

Status and plan for photo-detector tests in a 200-ton tank

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The 3rd Hyper-K open meeting
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Introduction

- New photo-detectors will be tested in the 200-ton water tank.
 - Since summer 2013 for a few years
 - 8-inch HPD and 20-inch high-QE PMTs at first.
 - Production of the photo-detectors has already finished.
- R&D and preparation for the proof test will be shown.
 - 8" HPD
 - 20" high-QE (HQE) PMT
 - 20" HPD, 20" PMT with different dynode for future test

Proof test in 200-ton tank

HPD R&D
at Kamioka, Hamamatsu

Production

Calibration

Measure gain, dark rate,
p.e. resolution of 10 HPDs

at Kamioka mine

2 HPDs

**Precise performance
evaluation**

Uniformity, rate tolerance, stability,
thermal • B-field dependence, etc.

Evaluated in dark box.

Install

8 HPDs

1st topic in this talk

Next talk

Test new photo-detectors

Proof test in EGADS tank

Several PMTs are replaced.

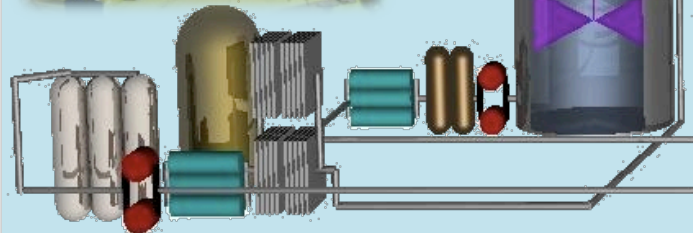
at Kamioka mine

20" PMTs x 240

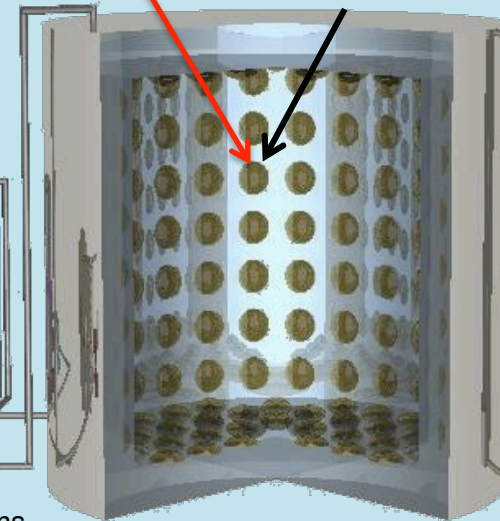
200t tank

7 m

200-ton
water tank



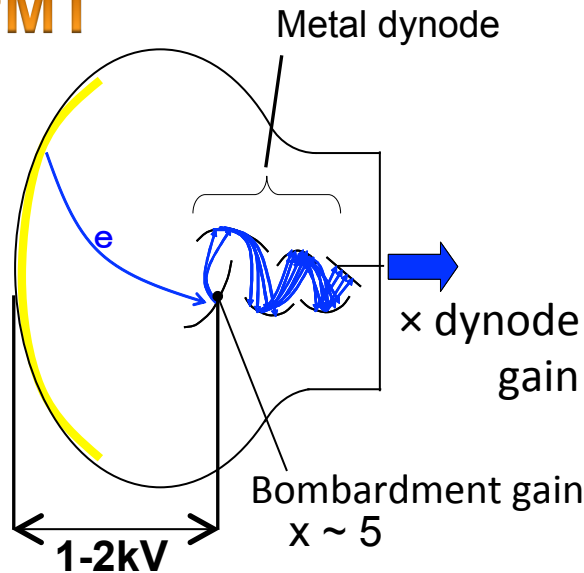
Evaluating Gadolinium's Action on Detector Systems



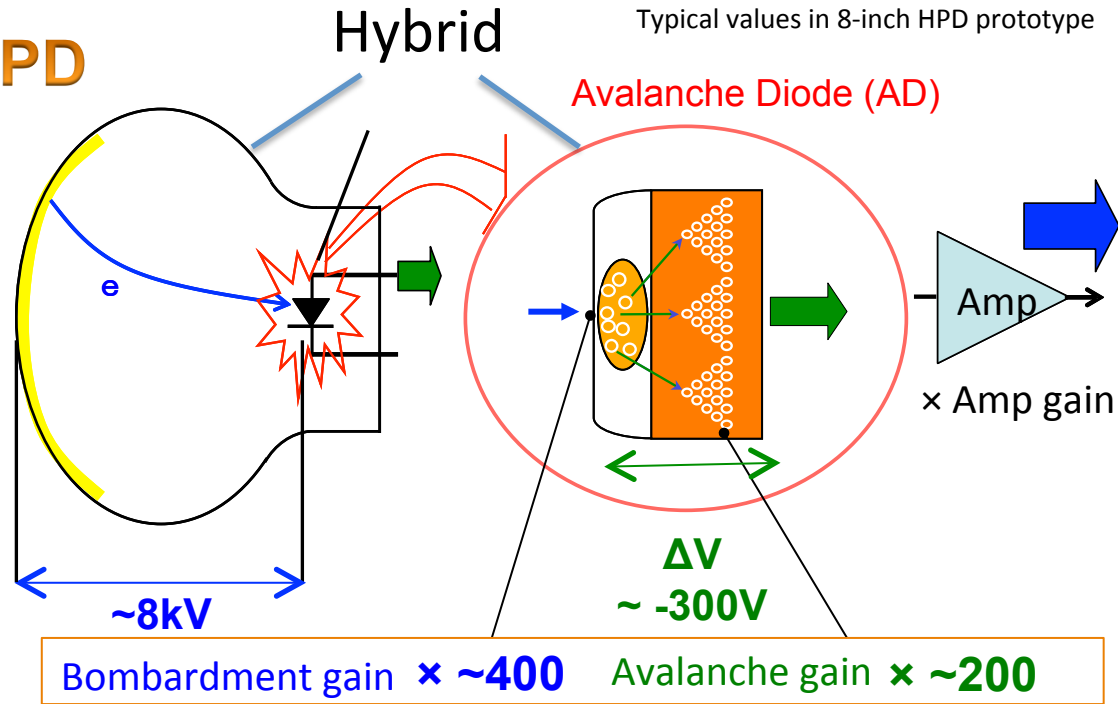
- In Jul, Aug 2013, 2 types will be installed in tank.
 - 8-inch HPD (normal QE) Test with 20-inch PMT (SK PMT)
 - 20-inch High-QE PMT

Hybrid PhotoDetector (HPD)

PMT



HPD



	PMT (20")	HPD (8")
HV	1-2kV	~8kV
Gain	~10 ⁷	~10 ⁴ - 10 ⁵
C.E.	~80%	~97%

Same photo cathode (Q.E.)

High voltage around 8kV is required

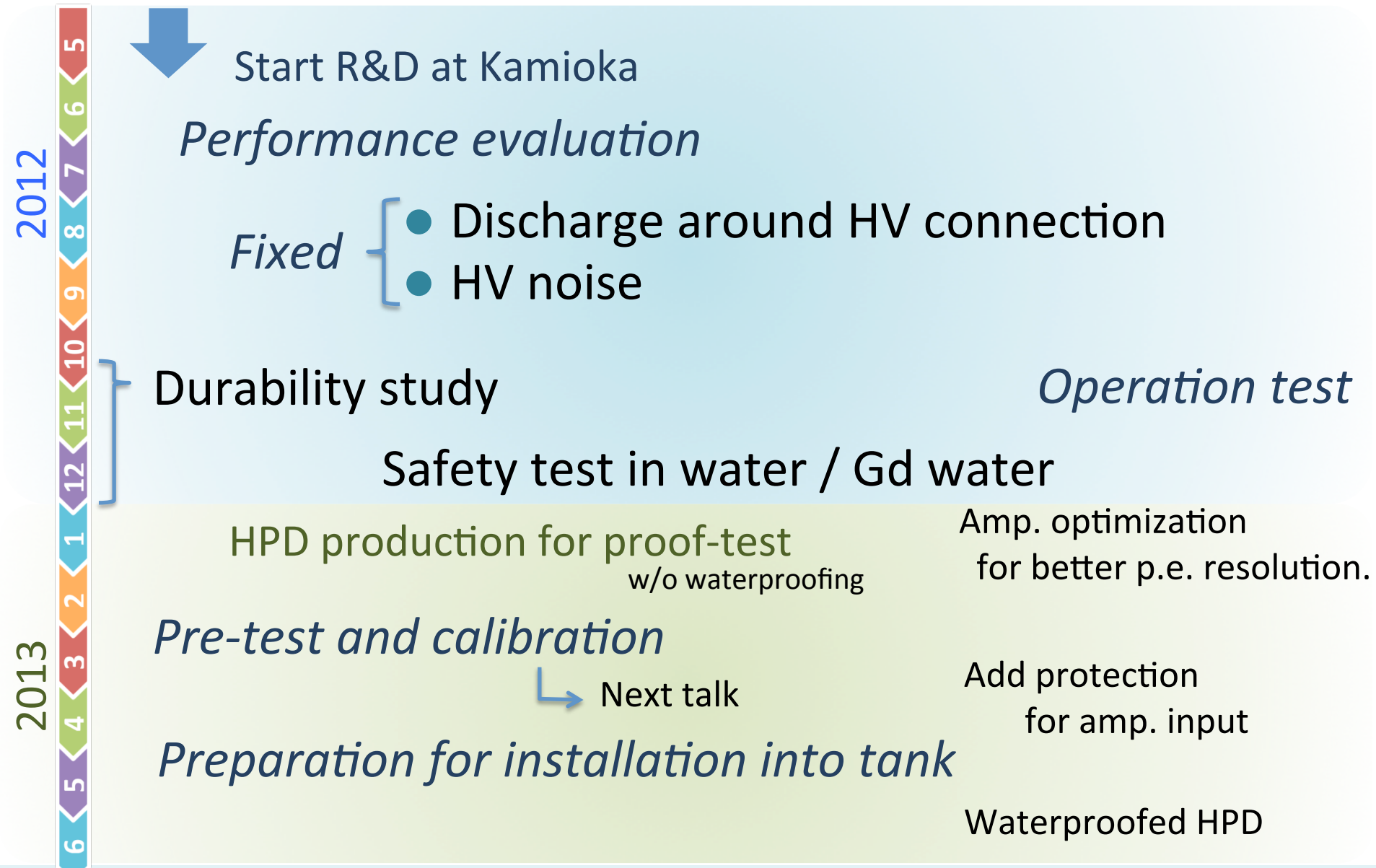
- to collect electrons in the small region of AD (5-20mm)
- to increase gain at electron-bombardment

- High performance and low cost

- However, factors to consider for viability in Hyper-K are:

- Dark noise from AD + Amp., HV around 8kV, low gain, thermal dependence of AD gain, No prior experience using

R&D of 8" HPD at Kamioka

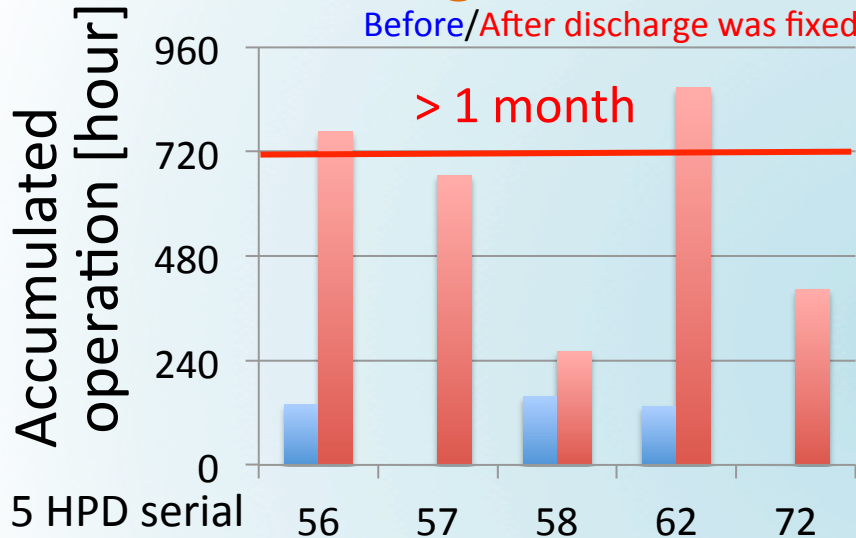


Durability test before production

Tested 5 HPD prototypes in 2012

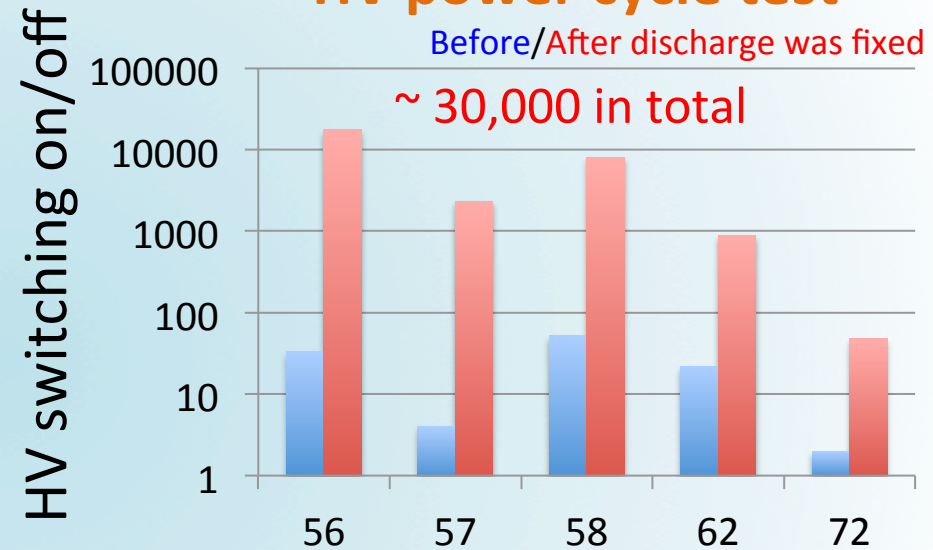
Long-term test

Before/After discharge was fixed



HV power cycle test

Before/After discharge was fixed



■ (- 18/Oct. 2012) 6 breakdowns of amp. In total, 18 days, power cycles < 200

↓ Fixed discharge around HPD

■ (19/Oct. – 31/Dec. in 2012) **Durability test** finished w/o breakdown.

(Breakdown report at last meeting was fake.)

→ Production of **10 HPDs** in Jan 2013

- Similar tests were done for new 10 HPDs in Feb. *Pre-test*
- Test for 3 days and 200 power cycles at least. → Problem occurred.

Calibration & pre-selection

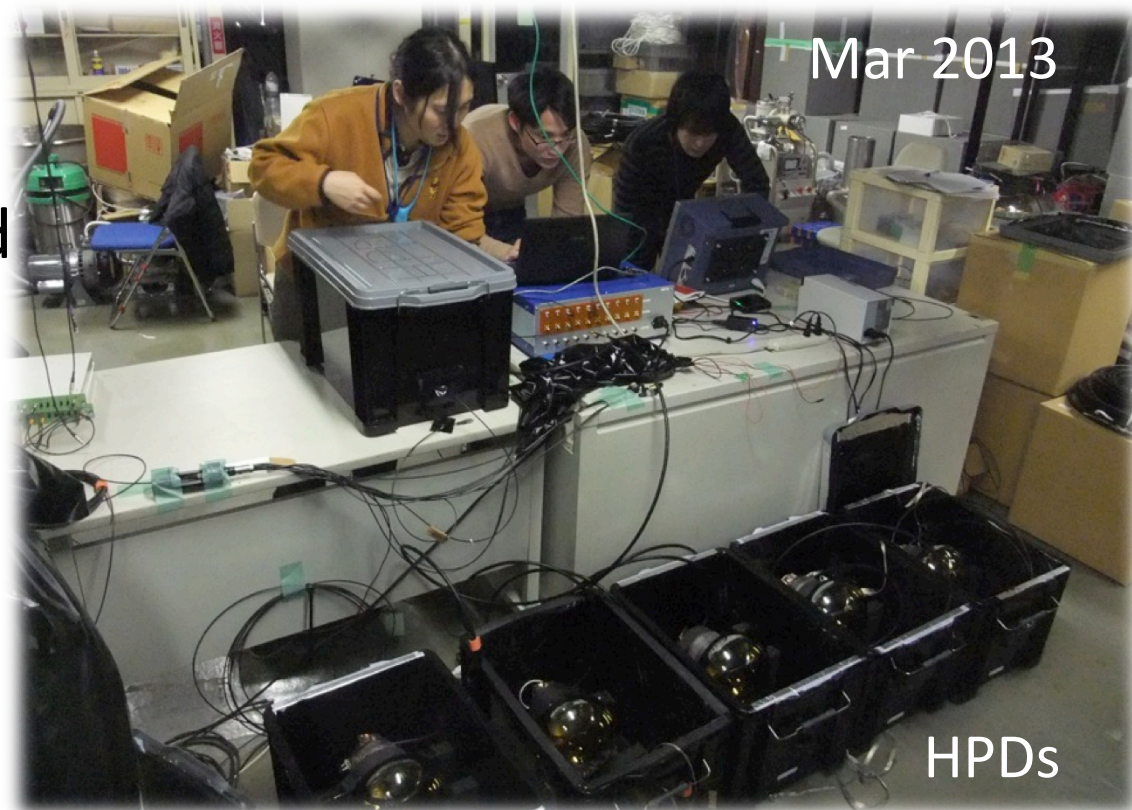
- Calibration and pre-selection were performed for all 10 8-inch HPDs and 8 20-inch HQE PMTs.

○ By Hirota, Suda, Tateishi and Nishimura

- Measured gain-HV curve, peak to valley height ratio, 1 p.e. peak and dark date.

→ Presented by next speaker (Hirota-san).

- Problem occurred during calibration as well as pre-test.



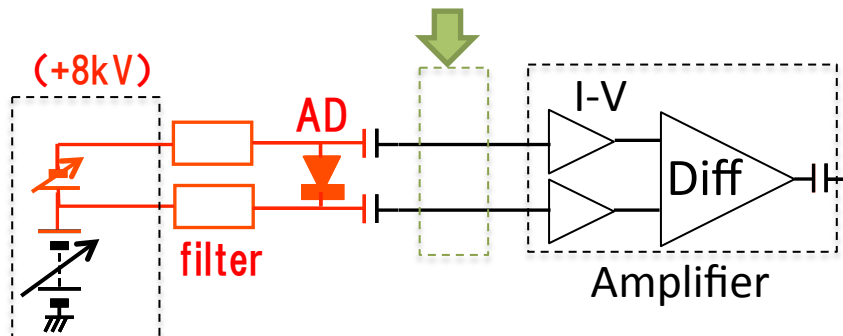
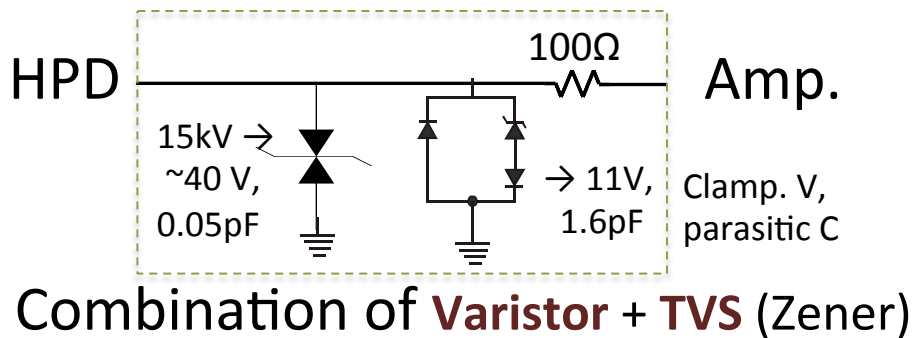
Improvement after production

- “Problem”: Some amplifiers of new 8” HPDs got broken.
 - Found that large input pulse causes damage of transistor.

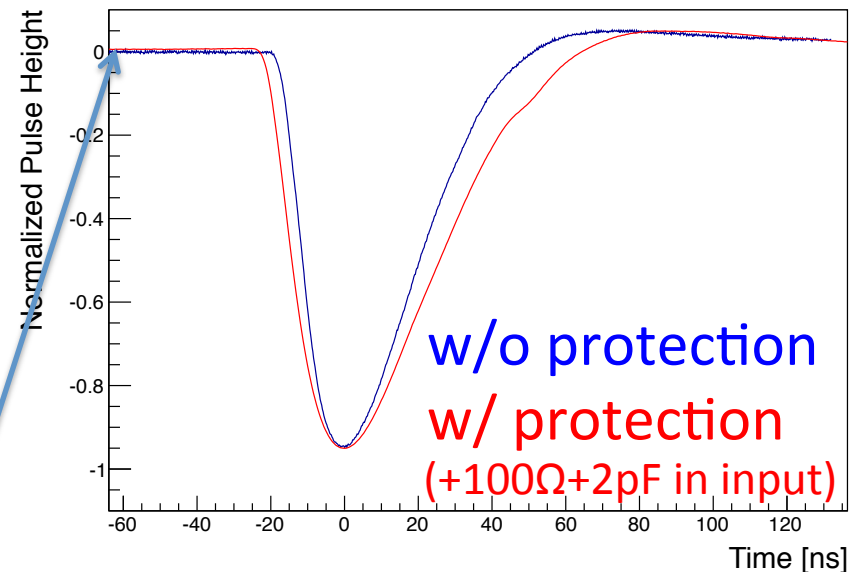
- Implement protection parts in input of amplifier.

(10^2 - 10^3) [V] is observed in input.

→ **Added protection circuit**



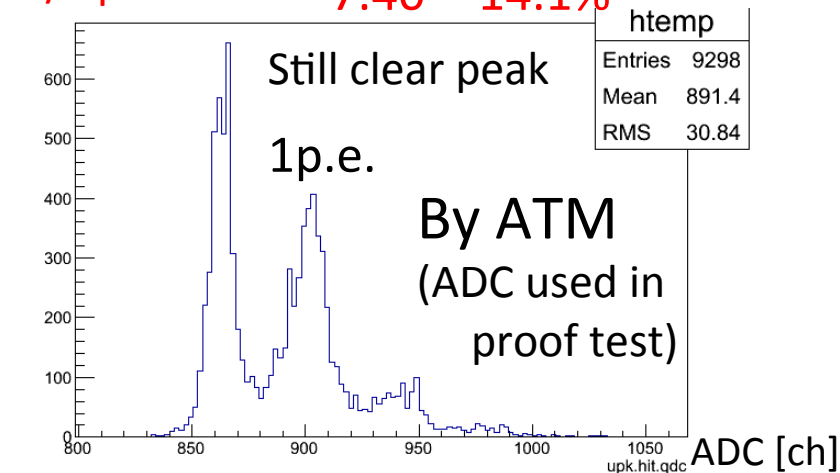
Waveform of amp. output
(w/o 70m cable)



Performance check

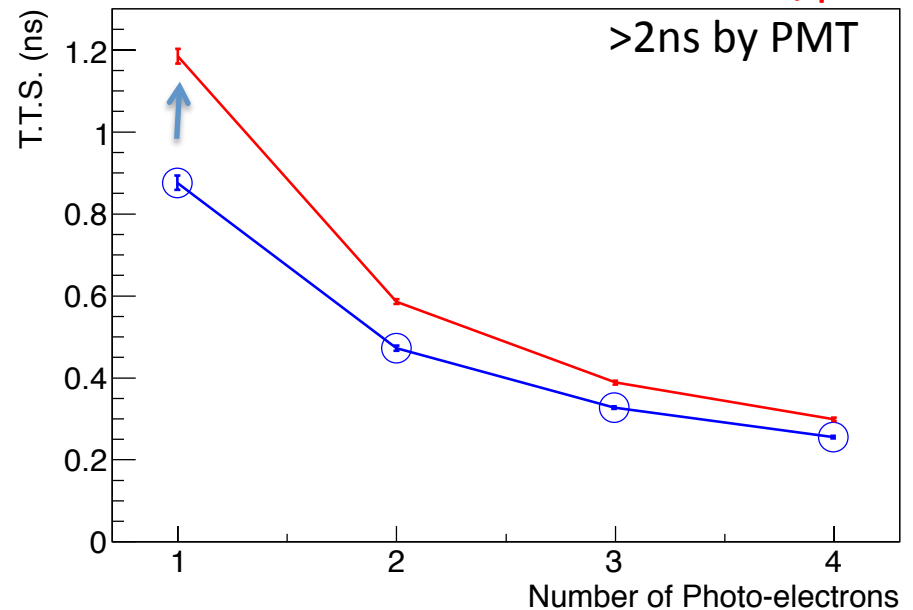
- Performance is expected to be worse slightly because stray capacitance increases by 2pF.

	By VME ADC	1p.e.	1p.e.
	[pC]	resolution	(σ)
w/o protection	7.75	12.4%	
w/ protection	7.40	14.1%	



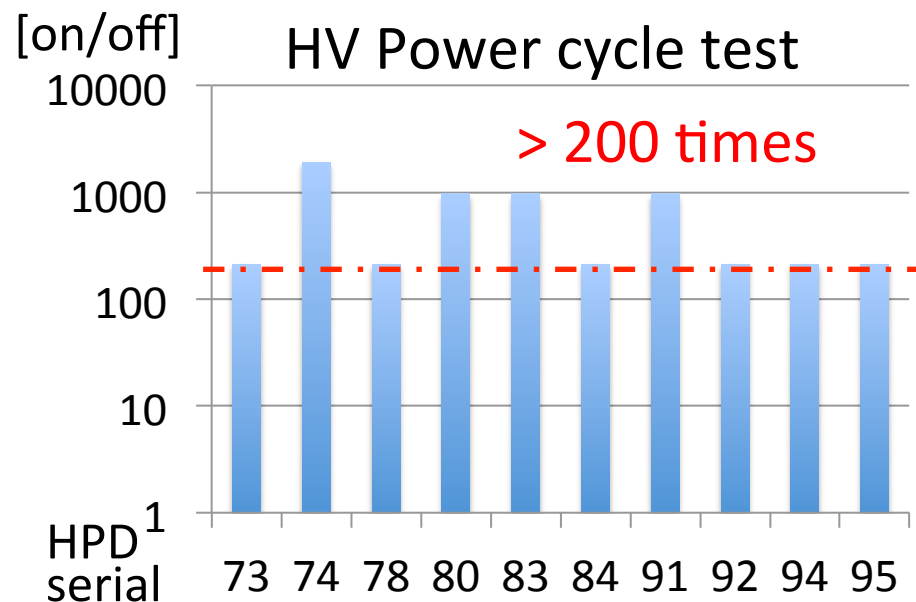
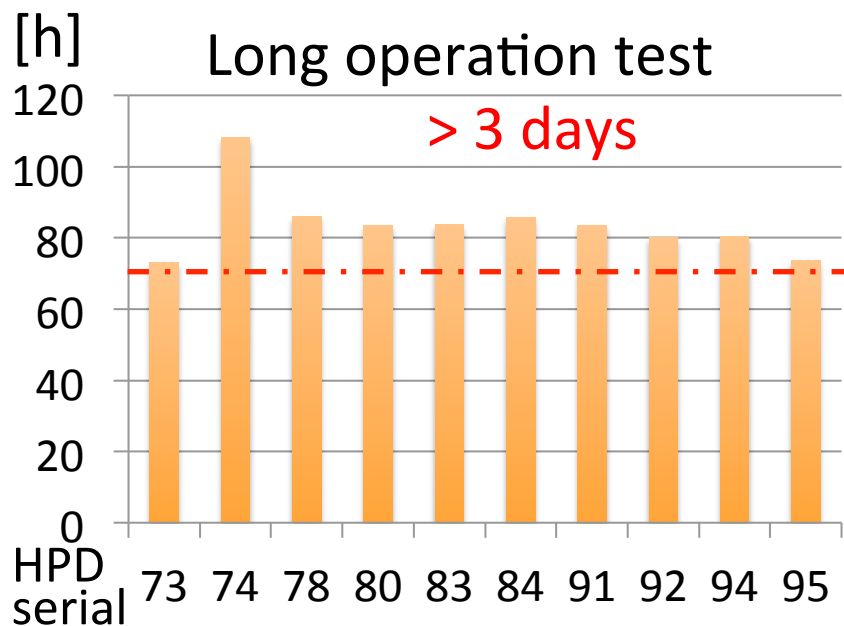
- Effect of protection is negligible and resolution is still better than PMT's.

T.T.S. (timing at 25% pulse height)
 w/o protection : **0.86 ns σ** at 1 p.e.
 13.4mV/p.e.
 w/ protection : **1.19 ns σ** at 1 p.e.
 13.7mV/p.e.



2nd durability test for 10 HPDs

- No breakdown was observed after implementation.



Problem was fixed.

- Amplifier has not been damaged even if large pulse is sent into input arbitrarily.
- Design was finalized and HPDs were waterproofed.

Waterproof 8-inch HPD

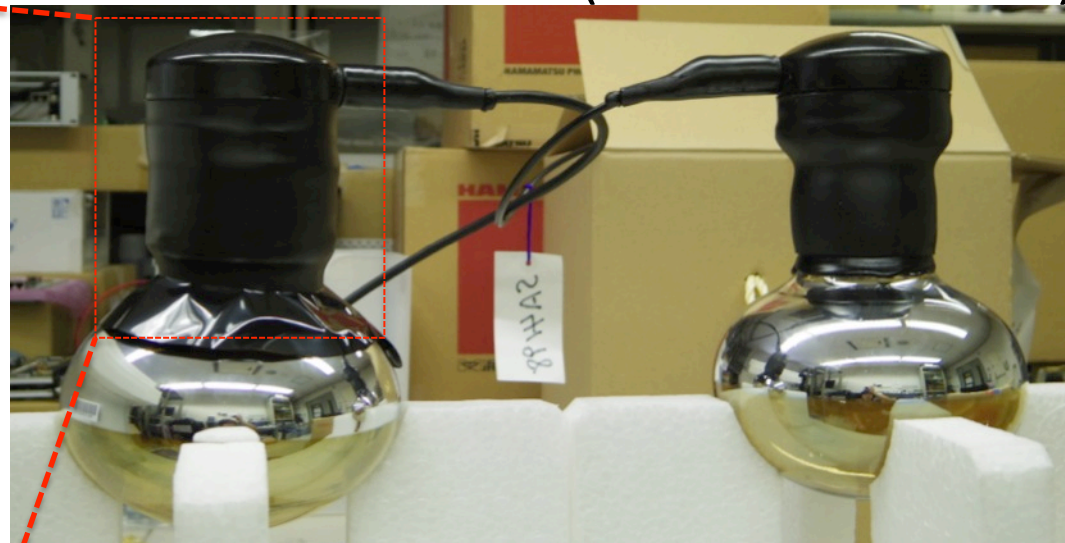
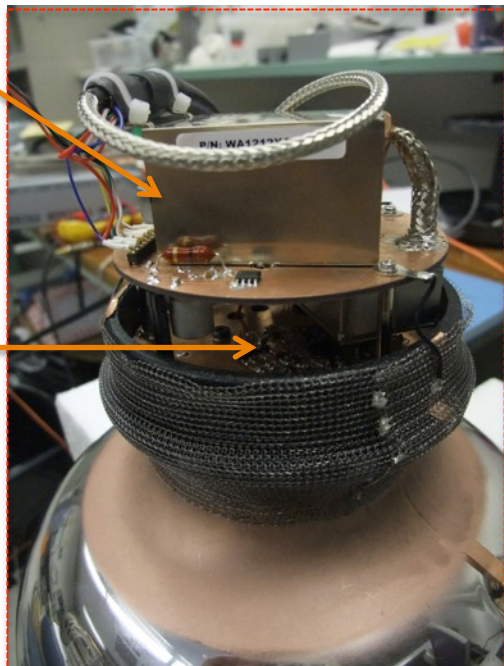
8-inch HPD

8-inch PMT
(SK outer detector)

2ch HV
(5V → 8kV,
300V)

Amplifier

HPD valve



HPD

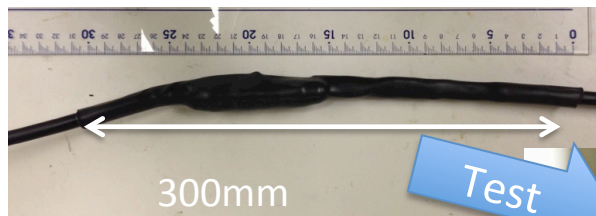
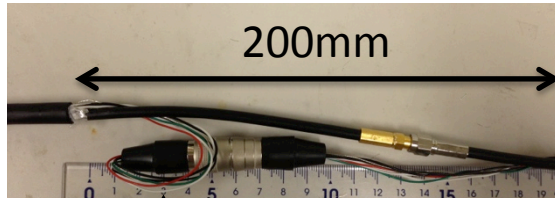
PMT



9 HPDs were prepared
with waterproofing
in Jun 2013.

Preparation for proof-test

Waterproof cable connection is tested in high pressure.



Test



Based on SK cable connection

Cable : PMT→HPD

Signal : BNC→SMA

Bias V : HV(2kV) → LV(10V)

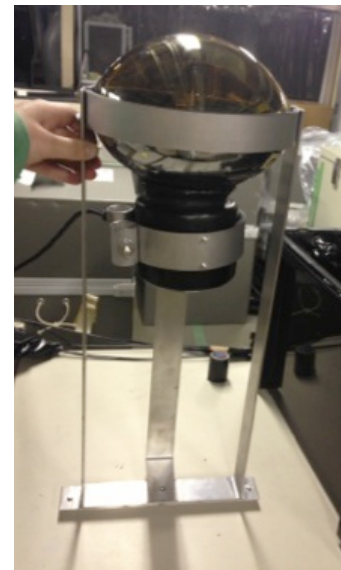
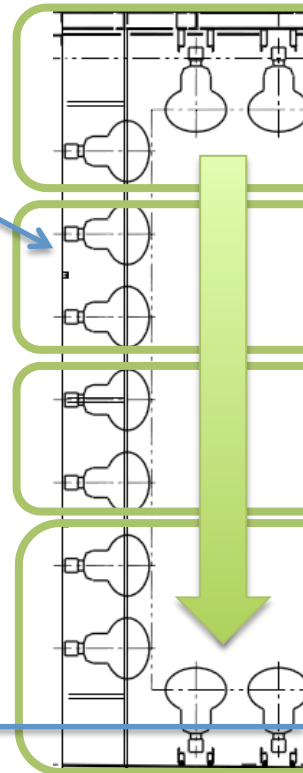
(Outside of cable is same)

- HPD cable and supporter were prepared.

Prepared for 8-inch size



6 HPDs for barrel



2 HPDs for top/bottom

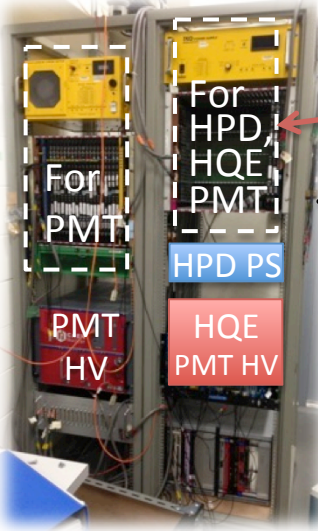
Electronics of proof test

NOT for Hyper-K case

- Trigger is issued by sum of hits with all photo detectors.
 - 1 hit = 1 HPD (PMT) with 1 p.e. or more signal
- In same DAQ system, electronics of HPD/HQE PMT is separated.
 - 1 p.e. level differs between PMT and HPD.
 - Photons/p.e. differs between normal and high QE.

DAQ of charge + time

ATM (Analog Timing Module)
12ch x (2TAC+2QAC) → ADC used in old SK



1 board for HPD (8/12ch)
1 for HQE PMT (5/12ch)
 Trigger threshold is set by each board (0-12mV)
 Set threshold separately (0.25p.e. in PMT case)
 ↓
 Calibrated HPD/HQE PMT.

*) ATM replaced with QBEE (current SK board) later

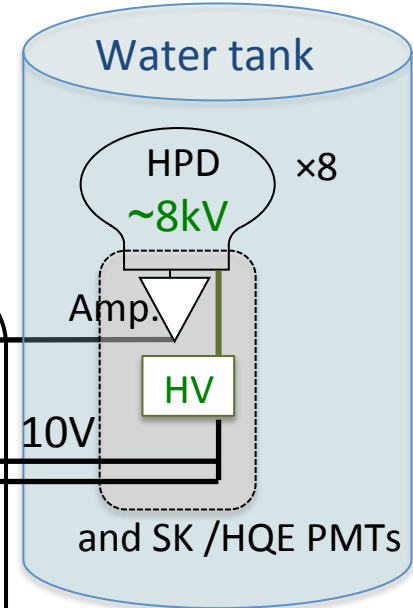
70m signal cable

Control Power Supply



10ch x 6 LV cables

- 2 Power supply lines (10V)**
 - For HV unit and Pre-amp. (<500mA) + GND
- 4 HV control lines (<1mA, 5V)**
 - HV control (0 - 4V out)
 - AD bias control (0 - 4V out)
 - Latch up monitor (+5V in)
 - Enable switch (+5V out)



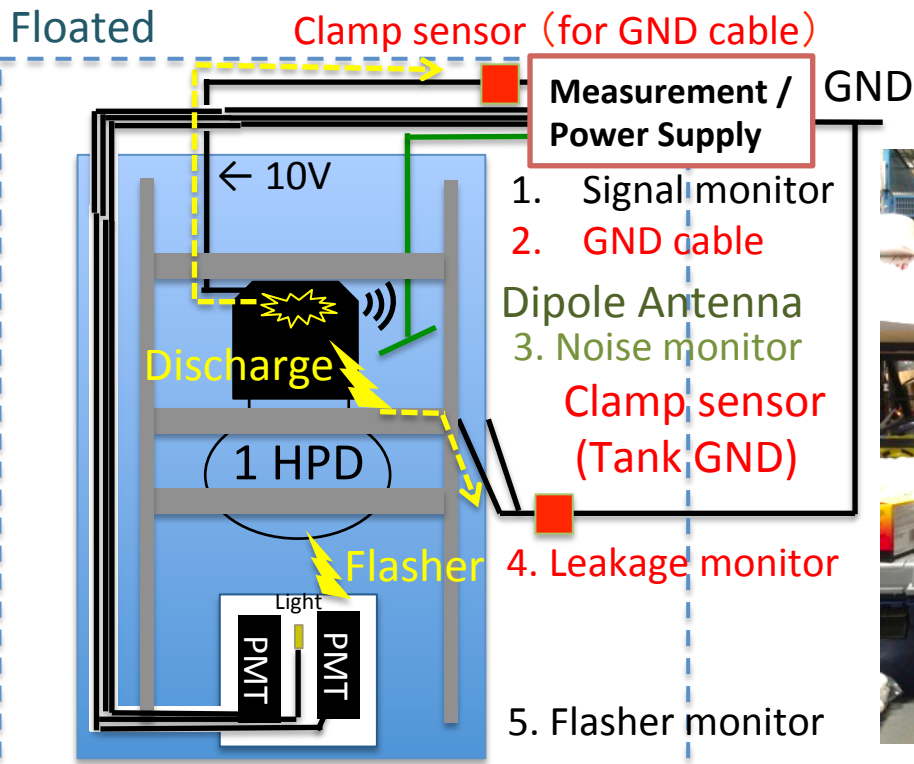
70m Low voltage (10V) + control cable (5V)



HPD test in Gd water

- 1 prototype waterproofed HPD was tested in advance in both water and Gd water with 8kV applied.
 - No clear discharge event was observed.
- All HPDs will be tested in Gd water before installation.

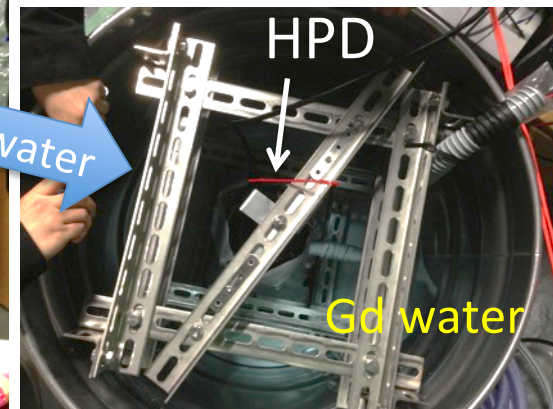
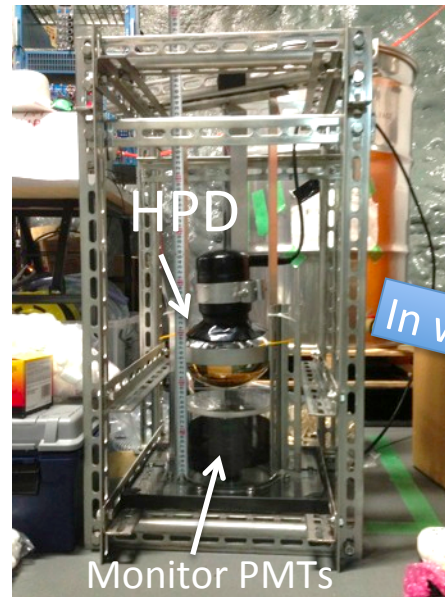
350L small tank Same setup as before to detect discharge/light leak



1st test of HPD with final design started.

Quick test for all HPDs because details were already measured.

Soaked in 350L tank



Schedule for HPD installation

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
June	17	18	19	20	21	22	23
	Gd water test (1 st 1HPD)			HK meeting			
	24	25	26	27	28	29	30
	Gd water test (8 HPDs, 2/day), calibration						
July	1	2	3	4	5	6	7
	High pressure test (9 HPDs)						
	8	9	10	11	12	13	14
	HPD cabling						
	15	16	17	18	19	20	21
	HPD/PMT installation			continues till 24/Aug.			

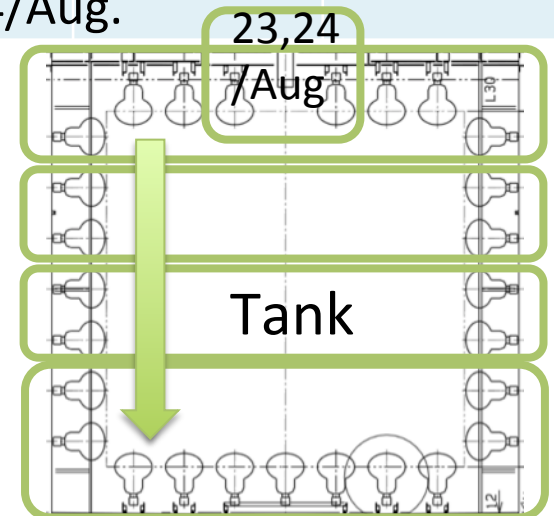
- Final calibration and HPD test in Gd water / high-pressure water for a next few weeks.
- Installation of 8 8" HPDs, 5 20" High-QE PMTs and 227 SK PMTs in Jul & Aug.

16/Jul - 22/Jul

23/Jul - 27/Jul

29/Jul - 2/Aug

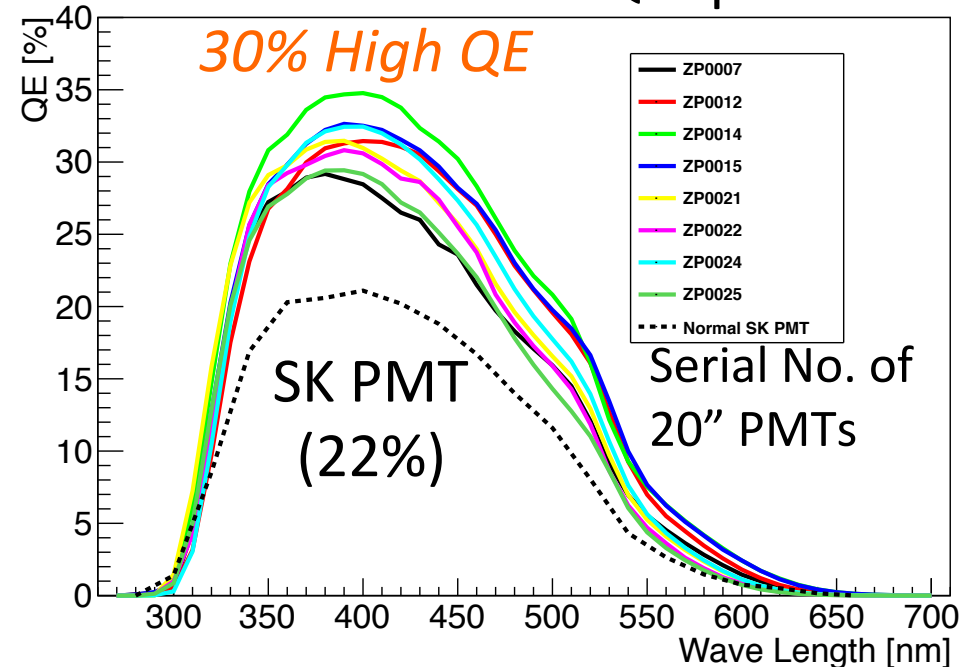
5/Aug - 20/Aug



High-QE PMT

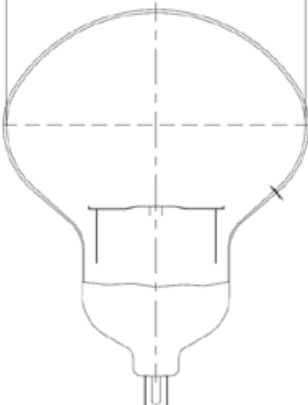
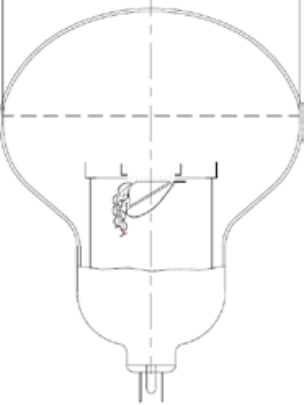
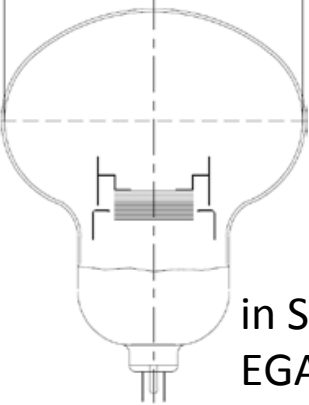
- High Q.E. study starts with PMT, later for HPD.
 - High Q.E. is the common upgrade option for both PMT and HPD.
 - Dark rate, stability, after pulse, etc. should be checked.

- **8 of 20" high-QE PMTs** available at Kamioka QE spectrum



- Completely same design and material as SK PMT, except for photocathode.
- Calibration finished (reported in next talk) and 5 will be installed.

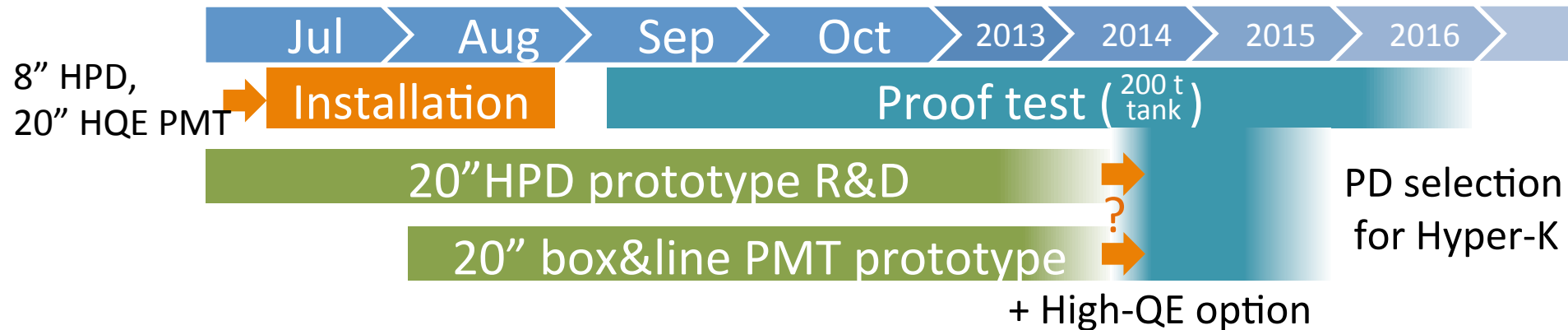
R&D of 20-inch photo-sensor

	HPD (1 st prototype)	PMT (Box&Line dynode)	PMT (Super-K PMT)
*) Expected values from simulation			 in SK, EGADS
(Bias)	8 kV	2 kV	2 kV
(C.E.)	95.5%*	93.2%*	80%
(T.T.S.)	0.75 ns (FWHM)*	2.7 ns (FWHM)*	5.5 ns (FWHM)

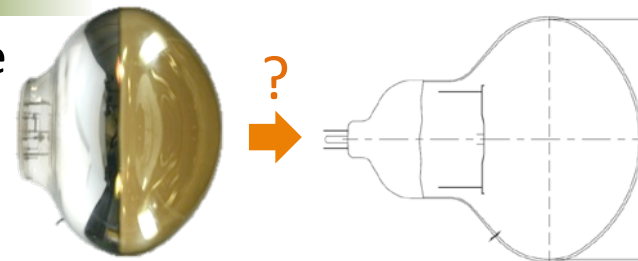
- Resolution and stress analysis show better performance.
 - Valve design differs among three 20-inch photo-sensors.
 - High-pressure water test of HPD valve was done.
 - 20mm (and 15 mm) Φ AD was manufactured and is under study.
- 1st prototype of 20" HPD and PMT(Box&Line) made within a few months.*

R&D schedule

Goal



Considering to optimize 8" HPD valve shape to avoid HV concern safely.
Fast and low noise amp and substitute HV power are also under consideration.



Performance evaluation

2 HPDs and 5 prototypes of 8-inch size are available now.
In addition, 4 HPDs are prepared for many detailed checks.

Uniformity of gain + C.E., cross talk, flasher, after pulse, band width, rate tolerance, thermal / B-field dependence, dark rate, stability, durability, heat, aging, ...

Case, light collector (cone, WLS, etc.), amp and readout will be also developed & tested.

Summary

- 10 HPDs (8-inch) and 8 high QE PMTs (20-inch)
 - Already provided and tested.
 - Calibration and pre-selection are presented in next talk.
- 8 HPDs and 5 HQE PMTs will be installed by Aug.
 - Test HPDs in Gd water and high-pressure water soon.
 - Cable and support structure are ready for proof test.
- New 20" HPD / PMT with box&line dynode
 - Prototype will be prepared soon within a few months.
 - Their performance evaluation in this year.