ÖAW AUSTRIAN ACADEMY OF SCIENCES

HEPHY INSTITUTE OF HIGH ENERGY PHYSICS

RD50 HV-CMOS Meeting

DESY Test Beam Apr. 24

It's about time (and charge)

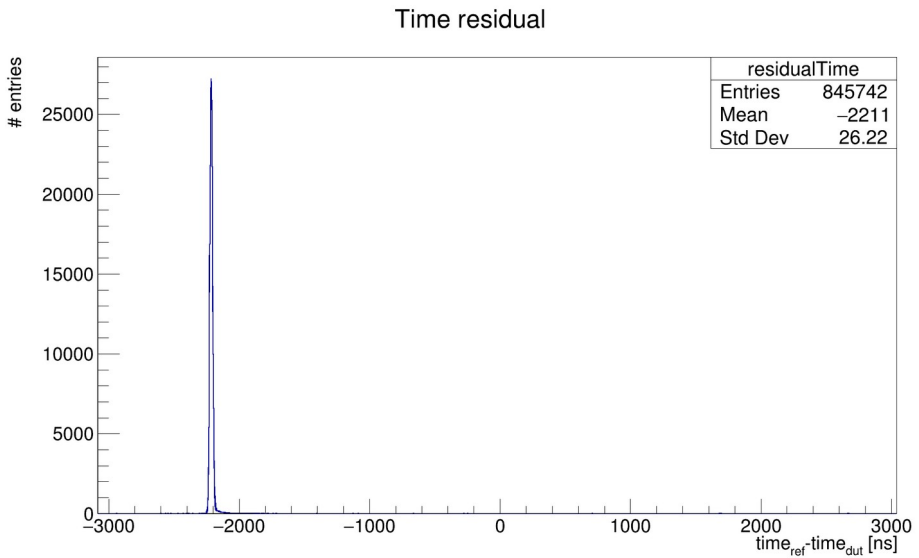
Bernhard Pilsl

Methods Timing Analysis

- Goals:
  - Calculate time residuals ($t_{Track} - t_{DUT}$)
    - σ corresponds to time resolution
  - In-time-efficiency
    - Cut on DUT-cluster-time; Discard hits at DUT with $t_{DUT} \notin (t_{Track} - x\ ns, t_{Track} + x\ ns)$
- What time to use?
  - Timestamp of DUT
    - Utilize TS-LE in combination with overflow counter (MPW4 output sampled by FPGA)
    - TLU clock counter based on 25ns clock of TLU (sampled by FPGA)
  - Timestamp of track
    - Timestamp from Telepix
    - Timestamp of TLU

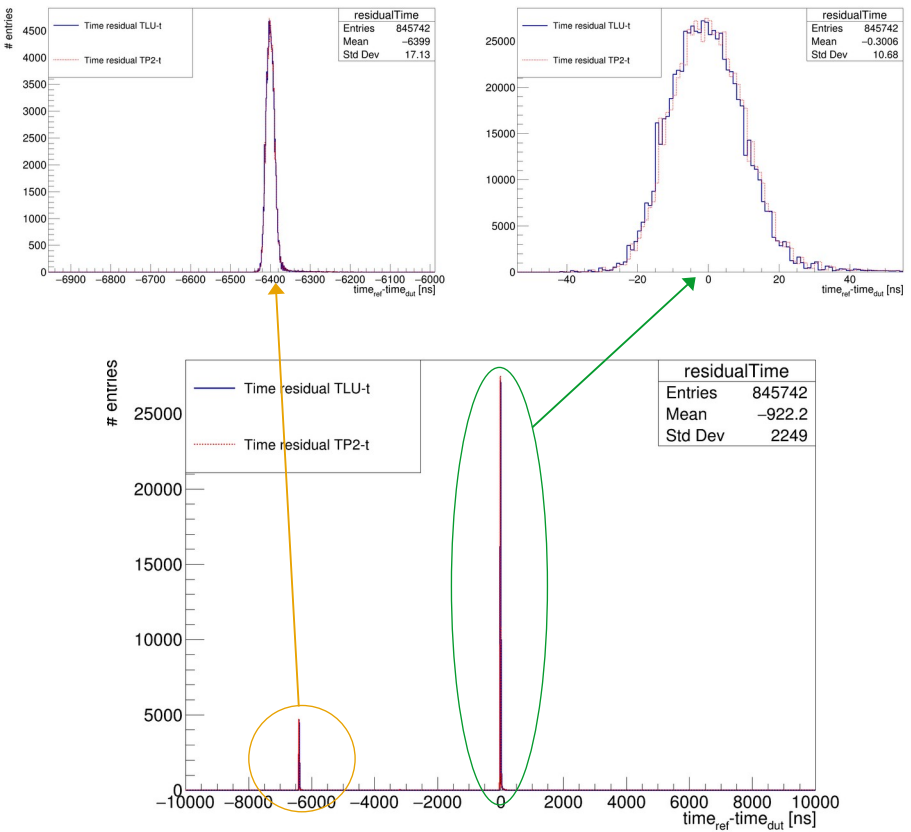
Time Offset

- Time residuals show offset of ~2.2µs
- $t_{MPW4} > t_{Track}$
- Possible systematic error due to measurement setup
- From now on offset corrected with „time_offset“ parameter in Corry geo file



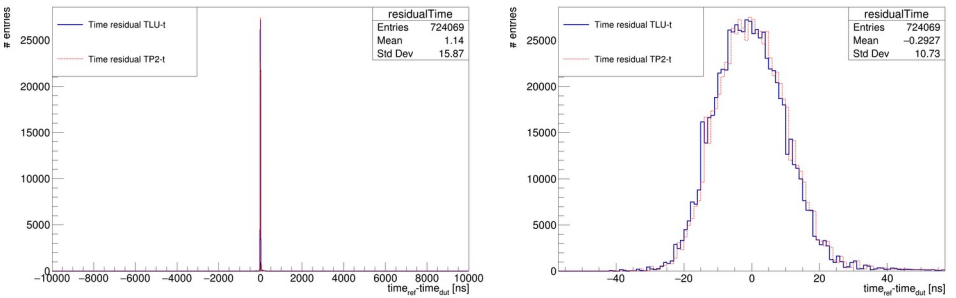
No time cuts

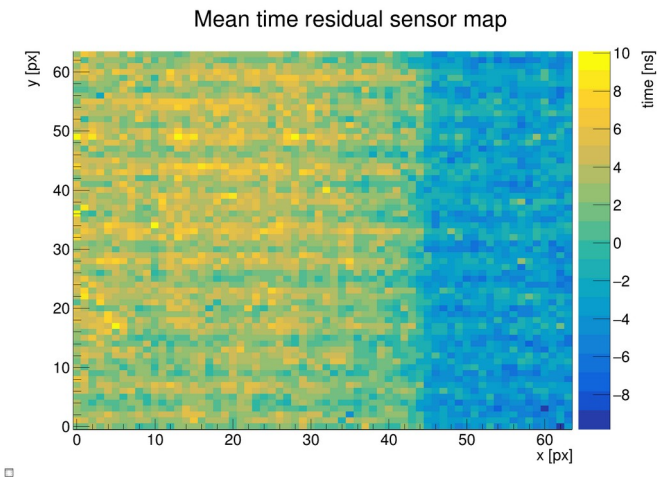
- MPW4 hits matched to tracks in 20µs window
- After applying offset main peak observed at ~0ns
  - Shows σ ~ 10.7ns
- Second peak observed at Δt ~ -6.4µs
  - 25ns * 256 = 6.4µs
  - Overflow counter too high by one
  - Possible when hits already buffered in chip / getting read out at the moment and overflow output triggers once more
  - Wrong assignment of overflow counter to frame
- No substantial difference between track time from TLU or Telepix



With time cuts

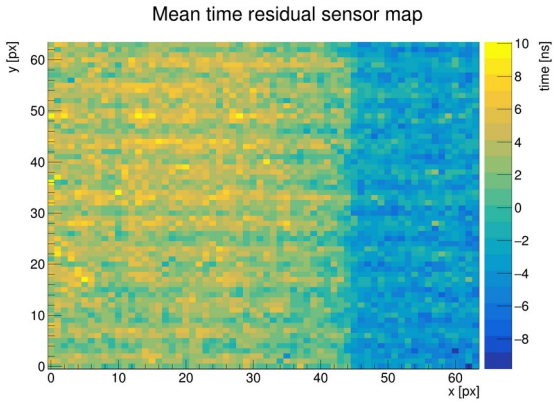
- Allow Δt of 5σ ~ 36ns
  - σ as expected MPW4 timing resolution of 25ns /$\sqrt{12}$ ~ 7.2ns
- Secondary peak „cut away“
- Timing resolution of ~10.7ns evaluated
- Mean time residual map shows column gradient
  - Δt between first and last double column ~15 – 20ns
  - Reason for our poor timing resolution?



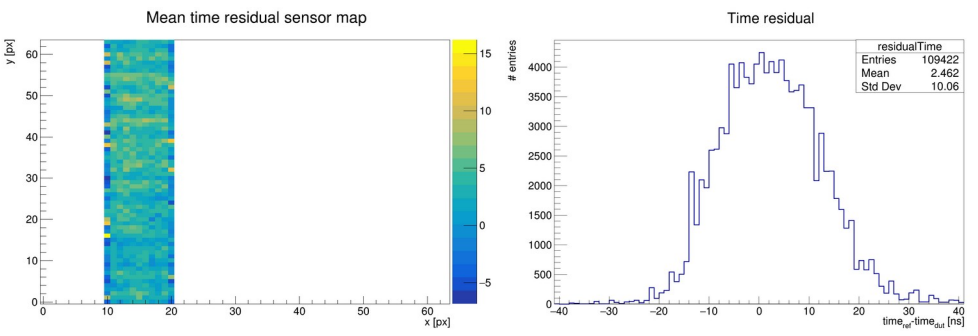


Poor timing resolution

- Is mean-time-residual gradient reason for poor timinng resolution?
- Test by masking all but 10 columns
- Gradient no longer clearly visible
  - Still ranging from (-5ns, 15ns)
  - σ ~ 10.06ns

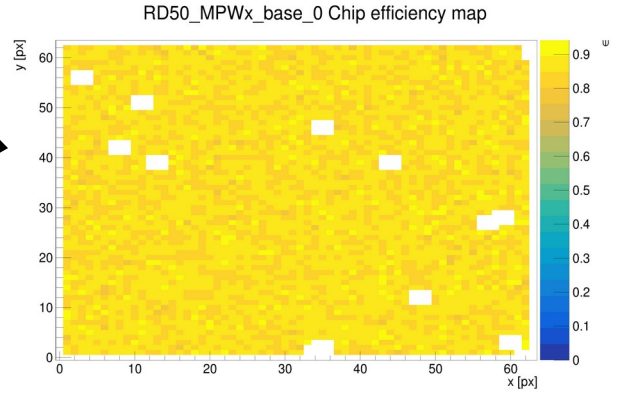


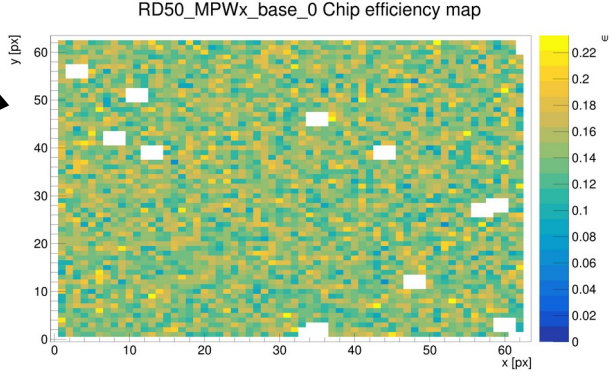
- Gradient is not the problem, inhomogenity is
- Does not look like time walk
- One could try “calibrating these effects away“



In time efficiency

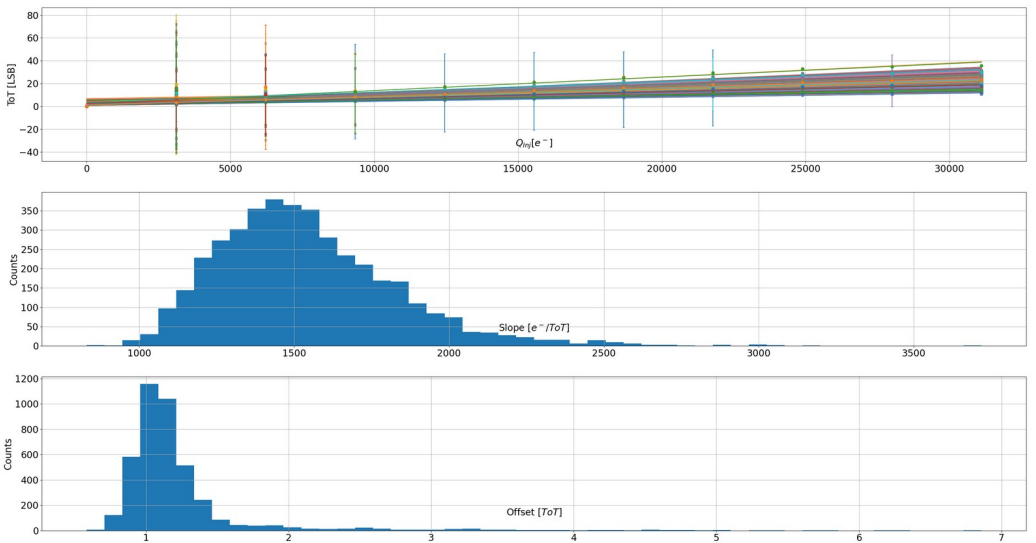
- 5σ t cut and t-offset of -2212ns → ε ~ 85%
- 15% of our hits are not within 5σ time
- Where are they lost?
  - Remember secondary peak in time-residals without DUT-t-cuts
  - Centered at ~ -6.4µs
- 5σ t cut and t-offset of -8612ns → ε ~ 15%
- → We loose 15% in-time-efficiency due to wrong assigned overflow counter
- Can’t be done much better in FPGA
- If timing is of importance future iteration needs larger timestamps





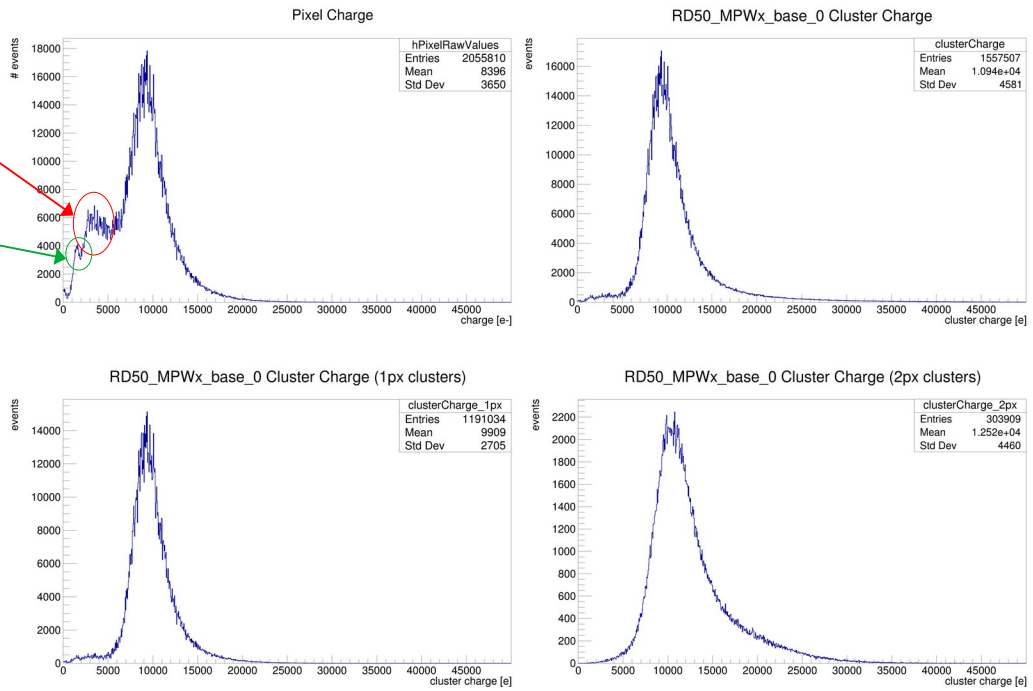
ToT [LSB] → Charge [e$^-$]

- Applied config from testbeam (HEPHY topside biased) to same chip in lab
- Performed “totCalibration” (new Peary method)
  - Inject into all pixels and sweep on injection voltage V_{inj}; record ToT vs. V_{inj}
- Convert V_{Inj} to Q_{Inj} (via 2.8fF capacitance)
- Perform linear fit to $ToT = k * Q_{Inj} + d$ → extract slope and offset → write to „calibration file“
- Each pixel gets its own set of {k, d}
- EUDAQ event converter gets calibration file from Corry and converts ToT [LSB] → Q [e$^-$]



Collected charge

- Mean collected pixel-charge ~ 8ke$^-$
  - Charge sharing peak at ~ 3.3ke$^-$ observed
  - Feature at 1.4ke-
- Cluster-charge ~ 10.1ke$^-$
- Expectation from simulations:
  - Pixel charge: 20.6ke$^-$
  - Cluster charge: 27.4ke$^-$
- Do we have such bad CCE?
- Or bad calibration
  - Is entire charge injected into single pixel?
  - Observed in injection scans: Unmasked pixels with **disabled** injection still get „hit“



Time walk

- Larger signals exceed threshold earlier → earlier timestamp
- Typical „banana“ like shape expected (if observable)
- Calibrated Q vs. Δt shows (very faintly) time walk behaviour
- Showcases necessity of larger ToT values