Test of new photo-detectors in a water tank

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6th Hyper-K Open Meeting

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Overview of proof test

2012 | 2013 | 2014 | 2015 | 2016 | 2017

20cmΦ HPD

8 HPDs

1st proof test (2013.8 -)

5 HQE PMTs

High QE
for SK PMT

1st test with
5 HQE PMTs and
8 20cm HPDs
over half a year so far

200-ton water tank

HK prototype test

Test ~200
HK sensors

Proof test

Select
HK photosensor
in 2016

Report today

Installed 3 high-QE
Box&Line PMTs
in 2014 summer.
Started 2nd phase test

New PMT
w/ box&line dynode

2nd (2014.9 -)

50cmΦ HPD

3rd, 1yr

(Under preparation)

50cm Photosensors

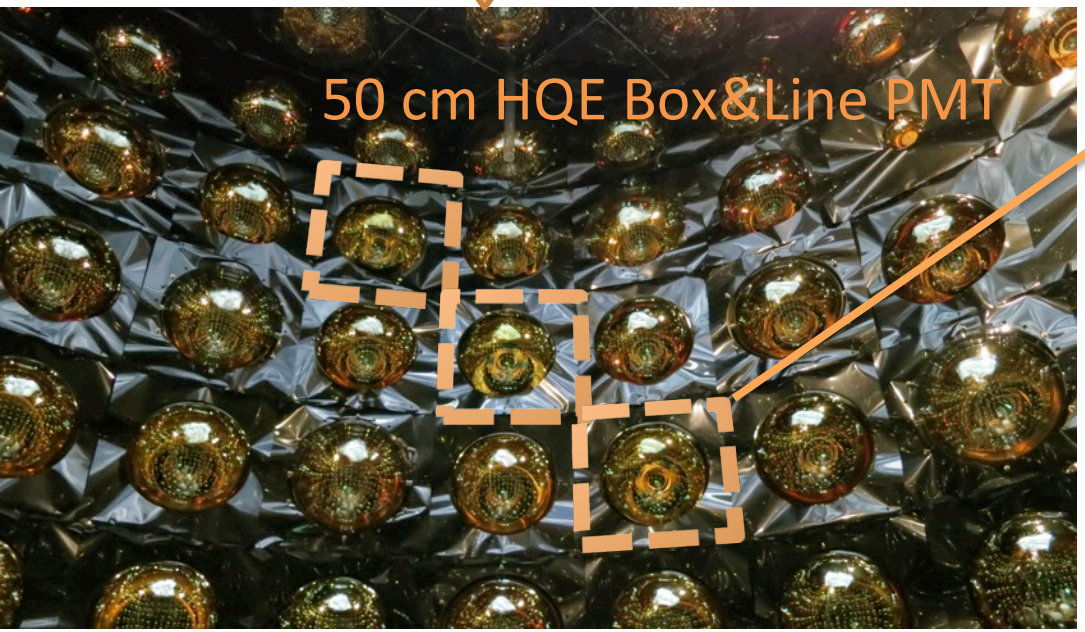
By Hamamatsu Photonics K.K.

- New 50 cm Φ photodetectors developed for HK.

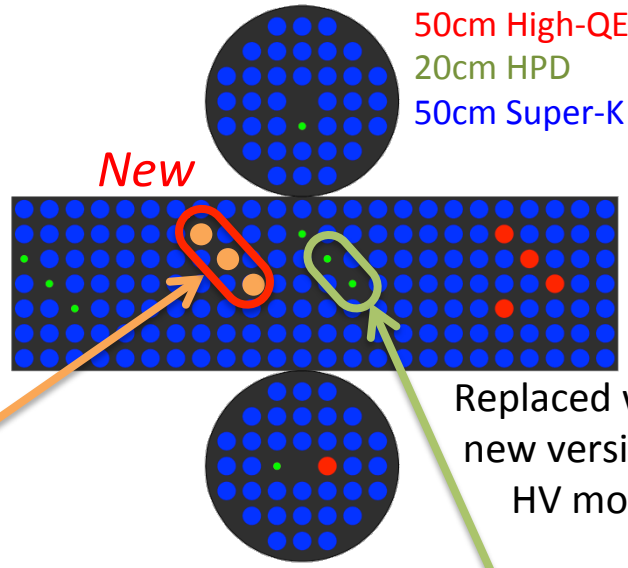
Model	R3600 (Used for 2-30 yrs)	R12860	R12850
Amplification	Venetian blind dynode	Box and line dynode	20mmΦ Avalanche diode
Q.E.	~22%	~30%	~30%
C.E. (calculated)	80%	93%	95%
T.T.S. (FWHM)	5.5 ns	2.7 ns	0.75ns (w/o Preamp.)
		High efficiency, good resolution and low cost	
Bias voltage	2 kV bias	2 kV bias	8 kV bias + AD bias (<1kV)
Proof test	1.4 yrs for HQE now	0.3 yrs now from Sep.2014	> 1 yrs expected

Installation in 2014 Jul/Aug

Replace 3 Super-K PMTs to **Box&Line PMTs**



- High-QE Box&Line PMTs



Replaced with new version of HV module

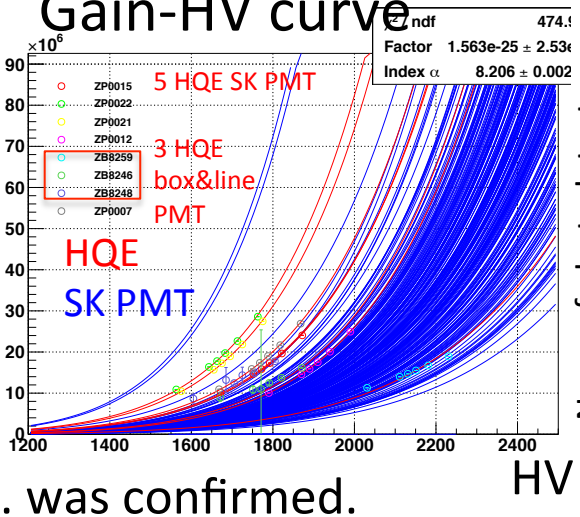
- Installation finished in 2014/8.
- Proof test restarted.

Calibration

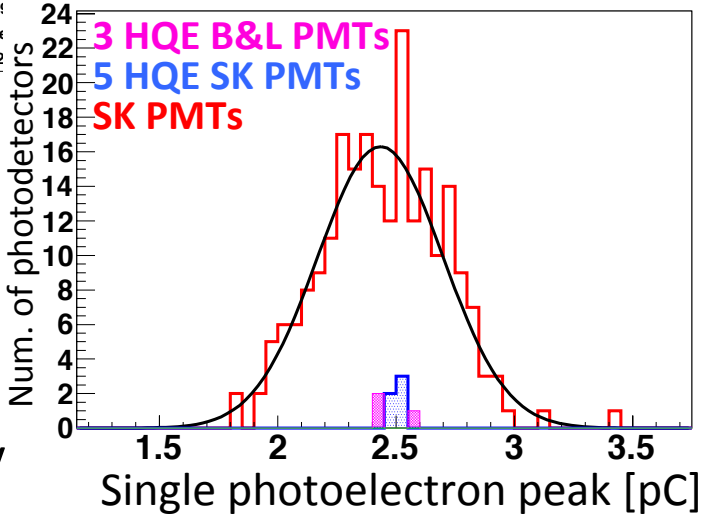
Calibration

- HV of SK PMTs in EGADS determined by QE×CE×Gain.
- Gain of HQE SK, Box&Line PMTs adjusted by 1 p.e. peak to get same gain as SK PMT's.

Gain-HV curve

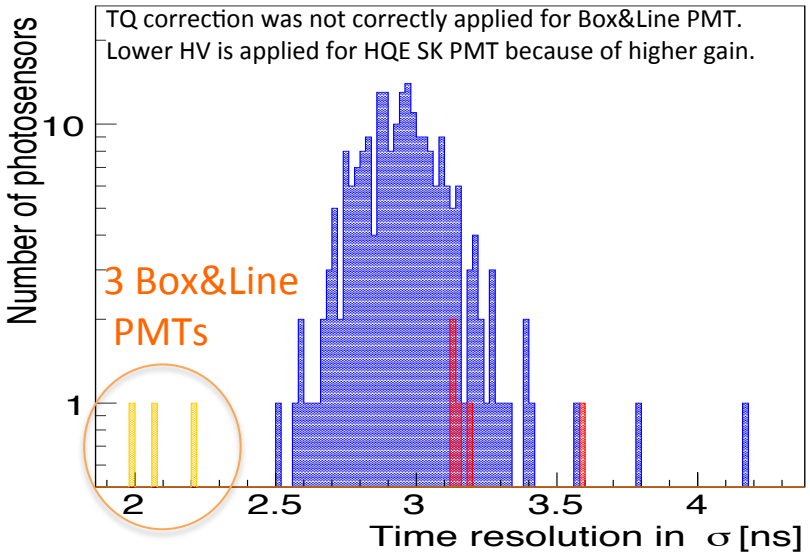


Gain after calibration (in pure water)

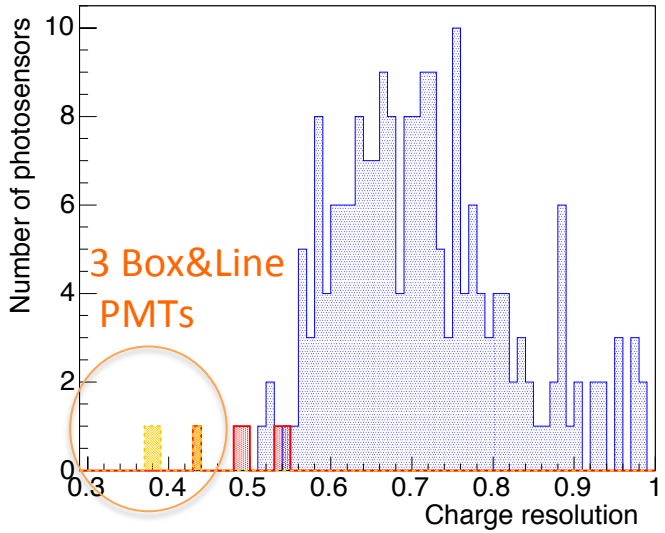


Good performance at 1 p.e. was confirmed.

Time resolution at 1 p.e.



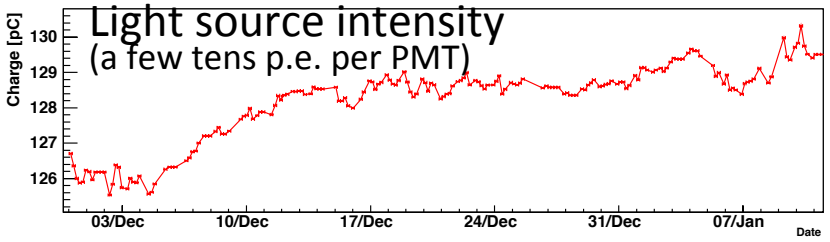
Charge resolution at 1 p.e.



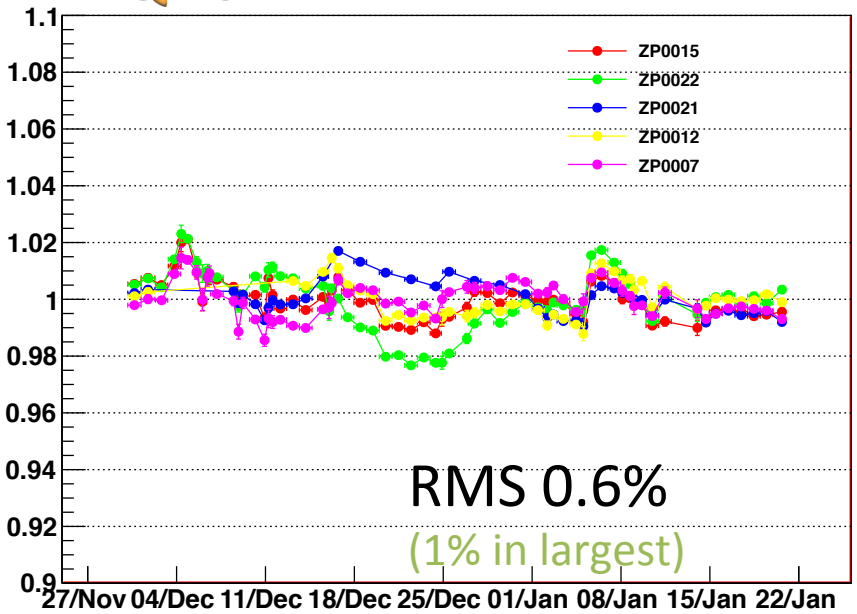
Gain Stability of HQE PMTs

Light peaks from Xe light flashing were monitored.

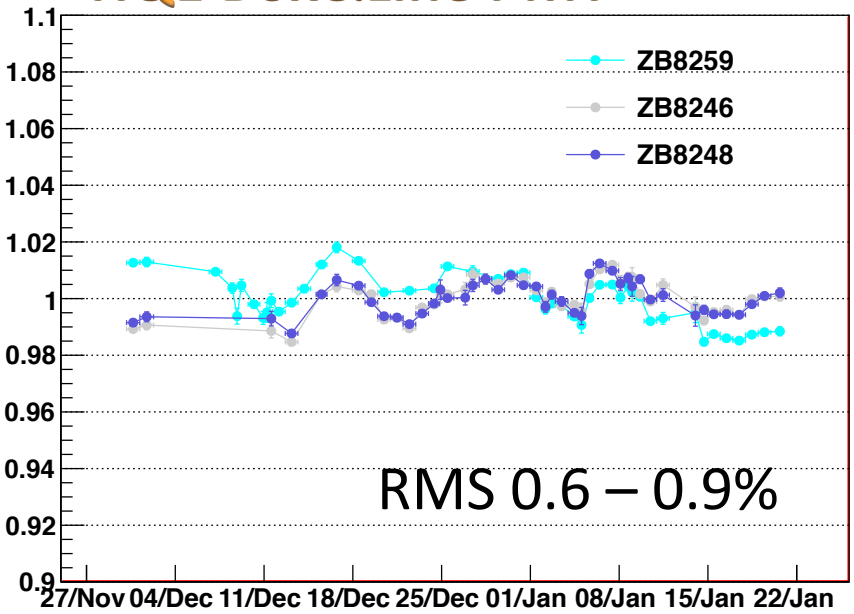
Peaks are corrected by reference intensity monitor.
Water quality such as attenuation and absorption might affect peak position if there was change.



HQE SK PMT



HQE Box&Line PMT

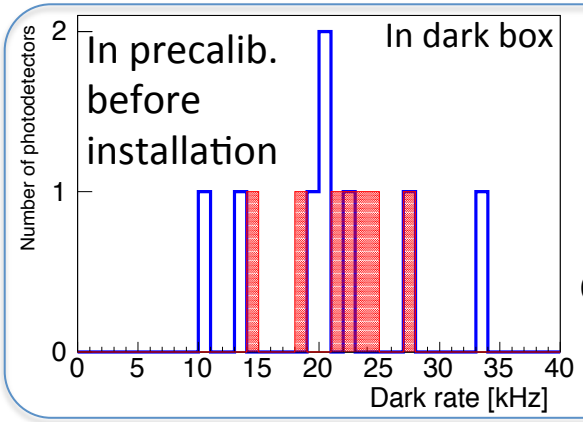


Date (week/div)

- Charge of high QE PMT seems stable.

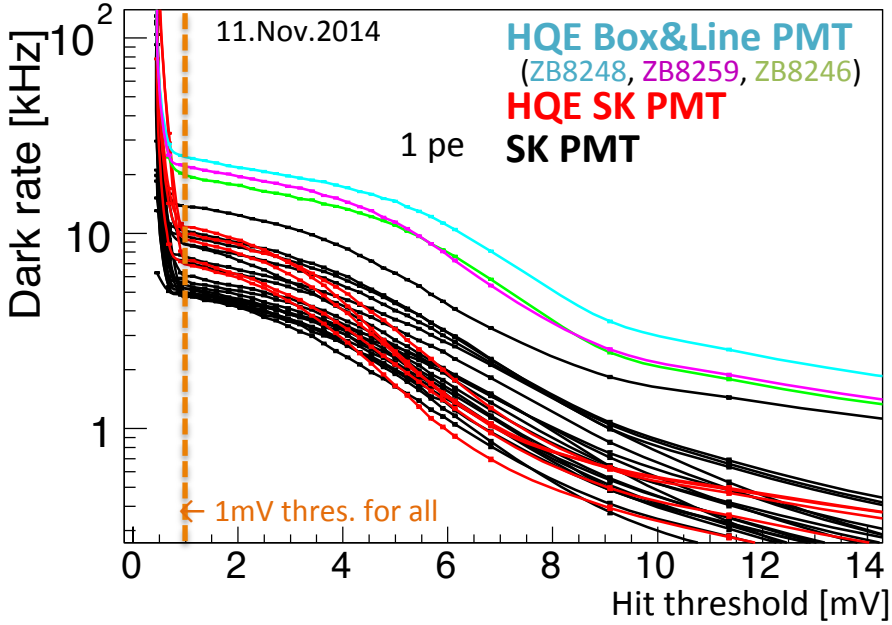
Dark rate

Dark rate measured before installation

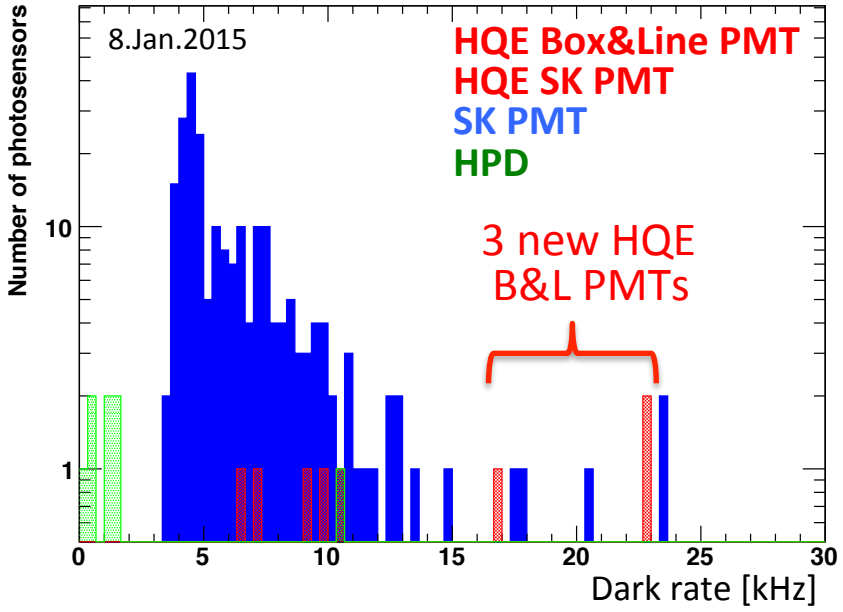


Measured just after darkened by pre-calibration.
At 1mV threshold by pre-calibration
in dark box
HQE Box&Line PMT (2014)
HQE SK PMT (2013)
Comparable level before installation
between HQE Box&Line and HQE SK PMTs

Dark rate measured in tank

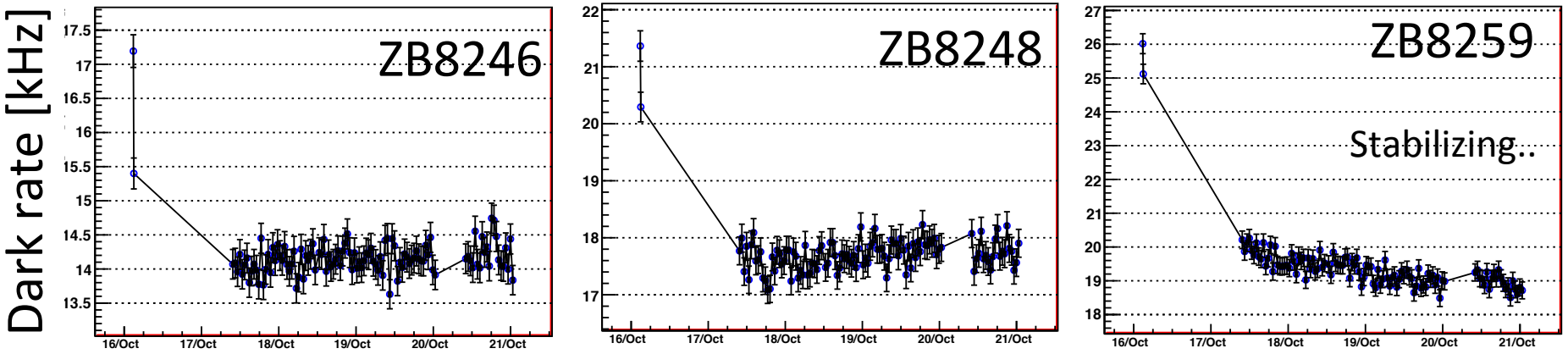


Dark rate distribution in all EGADS photosensors

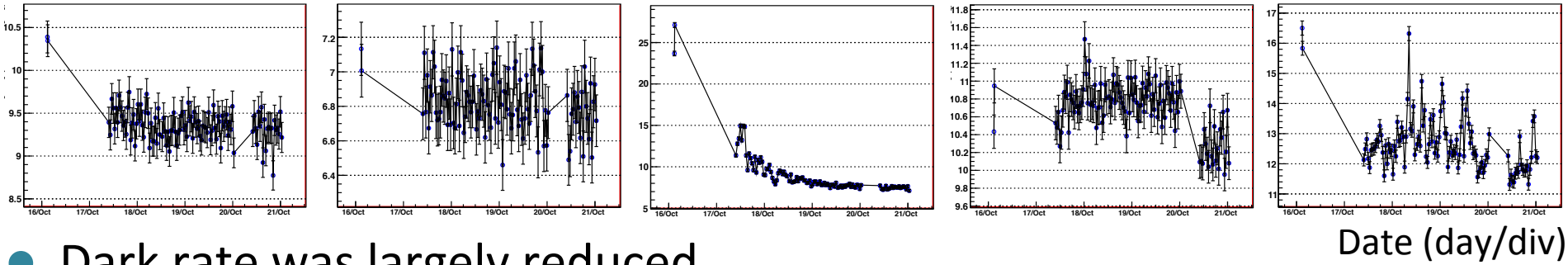


Dark rate stability (an initial few days)

HQE Box&Line PMT



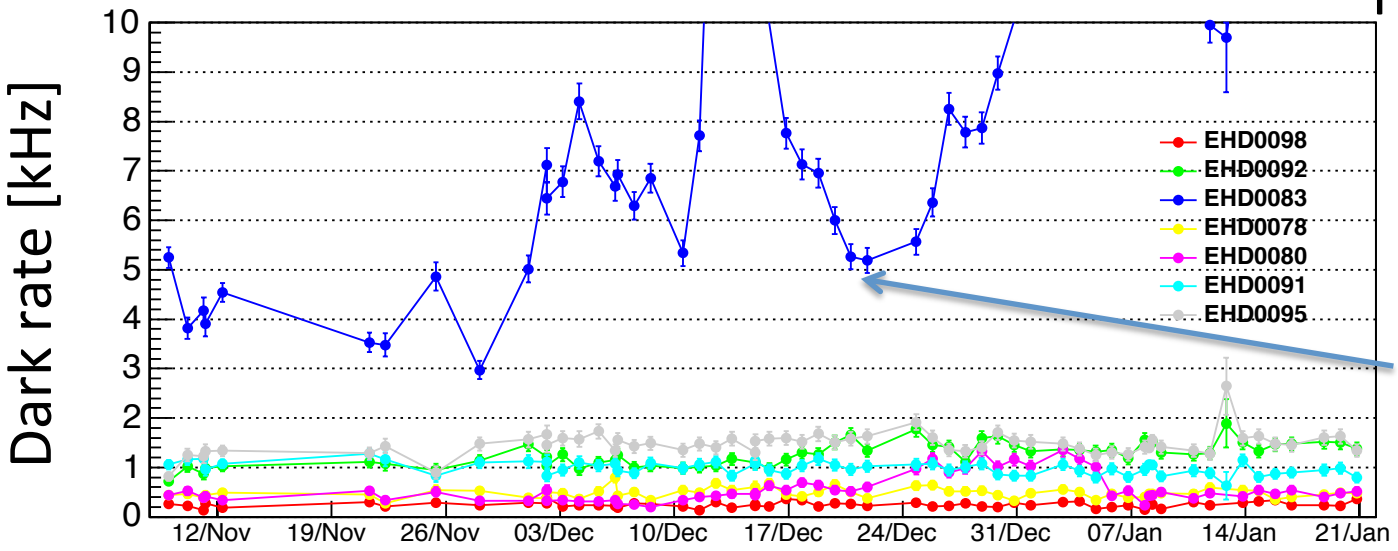
HQE SK PMT



- Dark rate was largely reduced
  for first few days after operation started.
- There is an individual difference of stabilization as well as SK PMT.
- Dark rate is being taken daily and monitored in 1 Hz dedicated trigger.

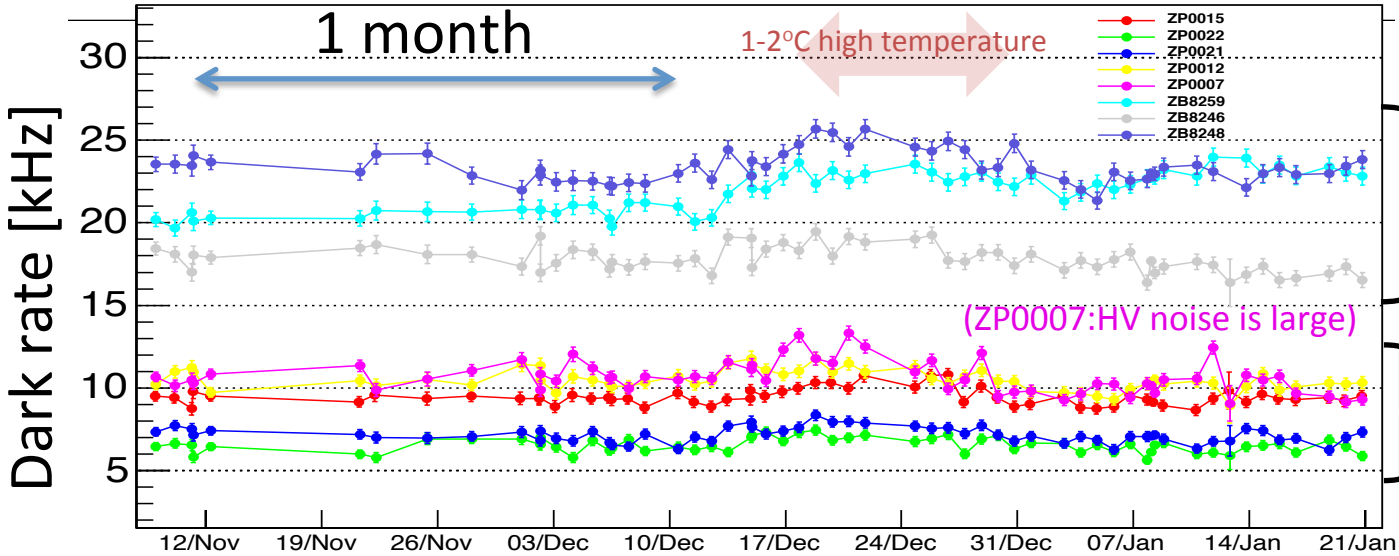
Dark rate - long stability

For a few months



20cm HPD

1 HPD got unstable rate, coming from external electronics noise, etc.



High QE PMT

3 HQE Box&Line PMTs

HQE Super-K PMT

Almost flat and stable

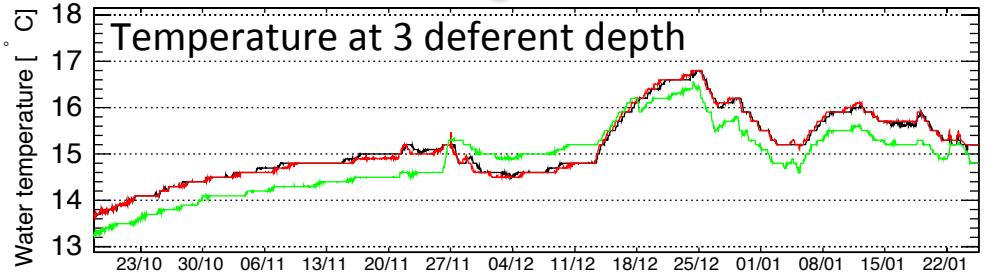
Factor on Dark rate

- It seems high-QE PMT, especially Box&Line PMT, shows higher dark count rate than SK PMT in tank.

- Some factors might cause the difference.
  - Environmental temperature
  - Bias voltage
  - Quantum efficiency
  - Collection efficiency (?)
  - After pulse (from dark rate)

Dark rate and water temperature

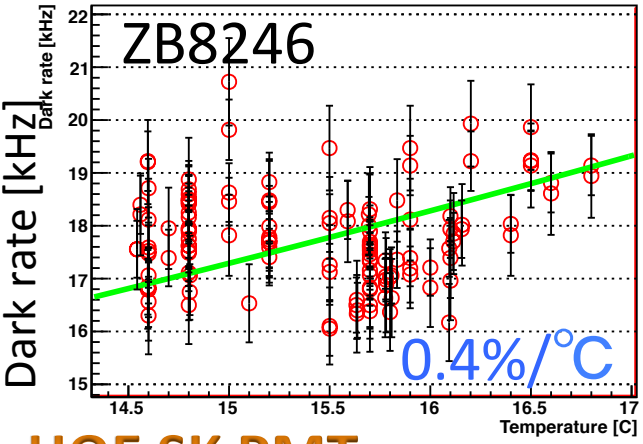
Dark rate depends on environment temperature especially for high QE.
Temperature monitor in tank shows change of a few degrees by loading Gd in water.

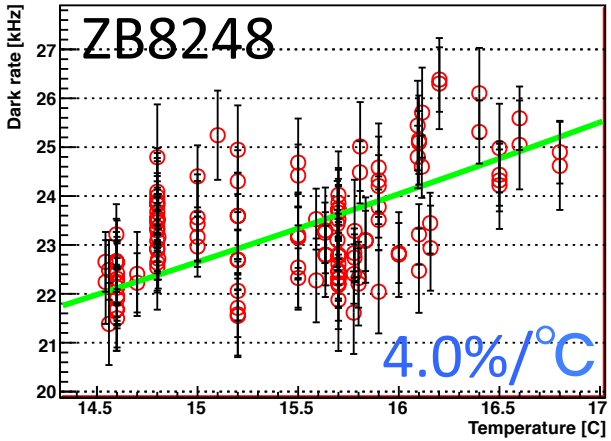


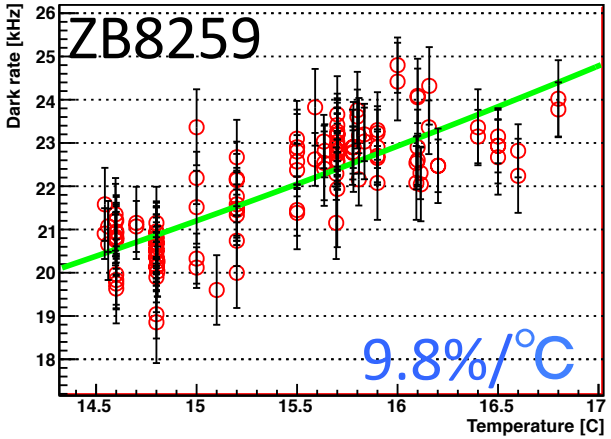
HQE Box&Line PMT

Fit by Richardson's law for thermionic emission of electron

Relative change obtained by a fit with linear function

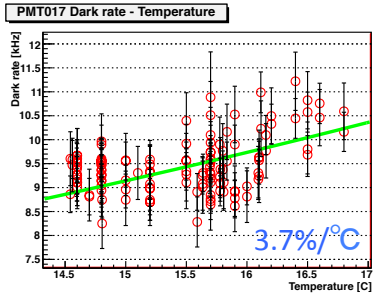


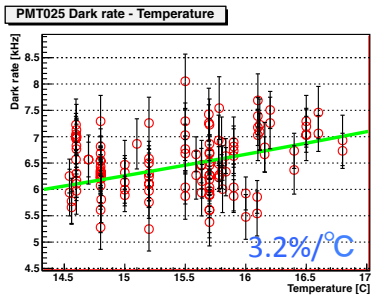


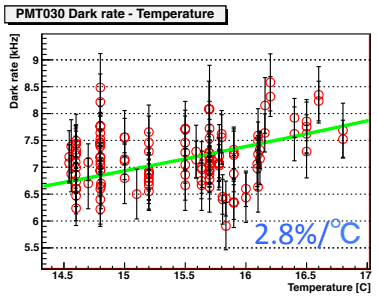


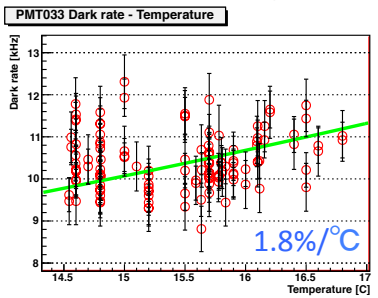
HQE SK PMT

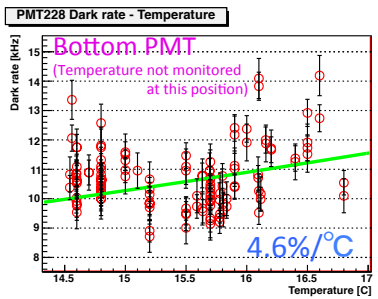
Temperature in water [°C]





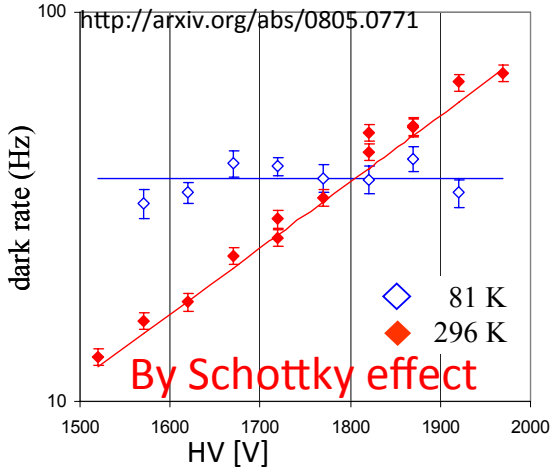






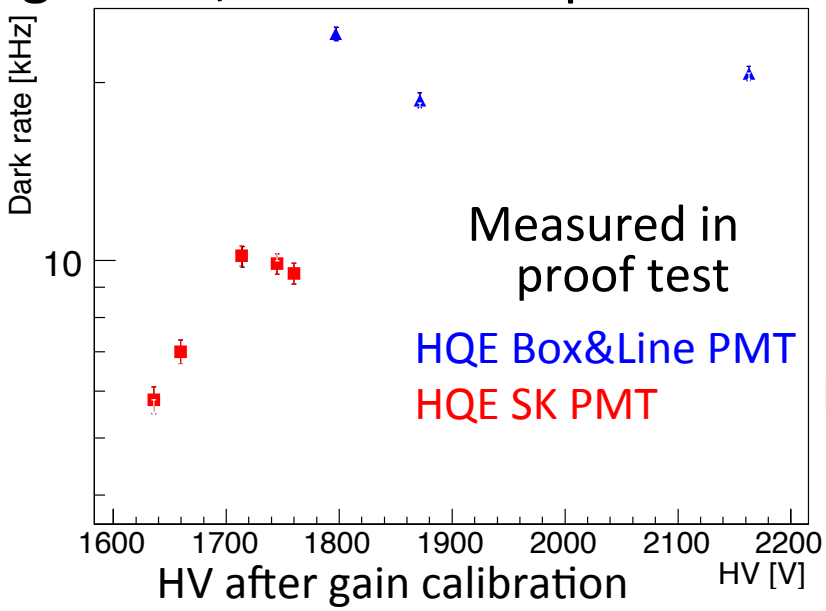
Dark rate and HV bias

Reference :
HV-dark rate dependency



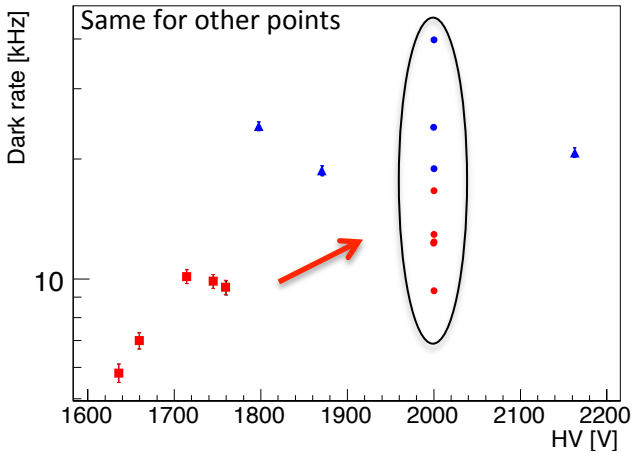
Correlation with applied HV is clearly seen.

In general, dark rate depends on HV.



(The High-QE SK PMT has high gain and HV was set low, depending on each production stage in part of R&D.)

Set all HV to 2000V



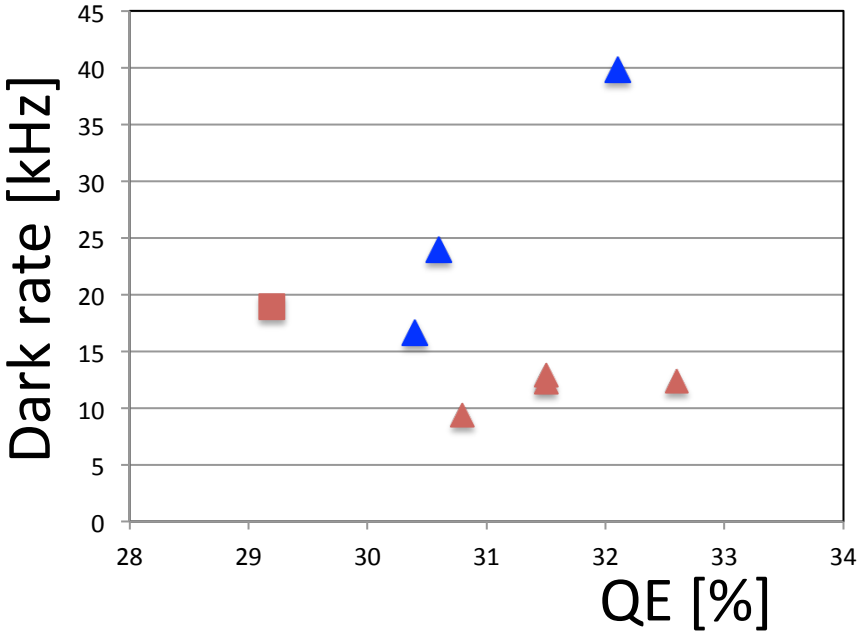
- Different HV set brings variation of dark rate.
- There is still difference even if bias HV becomes same.
- What's other factors?

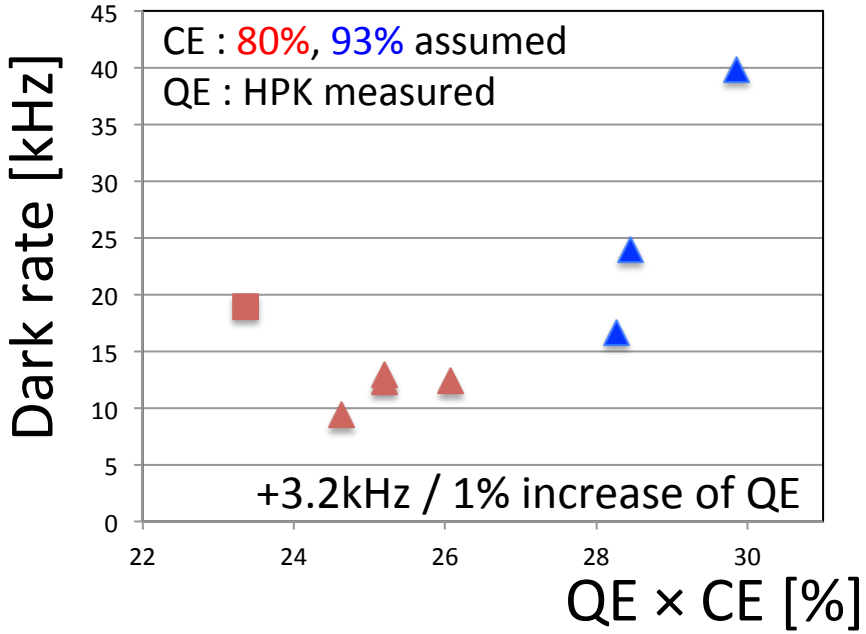
Dark rate and QE

It is known that higher QE tends to get higher dark rate.

- Dark rate at 1 mV threshold by setting all HV to 2000V

HQE SK PMT HQE B&L PMT (▲ Barrel, ■ Bottom of tank)



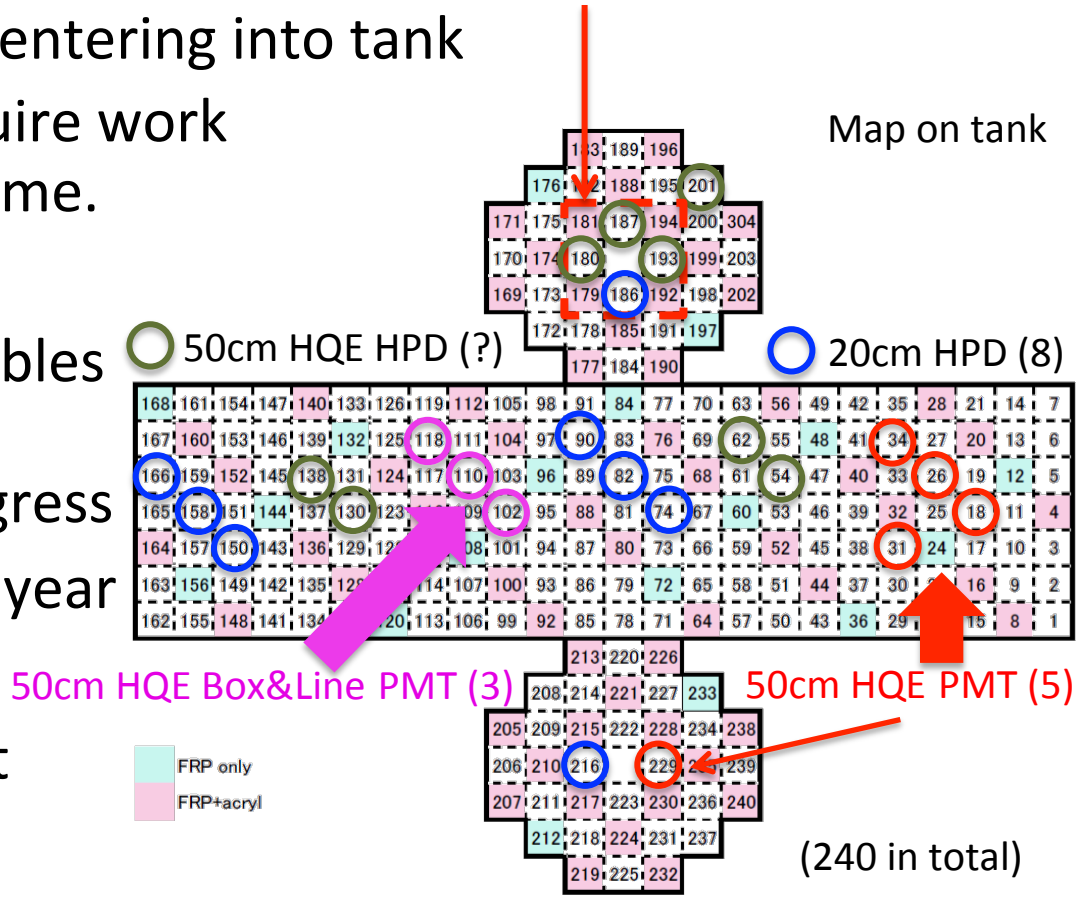


- Relation appears in total detection efficiency rather than QE only.
  - It seems reasonable because noise electron comes from photocathode.
- It might be better to consider possible effect of extra light BG in tank.
  - In dark box during pre-calibration, no difference was seen between two types.

Investigation is required to know how much high detection efficiency affects dark rate measured.

Proof test for 50cm HQE HPD

- 3 for quick installation is possible on top position
  - Installation work without entering into tank
  - Others on barrel wall require work in tank and it takes long time.
- 8 at maximum in total
  - Limited by num of HPD cables
- Plan depends on R&D progress
  - Expect installation within a year
- To Do
  - Preamplifier development
  - Optimization of AD
  - Waterproof and mounting design, and Gd soak test
  - Test in water and in Gd loaded water



Summary

- 3 HQE Box&Line PMTs were installed in Jul-Aug 2014.
  - Properly working with good resolution and stability
- HQE Box&Line PMTs show highest dark rate level in all types.
  - There are several factors to change dark rate.
  - Aim at finding way to suppress dark rate
- 20” HPD is still under development and will be ready in 2015.
  - Proof test starts during the second half of this year.