Study of MPPC at liquid nitrogen temperature

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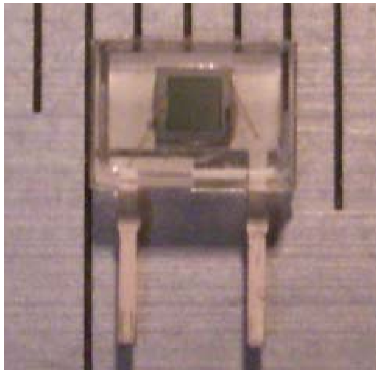
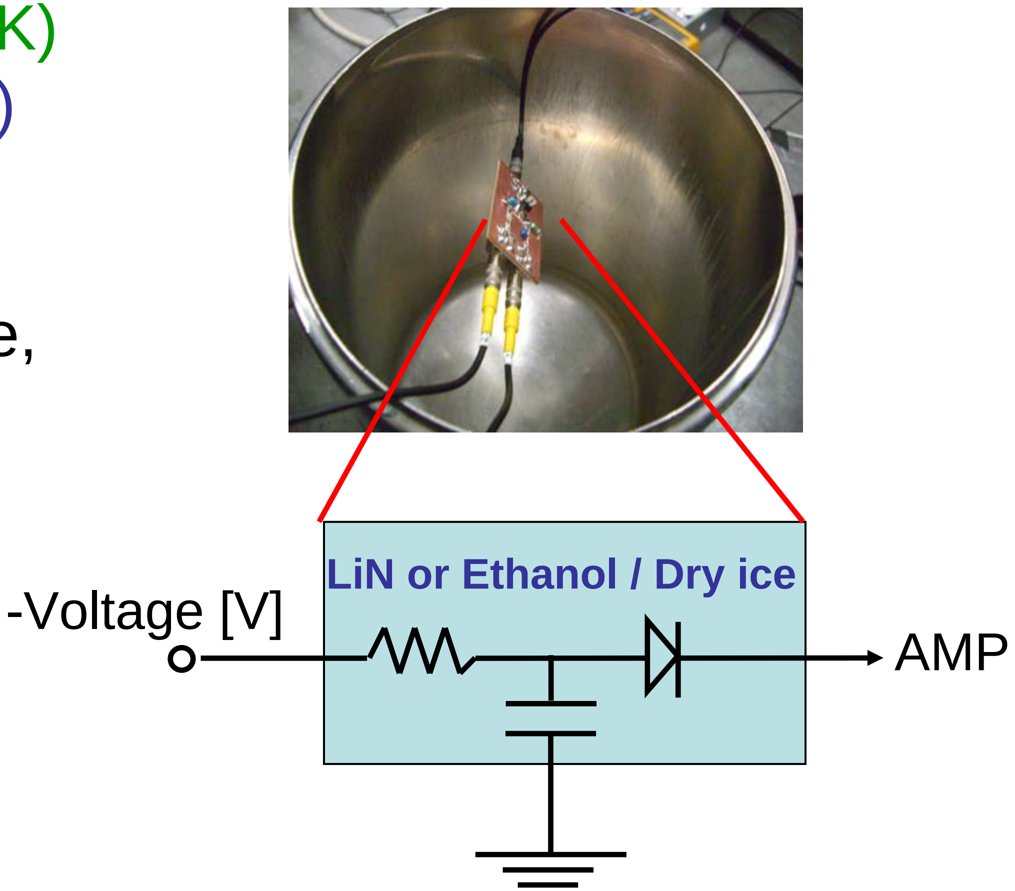
On behalf of the KEK Detector Technology Project

Introduction



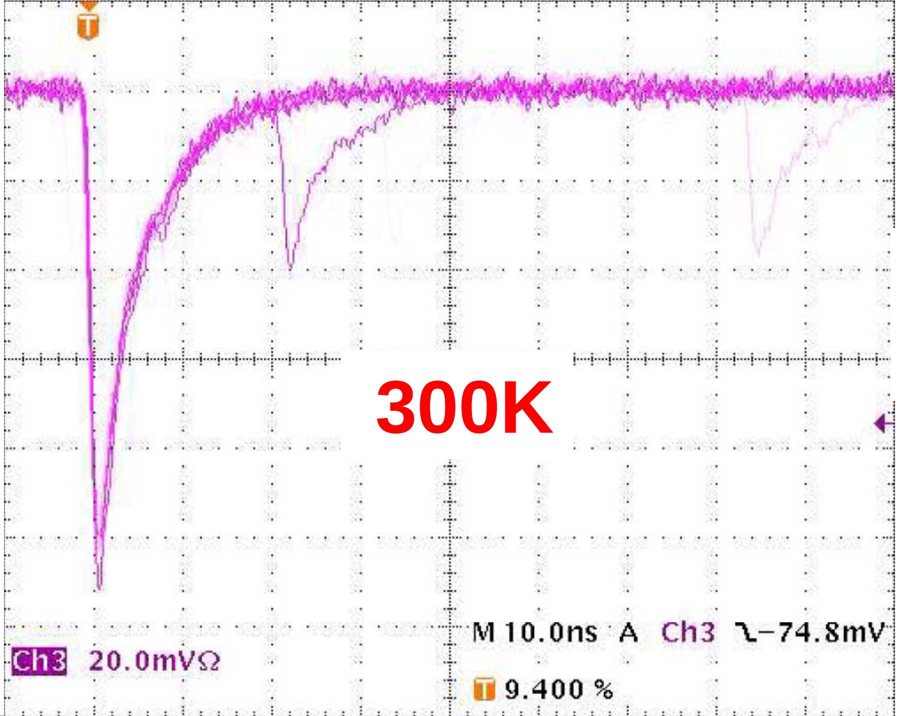
- We have measured **basic properties** of **1600 pix MPPC** produced by HPK at **low temperatures**.
- <u>Temperatures</u>
  - Room Temp. (300K)
  - Ethanol / Dry Ice (200K)
  - Liquid Nitrogen (77K)
- <u>Measured Items</u>
  - Waveform,
  - Quenching Resistance,
  - Pixel Capacitance,
  - Breakdown Voltage,
  - Noise Rate,
  - Cross-talk,
  - After-pulse

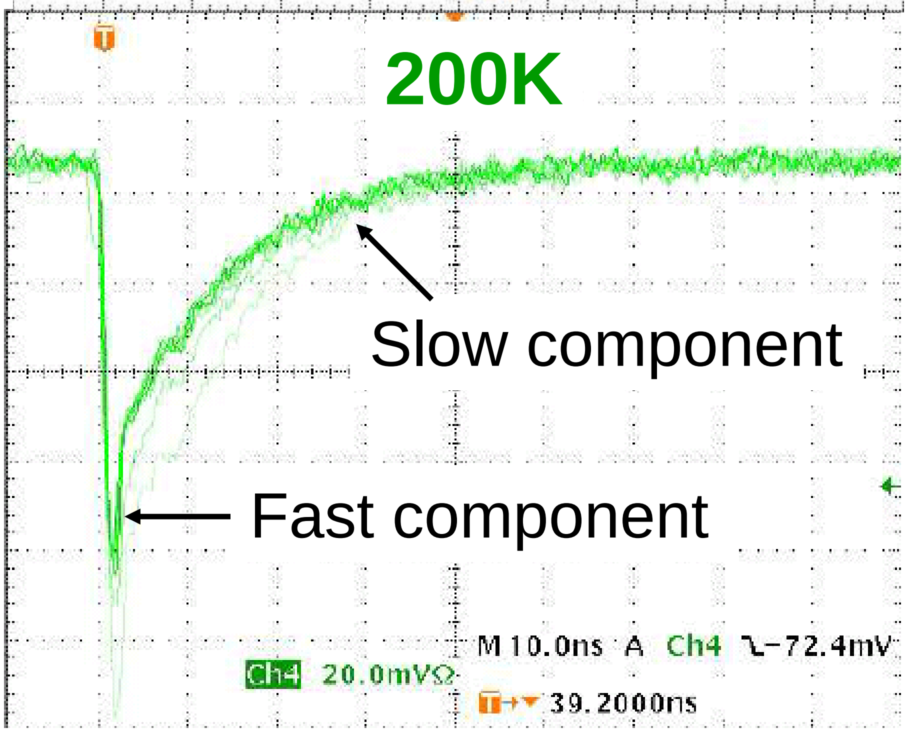
We **directly** cooled MPPC.

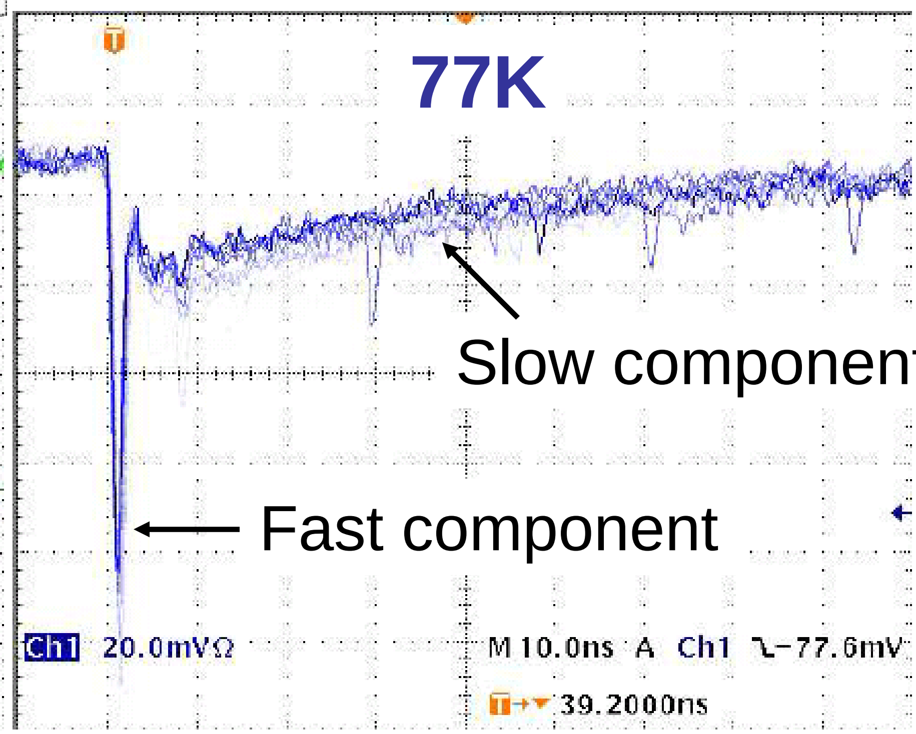


Pulse shape

- Fast/Slow components are clearly seen at low temperatures.

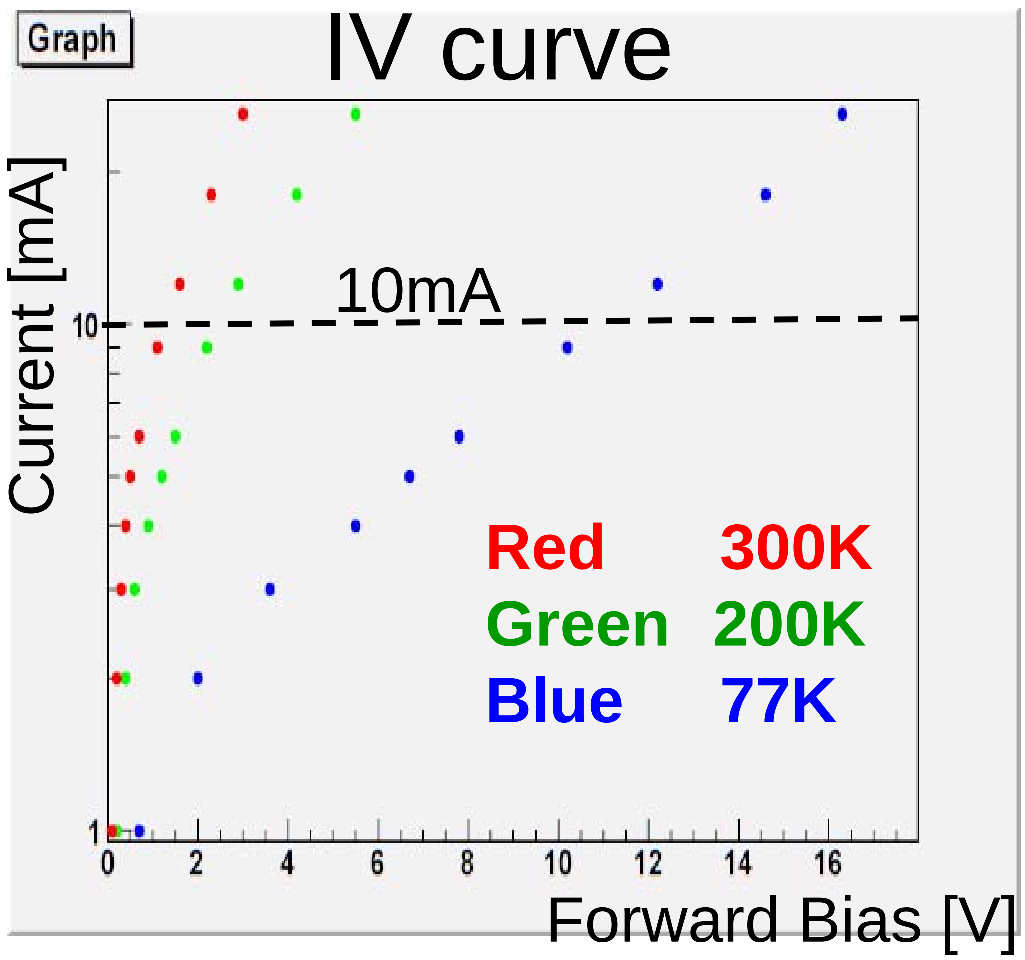




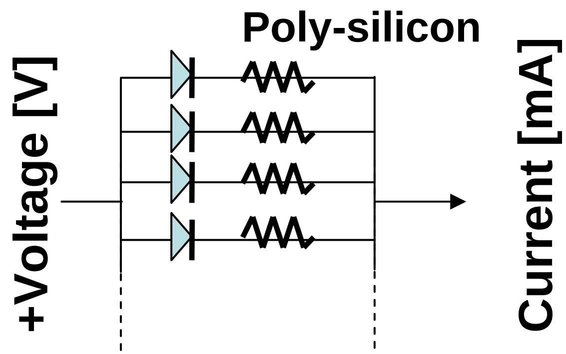


Quenching Resistance

- We measured **I-V curve** by applying **forward bias**.
  We evaluated quenching resistance value from the I-V curve.



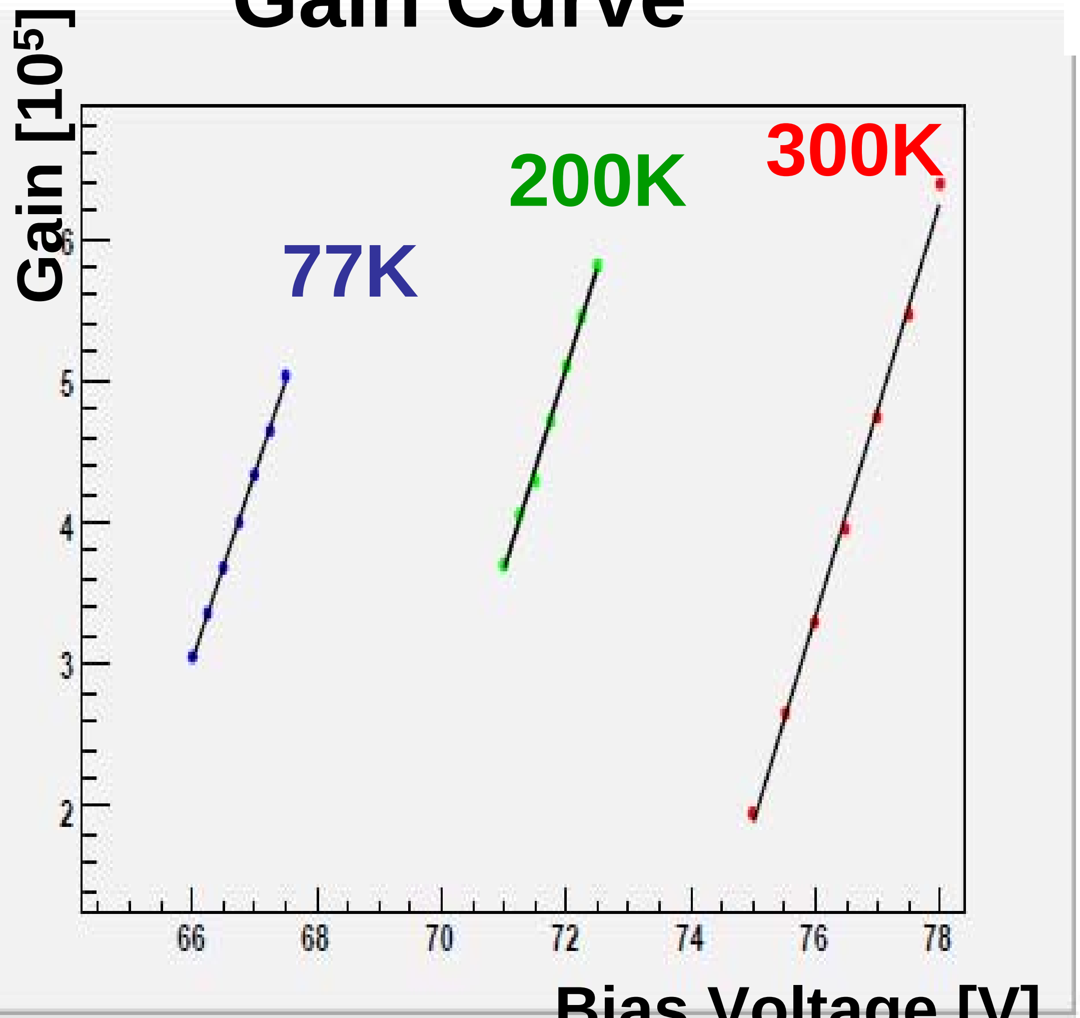
	Resistance@ current=10mA
300K	0.21MΩ
200K	0.40MΩ
77K	1.68MΩ



Pixel Capacitance

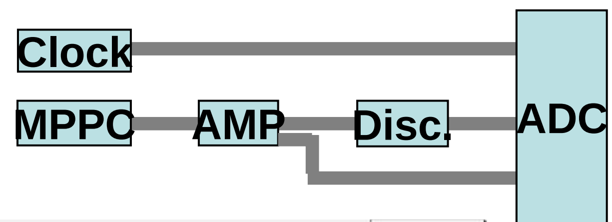
- We evaluated pixel capacitance from slope of gain curve.

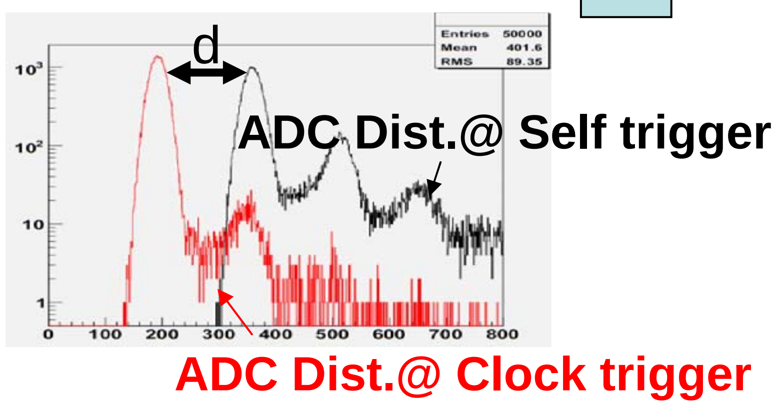
Gain Curve

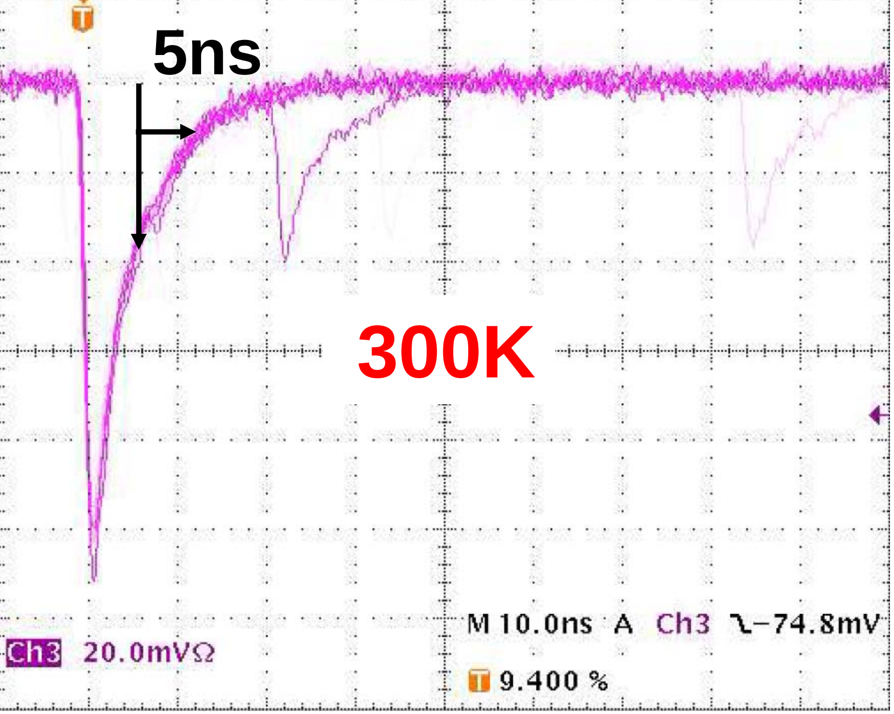


$$\text{Gain} = \frac{C}{e}(\text{Vbias} - \text{Vbreakdown})$$

	Pixel Capacitance
300K	22.1±0.8 fF
200K	22.0±0.7 fF
77K	21.3±0.5 fF

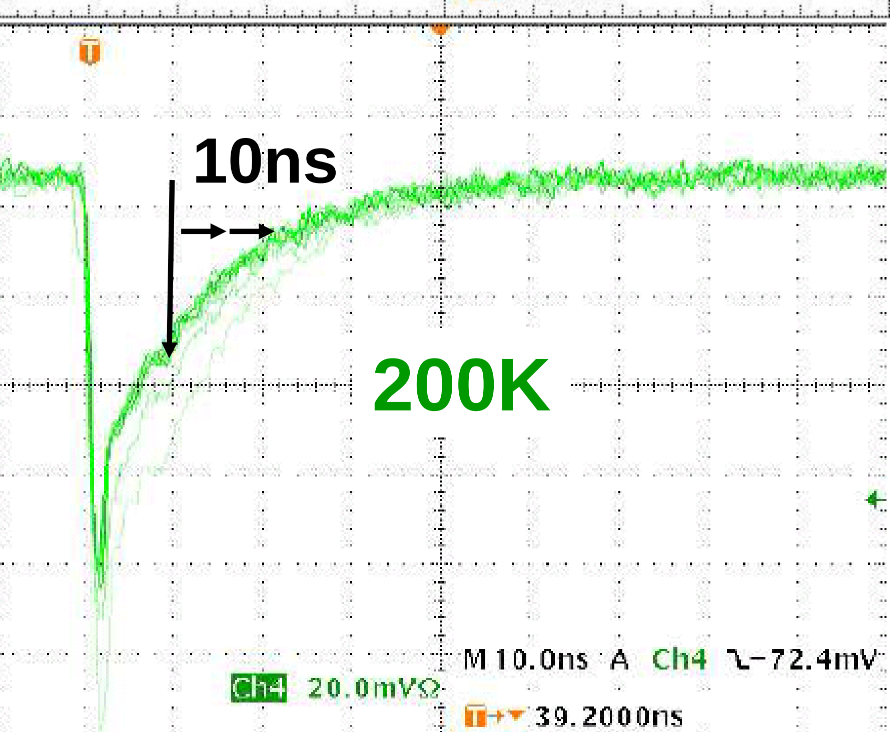


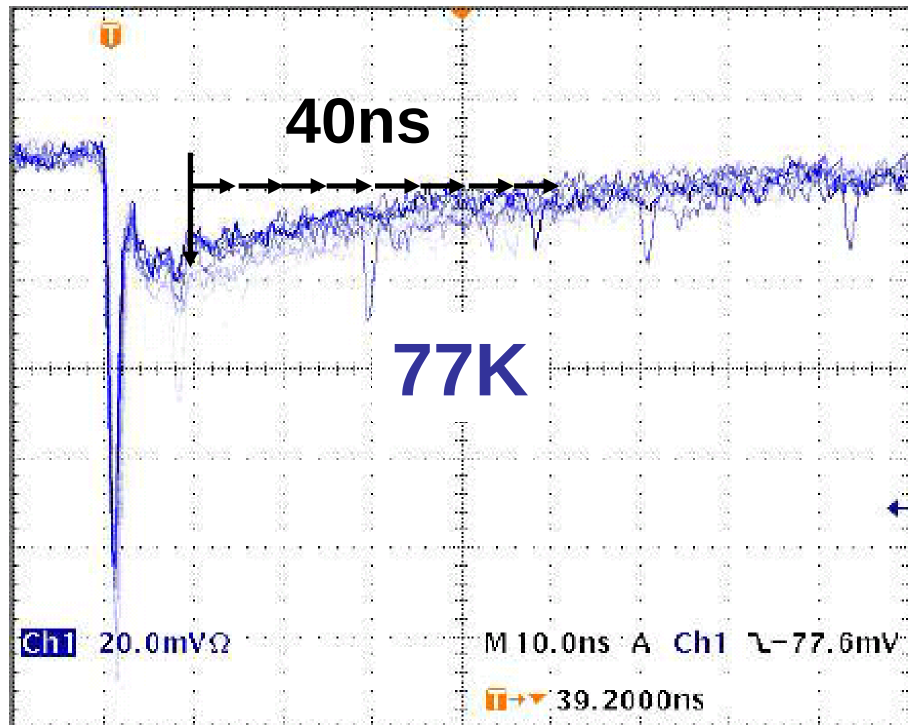




	Resistance (R)	Capacitance (C)	R x C
300K	0.21MΩ	22.1fF	4.6ns
200K	0.40MΩ	22.0fF	8.8ns
77K	1.68MΩ	21.3fF	35.8ns

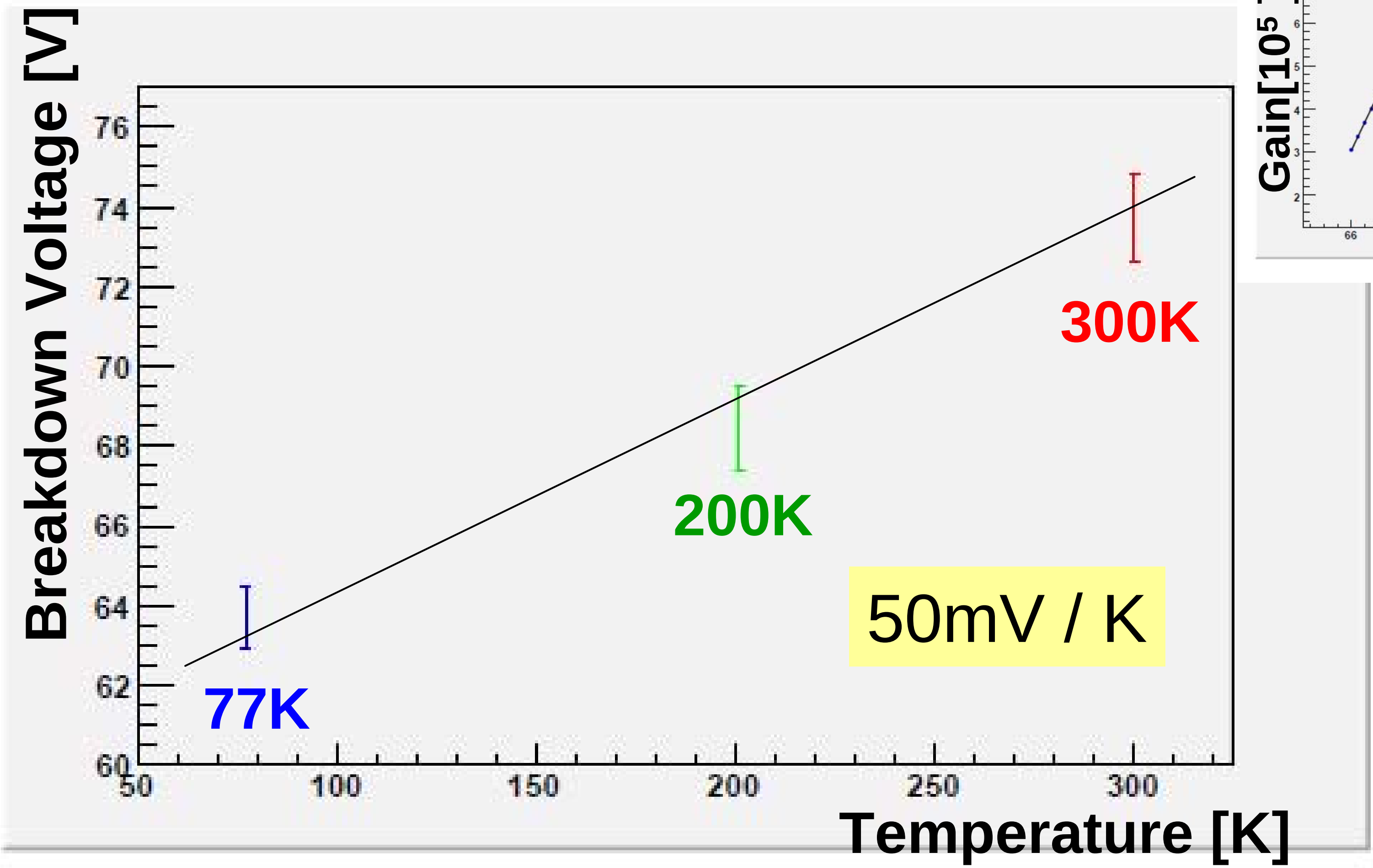
Pulse shape of slow component can be explained by RC time constant

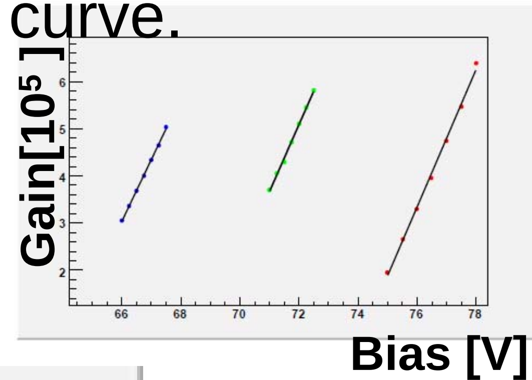




Breakdown Voltage

- We evaluated breakdown voltage from gain curve.

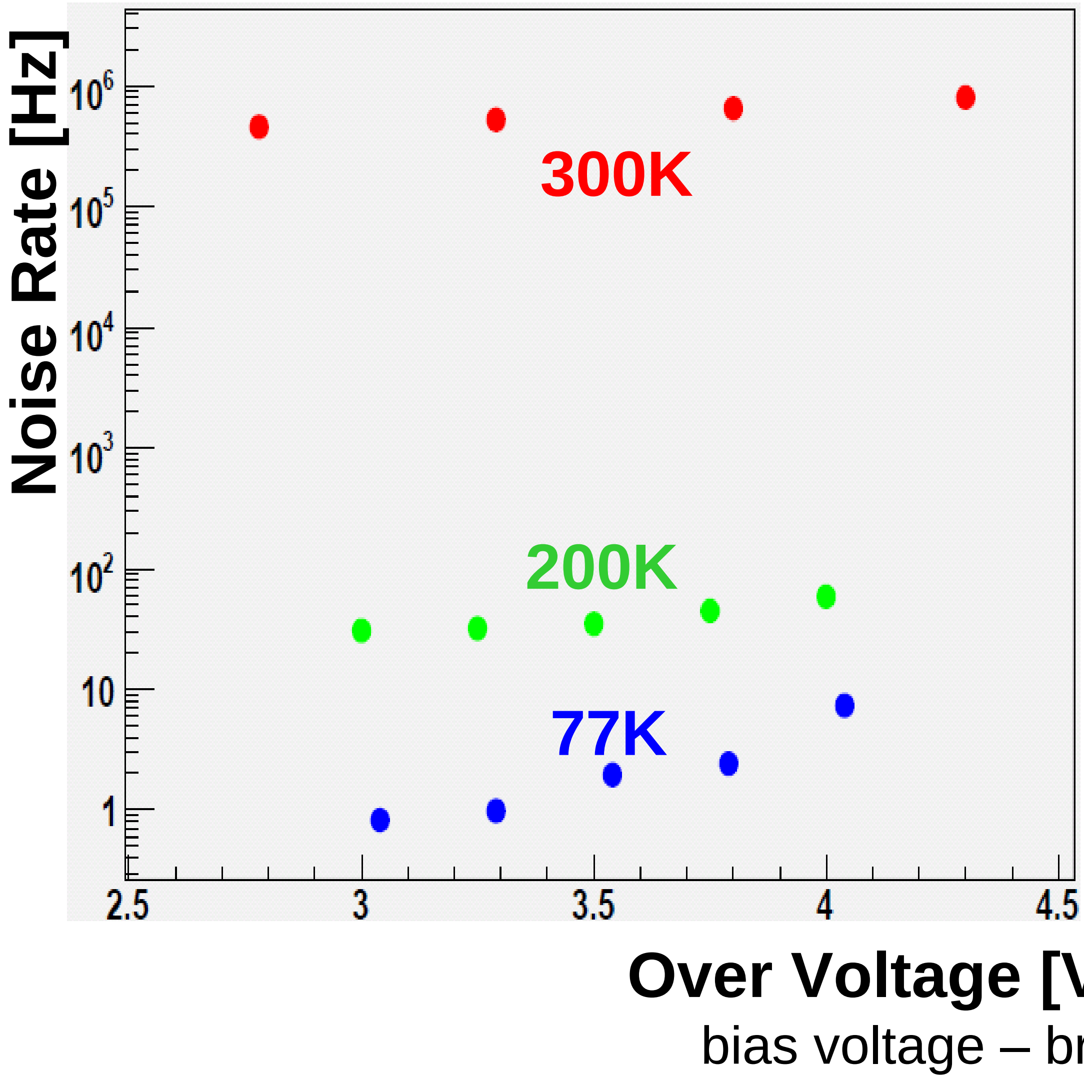




- Measured slope (50mV/K) is consistent with the slope observed around room temperature.

Dark Noise

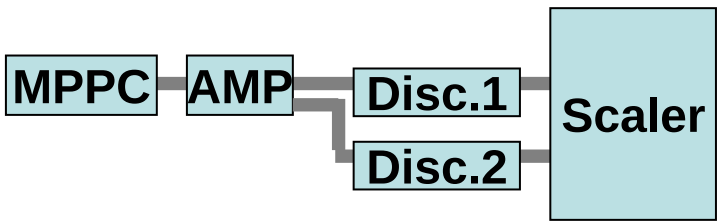
- We measured dark noise rate at each temperature.

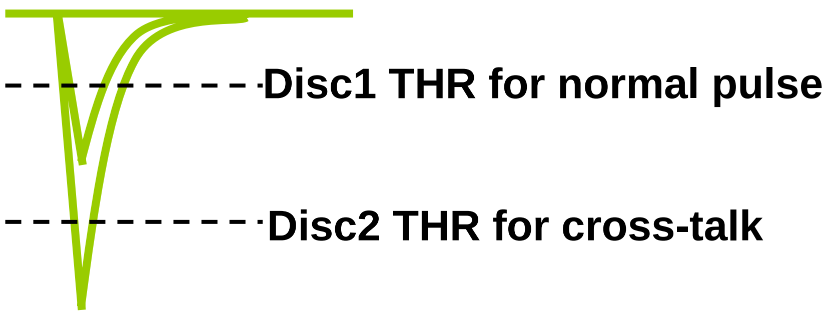


	Noise Rate
300K	100kHz~1MHz
200K	10Hz~100Hz
77K	1Hz ~ 10Hz

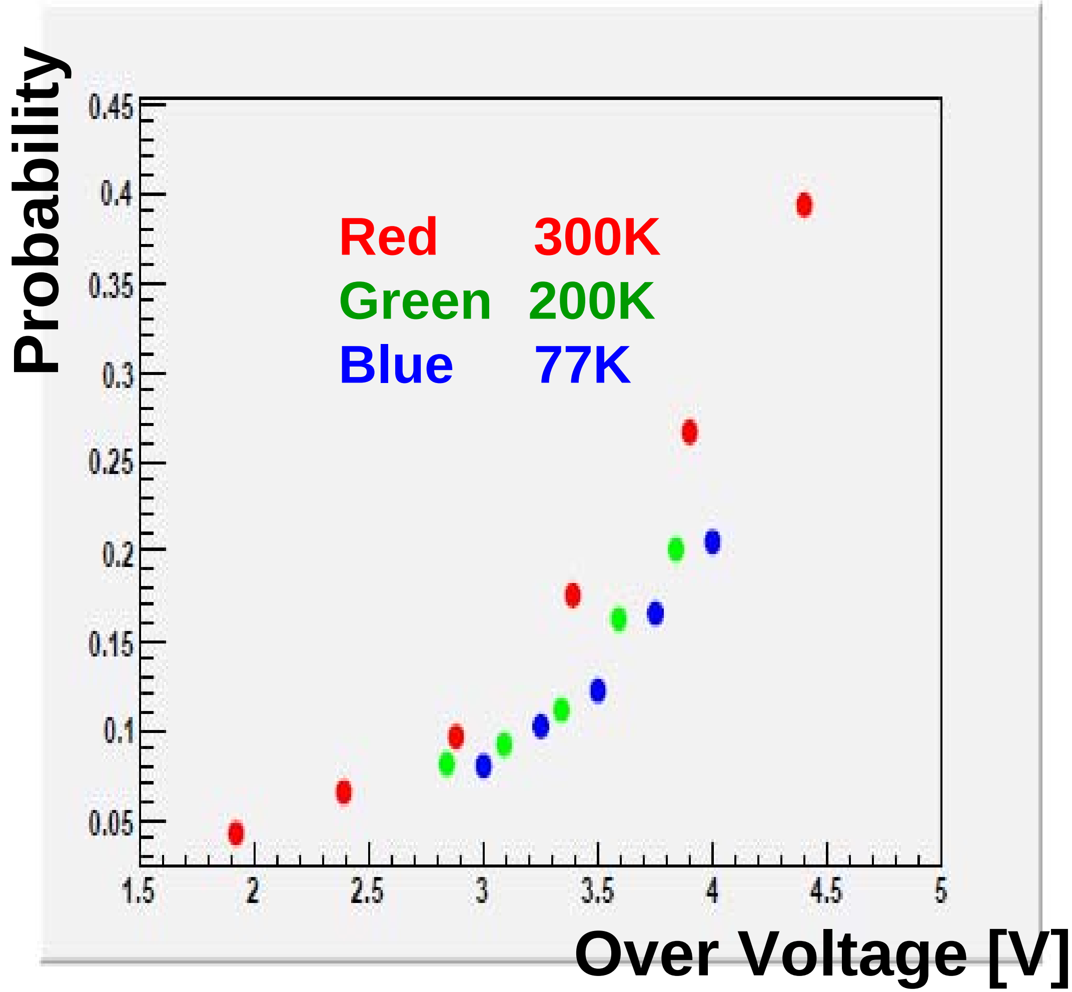
Cross-talk

- We measured probability that normal pulse generates cross-talk.





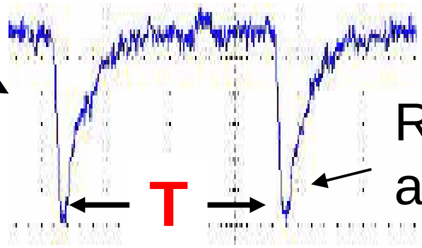
$$\text{Prob.} = \frac{\text{Output Of Disc2}}{\text{Output Of Disc1}}$$



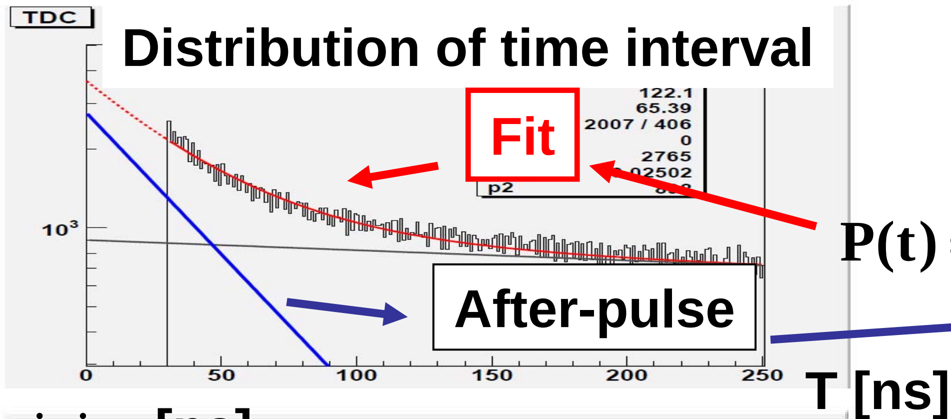
Cross-talk probability is slightly reduced at low temperature.

After-pulse

Original pulse

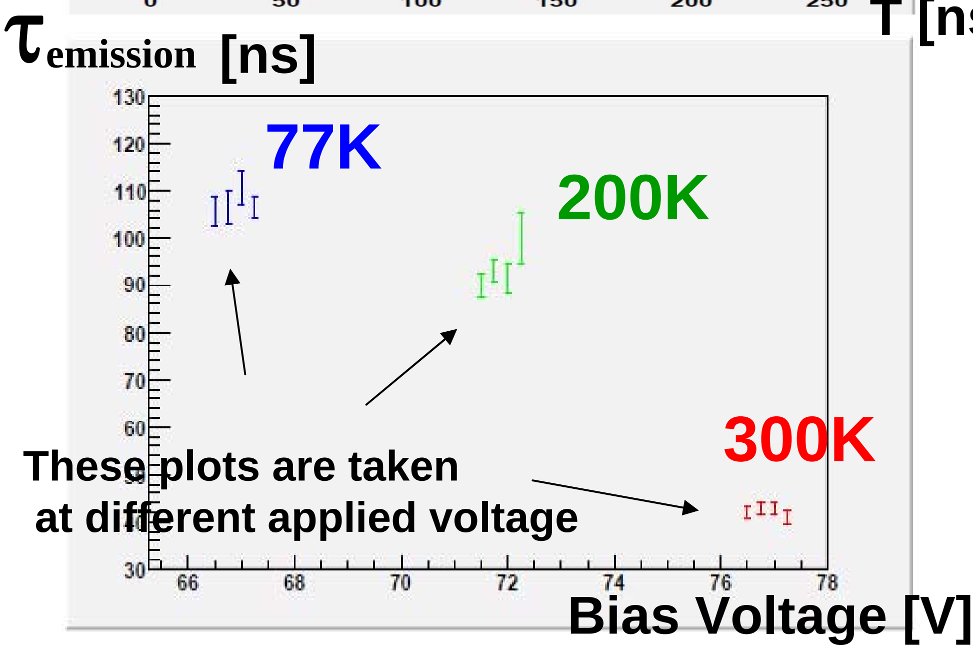


We obtained re-emission time constant by measuring time interval between two pulses (=T).



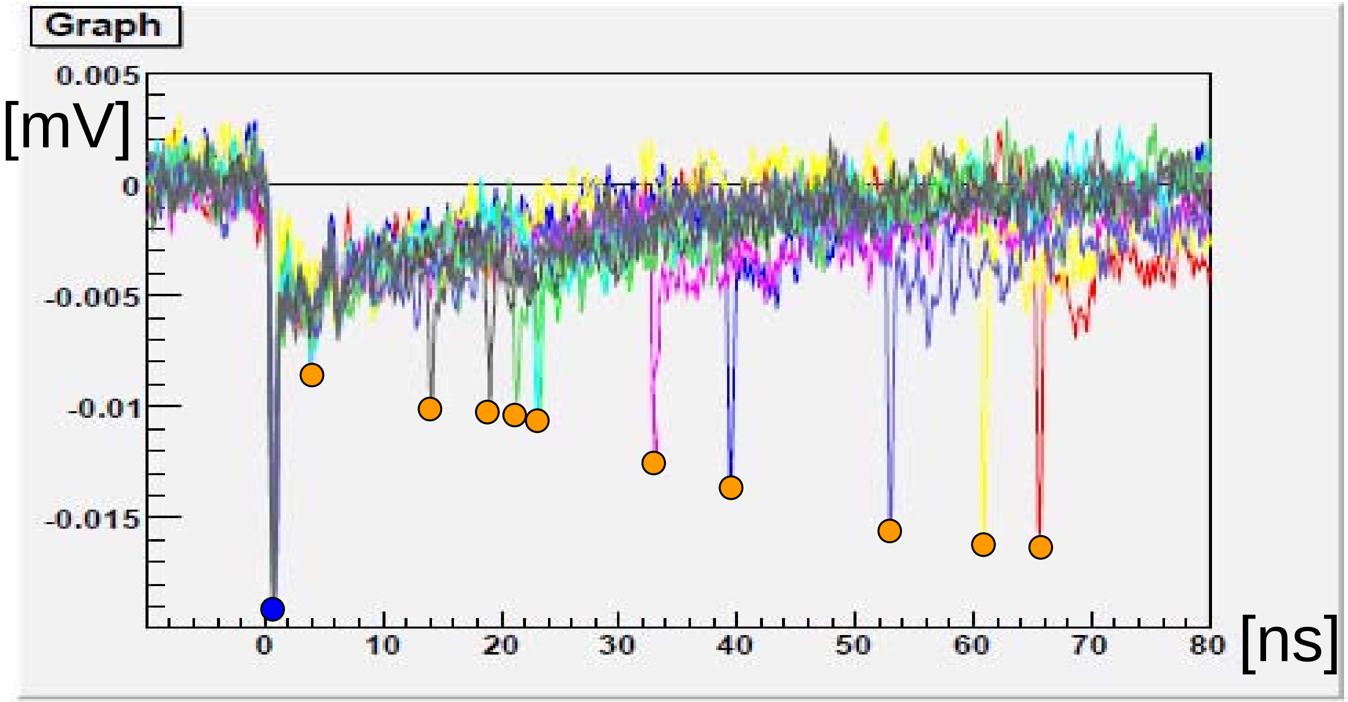
Entries of distribution
- After-pulse
- Accidental Noise ← known

$$P(t) = A\exp\left(-\frac{t}{\tau_{emission}}\right) + B\exp\left(-\frac{t}{\tau_{noise}}\right)$$



	$\tau_{emission}$
300K	41.8±2.2[ns]
200K	95.6±7.9[ns]
77K	107.6±4.6[ns]

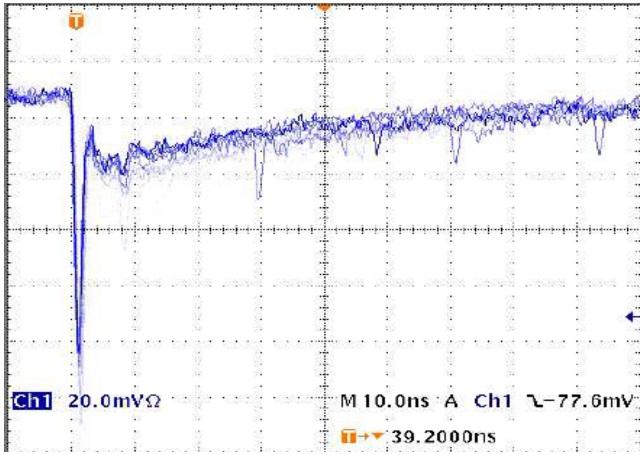
Recovery at 77K



By looking at the pulse shape at 77K, we observed recovery of pulse height after the first pulse.
Detailed analysis of this recovery at room temperature will be reported by next speaker.

Summary (1)

- We have studied the MPPC basic properties at low temperature.
  - Waveform
    Fast/Slow components are seen at low temperature.
    Pulse shape of slow component can be explained by RC constant.



  - Quenching Resistance and Pixel Capacitance
    300K : 0.21MΩ, 22.1fF
    200K : 0.40MΩ, 22.0fF
    77K : 1.68MΩ, 21.3fF
  - Breakdown Voltage
    Measured slope (50mV/K) is consistent with the slope observed around room temperature.

Summary (2)

- Dark Noise

  300K : 100kHz ~ 1MHz

  200K : 10Hz ~ 100Hz

  77K : 1Hz ~ 10 Hz

- Cross-talk

  Cross-talk probability is slightly reduced at low temperature.

- Re-emission time constant of After-pulse

  300K : 41.8±2.2[ns]

  200K : 95.6±7.9[ns]

  77K : 107.6±4.6[ns]

• Prospects
  – Measure quantum efficiency at low temperature.
  – Measure individual difference.

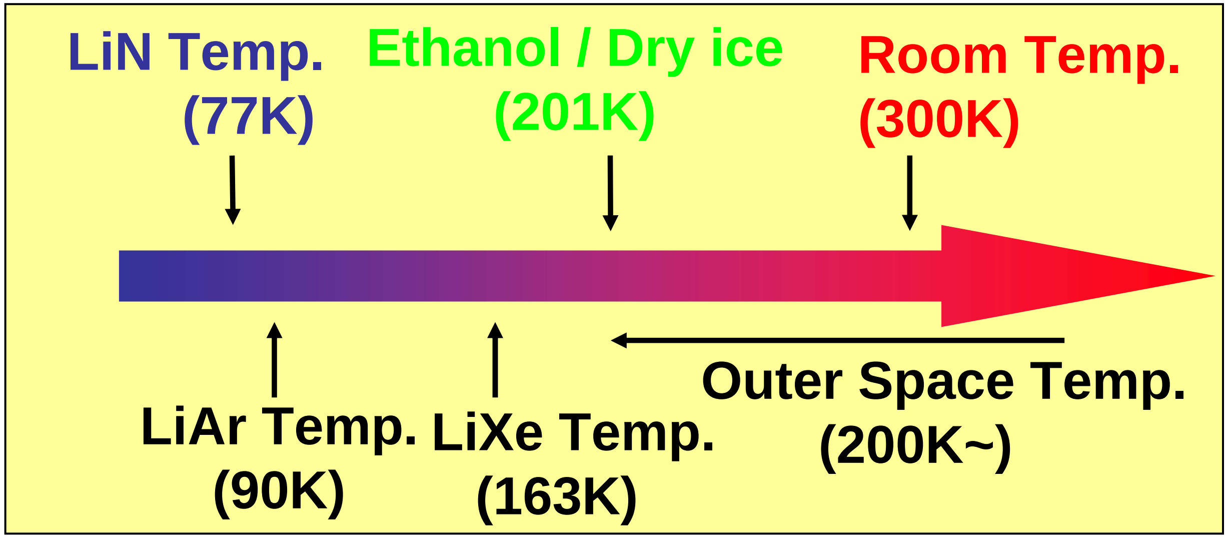
backup

Introduction

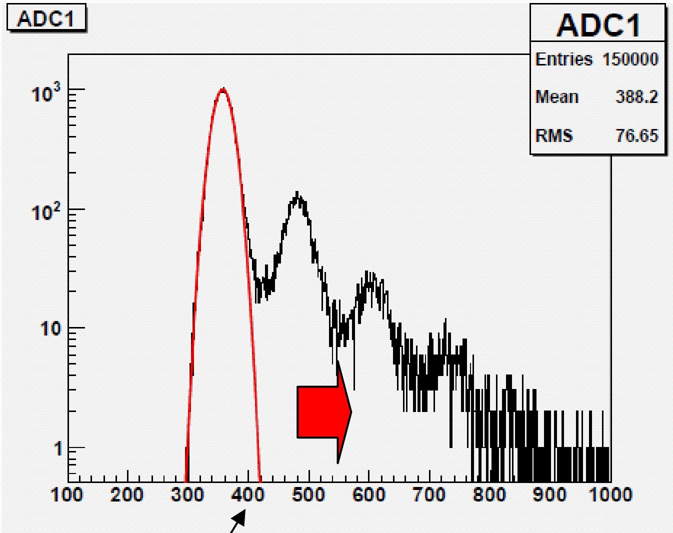
MPPC and other Geiger-mode APD are expected to be useful at low temperatures for several purpose.

- Use w/ liquid inorganic scintillators
  - LiAr(90K)
  - LiXe(163K)
- Use in outer space for astrophysics

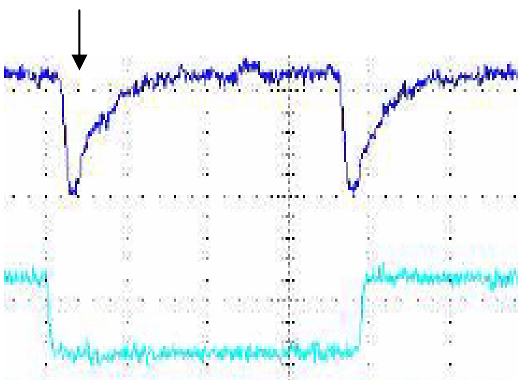
Our measurement at
300K : Room Temp.
201K : Ethanol / Dry ice
77K   : LiN2 Temp.



Probability which after-pulse comes in 50 ns



Normal Noise



Entries

- Normal Noise
- Cross-talk
- Accidental Noise
- After-pulse → Prob = After-pulse/Entries

(Normal Noise, Cross-talk, Accidental Noise: known)