Effects of long term annealing in p-type strip detectors irradiated with neutrons to $\Phi_{eq}=1\cdot10^{16}cm^{-2}$, investigated by Edge-TCT

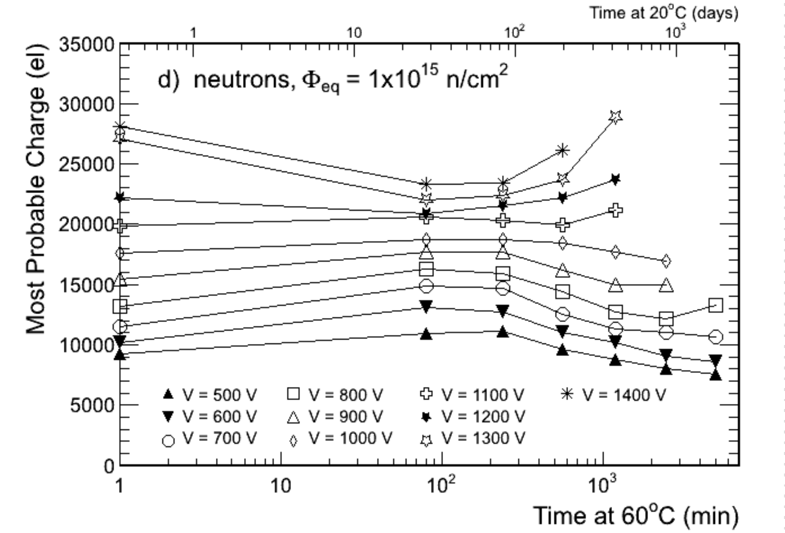
V. Cindro[1], G. Kramberger[1], I. Mandić[1], M. Mikuž[1,2], M. Milovanović[1], M. Zavrtanik[1]

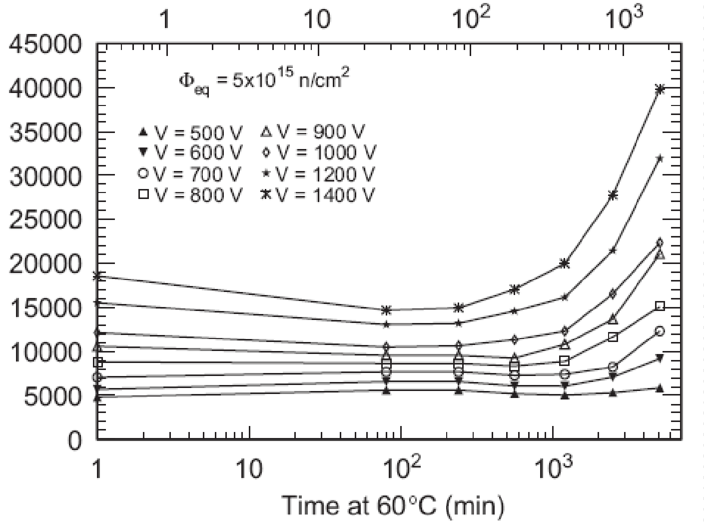
[1]Jožef Stefan Institute, Ljubljana, Slovenia
[2]Faculty of Mathematics and Physics, University of Ljubljana, Slovenia

Outline

- Motivation
- Sample, irradiation, annealing procedure
- Experimental setup, basics of the analysis
- Results - evaluation of induced current, CC and I-V profiles
- Conclusions

Motivation





- Charge multiplication effects are observed in highly irradiated FZ p-type strip detectors after long annealing times. [measurements by Igor Mandic, JSI Ljubljana]

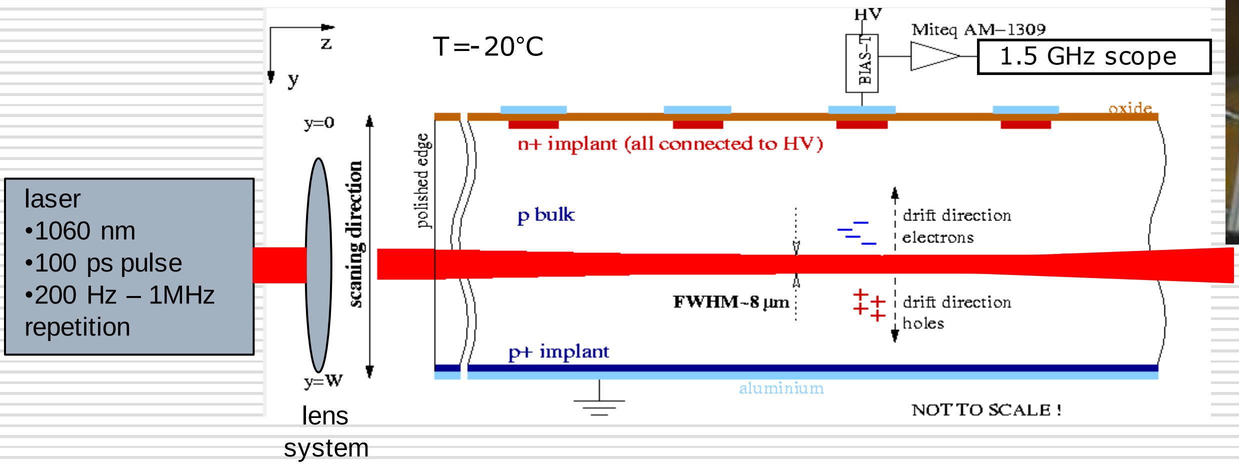
- The idea is to examine where the charge multiplication takes place inside the detector and how it affects the total charge collected.

The device, irradiation and annealing procedure

Sample	Fluence	Annealing
1) HPK (ATLAS-07 run) 1x1 cm^2, 300 μm thick, 100 μm pitch Material/type: FZ, p-type isolation: p-stop, narrow common initial V_{fd}~200 V	$\Phi_{eq}=1\cdot10^{16}cm^{-2}$ (Fluence history: $1,2,5\cdot10^{15}cm^{-2}$ with annealing up to 80min.)	Sequential steps (0,10,20,40,80,160,320, 640,1280,2560,5120 min) at 60ºC up to a cumulative time of 10240 min.

- Irradiation performed with 1MeV reactor neutrons at TRIGA (JSI, Ljubljana)
- At each annealing step, measurements of collected charge and leakage current performed at bias voltages from -500 (fw bias) ÷ 800V.
- Annealing performed with the sample mounted inside the setup
  - Stable position/laser (the same spot illuminated each time)
  - Sample temperature stabilized to less than 1°C
  - Constant laboratory temperature

Edge-TCT setup

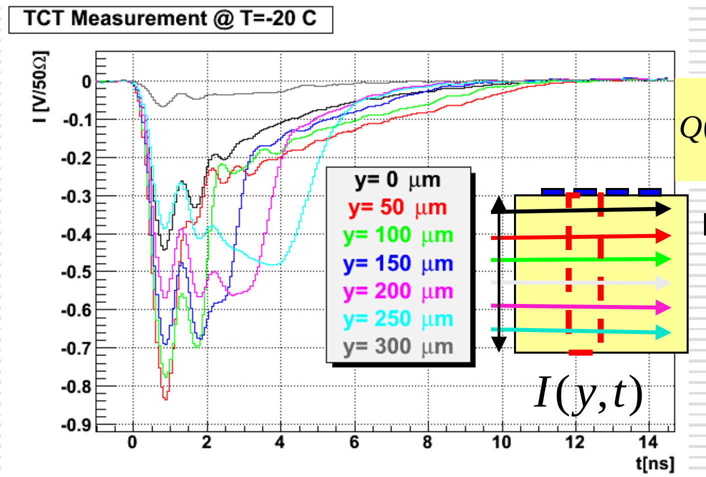


detectors on a Peltier cooled support in dry air atmosphere (down to -20ºC)

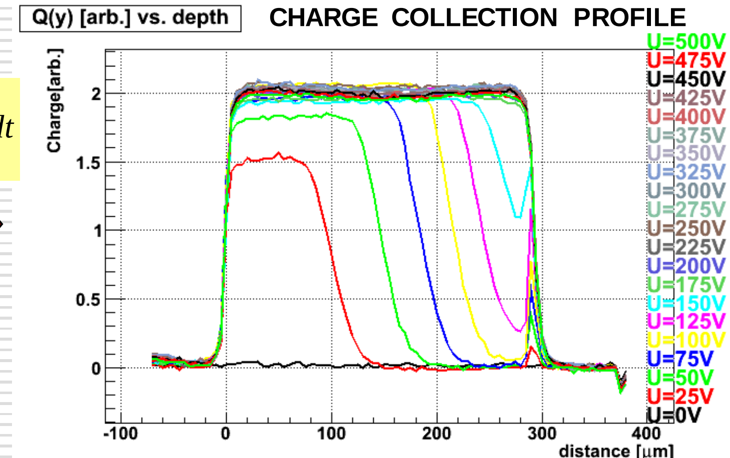
- Position of e-h generation can be controlled by 3 sub-micron moving tables (x,y,z)
- The amount of injected charge and frequency can be controlled (laser tune and frequency=200Hz constant throughout these measurements)
- Not possible to study charge sharing in used configuration (laser beam perpendicular to the strips) due to illumination of all the strips.
- Arbitrary units used for charge collection evaluation.

Charge collection and velocity profiles

HPK, non-irradiated



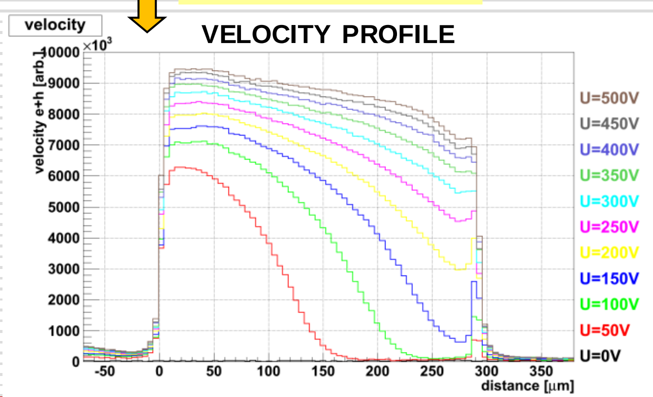
$$Q(y)=\int_0^{25ns} I(y,t)\,dt$$

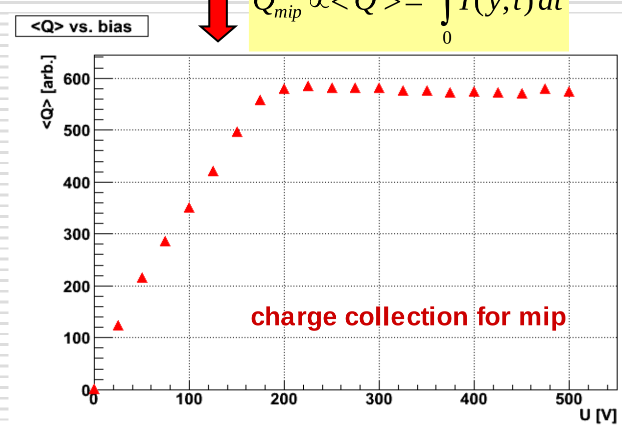


$$I(y,t\sim 0)\propto v_e+v_h$$

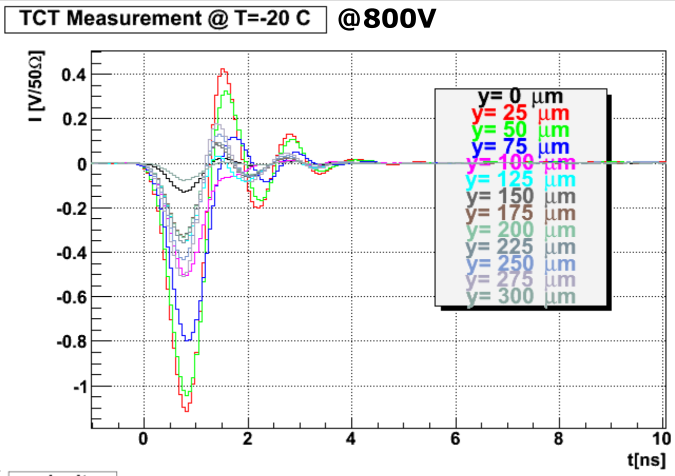
V_{fd}~200V

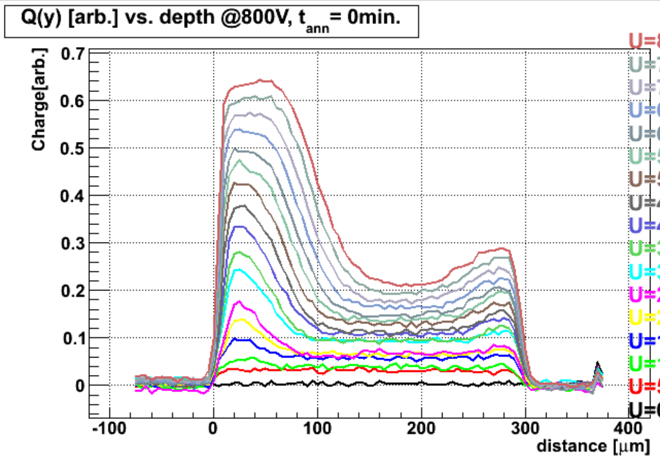
$$Q_{mip}\propto \langle Q\rangle=\int_0^{25ns} I(y,t)\,dt$$

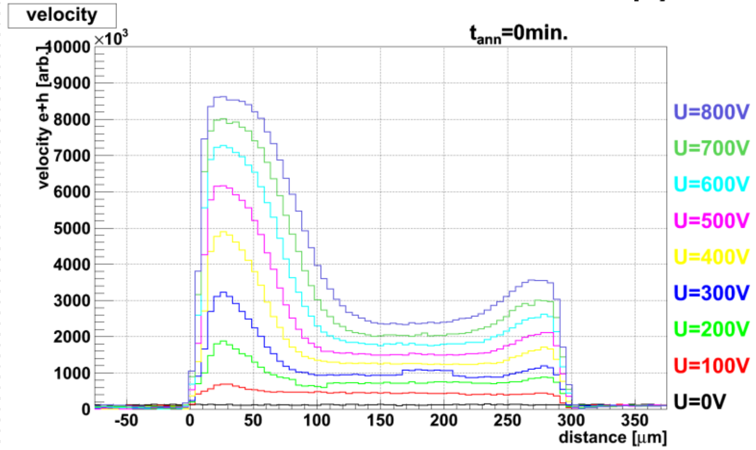


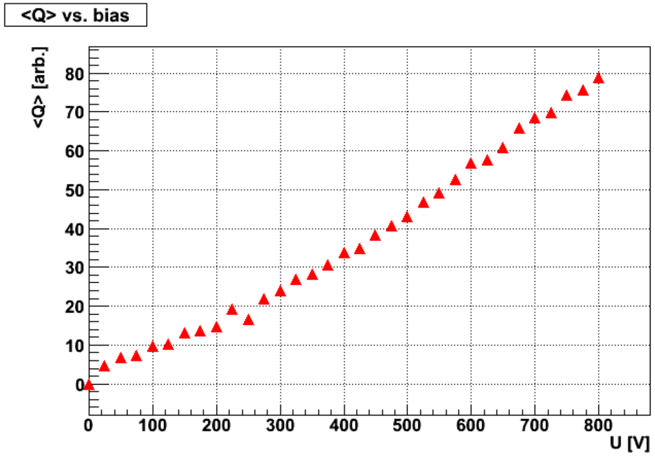


HPK – $\Phi_{eq}=1\cdot10^{16}$ n/cm^2, no annealing

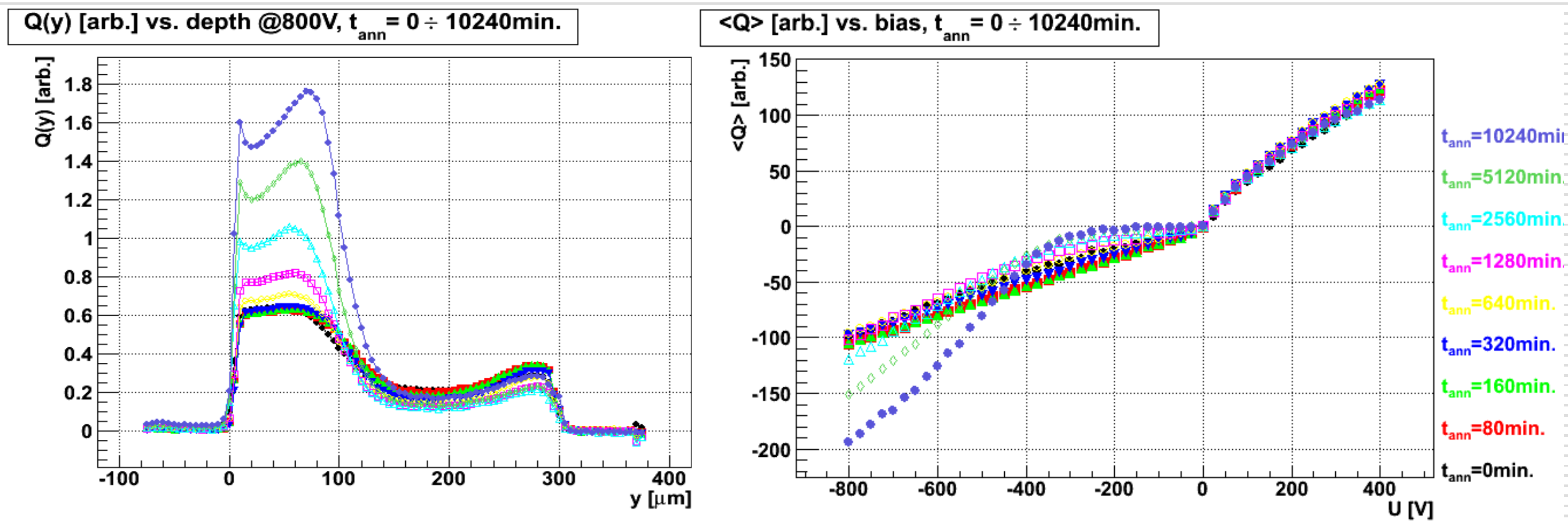






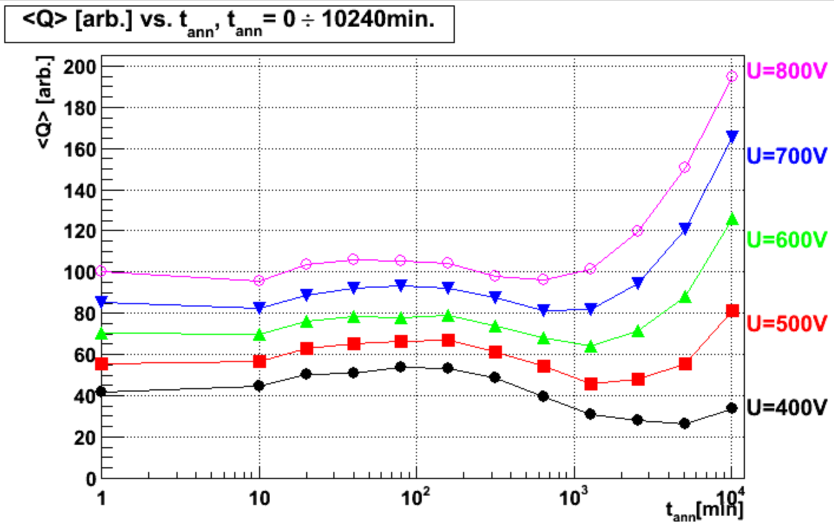


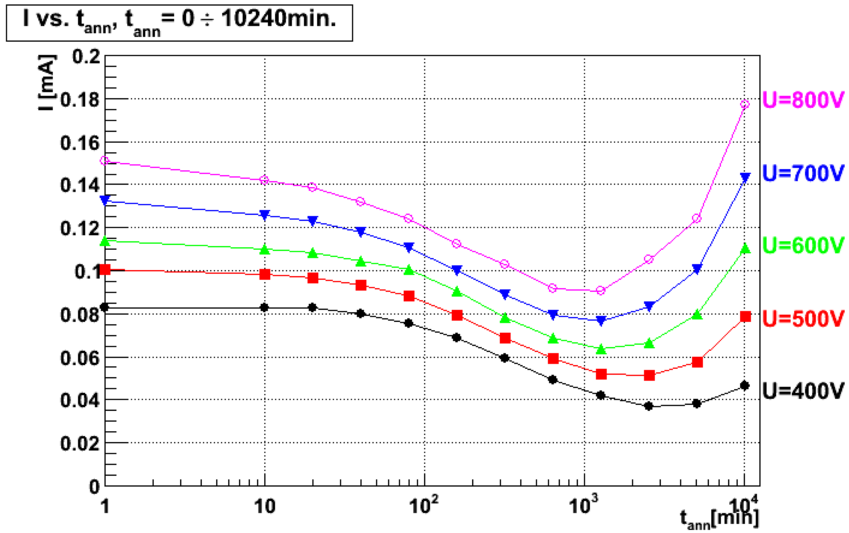
HPK – $\Phi_{eq}=1\cdot10^{16}$ n/cm^2, $t_{ann}=0 \div 10240$min.



- During long-term annealing, up to a total of 10240 min. at 60ºC, strong influence of multiplication can be observed in the high electric field region, near the strips and it starts to be obvious after 320 min. of annealing time.
- If a total charge (mip) vs bias is analyzed, a drop is noticed up to 400V due to lower charge collection with the annealing in the low electric field region. However, up to 160 min. the annealing does have a beneficial effect.

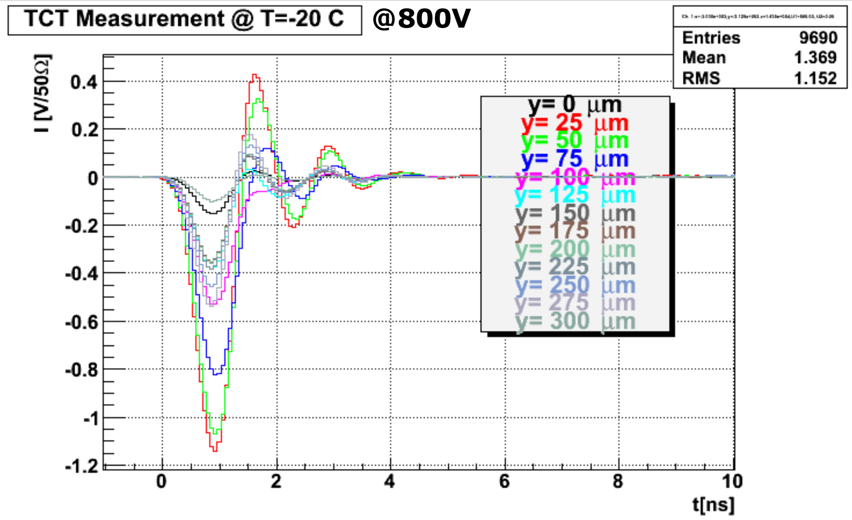
HPK – $\Phi_{eq}=1\cdot10^{16}$ n/cm^2, $t_{ann}=0 \div 10240$min.

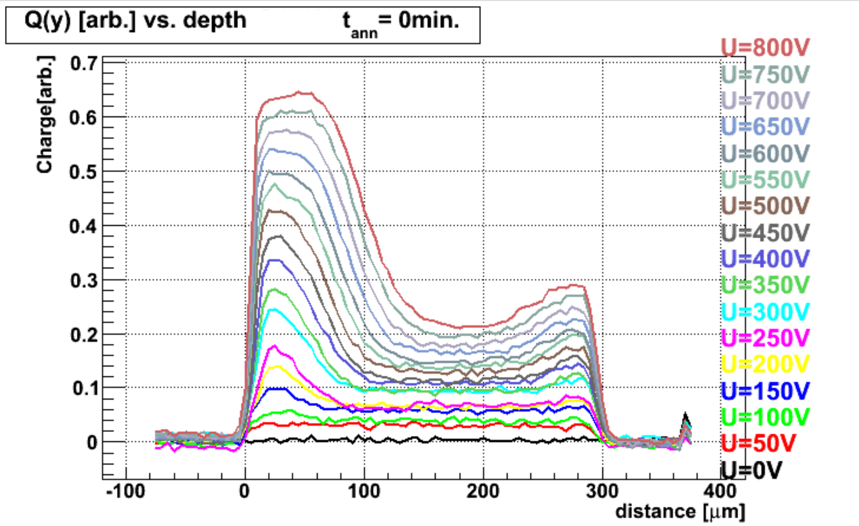




- Collected charge at higher voltages before annealing falls due to beneficial annealing of space charge. Rise again due to the increase of of space charge concentration. Multiplication noticed even at 400V!
- The annealing also has a beneficial effect to the leakage current up to the point where multiplication takes place, showing strong correspondence.
- Charge multiplication is also clearly recognized in the induced current pulse shapes.

HPK – $\Phi_{eq}=1\cdot10^{16}$ n/cm^2, $t_{ann}=0 \div 10240$min.





- The first peak, associated with the initial drift of primarily generated carriers spreads in the beginning, until double peaks become apparent and more distinct with the annealing time.
- The second peak becomes more dominant and shifts in time, due to beneficial annealing of space charge that increases, consequently the electric field as well and thus charge multiplication.

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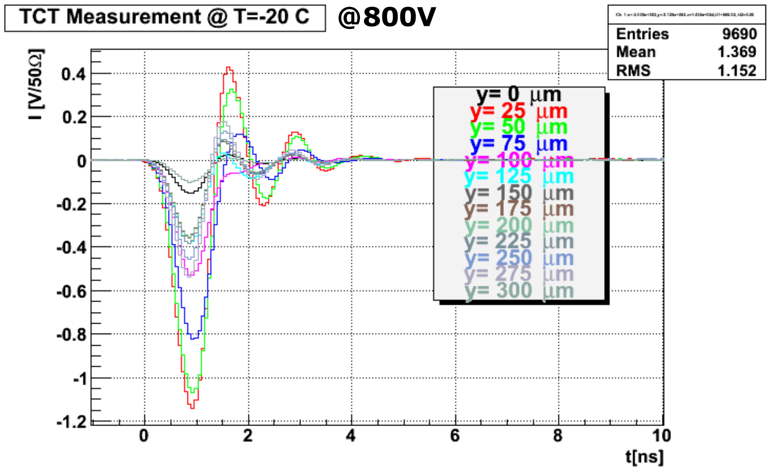
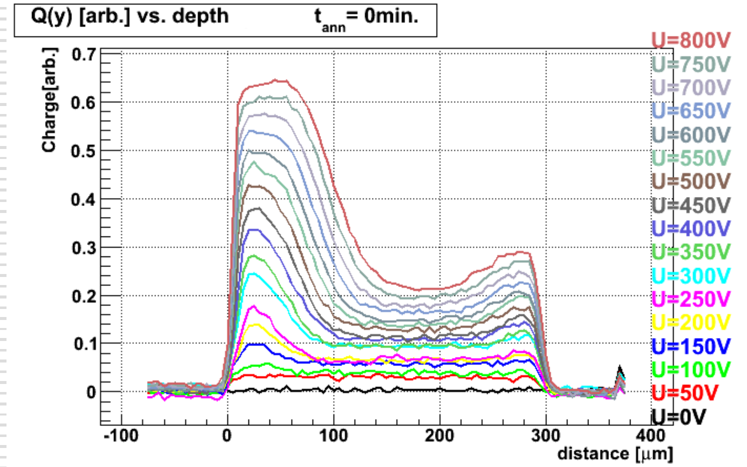
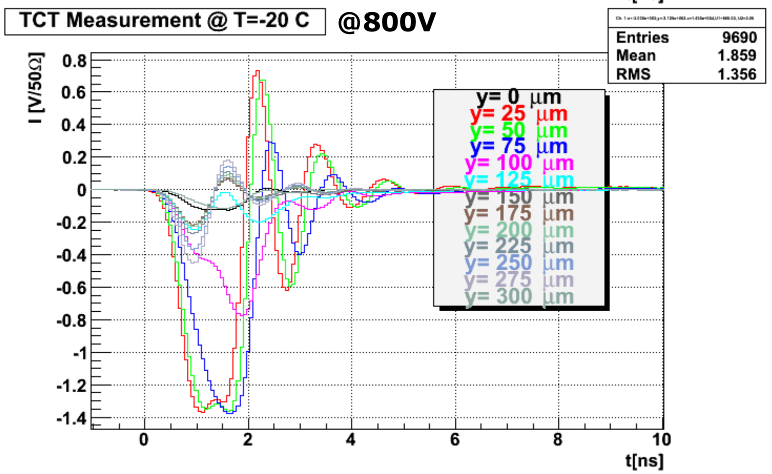
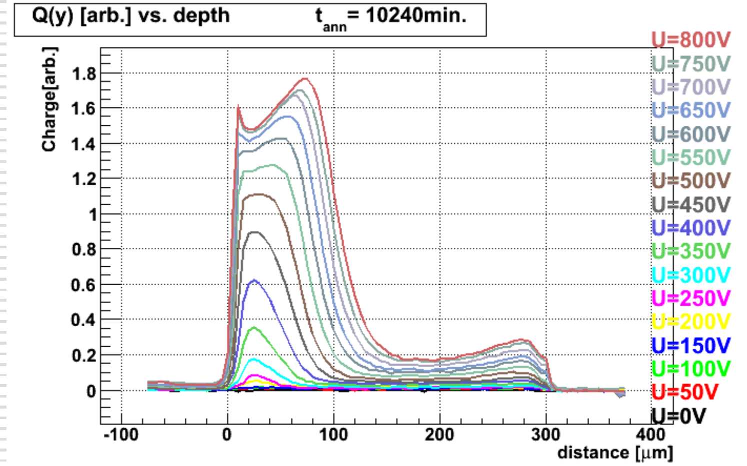
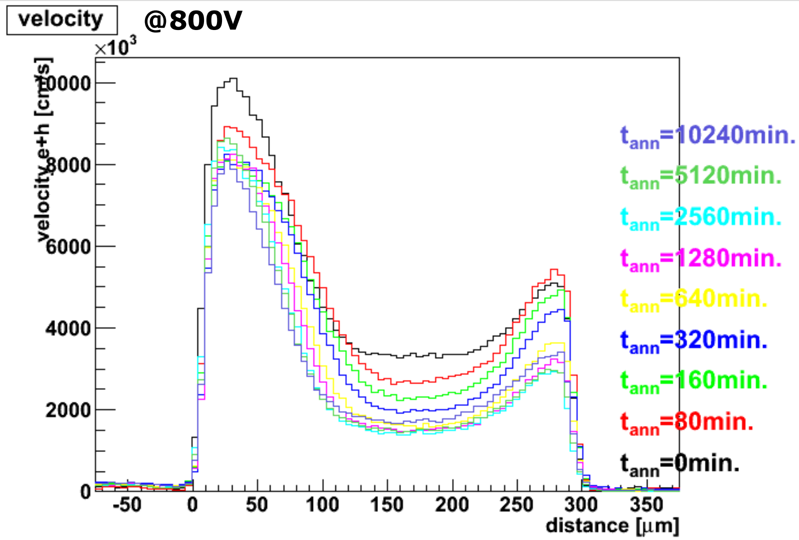


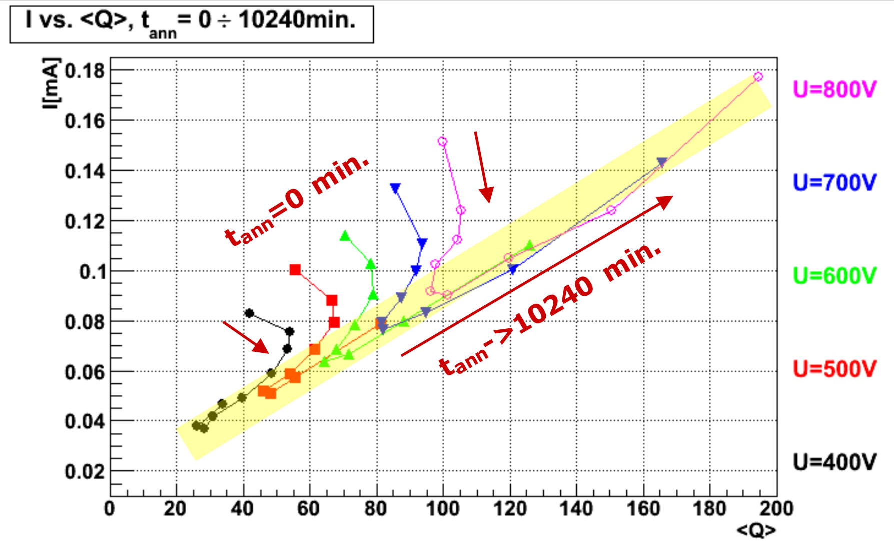






HPK – $\Phi_{eq}=1\cdot10^{16}$ n/cm^2, $t_{ann}=0 \div 10240$min.

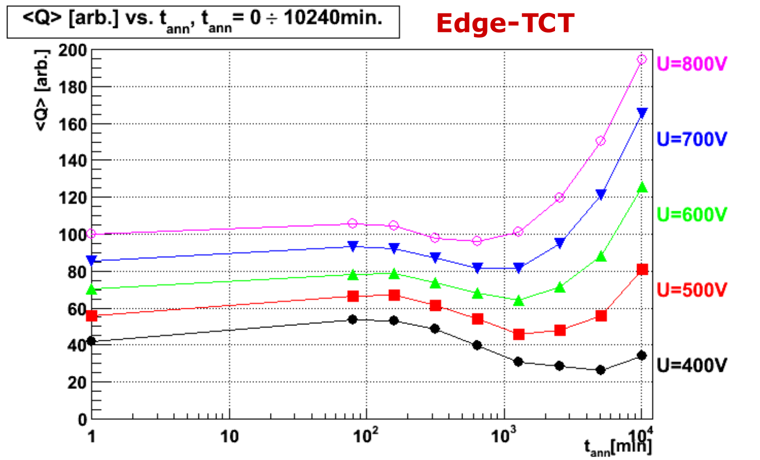


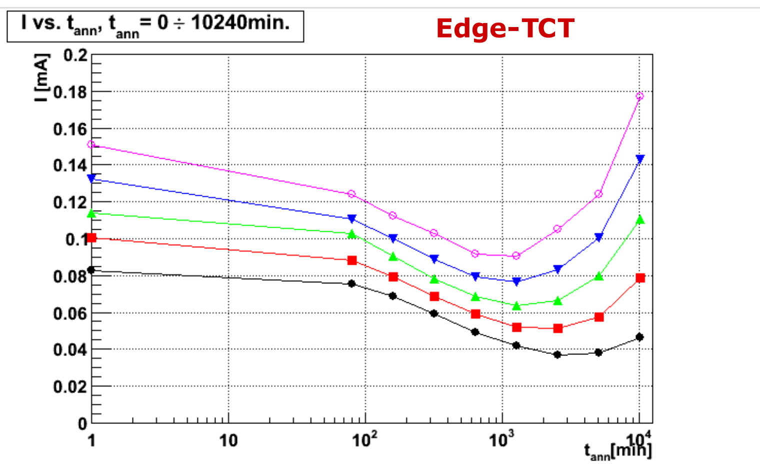


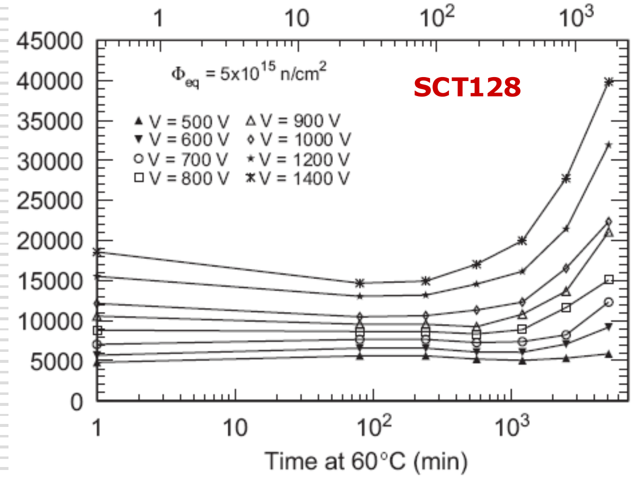
- The high electric field region profile was not possible to extract from the velocity profile because the drift velocity is already saturated in this area, however, it shows that the field in overall decreases with the annealing in the region towards the backplane.
- The leakage current shows strong correlation and near linear dependence charge multiplication, showing that the generation current also undergoes the same effect.

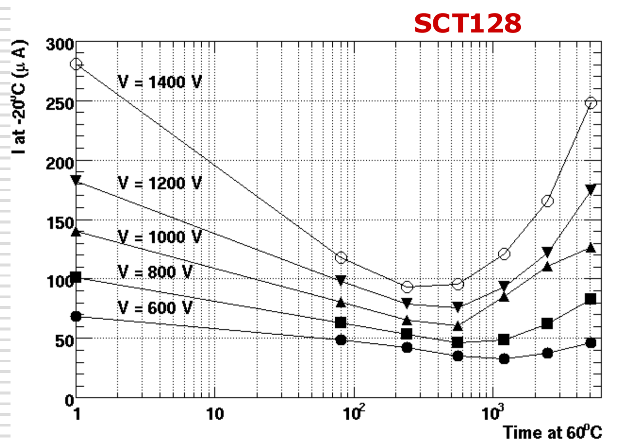
HPK – $\Phi_{eq}=1\cdot10^{16}$ n/cm^2, $t_{ann}=0 \div 10240$min.

Validation and Comparison with HPK - $\Phi_{eq}=5\cdot10^{15}$ n/cm^2, measured with SCT128 by Igor Mandic









Conclusions

- Charge collection efficiency increases with long-term annealing for highly irradiated ($\Phi_{eq} \geq 5\cdot10^{15}$ n/cm^2) p-type strip detectors due to increased space-charge concentration, hence the electric field in the strip region, consequently leading to the effect of multiplication even at voltages as low as a few hundred volts.
- The leakage current shows strong, near linear correlation with the charge multiplication.
- Measurements of Edge-TCT and SCT128 are compared and validated.

Thank you for your attention!