HPD R&D

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Outline

- Structure and characteristics
  - AD characteristics
  - Stability : sensitivity x gain variation
  - Pulse response
  - etc
- Readout system for performance test
  - Preamp
  - Waveform digitizer
  - Digital filter and data transfer
  - HV module for detector
- Performance
  - Signal
  - Timing resolution
  - Energy resolution
- Conclusion

Time and Energy resolution limiting factors for conventional PMTs

$$\text{Timing resolution}: \ \sigma_{total}^2 = \sigma_{pc\_em}^2 + \sigma_{em}^2$$

$$\sigma_{pc\_em} \propto 1/\sqrt{V_{pc\_em}}$$

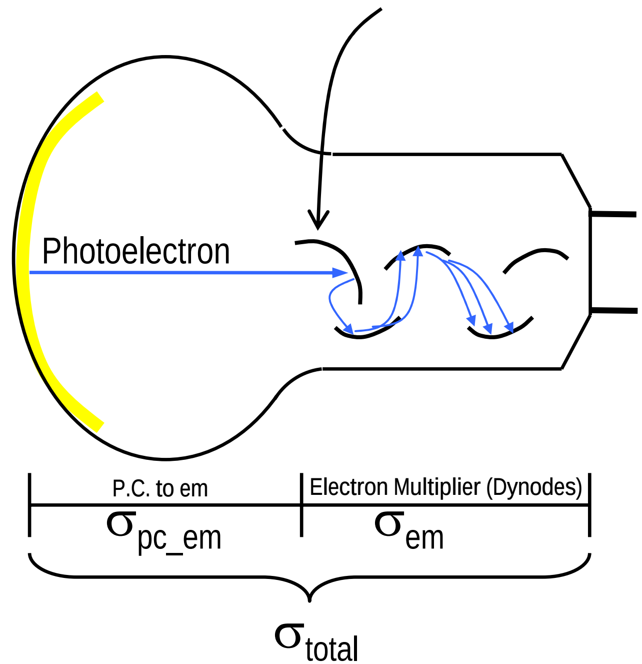
$$\sigma_{em} \propto 1/\sqrt{\delta^{1st}}$$

$$\textit{Energy resolution} \propto 1/\sqrt{\delta^{1st}}$$

Higher V_{pc_em} and δ^{1st} are the keys, but

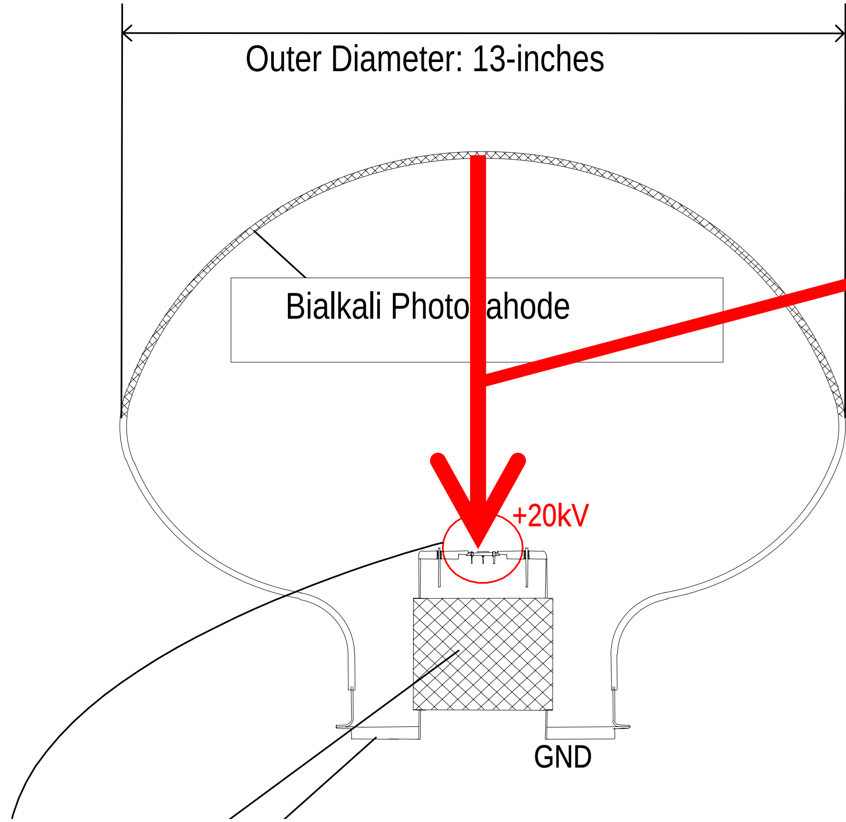
Conventional PMT has poor δ^{1st}: ~20 at best

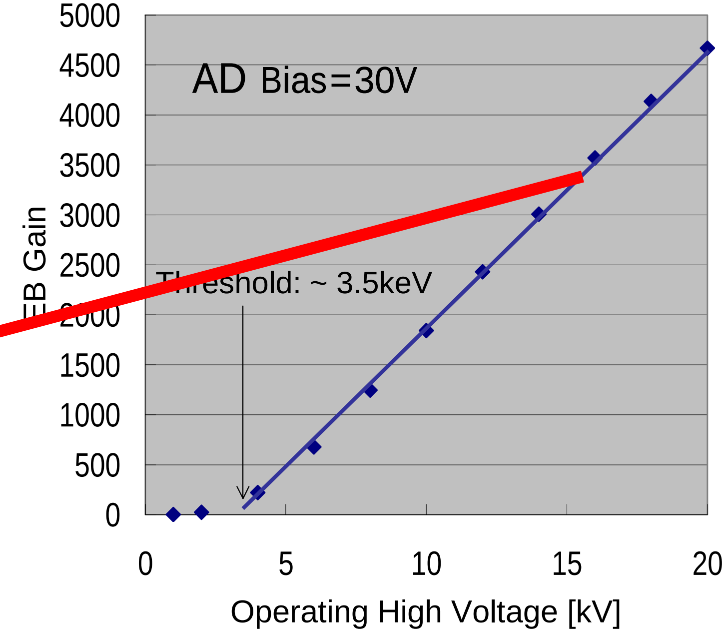
1st Dynode Gain, δ^{1st}: ~5 typ.

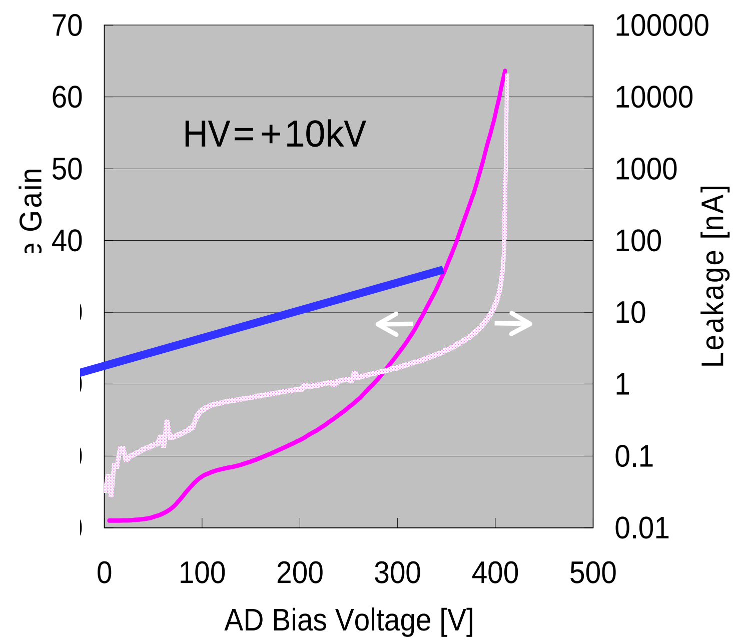


SK type PMT

Large-Aperture HPD







- ✓ Excellent δ^{1st} equivalent: ex. ~4000 at high V_{pc_em}
- ✓ High V_{pc_ad} also improves σ_{pc_em}
- ✓ No stationary divider current
- ✓ Simpler structure : ~1/30 parts of the SK PMT
- ➢ The drawback is its 1/100 smaller Gain_tot than conventional PMT and larger Cdet

Summary table

Aperture	13 inch (8inch under developing)
Photocathode	Bialkali
AD size & Cdet	5mmϕ ~40pF details in page 6
Gain	~10^5
Gain uniformity	~2%(0^o~70^o) < 5 photons
Gain stability	Described in page7
Pulse response	Described in page8
Collection eff	Described in page9
Dark count	< 20kHz@16kV
Dynamic range	~100pC
TTS	~400ps@20kV
# of parts	~1/30 of PMT
hydrostatic pressure	<1MPa

AD for HPD : C-V Characteristics

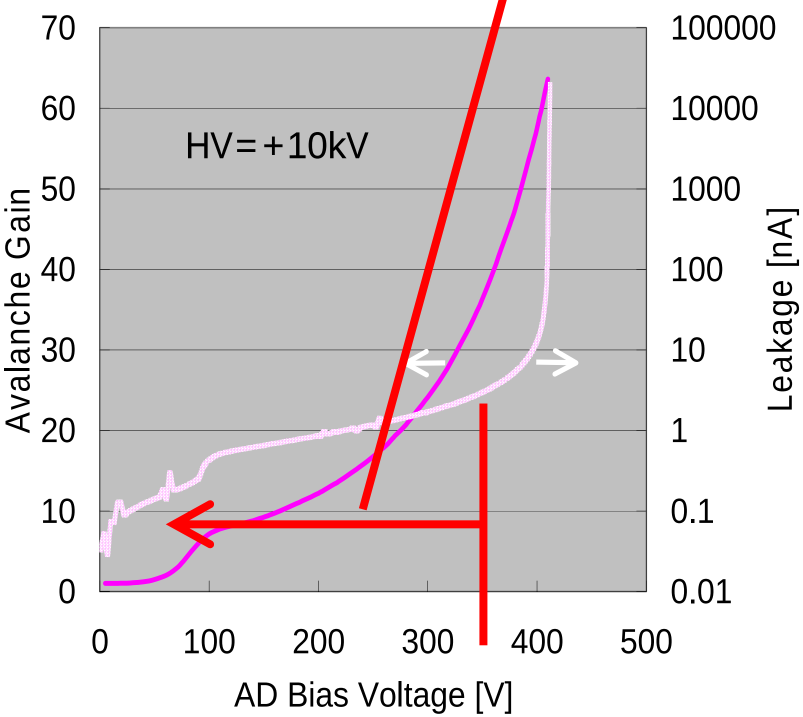
AD is fully depleted around 120V

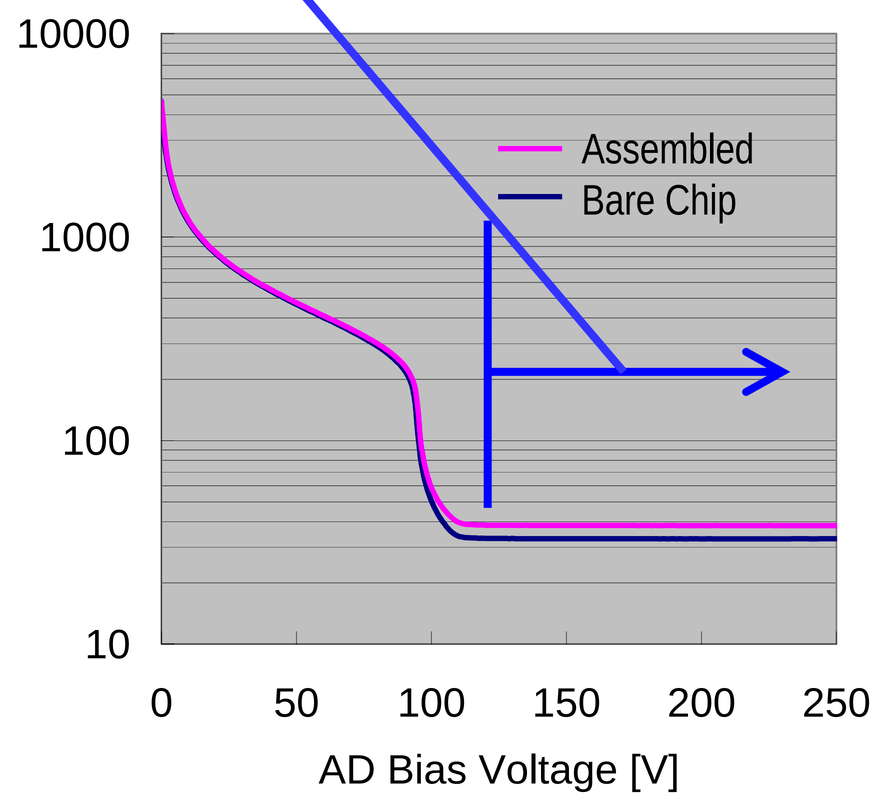
series noise source

The leakage current increases around 350V

parallel noise source

Capacitance: ~40pF over bias voltage of 120V





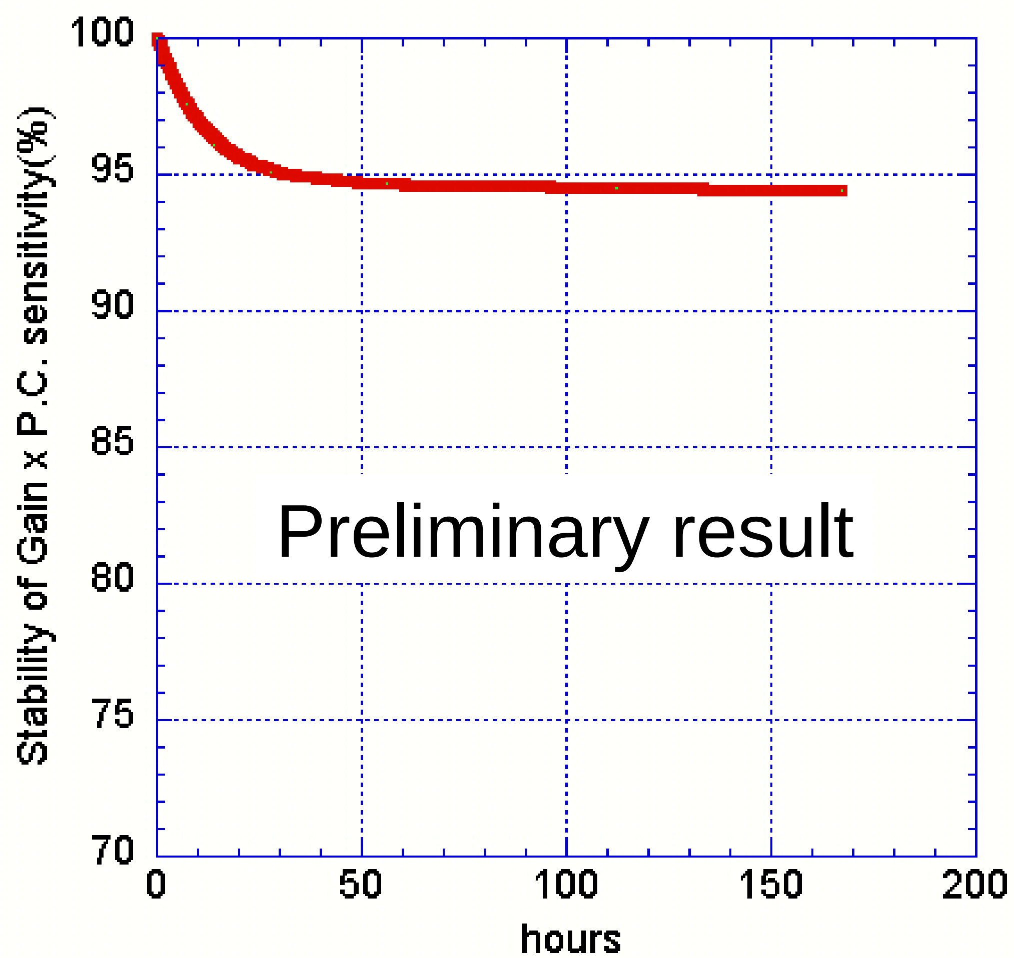
g profile

Acceleration test of HPD

Condition:

White light illuminates P.C.
4uA@HPD output
→ 10^15 photons/month

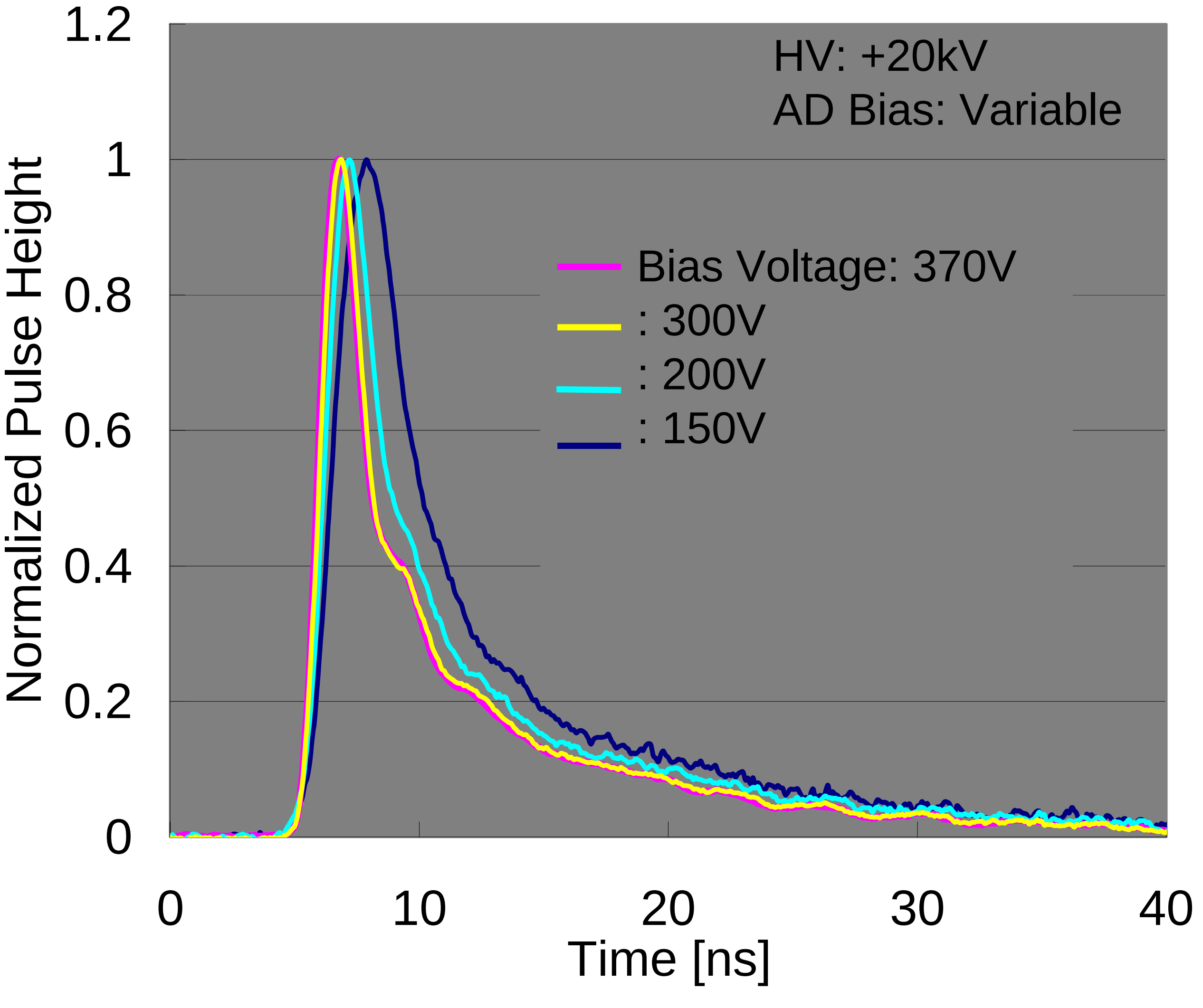
HV:18kV
AD bias: 210
Initial gain ~ 10^5



Pulse response

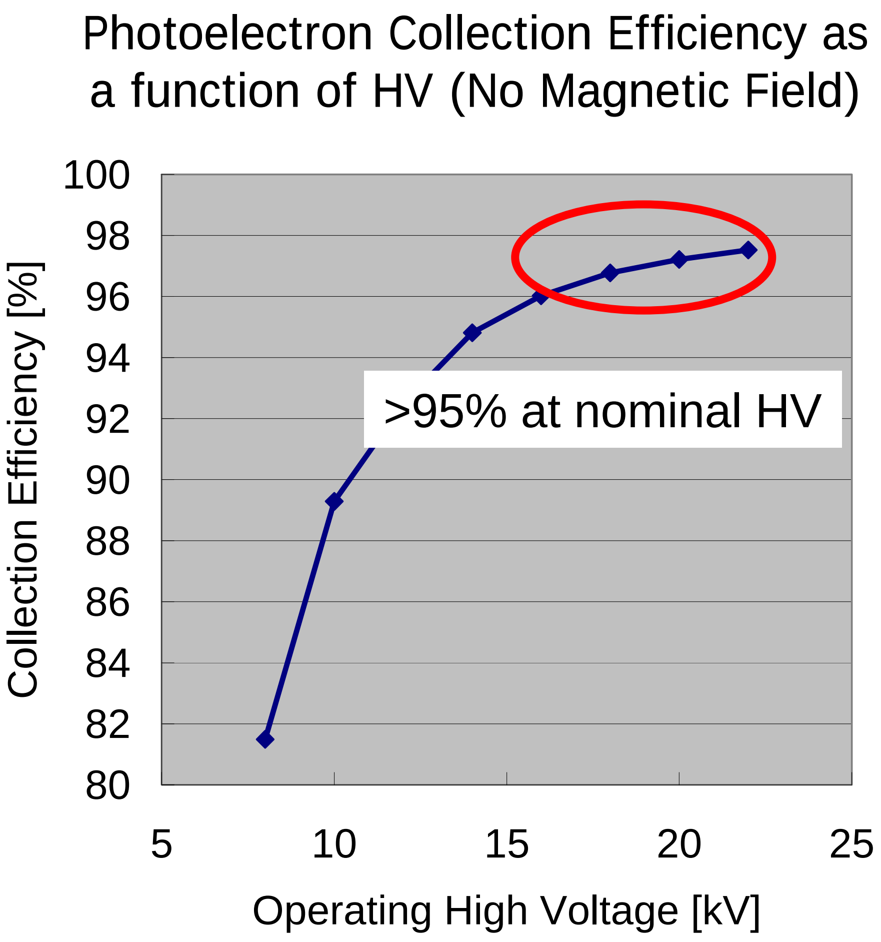
Time constant@leading edge : ~ 1nsec

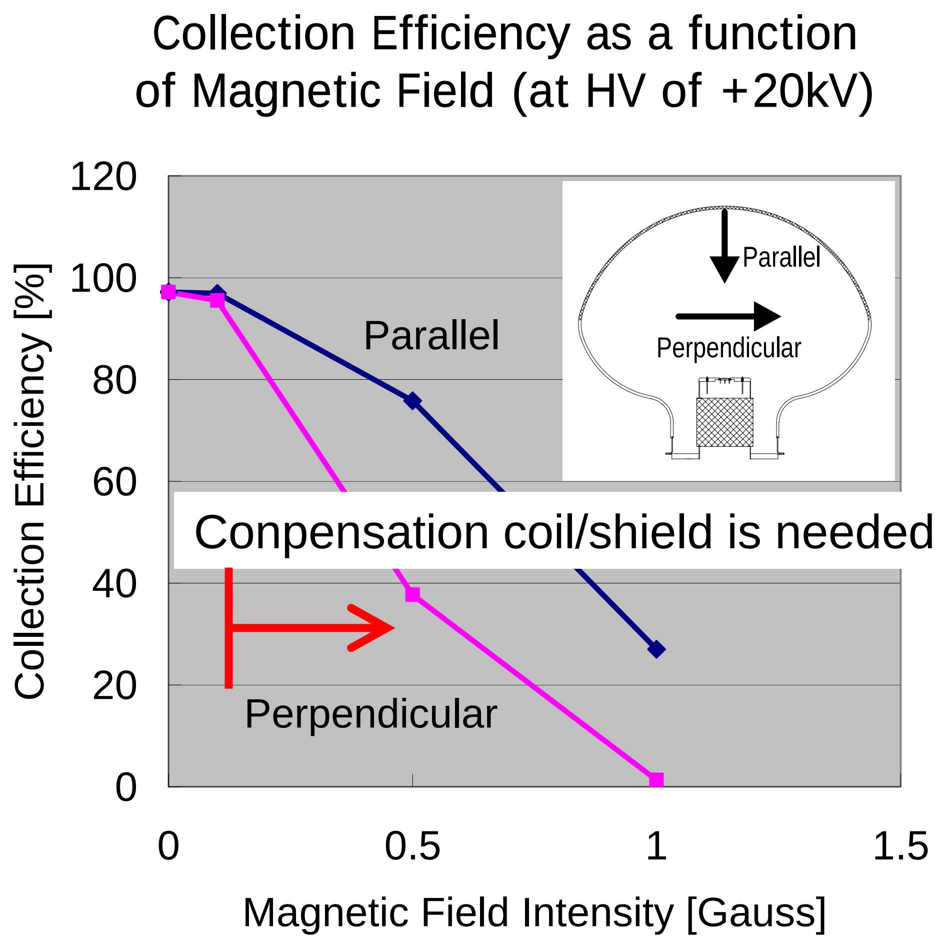
Noise doesn’t affect timing resolution.



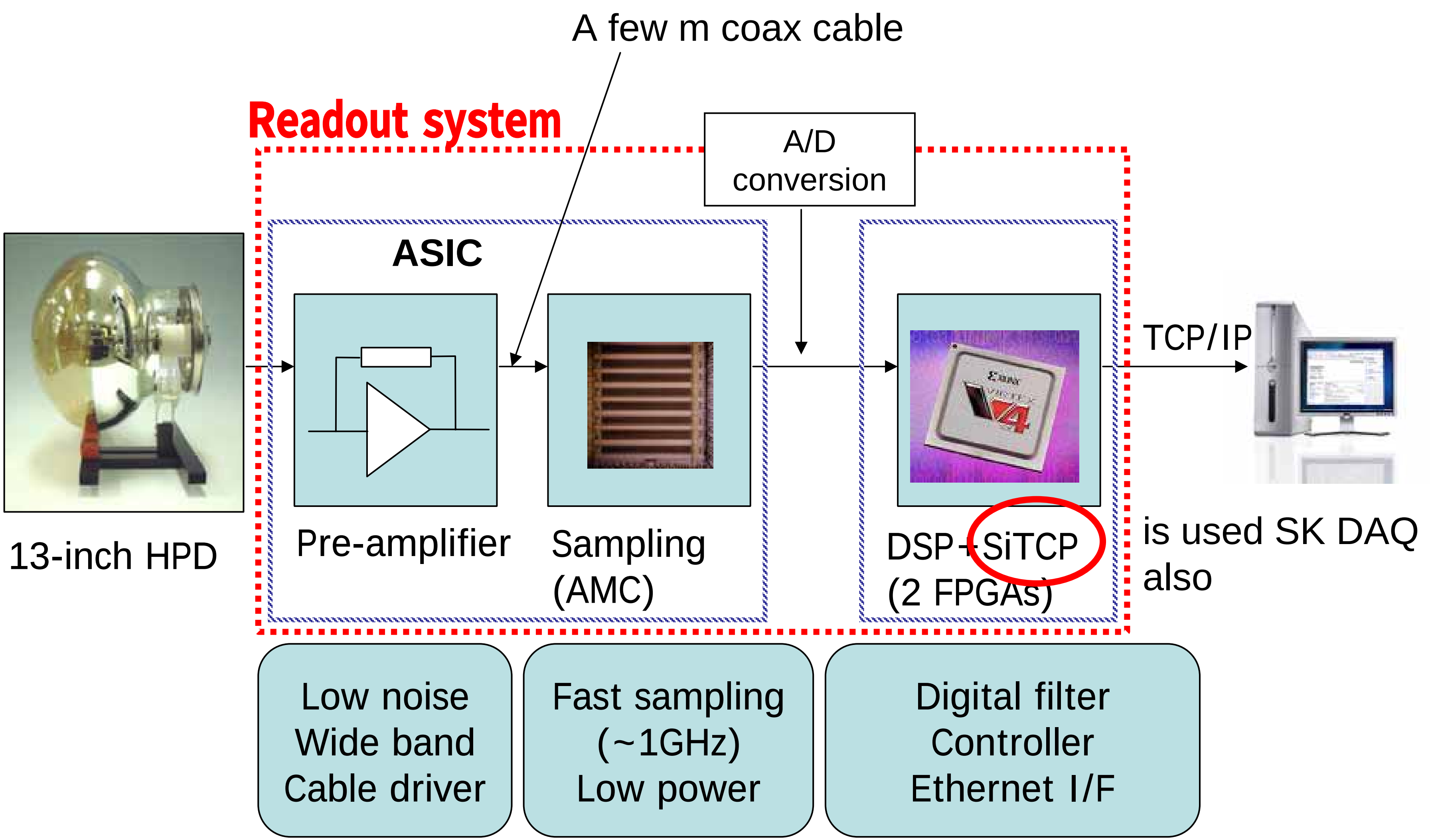
Light source : pulsed laser(PW:~70ps, ~400nm)

Photoelectron Collection Efficiency and Effect of Magnetic Field *(Simulation)*

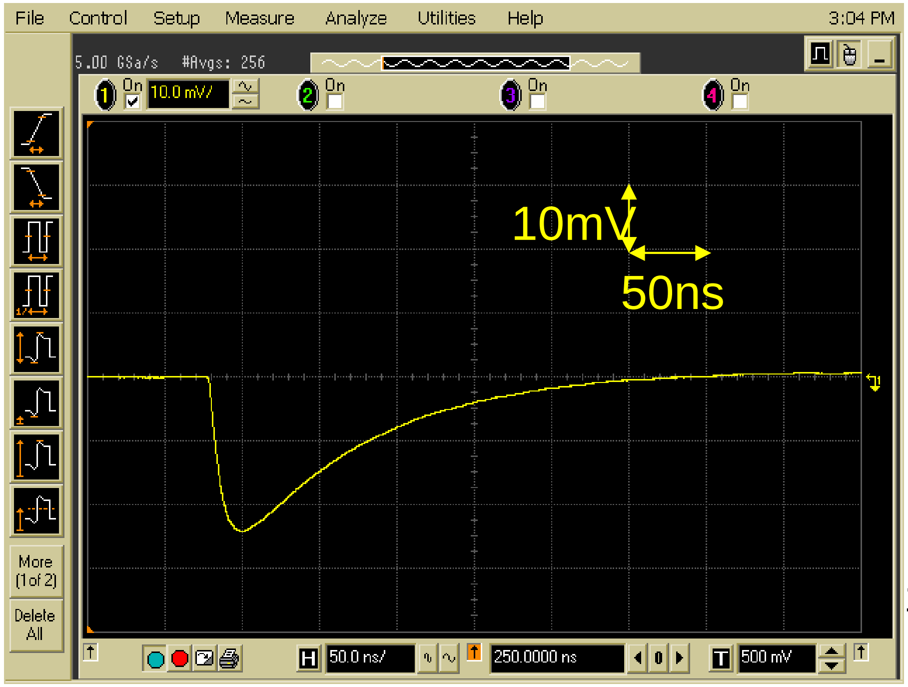




Readout system for performance test



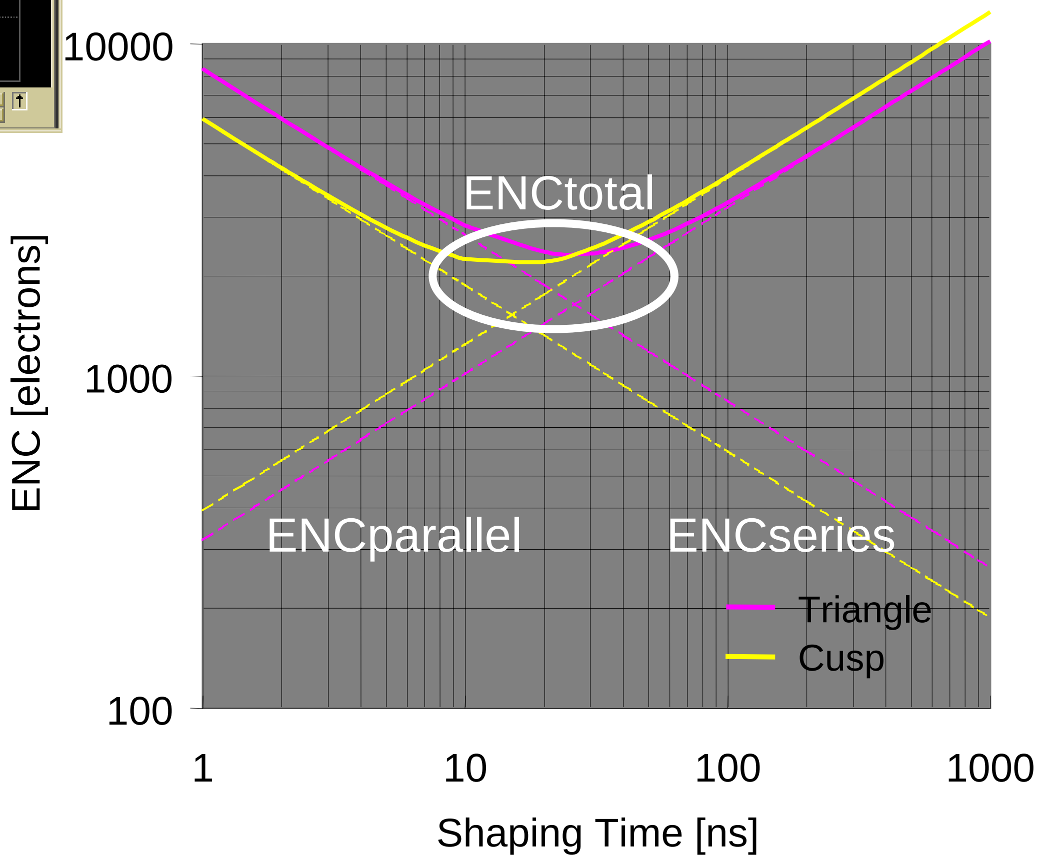
Front-end



Pulse shape at Frontend ASIC
Input : HPD signal

Noise(ENC)

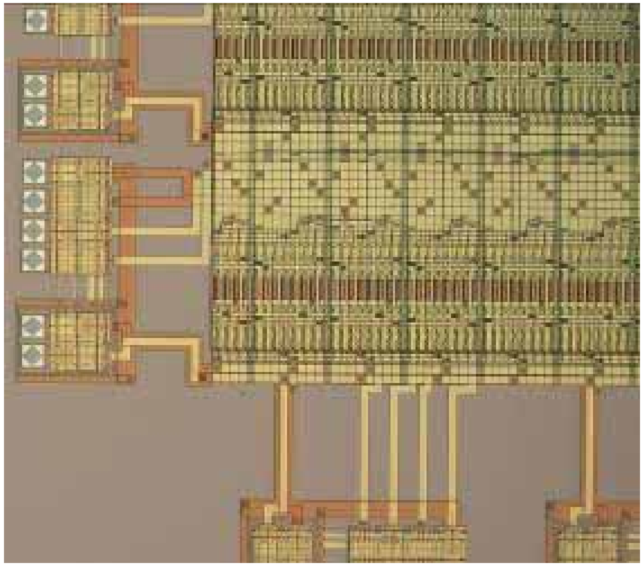
~2200 electrons Enough small



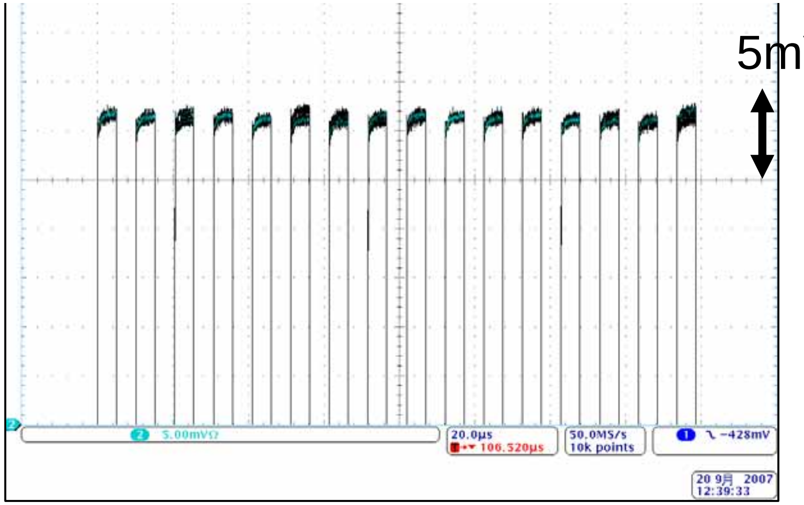
Frontend electronics specification

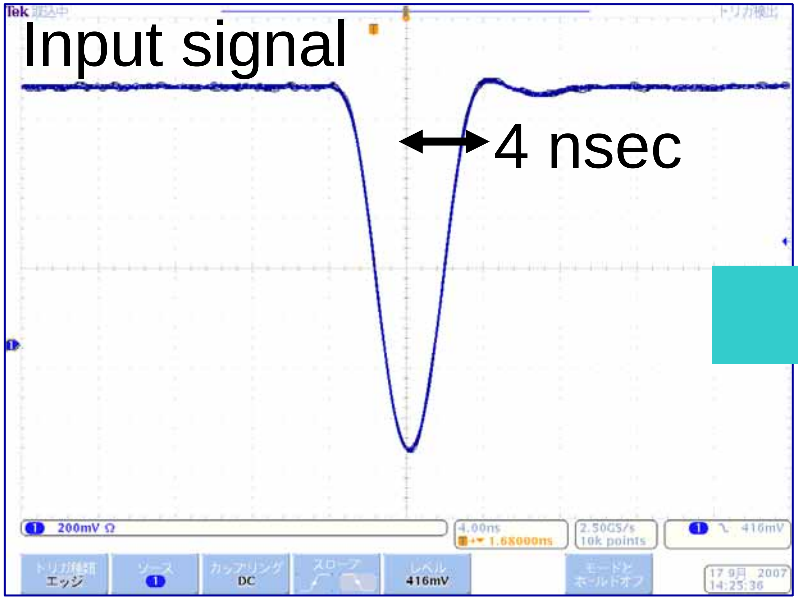
Parameters	Values
Rise Time	1ns
Slew Rate	>~300V/μs
Dynamic Range * at HPD gain of $1\mathrm{x}10^5$	125p.e. equivalent*
Estimated Attainable ENC	~2200 electrons for 40pF
$r_{bb'}$	~15Ω
ft of transistor	20GHz

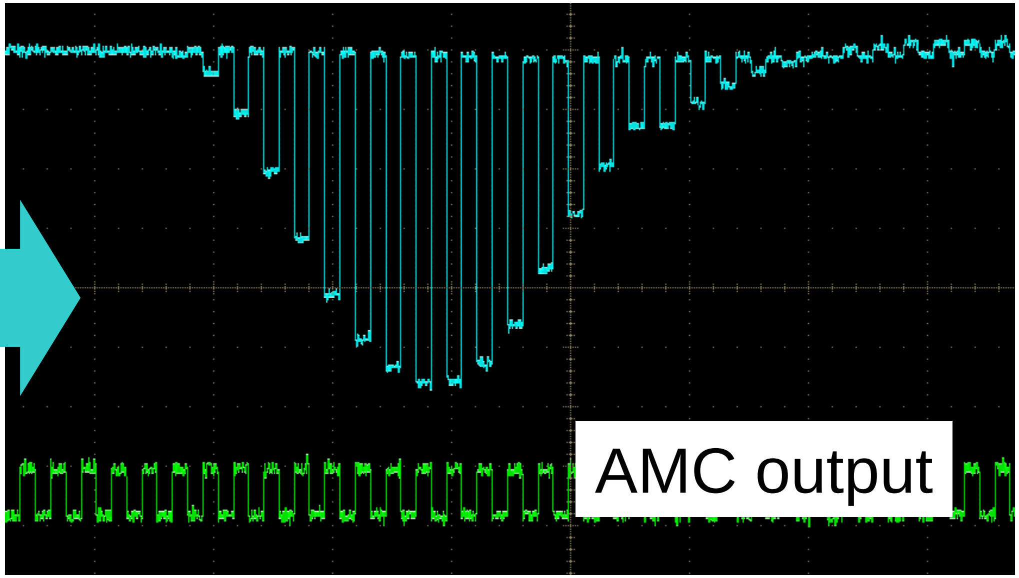
Waveform sampling



DC input : pedestal variation < 2mV

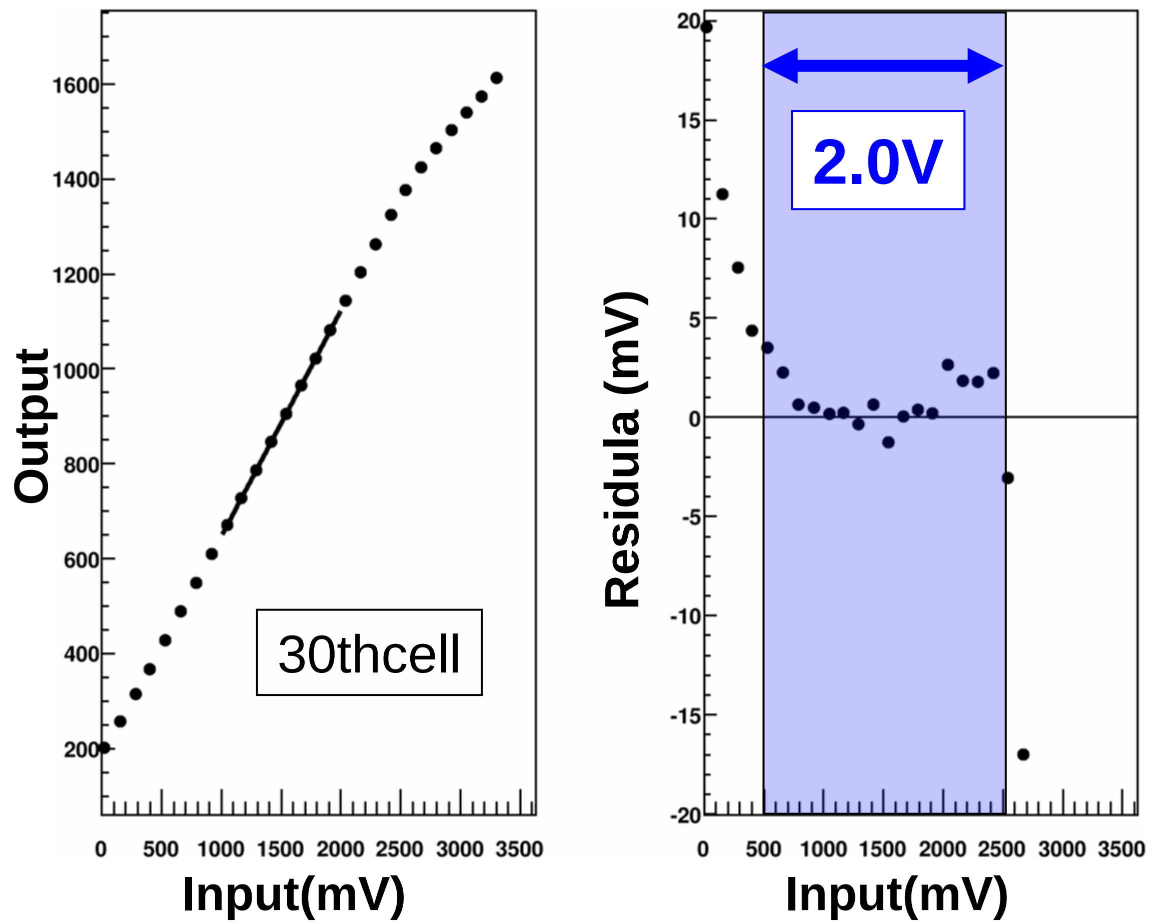






AMC characteristics

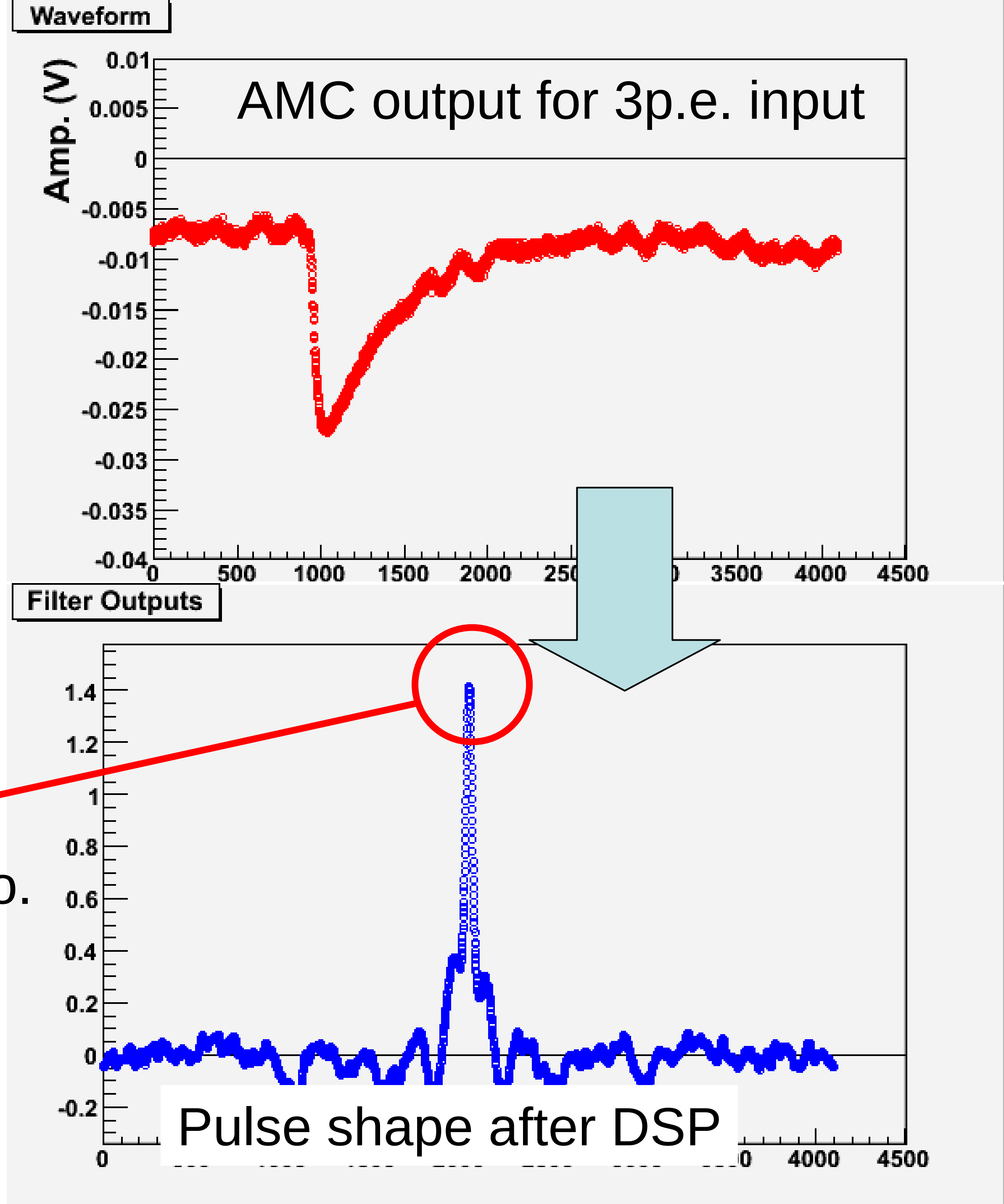
	AMC
Sampling rate	~1GHz
BWanalog	~100MHz
Power	~70mW/ch
Dynamic range	~2V
Depth(# of stages)	512~1024
INL	~0.1%
Noise	<1mV
δ Vped	<2mV
Readout time	<1.6usec



Deadtimeless daq can be designed

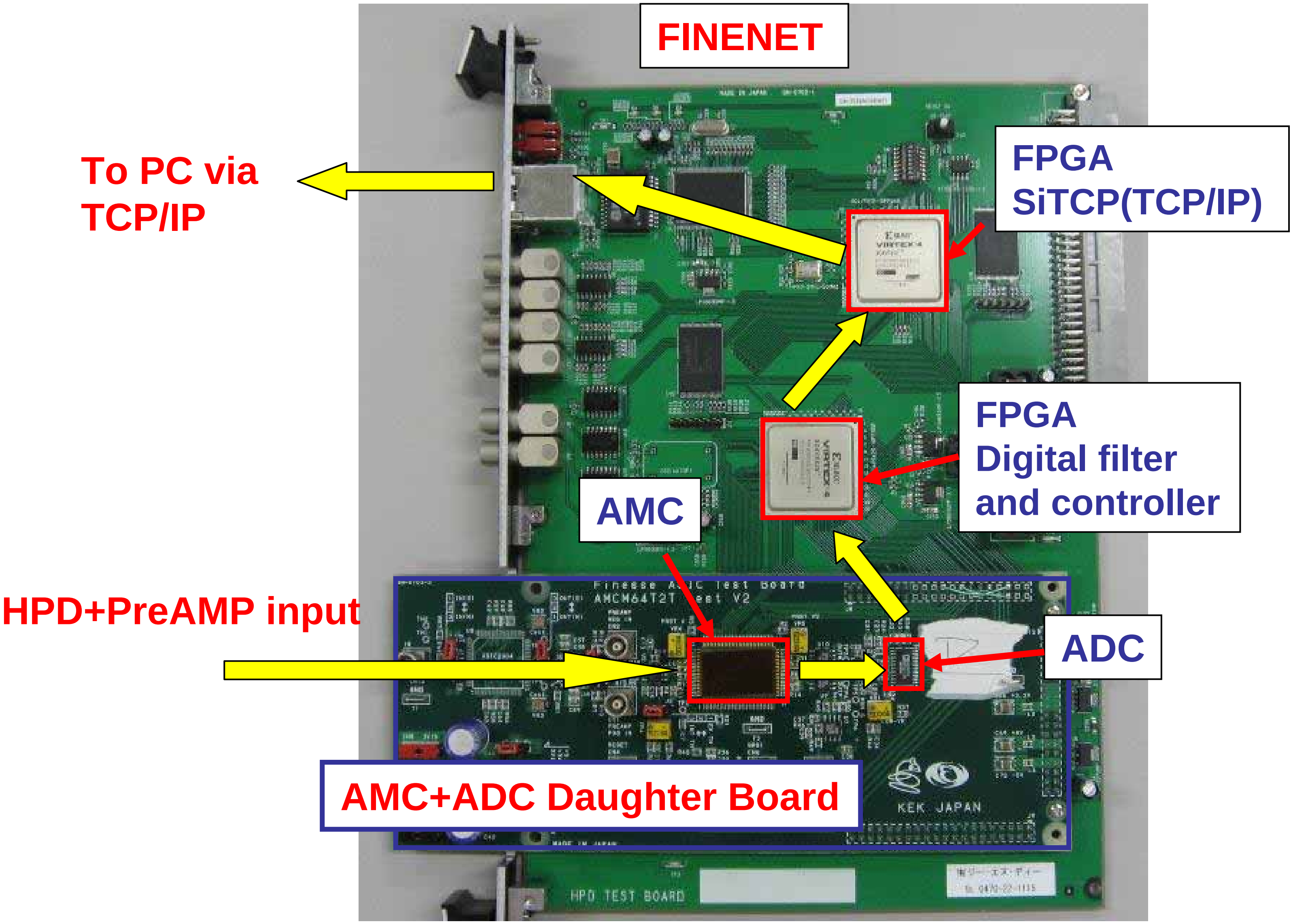
Digital filter

- Matched optimal filter is implemented in FPGA.



Extraction of Q and T info.

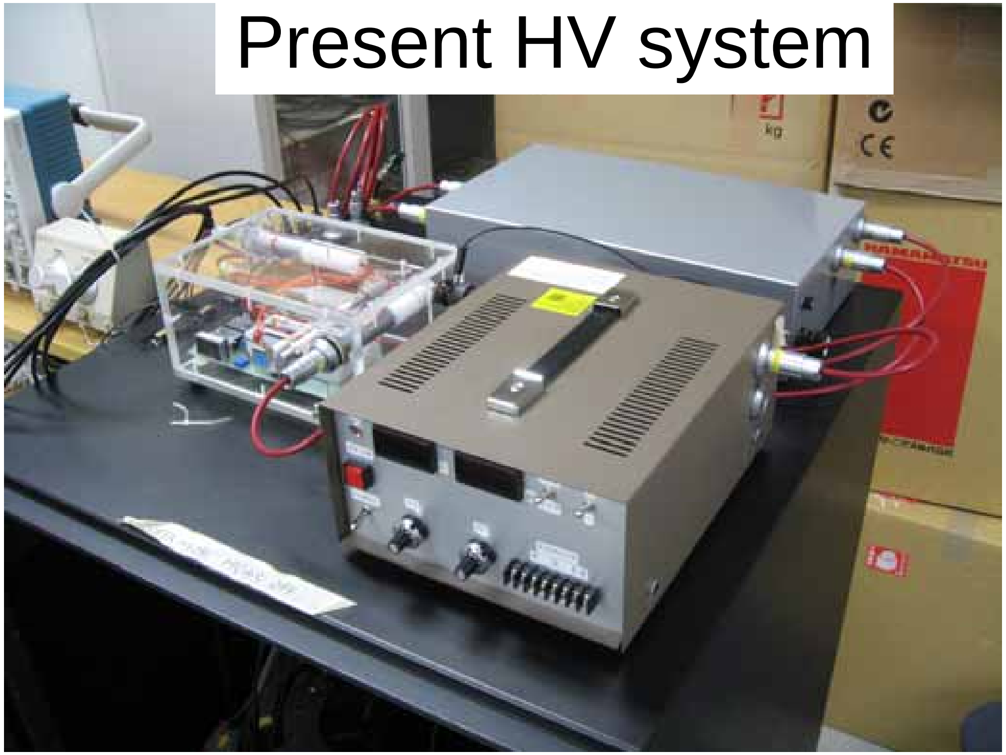
Developed components implementation for system test



This VME board was designed for general purpose.

HV supply

Present HV system



HPDs were sometimes broken

To avoid accident/trouble by improper use modular HV system is developed.

Size（~500 x 500x 100 mm)

developed HV system

Size（150 x 92 x 30 mm)

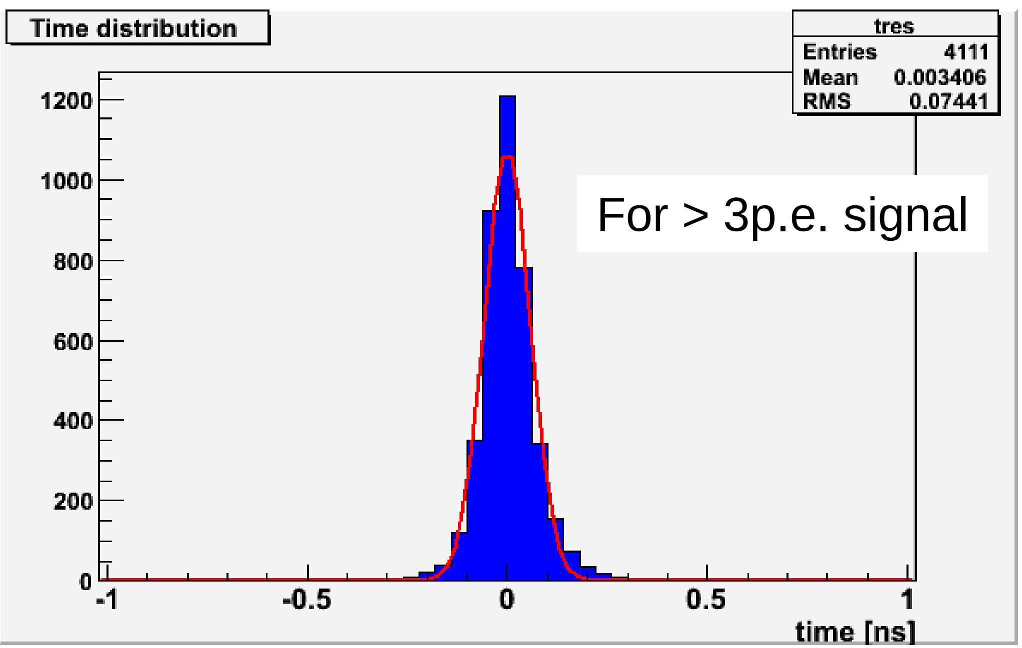
We’ve not started systemtest with the module yet.

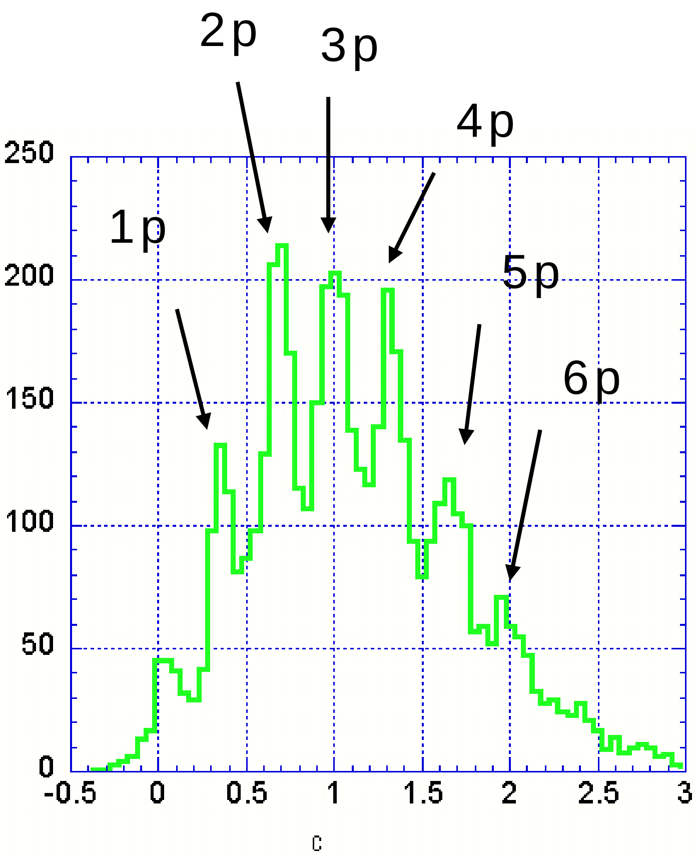
Performance

Timing resolution

Energy resolution

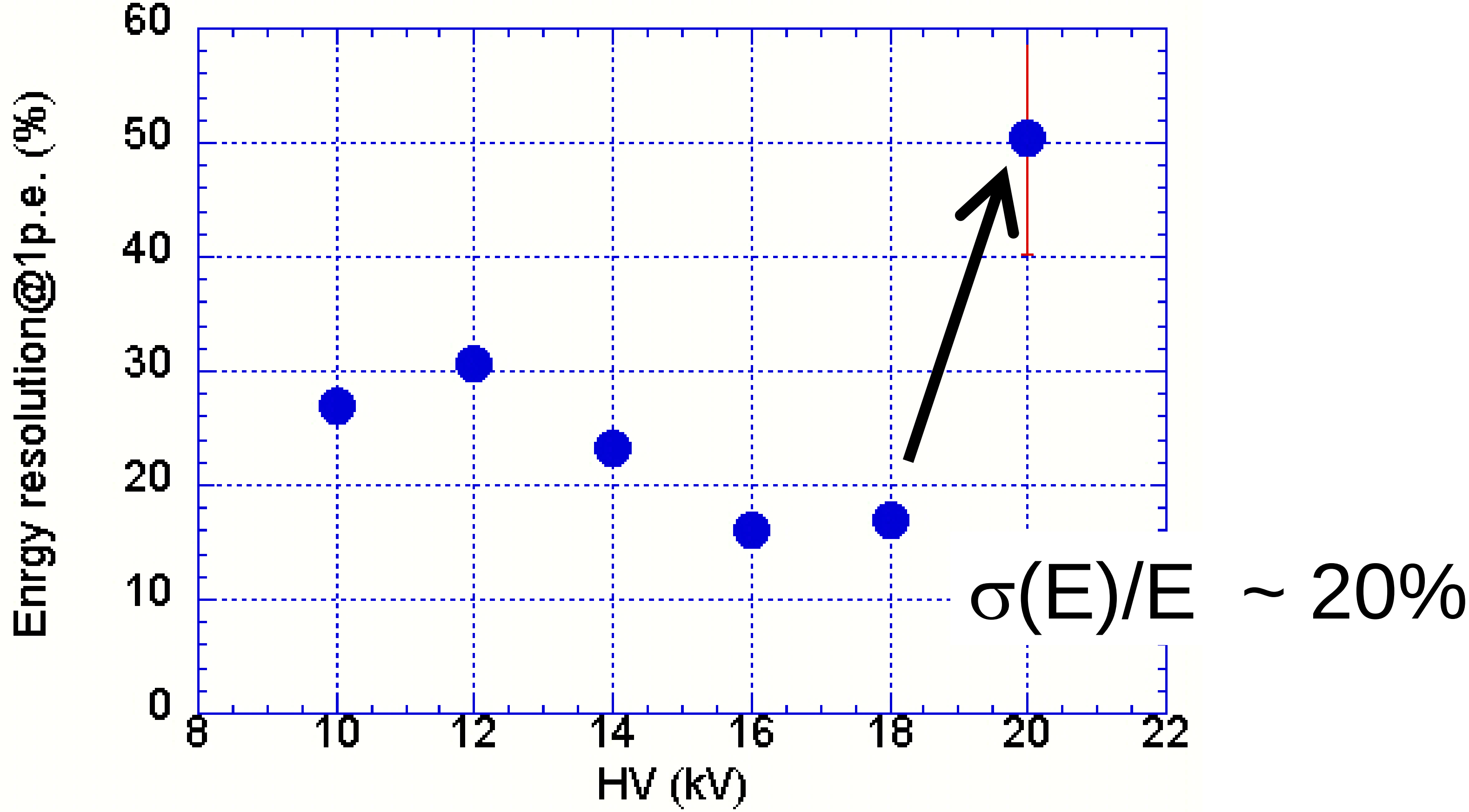
(16kV 240V)
0.8ns/20=0.04ns sigma=~0.06ns)





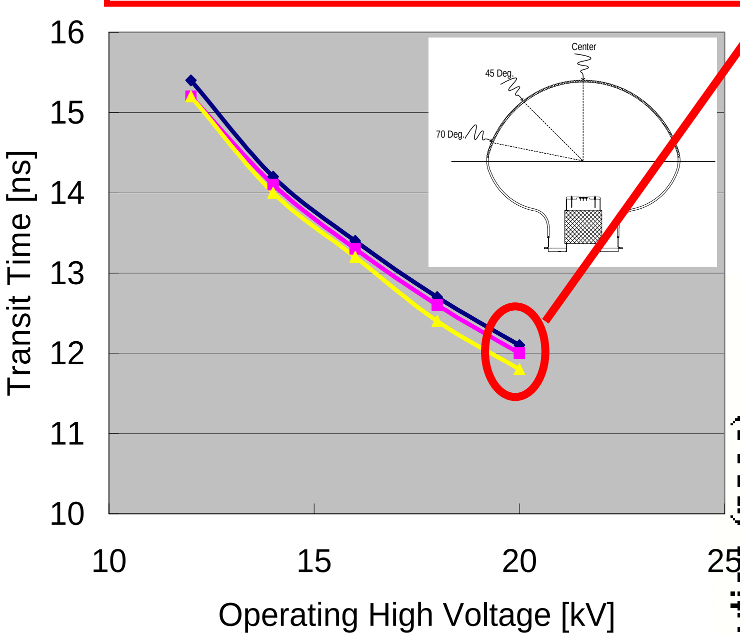
Energy resolution@1p.e. vs HV

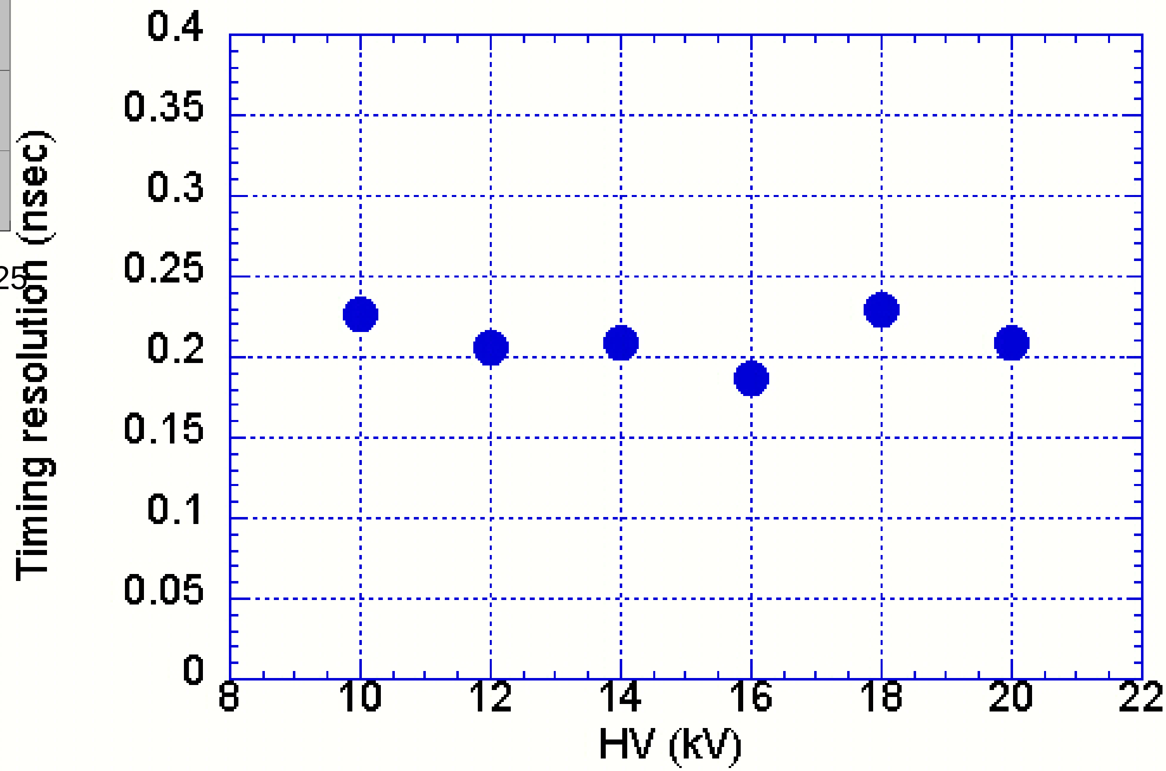
Noise due to weakness of dielectric strength at a part in HPD around 20kV



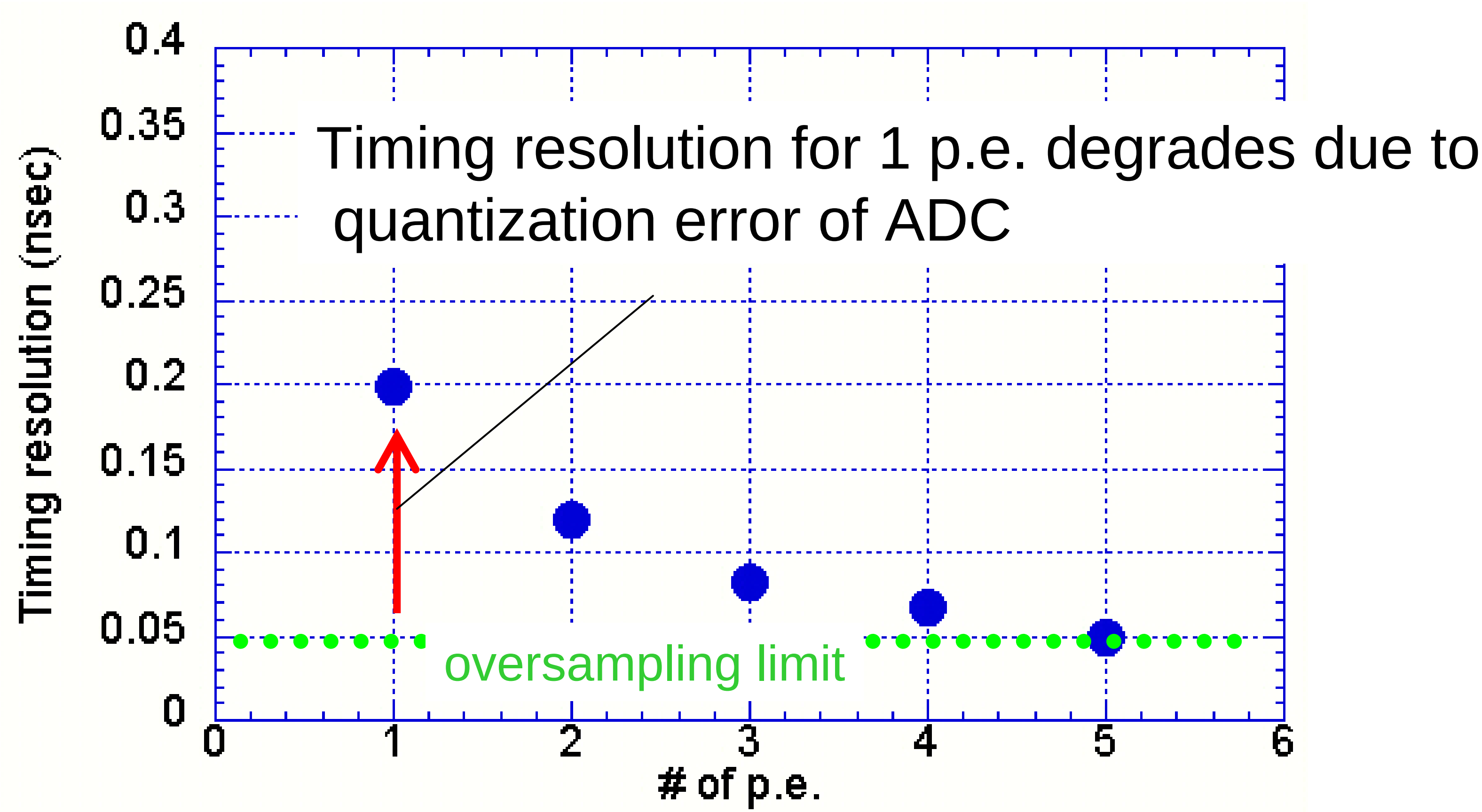
Timing resolution@1p.e. vs HV

The timing resolution of 0.2nsec is smaller than timing difference due to TTS position dep.





Timing resolution vs p.e.



Noise doesn't limit timing resolution at present.

Conclusion

- HPD characterization goes on.
- Long term stability test started.
  - HPD output became stable after ~10^13 photons illuminated.
- Developed all components (frontend, waveform sampler and digital filter) are implemented in DAQ system and used for HPD evaluation
  - Timing resolution:~200psec for 1 p.e.
  - Energy resolution:~20%
- Modular HV system is developed
- We’ll evaluate stability of the HPD system include HV system.