Development of large aperture HAPD

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2011/06/10

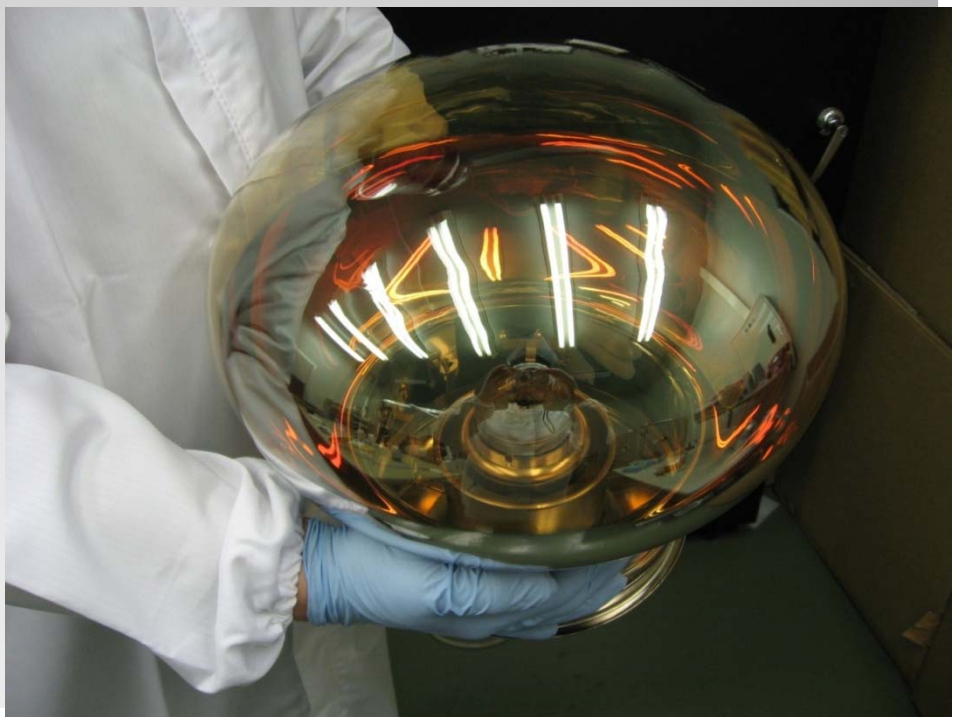
Introduction

- We develop large aperture Hybrid Avalanche Photo-Detector (HAPD) and its readout system for neutrino/anti-neutrino experiments.
- HAPD is scheduled to commercially release on the next March.
- We show current status of the HAPD development.

Themes

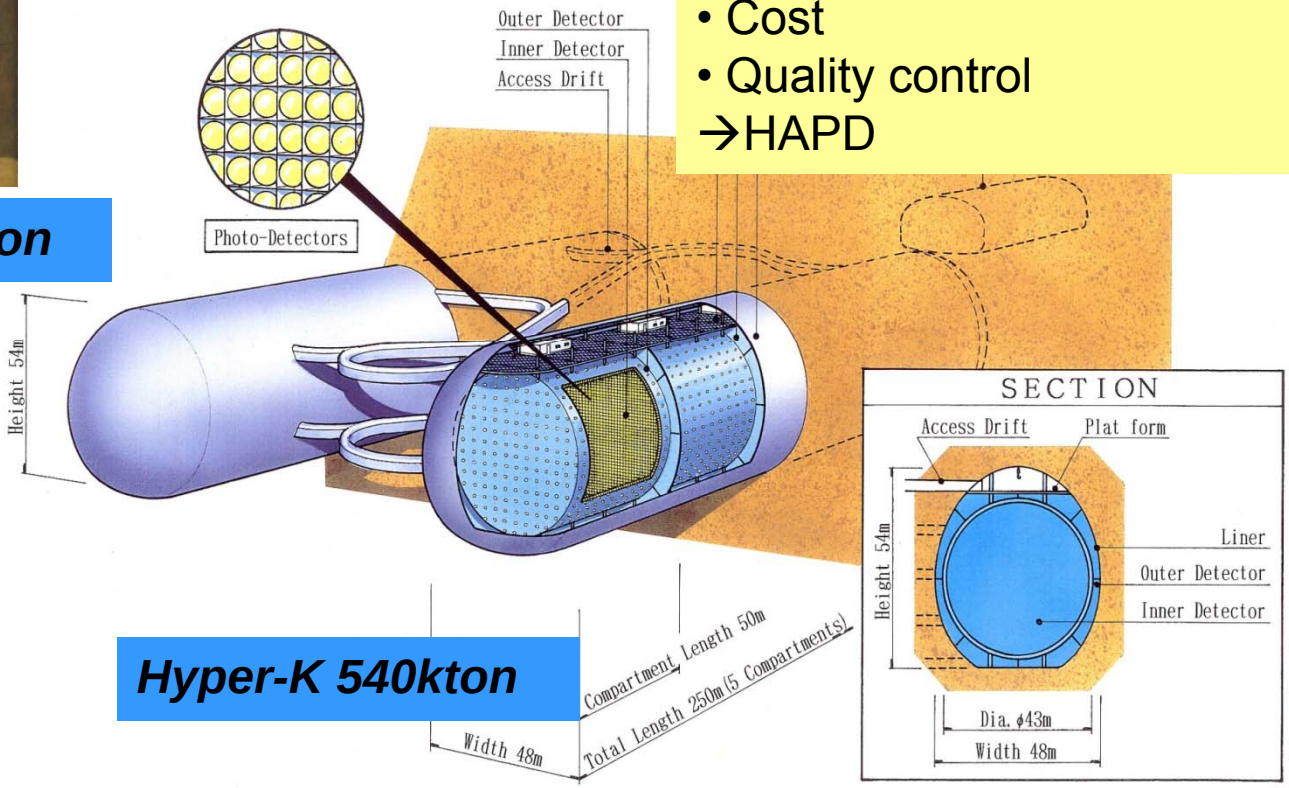
- Motivation
- PMT vs. HAPD
- Digital HAPD
  - All-glass HAPD
  - New HV supply
  - Readout
- Summary

13inch HAPD



Mega ton class Water Cherenkov detector (20xSuper-K)
→O(100,000) photo sensors
• Cost
• Quality control
→HAPD

Super-K 22kton



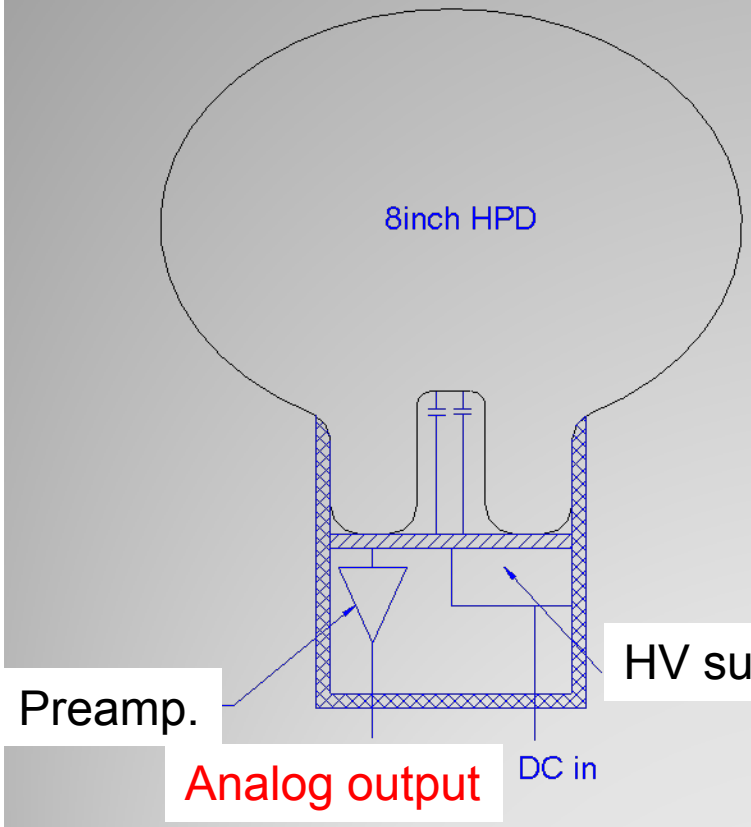
Hyper-K 540kton

Next generation water Cherenkov detector

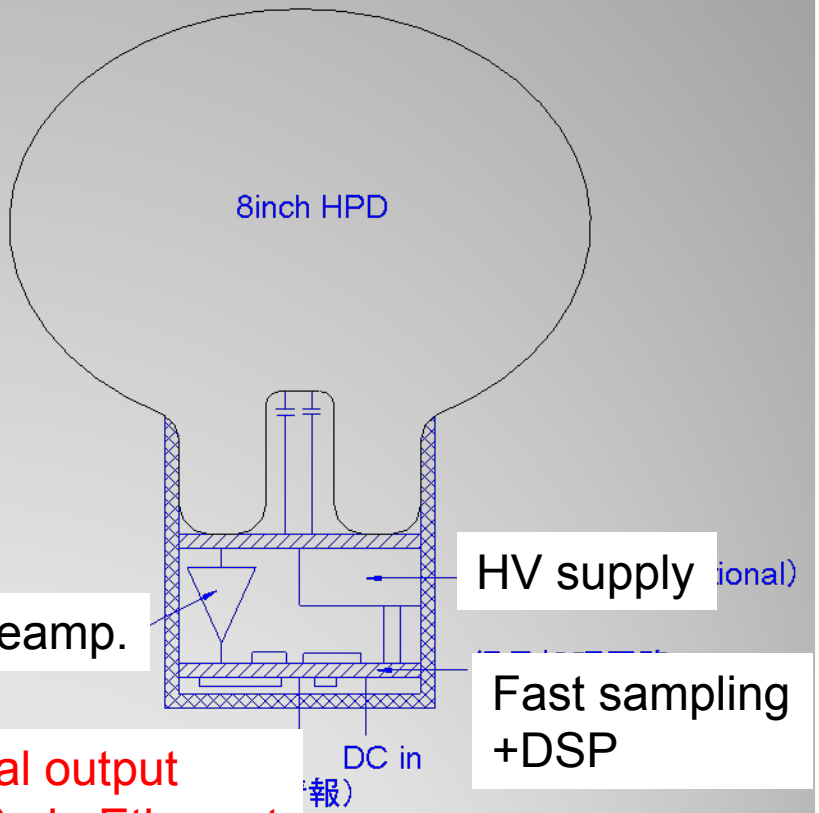
Parameters*	13inch HAPD	13inch PMT (R8055)	20inch PMT (for SK)
# of parts elements	~10	>200	>200
Single Photon Time Resolution (σ)	190ps	1400ps	2300ps
Single Photon Energy Resolution	24%	70%	150%
Quantum efficiency	20%	20%	20%
Collection efficiency	97%	70%	70%
Power consumption	<<700mW	700mW	700mW
Order of Gain	10^5	10^7	10^7

HAPD vs. PMT

HAPD + Preamplifier

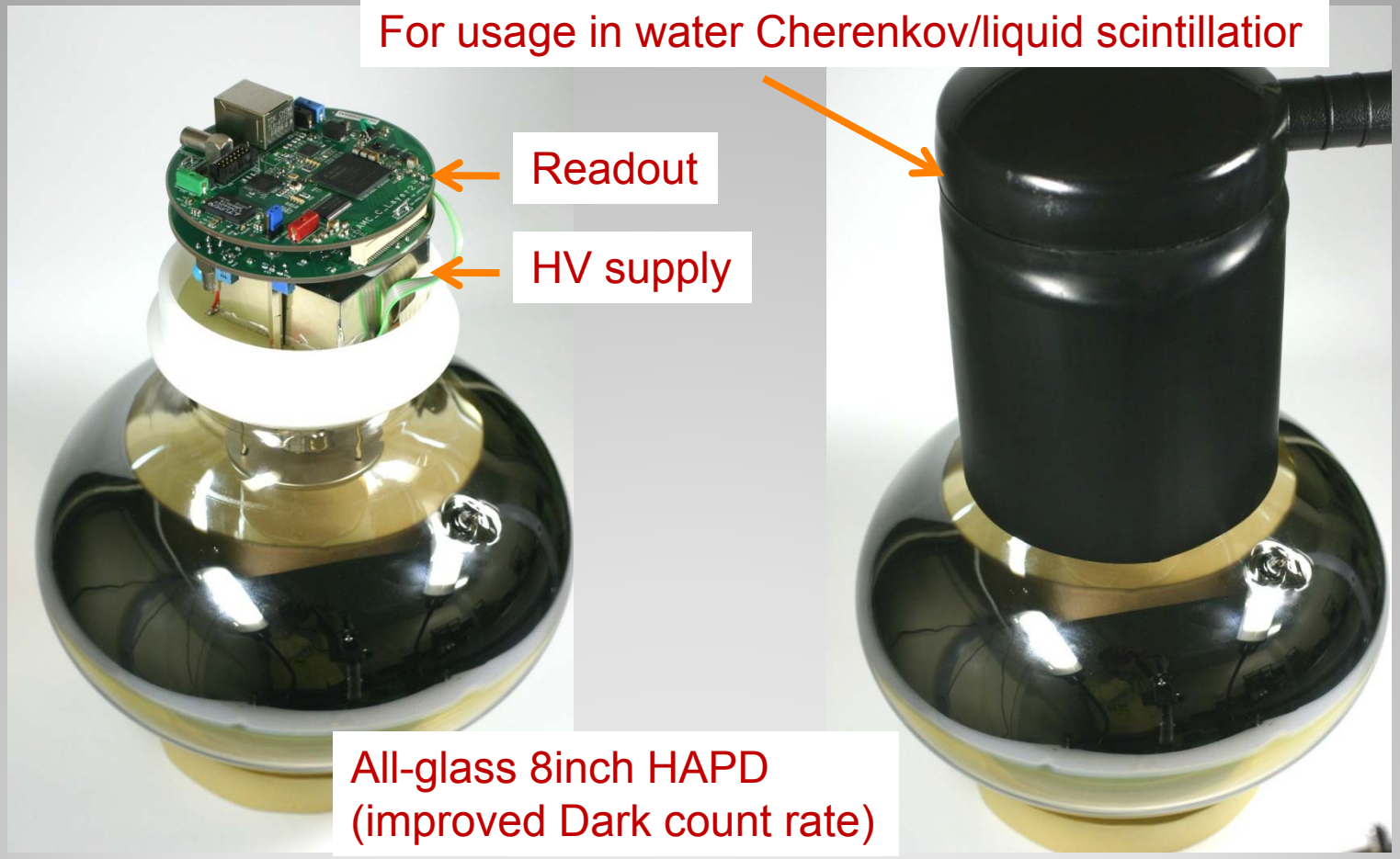


Digital HAPD

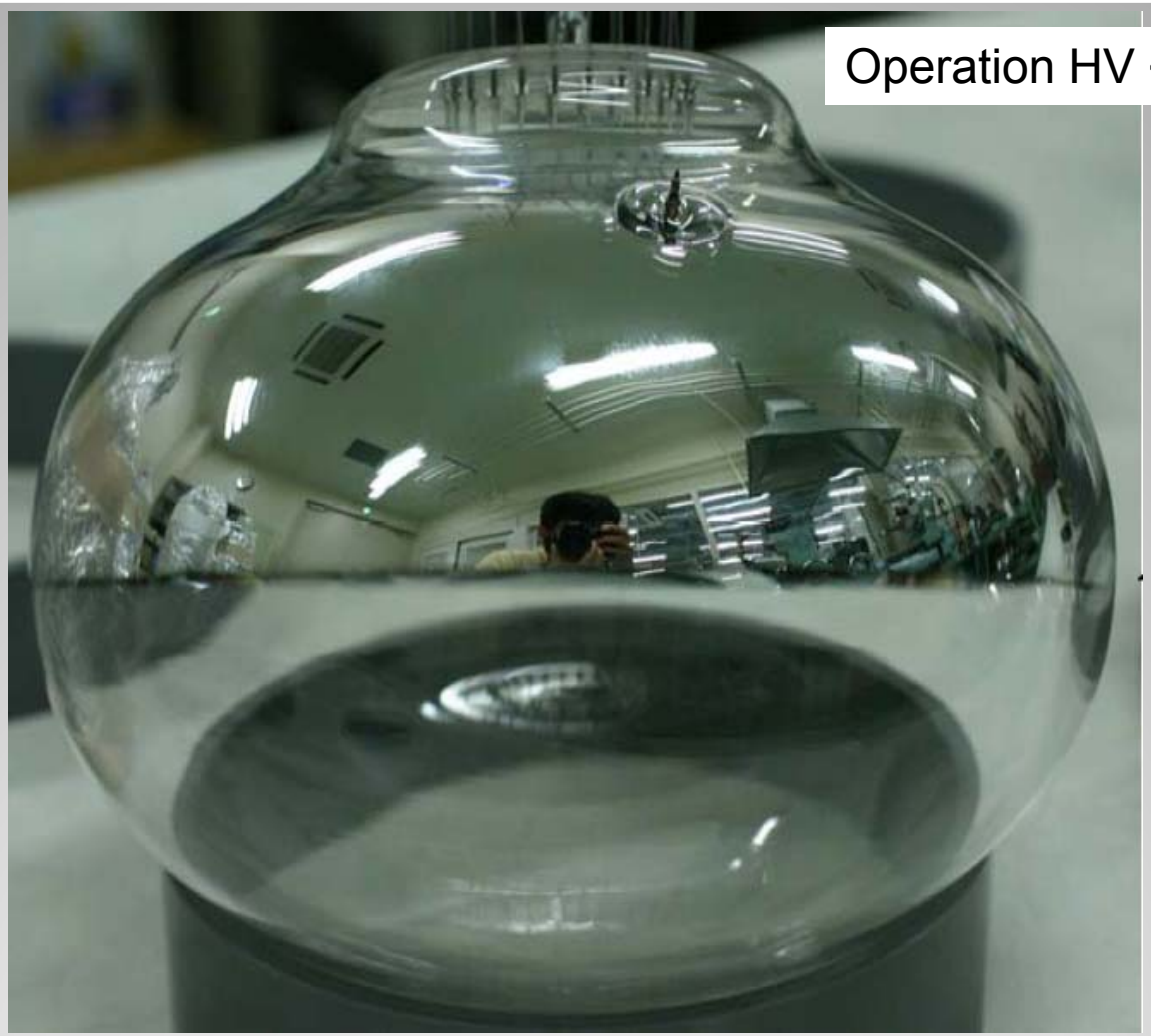


HAPD scheme planned for commercial production

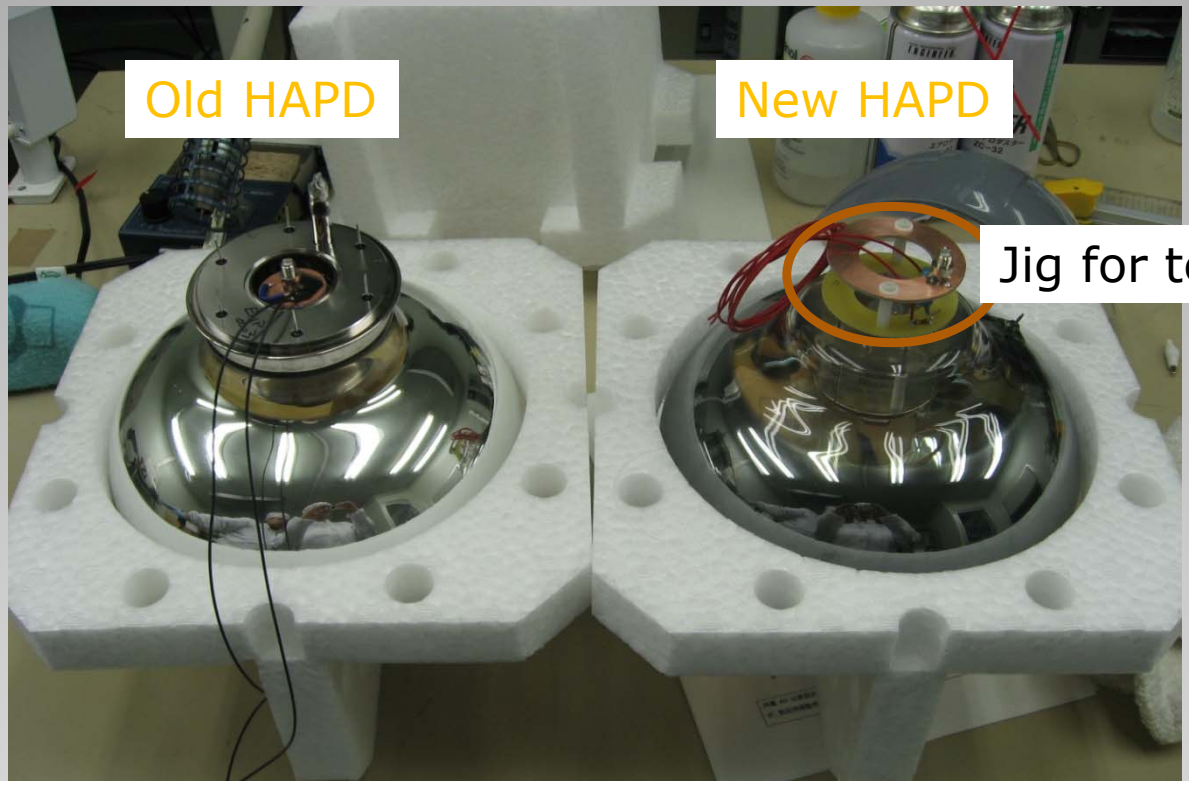
Prototype of digital HAPD



Planed to be tested in this JFY

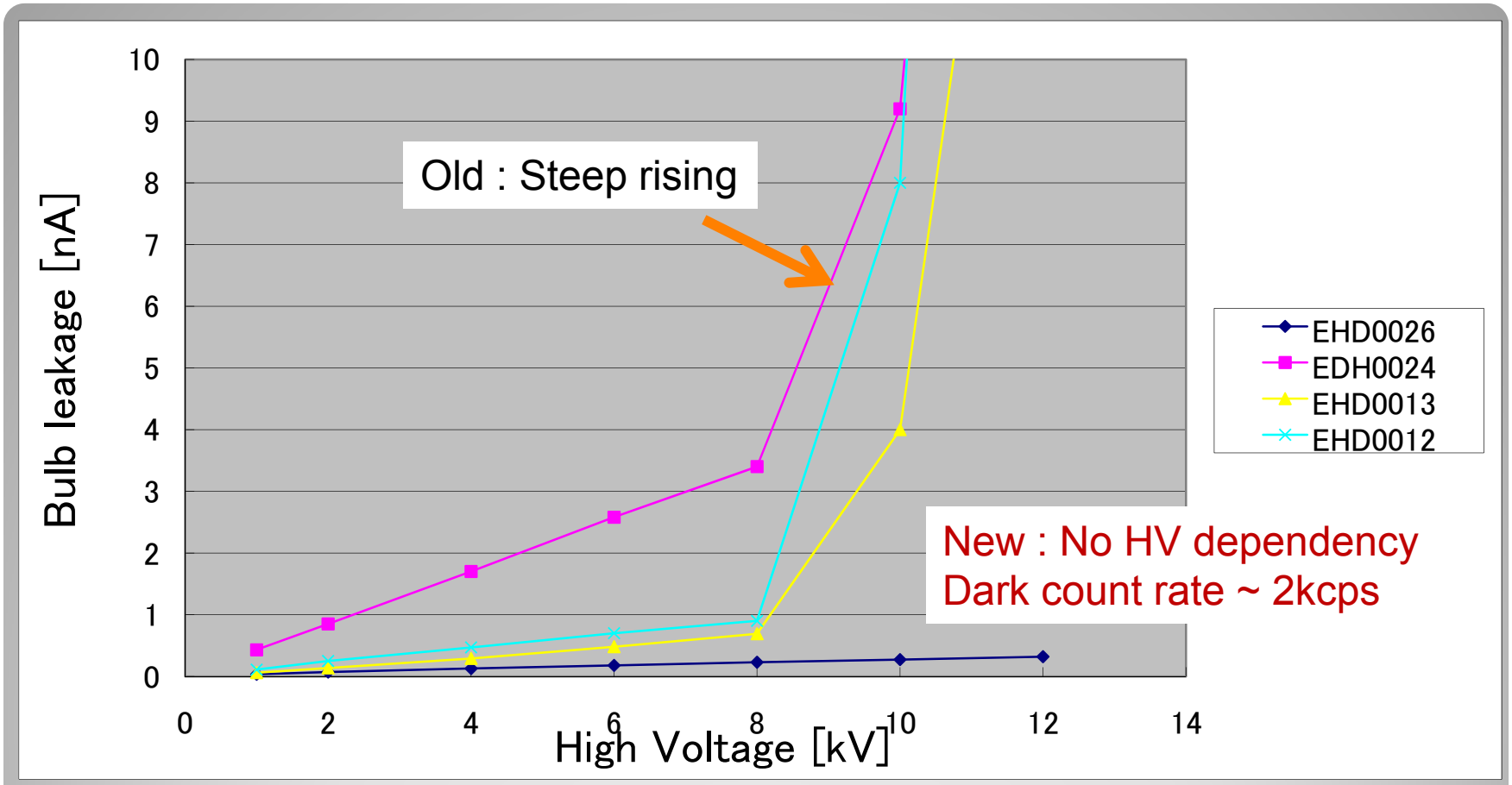


All-glass 8inch aperture HAPD



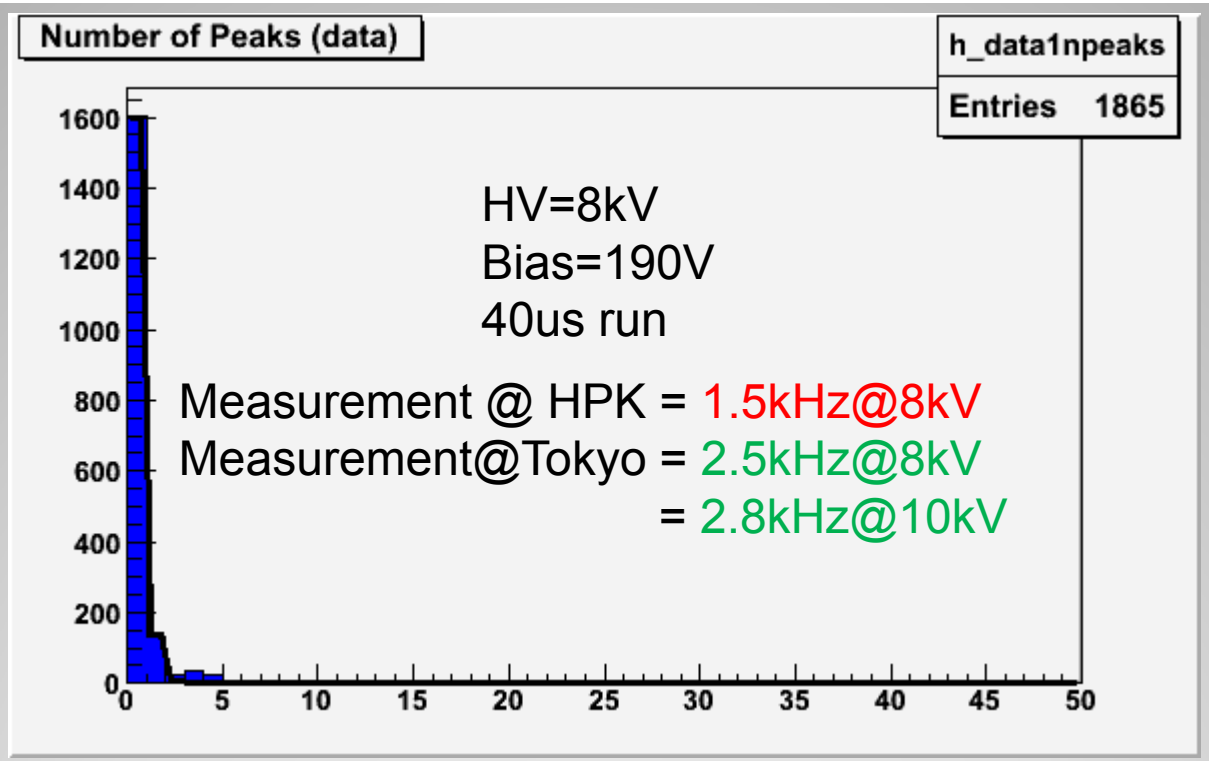
New HAPD made of almost glass to reduce production cost
→# of parts elements to be 6 from 10 (PMT:>200)

8inch aperture HAPDs



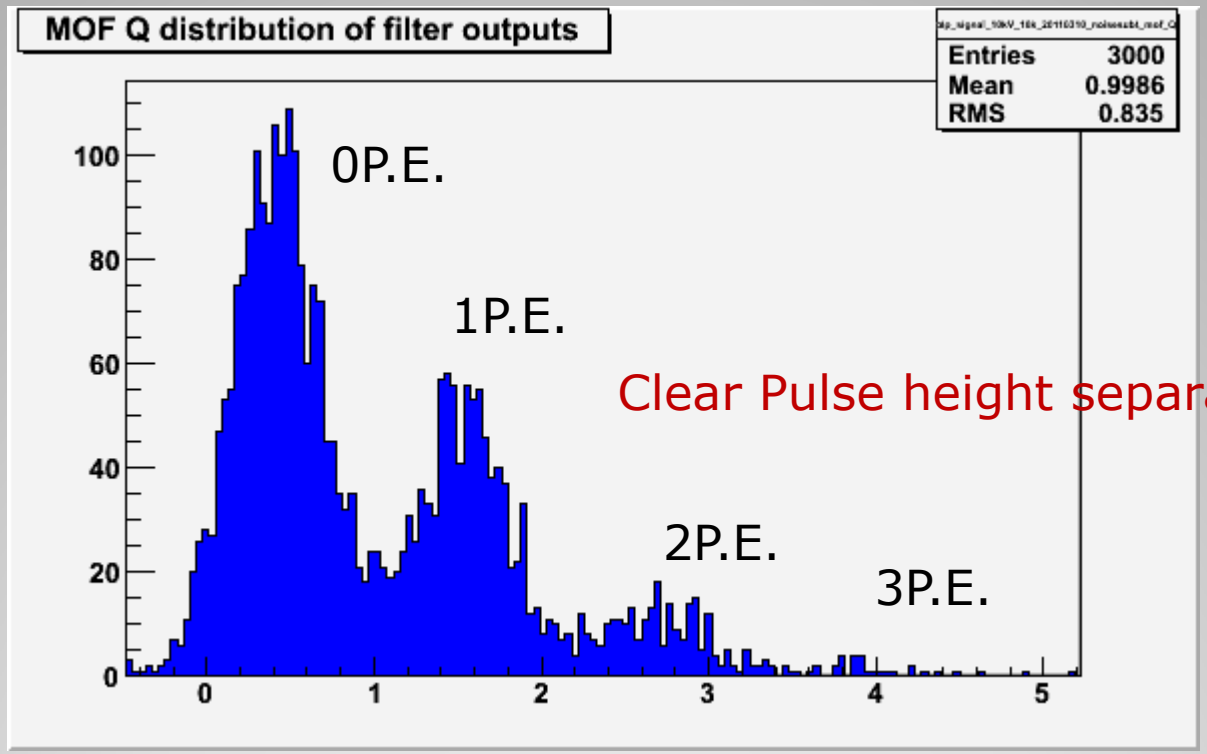
Dark Count Rate

Down to the same dark count rate of PMT!



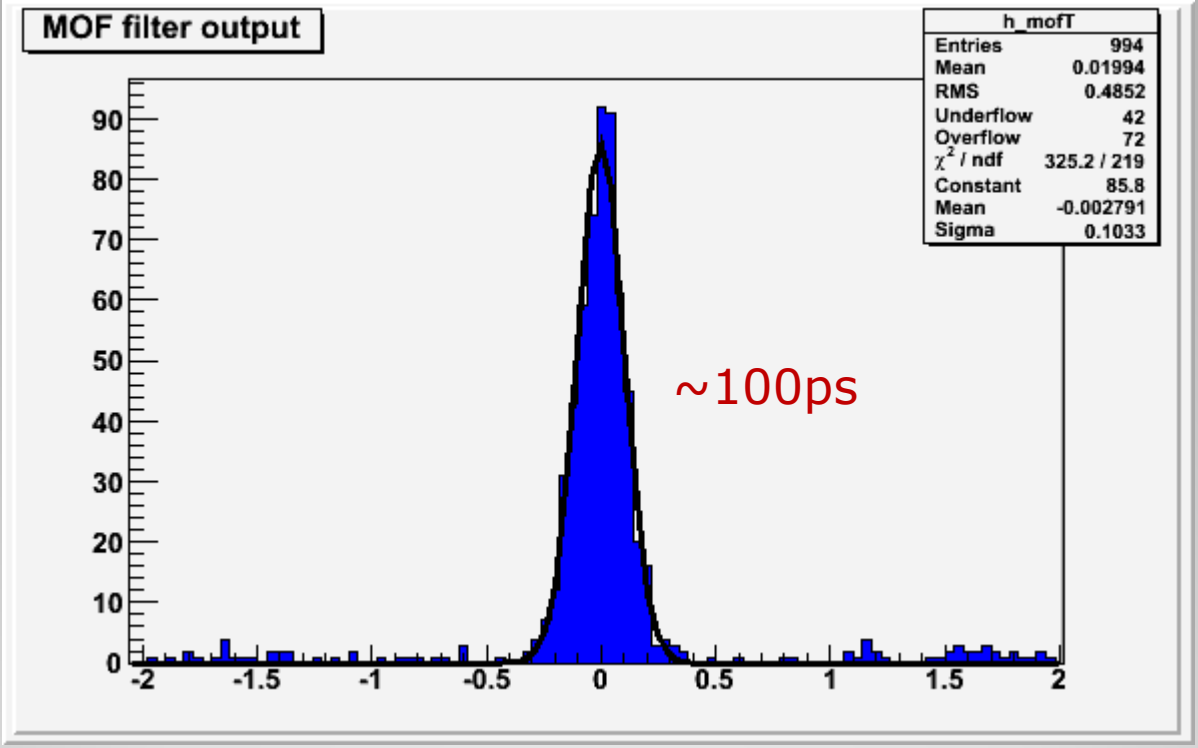
4kHz for 8inch PMT(R5912)

Dark Count Rate



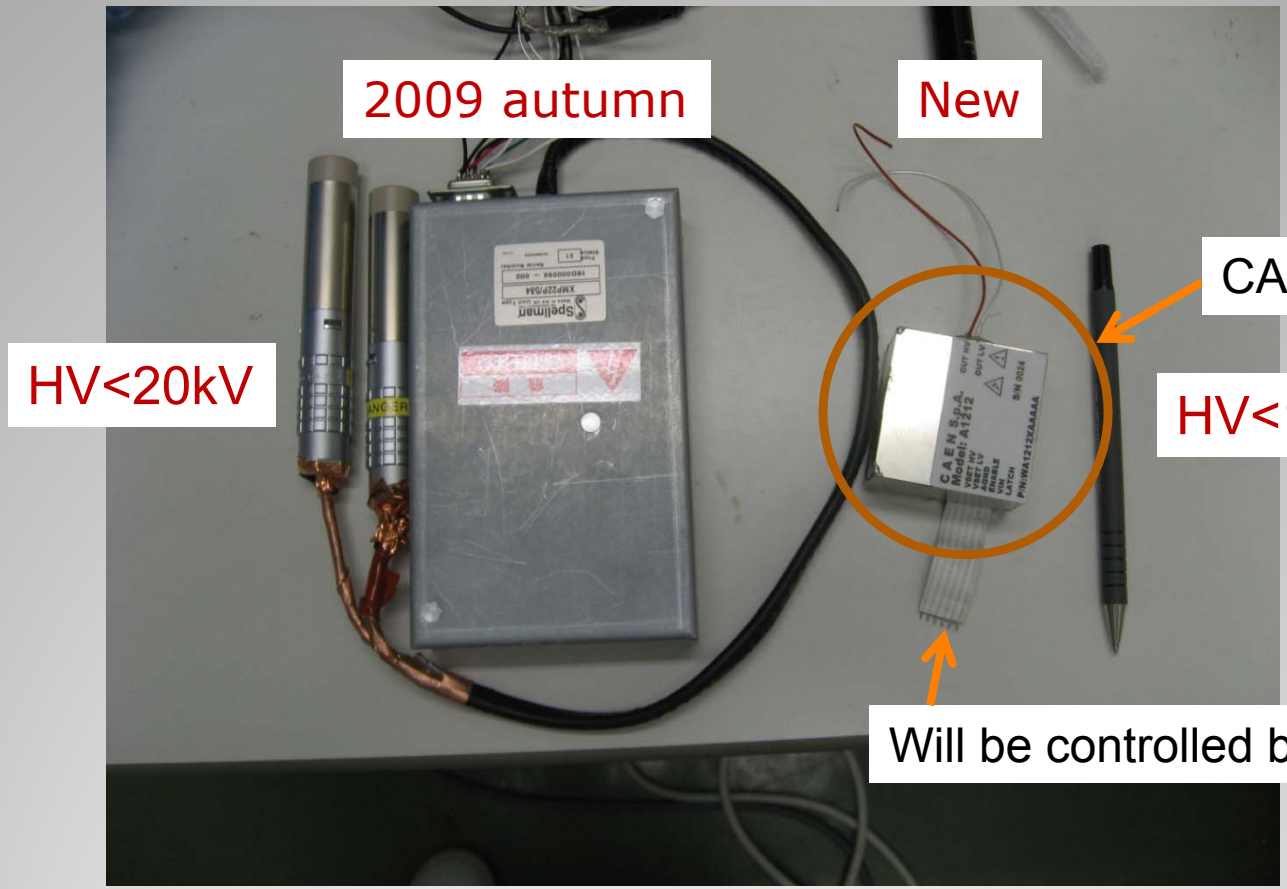
Clear Pulse height separation

Pulse height distribution

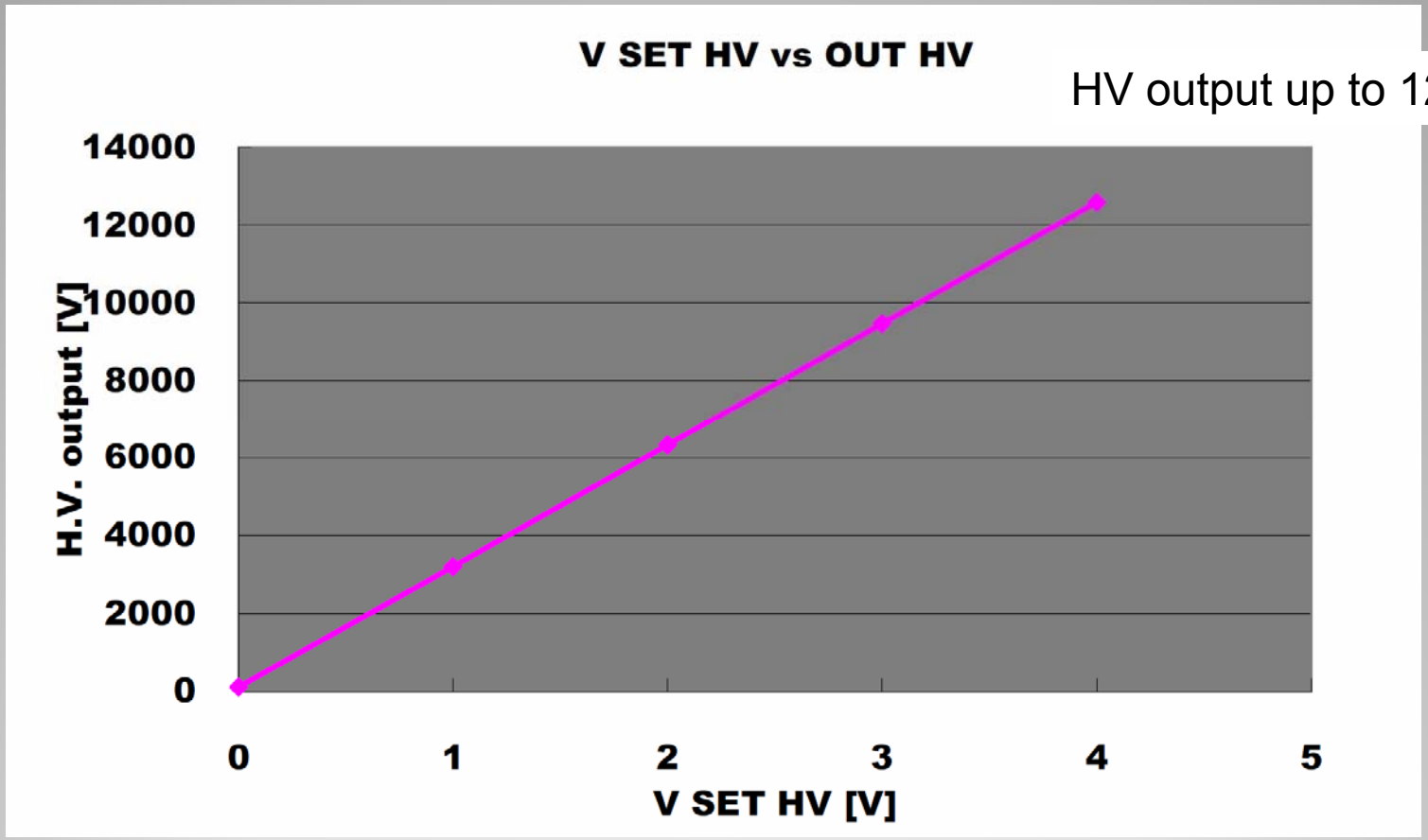


All-glass HAPD works well as we expected.

Time resolution

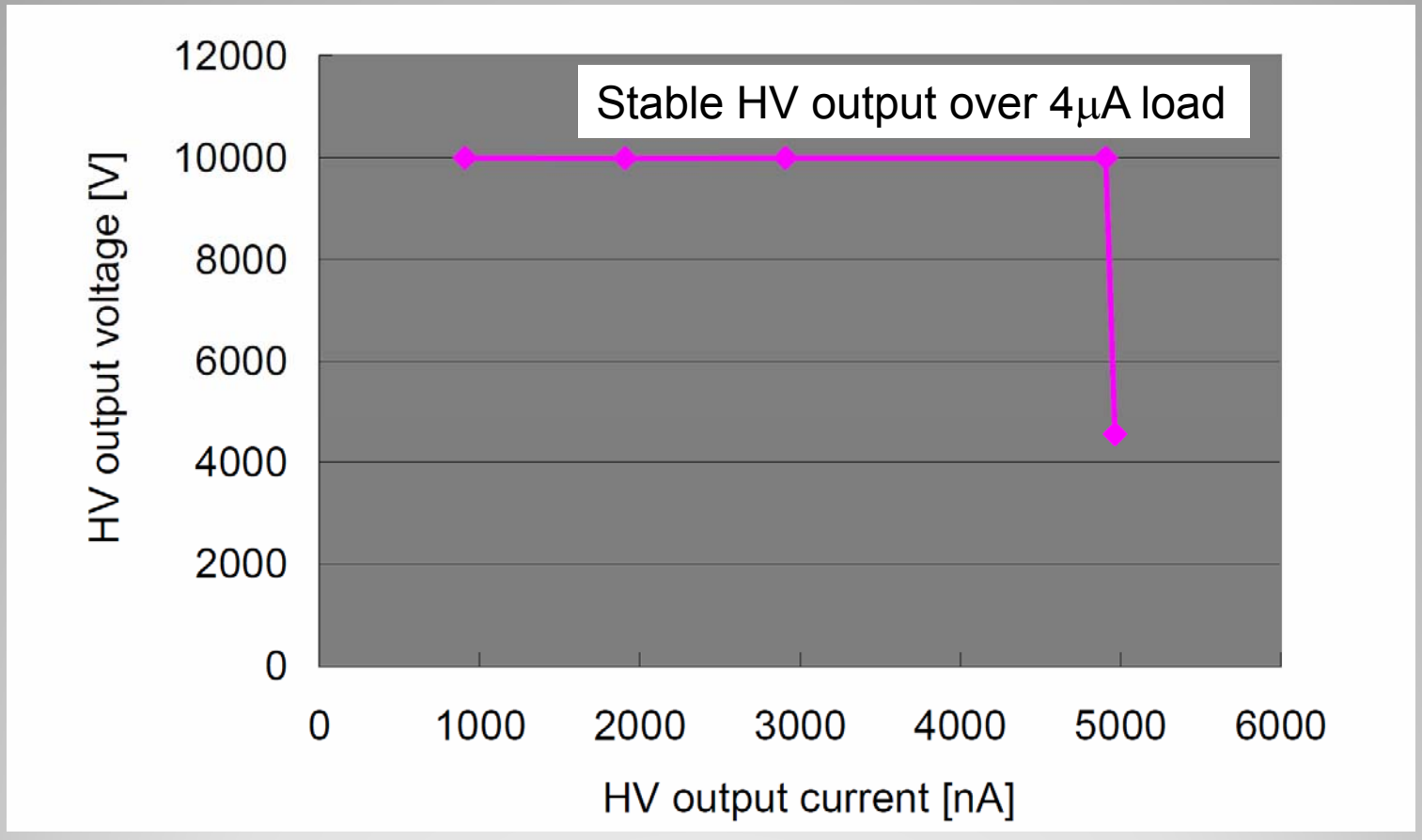


Compact HV supply



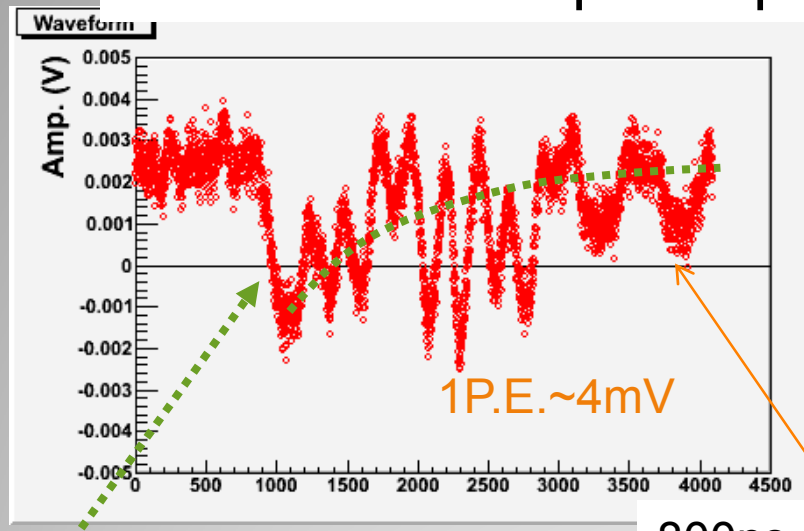
HV output up to 12kV

HV output



HV output vs. load current

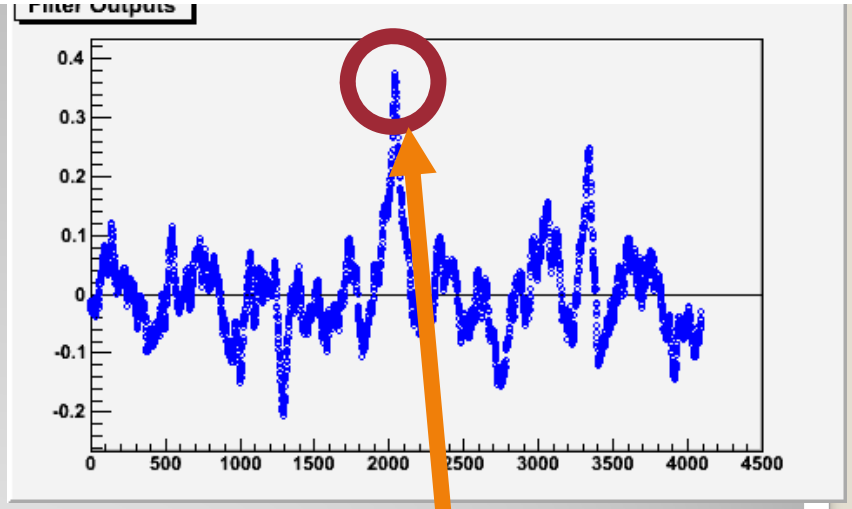
Waveform after preamp.



5GS/s 4096pts

Signal

After digital signal processing



Signal separation

- Robust again noise

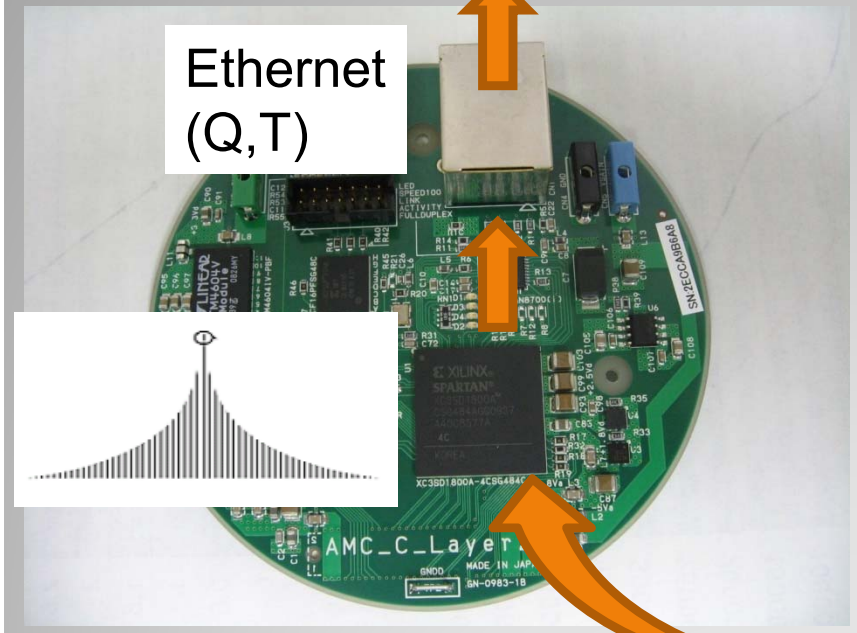
→meet HAPD usage

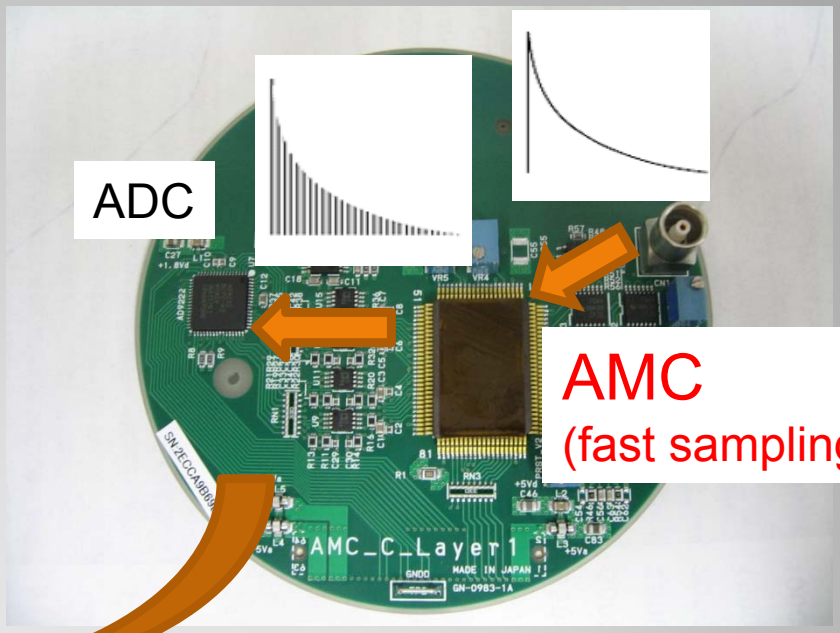
Measured under very NOISY environment for demonstration purpose

Digital signal processing

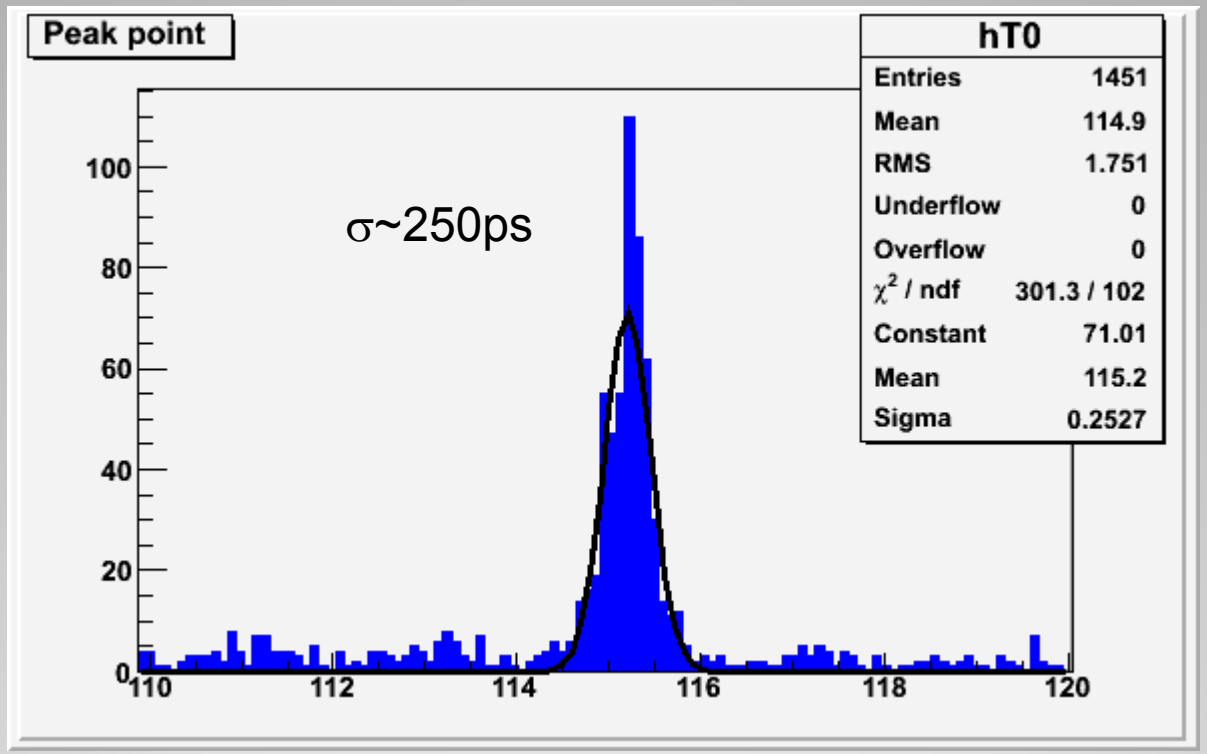
Digital part (DSP+Ethernet)

Analog part (fast sampling)





Readout system

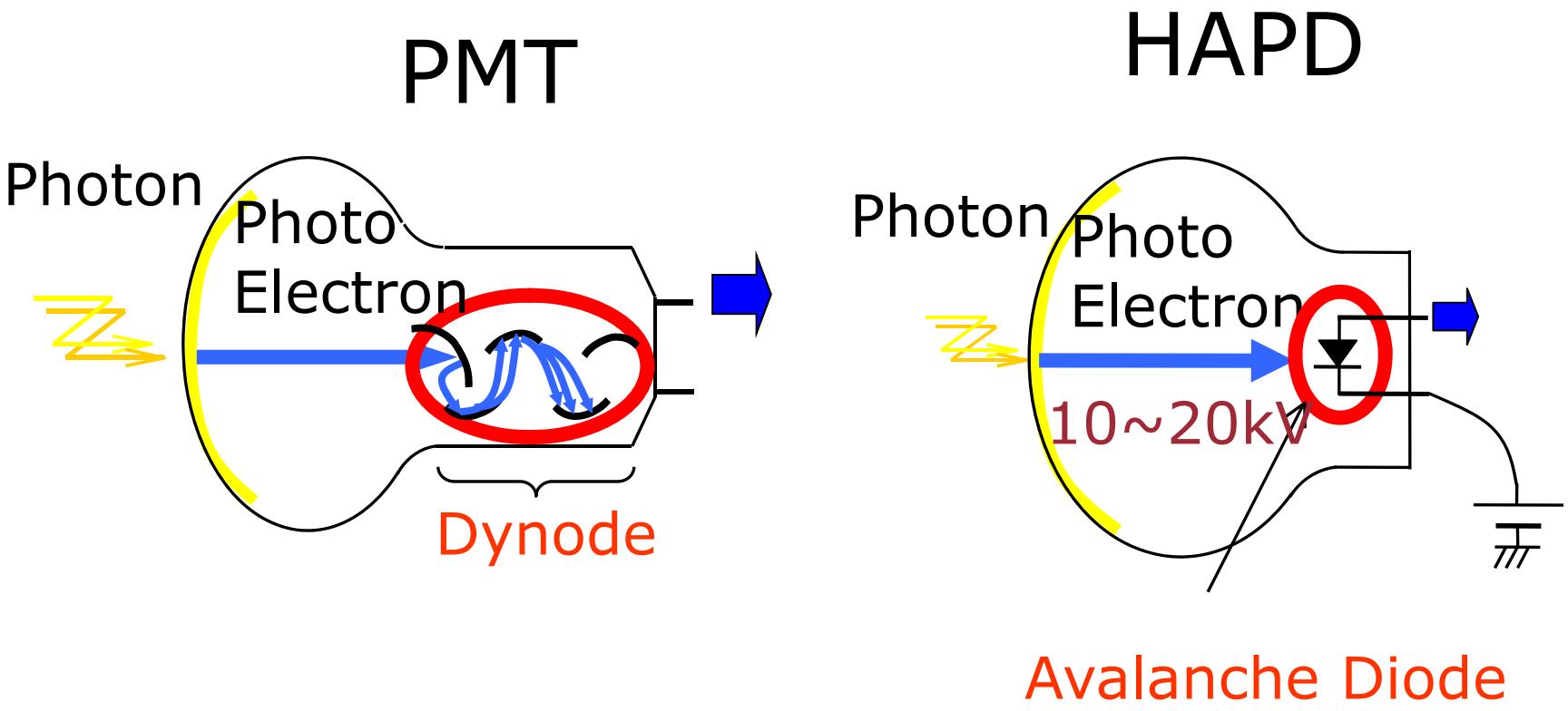


Time resolution

Summary

- We develop large aperture HAPD and its readout system showing superiority than conventional PMTs.
- HAPD will be commercially released on the next March.
- All-glass HAPD is developed and its dark count rate downs to PMT level.
- Compact HV supply is available.
- Compact readout system including fast sampling + DSP + Ethernet output is developed.

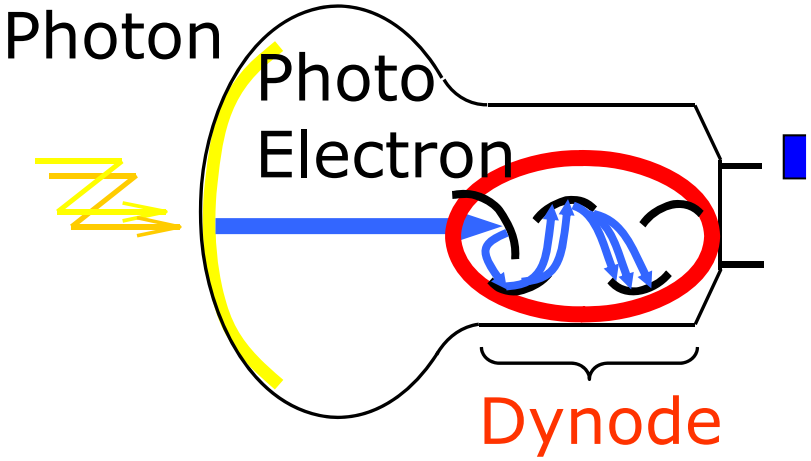
Backup slides



Operation principle

Operation Principle

PMT

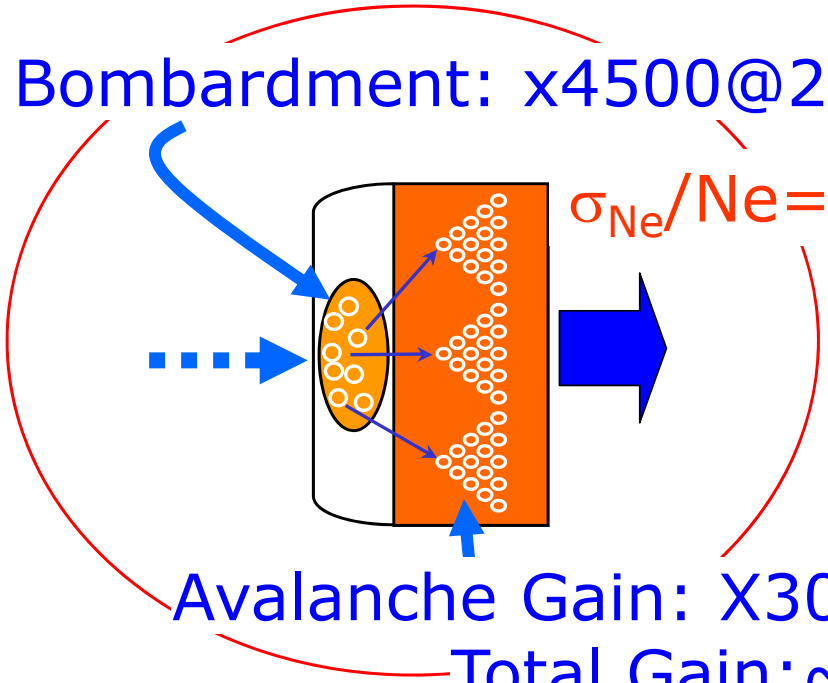


1st Dynode Gain:
x5

$\sigma_{Ne}/Ne=44\%$

Total Gain:~10^7

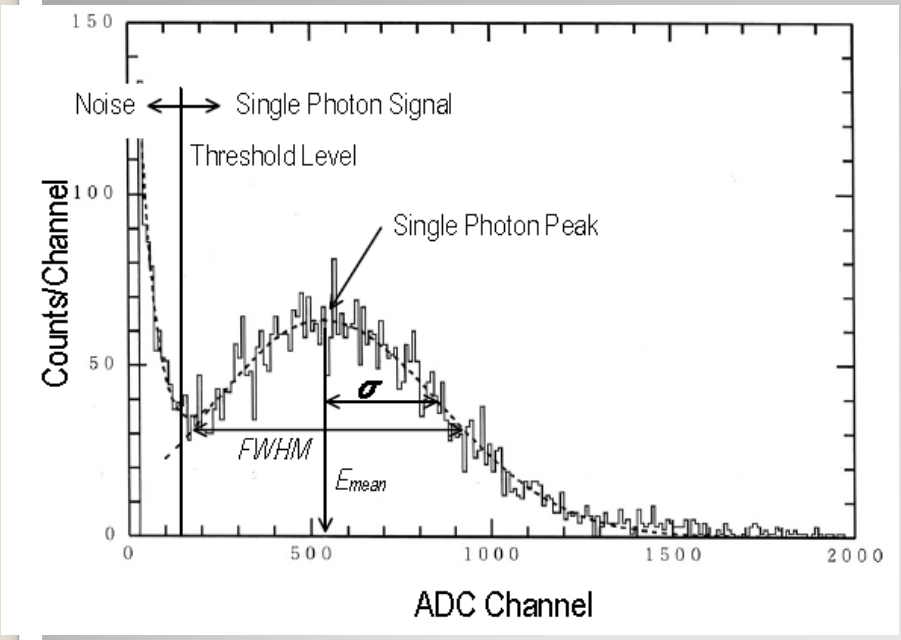
HAPD



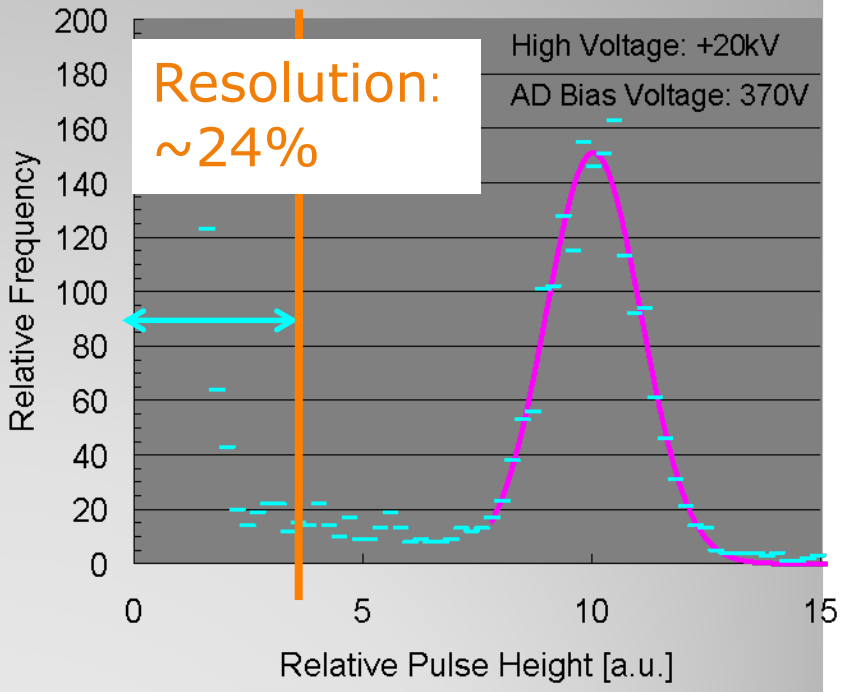
HAPD features

- Large gain at the first electron multiplication
  →Good single photon energy resolution and detection efficiency
- No dynode
  →Good time resolution
  →Cost reduction and easy quality control
- Low gain
  →Need dedicated readout system
- High voltage (10kV~20kV)

- PMT(SuperK)



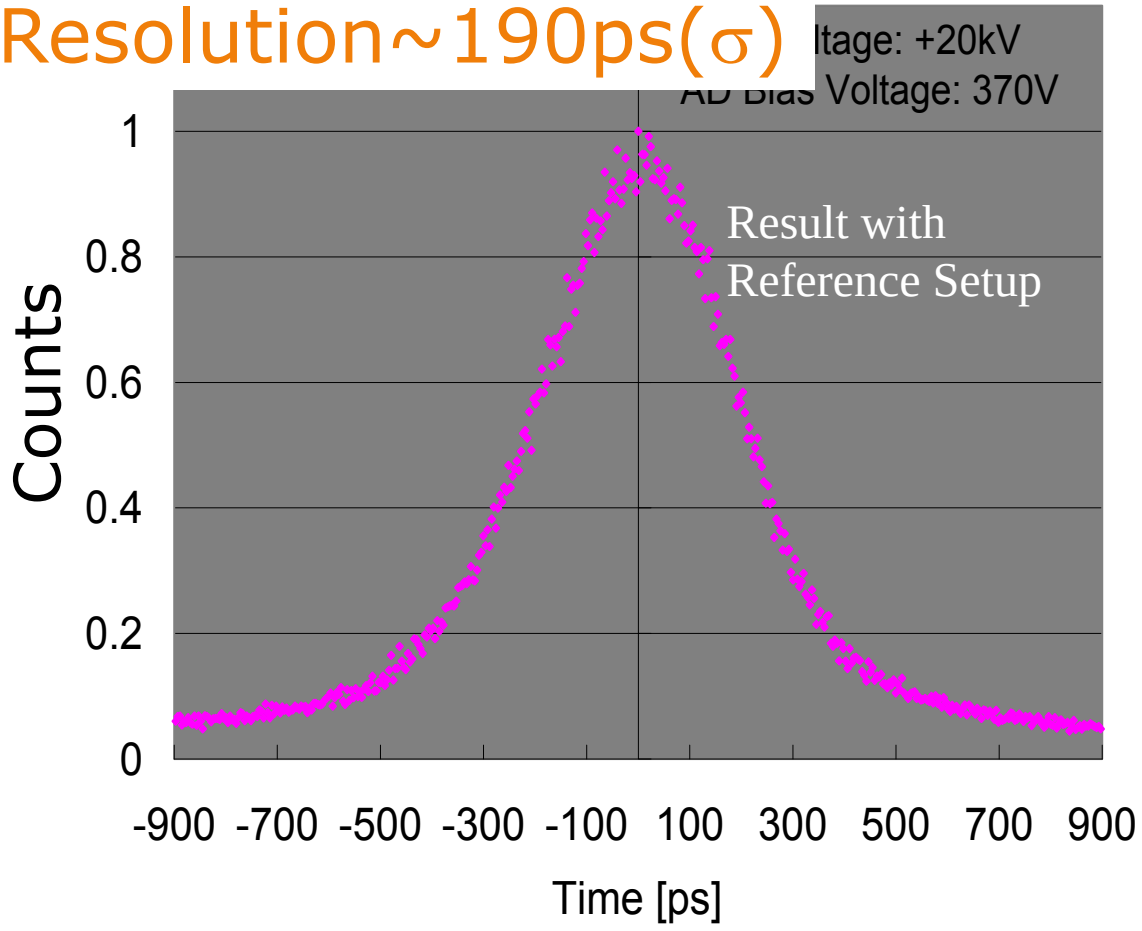
- HAPD



Excellent SN separation gives good single P.E. detection by threshold effect.

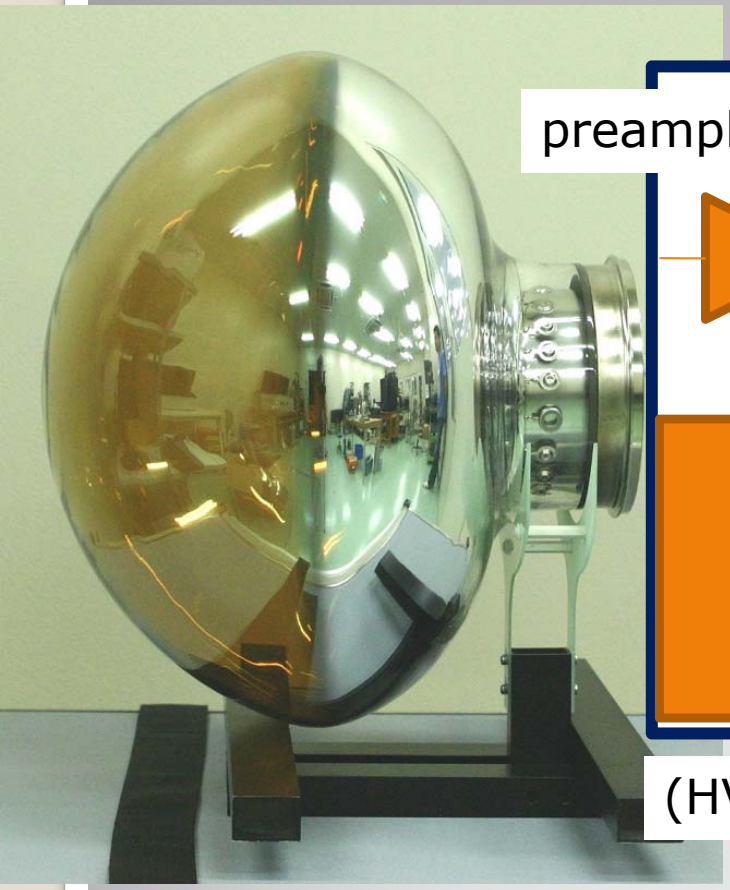
Pulse height resolution @ 1P.E.

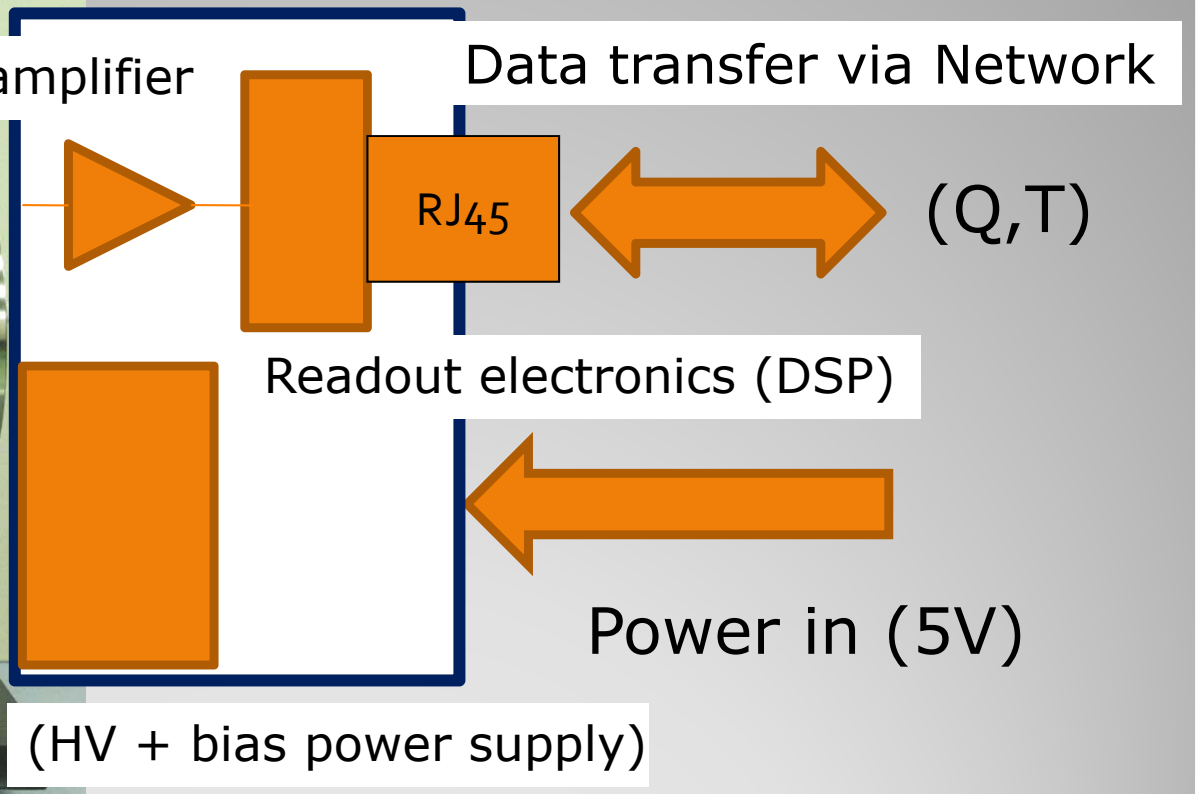
Resolution~190ps(σ)



Time resolution @ 1P.E.

Compact detector with only Network + Power supplies.





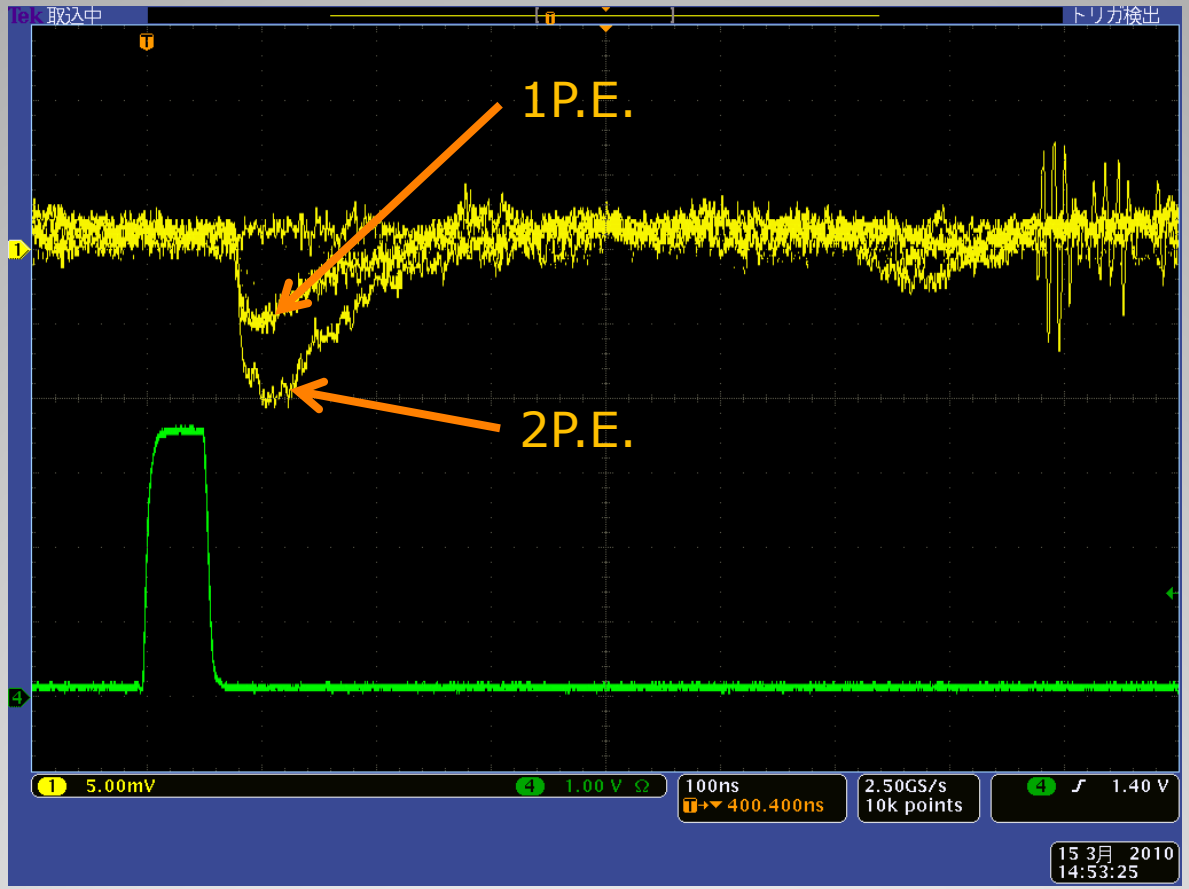
Digital HAPD

AMC vs. FADC

	AMC (+slow FADC)	FADC (ADC081000 N.S.)
Sampling Freq.	~1GHz	1GHz
Supply voltage	+5V	+1.9V
Power/channel	72mW(*) (+160mW FADC)	1.45W
Resolution	≥10bit	~8bit

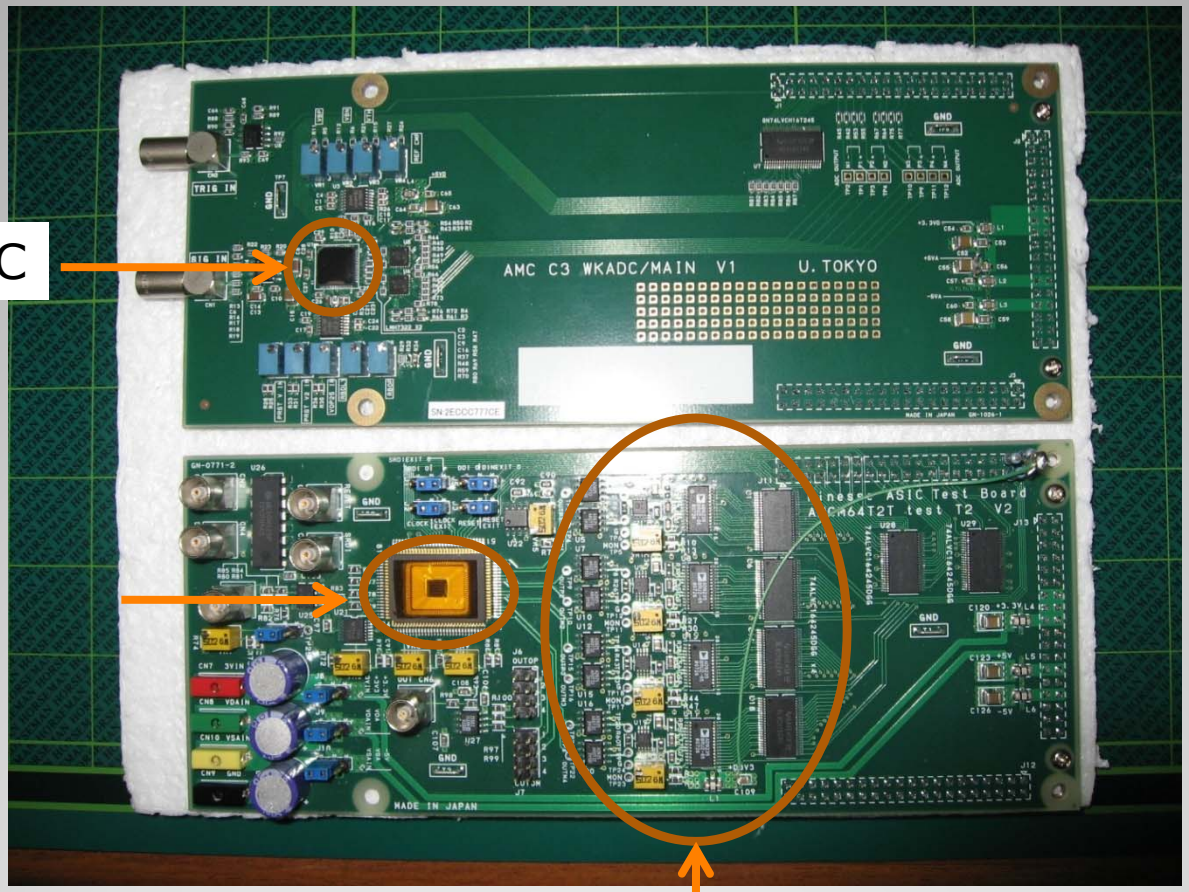
(*) readout clock=200kHz

Lower power consumption and higher resolution.



All-glass HAPD + New HV supply

AMC with ADC



ADC related parts are gone…