Update on charge collection annealing

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CONTEXT:

Accelerated annealing is a valuable tool for establishing the running scenario of the sensors installed in the experiments, undergoing severe hadron irradiation. Besides, the comparison of the properties of different sensors irradiated to equal doses has to take into account the effect of the annealing, being especially important at short annealing times, where sharper changes are expected. In the past, we have used to anneal sensors for 80 minutes at 60°C. What is the right procedure when the charge collection is taken into account?

As usual, precious irradiation work done by CERN/PS (M. Glaser), JSI (V. Cindro) and Karlsruhe (A. Dierlamm) colleagues, many thanks!

Annealing can be accelerated with “*known*” factors by mean of rising the temperature, e.g.:

40 ^{o}C f = 30

60 ^{o}C f = 550

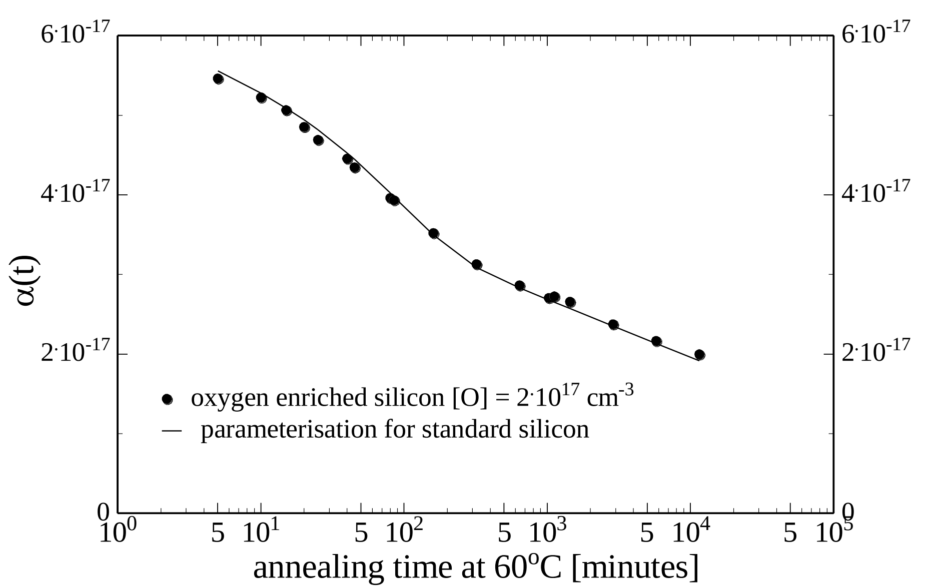
80 ^{o}C f = 7400

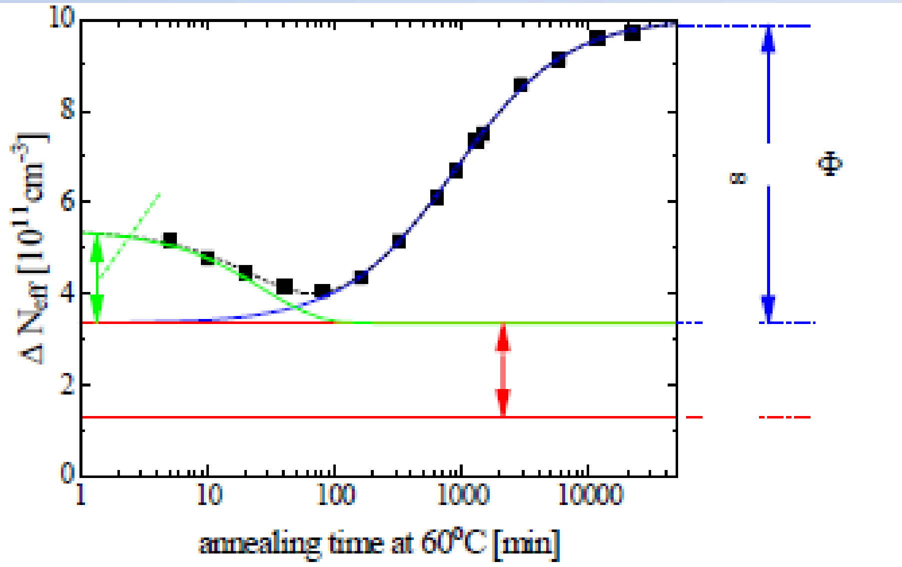
(relative to room temperature RT = 20^{o}C).

Using fixed annealing time for comparison of the electrical properties

Reverse current and full depletion voltage

Currently, in order to take the sensors to an annealing condition where the measured quantities show little variation in order to make more reliable comparison, the sensors are annealed for 80' at 60°C.



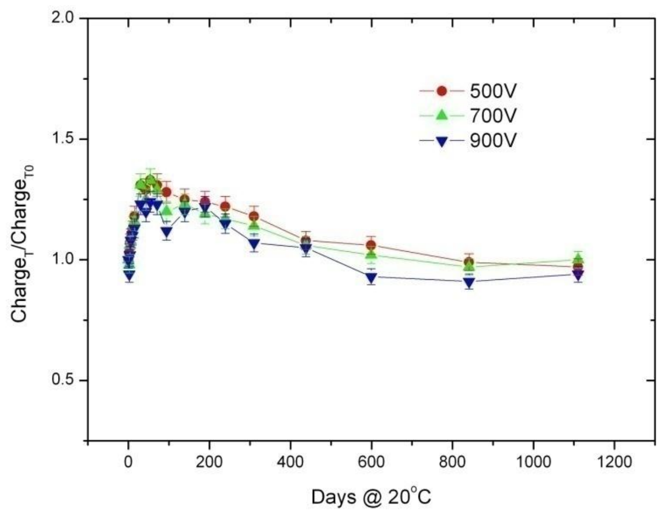


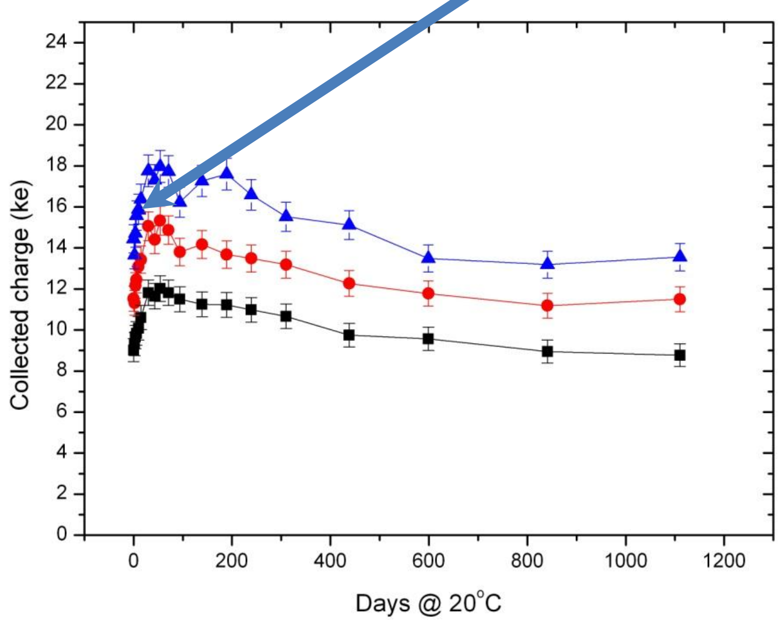
Data from M. Moll

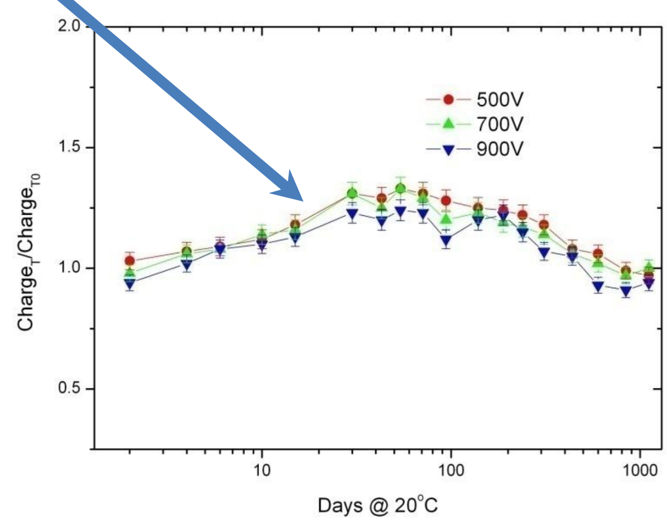
Using fixed annealing time for comparison of the electrical properties

HPK FZ n-in-p, 1E15 n_{eq} cm^{-2}

80 minutes at 60ºC (30 days at RT).

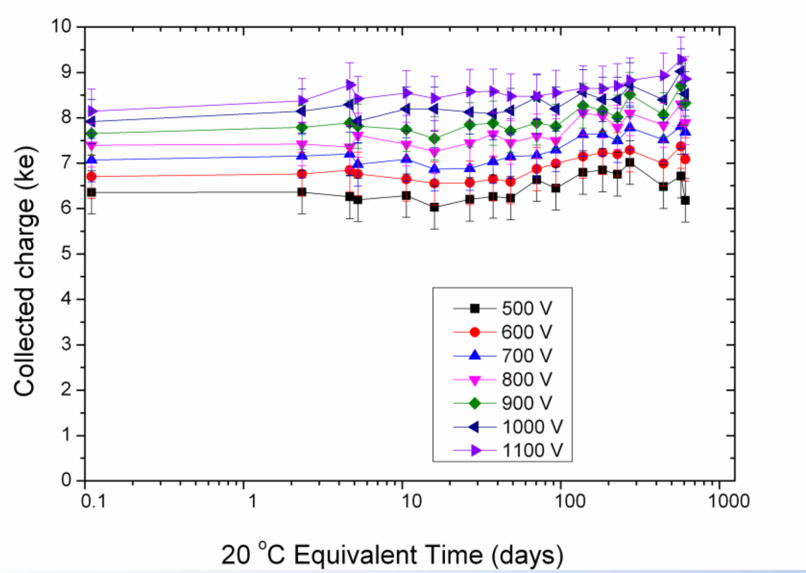




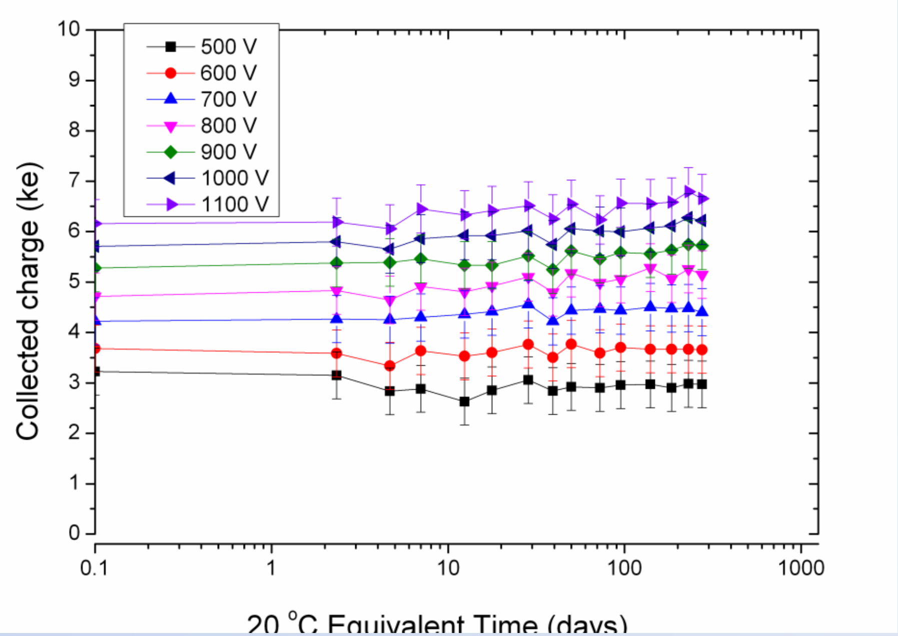


Neutron irradiations in Ljubljana.

Accelerated CCE Annealing 5 and 1.5E16 n cm^{-2}



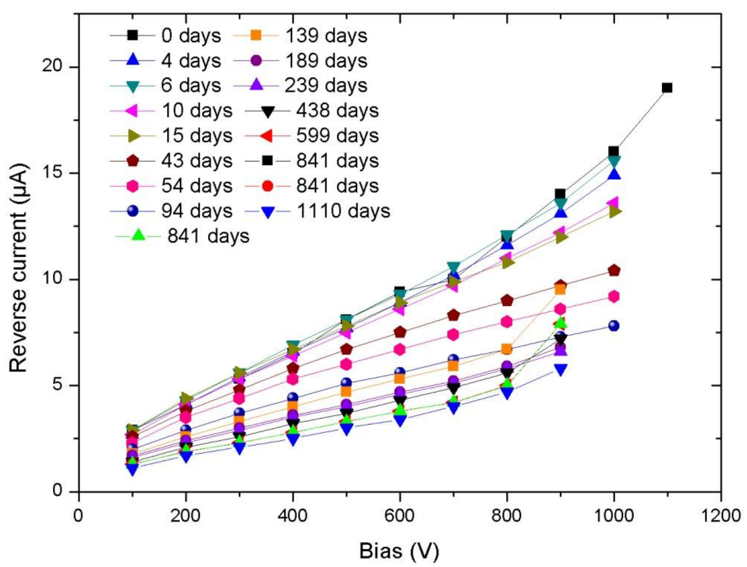
5×10^{15} n_{eq} cm^{-2}
Irradiated with 26MeV protons (Karlsruhe).

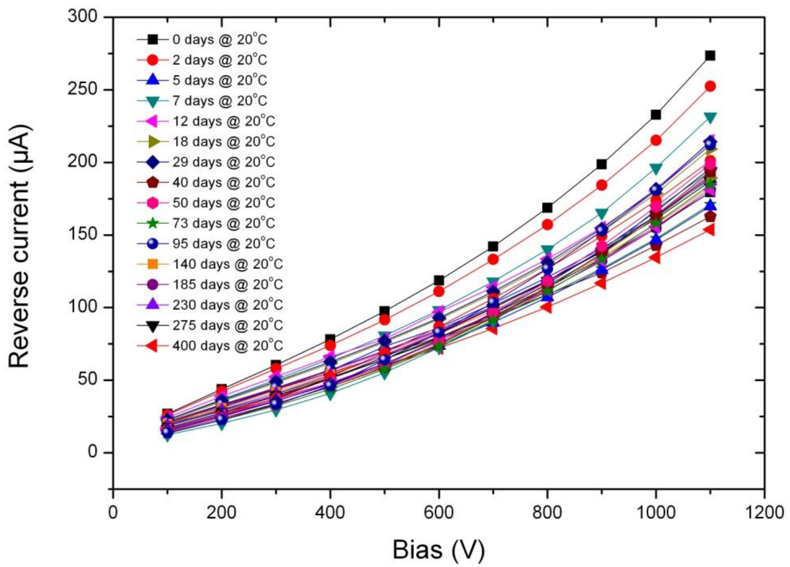


1.5×10^{16} n_{eq} cm^{-2}
Irradiated with 26MeV protons (Karlsruhe).

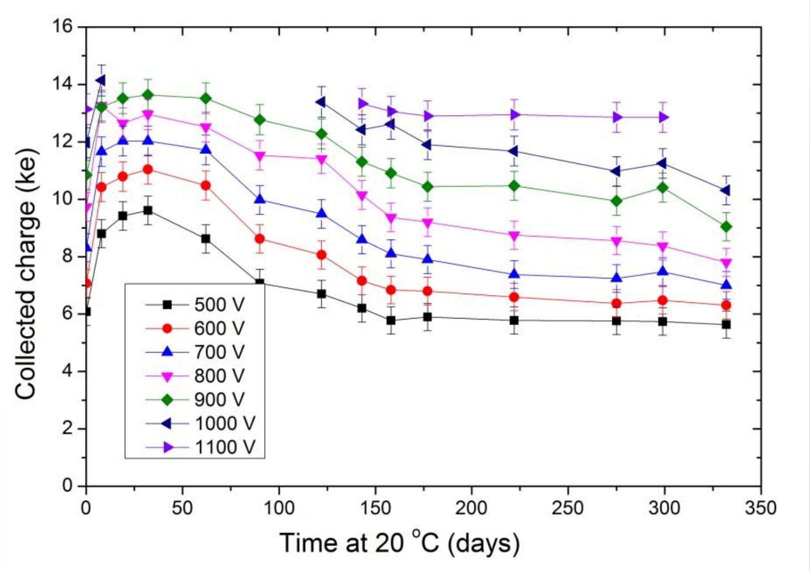
Accelerated annealing at 40, 60 and 80ºC. Alibava DAQ based on Beetle chip.

Accelerated Annealing of the reverse current, n-in-p sensors, 1E15 and 1.5E16 n cm^{-2}

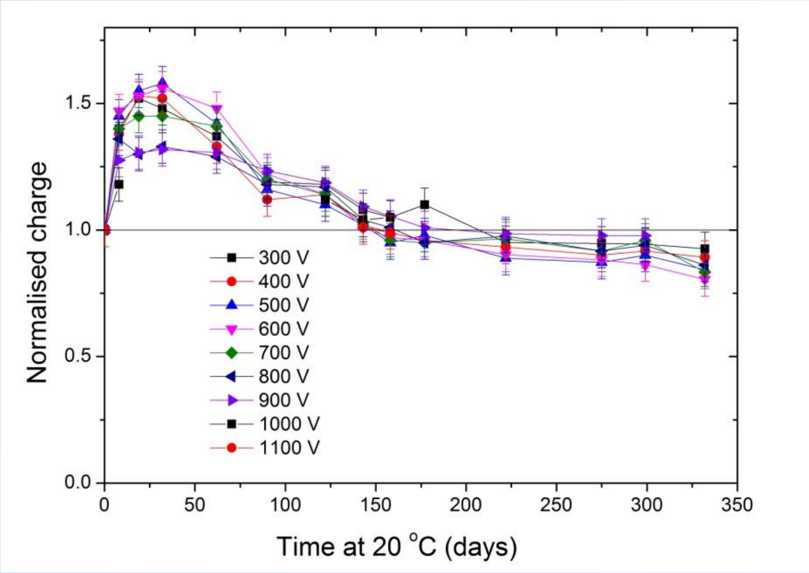




Room Temperature Annealing of the collected charge, HPK FZ n-in-p, 2E15 n cm^{-2} (26MeV p irradiation)

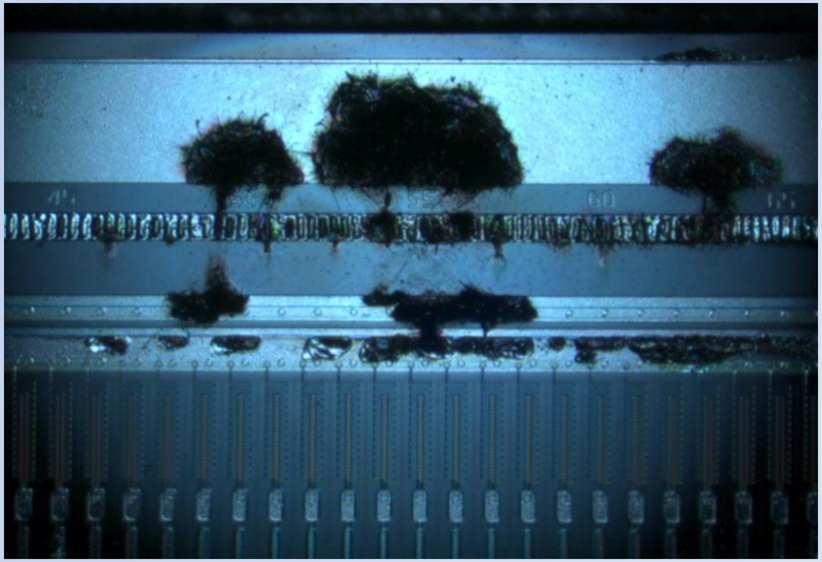


We make large use of accelerating annealing: is this a safe and correct approach?

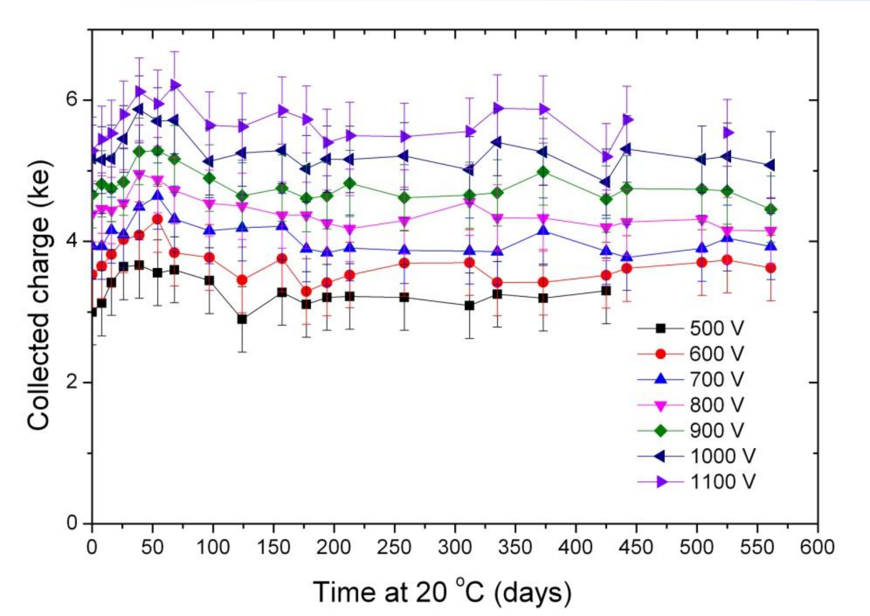


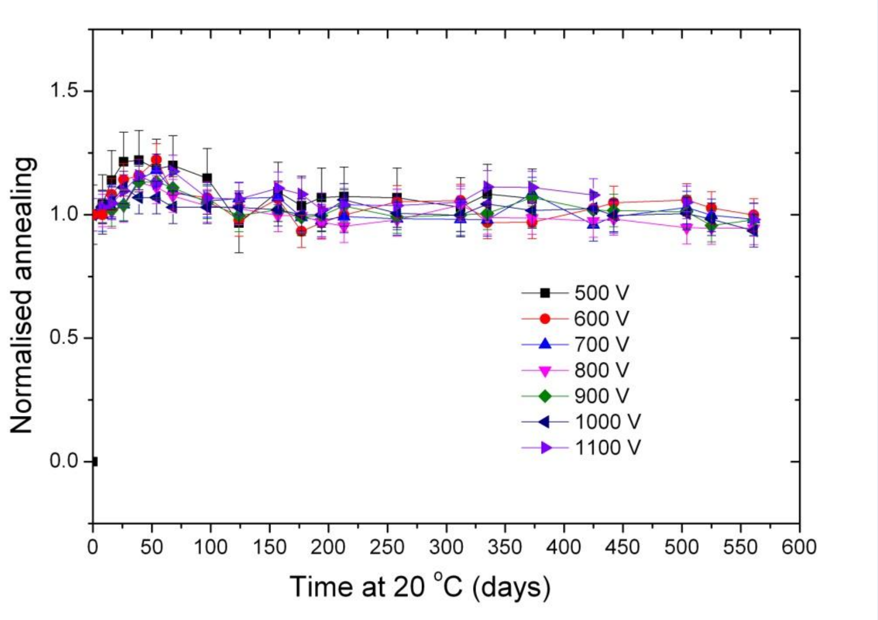
It can be difficult to carry on these measurements over years......

Failure of the sensor irradiated to 2E15 n_{eq} cm^{-2}, due to moisture formation after the extraction from the measurement freezer.

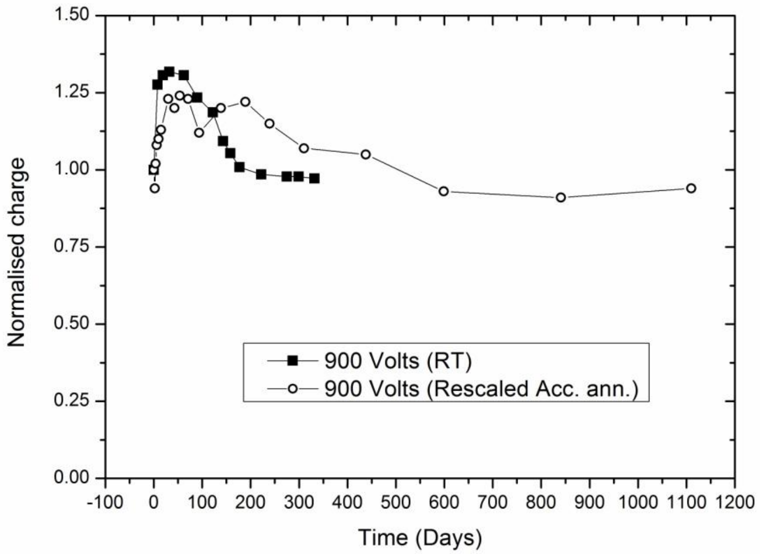


Room Temperature Annealing of the collected charge, HPK FZ n-in-p, 1E16 n cm^{-2} (26MeV p irradiation)

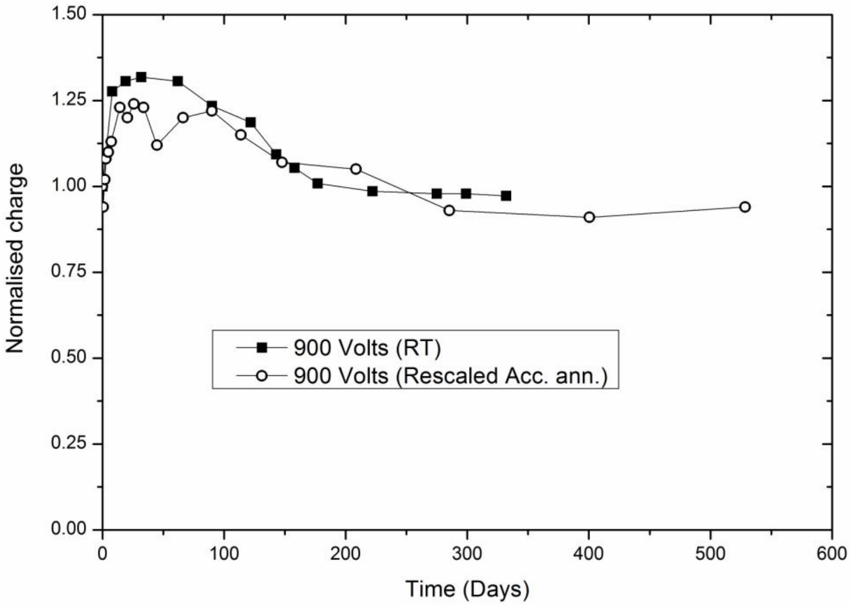




Comparison of Room Temperature and Accelerated Annealing of the collected charge, HPK FZ n-in-p, 1and 1.5E15 n cm^{-2} (26MeV p irradiation)



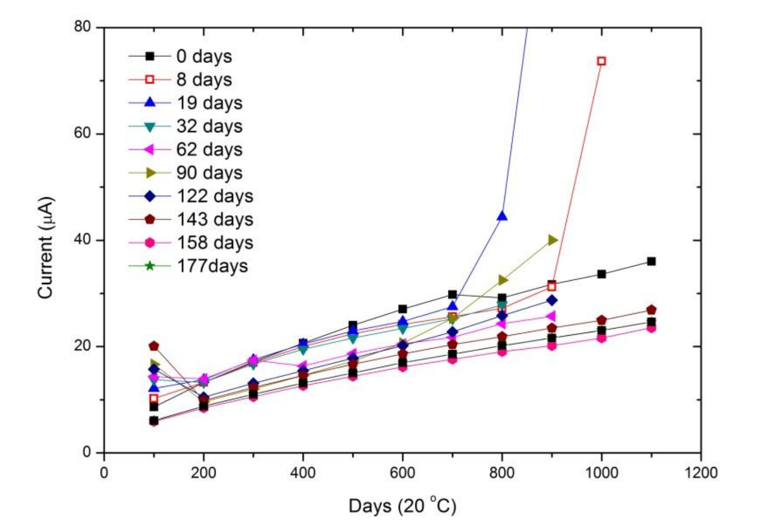
Accepted acceleration factor

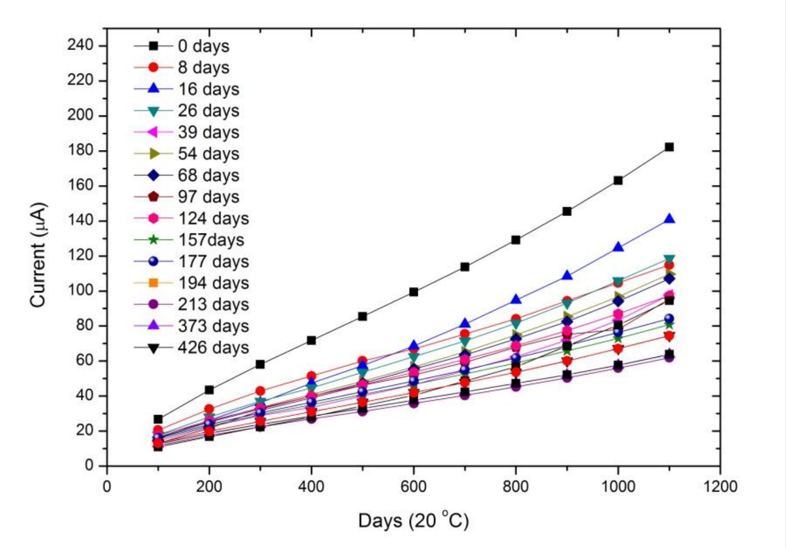


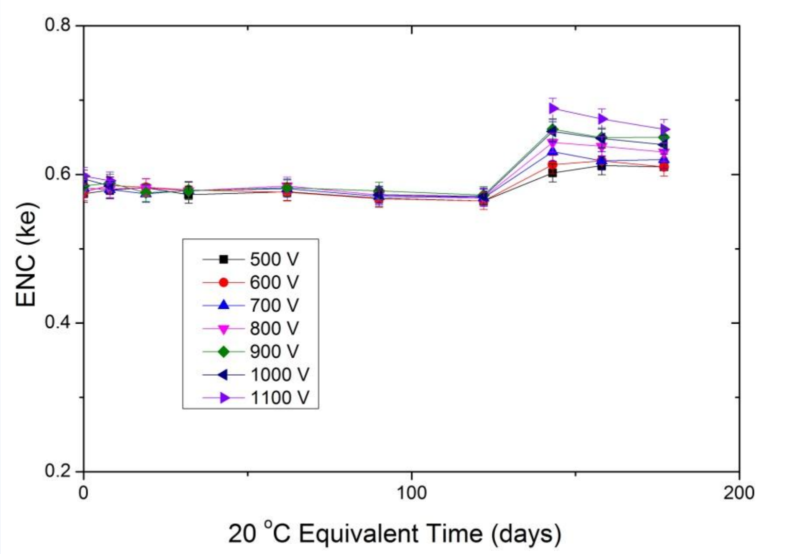
Acceleration factor divided by 2.1

Suggestion for comparing results (awaiting for systematic studies): 120 minutes at 60°C

Room Temperature Annealing of the reverse current, n-in-p sensors, 0.2 and 1E16 n cm^{-2} (26MeV p irradiation)

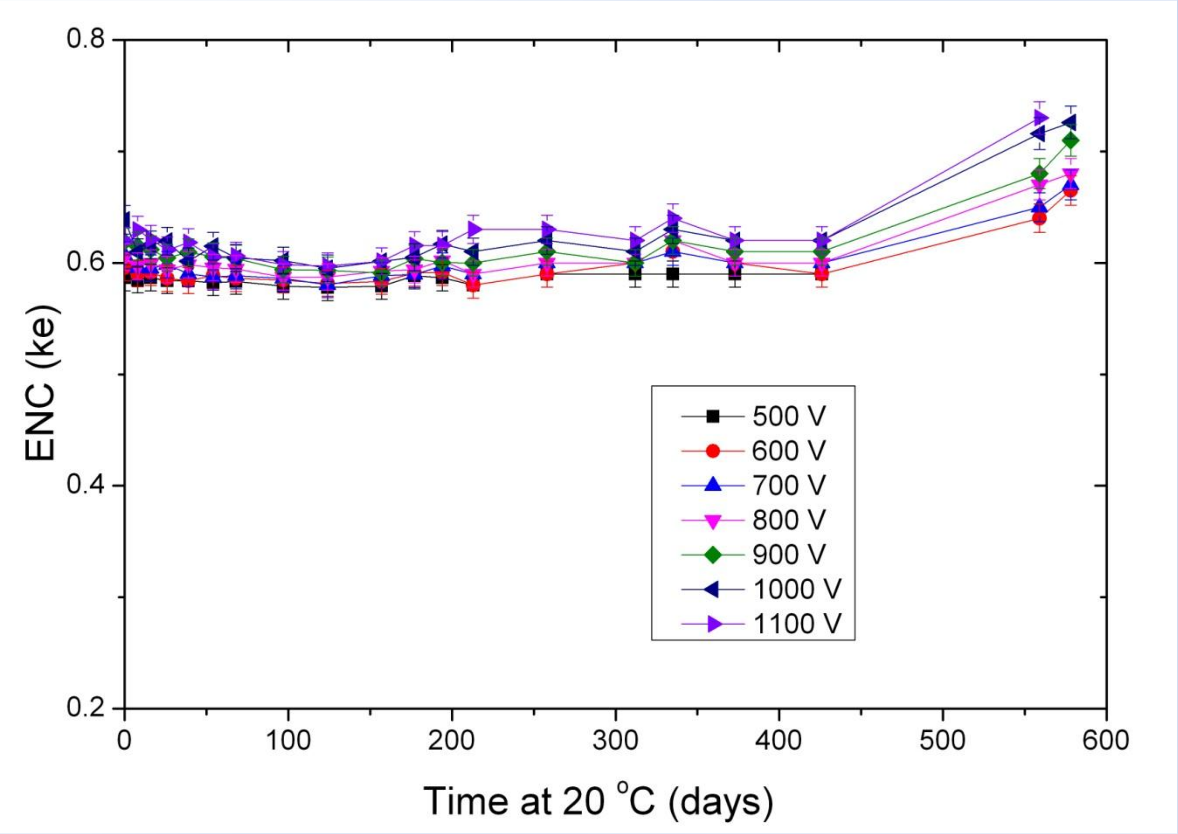






NOISE

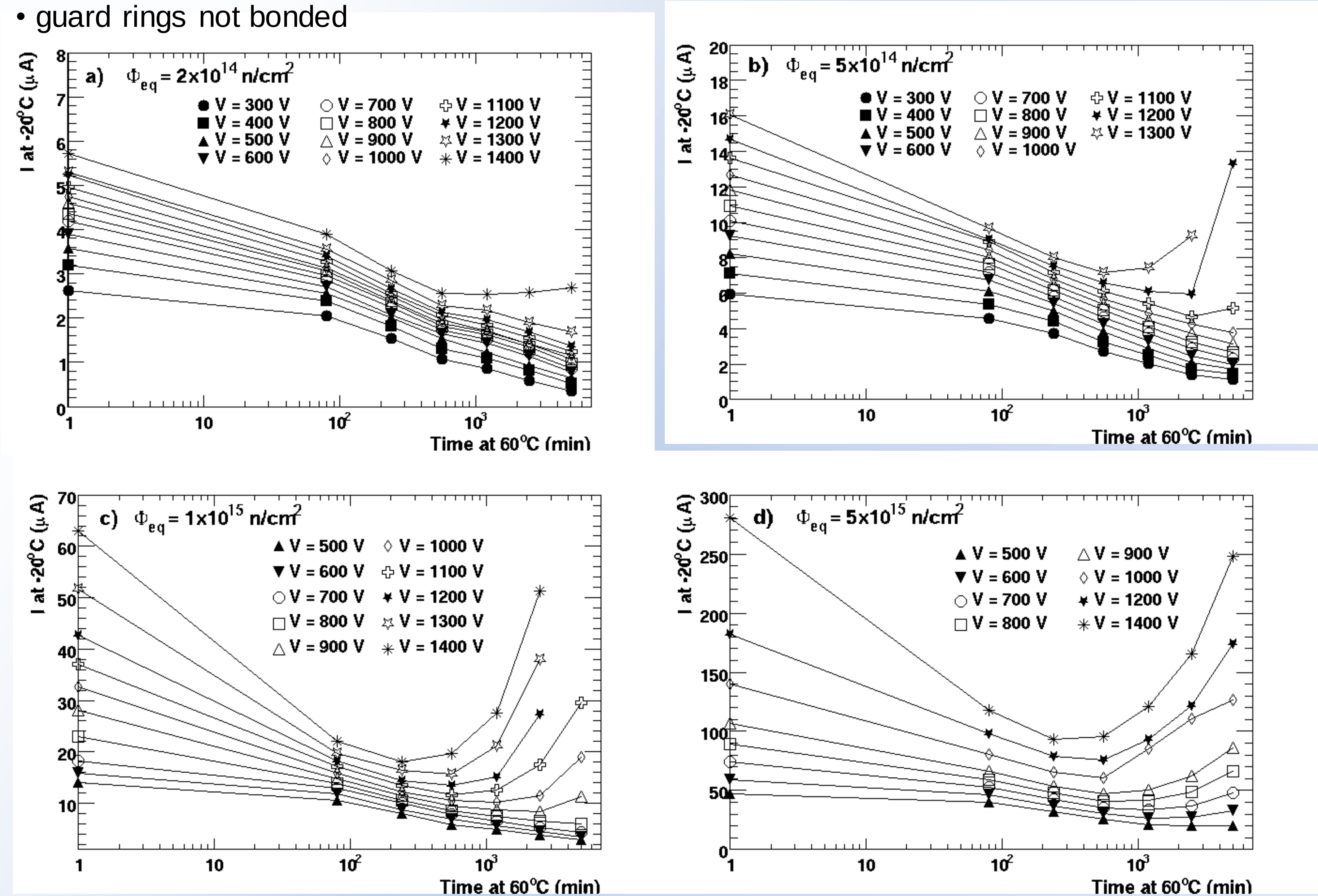
Noise



ENC (ke)
0.8
0.6
0.4
0.2
0
100
200
300
400
500
600
Time at 20 °C (days)
500 V
600 V
700 V
800 V
900 V
1000 V
1100 V

Leakage current

- guard rings not bonded



- Increase of leakage current with annealing ➔ multiplication

CONCLUSIONS

Annealing of the CC(V) and the reverse current emerges as a safety margin to be used when silicon sensors need to be operated at critical conditions. It looks that annealing scenario can be drafted with "ease": before annealing takes the sensors to a "negative" mode of operation, a significant amount of time at room temperature needs to elapse. More care needs to be taken if a proper acceleration is required. A number of systematic results both with diodes and segmented sensors would solidify our annealing recommendation to the experiments (an easy to apply model should be prepared).