Determination of depletion voltage from CV, IV and CCE measurements on Pad Detectors

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Introduction

Various methods to determine the depletion voltage

- Standard CV
- IV
- CCE vs. voltage:
  - from TCT with laser
  - with source (not via scope): β-source

Do they agree?

Material

Float Zone

– **CNM-03**	0.5 x 0.5 cm^2	V_{fd} ~20V (ρ ~ 15 kΩcm)	n-type
– **HIP-002-C**	0.25 x 0.25 cm^2	V_{fd} ~20V (ρ ~ 15 Ωcm)	n-type
– **CNM-20**	0.5 x 0.5 cm^2	V_{fd} ~2V (ρ ~ 470 kΩcm)	p-type

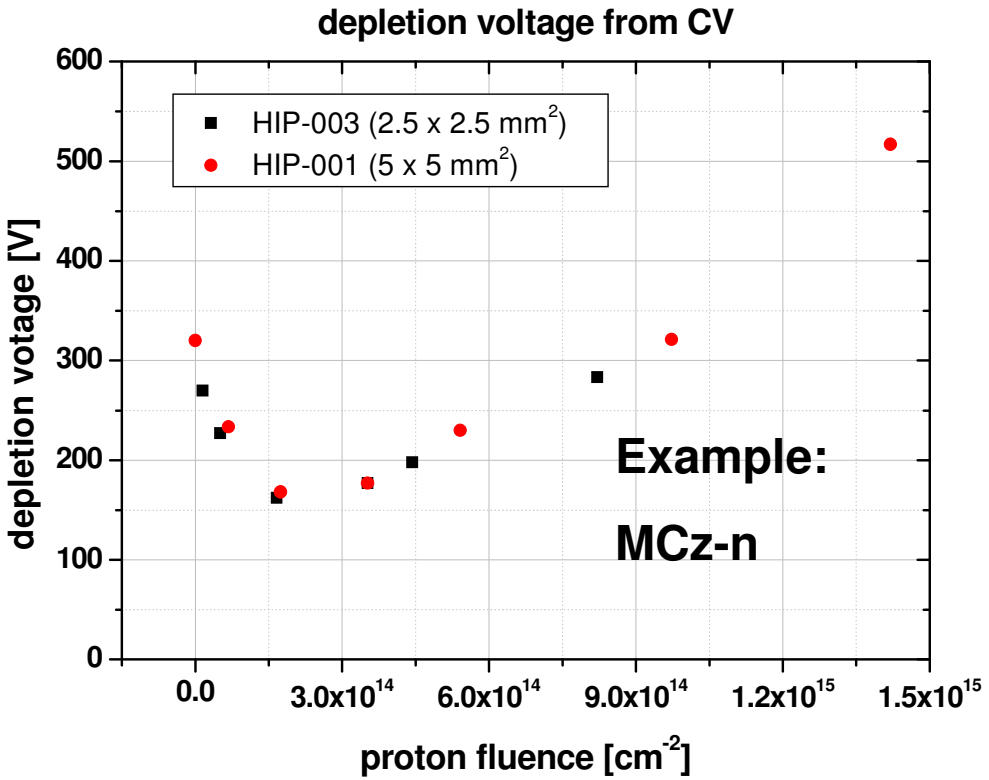
MCz

– **HIP-MCz-01-n**	0.5 x 0.5 cm^2	V_{fd} ~320V (ρ ~ 1 kΩcm)	n-type
– **8556-3 (CiS)**	0.5 x 0.5 cm^2	V_{fd} ~100V (ρ ~ 2.9 kΩcm)	n-type
– **HIP-003-C**	0.25 x 0.25 cm^2	V_{fd} ~300V (ρ ~ 1 kΩcm)	n-type
– **p069/8**	0.5 x 0.5 cm^2	V_{fd} ~115V (ρ ~ 7.4 kΩcm)	p-type

Epitaxial (150 µm)

– **HIP-004-C**	0.25 x 0.25 cm^2	V_{fd} ~150V (ρ ~ 500 Ωcm)	n-type
– **CNM-11**	0.5 x 0.5 cm^2	V_{fd} ~155V (ρ ~ 500 Ωcm)	n-type
– **CNM-22**	0.5 x 0.5 cm^2	V_{fd} ~210V (ρ ~ 980 Ωcm)	p-type

Material II



For a part of the CCE measurements diodes of smaller size were used. No differences were observed in comparing results obtained on small (2.5x2.5) and big (5x5mm2) diodes (except for the noise levels in CCE☺).

Experimental procedure

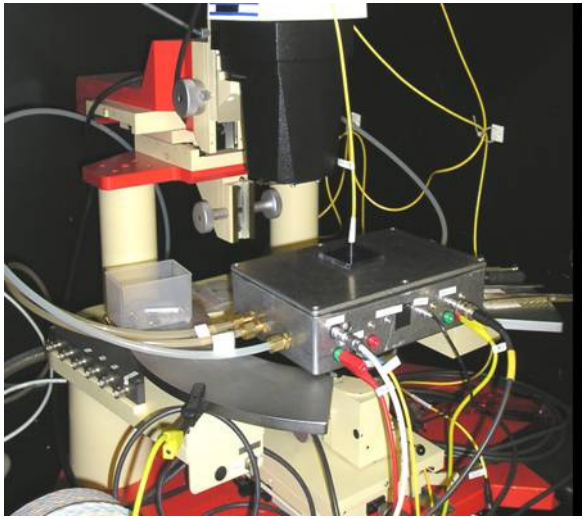
- **Irradiation**
  - 24 GeV/c protons at CERN at 27°C
  - 1 MeV neutrons in Ljubljana
- **Annealing**
  - 4 minutes at 80°C
- **CV/IV**
  - Measured at room temperature in parallel mode at 10kHz
- **CCE**
  - NIKHEF setup
- **TCT**
  - IR laser

TCT setup

- voltage applied with Cu/Be needle
- floating guard ring!!!

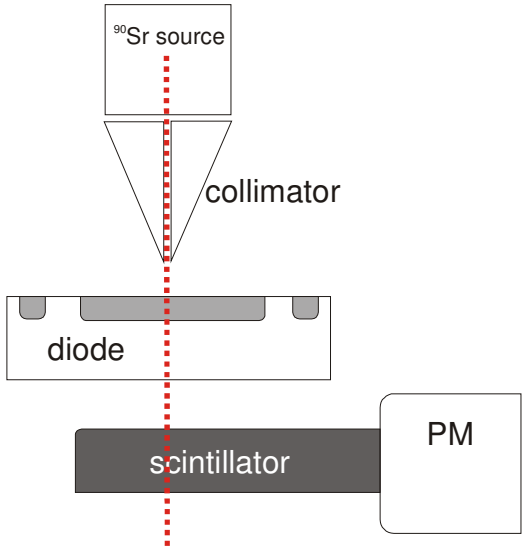
- N_2 atmosphere
- Peltier cooling

- 660nm red laser
- **1060nm IR laser**



- all detectors were measured at -5±0.1°C
- humidity in the box was around 15%

CCE setup



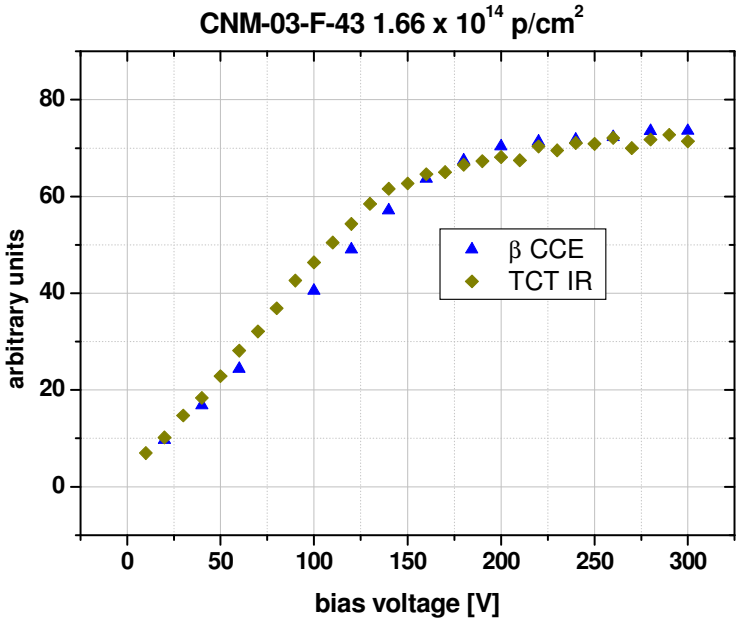
- all detectors were measured at -20±1°C
- humidity in the box was 18-30%
- gain of 247 e^-/mV for these conditions

NIKHEF setup by Fred Hartjes

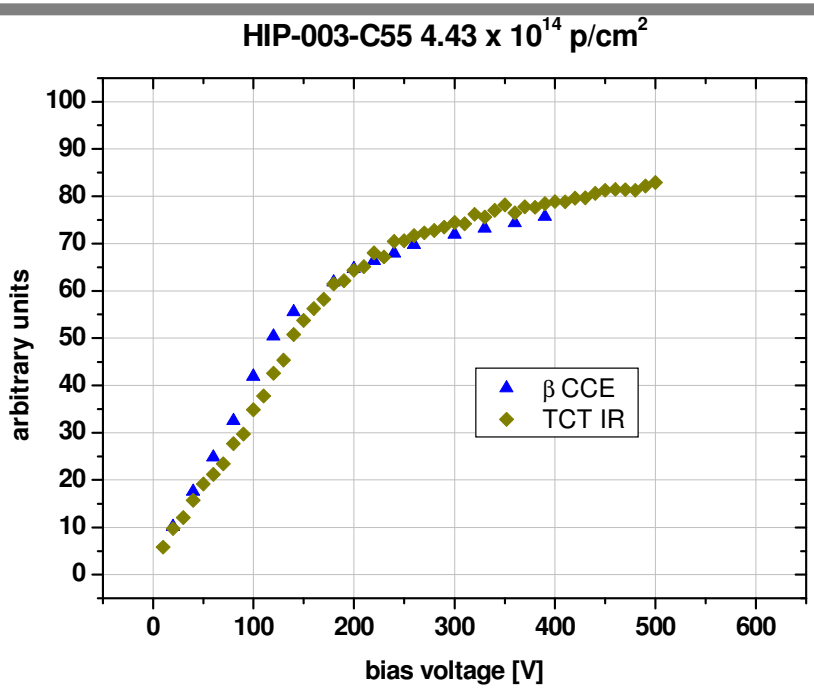
signal shaping time: 2.5 µs

guard ring connected to ground

IR laser vs. beta



Fz-n



MCz-n

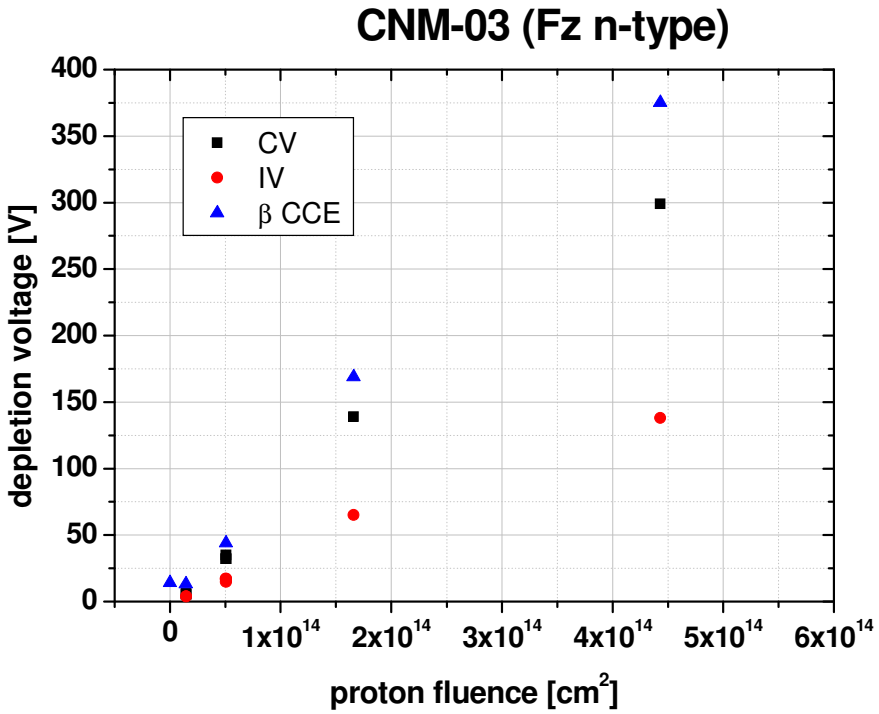
IR laser goes through sample (red laser only on surface) => similar to β particles

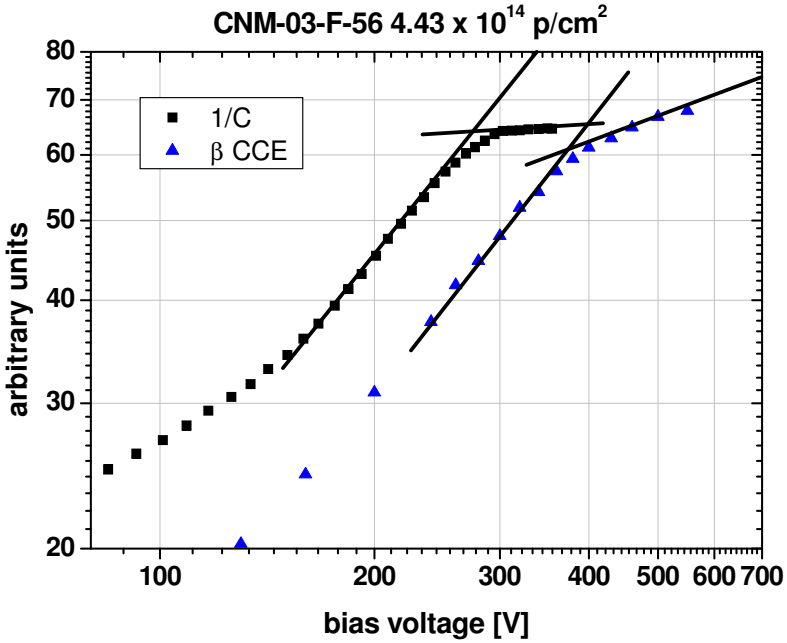
BUT: only very few samples investigated!

!!! Only for curve shape comparison, not CCE values!!!

Fz n-type

24 GeV/c proton irradiated

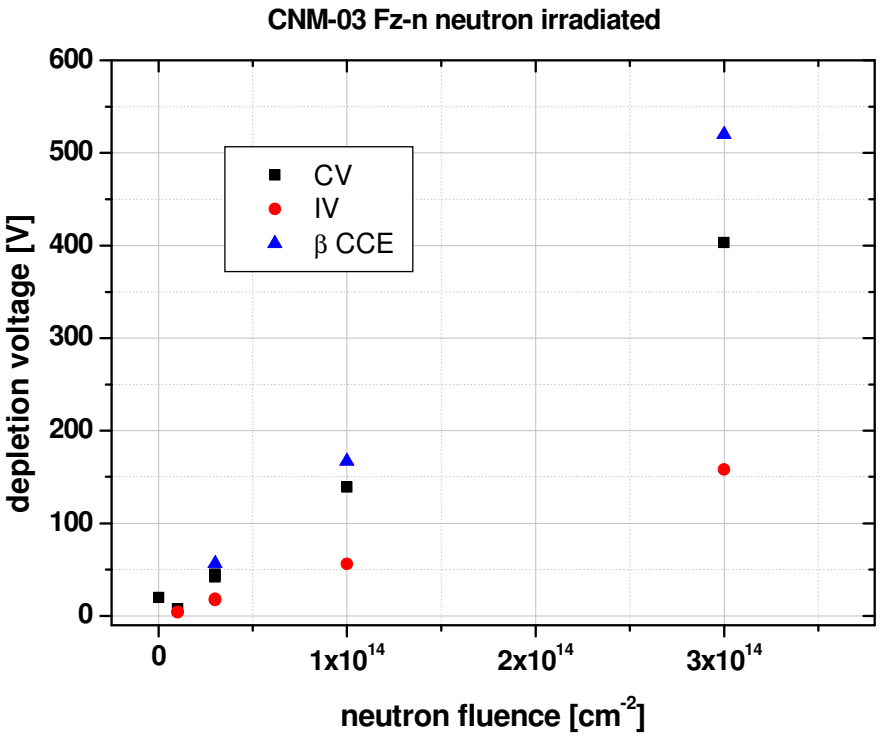


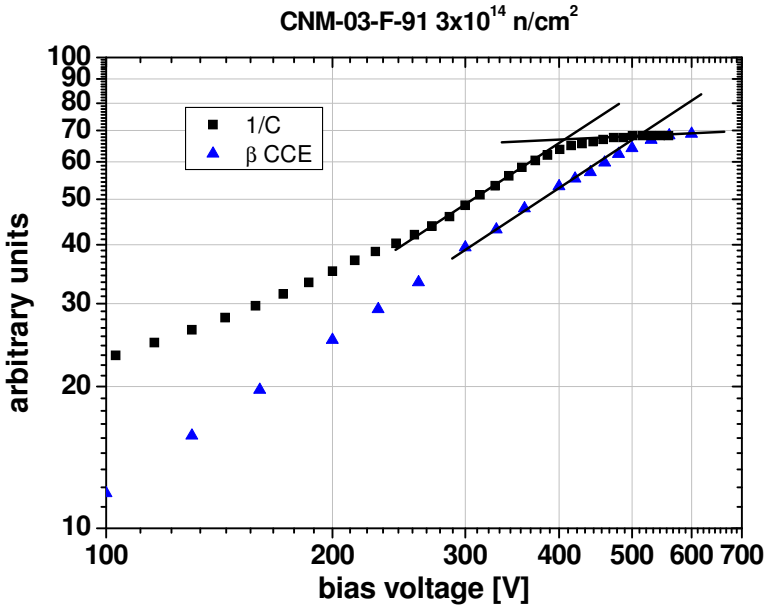


IV < CV < CCE (β)

Fz n-type

1 MeV neutron irradiated

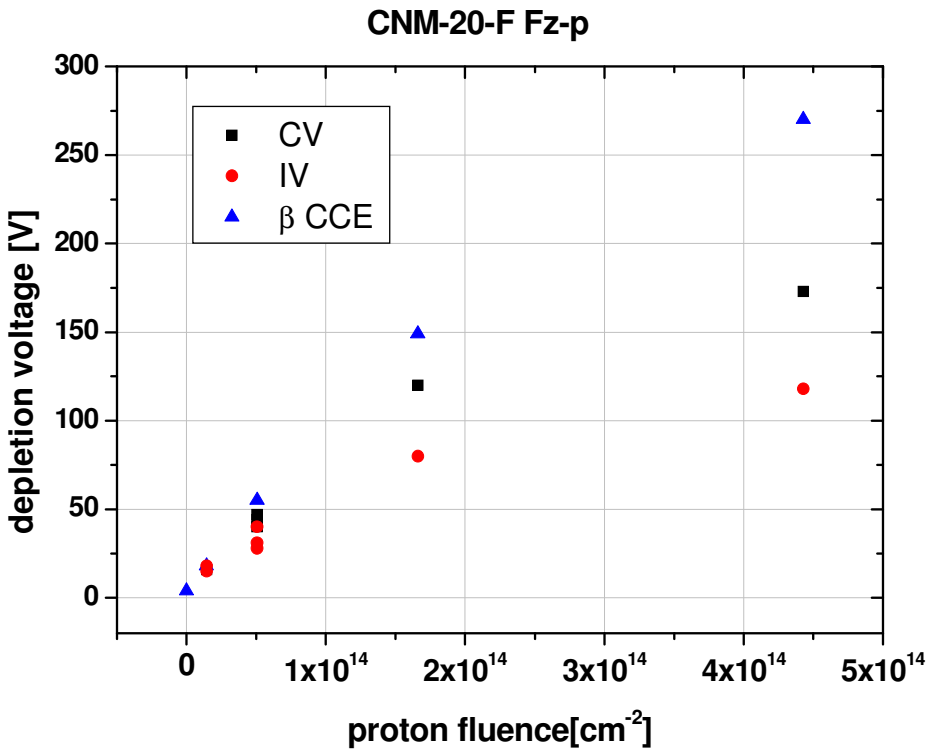


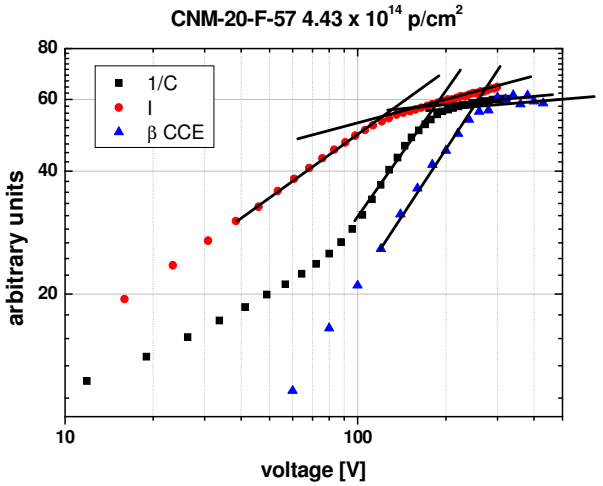


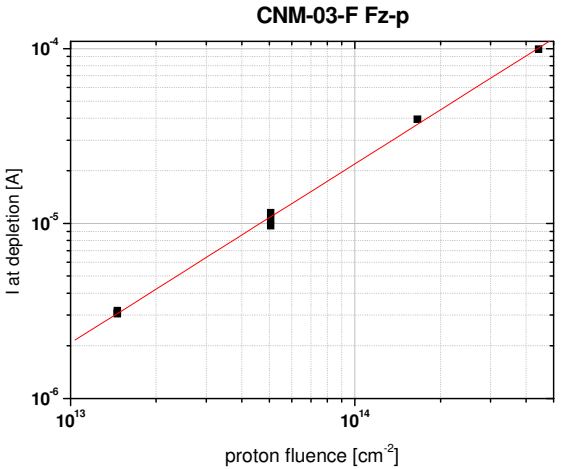
IV < CV < CCE (β) =>same as proton

Fz p-type

24 GeV/c proton irradiated





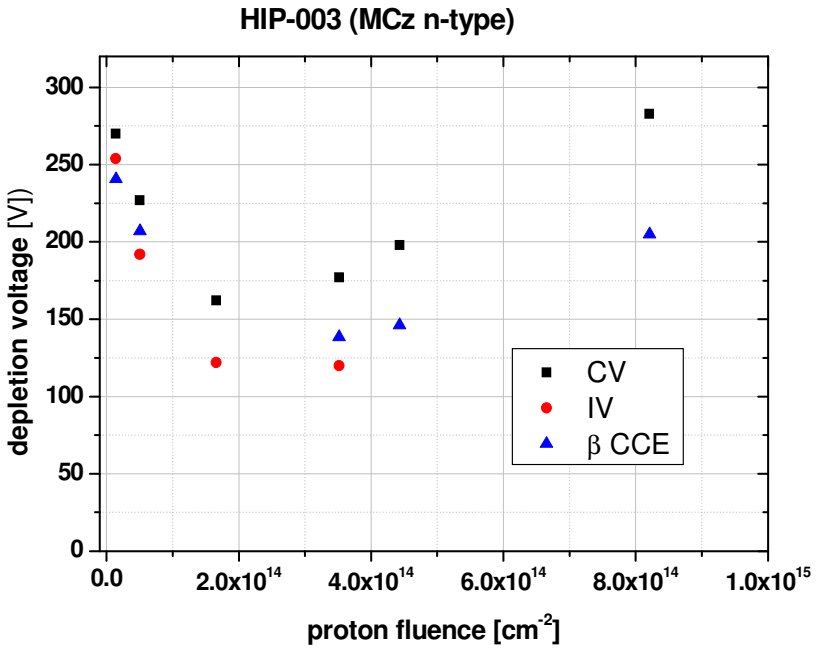


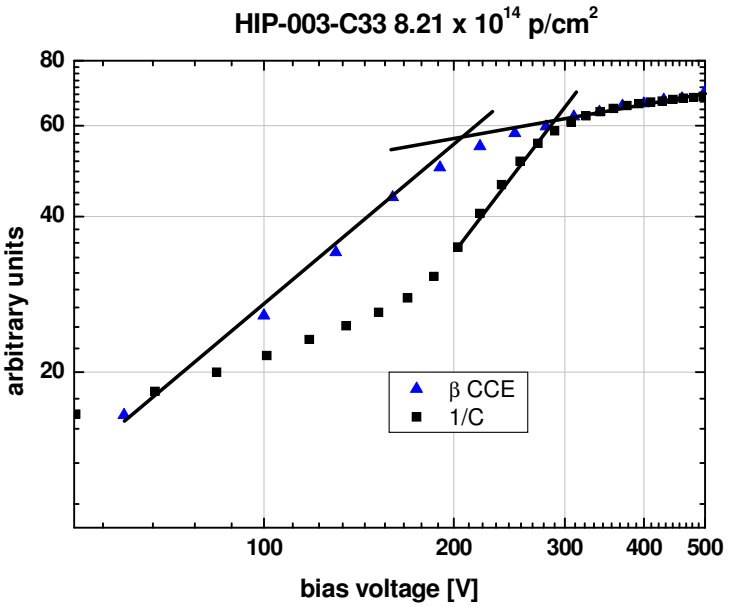
IV < CV < CCE (β)

Not linear at high fluences

MCz n-type

24 GeV/c proton irradiated

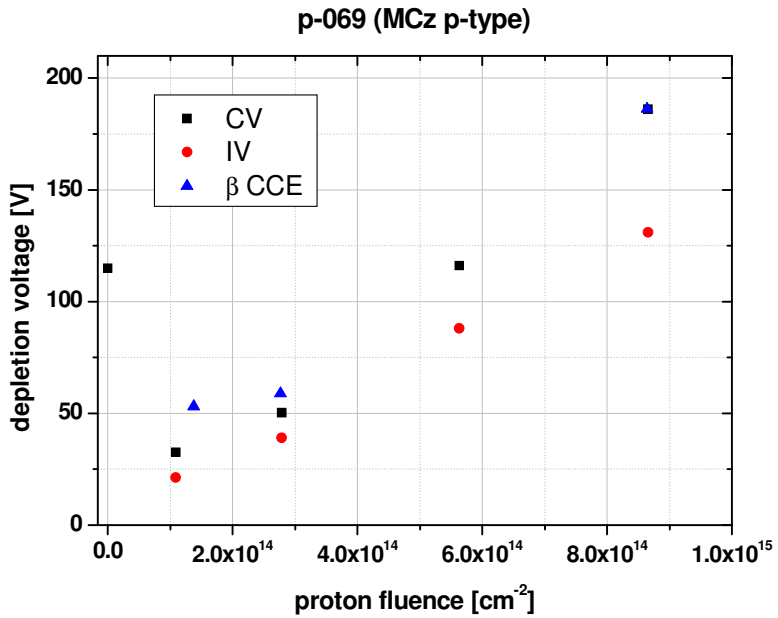


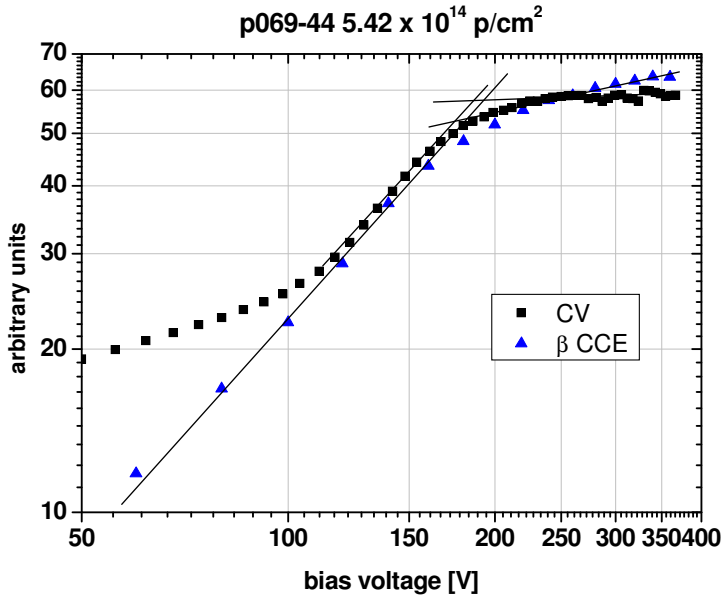


IV < CCE (beta) < CV => different from Fz

MCz p-type

24 GeV/c proton irradiated

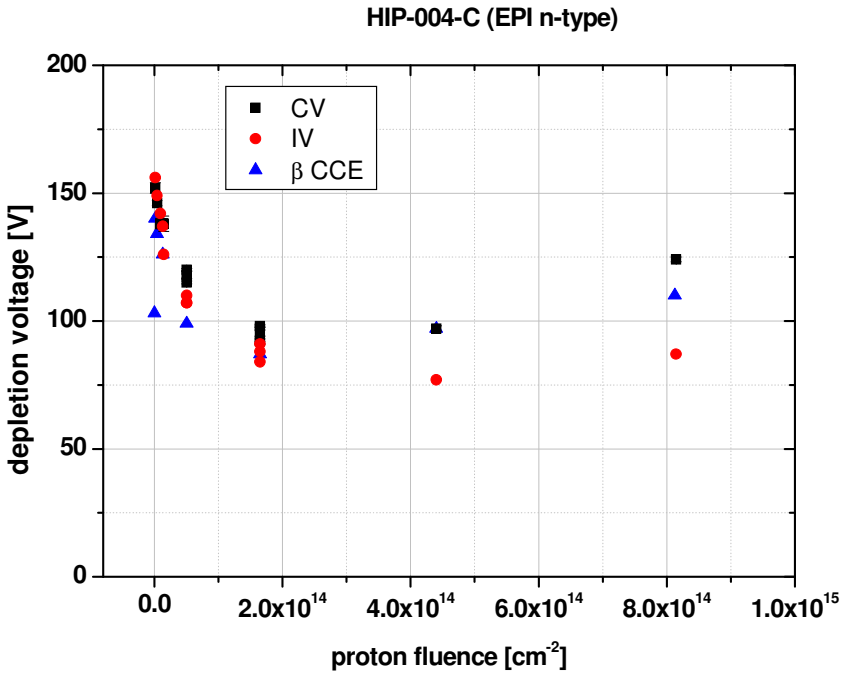


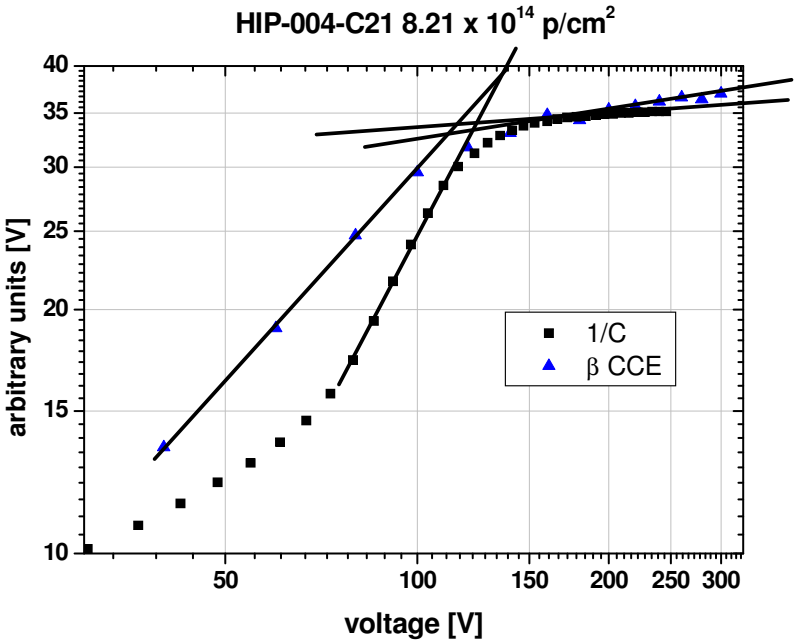


IV < CCE (beta) = CV

EPI n-type

24 GeV/c proton irradiated

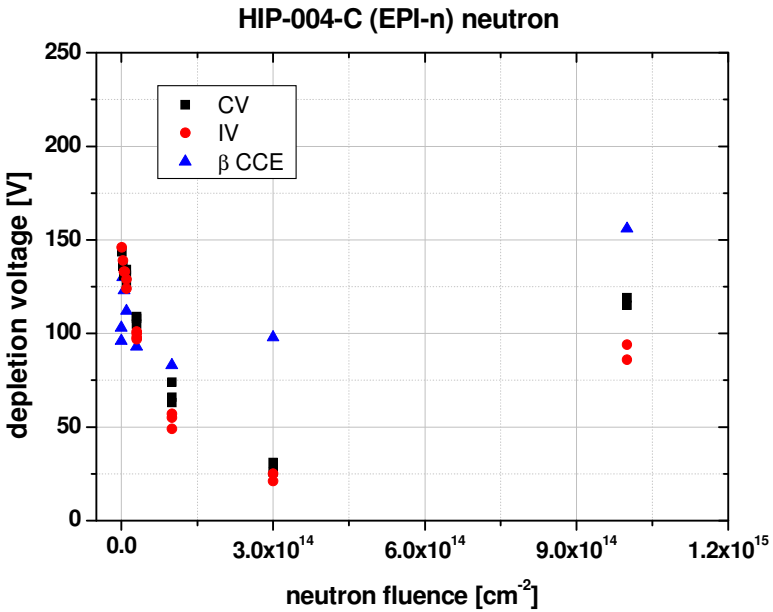


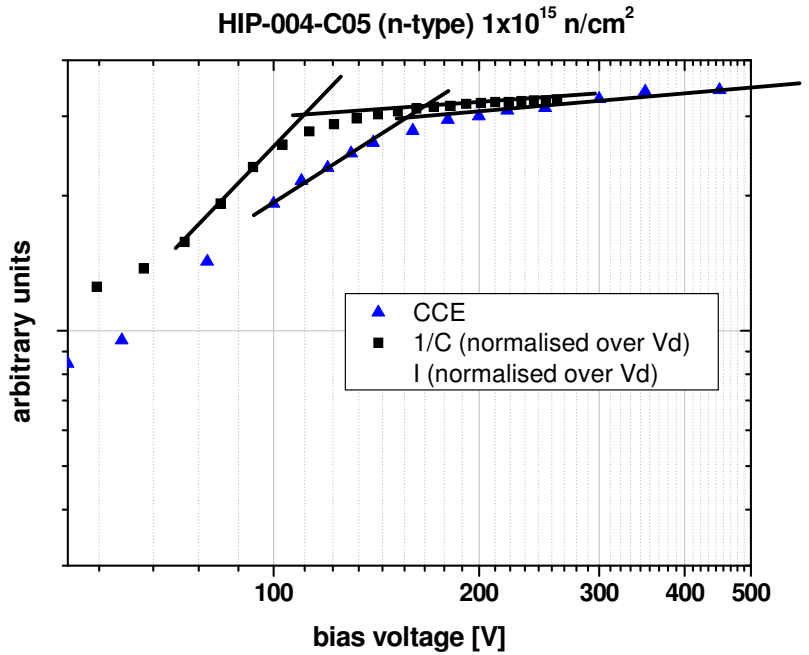


IV < CCE (β) < CV => same as MCz

EPI n-type

1 MeV neutron irradiated

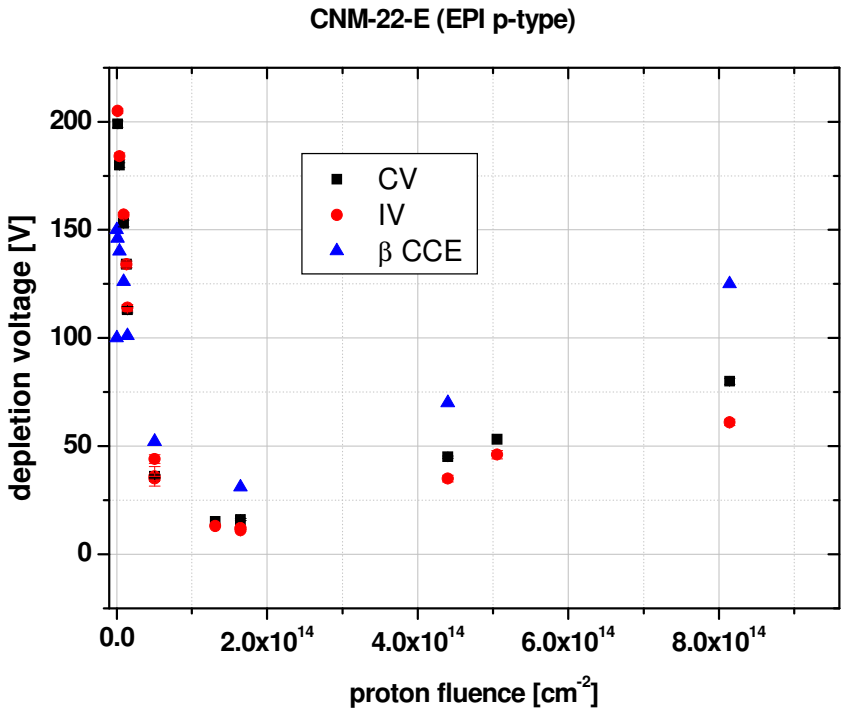


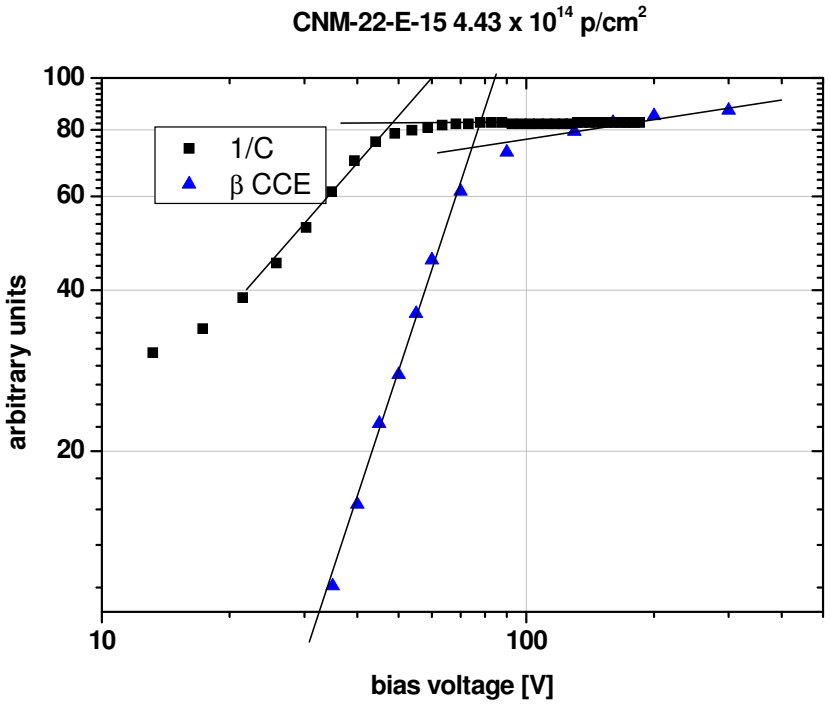


IV < CV < CCE (β) => different from proton irrad.

EPI p-type

24 GeV/c proton irradiated

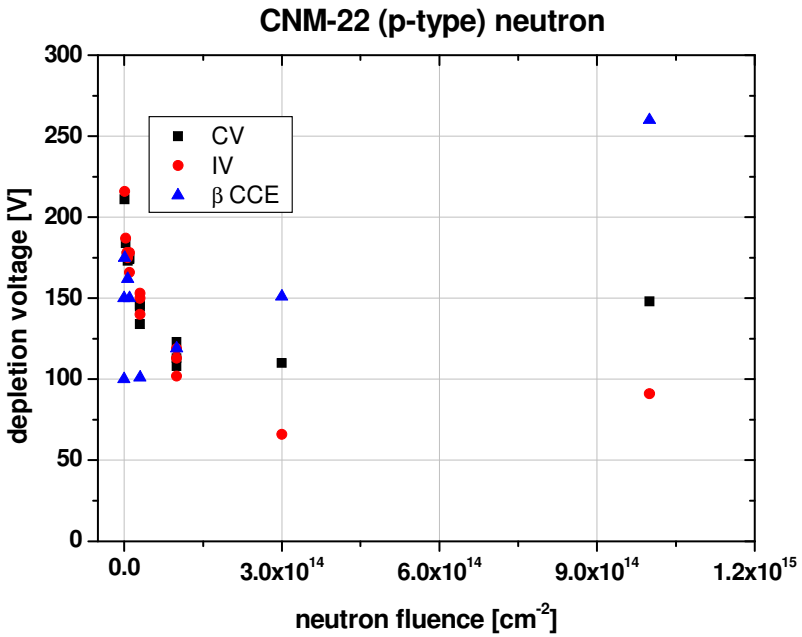


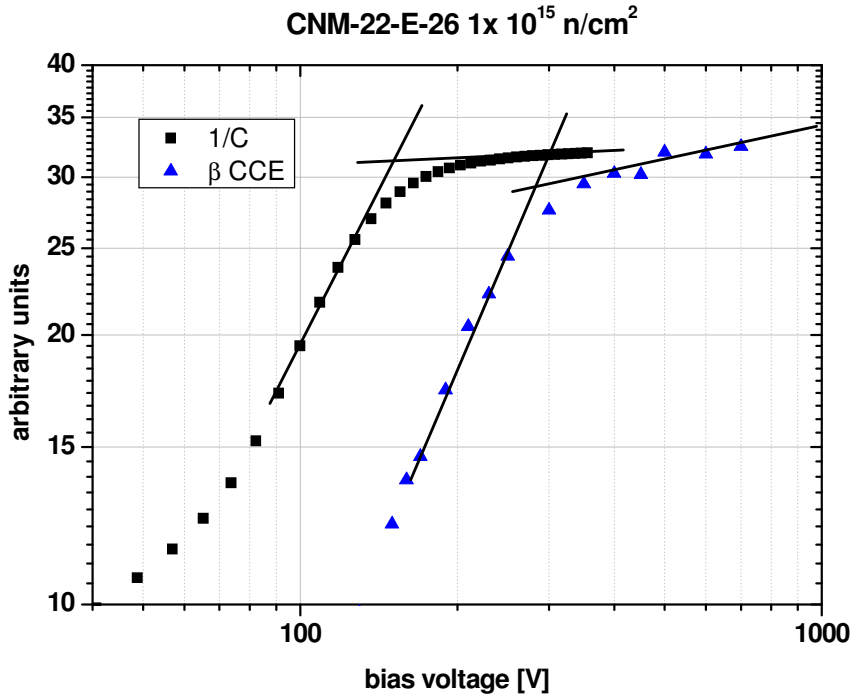


IV < CV < CCE (β)

EPI p-type

1 MeV neutron irradiated





IV < CV < CCE (β)

Overview

material	Irradiation	Highest values	Junction
Fz-n	proton	CCE	back
Fz-n	neutron	CCE	back
Fz-p	proton	CCE	front
MCz-n	proton	CV	?
MCz-p	proton	CV=CCE	?
EPI-n	proton	CV	front
EPI-n	neutron	CCE	back
EPI-p	proton	CCE	back
EPI-p	neutron	CCE	front

There seems to be no correlation with:

- material
- n- or p-type
- side of junction

Summery and outlook

Summery

- Depletion voltages from CV, IV and CCE were investigated for Fz, MCz and EPI material.
- All methods on their own show expected behaviour, but don't agree in values.
- No clear correlations with inversion, material and type.

Outlook:

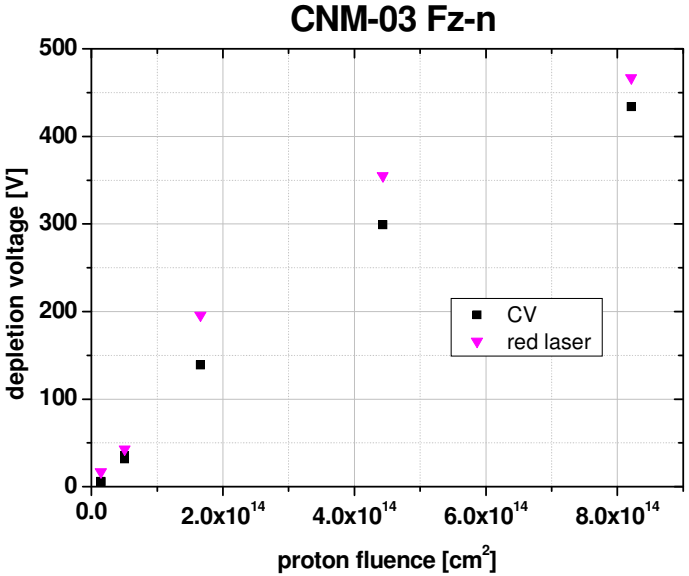
- Look at rest of methods
- Investigate after annealing (change in curve shape)

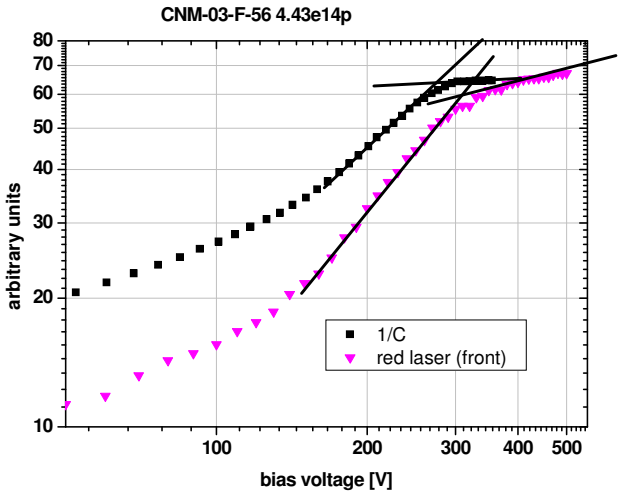
Thanks!

- **spares**

Fz n-type

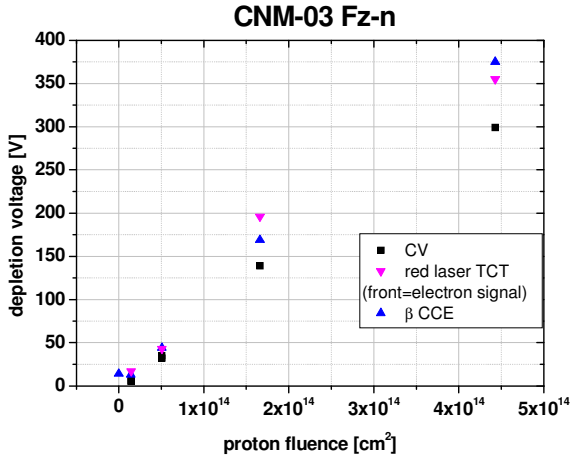
24 GeV/c proton irradiated





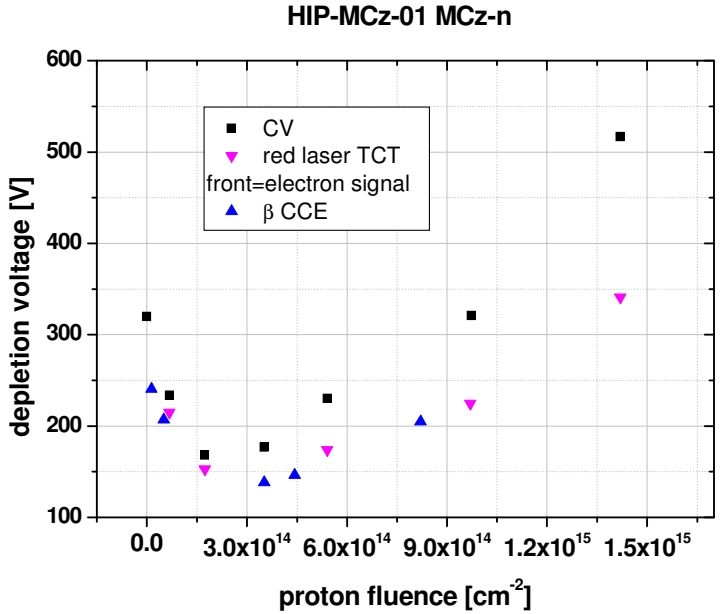
CV < red laser = CCE (β)

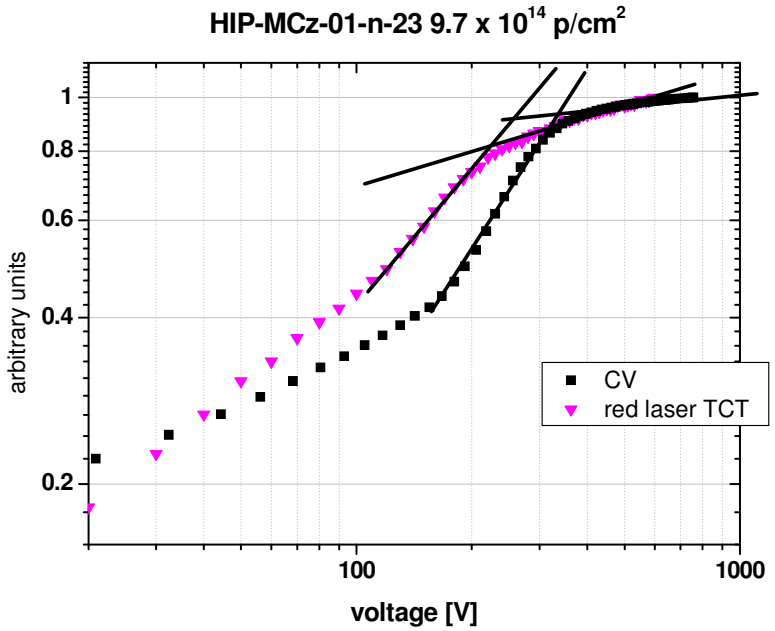
TCT with red laser from the front: electron signal in n-type



MCz n-type

24 GeV/c proton irradiated



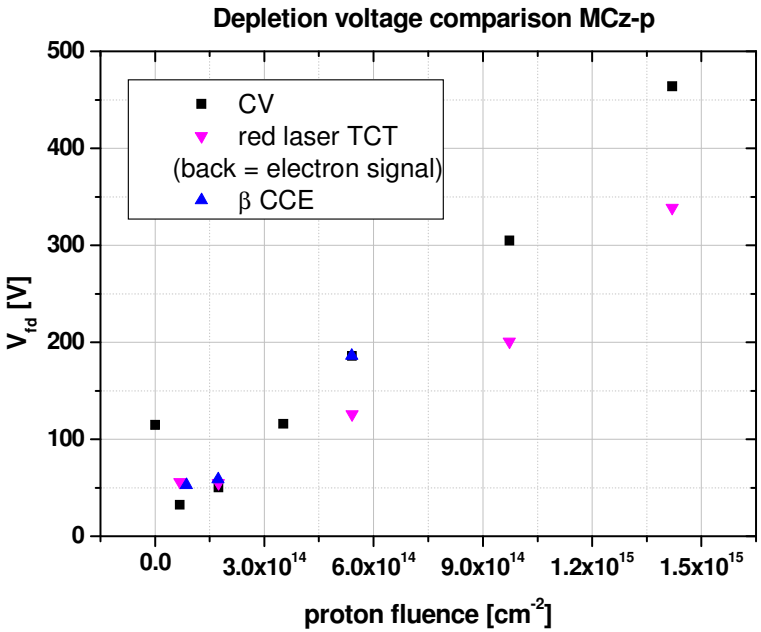


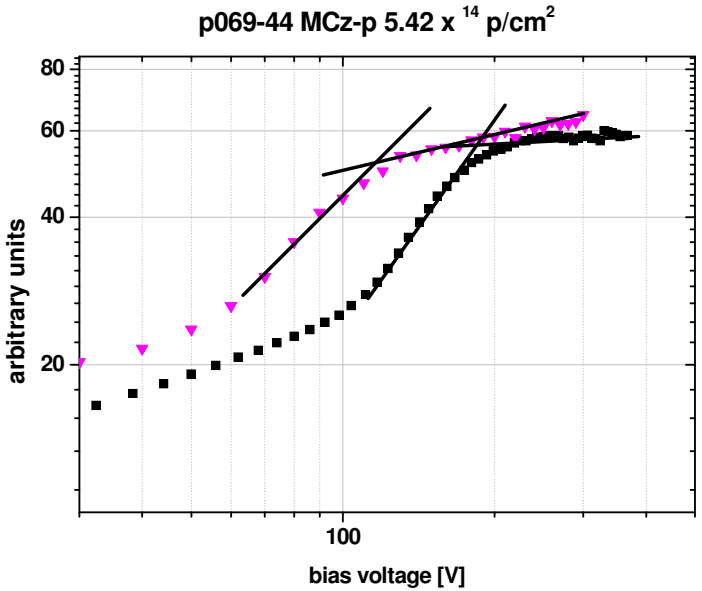
red laser = CCE (β) < CV

TCT with red laser from the front: electron signal in n-type

MCz p-type

24 GeV/c proton irradiated





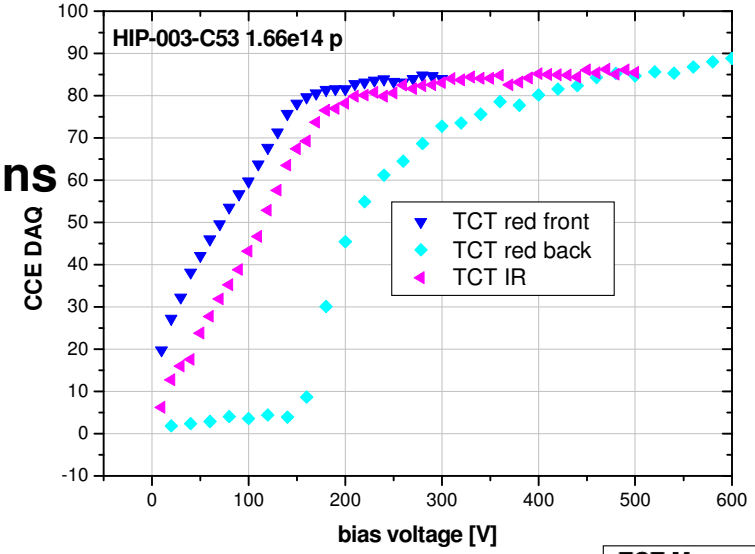
red laser < CCE (β) = CV

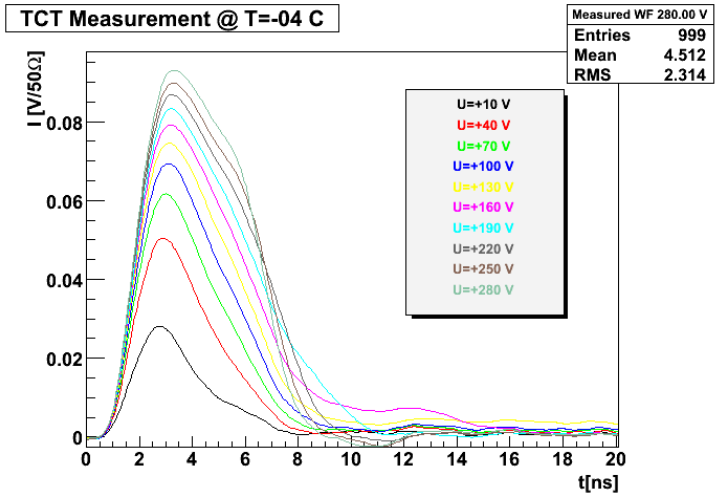
TCT with red laser from the back: electron signal in p-type

Front vs. back

Junction is on front.

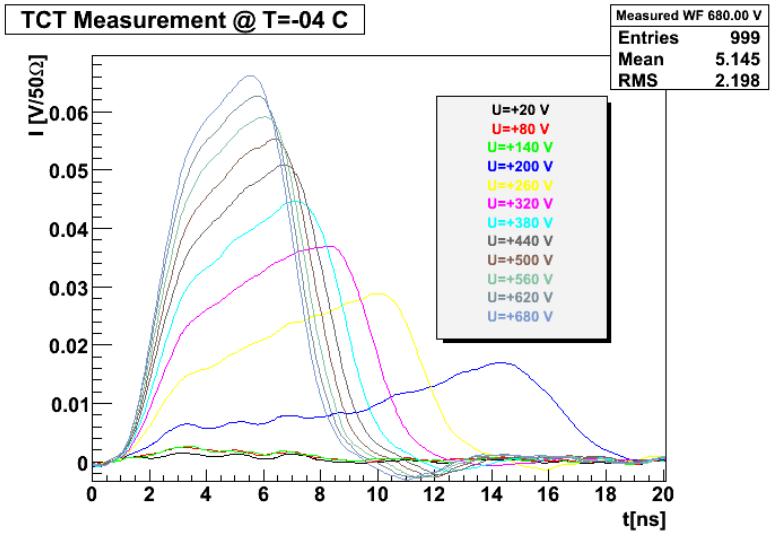
Front signal: electrons
Back signal: holes





proton

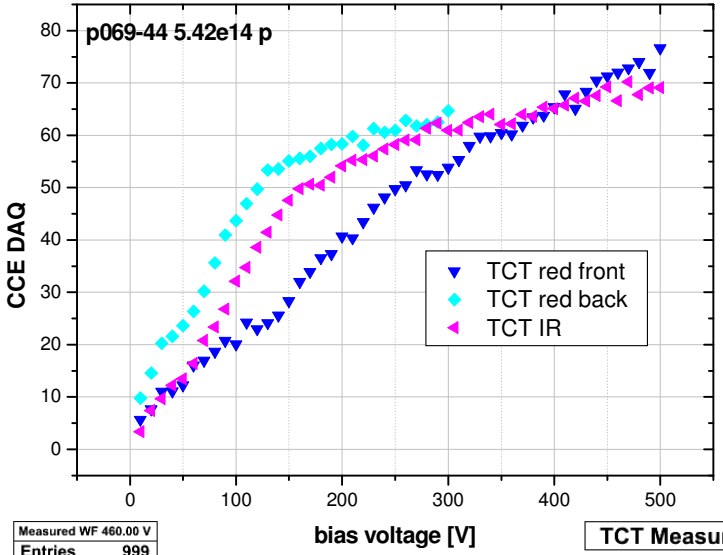
HIP-MCz-01-n-26
1.08×10^{14} n_{eq} cm^{-2}



Back vs. front

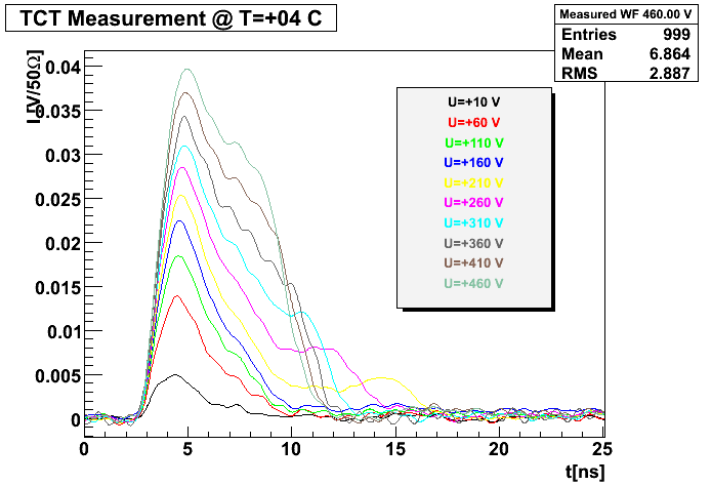
Front signal: holes
Back signal: electrons

MCz-p

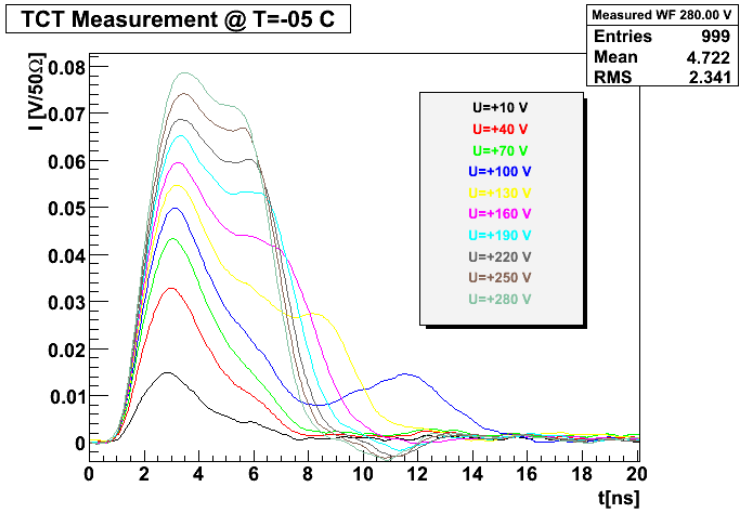


proton

p069-44
3.35×10^{14} n_{eq} cm^{-2}



front (holes)



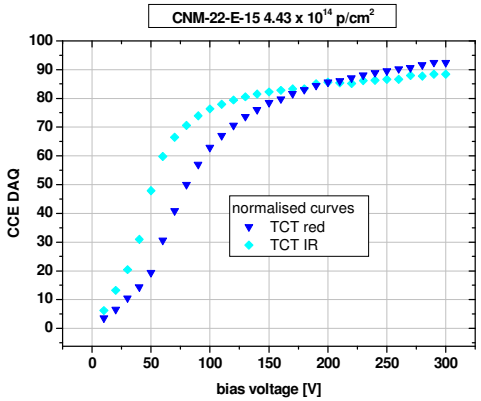
back (electrons)

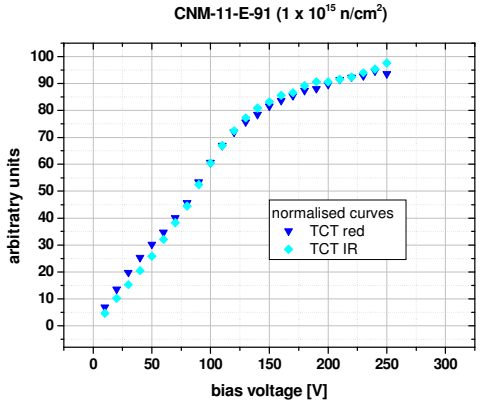
Protons vs. neutrons

proton

High fluences

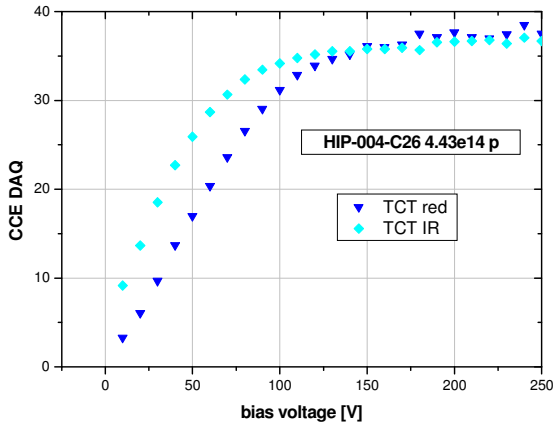
neutron

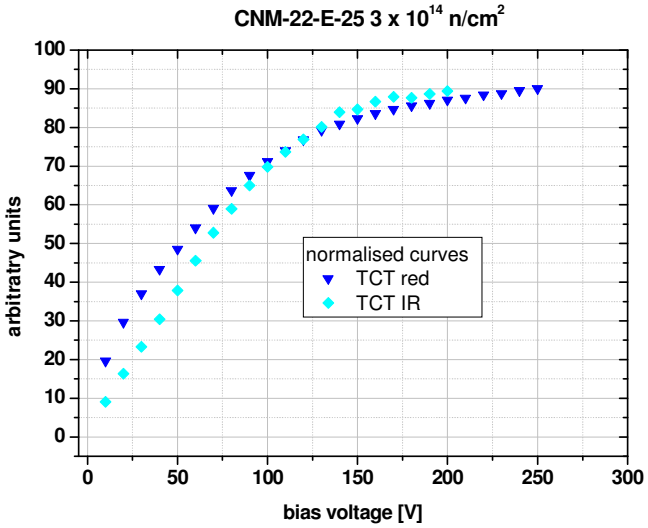




p-in-n diode (inverted)

inverted





n-in-p diode (not inverted)

Not inverted