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"First bent wafer-scale sensor in truly-cylindrical geometry for the ALICE ITS3 detector"

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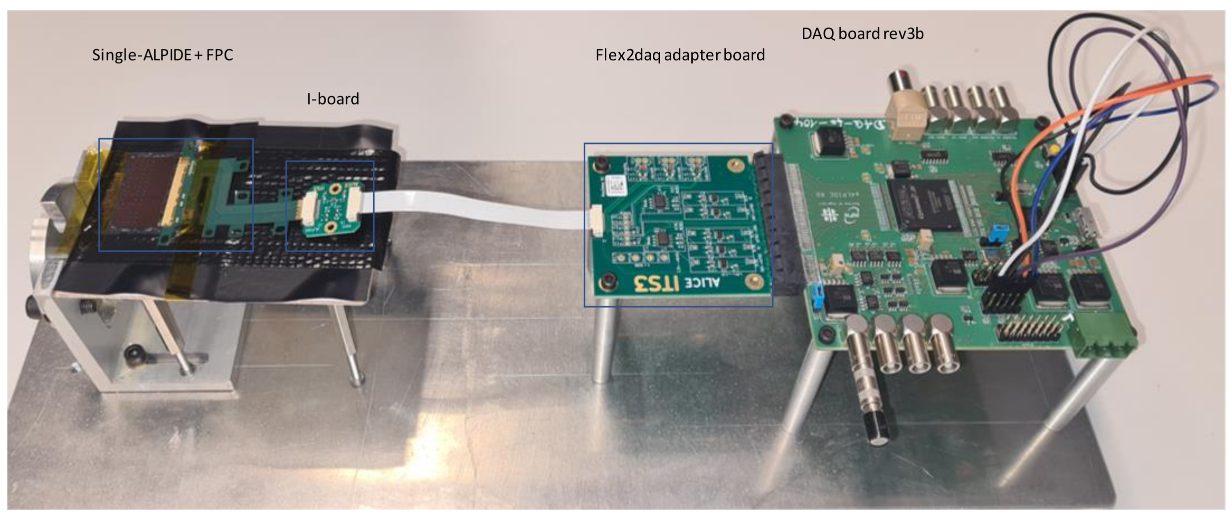
Abstract

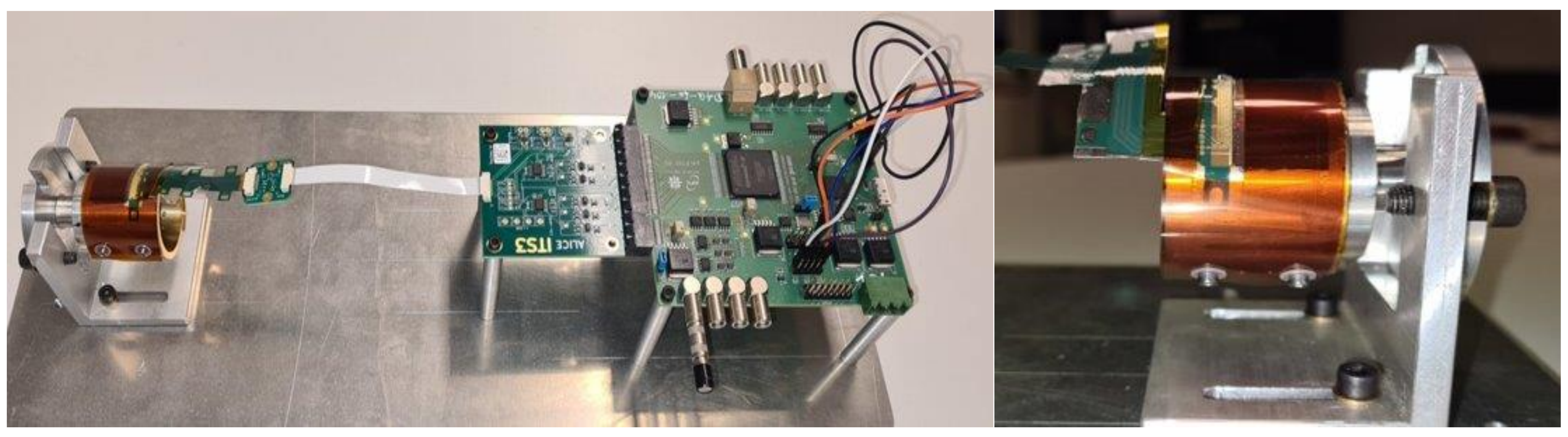
A pillar of the ALICE upgrade program is the improvement of the Inner Tracking System (ITS2) performance by the replacement of its three innermost layers during the next/third long shutdown of the LHC (LS3) . The proposal is based on a vertex detector consisting of three cylindrical layers composed by curved wafer-scale silicon sensors. The new detector will present a significant reduction of the material budget, thus improving the spatial resolution of the reconstructed charged tracks. Extensive characterization studies of bent single ALPIDE chips (used for the current ITS), have been carried out to evaluate their performance under the mechanical stress involved in the bending process and the results have demonstrated that none of the ALPIDE functionalities are affected by the curvature effect. These tests on small sensors have opened the way to the investigation of a large scale sensor: a full size demonstrator of a half-layer in a truly cylindrical shape is being assembled for the first time, based on so called super-ALPIDE chips. Such activity has required the development of special tools and procedures dedicated to bend and read out the new pixel matrix.

Electrical characterization of a single-ALPIDE chip

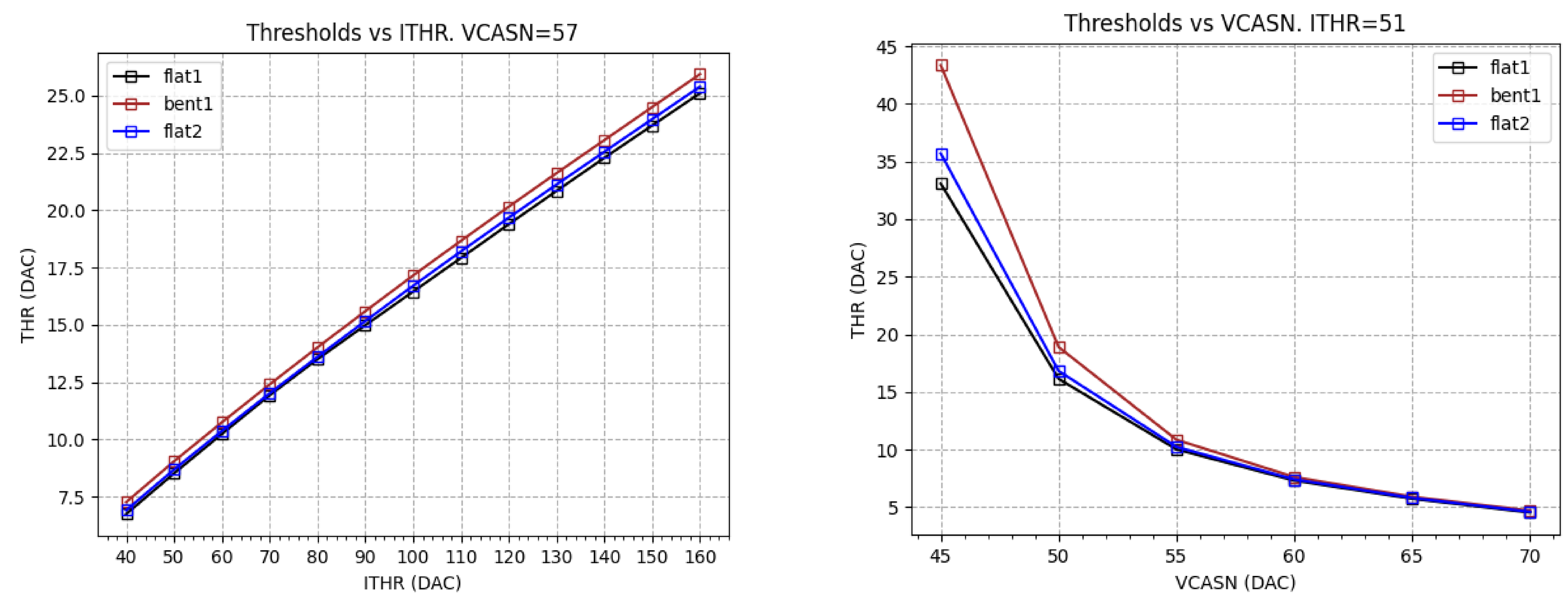
The ALPIDE chip was characterized in terms of threshold and fake-hit Rate. The variables were measured over ranges of the main front-end parameters (ITHR and VCASN). All the tests were performed and their results were compared for three positions of the chip in the following order: 1) Original flat configuration (flat1). 2) Bent at a radius of r=18mm, following the procedure described previously (bent1). 3) Flat position, turned back by manual unbending (flat2).



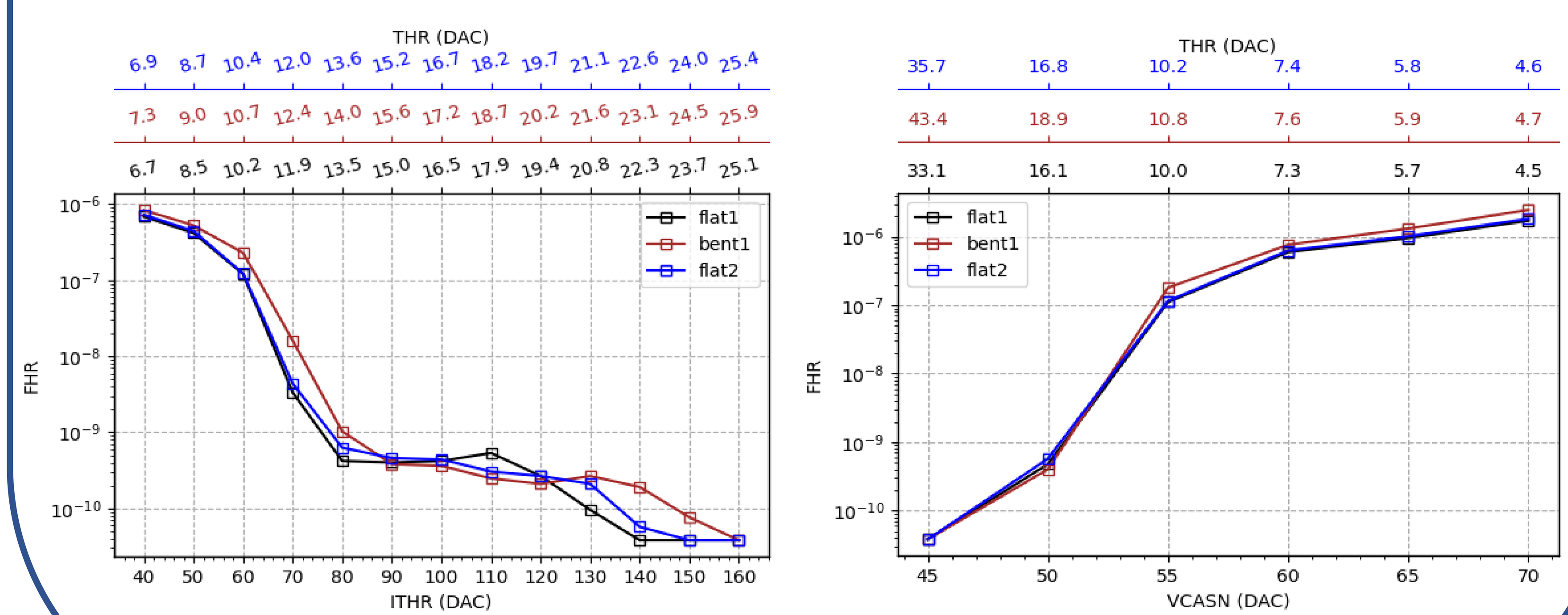
Setup assembled for the electrical tests with flat ALPIDE.



(left) Setup assembled for the electrical tests with the ALPIDE bent over a cylindrical jig. (right) Closed view if the ALPIDE bent along its long side over the cylindrical jig and held in position with a kapton foil screwed at the edges.



Threshold values as a function of ITHR (left) and VCASN (right).



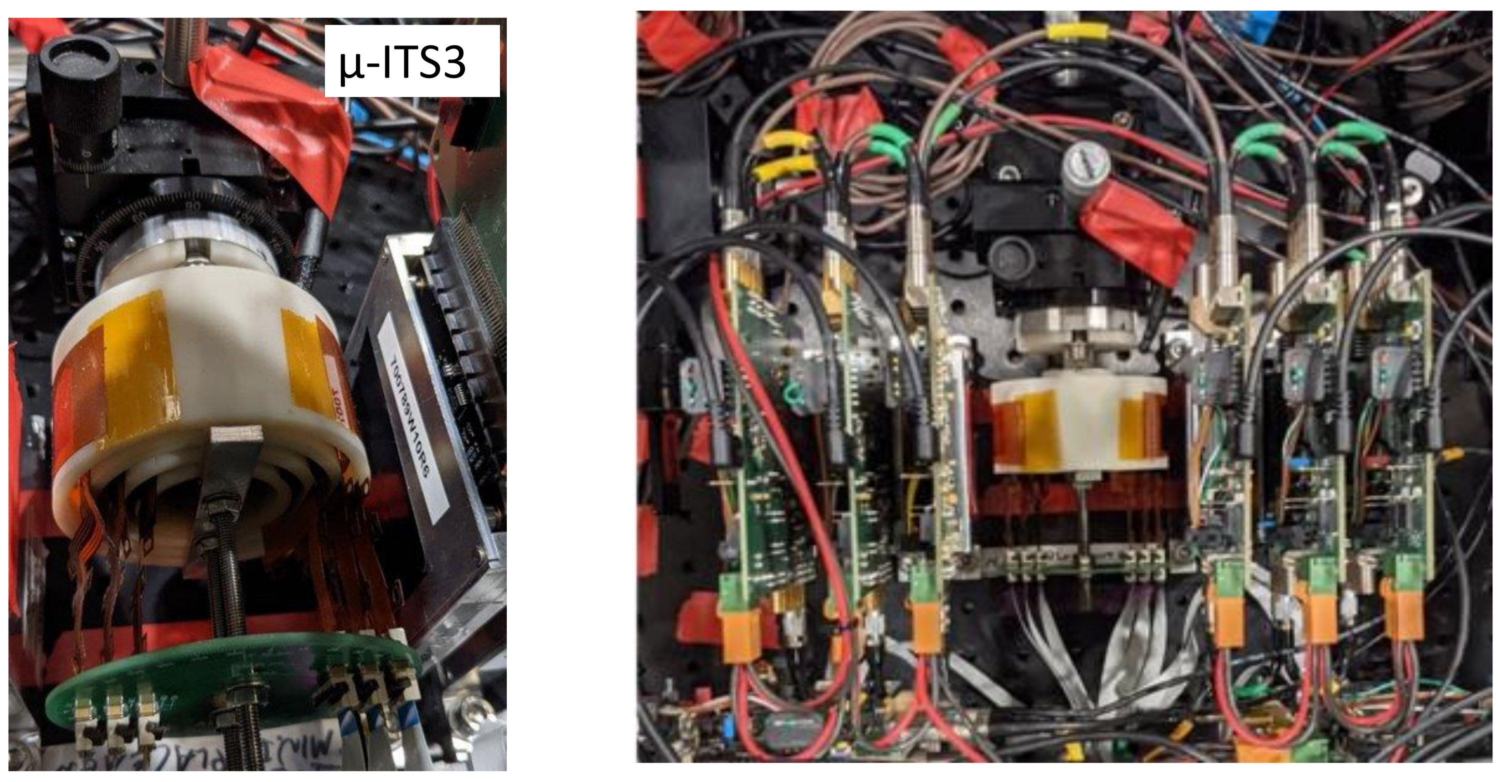
Fake-hit Rate values calculated as a function of ITHR (left) and VCASN (right).

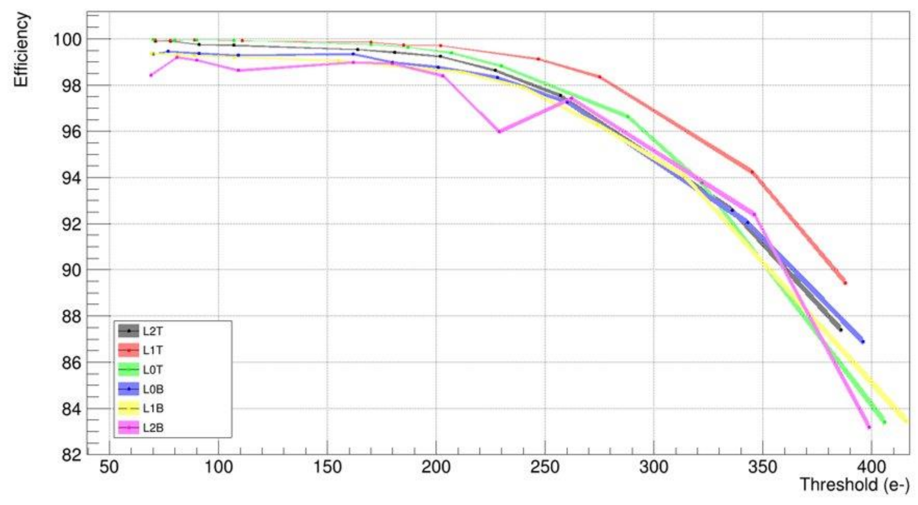
Conclusions

The realization of the new ITS3 in the future, envisages a detector consisting of three cylindrical layers composed only by curved wafer-scale silicon sensors. The test beams and electrical characterizations with bent ALPIDE chips have demonstrated that the chip functionalities are not affected by the curvature effect. The assembly for the first time of a large dimension bent MAPS detector (Super-ALPIDE) has required the development of specific tools and procedures as proof of concept for: large dimension chip handling, mechanical support design and implementation of powering, control and readout interface.

Performance of bent ALPIDEs in a test-beam

A beam telescope featuring six flat ALPIDE chips as reference detectors was used to measure the performance of other six ALPIDE chips, bent at the foreseen ITS3 layer radii, composing the so called μ-ITS3.

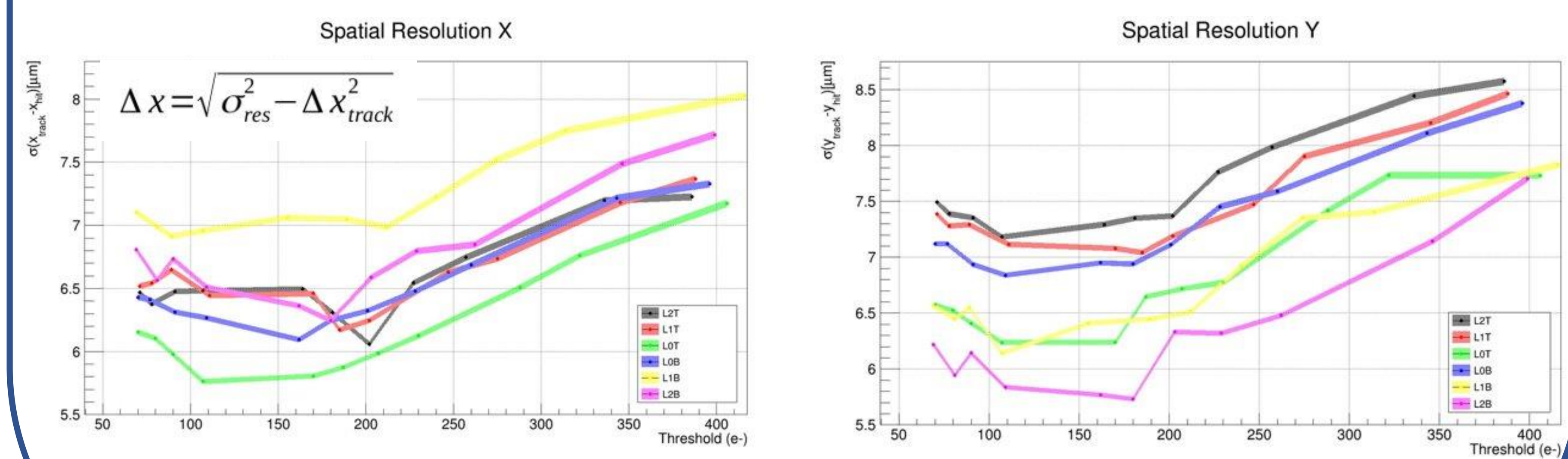




Detection efficiency: Fraction of tracks with associated clusters over the total accepted tracks on the DUT

Sensor efficiencies for different runs featuring different threshold values calculated for all the DUTs.

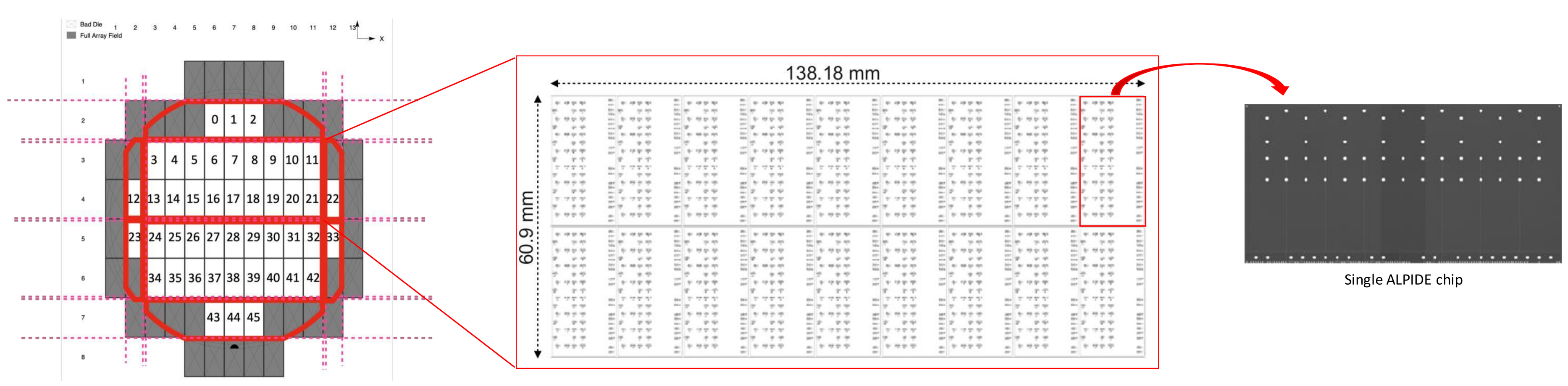
Spatial resolution: It is indirectly obtained by determining the standard deviation of the track residual distribution σ_{res}

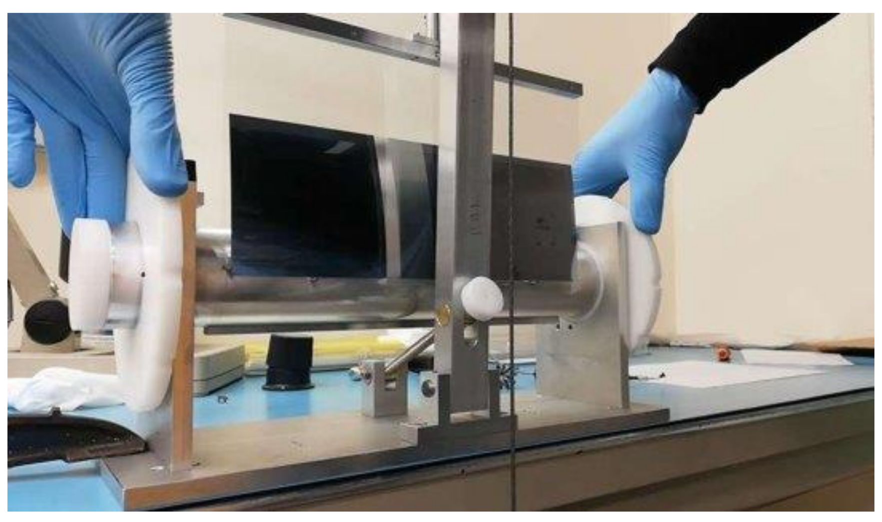


Width of the residual distribution in x (left) and y (right) vs runs at different thresholds calculated for all the DUTs.

Super-ALPIDE assembly

First large dimension bent MAPS detector. It's composed by 18 not-diced ALPIDE chips and intended to match a half-layer of the ITS3.





Mechanical tool developed for bending the super-ALPIDE