Status of JUNO

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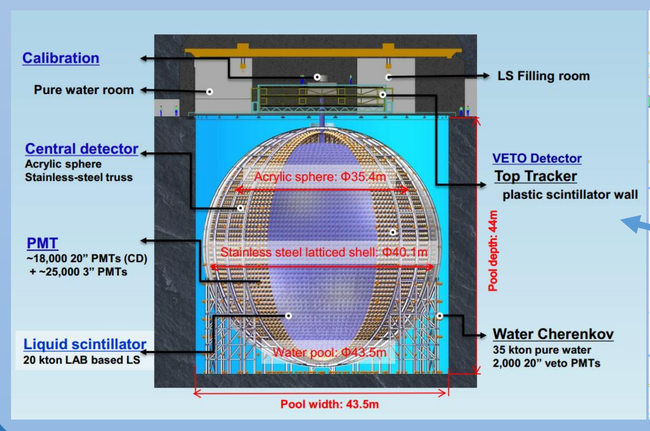
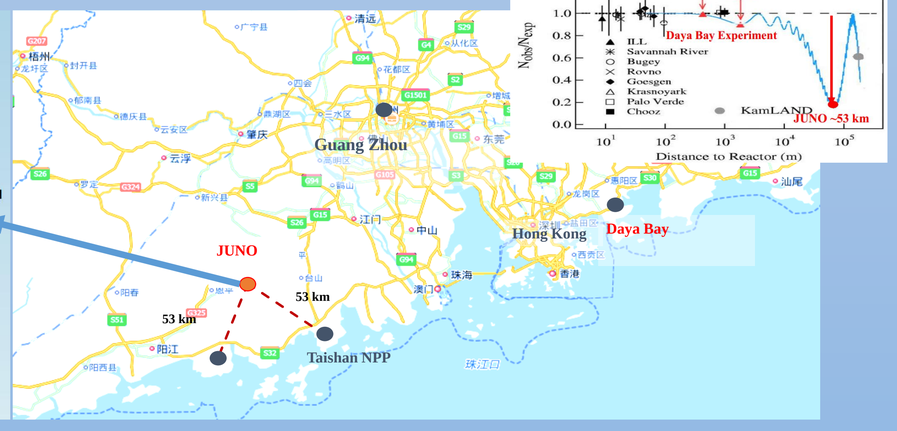
On behalf of JUNO Collaboration

The JUNO Experiment

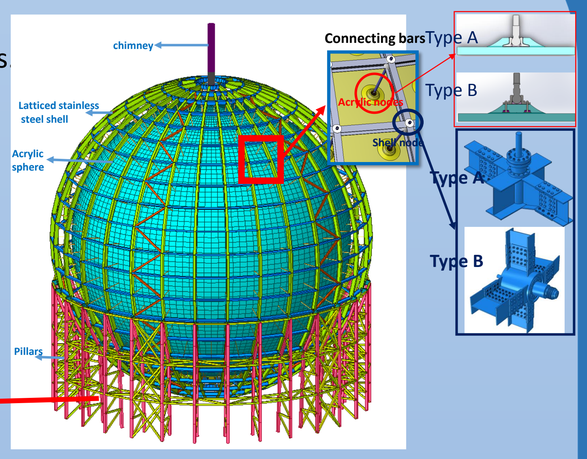
The Jiangmen Underground Neutrino Observatory (JUNO) , with its main purpose to determine neutrino mass hierarchy (MH), is located at Kaiping, Jiangmen in south China. It consists of a central detector, a water Cherenkov detector and a muon tracker. The central detector is a 35.4 meter diameter acrylic ball full filled with 20 kiloton liquid scintillator. In order to reach unprecedented $3\%/\sqrt{E(MeV)}$ energy resolution, ~18,000 20'' photomultiplier tubes (PMTs) and ~25,000 3'' PMTs will be used for photon detection.

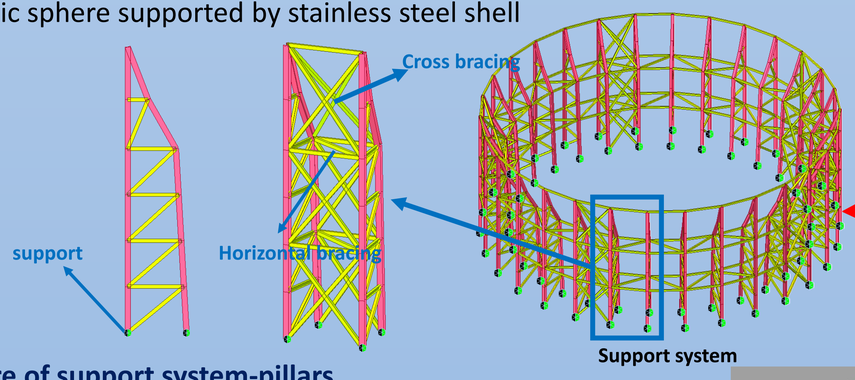




The Central Detector

- Acrylic sphere: Inner diameter 35.4m. Thickness 120mm.
- Stainless shell: Inner diameter 40.1m. Divided into 30 longitudes and 23 layers.
- Weight of acrylic sphere: ~600t.
- 590 connecting bars
- 60 pillars
- Acrylic sphere supported by stainless steel shell





Structure of support system-pillars

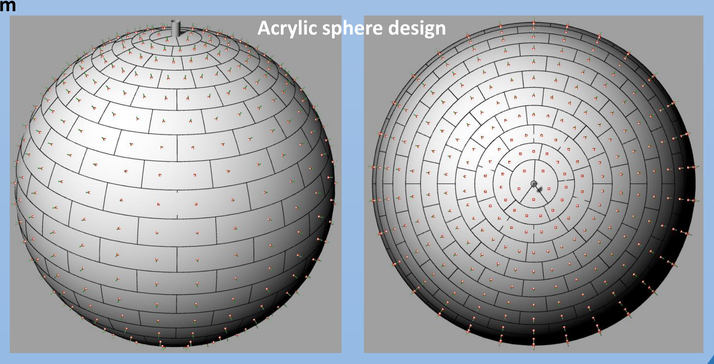
- 30 pillars
- 3 horizontal bracing
- 5 cross-bracing

Segmentation scheme

- 23 layers + 2 chimneys
- 291 pieces of acrylic panels in total
- Weight of acrylic sphere: 600t

Principles of Segmentation scheme:

- Minimize kinds of panels
- Meet the sizes of original panel: 2.8*8m
- Avoid cross connection seam
- Center distance of bars > 1.4m



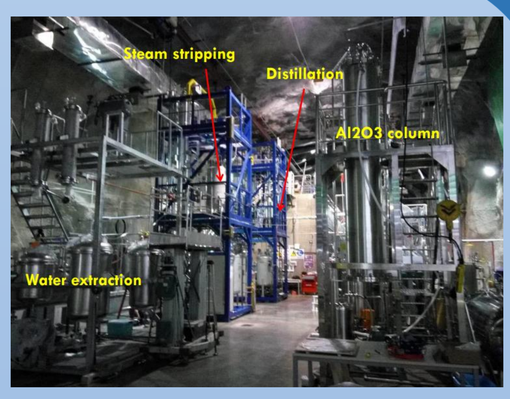
The liquid scintillator

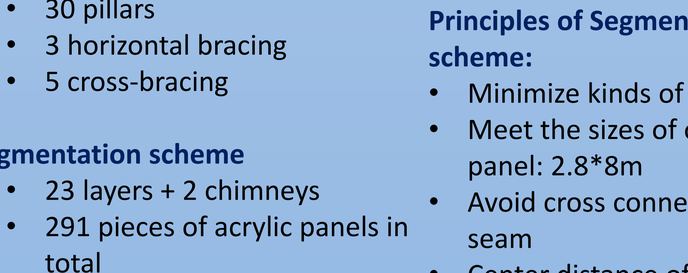
Requirements for LS

- Low background: $^{238}U < 10^{-15}g/g,\ ^{232}Th < 10^{-25}g/g,\ ^{40}K < 10^{-40}g/g$.
- High light yield: Optimize the concentrations of fluors
- Long attenuation length: >20m@430nm
- Purification:
  - Absorption, Distillation, Water extraction, Gas stripping.
- Preliminary recipe: LAB + 3g/L PPO + 15mg/L bis-MSB

LS Pilot Plants experiment

- Effects of light emitting substance
- Concentration to light yield and energy nonlinearity
- Check radioactive background
- Which purification method will be used and how to combine them ?
- Pre-study for JUNO LS mass production





Attenuation length is ~25m after purification

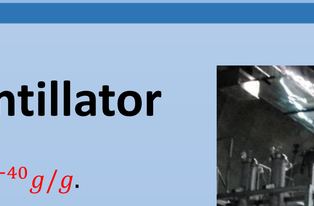
The Veto Detector

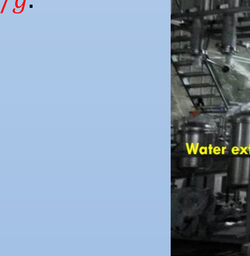
Targets of veto detector (top tracker + water Cherenkov detector)

- Cosmogenic isotope reduction ($^{9}Li/\ ^{8}He$)→requires a precise muon track reconstruction
- Fast neutrons background rejection → passive shielding and possible tagging.
- Radioactivity from rock shielding → passive shielding by water.

Top tracker

- 62 plastic scintillator walls in three layers for good muon tracking
- Cover half of the top area of the water pool
- Re-using the OPERA's Target Tracker





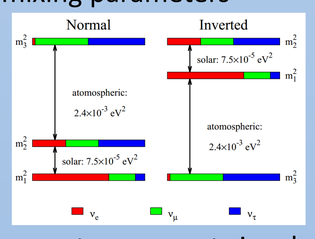
Water Cherenkov detector

- 2000 20'' PMTs and 35kton ultrapure water
- Detector efficiency expected to be >95%
- Fast neutron background ~0.1/day
- Radon control less than 0.2Bq/m3
- Earth magnetic field shielding

Physics Reach

The large fiducial volume and precision spectral measurements offer many opportunities for different physics researches.

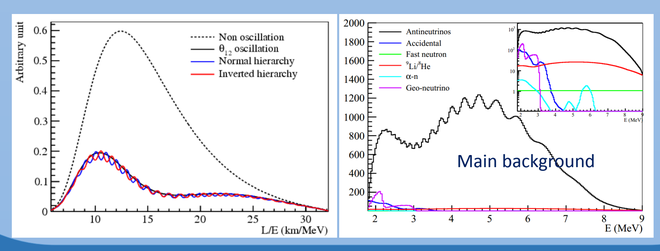
- **Mass hierarchy**
- Precision measurement of mixing parameters
- Supernova neutrino
- Geoneutrinos
- Sterile neutrinos
- Atmospheric neutrinos



- The inverse beta decay (IBD) reaction: $\bar{\nu}_e + p^+ \rightarrow e^+ + n$ generate a prompt signal (positron annihilation) and a delay signal (neutron capture), from which the antineutrino spectrum can be reconstructed.
- Electron antineutrino survival probability in vacuum:

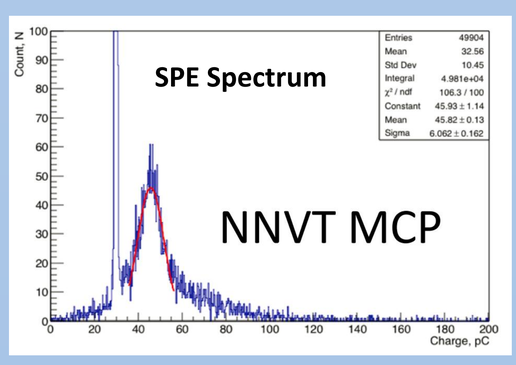
$$P_{\bar{\nu}_e \rightarrow \bar{\nu}_e} = 1 - \cos^4\theta_{13}\sin^2(2\theta_{12})\sin^2\Delta_{21} - \frac{1}{2}\sin^2 2\theta_{13}\left[1 - \sqrt{1 - \sin^2 2\theta_{12}\sin^2\Delta_{21}}\cos(2|\Delta_{ee}| \pm \phi)\right]$$

  - \+ for normal hierarchy
  - \- for inverted hierarchy



The PMT System

- **~5,000 20'' dynode PMT from Hamamatsu**
- **~15,000 20'' MCP-PMT from NNVT**
  - transmissive photocathode + reflective photocathode
  - High CE
  - Low background glass shell

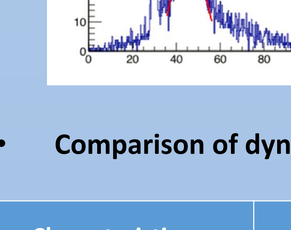


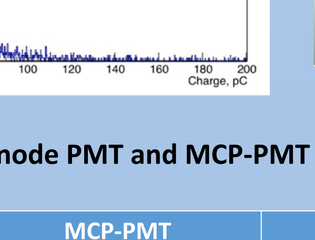
- **Comparison of dynode PMT and MCP-PMT**

Characteristics	MCP-PMT (NNVT)	R12860 (Hamamatsu)
Detection Efficiency(QD*CE)[%]	27%，>24%	27%, >24%
P/V of SPE	3.5, >2.8	3, >2.5
TTS [ns]	~12, <15	2.7, <3.5
Rise time/Fall time [ns]	R~2, F~12	R~5, F~9
Anode Dark Count [Hz]	20K, <30K	10K, <50K
After Pulse Rate [Hz]	1, <2	10, <15
Radioactivity of glass [ppb]	238U:50 232Th:50 40K:20	238U:400 232Th:400 40K:40

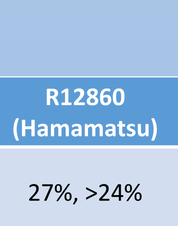
Protection cover and implosion tests

- Sufficient safety factor
- 75% PMT coverage
- Light absorption < 1%
- Compatible with pure water
- Low background

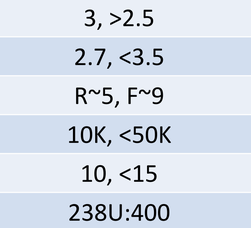




Transparency curve



Parameters	HZC response
QE×CE* @420 nm	24% (>22%)
TTS**(FWHM) of SPE	< 5 ns
Peak/Valley ratio of SPE	3 (>2)
SPE signal width(sigma)	35% (<45%)
Dark rate @1/4 p.e.	1 kHz (<1.8 kHz)
Pre/after pulse ratio	<5%, <15%
Non-linearity	<10% @1-100 p.e.
Radioactivity	^{238}U <400 ppb ^{232}Th <400 ppb ^{40}K <200 ppb



Particles and Nuclei International Conference 2017, Sep 1-5, 2017, Beijing, China