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SI LAB
Silizium Labor Bonn

A combined Mimosa26 and ATLAS FE-I4 test beam telescope with parallel triggerless readout

M. Daas, T. Hemperek, T. Hirono,
F. Hügging, J. Janssen, H. Krüger,
D-L. Pohl, P. Wolf and N. Wermes

Physikalisches Institut der Universität Bonn

BMBF-Forschungsschwerpunkt
ATLAS-EXPERIMENT

Physik bei höchsten Energien mit dem ATLAS-Experiment am LHC

FSP 103
ATLAS

Motivation

- Test beam is tedious work
- Beam time is always scarce
- Many things can go wrong
- Parameter spaces get bigger
  - → Gather more statistics in less time
  - → Higher event rates

→ Fast readout

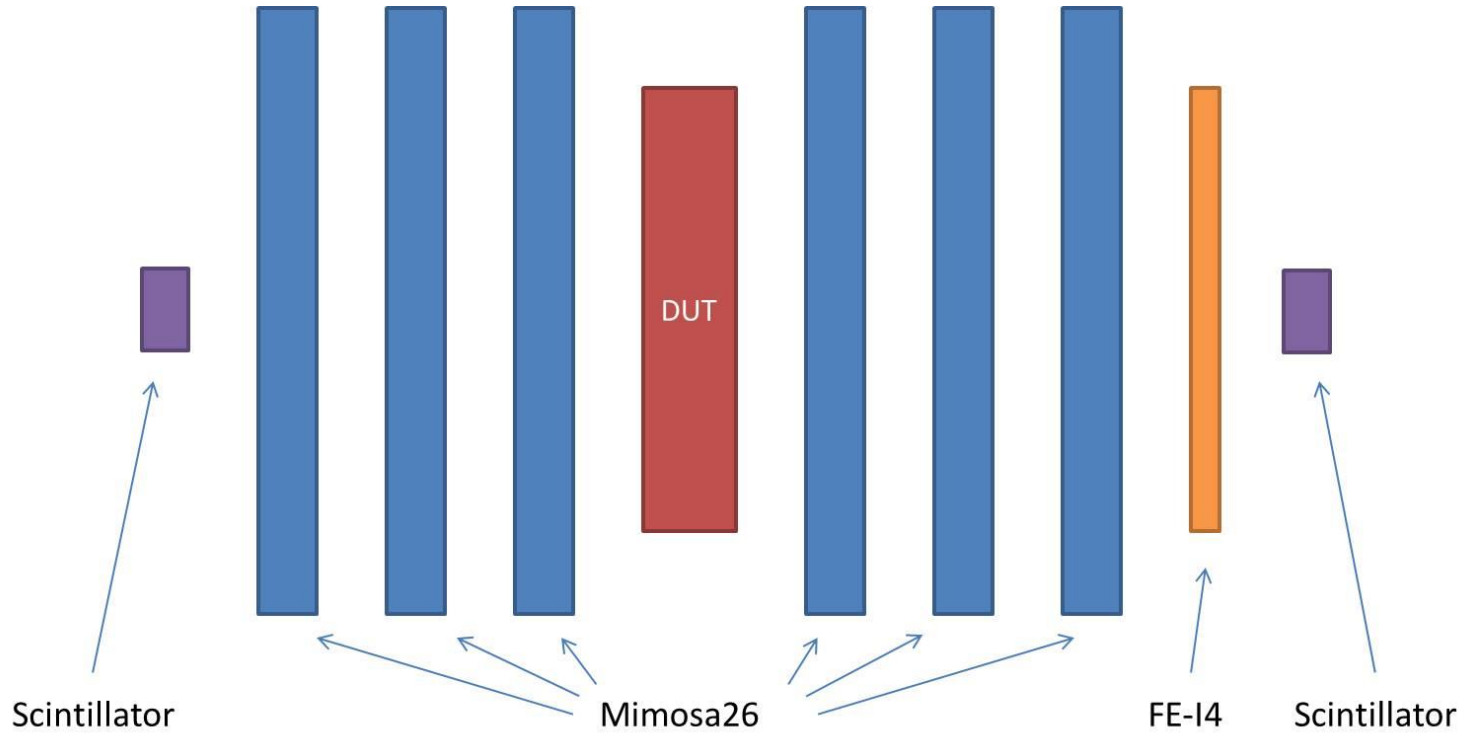
- Test beam areas can be narrow and difficult to access
- Remove as many independent parts as possible

→ Compact setup

Our goals

- Good spatial resolution → Mimosa26 based telescope
- Good timing resolution → ATLAS FE-I4 reference
- Reusing EUDET / AIDA hardware
- ROI support

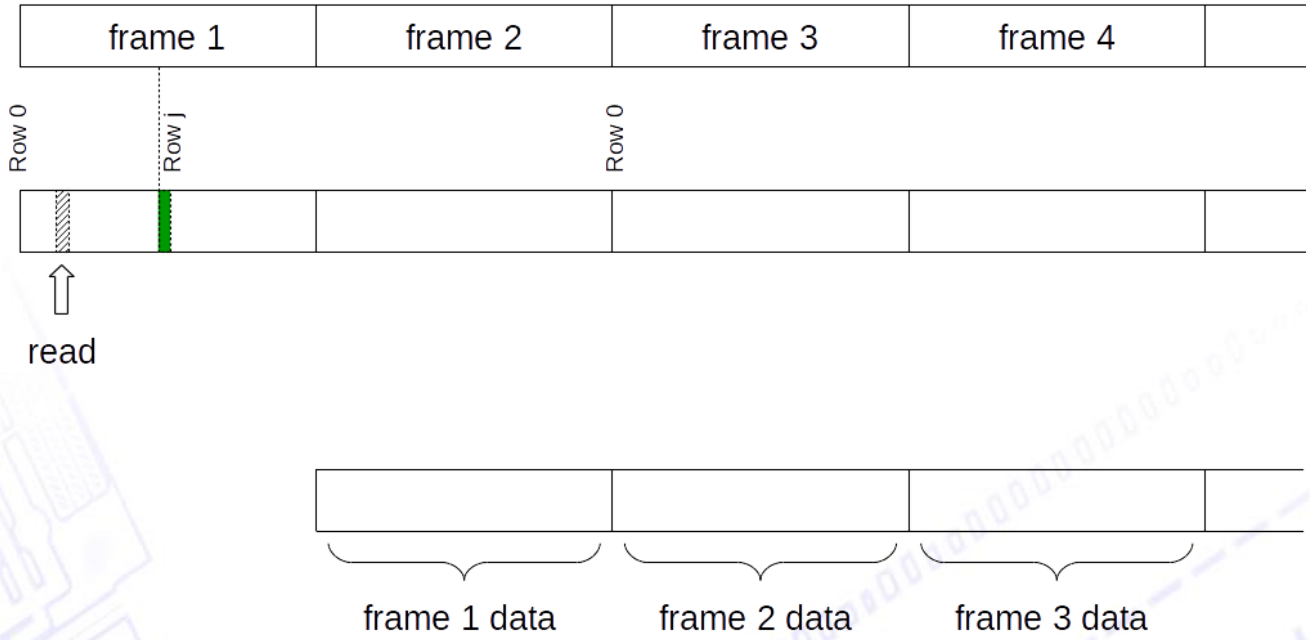
ANEMONE - A Nice EUDET Mimosa Bonn Telescope



- 6 Mimosa26 planes for spatial resolution
- ATLAS FE-I4 timing reference plane
- Scintillator for FE-I4 triggering and track selection
  - Using TLU

Triggered Rolling Shutter Readout

- Trigger → Rolling shutter readout of Mimosa26 planes
- One frame takes 115 µs
- Maximum rate: 1 trigger / 2 frames



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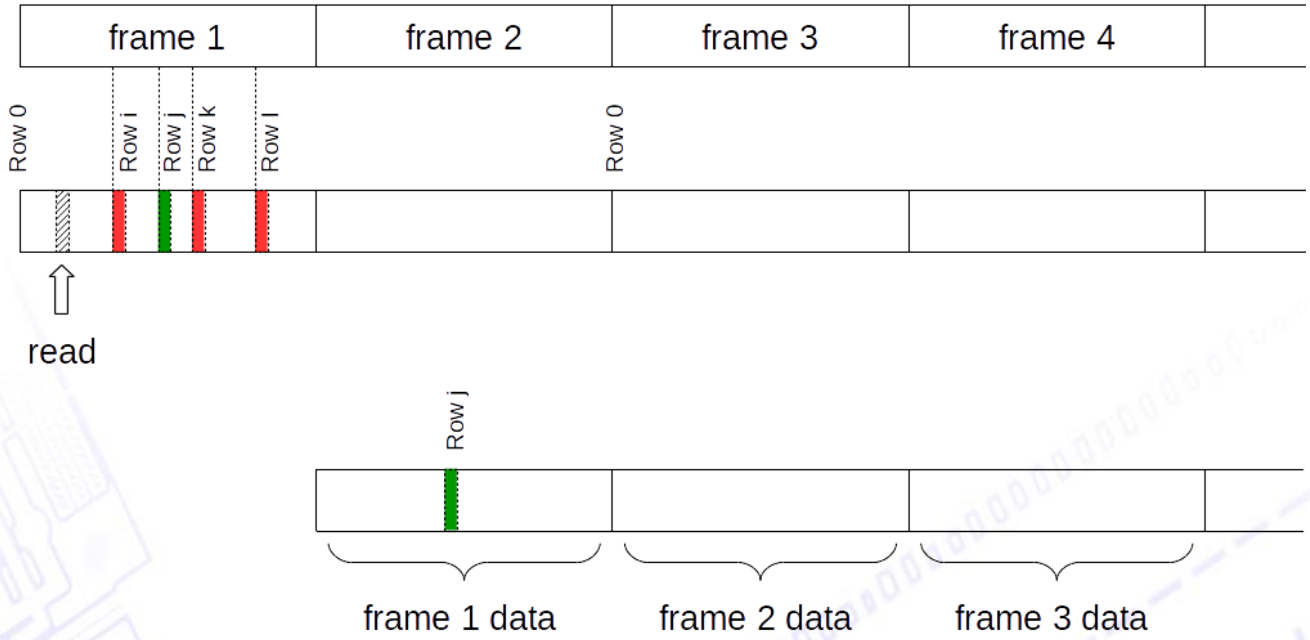
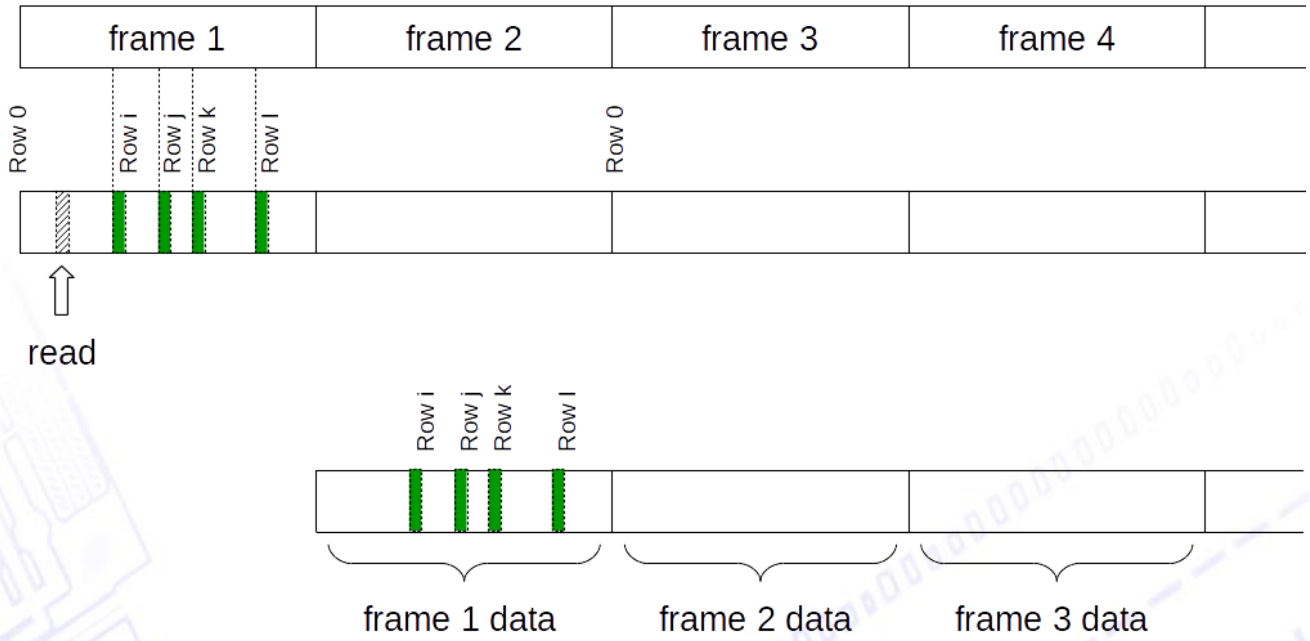


New Triggerless Readout

- Continuous rolling shutter readout of Mimosa26
- Asynchronous …
  - merging of frame n and frame n+1 data
  - matching of FE-I4 data to Mimosa26 data



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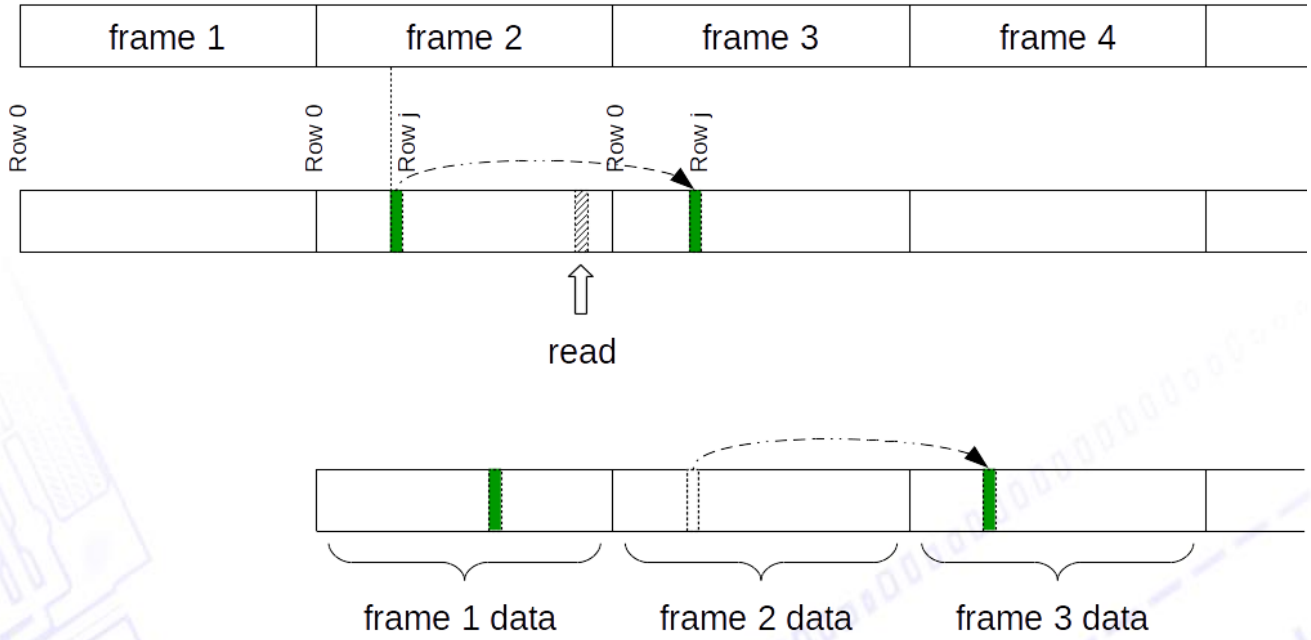

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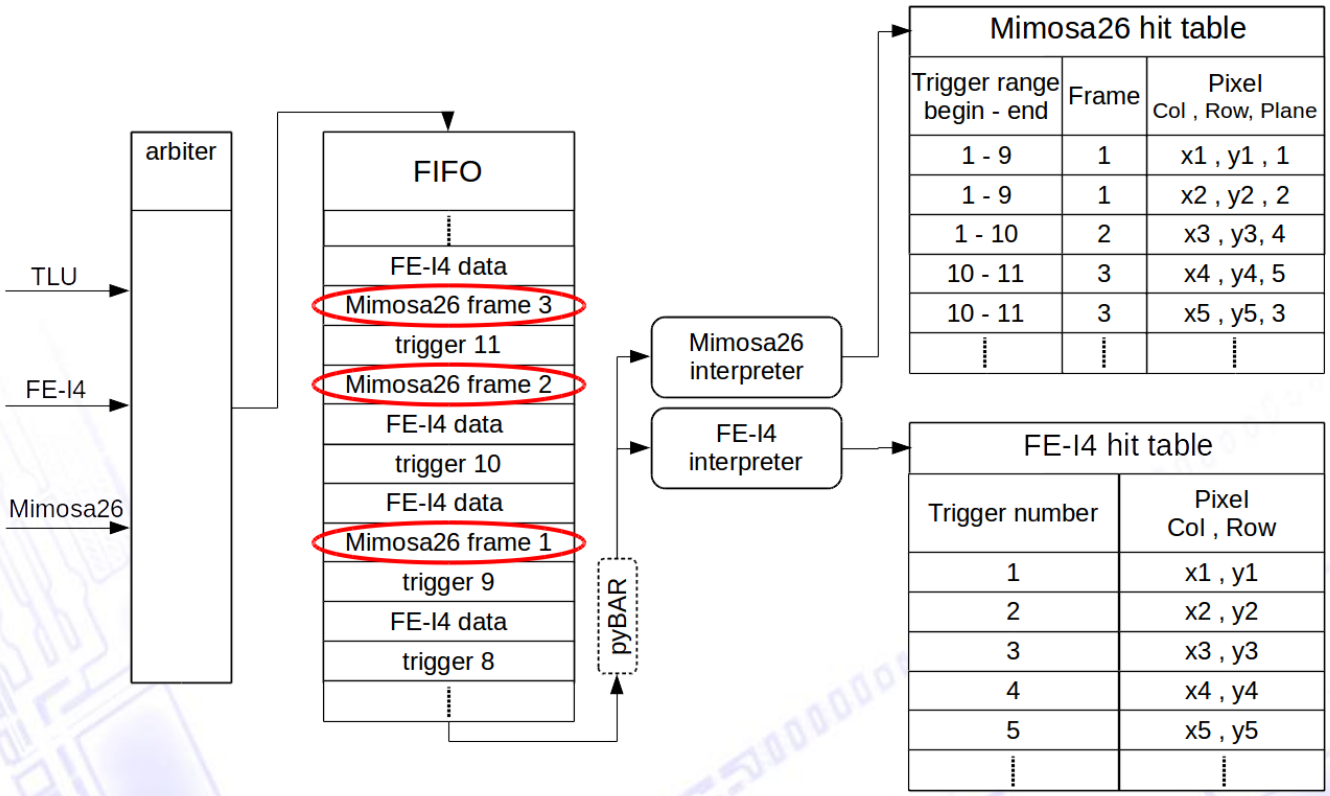


Mimosa26 hit table

Trigger range begin - end	Frame	Pixel Col , Row, Plane
1 - 9	1	x1 , y1 , 1
1 - 9	1	x2 , y2 , 2
1 - 10	2	x3 , y3, 4
10 - 11	3	x4 , y4, 5
10 - 11	3	x5 , y5, 3
⋮	⋮	⋮

FE-I4 hit table

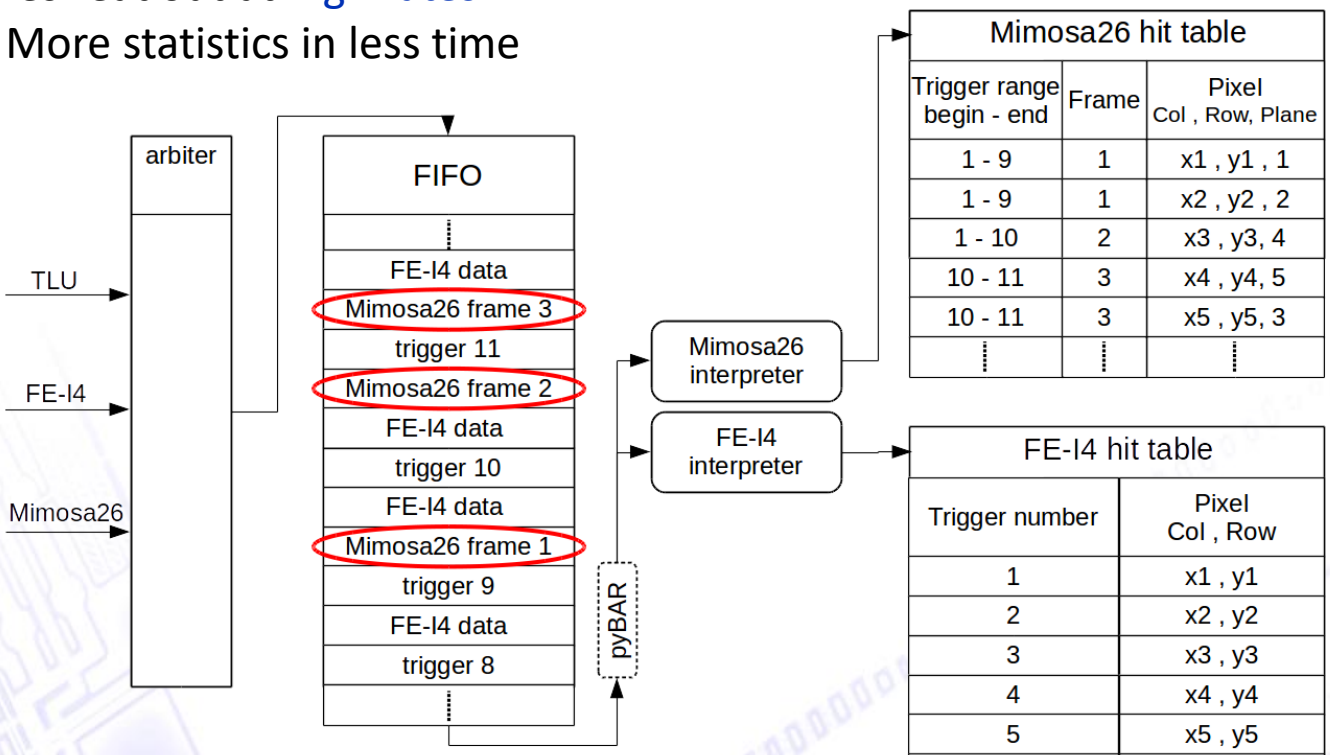
Trigger number	Pixel Col , Row
1	x1 , y1
2	x2 , y2
3	x3 , y3
4	x4 , y4
5	x5 , y5
⋮	⋮

New Triggerless Readout

- Continuous rolling shutter readout of Mimosa26
- Asynchronous …
  - merging of frame n and frame n+1 data
  - matching of FE-I4 data to Mimosa26 data

→ Enables readout at high rates

→ More statistics in less time



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Trigger number	Pixel Col , Row
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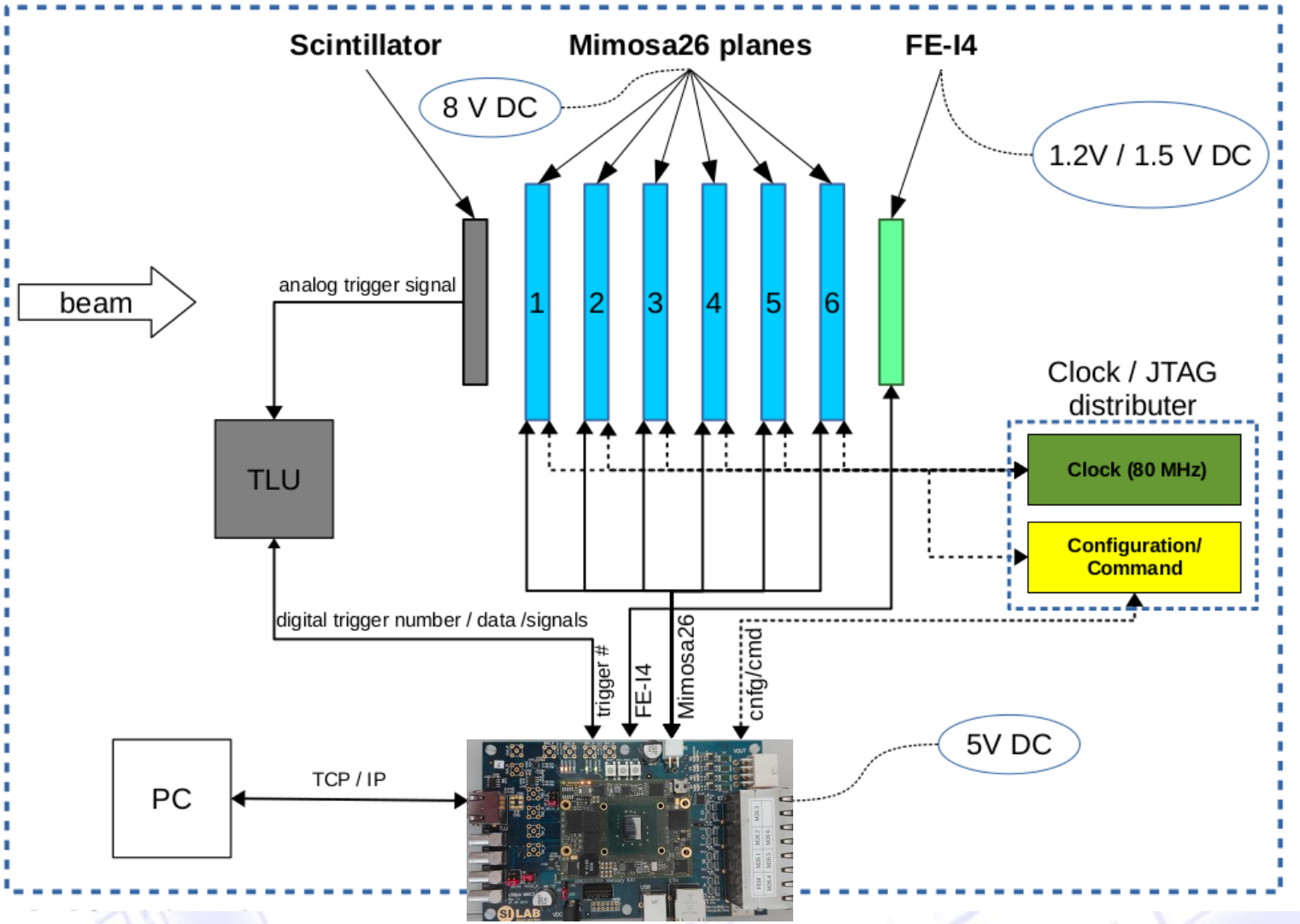
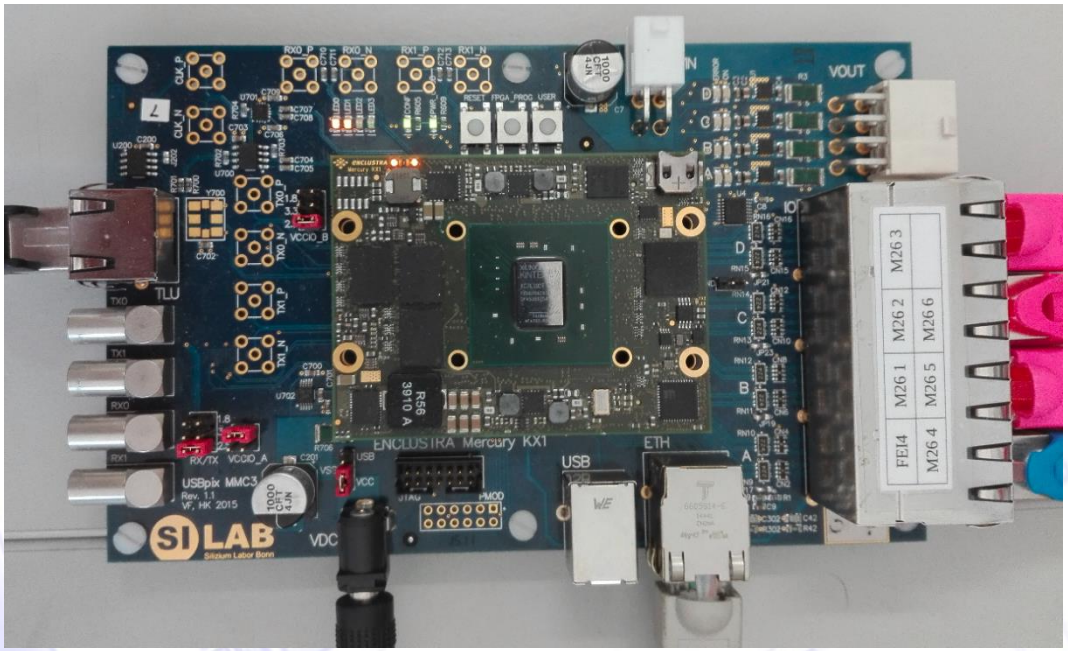
Setup

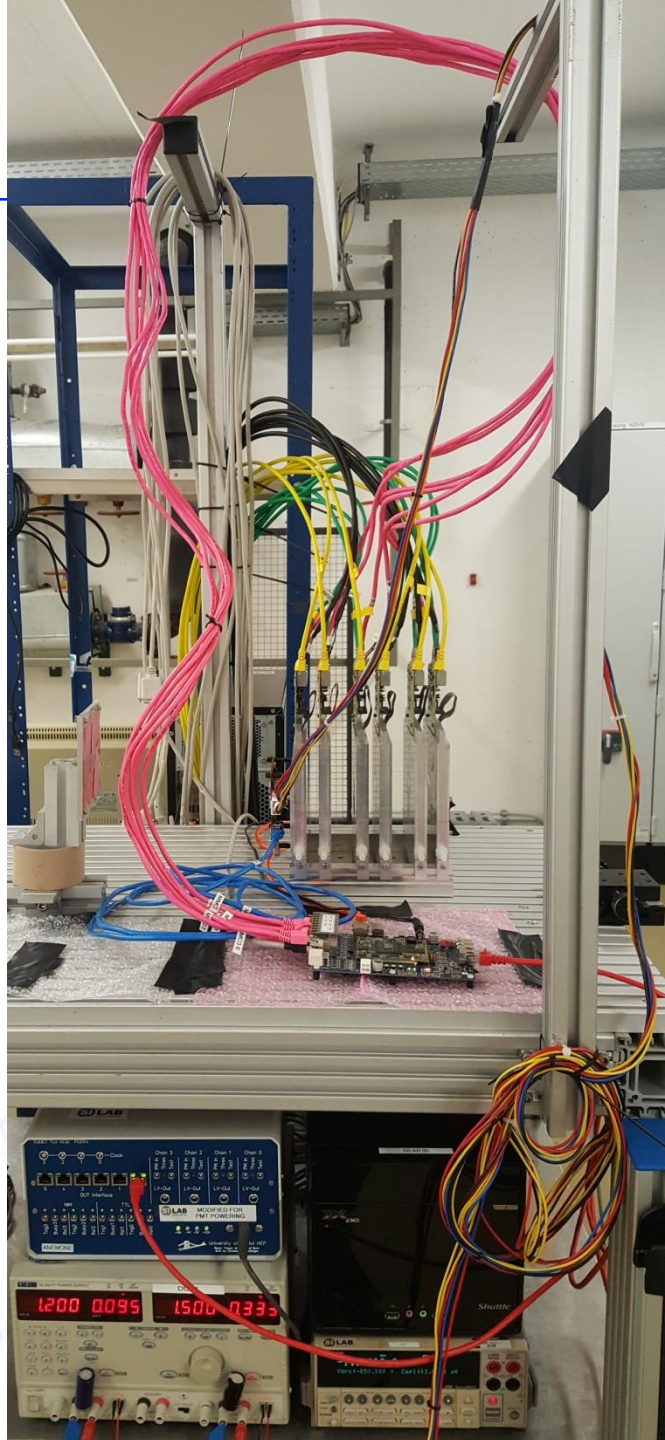

Scintillator
Mimosa26 planes
FE-I4
8 V DC
1.2V / 1.5 V DC
beam
analog trigger signal
1
2
3
4
5
6
TLU
Clock / JTAG distributer
Clock (80 MHz)
Configuration/ Command
digital trigger number / data /signals
trigger #
FE-I4
Mimosa26
cnfg/cmd
5V DC
PC
TCP / IP

Setup

USBPix MMC3 Readout Board

- Custom-made PCB based on Enklustra Kintex7
- Combining readout of 6 Mimosa26 planes and FE-I4
- Includes Mimosa26 configuration (JTAG)
- ROI definition
- TCP/IP data transmission to DAQ PC
- Affordable (ca. 1500€)

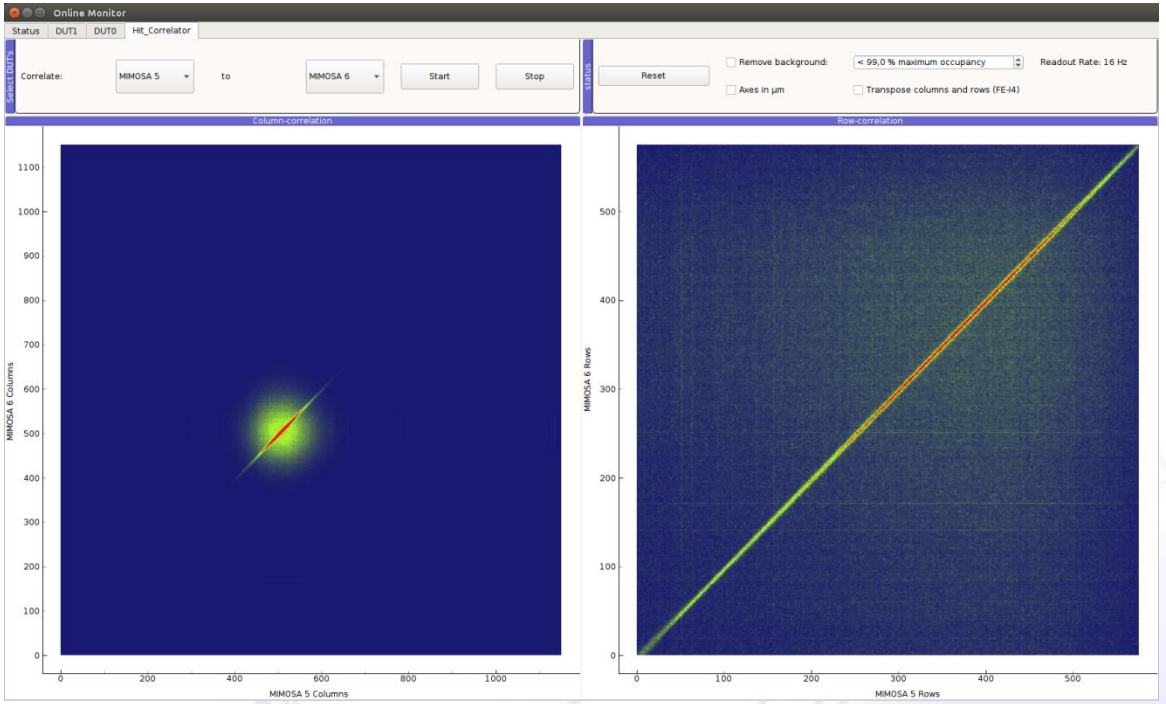




Software

- pyBAR (Bonn ATLAS Readout in Python)
  Fully integrated data acquisition framework
  - Integration of Mimosa26-, FE-I4- and TLU readout
  - Continuous data recording of all telescope planes
  - Compressed raw data storage
  - Open Source, available on GitHub

- Online Monitor
  - General status overview
  - Online event building
  - Online hit correlation
  - Power supply status and control
  - DUT status
  - Also on GitHub



https://github.com/SiLab-Bonn/
pyBAR
online_monitor
testbeam_analysis

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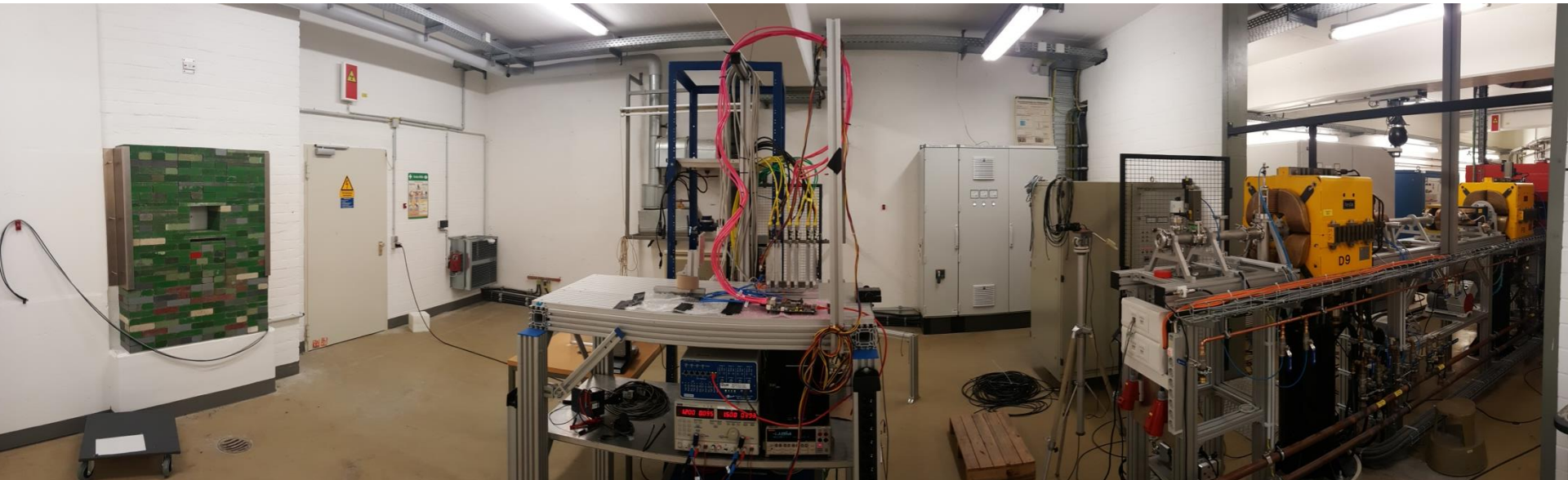
Testing

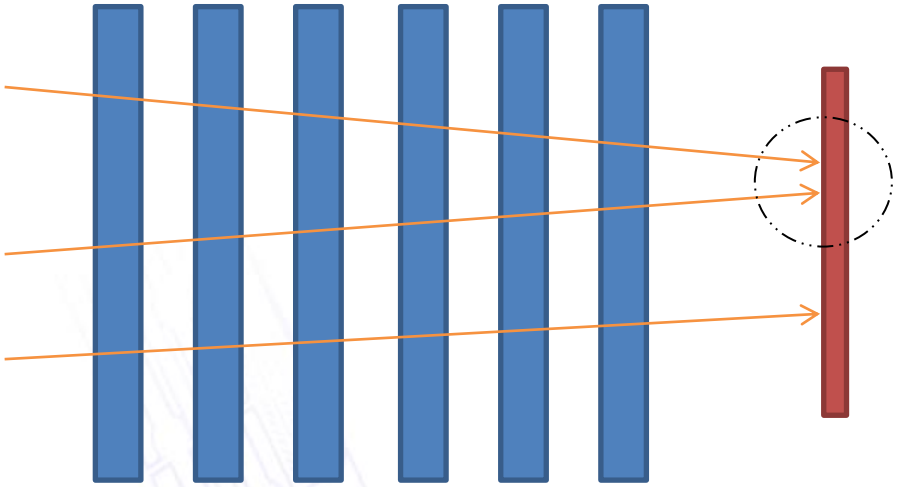
- Extensive testing at ELSA (Bonn Electron Stretcher Accelerator)
  - Dedicated test beam area for detector tests
  - Spacious and easily accessible
  - Complete infrastructure
  - Polarized electron beam up to 3.2 GeV
  - Full control over beam parameters



Results

- Estimate systematic error of track reconstruction efficiency calculation
- Three runs at 11, 23 and 51 hits / frame

→ Ambiguous hits due to restricted spatial resolution of FE-I4 and fake tracks



Results

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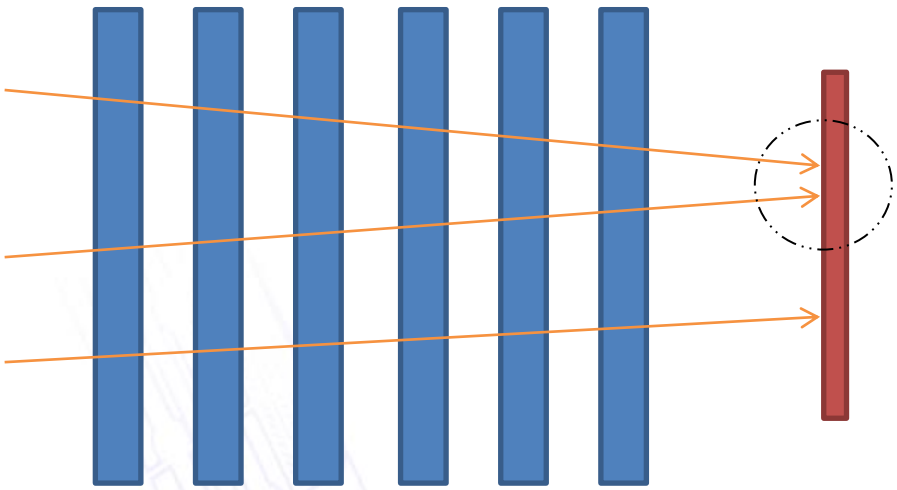
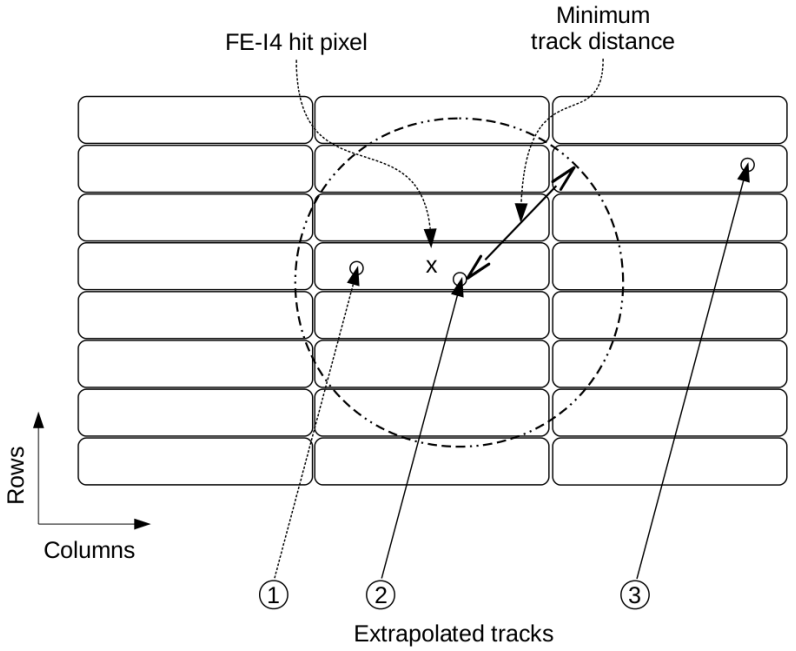
→ Ambiguous hits due to restricted spatial resolution of FE-I4 and fake tracks

→ Define minimum track distance and discard ambiguous tracks





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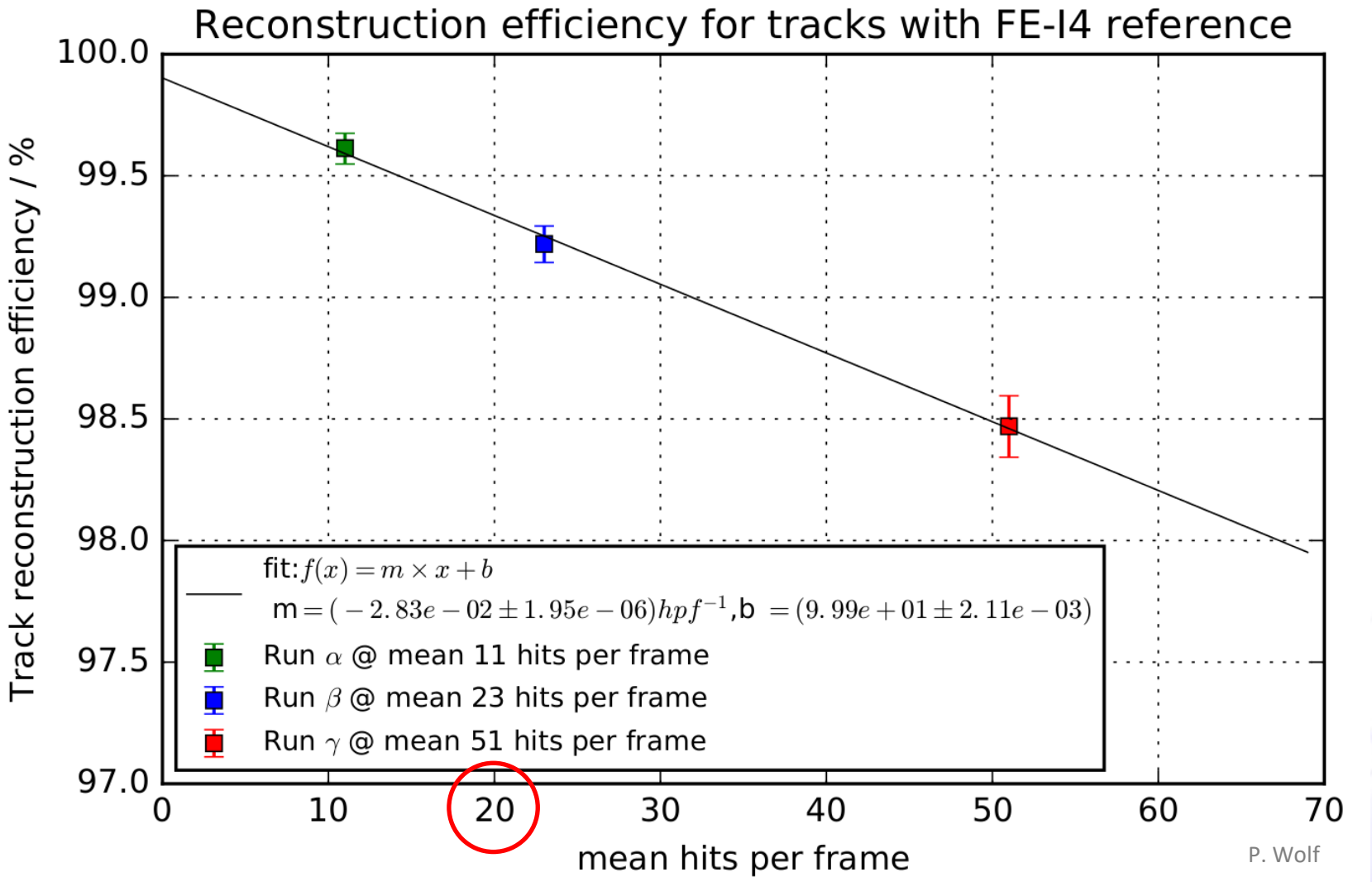
Reconstruction efficiency for tracks with FE-I4 reference
Track reconstruction efficiency / %
100.0
99.5
99.0
98.5
98.0
97.5
97.0
0
10
20
30
40
50
60
70
mean hits per frame
fit: $f(x) = m \times x + b$
m = $(-2.83e-02 \pm 1.95e-06) hpf^{-1}$, b = $(9.99e+01 \pm 2.11e-03)$
Run α @ mean 11 hits per frame
Run β @ mean 23 hits per frame
Run γ @ mean 51 hits per frame
P. Wolf

Conclusion

- USBPix MMC3 Readout Board
  - → Alternative readout system for Mimosa26- and FE-I4-based telescopes
  - → Very compact
  - → Affordable

- Testing of ANEMONE with new readout
  - → Good spatial resolution from Mimosa26 planes
  - → Good timing resolution from ATLAS FE-I4 plane
  - → Fast DAQ: 20 kHz (limited by TLU)
  - → Online monitor including hit correlation

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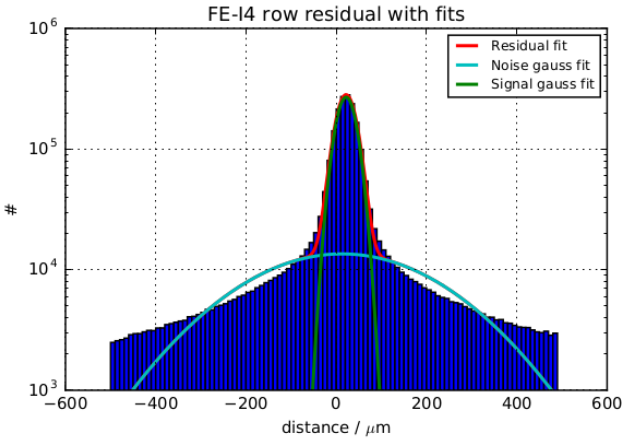
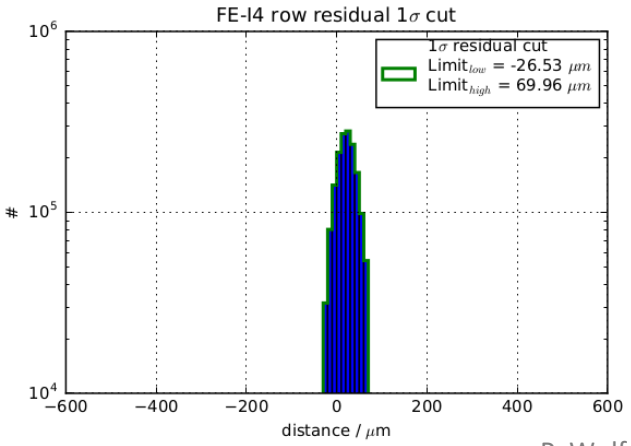
Thank You

Track reconstruction

Event selection:

1. BCID cut
   - Is the latency of the hit too large or too small → noise
2. Clustering
   - Can the individual hits be clustered?
3. Number of FE-I4 clusters
   - Ambiguous, if more than 1 cluster per trigger → discard
4. Minimum track distance
   - Ambiguous, if two extrapolated tracks on FE-I4 plane are too close → discard
5. 1σ residual cut
   - Remove all hits outside 1σ region of column and row residuals





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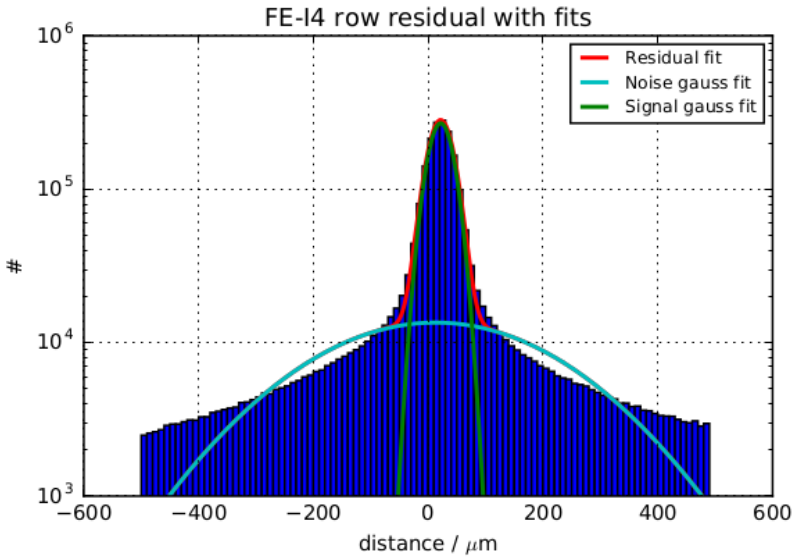

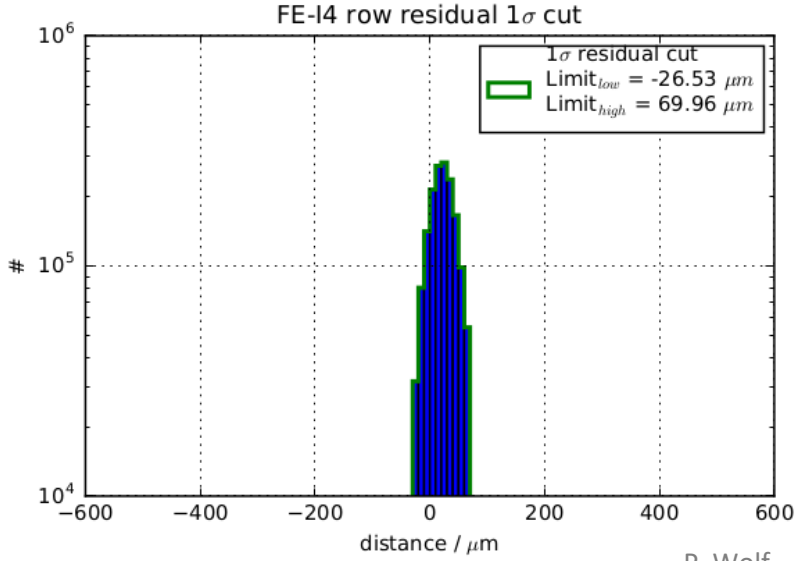

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