PROTOTYPE PIXEL LAYERS
FOR THE ALICE FOCAL UPGRADE

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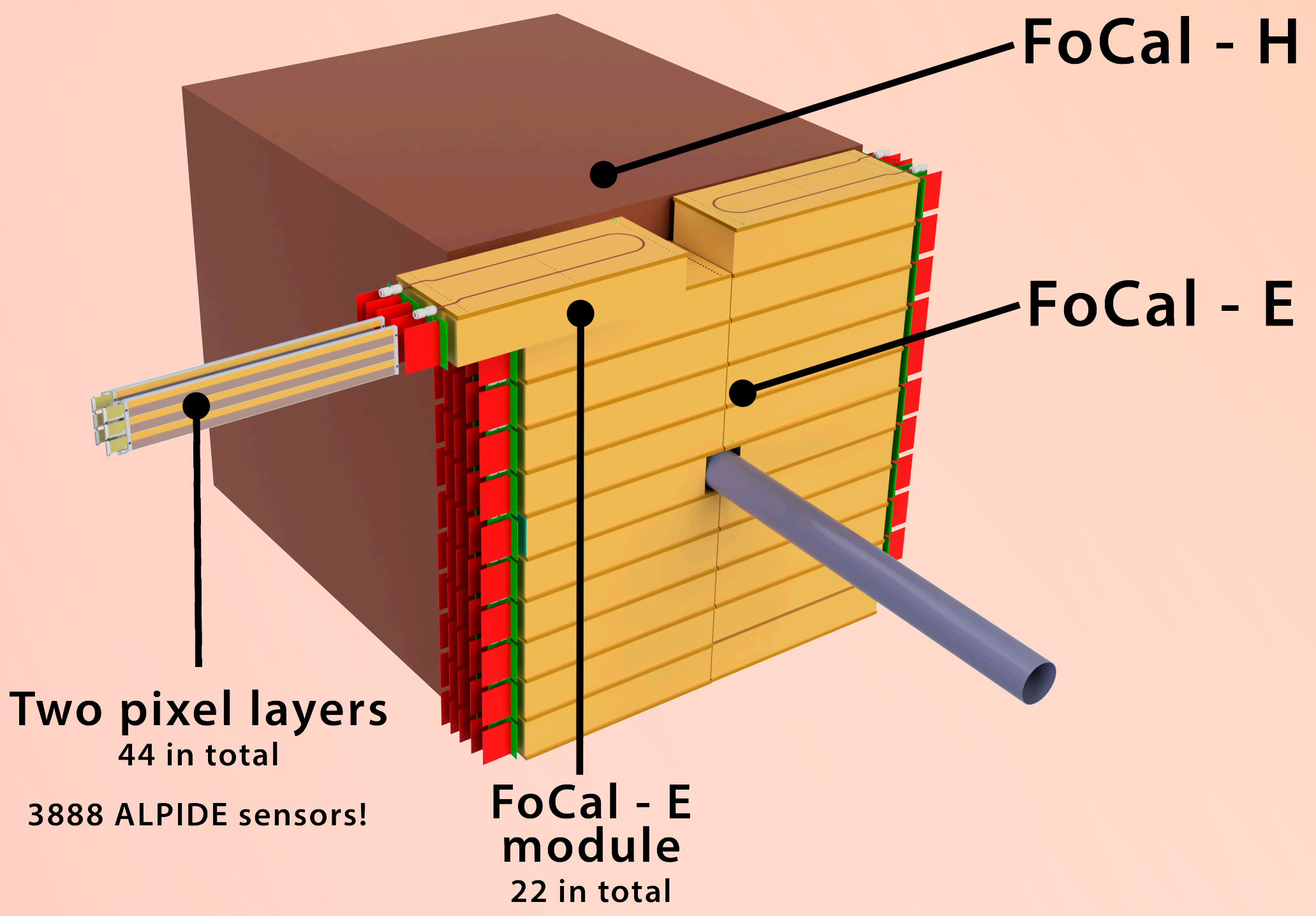
For the ALICE Collaboration



ABSTRACT

The University of Bergen is involved in developing two calorimeters: the pixel section of the Electromagnetic Forward Calorimeter (FoCal-E) for the ALICE Upgrade [1] and the Digital Tracking Calorimeter for the proton Computed Tomography [2]. Both designs utilize the ALPIDE sensors and both designs utilize specialized off-chip routing and bonding techniques to securely link the sensors with the remaining detector framework.

This contribution introduces the different production processes, describes the development of the first prototypes, and provides the first experience and challenges. As well as it provides the roadmap towards the final FoCal pixel layers.

DESIGN CHOICES

Utilizing ALPIDE sensors

originally developed for the Inner Tracking System in ALICE for Run3. It is a high-granularity MAPS implemented in 180 nm TowerJazz CMOS technology with a matrix of 1024 x 512 pixels and active area of 29.94 mm x 13.76 mm [3].

Assembling layers in a folded fashion

provides no dead area in one layer.

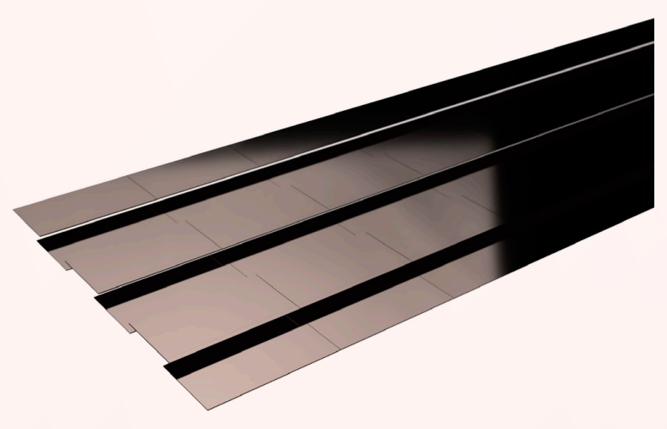
The ALPIDE sensors are arranged in so-called strings consisting of:

- a row of ALPIDE sensors
- flexible circuit; divided into chip cable and multilayered flex cable
- passive components (termination resistors, decoupling capacitors)

Initially, ALPIDE is bonded to a chip cable to characterize and select only good sensors for subsequent assembly. These selected sensors and a flex cable are then glued on an aluminium carrier, and then bonded together creating a string. Three strings are aligned on a single carrier, and an additional carrier, folded over, creates a unified active area.

Final design:

- matrix of six 15-chip strings
- 12-chip string used only on the side of the beam pipe
- active area of 82.2 mm x 451.4 mm



Ultrasonically welding aluminium chip-on-flex assembly

whereby the circuits are manufactured by use of adhesiveless aluminium-polyimide foiled dielectrics [4].

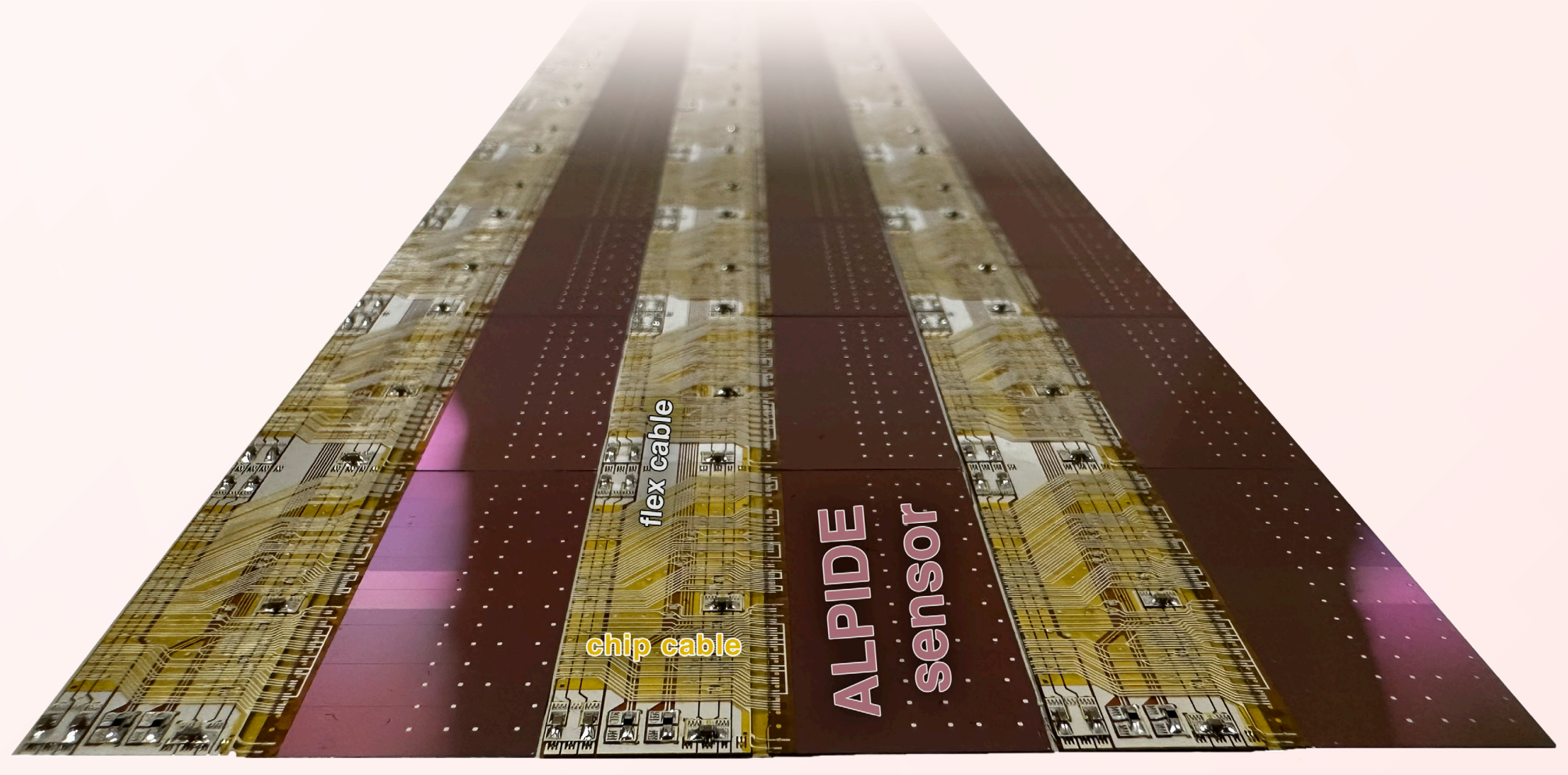
Why aluminium flex circuits?

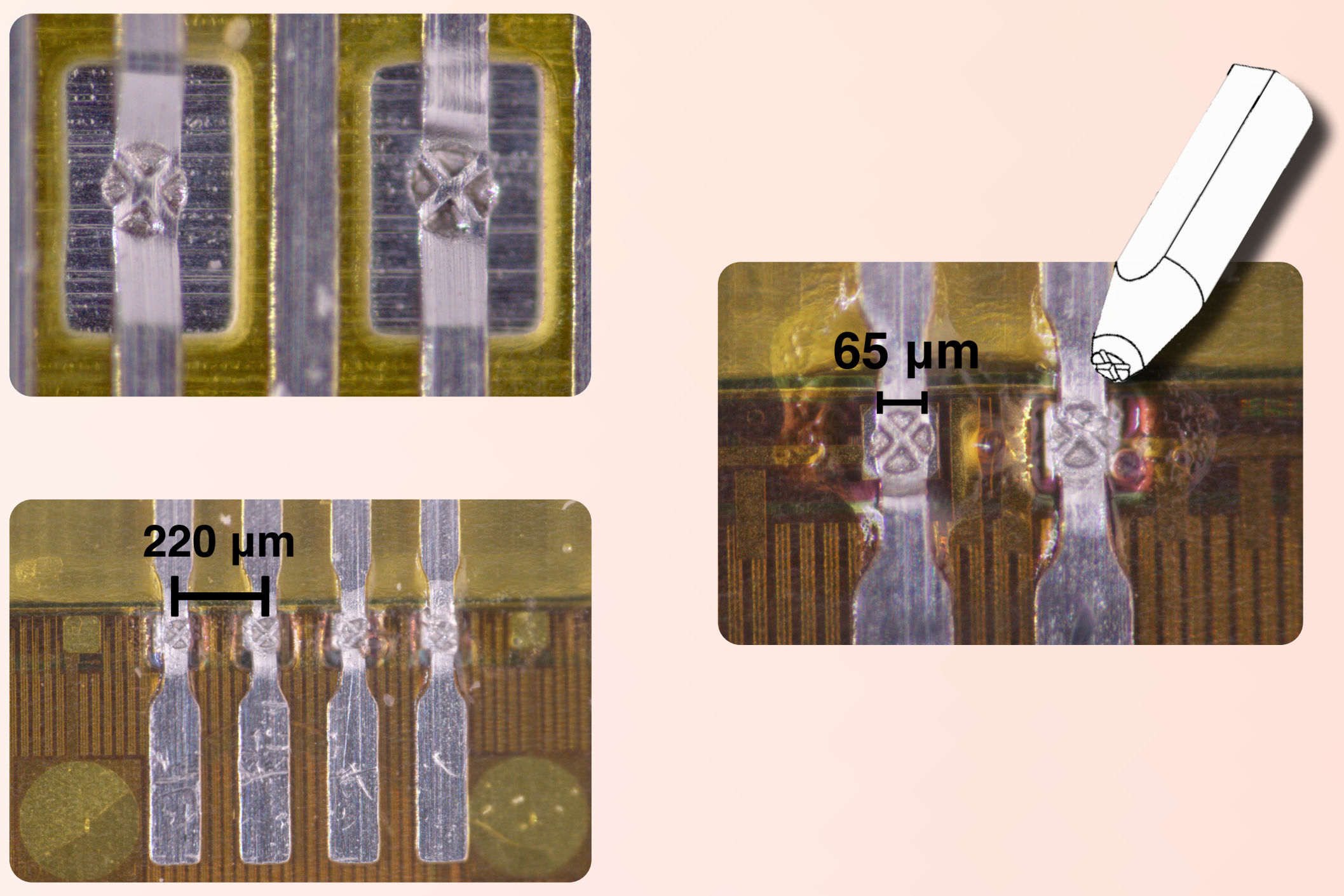
- downscaling both in weight and size, i.e. material budget in HEP.
- least possible gap between the layers
- compatibility - bonding pads of ALPIDEs are aluminium
- homogeneity - the assembly is glued on aluminium carriers
- high radiation length = less energy loss

Why ultrasonic welding?

Method commonly known as the Single-point Tape Automated Bonding (SpTAB).

- only one bonding joint instead of two as in case of a wire-bonding technique
- more reliable and secure connection
- bonded joints are encapsulated with glue





Utilizing bonding pads on the periphery

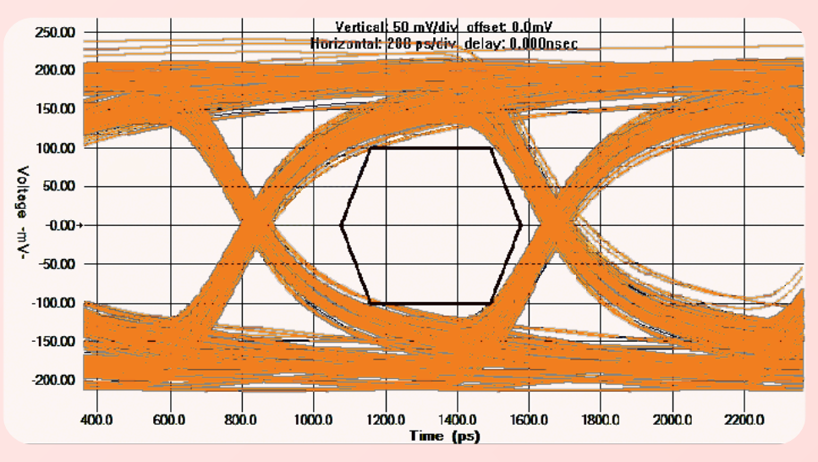
of the ALPIDE sensor which allows using shorter traces to the flex cables, i.e. a shorter length to decoupling capacitors.

Separating digital core and PLL domains

up to the end of the flex cable ensures minimal voltage drop on the power lines dedicated to the PLL by isolating its traces from digital traces up to the connector's end. This results in stable high-speed link at 1.2 Gbps.

Creating simulation framework

with HyperLynx for the flexible circuits helps decide the stack-up and layout before the production.

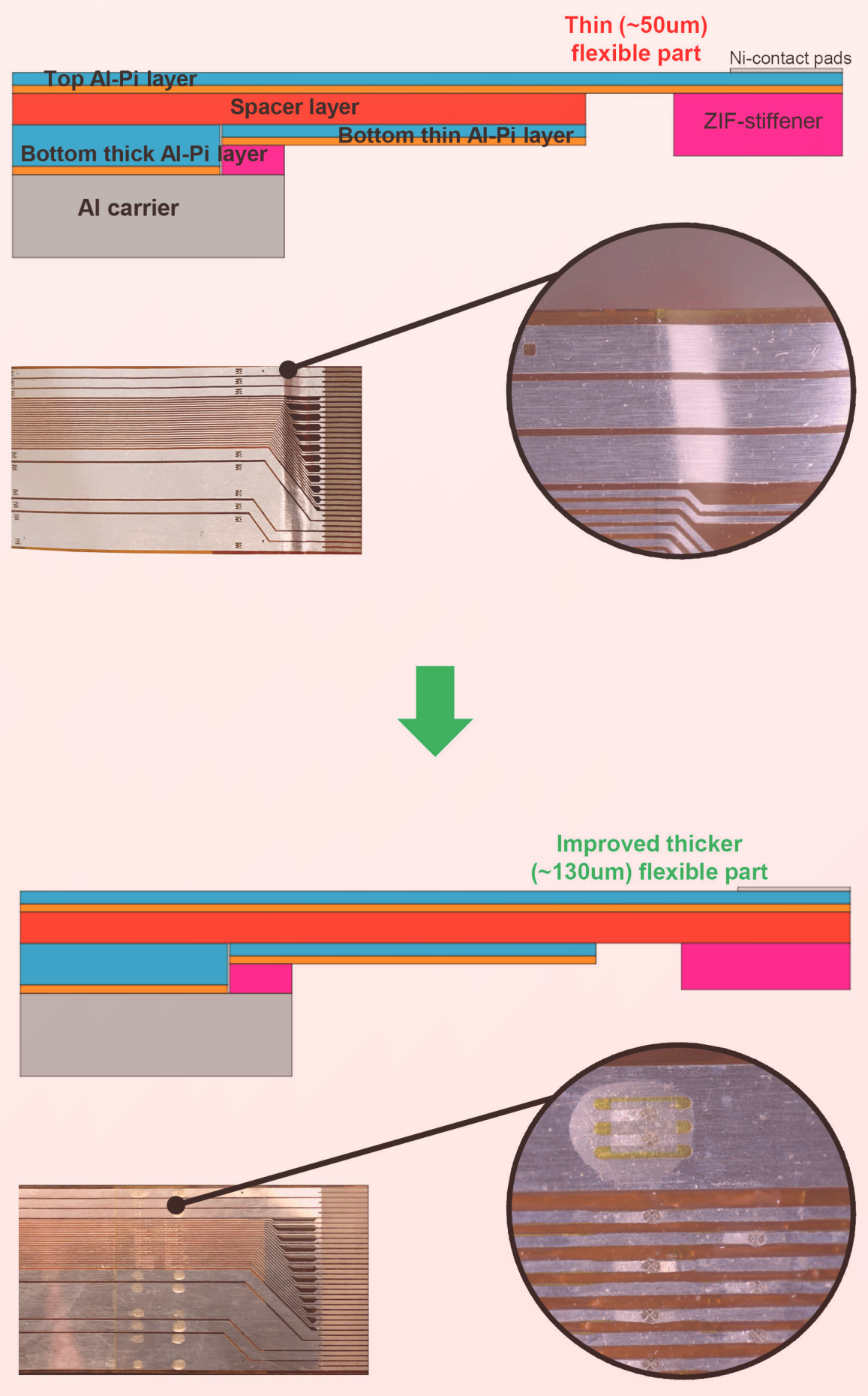


EXPERIENCE

What went wrong?

The flex cable's end has been intentionally thinner for easier insertion into a connector. However, this design sometimes caused bending at this transition, and unfortunately at times resulting in broken traces.

To address this unforseen issue, the full thickness of the flex cable along its entire length is now maintained. Furthermore, the broken traces have been successfully repaired without affecting the layers' performance.

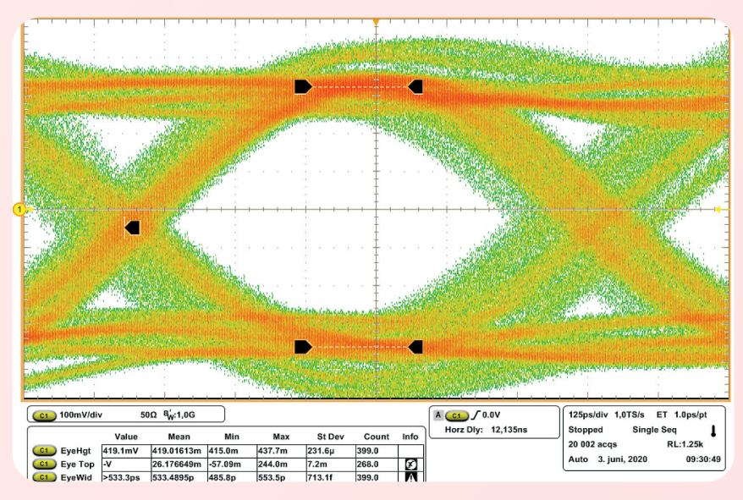


What went right?

Performance in lab

The first prototypes have shown excellent operation while analyzing:

- eye diagram measurements
- voltage drop measurements
- decode errors



This is true even for 8 m long twinax FireFly cable assembly from Samtec to the off-detector readout.

Performance in test beams

The prototypes have always performed reliably, and no signal or power integrity troubles have been detected during several test beams.

Note that the first prototypes have been produced with 9 ALPIDE chips instead of 15 as planned for the final design.

FROM PROTOTYPE TO FINAL LAYERS

Short-term:

- 15-chip string design and simulation
- 15-chip string production and verification

Long-term:

- Full pixel layer production
- Custom FPGA-based readout design and production
- Integration with the rest of the FoCal-E together with common power distribution.

REFERENCES

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[2] pCT Collaboration, "A High-Granularity Digital Tracking Calorimeter Optimized for Proton CT ", doi: 10.3389/fphy.2020.568243

[3] ALICE Collaboration, "Technical Design Report for the upgrade of the ALICE Inner Tracking System", CERN-LHCC-2013-024; ALICE-TDR-017

[4] Borshchov VM et al., " Innovative microelectronic technologies for high-energy physics experiments.", doi:10.15407/fm24.01.143

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