Testbeam Measurements for the Mu3e Experiment

Testing a HV-MAPS Pixel Sensor Prototype

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Abstract

The Mu3e[1] experiment searches for the lepton flavor changing decay μ → eee aiming for a sensitivity of 1 in 10^{16} decays, four orders of magnitude better than previous searches by the SINDRUM experiment. This sensitivity is achieved by a novel experimental design based on silicon pixel detectors and scintillating fibers and tiles. The principal component of the experiment is a high precision tracking detector based on thin high voltage monolithic active pixel sensors (HV-MAPS) optimized for the low momentum decay electrons.

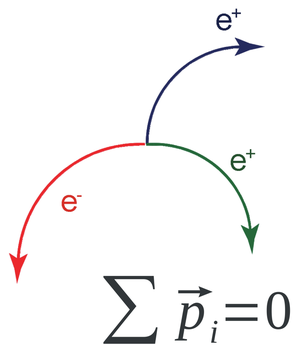
We present results from testbeam measurements with the MuPix4 HV-MAPS prototype performed in October 2013 at DESY using a 1-6 GeV electron beam.

1) *arXiv:1301.6113 [physics.ins-det]*

Requirements

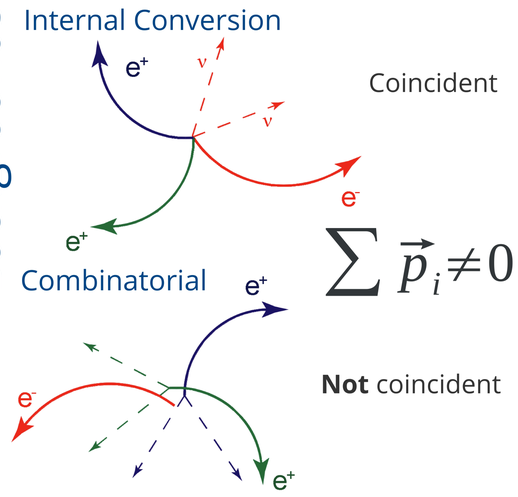
- High rates
- Excellent momentum resolution
- Great vertex resolution
- Good timing resolution
- Extremly low material budget

Signal μ → eee

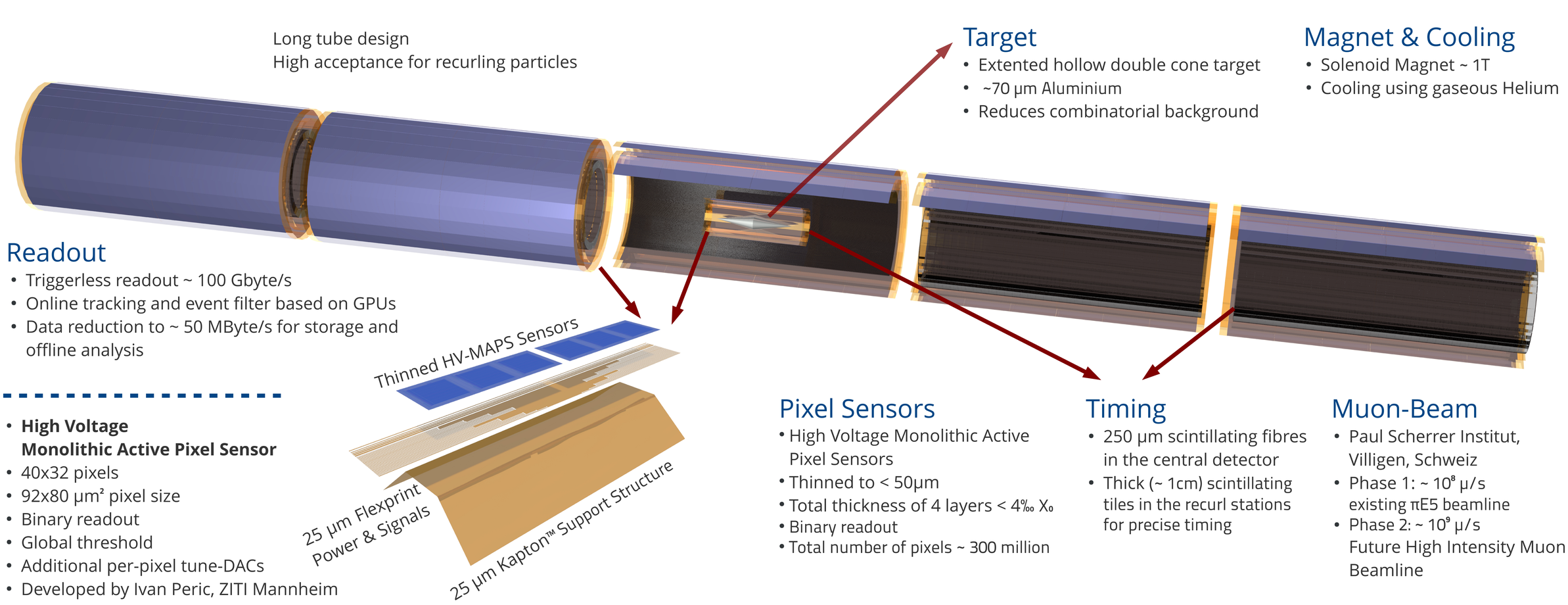


- Single vertex
- Coincident
- Vanishing total momentum

Backgrounds



Mu3e Detector Concept



Target

- Extented hollow double cone target
- ~70 µm Aluminium
- Reduces combinatorial background

Magnet & Cooling

- Solenoid Magnet ~ 1T
- Cooling using gaseous Helium

Readout

- Triggerless readout ~ 100 Gbyte/s
- Online tracking and event filter based on GPUs
- Data reduction to ~ 50 MByte/s for storage and offline analysis

Pixel Sensors

- High Voltage Monolithic Active Pixel Sensors
- Thinned to < 50µm
- Total thickness of 4 layers < 4‰ X_0
- Binary readout
- Total number of pixels ~ 300 million

Timing

- 250 µm scintillating fibres in the central detector
- Thick (~ 1cm) scintillating tiles in the recurl stations for precise timing

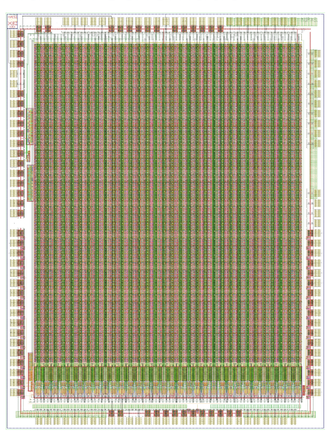
Muon-Beam

- Paul Scherrer Institut, Villigen, Schweiz
- Phase 1: ~ 10^8 μ/s existing πE5 beamline
- Phase 2: ~ 10^9 μ/s Future High Intensity Muon Beamline

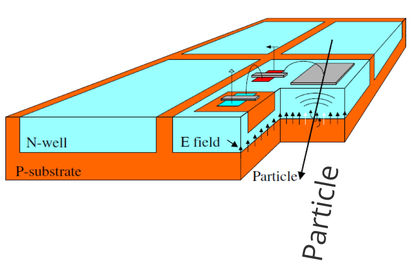
MuPix4 Prototype

- **High Voltage Monolithic Active Pixel Sensor**
- 40x32 pixels
- 92x80 µm² pixel size
- Binary readout
- Global threshold
- Additional per-pixel tune-DACs
- Developed by Ivan Peric, ZITI Mannheim

MuPix4 Schematic

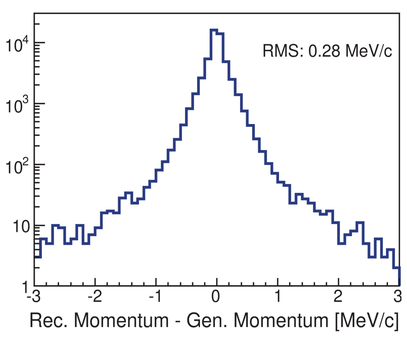


The HV-Maps Principle

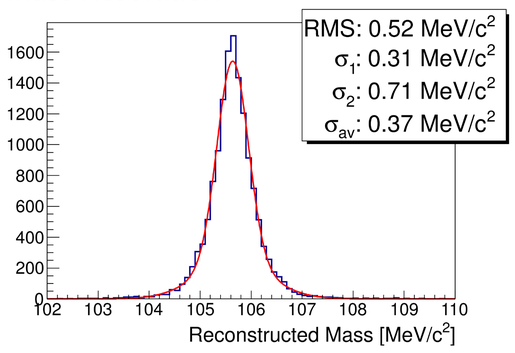


Expected Performance in Phase 2 (simulated)

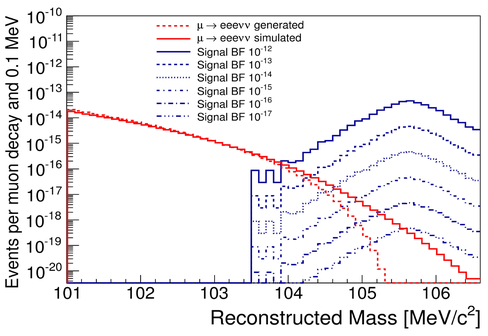
Single Track Momentum Resolution



Signal Decay Mass Resolution

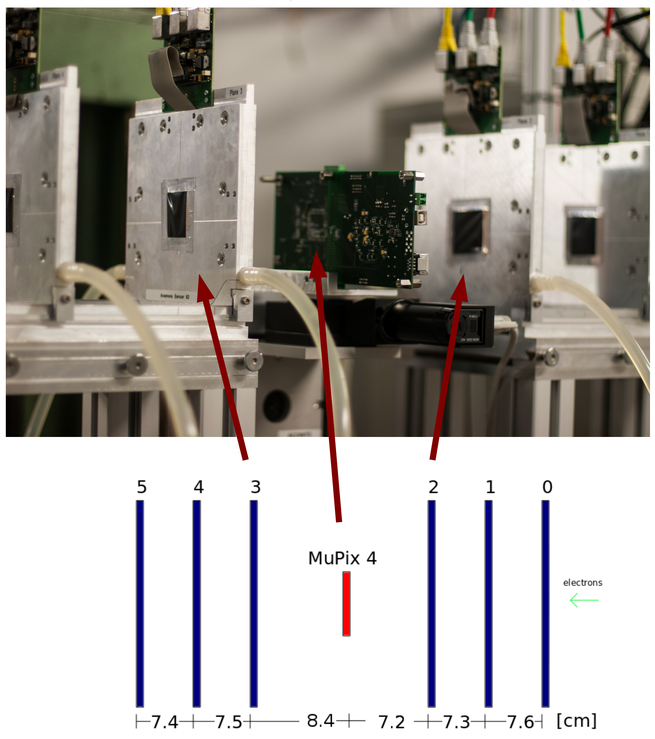


Branching Ratio Sensitivity



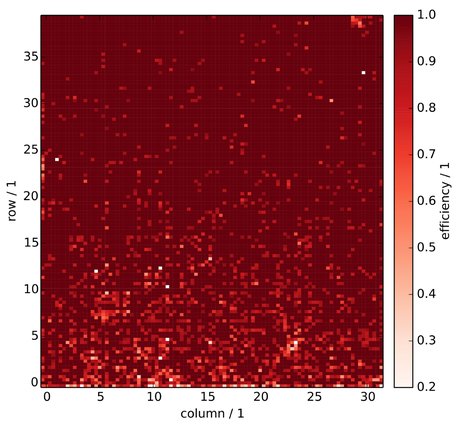
Testbeam Setup at DESY

Aconite Beam Telescope and MuPix4 Prototype



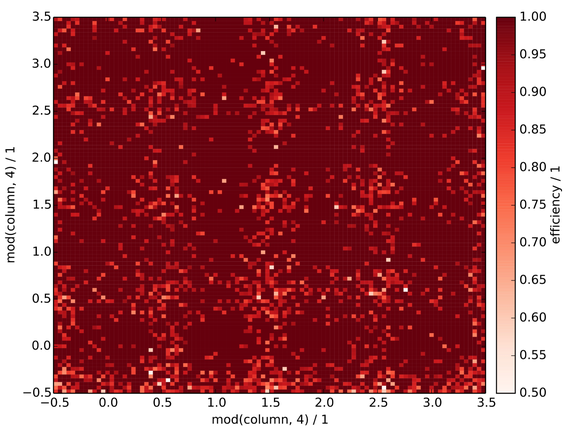
Testbeam Results

Full Sensor Efficiency



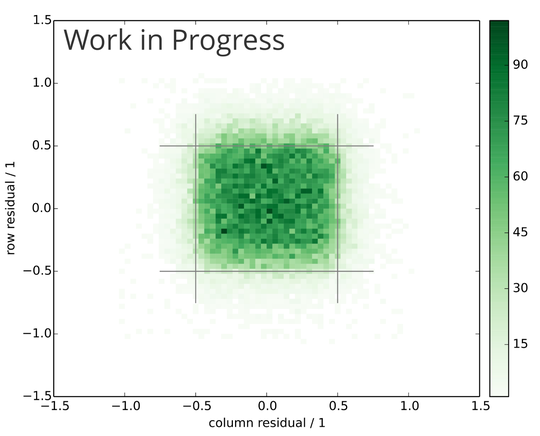
- First working prototype
- High efficiency ~ **99%** almost everywhere
- Small non-uniformity due to non-optimal tuning

Sub-Pixel Efficiency (4x4)



- Efficiencies folded to 4x4 submatrix
- **No** visible Substructure
- Small inefficiencies at pixel edges / corners

Resolution / Pixel Uniformity



- Resolution as predicted by size of a single pixel (gray markers)
- Uniform response

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