

Hybrid Photo-Detector study at Kamioka

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Hyper-K open meeting
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Photo-Sensors for Hyper-K

- Same Photomultiplier tube (20" PMT, as used in Super-K) is assumed to obtain Hyper-K sensitivity.
 - Upgrade of photo sensor is also under consideration.
 - Requirements of photo sensor for Hyper-K
 - ▶ Large sensitive area and high detection efficiency
 - ▶ Low cost
 - ▶ Better (or comparable) performance than 20" PMT
 - ▶ Long-term stability and safety
- } → Related to num. of photo sensors

Hybrid Photo-Detector (HPD) is one of good candidates to improve Hyper-K physics sensitivities

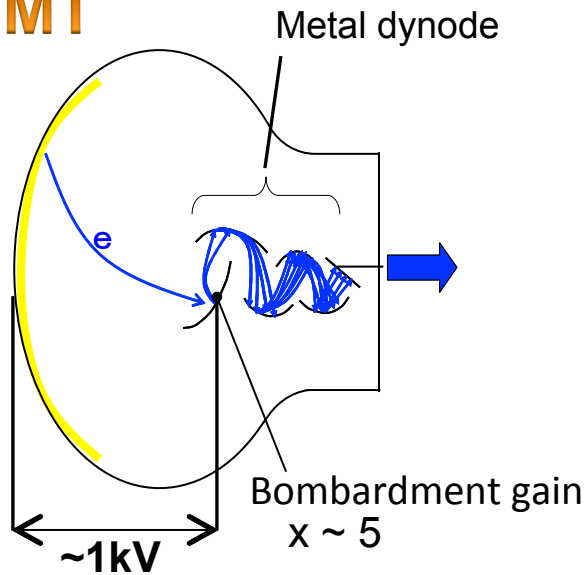
Contents

- Principle of HPD
- Design and performance of HPD
 - Started 8-inch HPD measurement in 2012
 - Look at HPD performance measured at Kamioka
- Plan to measure water Cherenkov light by HPD
 - Test with 200-ton water tank loaded with Gd
- First proof test to observe water Cherenkov light by HPD.
 - To confirm practical use of HPD for Hyper-K

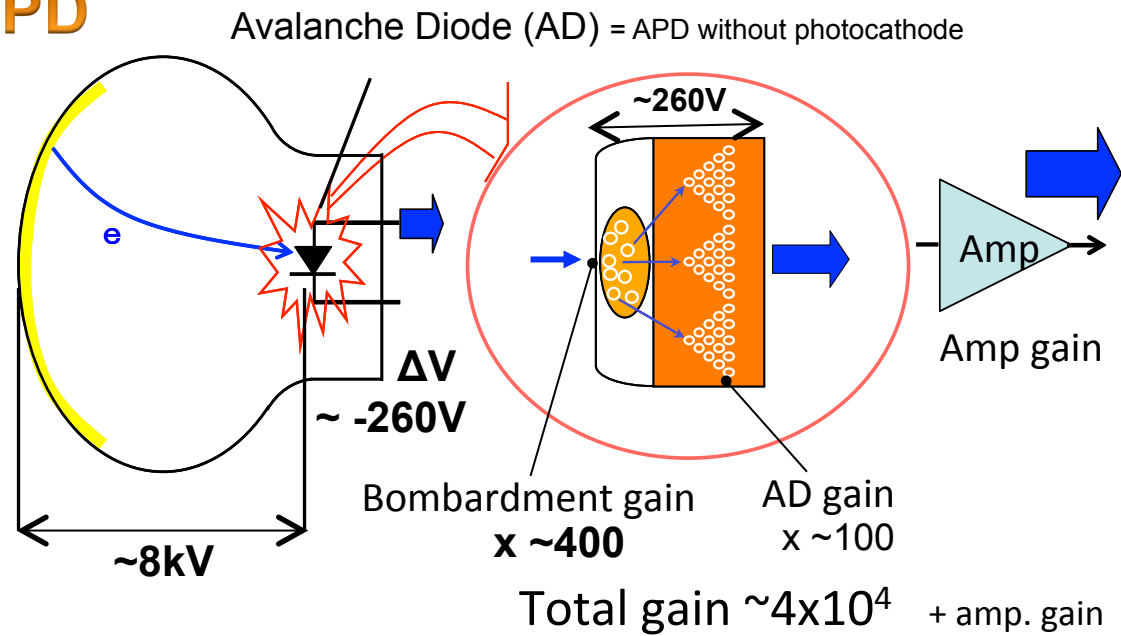
Hybrid Photo-Detector (HPD)

- HPD = Hybrid of phototube (pho→e) and electron detector (e→Q)
 - HPD with avalanche diode, HAPD (Hybrid Avalanche Photo-Detector), is studied for Hyper-K.

PMT



HPD



Typical values in 8-inch HPD prototype

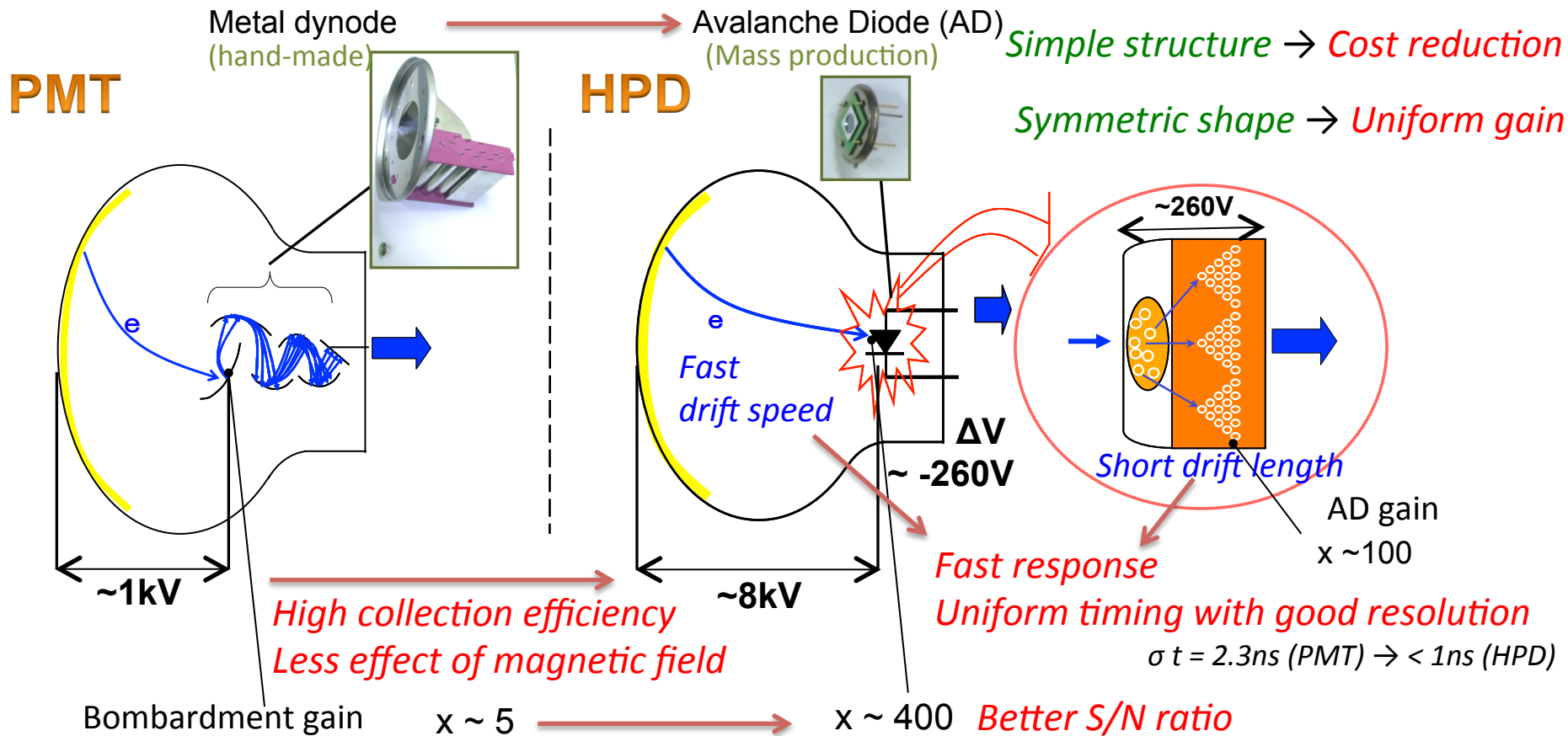
	PMT (20")	HPD (8")
HV	$\sim 1\text{kV}$	$\sim 8\text{kV}$
Gain	$\sim 10^7$	$\sim 10^4 \sim 10^5$
C.E.	$\sim 70\%$	$\sim 97\%$

High voltage around 10kV is needed

- to collect electrons in small region of AD ($\sim 5\text{-}10\text{mm}$)
- to increase gain at electron-bombardment

Q.E. (photocathode) can be same between two.

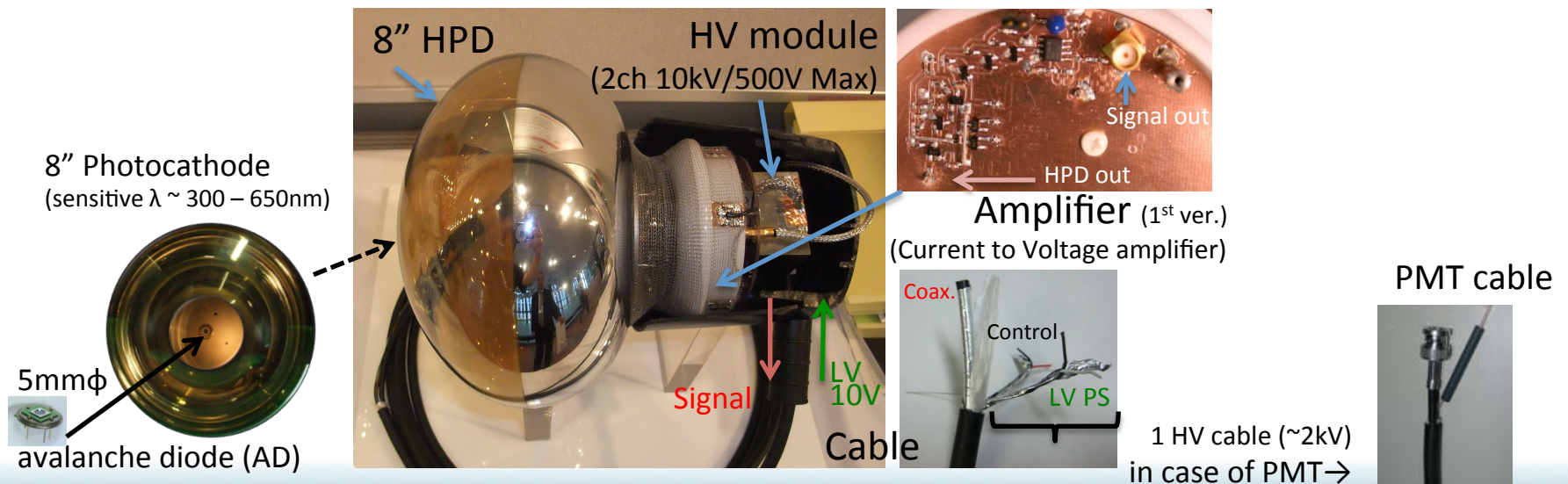
Benefits of HPD



- High performance and low cost
- Difficulties to consider viability for practical use in Hyper-K
 - Dark noise from AD + Amp., HV around 10kV, low gain, thermal dependence of AD gain, No prior experience using

8-inch HPD

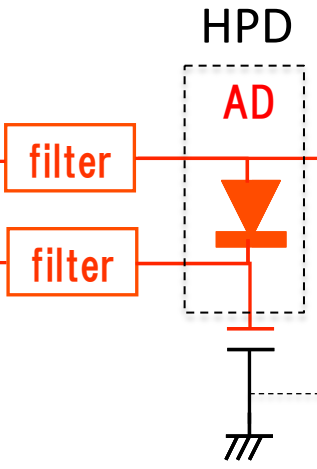
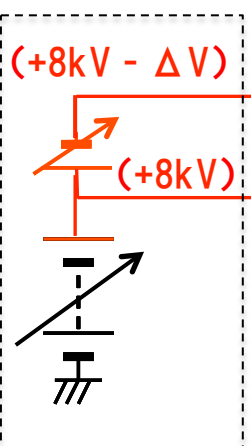
- For first proof test in water, 10 of 8-inch HPD will be provided by Hamamatsu photonics K.K. (HPK).
 - Also candidate for outer detector of Hyper-K.
 - First step before testing 20-inch HPD
 - This 8" HPD will be released to market after our test (~2013).
- Amplifier and HV Power Supply are packed inside end cap.
 - Low Voltage (10V) cable in water instead of HV in water.
- Currently we have 4 HPDs prototype at Kamioka.



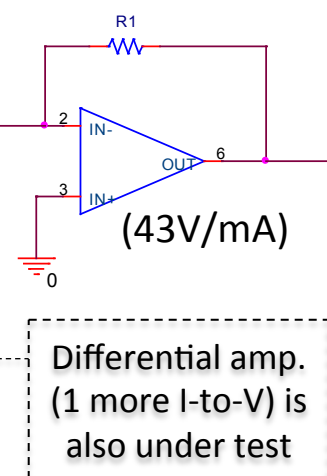
Amplifier and waveform

- Preamplifier converts current to voltage
- 5 - 10mV/p.e. comparable to PMT

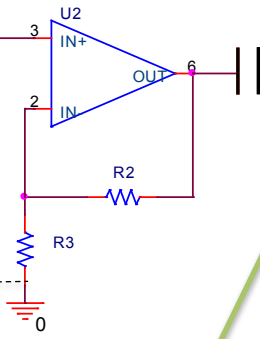
HV module



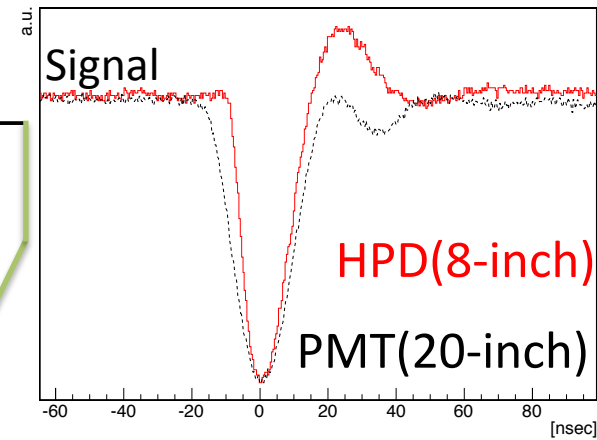
Inverting I-to-V converter



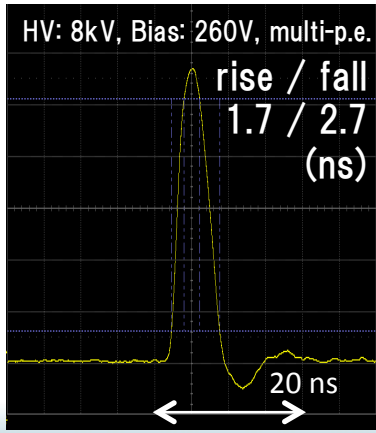
Amp. (x10)



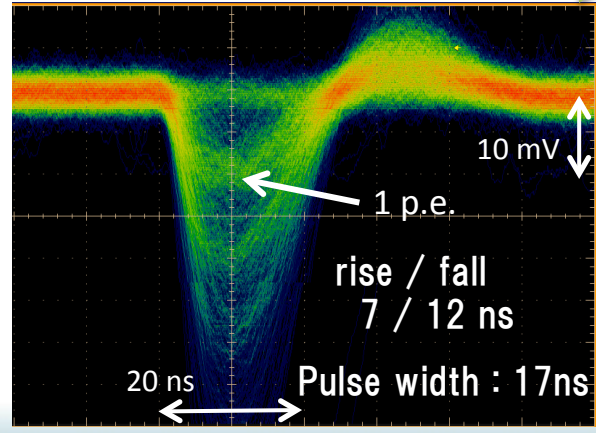
Differential amp. (1 more I-to-V) is also under test



Signal from AD



1~3 p.e. signal from amp.



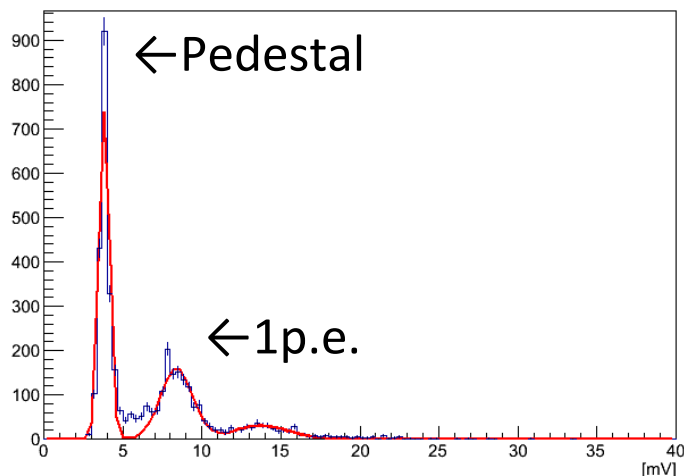
- Make similar shape to PMT's in current amp. (Not for Hyper-K case)
- Still under development
- Different type, noise reduction are tried.

1 photo-electron peak

- Clear 1 p.e. peak is observed by amplitude and charge.

Pulse height distribution

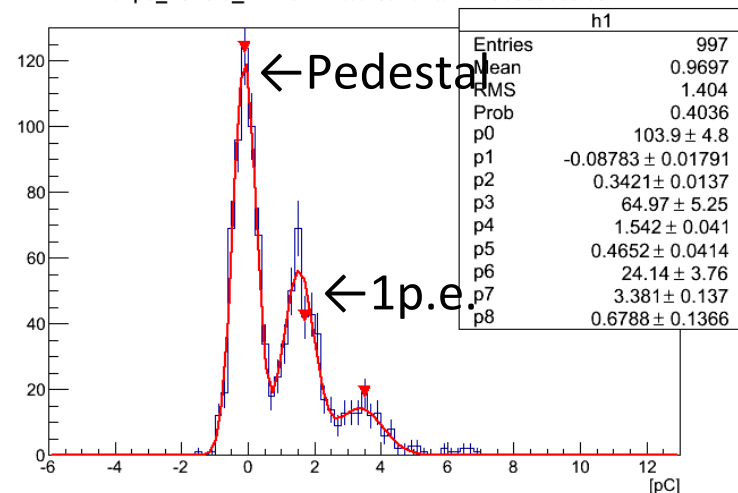
EHD0056 1p.e. amplitude



- Peak signal current from HPD is converted to amplitude by amp.
- Related to trigger performance
- Better 1p.e. resolution and narrower pedestal width

Charge distribution (75ns integration window)

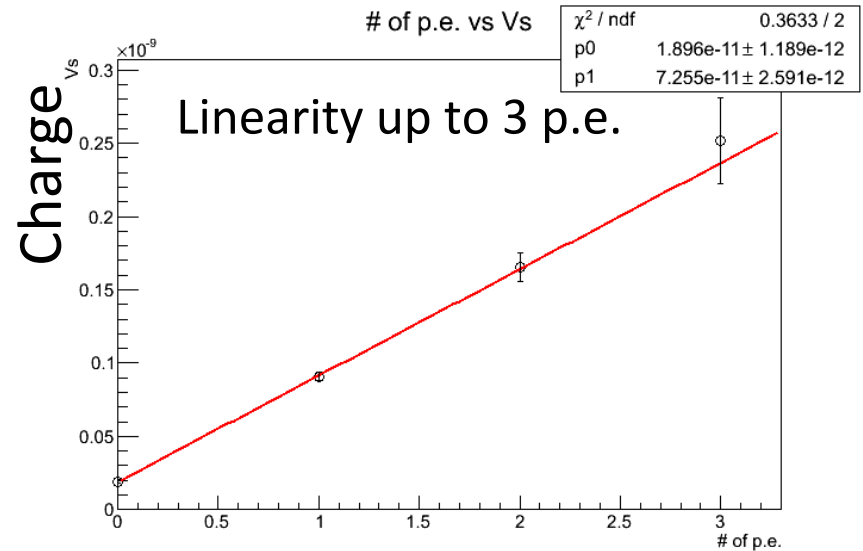
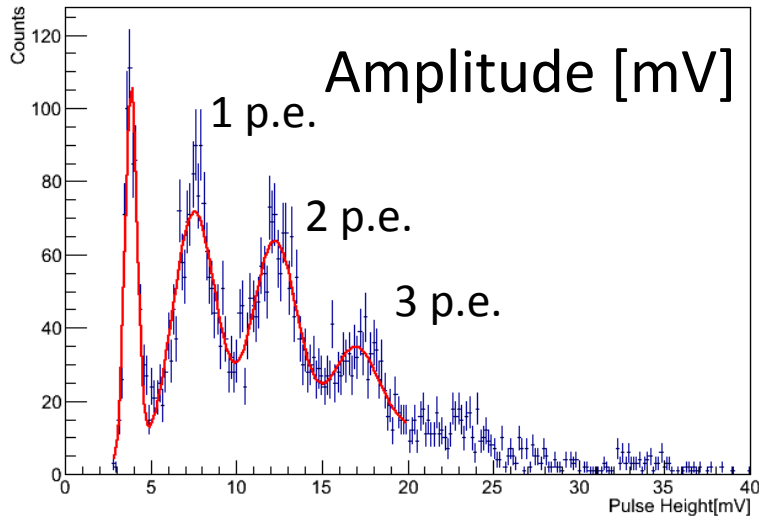
./1pe_LS18.9_HV2.5LV2.3/area75ns/F1Trace00000.csv



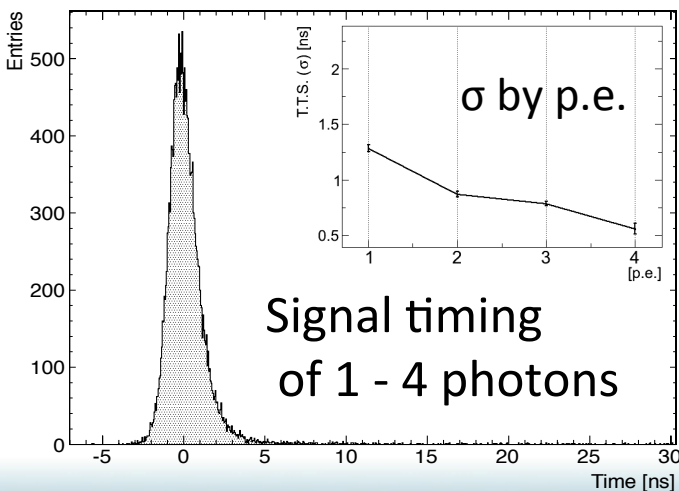
- Charge in 75ns range shows clear separation of 1p.e. peak.
- $P/V = 2.9$ ($> 1.7-1.9$ in 20" PMT)
- Pedestal width is wider.
- Need more noise reduction



Performance evaluation



Time Transition Spread (TTS) [ns]



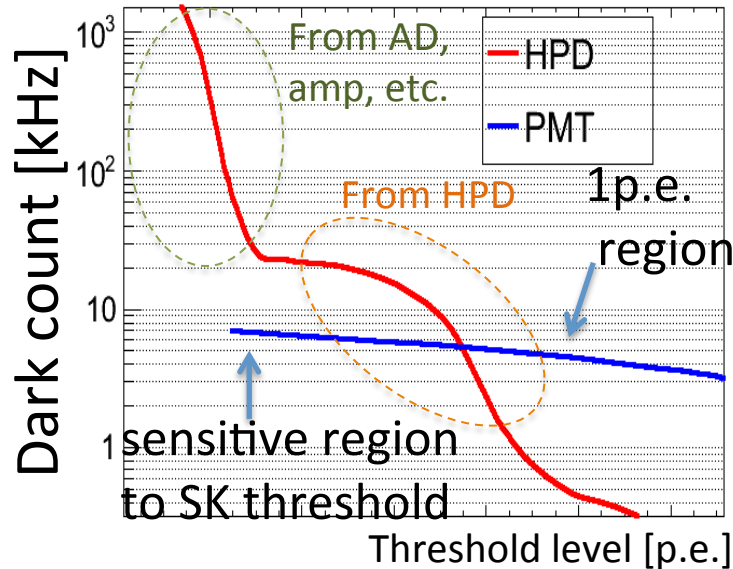
- Still preliminary results

- But these indicate a good performance of HPD.
- Need further study, as well as noise reduction, to improve HPD performance.

Dark count rate

- Compare dark count between HPD and PMT under same condition.
 - Need lower dark count so that trigger quality reaches similar level to SK-PMT.
 - ▶ Otherwise trigger cannot work and its efficiency becomes worse.
- Dark count rate of HPD is higher than that of PMT.
 - Consisting of two sources

Dark rate by threshold

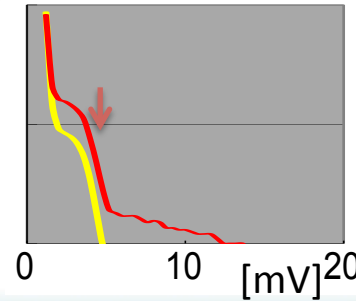
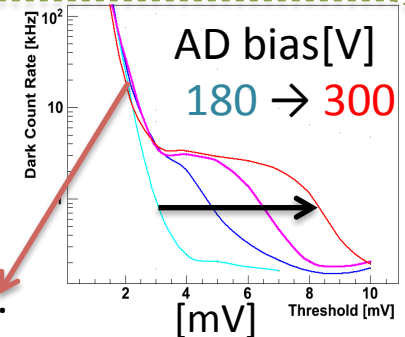


Under study to reduce dark count rate of HPD

Noise filter and low noise amp. are investigated.

Gain optimization also helps noise reduction.

This edge relatively lowered in p.e.



Grounding glass could suppress noise inside HPD

Low noise HPD valve is under development at HPK

NOTE : Just relative comparison rather than absolute value because HPD/PMT is not stabilized after shaded and grounding is still not sufficient to suppress noise.

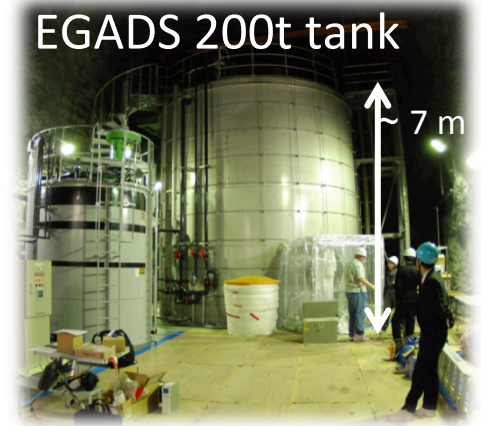
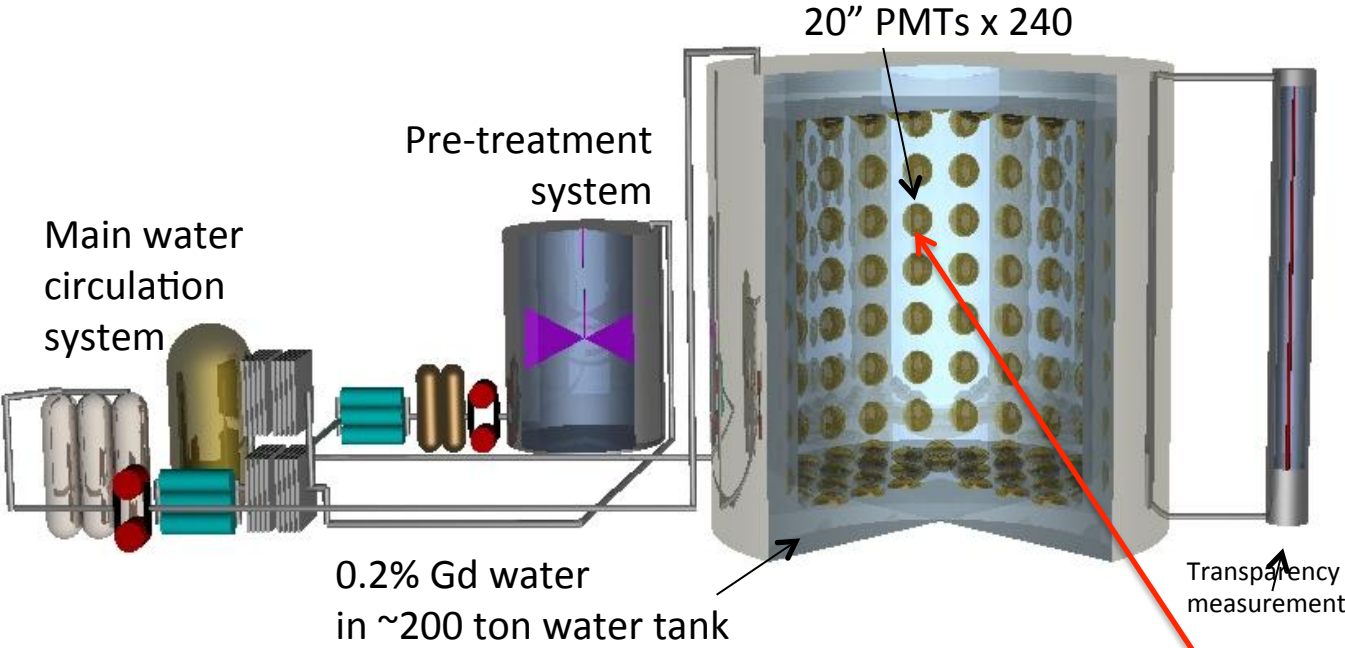
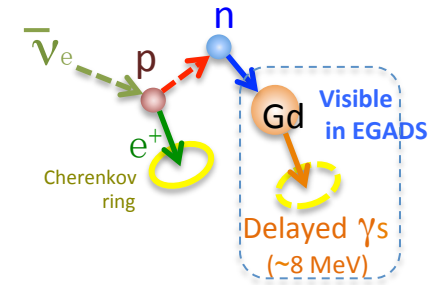
HPD proof test in EGADS tank

Evaluating Gadolinium's Action on Detector Systems

200-ton test tank to demonstrate the GADZOOKS! Idea.

(Gadolinium Antineutrino Detector Zealously Outperforming Old Kamiokande Super!)

Anti-neutrino tagging by neutron



- Replace several 20" PMTs with Hyper-K PD candidates during EGADS experiment

By much help of EGADS group

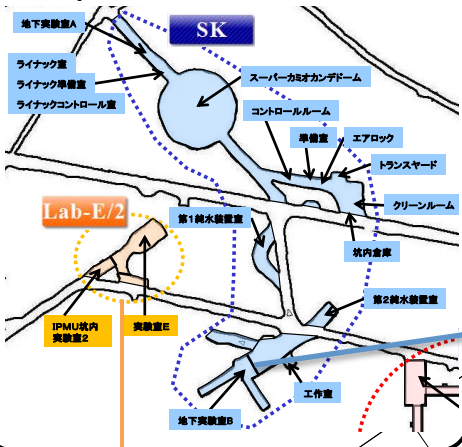


8-inch HPD and 20-inch PMT

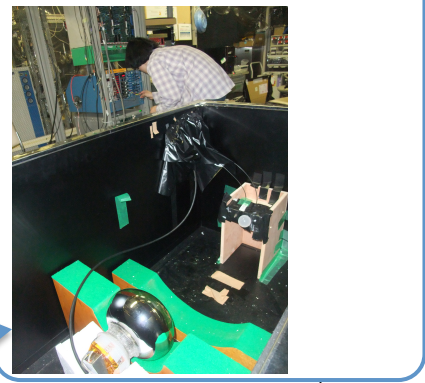
- Install 8 of 8" HPD at first proof test

Area map in Kamioka mine

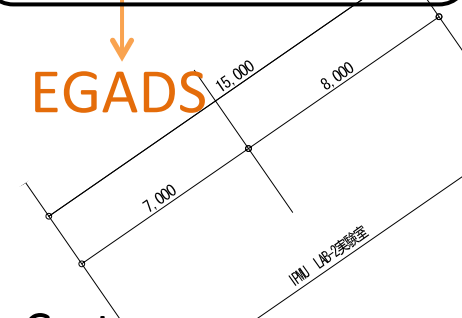
Map of Kamioka mine



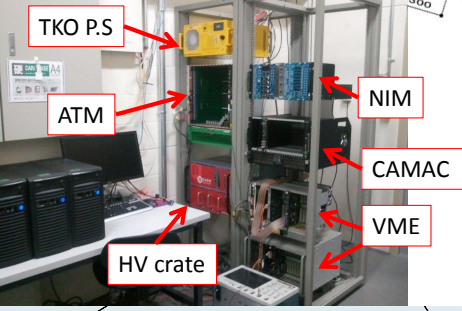
Pre-calibration



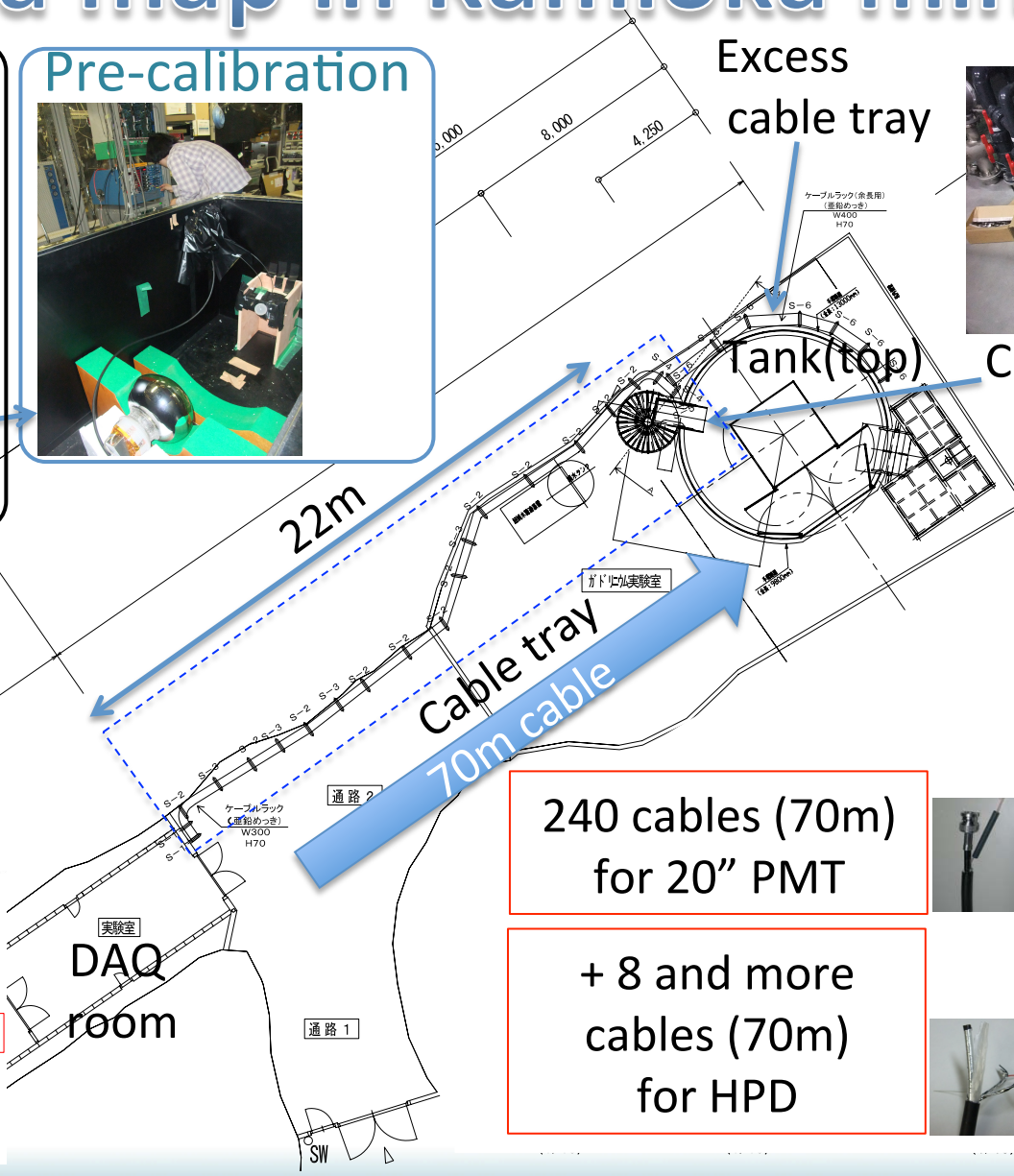
EGADS



Crate (NIM, VME, TKO)

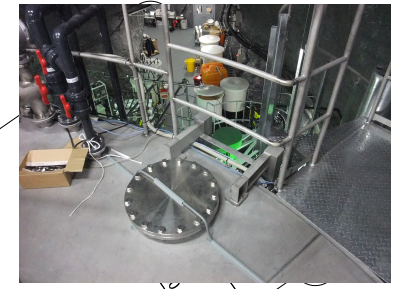


DAQ room



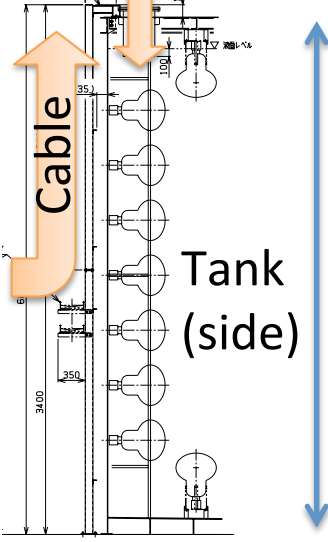
240 cables (70m) for 20" PMT

+ 8 and more cables (70m) for HPD



Cable thru

6.8m height



Electronics of 8-inch HPD in EGADS

- Setup for proof test in water
 - NOT Hyper-K case

Charge + time

ATM(Analog Timing Module)
used in old SK

12ch x (2TAC+2QAC)
400ns integration range



Rack for EGADS



+ 1 rack for HPD
with 1 ATM board
(QBEE used for
current SK later)
and LV PS

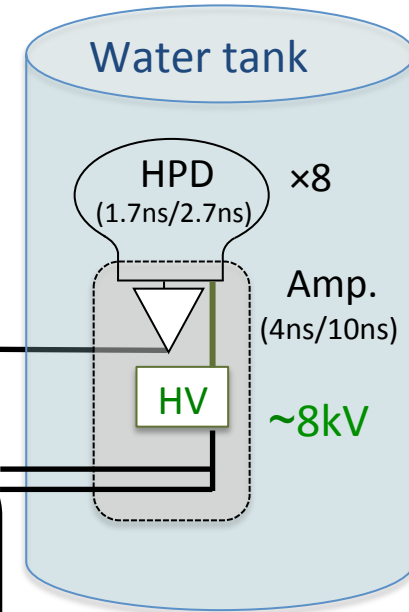
70m signal cable (BNC)

Control Power Supply



10ch x 6 LV cables

- **GND**
- **Power supply**
- 10V for HV unit and Pre-amp. (<500mA)
- **4 HV control line (<1mA)**
- HV control (0 - 4V out)
- AD bias control (0 - 4V out)
- Latch up monitor (+5V in)
- Enable switch (+5V out)



70m
Low voltage (10V)
+ control cable



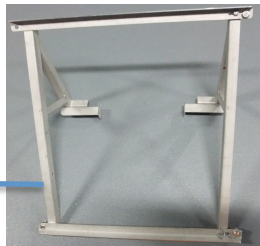
Installation

Procedure to install 8" HPD at first PMT installation of EGADS

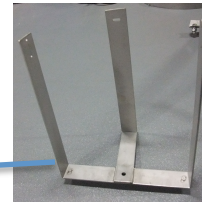
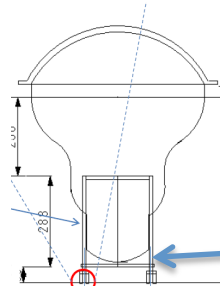
- PMT cables are put as well as HPD cables.
 - Start from December or a few months later
- PMTs (and HPDs) are fixed by band and attached in frame unit

(20" PMT case)

Barrel support frame

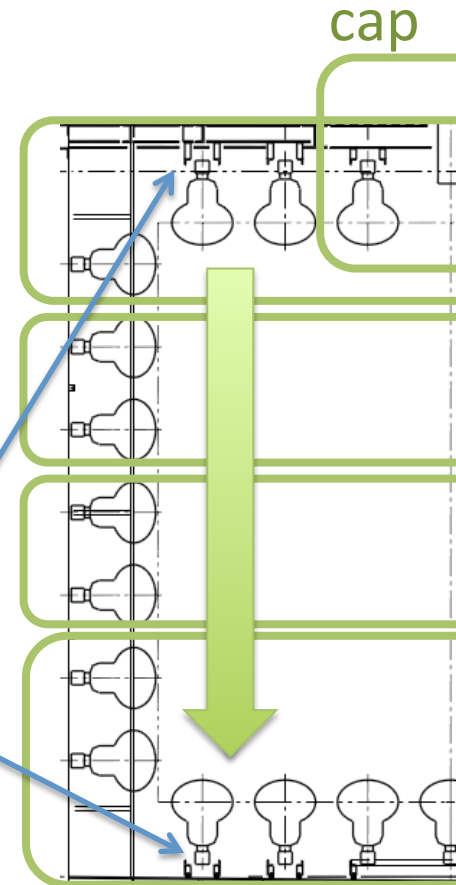


Top/bottom frame



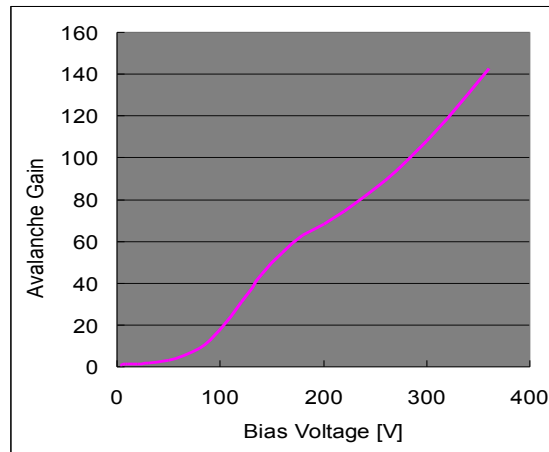
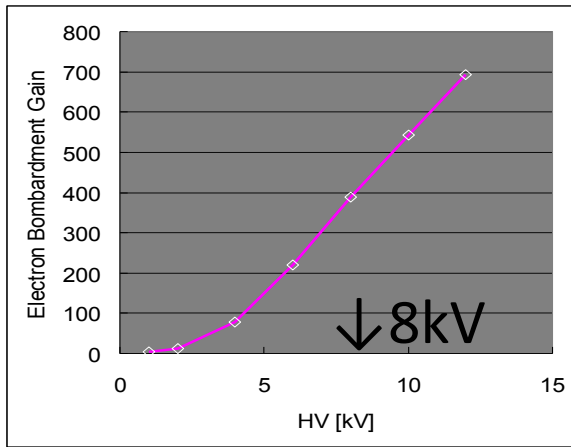
- Install all PMTs/HPDs from top to bottom, and cap
 - Cables are connected inside tank one by one.

- Other photo sensors (20" HPD, etc.) are mounted later.
- Performance is relatively compared with 20" PMT.

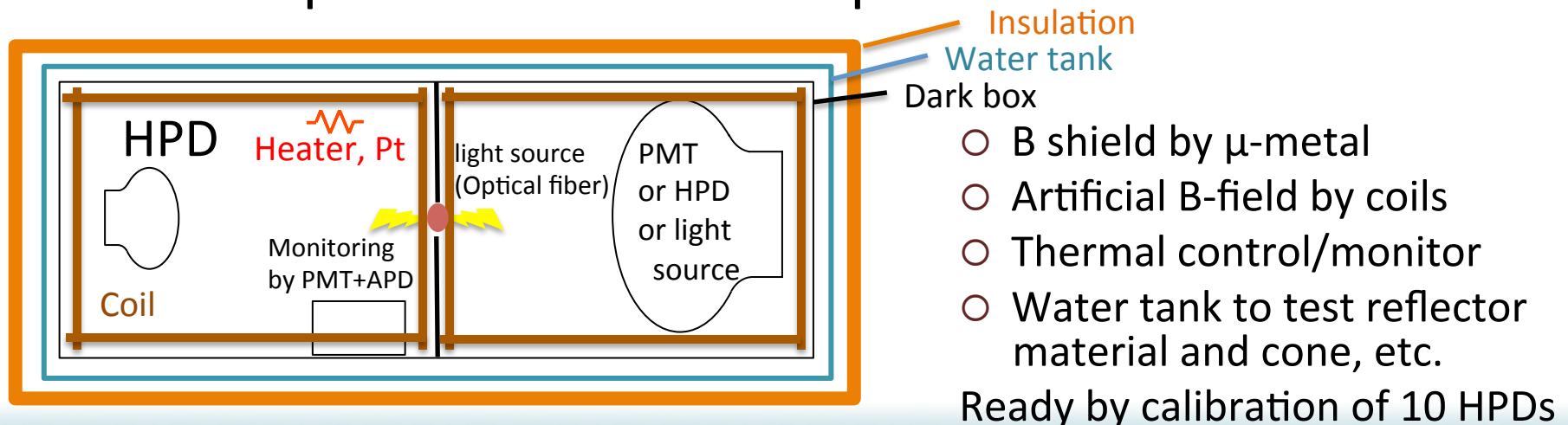


Pre-calibration and setup

- Gain adjustment by AD bias voltage



- Box setup for calibration and performance evaluation.



Measurement flow

4 HPD prototype now, 10 HPD from HPK (8 in tank, 2 for detailed study)

● Performance measurement ● 10 HPD calibration (in Dec.)

○ Basic performance

- ▶ (Gain, S/N, dark rate, timing, p.e. resolution, HV dependence, etc.)

May -

○ Linearity

- ▶ Pulse width, frequency, dynamic range, etc.

- Sep.

○ Thermal dependence of AD gain

Oct.

○ B-field dependence of bombardment gain

○ Gain uniformity (by B, HV) and so on.

Details can
be measured
even after
installation

2

○ Gain-HV adjustment

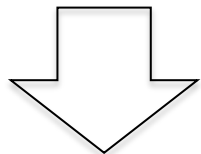
- ▶ 1 p.e. data
- ▶ Determine AD HV, 8kV constant
- ▶ ~1 week

○ Dark rate measurement

- ▶ ~ ½ week

○ and possible measurements in left lower list

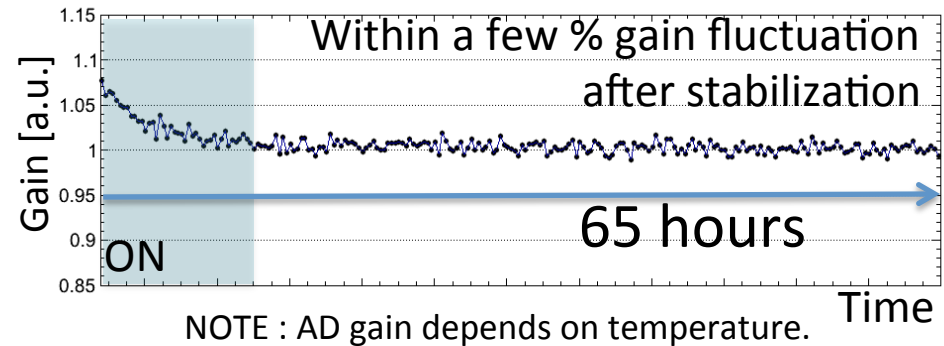
8 HPDs ready for
installation in tank



Stability and safety

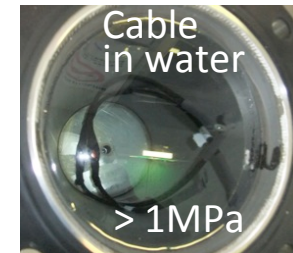
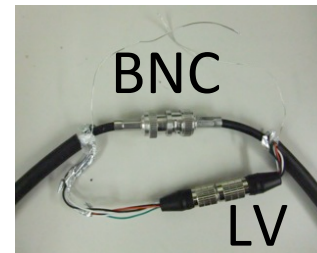
- Long-term stability, aging effect and durability are to be checked.

- 99k (Inner) + 25k (Outer) HPDs should work over 10yrs in HK.
- Monitoring gain stability started.



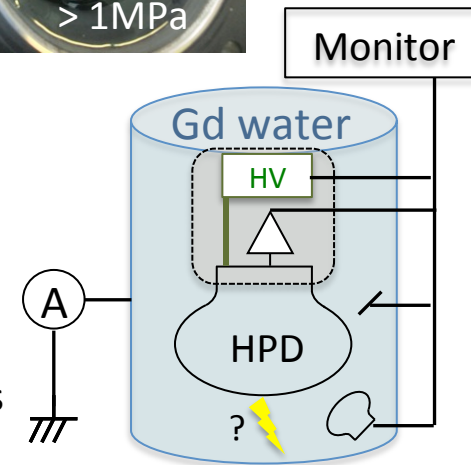
- Water-proof test

- Outside of cable and HPD is completely same material as used in SK 20" PMT
 - ▶ Cable is connected in water (Only for EGADS)
 - ▶ 1st cable connection check showed no problem.



- Safety test to check current leak in water under HV

- To ensure no discharge outside of HPD
 - ▶ Leak current monitor
 - ▶ Flasher monitor
 - ▶ Discharge monitor thorough signal cable and power cable

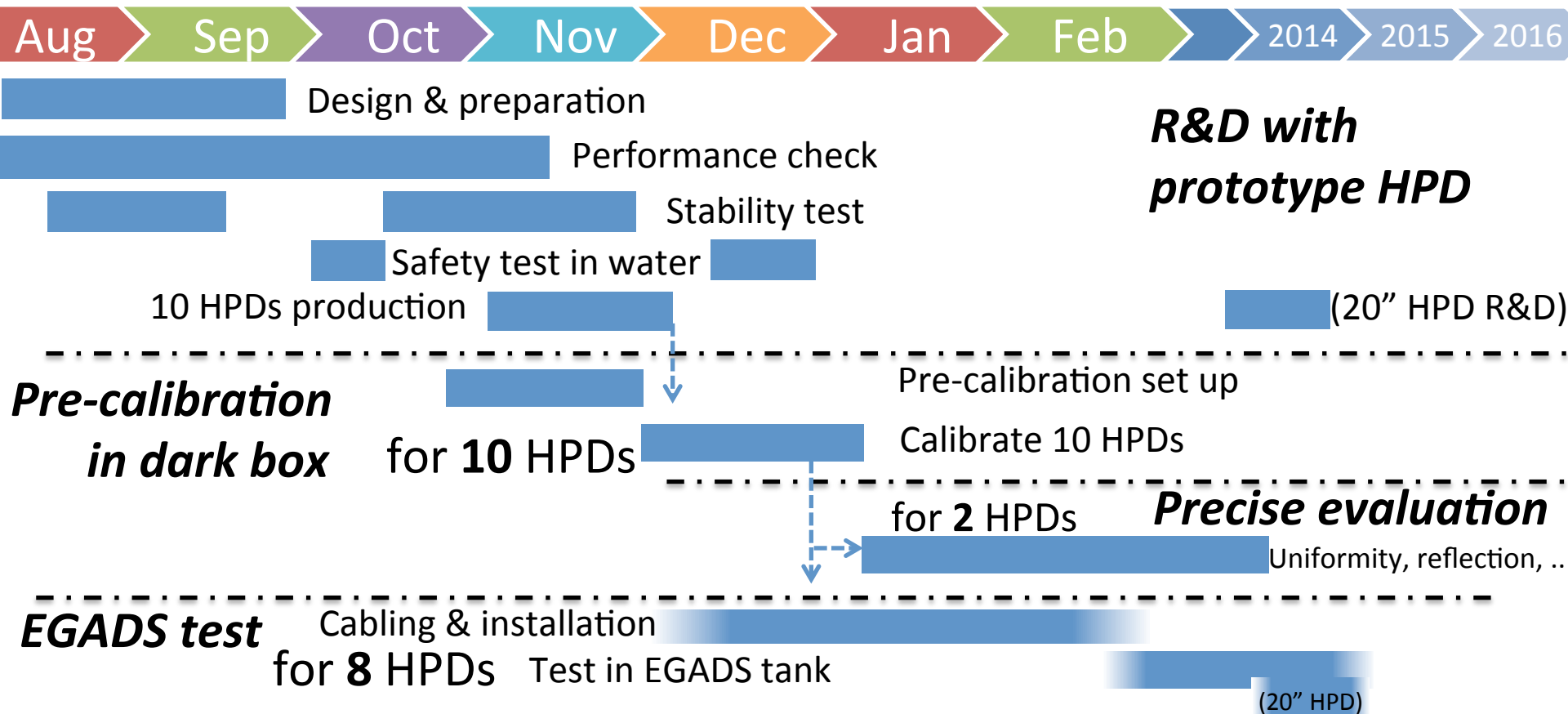


Setup small tank check for all HPDs

- All checks will be done very carefully by the end of this year.

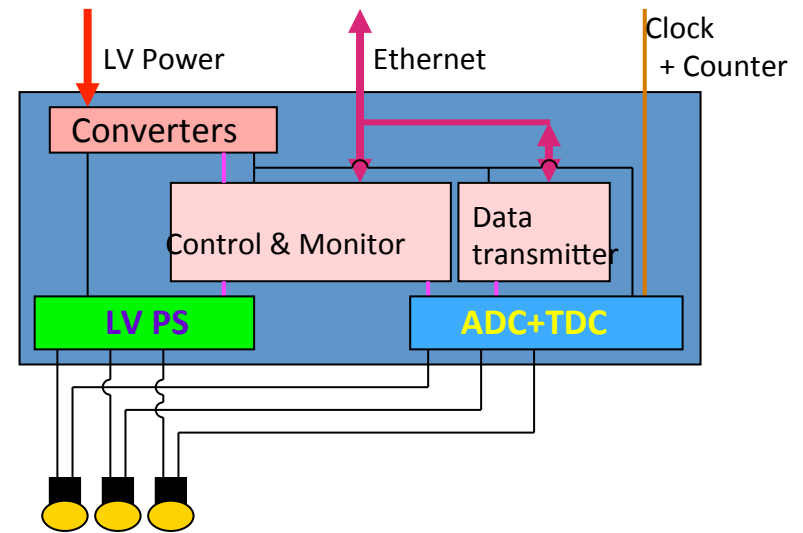
Schedule

To produce a lot of photo sensors (100k) in reasonable time scale,
R&D to determine Hyper-K photo sensor should finish till 2016.



HPD in Hyper-K case

- Development of 20-inch HPD needs several steps.
 - Prototype measurement by each step
- High QE around 30% is one of possibilities for upgrade
 - For both PMT and HPD, 22% QE at SK PMT
- Frontend electronics module might be immersed in water.
 - LV control, ADC+TDC
 - Test with HPD



Recent study

- HPD measurement started since May 2012.
- Current man power
 - Mainly worked by 4 students
 - ▶ S.Hirota (Kyoto),
I.Kametani, Y.Haga, Y.Suda (Tokyo)
- Ongoing works
 - Development
 - ▶ Noise filter, comparing different amplifiers, investigation of large pulse
 - Calibration
 - ▶ DAQ setup (VME/TKO), stability/linearity check
 - Evaluation
 - ▶ Gain optimization
 - Proof test
 - ▶ Endurance test of amp. with HV



Summary

- HPD is one of good candidates for Hyper-K photo sensor
 - With good performance (σ of 1pe, timing, ..) and low cost
 - But no prior experience using
- Proof test of HPD in 200t Gd water tank at Kamioka
 - 8 of 8-inch HPDs will be installed at first test.
 - Start around beginning of 2013.
- Measurement of 8" HPD started since May 2012.
 - 4 set of HPDs at Kamioka provided by HPK
 - Safety, stability and durability are carefully checked.
- 20" HPD will be also provided within a few years
based on an experience of 8"HPD test