PROCEEDINGS OF SCIENCE

The Veto System of the JUNO Experiment

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The Jiangmen Underground Neutrino Observatory (JUNO) is a new generation of reactor based experiments located in the Guangdong province in China. This experiment offers a rich physics program and will bring significant contributions in many neutrino areas, in particular concerning the determination of the neutrino mass ordering and the measurement of the oscillation parameters at the sub-percent level. The central detector consists of a sphere filled with 20 kilo-tons of liquid scintillator surrounded by 17612 photomultipliers (20 inches) and 25600 small photomultipliers (3 inches) for reading the light produced by the event interactions. Even if the detector is located at 700 m depth in an underground laboratory, the remaining background imposes the use of a Veto System for its rejections and to ensure an efficient event selection. In particular, the cosmogenic induced background due to the muons passing through the central detector represents the most dangerous contribution and needs to be precisely characterized. The Veto System consists of two subsystems, the Outer Veto (OV) and the Top Tracker (TT). The OV is a Water Cherenkov type detector surrounding the central detector and is equipped with 2400 large photomultipliers (20 inches) fixed on the support structure looking outward. The JUNO-TT uses the modules from the decommissioned OPERA experiment which are based on the well-known plastic scintillator technology equipped with wavelength shifting fibers. It will be placed on the top of the central detector for an efficient muon track reconstruction. In this poster, the status of the Veto System will be presented with some elements on the trigger strategy.

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1. The JUNO experiment

The Jiangmen Underground Neutrino Observatory (JUNO) is a new reactor based experiment located in the Guangdong province in China [1]. The central detector consists of a sphere filled with 20 kt of liquid scintillator allowing to detect the antineutrino $\overline{\nu_e}$ emitted by Taishan (2 x 4.6 GW_{th}) and Yangjiang (6 x 2.9 GW_{th}) Nuclear Power Plants (NPP) located at about 53 km from the JUNO site as shown in Figure 1.

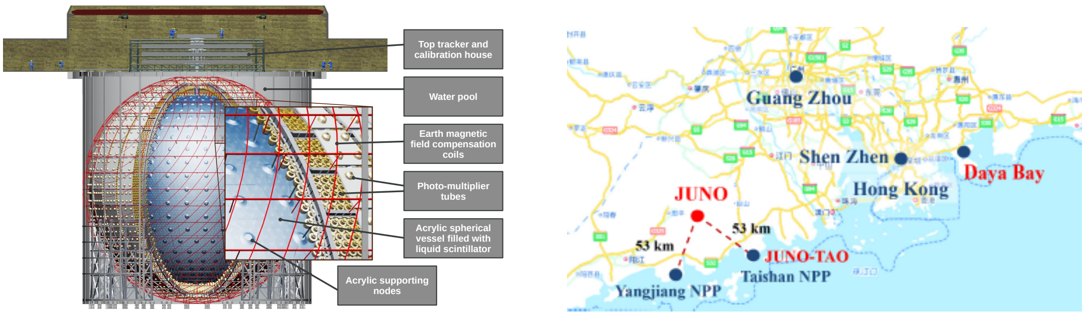

Figure 1: JUNO detector (left) and location in China (right).

JUNO will be able to determine the neutrino mass ordering (Figure 2), thanks to a very good energy resolution at 3% for 1 MeV and to measure the neutrino oscillation parameters at the sub-percent level. In addition, this experiment offers a rich physics program and will bring significant contributions in many neutrino areas such Supernova (CCSN and DNSB), solar and atmospheric neutrinos, geo-neutrinos, sterile neutrinos, dark matter, nucleon decay and other exotic research [2].

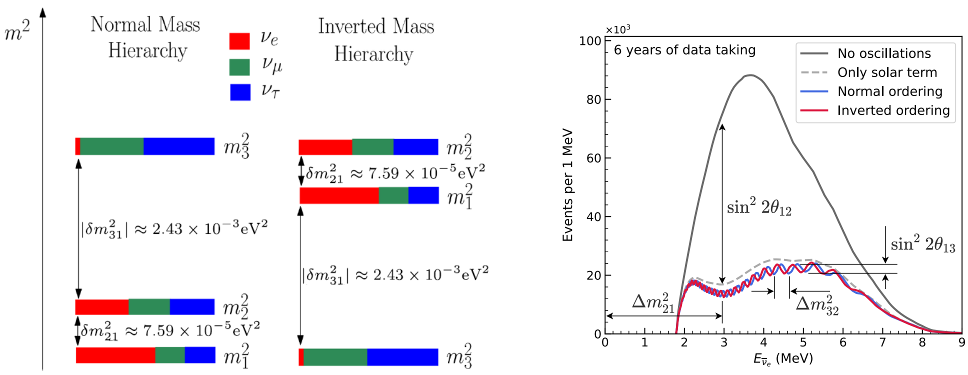

Figure 2: Neutrino mass ordering configurations (left) Neutrino oscillation spectrum [3] (right)

Even if the detector is located at 700 m depth in an underground laboratory, the remaining background imposes the use of an efficient Veto System. It consists of two subsystems, the Outer Veto (OV) and the Top Tracker (TT) allowing an efficient background reduction.

2. The Veto System

The $\overline{\nu_e}$ coming from the nuclear reactors are detected through the Inverse Beta Decay (IBD) reaction $\overline{\nu_e} + n \longrightarrow e^+ + n$ producing a two gamma prompt signal coming from positron annihilation and a delayed signal (~200 µs) by the neutron capture after thermalisation. The major sources of background are classified according the following items : **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) and **atmospheric ν's** (final state of ν_{atm} interaction with nuclei in Liquid Scintillator). The cosmogenics background rate has the same order of magnitude than the $\overline{\nu_e}$ signal. The veto system will precisely characterise the muon track thanks to the performance of its two sub-systems.

2.1 The Outer Veto

The OV is a Water Cherenkov type detector filled with 35 kt 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.

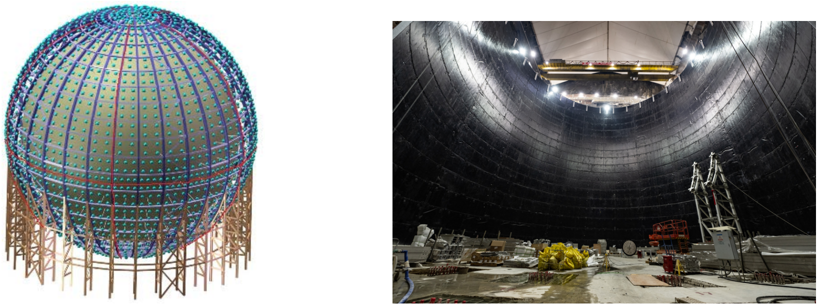

Figure 3: Outer Veto system (left) Inside view (right)

The whole inner surface of the pool will be covered with Tyvek material to improve light collection. The reflectivity is larger than 95% for wavelengths greater than 300 nm for a multi-layers configuration. An Ultrapure Water System is necessary to keep the quality of the water during the running of the experiment. In particular, it will stabilise the temperature at 21°C , keep the optical properties stable and ensure a very low level of background contamination, especially concerning the radon whose limit should be below 10 mBq m^{-3}. In order to protect the detection efficiency of large photomultipliers against the earth magnetic field, a coil system will be installed and will consists of one set of 32 circular shielding coils with a reduction of the magnetic field intensity at 10% at Central Detector and 20% at Veto PMT level [4].

2.2 The Top Tracker

The JUNO-TT, placed on the top of the Central Detector (Figure 4), uses the modules from the decommissioned OPERA experiment [5] which are based on the well-known plastic scintillator technology equipped with WLS[1] fibres and read by 64 channel multi-anode photomultipliers.

[1]WLS : wavelength shifting fibres

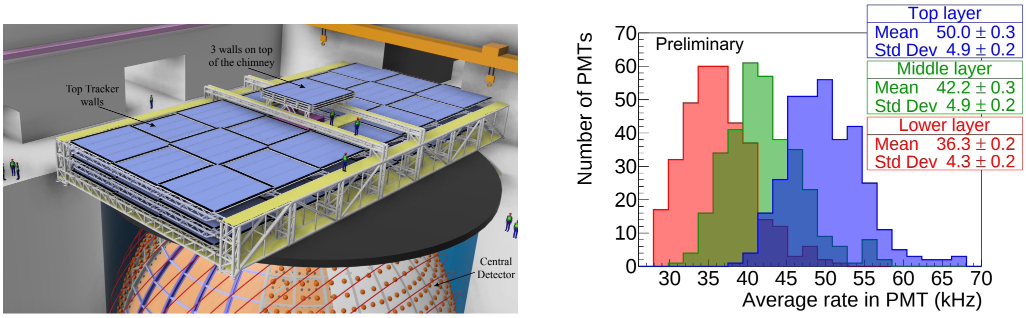

Figure 4: View of the Top Tracker (left) Trigger rate per layer (right)

The Top Tracker consists of 63 walls shared over three layers plus three additional walls on the top of the chimney which cover 60% area on top of Outer Veto. It will study the production of $^{9}Li/^{8}He$ cosmogenic isotopes and perform precise muon track reconstruction. The rock at JUNO site is two orders of magnitude more radioactive compared to OPERA experiment site at Gran Sasso laboratory in Italy and the simulated rate per PMT's for each of the three TT-planes is shown on Figure 4 (right). New developments of the electronic cards (Front End card and Read out Board) used in each modules were re-designed and are ready to be produced.

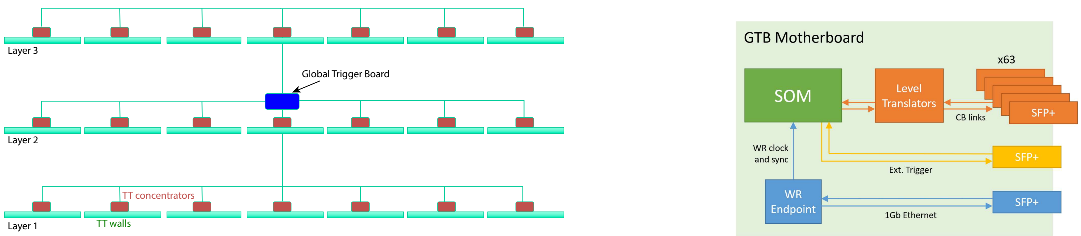

Figure 5: L2 trigger principle (left) Global Trigger Board (GTB) (right)

The trigger strategy for the muon track selection is based on two levels as shown in Figure 5. A first selection is done at the wall level (L1 trigger) thanks to the concentrator board collecting the signals of the modules of one TT-wall. All the signals of the 63 concentrator boards attached to each wall will be collected thanks to the Global Trigger Board to perform the second trigger level.

3. Conclusion

The building of the Veto System has started, the Side wall Liner (6000 m^2)/bird cage is installed, the tunnel slope (1300 m) for the Water System done. The Rn/Ra measurement System is developed with sensitivity of ~0.7 mBq m^{-3} for Rn. The Rn removal system prototype designed allows to reach ~5 mBq m^{-3} in water and the EMF coils are produced. For the Top Tracker, all the modules are on the JUNO site, 1134 Front End Boards accepted and produced, 1020 Read out Boards, 80 Concentrator boards, 2 Global Trigger Boards are designed and will be produced this year.

References

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