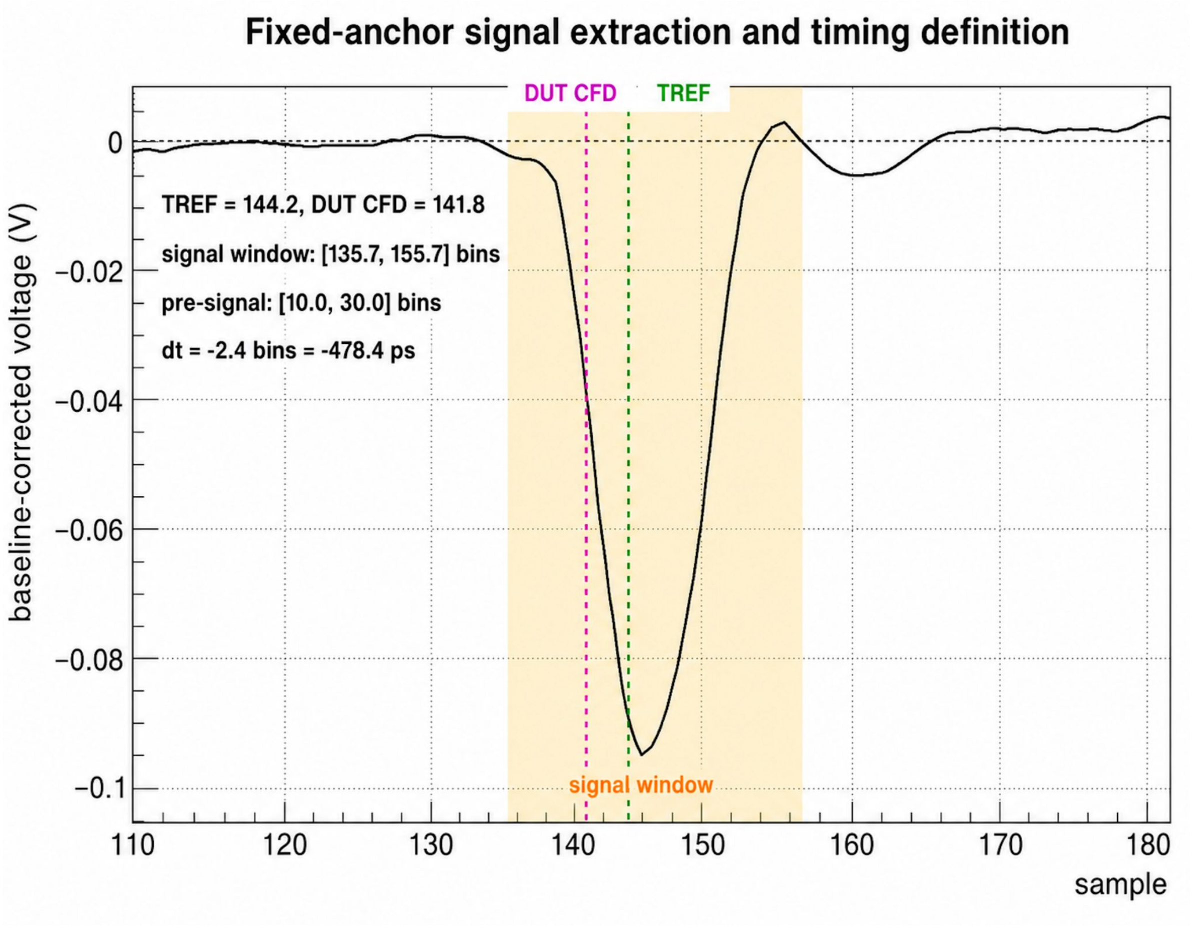
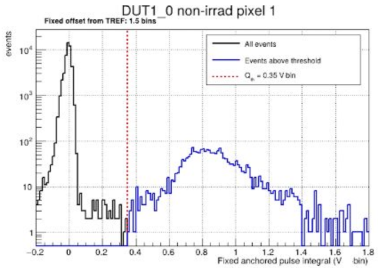
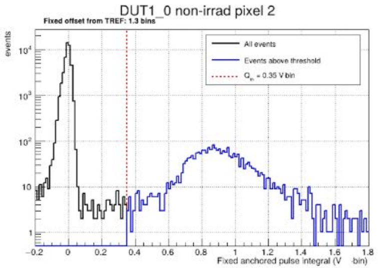
TREF-anchored signal definition of the DUT

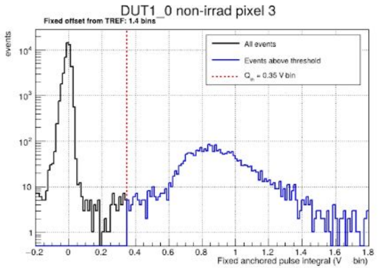


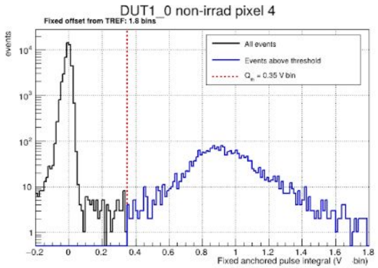

- TREF CFD defines the event time anchor
- Same-length pre-signal window used for baseline reference
- dt = t_DUT - t_REF
- The DUT charge is integrated in a fixed 20-bin window placed relative to the TREF CFD anchor, to avoid the pedestal bias of peak-centering while retaining the main part of the DUT pulse for the selected events in this run

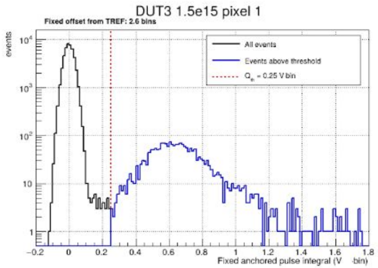
# TI LGAD structure:
# V2-TR1-TW2/TW3

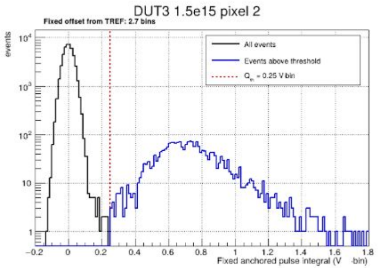


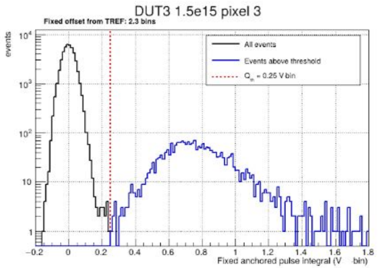



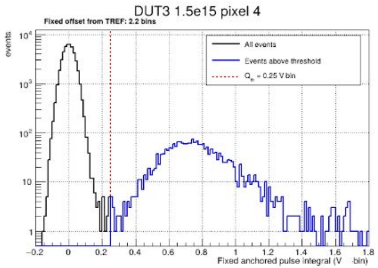



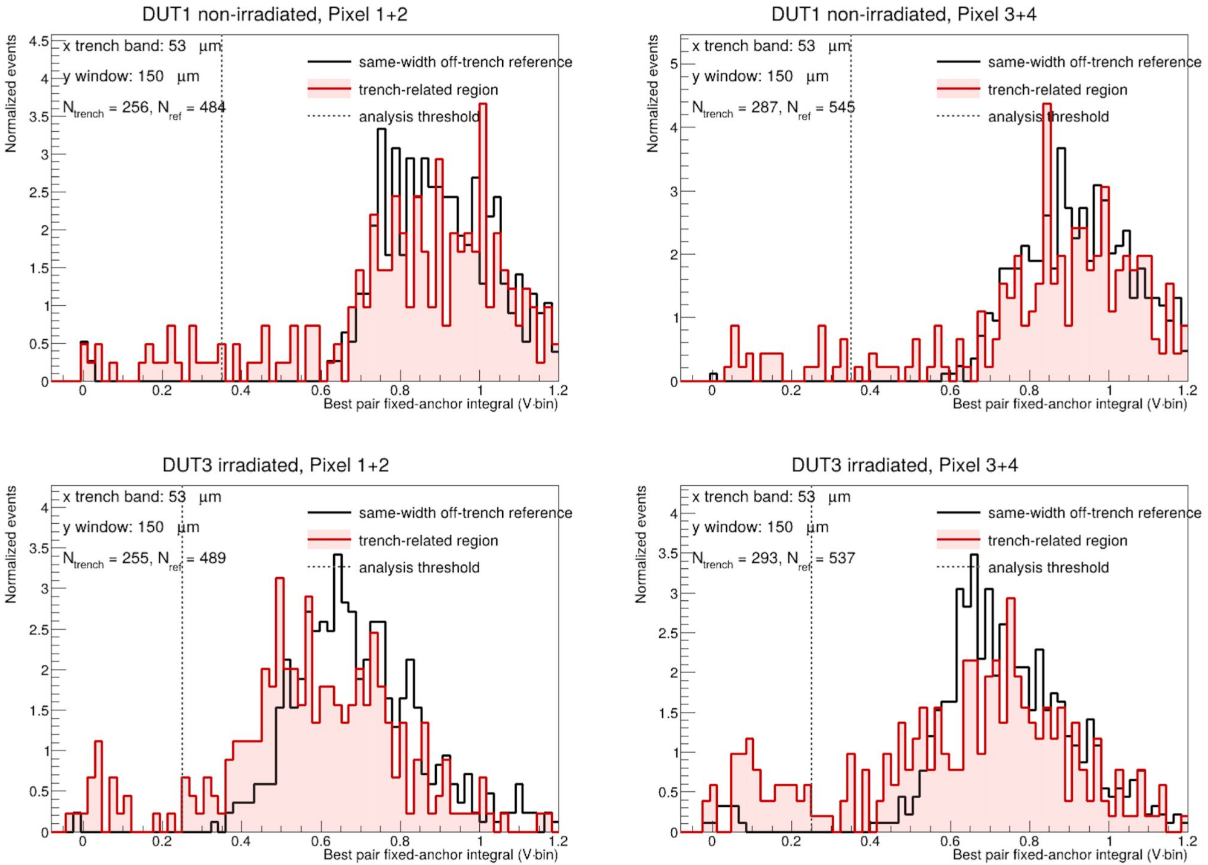



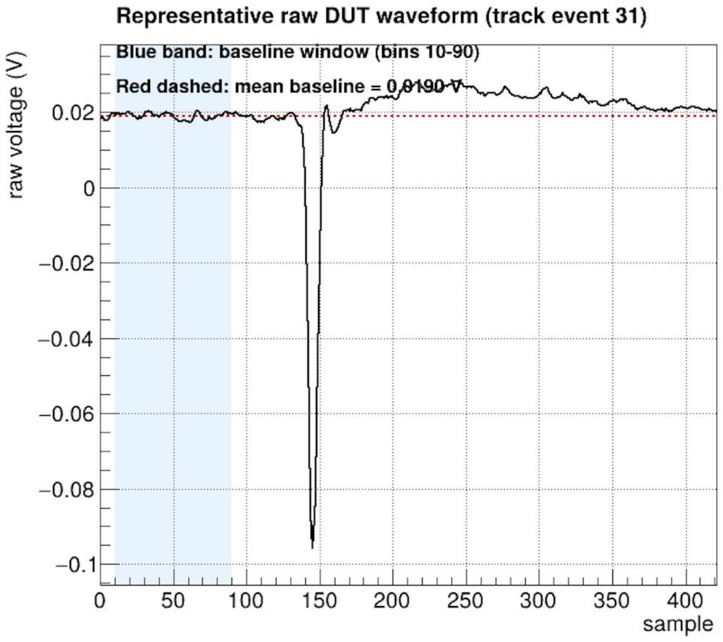
# How does the trench-region signal spectrum compare to a nearby non-trench region?

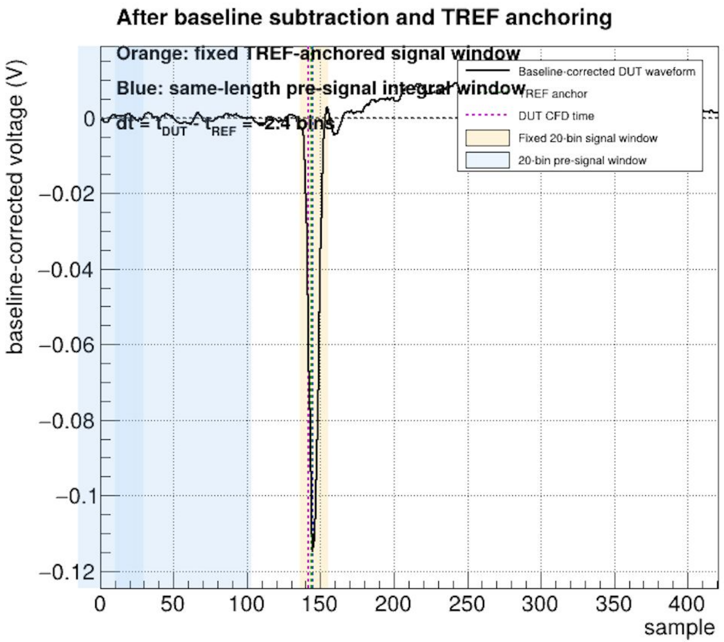



The trench-related region shows a lower-charge population than the off-trench reference region, which is consistent with the local efficiency loss.

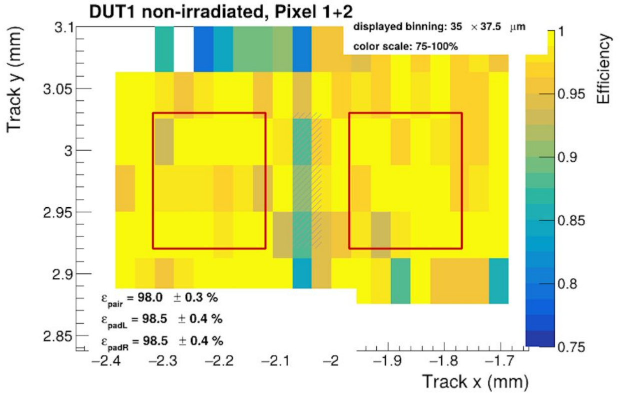
Example event showing the fixed TREF-anchored signal definition

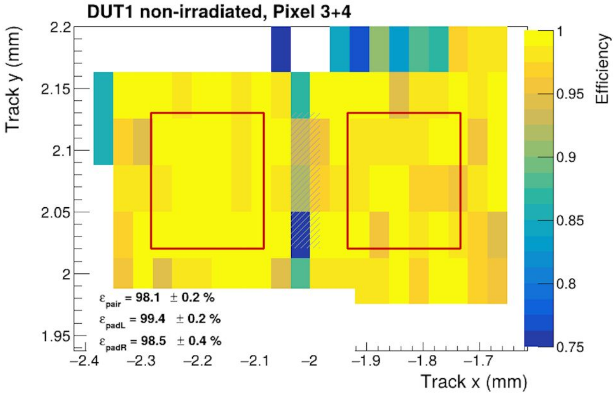
- REF waveform defines the time anchor.
- DUT signal is integrated in a fixed 20-bin window relative to that anchor.
- A same-length pre-signal window is used for the baseline reference.
- dt is the time difference between DUT and reference.

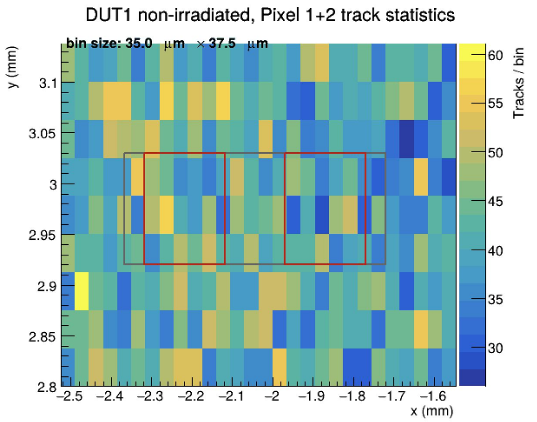


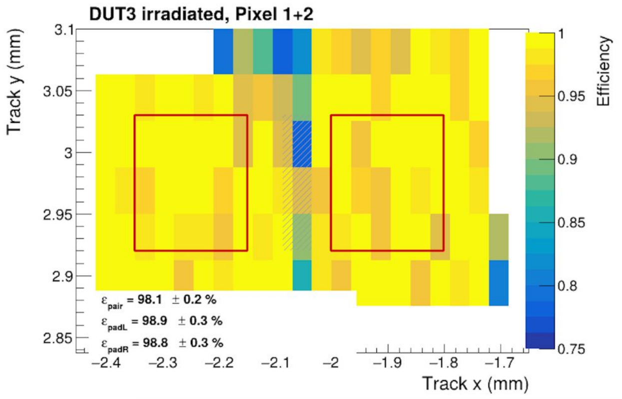



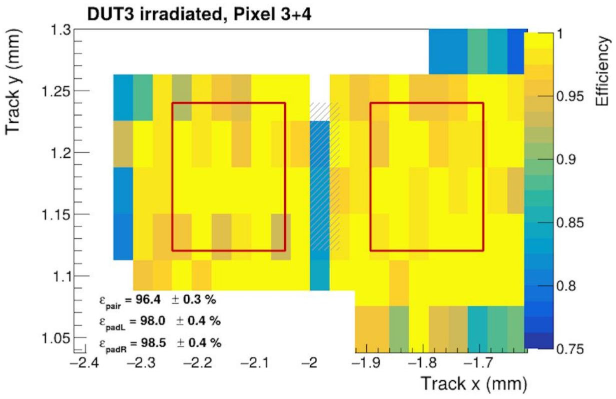
# Binning: 35 × 37.5 µm

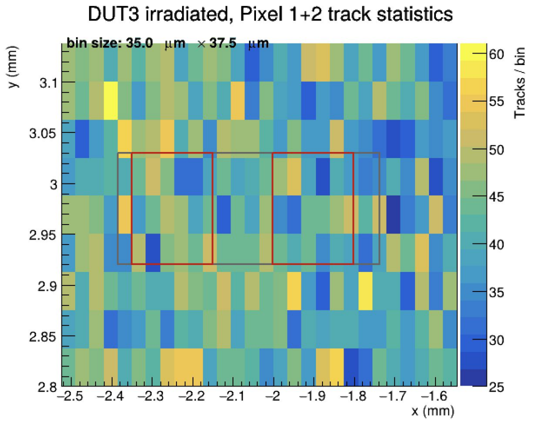


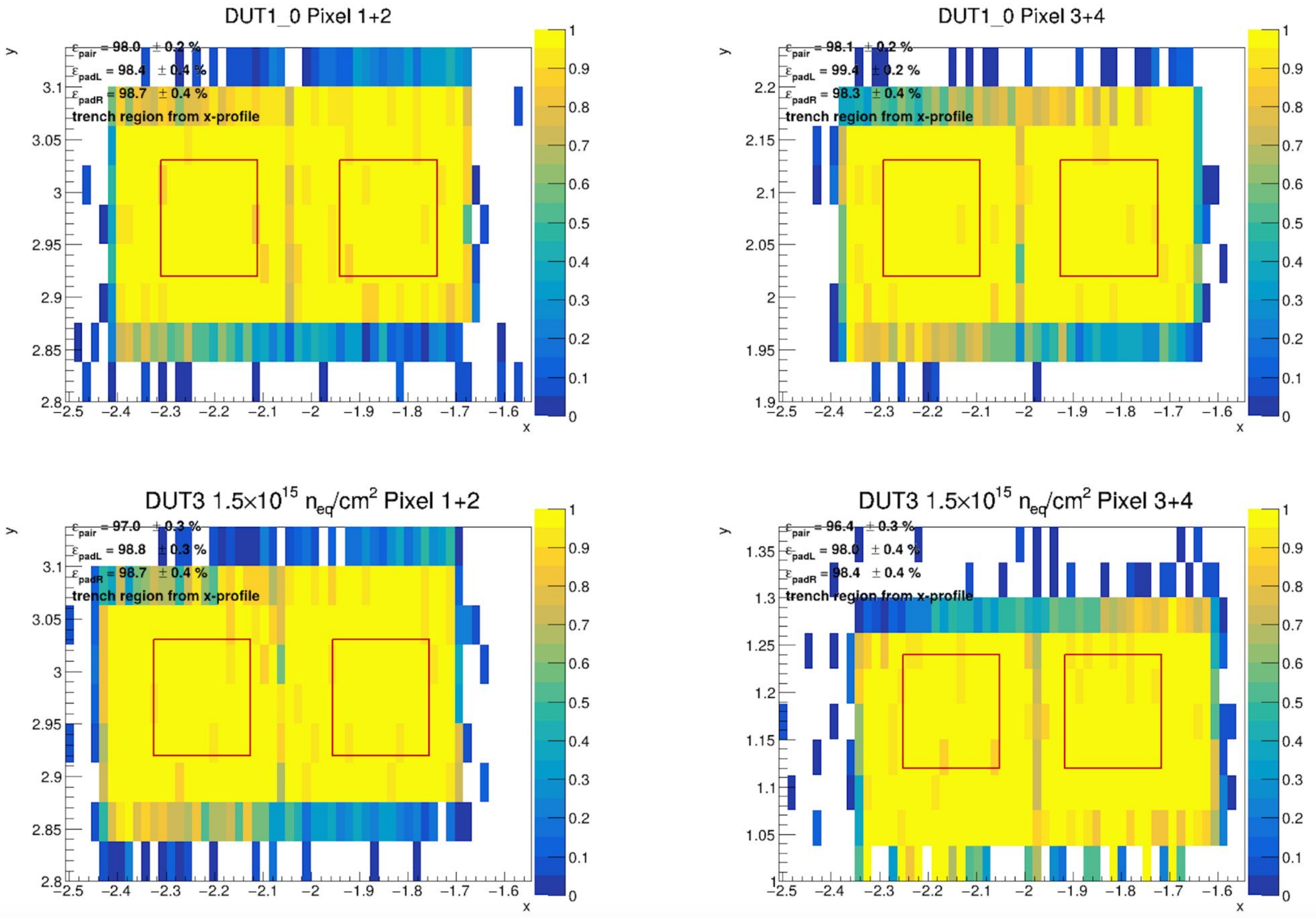



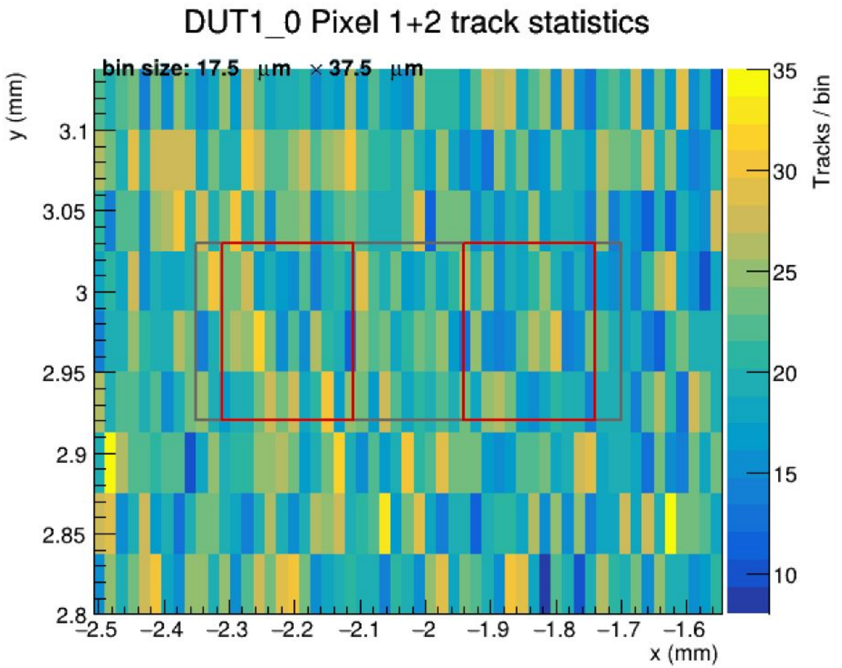

Typical local statistics: about 40–43 tracks/bin

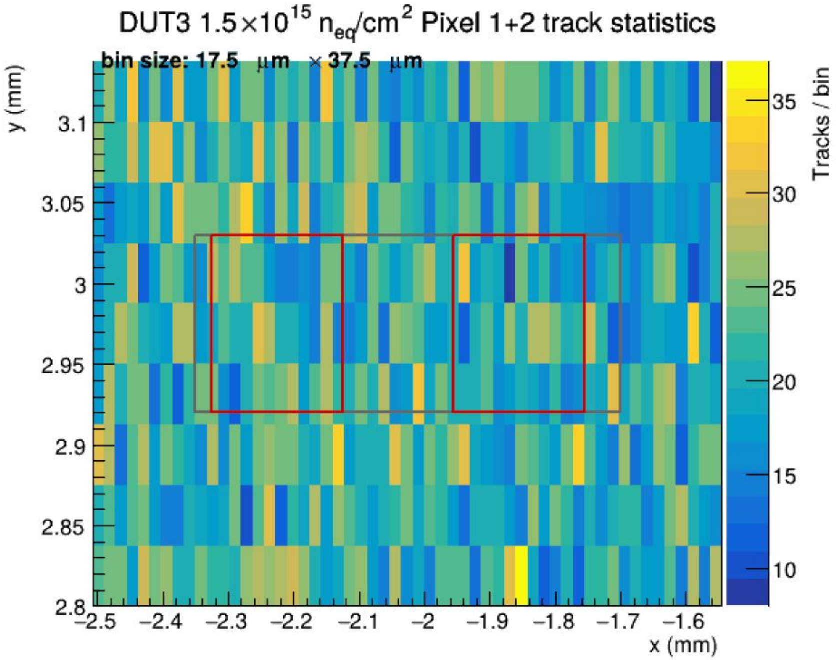
# Efficiencies

Binning: 17.5 μm × 37.5 μm

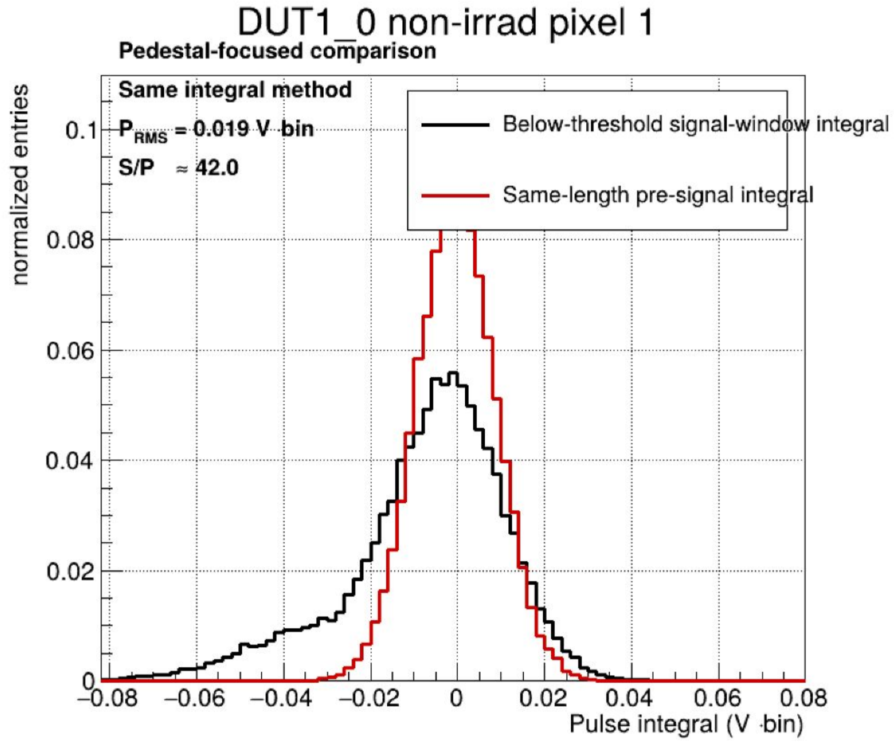



- Pad-only ROIs exclude the trench
- Left and right pad efficiencies quoted separately
- Pair inefficiency is partly driven by the trench region

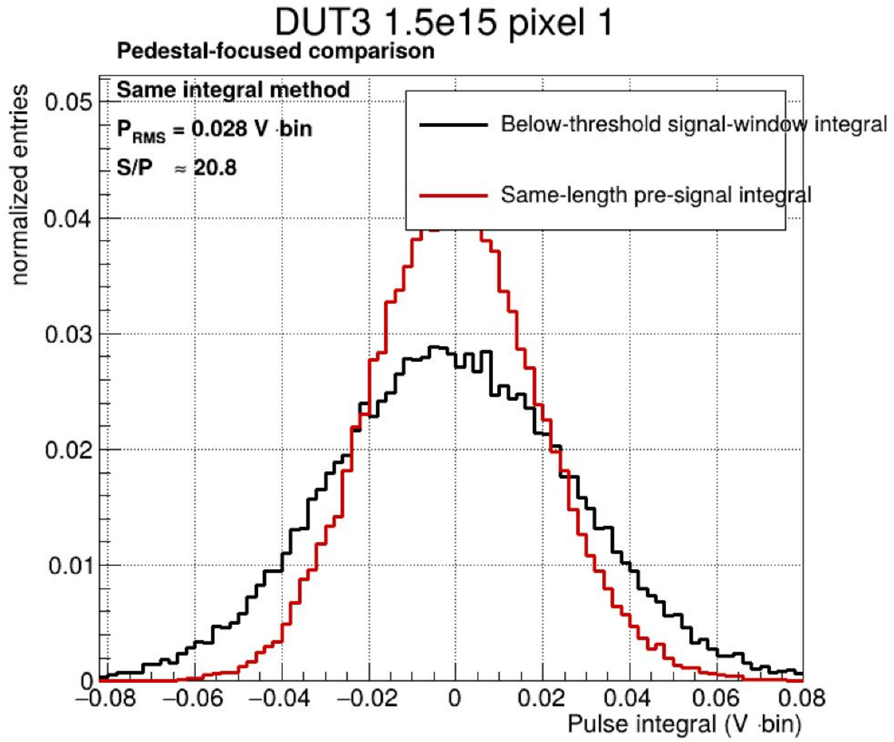



- Track-statistics map shown to indicate local entries per bin-> Typical local statistics: about 17 tracks/bin

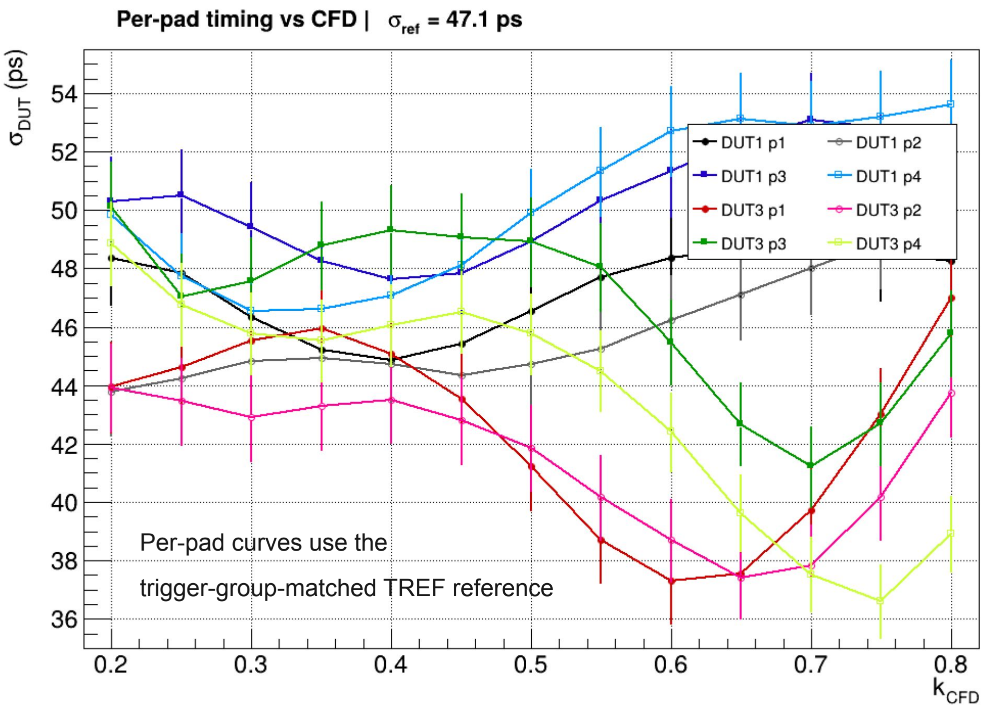


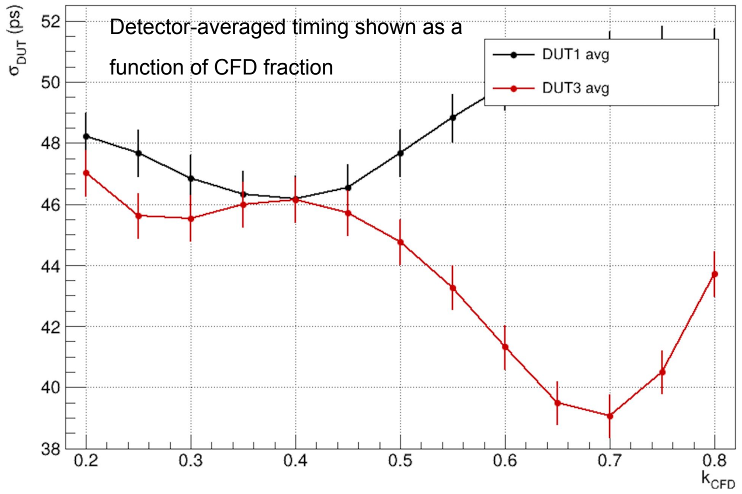
DUT1_0 non-irrad pixel 1
Pedestal-focused comparison
Same integral method
P_RMS = 0.019 V ·bin
S/P ≈ 42.0
Below-threshold signal-window integral
Same-length pre-signal integral
normalized entries
Pulse integral (V ·bin)
0.1
0.08
0.06
0.04
0.02
0
−0.08
−0.06
−0.04
−0.02
0.02
0.04
0.06
0.08

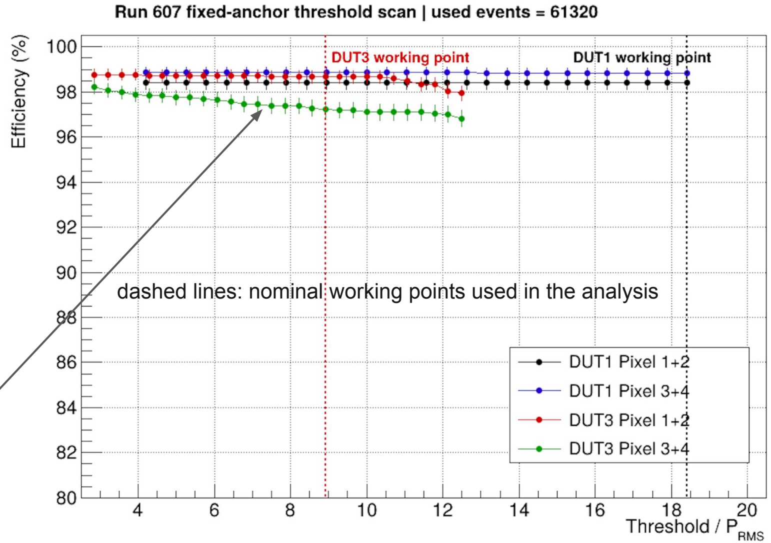



DUT3 1.5e15 pixel 1
Pedestal-focused comparison
Same integral method
P_RMS = 0.028 V ·bin
S/P ≈ 20.8
Below-threshold signal-window integral
Same-length pre-signal integral
normalized entries
Pulse integral (V ·bin)
0.05
0.04
0.03
0.02
0.01
0
−0.08
−0.06
−0.04
−0.02
0.02
0.04
0.06
0.08

# Threshold and CFD scans with track-based fixed-anchor selection

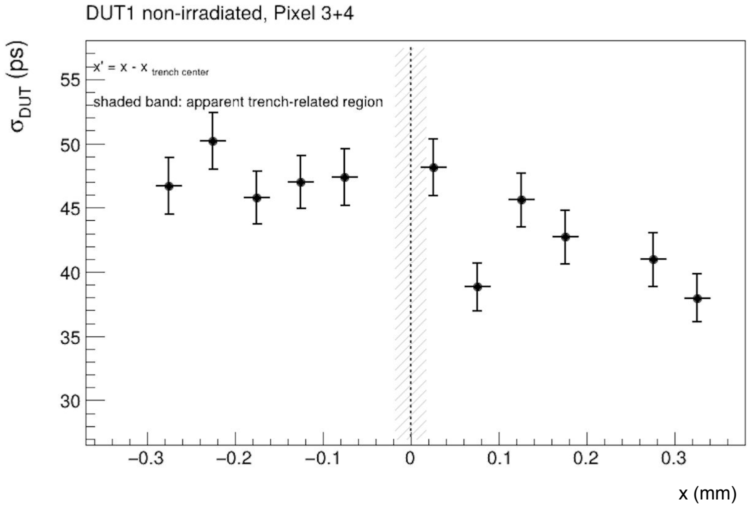


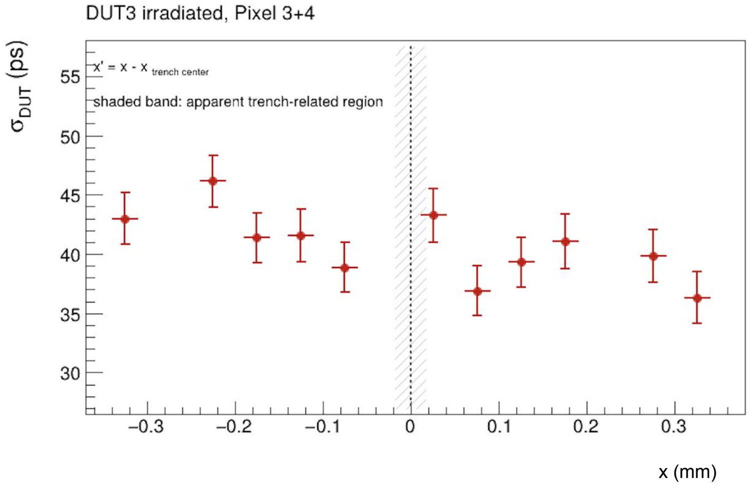



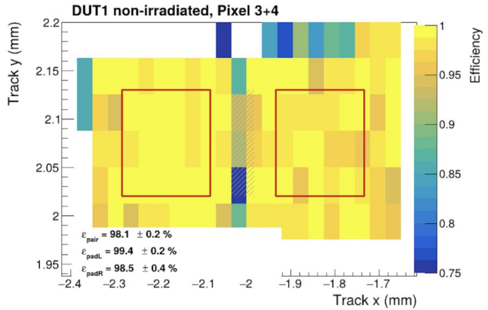

Threshold choice is much more critical for DUT3
than for DUT1

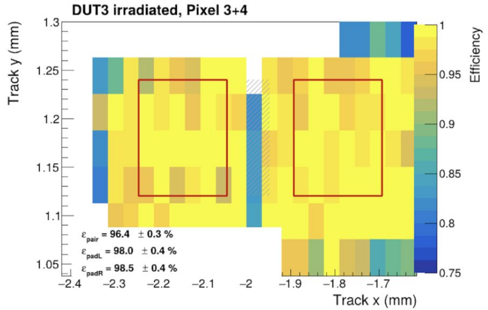
Trench-centered timing x-projection plots

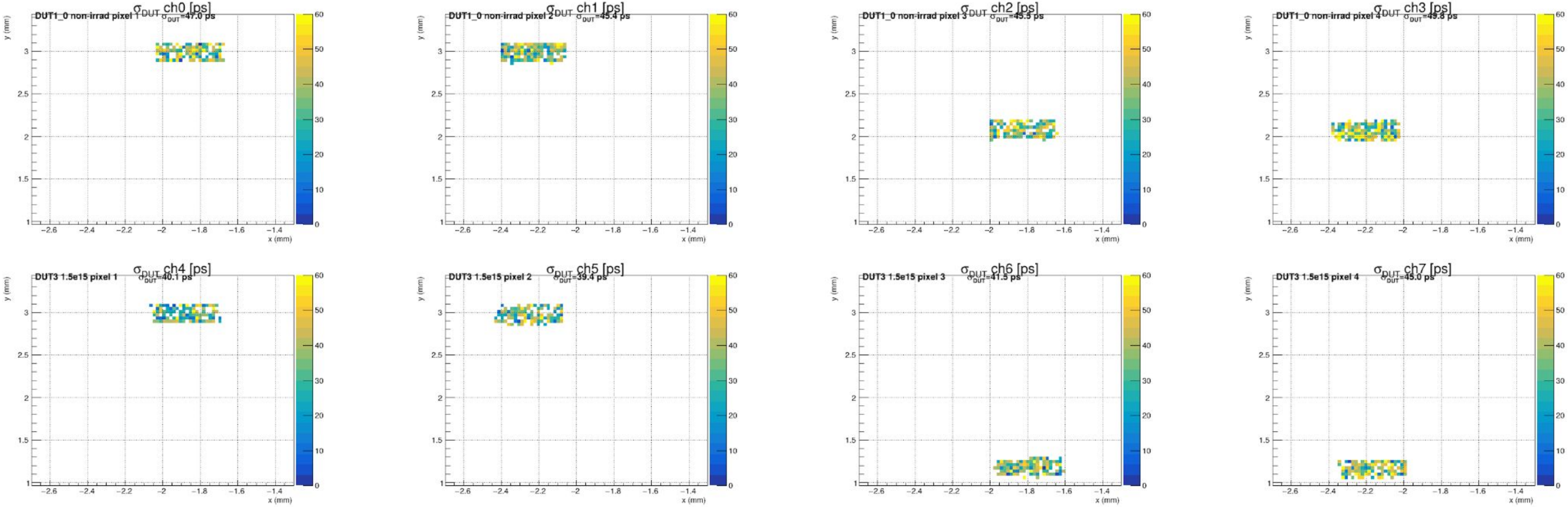



- Timing projected in x after aligning each pair to its own trench center
- Grey band: apparent trench-related region from the efficiency x-profile
- No strong universal timing degradation is observed

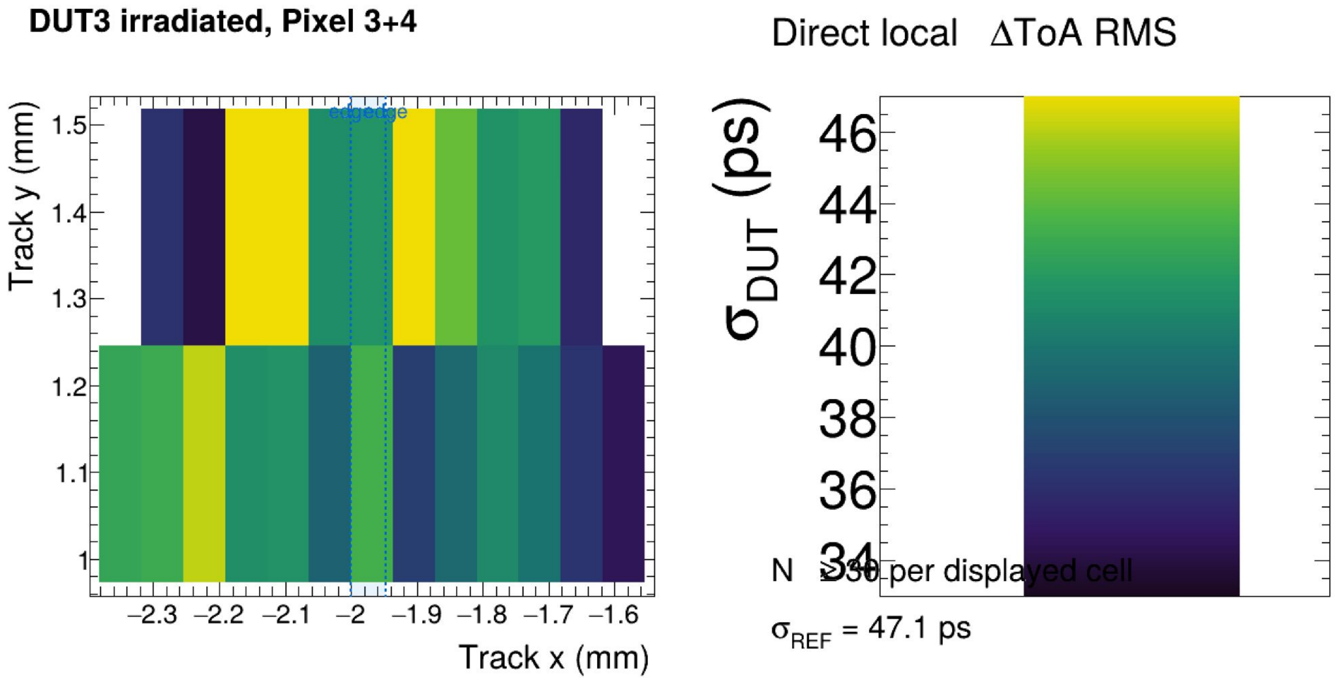


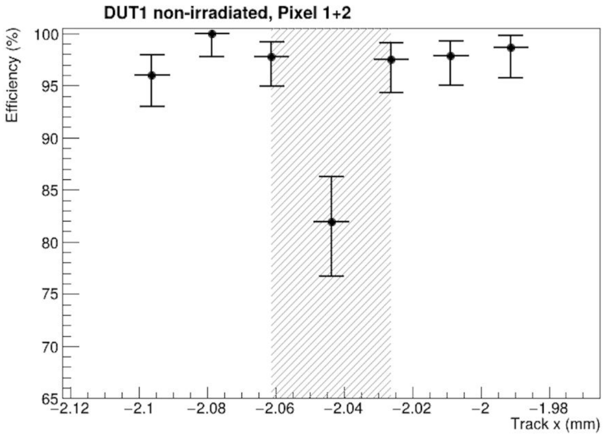


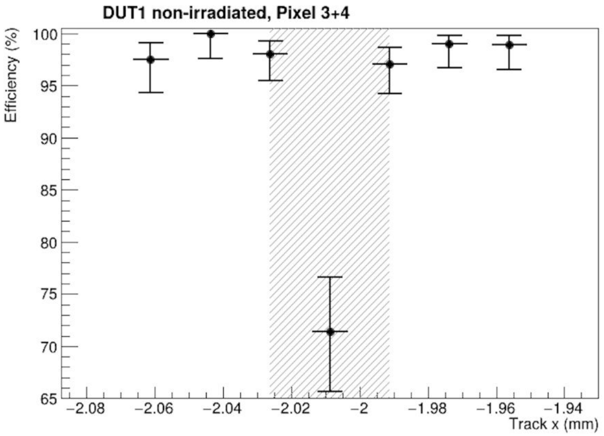

- Direct local ΔToA RMS map on the efficiency grid
- Same-grid timing map tested in a separate rerun
- Per-cell timing statistics are too sparse for a stable final 2D presentation
- Used as a validation cross-check, not as the main timing result

2D local timing map

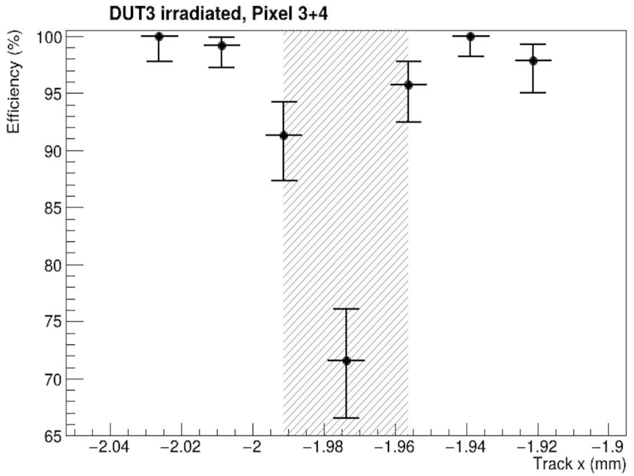



- Direct local ΔToA RMS map
- DUT3 irradiated, Pixel 3+4
- Blue dashed lines: trench edges from efficiency x-profile
- Only cells with N ≥ 30 timing entries shown

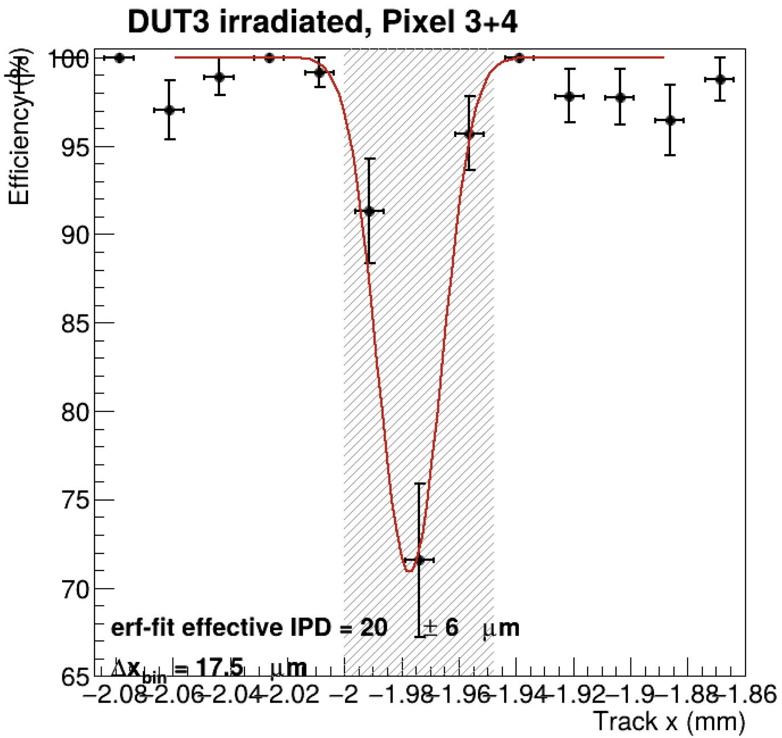



- Efficiency projected in x for the full pair ROI
- Error bars: Clopper–Pearson 68.3% confidence intervals
- Grey band: apparent trench-related region from the efficiency x-profile
- DUT3 shows a clear localized efficiency dip in the apparent trench-related region



# Effective IPD estimate from the efficiency dip




- Summed x projection for DUT3 irradiated, with an error-function fit to the trench-related efficiency dip

$$\varepsilon(x) = p - (A/2) * [\ \mathrm{erf}((x - xL)/\sigma) - \mathrm{erf}((x - xR)/\sigma)\ ]$$

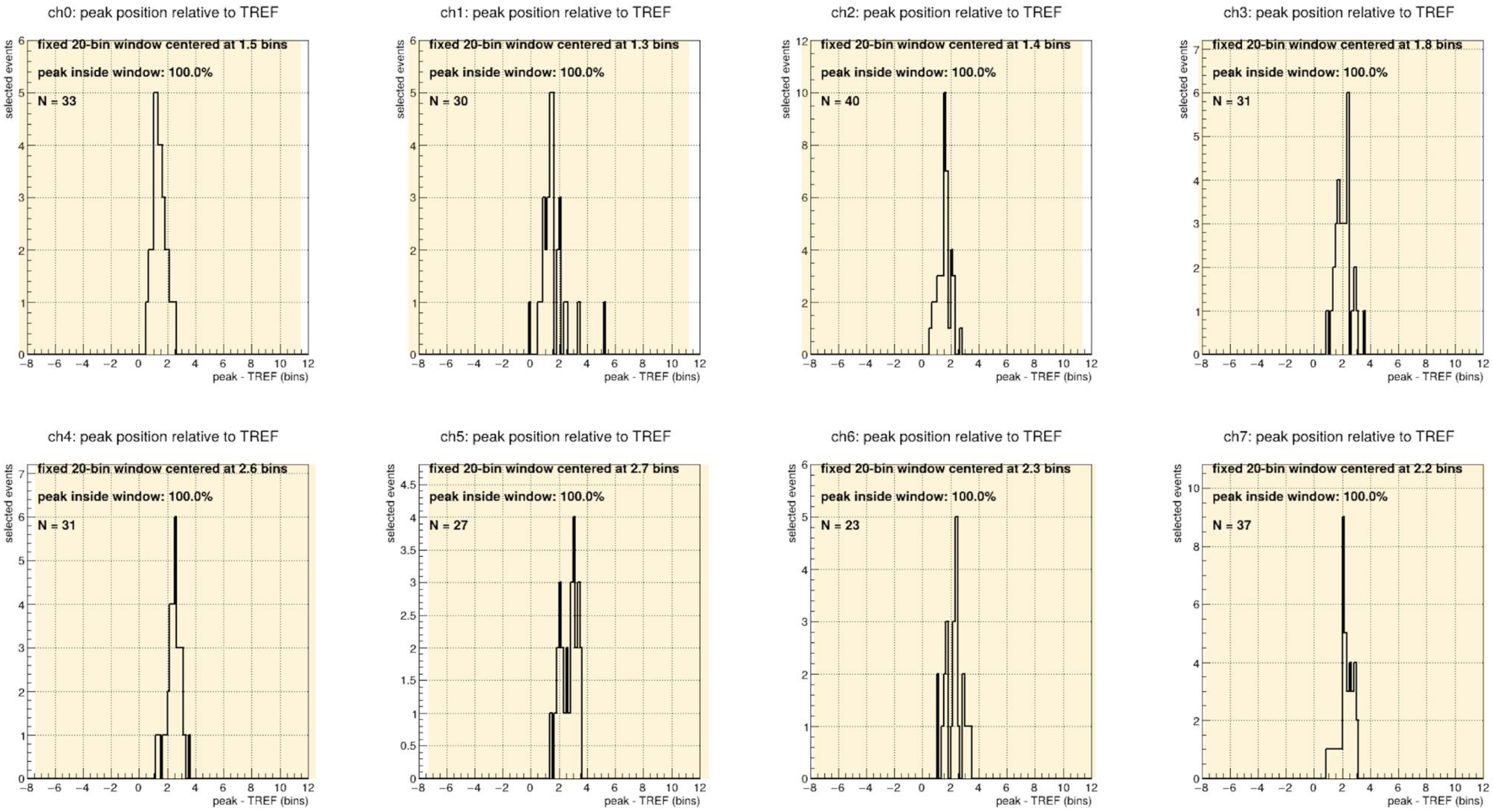
with parameters:

- `p`: plateau efficiency
- `A`: dip amplitude
- `xL, xR`: effective dip edges
- `σ`: edge-smearing scale

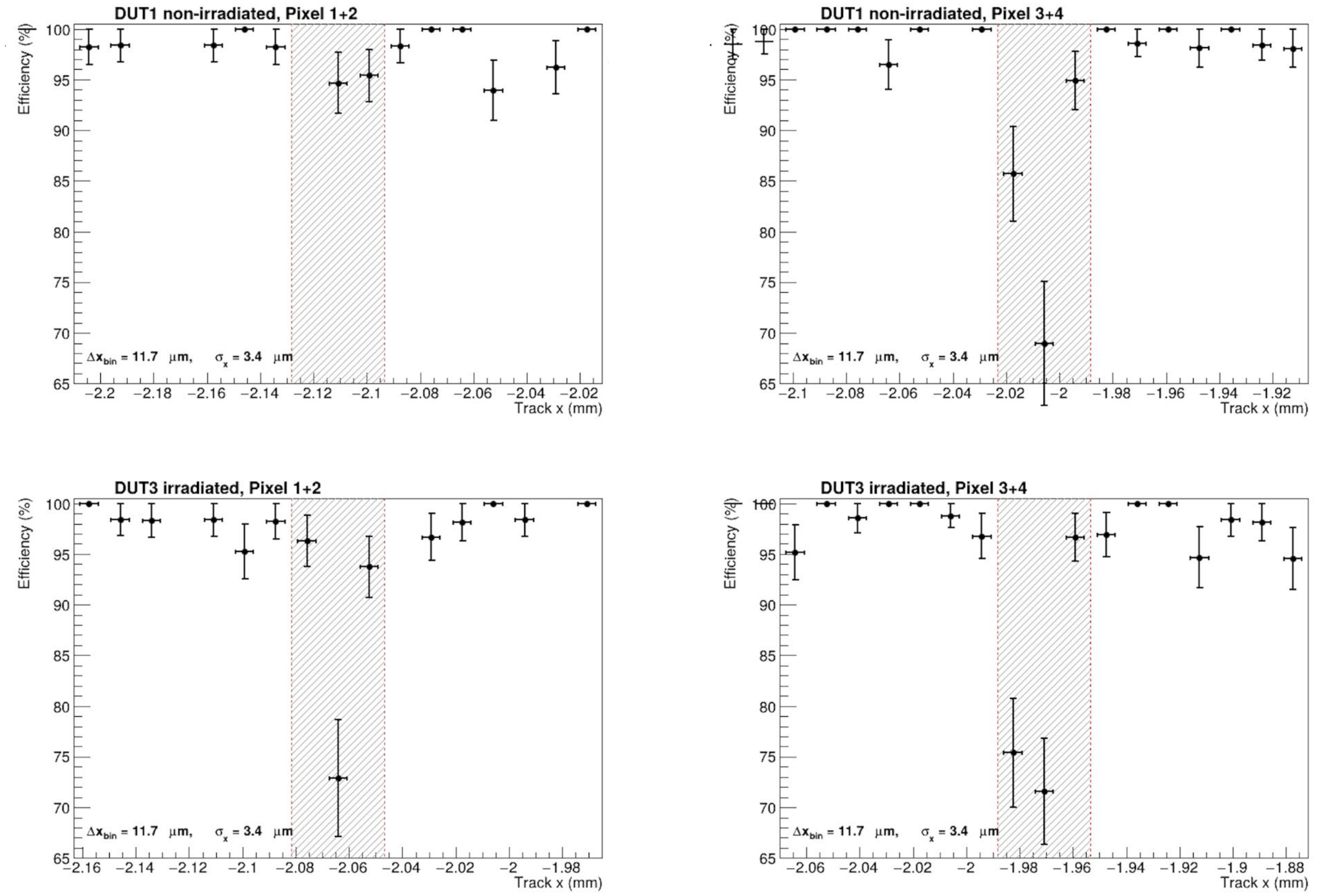
- Larger dip-region errors reflect lower local track statistics
- Grey band: data-driven apparent trench-related region from the efficiency x-profile
- Effective IPD: model-dependent response width of the dip, not physical trench width

# Validation for the signal definition: peakPos - tTREF

- Validation of the fixed TREF-anchored signal window
- Observed DUT pulse remains inside the chosen window

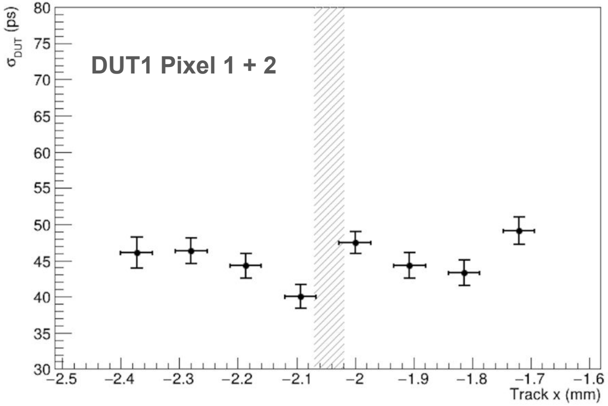


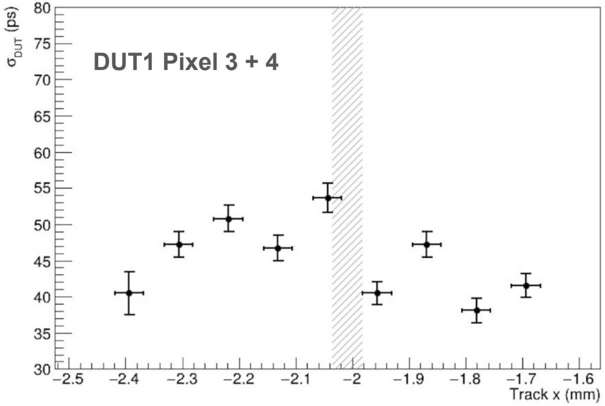
# Efficiency x projection: localized trench-related band

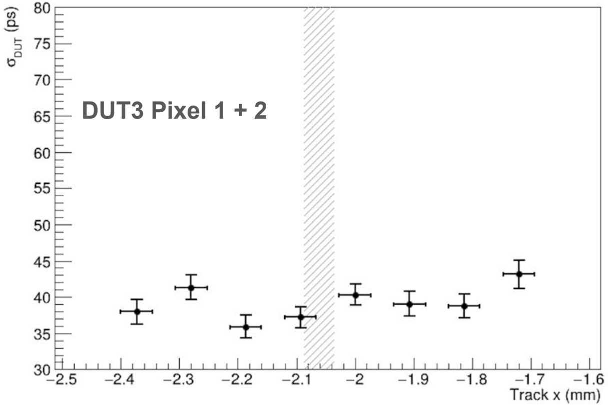


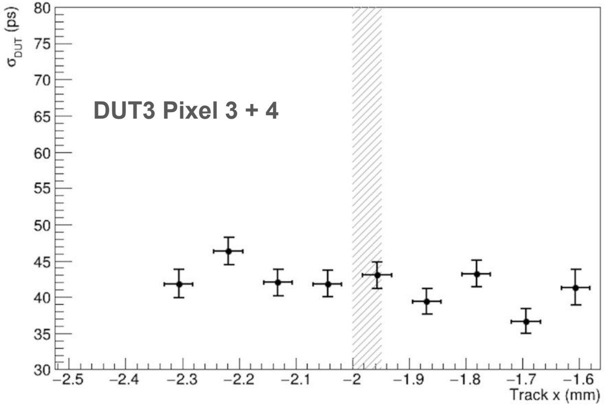

- Center-y efficiency projected in x
- Shaded band: trench-related inefficient region
- Used to localize the trench-related response dip

# Timing projected in x near the trench




- Timing evaluated as a function of track x
- Shaded band: apparent trench-related region from the efficiency x-profile
- No strong timing degradation is observed

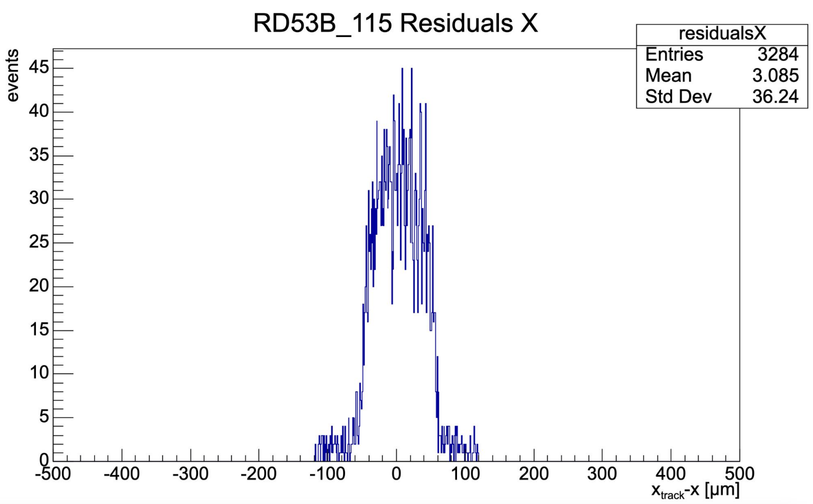
# Interesting testbeam runs to analyse >>

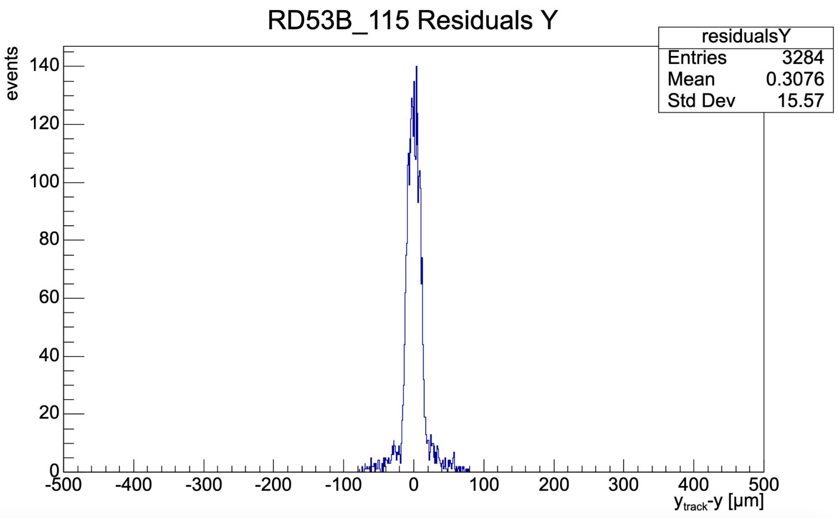
Important: calibration for Chubut2 board with PIN TI-LGAD to be done

# Ongoing analysis: Batch 1 -> March TB 2026; 100 um x 25 um CROC

| Batch 1 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Wafer** | **Version** | **Trench parameter** | **Fluence** | **# daughterboard** | **Chubut CH1,2** | **Chubut CH3,4** | |
| W5 | V2 | TW1-2 | | | V2TW1 | V2TW2 | |
| W5 | V2 | TW1-2 | | | V2TW1 | V2TW2 | Angled |
| W5 | V1-V2 | TW5 | | | V1TW5 | V2TW5 | |
| W5 | V1-V2 | TW5 | | | V1TW5 | V2TW5 | Angled |
| | | | | | | | |

| HV plane 1 (V) TREF1 - Genova | HV plane 2 (V) DUT1 - UZH | HV plane 3 (V) DUT2 - UZH | HV plane 4 (V) DUT3 - UZH | HV plane 5 (V) DUT4 - UZH |
|---|---|---|---|---|
| 200V; 0.07uA | 240V; 11.3uA | 240V; 12.9uA | 200V; 13.2uA | 200V 20.0uA |

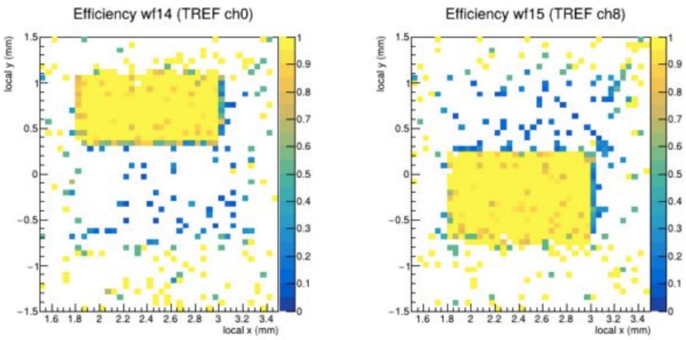


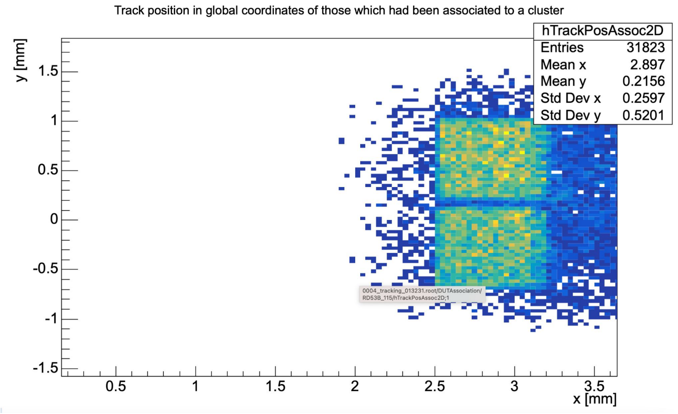



**Batch 1 -> March TB 2026; 100 um x 25 um CROC, efficiency plots with the CROC included;**
select only tracks that passed through the CROC active region; **run 13231 -> checked another batch -> improvement of associated tracks for the CROC ; batch 3 has masked columns in CROC**

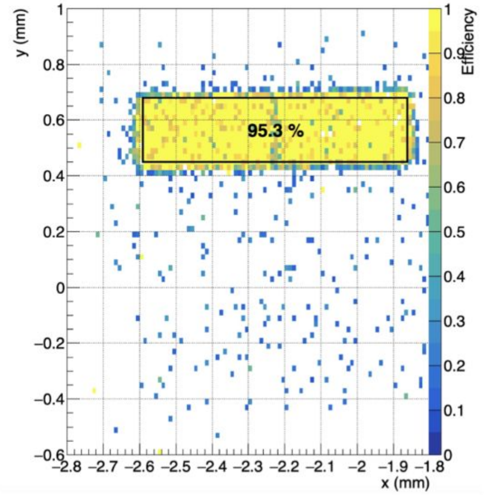
| | Batch 2+3 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Wafer** | **Version** | **Trench parameter** | **Fluence** | **# daughterboard** | **Chubut CH1,2** | **Chubut CH3,4** | | |
| | W5 | V2 | TW1-2 | 0 | | V2TW1 | V2TW2 | Angled | |
| | W5 | V2 | TW2-3 | 2.5e15 | | V2TW2 | V2TW3 | | |
| | W2 | V2 | TW2-3 | 2.5e15 | | V2TW2 | V2TW3 | | CH3+4 not used for Batch 3 |
| | W5 | V2 | TW4-6 | 1.5E15 | | V2TW4 | V2TW6 | | CH3+4 not used for Batch 2 |
| | **Batch 4** | | | | | | | | |
| | **Wafer** | **Version** | **Trench parameter** | **Fluence** | **# daughterboard** | **Chubut CH1,2** | **Chubut CH3,4** | | |
| MB13 | W2 | V1-V2 | TW5 | 1.5e15 | | V1TW5 | V2TW5 | Angled | DUT5 from March26 |
| MB#7 | W2 | V1-V2 | TW5 | 2.5e15 | | V1TW5 | V2TW5 | | DUT14 from March26 |
| ~~MB14~~ | ~~W2~~ | ~~V2~~ | ~~TW1-2~~ | ~~2,50E+15~~ | | ~~V2TW1~~ | ~~V2TW2~~ | | (DUT13 from Oct25) |
| ~~MB15~~ | ~~W5~~ | ~~V2~~ | ~~TW4-6~~ | ~~2.5e15~~ | | ~~V2TW4~~ | ~~V2TW6~~ | | DUT10 from March Sample broken |
| Update: | W2 | V1-V2 | TW5 | 1.5e15 | | V1TW5 | V2TW5 | | DUT6 from Oct 25 |
| | W5 | V2 | TW4/6 | 2.5e15 | | V2TW4 | V2TW6 | | DUT 9 from March |

| | Batch 6 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Wafer** | **Version** | **Trench parameter** | **Fluence** | **# daughterboard** | **Chubut CH1,2** | **Chubut CH3,4** | |
| 55um | W11 | V1-2 | TW5 | | | V1TW5 | V1TW5 | Angled |
| | W11 | V2 | TW2-3 | | | V2TW2 | V2TW3 | |
| | ~~W11~~ | ~~V2~~ | ~~TW4-6~~ | | | ~~V2TW4~~ | ~~V2TW6~~ | ~~TRIPS - broken~~ |
| | W11 | V3-4 | TW5 | | | V3TW5 | V4TW5 | |
| Replacement: | W3 | V1-2 | TW5 | | | V1TW5 | V2TW5 | Zurich Sample |

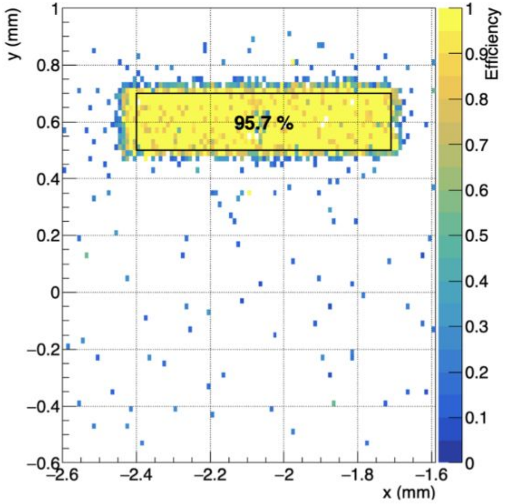


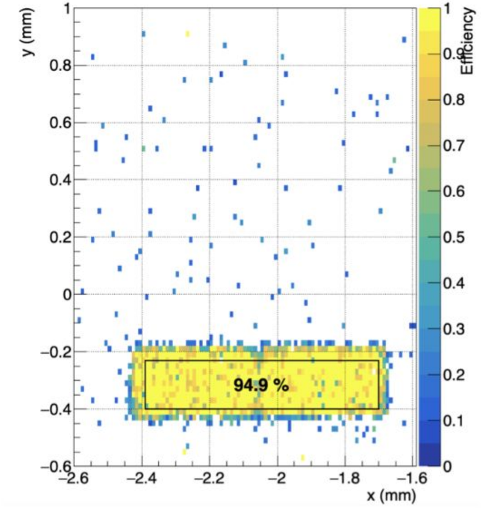
Next step: Testbeam October 2024 -> regenerate plots with the new TB analysis




(a) Unirradiated TW5, 50 V.
$S/N_{\text{peak}} = 48$, $S/N_{\text{cut}} = 13$




(b) Irradiated TW4, 530 V.
$S/N_{\text{peak}} = 68$, $S/N_{\text{cut}} = 25$




(c) Irradiated TW6, 530 V.
$S/N_{\text{peak}} = 68$, $S/N_{\text{cut}} = 25$