TCT measurements with SCP slim edge strip detectors

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Introduction:

- Scribe - Cleave - Passivate (SCP) slim edge strip detectors

  → p-type strip detectors from CiS, pitch 80 µm, V_{fd} ~ 50 V

  → SCP(alumina) processed by Santa Cruz

- TCT measurements with focused laser light:

  1) IR light beam directed on the surface of strip detectors

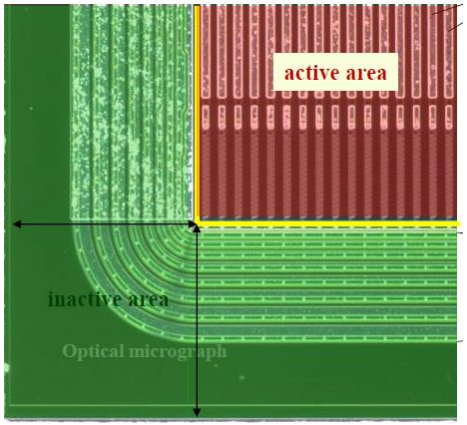
     → measure charge collection across the detector surface

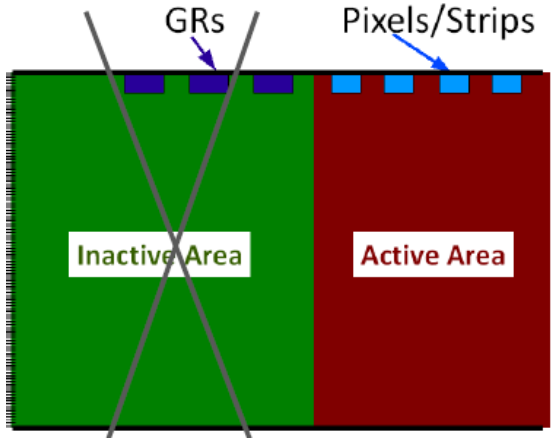
  2) red laser beam directed on the cleaved side of the strip detector

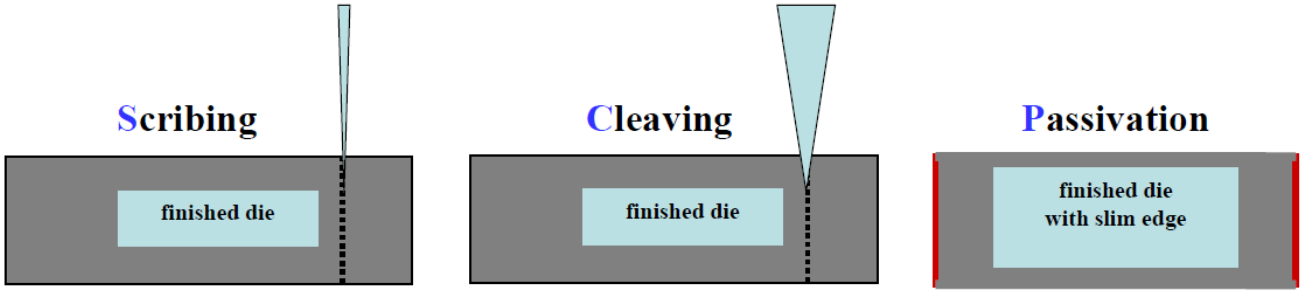
     → probe electric field on the cleaved edge surface

- measure before and after irradiation with neutrons in reactor in Ljubljana

Scribing Cleaving Passivation (SCP) method to reduce the inactive area of sensors







Laser or
XeF2 etching

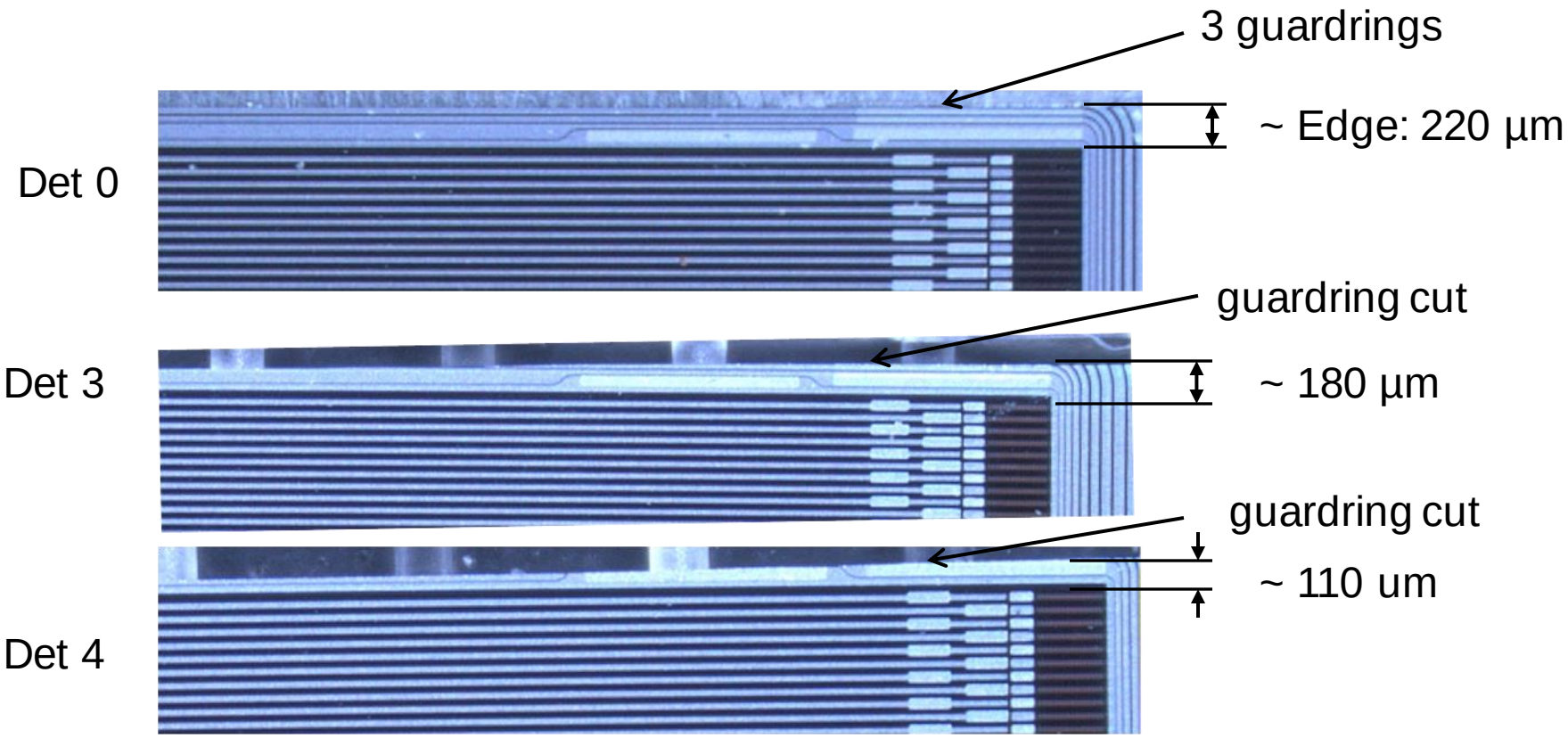
tweezers or
automated cleaving
machine

n-type: oxide
p-type: Al_2O_3 with ALD

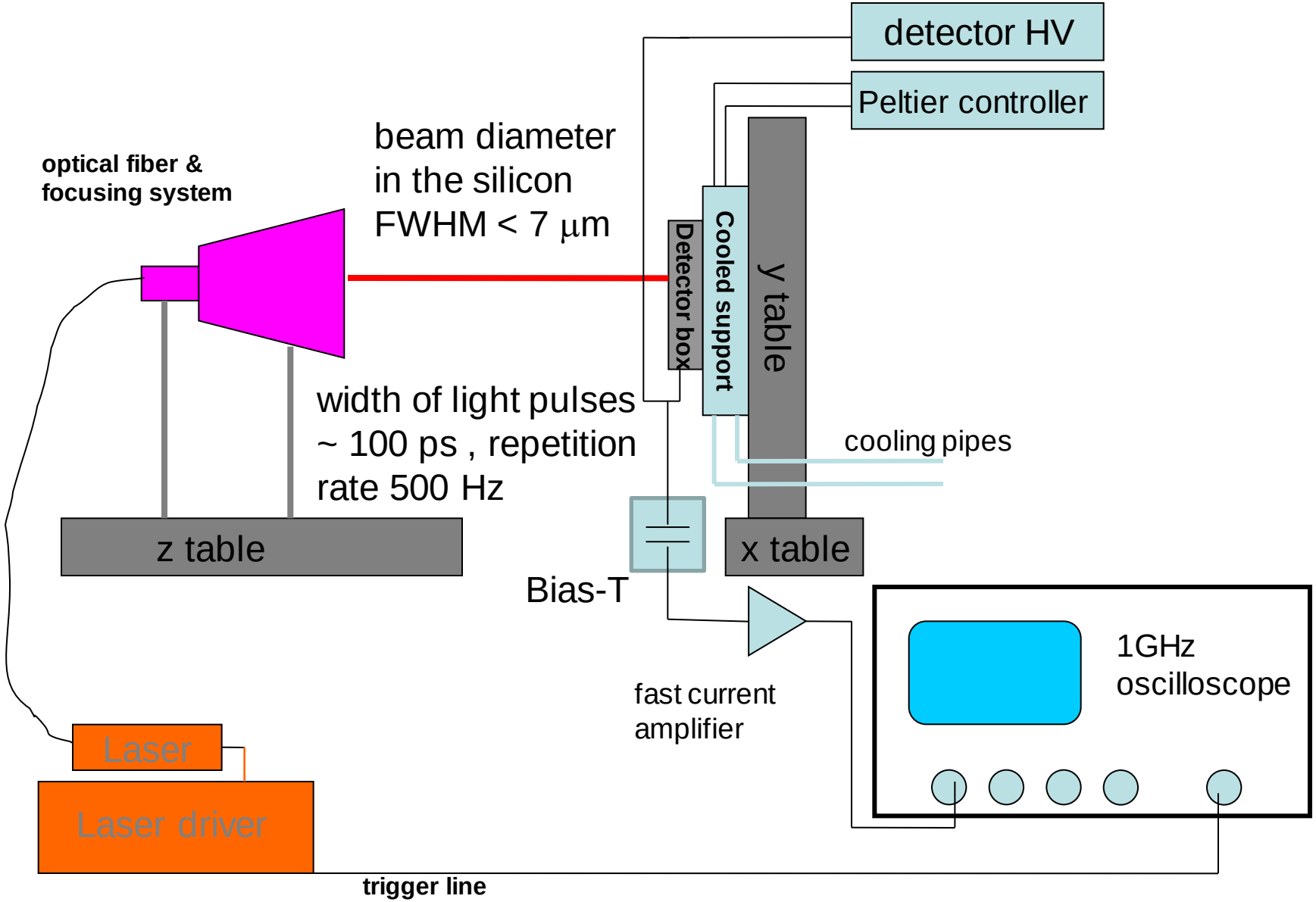
[V. Fadeyev, 20th RD50 Workshop, Bari, 2012]

Detectors:

- measurements with 3 strip detectors
- SCP cut at different distance from the edge

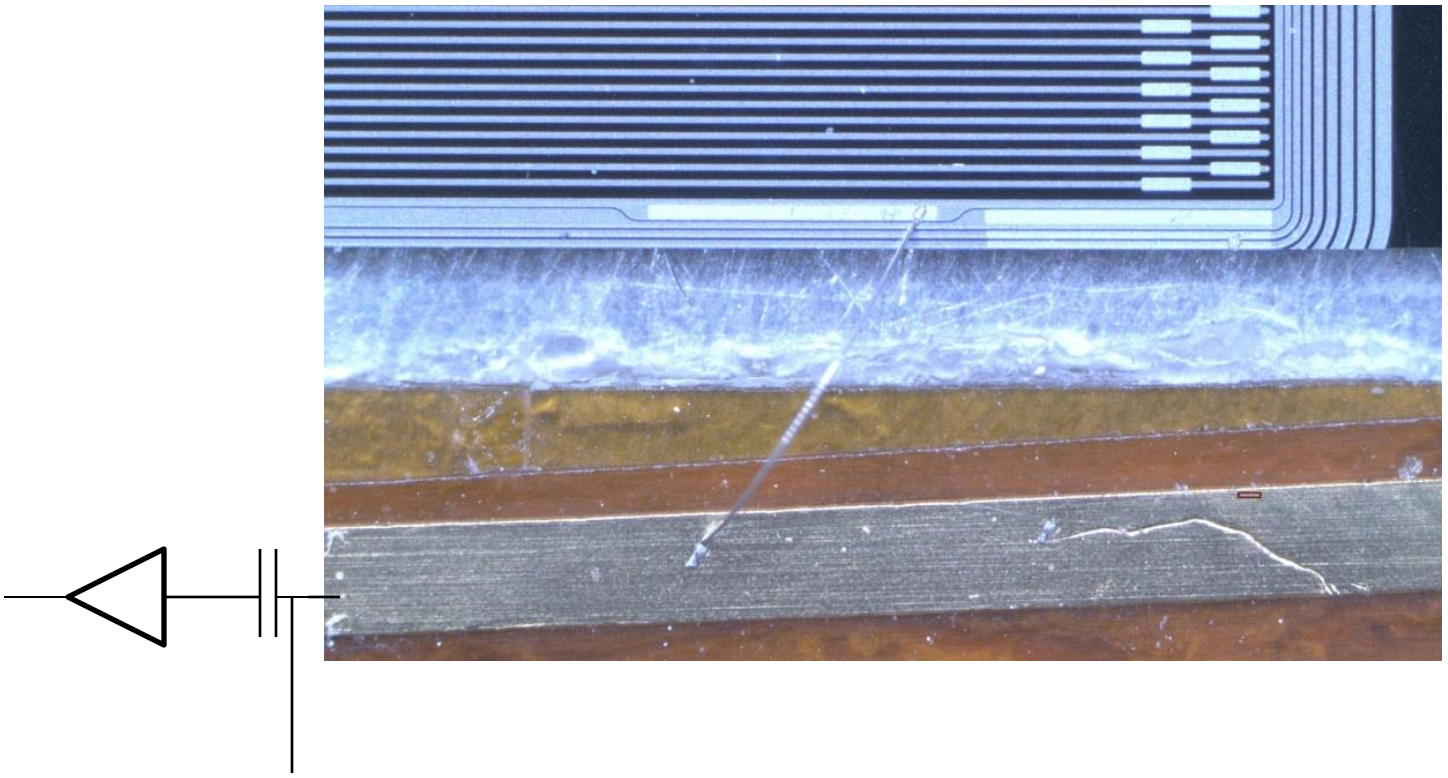


Standard focused laser TCT Setup

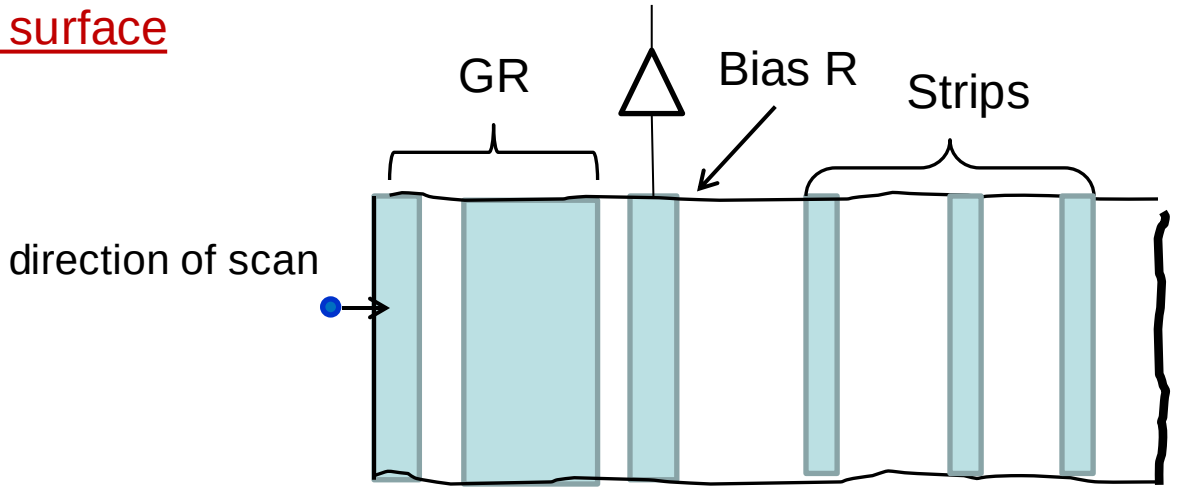


Connection

- only bias ring bonded
- measure signals induced on bias ring

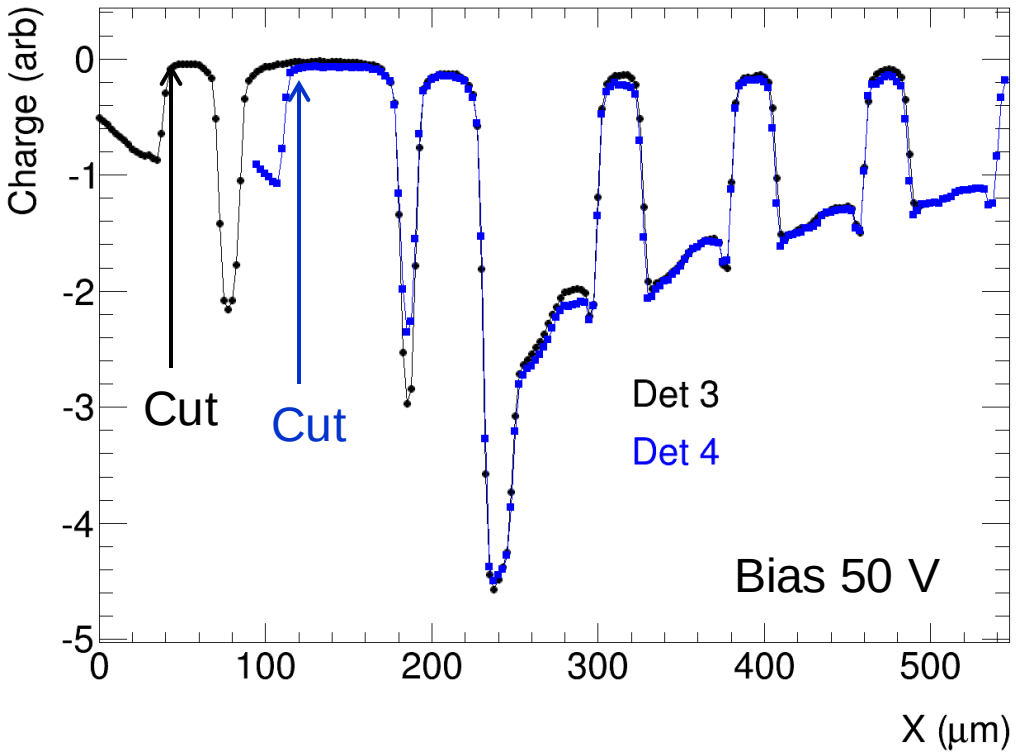


IR laser, scan top surface



Det 3: edge ~ 180 µm
Det 4: edge ~ 110 µm

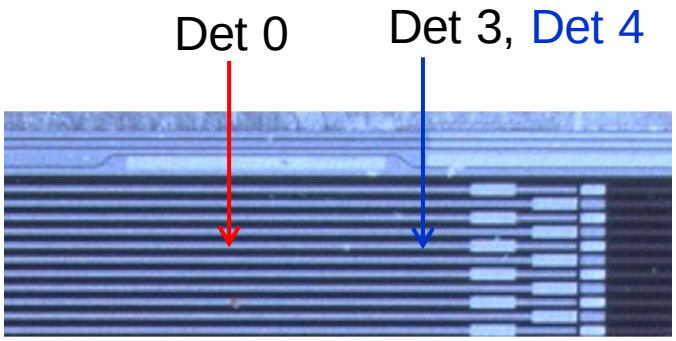
➔same CCE near strips for both detectors

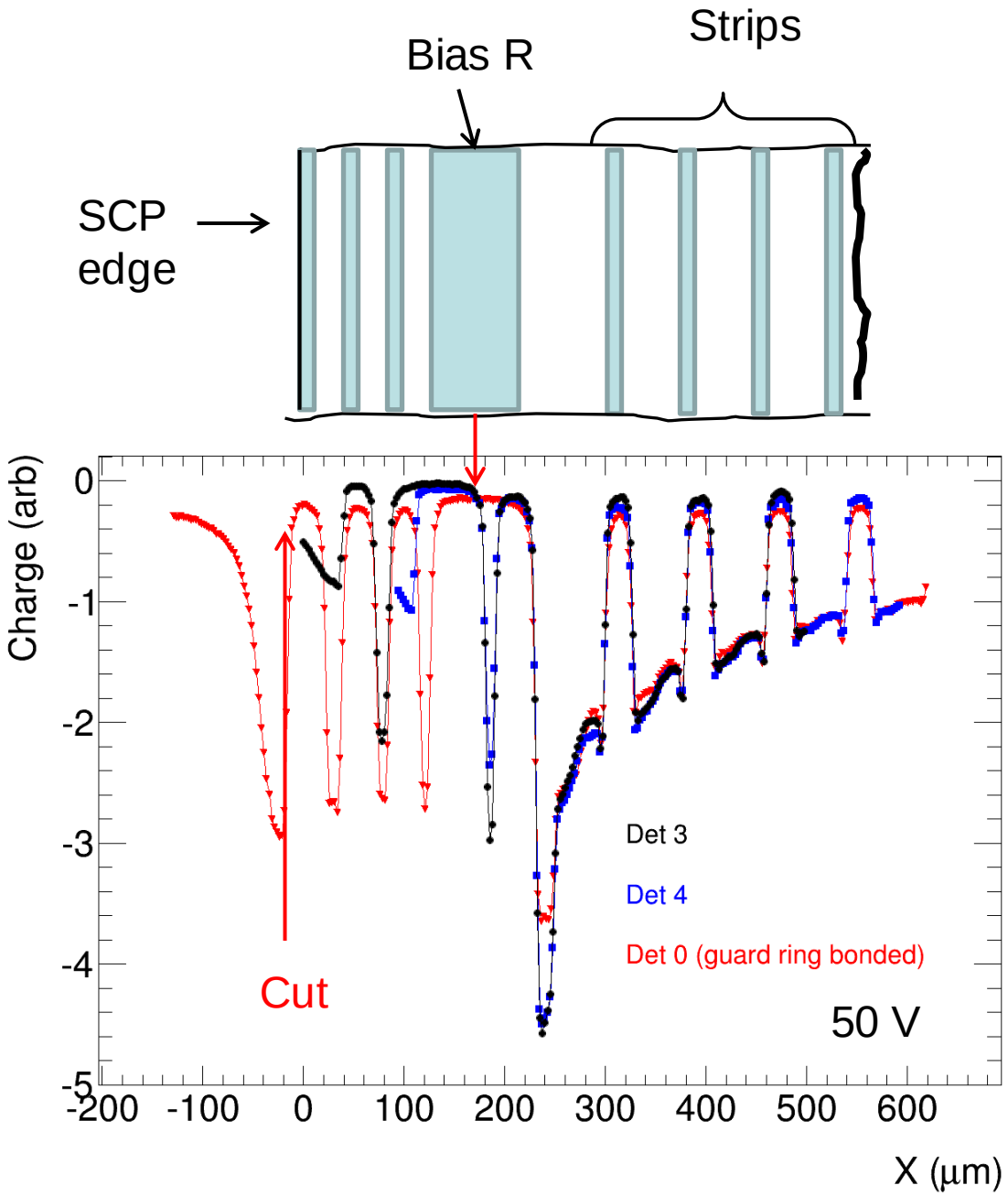


IR laser, scan top surface

→ the outermost guard ring also bonded for Det 0 measurement

→Det 0: scan over area with wider bias-ring metal



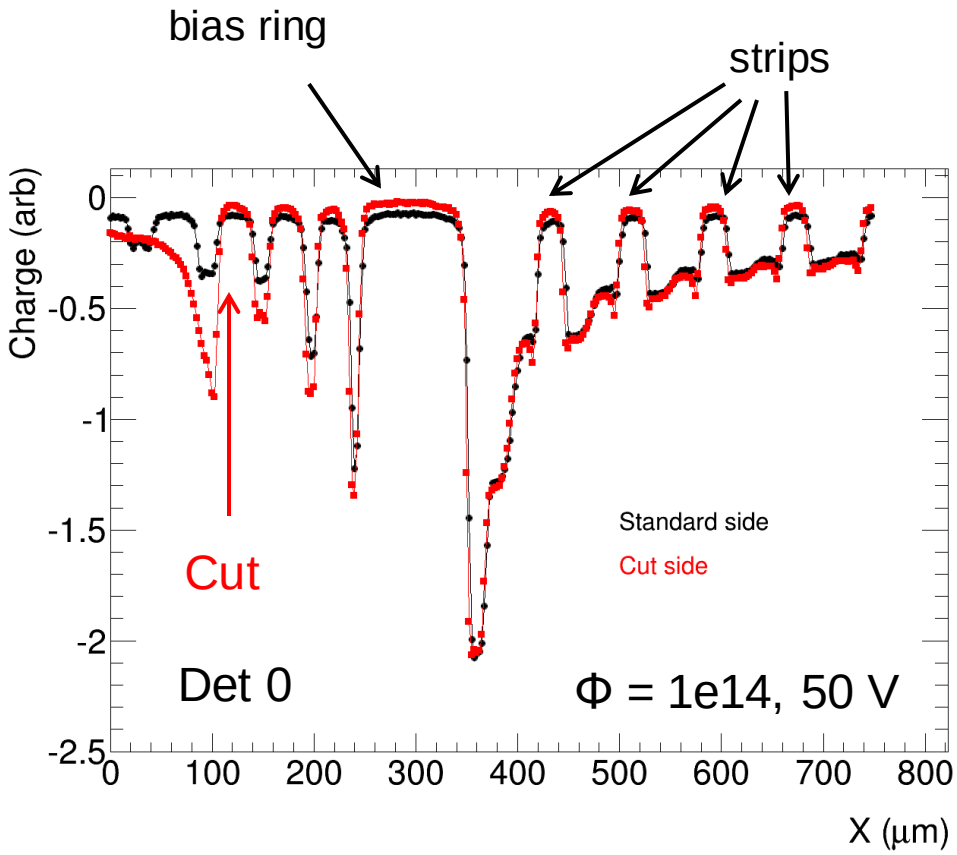


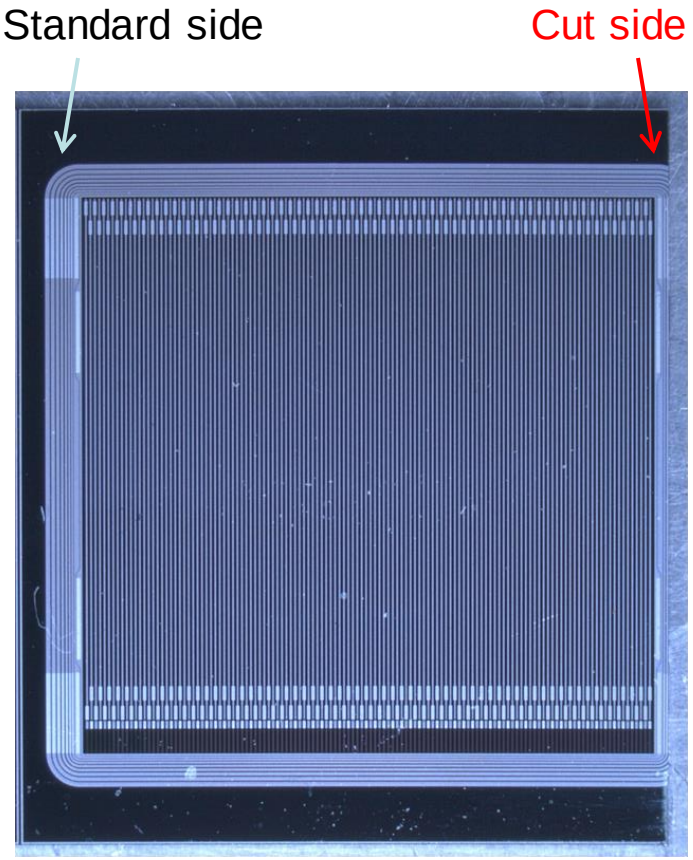
Det 0: edge ~ 220 µm
Det 3: edge ~ 180 µm
Det 4: edge ~ 110 µm

➔ same CCE at strips!

IR laser, scan top surface, irradiated detector

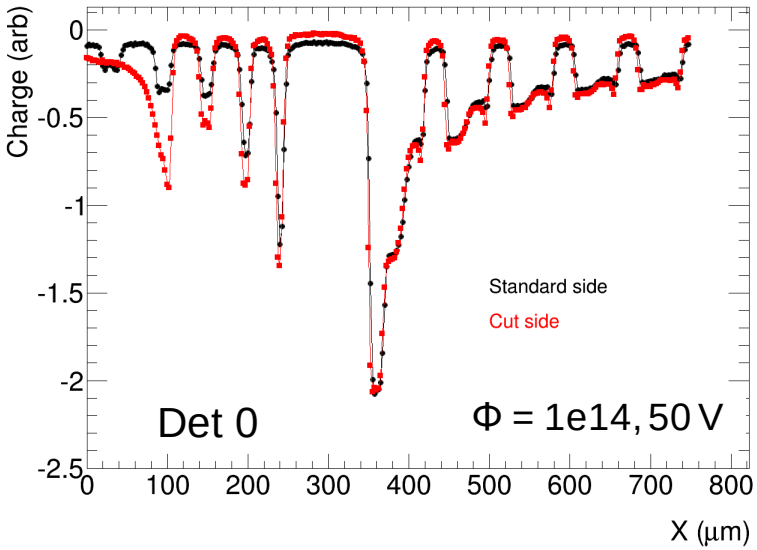
Scan with IR laser over detector on the SCP cut side and on the **standard side**

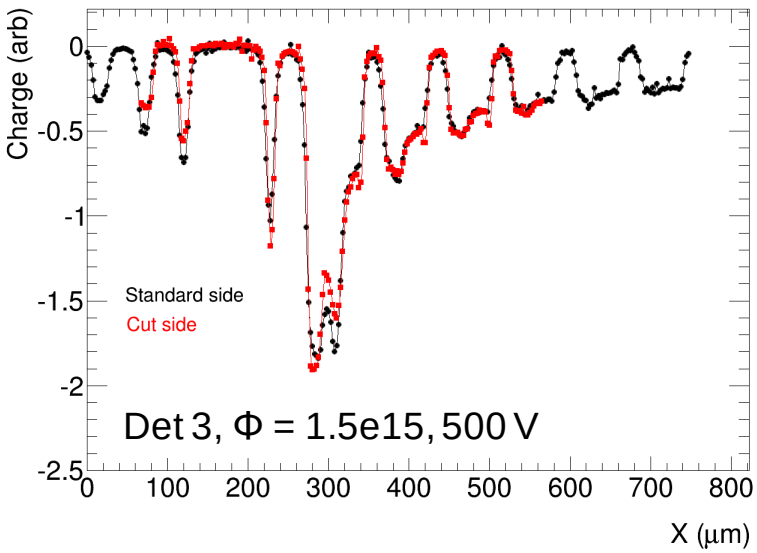


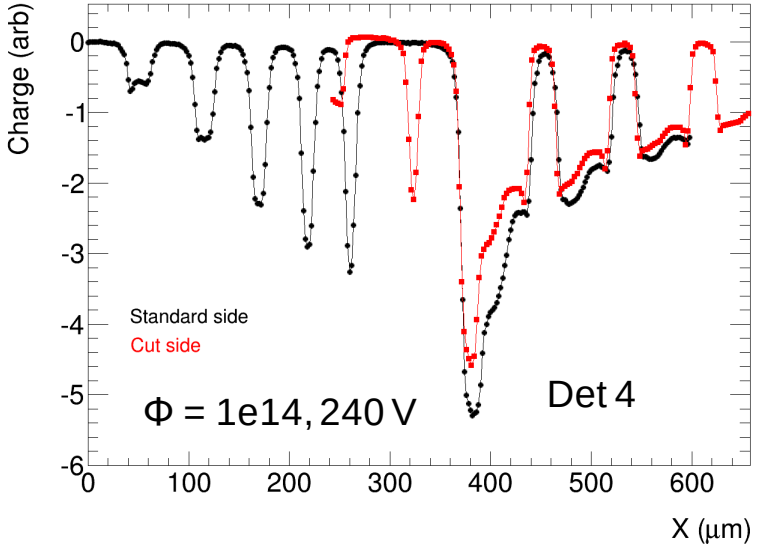


➔ Cut doesn't change CCE near strips

IR laser, scan top surface, irradiated detectors



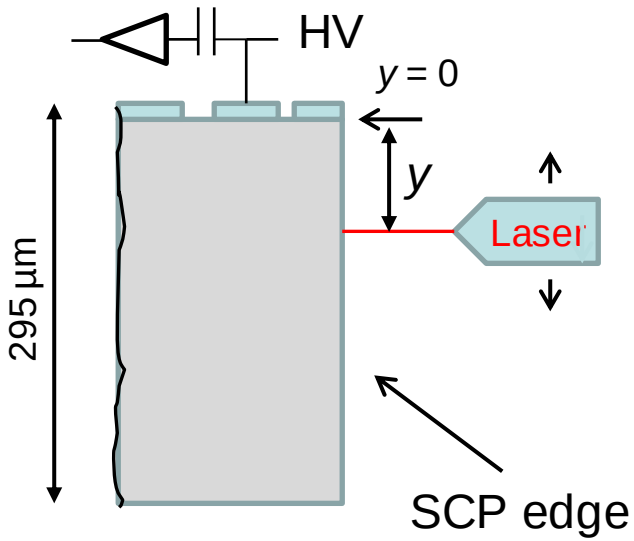


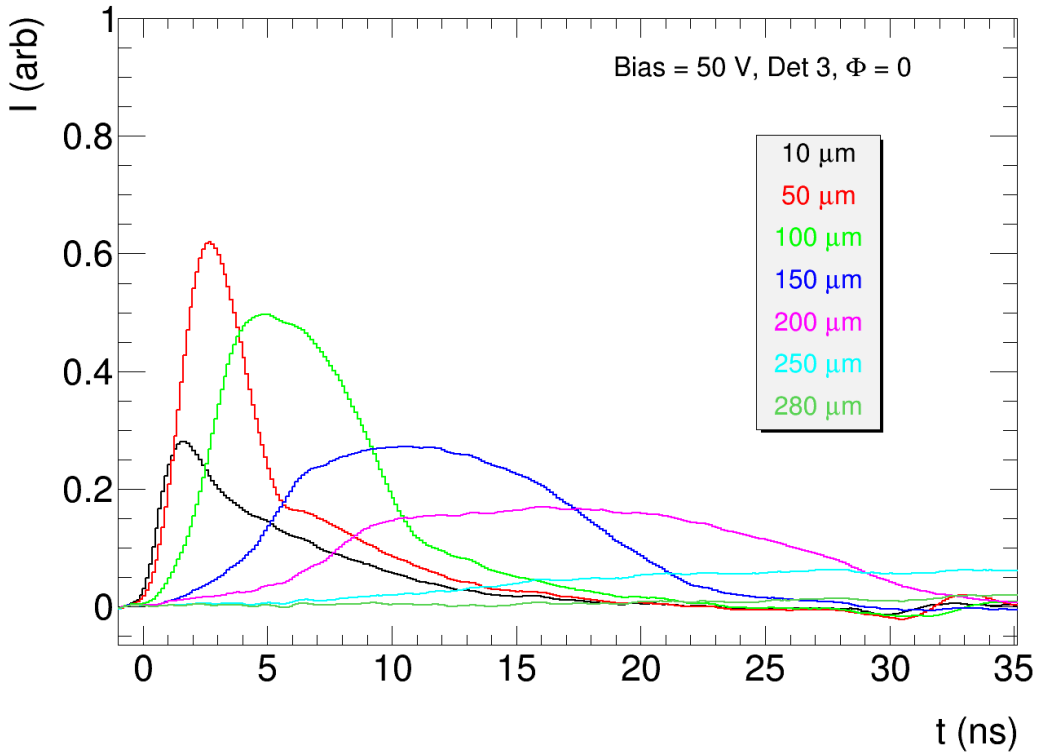


- negligible difference between cut and not-cut side after irradiation

Edge scan with red laser (preliminary!)

Red light enters ~ 3 µm into Si
→ probe the *E* field at the cleaved edge surface
→ similar to STCT measurements with CTS edgeless detectors (TOTEM)
(see e.g. *E. Verbitskaya et al., NIMA 604 (2009) p. 246*)





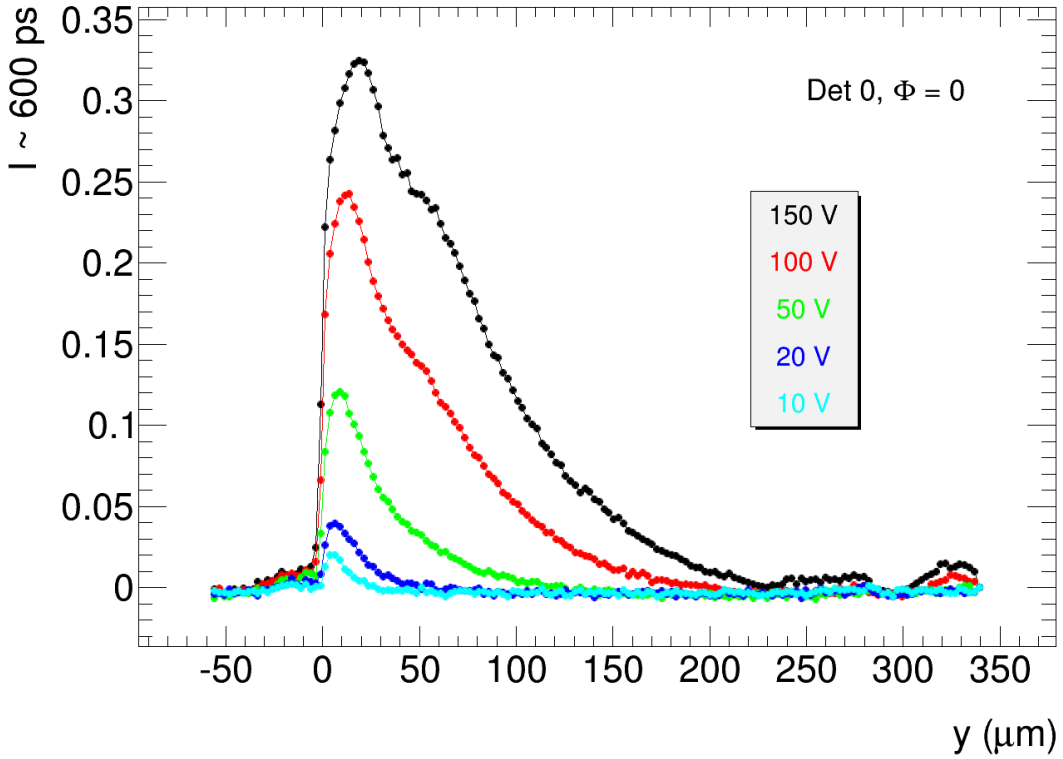
➔ electric field higher closer to the top (y = 0)
➔ at larger *y* carriers enter the field region by diffusion → long pulses
➔ similar pulses in all 3 detectors → no large effects of edge thickness

Electric field profile:

$$I(y,t\sim 0)\approx qE_w\left[\bar{v}_e(y)+\bar{v}_h(y)\right];\quad \bar{v}_e(y)+\bar{v}_h(y)\propto E$$

➔ induced current at *t ~ 0* proportional to carrier velocity at laser spot location

→ electric field profile *(only approximatelly because* $\boldsymbol{E_w}$ *is not constant)*



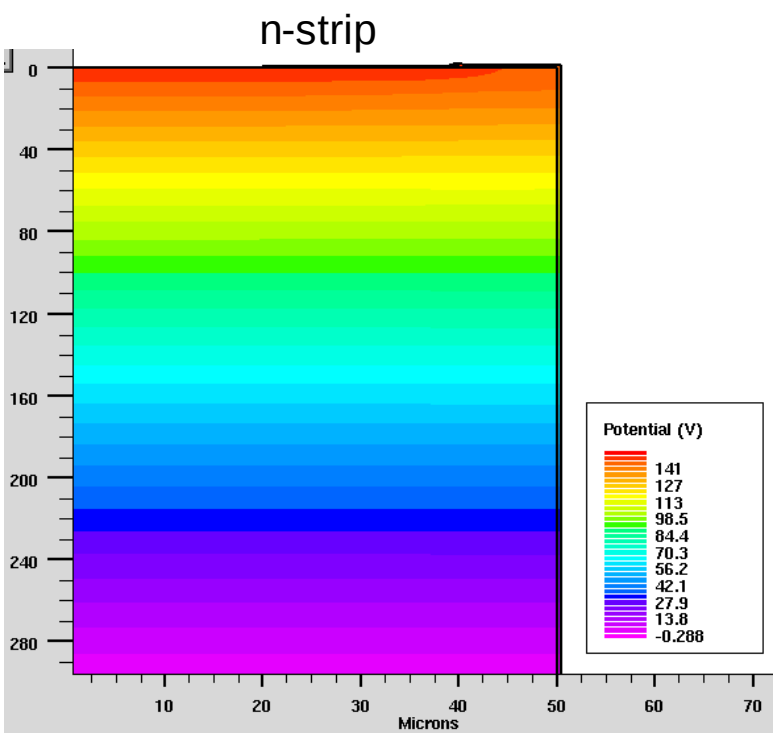
➔ at higher bias stronger field at larger distance from electrode

➔ also at 150 V >> V_{fd} weak field near the back side

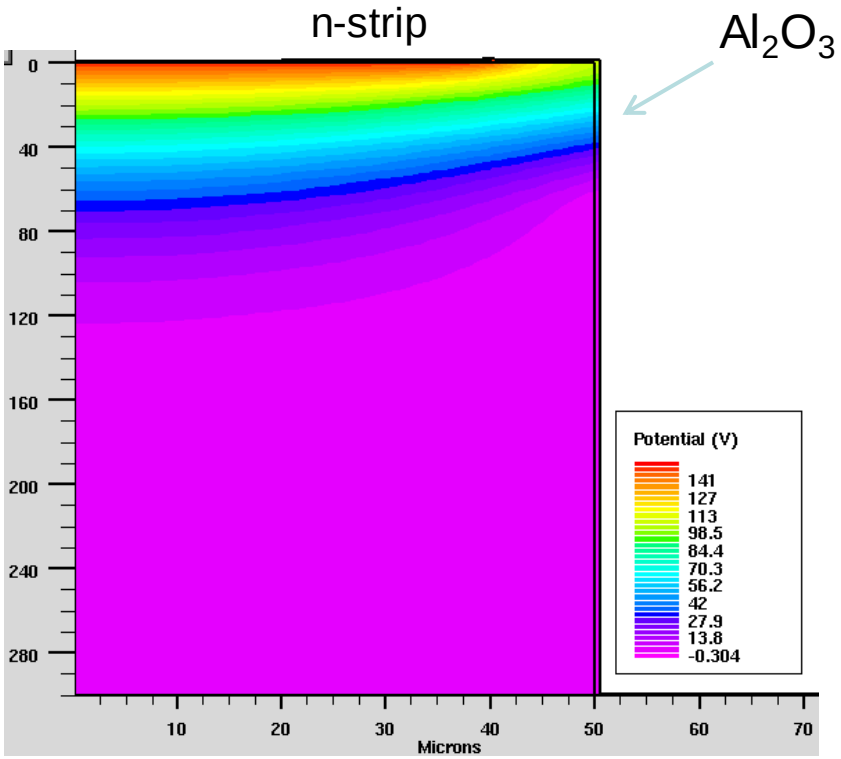
Simulation

from: *Marc Christophersen, "6th Trento Workshop", March 2-4, 2011*

No surface charge:



Negative charge (-1E11 cm^{-2}) :



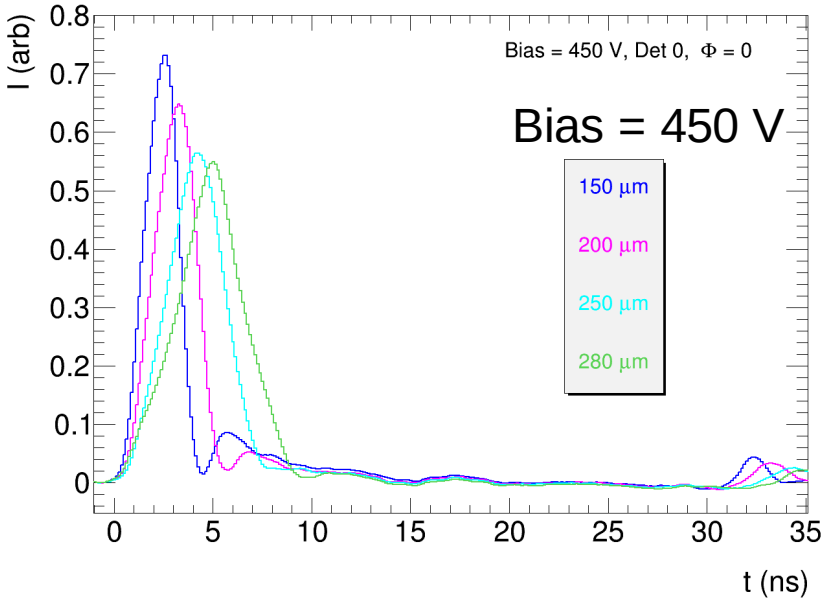
Not considering surface charges leads to *wrong* potential distribution at sidewall.

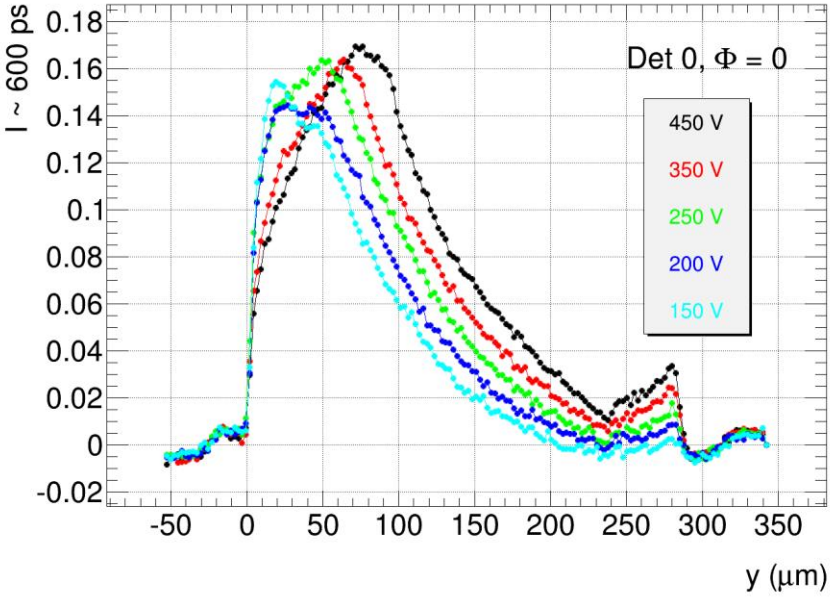
➔ low field at the back side because of surface charge

Edge scan with red laser

- measurements at higher voltages (V >> V_{fd} ~ 50 V)

Det 0, (220 µm edge)

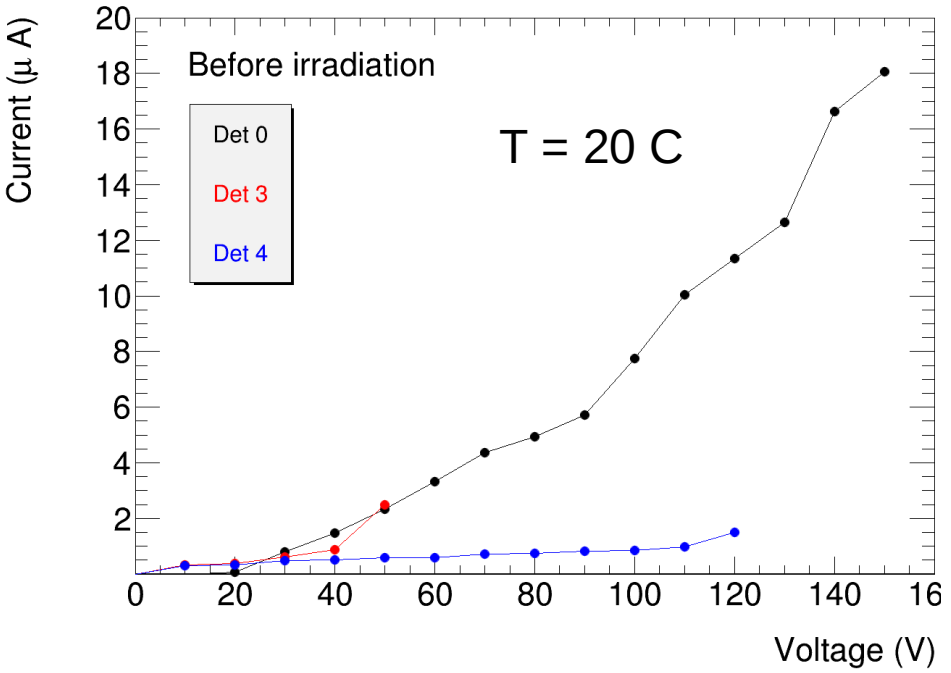


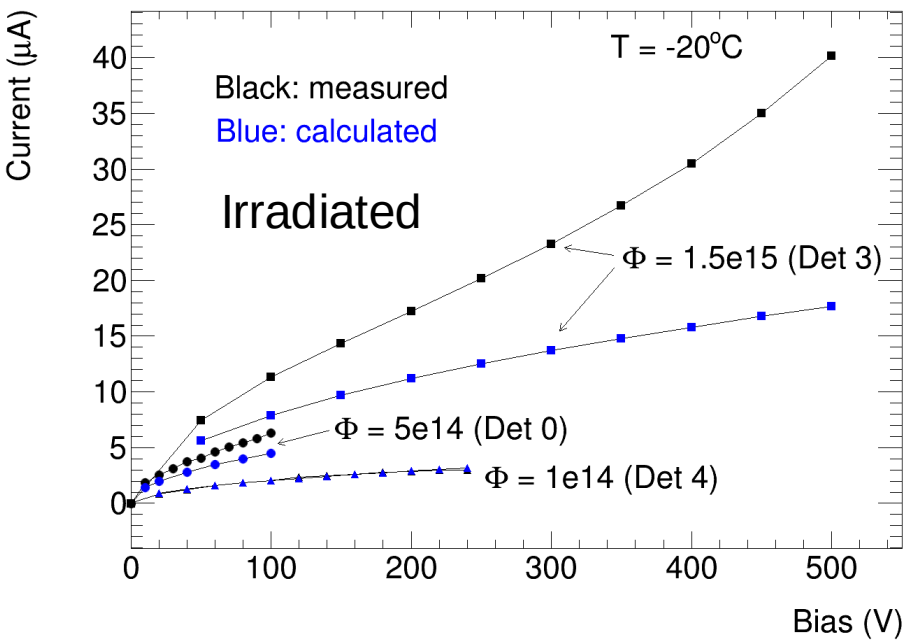


- electric field all over the cleaved edge

Current before and after irradiation

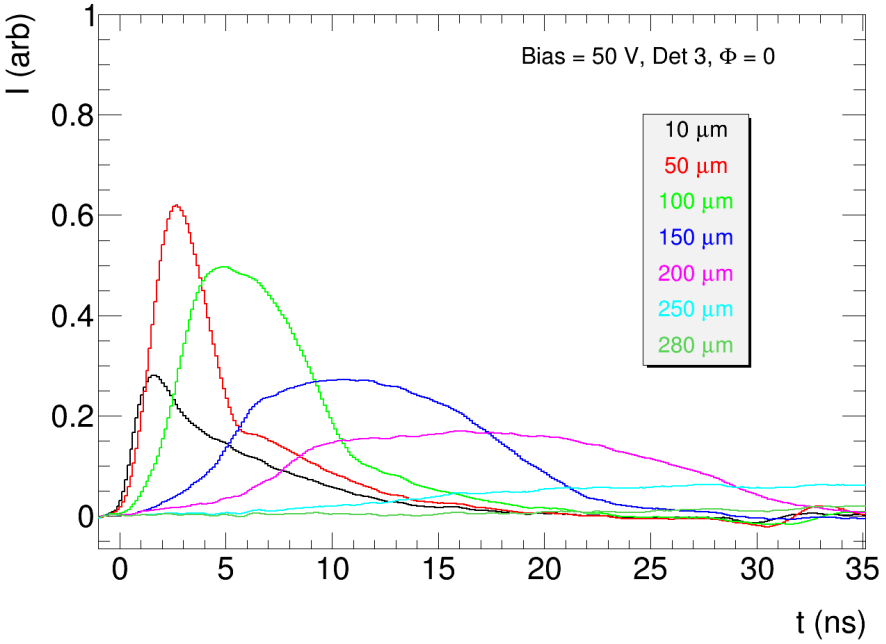
→ Det 3: 1e14, Det 0: 5e14, Det 3: 1.5e15
→detectors annealed for 80 minutes at 60°C
→ calculation: $I = \alpha \cdot \Phi \cdot V$; V from depleted depth in pad geometry

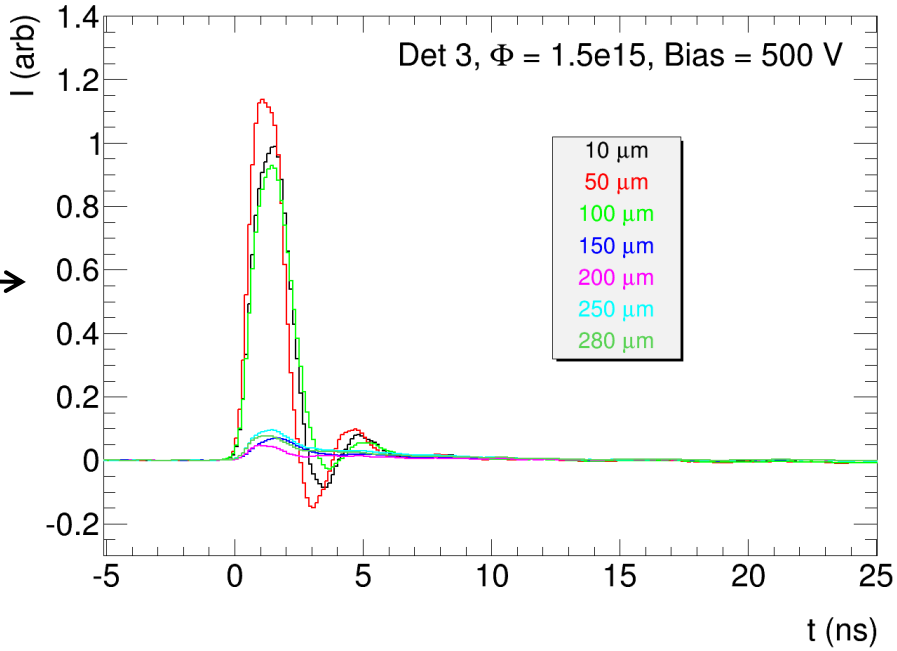




- higher bias could be applied after irradiation
- no large difference between measured and bulk current after irradiation

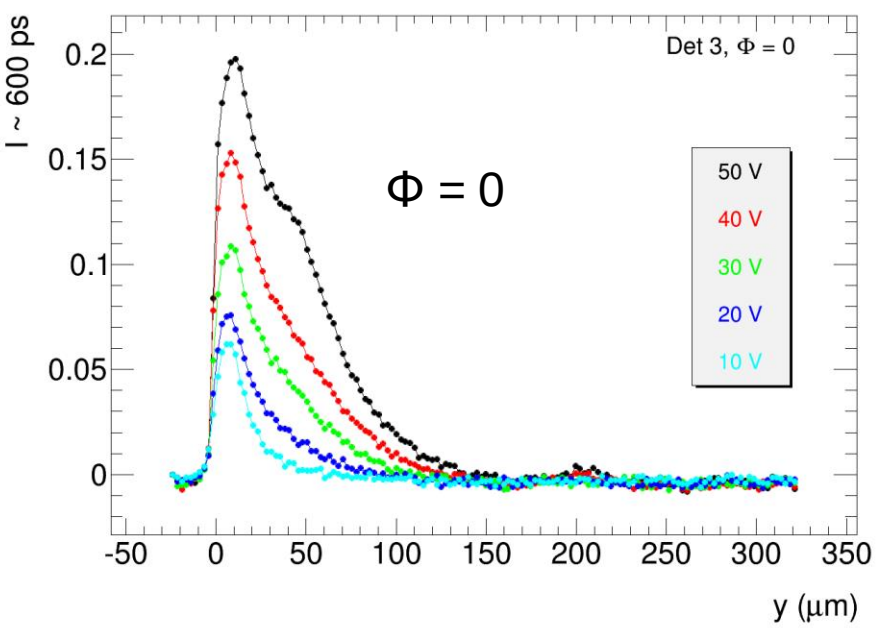
Pulses before and after irradiation

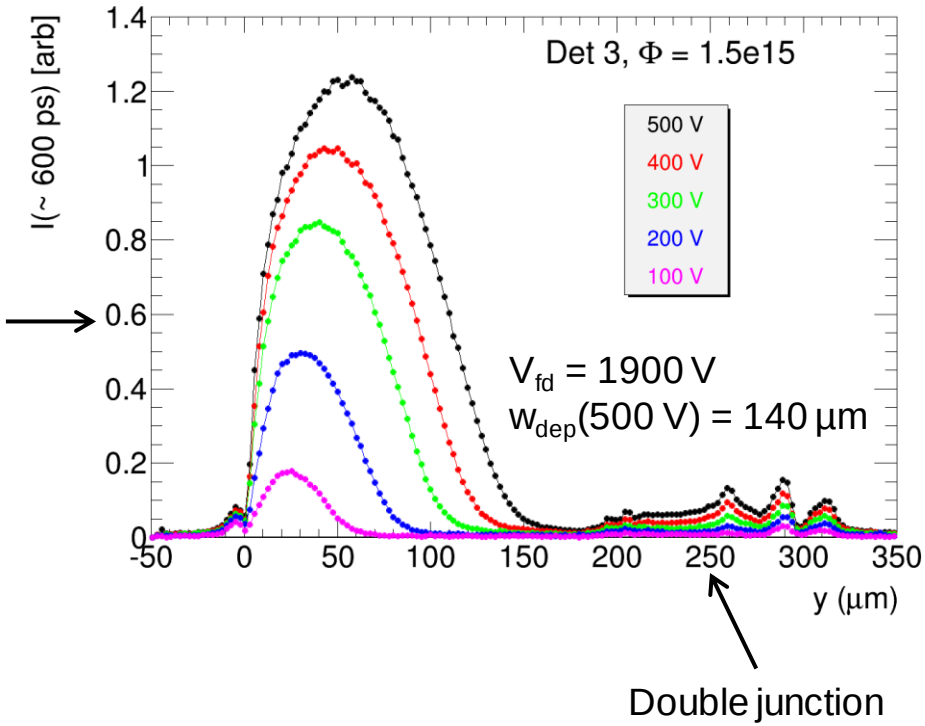




➔ after irradiation long pulses not seen because of trapping

Field profiles before and after irradiation



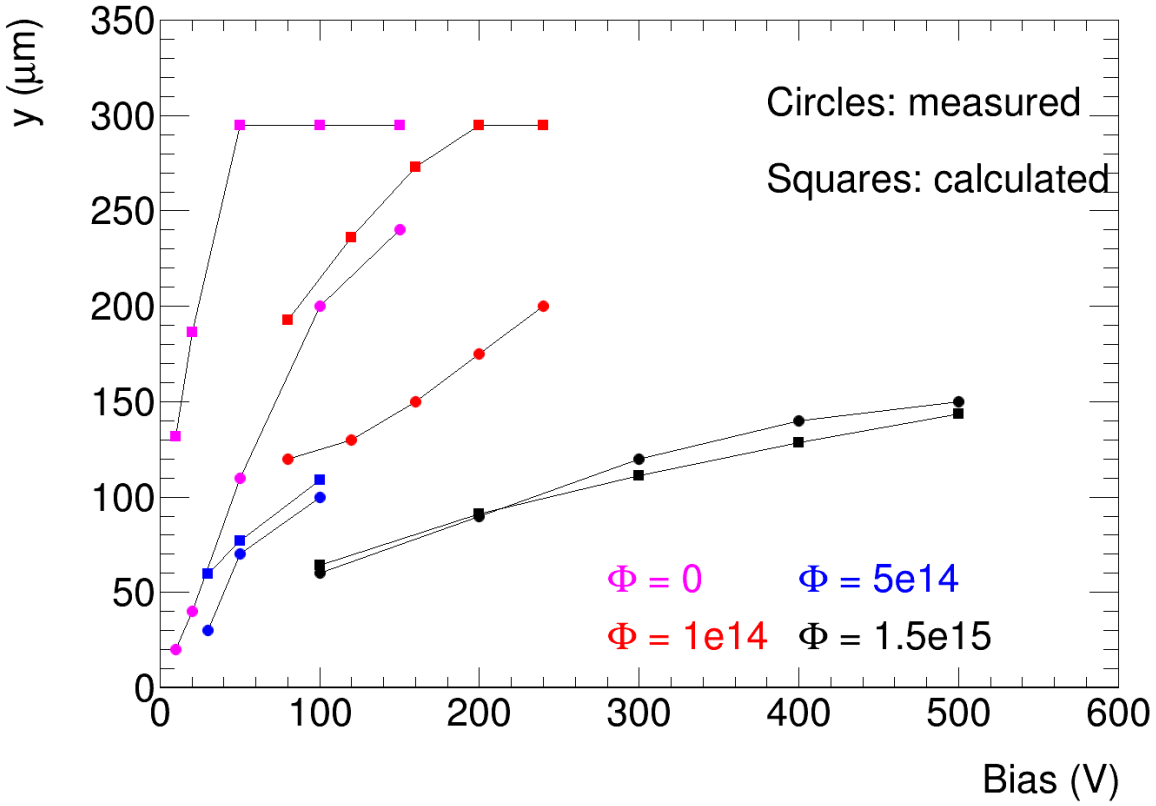


- depleted depth in planar diode: $w_{dep} = \sqrt{\frac{2\varepsilon\varepsilon_0 V_{bias}}{e_0 \left| g_c \Phi_{eq} \right|}}$

- after irradiation to 1.5e15 E field on the edge extends closer to value of w_{dep}

Depth of field at the edge

- measurement: max. *y* at which $E > 0$ (from field profile measurement)
- calculation: depletion depth in planar geometry



- measured and calculated values closer at higher fluences
  → after irradiation to high fluences field at the edge similar as in the bulk

Summary

- CCE measurements with focused IR laser light

  → no influence of cut edge on CCE at strips before or after irradiation

- measurements with focused red laser light

  → nice tool to probe electric field on the edge surface

  → lower electric field on the edge at the back side of the detector

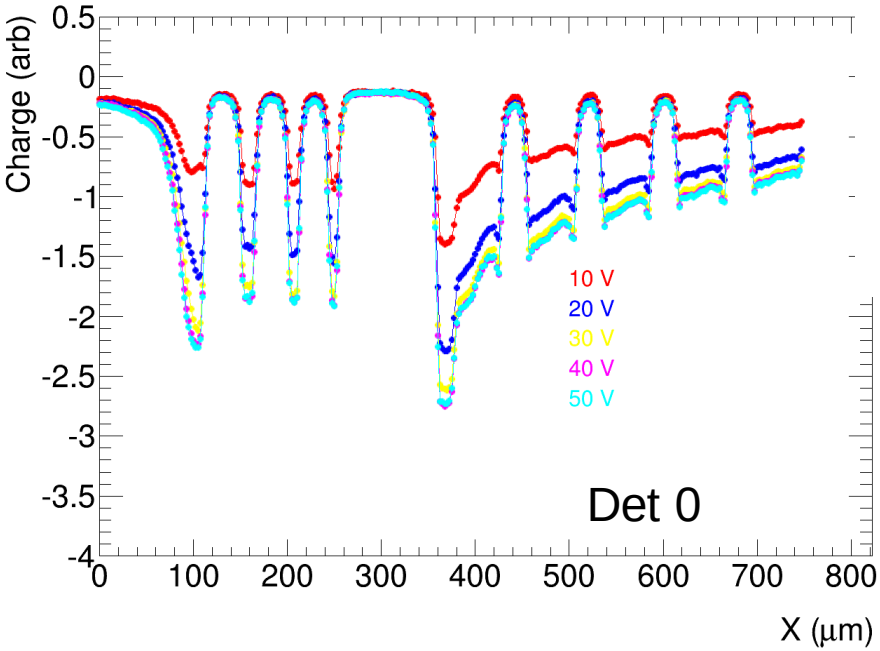
    → in agreement with simulations

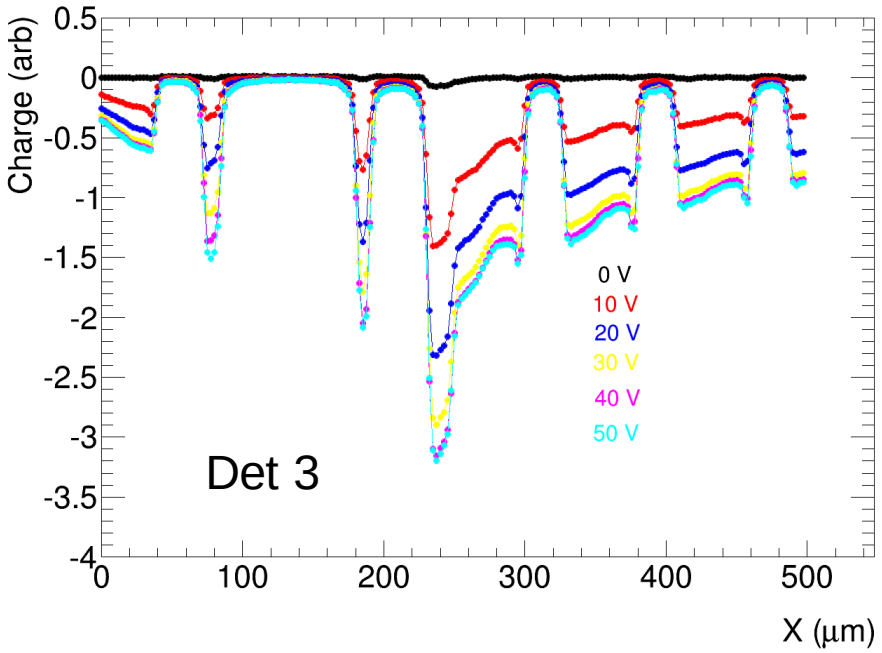
  → after irradiation:

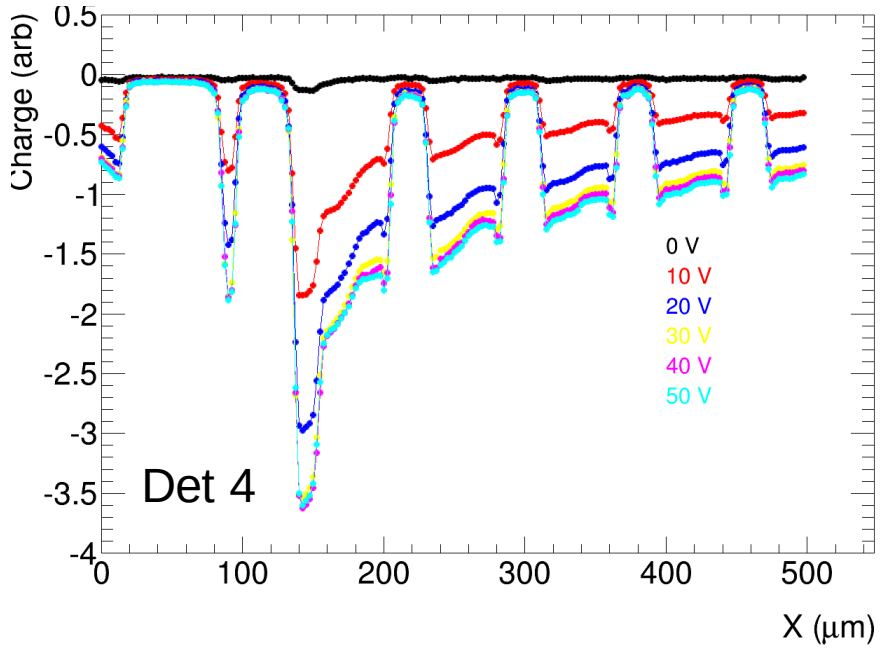
    → indication that field on the edge more similar to the field in the bulk

Scans at different voltages

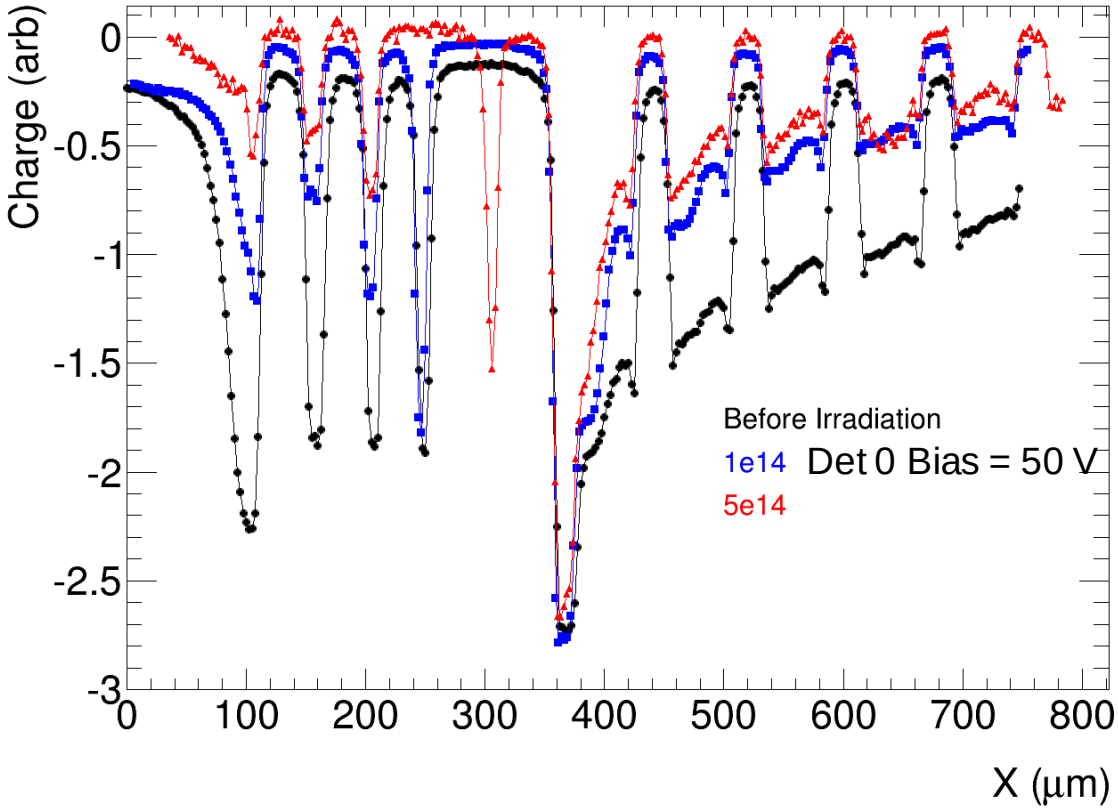
➔ V_{fd} ~ 40 V



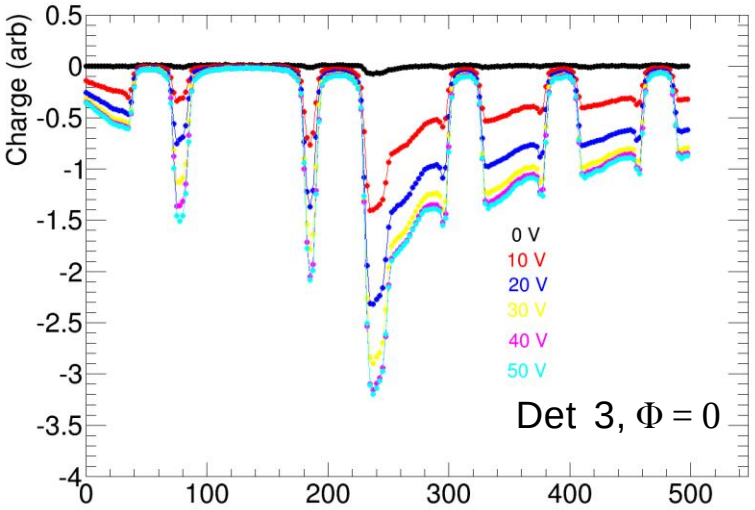


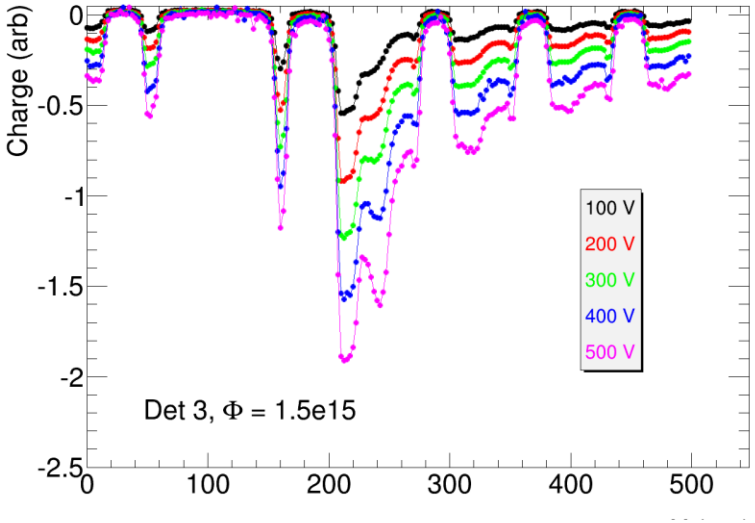


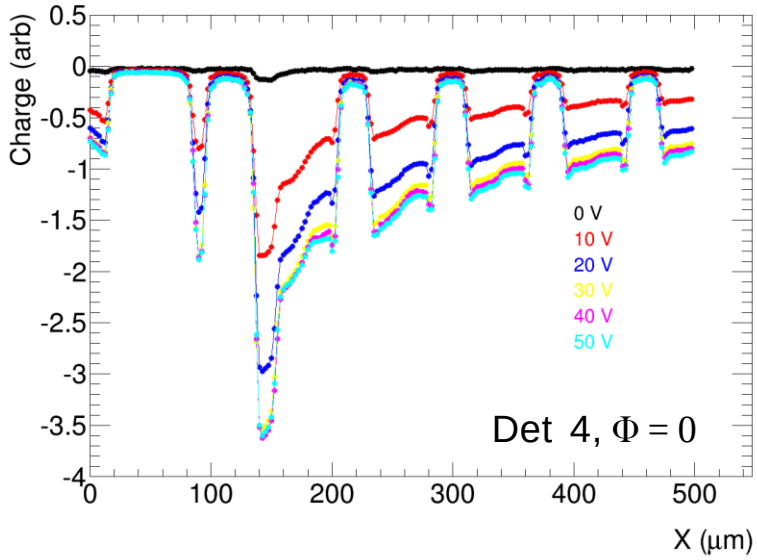
CCE scans at 50 V before and after irradiation

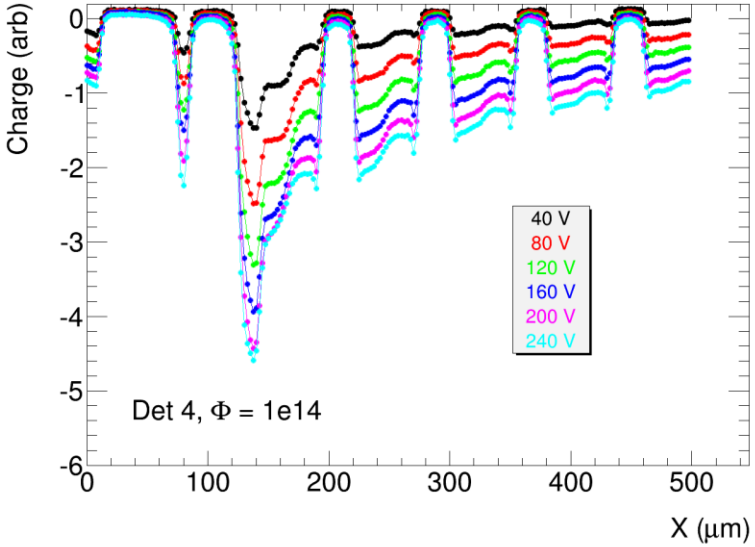


IR laser, scan top surface



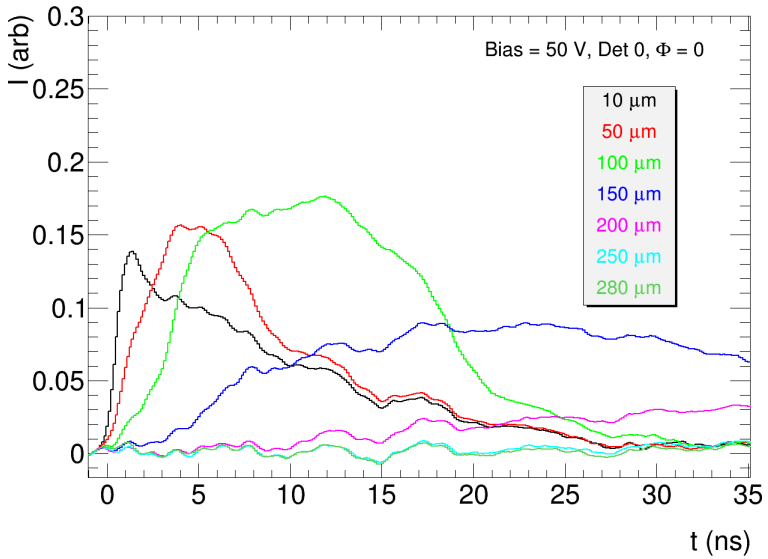


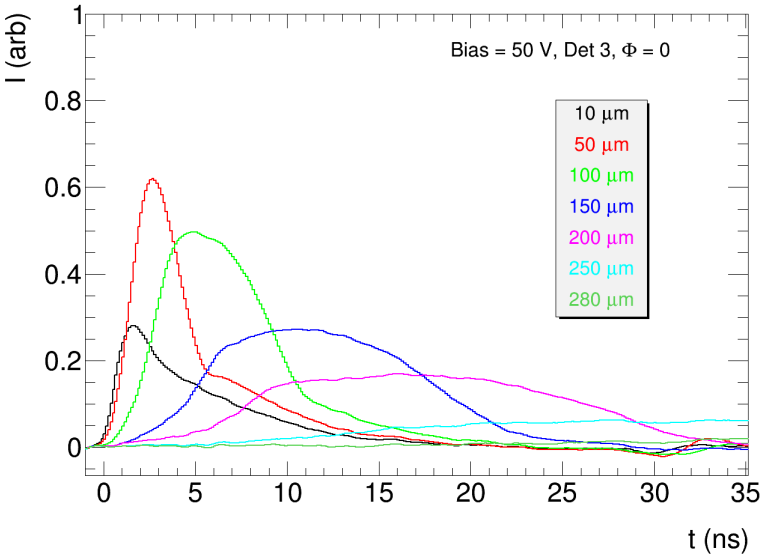




Edge scan with red laser

Pulses:

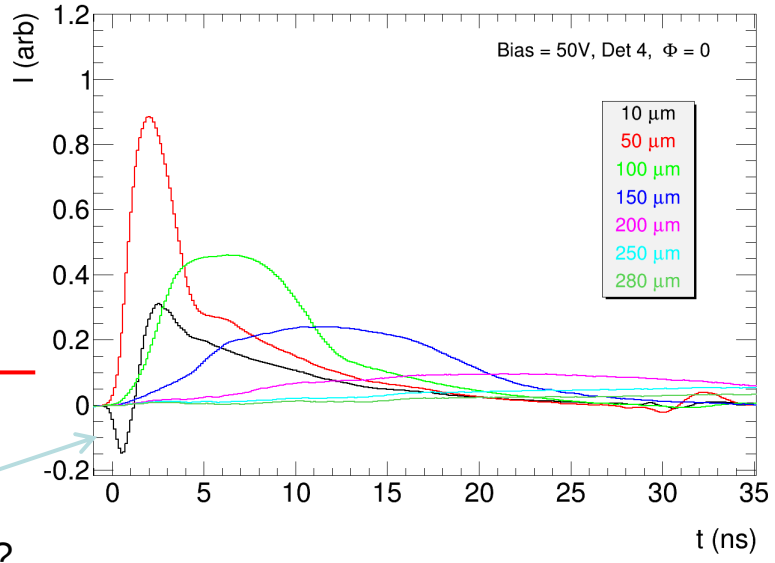




Edge thicknesses:

Det 0 ~220 um
Det 3 ~180 um
Det 4 ~110 um

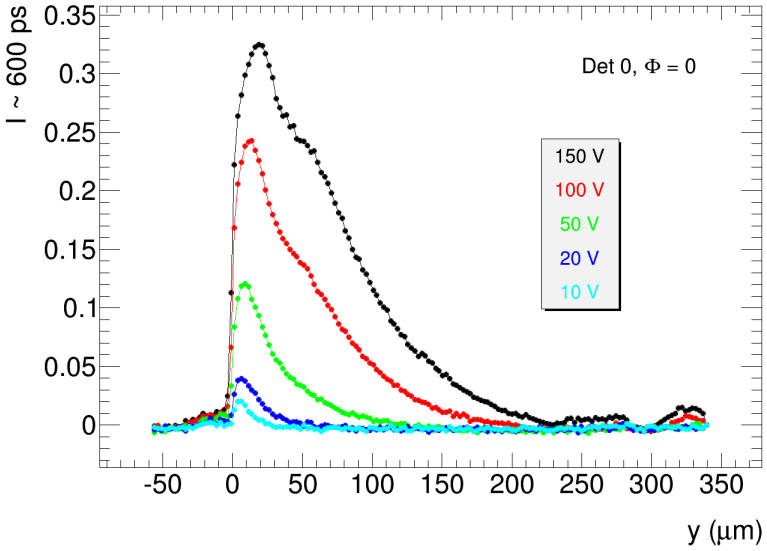
→ similar pulses
→ weak field at back side

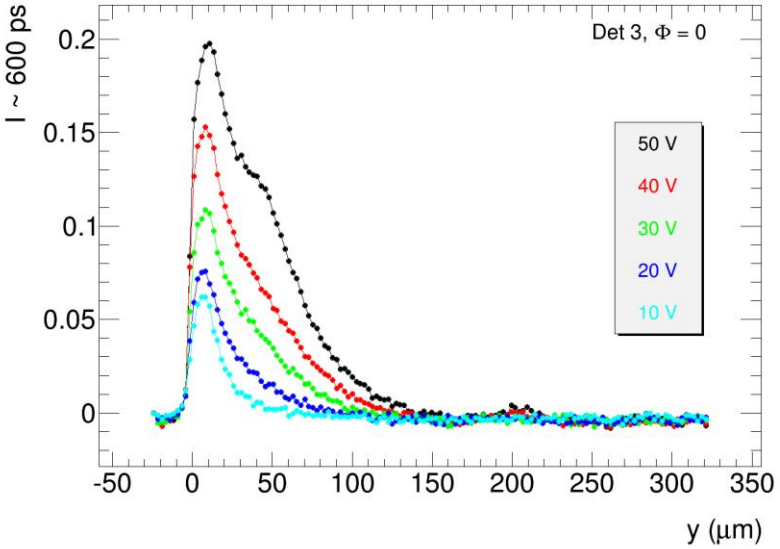


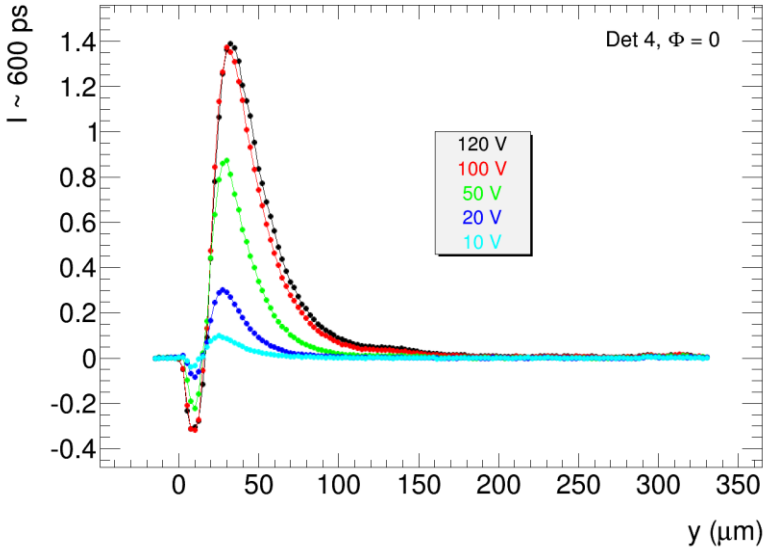
?

Light on top, detector not at 90 deg?

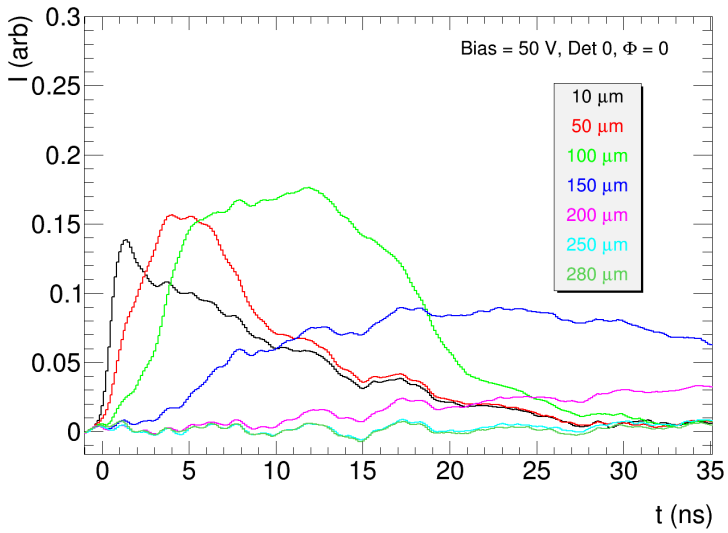
Profiles before irradiation

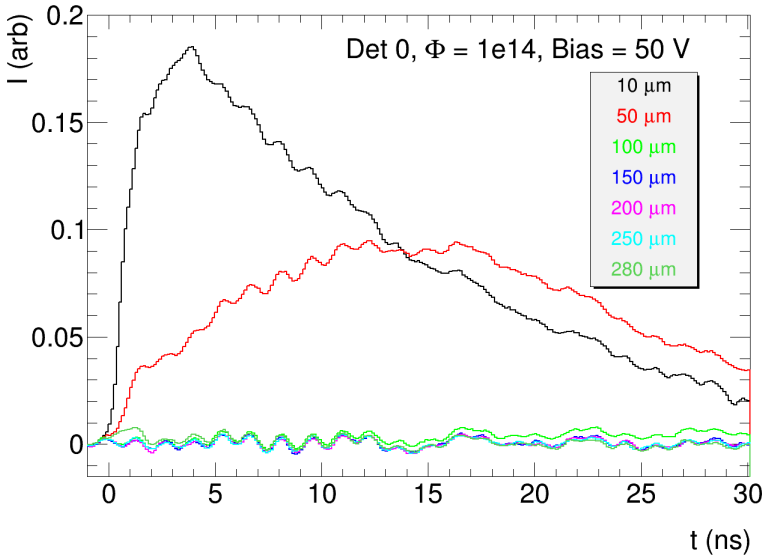


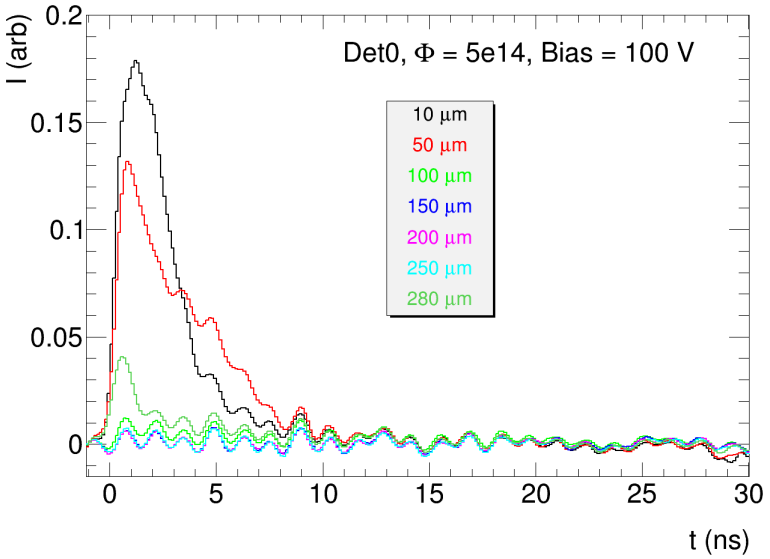




Pulses before and after irradiation



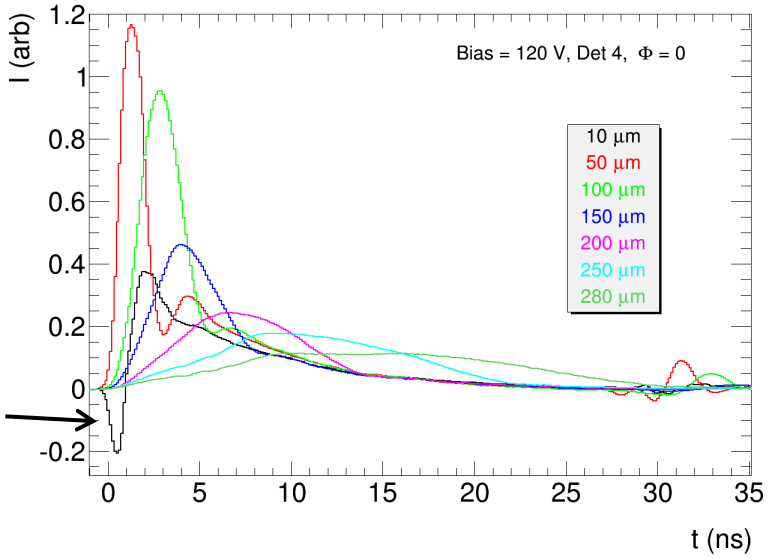


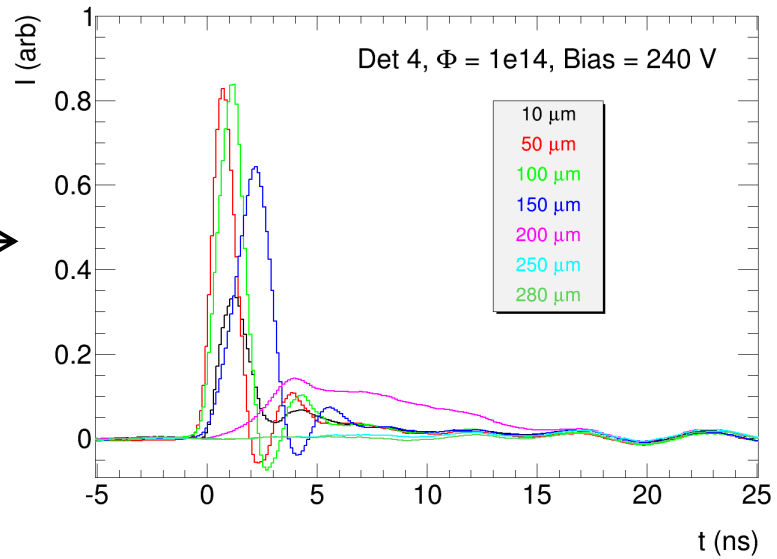


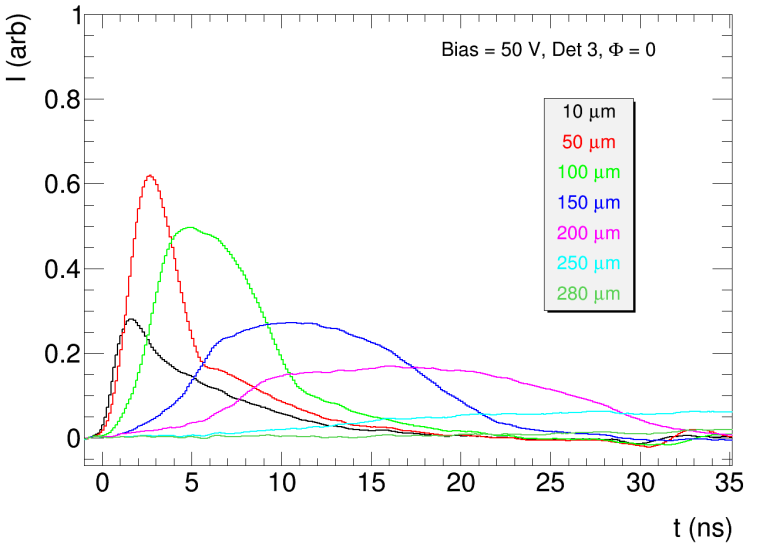
- maximum bias for this detector after irradiation to 1e14 50 V
- could go to 100 V after 5e14
- depletion depths:
  1e14, 50 V: ~150 µm
  5e14,100 V: ~100 µm

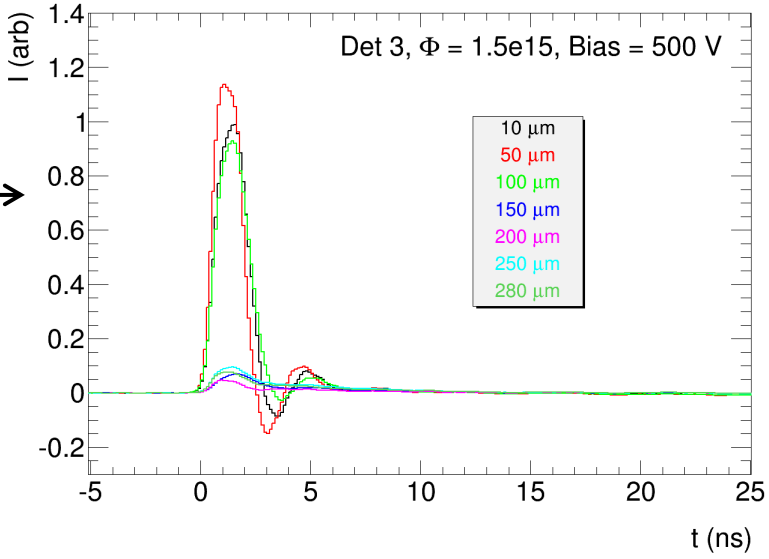
Pulses before and after irradiation

detector not well aligned, light on top?

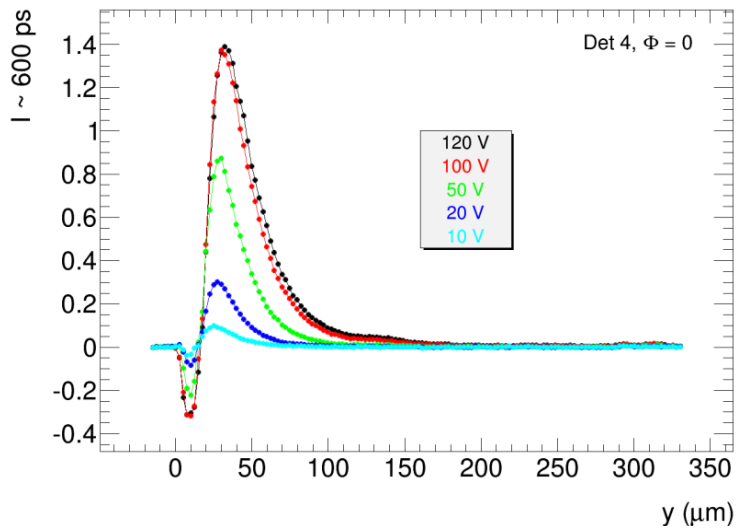


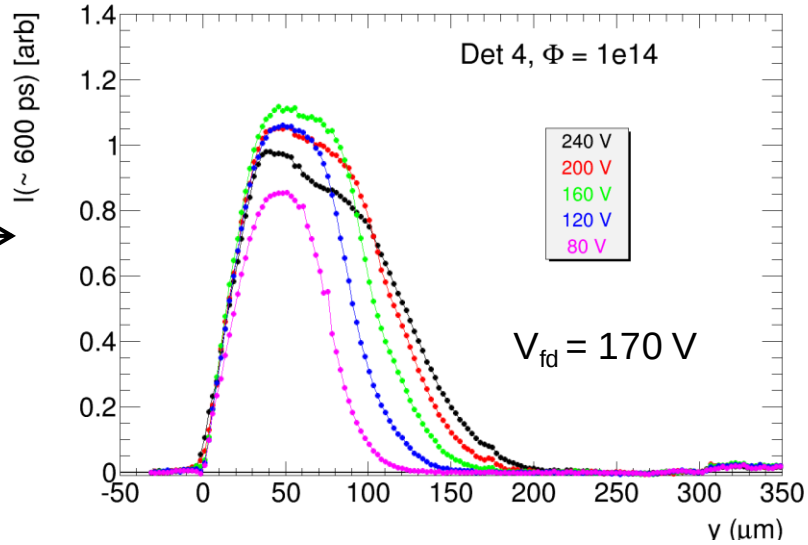


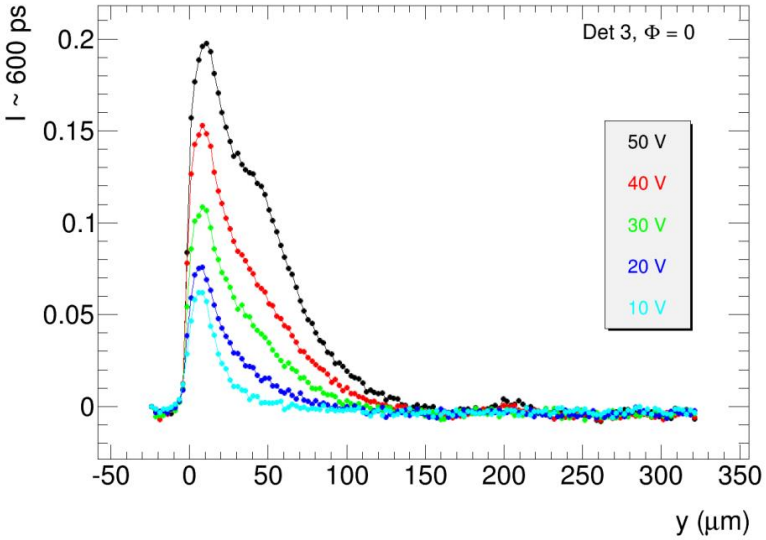


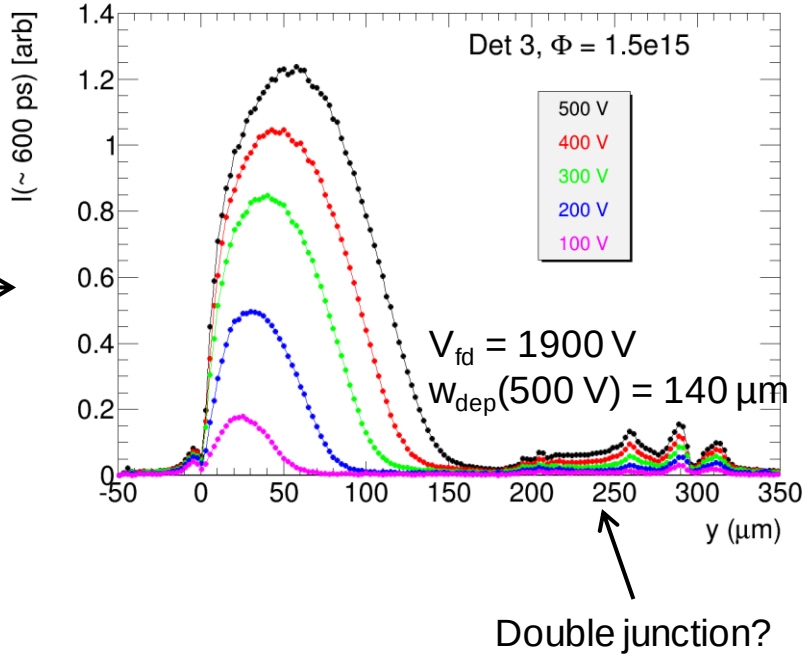


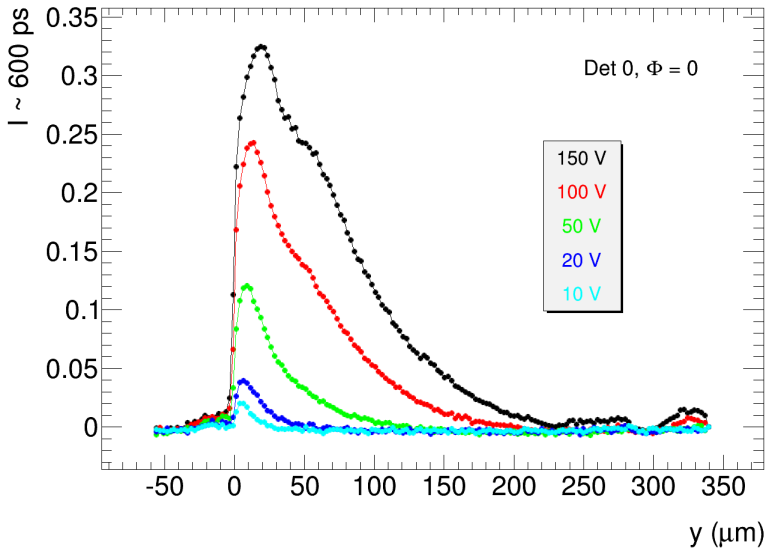
Field profiles before and after irradiation

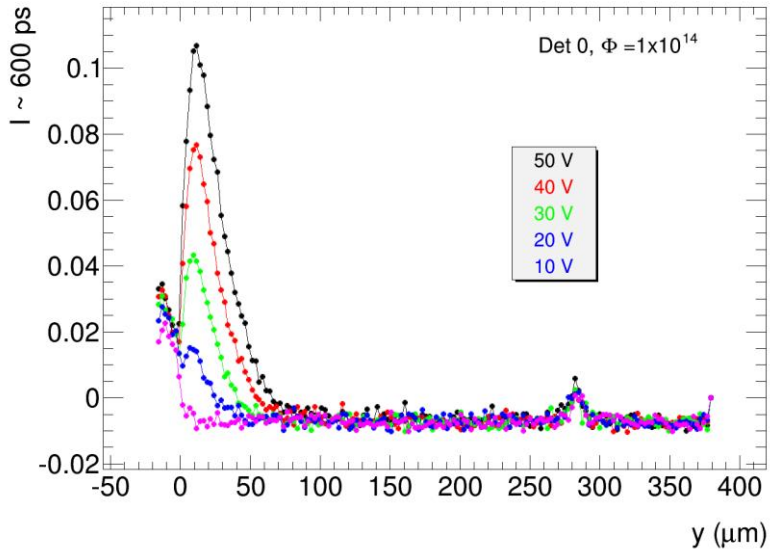


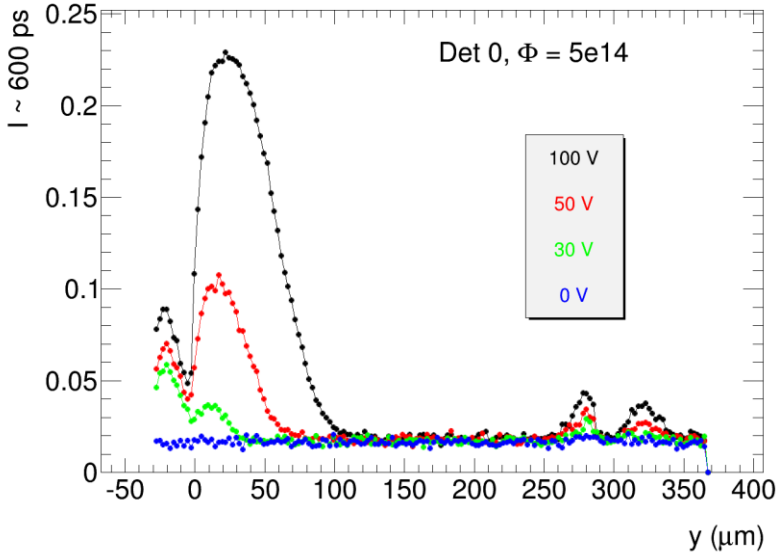







I ~ 600 ps
Det 0, Φ = 0
150 V
100 V
50 V
20 V
10 V
y (μm)


I ~ 600 ps
Det 0, Φ =1x10^14
50 V
40 V
30 V
20 V
10 V
y (μm)


I ~ 600 ps
Det 0, Φ = 5e14
100 V
50 V
30 V
0 V
y (μm)