

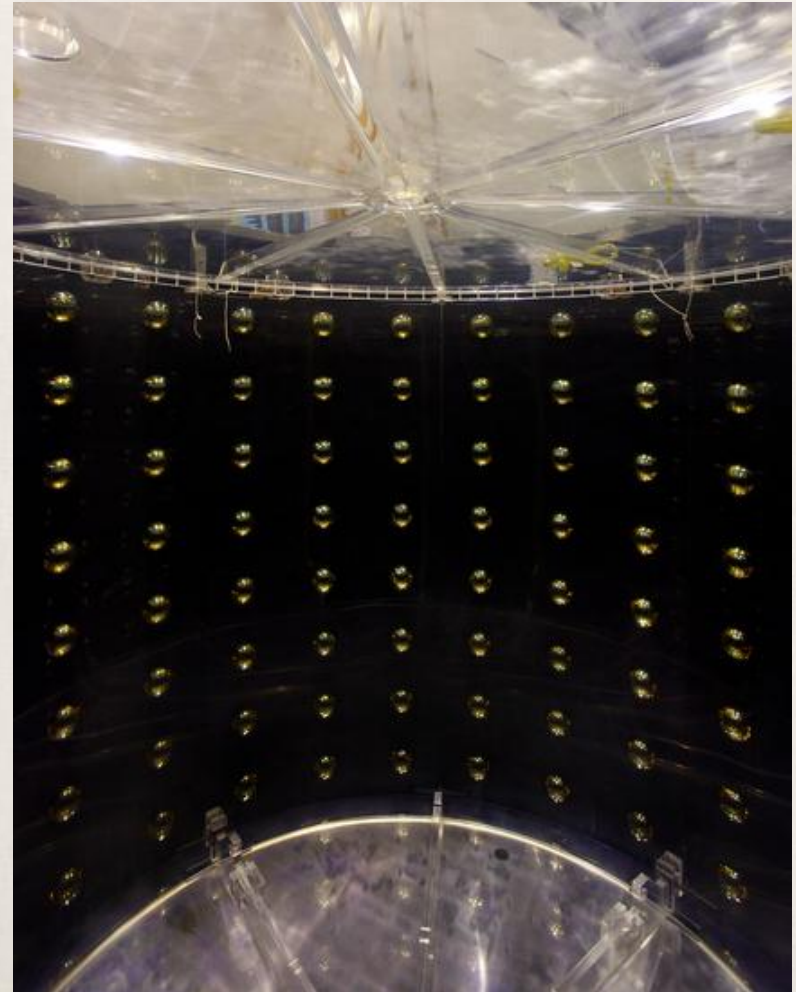
The PMT System for the Daya Bay Reactor Neutrino Experiment

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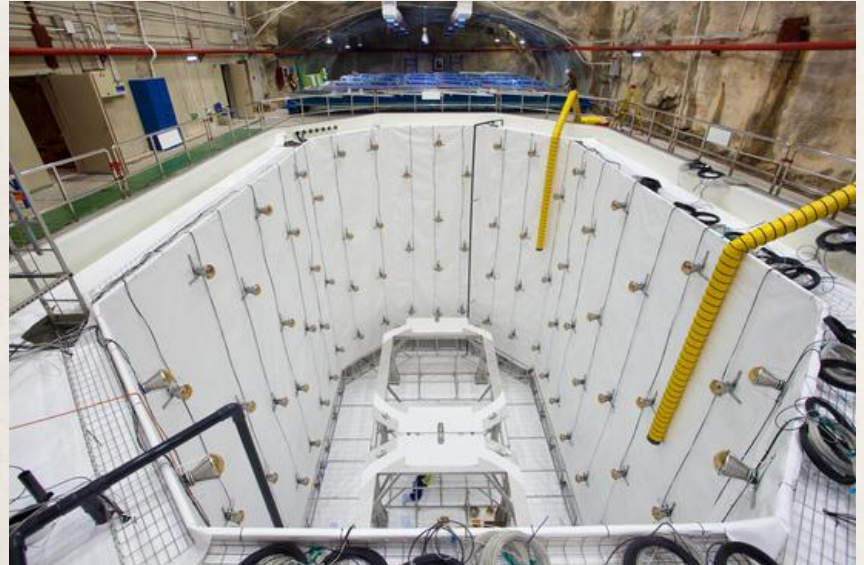
PMTs in Anti-neutrino Detector (AD)

- Eight ADs in three Experimental Halls (EH).
- Each AD has 192 8” photomultiplier tubes (PMTs).
 - 6% photocathode coverage,
 - 12% effective coverage with top and bottom reflectors.
- PMT: Hamamatsu R5912
 - Oil-proof assemblies,
 - Low-radioactivity glass.
- HV system:
 - Mainframe: CAEN SY 1527LC,
 - HV modules: 48-channel A1932AP.



PMTs in Muon System

- 288, 288 and 368 8" PMTs in the water Cerenkov detectors of Daya Bay, Ling Ao and far site EHs respectively.
- Each water pool has both Hamamatsu and MACRO PMTs.
- Hamamatsu R5912 PMTs:
 - Waterproof assemblies,
 - Withstand more than 2 atmospheric pressure.
- MACRO PMTs:
 - EMI 9350KA, 9350KB, D642KB
 - Custom-built waterproof assemblies
 - With stand 6~12psi gauge pressure
- Same HV system as ADs



Hamamatsu waterproof



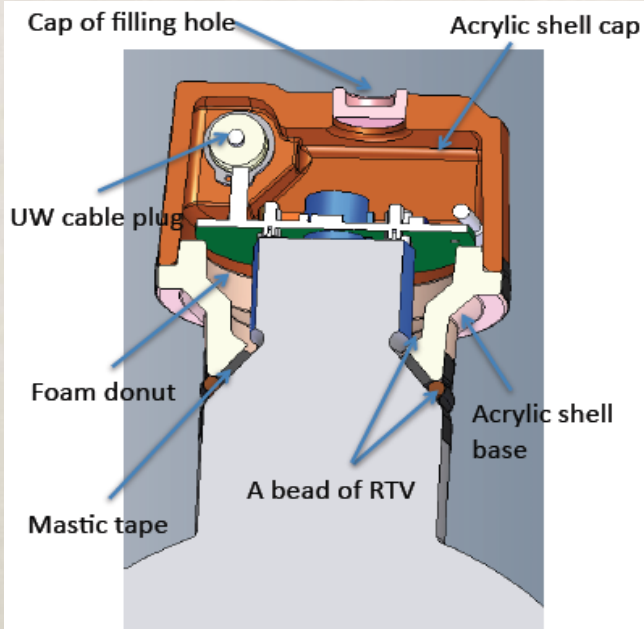
MACRO waterproof



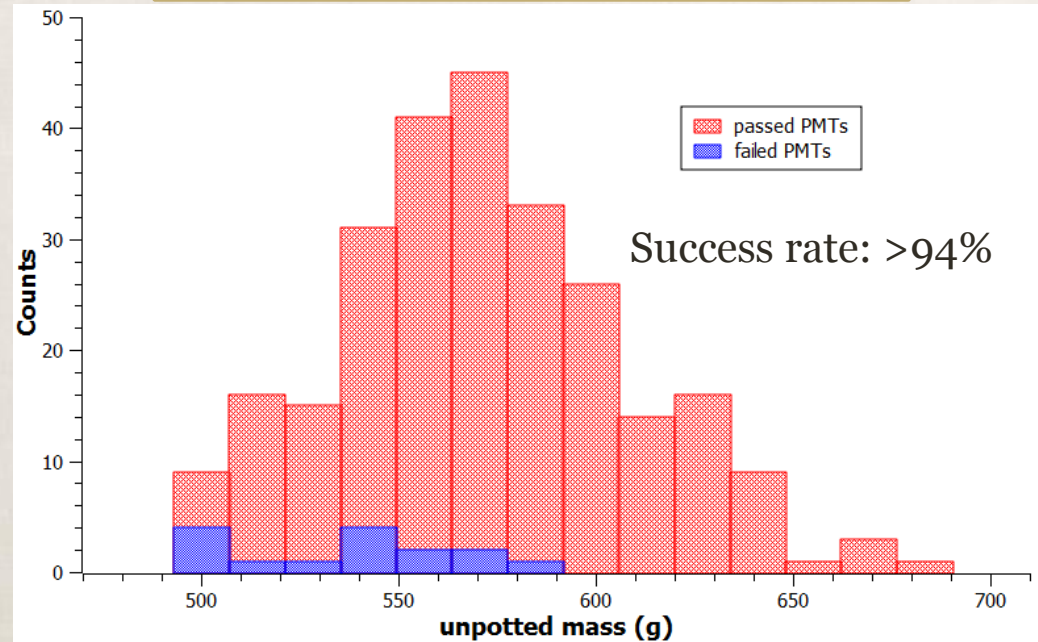
Fabrication of MACRO PMT Waterproof Assemblies

- We fabricated 394 MACRO waterproof assemblies
- Assemblies with different glass weights were subject to different gauge pressures (6psi ~ 12psi) in a water tank.
- They will be placed at different depth in the water pools

Potting shell design



Pressure Test Results VS PMT Weight



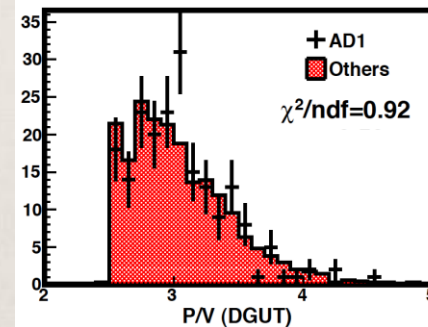
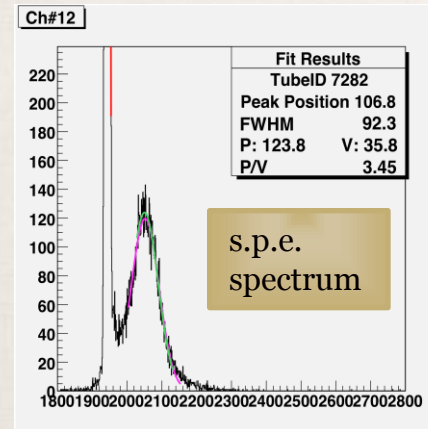
PMT Requirements & Characteristics

Requirements

Parameters	Specification
Quantum Efficiency	>25% @420nm
Gain	2×10^7
SPE P/V	≥ 2.5 at a gain of 10^7
Pulse Linearity	2% @ 40mA with tapered base
Dark Rate	<10KHz
After-pulsing	APR <10% for s.p.e. main pulse
Rise and Fall Time	rise time ≤ 6.5 ns, fall time ≤ 10 ns
Transit Time Spread	$< \sim 3$ ns (FWHM) at a gain of 10^7 for s.p.e.

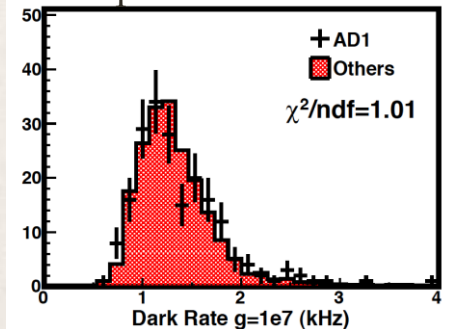
- PMTs are operated at positive high voltage.
- Single cable carries both HV and PMT signal.

Characteristics



PMT assemblies	Total	Fail
Hama. Oil	1625	29
Hama. Water	625	11
Macro Water	352	17

Failed-test tubes are sent back to the manufacture for replacement.



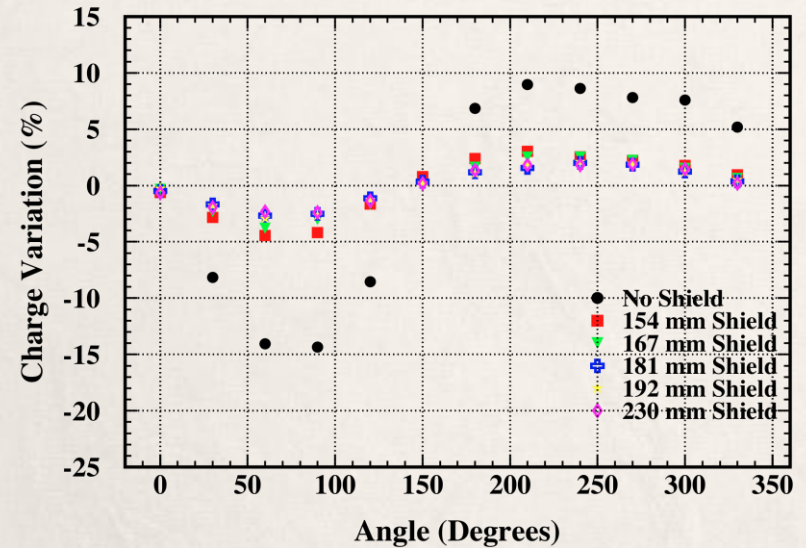
- PMTs in each AD are randomly chosen.
- PMT properties in different ADs are uniform.

Magnetic Shield

Finemet[®] foil



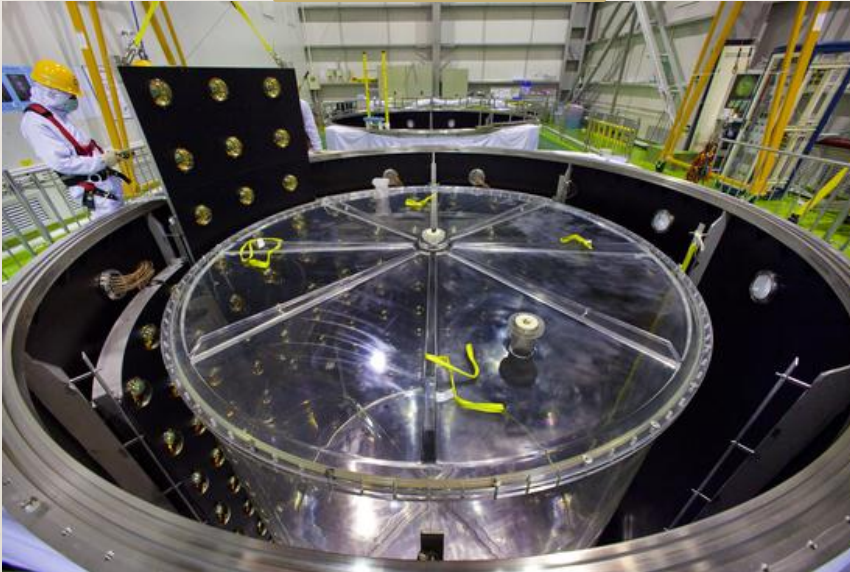
Hamamatsu R5912 SN:4338, Magnetic Shield Test



- Magnetic shield: 16 μ m thick conical FINEMET[®] foil
- Surround the region between base and equator of PMT with magnetic shield
- Magnetic shield reduces the charge variation from 25% to less than 8% peak to peak.

PMT Support Structure

AD



- AD PMTs are secured in individual mounts;
- Mounted PMTs are installed in PMT ladders;
- PMT ladders are installed into a stainless steel tank.

Water pool

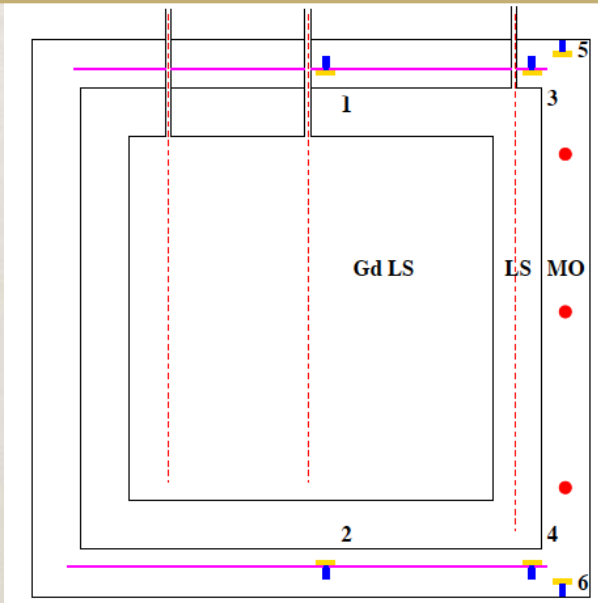


- Muon PMTs are secured in individual mounts;
- Mounted PMTs are installed onto T-shaped supports;
- Mounted PMTs on supports are installed onto standing structure in water pool.

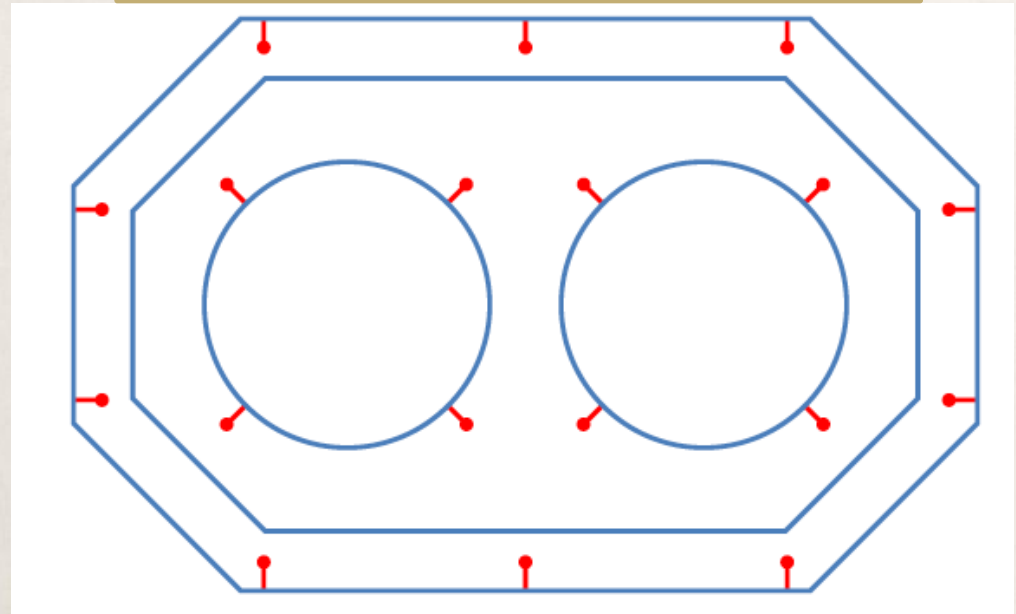
Monitoring of PMT Performance

- Calibration system
 - AD: LED diffuser balls and radioactive sources.
 - Water pool: LED diffuser balls.

AD calibration system:
LED and radioactive sources deployment



Water pool calibration system (Daya Bay near site) :
LED deployment (top view)

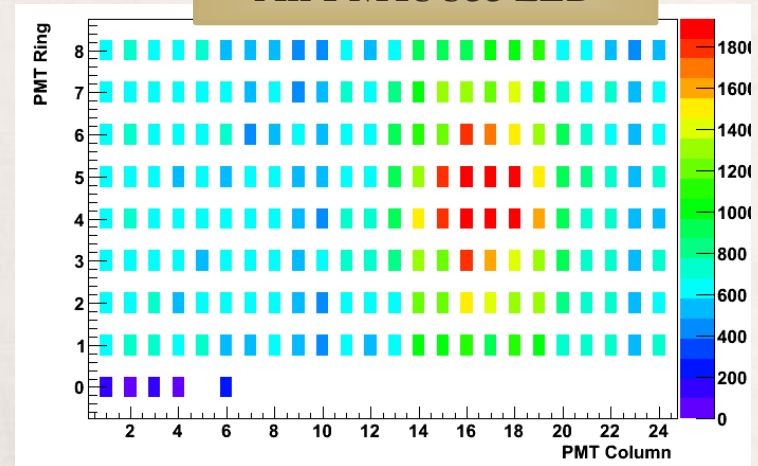


- Slow control for PMT HV system: High voltage, current, etc. monitoring.
- Real-time event display.

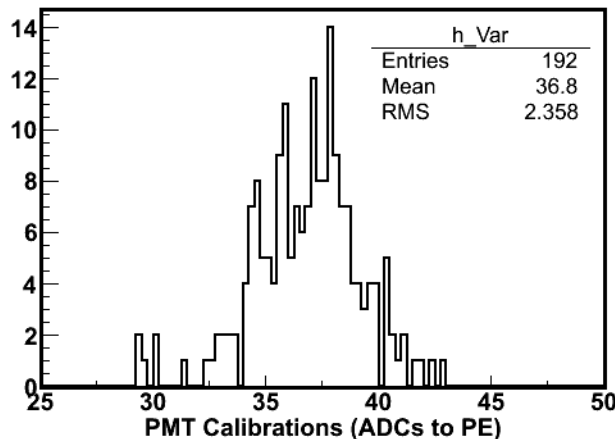
PMT Performance in AD Dry Runs

- All PMTs work as expected in AD1 – AD4.
- PMT gain in one AD is uniform within 6% without gain tuning.
- Gain drift less than 1% in 3-day stability runs.
- PMT dark rate is 3-4kHz on average.
- Further PMT calibration:
 - timing, after-pulse, linearity, ringing, etc.

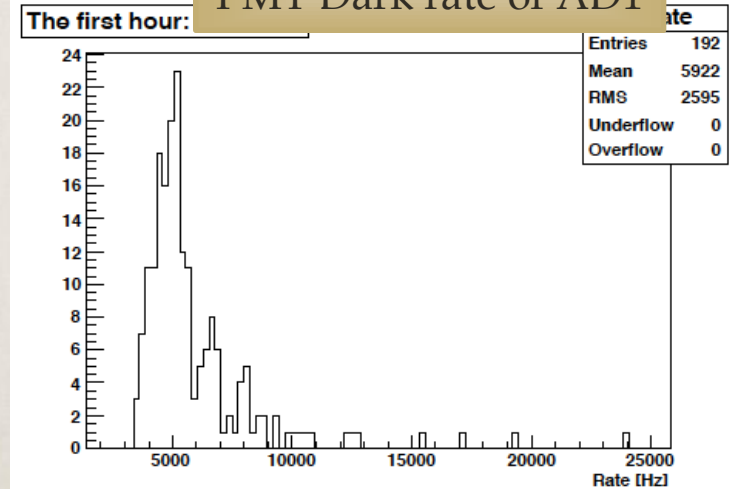
All PMTs see LED



PMT Gain calibration of AD2

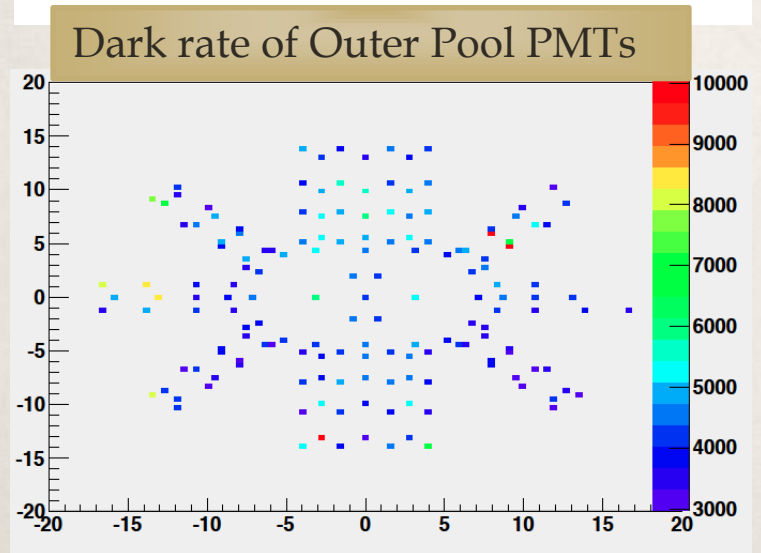
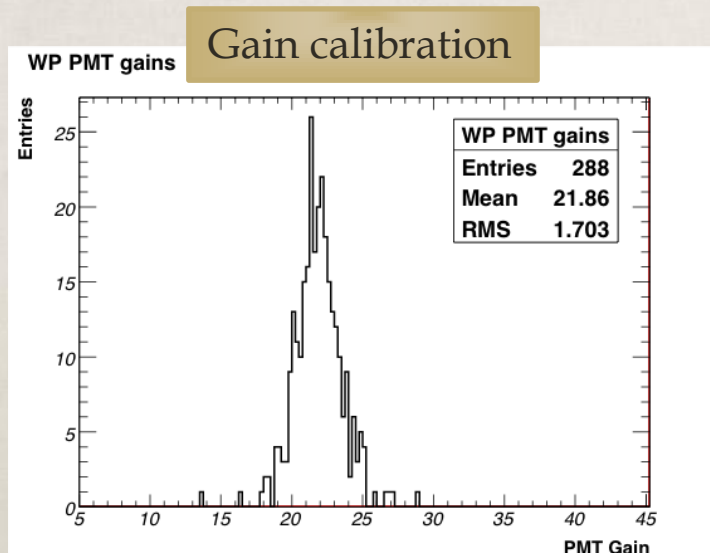
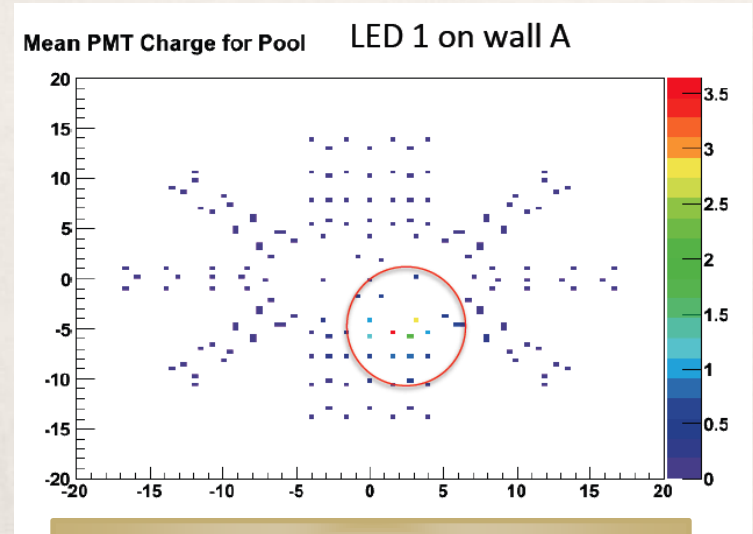


PMT Dark rate of AD1



PMT Performance in EH1 Water Pool Dry Run

- All PMTs are installed in the water pool of EH1.
- All PMTs and LEDs work.
- PMT gain calibration is preliminarily done.
- Preliminary dark rate of outer pool PMTs is ~ 5 kHz, and inner pool PMTs is ~ 10 kHz.



Summary



- ❖ Daya Bay Experiment is going well.
- ❖ PMT system is tested and ready. Daya Bay near site data taking will start in this summer.