New 50-cm diameter Photodetectors

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R&D of 50cm PDs

Goal

Development of a 50cm high performance photodetector which can be used in a water Cherenkov detector for a long time

R&D Flow

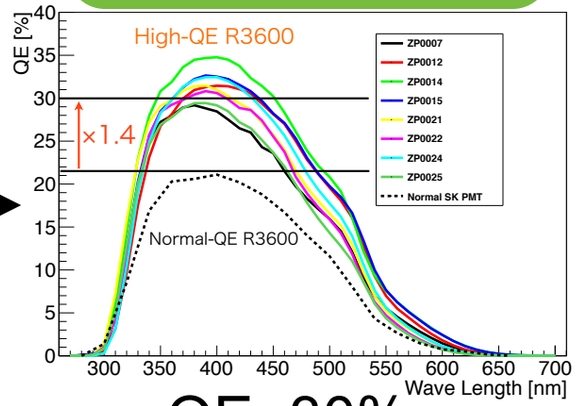
Super-K PMT

50cm

QE~22%

well-known

High-QE SK PMT



QE~30%

20cm Hybrid Photo-Detector (HPD)

50cm high-QE box&line PMT

50cm high-QE HPD

Test

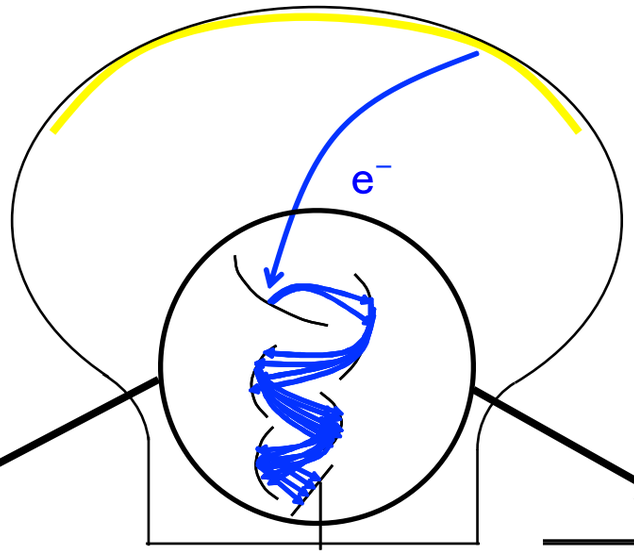
200-ton tank

- As a first step, we developed 20cm HPD and 50cm high-QE Super-K PMT
- Photodetector test in a 200-ton water tank to confirm the usability of new photodetectors is ongoing

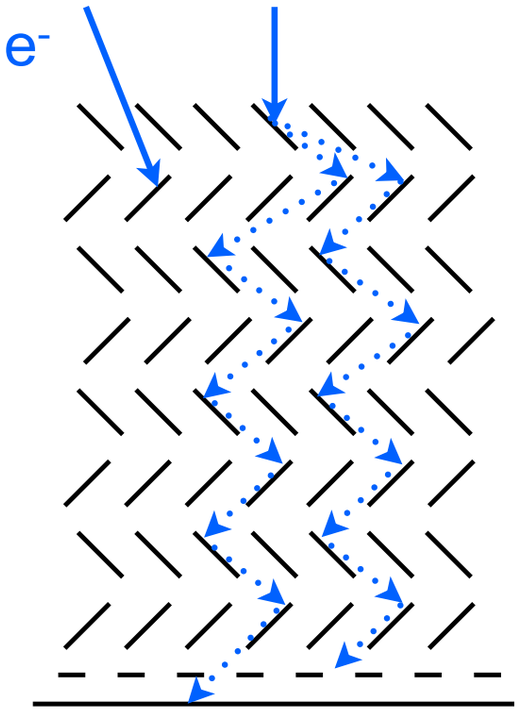
Okajima's talk

- We report the R&D status of 50cm high-QE HPDs and B&L PMTs

Box&line PMT

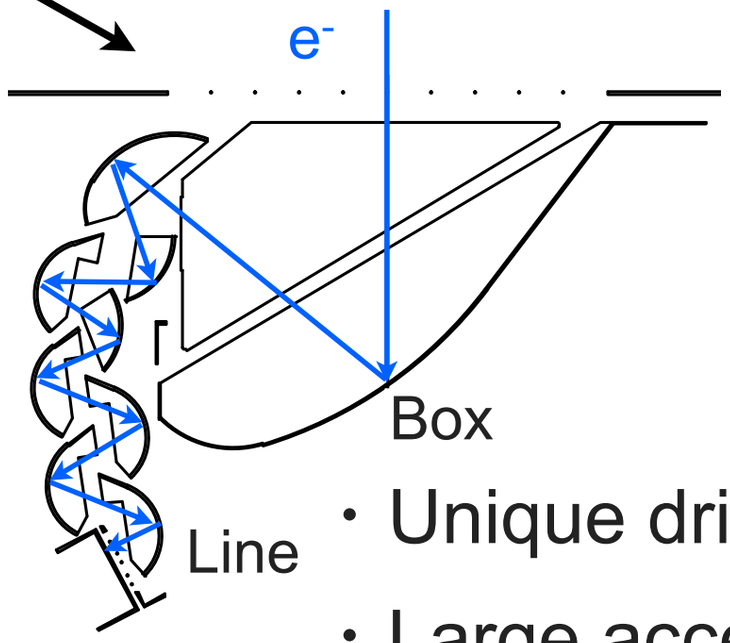


Super-K PMT (Venetian Blind dynode)



- Various drift path
- Might miss dynode

Box&line PMT (Box&line dynode)



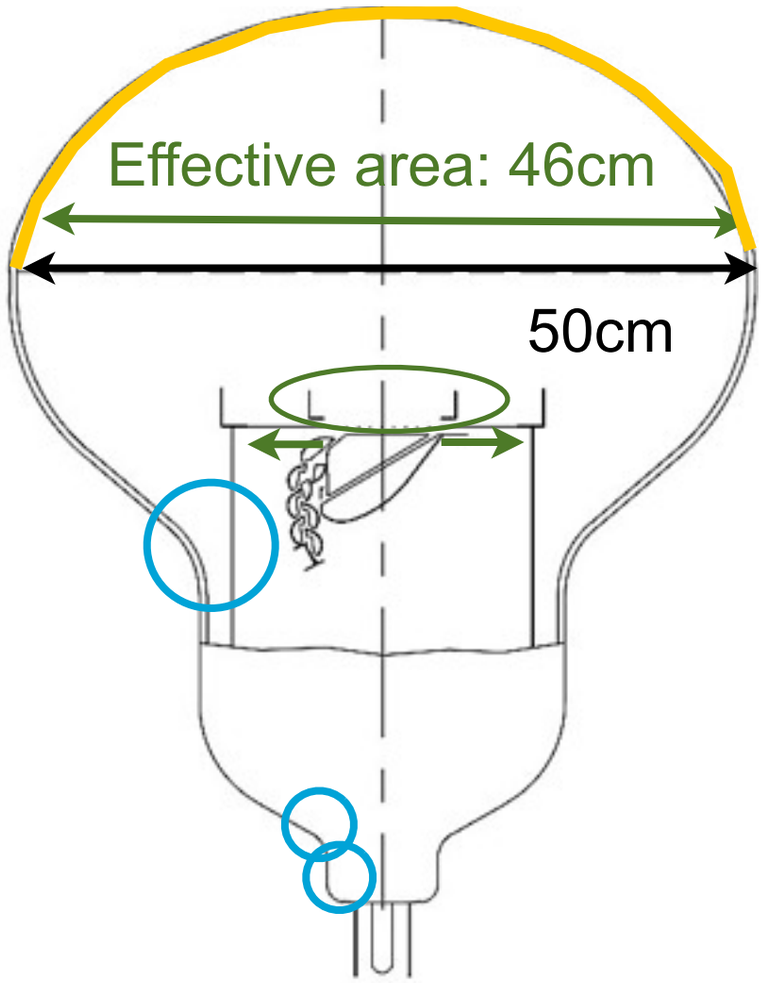
- Unique drift path
- Large acceptance

Advantage of B&L PMT

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

50cm B&L PMT prototype

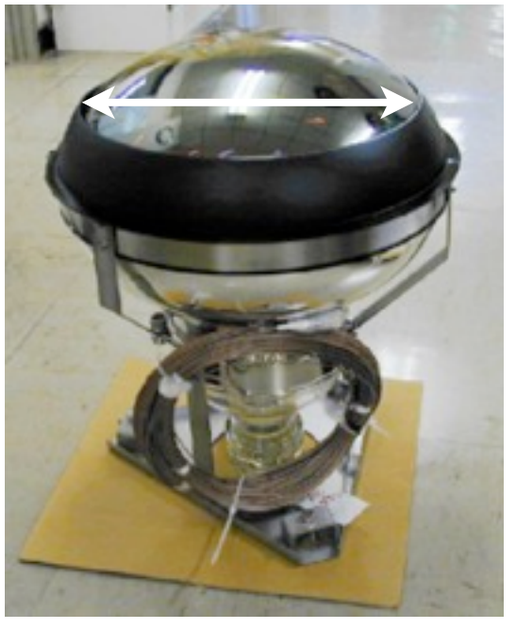
This prototype for HK is an improved version of 50cm B&L PMT used in KamLAND



- Apply the high-QE photocathode
- Change the photocathode shape
- Add a focusing electrode
- Expand the first dynode
- Change the bulb shape

- **High-QE**
- **Large effective area**
- **High Collection efficiency**
- **Survive under 90m water level**

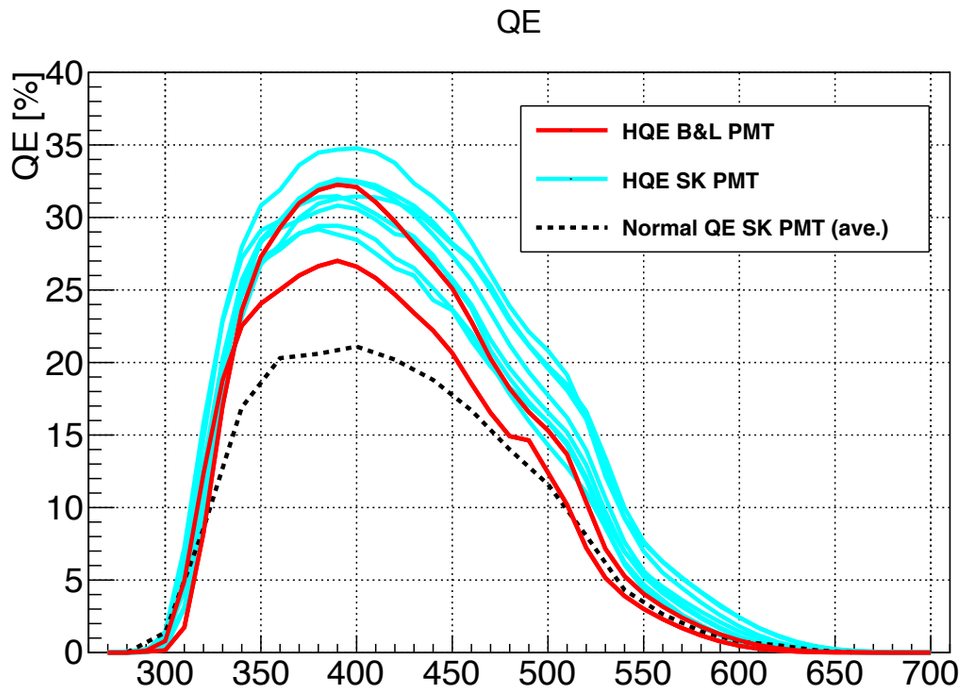
Effective area: 43cm

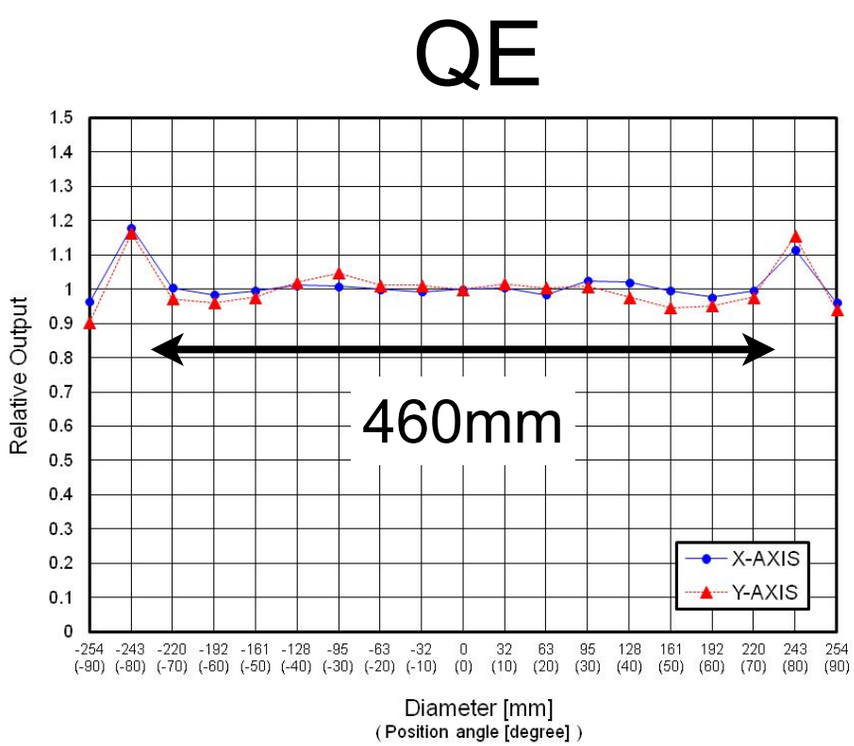


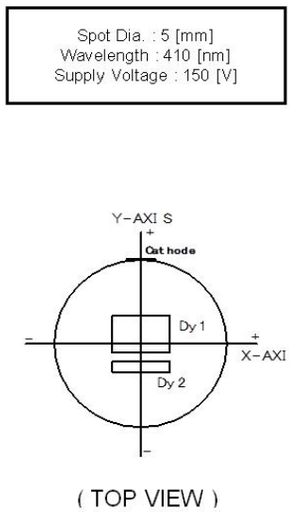
50cm KamLAND B&L PMT

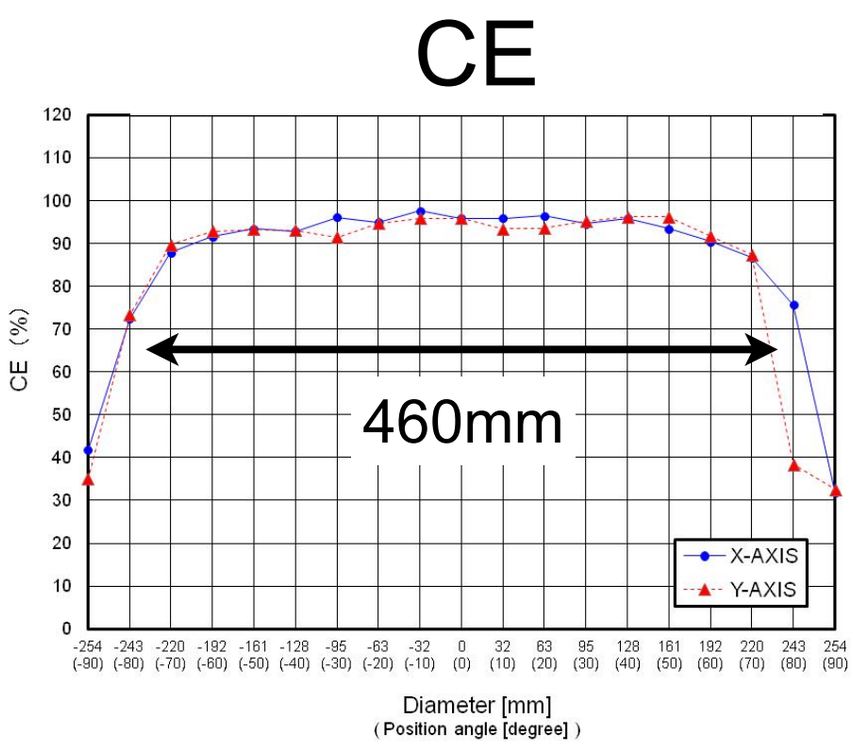
B&L PMT~QE, CE~

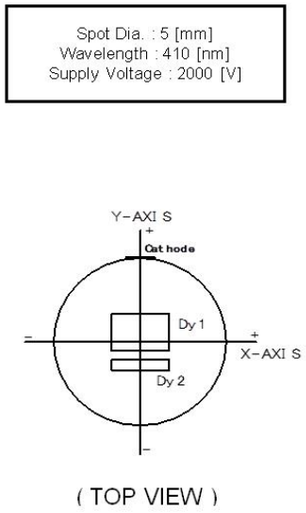
- High-QE photocathode
  - B&L PMT: 32% at 400nm (SK PMT: 22%)
- QE and CE are uniform over 46cm area of the photocathode



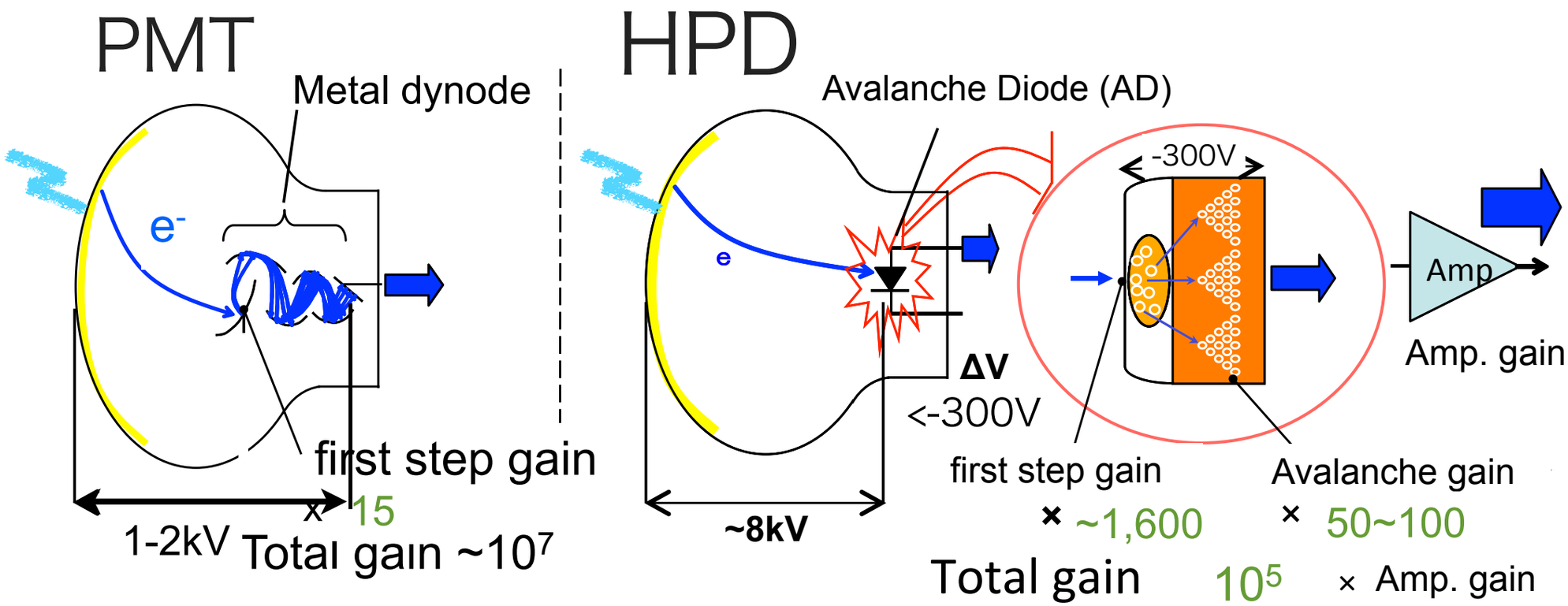








Hybrid Photo-Detector



HPD

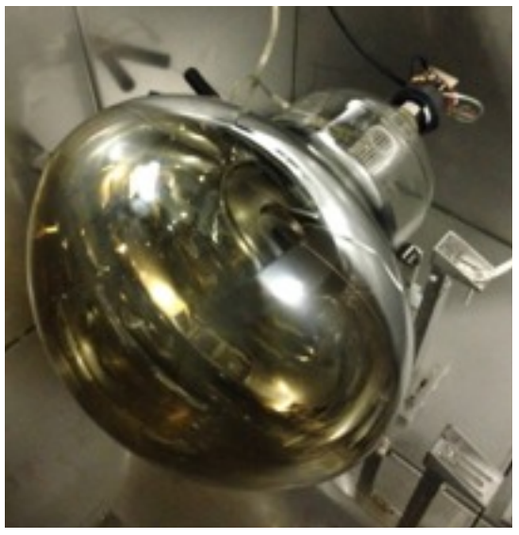
Advantage

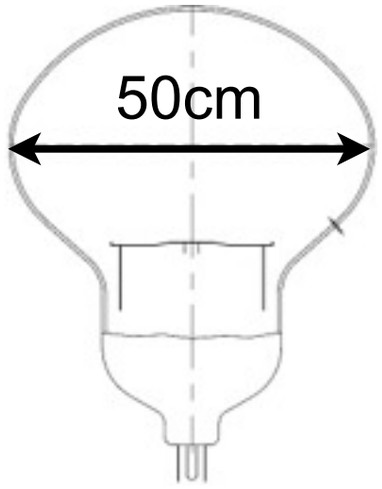
- Simple structure → Low cost production possibility
- Short drift length → Fast timing response
- High first step gain → High single photoelectron resolution

Challenge

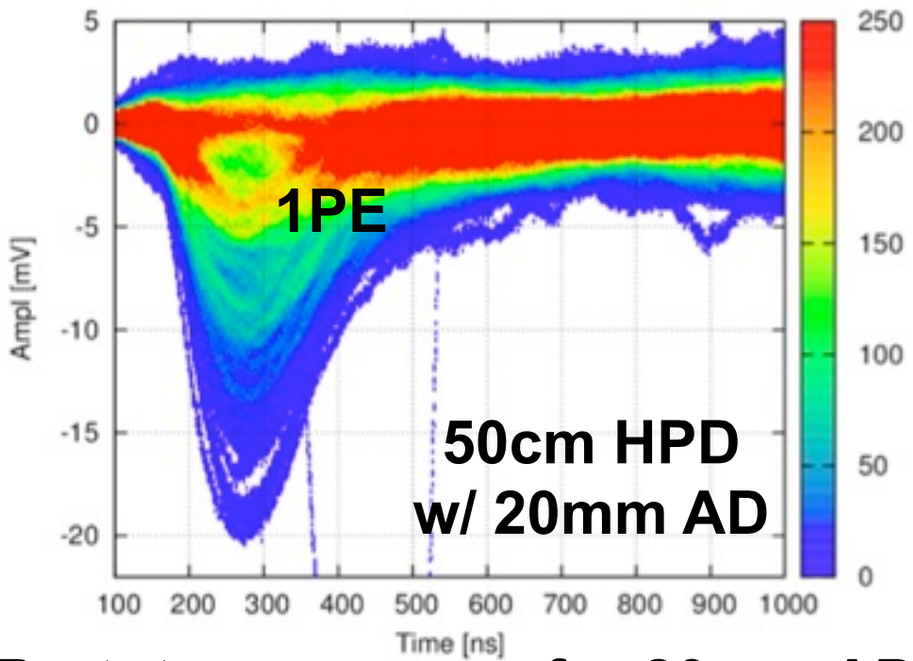
- Difficulty in handling 8kV
- No experience to use in a water Cherenkov detector

50cm HPD prototype





50cm high-QE HPD w/ 5mm AD

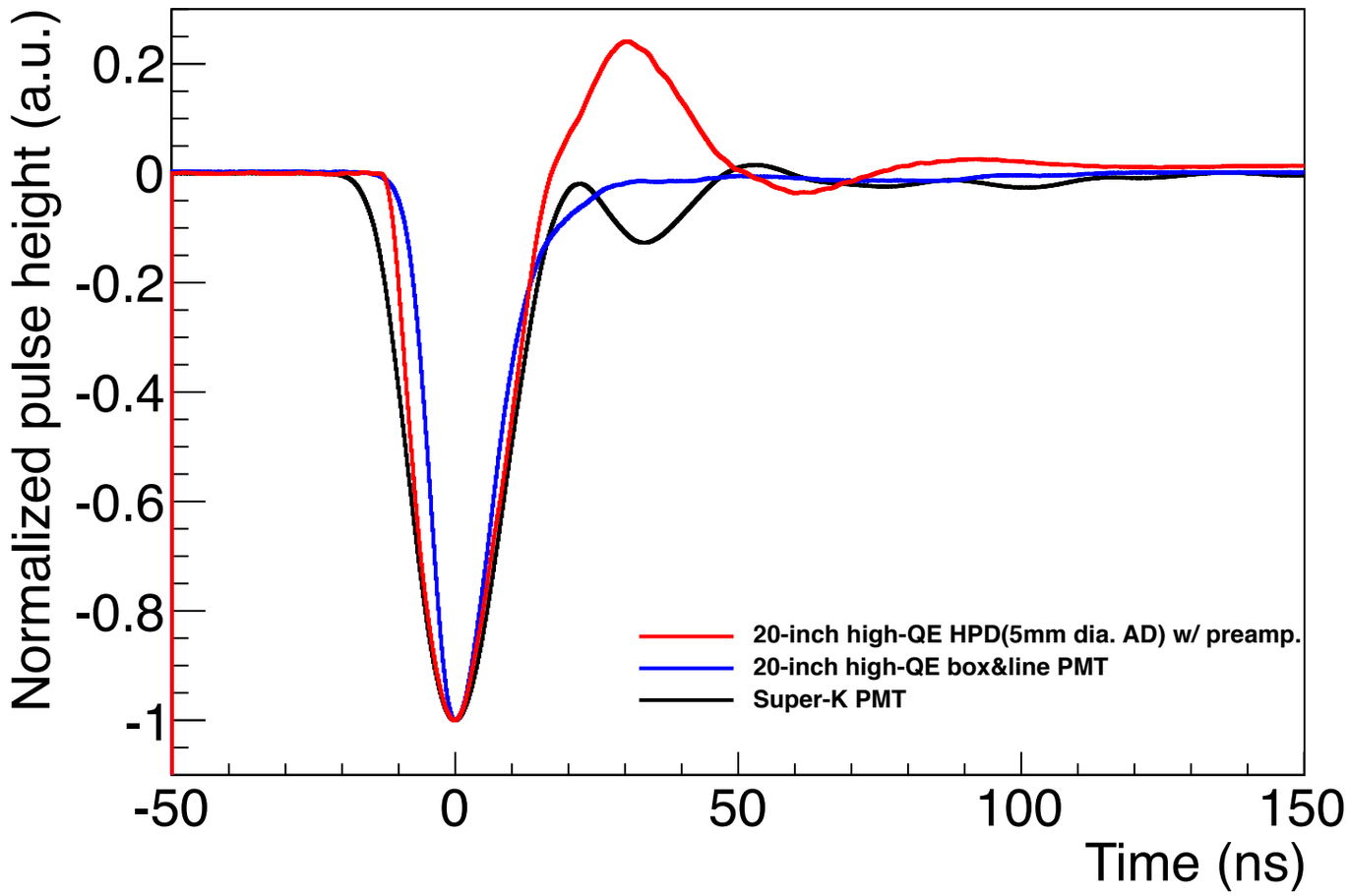


Prototype preamp. for 20mm AD

- To keep high-CE (~95%), the size of AD should be 20mm diameter
- Since 20mm AD has a large capacitance, we have been developing a low noise preamplifier
  - We have 2 types of preamp. and can see 1PE peak in both type
    - But not enough S/N and response speed
- For this test, we measured the prototype of HPD with 5mm AD (same AD size as 20cm HPD)

Waveforms

- HPD and B&L PMT are faster than SK PMT



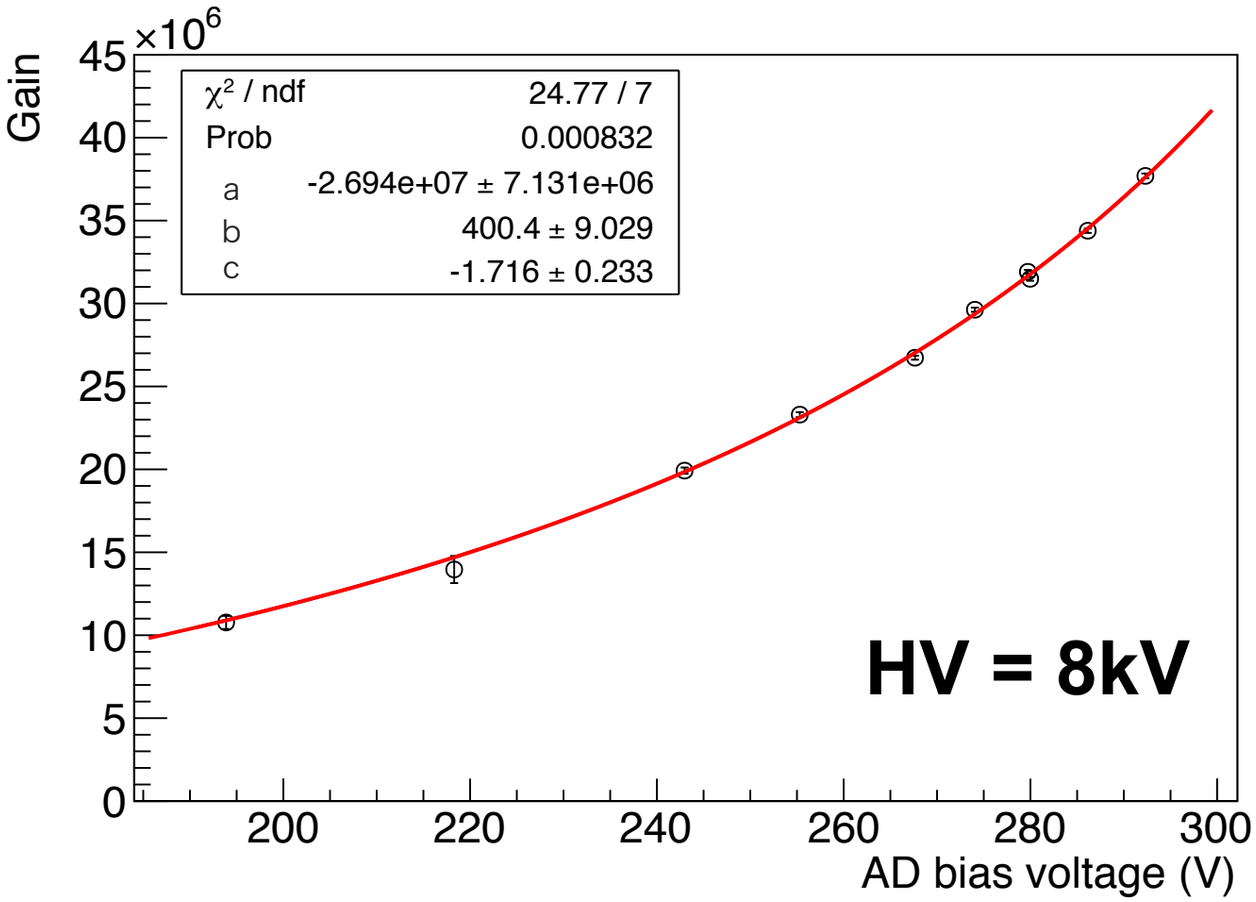
8” HPD w/o preamp.

HPD itself has very fast response.

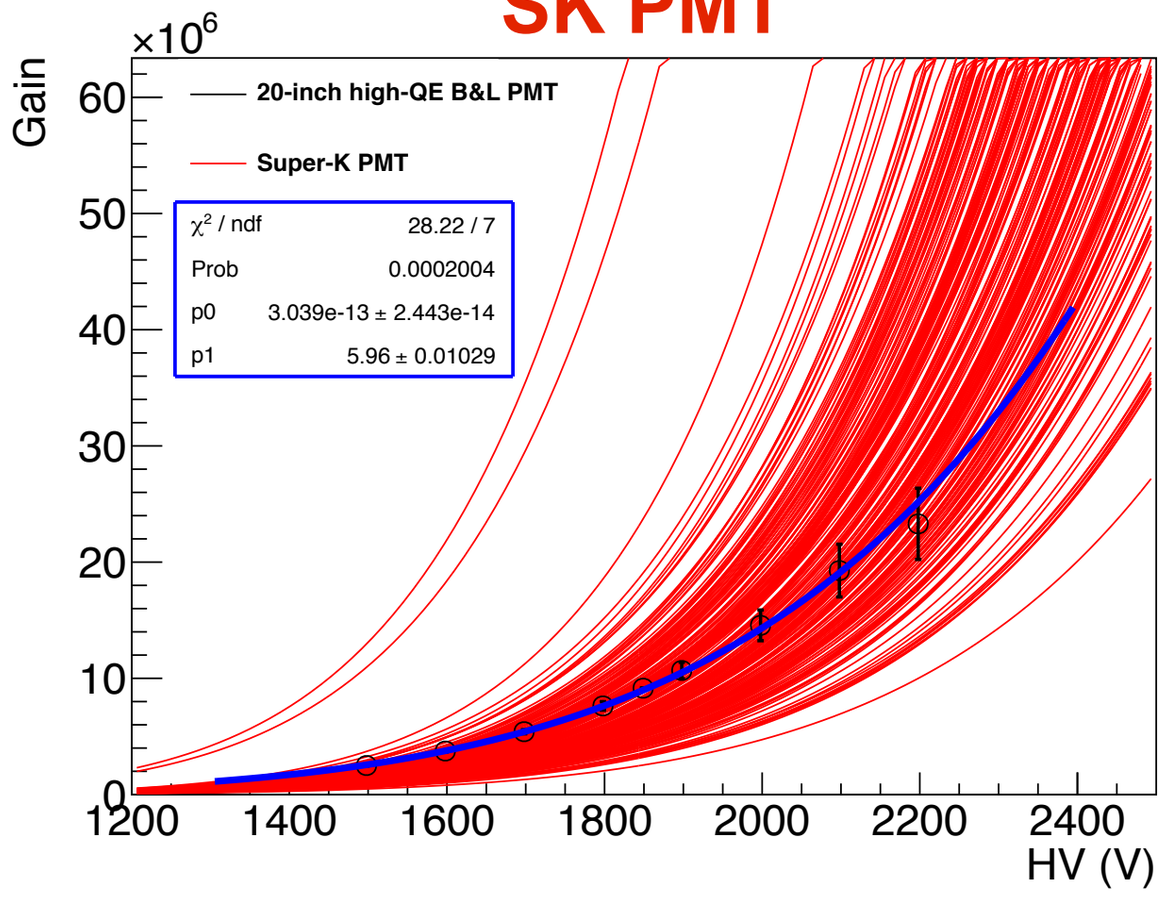
	HPD (20cm HPD w/o amp.)	B&L PMT	SK PMT
Rise time (ns)	7.4 (1.7)	6.7	10.6
Fall time (ns)	11.5 (2.7)	15.2	13.1
Pulse width in FWHM (ns)	17.1	13.0	18.5

Gain curve

50cm high-QE HPD w/ preamp.



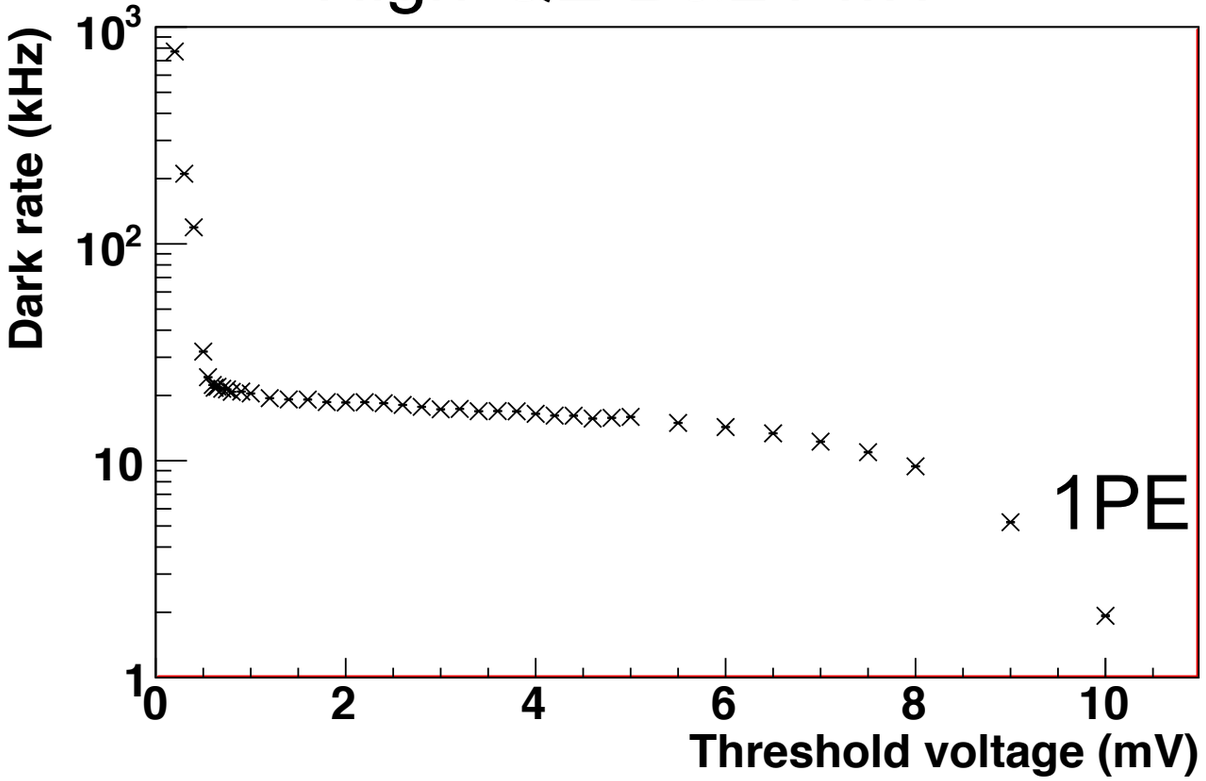
50cm high-QE B&L PMT
SK PMT



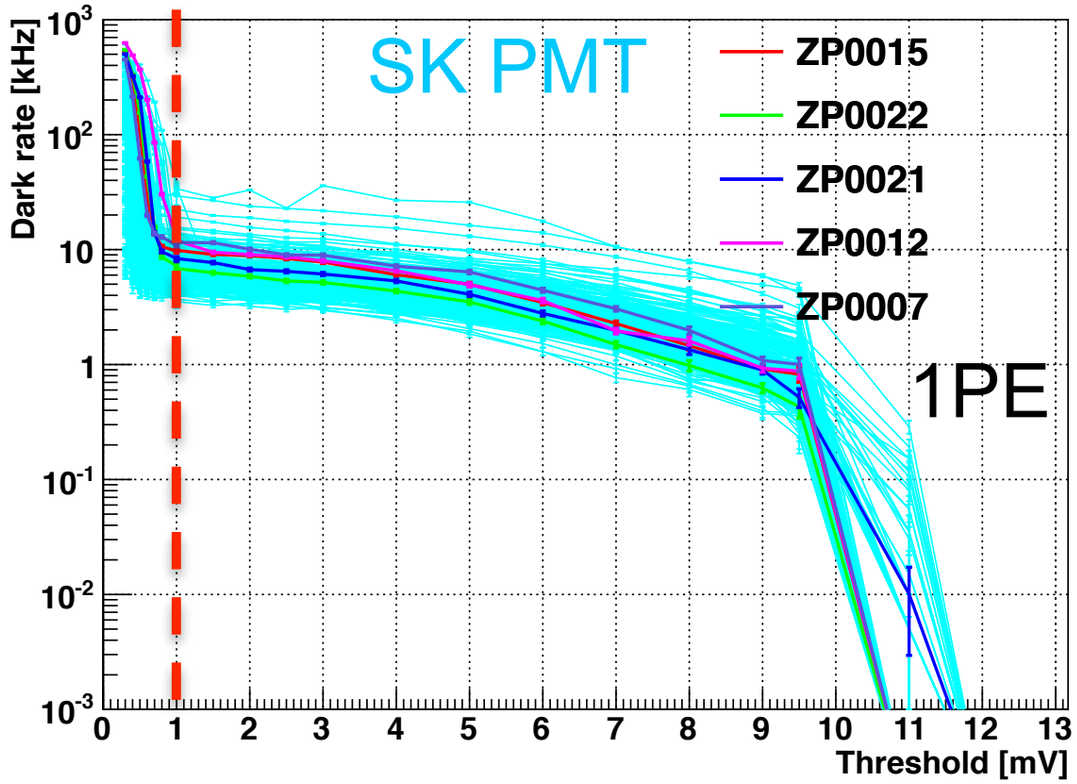
- The shape of gain curve of B&L PMT is almost same as that of SK PMT
- Both HPD and B&L PMT has the gain of 10^7

Dark rate

High-QE B&L PMT



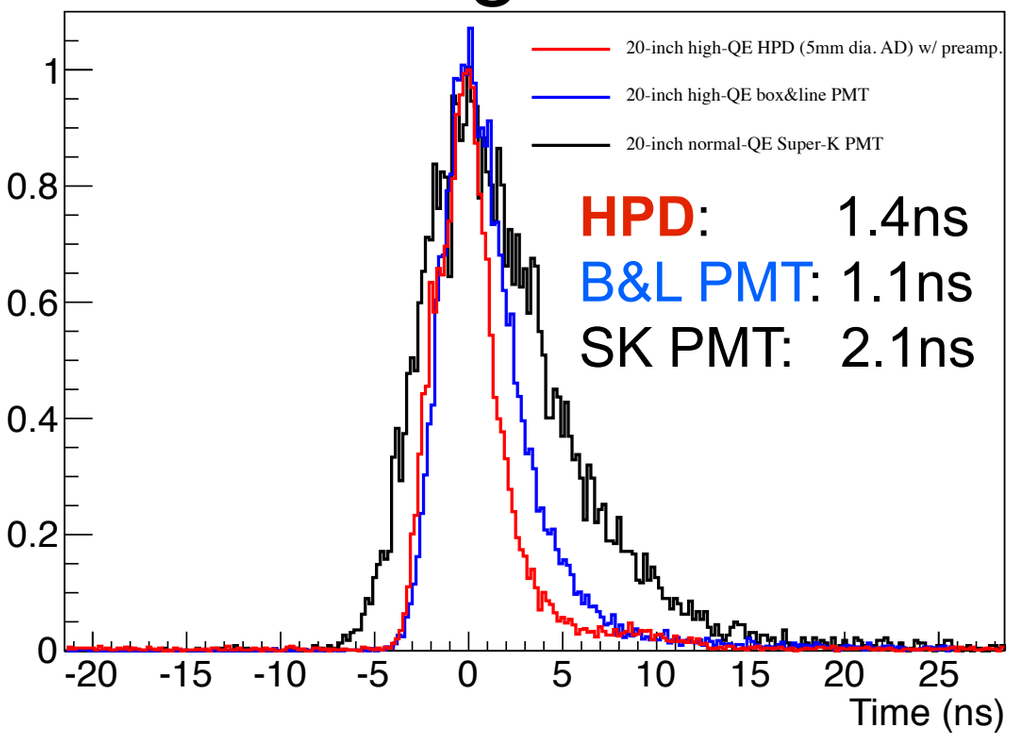
High-QE SK PMT



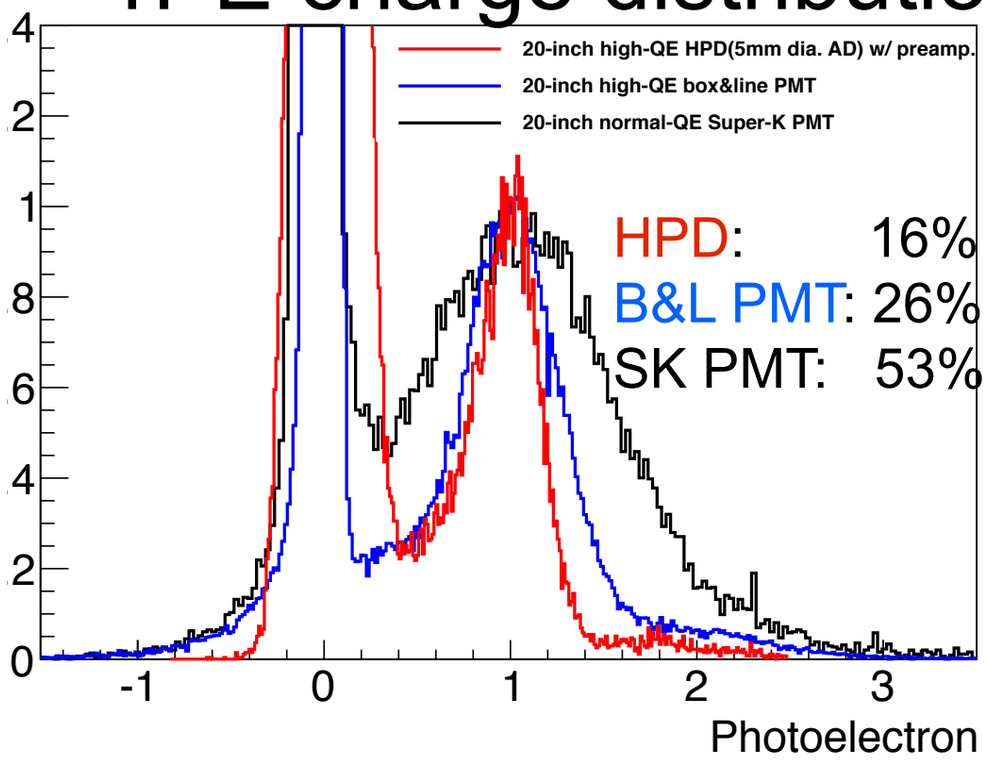
- Dark rate of high-QE B&L PMT is same level as that of high-QE SK PMT

Timing & Charge

1PE timing distribution



1PE charge distribution



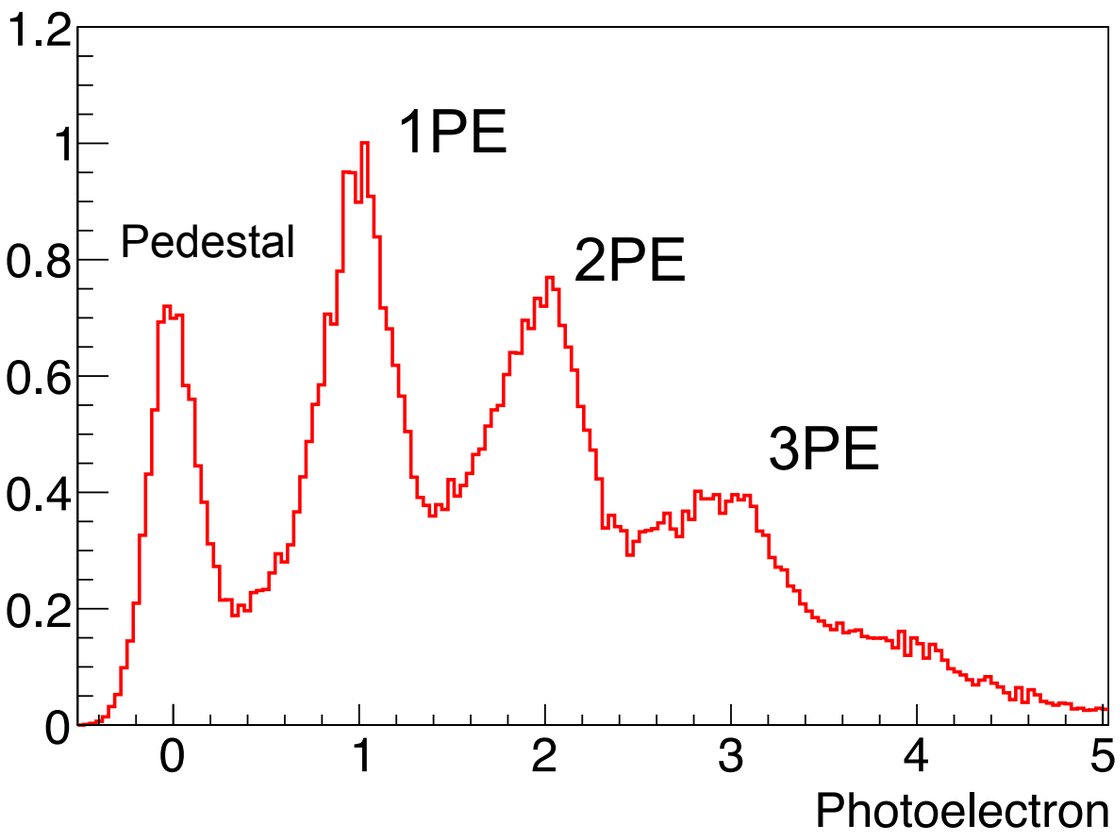
	HPD (20cm HPD)	B&L PMT	SK PMT
Timing resolution σ (ns)	1.4 (1.1)	1.1	2.1
FWHM (ns)	3.4 (3.3)	4.1	7.3
1PE resolution σ/μ	16% (12%)	26%	53%
Peak to Valley ratio	4.0 (5.2)	4.5	2.2

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

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

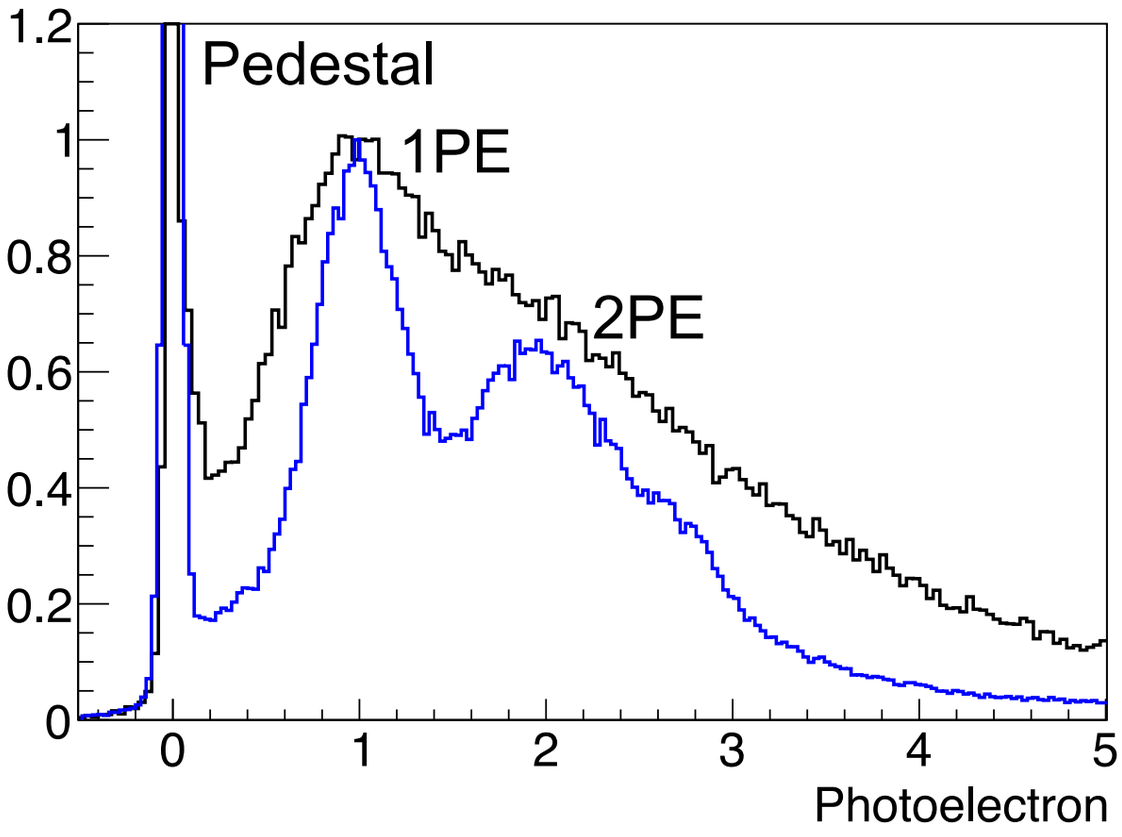
Multi-PE distribution

50cm high-QE HPD



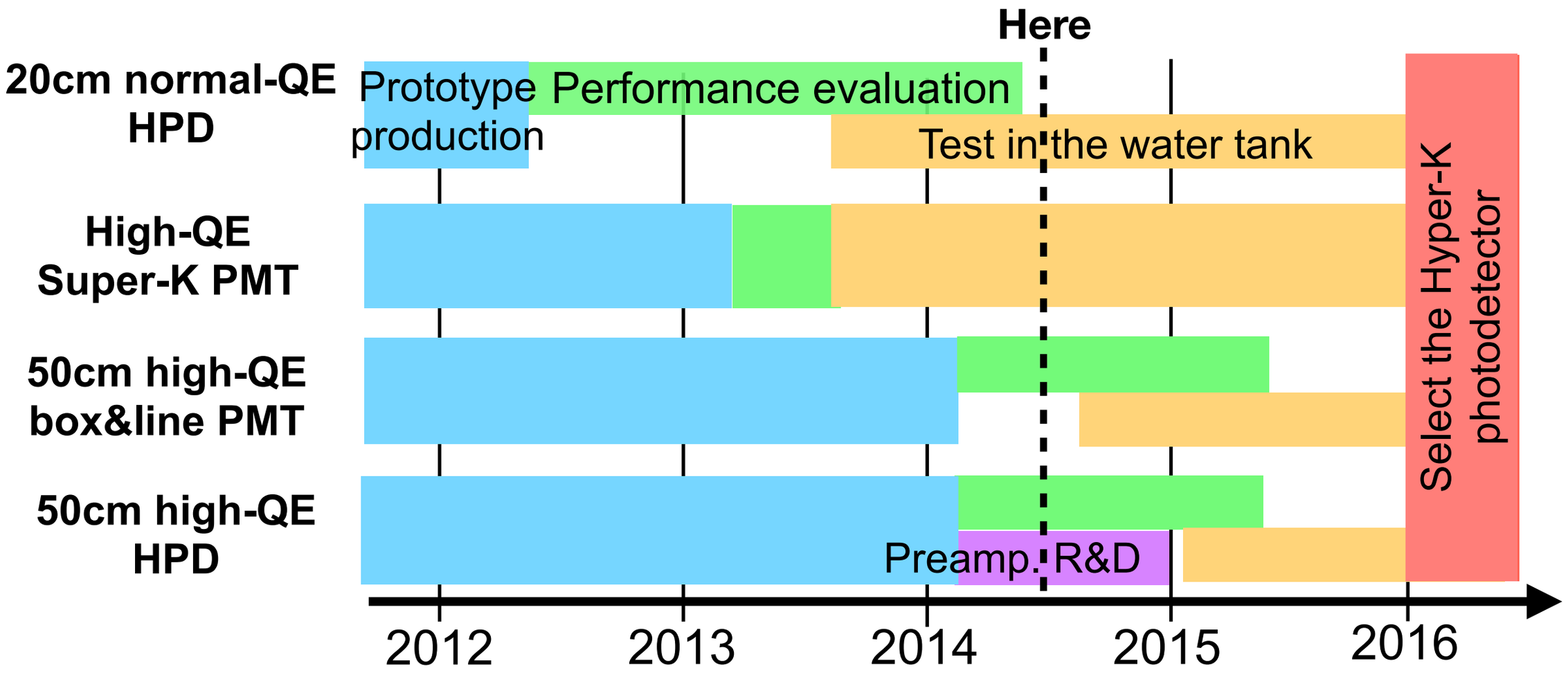
50cm high-QE Box&line PMT

High-QE SK PMT



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

Plan



- B&L PMT prototype is near final version
  - In this August, we install 3 high-QE B&L PMTs into the tank.
    We will start the test of these PMTs in the tank from this September
- Development of the preamplifier for 50cm HPDs
  will finish until this year

Summary

- **We have been developing new 50cm PDs for Hyper-K**
- **Basic performance of 50cm high-QE HPD and box&line PMT prototype was measured**
  - Confirmed better performance than Super-K PMT
  - Details (noise, efficiency, etc) will be also measured soon
- **Development of preamplifier for 20mm AD HPD is ongoing**
- **We will select the best photodetector in 2016**