Overview of the Photodetector Development

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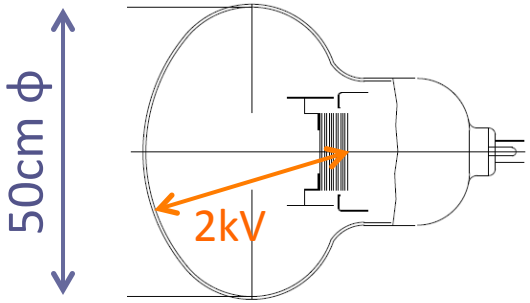
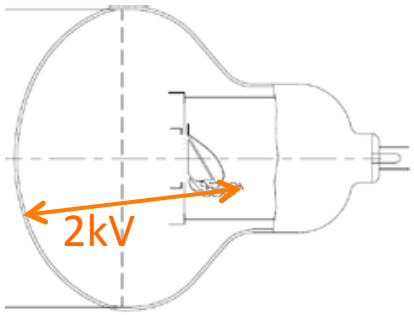
for the Hyper-K Photodetector (HK-PD) WG

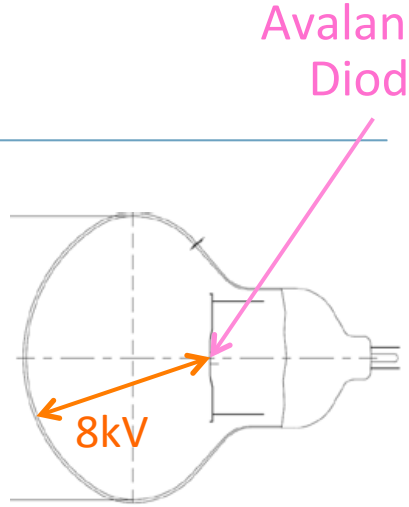
July 21, 2014

@ The 5th open Hyper-K meeting

Photodetector candidates (for ID)







Hamamatsu R3600 PMT (Venetian-Blind dynode)	50cmϕ Improved PMT (Box&Line dynode)	50cmϕ HPD (Hybrid Photodetector)
• Super-K PMT • Used for ~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

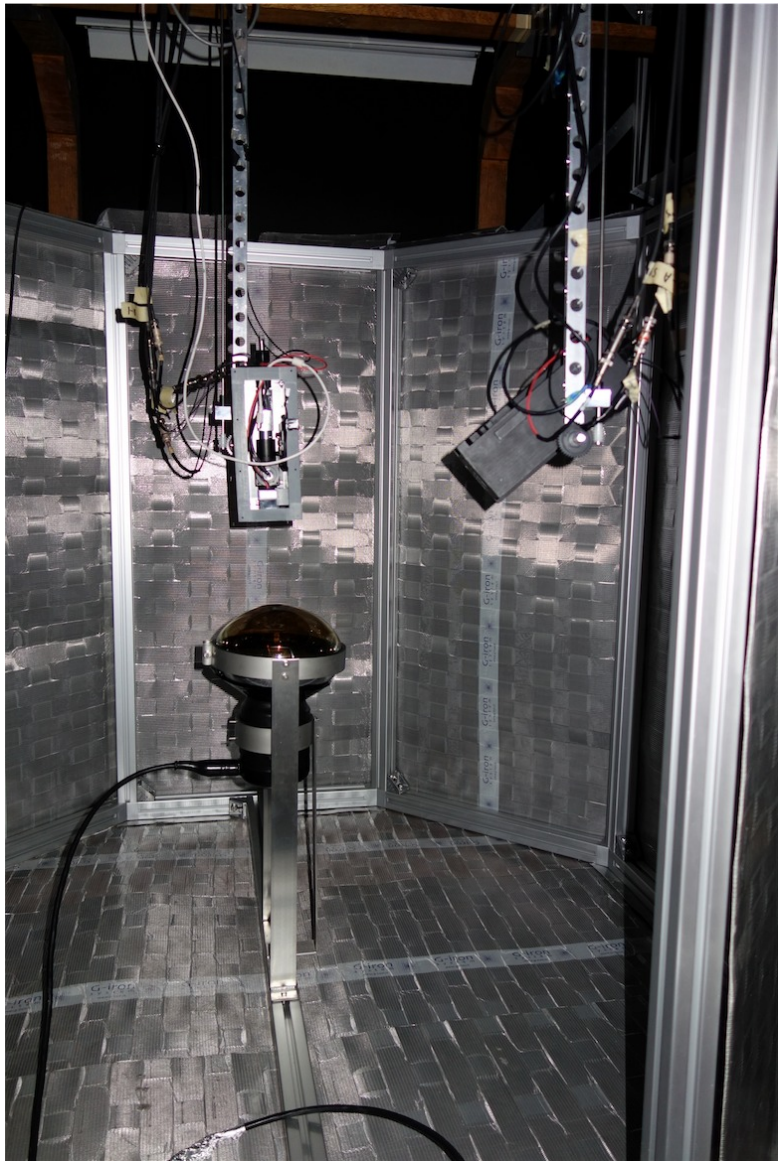
Lower Risk ← → Better Performance

R&D activities in Japan

- 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
- The first prototype of magnetic shielding cage is under production

Photodetector testing in Canada

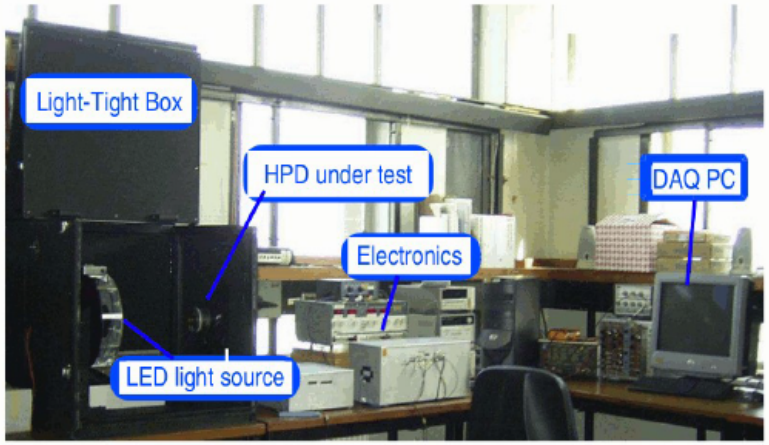
- Testing of the 20cmϕ HPD prototype has just started at Photosensor Testing Facility (PTF) in TRIUMF
- Tom will present the status and plan in the calibration WG session



Contributions from the UK

In contact with Hamamatsu UK. Ordered

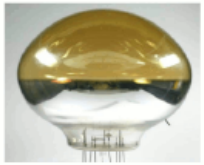
HPD Testing in Scotland:



Test station at Edinburgh, showing dark box and electronics

Recent photo

Photo-sensor HPD R12112 (A-type): General Specification



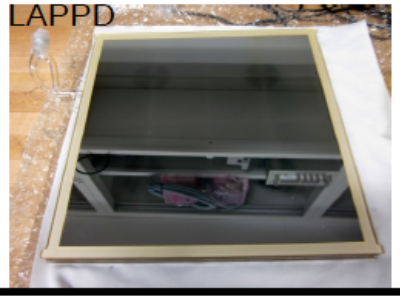
Parameter		Description/Value	Unit
Spectral Response		300 ~ 650	nm
Typical Maximum Photocathode Sensitivity (Quantum Efficiency)@380nm		20	%
Photocathode Material		Bialkali	-
Minimum Effective Photocathode Area		180	mm dia.
Window Material		Borosilicate glass	-
Electron Multiplication Method		Semiconductor Electron Bombardment Multiplying System	-
Target Semiconductor		5mmφ Backside Illumination Avalanche Diode	-
Absolute Maximum Ratings	Photocathode – Target Semiconductor	10	kV
	Target Bias Voltage	350	V

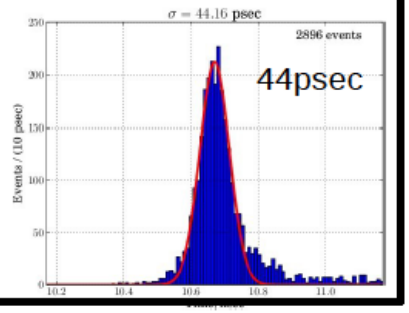
Planning to do quality checks, make tests in magnetic field and work on new preamp.

Experience in LHCb by Edinburgh:

- Responsible for HPD testing during construction and now operations
- Testing performance of multianode photomultipliers MaPMTs for LHCb upgrade

- Investigating the option of using the LAPPDs (Large Area Picosecond Photo-Detectors) at QMUL both sw and hw when available. Relevant for ND.





U.S. PMT Update

280 mm (11″) photomultiplier
D784KFLB provisional data sheet

	unit	min	typ	max
photocathode: bialkali				
active diameter	mm		270	
active surface area	cm^2		800	
quantum efficiency at peak	%		30	
luminous sensitivity	µA/lm		70	
with CB filter		8	12	
with CR filter			1	
dynodes: 12LFSbCs				
anode sensitivity in divider A:				
nominal anode sensitivity	A/lm		500	
max. rated anode sensitivity	A/lm		2000	
overall V for nominal A/lm	V		1400	1800
overall V for max. rated A/lm	V		1550	
gain at nominal A/lm	$x\ 10^6$		7	
dark current at 20 °C:				
dc at nominal A/lm	nA		20	200
dc at max. rated A/lm	nA		80	
dark count rate	s^{-1}		20000	
pulsed linearity (-5% deviation):				
divider A	mA		30	
divider B	mA		100	
pulse height resolution:				
single electron peak to valley	ratio		2	
rate effect (I_a for $\Delta g/g=1\%$):	µA		20	
temperature coefficient:	% $°C^{-1}$		± 0.5	
timing:				
single electron rise time	ns		5	
single electron fwhm	ns		6	
single electron jitter (fwhm)	ns		3	
transit time	ns		62	
weight:	g		2600	
maximum ratings:				
anode current	µA			100
cathode current	nA			2000
gain	$x\ 10^6$			30
sensitivity	A/lm			2000
temperature	°C	-30		60
V (k-a)[1]	V			2350
V (k-d1)	V			750
V (d-d)[2]	V			300
ambient pressure (absolute)	kPa			808

- Davis is expecting 20 11" prototype PMT's from ADIT/ ETEL, in Sweetwater Texas
- A first shipment of 11" HQE PMTs prototype was expected in May, but there was a delay. The shipment is now expected in September.
- ETEL/ADIT have all the internal parts and glass bulbs to construct the PMT's
- Properties will be tested at Davis and Penn and the results will be presented at the next Hyper-K open meeting
- May provide a cost-effective alternative to Hamamatsu for the veto PMT. Also for use in WATCHMAN.

Photodetector session

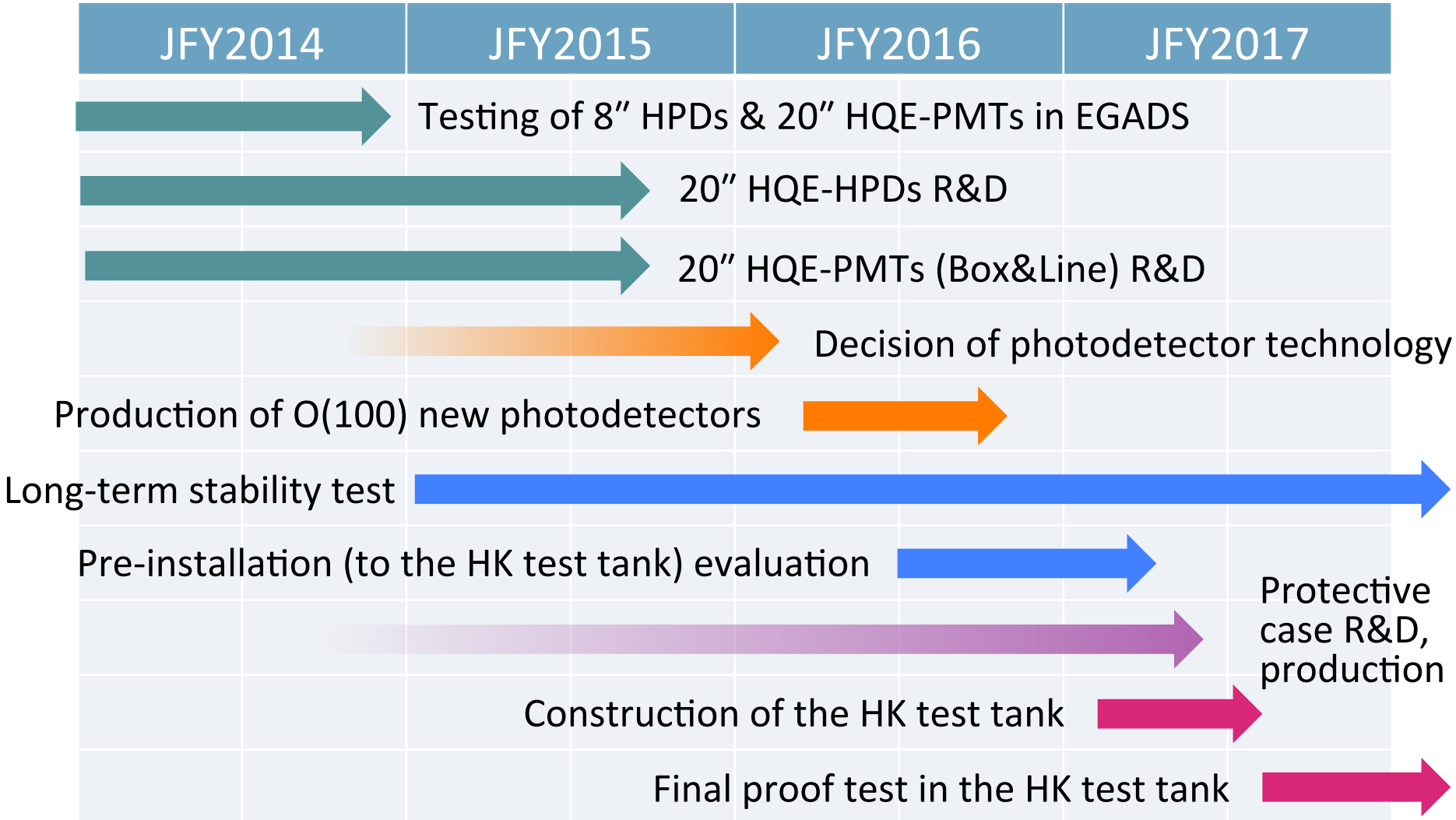
- Conveners: Dr. Nakayama, Shoei (Kamioka Observatory, ICRR, University of Tokyo); Dr. NISHIMURA, Yasuhiro (ICRR)

time	title	presenter
12:40	Overview of the photodetector development (00h10')	Dr. NAKAYAMA, Shoei (Kamioka Observatory, ICRR, University of Tokyo)
12:50	Viability test of photodetectors in the water tank (00h20')	Mr. OKAJIMA, Yuji (Tokyo Institute of Technology)
13:10	New 50-cm diameter photodetectors (00h20')	Mr. SUDA, Yusuke (University of Tokyo)
13:30	A status and prospect of the photodetector development in Kamioka (00h20')	Dr. NISHIMURA, Yasuhiro (ICRR)

Enjoy!

Supplement

Schedule (mid/long-term)



Protective cases and support structure

- A large photo-sensors in Hyper-K must be housed in protective cases to avoid a chain implosion
  - At least, inner detector photo-sensors
- It is likely enough that we need passive magnetic shielding instead of active magnetic compensation using coils
  - mu-metal case (like Double Chooz, etc.)
  - mu-metal cage (like Kamiokande, etc.)
- We are starting R&D for cases and support structures

Simulation study

- Hyper-K software WG has developed the detector simulation program (WCSim)
  - It is almost ready for detector optimization study and physics sensitivity study

- We should start detector simulation studies to investigate requirements for each photodetector option
  - From a viewpoint of physics sensitivities
  - In collaboration with the HK software WG
    - CE/QE, timing resolution, S/N, acceptance, dark rate, …
    - Size, number of sensors, …
    - Light collection idea

Documentation

- We will make a HK-internal document first.
  - Describing results from past/present studies
    - As for studies not specifically for Hyper-K, we need description on possible applications to Hyper-K in addition to references to relevant papers/documents.
  - The global R&D plan and to-do items
  - Expected to be updated accordingly as new results come
- Later, we will produce a public document.
  - By removing confidential information