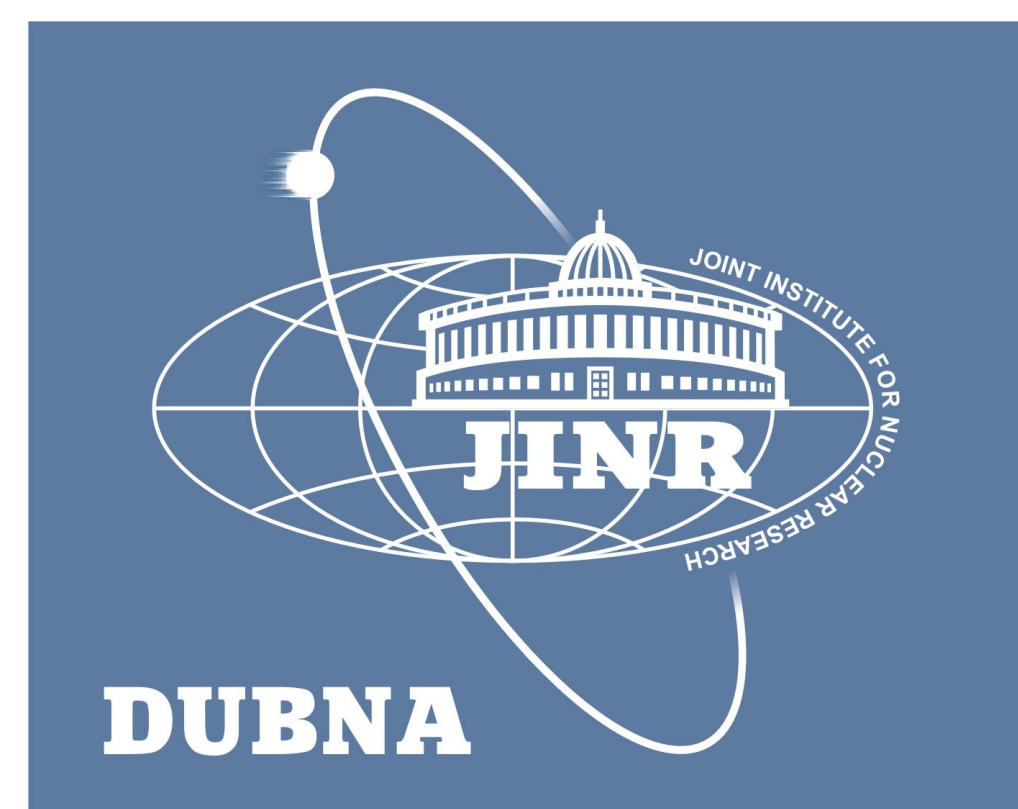


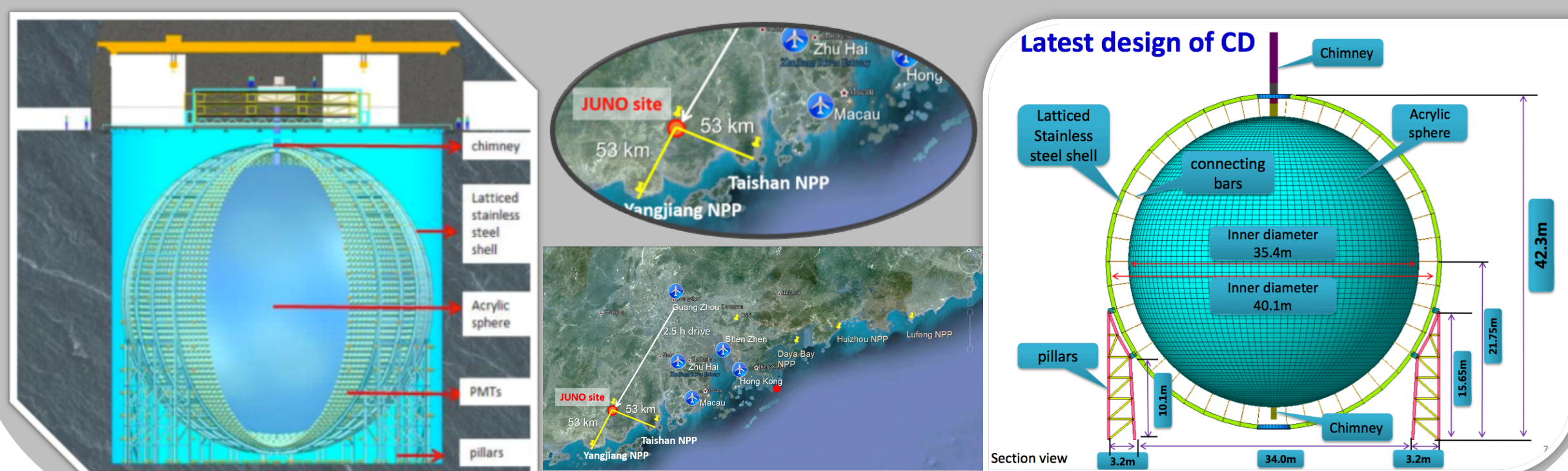


Testing methods for large 20-inch PMTs of the JUNO experiment

Nikolay Anfimov, Joint Institute for Nuclear Research (Dubna)
on behalf of the JUNO PMT Instrumentation Group



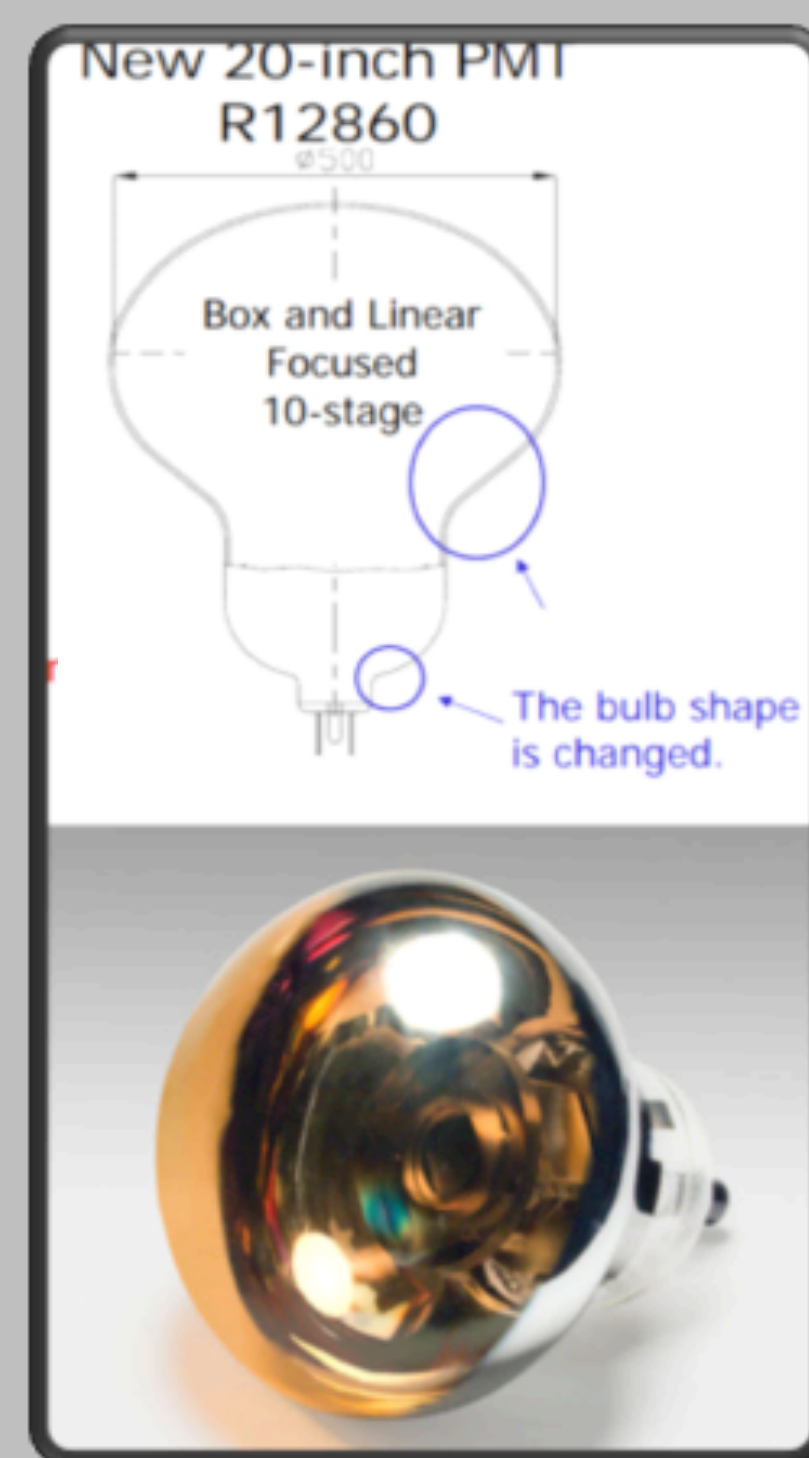
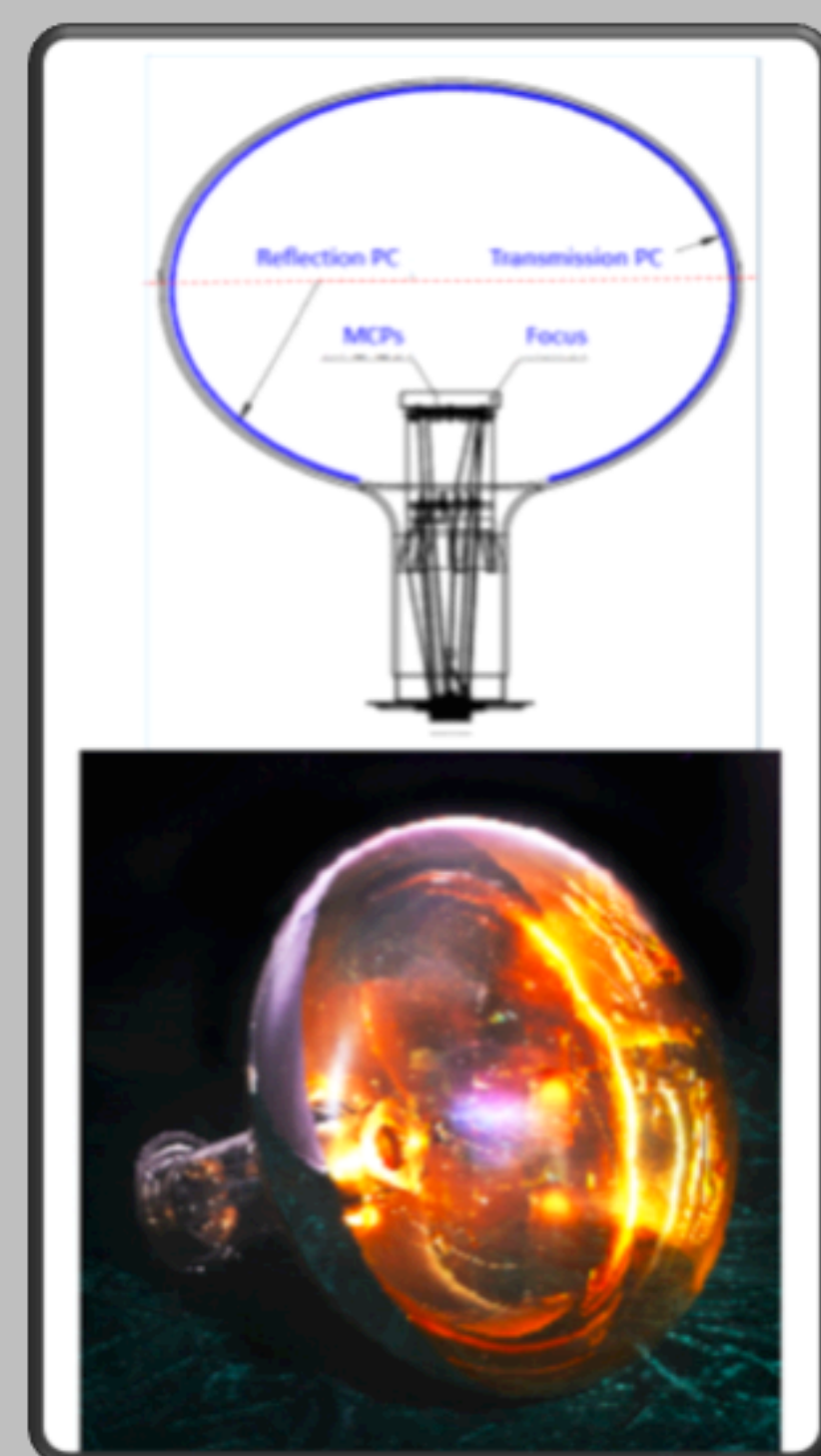
The **20kt liquid scintillator** JUNO (Jiangmen Underground Neutrino Observatory) detector is being built by the International collaboration in China with the primary goal to answer the question of neutrino mass ordering (hierarchy). The main JUNO challenge is to achieve an extreme energy resolution **~3% at 1MeV**, which is vital to perform mass hierarchy measurement. About 80% light detection coverage in JUNO detector is achieved by **~20'000 large 20" PMTs** with high photon detection efficiency (PDE) and good uniformity parameters.



The JUNO 20-inches Photomultiplier tubes

~15k NNVT
MCP-PMTs

~5k Hamamatsu
Dynode-PMTs



- High PDE (@420 nm)
PDE>24 %, <PDE>~27%
- Uniformity of PDE < 15%
- Gain = 10^7
- Magnetic field ~ 1/10 EMF
- P/V ratio > 2.5
- Dark rate < 50 kHz

About 5% of PMTs will be tested more precisely by 4 scanning stations. This instrument allows studying distribution of the PMT characteristics (PDE, Gain, P/V ratio, magnetic field sensitivity etc) along the photocathode.

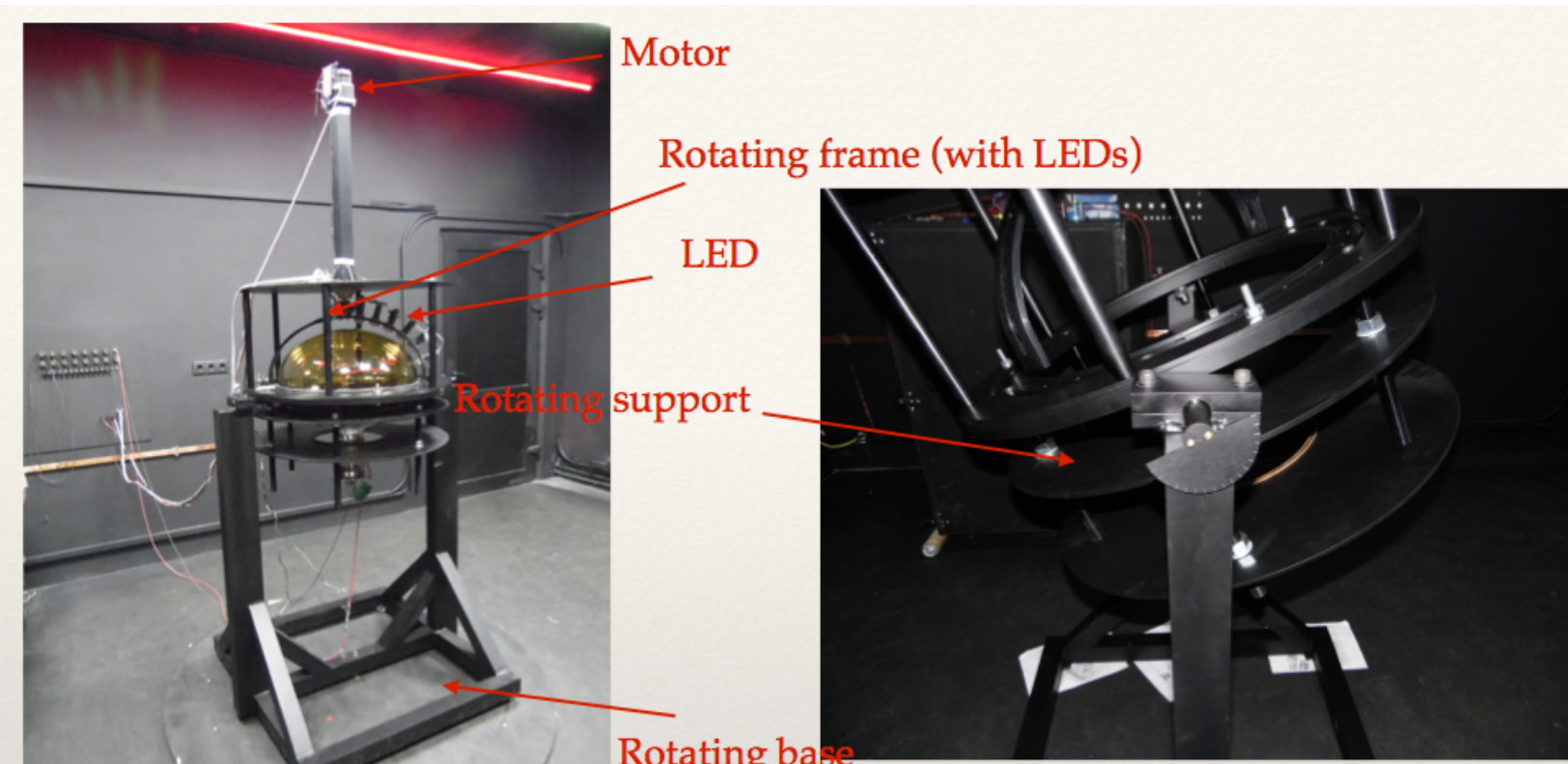
All of 20 000 PMTs will be tested by 4 containers. Each container allows checking 36 PMTs simultaneously.



PMT lab building

Black room

1. Light insulation
2. Red & white light
3. Electromagnetic shielding
4. Reduction of the Earth magnetic field (>10 times)
5. HV-off system
6. Climate system

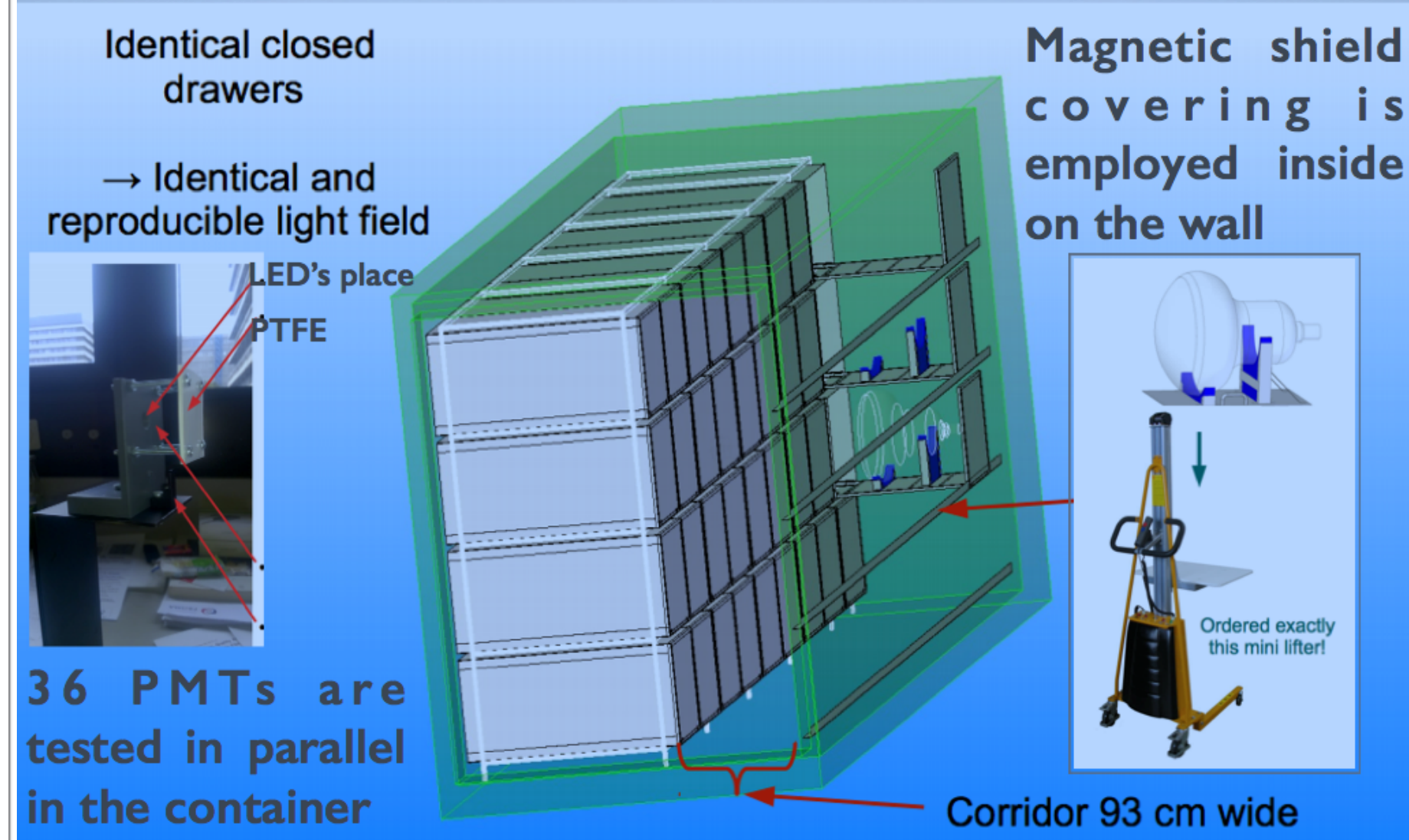


Scanning system for 20" PMT

Scanning system

1. Rotating frame scanning whole azimuth with precision < 1 deg.
2. Support rotation allows to perform measurements in different Earth and residual magnetic fields directions
3. Base rotation 360 deg.

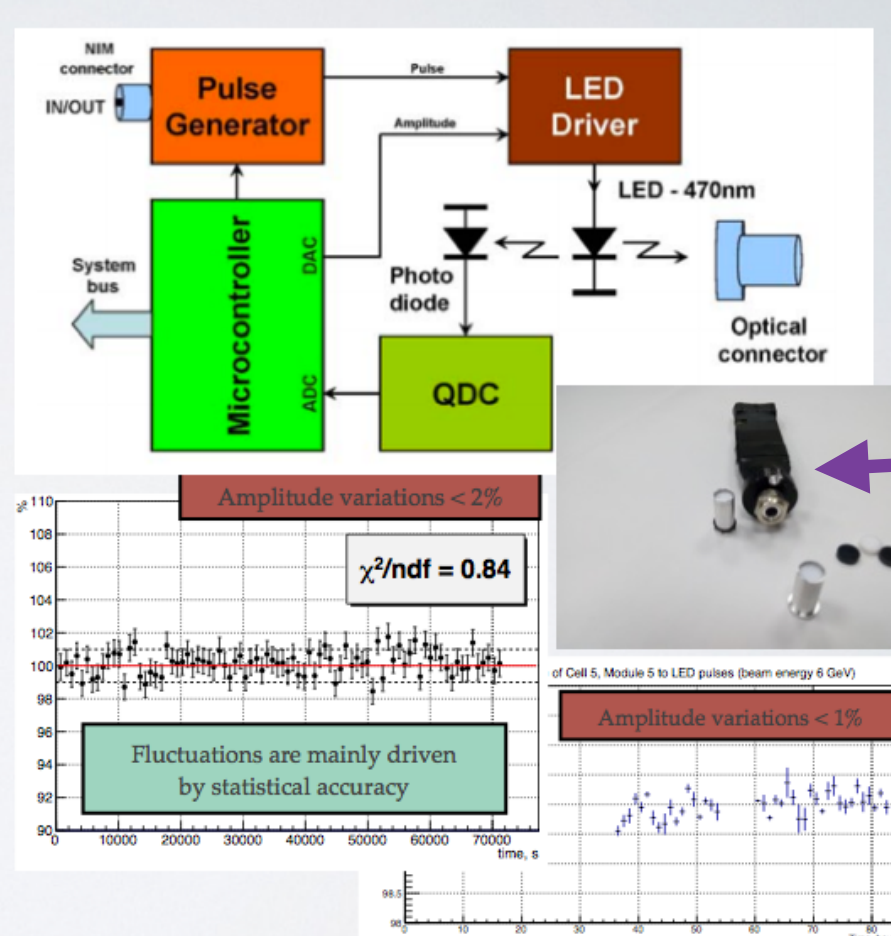
CONTAINER CONCEPT



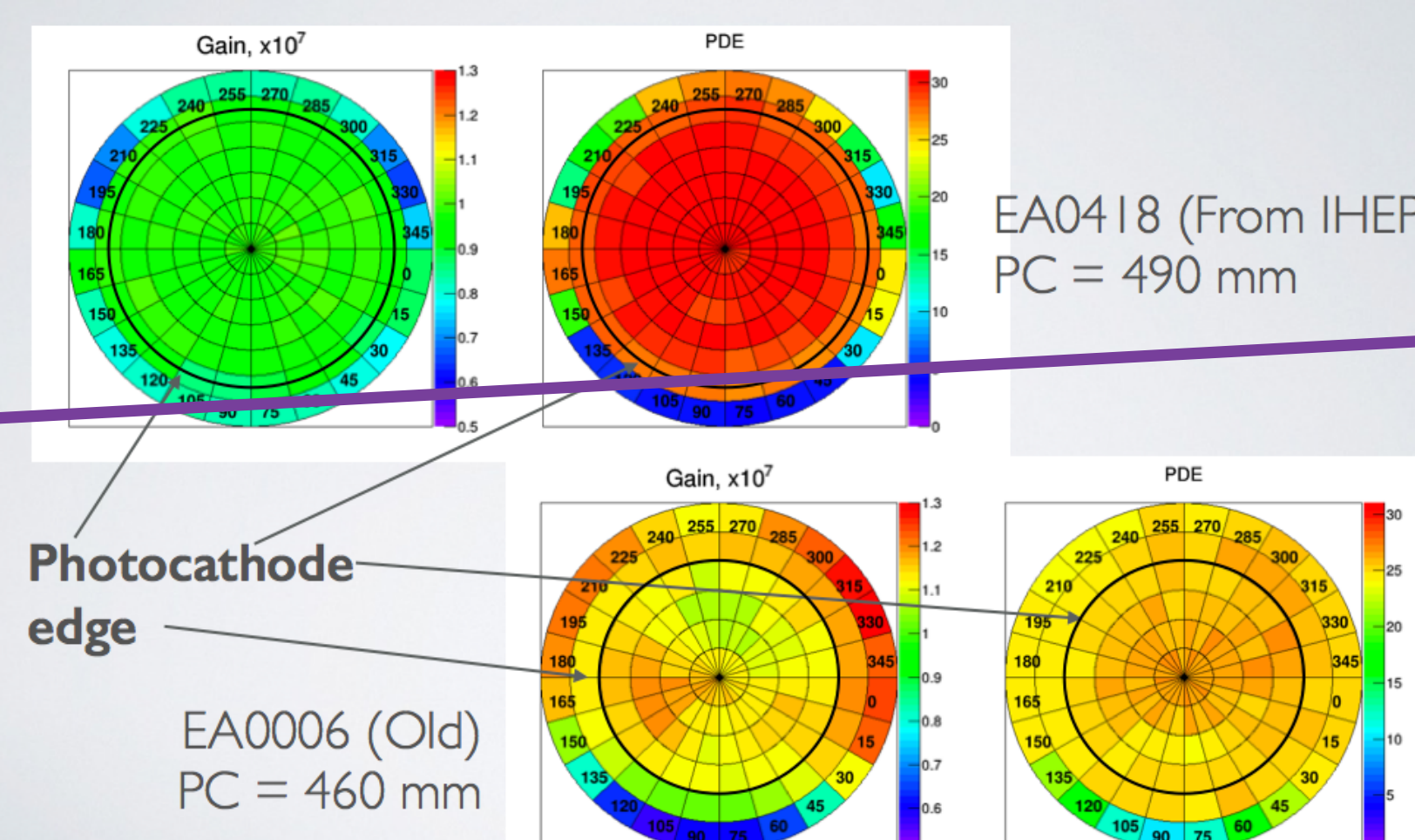
Each drawer provides reproducible plane-uniform light field. Allows easy to replace the PMT.

LIGHT SOURCE

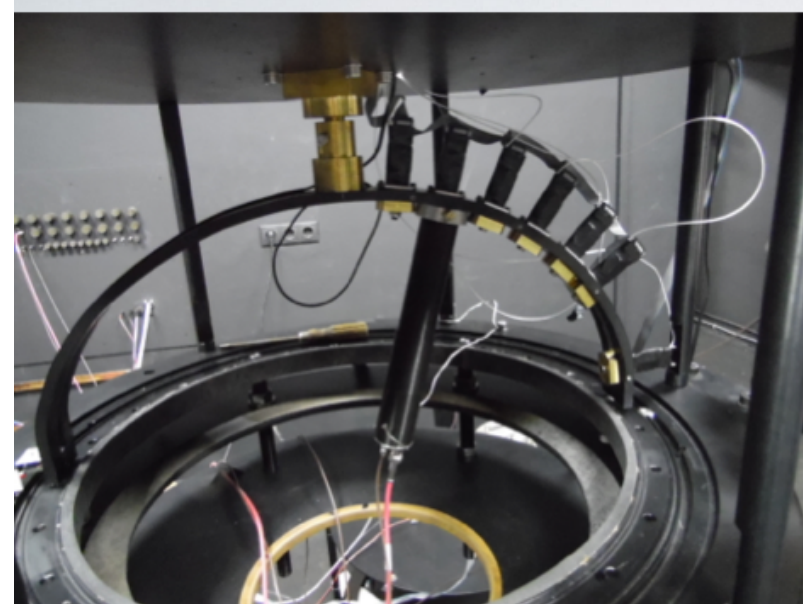
- Stability provided by PIN-photodiode <2%
- PIN->ADC->DAC feedback inside
- Digital control: 12-bit adjustable amplitude, int/ext - trigger, feedback on/off
- LED wavelength range 420-430 nm (each is calibrated)



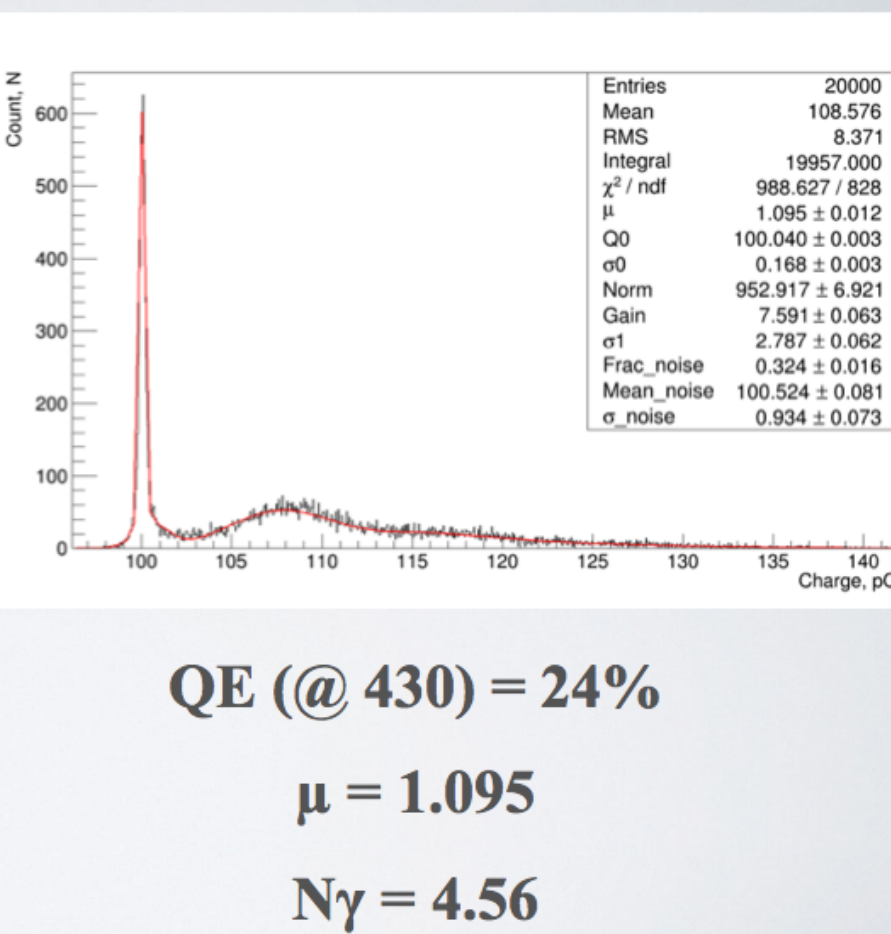
SCANNING MAPS



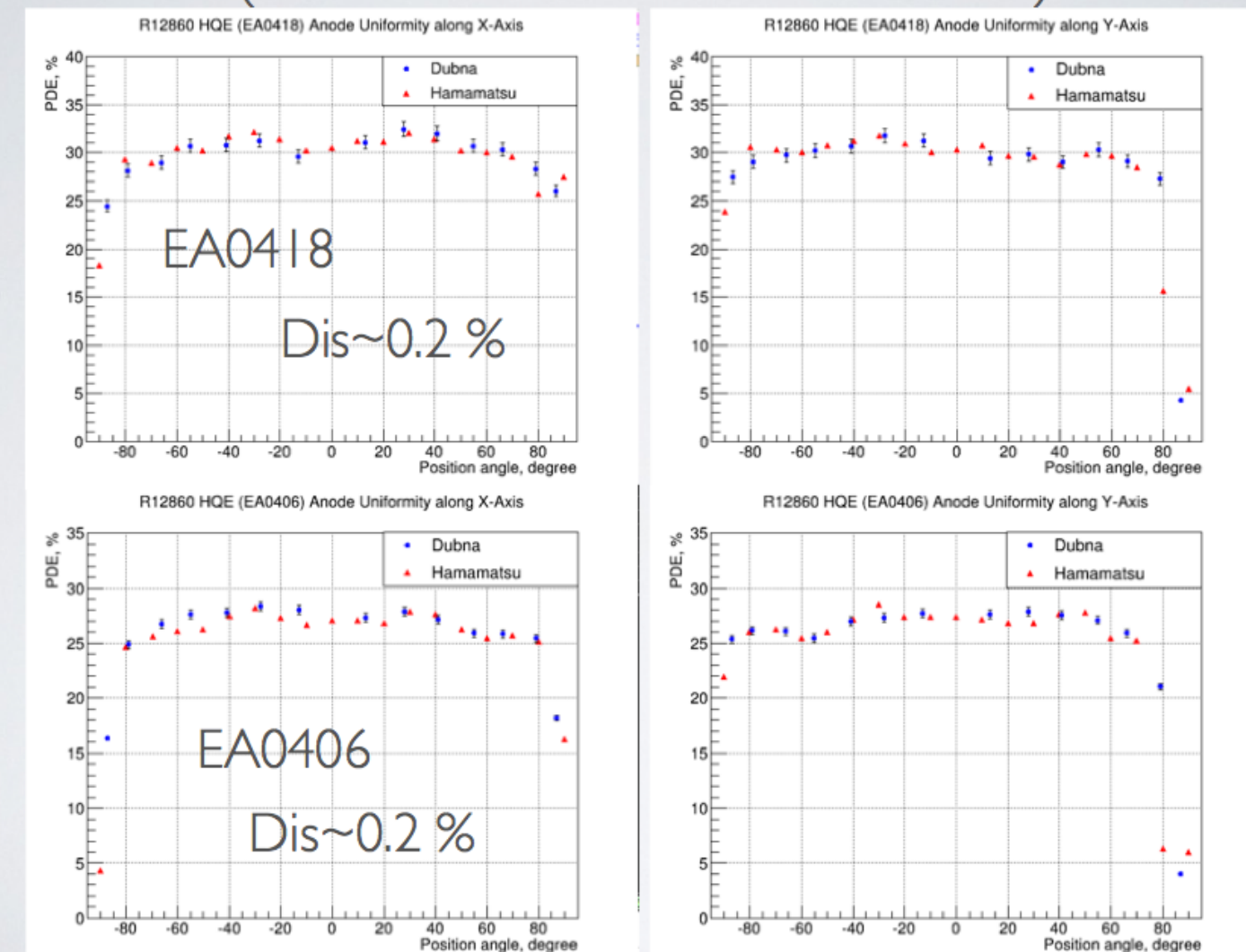
LED CALIBRATION



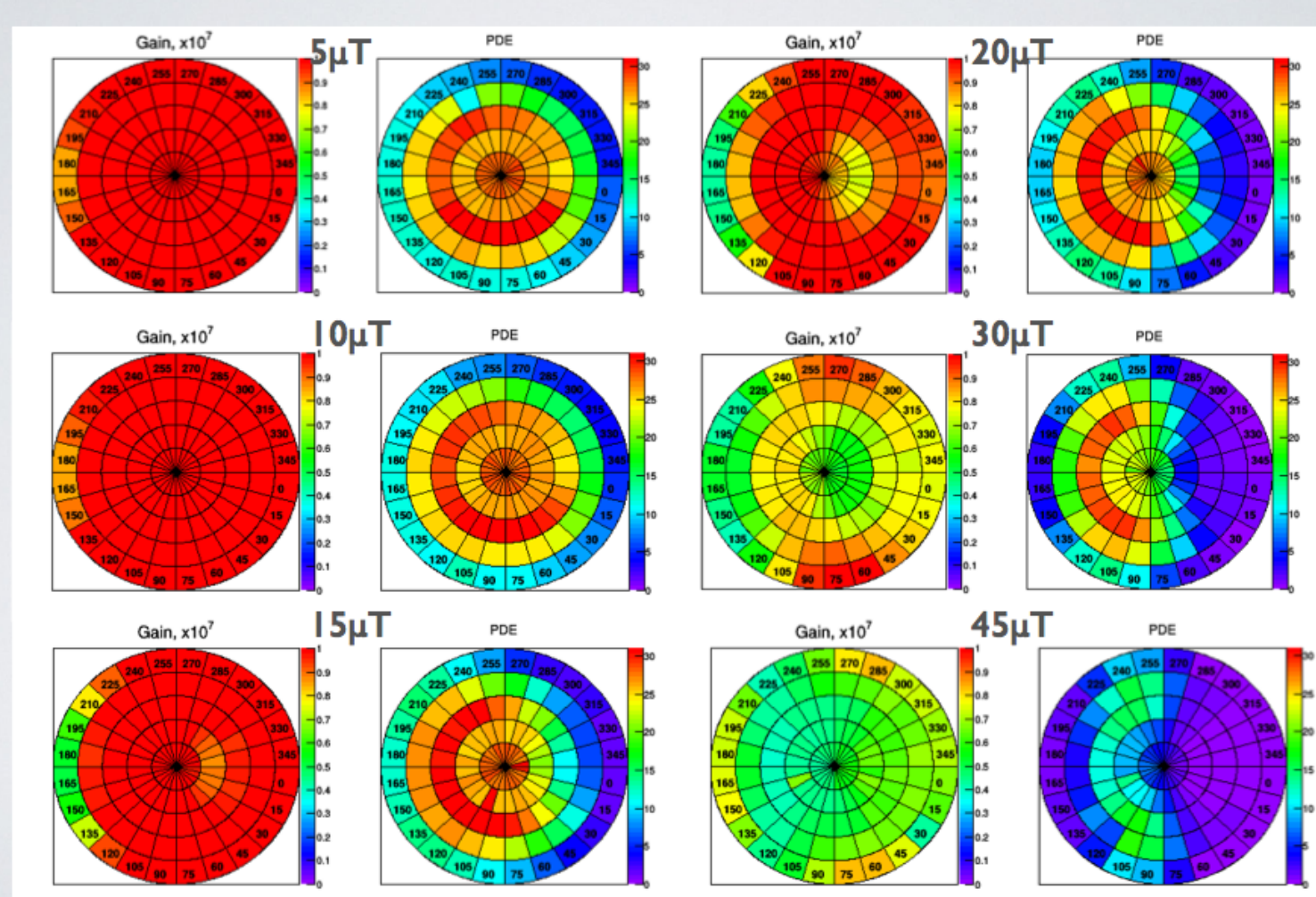
PMT Hamamatsu RI355
Was calibrated by certified PIN



COMPARISON WITH HAMAMATSU (CALIBRATED PMTs FROM IHEP)



MAGNETIC FIELD SENSITIVITY



Conclusions

To ensure proper characteristics of 20 000 large (20"-diameter) PMTs for JUNO neutrino detector, special test equipment was designed and constructed:

- 36-PMT Test container which allows measuring all necessary integral characteristics of PMTs
- Single PMT Scanning system for measuring differential parameters along photocathode

MAGNETIC SHIELDING

- Multi-layer soft Si-iron, aluminum
- Installation completed in August 2016
- Shielding factor better than 10
(one box needed additional shielding)

