Effect of bias voltage on full depletion voltage measured for different materials

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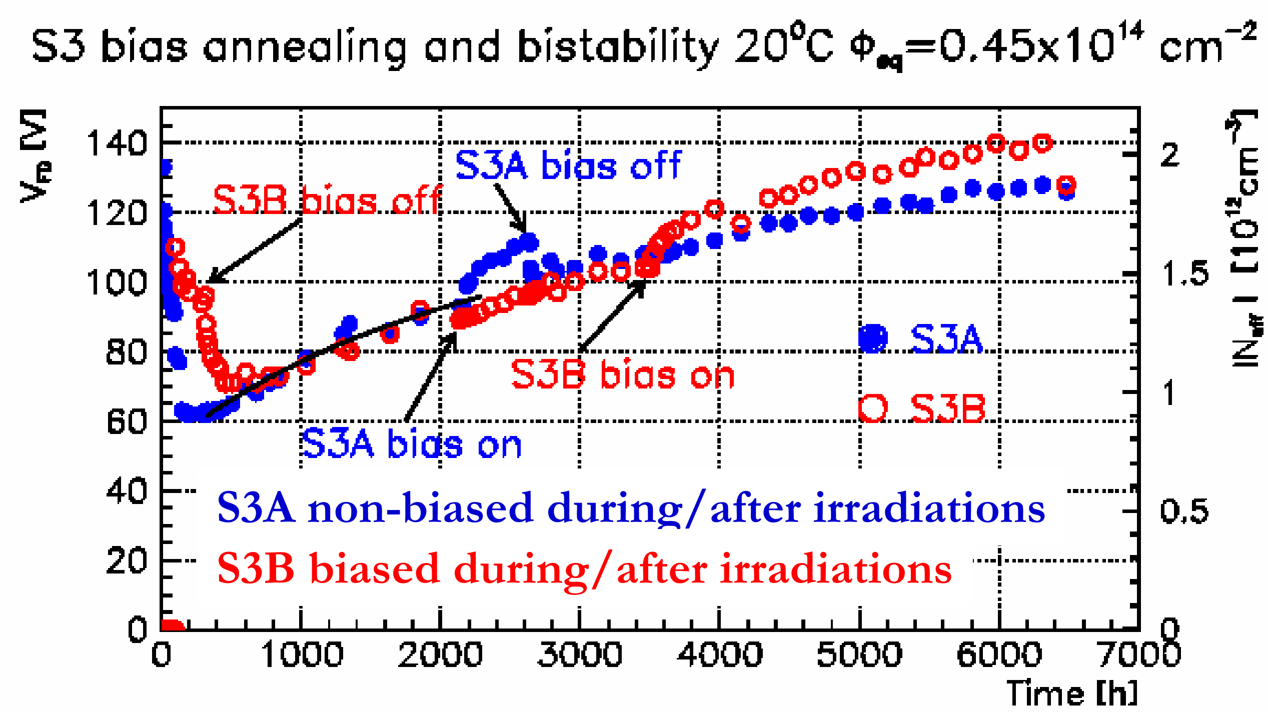
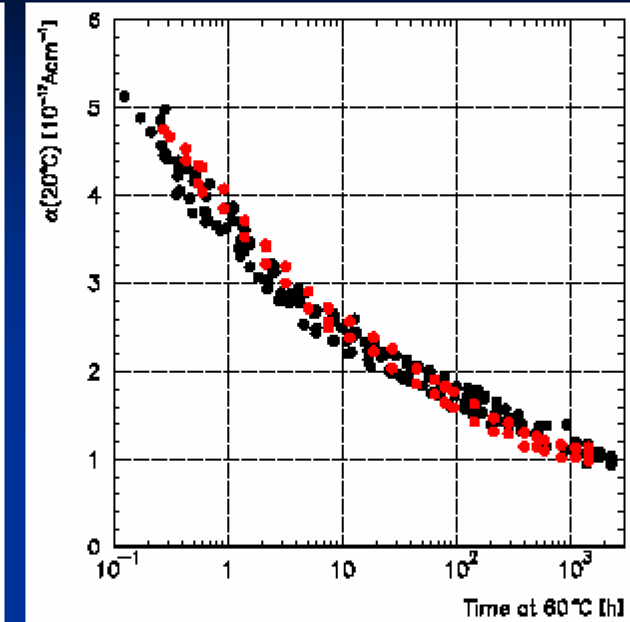
Outline

- Reminder of the "bias effect" – RD48 results
  - Observations with the CV
  - Observations with the TCT
- CV measurements with Fz (ST,C-en.), MCz n, Cz-n and Epi-Si irradiated with 24 GeV protons and reactor neutrons
- Leakage current
- Conclusions

Reminder (I)





No effect on reverse current!

•Bias dependent damage

- g_c bias ~ 2 · g_c unbiased
- g_y bias ~ g_y unbiased
- τ_{ra} bias ~ 2 · τ_{ra} unbiased

•Bistability

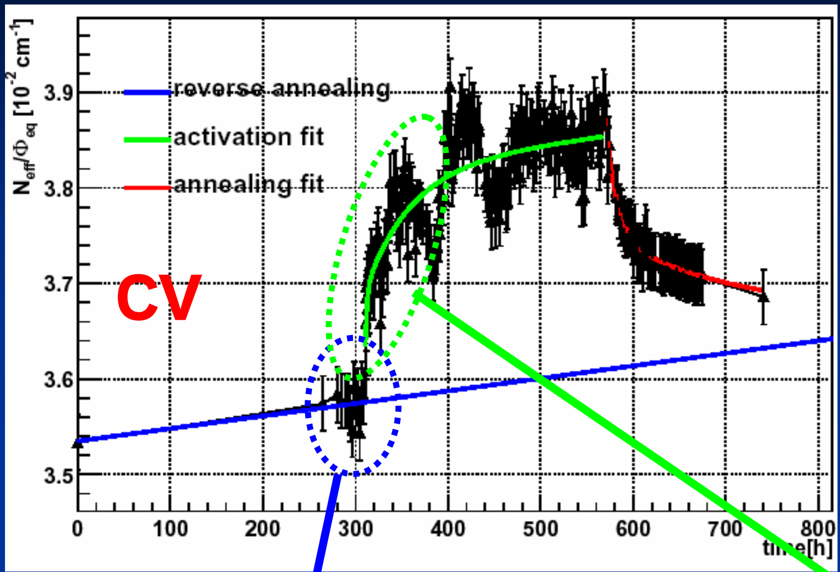
$g_a \sim 0.4 \cdot 10^{-2}\ cm^{-2}$

τ_a ~ 1 day @ room temperature, ~100 d at -7°C

τ_{da} ~ 1 day @ room temperature

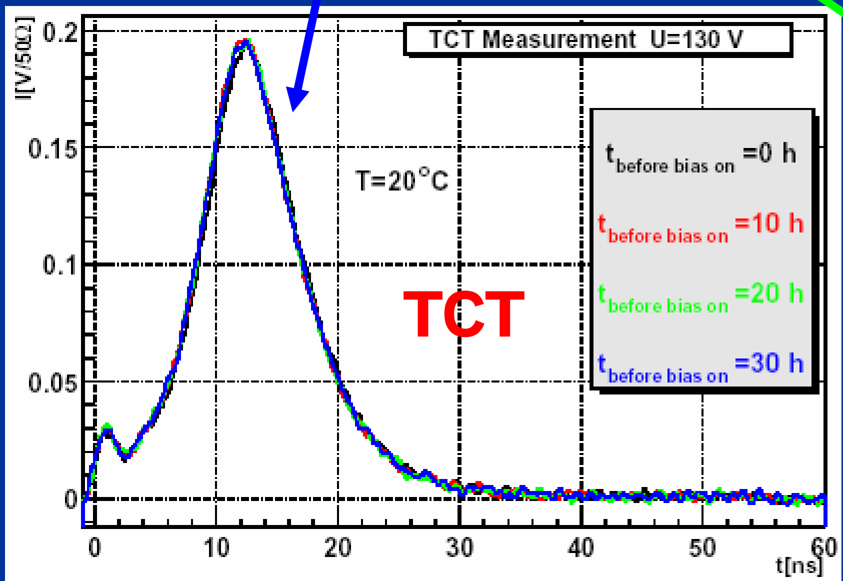
First observation: V. Cindro et al, NIM A419 (1998) 132.
Detailed studies: V. Cindro et al, NIM A450 (2000) 288.

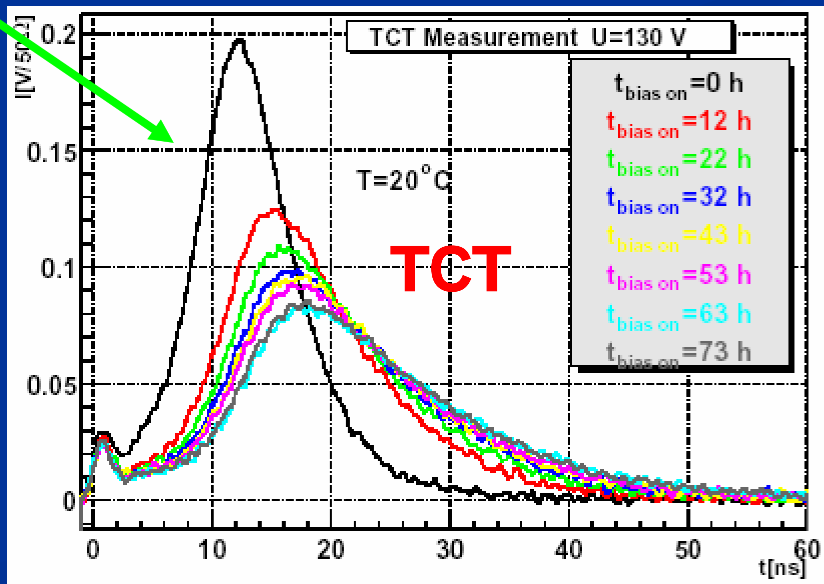
Reminder (II)



ITE - 5 kΩcm (STFZ-n material)
Irradiated to Φ_{eq}=5x10^{13} cm^{-2}
Annealed ~30% of the reverse annealing
V_{fd} ~ 130 V

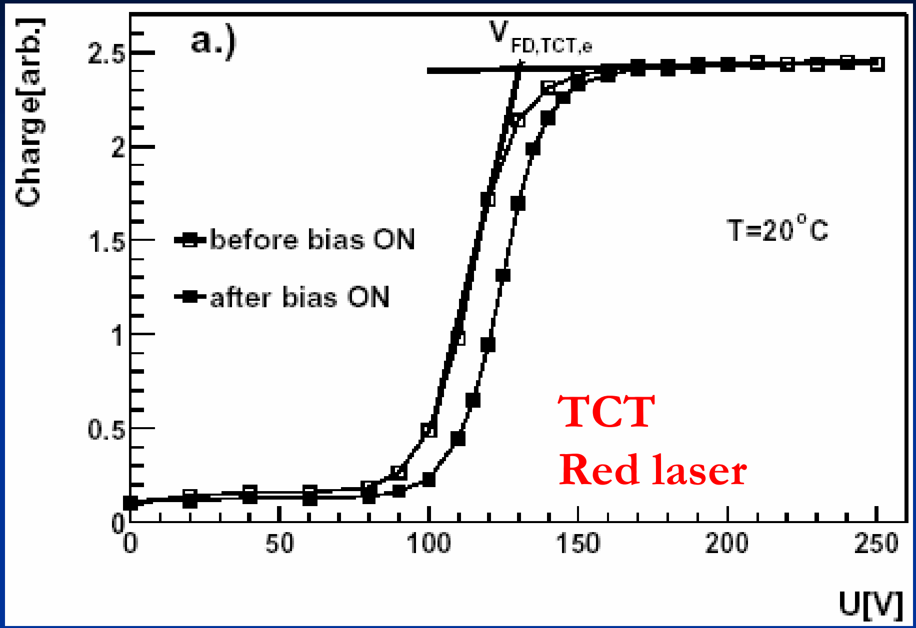
Electron injection **TCT**
clear changes in electric field observed!

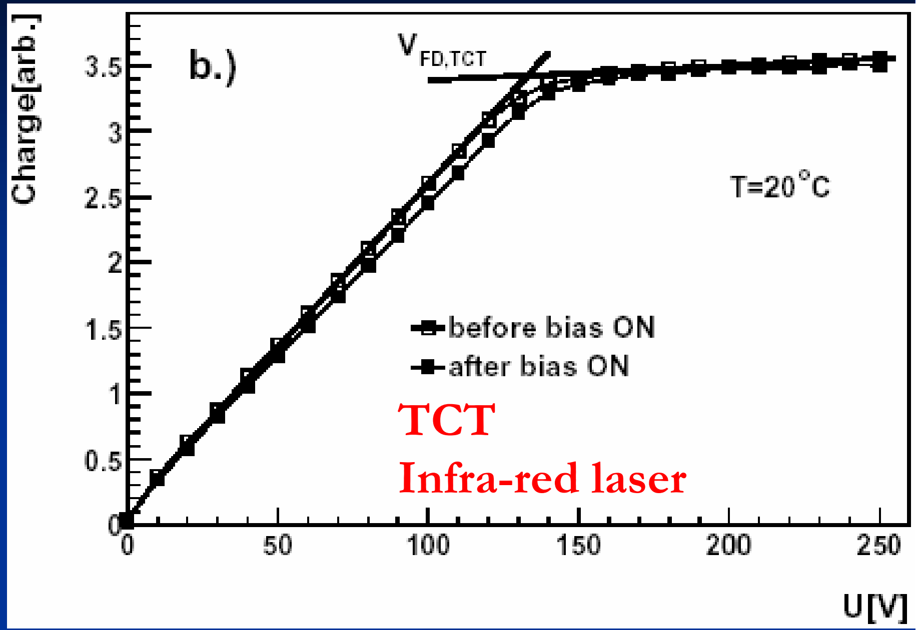




G. Kramberger, Effect of bias voltage on full depletion voltage measured for different materials, 9th RD50 Workshop, CERN

Reminder (III)





V_{fd} from TCT with red laser – electron injection

TCT with infrared laser – m.i.p. simulation

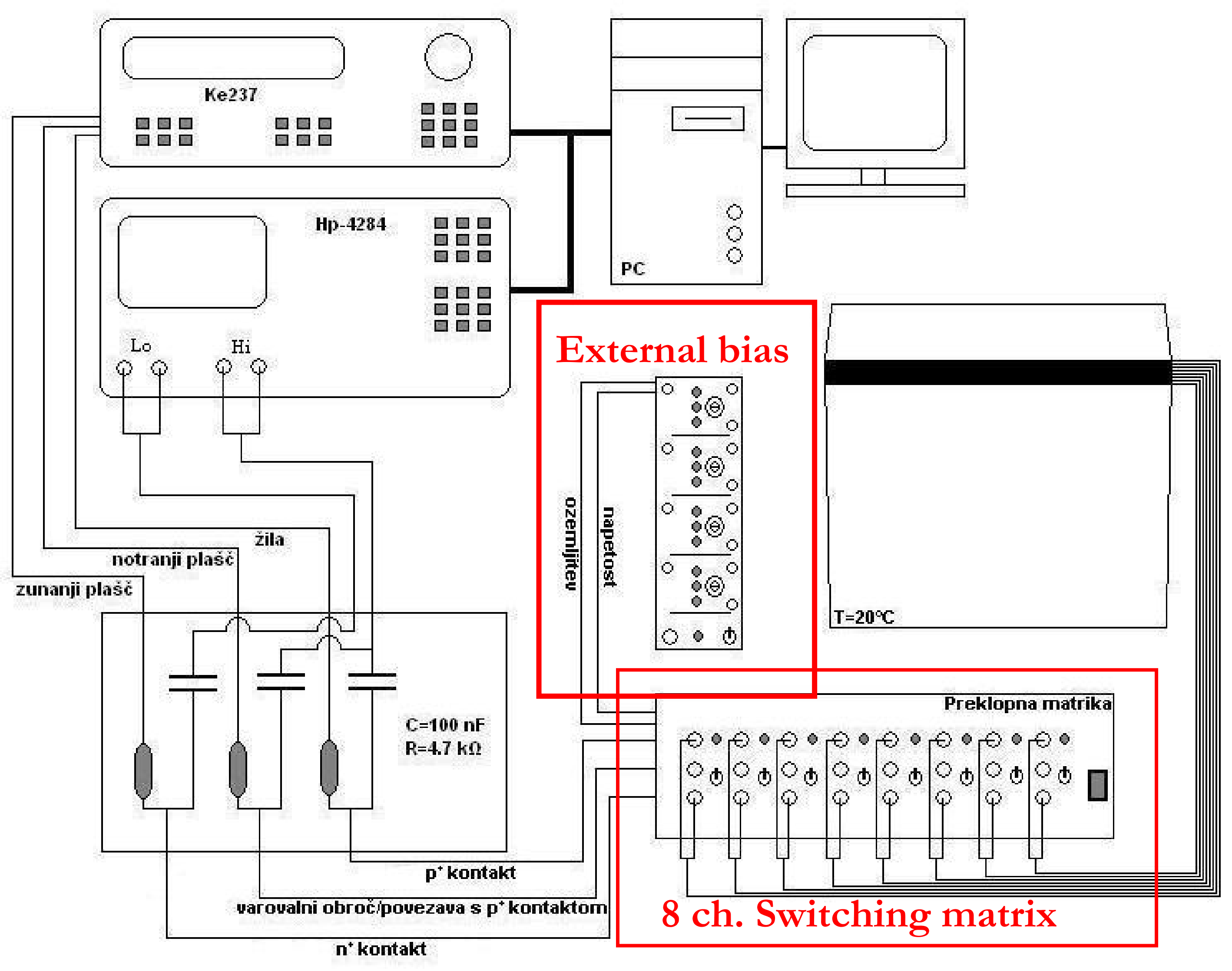
A clear increase of V_{fd} is observed after 70 h of bias applied

Same amplitudes when measeured by TCT or CV!

What is new 8 years after

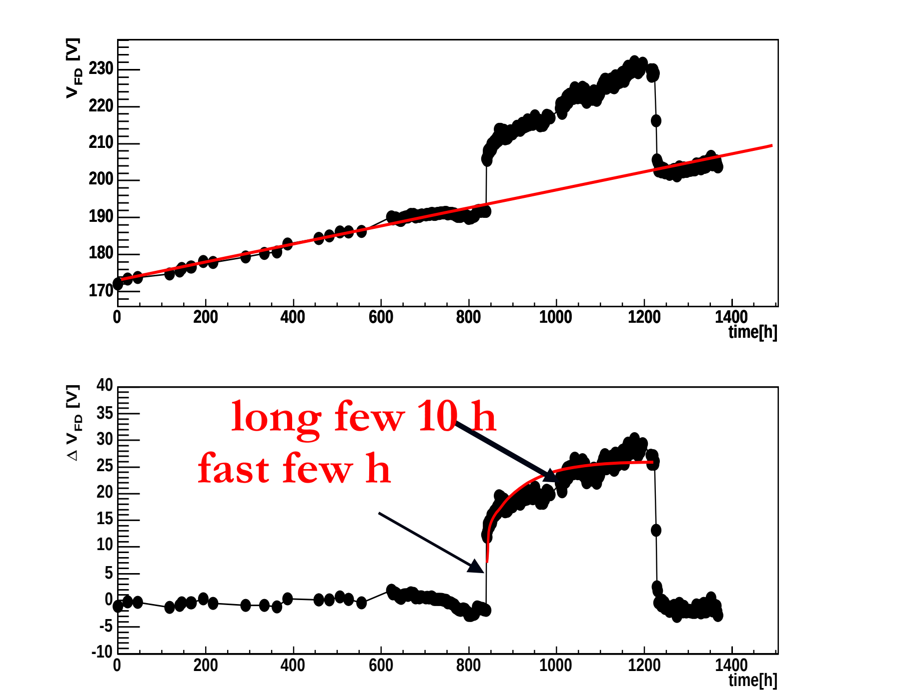
- We have materials that don't undergo SCSI (stay n type after irradiation) – according to our previous assumption V_{fd} should decrease!
- We have material with higher
  - [O] (MCz, Cz, Epi)
  - [C] (1.8e16 cm^{-3})
  - initial resistivity (as low as 50 Ωcm for Epi-Si)
- We had measurements with samples irradiated to 24 GeV protons (before 200 MeV pions, neutrons)

Setup

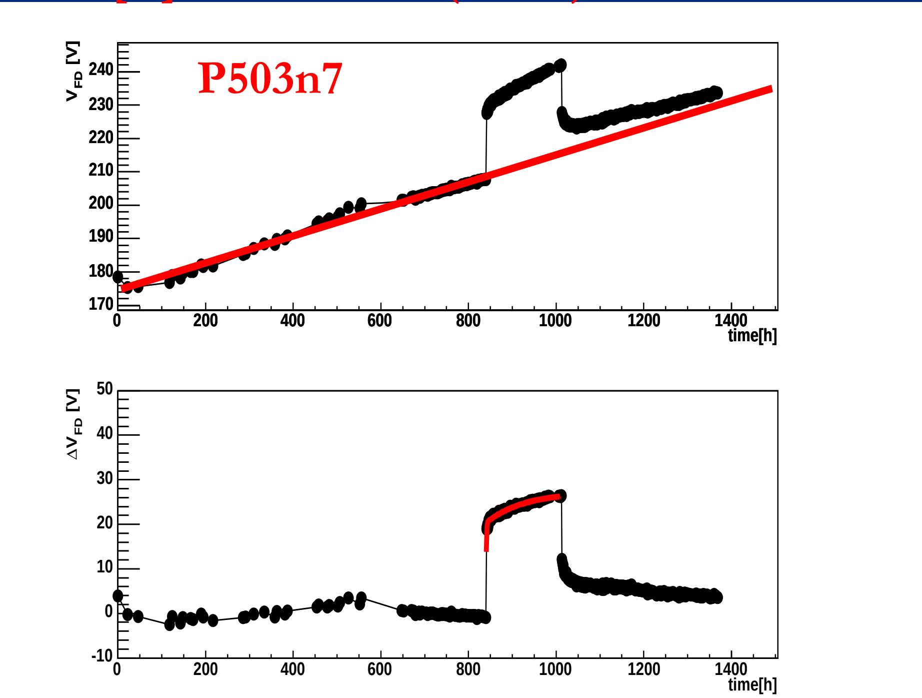

Ke237
Hp-4284
Lo
Hi
PC
External bias
ozemljitev
napetost
T=20°C
žila
notranji plašč
zunanji plašč
C=100 nF
R=4.7 kΩ
Preklopna matrika
p⁺ kontakt
varovalni obroč/povezava s p⁺ kontaktom
n⁺ kontakt
8 ch. Switching matrix

STFZ and C-enriched n-irradiated

STFZ-n type (15 kΩcm)
W339 , $\Phi_{eq}=10^{14}$ cm^{-2}



P503n7 , $\Phi_{eq}=10^{14}$ cm^{-2}
[C]=1.8e16 cm^{-3} (SIMS)



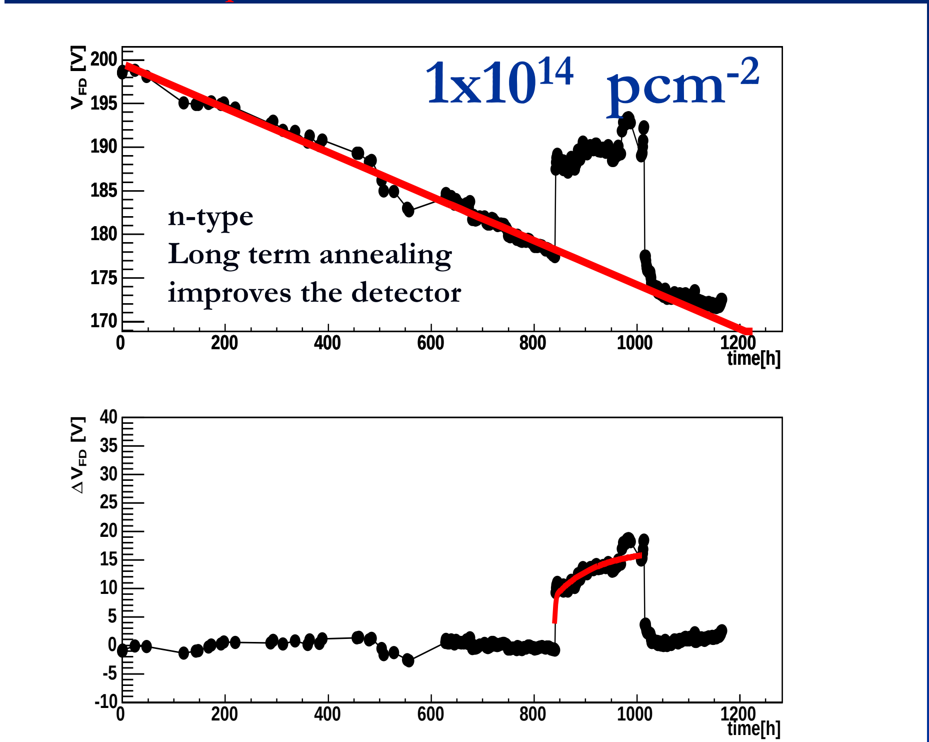
g_b~3.6x10^{-3} cm^{-1}

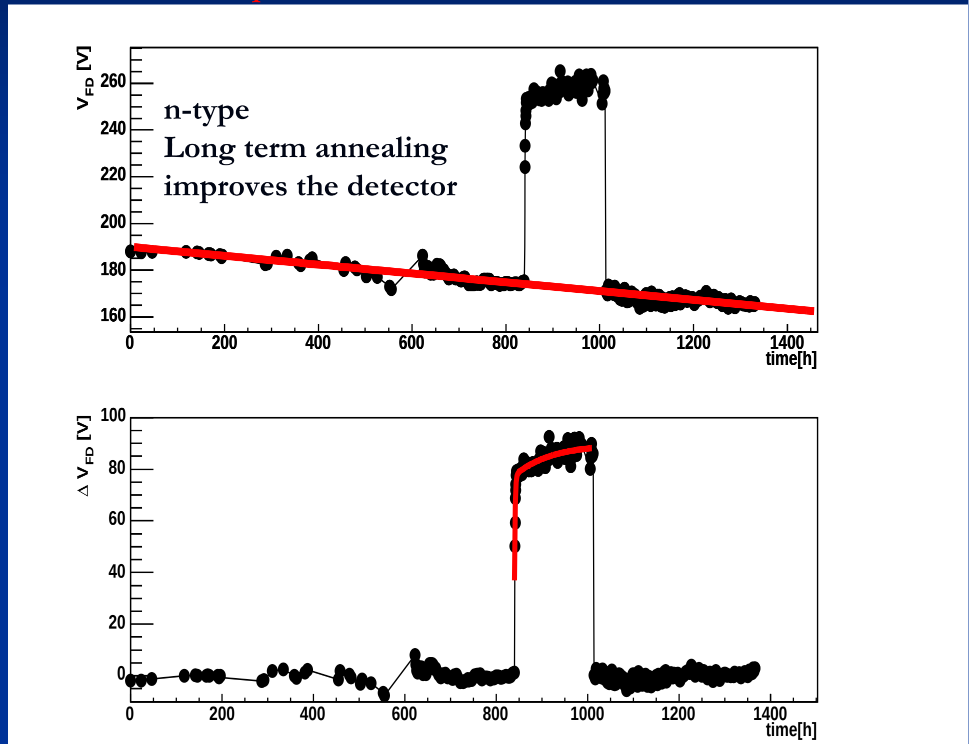
g_b~3.7x10^{-3} cm^{-1}

MCz-n , 24 GeV protons

MCz-n type (15 kΩcm)
$\Phi_{eq}=0.62\cdot10^{14}$ cm^{-2}

MCz-n type (15 kΩcm)
$\Phi_{eq}=3.1\cdot10^{14}$ cm^{-2}





$g_b \sim 3.5\cdot10^{-3}$ cm^{-1}

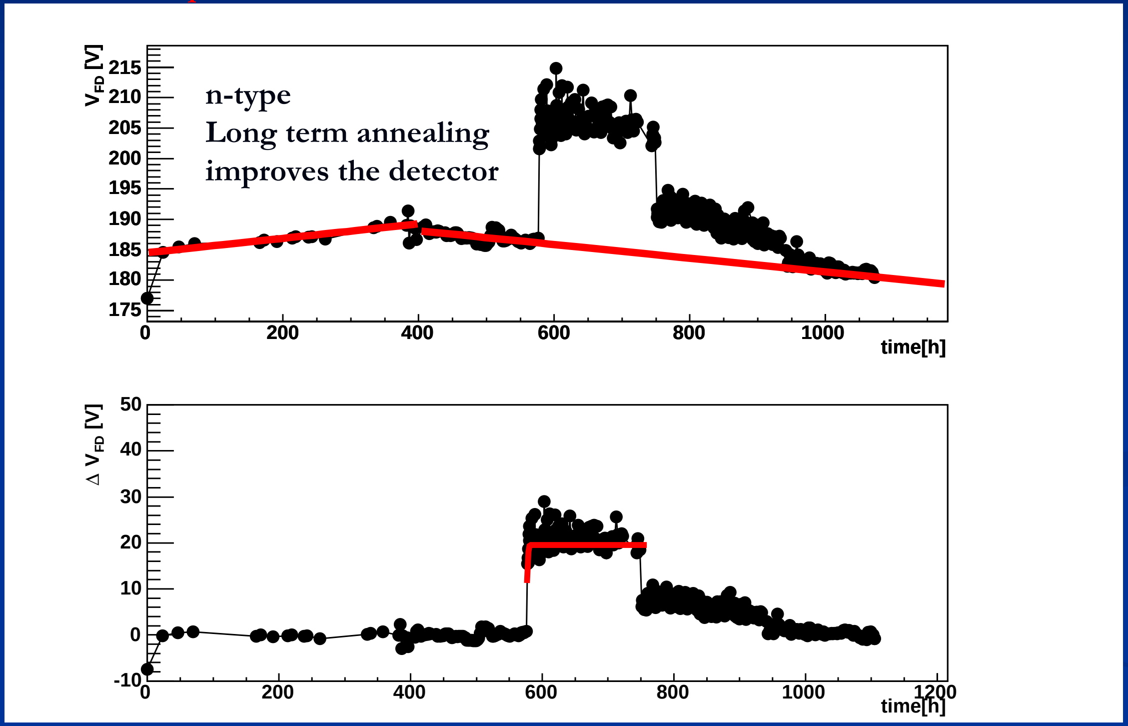
$g_b \sim 4.2\cdot10^{-3}$ cm^{-1}

Increase of V_{fd} also for n-type material -> What would be the explanation?
Does it has something to do with leakage current-polarization?

Cz-n , 24 GeV proton

Cz-n type (15 kΩcm) - Sumitomo

$\Phi_{eq}=0.75\cdot10^{14}$ cm^{-2}



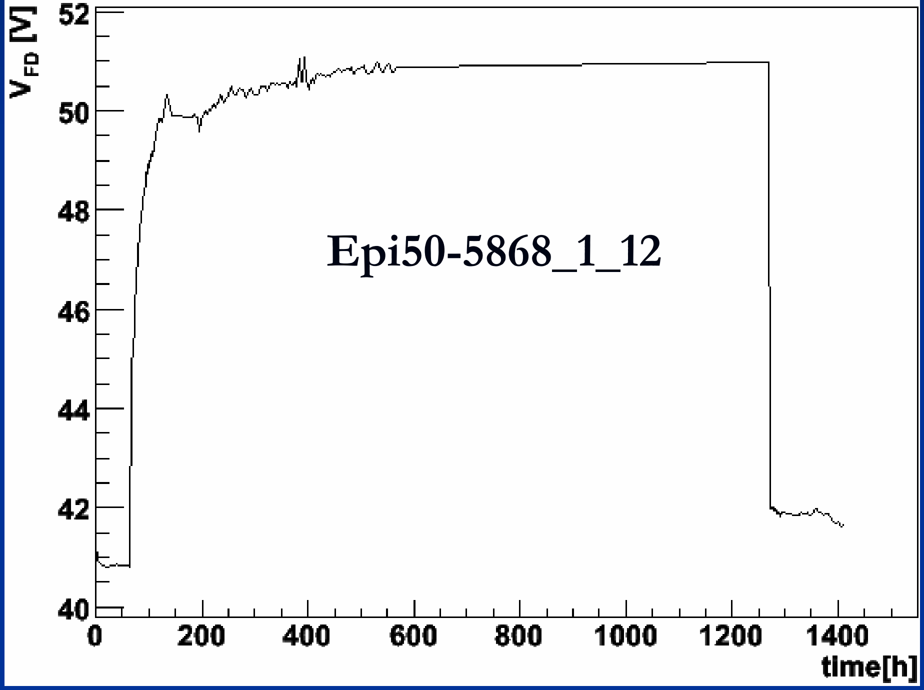
Measurements taken in the maximum of V_{fd} evolution with time!

g_b~$3.9\cdot10^{-3}$ cm^{-1}

τ_a~few h at room temperature (very fast increase)

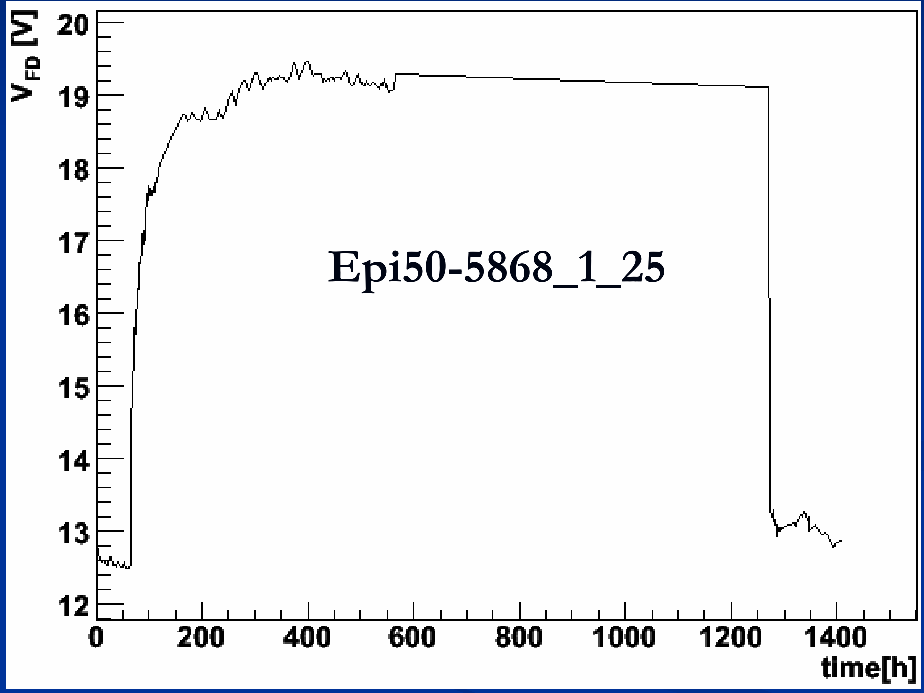
Epi-Si 50 μm , neutrons

Epi-n type (50 Ωcm) ITME
Φ_{eq}=0.75·10^{14} cm^{-2}



g_b~2.9·10^{-3} cm^{-1}

Epi-n type (50 Ωcm) ITME
Φ_{eq}=0.75·10^{14} cm^{-2}

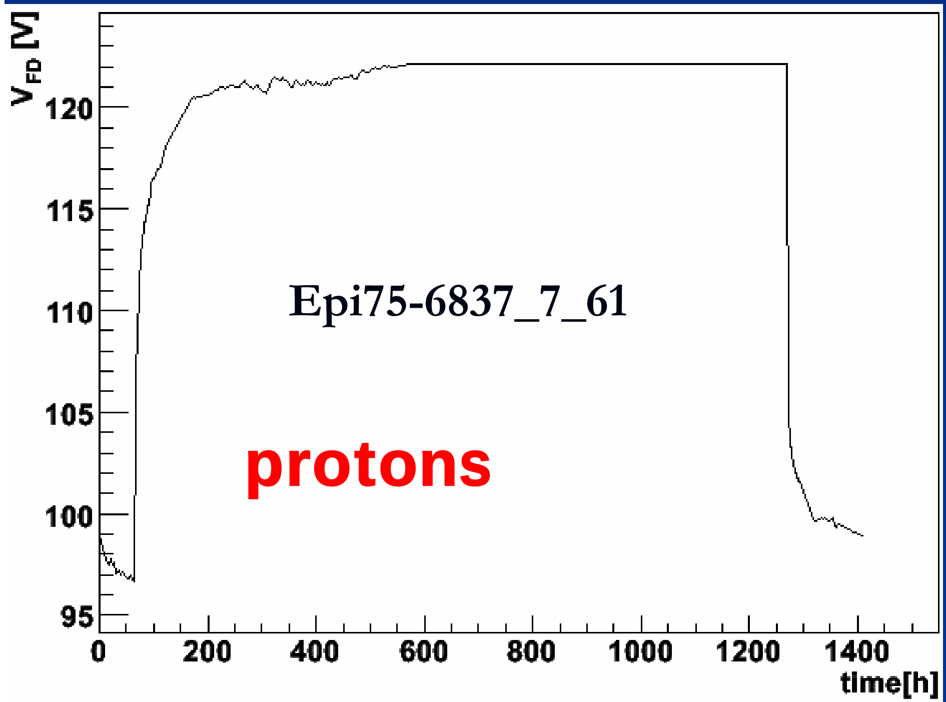


g_b~3.4·10^{-3} cm^{-1}

Epi-Si 75 μm

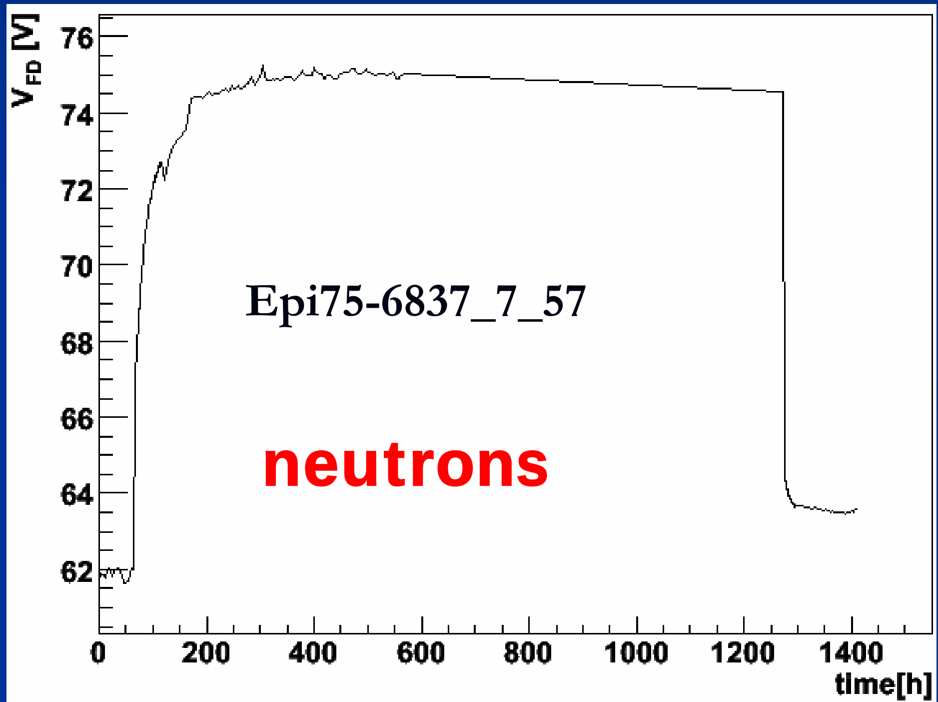
Annealed for 20000 h at 20°C

Epi-n type (50 Ωcm) ITME
$\Phi_{eq}=1.3\cdot10^{15}$ cm^{-2} (protons)



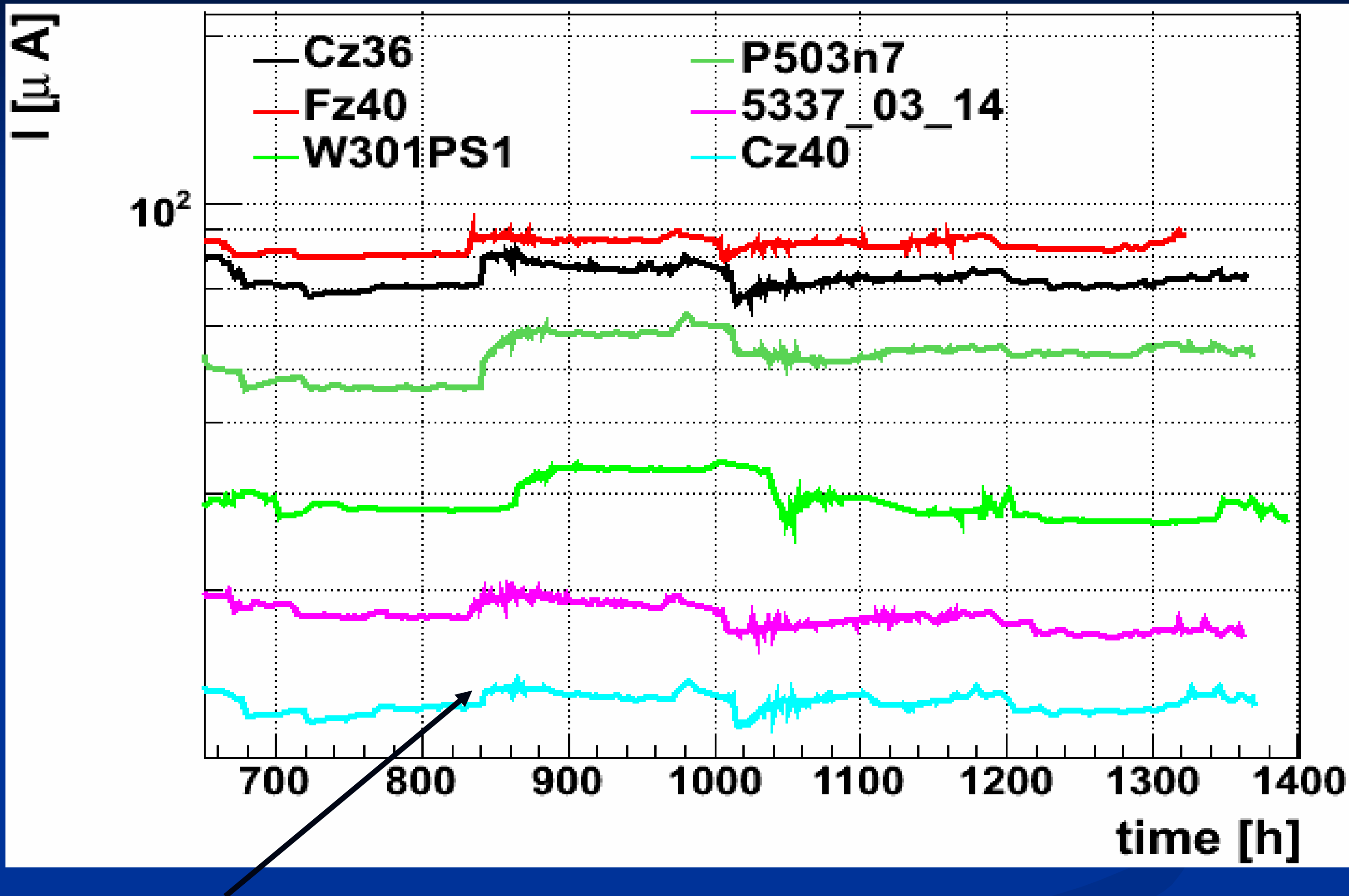
g_b~$4.3\cdot10^{-3}$ cm^{-1}

Epi-n type (50 Ωcm) ITME
$\Phi_{eq}=1\cdot10^{15}$ cm^{-2} (neutrons)



g_b~$3.1\cdot10^{-3}$ cm^{-1}

Leakage current



Not-ideal IV characteristic (increase of current with voltage also after V_{fd})

No effect on leakage current increase!

Conclusion

- Bistability is there also for Epi, Cz, MCz materials at the approximately the same introduction rate ($0.4 \cdot 10^{-2}$ cm^{-1}) and activation and decay time constants (fast few h and slow few 10 h at room temperature)
- It is also present for 24 GeV irradiated samples (expected)!
- What is the cause we don’t know!
- Is it important? Yes!
  - we need to accommodate operation scenario.
  - we need to extract activation energy to be able to scale the effect to more realistic (-10^{o}C) temperatures
- Future work: Is it present also in p-type material?