

# Tested Performance of JUNO 20" PMTs

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**Abstract.** The physics goal of the Jiangmen Underground Neutrino Observatory (JUNO) is mainly to determine the neutrino mass hierarchy by precisely measuring the oscillation spectrum with  $3\%/\sqrt{E_{vis}(MeV)}$  energy resolution. Totally, about 20,000 large area 20" tubes with high photon detection efficiency will be used to achieve this requirement, including 5,000 Hamamatsu dynode PMTs and 15,000 NNVT MCP PMTs. The JUNO collaboration has built two systems to check the performances of these tubes, which have been running since July 2017 and about 14000 tubes have been tested, so far. The key parameters compared with vendor data, including operating voltage, photon detection efficiency, dark count rate, rise time, fall time are presented. The selected PMTs meet all the requirements of the JUNO detector.

## 1. Introduction

The Jiangmen Underground Neutrino Observatory (JUNO) [1] is a multipurpose neutrino experiment designed mainly to determine neutrino mass hierarchy and precisely measure oscillation parameters by detecting reactor neutrinos from the Yangjiang and Taishan Nuclear Power Plants in China. The detector will be equipped with 20 kton LS with a 700-meter rock overburden and housing 20,000 large area photomultipliers (PMT) with 75% PMT coverage to achieve energy resolution (sigma) 3% at 1MeV [2].

The 20,000 large area 20" tubes with high photon detection efficiency, configured combinedly by 5,000 20" dynode PMTs from Japanese company Hamamatsu Photonics (HAMAMATSU) and 15,000 20" Micro Channel Plate (MCP) PMTs from Chinese company North Night Vision Technology Co. (NNVT), are supposed to be measured according to specified acceptance criteria before potting and installation. Since the experimental engineering progress and the large number of PMTs, two container testing system as well as two scanning stations are built and calibrated with different testing motivations, and they have been running since July 2017. The electronical performance, including operating voltage, photon detection efficiency, dark count rate, rise time and fall time, would be studied for each PMT in the acceptance test.

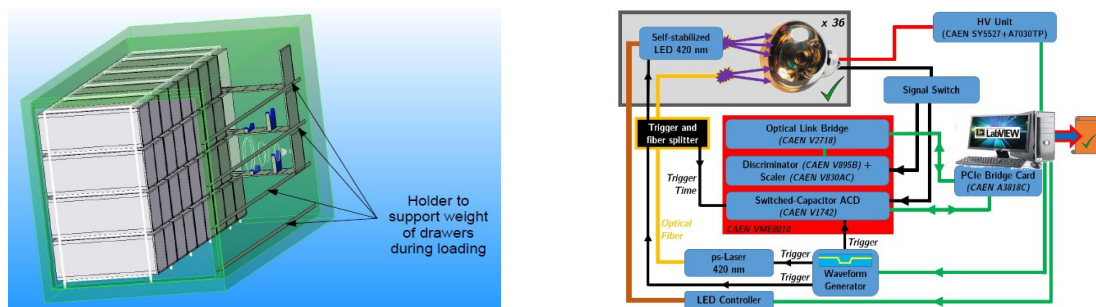


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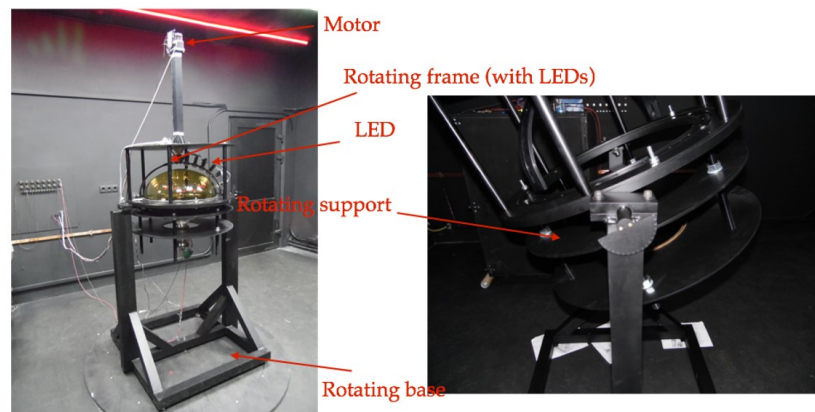
## 2. Performance testing system

The new-arriving PMTs are stored in Zhongshan Pan-Asia in south of China, where the performance testing systems are installed. Two containers test systems with electromagnetic shielding were designed for mass acceptance tests and converted from commercial shipping containers. Each container consists of 36 individual drawers as shown in the left of Fig.1. Commercial electronics are adopted for noise count as well as waveform acquisition, and a schematic layout is displayed in the right of Fig.1.

Besides, two scanning stations [3] are set up to calibrate the photon detection efficiency (PDE) from 168 point-like light sources to the surface PDE, which is crucial to obtain the PDE for large area PMTs. As well, the scanning station is used to scan the uniformity of tubes and double-check the PDE on the boundary of the requirement from the containers considering the system uncertainty.



**Figure 1.** The Container: general view (left) and schematic layout of the single channel commercial electronics setup (right).



**Figure 2.** Scanning station general view in the dark room (left) and rotating support(right).

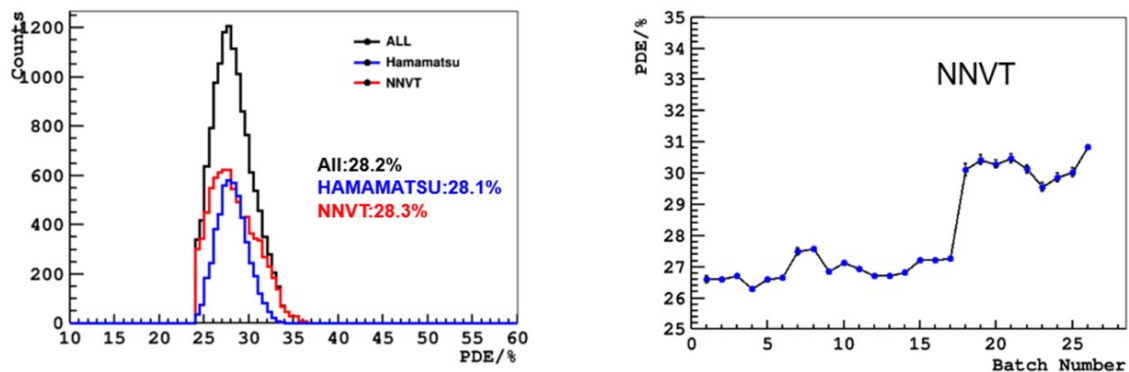
## 3. Testing and analysis procedures

PMT acceptance test procedures are designed and implemented, where several parameters (charge resolution, peak/valley, operating voltage applied to reach gain of  $10^7$ , pre-pulse, rise/fall time) would be re-tested in container systems if they are not satisfied as the contract defines in the first measurement. Besides, we handle the dark count rate (DCR) more carefully, since temperature and cool-down time would affect the DCR of PMTs. Following the procedures, another check in scanning station is needed if the DCR failed twice in container systems. PDE

is the most important parameter for JUNO PMTs. To ensure the average PMT detection efficiency is above 27%, the threshold has been set to 24% for PDE measurement. Considering the PDE absolute uncertainty is 1% for container systems, the PMTs would be rejected directly in container if their PDE value are below 23% and they also need to be confirmed in scanning stations when their PDE is between 23% and 25%.

#### 4. Preliminary results

Until now, more than 12500 (5000 Hamamatsu tubes and 7500 NNVT tubes) tubes has been tested with the two containers regarding the operating voltage, amplitude, resolution, P/V, rise time, fall time, DCR and PDE, and the preliminary mean of statistics based on the acceptance tubes has been listed in Table 1. It is worth mentioning that the average PDE of all NNVT tubes keeps the same level as the average PDE of HAMAMATSU. Furthermore, the NNVT PDE plot with bias shows a great improvement after the 18th delivery batch number and the average PDE of new tubes after 18th batch is higher than average PDE of HAMAMATSU. The distribution of PDE has been exhibited in Fig.3.



**Figure 3.** PDE distribution based on the acceptance tubes in container system. Left: PDE of NNVT and HAMAMATSU; right: PDE vs delivery batch number.

**Table 1.** Mean value of the parameter statistics(Amplitude (Amp), Resolution (Res))

PMT Type	HV /V	PDE /%	DCR /KHz	Amp /mV	Res /%	P/V	Rise Time/ns	Fall Time/ns
NNVT	1766	28.3	48.3	7.5	32.4	4.1	4.8	16.5
HAMA	1863	28.1	15.3	6.4	27.9	3.8	6.9	10.2

#### 5. Conclusion

Large area PMT acceptance tests on performances have been running since July 2017 following the test procedures. Until now, the mass test systems are working well and more than 14000 tubes inspection has been finished.

#### 6. References

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