ELECTRICAL CHARACTERIZATION OF P- AND N-TYPE 150 UM EPI-SI DIODES IRRADIATED WITH PROTONS AND NEUTRONS

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Tested samples are 150 um epi-Si pad diodes:

- 16 CNM-22, p-type Epi, 0.25 cm^2, 1000 Ω·cm;
- 9 RD50-23 (CNM), n-type, 0.19 cm^2, 500 Ω·cm;
- 9 W12 (ITC-IRST), n-type, 0.14 cm^2, 500 Ω·cm

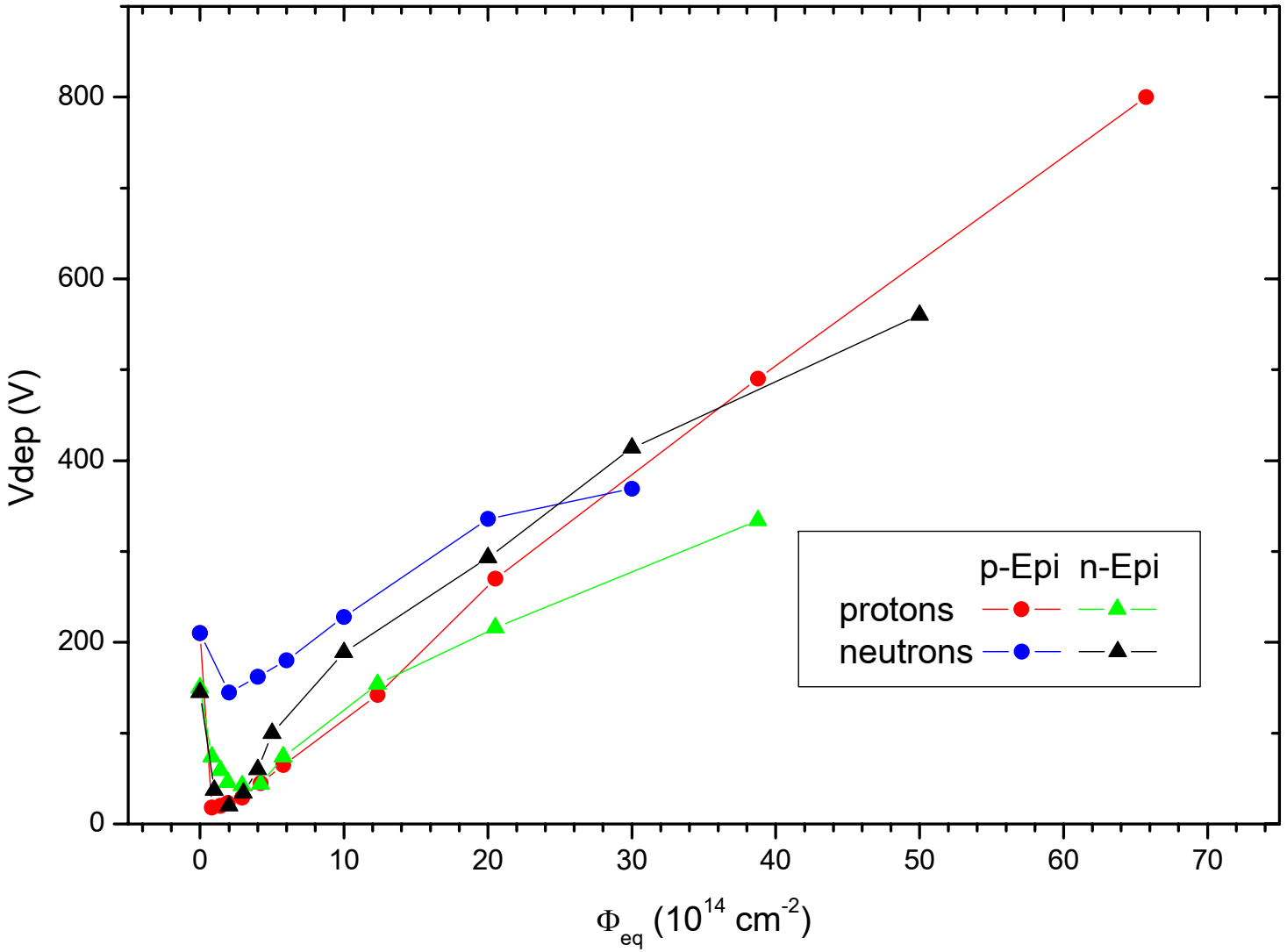
Irradiation sources and fluences:

- 23 GeV protons, CERN PS, (10^{14} – 10^{16}) p/cm^2;
- reactor neutrons, JSI Ljubljana, (10^{14} – $5 \cdot 10^{15}$) eq. 1MeV n/cm^2

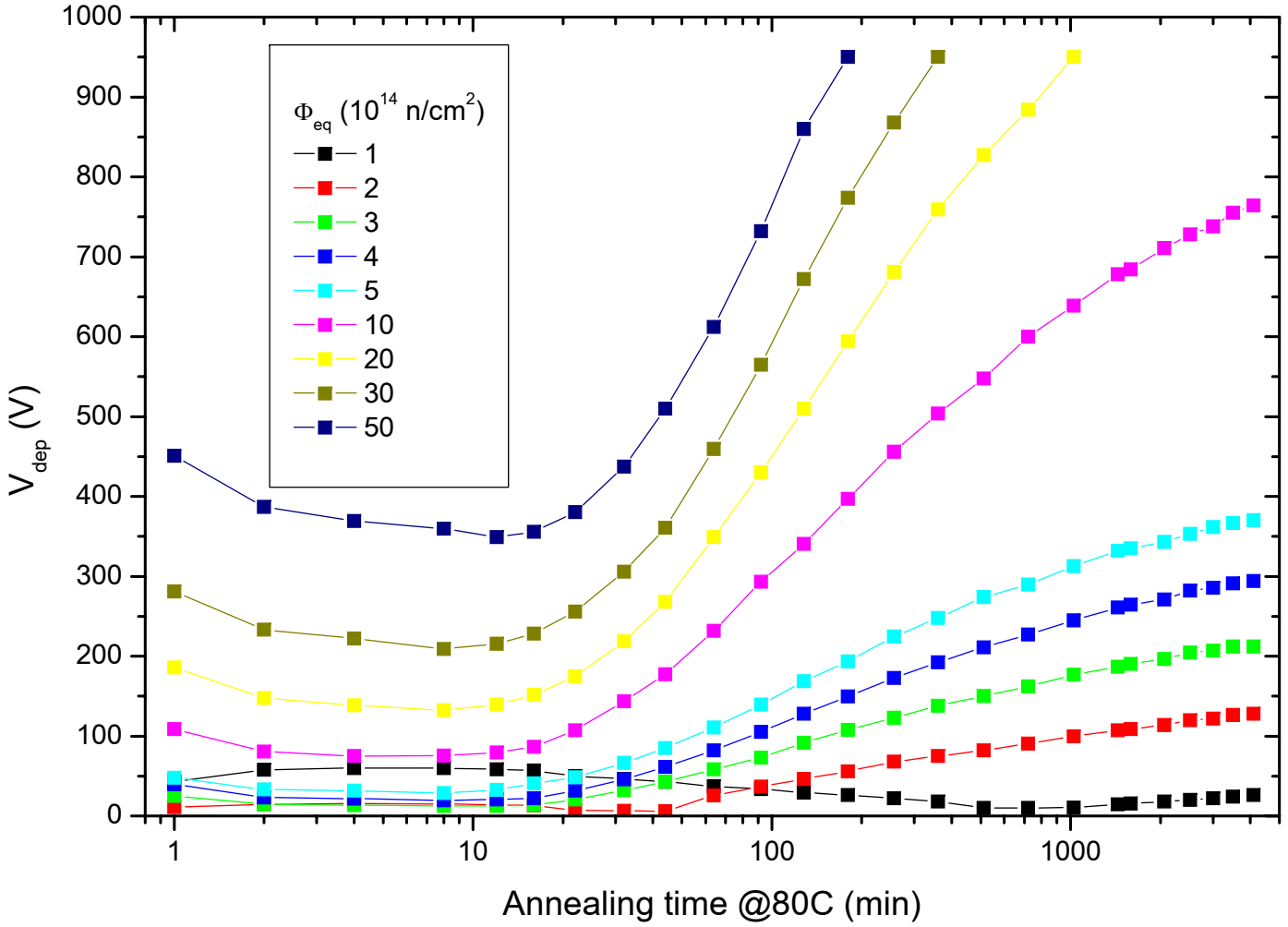
Measurement technique:

- Irradiation and following isothermal annealing at 80C in progressive time steps with electrical characterization at each step
- Characterization was done by measurement of CV (10kHz, parallel and serial mode) and IV dependence in the temperature range (2-5)C
- CCE was measured (JSI, Ljubljana) for some samples
- Between annealing steps the samples were stored at -20C

V_{dep} vs. Φ_{eq}, after irradiation

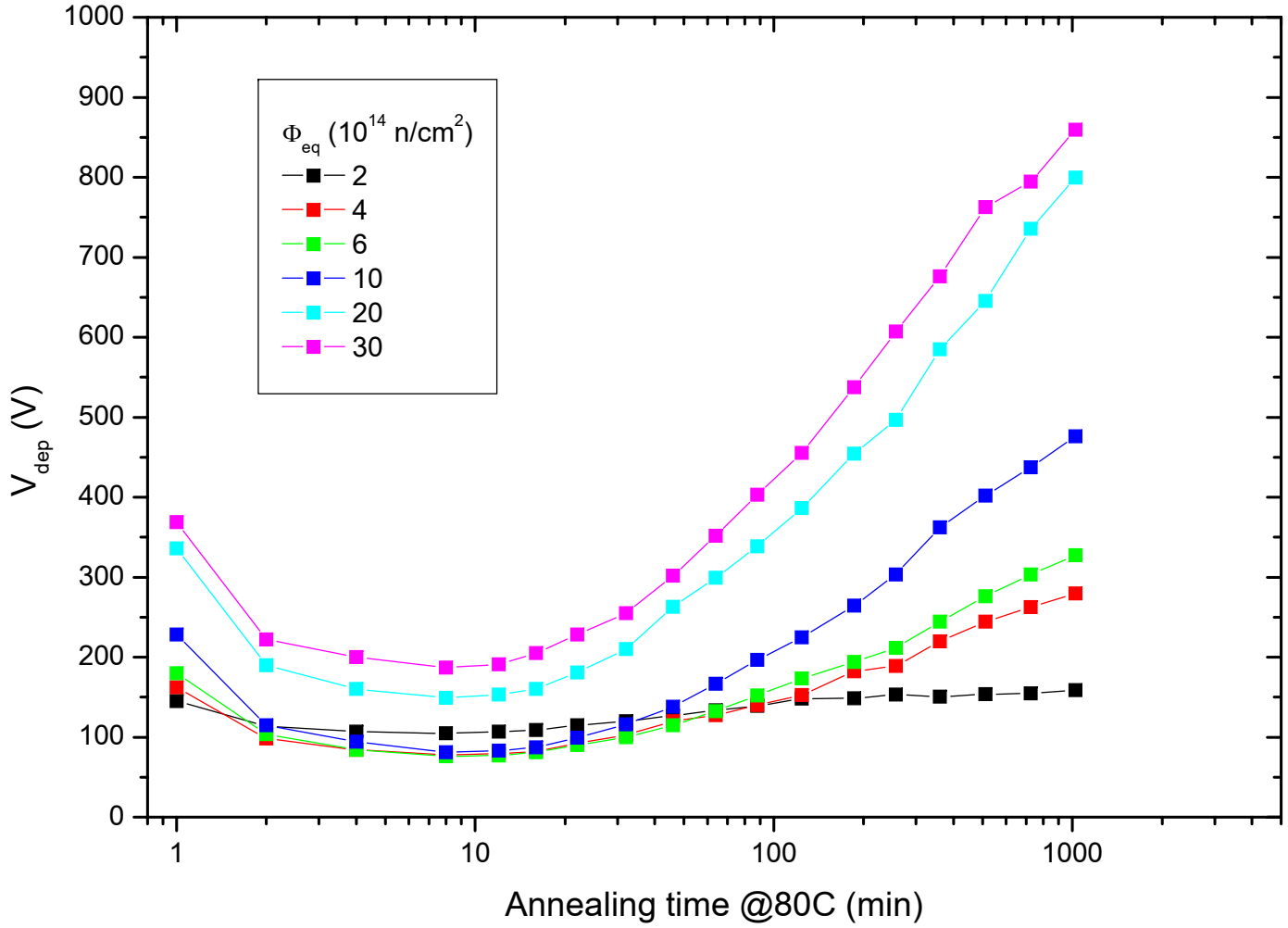


V_{dep} vs. t_{anneal}, n-type, neutrons



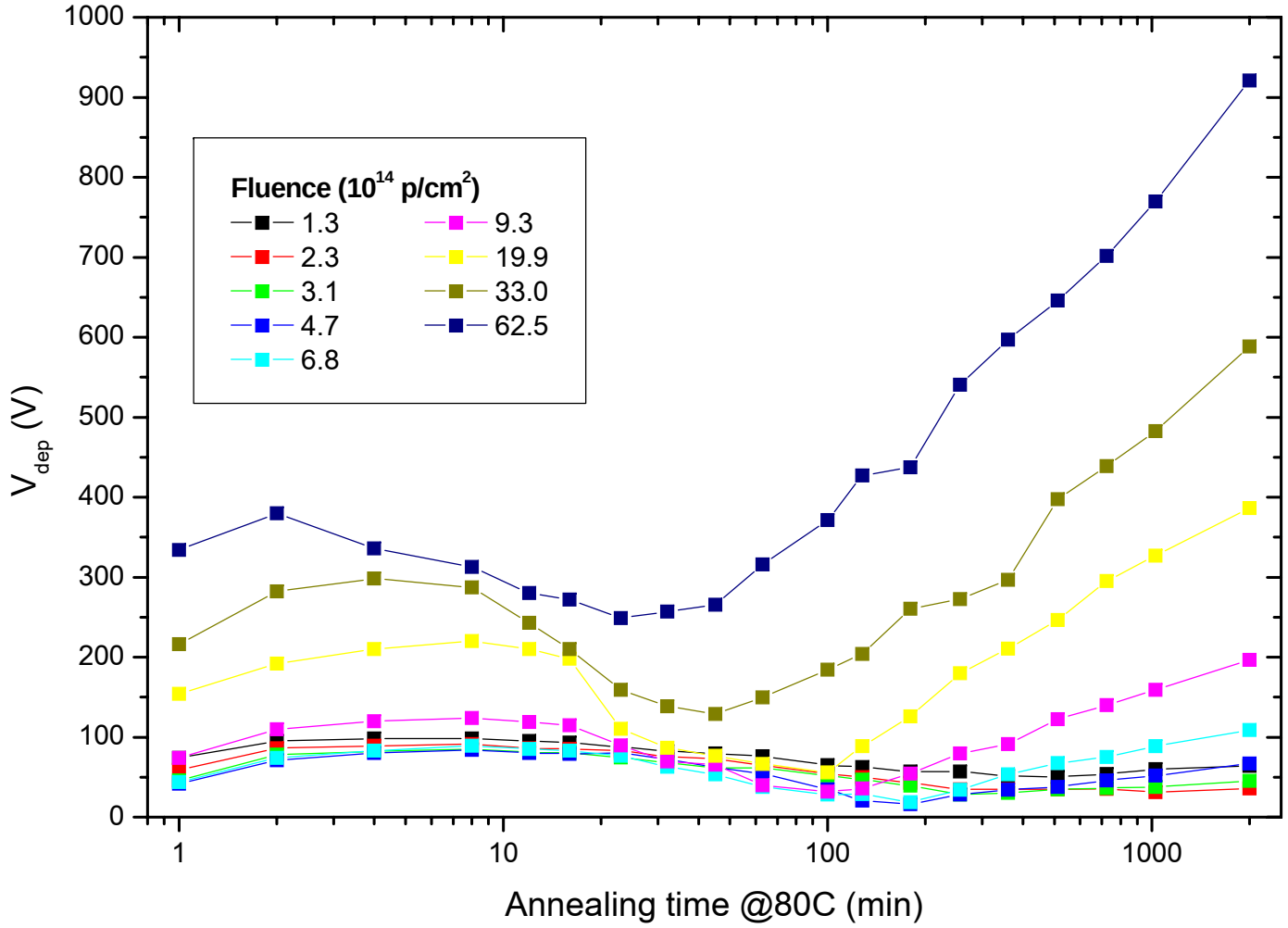
SCSI at $\Phi_{eq} > 3 \cdot 10^{14}$ cm^{-2}

V_{dep} vs. t_{anneal}, p-type, neutrons



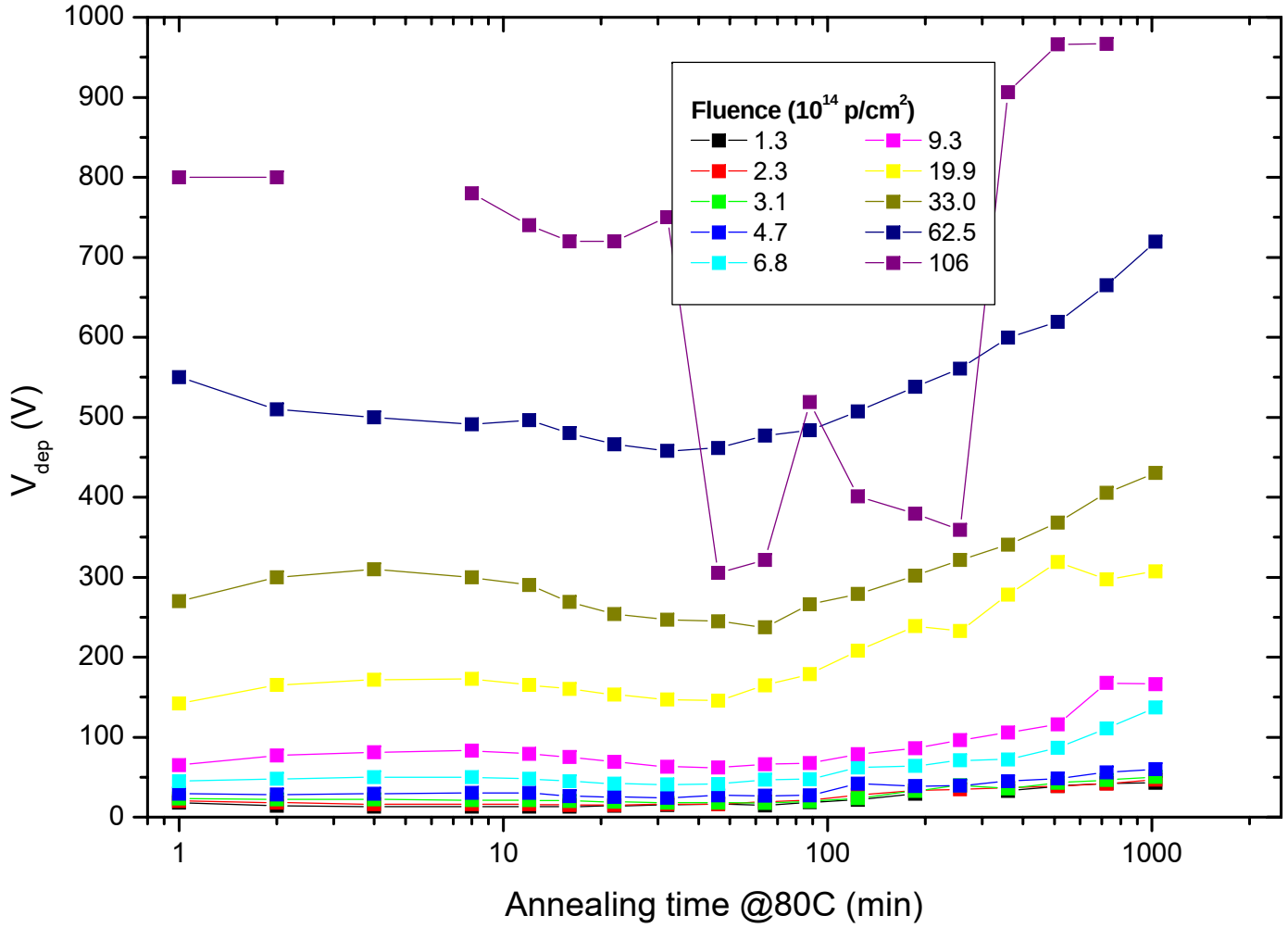
All samples remain of p-type

V_{dep} vs. t_{anneal}, n-type, protons



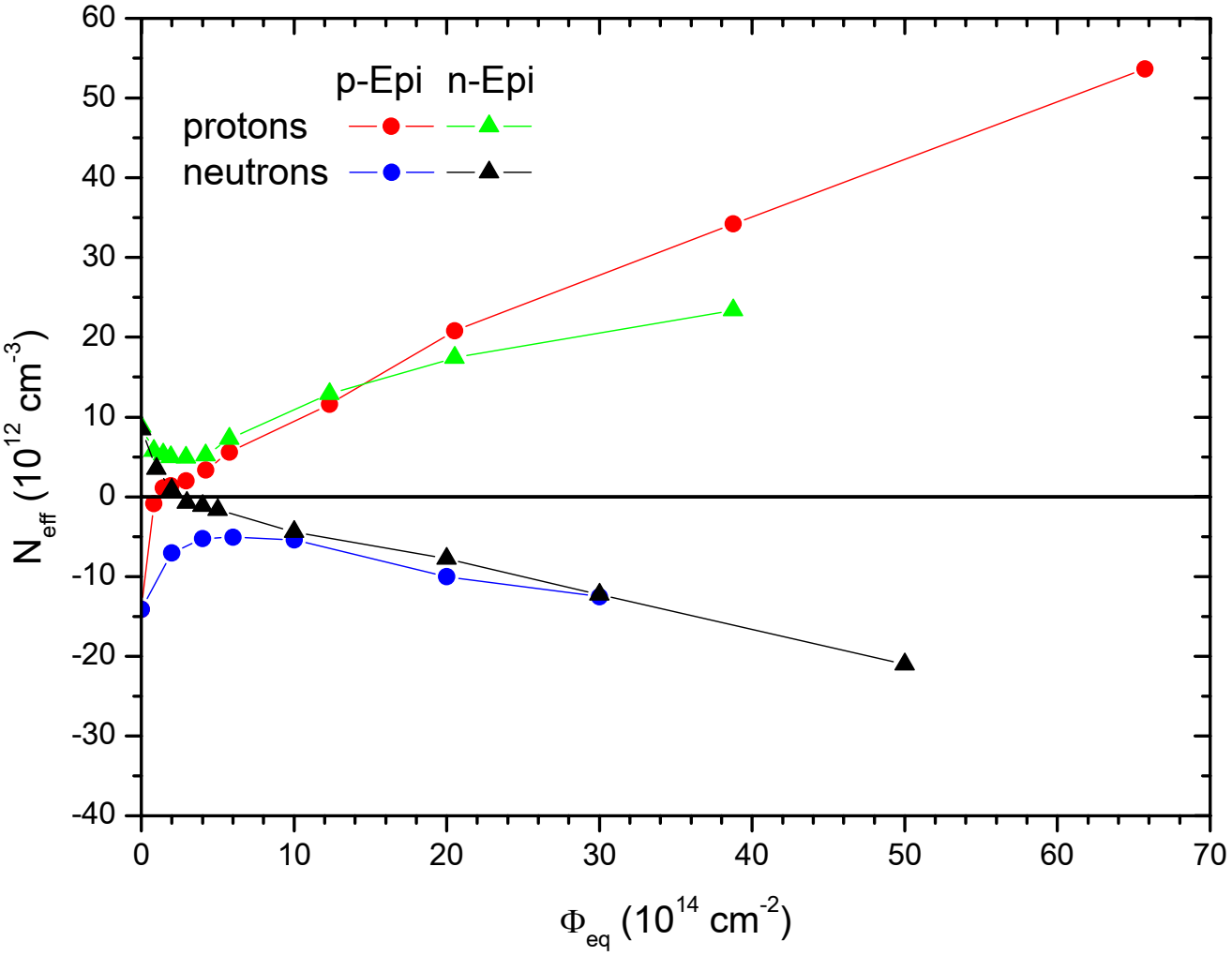
No inversion after irradiation up to $6 \cdot 10^{15}$ p/cm^2?

V_{dep} vs. t_{anneal}, p-type, protons



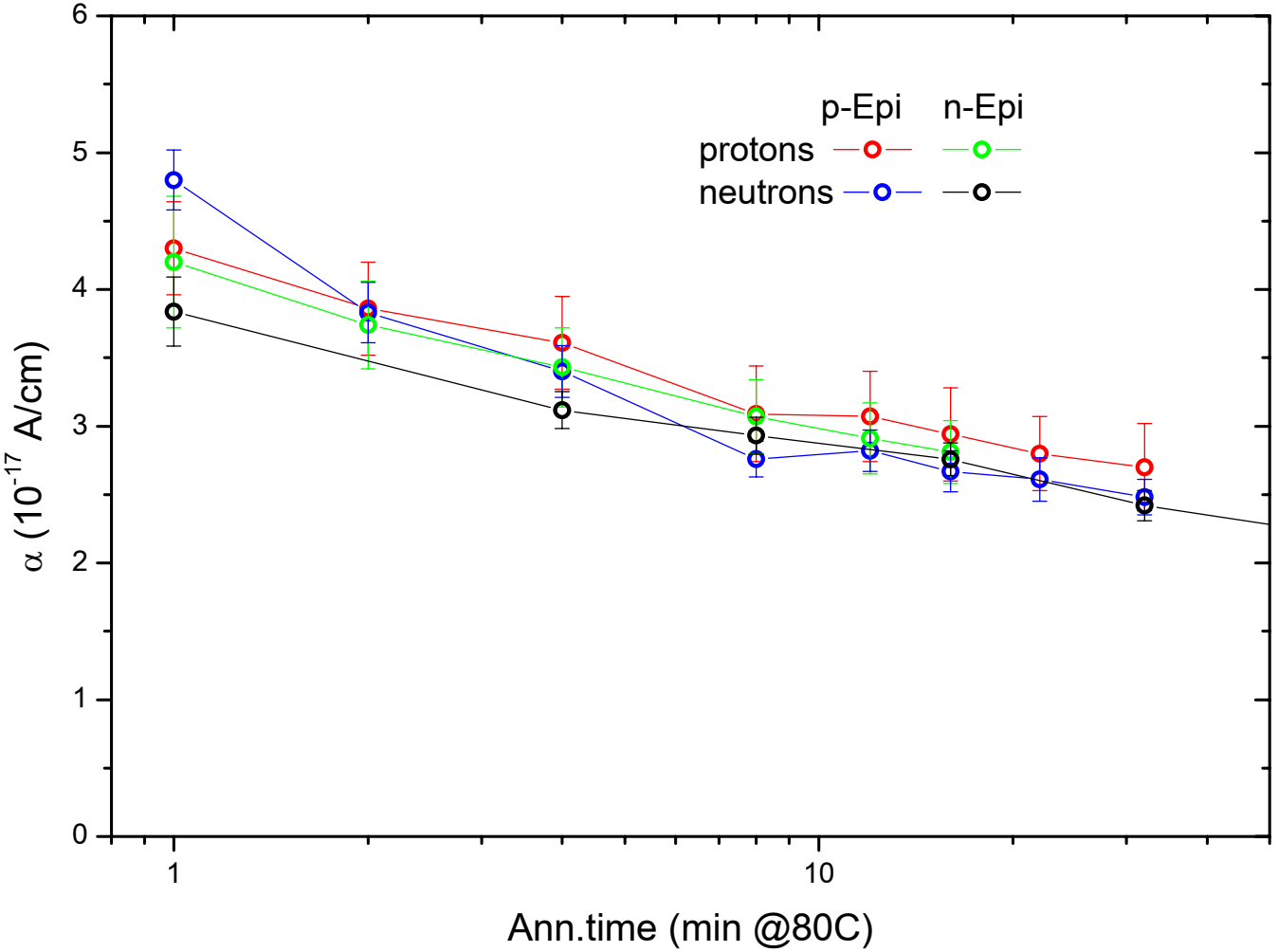
Change to n-type at $\Phi > 5 \cdot 10^{14}$ p/cm^2?

Stable damage component (8 min @ 80C)



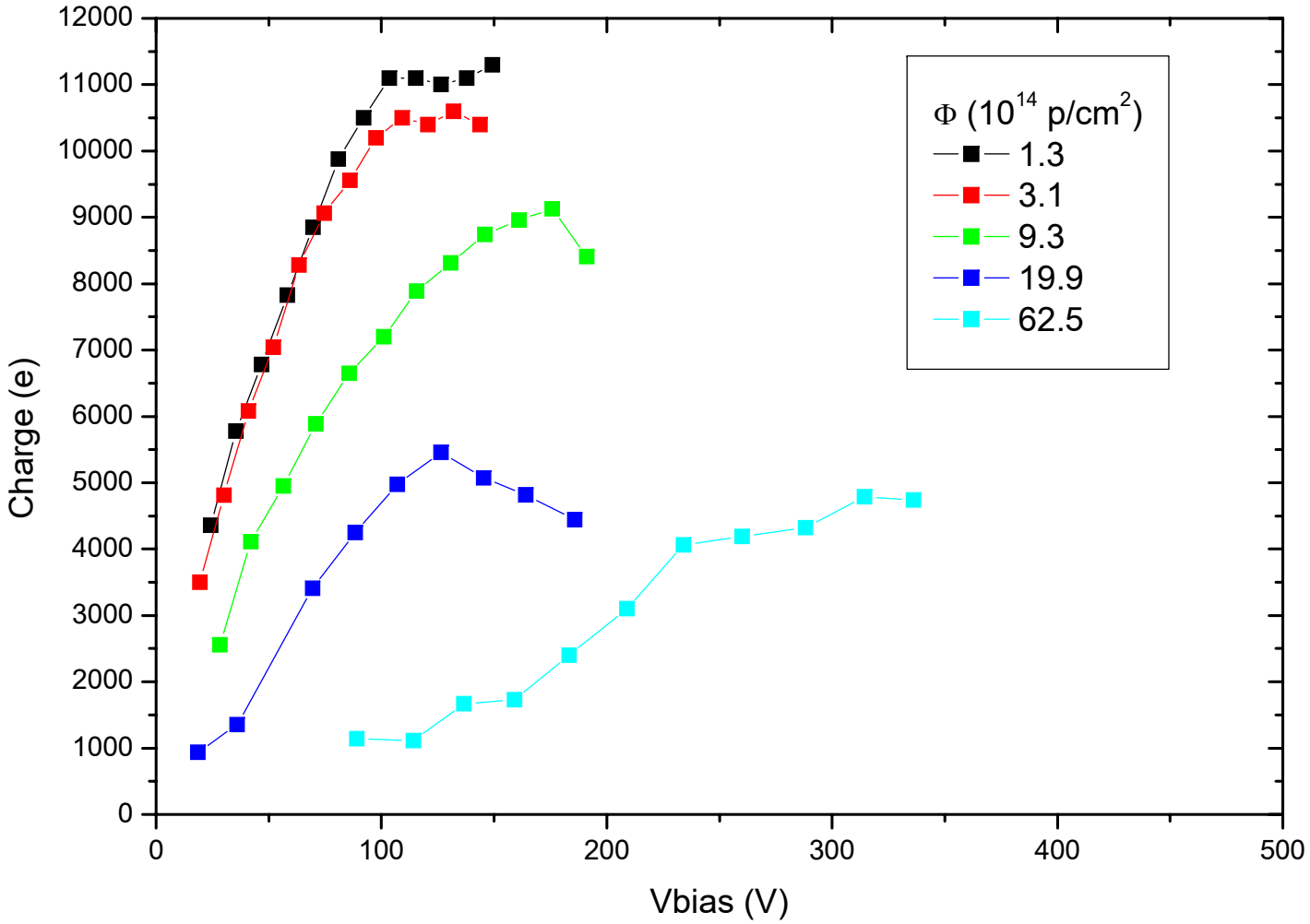
Epi-type, irradiation	g_C, 10^{-3} cm^{-1}
150 um, protons	from -5 to -8
150 um, neutrons	~ (3-4)
50 um, protons	-20 ± 2
50 um, neutrons	-8 ± 1

Current damage rate α vs. t_{anneal}

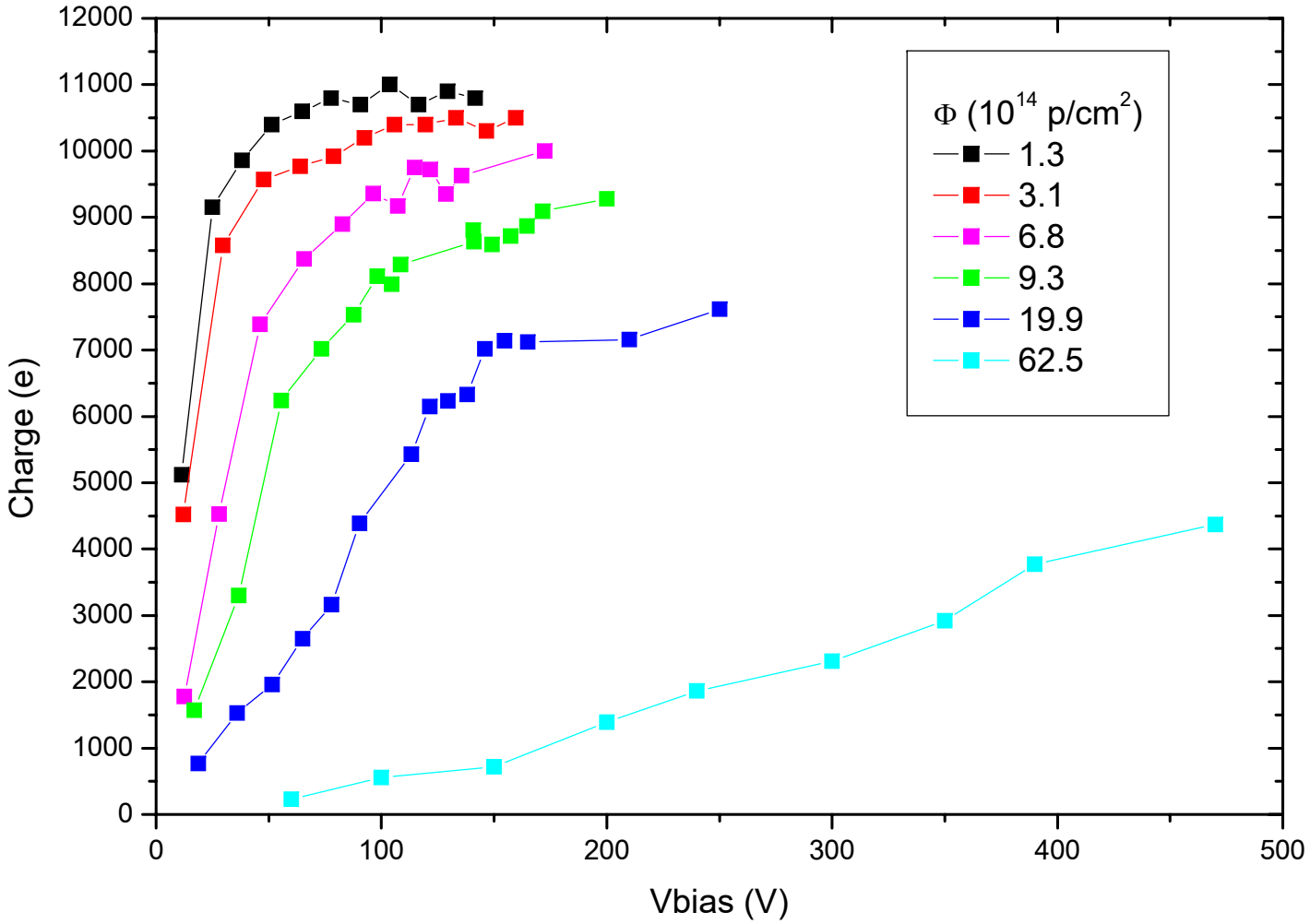


After 8min@80C average α = 3.0 ± 0.5

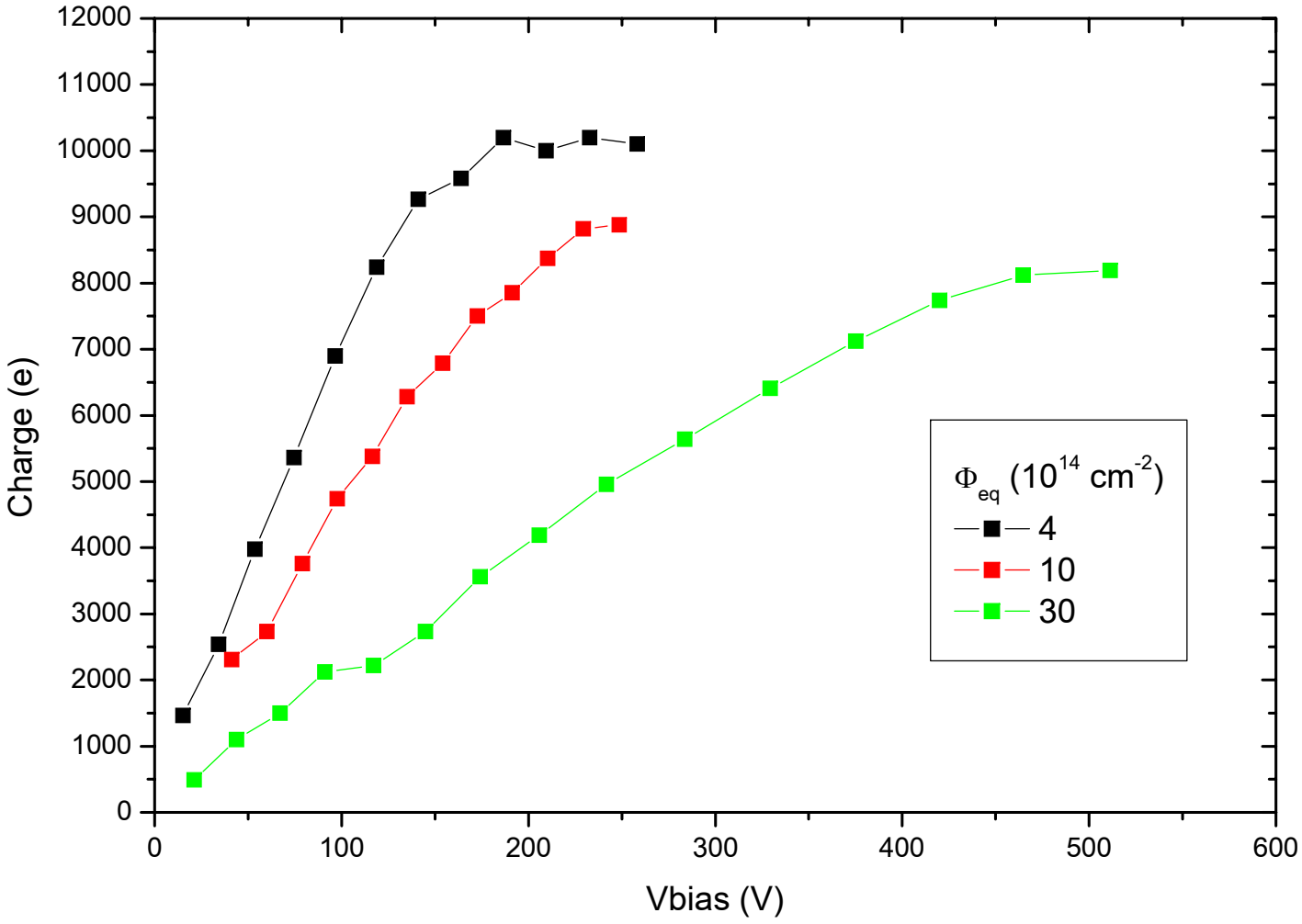
Charge collection, n-type, protons



Charge collection, p-type, protons



Charge collection, p-type, neutrons



Conclusions:

1) Epitaxial silicon again demonstrated high radiation tolerance. For both p- and n-type samples irradiated with both protons and neutrons up to the fluence $2 \cdot 10^{15}$ cm^{-2}:

- Depletion voltage remains moderate up to (50-100) min of reverse annealing at 80C;
- CCE exceeds 50% of value expected for non-irradiated diodes.

2) The stable damage generation rate is almost the same for both p- and n-type samples and depends on the type of particle.

3) Protons induce positive space charge in such a high rate that n-type samples do not invert, while p-type invert to n-type, which gives an advantage during reverse annealing. However, it seemed, that electrical characteristics of proton irradiated samples are more unstable than of neutron irradiated ones.