Characterization of the 20-inch Photomultiplier Tubes for the JUNO Central Detector

Liangjian Wen
(On behalf on JUNO Collaboration)
Institute of High Energy Physics, Beijing

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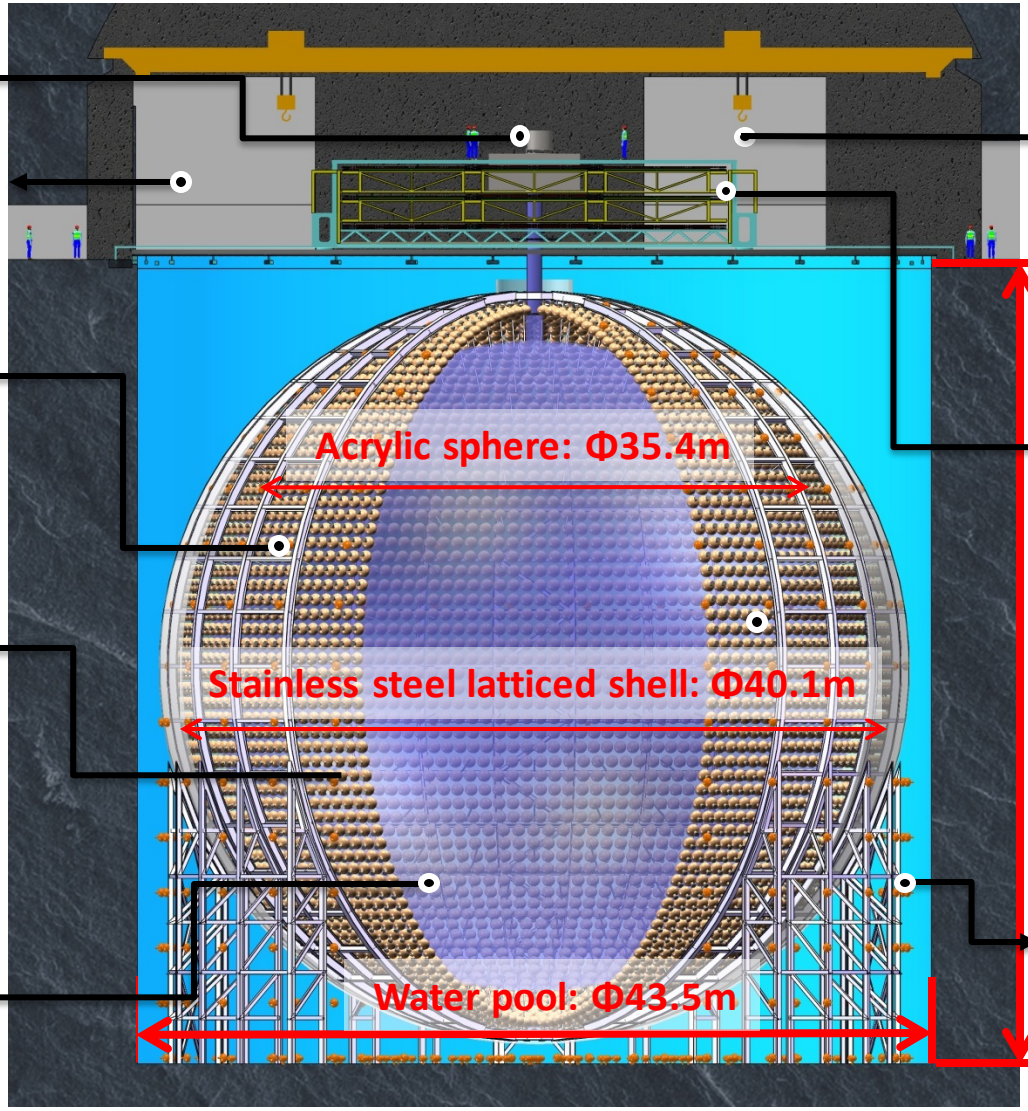
JUNO Detector



Calibration room

Pure water room

LS Filling room

Central detector
Acrylic sphere
Stainless-steel truss

Top Tracker

CD PMT
~18,000 20" PMTs
+ ~25,000 3" PMTs

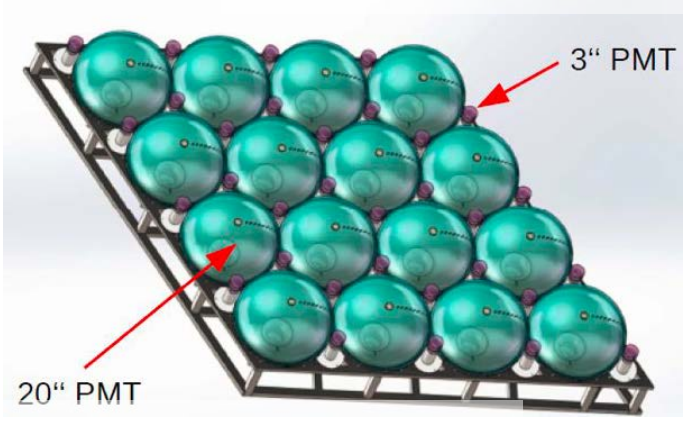
Liquid scintillator
20 kton

Water Cherenkov
35 kton pure water
2,000 20" veto PMTs

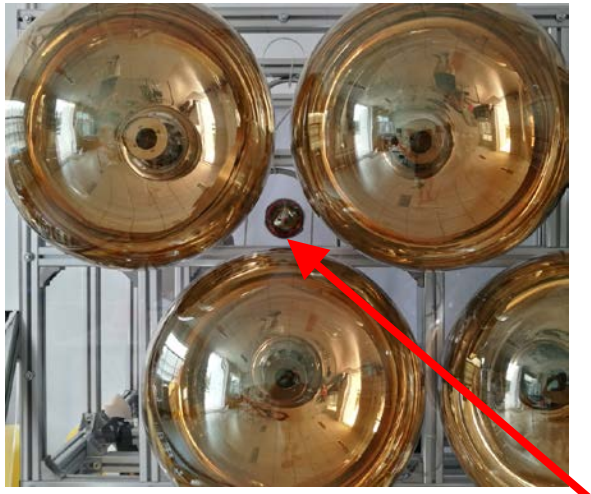
Reference talk by Qingmin Zhang, JUNO: A multi-purpose Underground Precision Detector (ID#940)

LPMT & SPMT systems

3” PMTs: ~2% photo-coverage



20” PMTs: ~75% photo-coverage



A Demo for the PMT module

SPMT system

- Cross-check the LPMT system. Energy measurement via “photon-counting”.
- Extend the dynamic range of detecting muons. Better muon tracking

20” MCP-PMT
15,000

20” Dynode-PMT
5,000

3.1” PMT, 25,000

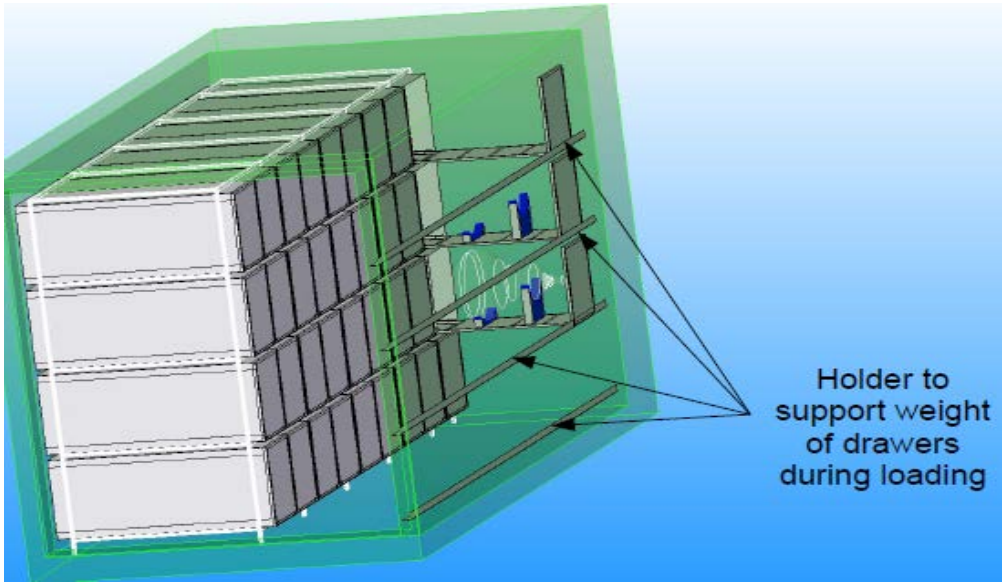
Zhonghua Qin, the 20-inch PMT system for the JUNO experiment (ID# 654)

Jilei Xu, 3-inch PMT system of JUNO experiment (Poster, ID# 827)

Close-to-onsite PMT Test Station

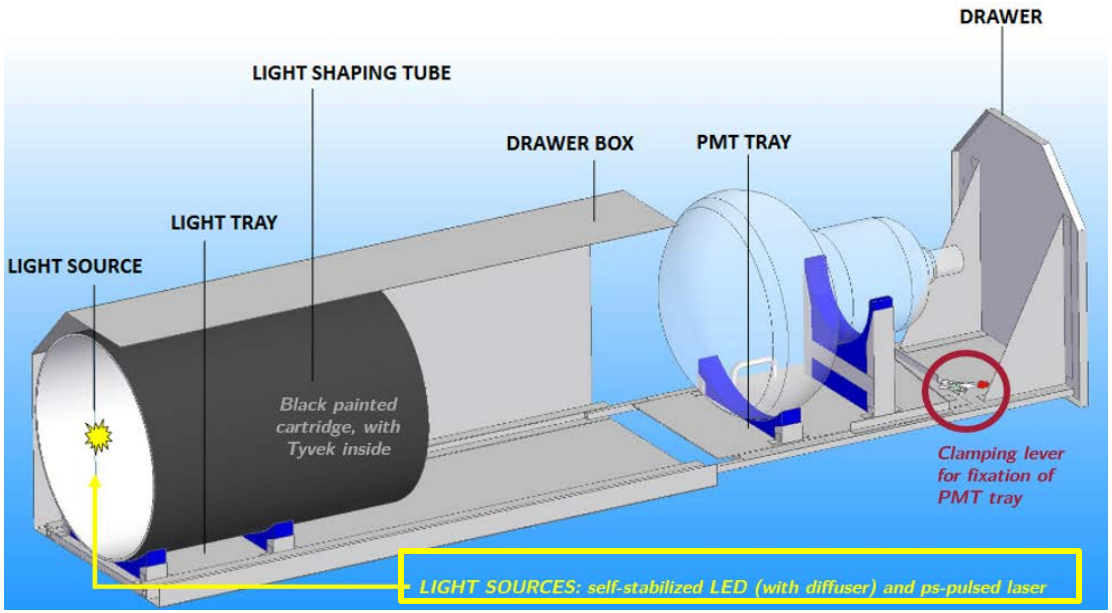
- The JUNO Pan-Asia PMT PMT potting & characterization station has been built in Zhongshan city, Guangdong Province, with great support from the host company.
- PMTs delivery since May 2017. First take visual check (bubbles, weight, scratches/damages, etc), then do performance test

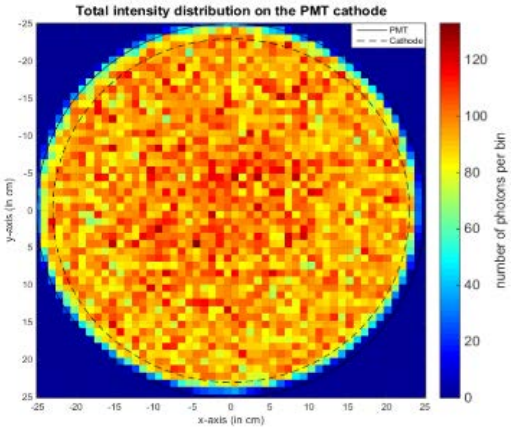
PMT MASS TESTING FACILITY IN COMMERCIAL SHIPPING CONTAINERS



Every PMT will be tested in this system at least 2 times: **acceptance test** with naked PMT after delivery, **full characterization test** after potting of the PMTs

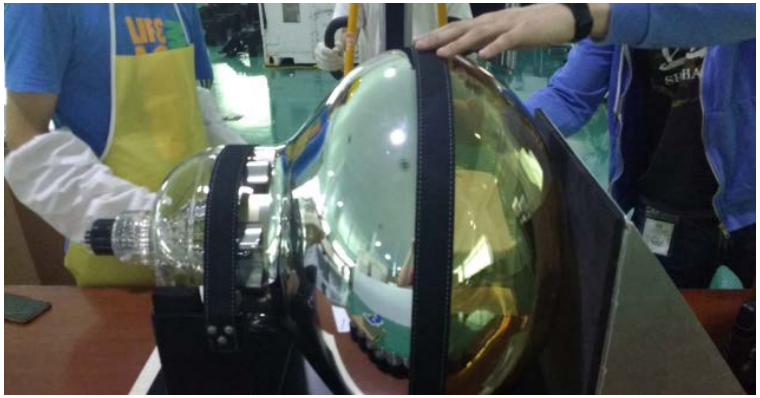
Shielding against Earth Magnetic Field with soft- iron/aluminum layers, reduced to ~ 5 µT (≤ 10% of EMF)

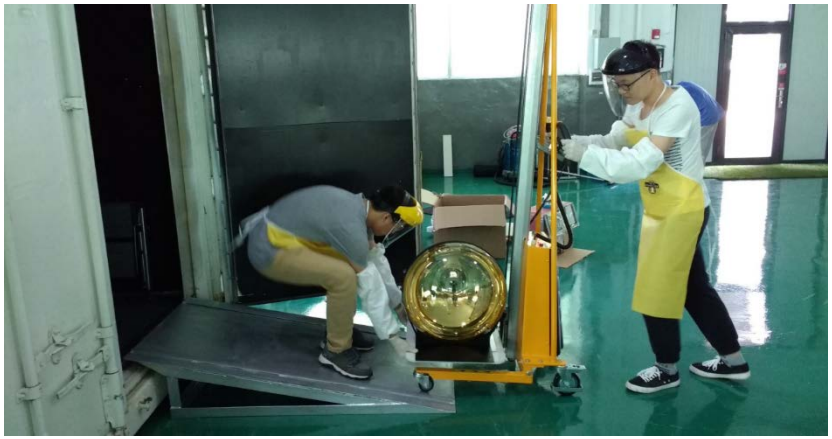




Uniform light field on PMT surface (simulation)

PMT MASS TESTING FACILITY IN COMMERCIAL SHIPPING CONTAINERS



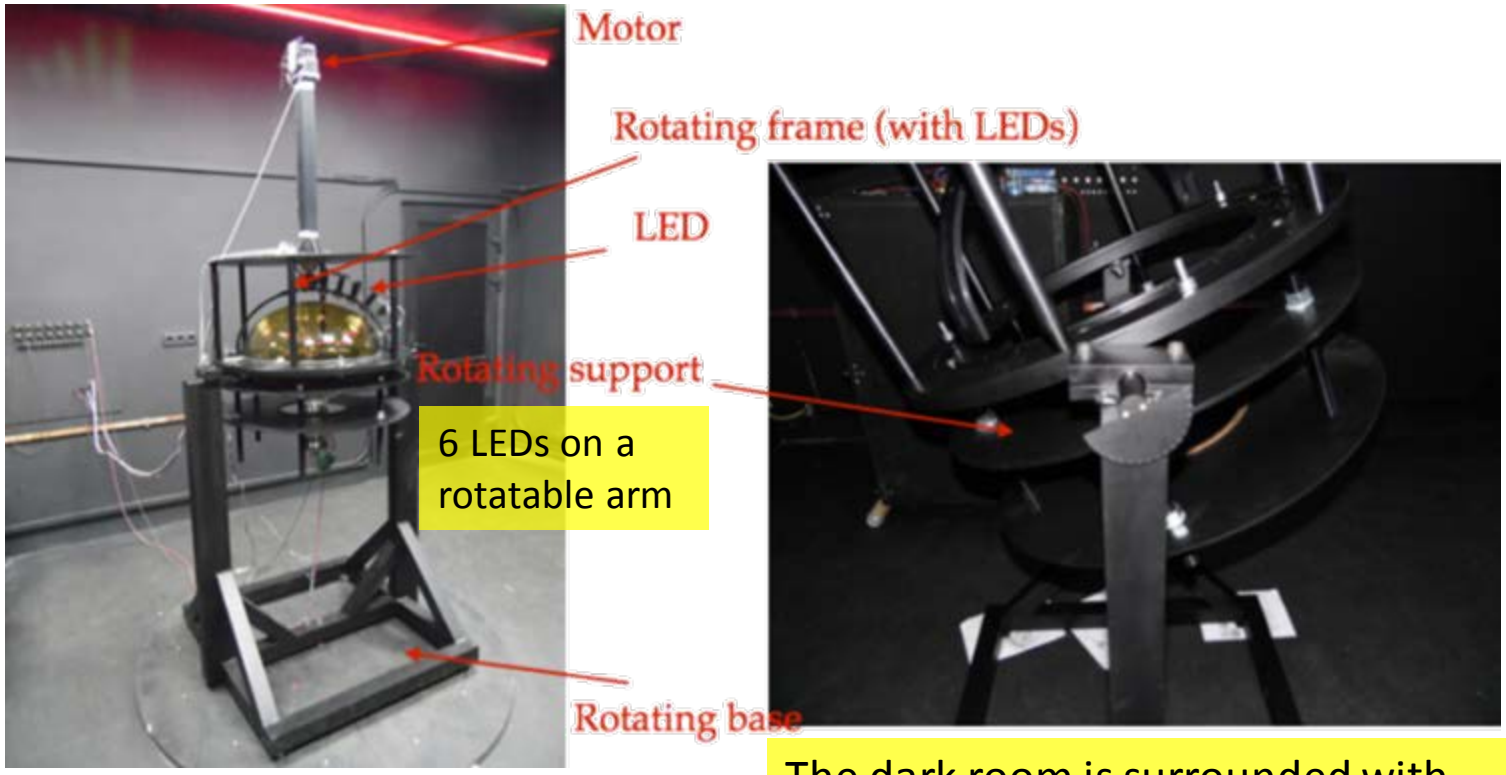


Cover most parameters and all tubes be measured

✓ Detection efficiency @ 420nm	(av. 27%, > 24%)
✓ TTS of Single Photon Events	(< 12ns)
✓ Rise time / fall time	(< 8ns / < 16 ns)
✓ HV applied to reach gain of 10^7	
✓ Dark Rate	(< 50 kHz)
✓ P/V ratio	(> 2.5)
✓ Pre- and after-pulse ratio	(< 5% / < 10%)

PMT Scanning Station

- Batch test of ~ 5% of all delivered PMTs to check for photocathode uniformity, and cross-checks of suspicious PMTs (PDE ~ 24%) from the container tests. Two stations in total



6 LEDs on a rotatable arm

LEDs: self-stabilized with monitored light intensity, periodical calibration with reference PMT

The dark room is surrounded with EMF compensation coils, the residual field at PMT position is ~ 2 μT

Test Status

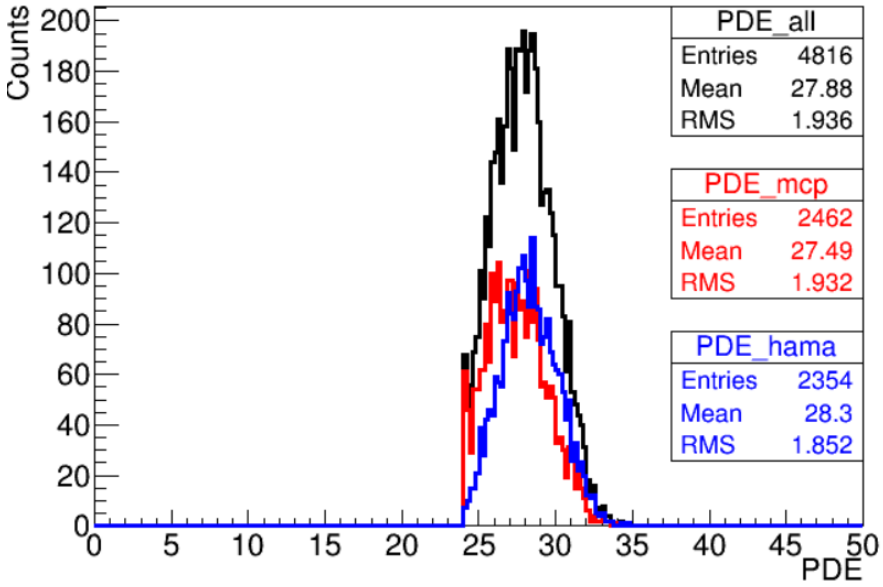
- Totally received 10048 tubes (till to 26th June, 2018)
  - MCP-PMT from NNVT: 6048 tubes
  - From Hamamatsu: 4000 tubes
- Each working day
  - Visual check: ~60 tubes
  - Container testing: ~60 tubes
  - Scan station: 2~4 tubes

Container #1:
Finished mass 221 (7735 tests)
Container #2:
Finished mass 34 (1224 tests)
Scan station: finished ~730 tests

Preliminary Test Results

Early delivered PMTs
(batch #1 to #17)

Averaged PDE: 27.9%
-- NNVT: 27.5%
-- Hamamatsu: 28.3%

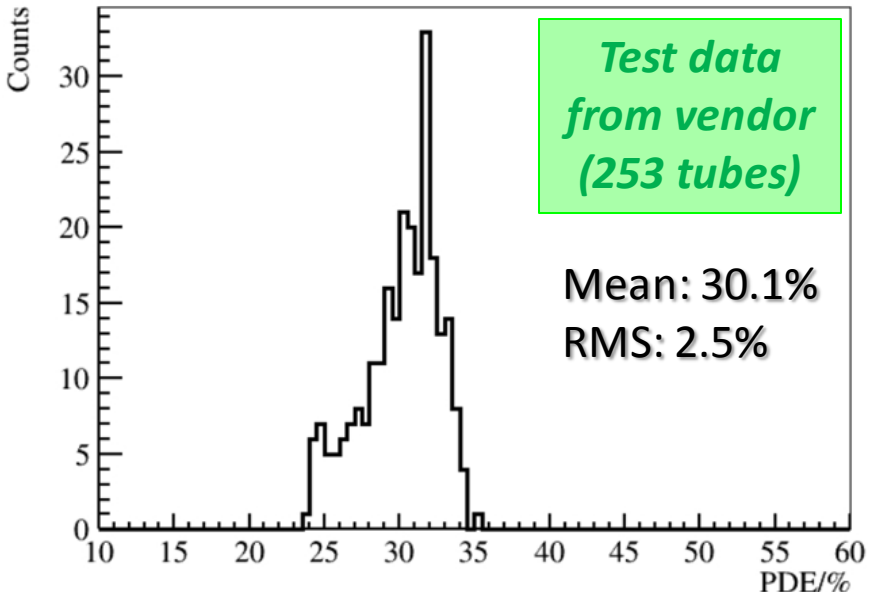


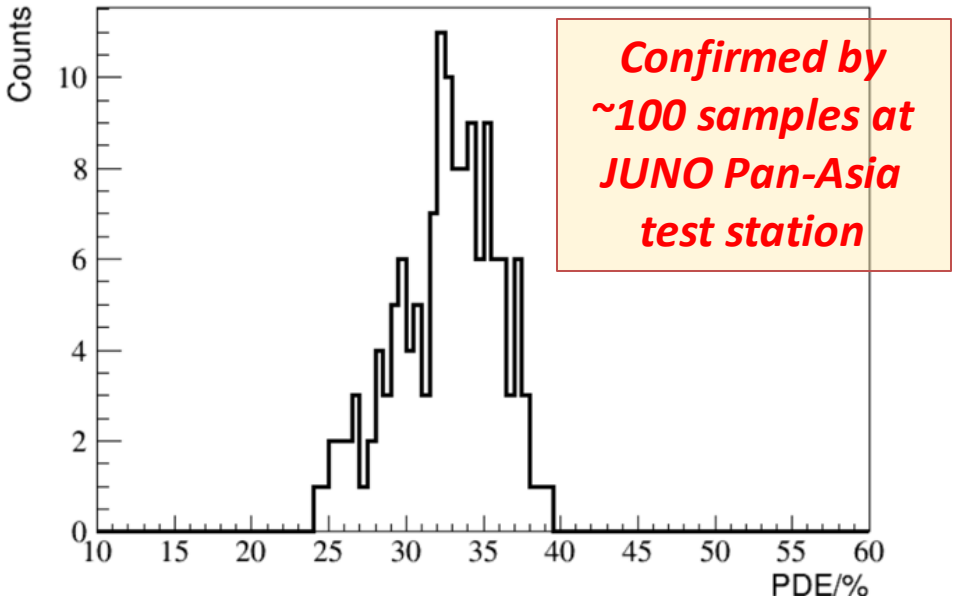
Preliminary

Quantity	NNVT MCP-PMT Mean (RMS)	Hamamatsu PMT Mean (RMS)
S/N	7.4%	7.6%
Amplitude (mV)	7.7 (1.1)	6.5 (0.4)
charge Resolution (%)	32.2 (2.7)	27.7 (2.6)
P/V	4.5 (1.5), all >2.5	3.9 (0.7), all >2.5
Rise time (ns)	4.5 (0.6)	6.8 (0.6)
Dark count rate (kHz)	41	17
DE Uniformity	7%	17%

High QE PMT

- The MCP-PMT producer (North Night Vision Technology Co. LTD) has kept improving the QE with new technologies
- The average QE of the most recent batch (18th) reached ~30%, with similar dark noise. It's expected that the rest batches are all high QE tubes.





Summary

- JUNO receiving the 20” PMT from both NNVT and Hamamatsu as planning
  - Half of total 20,000 tubes have been received
- JUNO Pan-Asia PMT characterization station storing and testing going smoothly
- Parameters from tested tubes meet JUNO’s requirements. Batch production of high QE MCP-PMTs (averge ~30%) become available