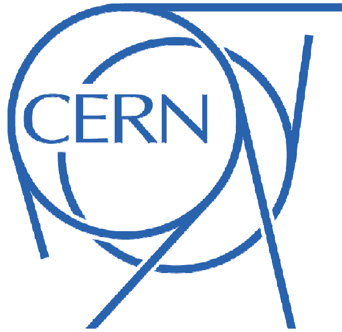

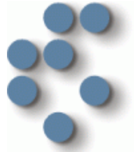

Effects of annealing on charge collection in heavily irradiated silicon micro-strip detectors

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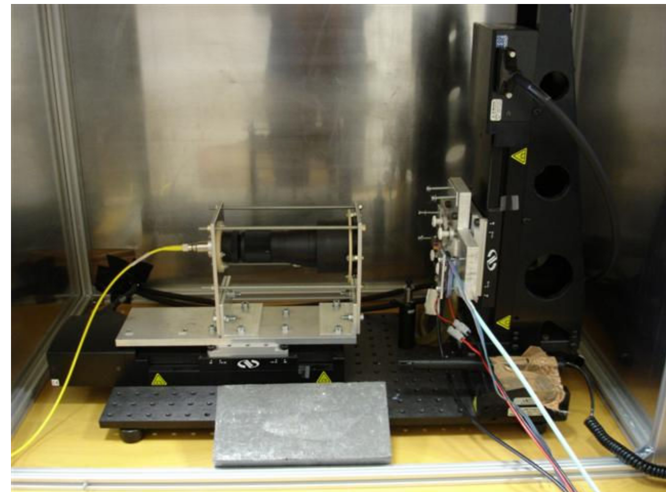
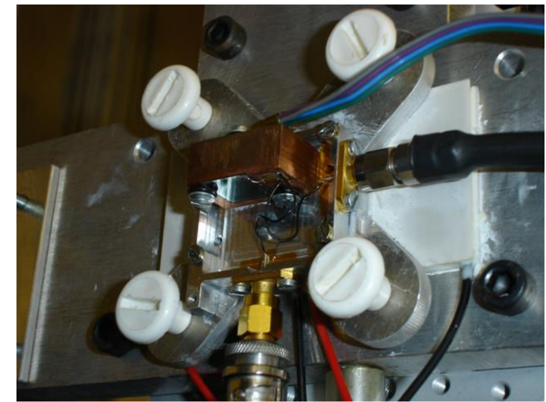
M. Mikuž, M. Milovanović, M. Zavrtanik

Motivation

- Long-term annealing does not seem to be as harmful as at lower fluencies (*measured by Liverpool, UCSC, IJS*)
- New method used to investigate CCE – Edge-TCT (*see previous talk*)
- Multiplication effects could be influenced by
  - τ_{eff} changes
  - Electric field changes.
- Forward bias?

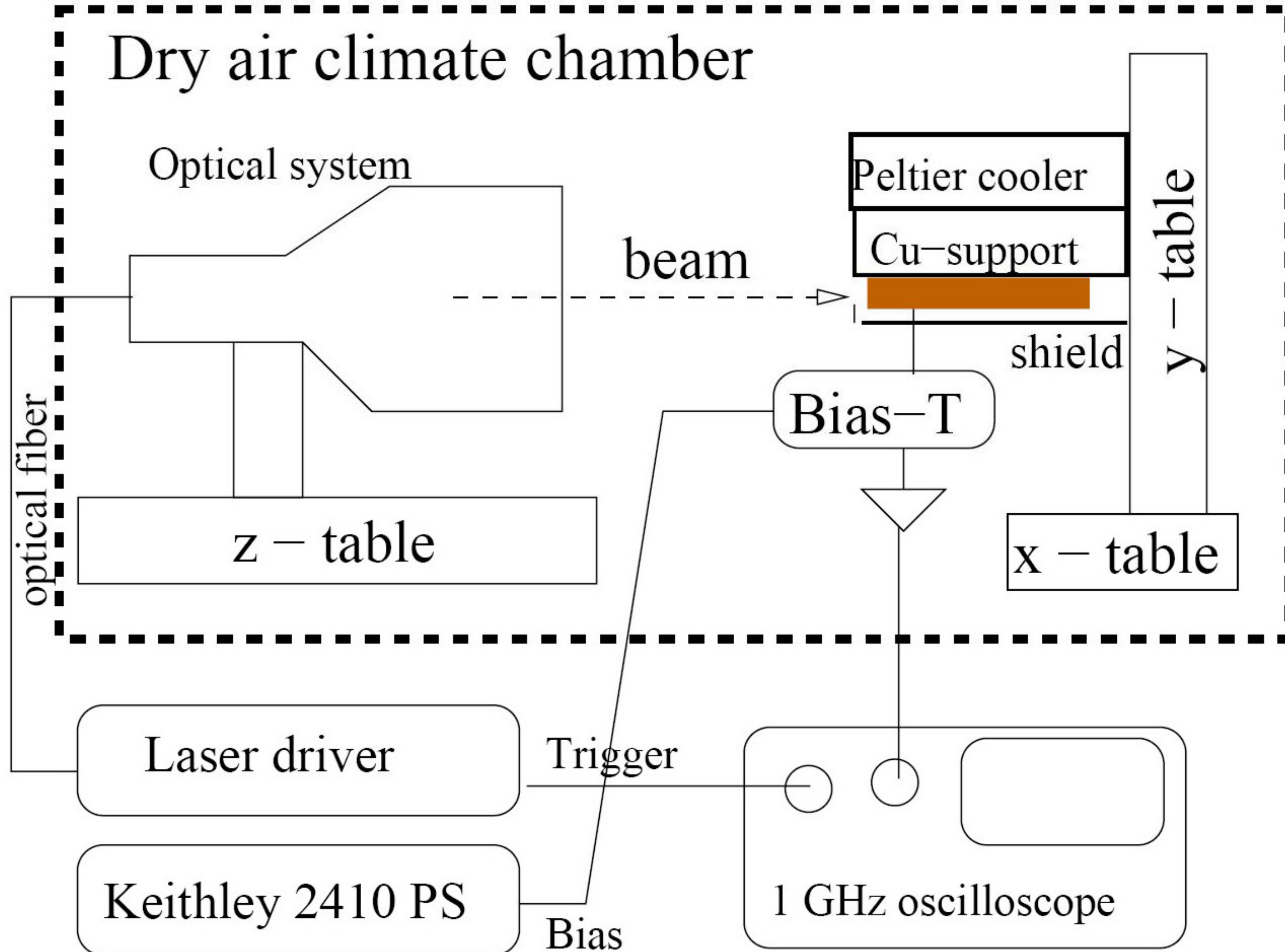


Experimental Setup

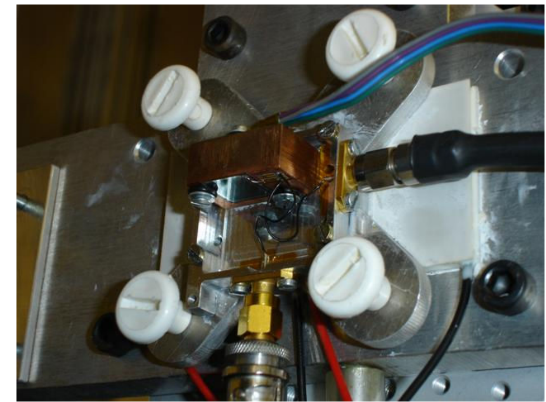


- <u>Detector:</u>
  - Manufacturer: Micron (RD50 Micron run)
  - Type: FZ Si, p-type micro-strip, initial V_{FD}≈16V
  - Irradiation fluence: $5x10^{15}$ neutrons/cm^2 (by TRIGA)
- <u>Setup (*see Gregor's talk*)</u>
  - Peltier cooler (-20 ÷ 60 ^oC)
  - Power supply: Keithley 2410
  - Wide band amplifier: MITEQ AM-1309 (10kHz-1Ghz)
  - Osciloscope: LeCroy 950 WavePro (1Ghz)
  - IR Laser: ALDS, λ=1060nm
  - Positioning system: Newport M-ILS100PP

Experimental Setup



Annealing process

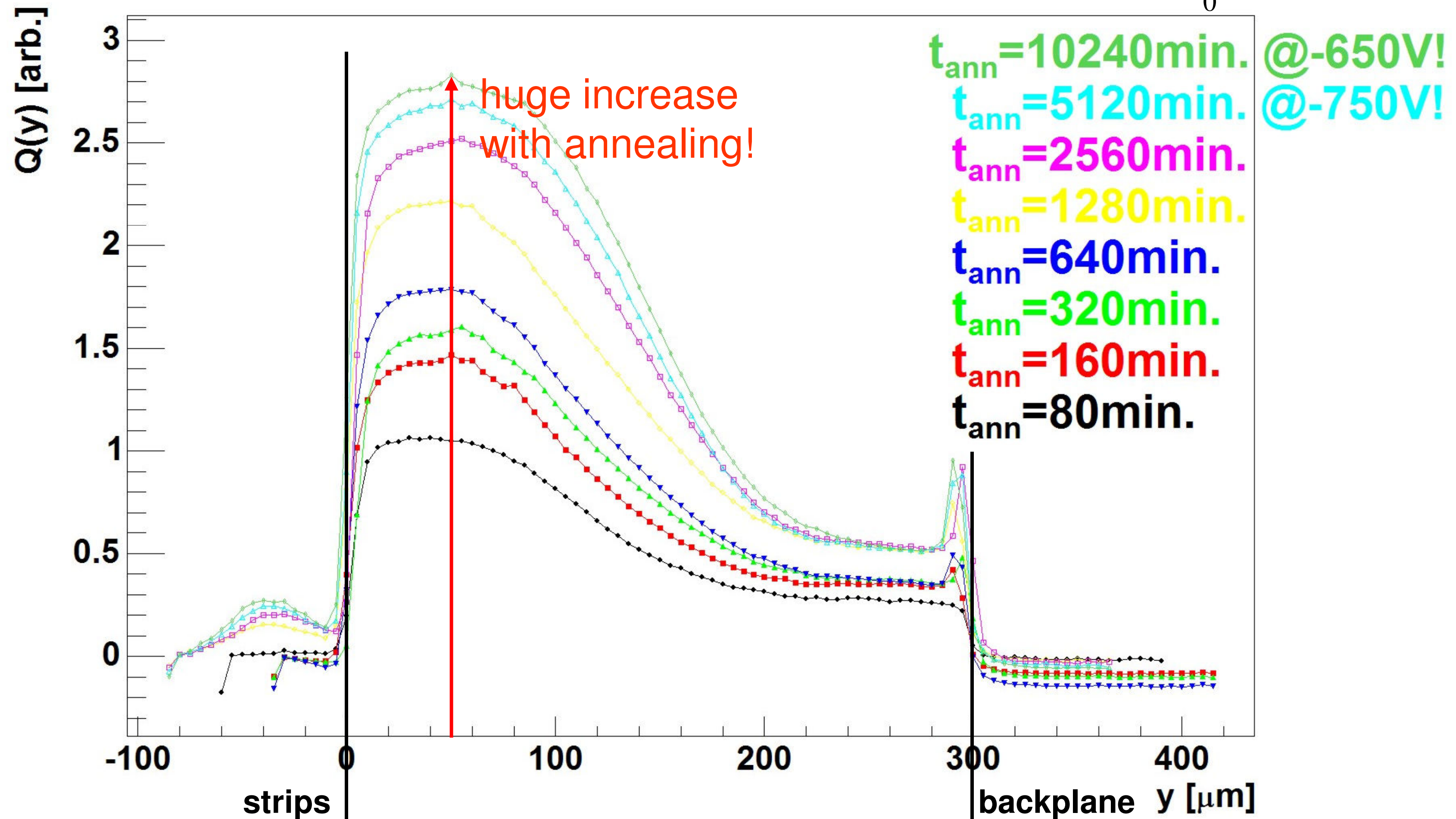


- Sample always annealed in the setup with the Peltier element
  - charge measurement (estimation of precision: a few percent)
    - constant laboratory temperature: 21 ^{o}C
    - stable position/laser (the same locations in the detector were illuminated for all annealing steps)
    - sample temperature stabilized to less than 1°C
- Annealing at 60°C up to cumulative time of 10240 min.
- After each annealing step, voltage scans from -800V up to 500V were performed

Charge collection @-800V (reverse bias)

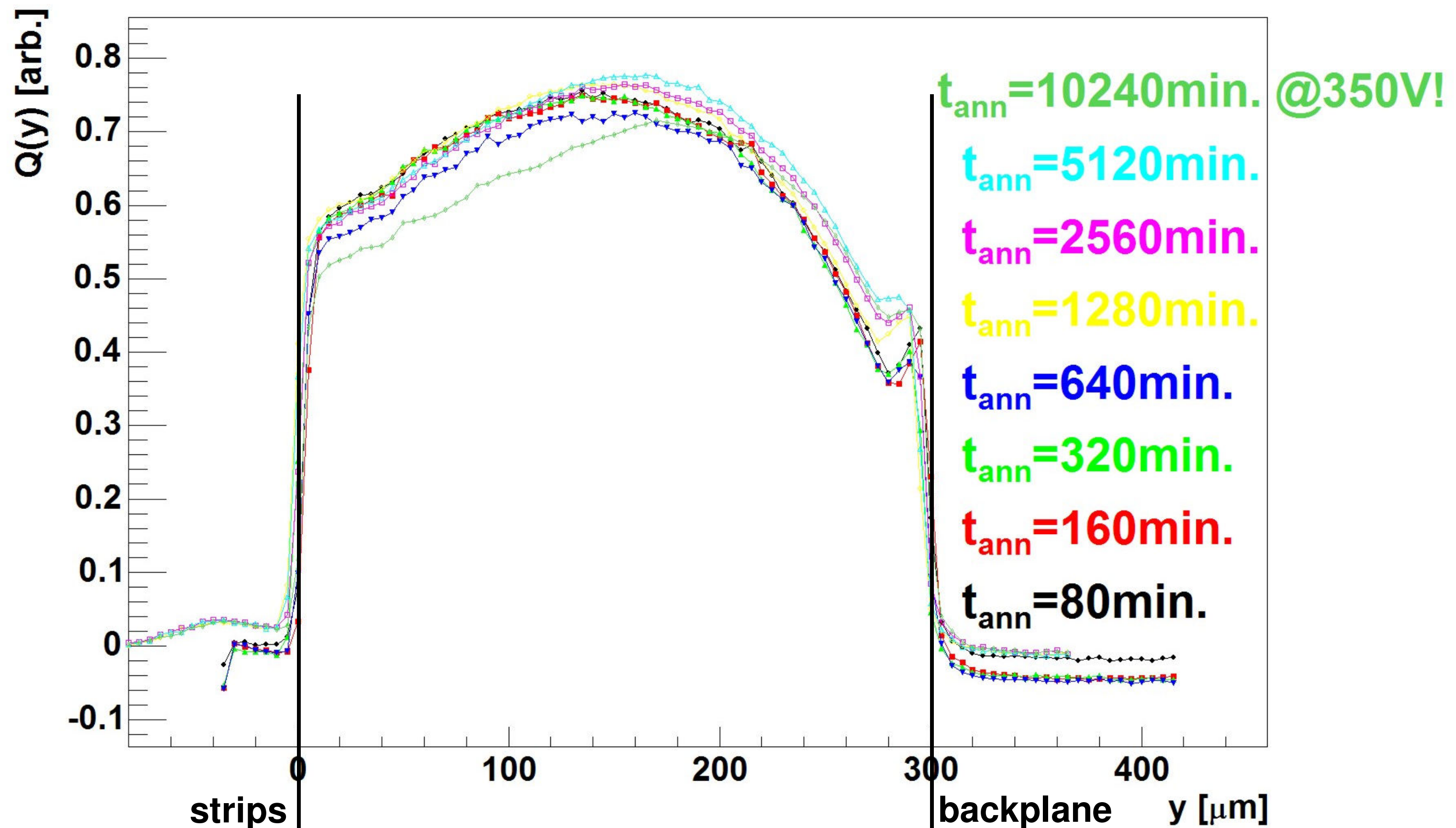
Detector: Micron, FZ-Si p-type micro-strip, $\Phi=5\times10^{15}$ cm^{-2}, T=-20°C

$$Q(y) = \int_0^{25ns} I(y,t)\,dt$$

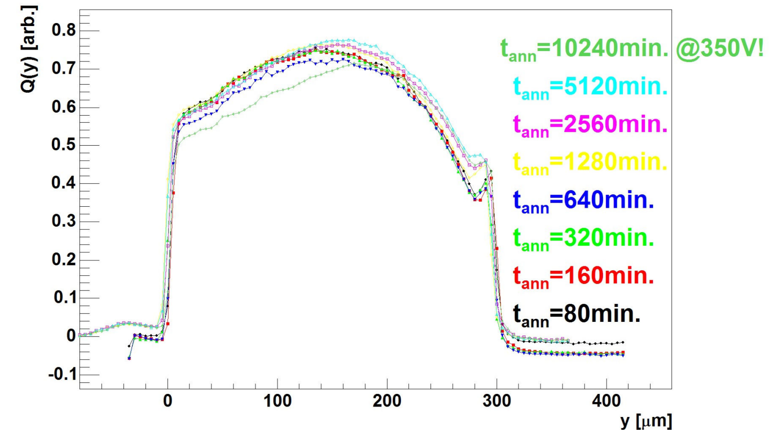


How can we be sure that this is not an artifact of the setup?!

a) Laser stability can be verified in **forward bias**



What can we see in forward direction?



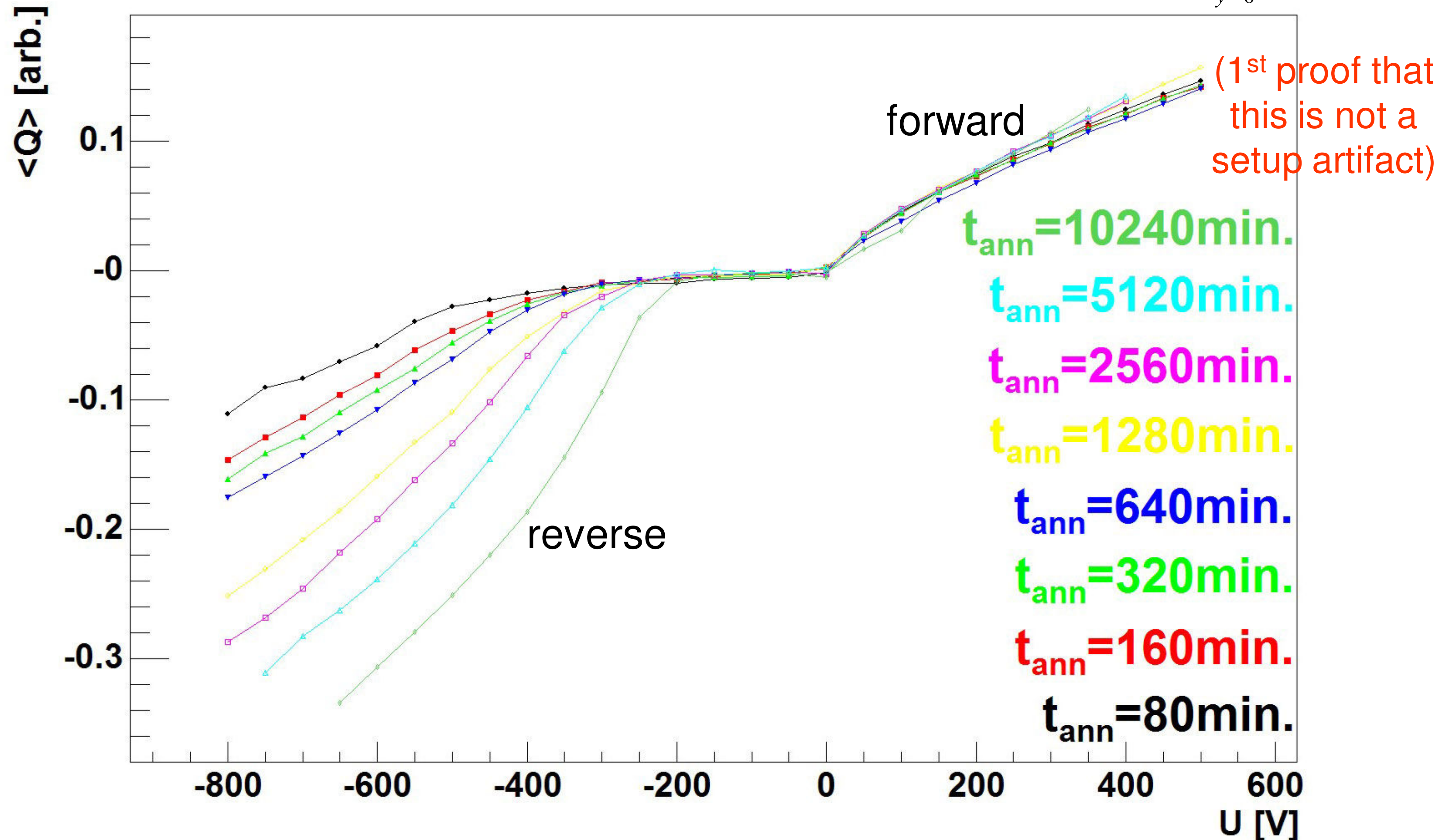
- Annealing process does not seem to influence charge collection efficiency
- The efficiency of the detector is best at its centre
- There is no peak in the electric field!

<Q> vs. bias for all annealing times

(MIP equivalent Q vs. bias)

Detector: Micron, FZ-Si p-type micro-strip, $\Phi = 5 \times 10^{15}\ \mathrm{cm}^{-2}$, T=-20°C

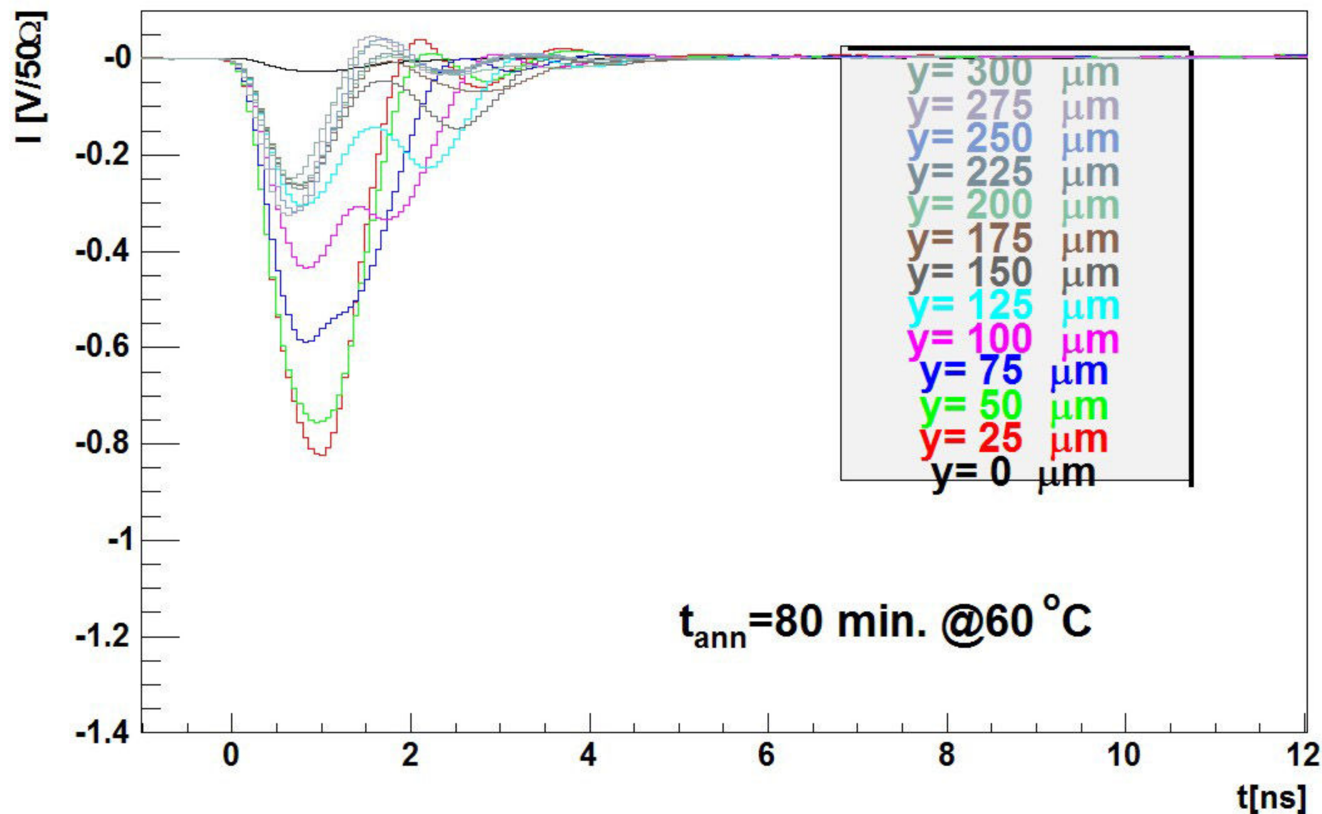
$$\langle Q \rangle = \frac{1}{W} \int_{y=0}^{y=W} Q(y)\,dy$$



E-TCT Measurements (reverse bias@800V)

Detector: Micron, FZ-Si p-type micro-strip, $\Phi=5\times10^{15}$ cm^{-2}, T=-20°C

b) Multiplication can be clearly seen in induced current pulse shapes (2nd proof that this is not a setup artifact!)



E-TCT Measurements (reverse bias@800V)

Detector: Micron, FZ-Si p-type micro-strip, $\Phi=5\times10^{15}$ cm^{-2}, T=-20°C

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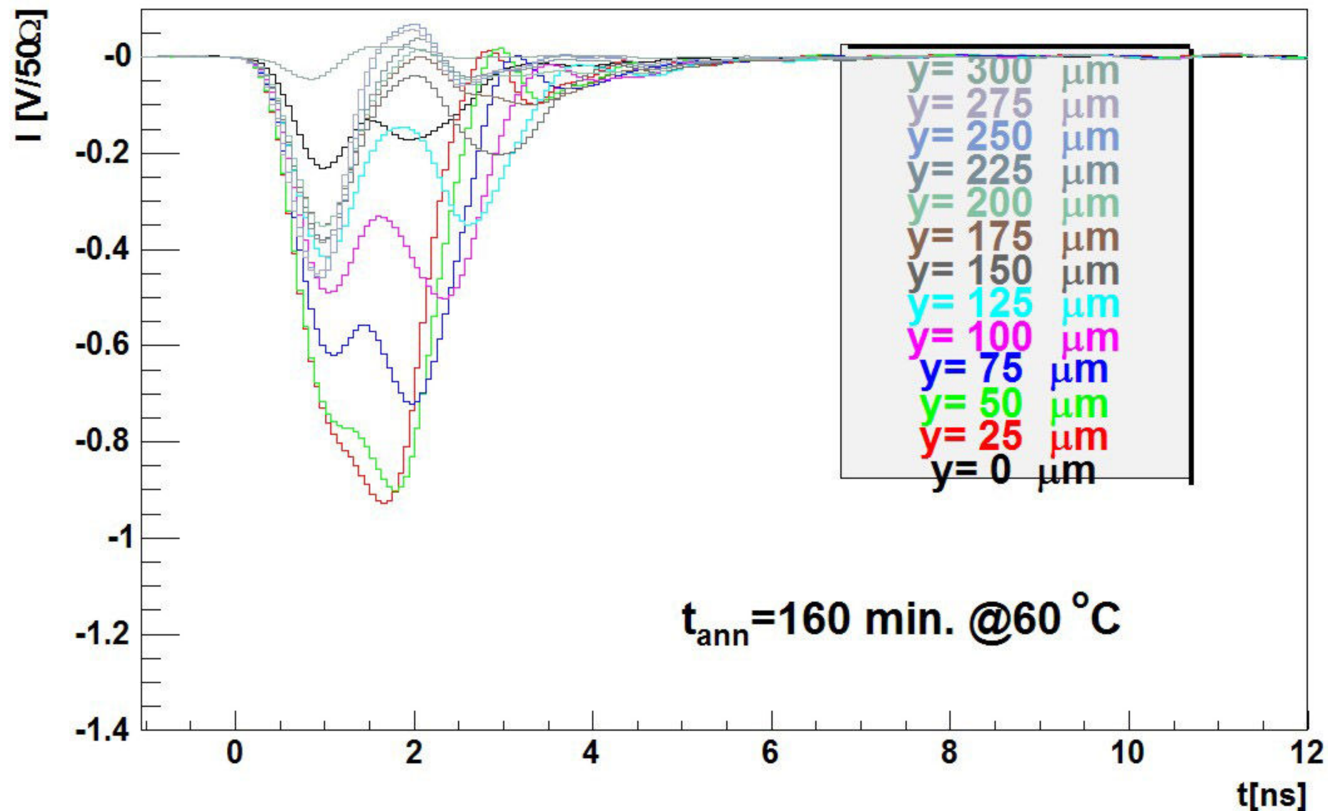

E-TCT Measurements (reverse bias@800V)

Detector: Micron, FZ-Si p-type micro-strip, Φ=5x10^{15} cm^{-2}, T=-20°C

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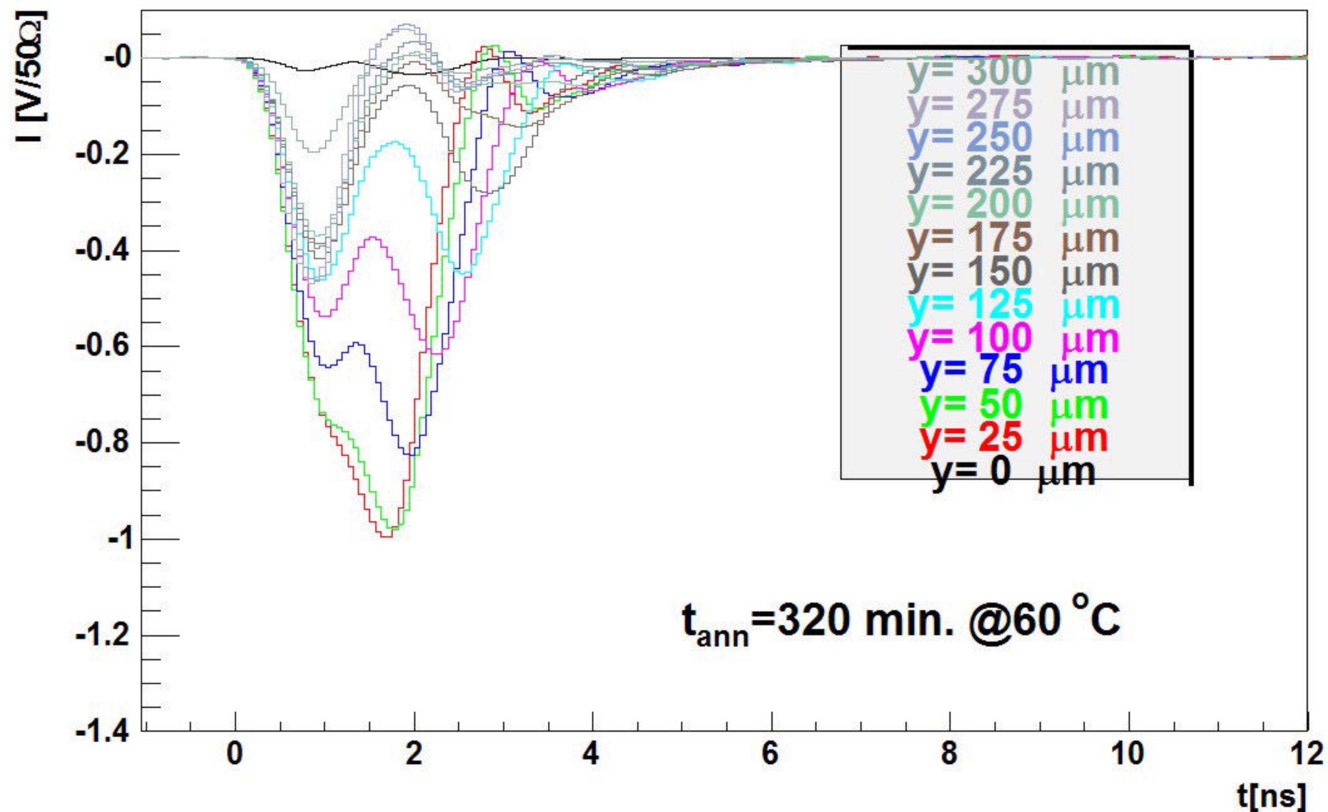

E-TCT Measurements (reverse bias@800V)

Detector: Micron, FZ-Si p-type micro-strip, $\Phi=5\times10^{15}$ cm^{-2}, T=-20°C

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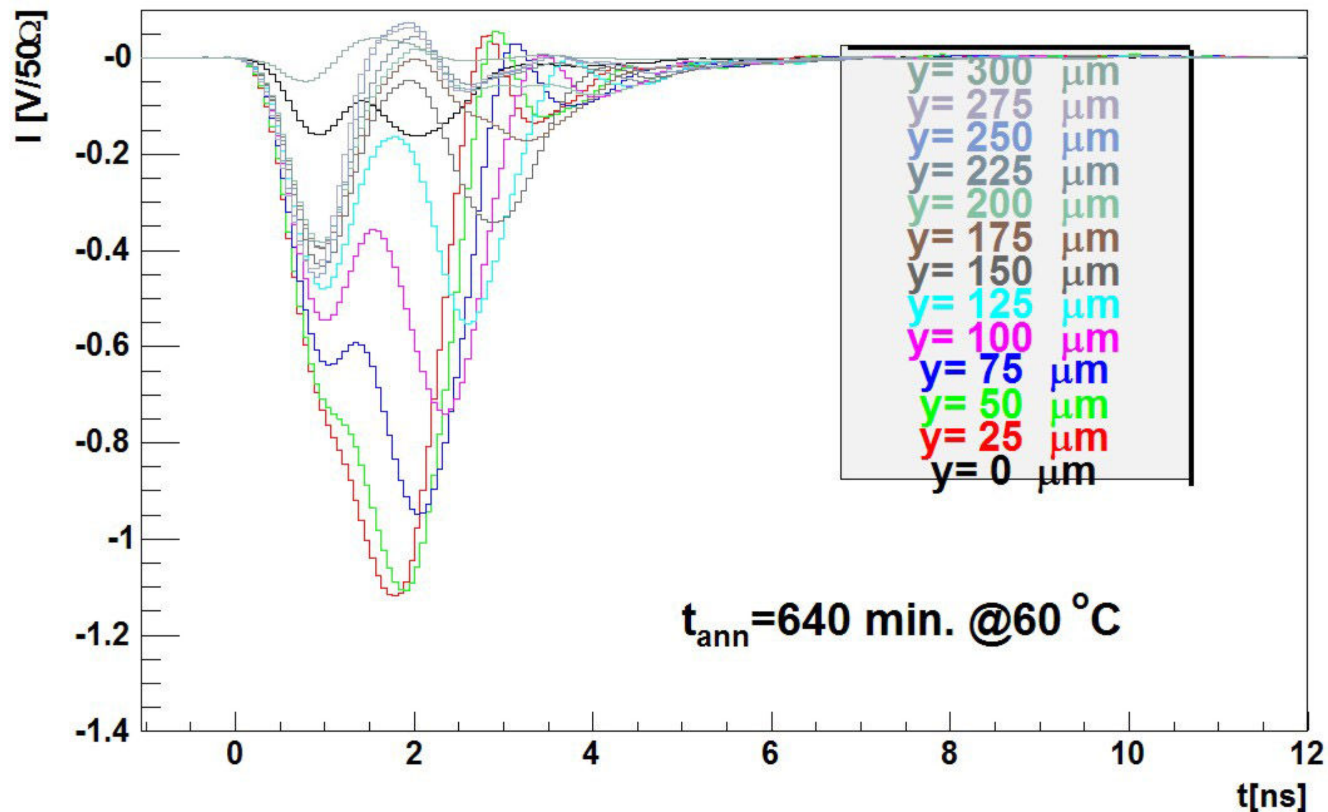

E-TCT Measurements (reverse bias@800V)

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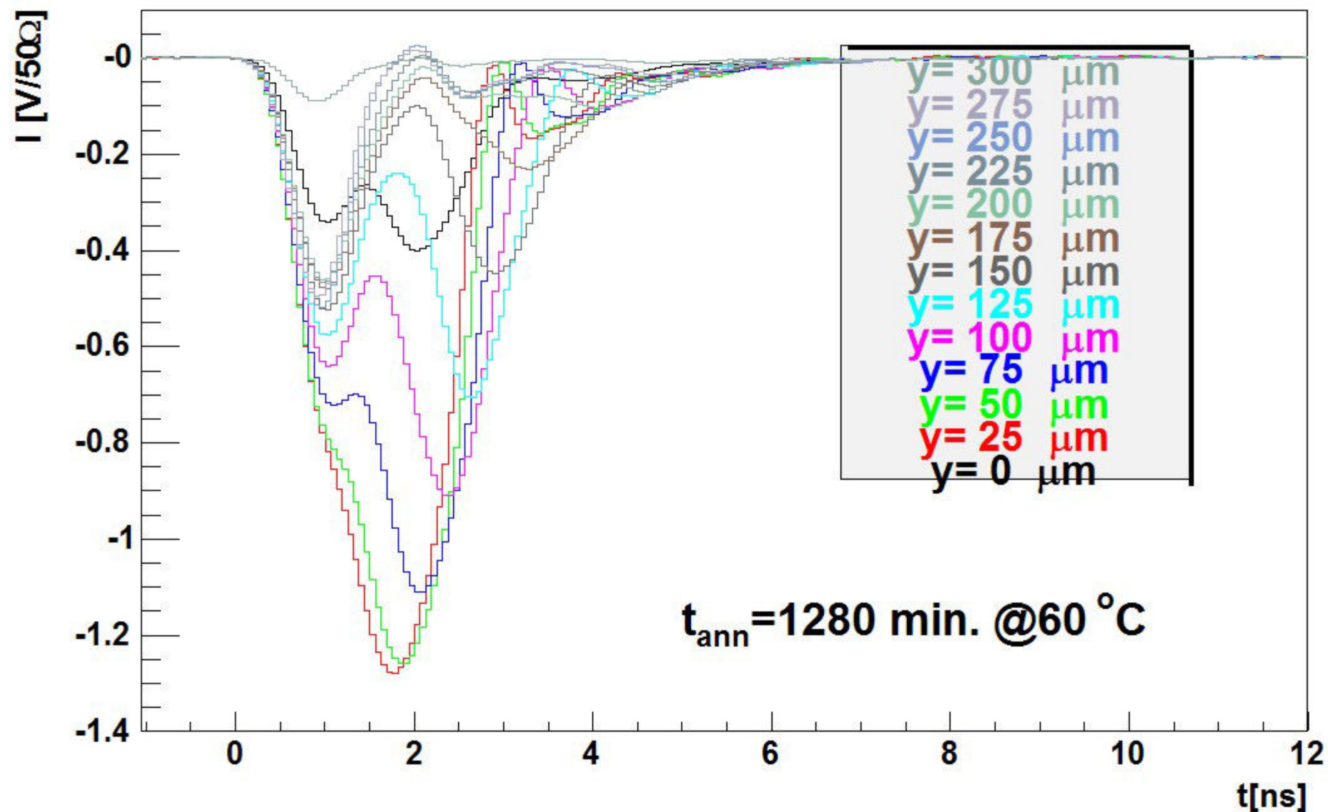
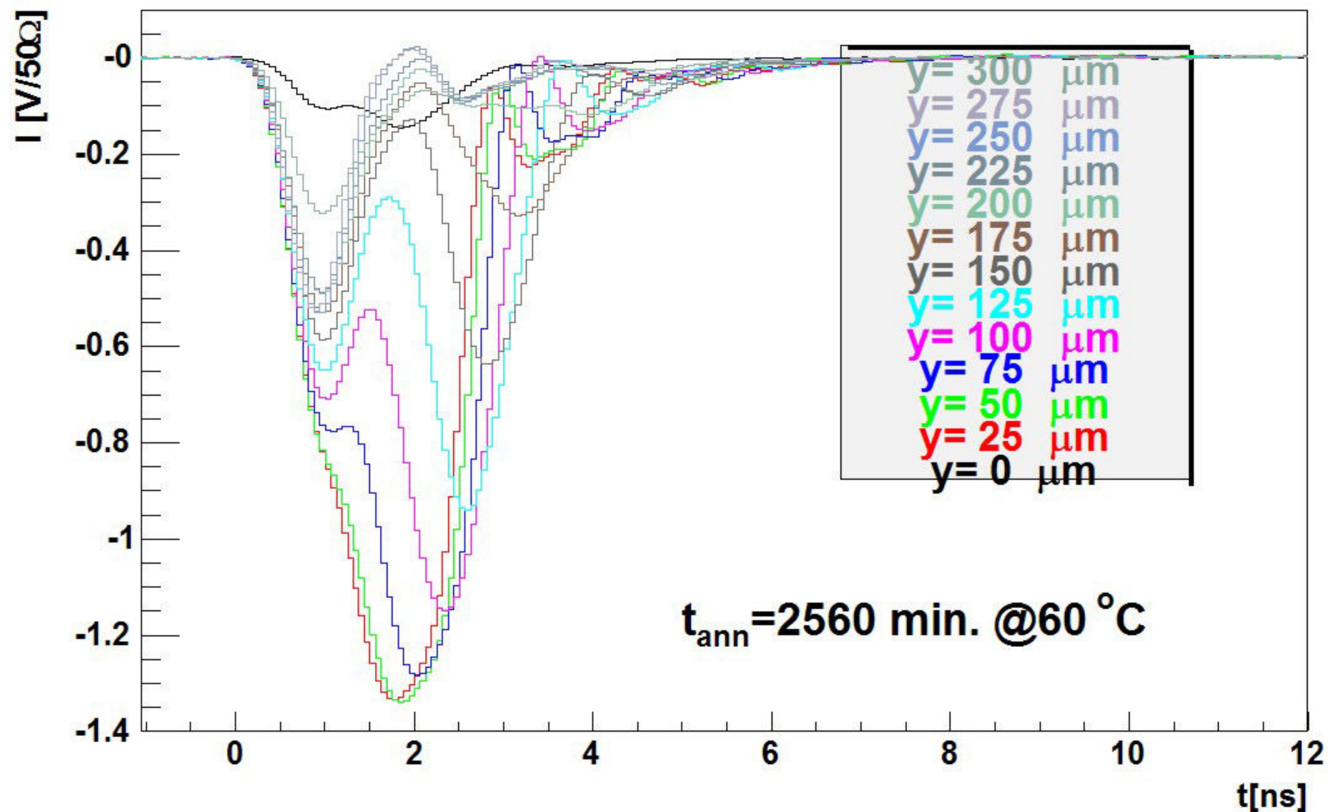


E-TCT Measurements (reverse bias@800V)

Detector: Micron, FZ-Si p-type micro-strip, $\Phi=5x10^{15}$ cm^{-2}, T=-20°C

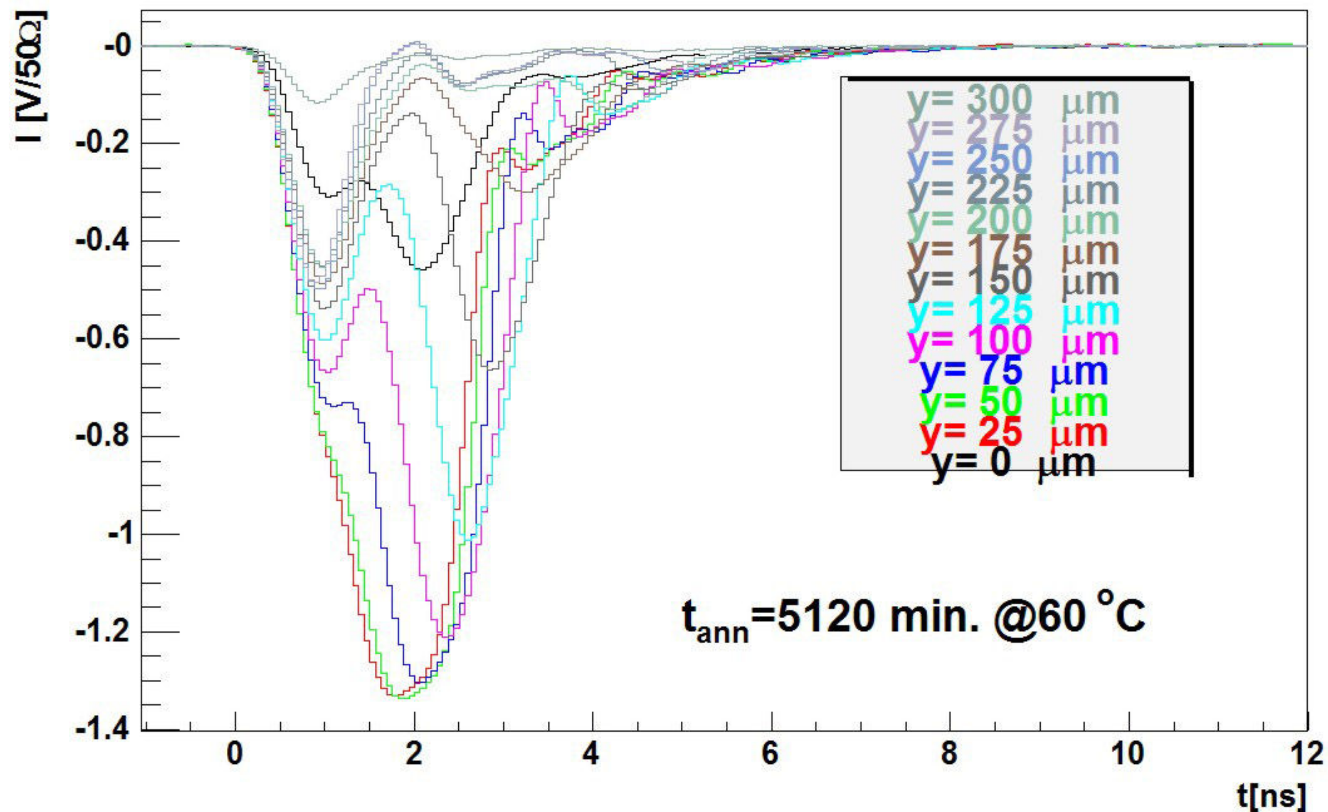
b) Multiplication can be clearly seen in induced current pulse shapes (2nd proof that this is not a setup artifact!)



E-TCT Measurements (reverse bias@750V)

Detector: Micron, FZ-Si p-type micro-strip, $\Phi=5\times10^{15}$ cm^{-2}, T=-20°C

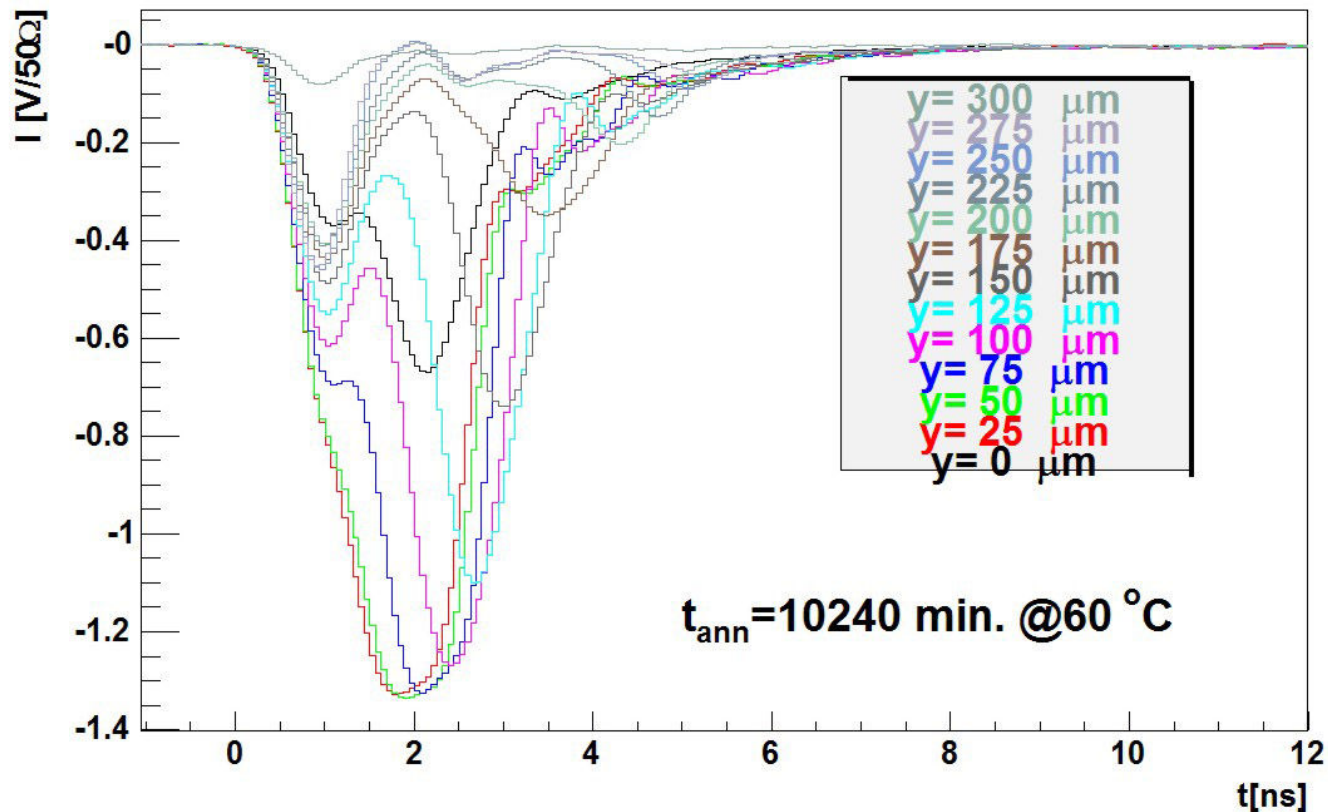
b) Multiplication can be clearly seen in induced current pulse shapes (2nd proof that this is not a setup artifact!)



E-TCT Measurements (reverse bias@650V)

Detector: Micron, FZ-Si p-type micro-strip, $\Phi=5x10^{15}$ cm^{-2}, T=-20°C

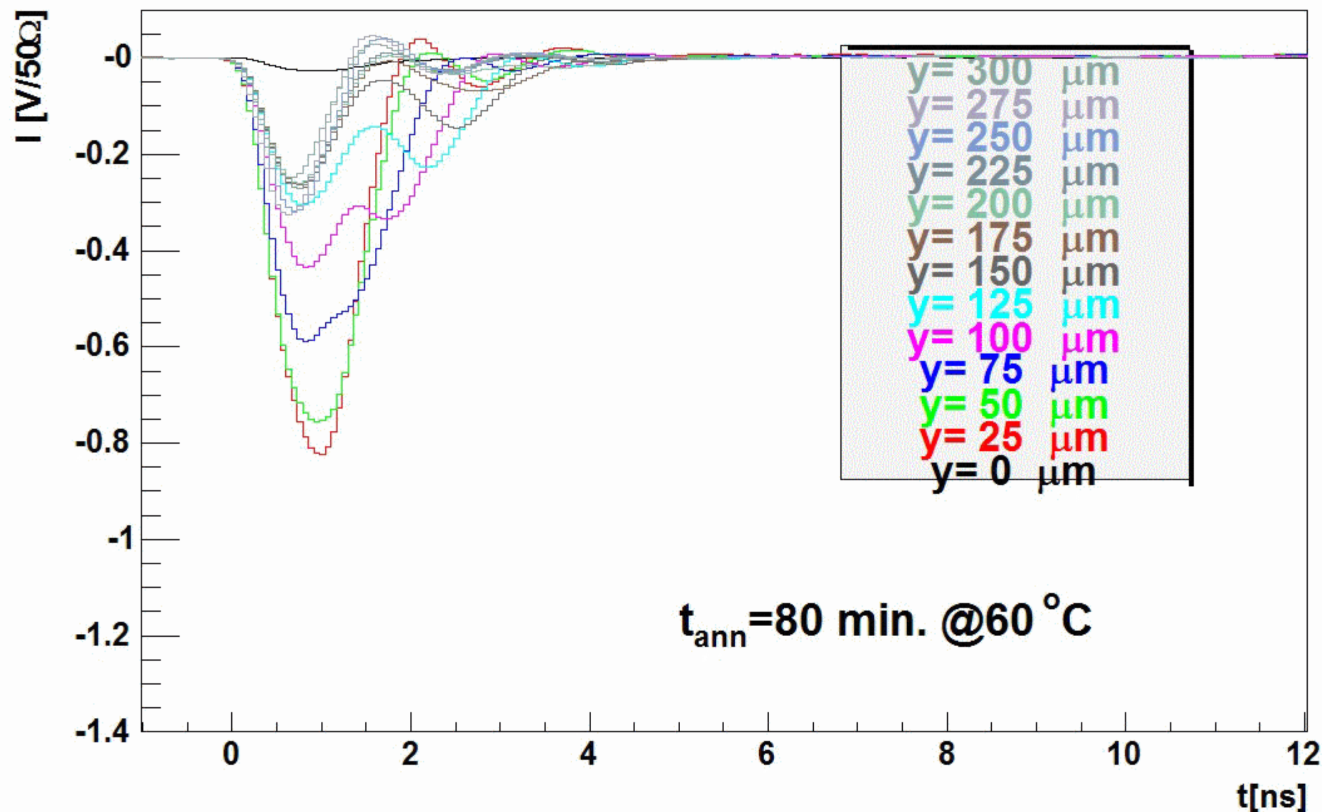
b) Multiplication can be clearly seen in induced current pulse shapes (2nd proof that this is not a setup artifact!)



E-TCT Measurements (reverse bias, up to: 800V)

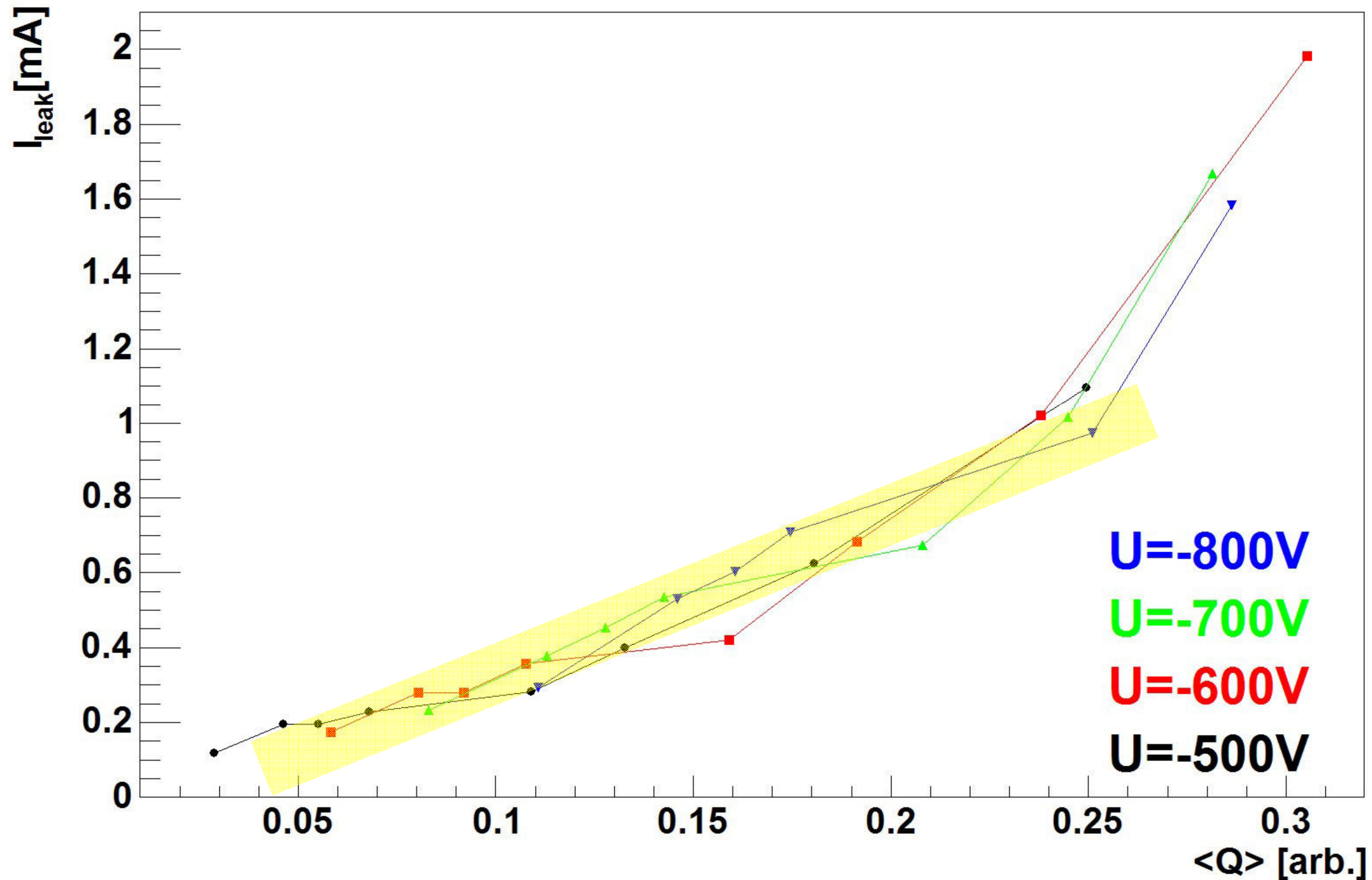
Detector: Micron, FZ-Si p-type micro-strip, Φ=5x10^{15} cm^{-2}, T=-20°C

b) Multiplication can be clearly seen in induced current pulse shapes (2nd proof that this is not a setup artifact!)



I_{leak} vs. <Q> for all annealing times

Detector: Micron, FZ-Si p-type micro-strip, $\Phi=5x10^{15}$ cm^{-2}, T=-20°C



Conclusion

- Charge collection efficiency increases with long-term annealing for highly irradiated ($\Phi \geq 5 \times 10^{15} cm^{-2}$) micro-strip detectors when reversely biased.
- No effect of annealing in forward bias
- Changes in charge collection due to enhanced multiplication effects induced by reduced trapping time and increased electric field during annealing
- Increase in I_{leak} correlated with $\langle Q \rangle$