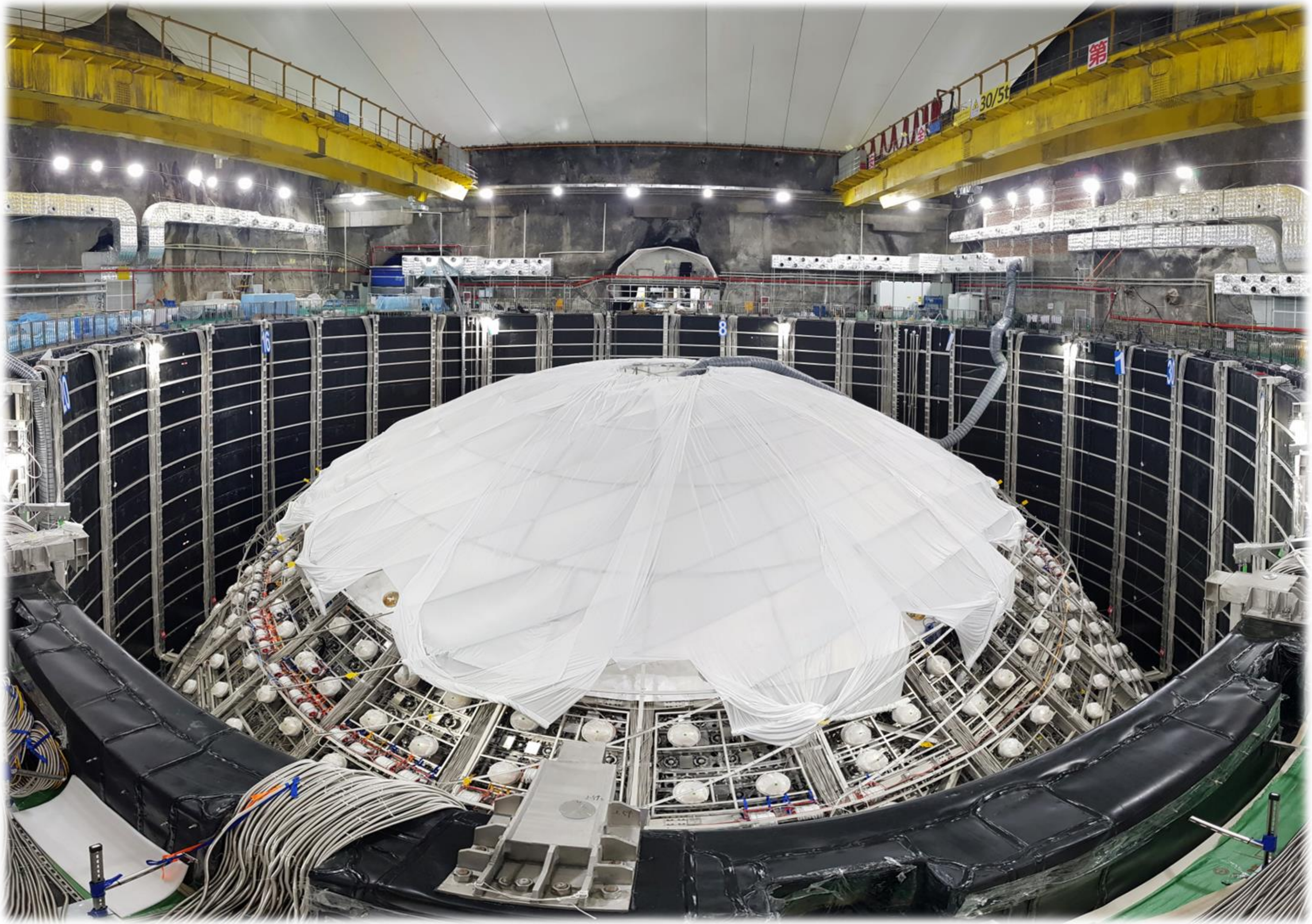
JUNO experiment:
detector status and physics opportunities



Beyond Standard Model 2023 – Hurghada (Egypt)
6-9 November 2023

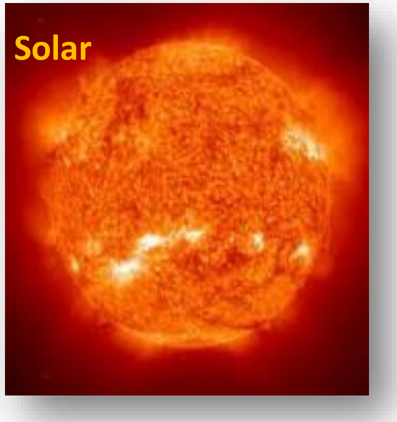
Andrea Barresi

on behalf of the JUNO collaboration

A multi-purpose liquid scintillator-based neutrino observatory

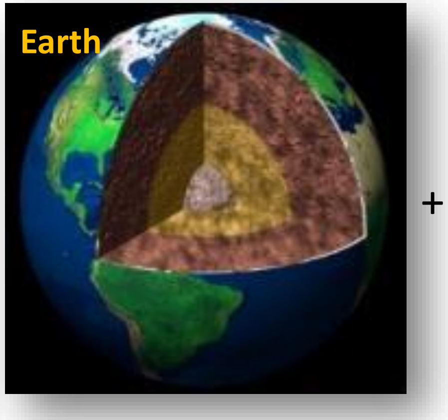
~60 IBDs per days

Several per day



Hundred per day

~5000 IBDs for CCSN @10 kpc

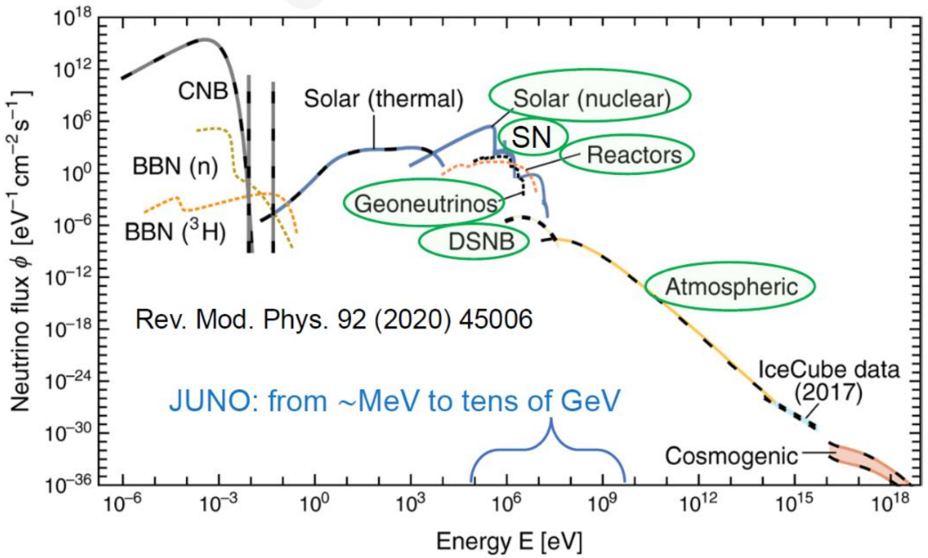


Several IBDs per day

\+ New physics

Neutrino properties

Neutrinos as a probe



Rev. Mod. Phys. 92 (2020) 45006

JUNO: from ~MeV to tens of GeV

"Neutrino Physics with JUNO," J. Phys. G **43** (2016) no.3, 030401

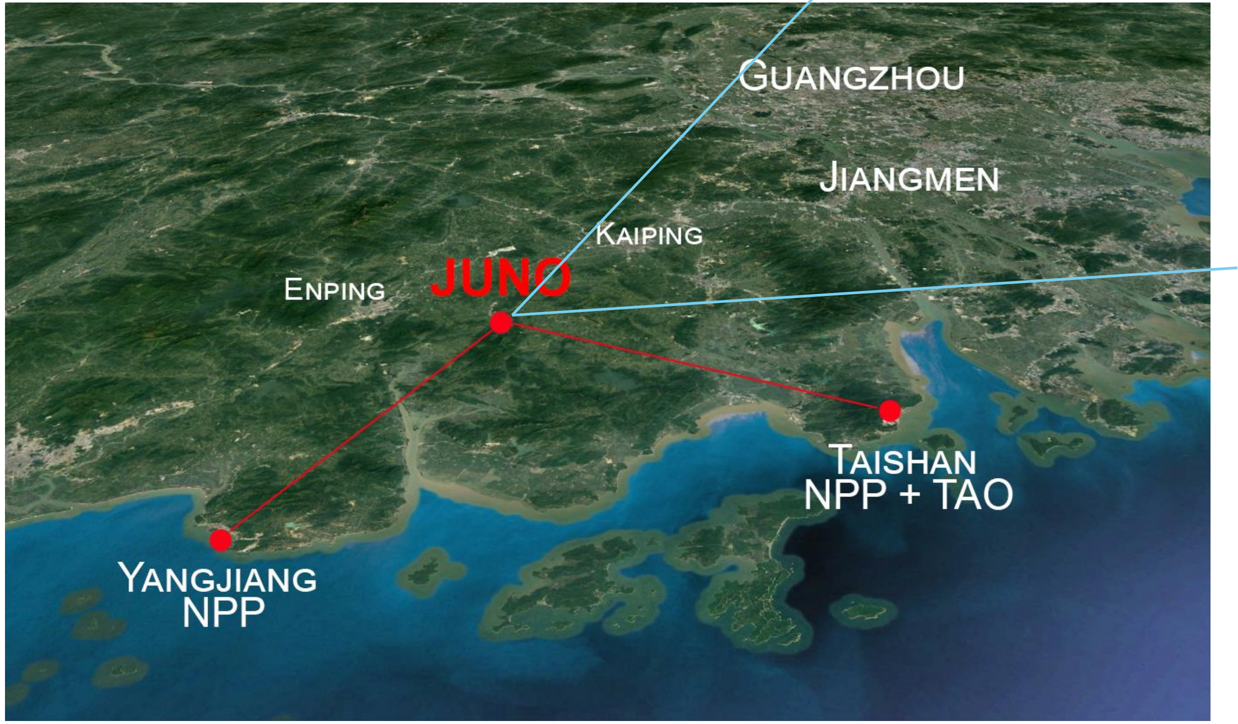
"JUNO Physics and Detector," Prog. Part. Nucl. Phys. **123** (2022), 103927

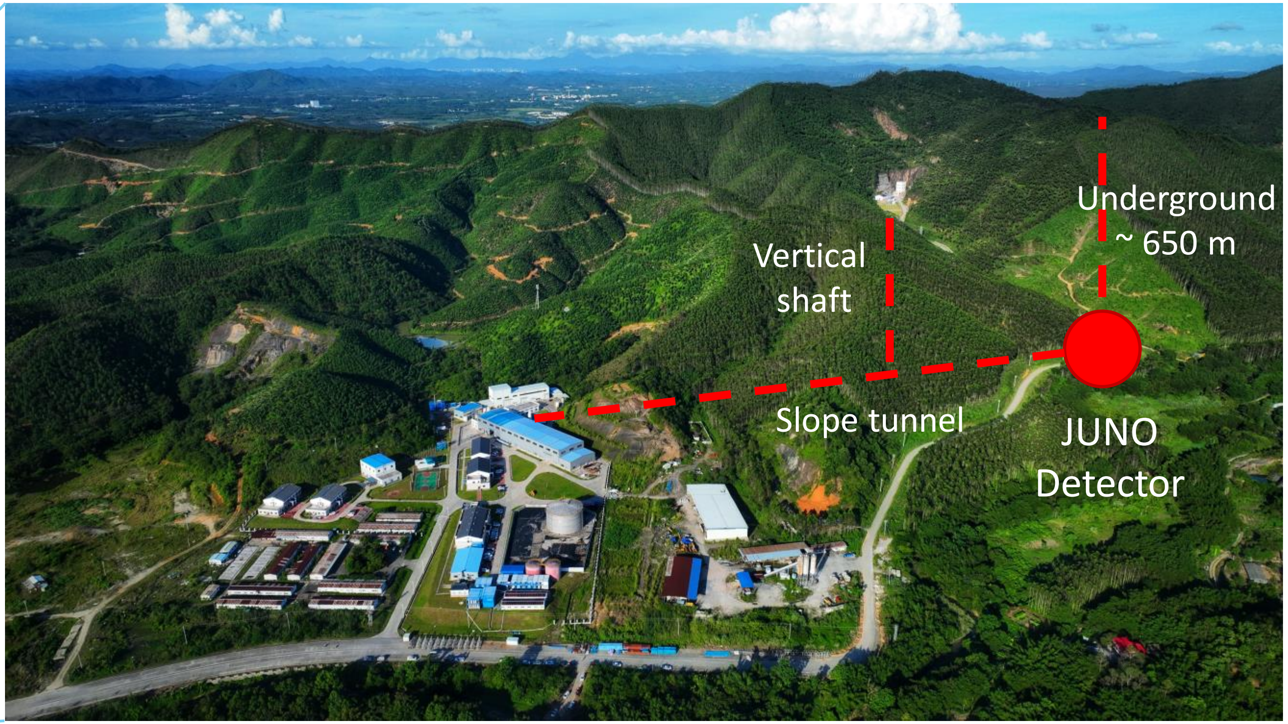
JUNO site

JUNO is under construction in the Guangdong province, in China, ~ 150 km from Guangzhou

Located at ~53 km from two nuclear power plants (NPP) to maximize the sensitivity to the mass ordering.

Collaboration of 74 institutes in 17 countries, ~700 collaborators





- Yangjiang NPP:
  6 x 2.9 GWth
- Taishan NPP:
  2 x 4.6 GWth

JUNO main physics goals

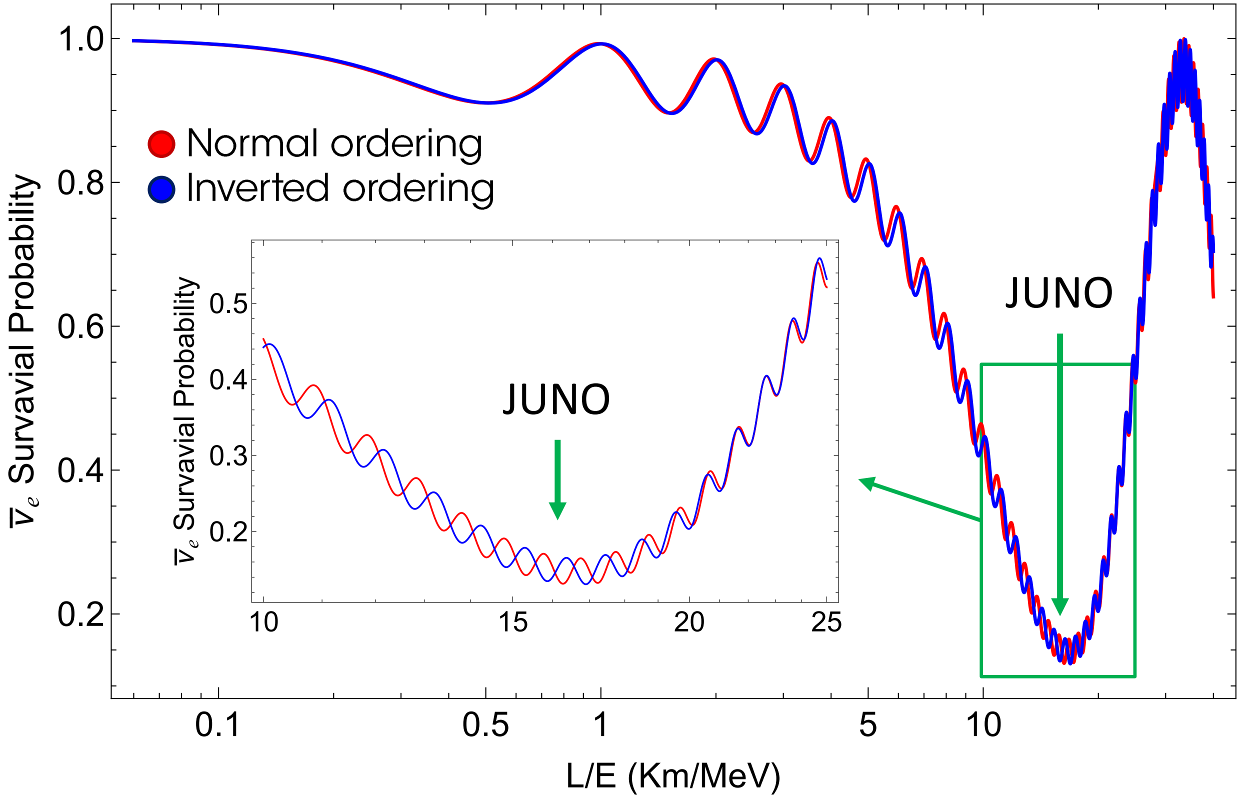
Main physics goals

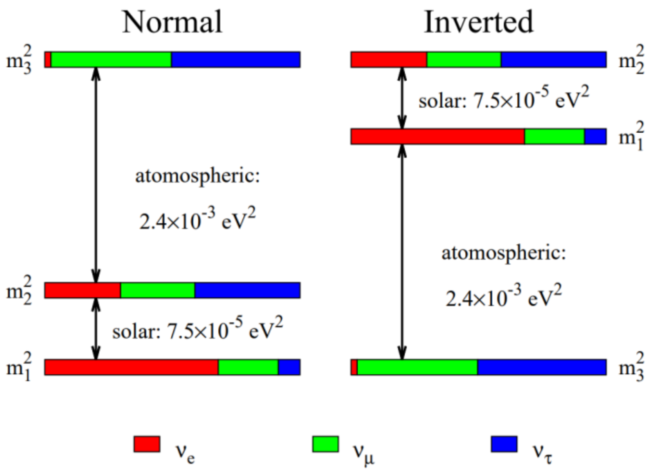
- 3σ measurement of the **neutrino mass ordering** with reactor antineutrinos in ~6 years
- Measuring **oscillation parameter** with a precision < 0.5 % $(sin^2\theta_{12}, \Delta m^2_{21}, \Delta m^2_{31})$

JUNO requirements

- Large signal statistics
- High energy resolution and highly controlled energy scale non-linearity for small spectral features identification
- Low background for low spurious events
- Low reactor antineutrino spectrum shape uncertainty

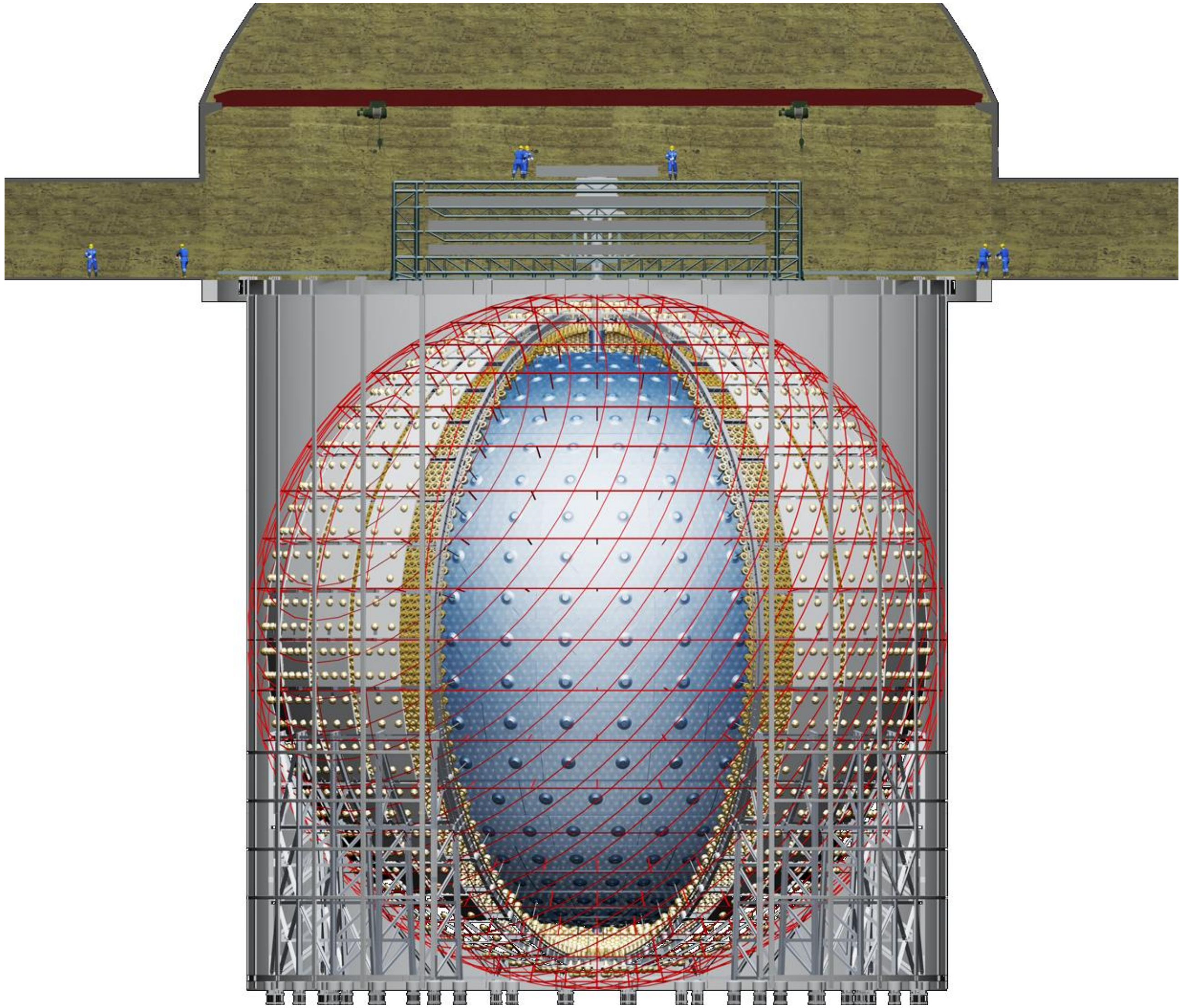
The detector location and design are optimized for the best sensitivity to NMO





Detector structure and status

JUNO detector solutions



JUNO features

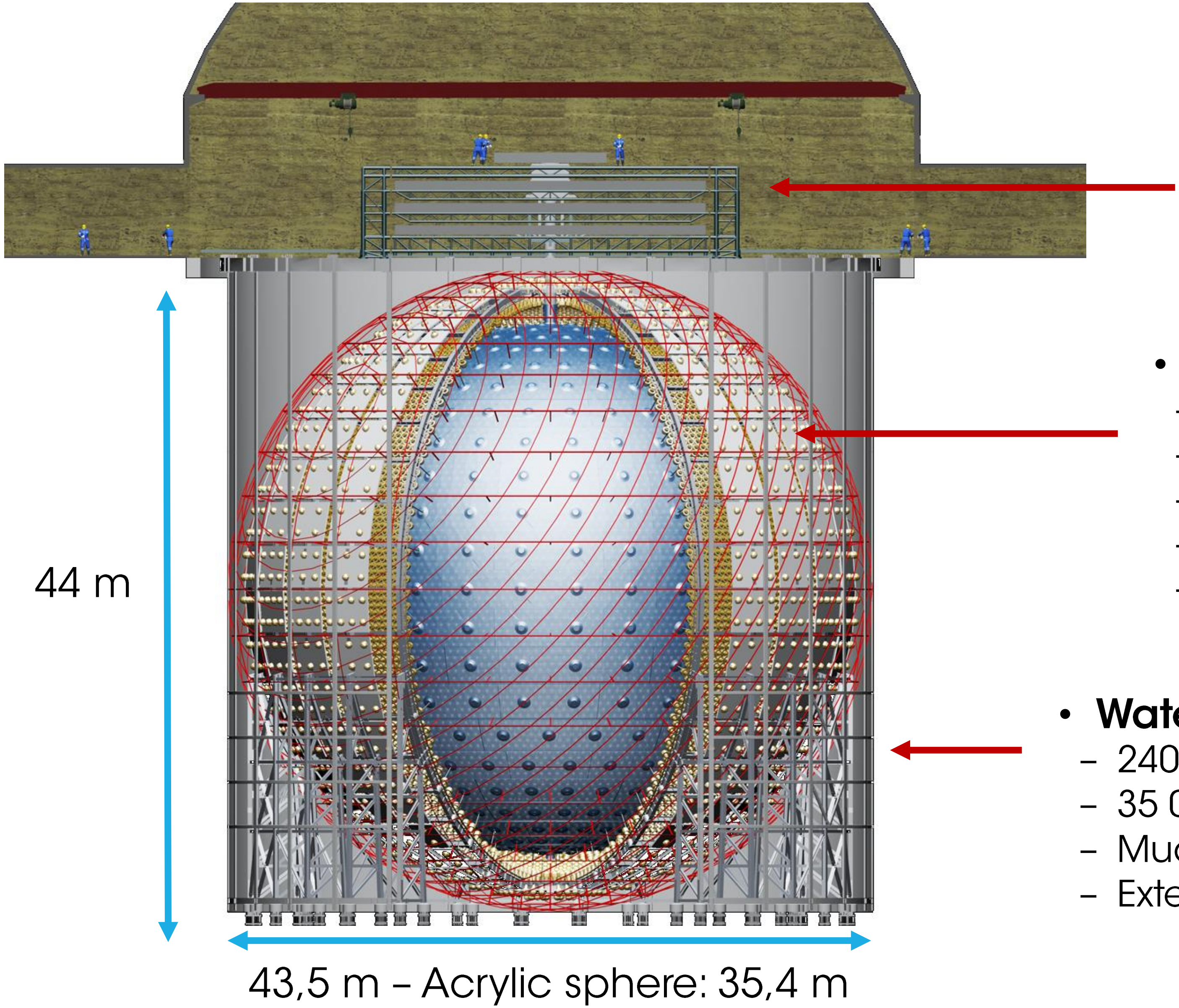
- Large signal statistics
    - Large active mass
    - Powerful antineutrino source (NPPs)

- High energy resolution
    - High photomultipliers coverage
    - High photomultipliers efficiency
    - High transparency of the liquid scintillator (LS)

- Low background
    - Accurate materials selection
    - LS purification
    - Clean environment control
    - Cosmic muons veto
    - Underground experiment

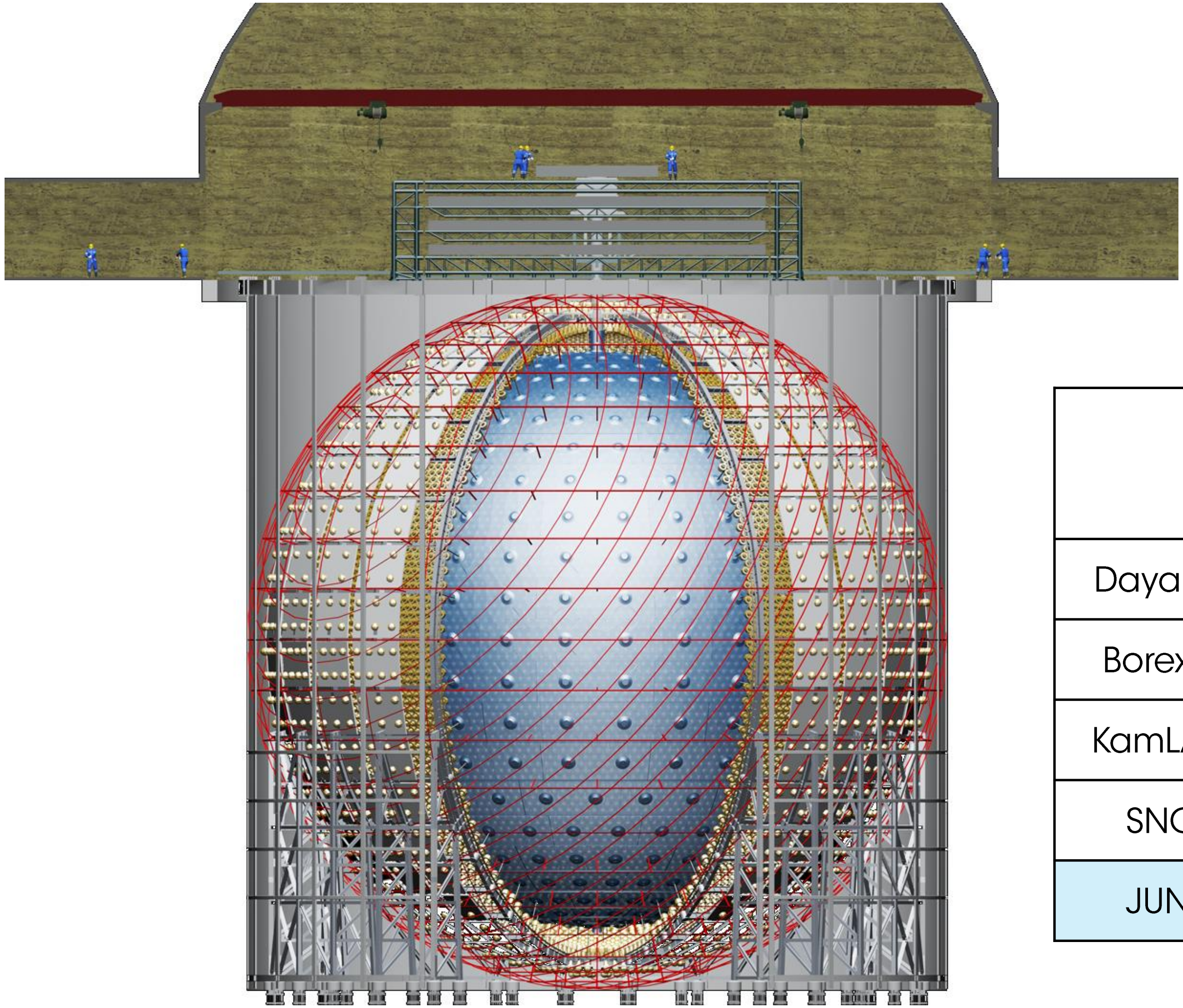
- Low reactor antineutrino spectrum shape uncertainty
    - Satellite detector (TAO)

JUNO detector structure



- **Top Tracker:**
  - 3 layer of plastic scintillators from OPERA
  - Top area coverage ~60 %
- **Central detector:**
  - ~ 20 000 t of liquid scintillator in acrylic vessel
  - 17612 large PMTs (20-inch)
  - 25600 small PMTs (3-inch)
  - ~ 78% PMT coverage
  - Earth magnetic field shielding coil
- **Water Cherenkov Detector**:
  - 2400 20-inch PMTs
  - 35 000 t ultra-pure water
  - Muon detection efficiency > 99%
  - External radioactivity shielding

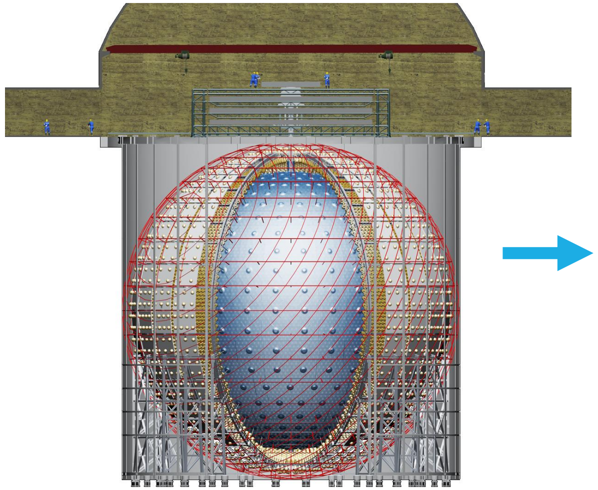
Why JUNO is different



JUNO is the biggest LS-based ever build with unprecedented characteristics

	Mass (t)	PMTs coverage (%)	Light collection (pe/MeV)	E resolution (%/√E)
Daya Bay	20 (x8)	12 %	~160	~8%
Borexino	300	30 %	~450	~5%
KamLAND	1000	34 %	~250	~6%
SNO+	780	50 %	~520	~6%
JUNO	20000	78 %	~1600	~3%

Detector construction: Stainless steel truss



Assembly precision
< 3 mm

Bottom SS structure and lifting
platform for acrylic panels installation:
May 2022

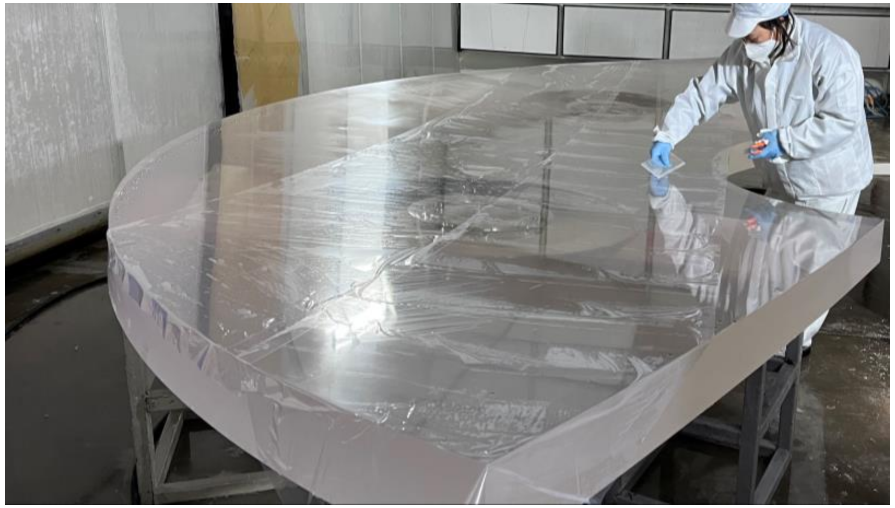
SS structure completed:
June 2022

Detector construction: Acrylic sphere

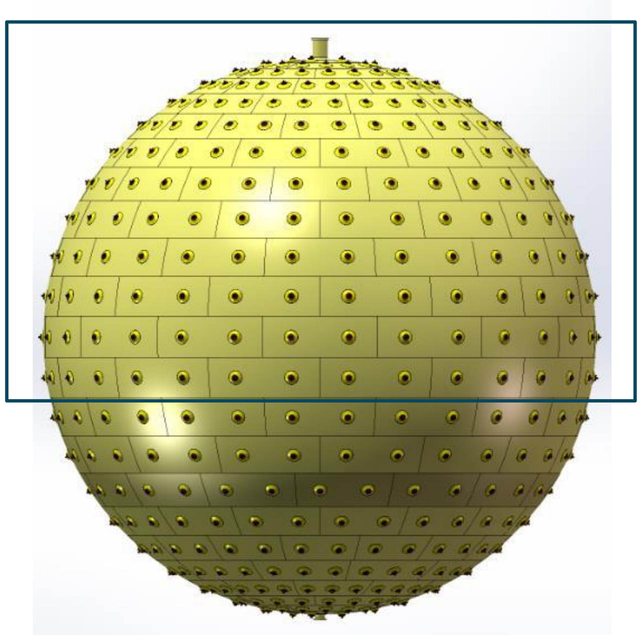
- Inner diameter: (35,40 ± 0,04) m
- Thickness: (124 ± 4) mm
- High transparency: > 96 % in pure water
- High radiopurity : U, Th, K < 1 ppt

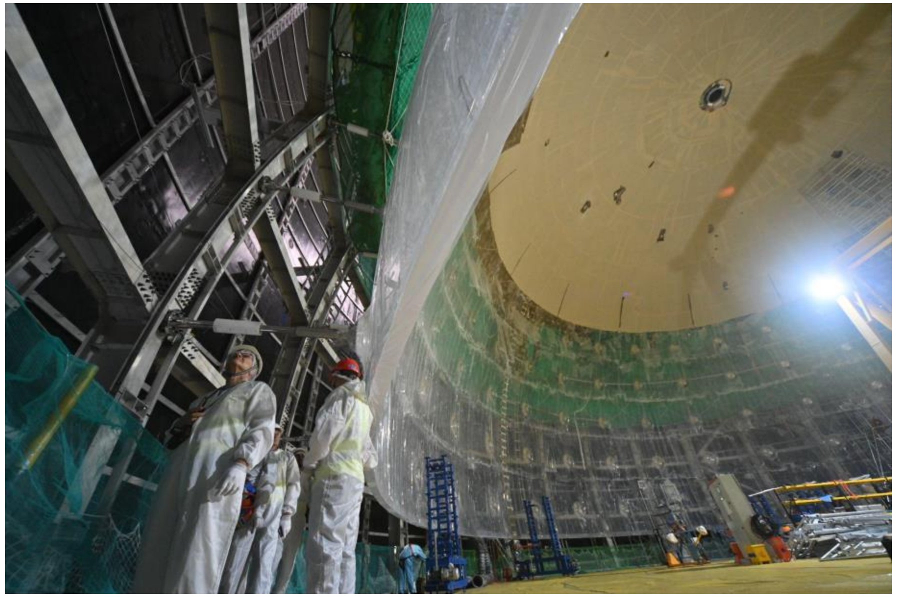
- # of panels: 256
- Total weight: 600 t

Connected to the SS truss via 590 connecting bars



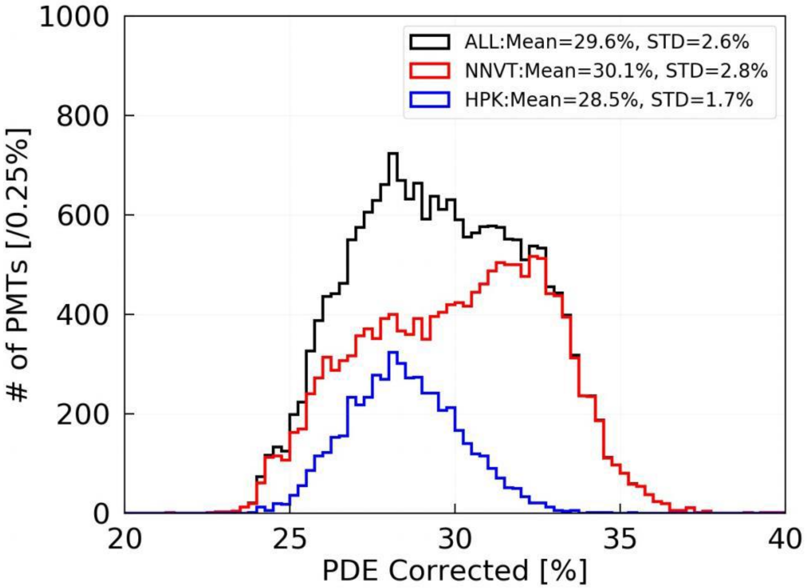
Already installed

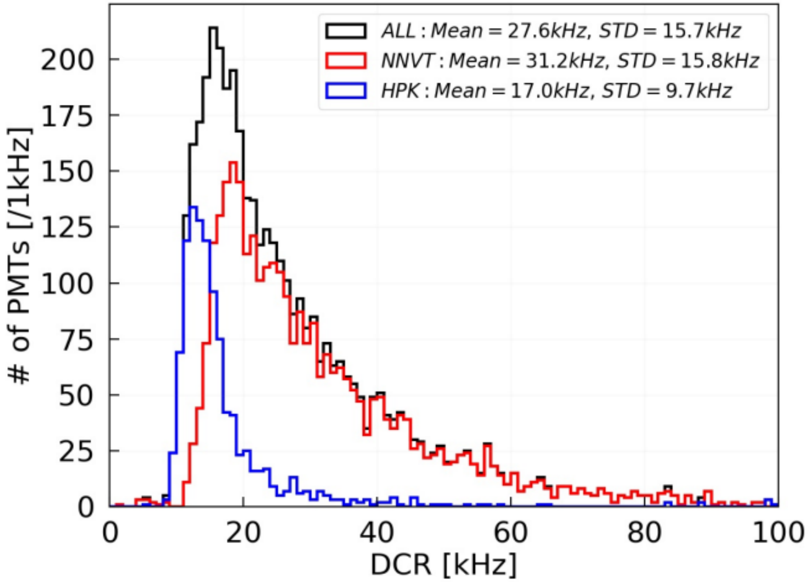




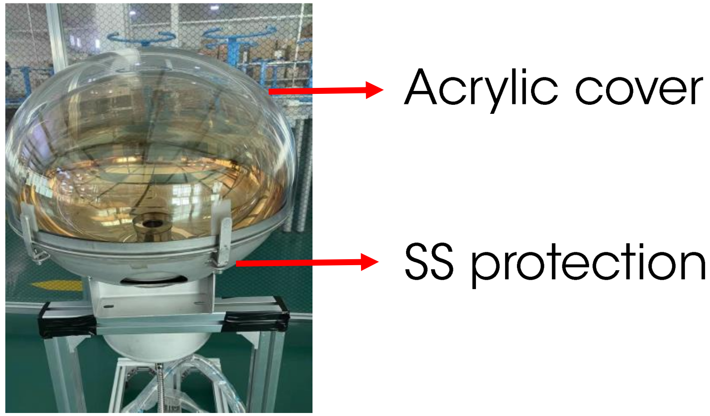
Detector construction: Photomultiplier tubes

	Hamamatsu 20″	**NNVT 20″**	**HZC 3″**
Number	5000 (CD)	12612 (CD) + 2400 (veto)	25600 (CD)
Change collection	Dynode	MCP	Dynode
Detection efficiency	28.5%	30.1%	25%
Dark count rate (kHz)	17.0	31.2	0.5
Transit time (ns)	1.3	7.0	1.6





All PMTs are produced, tested and instrumented with waterproof potting



Detector construction: Photomultiplier tubes

PMTs installation is ongoing

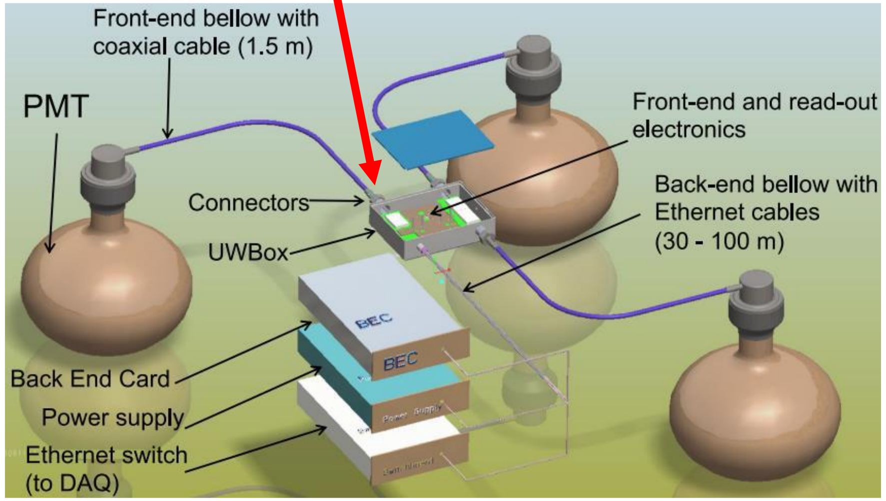
Clearance: 3 mm
Assembly precision: < 1mm

Detector construction: Electronics

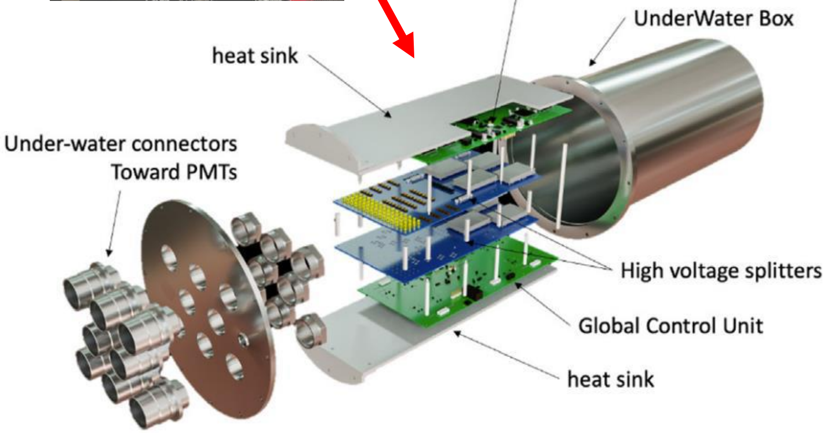
Underwater electronics is used to improve the signa-to-noise ratio for better energy resolution

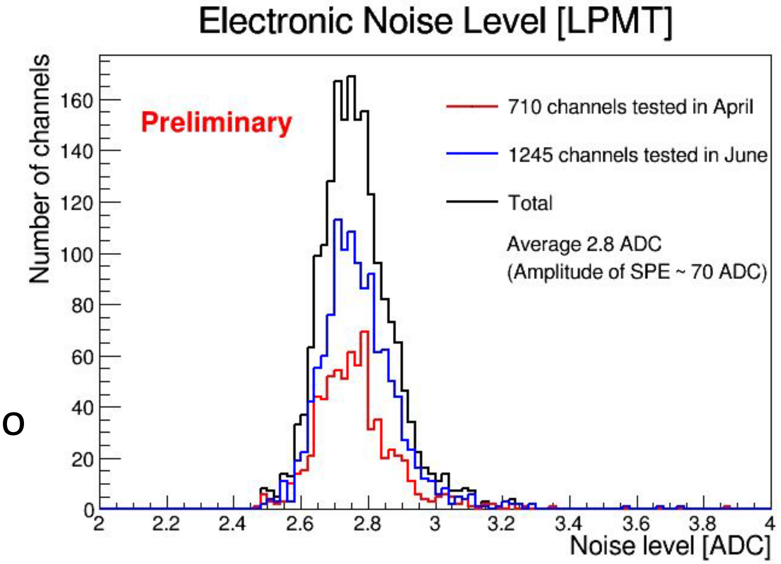
- High reliability (no access after installation)
- High precision
- Large dynamic range
- Stand high rates for short times (Supernovae)

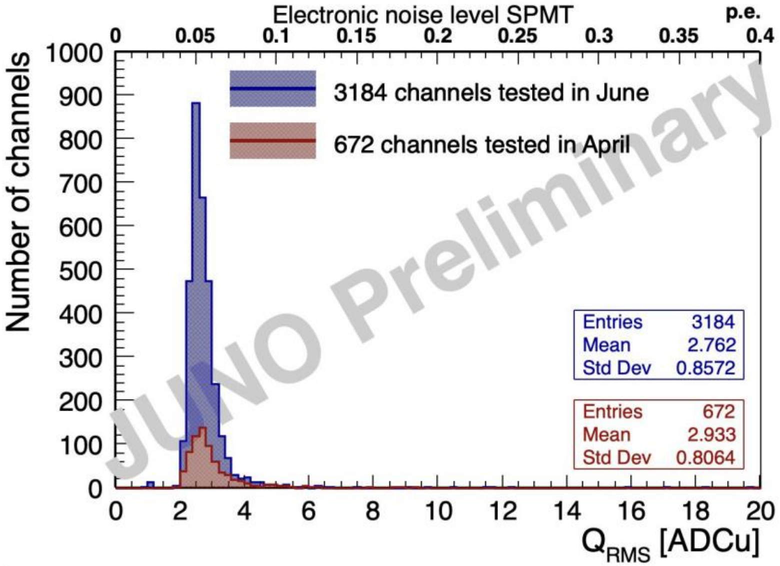
LPMTs:
3 PMTs connected to one underwater box



SPMTs:
128 PMTs connected to one underwater box

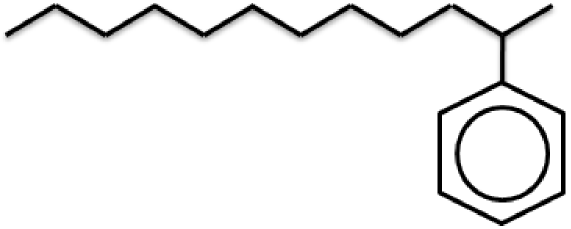






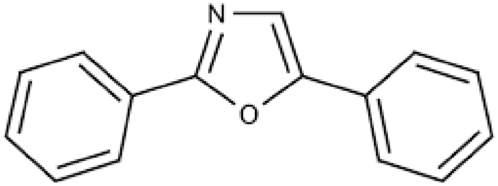
Detector construction: Liquid scintillator

Composition:



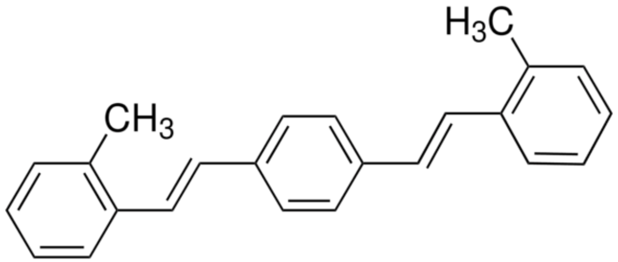
Linear alkyl benzene (LAB)

+

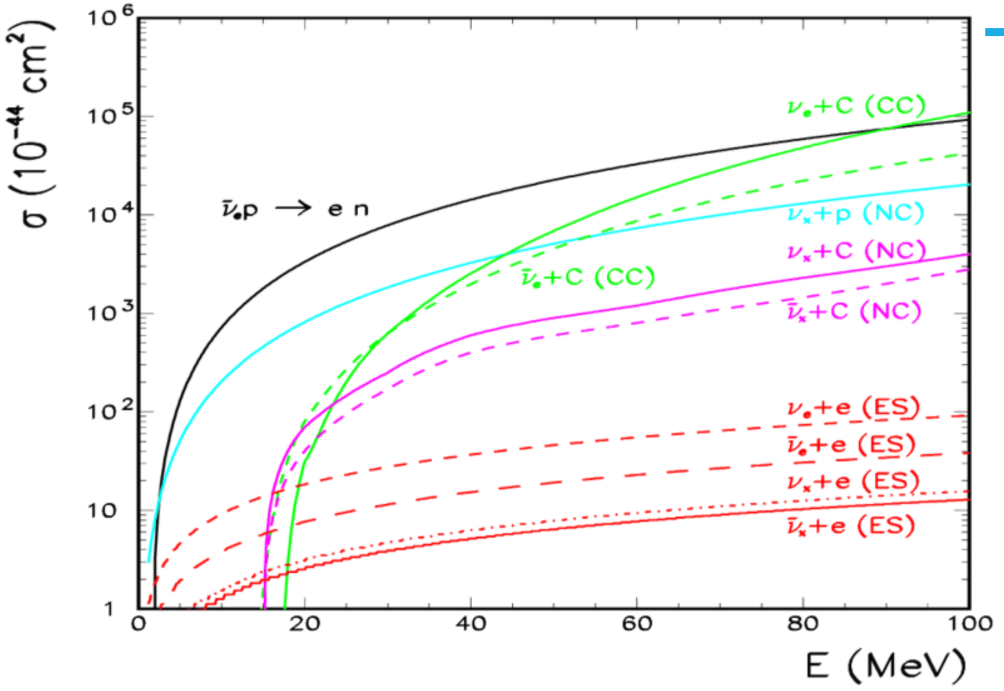


PPO (2,5 g/L)

+



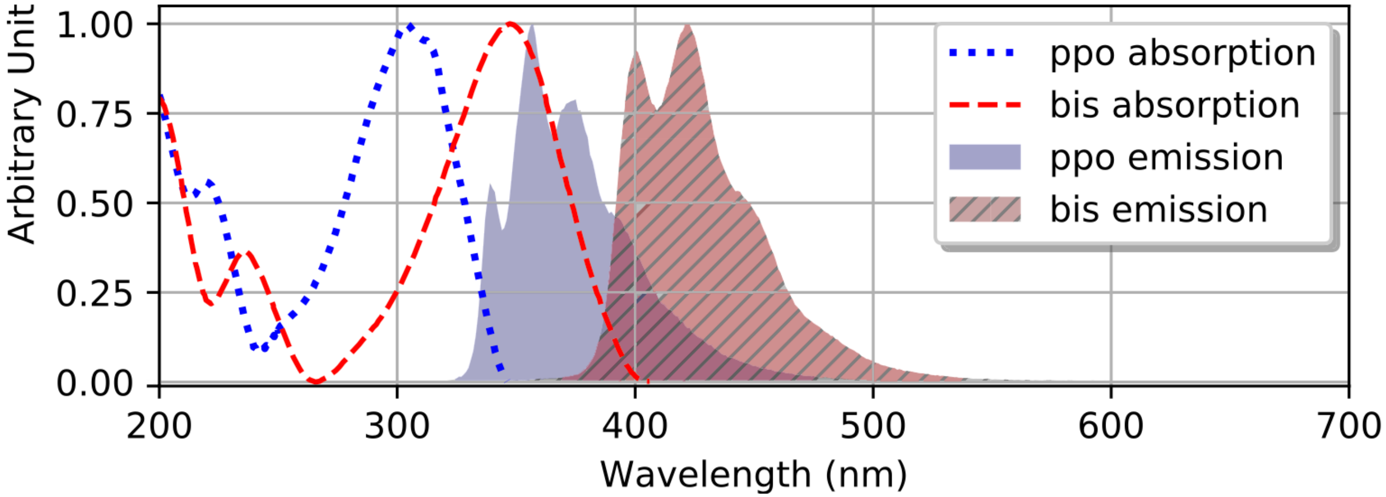
bis-MSB (3 mg/L)



Highest cross section:
CC on hydrogen (proton)

Mass ratio: 88% C – 12% H
Atomic density ratio: **37% C – 63% H**

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



Detector construction: LS purification and filling

LS is the most critical component for radiopurity: U, Th < 1 ppq, K < 0,1 ppq for NMO
Its optical properties play a crucial role for energy resolution:
light yield ~10 000 photons/MeV with >20 m @ 430 nm attenuation length

→ Dedicated purification system

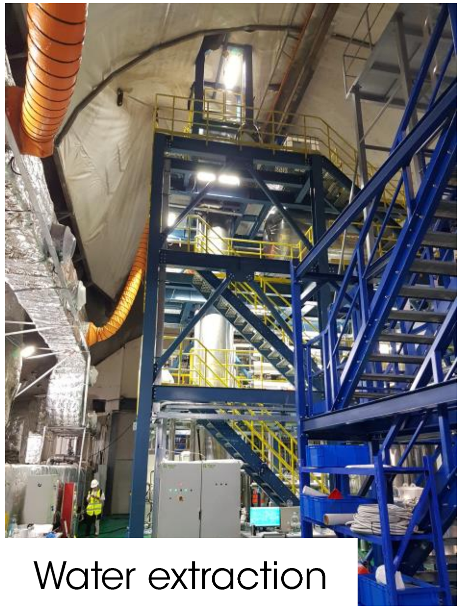

LAB tank


Filtration on Al_2O_3


Distillation


PPO & bis-MSB mixing

Underground

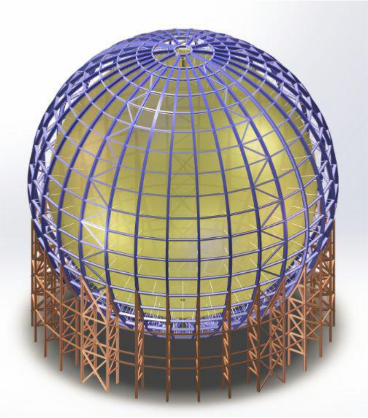

Water extraction


Gas stripping

15%


OSIRIS

85%



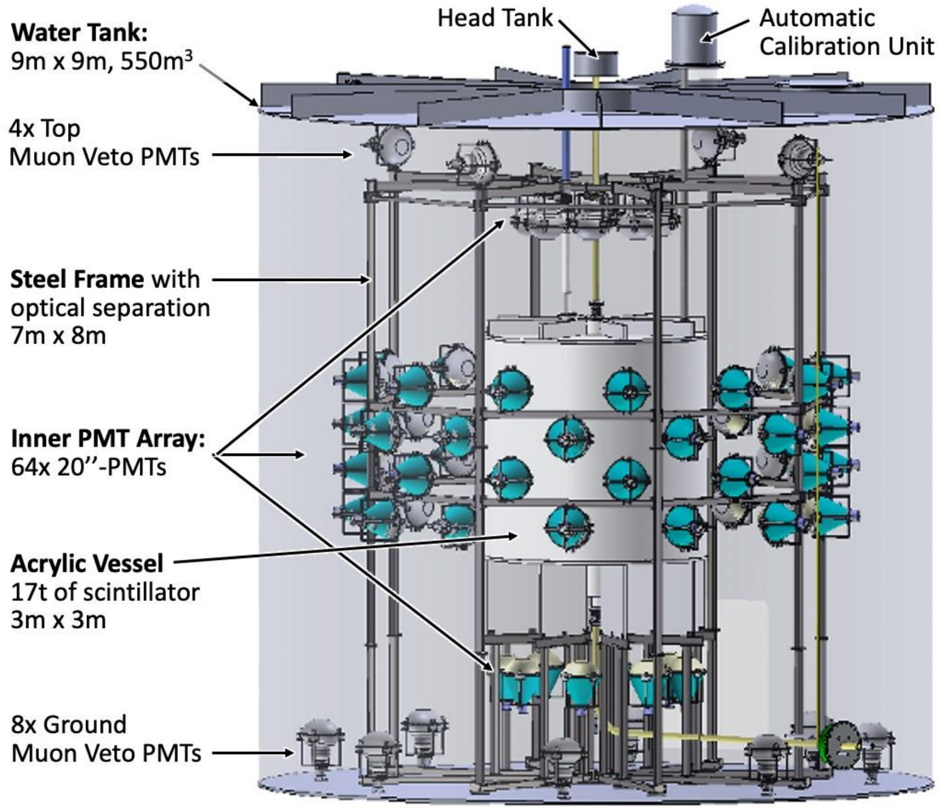
Detector construction: OSIRIS

Online Scintillator Internal Radioactivity Investigation System

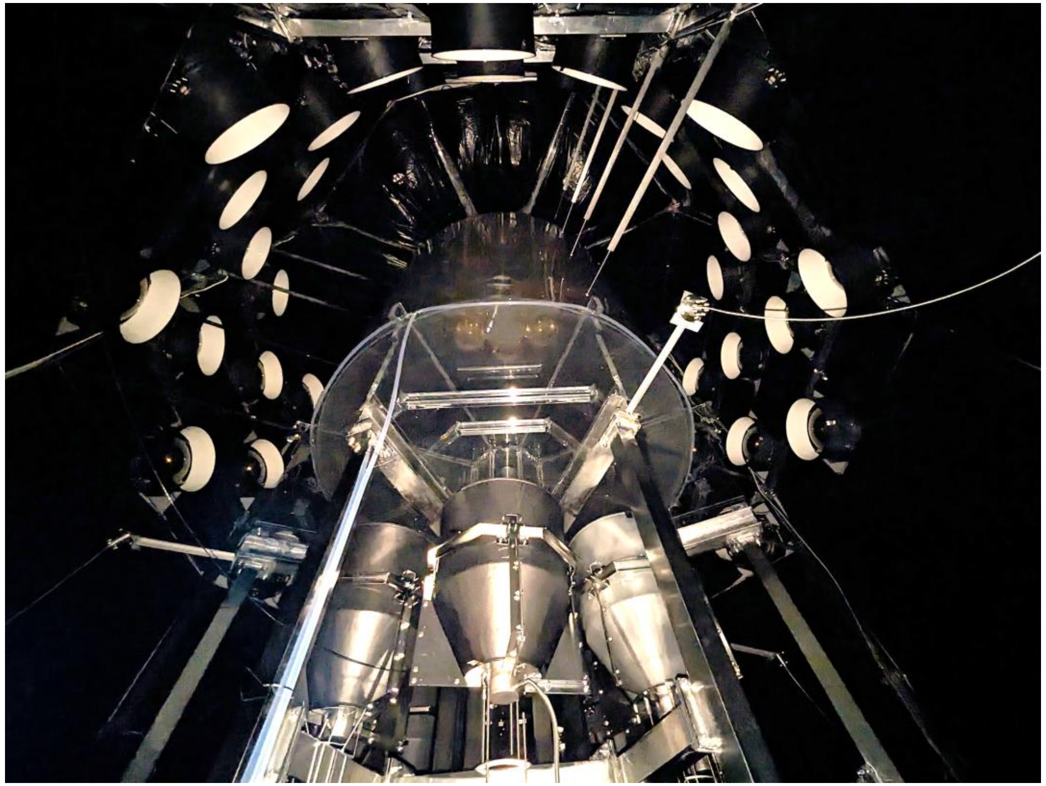
- Online monitor of LS radiopurity during filling
- **20 t LS** + 550 t H_2O
- Measure of U-Th using Bi-Po coincidence and ^{14}C, ^{210}Po, ^{85}Kr

Sensitivity:

- Few days: U/Th (Bi-Po) ~ 1×10^{-15} g/g (reactor baseline case)
- 2-3 weeks: U/Th (Bi-Po) ~ $1\times10^{-16÷17}$ g/g (solar ideal case)

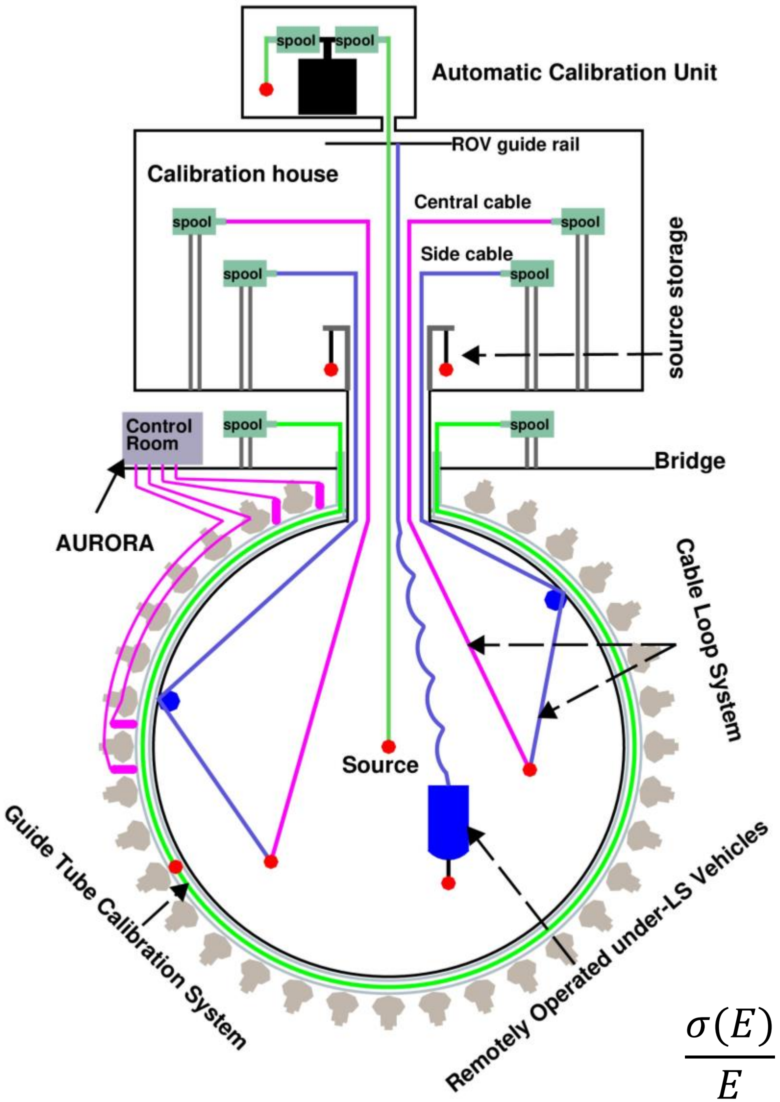


Under commissioning

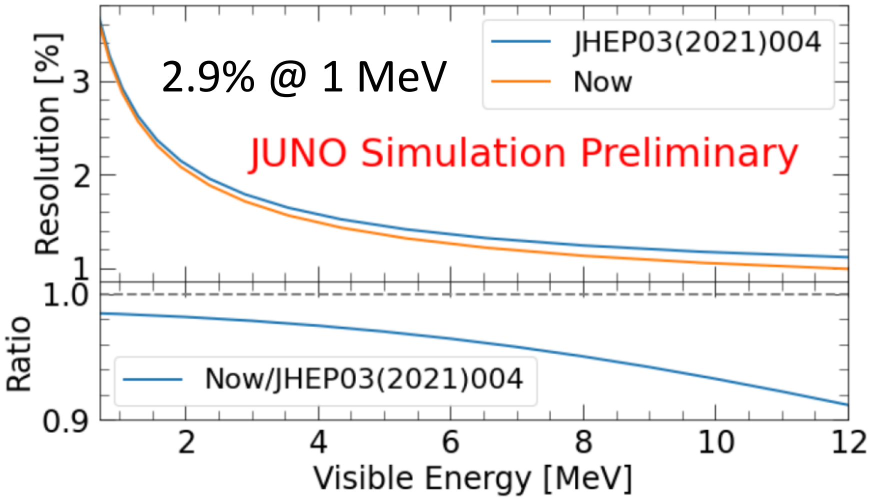


The design and sensitivity of JUNO's scintillator radiopurity pre-detector OSIRIS. Eur. Phys. J. C ***81****, 973 (2021)*

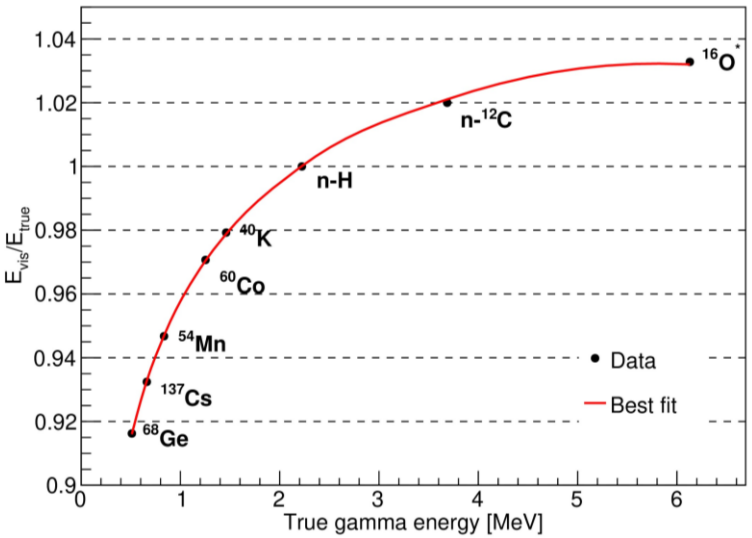
Energy calibration



- Multiple calibration systems with multiple sources:
  - 1D Automatic calibration unit
  - 2D Cable loop system + Guide tube calibration system
  - 3D Remotely operated vehicle
  - Auxiliary systems: Ultrasonic sensor system, LS transparency monitor
- Scan ensure energy scale, non-uniformity and non-linearity characterization
- 3″ PMTs used to correct 20″ PMTs non-linearity



Non-linearity calibration curve



$$\frac{\sigma(E)}{E} = \sqrt{\left(\frac{a}{\sqrt{E}}\right)^2 + b^2 + \left(\frac{c}{E}\right)^2}$$

Calibration strategy of the JUNO experiment. J. High Energ. Phys. ***2021****, 4 (2021)*

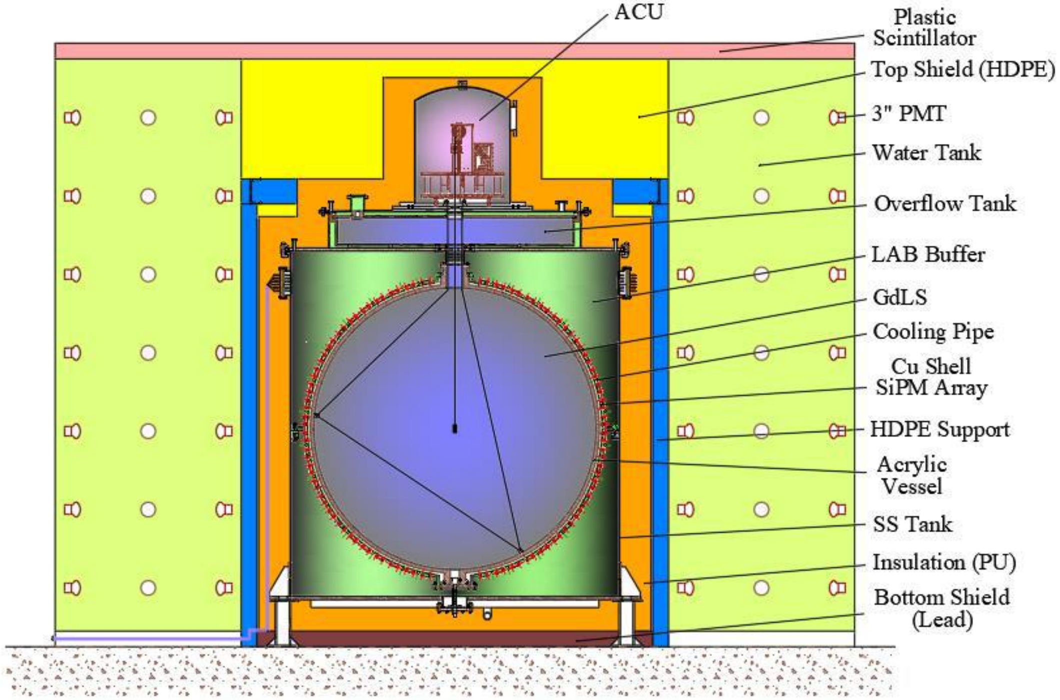
TAO satellite detector

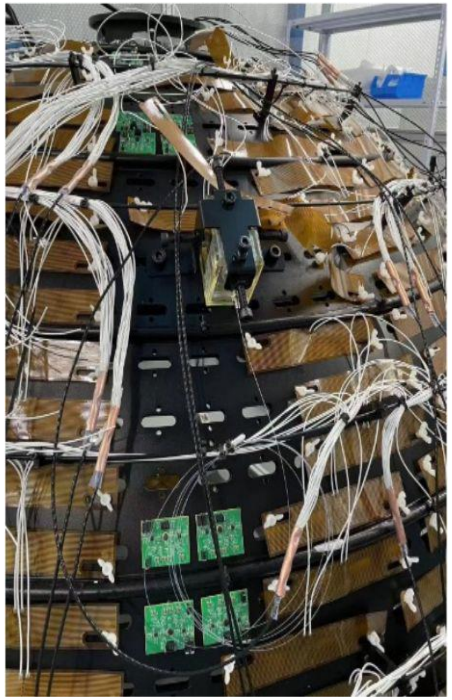
Taishan Antineutrino Observatory

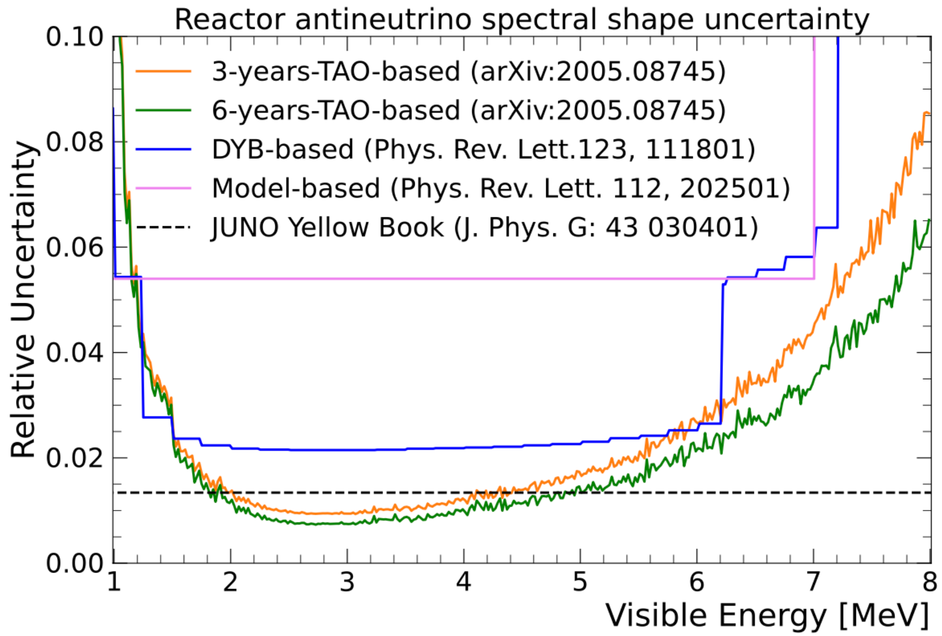
- Precise measurement of non-oscillated antineutrino spectra with high energy resolution (fine structure)
- Provide a reference spectrum for JUNO and nuclear databases
- Sensitive to light sterile neutrino

Detector features:

- Baseline ~ 30 m (near Taishan-1 NPP core 4,6 GWth)
- 2,8 t Gd-LS (1t Fiducial volume)
- ~94% coverage with SiPM
- Cooled at -50 °C (low SiPM dark rate)
- High E resolution: <2% @ 1MeV
- High statistic: 30x JUNO rate



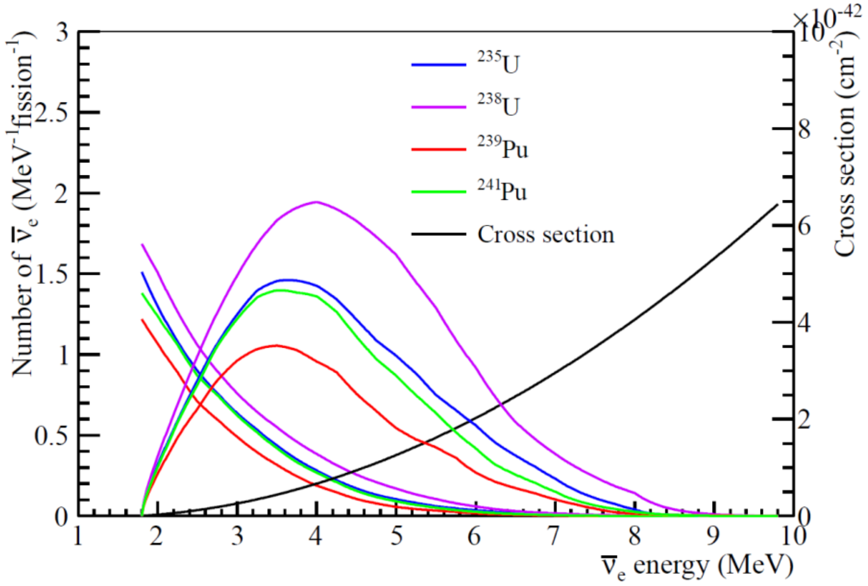




JUNO physics opportunities

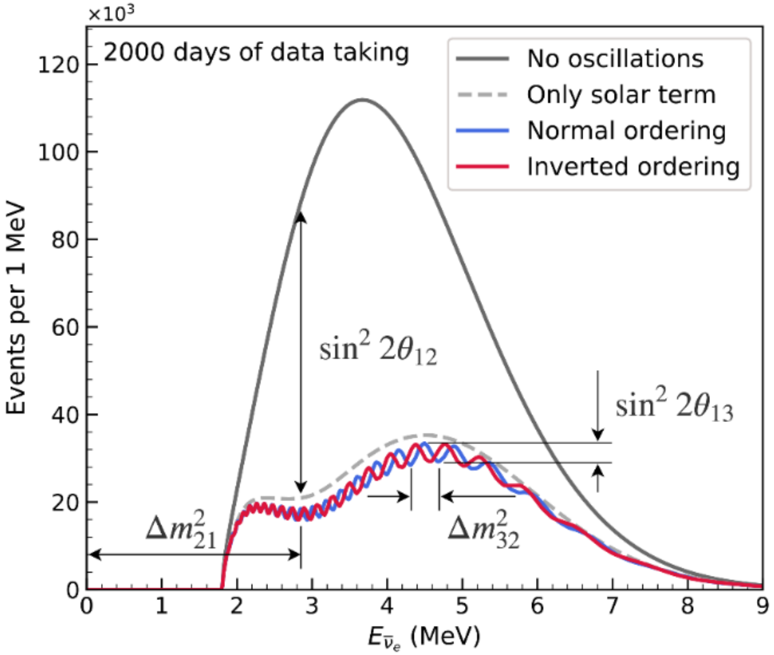
NMO with reactor antineutrino

Main physics goal of JUNO: Neutrino Mass Ordering via reactor antineutrino spectrum measurement (IBD interaction)

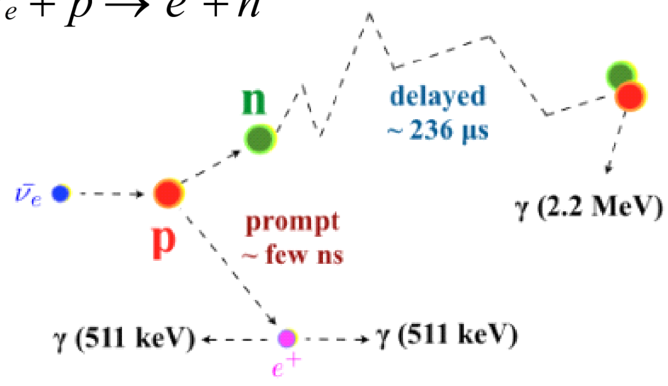


$$\begin{aligned} P_{\bar\nu_e\bar\nu_e} = 1 &- \cos^4(\theta_{13})\sin^2(2\theta_{12})\sin^2\left(\frac{\Delta m^2_{12}L}{4E}\right) \\ &- \cos^2(\theta_{12})\sin^2(2\theta_{13})\sin^2\left(\frac{\Delta m^2_{31}L}{4E}\right) \\ &- \sin^2(\theta_{12})\sin^2(2\theta_{13})\sin^2\left(\frac{\Delta m^2_{32}L}{4E}\right) \end{aligned}$$

- JUNO will be able to discriminate the two oscillation patterns (phase difference) thanks to its high energy resolution.
- Determination of NMO @ > 3σ in 6 years



$\bar\nu_e + p \rightarrow e^+ + n$



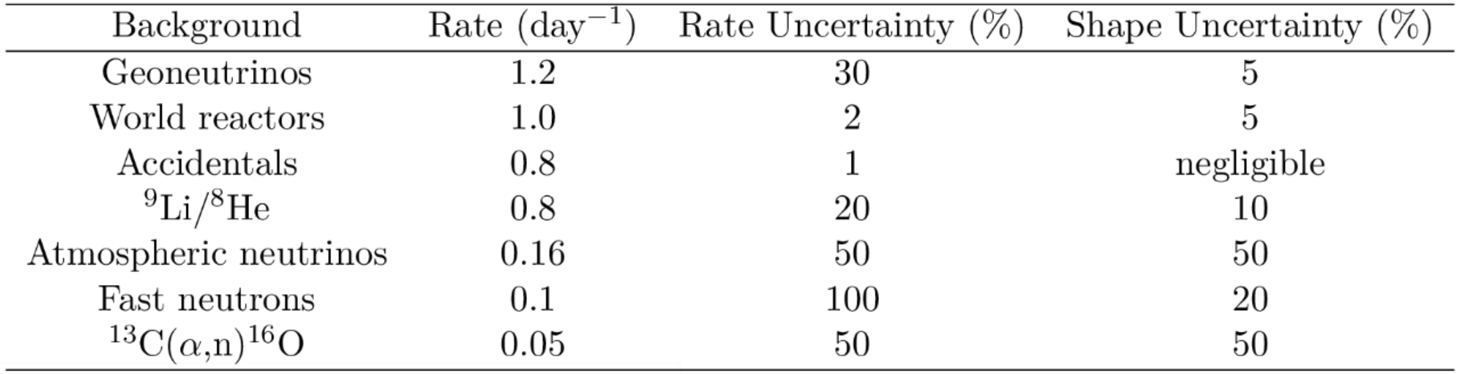
Prompt signal
handle for neutrino energy:
$E_\nu \approx E_{e^+} + \Delta m_{n-p} + T_n$
+
Delayed signal
neutron capture: 2.2 MeV (H) or 4.9 MeV (C) within ~200 µs

Selection criteria:

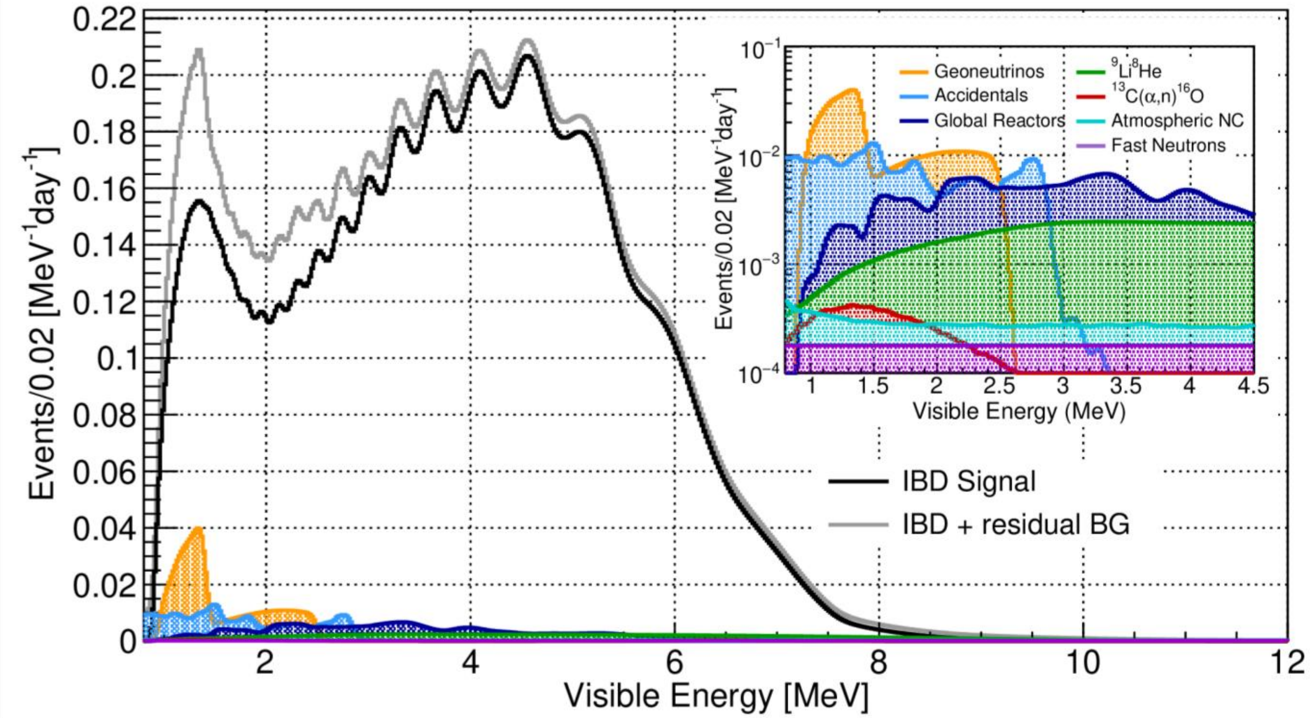
- Prompt energy: [0.7, 12] MeV
- Delayed energy: [1.9, 2.5] U [4.4, 5.5] MeV
- Time difference: < 1 ms
- Distance between prompt-delay signal vertexes: < 1.5 m

IBD Background

Main background sources for IBDs



Background	Rate (day^{-1})	Rate Uncertainty (%)	Shape Uncertainty (%)
Geoneutrinos	1.2	30	5
World reactors	1.0	2	5
Accidentals	0.8	1	negligible
^{9}Li/^{8}He	0.8	20	10
Atmospheric neutrinos	0.16	50	50
Fast neutrons	0.1	100	20
^{13}C(α,n)^{16}O	0.05	50	50

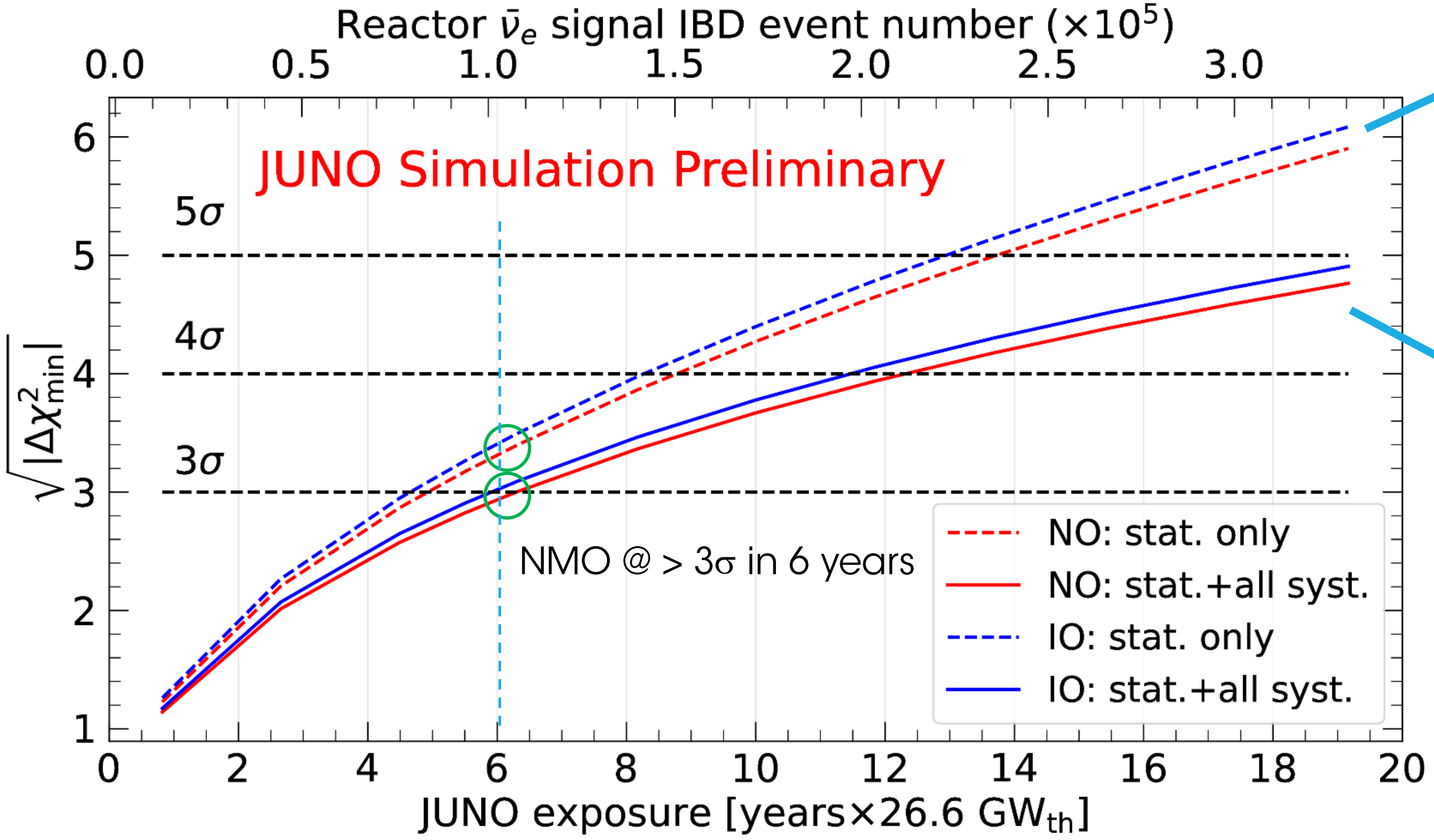


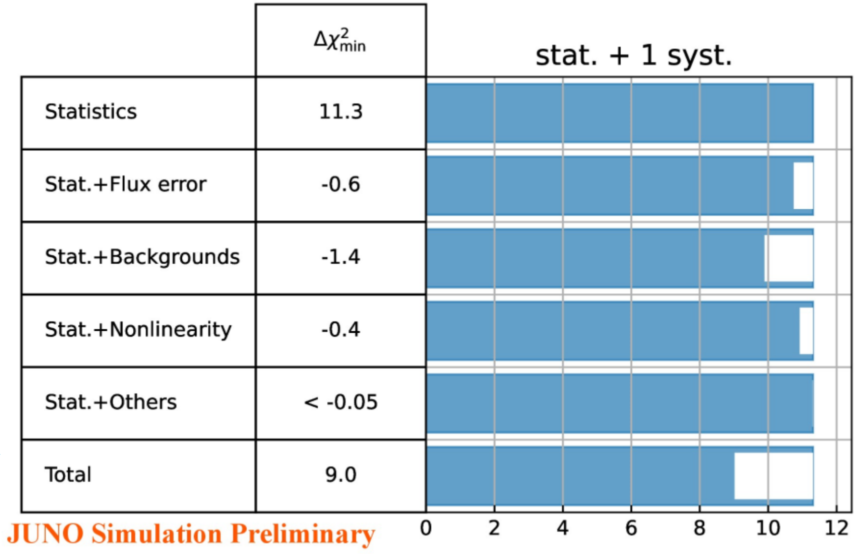
Event selection for background reduction:

- Muon veto for cosmogenic background
- FV cut + IBD cuts for accidental coincidences

	Efficiency (%)	IBD rate (day^{-1})
IBDs	100	57.4
FV cut	91.5	52.5
IDB selection	98.1	51.5
Muon veto	91.6	47.1
Combined	**82.2**	**47.1**

NMO – Sensitivity





	$\Delta\chi^2_{\min}$	stat. + 1 syst.
Statistics	11.3	
Stat.+Flux error	-0.6	
Stat.+Backgrounds	-1.4	
Stat.+Nonlinearity	-0.4	
Stat.+Others	< -0.05	
Total	9.0	

Main updates from JUNO yellow book *(JPG 43:030401 (2016))*

- 2 less reactor cores (36 -> 26,6 GWth, lower signal rate)
- 60 m less overburden (30 % higher muon flux)
- Improved detection and muon veto MC efficiencies
- Higher energy resolution (3% -> 2,9 %)
- TAO reference

Sensitivity can be improved:

- Combination of reactor and atmospheric neutrino analysis
- Combination with long baseline neutrino beam experiments

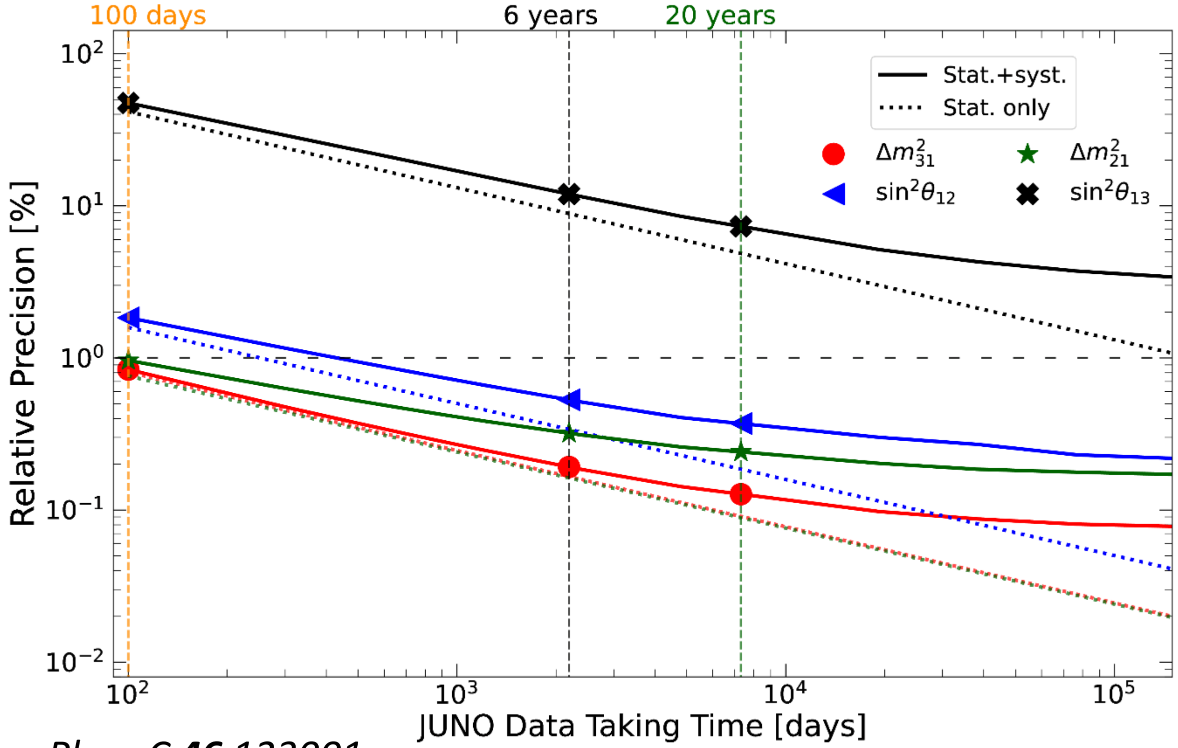
Sensitivity to oscillation parameters

Other main physics goals of JUNO: precise oscillation parameters measurement

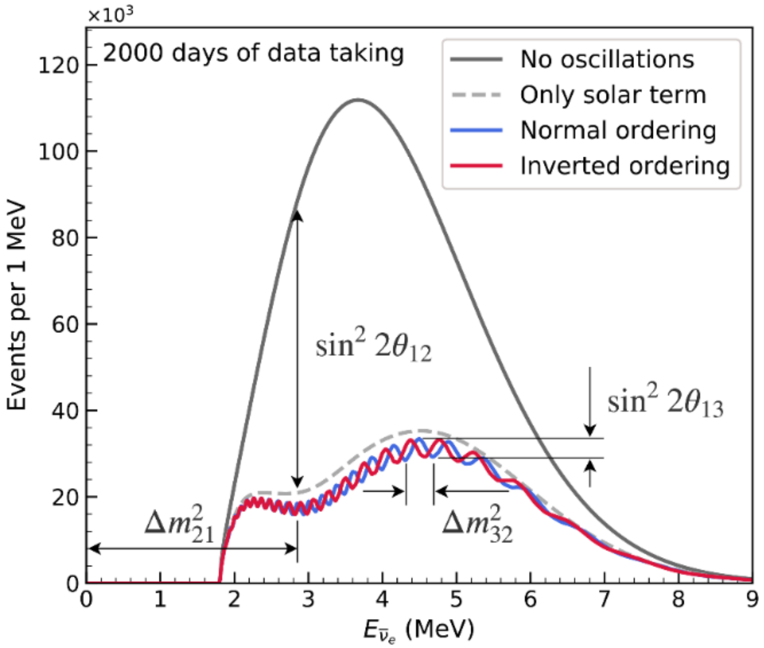
- JUNO will observe simultaneously fast and slow oscillations (first experiment)
- The probability depends on $\boldsymbol{\Delta m^2_{12}, \Delta m^2_{31}, \theta_{12}, \theta_{13}}$

$$\begin{aligned} P_{\overline{\nu}_e\overline{\nu}_e} = 1 &- \cos^4\boxed{(\theta_{13})}\sin^2\boxed{(2\theta_{12})}\sin^2\boxed{\left(\frac{\Delta m^2_{12}L}{4E}\right)} \\ &- \cos^2\boxed{(\theta_{12})}\sin^2\boxed{(2\theta_{13})}\sin^2\boxed{\left(\frac{\Delta m^2_{31}L}{4E}\right)} \\ &- \sin^2\boxed{(\theta_{12})}\sin^2\boxed{(2\theta_{13})}\sin^2\boxed{\left(\frac{\Delta m^2_{32}L}{4E}\right)} \end{aligned}$$

JUNO allows high precision measurements of **Δm^2_{12}, Δm^2_{31}, $sin^2\theta_{12}$ (< 1% in 2 years)**



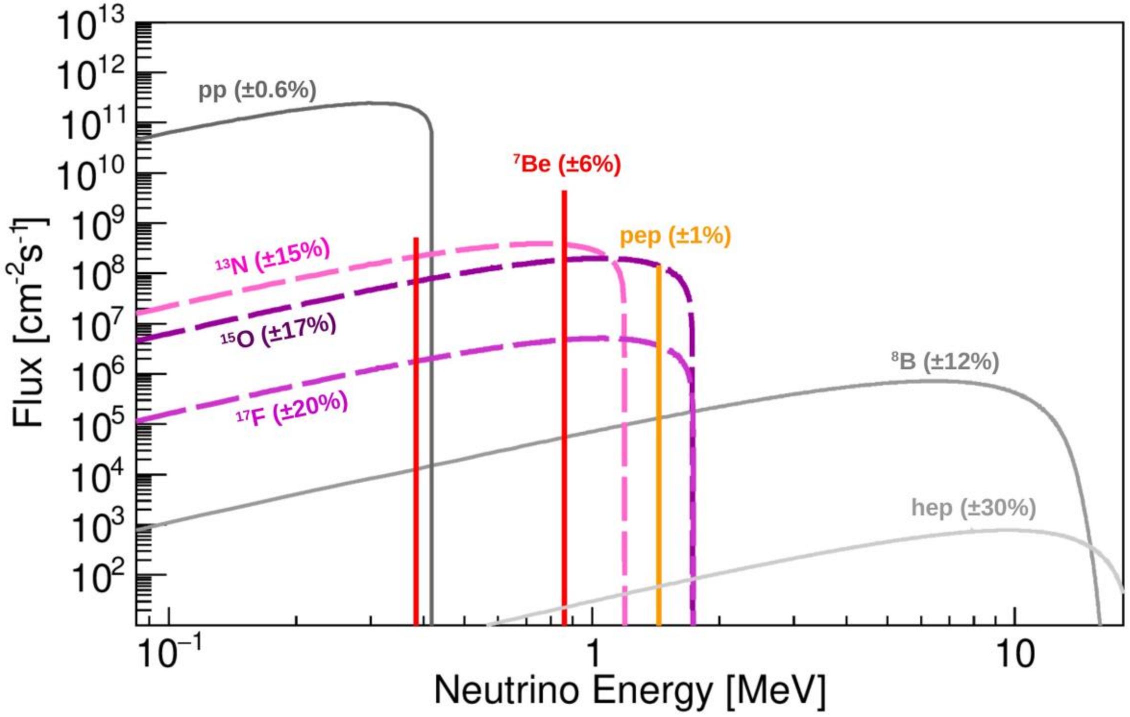
Chinese Phys. C ***46*** *123001*



	PDG 2020	**Nufit 5.2**	**JUNO 100 days**	**JUNO 6 years**
$\sin^2\theta_{13}$	3.2%	2.6%	48%	12%
$\sin^2\theta_{12}$	4.2%	4.0%	1.9%	0.5%
Δm^2_{21}	2.4%	2.8%	1.0%	0.3%
Δm^2_{31}	1.3%	1.1%	0.8%	0.2%

Solar neutrinos

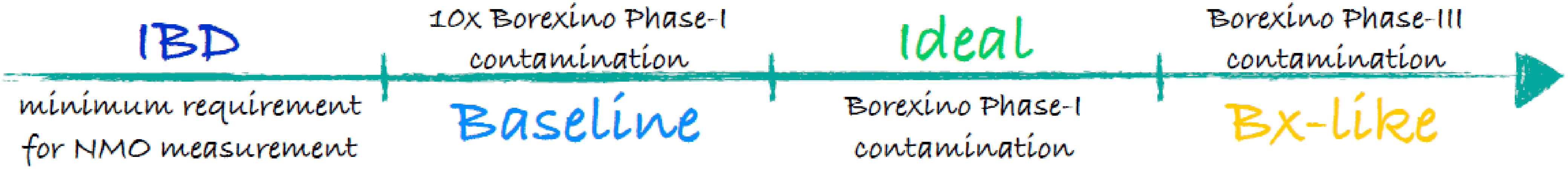
JUNO can measure solar neutrino in the ES channel: $e^- + \nu \rightarrow e^- + \nu$



- The only real-time probes for the sun core
- Neutrinos are produced in sun fusion reactions: pp chain (99%) and CNO cycle (1%)
- Can be used to measure the sun composition (metallicity)

➢ **A very low background level (LS radiopurity and cosmogenic ^{11}C) and accurate knowledge is required**

Different background scenarios:



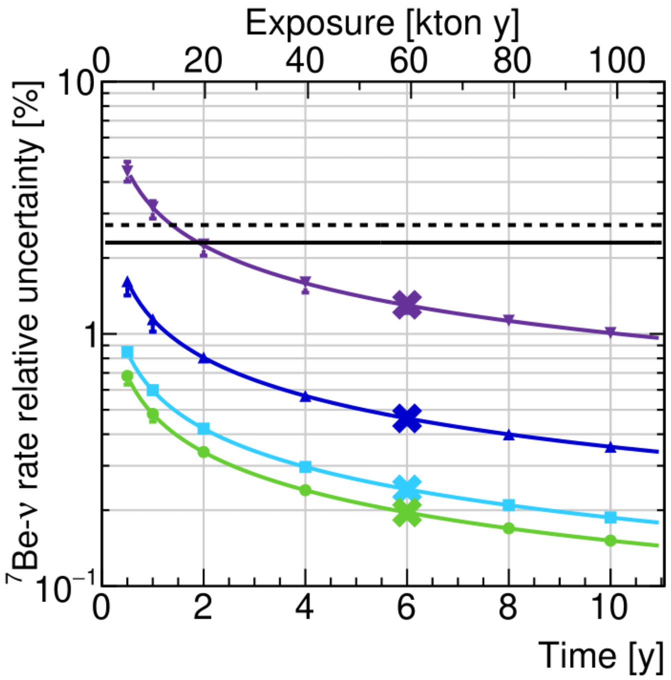
IBD	Baseline	Ideal	Bx-like
10^{-15} g/g ^{238}U-^{232}Th 10^{-16} g/g ^{40}K	10^{-16} g/g ^{238}U-^{232}Th 10^{-17} g/g ^{40}K	10^{-17} g/g ^{238}U-^{232}Th 10^{-18} g/g ^{40}K	~10^{-19} g/g ^{238}U-^{232}Th ~10^{-19} g/g ^{40}K

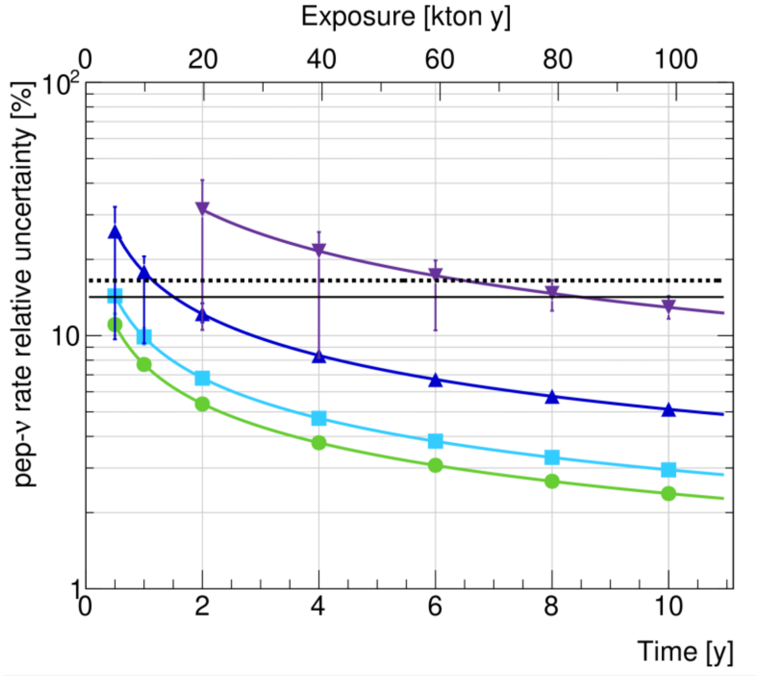
arXiv:2303.03910v1

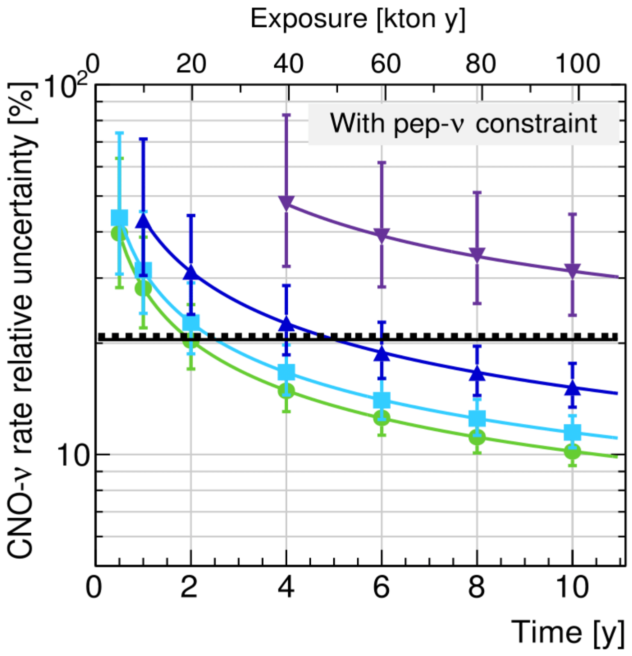
Solar neutrinos ^{7}Be, pep, CNO

Background scenarios:
- min. requirement for NMO (U-Th 10^{-15} g/g)
- 10 x Borexino Phase-I (U-Th 10^{-16} g/g)
- Borexino Phase-I (U-Th 10^{-17} g/g)
- Borexino Phase-III (U-Th 10^{-19} g/g)

- 7Be: <2,7% (Borexino) in 1-2 years
- pep: <17% (Borexino) in 6 years for IBD scenario and 1-2 years in other bkg scenarios
- CNO: <20% (Borexino) in 2-4 years based on bkg scenario (except IBD)





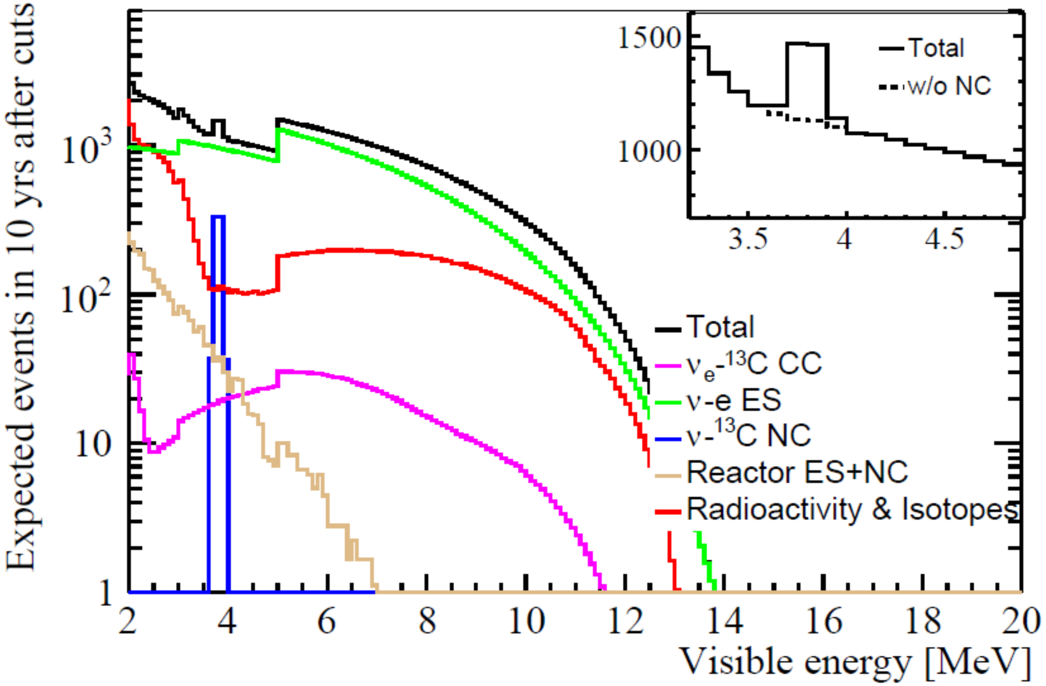


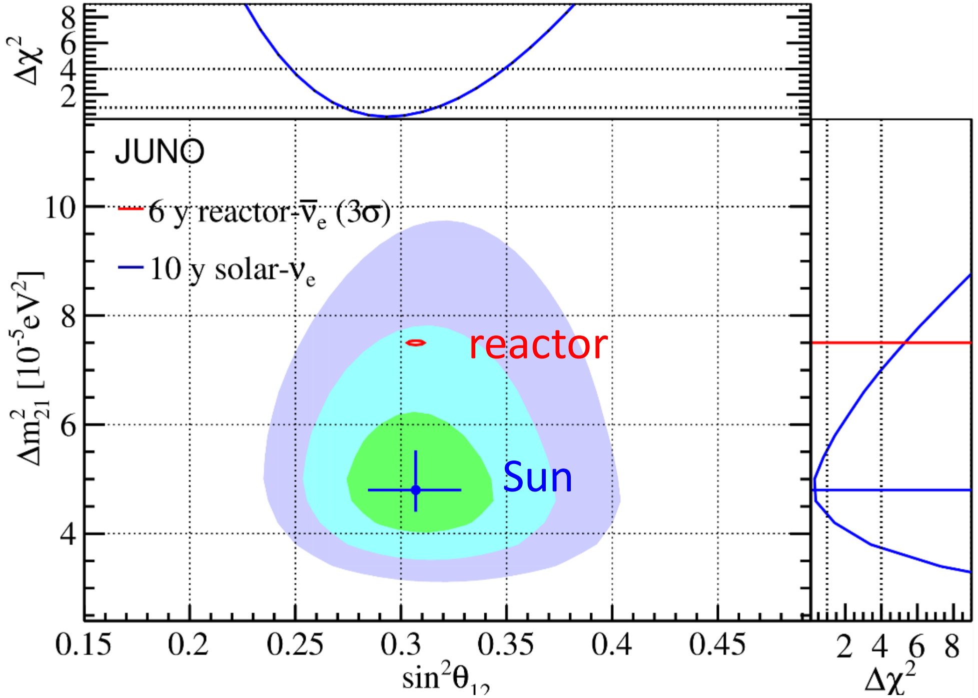
Solar neutrinos ^{8}B

^{8}B neutrino main channel: ES $e^- + \nu \rightarrow e^- + \nu$

Also visible via NC/CC on ^{13}C (200t): $\nu_e + {}^{13}C \rightarrow e^- + {}^{13}N$ and $\nu_x + {}^{13}C \rightarrow \nu_x + {}^{13}C$

Model independent measurement of ^{8}B neutrino flux (~5%) and oscillation parameters $\boldsymbol{\Delta m^2_{21}, sin^2\theta_{12}}$

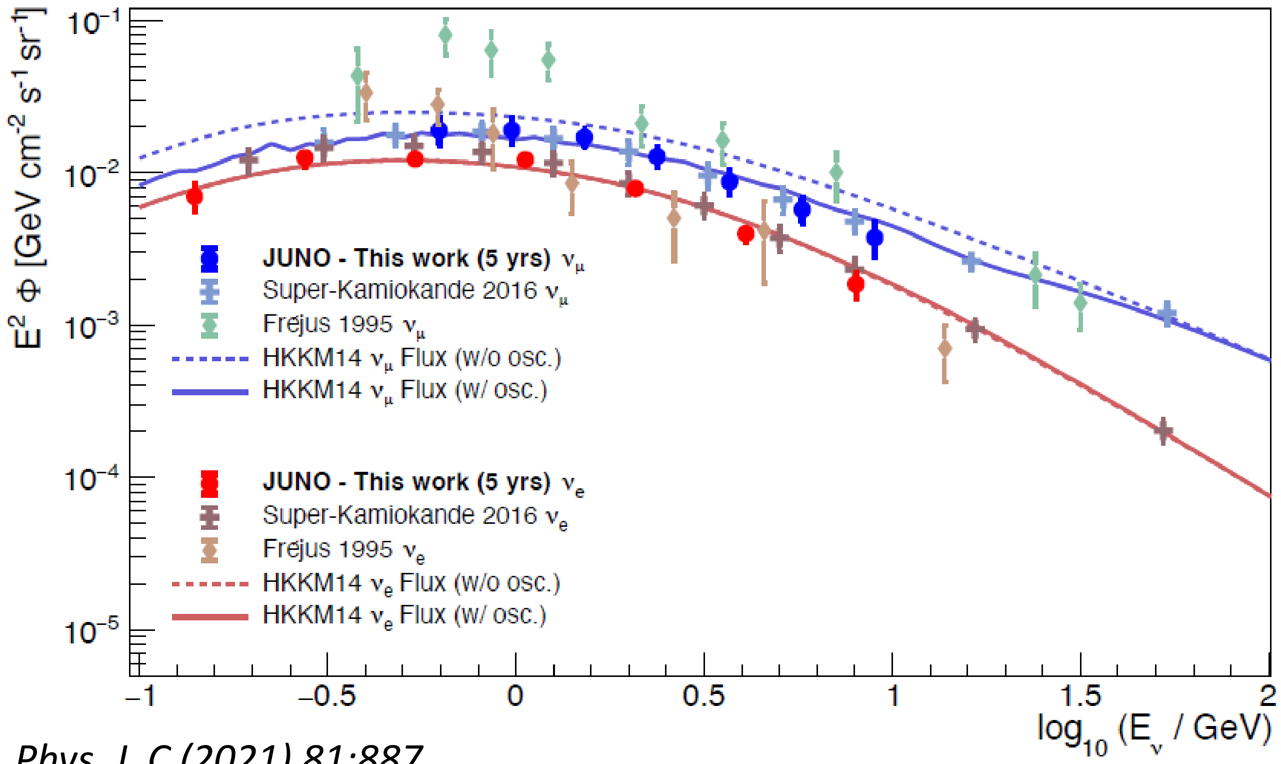




arXiv:2210.08437v1

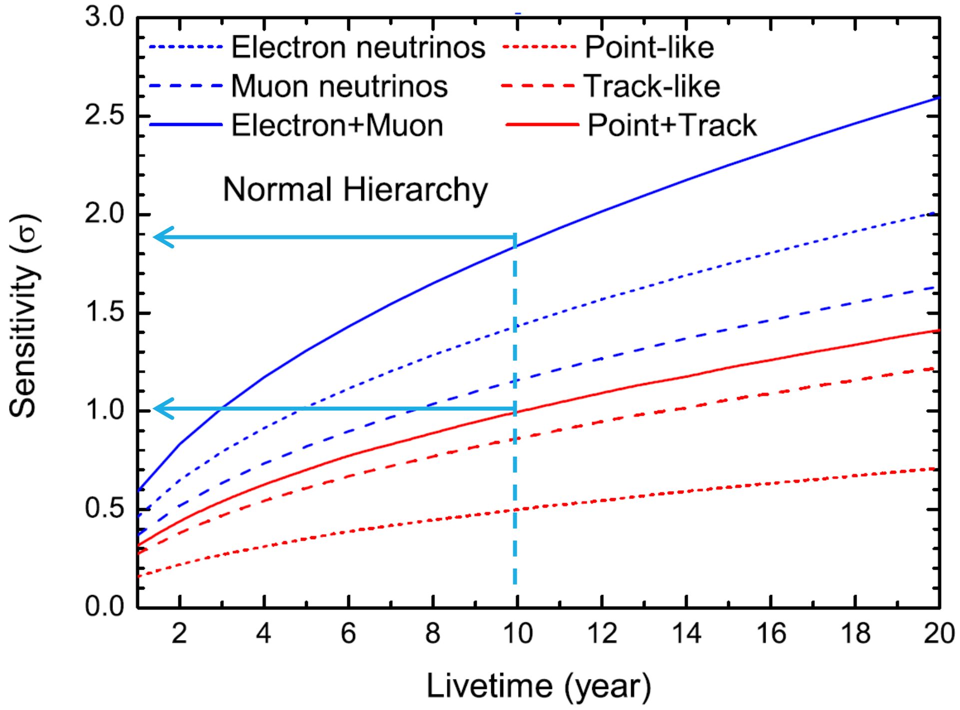
Atmospheric neutrinos

- One of the first measurement with a LS detector (the current are mainly based on Cherenkov detectors)
- Detection via CC (μ and e) and NC (all)
- μ/e flavor separation based on 3″ PMTs hit-time and LPMTs waveform features
- Measurement of θ_{23}
- Complementary measurement of NMO with matter effect (~ 1-1,8σ in 10 years)
- Validation of cross-sections in sub-GeV energy range



Eur. Phys. J. C (2021) 81:887

Yellow book (2016)

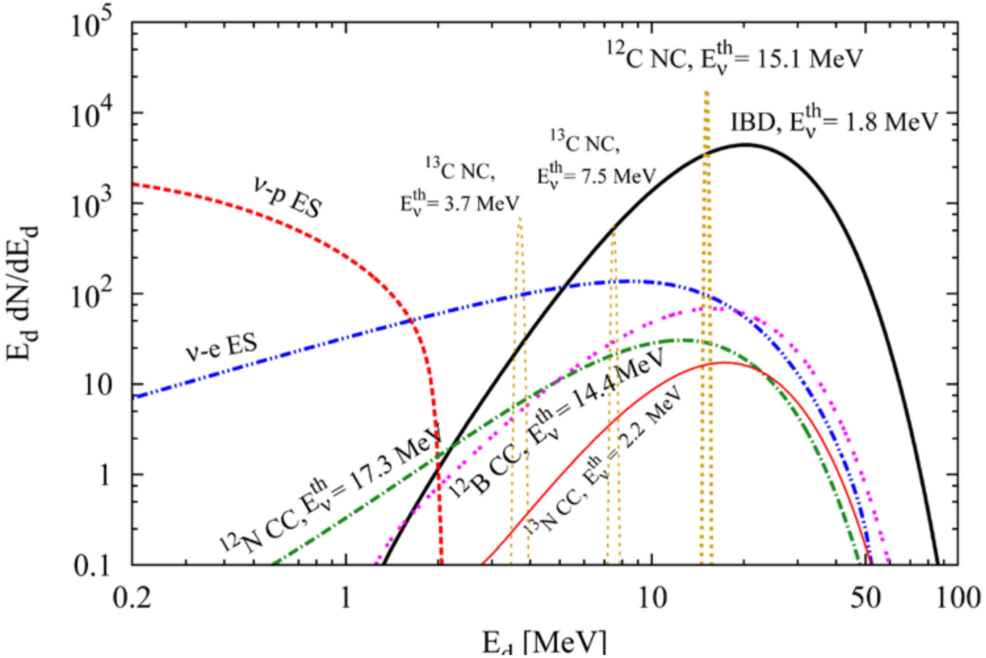


More realistic sensitivity study with reconstruction performance and combined with reactor anti-nu are in progress.

Supernova neutrinos: Core collapse and diffuse background

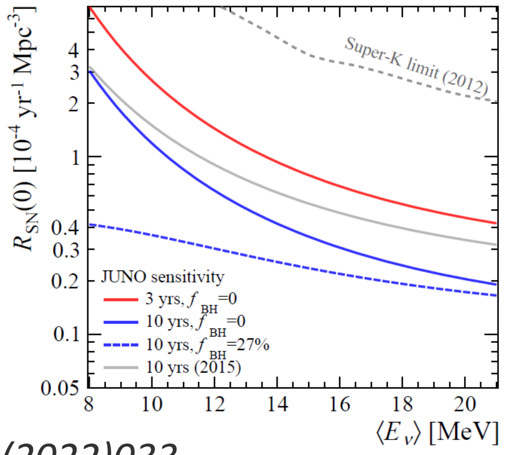
Core collapse SN

- Core-collapse SN emits ~99% of the energy via neutrinos
- SN rate: ~3 per century
- Multi-channel detection -> all flavor
- Determination of time evolution, energy spectra and flavor content
- Expected rate @ 10 kpc: 5000 IBD, 2000 pES, 300 eES, 300 NC, 200 CC



Diffuse SN neutrino background

- Integrated flux from past SN in the visible universe (SN rate: ~10 per second)
- Provide information about the star formation rate
- Many background sources (reactor IBD, atmospheric ...)
- Expected rate: 2-4 per year (IBD channel in 10-30 MeV)
- Expected discovery potential: 3σ in 3 years



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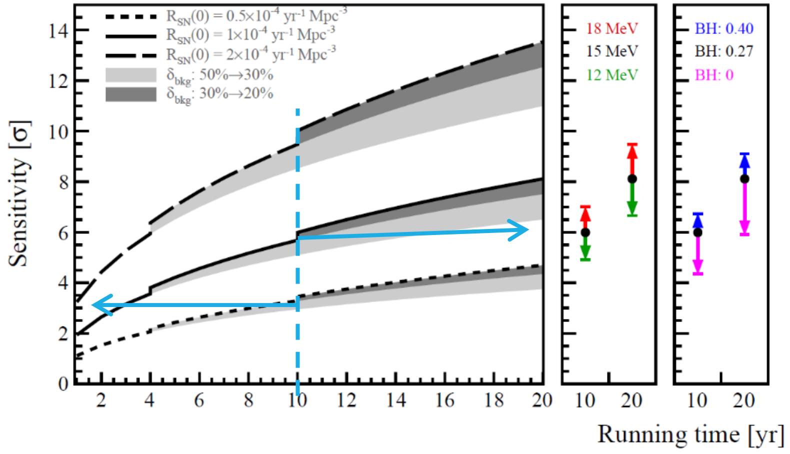
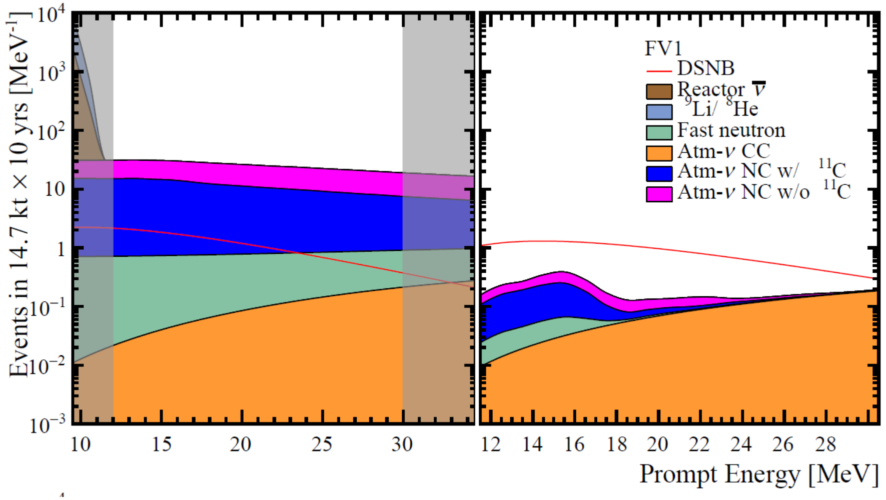


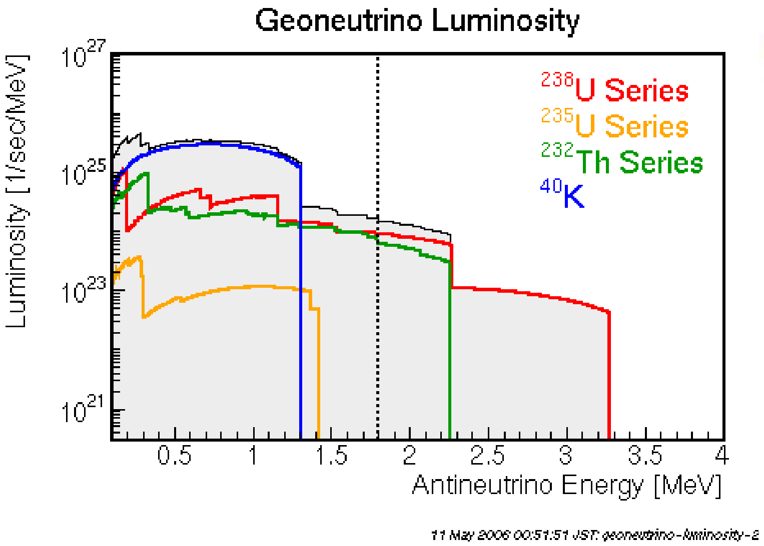


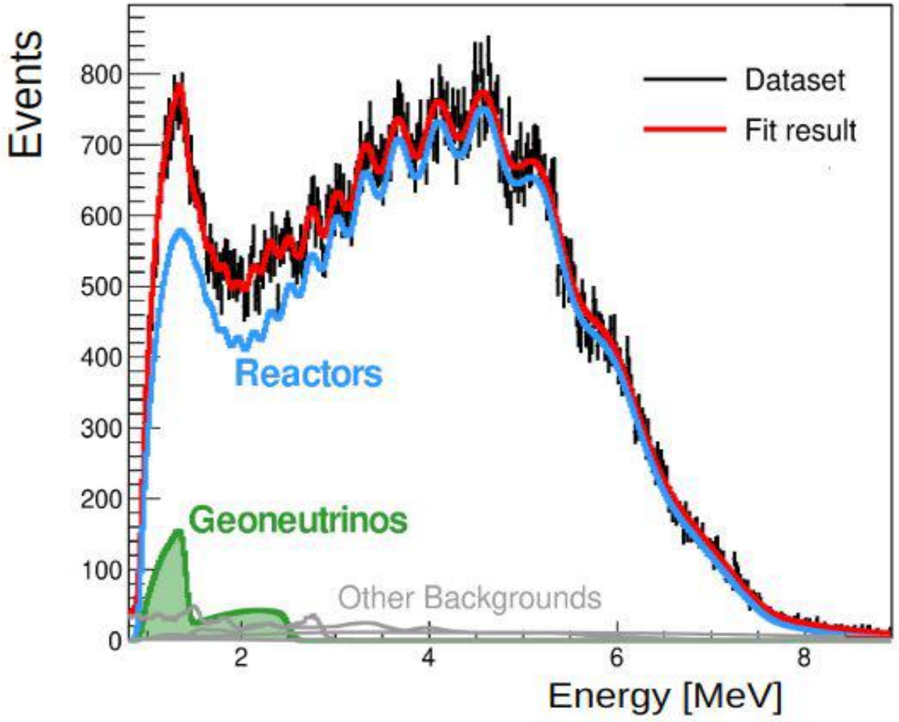
Geoneutrinos

- Geoneutrino are produced from β decays of radioactive nuclides in the earth crust and mantle
- Expected rate at JUNO: 400 events/year via IDB
- Current world sample (KamLAND+ Borexino): ~200
- High background from reactor antineutrino
- Geological study of the local crust is crucial to separate the mantle contribution (ongoing)
- The knowledge of the reactor spectrum shape is crucial (TAO)

- Expected results:
  - Precision measurement of total geoneutrino signal at fixed U/Th ratio: ~8% in 10 years (15% KamLAND)
  - Precision measurement of U and Th components:

	6 years	10 years
^{232}Th:	**~40%**	**~35%**
^{238}U:	**~35%**	**~30%**
^{232}Th+^{238}U:	**~18%**	**~15%**
^{232}Th/^{238}U ratio:	**~70%**	**~55%**

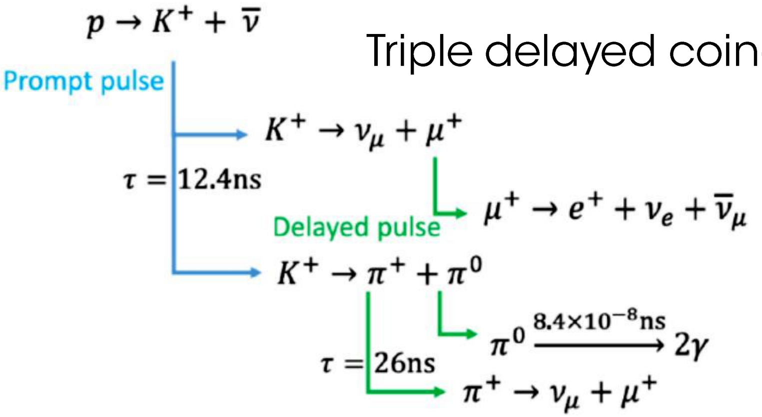




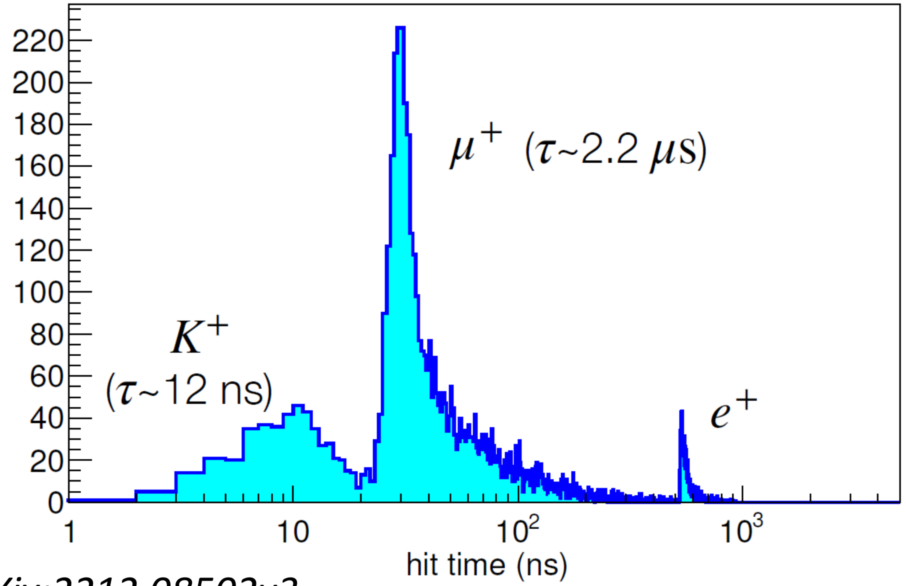
Proton decay

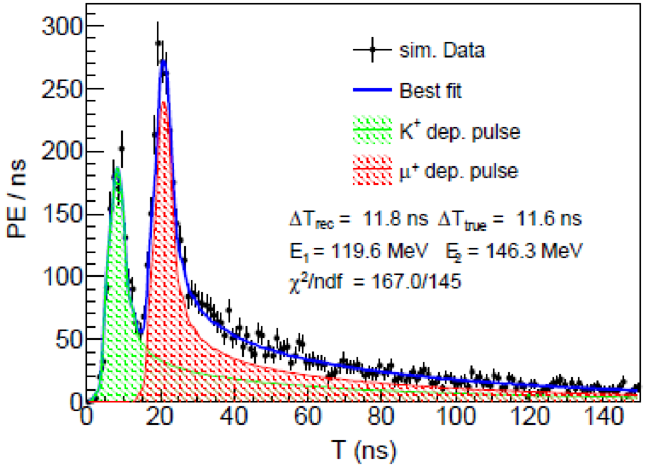
Huge mass of LS provide high sensitivity to proton decay: $p \rightarrow \bar{\nu} + K^+$

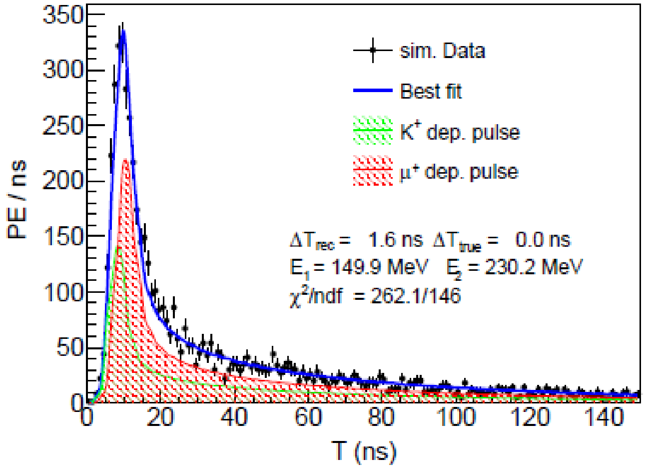
Triple delayed coincidence → background suppression

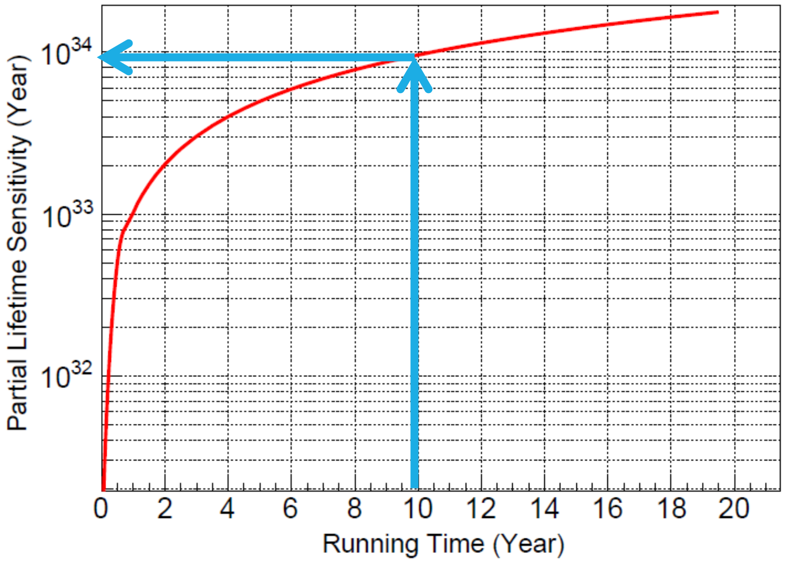


Time-of-flight-corrected Hit Time









Expected sensitivity in 10 years:
$9.6 \cdot 10^{33}\ y$ @90% CL

Super-K result: $> 5.9 \cdot 10^{33}\ y$ *@90% CL*

arXiv:2212.08502v3

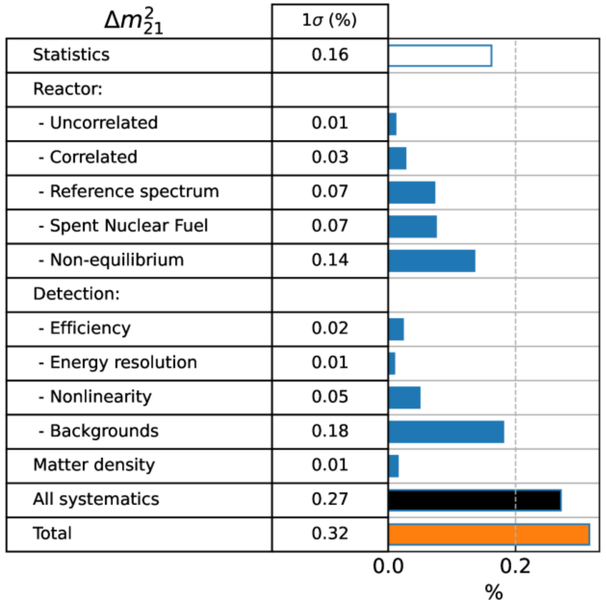
Summary

- JUNO is a neutrino observatory with unprecedented features
- Rich physics program in particle and astroparticle physics
- Main goal: determine the neutrino mass ordering at $> 3\sigma$ in 6 years
- Measurement of oscillation parameter at sub-percent level
- Measurement of other neutrino sources: solar, atmospheric, supernova and geo neutrinos
- Other physics topic (e.g. proton decay)
- Data taking start in 2024

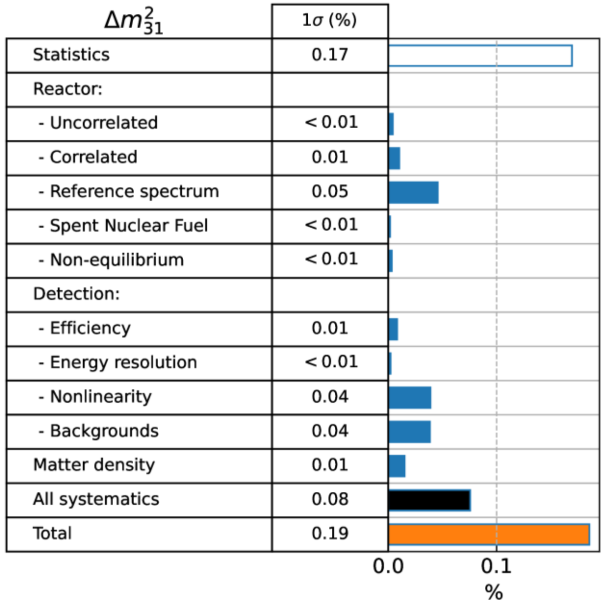
Thank you
for your attention!

Backup slides

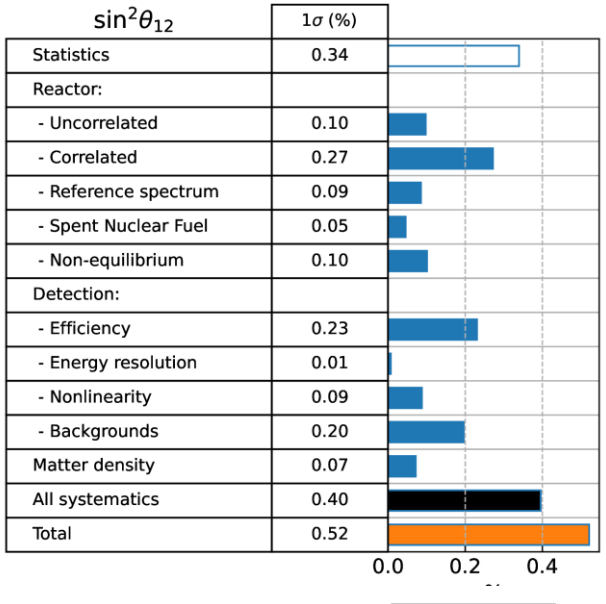
Oscillation parameters precise measurements



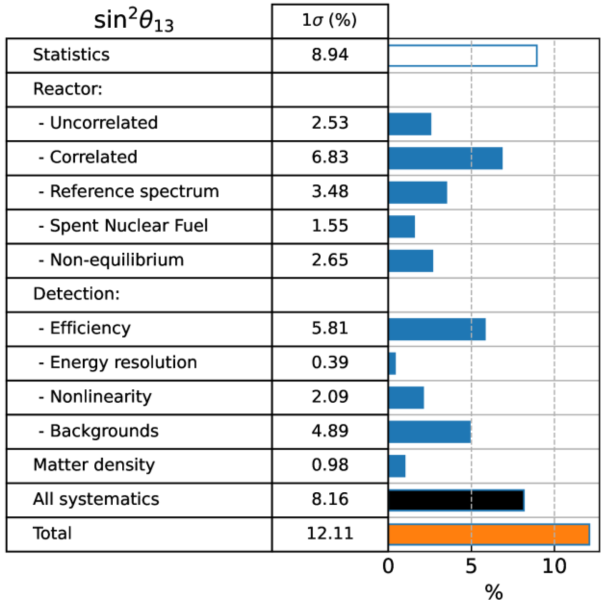
Δm^2_{21}	1σ (%)
Statistics	0.16
Reactor:	
- Uncorrelated	0.01
- Correlated	0.03
- Reference spectrum	0.07
- Spent Nuclear Fuel	0.07
- Non-equilibrium	0.14
Detection:	
- Efficiency	0.02
- Energy resolution	0.01
- Nonlinearity	0.05
- Backgrounds	0.18
Matter density	0.01
All systematics	0.27
Total	0.32



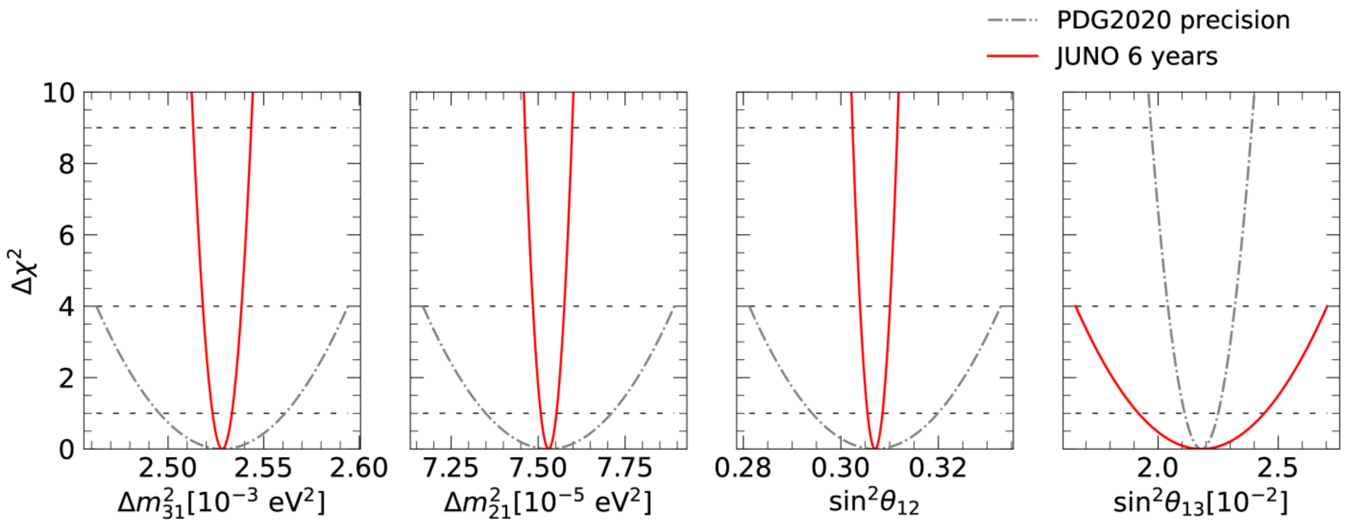
Δm^2_{31}	1σ (%)
Statistics	0.17
Reactor:	
- Uncorrelated	< 0.01
- Correlated	0.01
- Reference spectrum	0.05
- Spent Nuclear Fuel	< 0.01
- Non-equilibrium	< 0.01
Detection:	
- Efficiency	0.01
- Energy resolution	< 0.01
- Nonlinearity	0.04
- Backgrounds	0.04
Matter density	0.01
All systematics	0.08
Total	0.19

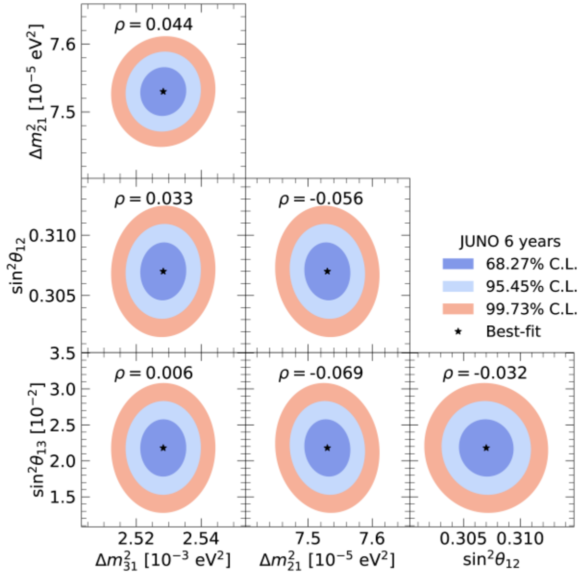


$\sin^2\theta_{12}$	1σ (%)
Statistics	0.34
Reactor:	
- Uncorrelated	0.10
- Correlated	0.27
- Reference spectrum	0.09
- Spent Nuclear Fuel	0.05
- Non-equilibrium	0.10
Detection:	
- Efficiency	0.23
- Energy resolution	0.01
- Nonlinearity	0.09
- Backgrounds	0.20
Matter density	0.07
All systematics	0.40
Total	0.52

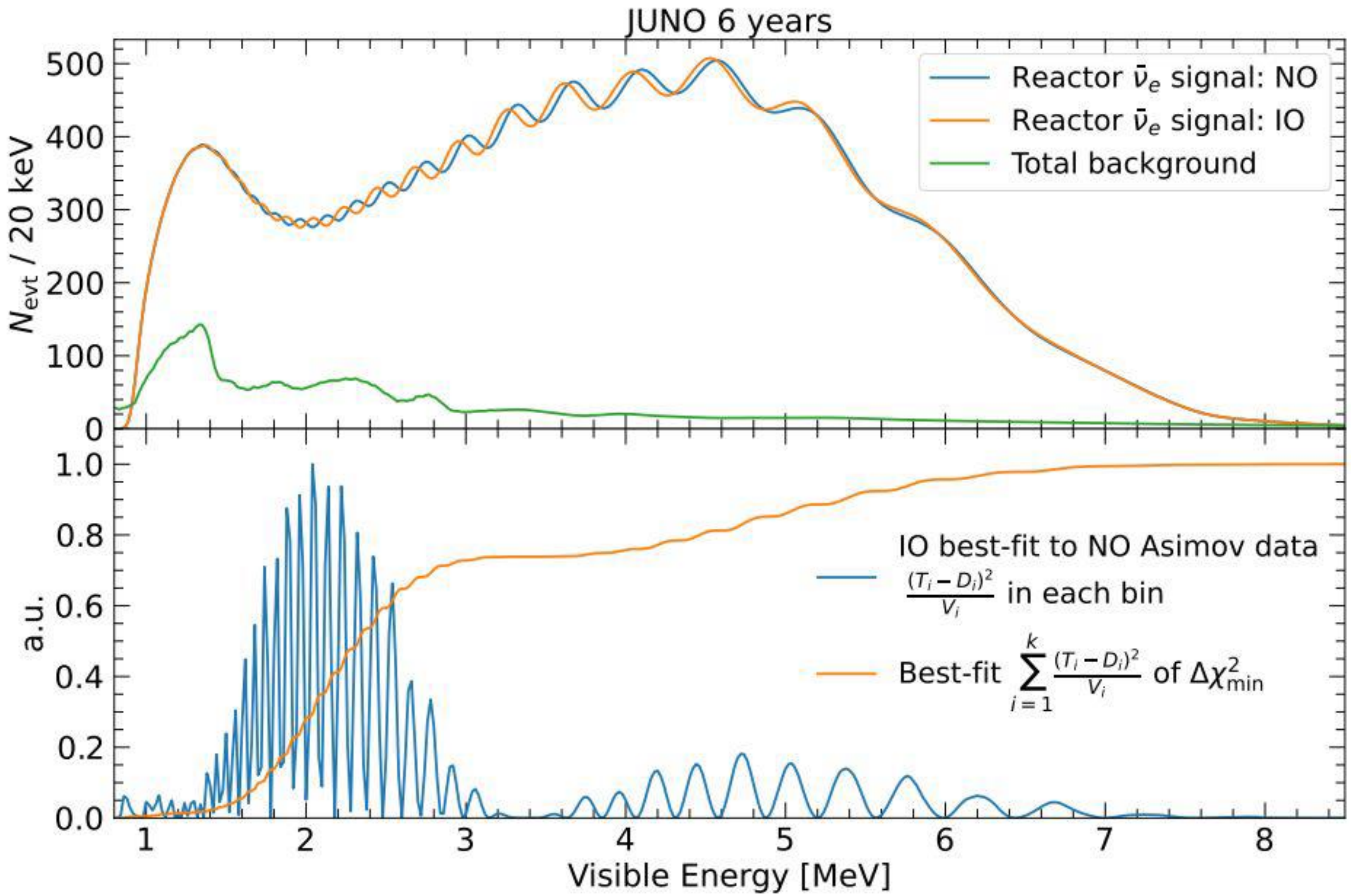


$\sin^2\theta_{13}$	1σ (%)
Statistics	8.94
Reactor:	
- Uncorrelated	2.53
- Correlated	6.83
- Reference spectrum	3.48
- Spent Nuclear Fuel	1.55
- Non-equilibrium	2.65
Detection:	
- Efficiency	5.81
- Energy resolution	0.39
- Nonlinearity	2.09
- Backgrounds	4.89
Matter density	0.98
All systematics	8.16
Total	12.11

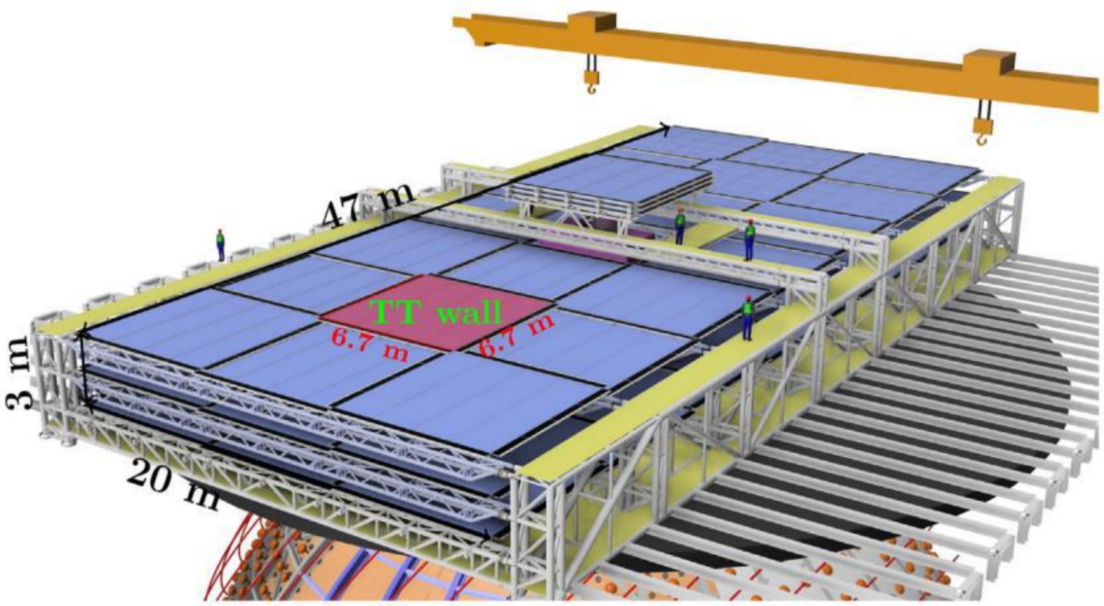


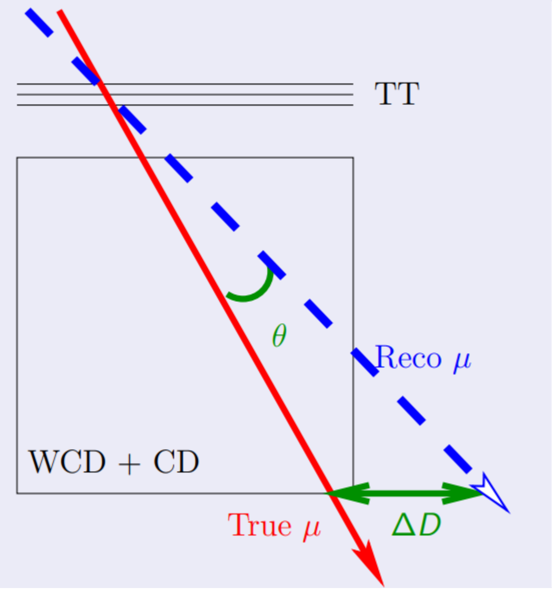


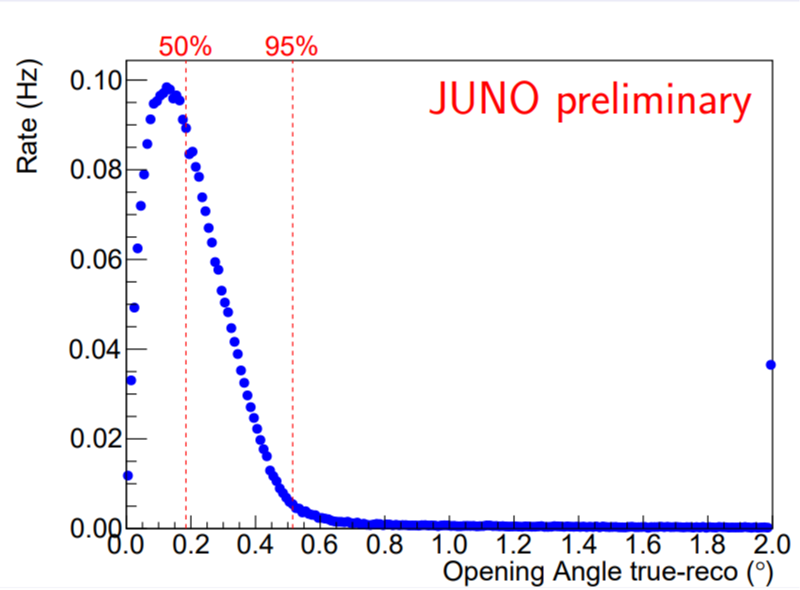
Spectral contribution to $\Delta\chi^2$



Top tracker for muon veto





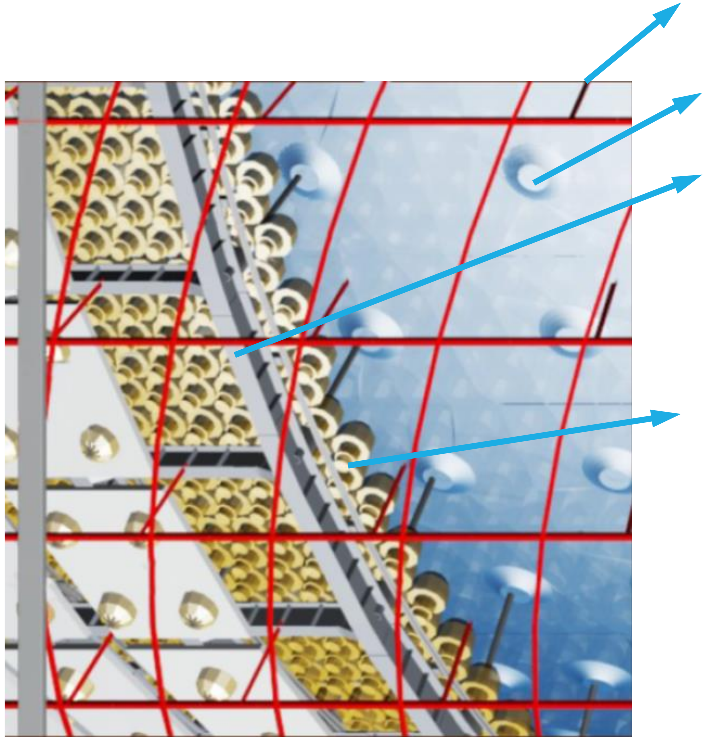


Plastic scintillator from the OPERA experiment

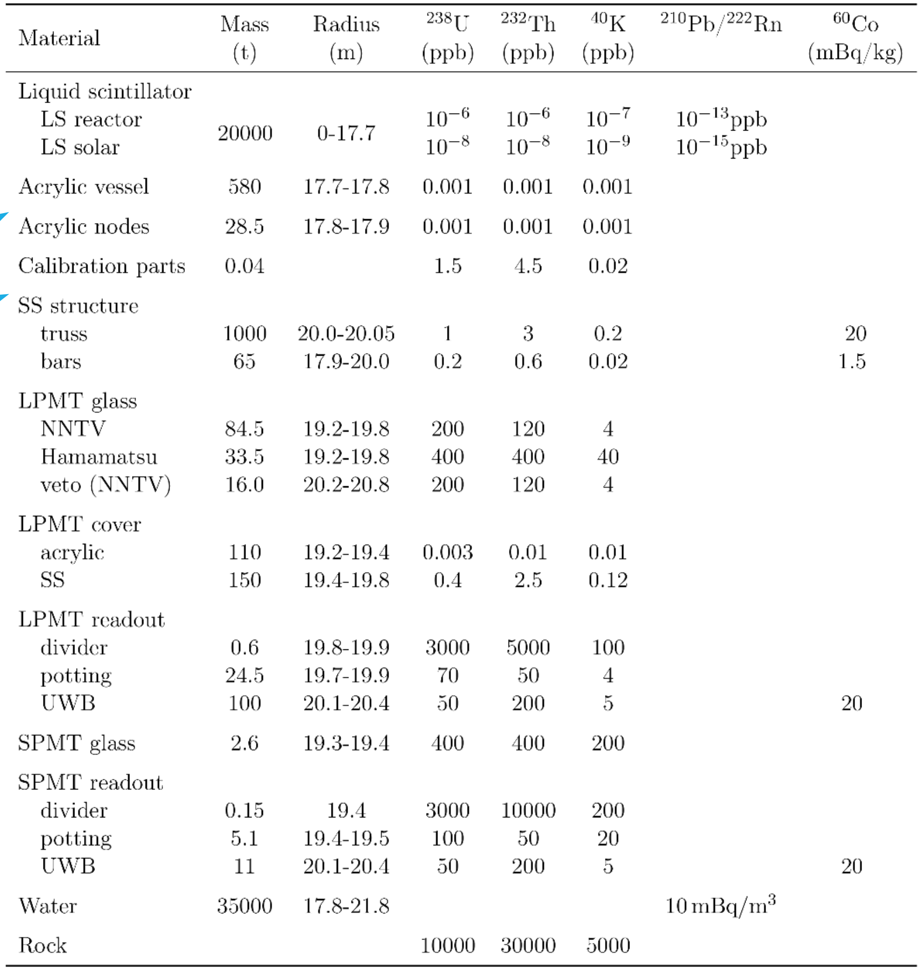
- About 60% coverage on the top, three layers to ensure precise tracking and reduce accidental coincidence
- High XY granularity (2,6x2,6 cm^2) and angular resolution (0,2° median)
- Provide well reconstructed muon sample for other system
- The Top Tracker support bridge is ready for production.

Radiopurity requirements

All materials must be selected for their radiopurity



Highest radiopurity requirement for inner material



Material	Mass (t)	Radius (m)	^{238}U (ppb)	^{232}Th (ppb)	^{40}K (ppb)	^{210}Pb/^{222}Rn	^{60}Co (mBq/kg)
Liquid scintillator							
LS reactor	20000	0-17.7	10^{-6}	10^{-6}	10^{-7}	10^{-13}ppb	
LS solar			10^{-8}	10^{-8}	10^{-9}	10^{-15}ppb	
Acrylic vessel	580	17.7-17.8	0.001	0.001	0.001		
Acrylic nodes	28.5	17.8-17.9	0.001	0.001	0.001		
Calibration parts	0.04		1.5	4.5	0.02		
SS structure							
truss	1000	20.0-20.05	1	3	0.2		20
bars	65	17.9-20.0	0.2	0.6	0.02		1.5
LPMT glass							
NNTV	84.5	19.2-19.8	200	120	4		
Hamamatsu	33.5	19.2-19.8	400	400	40		
veto (NNTV)	16.0	20.2-20.8	200	120	4		
LPMT cover							
acrylic	110	19.2-19.4	0.003	0.01	0.01		
SS	150	19.4-19.8	0.4	2.5	0.12		
LPMT readout							
divider	0.6	19.8-19.9	3000	5000	100		
potting	24.5	19.7-19.9	70	50	4		
UWB	100	20.1-20.4	50	200	5		20
SPMT glass	2.6	19.3-19.4	400	400	200		
SPMT readout							
divider	0.15	19.4	3000	10000	200		
potting	5.1	19.4-19.5	100	50	20		
UWB	11	20.1-20.4	50	200	5		20
Water	35000	17.8-21.8				10 mBq/m^3	
Rock			10000	30000	5000		

Radius

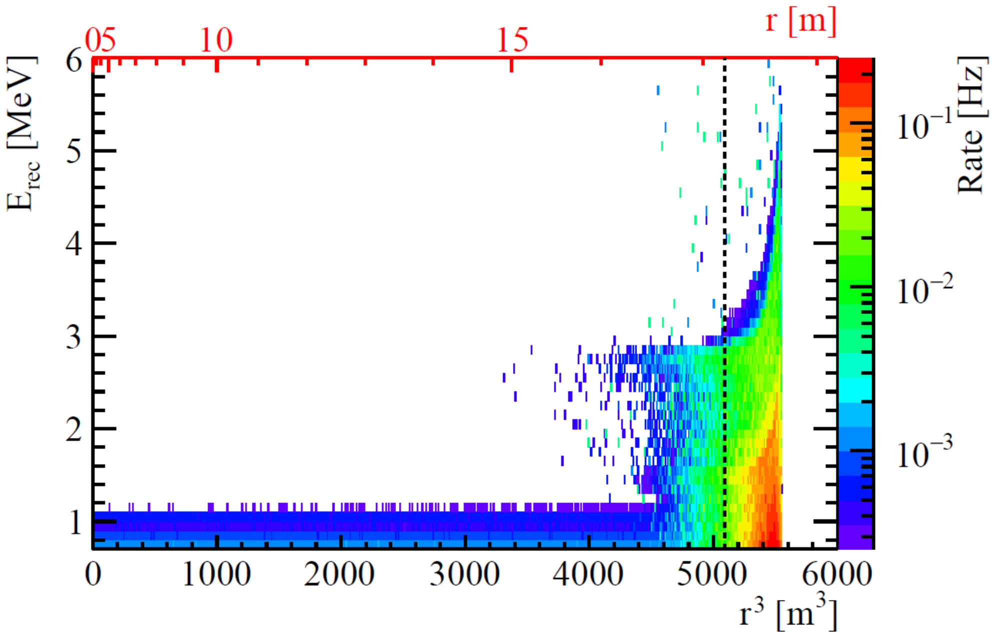
0 m	**~ppq -> 10^{-15} g/g** **10^{-8} Bq/kg (^{238}U)**
17,7 m	
17,82 m	~ppt -> 10^{-12} g/g 10^{-5} Bq/kg (^{238}U)
19,50 m	~ ppb /ppm
21,75 m	

Radioactive background budget

Material	Mass	Target impurity concentration					Singles	
	[t]	^{238}U [ppb]	^{232}Th [ppb]	^{40}K [ppb]	^{210}Pb [ppb]	^{60}Co [mBq/kg]	ALL [Hz]	FV [Hz]
LS-reactor	20000	10^{-6}	10^{-6}	10^{-7}	10^{-13}		2.5	2.2
Acrylic	610	10^{-3}	10^{-3}	10^{-3}			8.4	0.4
SS structure	65 1000	0.2 1	0.6 3	0.02 0.2		1.5 20	15.9	1.1
PMT glass	33.5 100.5 2.6	400 200 400	400 120 400	40 4 200			26.2	2.8
PMT readout	125 16.3	68 93	194 243	5 12		16 14	3.4	0.4
Other							2.5	0.3
Sum							59	7.2

E > 0.7 MeV (IBD cut)
FV cut: 17.2 m

-15% compared to the design



Accidental rate (IBD like signals)

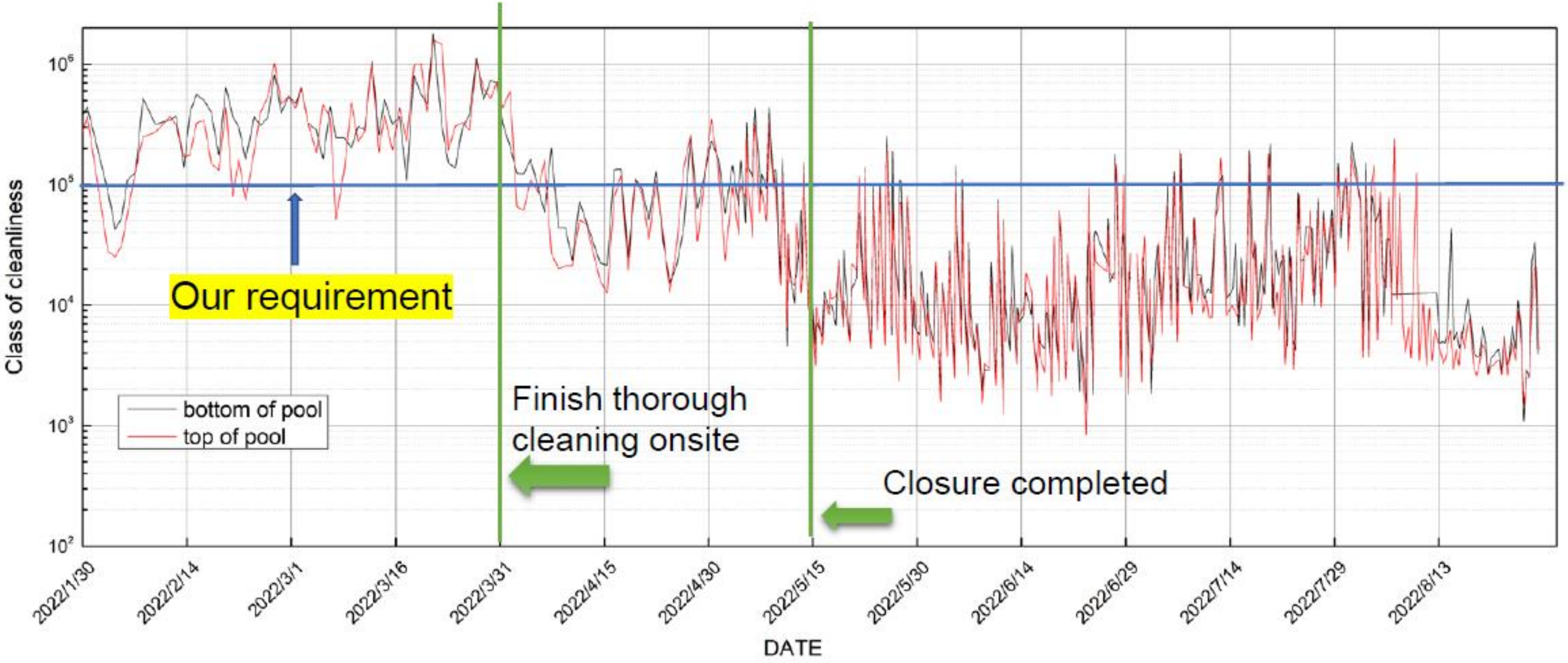
R_{acc} [cpd]	Fiducial volume radius [m]				
	17.0	17.1	17.2	17.3	17.4
E_{th} = 0.7 MeV	0.20	0.41	0.89	2.0	4.9
E_{th} = 0.8 MeV	0.19	0.38	0.83	1.9	4.6
E_{th} = 0.9 MeV	0.17	0.35	0.78	1.8	4.3

Experimental hall cleanliness

Temperature control:
(21±1) °C

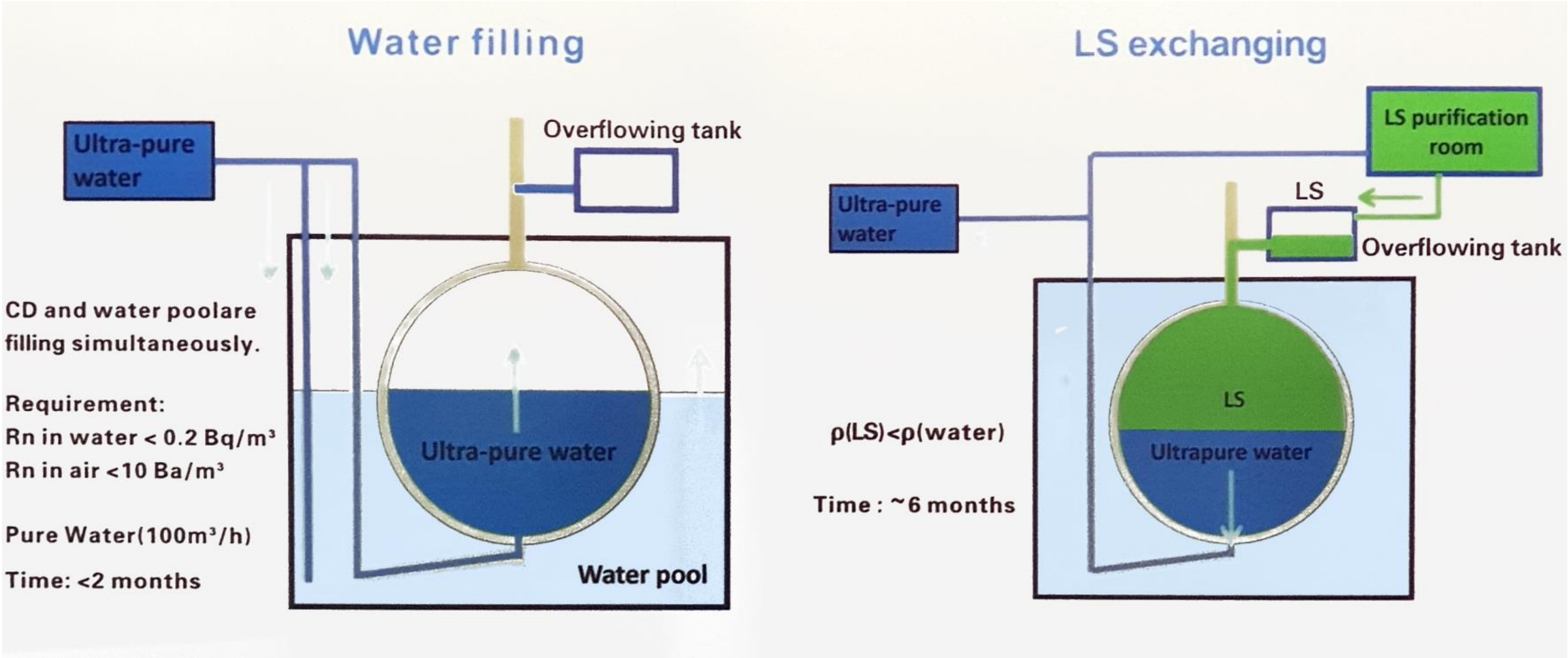
Clean environment during installation is crucial

- Class 100 k in WCD
- Class 10 k between PMTs and acrylic sphere
- Class 1 k inside the acrylic sphere



LS filling and CD commissioning

1. Filling water pool and CD with ultra-pure water (UPW) at the same level
2. LS-UPW exchange



CD and water poolare filling simultaneously.

Requirement:
Rn in water < 0.2 Bq/m³
Rn in air <10 Ba/m³

Pure Water(100m³/h)

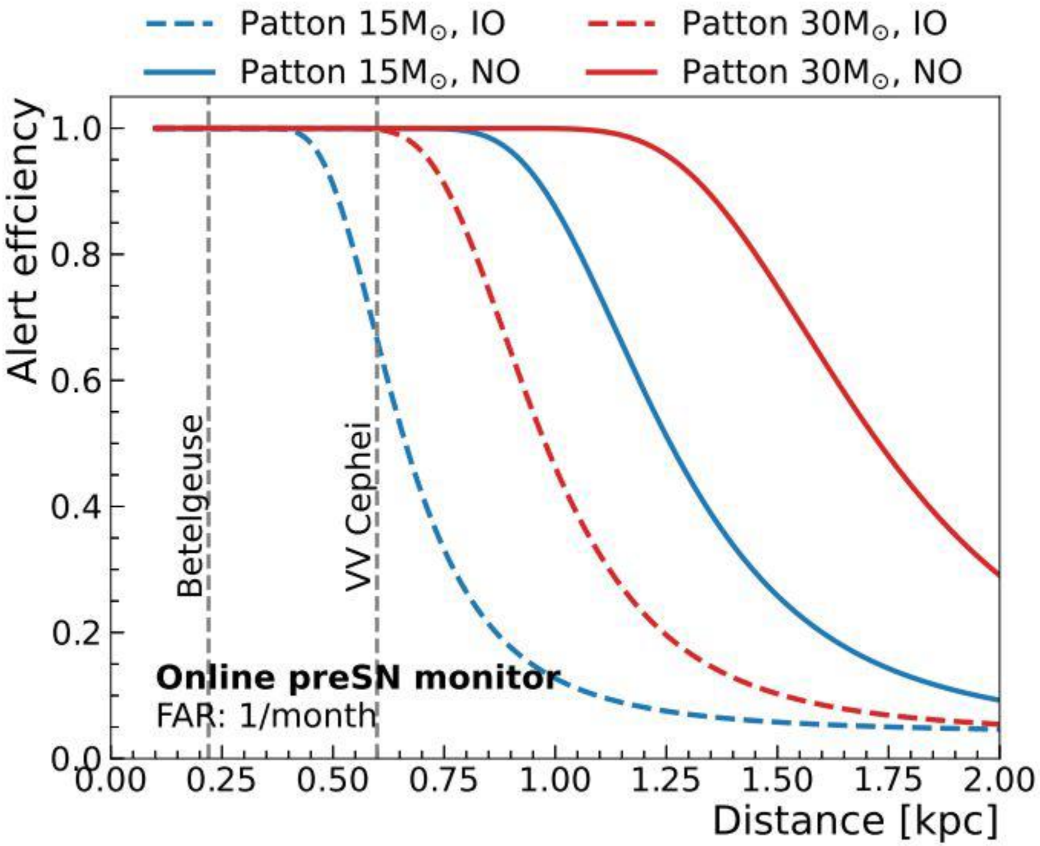
Time: <2 months

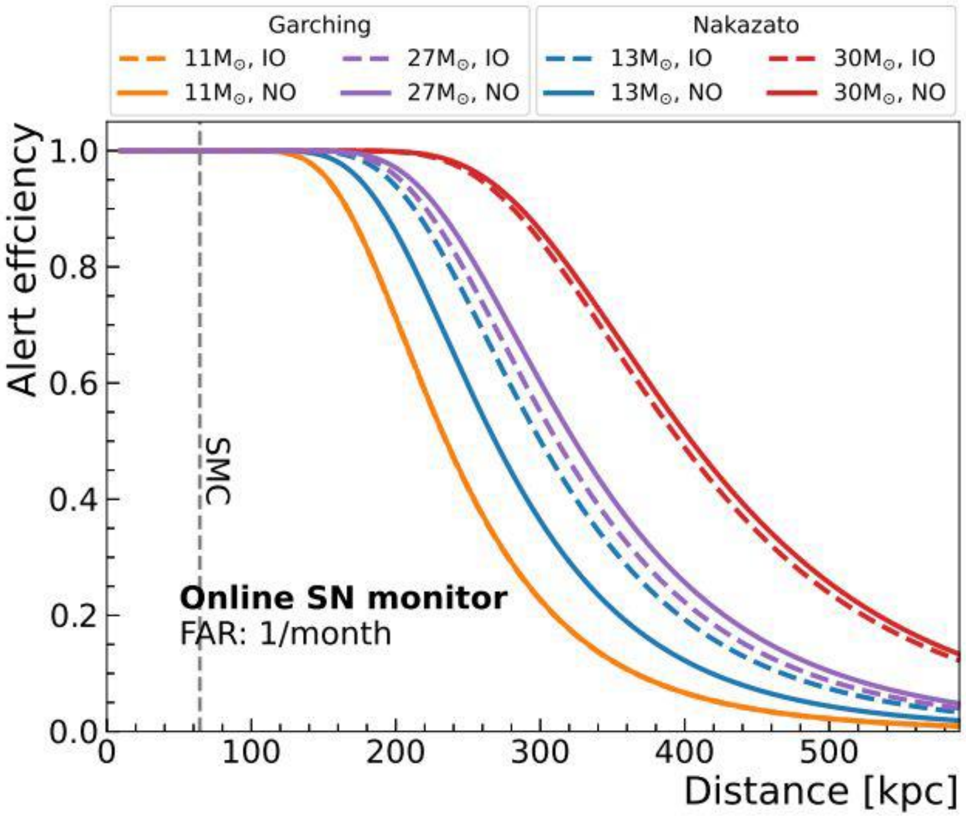
ρ(LS)<ρ(water)

Time : ~6 months

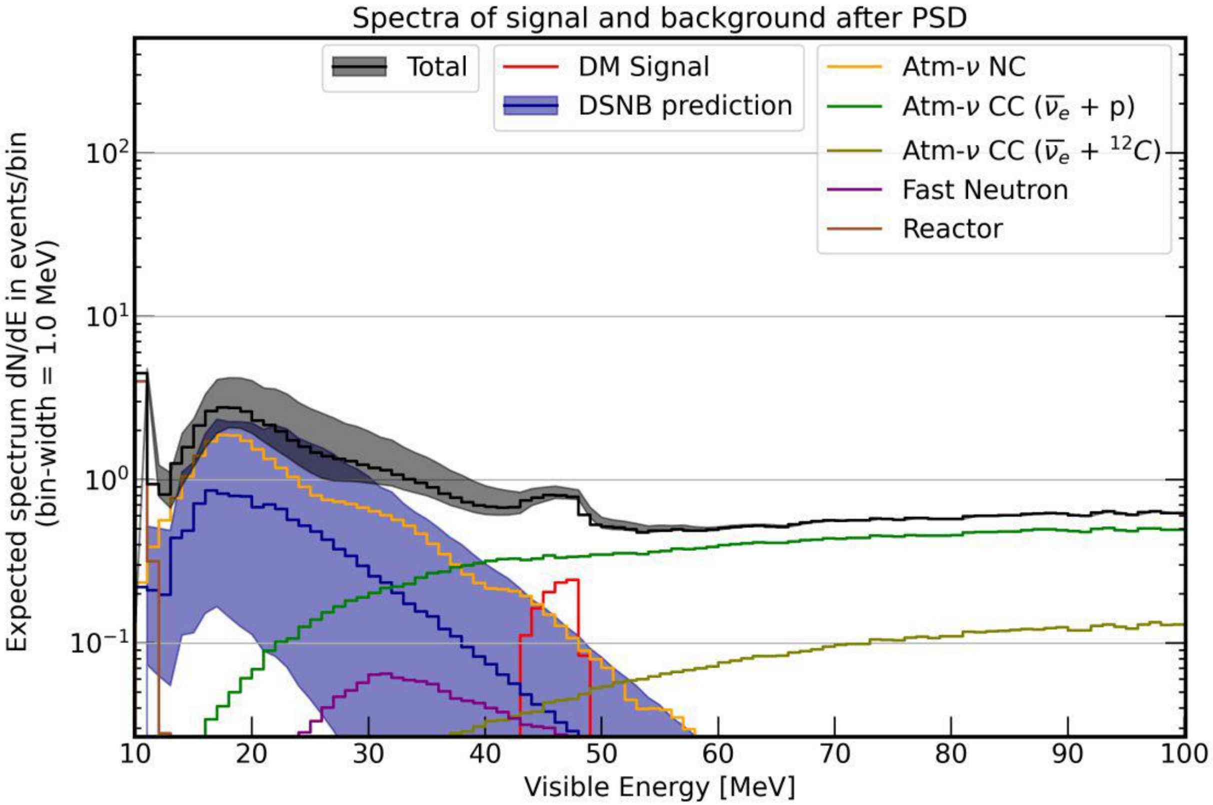
CCSN online monitor

- Capability to detect pre-SN neutrinos from close SN-candidates
- >50% efficiency to detect CCSN up to 250–300 kpc

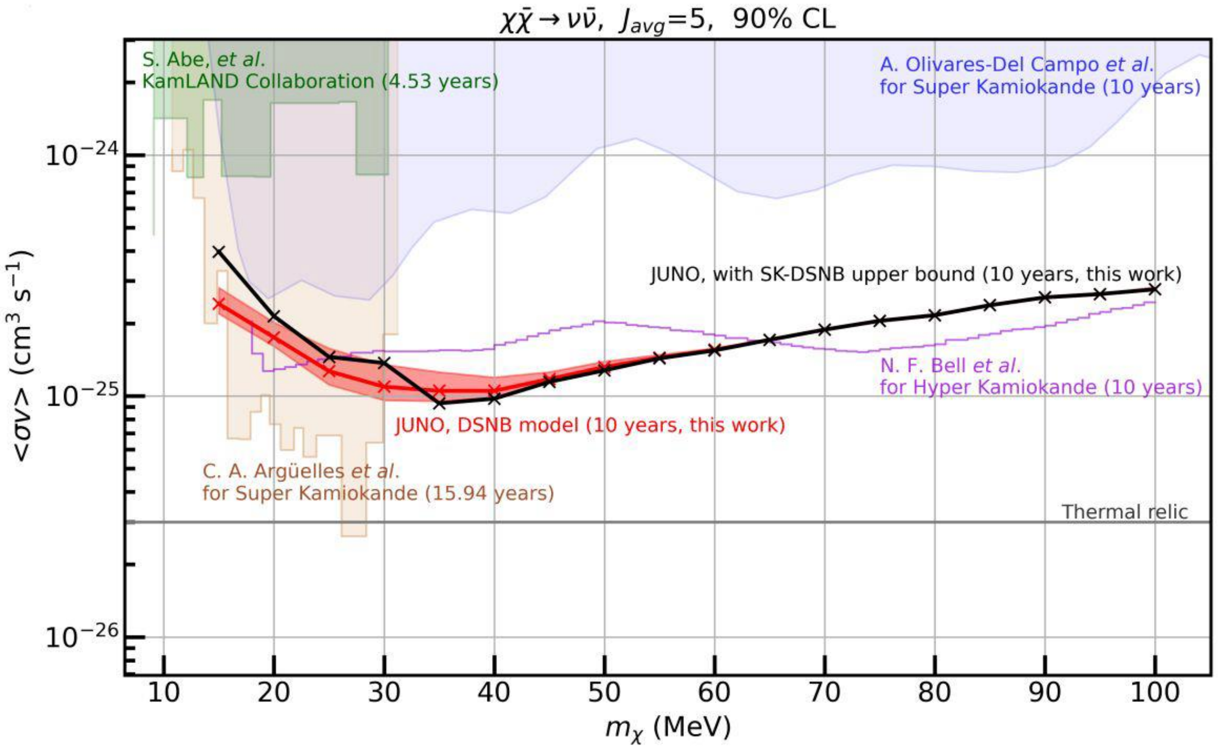




Dark matter search



- From dark matter self annihilation
- Detection in IBD channel in 15-100 MeV energy range
- PSD for atmospheric neutrino rejection



Expected sensitivity in 10 years:

$$\langle \sigma v \rangle = 1.1 \cdot 10^{-25} cm^3 s^{-1}$$

Sterile neutrino at TAO

- Very close to the Taishan NPP core (30m)
- High statistics (30x JUNO)
- High energy resolution (2% @ 1 MeV)

Sensitivity at the Δm^2 region of 0.05 – 1 eV^2:

complimentary to the longer baseline experiments