Results with thin and standard p-type detectors after heavy neutron irradiation

G. Casse

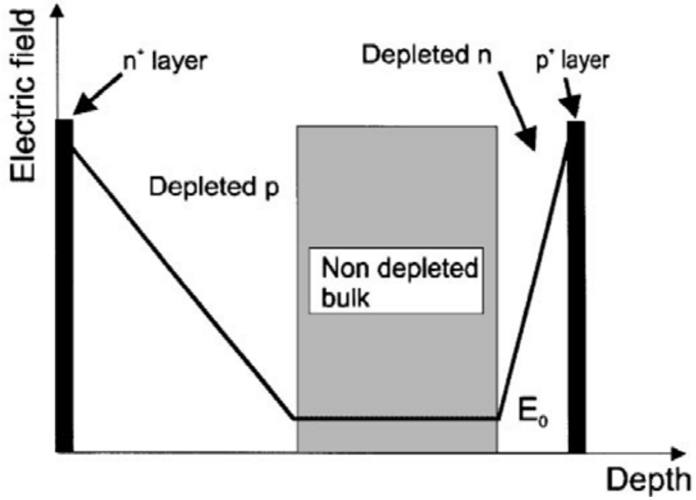
11th RD50 Workshop, CERN 12-14 Nov. 2007

OUTLINE:

- Introduction
- Motivations for using p-type substrates in high radiation environments
- Motivations for investigating thin (140µm) vs *standard* (300µm) detectors
- Charge Collection Efficiency results up to $1x10^{16}$ n cm^{-2}
- Summary and future work

N-side read-out for tracking in high radiation environments?

Schematic changes of Electric field after irradiation



Effect of trapping on the Charge Collection Efficiency (CCE)

$$Q_{tc} \cong Q_0 \exp(-t_c/\tau_{tr}),\ 1/\tau_{tr} = \beta\Phi.$$

Collecting electrons provide a sensitive advantage with respect to holes due to a much shorter t_c. P-type detectors are the most natural solution for *e* collection on the segmented side.

N-side read out to keep lower t_c

Effect of trapping on the Charge Collection Distance

$$Q_{tc} \cong Q_0 \exp(-t_c/\tau_{tr}),\ 1/\tau_{tr} = \beta\Phi.$$

$$v_{sat,e} \times \tau_{tr} = \lambda_{av}$$

$$\beta_e = 4.2\text{E}{-16}\ \text{cm}^{-2}/\text{ns}$$

$$\beta_h = 6.1\text{E}{-16}\ \text{cm}^{-2}/\text{ns}$$

From G. Kramberger et al., NIMA 476(2002), 645-651.

After heavy irradiation thin detectors should have a similar CCE as thicker ones.

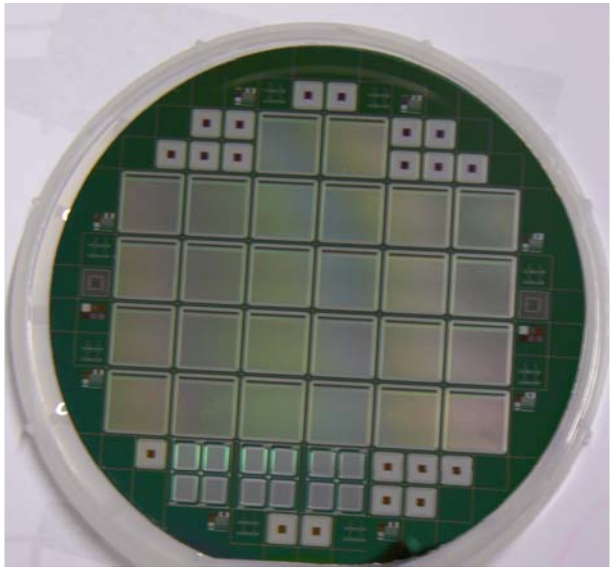
$$\lambda_{av}\ (\Phi=1\text{e}14) \cong 2400\mu\text{m}$$

$$\lambda_{av}\ (\Phi=1\text{e}16) \cong 24\mu\text{m}$$

Silicon miniature microstrip detectors and irradiation

RD50 mask (see: http://rd50.web.cern.ch/rd50/)

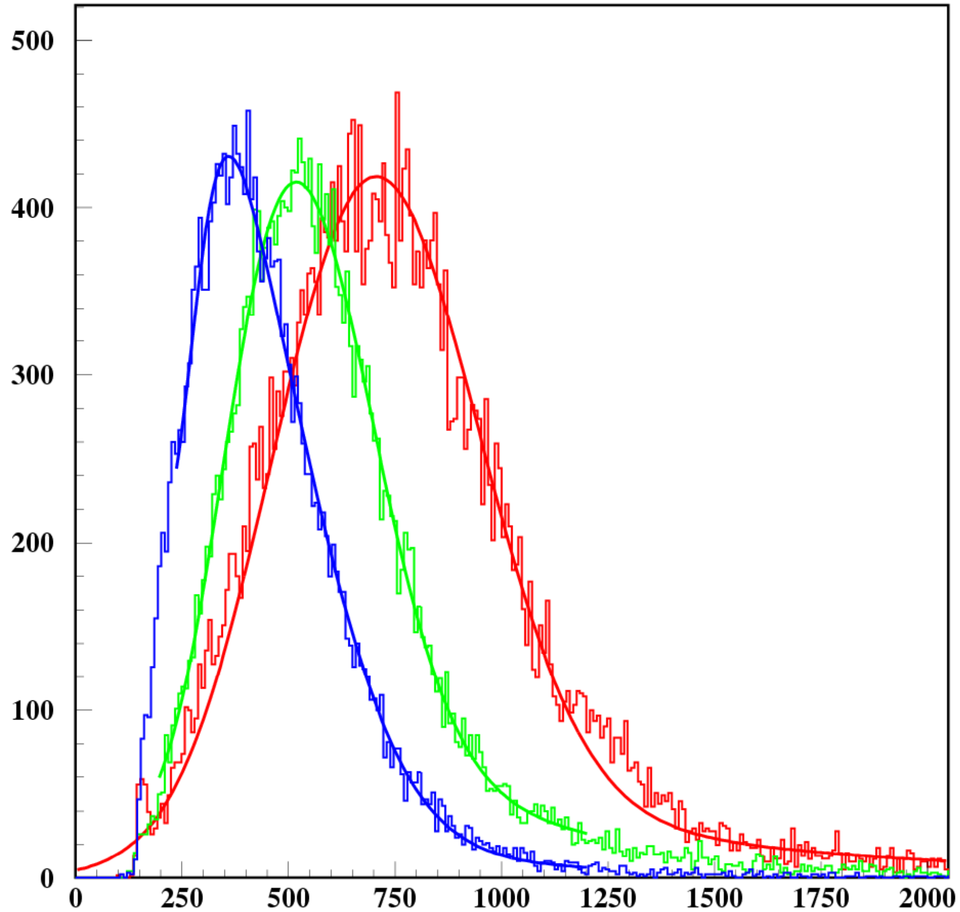
Mini microstrip, ~1x1 cm^2, 128 strips, 80 µm pitch, designed by Liverpool and produced by Micron on 300µm and 140µm thick wafers.



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

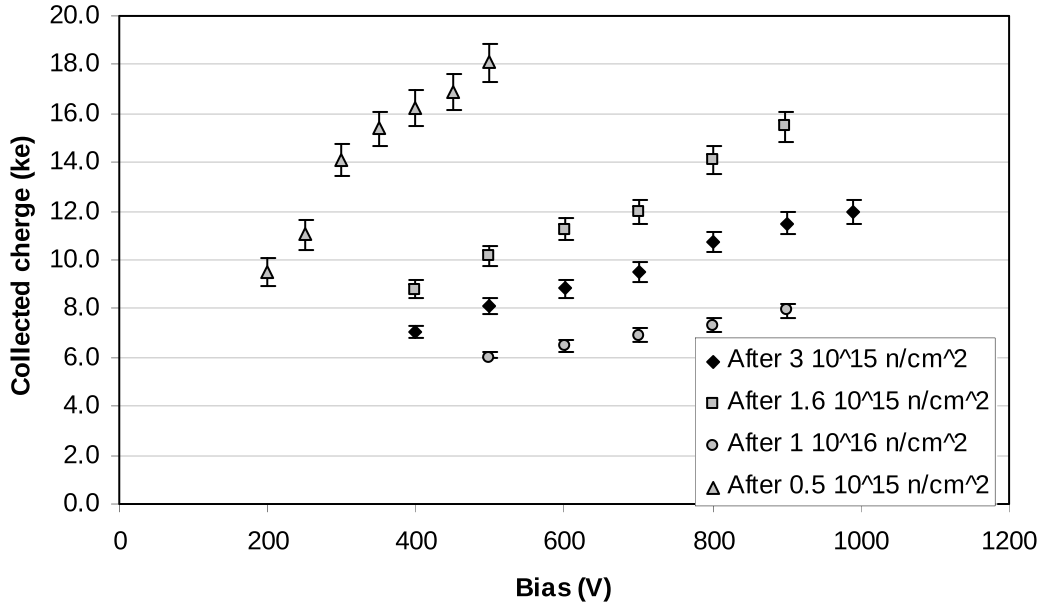
Method: measure the charge collection of the segmented devices using an analogue electronics chip (SCT128) clocked at LHC speed (40MHz clk, 25ns shaping time). The system is calibrated to the most probable value of the m.i.p. energy loss in a non-irradiated 300µm thick detector (~23000 e^-).

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



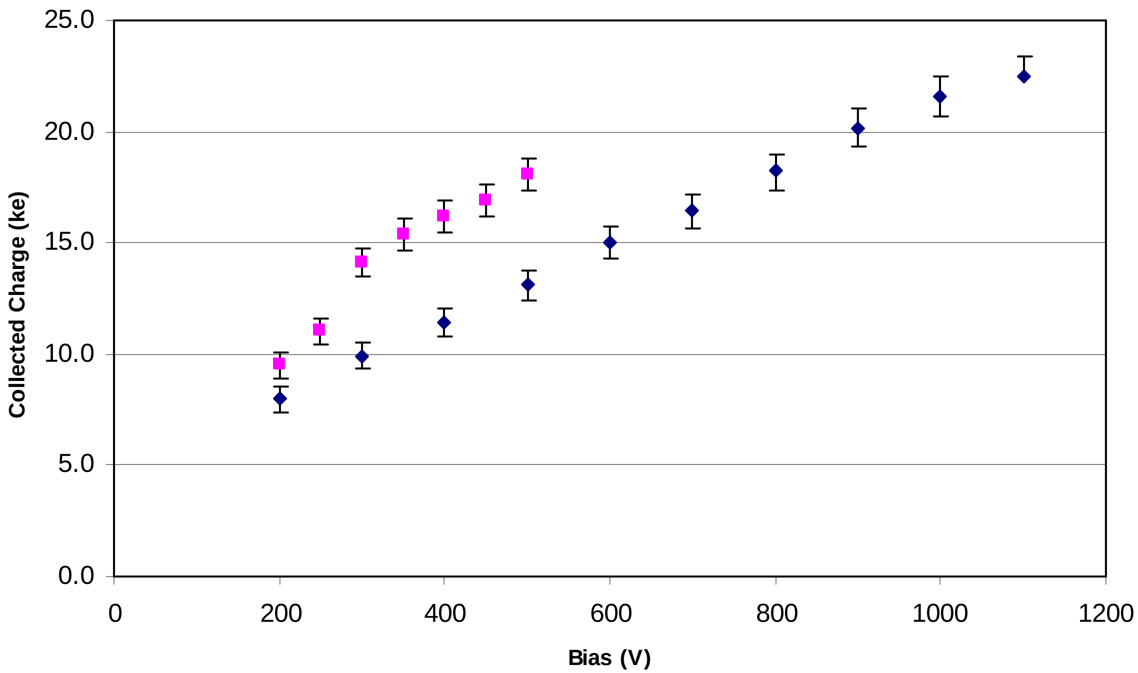
Results with neutron irradiated Micron detectors

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



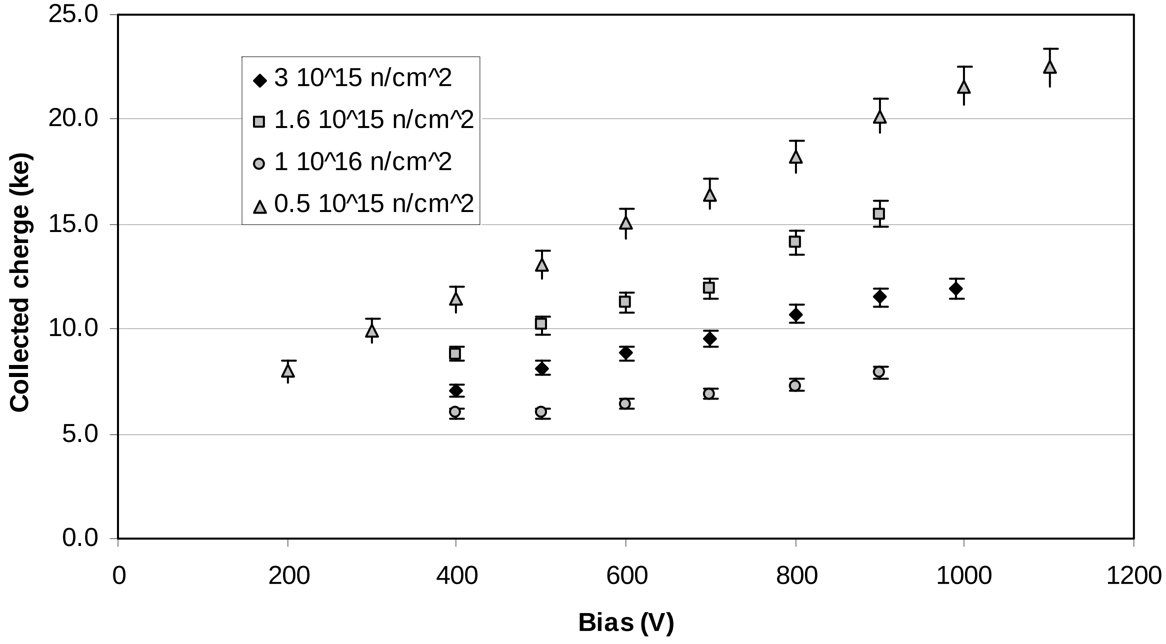
A correction of the result at $5x10^{14}$ n cm^{-2}

Comparison of the measurements on 30kΩ Micron detectors irradiated to the nominal Φ of $5x10^{14}$ cm^{-2} in March 2006 and October 2007

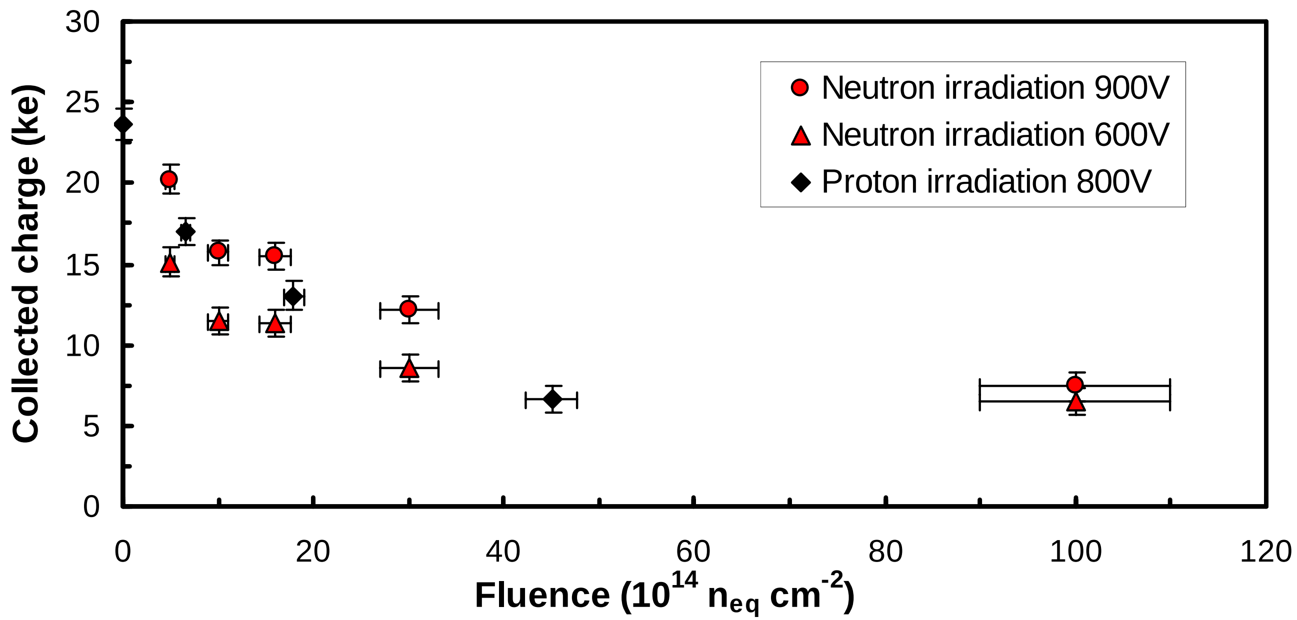


Results with neutron irradiated Micron detectors

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

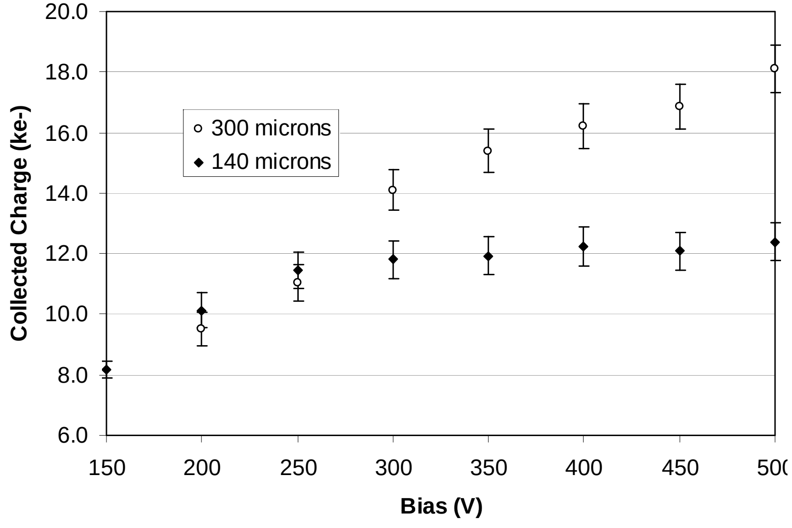


Charge collection efficiency vs fluence for micro-strip detectors irradiated with n and p read-out at LHC speed (40MHz, SCT128 chip).

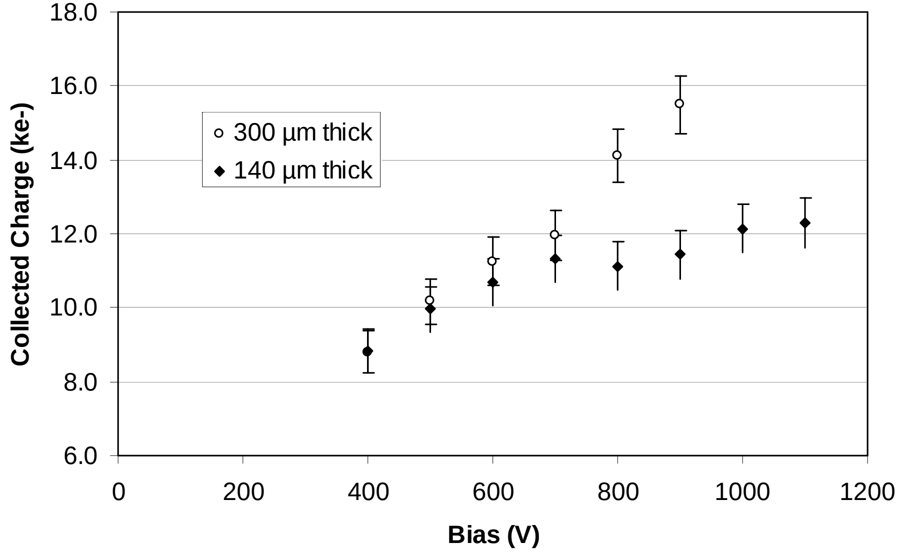


Comparison of CCE with 140µm and 300µm thick detectors from Micron irradiated to various n fluences, up to 1×10^{16} cm^{-2}!

5×10^{14} (?) n_{eq} cm^{-2}

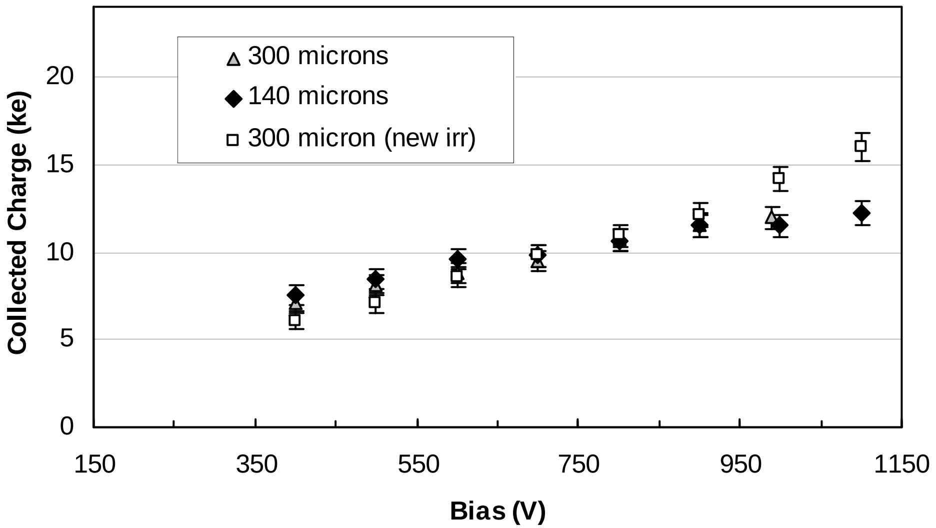


1.6×10^{15} n_{eq} cm^{-2}

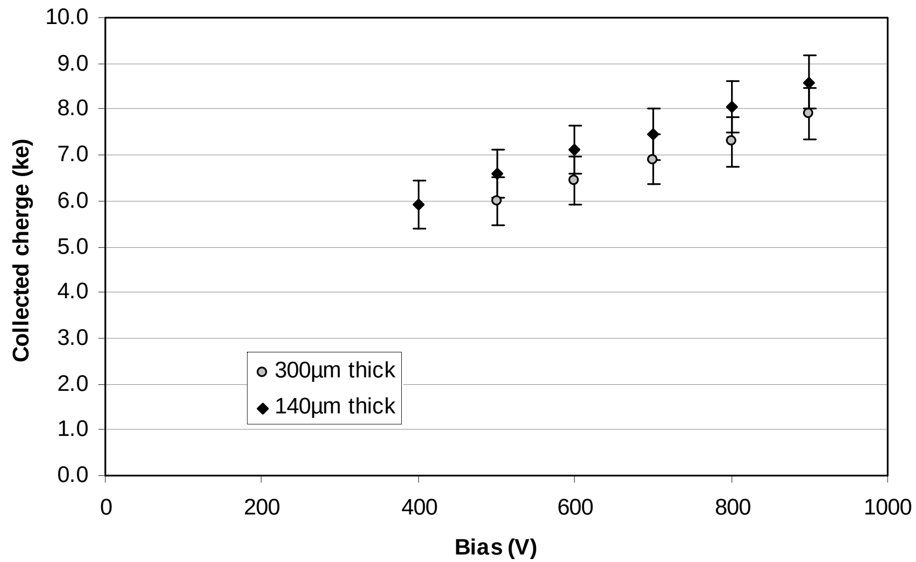


Comparison of CCE with 140µm and 300µm thick detectors from Micron irradiated to various n fluences, up to 1×10^{16} cm^{-2}!

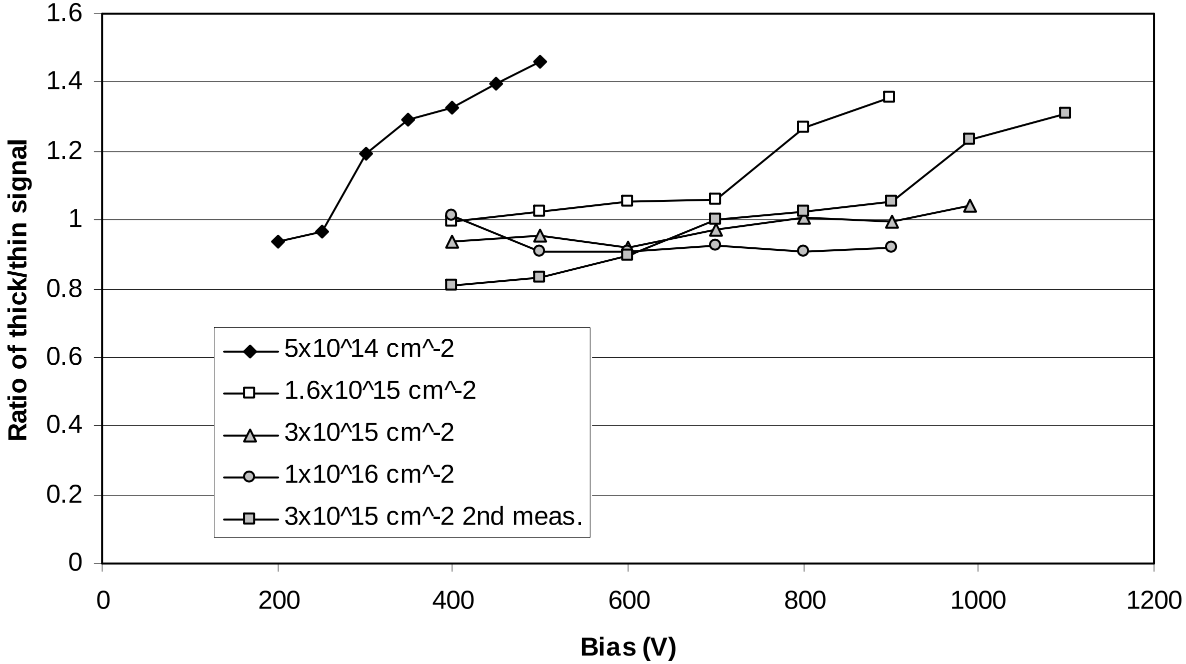
3×10^{15} n_{eq} cm^{-2}



1×10^{16} n_{eq} cm^{-2}

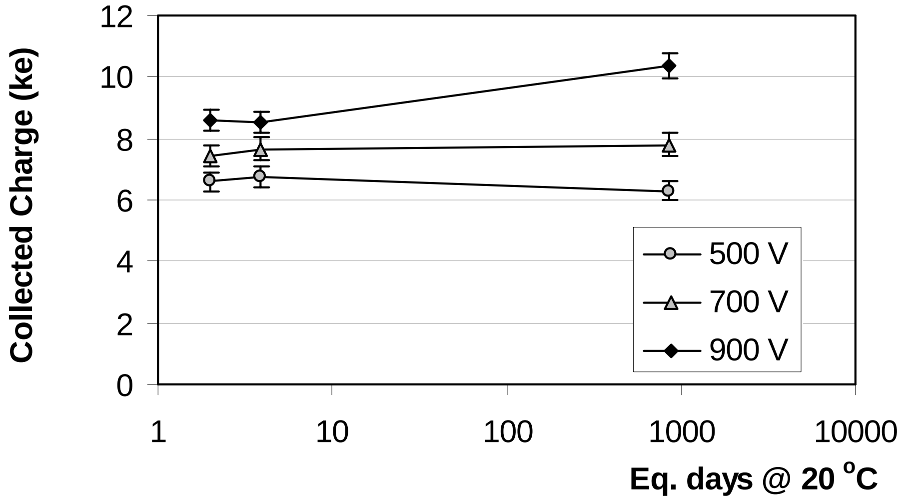


Ratio of the charge collected by thick to thin detectors as a function of fluence

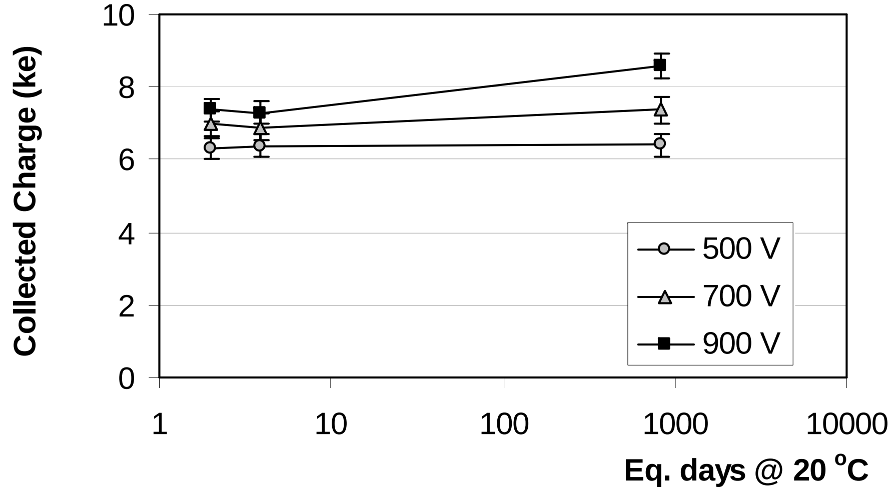


Annealing of irradiated dettectors after $1x10^{16}$ n cm^{-2}

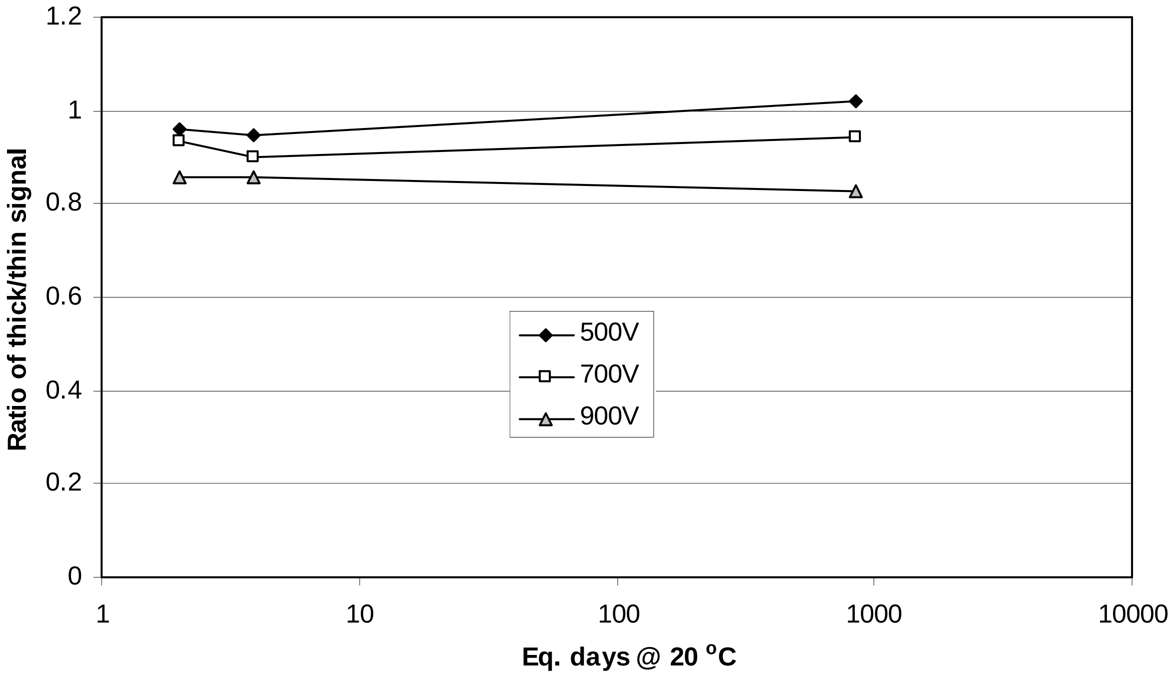
140 µm thick



300 µm thick



Ratio of the charge collected by thick to thin detectors as a function of the annealing time for detectors irradiated to $1x10^{16}$ n cm^{-2}



CONCLUSIONS:

P-type detectors tested up to $1x10^{16}$ n cm^{-2} show a extremely good signal and adequate radiation tolerance for the LHC upgrade to 10 times higher luminosity.

These measurements are the first reference measurements for highly segmented silicon detector made in planar technology (microstrip and pixel detectors) at these doses!

After heavy irradiations the CCE of thin and thick detectors becomes similar. The choice of optimal thickness can be dictated by the need of reducing the detector mass rather than increase of the signal after irradiation (at least up the remarkable dose of $1x10^{16}$ n cm^{-2}!!).