10th RD50 Workshop on Radiation hard semiconductor devices for very high luminosity colliders, Vilnius, Lithuania, 4-6 June 2007

Characterization of 150μm thick epitaxial silicon pad detectors from different producers after 24 GeV/c proton irradiation

Herbert Hoedlmoser[1], Michael Moll[1], Jaako Haerkoenen[2], Katharina Kaska[1], Matthias Kronberger[1], Julia Trummer[1], Pierre Rodeghiero[3]

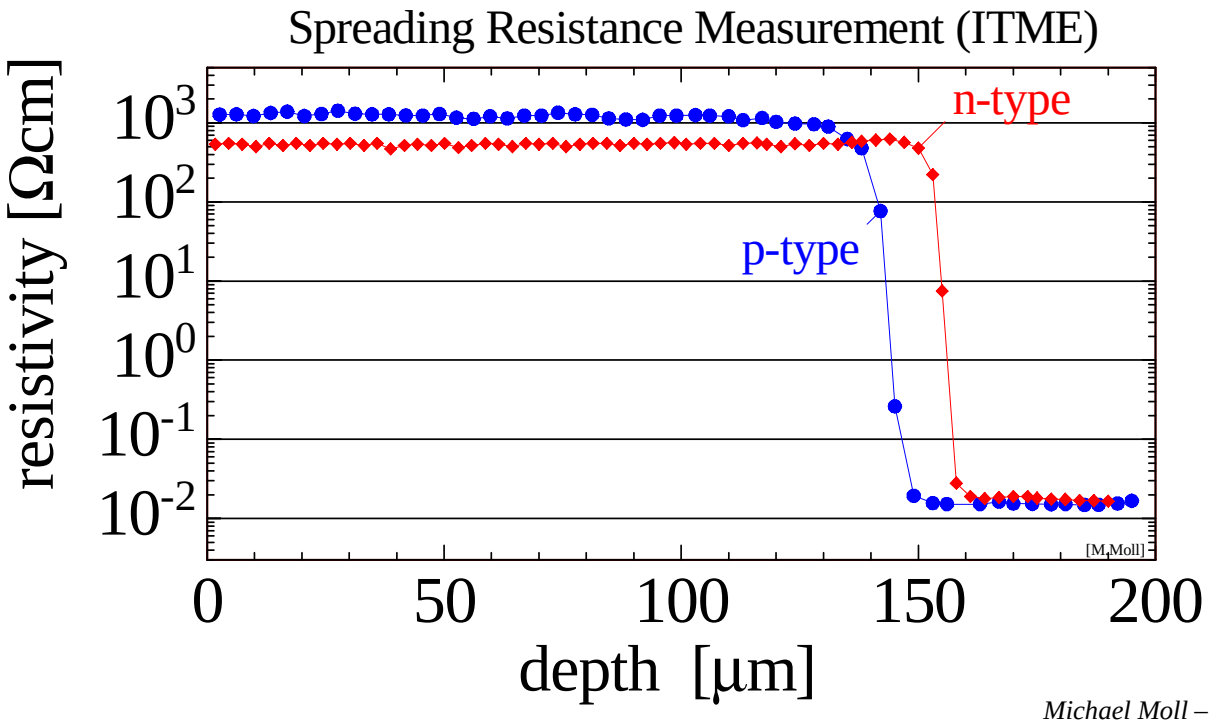
[1] CERN- PH-DT2 - Geneva – Switzerland
[2] Helsinki Institute of Physics – Helsinki - Finland
[3] Université Catholique de Louvain – Louvain - Belgium

Outline:

- Material, Detectors, Irradiation and Measurements
- Detector Characterization (IV, CV, CCE, TCT)
- Comparison to previous work
- Preliminary conclusions, open questions and further work

The epitaxial silicon

- **Produced by ITME (Institute of Electronic Materials Technology, Warzawa, Poland)**
  - **100 mm wafer**
- **n-type silicon**
  - **Epi-layer: 150µm, <111>, P-doped, ~500 Ωcm**
  - **Substrate: 525µm, <111>, Sb-doped, 0.015 Ωcm**
- **p-type silicon**
  - **Epi-layer: 150µm, <111>, P-doped, ~1000 Ωcm**
  - **Substrate: 525µm, <111>, B-doped, 0.015 Ωcm**



The detectors

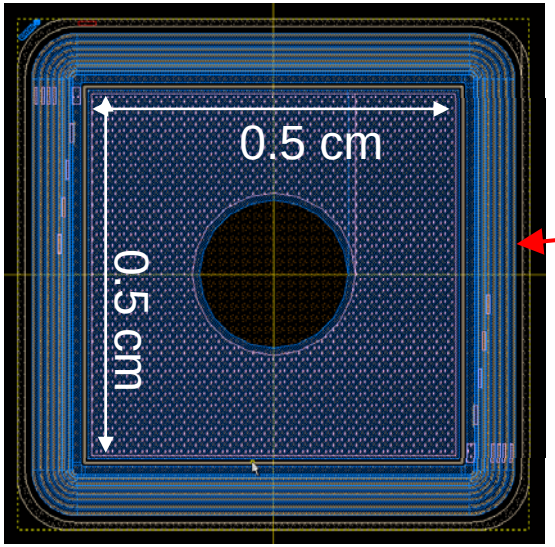
- **Detectors produced from epi-wafers of same batch by:**
  - **CNM (Centro National de Microelectronics, Barcelona, Spain)**
  - **ITC-IRST (Microsystems Division, Povo, Trento, Italy)**
  - **HIP (Helsinki Institute of Physics, Helsinki, Finland)**

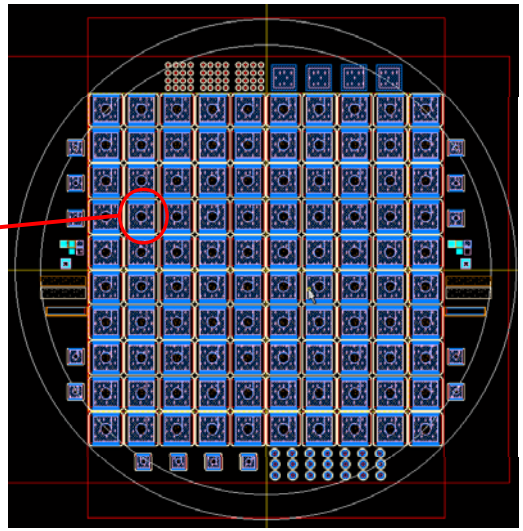
producer	series name	processing	type	size
CNM	CNM-22	pad detector	p-type	5 x 5 mm^2
CNM	CNM-11	pad detector	n-type	5 x 5 mm^2
CNM	RD50-23	strip detector	n-type	5 x 5 mm^2
CNM	RD50-16	strip detector	p-type	5 x 5 mm^2
ITC-IRST	ITC-W-11	strip detector	n-type	3.7 x 3.7 mm^2
HIP	HIP-004-B	pad detector	n-type	5 x 5 mm^2

different masks used
(some containing also strip detectors)

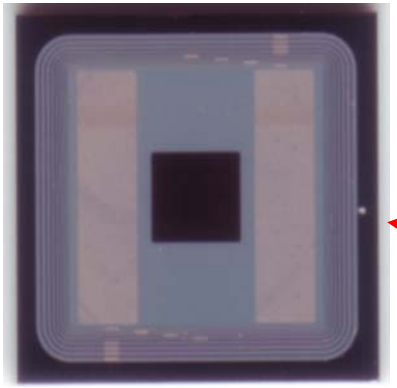
RD50 Detectors from CNM Barcelona

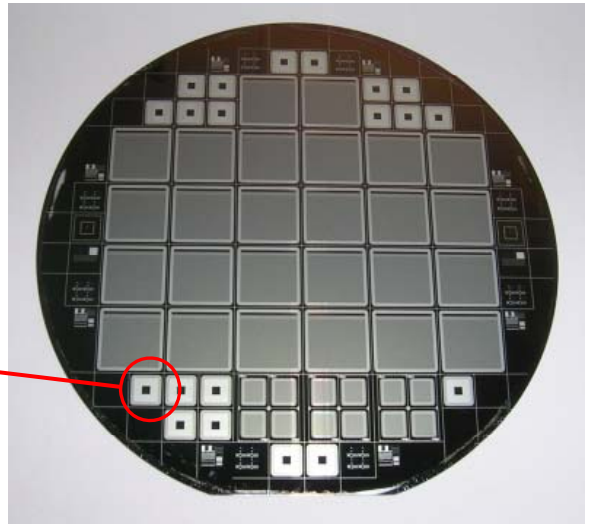
- **Detectors from pure pad mask (CERN-RADMON project)**
  - CNM-11 & CNM-22
  - size 0.5 x 0.5 cm^2
  - 9 guard rings
  - p-type: p-stop ring





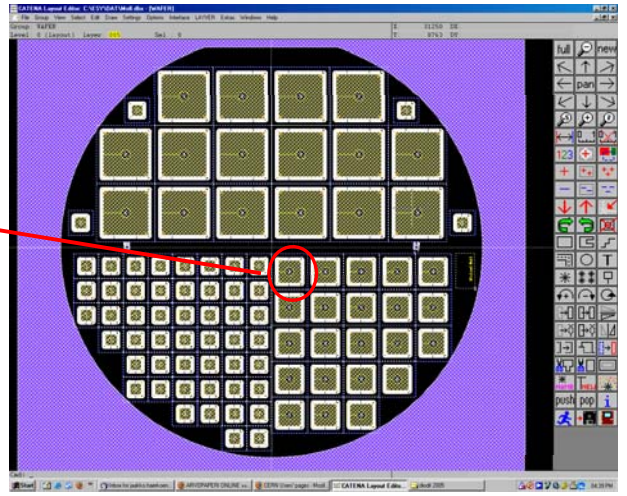
- **Detectors from strip mask (RD50 project)**
  - RD50-16 & RD50-23
  - size 0.5 x 0.5 cm^2
  - x guard rings
  - x-type: x-spray



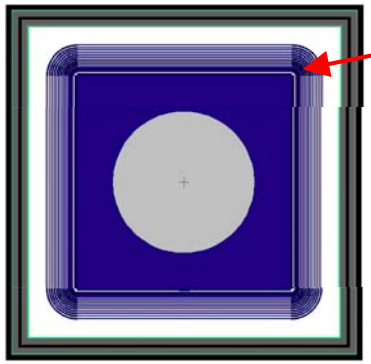


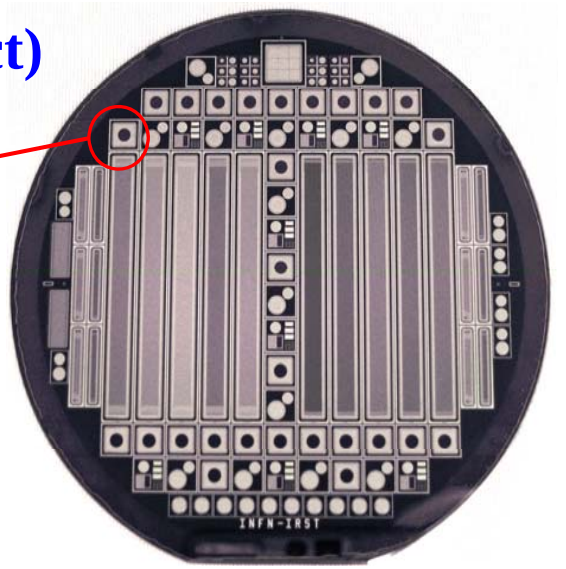
Detectors from IRST and HIP

- **HIP detectors - pure pad mask (CERN-RADMON project)**
  - **HIP-004**
  - **size 0.5 x 0.5 cm^2**
  - **17 guard rings**
  - **only n-type used**



- **Detectors from strip mask (SMART-RD50 project)**
  - **ITC-W11**
  - **size 0.37 x 0.37 cm^2**
  - **11 guard rings**
  - **only n-type used**





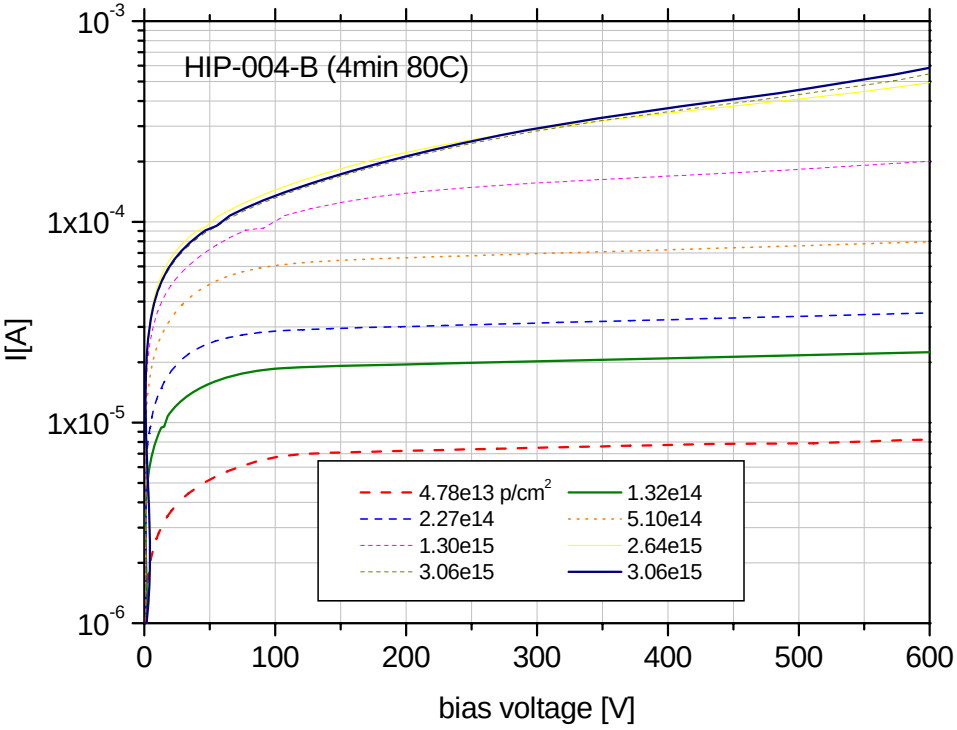
Before irradiation

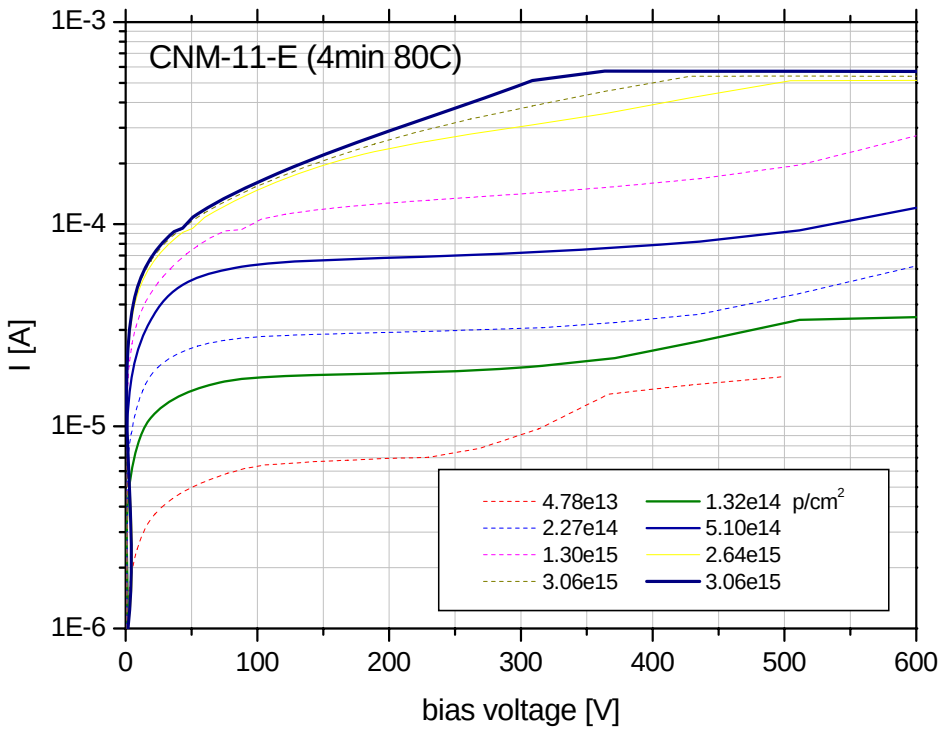
Detector series	Depletion Voltage (CV) V_{dep} [V]
HIP-004 (n-type)	147.4 ± 3.6
ITC-W11 (n-type)	150.0 ± 4.9
CNM-11 (n-type)	154.6 ± 7.5
RD50-23 (n-type)	155.0 ± 3.8
CNM-22 (p-type)	213.7 ± 12.7

Experimental procedure

- **C/V and I/V measurements**
  - **measured at room temperature (and at -10°C); parallel mode 10KHz (and at 120Hz)**
- **CCE measurements**
  - **NIKHEF setup (details in presentation of H.Hoedlmoser - last RD50 Workshop)**
  - **^{90}Sr – source; 2.5 μs shaping time; noise 567e$^-$ + 4.26e$^-$/pF**
  - **measured mainly at -22±1°C**
- **TCT measurements**
  - **RD39 setup at CERN used (details given in Jaakko's talk)**
  - **2 lasers used:**
    - infrared laser – simulation of mips
    - red laser – front illumination only
- **Irradiation**
  - **24 GeV/c protons at the CERN PS**
- **Annealing**
  - **4min at 80°C**

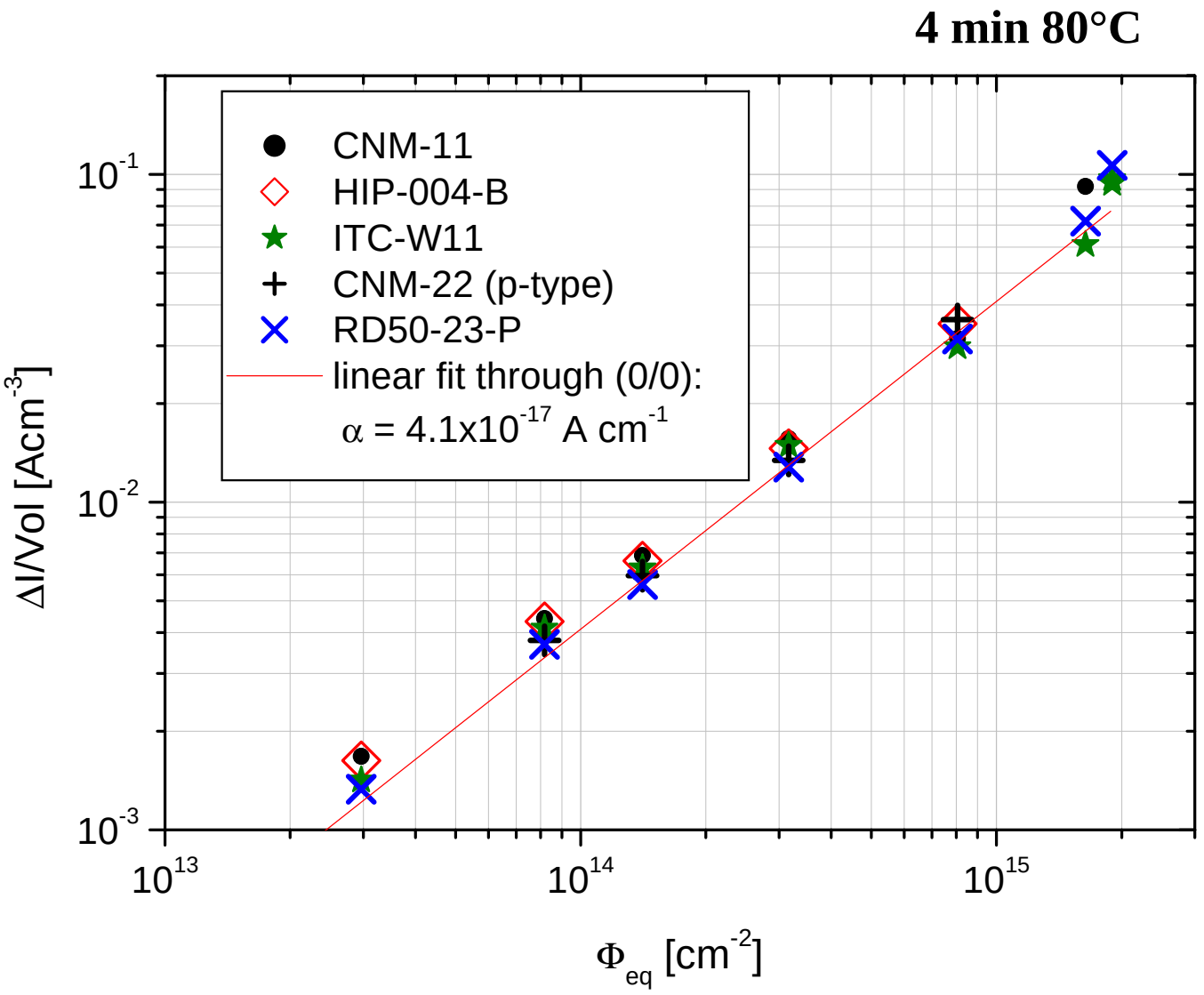
RD50 leakage current after irradiation



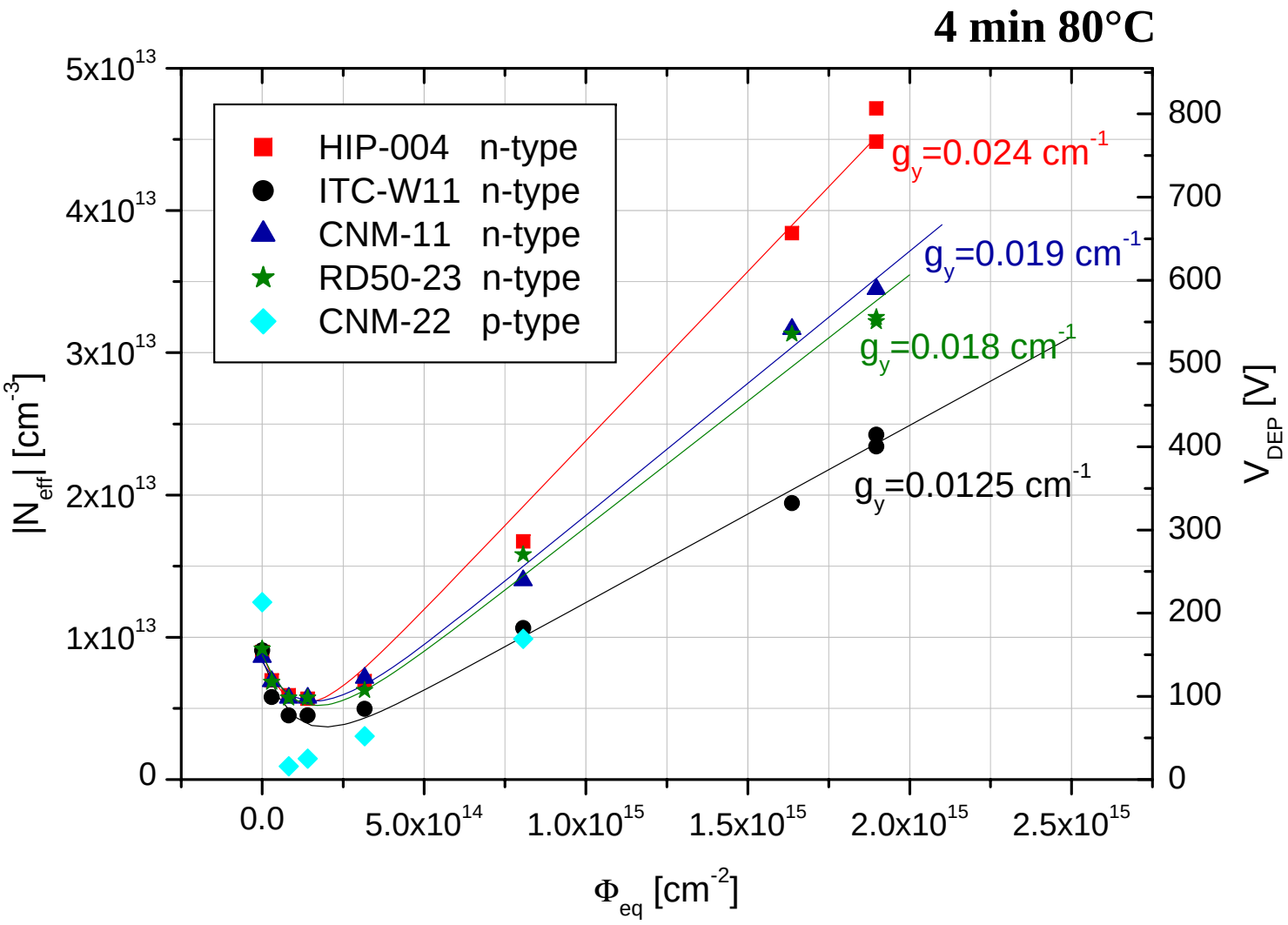


- **CNM detectors: Increase of leakage current around 300V caused noise problems for CCE measurements**

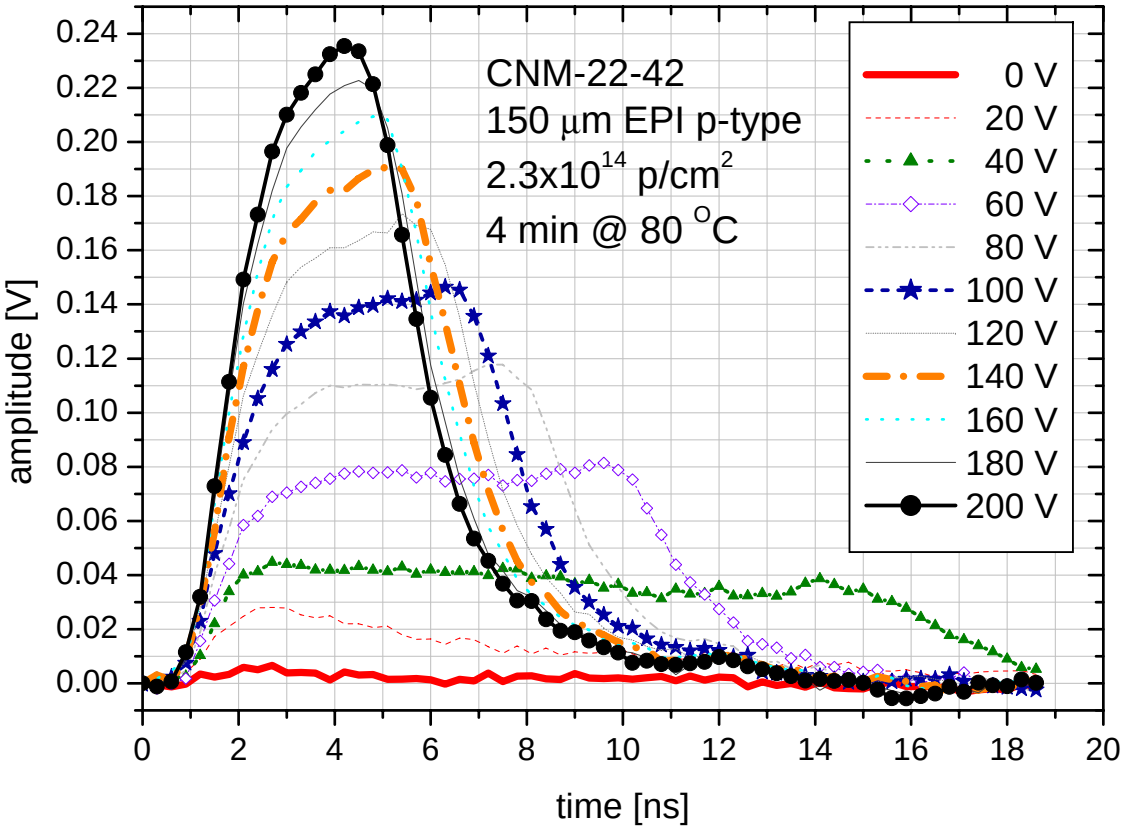
Leakage current



Depletion Voltage

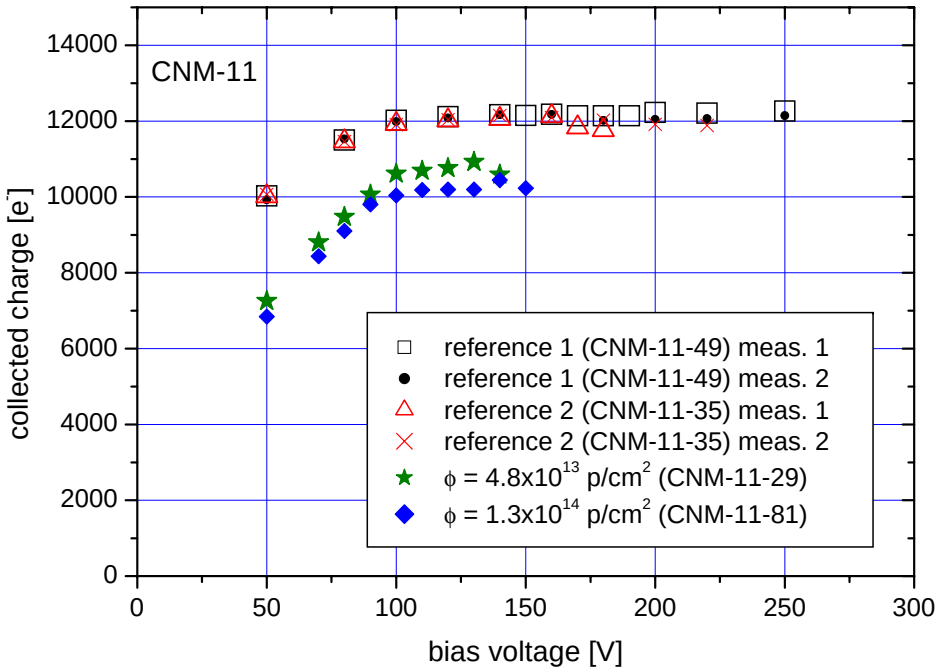


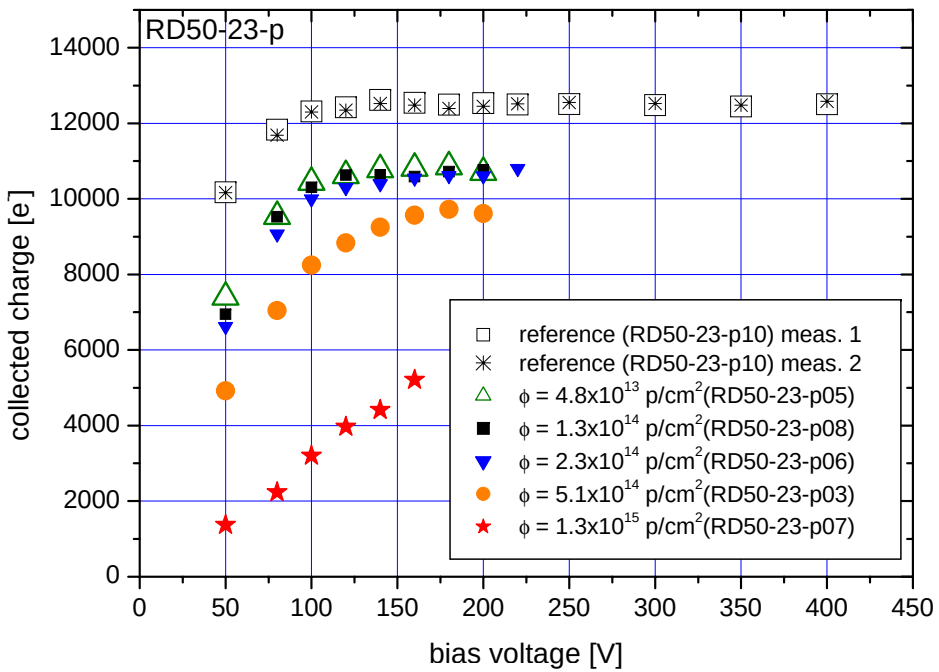
TCT measurements (red laser)



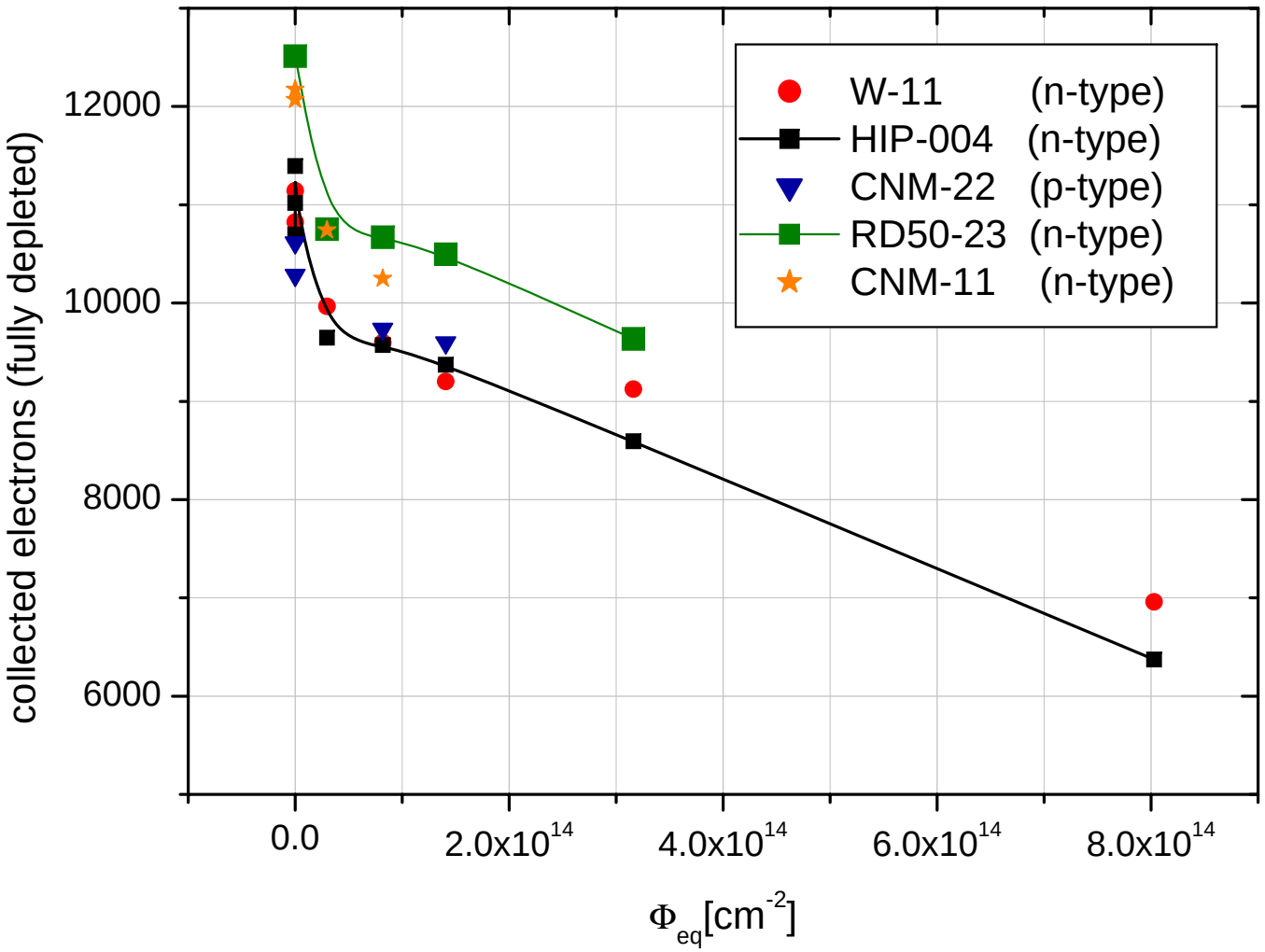
- **p-type epi silicon after 2.3x10^{14} p/cm^2**
- **data not corrected for trapping**
- **demonstrating that p-type has been inverted to n-type**

CCE measurements

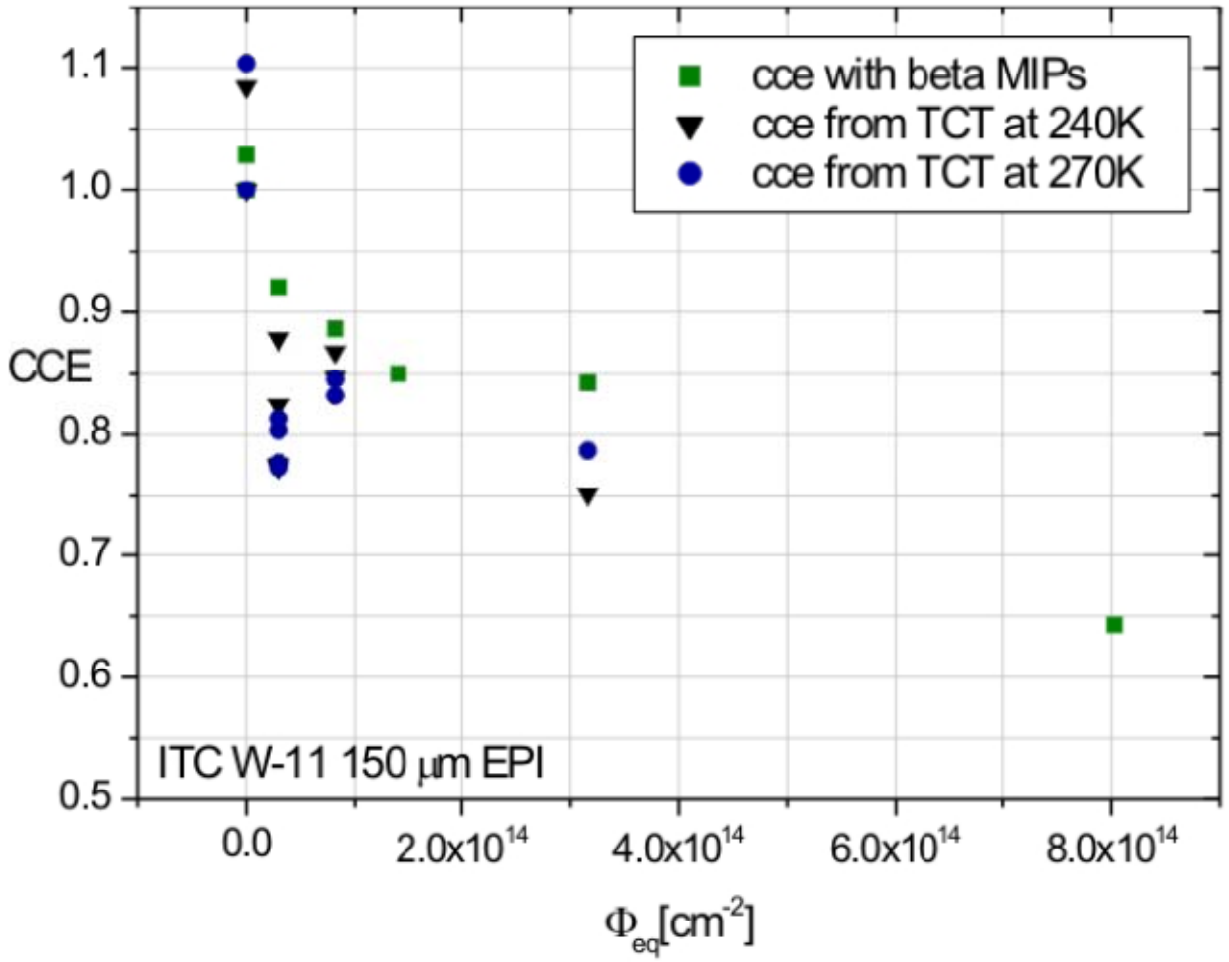




CCE measurements



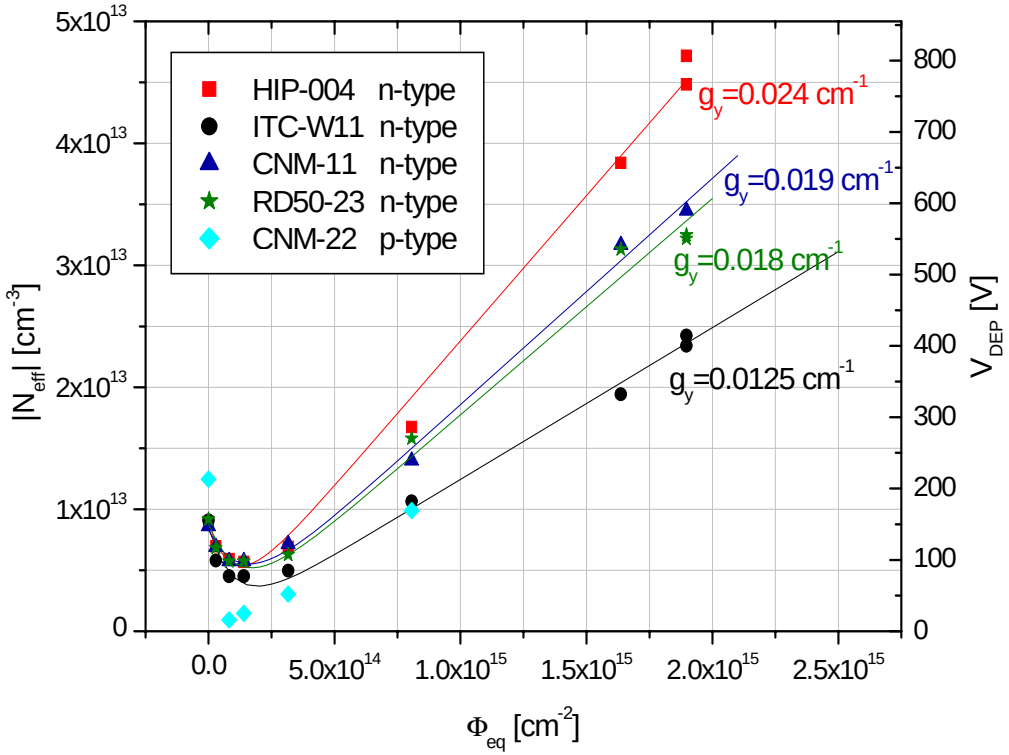
TCT – Infrared laser



- **Sharp drop in CCE at low fluences observed also with infrared laser (RD39 TCT setup)**

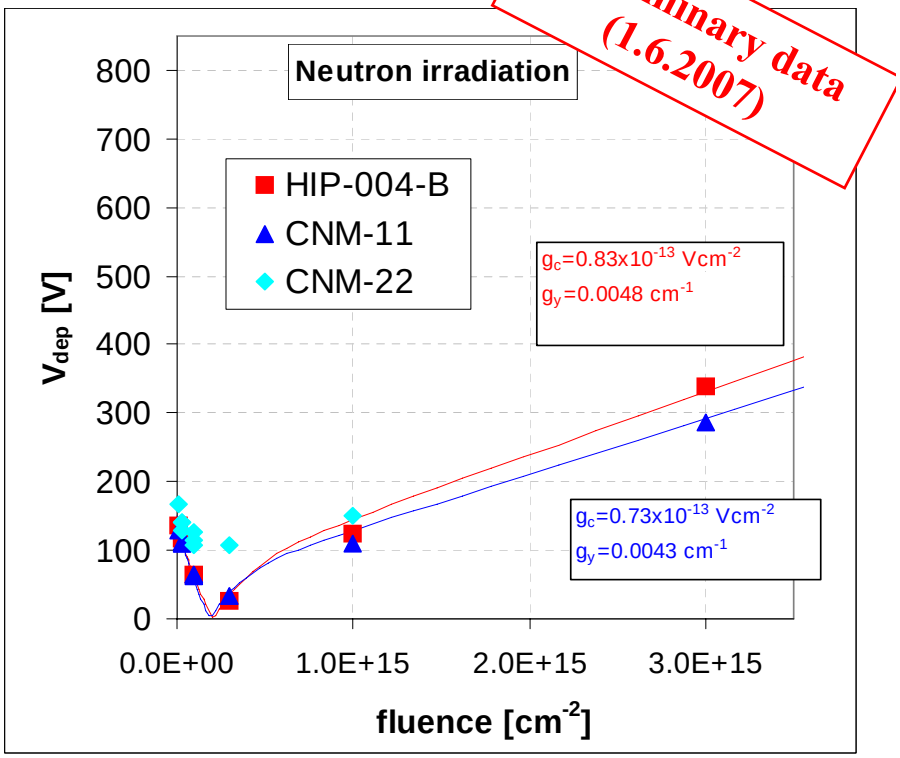
Depletion Voltage (CV)

24 GeV/c protons



Neutrons (Ljubljana)

preliminary data (1.6.2007)



4 min 80°C

Summary

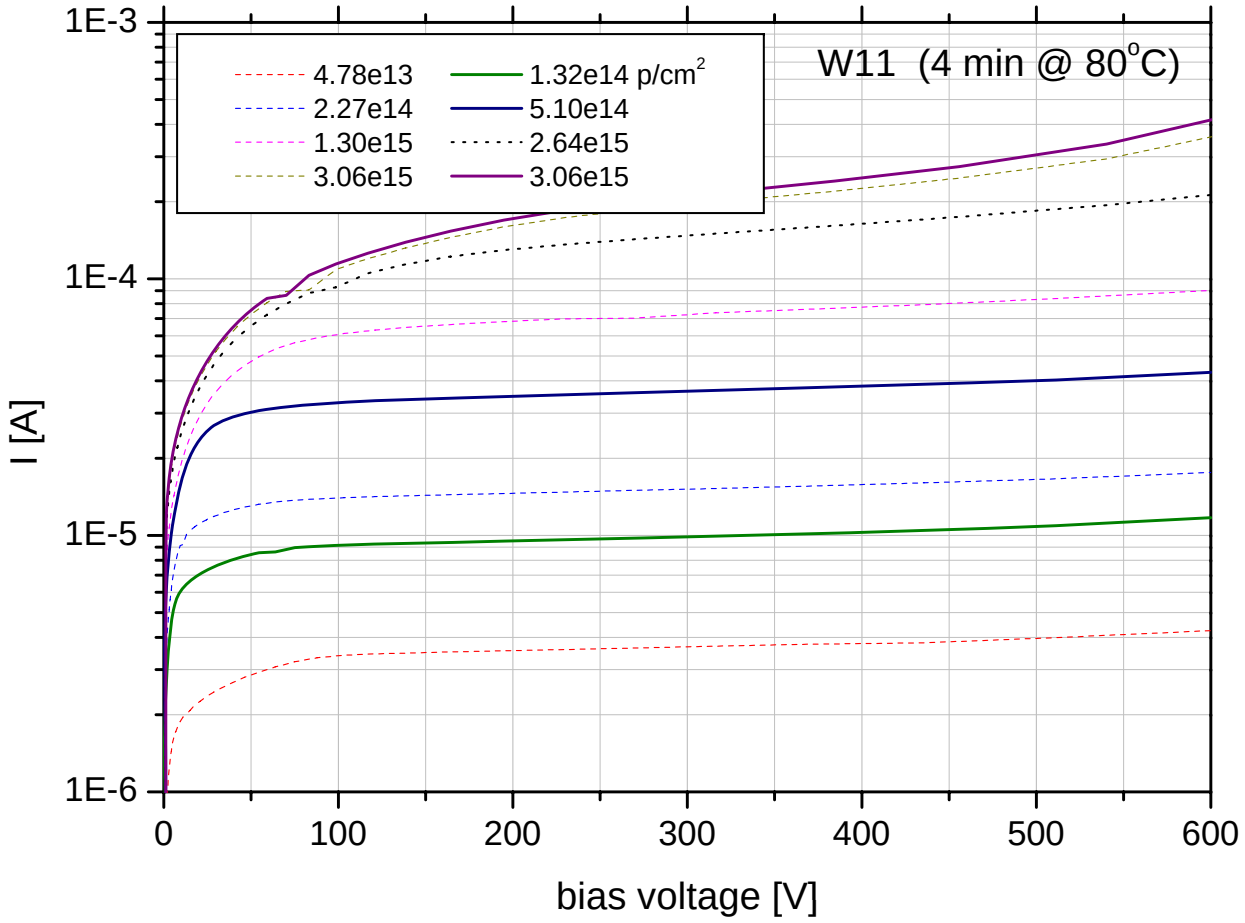
24 GeV/c proton irradiated n- and p-type 150 μm thick epitaxial detectors manufactured by 3 different producers have been investigated:

- **leakage current increase as expected (same for all detectors)**
- **increase of V_{dep} (donor generation) depending on processing – different for different manufacturers**
- **net space charge remains positive for n-type epi (no type inversion)**
- **net space charge becomes positive for p-type epi (inversion to n-type)**
- **unusual drop in CCE observed in low fluence range**

ongoing work:

- **neutron irradiated samples under investigation**
  preliminary data presented (less pronounced increase in depletion voltage !)

IV – ITC samples



IV – CNM samples