Core distribution	DYB and HZ	Shape	Background	$\lvert\Delta^2_{\mu\mu}\rvert$
$\Delta\chi^2$	16	-3	-1.7	-1	-0.7	+8

Oscillation parameters

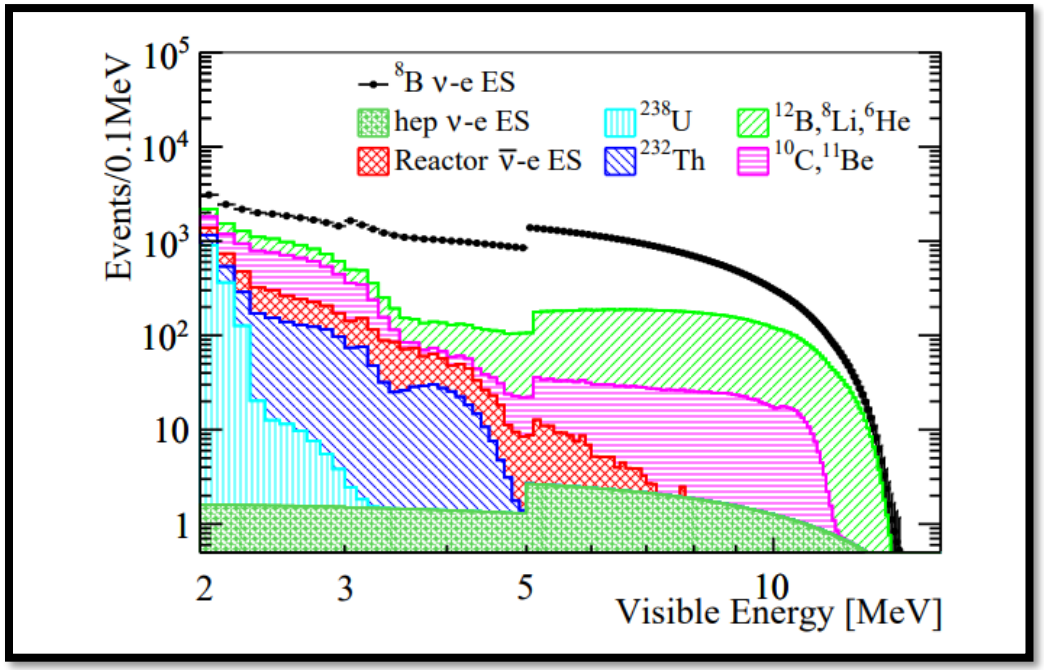
- With 6 years running, better than 1% precision is expected
- Essential to test the neutrino oscillation framework precisely
- An update of the precision measurement is under preparation

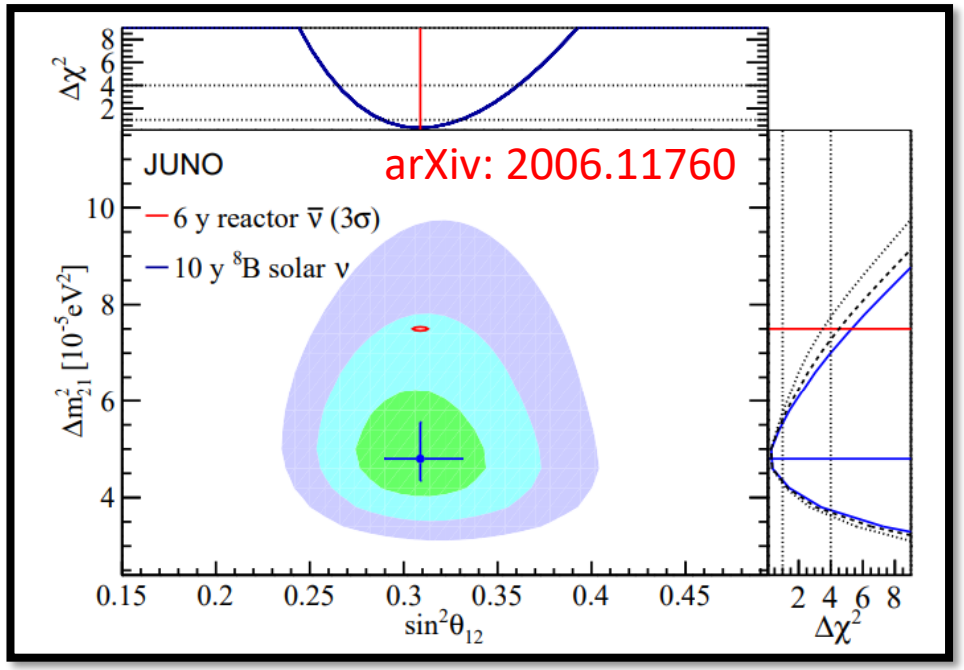


	Nominal	+ B2B (1%)	+ BG	+ EL (1%)	+ NL (1%)
$\sin^2\theta_{12}$	0.54%	0.60%	0.62%	0.64%	0.67%
Δm^2_{21}	0.24%	0.27%	0.29%	0.44%	0.59%
$\lvert\Delta m^2_{ee}\rvert$	0.27%	0.31%	0.31%	0.35%	0.44%

Oscillation parameters with solar ν

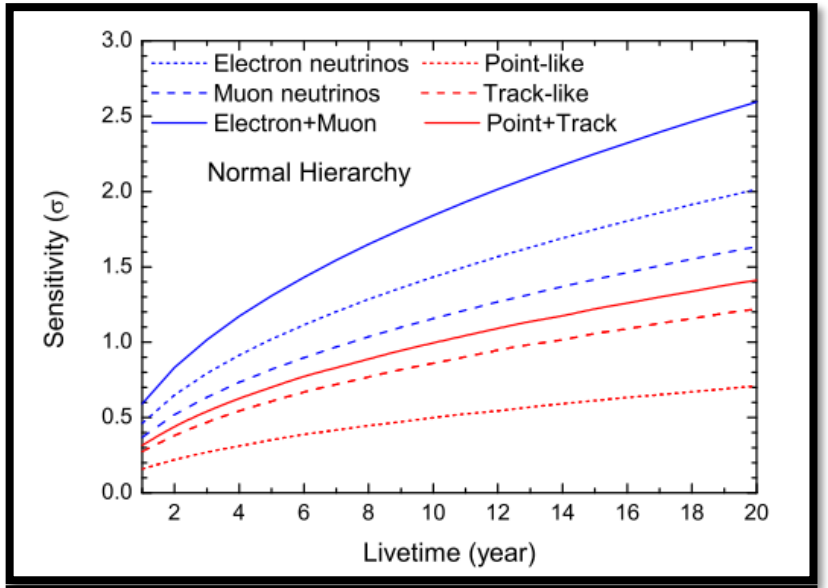
- Challenging measurement due to
  - Shallow overburden but new veto strategies
  - Higher requirement to intrinsic radiopurity (10^{-17} g/g U/Th) → 2 MeV threshold
- 60,000 ES signal and 30,000 background events in 10 years data taking
  - Solar oscillation parameters with solar ν_e and reactor $\bar{\nu}_e$ in the same detector

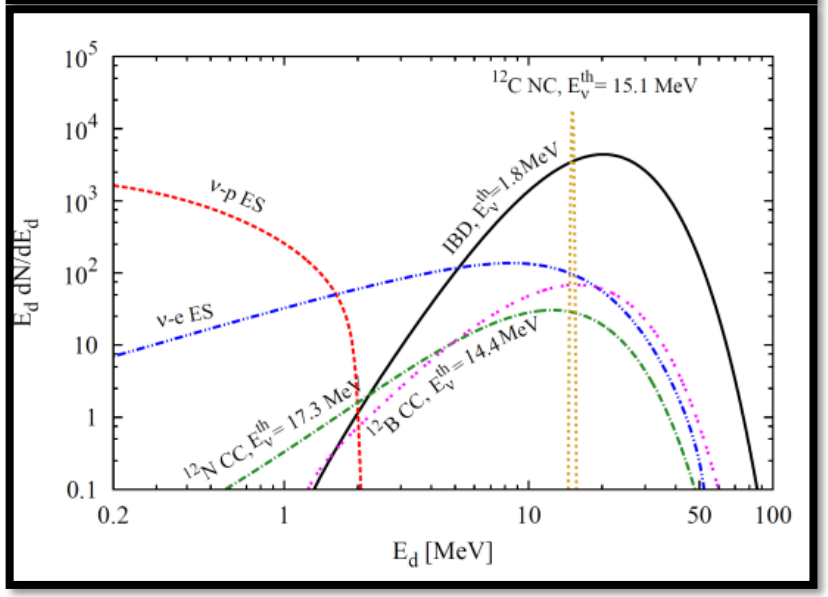




Other physics topics

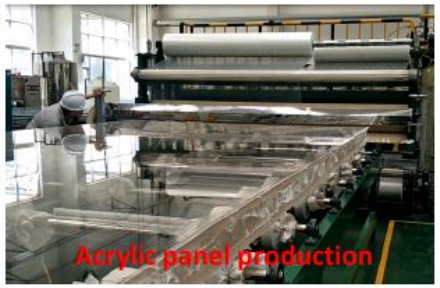
- Atmospheric neutrinos
  - Mass ordering sensitivity from MSW effect
- Diffuse Supernova Neutrino Background
  - Expected detection of ~3σ after 10 years
- Galactic core-collapse supernova neutrinos
  - Golden channel: IBD, ~5000 events for SN@10 kpc
- Geo-neutrinos
  - 400-500 neutrinos per year
  - Precision 6% in 10 years
- Proton decay

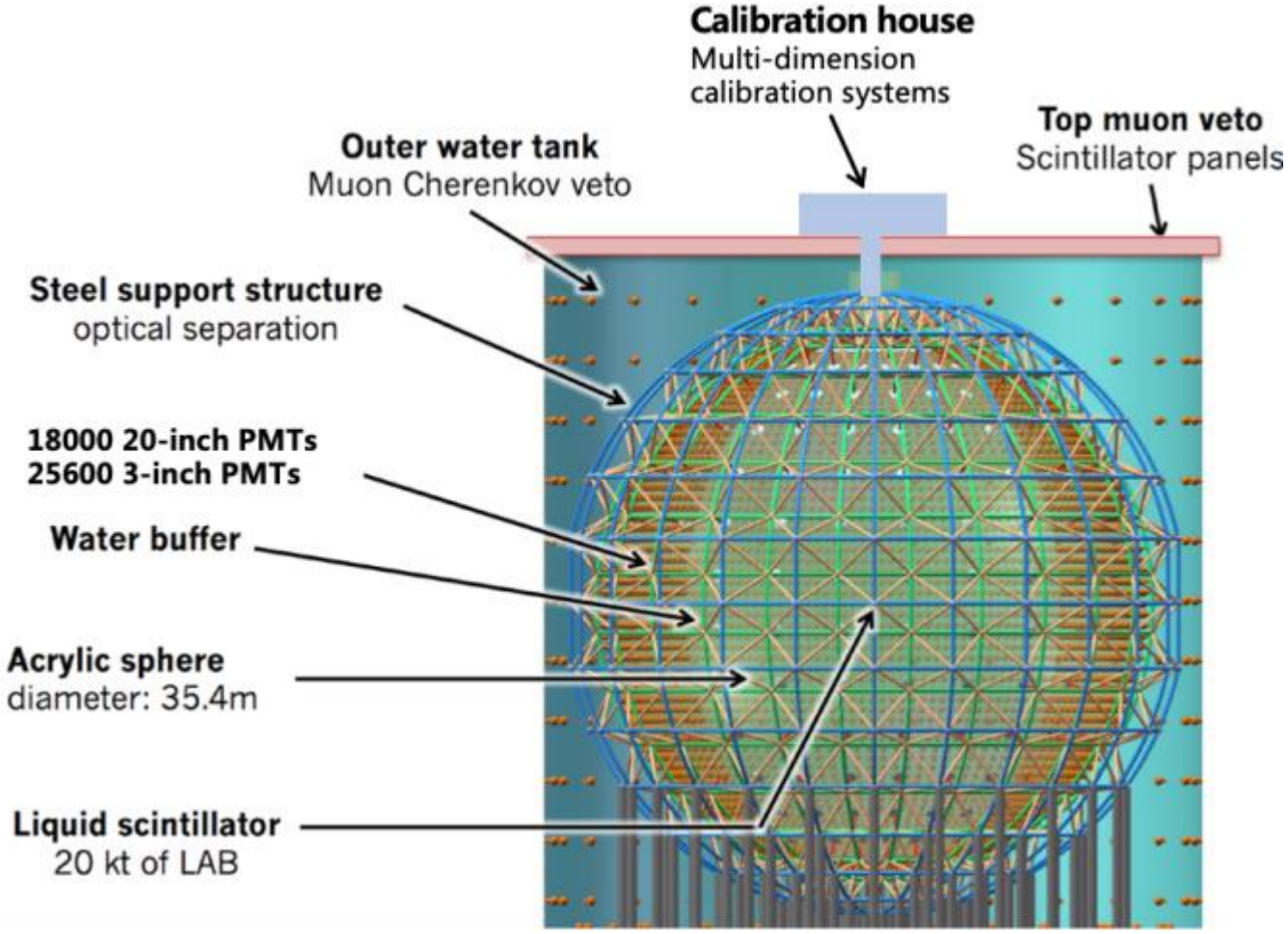




JUNO detector

- 35 m diameter acrylic sphere
- Stainless steel truss
- 20,000 tons purified liquid scintillator
- 18,000 20-inch PMTs
- 25,600 3-inch PMTs
- Filling/Overflow/Circulation (FOC) system





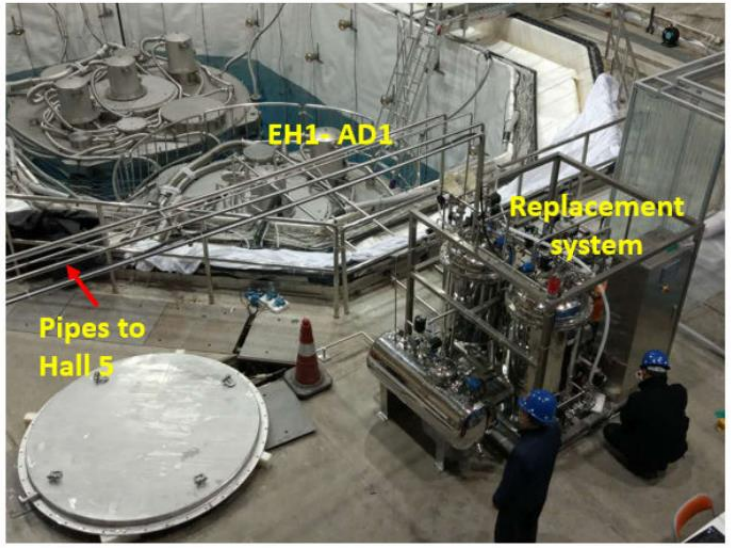
Liquid scintillator

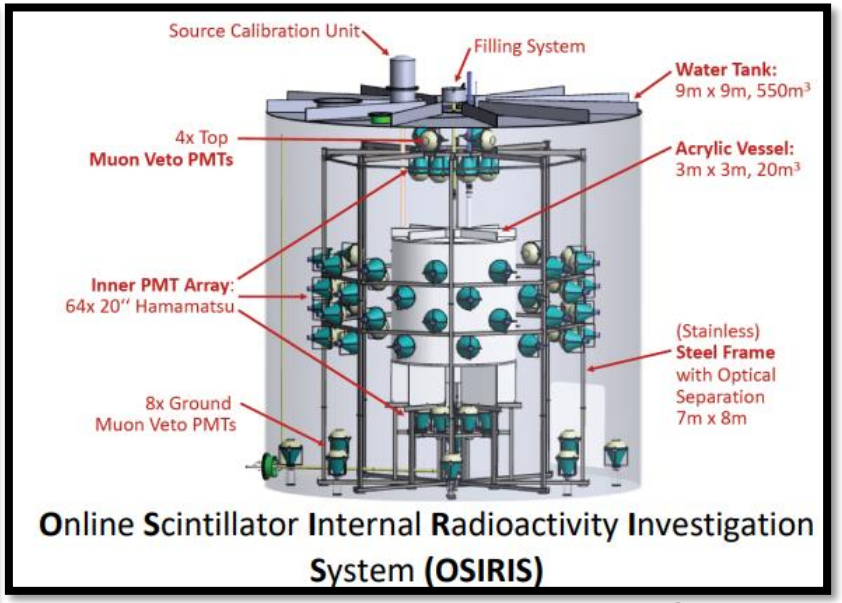
- Finished a pilot LS purification test at Daya Bay
- LS recipe: LAB + 2.5 g/L PPO + (1-4) mg/L bis-MSB
  - arXiv: 2007.00314
- Attenuation Length: > 20 m @430 nm

- Low radioactive backgrounds
  - 10^{-15} g/g U/Th for reactor antineutrinos
  - 10^{-17} g/g U/Th for solar neutrinos
  - An online radioactivity investigation system will be built

LS pilot plant at Hall 5

Experimental Hall 1



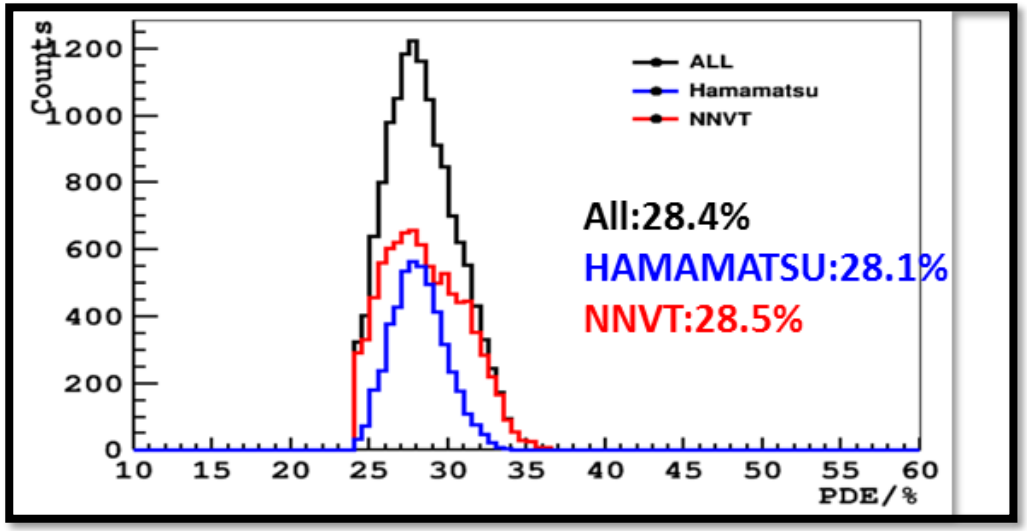


20-inch PMTs

- 20,000 20-inch PMTs in total
- Have received
  - 14000+ NNVT MCP-PMTs
  - 5000 Hamamatsu dynode PMTs

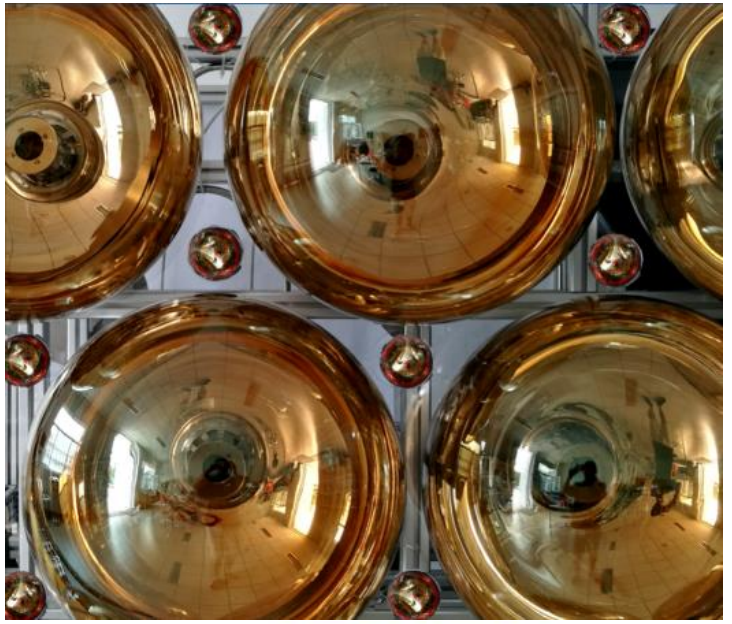
- PMT instrumentations
  - HV dividers mass production is ongoing
  - 7000 PMTs have been potted with multiple waterproof layers
  - Implosion protection covers were designed and produced

- Photon Detection Efficiency (PDE)
  - Required: 27%
  - Achieved: 28.4% in average



3-inch PMTs

- 25,600 3-inch HZC Photonics PMTs
  - Predominantly in photon-counting mode
- Look at the same events with two sets of "eyes" that have different systematics
- Other benefits
  - Standalone measurement of solar parameters
  - 3% more light
  - Muon track reconstruction
- All photomultipliers have been accepted

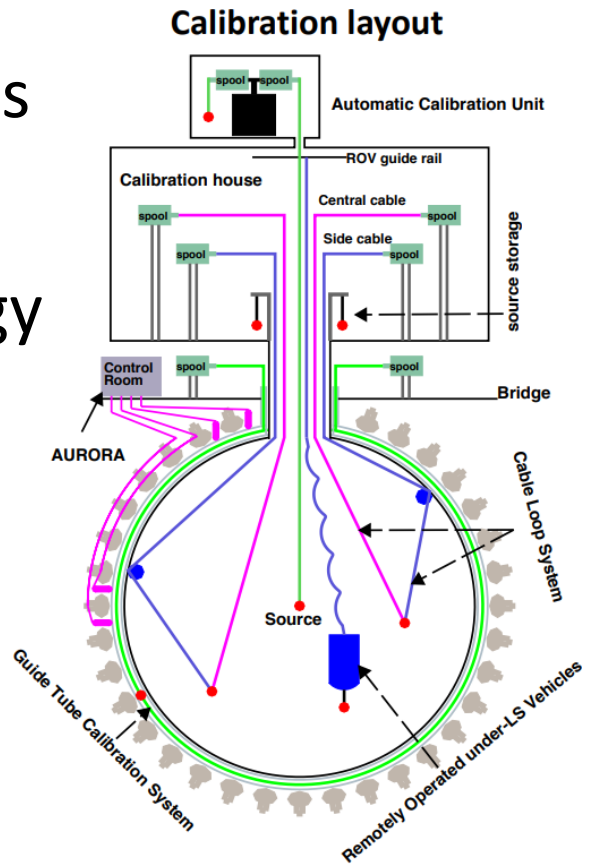


XP72B22

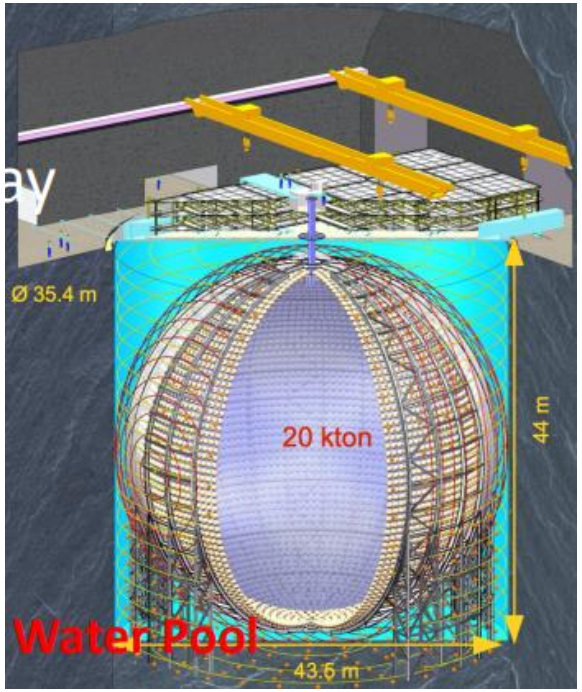
A custom design for JUNO!

Other systems

- 1-D, 2-D, 3-D calibration systems
- Calibration strategy under study



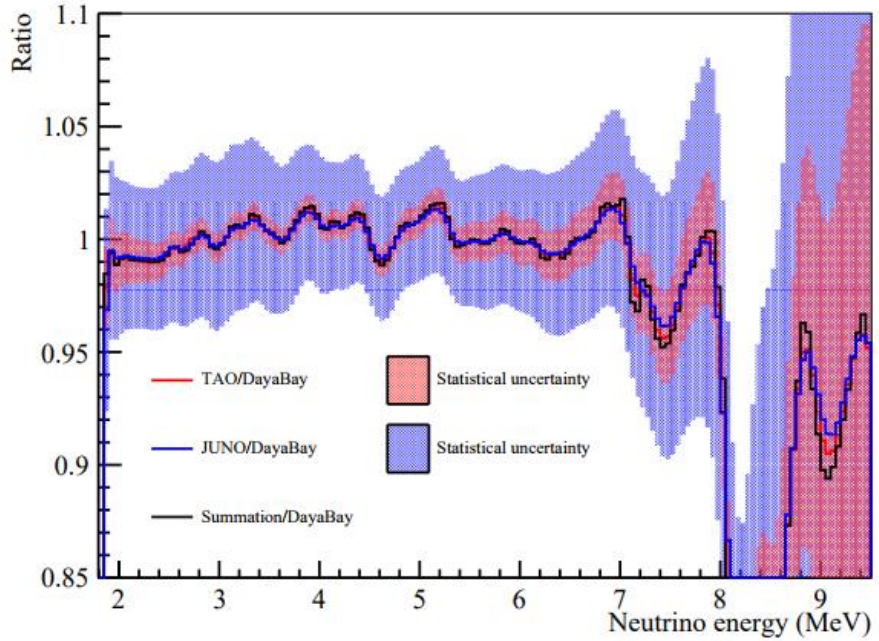
- Muon veto system
  - Water Cherenkov detector
  - Target Tracker walls from OPERA

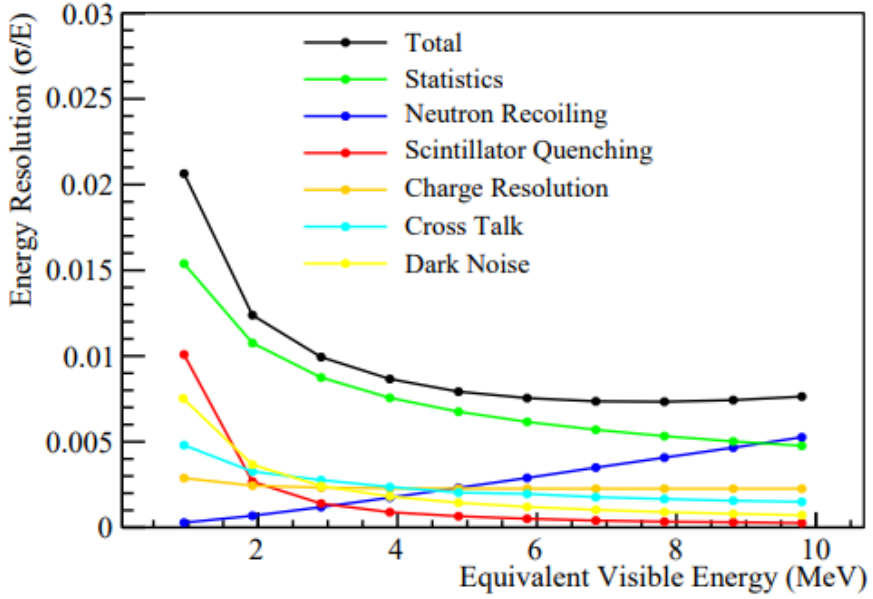


Taishan Antineutrino Observatory

CDR: arXiv 2005.08745

- A satellite experiment of JUNO with physics goals:
  - Provide model-independent reference spectrum for JUNO with sub-percent energy resolution in the major energy ranges
  - Provide a benchmark measurement to examine nuclear database
  - As a demonstration of the technology for reactor monitoring and safeguard

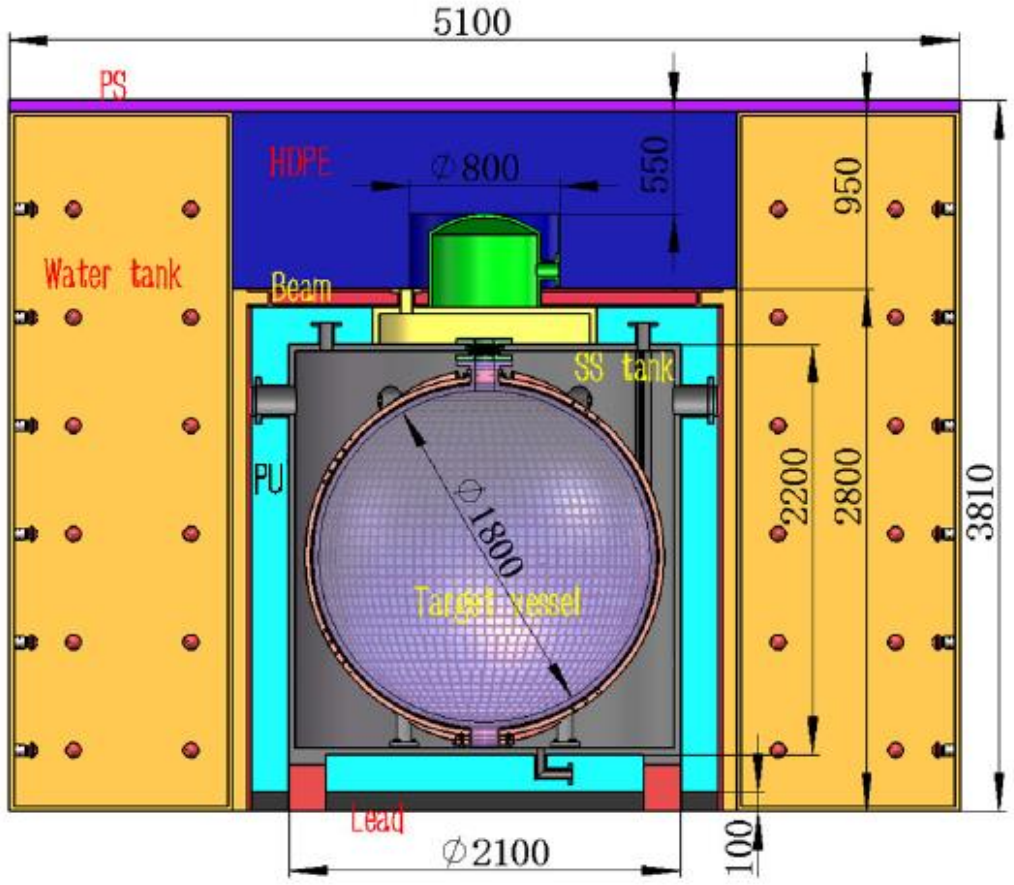




Taishan Antineutrino Observatory

CDR: arXiv 2005.08745

- Conceptual design released
  - Optical sensor: 10 m^2 SiPM with QE=50%
  - 2.8 ton GdLS (FV mass 1 ton) at low temperature, -50°C
  - 4500 p.e./MeV from MC simulation
  - 30 m from Taishan reactor (4.6 GW_{th})
  - 2000 antineutrinos/day with 50% efficiency
- Prototype will be tested at low. temperature w/o full SiPM
- Expected to start operation in 2022

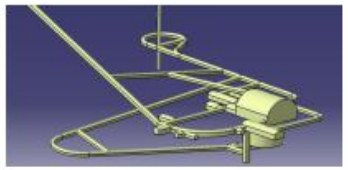


Civil construction

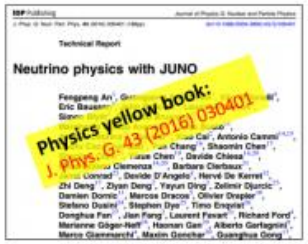
- Slope tunnels and vertical shafts are finished.
- Experimental cavern digging is ongoing.
- Expect to finish in 2020.

Timeline

2014
- International collaboration established
- Conceptual design



2015
- PMT production line setup
- CD parts R&D
- Civil construction start



2016
- PMT production start
- CD parts production start
- Yellow book published

2017
- PMT testing start
- TT arrived

2018
- PMT potting
- Start delivery of surface building
- Start production of acrylic sphere

2019-2021
- Electronics production starts
- Civil construction and lab preparation completed
- Detector construction

2022
- Detector ready for data taking

Stay tuned!