Characterization of TI-LGADs Using Laser TCT Measurements

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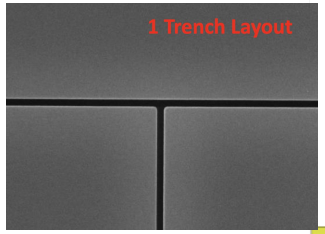
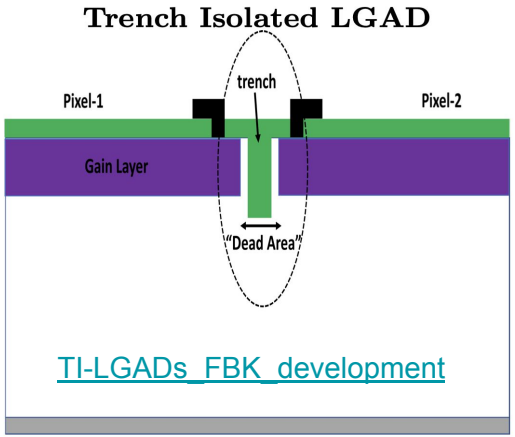
Introduction: Trench Isolated - LGADs: Solution?

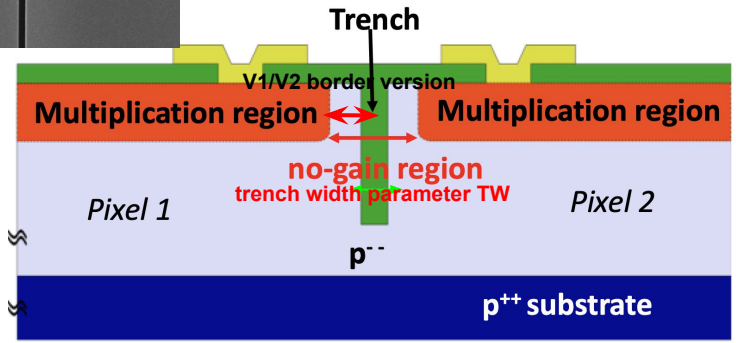
- New LGAD technology:
  The trench replaces JTE (Junction Termination Extension) & p-stop
  Trenches → Drift/diffusion barrier
  - Carbon co-implantation in the gain layer
- Solution considered for Phase 3 in the LHC experiments in the timing layer

(preventing charge carriers (electrons/holes) from drifting)

- Dead region is significantly reduced
- The trenches are < 1μm wide and few microns deep
- Smaller gain-loss region is expected
- Trenches of etched dielectric material, filled with SiO_2

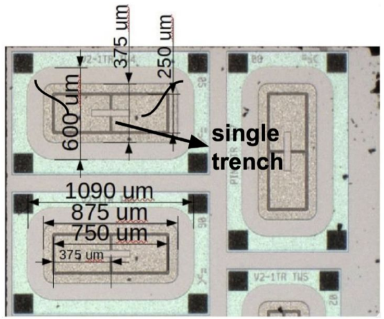






Samples characterized at SPS test beams

- Variations in trench depth (Dx) and trench width (TWx)
- **375 µm × 250 µm pixel pitch**
  - Fabricated @ FBK wafers: 2, 5 and 9
  - Trench width parameters TW5, TW1/2/3; TW4/6
  - Border version V1 and V2: distance between center of trench to the edge of the gain layer
  - Fluences: 0E15, 1.5E15 and 2.5E15 n_{eq}/cm^2
- Single-trench TI-LGAD devices



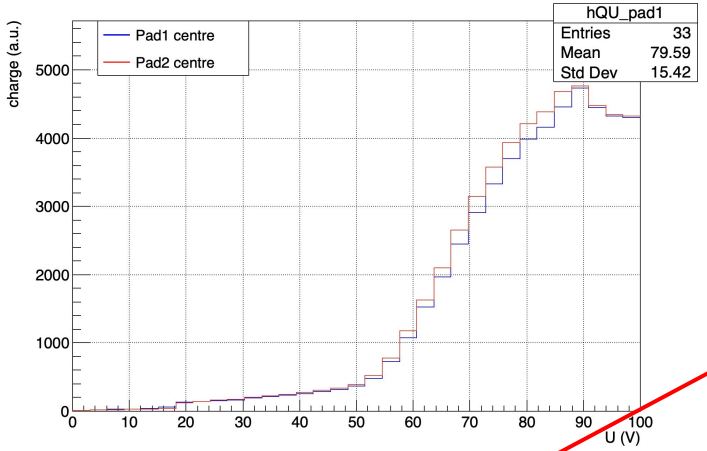
Measured in October 2024 and April 2025 testbeam
V2 border version

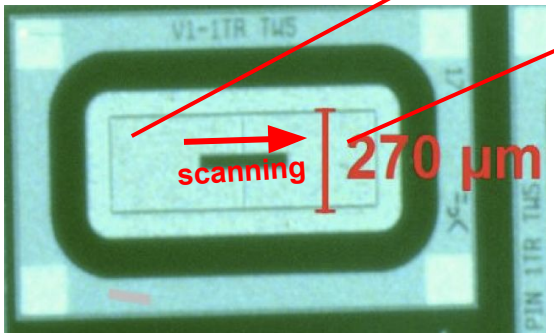
Measured in October 2025 testbeam
V1 and V2 border versions

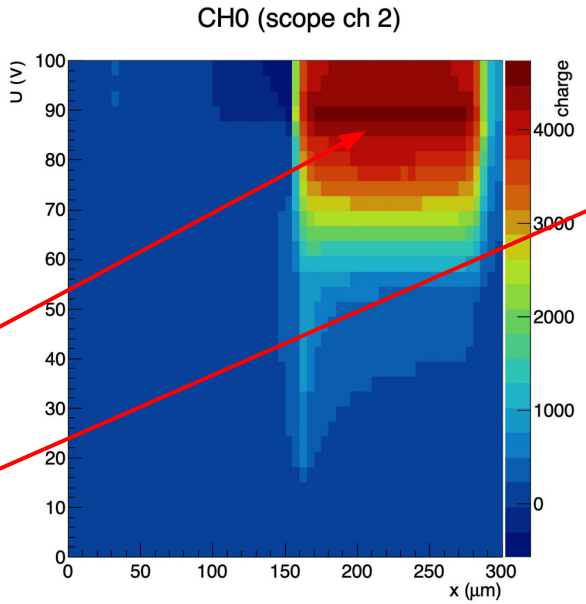
Wafer	Thickness	Carbon	Trench depth	Trench process
1	45	Y	D3	P2
2	45	Y	D2	P2
3	45	Y	D1	P2
4	45	Y	D1	P1
5	45	Y	D2	P1
6	45		D2	P2
7	45		D2	P2
8	45		D1	P1
9	55	Y	D3	P2
10	55	Y	D2	P2
11	55	Y	D2	P2
12	55		D2	P2

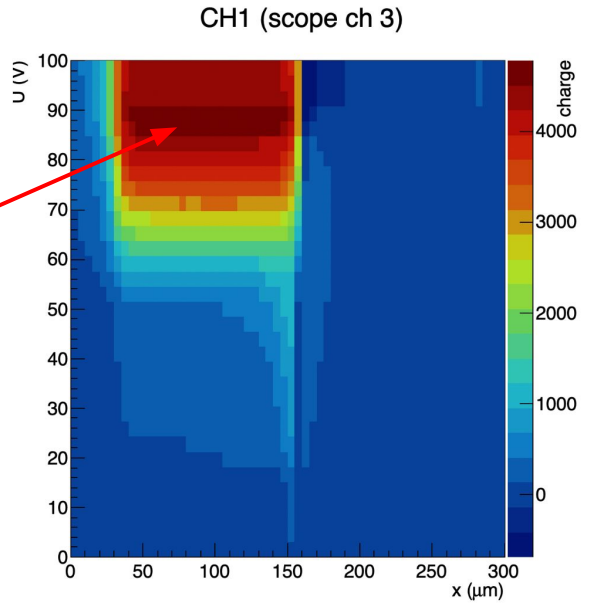
Wafer information provided by FBK:
https://zenodo.org/records/7515703

V1 voltage scan TR1 TW5 Wafer 9 with 660 nm red laser @100 V

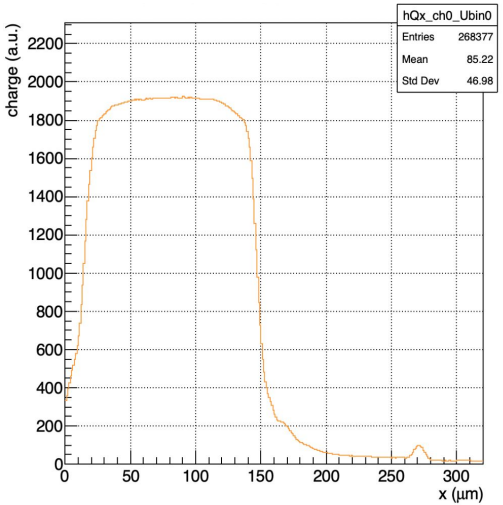


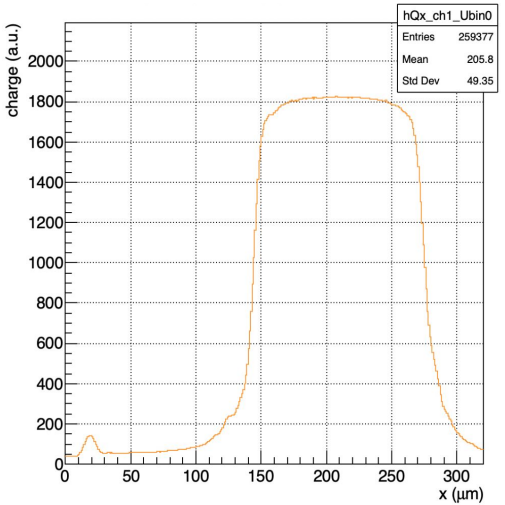


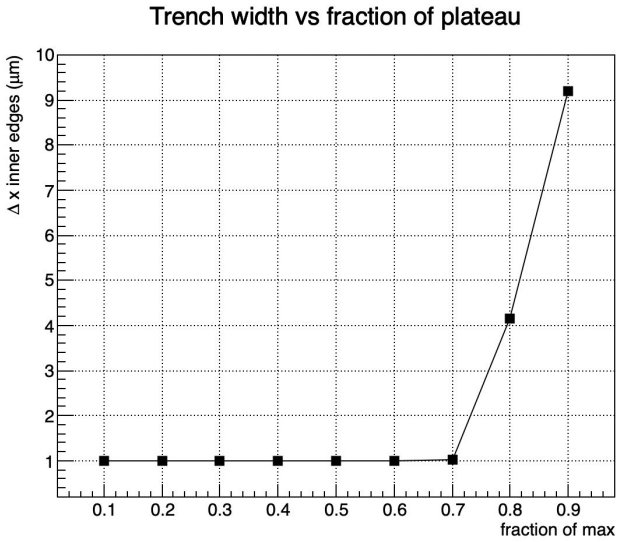


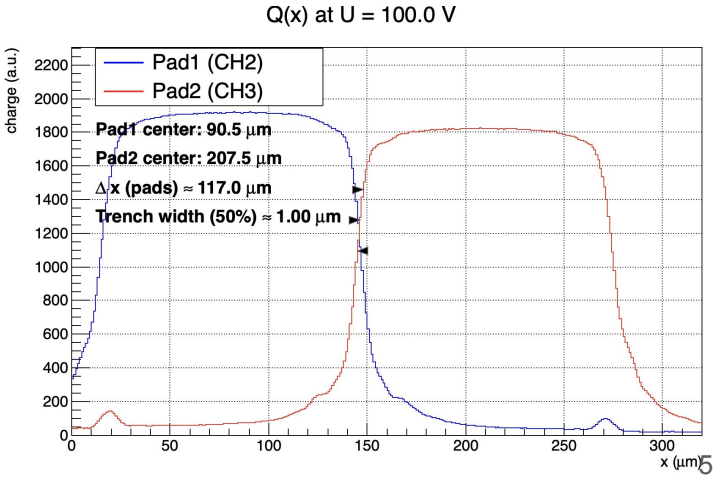


V1 voltage scan TR1 TW5 @ 100 V

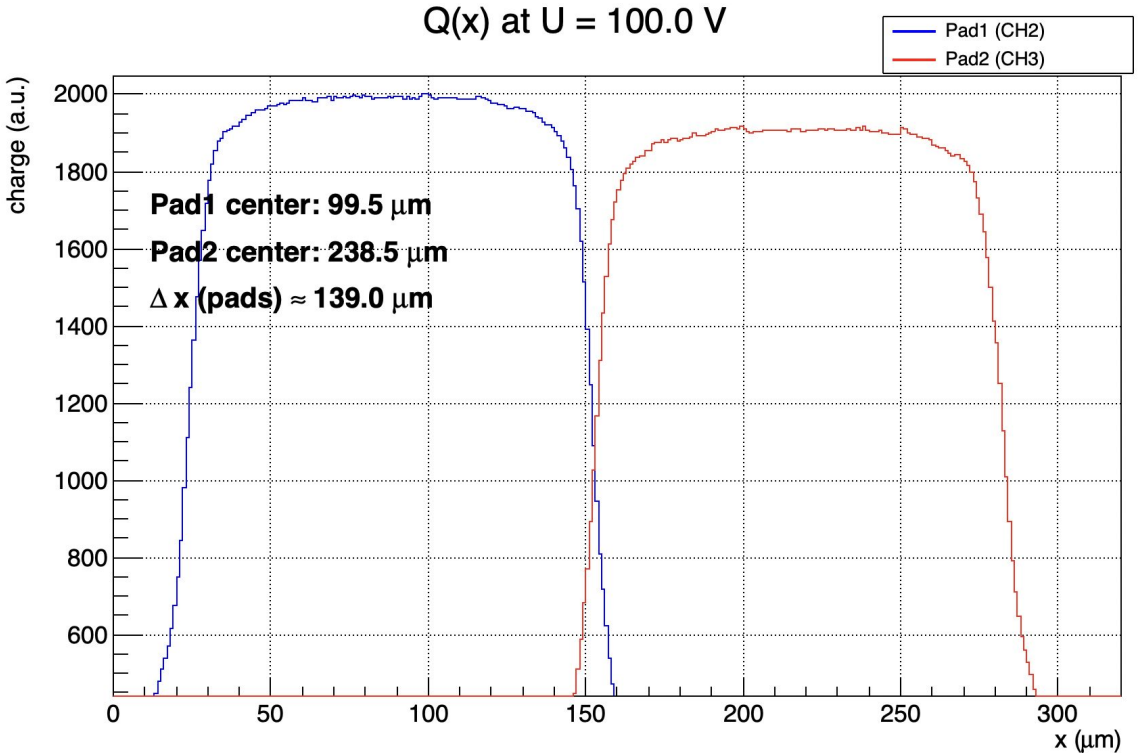


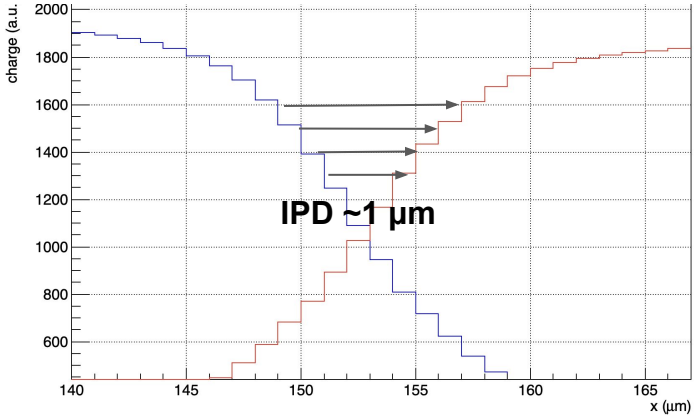






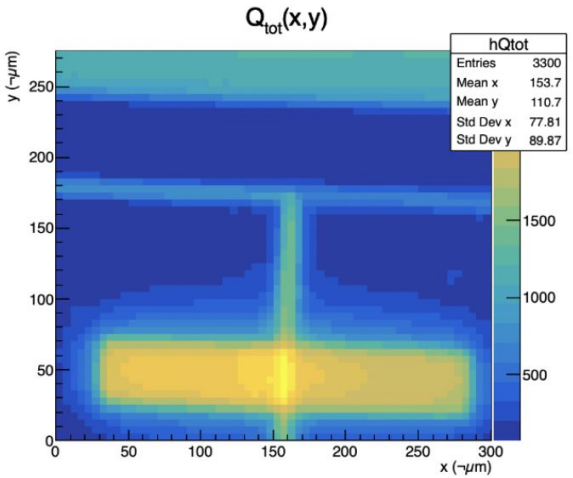
V2 voltage scan TR1 TW5 Wafer 9 operated @ 100 V



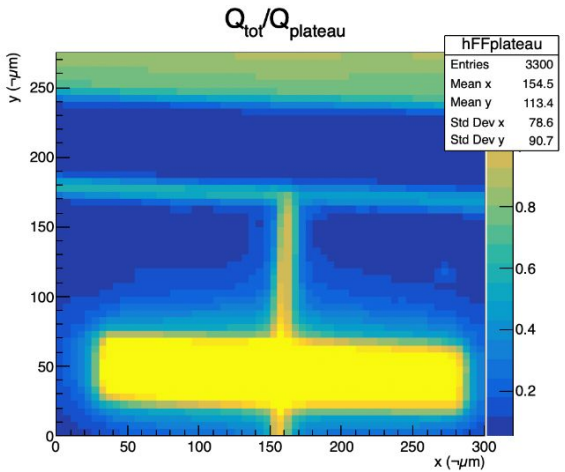


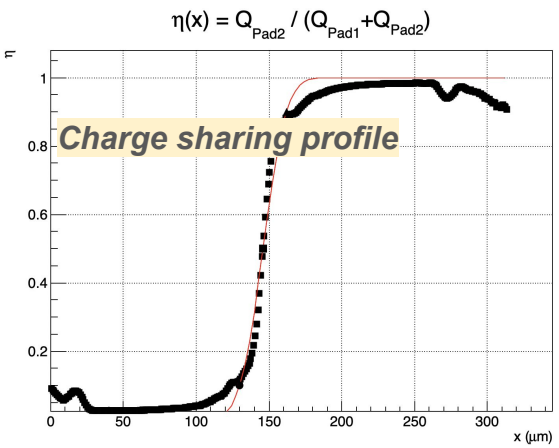
Collected charge for V1 TW5 structure from Wafer 9 with red 660 nm

Total Collected Charge map



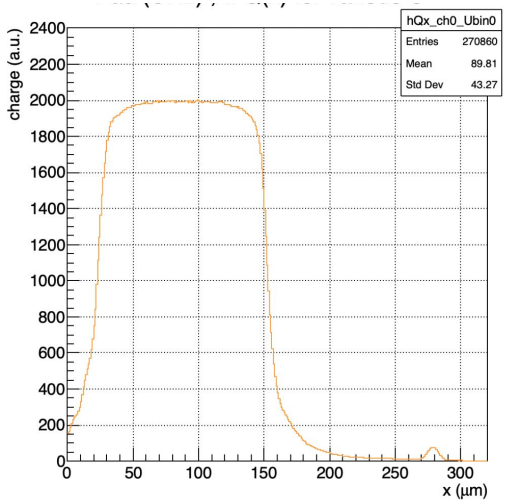
Normalized Charge Collection map

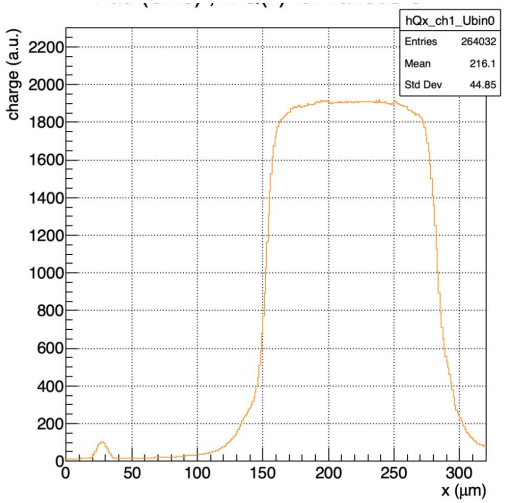


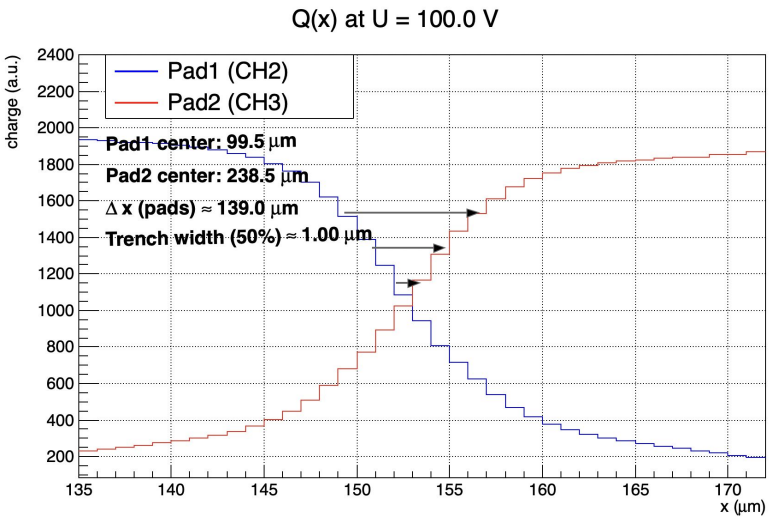


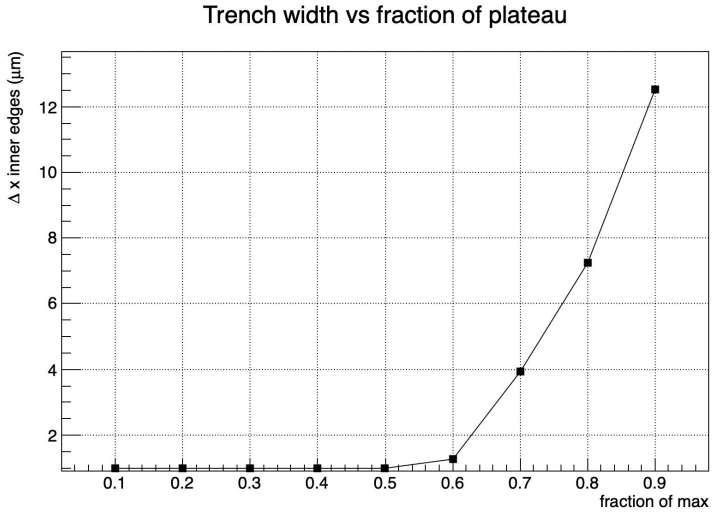
- @ 660 nm wavelength with absorption length of ~ 3.5 μm
- probing the gain layer + p^+ implant region + top of the bulk

Collected charge for V2 TR1 TW5 Wafer 9





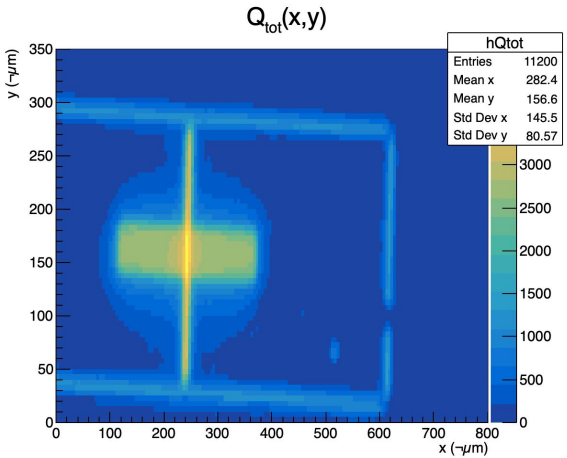




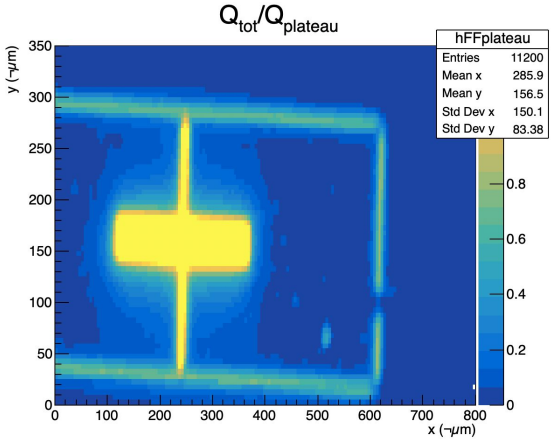
used a red laser with wavelength 660 nm

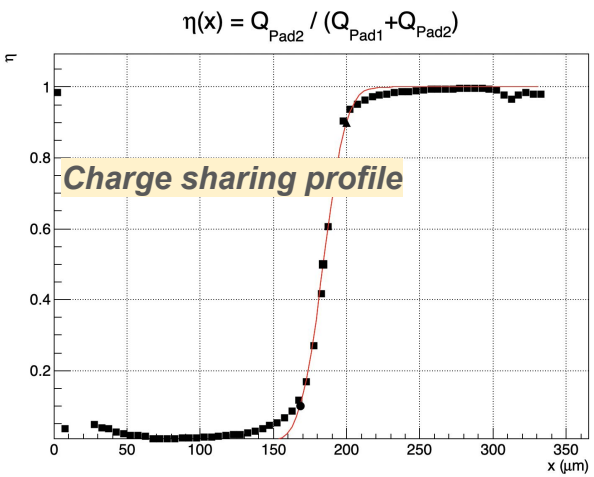
V2 TW5 structure from Wafer 9 @ 96 V with laser of wavelength 935 nm

Total Collected Charge map



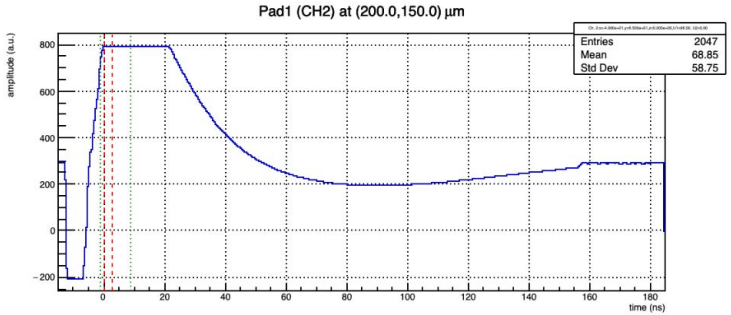
Normalized Charge Collection map

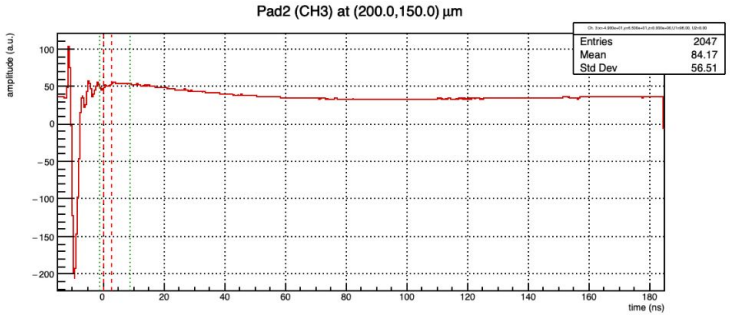


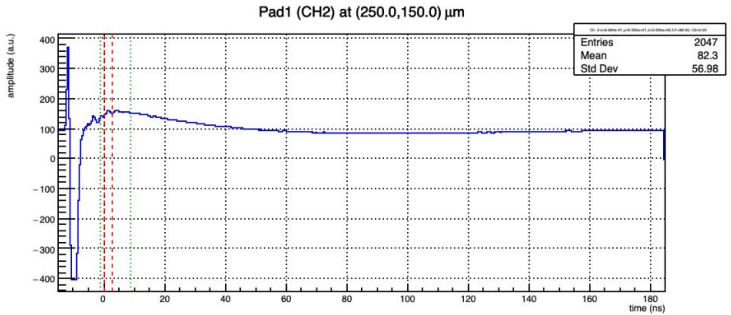


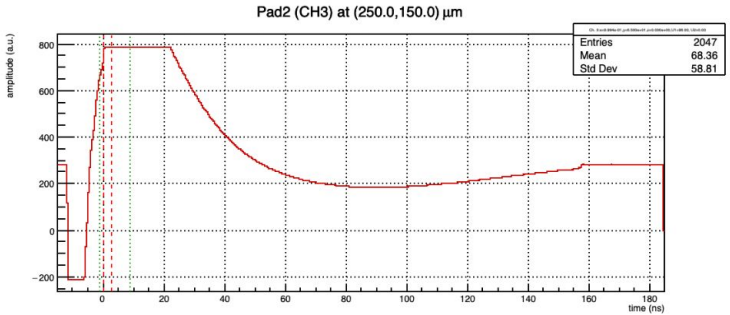
- @ 935 nm wavelength with absorption length of ~ 20-40 μm
- through a thicker slice of the bulk, not just surface
- carriers drift through the gain-layer edge near the trench

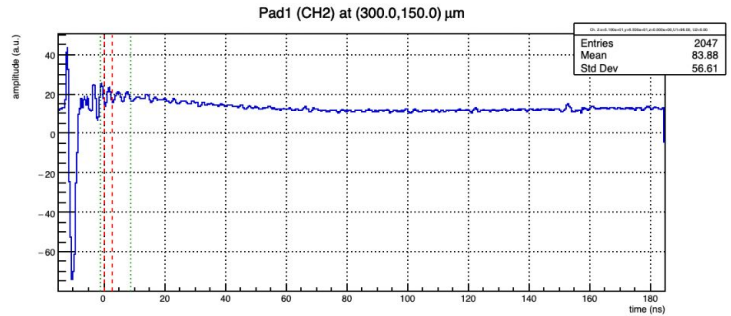
BACKUP

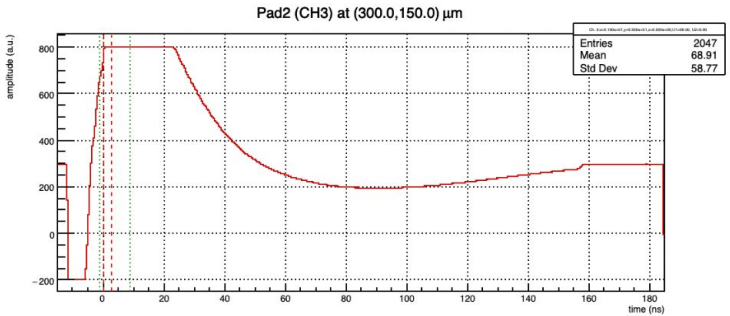

Pad1 (CH2) at (200.0,150.0) μm
Entries 2047
Mean 68.85
Std Dev 58.75
amplitude (a.u.)
time (ns)


Pad2 (CH3) at (200.0,150.0) μm
Entries 2047
Mean 84.17
Std Dev 56.51
amplitude (a.u.)
time (ns)

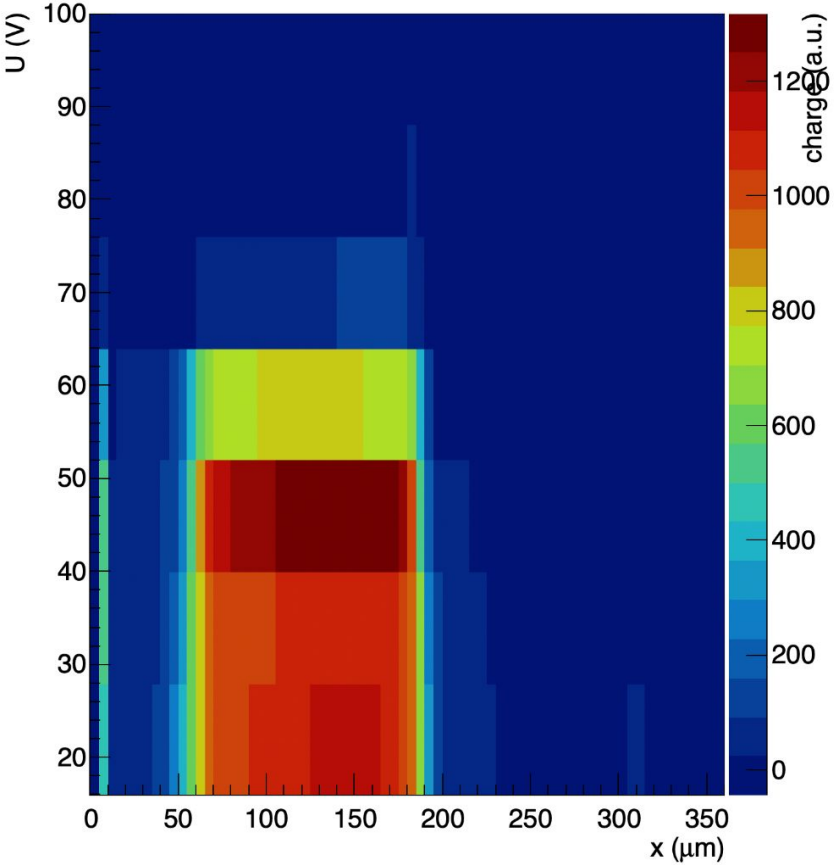

Pad1 (CH2) at (250.0,150.0) μm
Entries 2047
Mean 82.3
Std Dev 56.98
amplitude (a.u.)
time (ns)

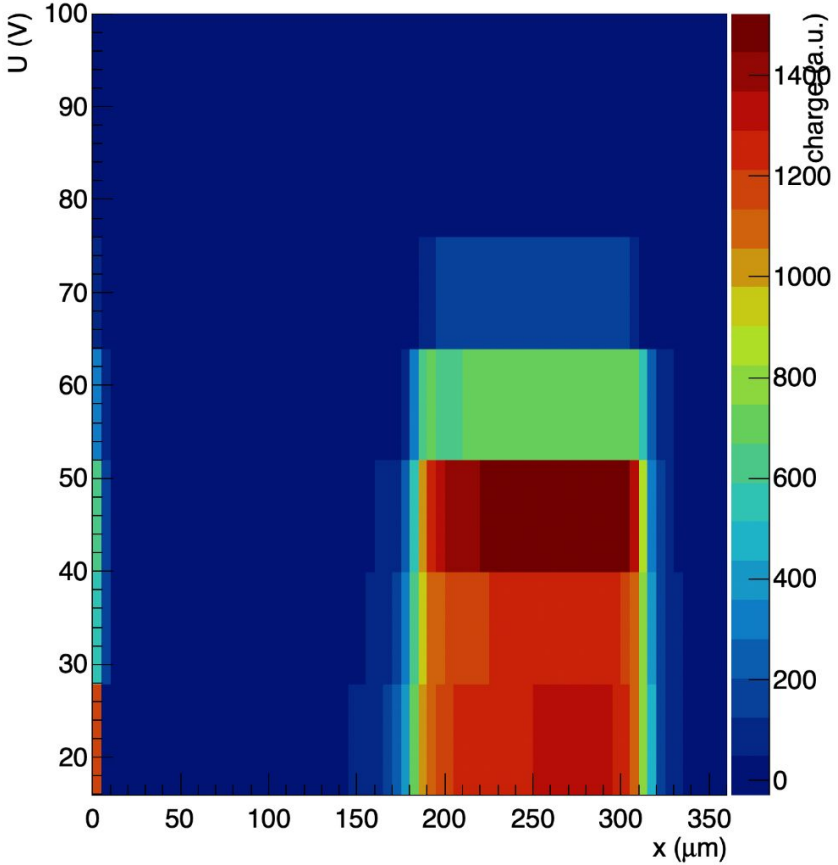

Pad2 (CH3) at (250.0,150.0) μm
Entries 2047
Mean 68.36
Std Dev 58.81
amplitude (a.u.)
time (ns)


Pad1 (CH2) at (300.0,150.0) μm
Entries 2047
Mean 83.88
Std Dev 56.61
amplitude (a.u.)
time (ns)


Pad2 (CH3) at (300.0,150.0) μm
Entries 2047
Mean 68.91
Std Dev 58.77
amplitude (a.u.)
time (ns)

Voltage scan for V2





V1 focus scan