MPPC photon sensor

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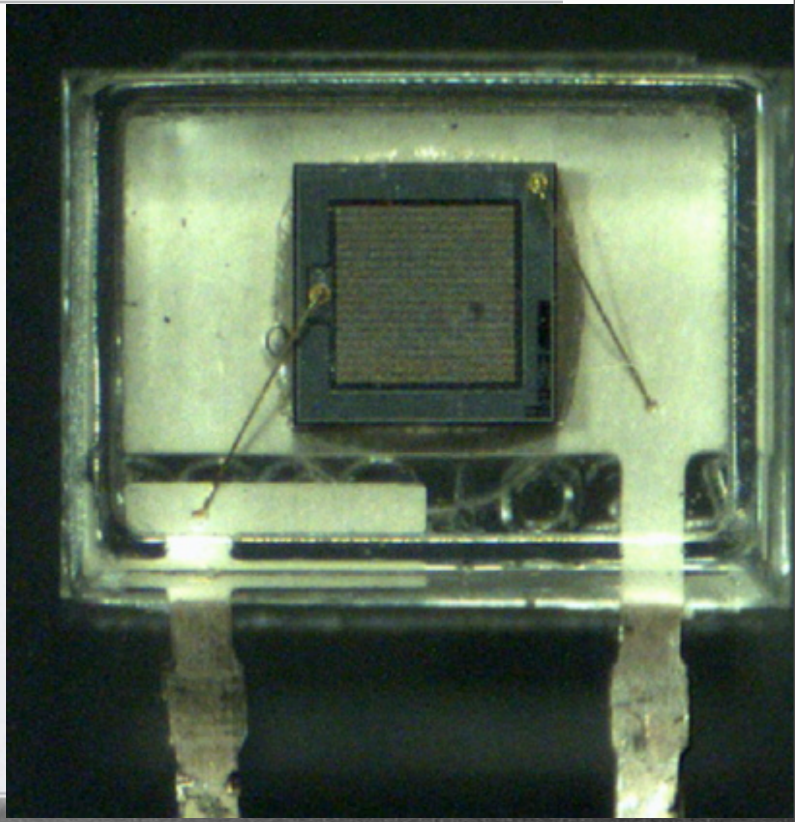
for CAL school at CCAST

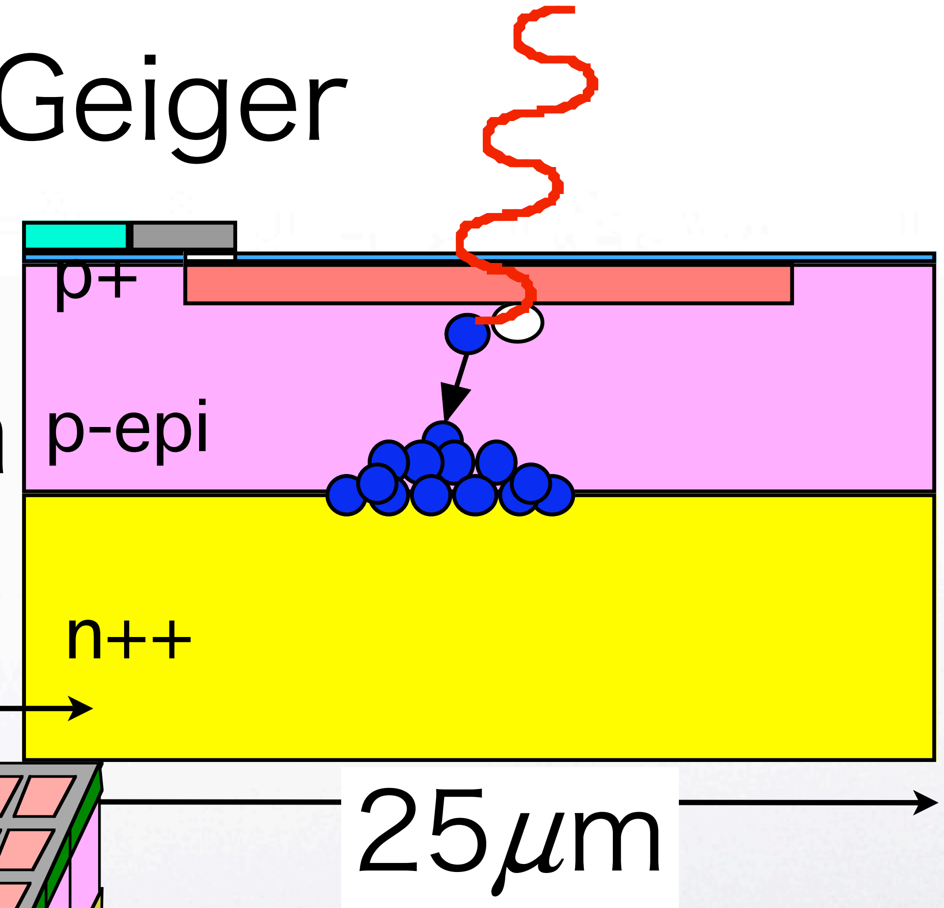
- MPPC in general
- Basic performances
- cross talk/after pulse
- saturation effect
- statistical experience

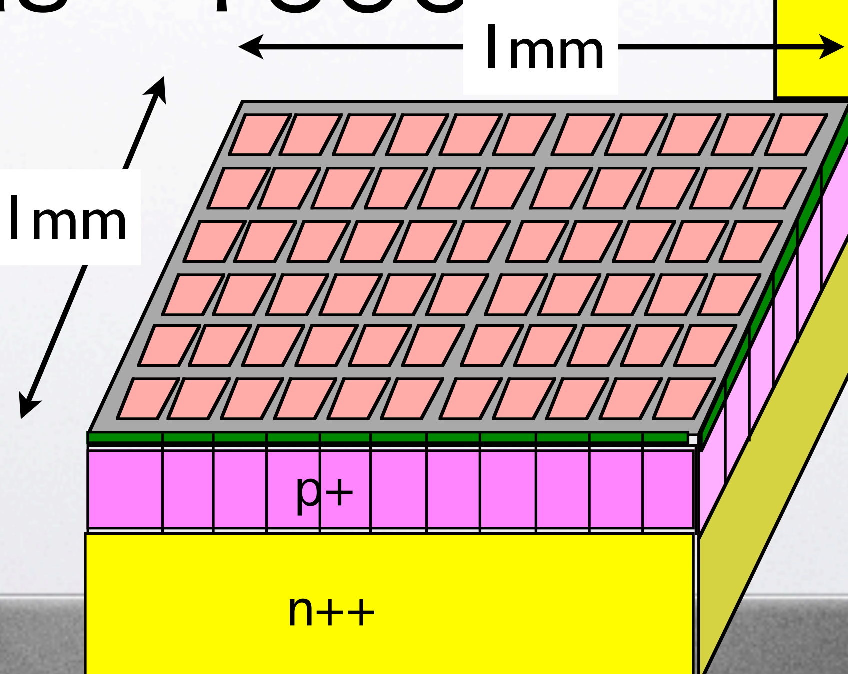


MPPC

Multi Pixel Photon Counter

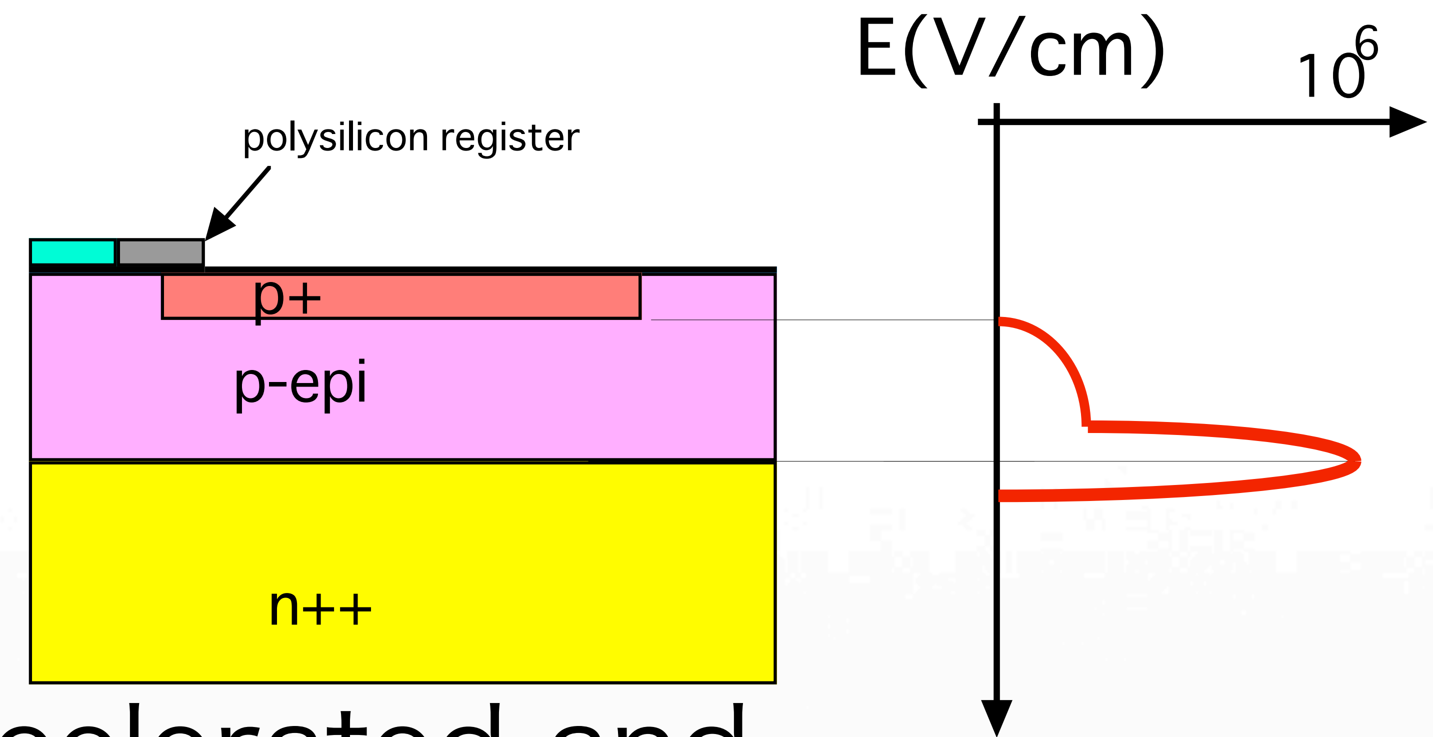
- Silicon photo sensor
- Avalanche photo diode with Geiger Mode operation
- one pixel firing = one photon
- with many pixels =1600
- in 1mm x 1mm



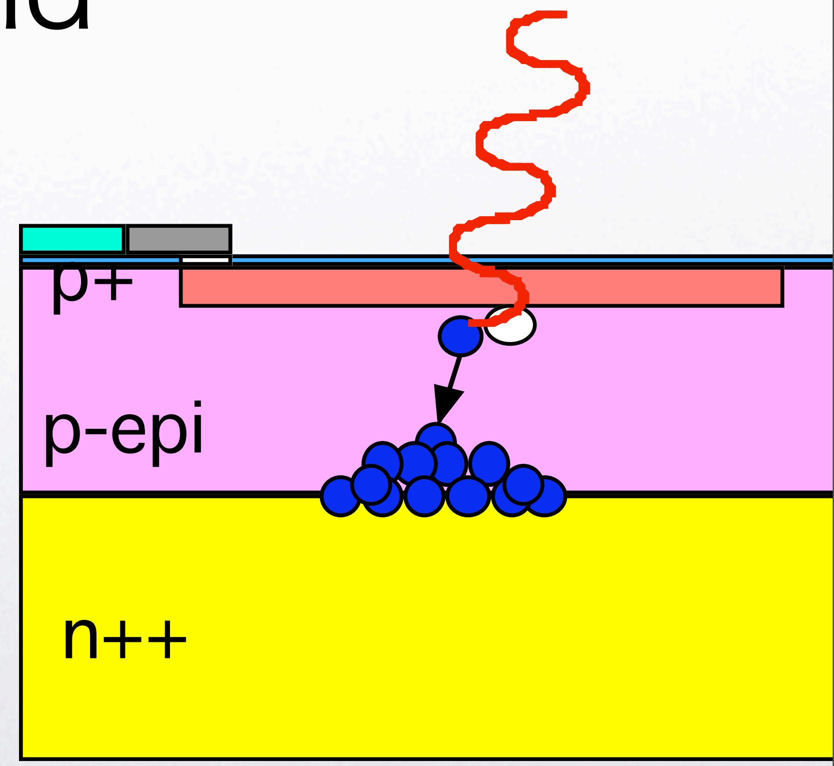


Geiger Mode

- strong electric field
- with very thin area in a pixel

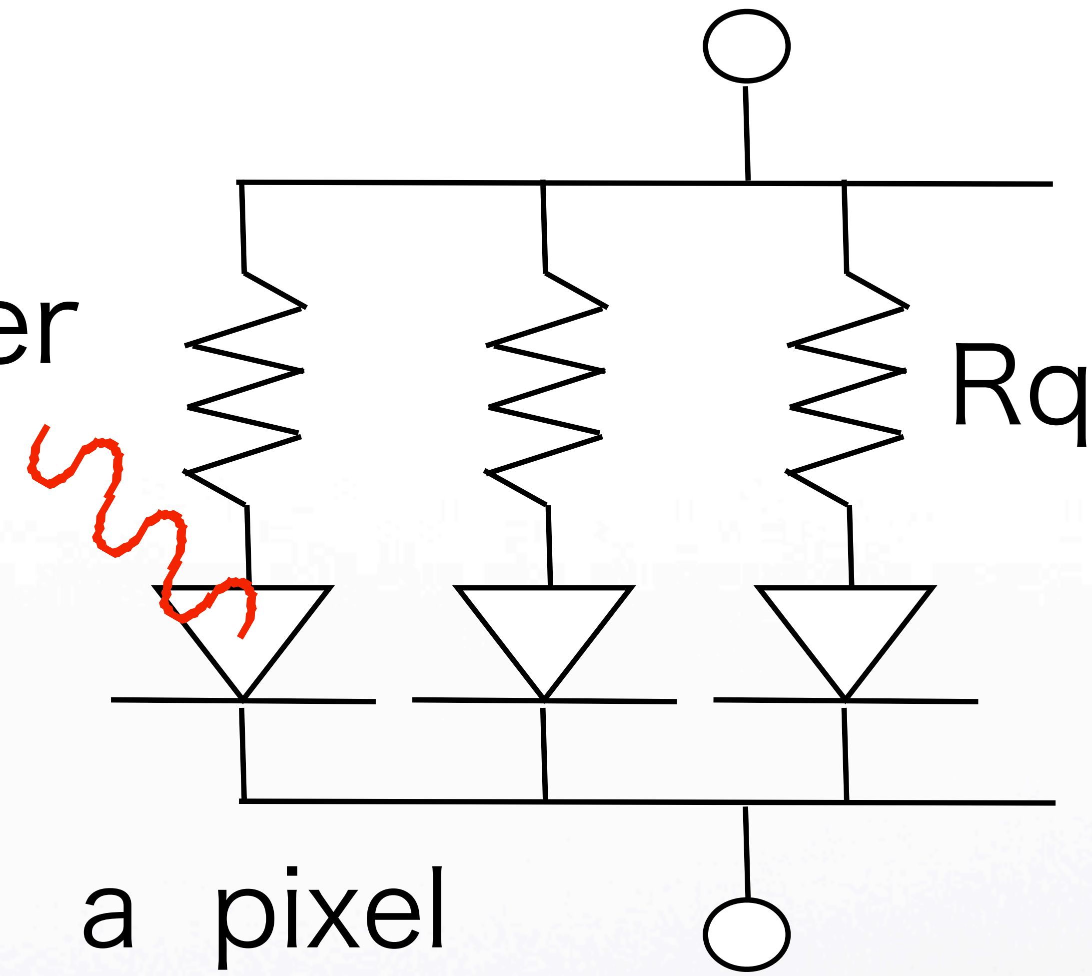


- electron will be accelerated and induce other elelctron/hole pair : multiplication
- V threshold called breakdown voltage
- same charge for a photon

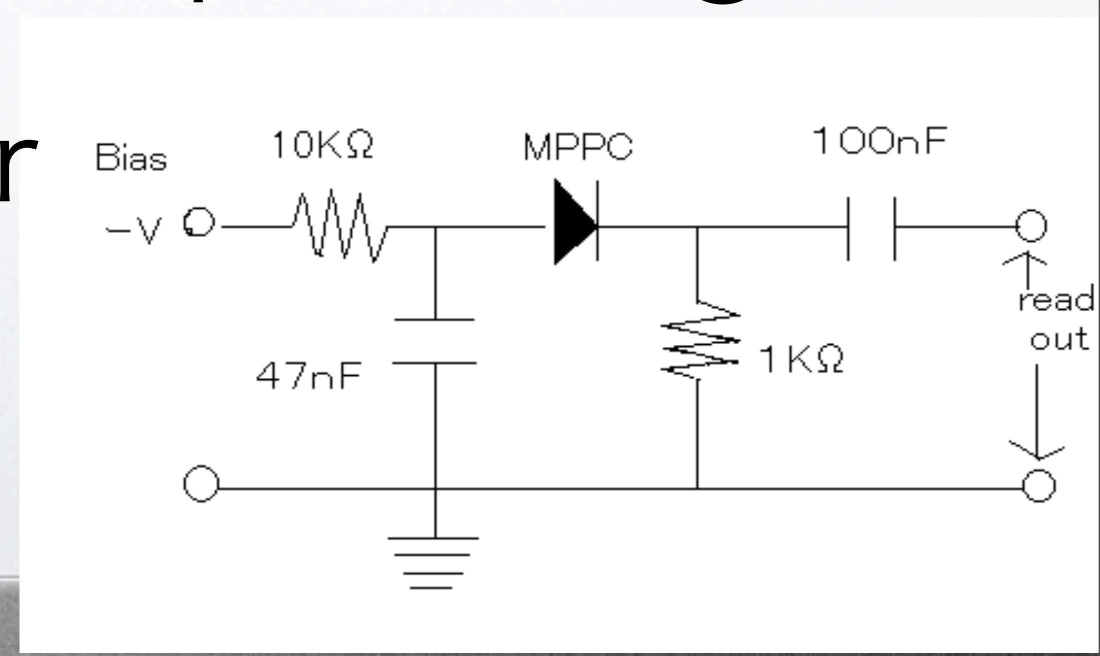


circuit

- equivalent circuit
- there is quenching register
- Rq ~ 500kΩ
- capacitance ~ 0.02pF
- time const. 10ns
- like a condensor/capacitor
- triggered by a photon

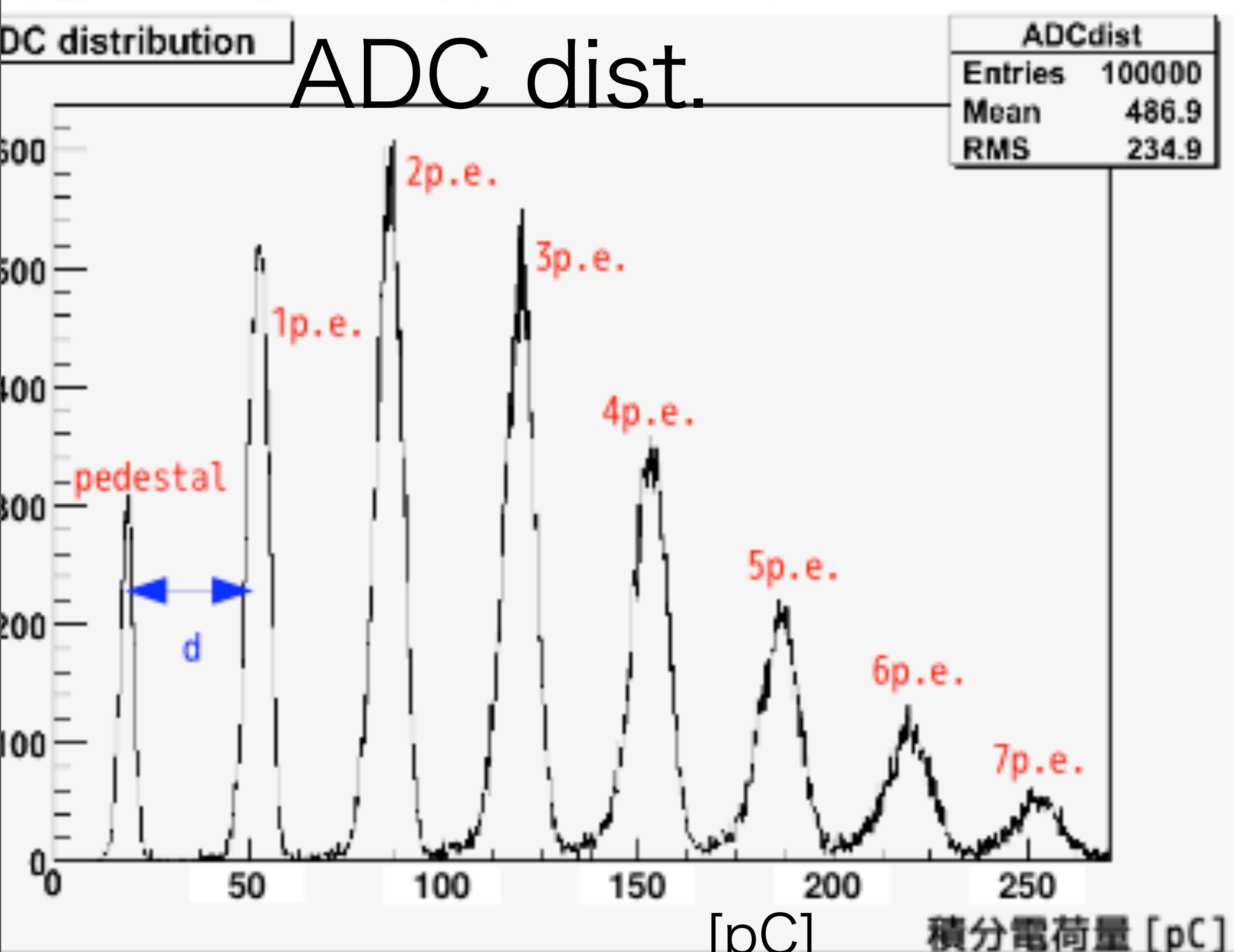


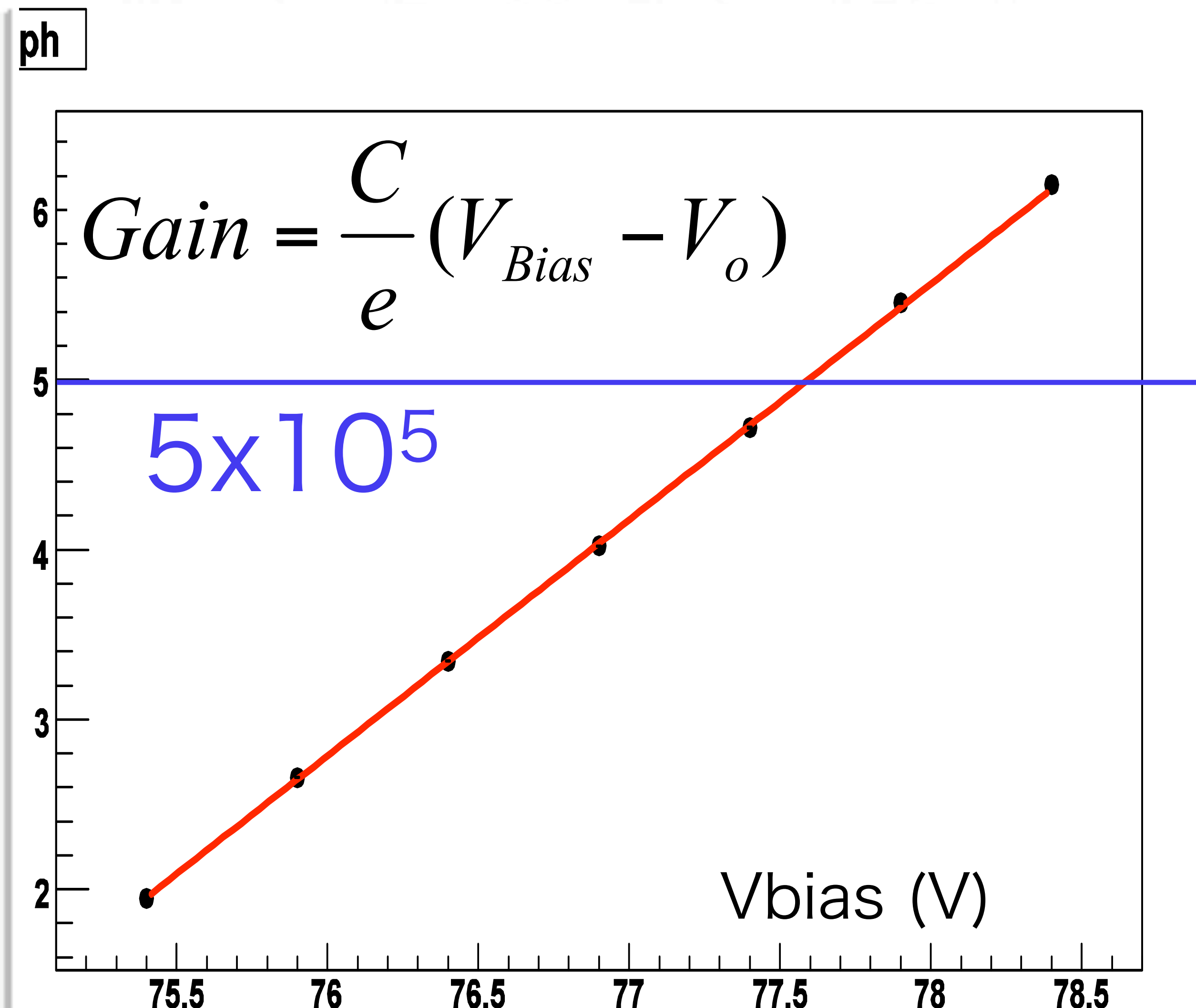
a pixel



Gain

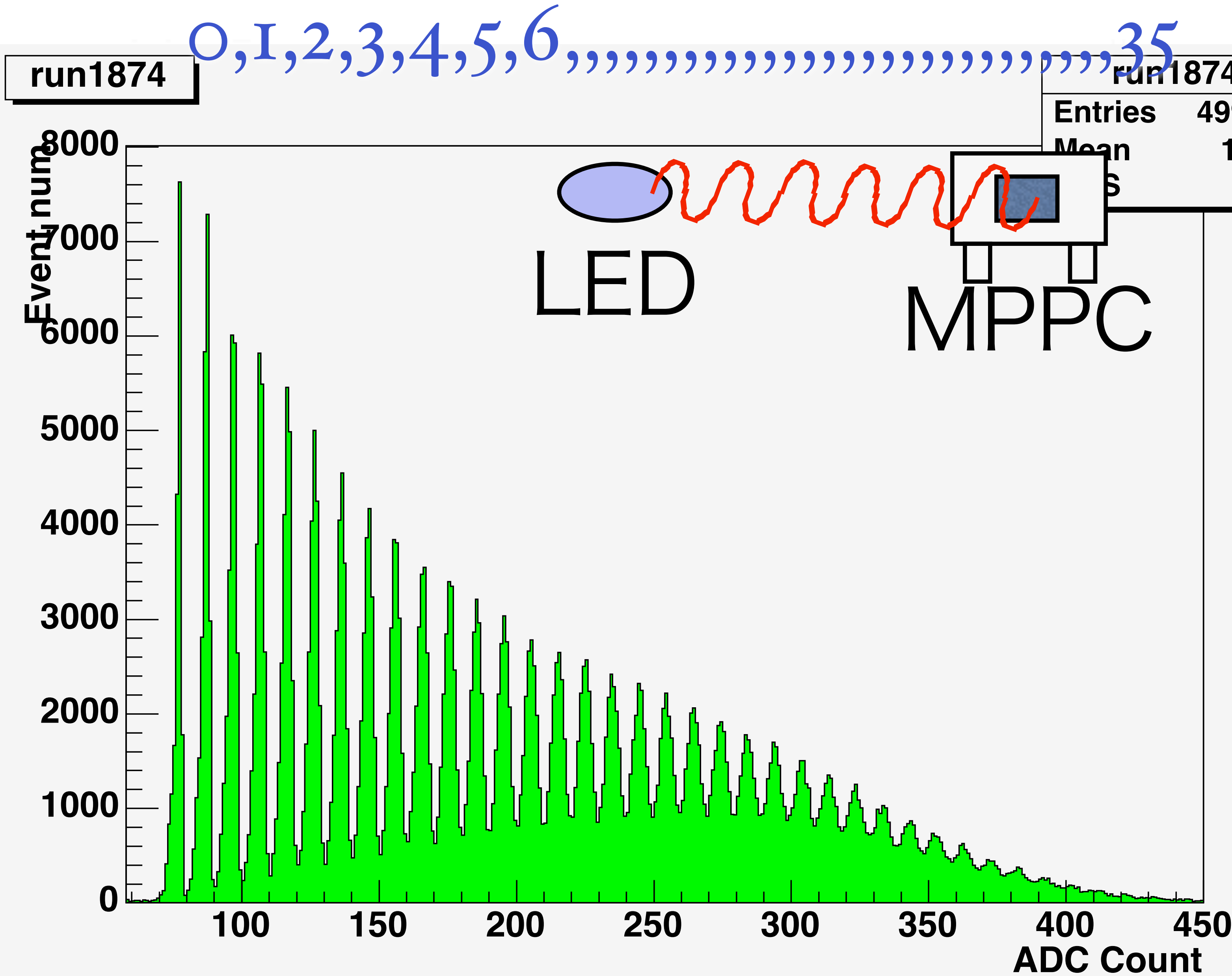
- Gain ~ $10^{5\sim6}$ with Geiger mode
- Gain ~ $(V_{bias}-V_{breakdown})C/e$
- photon counting capability

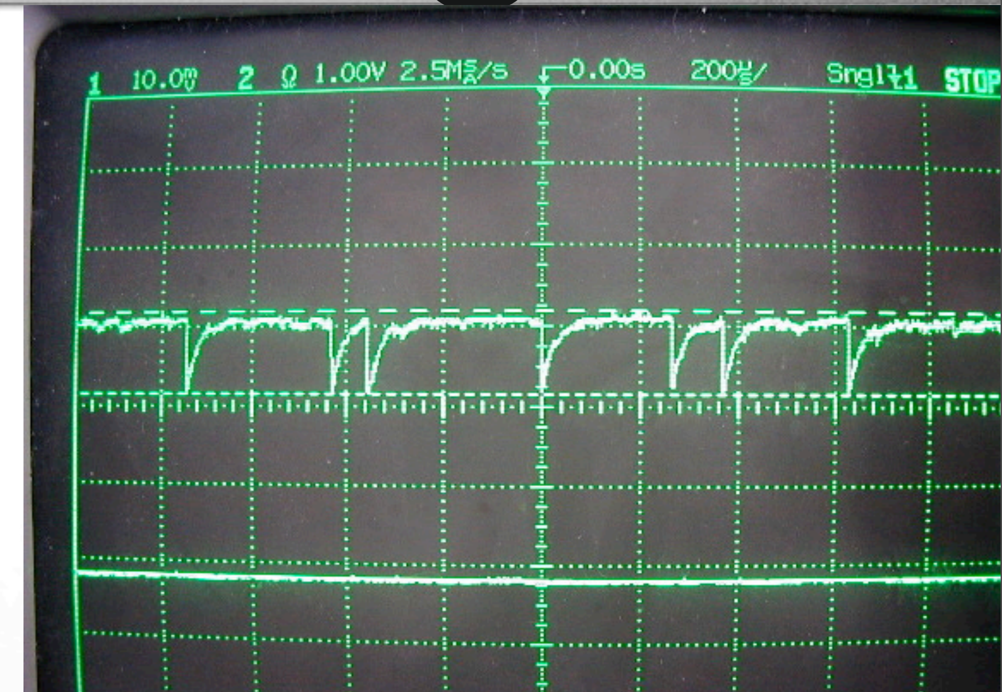


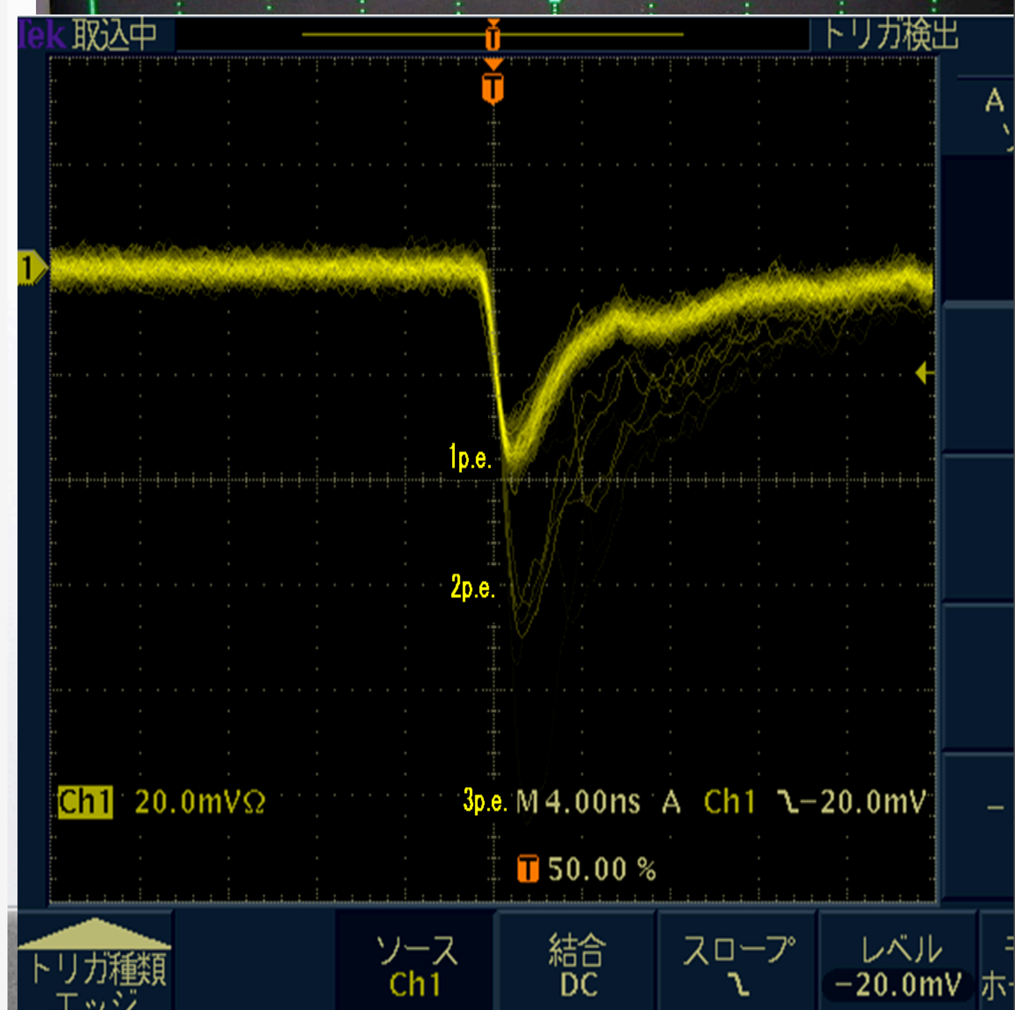


photon counting

- uniform response for all pixel
- # of photons ~ # of pixels



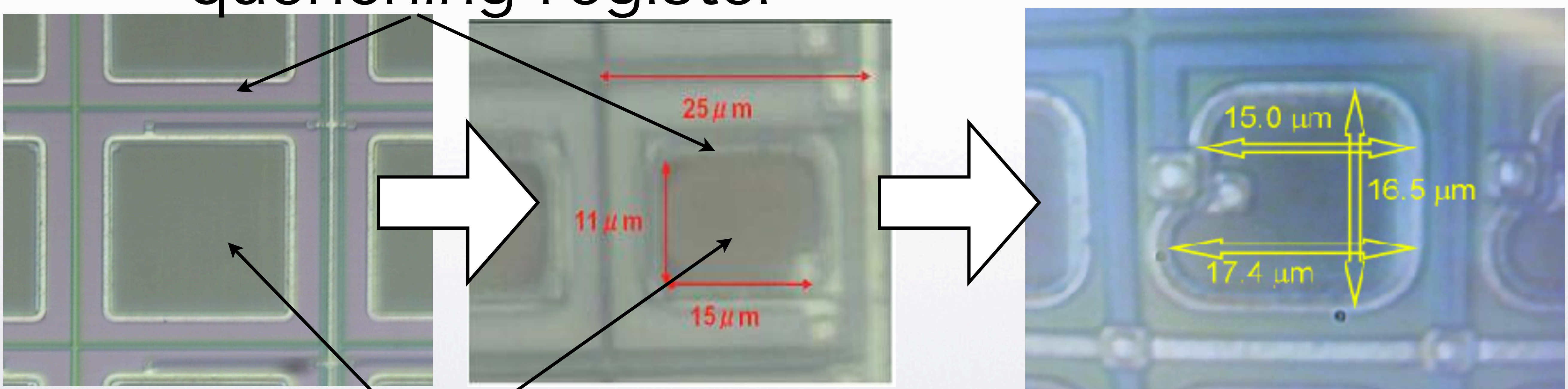




development with HPK

- Hamamatsu photonics company
- responsible MPPC prod.

quenching register

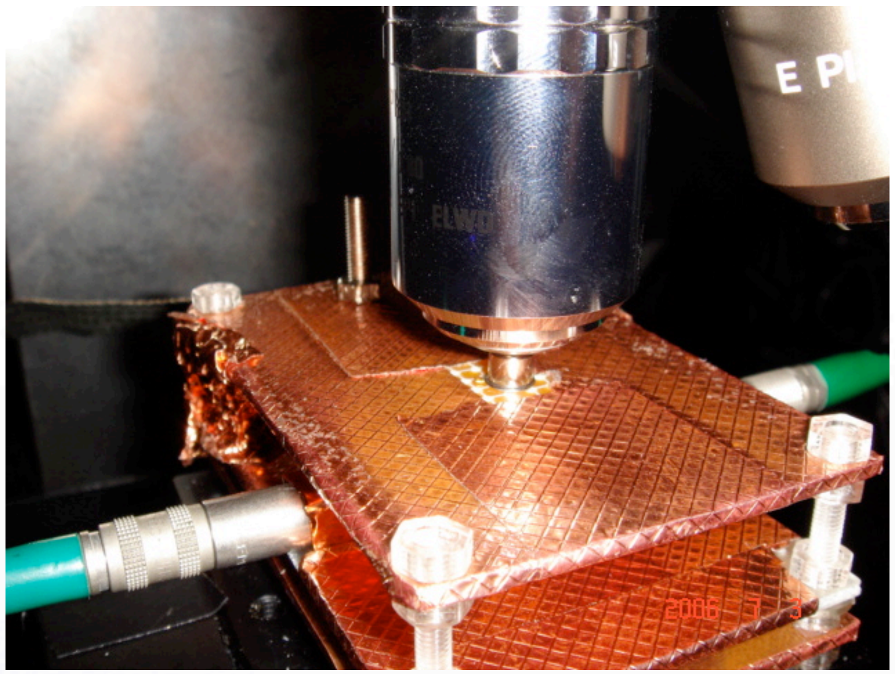


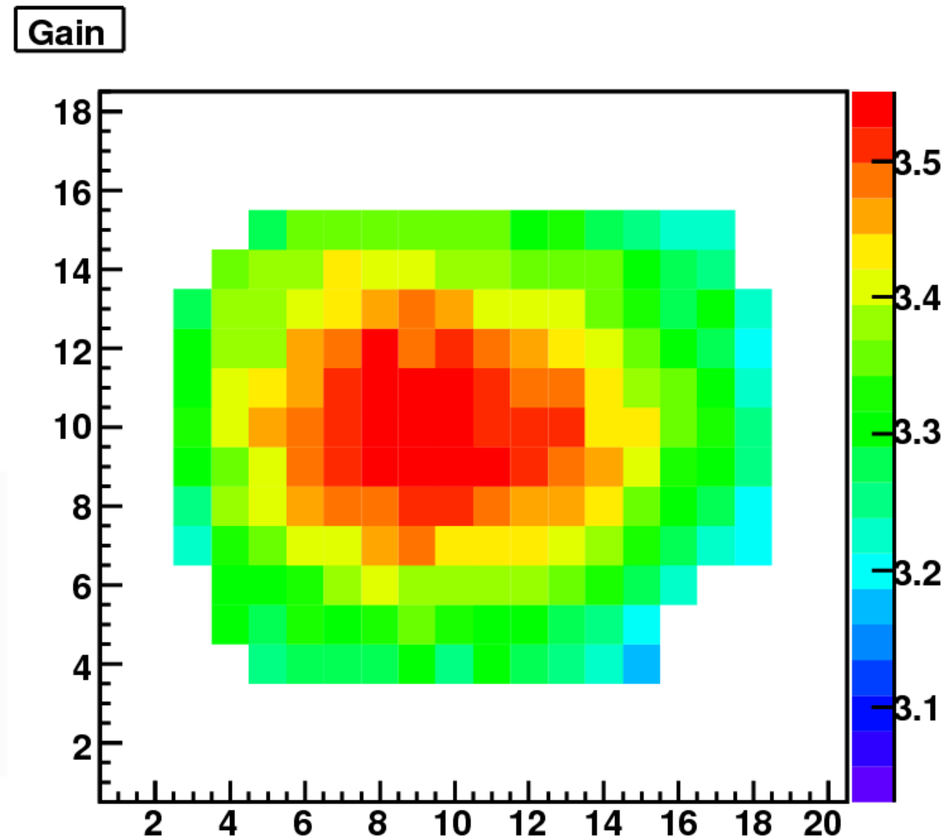
2005 2006 2008

sensitive area ~ 25%

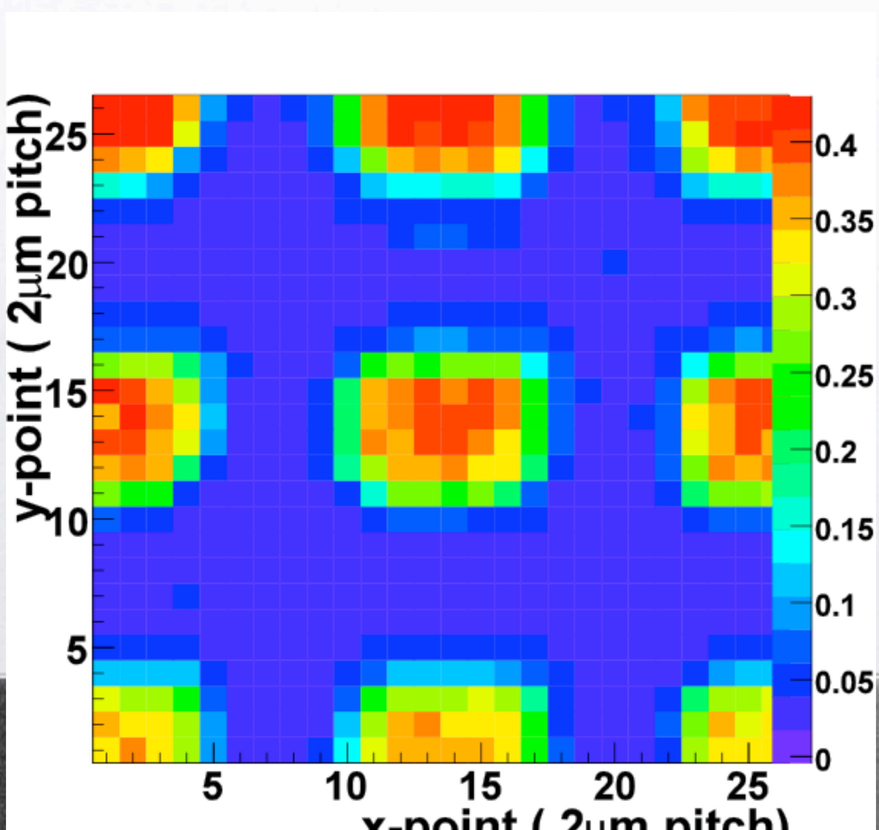
uniformity in a pixel

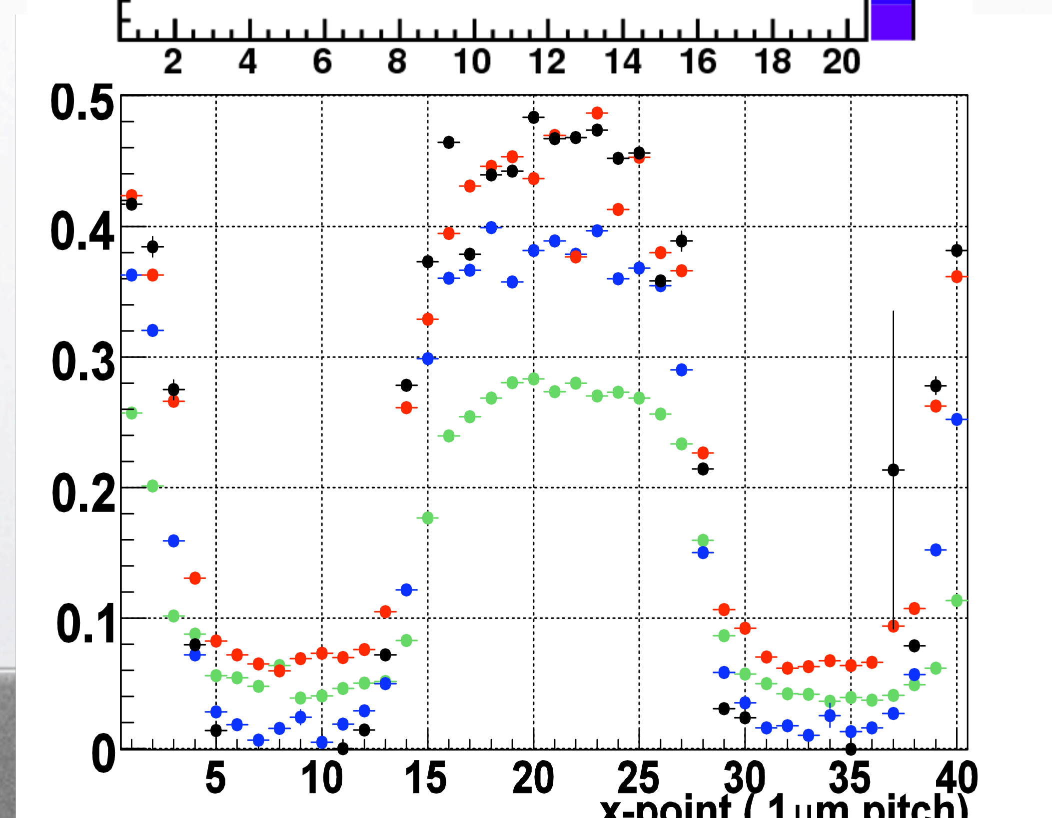
- tested by laser shot of 1μm





uniform response in a pixel

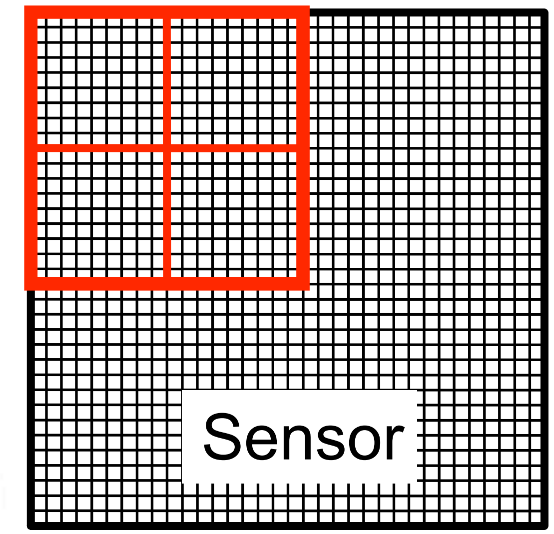


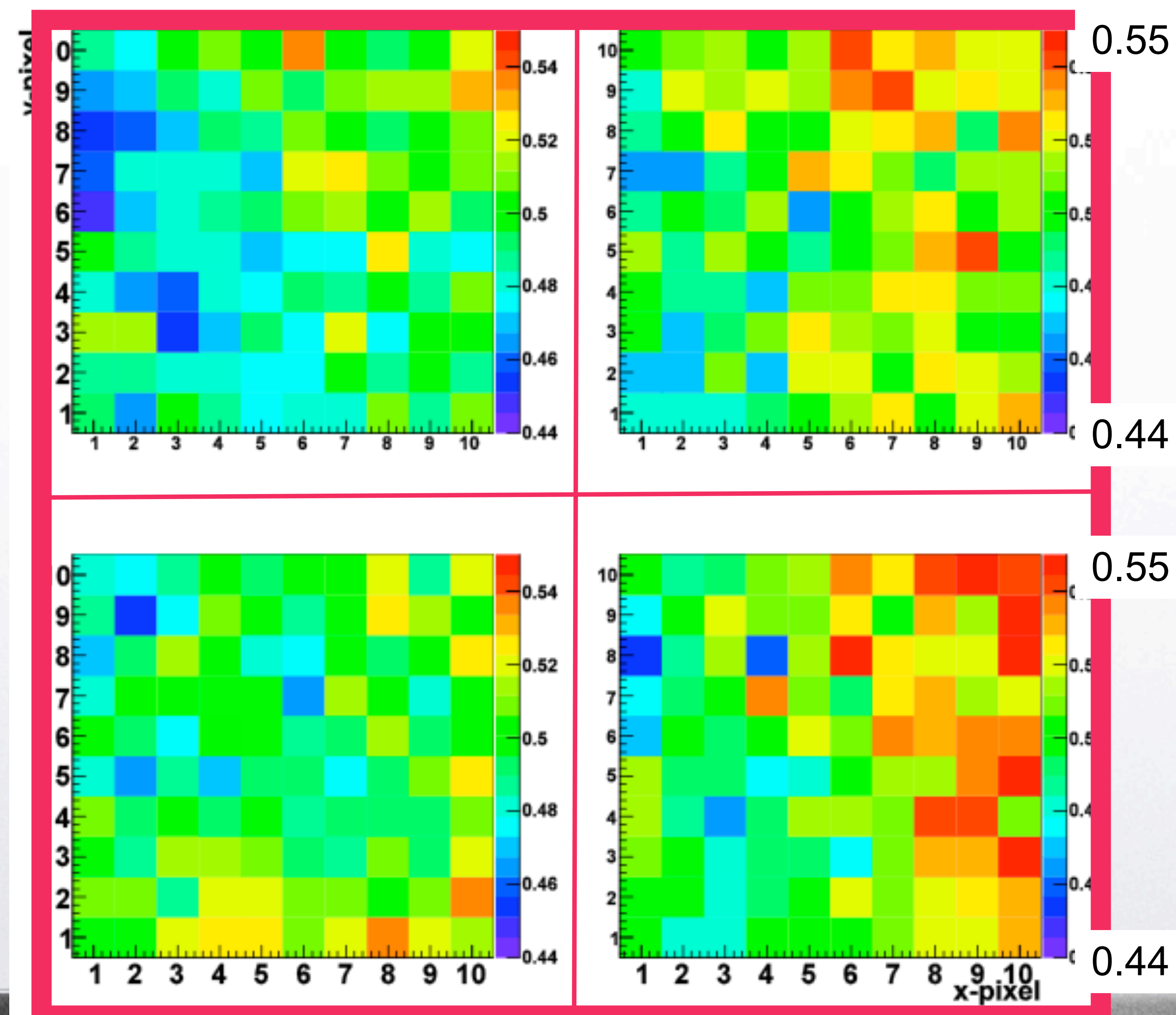


stable with Vbias

uniformity in pixels

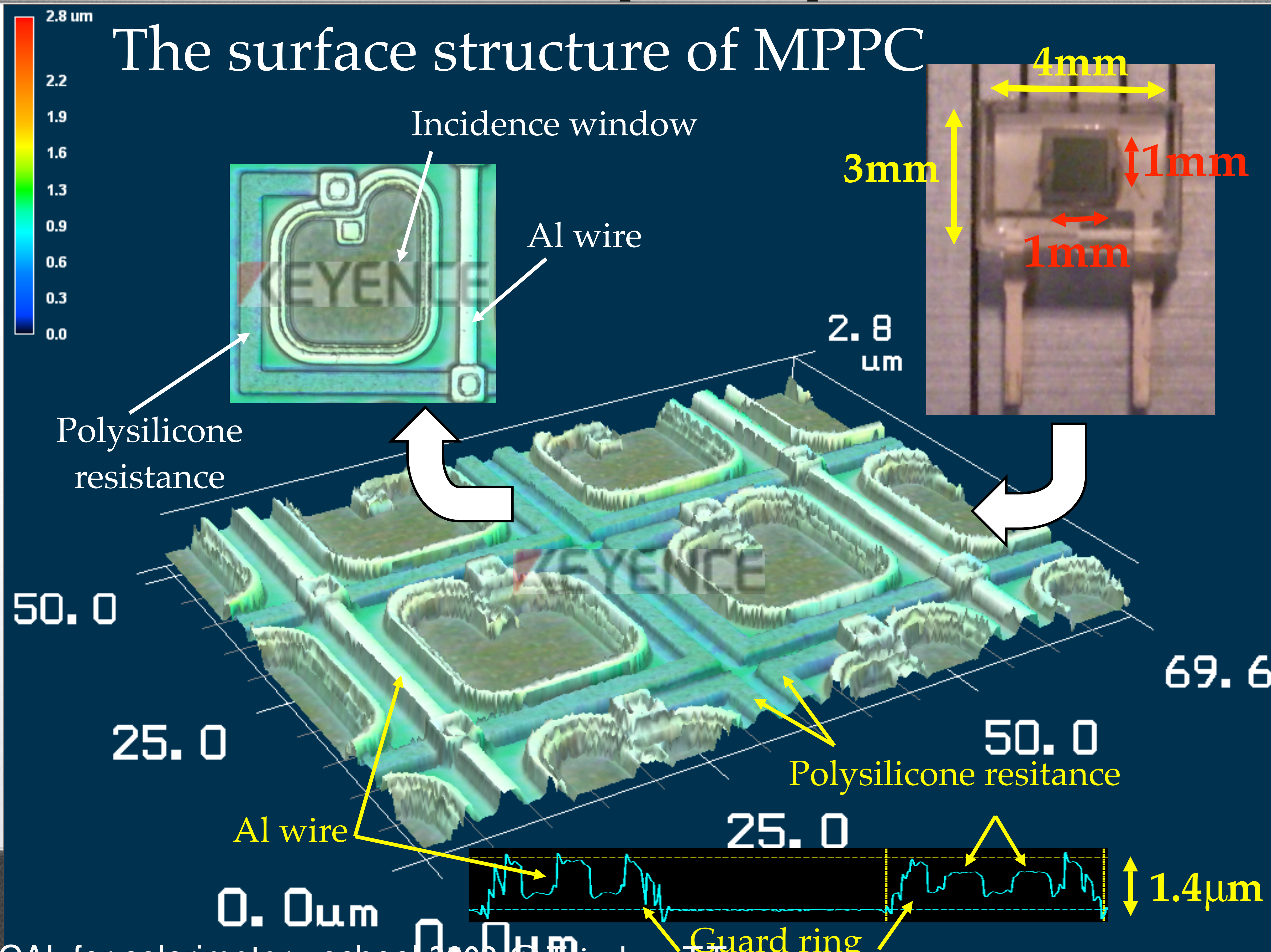
- pixcel uniformity is tested
- 20 x 20 pixels





very small variation
3%

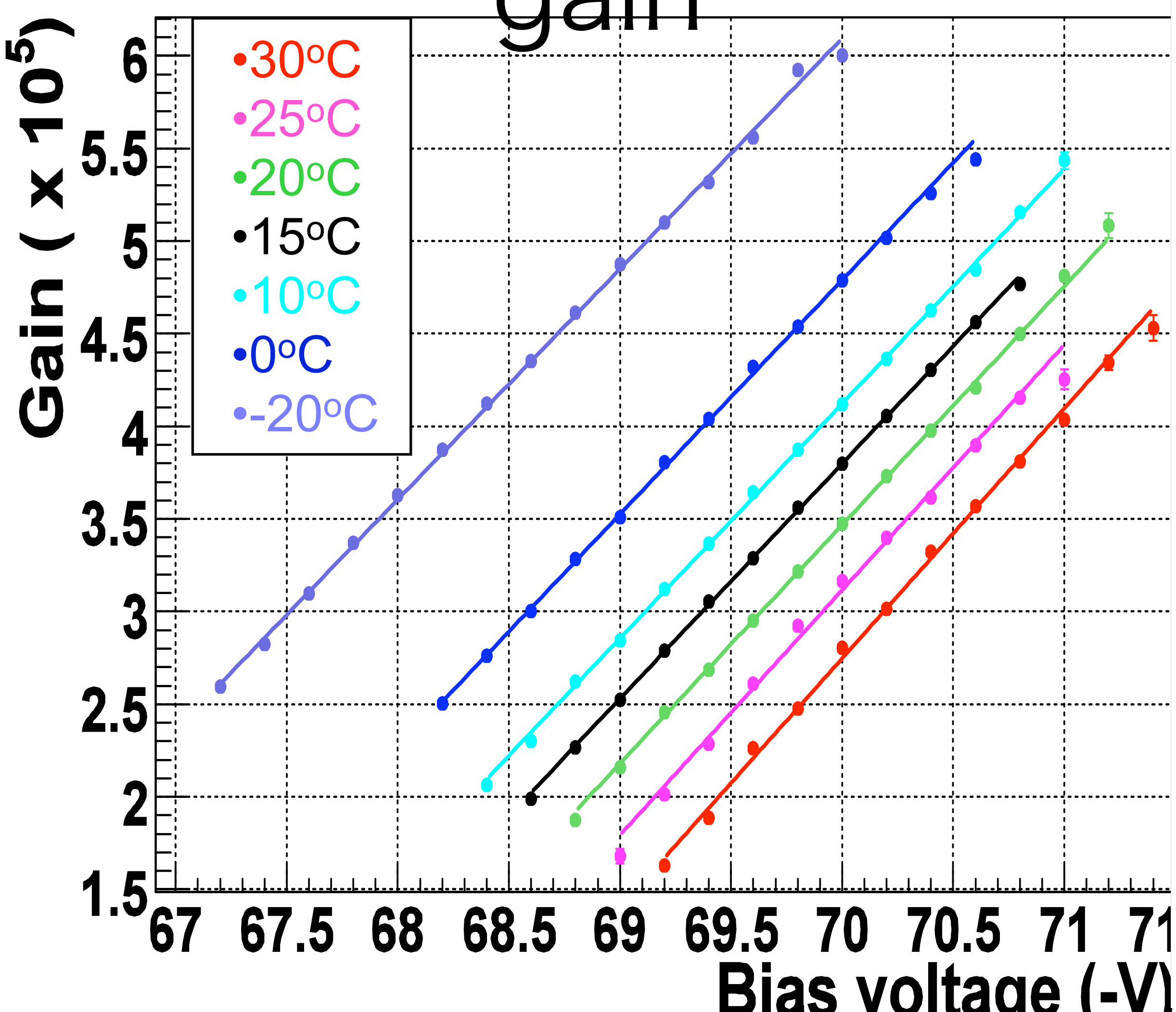
microscope picture



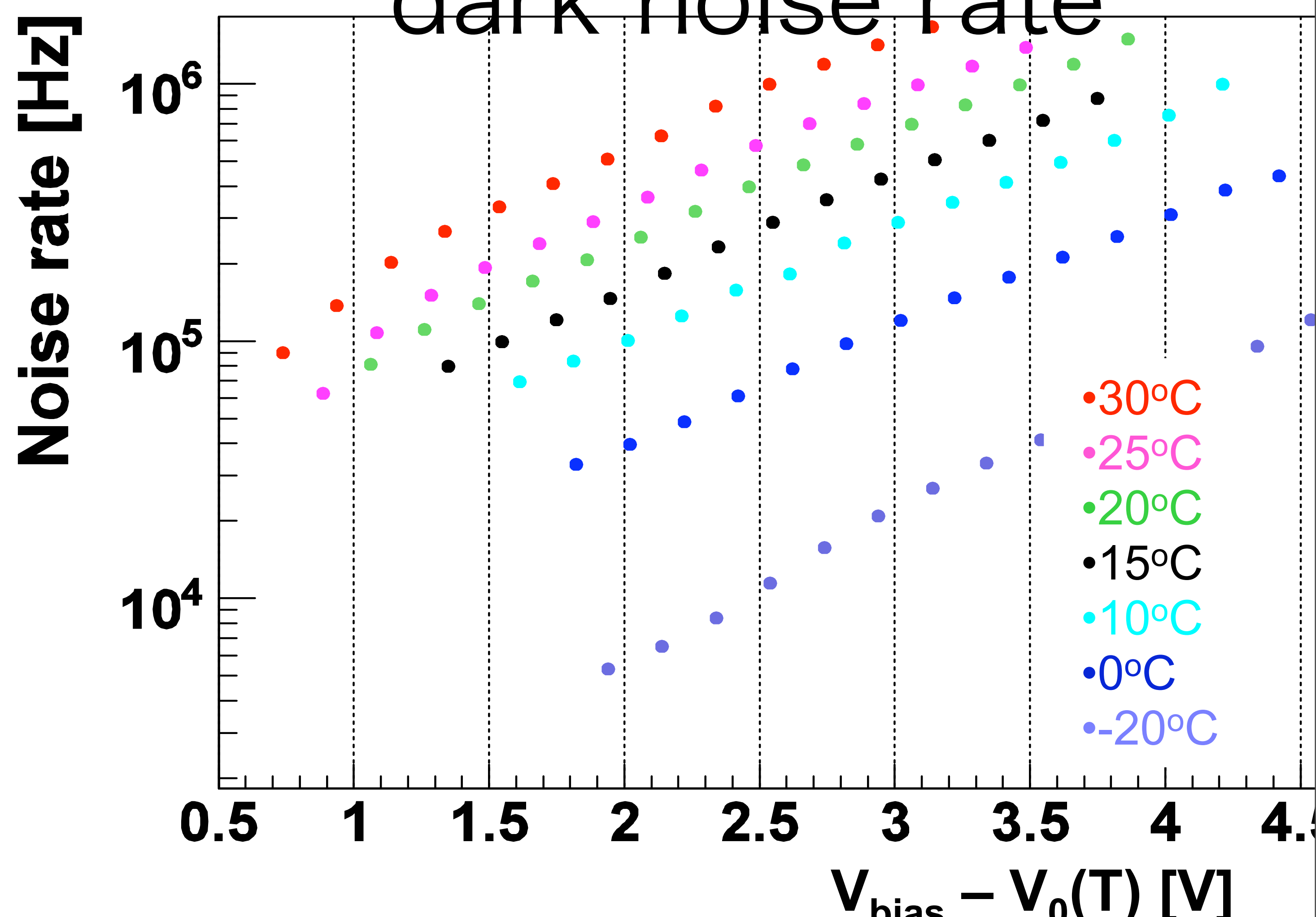
temperature dep.

- Gain depends of Temp. with ~ - 2%/K.
- DARK noise rate dep. Temp. with + coef.

gain



dark noise rate



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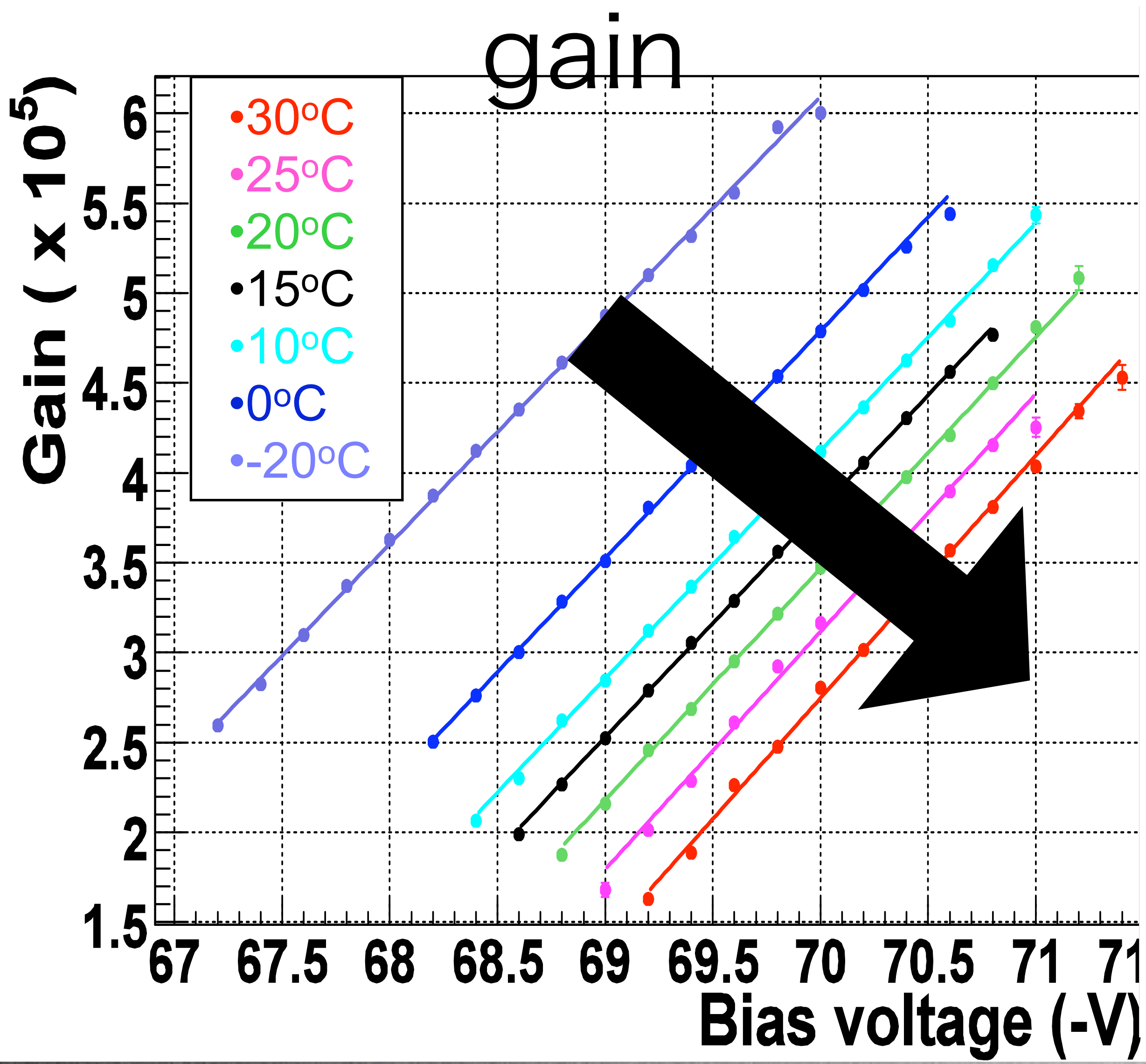

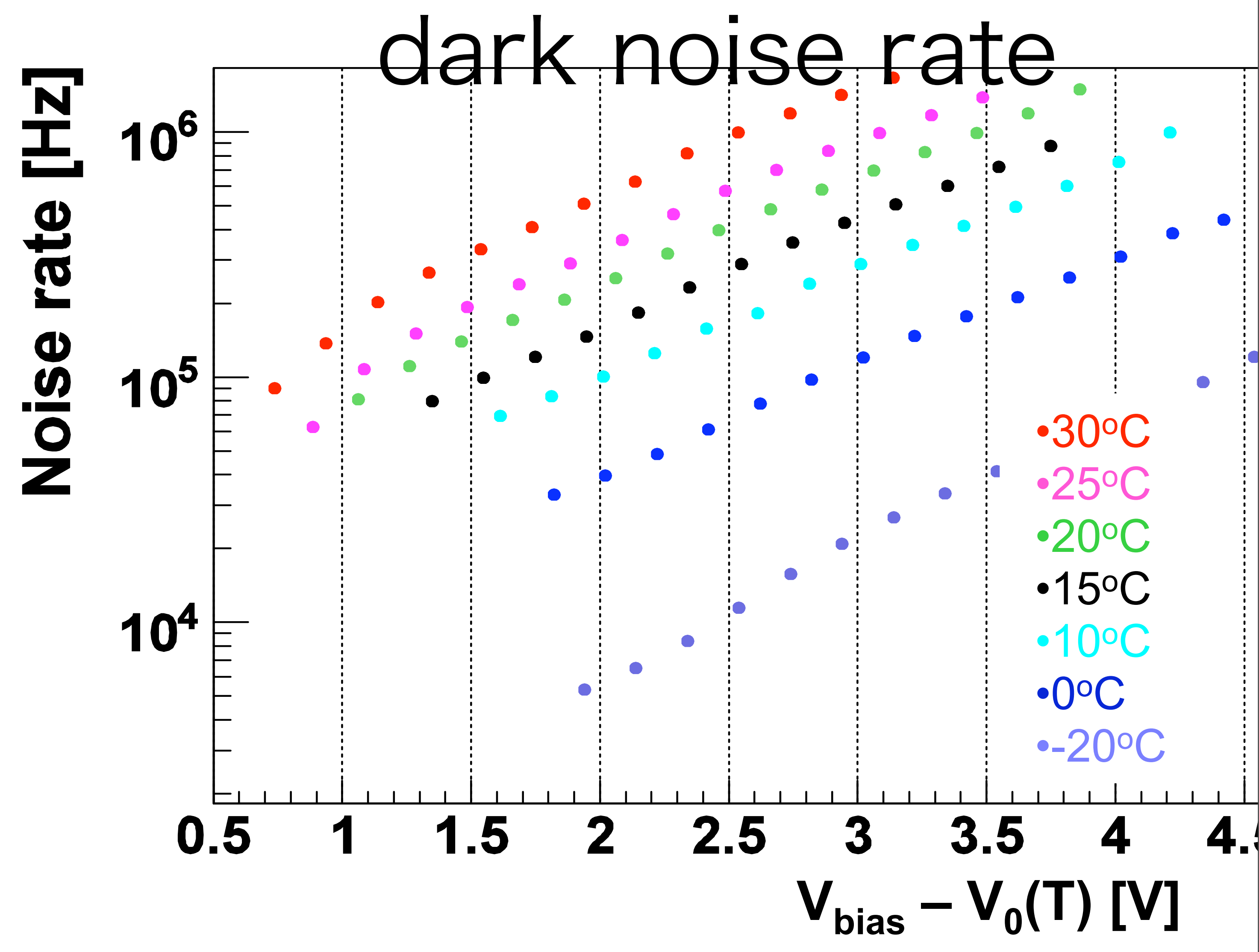

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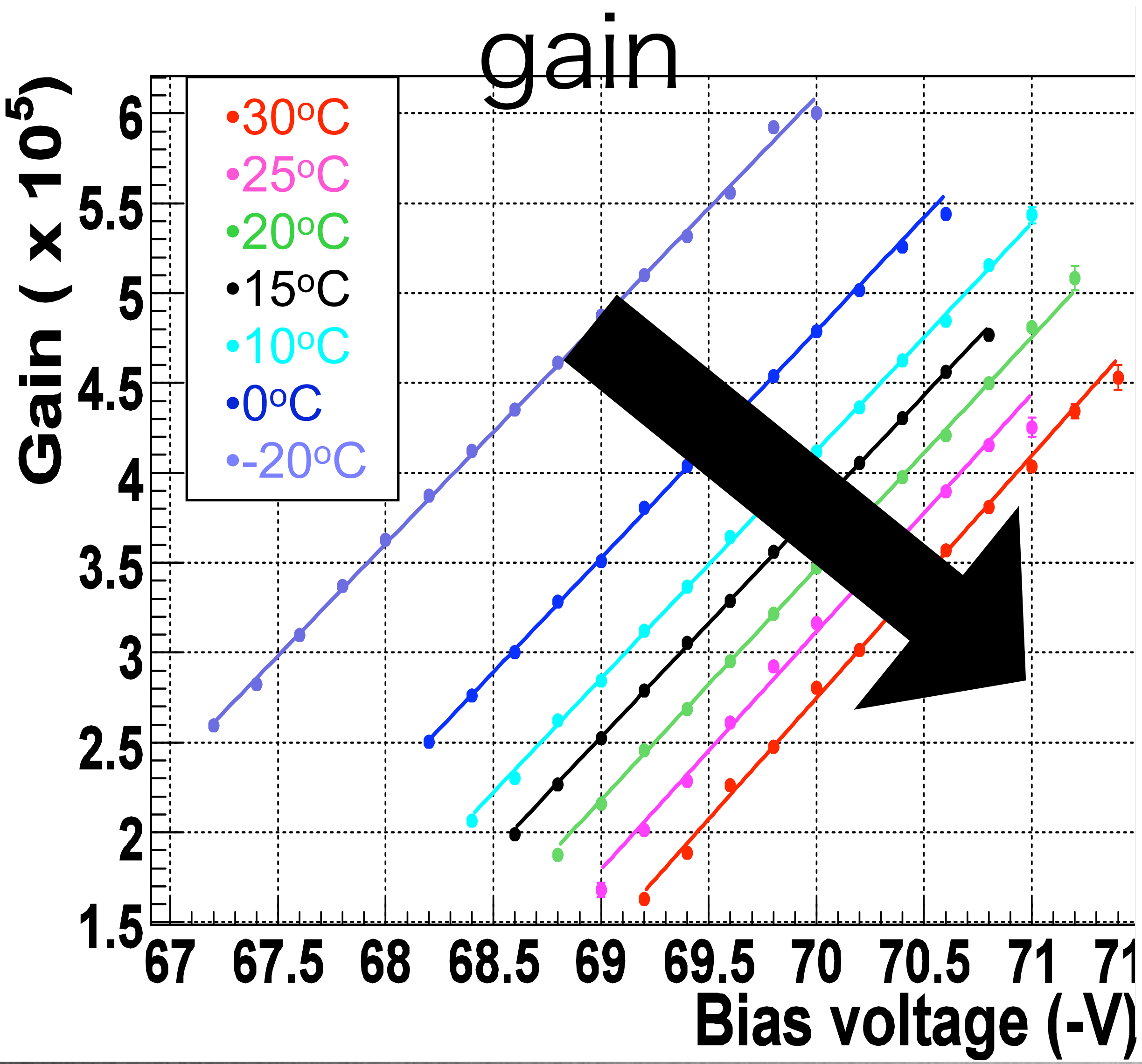
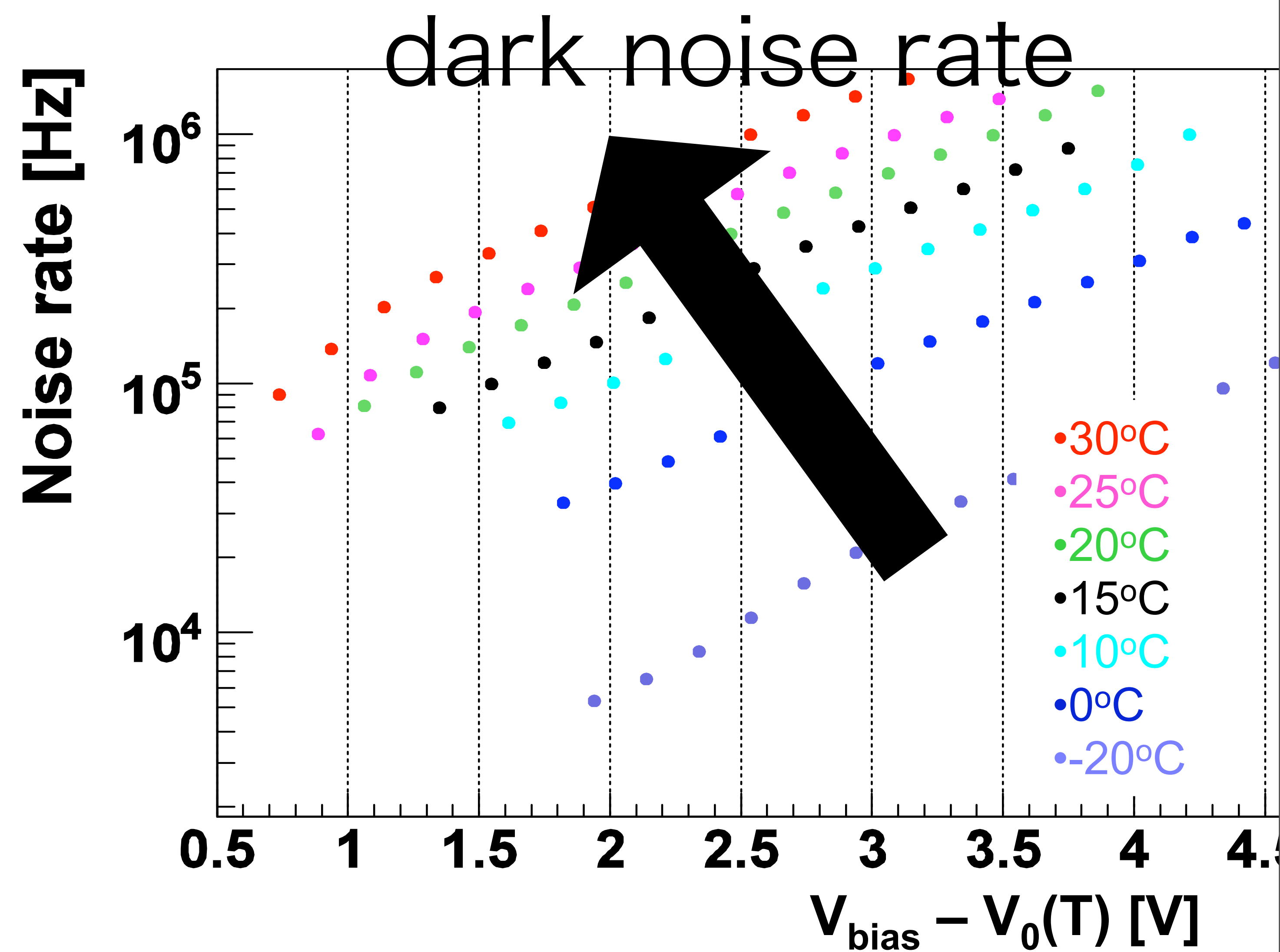
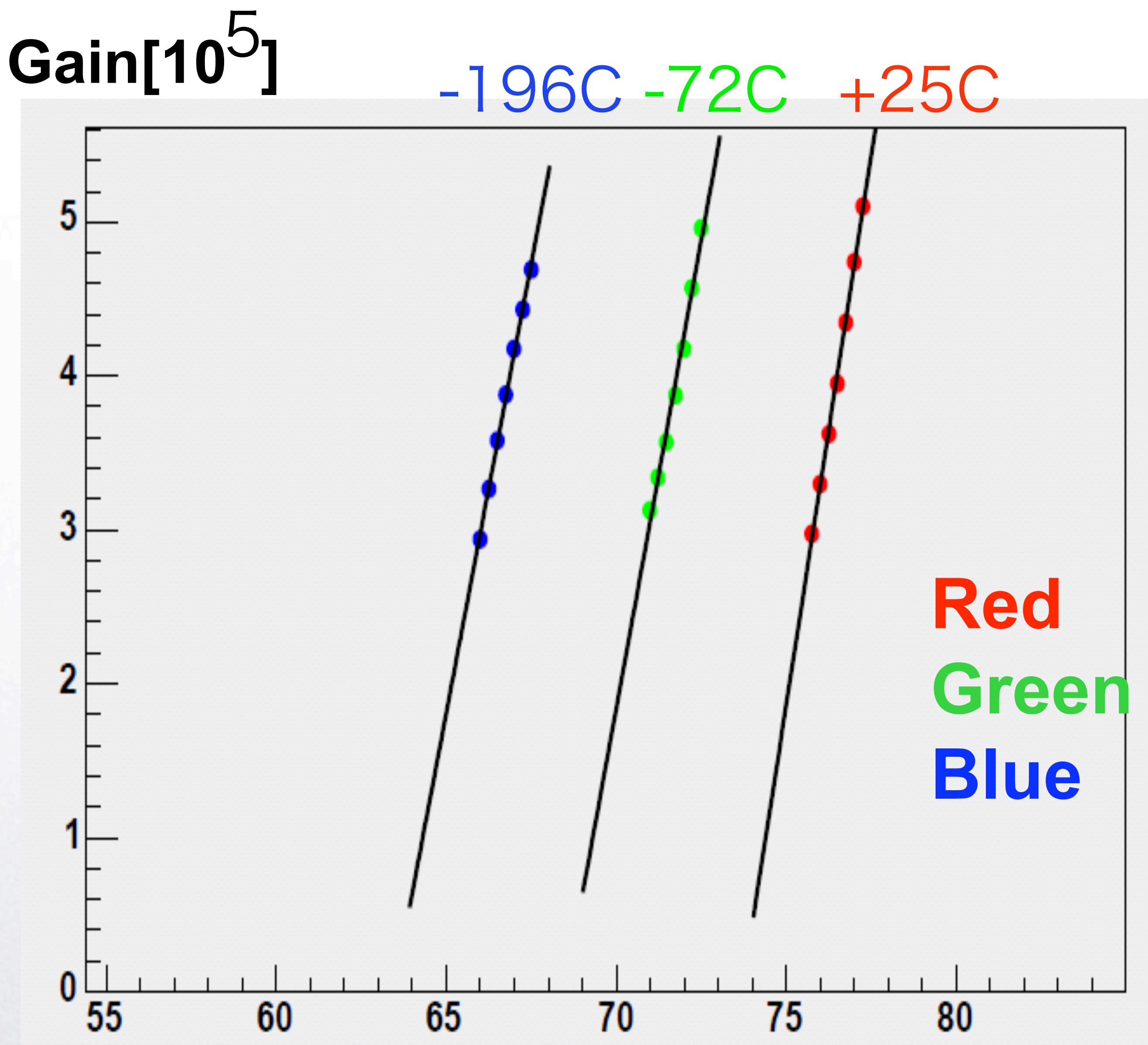


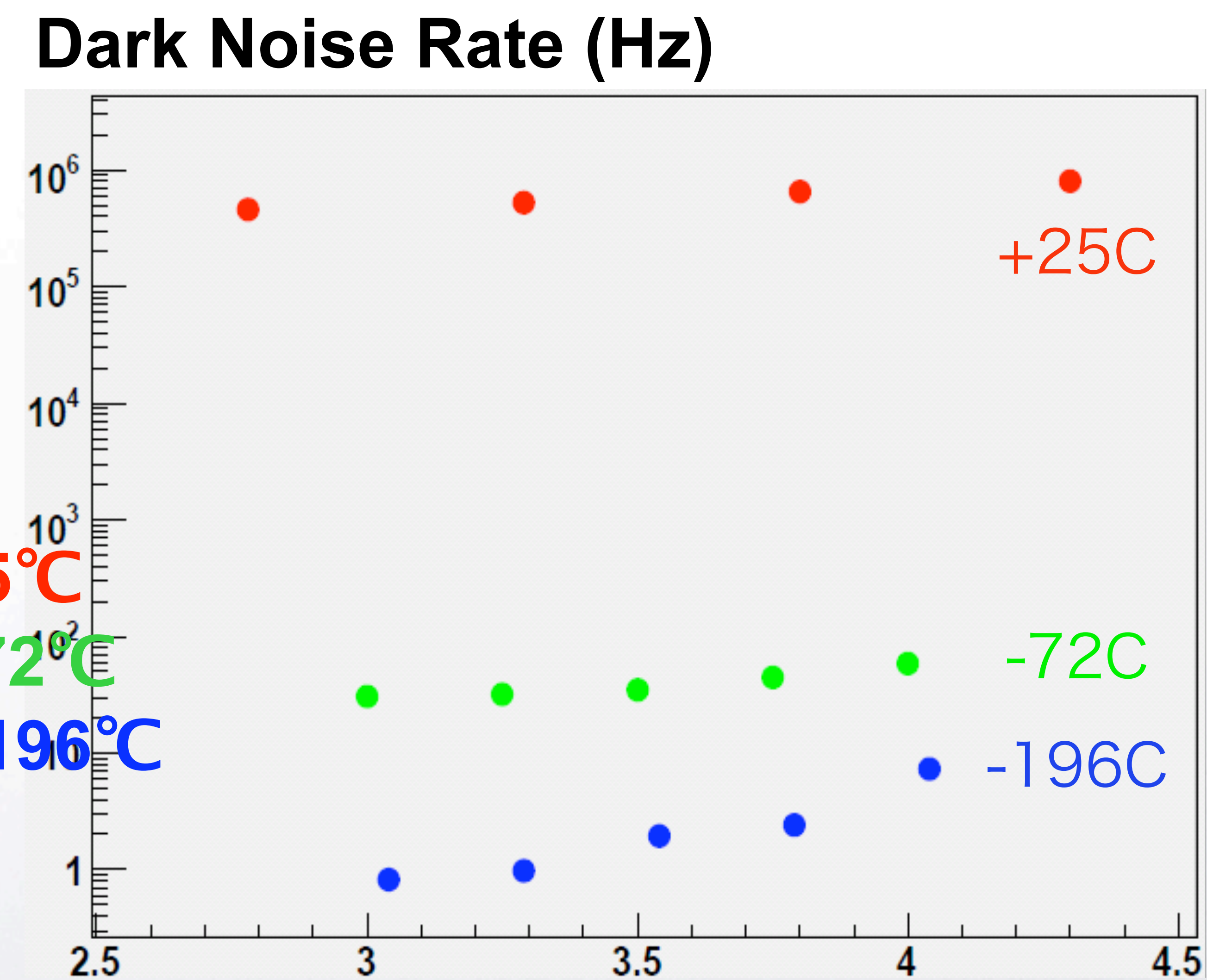


temperature dep. 2

- lower temperature
- capacitance stays const.



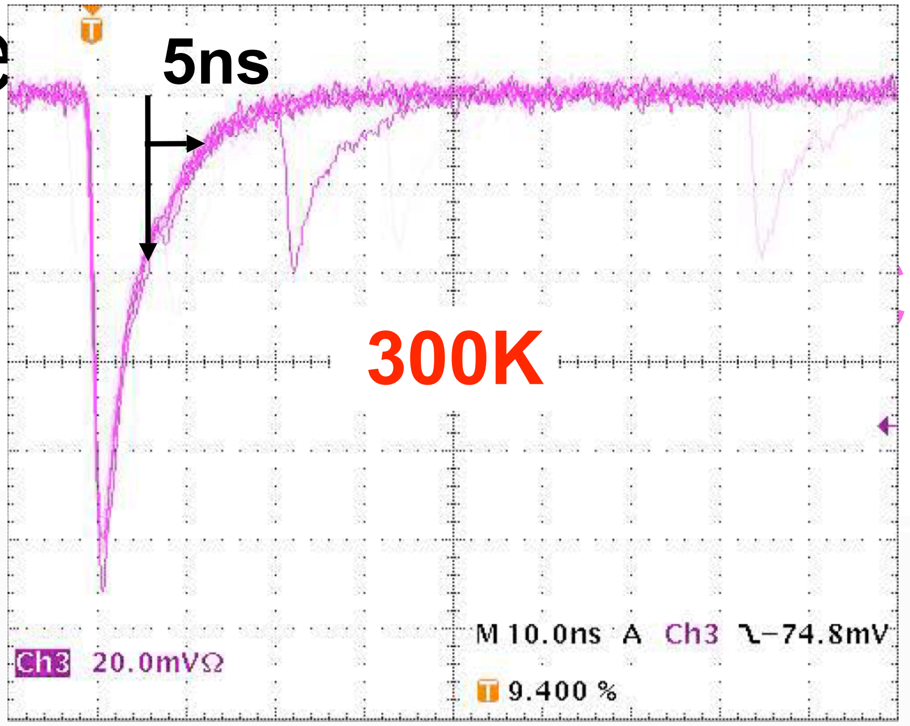
Vbias(V)

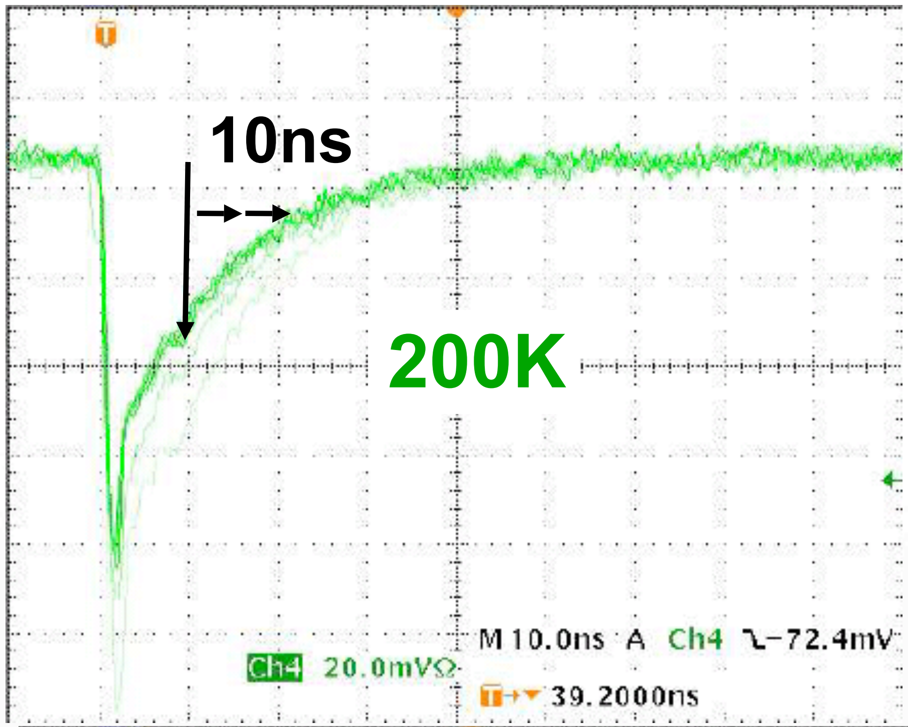


Vbias-Vbreakdown (V)

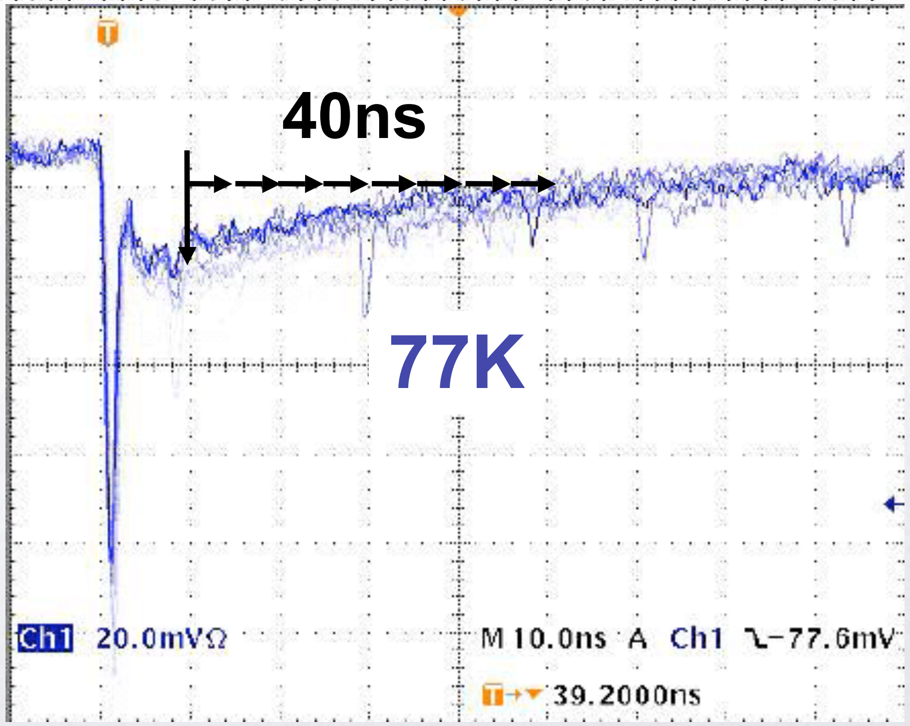
temperature dep. 3

- signal shape
- time const. of tail is understood
- by Rq(T)





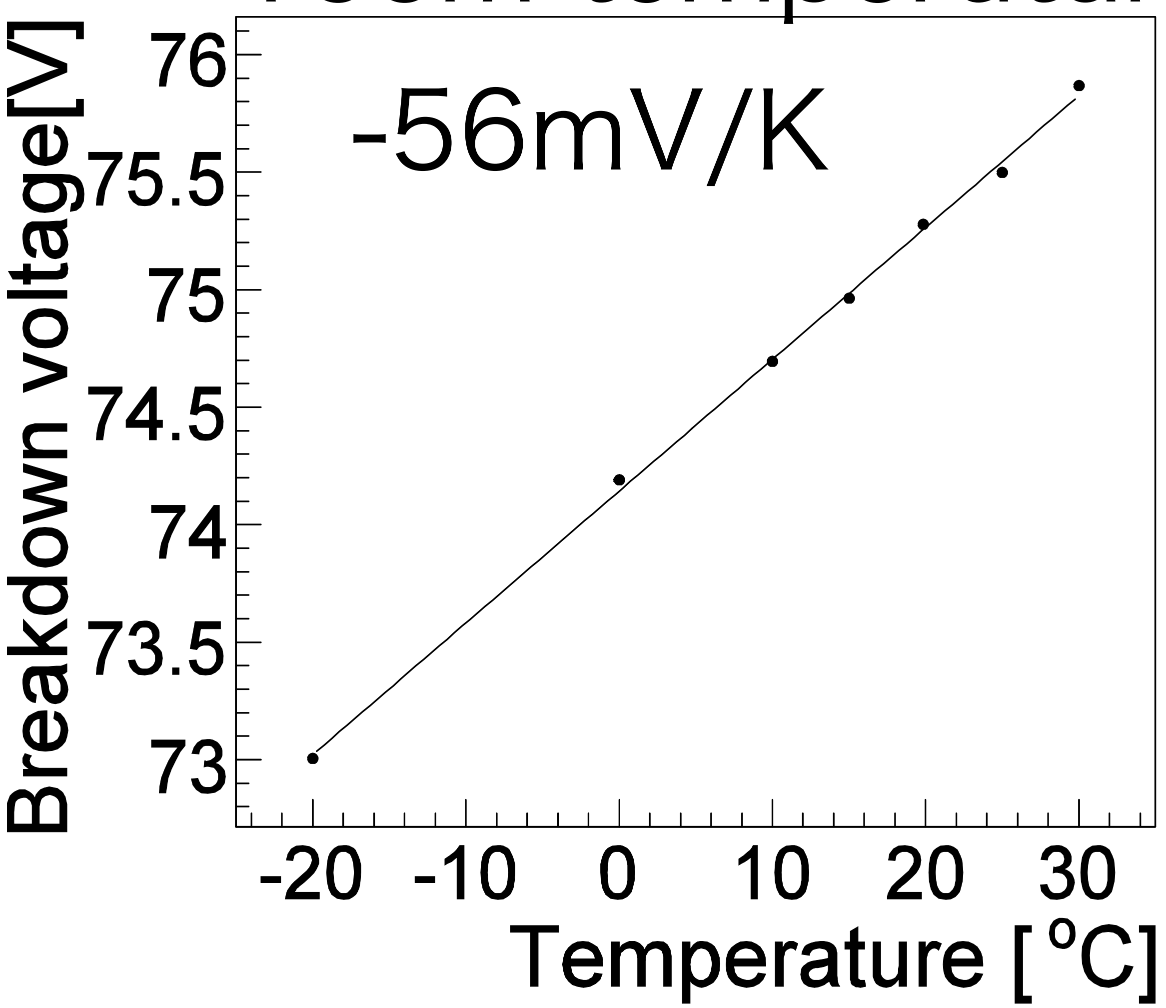
	Resistance (R)	Capacitance (C)	R x C
300K	0.21MΩ	22.1fF	4.6ns
200K	0.40MΩ	22.0fF	8.8ns
77K	1.68MΩ	21.3fF	35.8ns



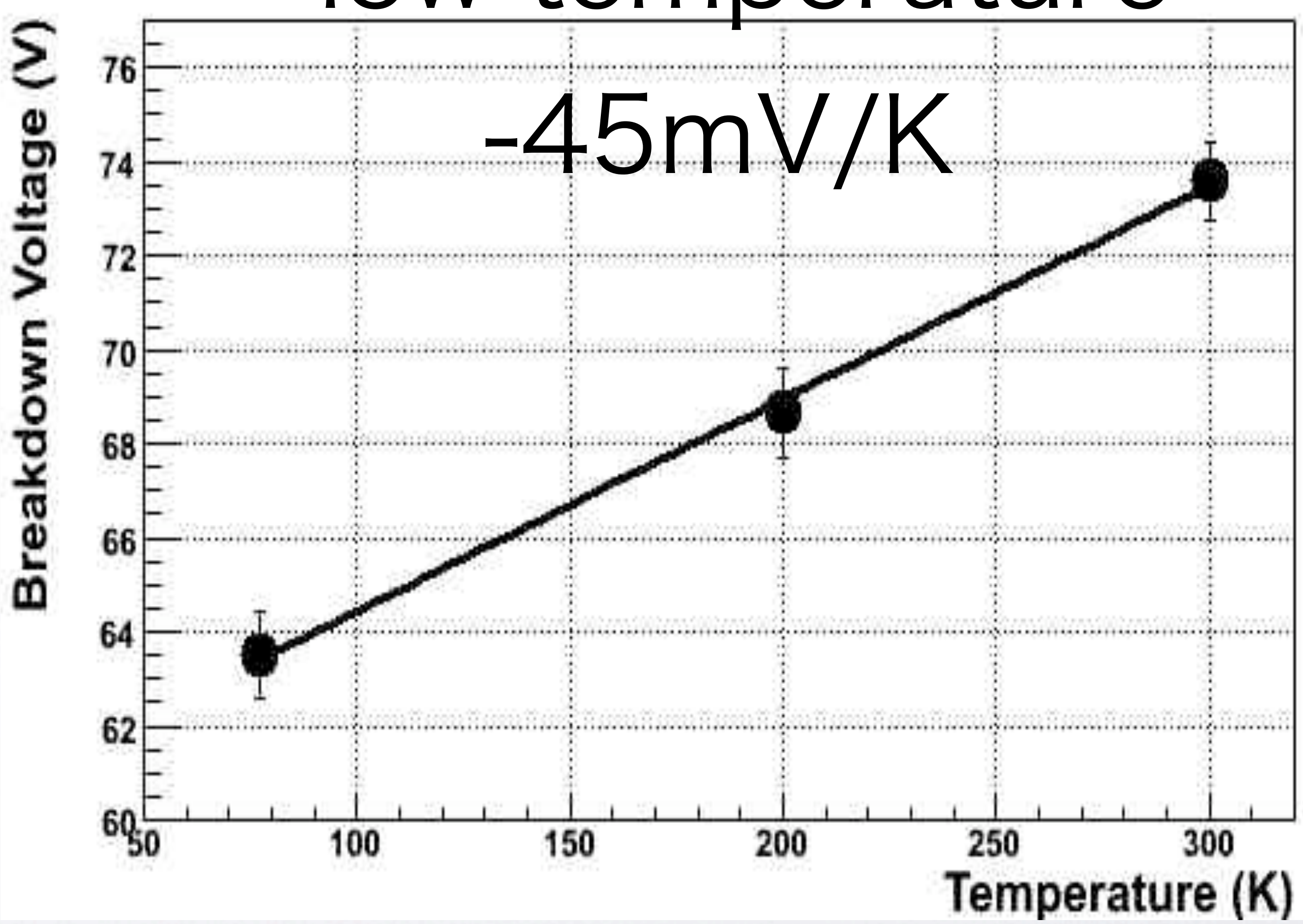
temperature dep. 3

- Breakdown Voltage vs Temperature

room temperature



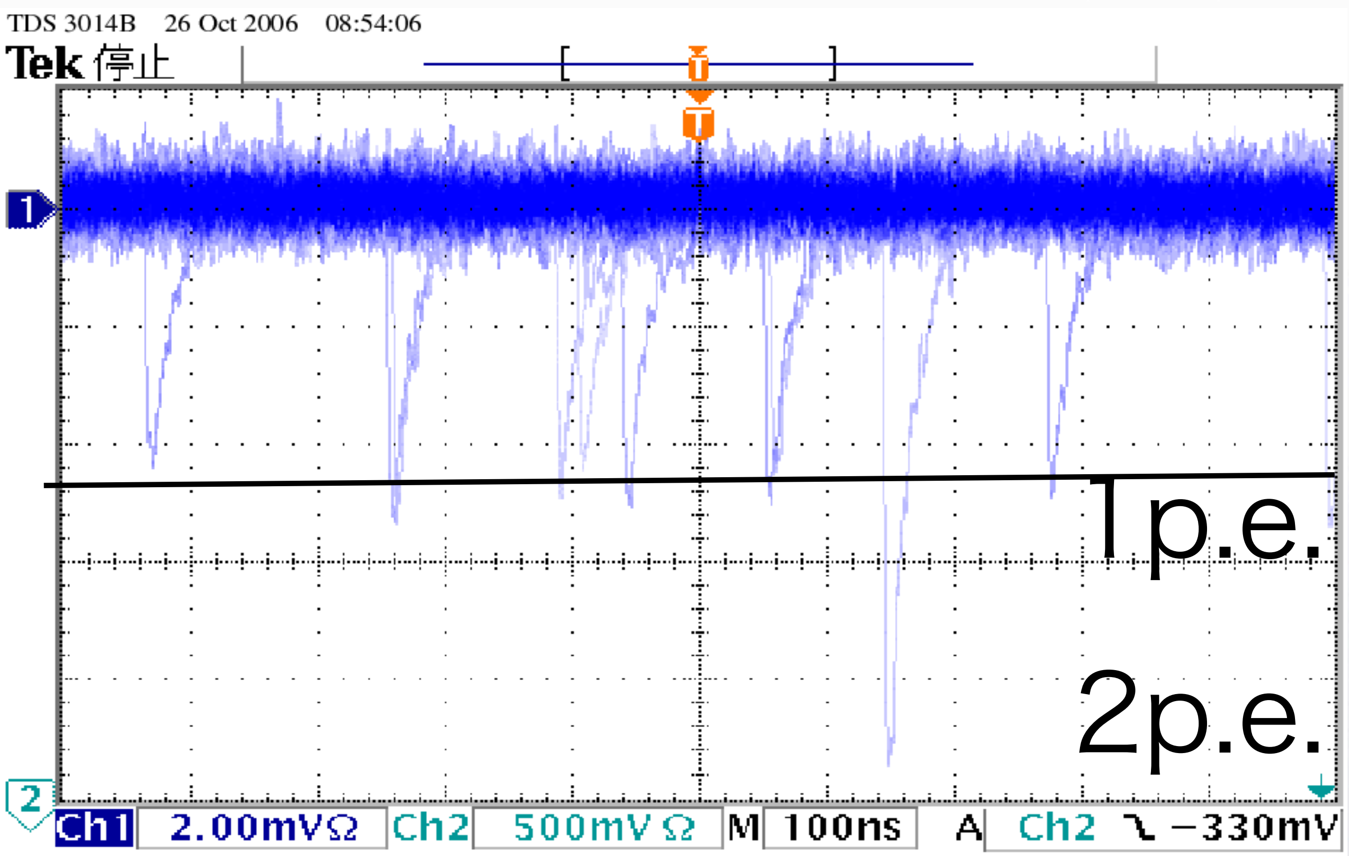
low temperature

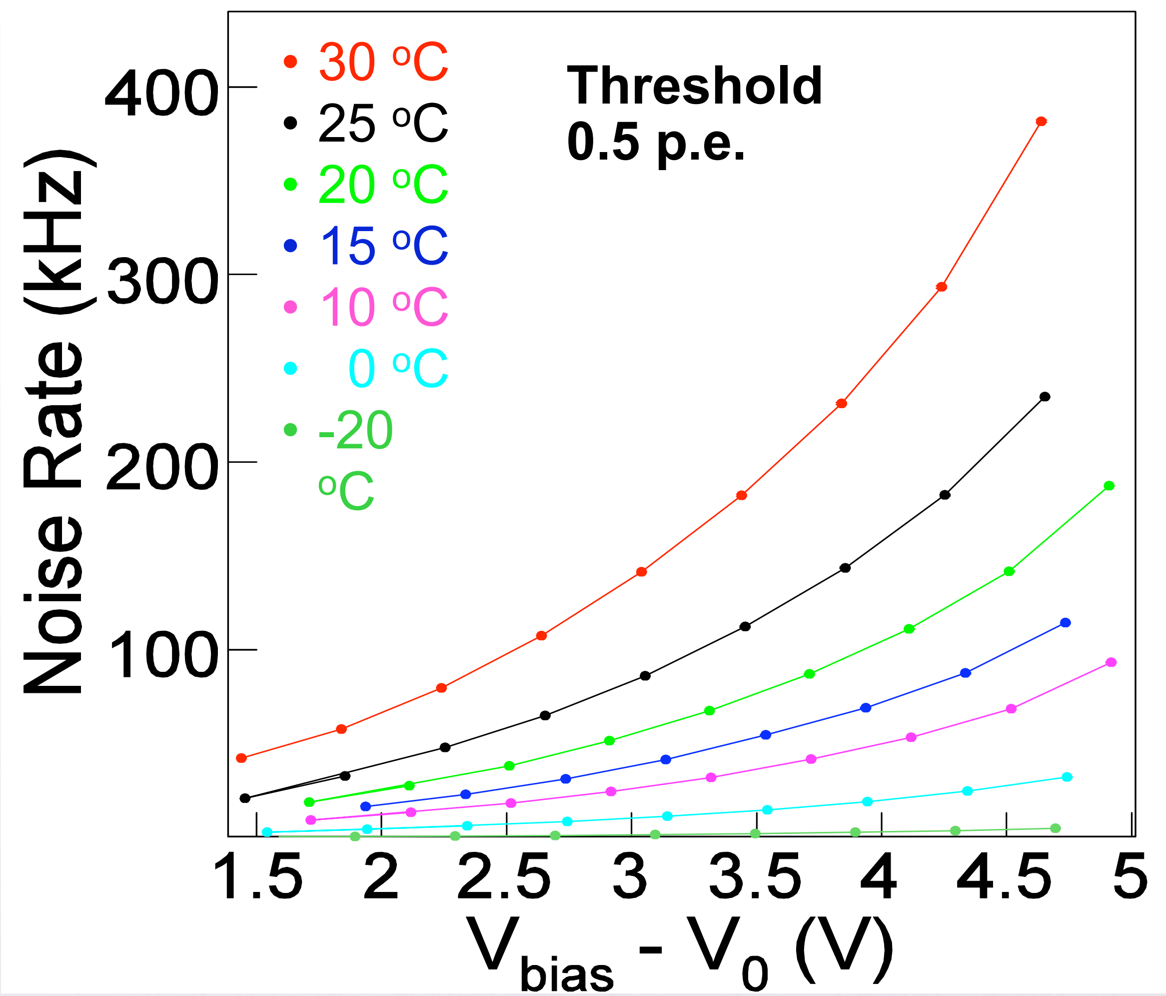


-196C -72C +25C

Dark noise

- silicon device
- thermal electron may occur avalanche in a pixel
- make an 1 p.e. equivalent signal
- ~1MHz

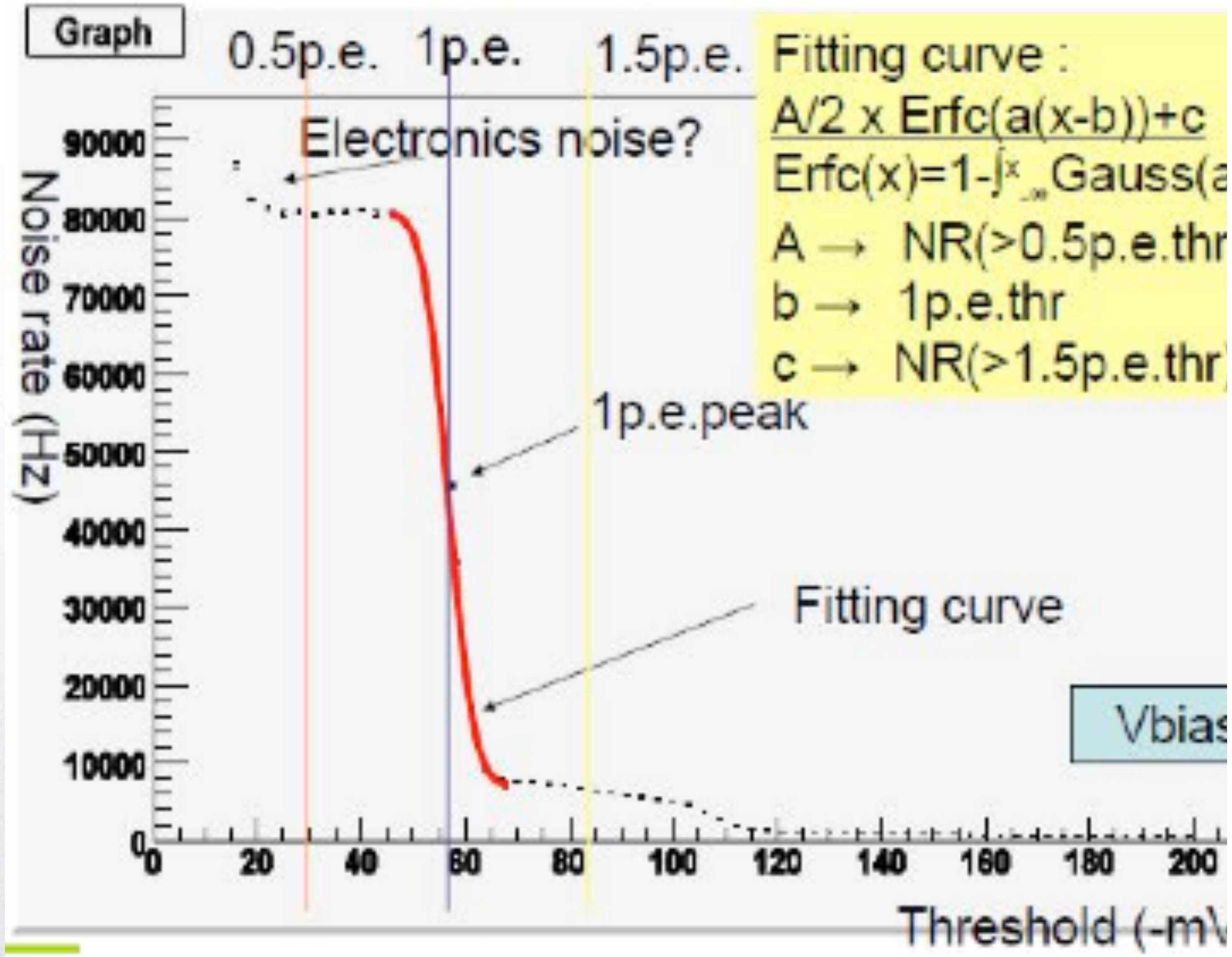


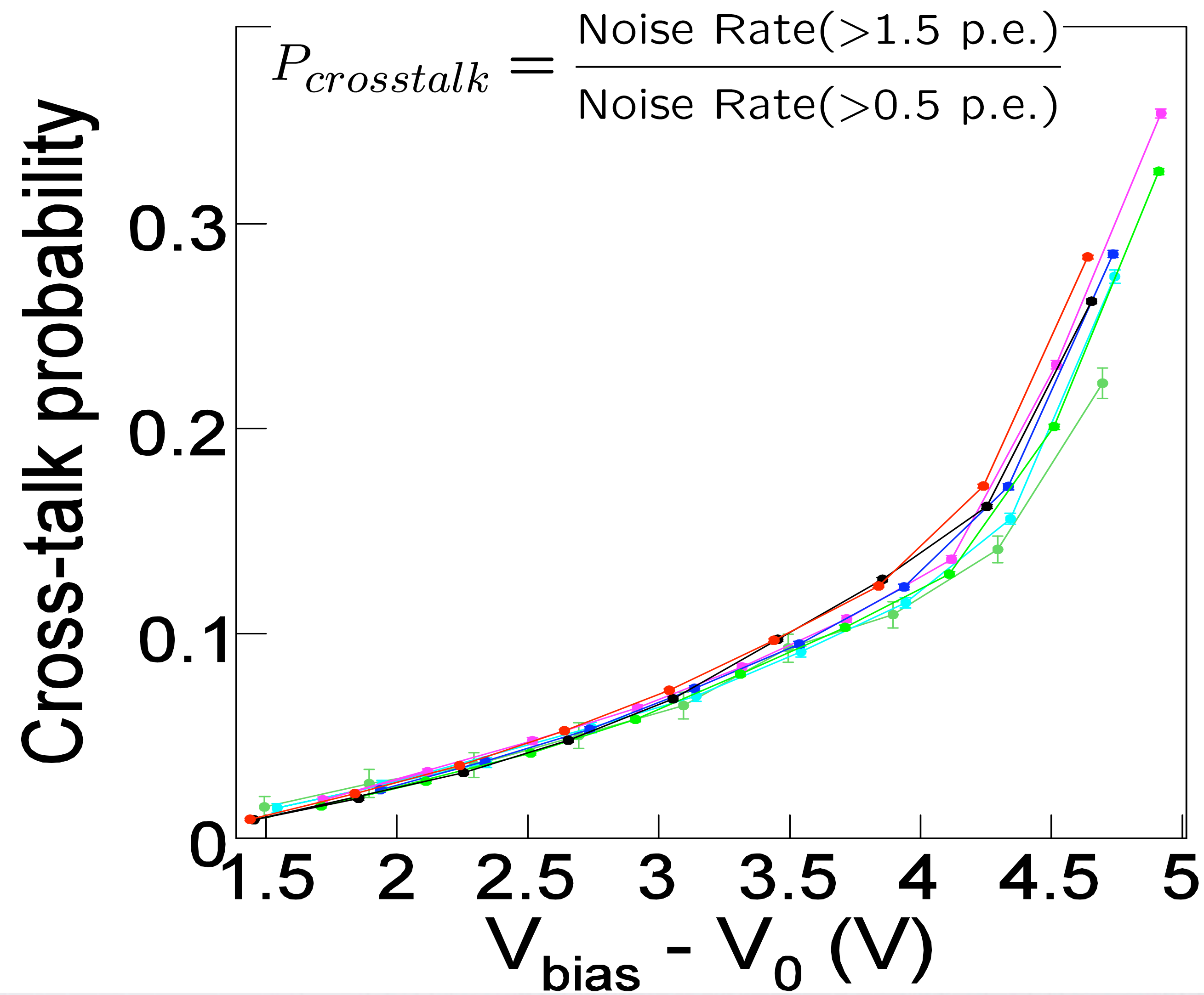


Dark noise 2

- threshold curve
- 2 p.e. signals due to cross talk

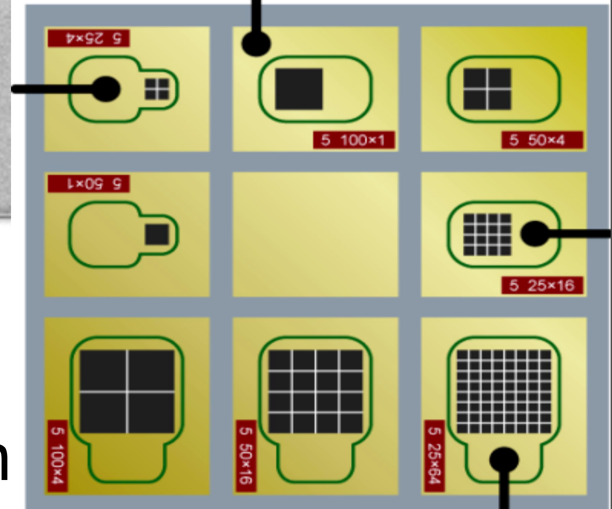
no temp. dep.



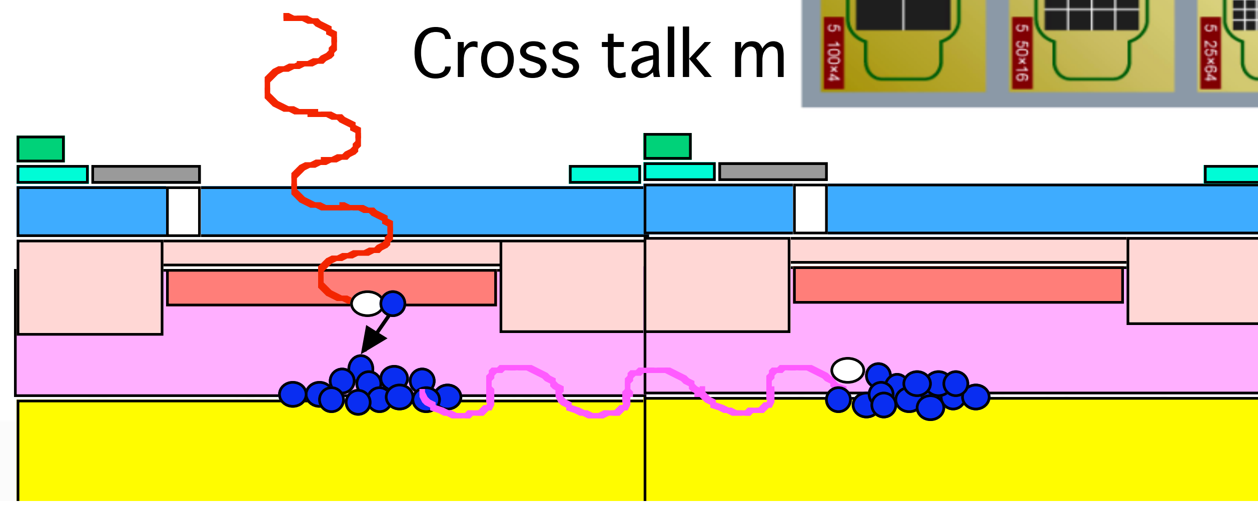


Cross talk

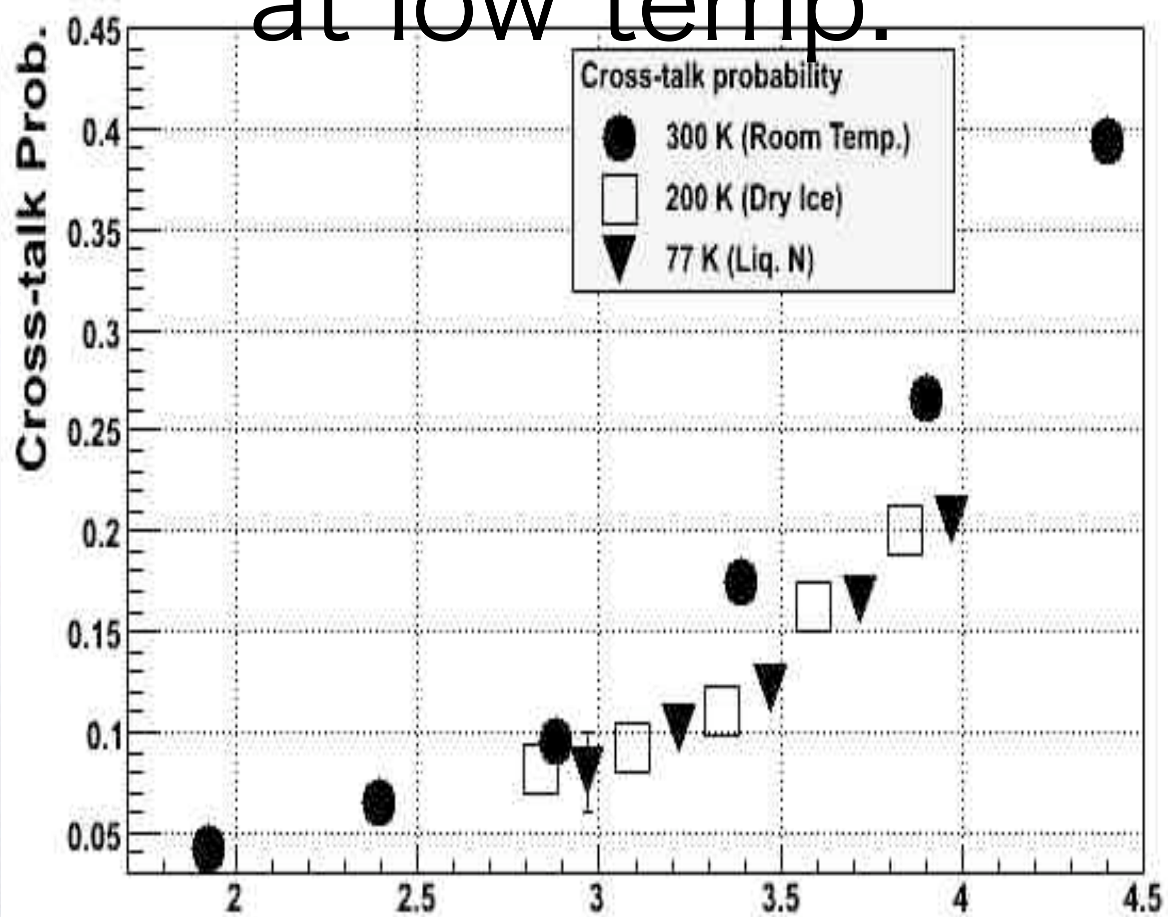
- between (neighboring) pixels
- 4,16,64,1600 pix



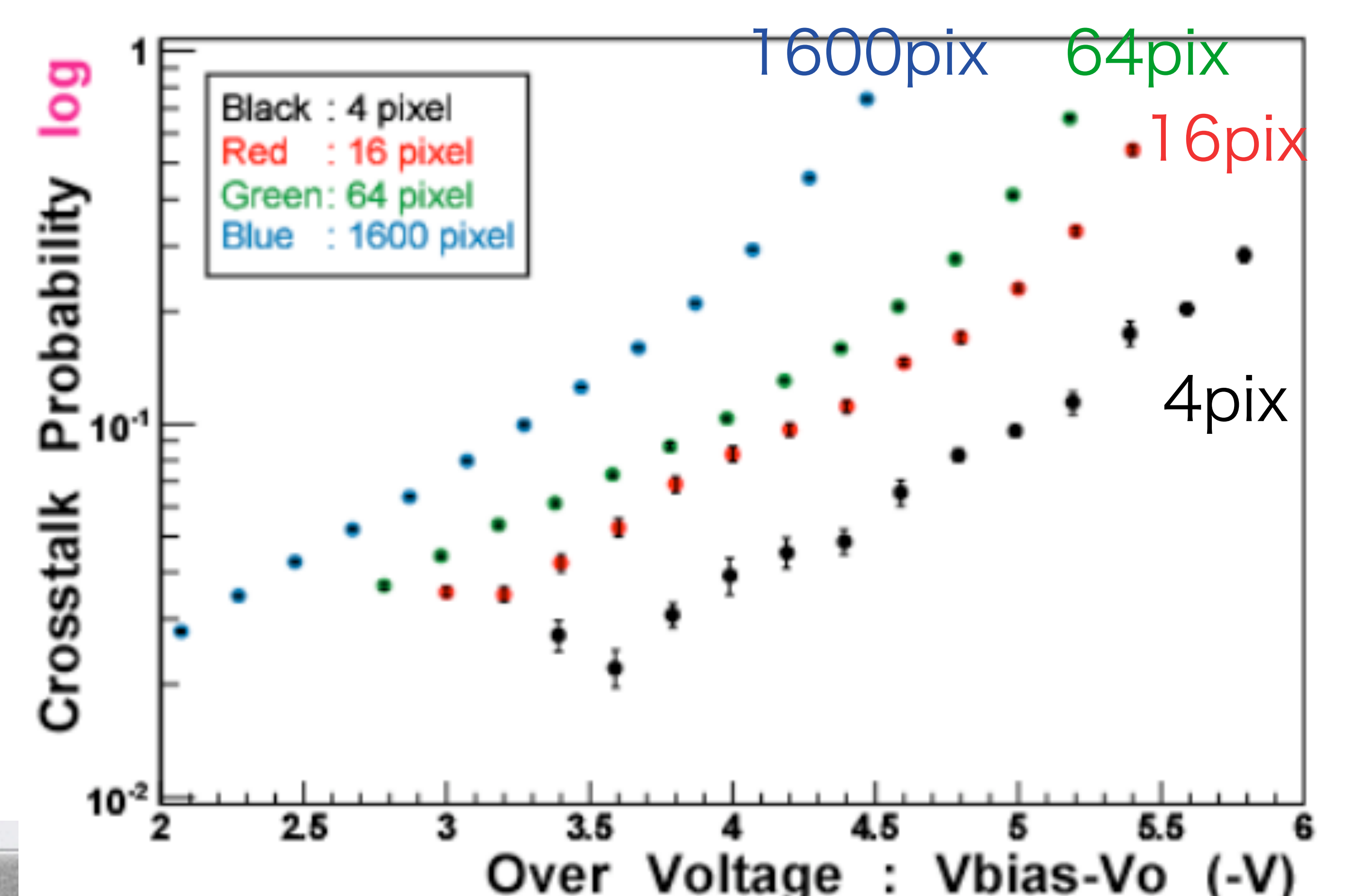
Cross talk m



at low temp.

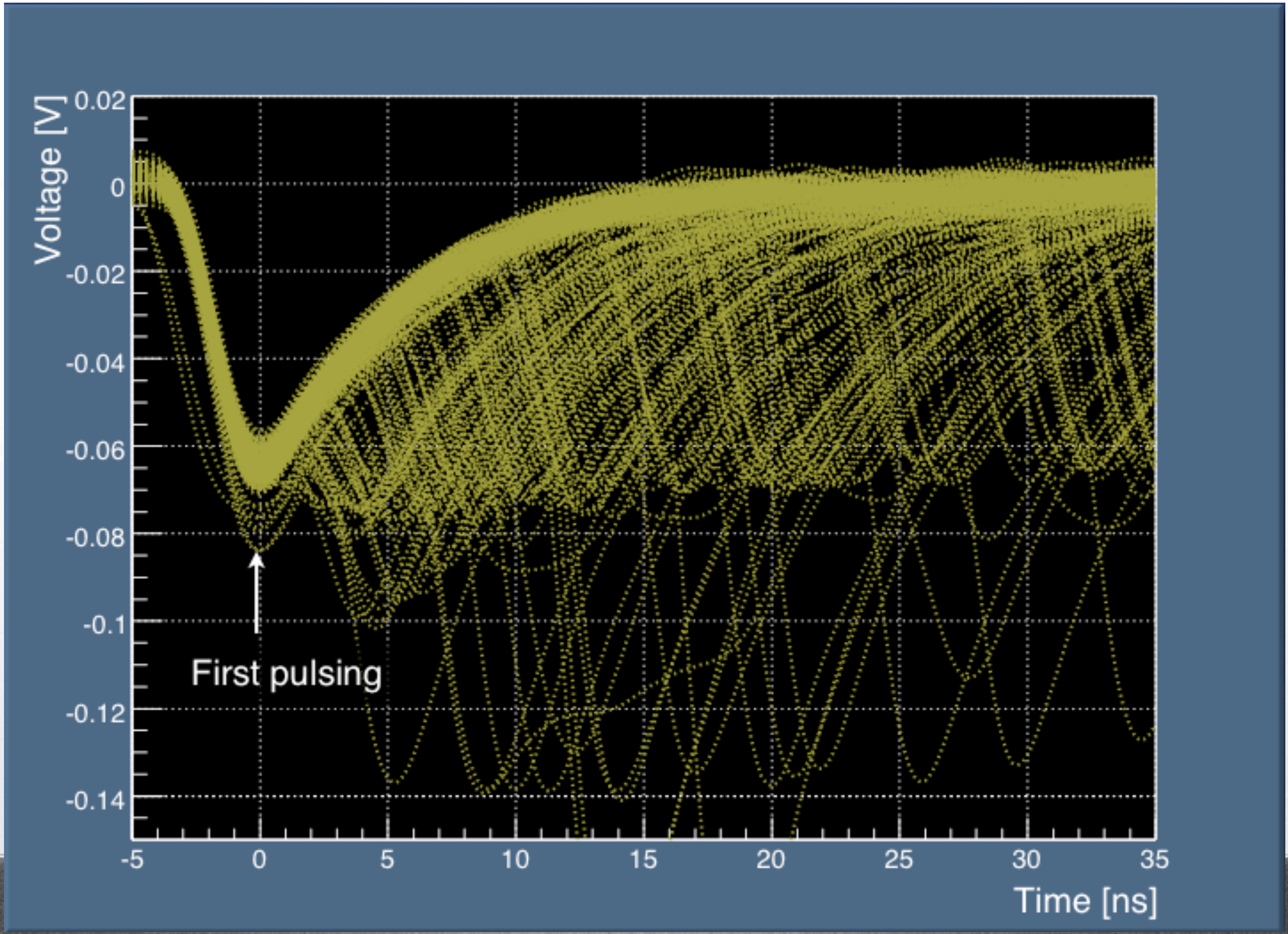


Vbias- Vbreakdown



signals by Oscillo.

- three lines: cross talk pulses
- after pulses and accidentals

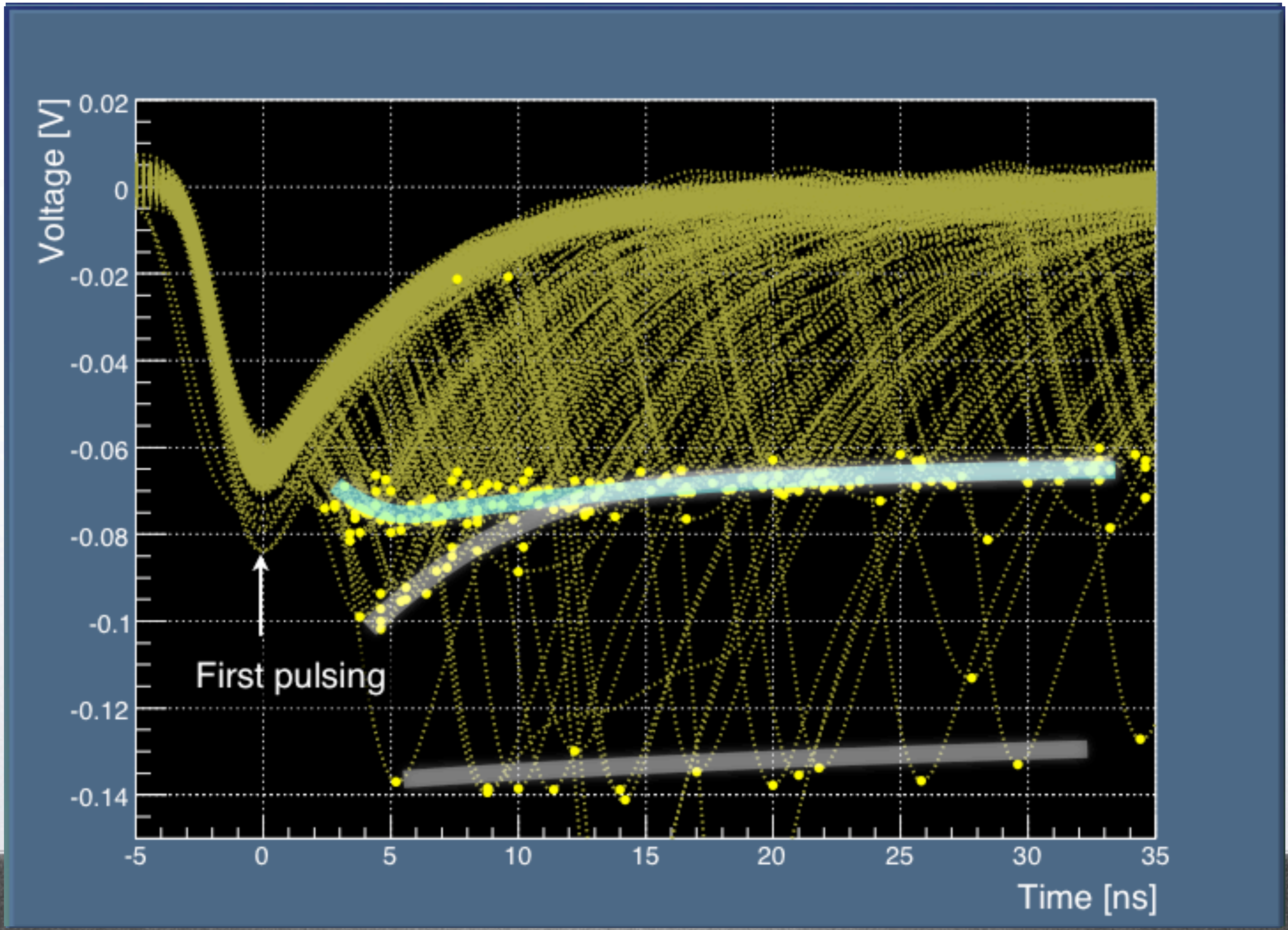


after pulse

cross talk

signals by Oscillo.

- three lines: cross talk pulses
- after pulses and accidentals

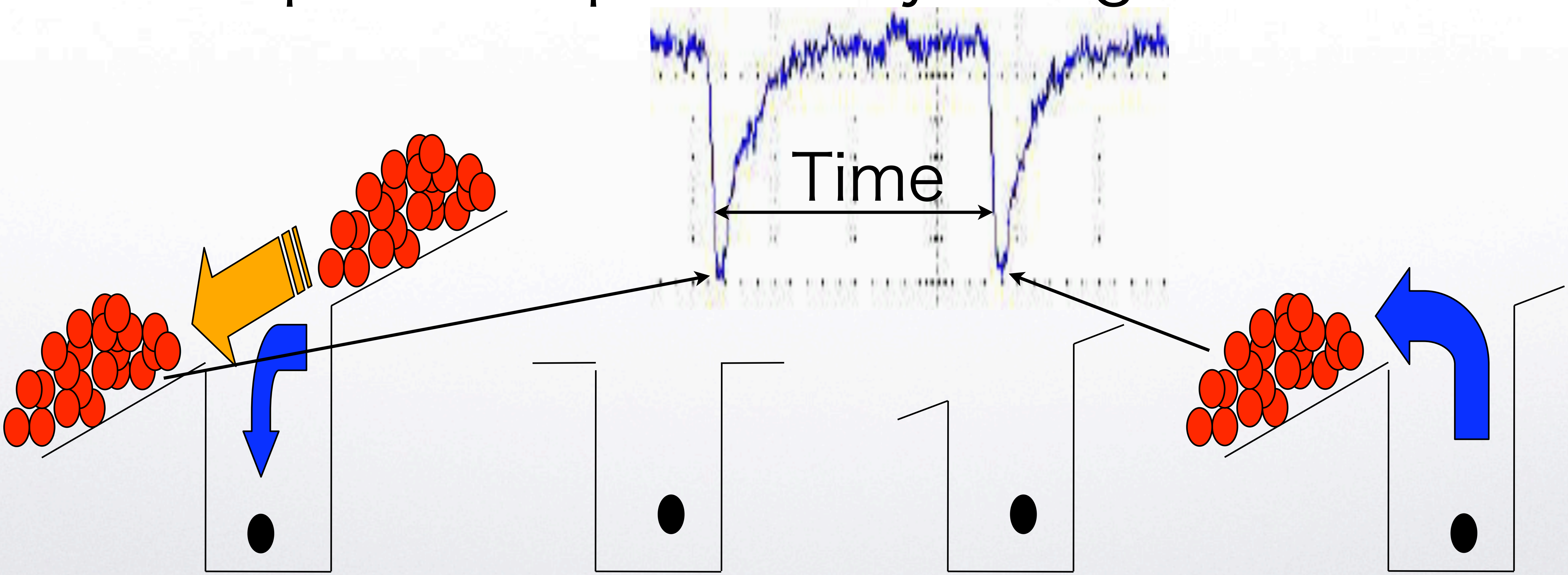


after pulse

cross talk

After pulses

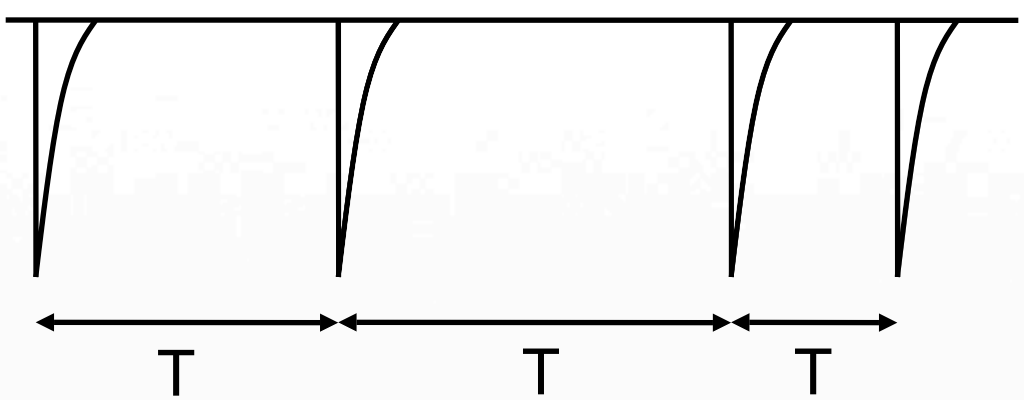
- Dark noise contains
- cross talk : 2 p.e. : light induced avalanche
- after pulse : 1 p.e. : delayed signals

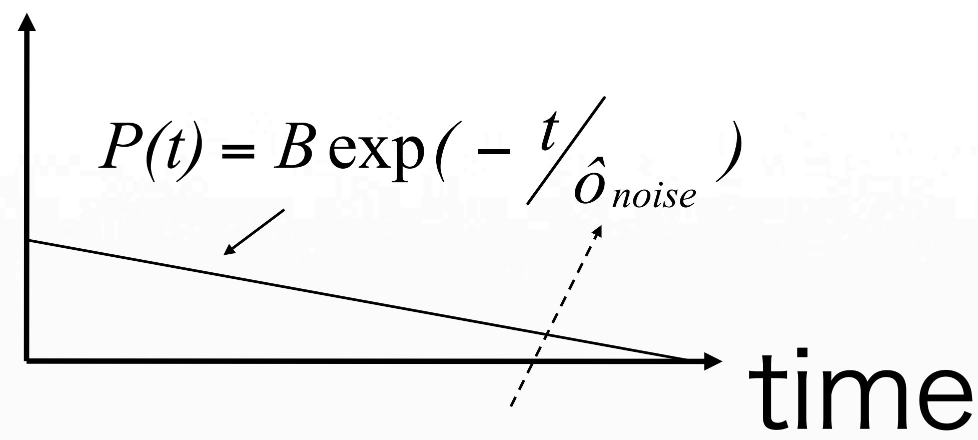


After pulses 2

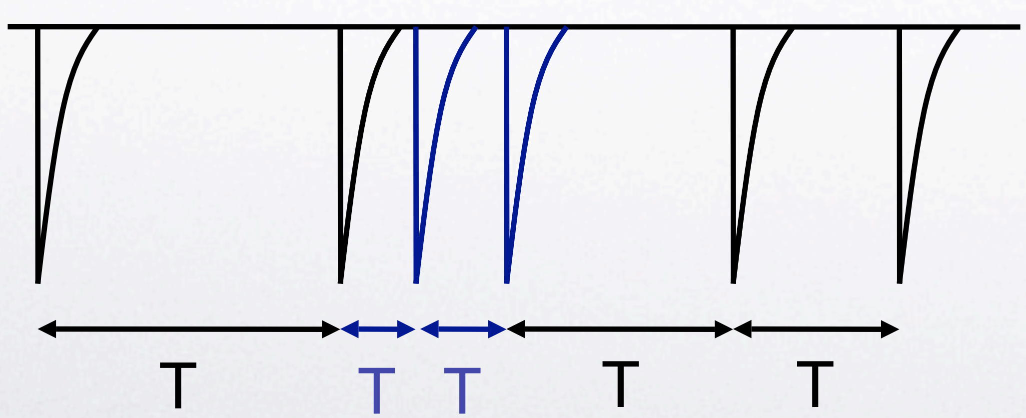
- difficult to separate from dark noise pulse

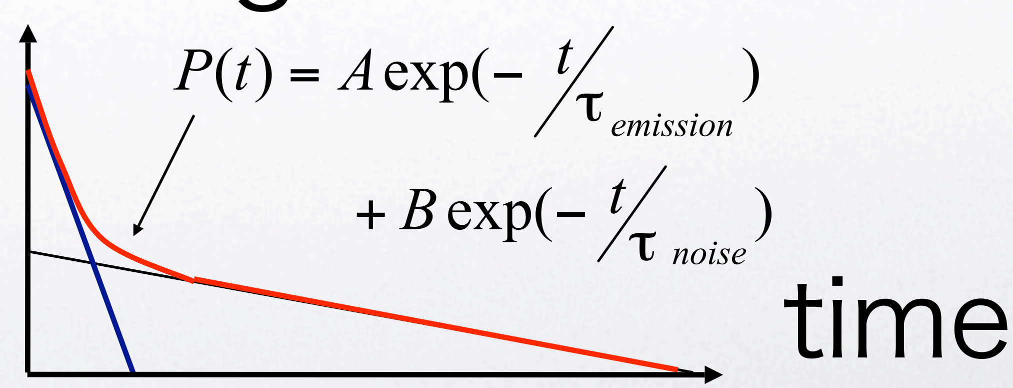
ideal case without after pulsing





real world with after pulsing

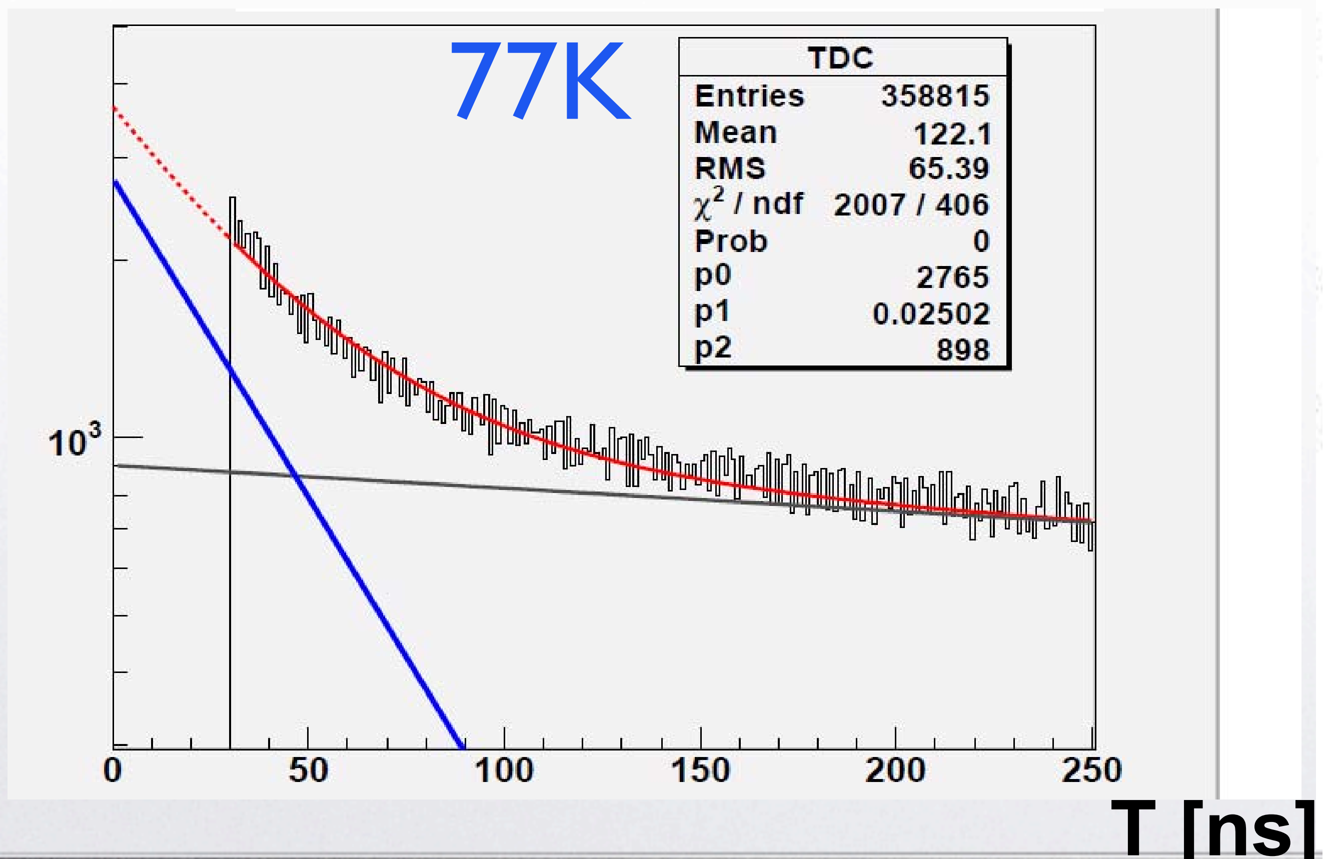




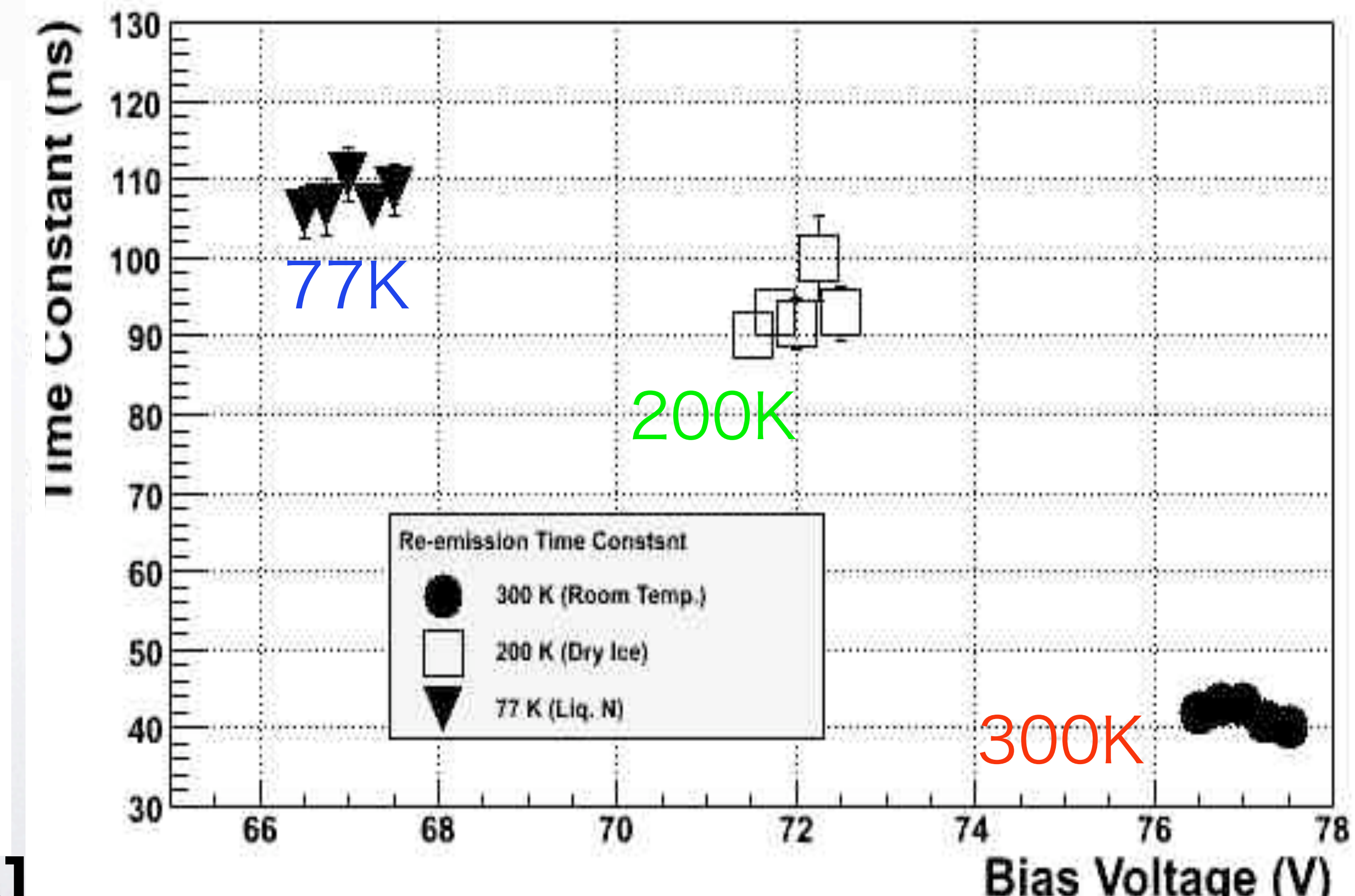
After pulses 3

- τ after pulse
- may depend on the temperature
- because of silicon nature

measured distribution

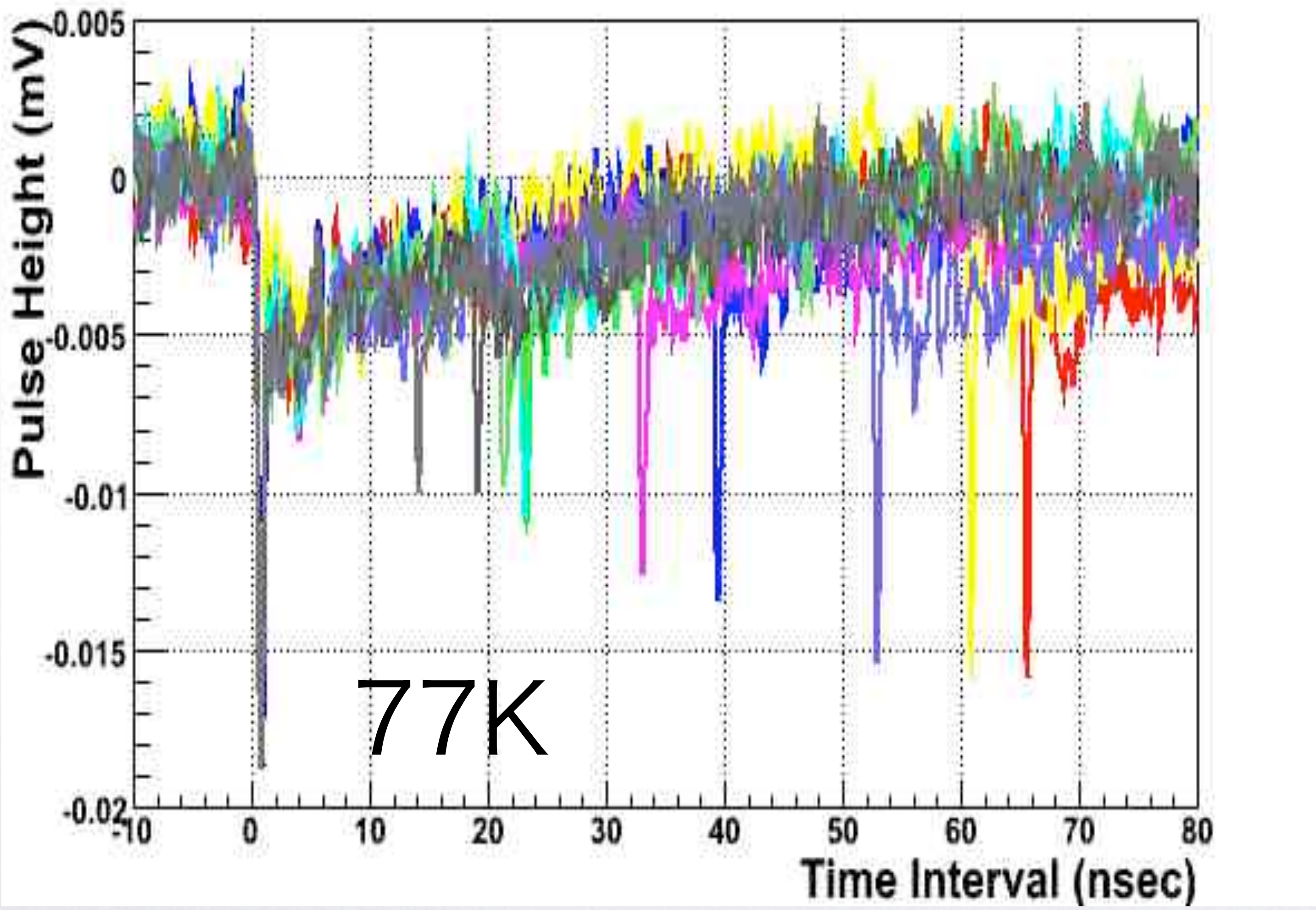


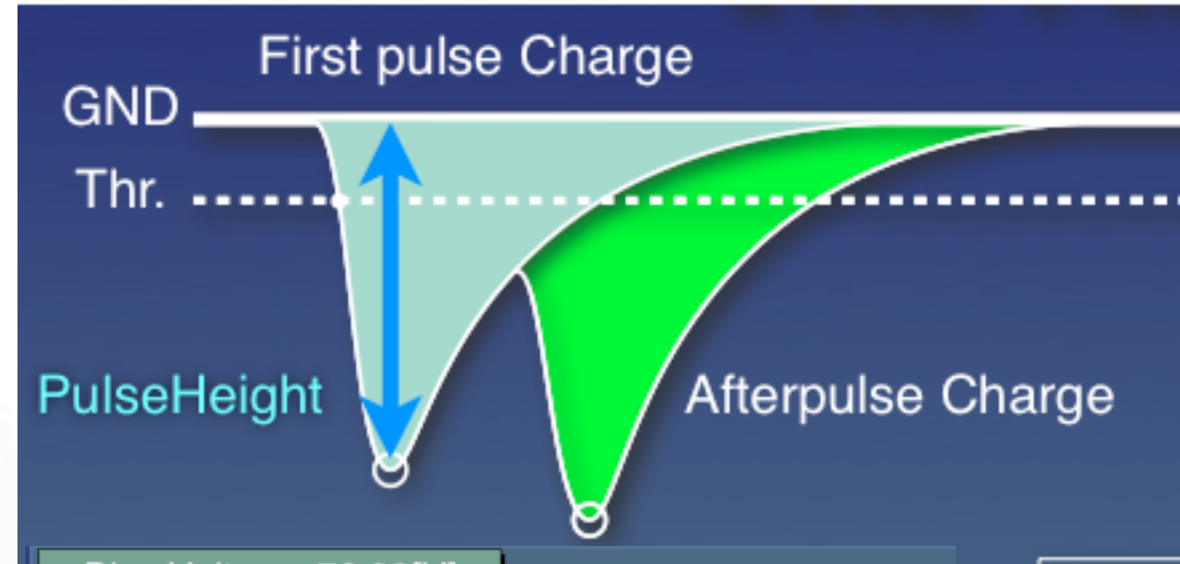
τ after pulse (ns)

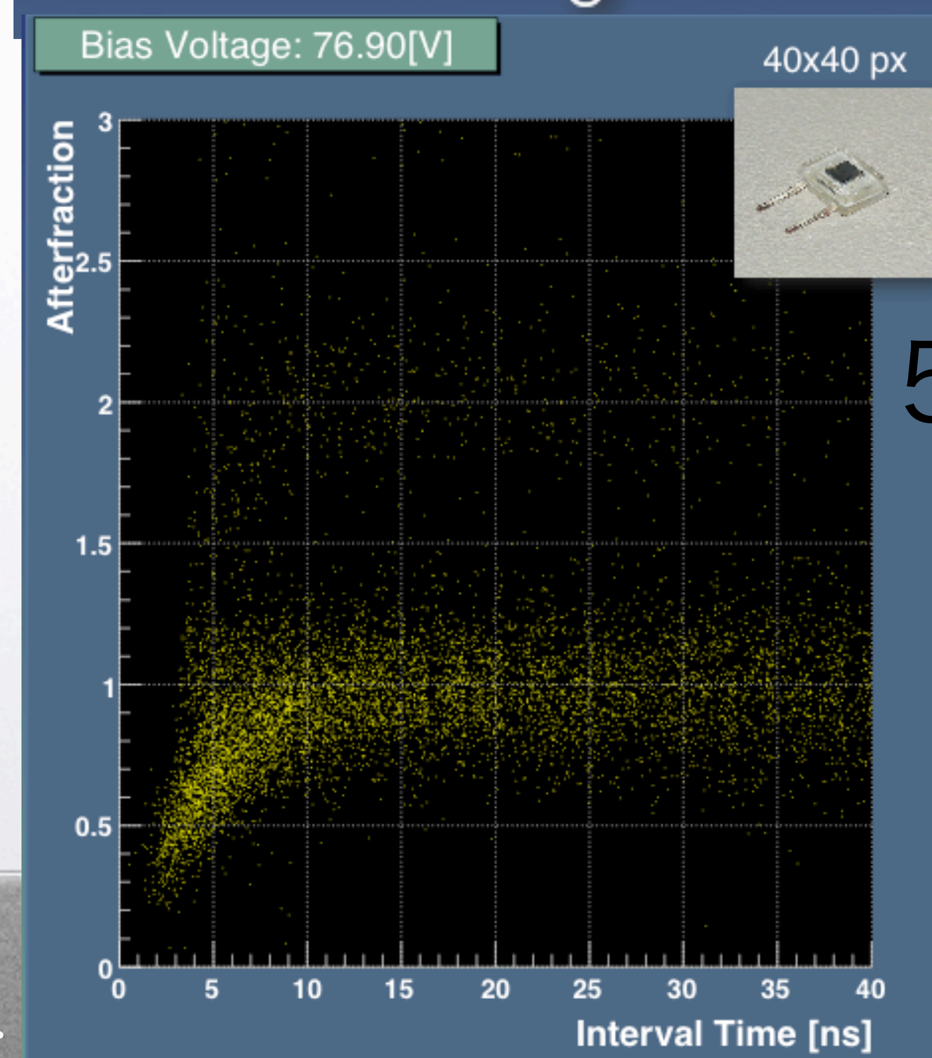


After pulses 4

- recovering due to Vbias filling
- time const. dep. R_{quench}



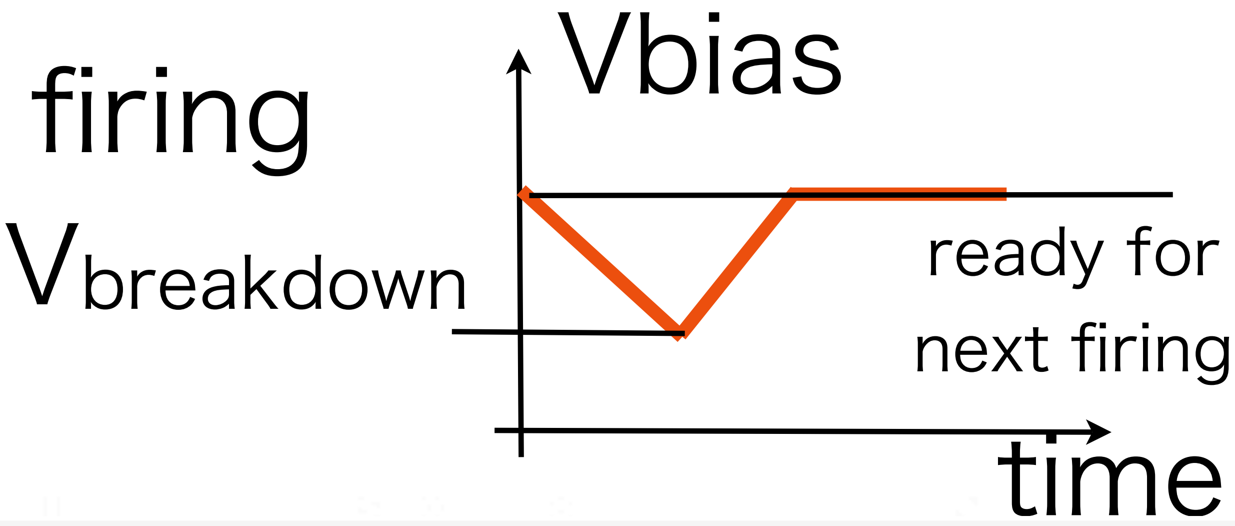


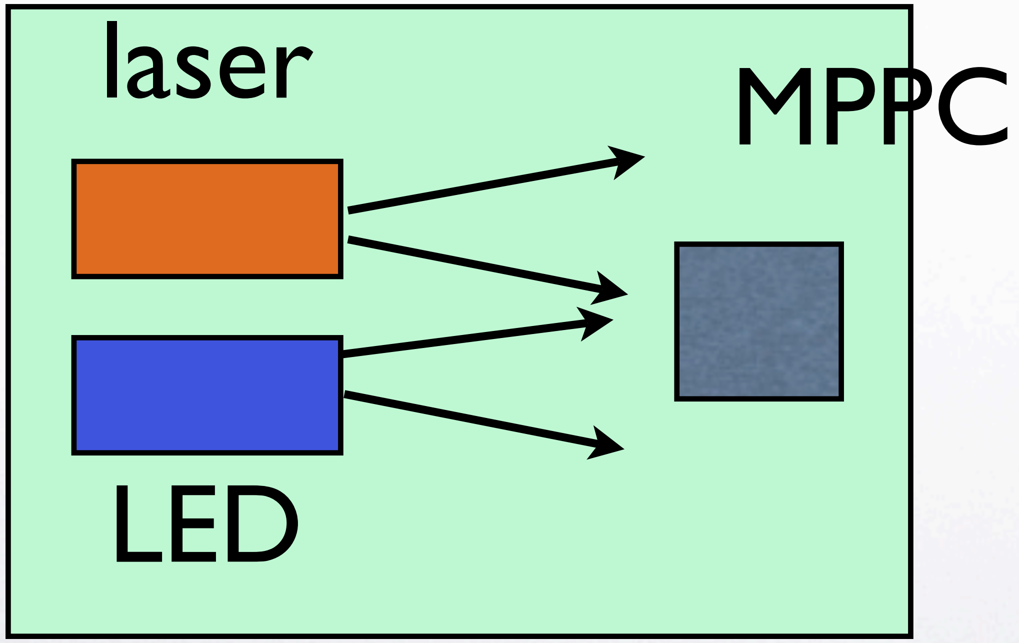


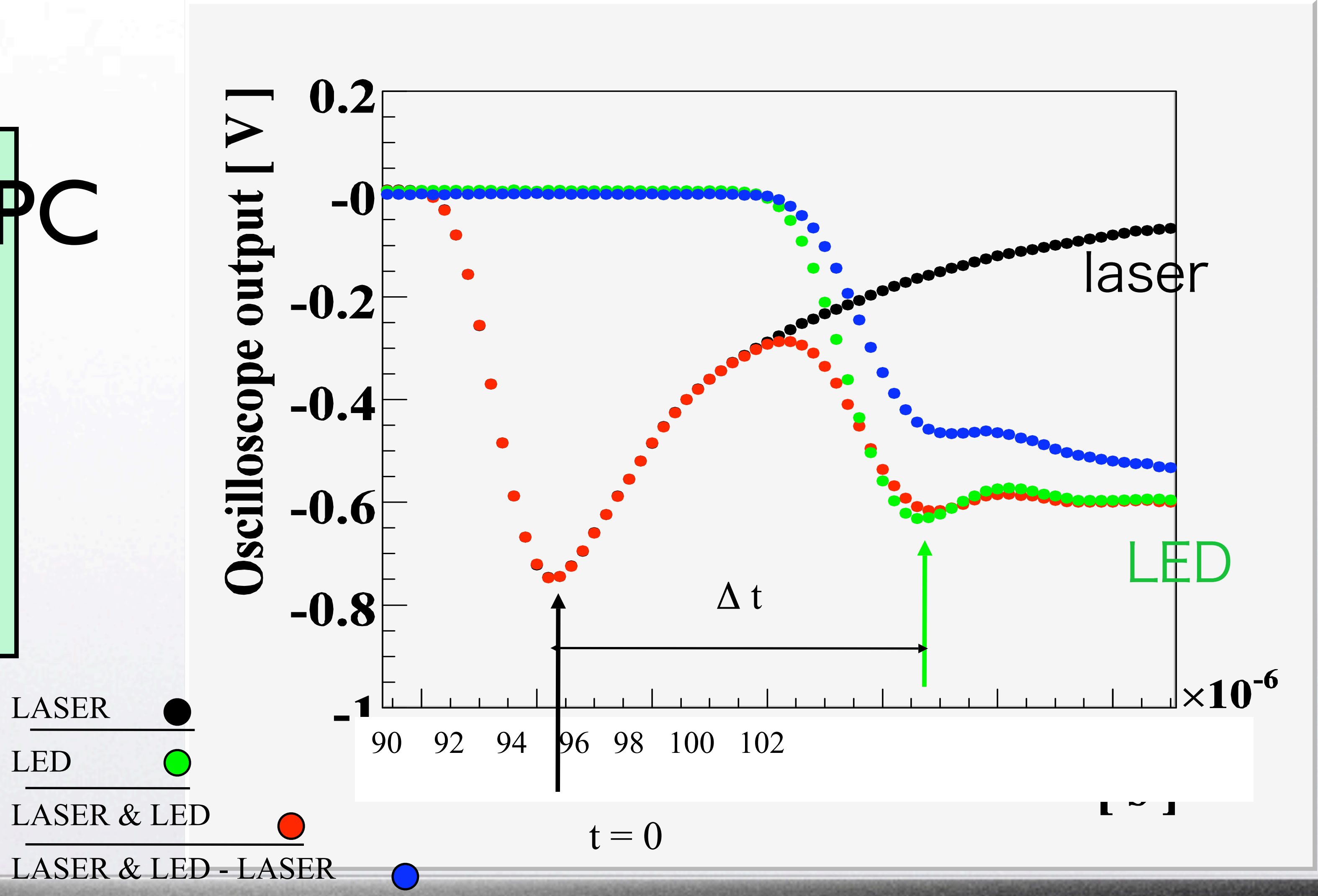
5-9ns

Recovering

- Vbias decrease after firing
- recovering time
- measurements





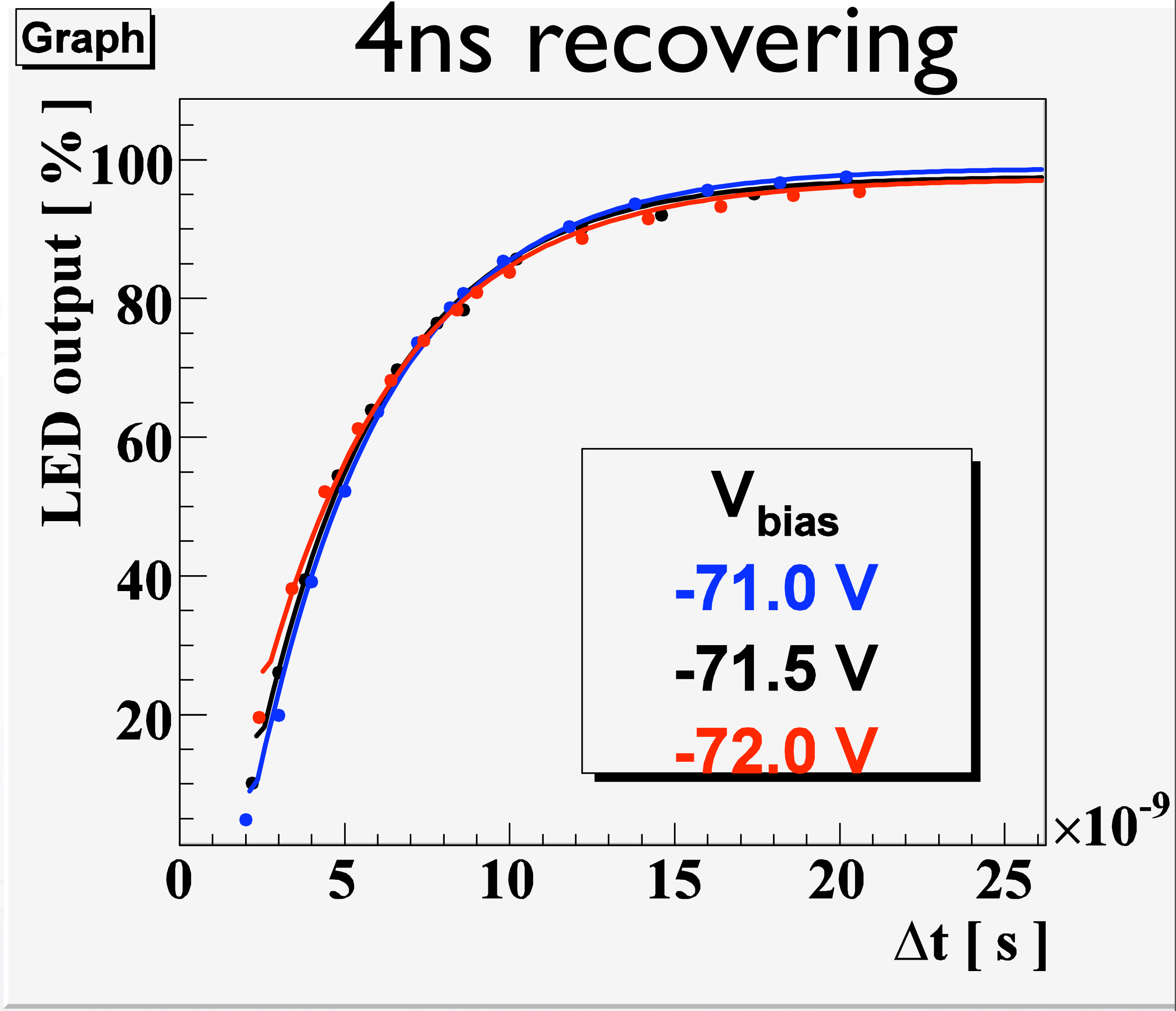


Recovering 2

- recovering fraction as a func. of time delay

$$\text{LED output} = \frac{(\text{LASER \& LED}) - \text{LASER}}{\text{LED}}$$

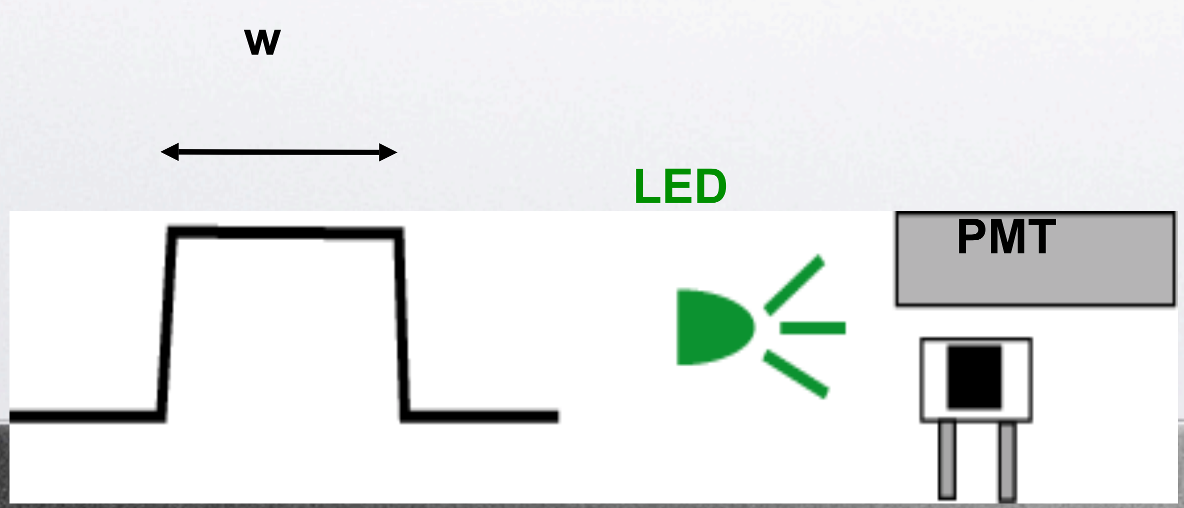
- indep. Vbias

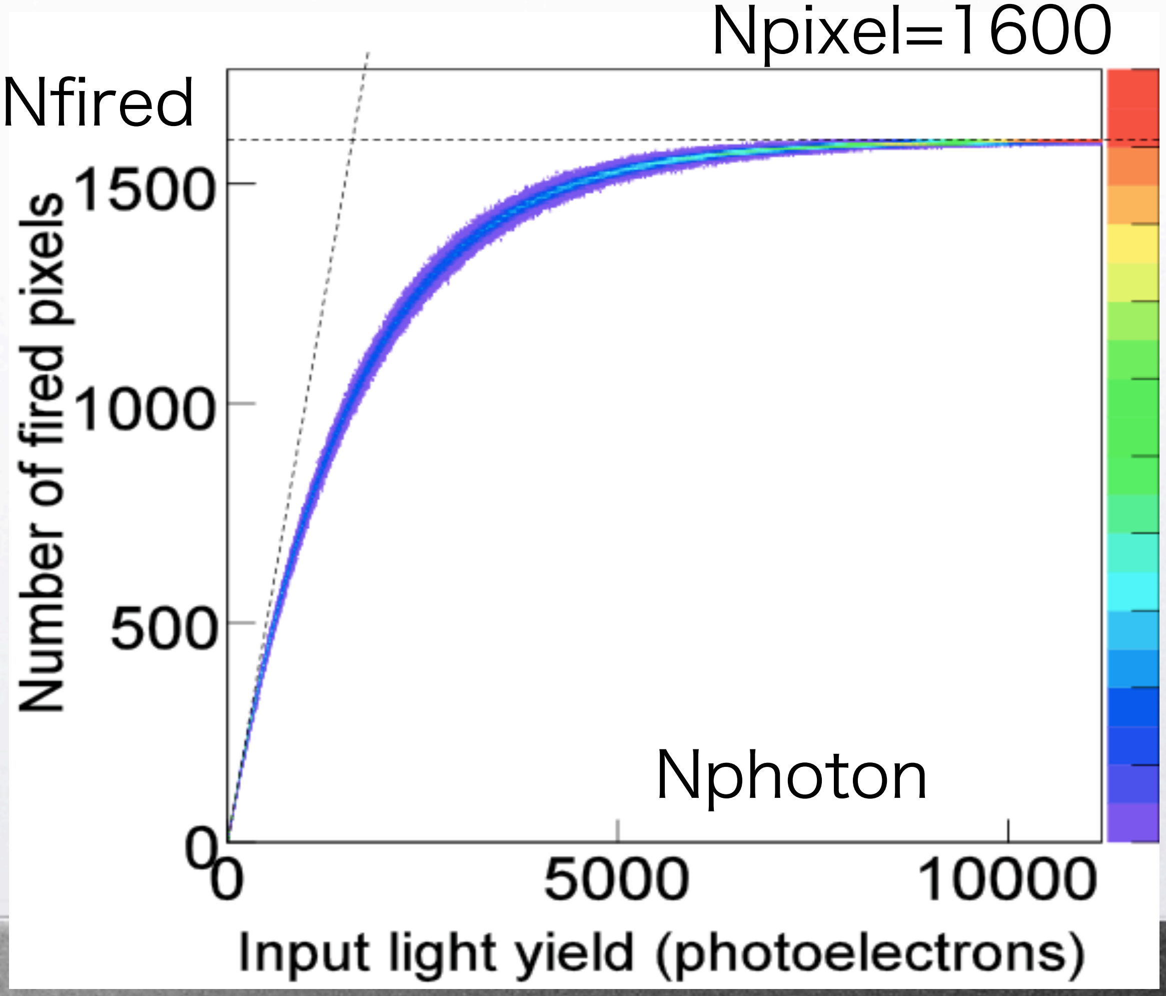


This time is consistent with oscilloscope measurement

saturation effect.

- for big number of photons > N_{pixel}
- in case of EM shower Max.
- output ~ N_{photon}
  $$N_{fired} = Npixel(1 - e^{-\frac{Nphoton}{Npixel}})$$
- ideal case (simultaneous inlet of photons)
- non linearity
- response curve

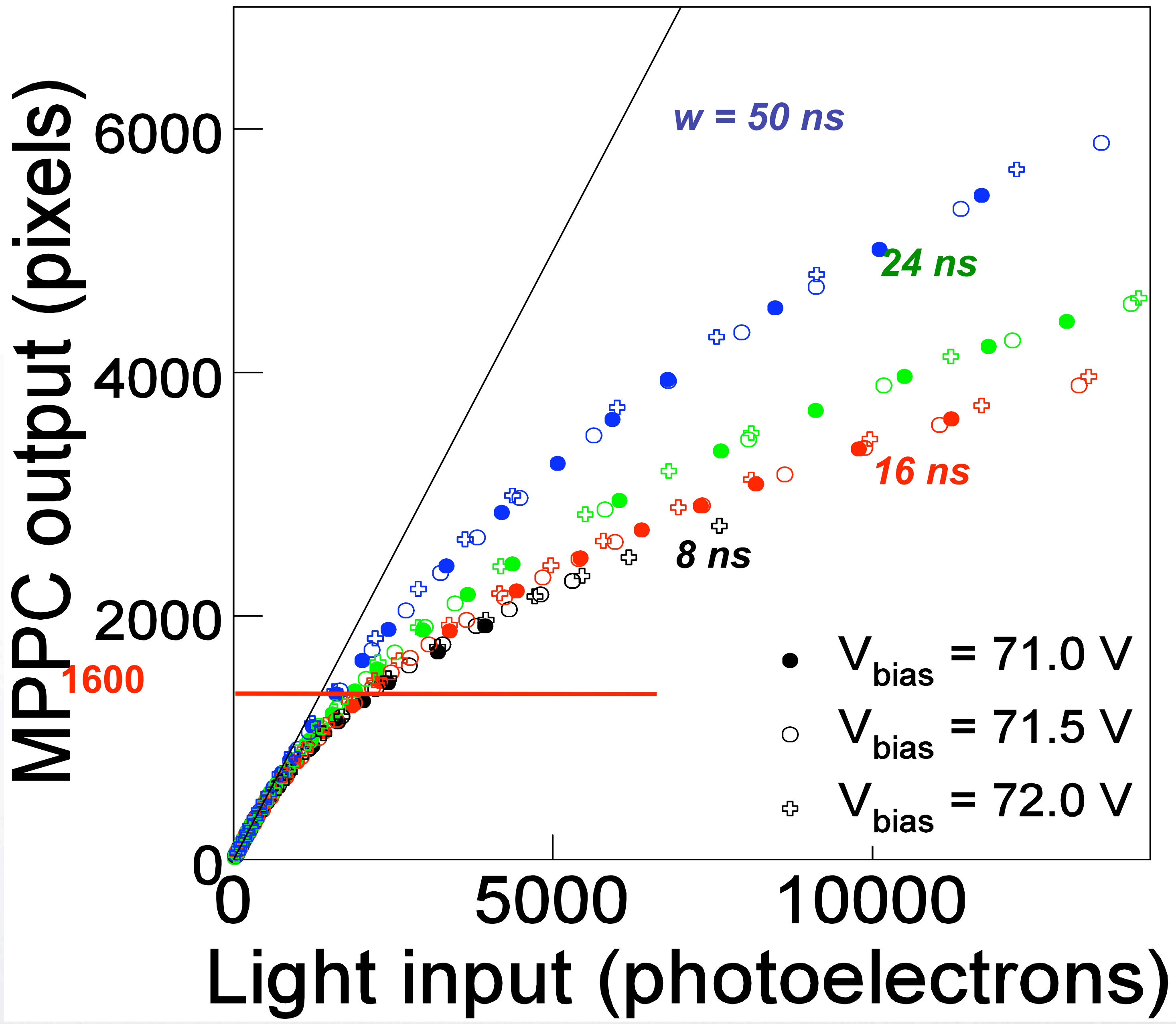




Saturation 2

- response curve
- up to 10000 photons
- dep. width

linear ~ 200p.e.



measured by PMT

Saturation 2

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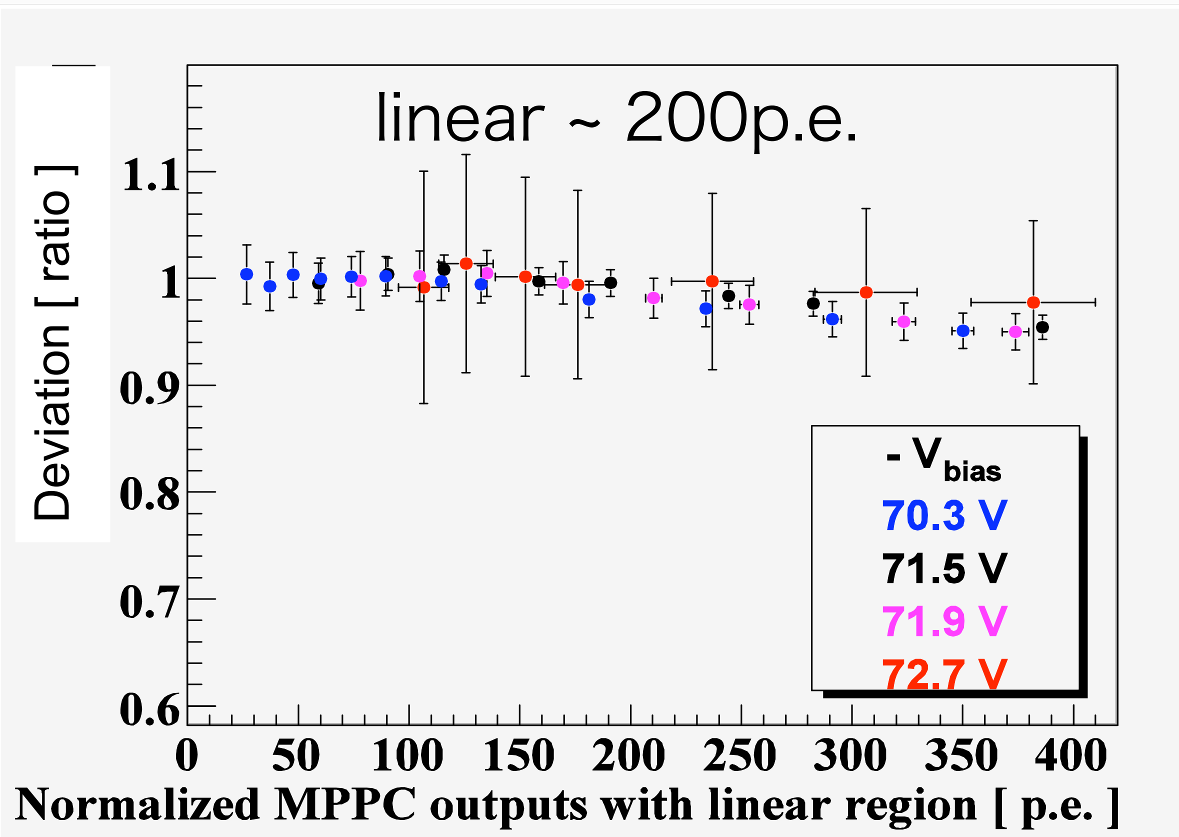
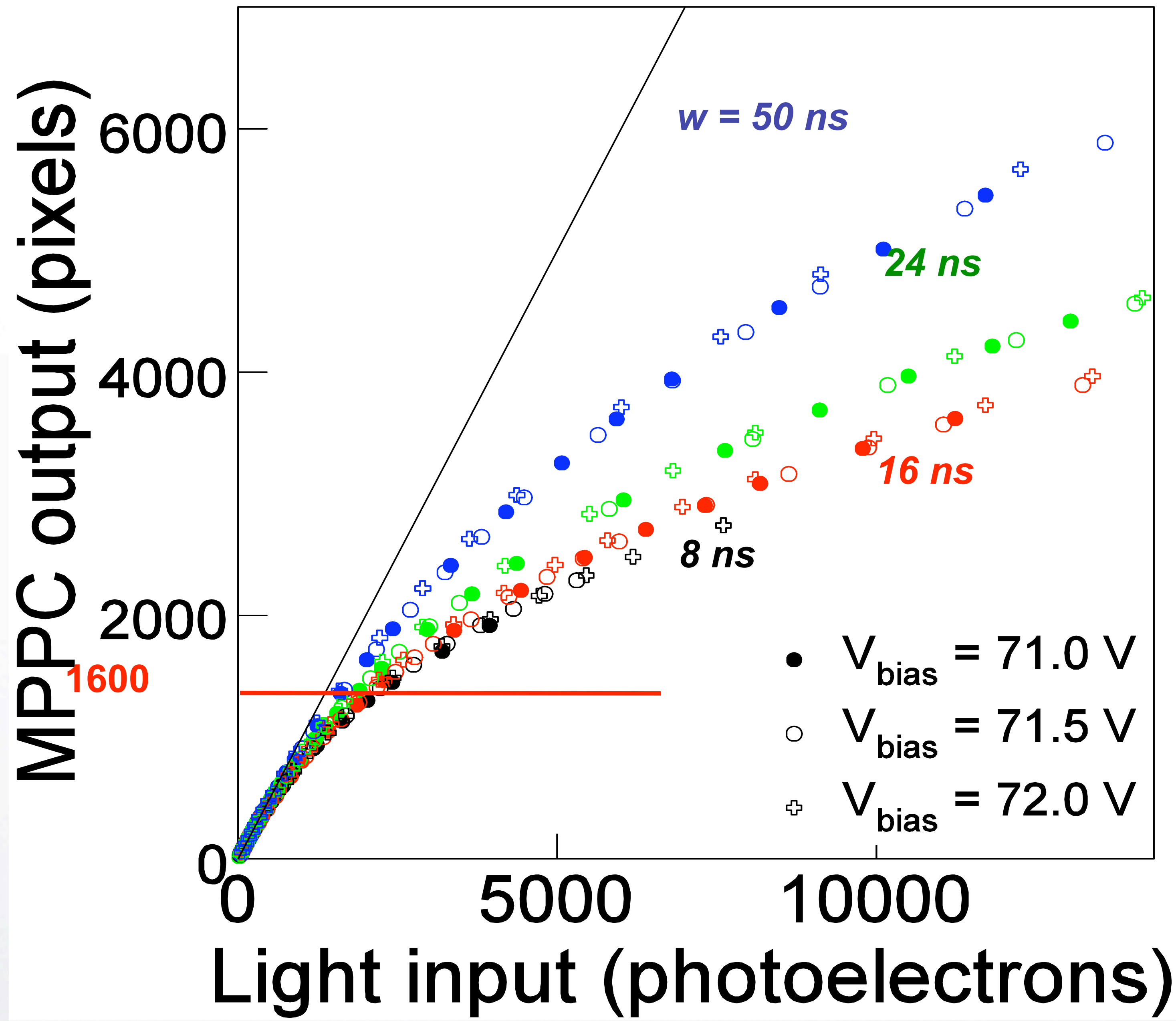
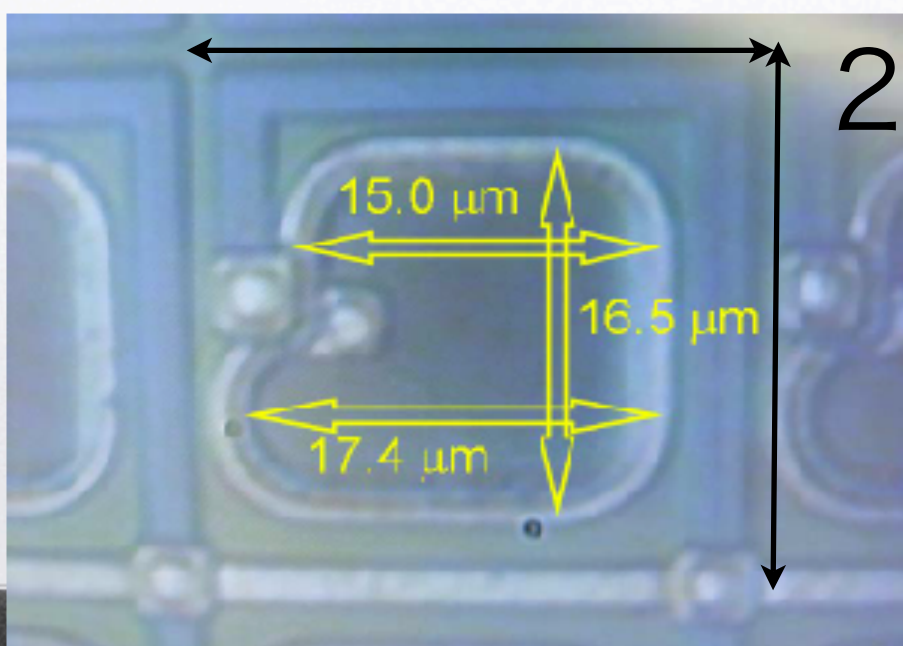




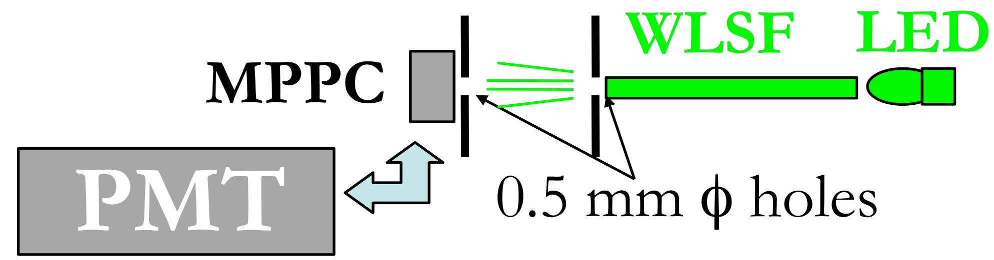
measured by PMT

PDE
photon detection eff.

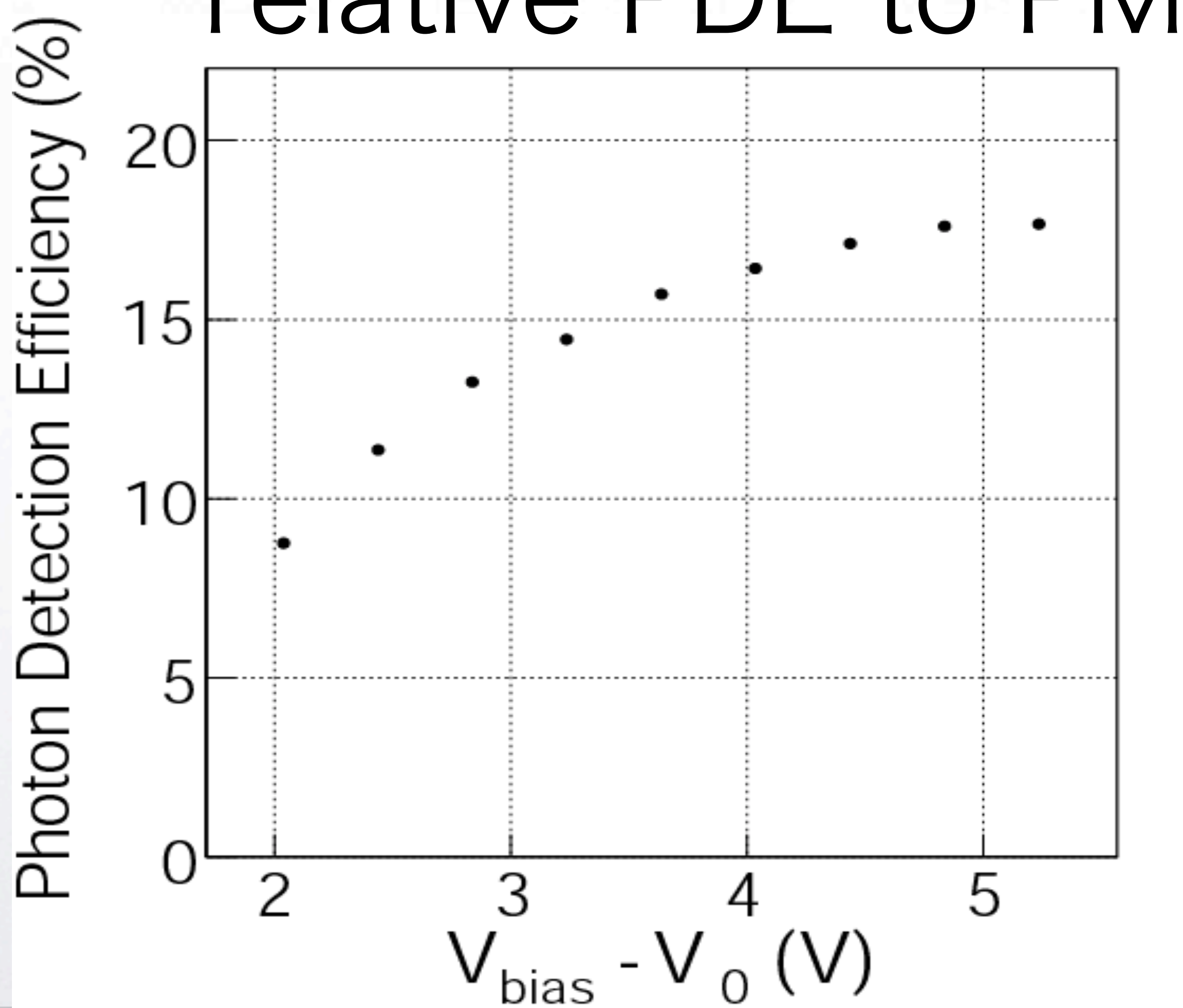
- PDE(Vbias)= (QE(λ)) *(GM) *(window) ~1 * 1 * 0.25 = 0.25 > QE (PMT)



25µm

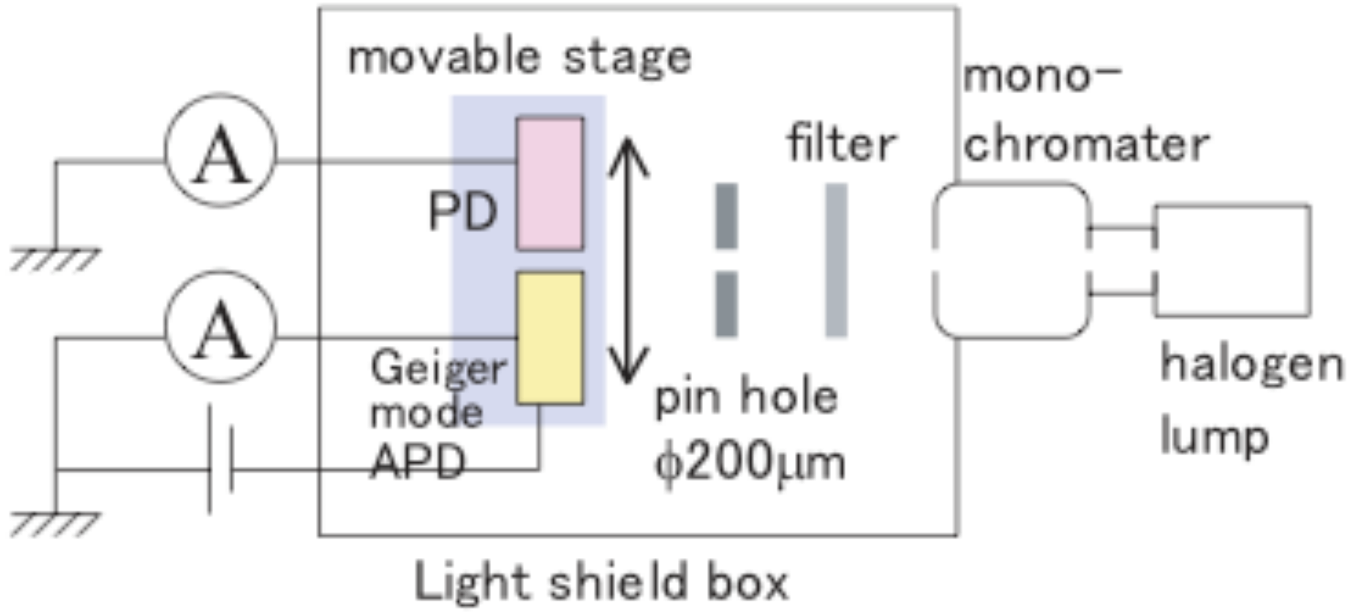


relative PDE to PMT

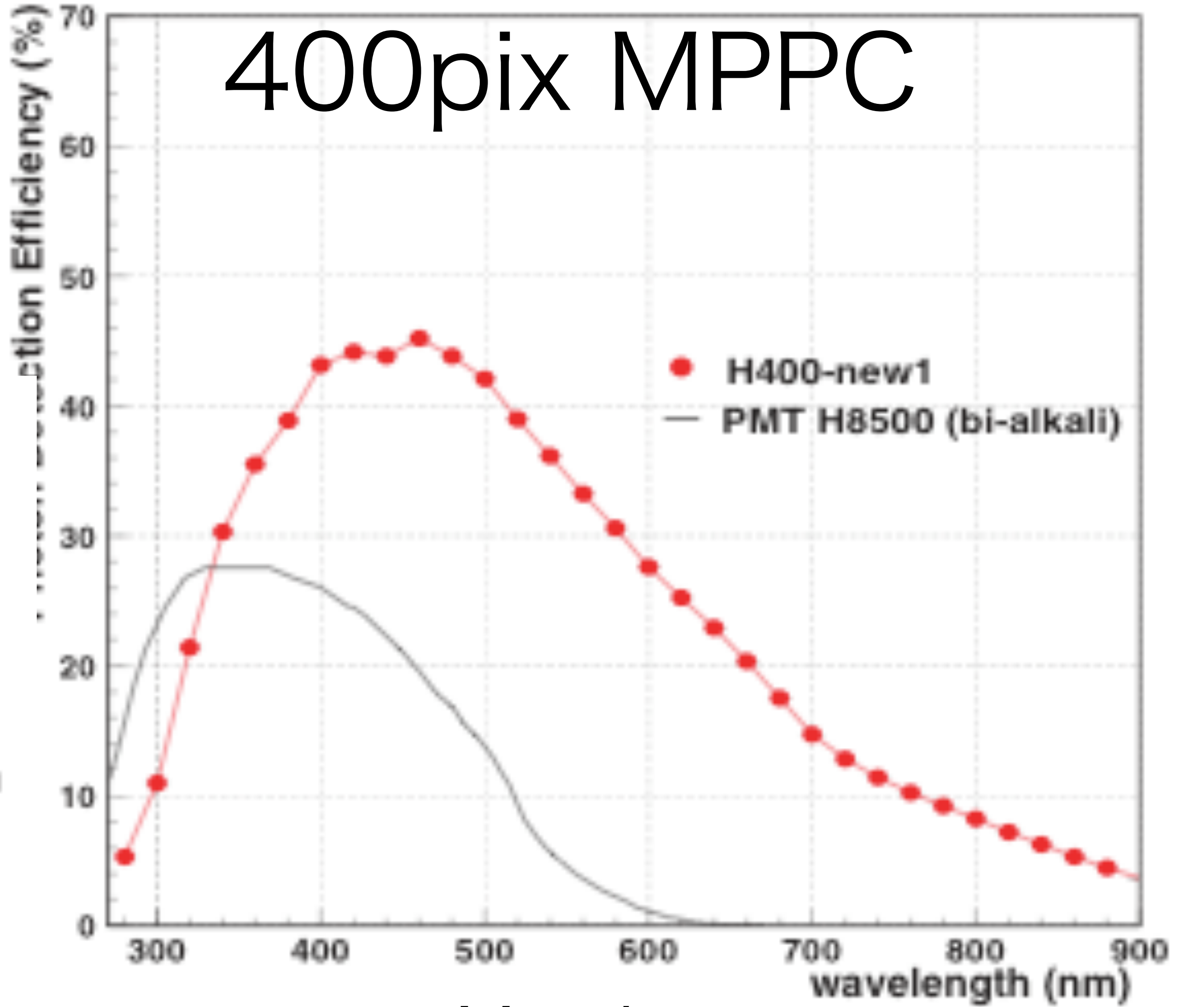


PDE 2

- PDE (b) wave length dep.
- blue sensitive
- good for scintillator



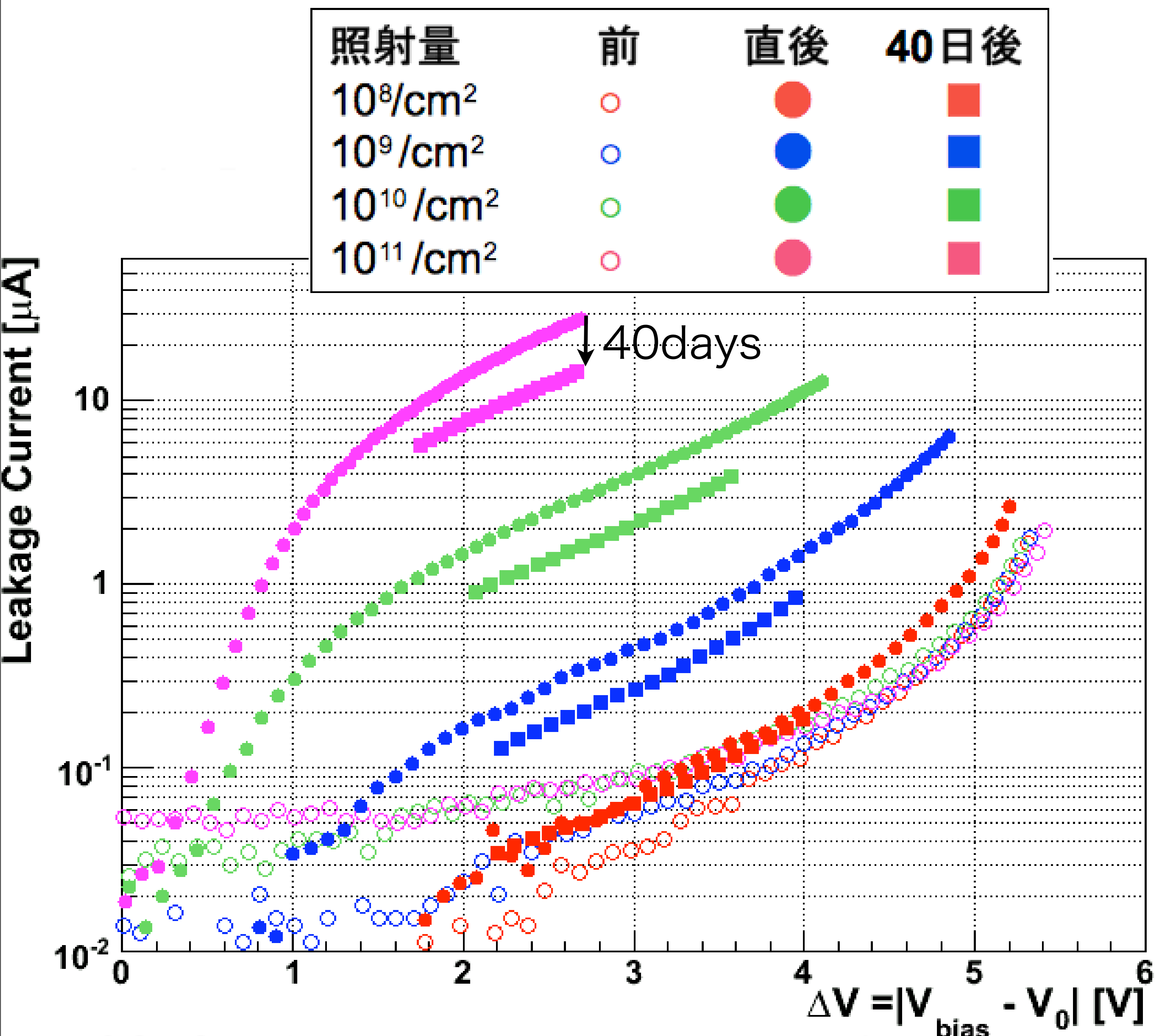
PDE including window si



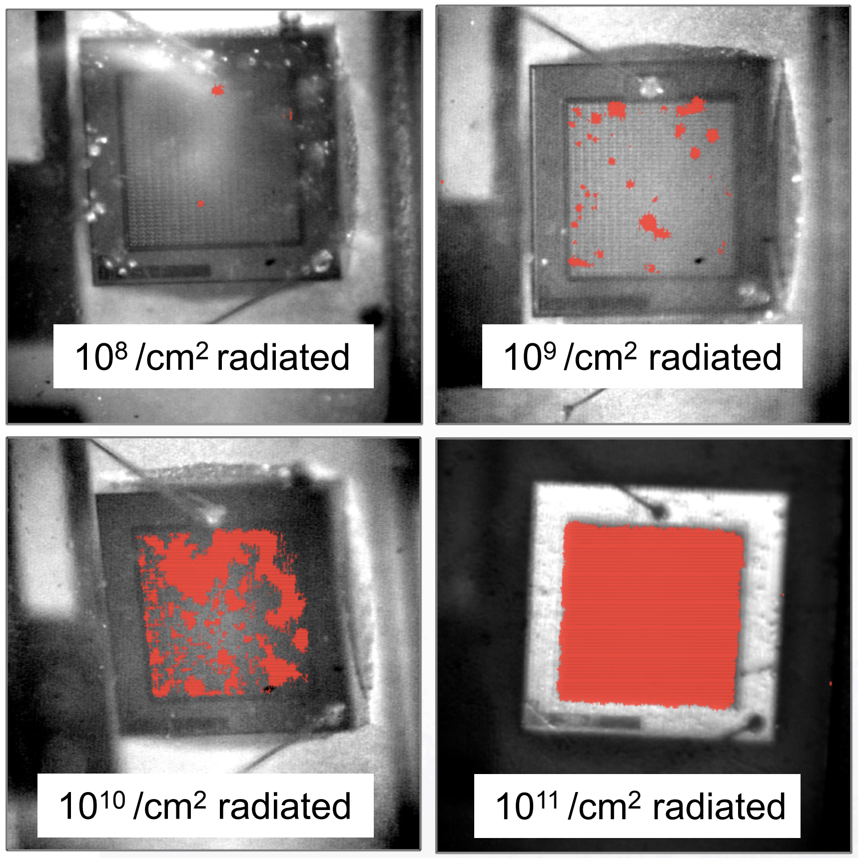
Mazuka

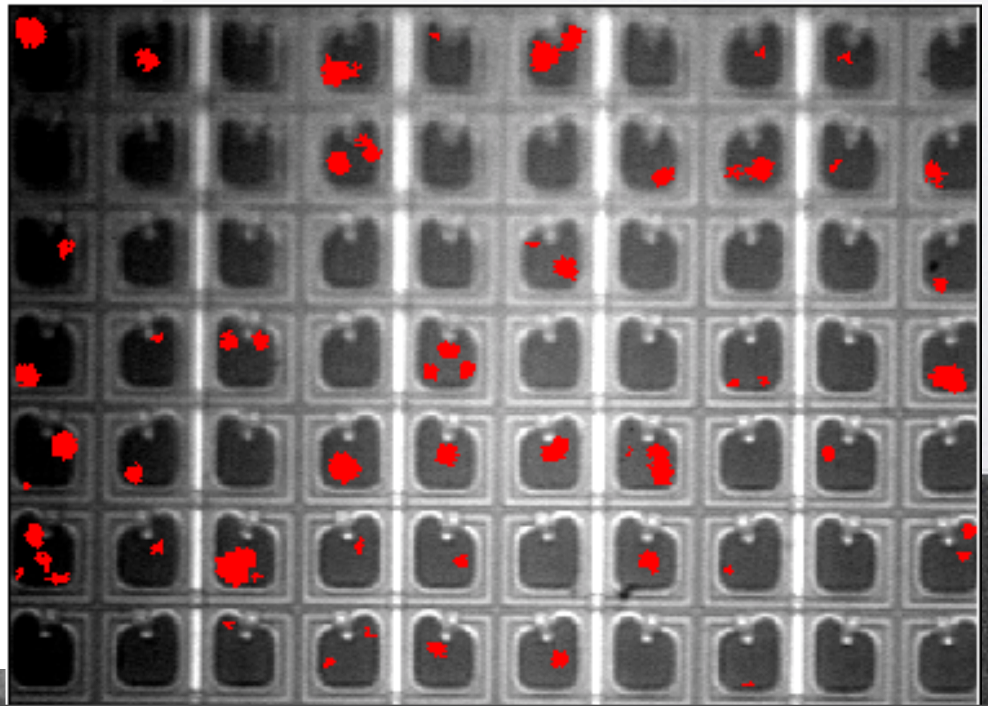
radiation tolerance

- neutron/ gamma tested



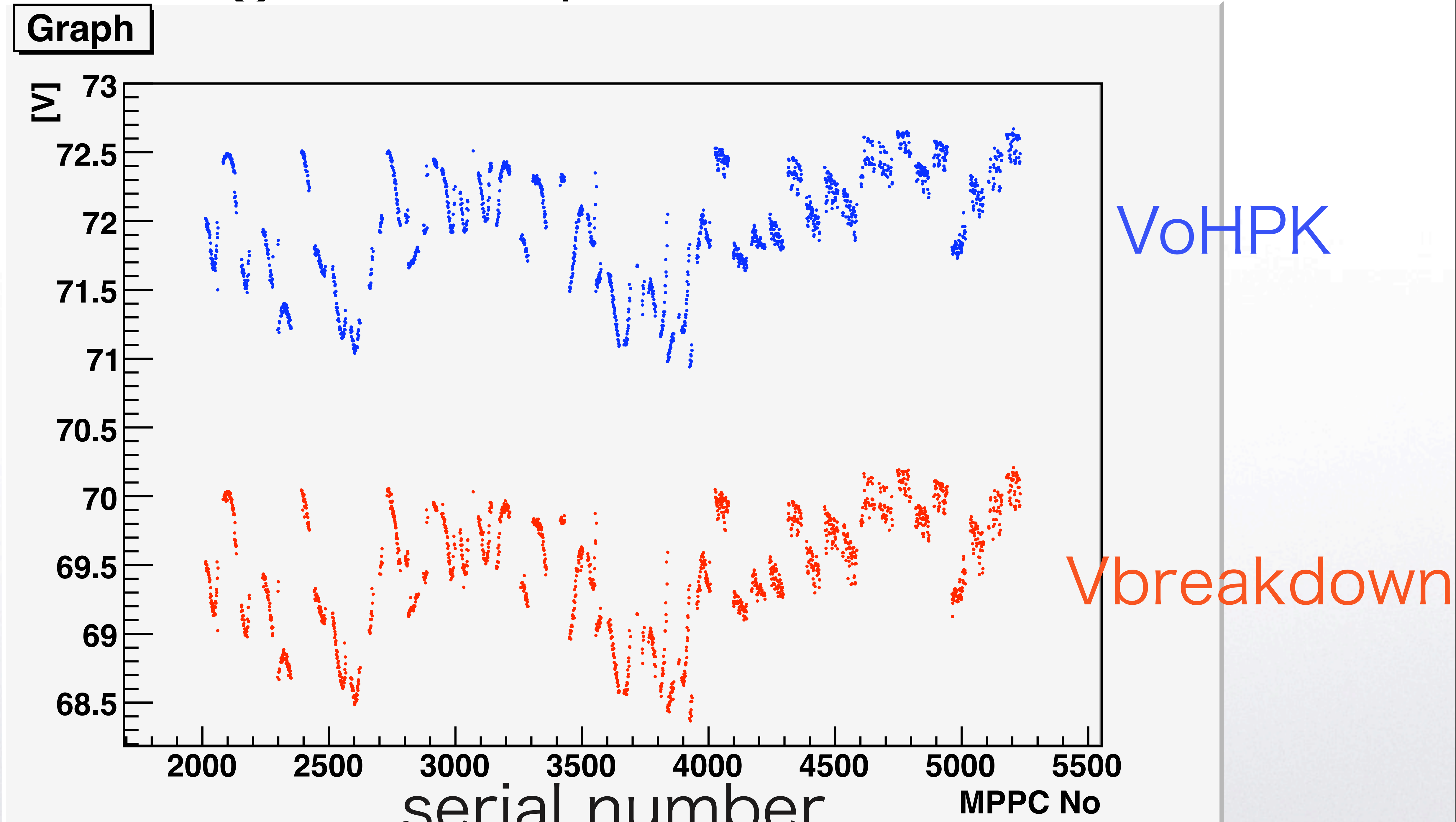
thermal cam.





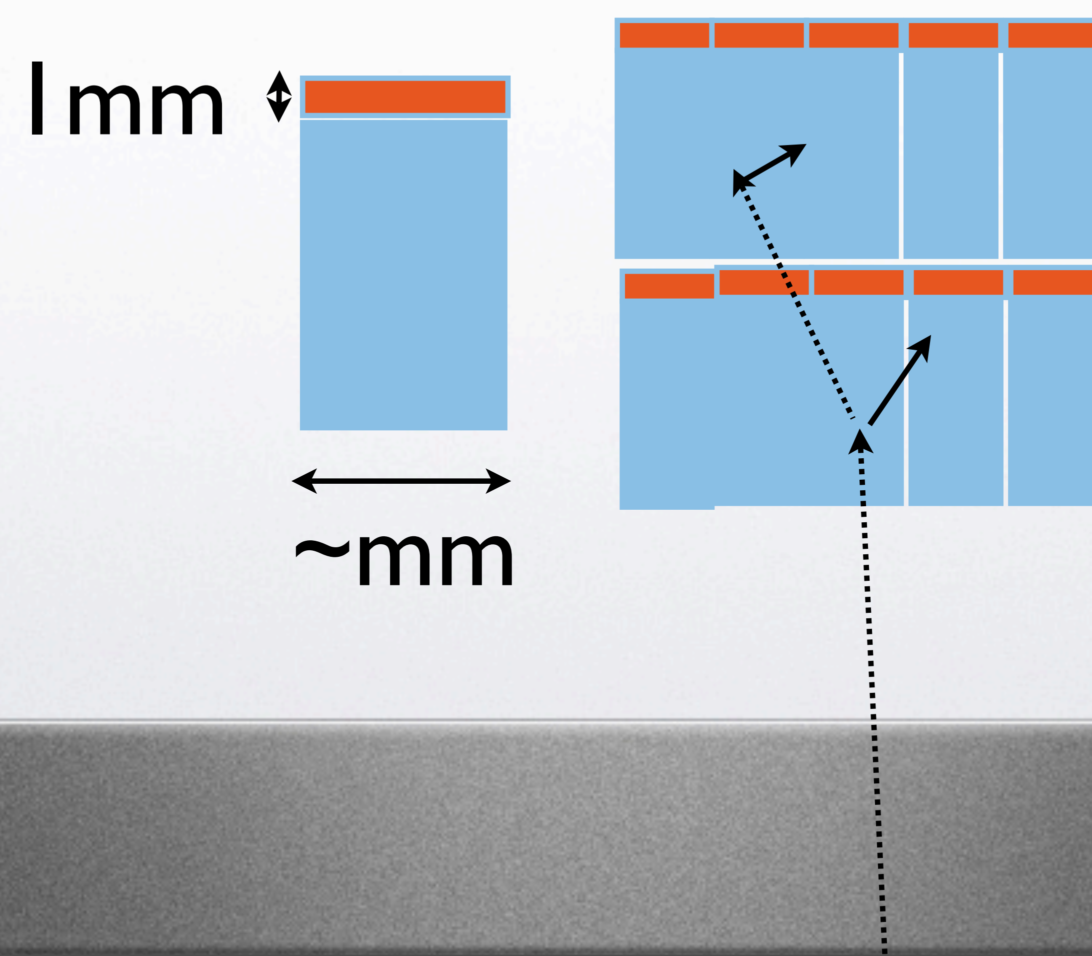
statistical experience

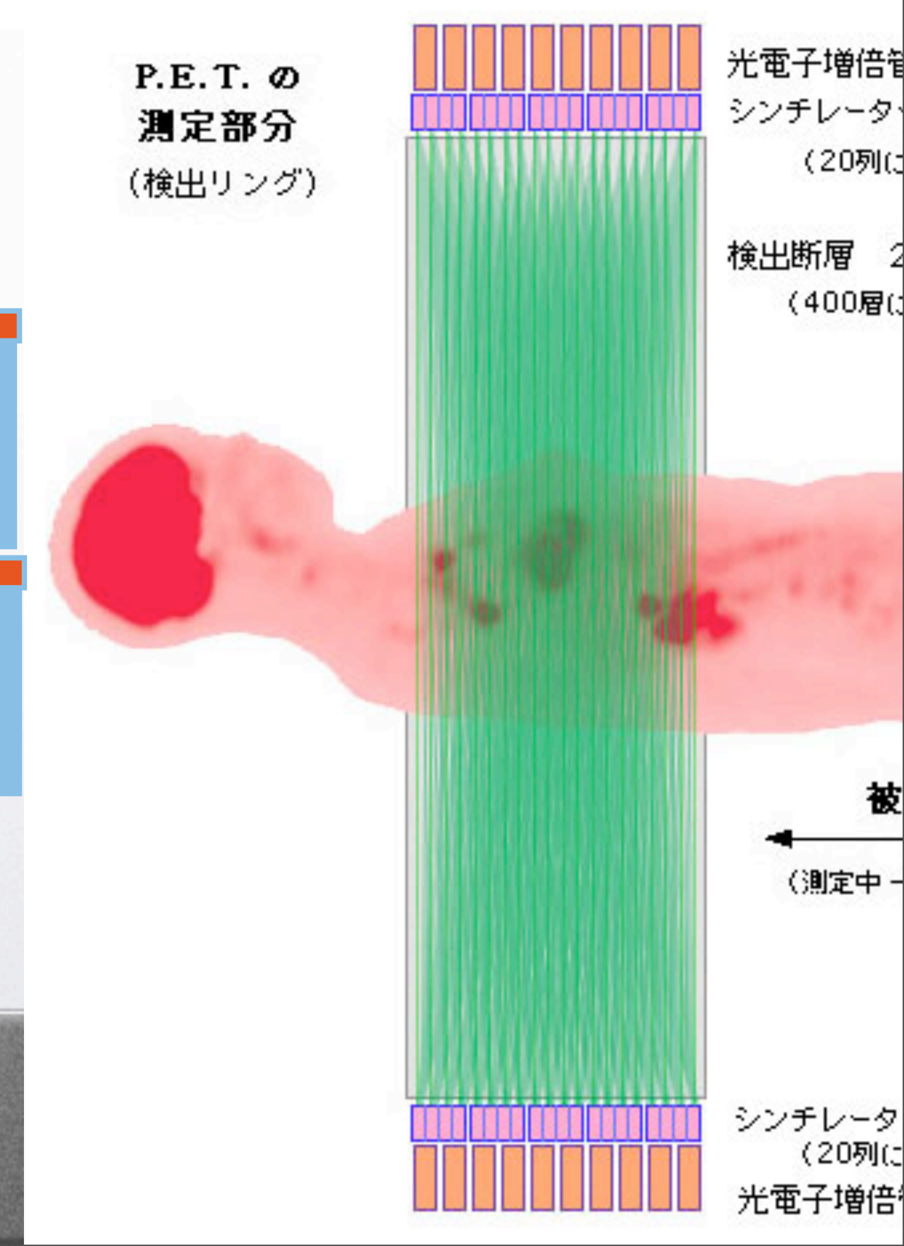
- we got 3000 pieces of MPPC



an application

- PET Positron Emission Tomography
- Cancer detection by e+e- > γγ , Eγ =0.511MeV
- current resolution ~10mm
- close to 1mm by smaller crystal
- & MPPC
- DOI





summary of MPPC

- R&D of MPPC is in progress
- good relation with HPK
- need more development
- more pixel
- less noise/cross talk
- improve after pulse shape