The Veto System of the JUNO experiment

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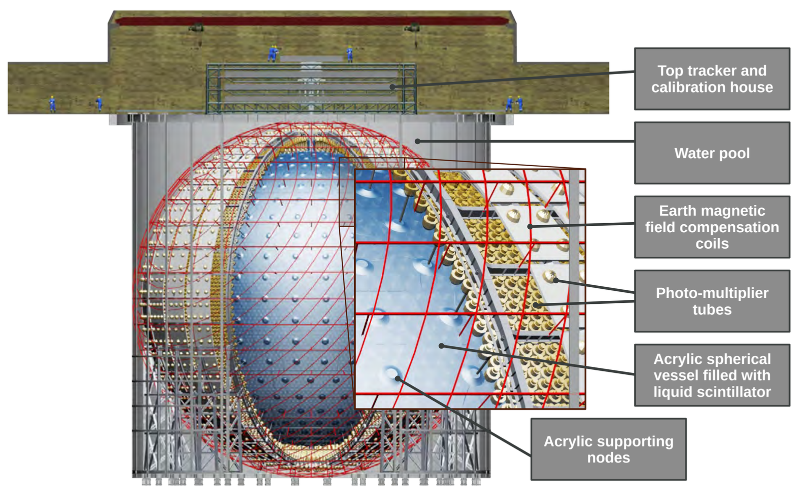
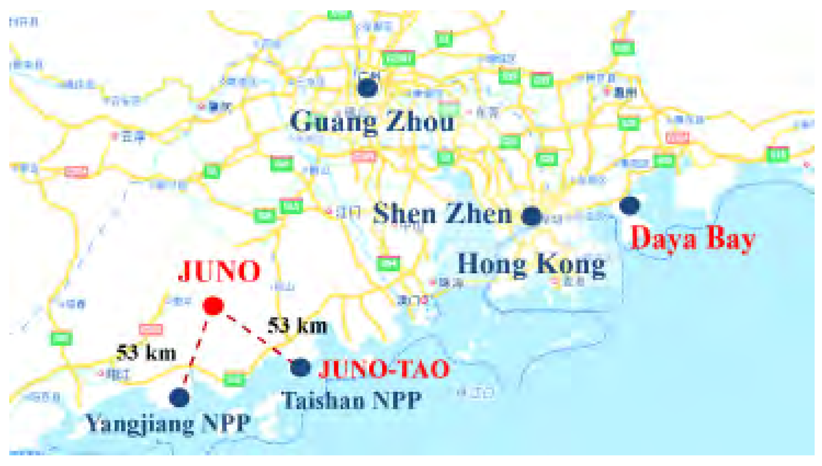
Introduction

The Jiangmen Underground Neutrino Observatory (JUNO) is a new generation of reactor based experiments located in the Guangdong province in China [1]. This experiment offers a rich physics program and will bring significant contributions in many neutrino areas. Even if the detector is located 700 m depth in an underground laboratory, the remaining background imposes the use of an efficient Veto System for its characterisation. It consists of two subsystems, the Outer Veto (OV) and the Top Tracker (TT) which will insure an efficient background reduction.

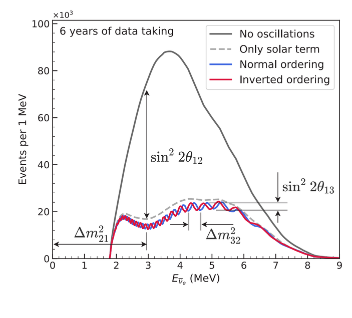
The JUNO Experiment

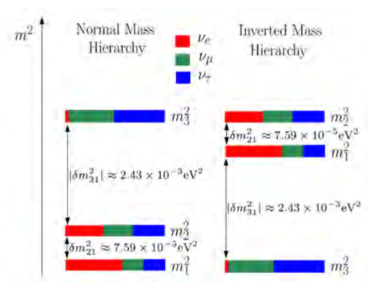




JUNO detector and location in China.

The experiment is a medium baseline detector experiment located in Jiangmen at about 53km from Taishan (2 x 4.6 GW_{th}) and Yangjiang (6 x 2.9 GW_{th}) nuclear power plants [2].





Oscillation spectrum

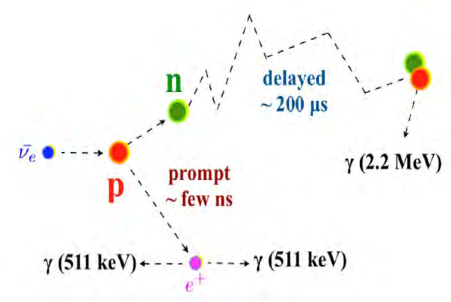
Rich physics possibilities:

- Neutrino mass ordering
- Precision measurement of Osc. Param.
- Supernova : CCSN and DNSB
- Solar neutrinos, Geo-neutrinos, Sterile neutrinos @ JUNO-TAO
- Atm. neutrinos and Dark matter
- Nucleon decay and other exotic

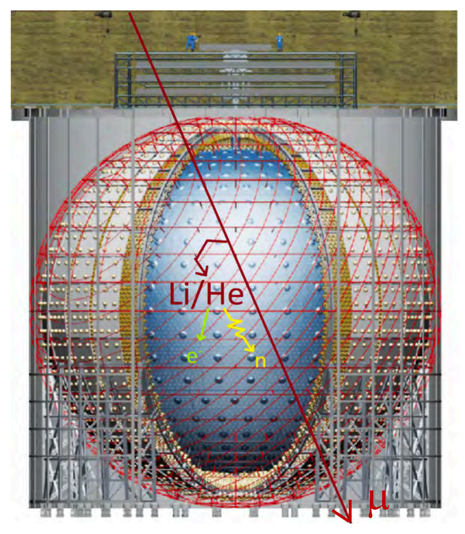
The Veto System

The detector will be equipped with an Veto system which consists of two subsystems: the **Outer Veto (OV)** and the **Top Tracker (TT)**.

The $\overline{\nu_e}$ coming from the nuclear reactors are detected through the Inverse Beta Decay (IBD) reaction:



Inverse Beta Decay process (IBD)



Cosmogenic isotope production.

Major sources of background:

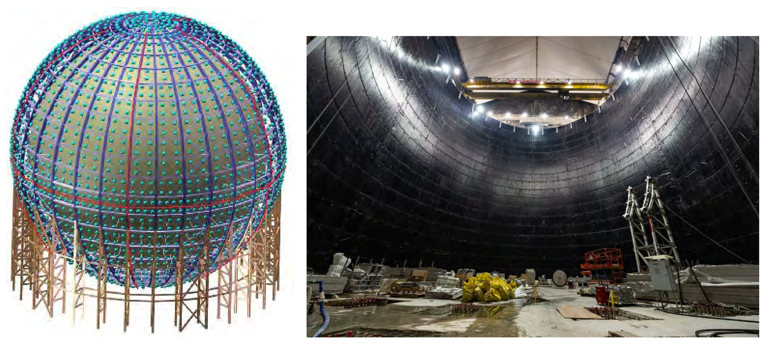
- **Distants $\overline{\nu_e}$'s**, distant reactor $\overline{\nu_e}$ and geoneutrinos
- **Accidentals**, coincidence of uncorrelated radiogenic events
- **Cosmogenics**, fast neutrons and unstable isotopes (^{9}Li/^{8}He) produced by muons on ^{12}C
- **Atmospheric's ν's**, final state of ν_{atm} interaction with nuclei in Liquid Scintillator

Background	Rate (day^{-1})
Geoneutrinos	1.2
World reactors	1.0
Accidentals.	0.8
^{9}Li/^{8}He	0.8
Fast neutrons.	0.1
Atmospheric neutrinos	0.16
$^{13}C(\alpha,n)^{16}O$	0.05

Reactor $\overline{\nu_e}$ signal **47 events.day**$^{-1}$

The Outer Veto

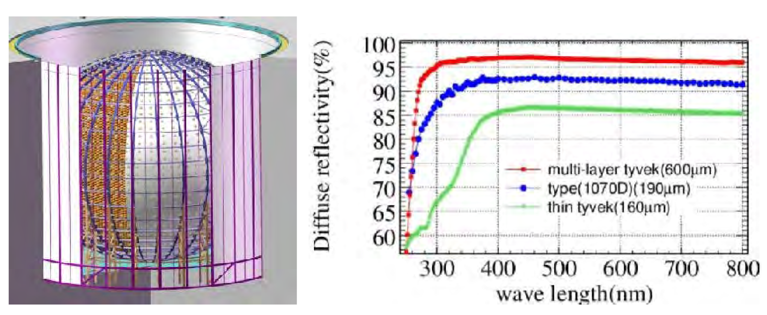
The OV is a Water Cherenkov type detector filled with 35 ktons of ultrapure water surrounding the central detector and is equipped with 2400 large photomultipliers (20-inches) fixed on the support structure looking outward. The tagging efficiency is greater than 99% and the fast neutron background can be reduced at 0.1 event/day.



Outer Veto System & Inside View

- **PMT's:** 2400 large PMT's (20-inches)
- **Liner:** Protect the water from the rock contamination
- **Muon Detector Calibration System** made of LED Flashers will be used for calibration task (gain monitoring, timing,..)

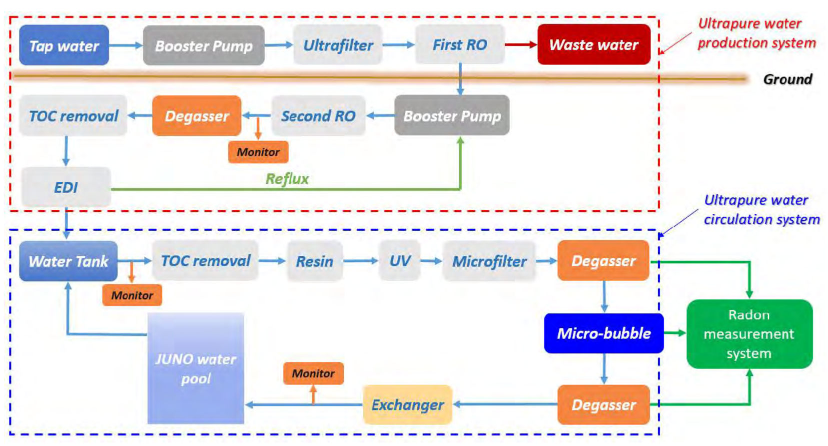
Tyvek Covering:



Wall covering and reflectivity measurement.

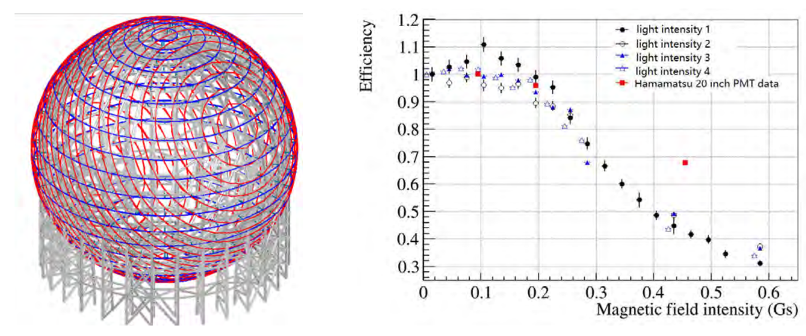
- Cover the whole inner surface of the pool to improve light collection
- Reflectivity larger than 95% for wavelengths > 300 nm

Ultrapure Water System:



- Control the water temperature at $21 \pm 1°$
- Keep optical properties stable
- Insure a very low level of background contamination, especially concerning the radon whose the limit should be below 10 mBq m^{-3}

Compensation Coils:

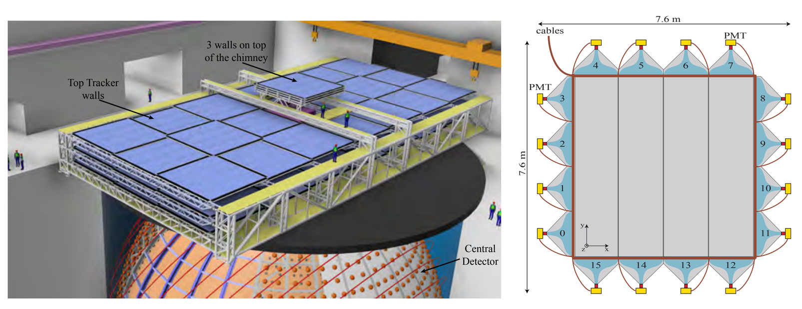


Coil System & Impact of the magnetic field on the detection efficiency of large PMT's [3].

- One set of 32 circular shielding coils
- Residual reduction of the magnetic field intensity: 10% at Central Detector and 20% at Veto PMT level

The Top Tracker

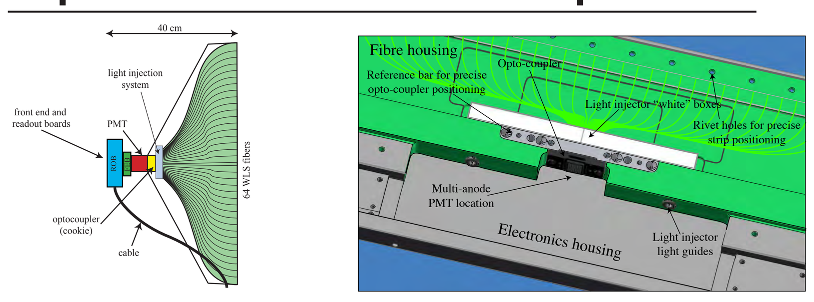
The JUNO-TT uses the modules from the decommissioned OPERA experiment [4] which are based on the well-known plastic scintillator technology equipped with wavelength shifting fibres and read by 64 channel multi-anode photomultipliers. It will be placed on the top of the central detector for an efficient muon track reconstruction.



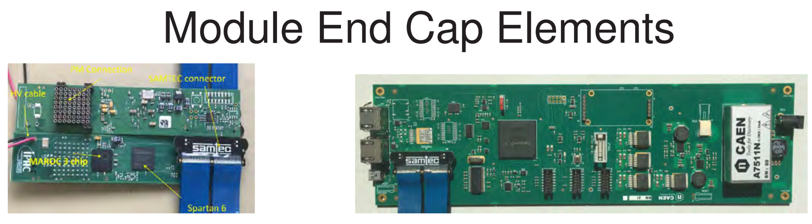
View of the Top Tracker & one wall

- TT consists of 63 walls shared over 3 layers + 3 walls on the top of the chimney
- 60% coverage on top of Outer Veto
- Study the production of $^{9}Li/^{8}He$
- Perform precise μ track reconstruction

Top Tracker Electronic Components:

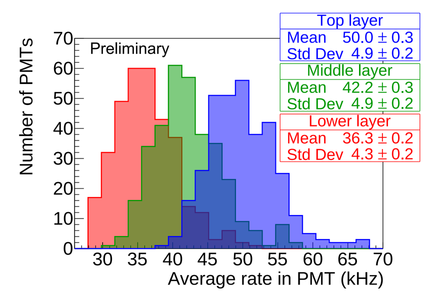


Module End Cap Elements



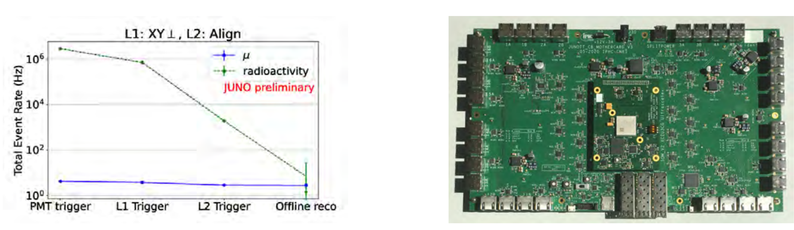
Front End Board (FEB) & Read Out Board (ROB)

Trigger Overview:

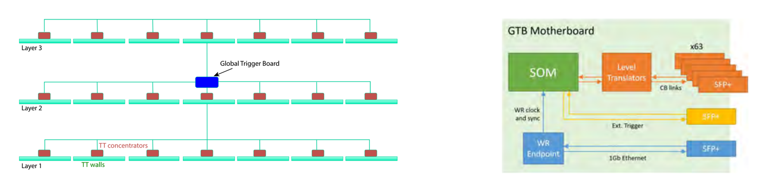


- Rock at JUNO site is x100 radioactive compared to OPERA experiment site
- News electronic developments necessary due to higher background
- Trigger required to reduce dead time
- Acquisition reseted if the event is invalid

Trigger Strategy:



Trigger Rate & Concentrator Board



L2 trigger principle & Global Trigger Board

References

[1] F. An *et al.* [JUNO], "Neutrino Physics with JUNO," J. Phys. G **43** (2016) no.3, 030401
[2] A. Abusleme *et al.*, "JUNO Physics and Detector," Prog. in Part. and Nucl. Physics (2021) 103927
[3] G. Zhang, H. Lu, J. Songwadhana, Y. Yan, N. Morozov, F. Ning, P. Zhang, C. Yang, K. Khosonthongkee and A. Limphirat, *et al.* JINST **16** (2021) no.12, A12001
[4] T. Adam *et al.*, "The OPERA experiment target tracker," Nucl. Instrum. Meth. A **577** (2007), 523-539

Status

- Side wall Liner (6000 m^{2}) / bird cage installed
- Water system: tunnel slope (1300 m) done
- Rn/Ra measurement System developed with sensitivity ($\sim$0.7 mBq m^{-3}) for Rn
- Rn removal system prototype designed allowing to reach $\sim$5 mBq m^{-3} in water
- EMF coils produced
- TT modules on JUNO site
- Mechanical support is designed
- 1134 FEB accepted & produced
- 1020 ROB, 80 CB, 2 GTB designed and will be produced this year