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Radiation hardness of Czochralski silicon studied by low energy protons

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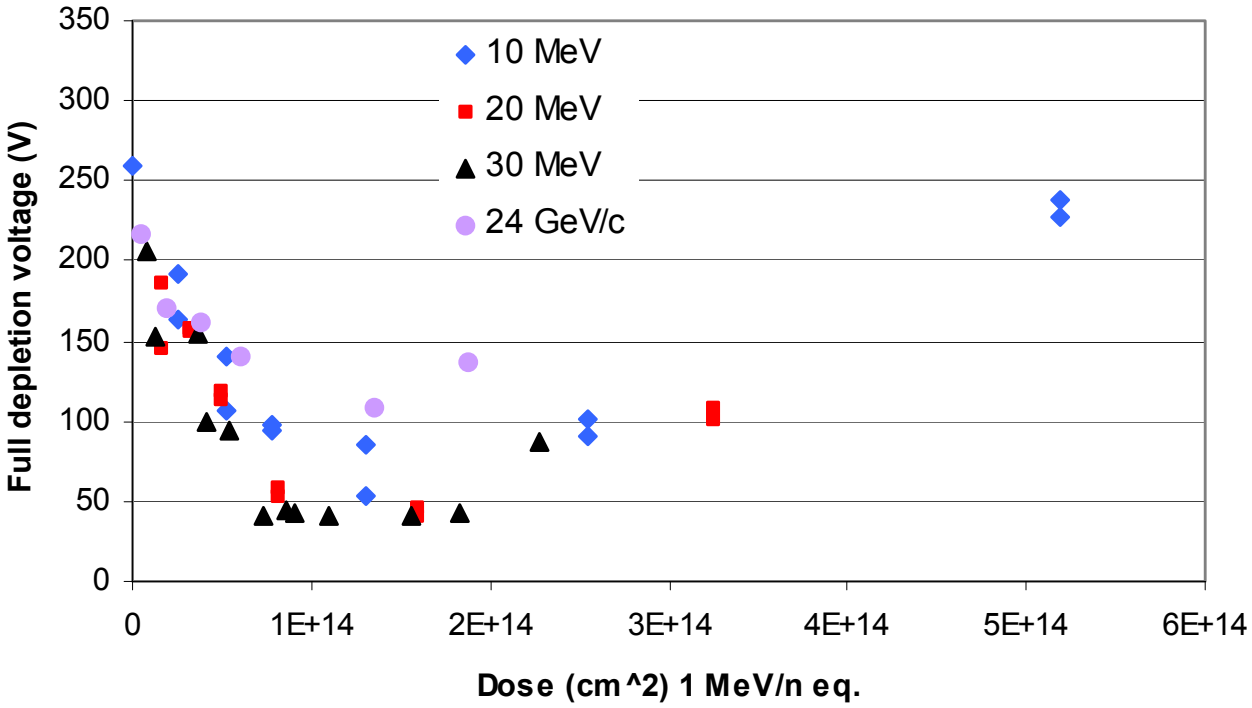
Outline

*Background
*Evolution of depletion voltage in proton irradiation
*Leakage current
*Space Charge Sign Inversion studied by TCT
*Defect analysis by DLTS
*Conclusions

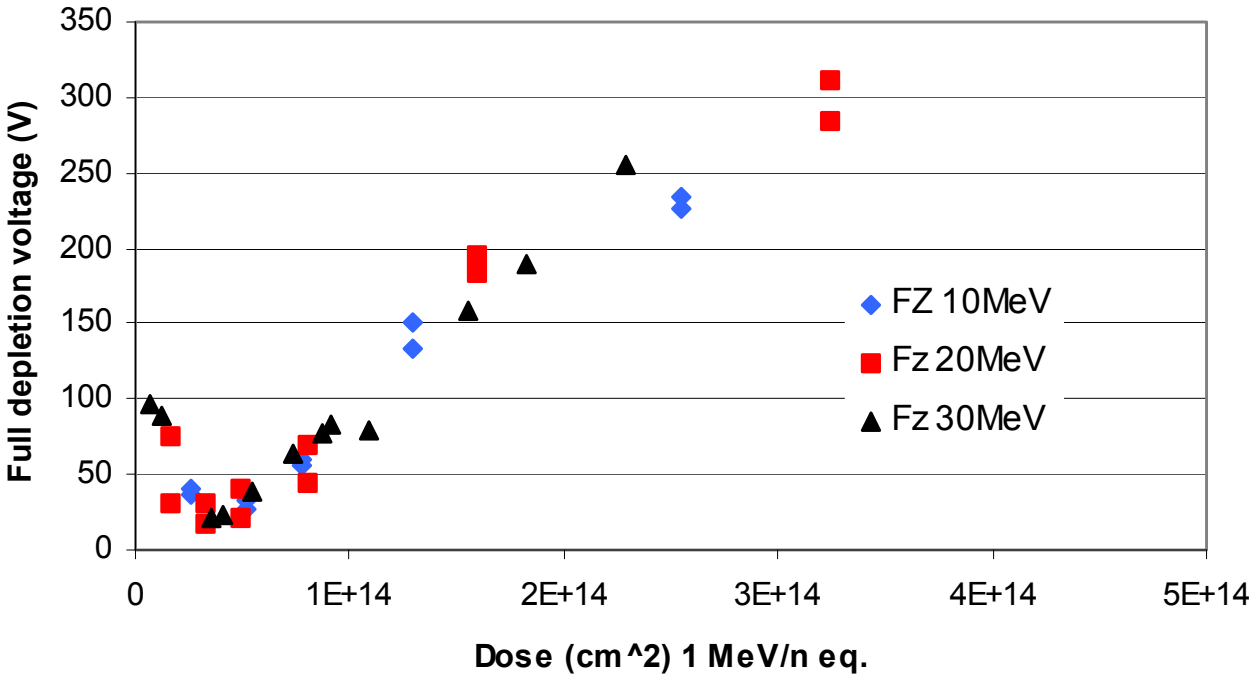
Background

* High resistivity (>1000 Ωcm) Cz-Si now available (Okmetic, Sitix)
* Promising material because of high oxygen concentration.
* This far by (CiS/HH, BNL, Helsinki/HIP, MEC/HUT) :
  - Test diodes and full size strip detectors have been processed.
  - Detectors proved to be operational by muon test beam run at H2 area of CERN.
  - Diodes irradiated with γ-rays, neutrons, pions, high and low energy protons.
  - Detectors irradiated with 10 MeV protons.

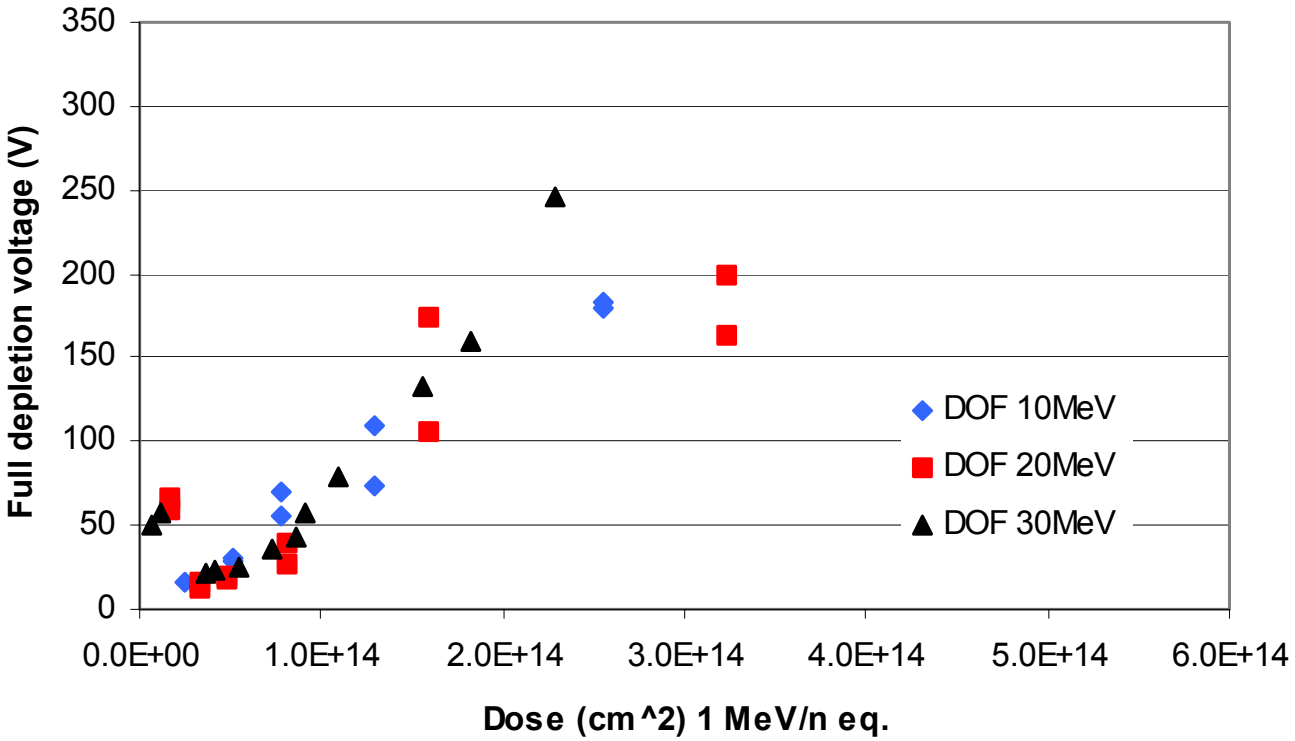
Depletion voltage evolution I (Cz)



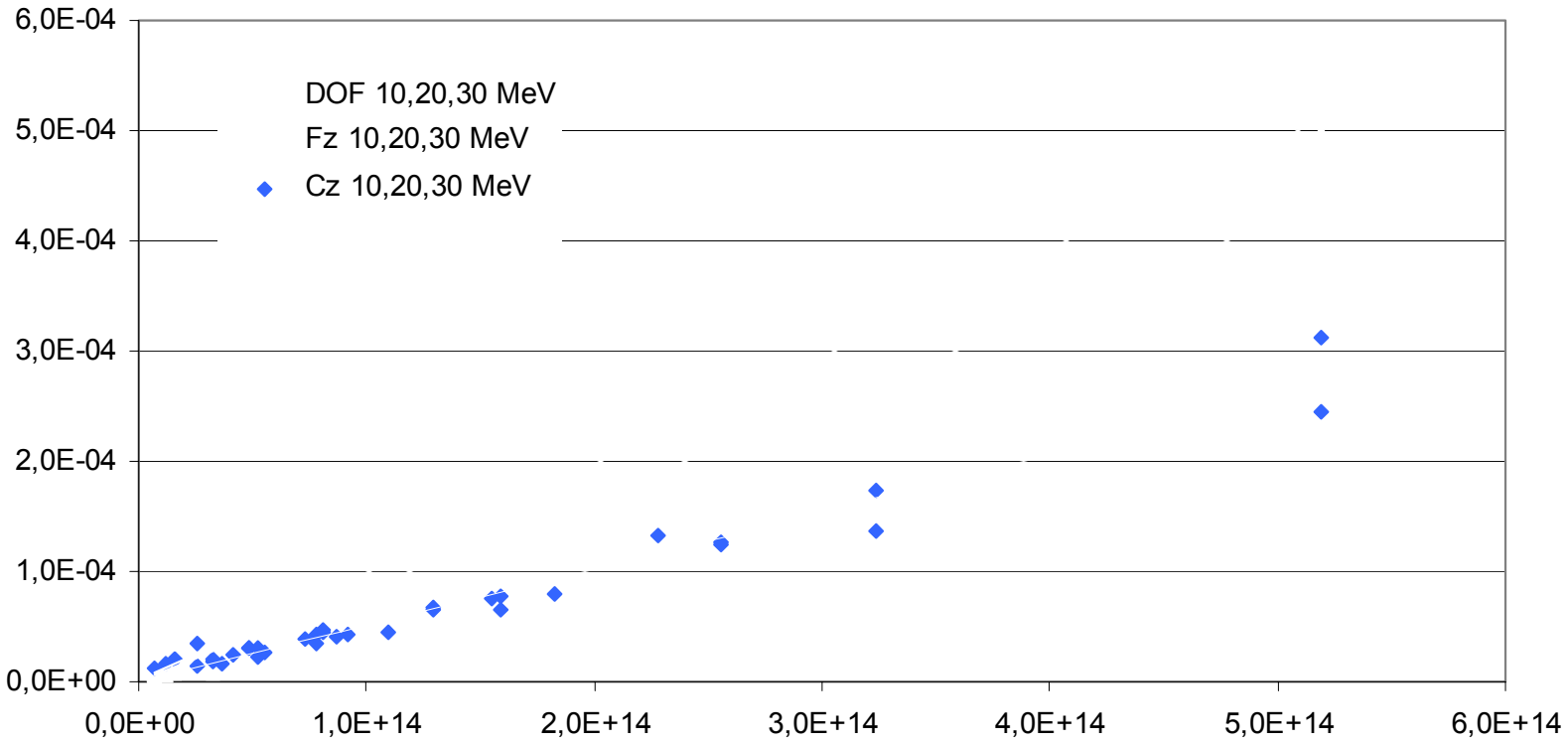
Depletion voltage evolution II (Fz)



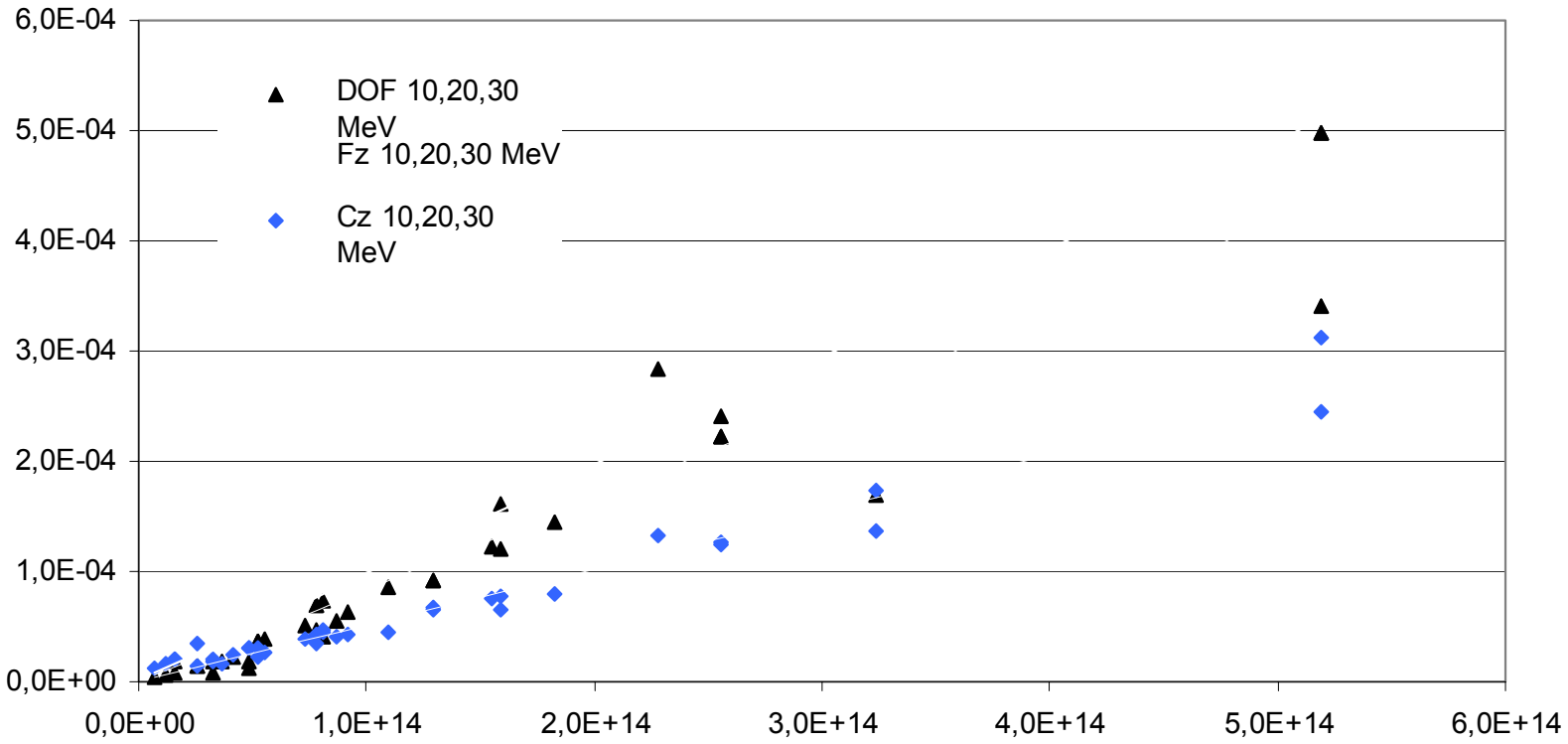
Depletion voltage evolution III (DOF Fz)



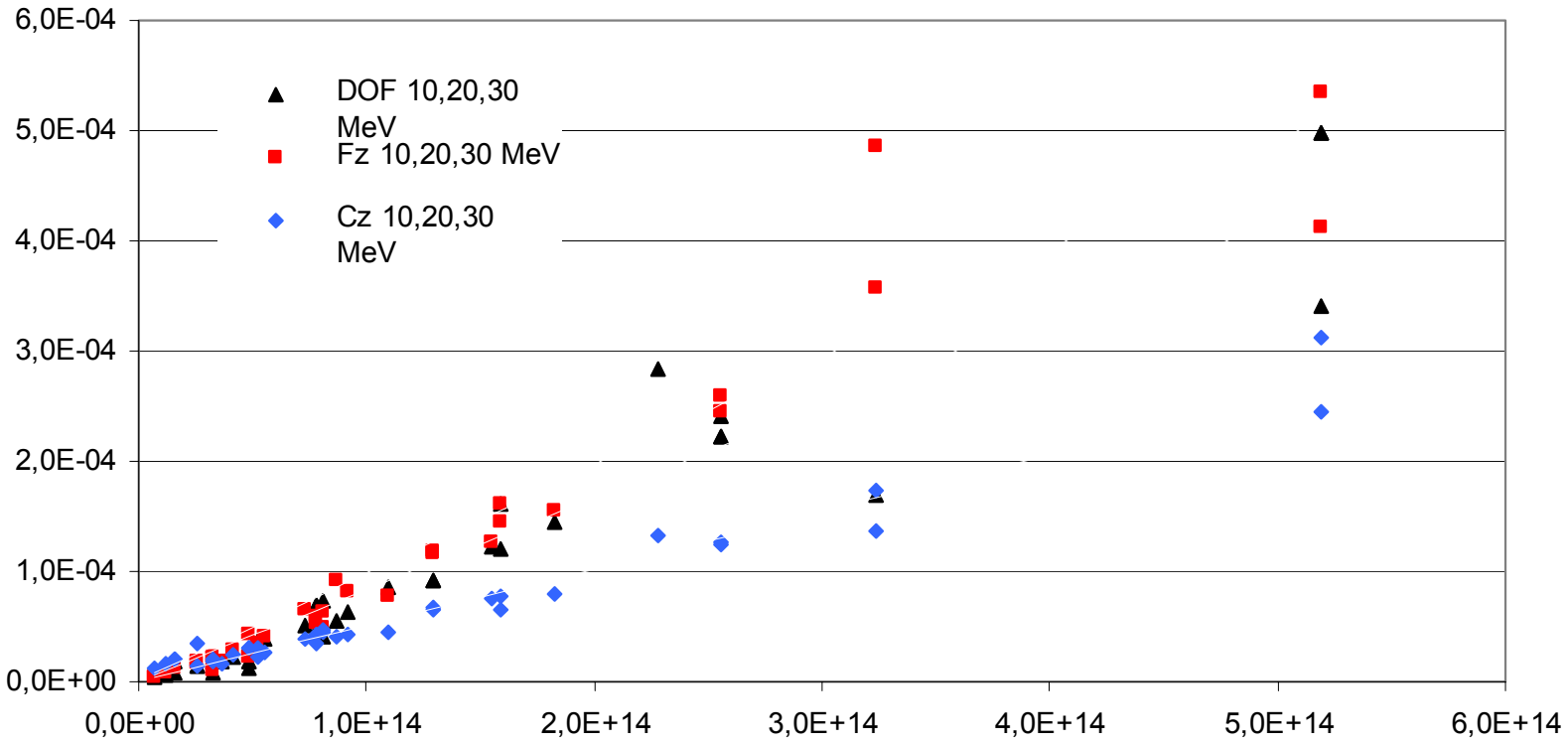
Leakage current



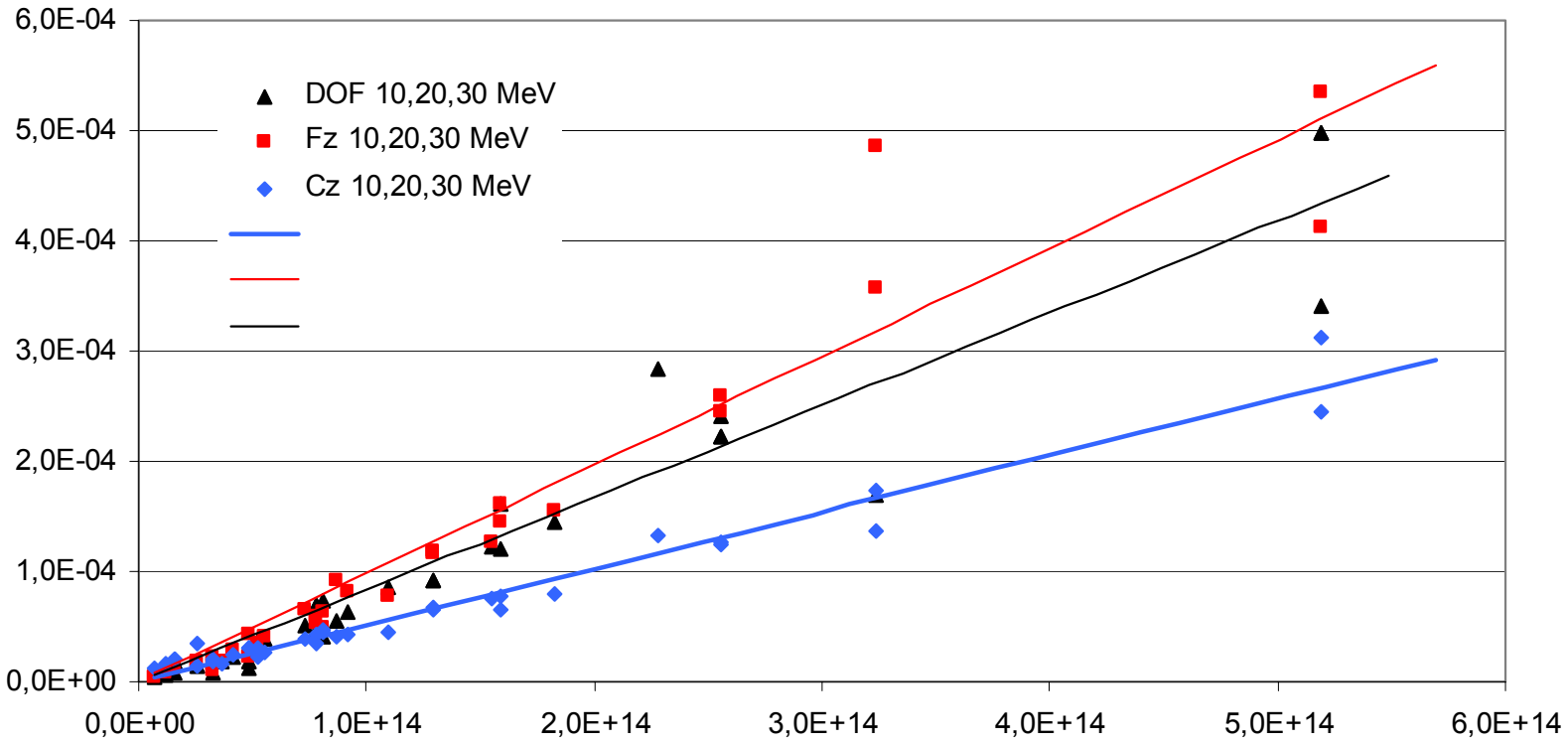
Leakage current



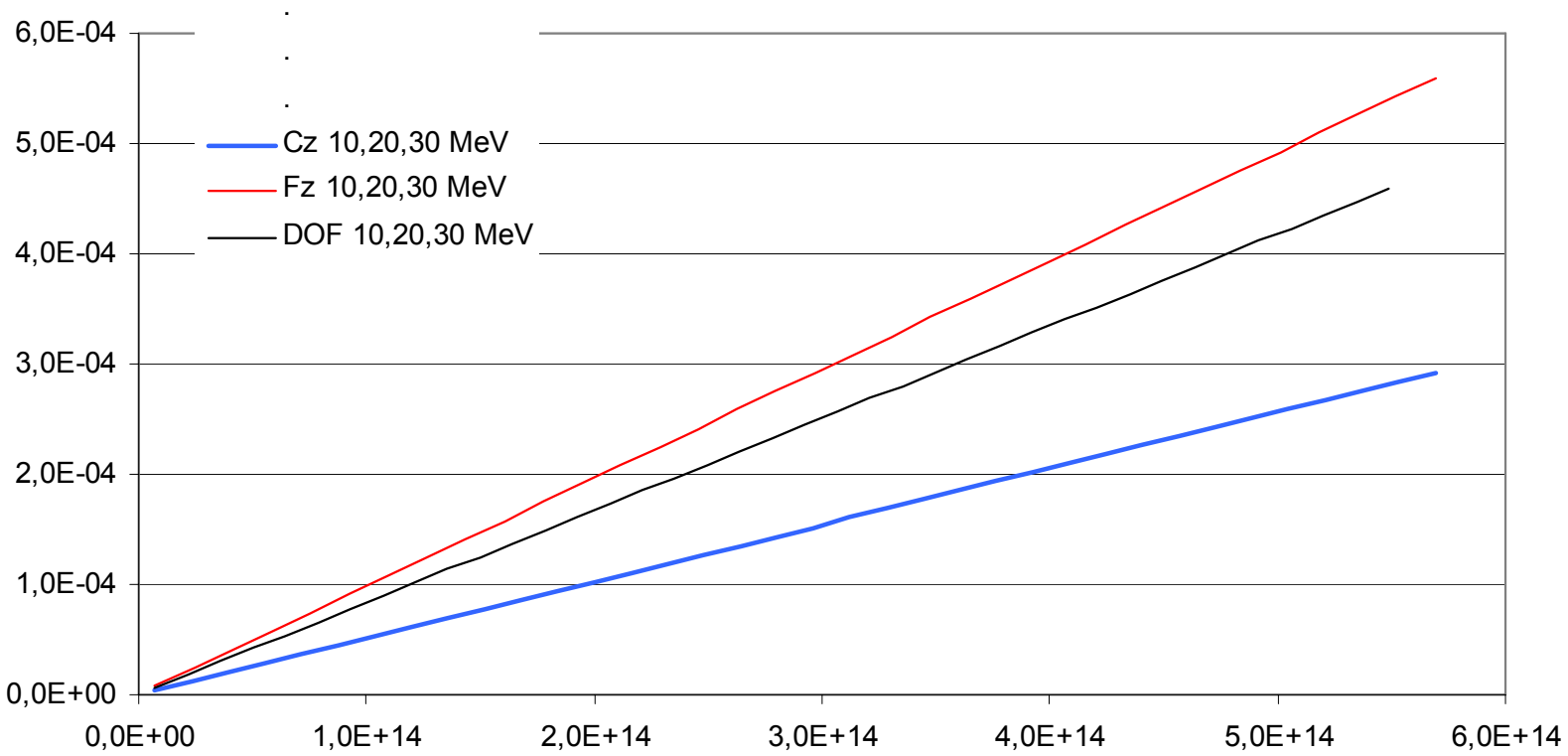
Leakage current



Leakage current



Leakage current

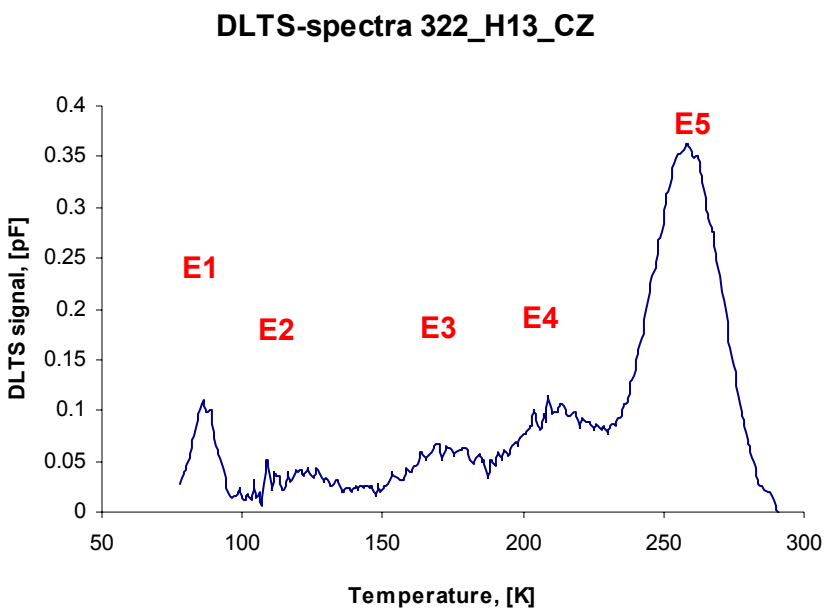


TCT analysis

Proton energy (MeV)	1 MeV/n eq. Dose (cm^{-2})	Full depletion voltage (V)	SCSI	SC sign	Double peak in TCT signal
10	$1,3*10^{14}$	215	No	+	Weak
10	$2,6*10^{14}$	134	Yes	-	Clear
10	$5,2*10^{14}$	260	Yes	-	Clear
20	$8,1*10^{13}$	225	No	+	No
20	$1,6*10^{14}$	213	No	+	Weak
20	$3,2*10^{14}$	188	Yes	-	Clear

TCT analysis of Cz-Si detectors irradiated with 10 and 20 MeV protons. The diodes have been annealed at 80^0C for 30 minutes before the measurements.

DLTS analysis



Fp (cm-2)	V-O			VV-			Ci-Oi		
	CZ	FZ	DOF	CZ	FZ	DOF	CZ	FZ	DOF
0	0	0	0	0	0	0	0	0	0
1.00E+10	1.80E+10	1.80E+10	1.70E+10	1.90E+10	1.10E+10	1.50E+10	3.40E+10	3.00E+10	3.20E+10
3.00E+10	3.50E+10	5.00E+10	8.88E+10	3.00E+10	2.85E+10	7.00E+10	6.50E+10	6.60E+10	**2.00E+11**

Conclusions

*Cz-Si is less prone to Vdepl changes than Fz-Si and DOF Fz-Si when irradiated with 10,20 and 30 MeV protons

*Leakage current seem to correlate with O concentration Fz>DOF>Cz with proton energies used in this study

*Space Charge Sign Inversion observed by TCT

*SCSI takes place at about $2*10^{14}$ cm^{-2} (1 MeV/n eq.) dose. That corresponds >10 years in LHC experiments