UNIVERSITY OF LIVERPOOL

Charge collection efficiency and annealing measurements for segmented silicon detectors irradiated to $1x10^{16}$ n cm^{-2}

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Outline

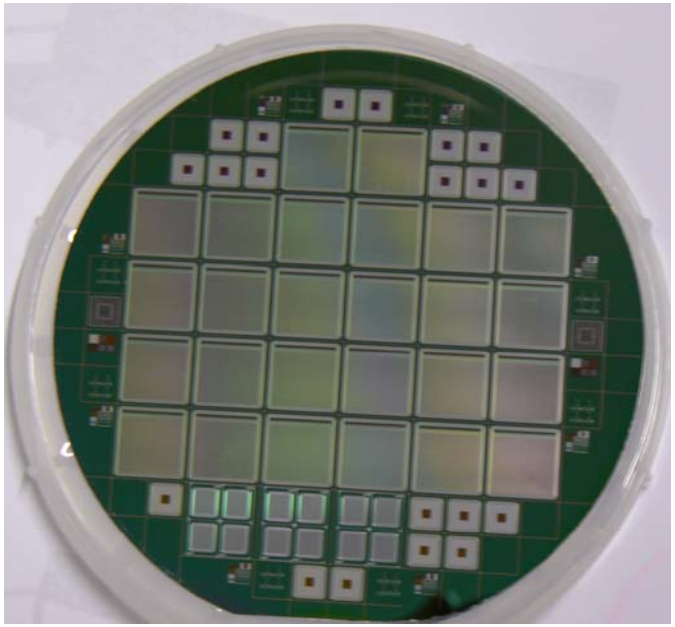
- Detector and experimental description
- Charge collection efficiency vs. resistivity results up to $1x10^{16}$ n cm^{-2}
- Charge collection efficiency vs. annealing results up to $1x10^{16}$ n cm^{-2}
- Summary and future work

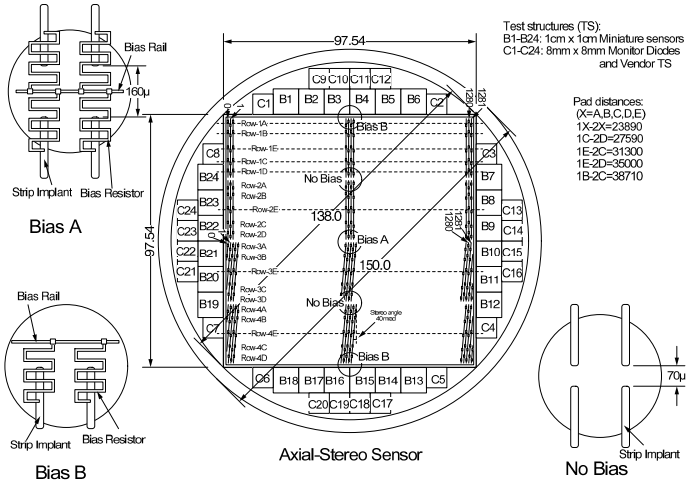
Miniature Silicon Micro-strip Sensors

Mini microstrip, ~1x1 cm^2, ~128 strips, ~80 μm pitch, 300 μm

- Micron/RD50
  - FZ (14 kΩ, 30 kΩ)
  - MCz (1.5 kΩ)
- HPK/ATLAS
  - FZ (5 kΩ)
  - MCz (2.1 kΩ)

Irradiation and dosimetry:
TRIGA Mark II research reactor
Reactor Centre of the
Jozef Stefan Institute, Ljubljana, Slovenia

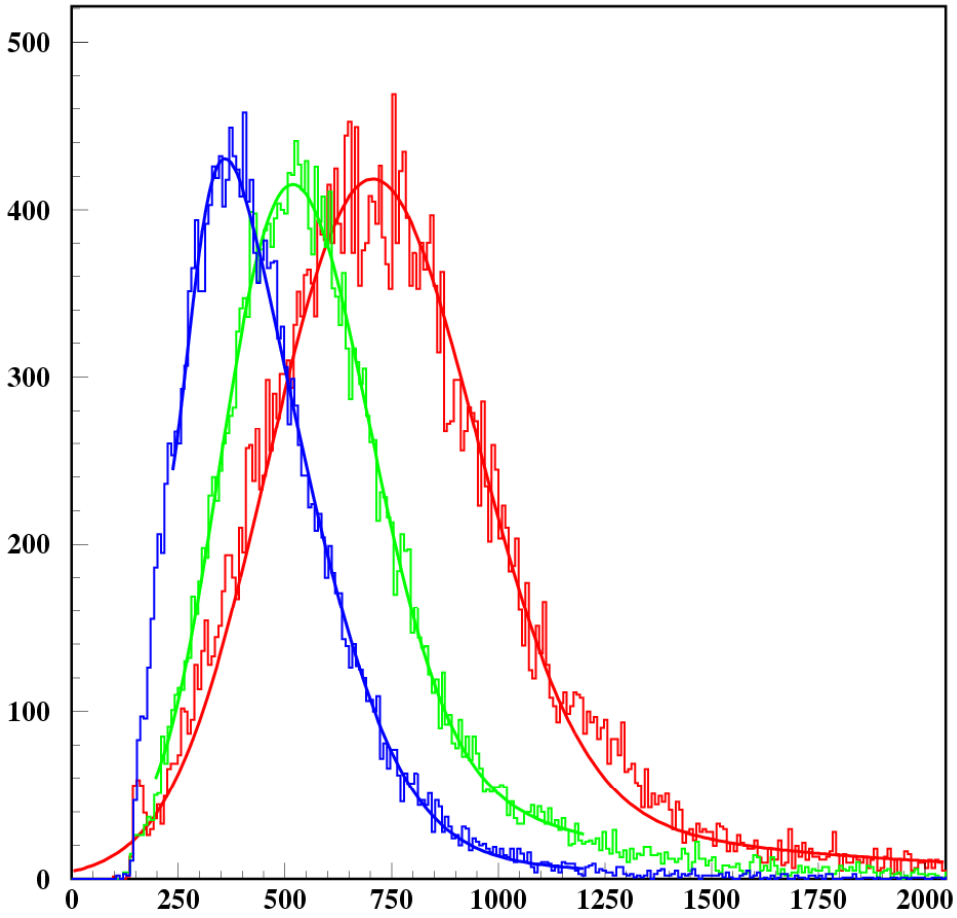




Experimental Setup

Measuring the charge collection of the segmented devices using an analogue electronics chip (SCT128) clocked at LHC speed (40MHz clk, 25ns shaping time). The system is calibrated to the most probable value of the m.i.p. energy loss in a non-irradiated 300µm thick detector (~23000 e^-).

Fast electron source: ^{90}Sr, triggered with scintillators in coincidence.

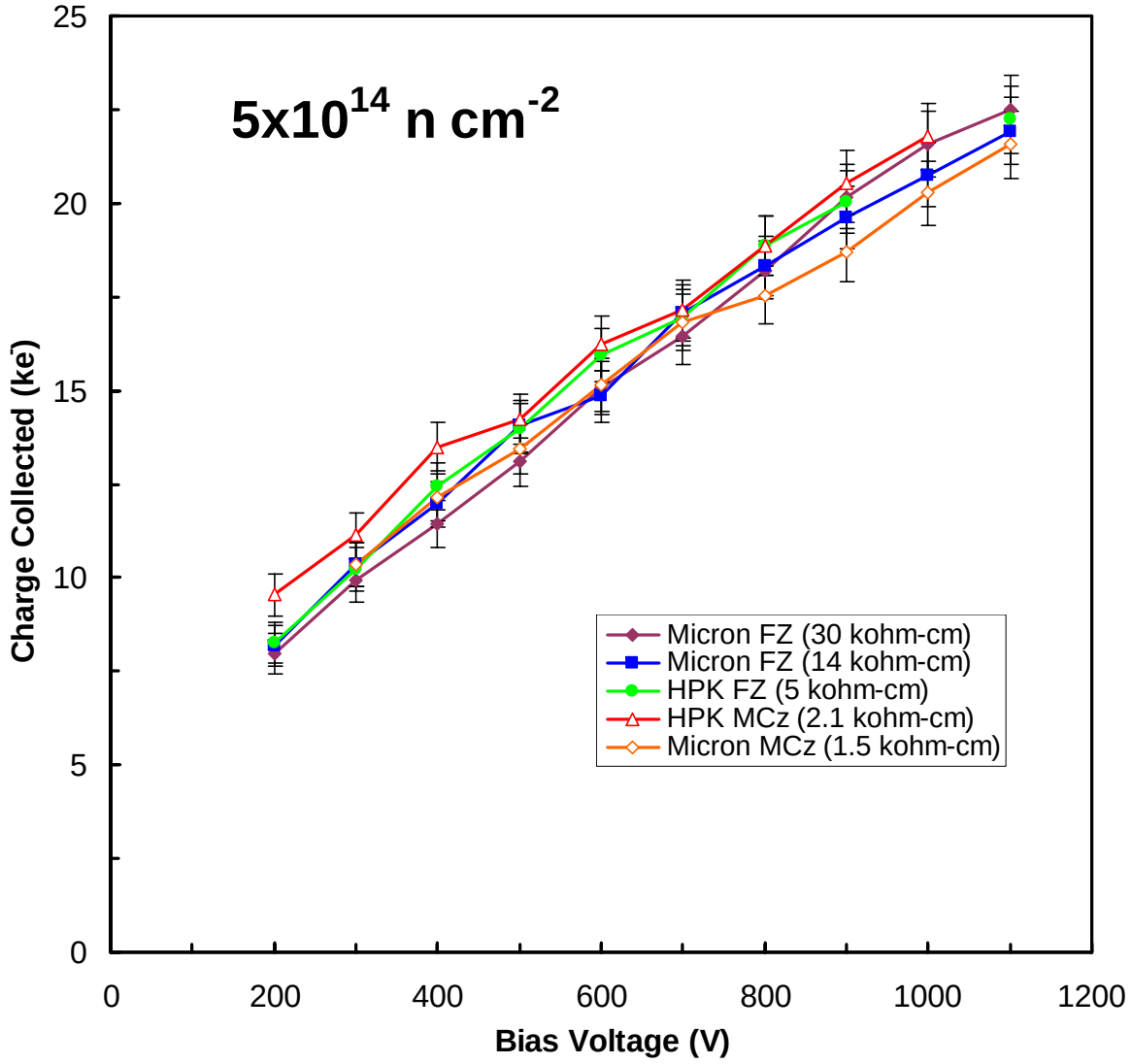


CCE vs. Resistivity

Dose motivated by long strip (9 cm) region of ATLAS SLHC straw-man design

No effect on CCE seen for different resistivities or FZ/MCz!!!

At 500 V, only 13-14 ke^- collected



CCE vs. Resistivity (2)

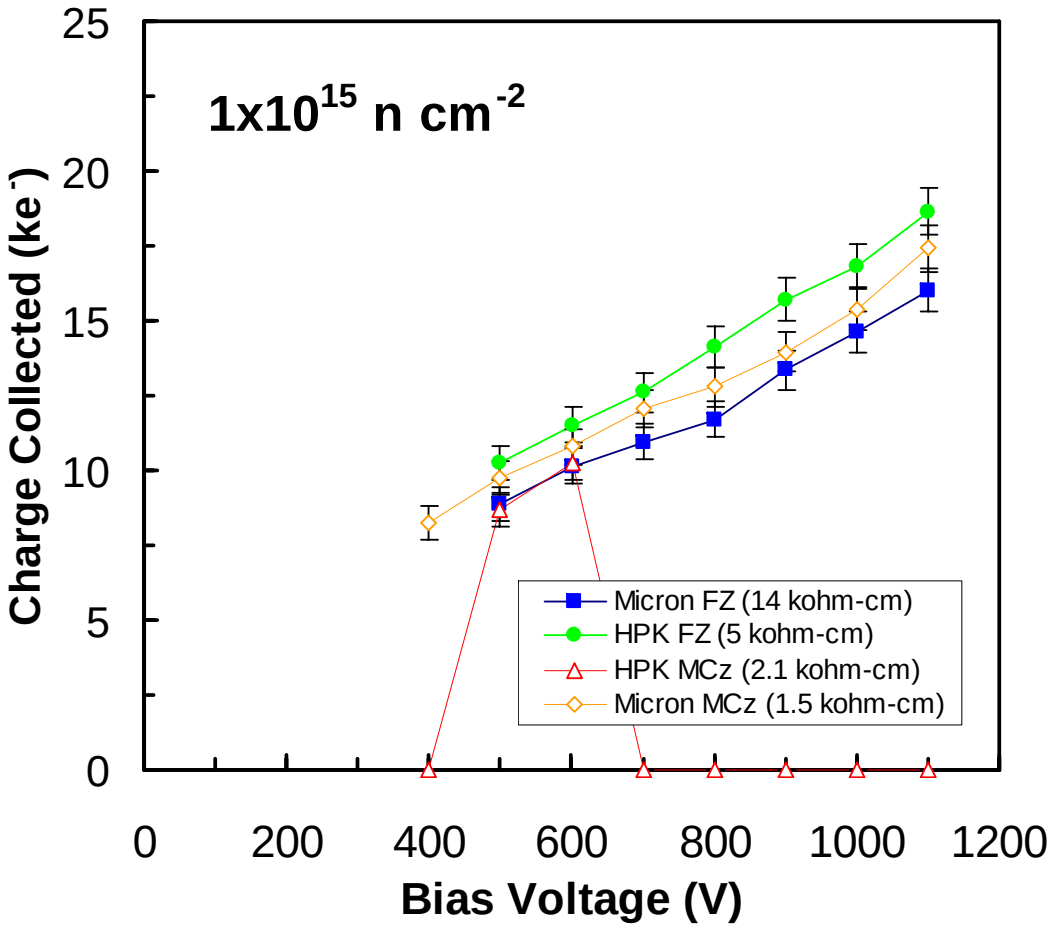
Dose motivated by short strip (2.5 cm) region of ATLAS SLHC straw-man design

No effect on CCE seen for different resistivities or FZ/MCz

- 30 kOhm-cm FZ forthcoming

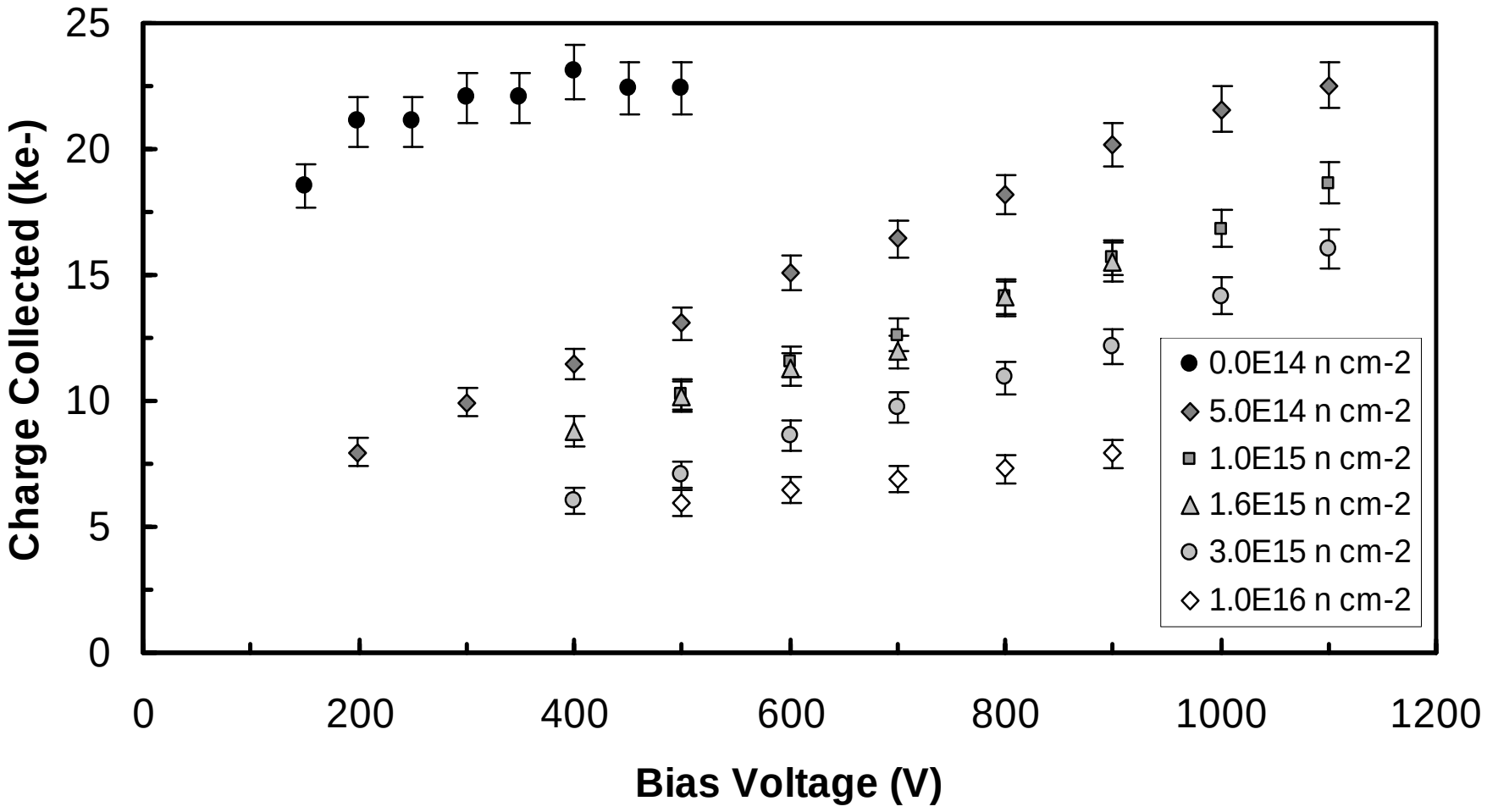
At 500 V, only 9-10 ke^- collected

- S/N:~12:1



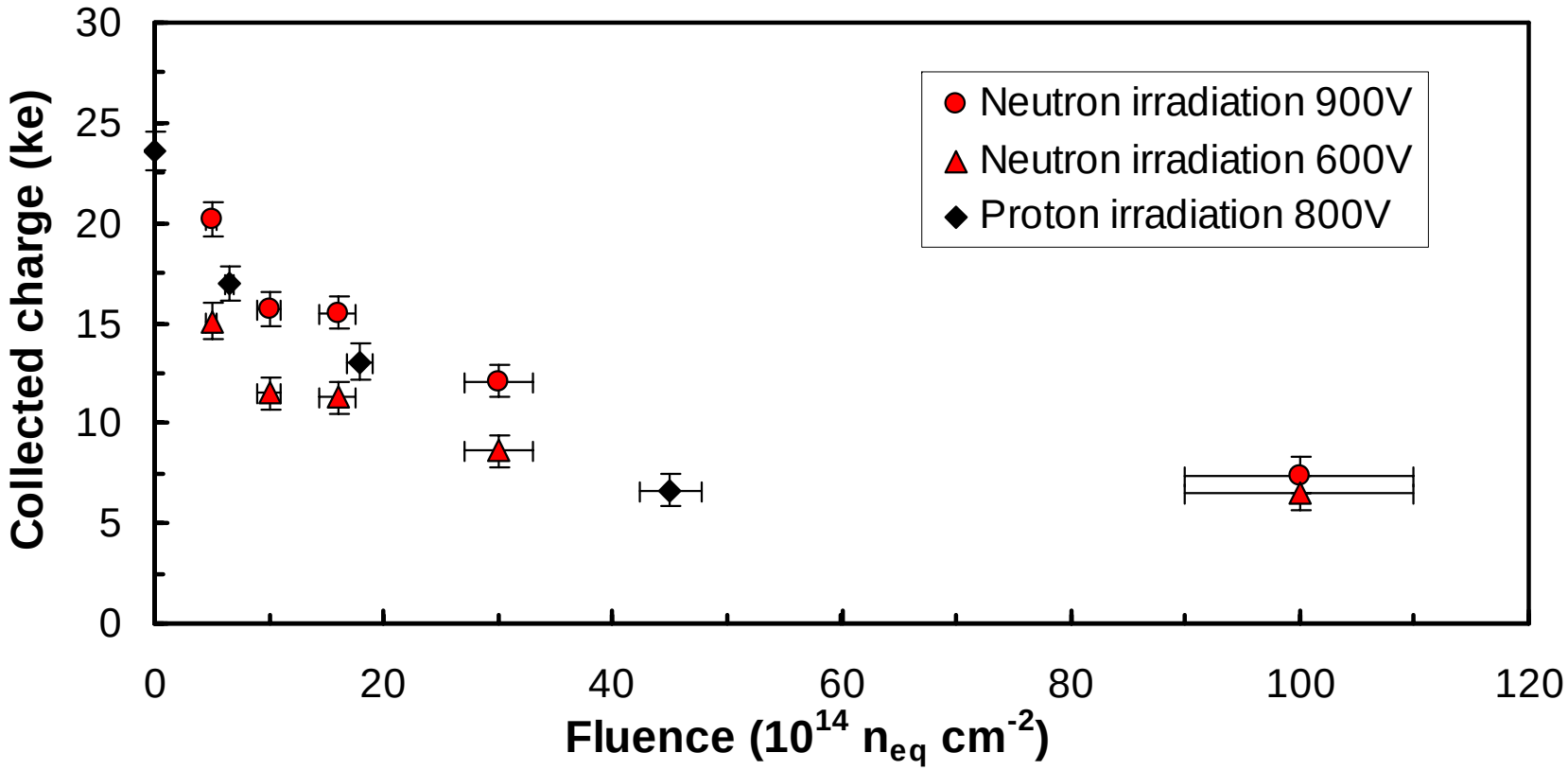
Plan on similar sets for 1.6×10^{15} n cm^{-2}, 3.0×10^{15} n cm^{-2} and proton irradiations

CCE vs. Fluence



Now μ-strip detector CCE measurements up to $1x10^{16}$ n cm^{-2}!!

CCE vs. Fluence (2)



Irradiated micro-strip detectors with n-in-p technology read-out at LHC speed (40MHz, SCT128 chip).

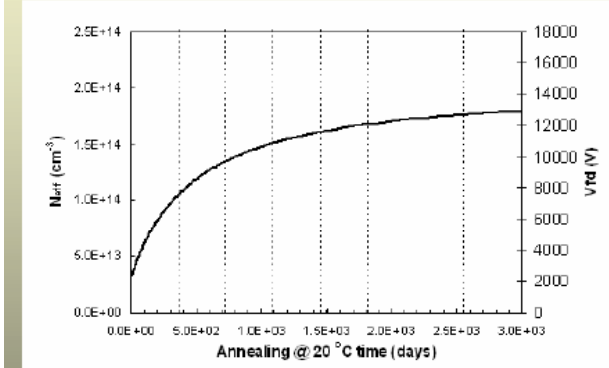
P-type Annealing

Another effect that has changed the way to regard at the reverse annealing has been measured on these devices. The reverse annealing has been always considered as a possible cause of early failure of Si detectors in the experiments if not controlled by mean of low temperature (not only during operations but also during maintenance/shut down periods). This was originated by accurate measurements of the annealing behavior of the full depletion voltage in diodes measured with the CV method.

Expected changes of full depletion voltage with time after irradiation (as measured with the C-V method) for detector irradiated to 7.5 10^{15} p cm^{-2}.

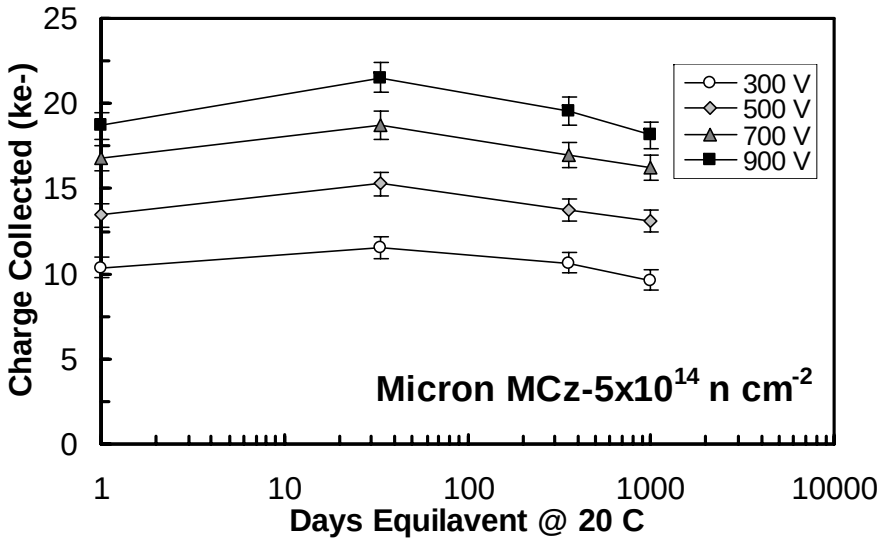
Please notice that according to CV measurements the so called V_{FD} changes from <3kV to >12kV!

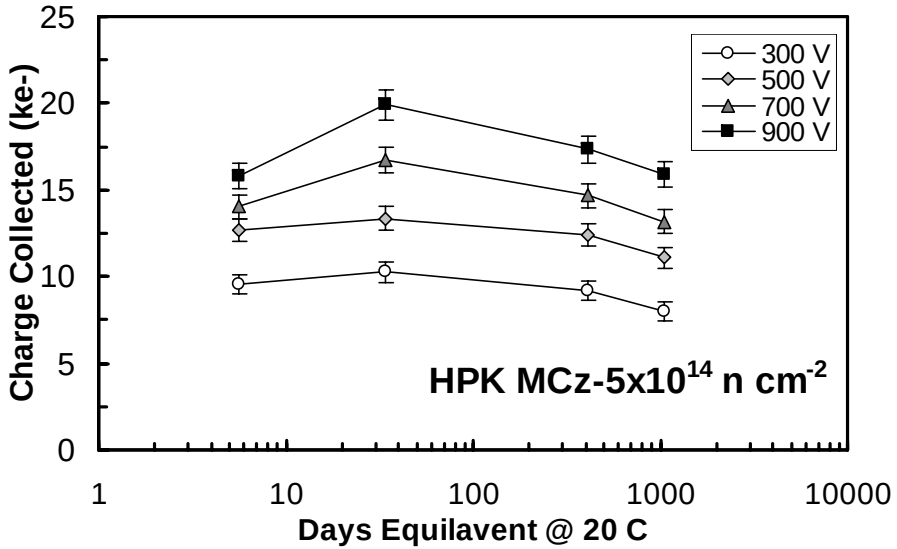
Initial V_{FD} ~ 2800V



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

CCE vs. Annealing



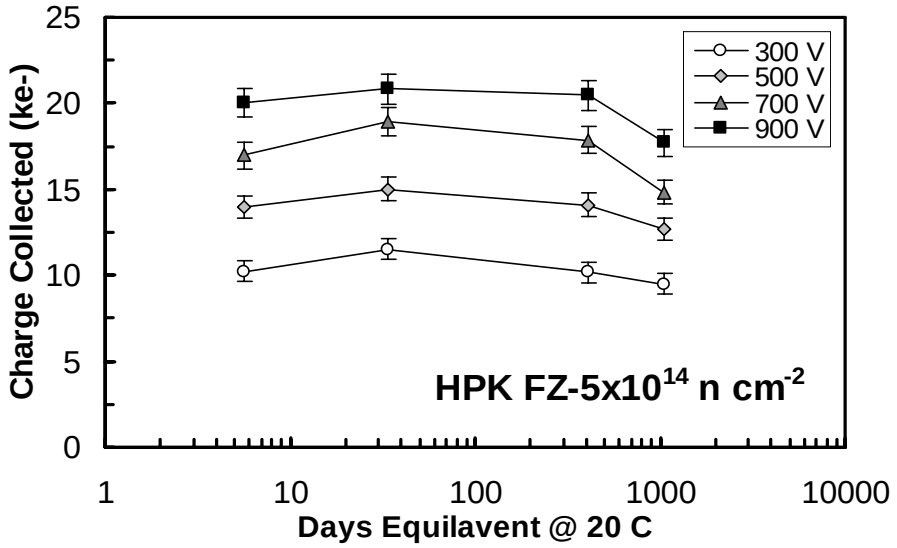


Appears independent of material

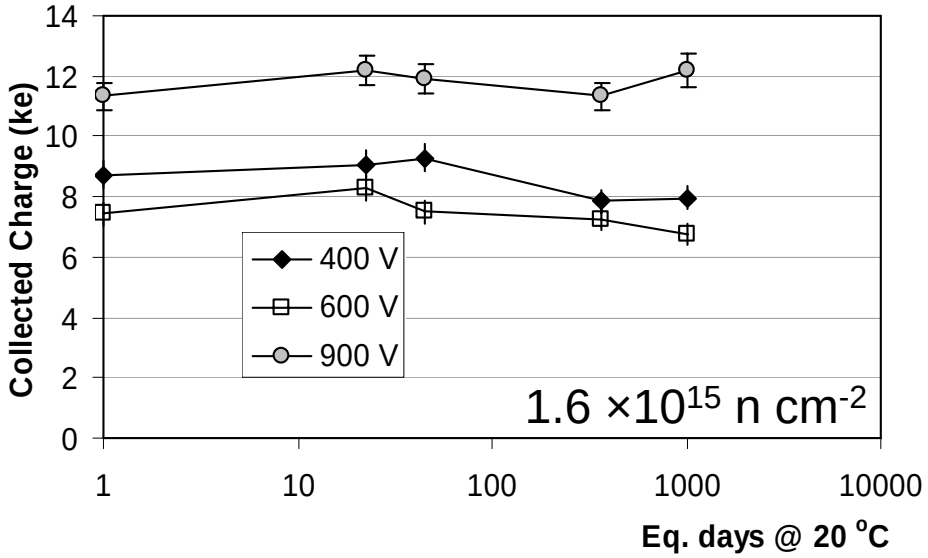
Initially, annealing improves the signal by ~10%

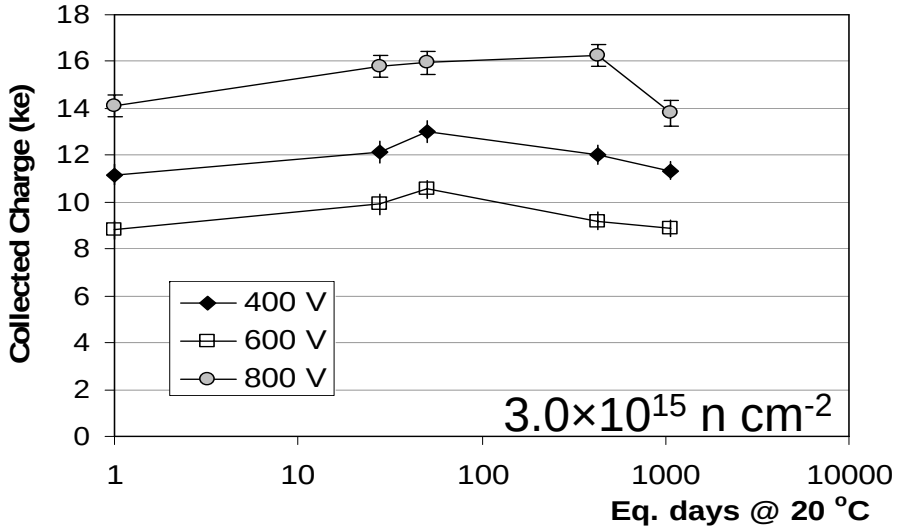
After 3 years equivalent, the signal decreases by ~10%

Will study in much finer time-slices

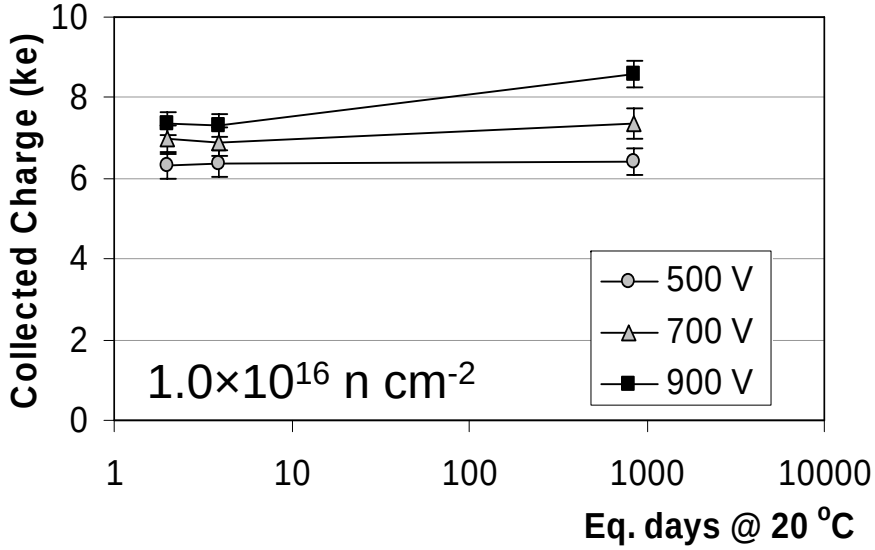


CCE vs. Annealing (2)





Micron FZ, 300 μm, 30 kΩ



Conclusions

For the SLHC ATLAS micro-strip regions, p-type detectors show adequate signal after the expected radiation doses. The signal appears to be independent of substrate material (resistivity, FZ/MCz)

We plan in the near future to complete the substrate studies for the differing SLHC pixel/strip systems for neutron and proton irradiations.

Annealing effects so far are independent of substrate types for p-type micro-strip sensors with the CCE changing by ±10%

We plan to systematically study the annealing effects in finer time-slices to try to develop annealing into a tool to increase the CCE of detector systems