CCE measurements with Epi-Si detectors

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Motivation

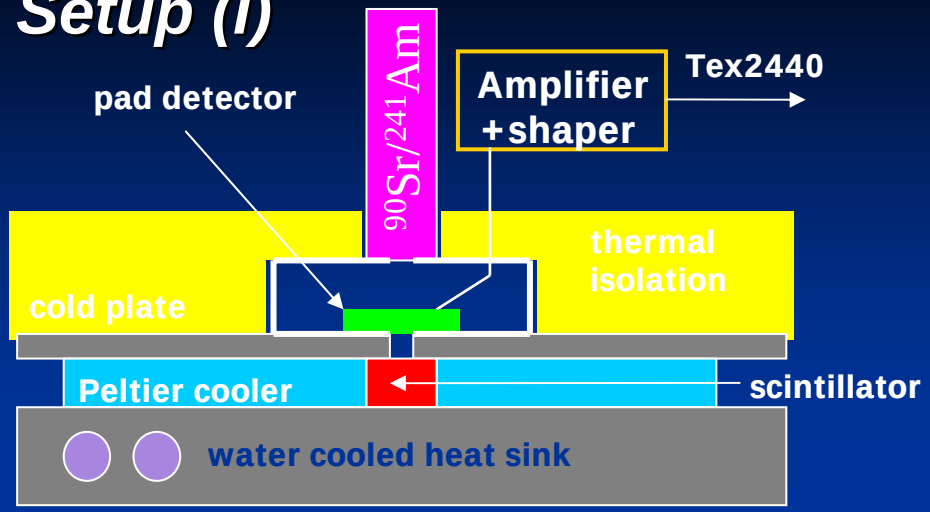
CCE measurements with heavily irradiated n-type silicon detectors:

- 50 μm epi-Si detectors processed by CiS: 50 Ωcm (p & n irradiated)
- 75 μm epi-Si detectors processed by CiS: 50 Ωcm,150 Ωcm standard and diffusion oxygenated (n irradiated)
- 150 μm epi-Si detectors processed by IRST: 500 Ωcm (n irradiated)

Why?

- to see if the V_{fd} makes any sense as a relevant parameter at high fluences
- to be able to extract trapping times at fluences where TCT fails
- to see how much charge can we collect at such high fluences with LHC speed elec.

Setup (I)



trigger signal is possible only for electrons passing through diode

↓

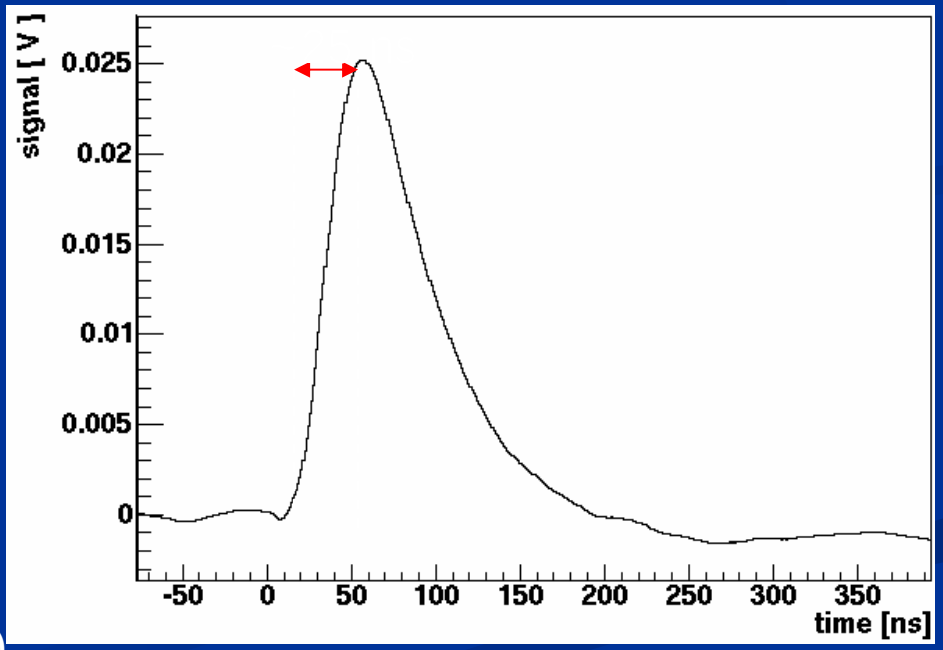
~98% purity assures good measurements also at low S/N<1

DAQ chain (rate to disk ~ 50 Hz)

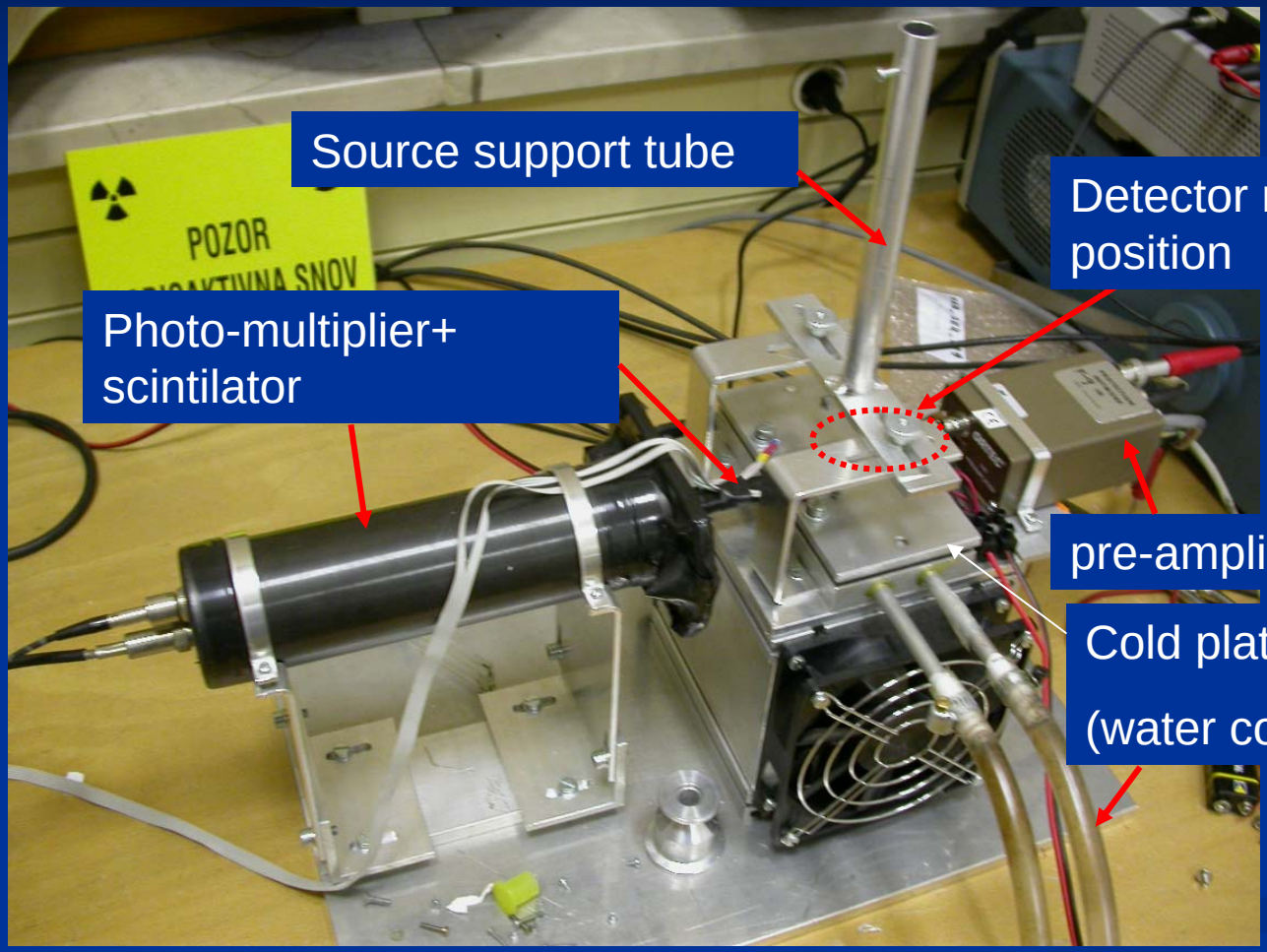
- ORTEC 142B preamplifier
- custom made shaping amp. (~25 ns)
- Tex 2440 oscilloscope connected to PC

Properties

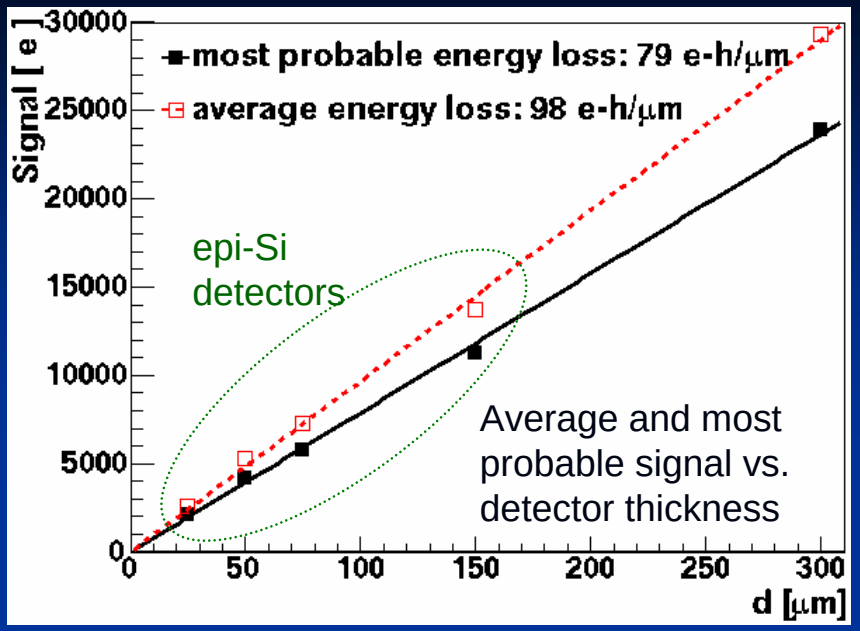
- Peltier cooling up to T=-30°C (stable to 0.1°C)
- HV (bias) up to 5 kV
- Full computer control (automatic scans)

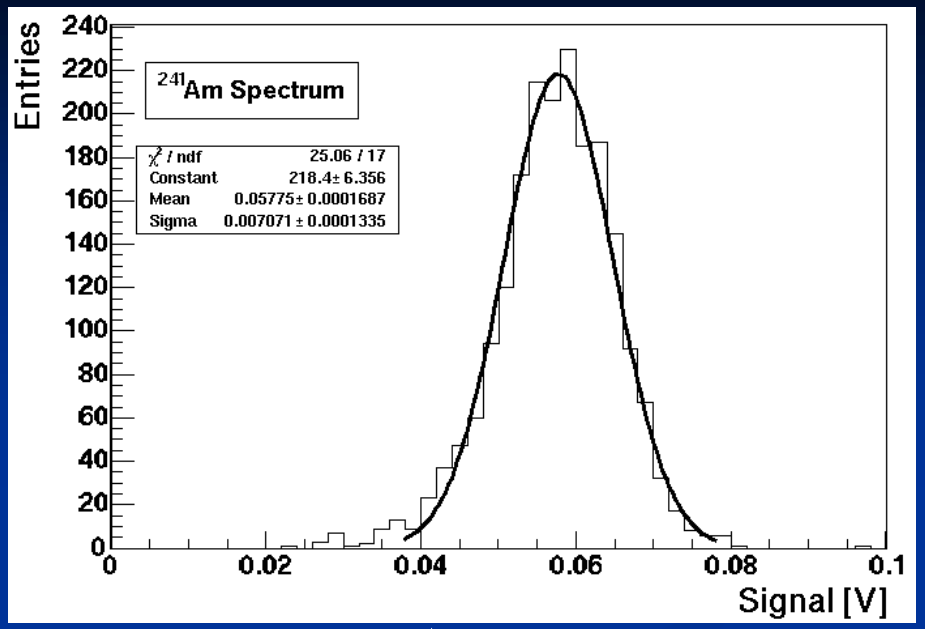


Setup (II)

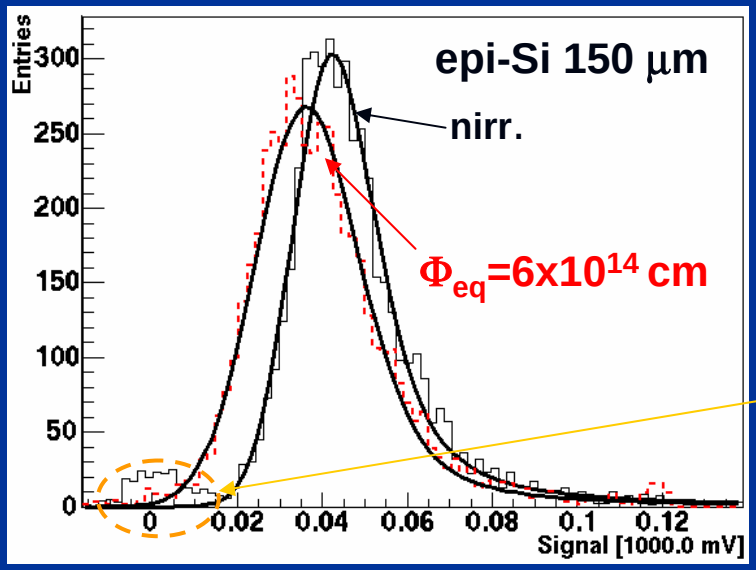

Source support tube
Detector mounting position
Photo-multiplier+ scintilator
pre-amplifier
Cold plate (Peltier cooled)
(water cooled back side)
POZOR

Setup (II) - Calibration



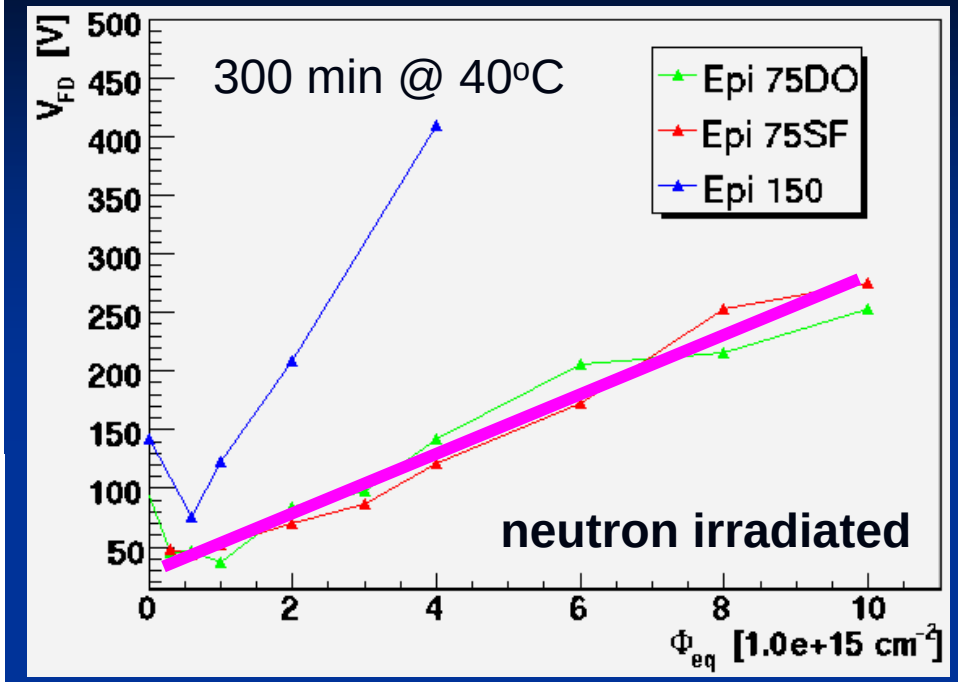


Scale calibrated with photons
from ^{241}Am (59.6 keV)



Example of energy loss spectra
Trigger inefficiency on 2-3% level

CV measurements



for 75 and 150 μm thick diodes (150,500 Ωcm)
What about the SCSI ?

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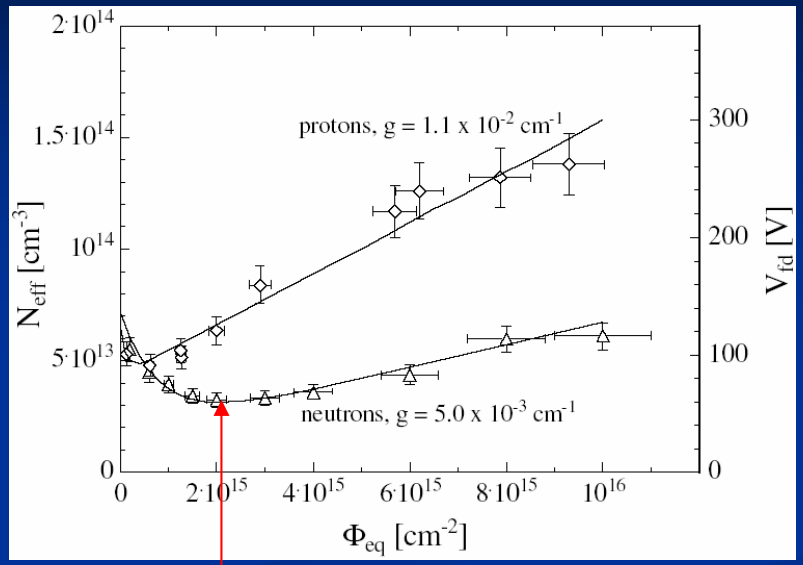
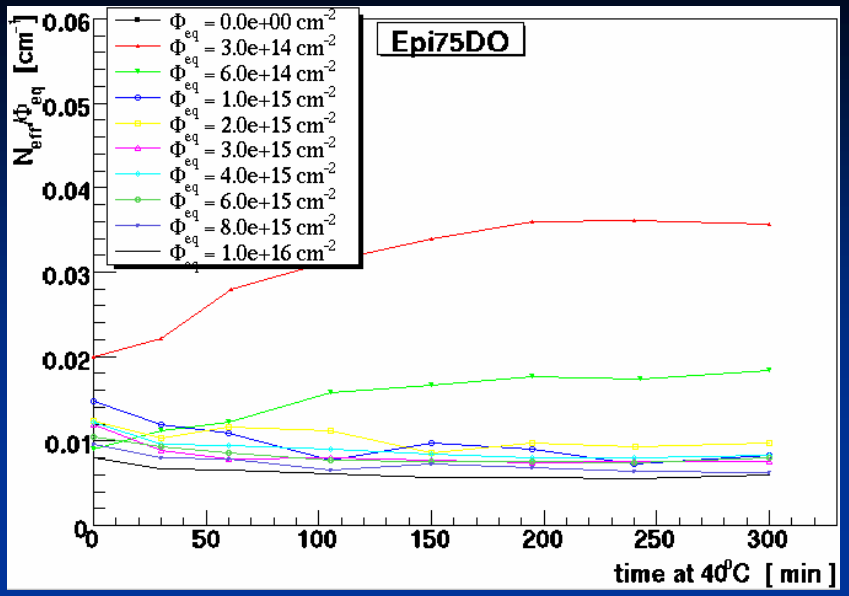
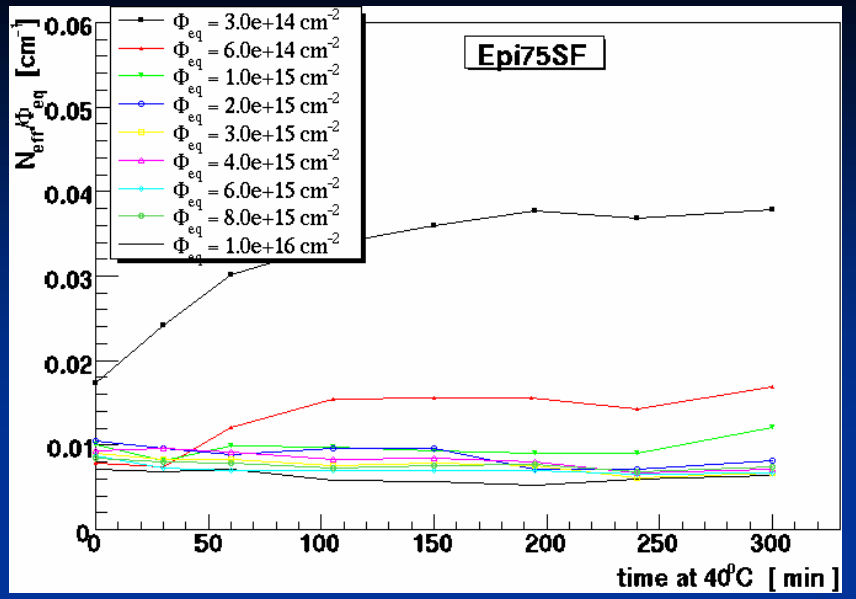


for 50 μm thick diodes and 50 Ωcm n irr.
From annealing plots -> no SCSI !
(introduction rate of donors>acceptors)

- V_{fd}(150 μm)/V_{fd}(75 μm)~4
- if N_{eff}≠constant it is interesting that th $V_{fd} \propto thickness^2$
- additional oxygenation doesn't help for neutron irradiation

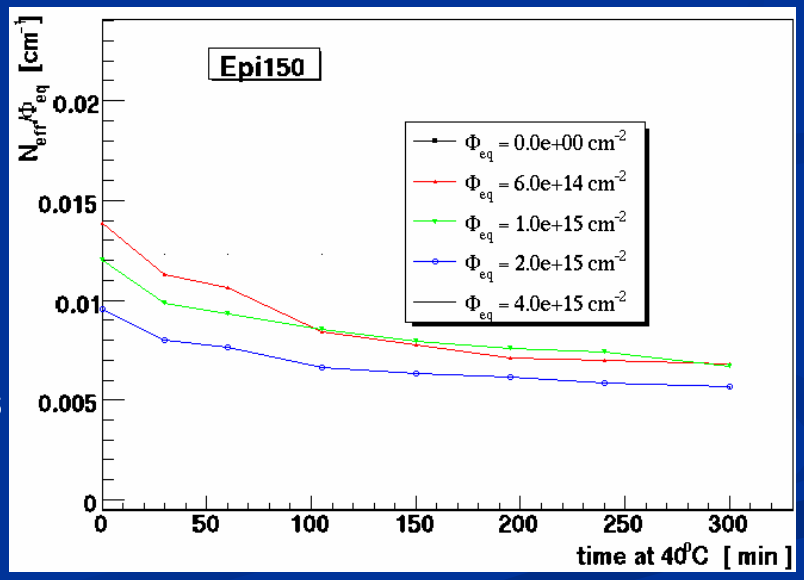




Lower fluences show annealing behavior typical for n type detector !

$|g_c| \sim 7 \times 10^{-3}$ cm^{-1}

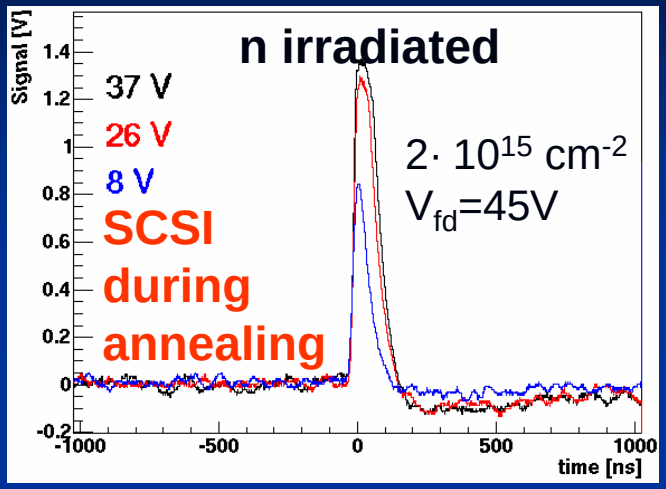
Measurements performed so far on 50 Ωcm epi-Si detectors **show no inversion** after neutron irradiation – also for the highest fluence the V_{fd} rises during "beneficial annealing"



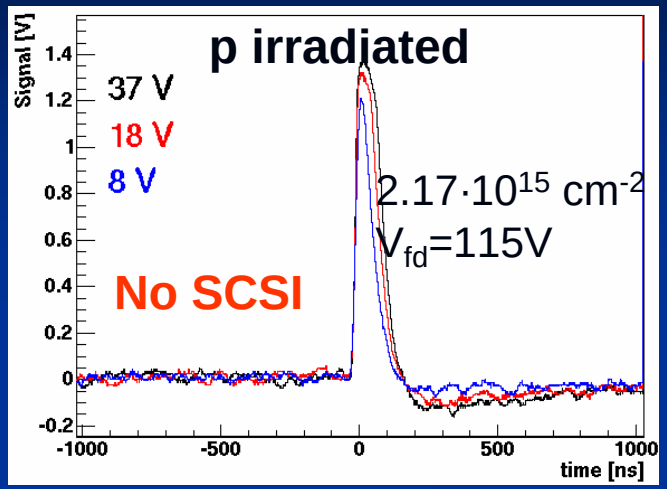
What about alpha particle measurements?

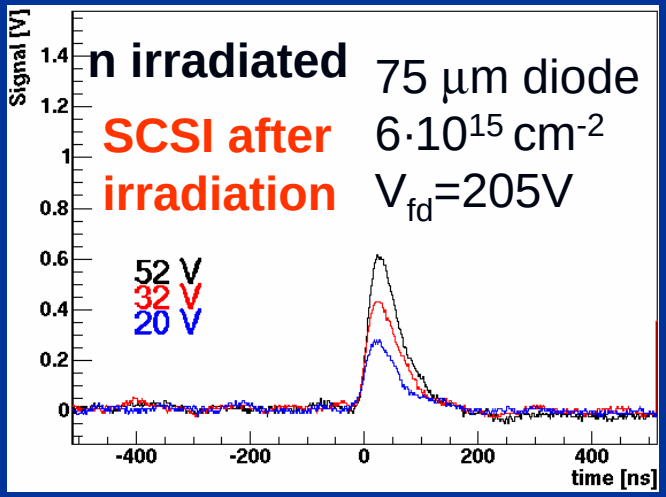
Alpha particle measurements

75 μm thick 50 Ωcm epi-Si detectors after long term annealing (>2 years @20C)!



Difference in field profile

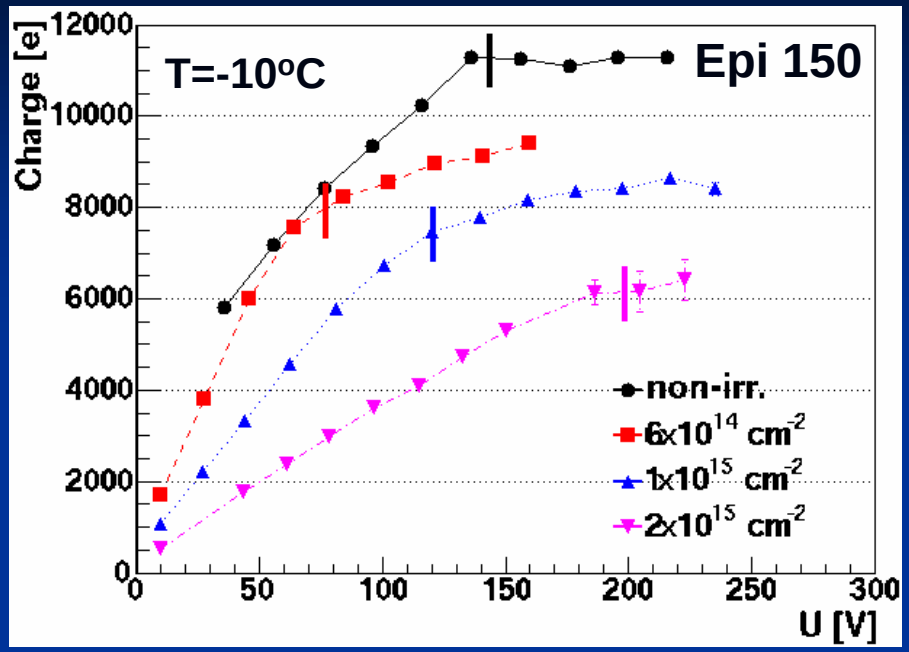


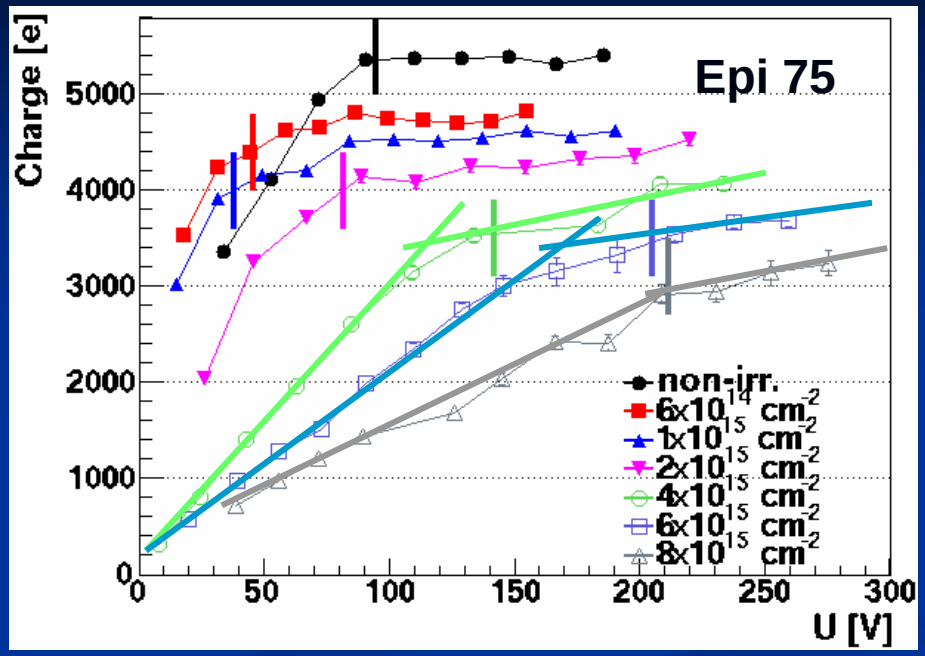


The detector is effectively of p-type

M.I.P. measurements

V_{fd} is denoted by short line for every sensor!

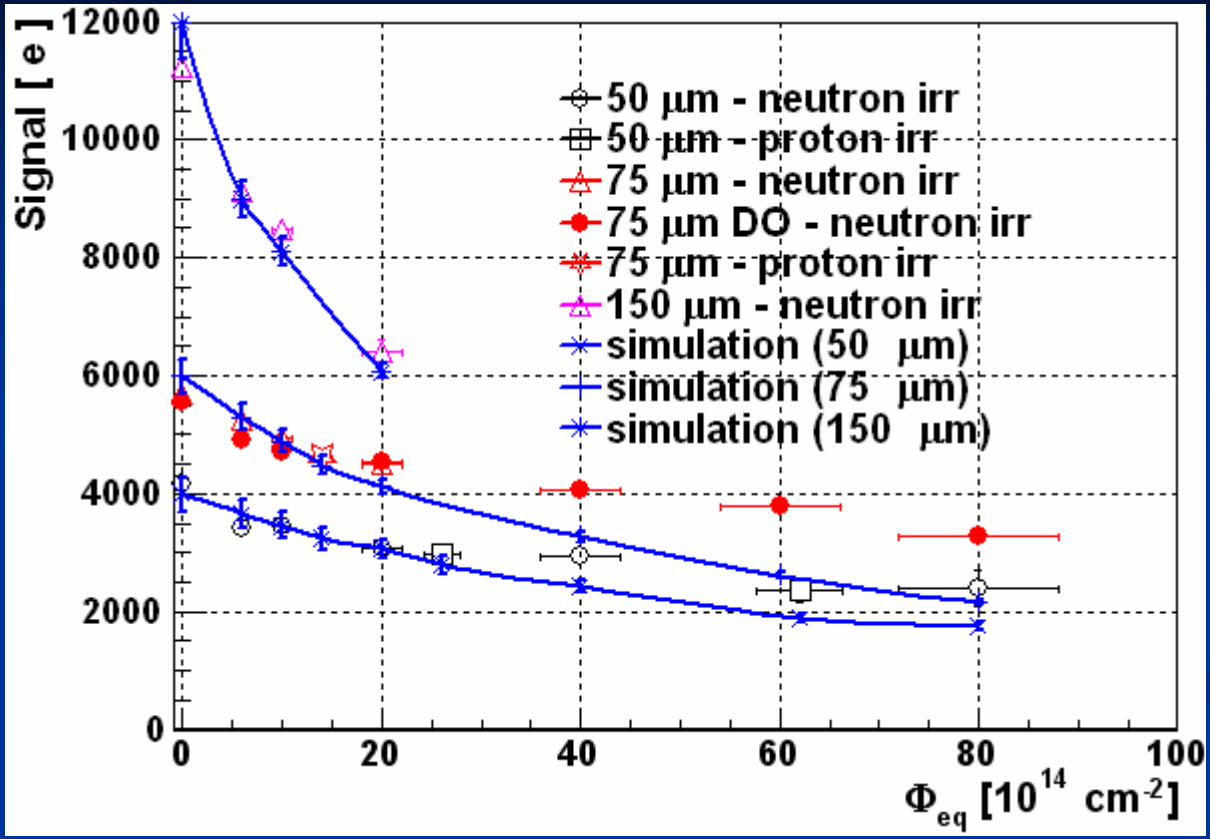




75 μm diodes perform superbly in term of noise (no break downs) also at very high fluences!

- **kink in charge collection plot coincides with full depletion voltage from CV measurements! Also for heavily irradiated silicon detectors the full depletion voltage has meaning**
- **the signal for heavily irradiated sensors rises significantly after V_{fd} (trapping)**
- **>3200 e for 8x10^{15} cm^{-2} neutron irradiated sensor! – more than expected**

M.I.P. measurements



- Each measurement point was simulated (Vfd, V as for measurements, constant N_{eff})
- Trapping times taken as "average" of measurements of several groups
- T=-10°C

- At lower fluences the simulation agrees well with data, at higher fluences the simulation underestimates the measurements
- What would be the reason? – very likely trapping probabilities are smaller than extrapolated (~ 40-50% smaller)

Conclusions

CCE measurements were performed on new epi-Si detectors (75 and 150 μm thick)

•after neutron irradiation the new sensors are effectively of p-type (V_{fd} annealing, α signals)

•at $8x10^{15}$ cm^{-2} the most probable signal of mip for 75 μm thick device >3200 e

•the kink in CCE vs. voltage coincides with V_{fd} ! V_{fd} is still a relevant parameter at very high fluences!

•The signal is underestimated by simulations at high fluences -> smaller trapping probabilities than extrapolated! At lower fluences the simulation agrees well with measurements.