

Viability Test of 20-cm Hybrid Photodetector in a Water Cherenkov Detector

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Photodetector for Hyper-Kamiokande

Super-Kamiokande (since 1995)
0.0225 (0.05) Mton
39.3m ϕ \times 41.4m
In Kamioka, Japan

Design of Hyper-Kamiokande
48(W) \times 250(L) \times 54(H) m³ \times 2 tanks
Fiducial (total) mass
For ν experiments and nucleon decay search

Next plan of a large water Cherenkov detector

Photodetectors

Inner detector (50 cm ϕ)	11,129	→	99,000
Outer detector (20 cm ϕ)	1,885	→	25,000
Photo-coverage	40%	→	20%

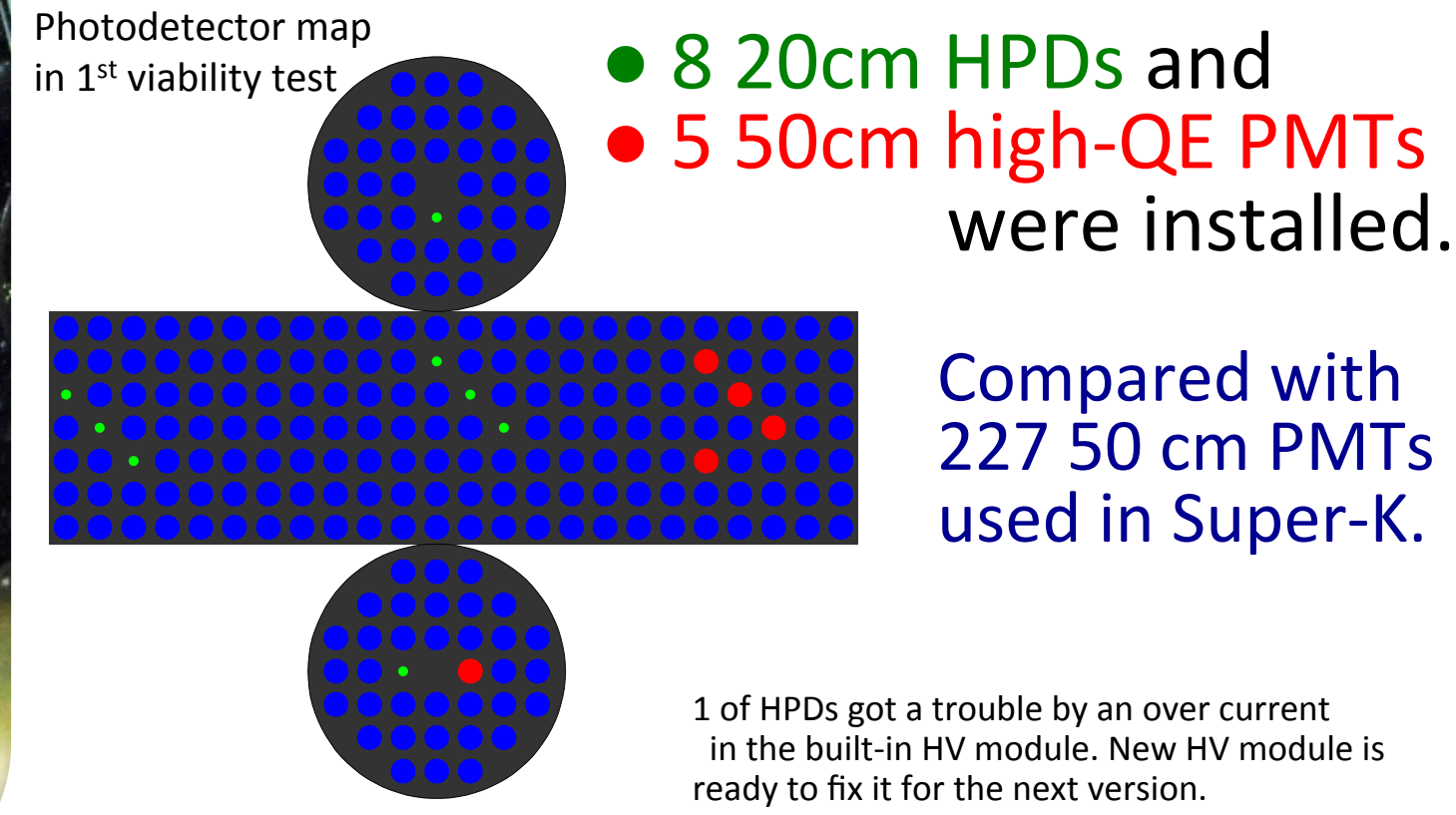
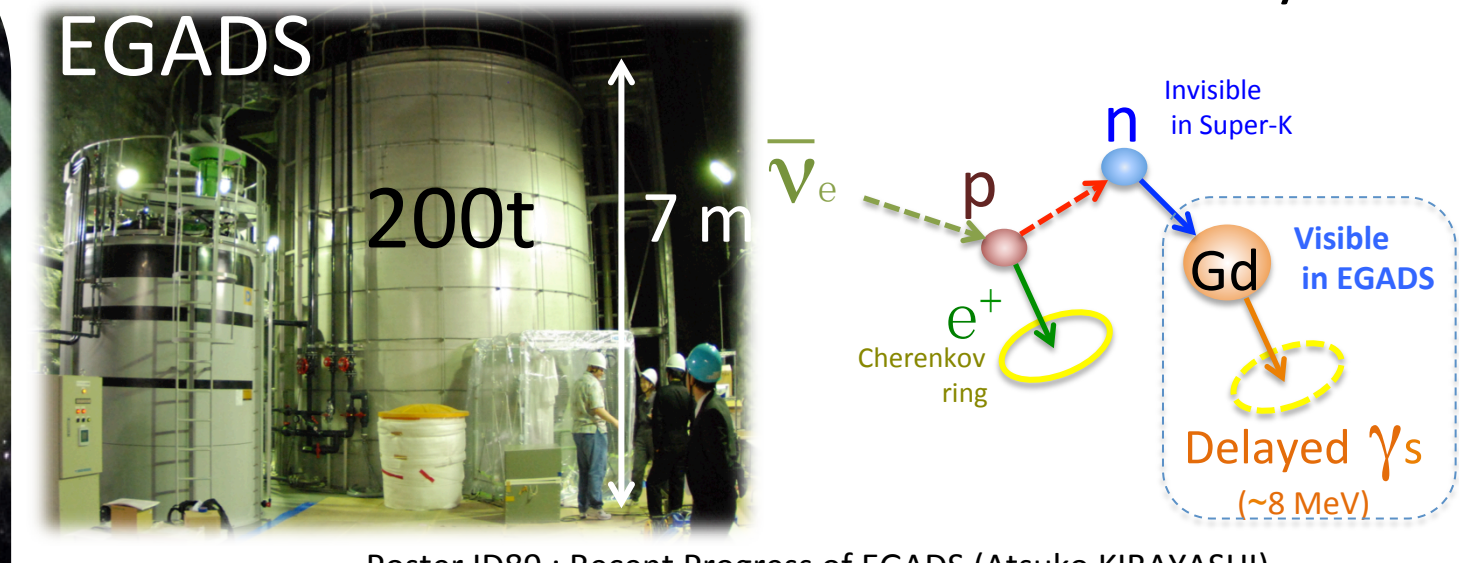
$\times 25$ (20)

A 50 cm- ϕ photomultiplier tube (PMT) had been developed for Kamiokande and improved for Super-Kamiokande. It shows a good performance and is well established for a few tens of years. New photodetectors with high performance and low cost are expected in Hyper-Kamiokande, however, it should be confirmed that they work for a long period without any troubles. R&D of photodetectors and viability test started recently on the new photodetectors.

Viability test in the 200-ton water tank

Two types of new photodetectors are under test since 2013 summer.

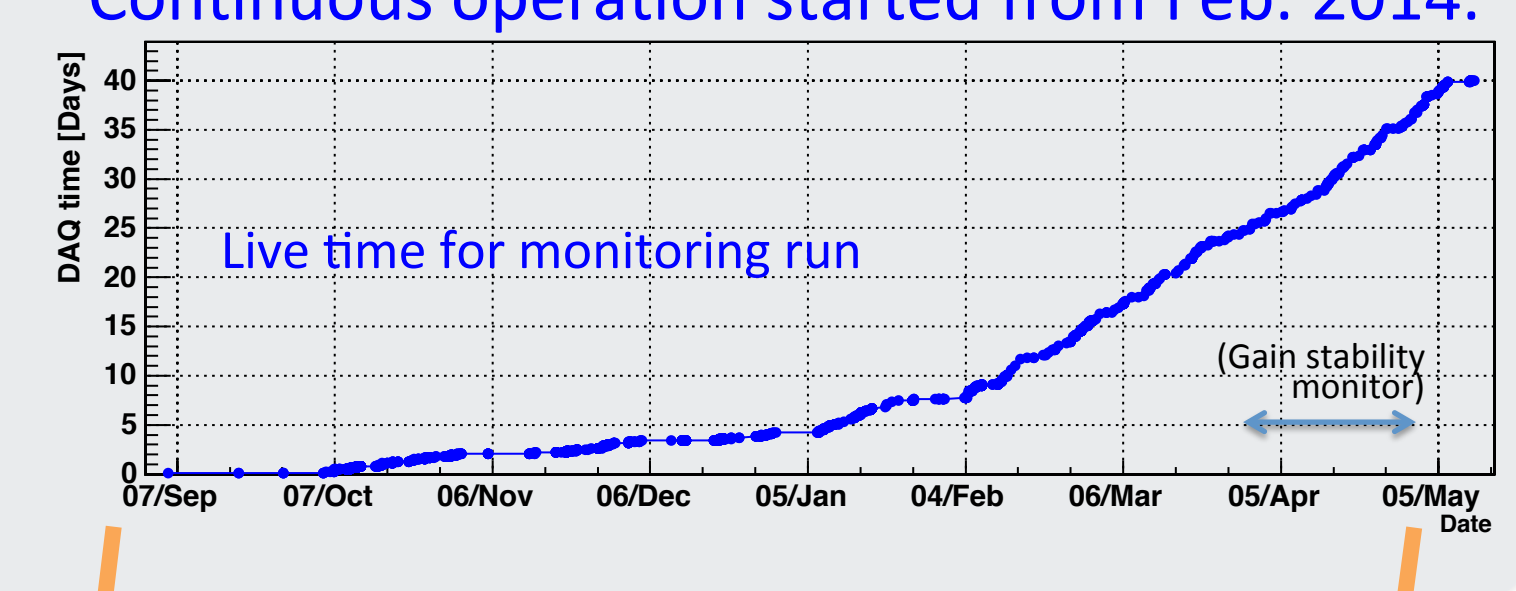
Use tank in Kamioka (Japan) for Evaluating Gadolinium's Action on Detector Systems



Construction finished in Aug. 2013.

Run

- Measurement started from Sep. 2014.
- Total DAQ time : **50 days** so far
- Calibration sources : Laser diode, LED, Xe lamp, Ni γ , Am/Be, etc.
- Continuous operation started from Feb. 2014.



New photodetectors for test

20 cm- ϕ HPD (Hybrid PhotoDetector)

HPD amplification

Avalanche Diode (AD)

200-300V

20cm

5 mm- ϕ Avalanche Diode (AD)

HV power module (2ch 10kV/500V Max)

Pre-amplifier

Signal +10V

Operated by 10V power / control lines ($< 5V$)

8 kV for photo-electron collection

2-300 V biased in Avalanche Diode

High resolution in both charge and time

High and uniform collection efficiency (98%)

Low cost is expected.

Simple

Total gain $\sim 3 \times 10^5$

AD gain $\times 100 \sim 200$

Bombardment gain $\times \sim 1600$

Fast drift

Good resolution

HPD electronics (built-in)

HV Power (+8kV - ΔV)

HPD AD

I-V inverted amplifier

Signal Out

55V/mA $\times 2$

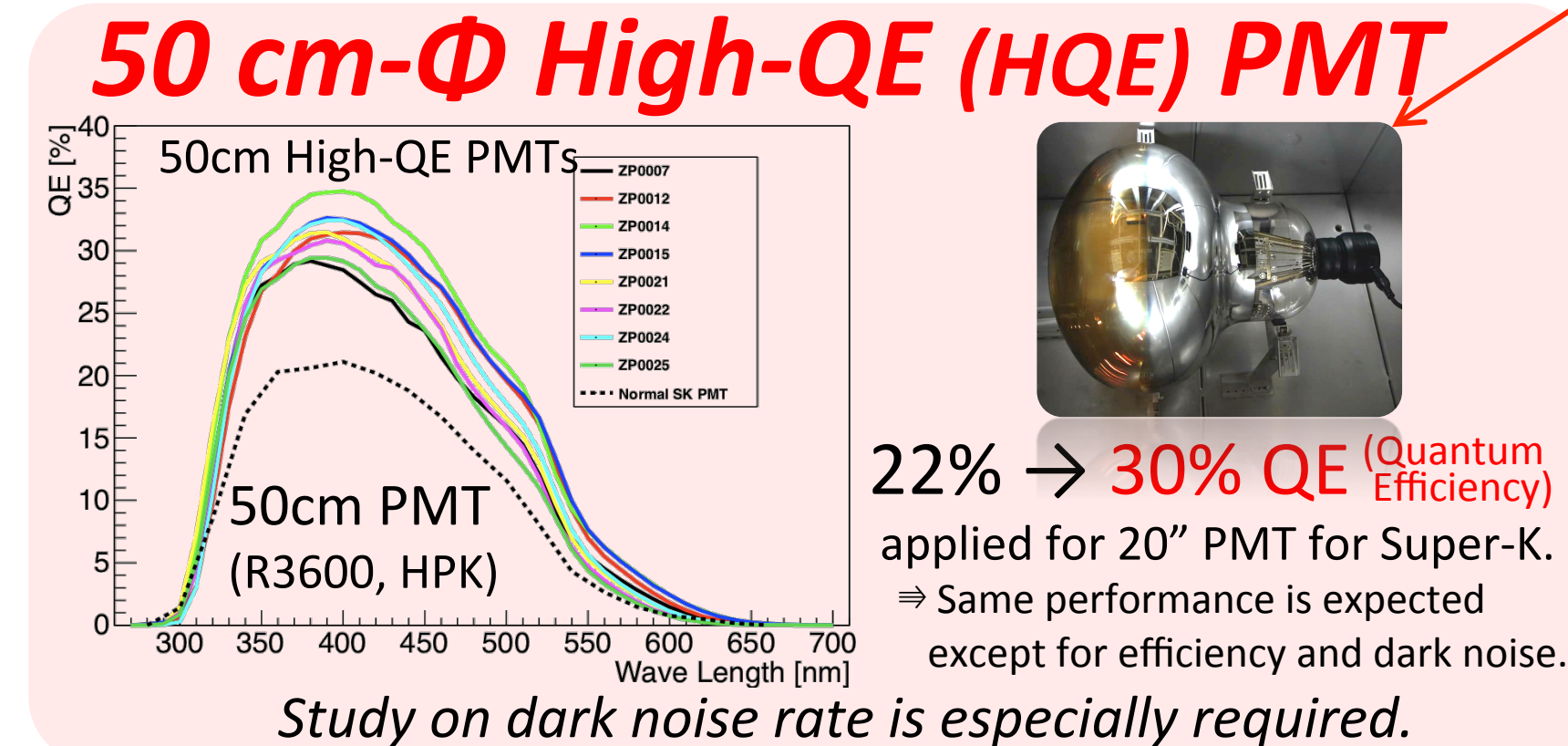
protection

No prior experience using in water for a long time

Durability was tested before installation.

Long running test for 1 month HV power cycle test $> 30k$ times

Proof test is required for Hyper-Kamiokande so that it should work over ten years.



DAQ setup

HPDs

Charge + Time DAQ

Coaxial signal cable

Control power supply

Low voltage cable $< 10V$

Analog Timing Module (ATM) used for old Super-K electronics

400 ns integration range (2TAC+2QAC) \times 12ch

PMTs

Charge + Time DAQ

Coaxial signal cable

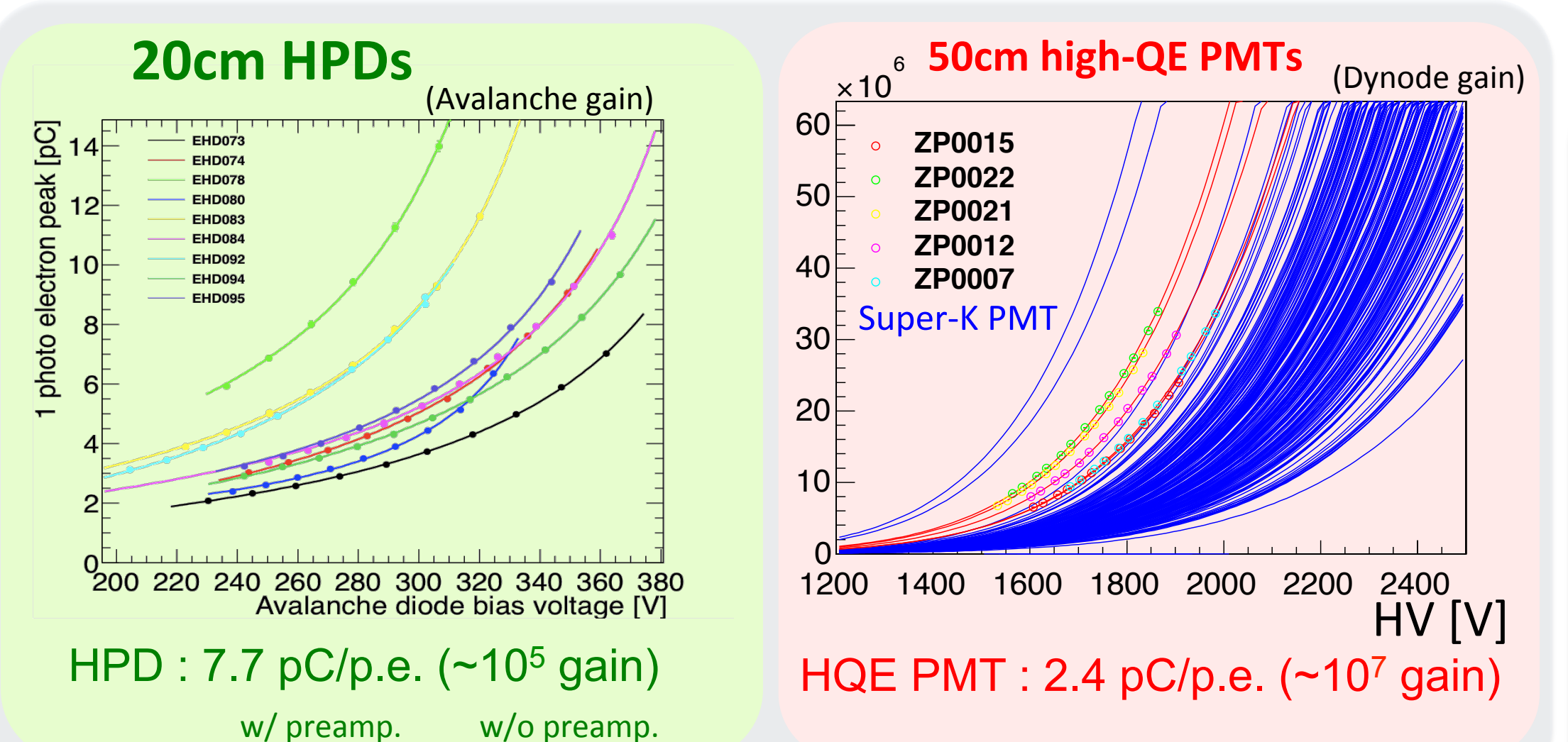
HV power supply

HV cable 1-2 kV

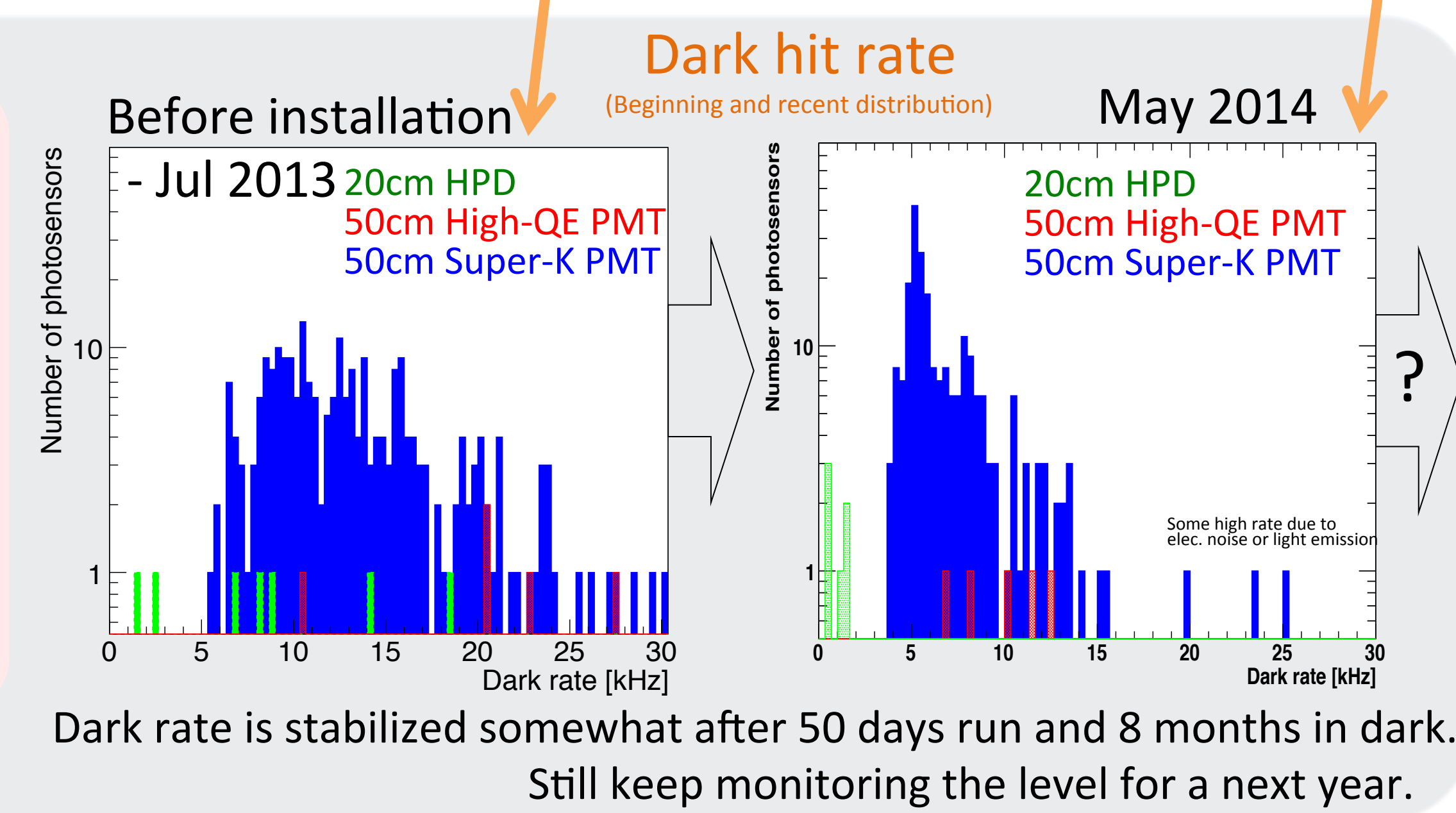
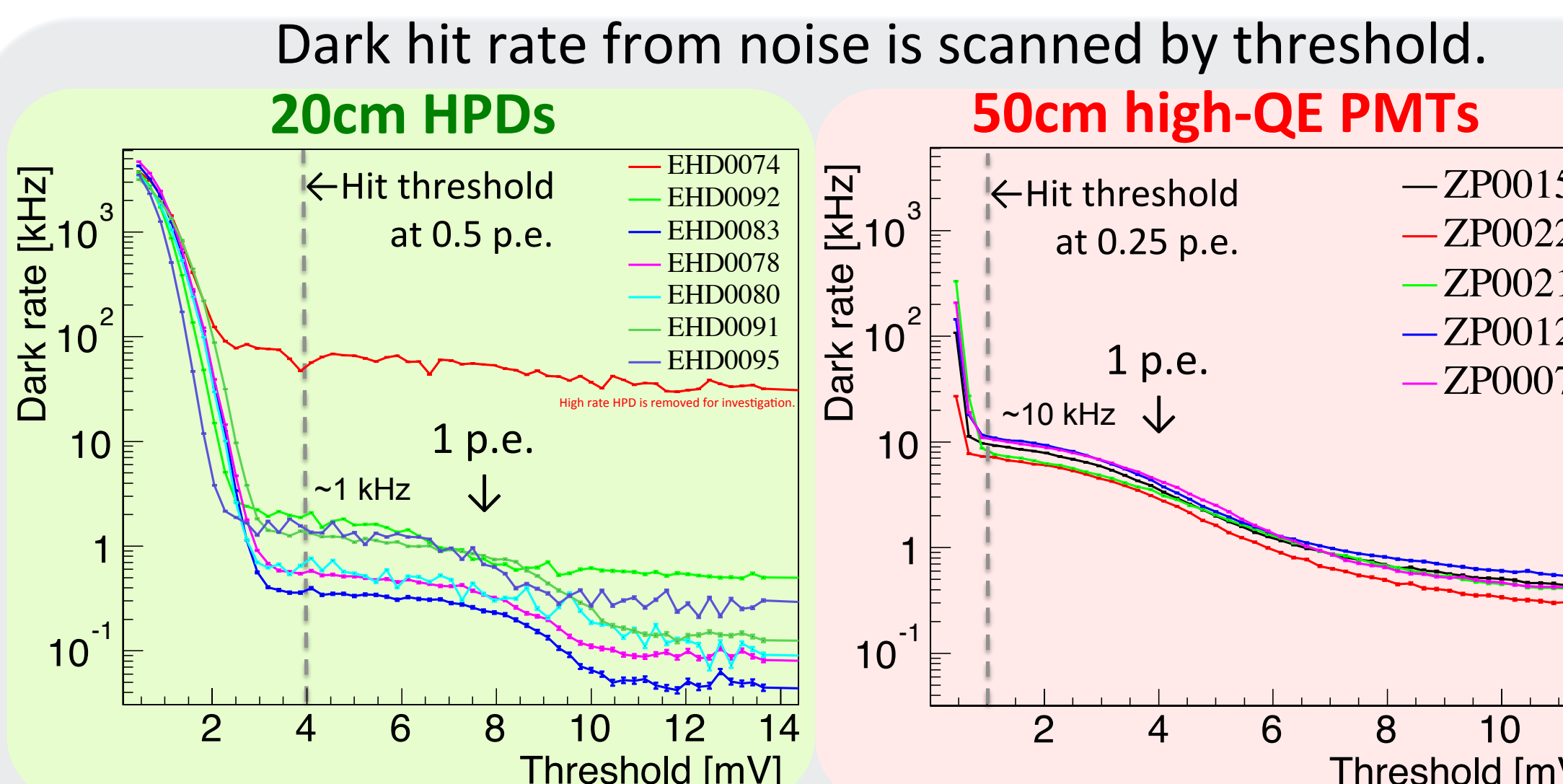
All hits over threshold are taken with charge and time in each photodetector.

Pretest for 50 cm high-QE HPD, and could be candidates.

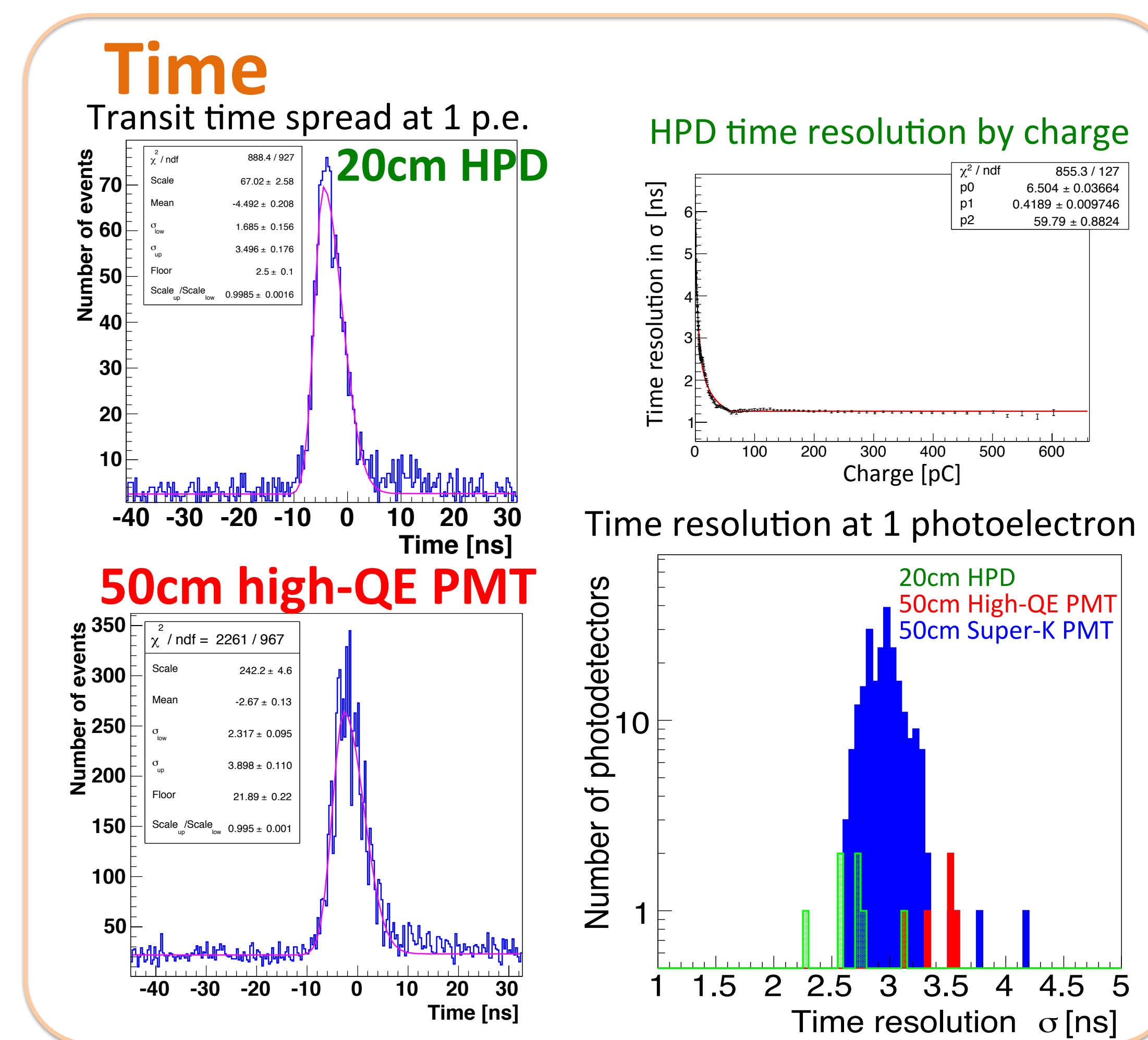
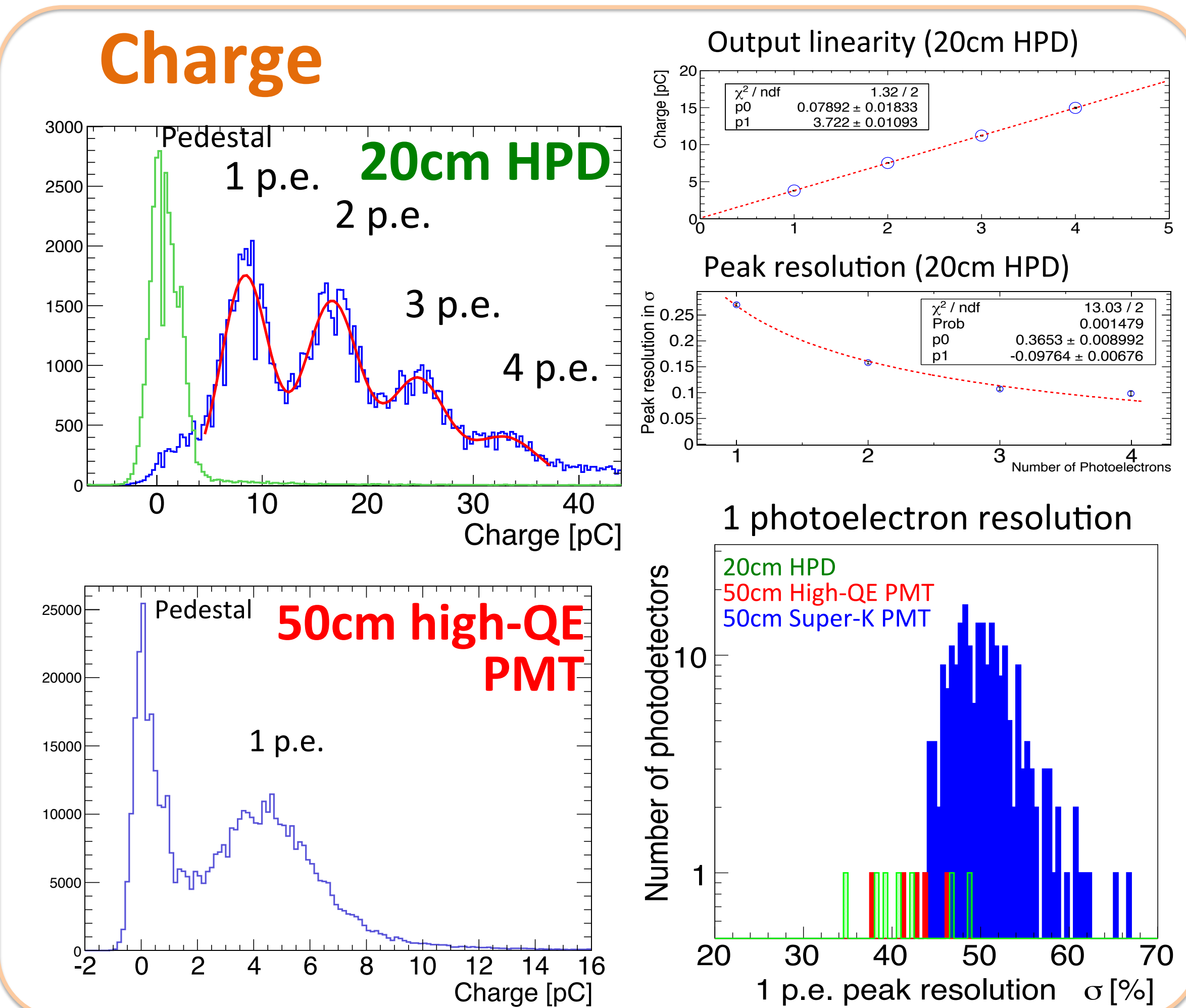
Gain



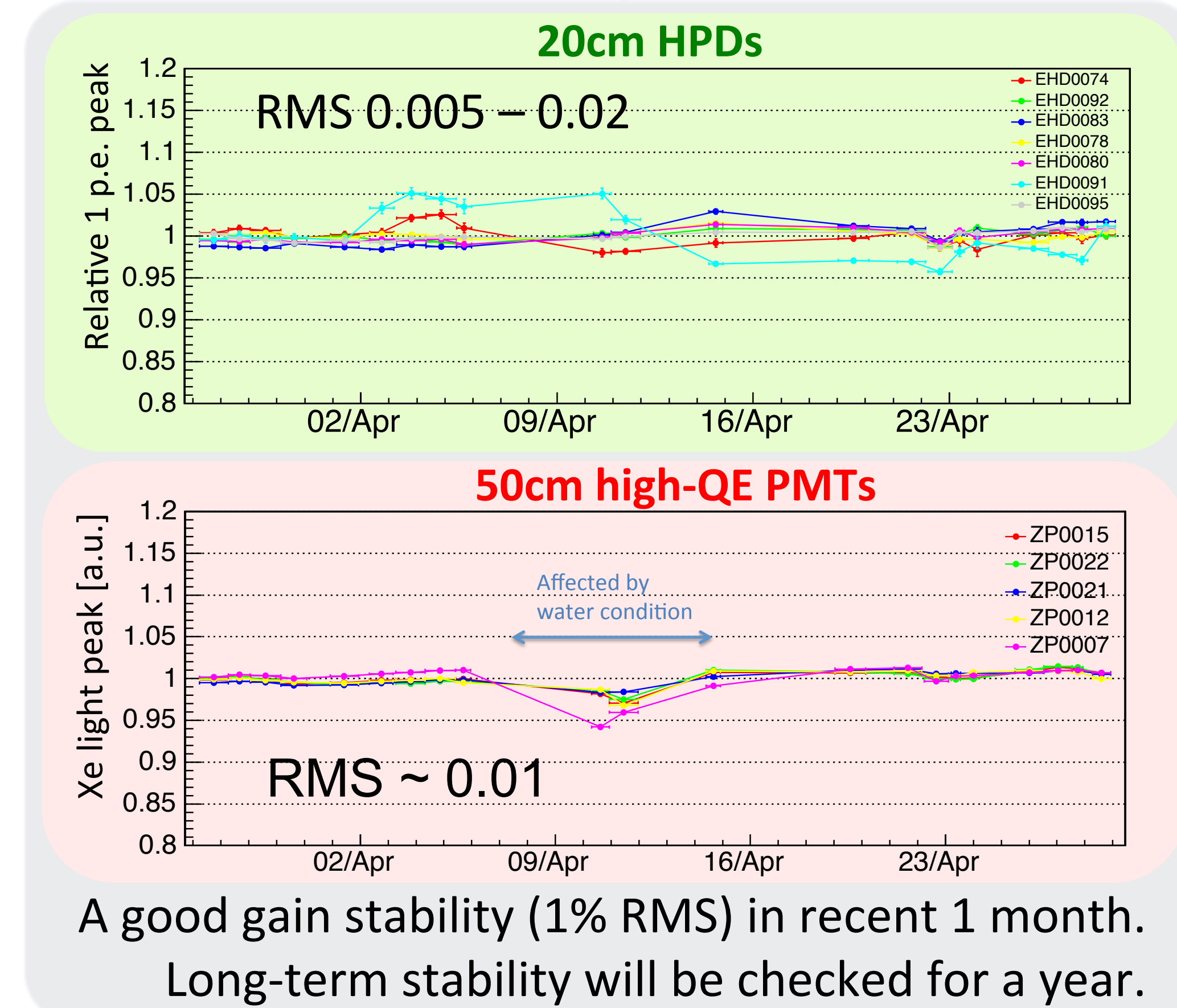
Noise hit rate



Performance



Gain stability



Plan and Goal

Viability test is going on to monitor a stability and confirm a long life over a year. 50 cm- ϕ photodetectors are also being developed and tested soon in the tank. In addition, a protective case, waterproof electronics and photon collector will be tested with photodetectors. R&D and viability test will continue for a few years to determine the best photodetector in 2016. A few hundreds of photodetectors adopted for Hyper-K will be tested again in final design.

50cm- ϕ photodetector R&D and next viability test

Existing: R3600 HPK (Used in Super-K)

New: R12850 HPK (Avalanche diode)

New: R12860 HPK (Box&line dynode)

PMT (Venetian blind dynode)	80%	95%	93%
C.E.	5.5 ns	0.75ns (w/o Preamp.)	2.7 ns
T.T.S. (FWHM)	2 kV bias	8 kV bias, 20mm ϕ AD	2 kV bias
Bias V			

Good performance was confirmed in measurement.

Poster ID330: Development of new 50-cm diameter photodetectors for Hyper-Kamiokande (Yuji OKAJIMA).