



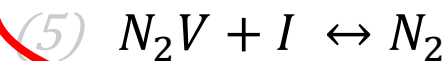
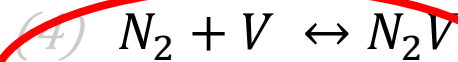
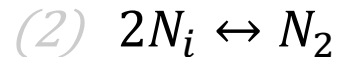
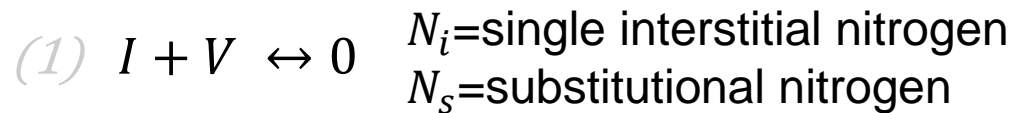
Nitrostrip

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PARZEFALL, GIULIO PELLEGRINI, JOAN MARC RAFI, JOERN
SCHWANDT, LIV WIJK-FUCHS, FRANZISKA MOOS**

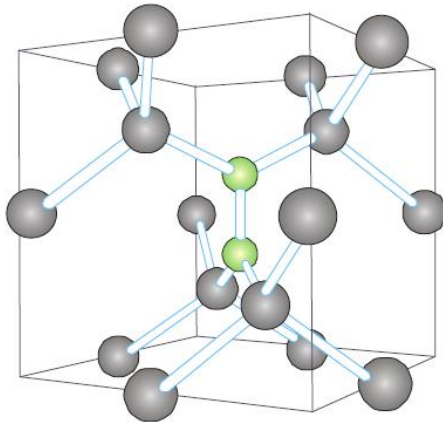
Albert-Ludwigs-Universität Freiburg

Nitrostrip – Nitrogen doped silicon

Floatzone silicon is enriched with nitrogen atoms:



Measurements done by [Kaminski](#) show nitrogen enriched silicon has a lower density of defect centers compared to pure silicon with low nitrogen content after irradiation with neutrons.

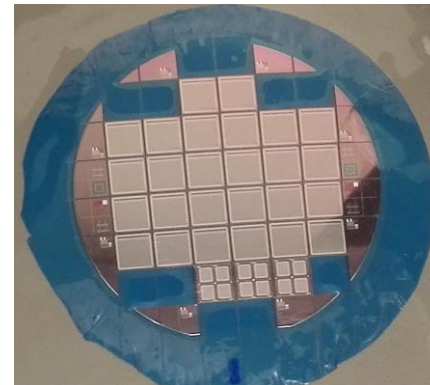


Talk by [Marta Baselga](#) from last RD 50 covers results from proton irradiated nitrostrip samples.

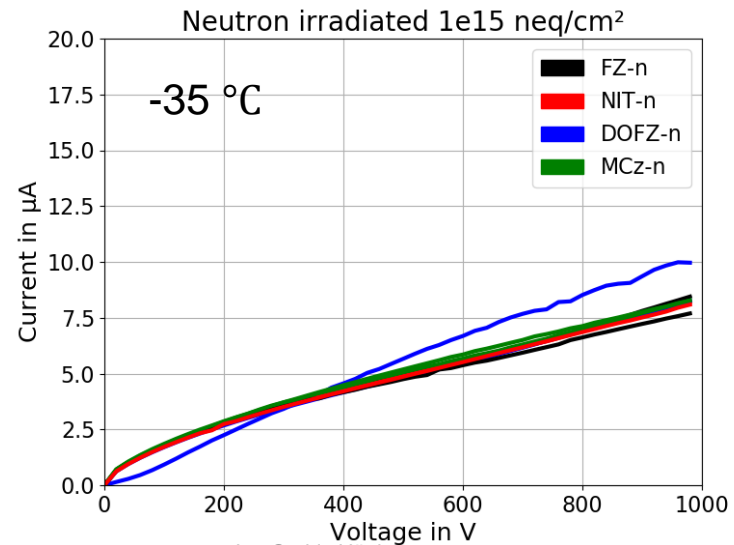
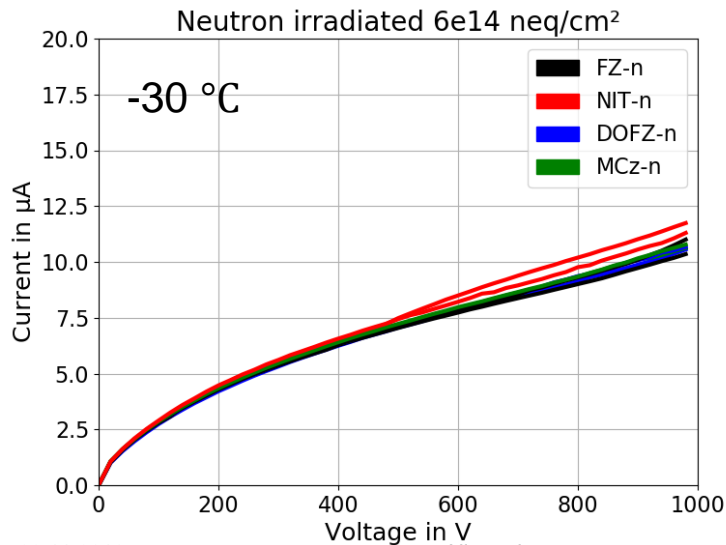
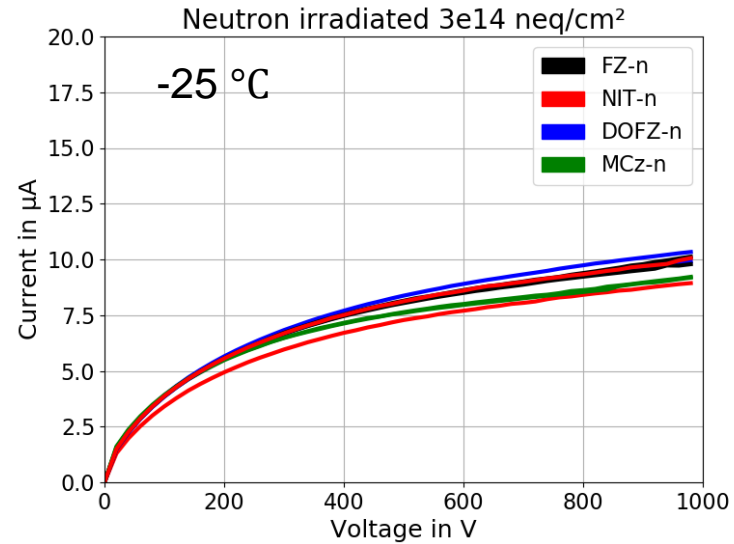
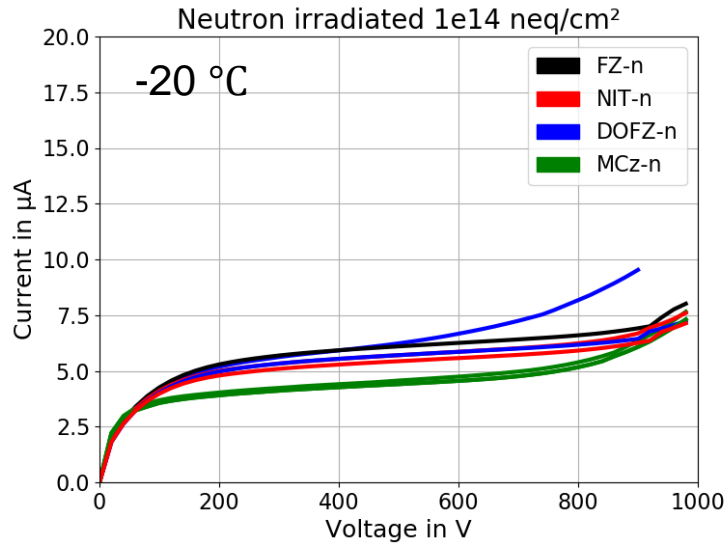
Wafers	Label	Substrate
1-6	FZ	HR-FZ 100 mm, <100>, n-type (phosphorus), 2000-2400Ω cm 300±15 μm, 1 side polished
7-12	NIT	HR-FZ Nitrogenated 100 mm, <100>, n-type (phosphorus), 1500-1900Ω cm 300±15 μm, 1 side polished
13-18	DOFZ	HR-FZ Oxygenated 100 mm, <100>, n-type (phosphorus), 2000-2400Ω cm 300±15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

Irradiation done in:

Ljubljana 1MeV neutrons
 KIT 23MeV protons
 CERN 24GeV protons

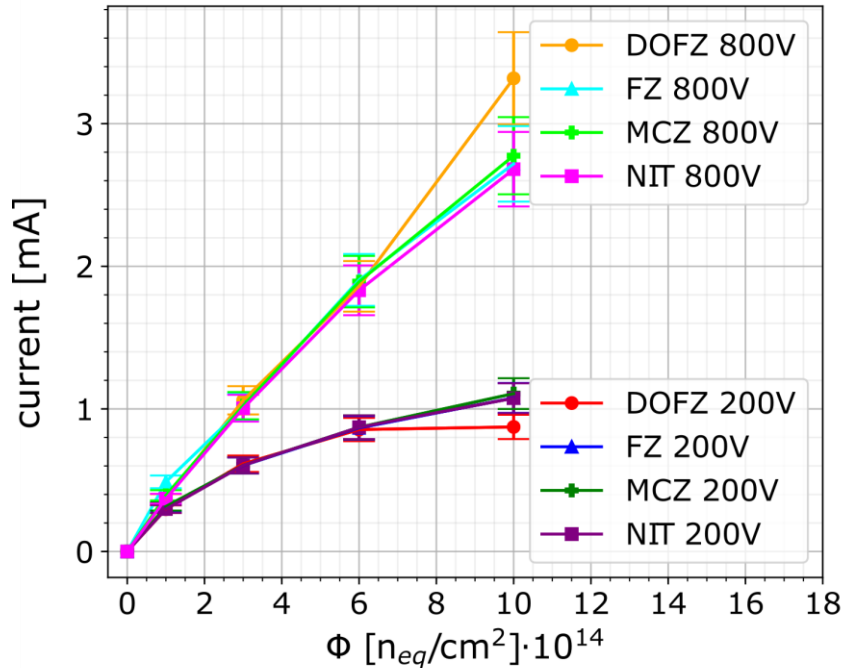


Electrical tests – neutron irradiated



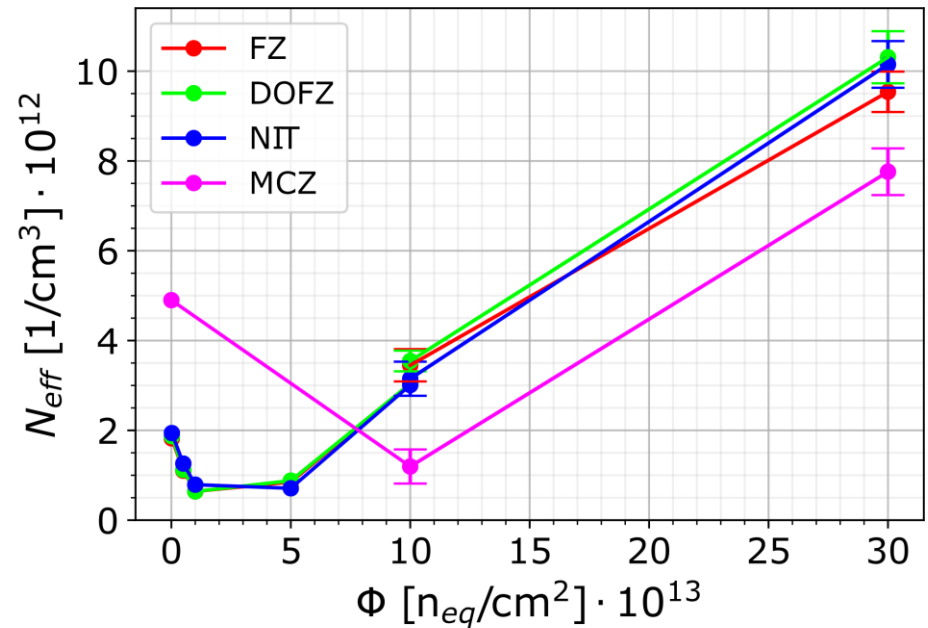
Electrical tests – neutron irradiated

Current comparison



Current normalized to 20 °C.
 Each fluence step corresponds to a different sensor.

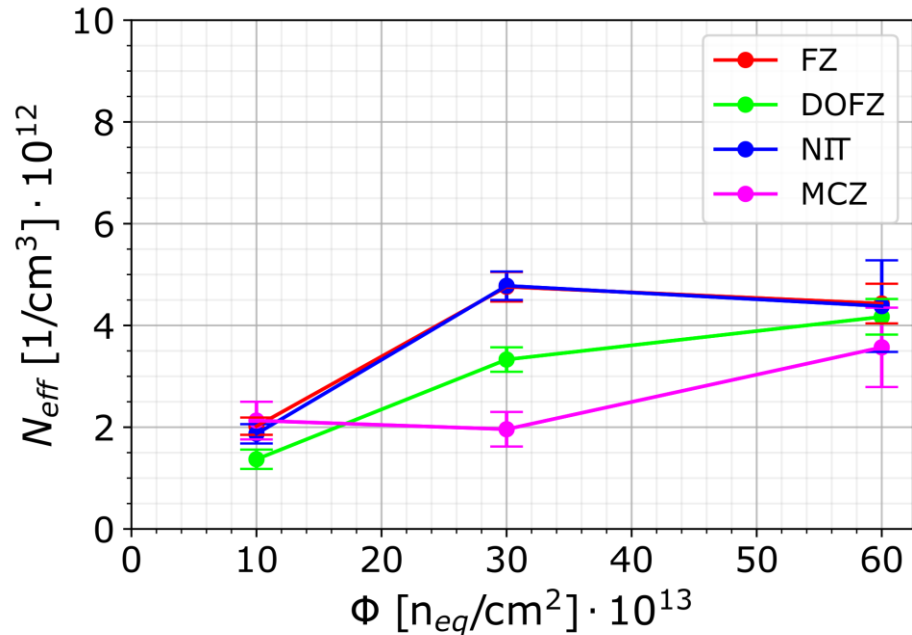
Effective doping concentration



No large difference in the effective doping concentration caused by different FZ processing techniques.

Electrical tests – proton irradiated

Effective doping concentration



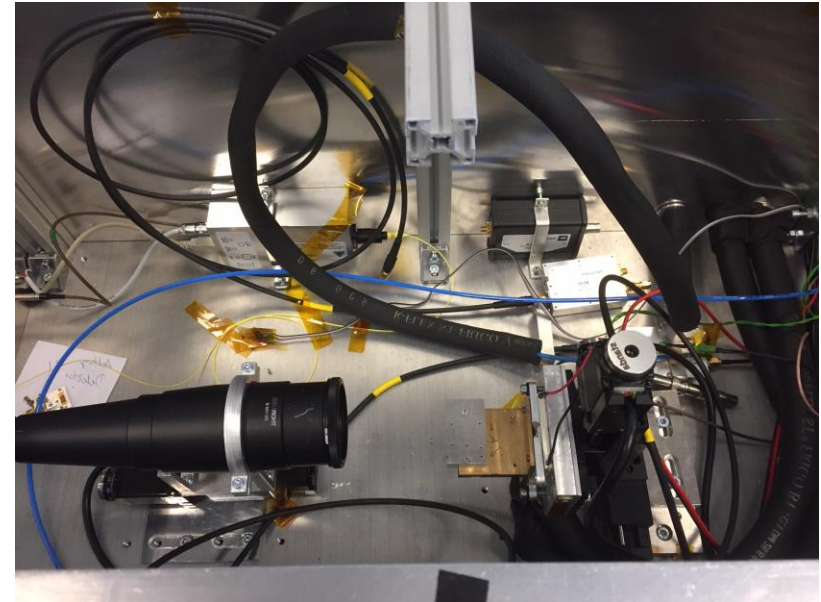
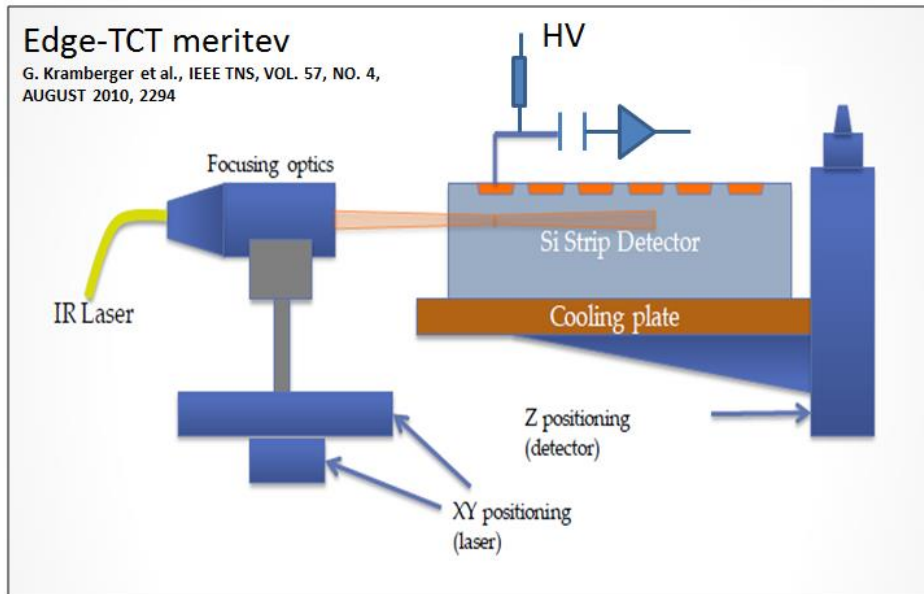
Sensor	$\Phi = 0$ [n _{eq} /cm ²]	$\Phi = 1 \cdot 10^{14}$ [n _{eq} /cm ²]	$\Phi = 3 \cdot 10^{14}$ [n _{eq} /cm ²]
DOFZ n	146 ± 3	242 ± 16	718 ± 39
DOFZ p		94 ± 13	228 ± 16
FZ n	151 ± 4	238 ± 22	660 ± 31
FZ p		138 ± 12	326 ± 20
NIT n	165 ± 5	218 ± 26	704 ± 37
NIT p		125 ± 13	327 ± 19

No large difference between FZ and NIT. DOFZ shows lower doping concentration.

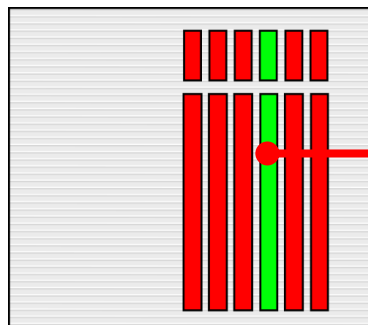
Full depletion voltages of the neutron and proton irradiated samples.

EdgeTCT – basic principle

Side view: Particulars EdgeTCT setup (similar to Freiburg setup)



Top view: Sensor



Laser



- Strip - grounded
- Strip - measured

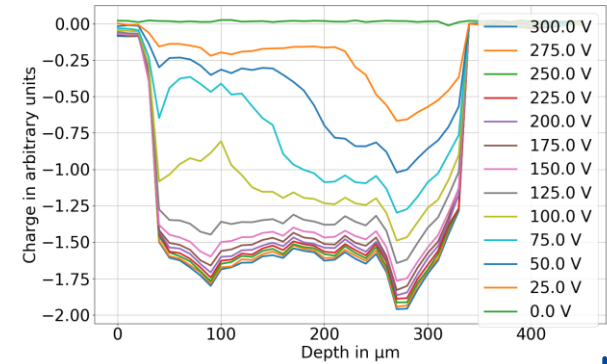
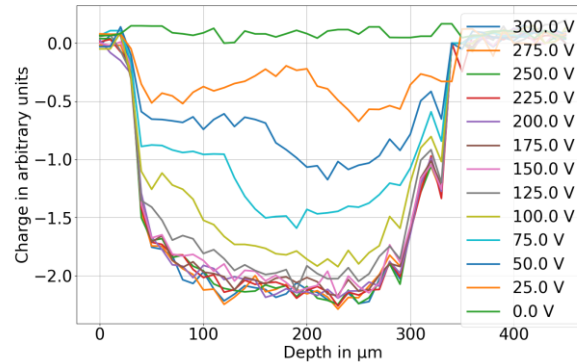
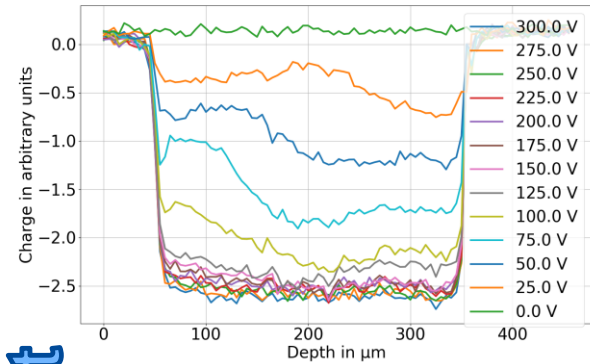
Neutron irradiated samples

Irradiation done at Jožef Stefan Institute Ljubljana.

NIT 1e14 neq/cm²

FZ 1e14

DOFZ 1e14

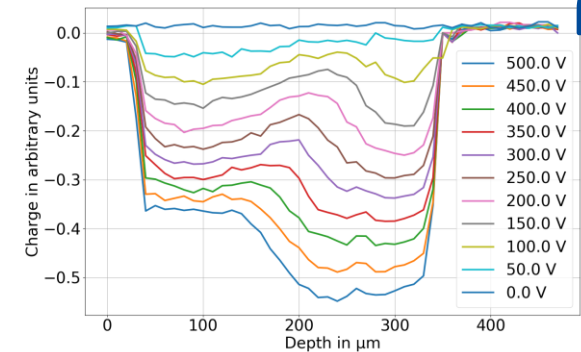
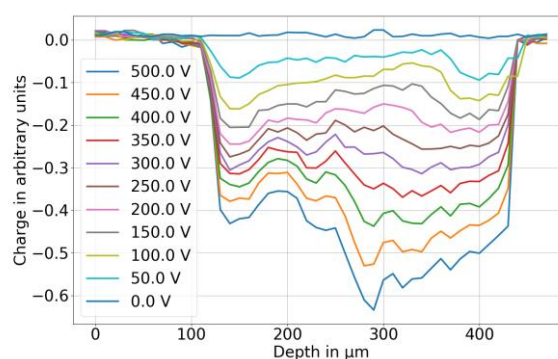
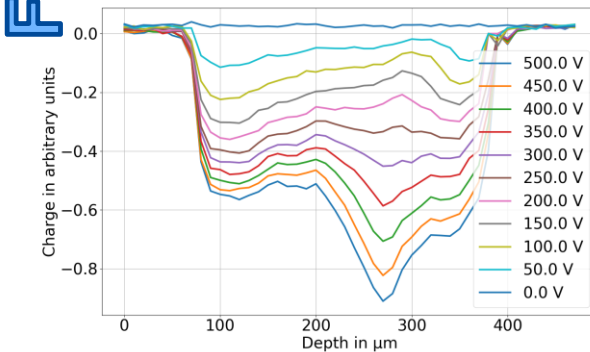


Front

NIT 1e15

FZ 1e15

DOFZ 1e15



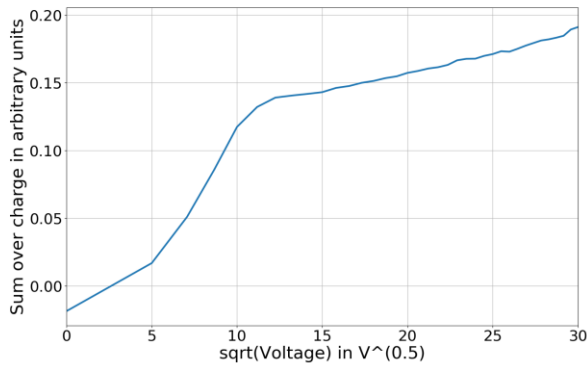
Back

NIT 1e14 & FZ 1e14 @ ~-20 °C
Rest @ ~(-18±1) °C

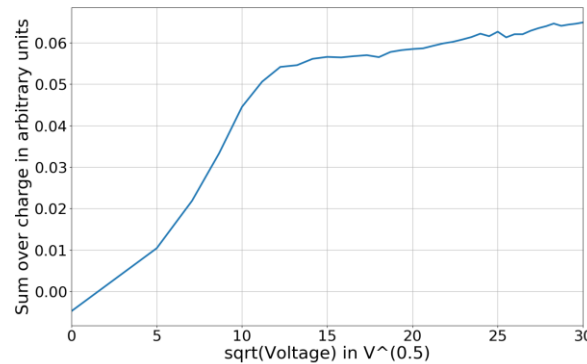
Integration window: 21.5 ns
Neutron irradiated

Depletion characteristic

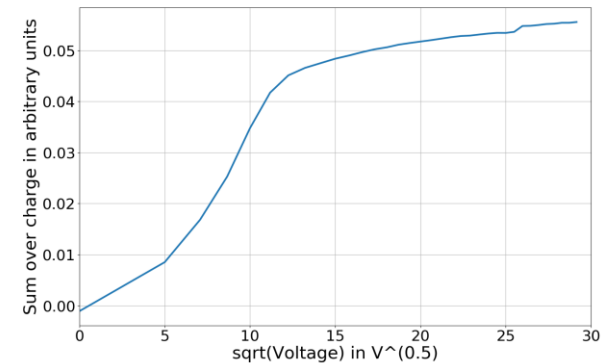
NIT 1e14 neq/cm²



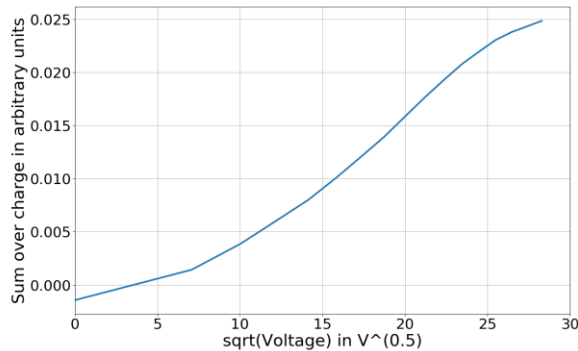
FZ 1e14



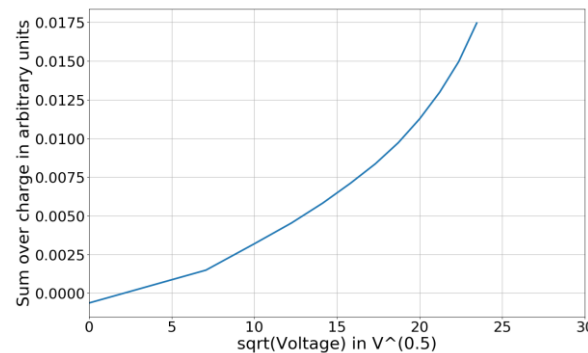
DOFZ 1e14



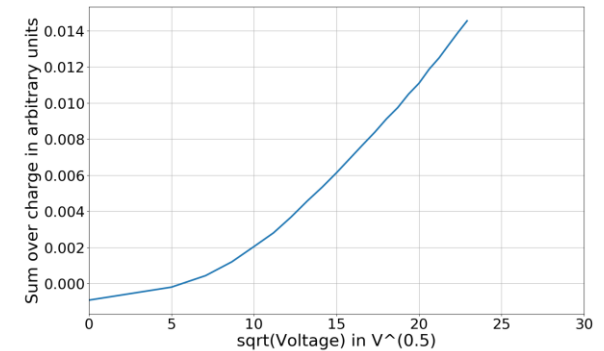
NIT 1e15



FZ 1e15



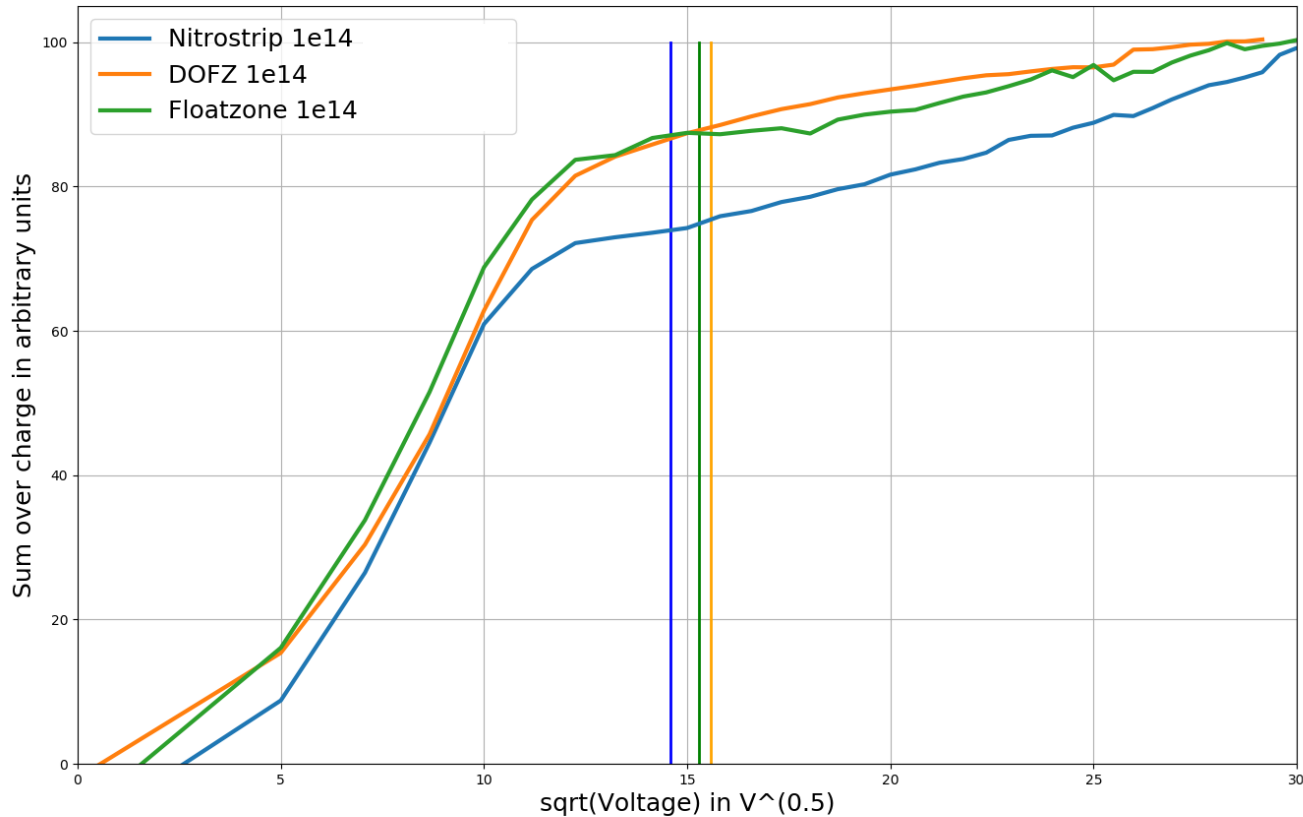
DOFZ 1e15



Integral over charge collection profile plotted against voltage.

Relative Depletion

Edge TCT results comparison 1e14

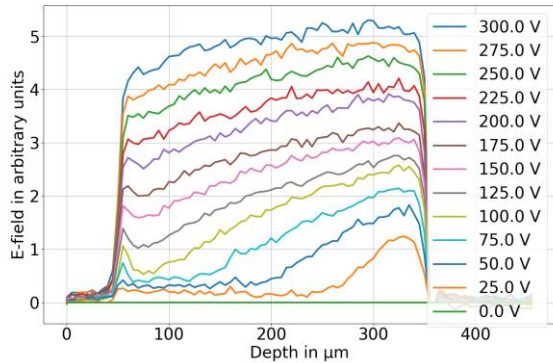


Electrical tests

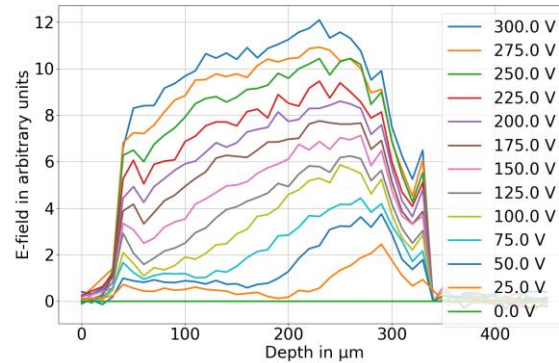
Sensor	Depletion Voltage [V]
NIT	213±24
FZ	234±24
DOFZ	243±25

Electrical test results could not be confirmed here.

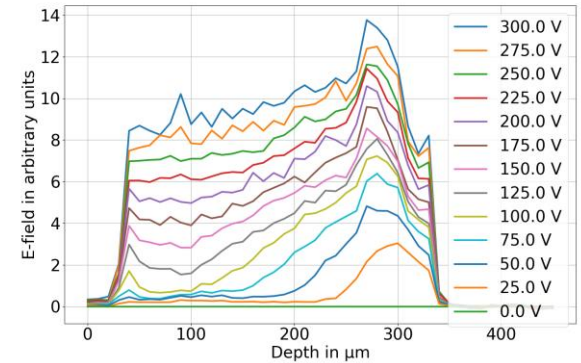
NIT 1e14 neq/cm²



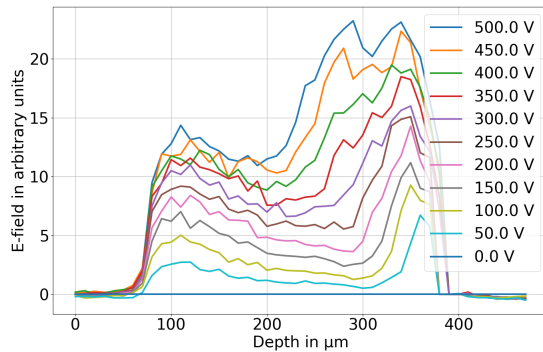
FZ 1e14



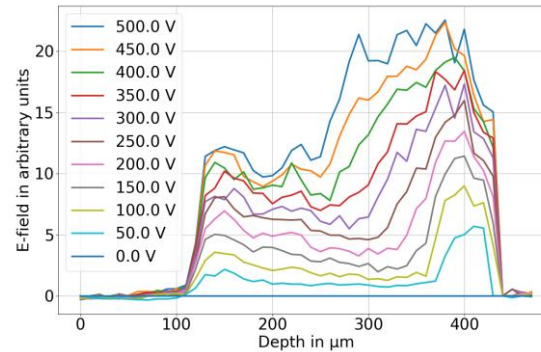
DOFZ 1e14



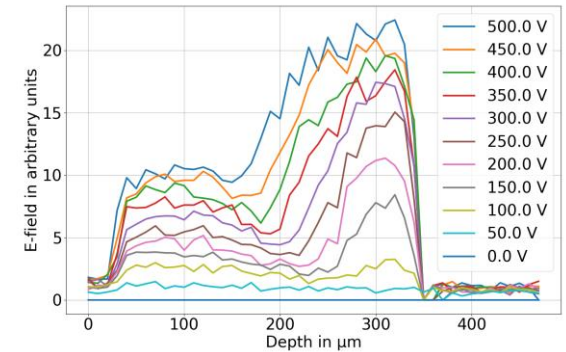
NIT 1e15



FZ 1e15



DOFZ 1e15

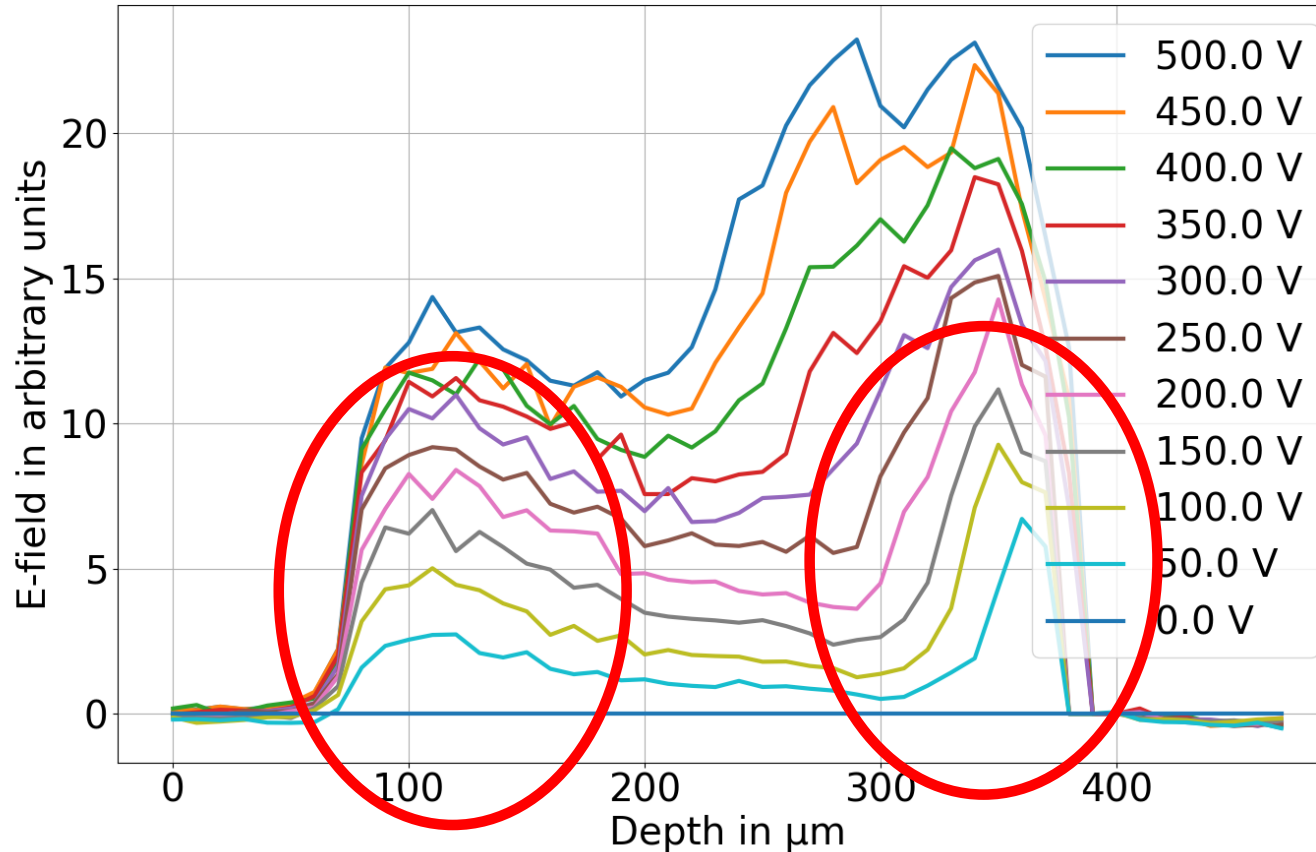


$$E(y) \propto \frac{I(y, t \sim 0)}{\alpha(V, I)}$$

Neutron irradiated

Double junction

NIT 1e15

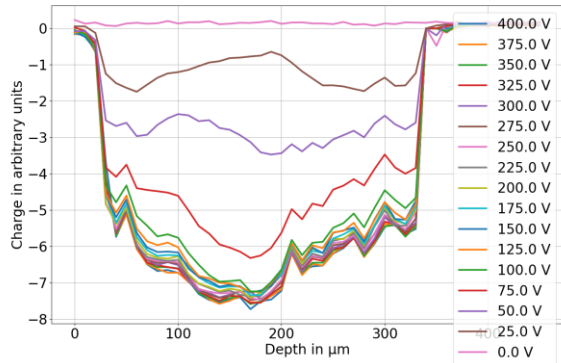


Depletion region grows from both front and back → double junction.

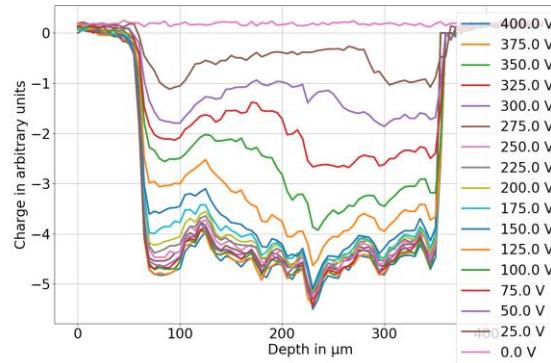
Proton irradiated samples

Irradiation done at SPS Cern.

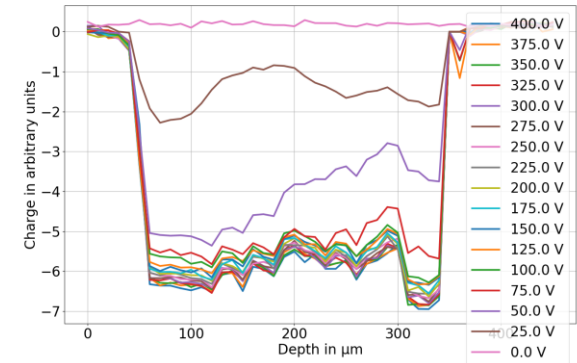
NIT 1e14 neq/cm²



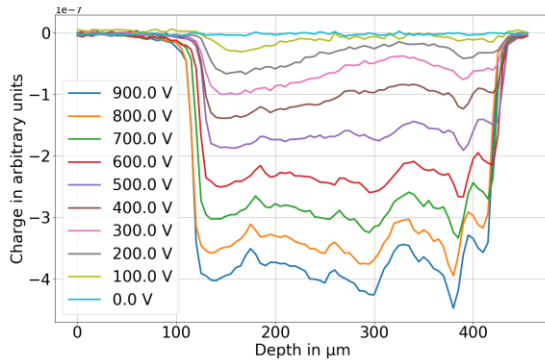
FZ 1e14



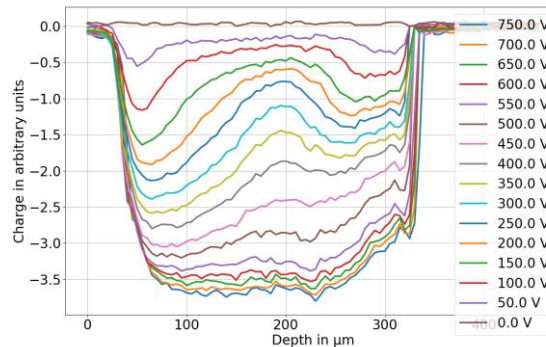
DOFZ 1e14



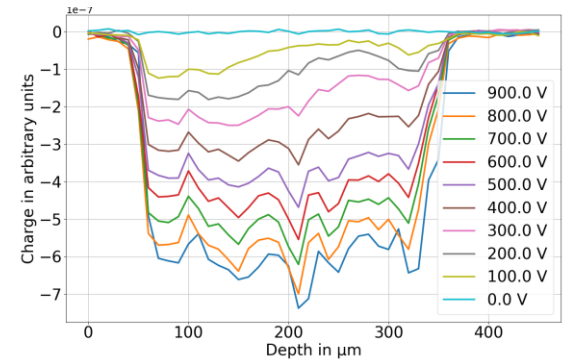
NIT 1e15



FZ 1e15



DOFZ 1e15

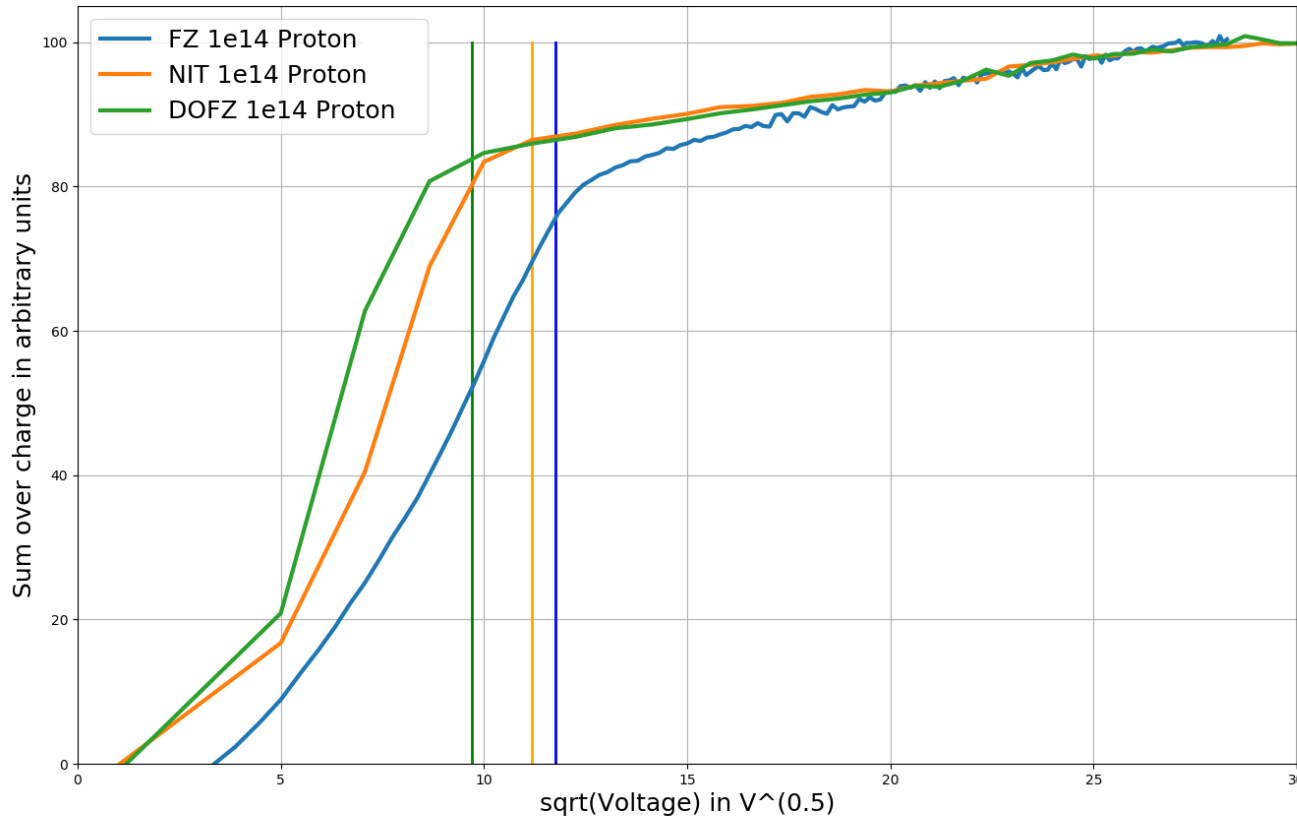


Measured @ $\sim(-20 \pm 1)^\circ\text{C}$

Integration window: 21.5 ns

Proton irradiated

Edge TCT results comparison 1e14

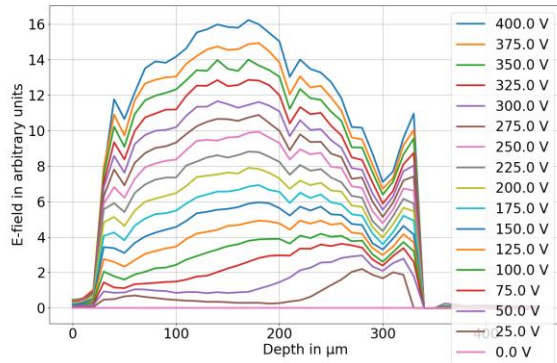


Electrical tests

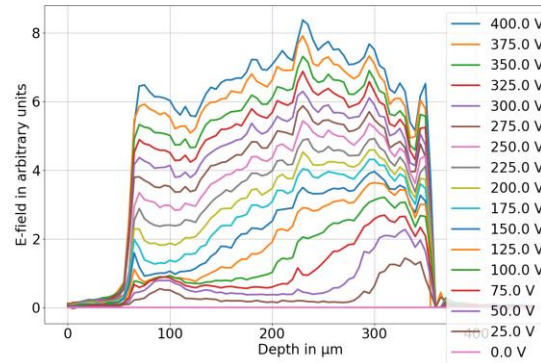
Sensor	Depletion Voltage [V]
NIT	125 ± 13
FZ	138 ± 12
DOFZ	94 ± 13

Edge TCT measurement in agreement with electrical tests.

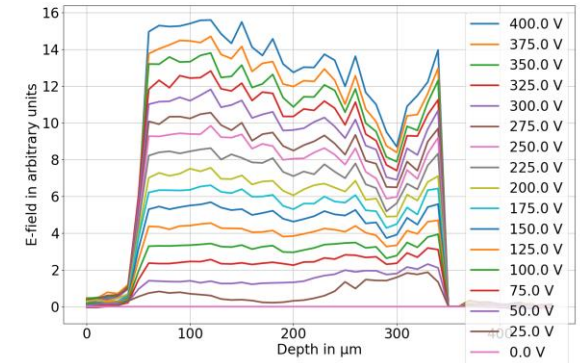
NIT 1e14 neq/cm²



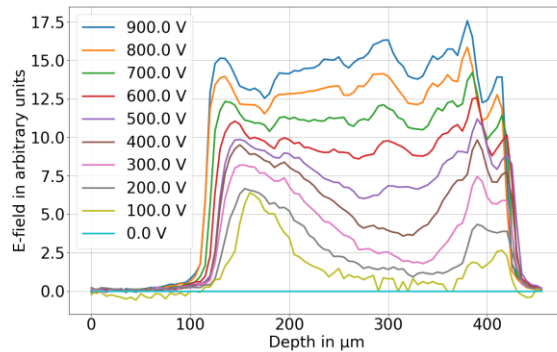
FZ 1e14



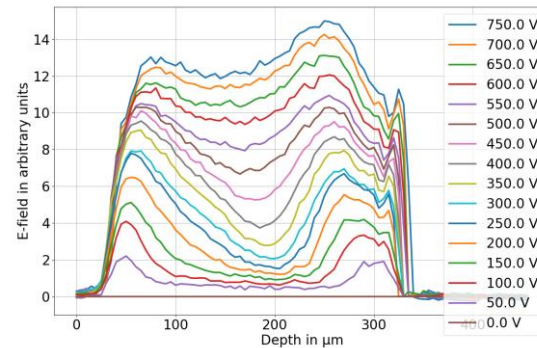
DOFZ 1e14



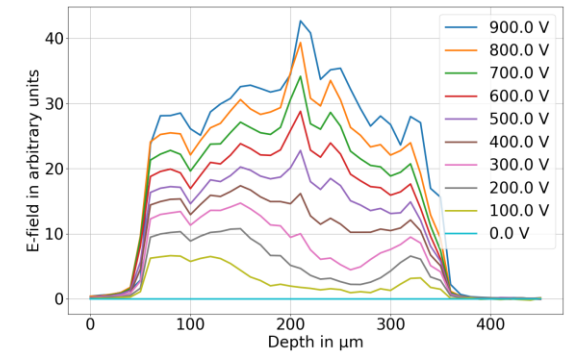
NIT 1e15



FZ 1e15



DOFZ 1e15



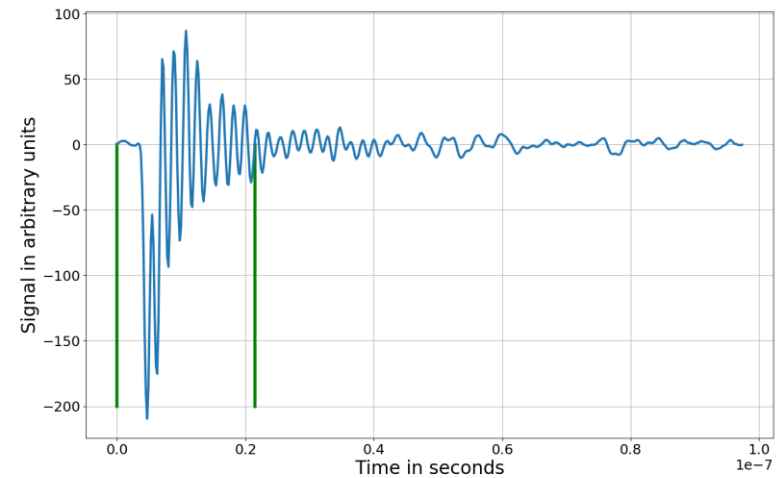
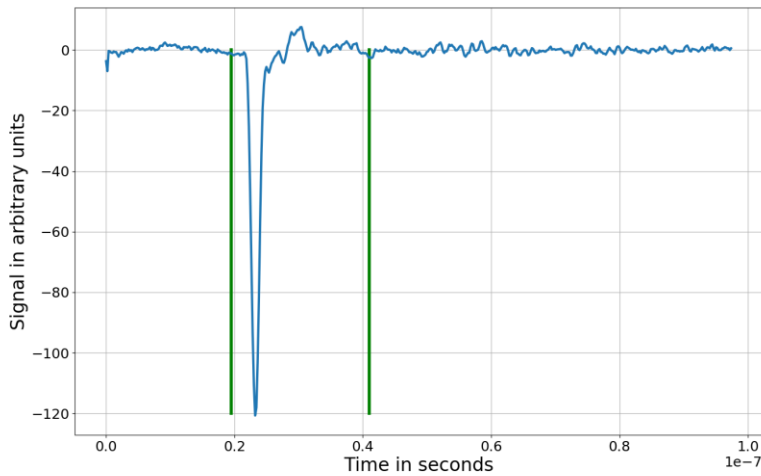
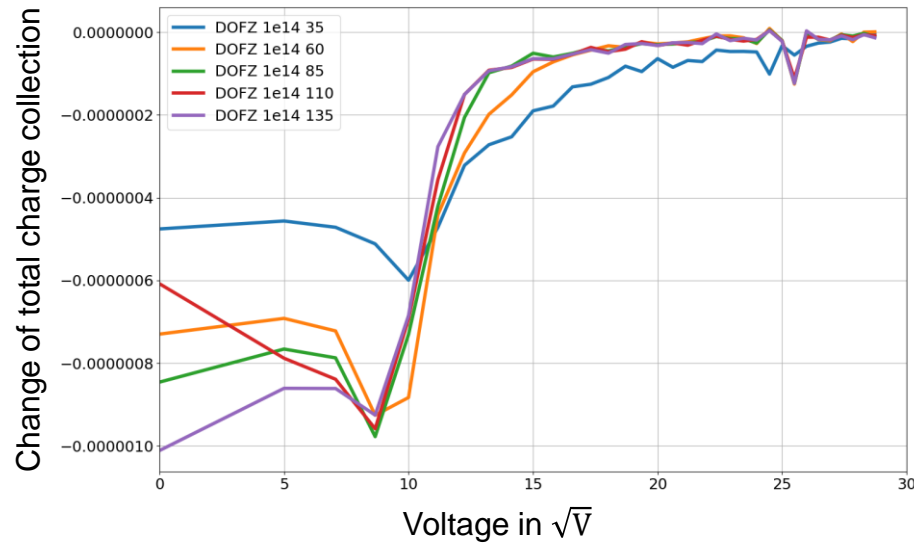
$$E(y) \propto \frac{I(y, t \sim 0)}{\alpha(V, I)}$$

Proton irradiated

- **Electrical tests:**
 - Under neutron irradiation FZ, NIT and DOFZ behave the same.
 - Under proton irradiation slower change of effective doping concentration observed for DOFZ.
 - Both show (small) variations in depletion voltage.
- **E-TCT:**
 - Already low fluencies show the formation of a double junction. For higher fluencies effect becomes more pronounced.
 - Slightly improved behavior of the $1e14 \text{ neq/cm}^2$ proton irradiated NIT sample compared to FZ.
- **Plans:**
 - Investigate oddities of $1e14 \text{ neq/cm}^2$ Nitrostrip and $1e15 \text{ neq/cm}^2$ neutron irradiated sensors.
 - Conduct E-TCT annealing study.
 - Measure E-field and charge collection temperature dependent.

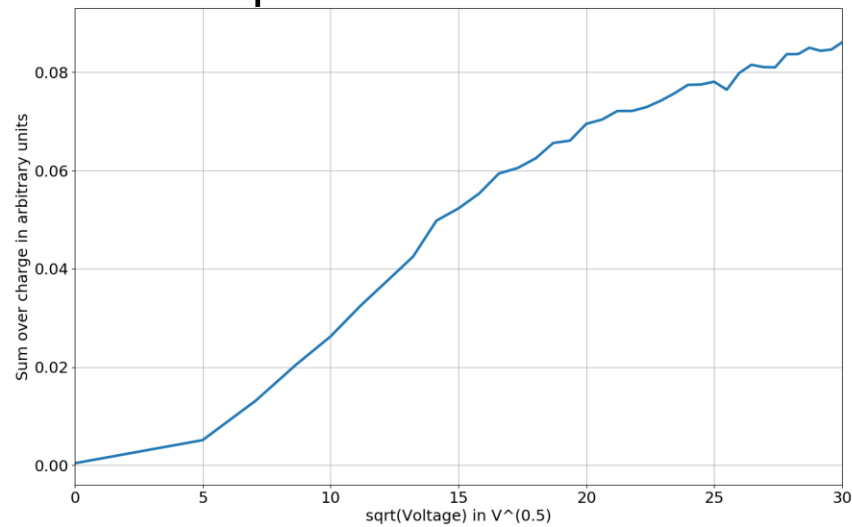
Backup

DOFZ 1e14

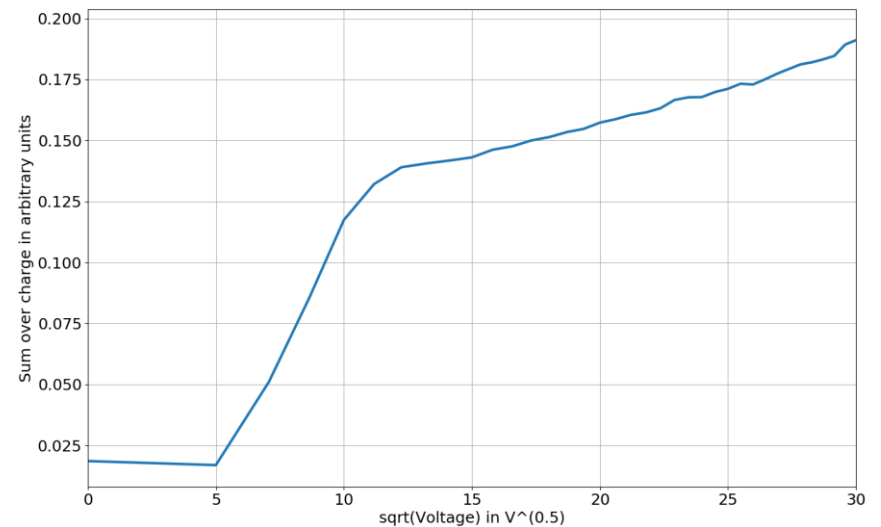


Nitrostrip depletion – neutron irradiated

Nitrostrip sensors 1e14

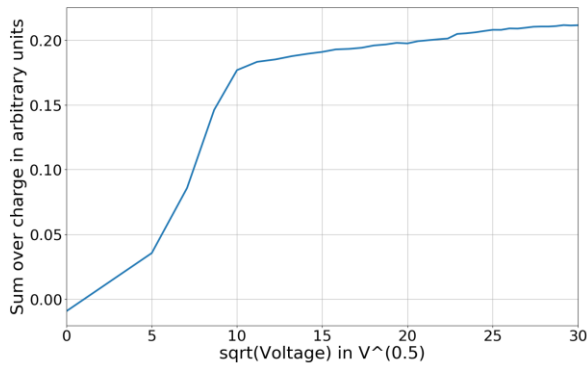


No annealing

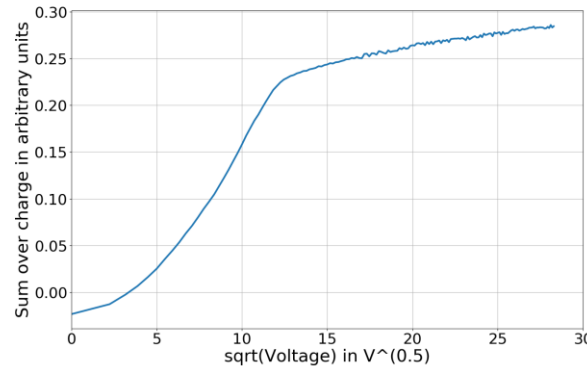


annealing ~7 days room temperature

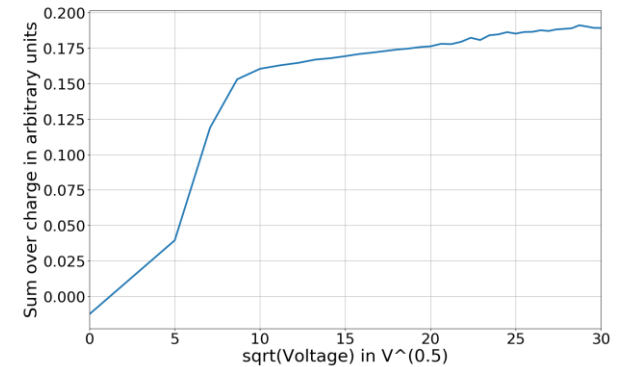
NIT 1e14 neq/cm²



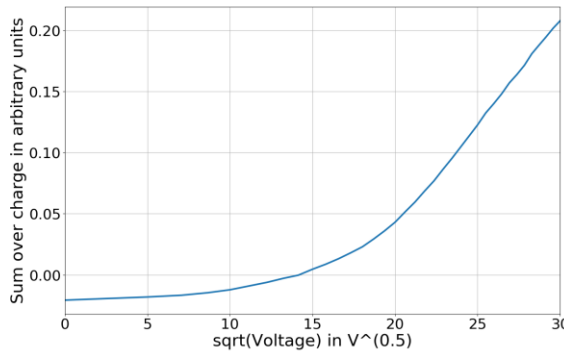
FZ 1e14



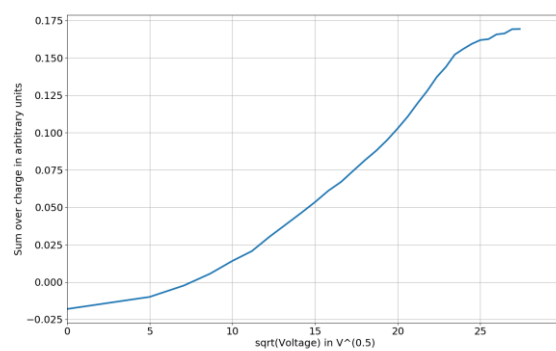
DOFZ 1e14



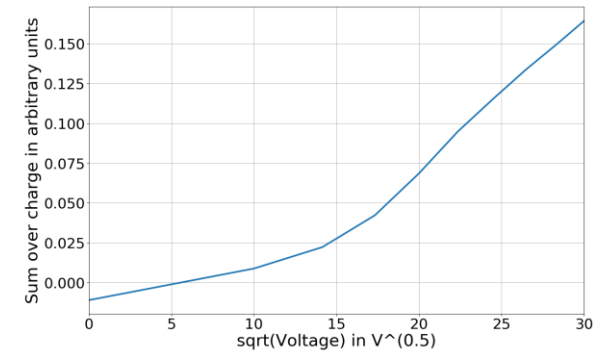
NIT 1e15



FZ 1e15



DOFZ 1e15

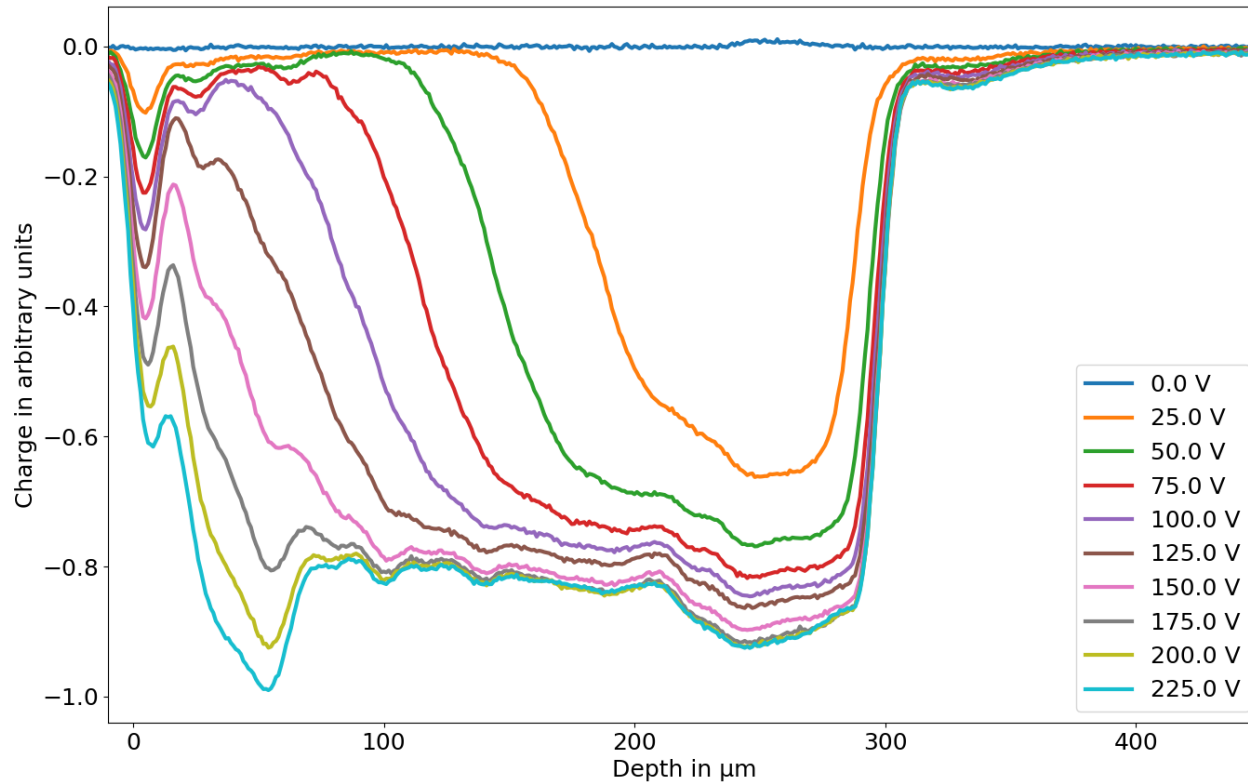


Integral over charge collection profile plotted against voltage.

Unirradiated Sensor

Diffusion Oxygenated Floatzone - Unirradiated

Back



Front