HV-MAPS
(High Voltage Monolithic Active Pixel Sensors)
for the $\overline{\text{P}}$anda Luminosity Detector

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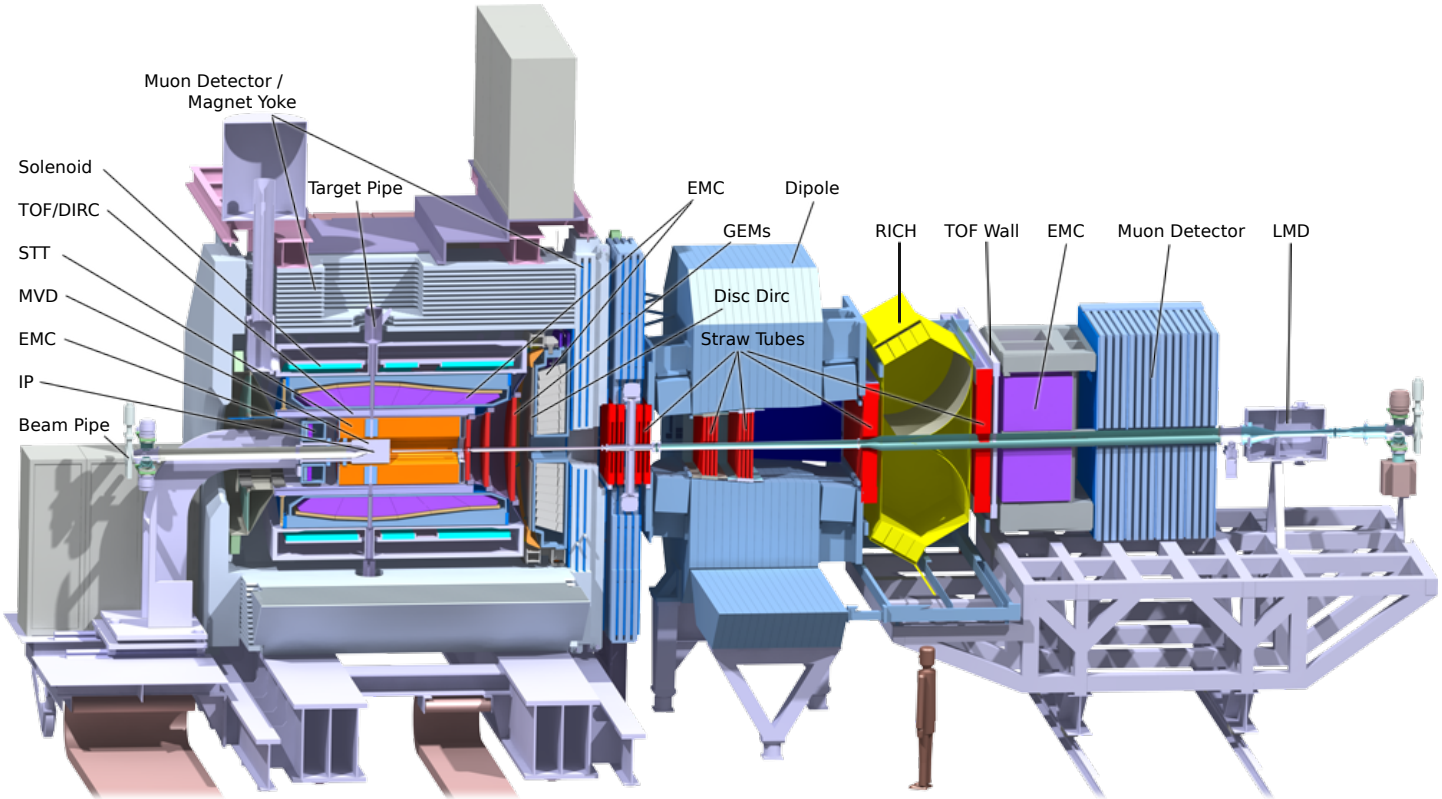
in collaboration with the Heidelberg Mu3e group

International Conference on Science and Technology for FAIR
15.10.2014

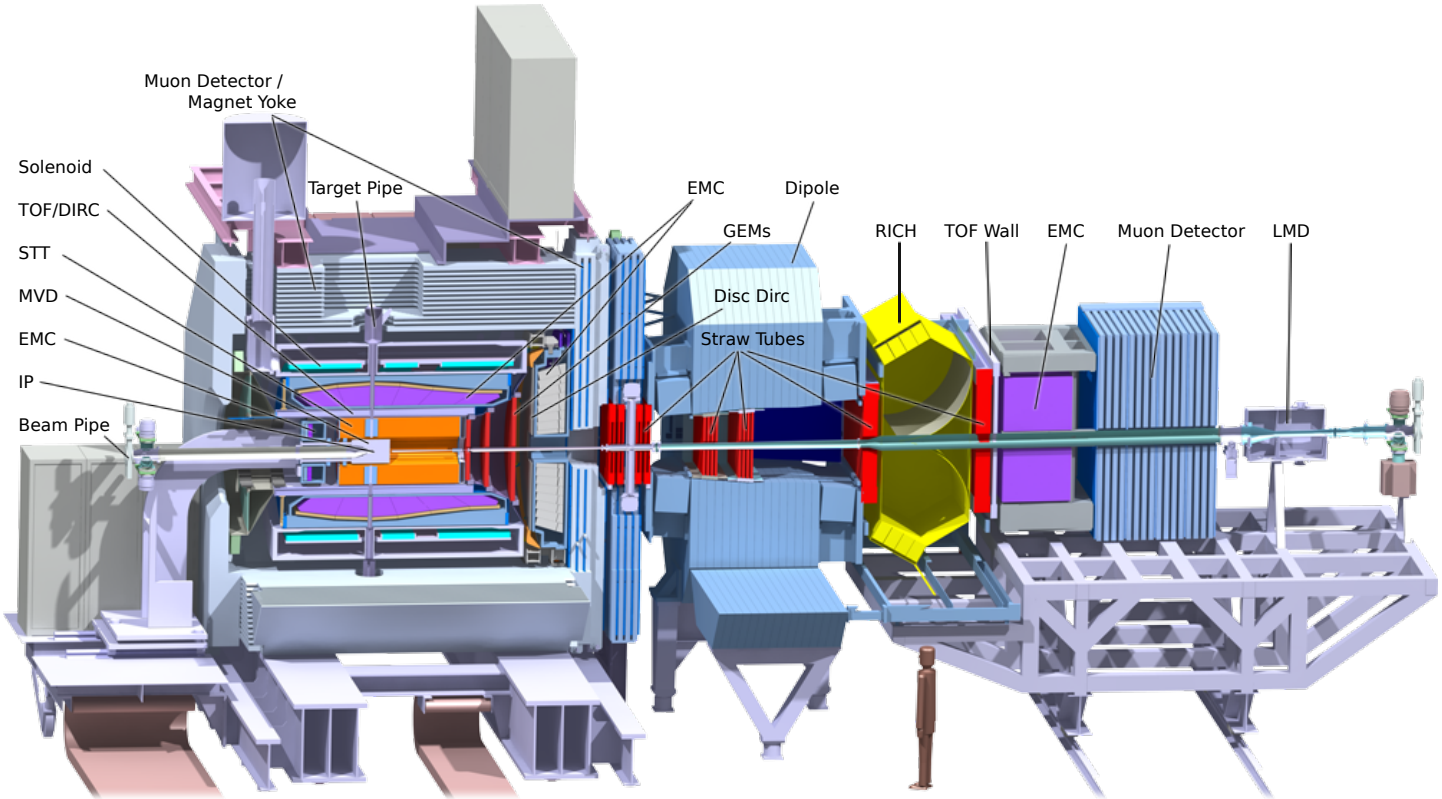
$\overline{\text{P}}$anda Experiment



Physics Program

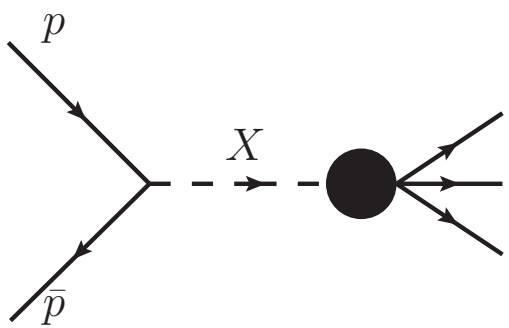
- hadron spectroscopy
- nucleon structure
- hyper nuclei
- hadrons in matter

$\overline{\text{P}}$anda Experiment

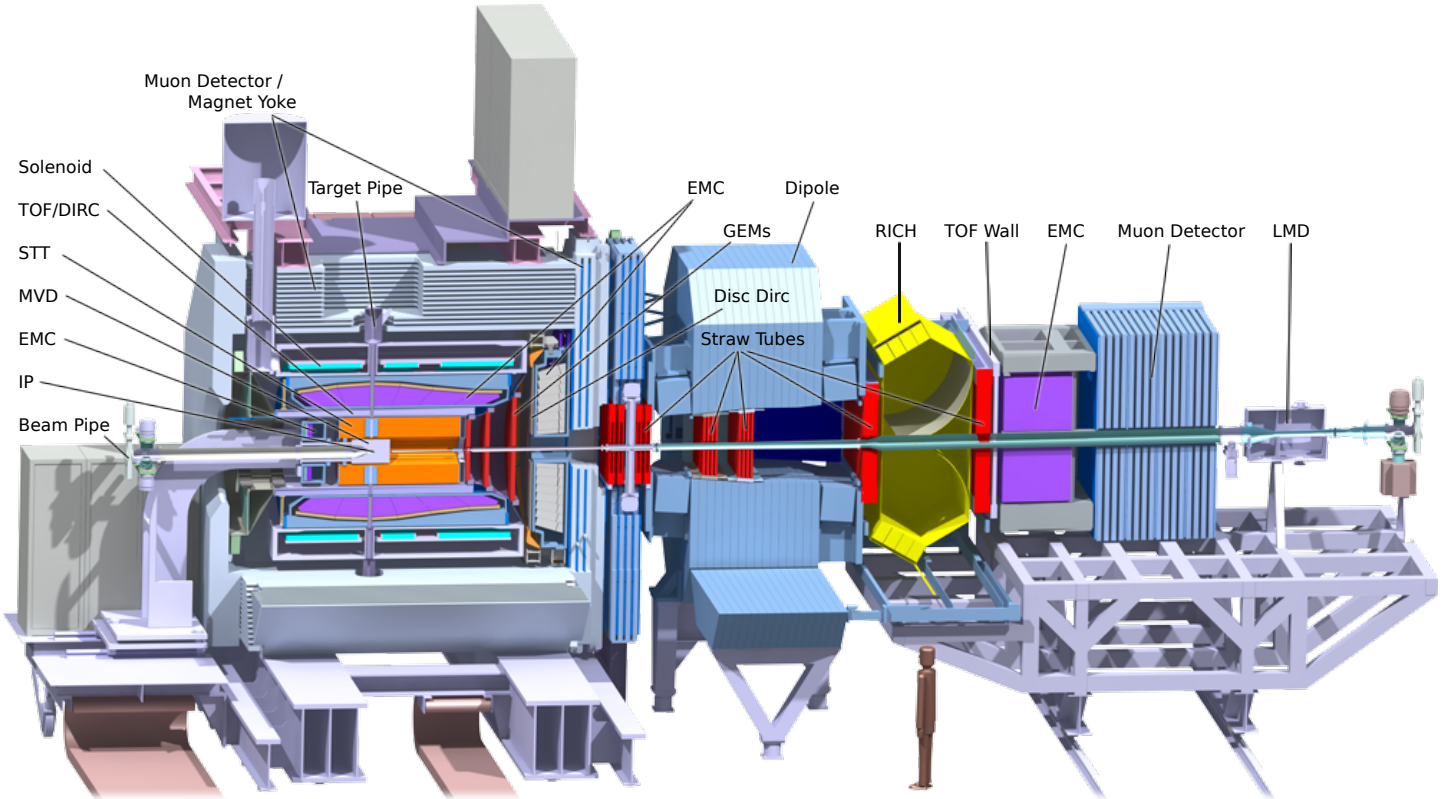


Measurements at PANDA

- $p\bar{p}$-formation experiments
  - resonance scans
  - threshold scans

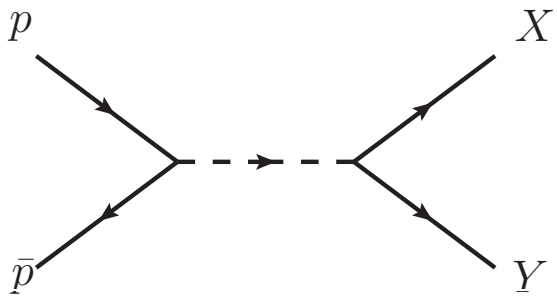


$\overline{\text{P}}$anda Experiment

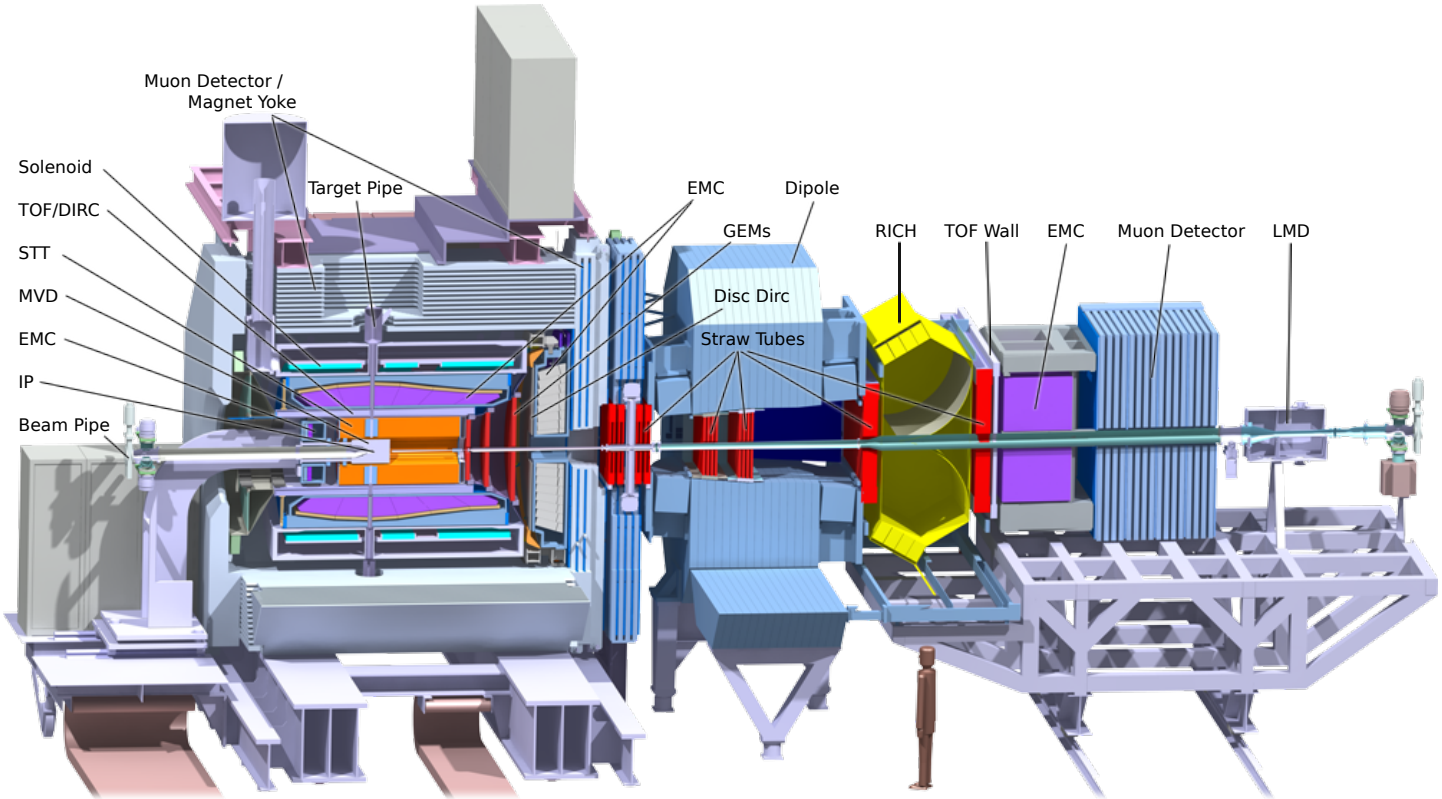


Measurements at PANDA

- $p\bar{p}$-formation experiments
- production experiments
  - search for new particles



$\overline{\text{P}}$anda Experiment

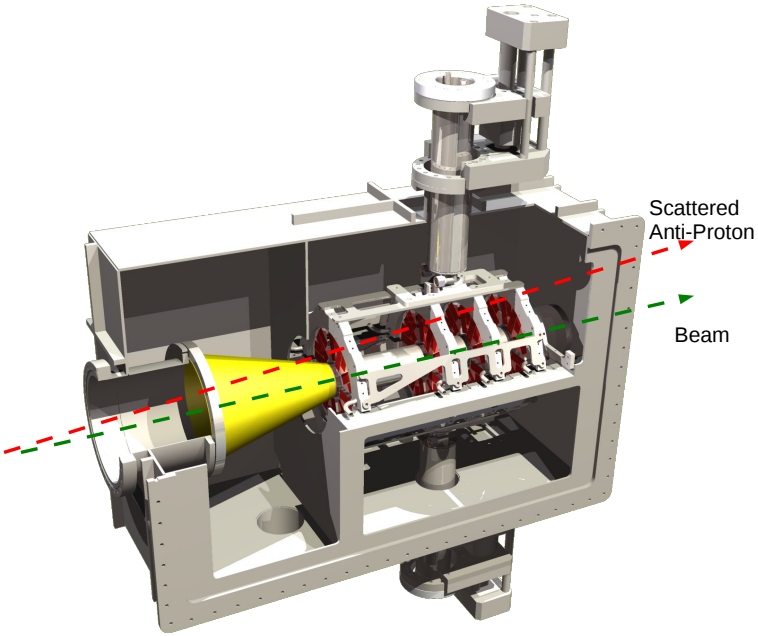


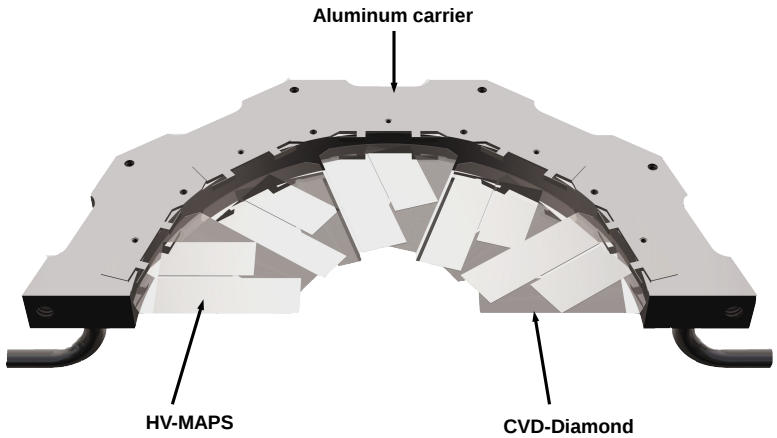
Measurements at PANDA

- $p\bar{p}$-formation experiments
- production experiments

$\Rightarrow$ luminosity measurement

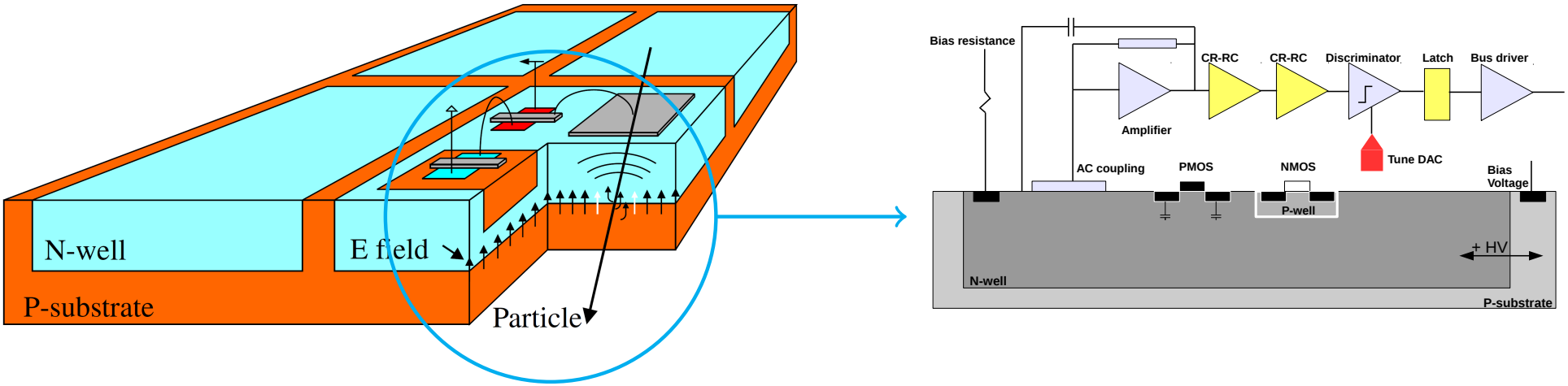
Luminosity Detector





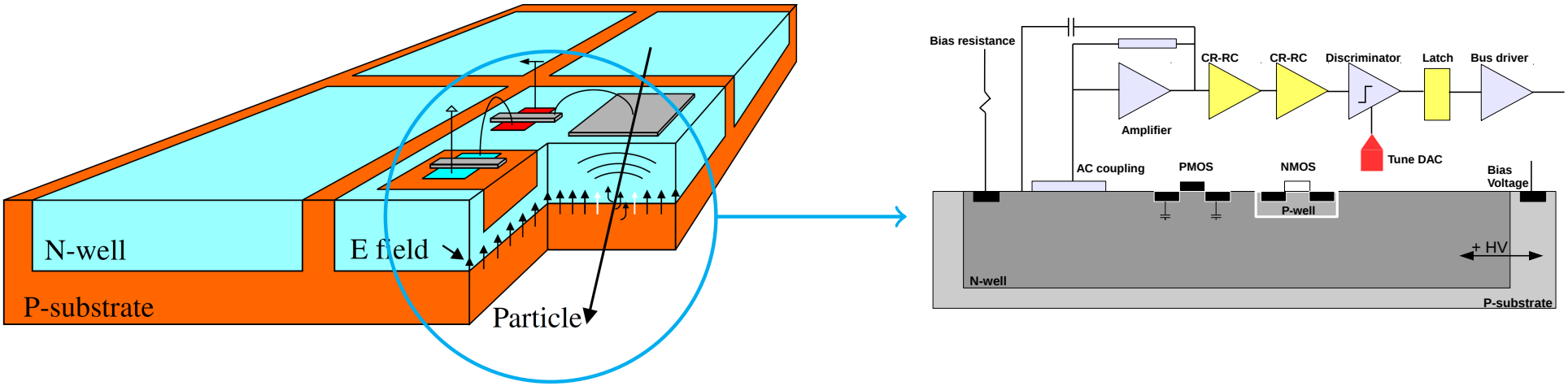
- reconstruction of scattering angle of elastic proton-antiproton scattering
- four silicon tracker stations
- 400 HV-MAPS in total

High Voltage Monolithic Active Pixel Sensors



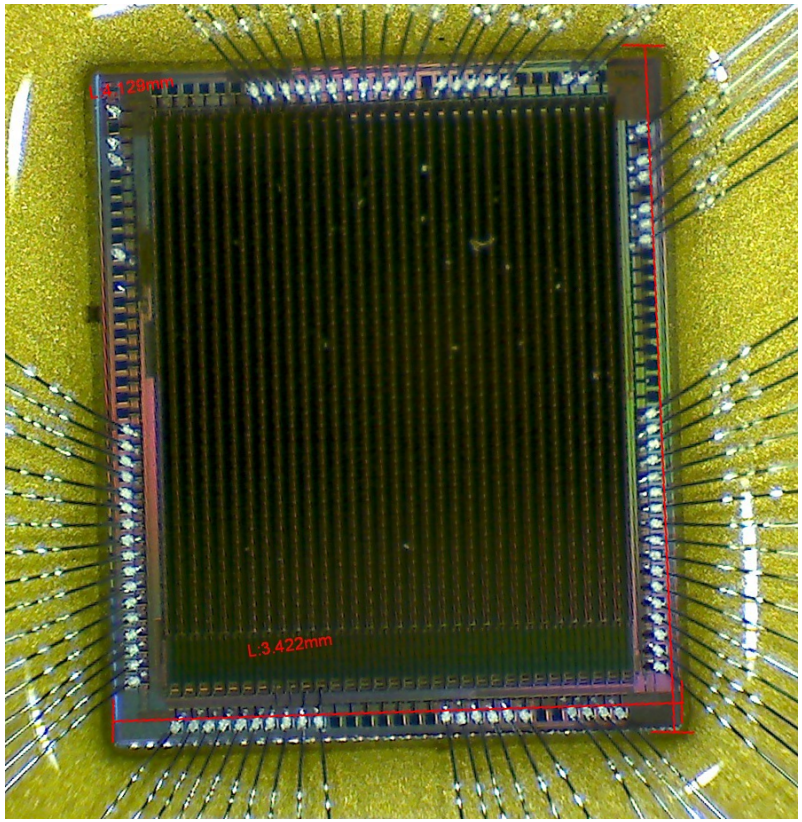
- 180 nm technology
- bias voltage ($\approx$ 60 V)
  - 14 µm depletion layer
  - fast charge collection
- radiation tolerant
- leading edge discriminator
- thinnable to less than 50 µm

High Voltage Monolithic Active Pixel Sensors



- size of 2x2 cm^2 with 80x80 μm^2 pixels
- digital part on one chip side, active area > 90%
- frequency up to 40 MHz
- LVDS-Link @ 400-800 Mbps

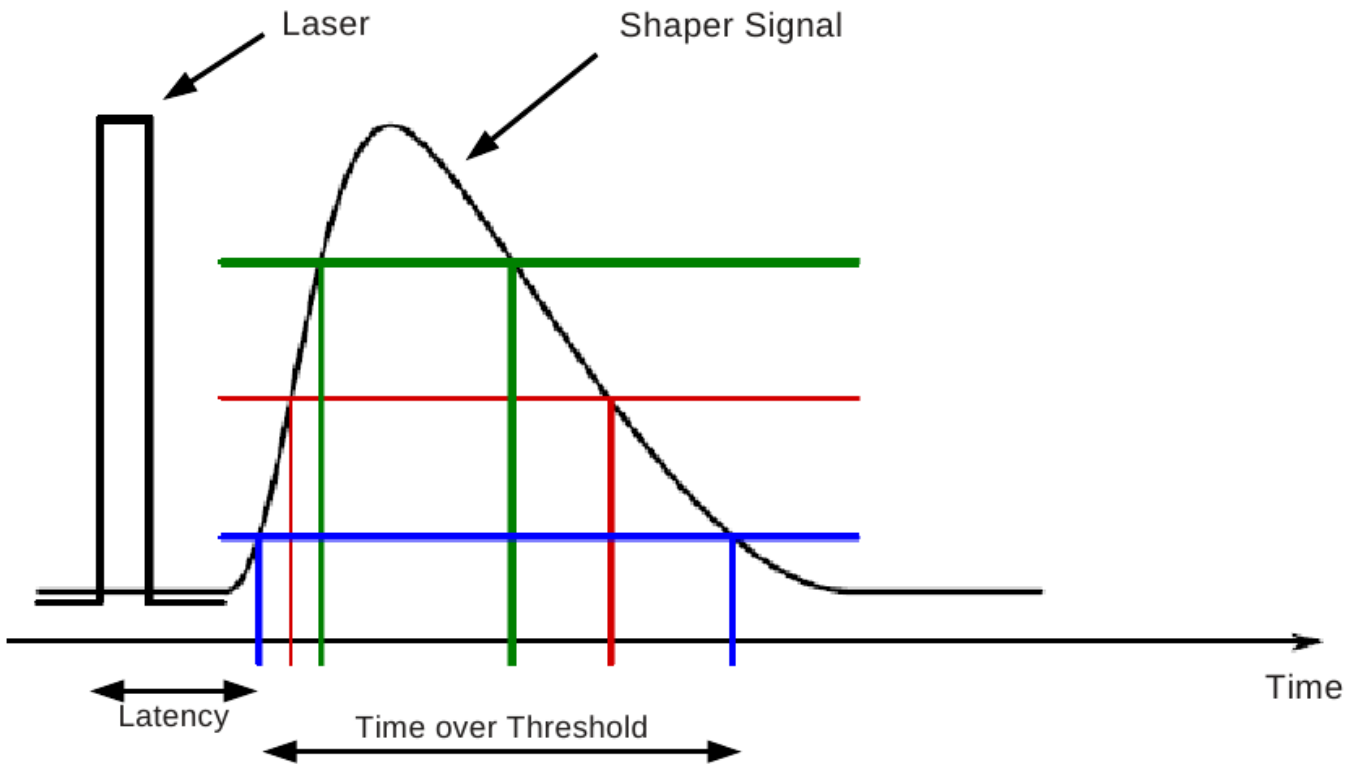
High Voltage Monolithic Active Pixel Sensors



MuPix 4 Prototype

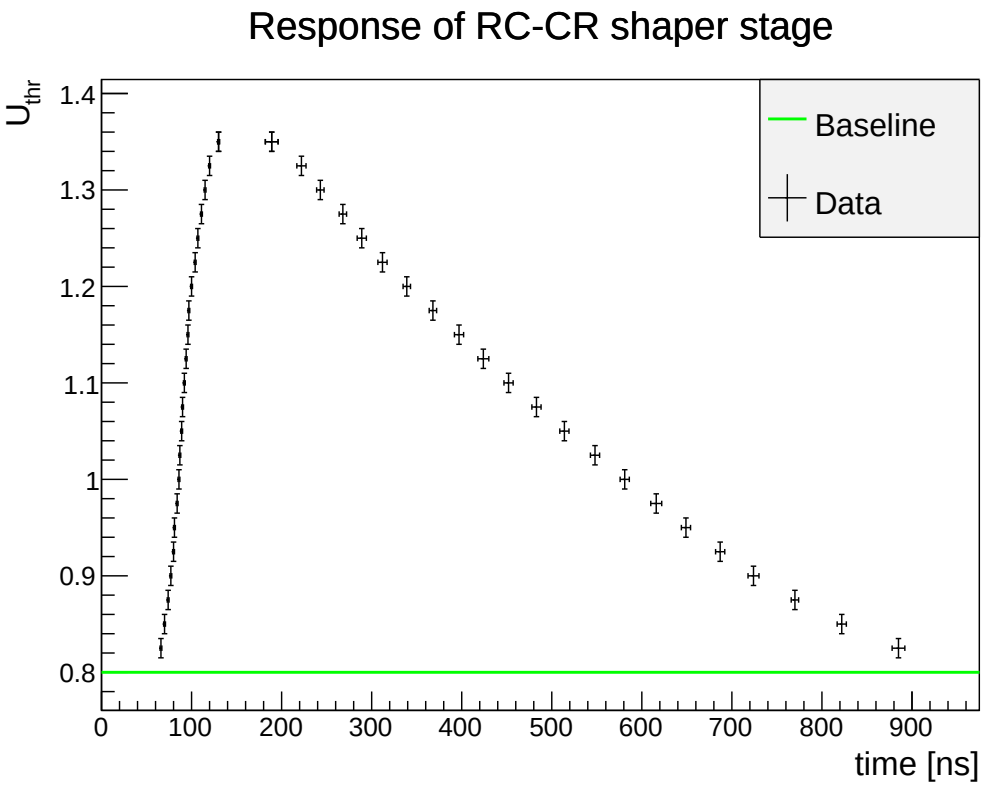
- 40x32 pixels with 80 µm x 92 µm
- column logic on chip
- parallel data readout (no serial link)
- readout and slow control by FPGA-Board
- time stamp generation on FPGA

Characterization of Analogue Part: Shaper



- use laser pulse to measure latency and ToT in dependence of threshold

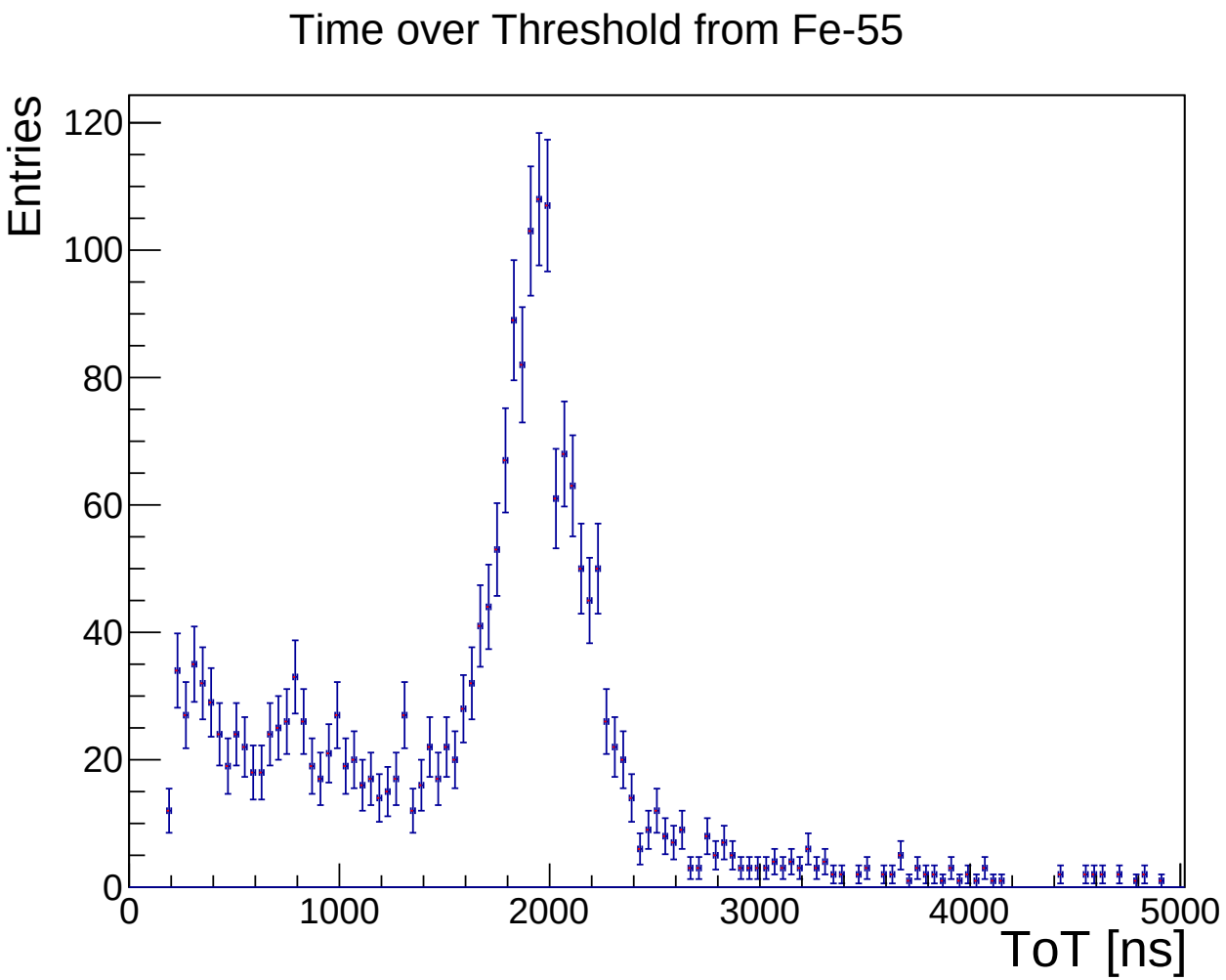
Characterization of Analogue Part: Shaper



- use laser pulse to measure latency and ToT in dependence of threshold
- shaping time well below 1 µs

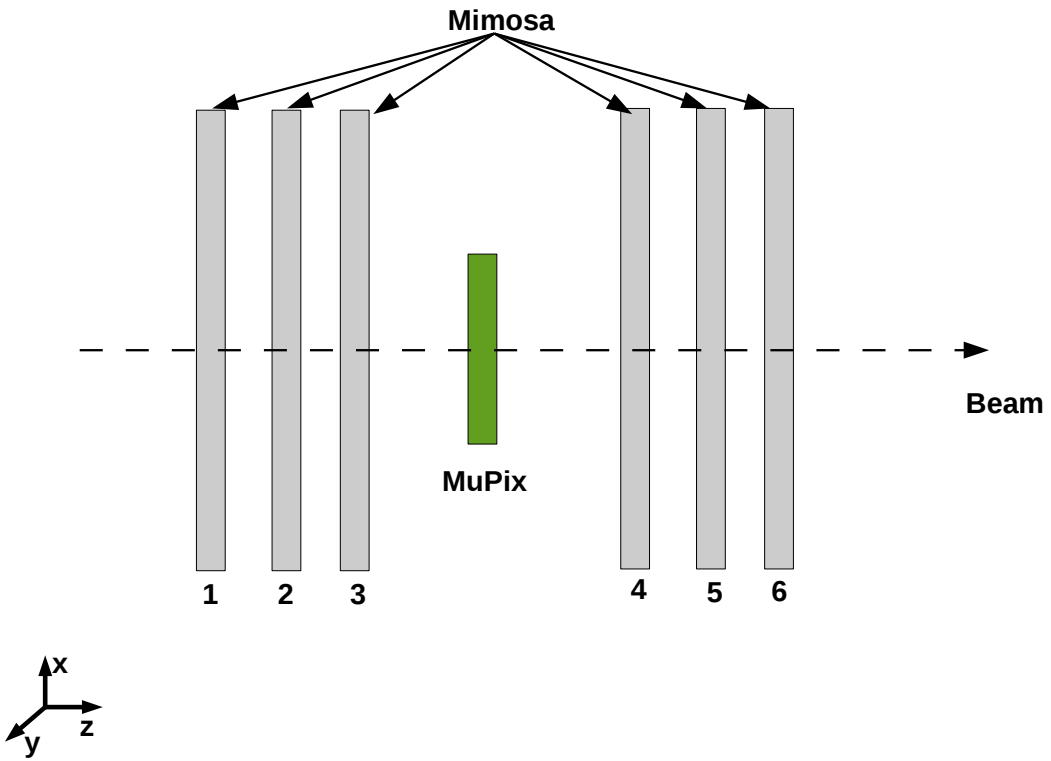
Characterization of Analogue Part: Energy Separation

$$^{55}\text{Fe} \xrightarrow{EC} {}^{55}\text{Mn}^{*} \rightarrow {}^{55}\text{Mn} + \gamma(5.8\ \text{keV})$$



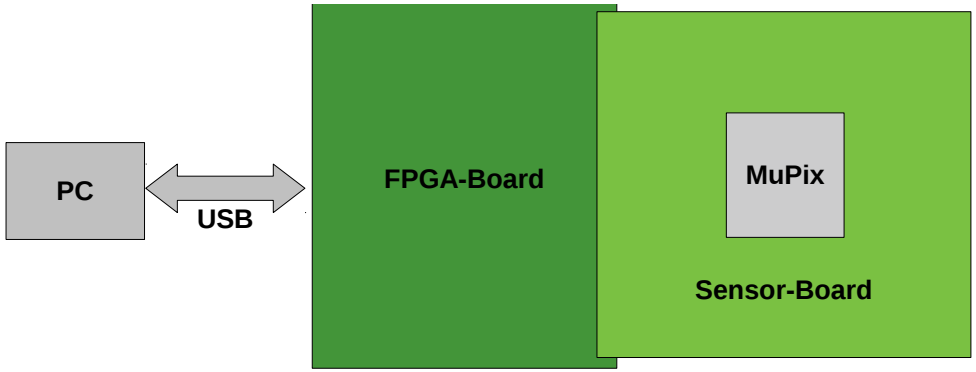
DESY Test Beam, October 2013

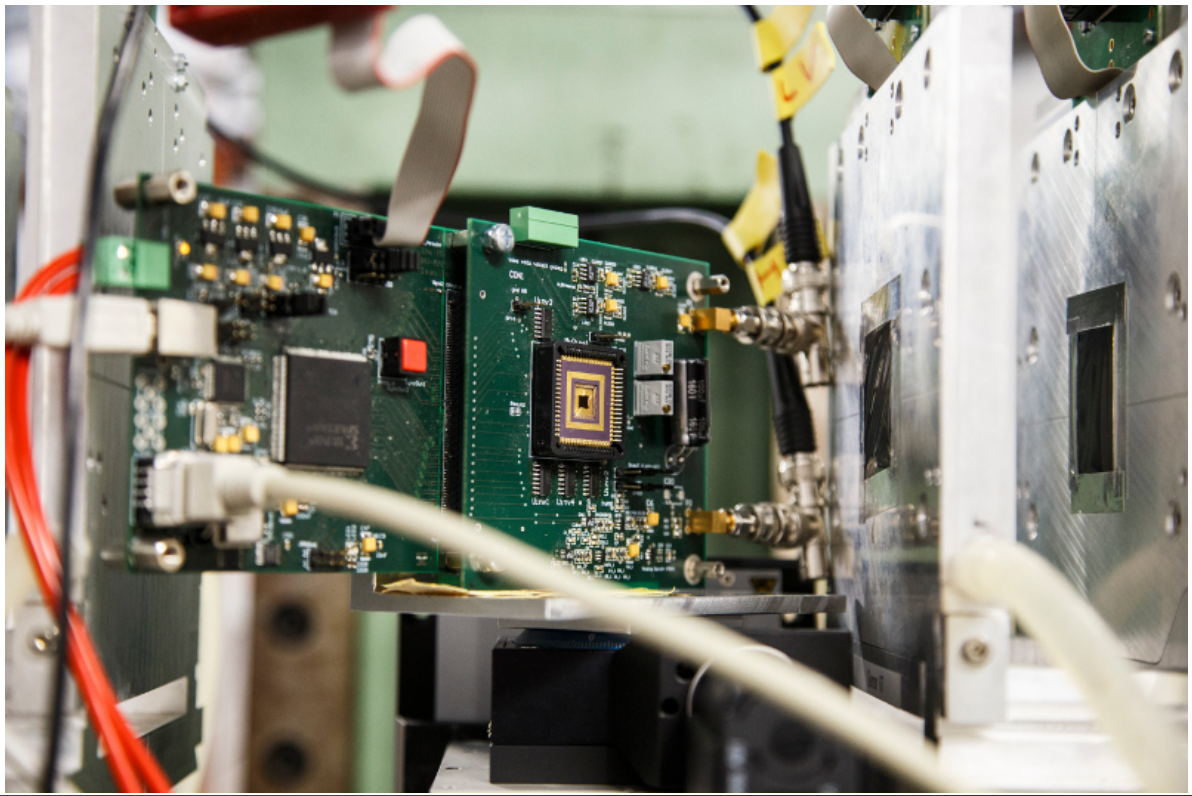
Mu3e group with EUDET-telescope



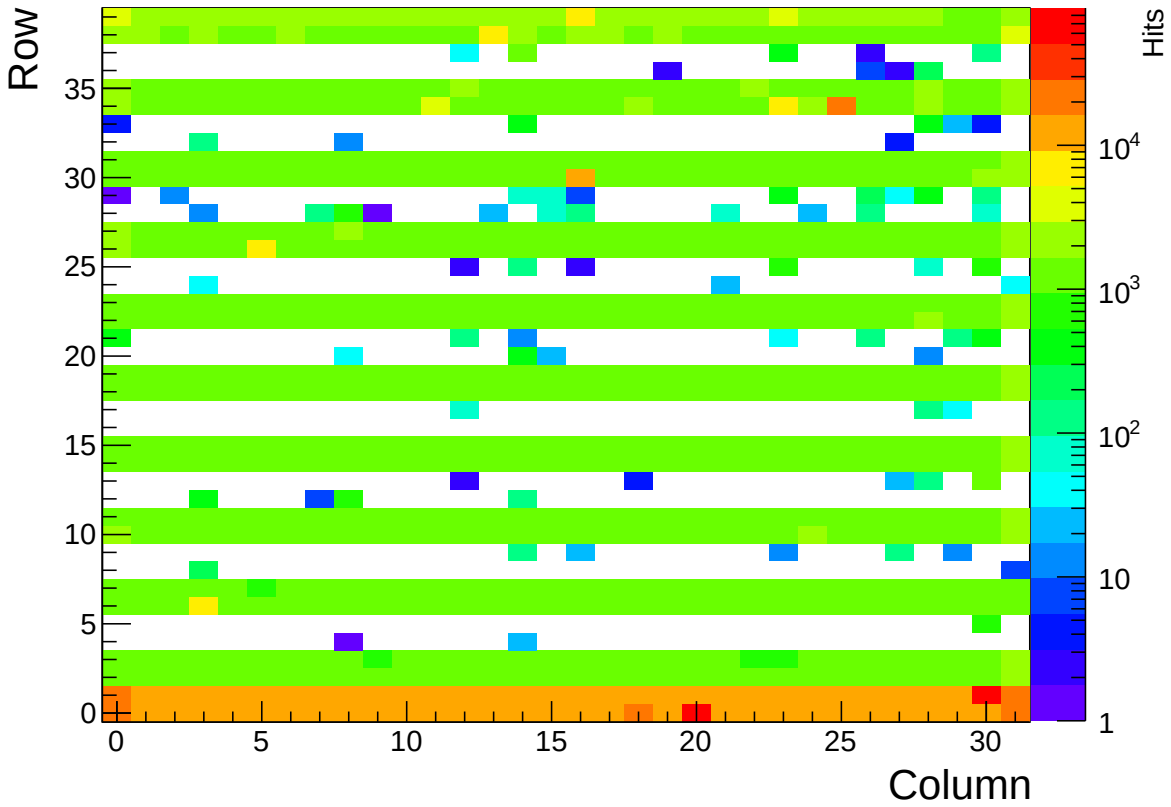
- electron beam with 3-5 GeV
- measurement of sensor efficiency

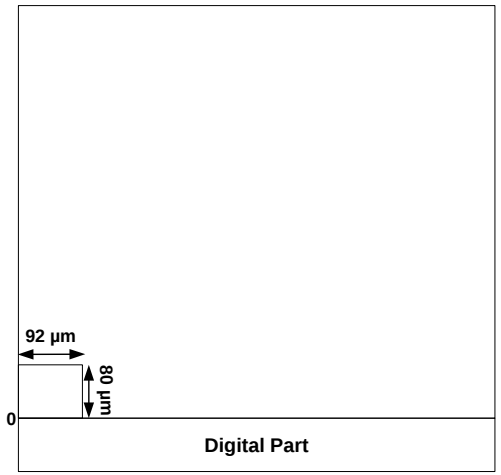
DESY Test Beam, October 2013





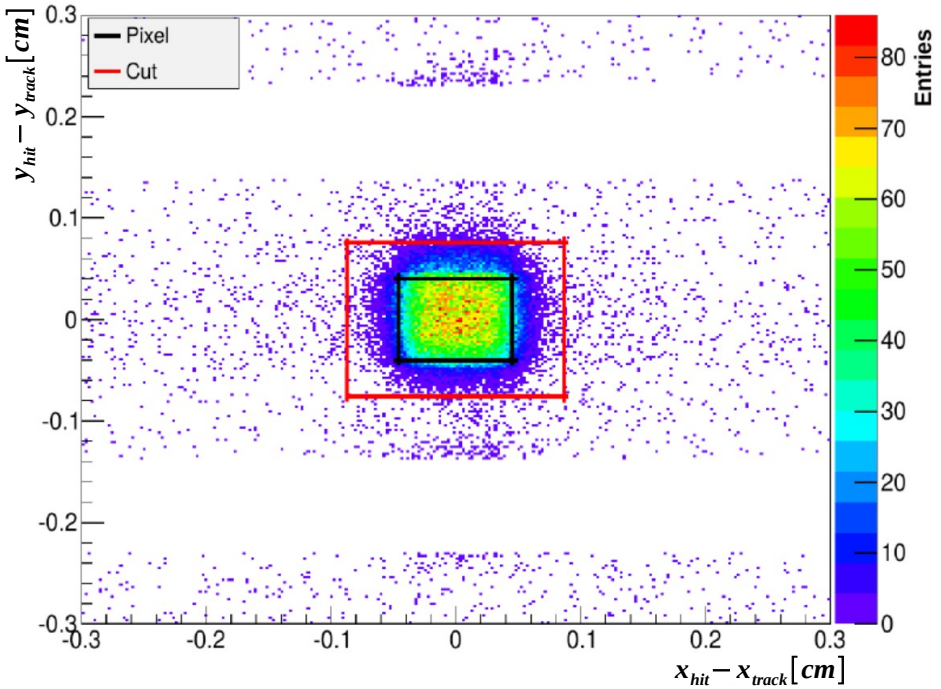
MuPix 4: A Hybrid Strixel





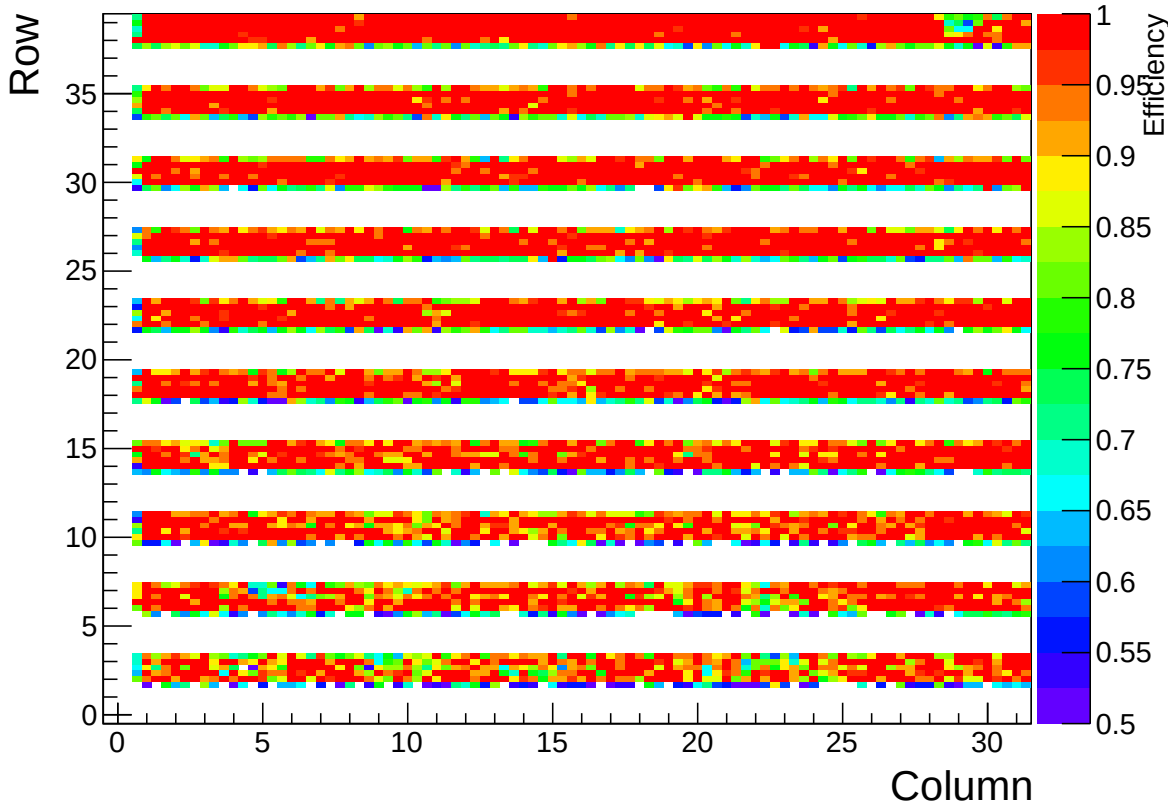
- timing problem in row address readout
  $\Rightarrow$ Projection of hits into first two rows
- high noise in few pixels

Spatial Resolution



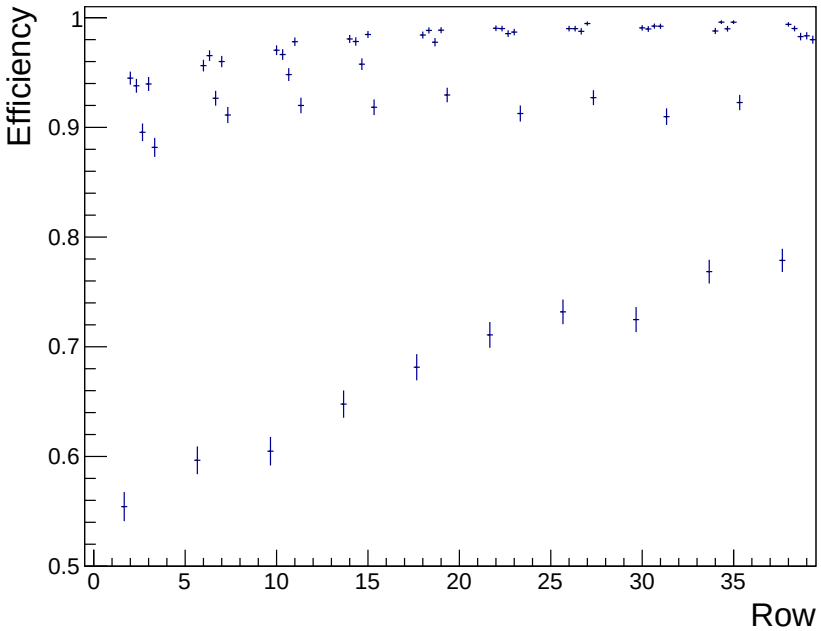
- spatial resolution given by pixel size
- charge sharing with surrounding pixels $\approx 10\%$
- rectangular cut on hit-track distance $|d_i| < 0.95 \cdot \text{pitch}_i$

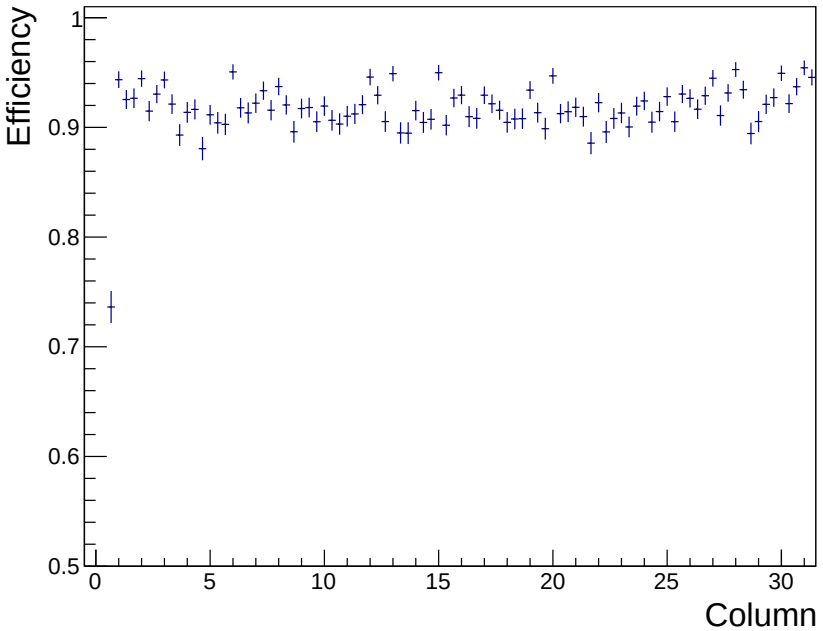
Global Efficiency



- efficiency up to 99%
- row dependence caused by tune DAC settings

Global Efficiency

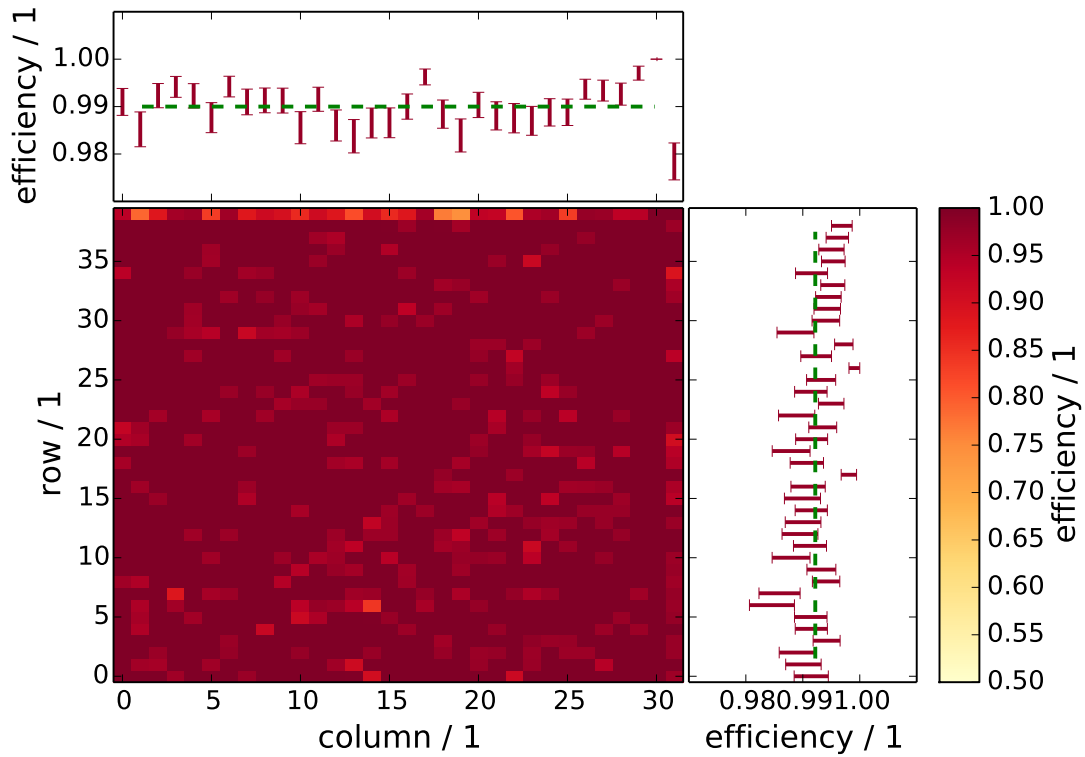




- efficiency up to 99%
- row dependence caused by tune DAC settings

Global Efficiency

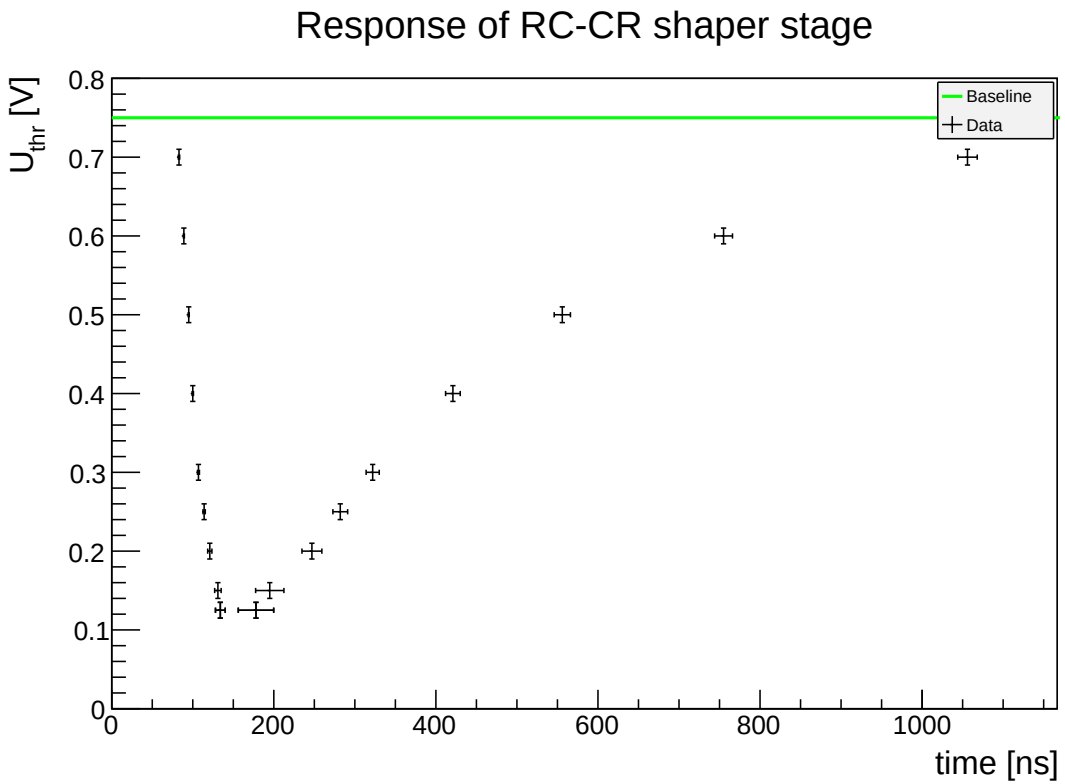
- row coordinate from track, column information for matching
- no usage of tune DACs



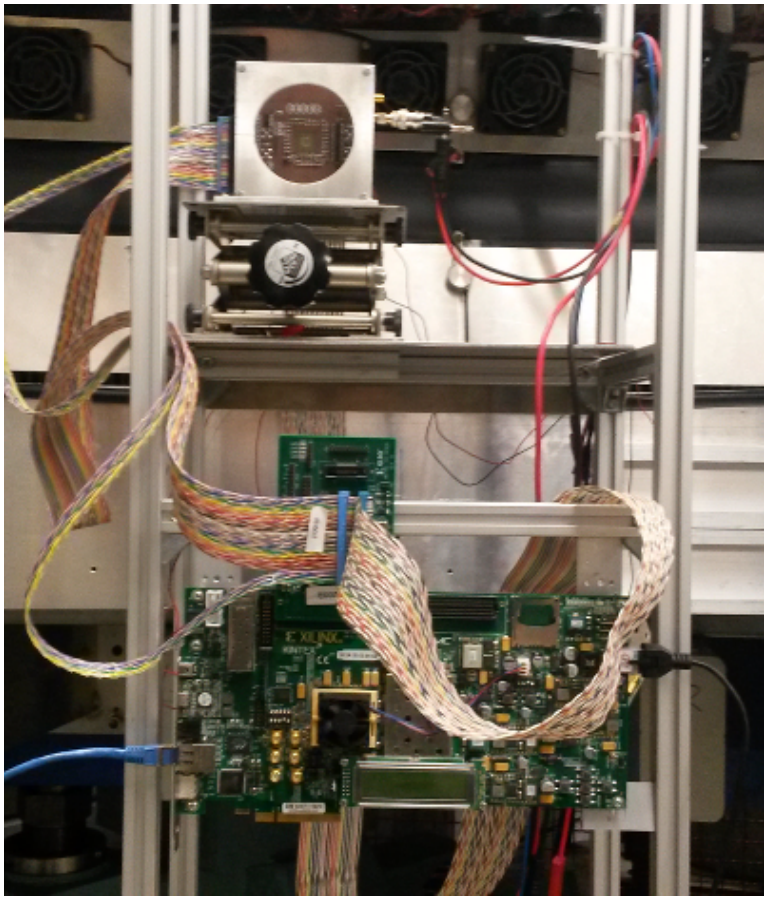
- homogeneous efficiency distribution of 99%

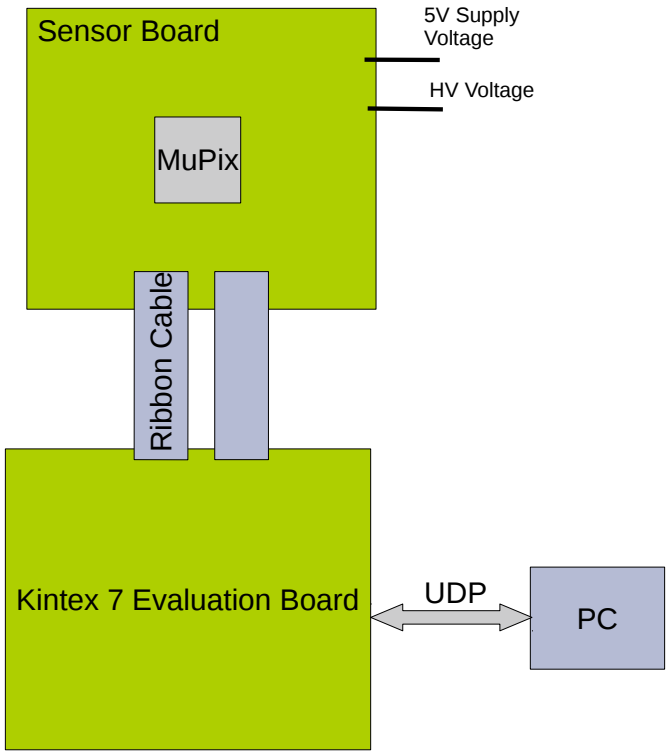
MuPix 6

- solve the MuPix 4 readout issues
- additional shaping stage to improve signal-to-noise
- 4 columns with MuPix 4 shaping stage for comparison



Test Beams at MAMI (Mainz) and COSY (Jülich)





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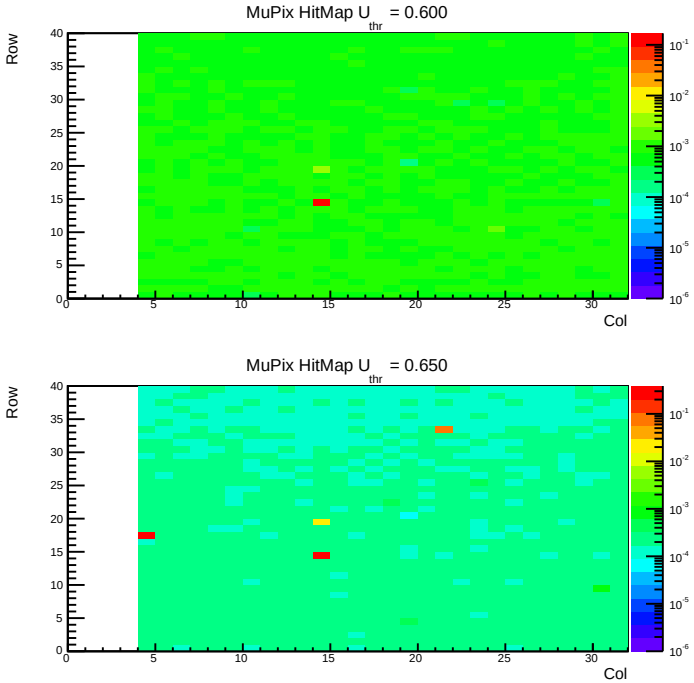
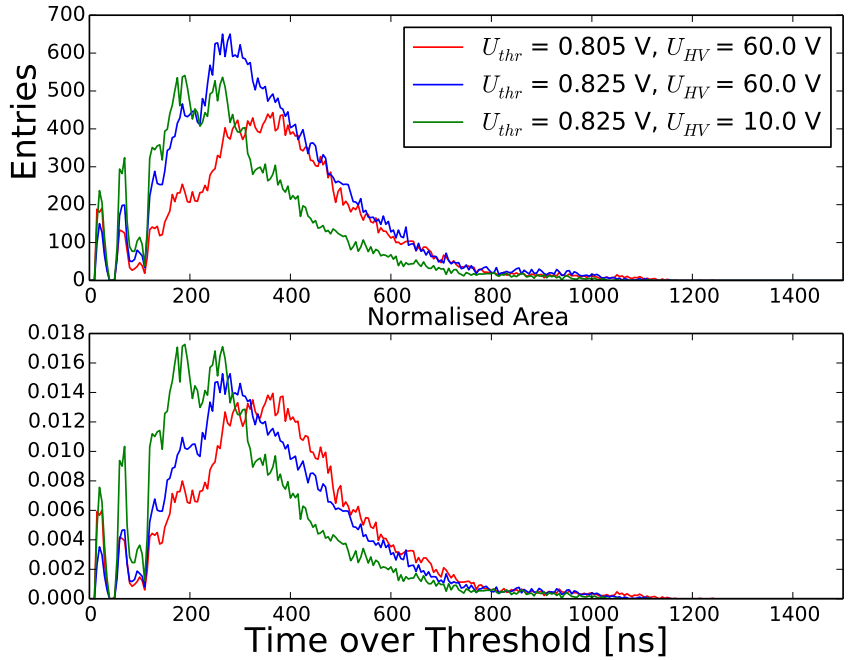
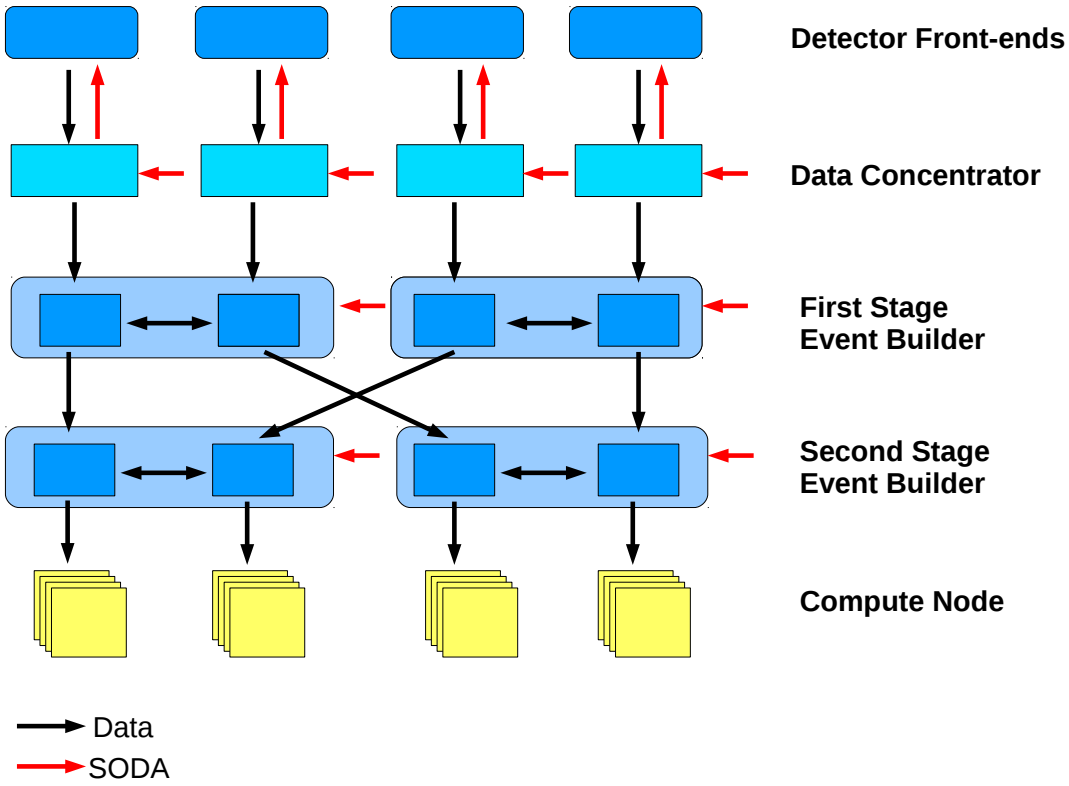




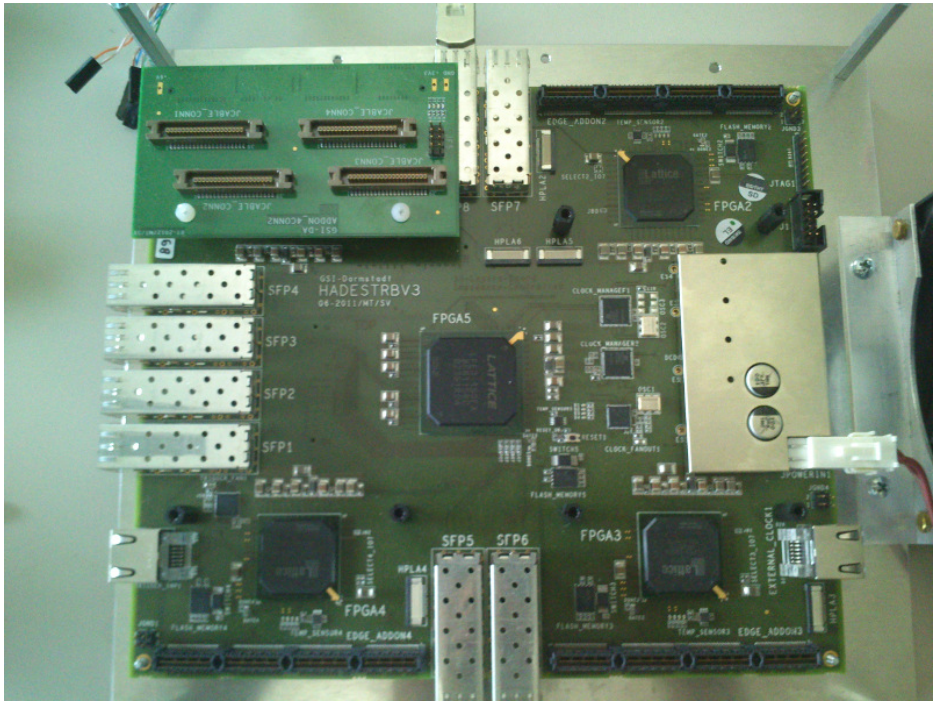
- digital readout working
- Landau shaped time-over-threshold distribution

PANDA DAQ



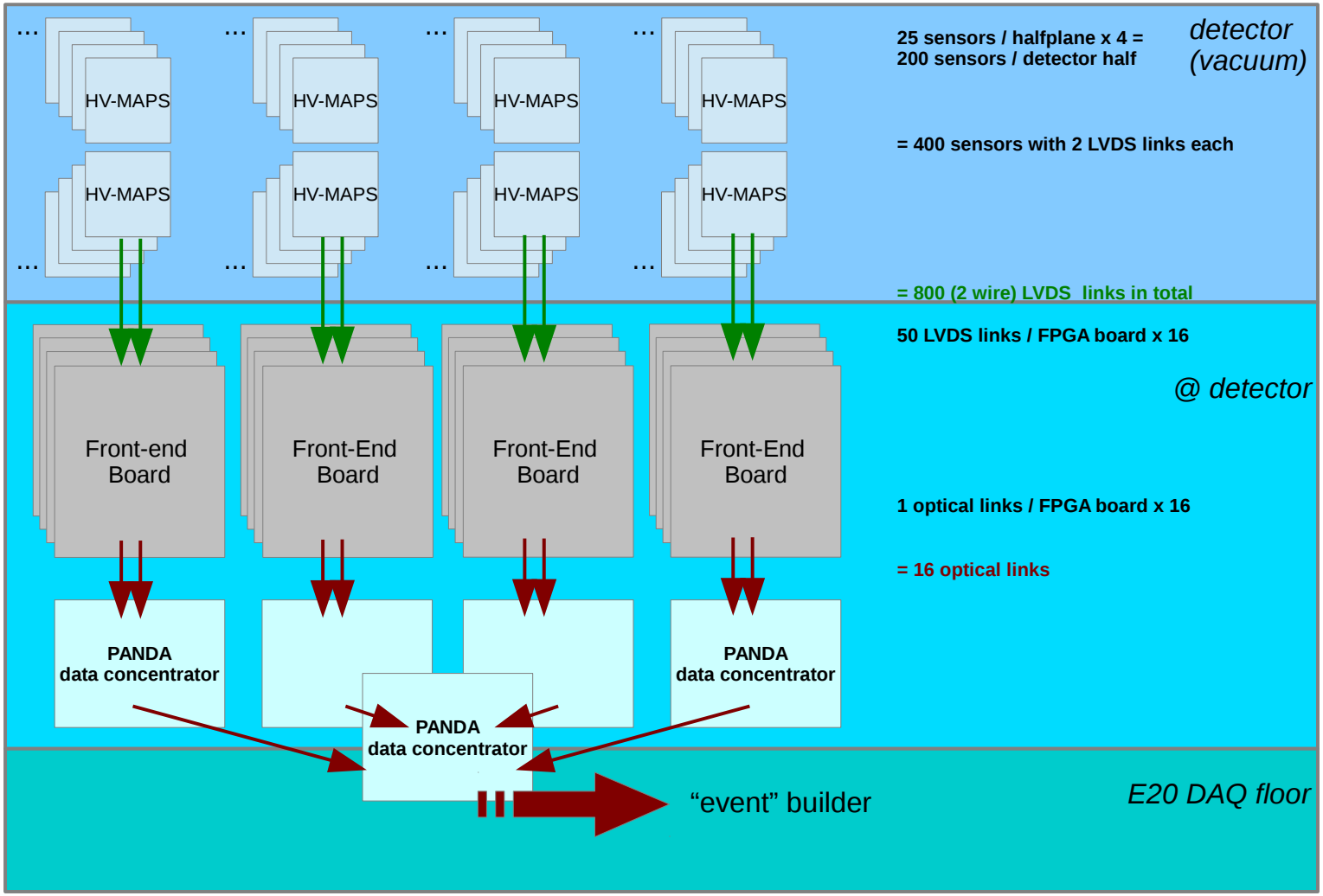
- generation of online trigger
- synchronisation of sub-detectors

Luminosity Detector Frontend Board



- Hades Trigger and Readout Board (TRBv3)
- 5x Lattice ECP3-150 FPGAs
- main FPGA for UDP/inter FPGA connectivity
- four side FPGAs for sensor IO

Luminosity DAQ



Summary

- test beam in October 2013 at DESY
  - efficiencies look promising
- test beams at MAMI and COSY in Summer 2014
  - problem with row address readout solved by MuPix 6

Outlook

- MuPix 7 submitted in September 2014
  - serial data link
  - time stamp generation on chip

Thank you for your attention!

Backup Slides

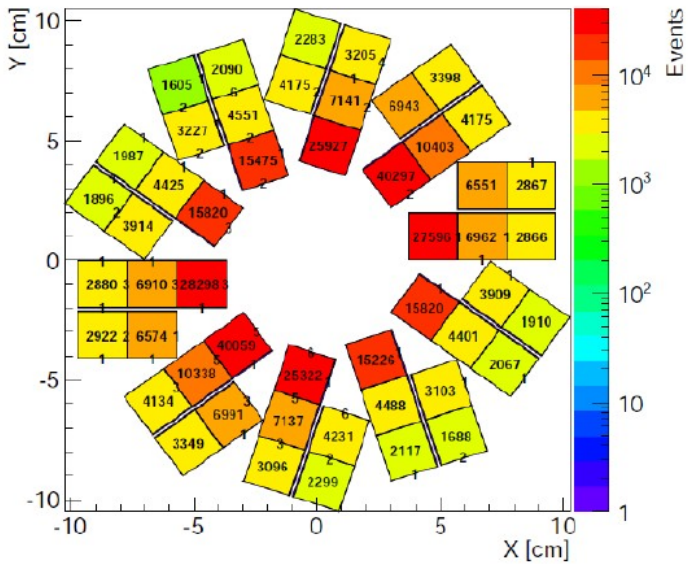


Abbildung 5.2: Ereignisraten auf der ersten Detektorebene bei $1.5\frac{GeV}{c}$ Strahlimpuls.

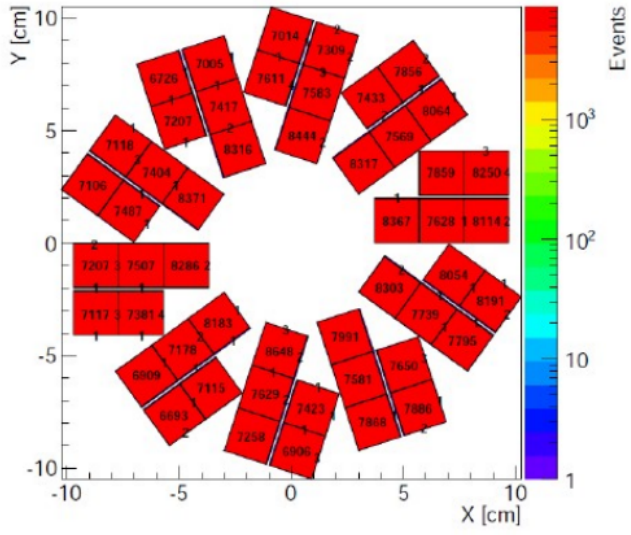


Abbildung 5.4: Ereignisraten auf der ersten Detektorebene bei $15\frac{GeV}{c}$ Strahlimpuls.

Antiprotonen Impuls $[\frac{GeV}{c}]$	Benutzter Wert	Rate [kHz]
1.5	Sensor 1	183, 2
1.5	Sensor 3	19, 0
15.0	Sensor 1	40, 0

Radiation doses

Ebene	Seite	Sensor	Dosis [Gy 0.795s]	Dosis [Gy a]
1	vorn	3	$6.64 \cdot 10^{-5}$	1317
1	vorn	1	$38.5 \cdot 10^{-5}$	7636
4	hinten	3	$16.4 \cdot 10^{-5}$	3253
4	hinten	1	$159.4 \cdot 10^{-5}$	31615

Tabelle 4.4: Maximal deponierte Dosis bei $1.5\frac{GeV}{c}$ aus der Simulation und extrapolierte Dosis für ein Betriebsjahr.

Ebene	Seite	Sensor	Dosis [Gy 1.6s]	Dosis [Gy a]
1	vorn	3	$6.98 \cdot 10^{-5}$	688
1	vorn	1	$7.19 \cdot 10^{-5}$	709
4	hinten	3	$20.2 \cdot 10^{-5}$	1990
4	hinten	1	$18.7 \cdot 10^{-5}$	1843

Tabelle 4.6: Maximal deponierte Dosis bei $15\frac{GeV}{c}$ aus der Simulation und extrapolierte Dosis für ein Betriebsjahr.

In additon ~250Hz neutrons/sensor @ 15GeV/c
→ **should not be an issue.**