Update on accelerated and room temperature annealing of the CC(V) of irradiated silicon sensors

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CONTEXT:

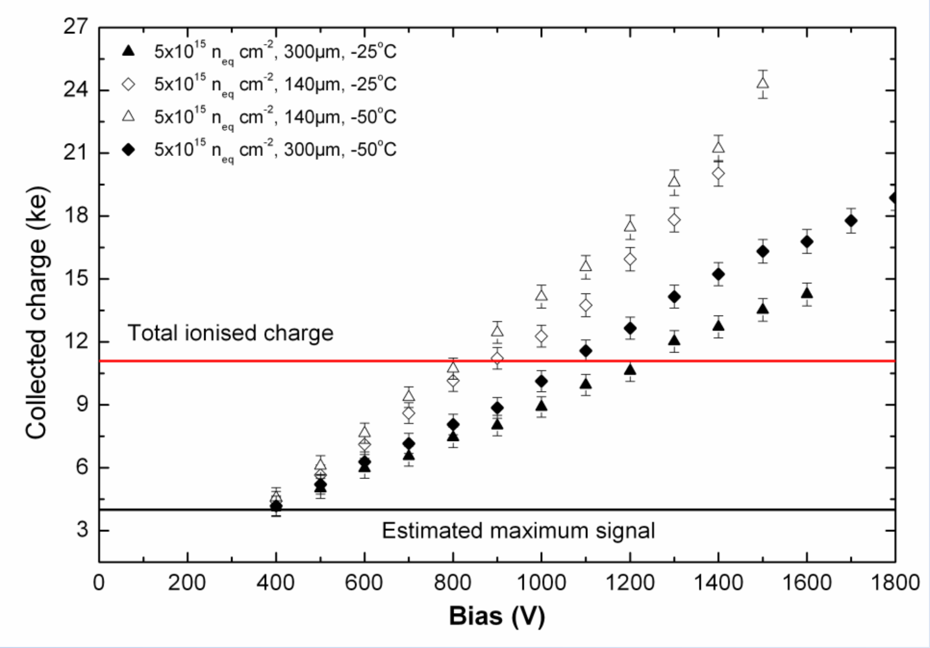
Accelerated annealing is a valuable tool for establishing the running scenario of the sensors installed in the experiments, undergoing severe hadron irradiation. Besides, the comparison of the properties of different sensors irradiated to equal doses has to take into account the effect of the annealing, 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^{o}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!

140 and 300 μm n-in-p Micron microstrip sensors after 5×10^{15} n_{eq} 26MeV p

Evidence of a charge multiplication effect: not only the whole charge is recovered, but increased by f = 1.75/2.1

This effect is probably crucial in annealing.



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

40 ^{o}C f = 30

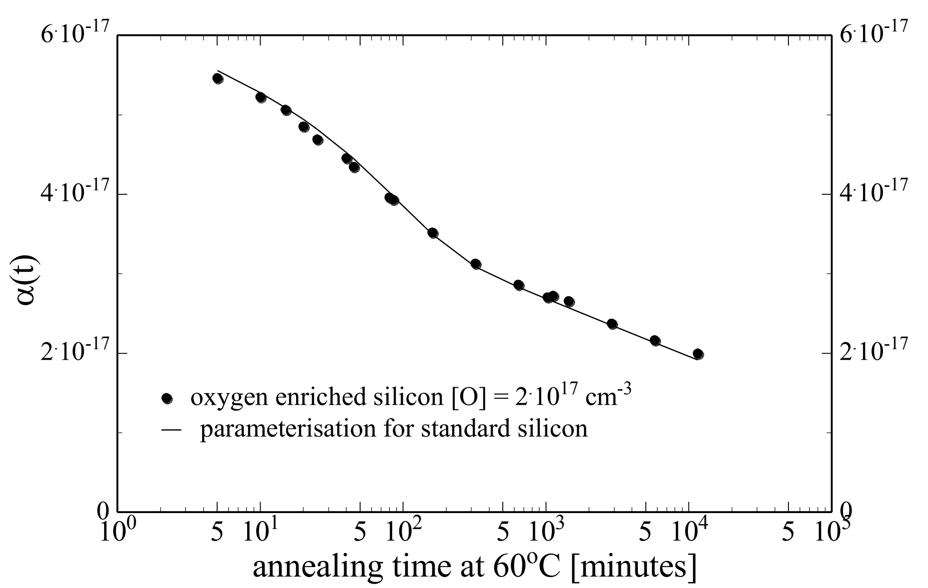
60 ^{o}C f = 550

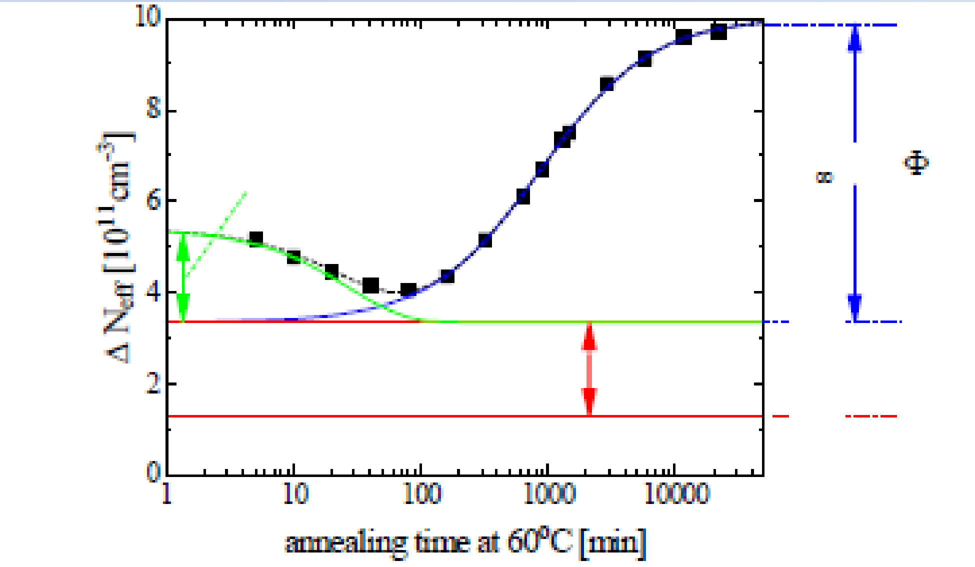
80 ^{o}C f = 7400

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

Using fixed annealing time for comparison of the electrical properties

Reverse current and full depletion voltage



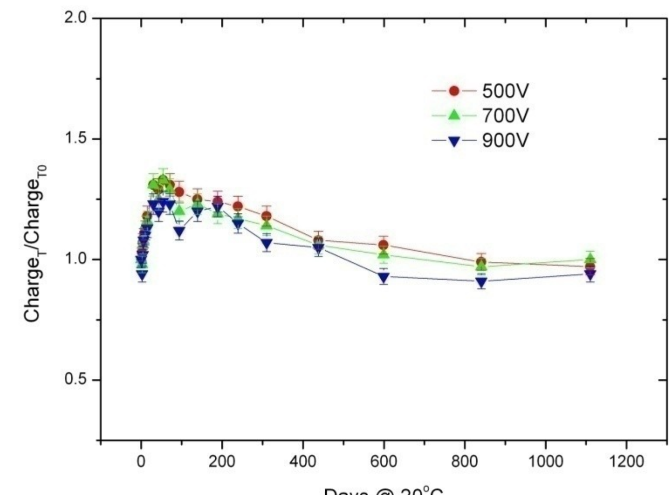


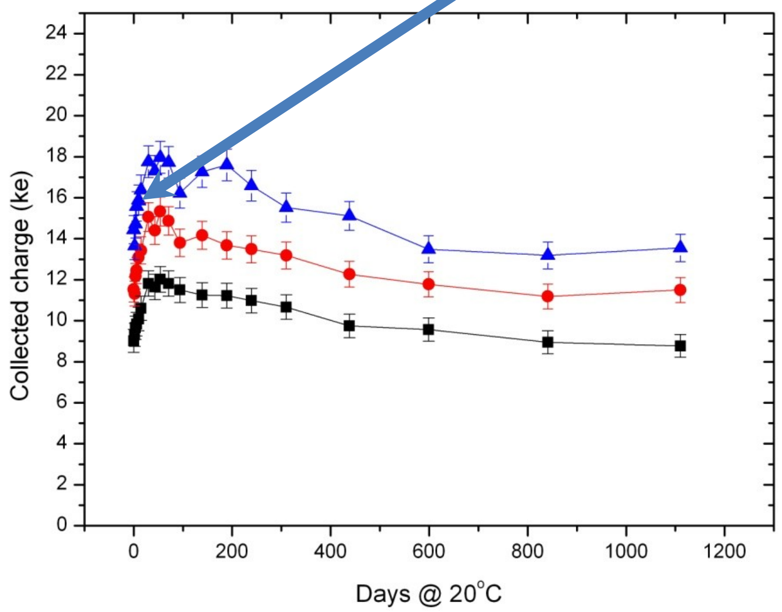
Data from M. Moll

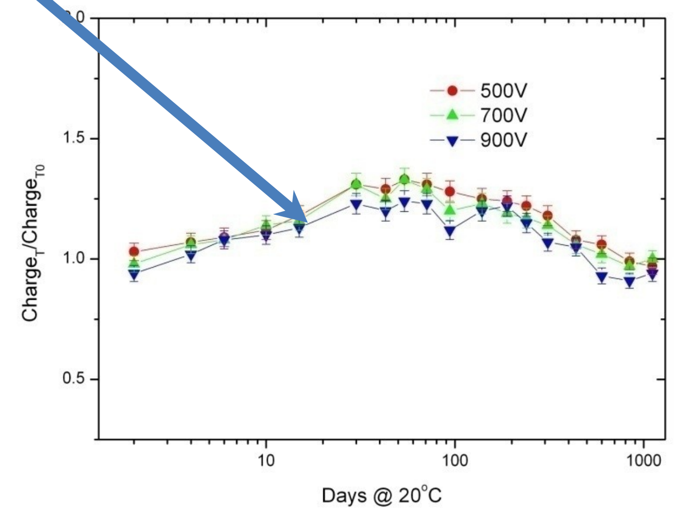
Using fixed annealing time for comparison of the electrical properties

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

80 minutes at 60^{o}C (30 days at RT).

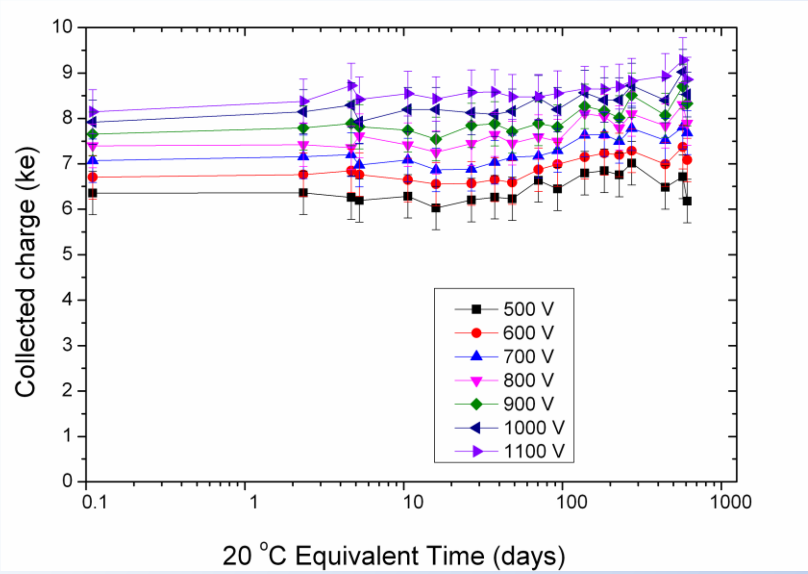






Neutron irradiations in Ljubljana.

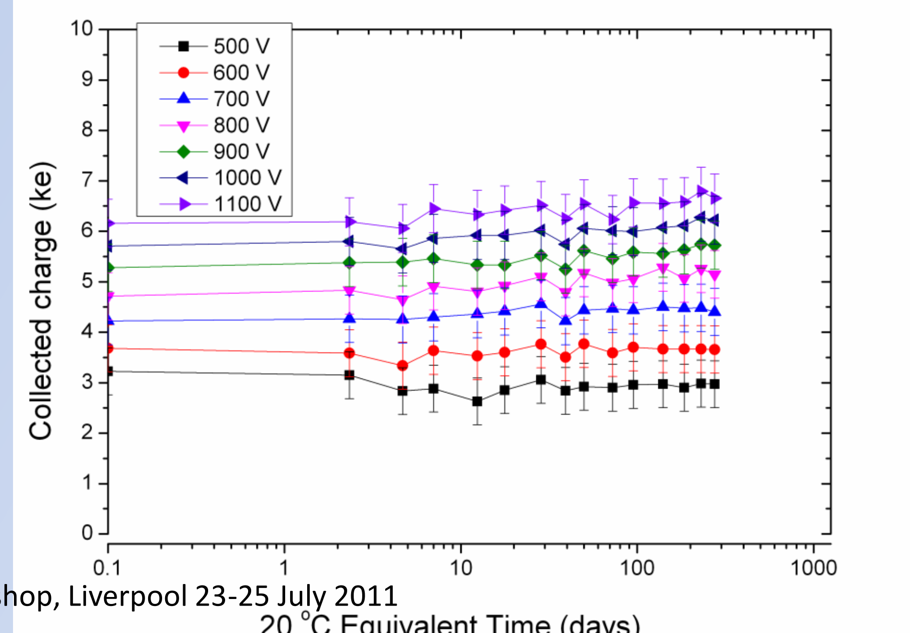
Accelerated CCE Annealing 5 and 1.5E16 n cm^{-2}



$5x10^{15}$ n_{eq} cm^{-2}
Irradiated with 26MeV protons (Karlsruhe).

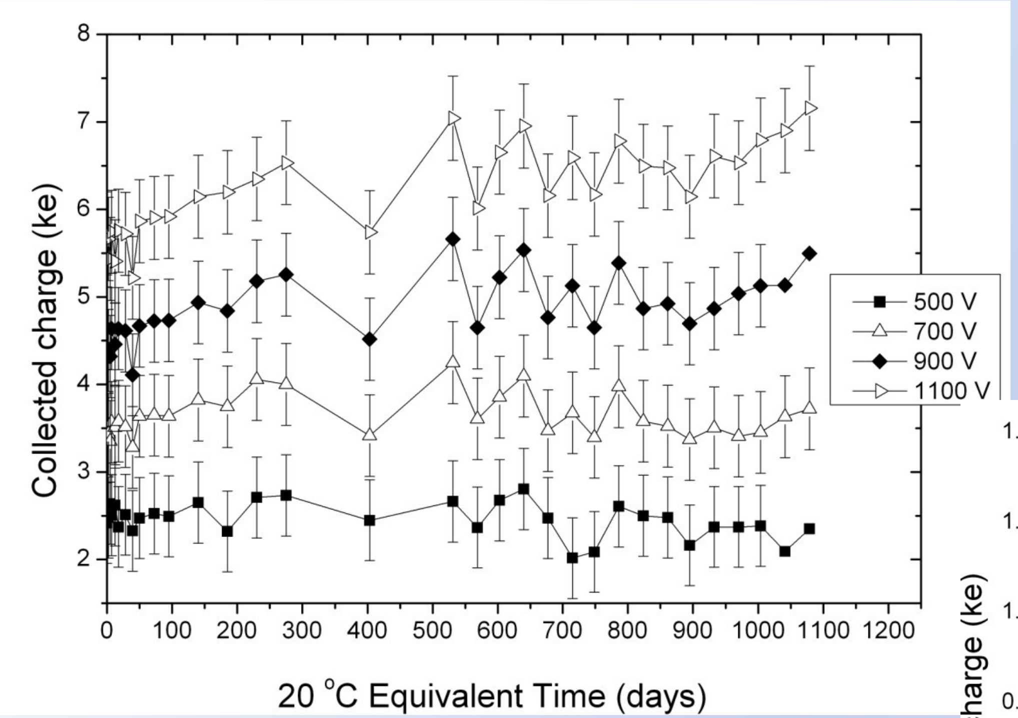
$1.5x10^{16}$ n_{eq} cm^{-2}
Irradiated with 26MeV protons (Karlsruhe).

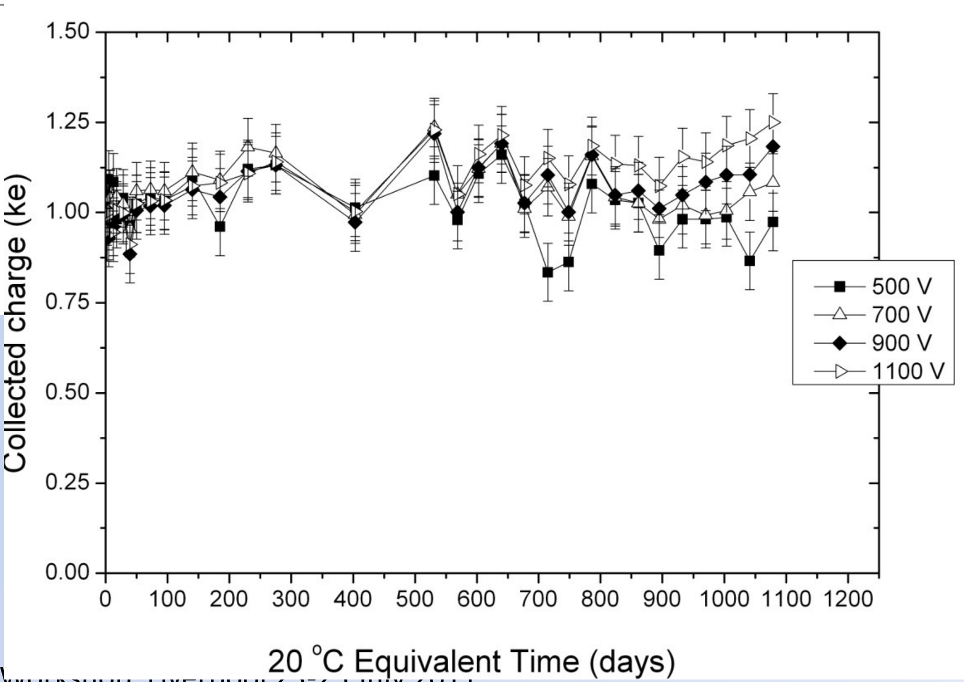
Accelerated annealing at 40, 60 and 80^{o}C. Alibava DAQ based on Beetle chip.



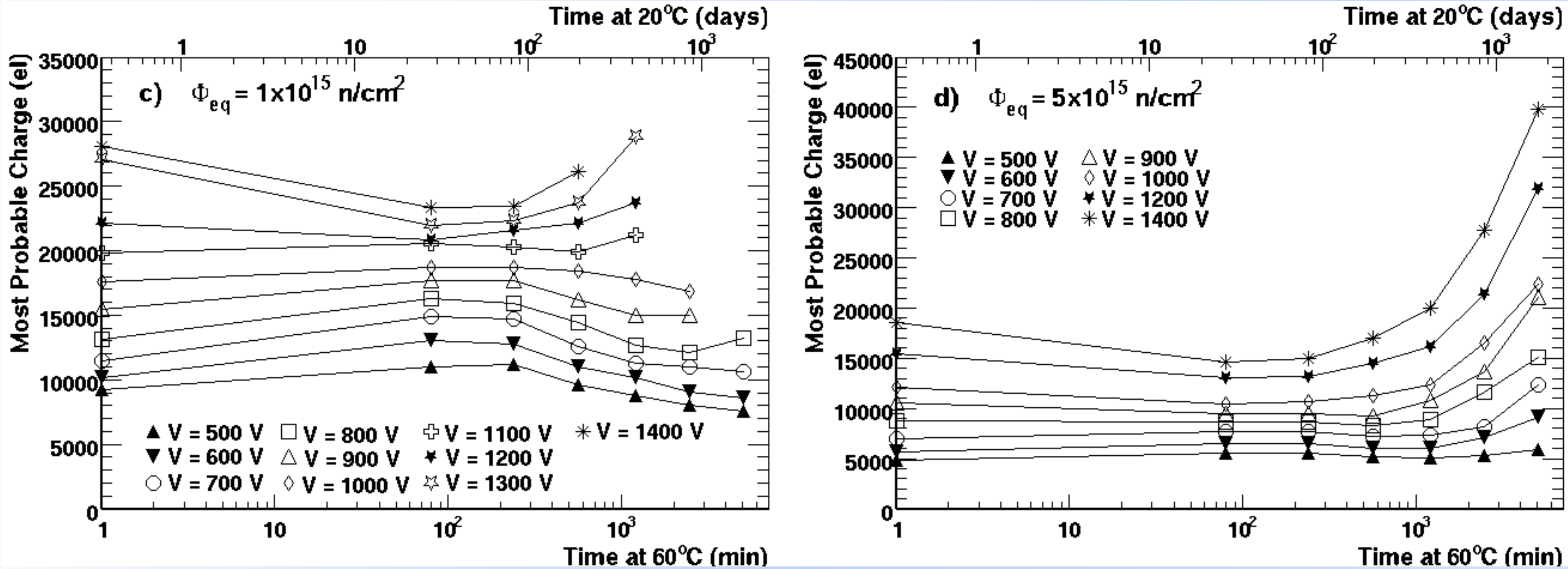
Accelerated CCE Annealing 1.5E16 n_{eq} cm^{-2} (Micron sensors)

Irradiated with 26MeV protons (Karlsruhe).





Annealing of collected charge

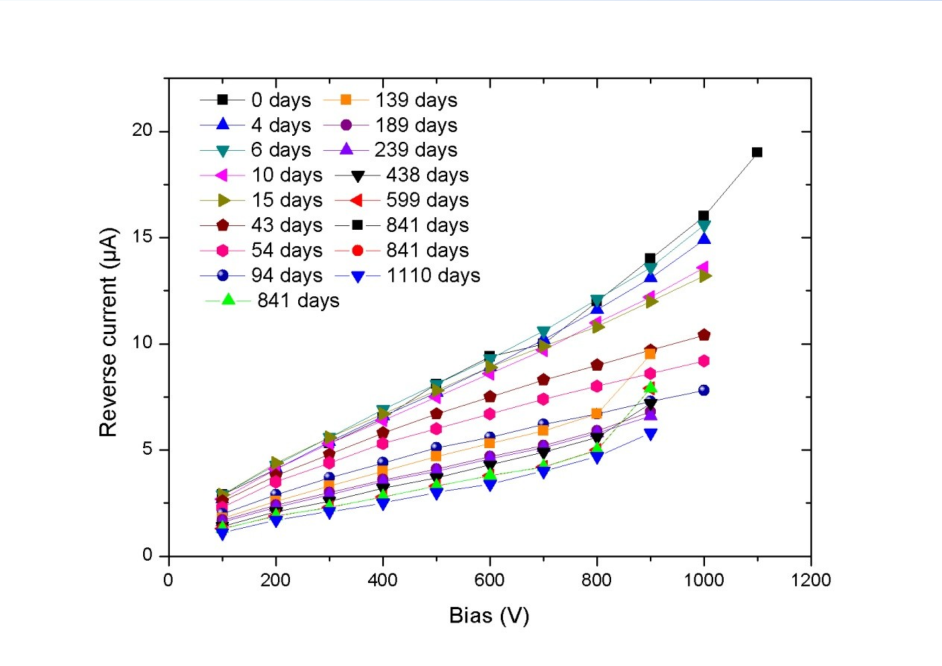


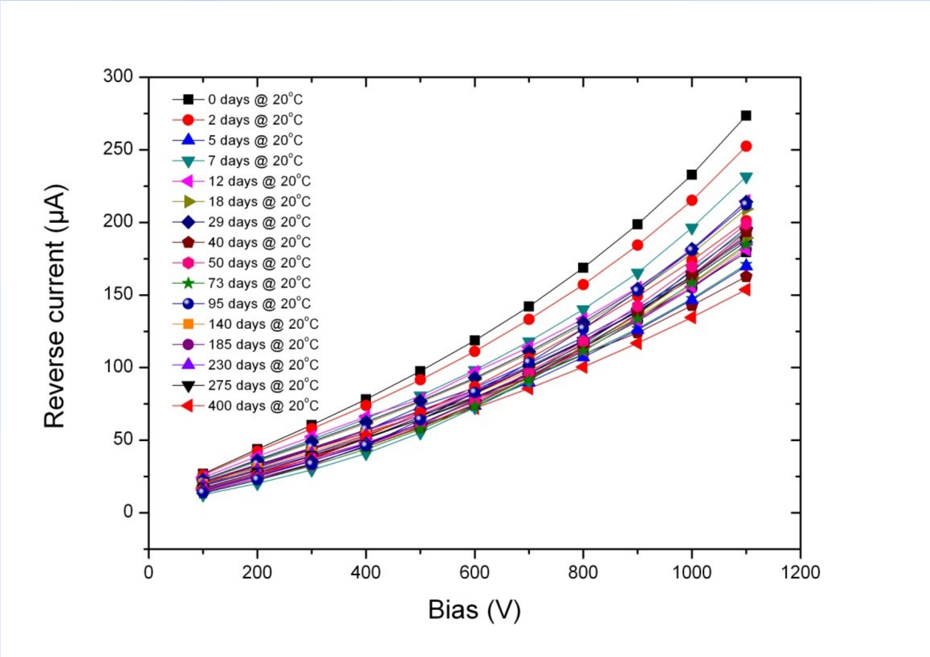
High fluences, high voltages:

- Most probable charge drops due to short term annealing:
  ➔ N_{eff} drops → smaller peak electric field → less multiplication
- Most probable charge rises due to long term annealing:
  ➔ N_{eff} rises → larger peak electric field → more multiplication
- Breakdown voltage is lower at $5\cdot10^{14}$ and $1\cdot10^{15}$ than at $2\cdot10^{14}$ and $5\cdot10^{15}$
  ➔ for detectors irradiated to $5\cdot10^{14}$ and $1\cdot10^{15}$
  breakdown voltage decreases with reverse annealing

I. Mandić, 17th RD50 Workshop, CERN, 17 – 18 November 2010

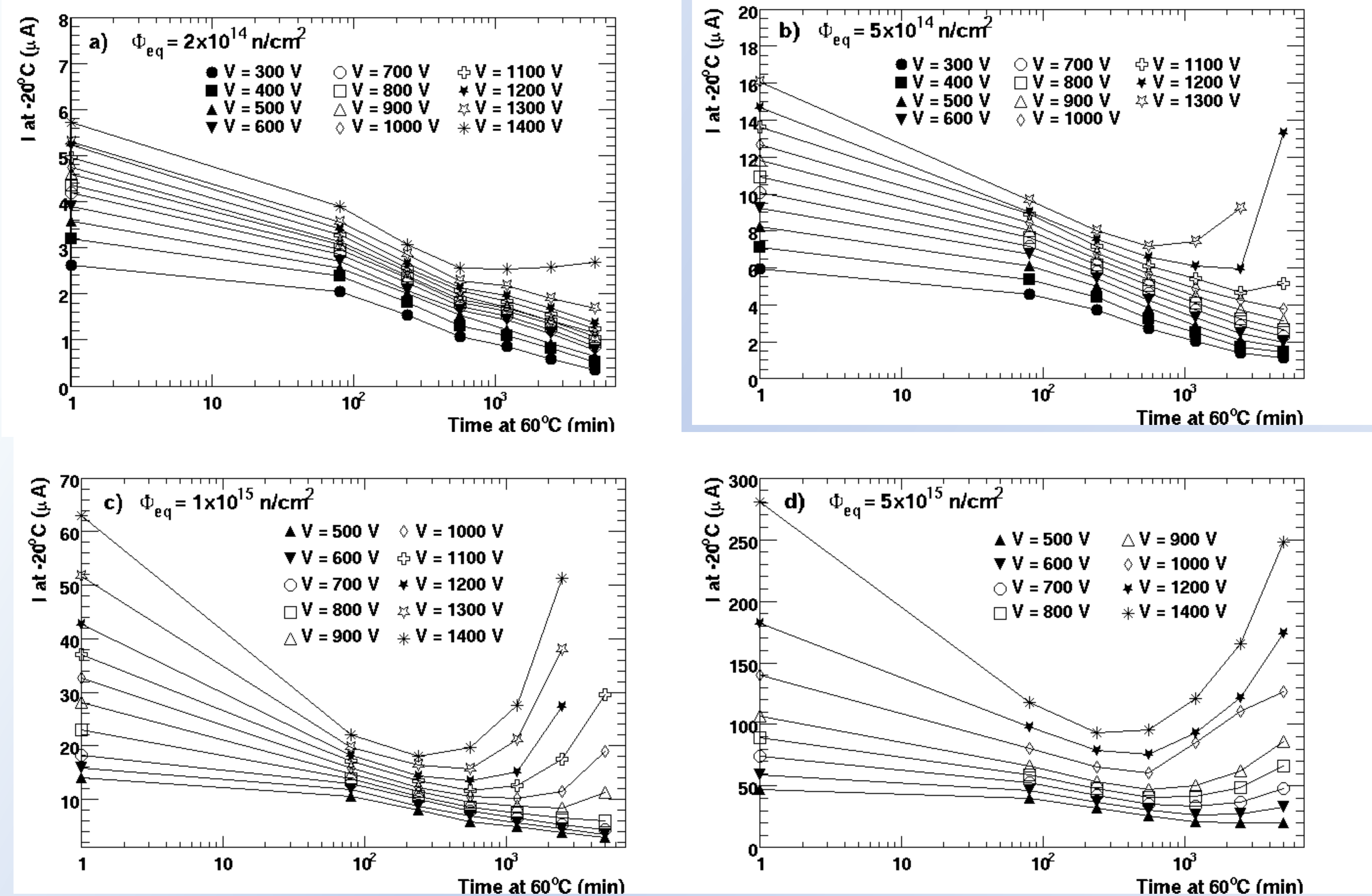
Accelerated Annealing of the reverse current, n-in-p sensors, 1E15 and 1.5E16 n cm^{-2}





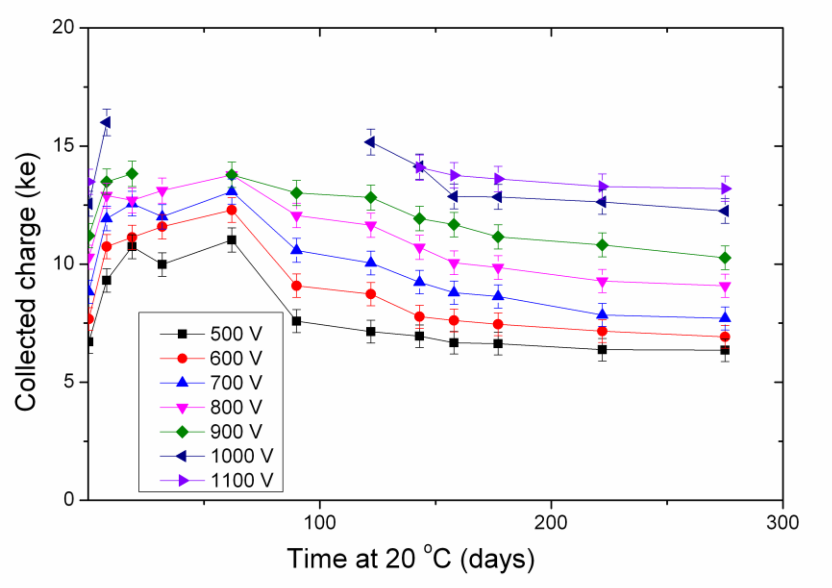
Leakage current

• guard rings not bonded

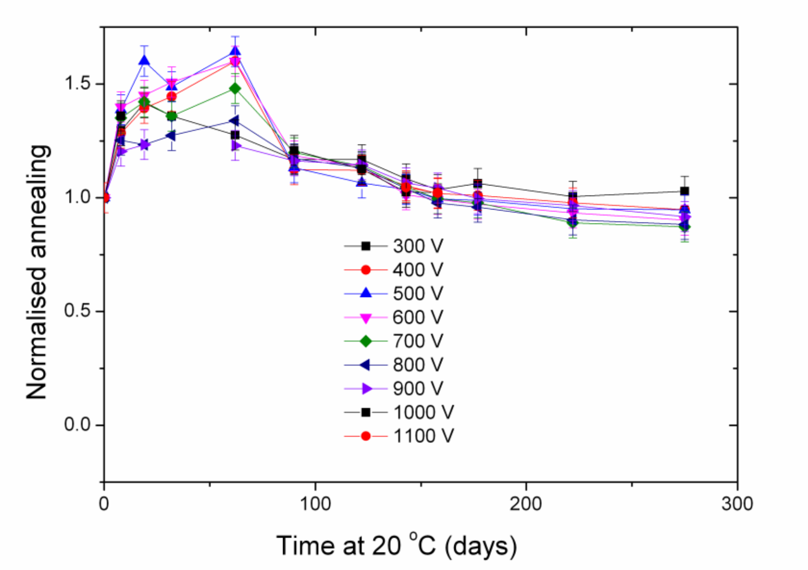


• Increase of leakage current with annealing ➔ multiplication

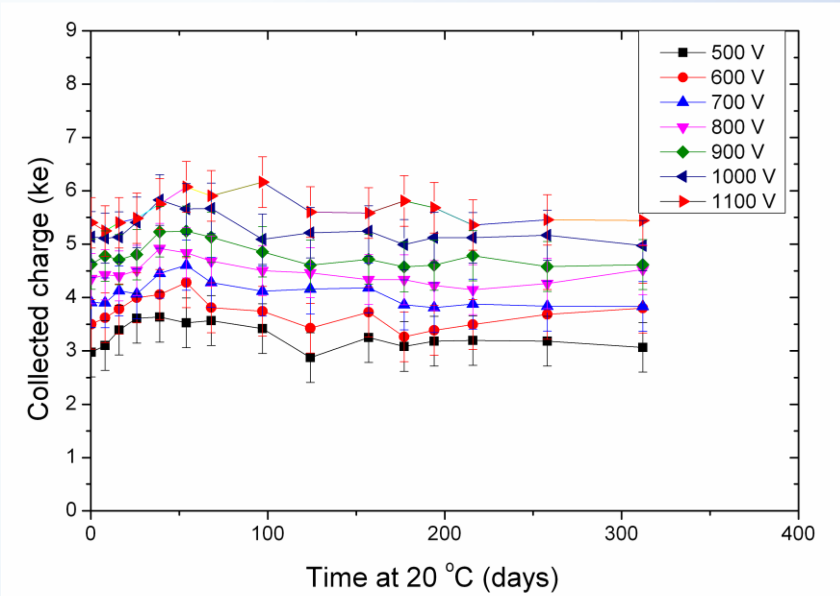
Room Temperature Annealing of the collected charge, HPK FZ n-in-p, 2E15 n cm^{-2} (26MeV p irradiation)



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



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



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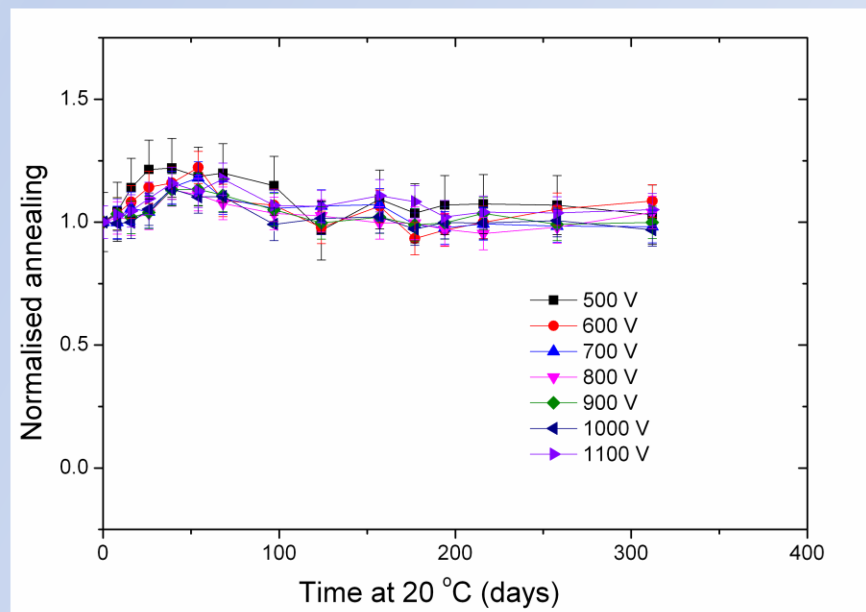
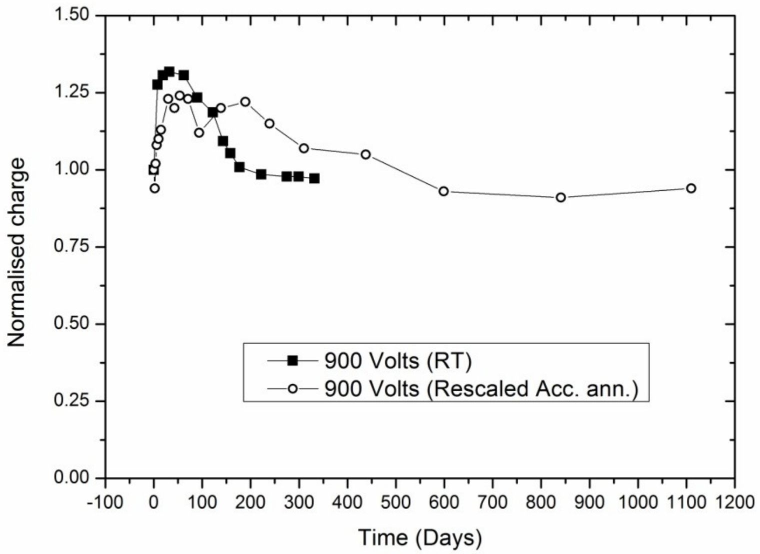
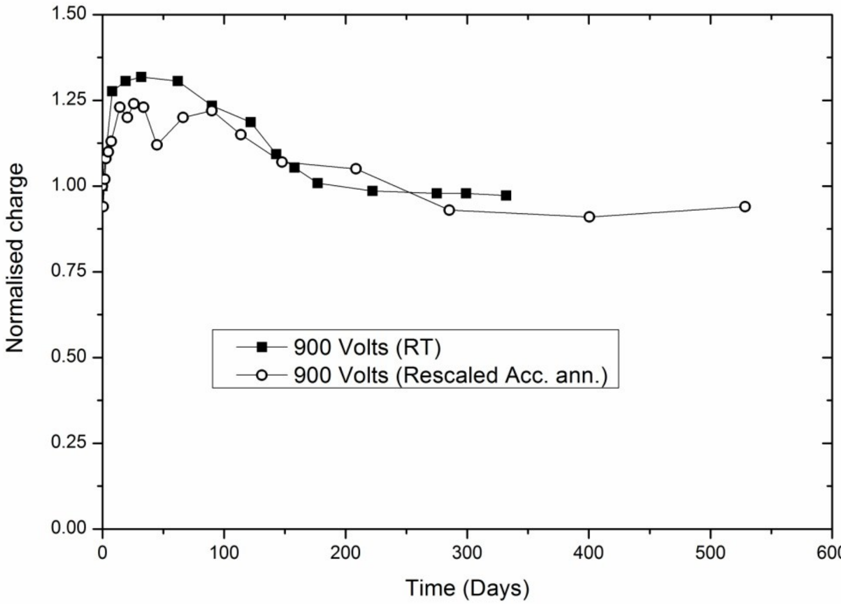


Comparison of Room Temperature and Accelerated Annealing of the collected charge, HPK FZ n-in-p, 1and 1.5E15 n cm^{-2} (26MeV p irradiation)

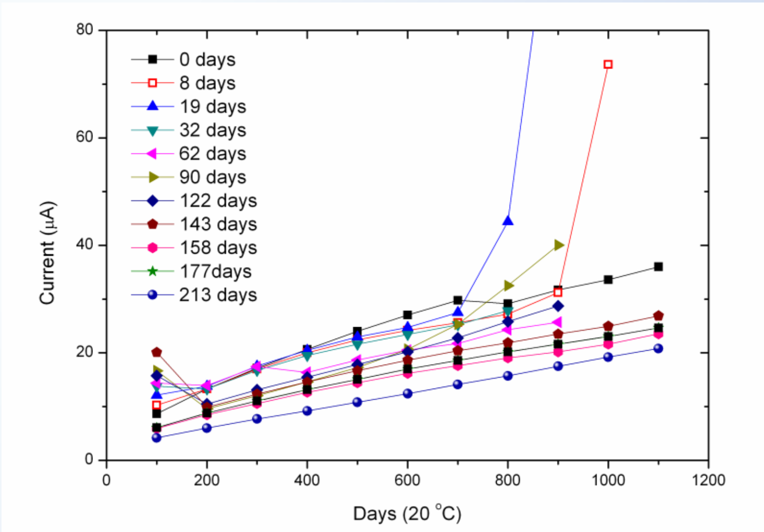


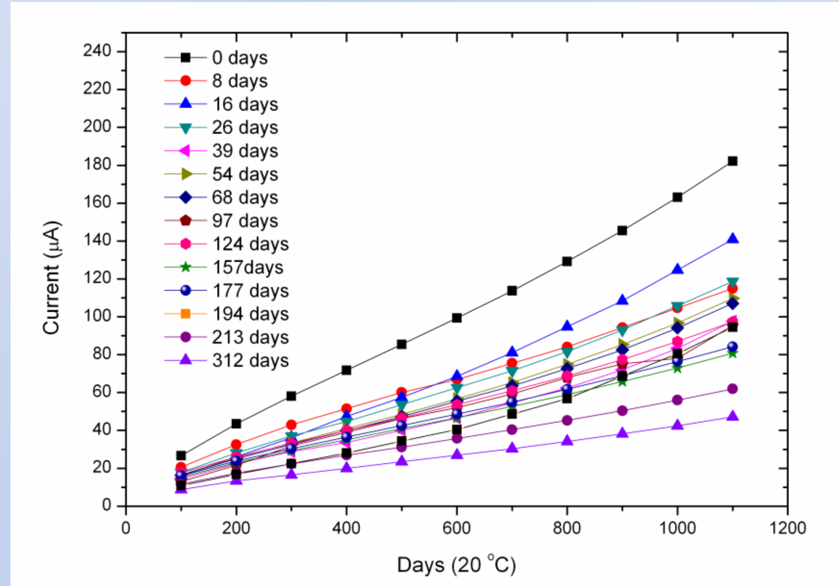
Accepted acceleration factor



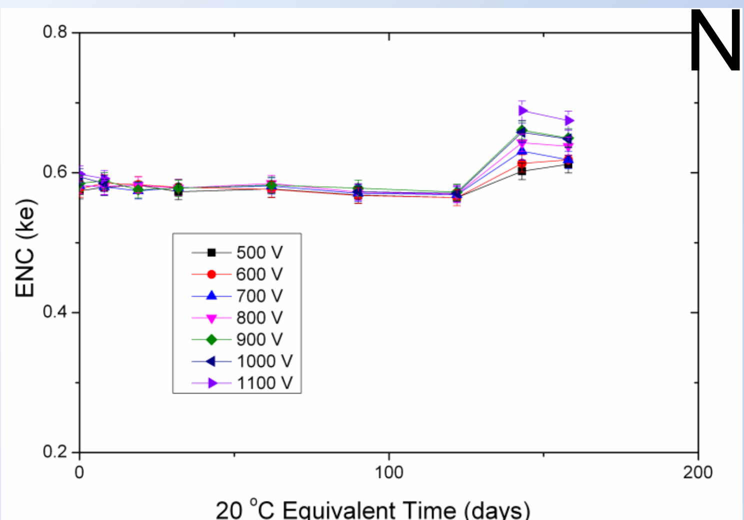
Acceleration factor divided by 2.1

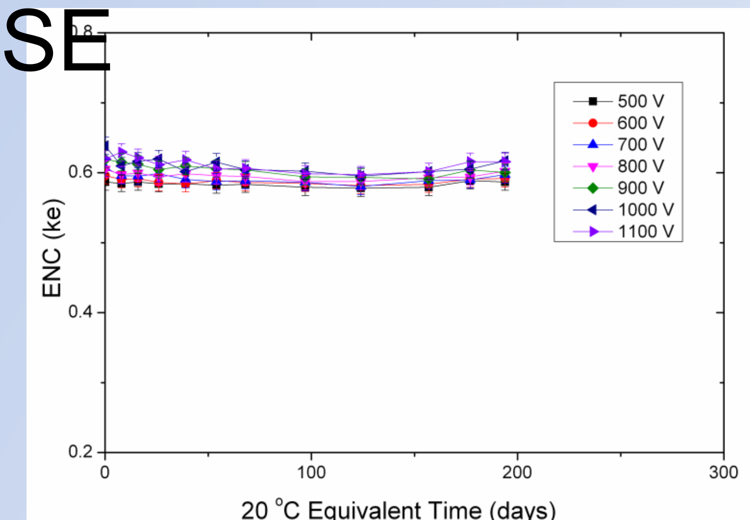
Room Temperature Annealing of the reverse current, n-in-p sensors, 0.2 and 1E16 n cm^{-2} (26MeV p irradiation)





NOISE





CONCLUSIONS

The annealing of the CC(V) shows discrepancies from the accepted rescaling of the time axis with temperature. The discrepancy is evident for the measurements with sensors irradiated up to 1-2E15 n_{eq} cm^{-2} (need more dense data as a function of fluence to clarify this point). At higher doses the difference seems smaller (trapping/charge multiplication dominated)? The reverse current has qualitatively a similar reduction (accelerated and RT). A more accurate measurement, making use of a better heat sink (possibly using pad sensor in thermal contact with a big mass) can give a more accurate insight.

Controlled annealing (at 20^0C) is still a very useful tool to reduce power dissipation and recover fraction of S/N in heavily irradiated silicon detectors. The discrepancies between the accelerated and RT annealing need to be studied to base the prediction for the changes of CCE with time according to the real operation and maintenance temperatures in the experiments.

An annealing procedure for comparison of the detector properties could be agreed instead of the present 80 minutes at 60^oC?