Analysis of test beam data with bent MAPS sensors for the ALICE upgrade

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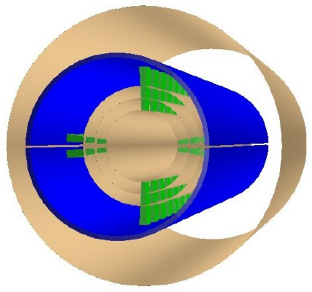
From the ITS2 to the ITS3

For Run 4 the inner barrel of the ITS2 will be replaced with bent chips → ITS3!

- Bent chips with air cooling set on the beam pipe without structural support
- Material budget ~ 0.02-0.04% X0 per layer (beampipe: 500 μm Be: 0.14% X0)
- First detection layer closer to the IP → improved tracking performance
- Flexible 300 mm wafer-scale sensors, fabricated using stitching and thinned down to 20-40 μm (0.02-0.04% X0)
- Mechanically held in place by carbon foam ribs

Engineering model

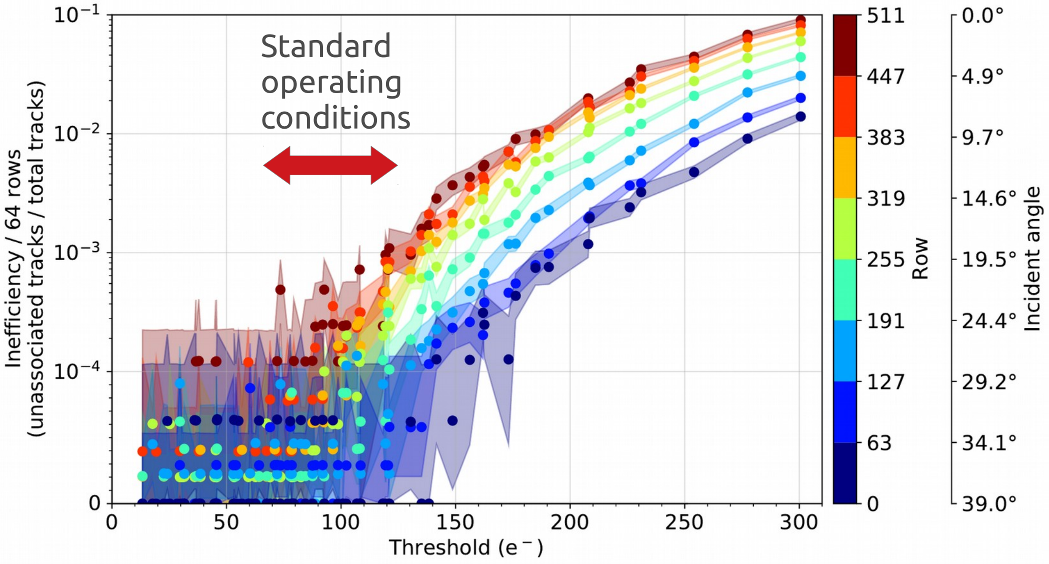


O2 geometry

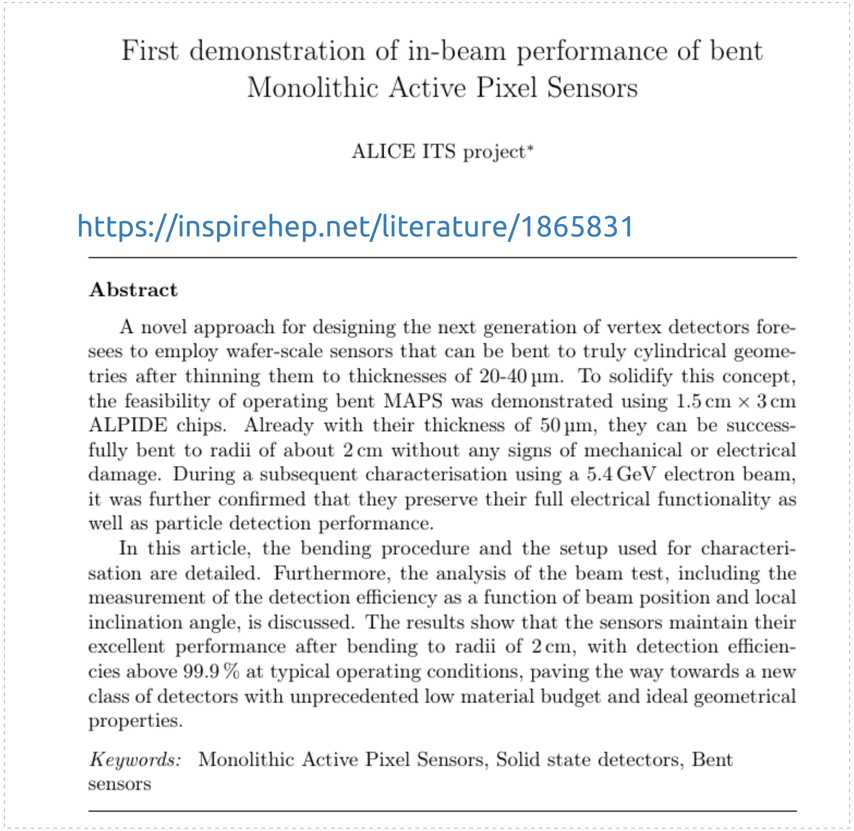
Beam pipe Inner/Outer Radius (mm)	16.0/16.5		
IB Layer Parameters	Layer 0	Layer 1	Layer 2
Radial position (mm)	18.0	24.0	30.0
Length (sensitive area) (mm)	300		
Pseudo-rapidity coverage	±2.5	±2.3	±2.0
Active area (cm^2)	610	816	1016
Pixel sensor dimensions (mm^2)	280 x 56.5	280 x 75.5	280 x 94
Number of sensors per layer	2		
Pixel size (μm^2)	O (10 x 10)		

First public results on bent chips

- First results on bent MAPS sensors show excellent performance
- Test on the bent 50 μm ALPIDE chips developed for the ALICE ITS2
- 1024 × 512 matrix (column × row)
- Binary output



- No efficiency loss at bending radii of ~2 cm



First demonstration of in-beam performance of bent Monolithic Active Pixel Sensors

ALICE ITS project*

https://inspirehep.net/literature/1865831

Abstract

A novel approach for designing the next generation of vertex detectors foresees to employ wafer-scale sensors that can be bent to truly cylindrical geometries after thinning them to thicknesses of 20-40 µm. To solidify this concept, the feasibility of operating bent MAPS was demonstrated using 1.5 cm × 3 cm ALPIDE chips. Already with their thickness of 50 µm, they can be successfully bent to radii of about 2 cm without any signs of mechanical or electrical damage. During a subsequent characterisation using a 5.4 GeV electron beam, it was further confirmed that they preserve their full electrical functionality as well as particle detection performance.

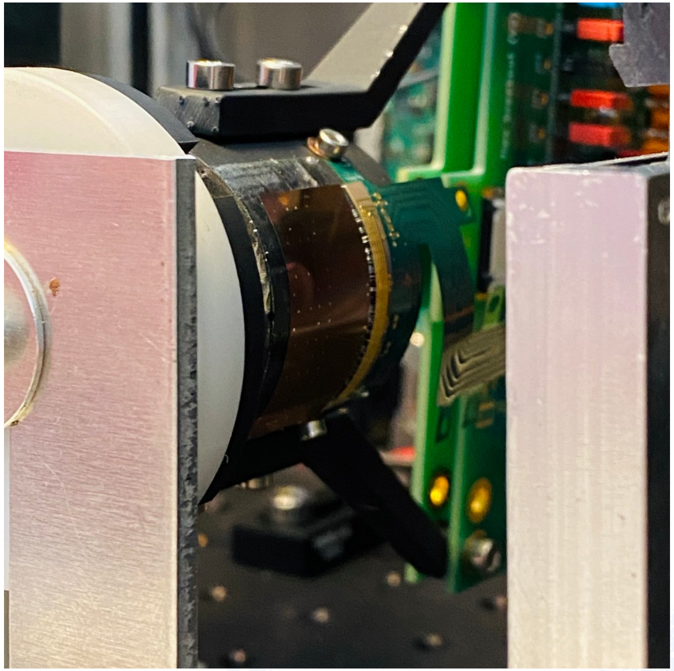
In this article, the bending procedure and the setup used for characterisation are detailed. Furthermore, the analysis of the beam test, including the measurement of the detection efficiency as a function of beam position and local inclination angle, is discussed. The results show that the sensors maintain their excellent performance after bending to radii of 2 cm, with detection efficiencies above 99.9 % at typical operating conditions, paving the way towards a new class of detectors with unprecedented low material budget and ideal geometrical properties.

Keywords: Monolithic Active Pixel Sensors, Solid state detectors, Bent sensors

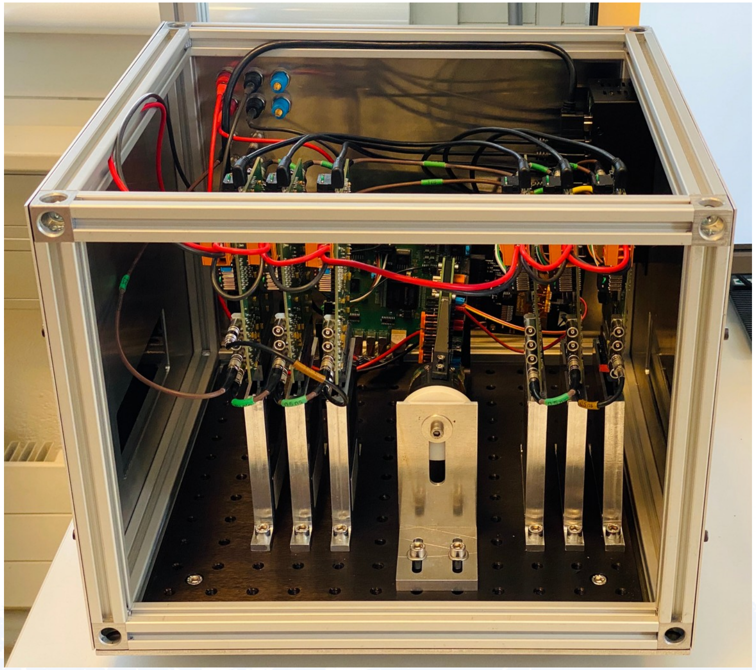
Bending chips

Support (jig)

Bent chip



Test beam telescope



- For the test beam campaing 50 μm bent ALPIDE chips are used
- Bent chips are attached to a cylinder jig to give mechanical support (long side bending)
- Full telescope put into the beam line (DESY, SPS) for testing

Analysis of the test beam data

Corryvreckan

The Maelstrom for Your Test Beam Data

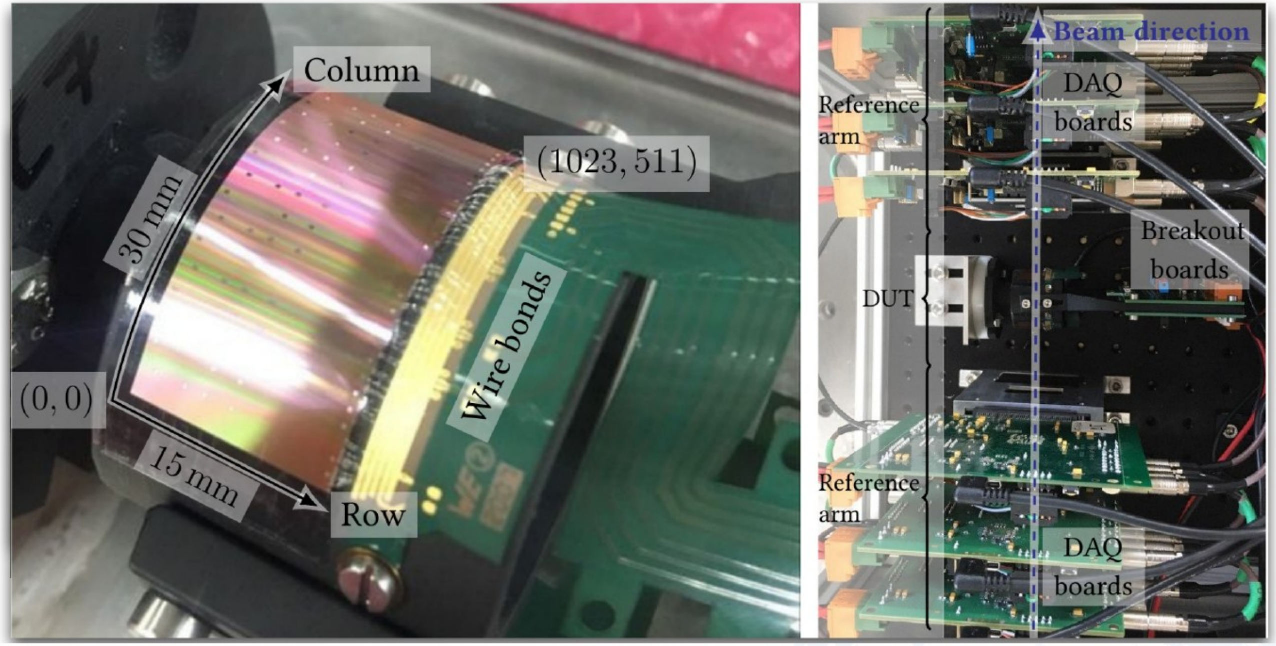
https://project-corryvreckan.web.cern.ch/

All analysis steps carried out in Corryvreckan:

- Noisy pixels masking, (pre)alignment of the apparatus
- Tracking and characterization of the DUT (e.g. efficiency/residuals)

Since December 2019 there were 9 test beam campaigns to test different setups

- DESY: 5.4 GeV electrons
- SPS: 120 GeV proton/pion



Analysis of the test beam data

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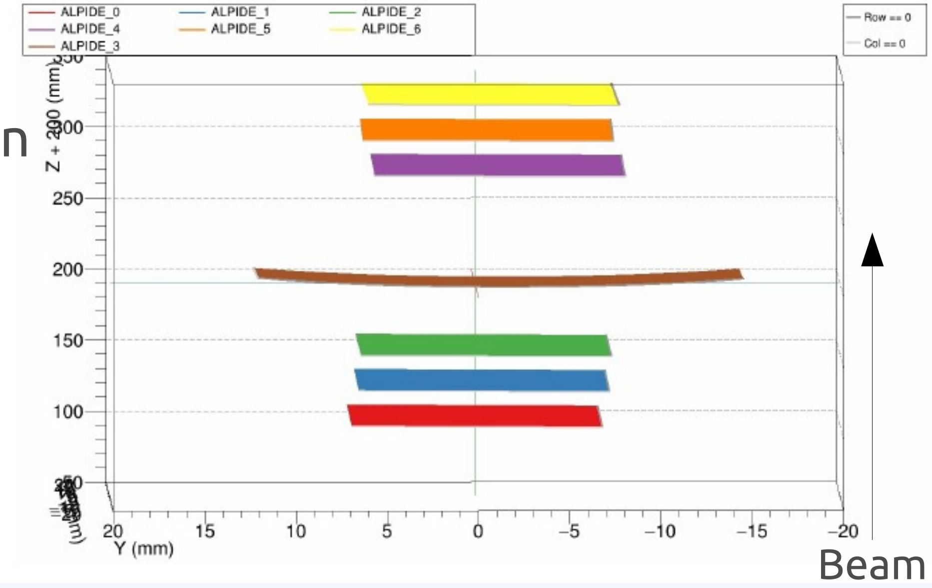
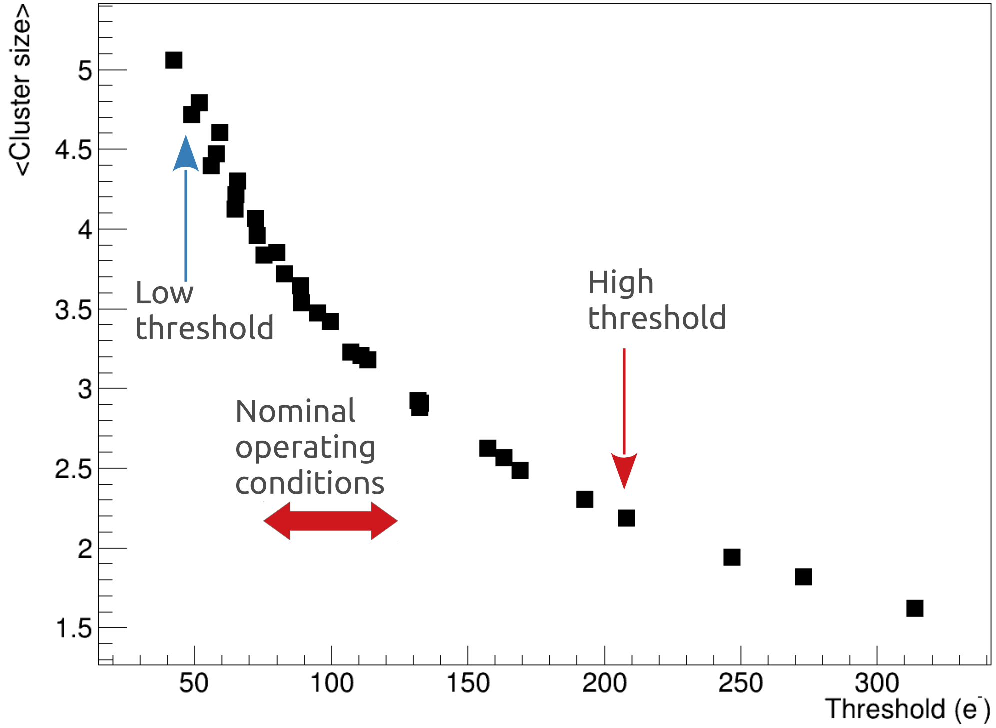
All analysis steps carried out in Corryvreckan:

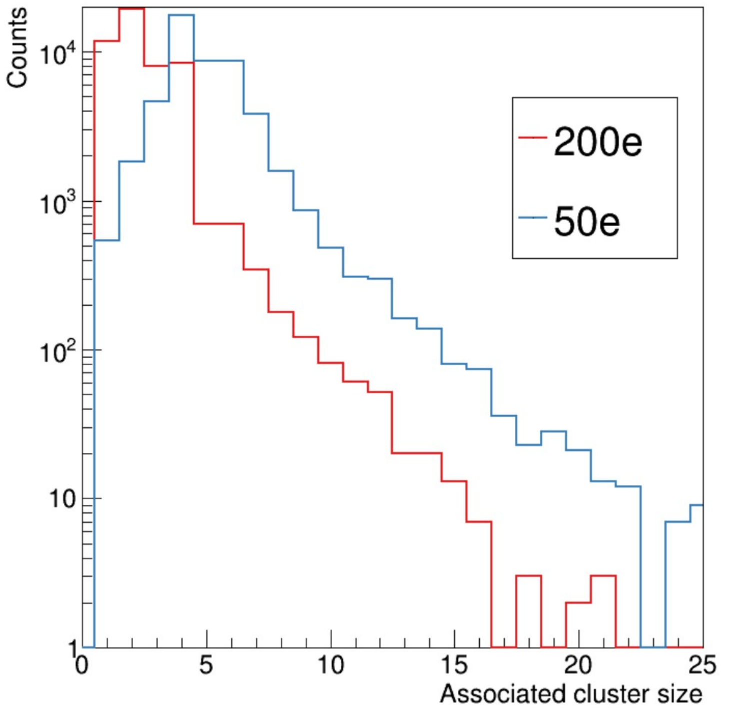
- Noisy pixels masking, (pre)alignment of the apparatus
- Tracking and characterization of the DUT (e.g. efficiency/residuals)
- Tracking with bent geometry implemented!
- Different radii can be fed in the configuration
- Event display of the setup (pay attention to the compressed scale in x and y!)



Apparatus seen by Corryvreckan

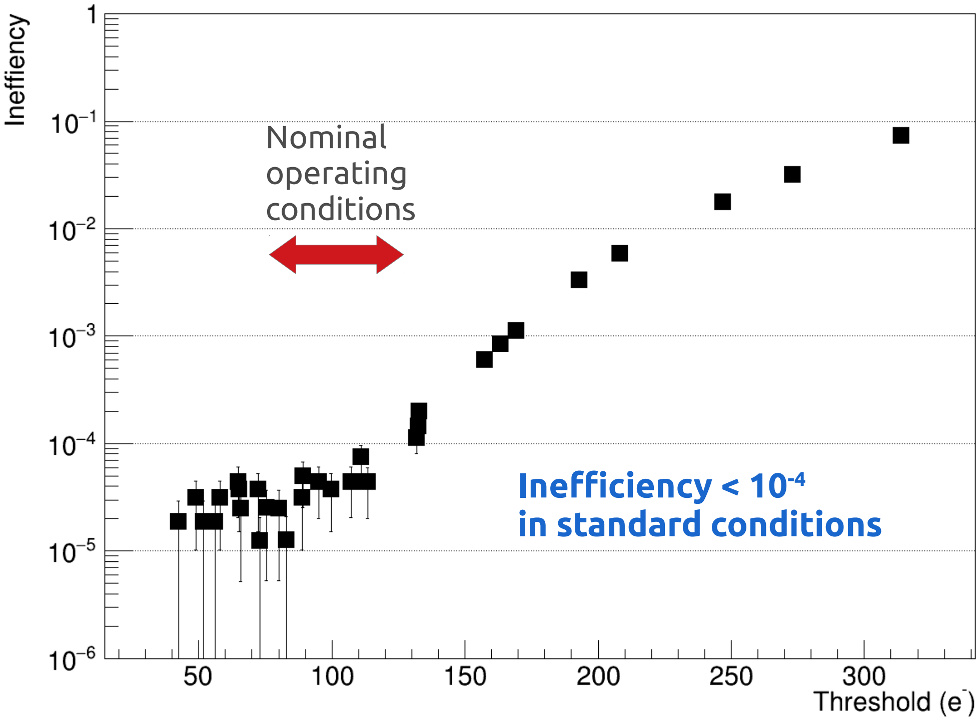
Cluster size for bent chips

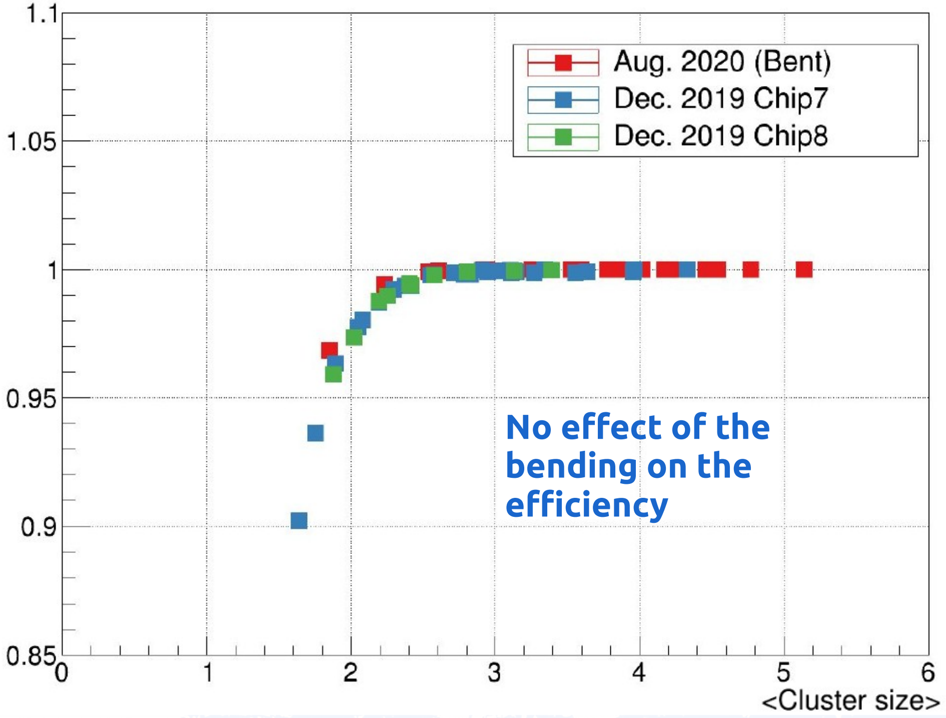




- Chip tested at different operating conditions resulting in different effective threshold
- Average cluster size at standard operating conditions close to ~3

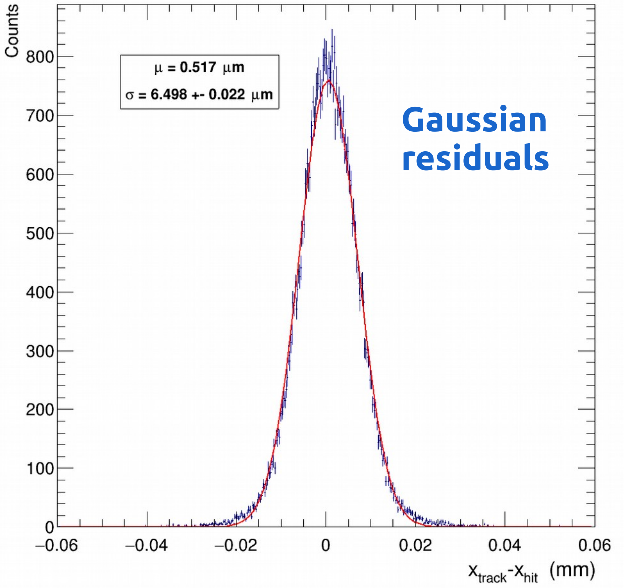
Inefficiency of bent chips

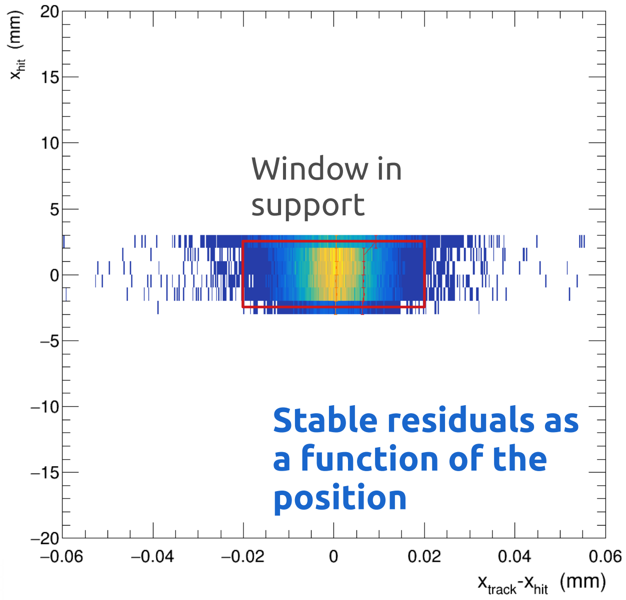


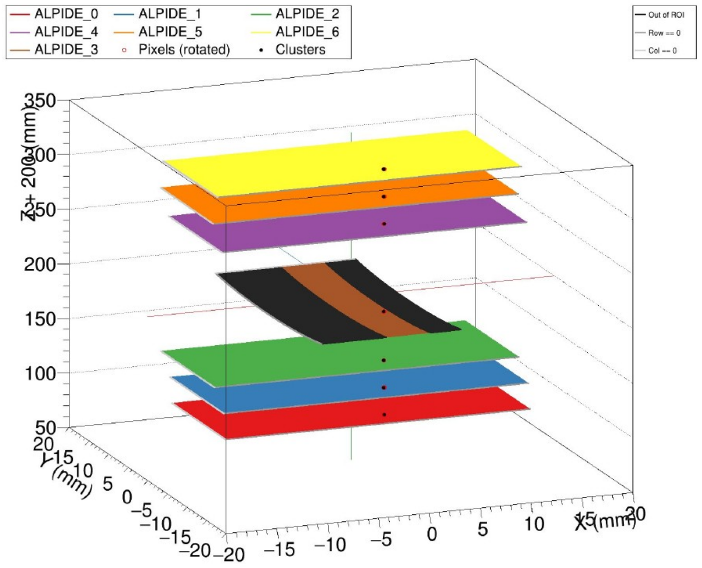


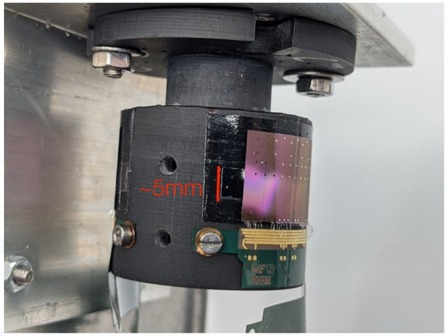
- The bent chip shows efficiency >> 99.9% at the nominal operating conditions (Threshold = 100 e^-)
- Comparison to the results with non bent ALPIDE shows no significant degradation of the efficiency

Residuals for bent chips





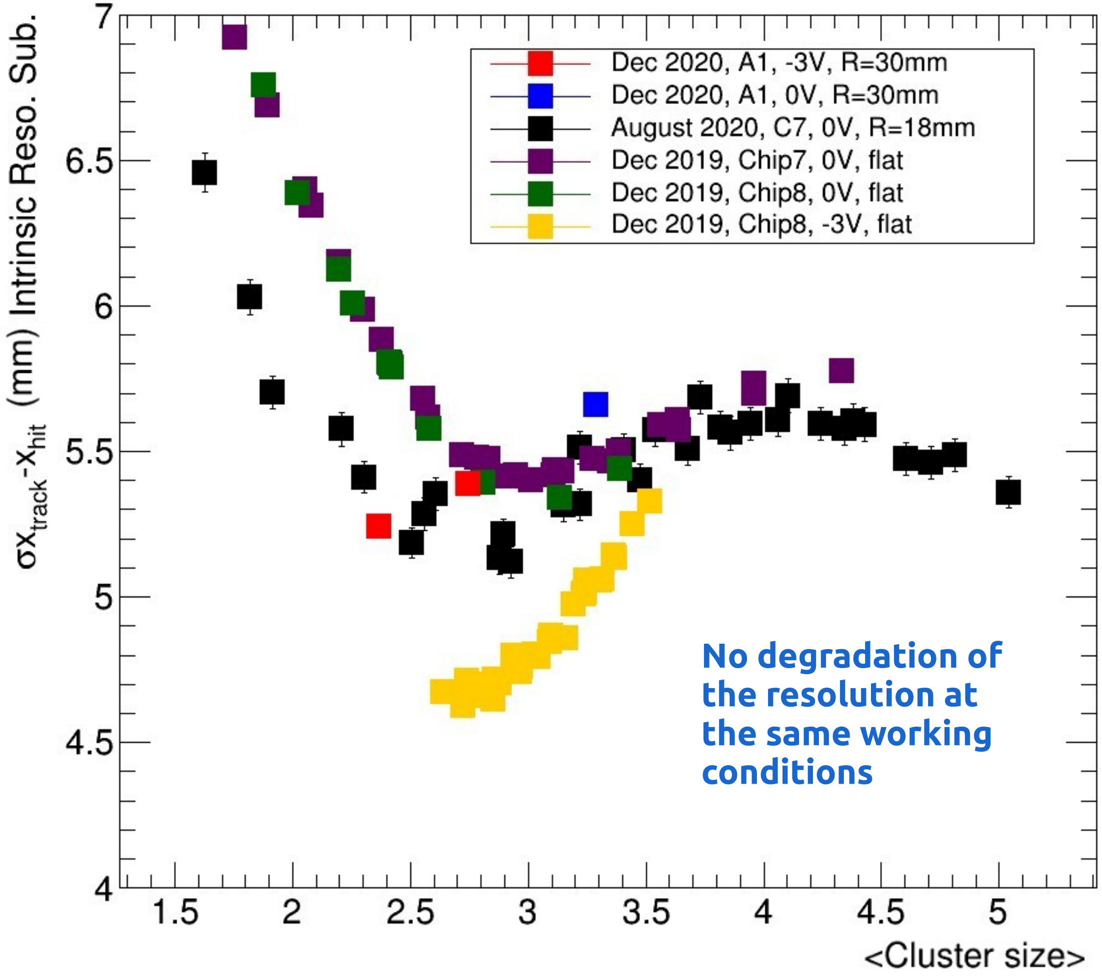




- Gaussian residuals are observed on the bent DUT
- No degradation of the residuals when selecting tracks that pass through the window on the support jig

Comparison with different radii

- No effect of the bending on the resolution across several radii
- Intrinsic uncertainty due to tracking substracted
- Different behaviour expected when comparing chip operated with and without back-bias voltage



Summary

The analysis of the test beam data with bent ALPIDE chips was shown

- Truly cylindrical bent chips
- Tracking with bent chips in use
- Efficiency does not depend on the bending
- Residuals agree with performance of the flat chips

Paper in preparation with full discussion of the results