Caracterization of neutron irradiated IMB-CNM SiC planar diodes with TPA-TCT

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Outline

- Sample description
- Experimental setup
- Raw data corrections
- Characterization results
  - → Non irradiated detectors
  - → Irradiated detectors
- Discussion and Summary

Silicon carbide detectors

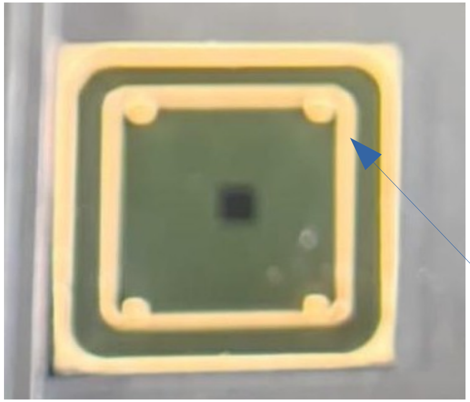
SiC sensors:

CNM SiC planar pad diodes P in N

Neutron-irradiated (ATI Vienna) July/Aug 2021

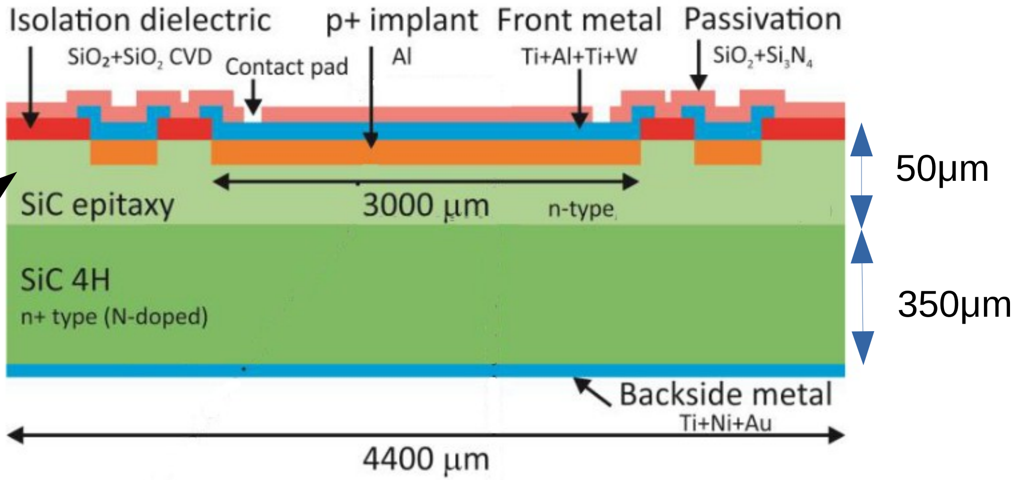
Samples (**non metallized contact**):

→ 1MW2 (Non-irradiated)
→ F2W1 (1e15 n_{eq}/cm^2)
→ K6W1 (4e14 n_{eq}/cm^2)

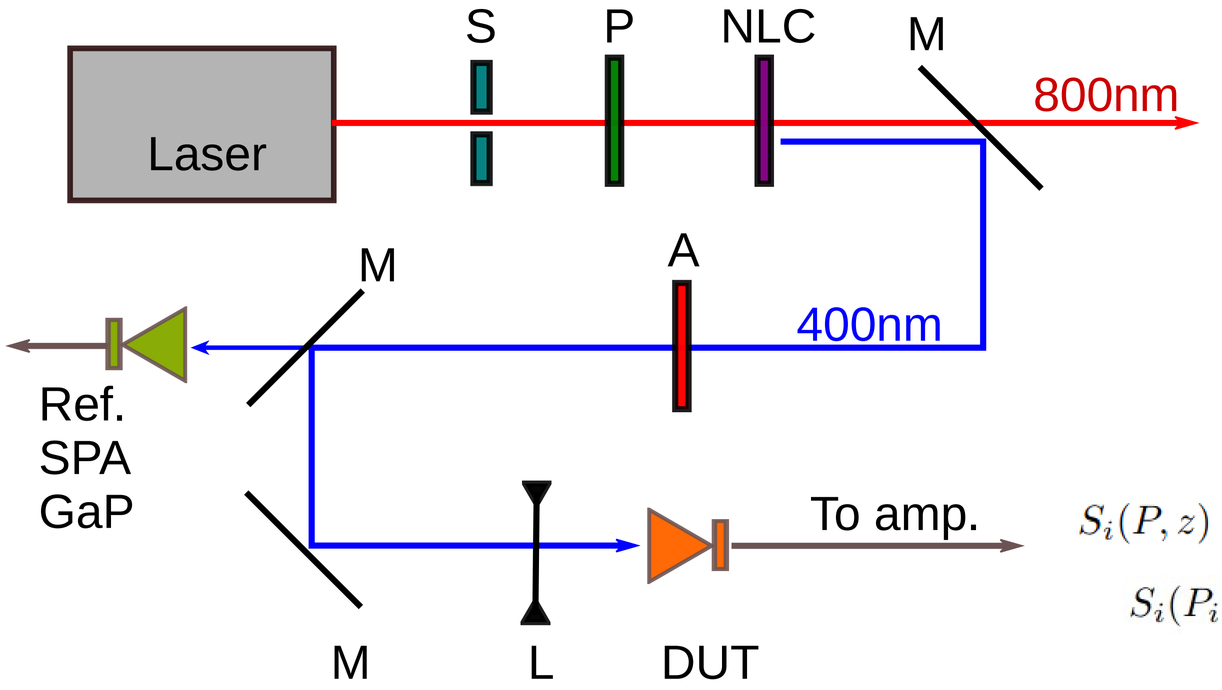


Signal collection ring

N_{eff} = 1.5e14 /cm³



Experimental setup for TPA-TCT



S: Shutter
P: Polarizer
NLY: Non linear crystal
M: Mirrors
A: Attenuator
Ref.: Laser power reference
L: focusing lens
DUT: Device under test

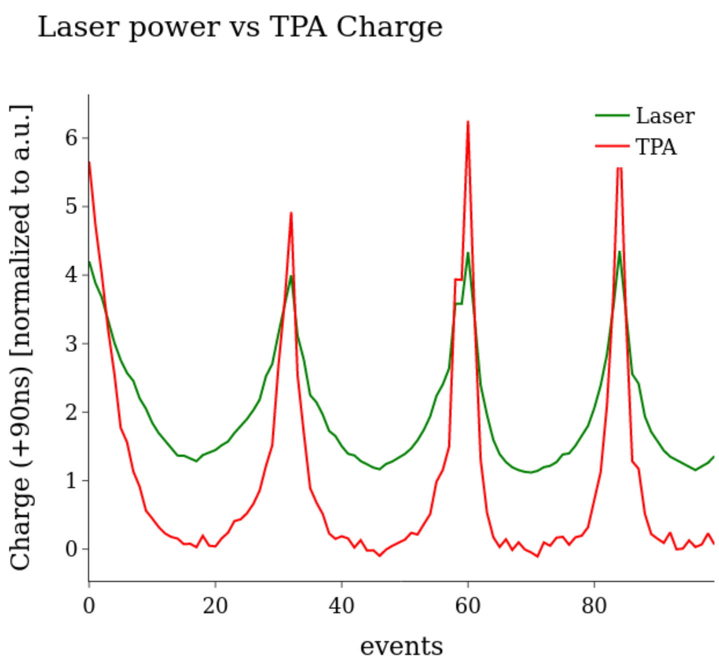
$$S_i(P,z) = S_i^{SPA}(P) + S_i^{TPA}(P,z)$$

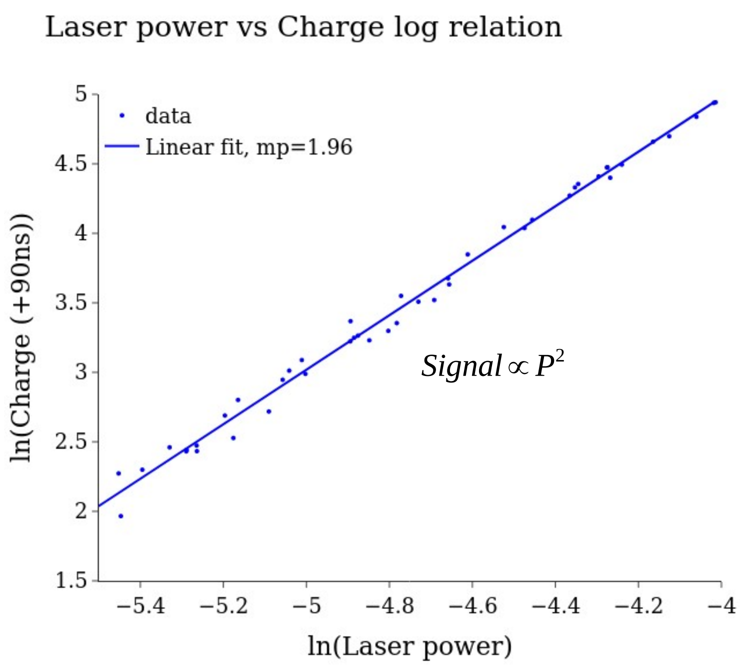
$$S_i(P_i,z_i) = \alpha P_i + \beta(z_i)P_i^2$$

Raw data corrections: Energy fluctuations

→ Analysis of short term variations on laser's power emission.
→ Power variation done with a variable attenuator

→ Correlation between the laser power and the signal.
→ Power of two correlation → TPA



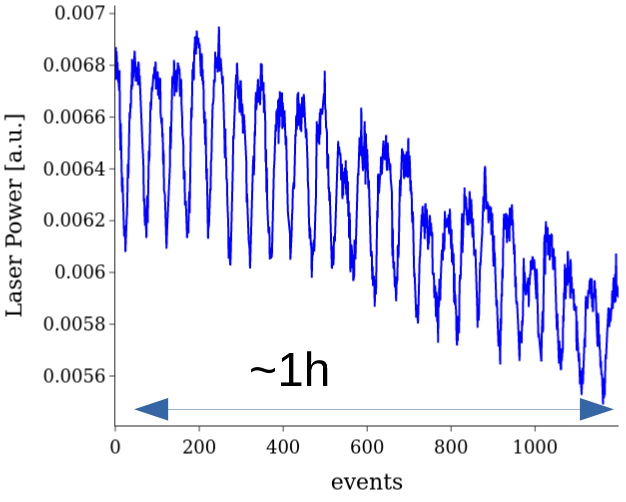


Raw data corrections: laser temporal instabilities

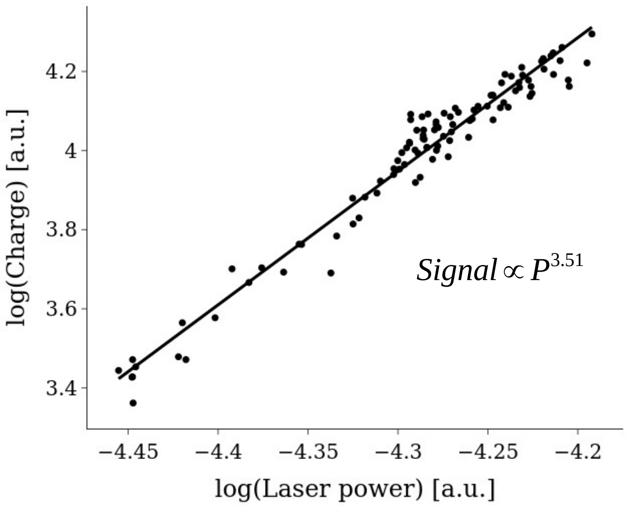
In longer time periods (several minutes) the temporal profile of the laser fluctuates
Laser oscillator at the end of its life time (will be replaced in two months)

→ These fluctuations cause variations in the TPA charge generation, which do not correlate quadratically.

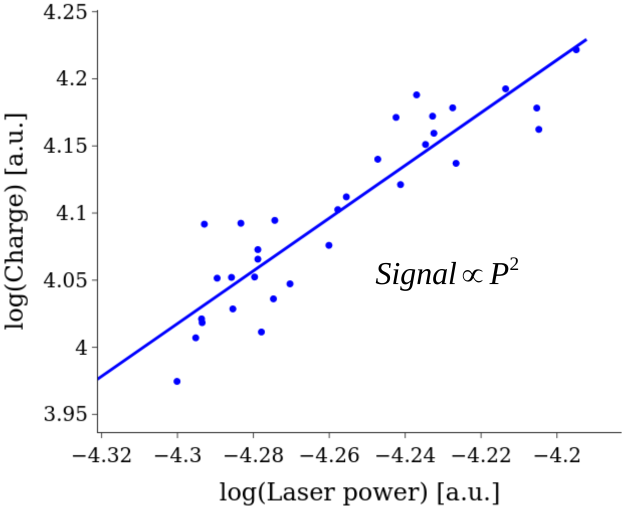
Laser power evolution



Temporal and power non-stability

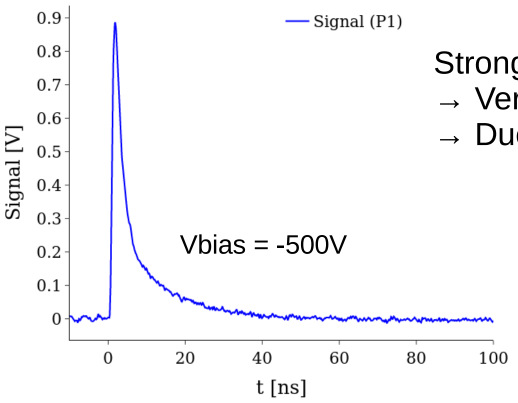


Power non-stability



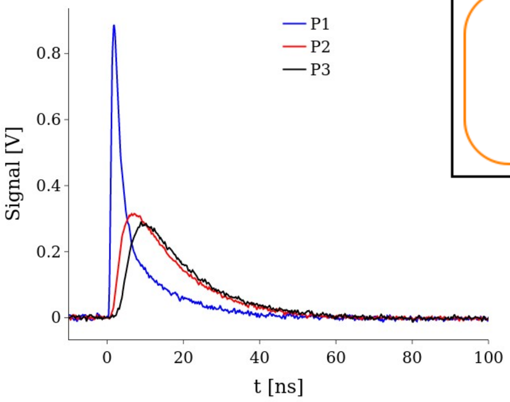
Raw data: Transient currents

1MW2 - Characteristic WF

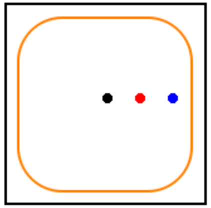


Strong RC behavior
→ Very long signals (~90ns)
→ Due to the large implant resistivity

1MW2 - Transient currents

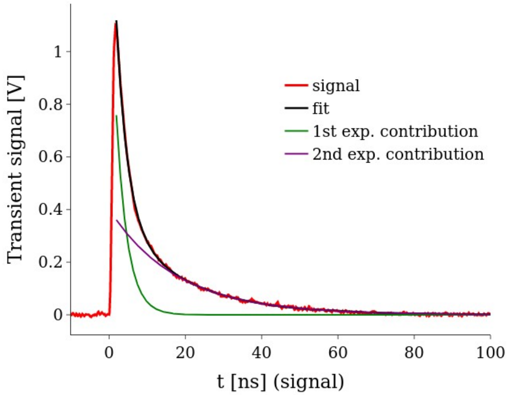


1MW2 Scheme:



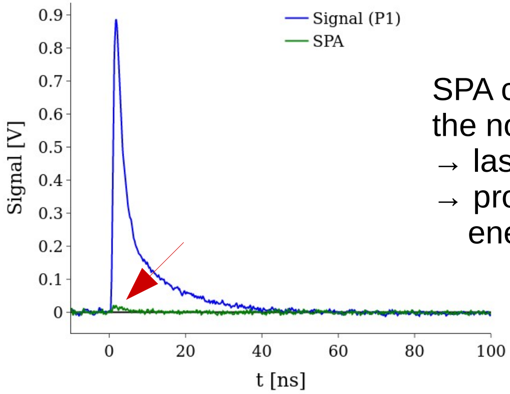
Positional dependence of the signal profile due RC attenuation

K6W1 (SiC, Vbias = -1kV) WF



Double exp. Fit.

1MW2 - TPA-SPA comparison

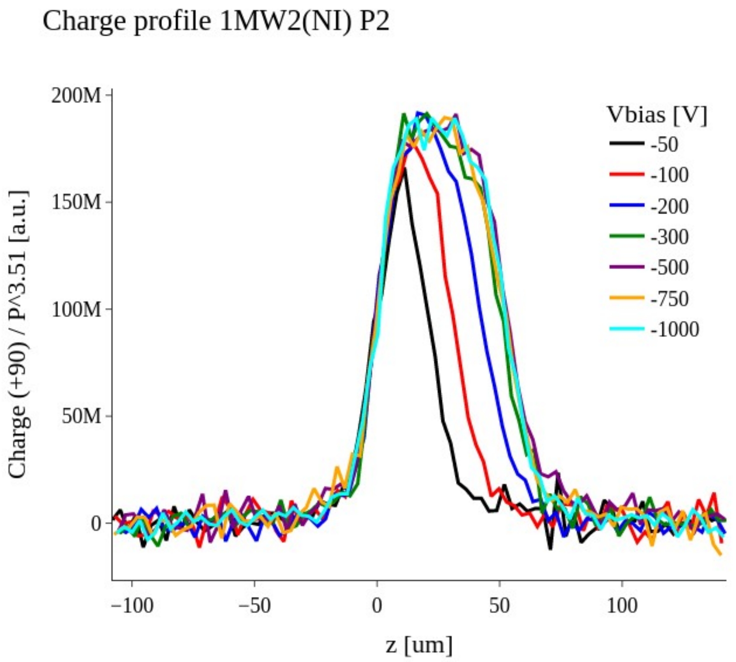


SPA contribution is present even in the non irradiated detector
→ laser spectrum bandwidth
→ proximity to the band gap energy

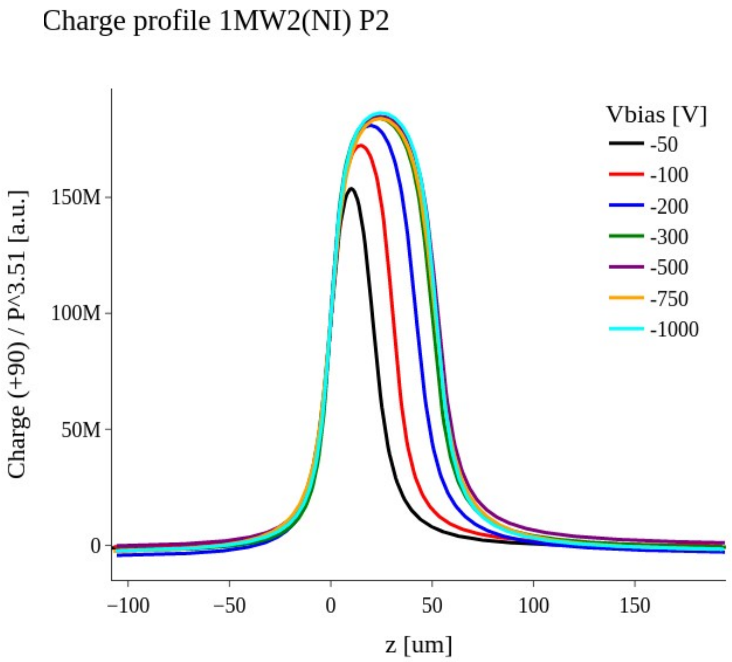
Z-scan charge profiles: non-irradiated diodes

$$Q(z) \propto tan^{-1}\left(\frac{z - z_r}{a}\right) + tan^{-1}\left(\frac{z_l - z}{b}\right)$$

$$z_r - z_l = z_{dep}$$



Fit

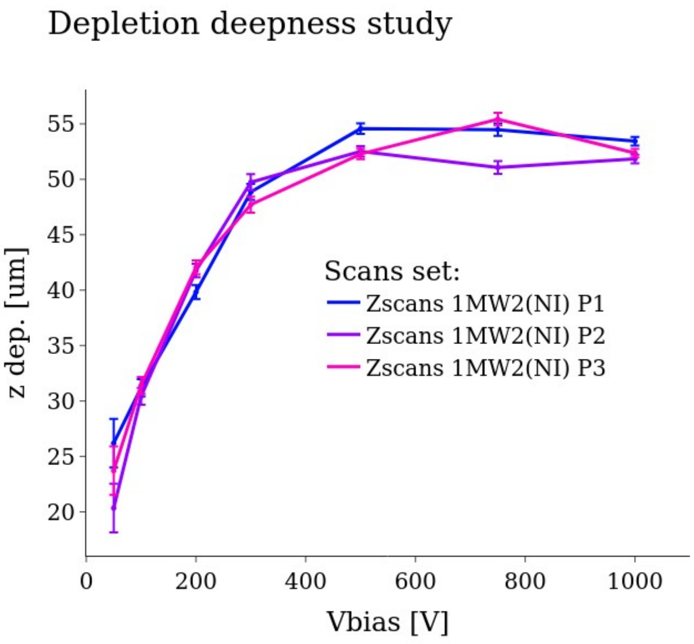


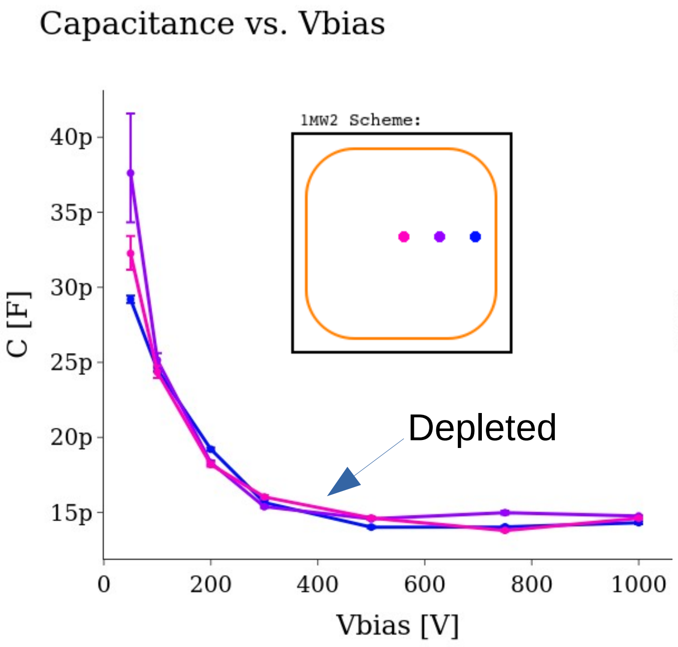
Development of a Two-Photon Absorption - TCT system and Study of Radiation Damage in Silicon Detectors
- Wiehe, Moritz Oliver - CERN-THESIS-2021-225

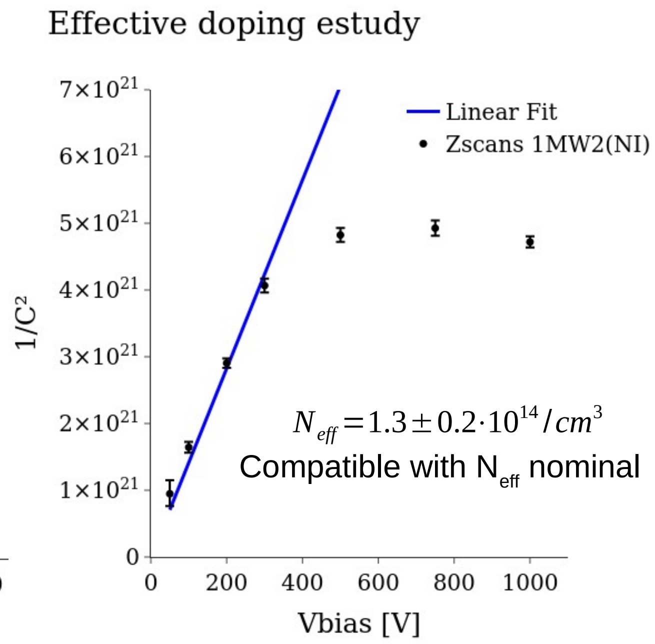
Depletion width vs bias: non irradiated

→ Diode behavior
→ Diode fully depleted between 300-500 volts.
→ Homogeneity in the sensor depletion

→ Capacitance value matches the direct capacitance measurements
→ Effective doping of the bulk over the real doping value: SiC vs Si at room temperature



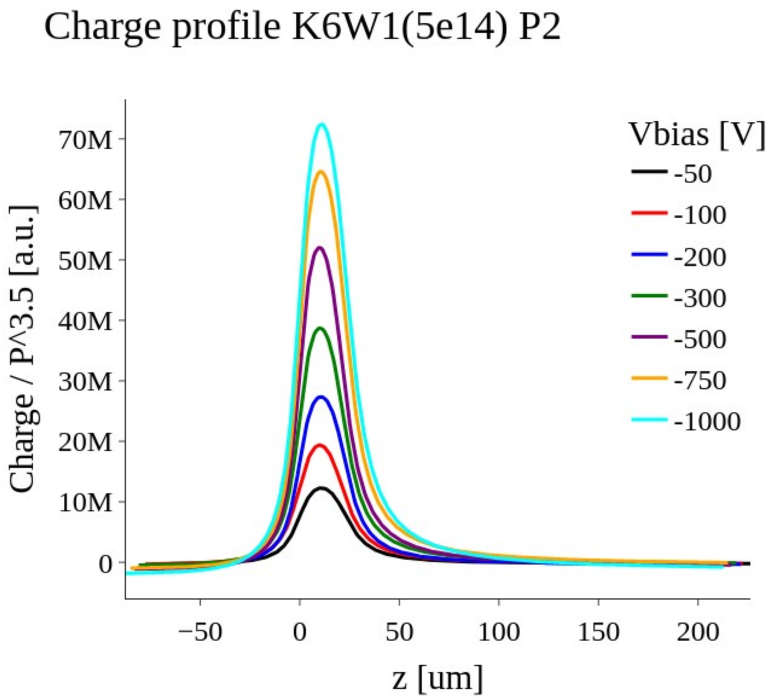


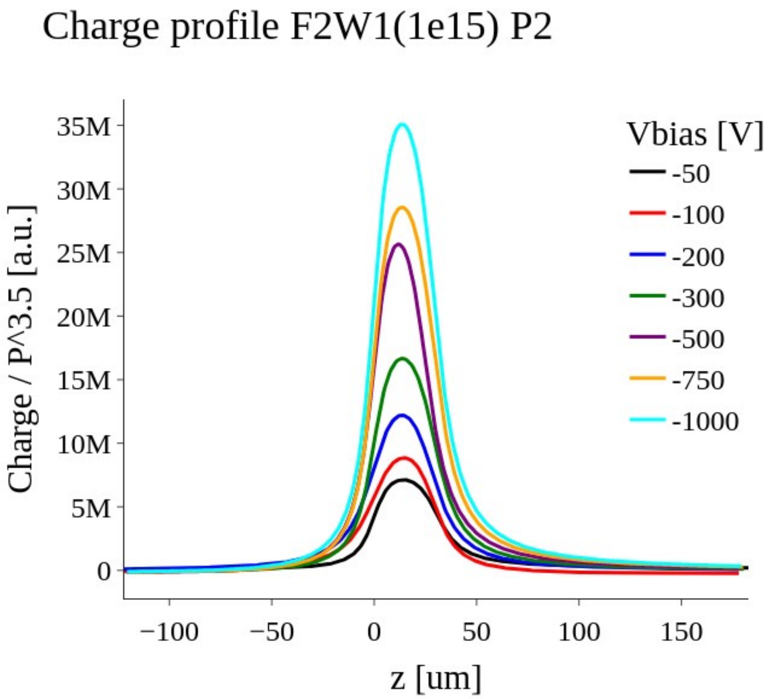


Z-scan charge profiles: irradiated diodes

→ The diode behavior lost!
→ Capacitor-like charge collection
→ No charge collection saturation with bias voltage

→ Same effect in both detectors
→ Charge collection drops with irradiation
→ Worse fits for F2W1 because the SNR is lower.

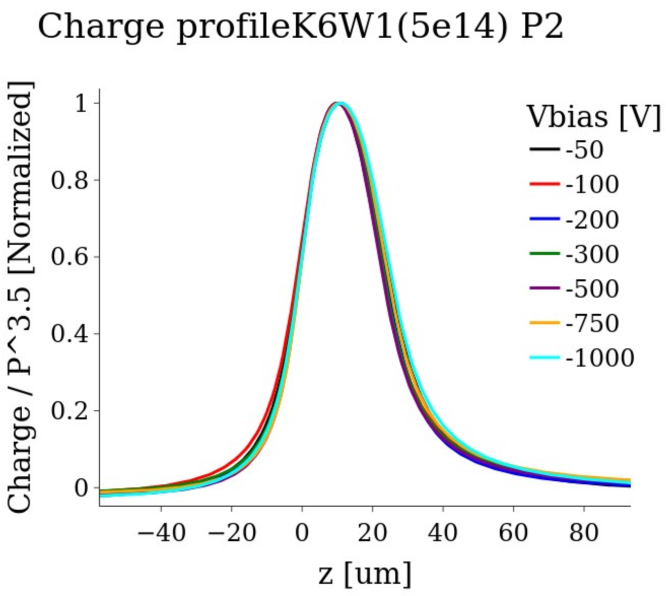




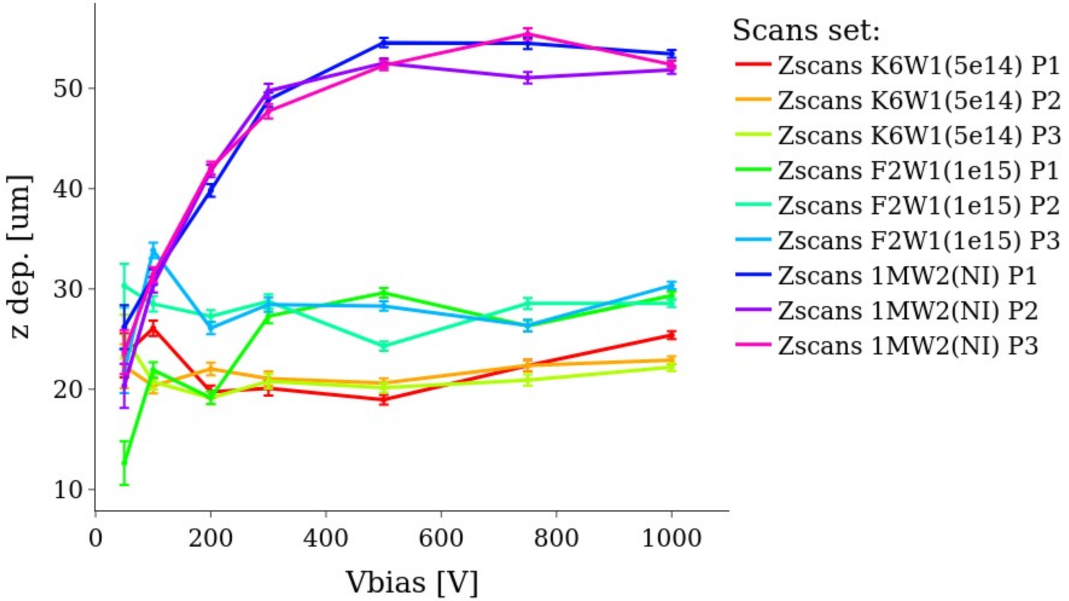
Depletion width vs bias: irradiated

→ Both figures show that the depletion width is constant for the irradiated detectors.

→ The depletion width is different if we compare irradiated and non-irradiated detectors, but also between the irradiated ones.



Depletion width vs bias



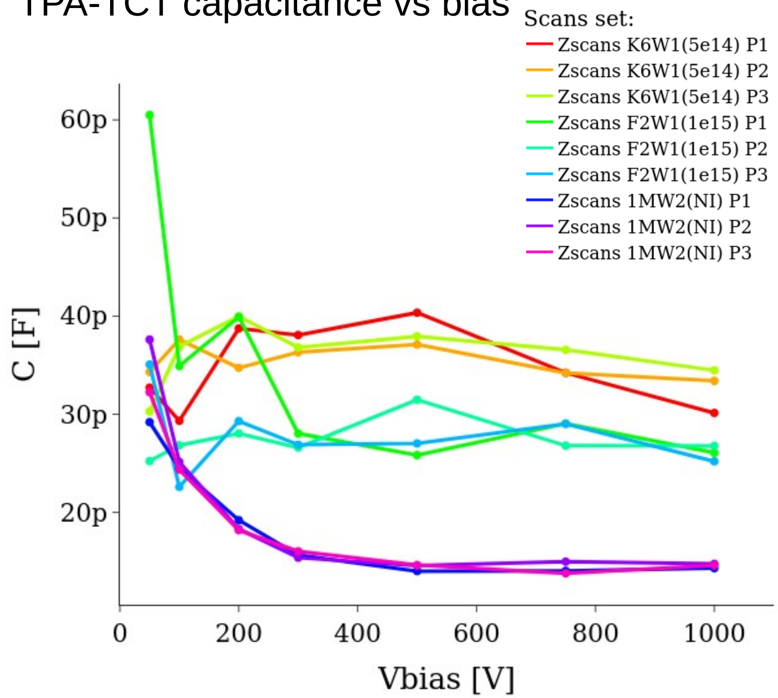
Electrical capacitance vs TPA capacitance

→ Very similar capacitance values for non-irradiated. The difference could be attributed to an error in the estimation of the effective area of the diode.

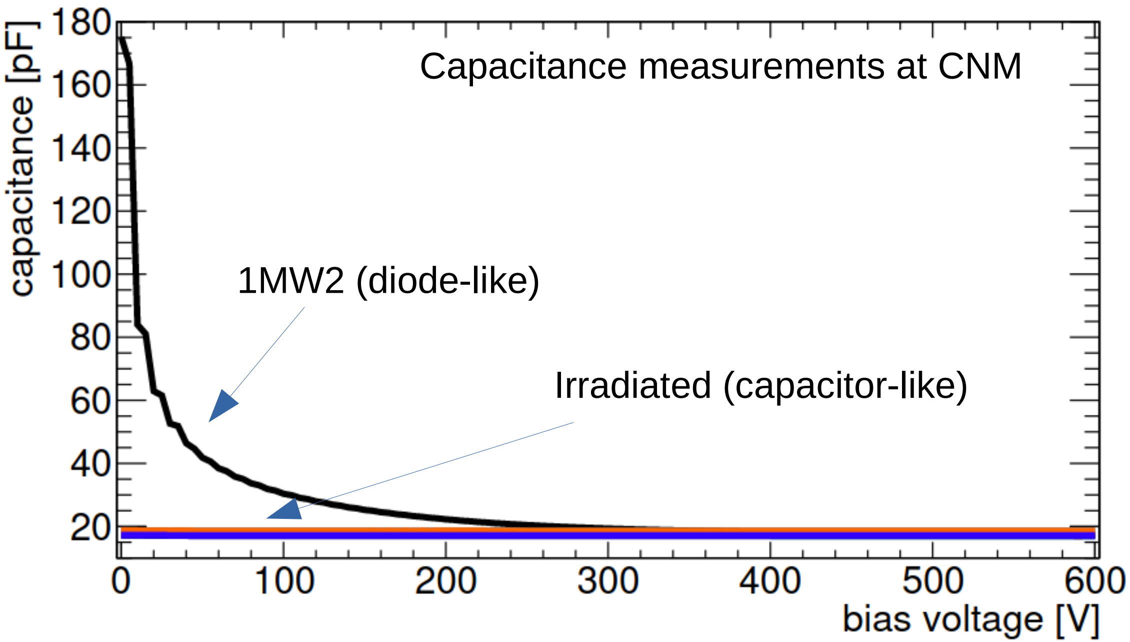
→ Irr: Constant capacitance (as z-dep) but different values.

→ Final TPA-TCT capacitance different for each fluence

TPA-TCT capacitance vs bias



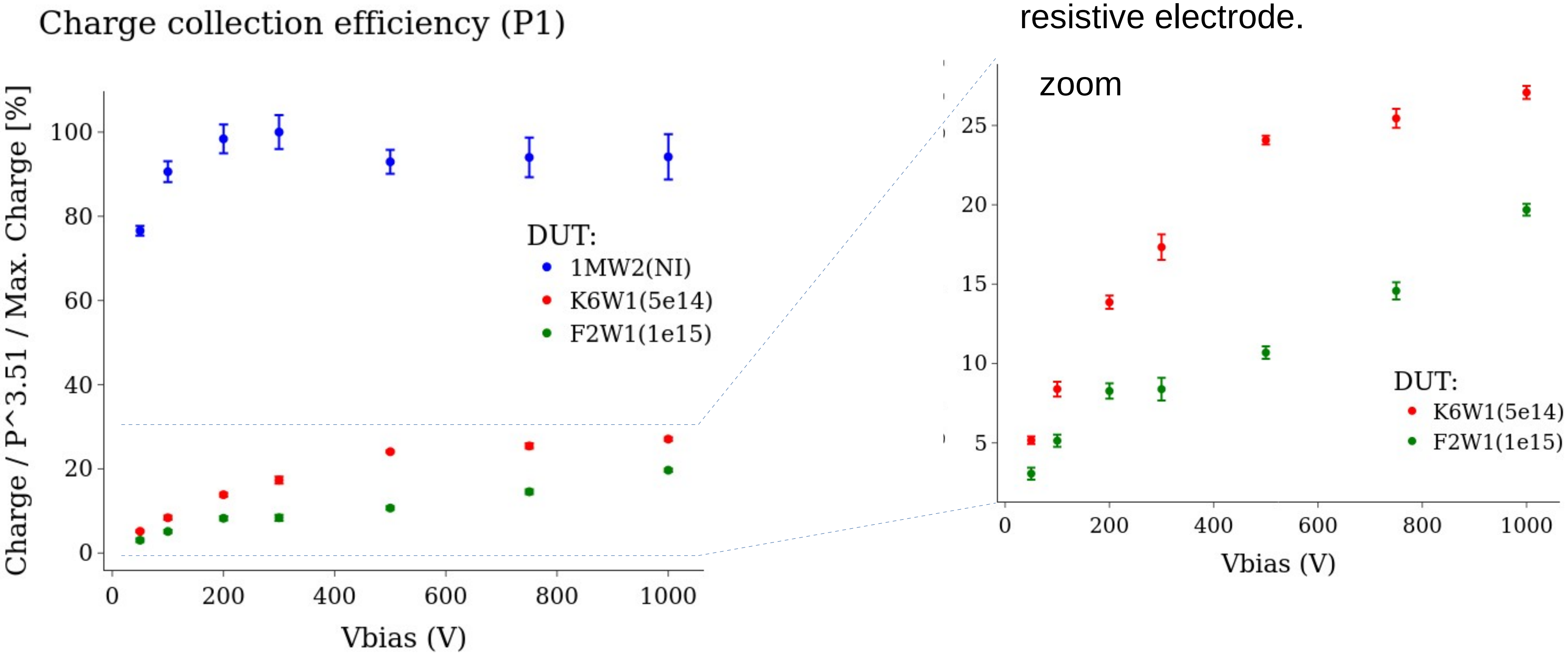
Electrical capacitance vs bias



Charge collection efficiency vs fluence

P1: Closest point to the charge collection ring.

Dependence with irradiation:
→ Charge collection increases with bias
→ Charge collection decreases with irradiation.
→ Lost of charge due to signal trapping in the resistive electrode.

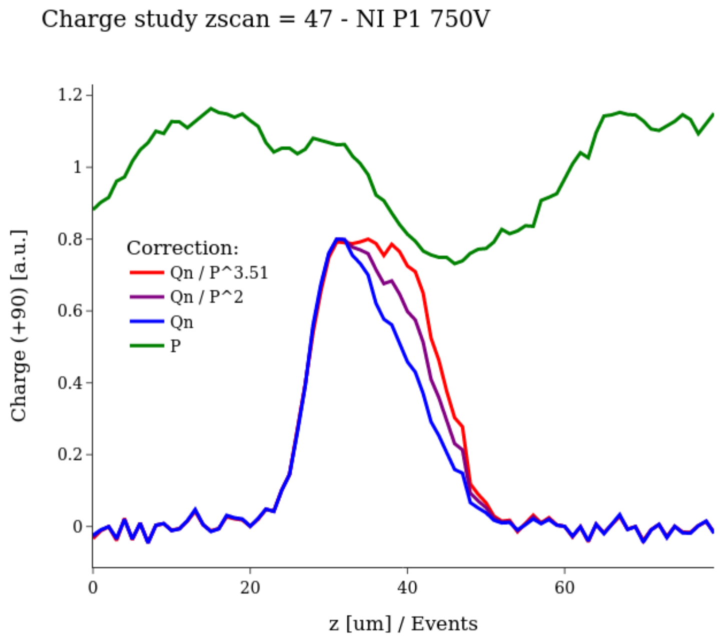


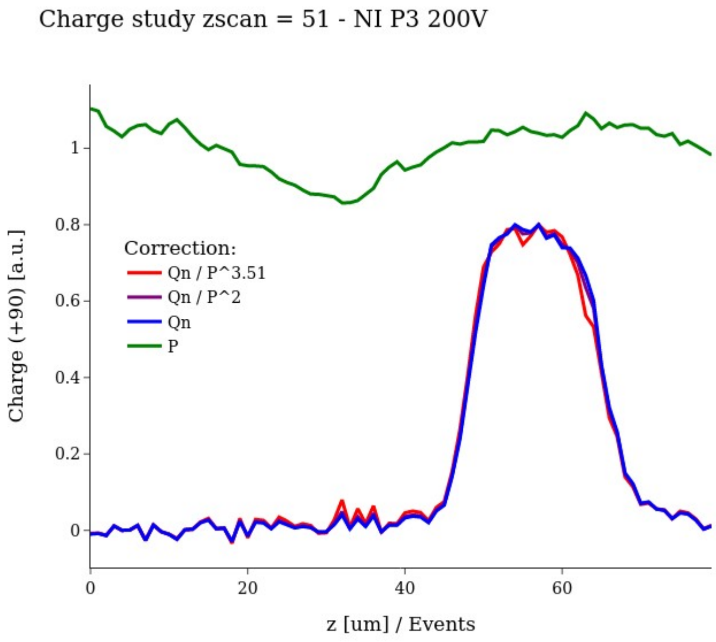
Discussion - Summary

- We have successfully applied the TPA-TCT method for the first time to SiC diodes.
- The measured effective doping of the silicon carbide substrate agrees with the nominal doping value.
- Neutron irradiated samples do not present a diode-like behavior (bias-independent sensitive region).
- The width of the sensitive region depends on the fluence.
- Further TPA-TCT and TRIBIC (at CNA) campaigns scheduled.

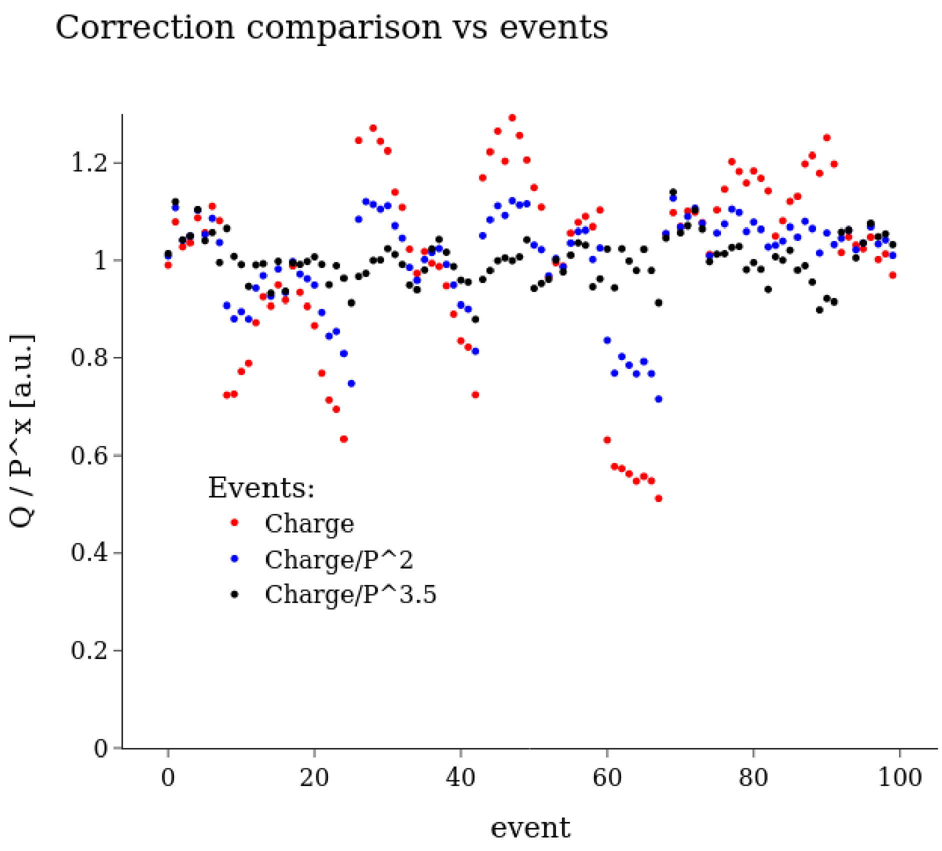
Thanks for your attention

Laser fluctuations correction (I)





Laser fluctuations correction (II)



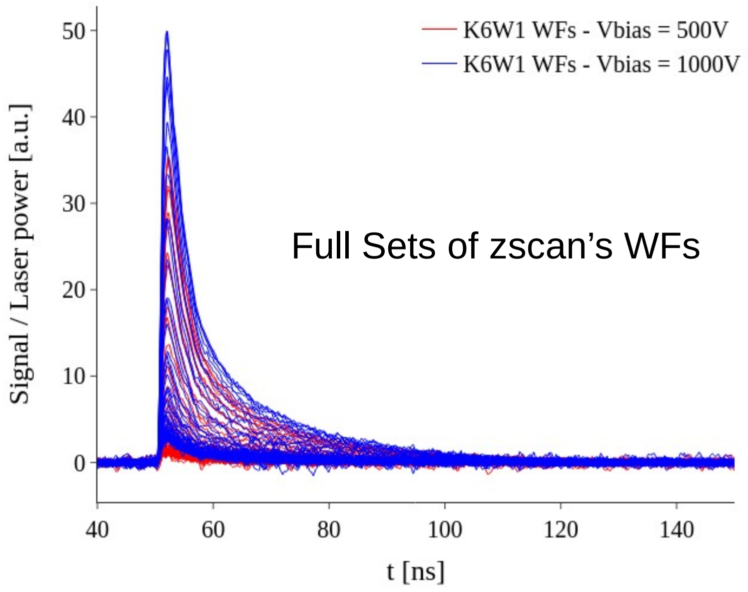
SPA subtraction (on z-scans) I:

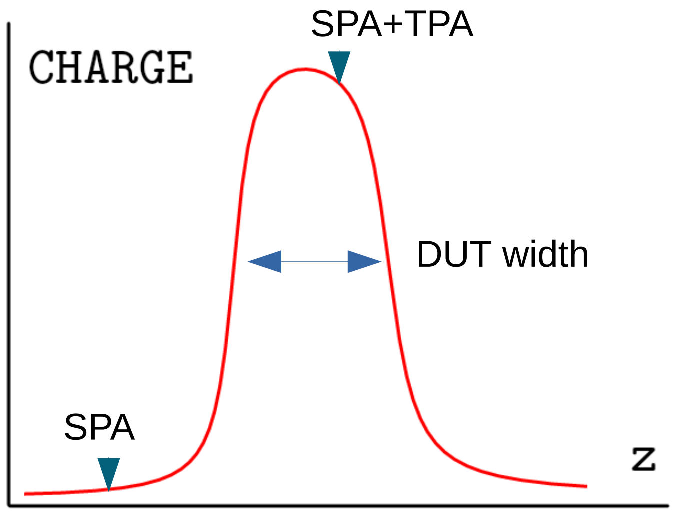
$$S_i(P, z) = S_i^{SPA}(P) + S_i^{TPA}(P, z)$$

$$S_i(P_i, z_i) = \alpha P_i + \beta(z_i) P_i^2$$

Signal generation as the contribution of two components, the SPA (always present) and the TPA (only if the focus is inside the detector)

K6W1 - Transient currents and SPA contribution





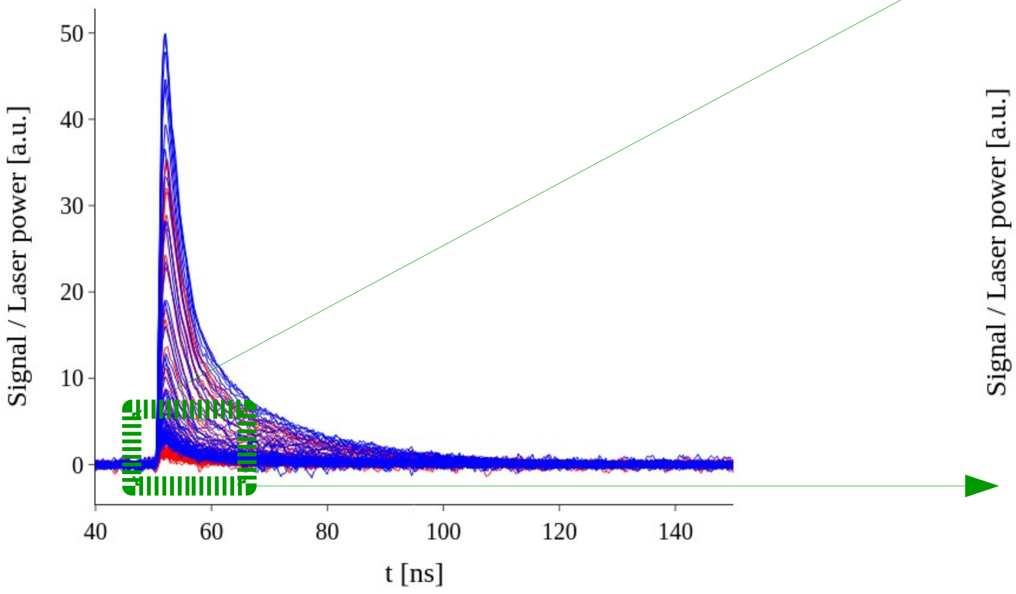
Zscan typical profile on PIN detector

SPA subtraction (on z-scans) II:

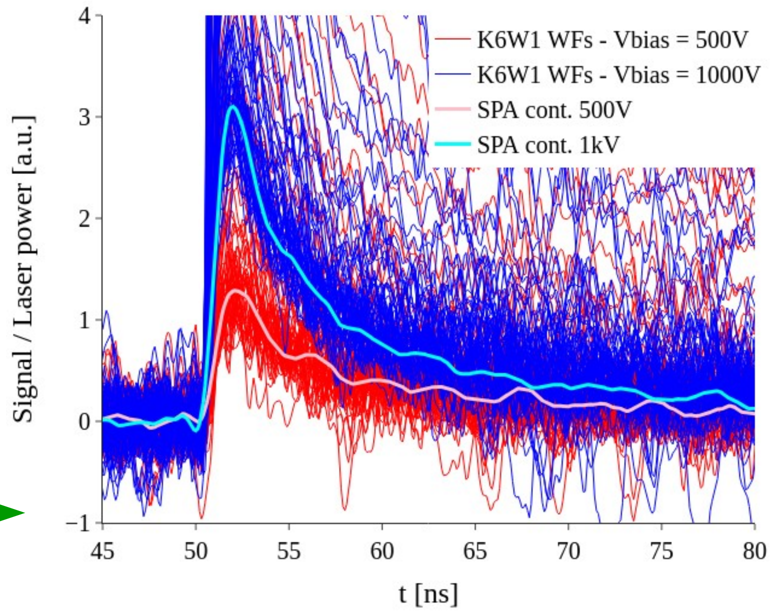
$$S_i(P, z) = S_i^{SPA}(P) + S_i^{TPA}(P, z)$$

$$S_i(P_i, z_i) = \alpha P_i + \beta(z_i) P_i^2$$

→ SPA dependence with bias voltage
→ SPA dependence with irradiation level

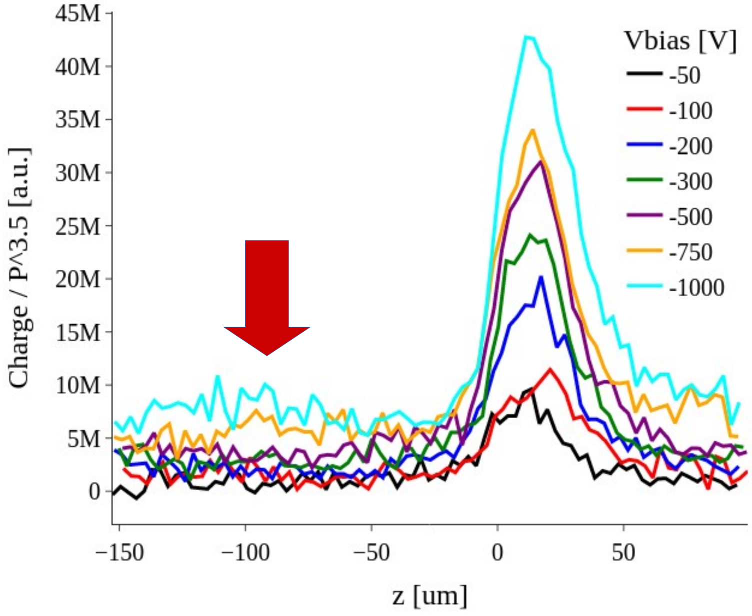


K6W1 - Transient currents and SPA contribution

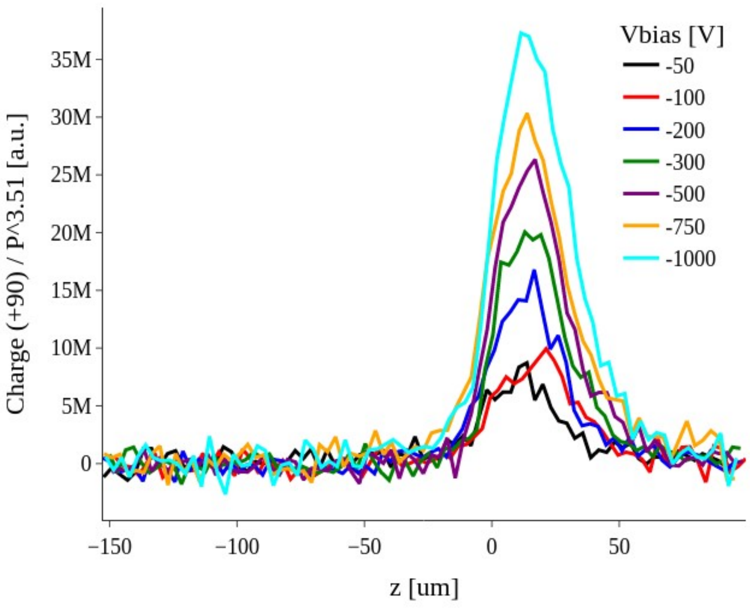


SPA correction

Before



After



Raw z-scan charge profiles