Edge-TCT studies of irradiated HVCMOS sensor (an update)

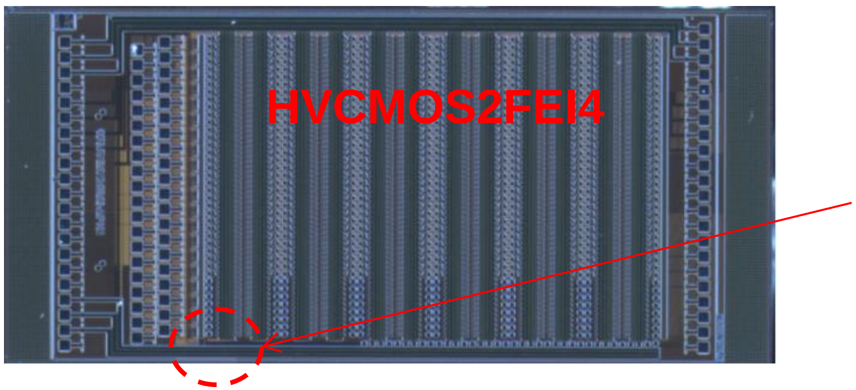
G. Kramberger

Jožef Stefan Institute, Ljubljana

on behalf of HVCMOS collaboration

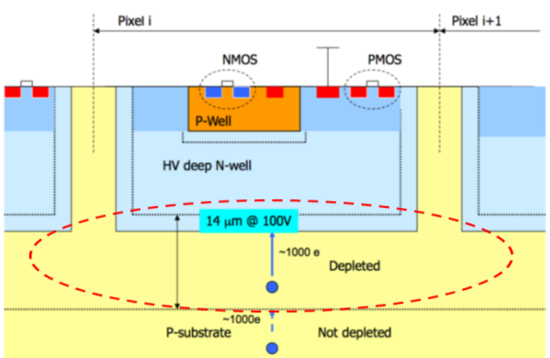
Motivation

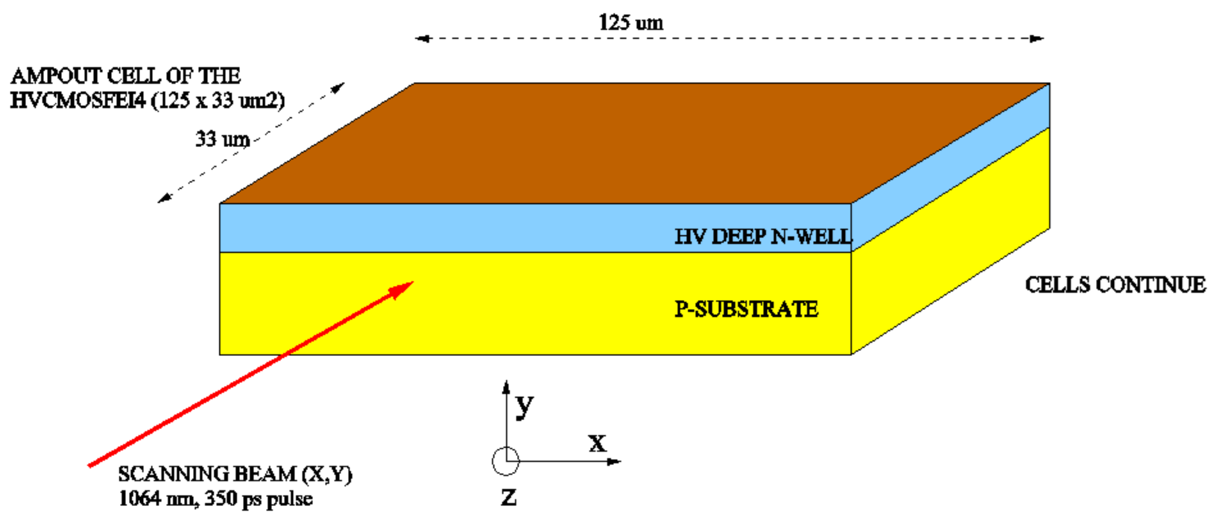
- Thanks for the first two speaker, which saved some of my minutes… (have a look also our presentation at 24th RD50 meeting)



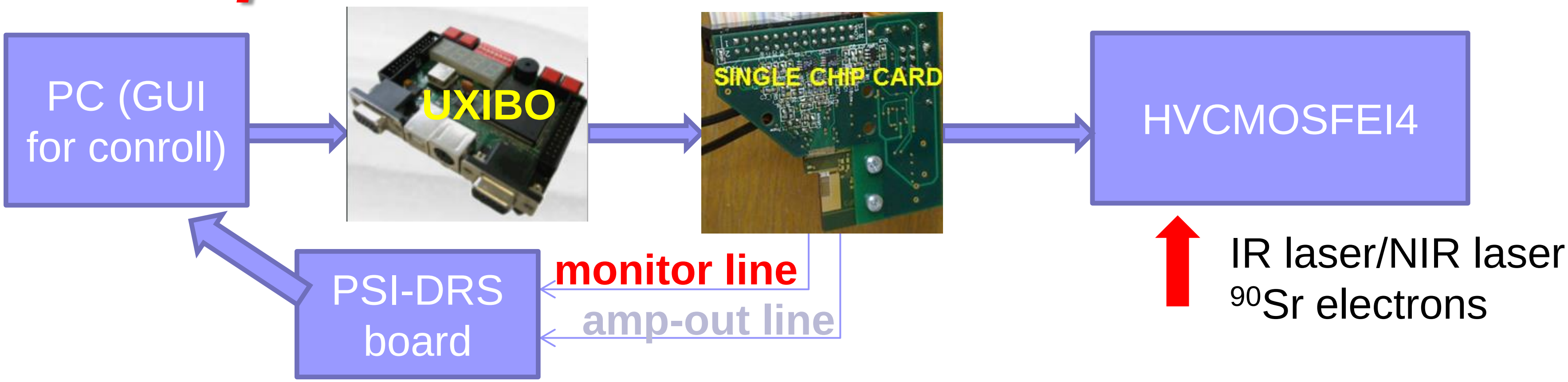
A single cell of 125 x 33 μm^2 was investigated – output to readout after the charge sensitive amplifier.

Not ideal (not observing induced current) , but good enough!

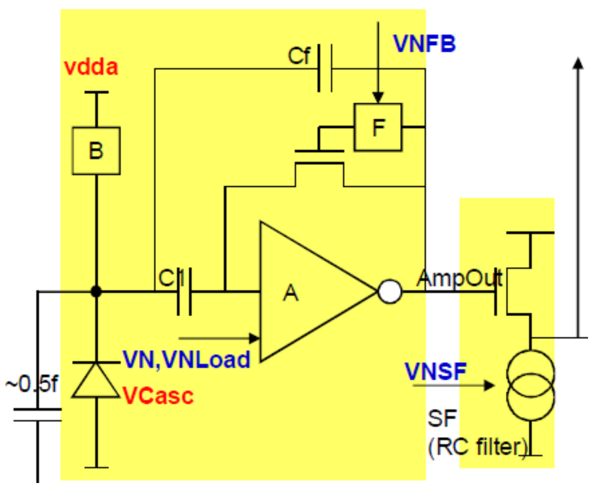




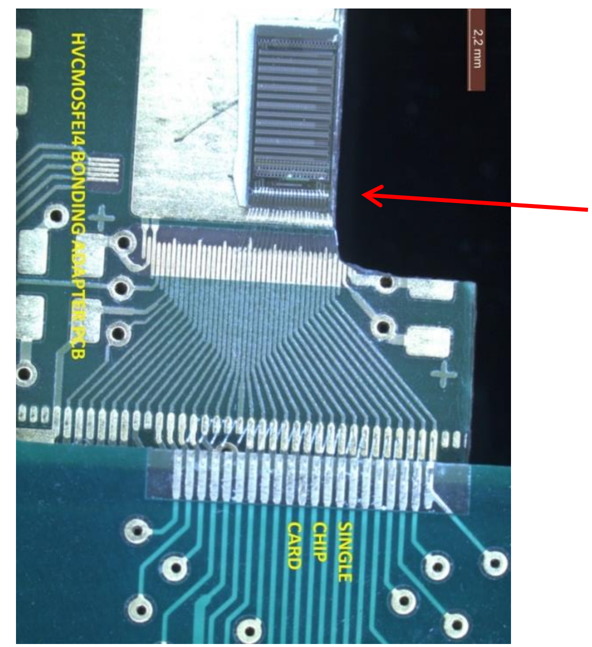
Setup



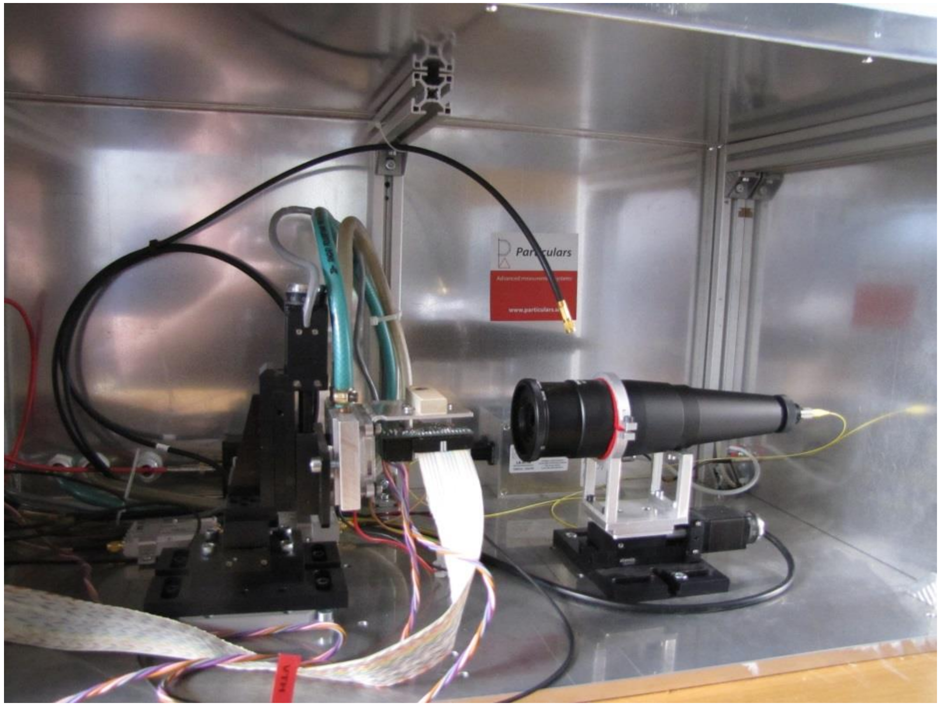
Single cell readout

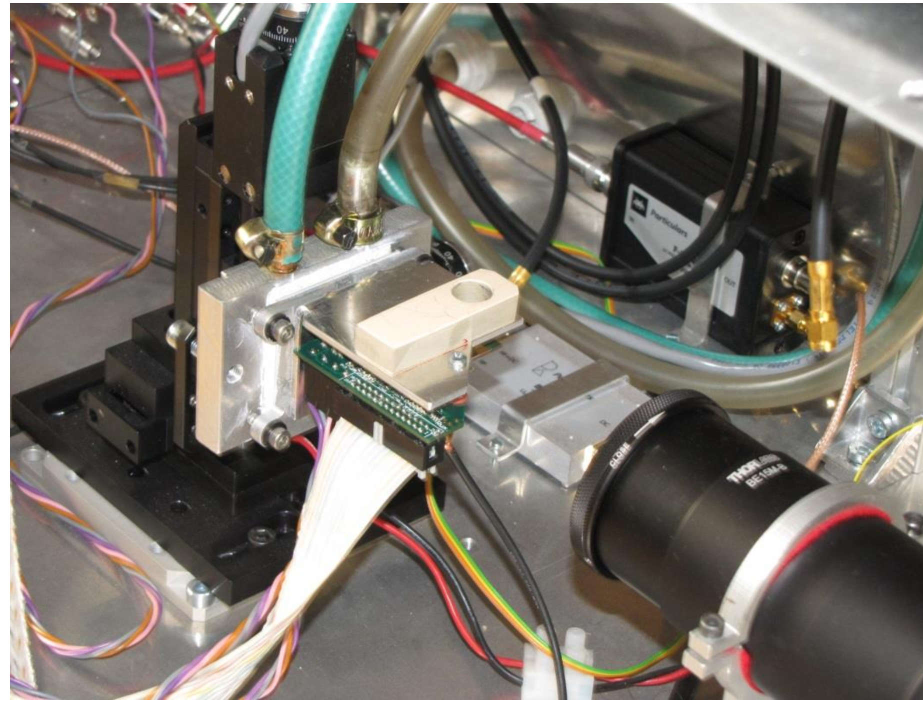


The line
monitored
in the
oscilloscope



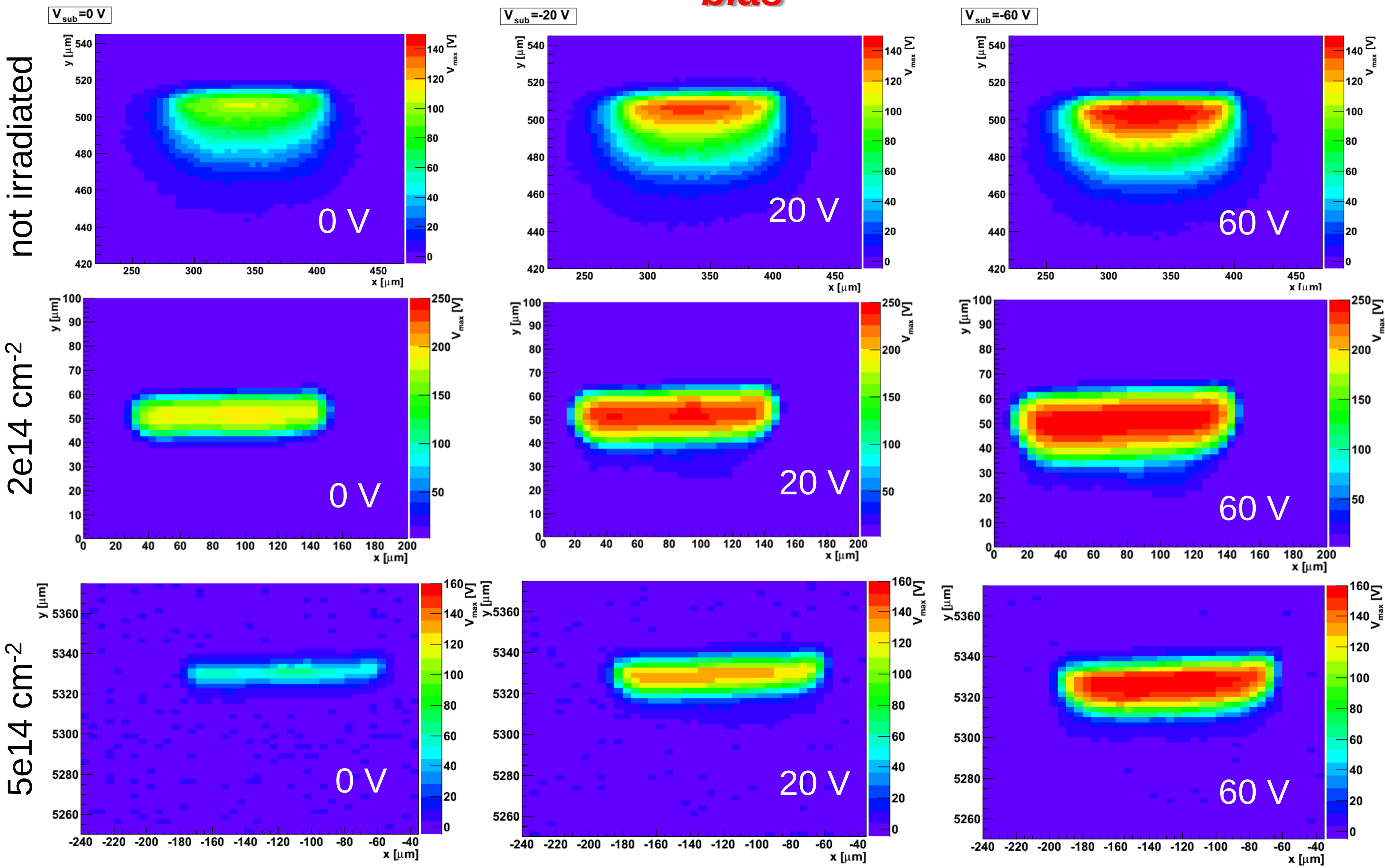
Sample and technique



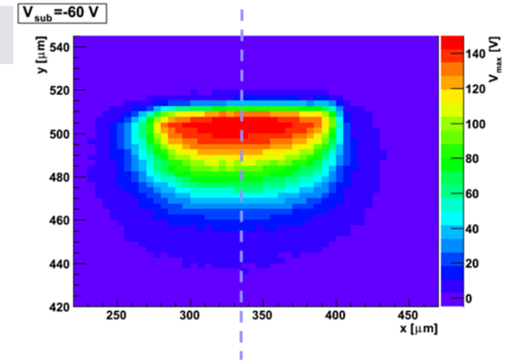


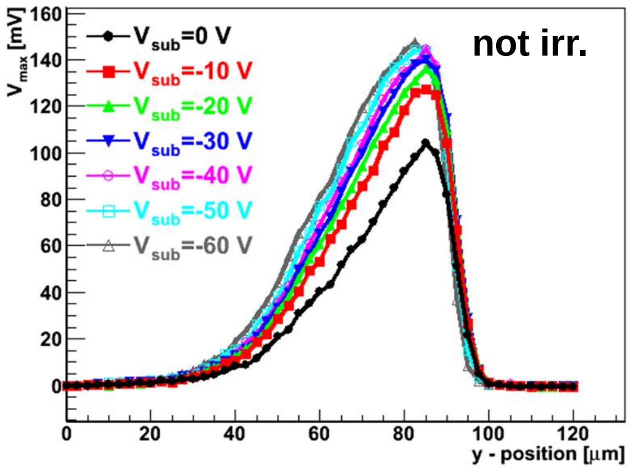
- A single detector was irradiated in steps with neutrons to 2, 5e14 cm^{-2} in steps (80min@60C annealing in between)
- *Particulars Scanning-TCT system* used:1060 nm pulse laser, 350 ps, 500 Hz
- At the moment the chip can not be actively cooled with measurements at 24^{o}C
- We FWHM of the beam was around 10 μm (although is seems better with HVCMOS around 7-8 μm – see our presentation at 24th RD50 meeting)

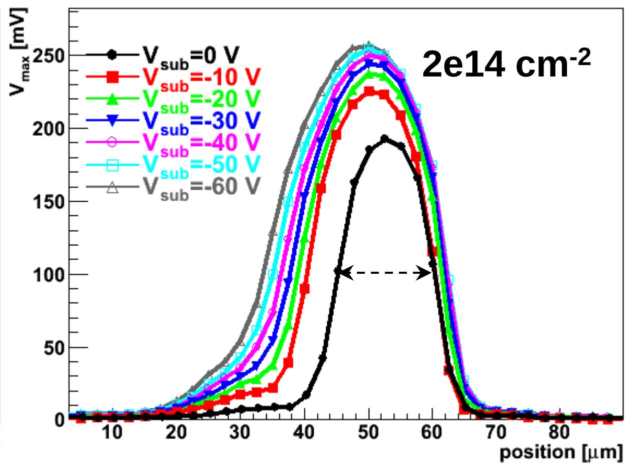
XY scan at different V_{bias} and fluences

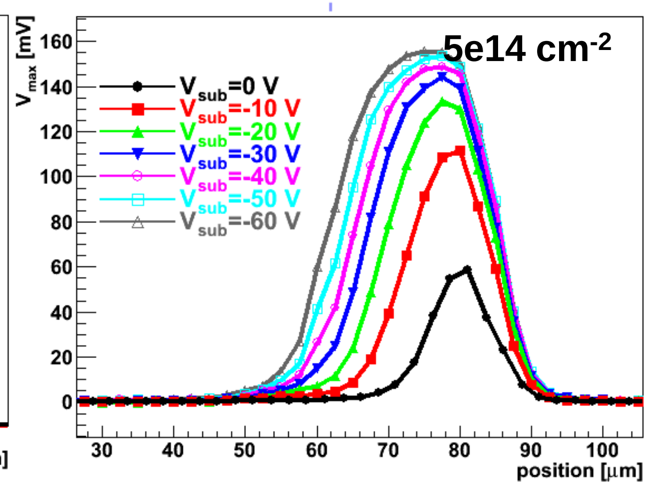


Charge collection profiles along the depth at the pixel center



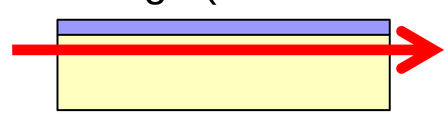






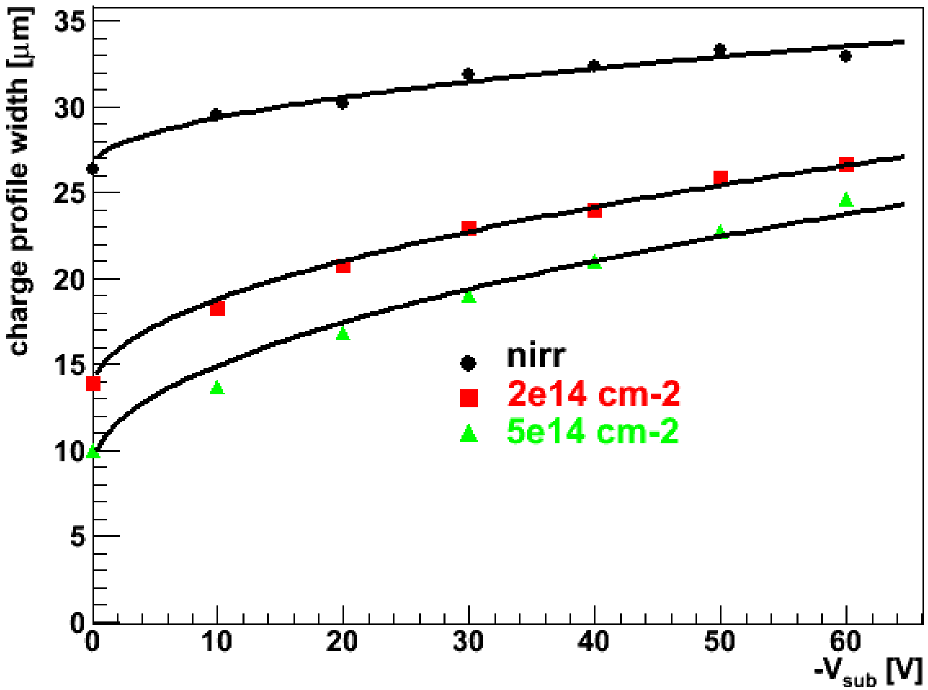
$$\sigma_{measured}^2 \sim \sigma_{coll.region}^2 + \sigma_{beam}^2$$

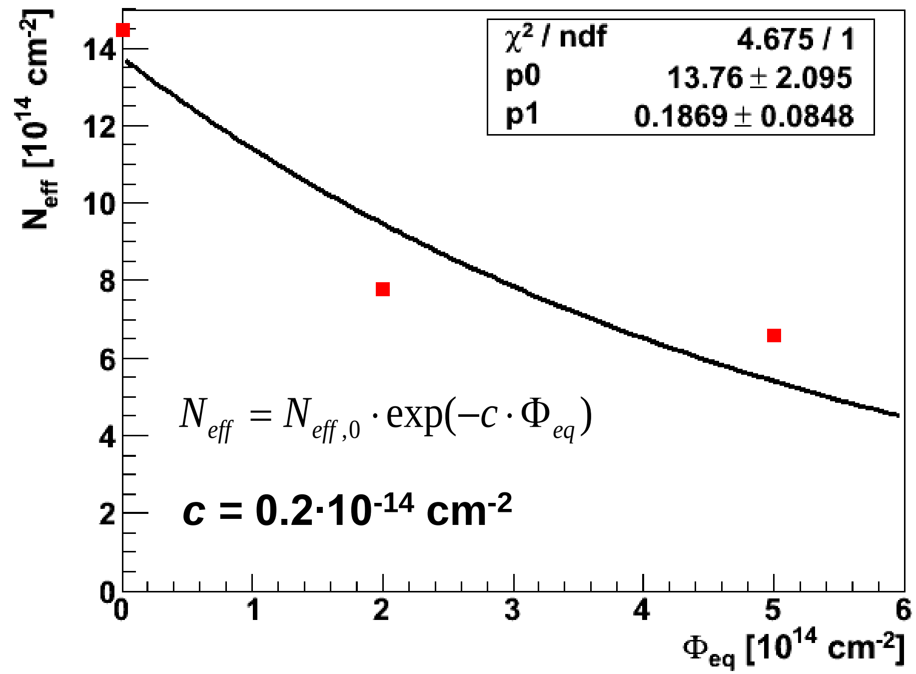
- Tail coming from diffusion before irradiation, still some after 2e14 cm-2, almost completely disappears at 5e14 cm-2
- Weak dependence of signal on voltage (beam contained in the field region)



- Profile width (FWHM) is a measure of charge collection region (diffusion + depleted), but the width of the beam should be taken into account

Effective doping concentration in p substrate





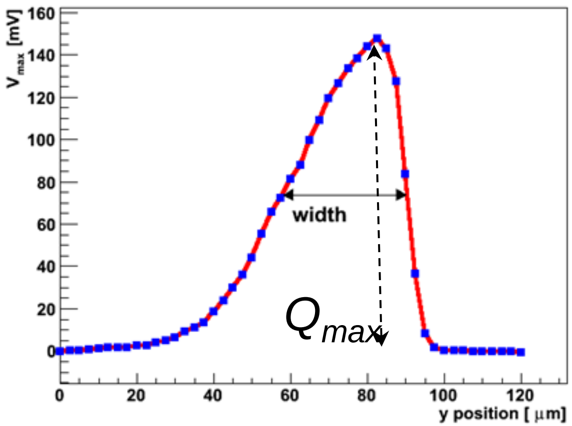
- Dependence of depleted region on substrate bias for constant space charge
  - At V_{sub}=0 V it is assumed that charge is collected by diffusion (note the FWHM of the beam)
  - Any additional bias depletes the certain amount which adds to the diffusion contribution:

$$\Delta d = \frac{2\varepsilon\varepsilon_0}{e_0 N_{eff}} \sqrt{V_{sub}}$$

Effective doping concentration is extracted from the fit for each fluence!

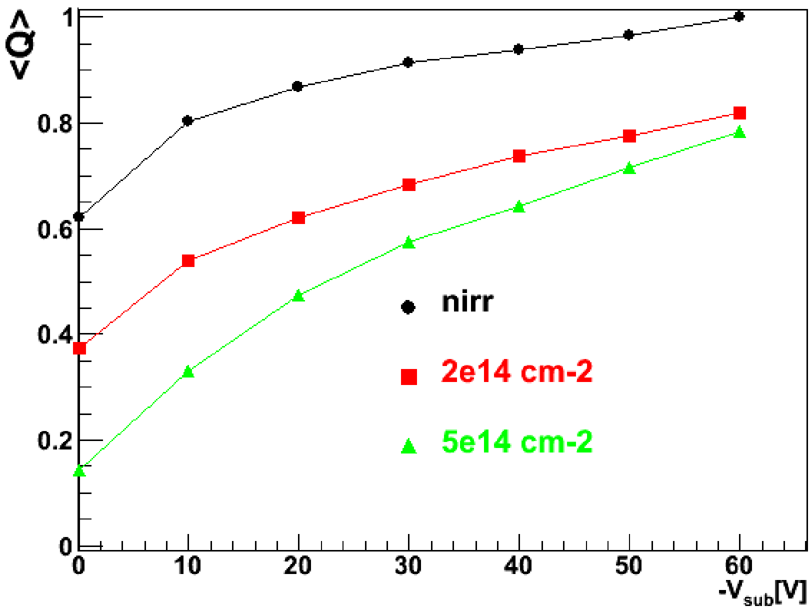
- The effective doping concentration seems to decrease with fluence – depletion region penetrates deeper after irradiation! This points to effective acceptor removal – not conclusive enough to claim B removal.

CCE for minimum ionizing particle



Integral of charge collection profile is proportional to the charge generated by minimum ionizing particle!

$$Q_{mip} \propto < Q > = \int_0^W Q(y)\, dy$$

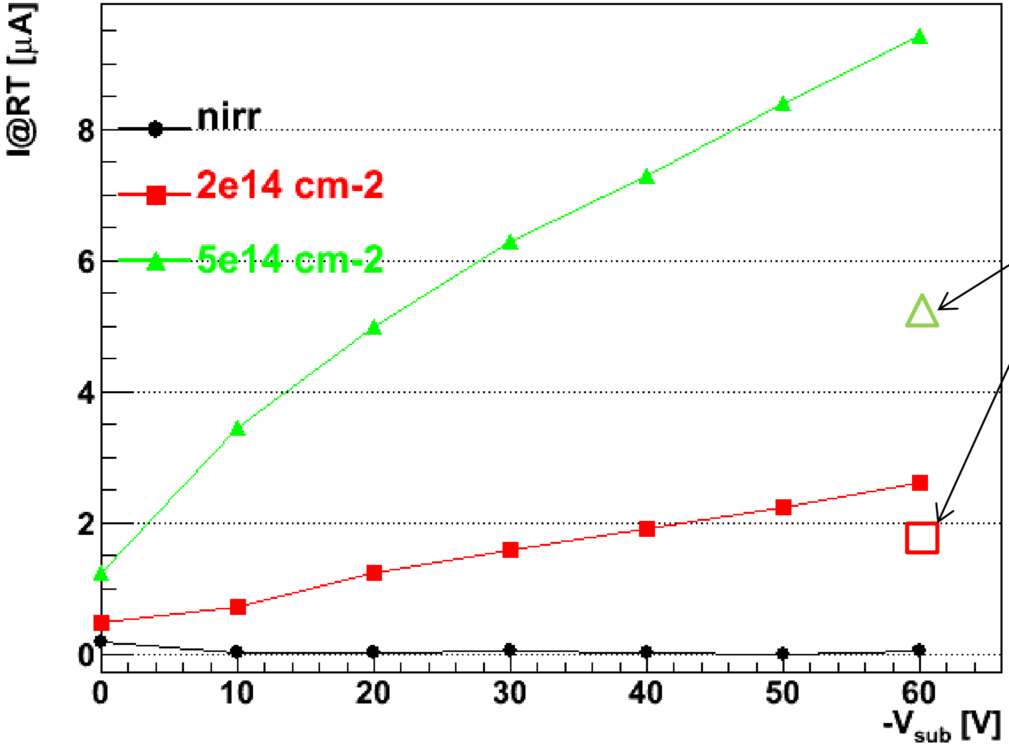


- Signals Q_{max}=Max($Q(y)$) for different fluences were normalized to the same value – trapping should not play a major role at that fluences
- $<Q_{nirr}>$ (60 V) = 1

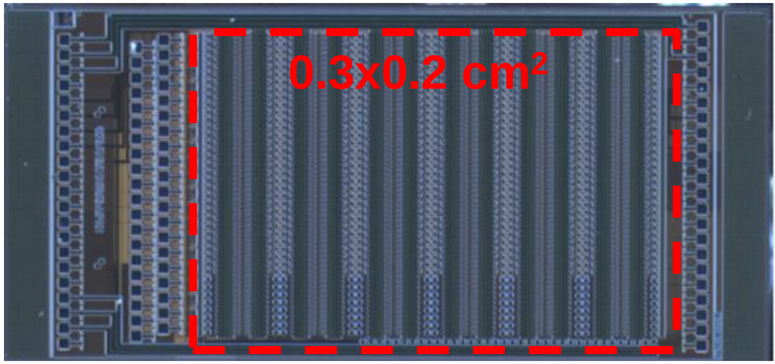
- The difference at high applied bias voltages is smaller
- The performance is far better then expected, owing to the wider depleted region – with fast LHC speed electronics it should be better for irradiated sensors
- Almost no difference between 2e14 cm^{-2} and 5e14 cm^{-2} at 60 V.

Leakage current

- Temperature was not controlled/stabilized, but the room temperature was always the same 24+/-0.5C

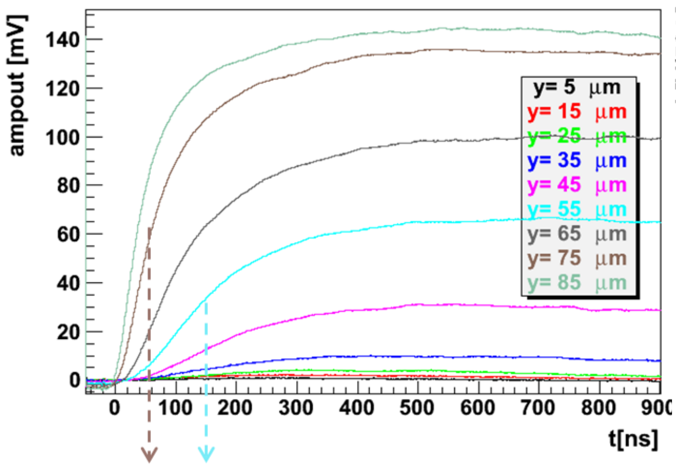


Calculated leakage current
$\alpha(20^{o}C)=4e\text{-}17\ A\ cm^{-1}$
$V=0.3x0.2x0.0025\ cm^3$

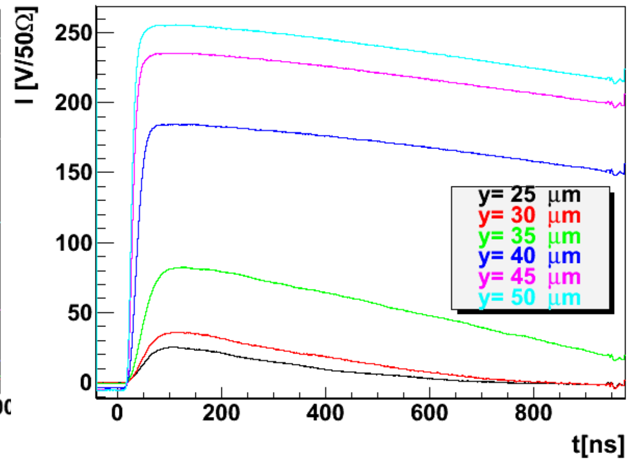


Shapes of the amplifier response

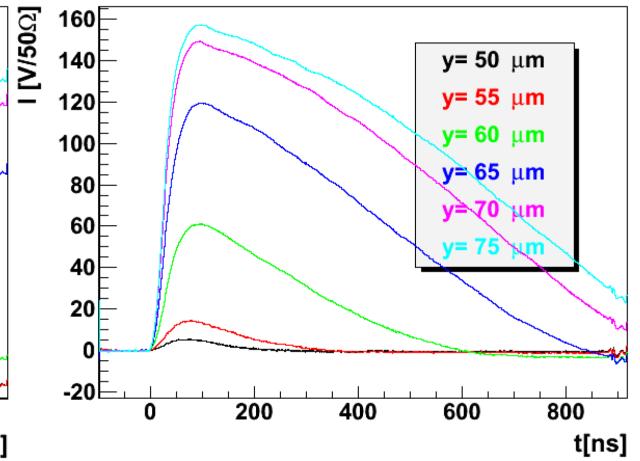
Not – irradiated



2e14 cm^{-2}



5e14 cm^{-2}



delayed 50% crossing points in indication of contribution from diffusion

- Changes in output – radiation induced?
- 50% crossing point of the max. amplitude can not be used for irradiated samples – small diffusion component/changes in amplified output

Conclusions

Edge-TCT was performed on HVCMOS2FEI4 structure using a cell amplifier output after initial amplifying stage

- Irradiation with neutrons decreases the depth from which the carrier are collected:
  - the depleted region **increases** with irradiation at the same bias voltage – pointing to reduced N_{eff} (initial acceptor removal ?)
  - The "diffusion region" **decreases** with irradiation – almost non-existent at 5e14 cm^{-2}
  - The combined effect may be beneficial with LHC speed electronics
- Estimated charge collection efficiency after irradiation to 5e14 cm^{-2} for ^{90}Sr changes only slightly for slow amplifier (it may increase with LHC speed electronics).
- Leakage current increase is compatible with expectations