The New Kid on the Timing Frontier: TelePix2

Characterising a Novel Timing and Triggering Plane for use with the EUDET Telescopes at the DESY II Test Beam Facility

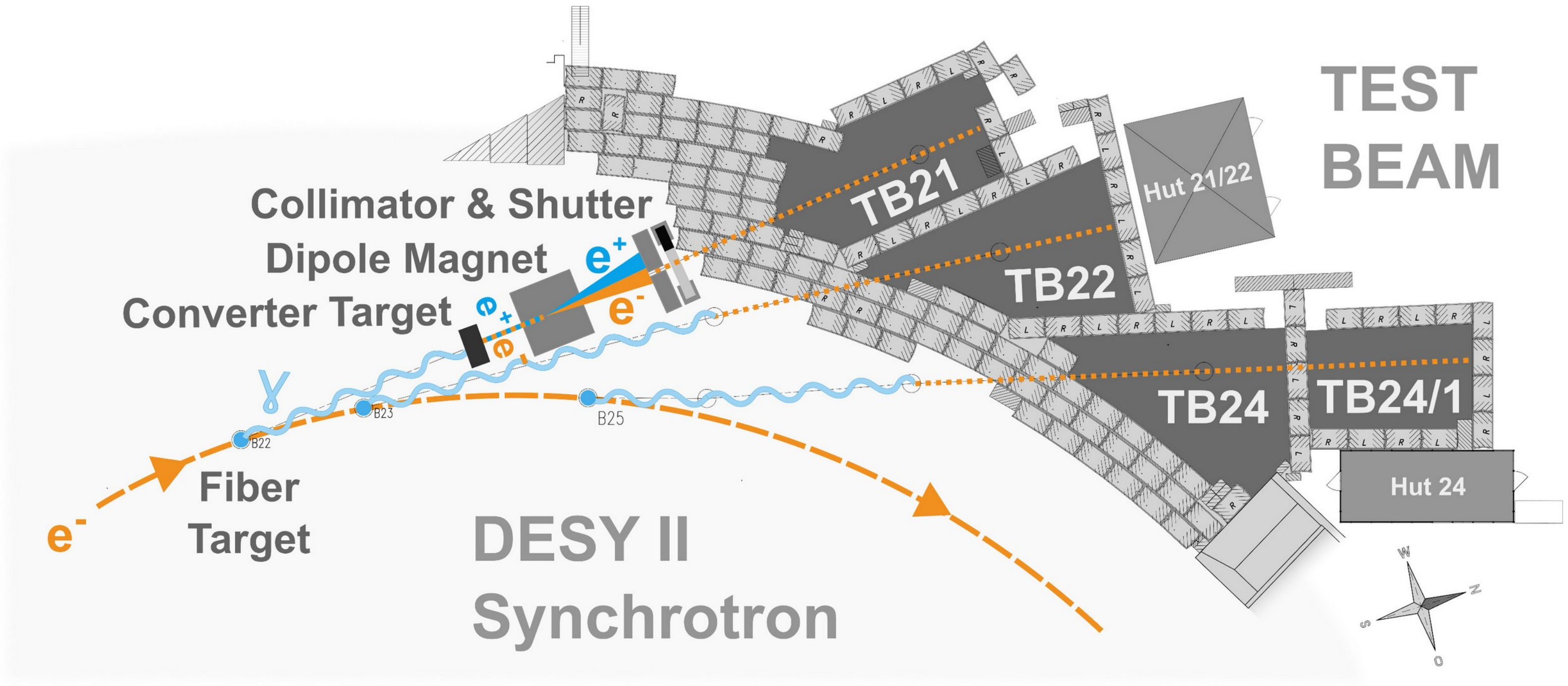
Arianna Wintle on behalf of the TelePix2 Team, Detector R&D Retreat

19/01/24

EXZELLENZCLUSTER QUANTUM UNIVERSE

HELMHOLTZ FTX HGSFP HighRR UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386 KIT DESY TEST BEAM. DESY.

The DESYII Test Beam Facility



Three independent beamlines at the DESY II synchrotron

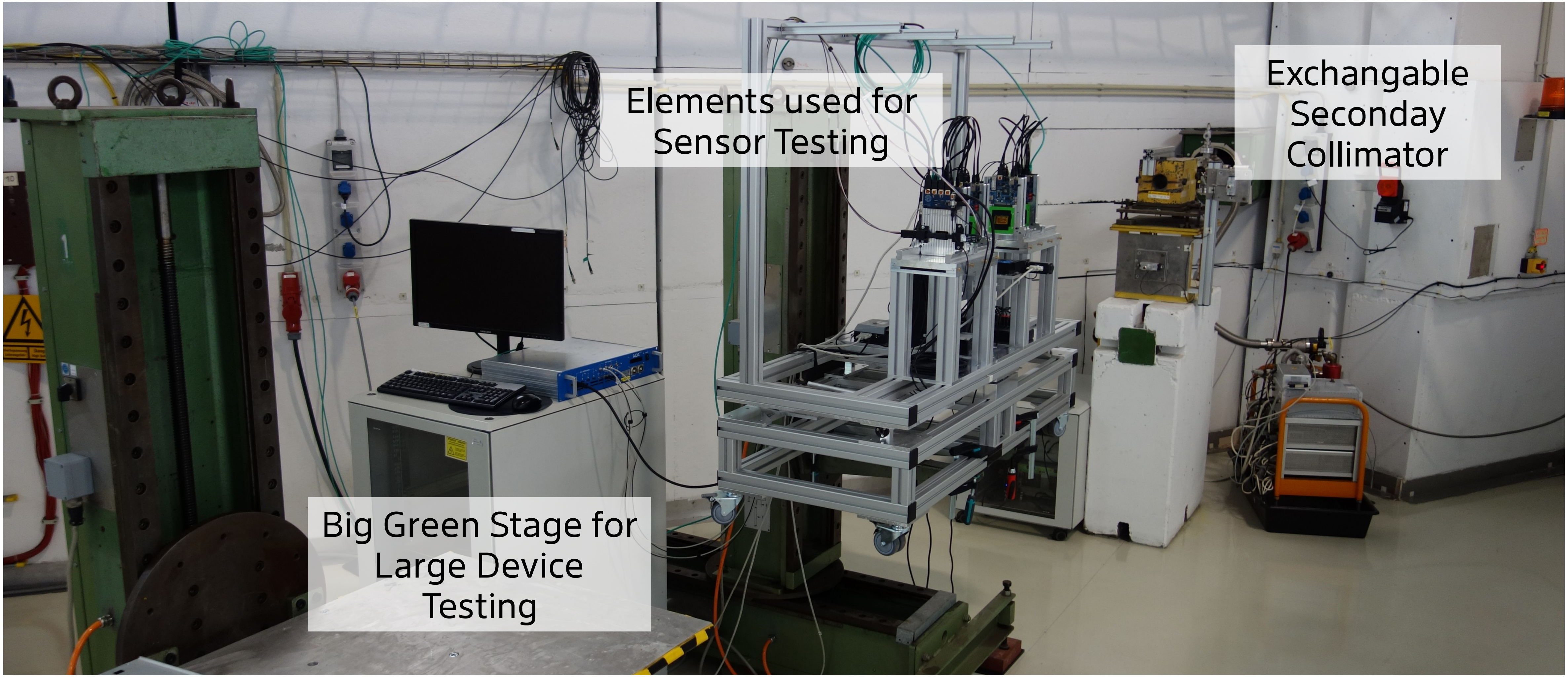
→ Typically used for **detector R&D for characterisation**

→ Offers **e^- or e^+** beam with user selectable momentum from **1-6 GeV/c**

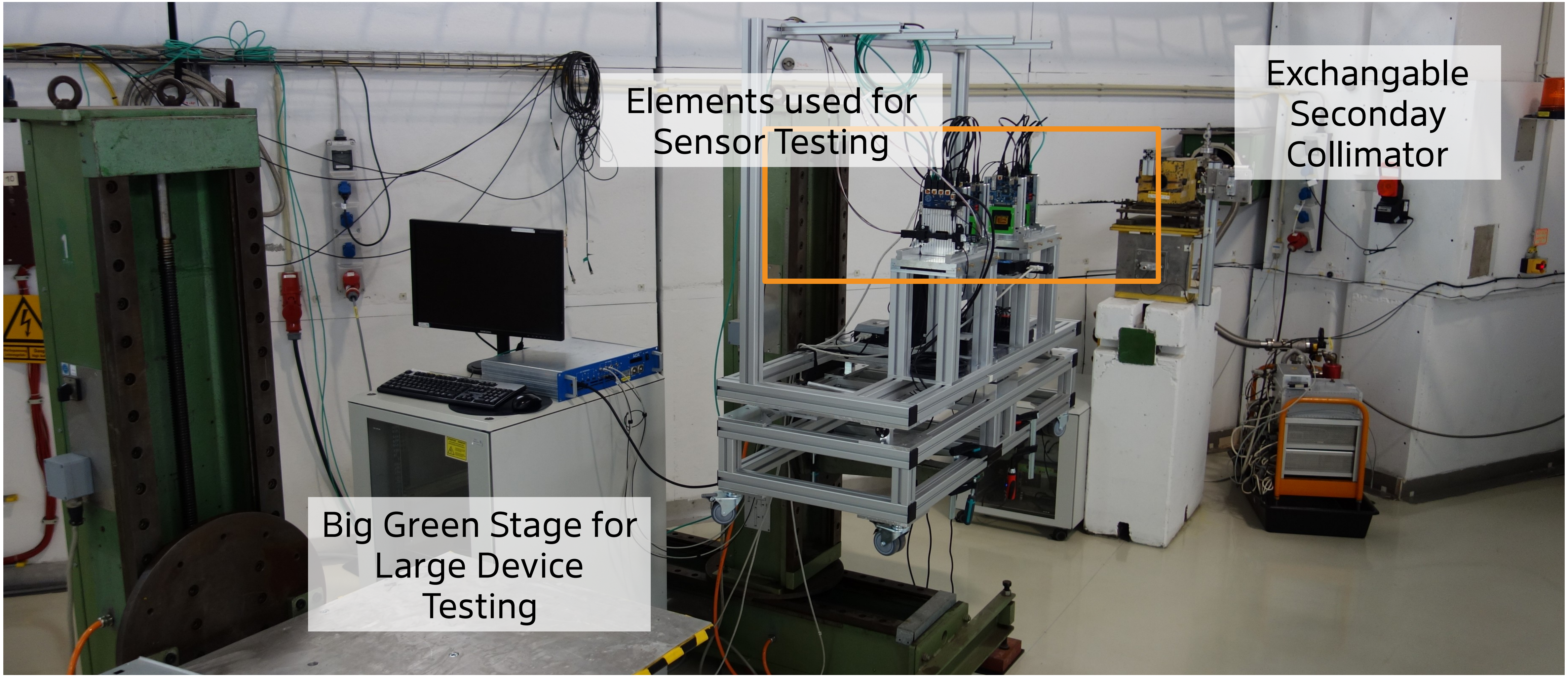
→ **Shutter and primary collimator** remote controllable

→ Exchangeable fixed size **secondary collimator**

Inside the Test Beam Area



Inside the Test Beam Area

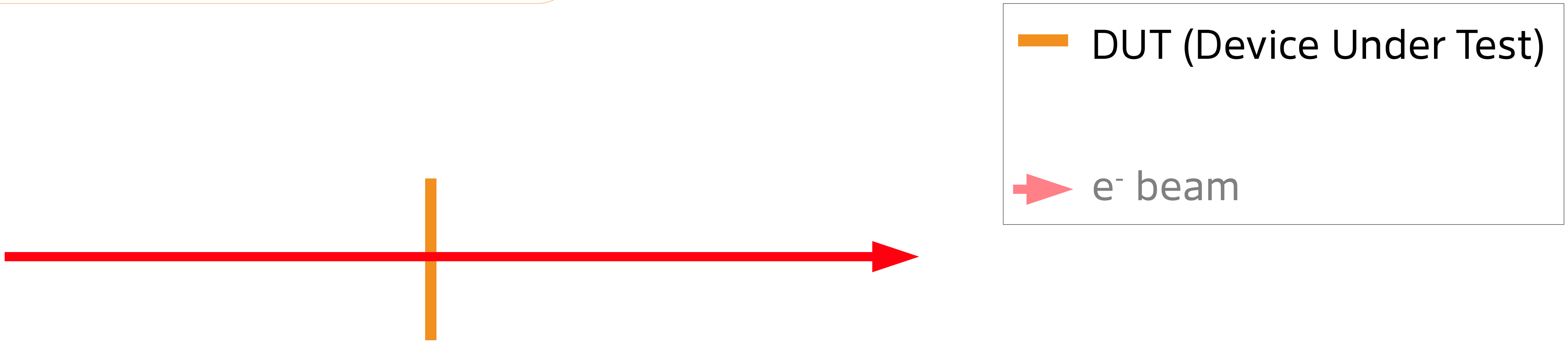


Test Beam Set Up

For Sensor Characterisation

DUT (Device Under Test)
Range of different sizes and operating conditions

Parameters to test:
- Efficiency
- Time Resolution & Spatial Resolution
- Behavior under a magnetic field

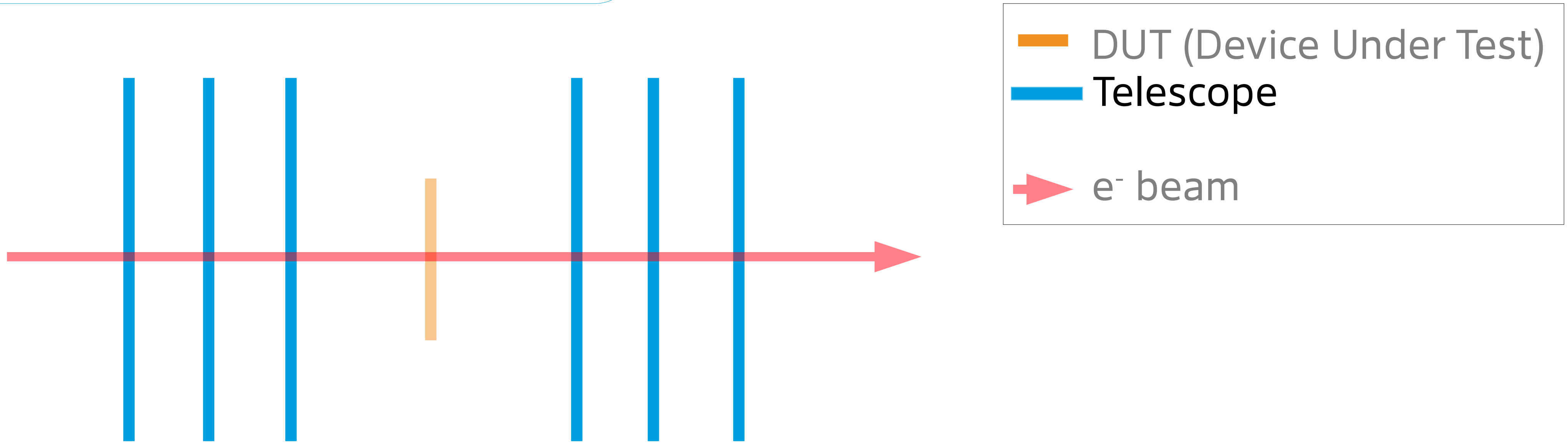


Test Beam Set Up

For Sensor Characterisation

Telescope
Multiple sensor planes
Allow precise track reconstruction

At DESY II Test Beam Facility two types with two different readout times:
Mimosa (~ 230 µs) & **Adenium** (~ 10 µs)

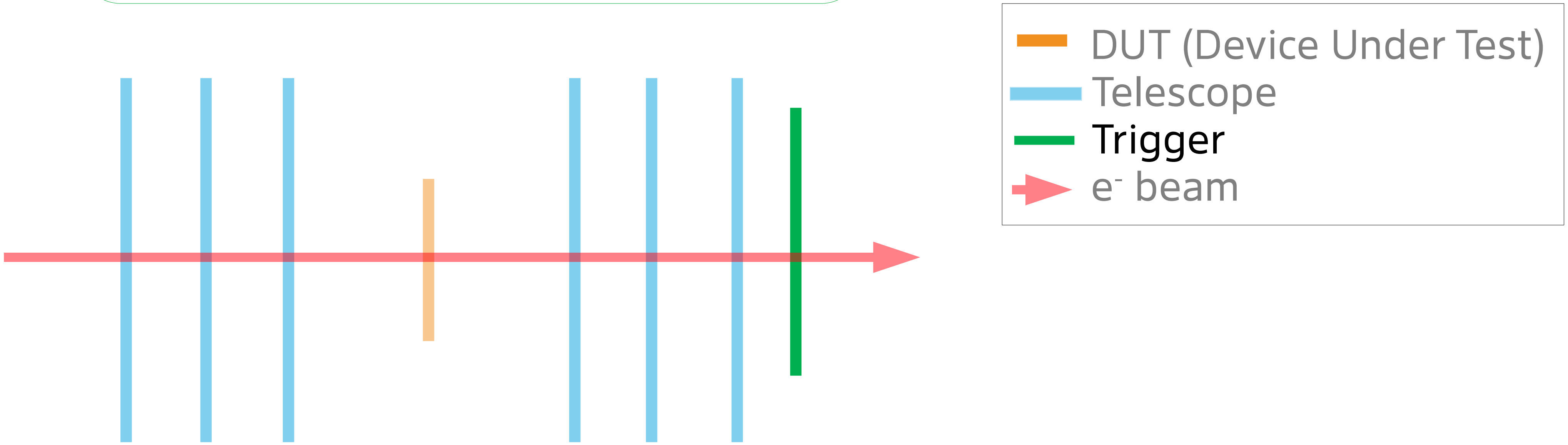


Test Beam Set Up

For Sensor Characterisation

Trigger

- Tag the presence of particles
- Important for reducing noise (event based readout)

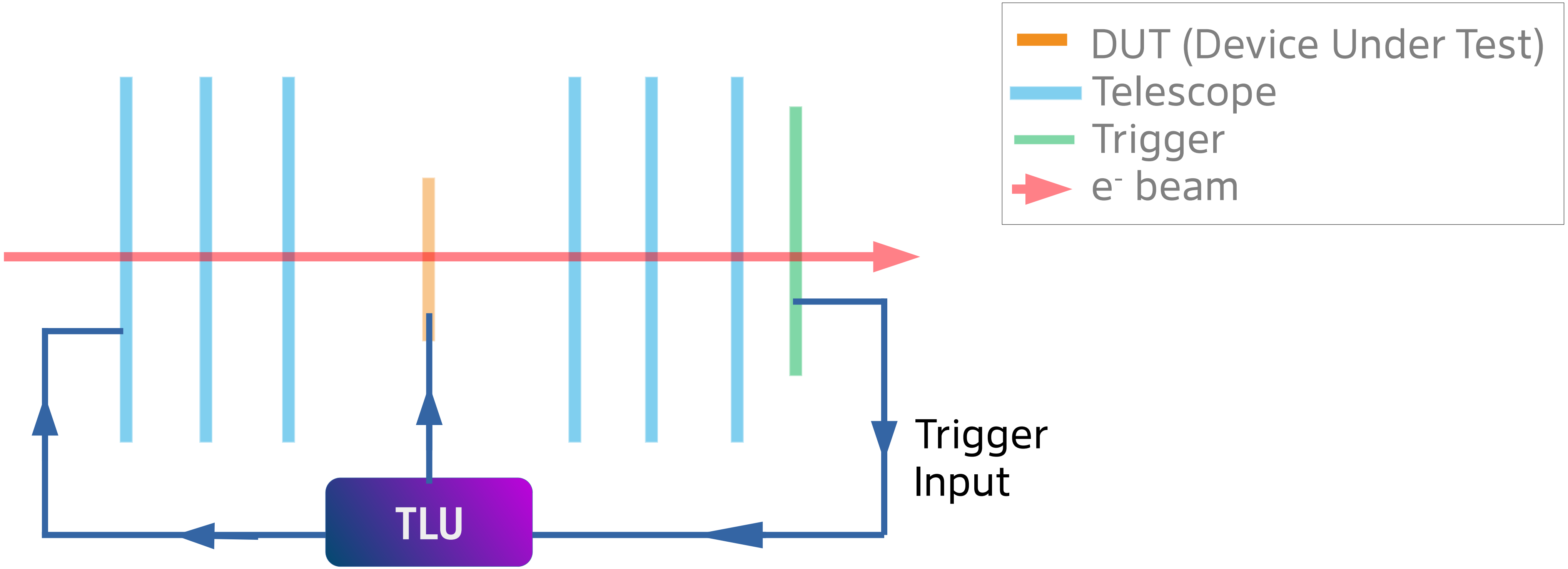


Test Beam Set Up

For Sensor Characterisation

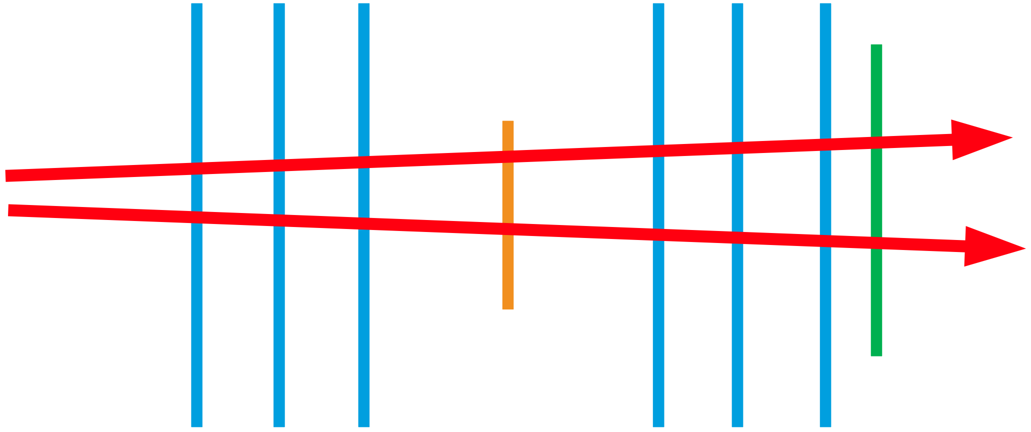
Trigger Logic Unit

- Trigger on an arbitrary logical combination of 6 triggering inputs
- Synchronisation of multiple devices: exchange trigger ID or common clock and reset



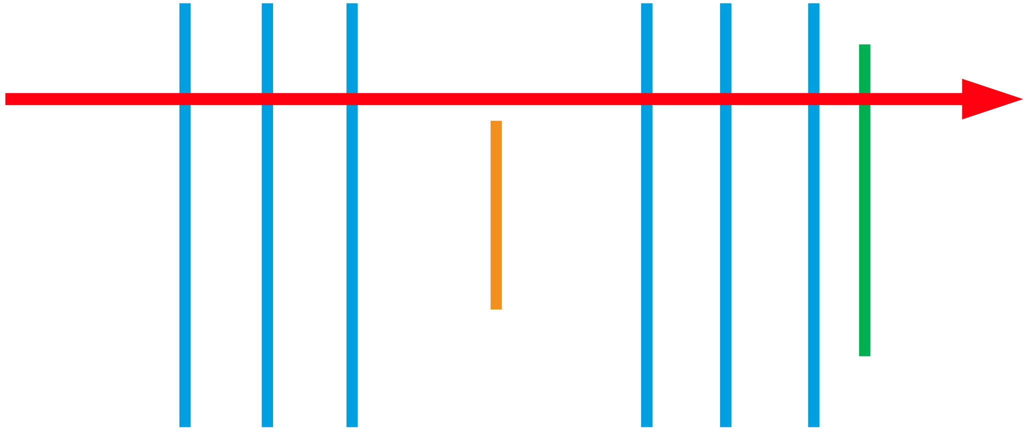
Timing and ROI Triggering Plane

Slow telescope readout & high particle rates



Multiple tracks within one readout
→ Impossible to associate which track belongs to which trigger

Mismatch in trigger and DUT size



Trigger on uninteresting events
→ Inefficient data taking

Timing and ROI Triggering Plane

DUT
Telescope
Trigger
e^- beam

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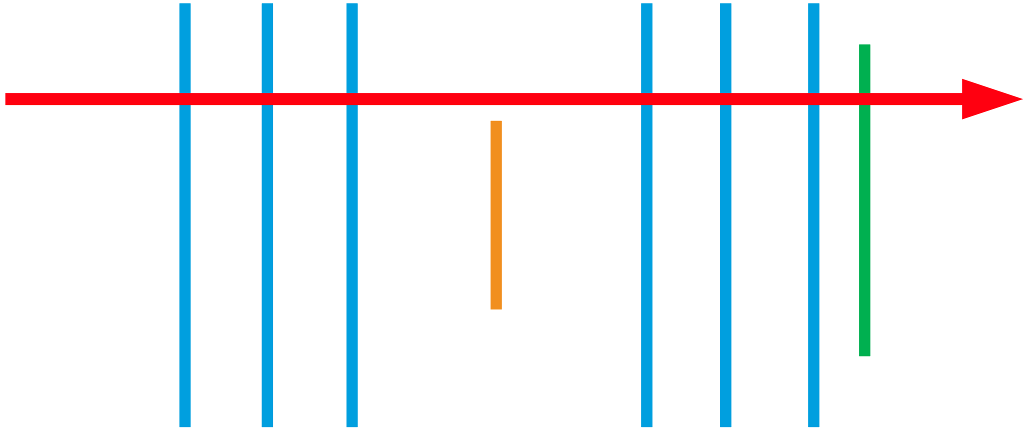

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Timing and ROI Triggering Plane

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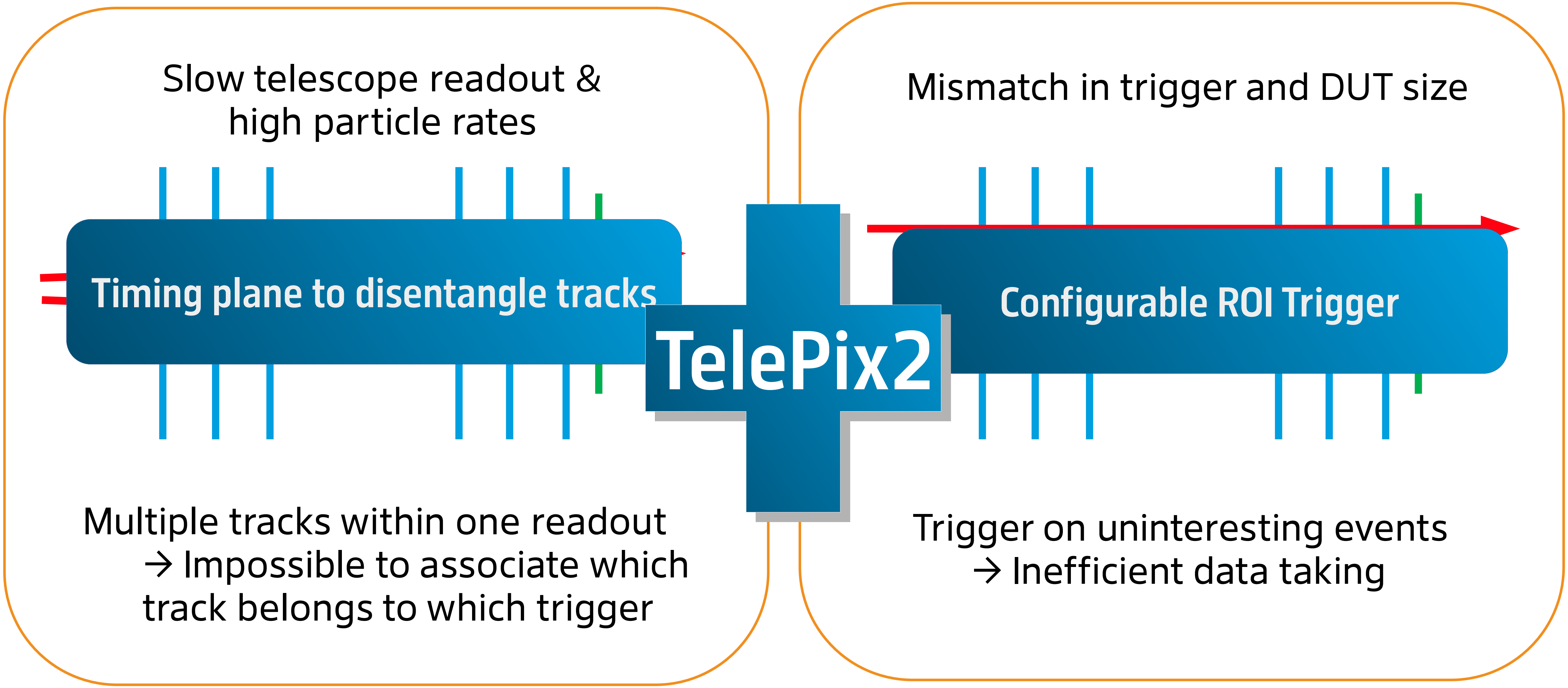
Timing and ROI Triggering Plane

DUT
Telescope
Trigger
e⁻ beam

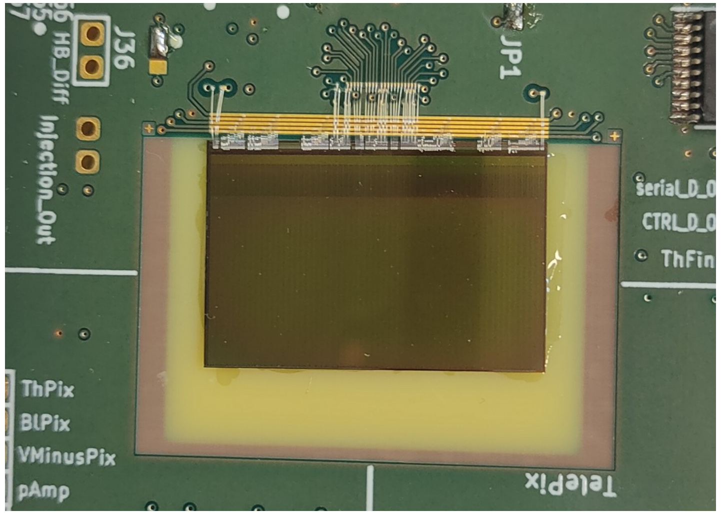


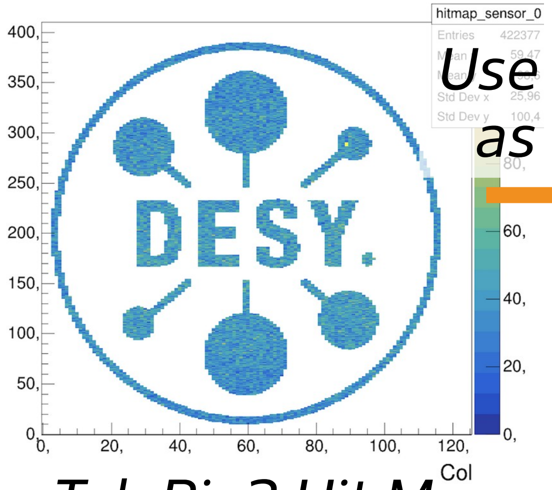
TelePix2

Key Features

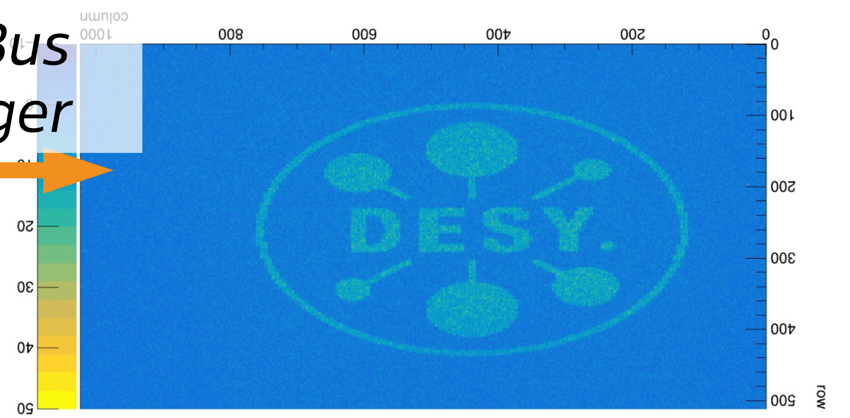
- **HVMAPS** sensor with a **fine timestamp (4 ns)**
- Fast output for a **user-configurable ROI trigger** (HitBus)
- A **low material budget** (0.0011 from 100 µm silicon)

Pixel Size : 165 x 25 µm
Columns x Row : 120 x 400
Chip size : 20.015 x 13.130 mm





Use HitBus as trigger



TelePix2 Hit Map

Telescope Plane Hit Map

Work in Progress

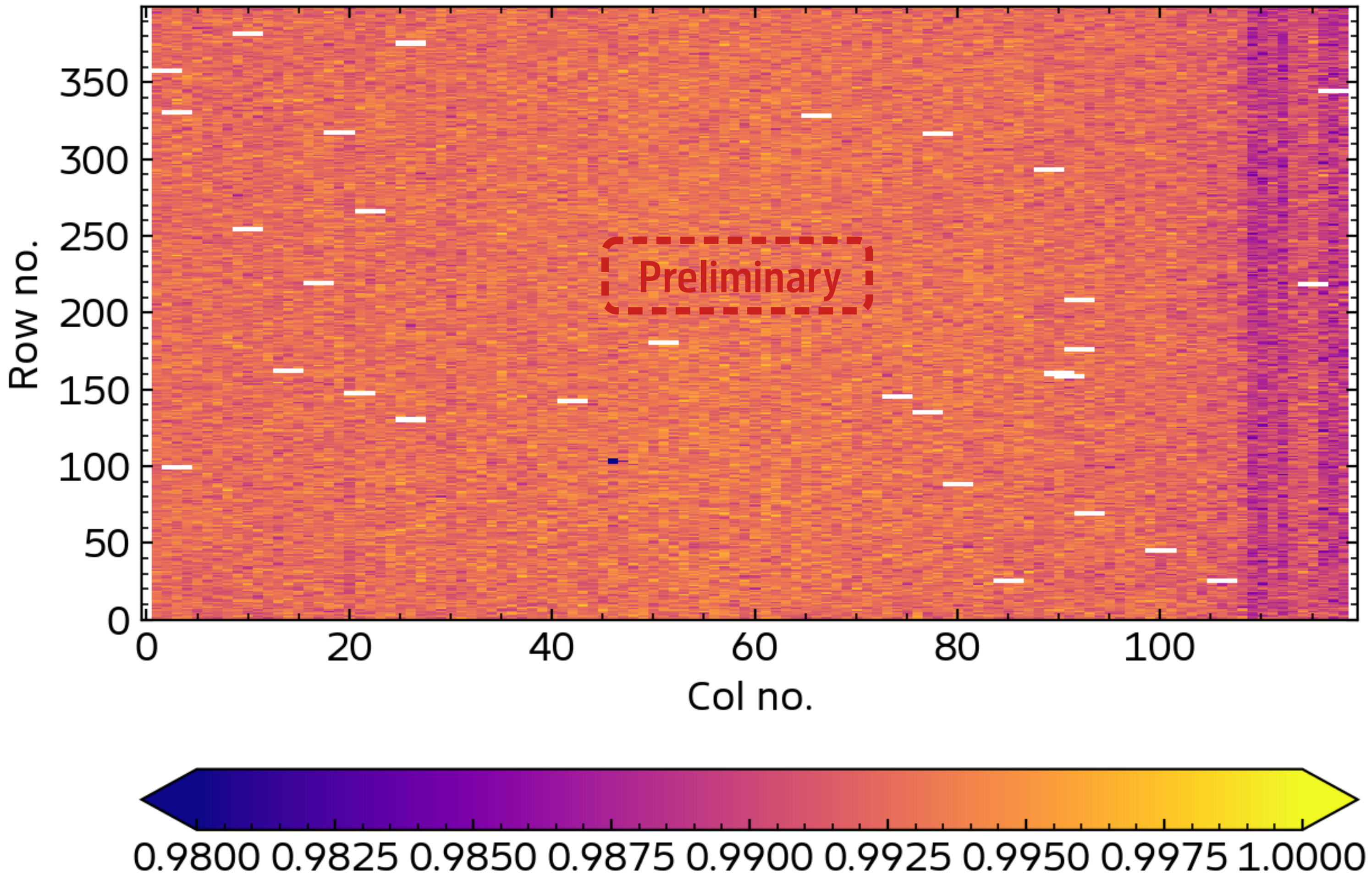
Preliminary

All the following results are preliminary, the analysis is a work in progress and results might still change.
Data was taken from a test beam at the DESY II test beam facility (area 22 beam energy 4 GeV) carried out in October 2023.

Another alignment, systematic checking of various cuts, is still being carried out.

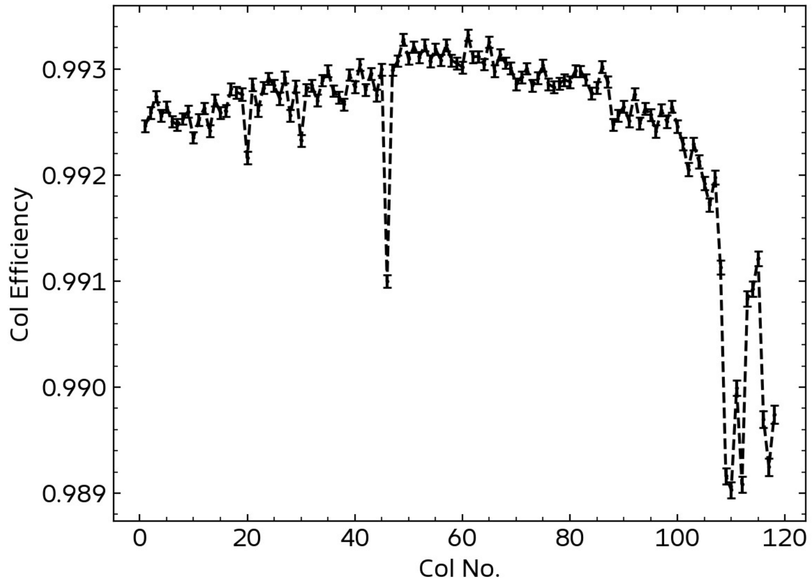
Efficiency

Efficiency = $\frac{\text{Tracks with an Associated DUT Hit}}{\text{Tracks that intersect the DUT}}$



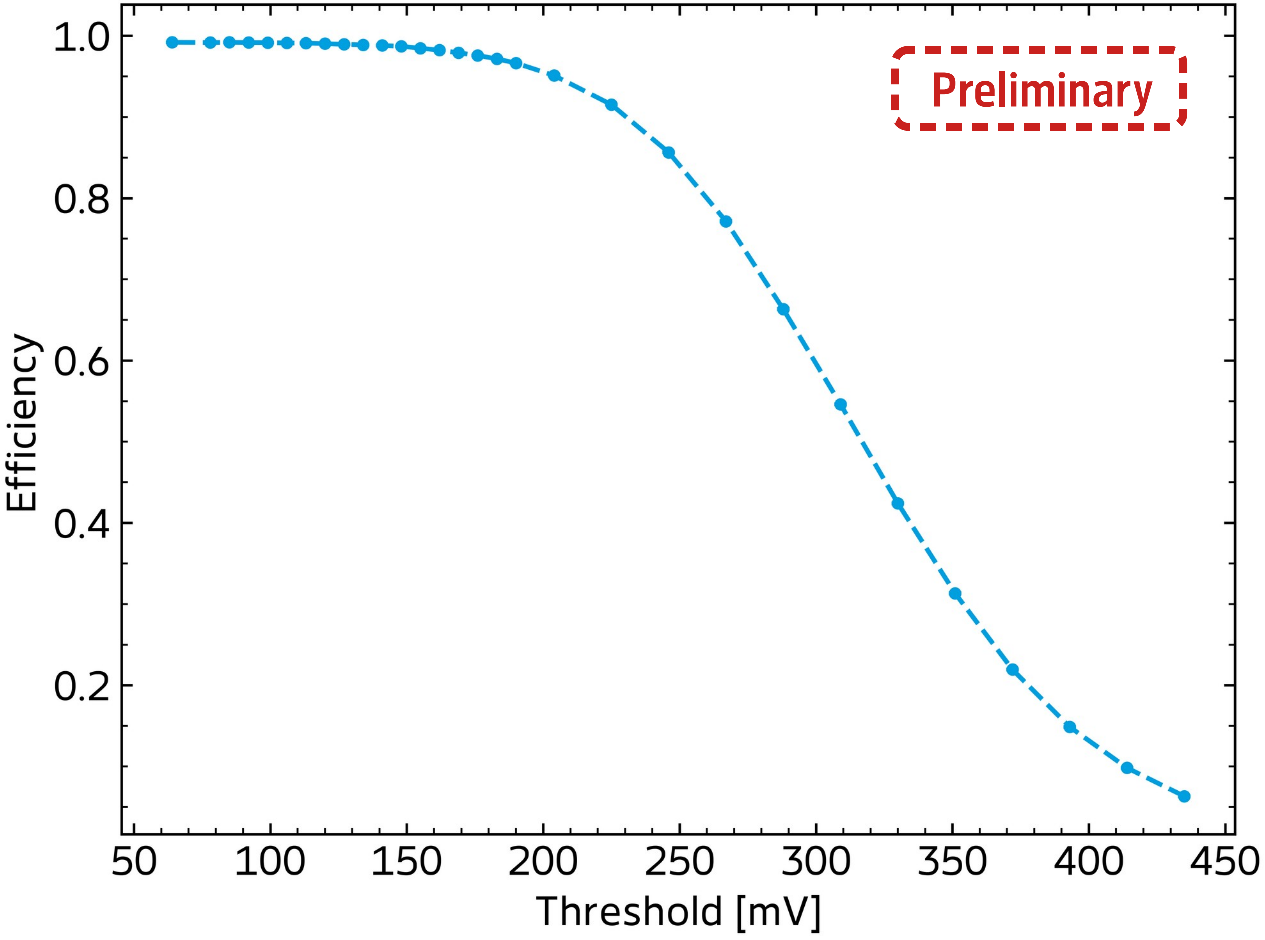
* Statstical efficiency

At a bias of 85 V
& a threshold of 57 mV
Efficiency of
99.204 ± 0.008 %



Efficiency vs Threshold

Efficiency changes with respect to threshold of pixel comparator

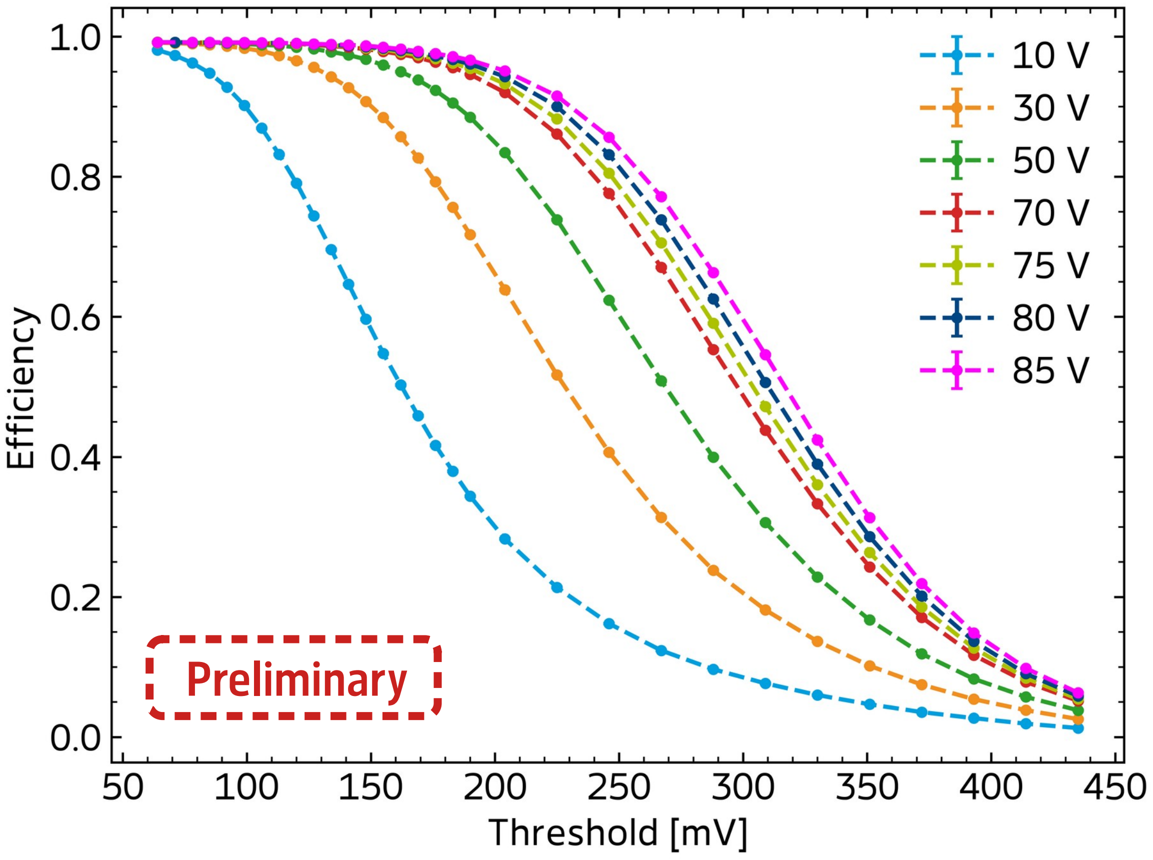


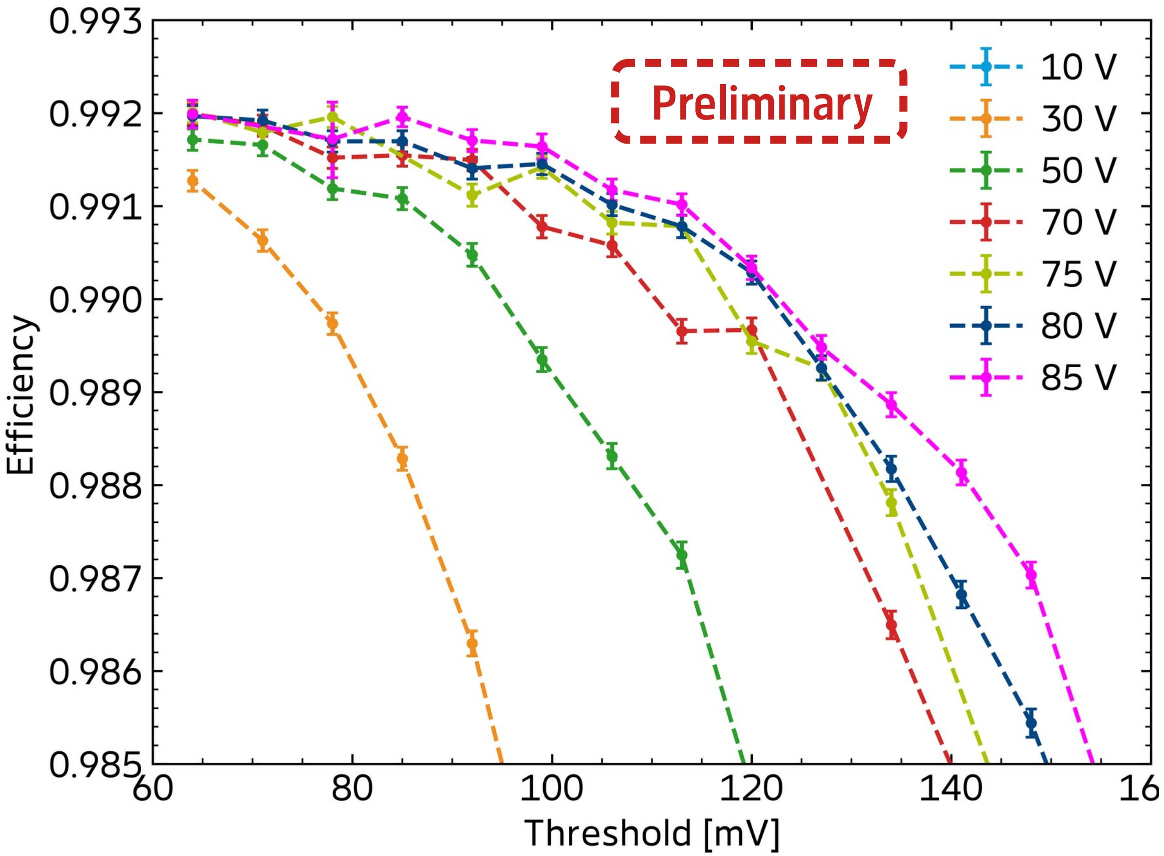
- Greater the plateau →
  Greater the suitable operating region

- Could not decrease threshold further
  Started to be effected by noise

Bias is at 85 V

Efficiency vs Threshold for Different Voltages

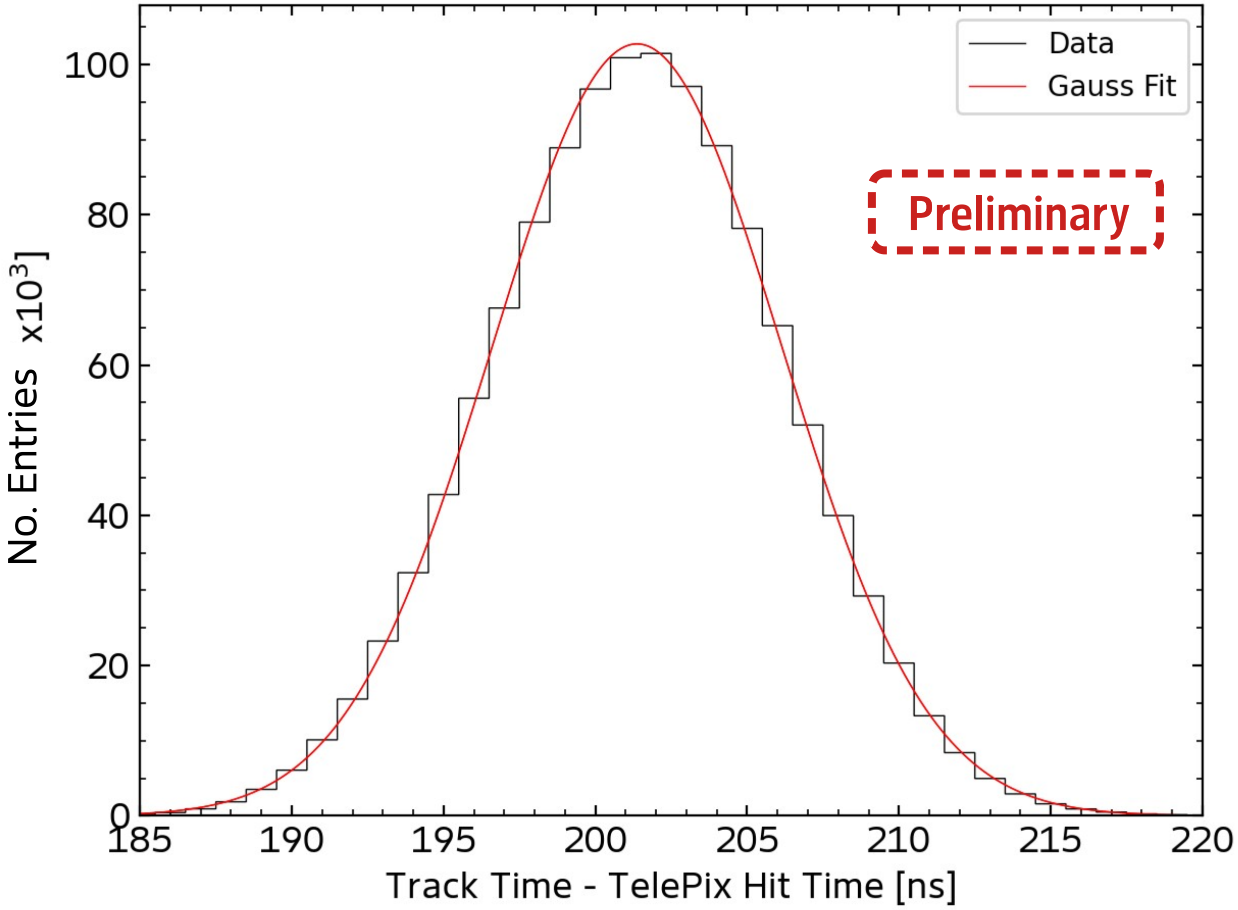




Higher bias voltage → Greater depletion region → More charge collected

Timing Resolution

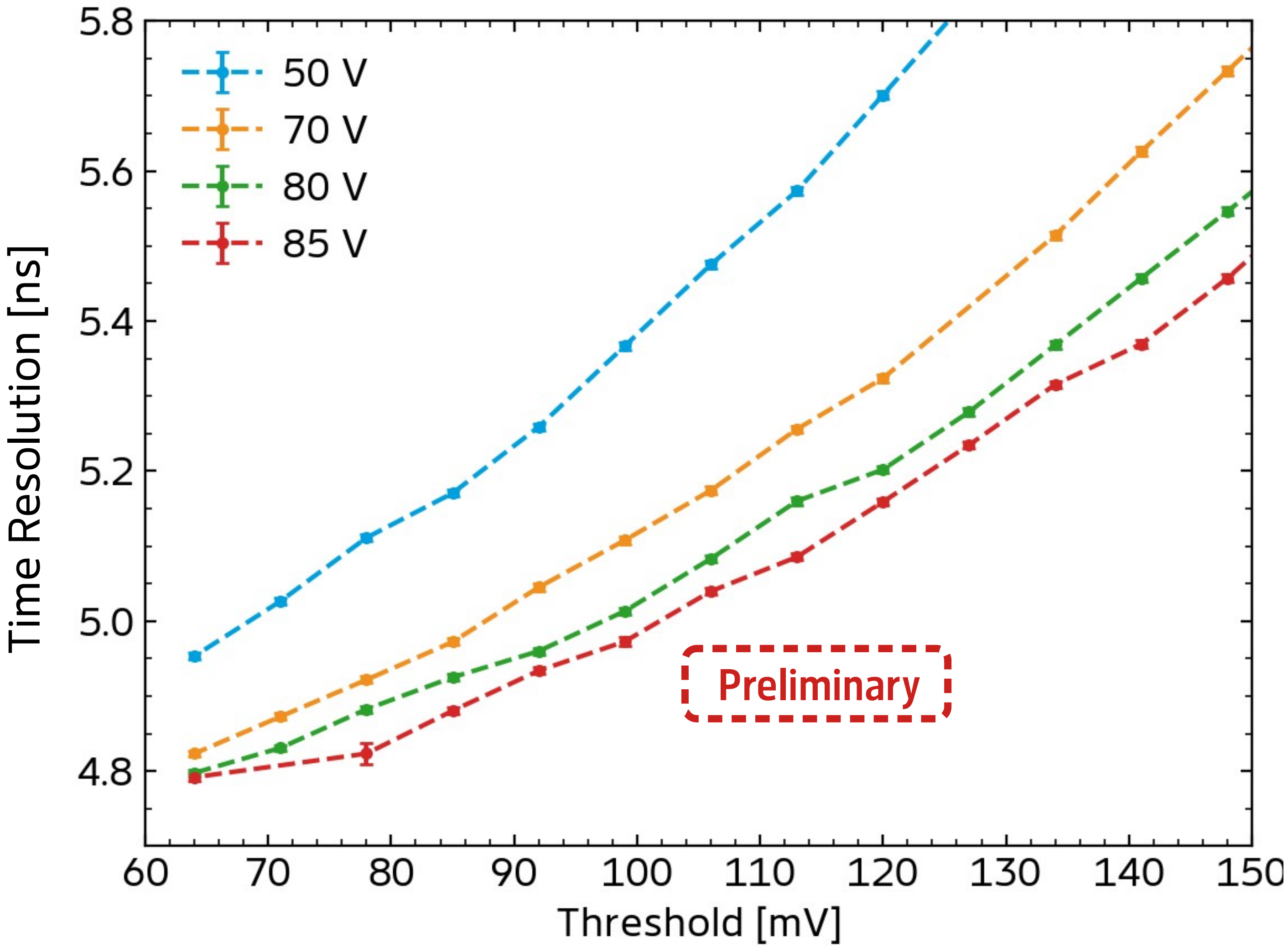
Ideal Case



Time resolution taken as the **σ of a Gaussian fit** of the time residual

At a bias voltage of 85 V and a threshold of 57 mV a time resolution of **4.781 ± 0.003 ns.**

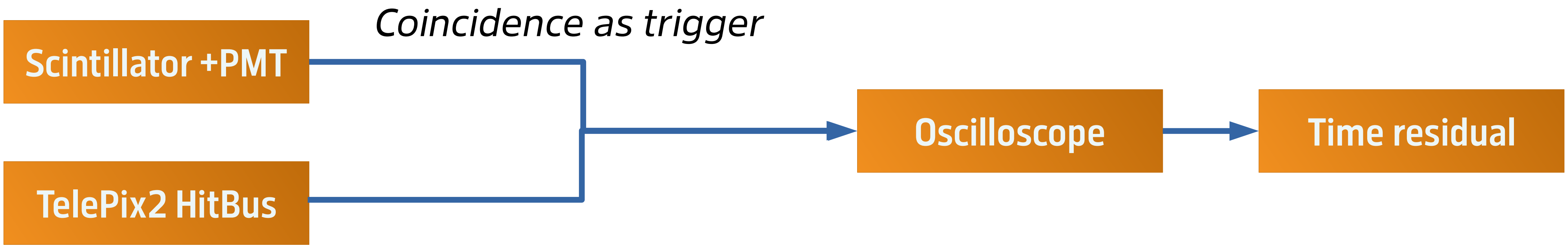
Timing Resolution with Threshold and Voltage



Still a benefit in time resolution with a reduction in threshold

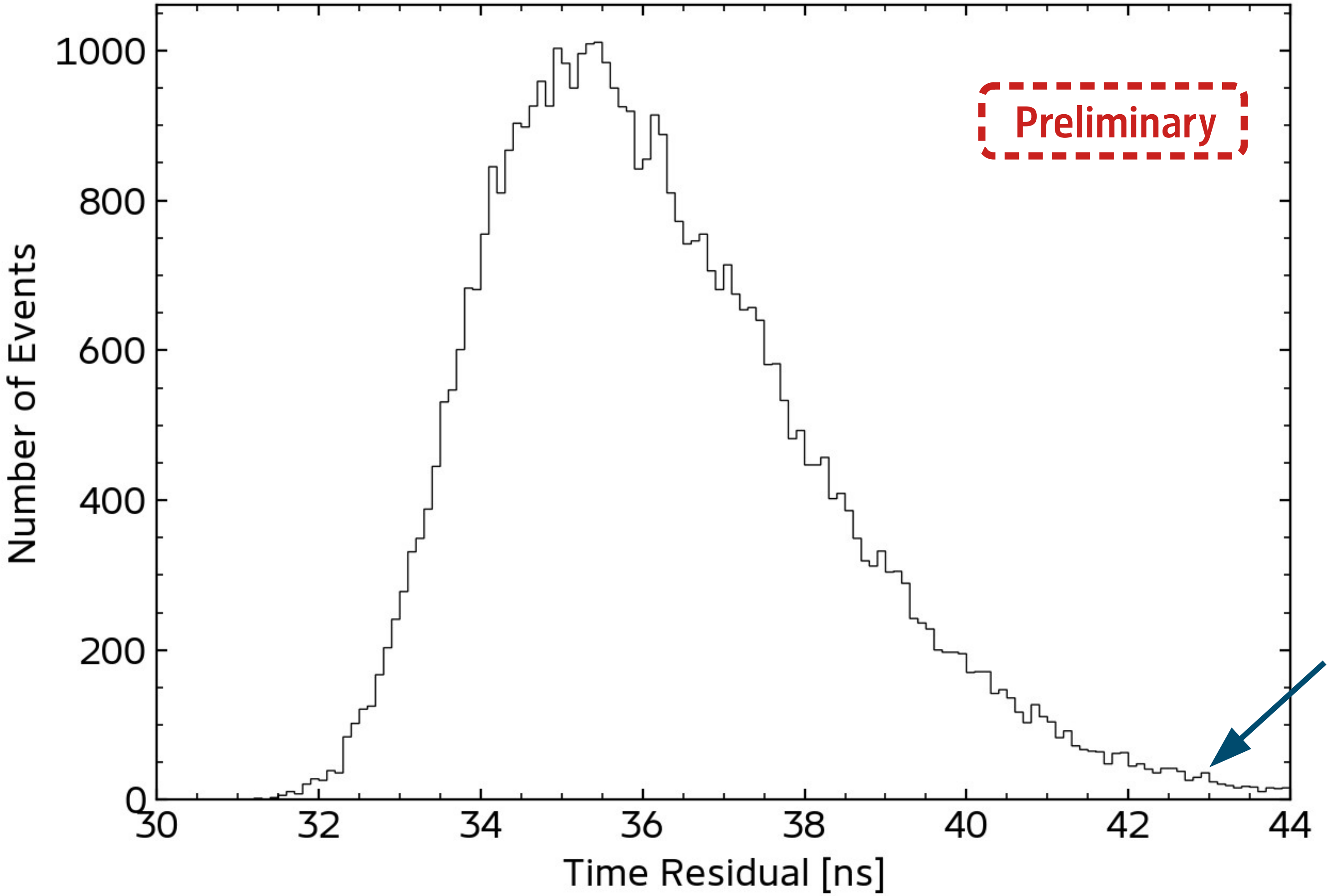
HitBus Measurements
Method

HitBus = Fast trigger output



Time Residual = Time at half maximum of scintillator – Time at half maximum of TelePix Hitbus

Hitbus Measurements
Result



Deviations from the standard Gauss distribution yet to be understood.

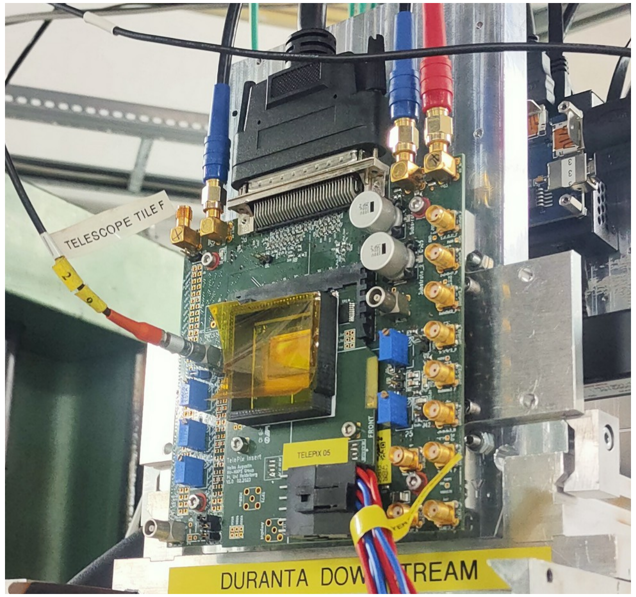
Preliminary measurements show an RMS of **≈ 2 ns**

Taken with at a bias of 85 V and threshold of 64 mV

Slight background from imperfect triggering scheme

Conclusion

TelePix2 currently being used by users!



- Working ROI trigger
- Hitbus time resolution of ≈ 2 ns
- Efficiency 99.204 ± 0.008 %
- Uncorrected time resolution 4.781 ± 0.003 ns

The measurements leading to these results have been performed at the Test Beam Facility at DESY Hamburg (Germany), a member of the Helmholtz Association (HGF)

Thank you for listening!

Questions?

High-Voltage Monolithic Active Pixel Sensors

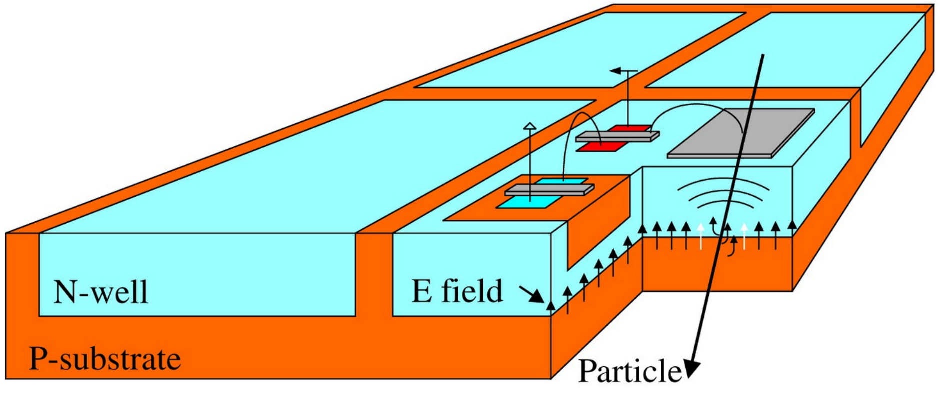
HV-MAPS

- **Hybrid** sensors bump bond a separate readout and sensor chip together
  - Can be **costly** to manufacture and have a **high material budget**

- **Monolithic** sensors integrate readout and sensor onto one chip:
  - But charge collection **via diffusion** → **too slow** for high rate applications

HV-MAPS embed readout inside pixel electrode

- **Higher biasing voltage** → collection **via drift (faster)**
- Can result in improved:
  - Signal amplitude
  - Charge collection speed
  - Radiation tolerance



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Beam Telescopes at DESY II Testbeam facility

Most requested infrastructure by users (82% in 2022)

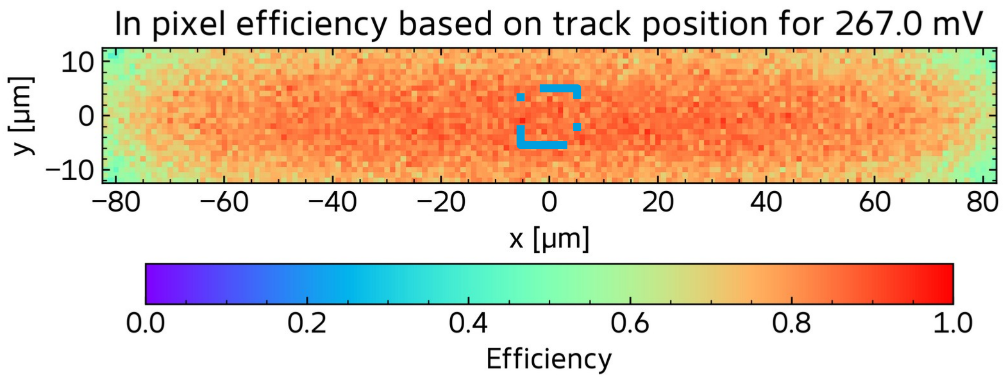
2 different types installed at desy **EUDET-Type** (TB21 & TB24) and **Adenium** (TB22)

	EUDET-Type	Adenium
Sensor	Mimosa26	Alpide
Active Area	2 x 1 cm	3 x 1.5 cm
Pixel Pitch	18.4 x 18.4 µm	29.24 x 26.88 µm
Read Out Time	> 115 µs	10 µs

In Pixel Efficiency

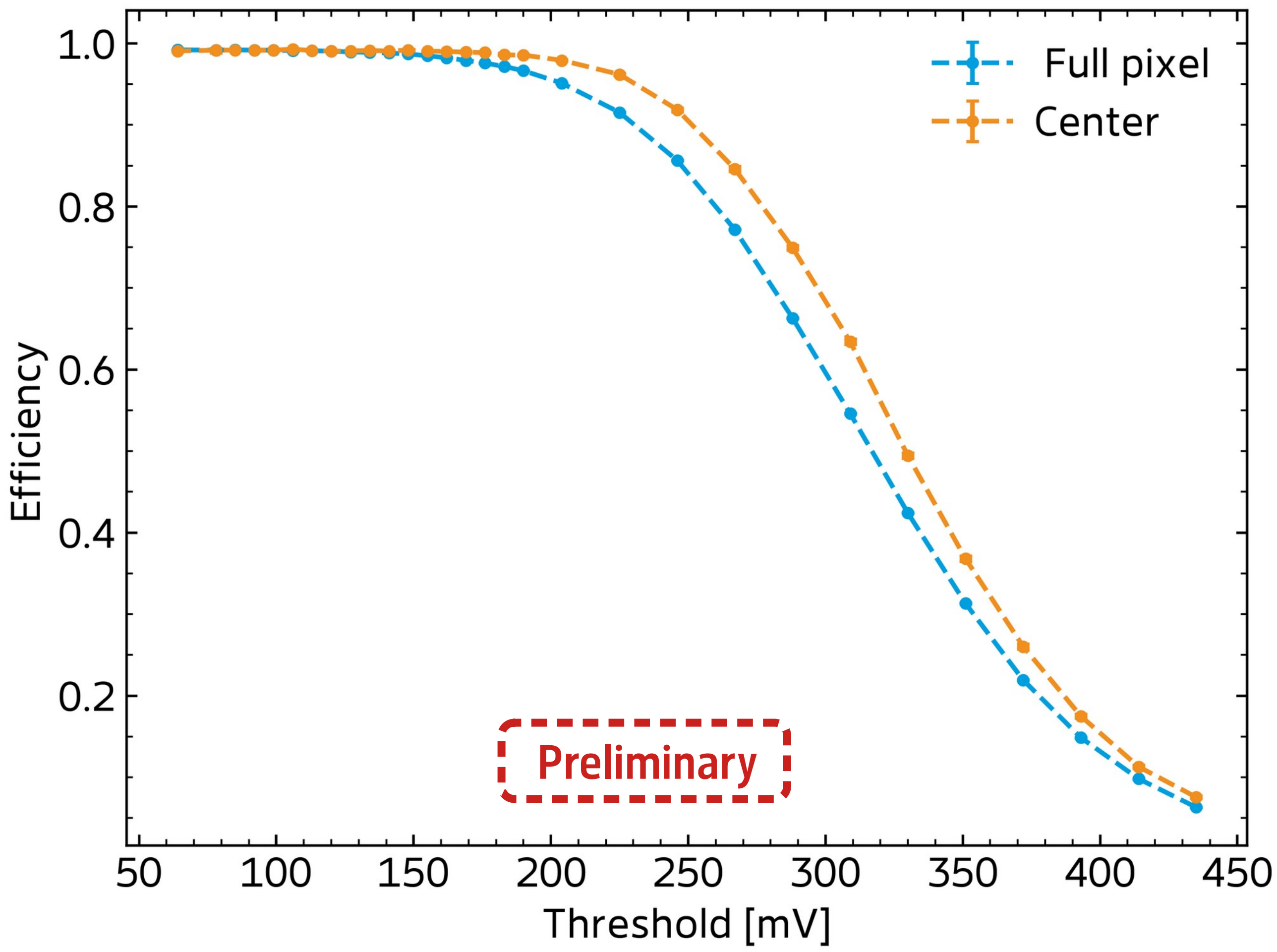
Full Pixel and Center of Pixel Comparison

- Efficiency in the center 10 x 10 µm in each pixel calculated



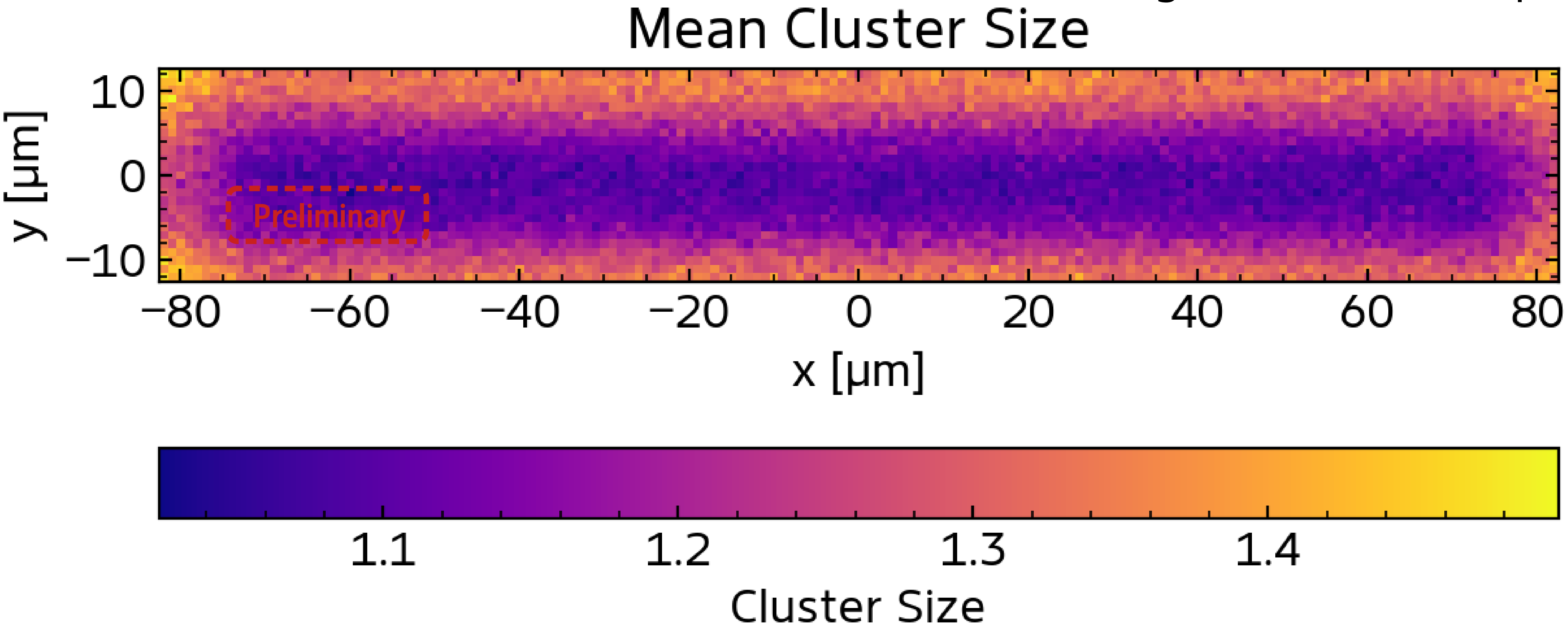
- Larger plateau when looking at center of each pixel only

- Bias of 85V



In-Pixel Mean ClusterSize

Larger cluster size in pixel



Bias 85 V and threshold 57 mV

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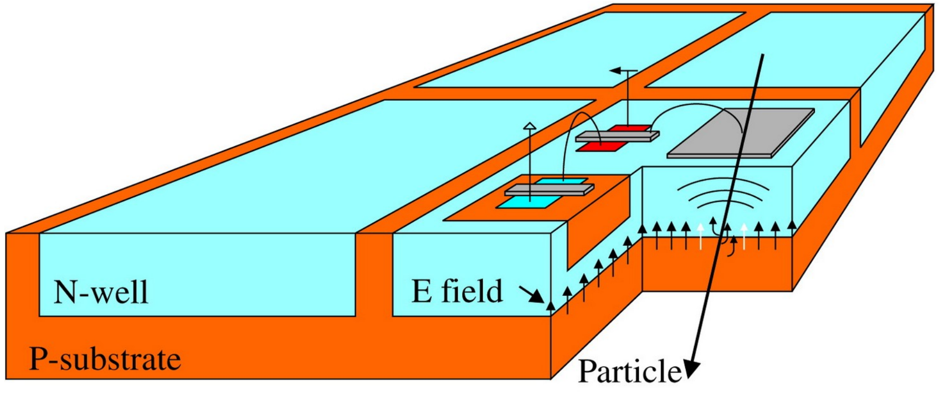

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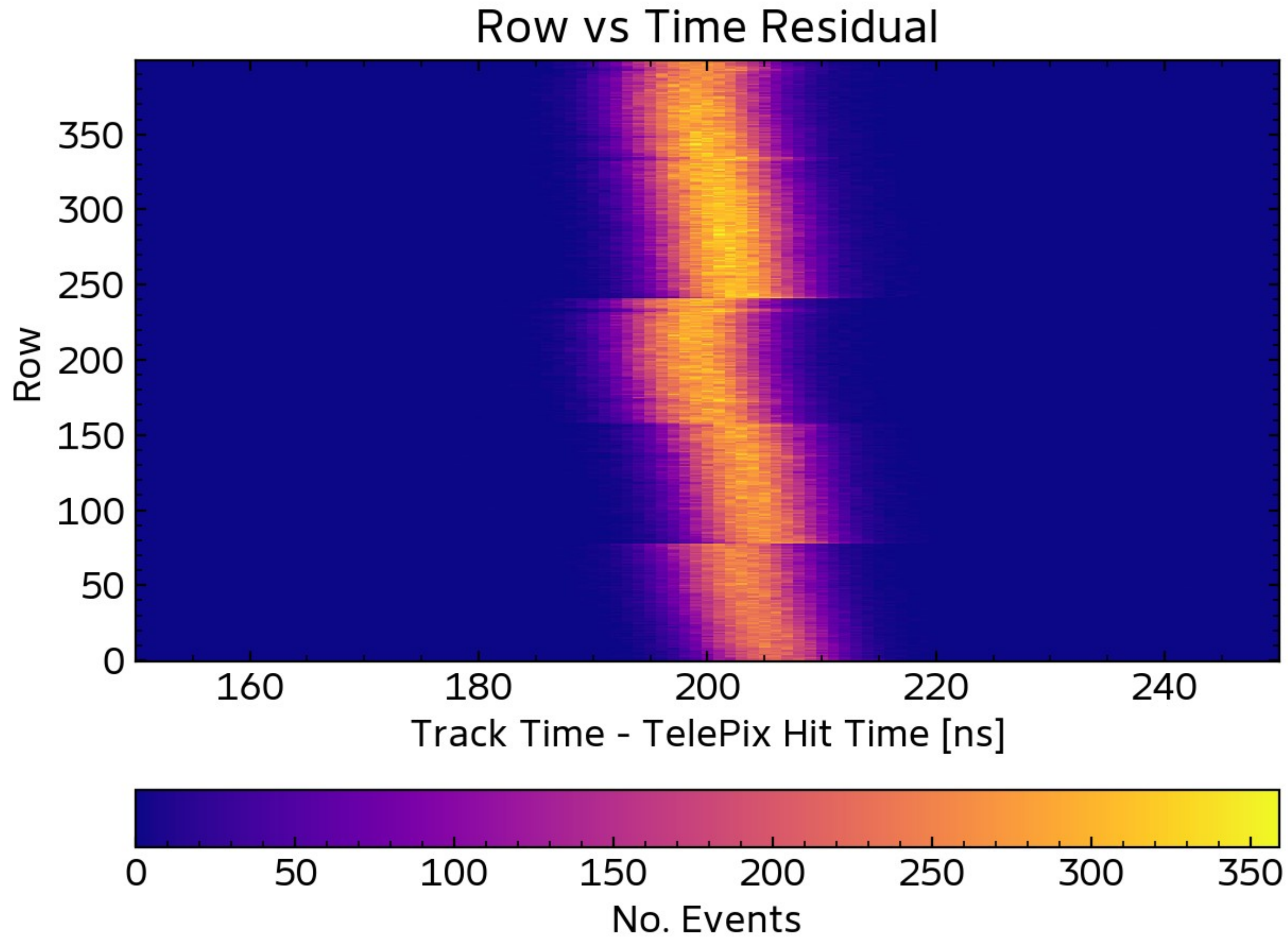
Time Residual Corrections

Preliminary



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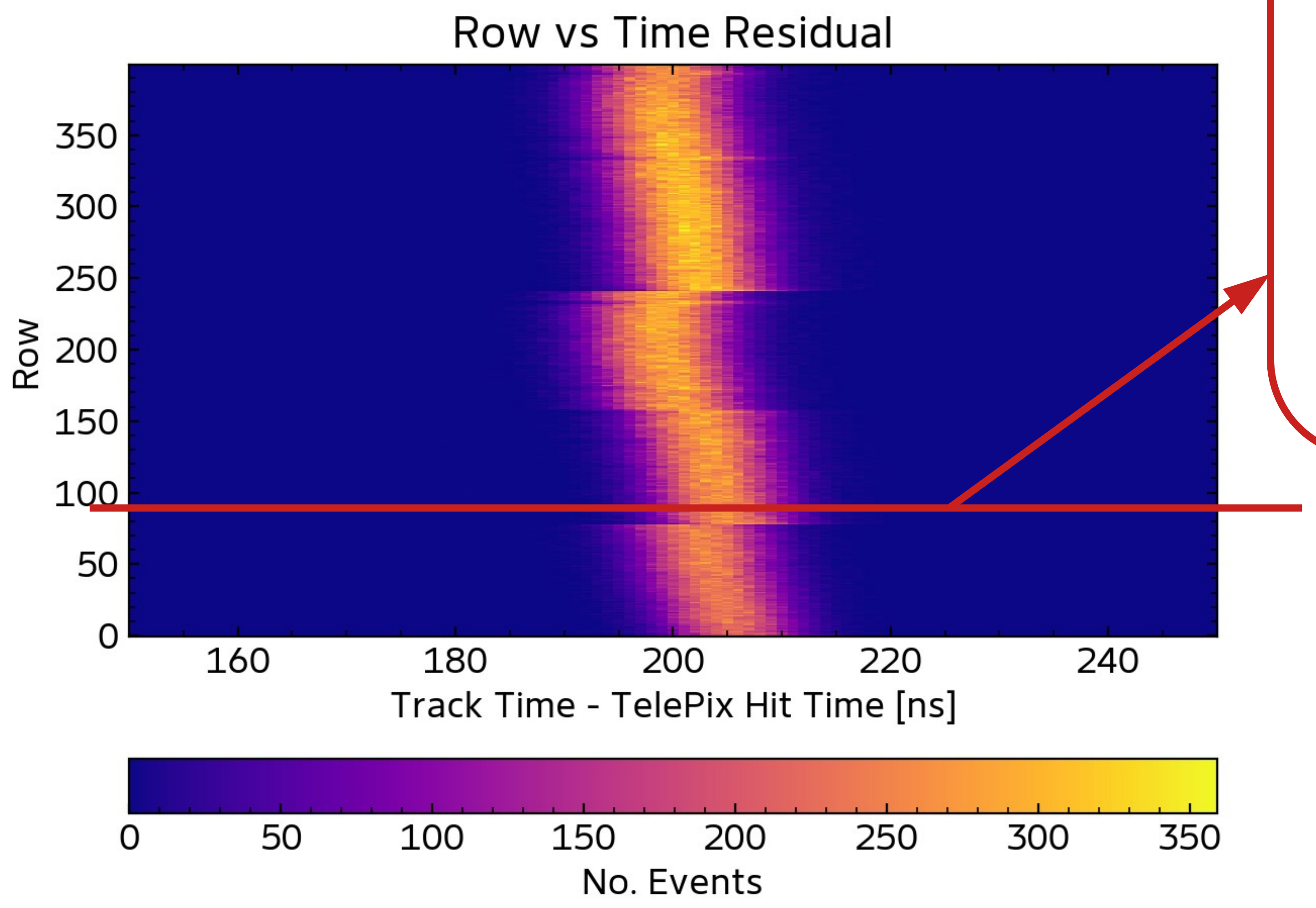

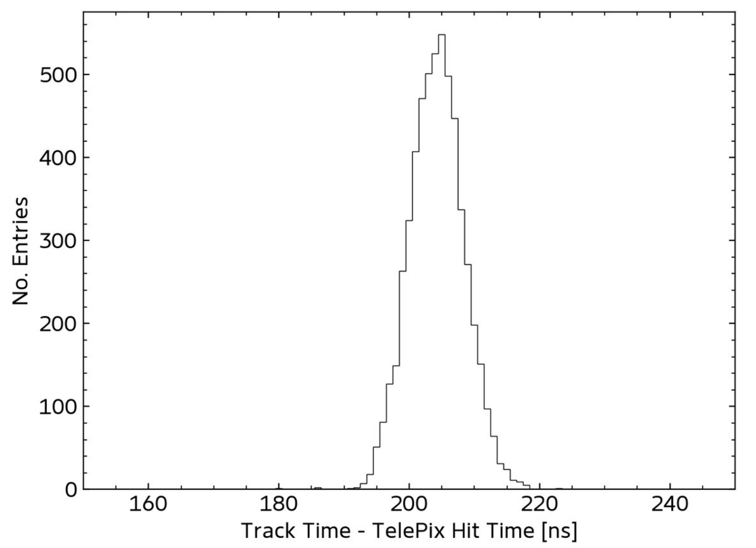

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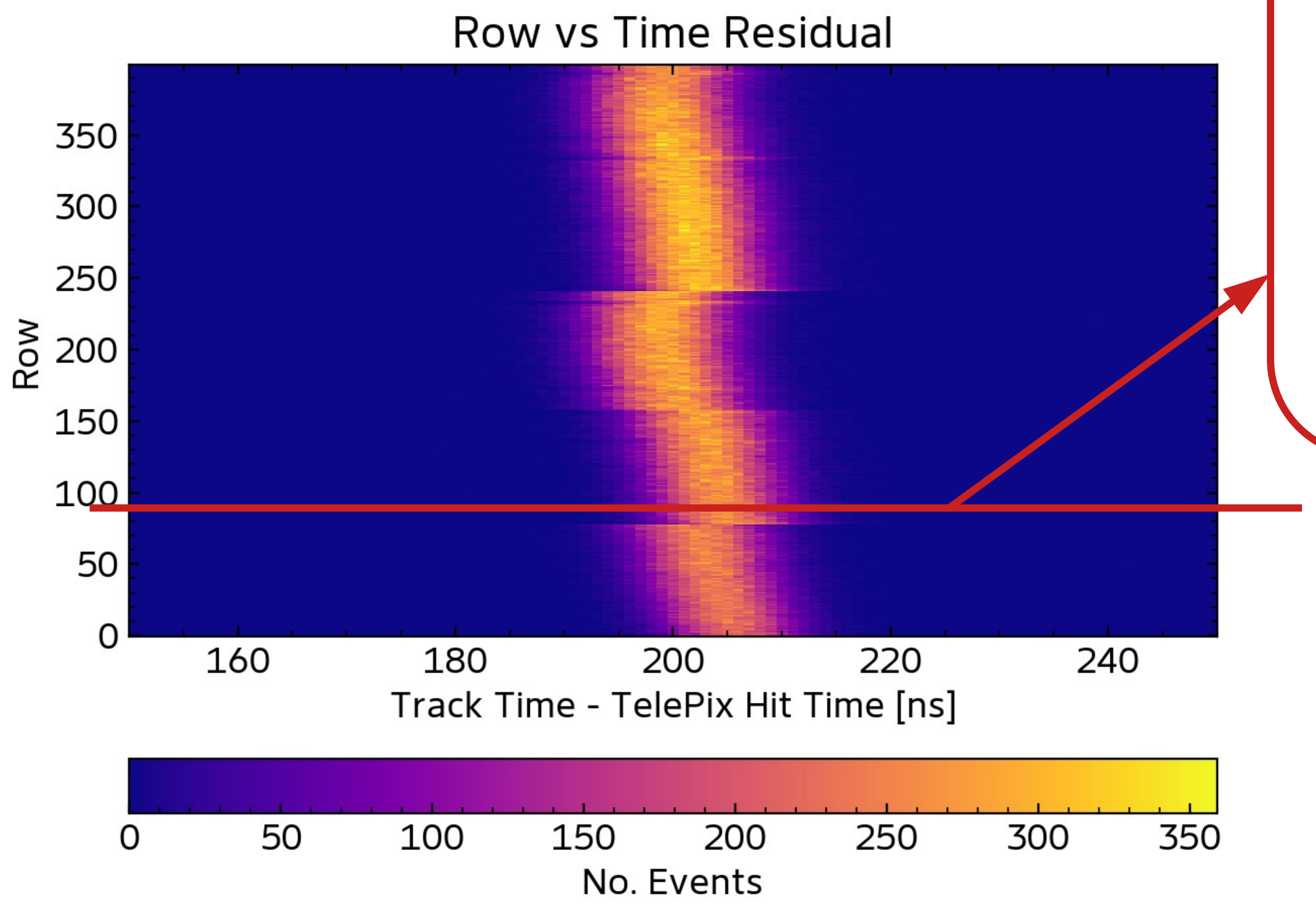
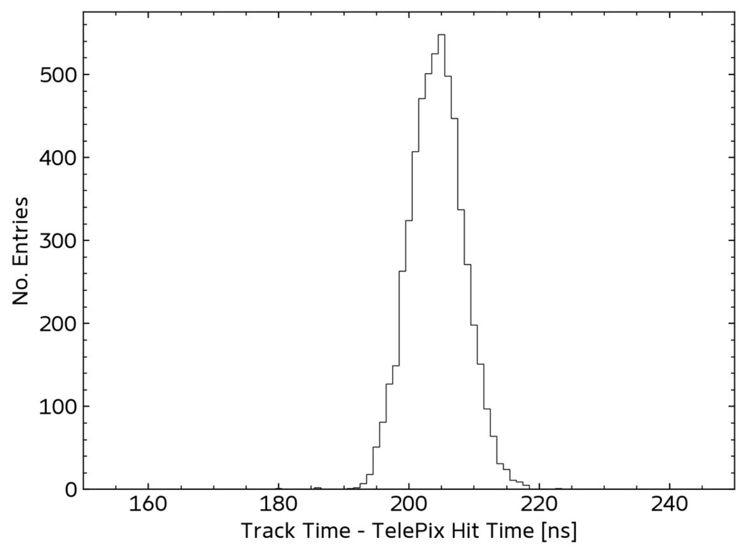




Gauss Fit

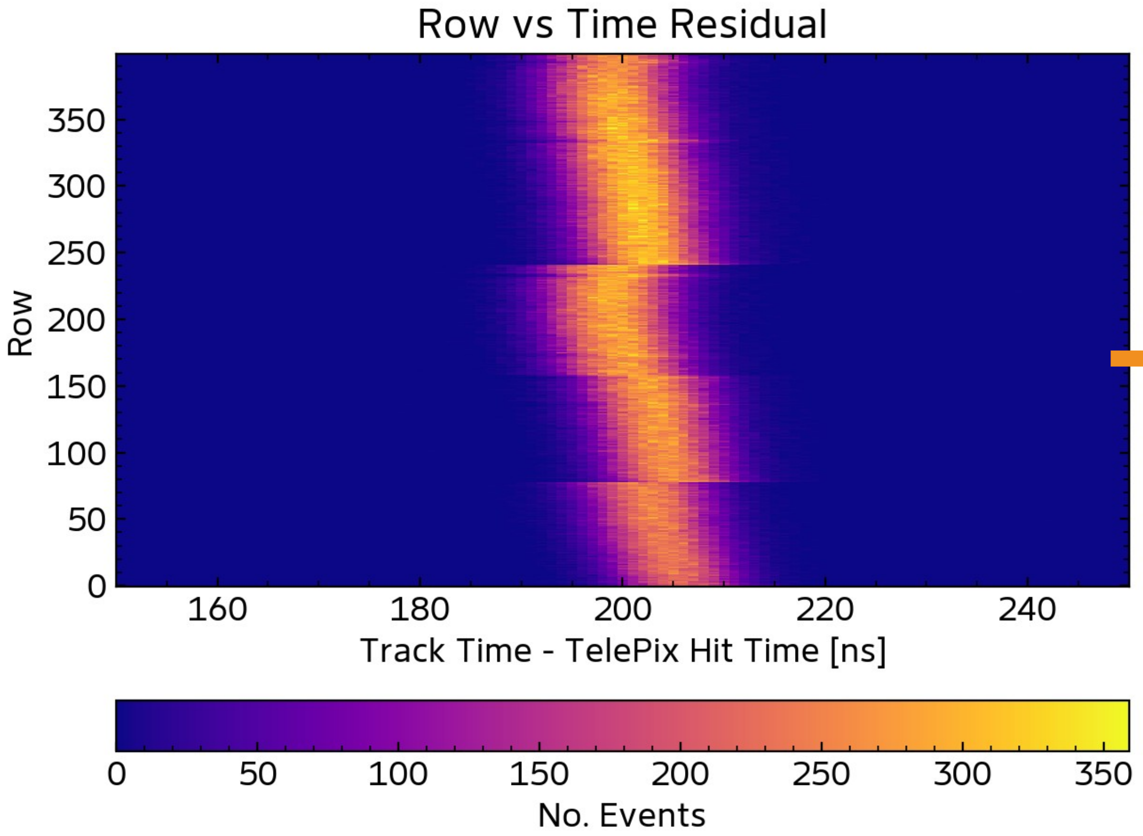
Extract Mean

Reload data &
Shift each timestamp by the mean

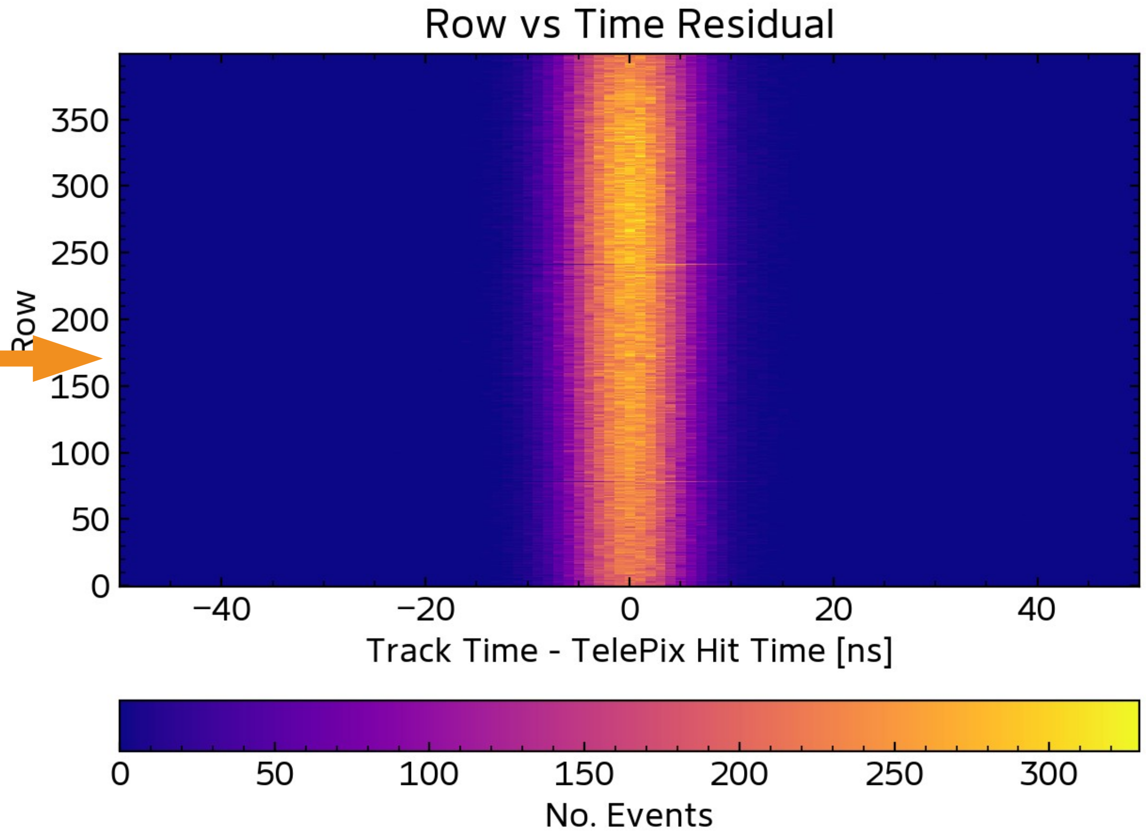
Bias 85 V and threshold 57 mV

Time Residual Corrections

Before Corrections



After Corrections



This must be done offline
And requires processing the data twice

Bias 85 V and threshold 57 mV