



Performance evaluation of new photodetectors for Hyper-Kamiokande

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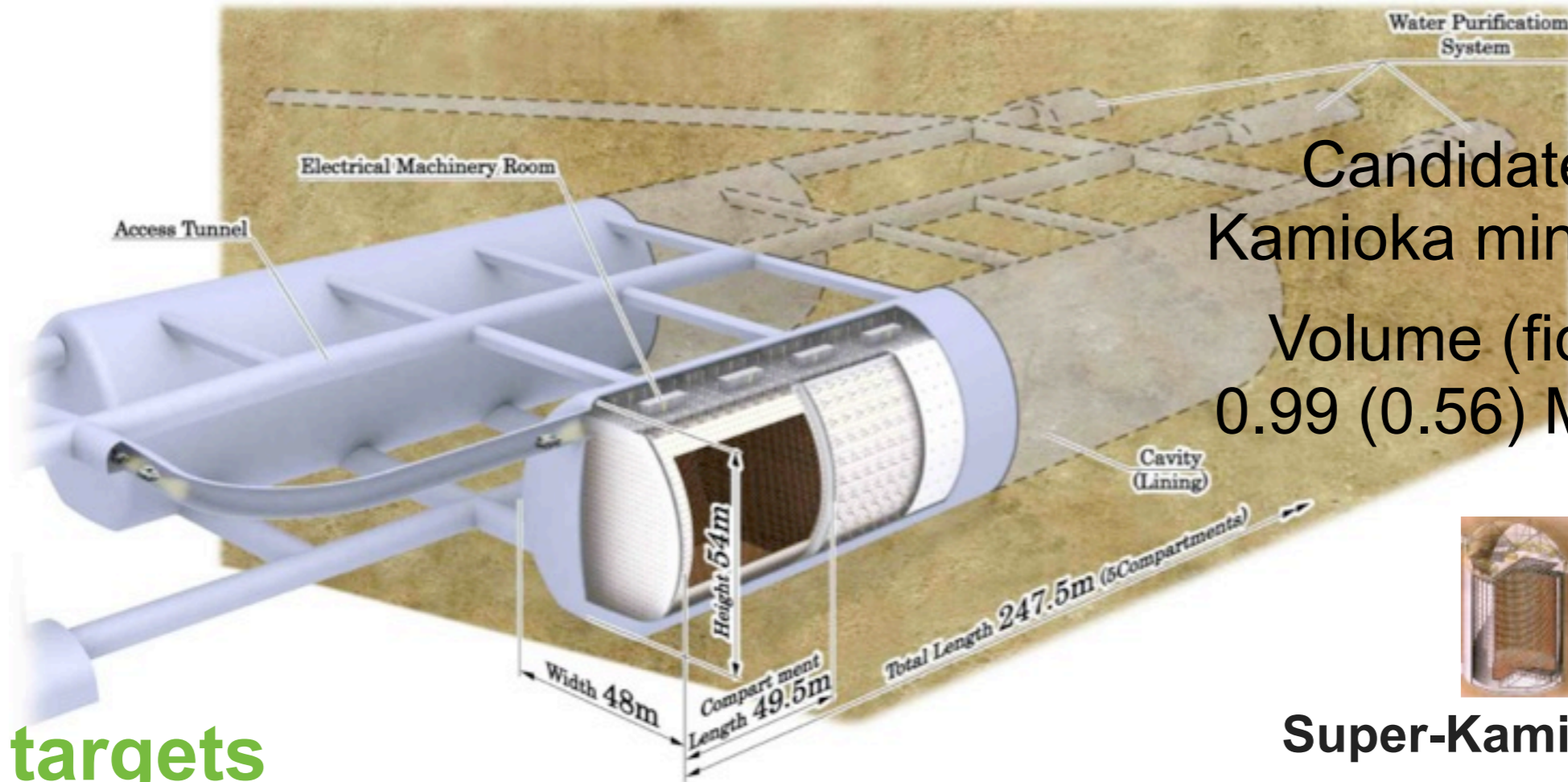
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Instrumentation in Particle Physics 2014
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Hyper-Kamiokande

Next generation **Mega**-ton water Cherenkov detector



Candidate site:
Kamioka mine, Japan

Volume (fiducial):
0.99 (0.56) Mega-ton

Many targets

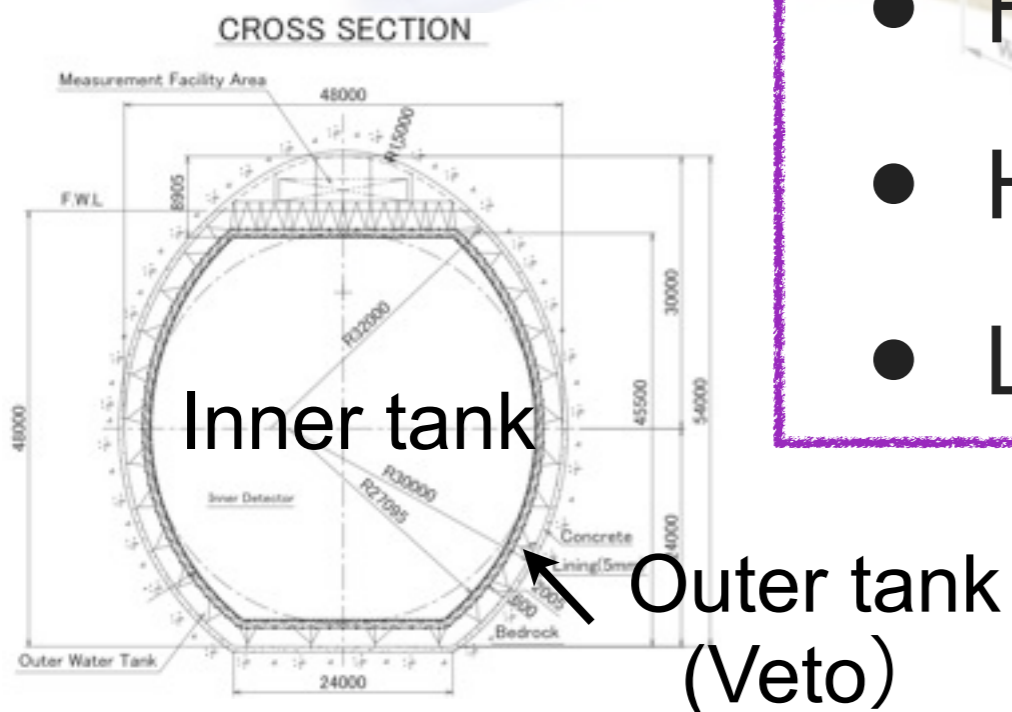
- Proton decay search
- Neutrino physics
- Leptonic CPV, mass hierarchy, supernova, ...

Hyper-K Photodetector

- Inner tank: **99,000** 20-inch photodetectors (50cm)
- Photo coverage **20%** (Super-K 40%)
- Outer tank: **25,000** 8-inch photodetectors (20cm)

Requirements for photodetector

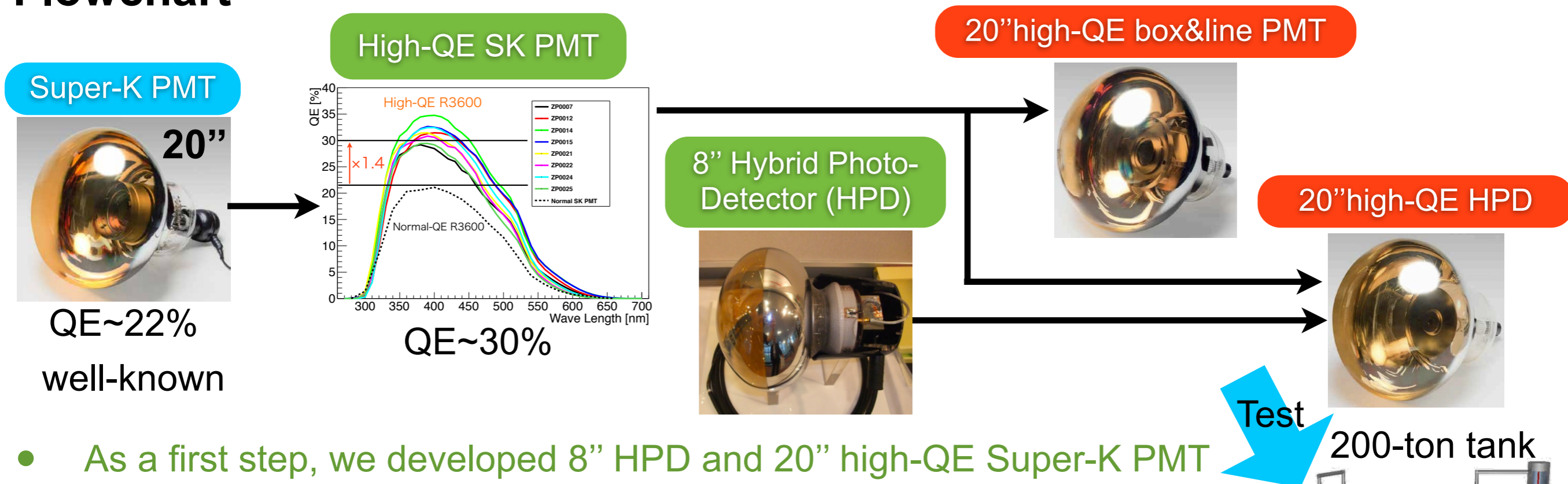
- High performance
- High quantum efficiency photocathode
- Low cost (if possible)



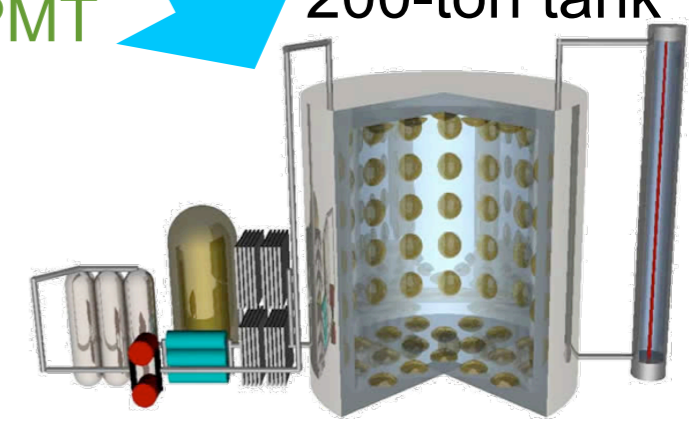
R&D of HK photodetector

Goal Development of a 20-inch high performance photodetector which can be used in a water Cherenkov detector for a long time

Flowchart

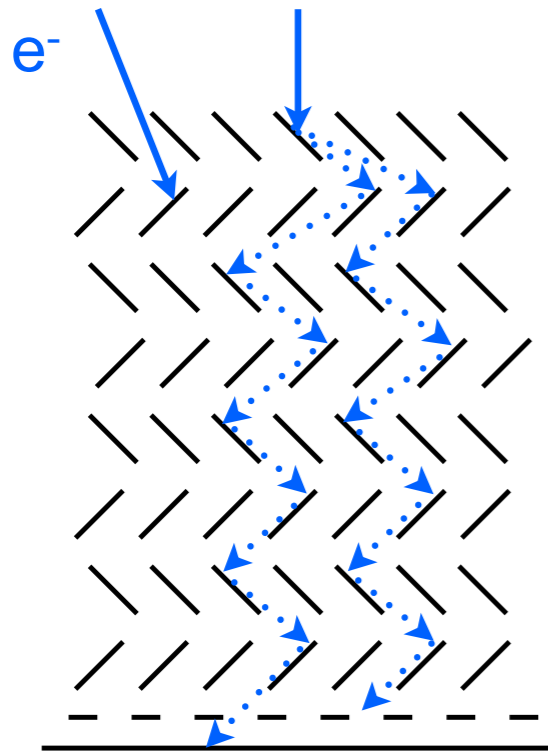


- As a first step, we developed 8" HPD and 20" high-QE Super-K PMT
- Photodetector test in a 200-ton water tank to confirm the usability of new photodetectors is ongoing
- We report the status of the test in the tank and the performance of 20" high-QE HPD and 20" high-QE B&L PMT



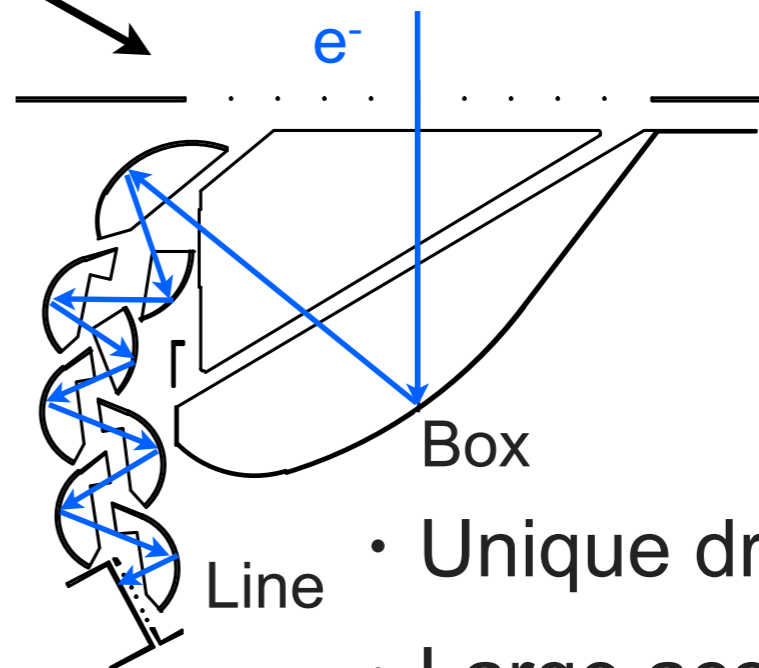
Box&Line PMT

Super-K PMT
(Venetian Blind dynode)



- Various drift path
- Might miss dynode

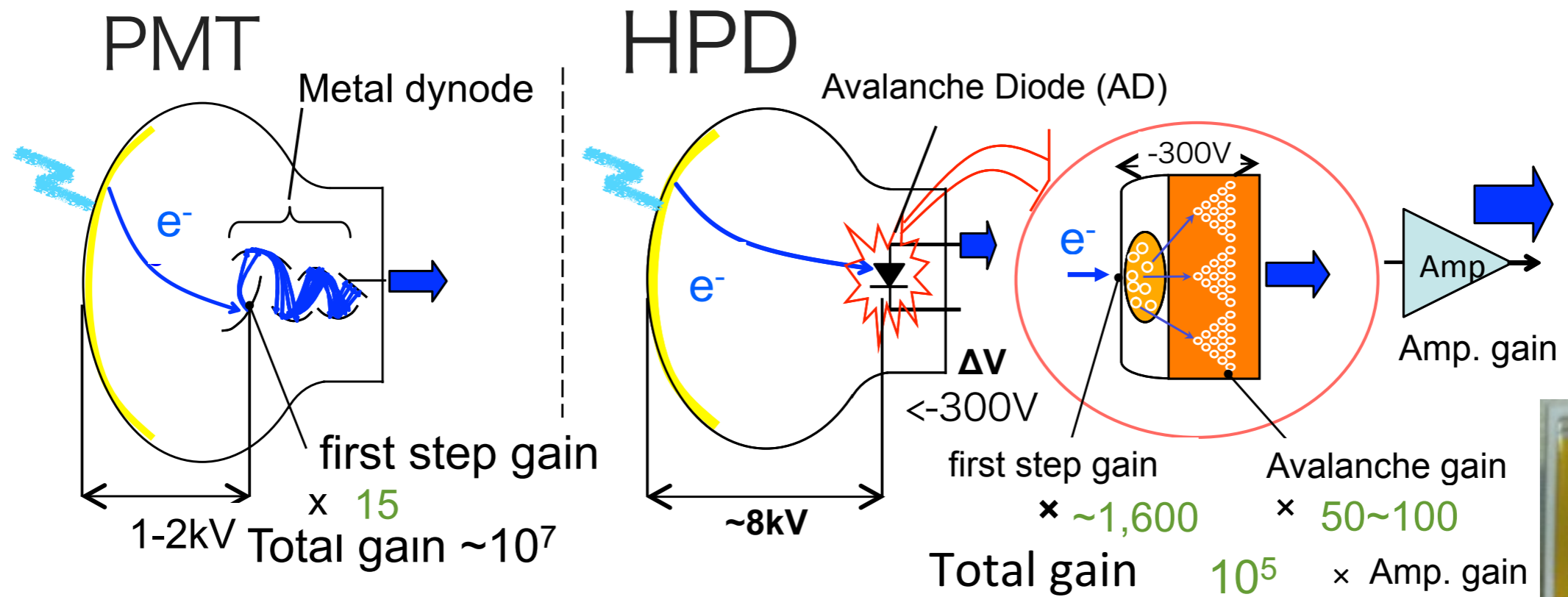
Box&line PMT
(Box&line dynode)



- Unique drift path
- Large acceptance

- Unique drift path → Better timing and 1PE resolution
- Large acceptance → Better collection efficiency

Hybrid Photo-Detector



HPD

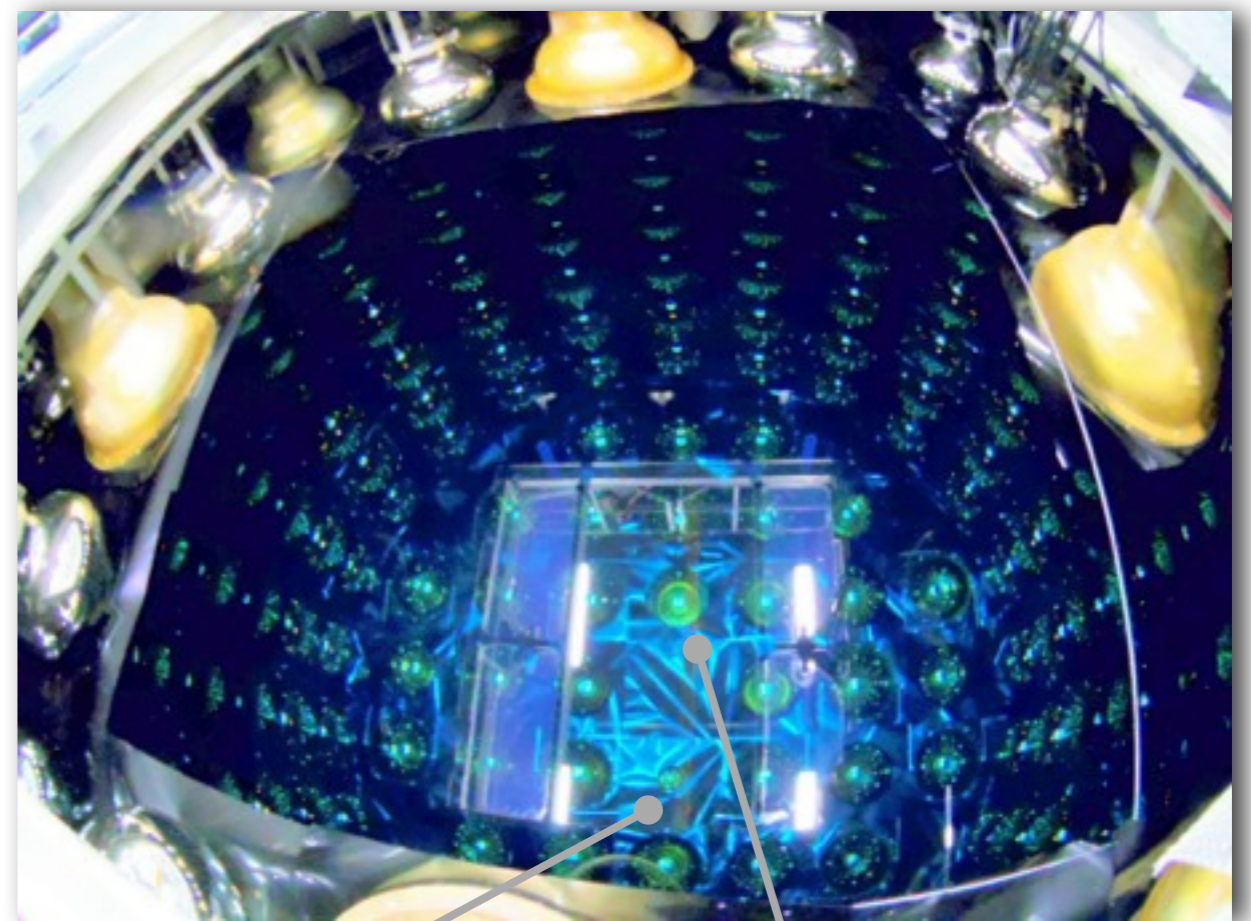
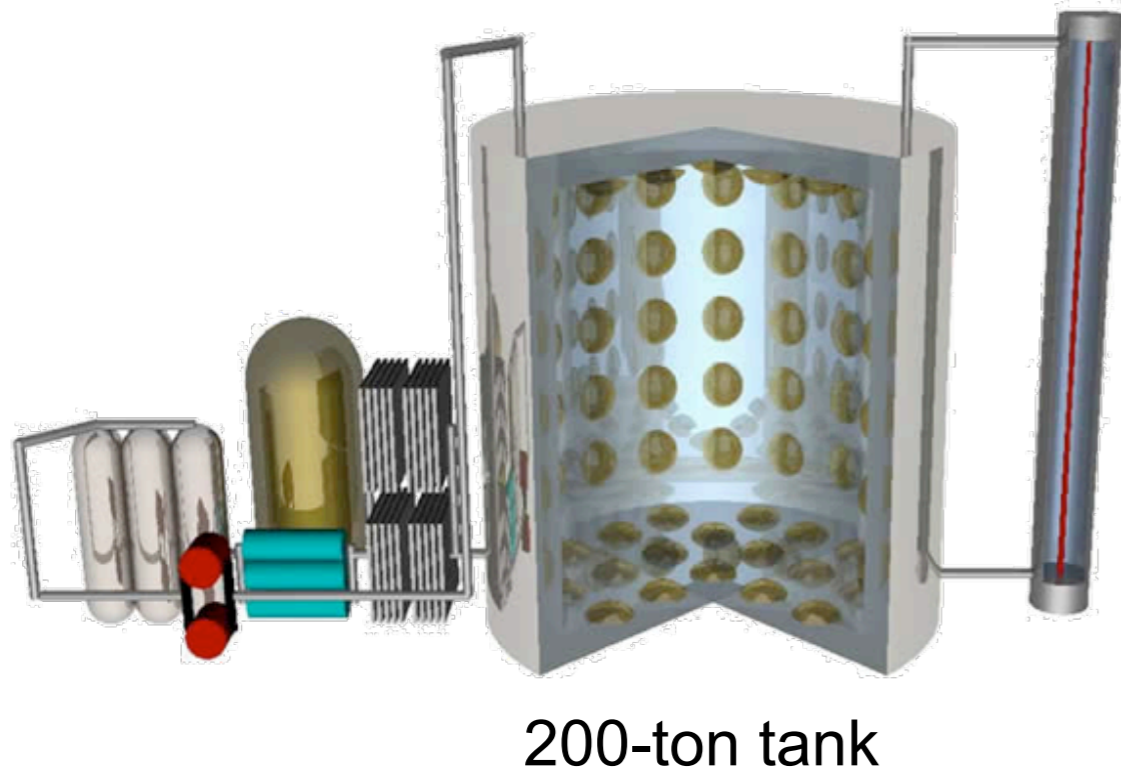
Advantage

- Simple structure \rightarrow Low cost production possibility
- Short drift length \rightarrow Fast timing response
- High first step gain \rightarrow High single photoelectron resolution

Challenge

- Difficulty in handling 8kV
- No experience to use in a water Cherenkov detector

Photodetector Test in the Water Tank



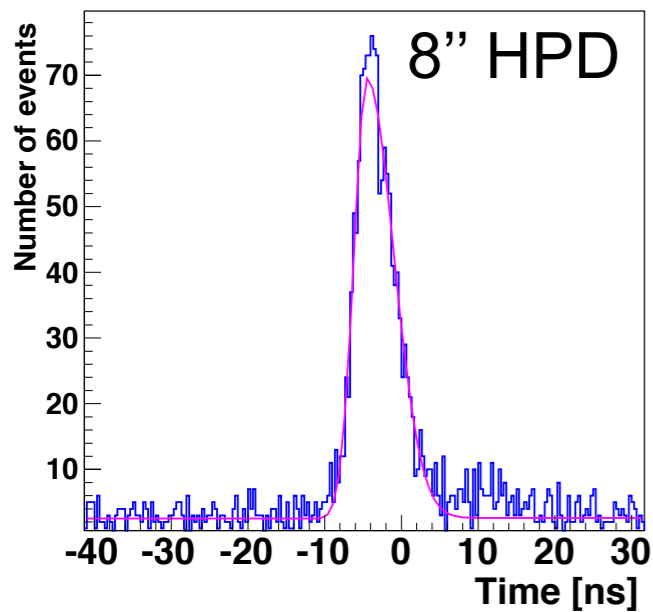
7

8" normal-QE
HPD

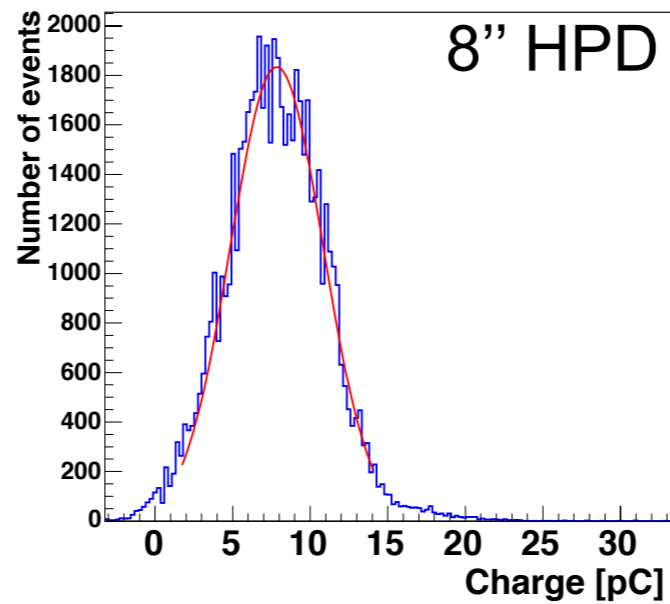
20" high-QE
Super-K PMT

Performance

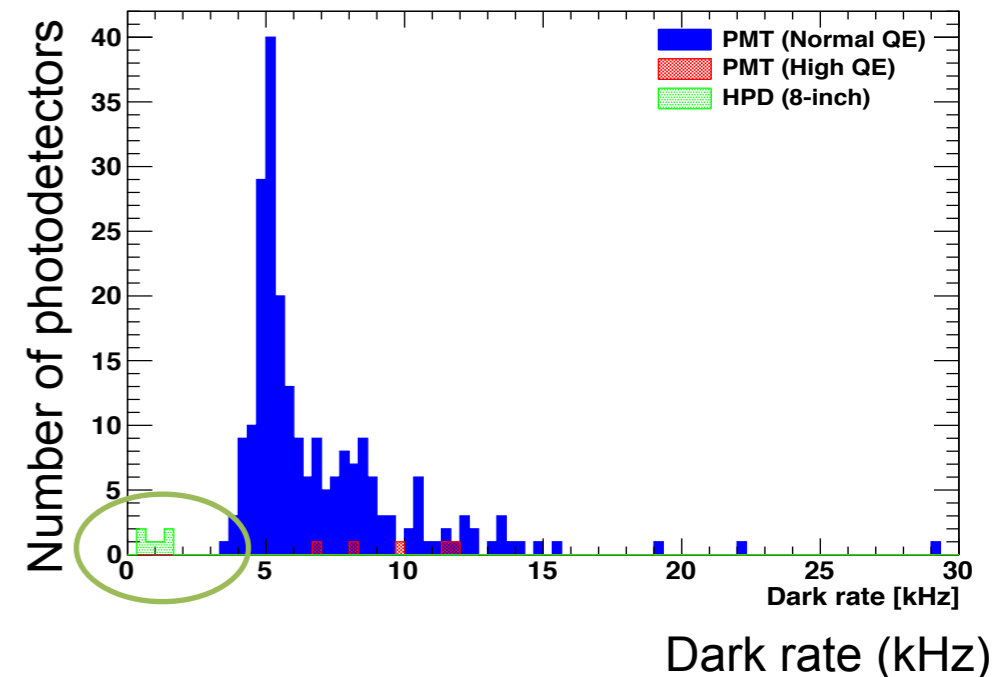
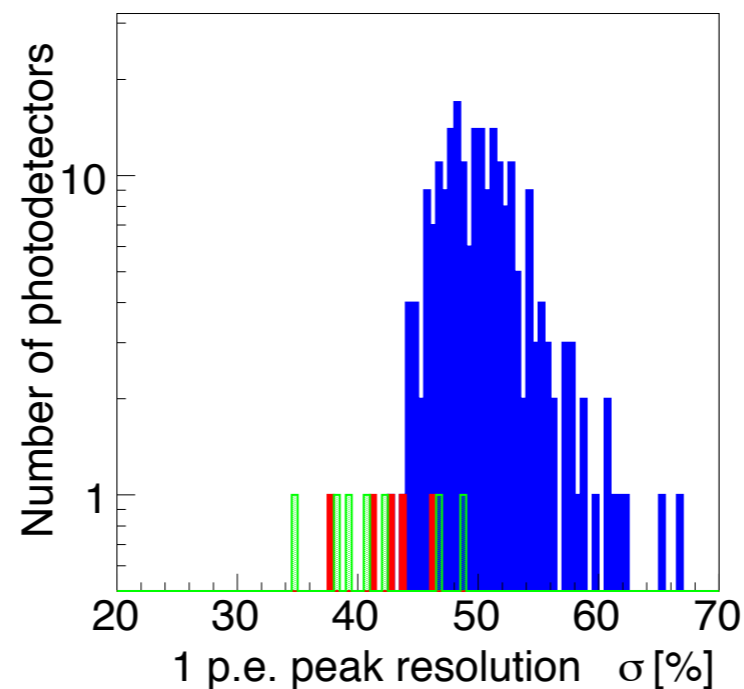
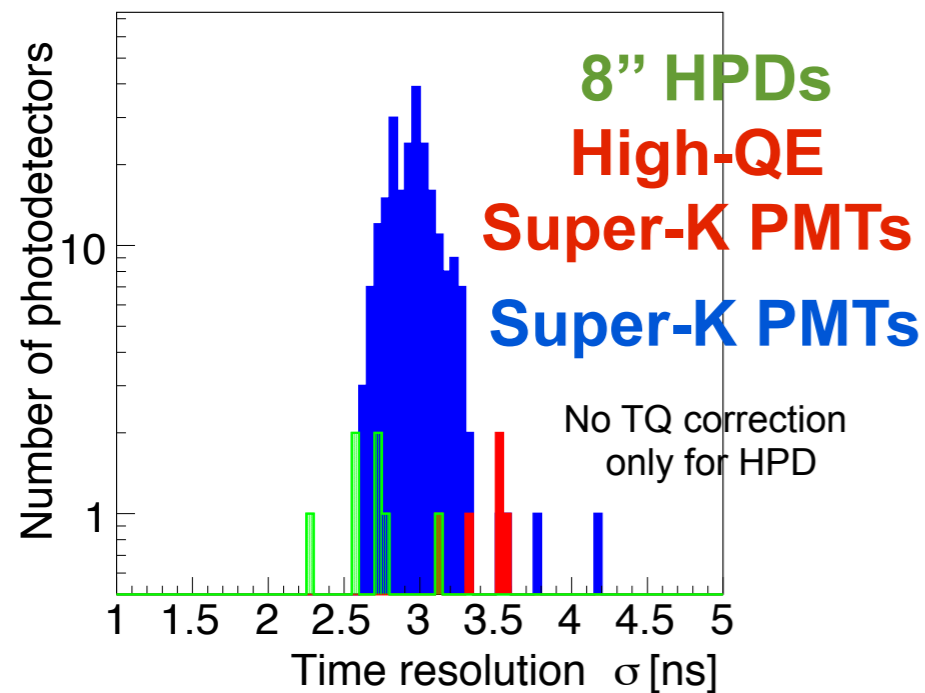
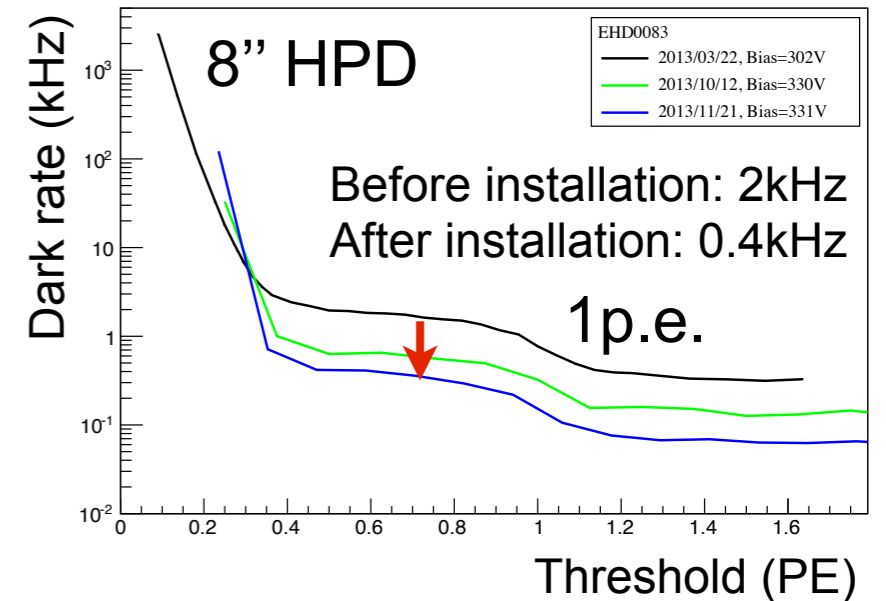
1PE timing distribution



1PE charge distribution



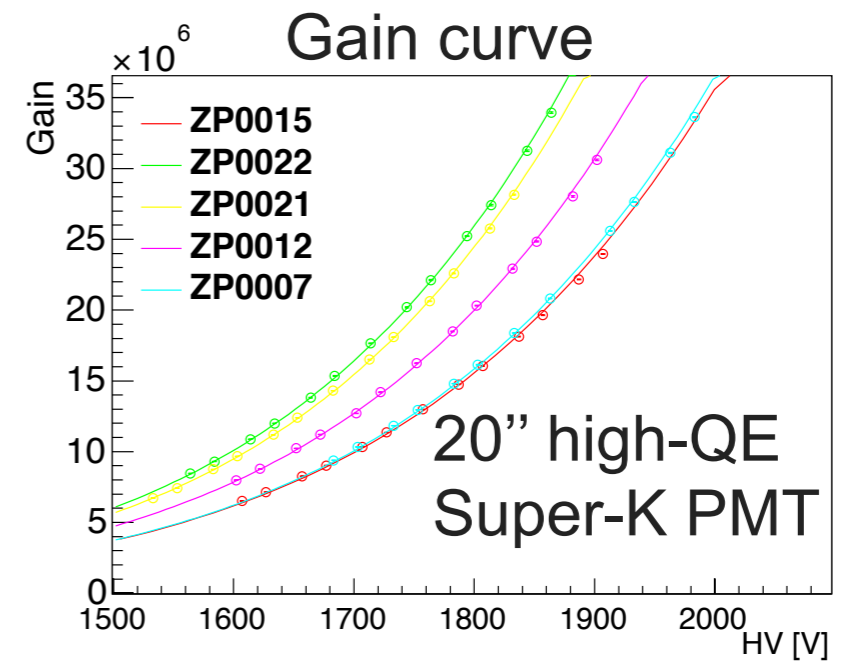
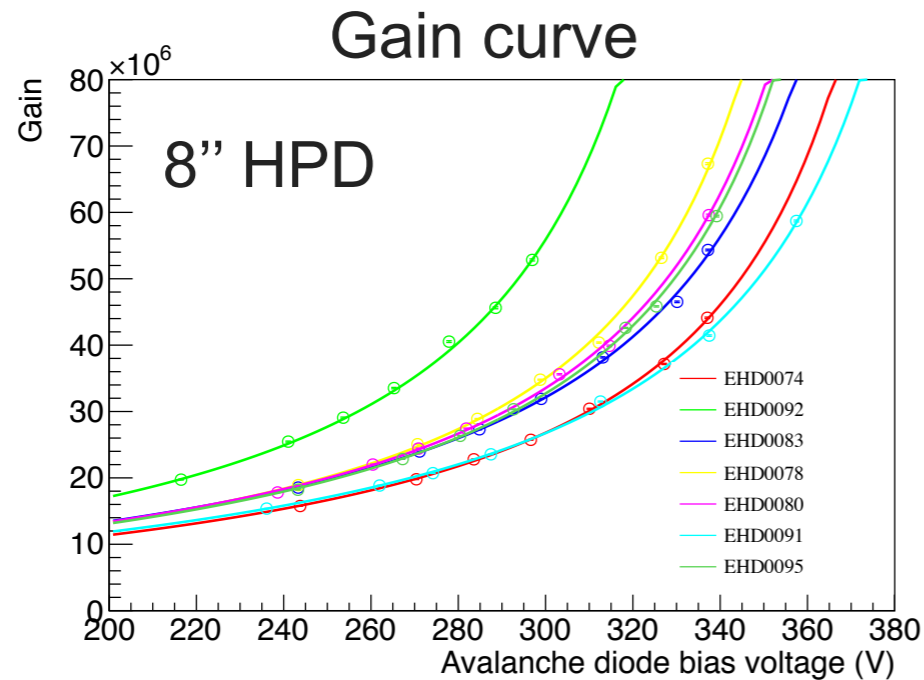
Dark rate distribution



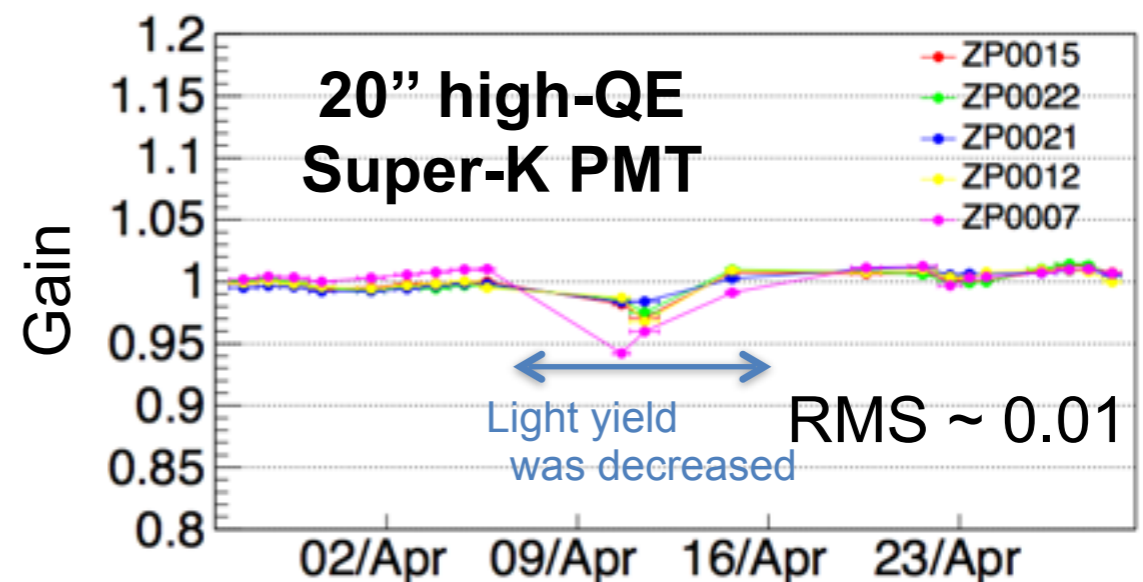
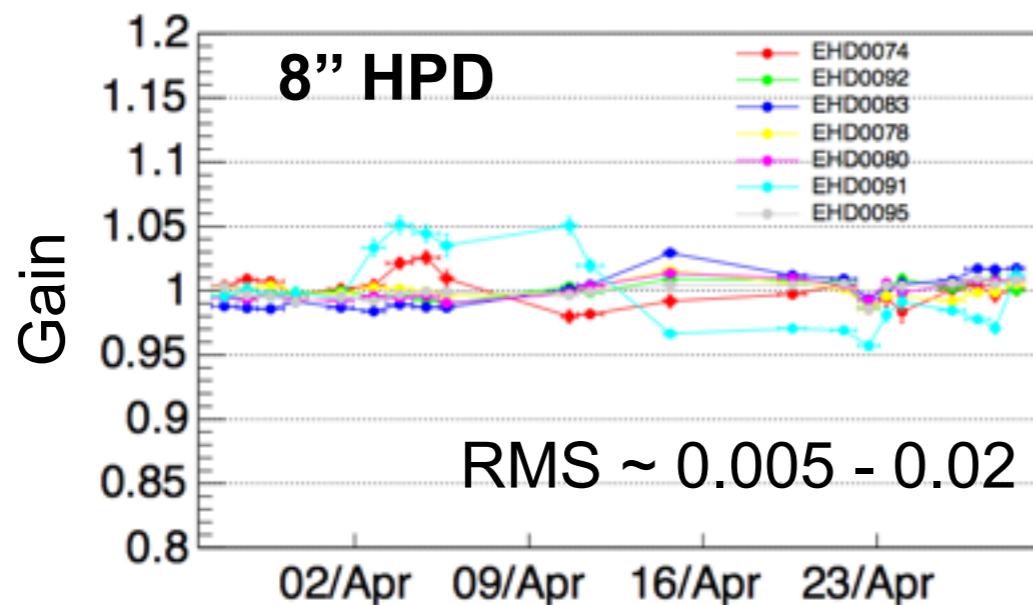
8" HPD shows better timing & charge resolution and dark rate

Calibration and Stability

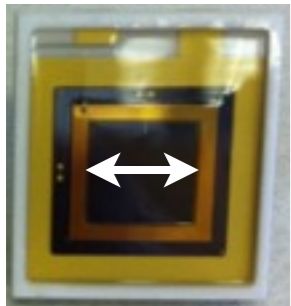
We calibrated all photodetectors in the tank.



Confirmed the gain was stable for 1 month run.
We will continue stable data taking.



New 20" Prototypes



5mm Φ AD



20" high-QE HPD
(w/ 5mm Φ AD)



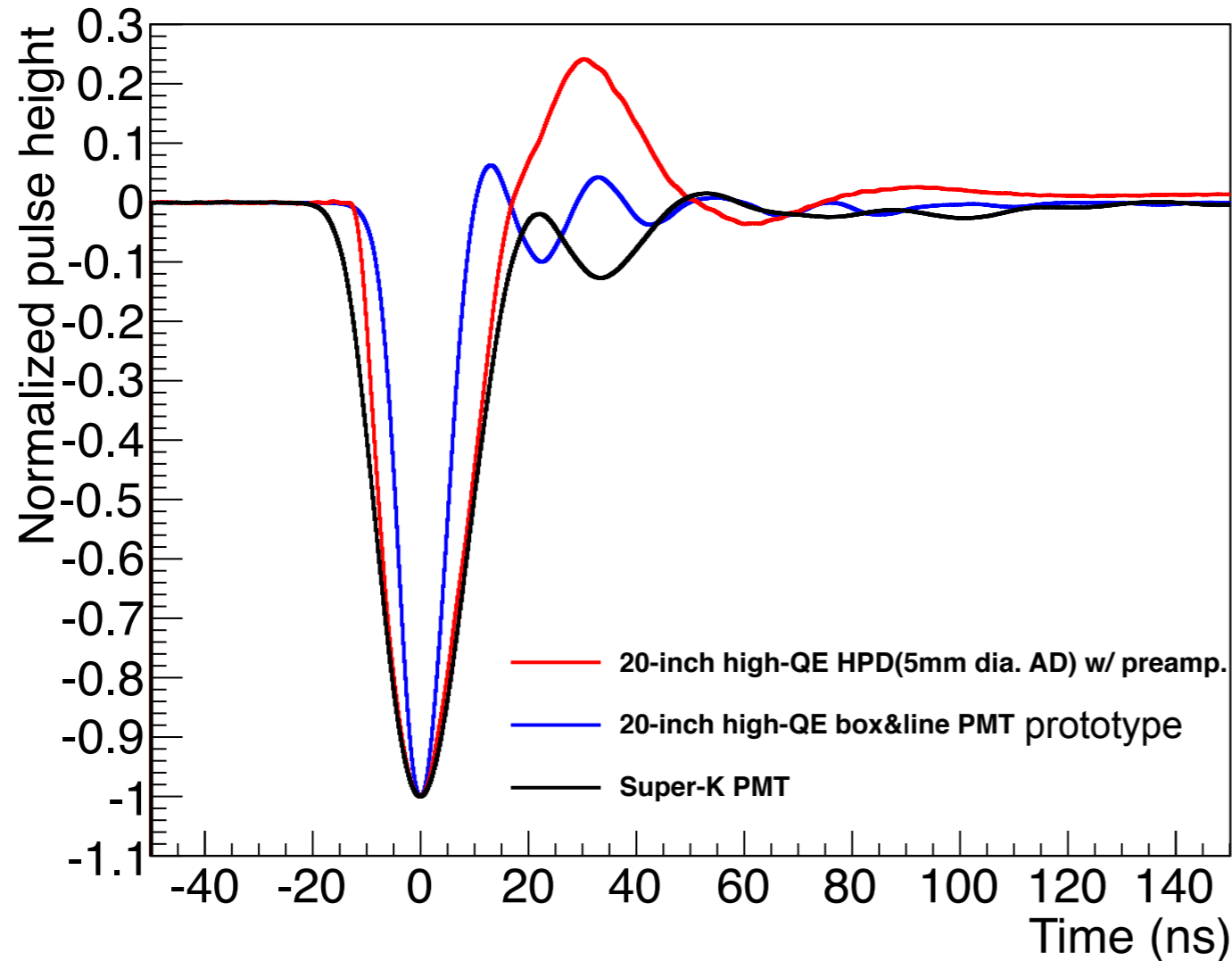
20" high-QE box&line PMT

Note

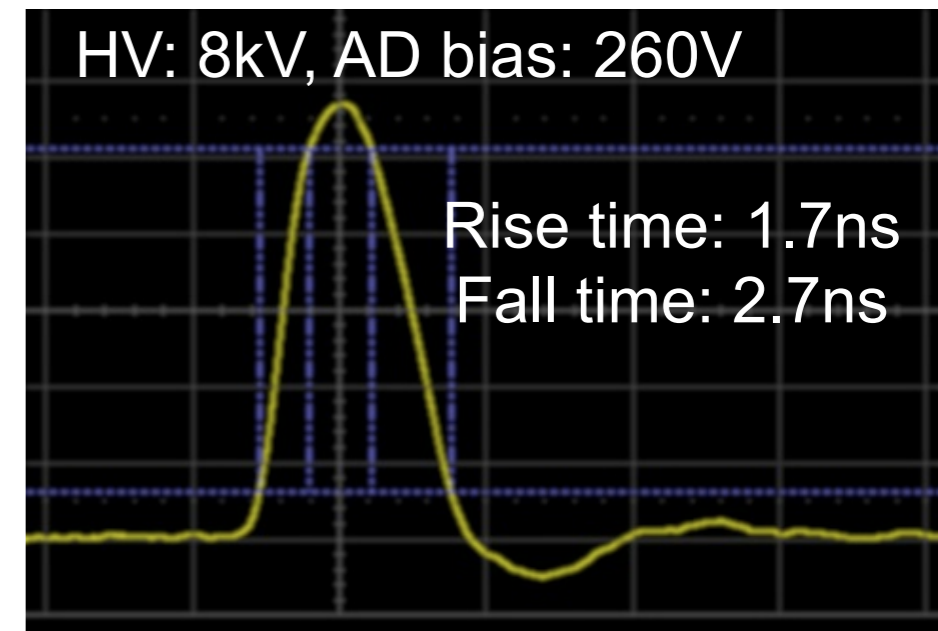
- Target AD size: 20mm Φ AD
- AD used for the evaluation is smaller size, same as 8" HPD
- 20" HPD w/ 20mm ϕ AD will be later measured with coming new preamplifier.

Waveforms

- Box&line PMT and HPD are faster than Super-K PMT



8" HPD w/o preamp.



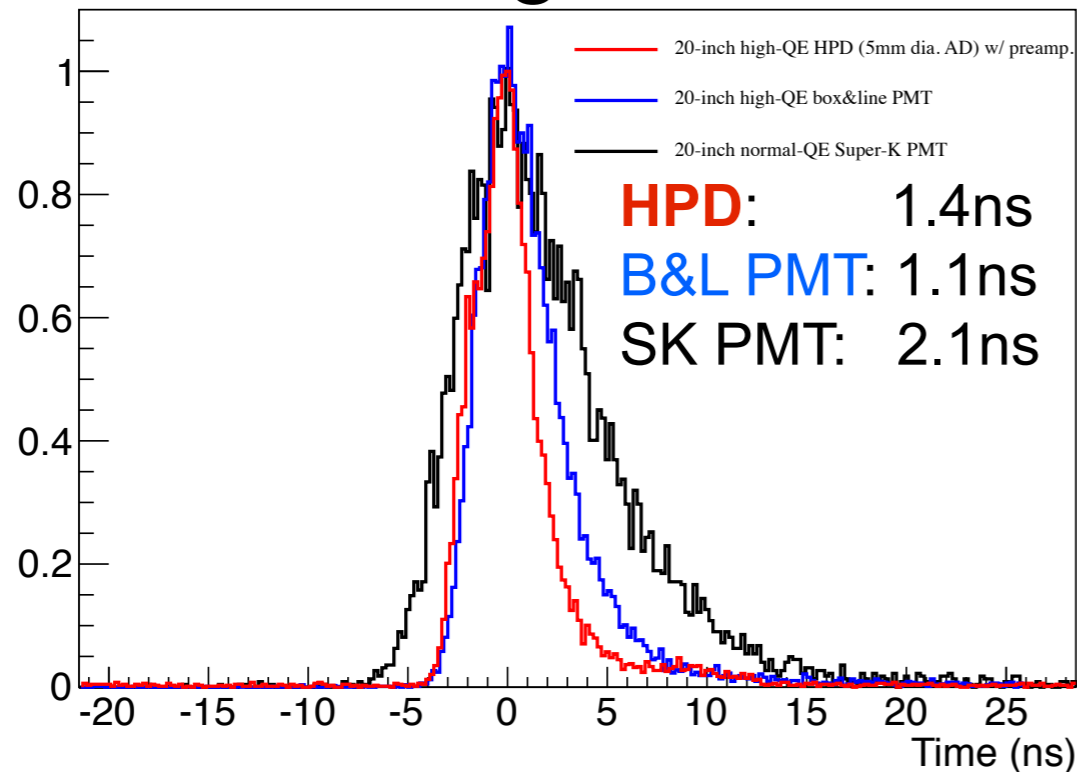
HPD itself has very fast response.

Preamplifier R&D to get a fast response is ongoing.

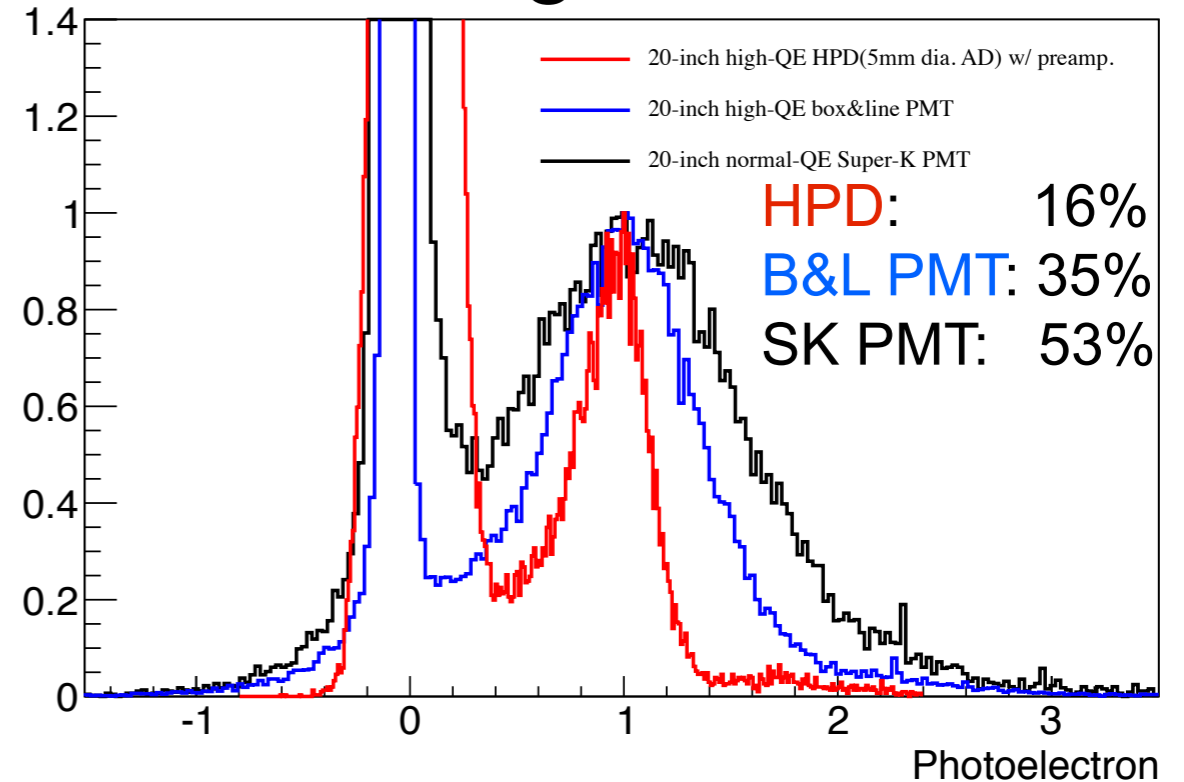
	HPD	B&L PMT	SK PMT
Rise time (ns)	7.4	6.2	10.6
Fall time (ns)	11.5	6.3	13.1
Pulse width (ns)	25.5	16.7	31.4

Timing & Charge

1PE timing distribution



1PE charge distribution



	20" HPD (8" HPD)	B&L PMT	SK PMT
Timing resolution σ (ns)	1.4 (1.1)	1.1	2.1
FWHM (ns)	3.4 (3.3)	4.1	7.3
1PE resolution σ/μ	16% (12%)	35%	53%
Peak to Valley ratio	3.9 (5.2)	4.3	2.2

HPD calculated timing resolution FWHM: 0.75ns (20mm ϕ AD w/o preamp)

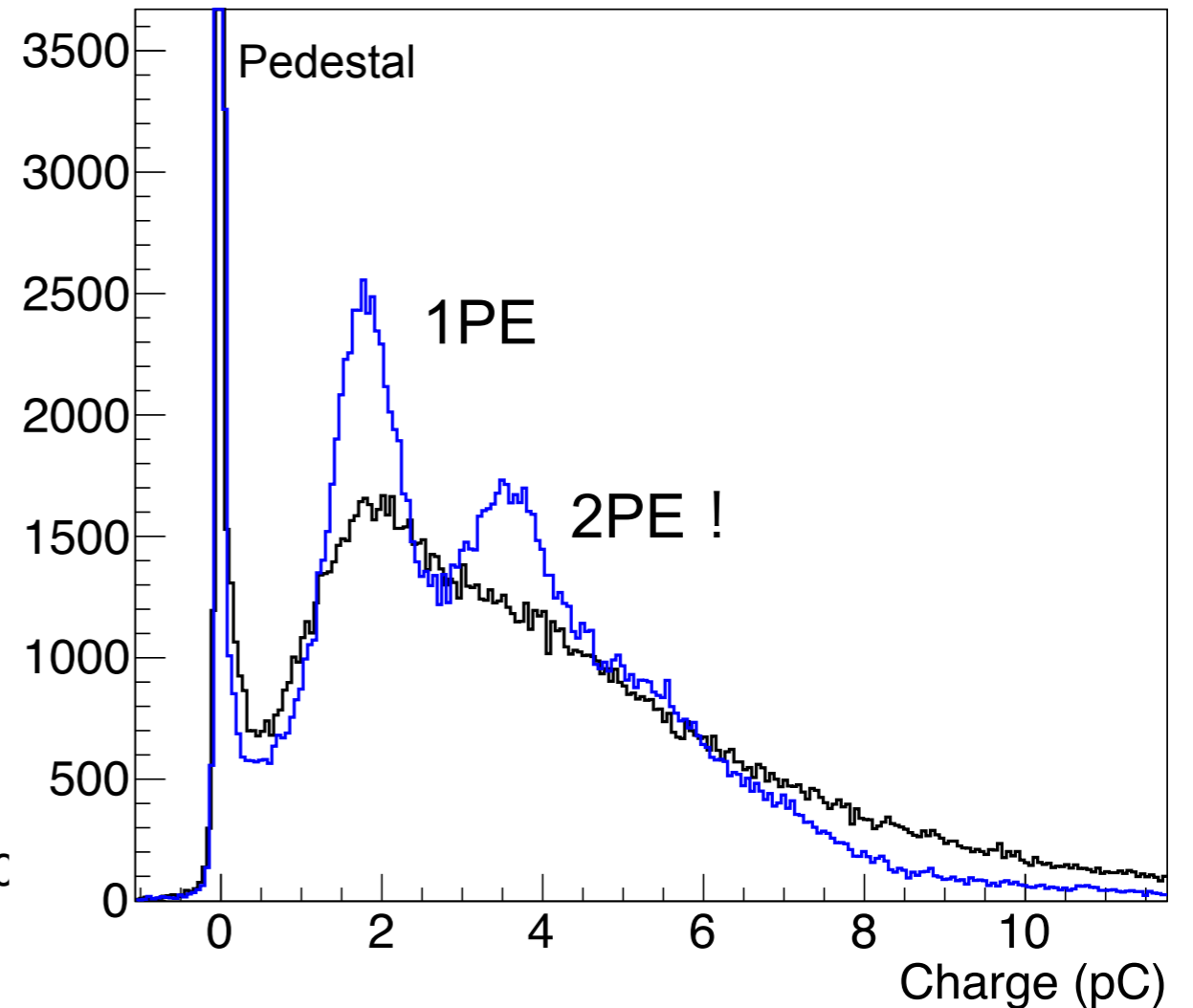
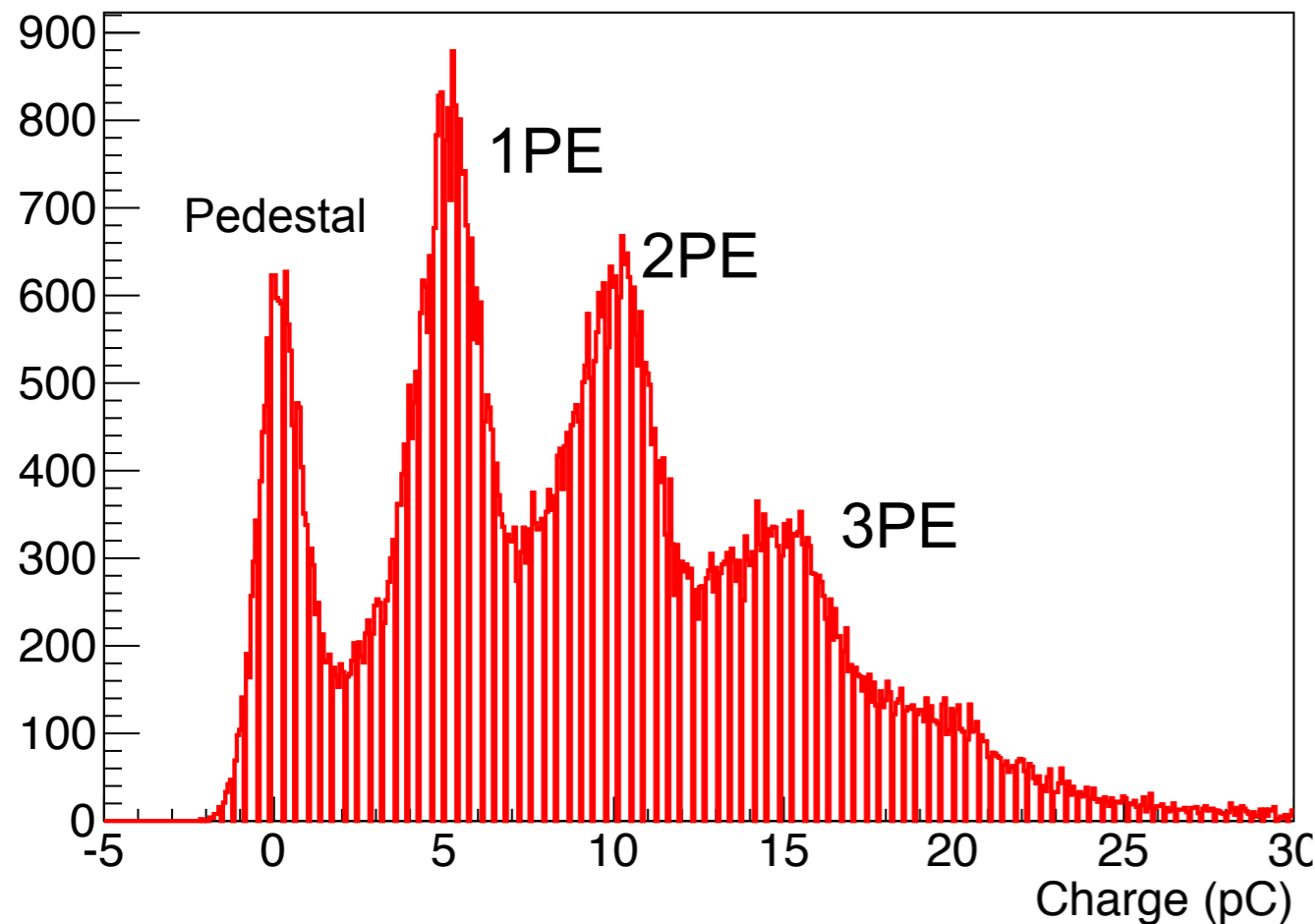
- Both box&line PMT and HPD show better timing and charge resolution than Super-K PMT

Multi-PE Distribution

20" high-QE HPD

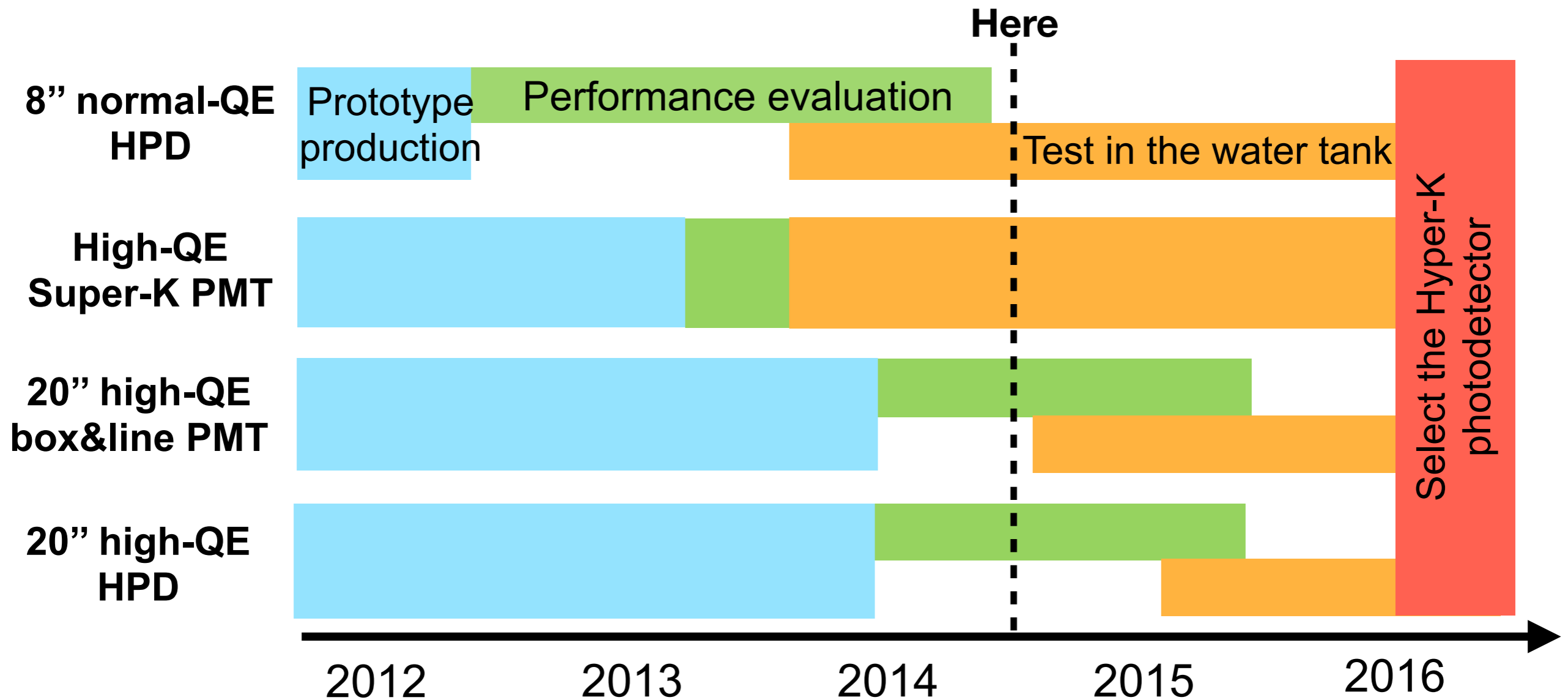
20" high-QE Box&line PMT

20" high-QE Super-K PMT



Multi-photoelectron peaks are clearly seen

Schedule



- Development of 20'' HPD is still ongoing
- Preamplifier for large AD size, Low capacitance AD
- In this summer, 20'' high-QE box&line PMT will be installed in the tank

Summary

- **We have been developing new photodetectors for Hyper-K**
- **We evaluated photodetectors in the 200-ton water tank**
 - 8" HPDs show good performance
 - Test of 20" high-QE box & line PMT will start this summer
- **Performance of 20" high-QE HPD and 20" high-QE box&line PMT prototype was measured**
 - Confirmed better performance than Super-K PMT
 - Details (noise, efficiency, etc) will be also measured soon
- **We will select the best photodetector in 2016**

5th Hyper-K Open Meeting

5th Open Meeting for the Hyper-Kamiokande Project

19-22 July 2014 Irving K. Barber Center, UBC, Vancouver, CANADA

Asia/Tokyo timezone

4th meeting
(Jan. 2014)

@Kavli IPMU, Japan

Overview

Meeting photo [last HK meeting]

Important Dates

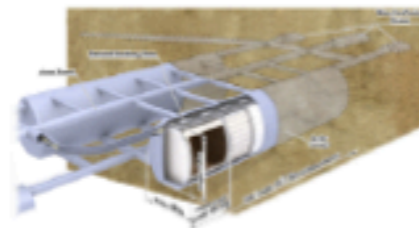
Registration

Registration Form

Call for Abstracts

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Overview

The Hyper-Kamiokande project is being designed as a flagship experiment for the study of neutrino oscillation and astrophysical neutrinos.

Following the successful format of the previous 4th International Open Working Group Meeting for Hyper-K, the 5th International Open Working Group Meeting for Hyper-K will be open to all interested scientists and researchers.

The outline of the meeting is:

- **19 July (Sat.):** Premeetings and IBR (International Board of Representatives) Meeting
- **20 July (Sun.):** Plenary Sessions, Workshop Dinner
- **21 July (Mon.):** Plenary Sessions
- **22 July (Tue.):** Plenary Session till noon, followed by tour of TRIUMF.



- **Everyone** who are interested in Hyper-K can join the meeting

- Date: 19-22 **July** 2014

- Place: UBC, Vancouver, **CANADA**

Join us!

<http://bit.ly/5th-hyperk>