Epitaxial silicon detectors irradiated with protons and neutrons

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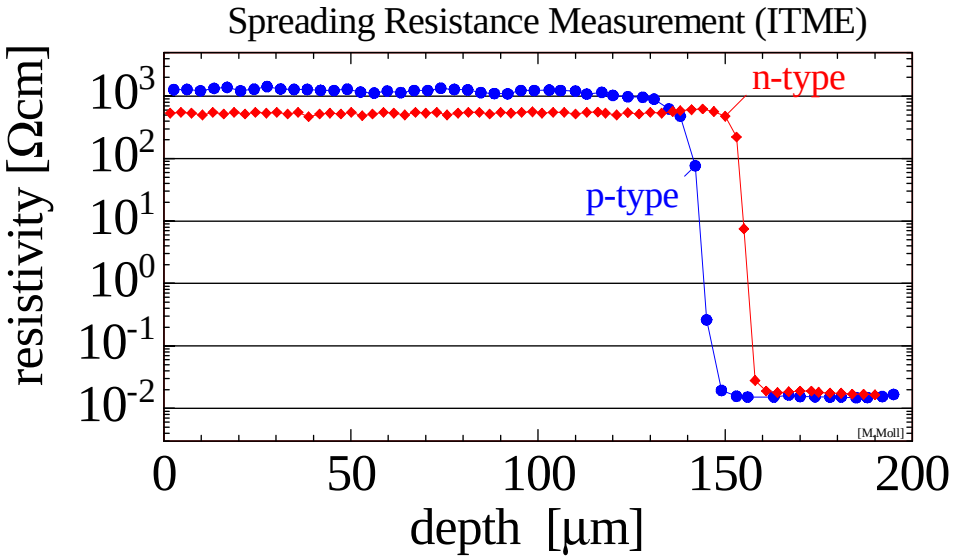
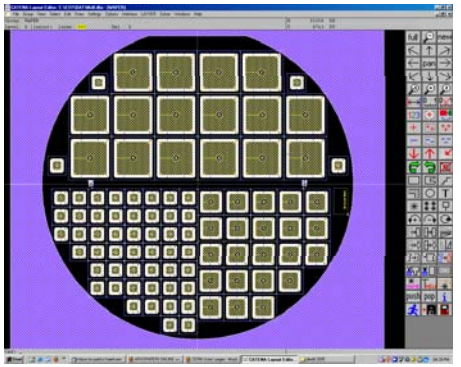
Wafers

- **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

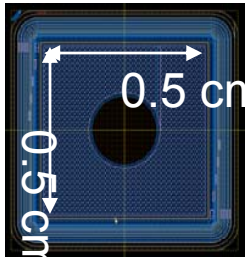


Detectors used

- **HIP-004-C**
  - Produced by Helsinki Institute of Physics, Helsinki, Finland
  - Size 0.25 x 0.25 cm^2, thickness 150 um
  - n-type
  - Depletion voltage (CV) before irradiation:
    Vdep = 147.4 $\pm$ 3.6 V



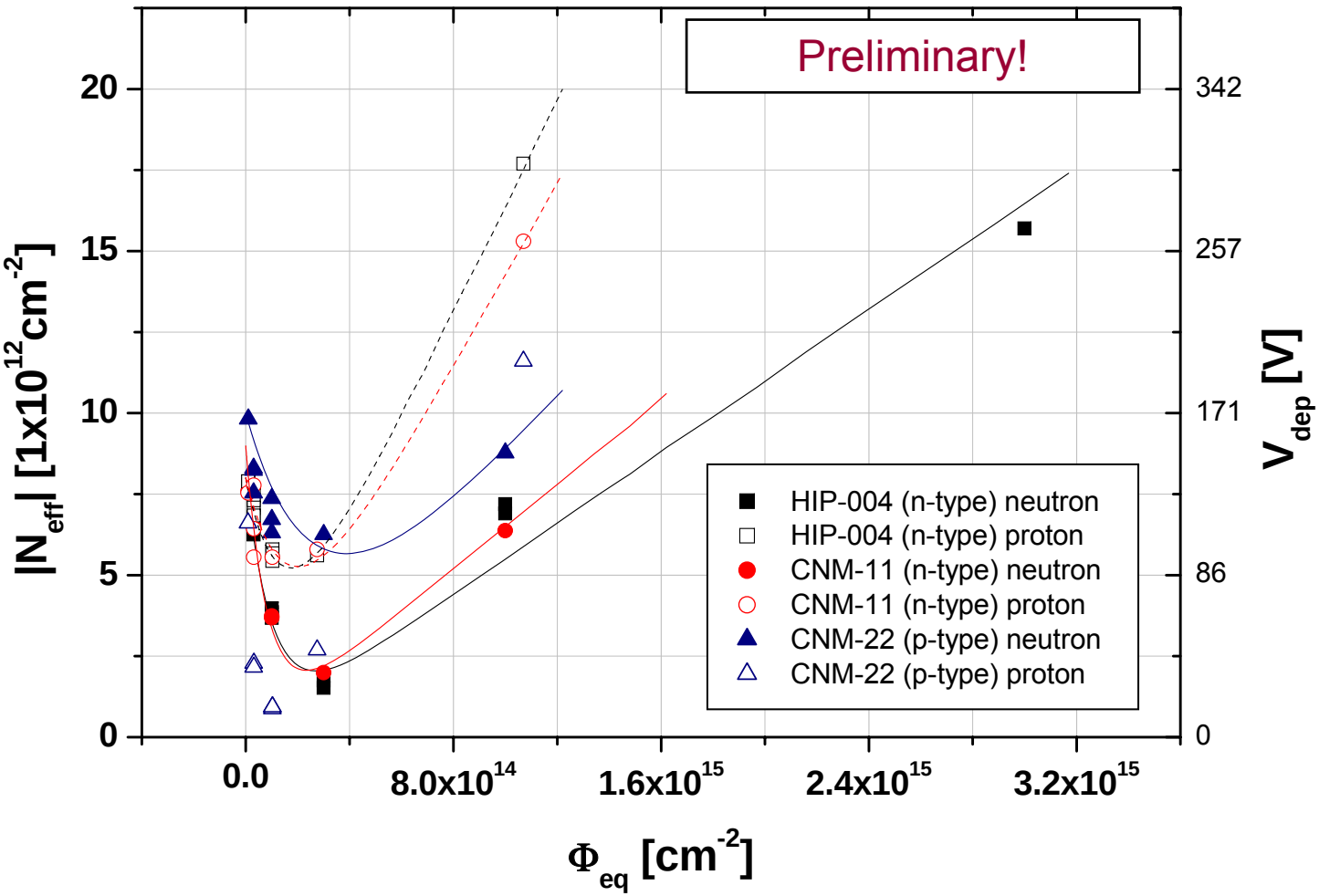
- **CNM-11**
  - Produced by Centro National de Microelectronics, Barcelona, Spain
  - Size 0.5 x 0.5 cm^2, thickness 150 um
  - n-type
  - Depletion voltage (CV) before irradiation:
    Vdep = 154.6 $\pm$ 7.5 V
- **CNM-22**
  - Size 0.5 x 0.5 cm^2, thickness 150 um
  - p-type
  - Depletion voltage (CV) before irradiation:
    Vdep = 213.7 $\pm$ 12.7 V



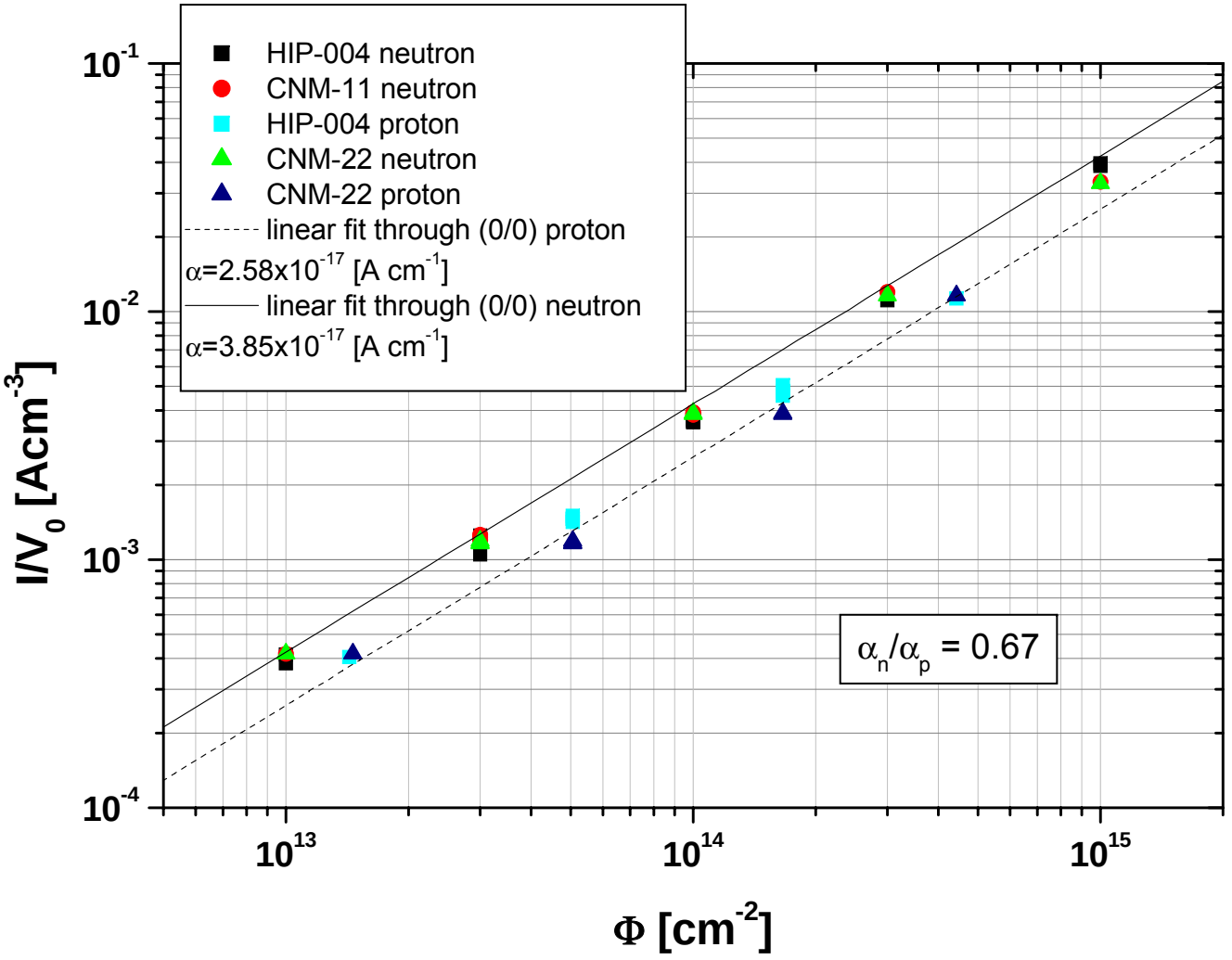
Experimental procedure

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

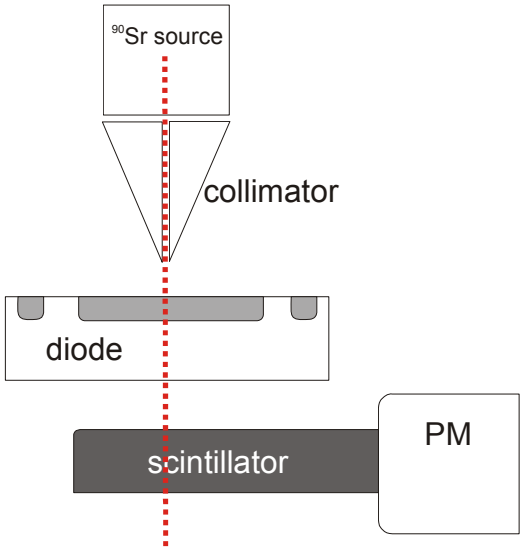
Depletion voltage (CV)



Leakage current



CCE setup



NIKHEF setup by Fred Hartjes

signal shaping time: 2.5 µs

guard ring connected to ground

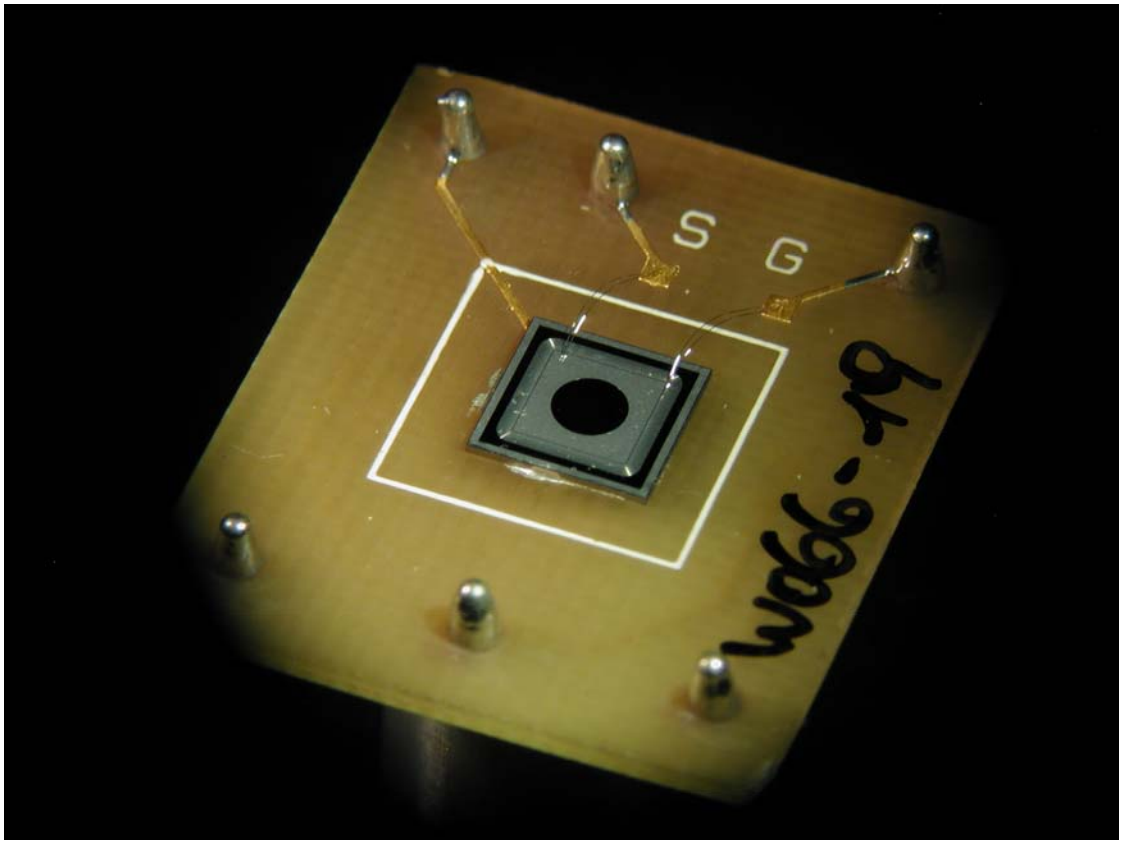
Temperature control:

- internal cooling with peltier
- whole box can be put into freezer

Temperature measurement:

- directly on sample board
- in box with additional humidity sensor

Sample mounting



- Detector glued on board with silver glue
- Guard ring connected to ground

CCE measurements

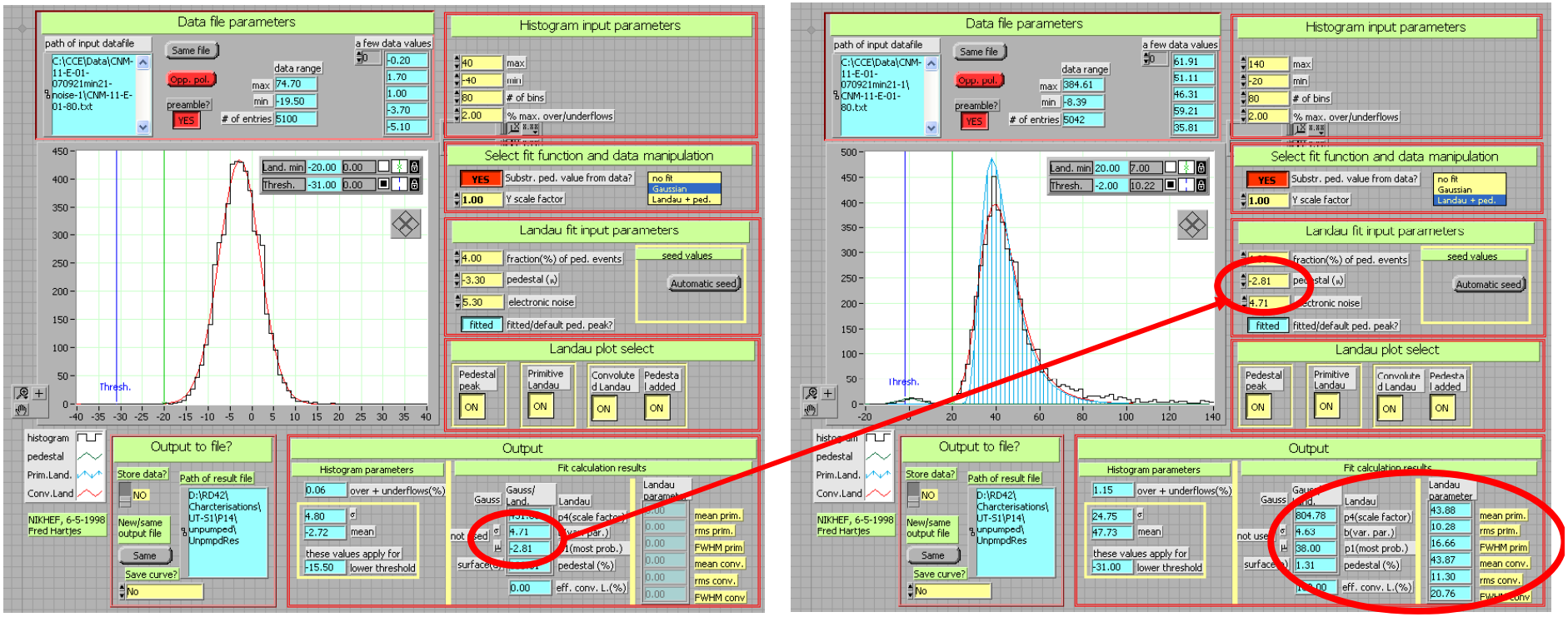
- all detectors were measured at -20±1°C (only external cooling)
- humidity in the box was 18-30% (flushed with dry nitrogen)
- Repeated gain measurements showed a gain of 247 e^-/mV for these conditions

Data fitting

Example: CNM-11-01 (n-type)

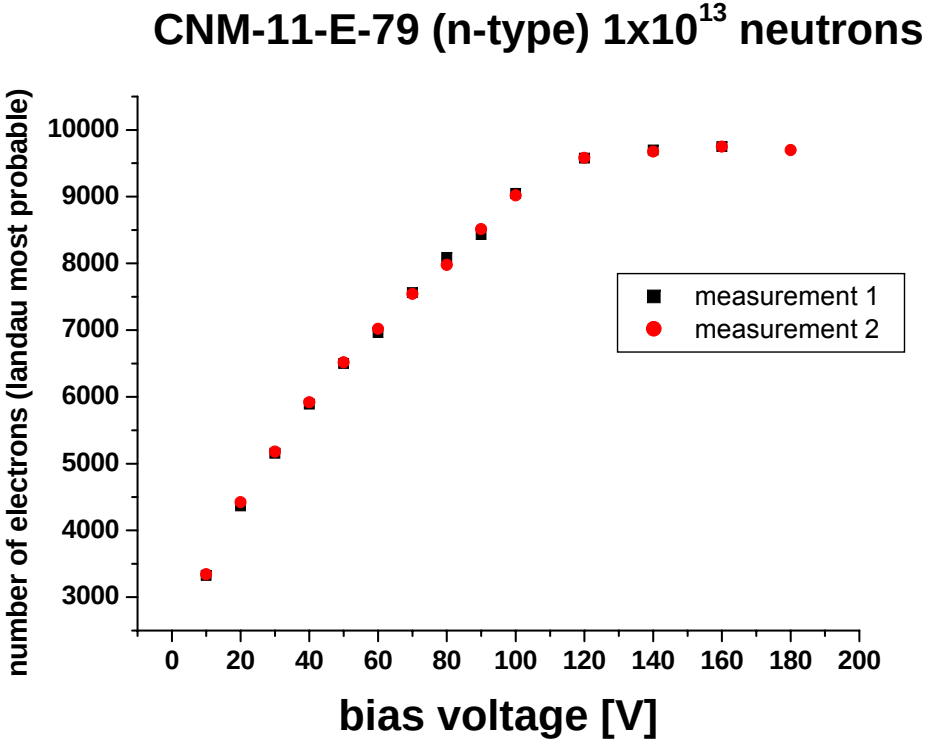
irradiation: $\Phi = 1\times10^{14}$ p/cm^2 temperature: -21 ^{o}C

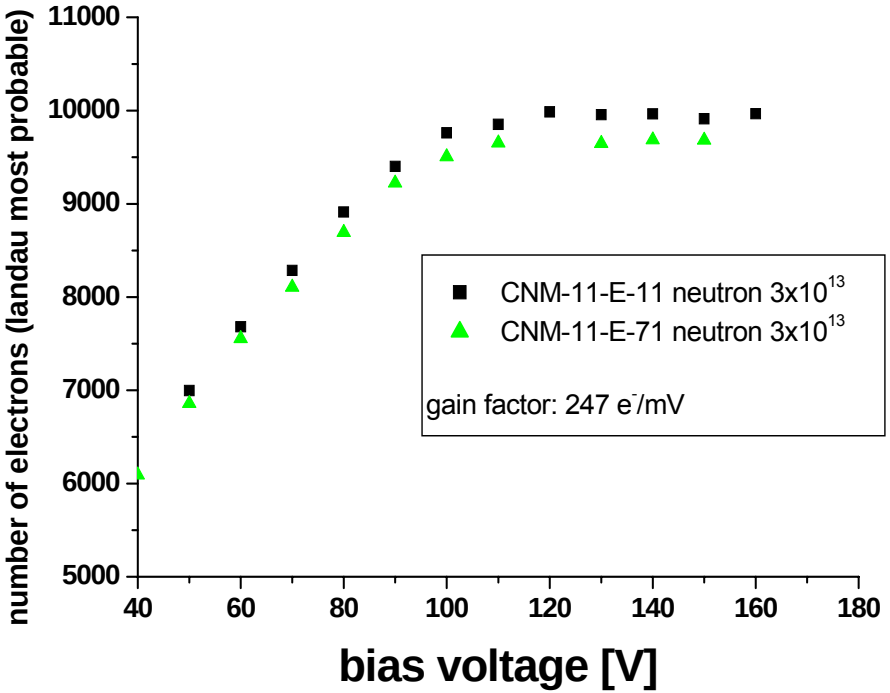
bias: 80 V



Noise/pedestal measurement for each bias point => values used for deconvoluted landau distribution

Reproducibility

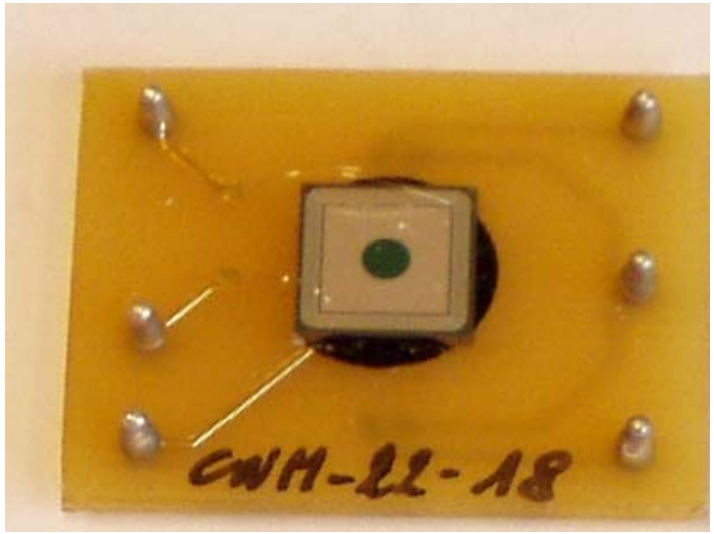


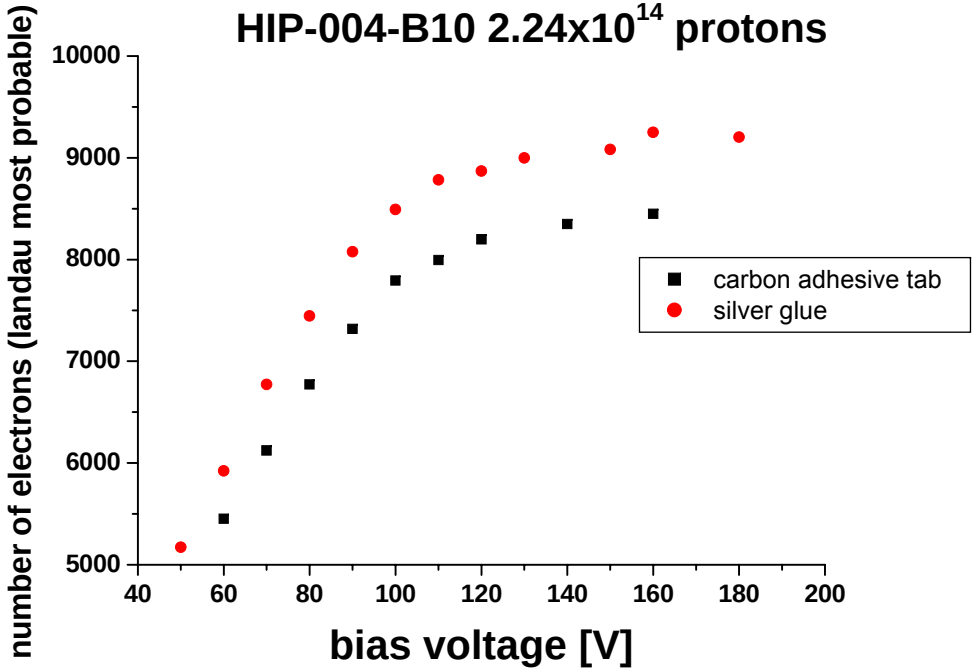


- Detector was **taken out** of the setup and remounted between measurements
- Temperature and humidity were approximately the same

- Different detectors, same fluence
- Temperature and humidity were approximately the same
- 3-4 % difference over depletion

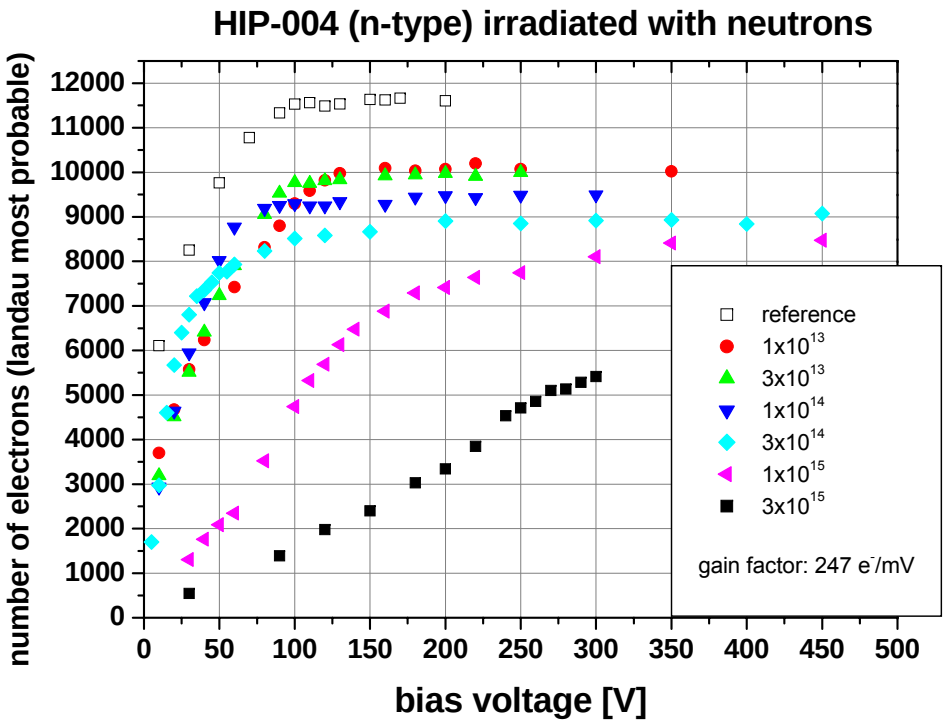
What can go wrong

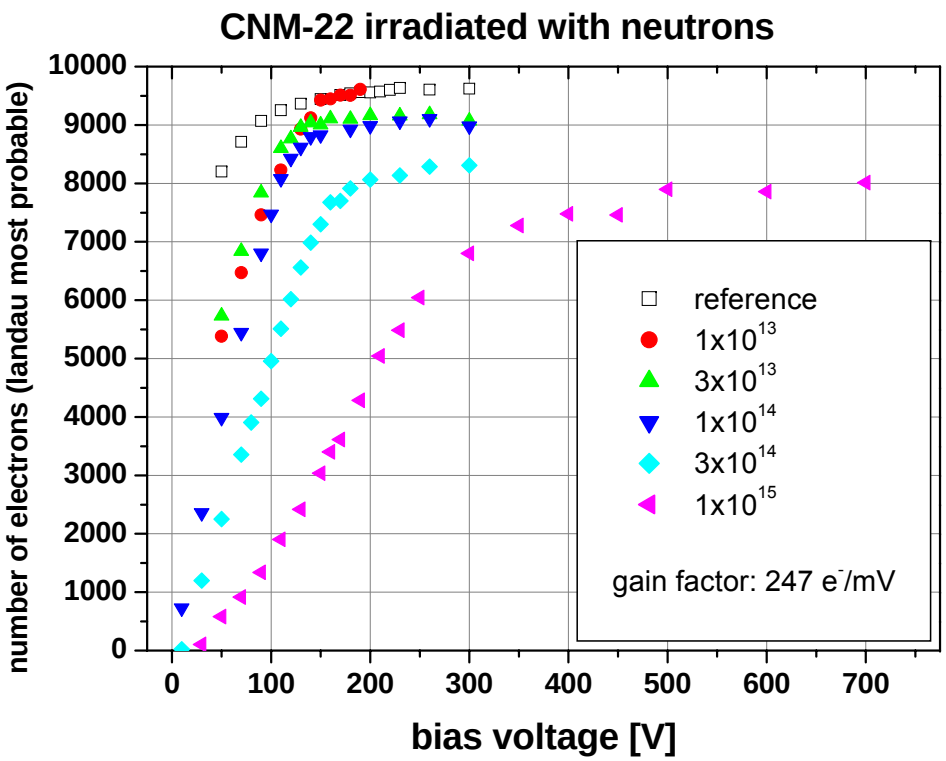




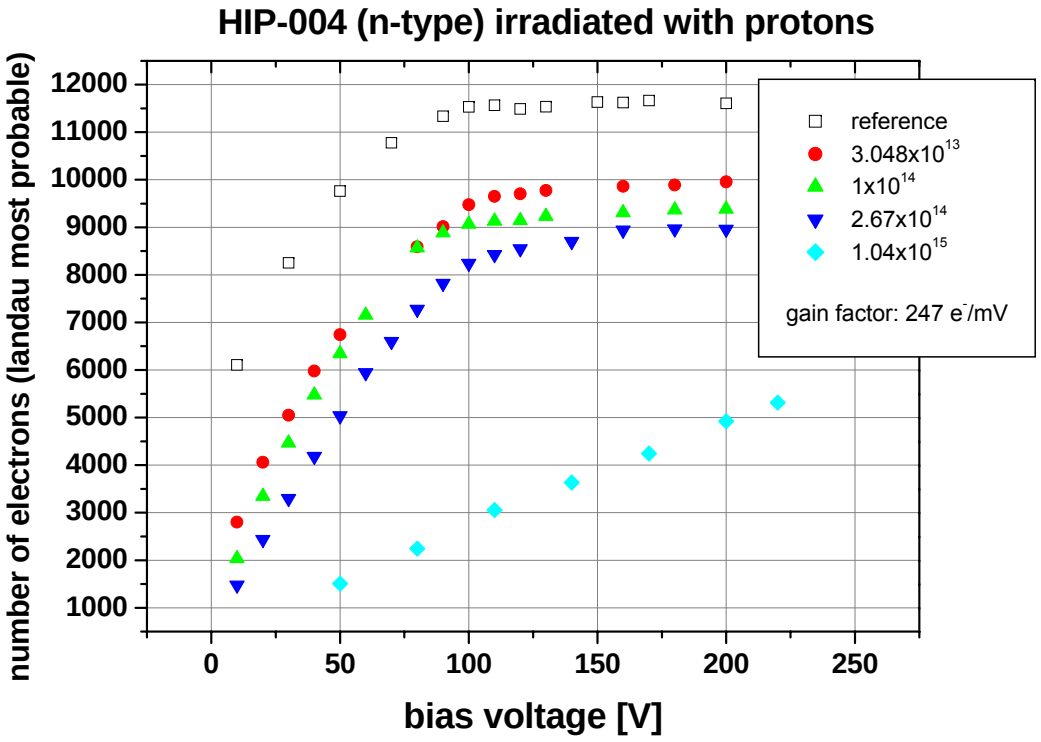
- The same detector was first measured fixed to the board with carbon adhesive tabs, then removed from the board and fixed with silver glue.
- The environmental conditions were approximately the same for both measurements (- 21°C, 20%).
- 8-10% difference over depletion
- We didn't investigate the problem further (CV, IV…) and abandoned the carbon adhesive tabs.

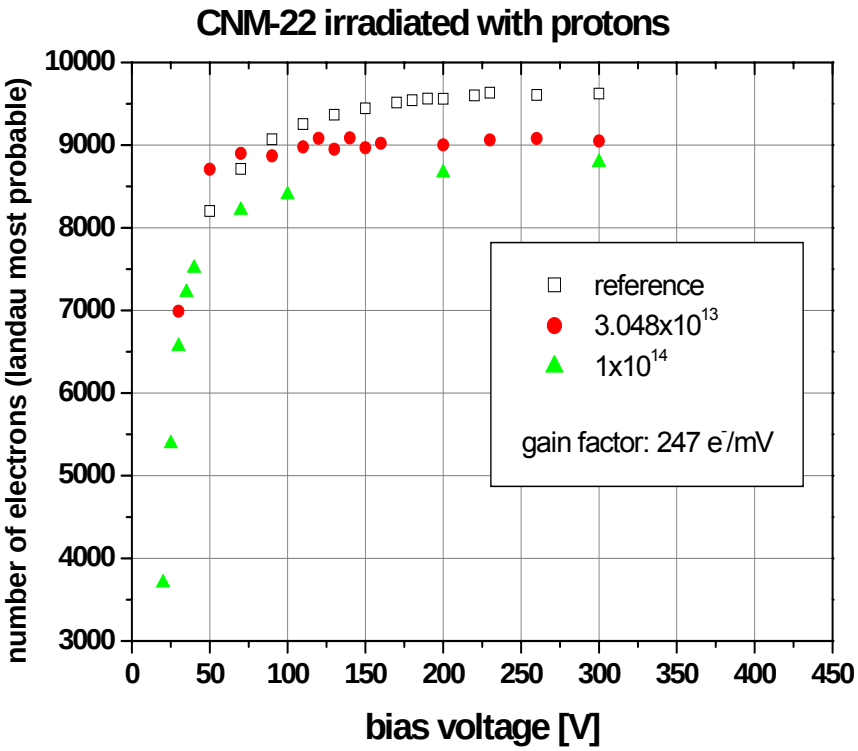
CCE neutrons



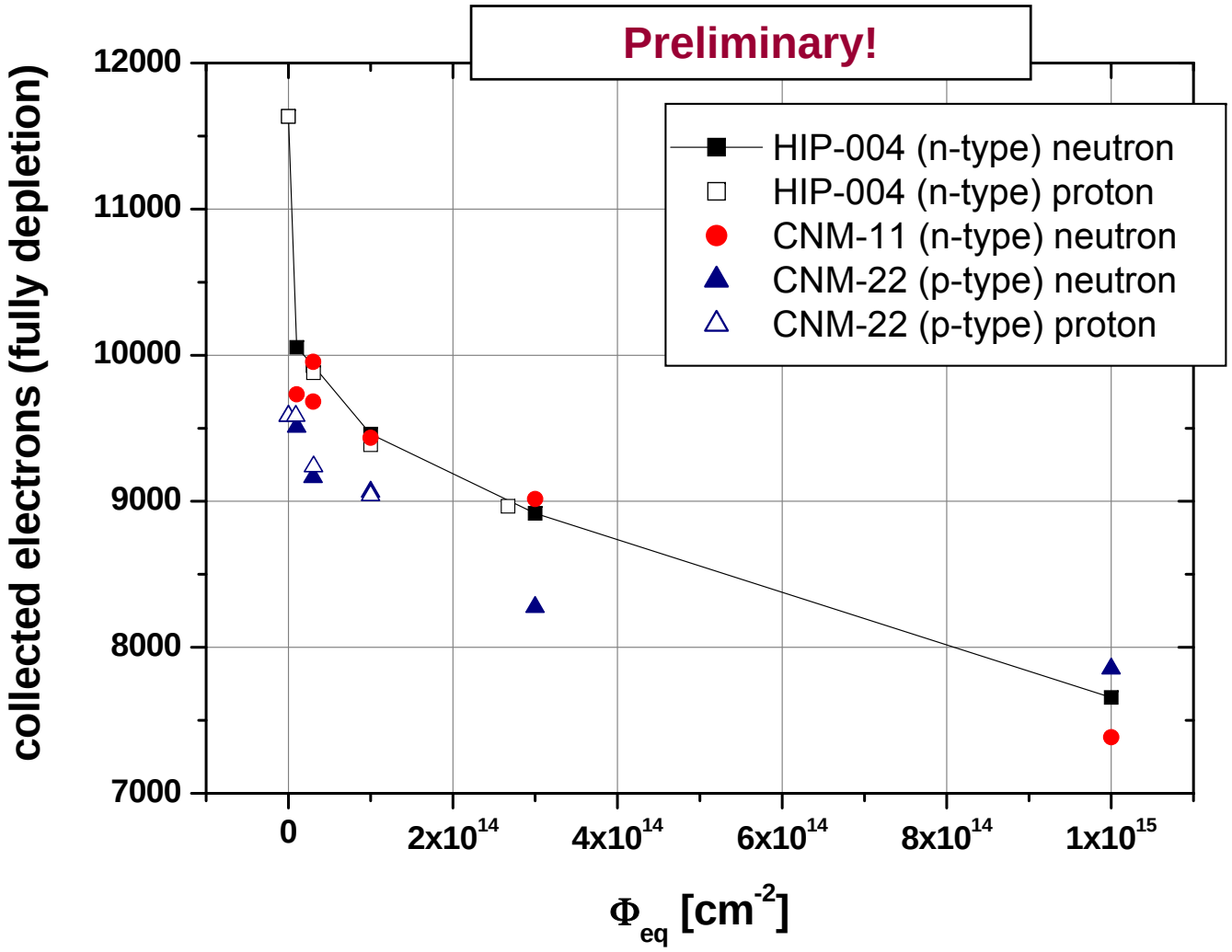


CCE protons

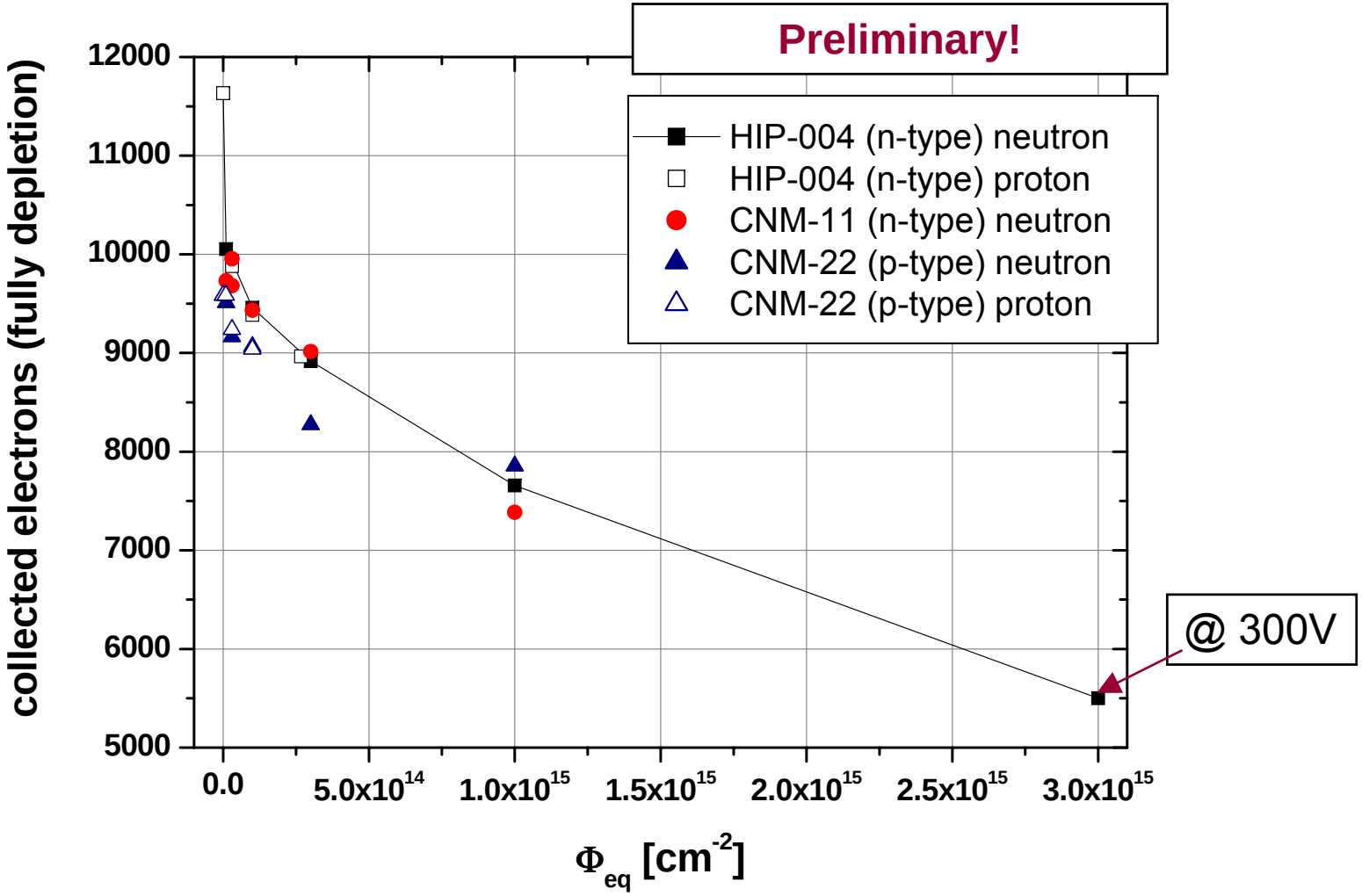

HIP-004 (n-type) irradiated with protons
number of electrons (landau most probable)
bias voltage [V]
reference
3.048x10^13
1x10^14
2.67x10^14
1.04x10^15
gain factor: 247 e-/mV


CNM-22 irradiated with protons
number of electrons (landau most probable)
bias voltage [V]
reference
3.048x10^13
1x10^14
gain factor: 247 e-/mV

CCE over depletion



CCE over depletion



Summary and outlook

Summary

- Increase of depletion voltage different for different manufacturers
- Increase of depletion voltage faster for proton irradiation
- Unusual drop in CCE at low fluences, for both neutron and proton irradiation

Outlook

- Finish the measurements for the proton irradiated series and add a few more fluence points between $5x10^{14}$ p/cm^2 and $3x10^{15}$ p/cm^2
- A set of detectors was already irradiated with protons at fluences between $1x10^{12}$ p/cm^2 and $1x10^{13}$ p/cm^2 to investigate the drop in the CCE further

Carbon adhesive tabs