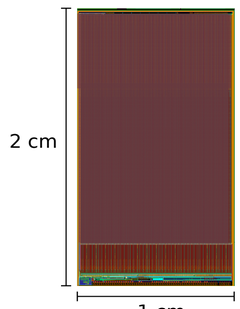
MuPix8 – Large Area Monolithic HVCMOS Pixel Detector for the Mu3e Experiment

Alena Weber[1,2], Heiko Augustin[2], Niklaus Berger[3], Sebastian Dittmeier[2], Felix Ehrler[1], Lennart Huth[2], Mridula Prathapan[1], Ivan Perić[1], Rudolf Schimassek[1], André Schöning[2], Dirk Wiedner[2], Hui Zhang[1]

[1]Karlsruhe Institute of Technology, [2]University Heidelberg, [3]University Mainz

Highlights of MuPix8

- Large area: 1 x 2 cm²
- 180 nm High Voltage CMOS (HVCMOS) technology on high resistivity wafers (AMS aH18)
- 128 columns, each with 200 pixels, monolithic readout
- Fast hit scan logic
- New readout electronics with several readout modes for timewalk correction
- Efficieny greater than 99.6%

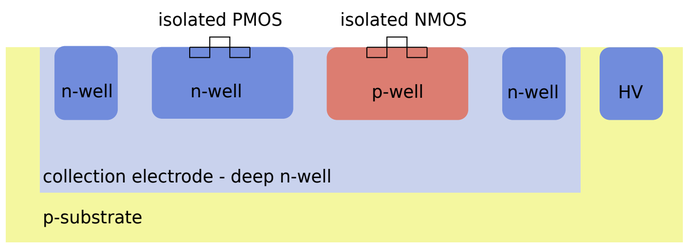


Application of the MuPix in the Mu3e experiment

- Requirements of the pixel detectors for the Mu3e experiment at PSI
  - Vertex resolution: ~100 µm
  - Time resolution: 20 ns
  - Detector thickness: max. 50 µm
- Can be achieved by HVCMOS technology

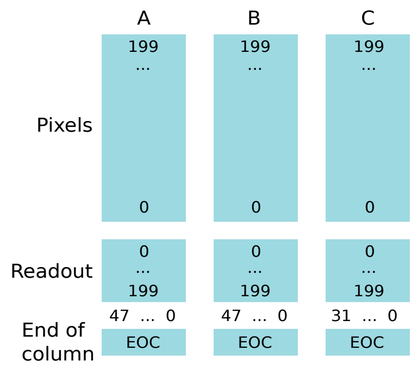
HVCMOS Technology

- CMOS monolithic pixel sensors with depleted sensitive volume
- Monolithic means the sensor and the readout electronics are integrated on a single silicon chip
- High voltage usage for fast charge collection and larger active area



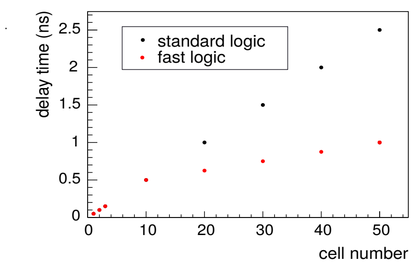
Structure of MuPix8

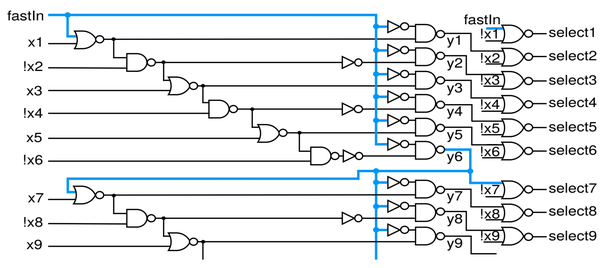
- The pixel matrix is divided into three submatrices with different signal transmission modes from pixel to readout
- Submatrix A uses voltage signal transmission, submatrices B and C use current signal transmission



Fast Hit Scan Logic

- MuPix8 uses a scan logic which allows a faster search for a hit
- The scan logic works with pixel groups, if a hit is detected in a group the following groups are skipped
- This leads to a faster hit transmission to the end of column



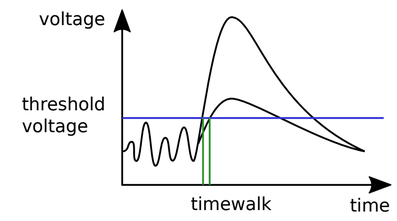


New readout electronics with several readout modes

- The MuPix8 has new readout electronics for timewalk correction
- Two comparators for each pixel are used

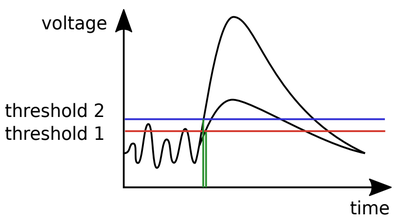
Timewalk Problem

- The timestamp marks when the signal crosses the threshold voltage, however there is a delay between the particle hit and the threshold crossing moment
- This delay depends on signal amplitude and is called timewalk
- The standard method for the timewalk correction is a ToT (time over threshold) measurement



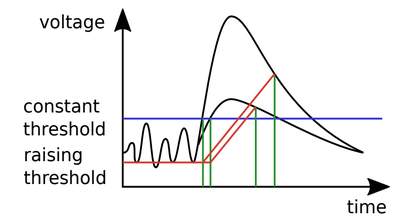
Mode with two threshold voltages

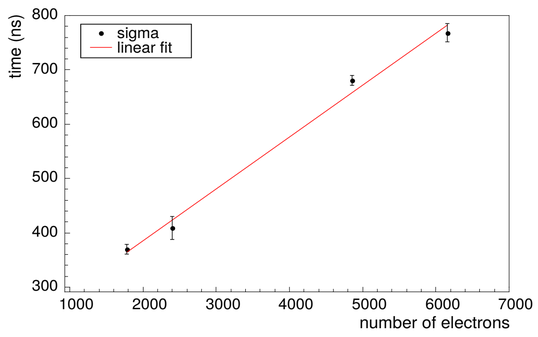
- The lower threshold voltage delivers a time-stamp with less timewalk
- The higher threshold voltage confirms that the first timestamp belongs to a signal
- Advantage: less timewalk, small noise rate



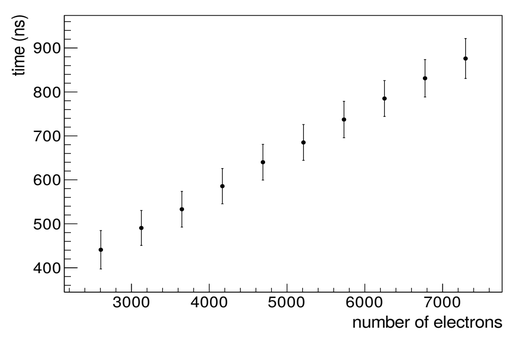
Mode with ADC threshold voltage

- The constant threshold delivers the timestamp and activates the ramp signal
- The ramp signal crosses the signal level, delivering a second timestamp for amplitude information
- Advantage: better linearity, less noise





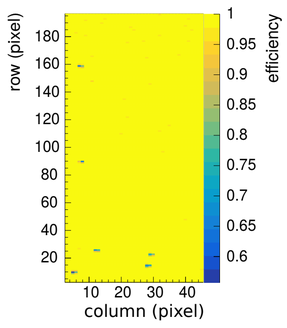
X-ray calibration with Fe, Zn, Mo, Ag targets

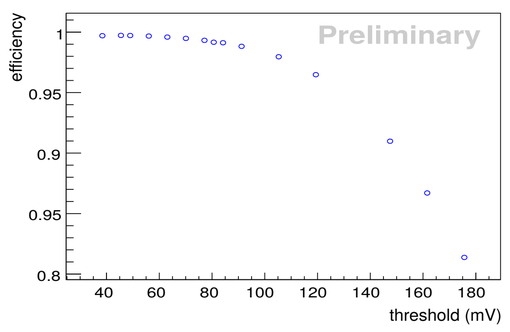


test signal callibration for linearity check

Efficiency

- In 2017, first testbeams with MuPux8 at DESY and at CERN were performed
- Results show a high efficiency > 99.6% at 125 MHz clock





Outlook

- A new HVCMOS pixel detector (MuPix9) has been submitted in 2017 to test the following improvements:
  - New slow control
  - New power regulators, to evaluate serial powering concepts
- Design of 2 x 2 cm² chip ongoing

Alena Weber Email: alena.weber@partner.kit.edu Phone: +49 721 608 26304