Edge-TCT and Alibava measurements with pion and neutron irradiated micro-strip detectors

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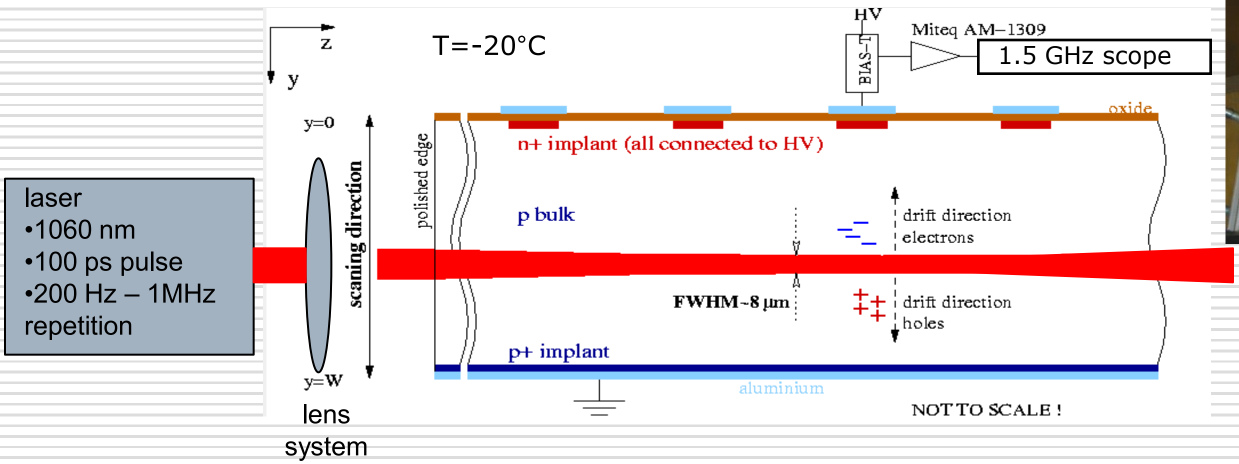
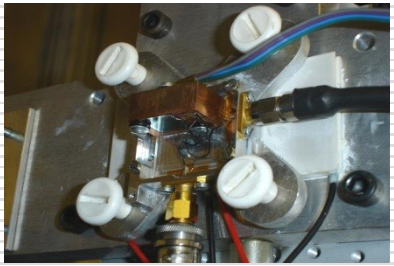
Outline

- Edge-TCT and Alibava setup, samples
- Basics of analysis
- Evaluation of charge collection profiles with fluence, annealing and temperature
- Conclusions

Edge-TCT setup

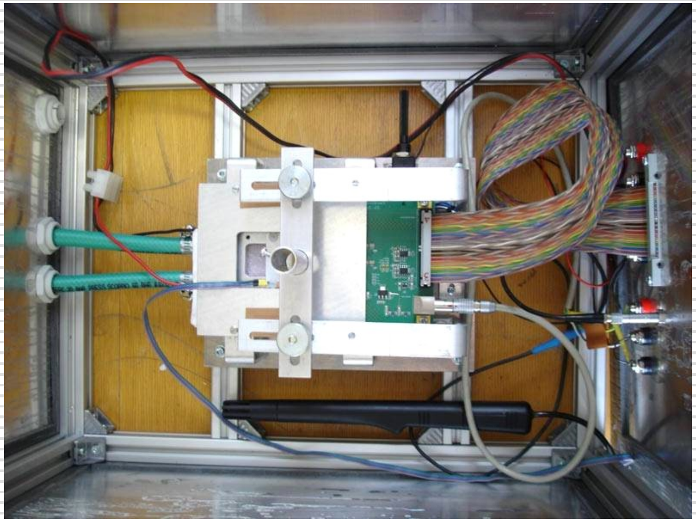


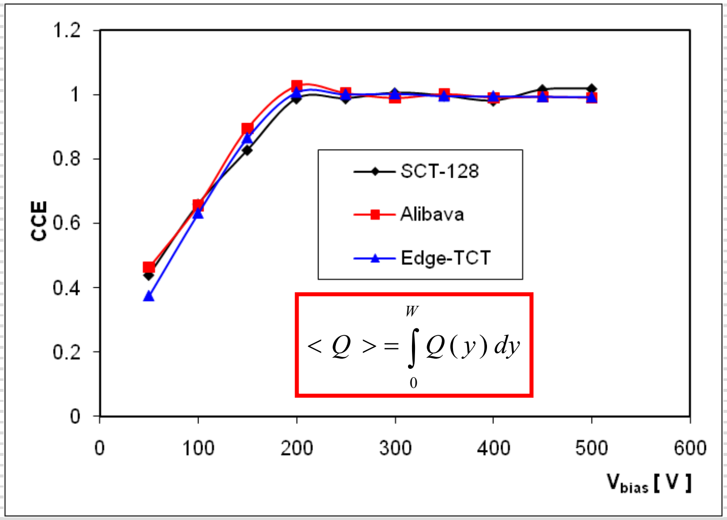


detectors on a Peltier cooled support in dry air atmosphere (down to -20°C)

- Position of e-h generation can be controlled by 3 sub-micron moving tables (x,y,z)
- The amount of injected charge can be controlled by tuning the laser power
- Not possible to study charge sharing due to illumination of all strips
- Absolute charge measurements are very difficult
- Annealing done with samples mounted in the setup => the same spot in the detector is illuminated at all times
- Measurements performed at different temperatures, from -20 to +10°C

The Alibava setup





- Successful commissioning of the setup utilizing absolute charge measurements using a ^{90}Sr
- A Peltier element for cooling and annealing (-40 to 60°C)
- Results compared with Edge-TCT and SCT128A and shows very good agreement of all three, which also validates the E-TCT <Q> technique as well.
- Problems with Noise

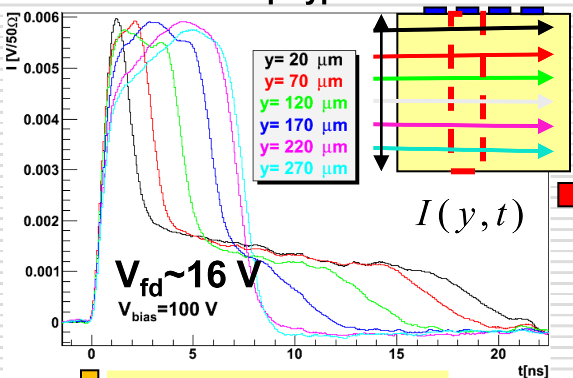
Samples

Samples	Fluences	Annealing
1) HPK (ATLAS-07 run) x3 1x1 cm^2, 300 μm thick, 75 μm pitch FZ p-type isolation: p-stop + p-spray initial V_{fd}~200 V	Φ_n=4.14·$10^{14}cm^{-2}$ x2 Φ_n=1.42·$10^{15}cm^{-2}$	sequential steps at 60ºC up to 80 min (0,10,20,40,80 min) at each fluence
2) HPK (ATLAS-07 run) 1x1 cm^2, 300 μm thick, 100 μm pitch FZ p-type isolation: p-stop, narrow common initial V_{fd}~190 V	non-irradiated Φ_{eq}=1,2·10^{15} cm^2 neutron irradiated in steps	

- Measurements of collected charge and leakage current performed at different bias, temperature and annealing steps.

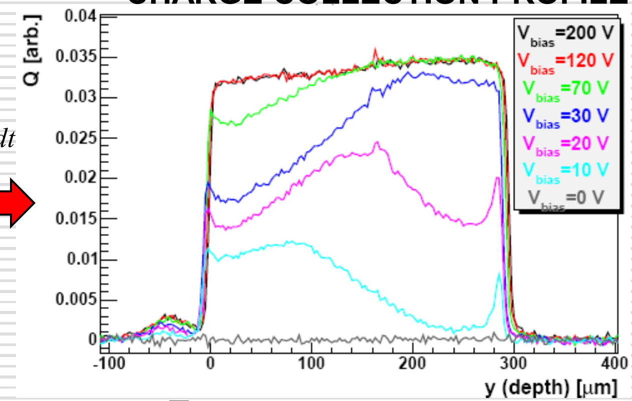
Charge collection and velocity profiles

RD50 Micron p-type sensor



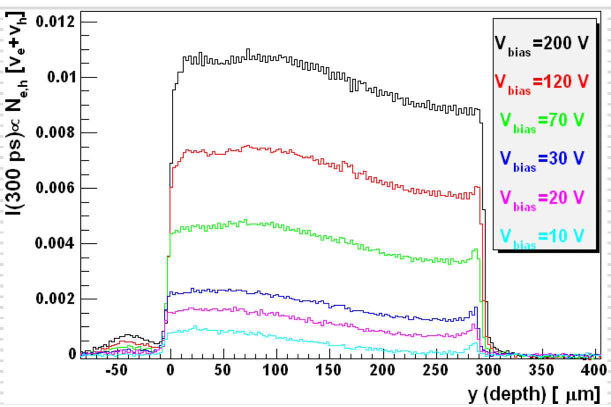
$$Q(y) = \int_0^{25\,ns} I(y,t)\,dt$$

CHARGE COLLECTION PROFILE

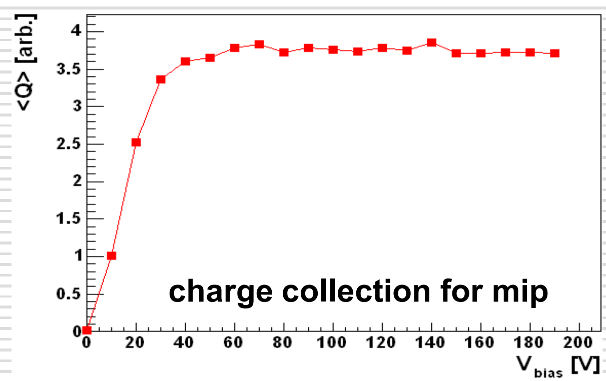


$$I(y, t \sim 0) \propto v_e + v_h$$

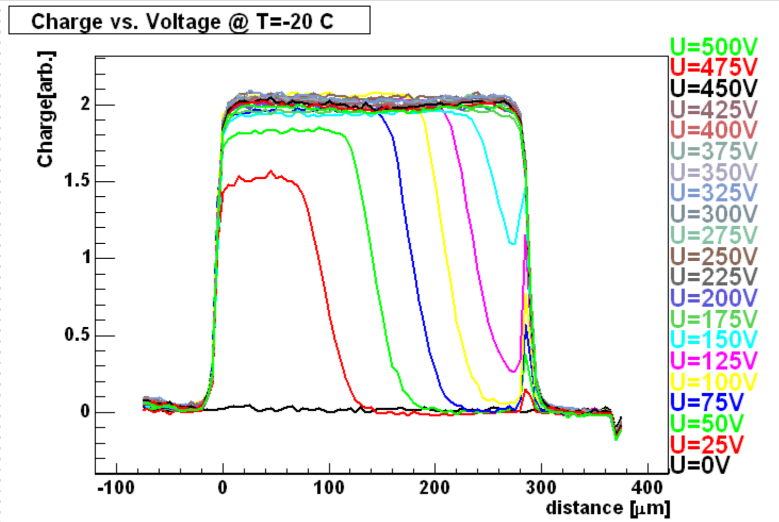
VELOCITY PROFILE

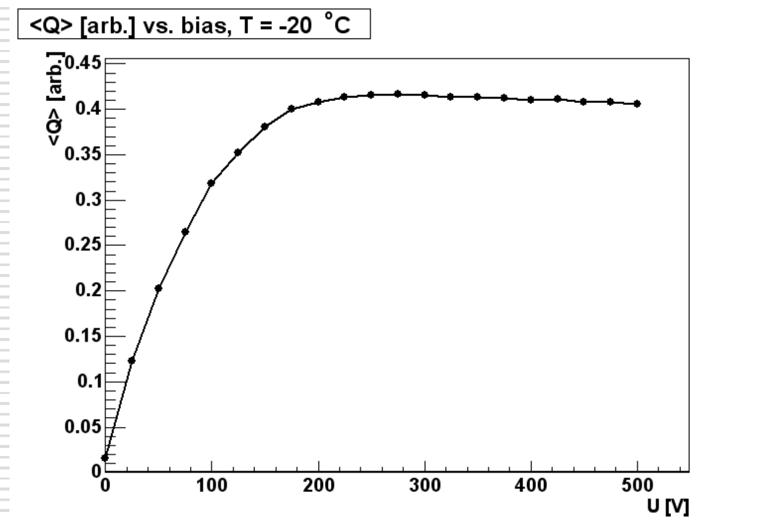


$$Q_{mip} \propto \langle Q \rangle = \int_0^{25\,ns} I(y,t)\,dt$$



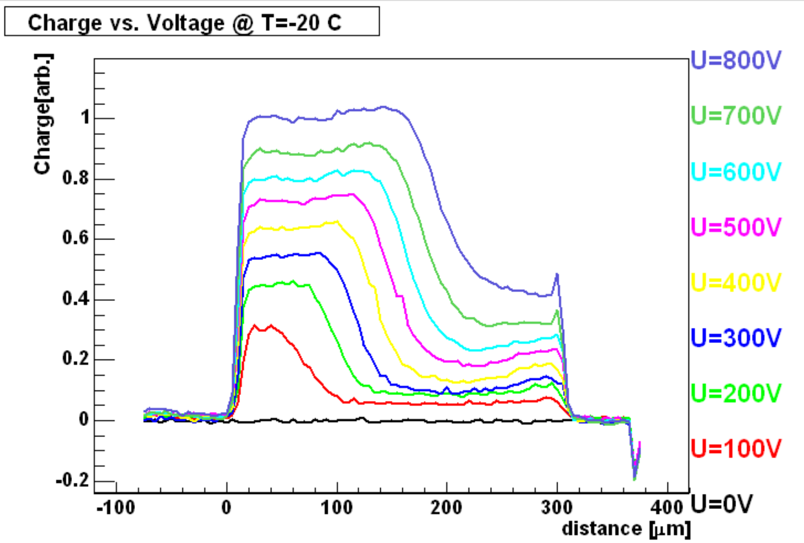
HPK – non-irradiated

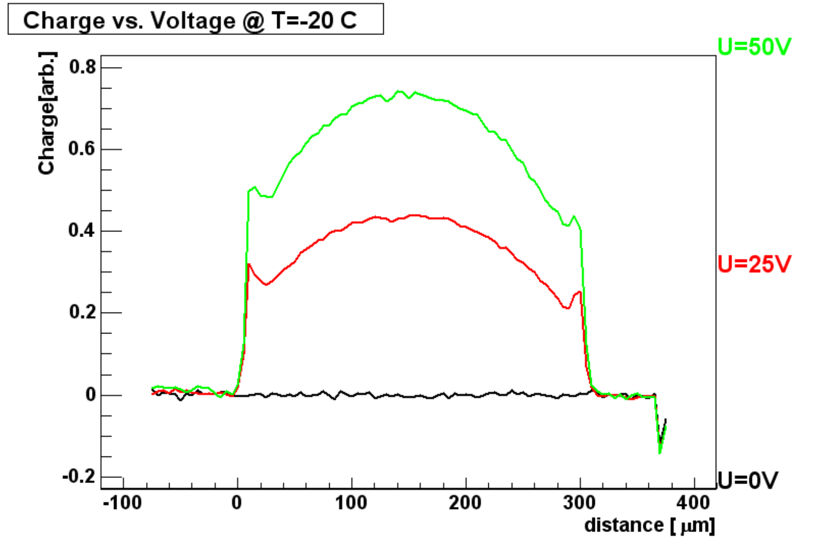




- At 200V, detector is fully efficient
- Double junction visible for $V<V_{fd}$
- Growth of "active region" with bias can be observed (agrees with homogenous N_{eff})
- The current pulses show expected behaviour
- The <Q> plot validates the method

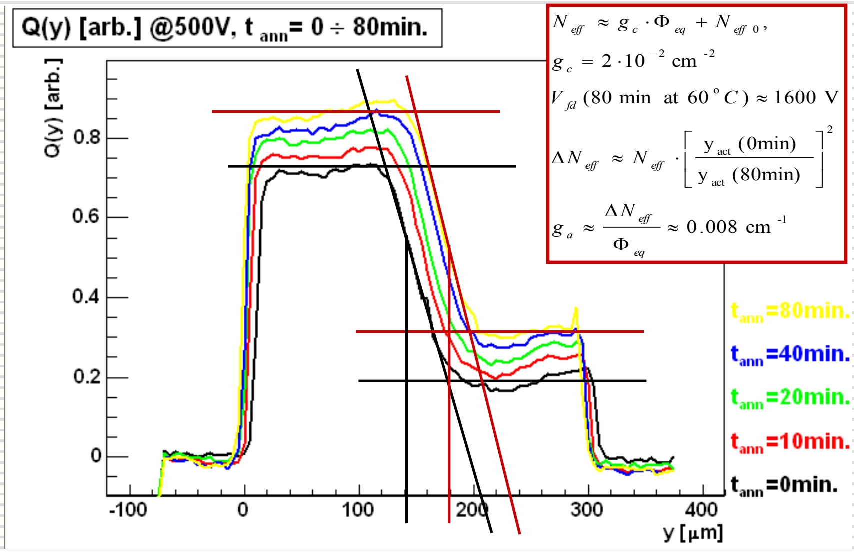
HPK – $\Phi_{eq}=1\cdot10^{15}$ n/cm^2

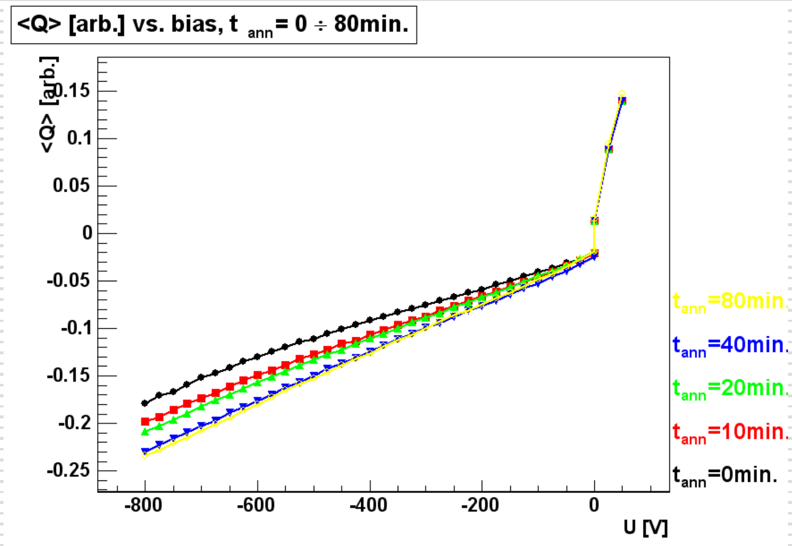




- Charge collection profiles show increase of both active and "un-active" region of the detector with higher bias.
- Electric field at the back is much smaller than at front; "double junction effect" is small due to oxygen lean detectors and neutron irradiations
- No evidence of charge multiplication
- CC for forward bias is very high, even at low voltages, mostly due to long drifts of charge carriers
- The detector is active throughout the whole detector depth - efficiency is best at it's centre

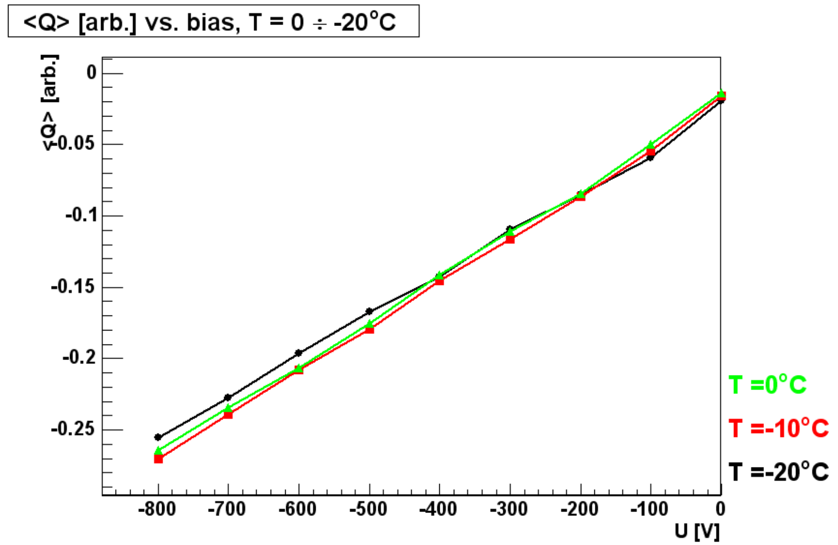
HPK – $\Phi_{eq}=1\cdot10^{15}$ n/cm^2

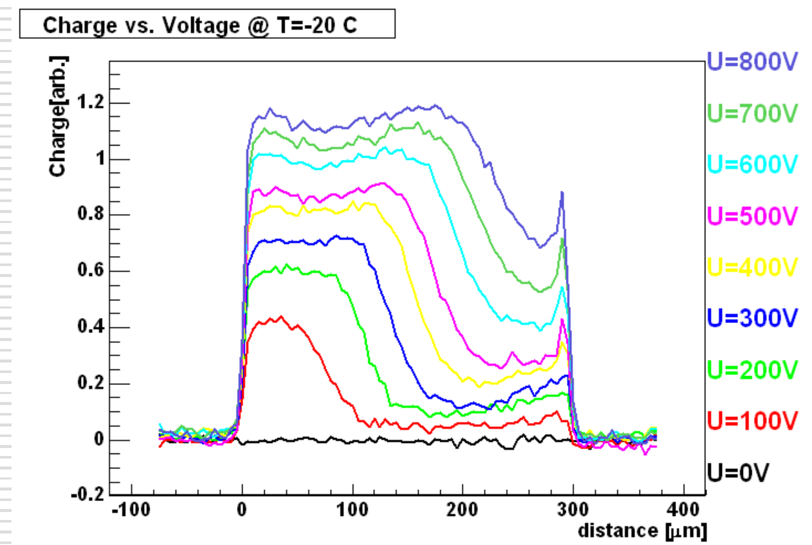




- The border of the “depleted-active region” and “active bulk” determined from intersection of the two lines
- Charge collection Q(y) and the active show expected increase with annealing up to 80min at 60°C;the active region increase: ≈35µm at 500V, as predicted
- <Q> profile shows ~30% of CC increase at 800V
- High charge collection in forward bias even at very low voltages; at 50V CC more than 50% of CC at 800V reverse bias.

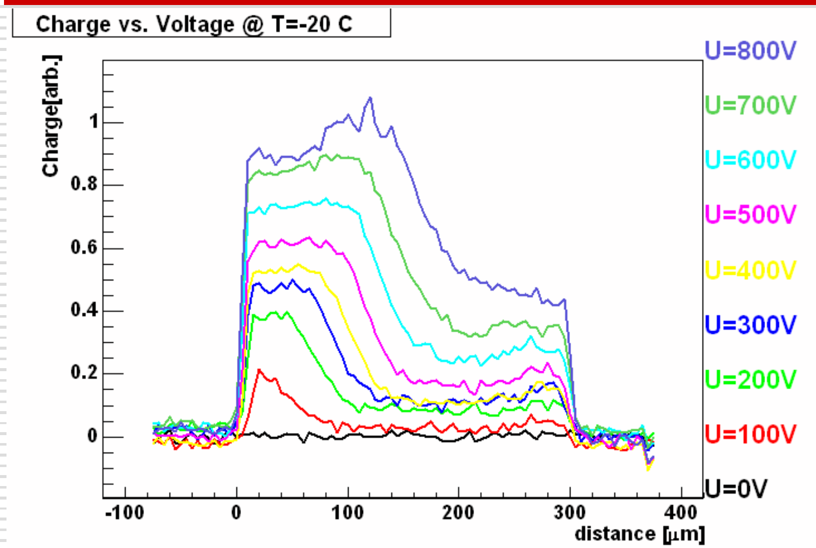
HPK – $\Phi_{eq}=1\cdot10^{15}$ n/cm^2

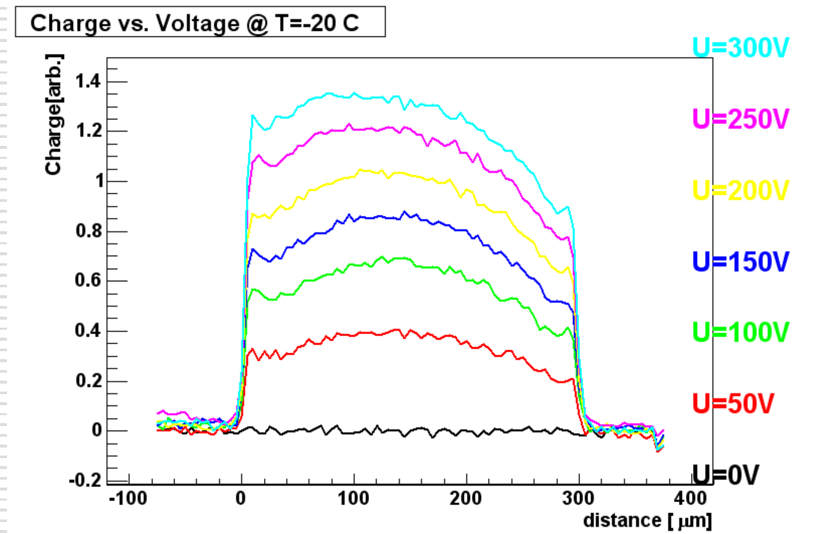




- <Q> profile vs. temperature shows almost no change
- However, charge collection profiles at different temperatures show:
  - Increase of “non-active” region with temperature (due to better detrapping?)
  - Decrease of CC in the active region (higher V_{fd} due to change of N_{eff}, higher generation current?..)
- These two effects obviously even out, causing no significant change in <Q>

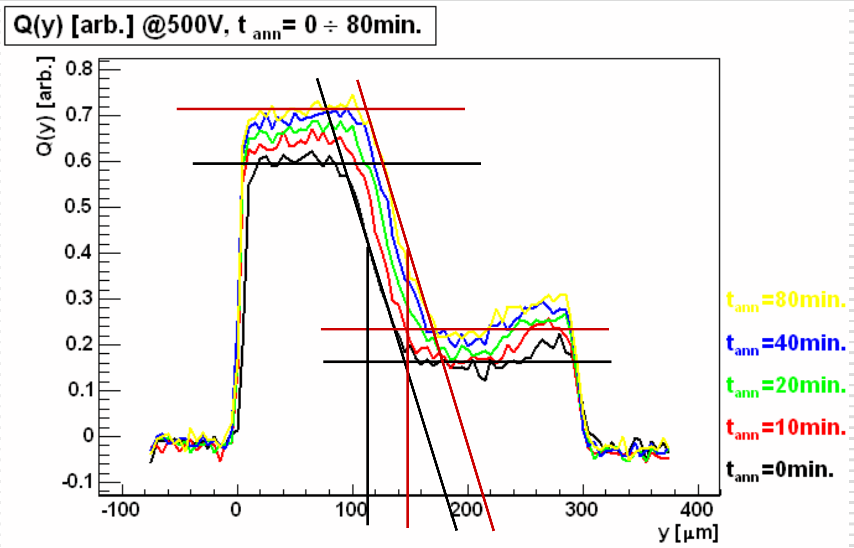
HPK – $\Phi_{eq}=2\cdot10^{15}$ n/cm^2

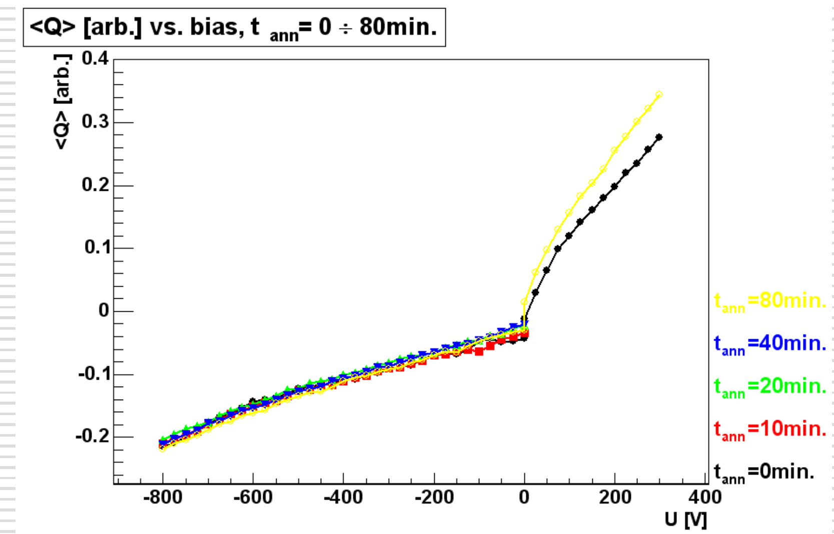




- The "active region" is reduced with respect to higher fluence, as expected
- Charge collection in the "non-active" region becomes significant
- Forward bias shows better CC and stable profile.

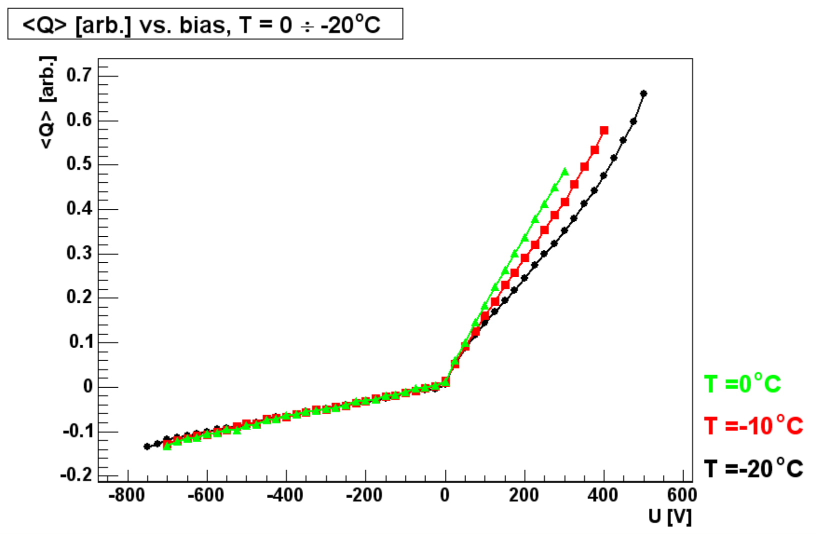
HPK – $\Phi_{eq}=2\cdot10^{15}$ n/cm^2

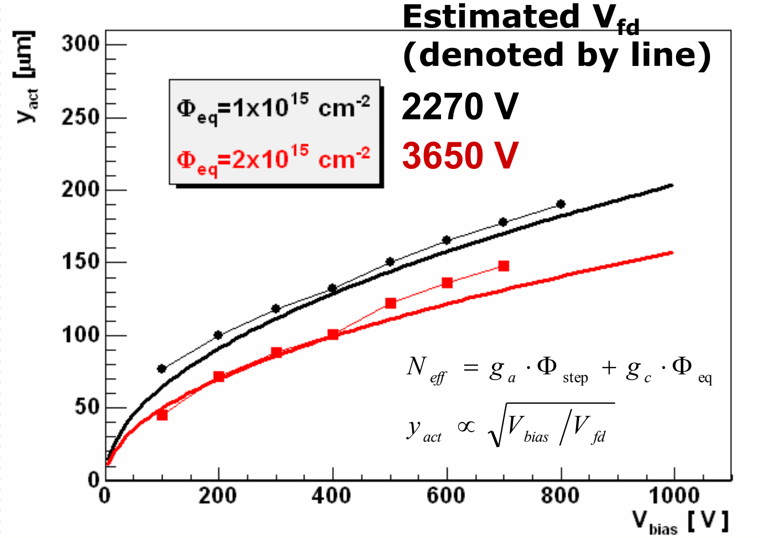




- The active region decreases with fluence, as predicted
- <Q> profile shows virtually no increase after annealing in reverse bias
- Forward bias positively influenced by the annealing

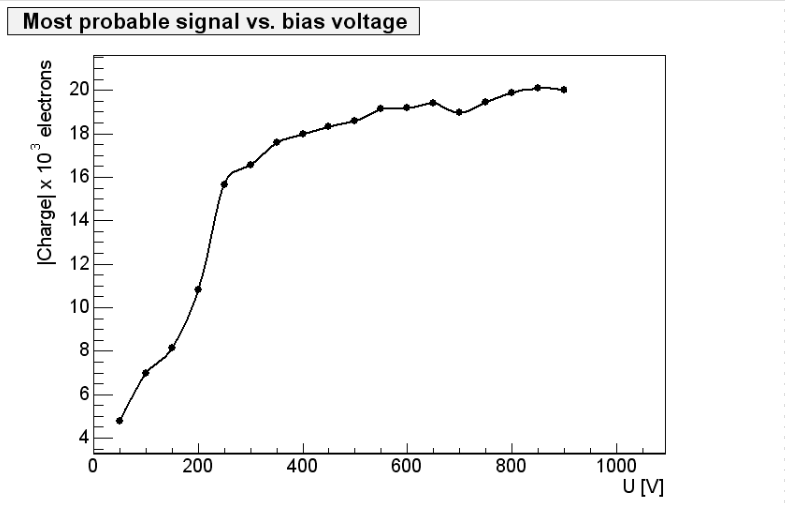
HPK – $\Phi_{eq}=2\cdot10^{15}$ n/cm^2

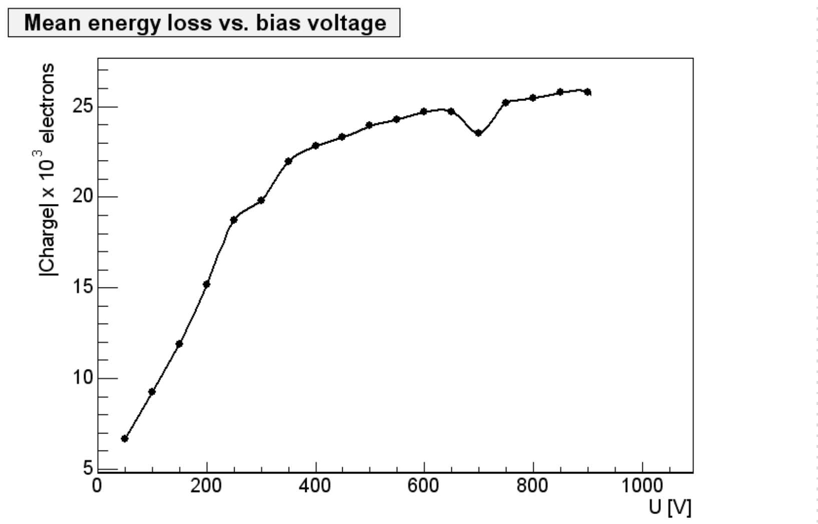




- <Q> profile vs. temperature shows almost no change for reverse bias – the same mechanism as with previous irradiation step
- Estimations of the active regions show pretty good correspondence with the estimated values (≈10%)
- The difference due to the “non-active” region

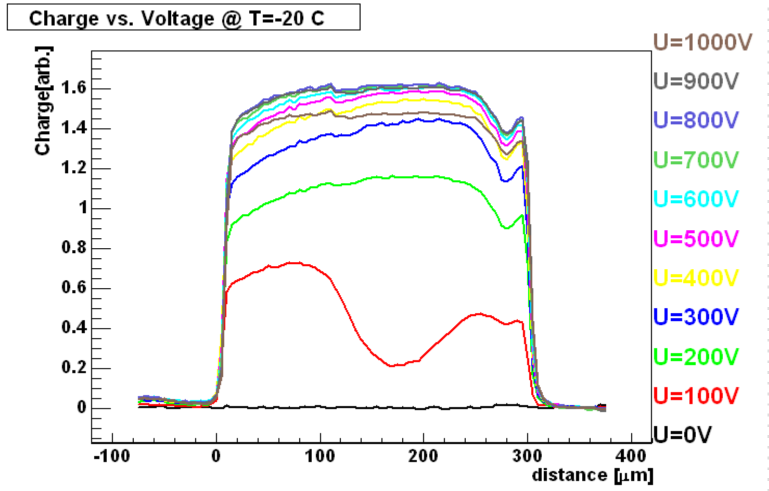
HPK – $\Phi_{\pi}=4.14\cdot10^{14}cm^{-2}$ (Alibava)

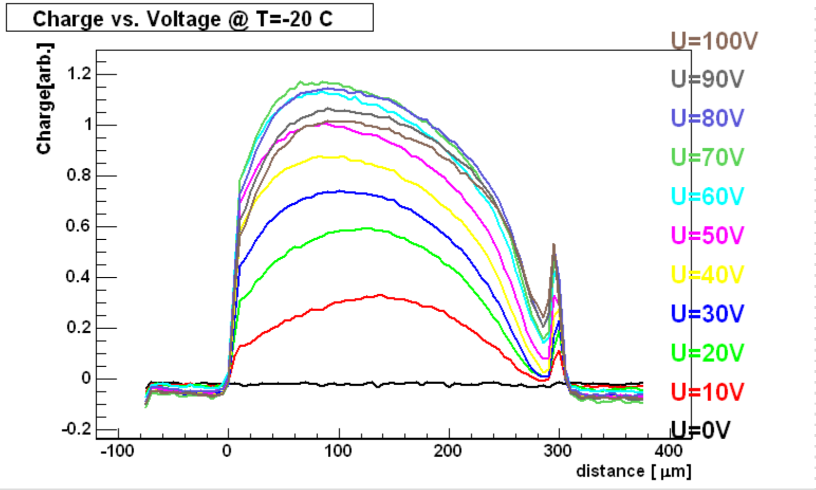


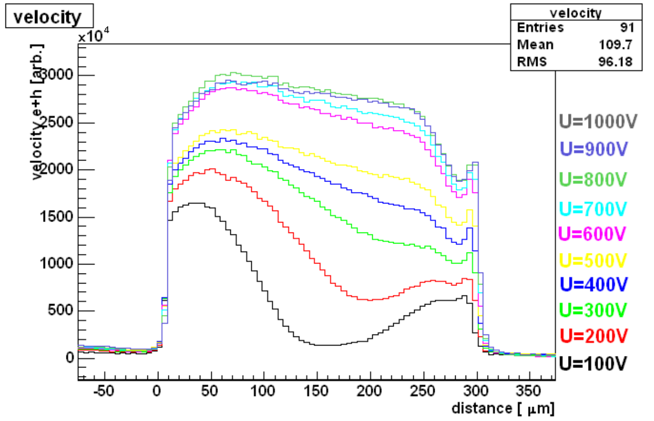


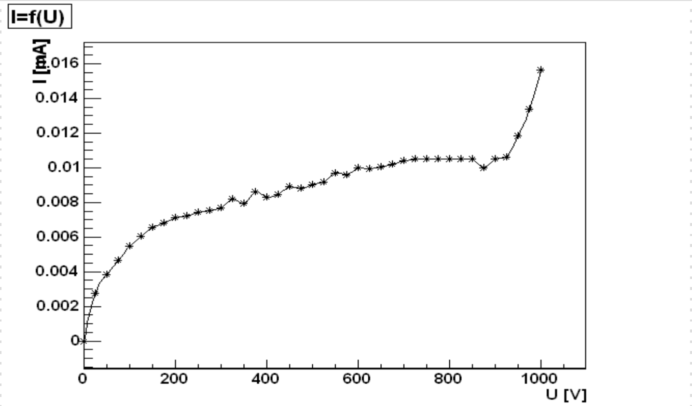
- Low depletion voltage ($V_{fd}\approx300V$ instead of expected ~940V)
  - The detectors were already annealed during the irradiations @PSI, at T=26°C (108h for this detector)
- Low and stable current in agreeement with expectations

HPK – Φ_n=4.14·10^{14}cm^{-2} (Edge-TCT)

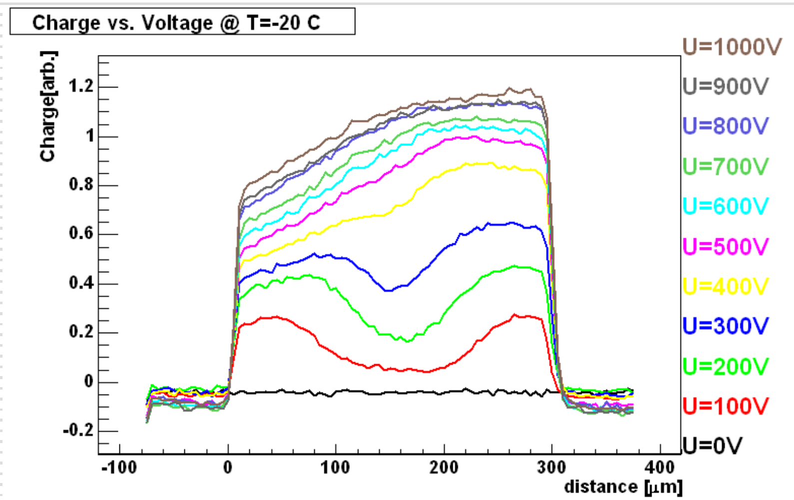


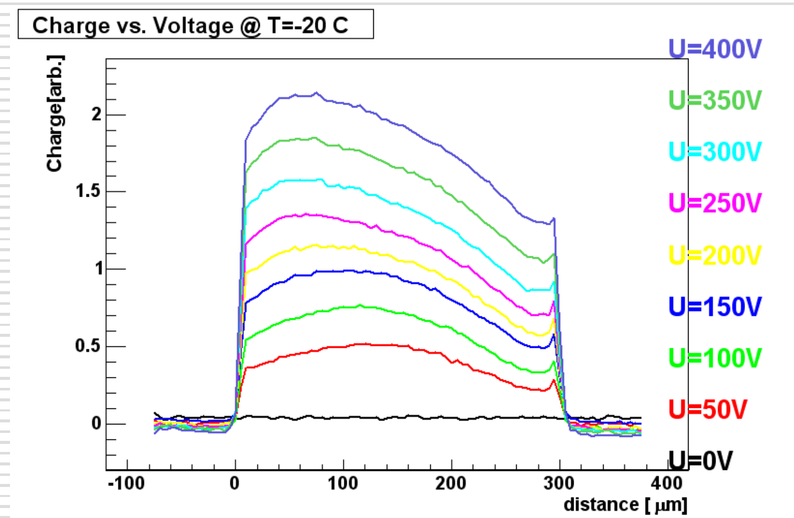






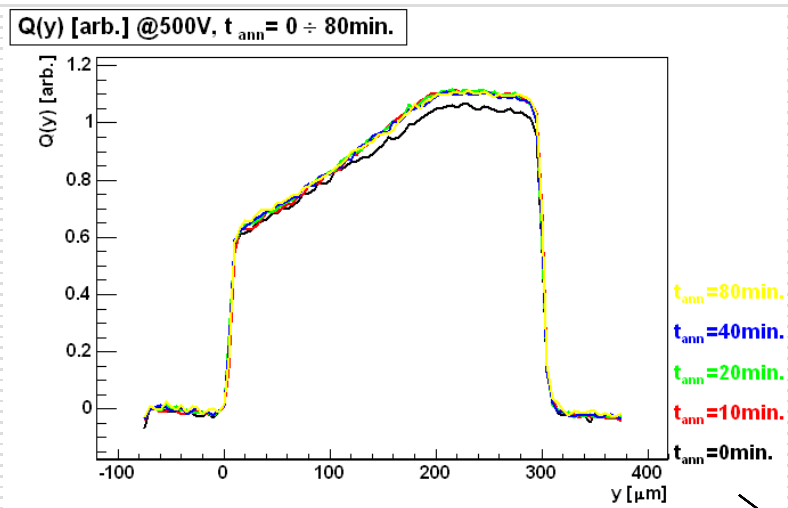
HPK – $\Phi_n = 1.42 \cdot 10^{15} cm^{-2}$ (Edge-TCT)

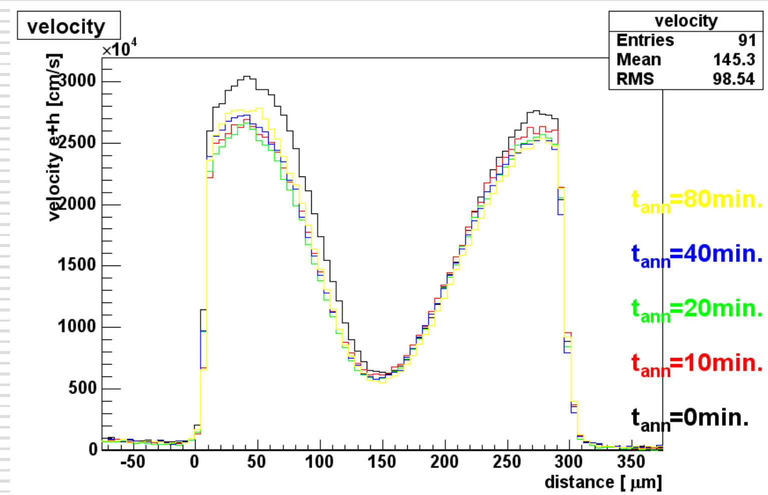


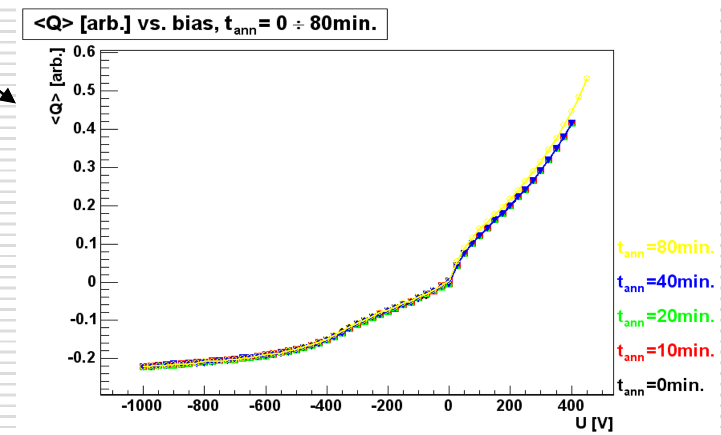


- A non-square charge collection profile most likely shows different trapping effects for electrons and holes
- Again, we see a large CC for forward bias due to long drift of charge carriers.

HPK – $\Phi_n = 1.42 \cdot 10^{15} cm^{-2}$ (Edge-TCT)

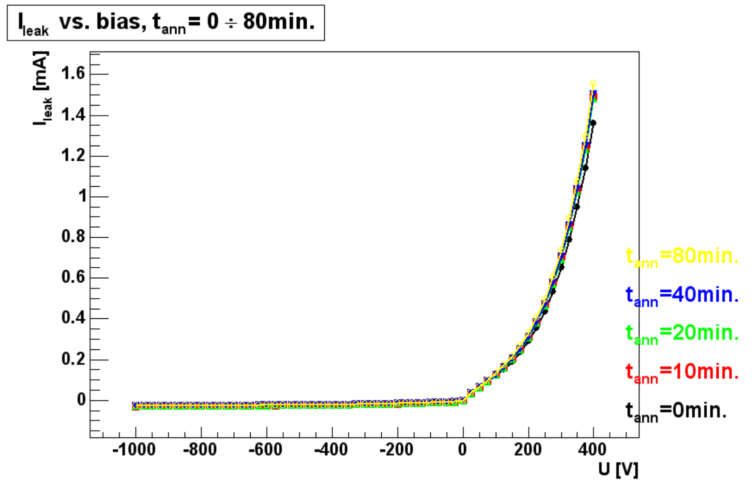


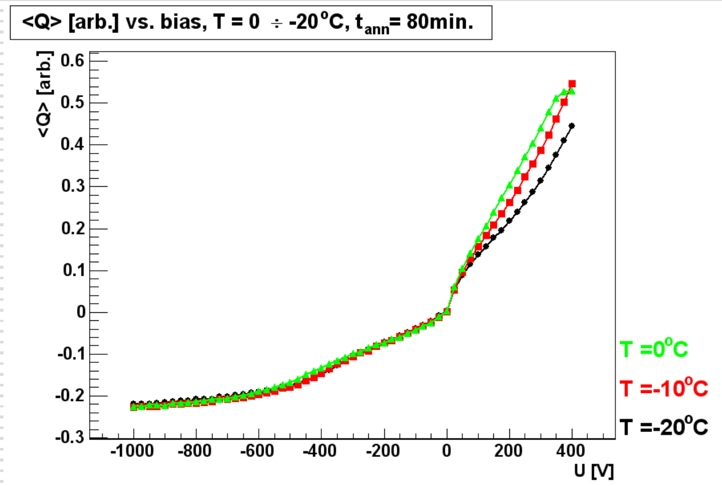




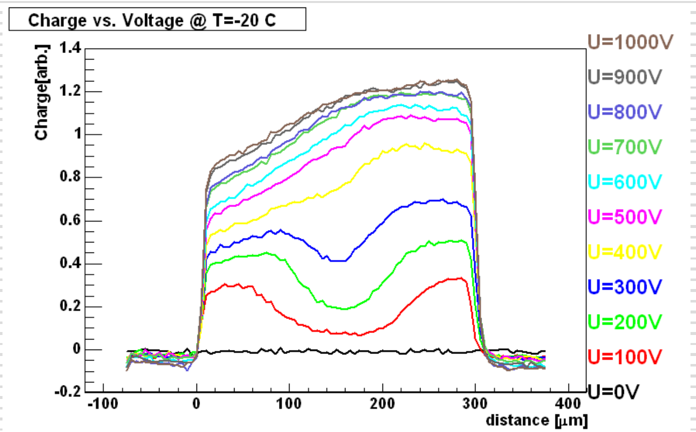
- Virtually no influence of short-term annealing for reverse, and forward bias.
- Velocity profiles confirms that only trapping difference between e and h can be the cause for such a charge collection profile

HPK – $\Phi_n = 1.42 \cdot 10^{15} cm^{-2}$ (Edge-TCT)





- The leakage current remains stable.
- Temperature scan shows difference only in forward bias, however, the underlying change of V_{fd} is vissible in charge collection profiles
- Change in Vfd≈100V!



Conclusions

- V_{fd} retains the validity as the parameter determining active region (high CCE region) up to 1-2·10^{15} cm^{-2} for neutron irradiated HPK sensors
- Substantial electric field is present in whole detector at high fluences already for moderate voltages
  - The difference between efficiency of different regions in the detector is reduced with fluence
- Short-term annealing affects the detector performance in positive way
  - before significant contribution from amplification the beneficial annealing is similar to the predicted from low fluence data
- Pion irradiated samples show:
  - Very small V_{fd}
  - Trapping effects for electrons and holes seem to be different for higher fluence, resulting in distorted charge collection profile
  - Full depletion voltage significantly changes with temperature (~100V)
- Future plans
  - More measurements with HPK sensors and Micron RD50 run (p-on-n, n-on-p and n-on-n)
  - Studies on mixed irradiated sensors (pion+neutron)
  - Edge-TCT parallel with strips (charge sharing, weighting field impact)