

Development of New Large-Aperture Photodetectors for Hyper-Kamiokande

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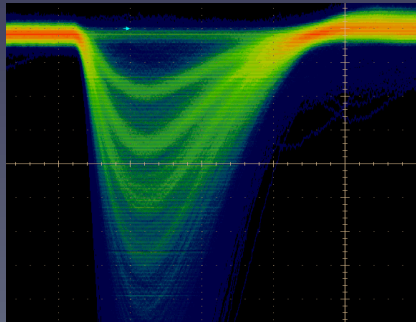
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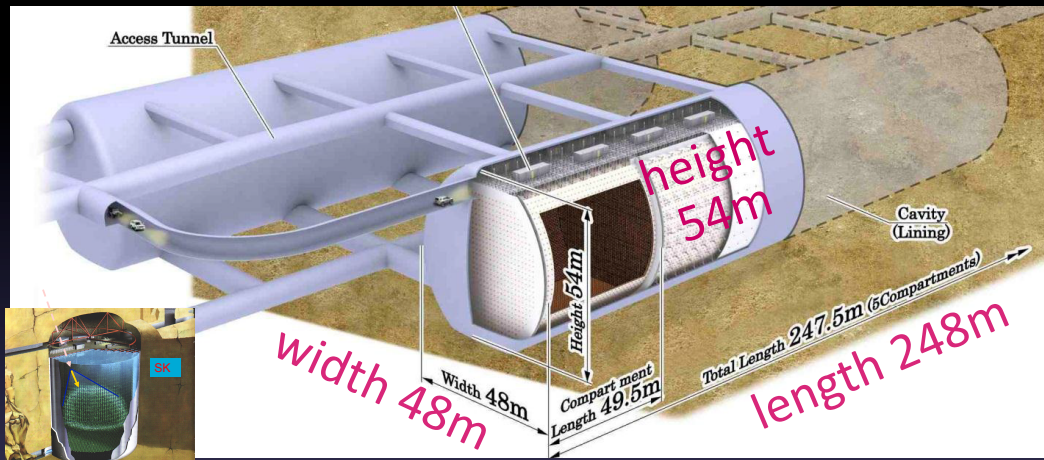
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for the Hyper-Kamiokande working group



Hyper-Kamiokande

Next generation Mega-ton water Cherenkov detector



Total Mass : 0.99 Mton
Fiducial Mass : 0.56 Mton
(x 25 of Super-K)

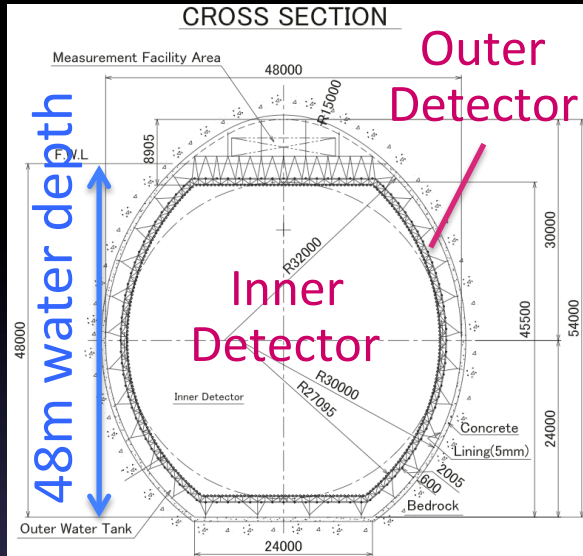
Aiming to start observation in 2025
(3yrs for full survey & final designing
+ 7yrs for construction)

Wide physics program

- Proton decay search
- Full picture of neutrino oscillation (leptonic CP violation, ...)
- Astrophysical neutrinos (solar ν , supernova ν , WIMP, ...)
- Neutrino geophysics

Great potential to discover new physics !

Photodetectors in Hyper-K



Inner Detector

- 99,000 50cm ϕ photodetectors (11,129@SK)
- 20% photocathode coverage (40%@SK)

Outer Detector

- 25,000 20cm ϕ photodetectors (1,885@SK)

Wide energy range (a few MeV \sim 100GeV)
Precise event reconstruction
Successive events ($\mu \rightarrow e$ decay, prompt γ , ...)
Long term operation (>15 years)

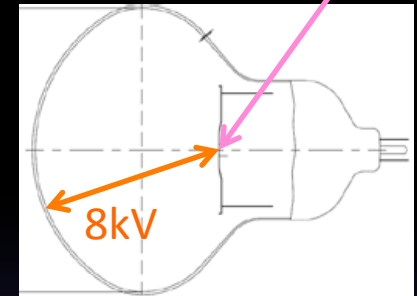
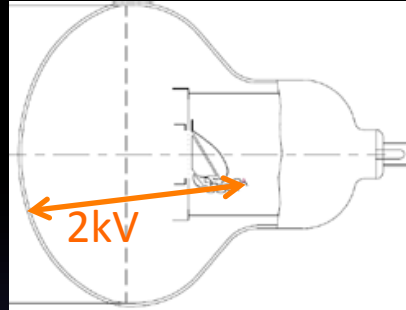
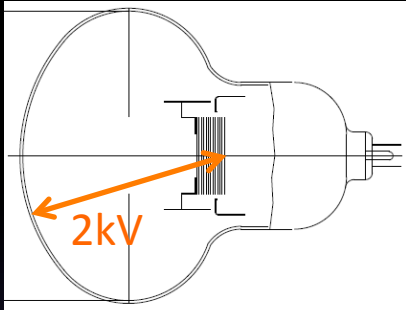
Requirements for photodetectors

- High efficiency single photon detection
- Good Q resolution and linearity in a wide dynamic range (1-1000PE)
- Good T resolution (a few ns for 1PE)
- Low dark rate (<several kHz)
- Long-term stability

with low cost!

Photodetector candidates

50cm ϕ



Avalanche Diode

Hamamatsu R3600 PMT
(Venetian-Blind dynode)

50cm ϕ Improved PMT
(Box&Line dynode)

50cm ϕ HPD
(Hybrid Photo-Detector)

- Super-K PMT
- Used for \sim 20 years
→ Guaranteed
- Complex production
→ Expensive

- Under development
- Better performance
- Same technology
→ Lower risk

- Under development
- Far better performance
- Simple structure
→ Lower cost
- New technology
→ Higher risk

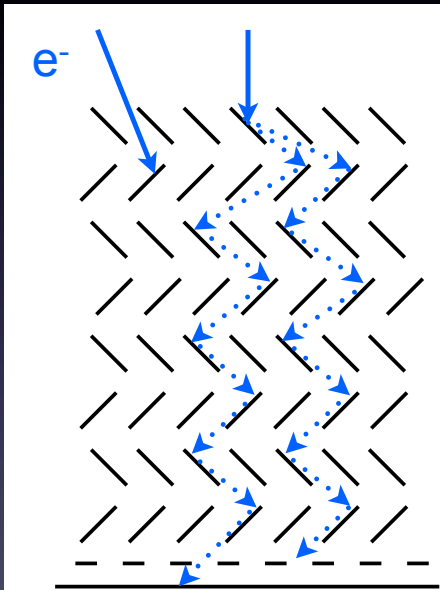
Lower Risk



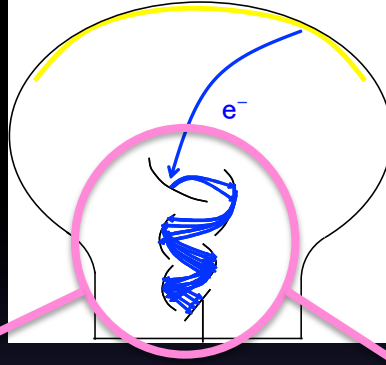
Better Performance

Box&Line PMT

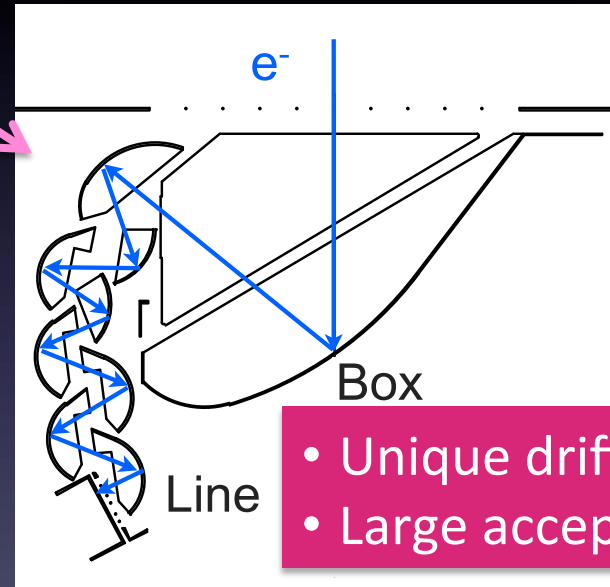
Super-K PMT
(Venetian-Blind dynode)



- Various drift pass
- Might miss a dynode



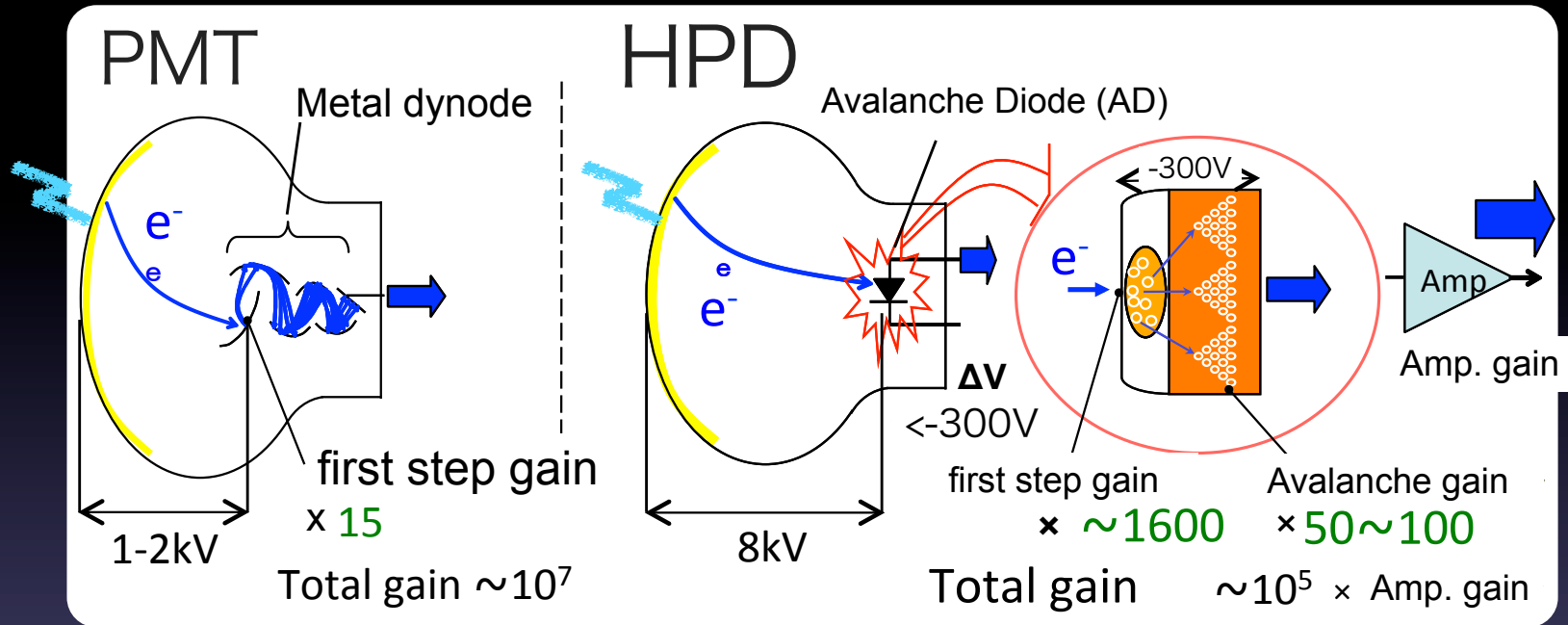
Box&Line PMT
(Box&Line dynode)



- Unique drift pass
- Large acceptance

Unique drift pass \rightarrow Better timing and 1PE Q resolution
Large acceptance \rightarrow Better photoelectron collection efficiency
(CE: 80% for VB \rightarrow >90% for B&L by simulation)

Hybrid Photo-Detector (HPD)



HPD

Challenge Advantage

- Short drift path \rightarrow Fast response, high timing resolution
- High 1st step gain \rightarrow High 1PE charge resolution
- Simple mechanical structure \rightarrow Low production cost
- Difficulty in handling 8kV
- No prior experience to use in a water Cherenkov detector

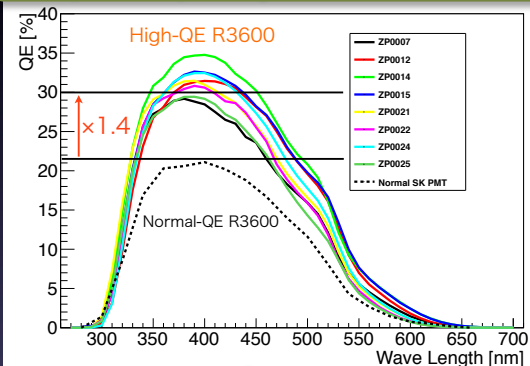
Super-K PMT



R&D flow

Initial prototypes

High quantum efficiency (HQE) Super-K PMT



20cm HPD



50cm HQE B&L PMT



50cm HQE HPD



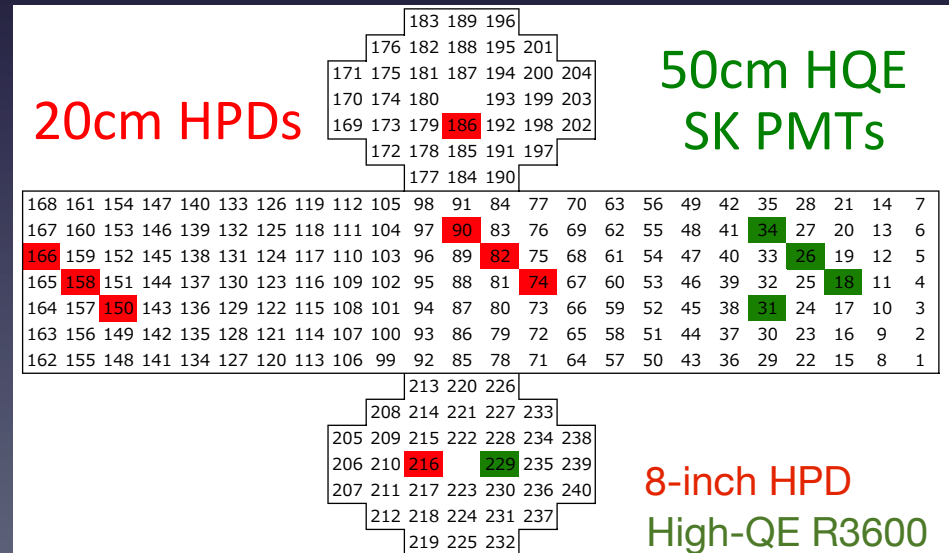
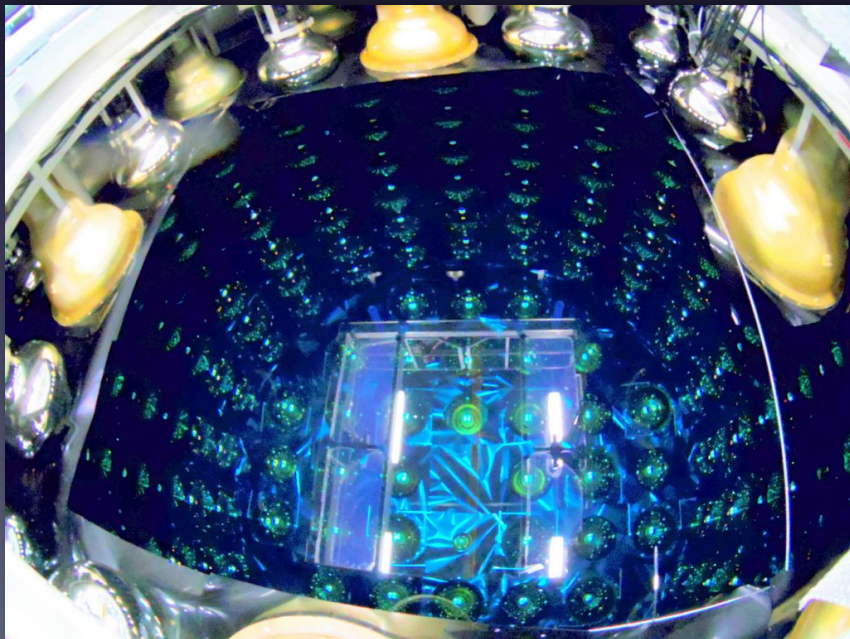
Near-final prototypes

- High Quantum efficiency SK PMTs
Testing of HQE photocathode
(common option for all candidates)
 - 20cm HPDs
Smaller prototype for checking
usability of the new technology
- Testing in a water Cherenkov detector since last Autumn

- Based on experience of using
1st prototypes
- Now under testing in the air

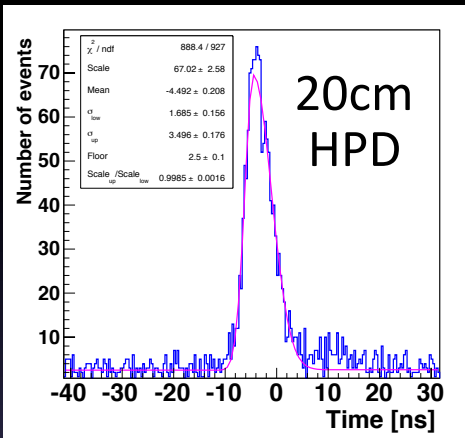
Testing in a water Cherenkov detector

- To confirm the usability of new photodetectors in Hyper-K
- EGADS tank in Kamioka mine : 200ton scale model of Super-K
 - A total of 240 photodetectors in the tank
 - Records integrated charge and time of each photodetector hit
- **Eight 20cm HPDs, five 50cm HQE SK PMTs, and 227 SK PMTs** were installed in summer 2013

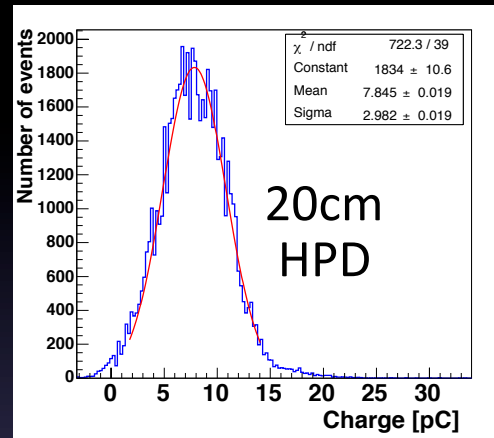


Performance (measured in a water Č detector)

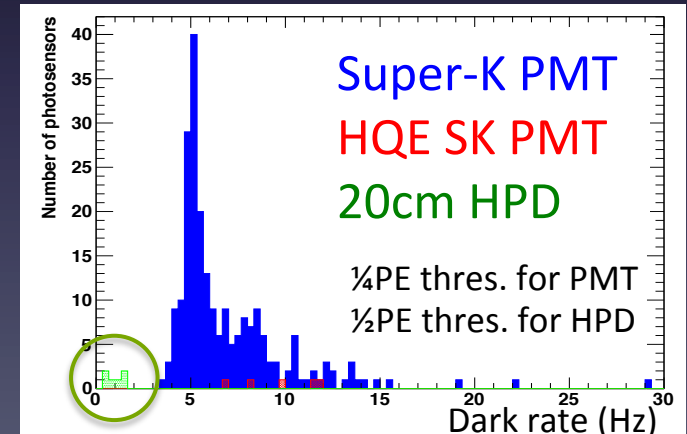
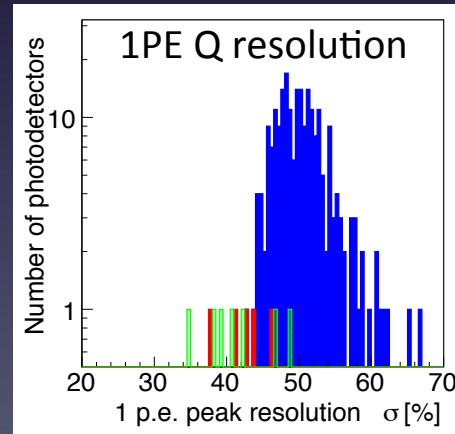
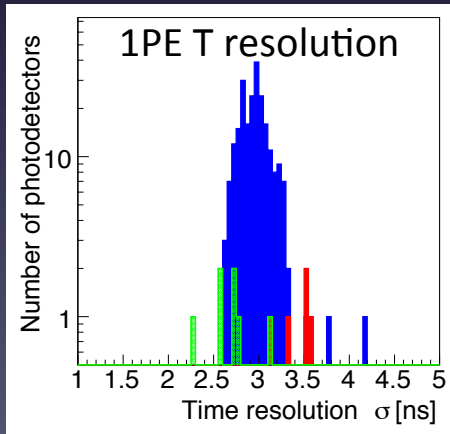
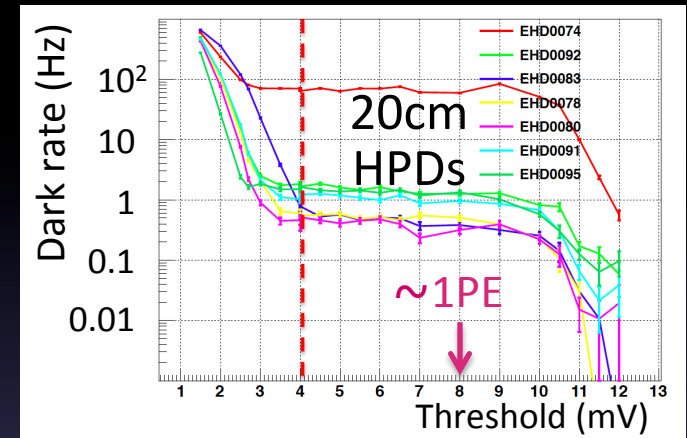
1PE timing response



1PE charge response



Dark rate

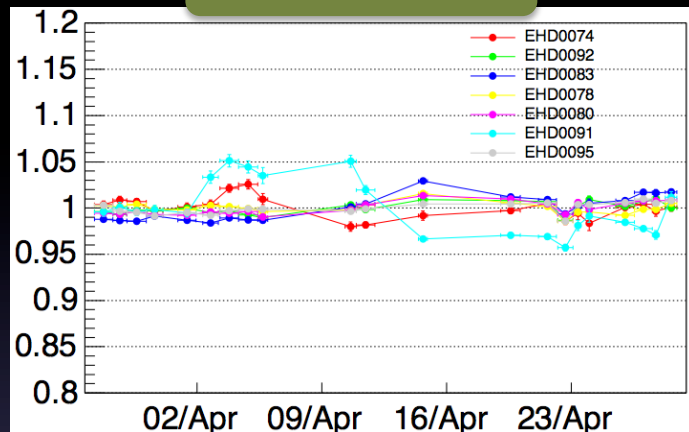


20cm HPD shows better performance (T/Q resolution and dark rate)

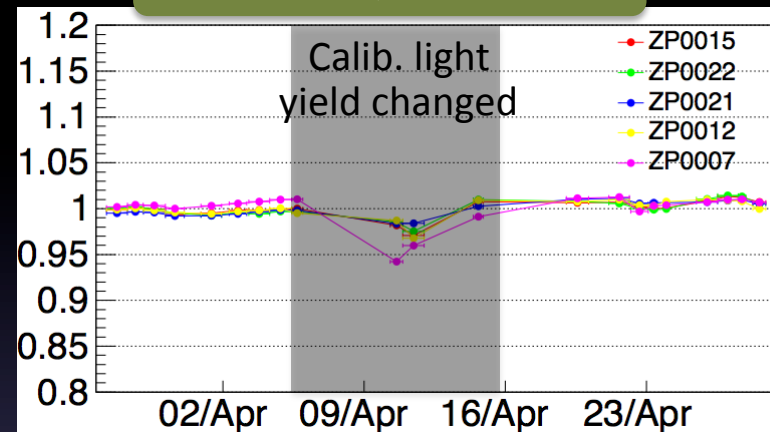
Stability (measured in a water Č detector)

Gain
(relative to the
initial gain)

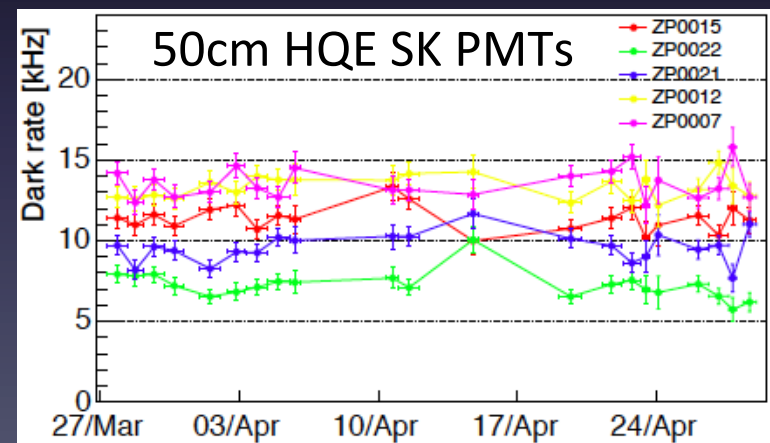
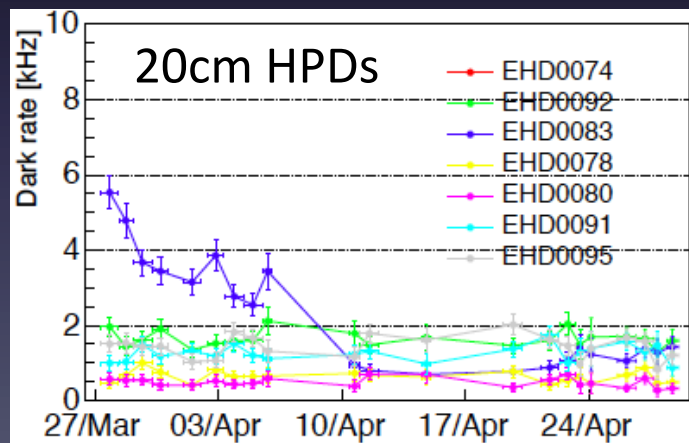
20cm HPDs



50cm HQE SK PMTs



Dark rate
(kHz)



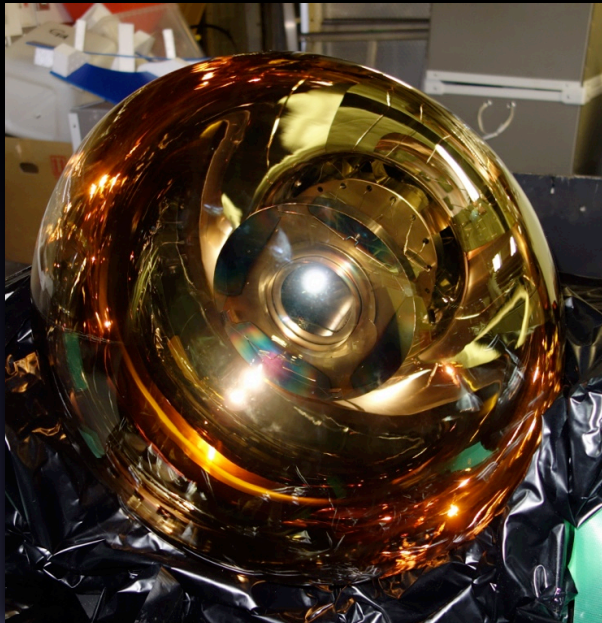
~1 month

~1 month

Small variation over a month. Will keep monitoring (>1yr)

New 50cm ϕ prototypes

50cm HQE Box&Line PMT



50cm HQE HPD

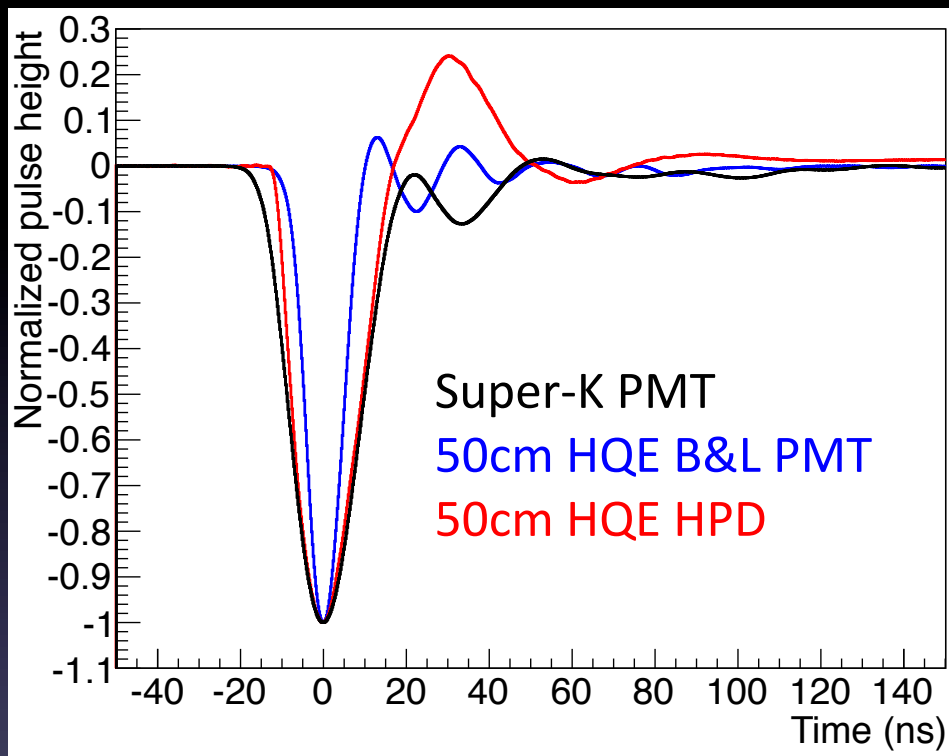


Just created in spring 2014

5mm ϕ AD is used in this HPD prototype (same as the 20cm prototype).

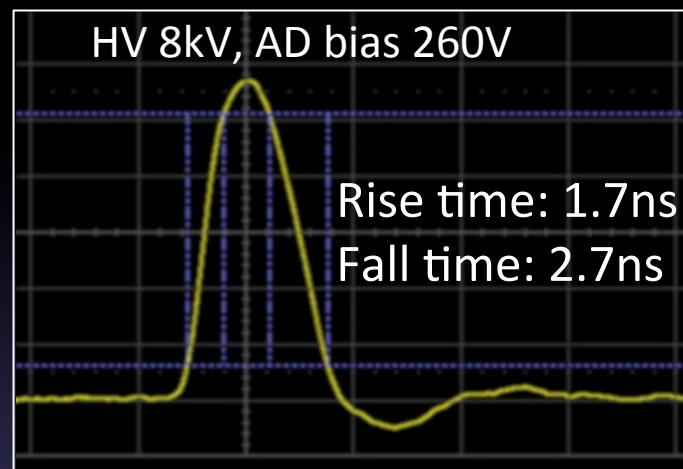
HPDs with 20mm ϕ AD (= our target design) will be tested later with new preamplifiers under development.

Waveforms



20cm HPD w/o preamplifier

HV 8kV, AD bias 260V



HPD itself has very fast response.

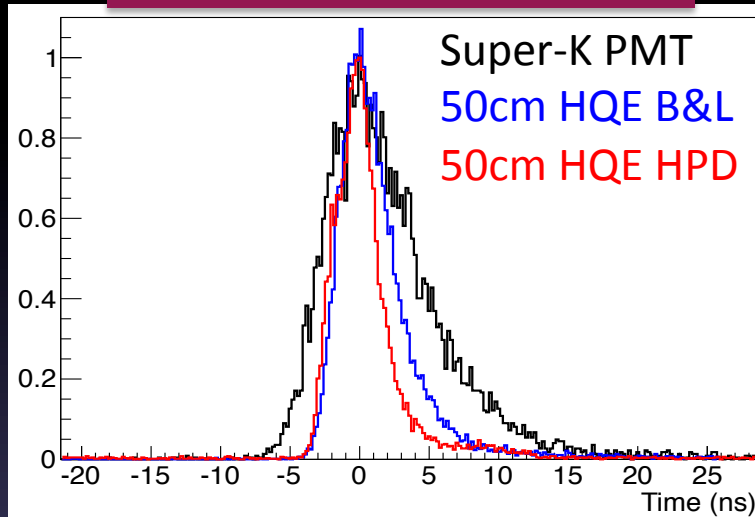
Preamplifier R&D to get a faster response is ongoing.

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

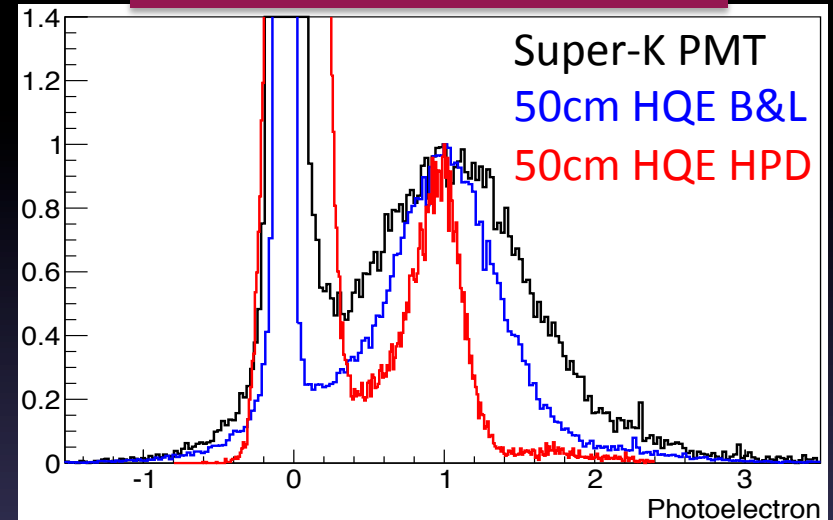
Both new sensors are faster than Super-K PMT

Timing and charge response

1PE timing distribution



1PE charge distribution

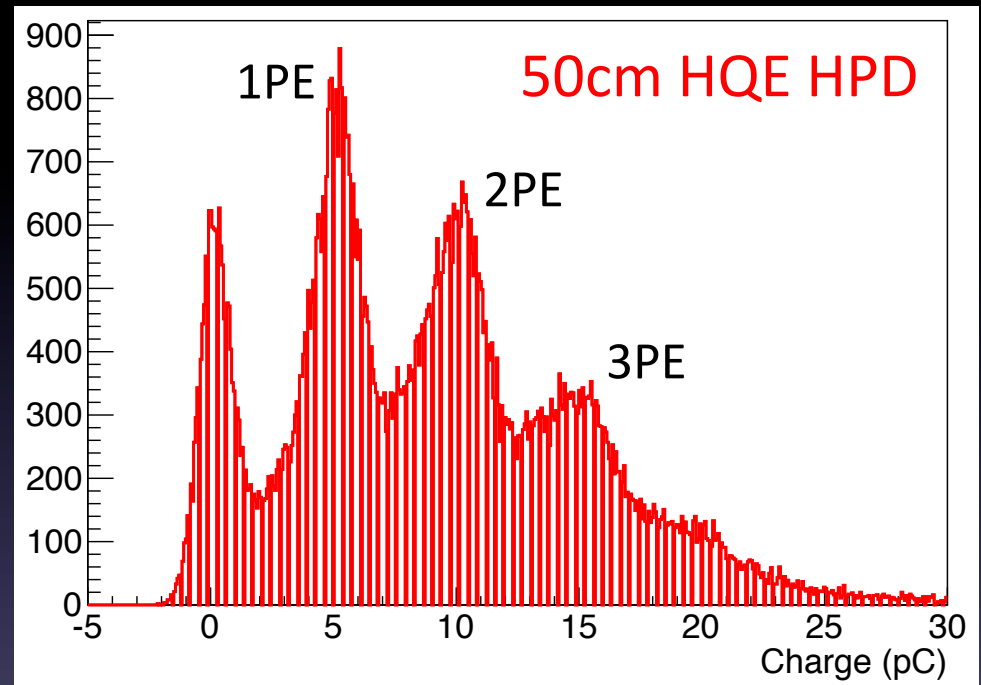
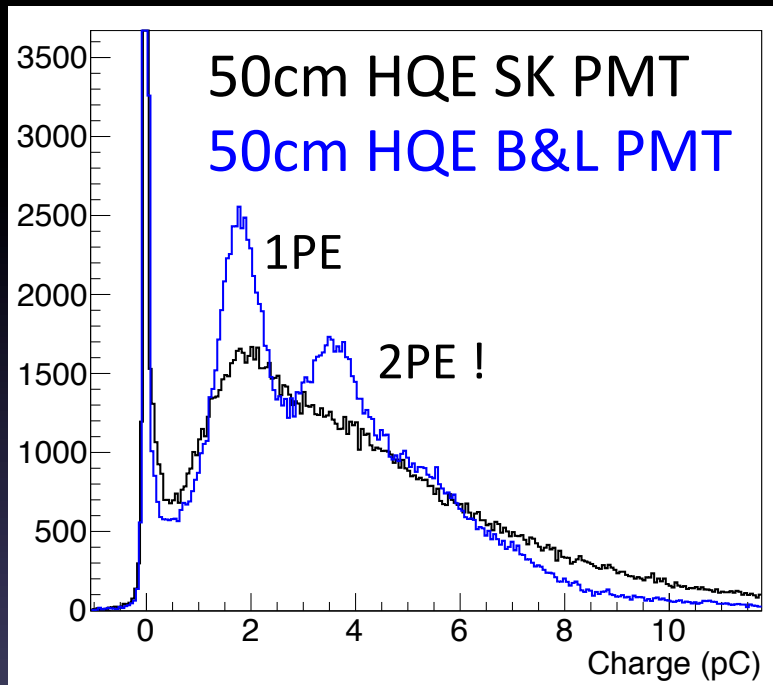


	SK PMT	B&L PMT	50cm HPD (20cm HPD)
Timing resolution σ (ns)	2.1	1.1	1.4 (1.1)
FWHM (ns)	7.3	4.1	3.4 (3.3)
1PE resolution, σ/mean	53%	35%	16% (12%)
Peak-to-Valley ratio	2.2	4.3	3.9 (5.2)

Calculated T-resolution of HPD w/ preamp (20mm AD) : 0.75ns FWHM

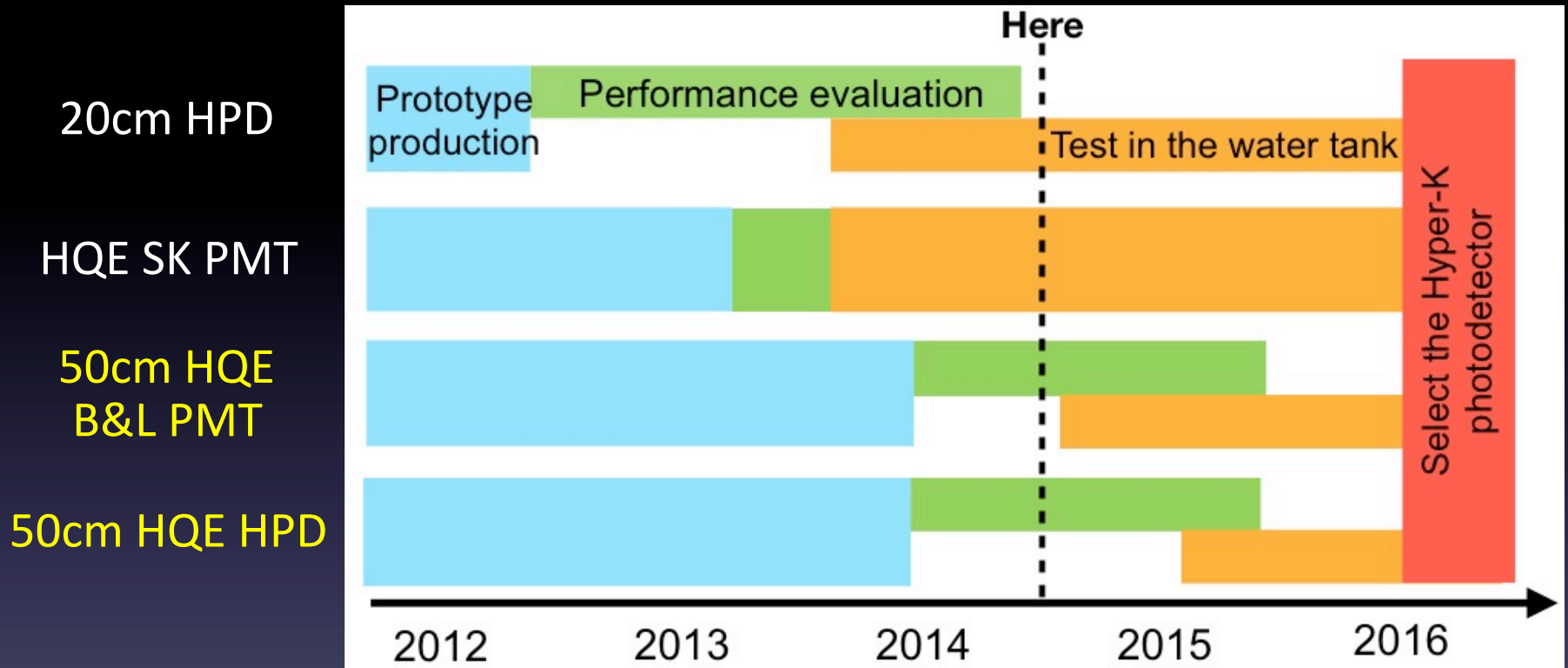
Both new photodetectors have much better T/Q resolution than SK PMT

Multi-PE distribution



Multi-PE peaks are clearly visible in HPD and B&L PMT

Schedule



- Basic characterization of 50cm B&L PMT in the air will be completed in a few months → Start testing in a water Cherenkov detector
- R&D work of 50cm HPD before starting a test in a water tank
 - Low noise preamplifier for a larger AD, lower capacitance AD, ...

Summary

- New high efficiency and high resolution large-aperture photodetectors are under development for Hyper-K
- Evaluated initial prototypes in a water Cherenkov detector
 - 20cm HPDs show good performance (T/Q resolution, dark rate)
 - Will keep monitoring photodetector stability
- Started performance evaluation of 50cm prototypes
 - HQE Box&Line PMT and HQE HPD
 - Showing much better performance than SK PMT
 - Characterization of B&L PMT in the air to be completed in a few months, followed by testing in a water Cherenkov detector
- We will select the photodetector for Hyper-K in 2016

5th open Hyper-K meeting

5th Open Meeting for the Hyper-Kamiokande Project

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

Asia/Tokyo timezone

Overview

Meeting photo [last HK meeting]

Important Dates

Registration

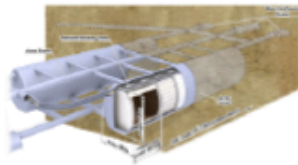
Registration Form

Call for Abstracts

View my abstracts

Submit a new abstract

Contact Information



Overview

The Hyper-Kamiokande project is the flagship experiment for the study of neutrinos and astrophysical neutrinos.

Following the successful format of the 5th International Open Working Group meeting will be open to all interested

The outline of the meeting is:

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

4th meeting in 2014Jan
@Kavli IPMU, Japan



- Hyper-K is proposed by an international working group (currently, 240 members from 67 institutes in 12 countries)
- Everyone interested in HK is welcome to the meeting
- 19-22 July @ UBC, Vancouver, Canada

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

Supplement

20cm HPD 1PE distribution

