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Neutron irradiation results with Si miniature detectors

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OUTLINE

- Summary of previous results with 24GeV/c protons
- New results with neutron irradiated devices

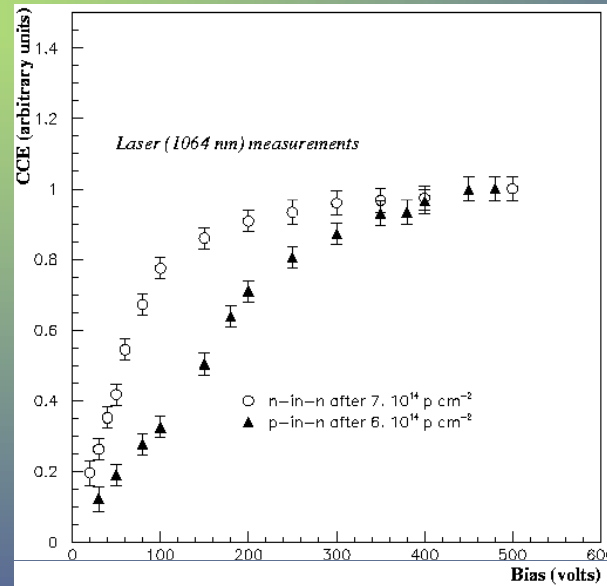


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Accepted facts about Si segmented devices for increased radiation hardness:

N-side read-out on n-type substrates gives the main advantage (ATLAS and CMS pixels, LHCb-VELO microstrips).

Comparison n
to p-side read
out

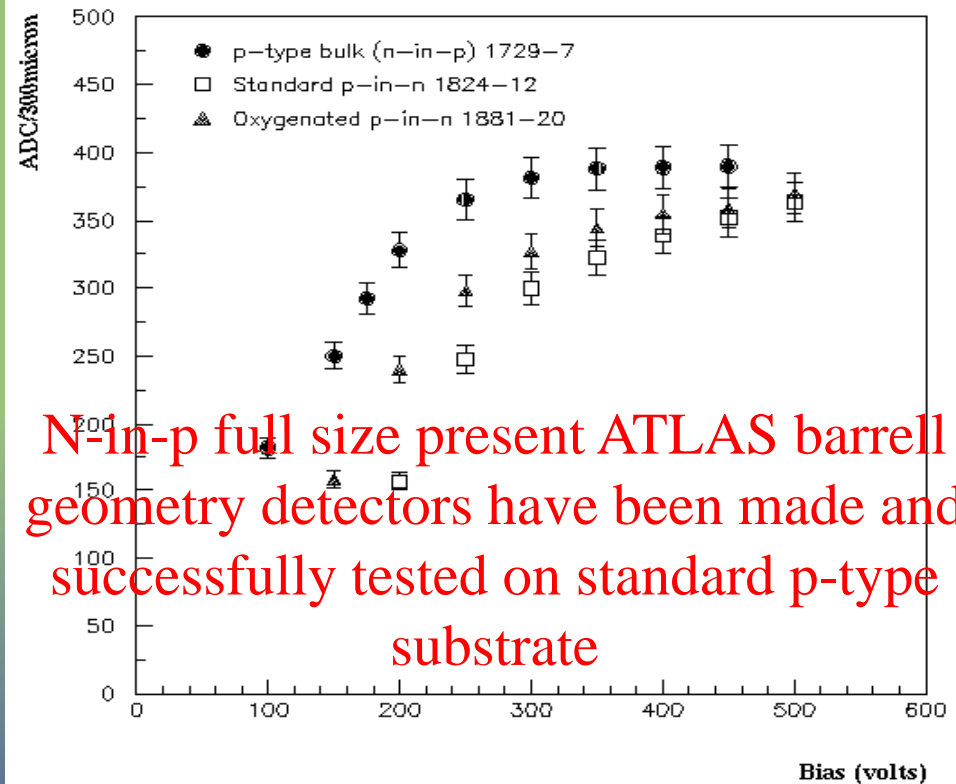




Implementing n-side read-out on p-type silicon

The n-side read-out can be equally well implemented on a p-type substrate and keep the same advantages for CCE after irradiation and exhibiting two additional advantages compared to the n-type bulk.

- The p-type bulk doesn't invert, so the junction side will always be on the same side before and after irradiation
- The p-type substrate devices don't require backplane processing, which turns out being cheaper (40-50%) than the n-type. This argument can be very important for large area coverage.



Improvements of CCE(V) confirmed



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Facts about Si segmented devices for increased radiation hardness: n strip read-out on p-type silicon

24 GeV/c proton irradiation in CERN/PS (thanks to M. Glaser)

After $7.5 \cdot 10^{15} \text{ p cm}^{-2}$ 7000e are collected at 900V.

The charge collected at these doses is determined predominantly by trapping.

At low temperature the noise can be controlled.

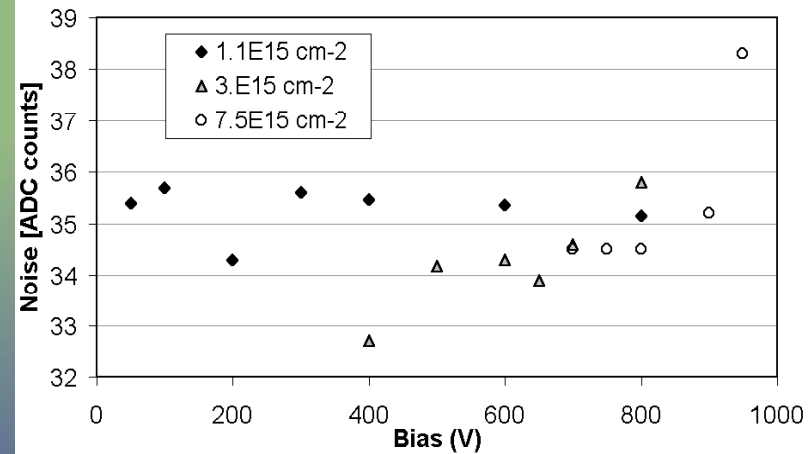
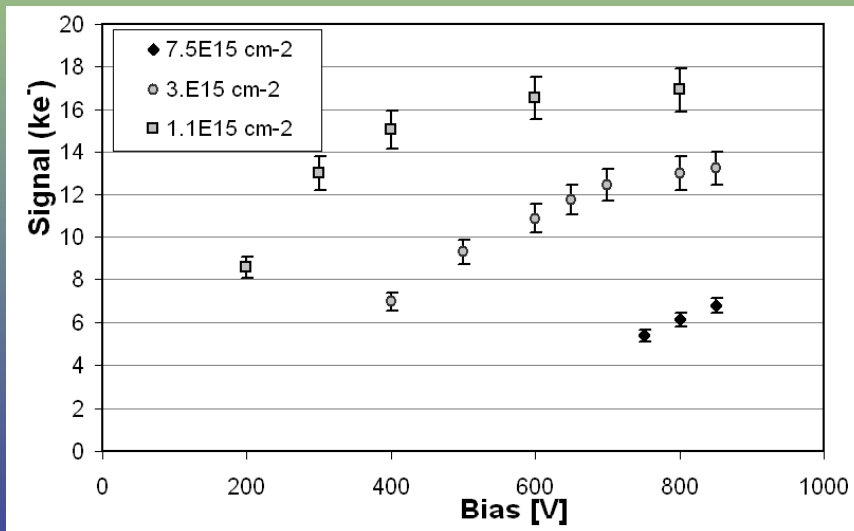


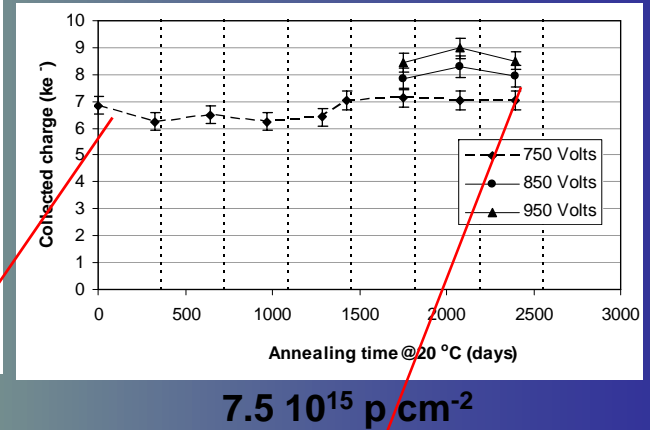
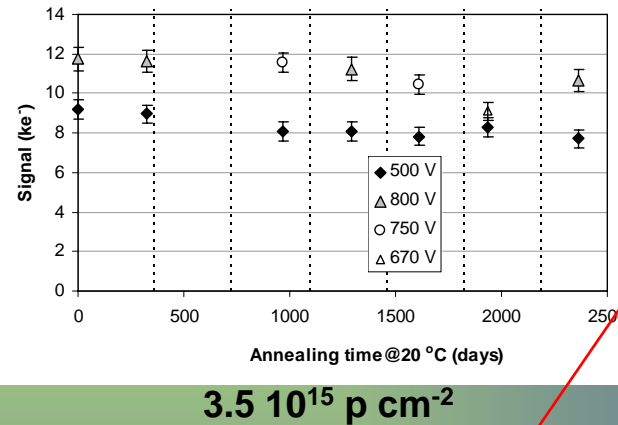
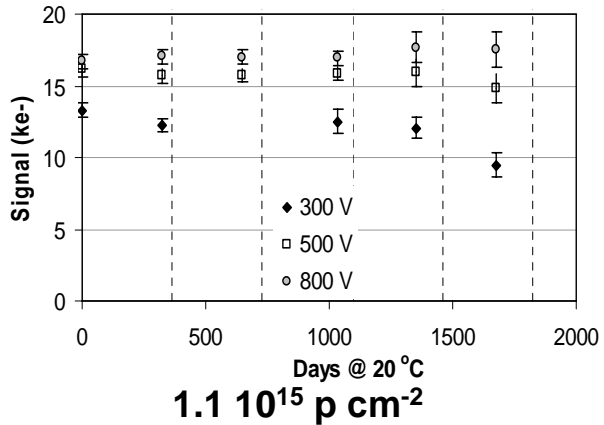
Fig. 1 Noise as a function of the applied voltage for the three different irradiation doses. The pre-irradiation value is about 35 ADC counts, similar to the value found after irradiation.



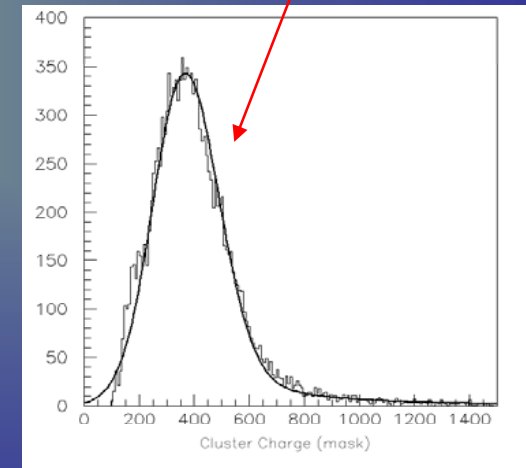
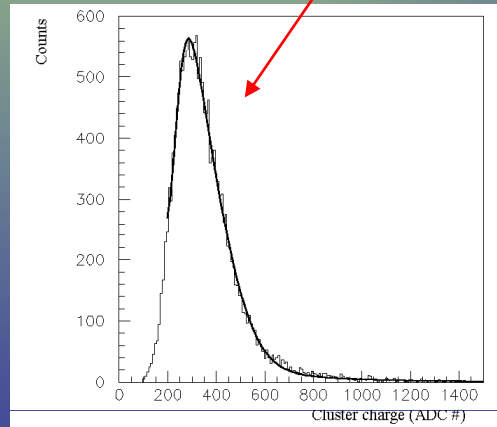
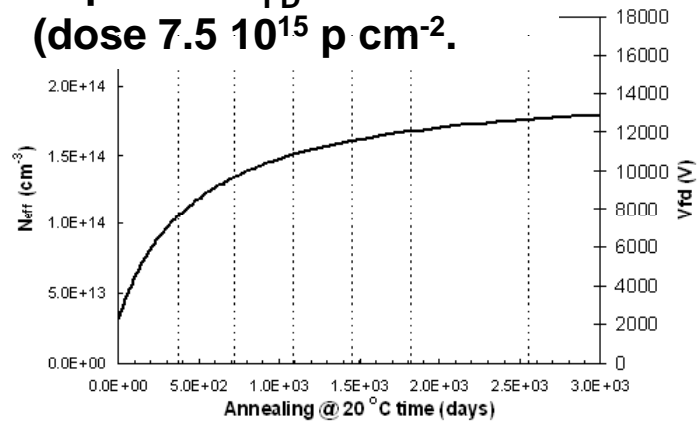
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Annealing after proton irradiation

The signal doesn't degrade significantly with annealing time up to 7y equivalent at room temperature (while V_{FD} is expected to rise from 2.8kV to 12kV)!



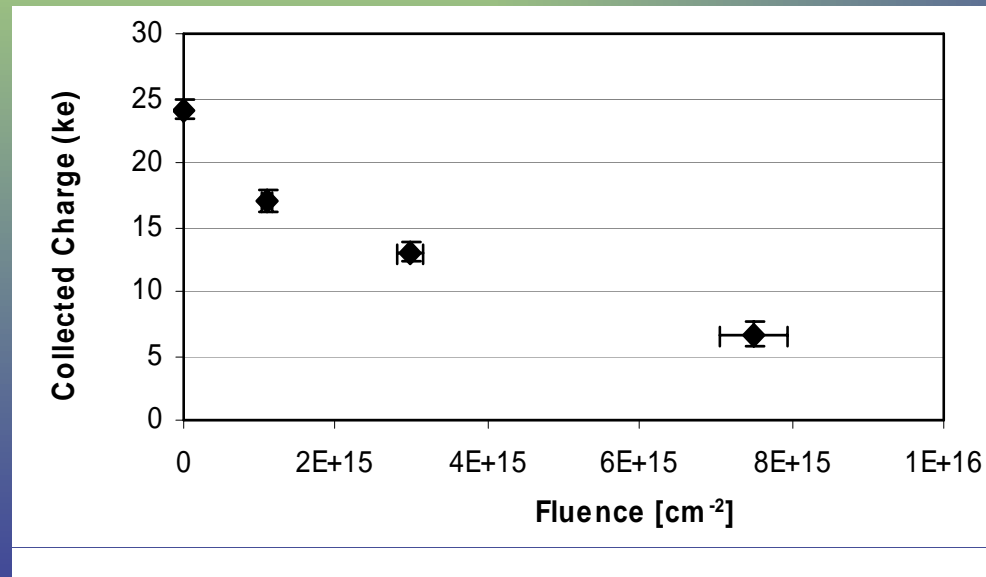
Expected V_{FD} from CV (dose $7.5 \cdot 10^{15} \text{ p cm}^{-2}$.)





Summary of degradation after proton irradiation

Below is the figure for the charge collection degradation after proton irradiation of miniature μ -strip detectors read-out with 40MHz analogue electronics. According to what observed above, this figure is not significantly changing with time at 20°C after irradiation.





Need for neutron irradiation tests

The radiation damage in SLHC will be due to particles emerging from the interactions and to backscattered neutrons. The radius at which the two contributions are about equal is between 20-25 cm. For further radii the neutron contribution becomes dominating. The μ -strip detectors therefore will be operated in an area where the neutron contributes to the radiation damage for more than 50%.

It is therefore necessary to prove the radiation resistance of the μ -strip devices with neutron irradiation as well as with charged particles.



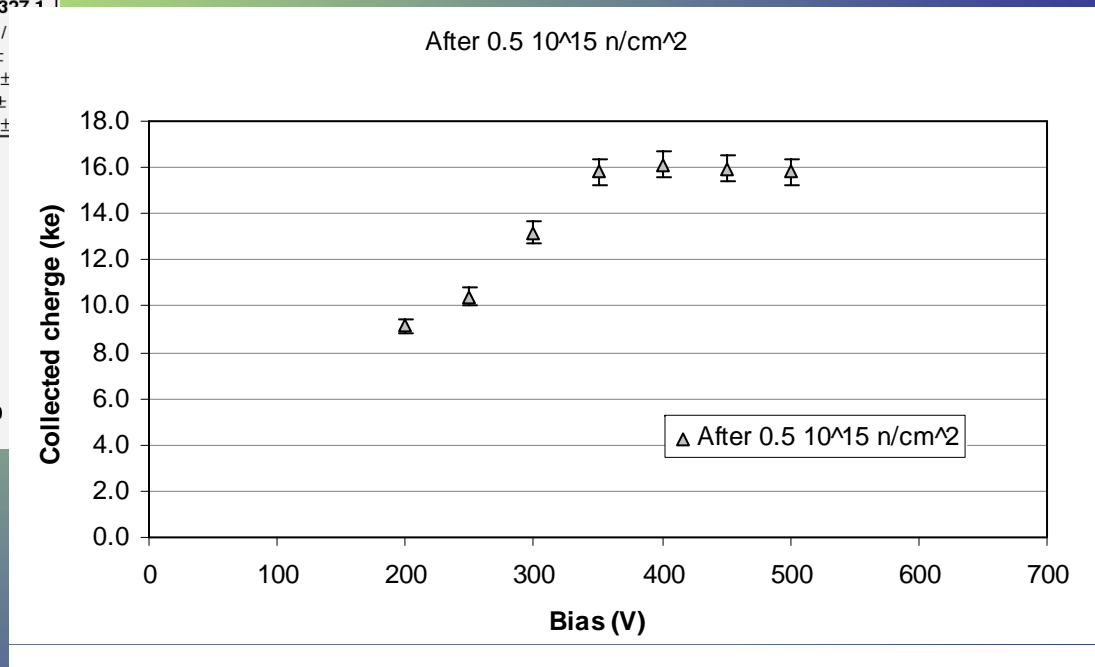
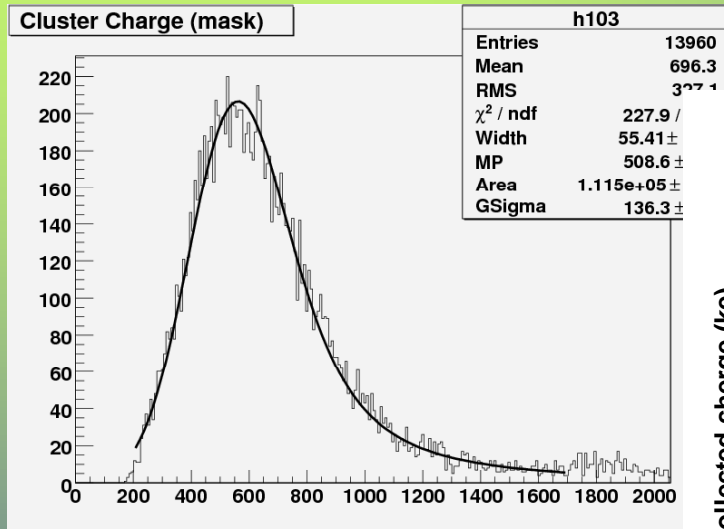
Neutron irradiations

A few μ -strip detectors ($1 \times 1 \text{ cm}^2$) made by Micron on 140 and $300 \mu\text{m}$ thick high resistivity ($>10 \text{ kW cm}$) p-type wafers and irradiated in the Ljubljana research reactor to 0.5 , 1.6 and $3 \times 10^{15} \text{ n cm}^{-2}$ (thanks V. Cindro, M. Mikuz

Two detectors irradiated to 1.6 and $3 \times 10^{15} \text{ n cm}^{-2}$ have been measured with LHC speed analogue electronics (SCT128A). The higher dose detector has also been measured after accelerated annealing to almost 3 years room temperature equivalent (two steps at 60°C and two at 80°C).

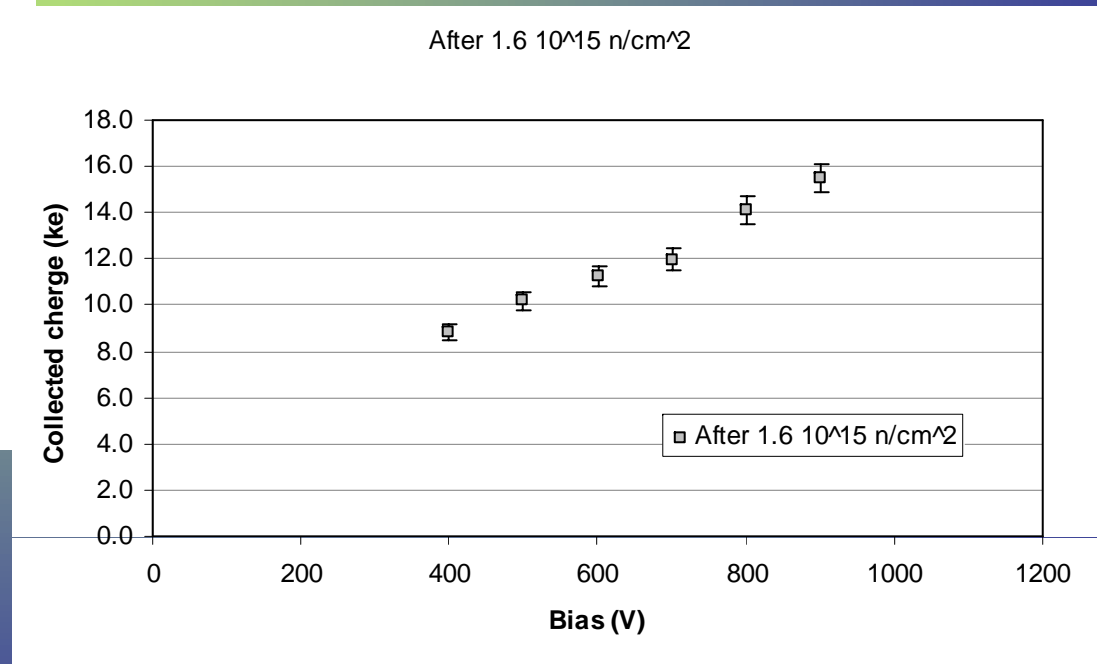
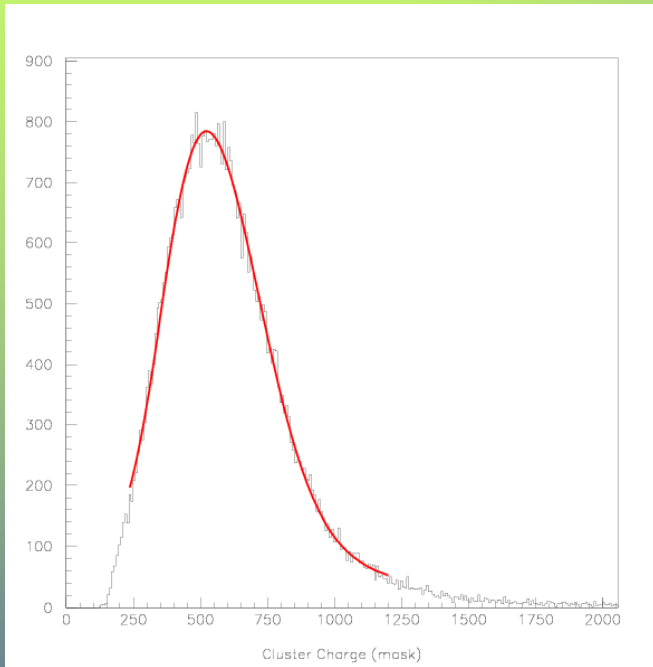


Neutron irradiations: $0.5 \cdot 10^{15} \text{ n cm}^{-2}$



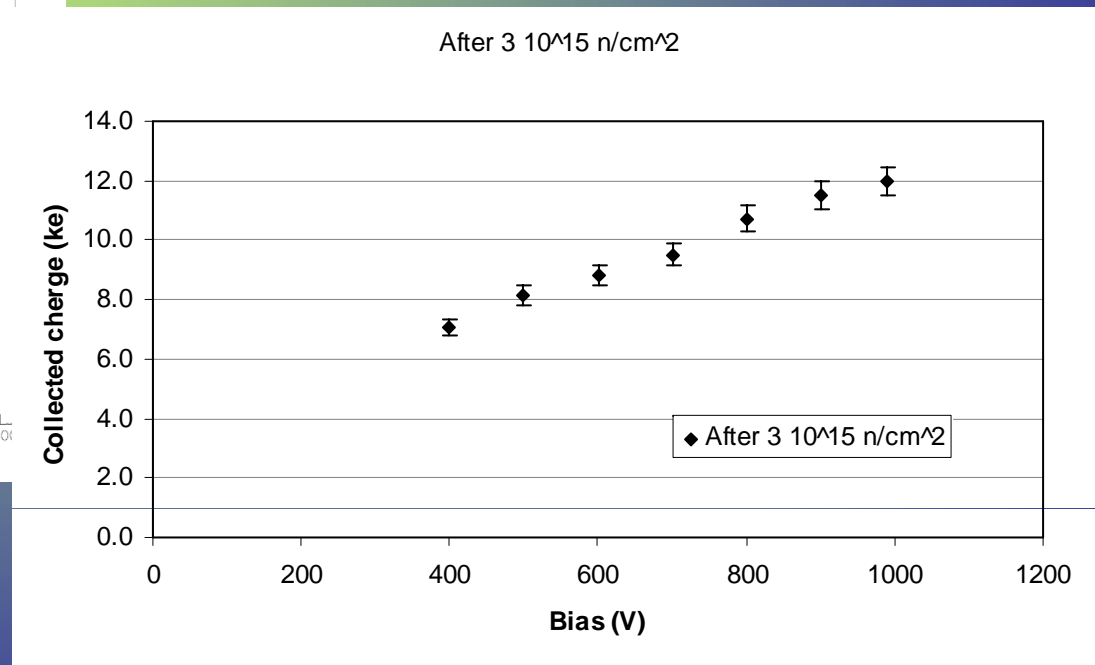
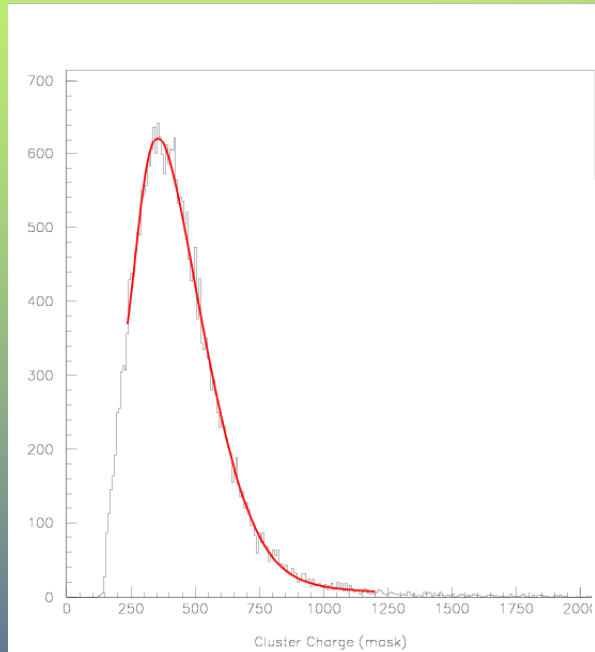


Neutron irradiations: $1.6 \cdot 10^{15} \text{ n cm}^{-2}$



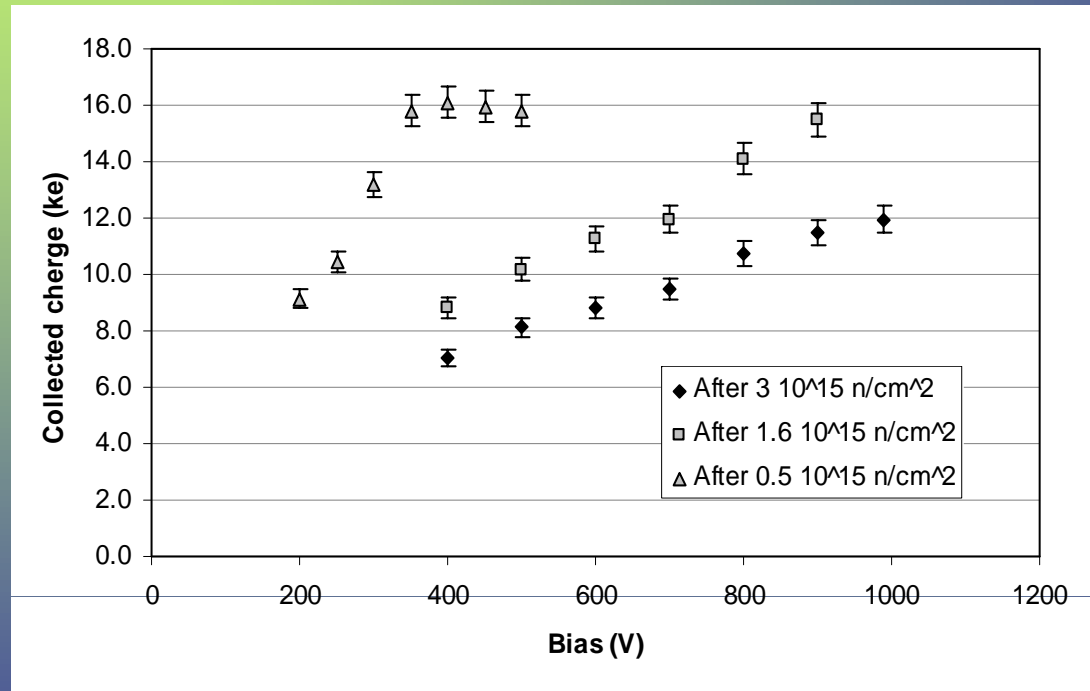


Neutron irradiations: $3 \cdot 10^{15} \text{ n cm}^{-2}$





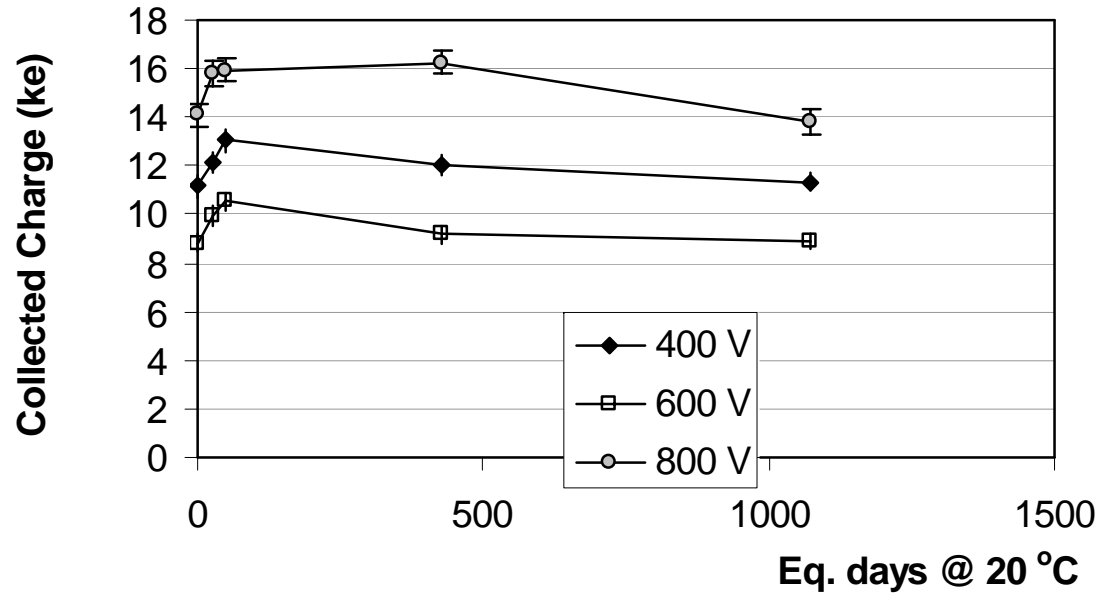
Summary before annealing





Neutron irradiations: $1.6 \cdot 10^{15} \text{ n cm}^{-2}$

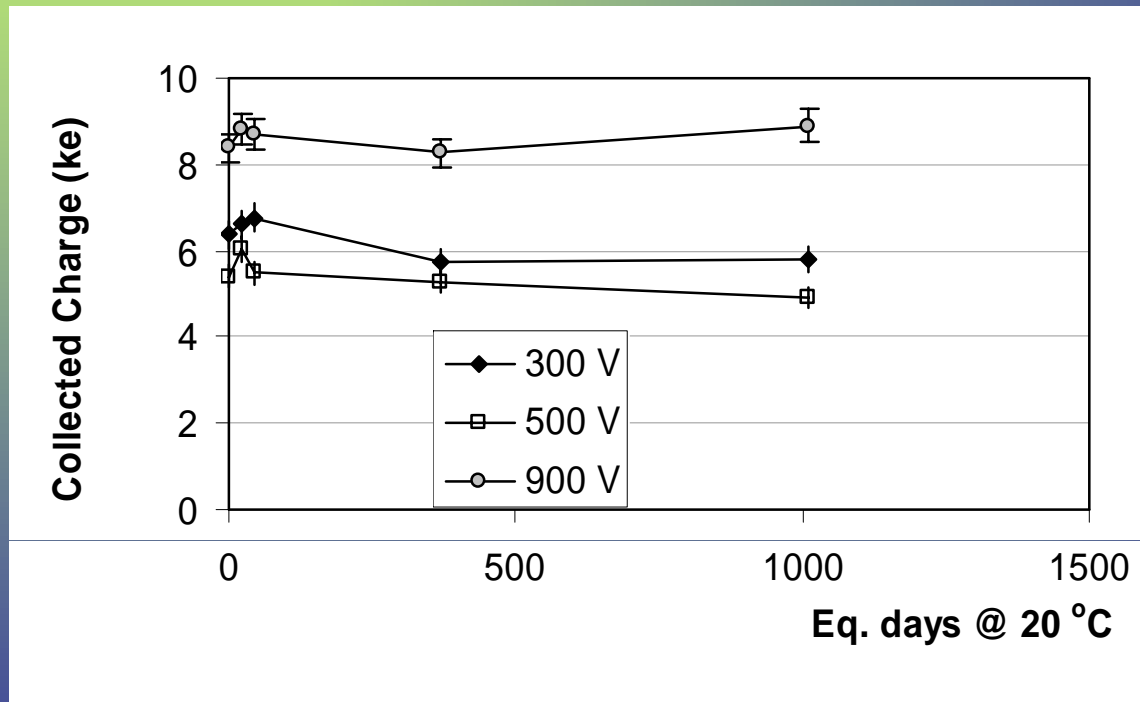
Annealing





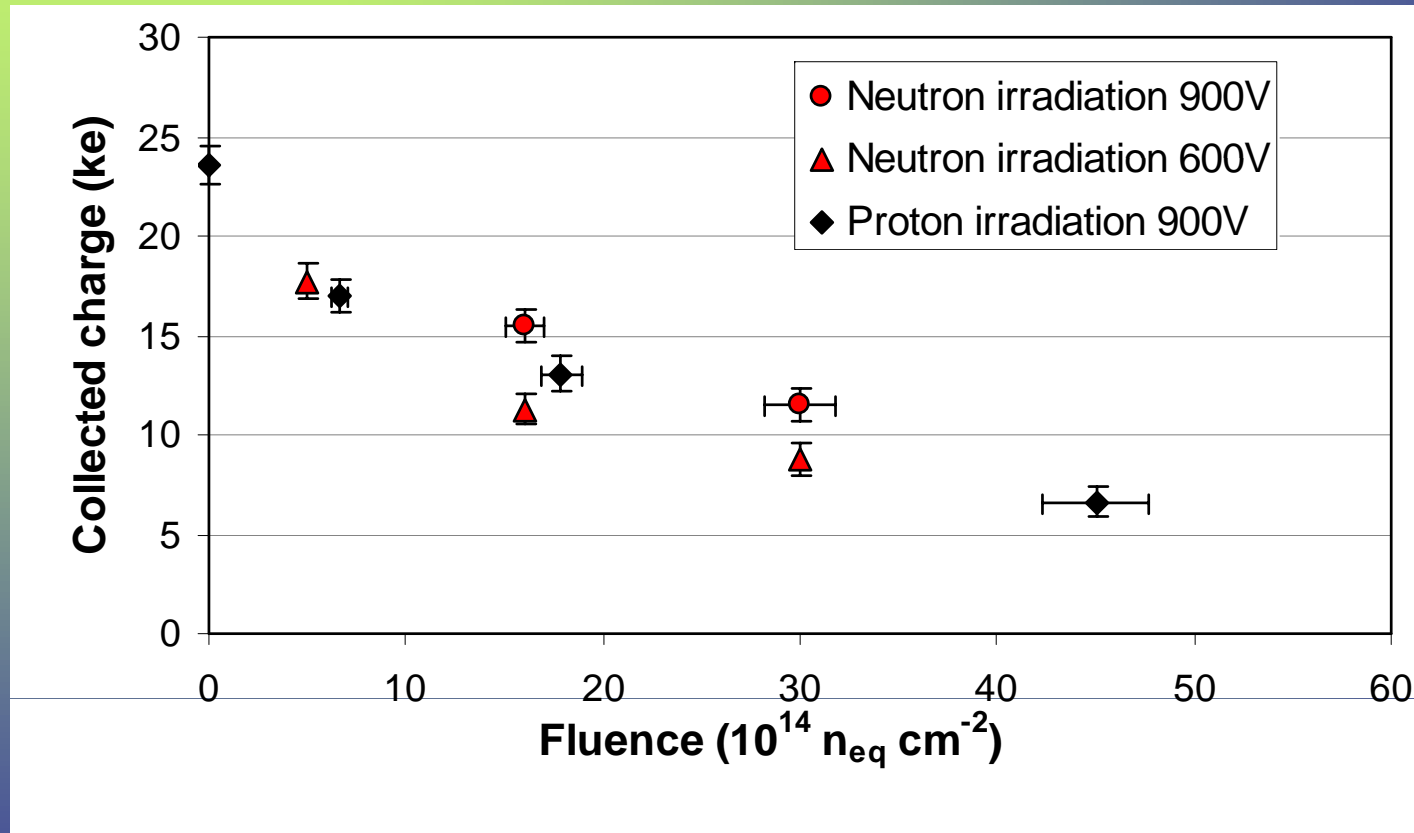
Neutron irradiations: $3 \cdot 10^{15} \text{ n cm}^{-2}$

Annealing





Neutron and proton irradiations summary



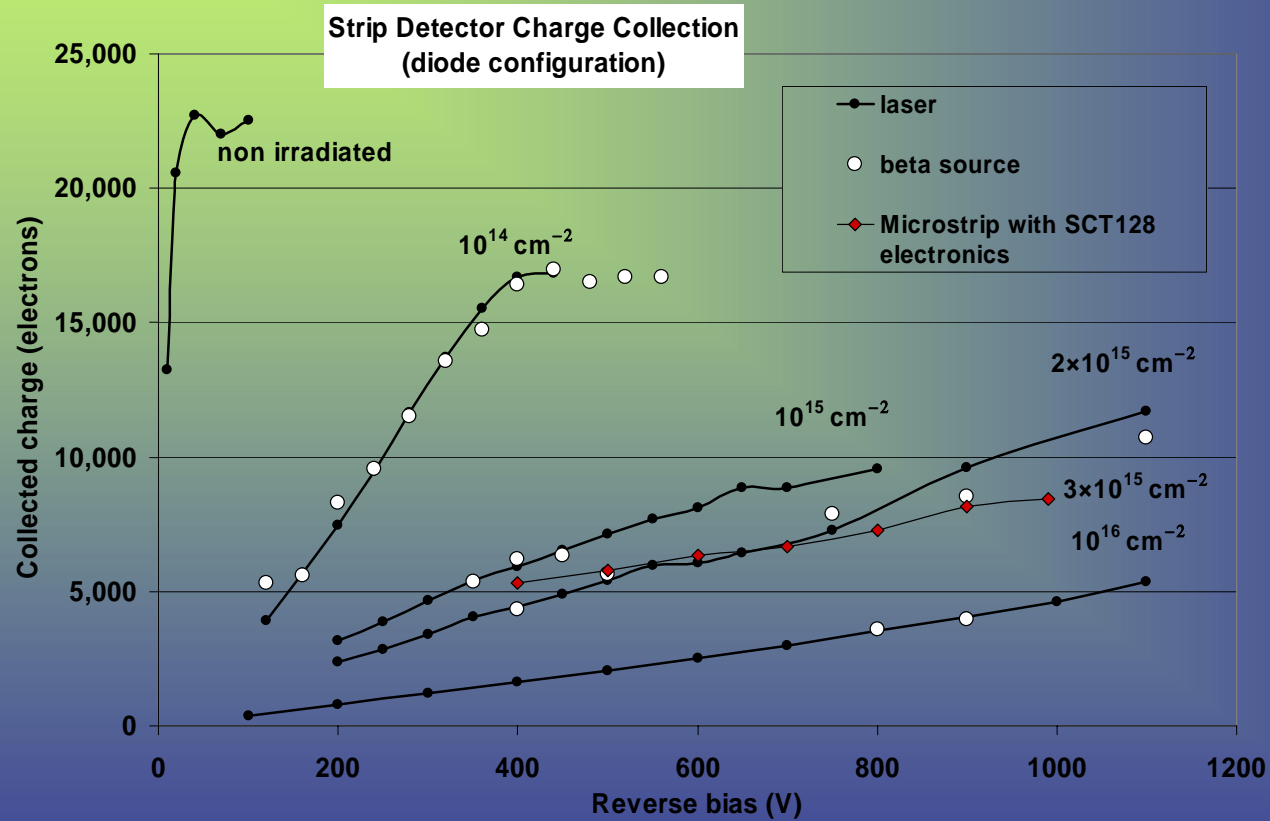


Neutron irradiations

More μ -strip detectors ($1 \times 1 \text{ cm}^2$) made by CNM Barcelona on $300 \mu\text{m}$ thick high resistivity p-type wafers were irradiated in Ljubljana to various fluences. They have been measured in Valencia and Barcelona with a different method from the measurements just shown: the strips were connected to a common metal rail (*diode* configuration) and read-out with a high-bandwidth current amplifier.



Neutron irradiations: comparison “diode” vs μ -strips





Conclusions

- New results with μ -strip detectors irradiated with neutrons to SLHC fluences and read-out with LHC-speed electronics are here shown. The collected charge seems to scale with the NIEL function. Long term annealing doesn't effect substantially the measured signal, at least within a practical time for operations.
- The differences found with other measurements can be due to the difference in the read-out scheme (individual strips or diode configuration)