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The design of the JUNO veto system

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Abstract. The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose 20 kton liquid scintillator detector. The detector will be built in a 700 m deep underground laboratory, and its primary physics goal will be to determine the neutrino mass hierarchy. Due to the low background requirement of the experiment, a multi-veto system for cosmic muon detection and background reduction is designed. The volume outside the central detector is filled with pure water and equipped with 2000 MCP-PMTs (20 inches) to form a water Cherenkov detector for muon tagging. A Top Tracker system will be built by re-using the Target Tracker plastic scintillator modules of the OPERA experiment and will cover half of the top area. This will provide valuable information for cosmic muon induced $^9\text{Li}/^8\text{He}$ study.

1. The JUNO experiment
After the success of the neutrino reactor experiments of measuring the value of the last mixing angle\textsuperscript{[1]} of the MNSP mixing matrix, the next generation of experiments will concentrate on the CP violation observation in the lepton sector and the mass hierarchy determination. In this context, reactor experiments can determine the mass hierarchy in a medium baseline configuration\textsuperscript{[2]}. The difference in the normal and inverted mass ordering appears as a tiny phase shift in the oscillation probability. The observation of this phase shift requires a very good energy resolution (Fig.1). JUNO is a new reactor experiment designed to reach 3\% energy resolution at 1 MeV. The central detector consists of a 20 kton liquid scintillator located at 53 km baseline from the nuclear power plants. In addition, the experiment offers a rich complementary program in neutrino physics as solar, supernovae, atmospheric and geo-neutrinos. It will perform precision measurements of the MNSP mixing matrix elements at the percent level and will open the door to unitary tests \textsuperscript{[3]}.

2. The VETO System
The cosmic muon induced background is the main background of JUNO experiment. The detector will be located at 700 m depth in an underground laboratory reducing the cosmic ray flux in the central detector to a rate of about 3 Hz. These muons produce instable cosmogenic isotopes, in particular $^9\text{Li}/^8\text{He}$ whose decays produce an experimental signature similar to the inverse beta neutrino interactions. The experiment will be equipped with two veto systems for cosmic muon detection background reduction and study: Outer Veto and Top Tracker(TT) detectors. The whole veto detector will also efficiently reduce the environmental background and will provide valuable information for cosmic muon track reconstruction.
3. Outer Veto (Water Cherenkov detector)

The outer part of the central detector will be filled with 20-30 kton of ultrapure water and equipped with 2000 20" MCP-PMTs as shown in Fig.2. The photodetectors are on the surface of the sphere containing the Central Detector and on the wall of the water pool configuration obtained after optimization. Tyvek reflector film is coated on the Outer Veto surface to increase the light collection efficiency. A circulation/purification water system will be implemented (~2 weeks of circulation are necessary to clean the entire volume) to keep a good water quality including radon concentration (<0.2 Bq/m³). The detector efficiency for cosmic muons rejection has be estimated by simulation to be >95%. Fast neutron background can be maintained at 0.1 event/day by passive shielding and muon veto tagging. The radioactivity from the rock is greatly reduced by passive water shielding.

![Figure 2. The Water Cherenkov detector.](image)

The presence of the Earth geomagnetic field with of 0.5 Gauss will affect the photomultiplier properties. An active shielding based on compensation coils will be included in the veto system. It will be able to compensated the field surrounding the detector. The residual intensity is expected to be less than 10% after coil shielding.
4. The Top Tracker
The Top Tracker is a complementary sub-detector of the experiment which is essential for the background reduction strategy (Fig.3). The detector will re-use the Target Tracker of the OPERA experiment based on the well known plastic scintillator technology. The TT consists of 62 walls made of plastic scintillation strips equipped with WLS fibres, with dimensions of $6.8\times6.8\text{m}$ each. Each wall consists of 4x and 4y module, allowing a good tracking reconstruction capability. One module consists of 64 scintillator strips equipped with WLS fibers allowing a good detection efficiency and tracking performance [5]. All the 64 WLS fibers of one module are read at both ends by two 64 channels multianode photomultipliers (MaPMT). All walls will be rearranged in three horizontal layers to cover half of the top area. The three layers are spaced by 1 m and require a specific mechanical support for maintenance and accessibility. The three layer structures of the TT with its appropriate trigger electronics will reduce the background rate at an acceptable level and will perform a precise muon tracking for cosmic muon induced $^9\text{Li}/^8\text{He}$ study.

![Figure 3. Top Tracker.](image)

Each of the TT walls will be equipped with fast electronics able to deal with high event rate. The MaPMT signals will be treated by a MAROC3A[6] chip on a front end card which provides triggers and measure the charge [0.3pe-100pe] for the 64 channels of each MaPMT. The readout board stores the trigger and charge informations. If a trigger is detected by a MaPMT, a signal is sent from the front end and readout boards to a Concentrator Board which performs x-y correlations and validates or rejects the event. The data are then transferred to a Global Trigger Board managing the three TT layers.

5. Conclusion
The experiment is under development. The civil construction will be completed in 2018. The detector component production be done during 2016-2017 and the detector assembly/installation will be in 2018-2019. The data taking is foreseen to start in 2020.

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