# Juno experiment at CNAF

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**Abstract.**
The Jiangmen Underground Neutrino Observatory (JUNO) is a 20 kton multi-purpose underground neutrino detector designed to determine, as its primary goal, the neutrino mass hierarchy. The large fiducial volume, combined with the excellent energy resolution foreseen, would allow to perform also a series of important measurements in the field of neutrinos and astro-particle physics.
The JUNO detector will be surrounded by a cluster of nuclear power plants at a distance of around 50 km. The resulting reactor antineutrino flux gives the possibility to determine the neutrino mass hierarchy with a significance level of 3-4$\sigma$ in six years of data taking. The measurement of the antineutrino spectrum with excellent energy resolution will lead also to a precise determination of the solar neutrino oscillation parameters, $sin^2\theta_{12}$ and $\Delta m^2_{21}$, with an accuracy below 1%.
The JUNO characteristics make it a suitable detector not only for reactor neutrinos, but also for neutrinos generated inside the Sun, or in supernovae explosions, or even in the Earth's crust and atmosphere. Other topics of interest potentially accessible to JUNO include the search for sterile neutrinos, proton decay and dark matter annihilation.
Data taking is expected to start in 2021.

## 1. The JUNO experiment

The standard electroweak model has been proved by many experiments to be a successful theory that not only unifies the electromagnetic and weak interactions, but also explains almost all the phenomena observed in nature, below the electroweak scale. In its original formulation of Weinberg in 1967 [1], neutrinos were assumed to be massless and hence not allowing any lepton flavor mixing. Later observations of a flux deficit for solar neutrinos [2, 3] turned out to be a solid evidence of physics beyond the Standard Model: the deficit was explained in terms of a neutrino flavor oscillation, which takes place due to the fact that neutrinos do have mass.
Neutrinos oscillation is today a well observed phenomenon. By means of a simple extension of the Standard Model, it can be mathematically described in terms of two separated sets of eigenstates, which do not correspond: three flavor eigenstates ($\nu_e$, $\nu_\mu$, $\nu_\tau$) and three mass eigenstates ($\nu_1$, $\nu_2$, $\nu_3$). The mixing between the eigenstates is described by the three mixing angles $\theta_{12}$, $\theta_{23}$, $\theta_{13}$. So far, the absolute value of the three neutrinos mass is still unknown. The relative square differences $\Delta m^2$ have been measured by several experiments, with a precision of few percents, but not the ordering. Such mass hierarchy (i.e. the sign of the square mass difference $\Delta m^2_{13}$) is still unknown. The knowledge of this crucial information would have several important implications for fundamental physics.

The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose neutrino experiment, proposed in 2008 to determine the neutrino mass hierarchy by detecting reactor antineutrinos [4]. The detector site has been chosen in order to achieve the best sensitivity to neutrino mass hierarchy. The JUNO complex is currently under construction in China, with a rock overburden above the experimental hall of around 700 m, and is located 53 km away from both Yangjiang and Taishan nuclear power plants. The neutrino detector consists of a 20 kton fiducial mass liquid scintillator (LS), where antineutrinos can interact via inverse beta-decay interactions, producing a positron and a neutron in the final state. Both these secondary particles are then captured and generate scintillation light, which is collected by about 40.000 photo-multiplier tubes (PMTs) installed on a spherical structure with radius $\simeq$ 20 m. PMTs are submerged in a buffer liquid to protect the LS from the radioactivity of the PMT glass. The scintillator liquid is composed of a mixture of *Linear Alkyl-Benzene* (LAB), 2.5-diphenyloxazole (PPO) and p-bis-(o-methylstyryl)-benzene (bis-MSB), to maximize the collection of light. The central scintillator detector is surrounded by a cylindrical water pool, instrumented with $\sim$2000 PMTs, acting as a Cerenkov veto against cosmic muons and environmental radioactivity. On top of the water pool another muon detector, made of scintillating strips, is used to accurately measure the muon tracks. The detector design is still developing in the carrying on of R&D.
JUNO will achieve a design $3\%/\sqrt{E[MeV]}$ energy resolution target by maximizing the light yield and the PMT coverage. The current R&D status includes 20" PMTs for the central detector and the water pool, to achieve the high photon statistics. The central detector will be also instrumented by a series of 3" PMTs to improve the energy reconstruction.
Given the planned resolution and the neutrino flux coming from the power plants, the mass hierarchy is expected to be determined in six years of data taking, with a confidence level between $3\sigma$ and $4\sigma$. Beside the JUNO main goal, additional measurements can be performed by the detector. The analysis of the reactor antineutrino spectrum, given the large fiducial volume and the excellent energy resolution, can be exploited also for a measurement of the solar oscillation parameters $sin^2\theta_{12}$ and $\Delta m^2_{21}$ with a sub-percent accuracy. This will represent the most precise measurement in the neutrino solar sector. Supernovæneutrinos can also be observed, inferring important informations on the acceleration processes at the source. The properties of the scintillator can also be exploited to observe the solar neutrino flux by means of elastic scattering on electrons. JUNO will also be able to measure the atmospheric neutrino flux thus providing an independent measurement of the atmospheric mixing angle $\theta_{23}$. Geoneutrinos, emitted in the decay of radionuclides naturally occurring in the Earth, are potentially accessible to JUNO. Exotic searches include non-standard interactions, sterile neutrinos and dark matter annihilation signals.

## 2. JUNO experiment at CNAF

The JUNO DAQ system and the JUNO trigger system are now in the final designing phase allowing in the next future a better definition of the computing resources needed to manage the data. The expected throughput is of the order of several PB's/year. In order to reduce the amount of data to be moved, data compression, data filtering and zero's suppression are under study.
The raw data collected by the experiment will be temporary stored in a computer farm located at the experimental site. Data will therefore be transferred to the IHEP Computing Center in Beijing by using a dedicated optical fibre link. The reconstruction of the data will be performed at the IHEP computing farms. Both raw data and reconstructed ones will be transferred to CNAF Computing Center. Data will be reprocessed and stored at CNAF where the end user analysis will be supported. JUNO will maintain a copy of the raw data at CNAF. The JUNO Monte Carlo event production, needed for the detector design phase, to investigate the performances and to prepare the data analysis, will be arranged between IHEP and CNAF. A

single full Monte Carlo sample consists of about 40TBn and it requires about 4000HS06 for more than three months. Several Monte Carlo samples are now available both at CNAF and IHEP are used by the JUNO members. The Monte Carlo production will start accordingly to the software releases.

## References


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