# Dosimetry cross check on HGTD QCTS

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F9 HGTD Weekly

# Background



- We performed multiple different irradiations to measure acceptor removal in HGTD QCTS:
  - HGTD TRIGA: cn = 1.2e-16 $cm^{-2}$
  - Birmingham 24 MeV protons: cp = 2.9e-16 $cm^{-2}$
  - Krakow 60 MeV protons: cp = 2.3e-16 $cm^{-2}$ (uncertain annealing history)
  - Cyric 70 MeV protons: cp = 3.2e-16 $cm^{-2}$
  - PS IRRAD 24 GeV protons: cp = 2.9e-16 $cm^{-2}$
- Precise dosimetry is essential to determine the absolute value of c
  - Neutron irradiation: we use nominal (=requested) fluence
  - Proton irradiation: we measure Ileak in the PIN at 20 °C after annealing 80 min @ 60°C
- We consistently measure 3x lower NIEL fluence in the PIN than reported by Birmingham, Krakow and Cyric

$$\emptyset_{\mathrm{eq}} = \frac{I_{\mathrm{PIN}}}{\alpha V} \qquad \emptyset_{\mathrm{eq}} = 2.94e14 \times I_{\mu\mathrm{A}}$$

# Krakow cross check with CNM PIN



- At Krakow we irradiated
  - 2 batches of CNM diodes (2e13p and 1e14p nominal)
  - 4 batches of QCTS (2e14p–8e14p nominal)
- Ratios of reported fluences, as well as PIN-measured fluences are consistent (except 2e14p PIN – could be misplaced in the beam)
- This indicates **same NIEL rate in CNM PIN and QCTS**

| Nominal fluence (p/cm2) | Reported fluence (neq/cm2) | Measured fluence (neq/cm2) | Reported normalized | Measured normalized |
|---|---|---|---|---|
| 2e13 (CNM) | 0.98 E14 | 0.31 E14 | 1 | 1 (0.32x rep) |
| 1e14 (CNM) | 3.7 E14 | 1.2 E14 | 3.8 | 3.9 |
| 2e14 | 7.6 E14 | 1.0 E14 | 7.8 | 3.2 |
| 4e14 | 14.6 E14 | 3.8 E14 | 15 | 12 |
| 6e14 | 13.2 E14 | 3.1 E14 | 14 | 10 |
| 8e14 | 25.2 E14 | 10 E14 | 26 | 32 |

# List of checks



1. Measure 10 QCTS from the HGTD production (63 kW , CC, 2.5e15) and see what is the equivalent fluence that we get on PINs with neutrons.

2. One of the possible reasons may well be that volume is for some unknown reasons different (lateral contraction of the depleted region?). That can be probed with removing metallization at the back and using the IR TCT across the detector measuring the border of single LGADs. That should be done for neutron irradiated sample as well. We will learn about x,y and assume z = nominal.

3. Use TCT in the IT-HGTD mode for B7-11-10 cyric sample (1.1e15 nominal) and compare the Gain at 40-50 V. Measure the I-V of the both LGADs (1x2 LGAD) and use G(50V) to extract the I_gen and from it \Phi_{eq}. Compare it to IV of single PIN and LGAD and see if single I_lgad/I_pin (50V) gives you comparable gain.

# 1. TRIGA dosimetry

# TRIGA dosimetry



| | | Ileak at 40 V, 20 C | Fluence 1e15 | Vgl | Comment | |
|---|---|---|---|---|---|---|
| Delivery 1.1 | B6-25-30 | 6.4 | 1.88 | 18.5 | 60kW, first biasing | |
| | B7-21-30 | 6.5 | 1.91 | 19.5 | 60kW, first biasing | |
| Delivery 1.2 | B18-8-30 | 8.2 | 2.41 | 19.3 | 66 kW | Ileak at 50 V, second biasing |
| | B21-13-30 | 7.7 | 2.26 | 19.3 | 66 kW | 50V |
| Delivery 2 | B31-15-30 | 7.8 | 2.29 | 19.2 | 63 kW | 40V |
| | B23-24-30 | 7.5 | 2.21 | 19.7 | 63 kW | 40V |
| | B33-16-30 | 8 | 2.35 | 19.8 | | … |
| | B36-8-30 | 8 | 2.35 | 19.4 | | |
| Delivery 3 | B28-3-30 | 7.6 | 2.23 | 19.5 | | |
| | B10-7-30 | 7 | 2.06 | 19.8 | | |
| | | | 2.20 | AVERAGE | 0.11 stdev | |

Triga fluence is 88 % ± 4 % of the nominal fluence

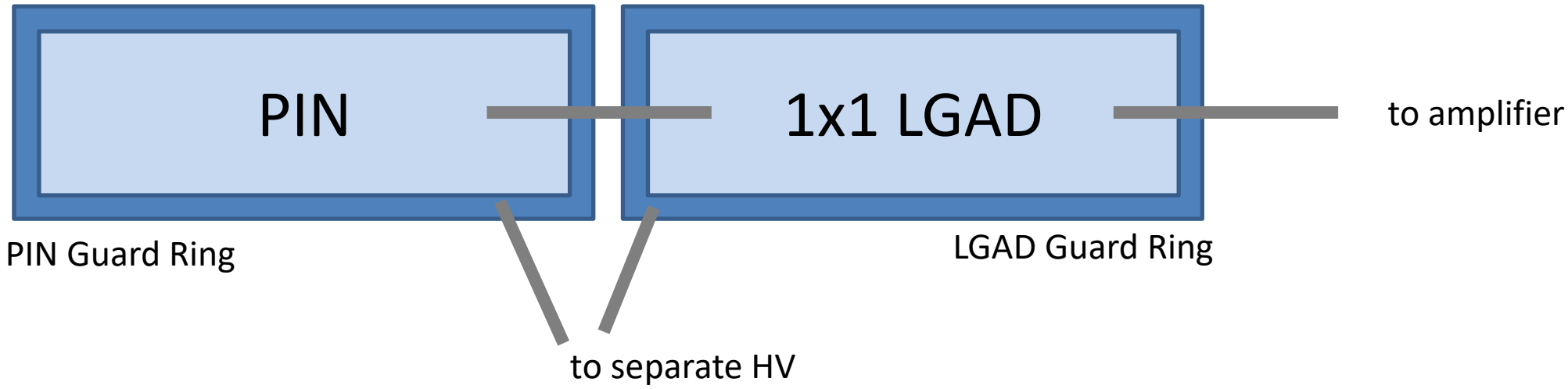
This can be partially explained by active thickness being slightly less than 50 µm

# 2. TCT of the active volume

# TCT of active volume

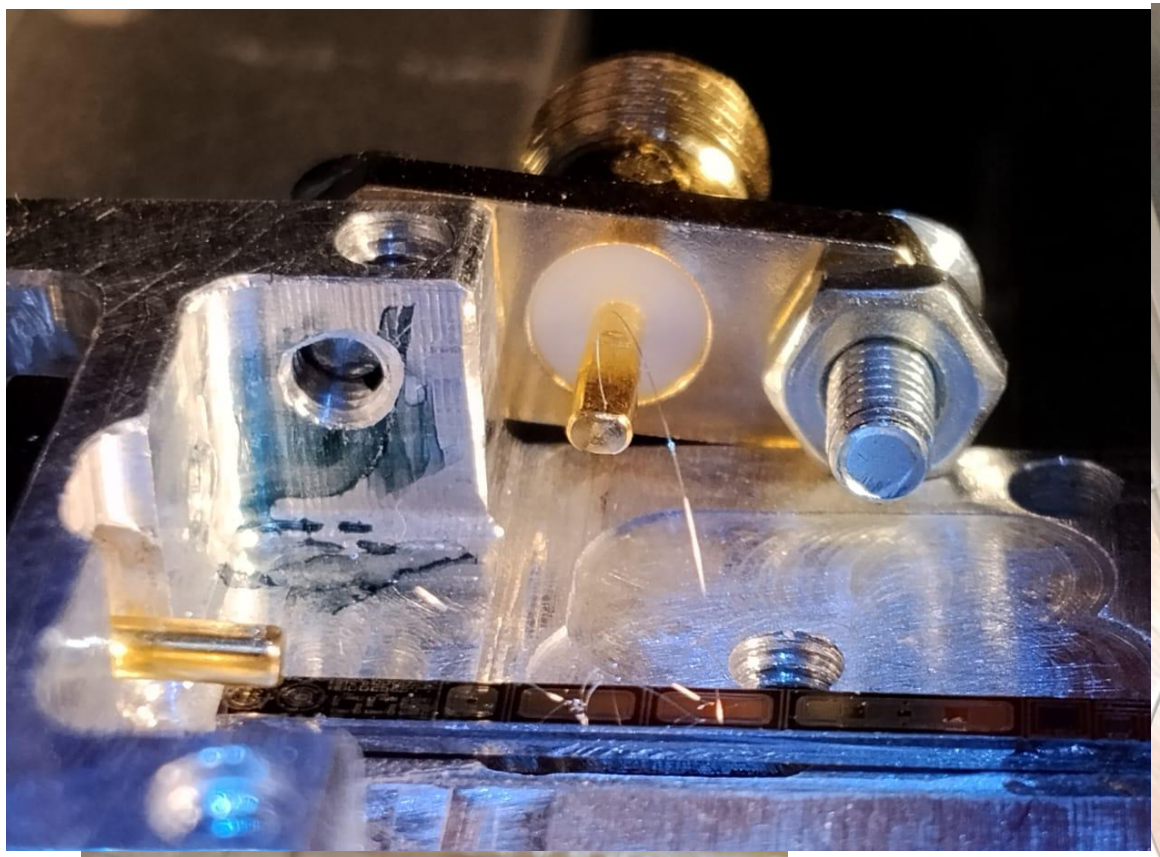


- Back side TCT 1064 nm
- Removed back side metal with NaOH
- PIN and 1x1 LGAD pads connected together to bias-T + amp
- PIN GR and LGAD GR connected together to HV using separate filter
- Measured beam focus > 100 µm (knife edge from back side)

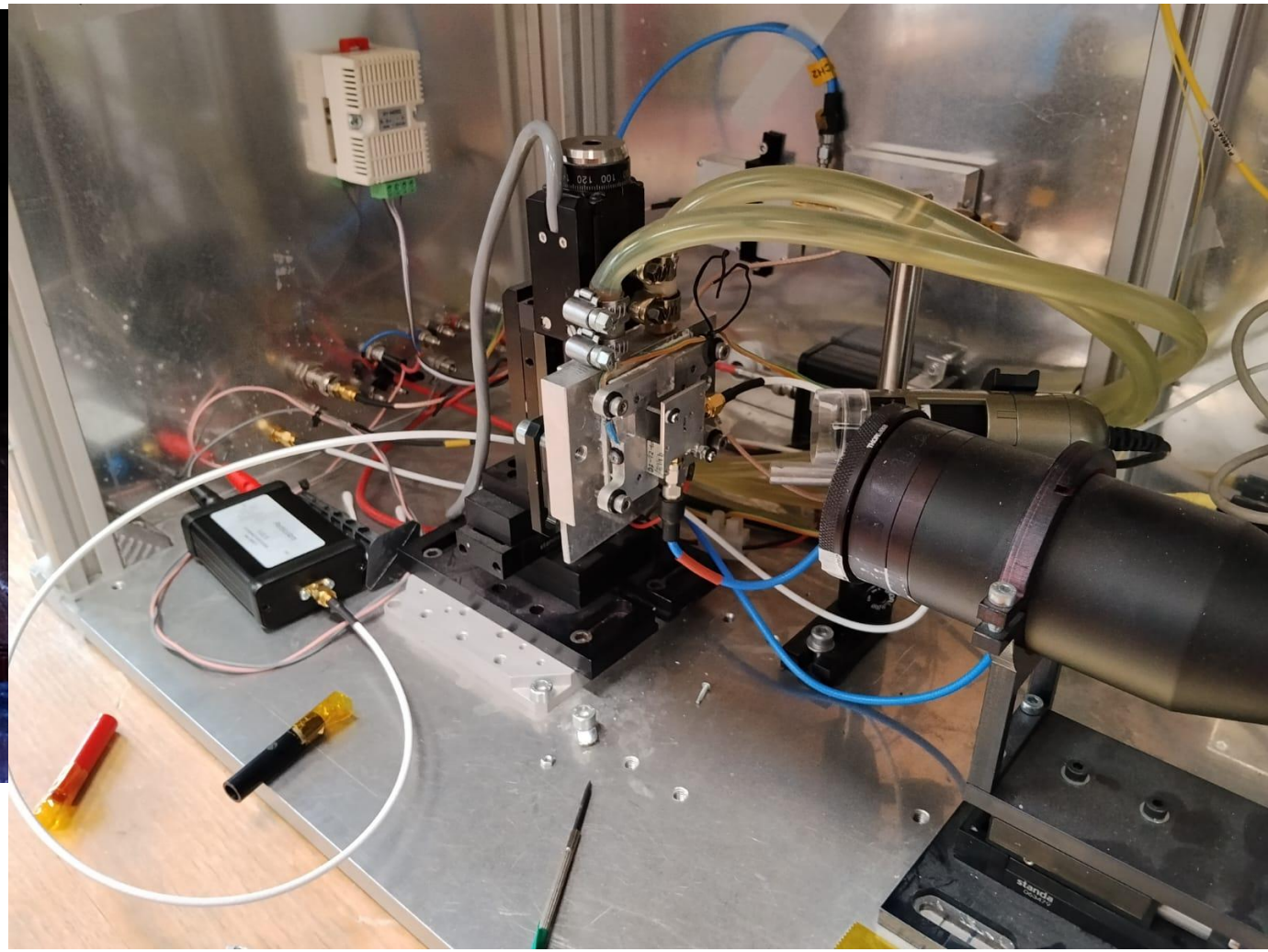


# TCT of active volume



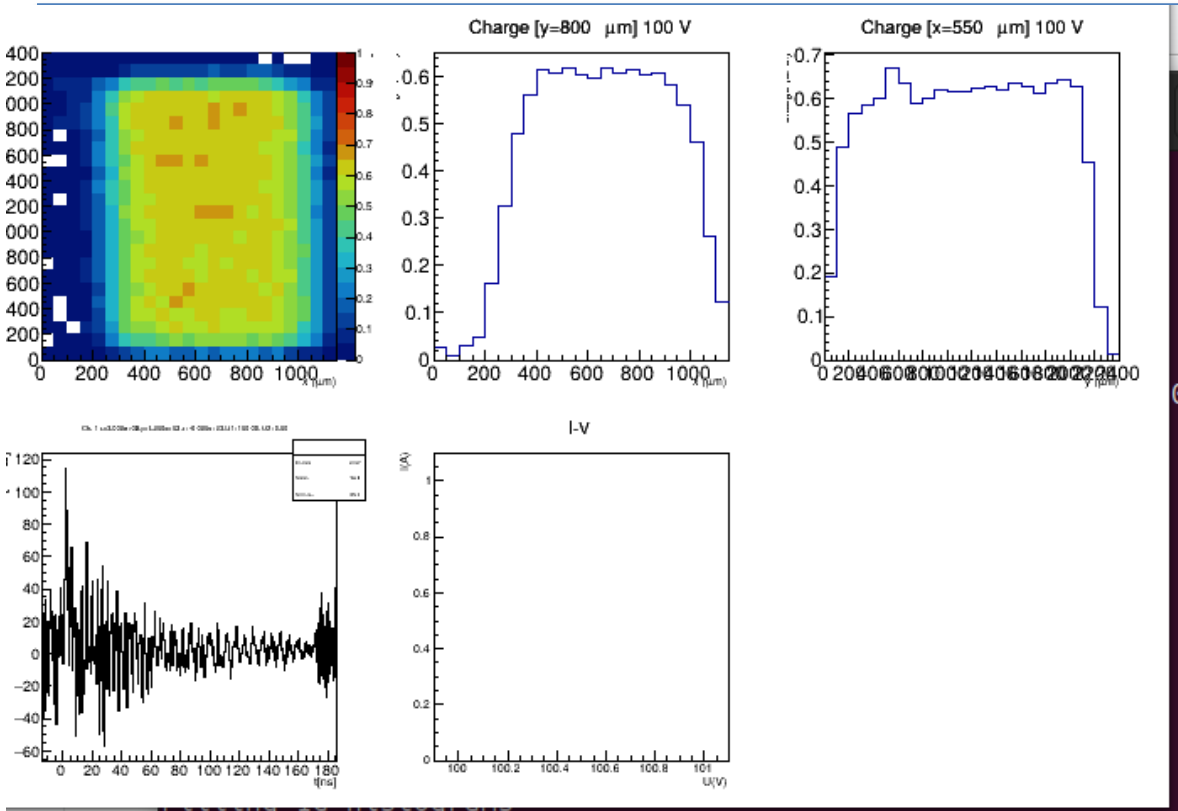






# TCT Results (B36-8-30 2.5e15 neutrons)

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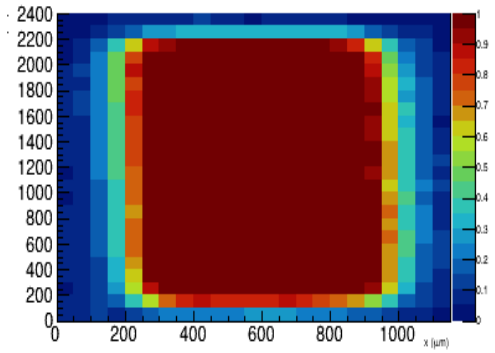


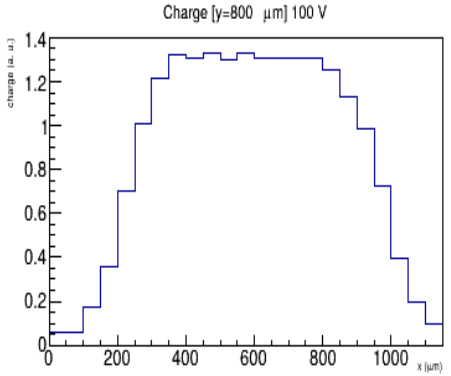
**PIN**

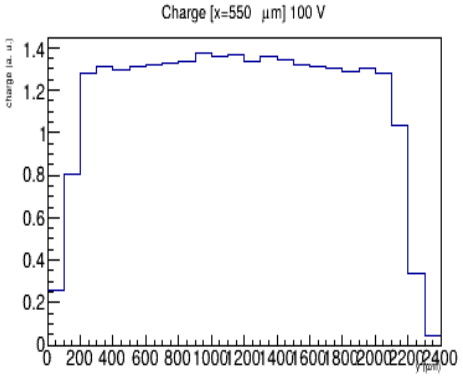
FWHM of the active volume is:
2090 µm in length
790 µm in width
1.66 mm2 area

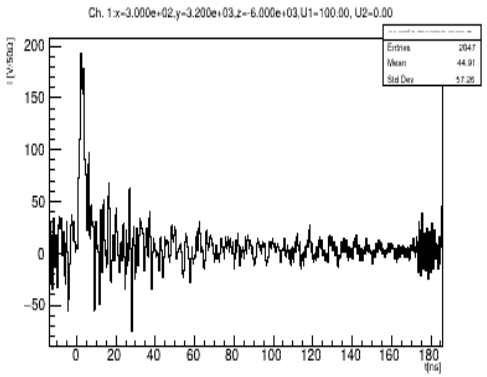
# TCT Results (B36-8-30 2.5e15 neutrons)

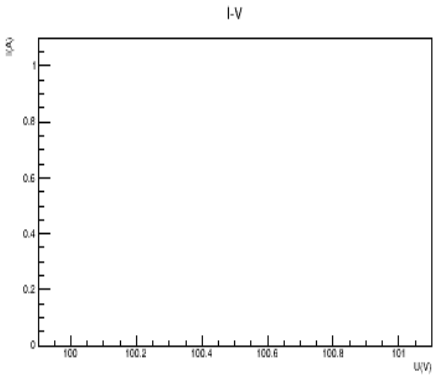







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122 1d historgrams filled
123 Plotting 2d
124 753.939 um
125 2070.53 um
126 1.56105 mm2
127 root [1]
128
```

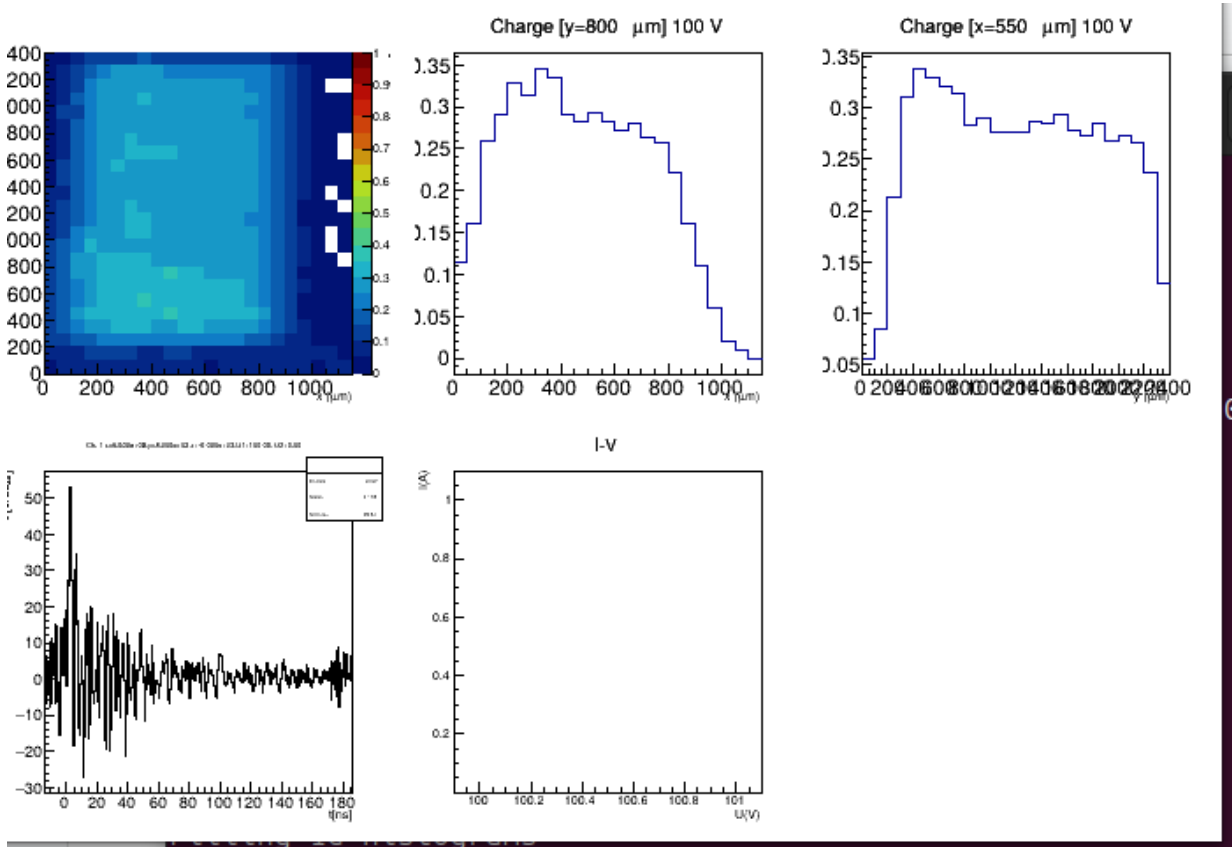
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iy*aa->dy, U[ivo]);
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**LGAD**

FWHM of the active volume is:
2070 µm in length
750 µm in width
1.56 mm2 area

# TCT Results (B7-12-10 7e14p CYRIC nominal)

Institut "Jožef Stefan", Ljubljana, Slovenija





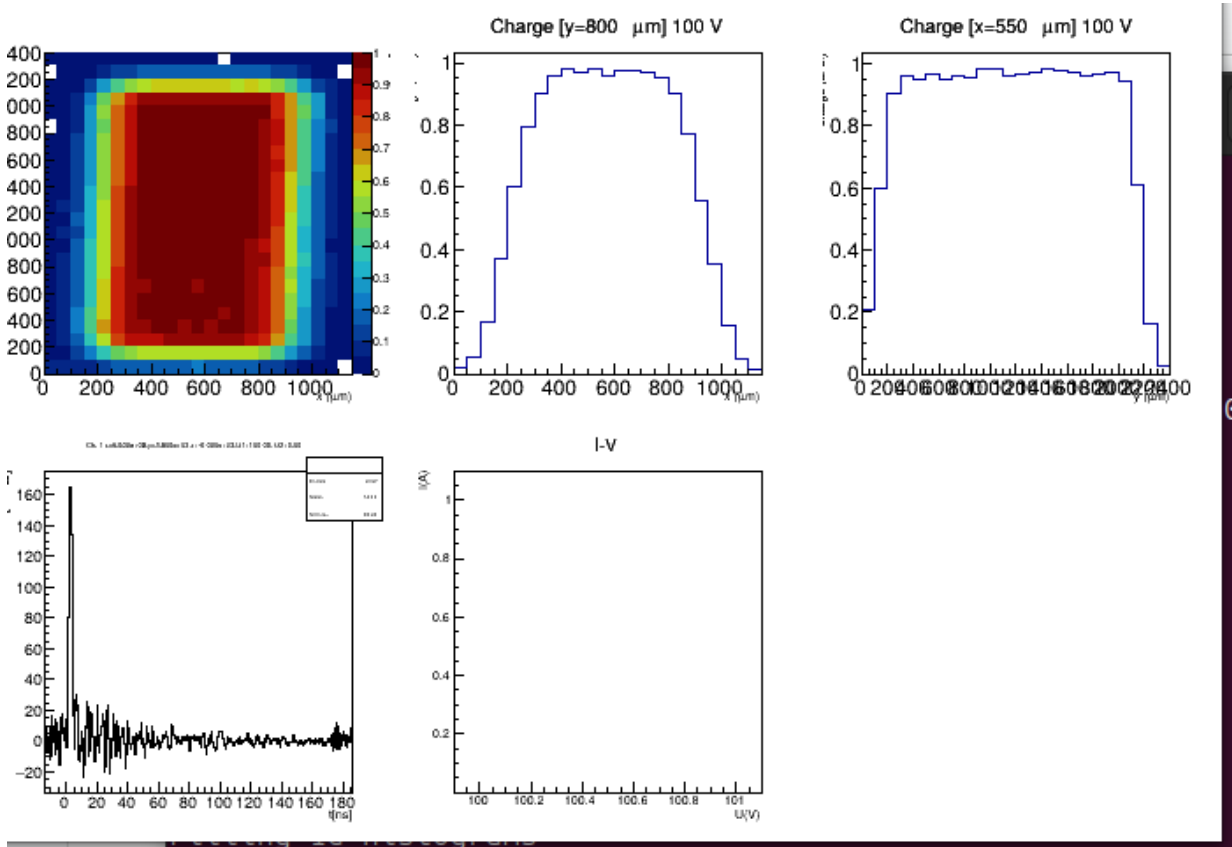


**PIN**

FWHM of the active volume is:
2100 µm in length
770 µm in width
1.62 mm2 area

# TCT Results (B7-12-10 7e14p CYRIC nominal)

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**LGAD**

FWHM of the active volume is:
2050 µm in length
740 µm in width
1.51 mm2 area

# 3. TCT-IT

# IT results

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- Tested sample: B7-11-10, 7e14p CYRIC nominal
  - Without and with GR bonded together with the pad (same connector)
- Results:
  - Vgl = 21.5/21.2 V (with GR) 21.4/21.3 V (without GR)
  - Gain at 100 V: 7.2 / 7.2 (with GR) 7.0 / 6.9 (without GR)
  - Ileak at 100 V 17.6 µA (with GR) 17.1 µA (without GR)
  - Gain at 50 V: 4.8 / 4.8 (with GR) 4.9 / 5.0 (without GR)
  - Ileak at 50 V: 13.9 µA (with GR) 12.5 µA (without GR)
  - Igen at 50 V: 2.9 µA (with GR) 2.5 µA (without GR)
  - Phi_eq: 4.3e14 neq/cm2 3.7e14 neq/cm2
- CV/IV:
  - Ileak@50 V, 20 °C: 5.6 µA (LGAD) 1.6 µA (PIN) GI = 3.5 Phi_eq = 4.7e14 neq/cm2

# Summary



- TRIGA dosimetry: 88 % ± 4 % of nominal fluence (2.20e15)
- CNM PIN and QCTS PIN have similar alpha for Krakow irradiation
- TCT active volume scan: PIN volume above 1.6 mm2
- IT: inconclusive, TCT derived fluence is 80–90 % of the PIN derived fluence