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To cite this article: Zhimin Wang and JUNO Collaboration 2017 *J. Phys.: Conf. Ser.* **888** 012052

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# JUNO PMT system and prototyping

Zhimin Wang

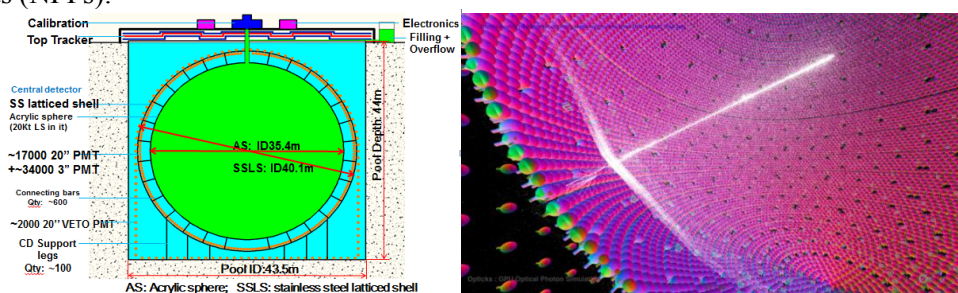
On behalf of the JUNO Collaboration

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**Abstract.** The Jiangmen Underground Neutrino Observatory (JUNO) is a multi-purpose underground experiment and the largest liquid scintillator (LS) detector going for neutrino mass hierarchy, precise neutrino oscillation parameter measurement and studies of other rare processes, including but not limited to, solar neutrino, geo-neutrino, supernova neutrinos and the diffuse supernova neutrinos background. The 20" PMT system with  $\sim 17000$  high quantum efficiency tubes, including Hamamatsu 20" and newly developed MCP 20" tubes, is one of the keys of JUNO experiment for better energy resolution, good detector response etc. We are doing prototypes for PMTs, detectors to study/understand more detailed characteristics of the future detector. Here plans to give you a full view about the JUNO PMT system and its prototyping, including the PMT system layout, PMT testing system design, PMT water proof potting with electronics, installation ideas and the basics PMT performance.

## 1. Introduction

The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose underground Neutrino experiment. It will be constructed in an underground laboratory (700 m vertical overburden) under excavation in Jinji town, Kaiping, Jiangmen, Guangdong province. The main scientific goal is the determination of the neutrino mass hierarchy (MH) by detecting reactor antineutrinos from nuclear power plants (NPPs).



**Figure 1.** JUNO detector layout and simulated event display.

JUNO consists of a central detector, a water Cherenkov detector and a muon tracker. The central detector is 20 kt liquid scintillator (LS) and 17000 (20") PMTs with  $\sim 3\%/\sqrt{E}$  (MeV) energy resolution, also including another proposed  $\sim 34,000$  3" PMT array as a standalone calorimetry. An inner acrylic sphere with a diameter around 35.4 m is designed as LS vessel, and a stainless steel struss with diameter 40 m is needed to support the inner sphere as well as the PMTs. The central detector is submerged in a water pool, to be shielded from natural radio-activities from the surrounding rock and

air.

The PMT instrument sub-system will cover the PMT test, HV divider, implosion protection, integration, water proof potting and PMT installation.

## 2. PMT system

### 2.1. PMT and Testing

The PMT system in JUNO includes PMT test, HV divider, PMT water proof potting, implosion protection and installation, all play a key job for the JUNO detector.

JUNO decided to use 5,000 Hamamatsu R12860-HQE and 15,000 NNVN MCP PMT for photon detection. While the proposed 3" PMT array is still under investigation and test.

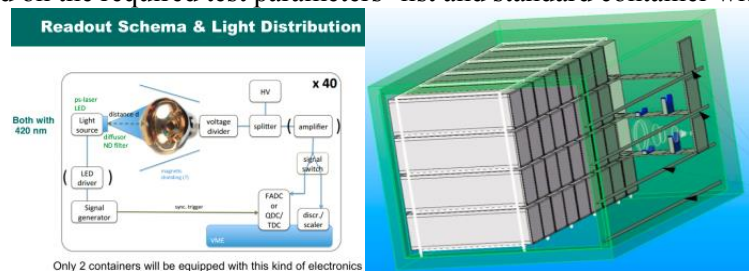


Photograph of MCP-PMT

**Figure 2.** JUNO selected 20" PMTs: left, Hamamatsu R12860, Right NNVN 20" MCP-PMT.

According to the project design, JUNO PMTs will be installed in the detector after several works: delivery from factory, open box check, acceptance tests, storage, integration with HV divider and electronics check, check and characterization after water proof potting, storage, transfer/deliver to onsite for assembly, and installation (in-situ tests).

In order to cover both the acceptance test and characterization test after potting, a PMT test system was designed based on the required test parameters' list and standard container with drawers.



Only 2 containers will be equipped with this kind of electronics

**Figure 3.** JUNO PMT test system: left, bench test scheme, Right, the designed container system.

### 2.2. PMT water proof potting

JUNO designed PMT with electronics dipped in pure water as deepest as 40 m, and PMT water proof potting will be one of the key designs to ensure the detector work longer than 20 years.



**Figure 4.** PMT potting: left, 1<sup>st</sup> stage potted tubes, middle, pressure test tank, right, latest designed structure for potting with electronics.

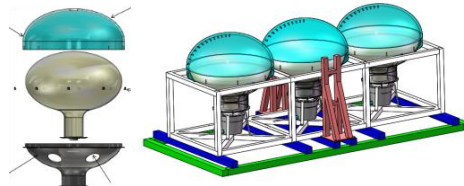
JUNO already finished a lot of R&D works to this task. The first stage of preparation, water proof potting of PMT with PMT+HV divider and single cell cable, was completed in 2015. Such PMTs were used in the JUNO prototype detector, which worked well for 6 months.

In this year, more R&D is going on with front electronics, where the risk is the high temperature from high power consuming with limited materials and geometry.

### 2.3. Implosion protection

There is a risk of implosion with 20" PMT is working under 40m water. To avoid PMT implosion, a shielding structure with acrylic shell on top and stainless steel on the bottom was designed to protect the PMTs from chained implosion triggered by any accidents or defective tubes, with, considering strength of the structure, good transparency for less light absorption and attenuation, dimension limitation of PMT photocathode coverage, compatible with pure water, and low radioactivity.

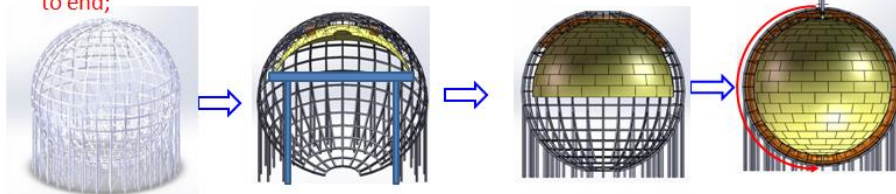
Till now, all the tests with tubes and shielding structure in pressured water tank in 2016 reached the designed goal.



**Figure 5.** PMT implosion protection design and test configuration: left, protection design, right, implosion test with 3 tubes configuration

### 2.4. Installation

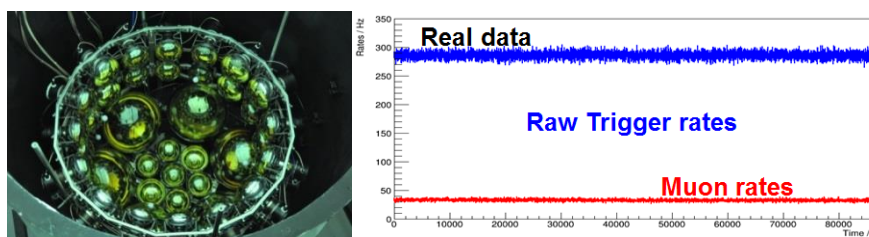
Scheme 4. Partial alternation: SS truss → Some circles Acrylic Ball → One circle PMT → Cycling to end;



**Figure 6.** One option for PMT installation: Install the Central detector and PMT in parallel

JUNO PMT installation is more difficult and complicate rather than other experiments in limited operational space with so many channels, high clean requirements and tight schedule. Till now still many installation options are under discussion with companies to compare all the possibilities.

### 2.5. Prototyping



**Figure 7.** left, Installed JUNO prototype detector with 8'', 9'', 20'' of dynode and MCP PMTs, right, trigger rates and muon rates from the detector

In order to Bench mark and preparing for PMT mass testing, test for new developed MCP PMTs, large PMT mounting and installation, PMT water proof potting, a prototype detector of JUNO was built with similar structure to future JUNO detector design. And most of the things are going well.

## 3. Schedule

JUNO planned to take data in 2020. And all the sub-systems are going well.