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Can we claim charge multiplication in heavily irradiated segmented detectors?

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OUTLINE

- Comparison of thin and thick sensors after proton irradiation
- Studies at low temperature (-50^{o}C)
- Non-linearity of N_{eff} vs Φ
- Conclusions

Irradiations:

24GeV/c protons Irrad1 CERN/PS: shuttle at Room Temperature (~30^{o}C) and cold (<5^{o}C) irradiations. Many thanks to M. Glaser.

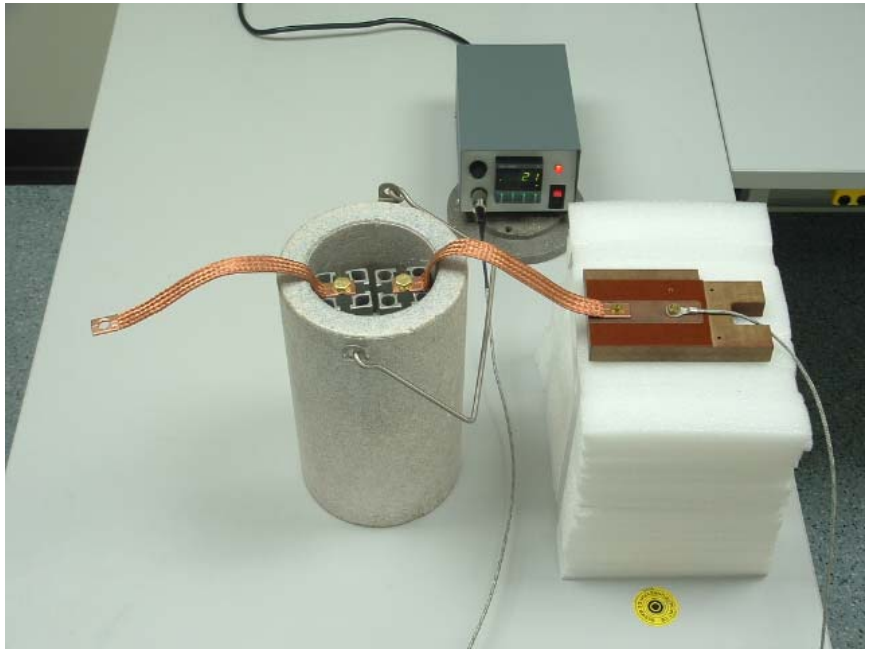
26MeV p, Karlsruhe Cyclotron, cold. Many thanks to A. Dierlamm and W. De Boer

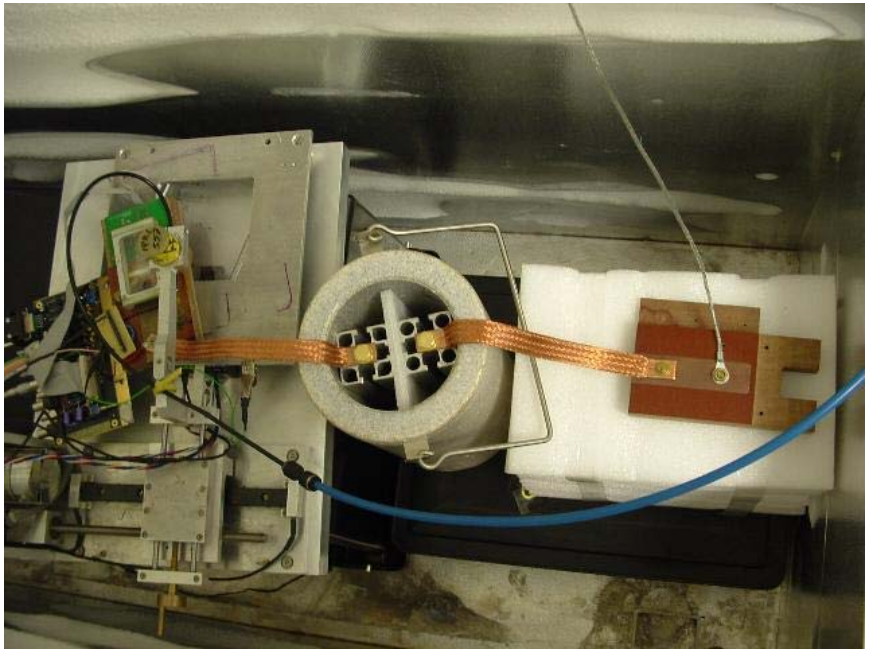
Samples:

140 and 300μm thick miniature strip sensors, 1x1 cm^2 produced by Micron on RD50 4" mask.

MEASUREMENTS: at -25 and -45/50 °C.

Rather nice and efficient method to have almost stable temperature using liquid N for cooling

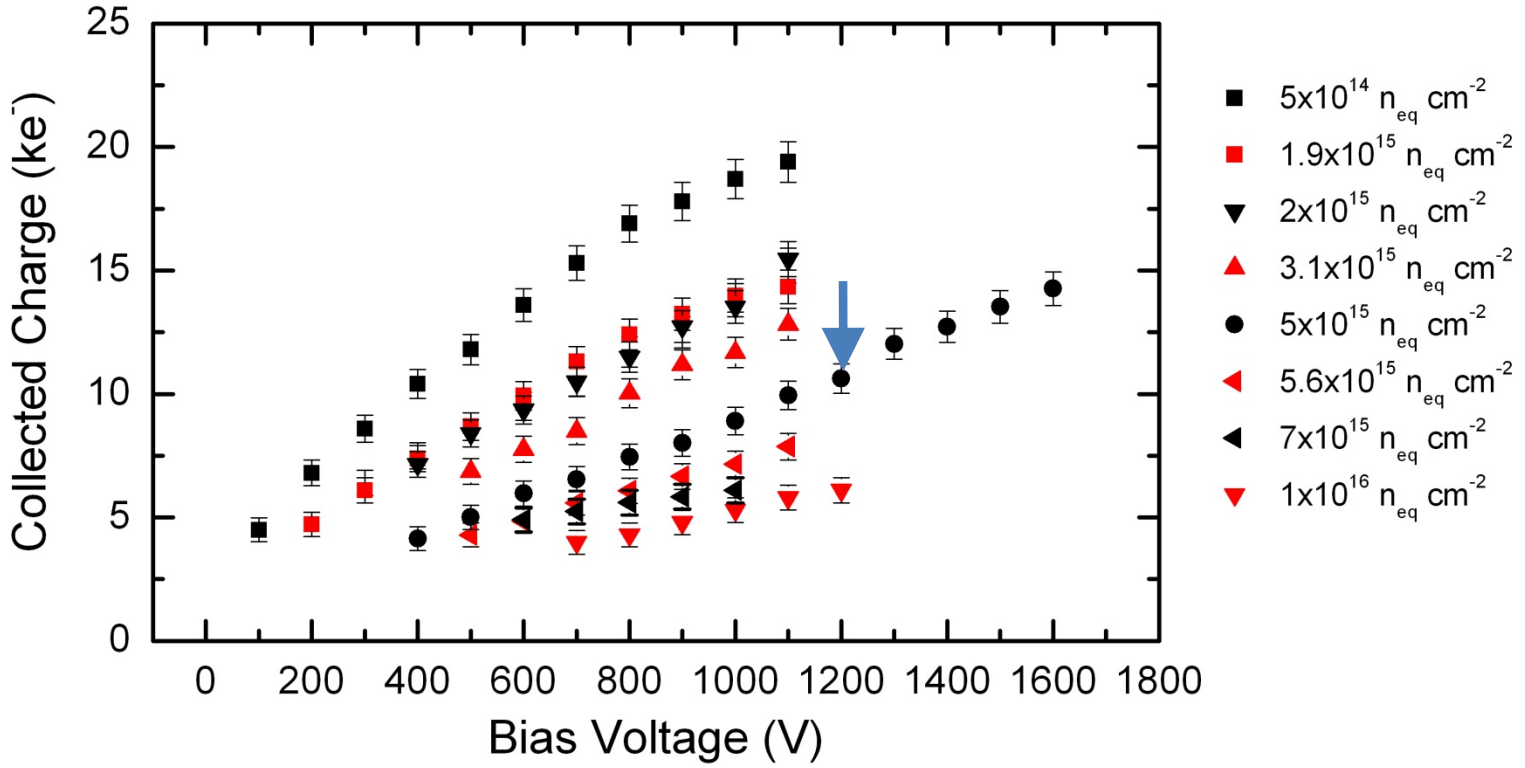




300 mm n-in-p Micron sensors

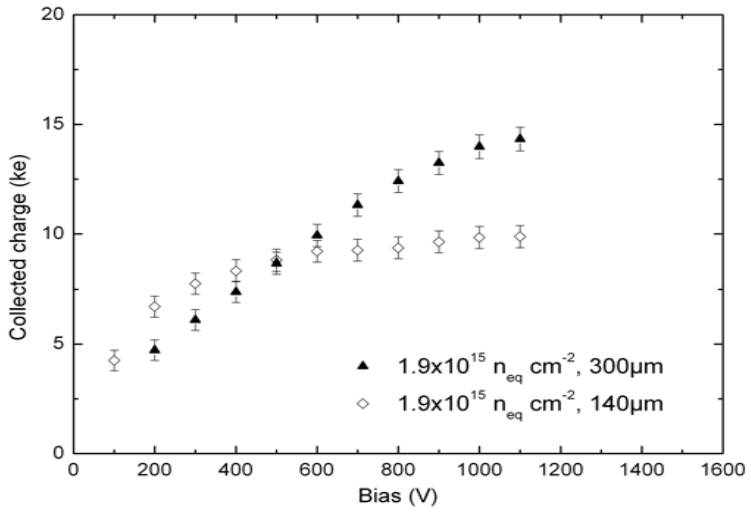
RED: irradiated with 24GeV/c protons
Other: 26MeV protons

24GeV/c protons irradiated COLD, all but the 3.1E15 cm^{-2} series

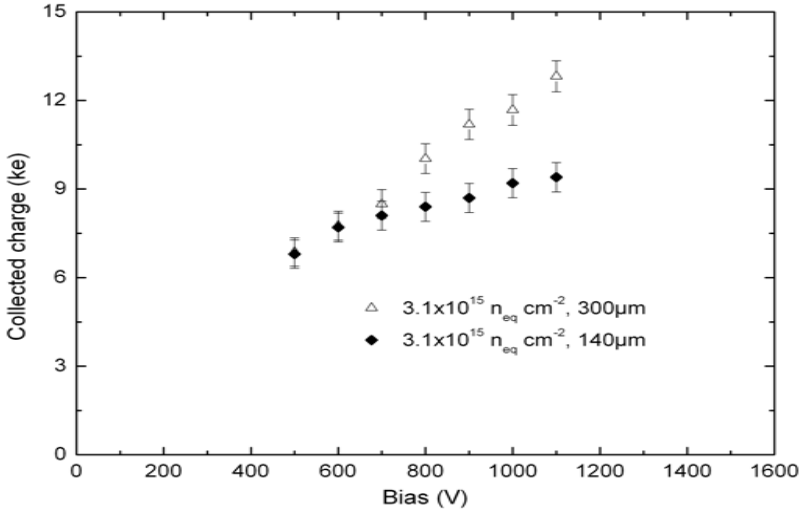


140 and 300 μm n-in-p Micron sensors after 1.9 and 3.1x10^{15} n_{eq} 24GeV/c p

Cold(0-5 ^{o}C) irradiation

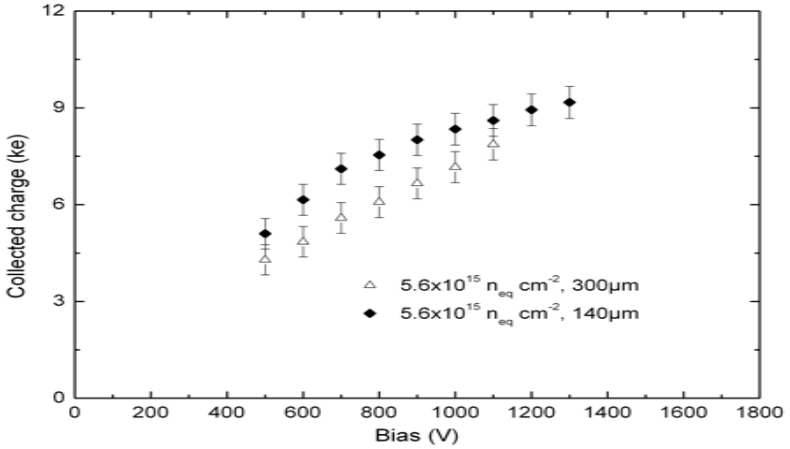


Room T (29-31 ^{o}C) irradiation

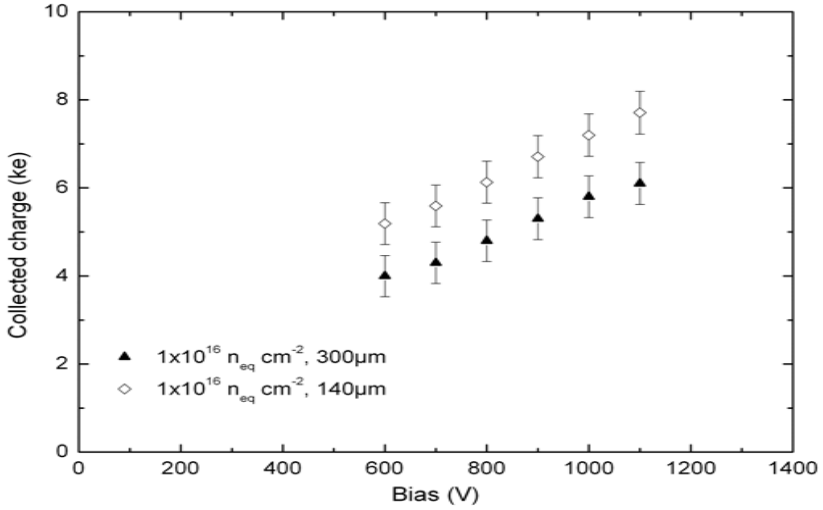


140 and 300 μm n-in-p Micron sensors after 5.6 and $1x10^{16}$ n_{eq} 24GeV/c p

Cold(0-5 °C) irradiation

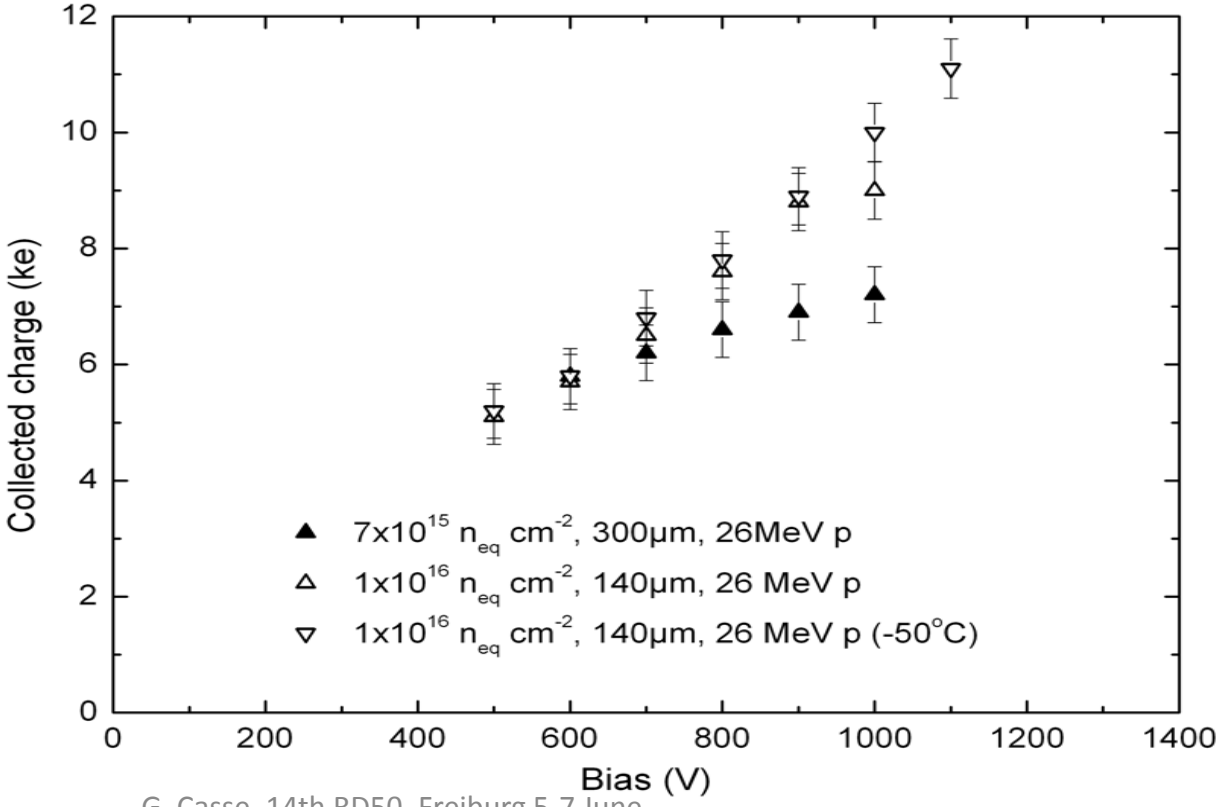


Cold(0-5 °C) irradiation



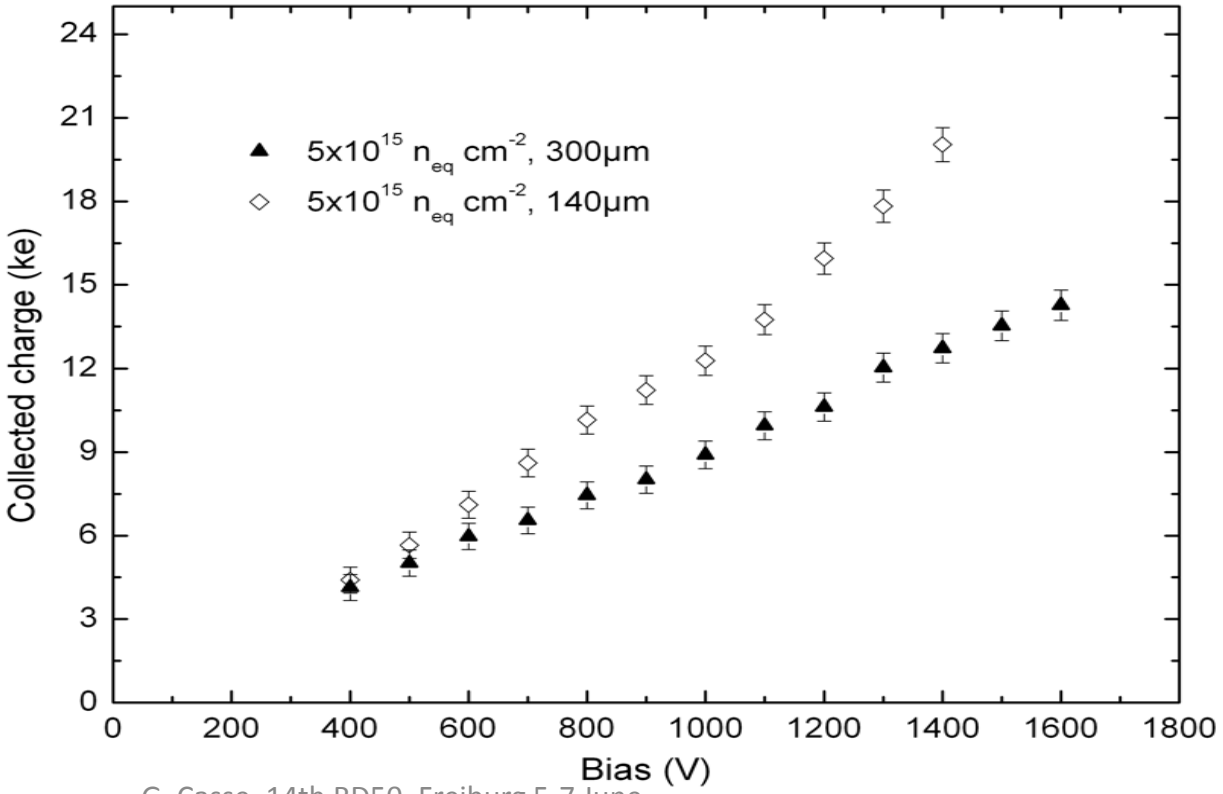
140 and 300 μm n-in-p Micron sensors after $1x10^{16}$ n_{eq} 26MeV p

Evidence for multiplication? Or other effect, like field dependent de-trapping? Even after heavy irradiation it is possible to recover the entire ionised charge.



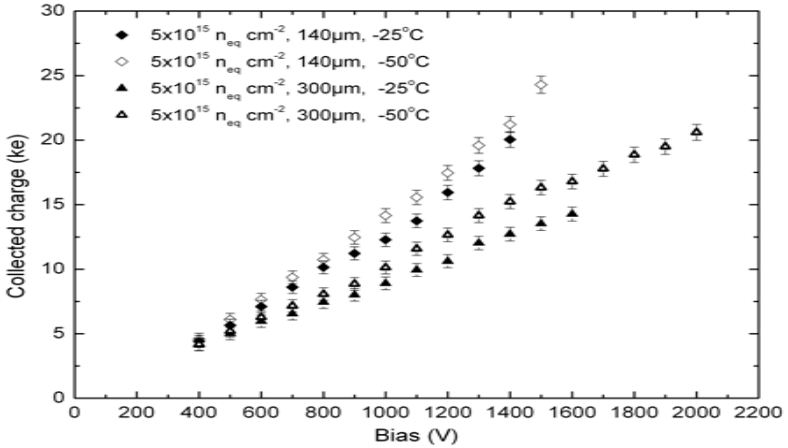
140 and 300 μm n-in-p Micron sensors after $5x10^{15}$ n_{eq} 26MeV p

Cold irradiation, **evidence of charge multiplication effect: not only charge is recovered, but increased by f = 1.75**

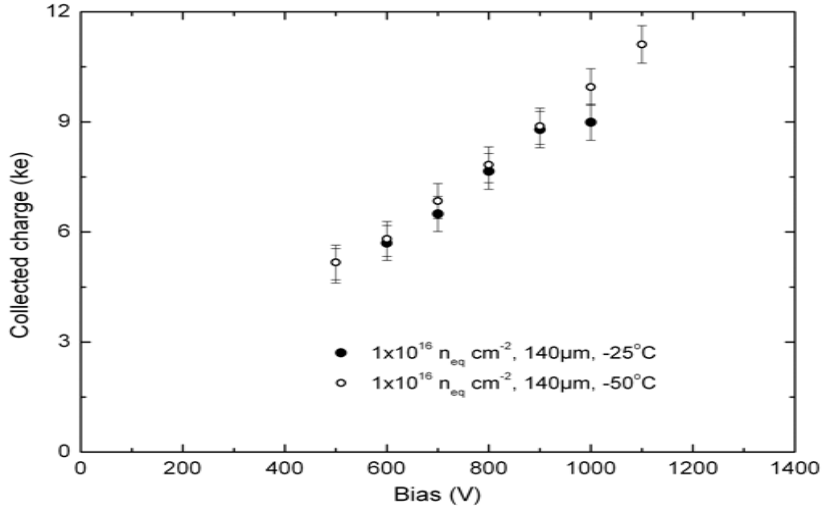


140 and 300 μm n-in-p Micron sensors after 5 (26MeV p) and 10x10^{15} n_{eq} (24GeV/c p) at low (-50°C) T.

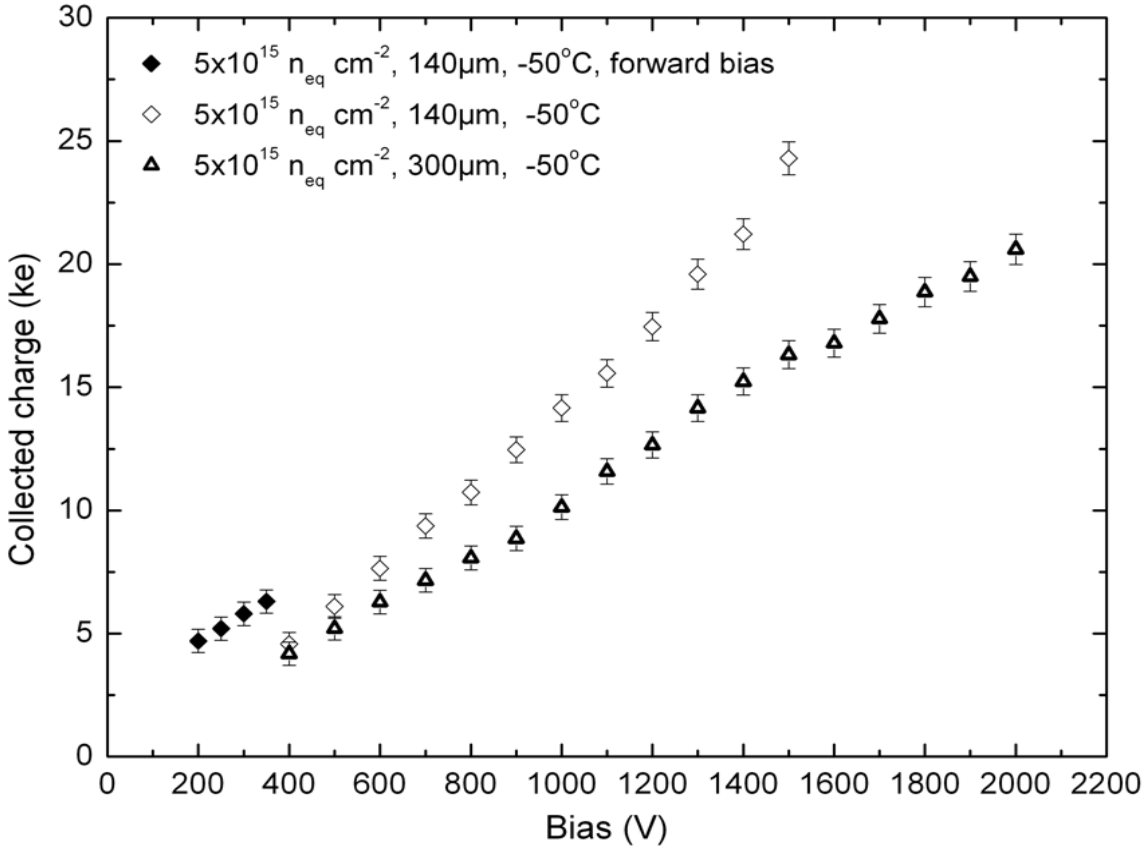
F = 2.1 at -50°C!



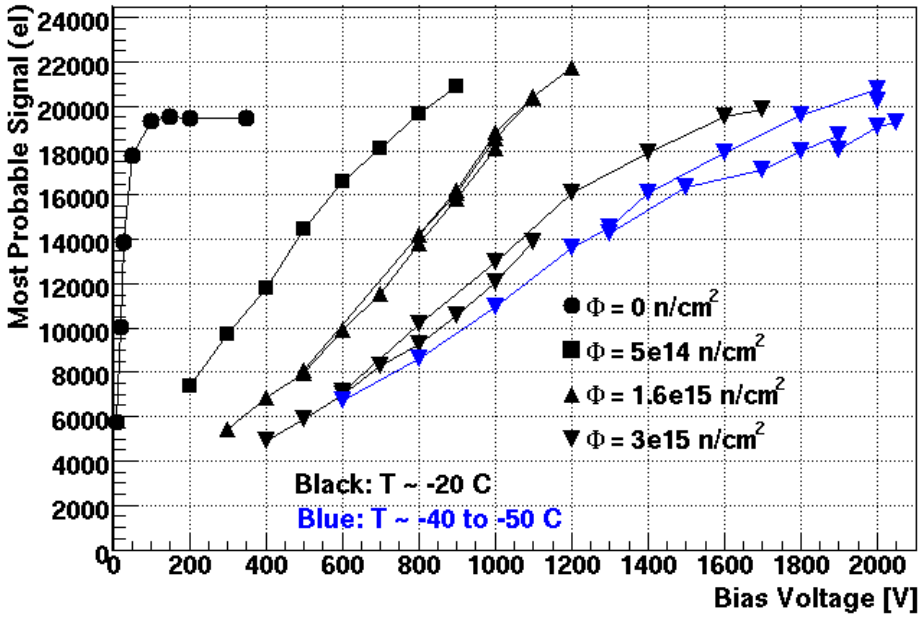
Pre-irradiation charge recovered after 1x10^{16} n_{eq}.



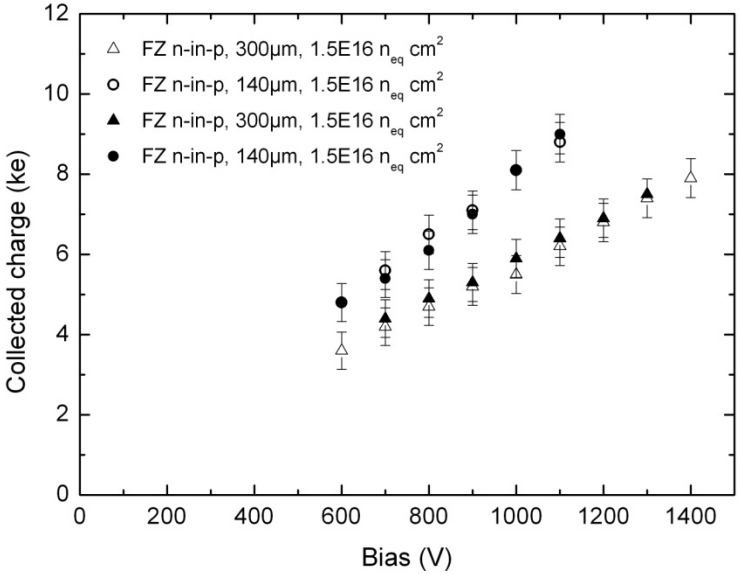
Special effects: forward bias

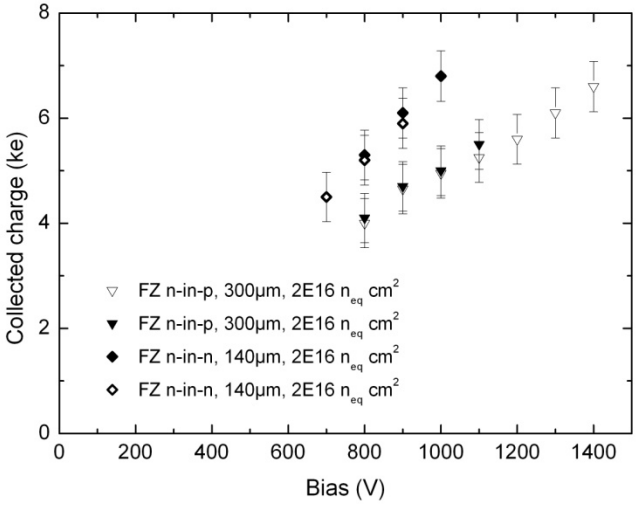


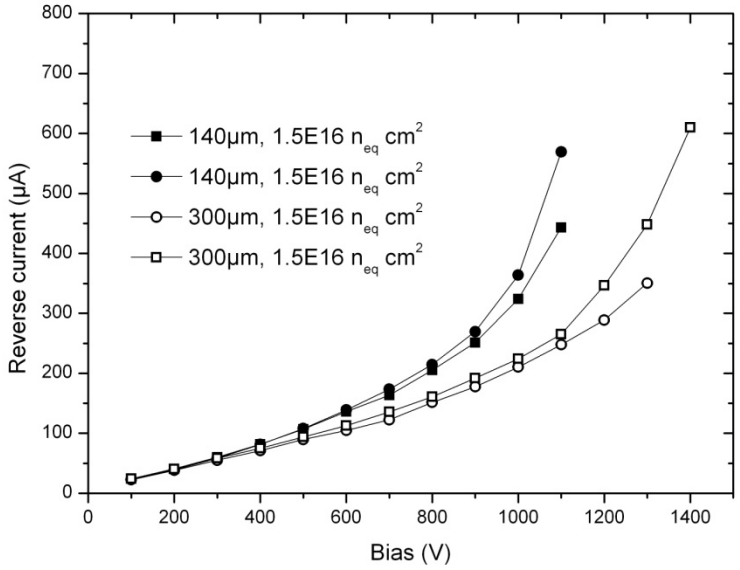
Comment: this multiplication concept takes time to sink-in, but it has been a while since the CCE results puzzled us for being much better than expected from the anticipation of trapping. Just remind another direct result of this, from I. Mandic at the 12th RD50 workshop.

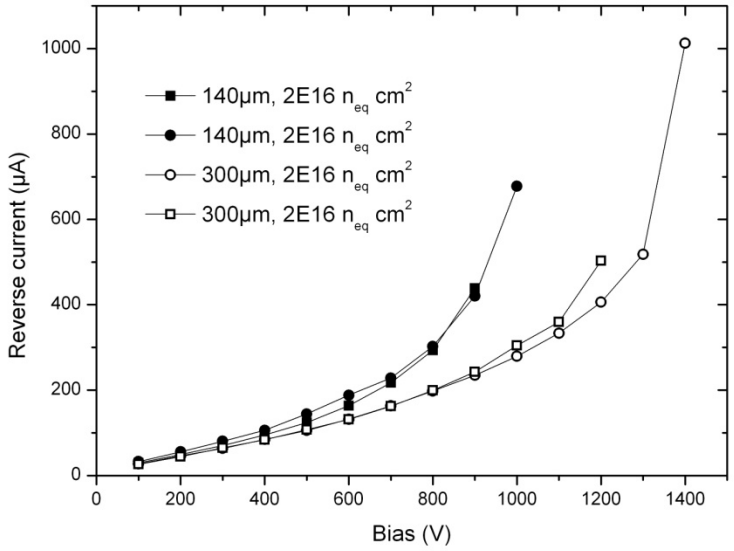


CCE and currents after neutron irradiations

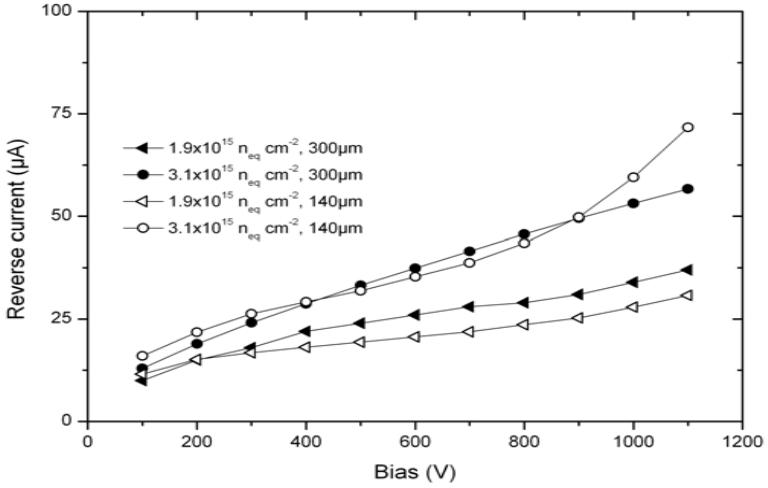


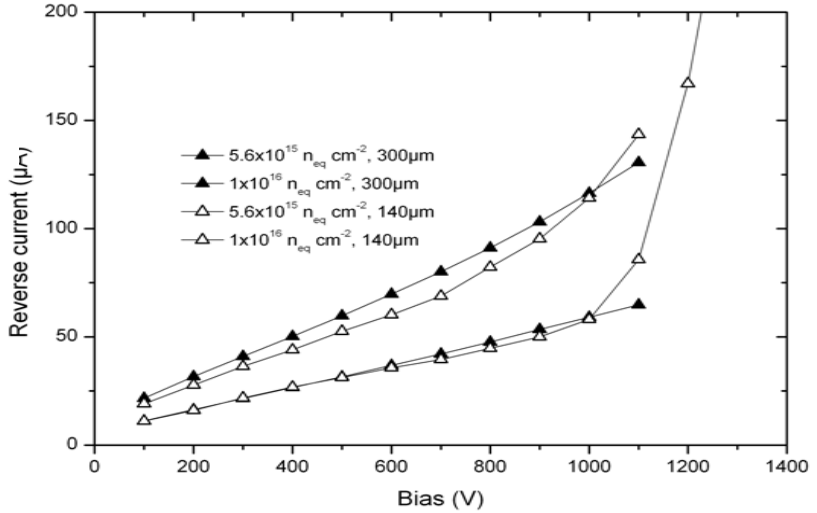






Reverse currents of 140 and 300 μm n-in-p Micron sensors after various proton doses





N_{eff} vs ϕ measured with the CV characteristic of 300 μm n-in-p Micron sensors after 80 min 60^{o}C annealing time

$\beta = 0.028 \pm 0.002\ cm^{-1}$

N_{eff} vs ϕ measured with the CV characteristic of 140 μm n-in-p Micron sensors after 80 min 60^{o}C annealing time

β calculated for dose up to 5×10^{14} n_{eq} cm^{-2}

$\beta = 0.023 \pm 0.002$ cm^{-1}

β calculated for dose up to 5×10^{14} n_{eq} cm^{-2}

$\beta = 0.0022 \pm 0.0003$ cm^{-1}

Seen also by Ljubljana (G. Kramberger et al., 12th RD50 workshop)

CONCLUSIONS

Can we claim charge multiplication in heavily irradiated segmented detectors?

YES, WE CAN!

But for the time being we proved it with Micron detectors only. This could well not be a coincidence, related to the junction formation and depth profile.
But also other effects are contributing to enhancing the collected charge after heavy irradiations: field dependant charge de-trapping(?), lower than expected (non-linear behaviour, saturation?) so-called full depletion. This is nice, more investigations to do!

Spare slides

α (300μm thick) = 3.2×10^{-17} A cm^{-2}.
α (140μm thick) = 2.7×10^{-17} A cm^{-2}.