Test-Beam Instrumentation and Results of the RD50-MPW3 HV-CMOS Detector

BTTB11

Bernhard Pilsl on behalf of RD50

- **17 institutes**

- **Developing radiation hard DMAPS**

  - So far 3 detectors (RD50-MPW1, -MPW2 and -MPW3) developed

- **ASIC design**

- **TCAD studies**

- **DAQ development**

- **Detector Characterization**

- **No specific target experiment**

- **Generic RnD for future detector goals**
  - According to the ECFA roadmap (2021)

- **Focus on radiation hardness and low material budget**
  - DMAPS with large collection electrode
  - Manufactured by LFoundry in 150nm process
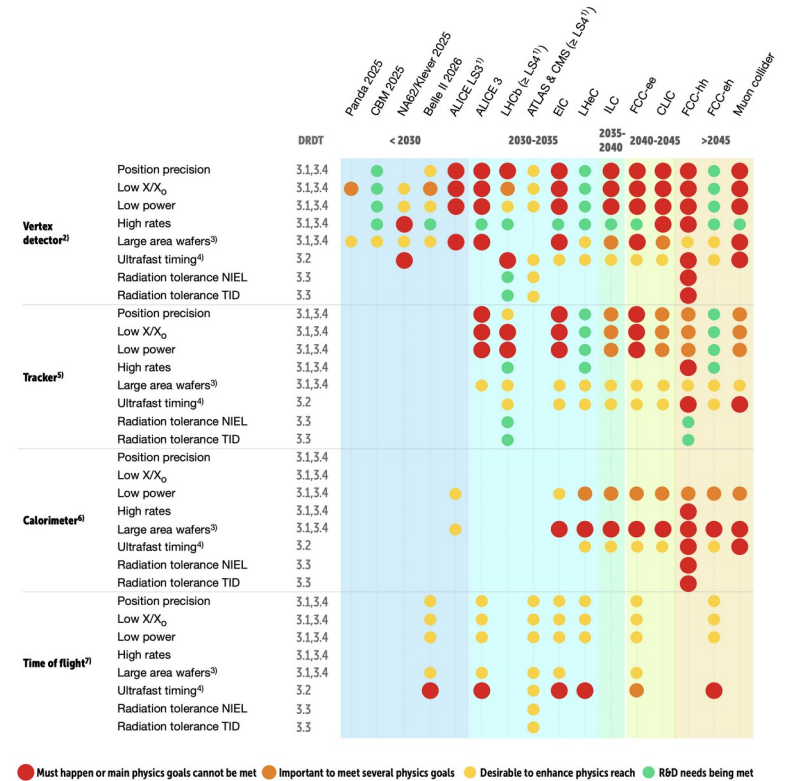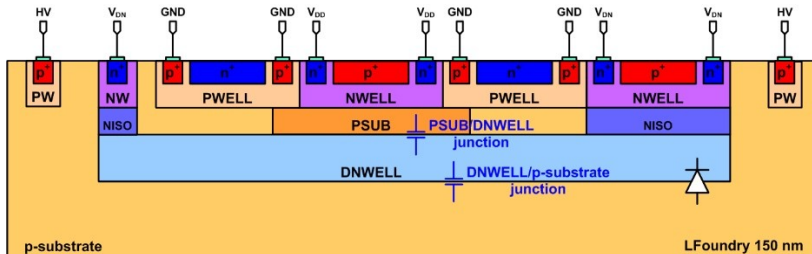
- **64 x 64 Pixel with pitch of 62μm**

  – Arranged in 32 double columns

- **Full analog and digital electronics inside pixel**

- **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

5.1mm
6.0mm
64x64 Pixel Matrix
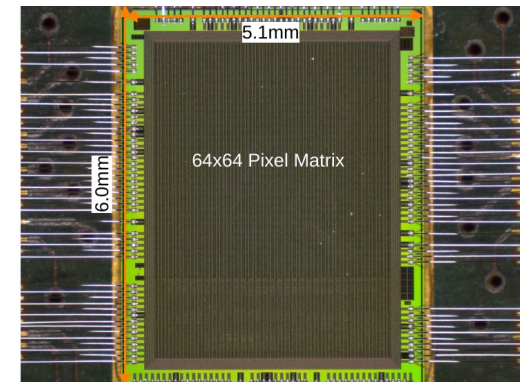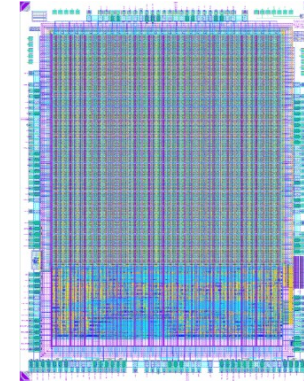
- **Caribou system**

- **Implemented Peary Device**

  – Custom I2C interface
    (16 bit addresses)

- **GUI for configuration**

  – Generating Peary config files
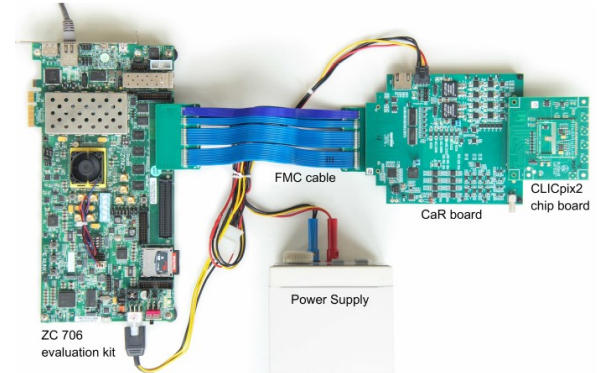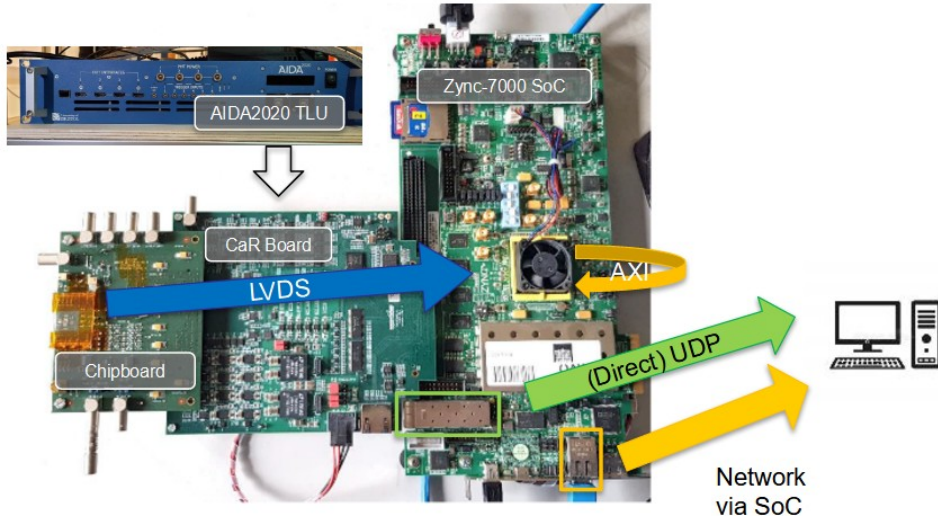
- **Fully integrated into EUDAQ2**

- *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-Run-Control for submission of run info to *ELog* server**

- **MPW3 has a data-driven readout**

  - Syncing via timestamps (TS)

  - Faster than sampling trigger-numbers

- **Telescope triggered by scintillators**

- **AIDA-TLU**

  - EUDET mode for telescope

  - Synchronous AIDA mode for MPW3

- **EUDAQ *AidaTluProducer***

  - Matching trigger-numbers to TS
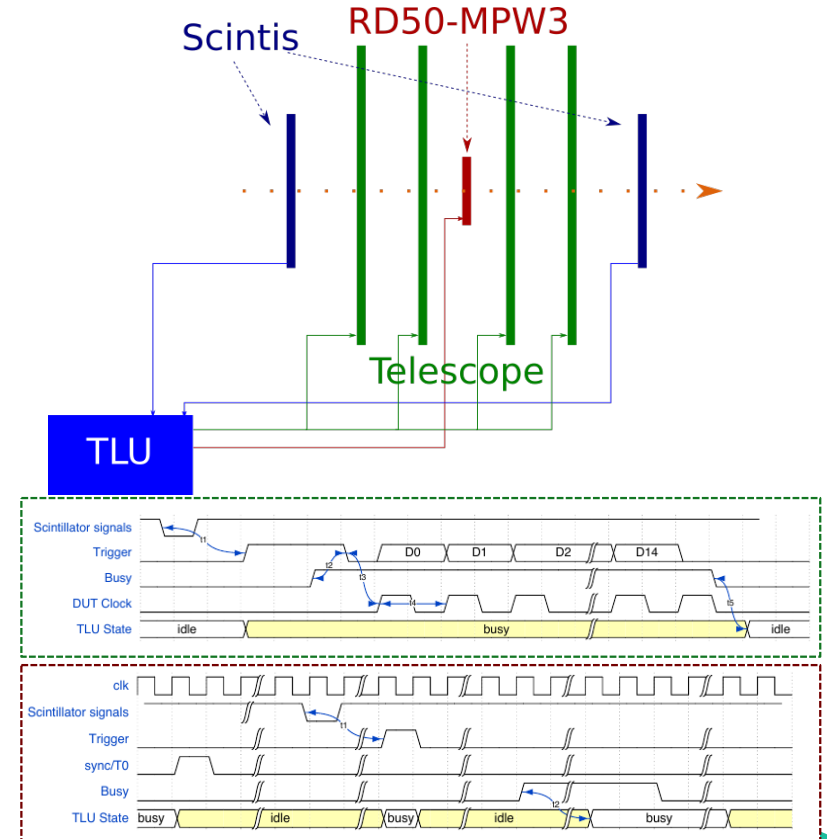
MedAustron

- *MedAustron* **is a medical facility located close to Vienna**

- **800MeV 200kHz proton beam**

  – Gaussian shape of Ø ~ 3mm

- **Telescope consisting of 4 DSSD planes**

  – 512 x 512 "quasi" pixel with pitch of 100μm x 50μm

  – Telescope veto time ~25μs

- **2 scintillators and AIDA-TLU for triggering**
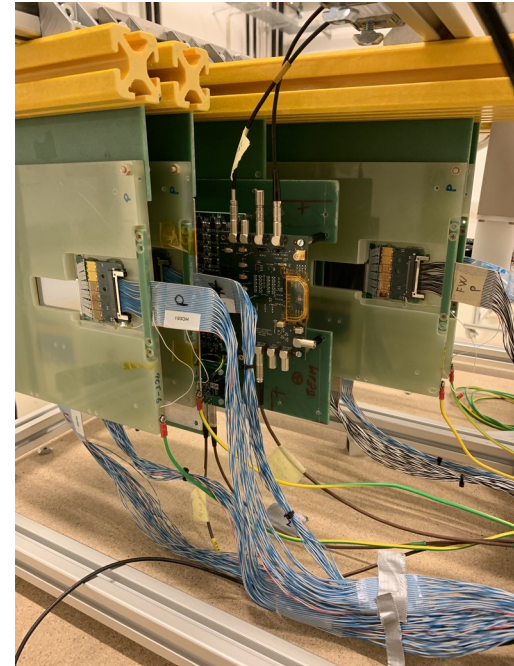
- *Corryvreckan* ⟳ used for data analysis

- **TLU defines events with trigger-number and time window**

  – Initially *[EventLoaderEUDAQ2]* used

- **Telescope hits matched to trigger-number**

  – Custom event loader developed

- **RD50-MPW3 hits matched to TLU time windows**

  – *[EventLoaderEUDAQ2]* used

- **Beam structure well represented**

  – 5 sec spill, 5 sec pause, ...

- **TLU and MPW3 events seem to line up fine**

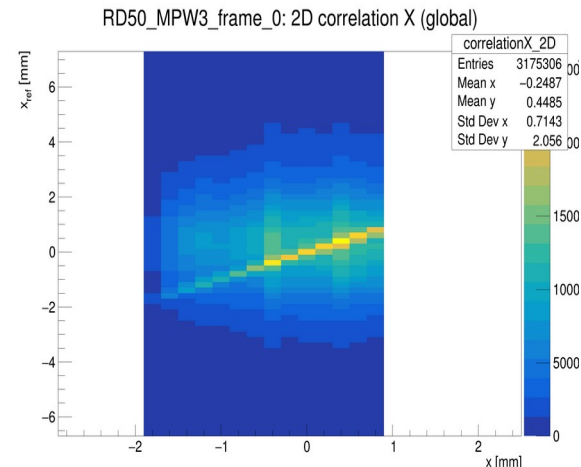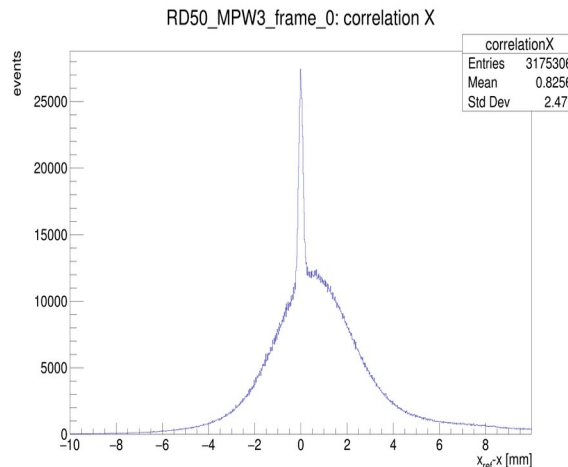- **Very few hits matched, no correlations**

RD50_MPW3_frame_0: correlation X

correlationX	
Entries	13178
Mean	1.096
Std Dev	2.827

Road to Correlations
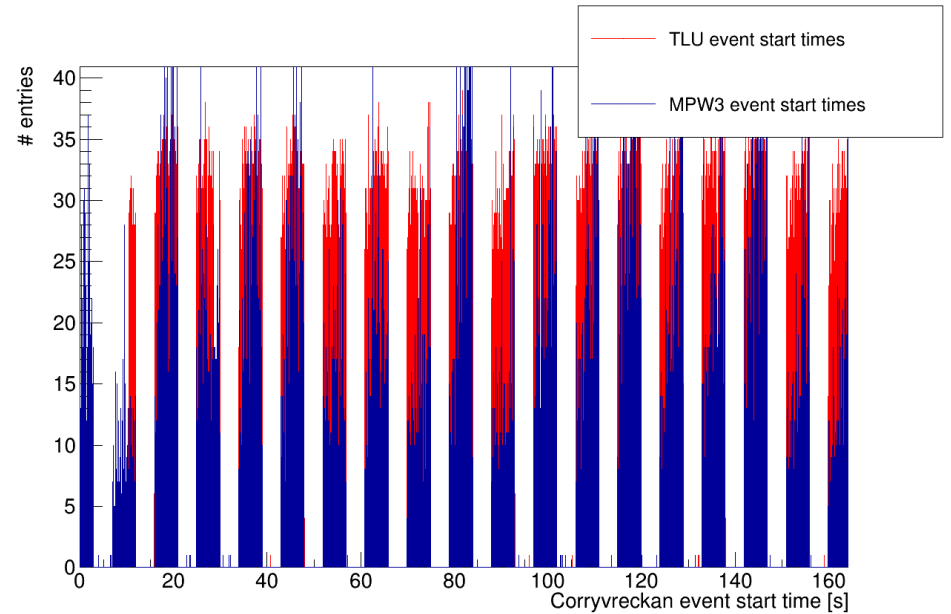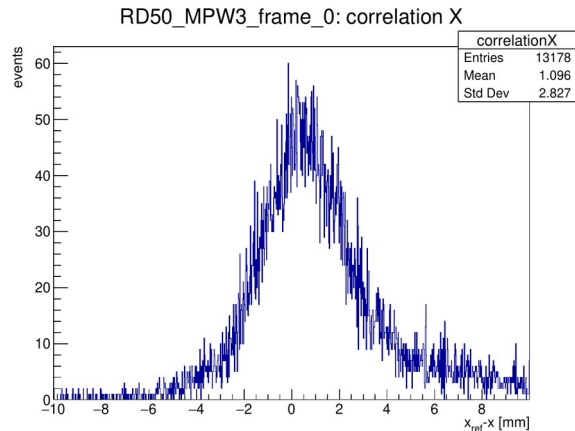
- **TLU event length mostly 25ns**

- **MPW3 time resolution: 50ns**

- **Hits matched only when start times line up perfectly**

- **Enlarged TLU event-window**

- **Anti correlations between X → Y**

  – Wrong initial orientation

Z → +90°
X → +180°
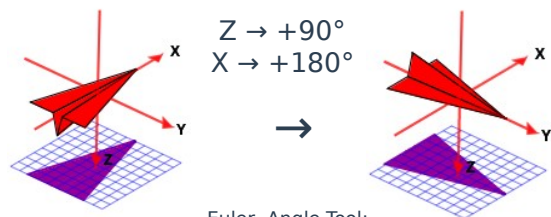
Euler -Angle Tool:
https://danceswithcode.net/engineeringnotes/rotations_in_3d/demo3D/rotations_in_3d_tool.html

RD50_MPW3_frame_0: 2D cross-correlation X/Y (global)

RD50_MPW3_frame_0: correlation X

RD50_MPW3_frame_0: 2D correlation X (global)
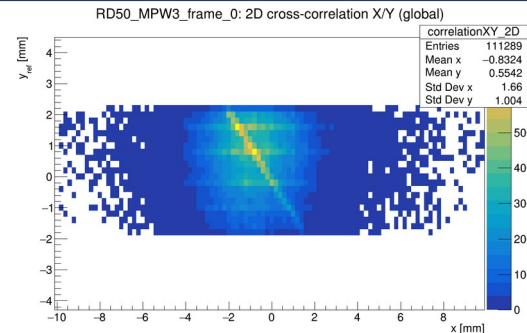
- **Correlations fine - Everything fine (right?)**

- **Almost exclusively 1 hit clusters**
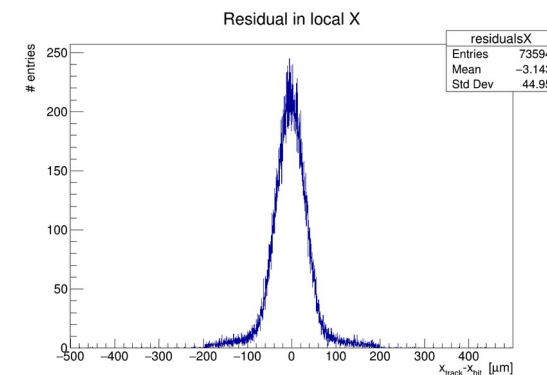
  - High bias voltage of ~100V

  - High threshold voltage applied

- **DUT Alignment not working properly**

  - Procedure *[AlignmentDUTResidual]* finishes "too fast"

  - Residuals not well centered at 0

- **Bad efficiency of ~3%**

  - Even with *[DUTAssociation]* cuts of 200μm

RD50_MPW3_frame_0 Cluster size

Residual in local X

Residual in local X

residualsX	
Entries	95073
Mean	0.08895
Std Dev	19.11

Collection well
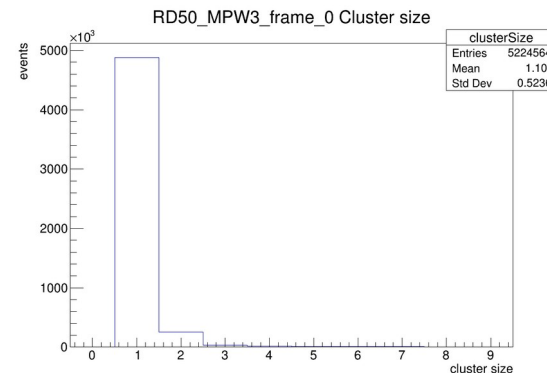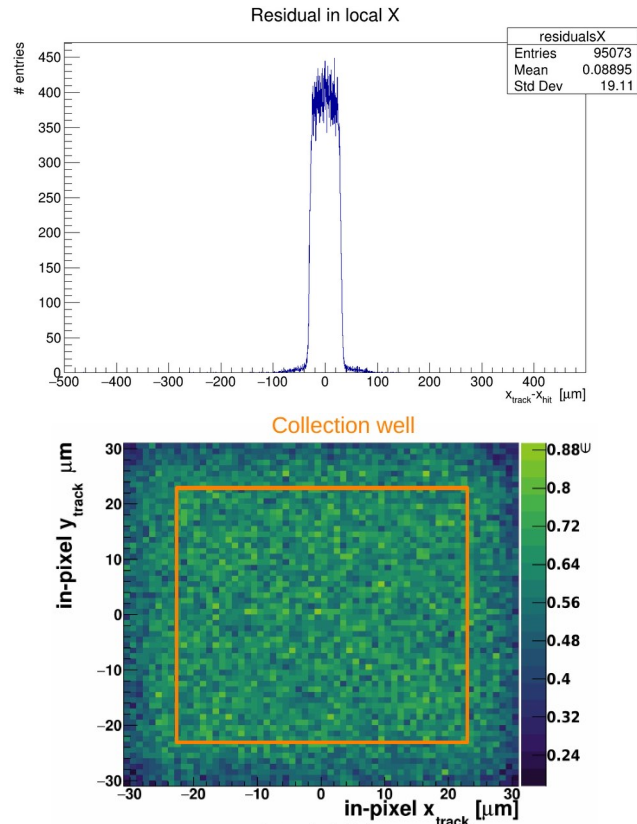
- **Earlier TB at CERN SPS in Sep. 2022**

- **EUDET-type telescope with 5 MIMOSA26-planes used**

- **Event building with [EventDefinitionM26] module**

- **Total efficiency of ~60% evaluated**

  - Problem most likely due to high threshold voltage

- **Some problems with timestamp assignment to MPW3 hits**

  - DAQ did not provide sufficient range

Possible Problems

- **Telescope operated for the first time in this way**
  - Never used to match to timestamped events before
  - So far (mostly) used stand-alone
  - Possibly trigger-number shift in the data
- **Bug in DAQ system**
  - Timestamping not working properly?
- **Event building procedure not matching MPW3 hits properly**
  - 5M clusters, but only 100k inside an event with a track
 - Time offset in the data?
- **Work in progress**

- **Debug event-building**

  – Implement a trigger-number based synchronization

- **File merge-requests**

- **Upcoming testbeams: May at _MedAustron_, July at _DESY_**

- **Evaluate irradiated samples**

- **Use multiple MPW3 as "small telescope"**

- **RD50-MPW4 currently in design-phase**
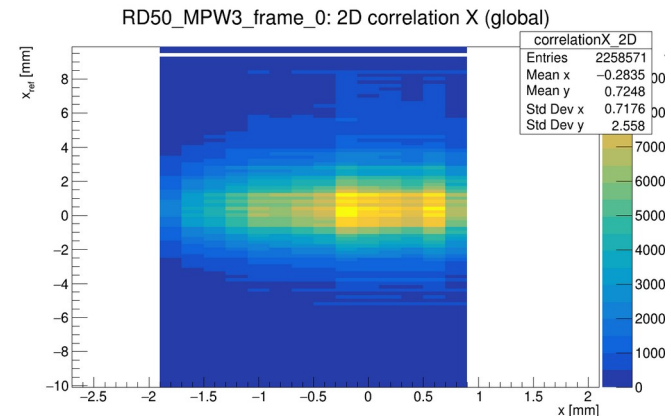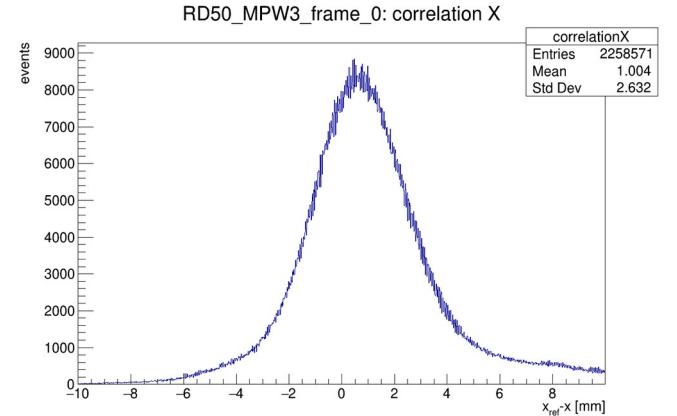
  – Targeted submission in May

- **Thanks for your attention!**
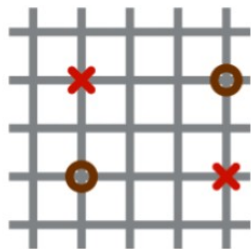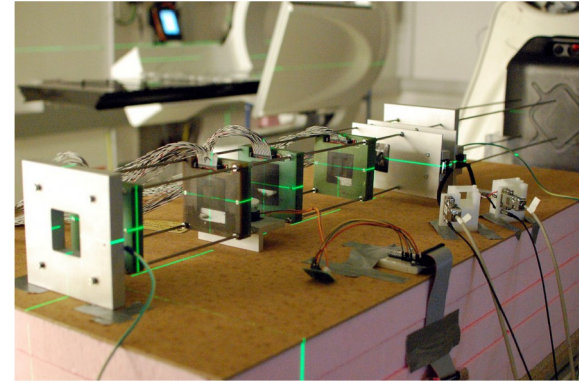
- **Questions?**

Backup

- **Custom event definition module written**

  – Defines Corry event time frames

- **Basically spans whole run-time**

  – Start / end time in middle of two consecutive TLU events

- **Almost all MPW3 hits matched to an event**

  – Most of them to the wrong one(?)
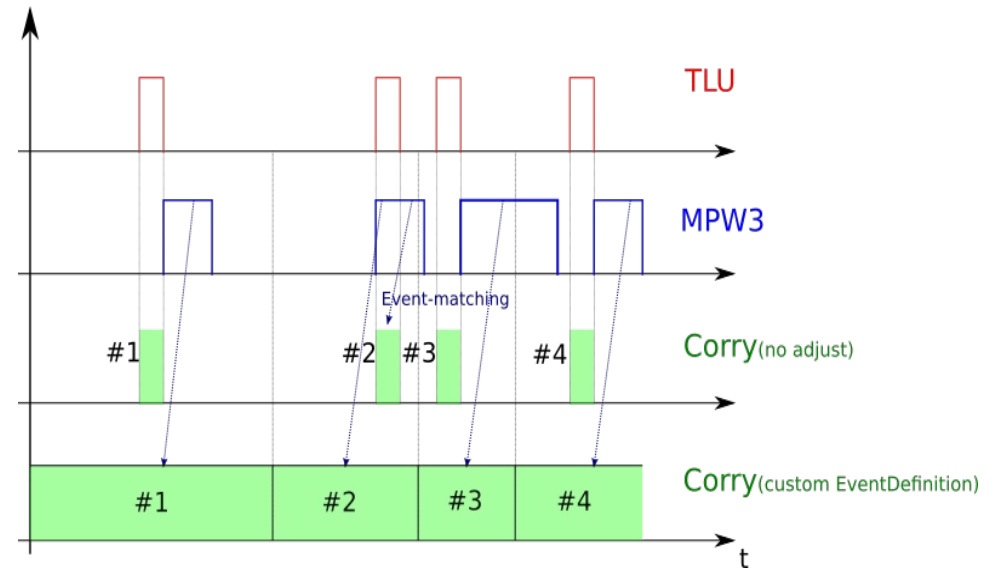
- **3% efficiency just random matches?**

- **Analyzed different DUT run with same telescope data**

- **No proper correlations observed**

  – No correlations → No alignment

- **Efficiency ~0.2%**

RD50_MPW3_frame_0: correlation X

correlationX	
Entries	2258571
Mean	1.004
Std Dev	2.632

RD50_MPW3_frame_0: 2D correlation X (global)

correlationX_2D	
Entries	2258571
Mean x	−0.2835
Mean y	0.7248
Std Dev x	0.7176
Std Dev y	2.558

- **Triggered analog readout**

  - Calibrated trigger latency

- **Voltages > threshold → Hit**

- **Hits on n-side combined with p-side → "quasi" pixel**

- **Ghost hits ruled out**

  - Only accepting one hit per event (in event loader)

× real tracks

○ "ghosts"

Y-side (n-side)

DSSD

APV25

X-side (p-side)