Photodetector R&D progress and plan

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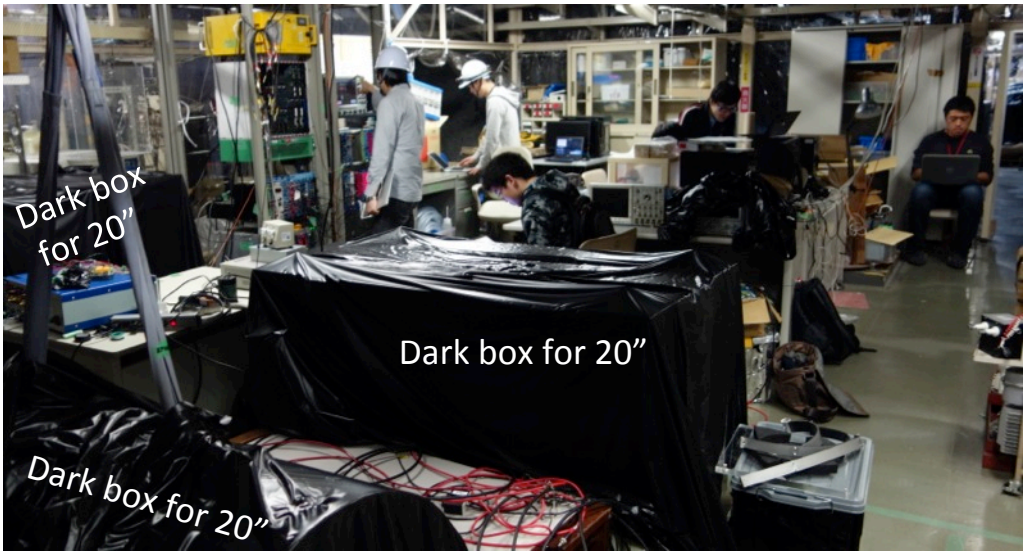
6th Hyper-K Open Meeting

30/Jan/2015

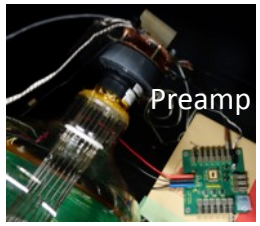
Current activities

Evaluation t Kamioka



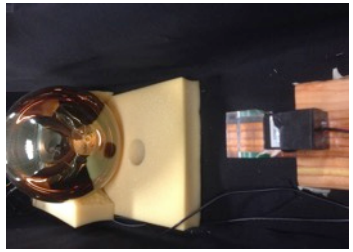
50cm photosensor (HAMAMATSU)

HPD electronics (KEK, ERI, U.Ttokyo, …)

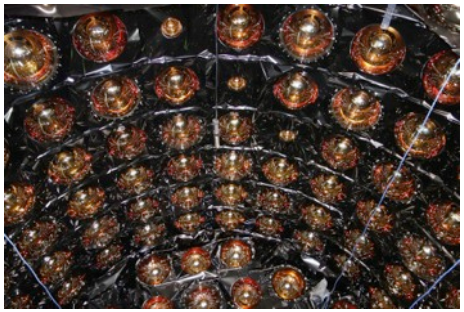


New 8” HPD study (UK, ..)

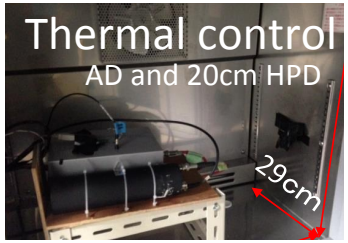
28cm PMT (ETEL/ADIT, US)

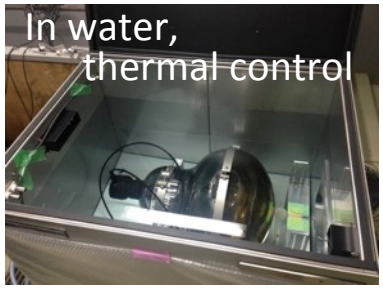


Proof test (Kamioka)



8” HPD thermal effect (Kyoto-U)





Stability (Kashiwa ICRR)

Photosensor test facility (TRIUMF)

- There are many activities, but still not sufficient to cover all necessary developments.

Overview of R&D items

Cooperative work with other groups

Electronics	Software	HK prototype	Calibration, cavity, physics
• HV, cable, connector • DAQ optimization	• Implementation • Performance	• Over all test w/ elec, etc. • Mass test (~200)	• Calibration test • Sensitivity study
Thomas, HK.Taketa, Nishimura	Okajima (WCSim), Yano(Lowe), ?(ATMPD)	Yano, Nakayama	HK.Tanaka, Tom

Activity from photosensor group

HK photosensor sub WG (49 members)

Conveners: S.Nakayama, Y.Nishimura, and more

Progress status
- ○ Ongoing
- △ Started
- × Need more activity or help

Urgent

R&D items

Case and supporter	Proof and safety test	Photosensor development	Photosensor for OD
• Protective case • + Supporter to tank • RI BG study for lowE • Elution in pure/Gd water • Magnetic shield	• Test in 200t tank • High pressure test • Preparation for HK prototype test • Quality control • Implosion test	• HPD, B&L PMT, HQE • Performance evaluation • Electronics R&D (preamp, HV, …) • Summary for selection	• 20cm photosensor • Light collection • Reflector • Layout in OD layer • Electronics (HV, DAQ)

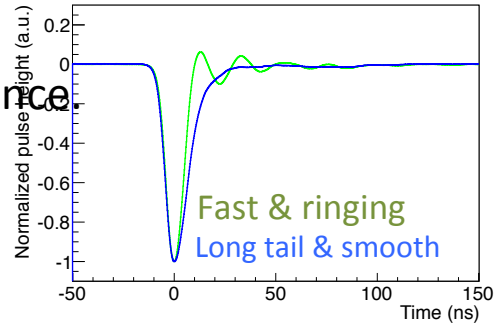
Many members are working, but still more activities and promotion are desired.

R&D for HQE Box&Line PMT

Possible several options according to our special requirement

These are not aimed now, but possible options depending on our demand in HK.

- **Fast signal** or smooth signal with less ringing
  - Both was evaluated and there is no large difference in performance.
  - Adopted latter with less ringing in proof test
  - Fast signal is possible to obtain a little better resolution, pulse discrimination.



- Another glass shape for high pressure tolerance
  - Stress analysis implies better pressure resistance for HPD.
  - **HPD bulb shape** can be applied on Box&Line PMT, but time performance becomes worse (maybe down comparable to SK PMT)
  - If more safe design or deeper tank is desired, more pressure resistant with optimizing bulb would be possible by sacrifice of performance

- **Built-in high voltage power supply** for Box&Line PMT (Not baseline now)
  - To expect possibility of cost down and reliability of long life
  - Prototype board showed 1 p.e. peak. Its design can be replaced with bleeder circuit.
- Normal QE (Same as Super-K PMT, if lower dark rate is desired)
- After pulse reduction (next page)

After pulse reduction in Box&Line PMT

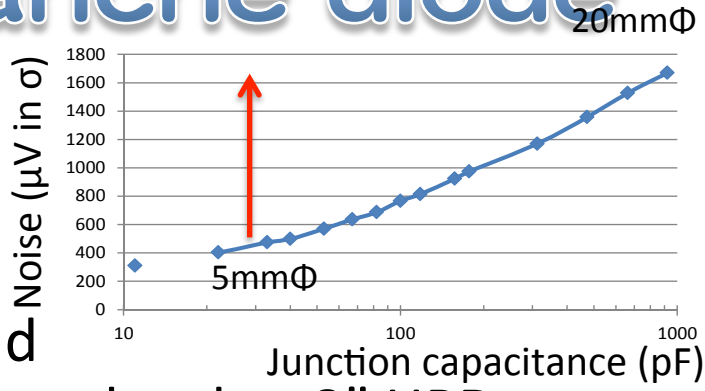
- Much after pulse rate is one of concern on Box&Line PMT.
  - We don't know how it will be matter. Its effect on analysis should be evaluated.

Recent improvement at Hamamatsu

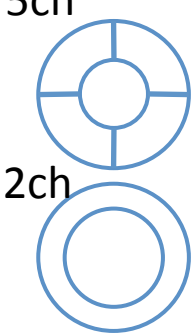
- Feedback from dynodes to photocathode is one of sources as indicated in simulation.
- Two ideas to reduce after pulse were tested.
  - Optimizing dynode shape to prevent feedback of after pulse source.
    - With keeping performance. Confirmed with several prototypes.
  - Adjusting voltage divider ratio to minimize the source generation.
    - Will worse the time performance and gain a little. Its effect was measured.
- Suppression around half factor was achieved so far.
- We will evaluate new version of Box&Line PMT with after pulse reduced from March 2015.
- After pulse profile of current one was measured in both rate and charge probabilities. (Reduced after pulse will be measured, too.)

  → Investigate effect on physics sensitivity by MC and set a minimum requirement.

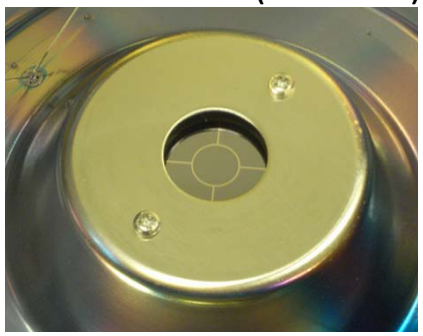
50cm HPD and avalanche diode



- Full efficiency will be achieved by 20mm diameter, but it accompanies increase of junction capacitance and noise.
- Half capacitance AD will be available around next summer, but not sufficient to reach same level as 8" HPD.
- Options for proof test :
  - 5ch or 2ch segmented AD with sum amp
  - 15mm AD realizes 87% CE
    (lower than 95% for 20mmΦ AD,
    but higher than 70% CE of SK PMT)
  - Still trying to minimize focusing area at HPD to reduce AD diameter, but seems difficult.
  - Preamplifier for 20mmΦ is also under development.



5ch Avalanche Diode (20mmΦ)



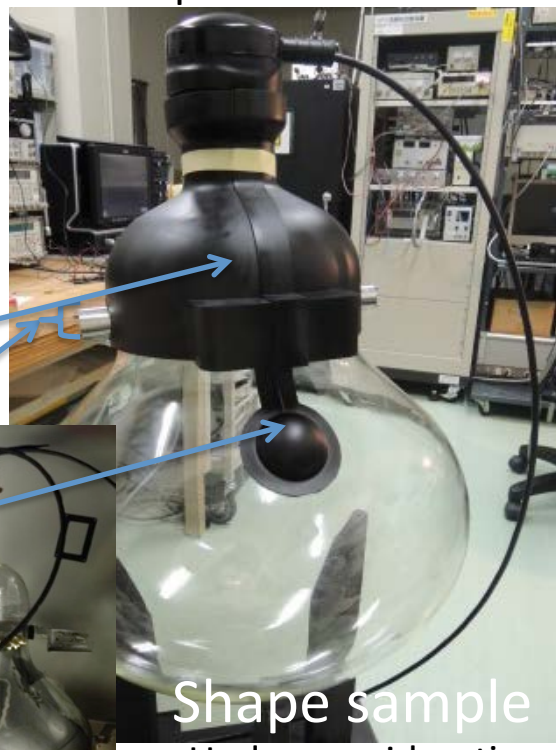
- We will start evaluation of 5ch or 2ch HPD from March 2015. Those with half junction capacitance applied will be ready later and be candidate for proof test.

HPD waterproof design

(For proof test)

- Two difficulties, but will be fixed:
  - Built-in HV makes total length enlarge compared with PMT. 2cm shorter design is necessary for proof test.
  - Tungsten GND pin is penetrating bulb glass to take ground from HPD inside to electronics, while it should be covered from water.
    - Difficult to treat band with avoiding GND shield
- One of initial idea for waterproof HPD
  - GND shield cover
  - Band and spacer for HPD supporter
  - Waterproof GND sealing
  - Length should be shorter for proof test.
- Better design for HK considered
  - Unified with protective case, band

One of initial idea for waterproof 50cm HPD



Under consideration for proof test

HPD cable and connector

- Considering a way to supply HV from outside of HPD as another option, though it is difficult to connect 8 kV in water and different largely from 2 kV (PMT).

HV place	HV cable	Cable & Connector	HV module cost	Failure
Built-in HPD (current)	No HV cable (long LV)	△ Easy for LV, but number of lines might be large	✕ Expensive in small size for each channel	✕ Dead if HV module is broken.
In waterproof module (HK base?)	10 - 20 m	✕ Need 8kV connection in water. No connector and cable, and those will be difficult and expensive. Need R&D and cost down.	△ Cost reduction expected by multi channelize and more space	△ Redundancy is possible in multi ch. HV module
On tank (SK style)	> 70 m		△HV can be accumulated, but HV cable becomes long	◯ Can be replaced

- Asking cable complex design with 8kV line, signal and preamp power.
  - Sample of HV cable is almost ready. Will test HPD with long HV cable.
- Several options for waterproof connector is under development.
  - Design and test HV and other LV separately, and combine all together later
  - Connector requires a large diameter and long length in conventional design by waterproof and high voltage
    - Around 8 cm dia.
  - Asking design to a few manufacturer
  - Prototype and test within a year, and consider more cheap design

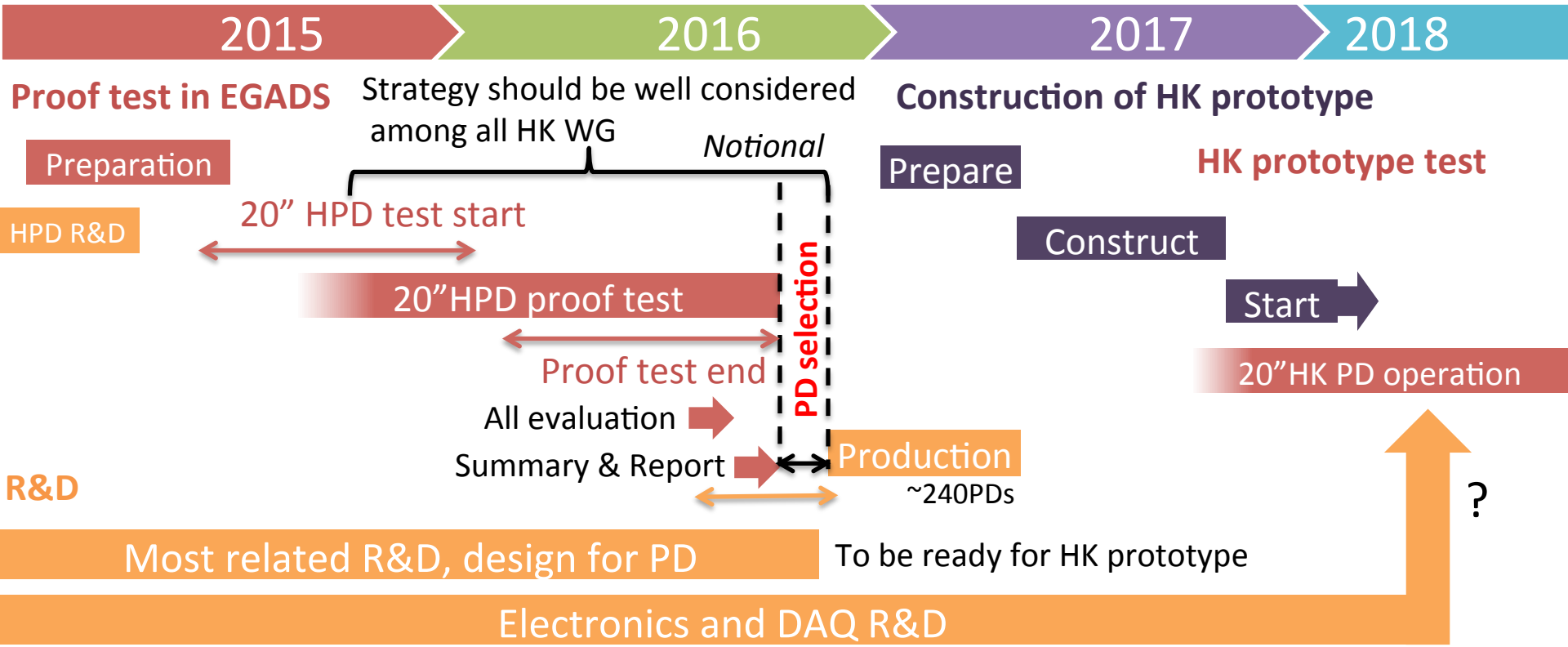
Inputs for software, and feedback

- Performance for software
  - 20cm HPD : Ready
  - Box&Line : Performance is available, need implementation
  - 50cm HPD : Assume similar one to 20cm size, measured data after half a year
  - PTF at TRIUMF will provide more precise response map and optical property.

- Need to be investigated to select best photosensor and tank option
  - High QE and CE
  - Number and coverage of photosensors
  - OD optimization

- Need a feedback to set a reasonable goal in photodetector R&D
  - Dark rate : Limited by DAQ and trigger. Restrict low energy threshold
  - After pulse : Tagging of decay electrons or neutron, BG in super nova, ..
  - RI and background : Sensitivity in low energy physics
  - Hit rate, linearity, resolution, ..

Timeline



PTF at TRIUMF

20cm HPD | In water

50cm SK PMT

PMT case in SK, Box&Line PMT, HPD, HK PD case

Start from 2 SK PMTs and 1 HQE SK PMT for 50cm PD measurement

HK prototype test aiming at demonstration of HK. R&D of new photosensor and its accessories would be promoted as much as possible.

Tour - Kashiwa photosensor test

- Visit a photodetector testing setup at ICRR, Kashiwa
  - Anybody is welcome to join.
    - Contact to Nishimura if you have questions.
  - Short tour 12:00 – 12:25 to see 1F/B1F in ICRR,
    - next building of the IPMU, 2 min. by walk
  - 50cm SK PMT, Box&Line PMT, HPD, and 20cm HPD, thermal control room, SK electronics, DAQ, etc.

- Meet at 12:00 on 31 Jan (Sat) in front of IPMU building after HK meeting at IPMU is over.
  - Or 5 min after meeting end if it is delayed.
  - Public bus for nest symposium will depart at 12:36, 12:48

Summary

- Many activities and members, but we have to proceed more R&D items.
- There is still a room to improve 50cm Box&Line PMT for after pulse reduction, etc.
- It is difficult to read signal from 50cm HPD now. Electronics and AD are under development.

- We'd like to promote R&D more, especially for electronics, OD photodetector and light collector, and safety related (case, test in high pressure).
  - ○ Evaluation on HK performance is also required in several photosensor options.
  - ○ Any help and cooperation would be appreciated.