# TCT measurements with irradiated strip detectors

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Most measurements made by diploma student **Mitja Krnel**

## Introduction:

- TCT with focused IR laser light
- light beam directed on the surface of strip detector: Top-TCT
- "Spaghetti" detectors produced by Micron:
  - p-type, FZ, 300 µm thick, 4x4 $mm^2$
  - strip pitch: 80 µm
  - implant width: 20 µm, DC coupled

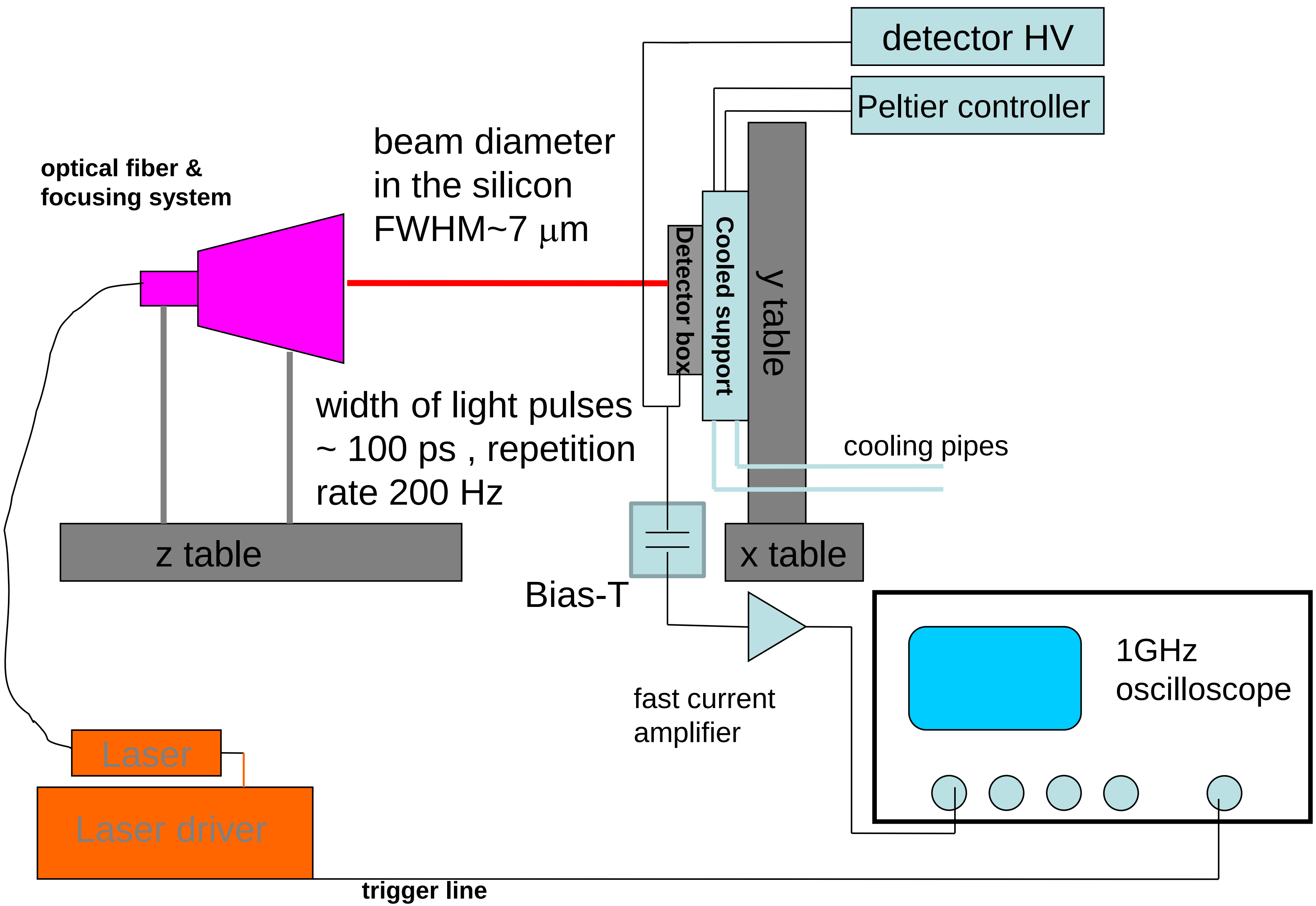
  **Spaghetti:** all strips connected on one side
  ➔ only one wire bond → faster work…
  ➔ *E* field as in strip detector, weighting field as in pad detector

  **Spaghetti Type 1** ➔ 500 µm of implant not covered by metal

- detectors irradiated to $1\cdot10^{15}$ , $2\cdot10^{15}$ and $5\cdot10^{15}$ n/$cm^2$
- measurements after several annealing steps at 60°C up to total annealing of 5120 minutes at 60°C

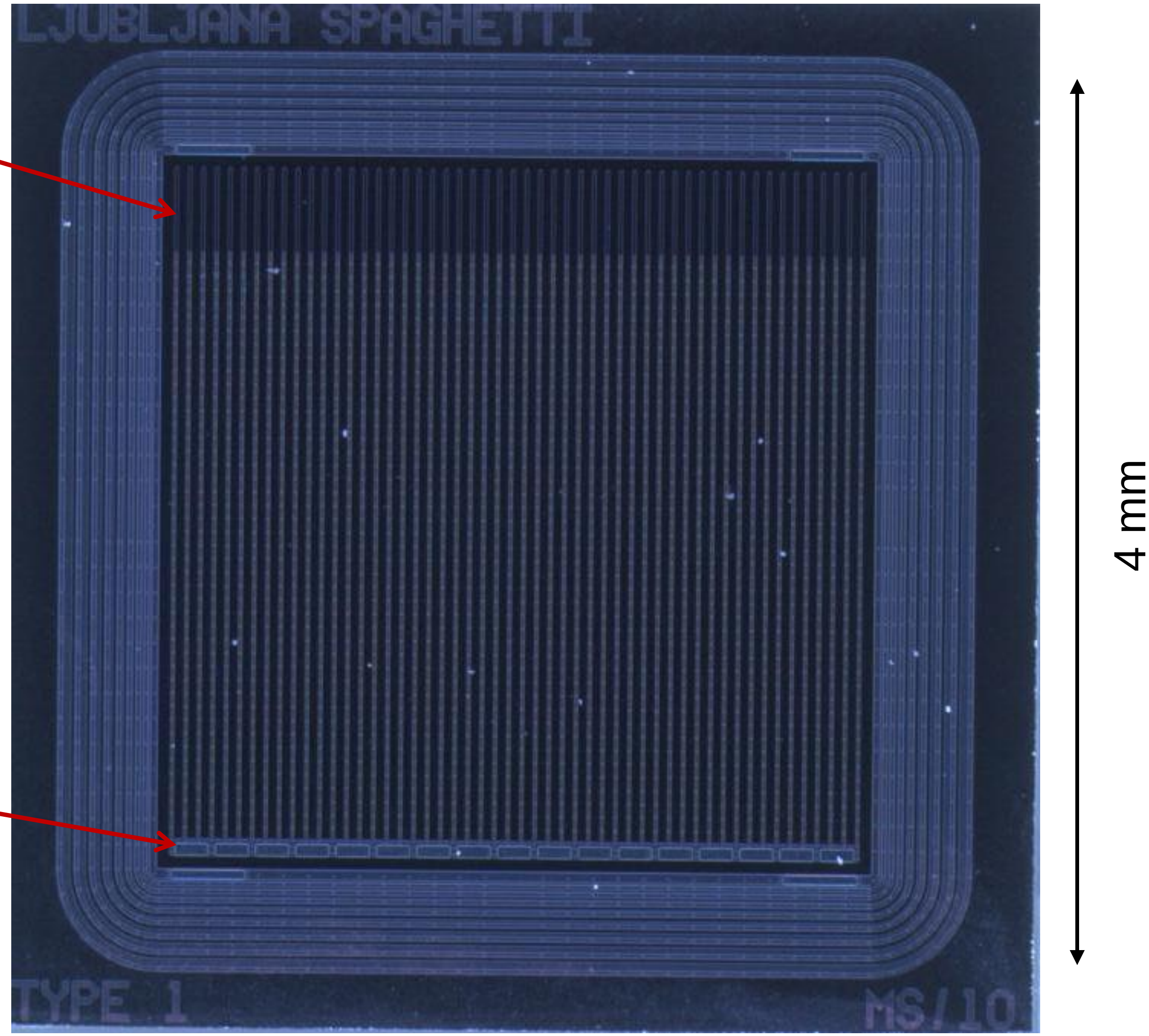
Motivation: check the uniformity of response
→ **with Spaghetti T1 laser measurement possible also under implants**

# Setup


detector HV
Peltier controller
optical fiber &
focusing system
beam diameter
in the silicon
FWHM~7 μm
Detector box
Cooled support
y table
width of light pulses
~ 100 ps , repetition
rate 200 Hz
cooling pipes
z table
x table
Bias-T
1GHz
oscilloscope
fast current
amplifier
Laser
Laser driver
trigger line

# Detector

Last 500 µm of implants not covered with metal




All strips connected together

→ *E* field as in strip detector

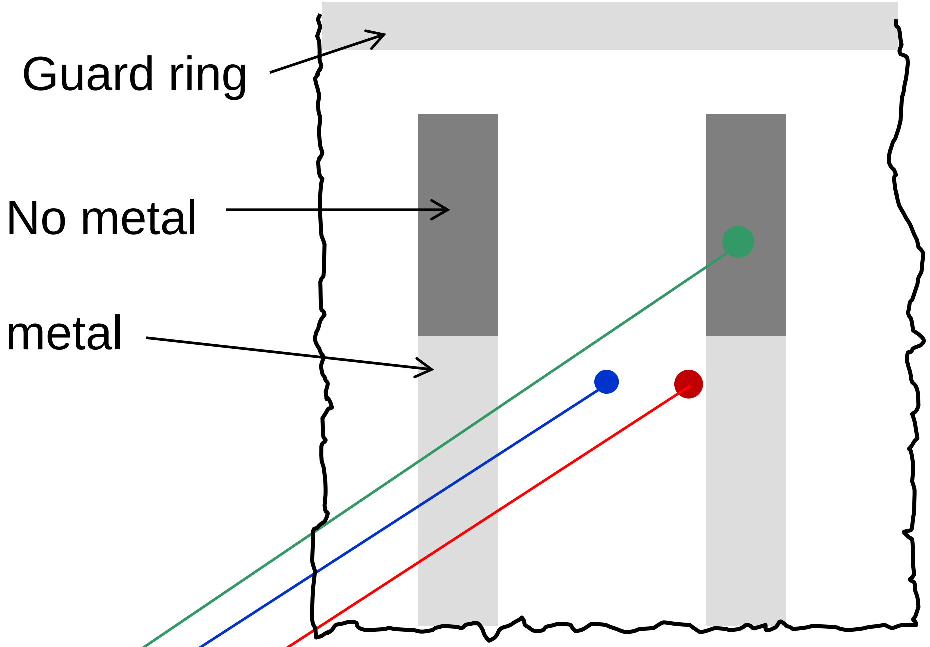
→ weighting field as pad detector

➔ signal is a sum of currents induced on all strips

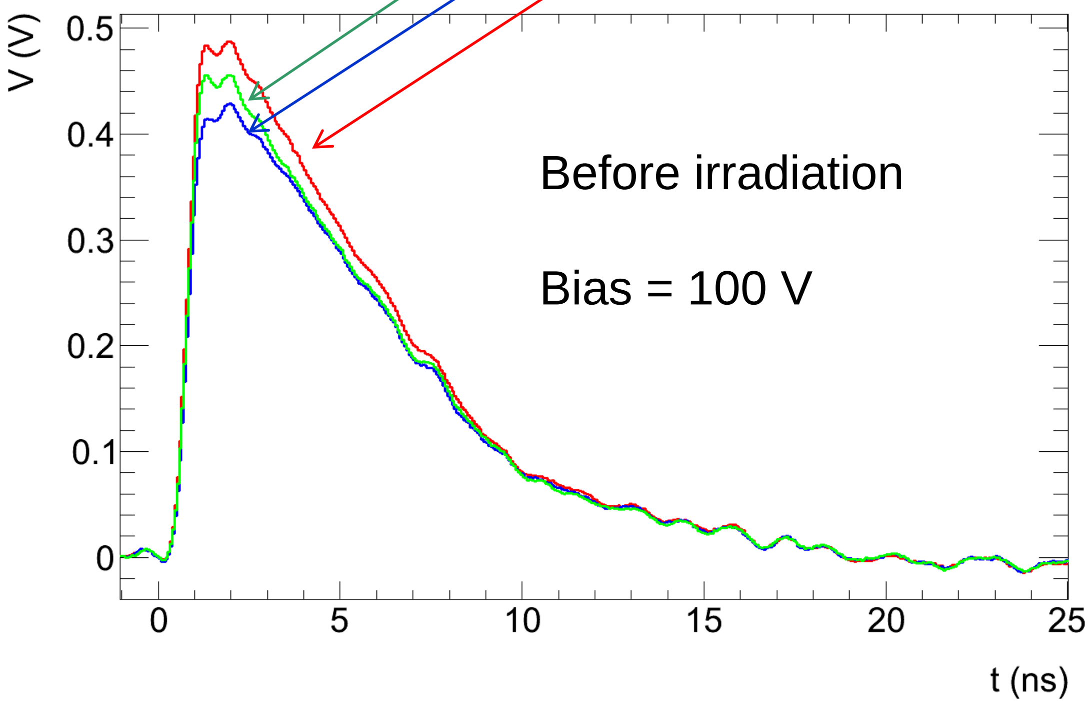
## Signals

- before irradiation
- bias = 100 V (depleted)

→scan laser spot across the surface



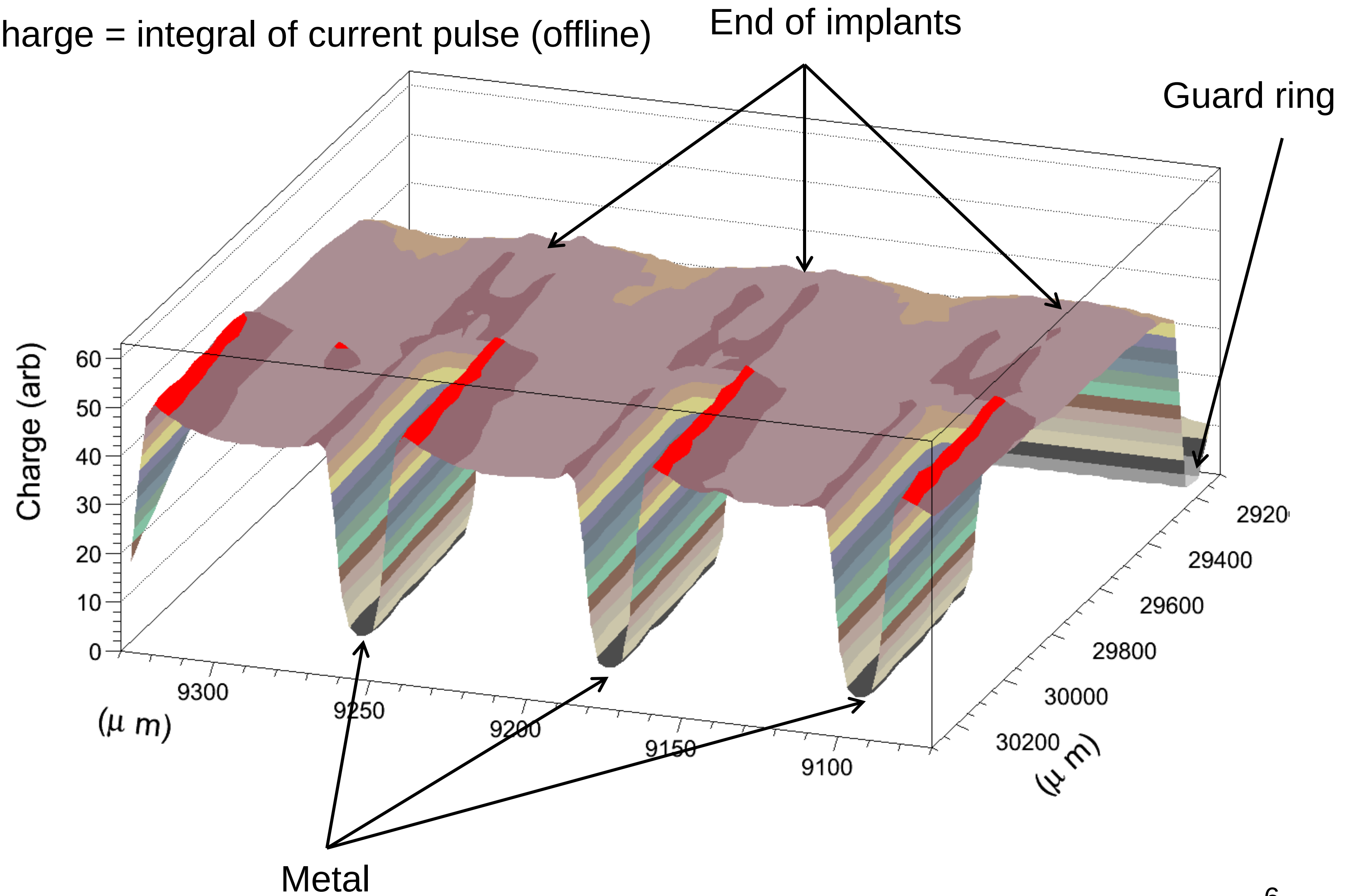

Signals induced by laser beam at different locations:



## Before irradiation: scan over detector surface (step x: 2.5 μm, y: 50 μm)

Bias = 100 V (depleted)

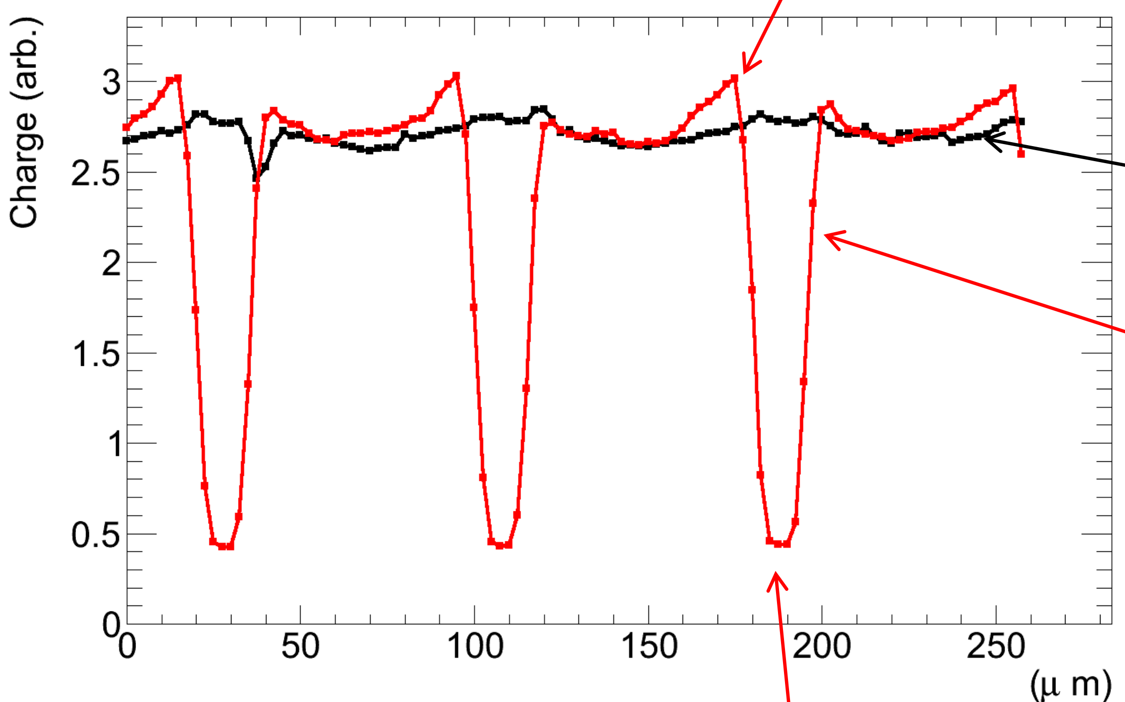
Charge = integral of current pulse (offline)

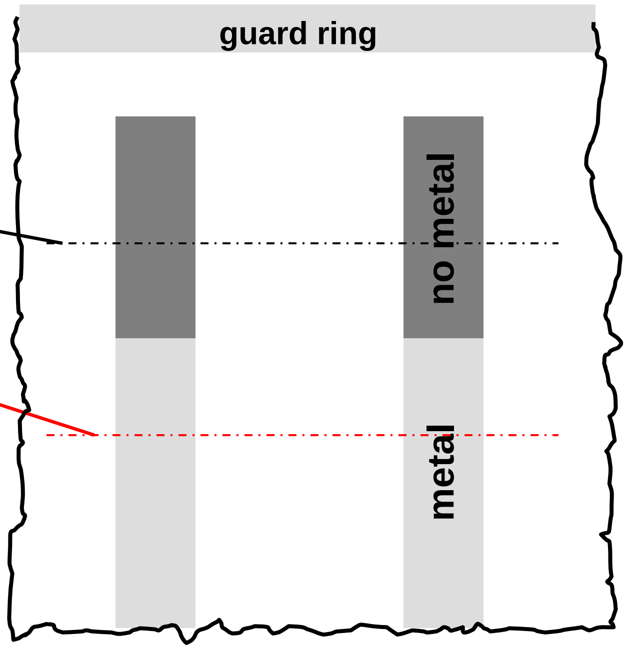


## Before irradiation

Bias = 100 V

Reflection from metal



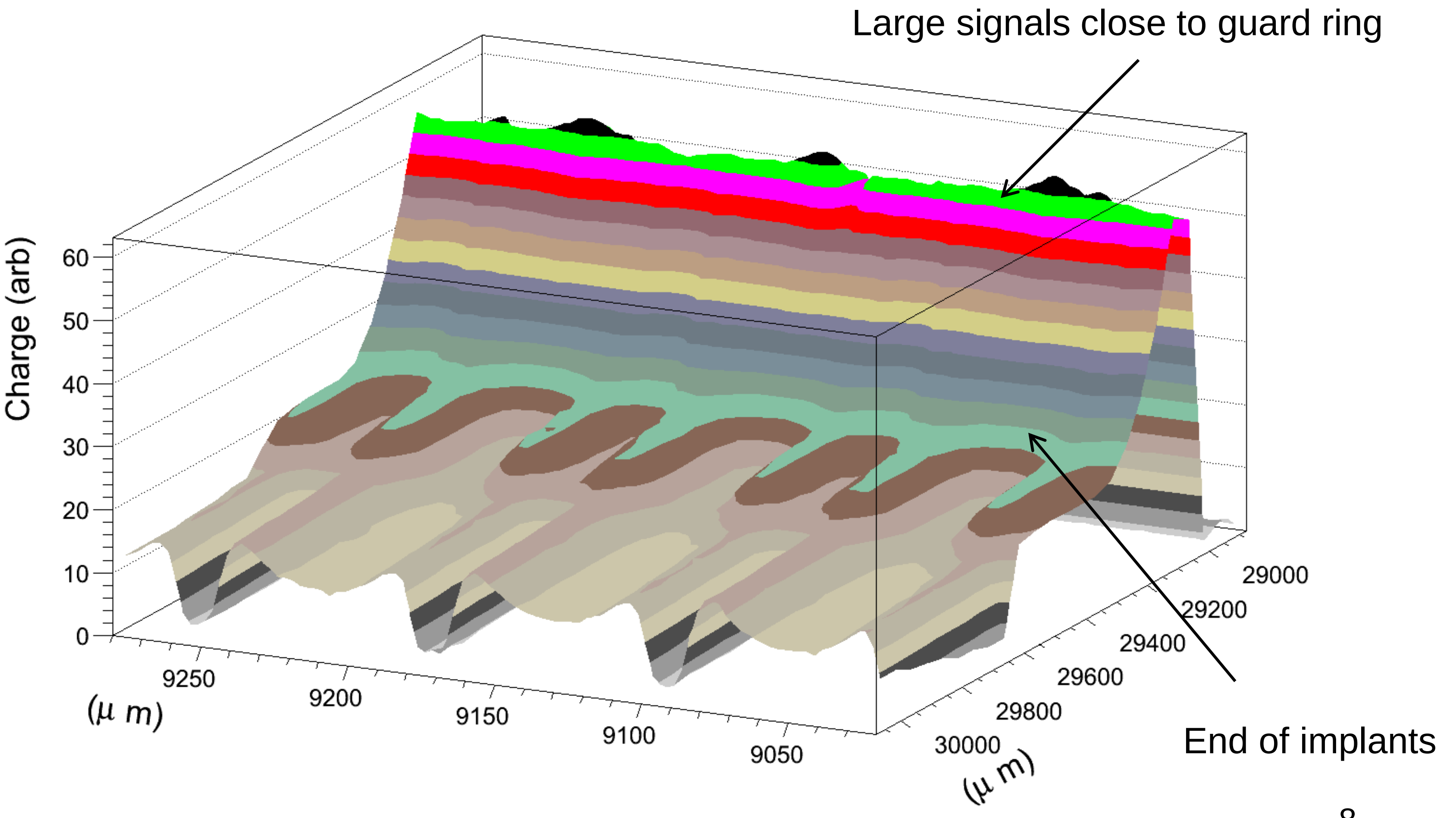

Some signal also when beam on metal → tails of light spot

No significant difference between metal and no-metal!

## Irradiated detector

$\Phi_{eq}$ = 5·10$^{15}$ n/cm$^2$
Bias = 1000 V
Annealed 5120 minutes at 60°C

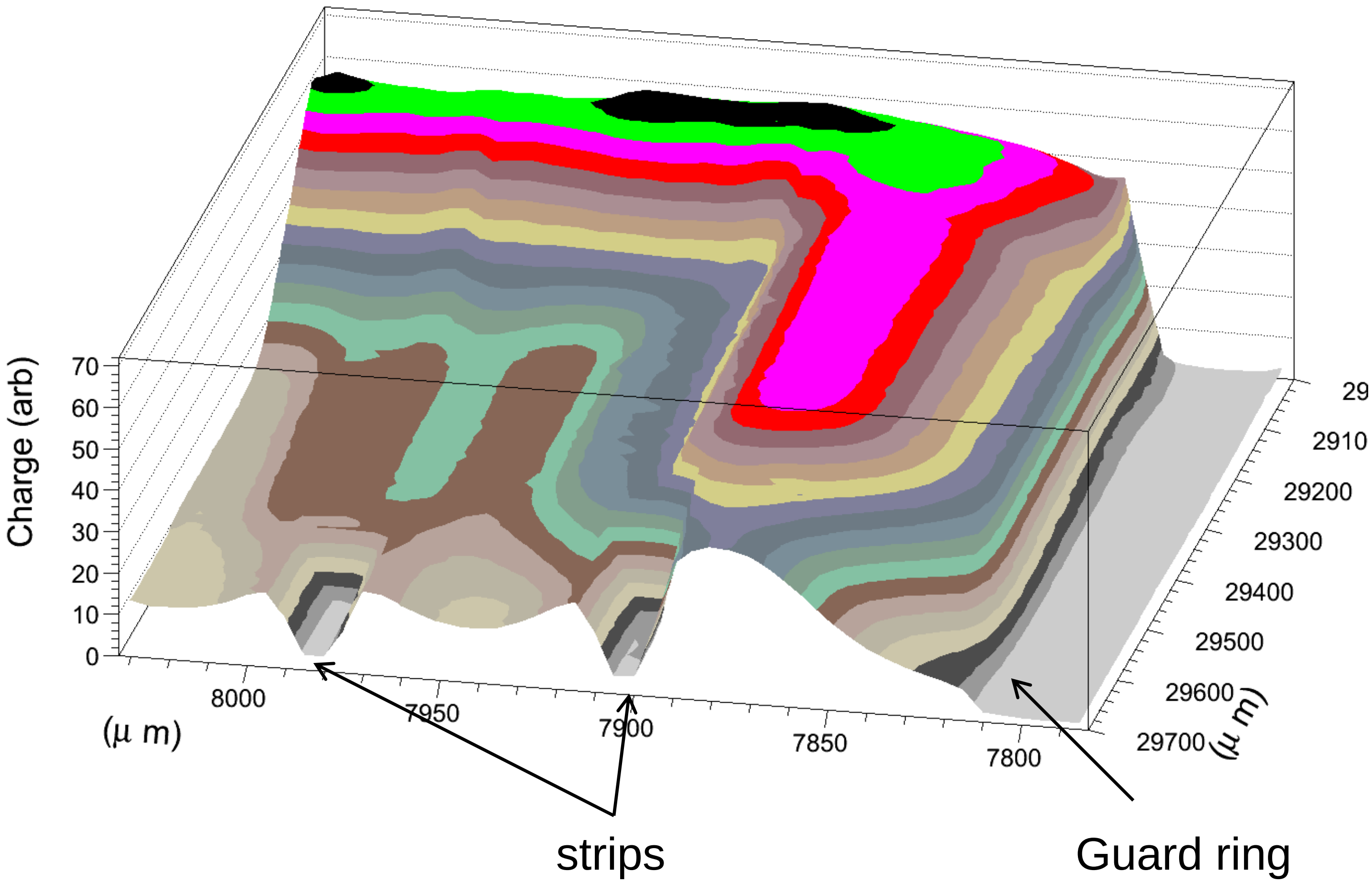
} multiplication expected



# Irradiated detector

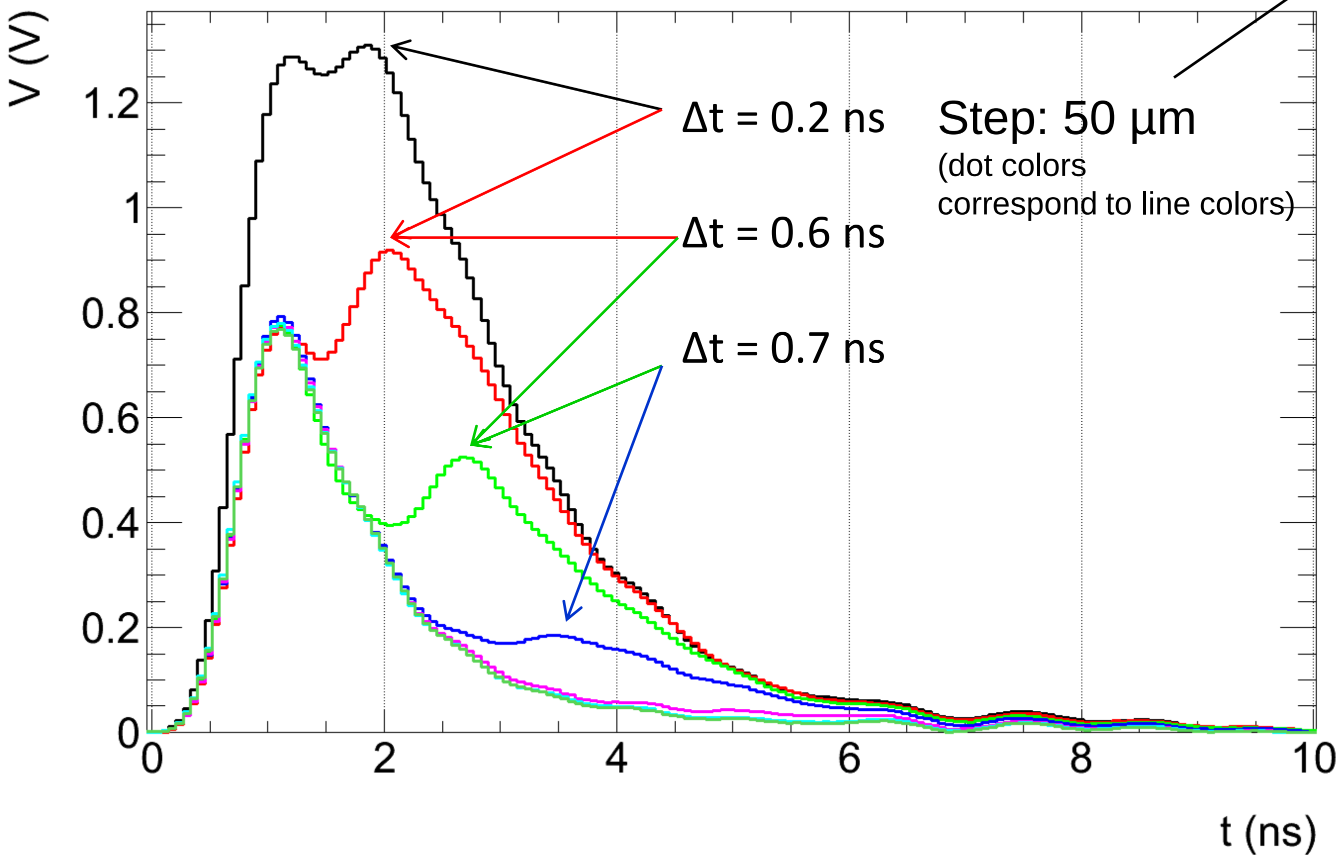
$\Phi_{eq} = 5 \cdot 10^{15}$ n/cm$^2$; Bias = 1000 V; Annealed 5120 minutes at 60 C

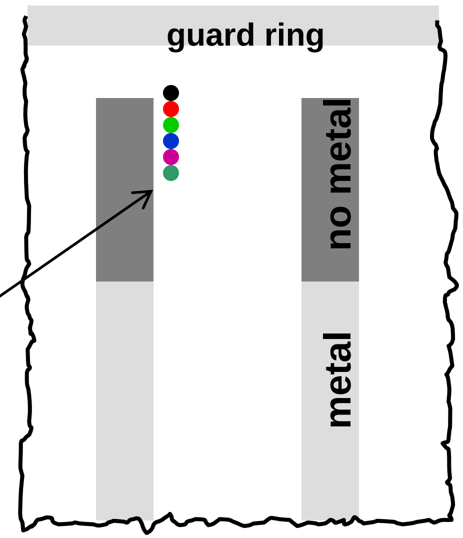
➔ high signals also near the guard-ring parallel to the strip



## Irradiated detector

$\Phi_{eq} = 5 \cdot 10^{15}$ n/cm$^2$
Bias = 1000 V
Annealed 5120 minutes at 60°C



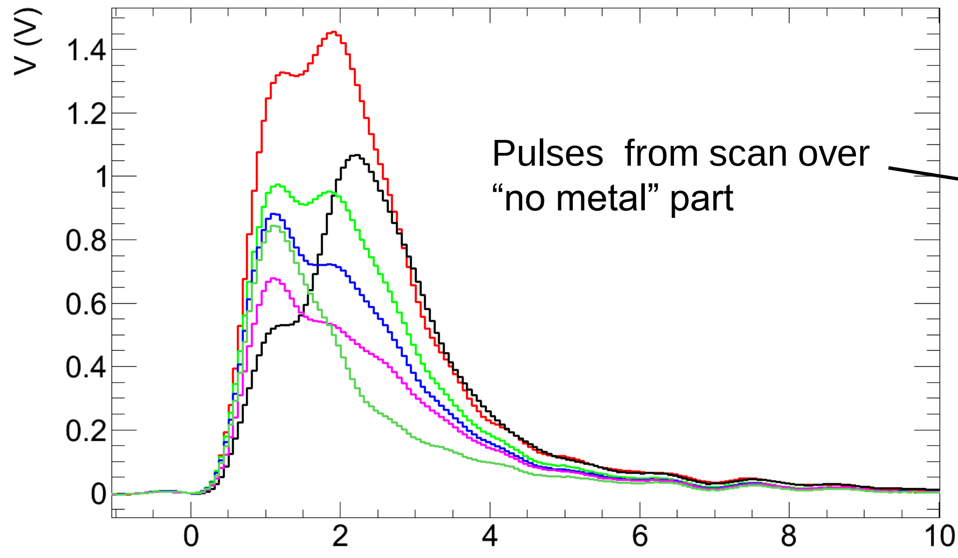



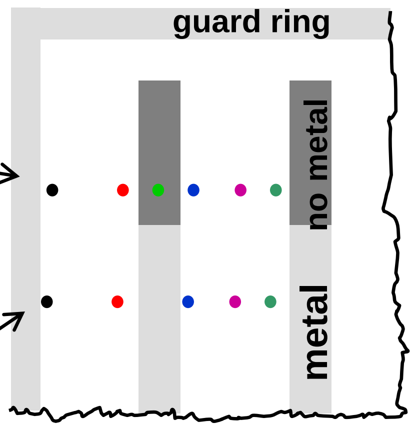

$v = 10^7$ cm/s
$\Delta t \sim 0.5$ ns
➔ $v \cdot \Delta t \sim 50$ μm

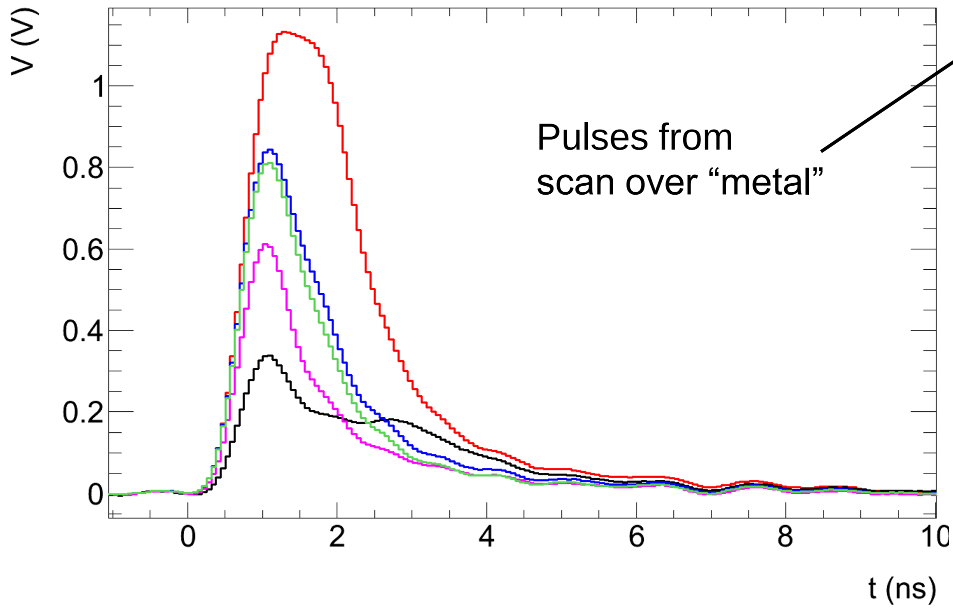
The second peak from high field at the end of implant.

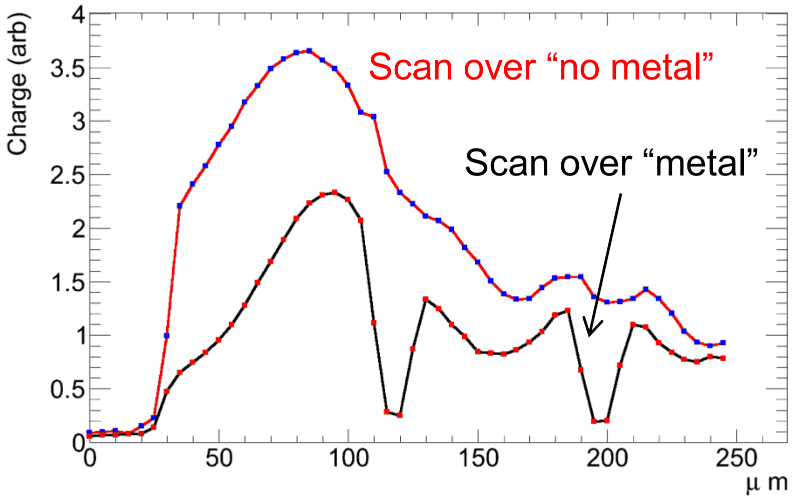
# Irradiated detector

$\Phi_{eq} = 5\cdot10^{15}$ n/cm$^2$ ,Bias = 1000 V, annealed 5120 minutes at 60°C



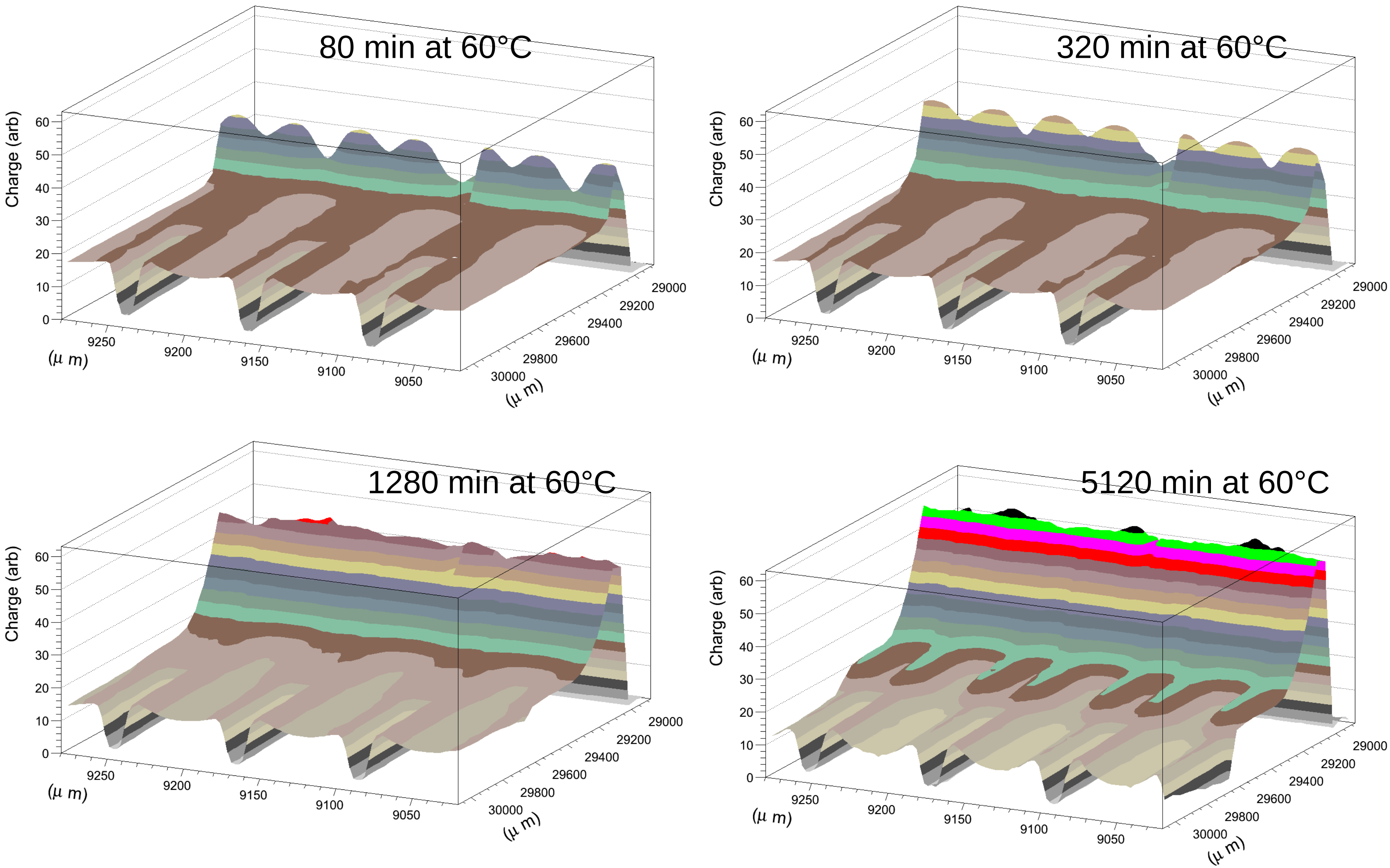




Complicated behavior near guard rings!

# Irradiated detector   $\Phi_{eq} = 5\cdot10^{15}$ n/cm$^2$ , Bias = 1000 V

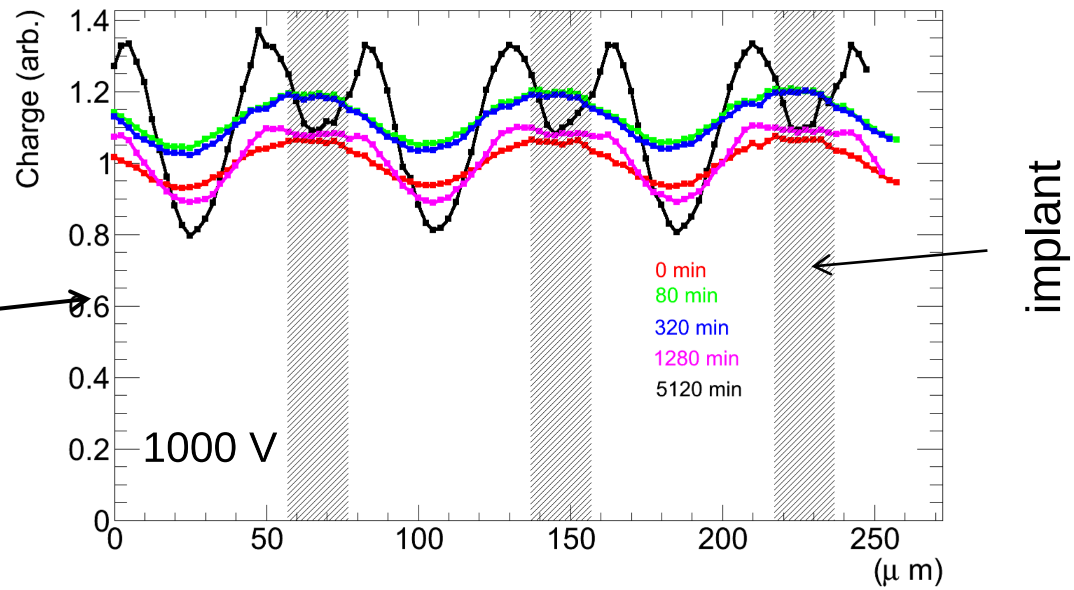
Signals on edges increase with long term annealing → multiplication effects



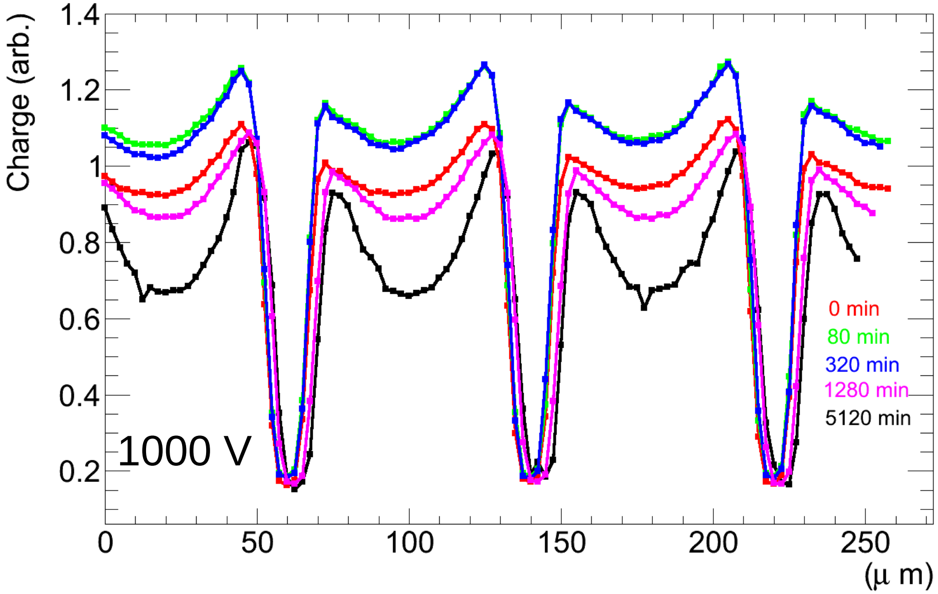
# Irradiated detector: effect of annealing

$\Phi_{eq} = 5 \cdot 10^{15}$ n/cm$^2$;
Bias = 1000 V;

Scan over **non metalized** implants
(~ 0.5 mm from guard ring)




Scan over **metalized** strips
~ 1 mm from guard ring




➔ more non-uniform with annealing →**multiplication at the edge of implants**

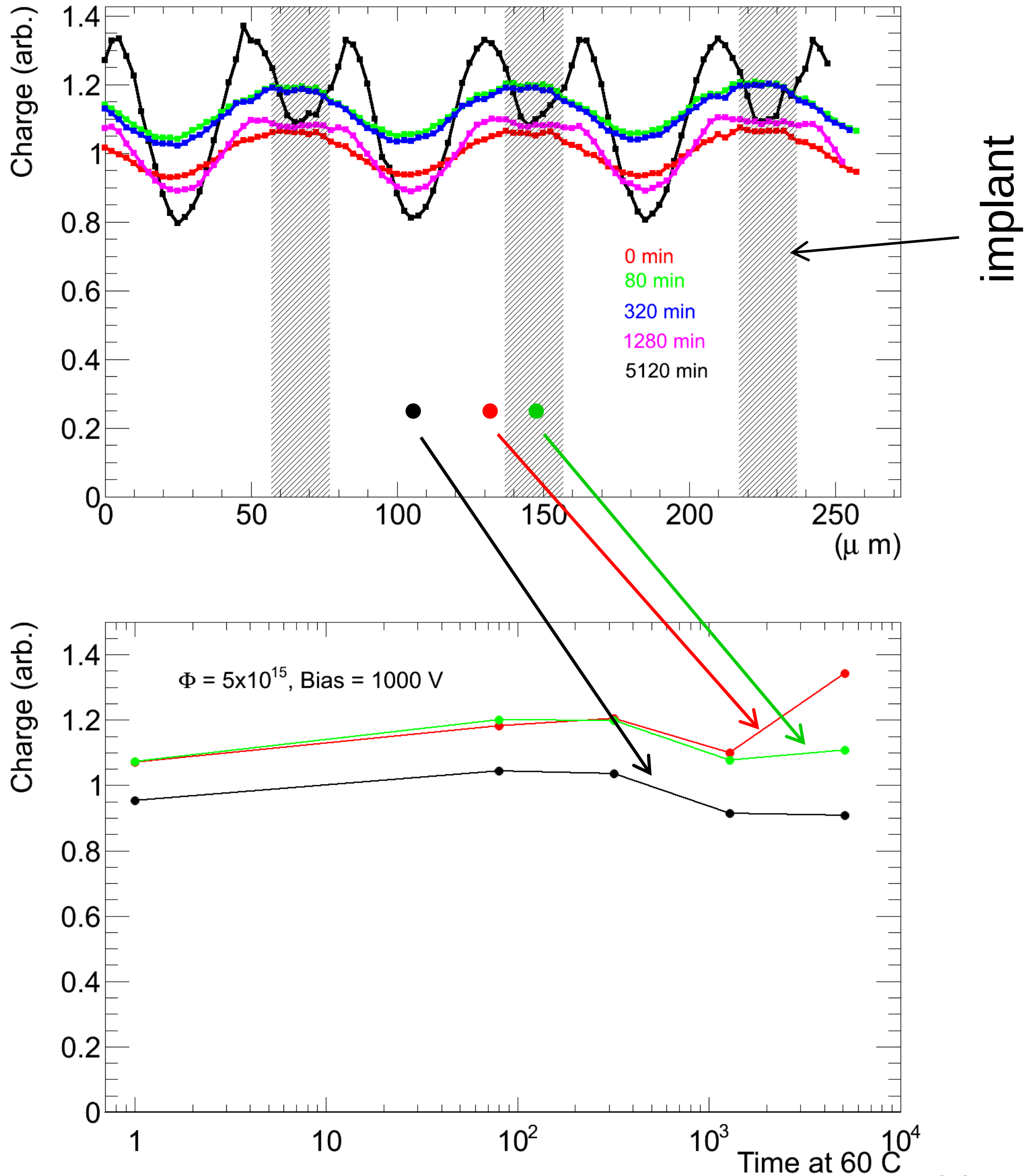
- effect increases closer to guard-ring

# Annealing $\Phi_{eq} = 5 \cdot 10^{15}$ n/cm$^2$

Bias = 1000 V

- Annealing of CCE depends on location

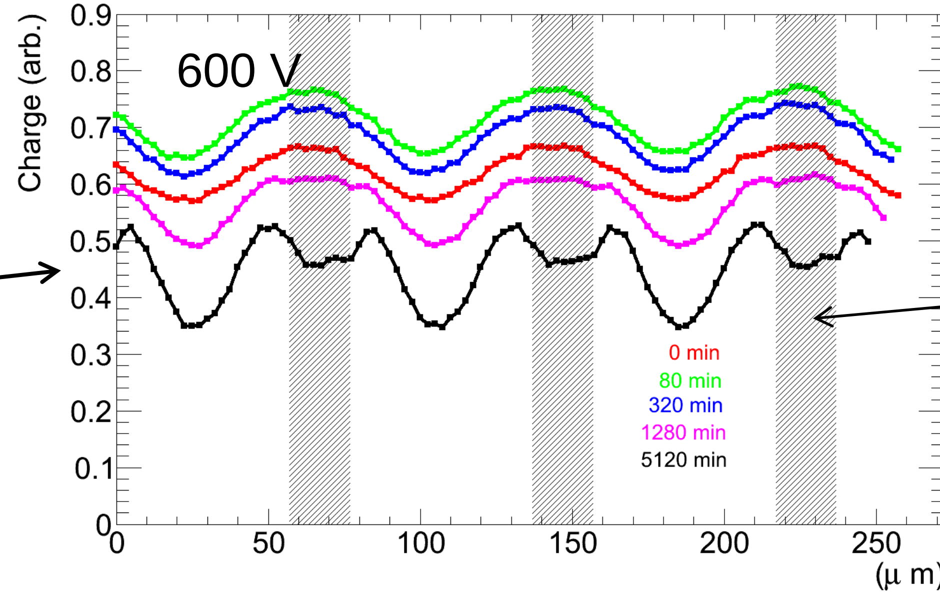
➔ Increase of charge with long term annealing near implant edge



# Irradiated detector: annealing at lower bias voltage

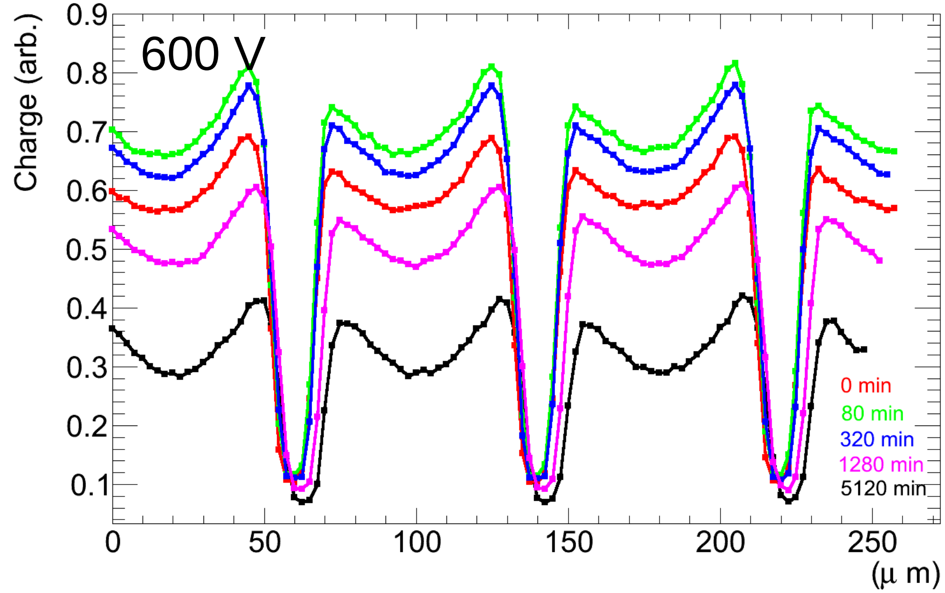
**Bias = 600 V**;
$\Phi_{eq} = 5\cdot10^{15}$ n/cm$^2$;

Scan over **non metalized** implants
~ 0.5 mm from guard ring



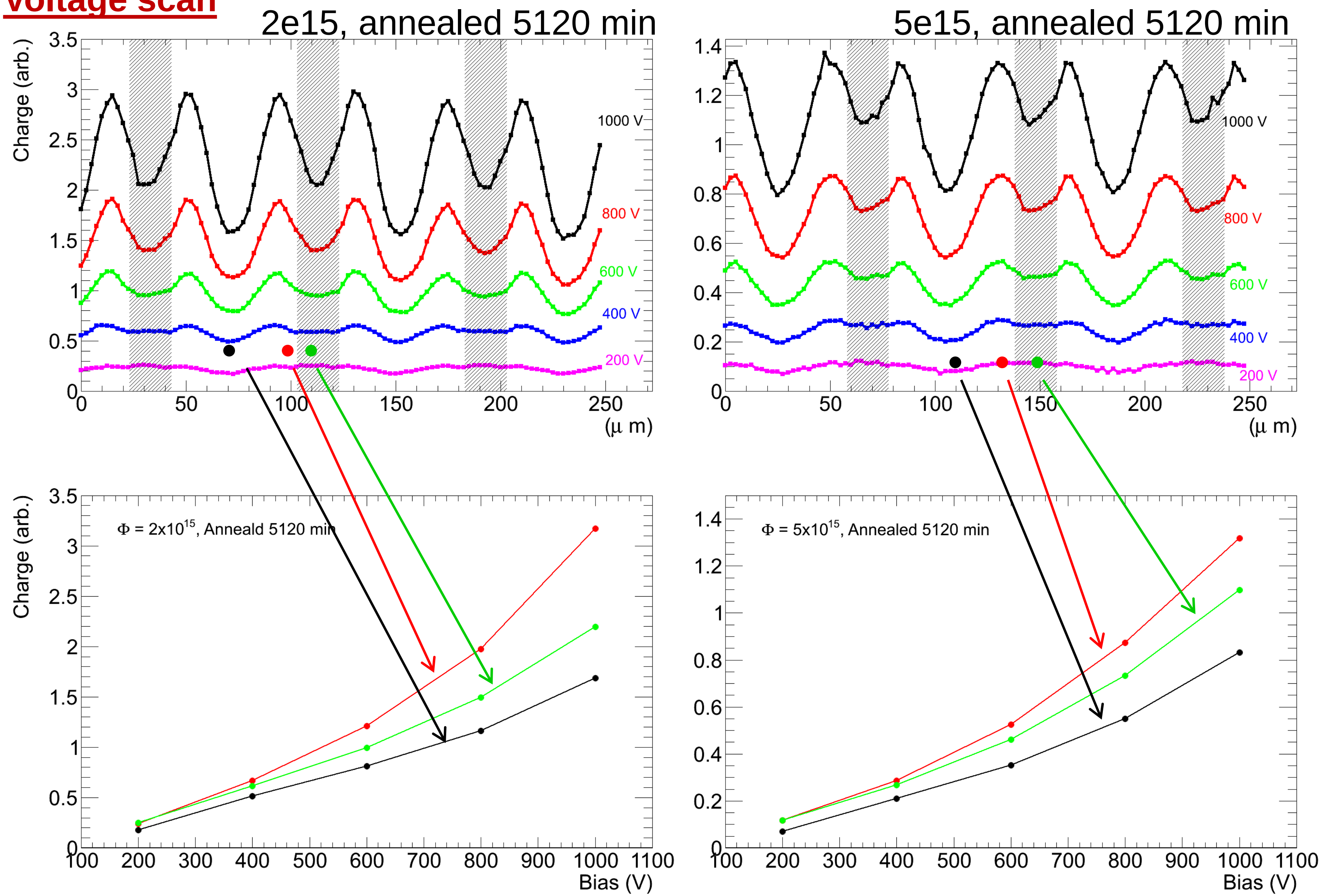

implant

Scan over **metalized** strips
~ 1 mm from guard ring




→ smaller changes of charge variations with annealing
→ charge drops with reverse annealing ➔ no (or less) multiplication

# Voltage scan

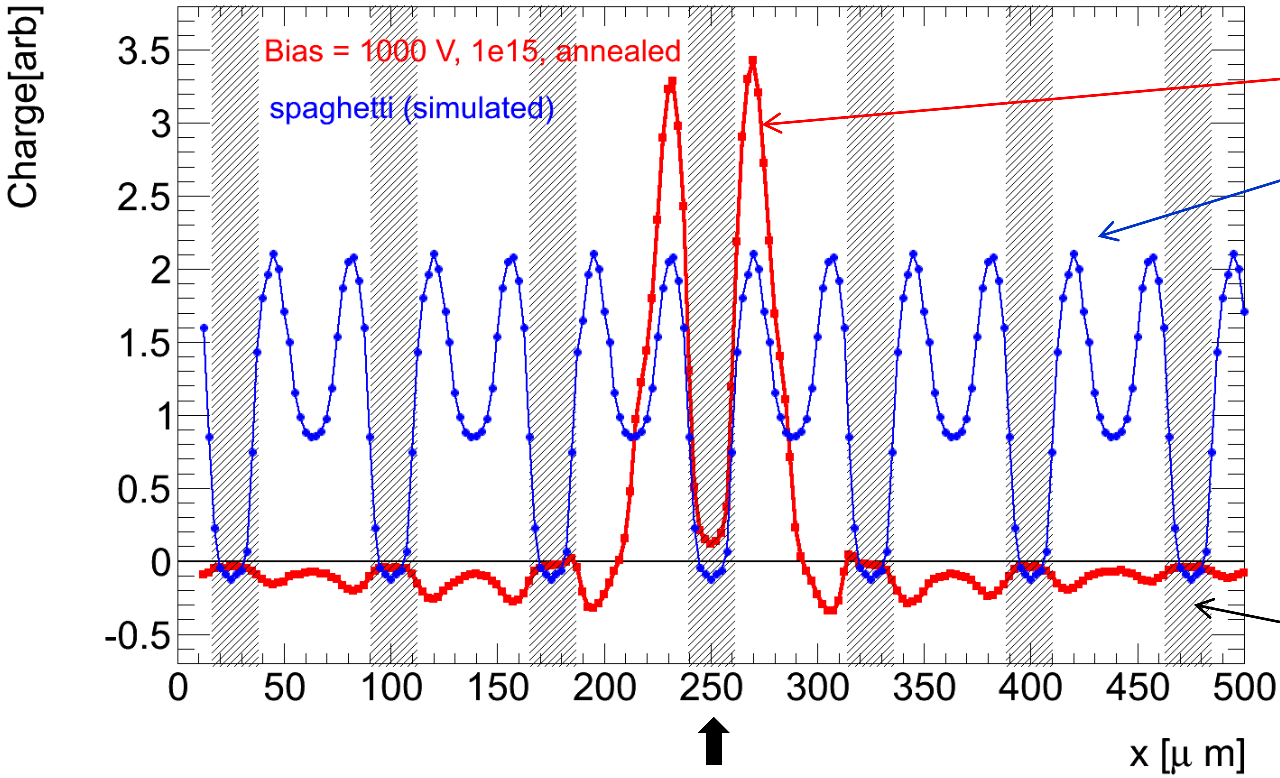



Charge variations increase with bias voltage!

# Spaghetti detectors:

→ all strips connected → **sum** of signals from all strips measured
→ opposite polarity contributions from neighbor strips added
→ **variations of CCE dumped in spaghetti detectors!**

Hamamatsu detector irradiated to $10^{15}$ , ~5000 min at 60C, **only one strip connected to amplifier**:
(see talk from Bari: https://indico.cern.ch/materialDisplay.py?contribId=5&sessionId=5&materialId=slides&confId=175330)




Red: measured

Blue: sum of signals from all strips at equivalent location:

$$s(x_i) = \sum_k s(x_{i+k\times Pitch})$$

metalized strips

to amplifier

## Summary

- Top – TCT measurements with spaghetti detectors

- large signals (multiplication) close to guard ring
  → care should be taken to get realistic CCE (e.g. in test beam ….)

- largest charge measured at edges of implants
  → signs of charge multiplication (annealing behavior, bias dependence … )
  largest at the edge of implant

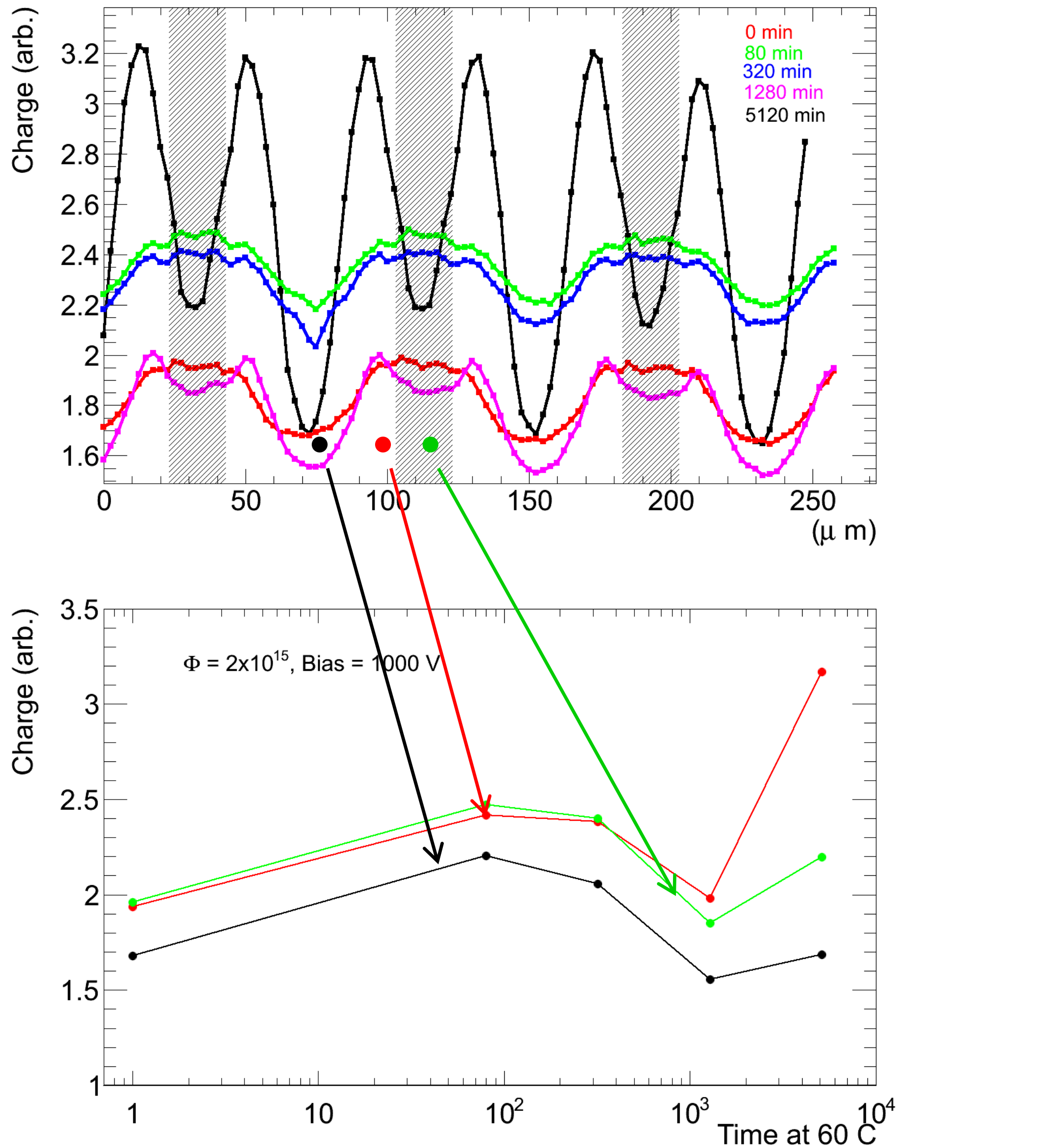
- variations of collected charge across detector increase with multiplication

  ➔ variations are dumped in spaghetti diodes because of negative contributions from neighbor strips

  ➔ test beam experiment can tell how problematic are these variations, if there are dead regions where CCE falls below threshold ….
  ( in HEP experiments most tracks are crossing the detector at an angle)

## Annealing $\Phi_{eq}$ = $2\cdot10^{15}$ n/cm$^2$

Bias = 1000 V

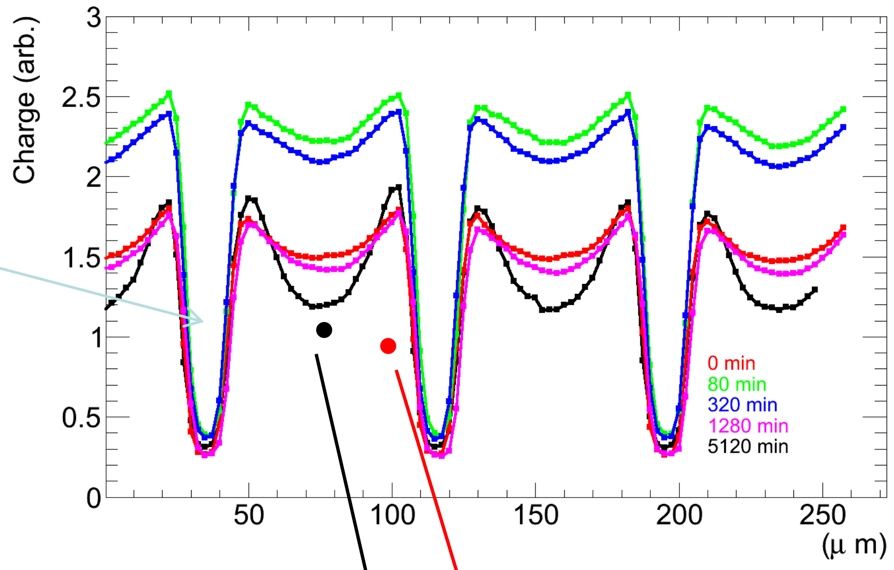


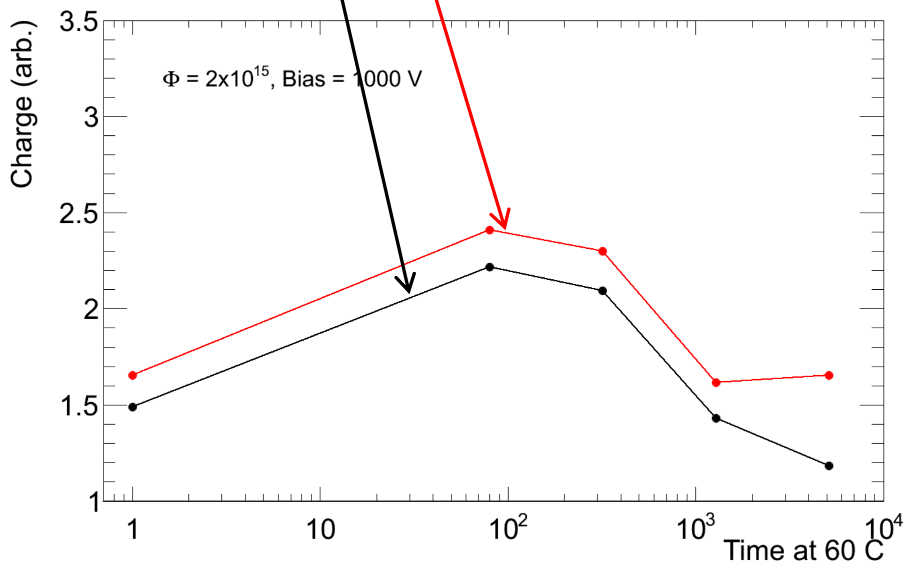

- larger non-uniformity after long annealing
- annealing of CCE depends on location
- increase of charge with long annealing larger closer to implant edge

# Annealing $\Phi_{eq} = 2 \cdot 10^{15}$ n/cm$^2$

Bias = 1000 V

metal




- slightly different behavior at larger distance from guard-ring