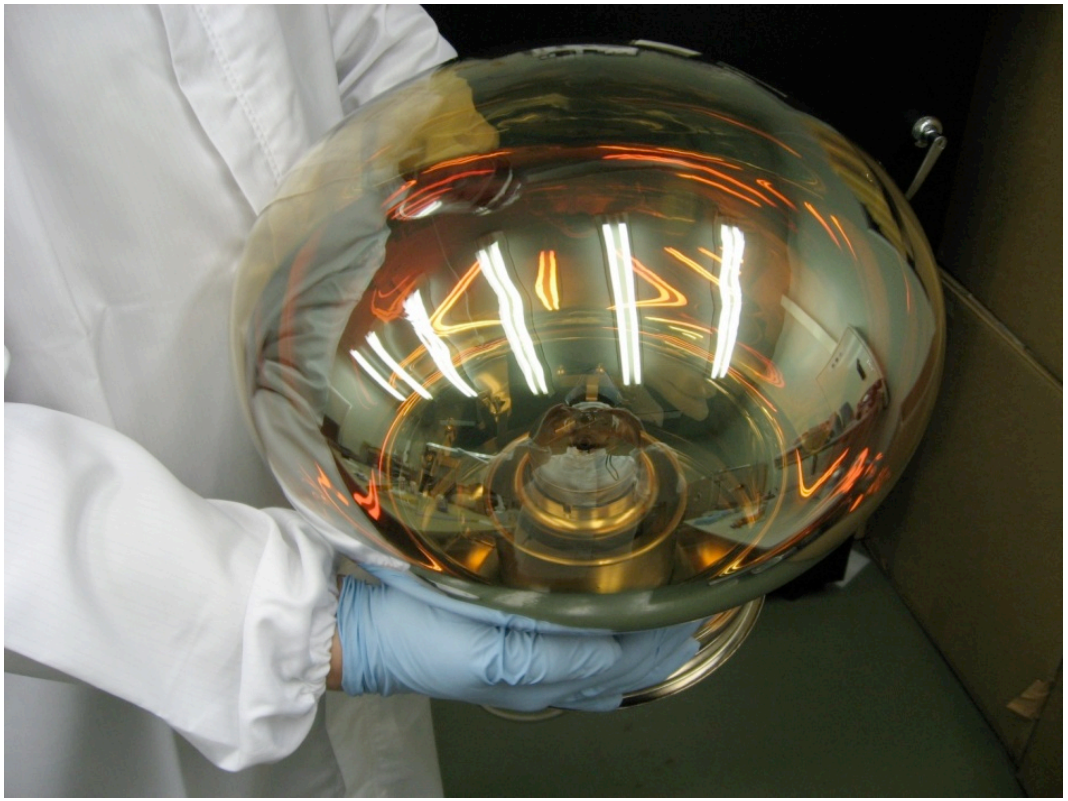
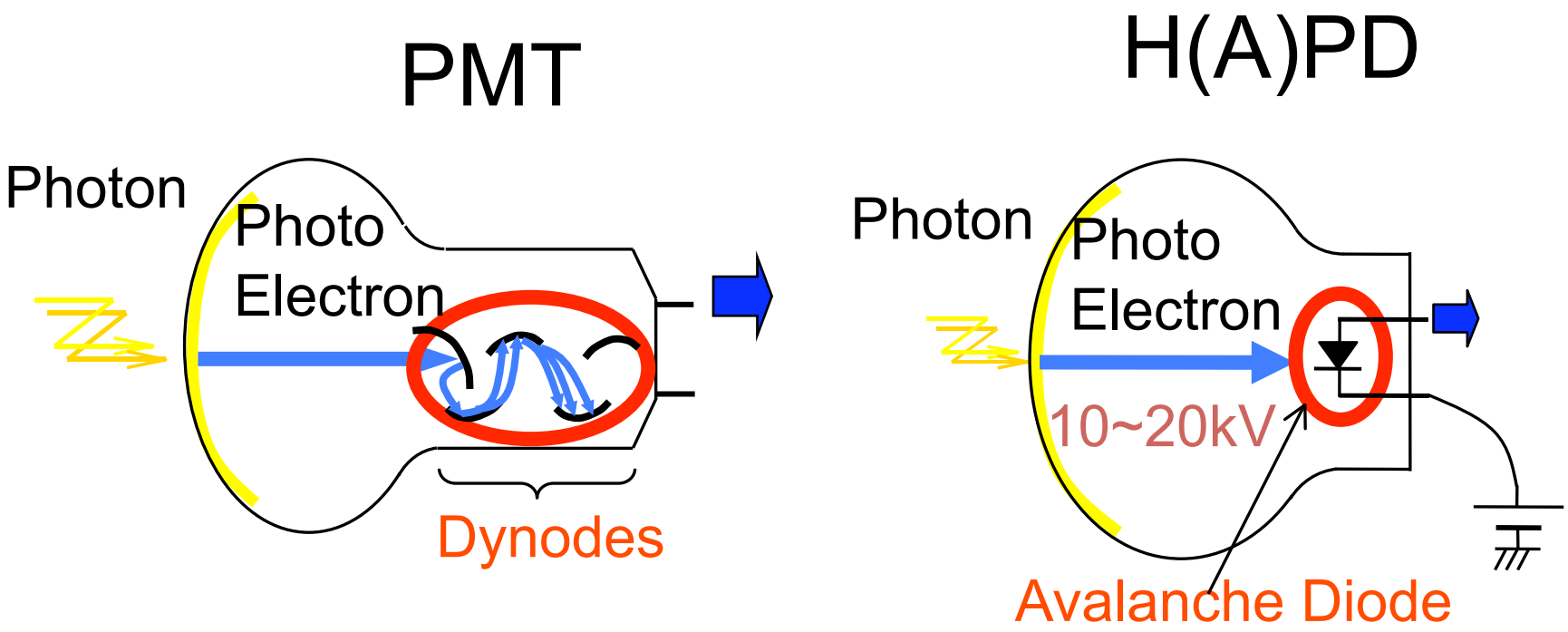
R&D of Large Aperture Hybrid Photodetector

H. Aihara, T. Abe, H. Fujimori, M. Iwasaki,
K. Kasimura, S. Mineo, T. Uchida
(University of Tokyo)
M. Tanaka
(KEK)
Y. Kawai, H. Kyushima, M. Suyama
(Hamamatsu Photonics)



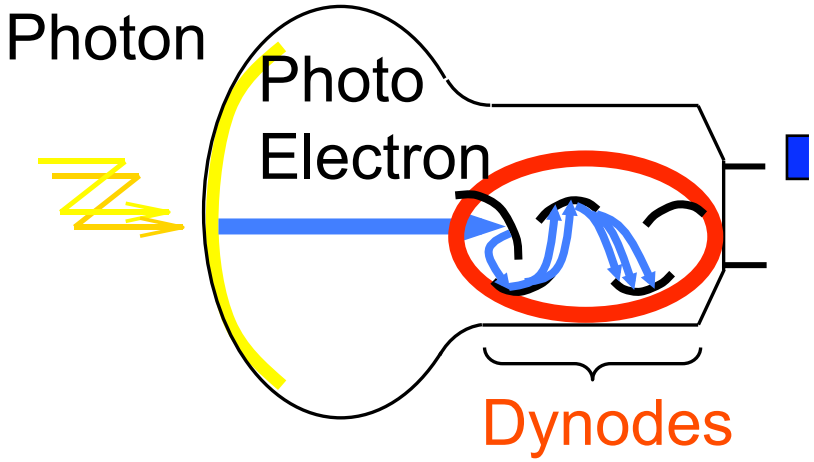
NNN08 International Workshop on Next Nucleon decay and Neutrino detectors, Paris, 1-13 September 2008.

Operation Principle of HPD



Operation Principle

PMT

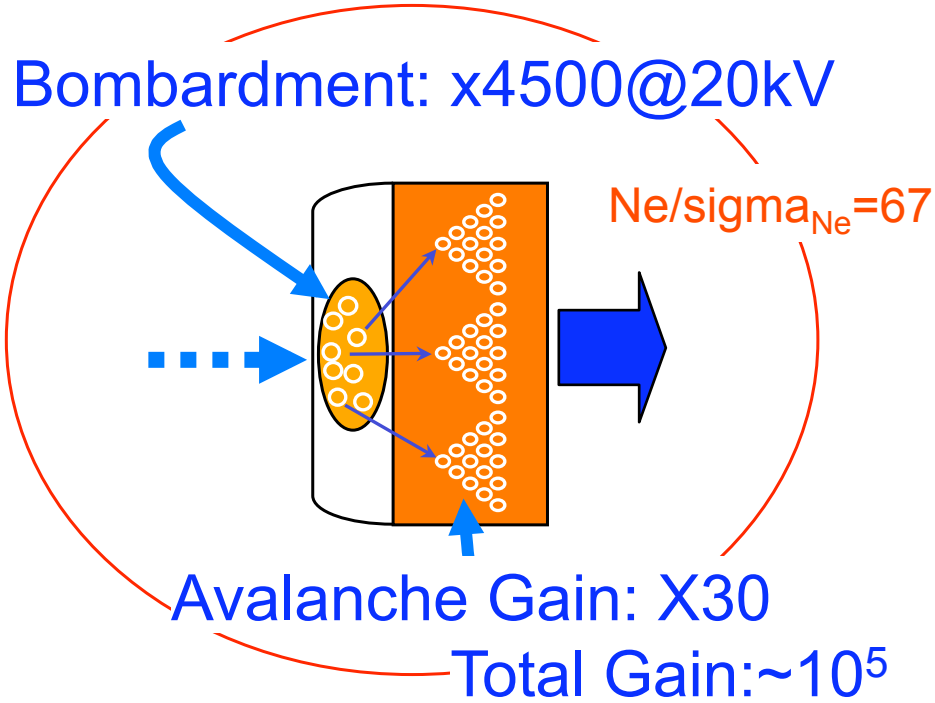


1st Dynode Gain: x5

$Ne/sigma_{Ne}$=2.2

Total Gain:~10^7

HPD



HPD features

- Large gain at the first electron multiplication

  →Good single photon energy resolution and detection efficiency

- No dynodes

  →Good time resolution

  →Cost reduction and better quality control

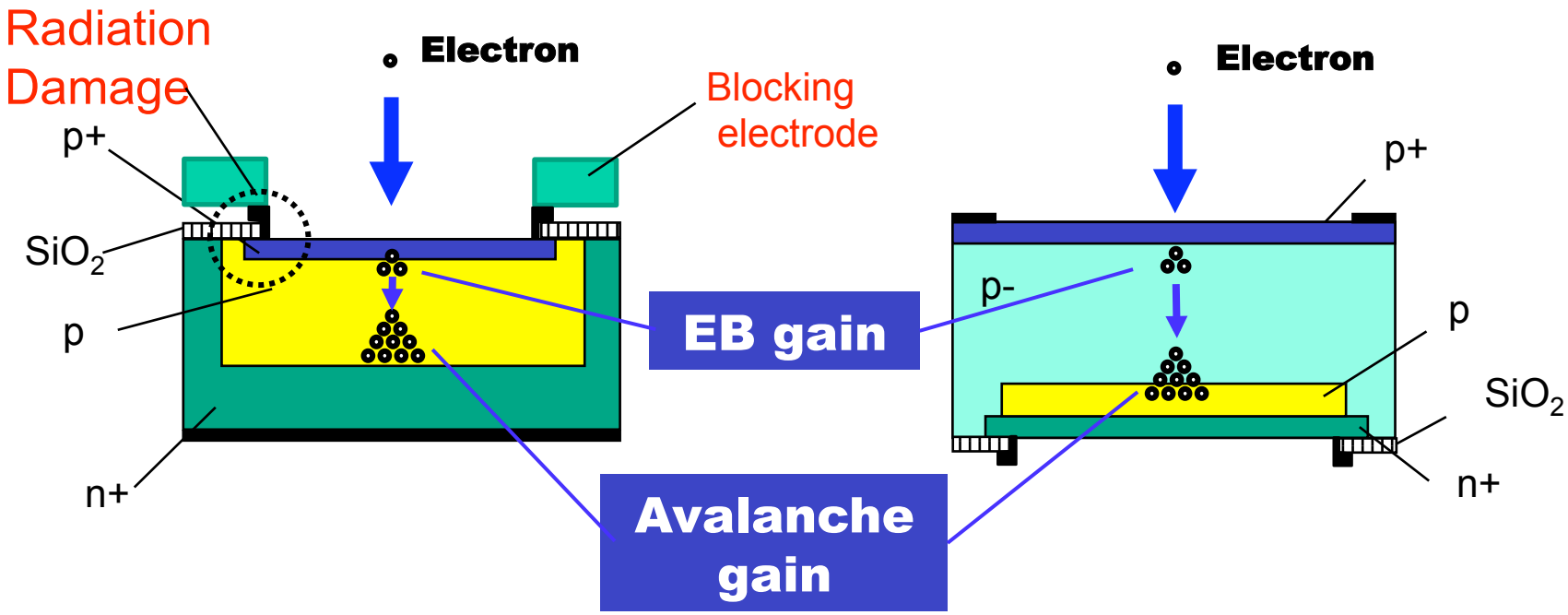
- Low gain

  →Need low-noise readout system

Major difficulties have been overcome.

- Large avalanche diodes.
- Activation of photocathode with AD inside.
- Sustaining HV (up to 20 KV)
- Low noise electronics
- Waveform sampling

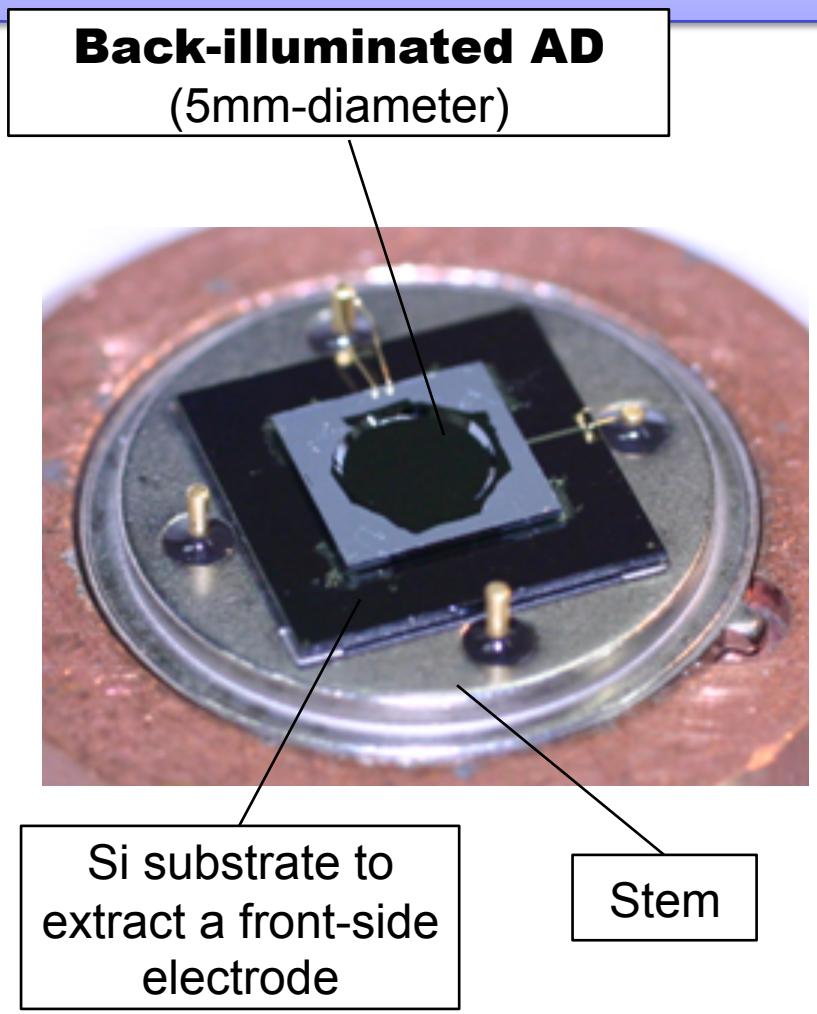
Front- vs Back-illuminated AD



Front-illuminated AD

Back-illuminated AD

Back-illuminated AD has advantages



EB-Gain: 4500 at -20kV

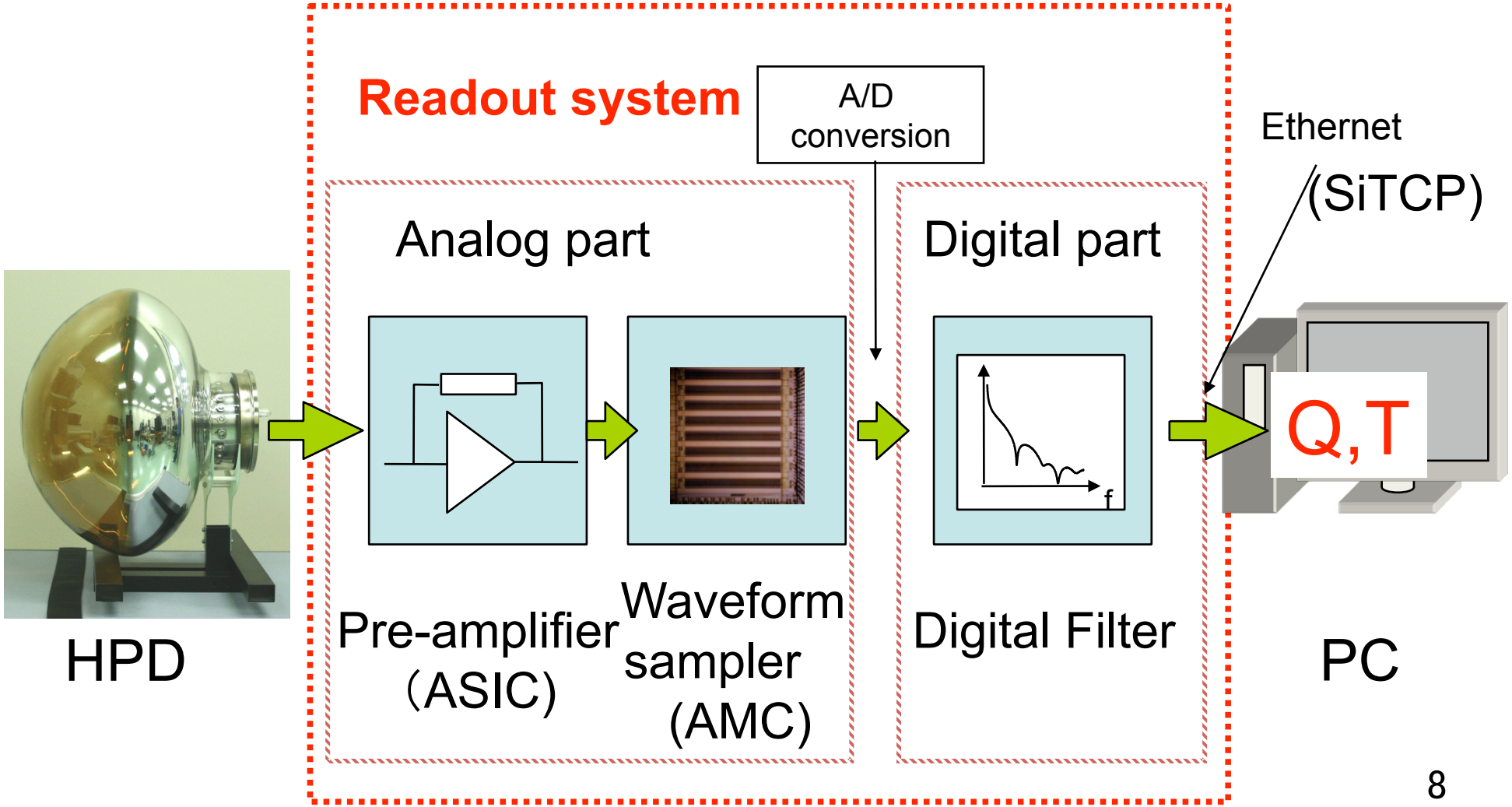
AD-Gain: 50 at 390V

No increase in dark current after 1000h operation at 4mA.

Front-illuminated AD shows gain drop and increase of dark current, even with the blocking electrode.

A sign of radiation damage.

HPD readout system

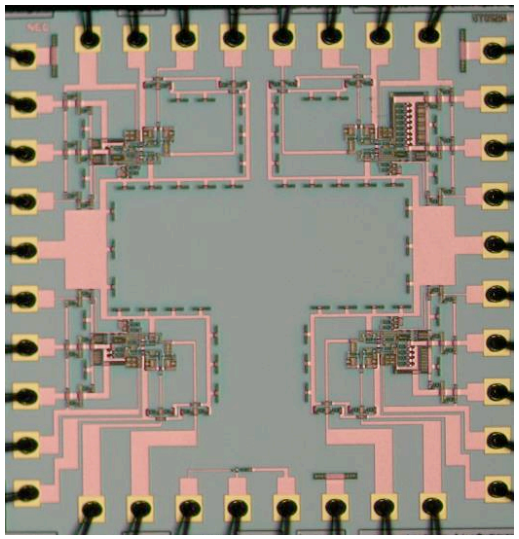


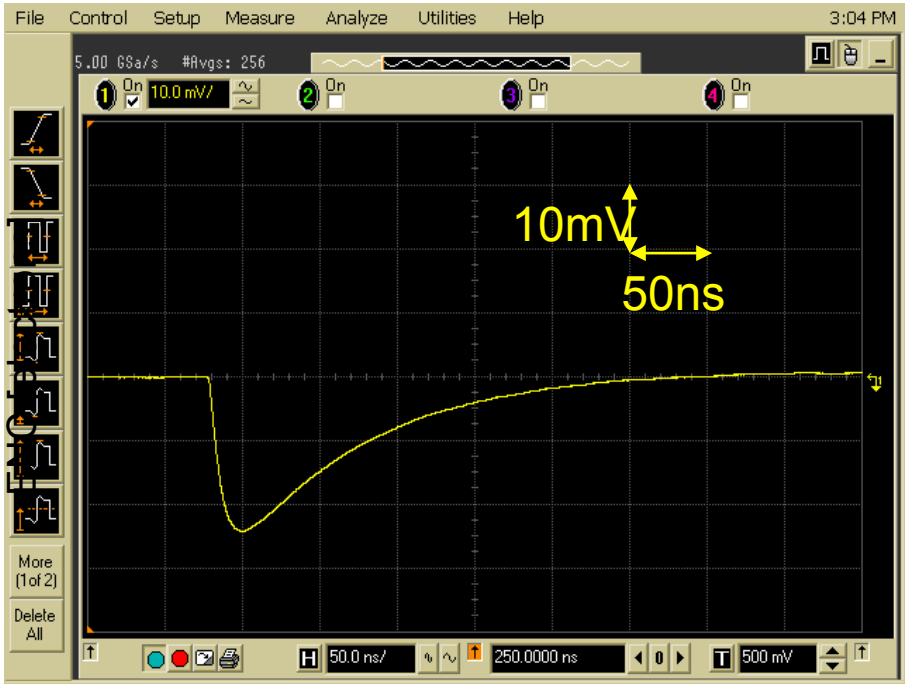
Front-end

Gain=1V/pC

Pulse shape at frontend ASIC

Preamplifier (ASIC)





Charge-sensitive amp.

Rise time =5.8ns at Cd=40pF

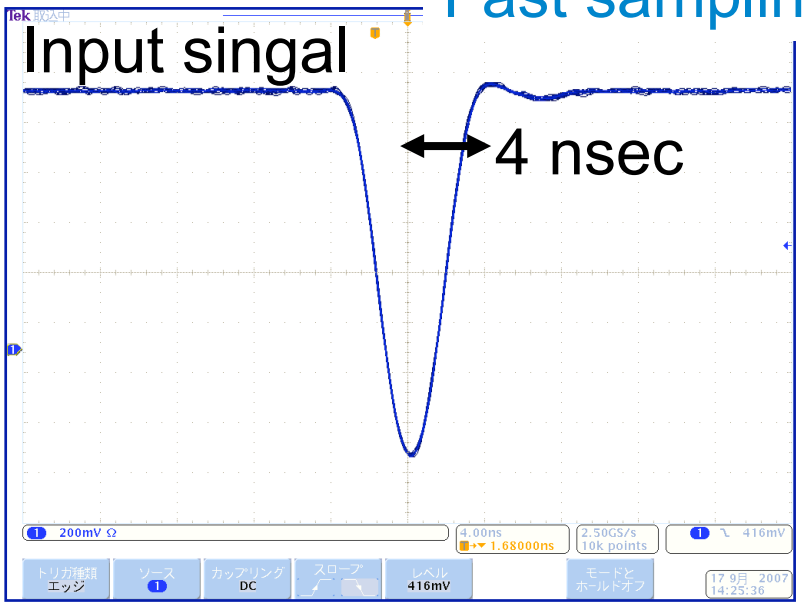
Input: HPD signal

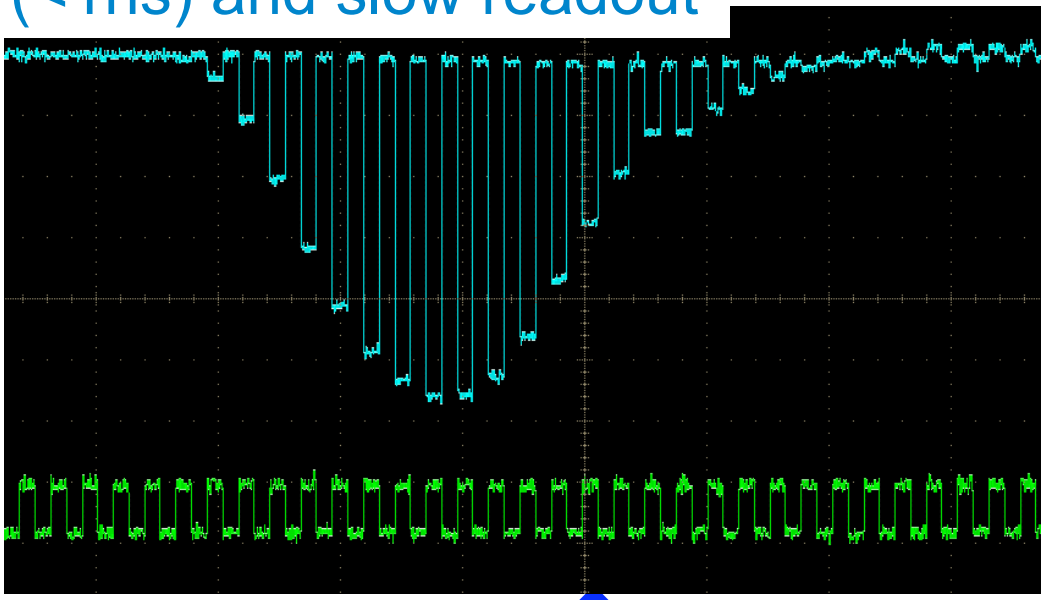
Intrinsic noise (ENC) ~3400 electrons at Cd=40pF

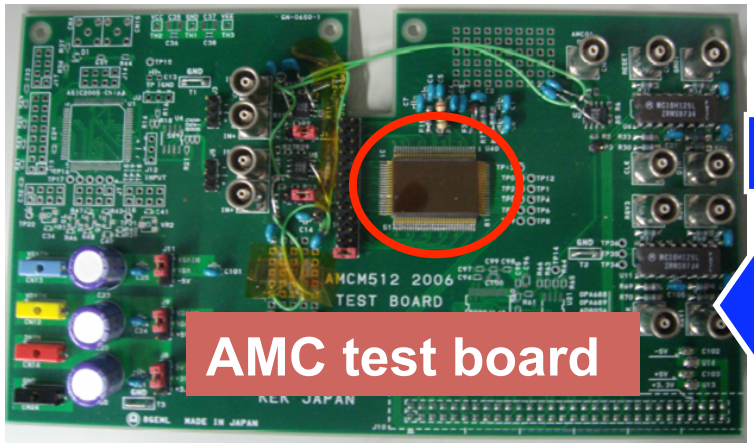
S/N(ideal)=100000/3400~30

Analog Memory Cell operation

Fast sampling (<1ns) and slow readout





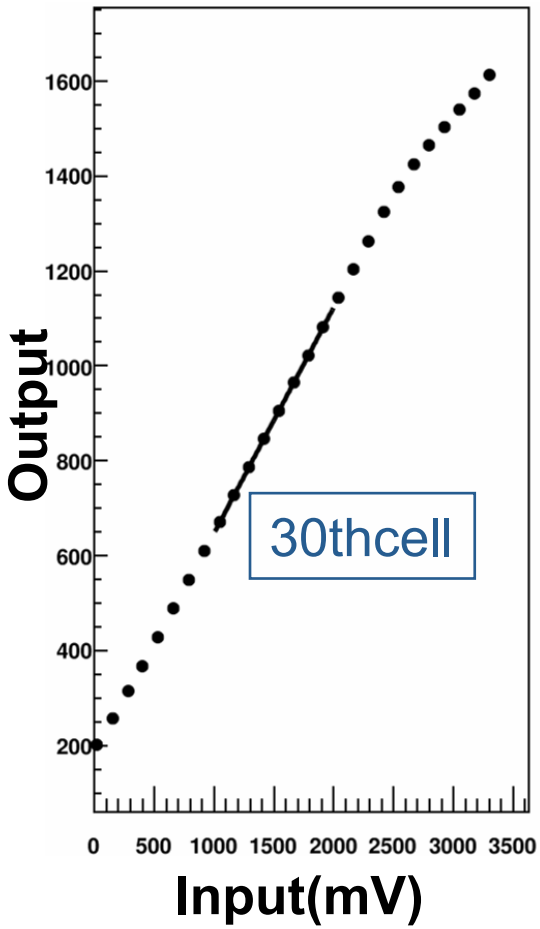


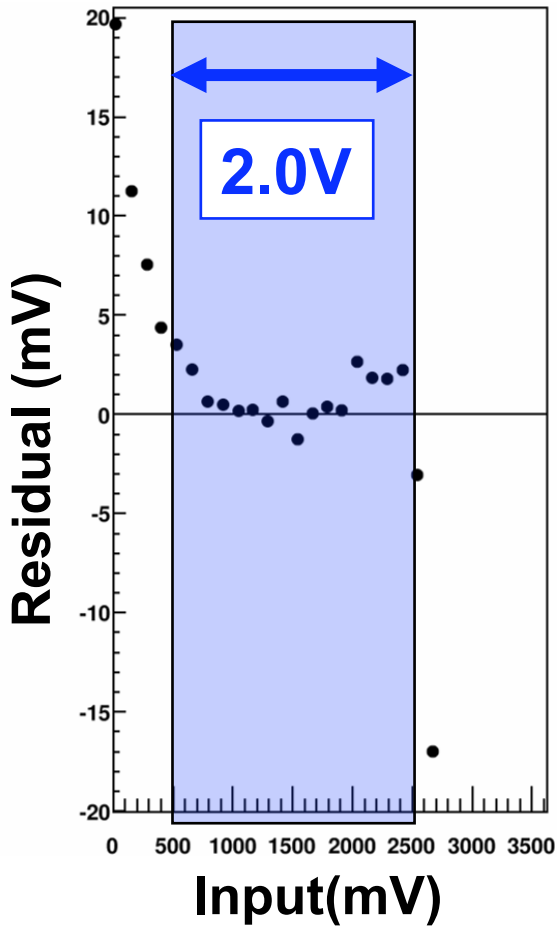
trigger

Clock

AMC characteristics

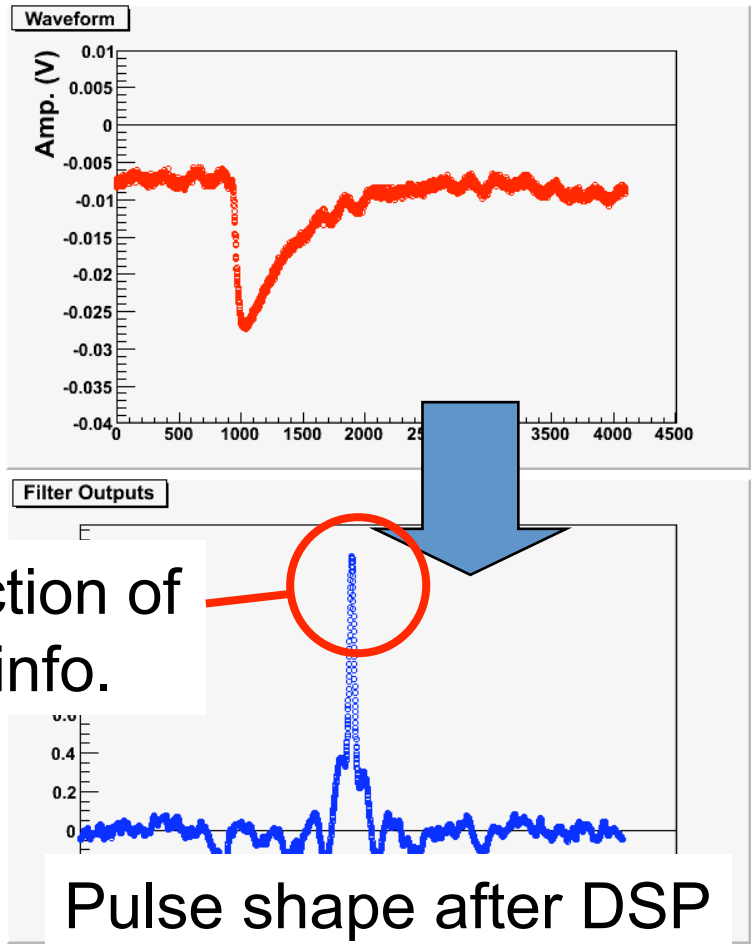
Sampling speed	1Gsps
Analog band width	>100MHz (~500MHz design)
Power	~70mW/ch
Dynamic range	~2V/0.7mV (11bit)
Sampling depth	512-1024
Integral non-linearity	0.1% over 2V range
Noise	<1mV
Pedestal variation	~2mV
Readout clock	30 MHz





Deadtimeless daq can be realized

Digital part (DSP+SiTCP)



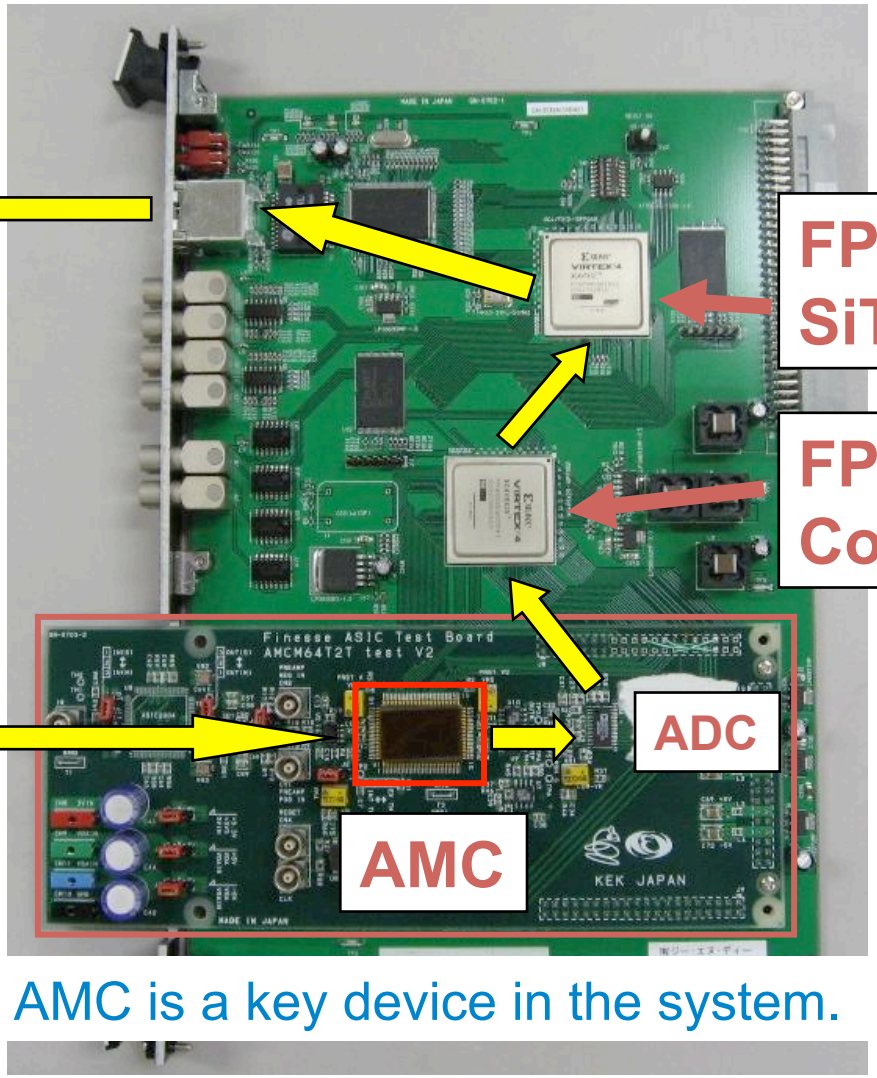
- Real-time signal processing
- Digital signal processing (matched optimal filter in FPGA)
- High speed data transfer with SiTCP (~1Gbps on Ethernet)

Prototype of readout system

Ethernet(<1Gbps)

(Q,T)

Signals from HPD



FPGA: SiTCP(Ethernet)

FPGA: Controller +DSP

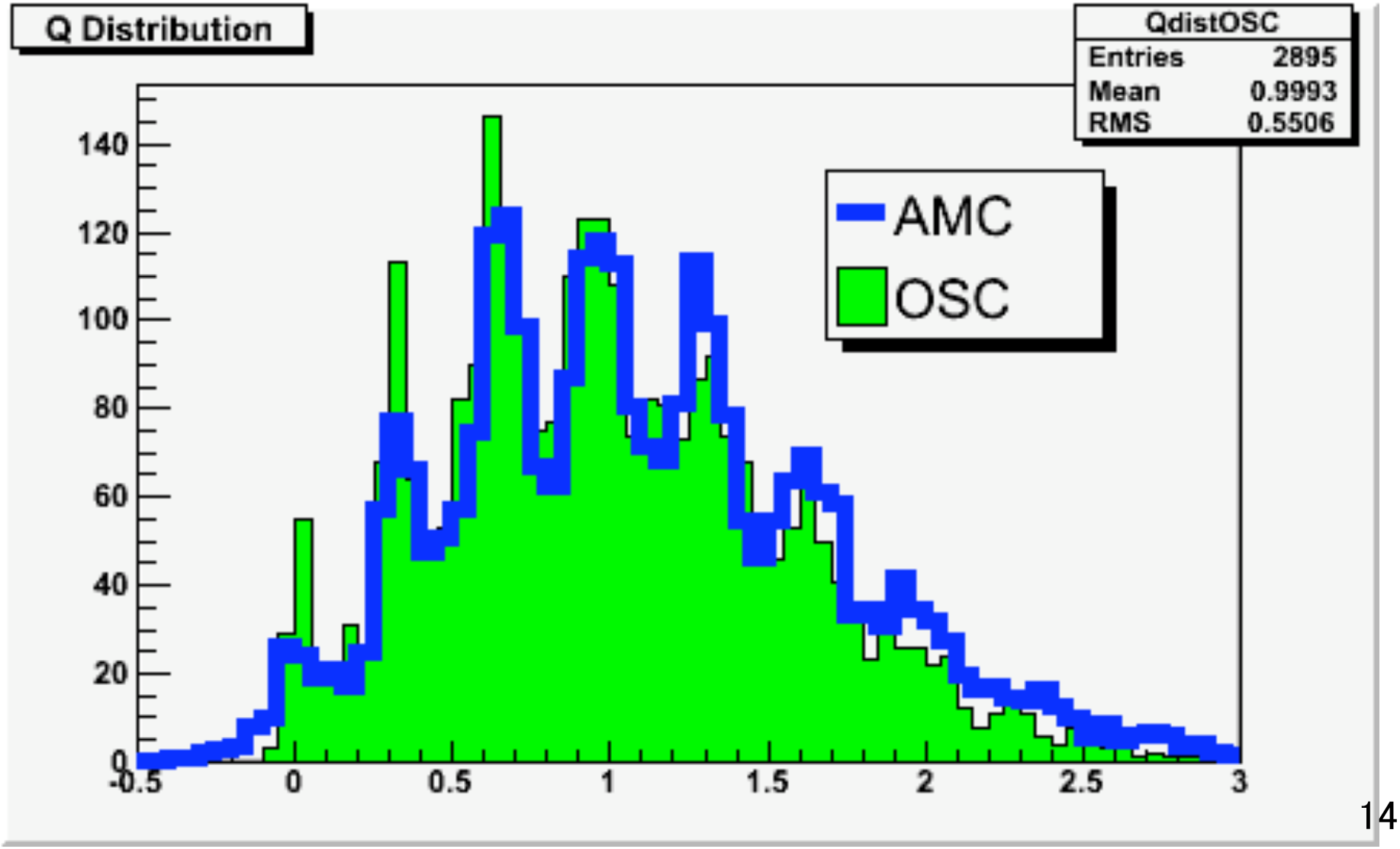
ADC

AMC

AMC is a key device in the system.

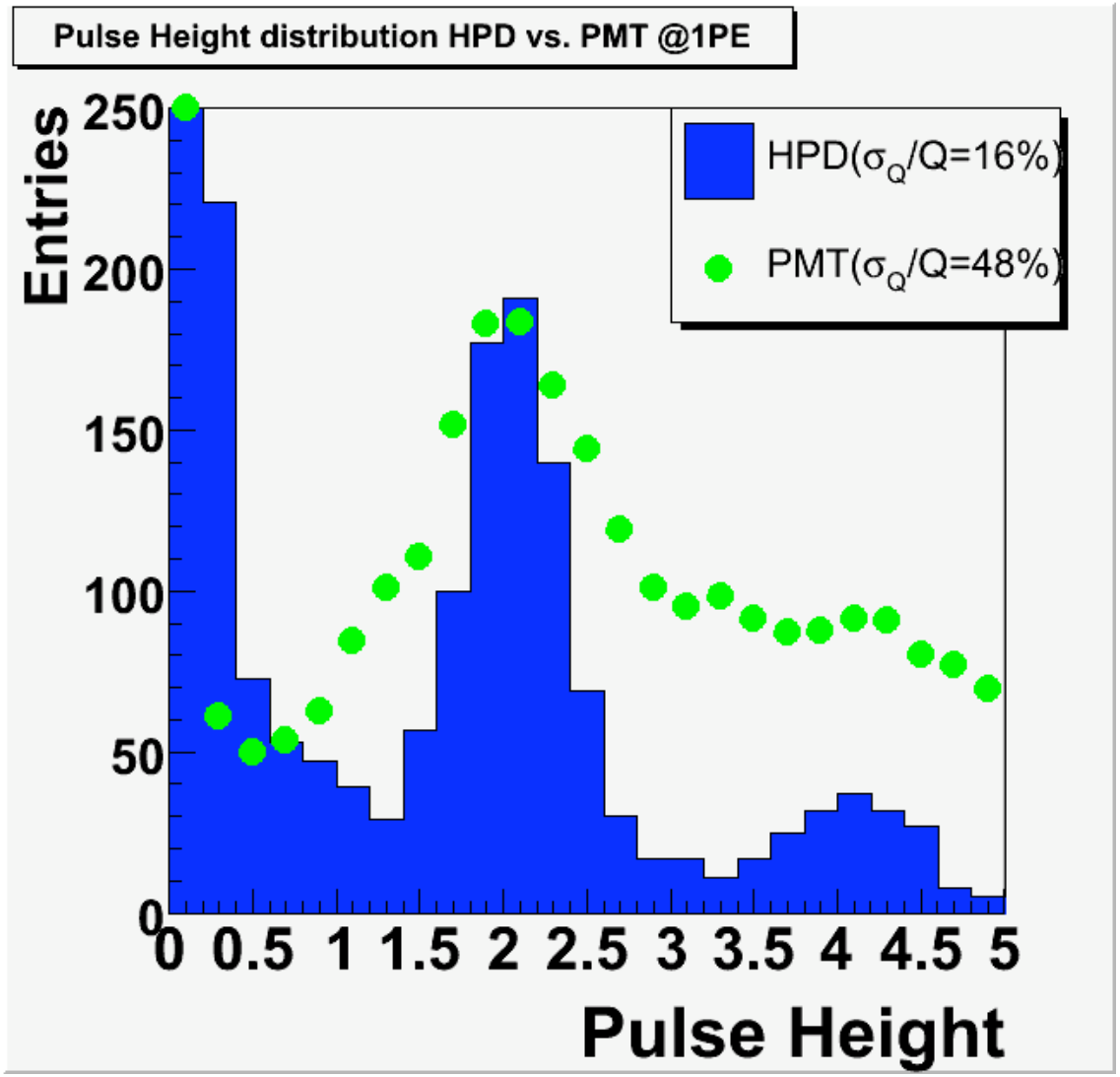
Energy distribution

Clear P.E. peaks up to 5.



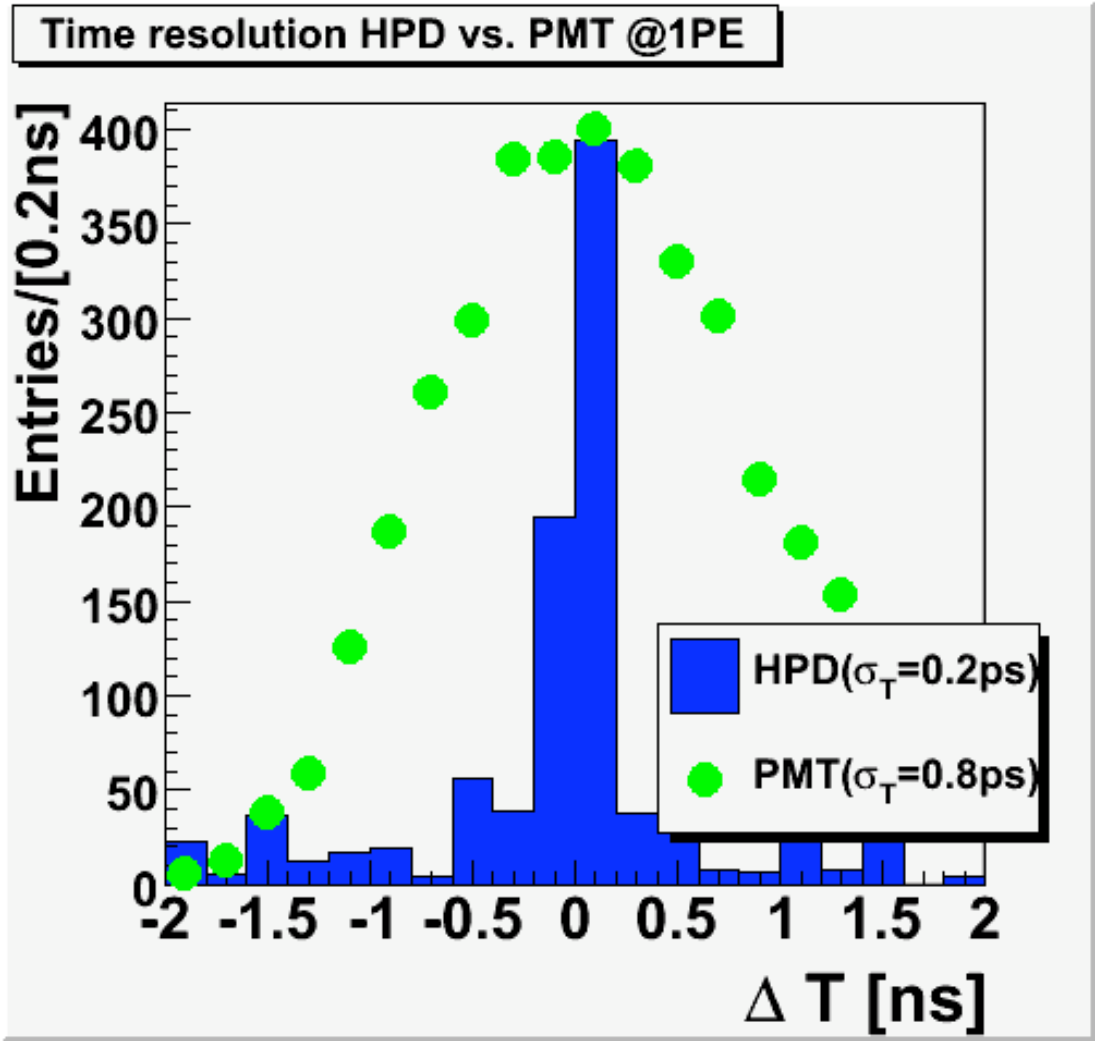
Energy resolution
13inch HPD vs. 13inch PMT

Spot PLP illumination

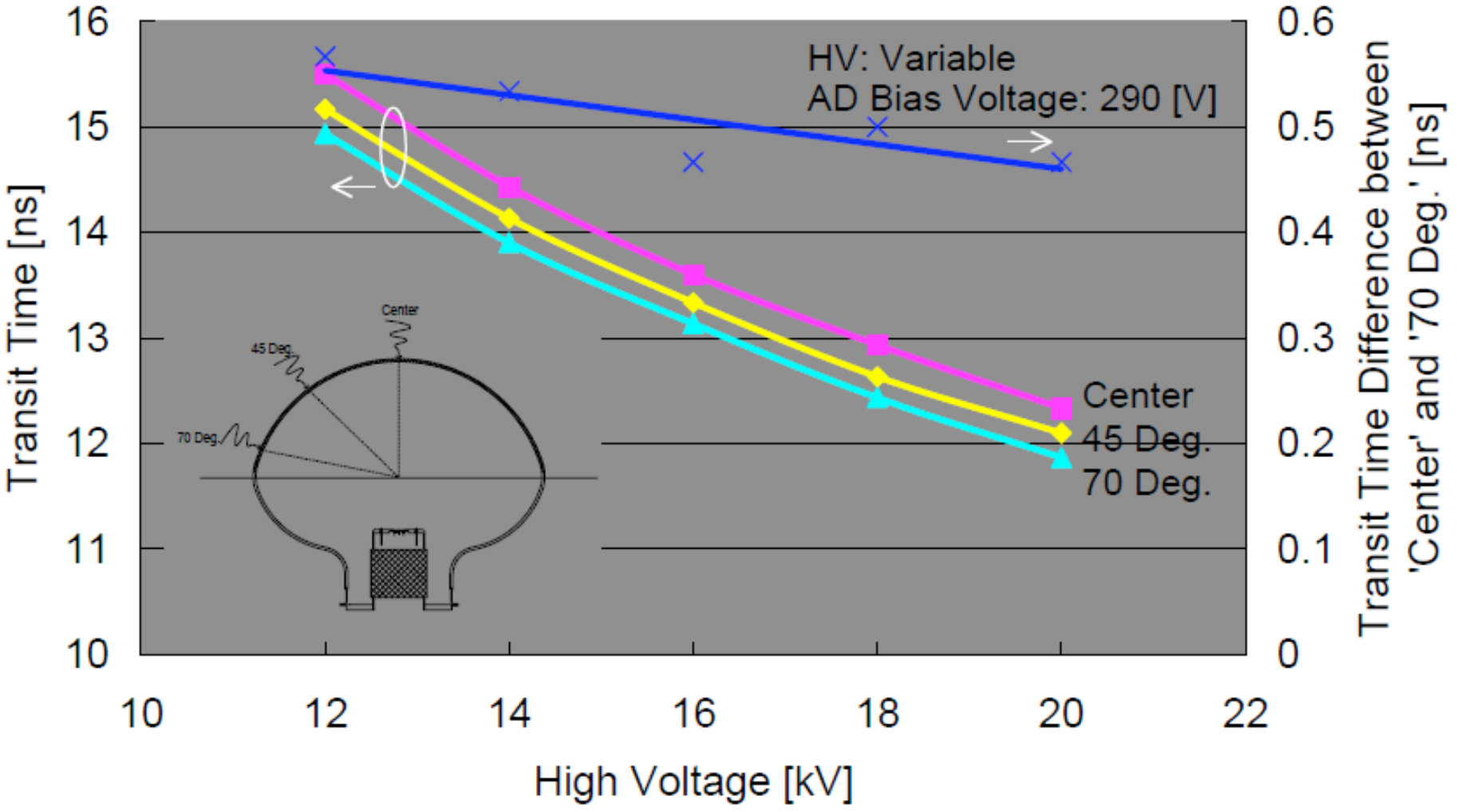


Time resolution (TTS) (13inch HPD vs. 13inch PMT)

Spot PLP illumination

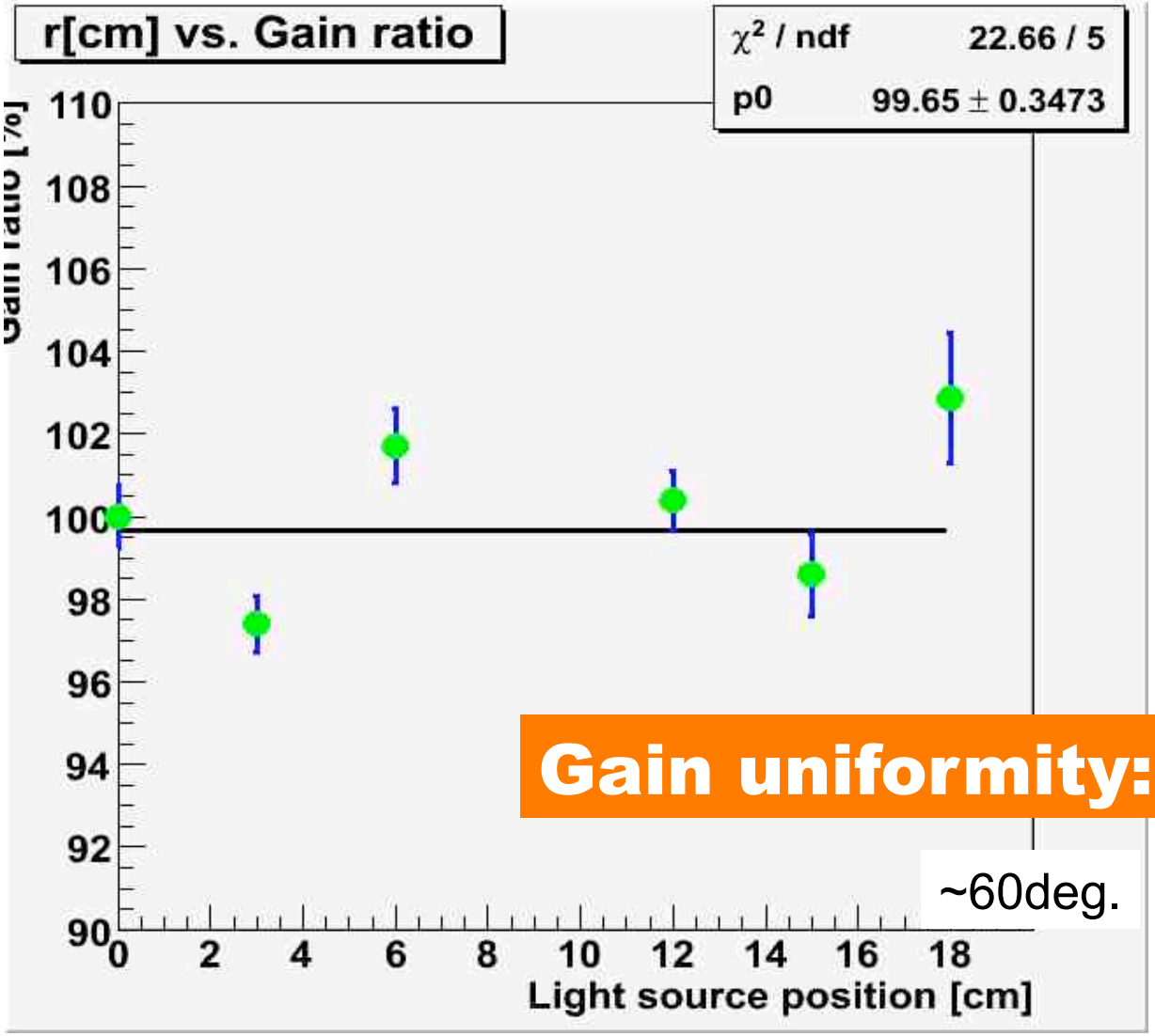


Timing resolution @ 1P.E.



Gain uniformity

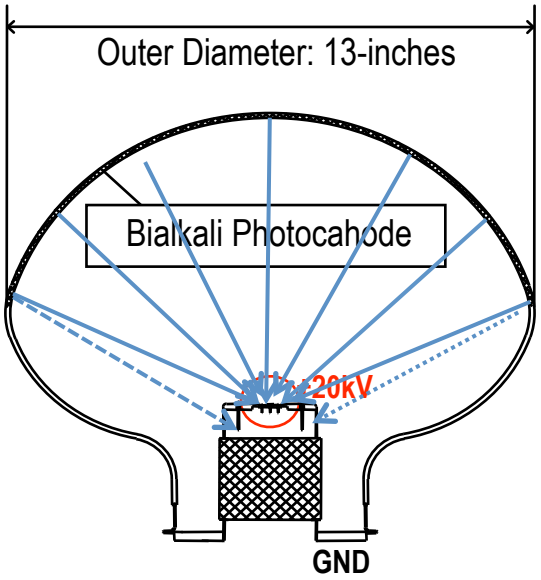
for photons<5



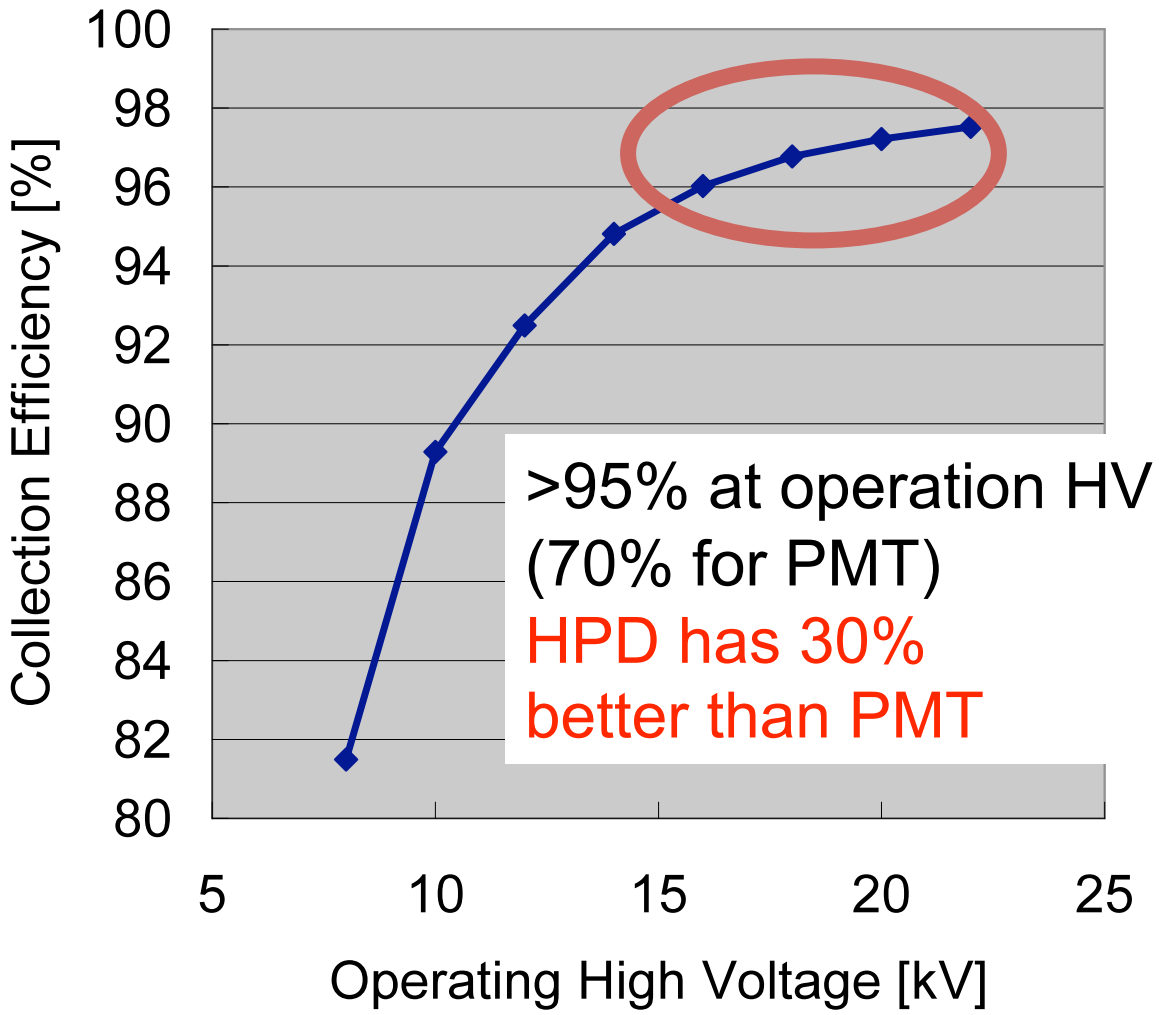
Gain uniformity:σ~2%

~60deg.

P.E. collection efficiency



Simulation

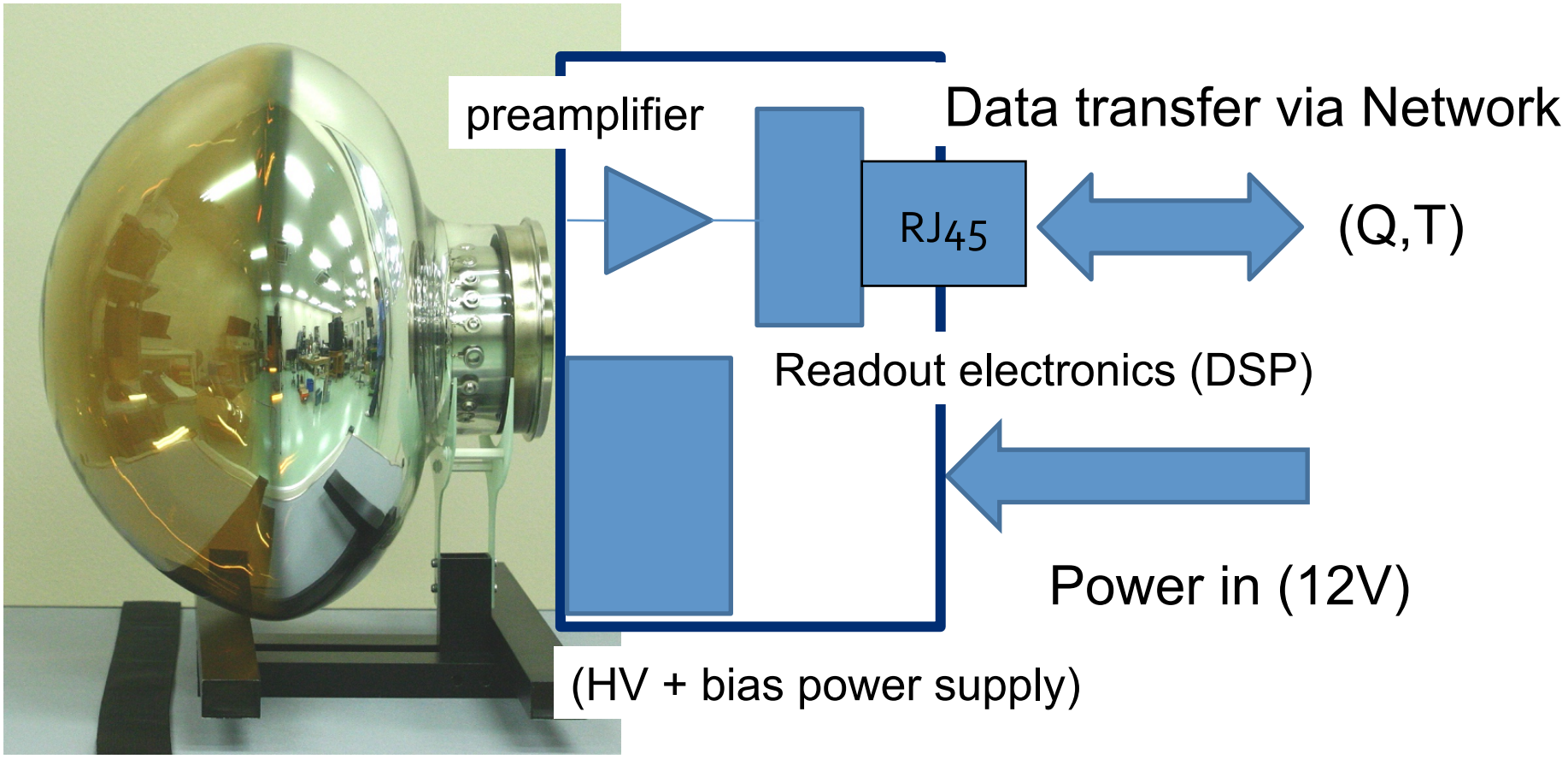


HPD vs PMT

	13inch HPD	13inch PMT (R8055)	20inch PMT (for SK)
Single Photon Time Resolution	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
Gain	10^5	10^7	10^7

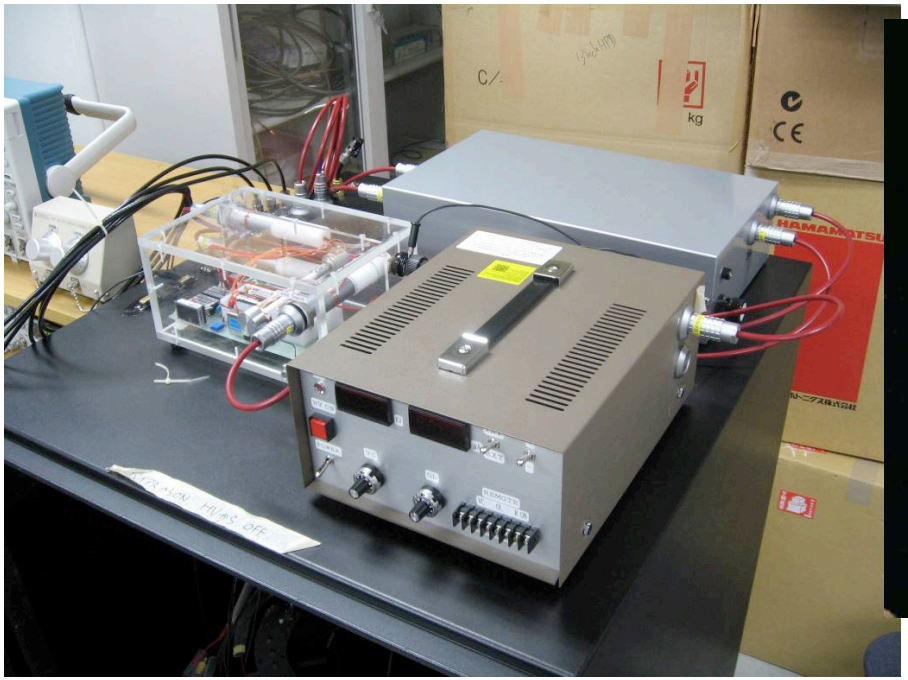
Digital HPD

Compact detector with Network + Power supply



HV supply

New



Size（~500 x 500x 100 mm)

Size（150 x 92 x 30 mm)

HPD’s small power consumption allows a small HV supply.

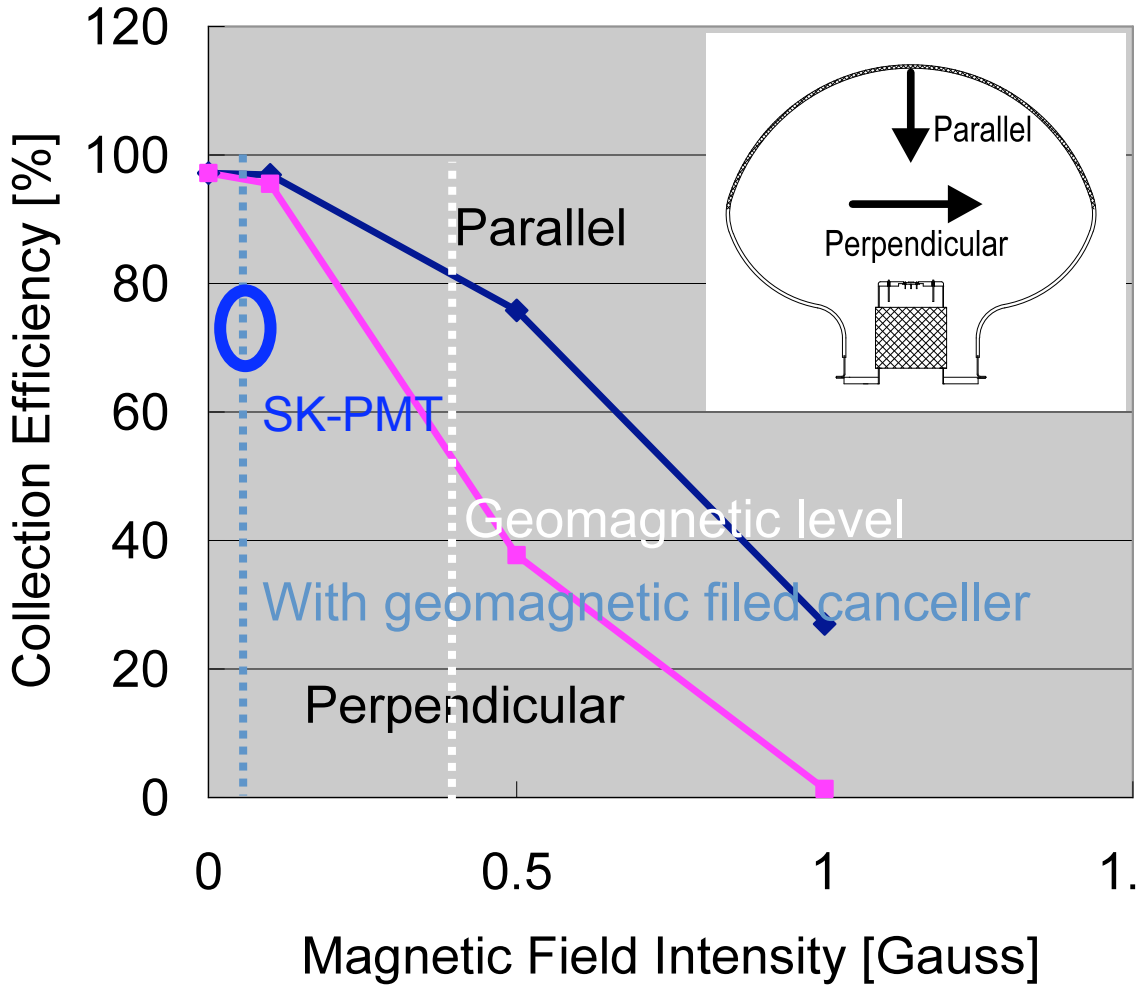
Marketing Schedule (tentative/conservative)

- HPK plans to supply large aperture (13- and 8-inch) HPDs by spring 2012.
  - Option 1: HPD + preamplifier + HV system
  - Option 2: all of the above plus Digital board
- Price : careful optimization required.

End

Collection efficiency vs. magnetic field

Simulation



<2%degradation
with canceller