

TelePix2

A HV-CMOS sensor for Fast Timing and ROI Triggering

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Pixel 2024, Strasbourg, 19/11/24

HELMHOLTZ

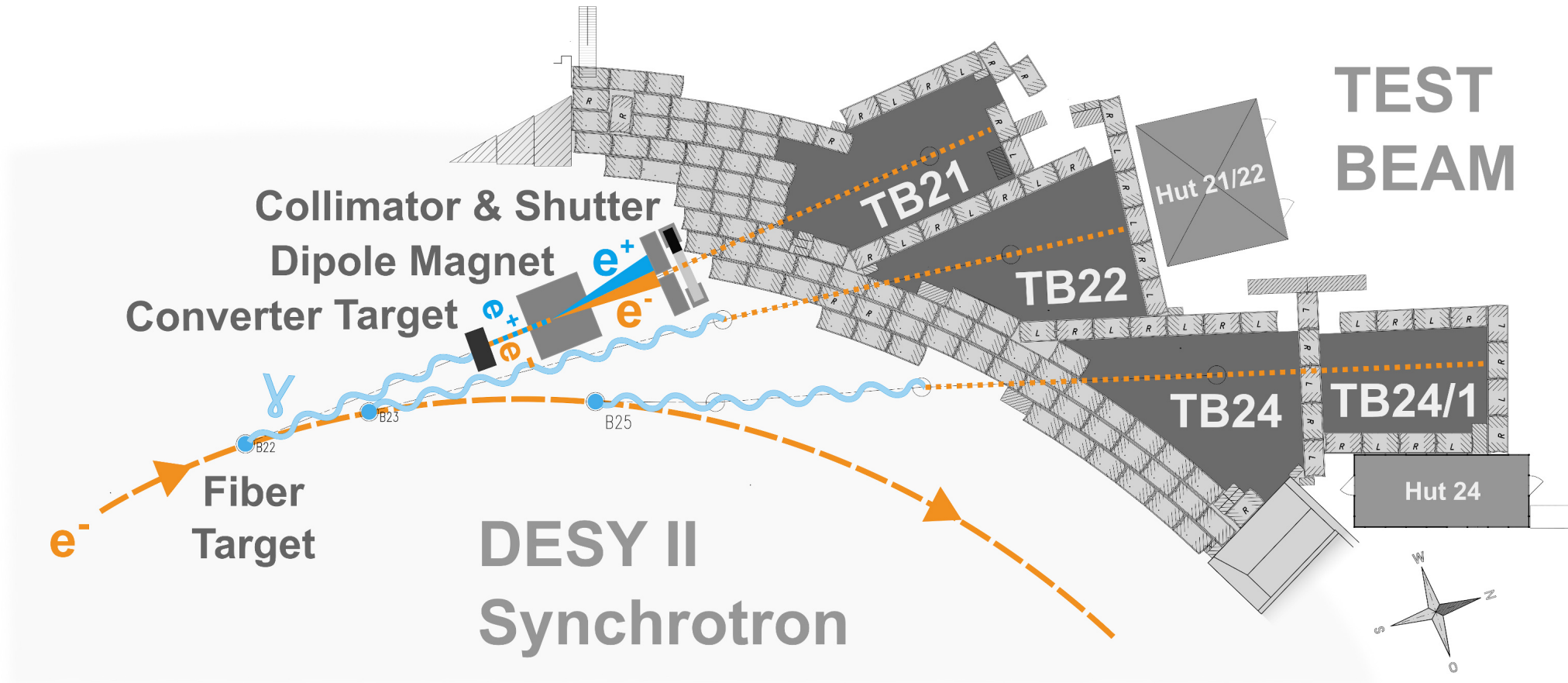
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The DESY II Test Beam Facility

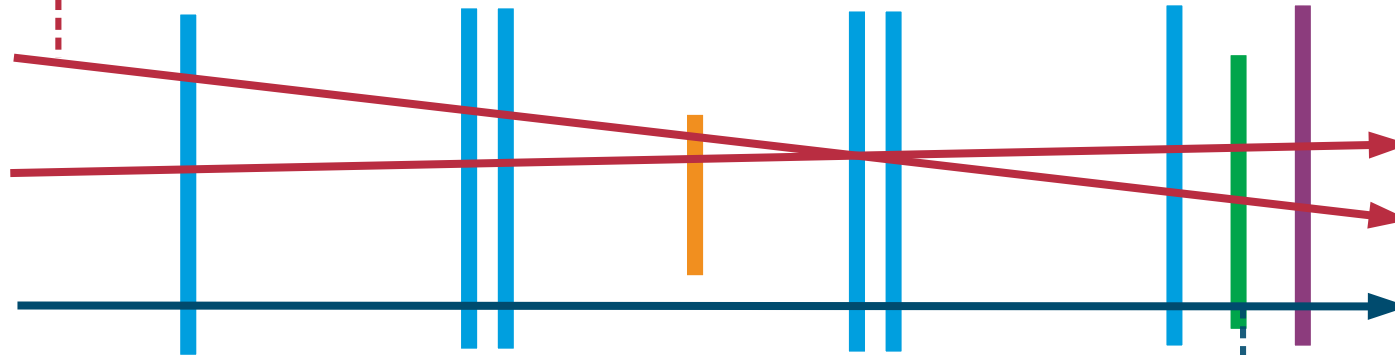


- detector characterisation
- e^- or e^+ 1-6 GeV/c

Timing and ROI Triggering Plane

Multiple electrons within readout frame
→ Timing plane needed

TelePix2
New user infrastructure



Telescope Planes
Device Under Test
Trigger

Inefficient data taking
→ Configurable region of interest trigger needed

TelePix2

Key Features

- **180 nm HV-CMOS** process of TSI
- Fast **user-configurable ROI trigger** (HitBus)
- **4 ns timestamp**
- A low material budget compared to hybrid sensors
- 3-bit trimming
- Amplifier and comparator within pixel
- Self-triggered readout with zero suppression
- Pitch: $165 \times 25 \mu\text{m}^2$
- Pixels: 120×400
- Active Area: $2 \times 1 \text{ cm}^2$

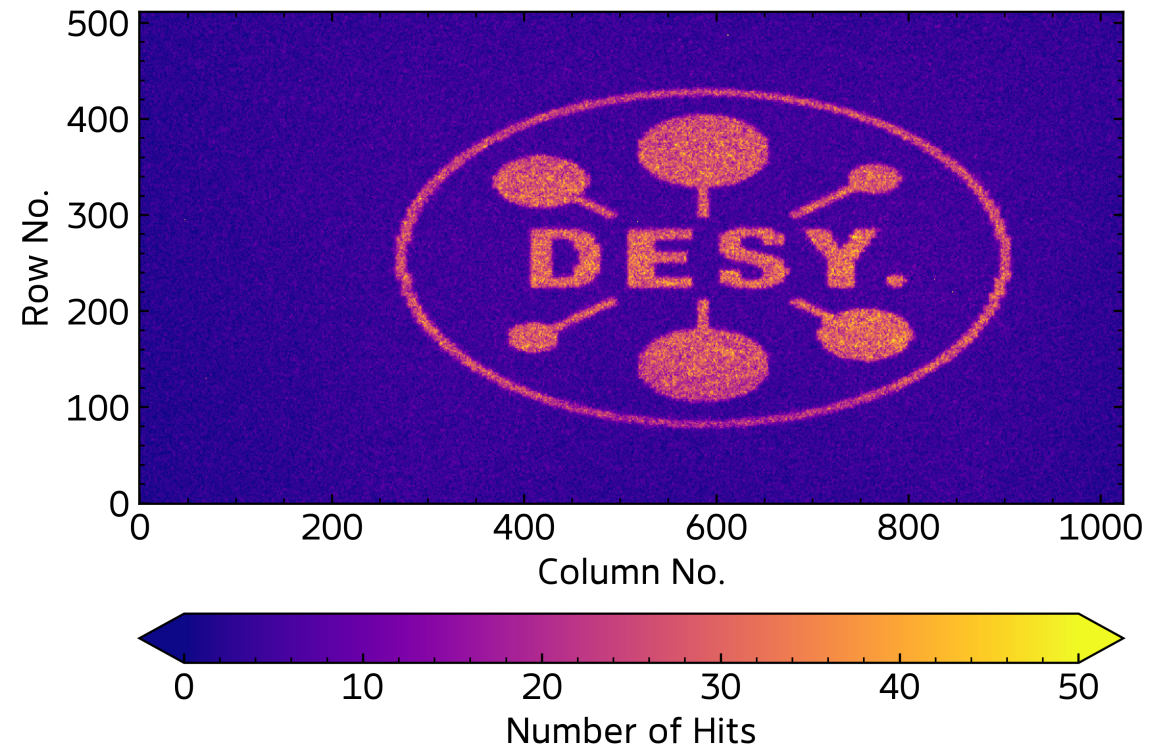


Trigger and Masking Capabilities

TelePix2 Trigger Mask



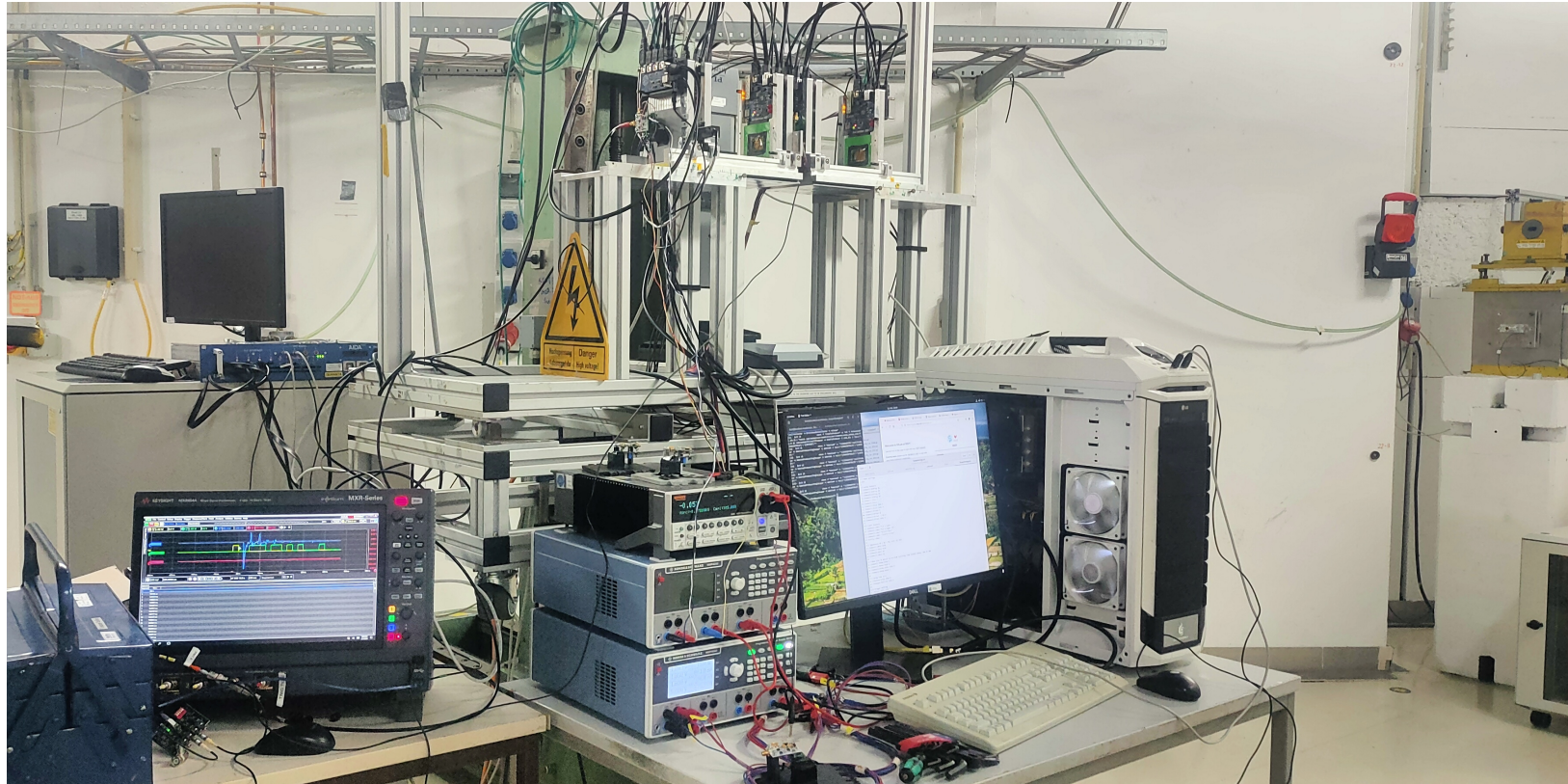
Triggered Telescope Hit Map



DESY Test Beam Campaign

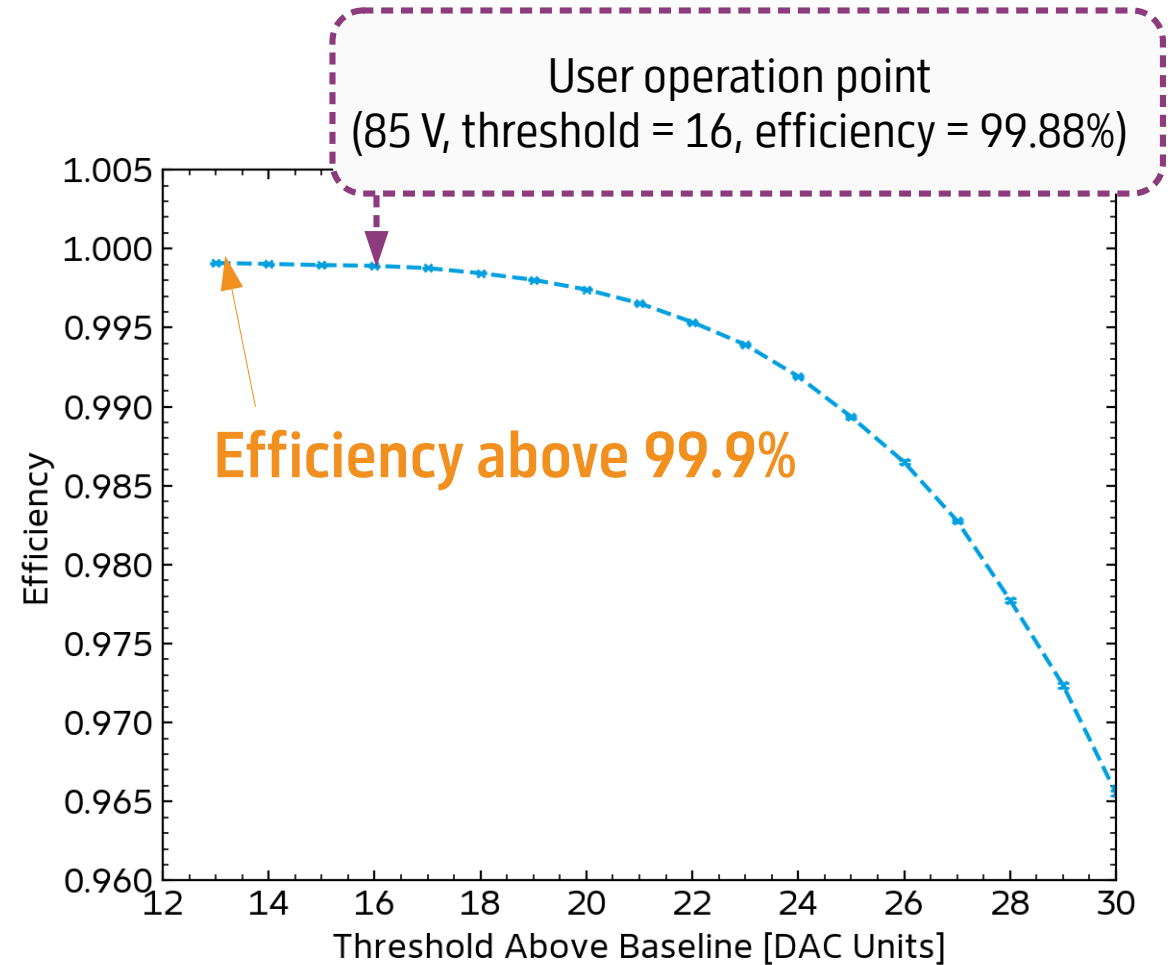
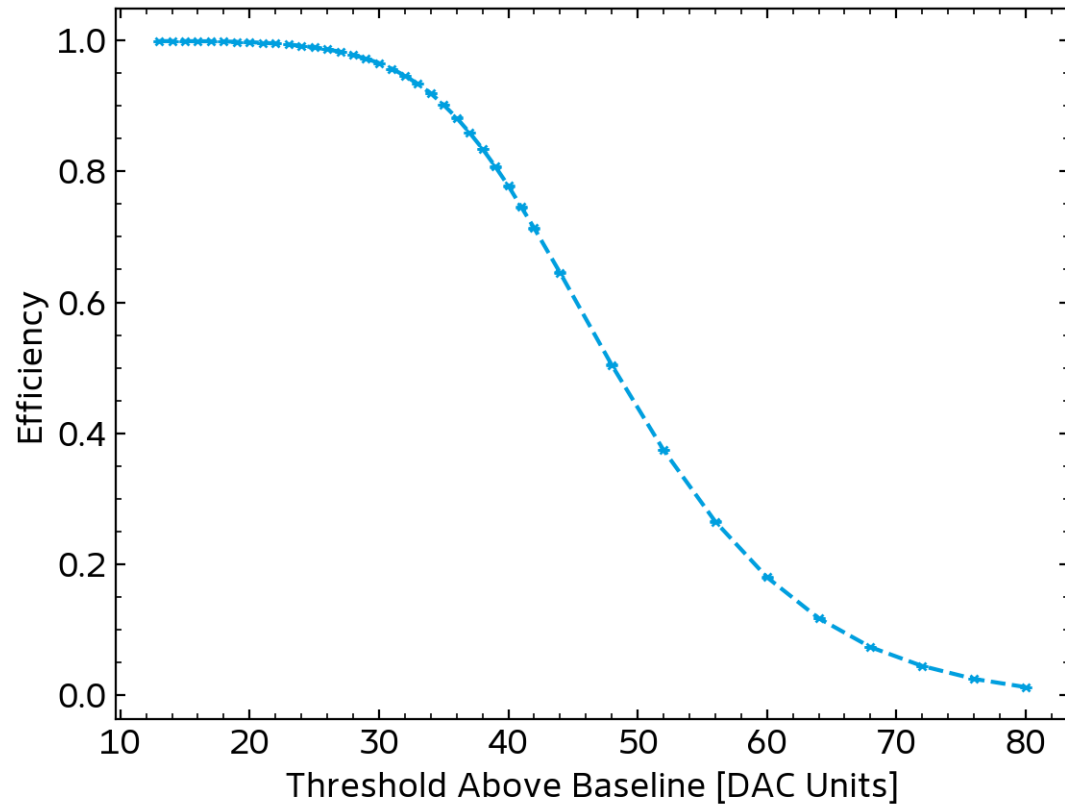


Adenium Telescope in test beam area 22 with a 4 GeV electron beam
The TelePix2 sensor had a thickness $\sim 740 \mu\text{m}$ and was not cooled.



Analysis was carried out using the test beam reconstruction framework [Corryvreckan](#).

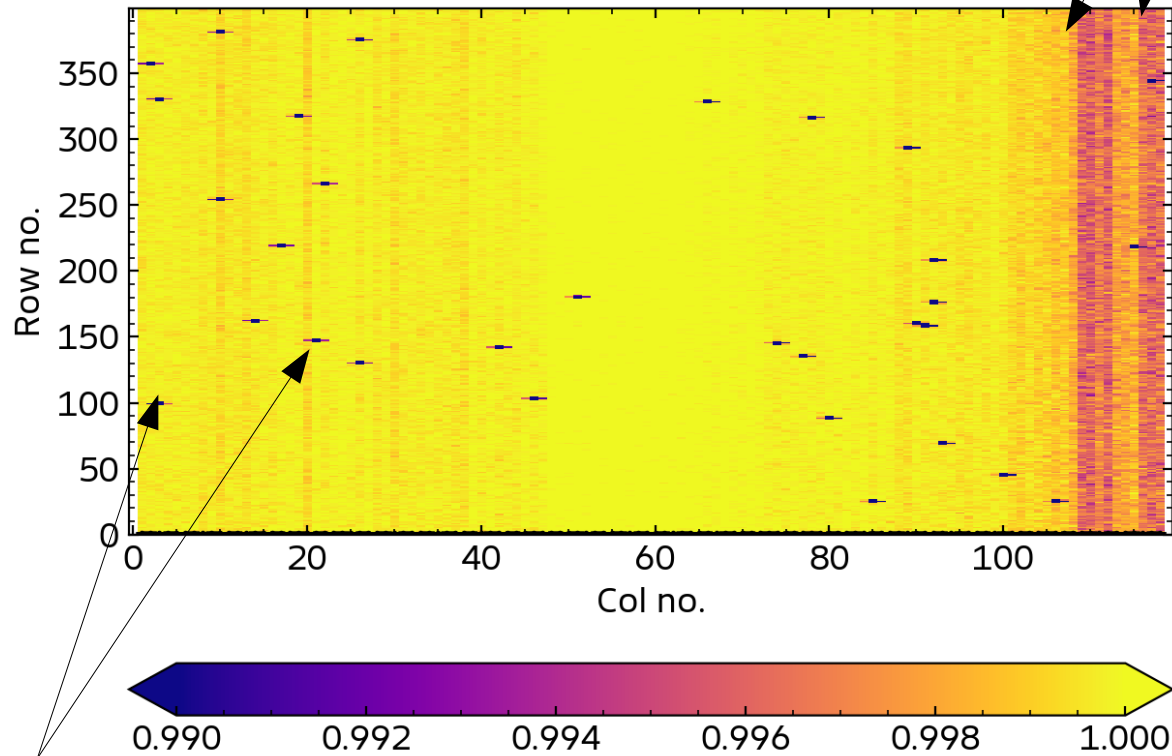
Efficiency vs Threshold



Efficiency

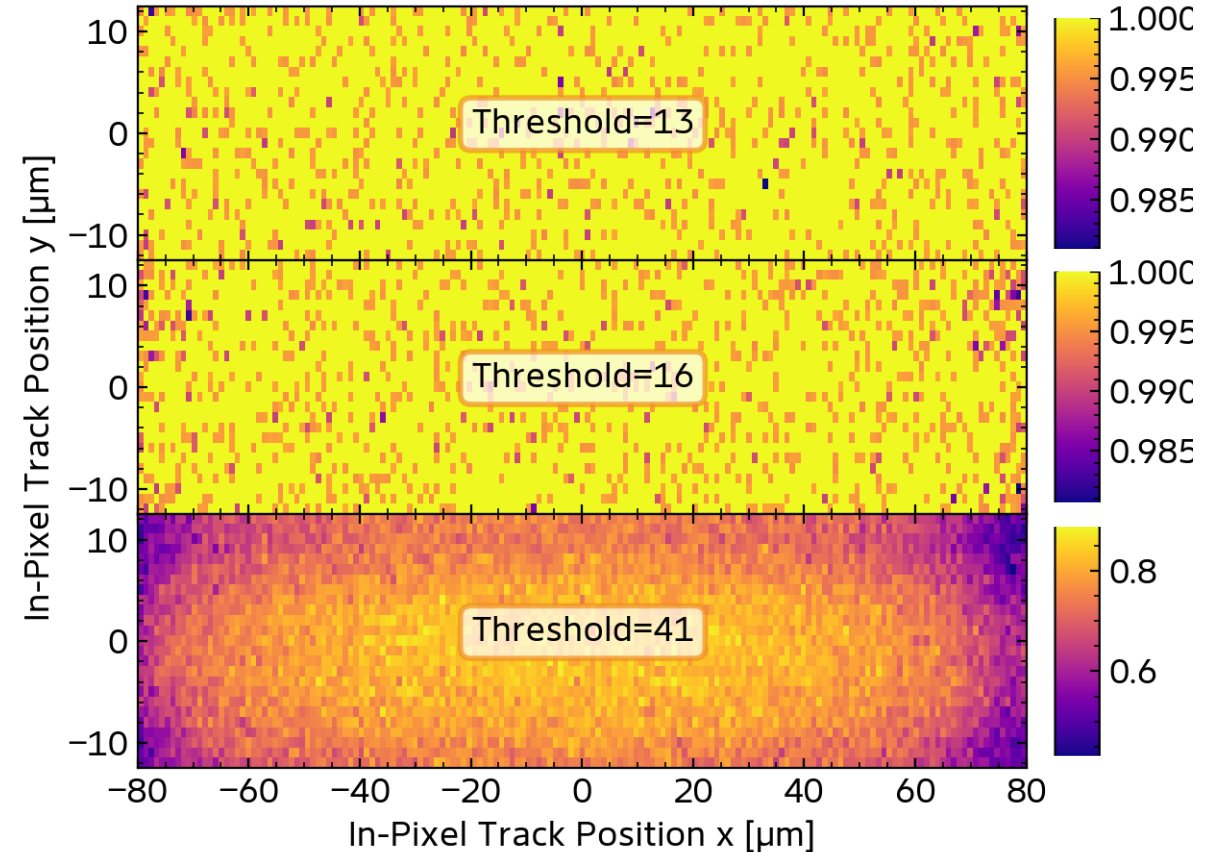
Slightly lower efficiency ($< 1\%$) columns still under investigation

Full Chip Efficiency (1 threshold unit below user operation)



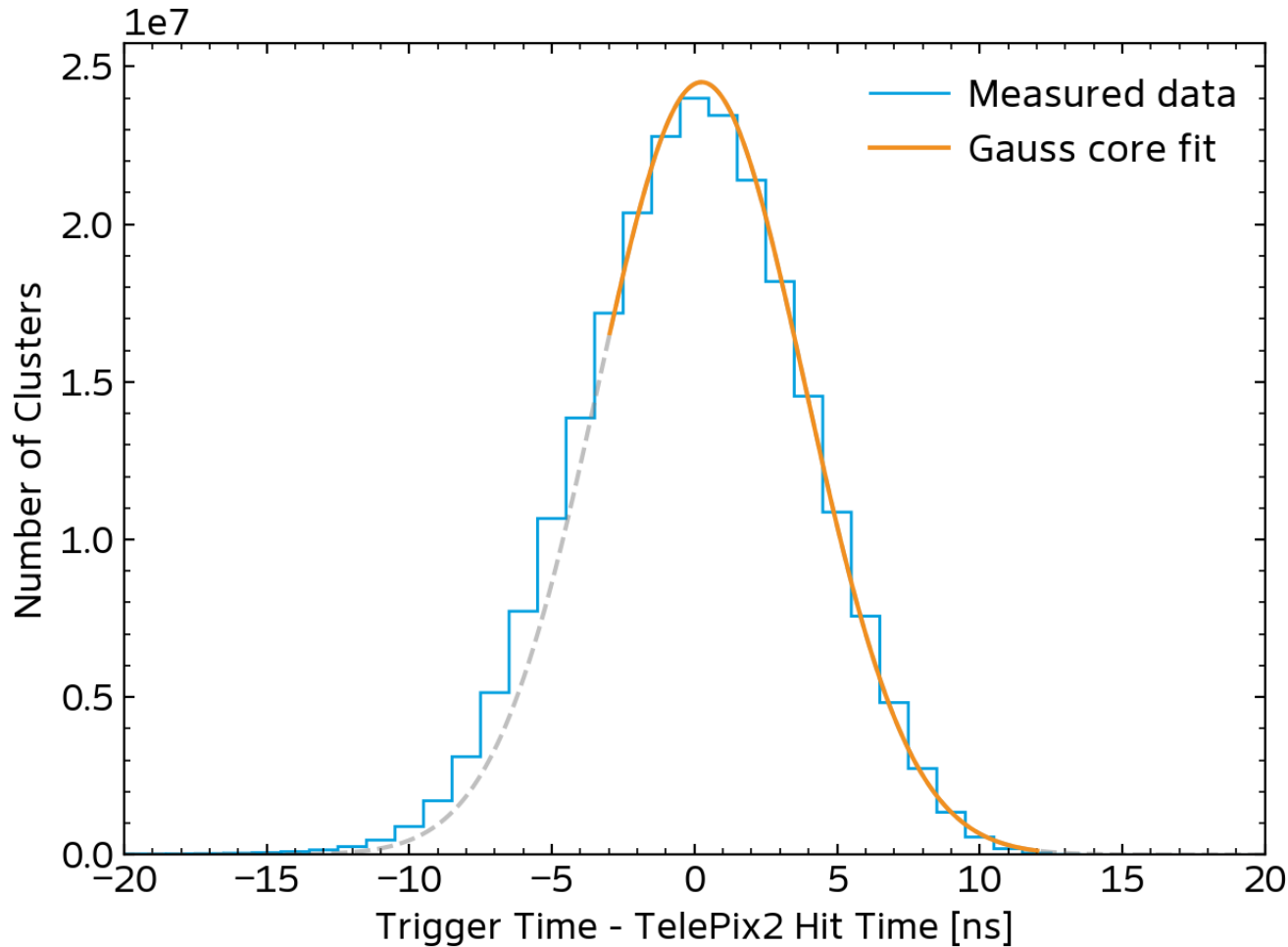
Noisy pixels masked online

In-Pixel Efficiency



Time Resolution

Without Corrections



$$f(x) = f_0 \cdot e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

$$\sigma_{\text{GaussCore}} = 3.6346 \pm 0.0003 \text{ ns}$$

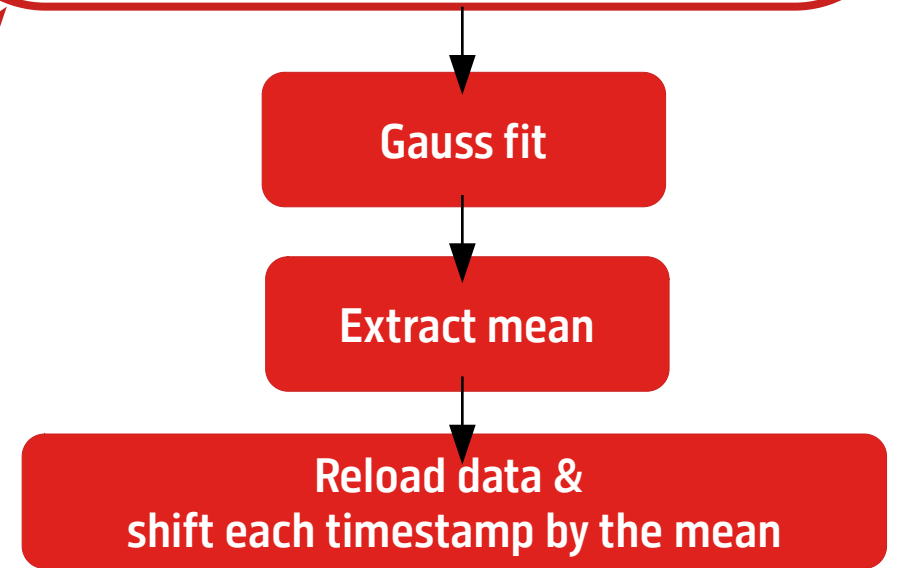
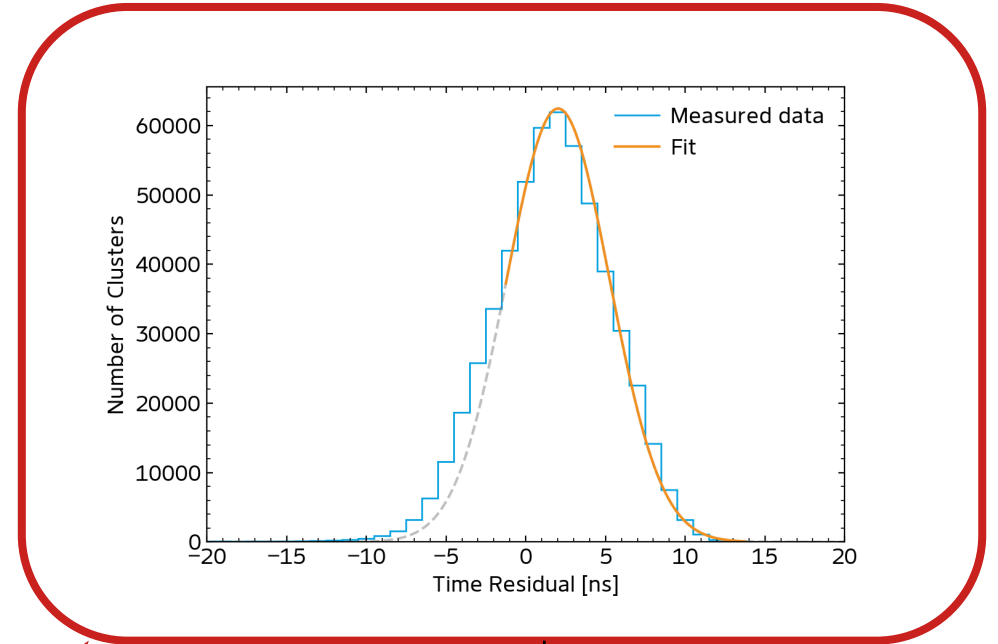
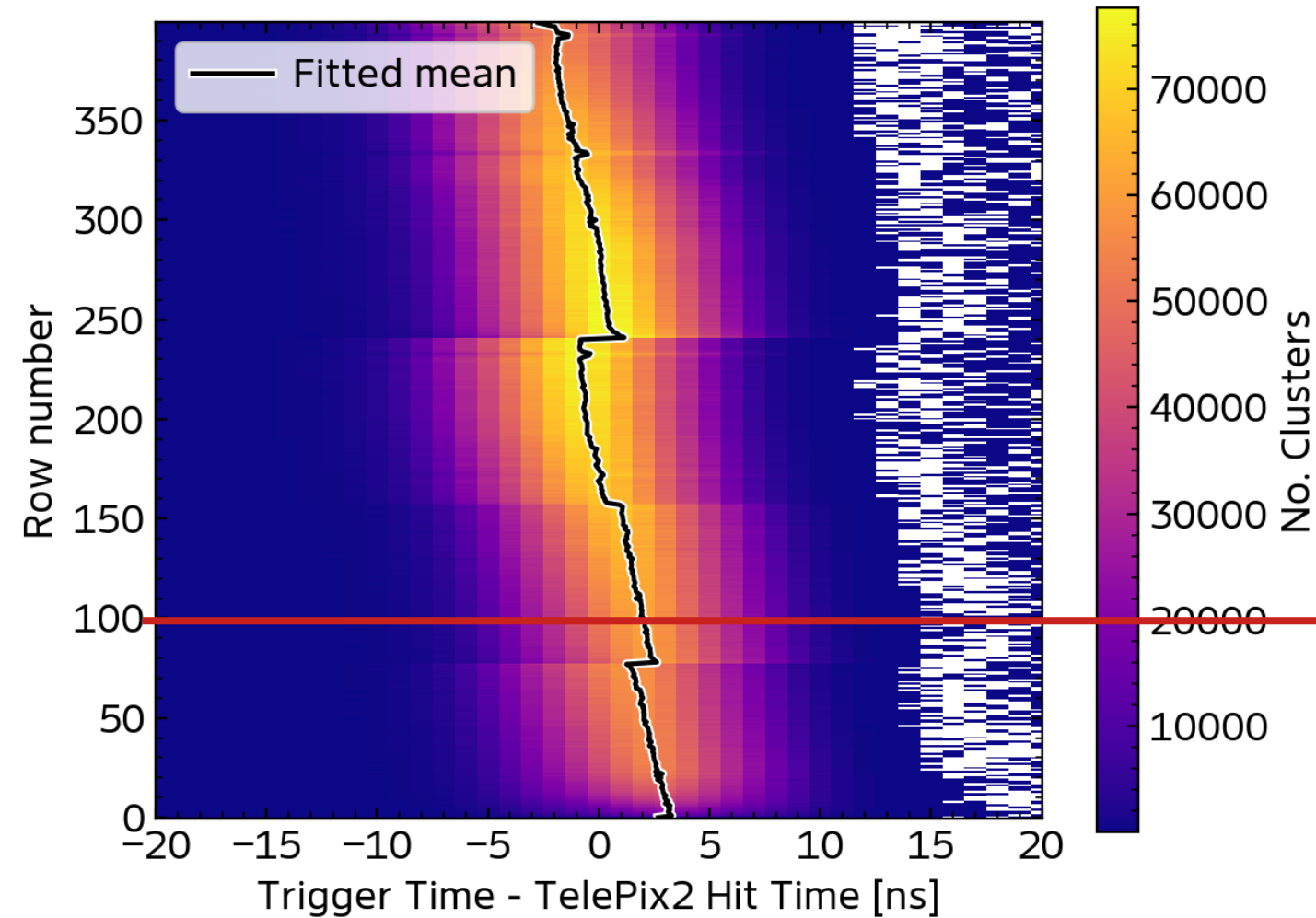
in-time fraction **0.998**

$$\frac{\text{Hits within 25 ns}}{\text{Hits within 100 ns}}$$

$$\sigma_{\text{FullDistribution}} = 3.90 \text{ ns}$$

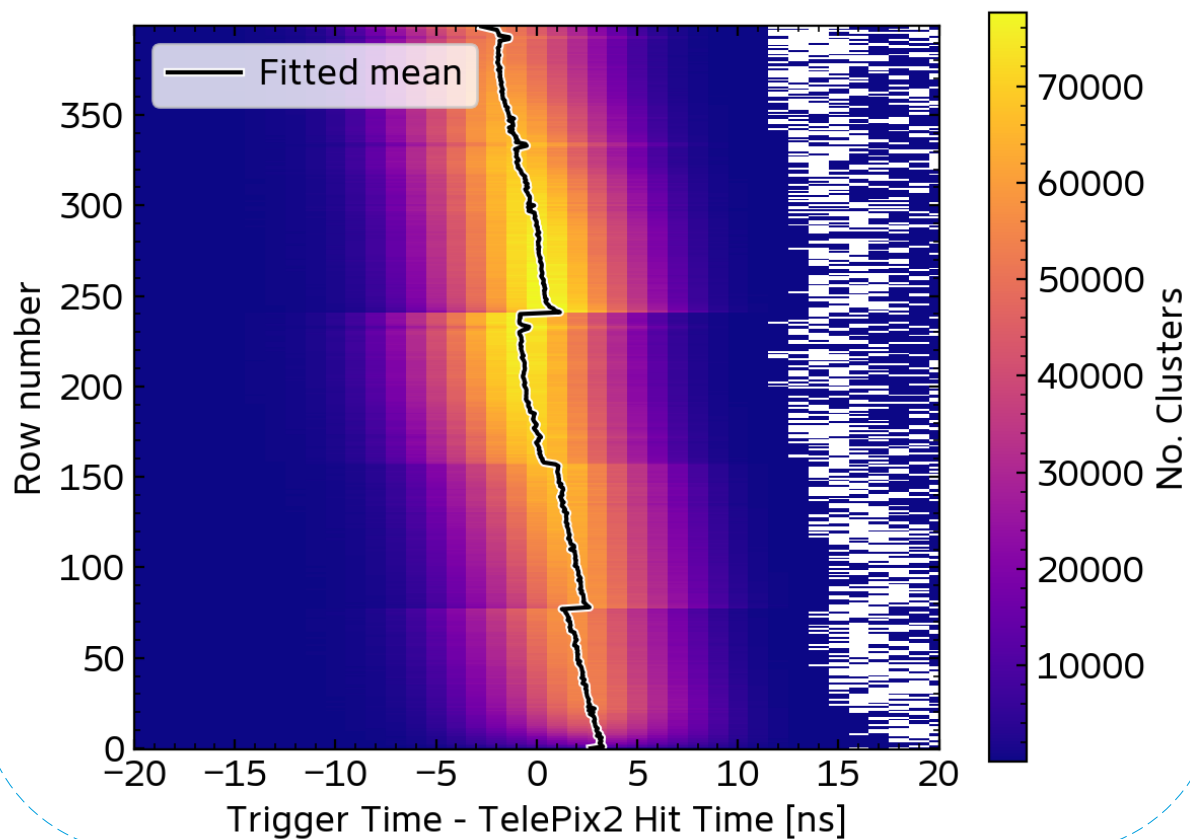
$$\sigma = \sqrt{\frac{1}{N} \left(\sum (x_i - x_{\text{mean}})^2 \right)}$$

Row Delay Corrections

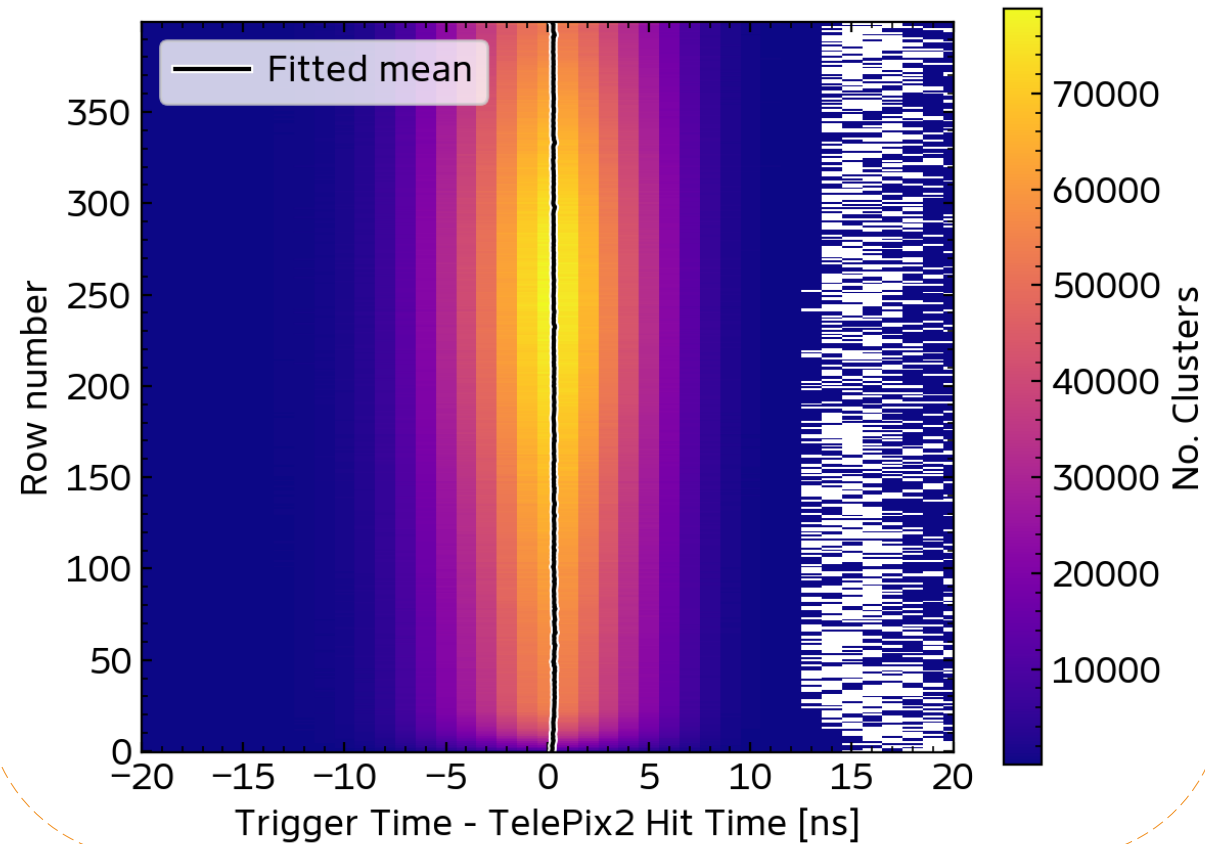


Row Delay Corrections

Before Corrections

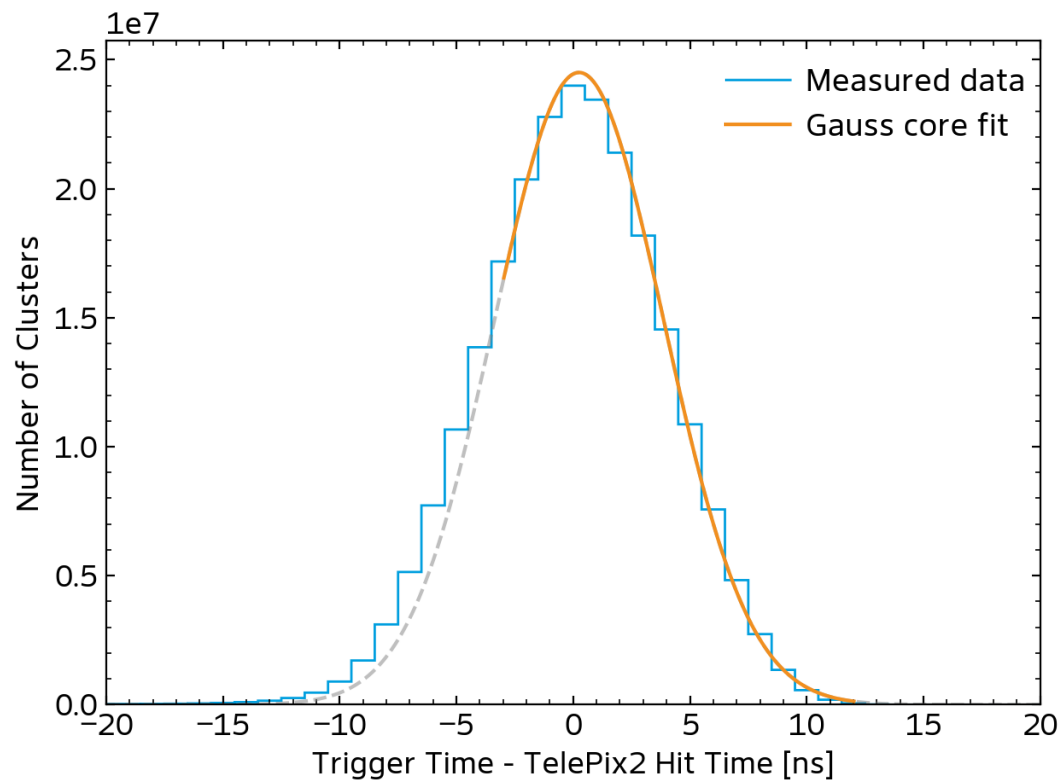


After Corrections



Row Delay Corrections

Before Corrections

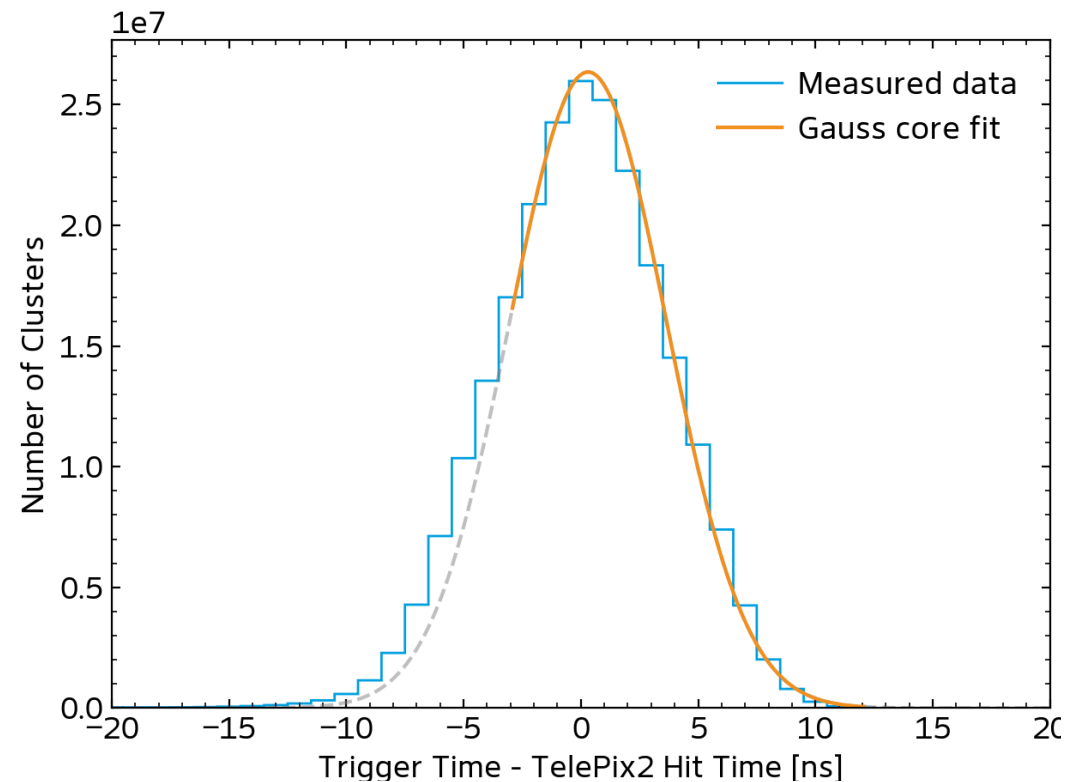


$$\sigma_{\text{GaussCore}} = 3.6346 \pm 0.0003 \text{ ns}$$

in-time fraction 0.998

$$\sigma_{\text{FullDistribution}} = 3.90 \text{ ns}$$

After Corrections



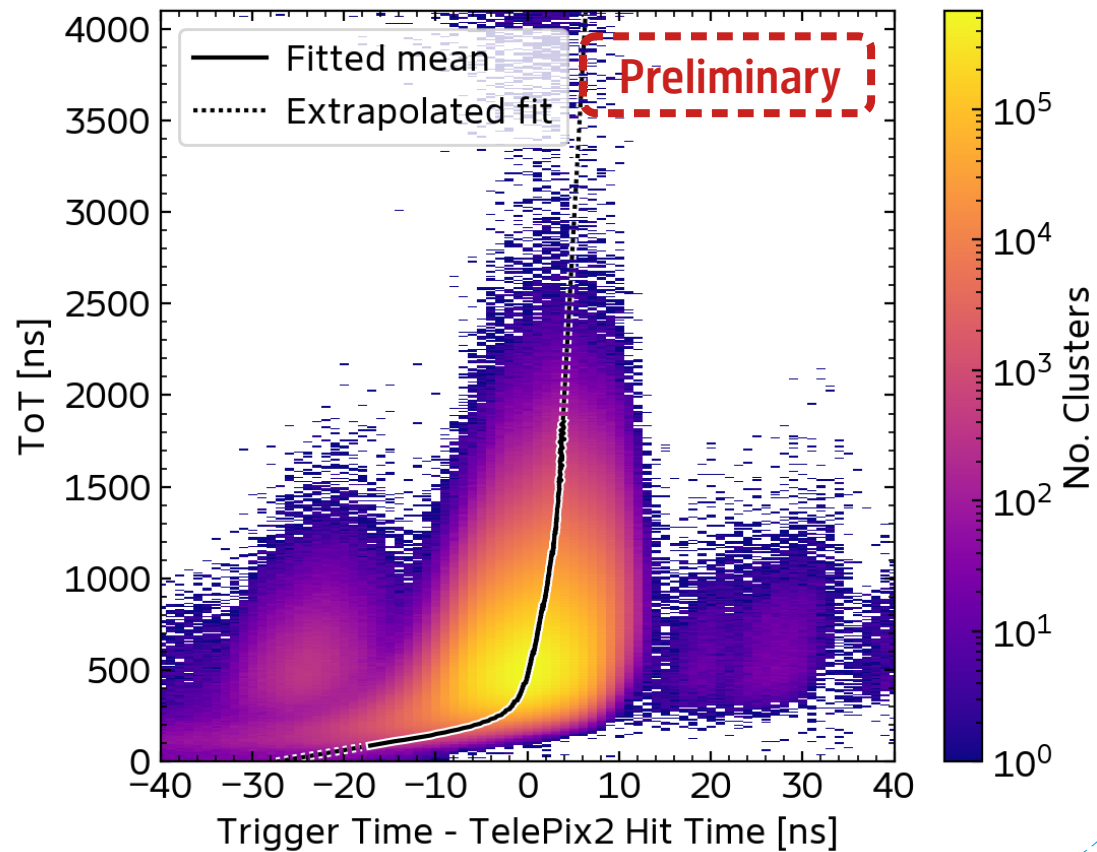
$$\sigma_{\text{GaussCore}} = 3.3515 \pm 0.0002 \text{ ns}$$

in-time fraction 0.998

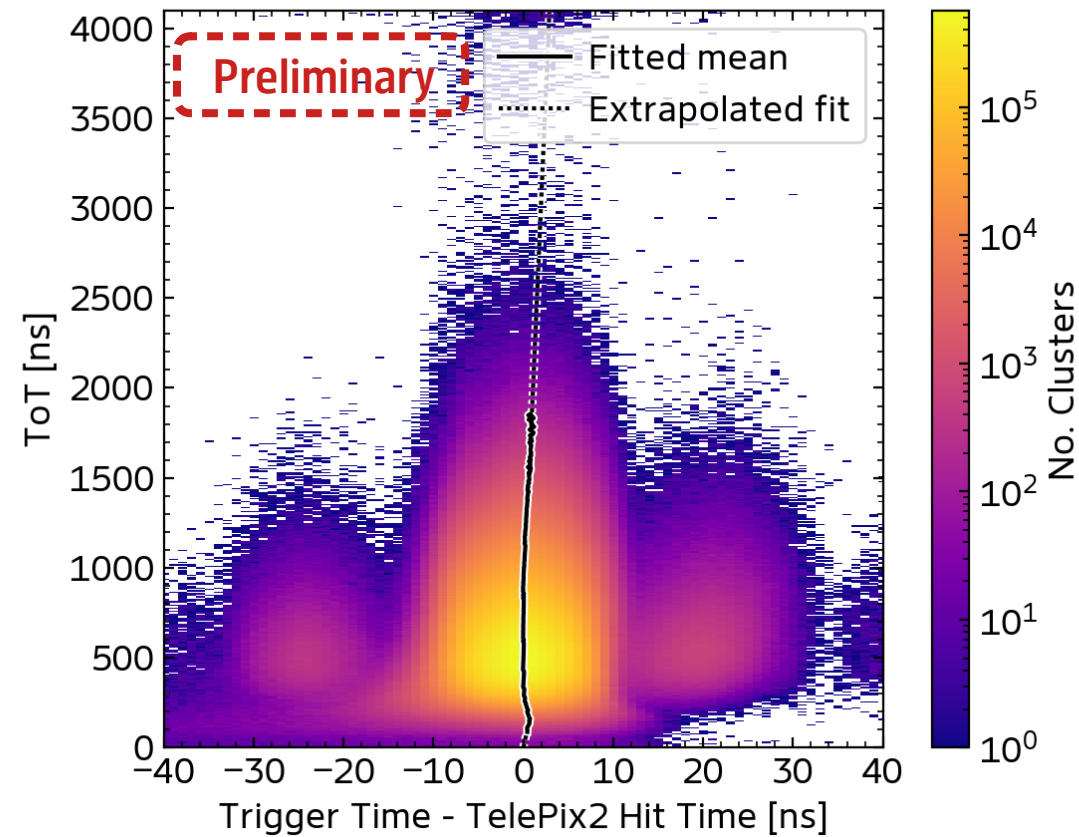
$$\sigma_{\text{FullDistribution}} = 3.67 \text{ ns}$$

Time Walk Corrections

Before Corrections

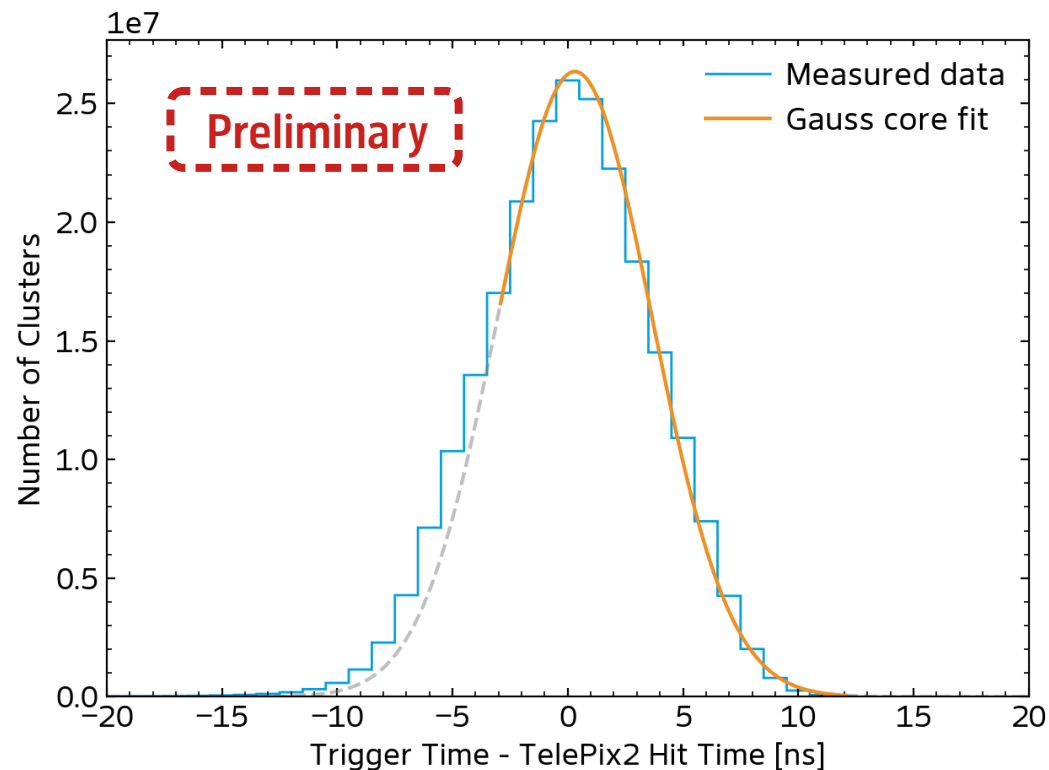


After Corrections



Time Walk Corrections

Before Corrections

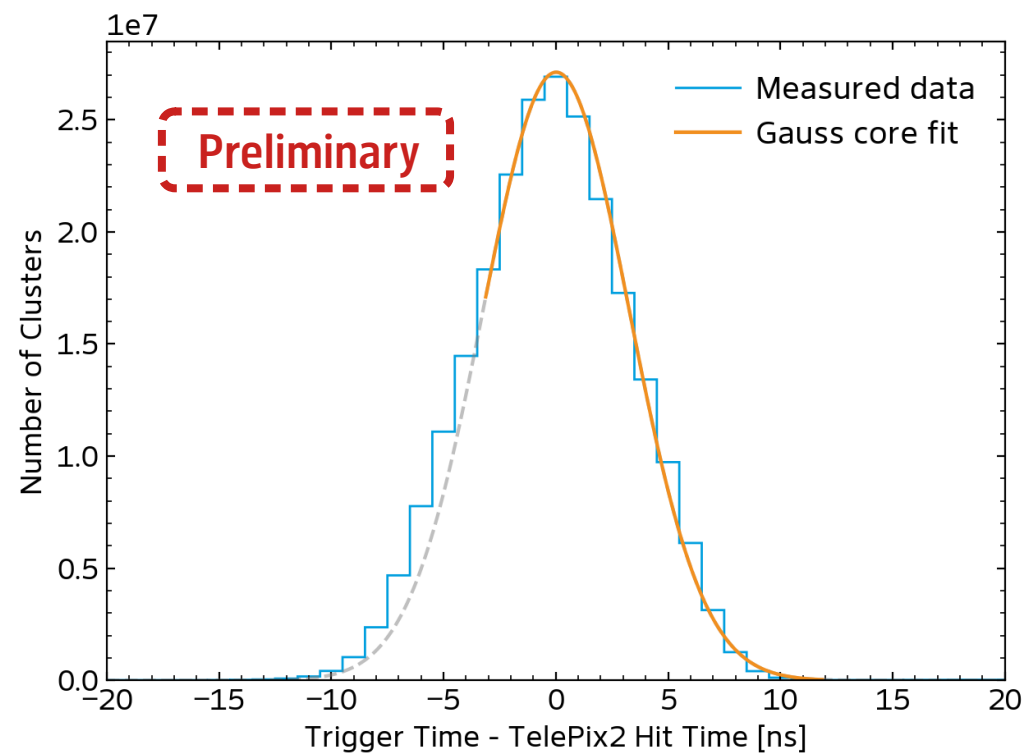


$$\sigma_{\text{GaussCore}} = 3.3515 \pm 0.0002 \text{ ns}$$

in-time fraction 0.998

$$\sigma_{\text{FullDistribution}} = 3.67 \text{ ns}$$

After Corrections



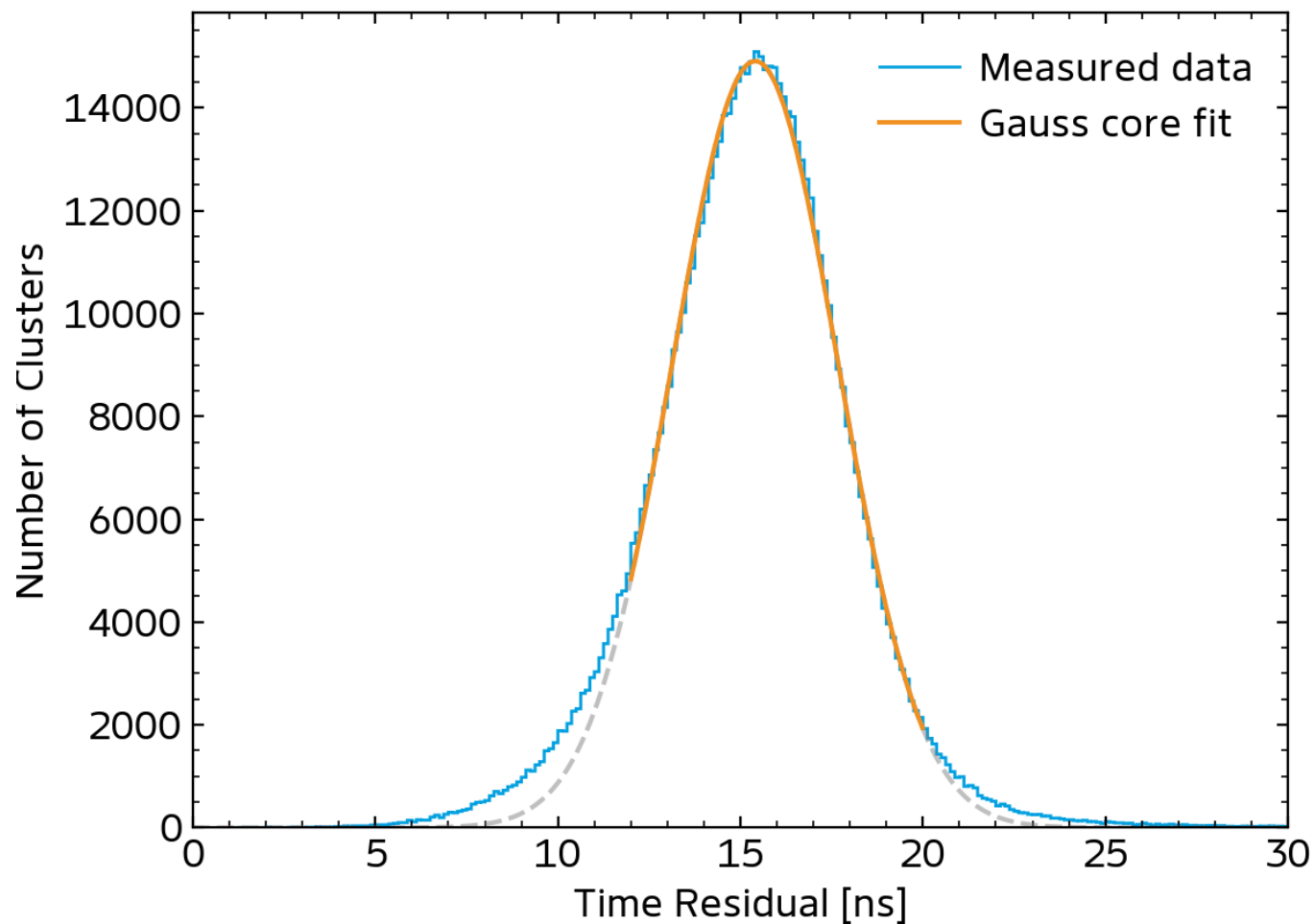
$$\sigma_{\text{GaussCore}} = 3.2673 \pm 0.0002 \text{ ns}$$

in-time fraction 0.998

$$\sigma_{\text{FullDistribution}} = 3.53 \text{ ns}$$

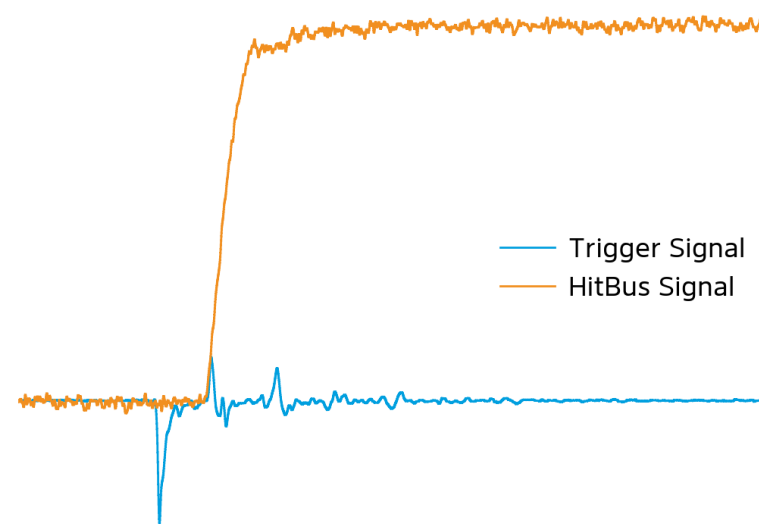
HitBus Measurements

Timing Performance of the TelePix2 Trigger via Oscilloscope Waveforms



$$\sigma_{\text{gaussCore}} = 2.270 \pm 0.004 \text{ ns}$$

$$\sigma_{\text{FullDistribution}} = 2.41 \text{ ns}$$

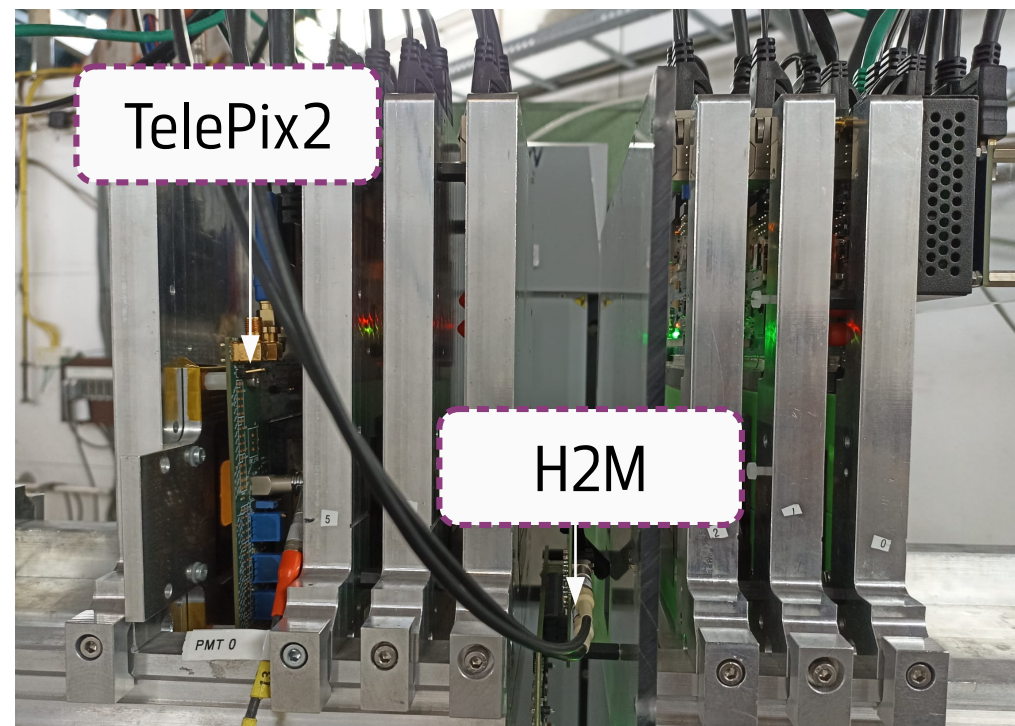


User Operation

New infrastructure at the DESY II Test Beam facility as **both** a ROI triggering and timing plane

User groups including RD50-MPW4, Atlas-ITK and Tangerine

Existing module within Corryvreckan for easy integration into analysis workflows



See talk by Sara Ruiz Daza on H2M on Thursday

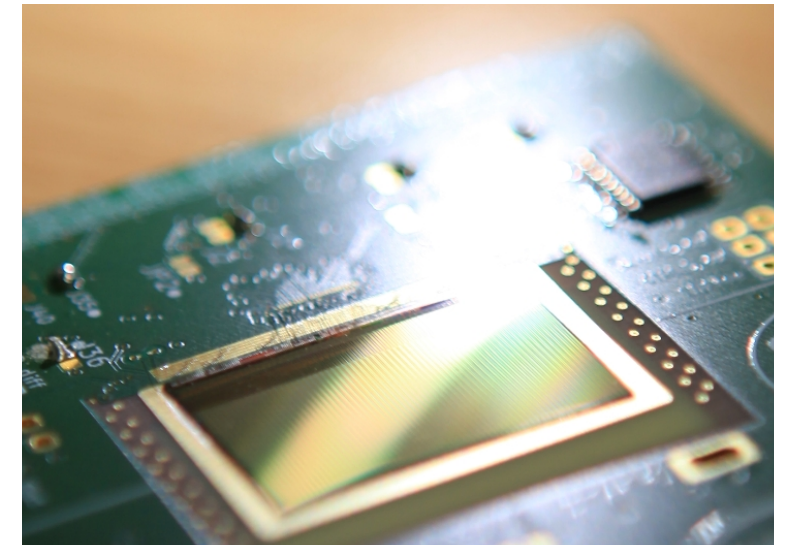
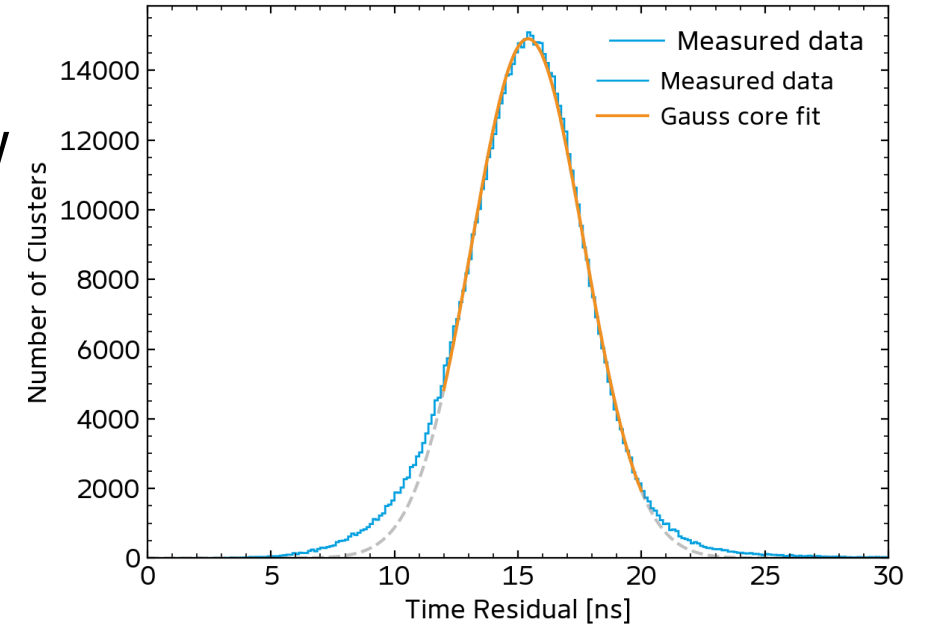
Summary

- TelePix2 developed for the DESY II Test Beam Facility
- Efficiency above 99 %
- Time resolution below 4 ns
- Trigger time resolution below 3 ns

Outlook

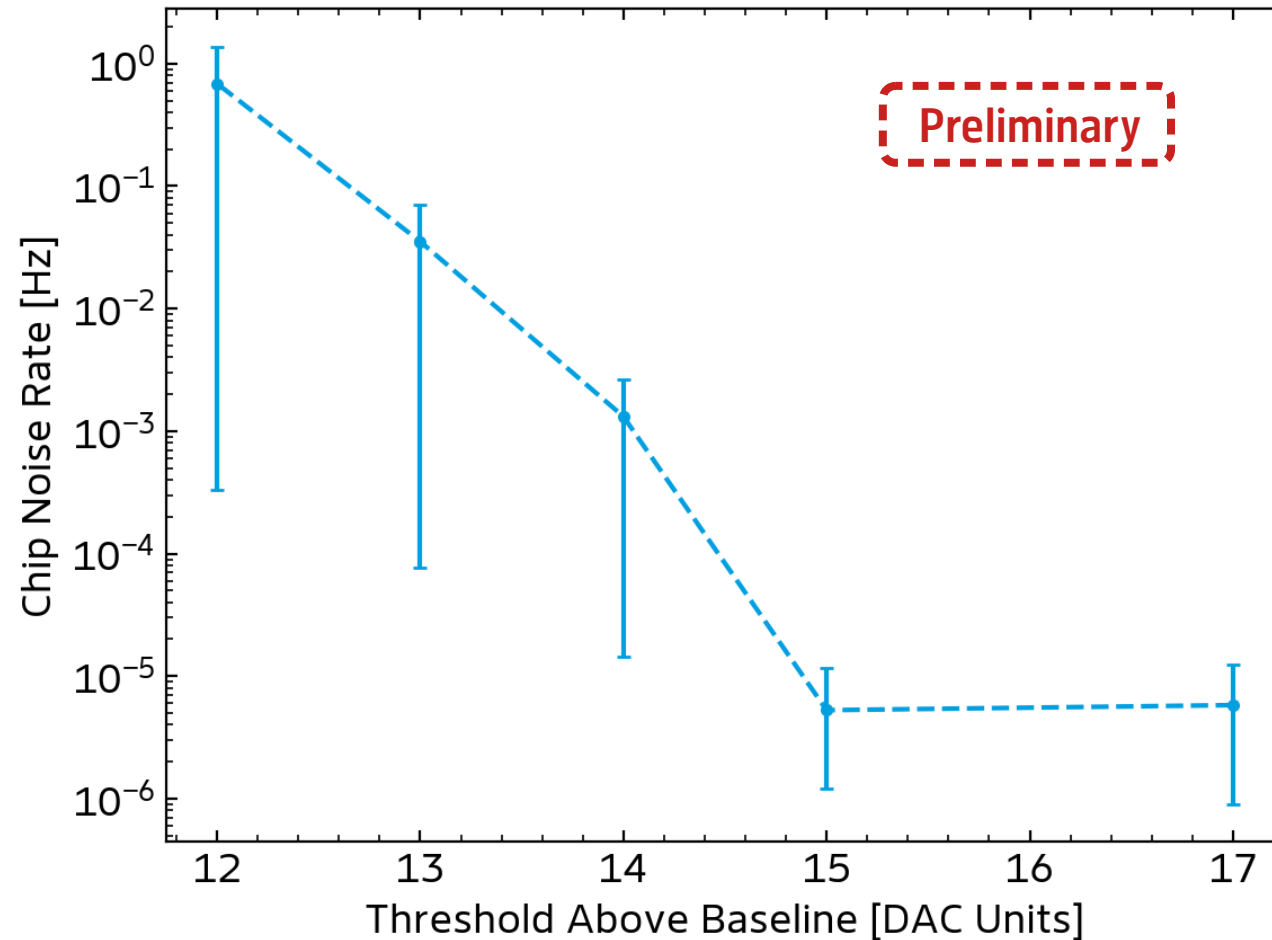
- Trimming performance currently being evaluated
- Aiming to equip all beamlines

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)



Appendix

Noise Measurements

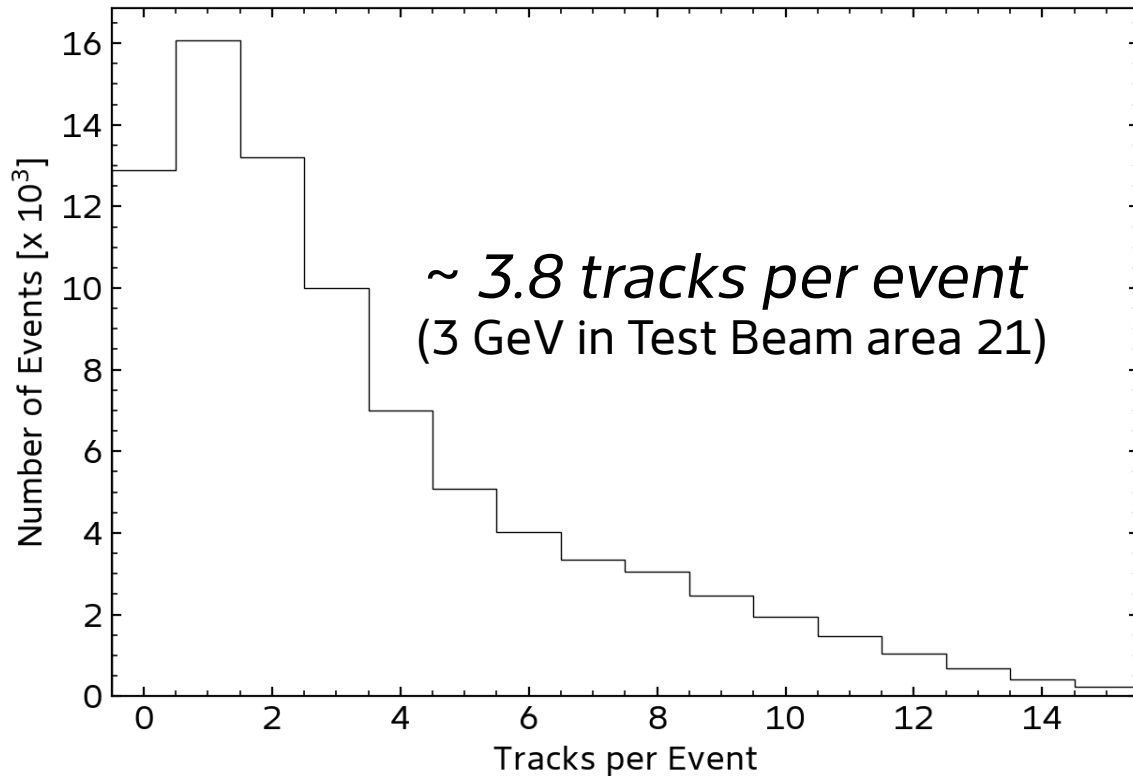


With air cooling and 80 V bias

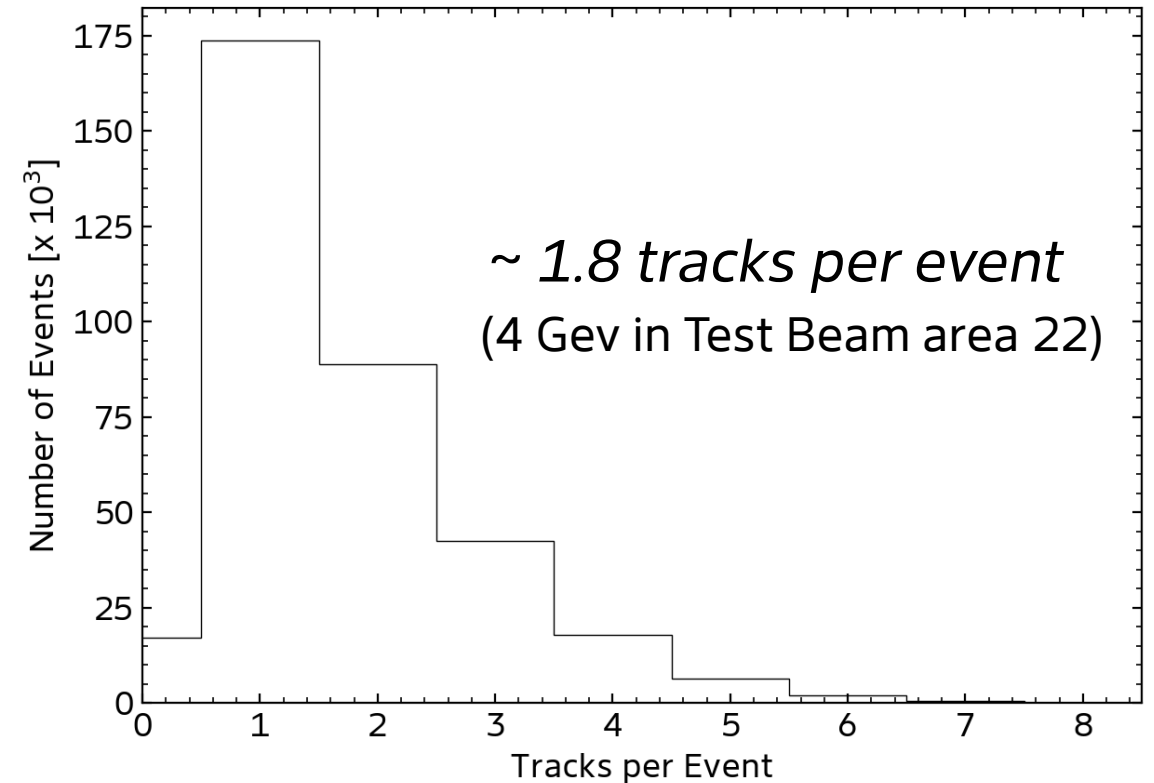
Error bars are poisson confidence interval of 68.27%

Track Multiplicity

Mimosa Track Multiplicity

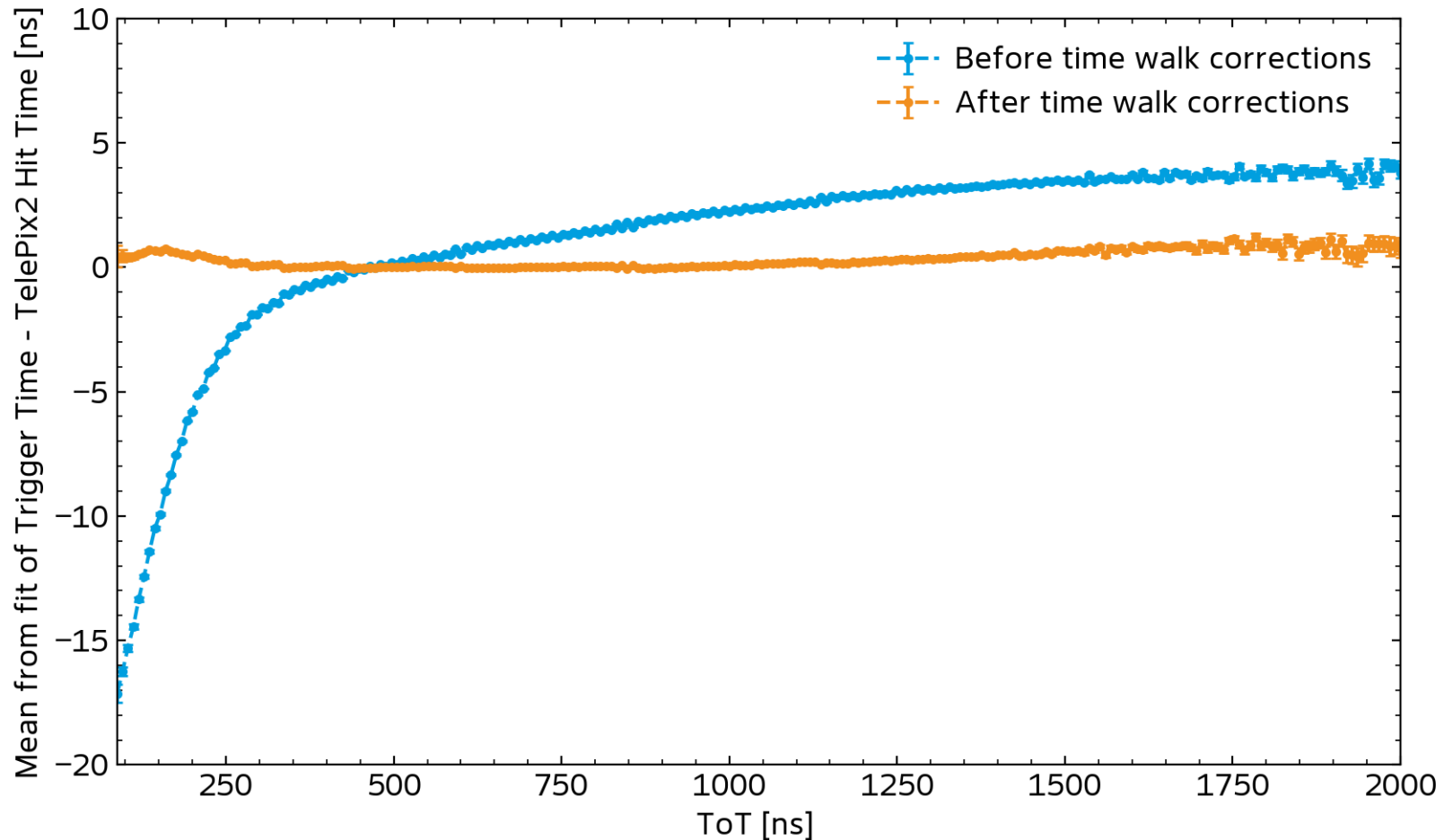


Adenium Track Multiplicity



Rate varies dependent on factors such as:
which beamline is in use, selected energy and target position
The plots above should only be taken as a rough guide

Shift from Time Walk Correction



Shift from Row Delay Correction

