High rate electron beam tests with HV-MAPS at MAMI

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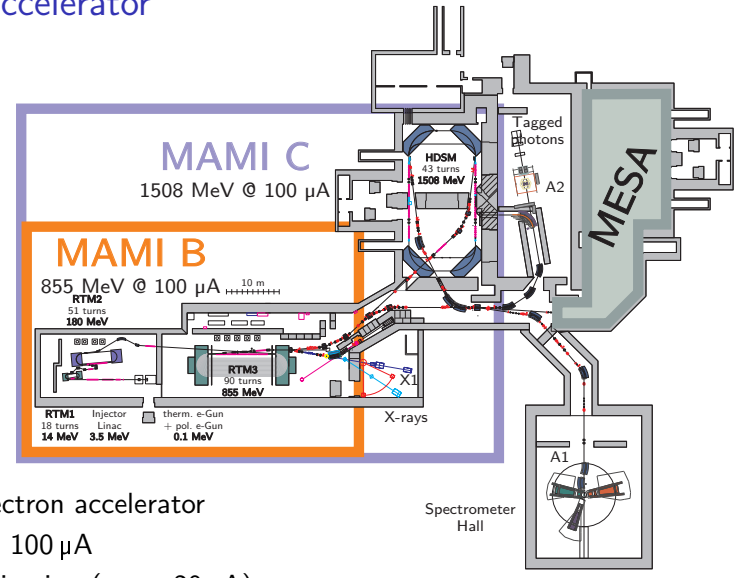
Outline

- Mainz Microtron (MAMI) accelerator
- The MuPix8 prototype
- March 2019 testbeam
- November 2019 testbeam

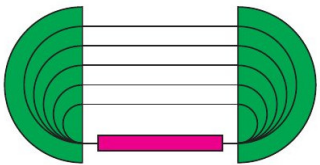
The MAMI accelerator



- 4 stage electron accelerator
- 1.5 GeV at 100 µA
- 82 % polarization (max. 20 µA)

Accelerator stages 1-3 - MAMI-B

- Linear injector
- 3 stage racetrack microtrons
- Energies[MeV]: 14, 180, 855



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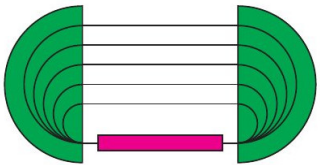
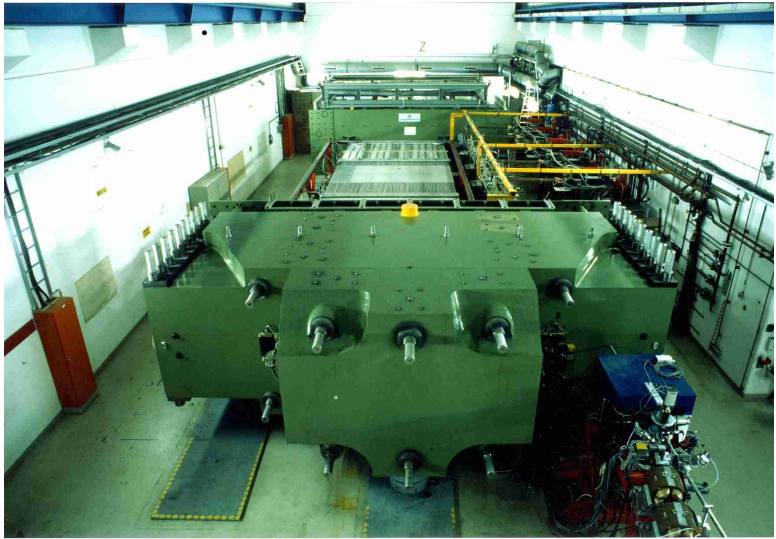
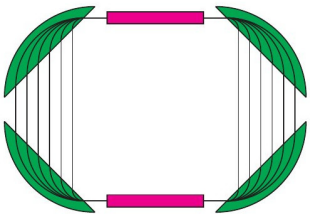
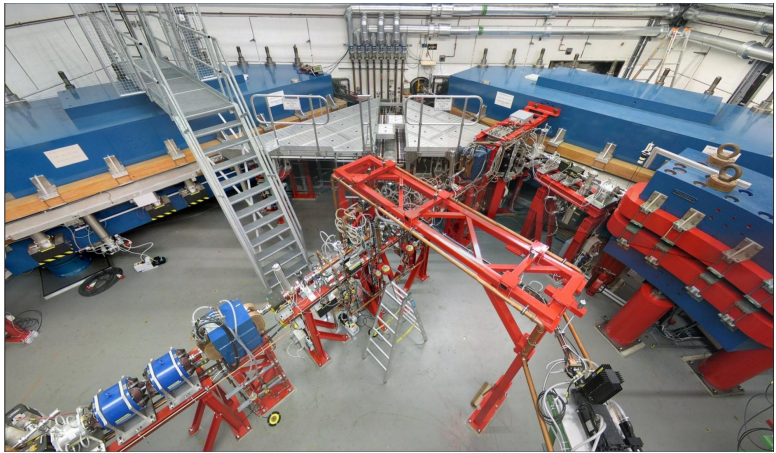




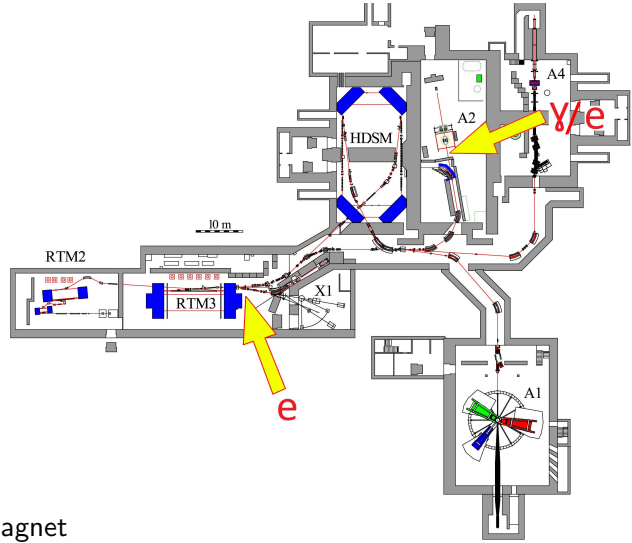
Accelerator stage 4 - MAMI-C

- Harmonic double-sided microtron
- Output energy: 1.5 GeV



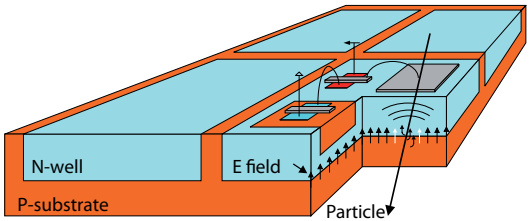


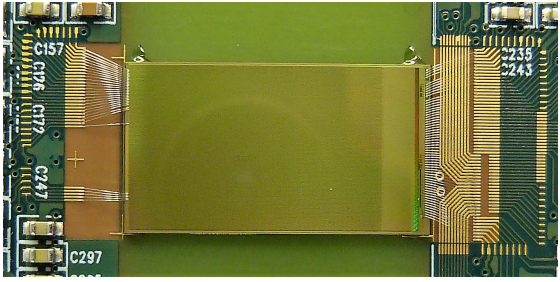
Testbeam locations at MAMI



- A2 hall: tagger magnet
- X1: behind RTM 3

HV-MAPS - MuPix sensor prototype



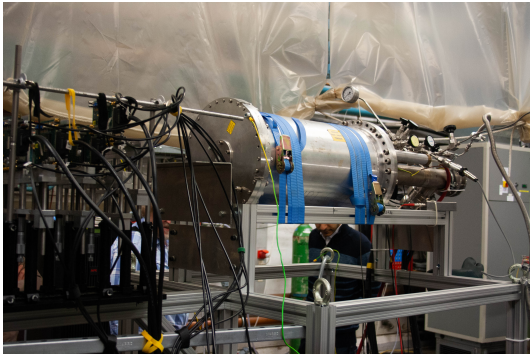


- 180 nm HV-CMOS technology
- Reverse biased up to 90 V
- Readout logic on chip
- Thinnable down to 50 µm

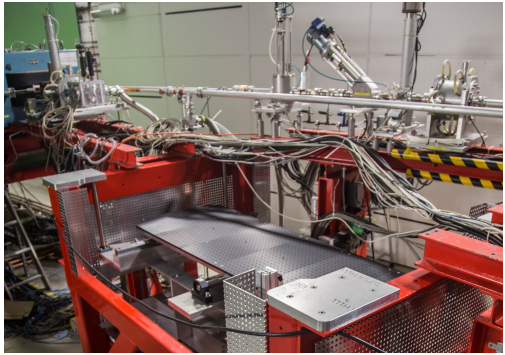
- MuPix8
- Pixel size: $80 \times 81\,\mu m^2$
- Sensor size: $2 \times 1\,cm^2$
- Used in Mu3e, P2, Panda...

2019 testbeams

March - A2

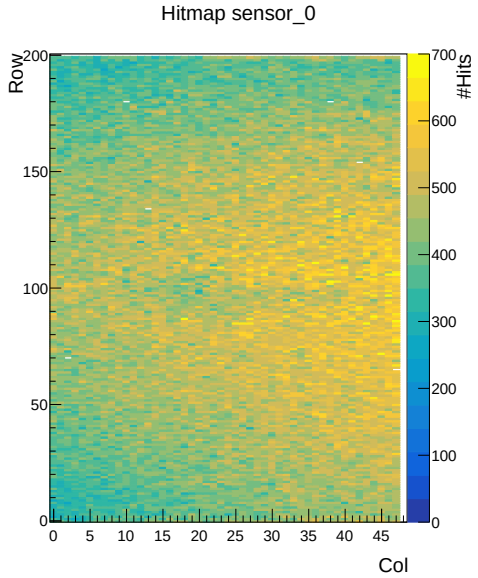


November - X1



Observations from 2018 testbeams

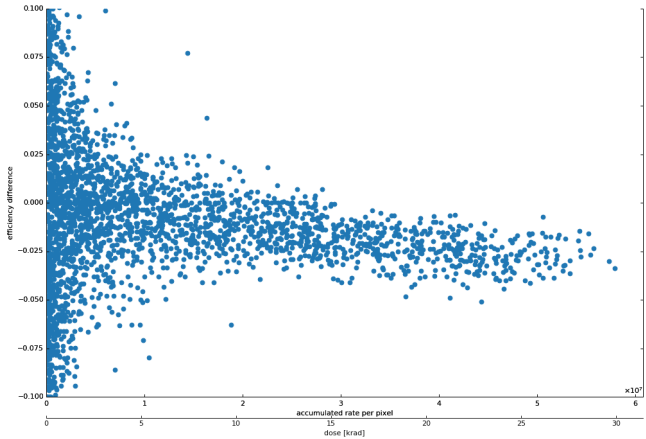
- MuPix8 high rate test (up to 10 MHz)
- observed efficiency loss
- dose/rate dependency?
- hitmap: Sr-90 response after testbeam



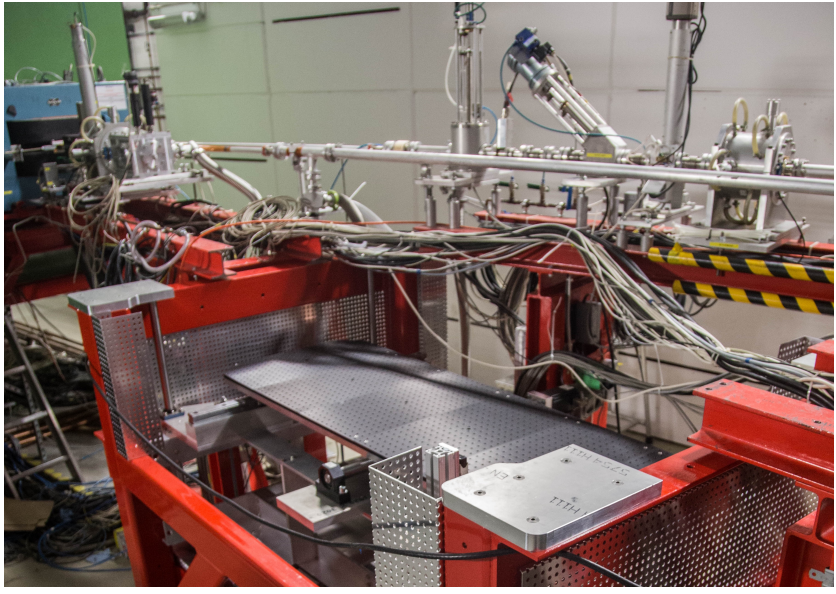
March 2019 testbeam - Efficiency loss versus acumulated hits (dose)

Idea: run at lower rate, accumulated same number of hits

- beam rate: 1 MHz
- 2018: up to 10 MHz

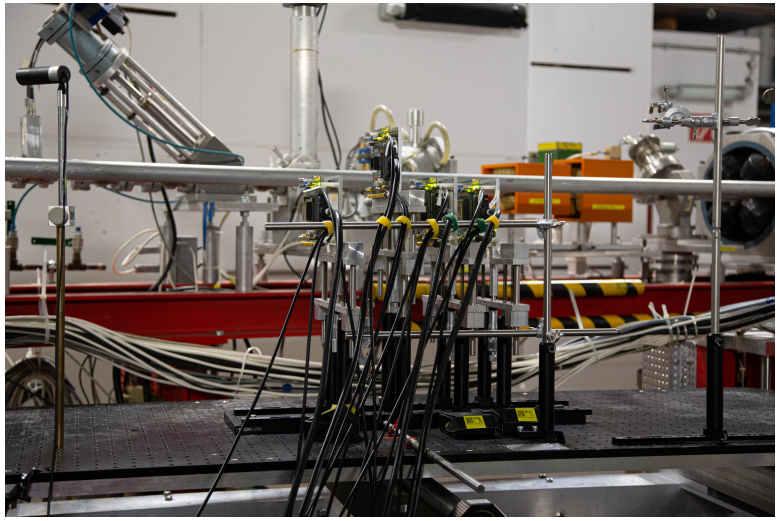


November 2019 testbeam - X1



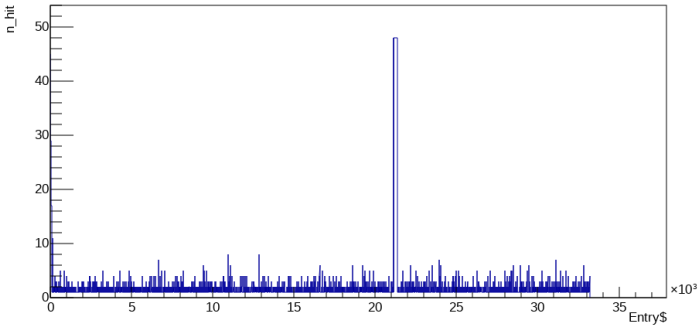
November 2019 testbeam - MuPix8 setup

- MuPix8 telescope reference
- single MuPix8 in pulsed beam
- MuPix8 telescope ref. again
- also: MuPix7, AtlasPix



November 2019 testbeam - Pulsed electron beam

- square pulses, 40 µs
- beam current $<$250 nA
- simulate beam loss
- shared with Belle II group, testing switcher ASIC

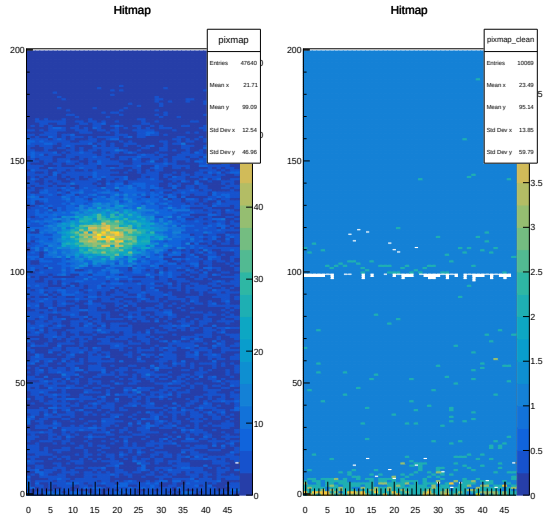


Number of hits per readout frame

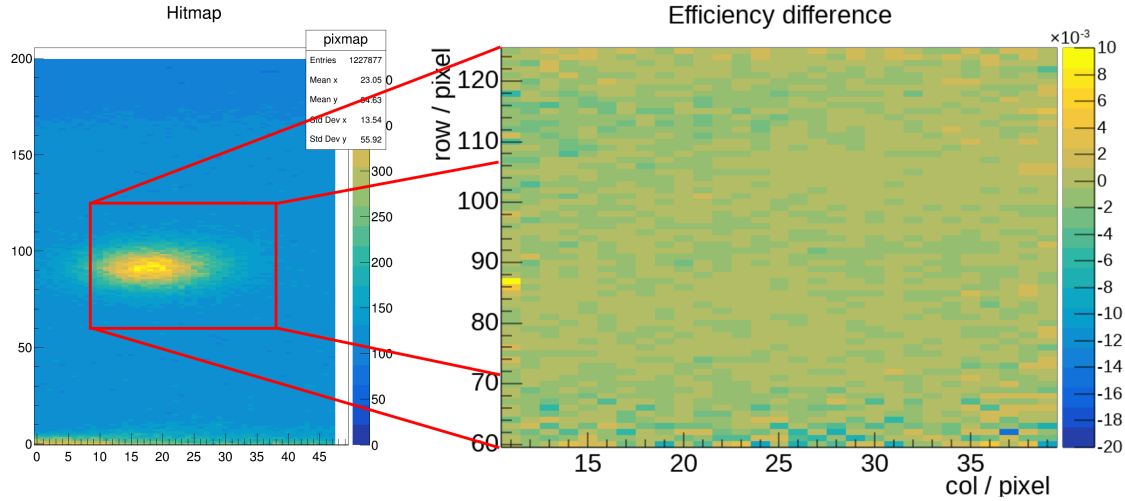
November 2019 testbeam - Readout saturation

MuPix8 readout frame

- columnwise RO
- always start from lower rows (digital)
- hits in upper rows lost

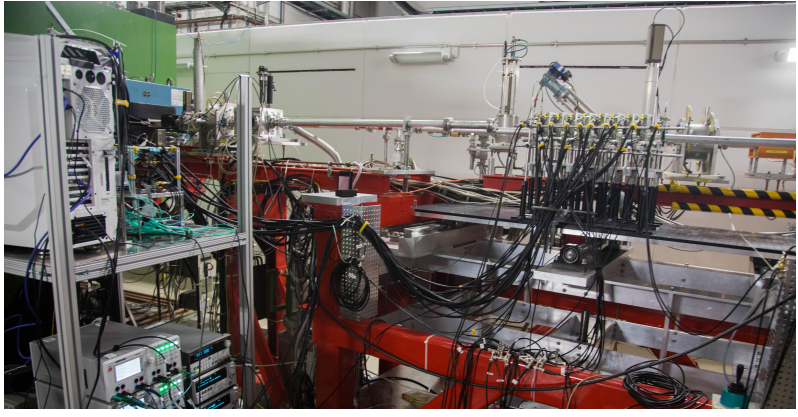


November 2019 testbeam - No efficiency loss observed



Summary

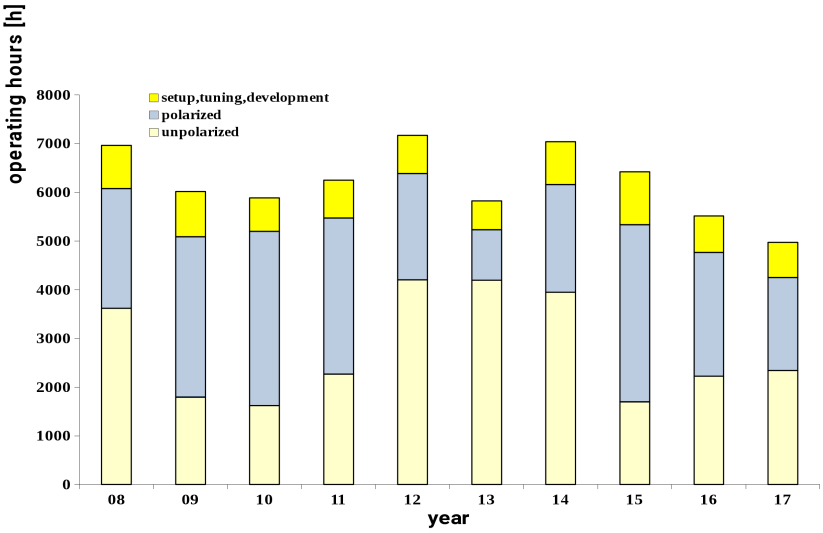
- MAMI provides high intensity electron beam up to 1.5 GeV
- 2 testbeams with HV-MAPS conducted in 2019
- dose dependency of energy loss for MuPix8
- no efficiency loss for pulsed beam observed



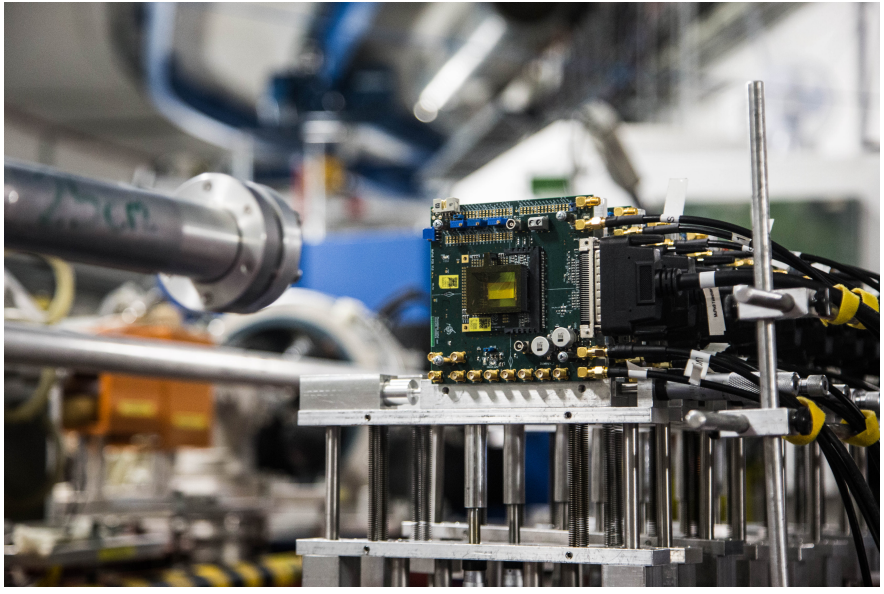
Section 2

Backup

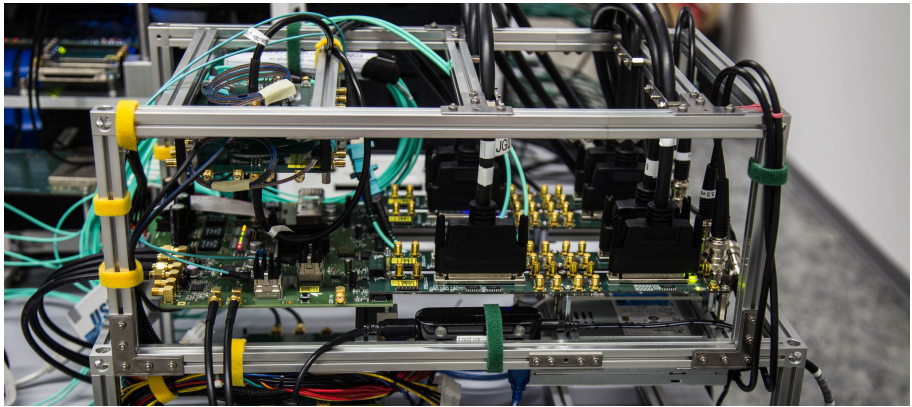
MAMI operation



High rate electron testbeam

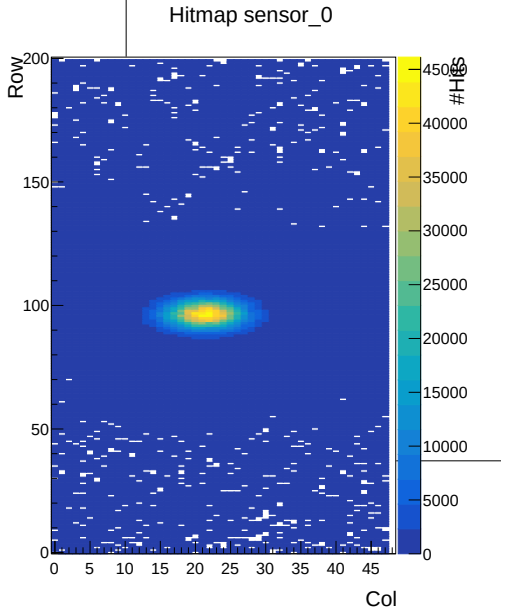


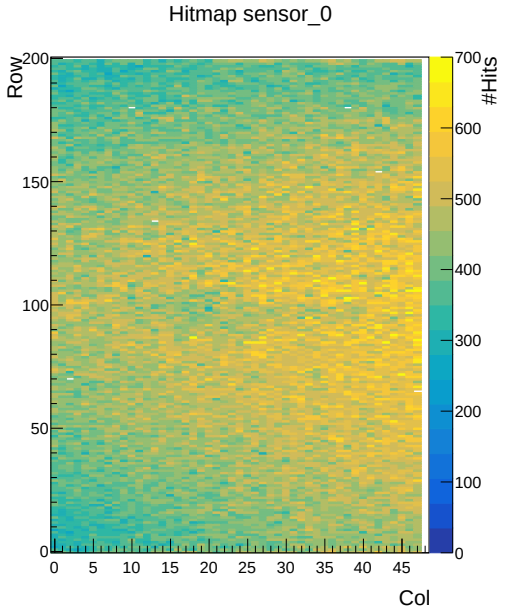
High rate electron testbeam



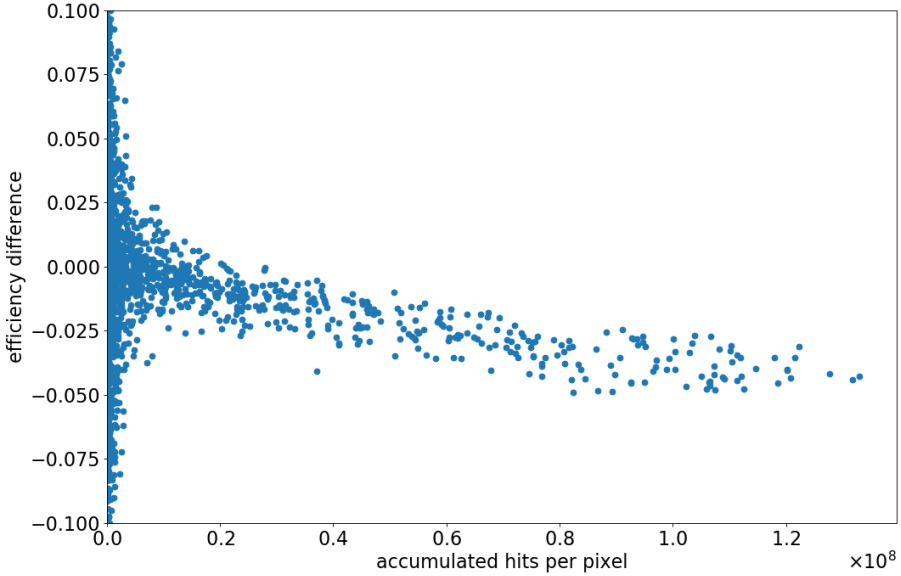
- Max. sensor rate: 7 MHz
- mu3e frontend RO board prototype tested

High rate electron testbeam - observations

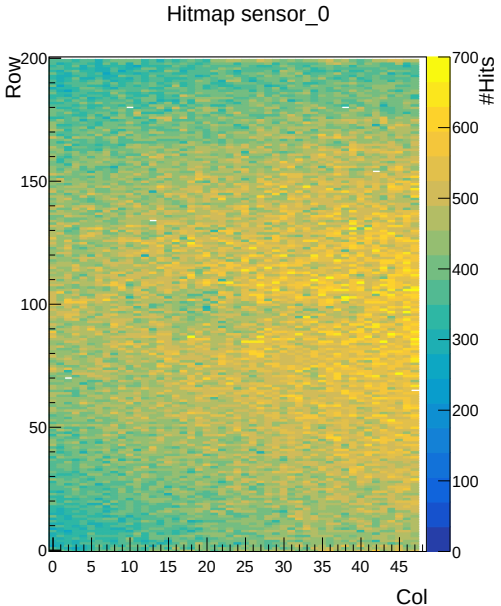


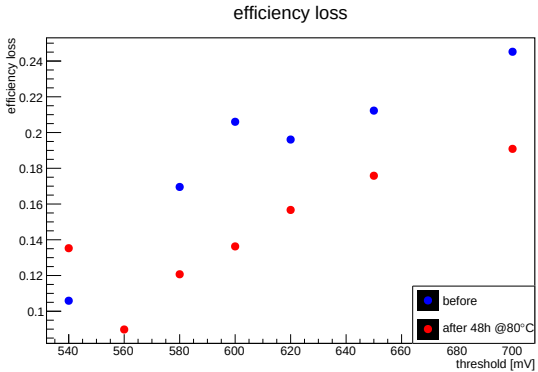


High rate electron testbeam - efficiency analysis

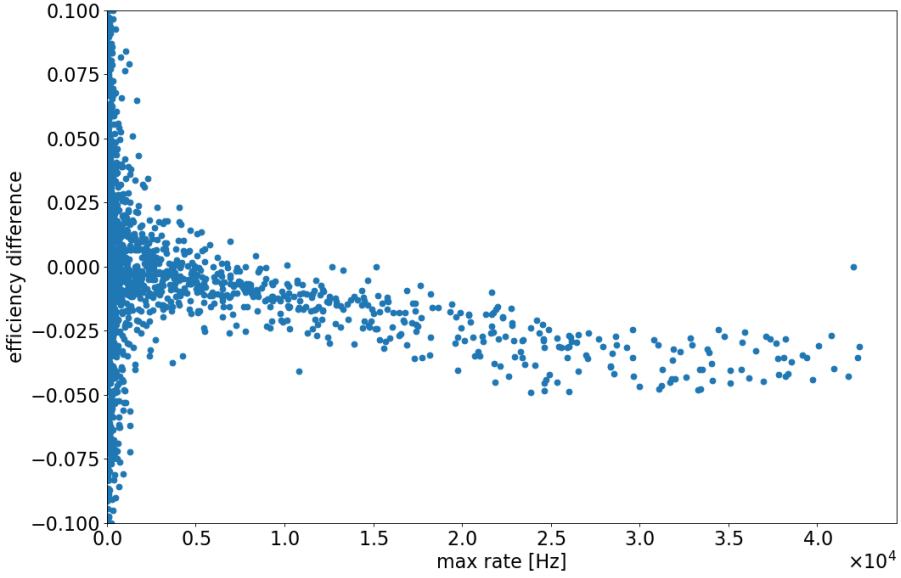


High rate electron testbeam - laboratory measurements

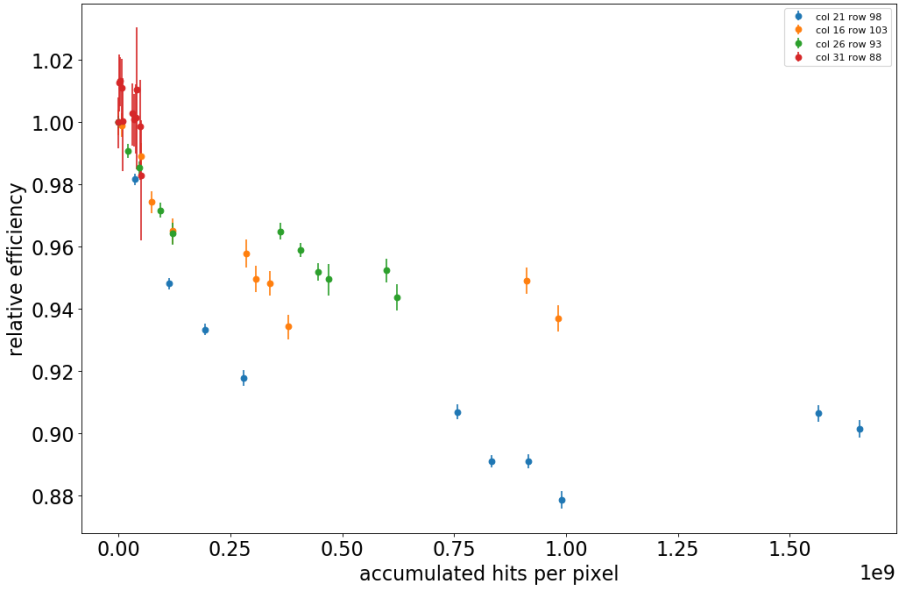




Backup - Max. rate

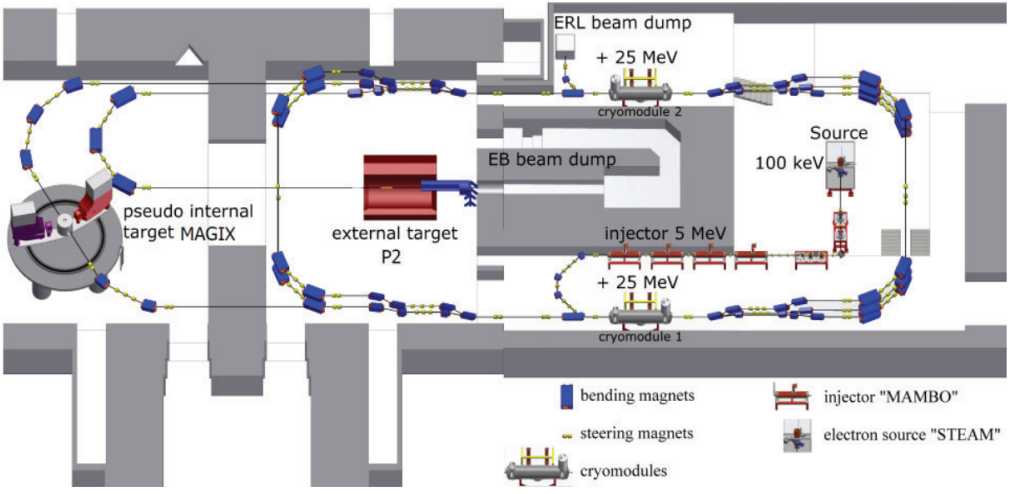


Backup - Pixel history

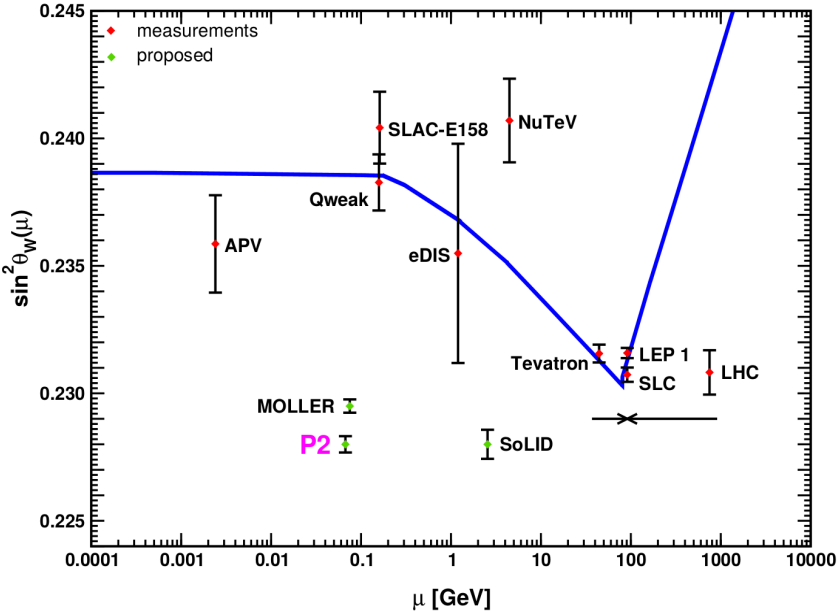


Backup - MESA

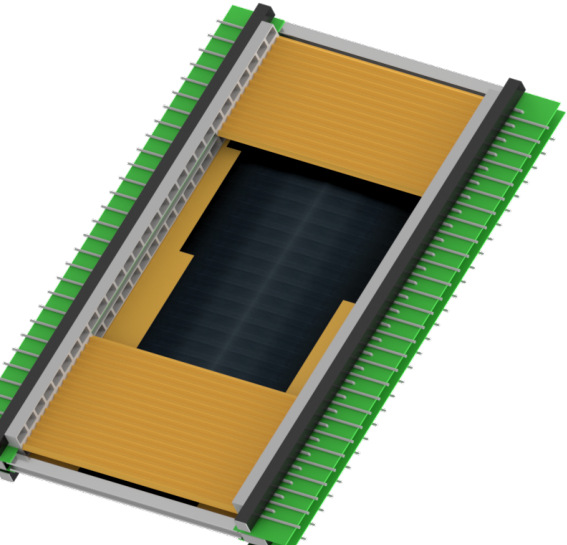
- Mainz Energy Recovering Superconducting Accelerator **(MESA)**
- 2 modes, up to 155 MeV, 85 % polarization



Backup - Weak Mixing Angle



Backup - P2 tracking detector



- Pixel sensors, electronics, gaseous helium cooling, mechanical support
- Low material budget
- 2×4 modules, double layers, 300 sensors per layer