P-type Silicon irradiated with 24 GeV/c protons

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Outline

- p-type Si serious candidate for trackers at LHC upgrade
- CCE depends on trapping. High E field, short drift length, proper readout side (electron signal dominates on n-strips) can reduce the effect of trapping on CCE
- p-type microstrip detectors with n-side readout have shown good performance after irradiation to high fluences

Description of silicon detectors

- Diodes n+-p-p+. Characteristics:
- active area: 5×5 mm2
- substrates:
- Silicon <100>; 300 ± 15 μm; 20kΩ·cm
- DOFZ <100>; 300 ± 15 μm; 20kΩ·cm, [O]~2*10^{17}
- MCZ <100>; 300 ± 15 μm; 5 kΩ·cm , [O]~5*10^{17}
- guard ring: 200 μm wide at 100 μm distance from the central diode
- n+-p junction depth: 2 μm
- P concentration on surface: $2 \cdot 10^{19}$ cm^{-3}
- p+-n junction depth: 1.5 μm
- B concentration on backside surface: 10^{20} cm^{-3}
- Total dimensions of the device: 7.11×7.11 mm^2
- Isolation: p-spray blanket, depth~2um, peak=$10^{15}$$cm^{-2}$

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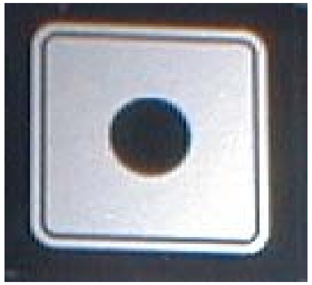
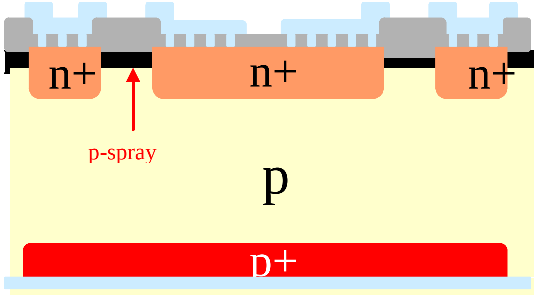




Fabrication procedure (CNM Barcelona)

- Summary of fabrication steps:
- Thick oxide growth (1 μm)
- Oxide patterning
- N+ implant
- Backside P+ implant
- Implant annealing (950ºC, 30 min)
- Contact opening
- Metal deposition and patterning
- Metal annealing (350ºC, 30 min)

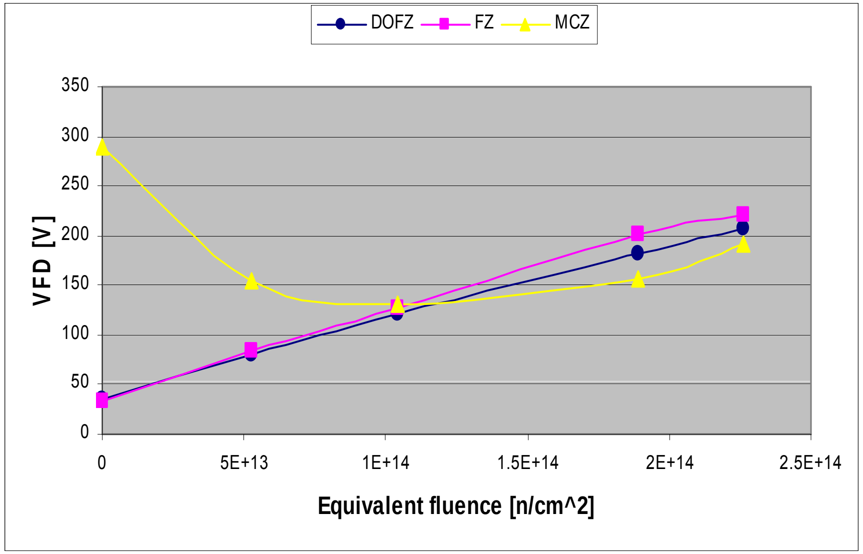
Irradiations:

- Irradiations with 24 GeV/c protons at CERN
- Samples kept cool to prevent annealing

Fluence dependence of N_{eff}: p

CV Measurements taken after 3 weeks at 20°C (approxim. “stable” damage)

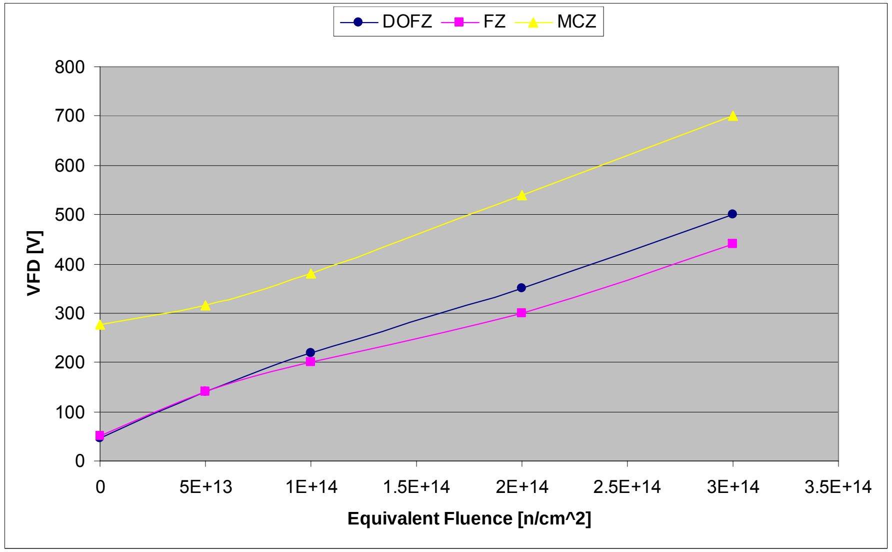
Protons



If $\Delta N_{eff} = g\ \Phi_{eq} \rightarrow\ g \sim 1.05\ 10^{-2}\ cm^{-1}$

CERN measur. $0.75\ 10^{-2} cm^{-1}$ (last workshop)

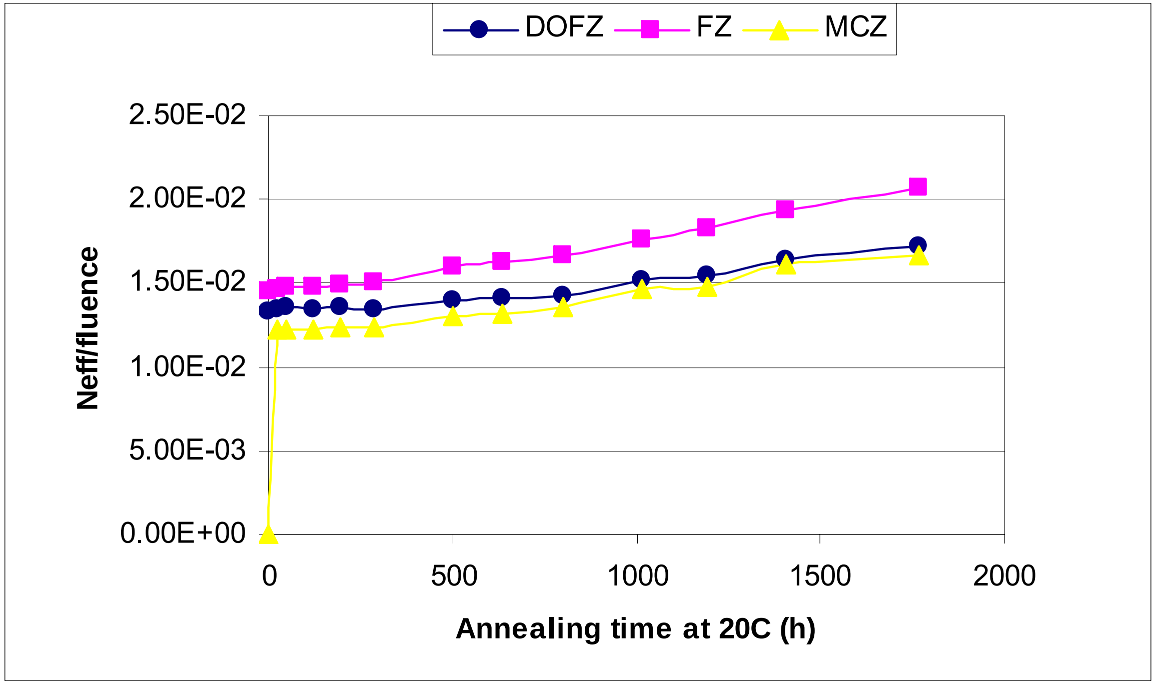
Neutrons



$g \sim 2\ 10^{-2}\ cm^{-1}$

Annealing of N_{eff}:

Proton irradiated, Φ_{eq} = 1.95 10^{14} cm^{-2}



Slopes:

FZ 3.9 ± 0.2 10^{-6} h^{-1}

DOFZ 2.8 ± 0.2 10^{-6} h^{-1}

MCZ 3.9 ± 0.2 10^{-6} h^{-1}

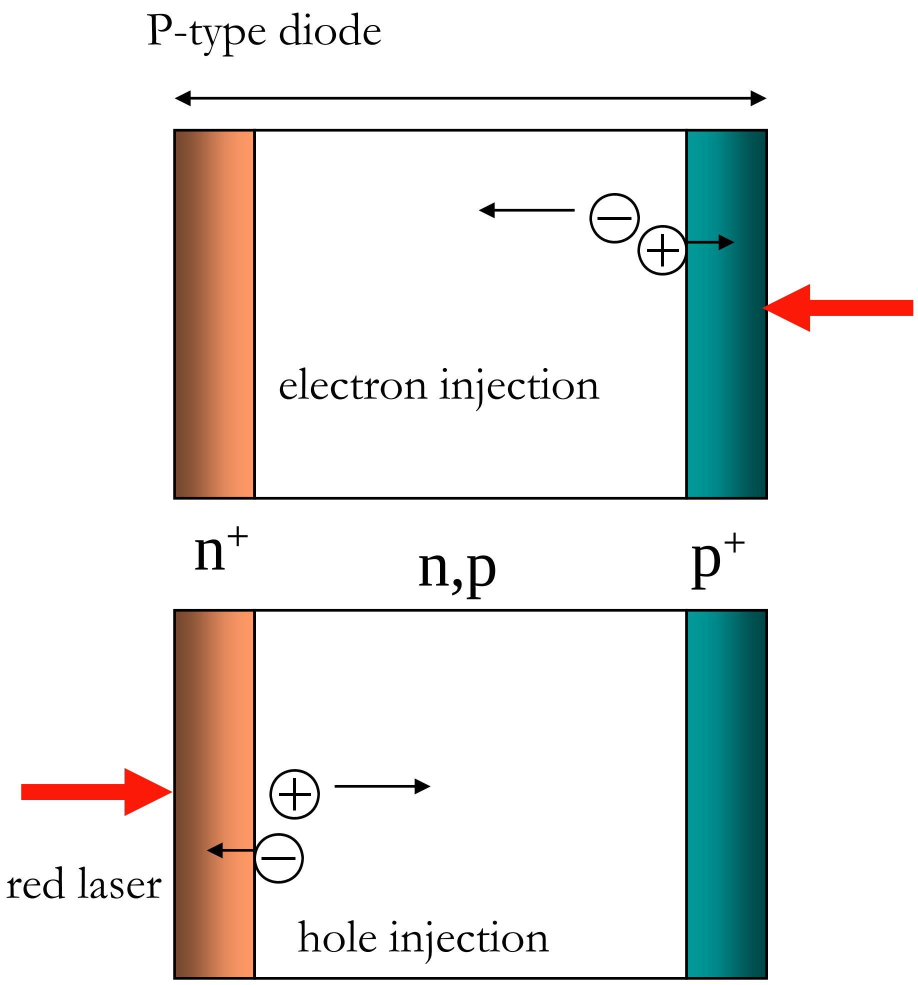
n-type, n irradiations

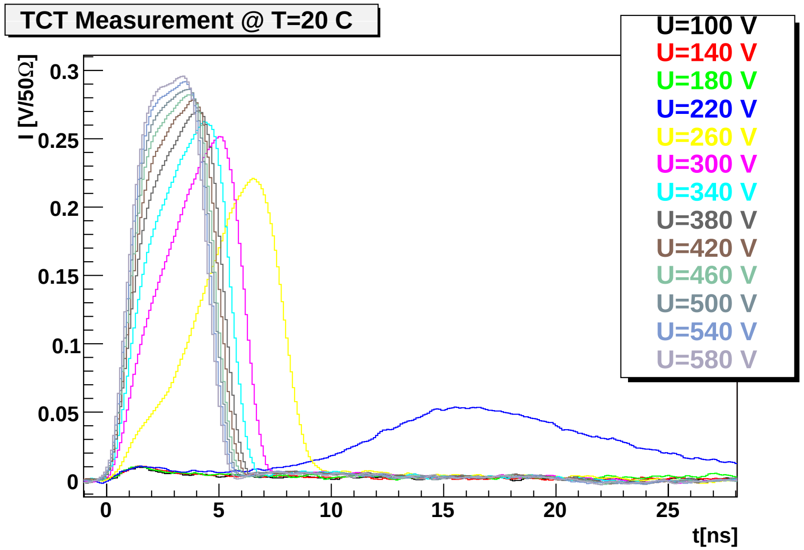
4.25 ± 0.3 10^{-6} h^{-1}

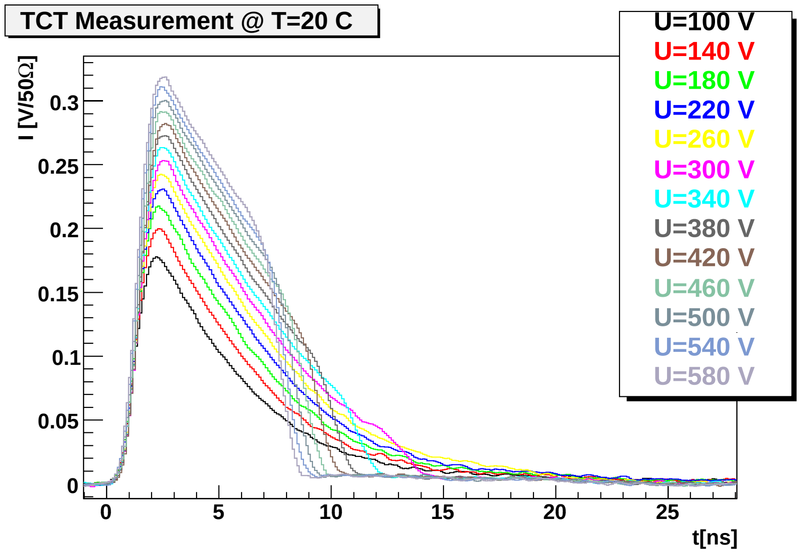
→ similar long term annealing in n and p-type material

Annealing at 60°C → activation energy 1.25 ± 0.05eV

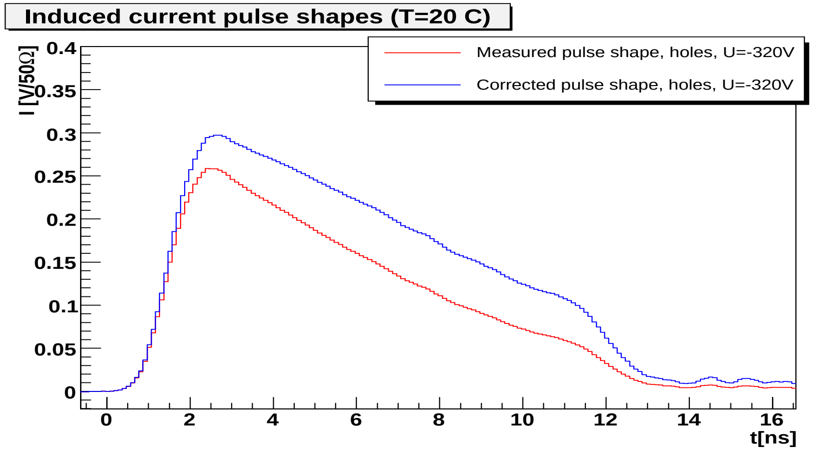
Determination of $t_{eff,e,h}$ – Charge correction method (I)

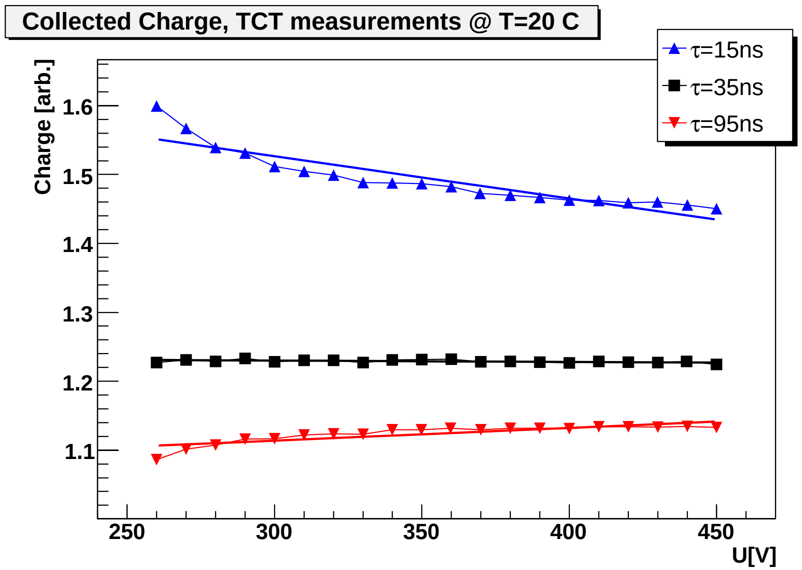






Determination of $t_{eff,e,h}$ (II) – Charge correction method (II)





Charge increases with V for $V > V_{fd}$!

Measured

$$I_m(t) = I_{e,h}(t) = \left[e_0 \, N_{e,h} \frac{1}{D} v_{e,h}(t) \right] \exp\left(\frac{-t}{\tau_{eff,e,h}}\right)$$

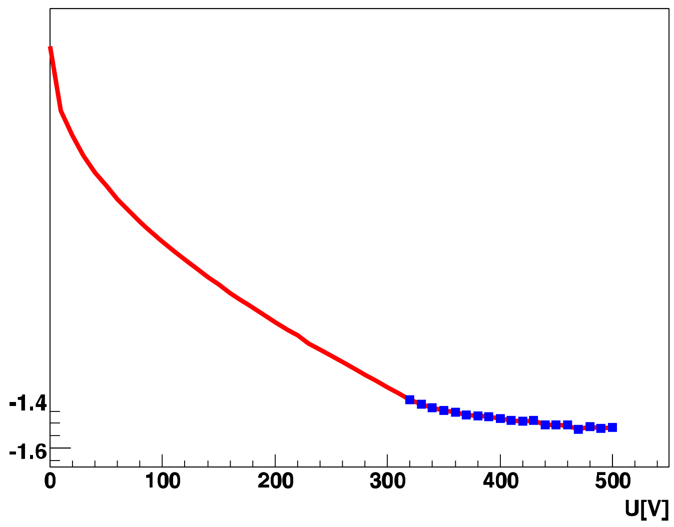
Corrected

$$I_c(t) = I_m(t) \exp\left(\frac{t - t_0}{\tau_{tr}}\right)$$

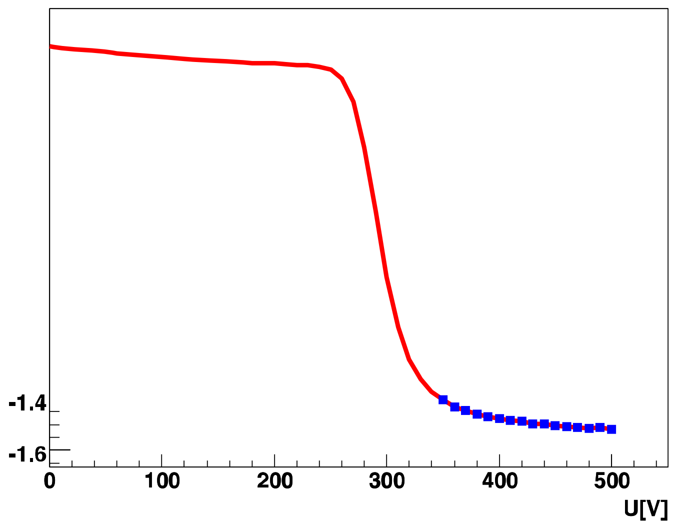
Q_c=**constant for** $V > VFD \longrightarrow \tau_{tr} = \tau_{eff}$
(without trapping the signal of fully depleted detector doesn't depend on voltage)

Integral of signal

Hole signal



Electron signal



Bulk remains p-type

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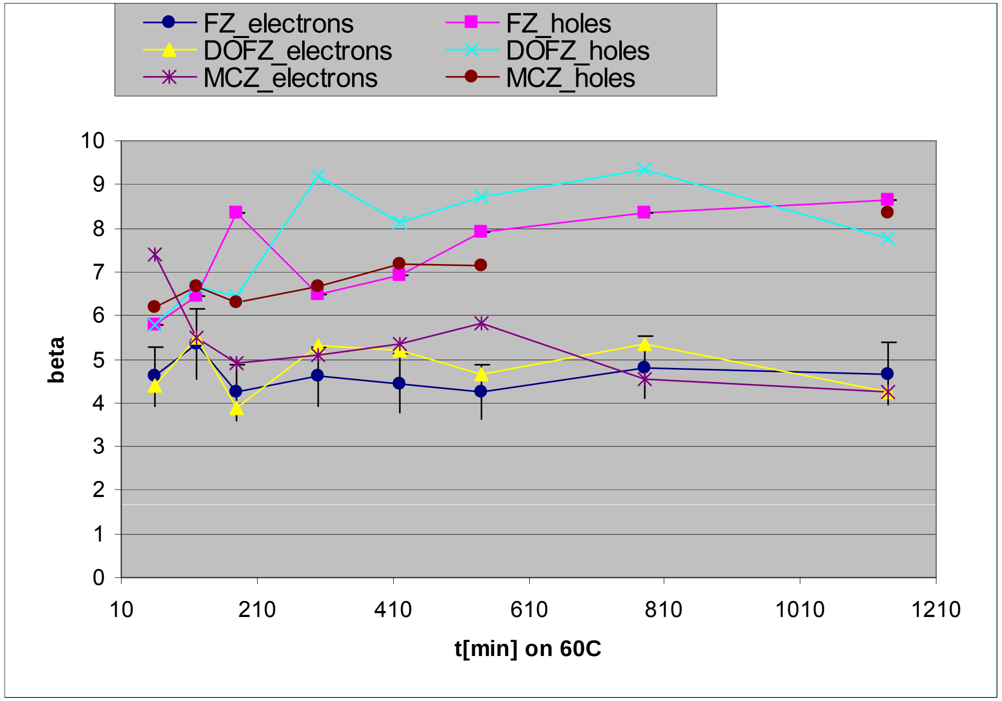
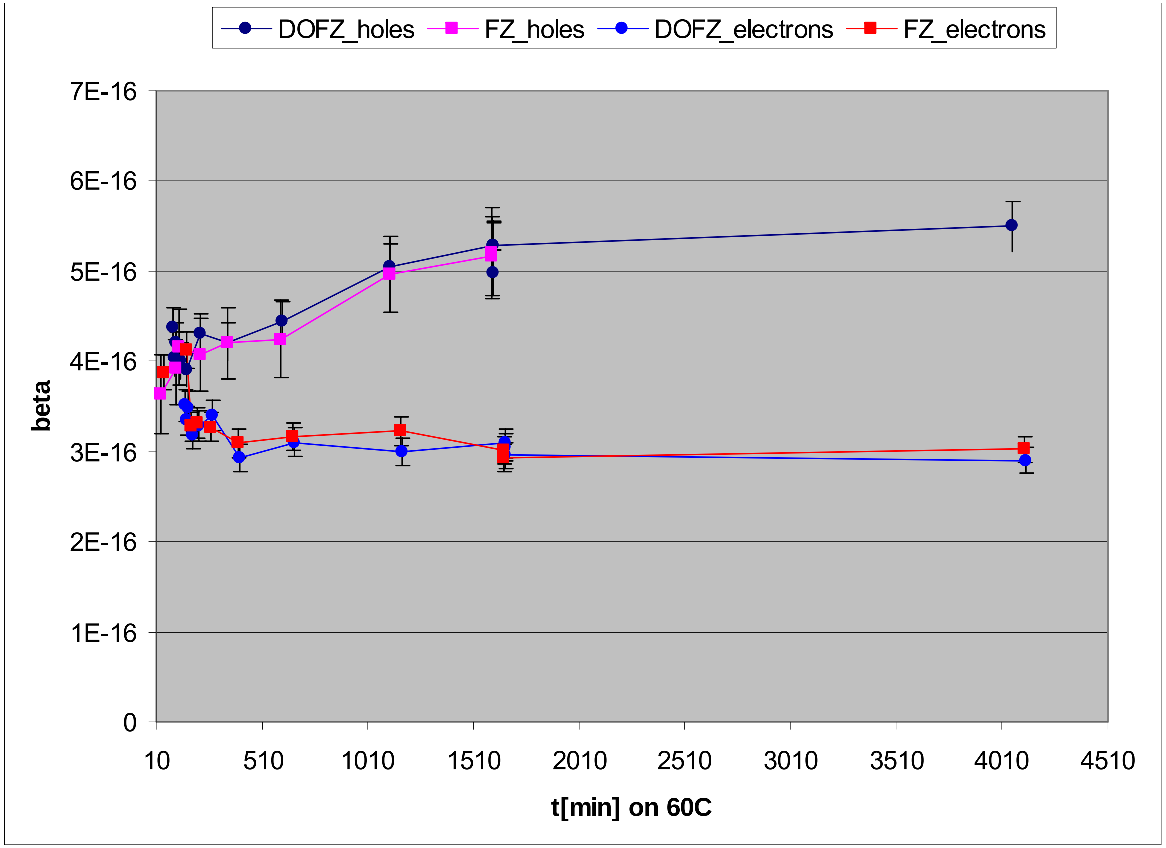
Trapping after annealing aq 60^{o}C, measured at 20^{o}C

Protons Φ_{eq}= 1.07 10^{14} cm^{-2} 1/τ =$\beta\Phi_{eq}$



1000 min at 60^{o}C $\rightarrow$ 80 days at 20^{o}C if E_a= 1.0 eV

Trapping after annealing at 60^{o}C, measured at 20^{o}C (neutrons)



1000 min at 60^{o}C → 80 days at 20^{o}C if E_a= 1.0 eV

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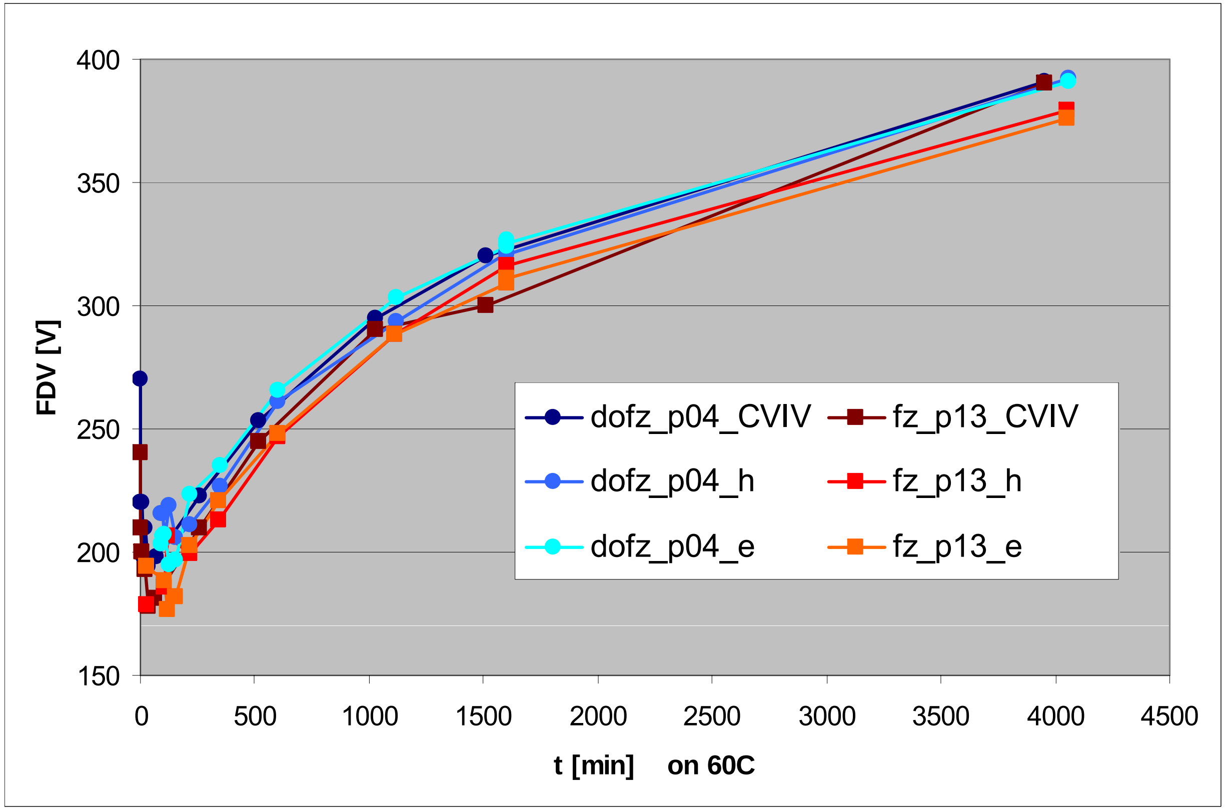
Summary

- long term annealing of N_{eff} in p-type material has same slope as in n-type
- activation energy is 1.25 ± 0.05 eV.
- protons produce about 40% more trapping than neutrons at same NIEL
- Trapping in in p-type silicon similar to trapping in n-type also after proton irradiation
- beneficial annealing of e-trapping not as evident as with neutron irradiated samples (annealing before the measurements started)
- harmfull annealing of h-trapping

FDV during annealing
Pad detectors irradiated to 10^{14}cm^{-2}



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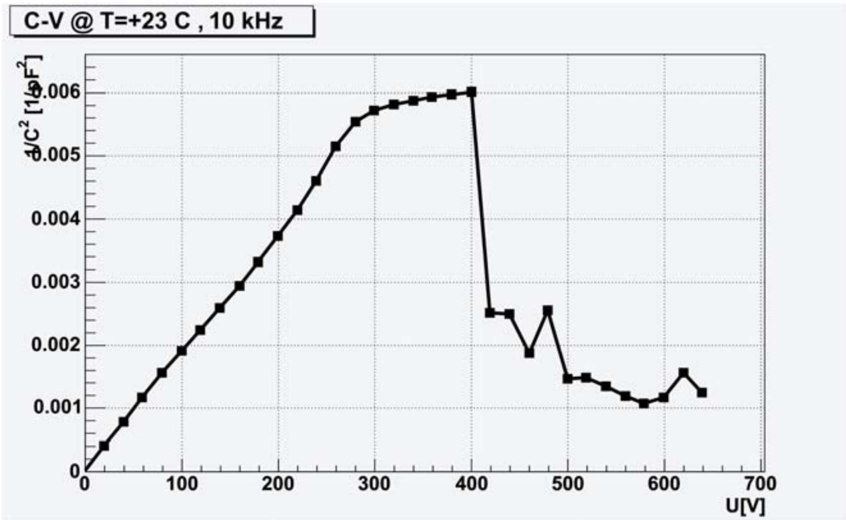

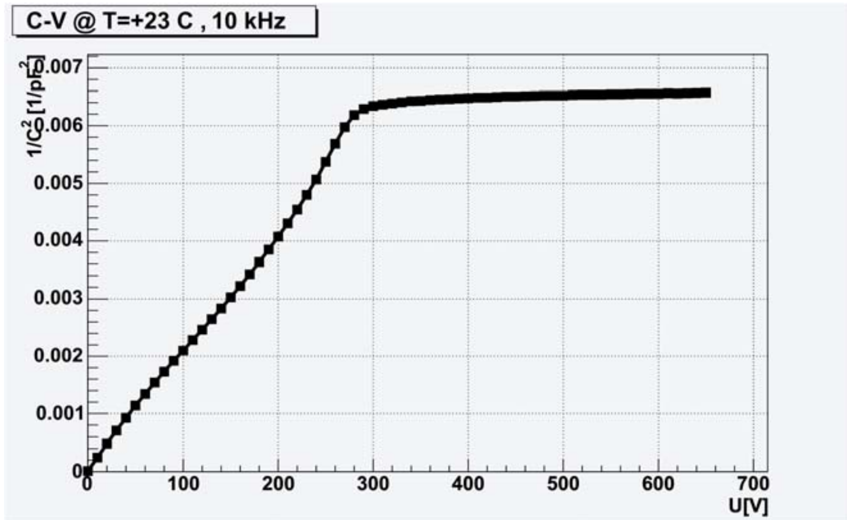

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