

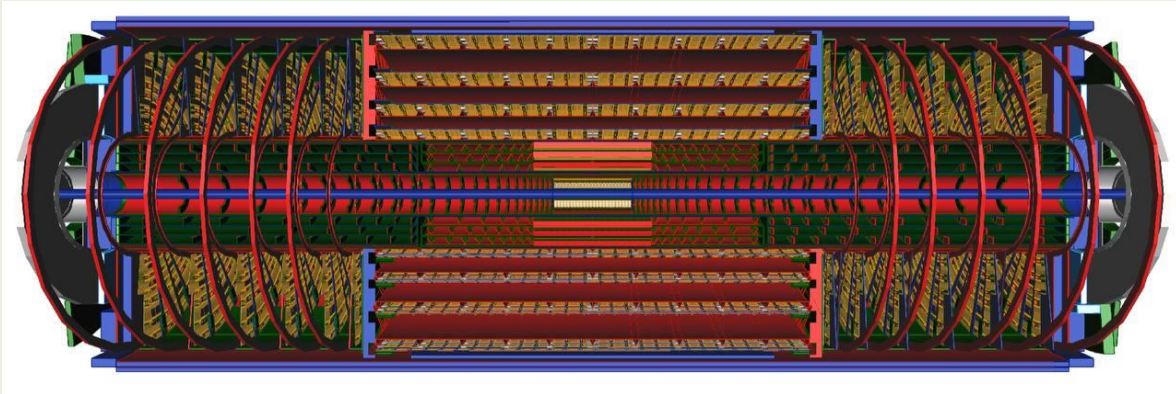
Testbeam characterisation of the silicon-strip modules in ATLAS ITk

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DESY Summerstudent Project



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DESY ATLAS Group

Intro



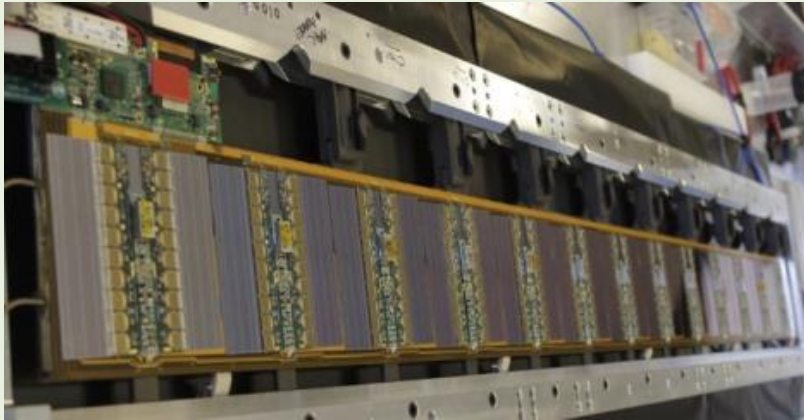
[1]

HL-LHC:

- instantaneous luminosity increased 10X
- more interactions by bunch crossing (up to 200)
- integrated luminosity of 4000 fb⁻¹ in 10 years

Inner Tracker (ITk) is a new all-silicon tracker, designed to withstand harsh HL-LHC environment

Innermost region is composed of pixels, while outermost – of strips. Central region of strip detector is called barrel (4 layers), two forward regions – endcaps (6 + 6 disks)



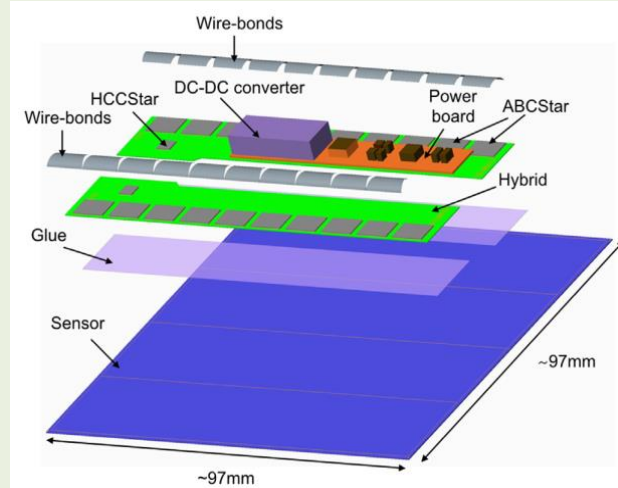
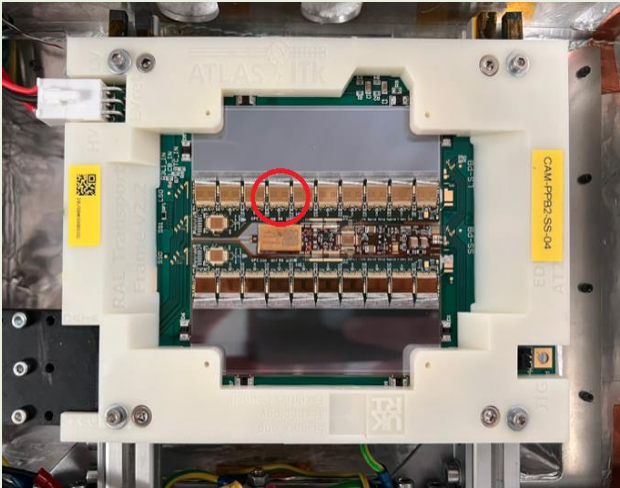
Strip barrel stave

[2]



Strip endcap petal

Module



[3]

Unirradiated short strip barrel module

Module consists of:

- n-in-p sensor
- Powerboard
- DC-DC converter
- 10 FE readout chips ABCStar
- 1 Hybrid Controller Chip HCCStar (interface between FE chips and electrical signal on bus tapes)

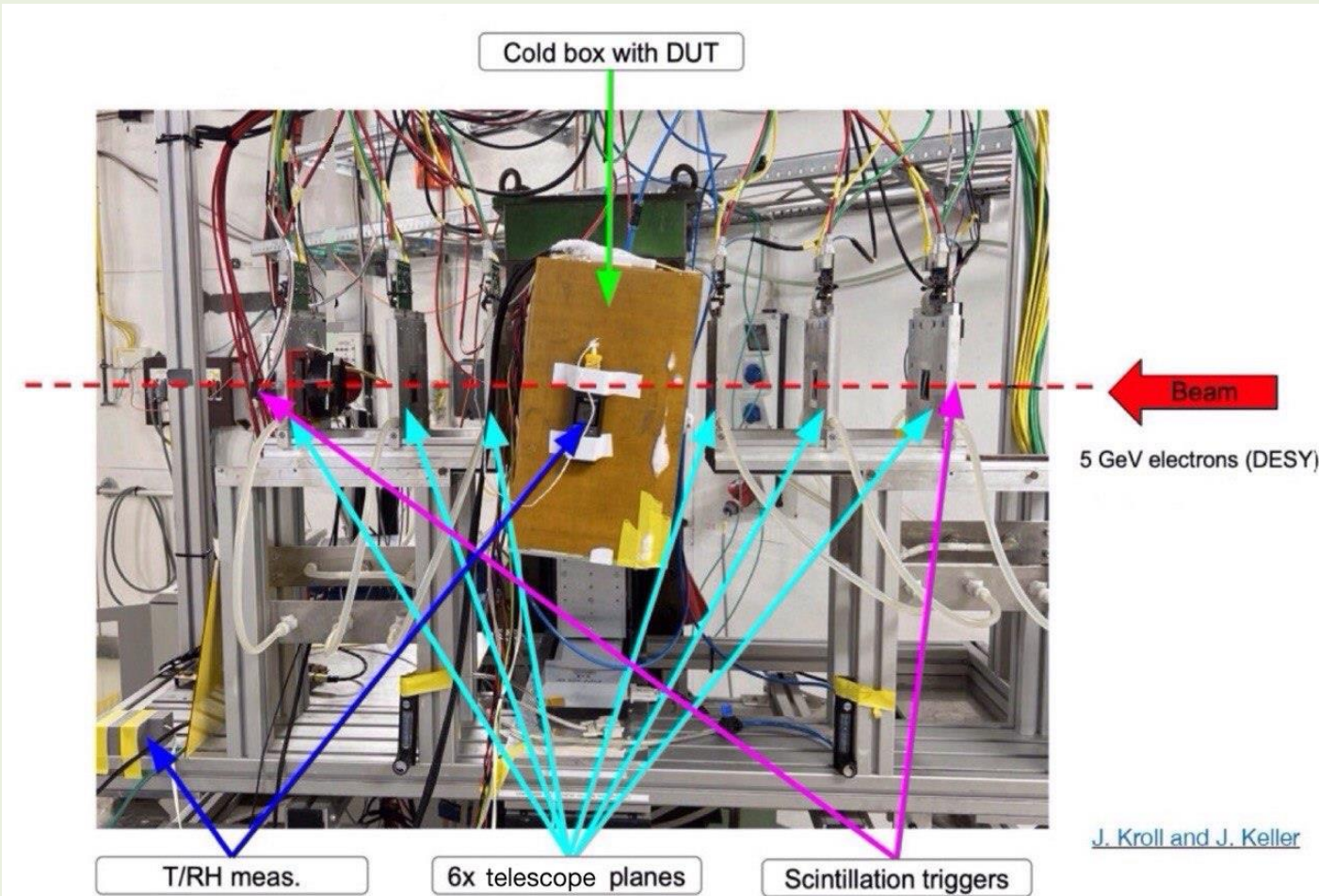
Pitch size: 75 μm , thickness: 300 μm

Strip length: 2.5 cm

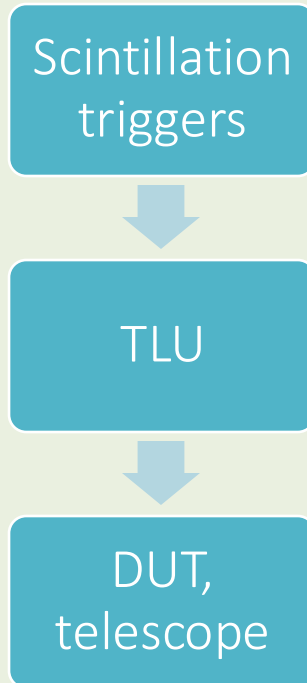
Bias voltage: -350 V

Environment temperature: -40°C

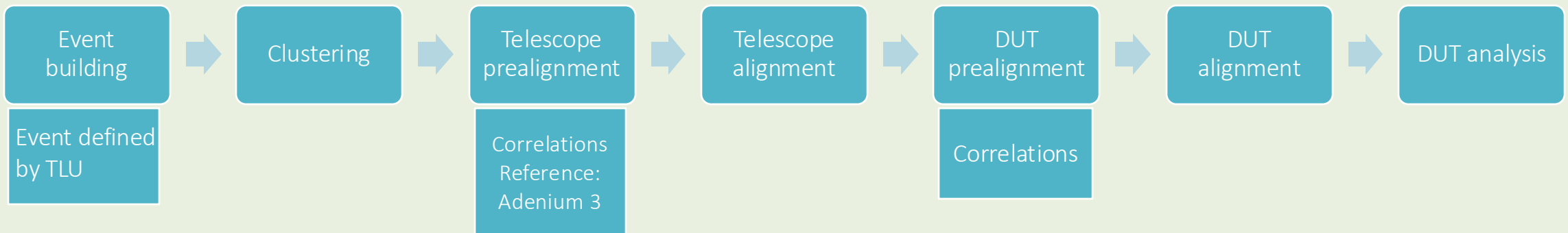
Testbeam setup



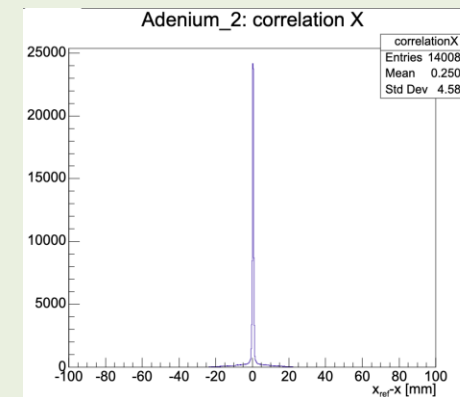
- ADENIUM telescope
- Pixel pitch : $26.88 \times 29.24 \mu\text{m}$
- Thickness: from 50 to $100 \mu\text{m}$
- Pixel matrix: 512×1024



Workflow of data processing using the Corryvreckan



Correlation is a difference of any cluster on a given detector plane minus the position of any cluster on the reference plane



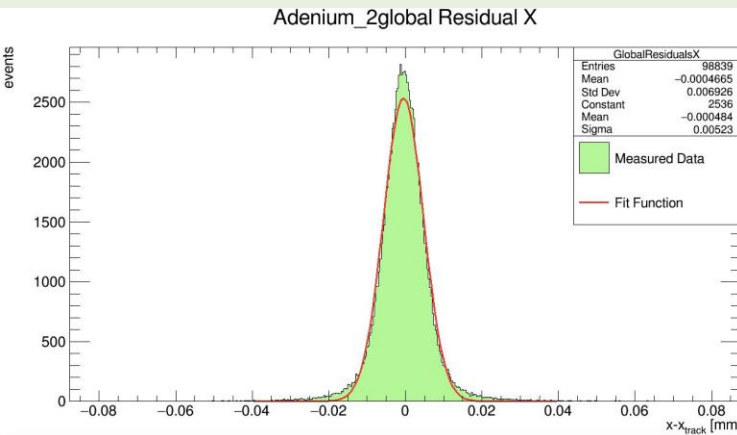
Telescope alignment

	Adenium 0	Adenium 1	Adenium 2	Adenium 3	Adenium 4	Adenium 5
Mean residual , μm	-0.1	-0.7	-0.5	-1	-0.9	-0.02
Std dev x , μm	5	5	7	6	6	5
Mean residual y , μm	-0.3	-0.2	-0.06	-0.2	-0.2	0
Std dev y , μm	5	5	7	6	5	5

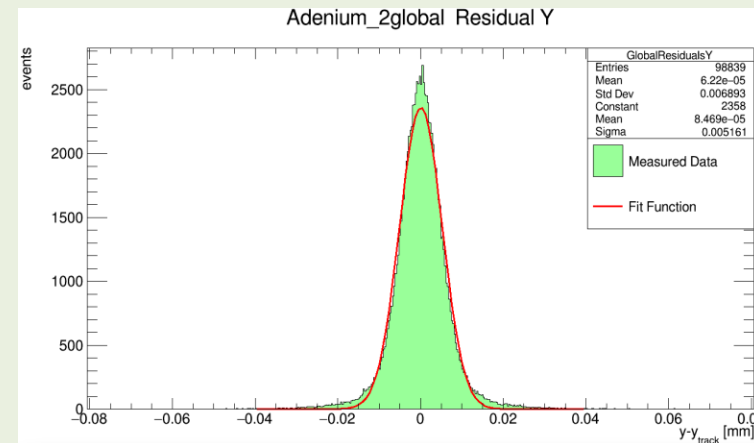
Residual – the difference of the interpolated track intercept onto a given plane minus the position of its associated cluster

Goal – residuals centered around zero, RMS (σ) - less than pixel pitch/ $\sqrt{12}$: $\sigma_x = 7.76 \mu\text{m}$, $\sigma_y = 8.44 \mu\text{m}$

Three iterations

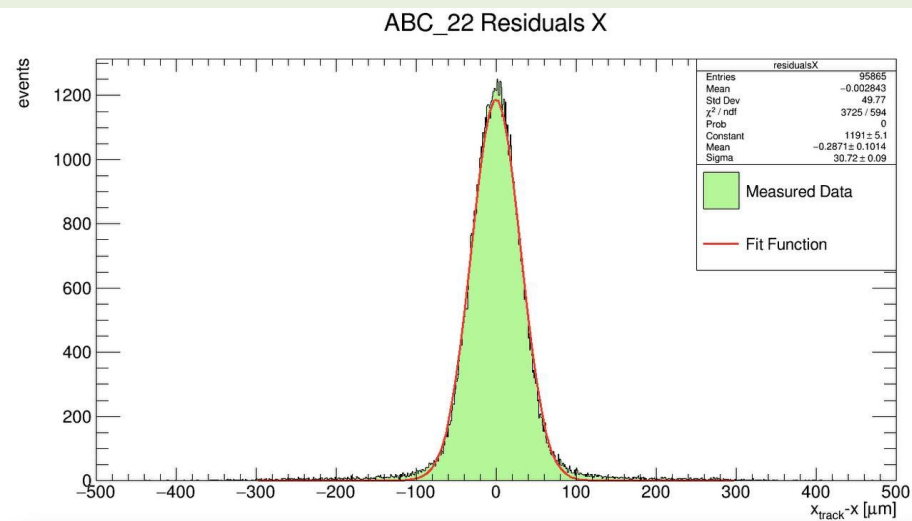


Fit: mean = $-0.5 \mu\text{m}$, sigma = $5 \mu\text{m}$

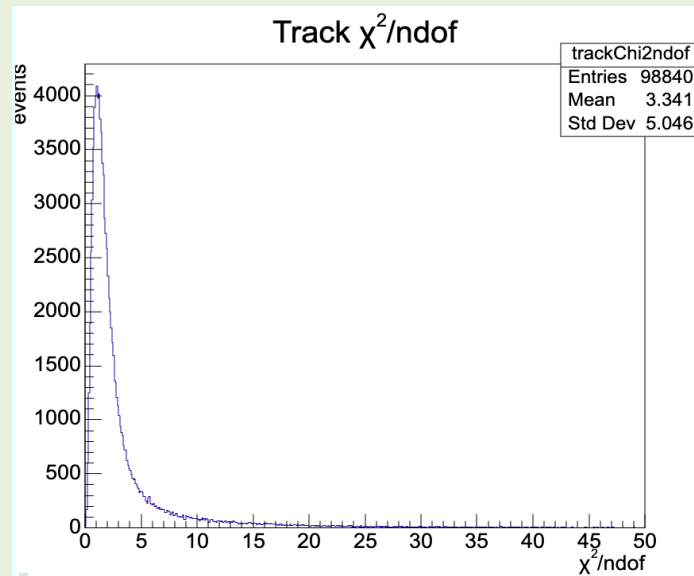


Fit: mean = $-0.01 \mu\text{m}$, sigma = $5 \mu\text{m}$

DUT alignment



Fit: mean = 0.3 μm , sigma = 31 μm

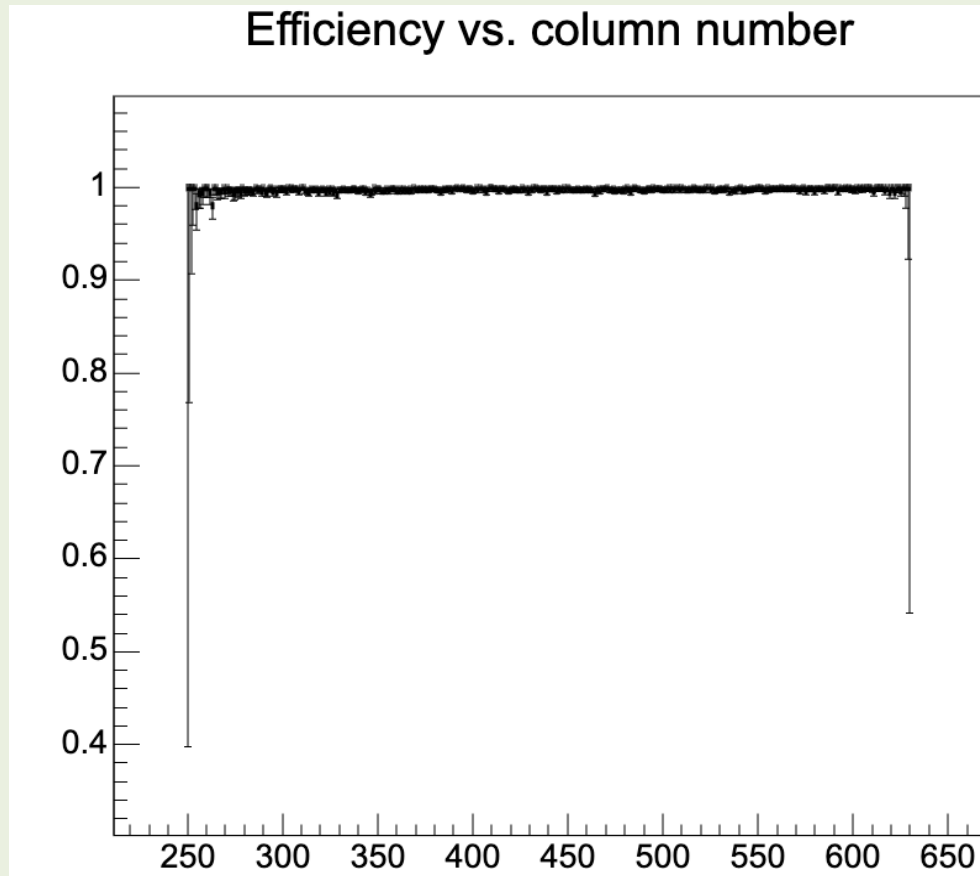


Fixed telescope geometry

Goal – residuals centered around zero, RMS (σ) - less than pixel pitch/ $\sqrt{12}$: $\sigma_x = 21.8 \mu\text{m}$

Four iterations

DUT analysis

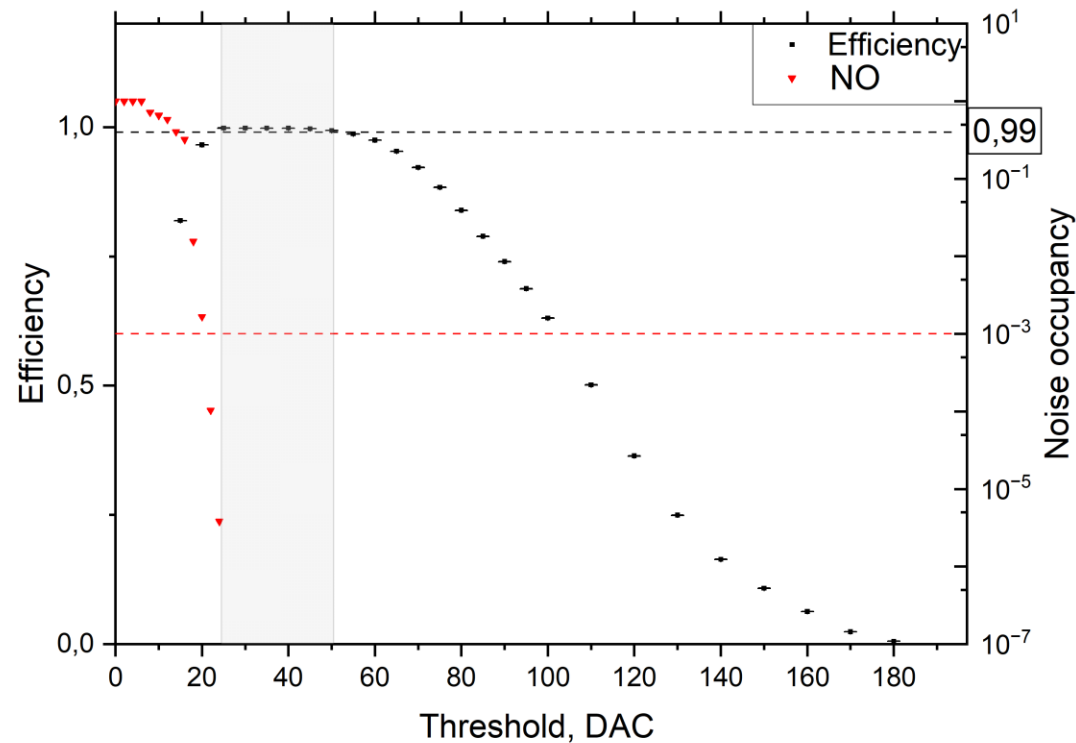


Threshold = 30 DAC

$$\text{Efficiency } \varepsilon = \frac{N_{\text{tracks}+\text{clusters}}}{N_{\text{tracks}}}$$

From threshold 15 to 180 DAC

Results and summary



Operational window (OW) – efficiency is above 0.99, while NO –below 0.001 (ITk requirement)

From threshold 25 to 50 is an operational window

Module has big OW

Module is already irradiated and going to be tested in September



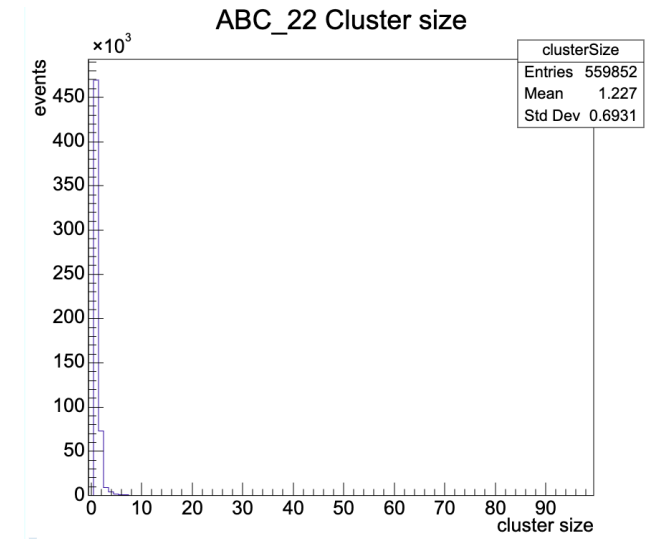
Thank you

References

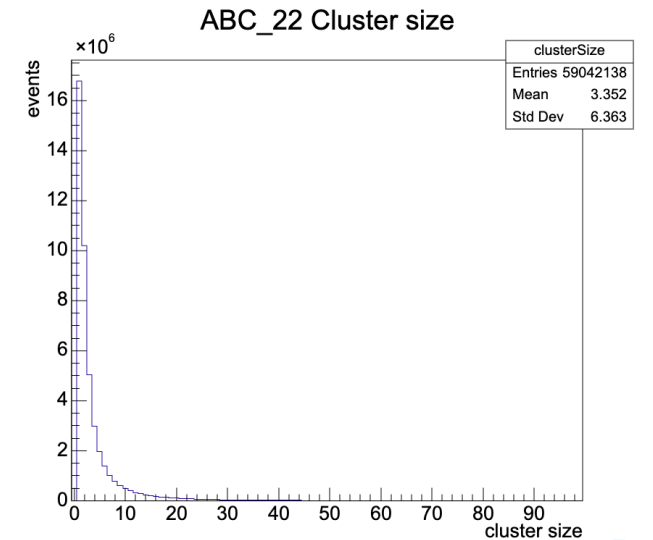
- [1] ATLAS Collaboration, Expected tracking and related performance with the updated ATLAS Inner Tracker layout at the High-Luminosity LHC, ATL-PHYS-PUB-2021-024, CERN, Geneva (2021), url: <https://cds.cern.ch/record/2776651>
- [2] First test beam insights for ATLAS ITk strip modules with cold noise, Yajun He
- [3] ATLAS Collaboration, Technical Design Report for the ATLAS Inner Tracker Strip Detector, CERN-LHCC-2017-005, ATLAS-TDR-025, 2017.

Backup

At low threshold: high NO -> bigger cluster size -> lower efficiency



Threshold 35 DAC



Threshold 15 DAC

12

Backup

S-curve shape

The spectrum of the deposited charge – Landau-Function.
Electronic read-out of the charge – gaussian noise

Long S-curve's "tail" due to convolution of Landau and Gauss distributions

Correlations

Correlation is a difference of any cluster on a given detector plane minus the position of any cluster on the reference plan. No tracking is required

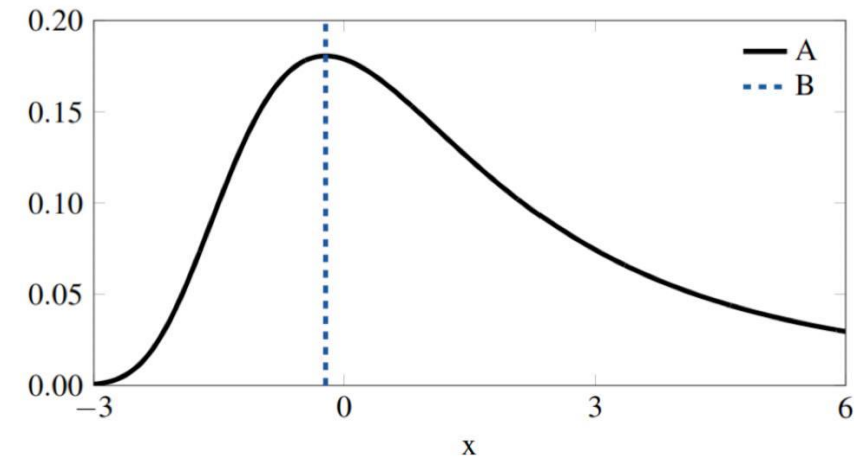


Figure 4.8 Landau-Function [A] Probability density function. [B] MP-Value

Backup

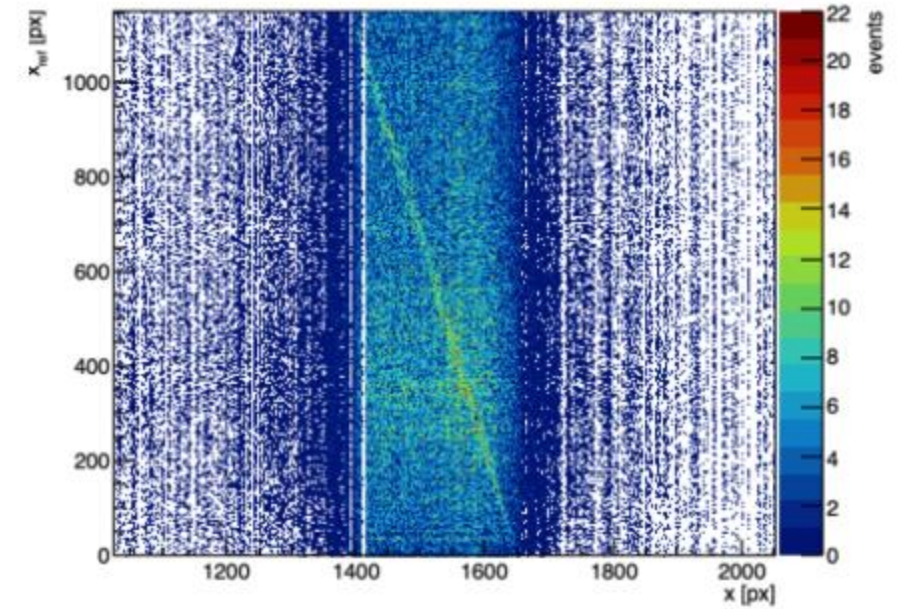
Mimosa vs Alpide telescopes

	Mimosa 26	Alpide
Chip thickness	50 μm to 70 μm	50 μm to 100 μm
Pixel pitch	18.4 μm X 18.4 μm	26.88 μm X 29.24 μm
Typical frame readout time	115.2 μs	10 μs

RMS from slide 6 and 7

$$\sigma_x^2 = \frac{1}{a} \int_{-\frac{a}{2}}^{\frac{a}{2}} \Delta_x^2 d(\Delta_x) = \frac{a^2}{12} \Rightarrow \sigma_x = \frac{a}{\sqrt{12}}, \text{ where } \Delta_x = x_{rec} - x, < \Delta_x > = 0$$

DUT VS Mimosa (ref)



DUT VS Alpide (ref)

