Questions about extrapolation at SLHC doses of silicon parameter measured after lower fluences

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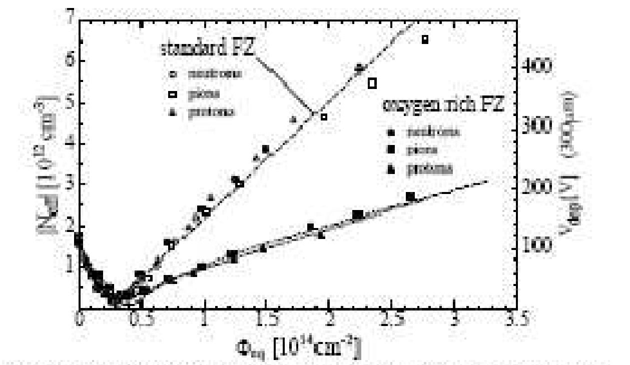
Full depletion voltage (V_{FD}) vs fluence



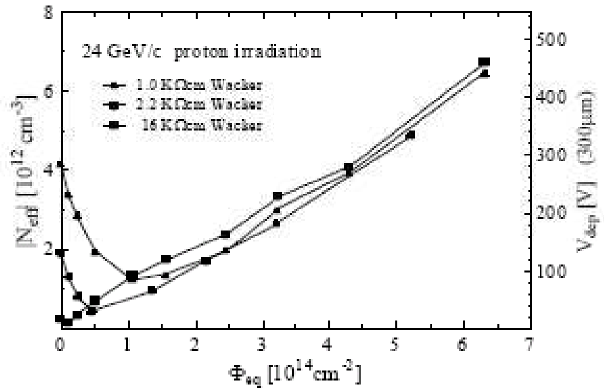


Fig. 11.: 24 GeV/c proton irradiation of O-rich diodes with different resistivity.

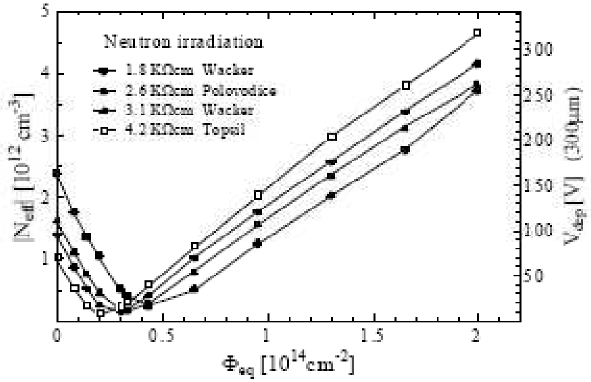
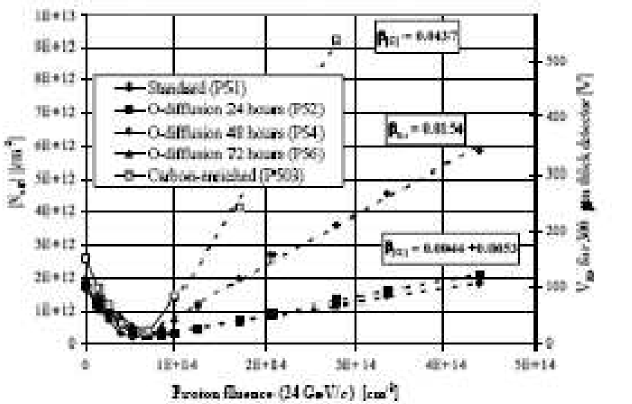


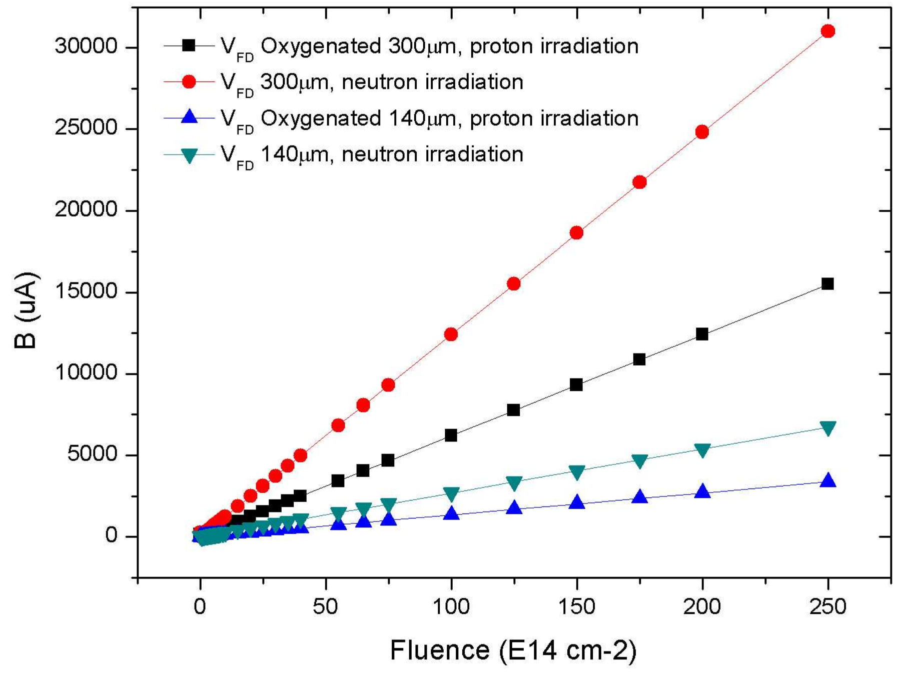
Fig.12: Reactor neutron irradiation of O-rich diodes with different resistivity.



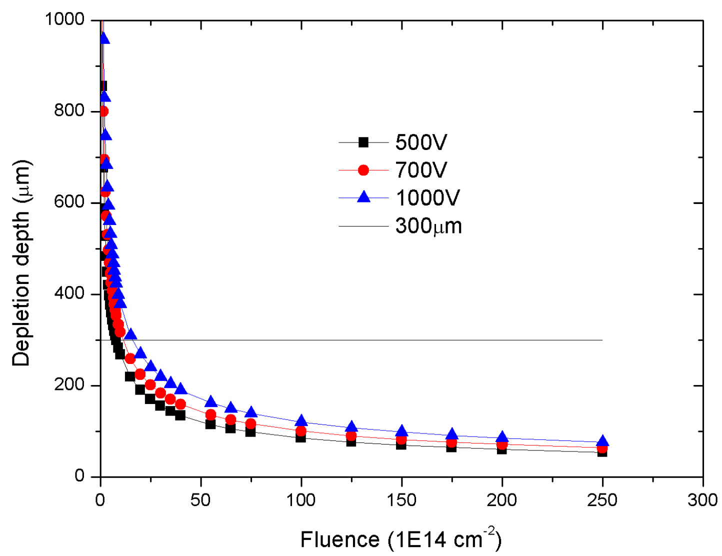
RD48 (ROSE) results

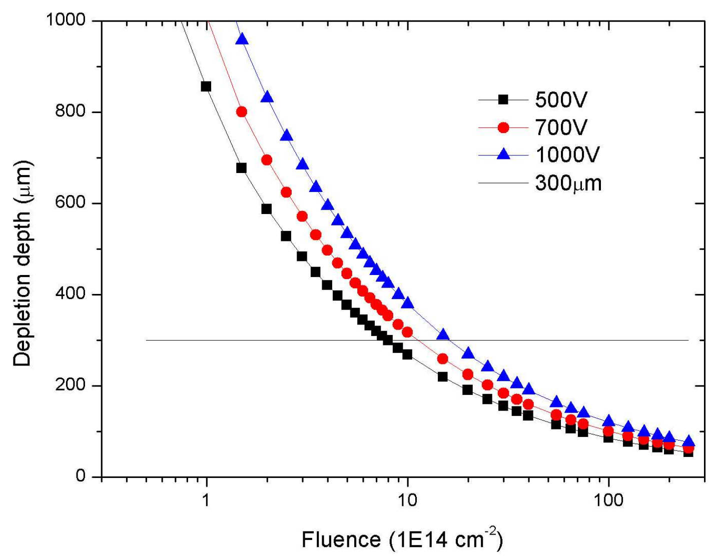
Full depletion voltage (V_{FD}) vs fluence

Extrapolation:



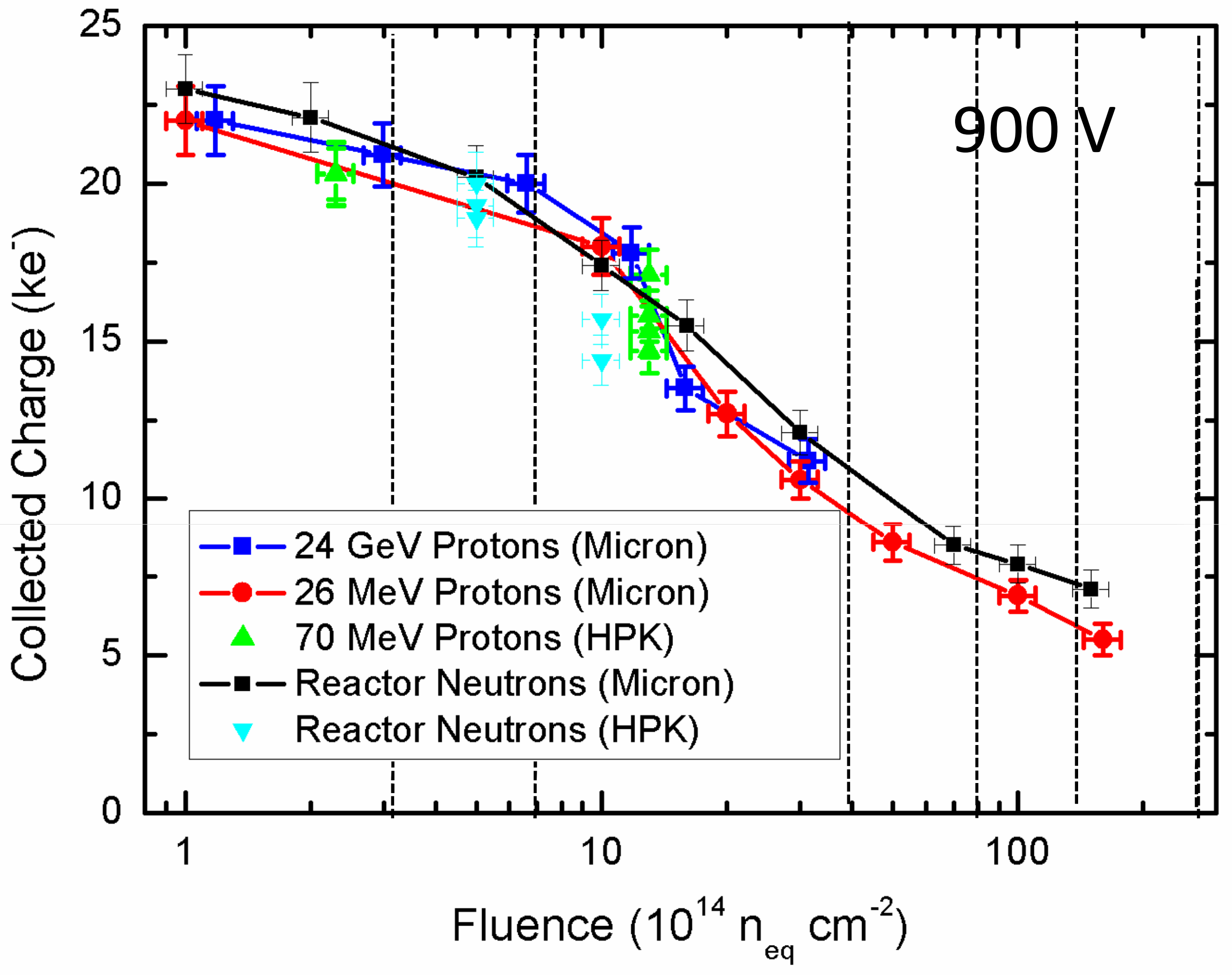
Depletion depth vs fluence ("best case" with oxygen enriched 300μm thick diodes, irradiated with protons)



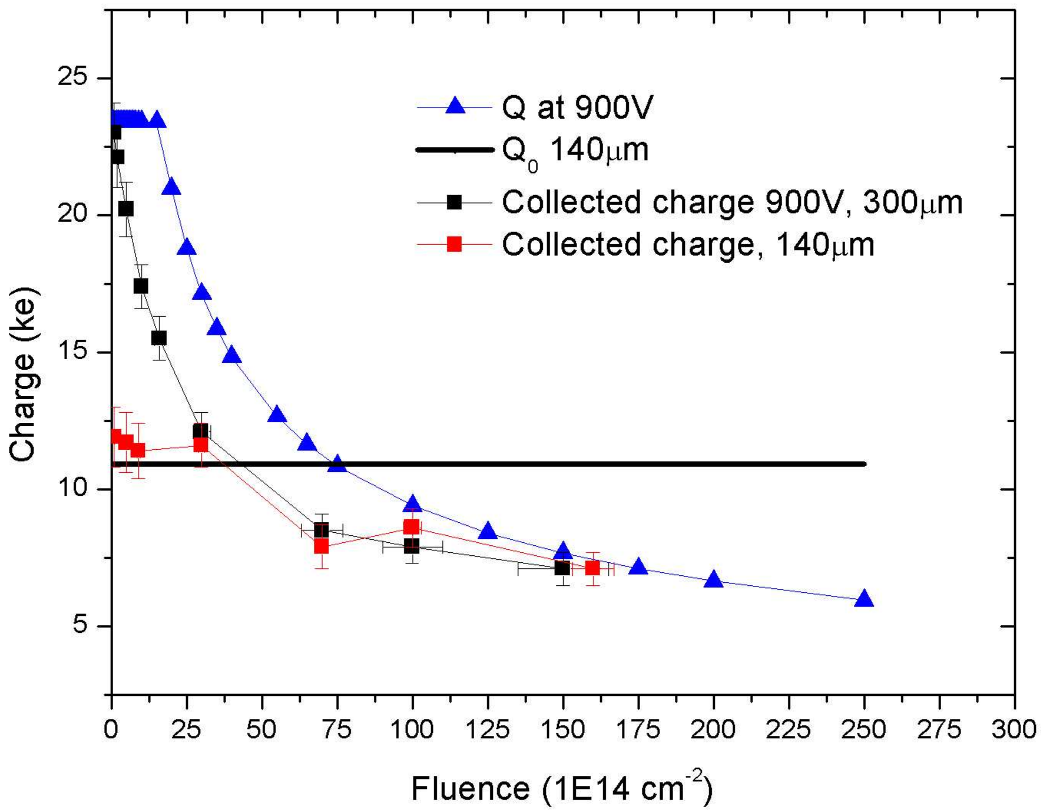


n-in-p FZ Irradiation Comparisons

The collected charge seems high If compared to the ionised charge in the depletion volume and the effect of trapping.



Charge collected and charge ionised in the "depletion volume")

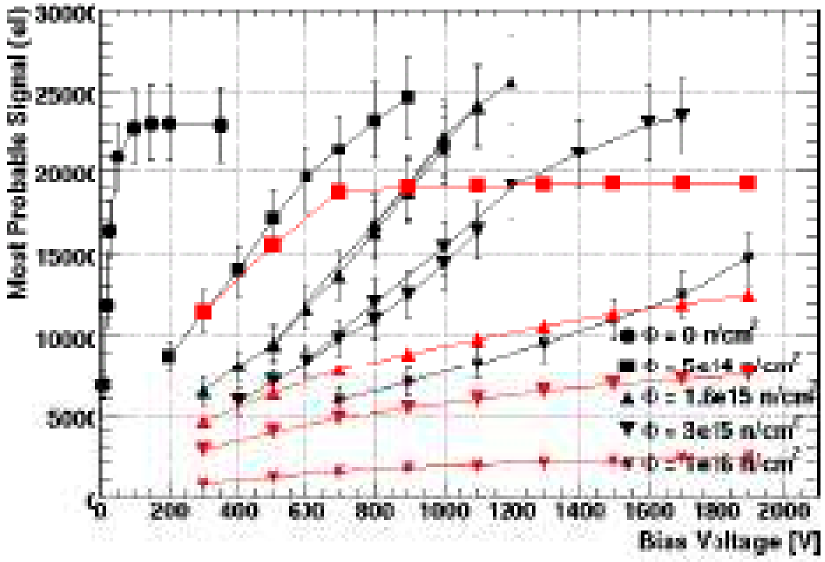


- space charge: $N_{eff} = g_c \cdot \Phi_{eq}, \; g_c = 0.017\,cm^{-1}$
- trapping: $1/\tau_{e,h} = \beta_{e,h} \cdot \Phi_{eq}$

- β and g_c from TCT and C-V measurements on p-type detectors made by V. Cindro et al. in Ljubljana

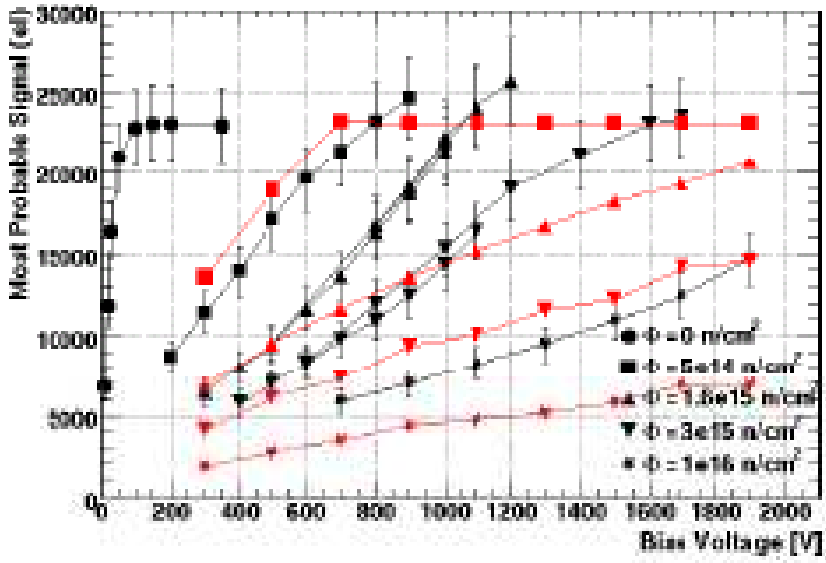
Black: measured, Red: simulation

$\beta_e = 3.2 \cdot 10^{-16}\,cm^2/ns$
$\beta_h = 3.5 \cdot 10^{-16}\,cm^2/ns$



Black: measured, Red: simulation

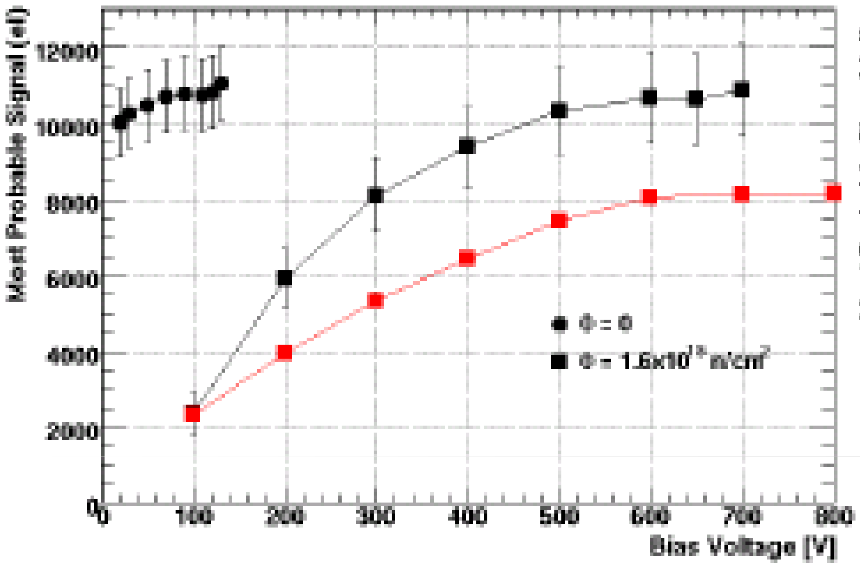
No trapping, only N_{eff}:



Thin (140 µm) detector

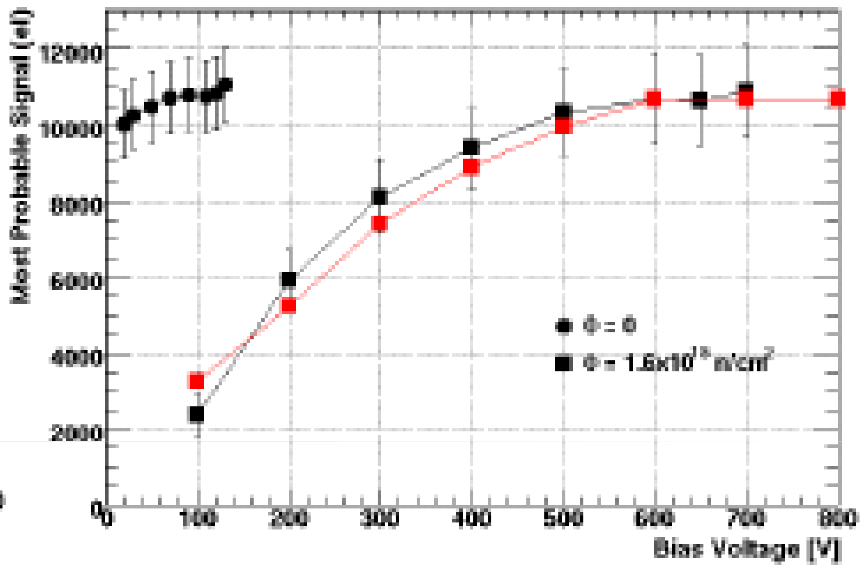
Black: measured

Red: simulation + trapping



Black: measured

Red: simulation, no trapping (only N_{eff})



- agreement with simulation only at low fluences and low bias voltages
- g_c and $\beta_{e,h}$ measured at low fluences can not be used at high fluences and high bias voltage
- not possible to explain the high CCE if trapping > 0

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V_{FD} vs annealing time

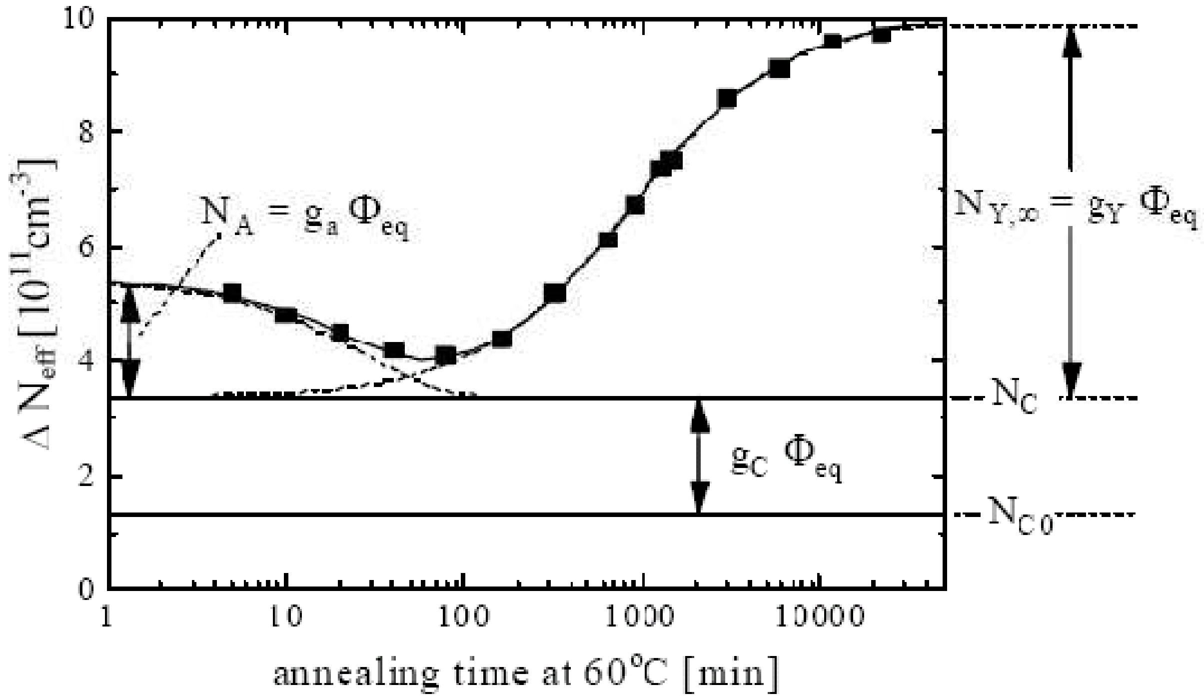


Fig.13: Annealing behaviour of the radiation induced change in the effective doping concentration ΔN_{eff} at 60°C.

“Old” assumption:

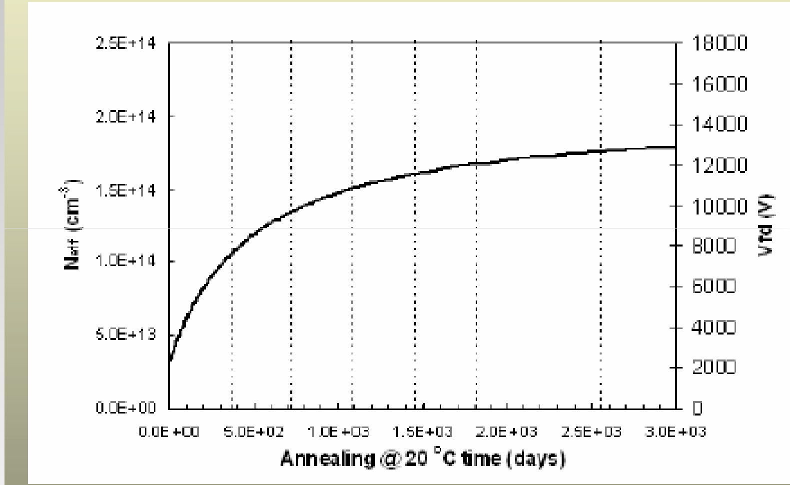
Avoid to warm the irradiated detectors above 0ºC, even during beam down and reduce maintenance at room temperature to minimum.

V_{FD} undergoes reverse annealing and

becomes progressively higher if the detectors are kept above 0ºC.

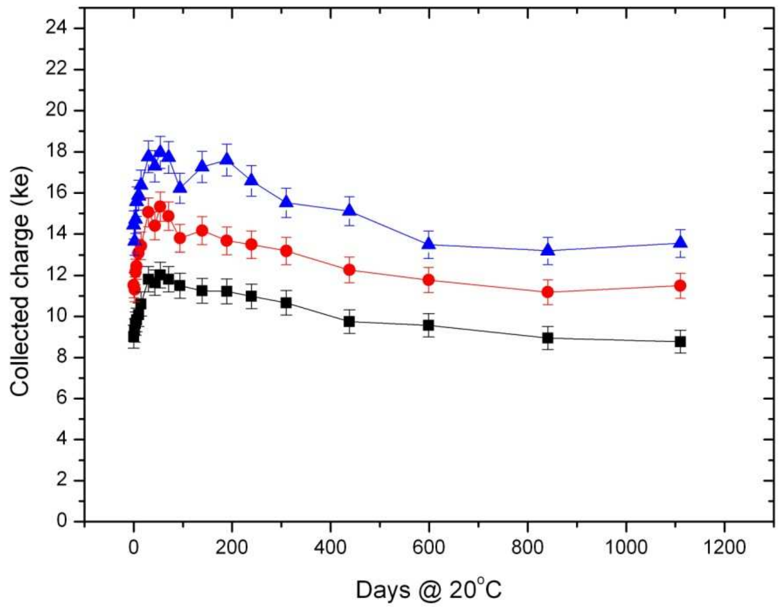
But what happens to the reverse current and the CCE of n-side readout detectors?

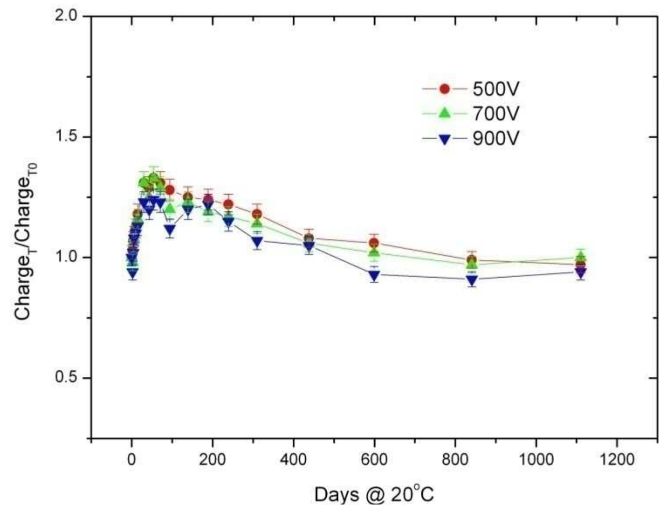
Initial V_{FD} ~ 2800V

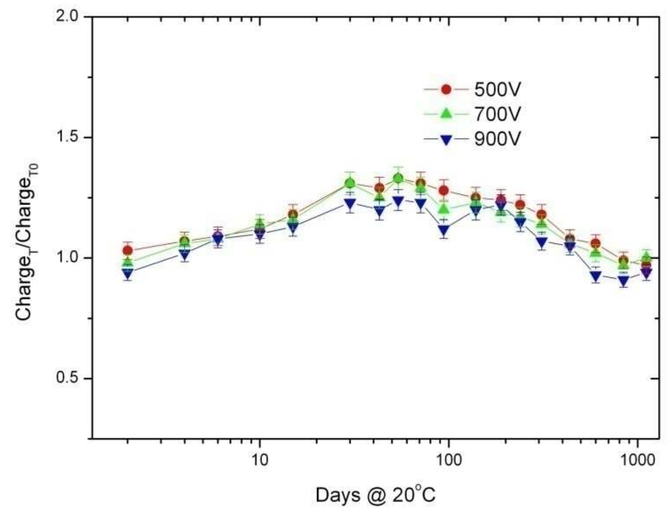


Predictions from RD48 parameters for Oxygen enriched devices (best scenario: after 7 RT annealing years the V_{fd} goes from ~2800V to ~12000 V!

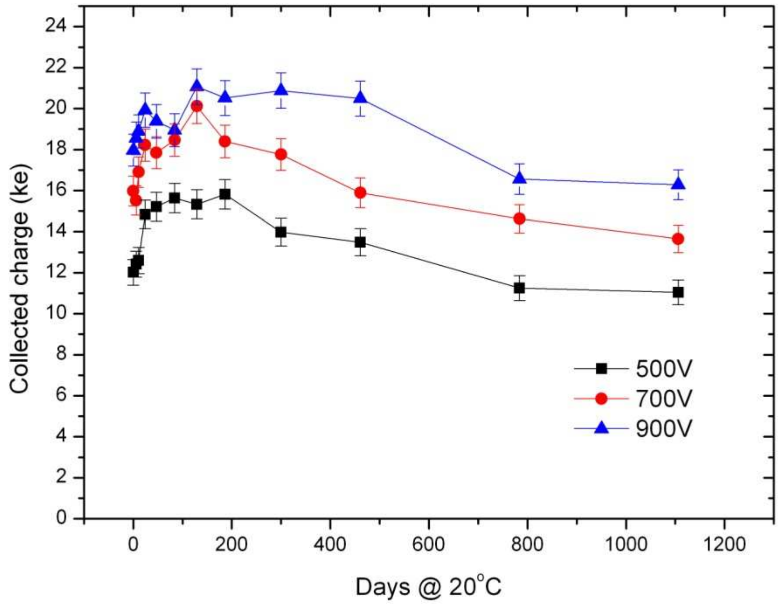
“Fine step” Annealing of the collected charge, HPK FZ n-in-p, 1E15 n cm^{-2}

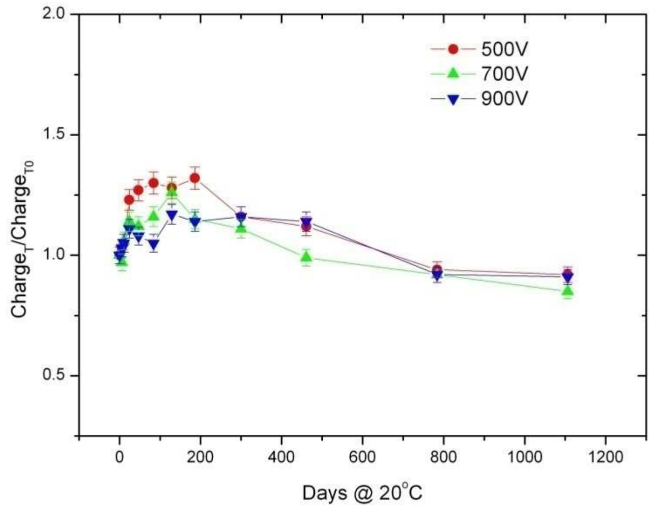


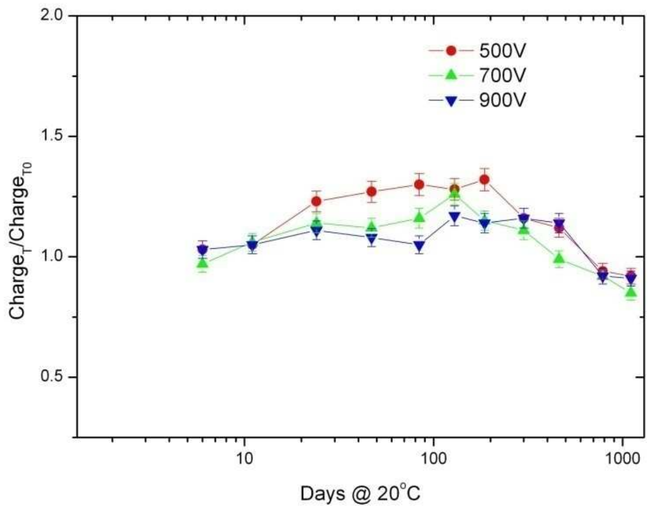




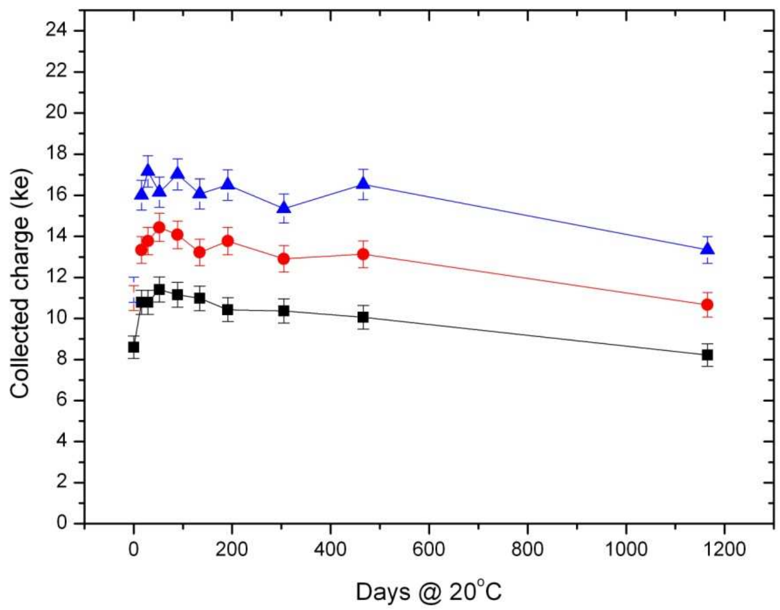
"Fine step" Annealing of the collected charge, Micron FZ n-in-p, 1E15 n cm^{-2} (26MeV p irradiation)

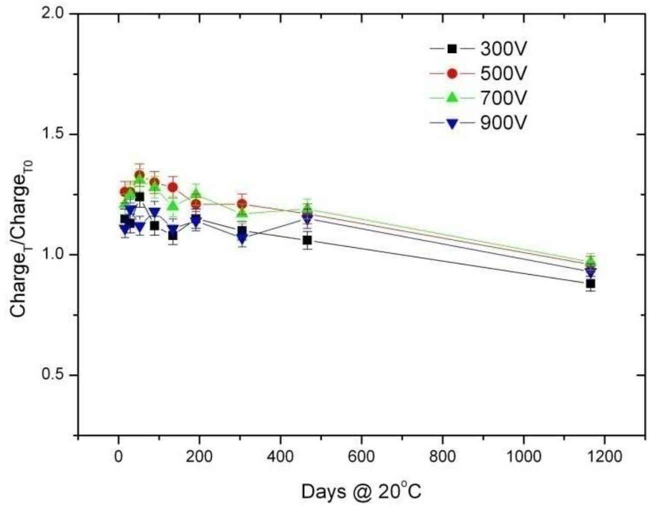


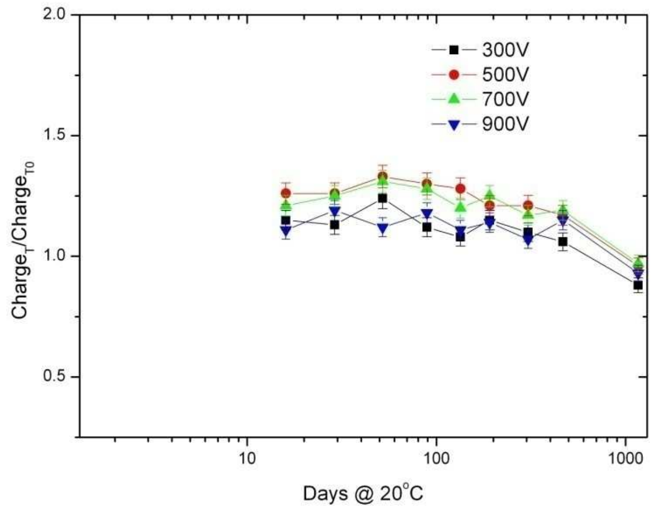




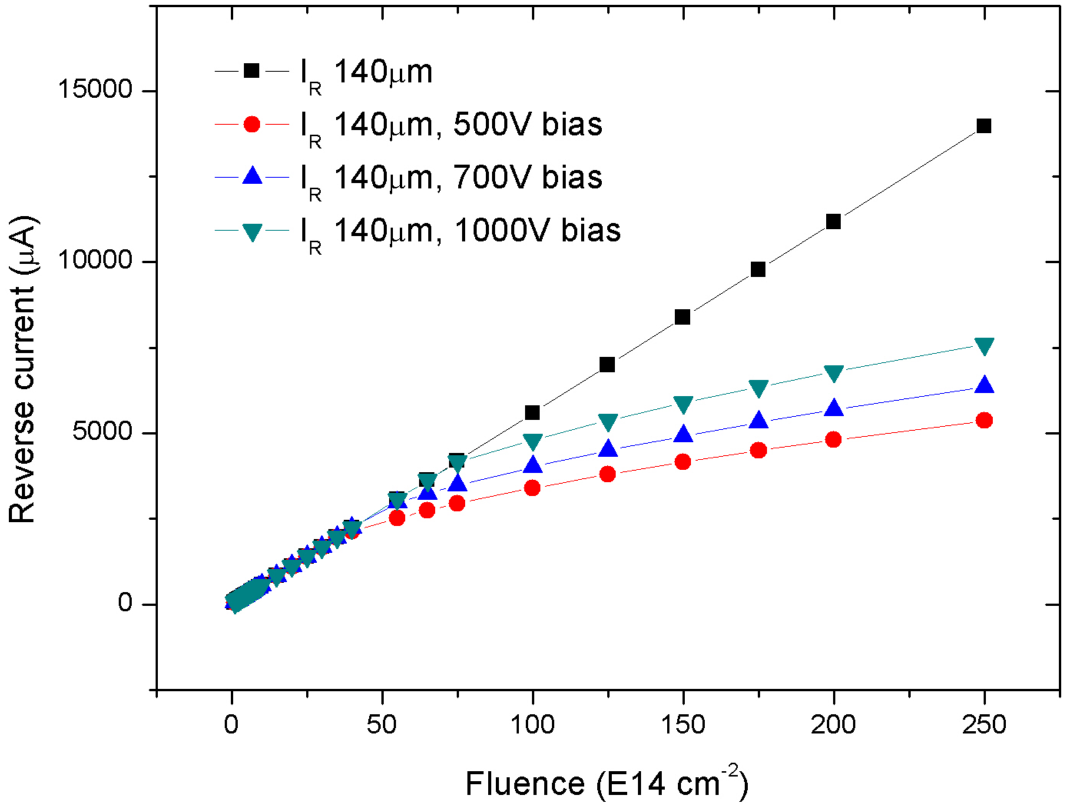
"Fine step" Annealing of the collected charge, Micron FZ n-in-n, 1.5E15 n cm^{-2}



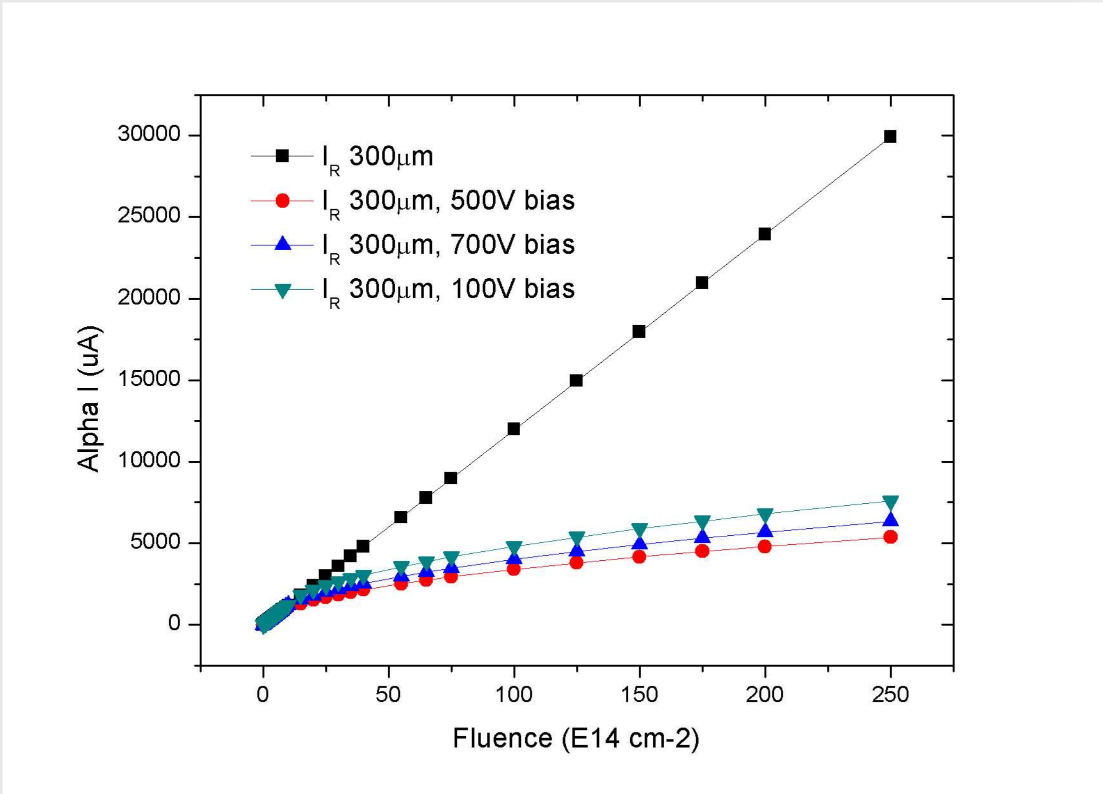




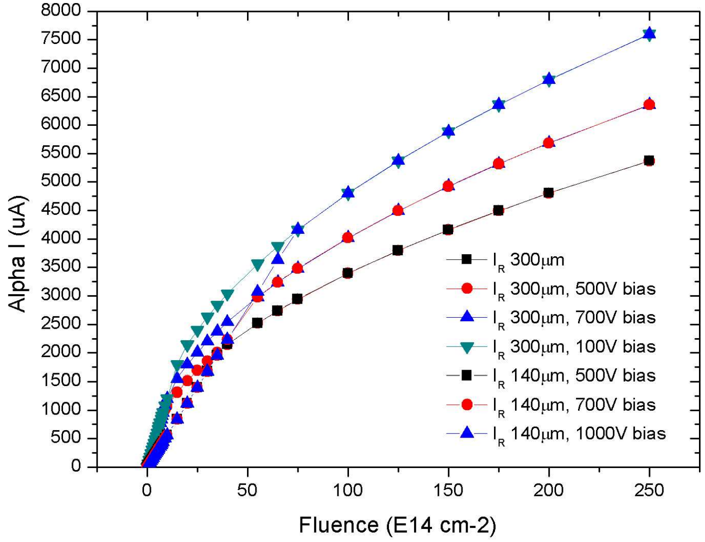
Reverse current (I_R) vs fluence

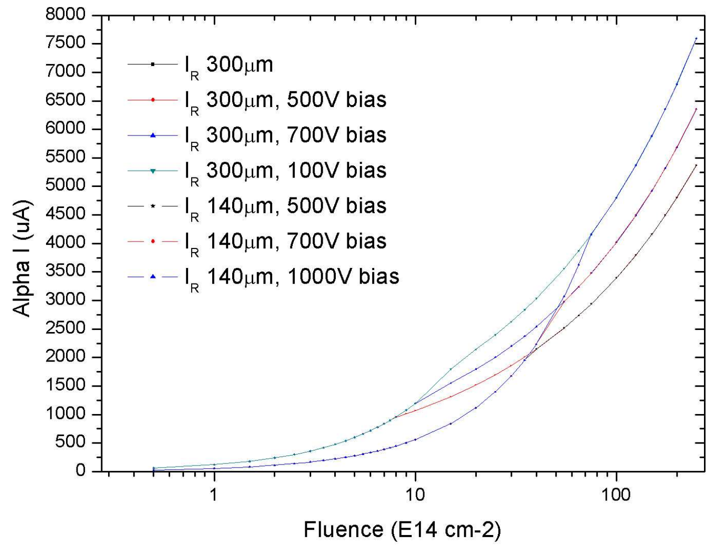


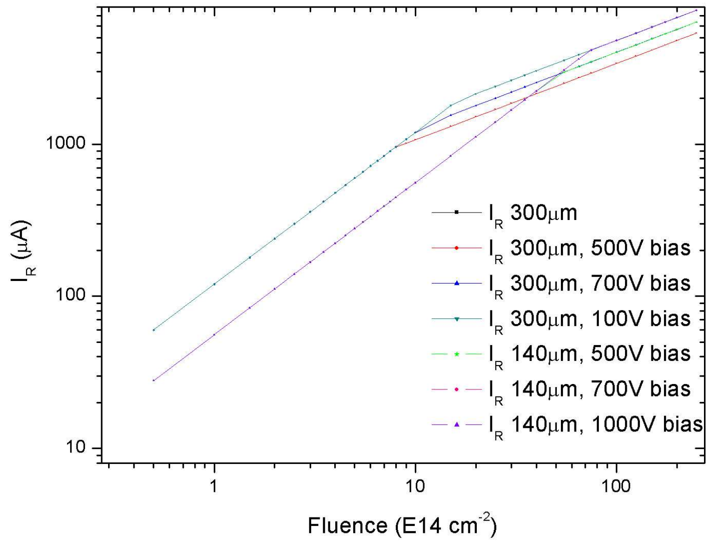
Reverse current (I_R) vs fluence



Reverse current (I_R) vs fluence







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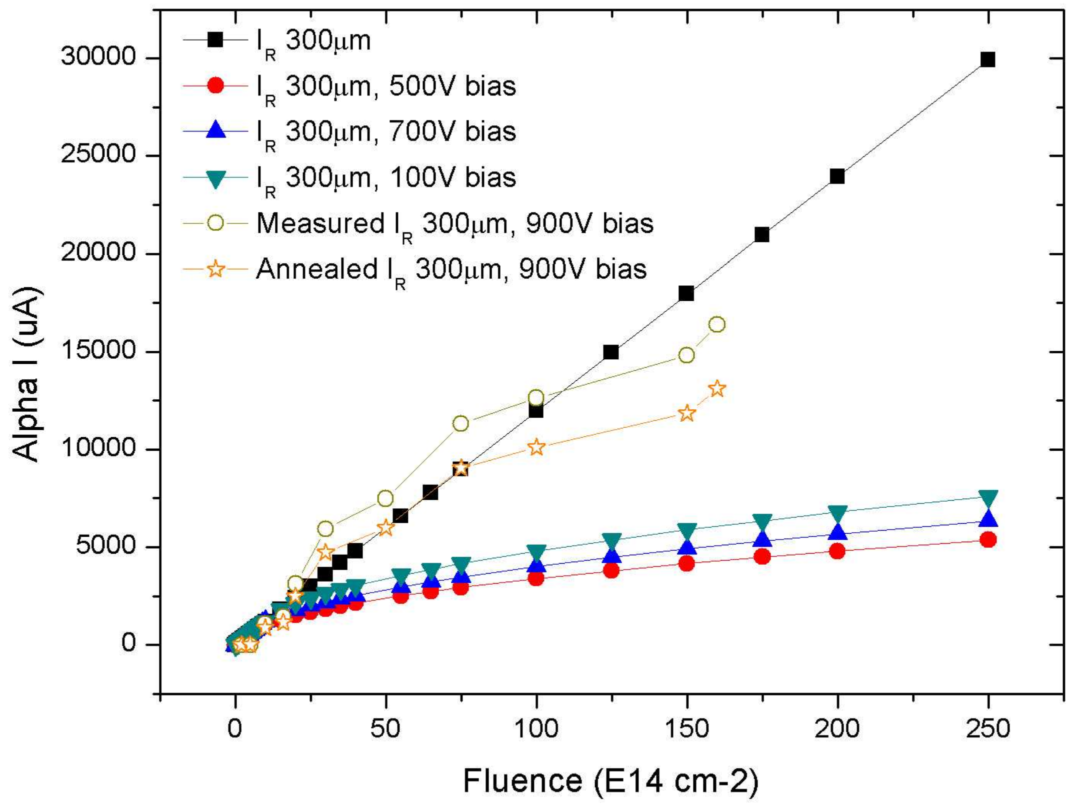
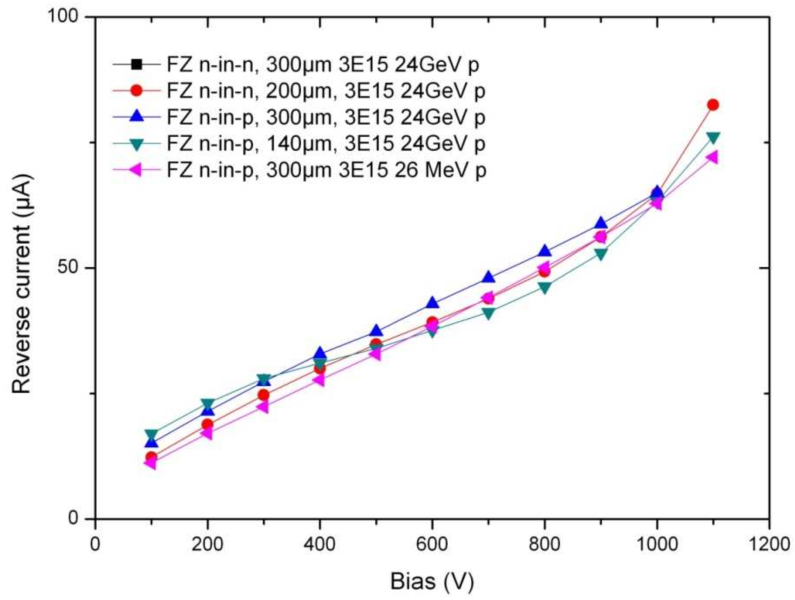
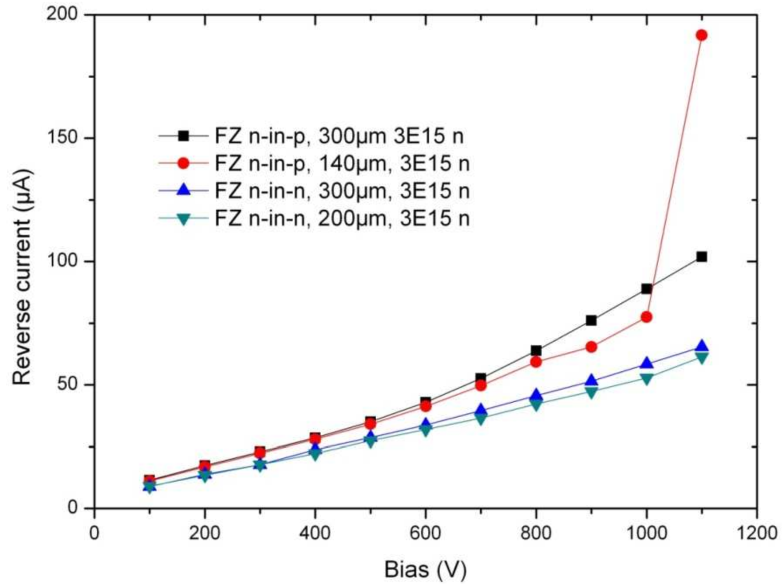
Reverse current (I_R) vs fluence

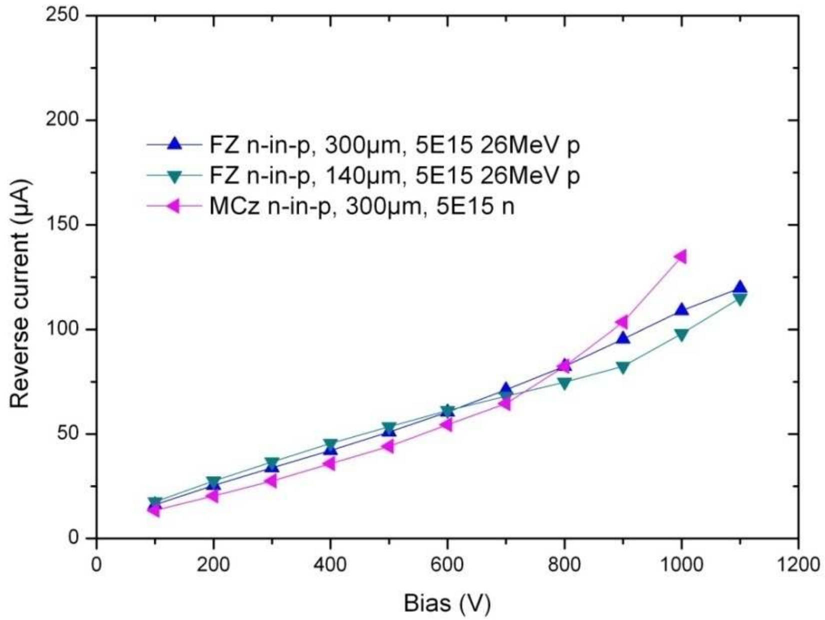


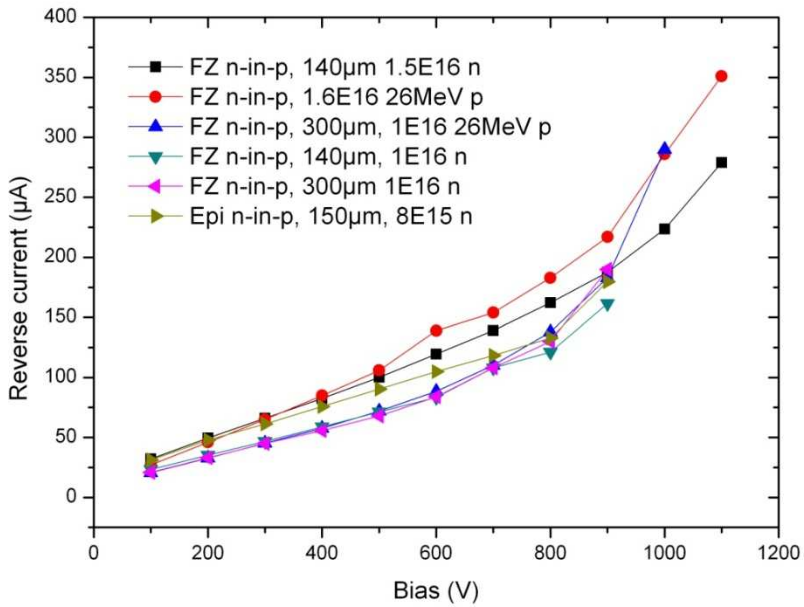
IV thin vs standard, various irradiation





IV thin vs standard, various irradiation





CONCLUSIONS

The charge collection efficiency at very high fluences is very close to fully collect (with NO TRAPPING) the ionised charge in the extrapolated “depleted volume”. It seems unlikely that both the trapping and the “depleted volume” are what expected from the measurements at lower doses.

The annealing of the depleted charge cannot be described by the annealing of the full depletion voltage.

The reverse current at high fluences is much higher than expected from the extrapolated depleted volume. The reverse current of thin and thick detectors is very close, adding to the idea that it does not seem to be correlated to the volume.

I would suggest that the knowledge of the electric field profile is the only method to allow prediction/modelling of the detectors at these severe doses.