Nitrostrip

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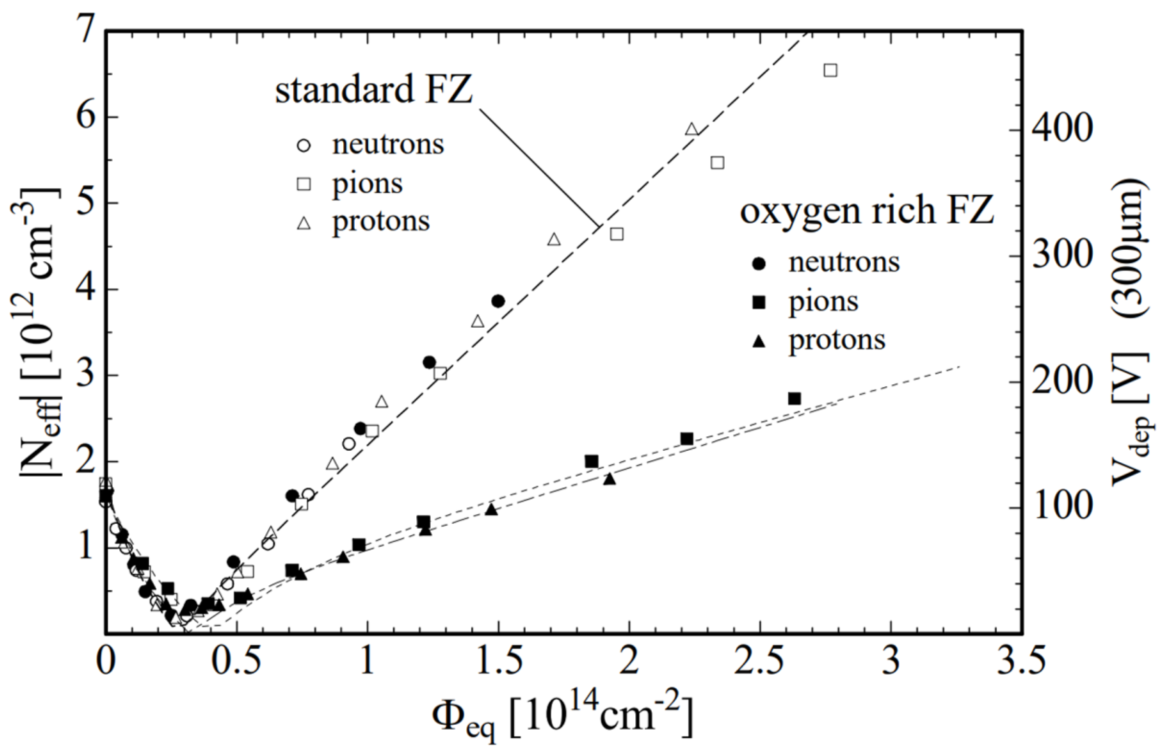
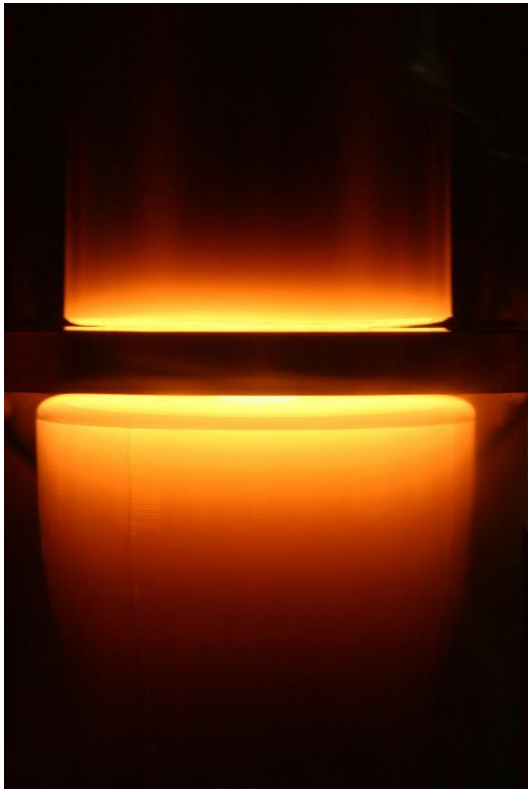
RD48 and foreign atoms

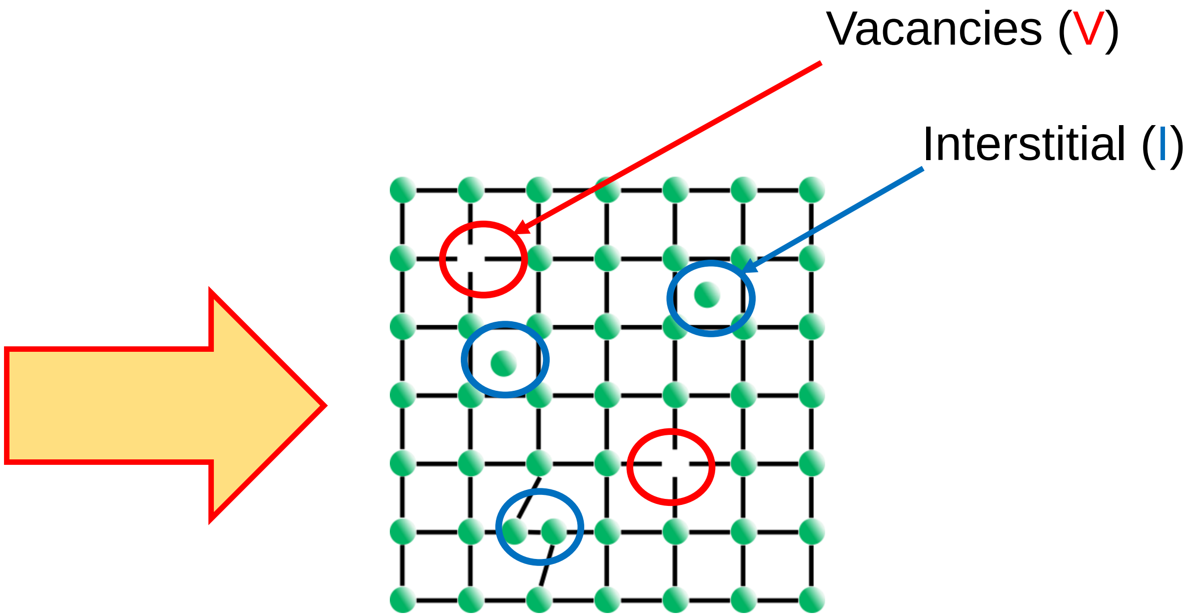


The RD48 Collaboration observed a change in the relation between fluence and effective doping concentration for oxygenated silicon.

This showed potential of enrichment with foreign atoms.

Silicon defects



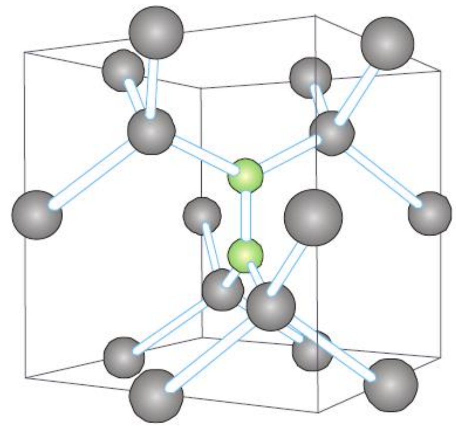


During crystal growth imperfections and defects are formed within the silicon.

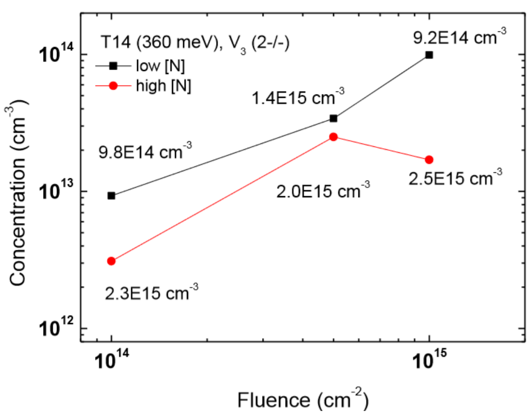
Nitrostrip - Nitrogen doped silicon

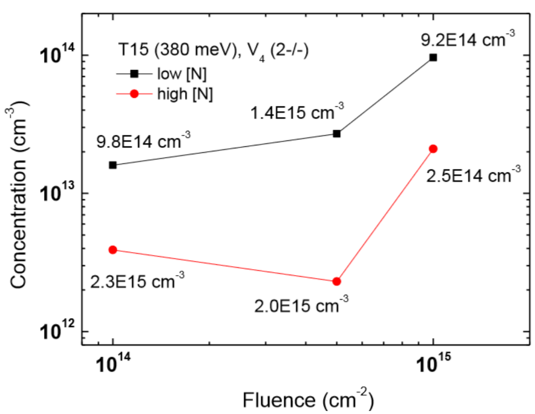
$$I + V \leftrightarrow 0 \quad (1)$$
$$2N_i \leftrightarrow N_2 \quad (2)$$
$$N_s + N_i \leftrightarrow N_2V \quad (3)$$
$$N_2 + V \leftrightarrow N_2V \quad (4)$$
$$N_2V + I \leftrightarrow N_2 \quad (5)$$

N_i=single interstitial nitrogen
N_s=substitutional nitrogen



M. Kwestarz, RD50 Workshop, November 2014





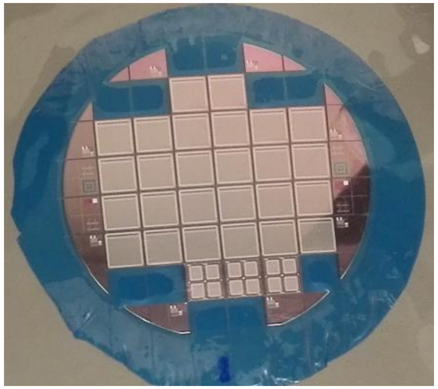
Kaminski shows:
Nitrogen rich silicon lower defect density than low nitrogen silicon.

Samples and irradiation facilities

Wafers	Label	Substrate	Type	Resistivity [Ω·cm]	Nitrogen content [N/cm^3]
1-6	FZ	Float Zone	n-type	2000-2400	$<2x10^{14}$
7-12	NIT	FZ Nitrogenated	n-type	1500-1900	$(1.3-1.6)x10^{15}$
13-18	DOFZ	FZ Oxygenated	n-type	2000-2400	$<2x10^{14}$
19-24	MCz	Magnetic Czochralski	n-type	800-1000	unknown

Irradiation done in:

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



Measurement campaign

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

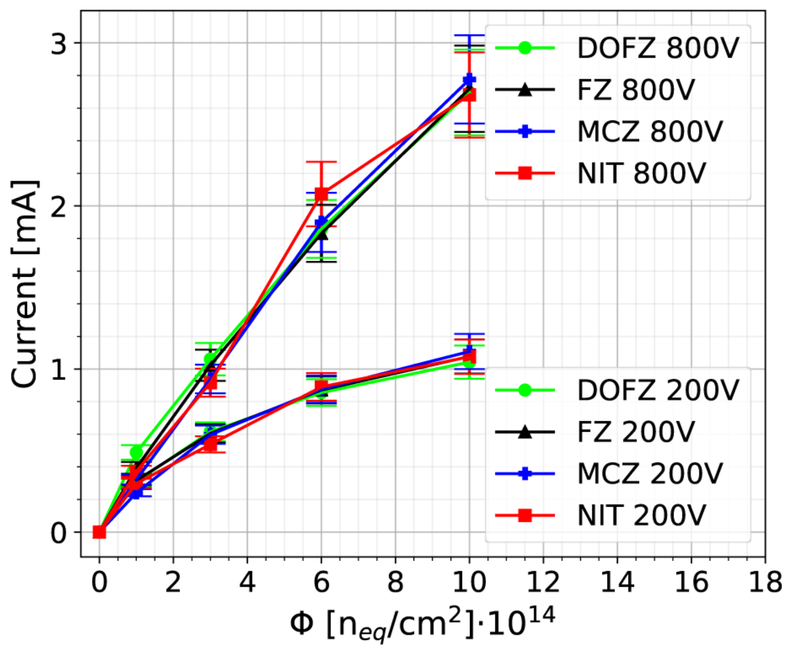
Planned measurements:

- IV curves
- Source (AliBaVa)
- Edge **T**ransient **C**urrent **T**echnique (Edge-TCT)
- **T**hermally **S**timulated **C**urrent technique (TSC)

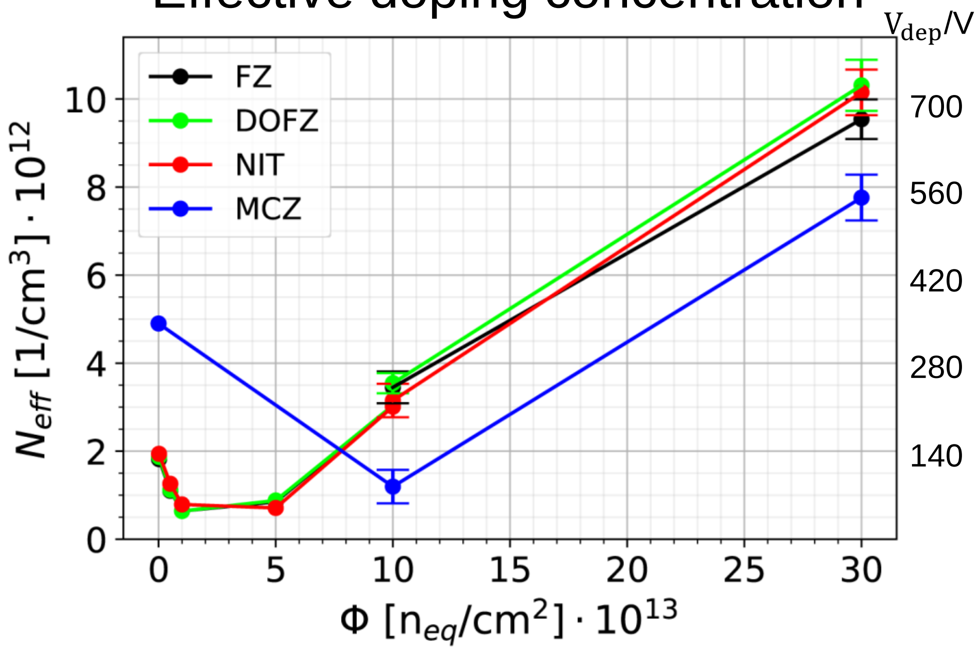
Measurements repeated for fluence, detector type and irradiation facility!

Electrical tests – neutron irradiated

Current comparison



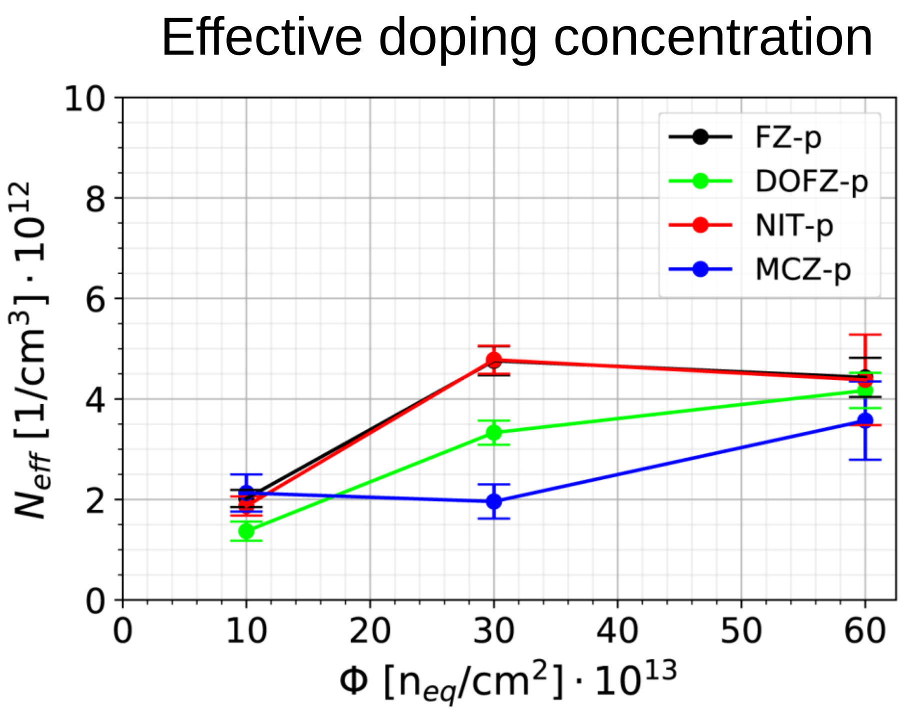
Effective doping concentration



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

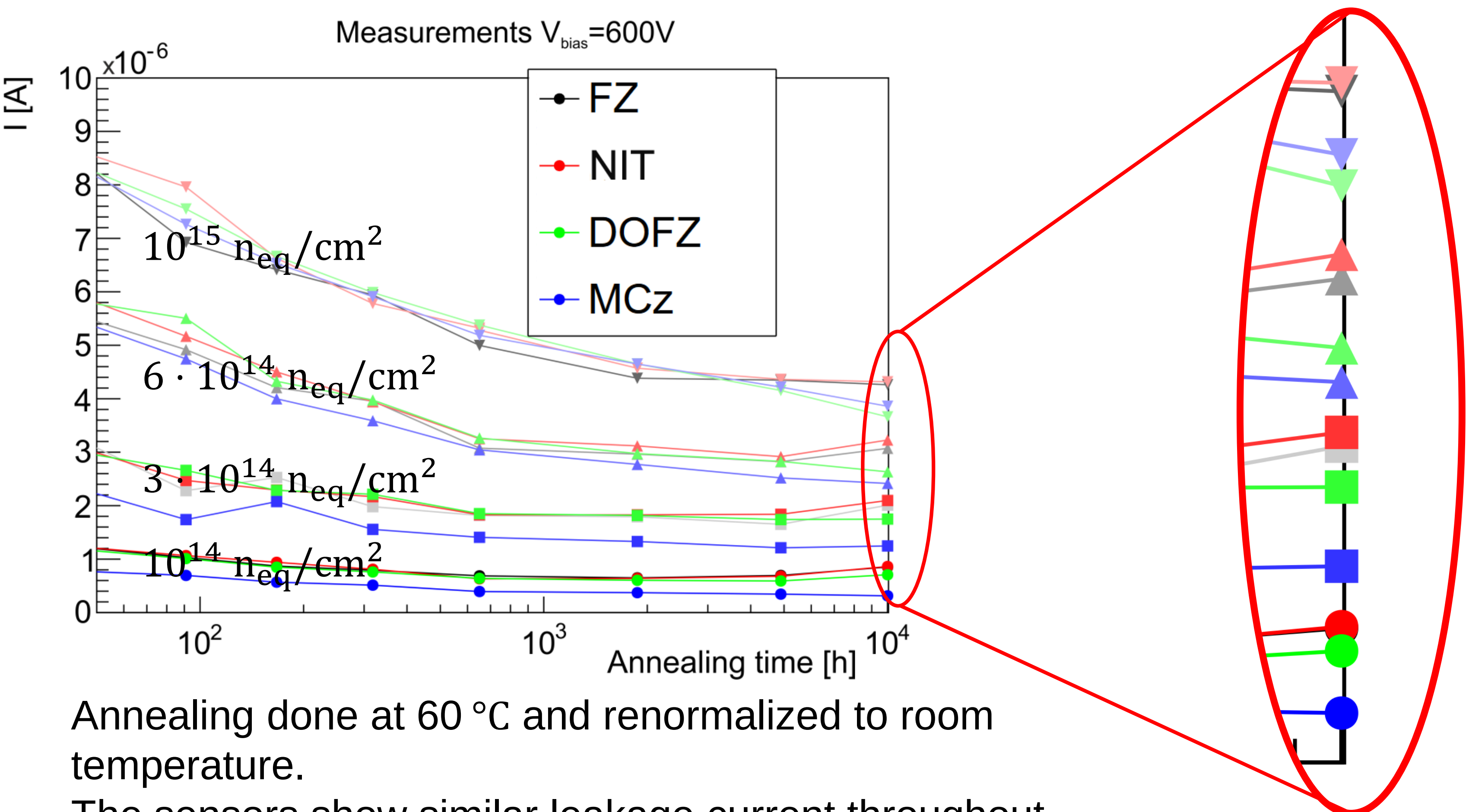
No large difference in the effective doping concentration caused by different FZ processing techniques.

Electrical tests – proton irradiated



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

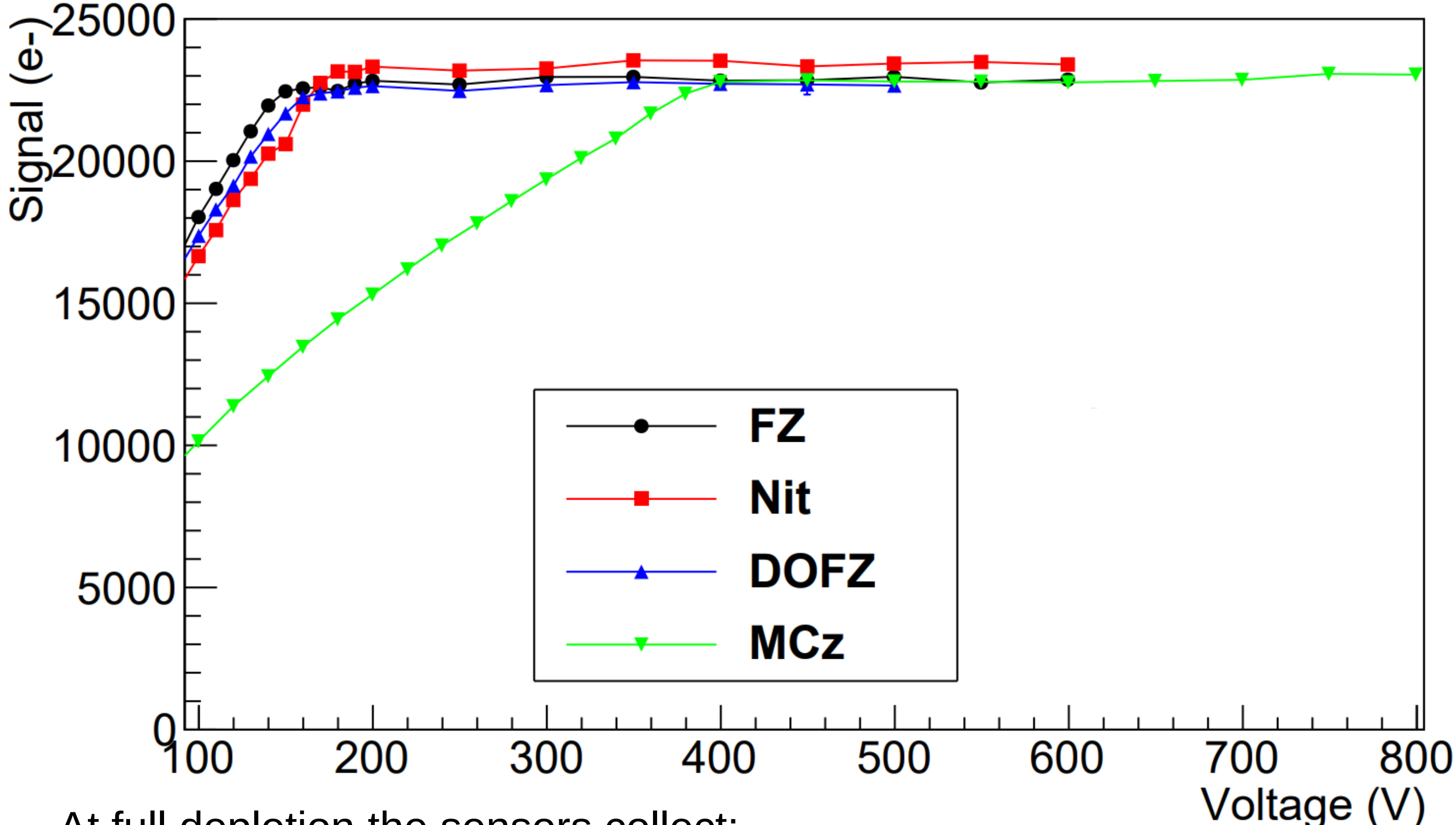
IV annealing - proton irradiated



Annealing done at 60 °C and renormalized to room temperature.
The sensors show similar leakage current throughout the annealing.


UGH

Source measurements



At full depletion the sensors collect:

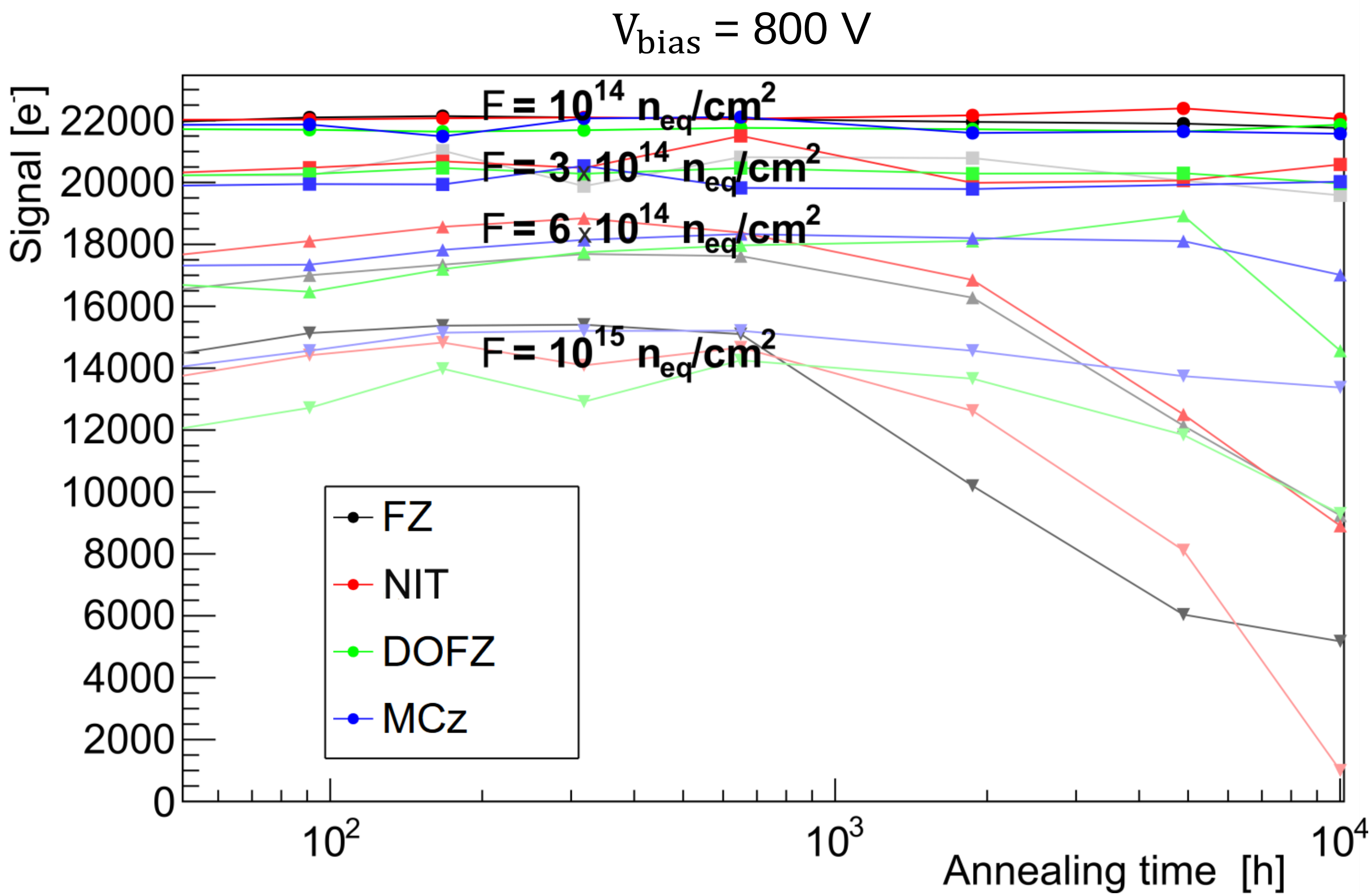
FZ ~ 23k electrons

Nit ~ 23.5k electrons

DOFZ ~ 23k electrons

MCz ~ 23k electrons

Source measurement- proton irrad.



For higher radiation doses DOFZ and MCz show advantages in terms of charge collection.

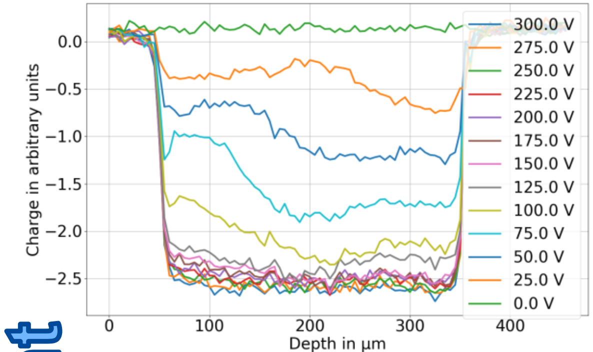
Edge-TCT measurements

Neutron irradiated samples

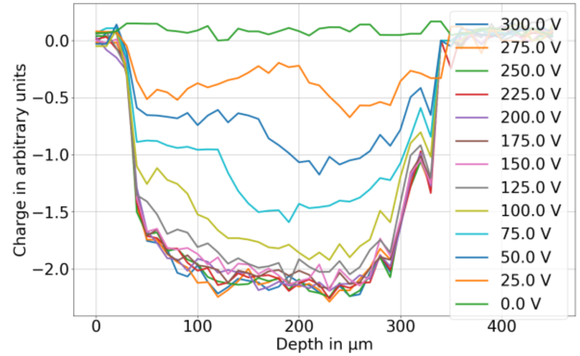
TCT-charge collection profile

Front

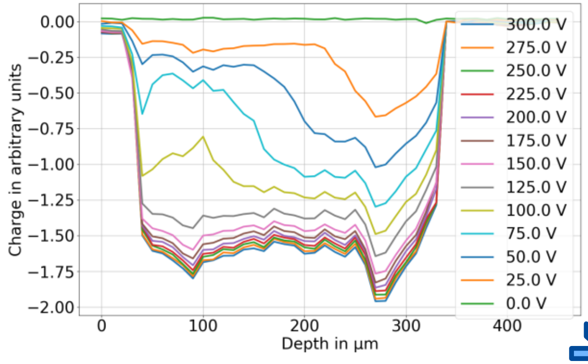
NIT 1e14 neq/cm^2



FZ 1e14

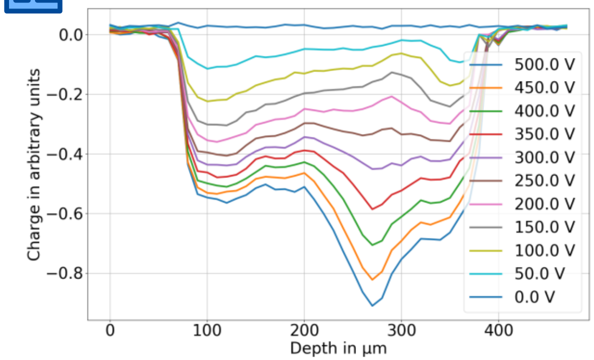


DOFZ 1e14

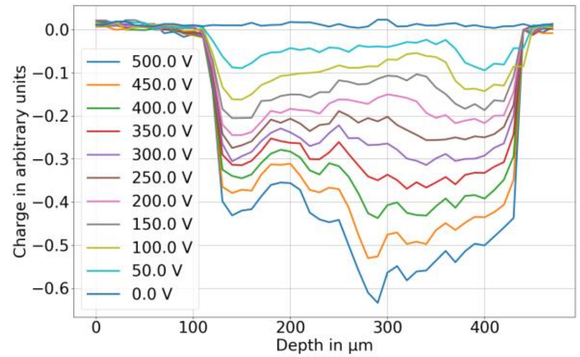


Back

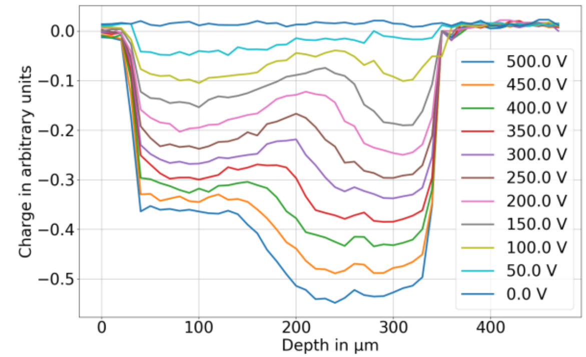
NIT 1e15



FZ 1e15



DOFZ 1e15



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

Integration window: 21.5 ns

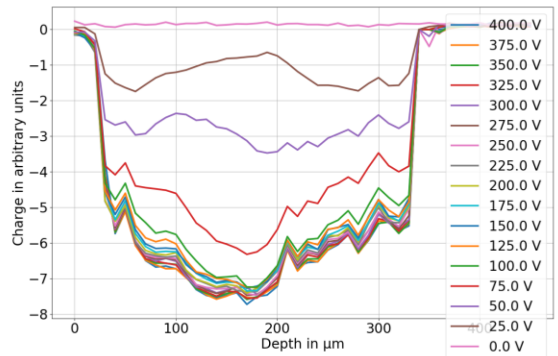
Neutron irradiated

Proton irradiated samples

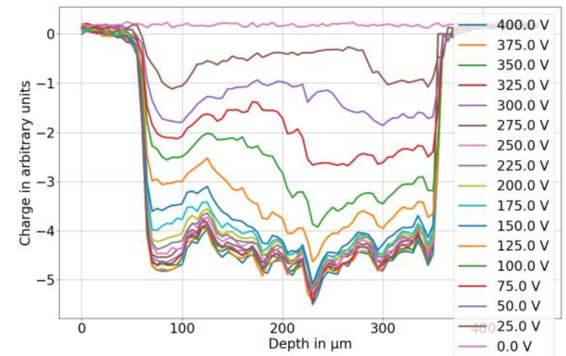
Irradiation done at PS Cern.

TCT-charge collection profile

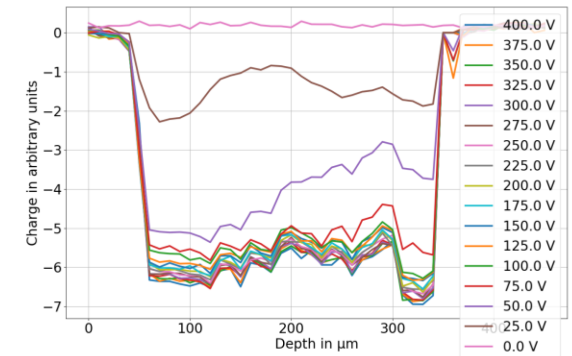
NIT 1e14 neq/cm^2



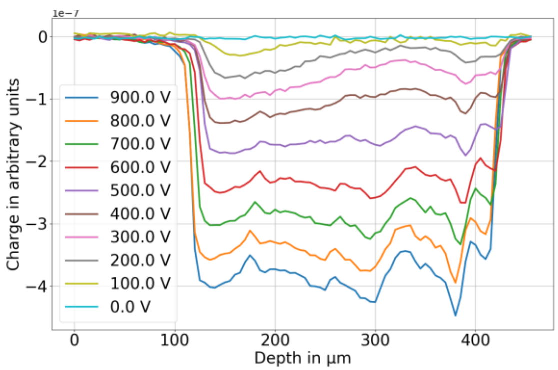
FZ 1e14



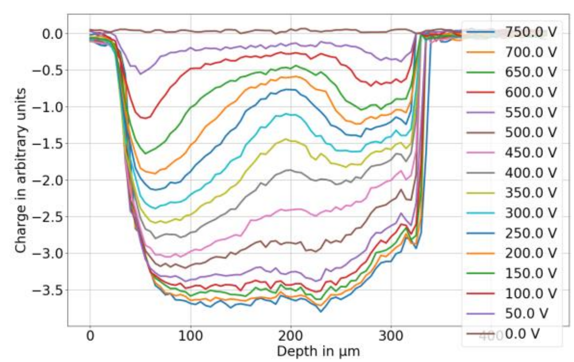
DOFZ 1e14



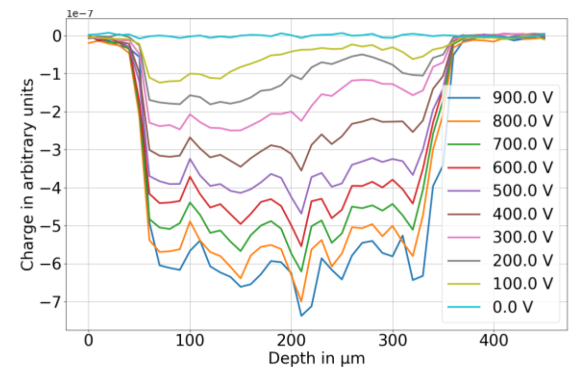
NIT 1e15



FZ 1e15



DOFZ 1e15



Measured @ ~(-20 ± 1) °C

Integration window: 21.5 ns

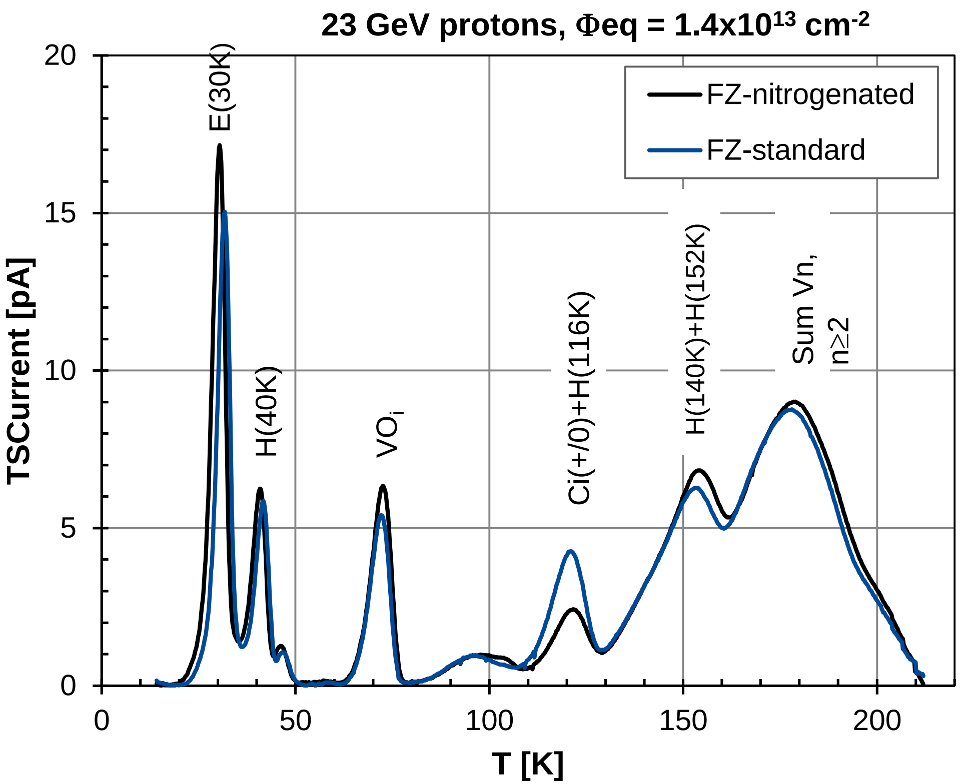
Proton irradiated


UGH

TSC measurements

Hamburg setup

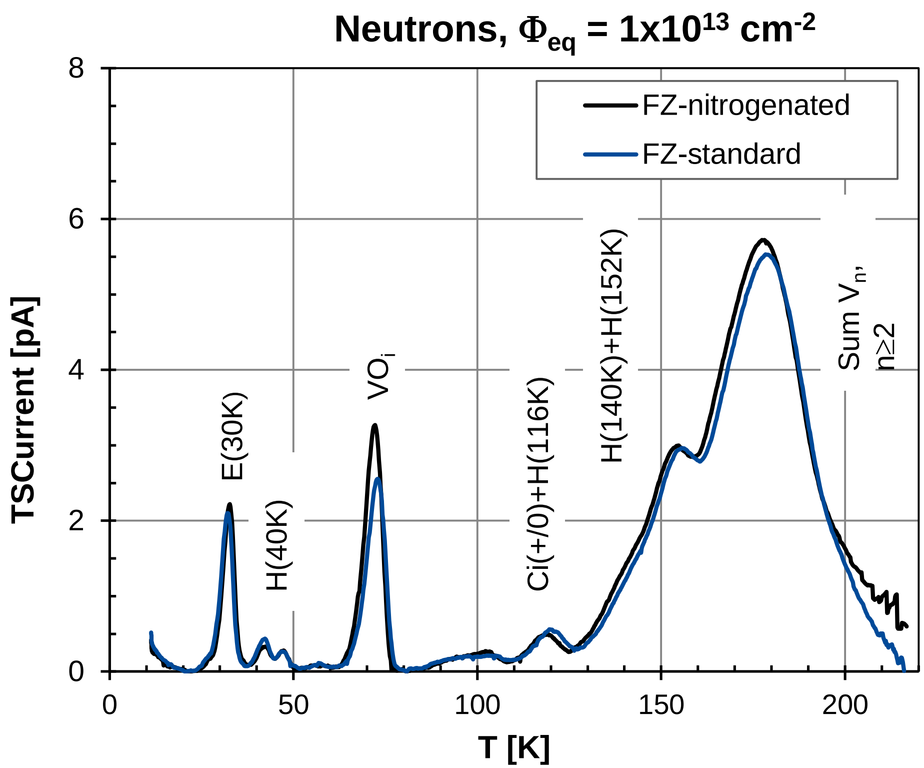
TSC –Spectra, 23 GeV protons



Defect	FZ-NIT	FZ-STD
E(30K)	9.5×10^{11}	7.7×10^{11}
H(40K)	4.0×10^{11}	3.4×10^{11}
VO	5.2×10^{11}	4.2×10^{11}
Ci+H(116K)	3.4×10^{11}	5.9×10^{11}
Sum(H)	1.6×10^{12}	1.4×10^{12}
Sum(Vn)	3.7×10^{12}	3.6×10^{12}

Vacancy defect concentration remains unchanged after enrichment with nitrogen.

TSC –Spectra, 1 MeV neutrons



Defect	FZ-NIT	FZ-STD
E(30K)	$1.1x10^{11}$	$1.1x10^{11}$
H(40K)	$2.0x10^{10}$	$2.4x10^{10}$
VO	$2.5x10^{11}$	$2.0x10^{11}$
Ci+H(116K)	$6.5x10^{10}$	$7.3x10^{10}$
Sum(H)	$5.7x10^{11}$	$6.0x10^{11}$
Sum(Vn)	$2.3x10^{12}$	$2.2x10^{12}$

The neutron irradiated sample confirms that vacancy defect concentration remains unchanged after enrichment with nitrogen.

Conclusion & Outlook

- TSC measurements leave doubts, if desired nitrogen content was injected in the sensors!
- Electrical tests:
  - Under neutron irradiation FZ, NIT and DOFZ behave the same.
  - Under proton irradiation slower change of effective doping concentration observed for DOFZ.
- Source measurements:
  - Improved behavior seen in DOFZ, but NIT shows same characteristics as FZ.
- 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 neq/cm^2 proton irradiated NIT sample compared to FZ.
- Plans:
  - Investigate Nitrogen content of NIT samples at EAG.

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