MuPix8 Status and Reworking of DAQ

– PANDA Collaboration Meeting 2019/3 –
Luminosity Detector Session

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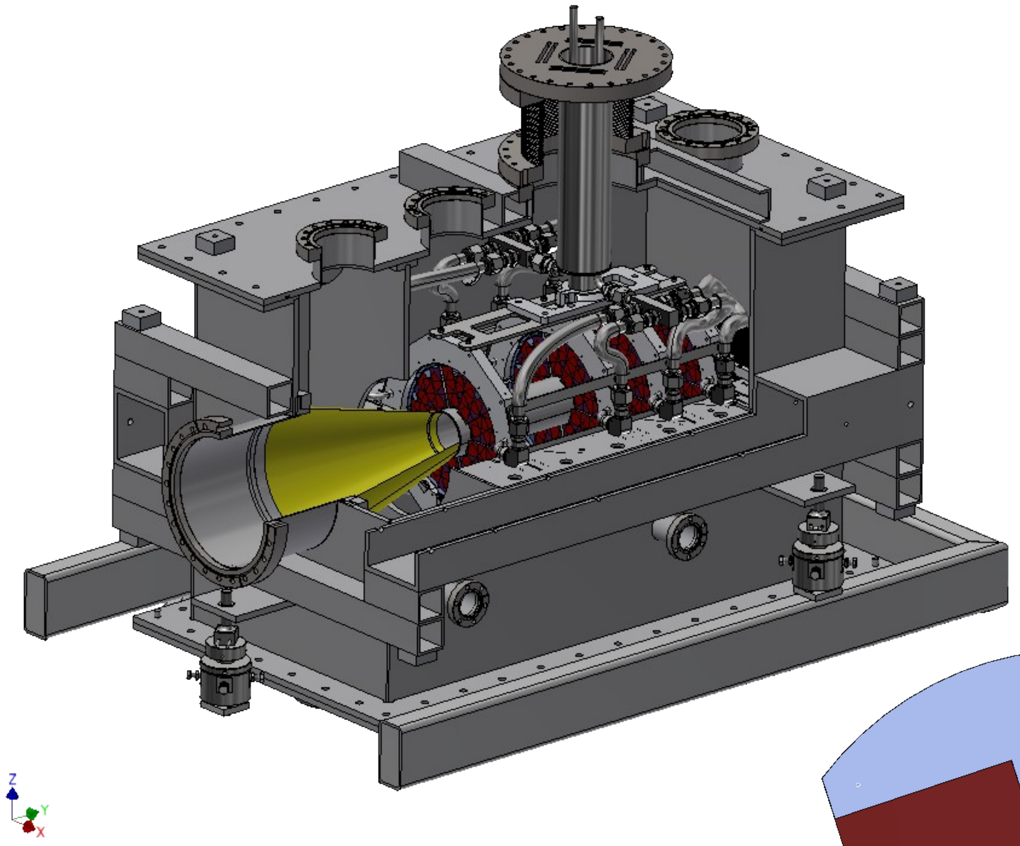
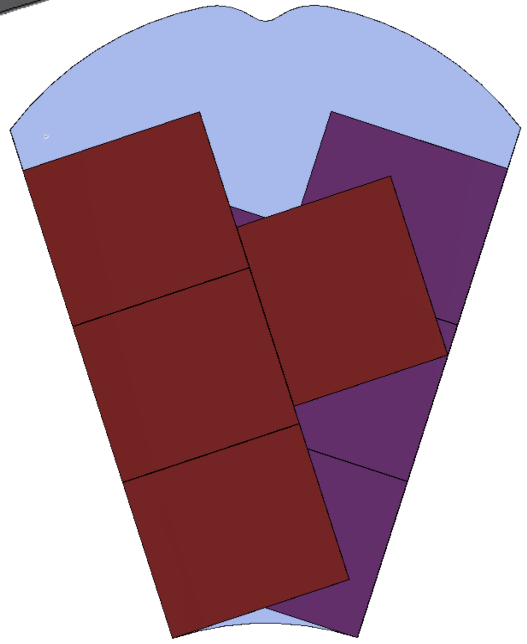
Luminosity Detector (LMD)

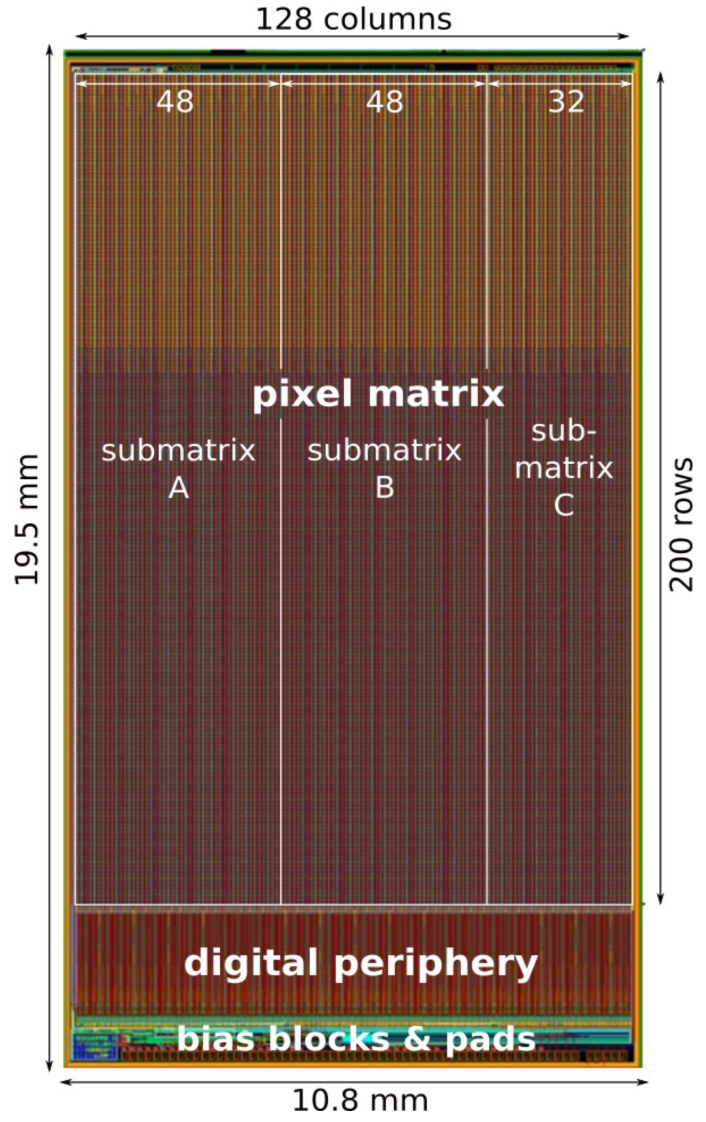
- 11 m behind IP
- Measure tracks of elastically scattered anti-protons
- Anti-protons enter detector vacuum through transition cone
- 4 detector layers with HV-MAPS on both sides
- 10 sensor modules per layer
- Aluminum holding structure with embedded steel pipe for cooling (coolant: -20°C ethanol)
- Total number of sensors: 320
- Active area of one sensor: 2 × 2 cm²
- Pixel size: 80 × 80 µm²





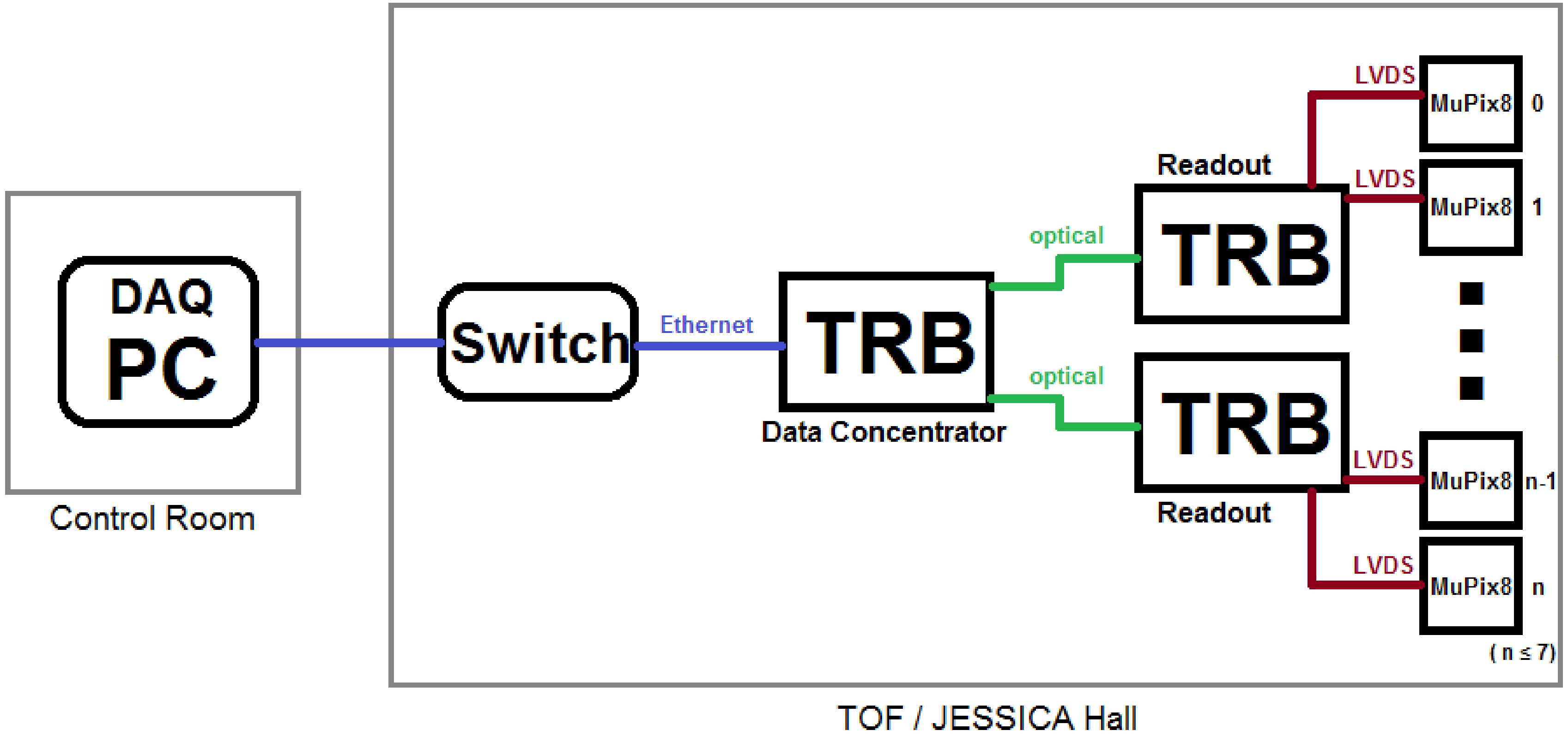
The MuPix8 Chip

- Originally developped for Mu3e
- Physical size: 10.8 × 19.5 mm²
- Active area: ~ 10.2 × 16.2 mm²
- Matrix: 128 × 200 Pixels, three Submatrices
  MatA: source follower
  MatB/C: current mode
- Pixel: 80 × 81 μm²
- Charge sensitive amplifier in each pixel
- Two comparators in each periferal cell (timewalk compensation)
- 4 LVDS links (each submatrix + select/mux)
- Analog readout of Hitbus (ToT information) and amplifier output (for leftmost column only)



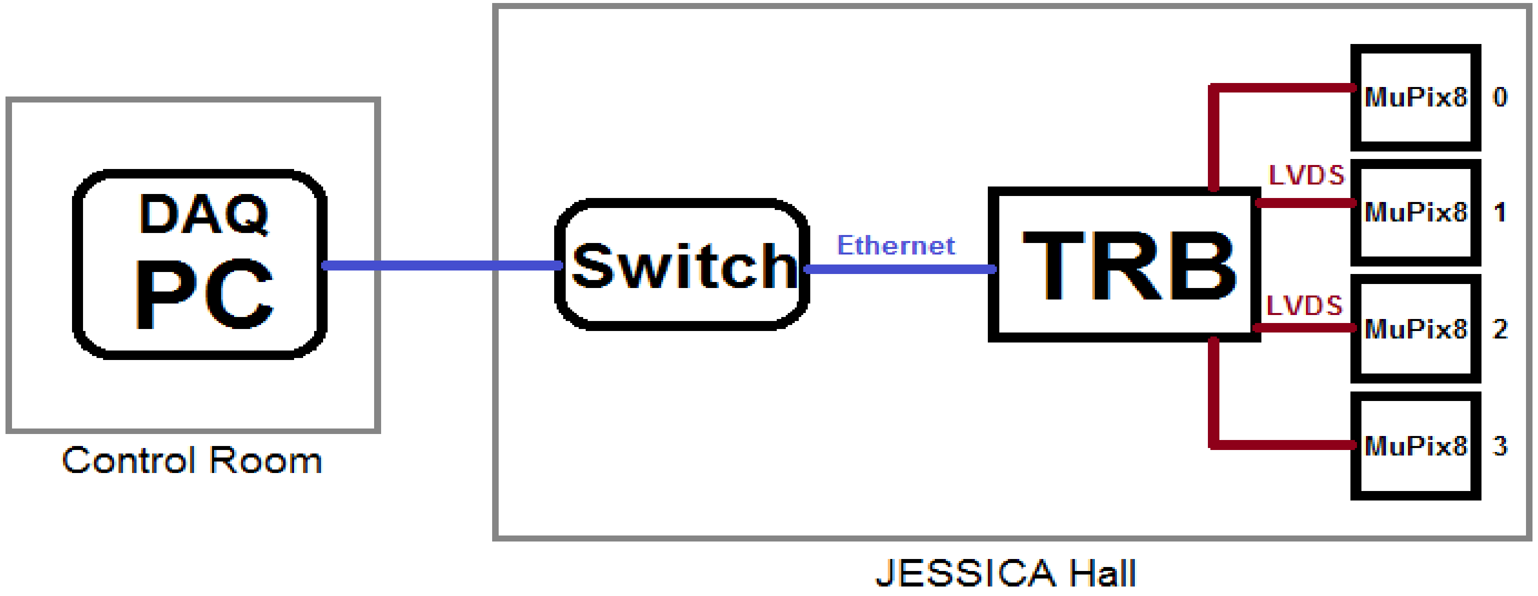
Planned Testbeam with several TRBs

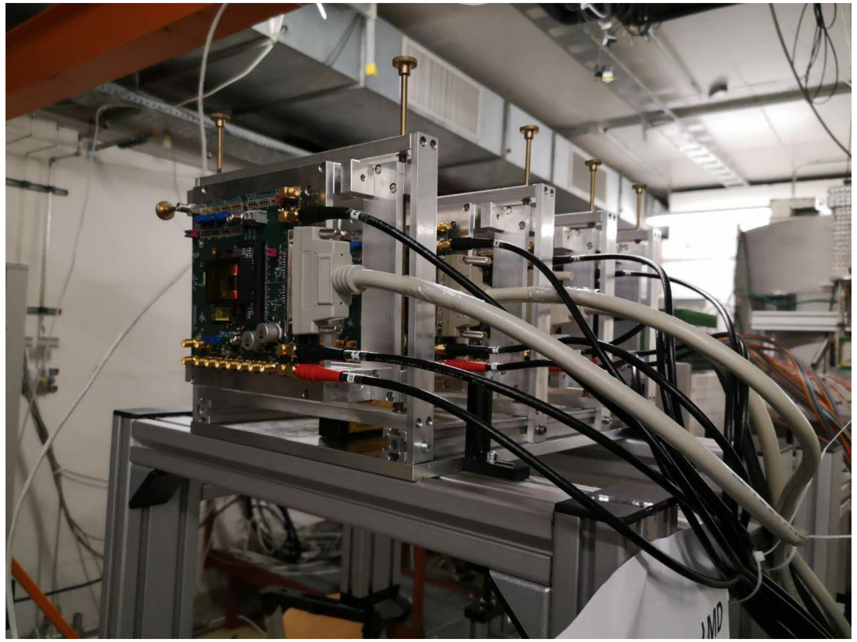
- Testbeam September 2019 – Idea: Use setup similar to final LMD readout scheme
  - Only one TRB as data concentrator / interface to DAQ PC
  - Use seperate TRB(s) as readout unit(s)
  - Optical connection
  - *Syncronize via SODAnet* → **DID NOT WORK OUT FOR SEPTEMBER TESTBEAM**

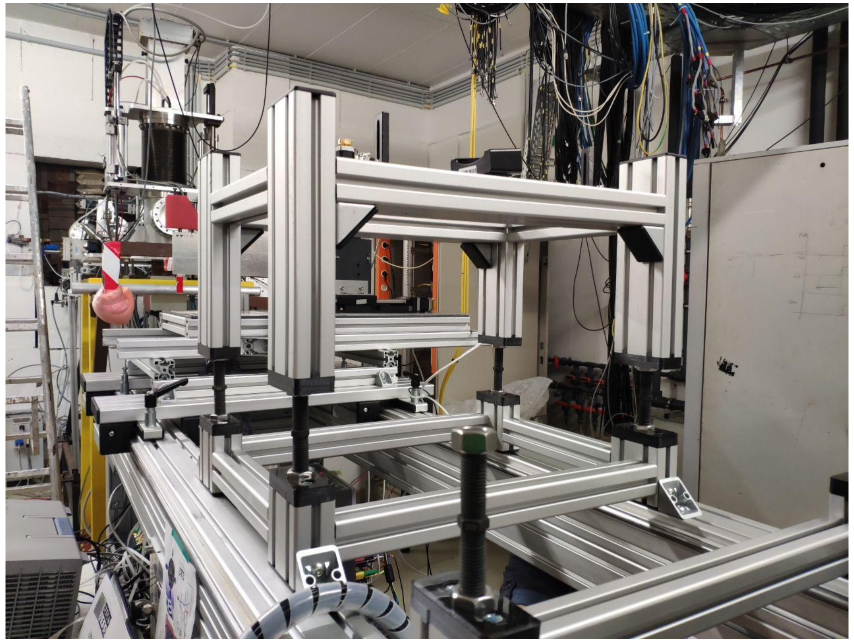


Four-Layer MuPix8 Setup at COSY

- Testbeam in September 2019
- Four MuPix8 chips in beam (JESSICA hall)
- x-y-adjustable holding frames and positioning rail from HIM + height adjustable pedestal
- Goals: Readout of all submatrices (A,B,C) of four chips, test new control software based on EPICS for LV/HV and sensor configuration
- Old DAQ with only one TRBv3



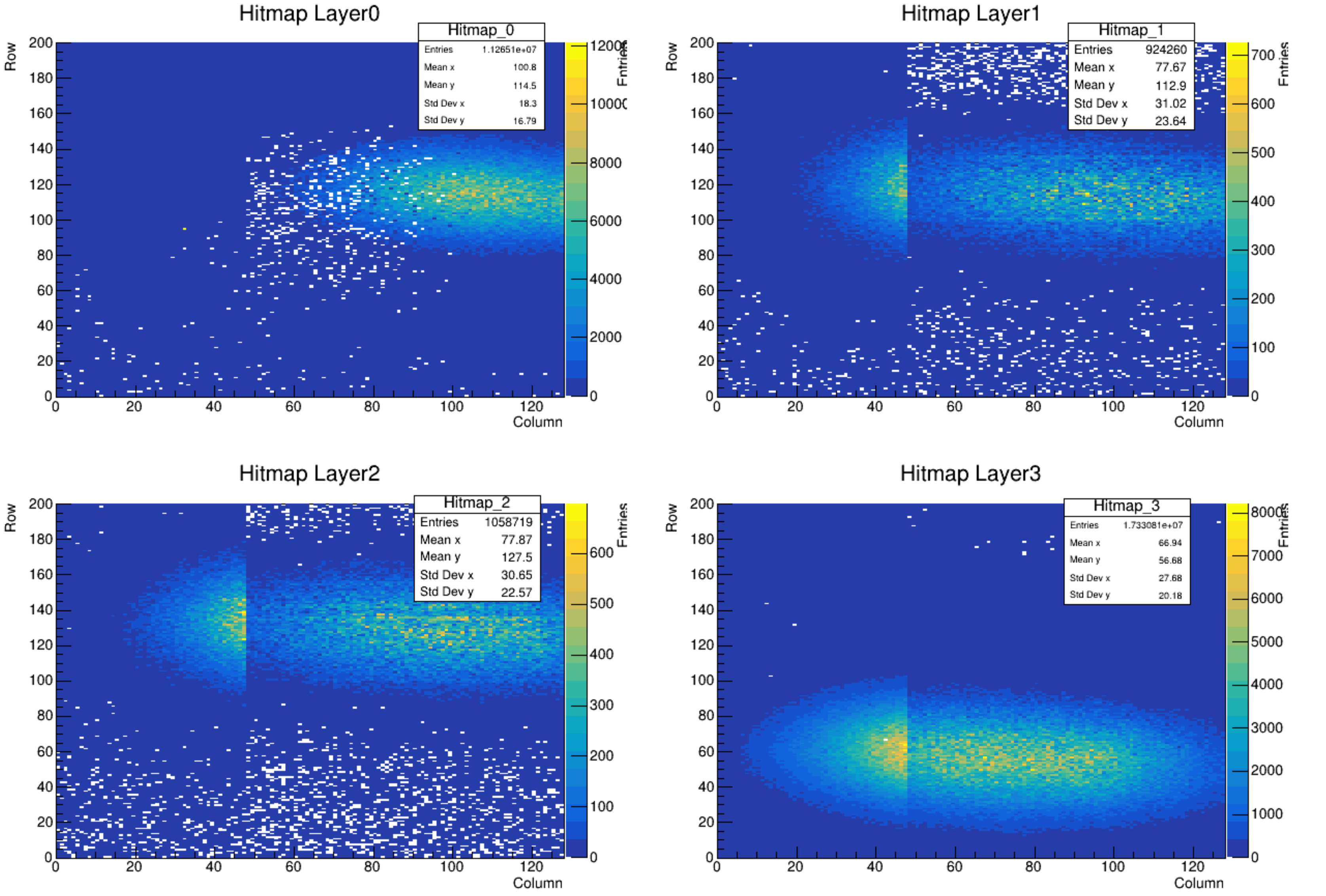




First Run

- Hitmaps of first run (w/o MWPC)
- HV = 0 V, ThHigh = 600 mV for all layers
- Beam spot visible in all layers
- Sharp cut between Matrix A and B/C

Beam parameters:
$p \lesssim 2.9$ GeV/c
~ 10^6 protons / s

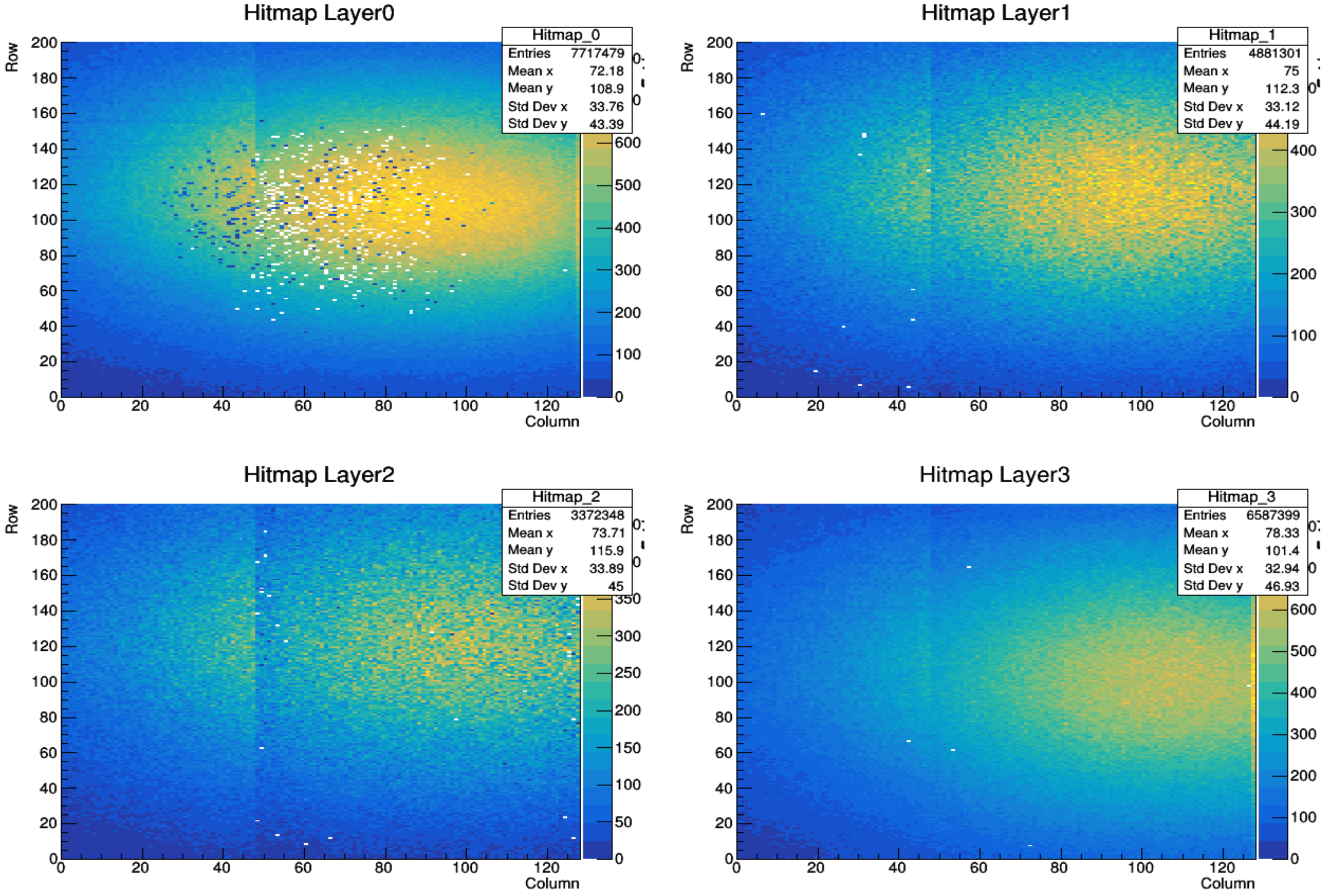


Hitmaps @ HV = 0 V and ThHigh = 600 mV

Alignment & Data Taking

- Inserted MWPC into beam to get wider spread
- Only used matrix A for alignment

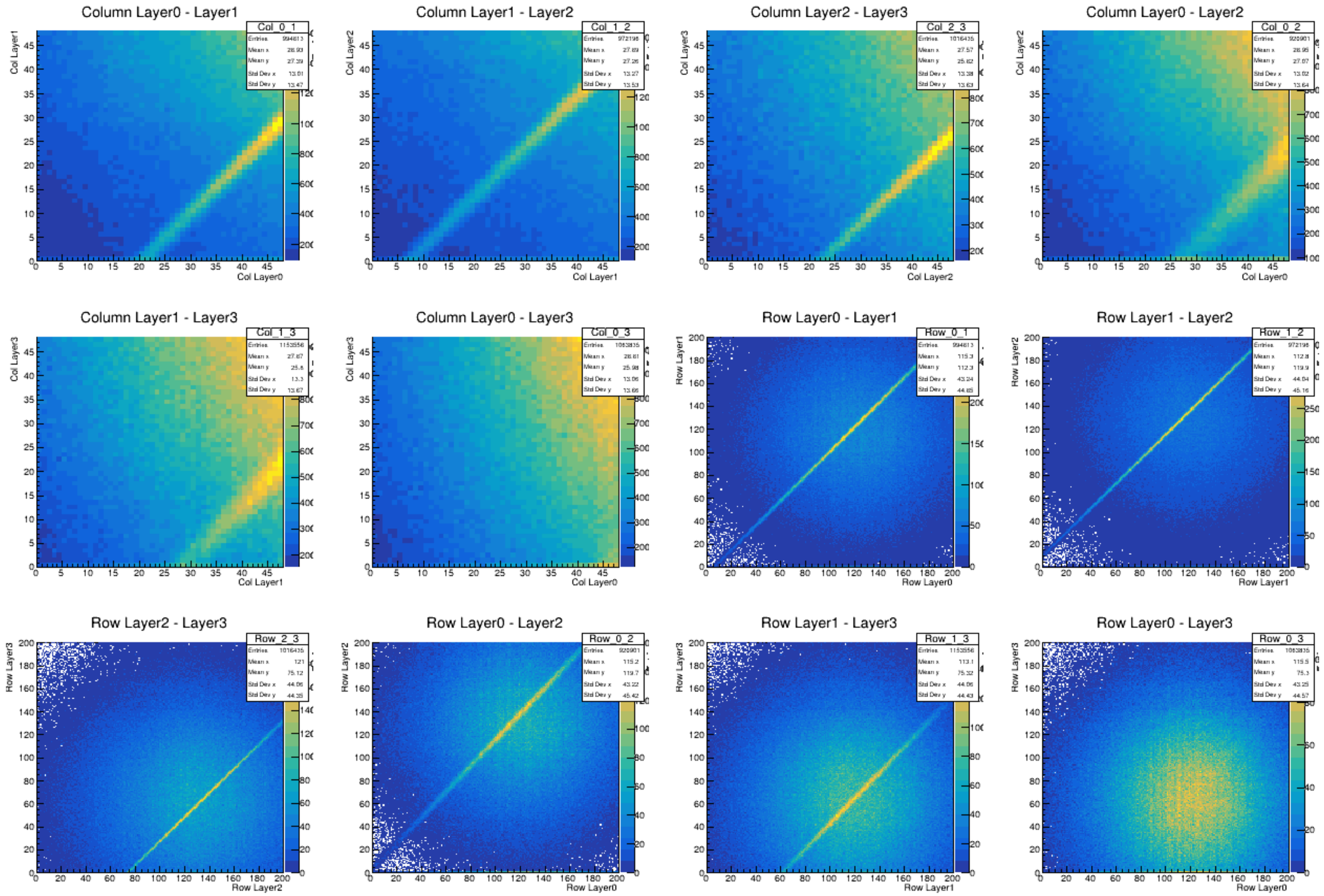
Hitmaps with MWPC in beam
HV = 50 V and ThHigh = 600 mV



Alignment & Data Taking

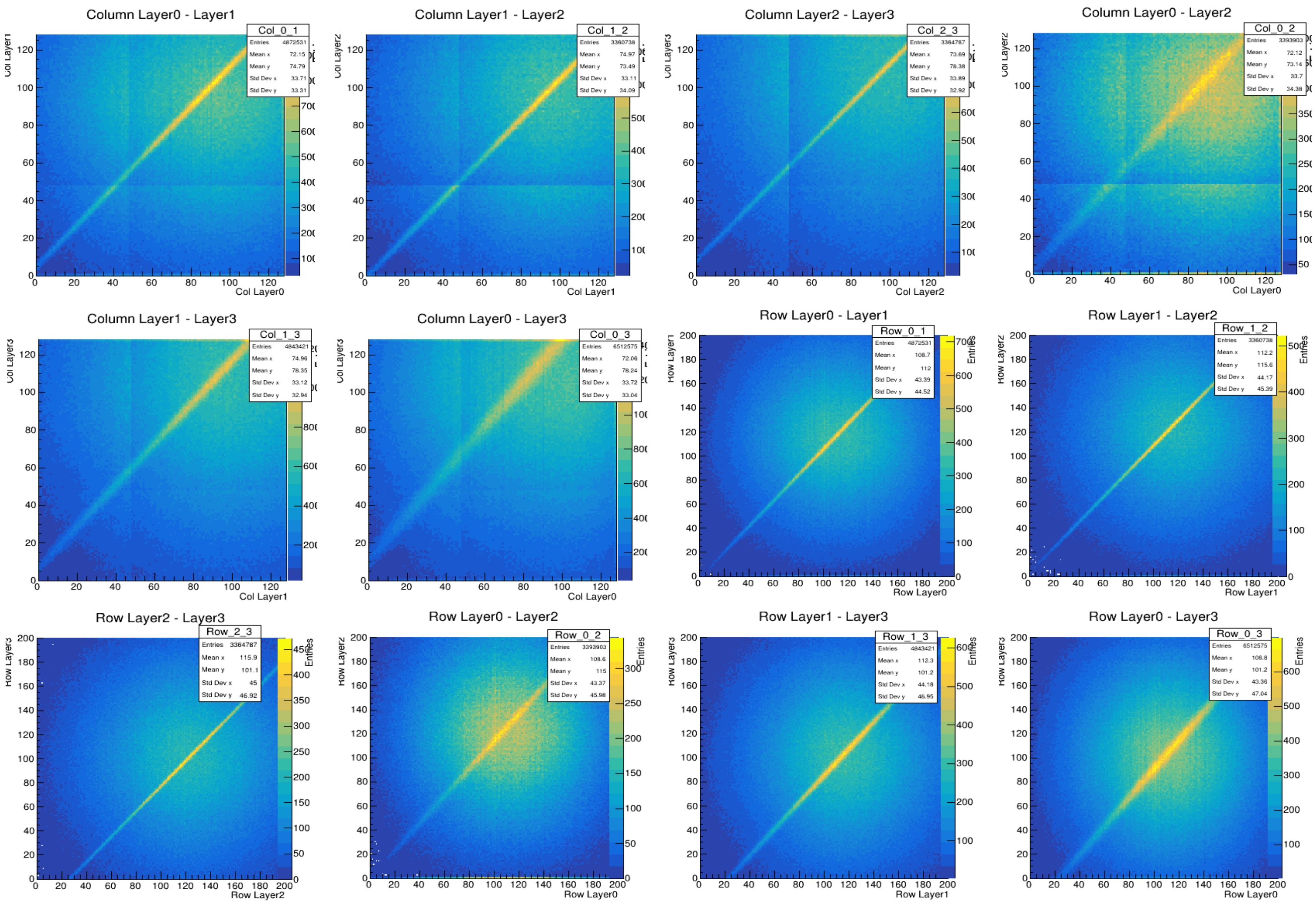
- Inserted MWPC into beam to get wider spread
- Only used matrix A for alignment

Column and Row Correlations for matrix A before alignment:
DUT: HV = 50 V and ThHigh = 600 mV

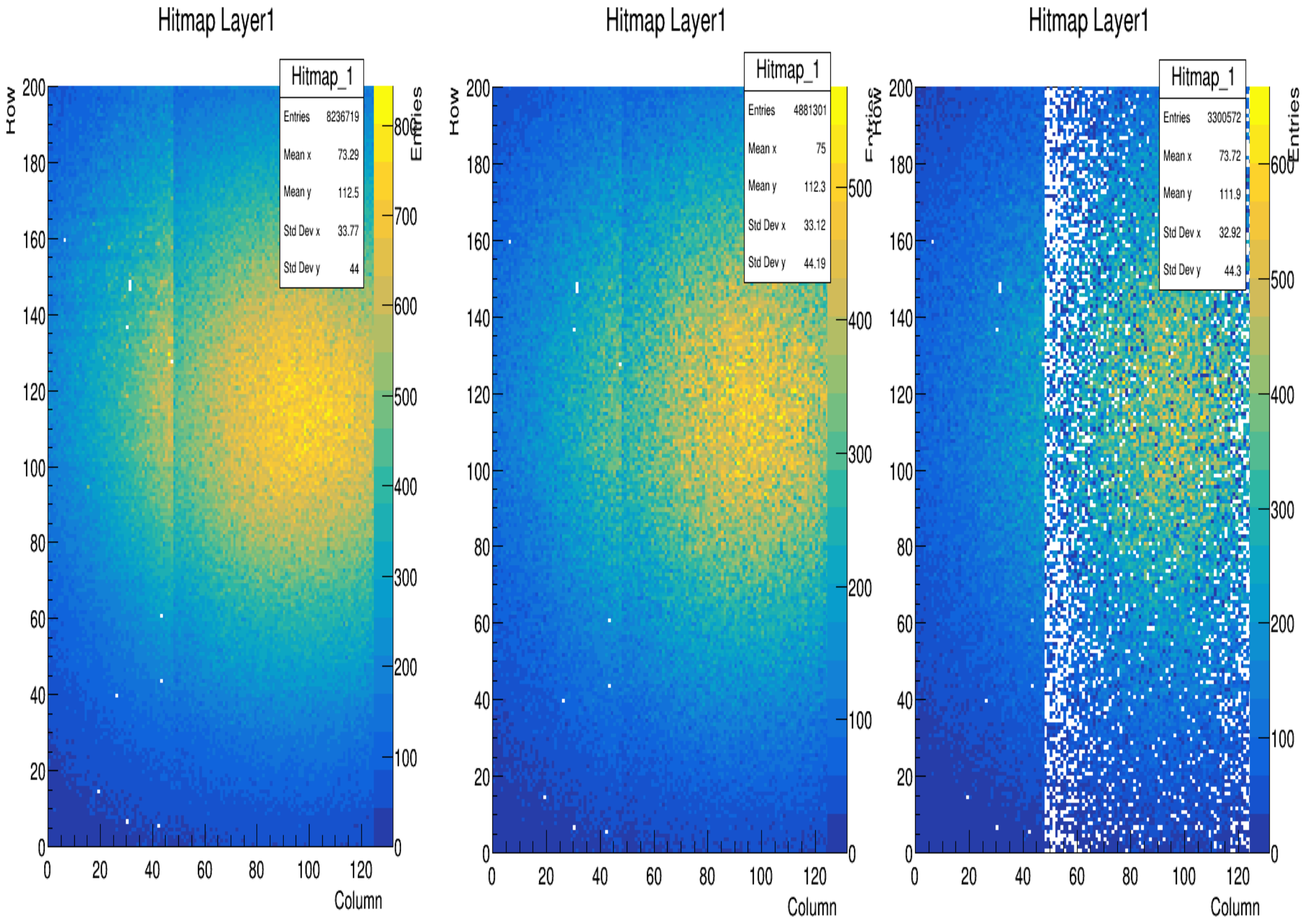


- Inserted MWPC into beam to get wider spread
- Only used matrix A for alignment
- For data taking:
  Keep tracking layers (L0, L2, L3) at
  HV = 50 V and
  ThHigh = 600 mV (100 mV above baseline)
- Vary DUT (L1): HV 10 V – 50 V (10 V steps),
  ThHigh 550 mV – 650 mV (5 mV steps)
- Faster RO statemachine settings for MuPix (timerend = 0)
- No rate problems due to beam intensity (usually seen in row correlations)

Column and Row Correlations for all matrices after alignment:
DUT: HV = 50 V and ThHigh = 600 mV



- Overall different response from matrix A and B/C (sharp cut)
- Smaller / different Threshold range to operate Matrices B/C
- No difference in response between B and C (at least at lower beam intensity)



DUT @ HV = 50 V and ThHigh = 550 mV, 600 mV, 650 mV

Reworking of DAQ

- Limitations of the TRBv3:
  - Current mupix firmware incompatible with SODAnet
  - black box / magic
  - Unsuitable for Lumi prototype (max. one Sensor per peripheral FPGA)

- Use new readout unit based on EMC Digitizer (designed by P. Marciniewski)
  - Uses Kintex7 FPGA

- Kintex7 Evaluation Board for first tests in Bochum and for Lumi prototype

Kintex7 Evaluation Kit by Xilinx

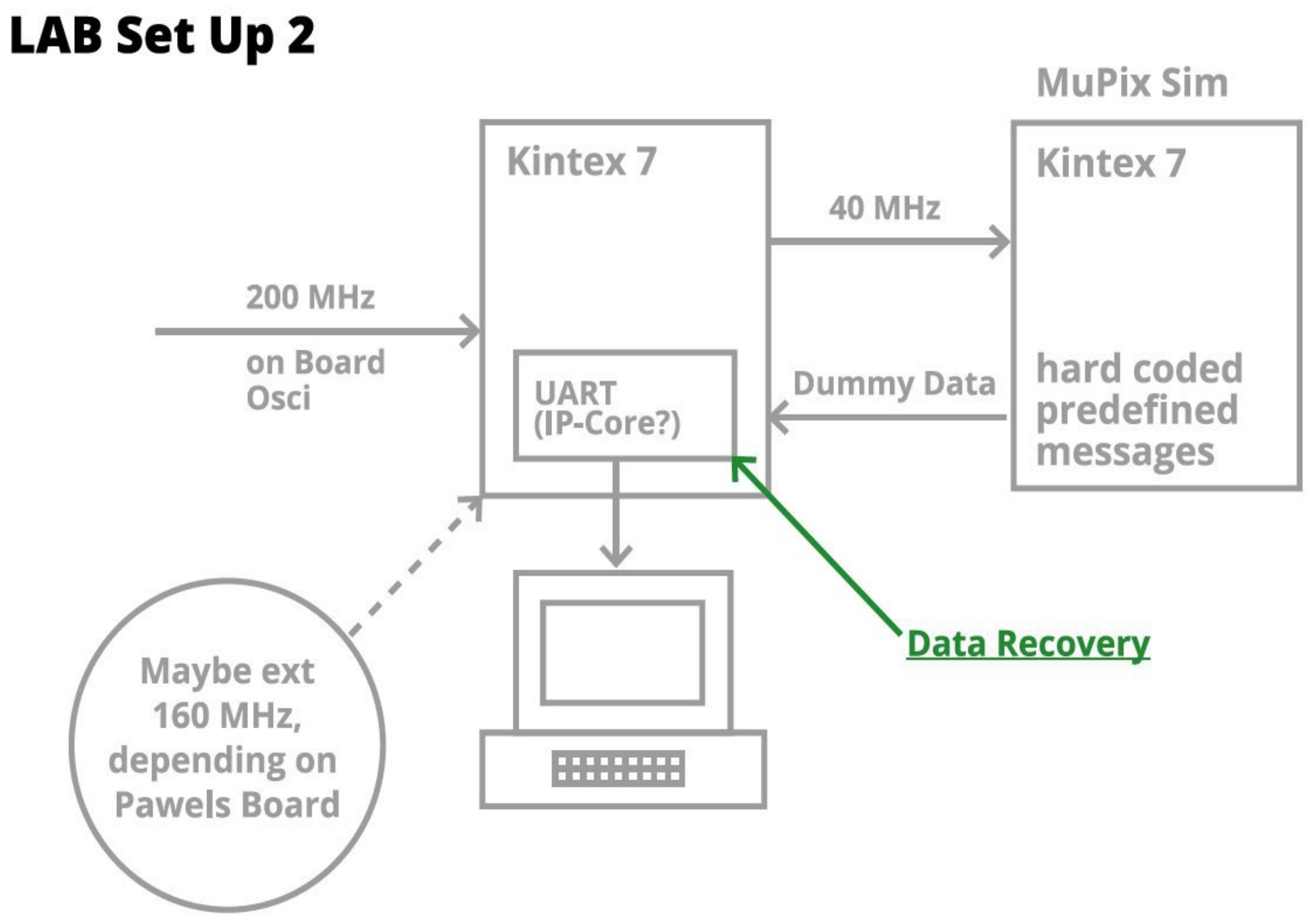
https://www.xilinx.com/products/boards-and-kits/ek-k7-kc705-g.html

First Steps with Kintex7

- MuPix Simulation:
  1) Create 40MHz clk on one board and send it to second board
  2) Create dummy data with fixed known datawords and send it back to first board at 400Mbit/s
  3) Synchronize, de-serialize, and 8b/10b decode incoming data stream to recover dummy data

  …

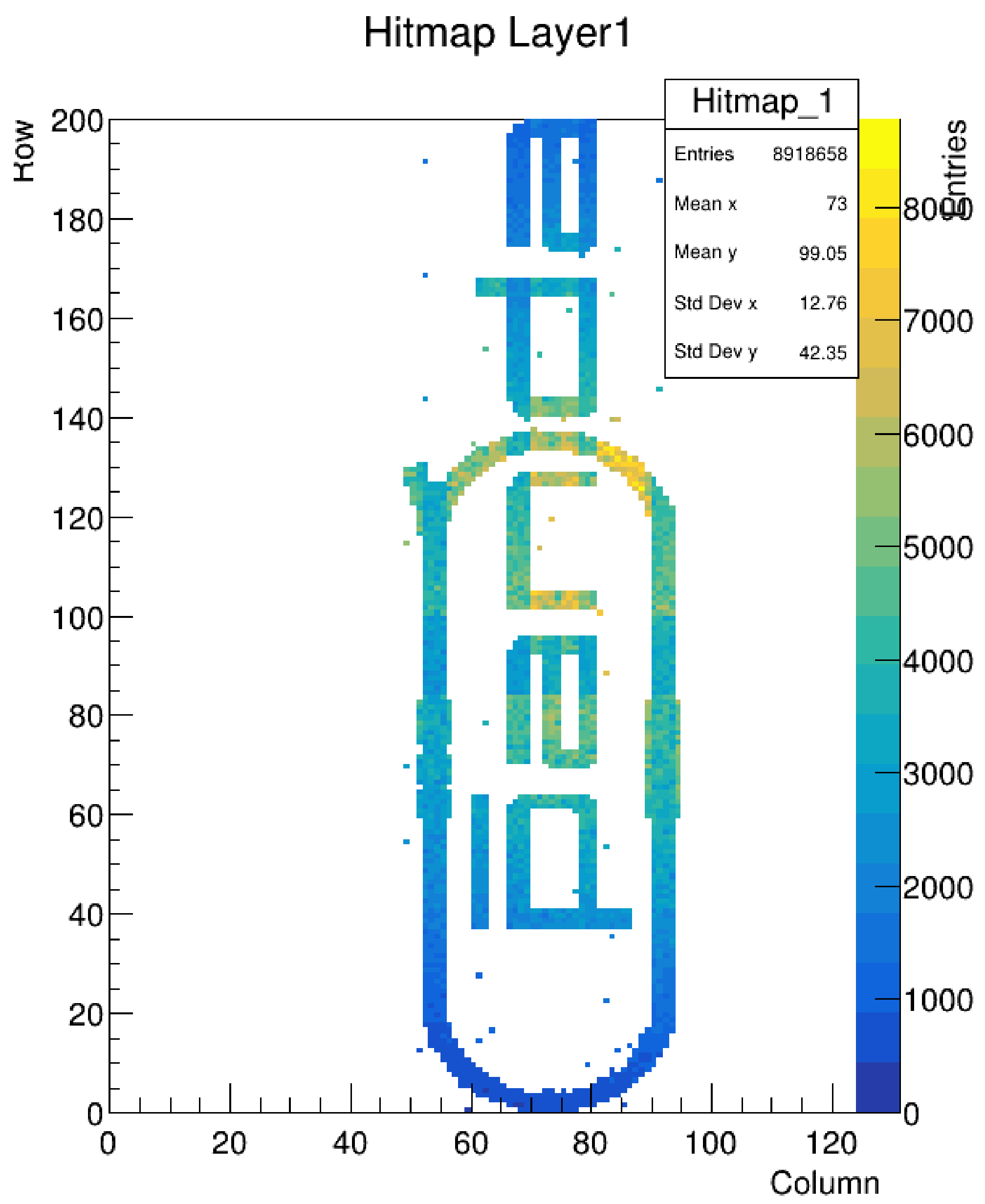
  n) Connect upto 8 MuPixes to one eval board using FMC adapter board
- Later: Use two Kintex7 boards for readout of Lumi prototype (16 MuPixes)
- Final detector: Upto 16 MuPixes per *Pawelboard* (two FPGAs on one board)
  → 20 boards needed for full LMD readout



Summary

- Testbeam at COSY with four layer telescope
  - Observed correlations in rows and columns
  - New settings for MuPix8 RO state machine → higher rates w/o readout errors
  - All submatrices read out simultaneously differences in behaviors are seen
  - Efficiency studies, cluster analyses, etc. are WIP

- New DAQ with Kintex7 FPGA
  - First evaluation kit purchased
  - Planned MuPix data simulation with second board
  - Read out Lumi prototype with two Kintex7 boards



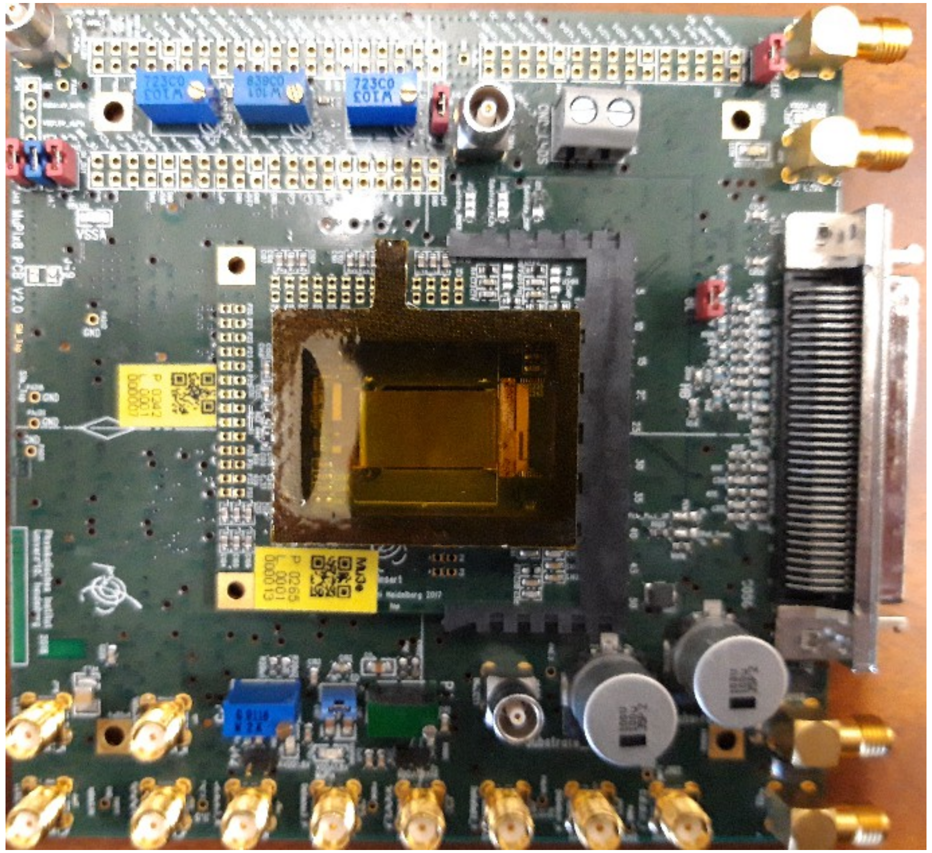
Matrix B of MuPix8 with PANDA Mask

– Backup –

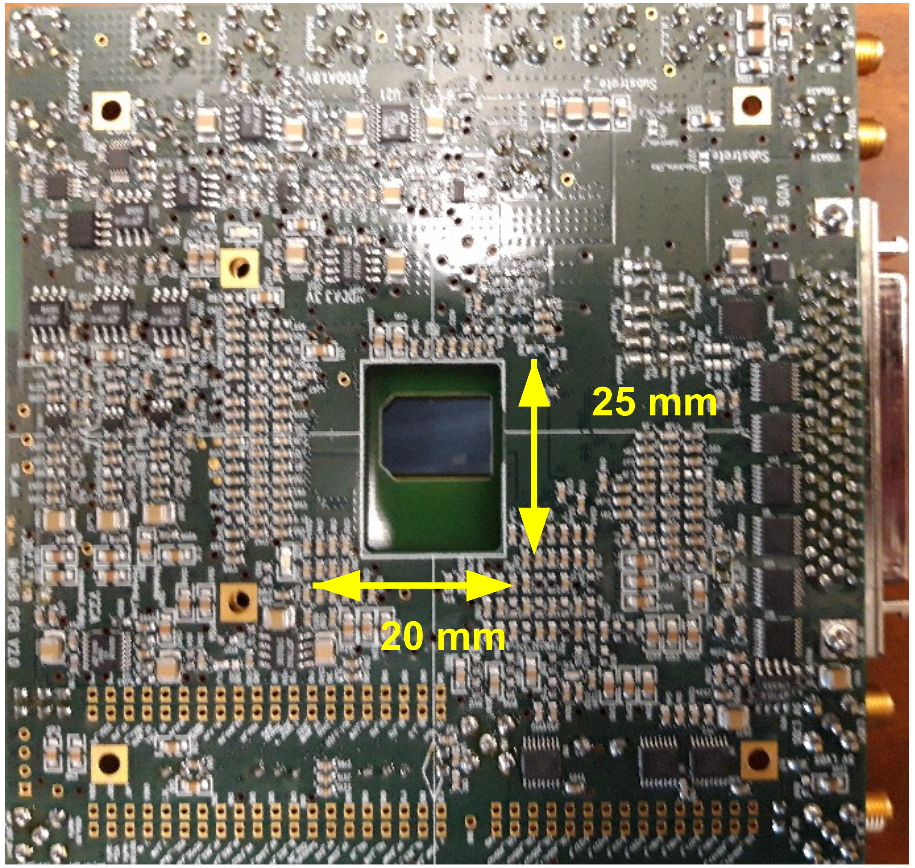
New Chips and Sensorbords in Bochum

- Different substrate resistivities (80 Ωcm and 200 Ωcm)
- New Sensorboards with adjustable VDD
  (1.9 V for more stable working point)
- PCB cutout → ideal for usage in telescope setup

Front side

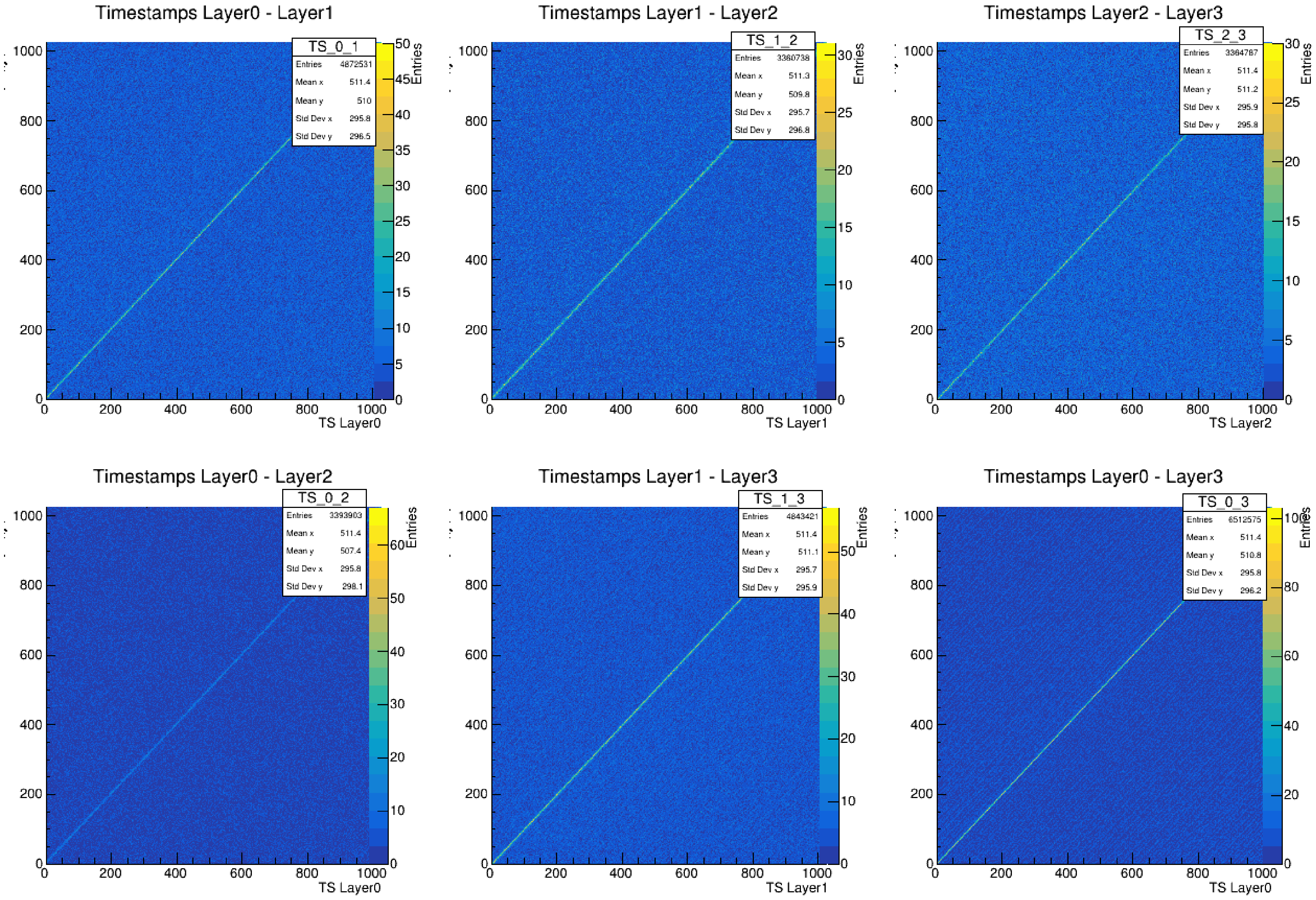


Back side



Timestamp Correlations

- All 4 Layers synchronized

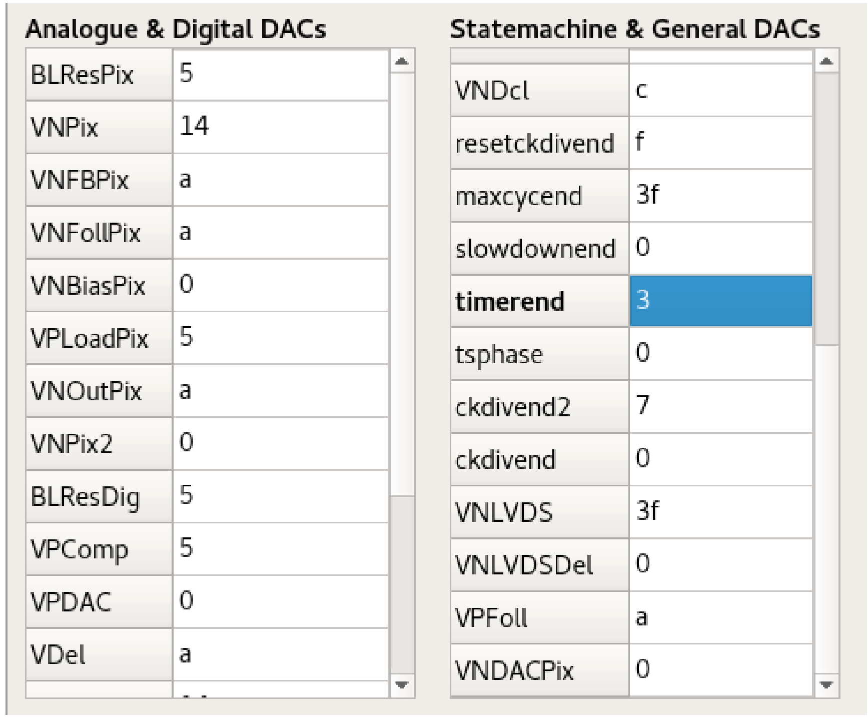


High Rate Problem

Digital Row Address	Pixel Row
0 – 55	——
56 – 139	0 – 83
140 – 239	100 – 199
240 – 255	84 – 99

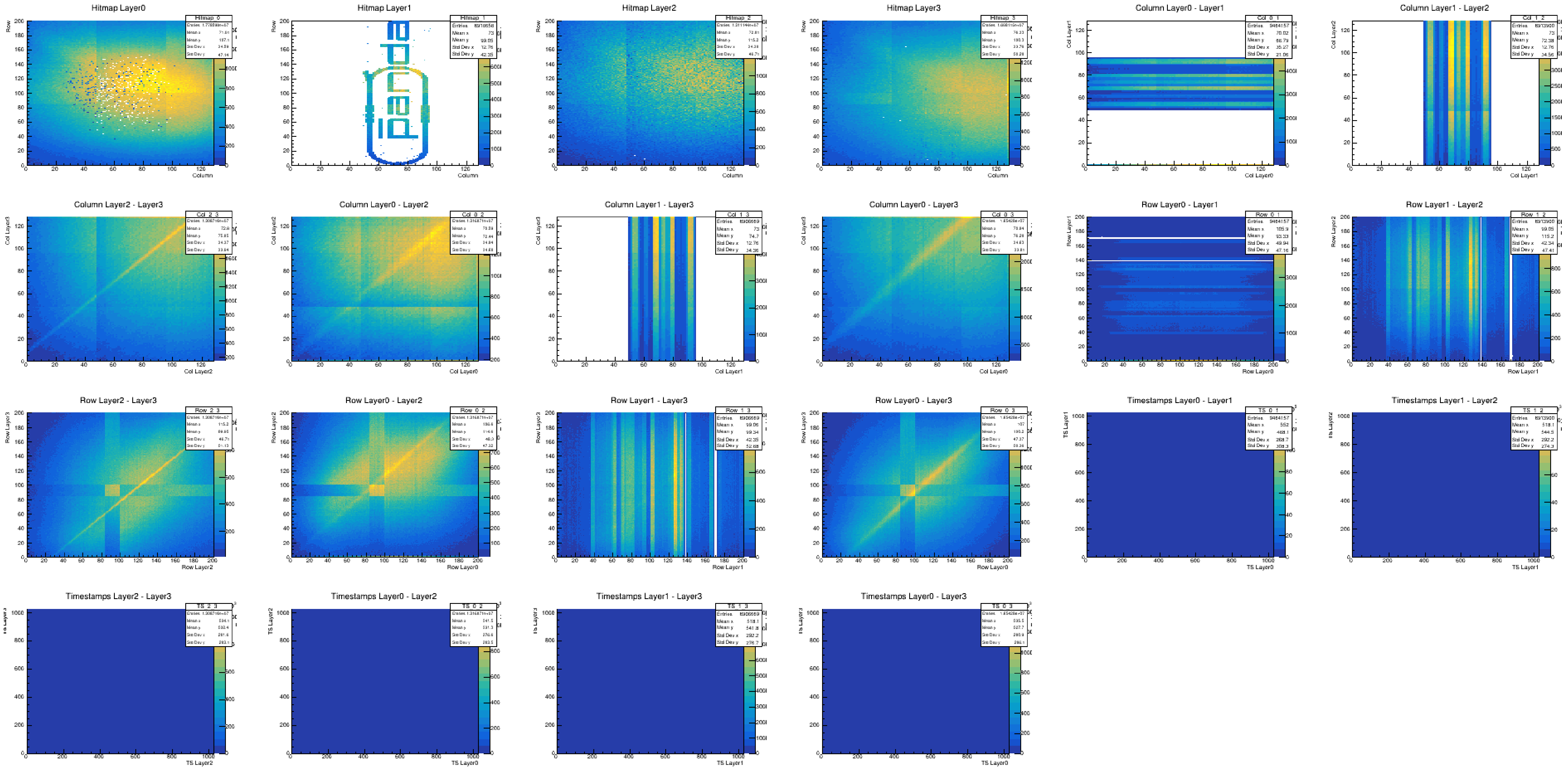
Row addresses of digital cells (8 bit)

- Priority based readout of digital cells:
  Lower row addresses get read out first
- Physical rows 84 – 99 have highest digital addresses
- Hits get stuck in cells and are read out at a later cycle
  → pixels are insensitive to further hits during that time
- Current settings:
  ref_clock = 40 MHz and timerend = 3
  → approx. max hit rate: 2.3 MHz
- For future: set timerend = 0
  → max. hit rate ≈ 9.2 MHz



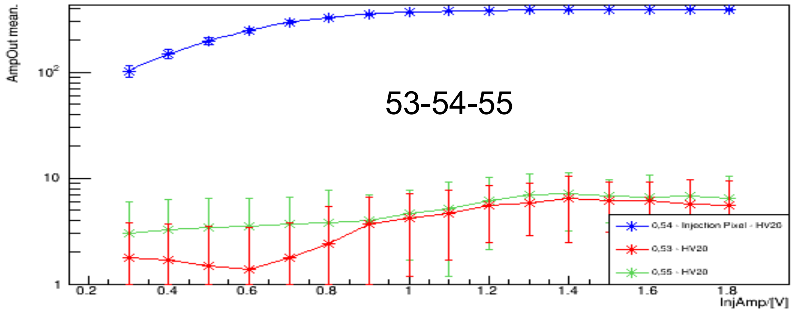
Excerpt from chip config GUI. timerend sets a clock divider that reduces the speed of the readout FSM by (timerend + 1)

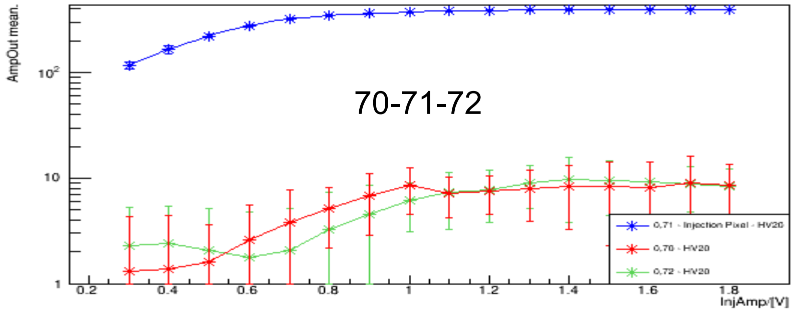
Matrices at High Rates

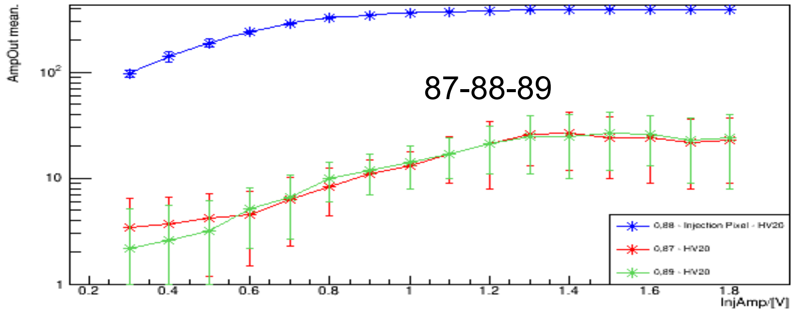


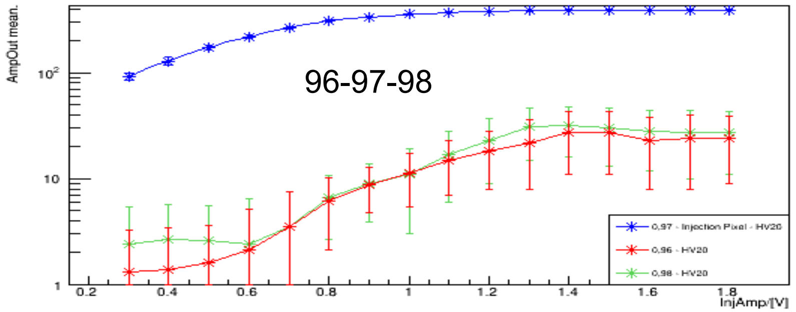
Crosstalk

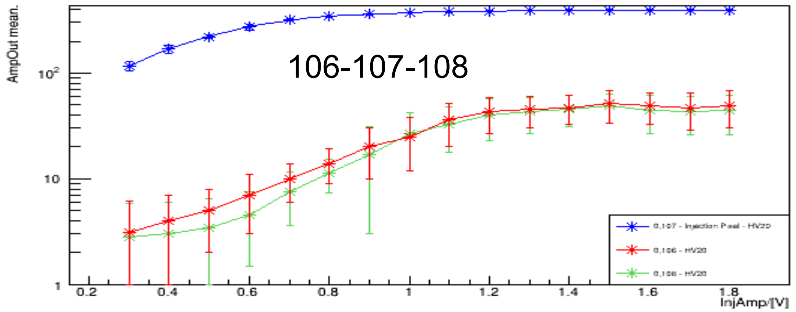
- Row dependence of crosstalk in Matrix A
- Using analog amplifier readout
- Injected pixel (blue) and neighboring pixels (red/green)

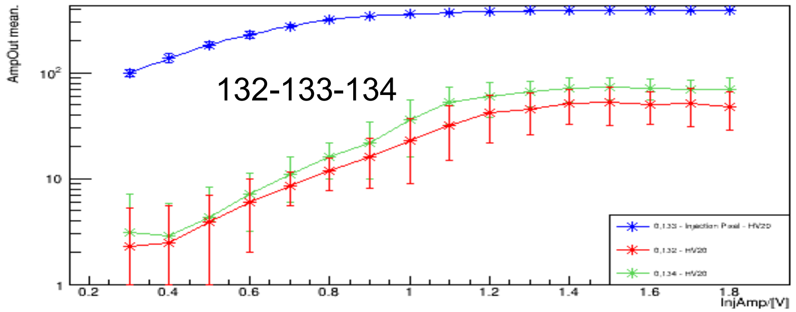


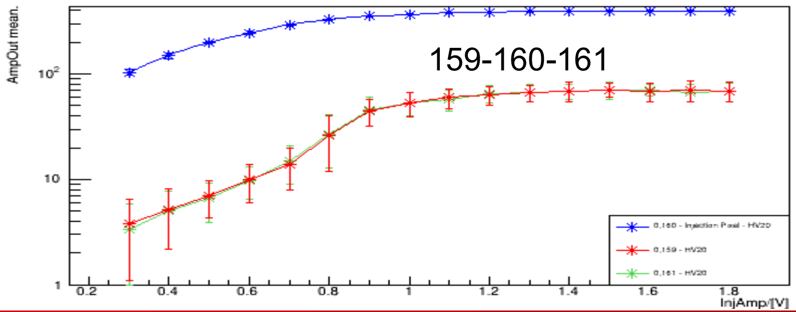












Recap: Last November

- Cluster analysis of testbeam data (MAMI october 2018)
- Different cluster sizes show different distributions
- Multi clusters (three or more pixels) show pattern related to crosstalk