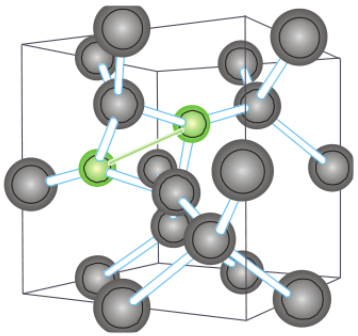
Update on RD50 project NitroStrip

Marta Baselga, 31st RD50 Workshop, CERN

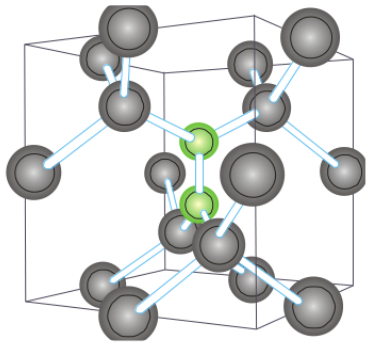
ETP -KIT

Motivation

- As shown in previous RD50 Workshops Nitrogen enriched wafers show promising behaviour after irradiation:
  - The concentrations of defect centers with the activation energies of 30 meV, 310 meV, 360 meV, 380 meV, and 460 meV are found to be significantly lower in the material with a higher nitrogen concentration

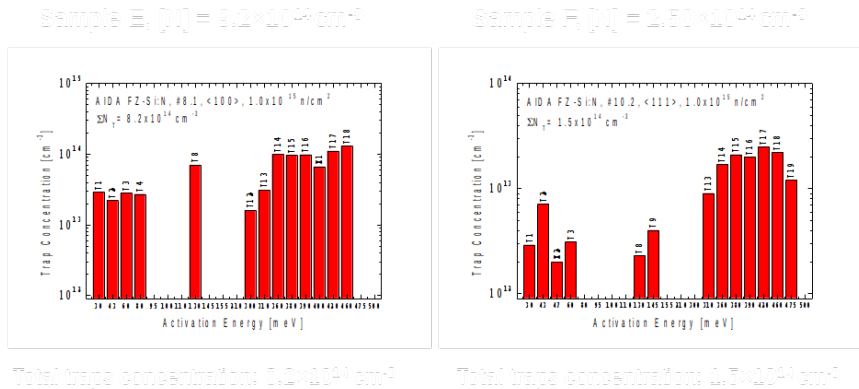


N_iN_i dimer
two split-interstitials



N_iN_S pair
N_S + split-interstitial

- R. Jones *et all*. Solid State Phenomena 93, (2004) 95-96



[Kaminski, RD50 Workshop, November 2014]

- Fluence $1 \times 10^{15}\, n_{eq}/cm^2$

Suppression of interstitials and vacancy-related defects for FZ-Si with nitrogen

Dominant reaction for vacancy suppression:[1]

$$N_2 + V \rightleftharpoons N_2V$$

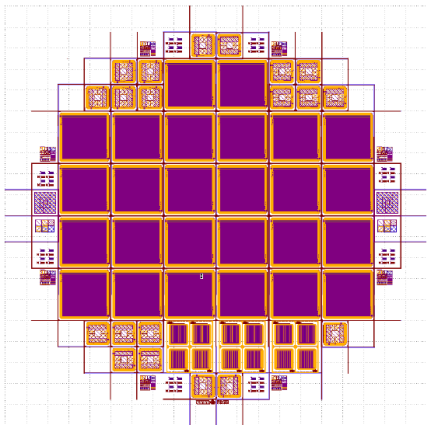
Suppression of interstitials aggregation:

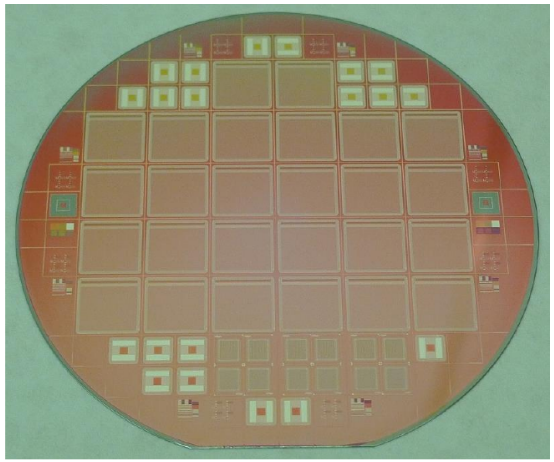
$$N_2V + I \rightleftharpoons N_2$$

[1] W. von Ammon et al. J. Cryst. Growth 226, 19 (2001)

Fabrication NitroStrip at CNM

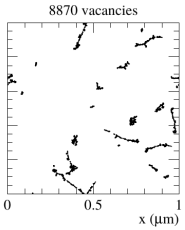
Wafers	Label	Substrate
1-6	FZ	HR-FZ 100 mm,<100>, n-type (phosphorus), 2000-2400Ω cm 300±15 µm, 1 side polished
7-12	NIT	HR-FZ Nitrogenated 100 mm,<100>, n-type (phosphorus), 1500-1900Ω cm 300±15 µm, 1 side polished
13-18	DOFZ	HR-FZ Oxygenated Same as FZ but oxygenated
19-24	MCz	HR-MCz 100 mm,<100>, n-type (phosphorus), 800-1000Ω cm 300±15 µm, 2 side polished





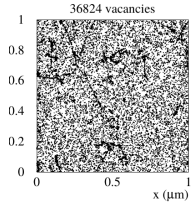
[RD50 NitroStrip: First C-V and I-V results on run 9802 diodes and microstrips, J-M Rafí, 2017]

Irradiation status



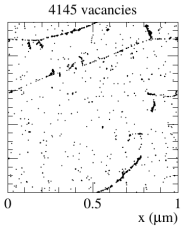
1 MeV Neutron

Ljubljana neutrons



10 MeV Proton

KIT 23 MeV protons



24 GeV/c Proton

CERN 24 GeV protons

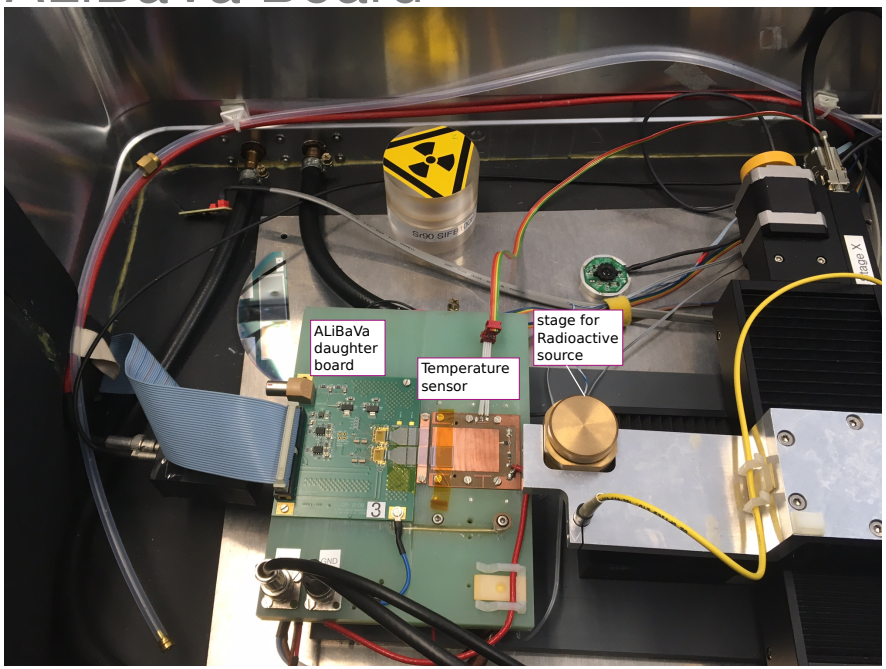
[Huhtinen CERN 2001, Si-RadHard Workshop]

Fluences

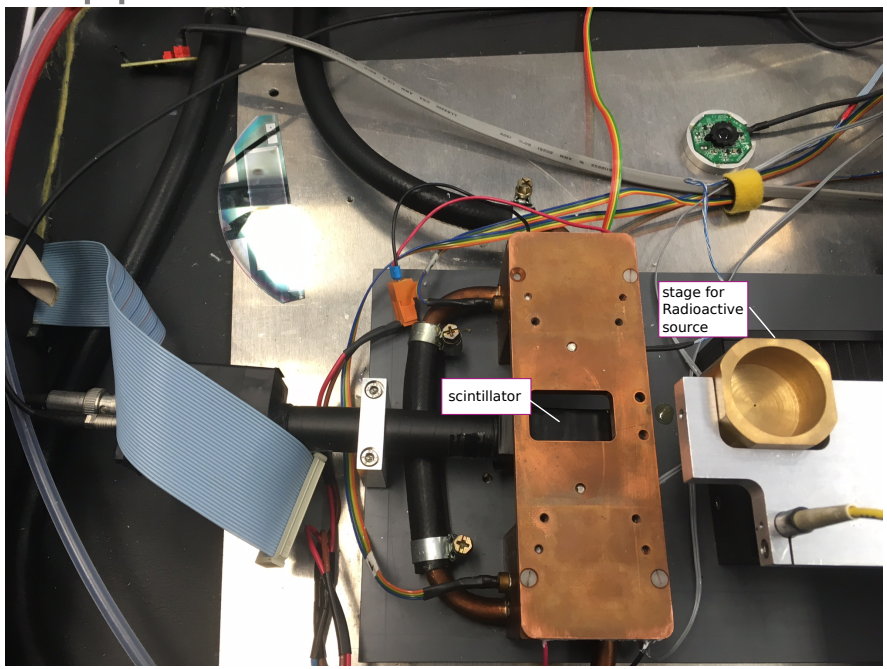
$2 \cdot 10^{11} n_{eq}/cm^2$
$5 \cdot 10^{12} n_{eq}/cm^2$
$1 \cdot 10^{13} n_{eq}/cm^2$
$5 \cdot 10^{13} n_{eq}/cm^2$
$1 \cdot 10^{14} n_{eq}/cm^2$
$3 \cdot 10^{14} n_{eq}/cm^2$
$6 \cdot 10^{14} n_{eq}/cm^2$
$1 \cdot 10^{15} n_{eq}/cm^2$

ALiBaVa Setup at KIT

ALiBaVa Board

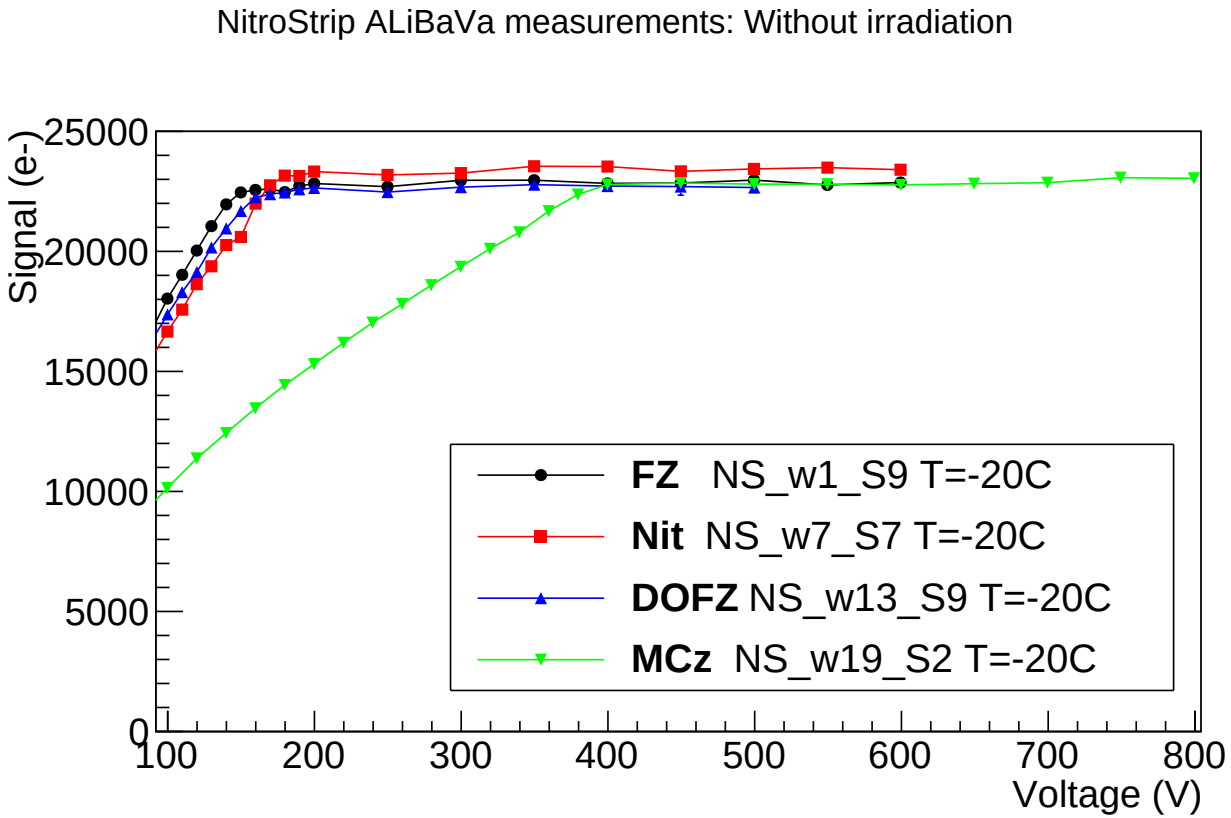


Support and scintillator



ALiBaVa measurements unirradiated sensors

Measurements taken with the same ALiBaVa board and ^{90}Sr radioactive source
Trigger events 100000

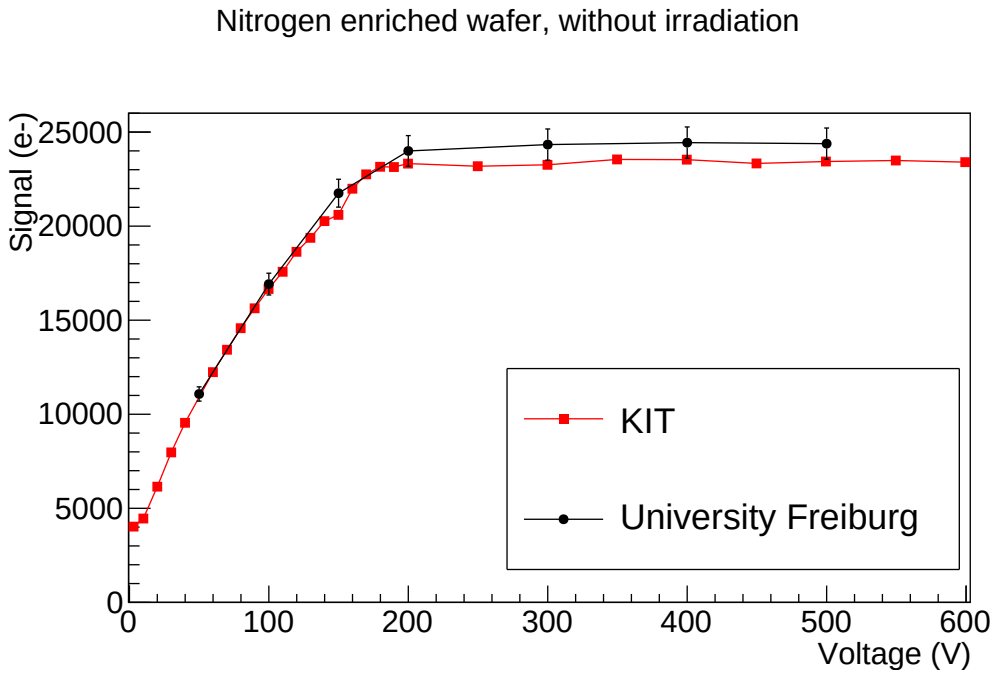


Once depleted, the detectors have:

- FZ $\sim$ 23ke$^-$
- Nit $\sim$ 23.5ke$^-$
- DOFZ $\sim$ 23ke$^-$
- MCz $\sim$ 23ke$^-$

Measurement uncertainty estimated to be $\sim$5%

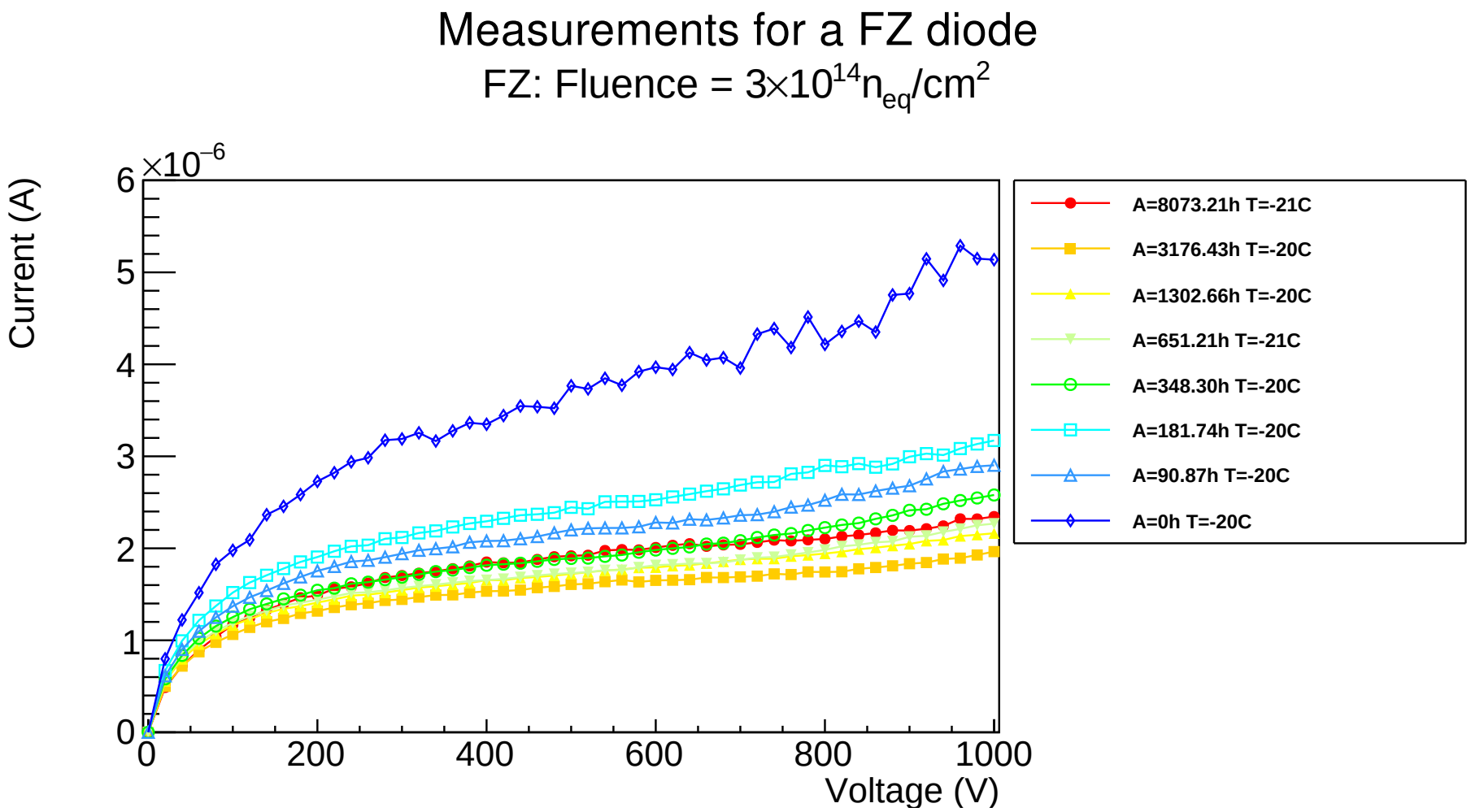
Comparison between KIT and University Freiburg measurements



The difference between setups is small, and it might be due to differences of the thickness of the wafers, or error in the measurement (KIT have 5% error in the measurement).

Thanks to Liv and Cedric for the data!

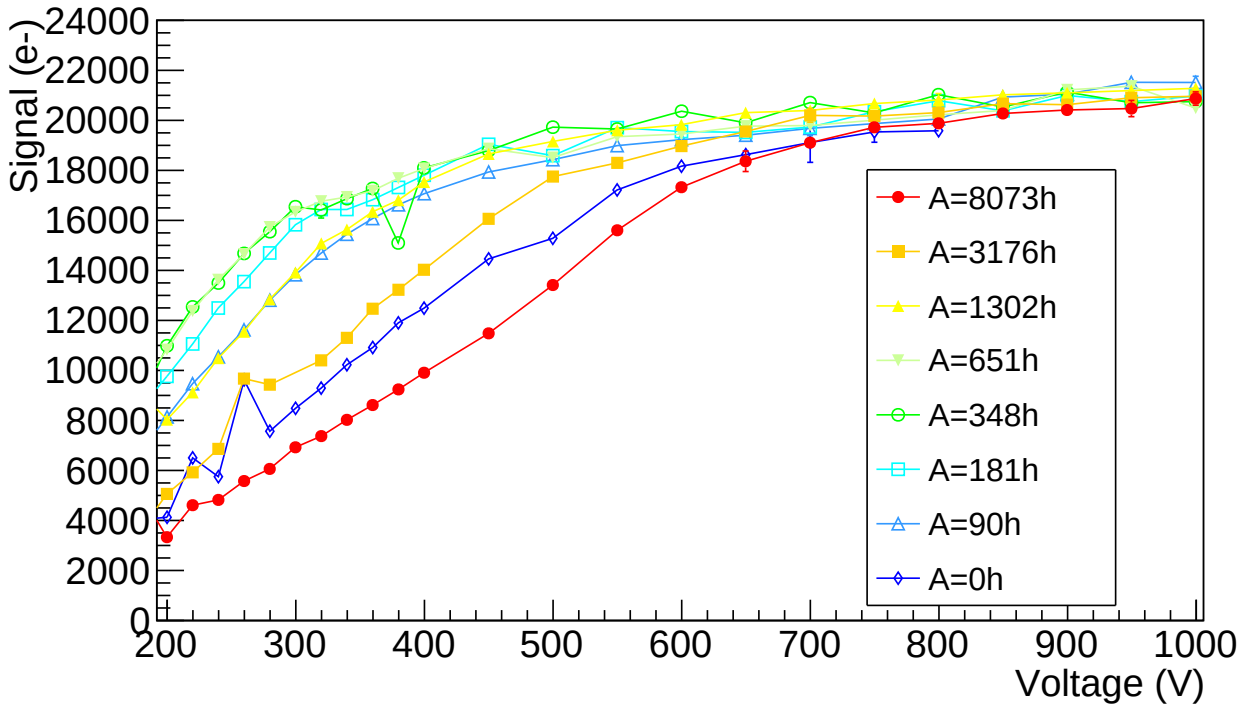
Irradiated FZ samples with 23 MeV protons



Irradiated FZ samples with 23 MeV protons

Measurements taken with the same ALiBaVa board and ^{90}Sr radioactive source at $-20\,^{\circ}C$
Trigger events 100000

Nitrostrip: FZ wafer Fluence = $3\times10^{14} n_{eq}/cm^2$



Once depleted, the detectors have:

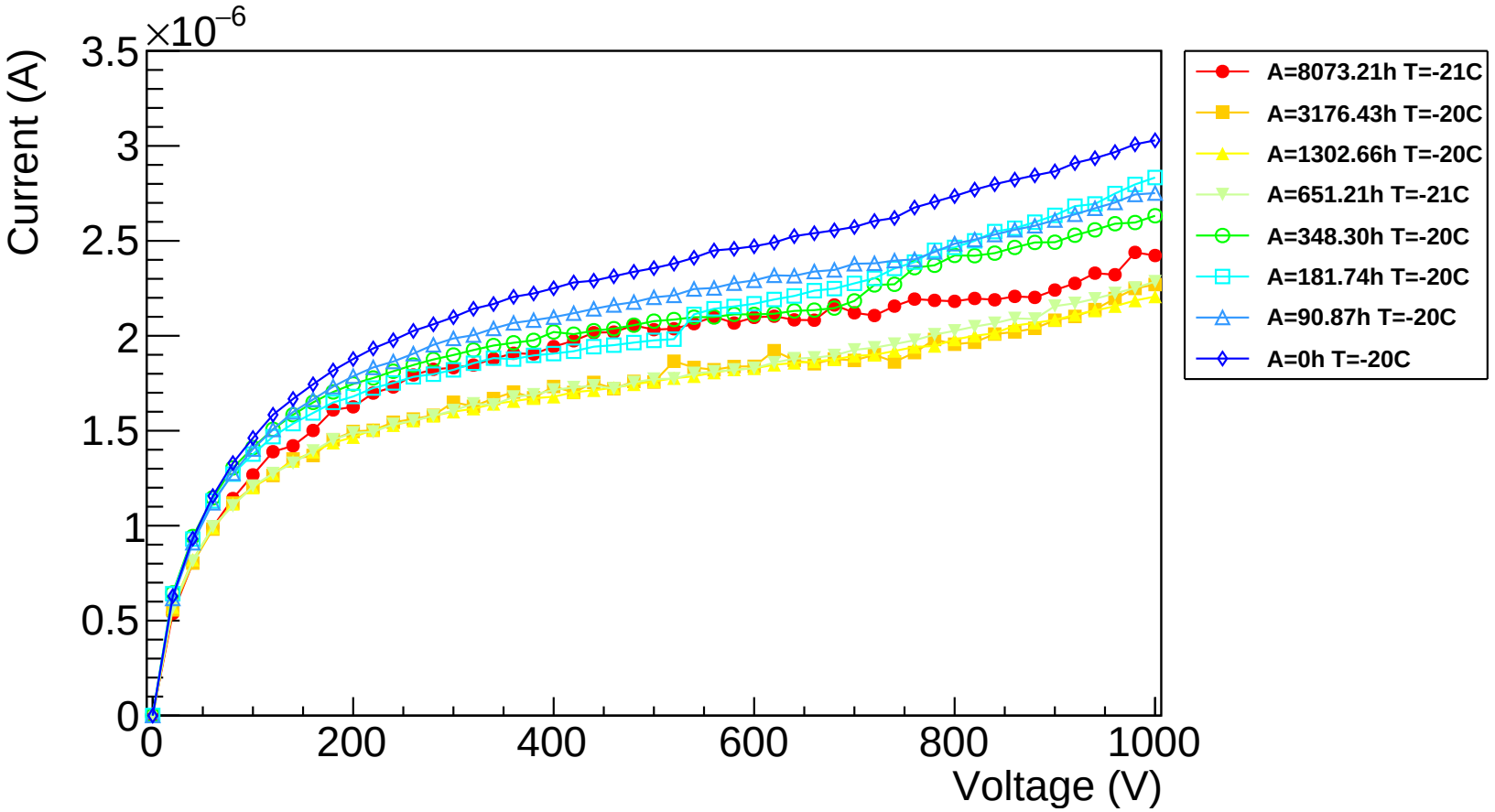
- FZ $\sim$ 21ke$^-$

Measurement uncertainty estimated to be $\sim$5%

Irradiated Nit samples with 23 MeV protons

Measurements from a Nitrogen enriched diode

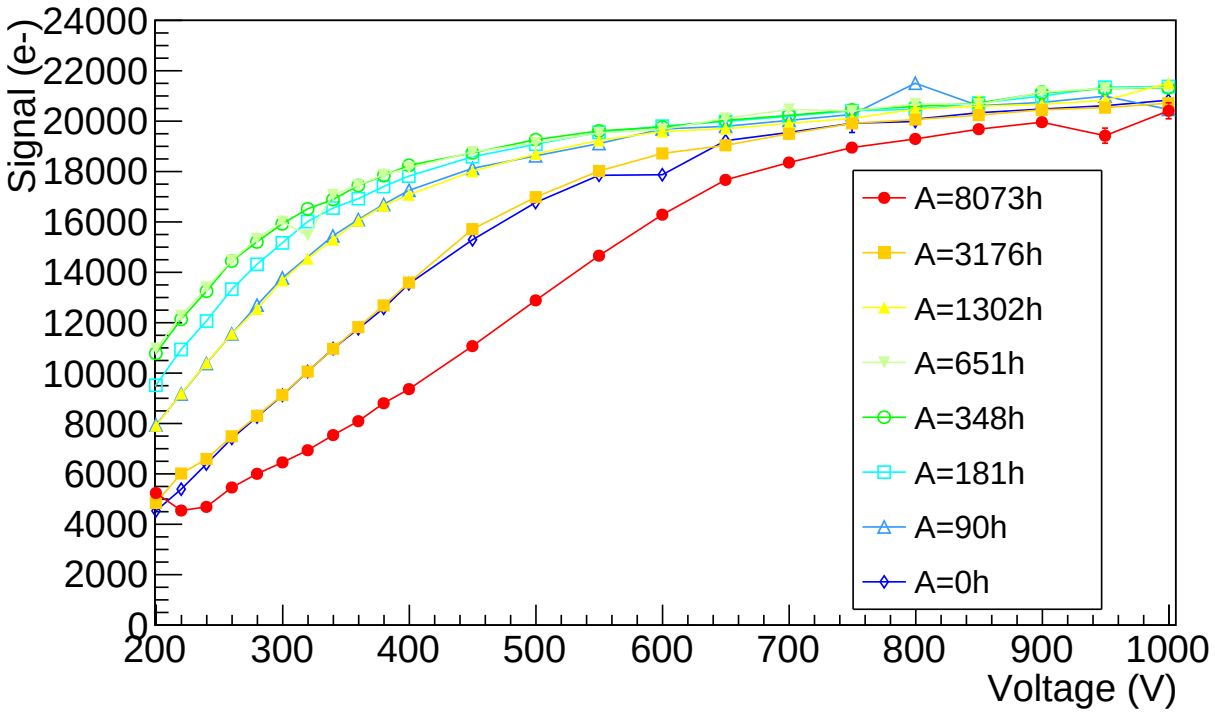
Nit: Fluence = $3\times10^{14} n_{eq}/cm^2$



Irradiated Nit samples with 23 MeV protons

Measurements taken with the same ALiBaVa board and ^{90}Sr radioactive source at $-20\,^{\circ}C$
Trigger events 100000

Nitrostrip: Nit wafer Fluence = $3\times10^{14} n_{eq}/cm^2$



Once depleted, the detectors have:

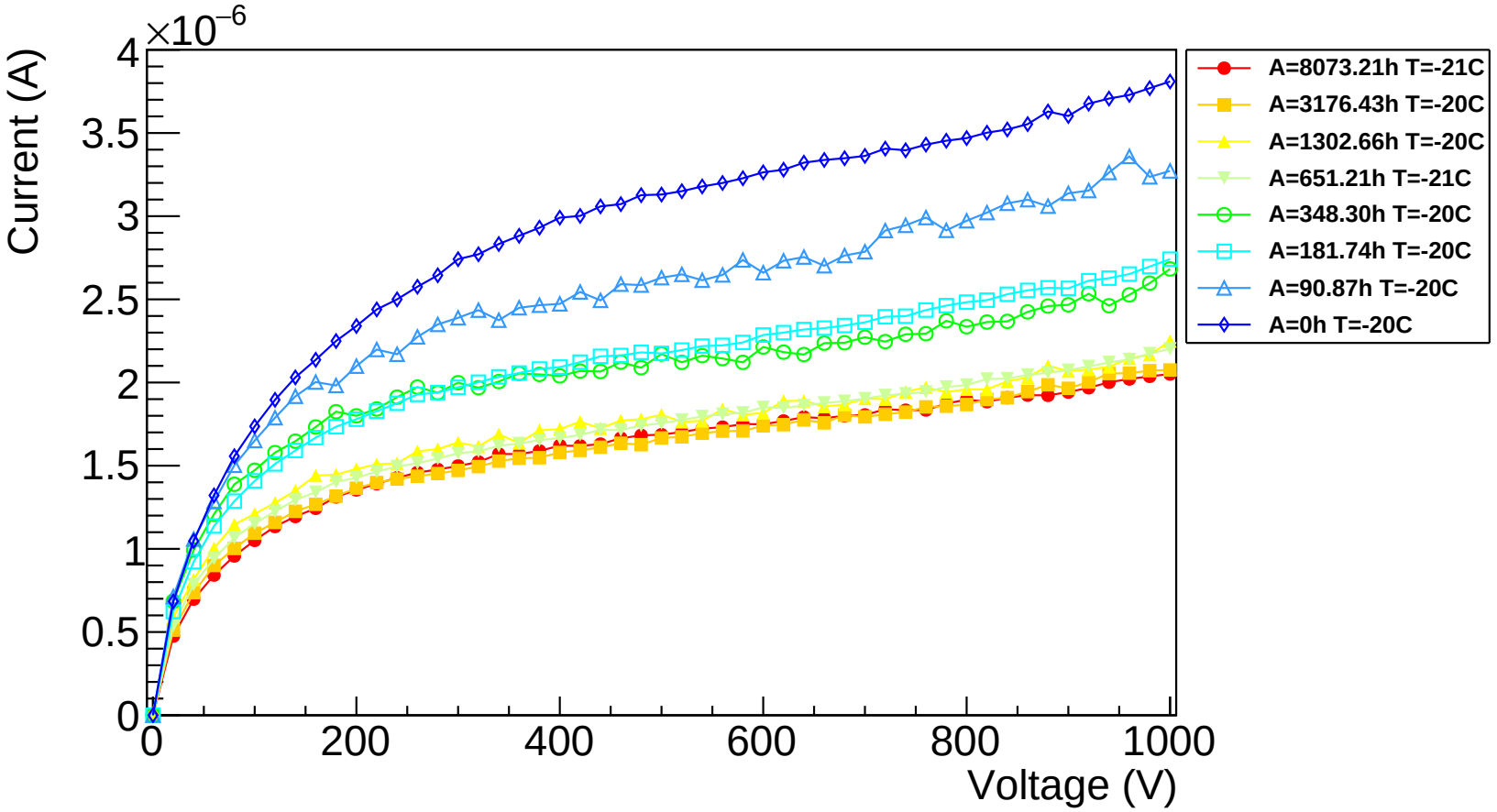
- Nit $\sim$ 21ke$^-$

Measurement uncertainty estimated to be $\sim$5%

Irradiated DOFZ samples with 23 MeV protons

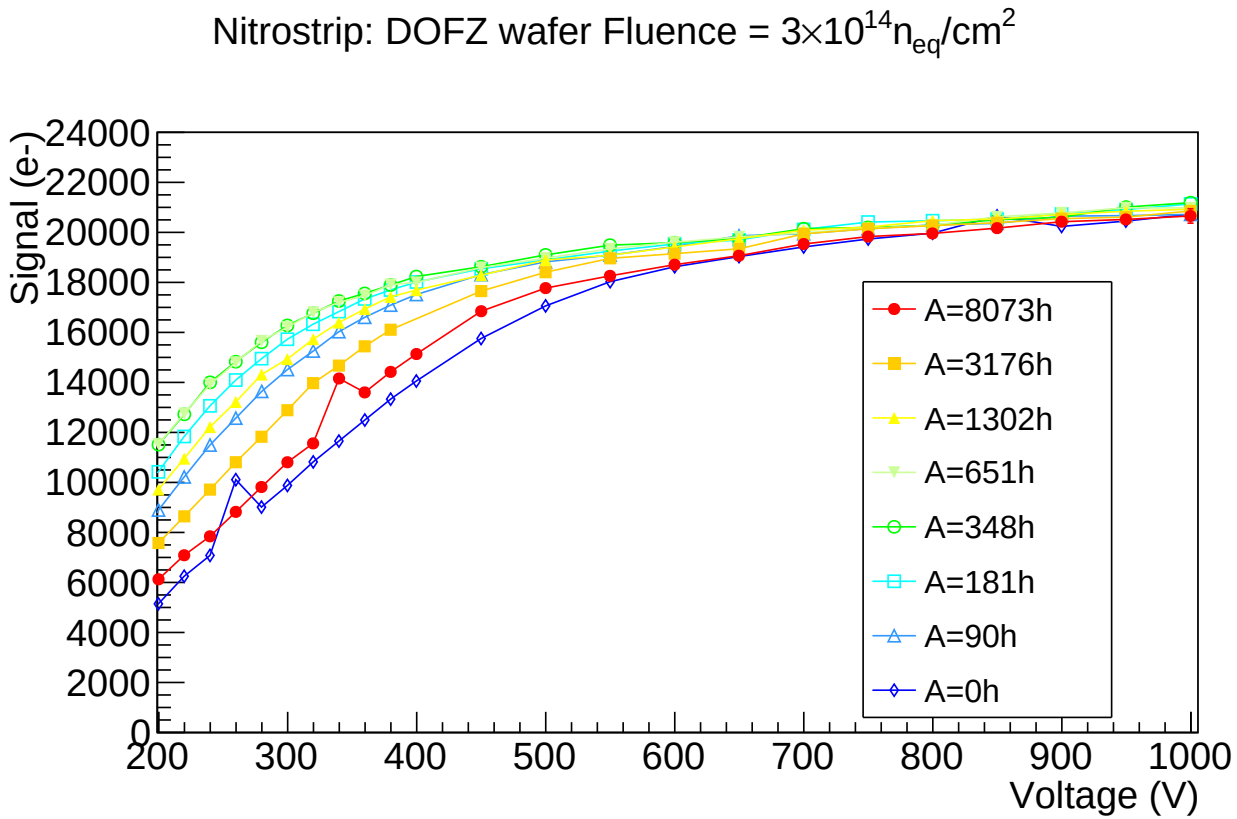
Measurements from a DOFZ diode

DOFZ: Fluence = $3 \times 10^{14} n_{eq}/cm^2$



Irradiated DOFZ samples with 23 MeV protons

Measurements taken with the same ALiBaVa board and ^{90}Sr radioactive source at $-20\,^{\circ}C$
Trigger events 100000



Once depleted, the detectors have:

- DOFZ $\sim$ 21ke$^-$

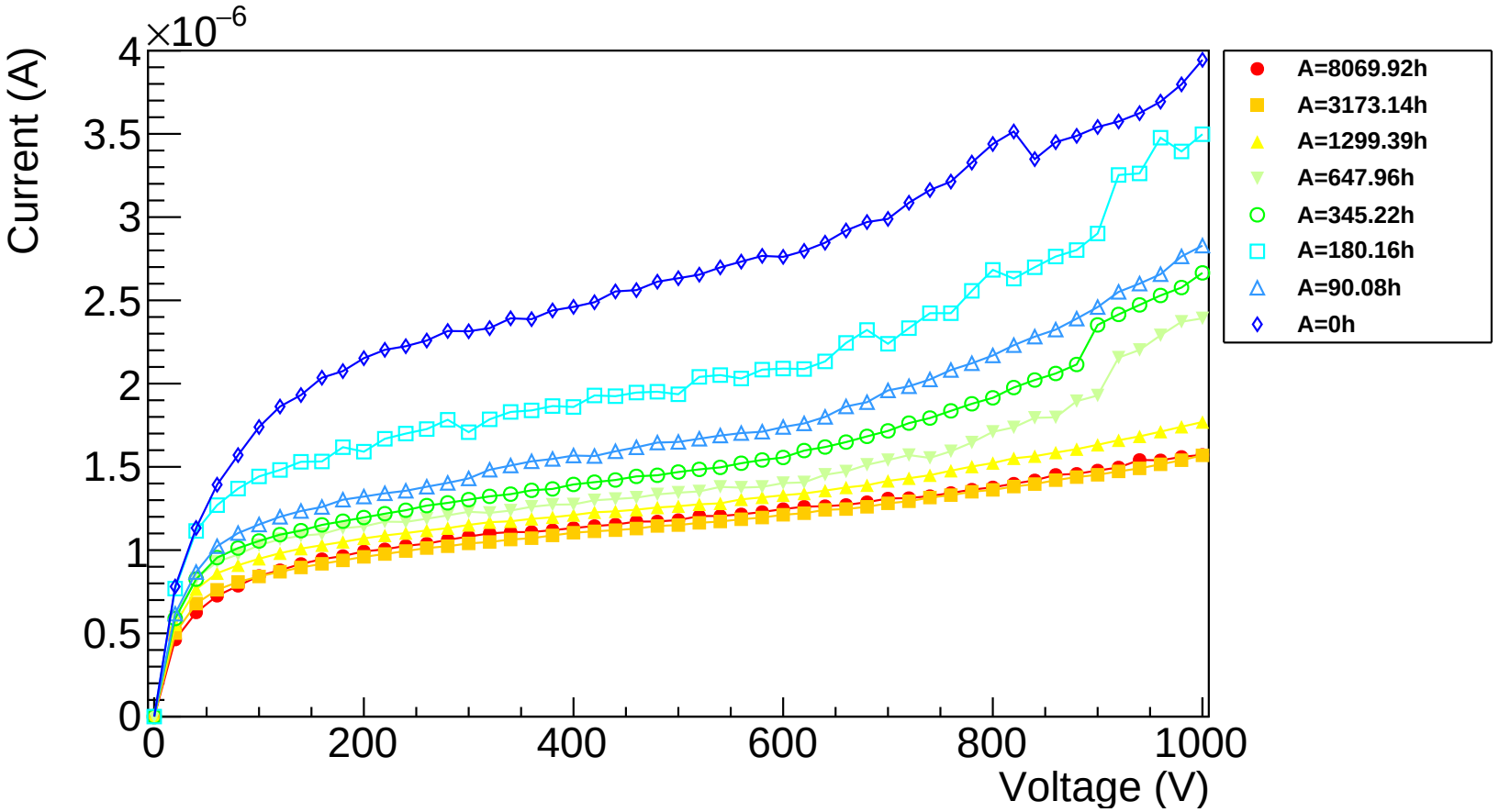
Measurement uncertainty estimated to be $\sim$5%

Irradiated MCz samples with 23 MeV protons

Karlsruhe Institute of Technology

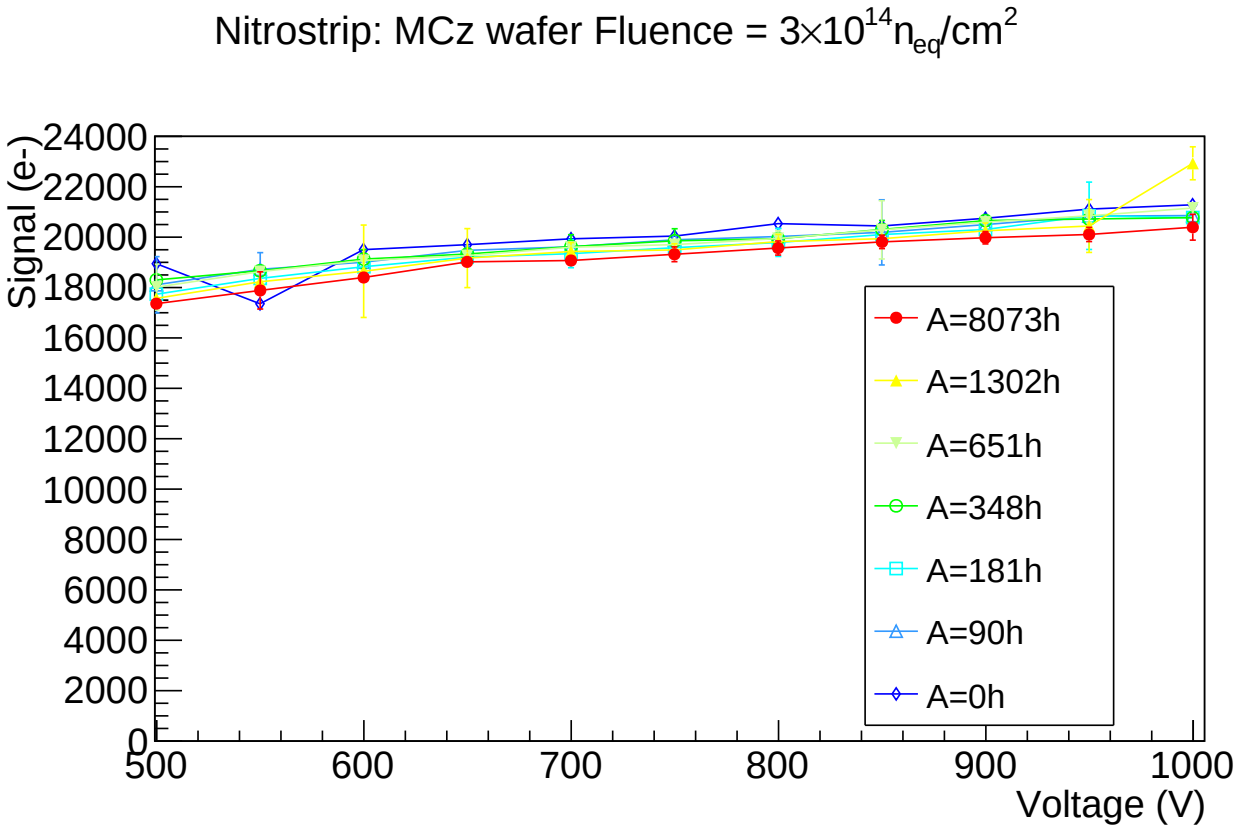
Measurements from a MCz diode

MCz: Fluence = $3\times10^{14} n_{eq}/cm^2$



Irradiated MCz samples with 23 MeV protons

Measurements taken with the same ALiBaVa board and ^{90}Sr radioactive source at $-20\,^{\circ}C$
Trigger events 100000

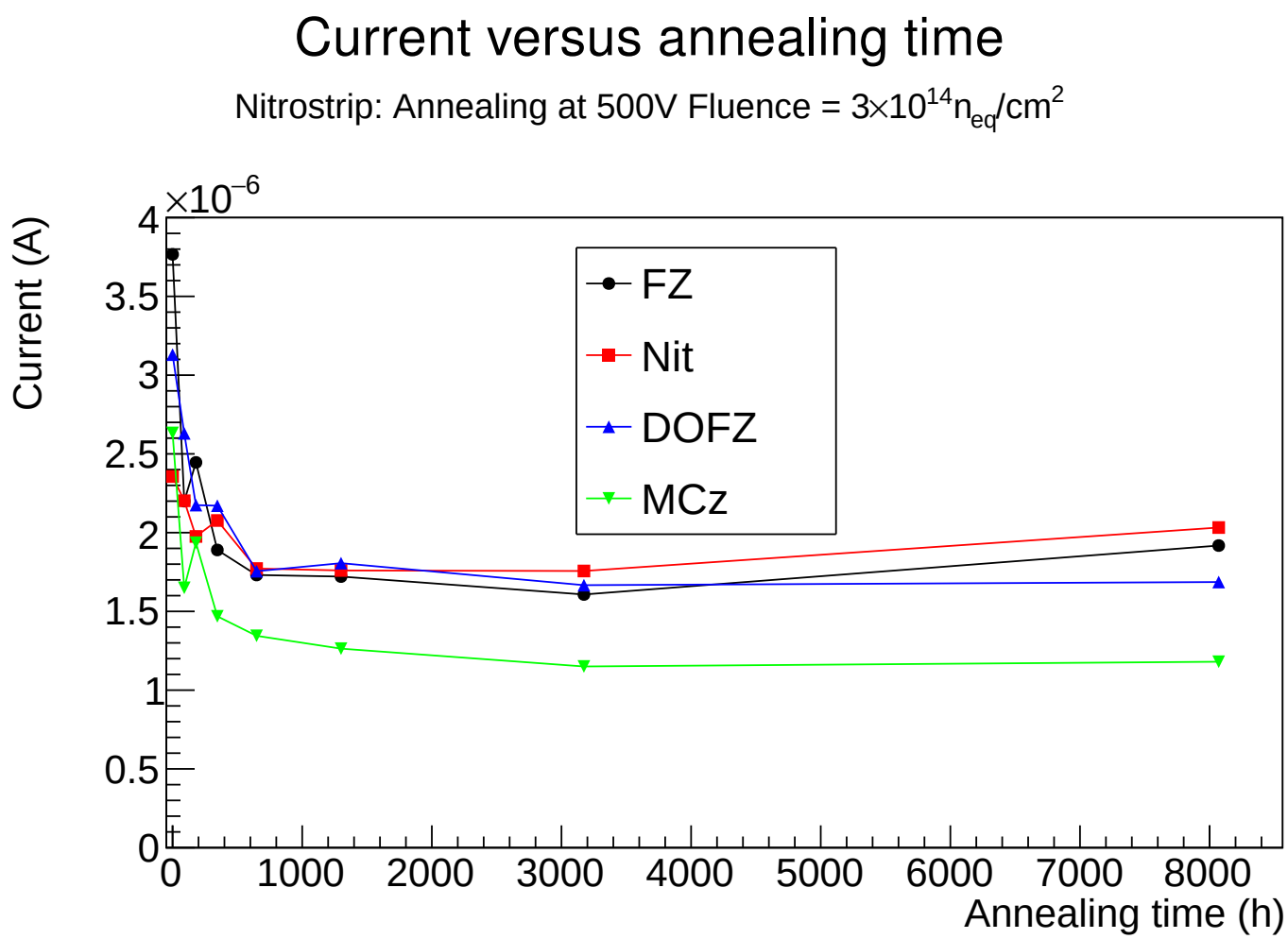


Once depleted, the detectors have:

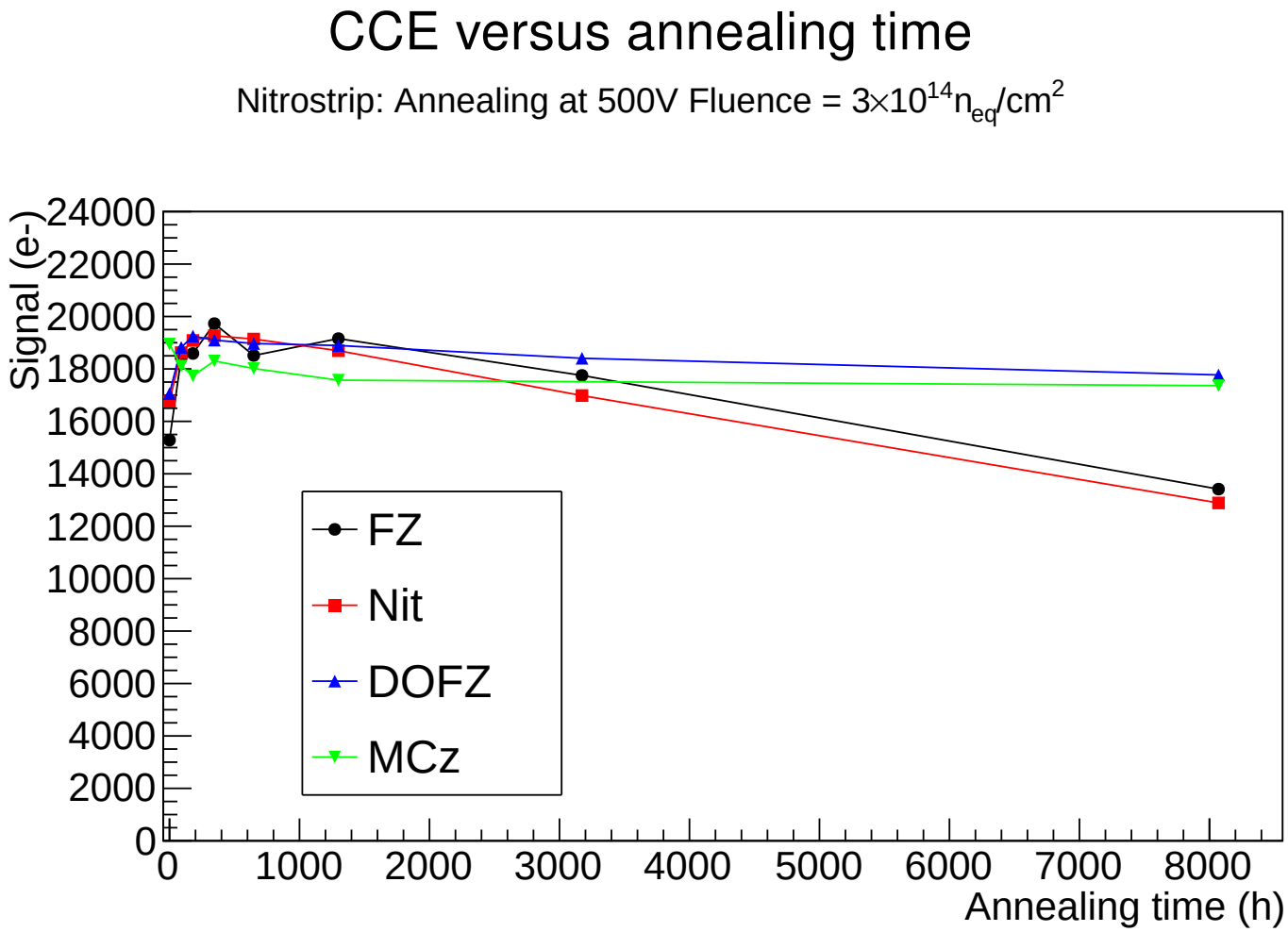
- MCz $\sim$ 21ke$^-$

Measurement uncertainty estimated to be $\sim$5%

Irradiated diodes with 23 MeV protons



Irradiated strips with 23 MeV protons



More degradation after annealing for the FZ and Nit wafers.

Conclusions

- Sensors after proton irradiation show good behaviour
- Nitrogen enriched wafers do not show any improvement for the charge collection after 23 MeV proton irradiation at $3 \times 10^{14}\, n_{eq}/cm^2$ regarding the other wafers

Future work

- Complete initial measurement program
- edge-TCT measurements, DLTS, ...

Acknowledgements

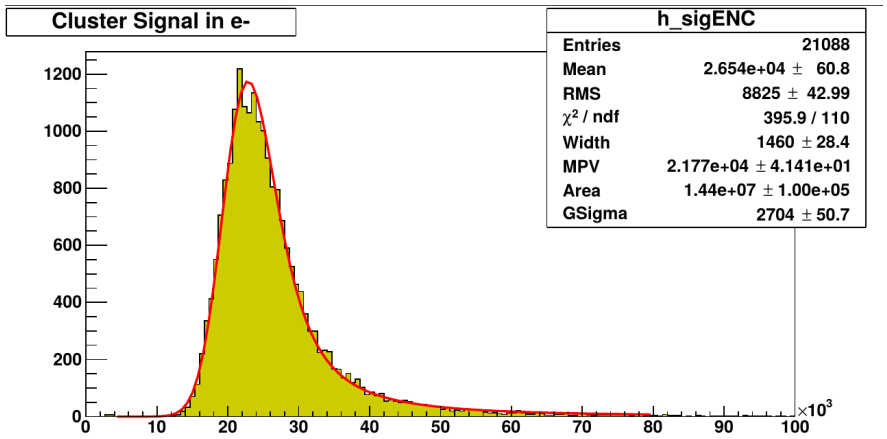
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168

Backup

Measurements with trigger attenuation

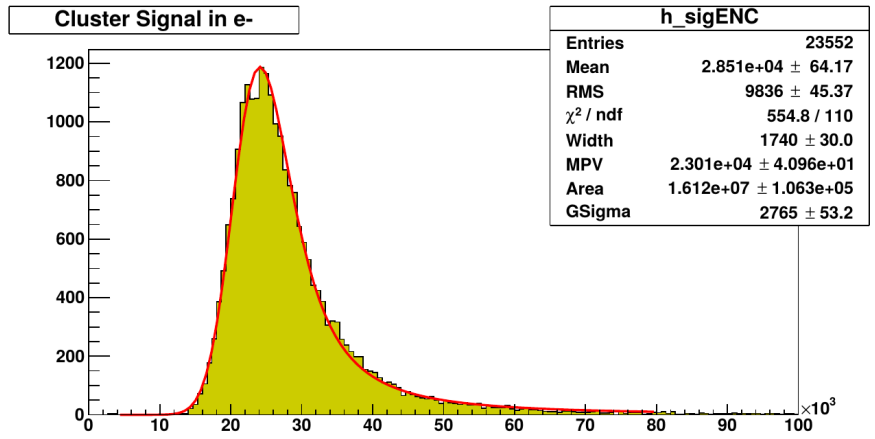
Some measurements were taken with a silicon piece between the sensor and the scintillator. Measurements taken for the MCz wafer

With silicon piece



- MPV 21700 electrons

Without the silicon piece



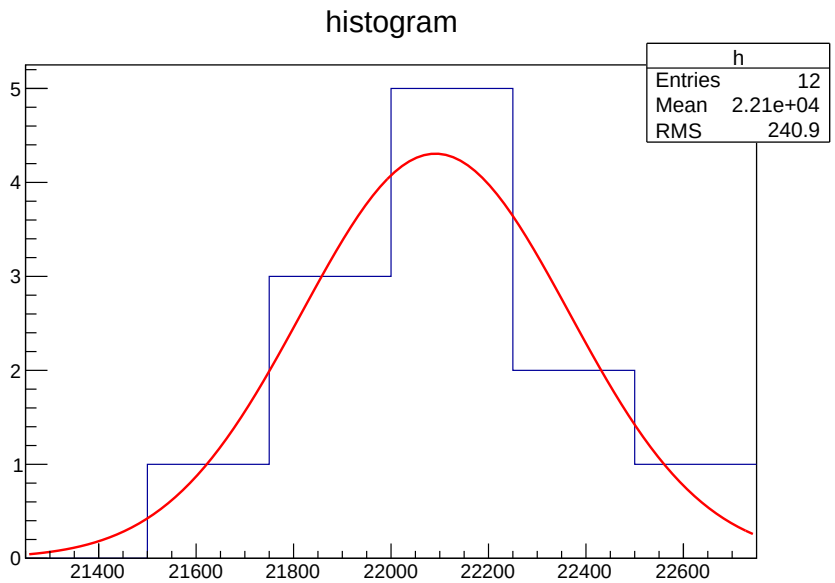
- MPV 23010 electrons

5% difference between the two measurements

Error and attenuation

Error associated in the measurement is approximately 5%

Repetition of the same measurement several times without changing the conditions



σ=274e^{-}