ÖAW AUSTRIAN ACADEMY OF SCIENCES

HEPHY INSTITUTE OF HIGH ENERGY PHYSICS

43rd RD50 Workshop

Beam test characterization of RD50-MPW3

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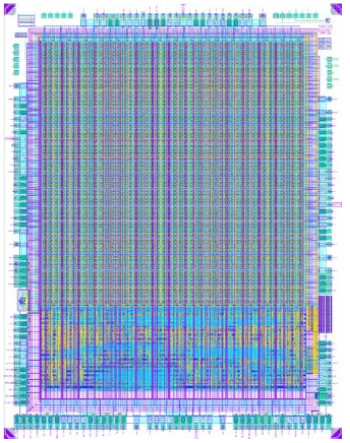
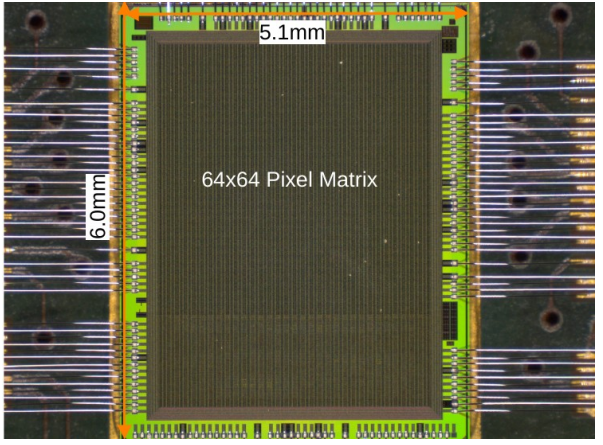
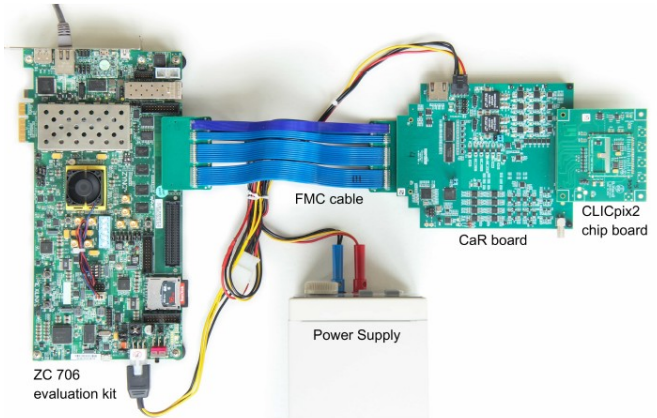
The RD50-MPW3

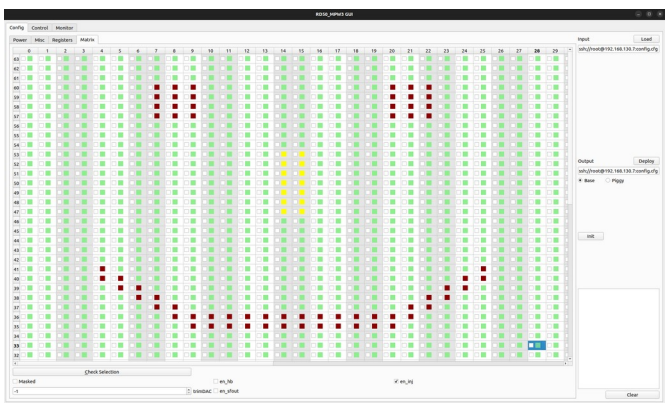
- 64 x 64 Pixel with pitch of 62µm
  - Arranged in 32 double columns
- Full analog and digital electronics inside pixel
- *LFoundry* 150nm HVCMOS process
- Large collection electrode design
- Fast clock at 320MHz
- 8 bit 50ns timestamps for ToT
- Digital periphery
  - I2C server for configuration
    - 8 bit per pixel
  - Data FIFO depth of 32 words for each double column





Base DAQ

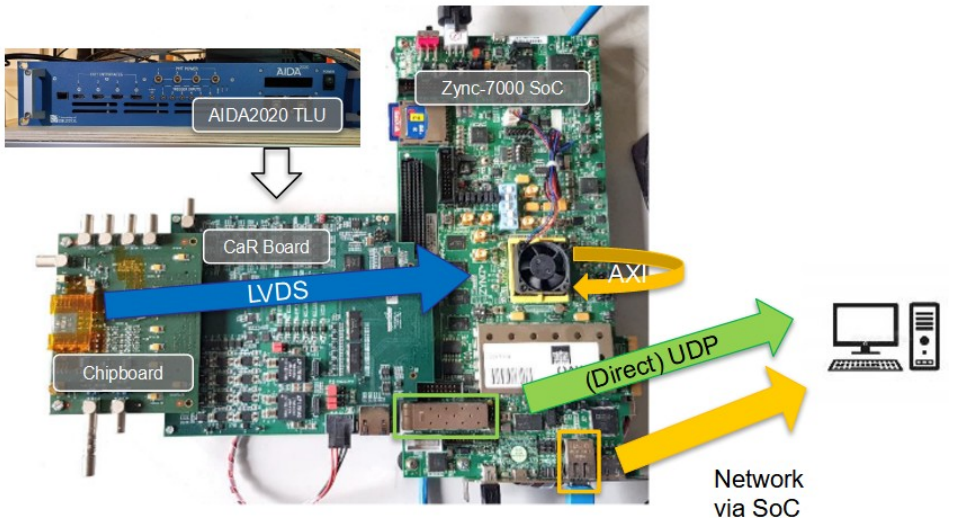




- Caribou system
- Implemented Peary Device
  - Custom I2C interface (16 bit addresses)
- GUI for configuration
  - Generating Peary config files

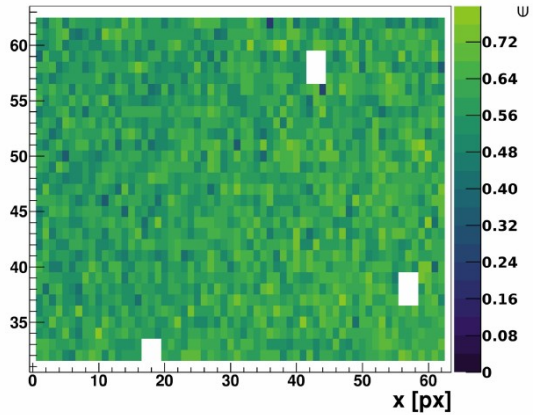
Testbeam DAQ

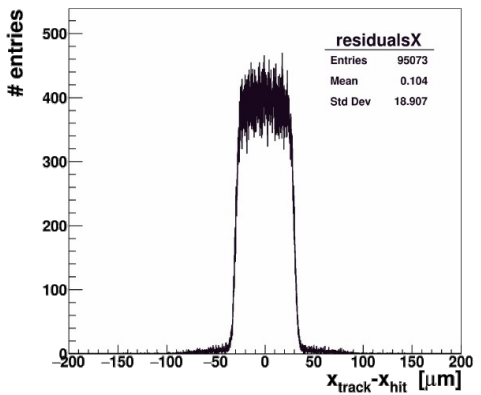
- Fully integrated into EUDAQ2
- CaribouProducer too slow for full read-out rate
  - Only used for run-control commands
- Custom UDP (1 Gbit/s) Data-Collector implemented
  - Multi–threaded approach
  - More like a EUDAQ-producer, but directly storing to disk
- EUDAQ-monitor integrated in GUI
- EUDAQ-Producer for submission of run info to ELog server
- Analysis done with *Corryvreckan*

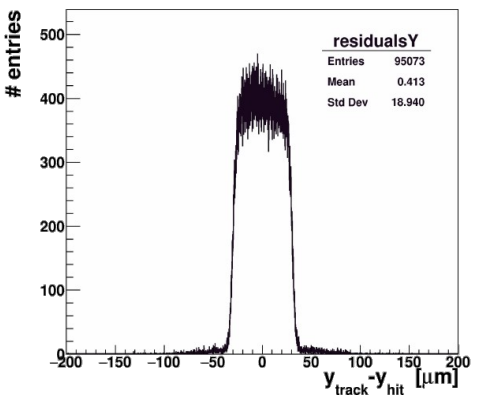


Reminder:
Testbeam at *CERN SPS*

- Beam test at CERN SPS facility in Oct. 2022
- Severe issues with synchronization
- Only low statistic runs taken due to bugs in measurement setup
- Total efficiency of ~60% evaluated
- ~Binary spatial resolution measured ~18.9µm





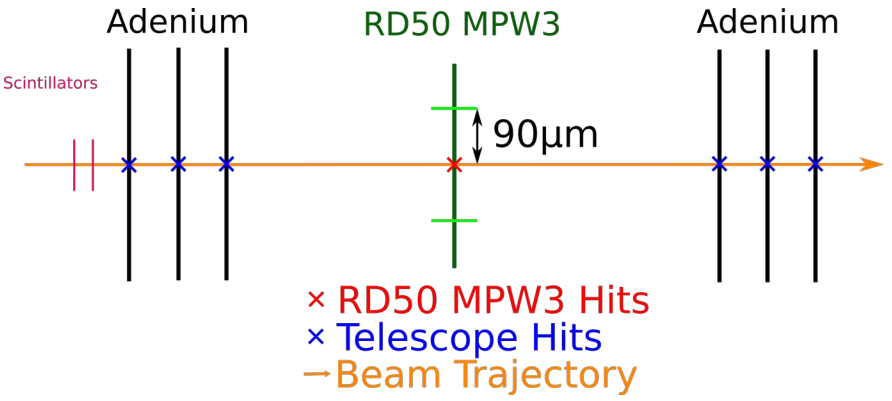


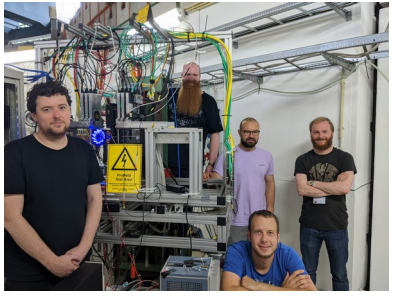
DAQ improvements

- Problem at *CERN*: synchronization
  - 1 global timestamp for ~1300 hits
  - Data preprocessor looking for overflows in TS-LE to refine hit-timestamps
- FW adjustments allow for global timestamp for ~each hit

Testbeam Setup *DESY*

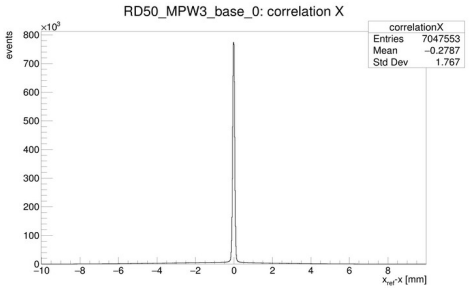
- Utilizing *Adenium* telescope
  - Based on *Alpide* chip
  - Pitch: 29µm x 26µm
  - 1024 x 512 pixel matrix
  - 6 planes
- Setup triggered by 2 scintillators operated in coincidence
- Telescope synchronized via trigger-numbers
- DUT (MPW3) synchronized via time-stamps
- Matching done by AIDA2020-TLU
- Electron beam with (mostly) 4.2 GeV, 6kHz used

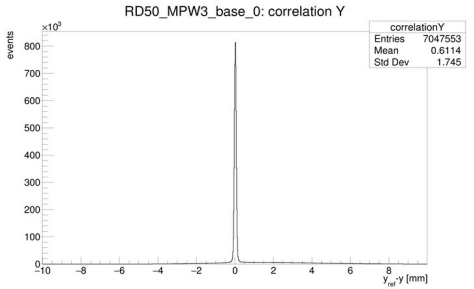


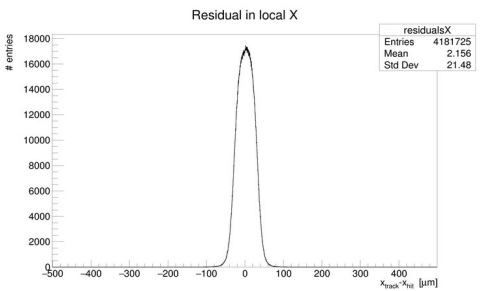


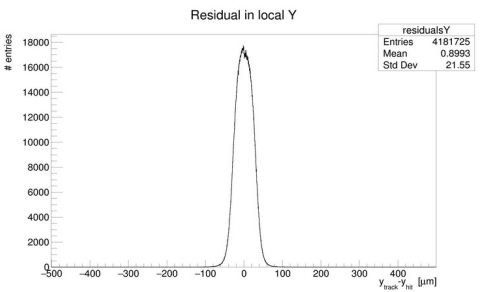
General Results *DESY*

- Correlations with very little background observed
  - Properly synchronized
- Std. dev. of residuals show spatial resolution of ~21.5µm
  - Slightly worse than binary resolution of $\frac{62\,\mu m}{\sqrt{12}} \approx 18\,\mu m$
  - Reason pitch of telescope and alignment
    - Simulations (Allpix²) show resolution of telescope at DUT position of TODO

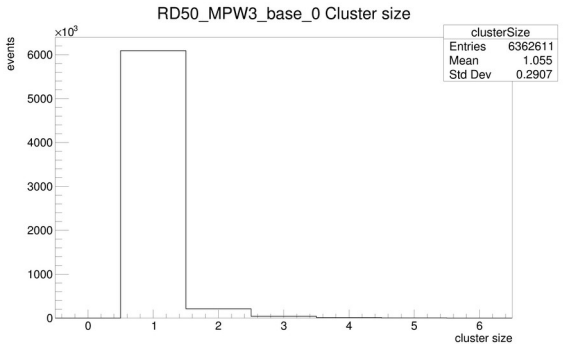


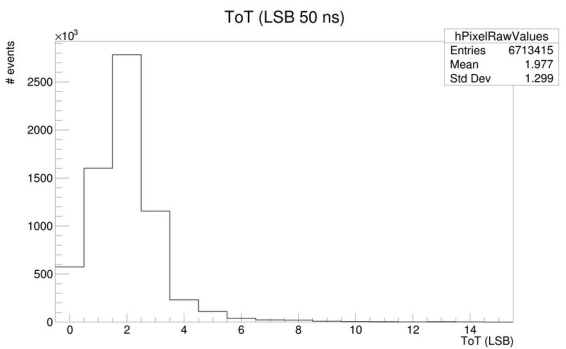






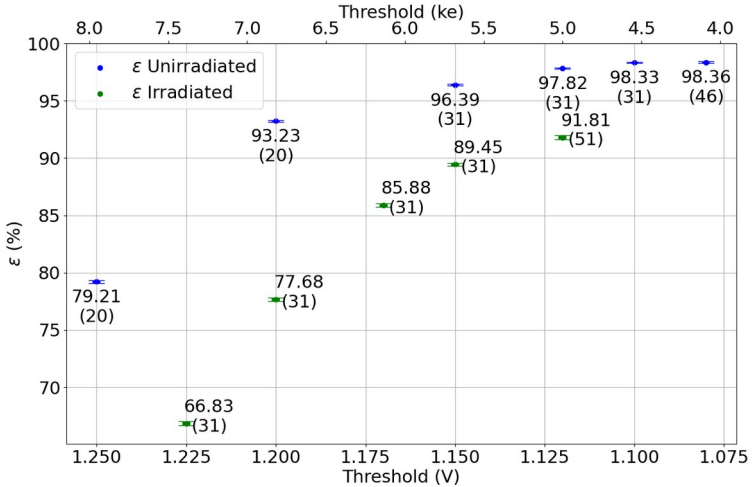
General Results *DESY* (2nd)

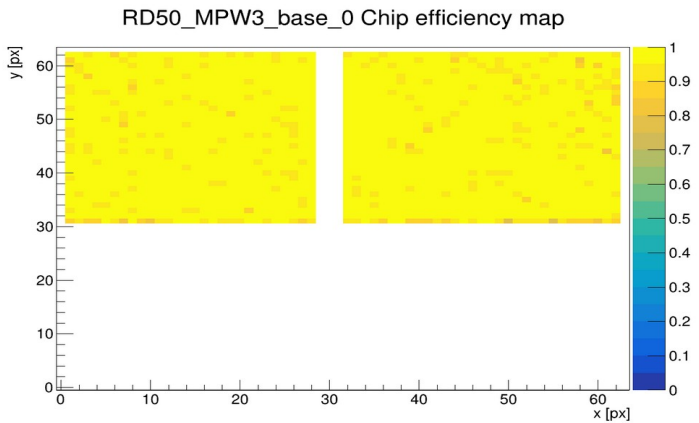




- ToT values of ~1.98 LSBs (on 50ns base) measured
- Mean cluster size ~1.06 pixel / cluster
  - Center of gravity approach to increase spatial resolution not possible

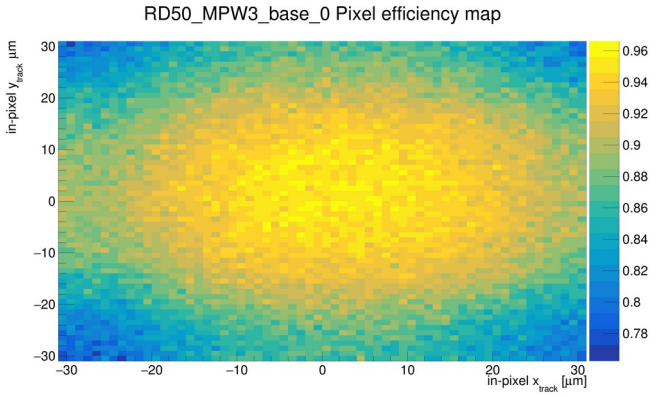
Chip - Efficiency *DESY*

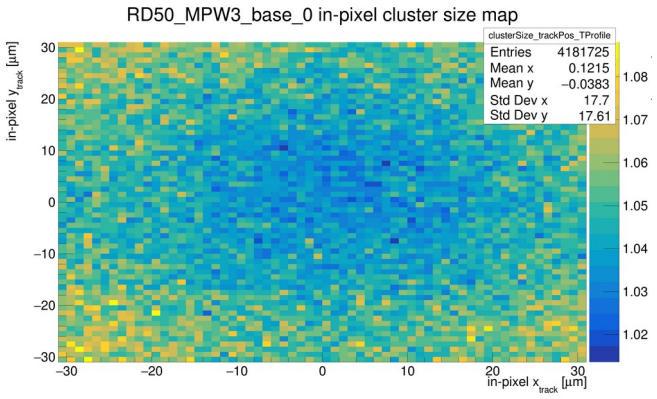




- Best total efficiency of ~98% encountered at threshold of ~4.09ke$^-$
- Take efficiency values with a grain of salt
  - Numbers in brackets indicate numbers of rows masked during data taking (noise issue)
- Efficiency values in green correspond to irradiated (10^{14} 1MeV n_{eq}) sample
  - Efficiency decreases after irradiation
  - Noise also increases

In-Pixel Efficiency *DESY*

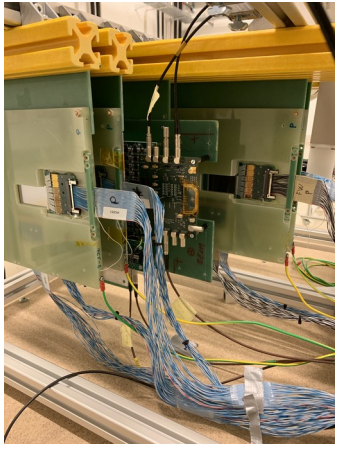




- In-pixel efficiency (shown for 1.15V thr.) shows worse efficiency in corners
- Cluster size map shows increased cluster-size in the corners
  - Tracks intersecting pixel corners cause bigger clusters → Charge sharing
- Charge sharing with neighboring pixels attenuated by high threshold

Setup *MedAustron*

- *MedAustron* is a medical facility located close to Vienna
- Telescope with 4 DSSD planes
  - 512 x 512 “quasi” pixel
  - Pitch: 100µm x 50µm
- Triggered with 2 scintillators operated in coincidence
- 800 MeV proton beam with ~10kHz rate
  - No MIPs
- Worse tracks compared to DESY
- 2 DUTs
  - Base board 1.9kΩcm non-irradiated
  - Piggy board 3kΩcm non-irradiated
  - 32 bottom rows masked
  - Threshold 1.25V ~ 7900e^-
  - Biased to -90V

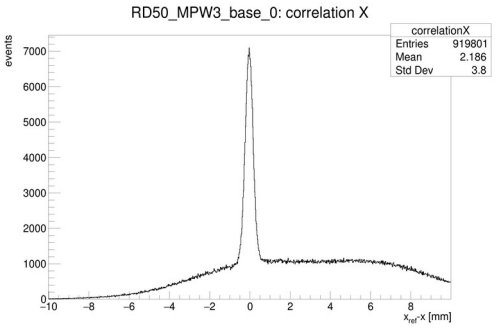


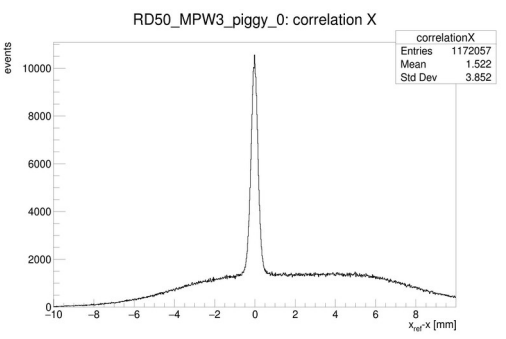
The Piggy Board

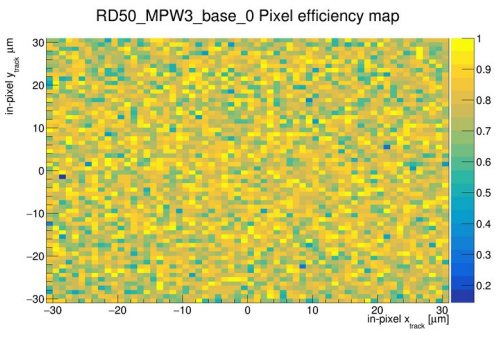
- Allows to operate to RD50-MPW3s with only one Caribou system
- High speed signals connected via ethernet cable
- Supply voltages connected via standard ribbon cable
- Was also installed at DESY, but DAQ not able to synchronize data
- Planned usage:
  - Easier to install / exchange in a telescope than base board (needs to be plugged into the CaRboard)

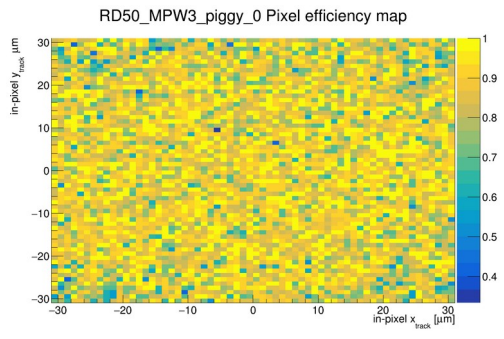
MedAustron Results

- DUTs operated at 1.25V ~ 7900e⁻ threshold and -90V bias
- 32 bottom rows masked
- Managed to properly synchronize Piggy board
- Correlations show increased background compared to *DESY* results
  - Synchronization parameters of the DSSD-telescope not known as well
- Total-efficiency Base *74.21(+0.18, -0.18)%*
- Total-efficiency Piggy *86.33(+0.16, -0.16)%*
- *Efficiency at this threshold at DESY: ~79.2%*



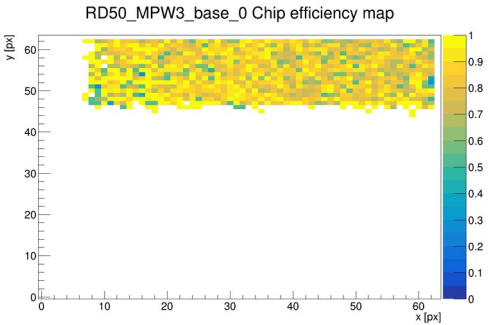


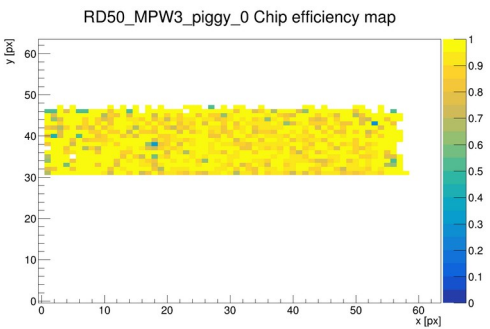




MedAustron: Extending the telescope

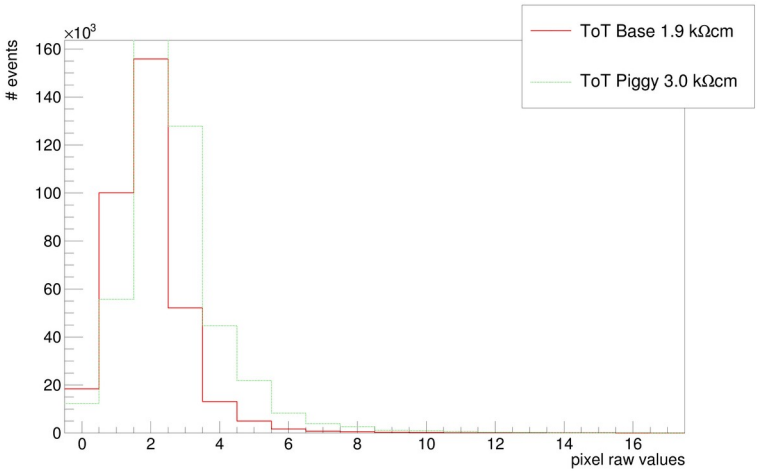
- Sacrificing one DUT in Corryvreckan analysis to act as extra telescope plane
  - Require 5 telescope-hits for each track
  - Allows to counter systematic (synchronization) errors in the analysis (same DAQ used for both DUTs)
  - Tracks get better resolution
- Efficiency base *81.73(+0.38, -0.39)%*
  - In better agreement with DESY
- Efficiency piggy *92.26(+0.28, -0.29)%*
- Misalignment of base and piggy → Only small area of chip taken into account





Discrepancies

- Base and Piggy:
  - Only significant difference: resistivity of substrate
  - Differences also seen in ToT values
    - 1.9kΩcm: 1.94 LSB
    - 3kΩcm: 2.68 LSB
  - Different threshold behavior?
  - Greater depletion depth for 3kΩcm?
  - Work in progress
- *MedAustron* vs. *DESY*
  - *Efficiency at MedAustron* ~2% higher at same threshold
  - Lower beam energy at *MedAustron* → More energy deposited in detector



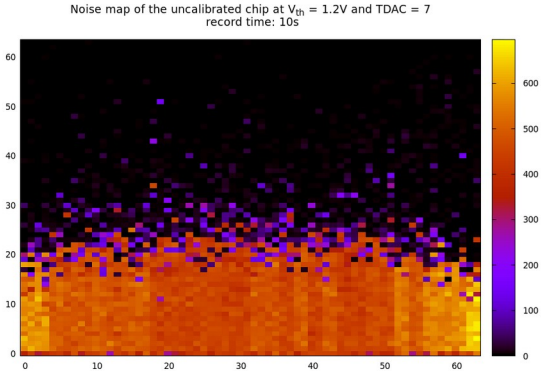
Outlook

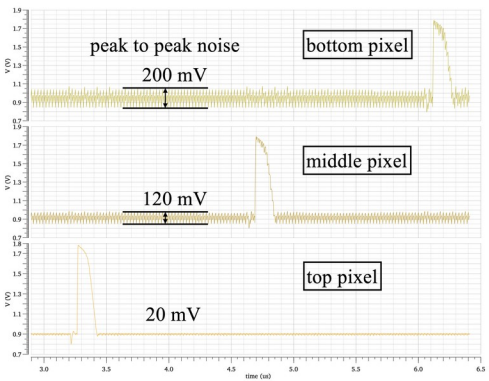
- MPW3:
  - Work on Allpix^2 simulations started
    - Aiming to reproduce *DESY*-TB results to improve understanding of chip
  - Annealing studies with irradiated samples
- MPW4:
  - Should be delivered by *LFoundry* in the next few weeks
  - Noise issue should (hopefully) be resolved
  - Lab work: I-V measurements, proper calibration with injections
  - 2 Beam test campaigns already scheduled in 2024
    - End of Mar. at *MedAustron*
    - End of Apr. at *DESY*

BACKUP

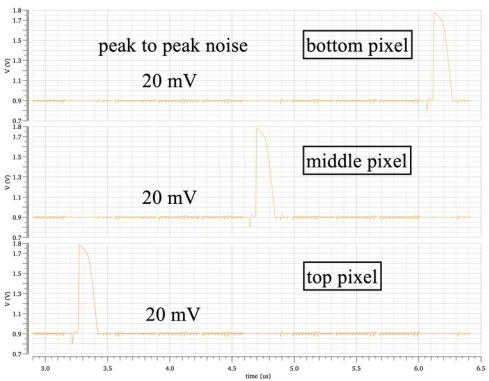
Noise Issue

- Shared power lines between pixel matrix and digital periphery
  - High noise occurence in bottom rows correlated to digital activity
- Analog simulations as reported in last RD50 workshop reproduced the measured behaviour
- Changes in design of upcoming RD50-MPW4 should (hopefully) fix this behavior





Common Power and GND



Seperated Power and GND

Efficiency too high?

- According to (Allpix^2) simulations on average 50ke$^-$ deposited in 300µm silicon with *DESY* beam
- Assuming depletion depth of 100µm
- (Back of the envelope) collection yields ~ 16ke$^-$ transferred to implants
- With threshold of ~5 ke$^-$ efficiency of 98% plausible