The MuPix Telescope

Integrating a novel HV-MAPS chip into a tracking detector system

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Motivation

New physics is predicted to be observable in lepton flavour violation and many theories predict measurable violations also in charged currents. The decay of a muon into three electrons is currently excluded to a branching ratio (BR) of 10^{-12} by SINDRUM[1]. Any observation would be a clear sign for new physics. New detector technologies allow for a more precise measurement. Mu3e is going to search for this decay with a target sensitivity of 1 in 10^{16} decays.

A continous high rate beam at PSI will provide up to 10^8 muons/s (10^9 muons/s on future beamline), which will be stopped on target. The decay particles are tracked in a constant magnetic field using four thin pixel layers and additional timing detectors.

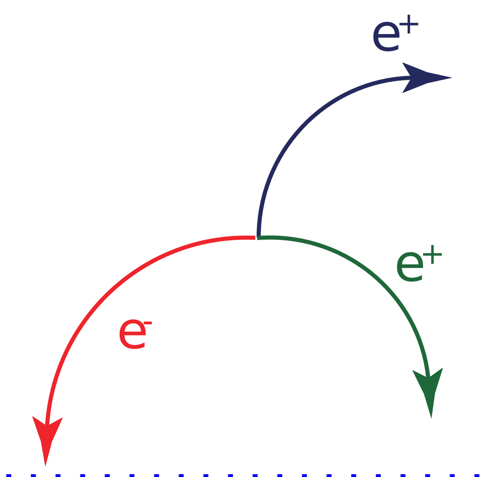
The pixel tracker will be constructed out of a novel high voltage monolithic active pixel sensor (HV-MAPS) technology. For testbeam characterization and intergration studies, a particle tracking telescope was developed.

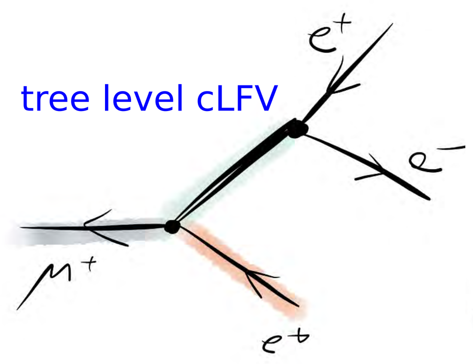
[1] [SINDRUM Collaboration] "Search for the decay muto3e" Nucl. Phys., **B299** 1,1988

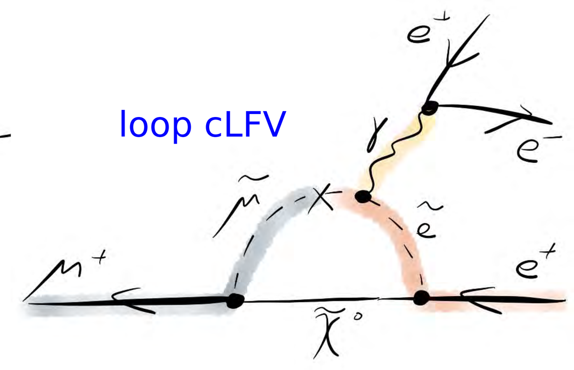
$\mu^+ \rightarrow e^+ e^- e^+$

Signal Topology

- Common vertex
- Coincident in time
- $\Sigma\, p = 0$
- $E < 53$ MeV
- $E_{tot} = m_\mu$







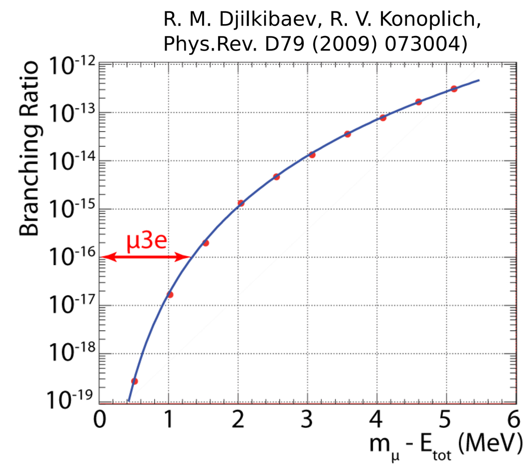
Background

Internal Conversion

$\mu^+ \rightarrow e^+ e^- e^+ \nu_e \nu_\mu$

- $E_{tot} \neq m_\mu$

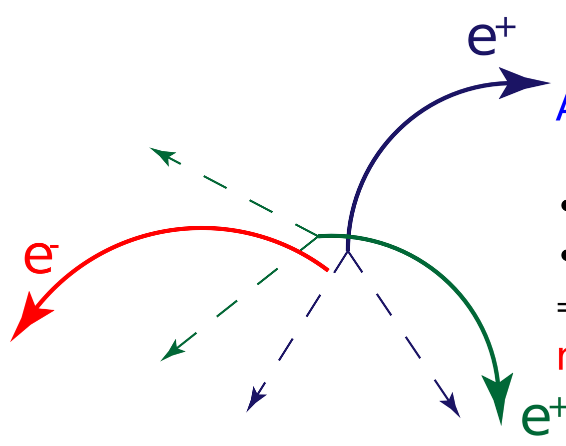
⇒ Suppressed by good momentum resolution



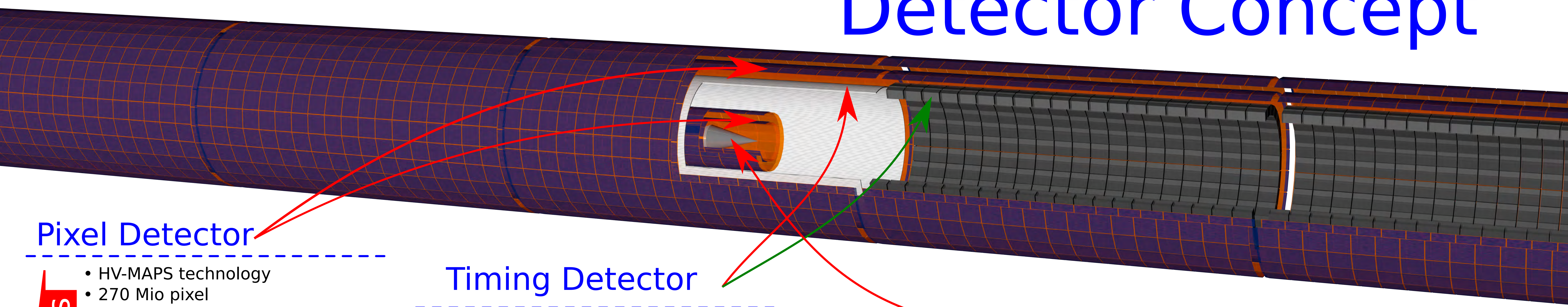
Accidental Background

- No common vertex
- Incoincident in time

⇒ good time and vertex resolution



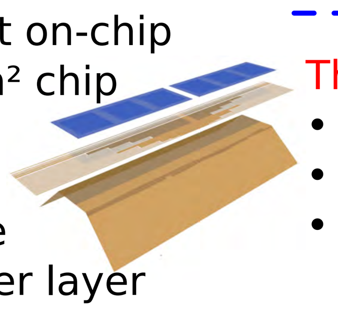
Detector Concept



Pixel Detector

Details

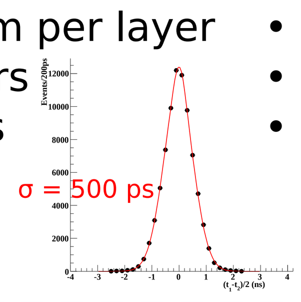
- HV-MAPS technology
- 270 Mio pixel
- Fully integrated readout on-chip
- 80 x 80 µm² pixel, 4 cm² chip
- 50 µm thin
- < 20 ns time resolution
- Kapton™ support frame
- 1 ‰ radiation length per layer



Timing Detector

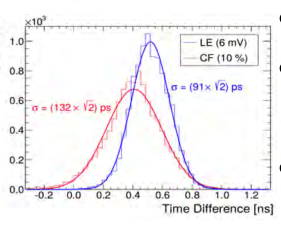
Thin Fibres

- 250 µm per layer
- 3 layers
- 500 ps



Thick Tiles

- 1 cm² per tile
- 100 ps
- Electrons stopped

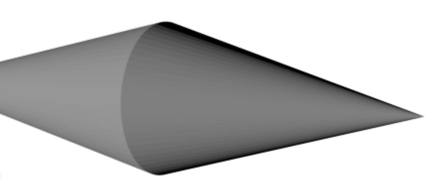


Target

- 75-85 µm Mylar
- Large surface

⇒ vertex separation

- Stopping power: 95 %



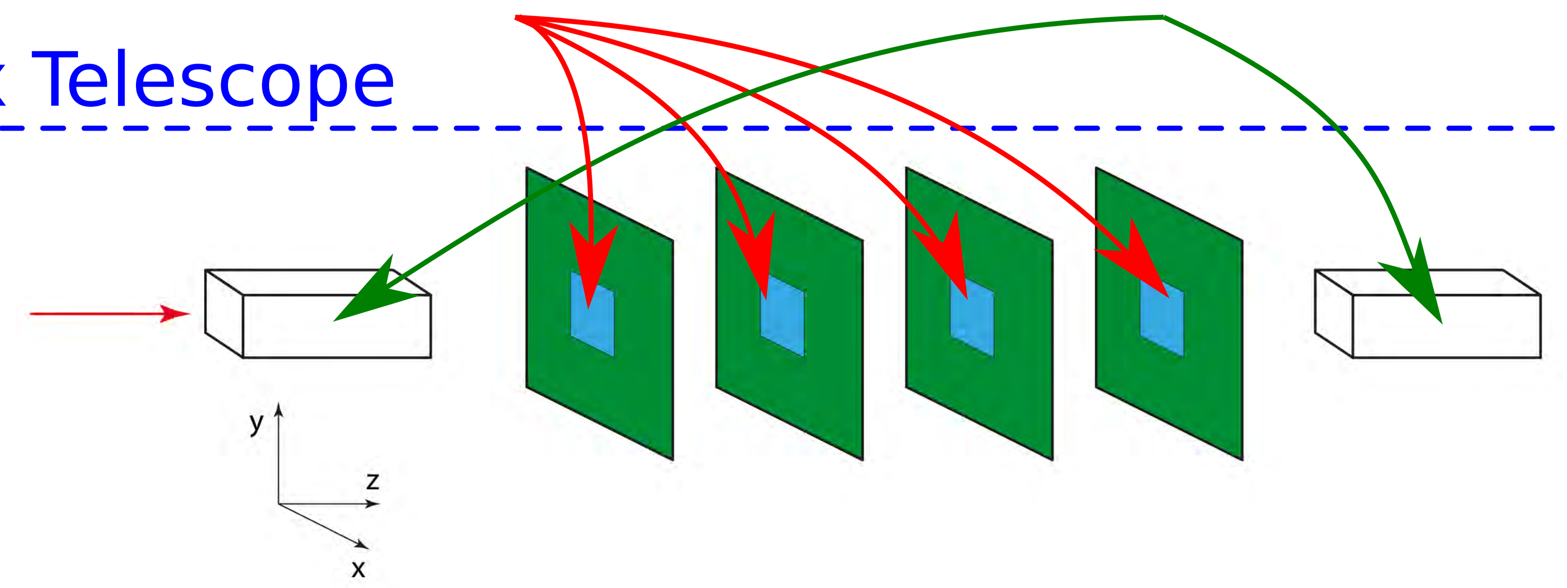
Beam

- Accelerator: HIPA at PSI
- Up to 10^8 µ/s
- p= 28 Mev/c²
- Future beamline: 10^9 µ/s

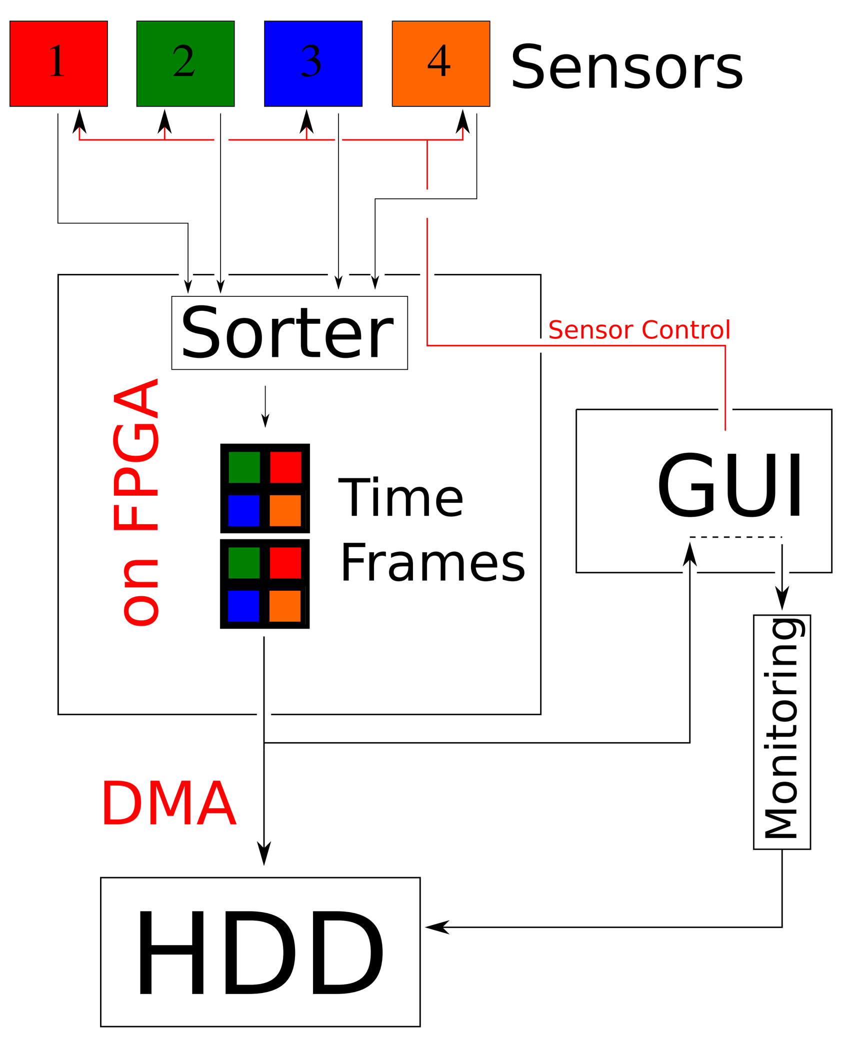
Magnet

- 1 T
- 1m diameter
- 3m long

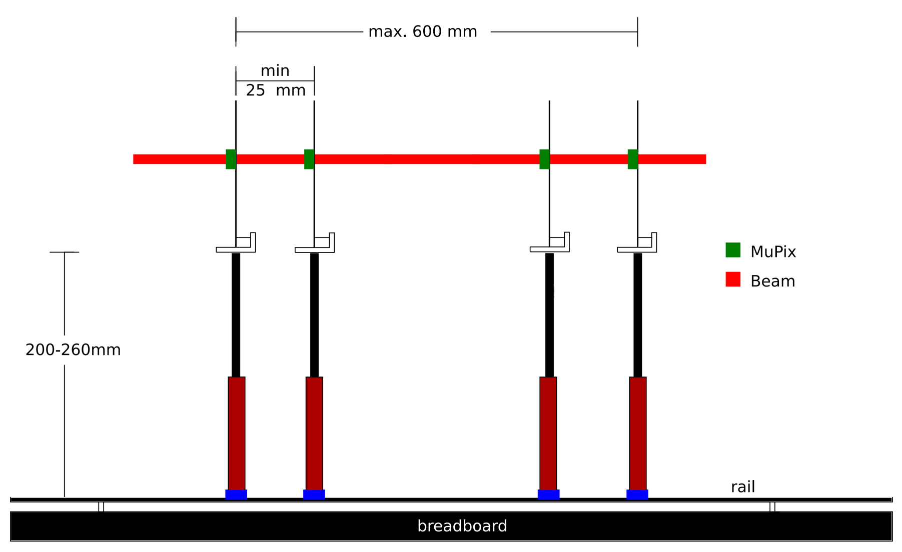
MuPix Telescope



DAQ System



Mechanics



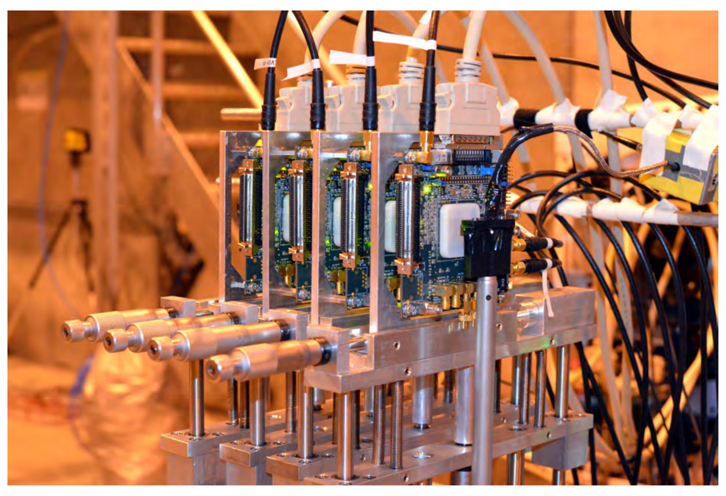
- Based on Thorlabs™ components
- PCB holder custom design
- 10 µm precision in x/y
- Stable and compact

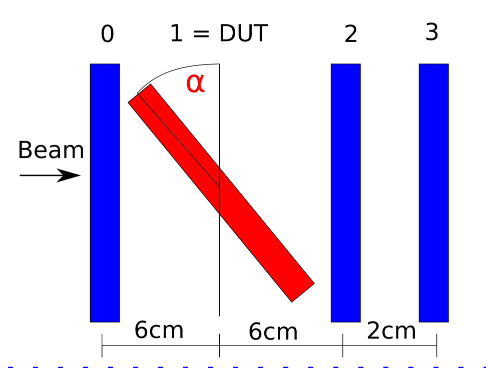
Design Goals

- Track rate capability: 20 MHz
- Time resolution: 10 ns
- Position resolution: 150 µm
- Online tracking
- Tracking efficiency: 90%

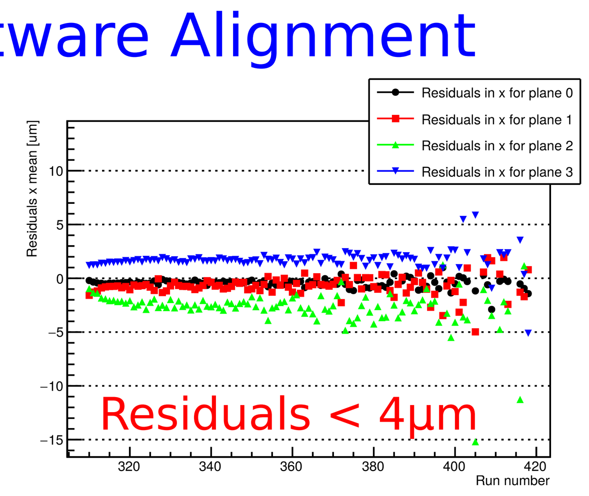
Testbeam Results

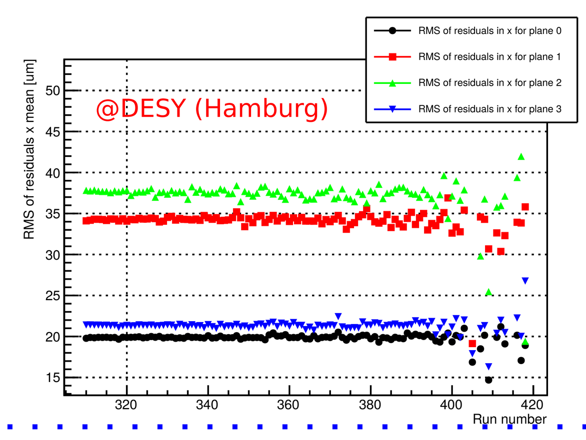
Setup



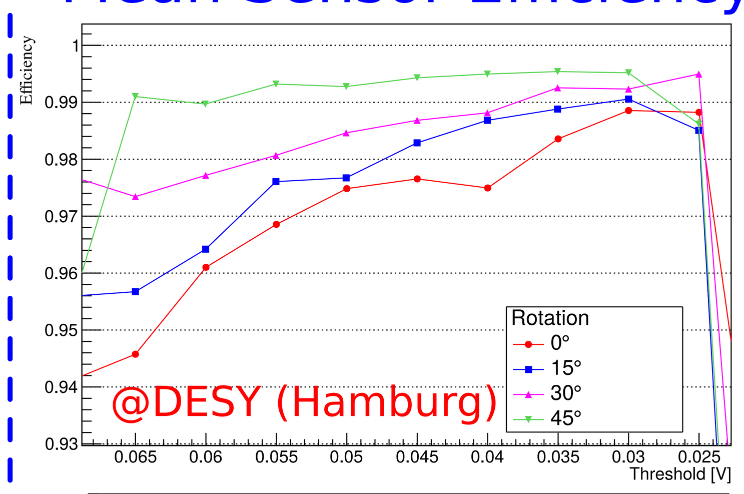


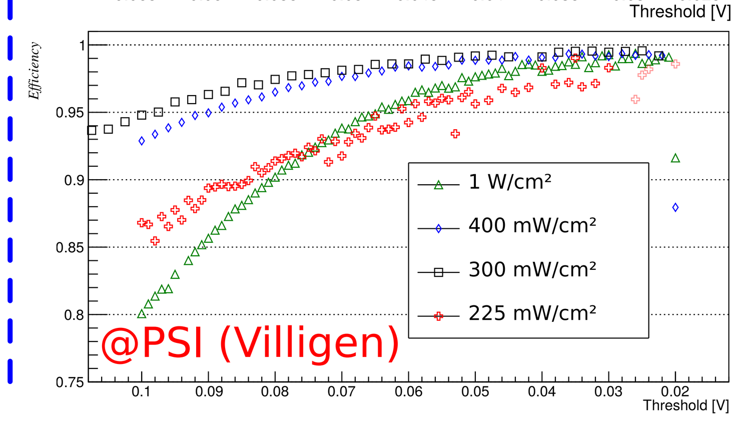
Software Alignment





Mean Sensor Efficiency

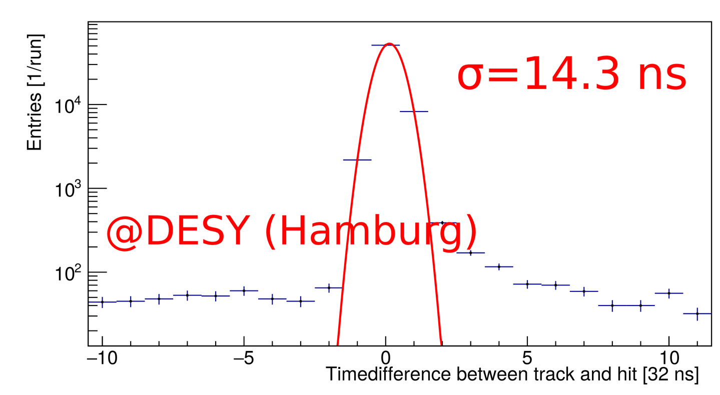




Performance

- Max track rate: 2 MHz
- Mechanical precision: 100 µm
- Automized measurement procedures
- Direct memory access and GPU tracking successfully tested

Time Resolution



Summary & Outlook

Mu3e

- Large scale pixel sensor prototype 2nd quarter 2016
- Detector module by the end of 2016

MuPix Telescope

- Useful tool for integration test and testbeams
- High system efficiency (≈ 99%)
- Evaluate next sensor prototypes

Acknowledgements

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We also like to thank PSI for providing beam time.