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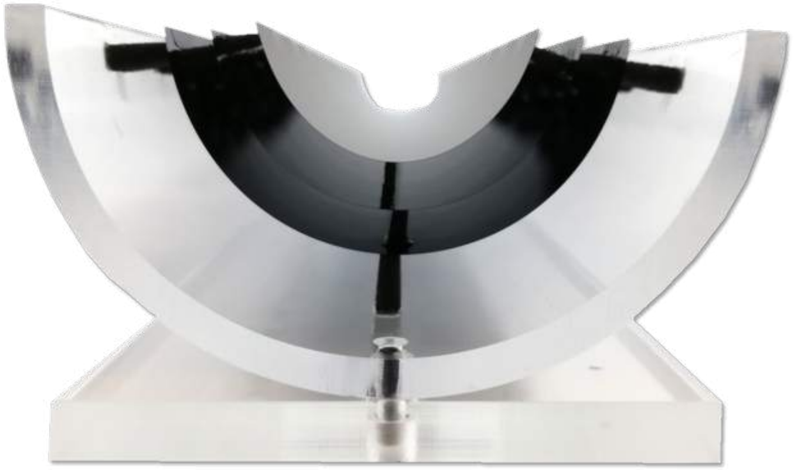
ALICE ITS3
the first truly cylindrical inner tracker



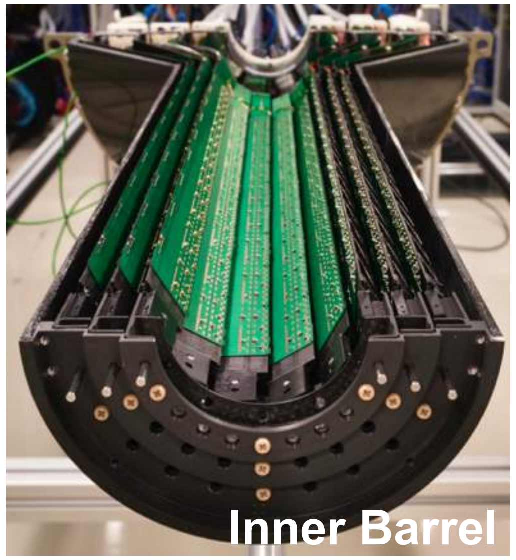
Cosimo Pastore
INFN Bari
on behalf of the ALICE Collaboration

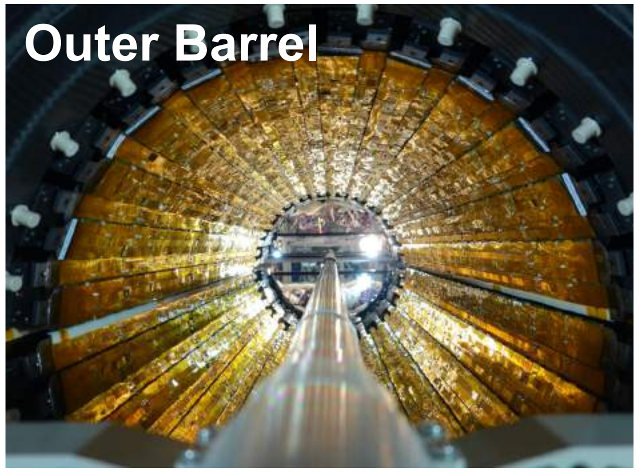
ALICE Inner Tracking upgrade roadmap

ITS2 for LHC Run 3

- 🟦 Shutdown/Technical stop
- 🟩 Protons physics
- 🟩 Ions
- 🟧 Commissioning with beam
- 🟦 Hardware commissioning/magnet training

ITS3 for LHC Run 4

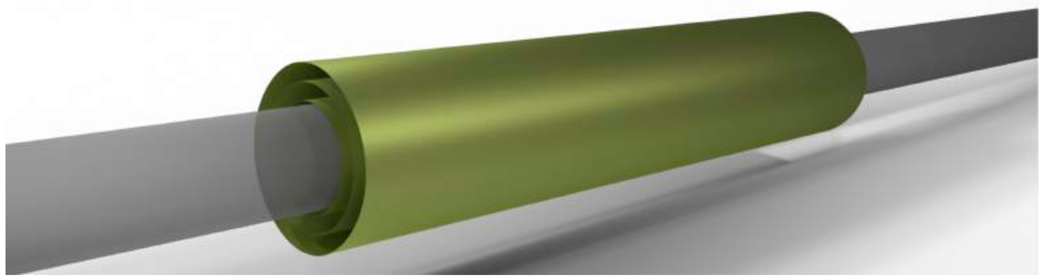




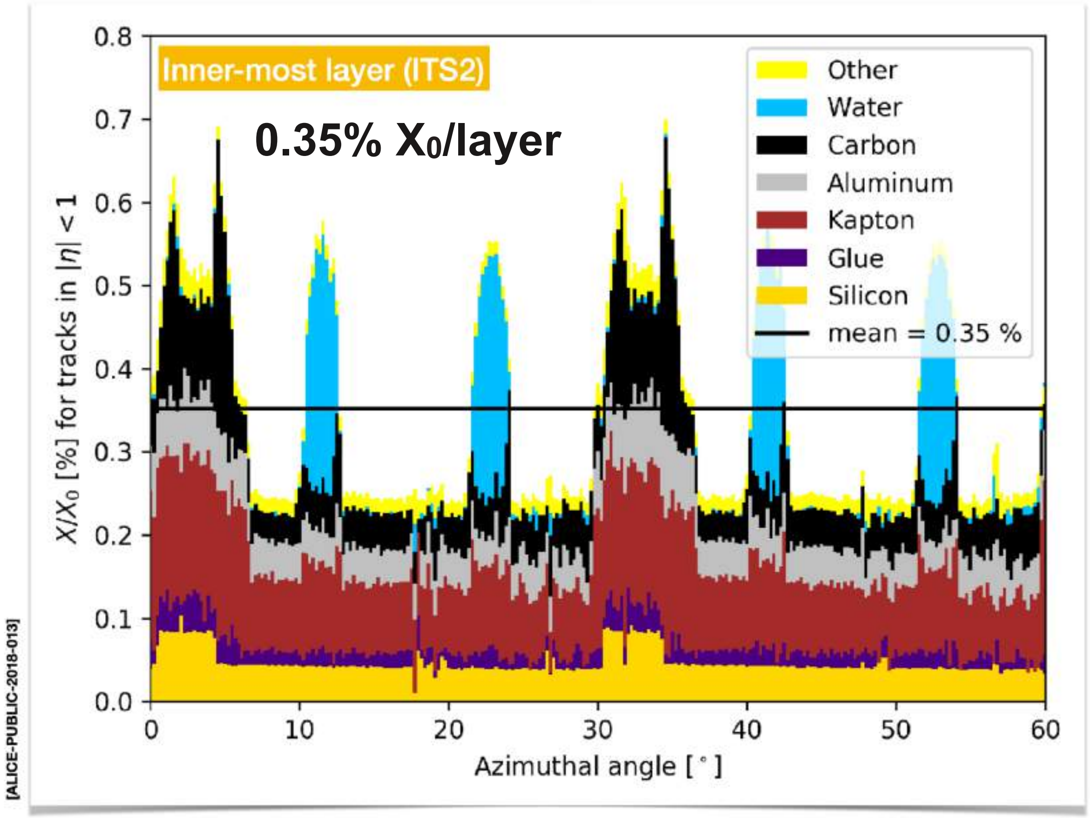
ITS2 installed and under commissioning

Can we get closer to the IP?
Can we reduce the material budget?

The way: replace detector staves (3 innermost layers) by wafer-scale sensors bent around the beam pipe



Motivation for ITS3



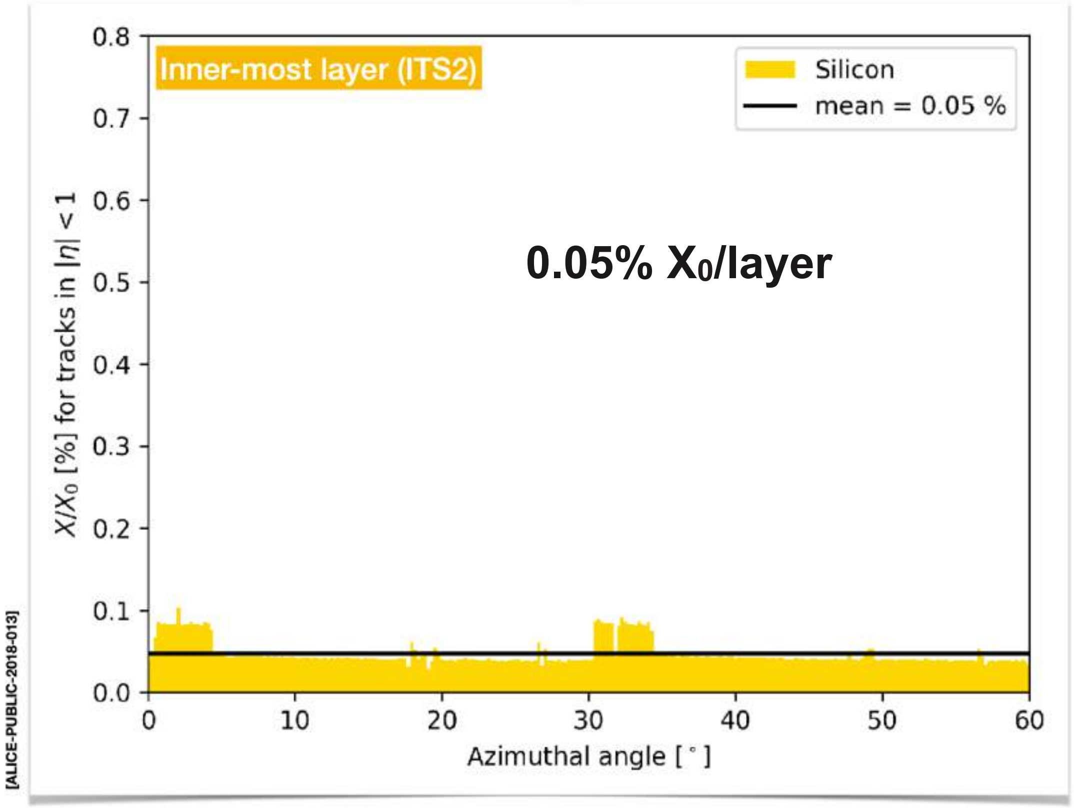
0.35% X_0/layer

[ALICE-PUBLIC-2018-013]

Observations

» Silicon makes only about 15% of total material

» Irregularities due to support/cooling and overlap



0.05% X_0/layer

[ALICE-PUBLIC-2018-013]

Improvements

» *Removal of water cooling*

→ **possible** if power consumption stays below 20 mW/cm^2

→ move to (low flow) air cooling system

» *Removal circuit board* (power+data)

→ **possible** if integrated on chip

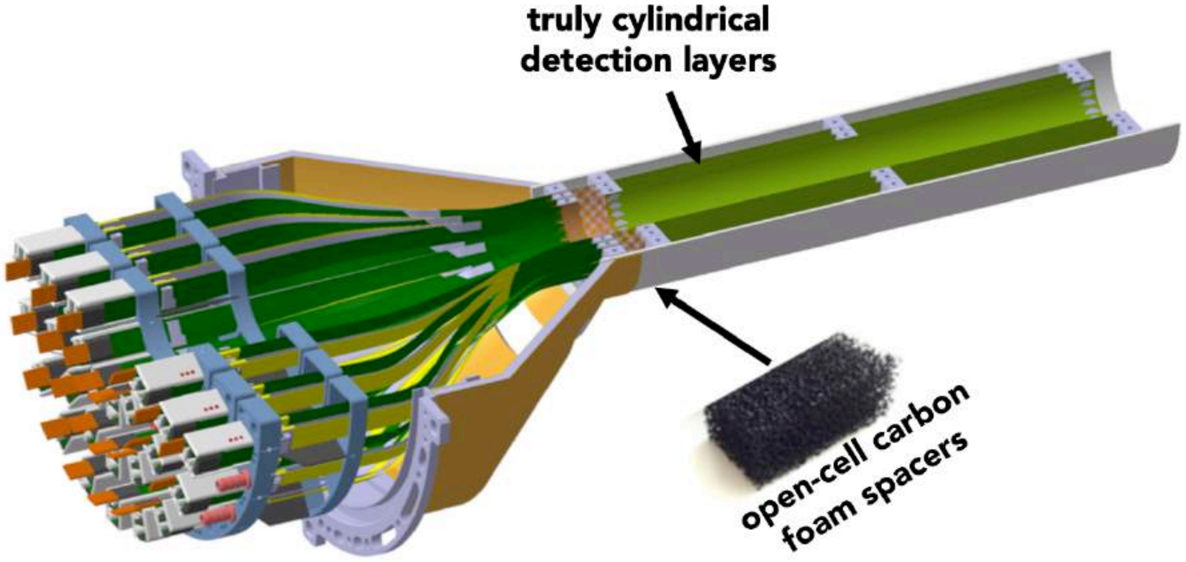
» *Removal of mechanical support*

→ **benefit** from increased stiffness by rolling Si wafers

ITS3 detector concept

Key ingredients

- Wafer-scale chips (up to ~28x10 cm), fabricated using stitching
- Sensor thickness 20-40 µm
- Chips bent in cylindrical shape at target radii
- Si MAPS sensor based on 65 nm technology
- Carbon foam structures
- Smaller beam pipe diameter and wall thickness (0.14% X_0)



The whole detector will comprise six chips (current ITS IB: 432) and barely anything else!

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 of sensitive area (mm)	300.0		
Pseudo-rapidity coverage	±2.5	±2.3	±2.0
Active-area (cm²)	610	816	1016
Pixel sensor dimension (mm²)	280 × 56.5	280 x 75.5	280 x 94
Number of sensors per layer	2		
Pixel size (µm²)	O (10 x 10)		

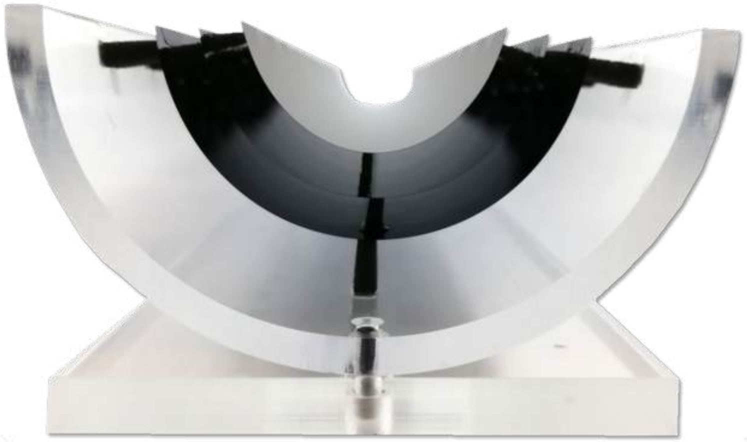
Key benefits

- Extremely low material budget: 0.02-0.04% X_0
- Homogeneous material distribution: negligible systematic error from material distribution

ITS3 R&D lines

Detector Integration

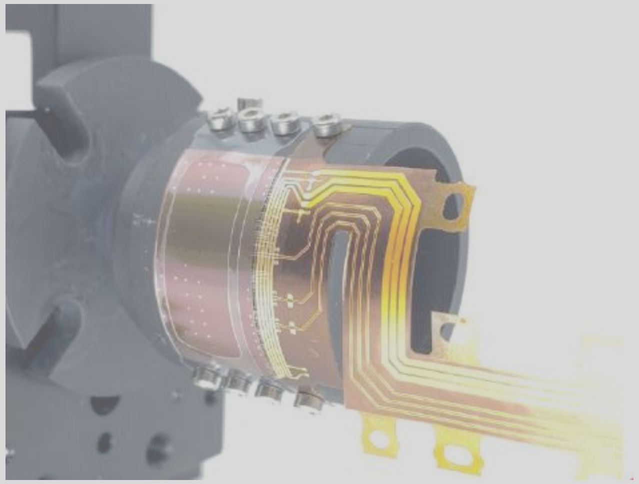
Tests with wafer-scale dummy chips for mechanical integration



This talk!

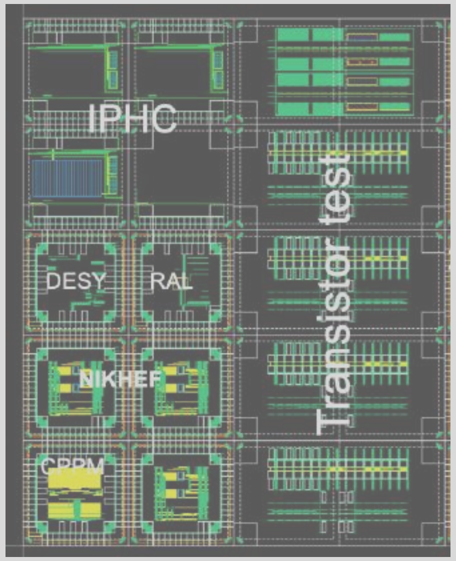
Sensor performance

Tests with existing bent ALPIDE chips (ITS2) for (in-beam) performance assessment



Chip design

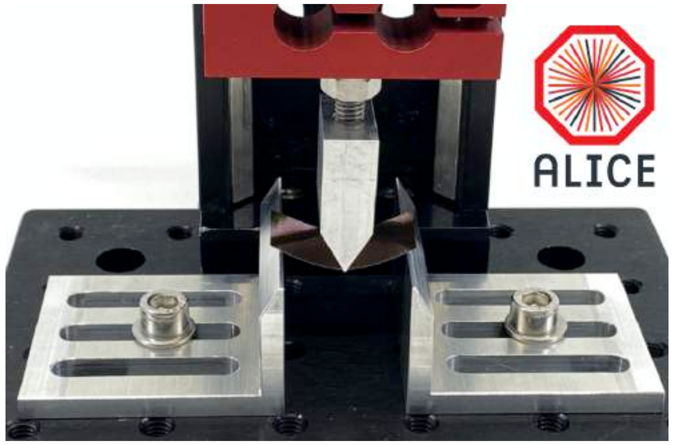
New, stitched sensor in 65 nm technology on 300 mm wafers

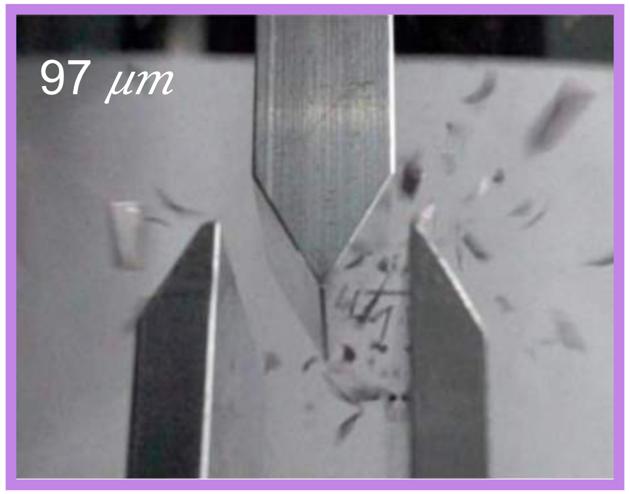


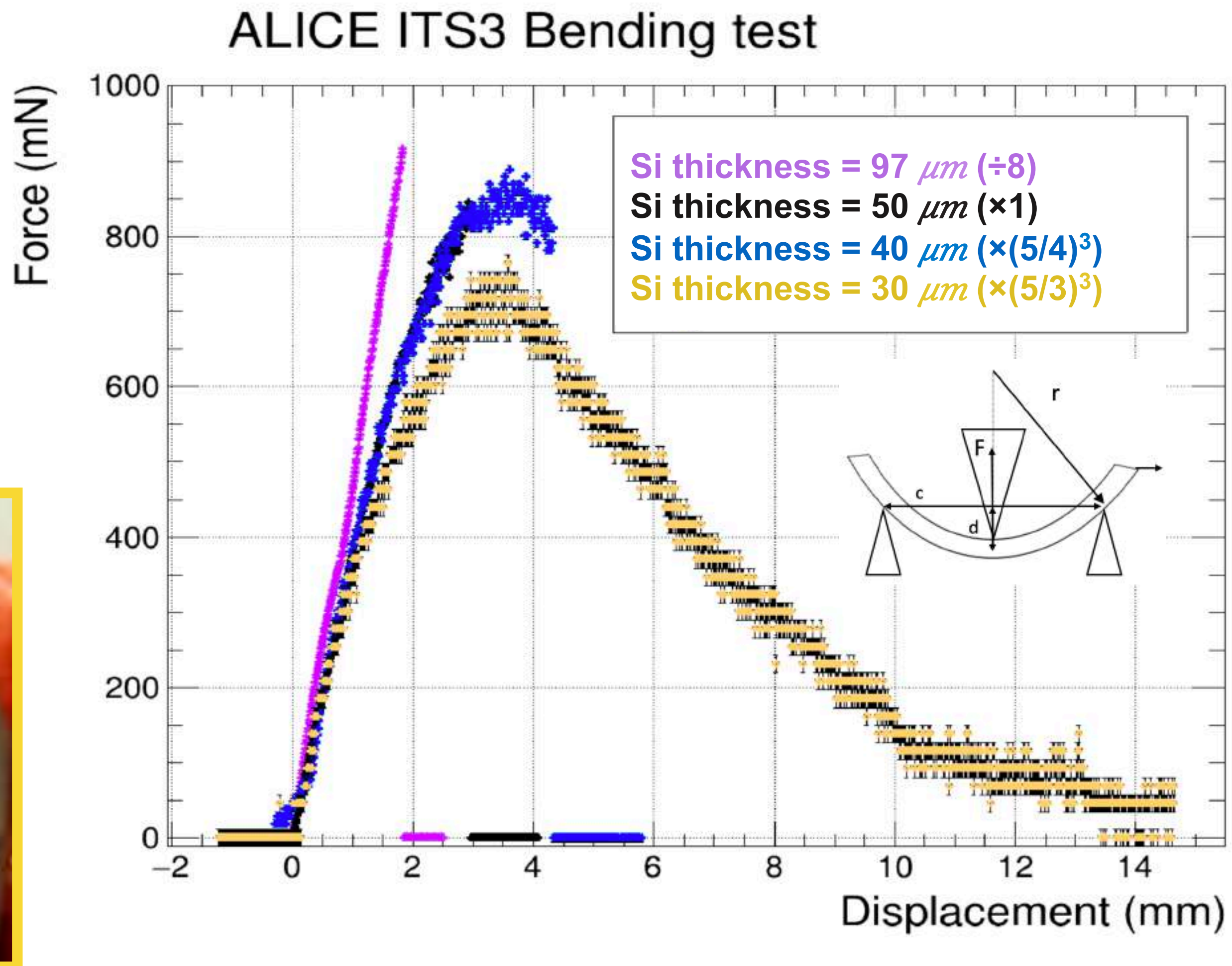
ITS3 R&D lines - Detector Integration

ALPIDE CHIP BENDING

- MAPS at thickness used in current detectors (~50 μm) are quite flexible
- Large benefit from going even a bit thinner: the bending force scales with thickness to the third power
- The breaking point moves to smaller bending radii when going thinner
- Project goal thicknesses and desired bending radii are in a “not breaking” regime



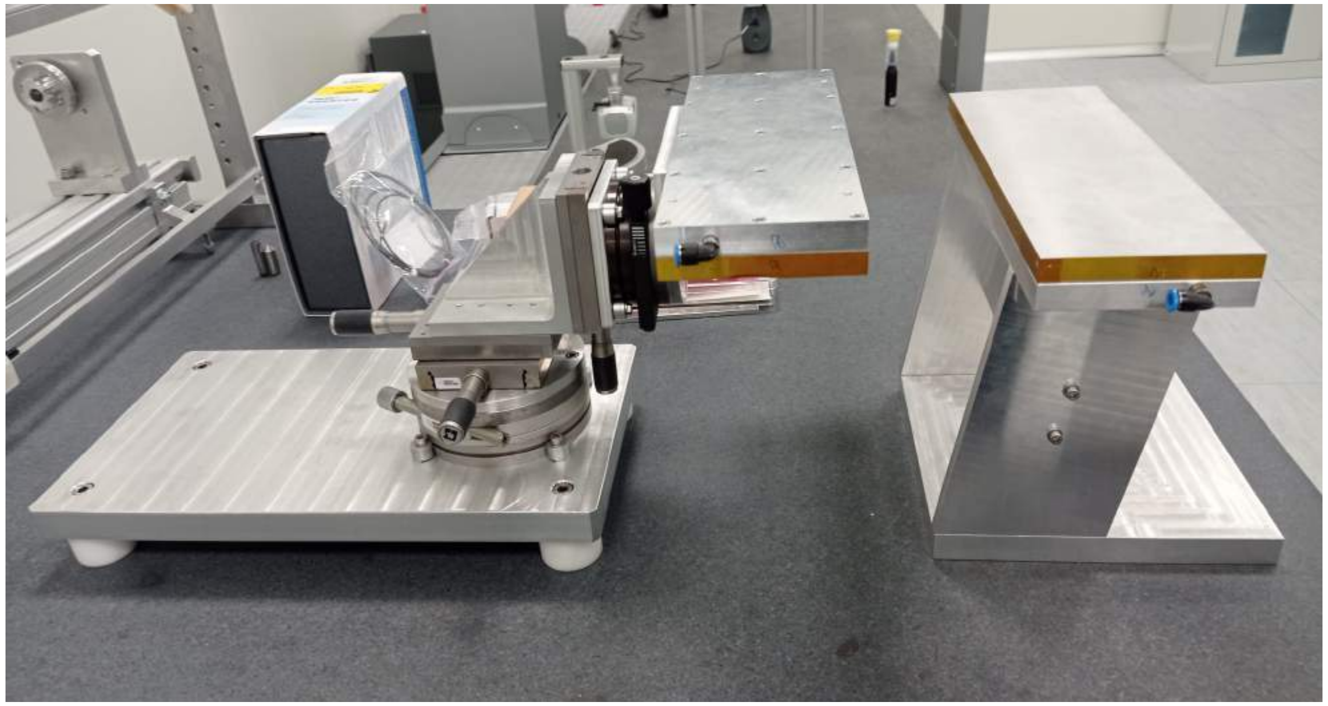




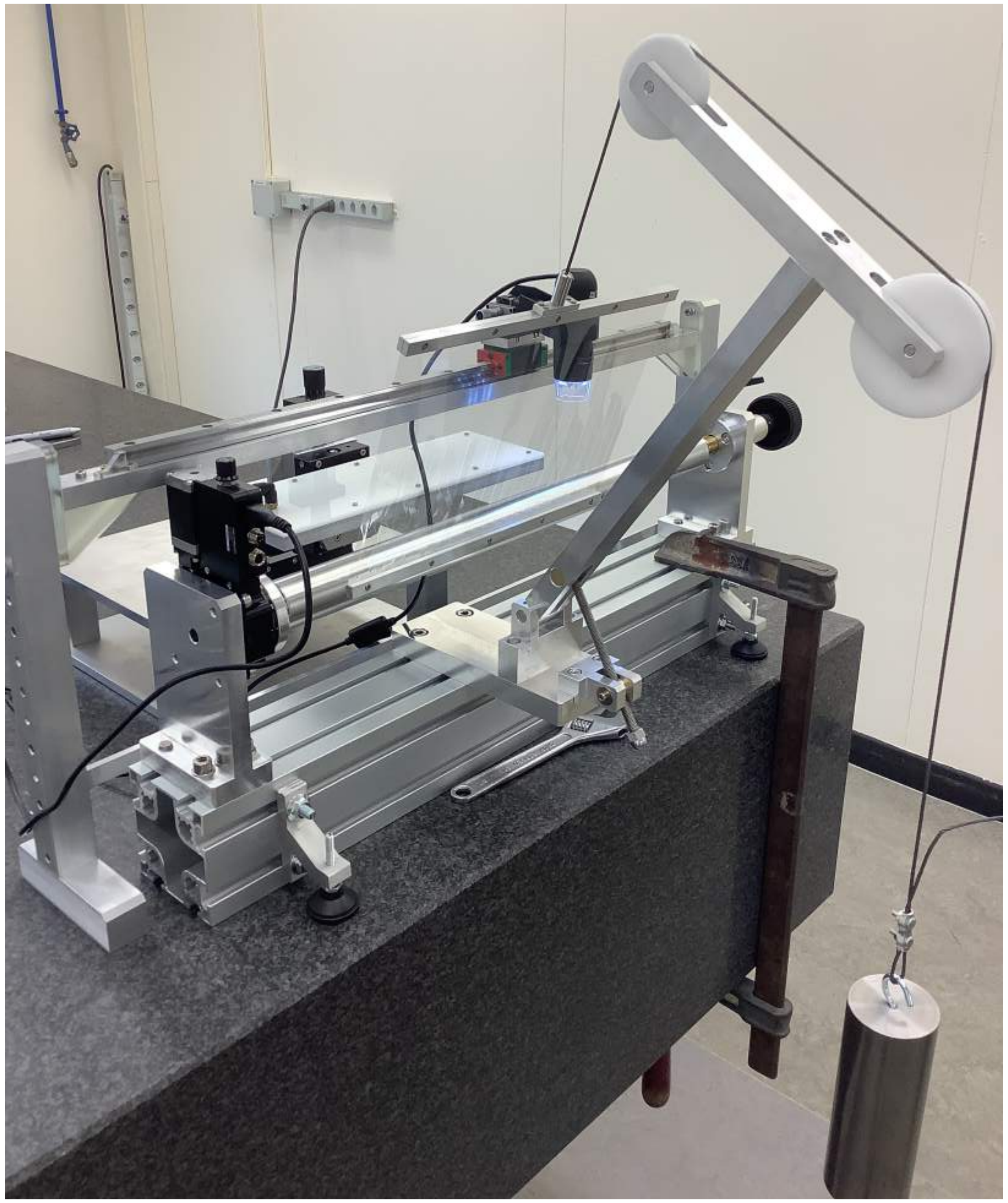
ITS3 R&D lines - Detector Integration

WAFER-SCALE CHIPS BENDING

- » Developed procedure allows silicon bending in a repeatable reliable way
- » Bending tool: tensioned mylar foil wrapping around a cylindrical mandrel



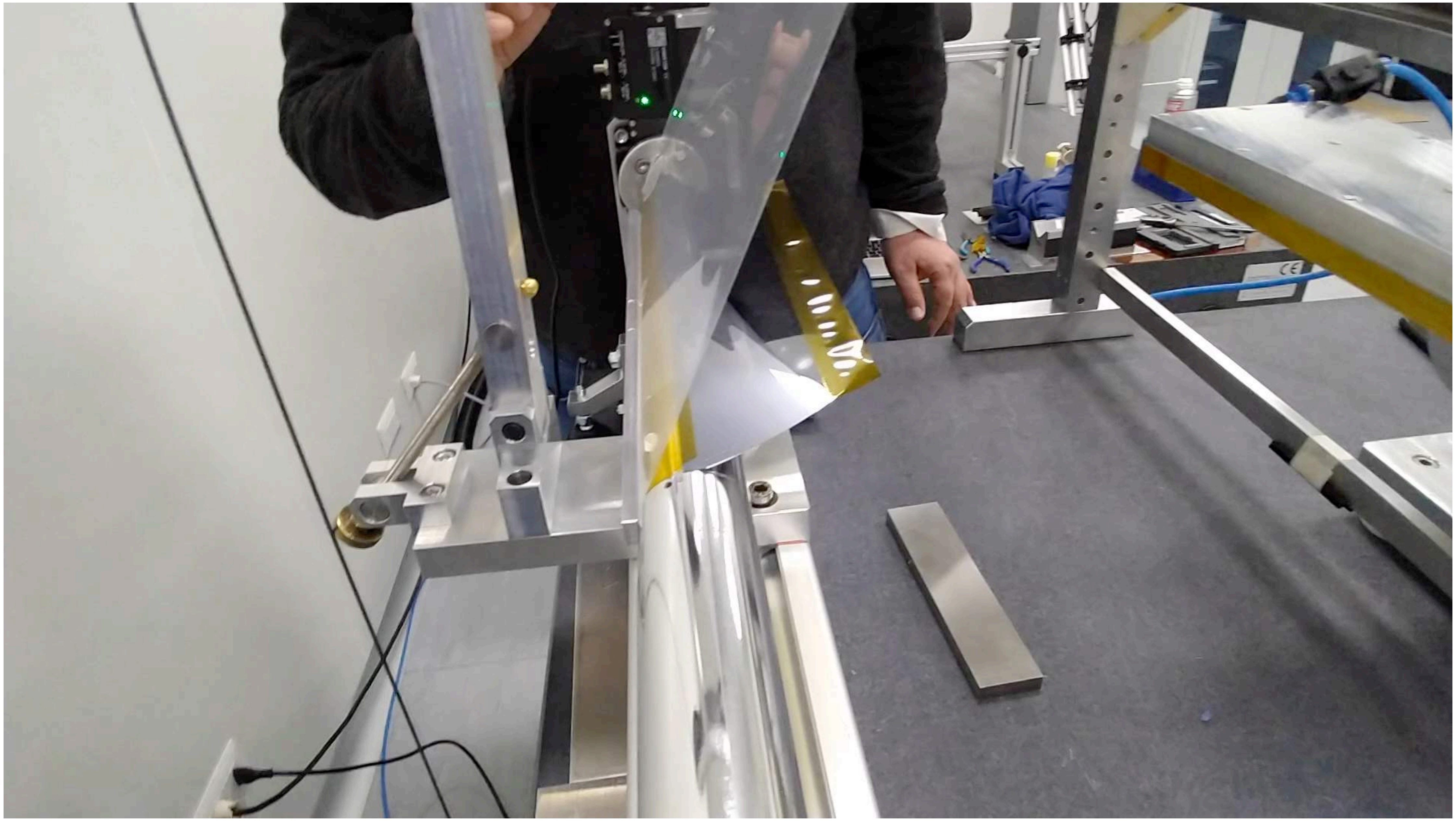
Vacuum tools to handle and align large-size silicon piece



Bending tool equipped with: cylindrical mandrel, rotary motor, arm with weight to tension mylar foil, camera for alignment

ITS3 R&D lines - Detector Integration

WAFER-SCALE CHIPS BENDING



Bent silicon piece kept in position with Kapton adhesive tape

ITS3 R&D lines - Detector Integration

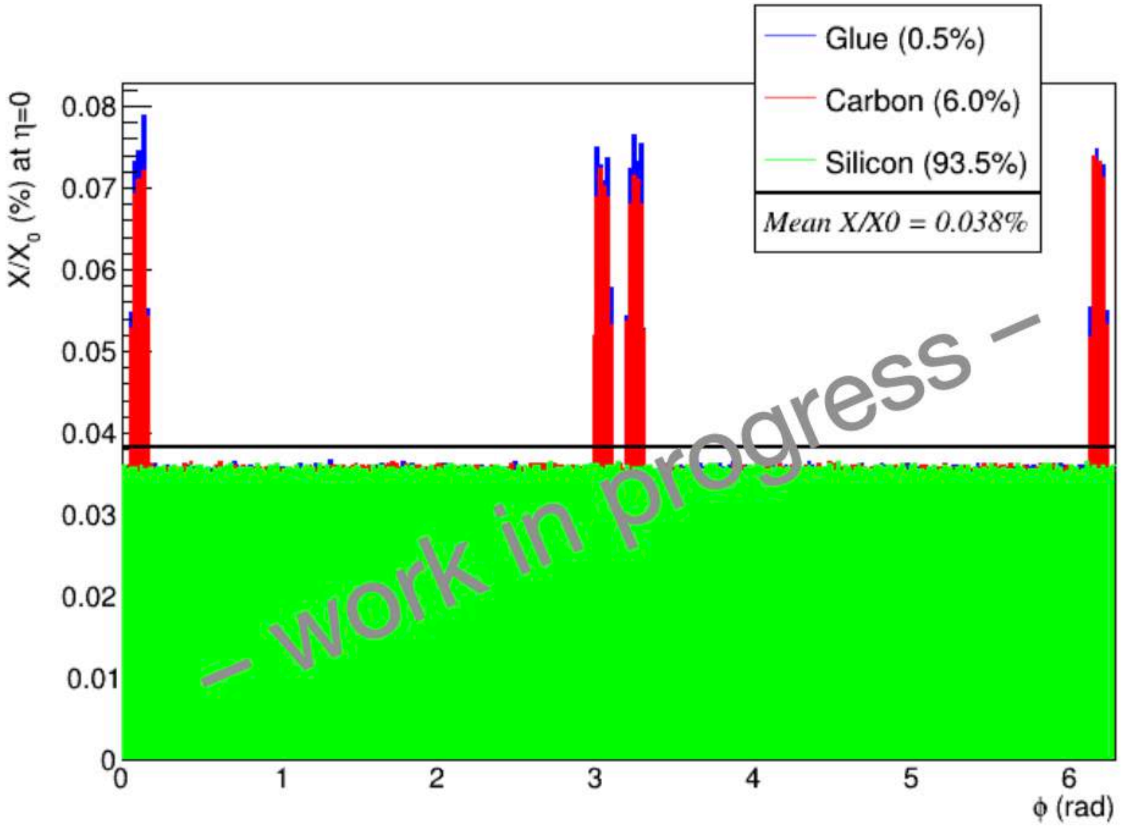
WAFER-SCALE CHIPS BENDING

Bent silicon piece kept in position with Kapton adhesive tape

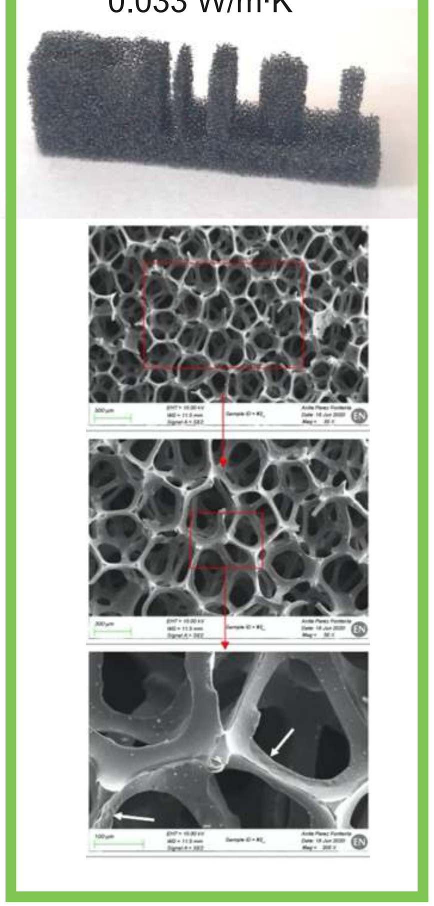
ITS3 R&D lines - Detector Integration

CARBON FOAM SUPPORT STRUCTURE

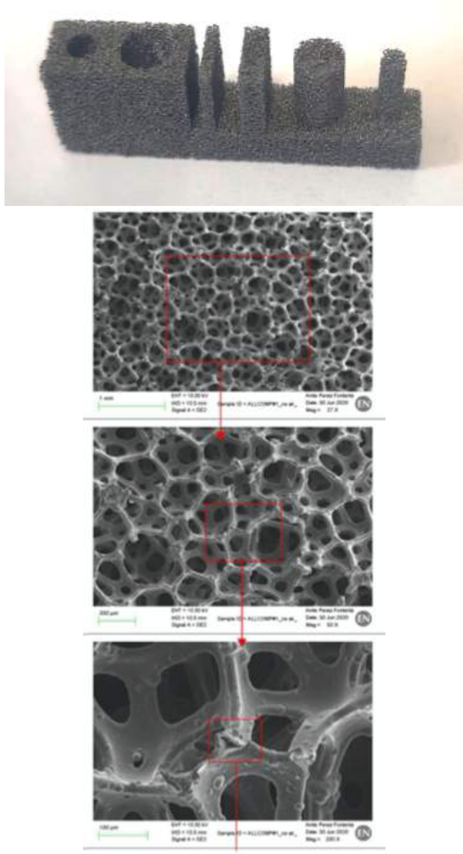
- » Different foams characterised for machinability and thermal properties
- » Baseline is ERG DUOCEL_AR, which also features the largest radiation length



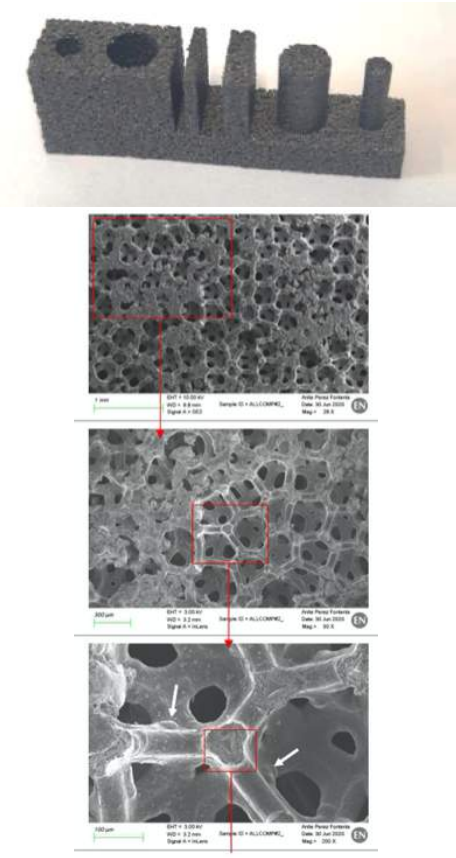
ERG DUOCEL_AR
0.06 kg/dm^3
0.033 W/m·K



ALLCMPO_LD
0.2-0.26 kg/dm^3
>17 W/m·K

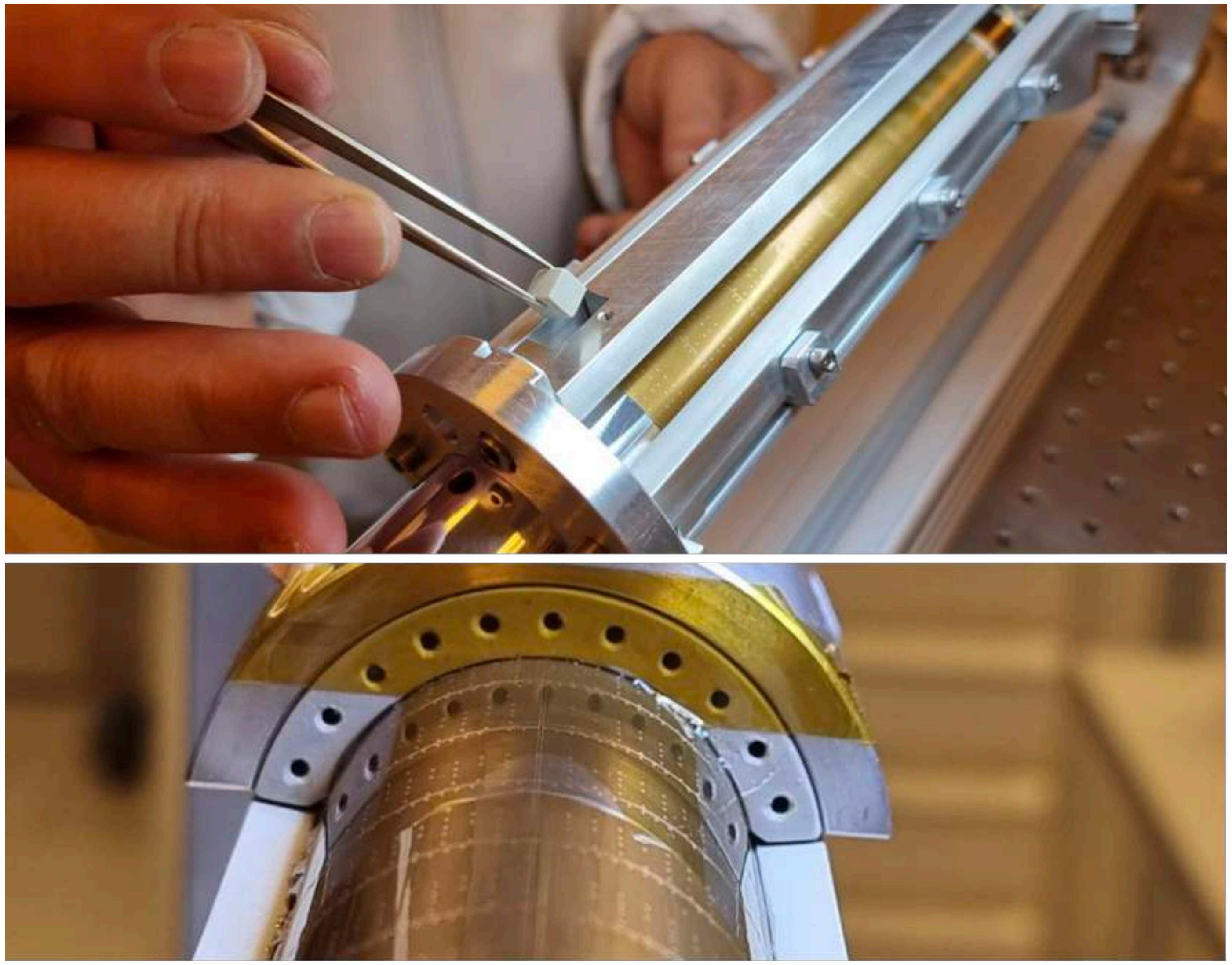


ALLCMPO_HD
0.45-0.68 kg/dm^3
85-170 W/m·K

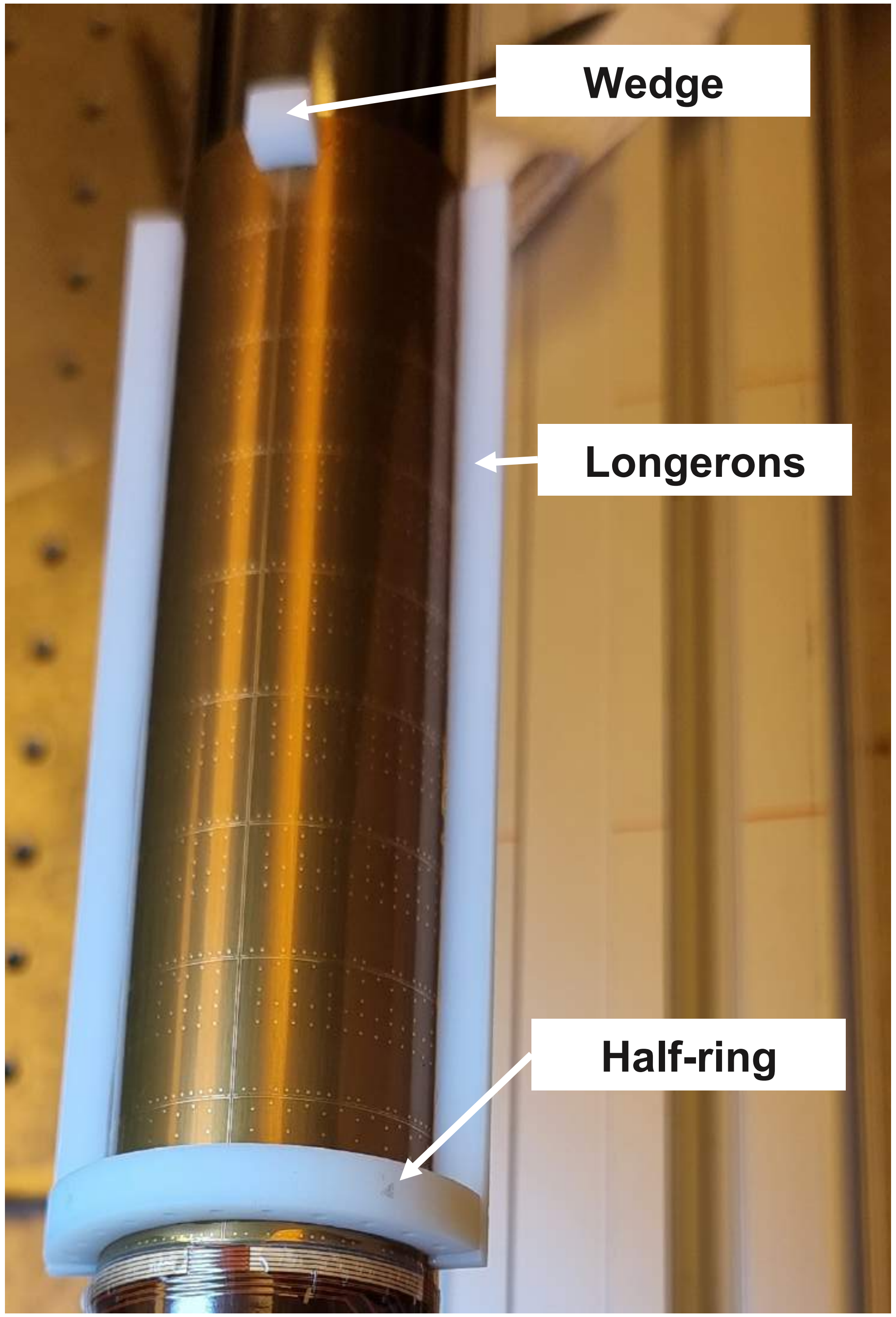


ITS3 R&D lines - Detector Integration

PEEK SUPPORT STRUCTURE



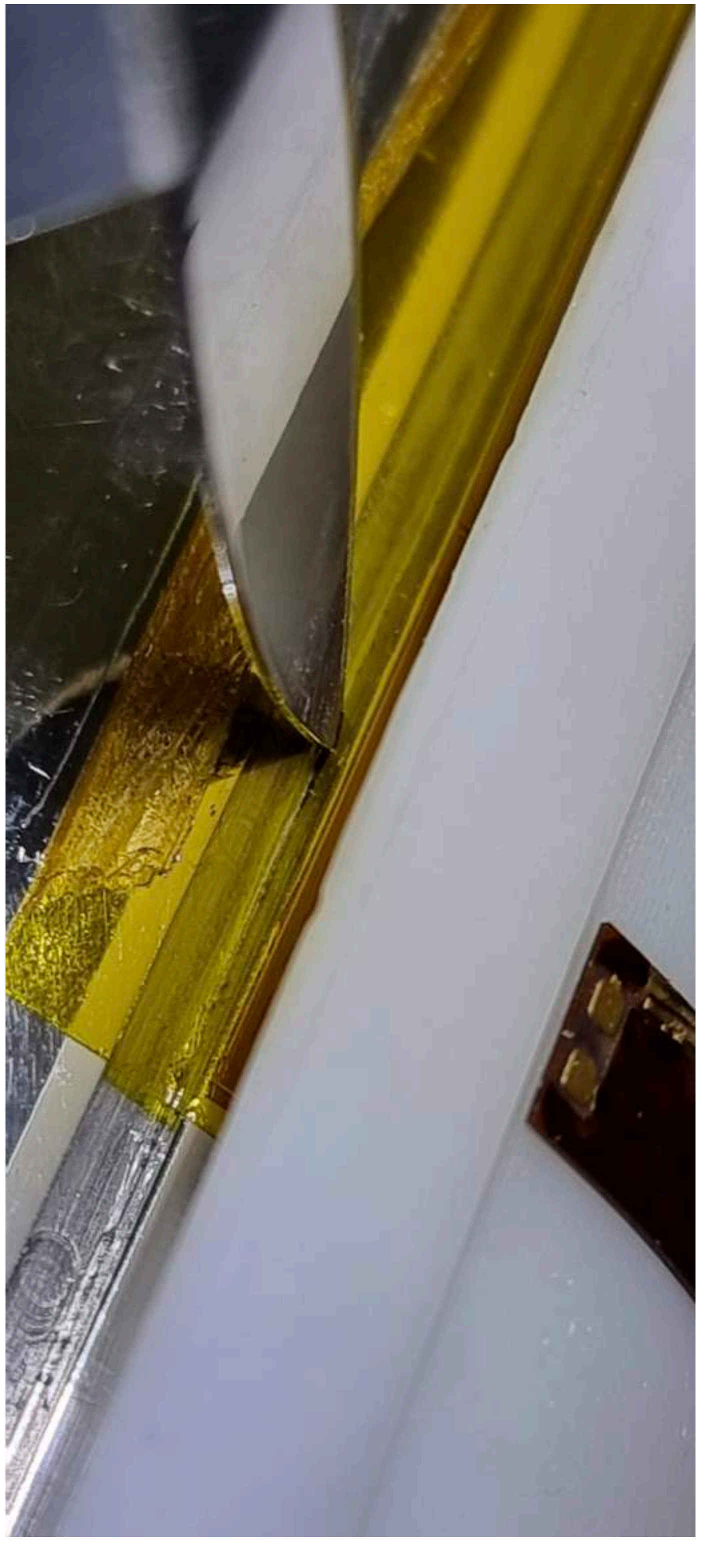
Alignment/gluing tools for support structures



ITS3 R&D lines - Detector Integration

ADHESIVE TAPE CUT TOOL

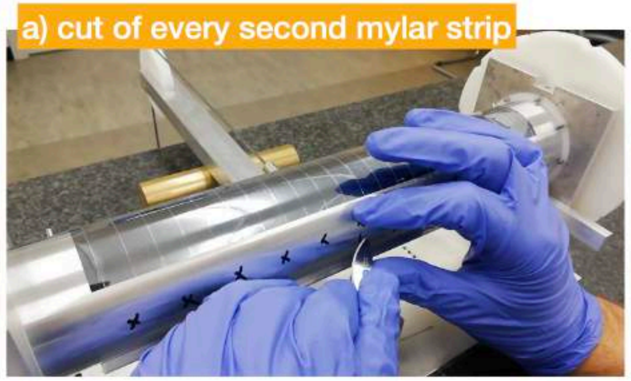
Precision and controlled cut close to the edge of the silicon

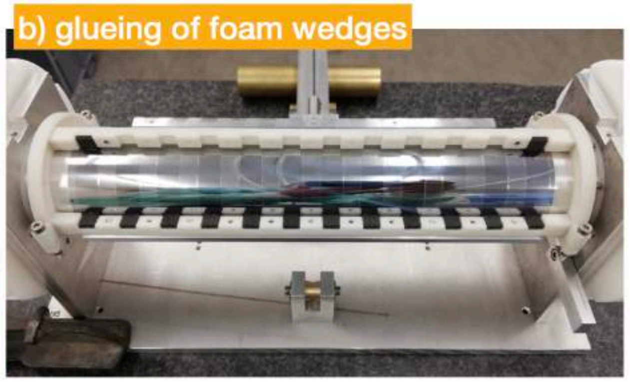


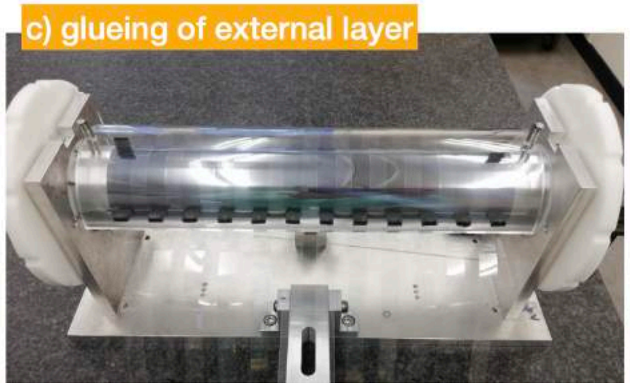
ITS3 R&D lines - Detector Integration

LAYER ASSEMBLY PROCEDURE

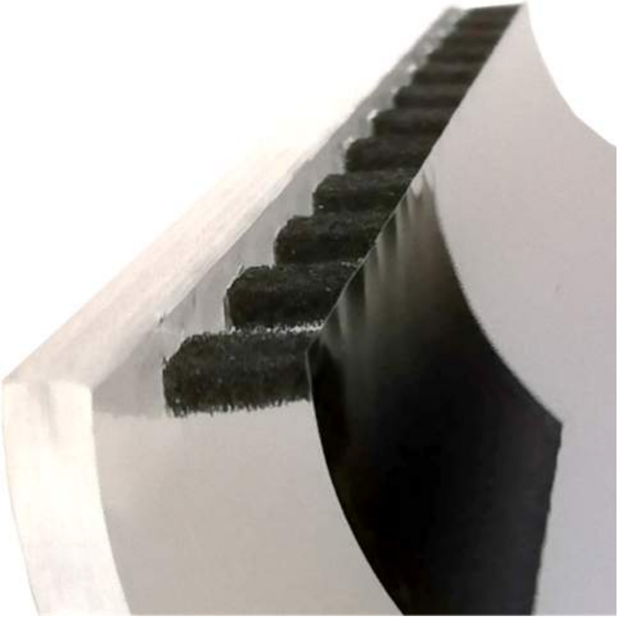
- Different options under study (including vacuum clamping)
- Currently working solution based on segmented mylar foil


a) cut of every second mylar strip

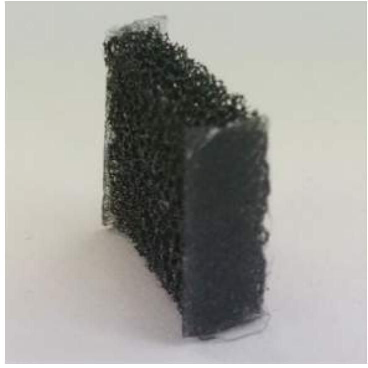

b) glueing of foam wedges


c) glueing of external layer


d) removal of remaining strips

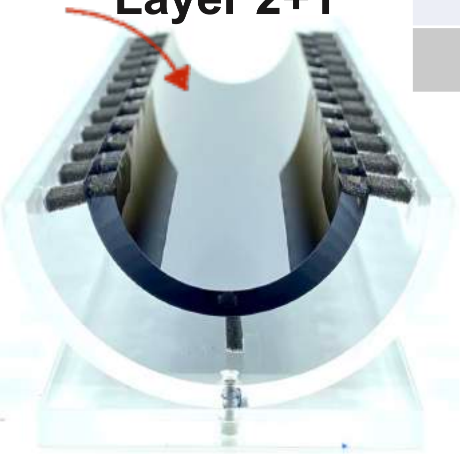

footprint effect
+ bending between wedges

Carbon foam wedges
+ fleece (to reduce glue)

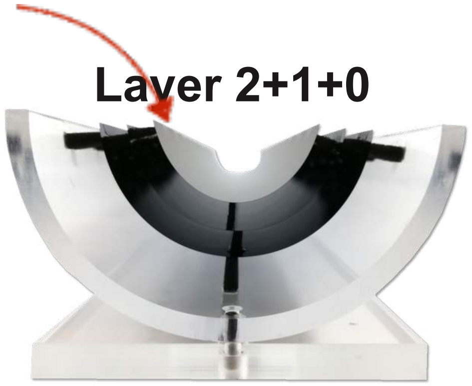


Layer 2

Layer 2+1



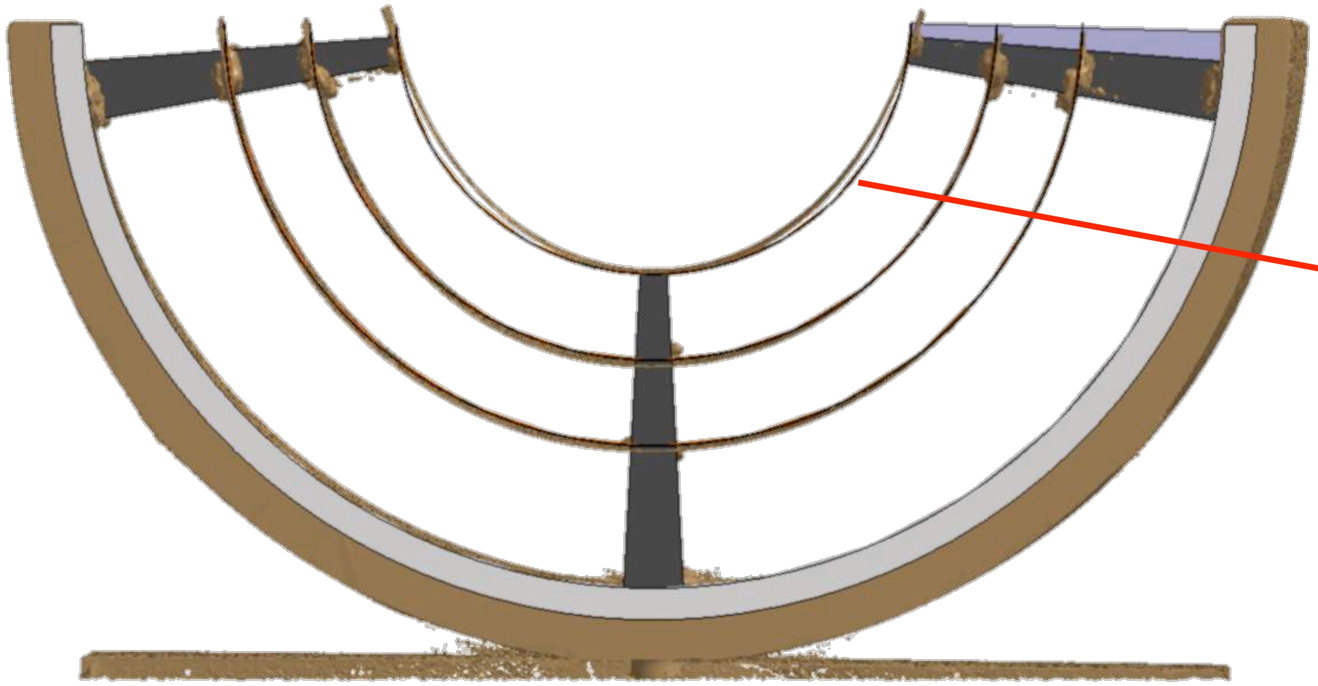
Layer 2+1+0



Items	Th. [μm]	L [mm]	Circ. [mm]
L0	50	280	56.5
L1	40	280	74.4
L2	40	280	93.2

ITS3 R&D lines - Detector Integration

Engineering model1 → geometrical accuracy-global



~0.7 mm largest out of tolerance on L0

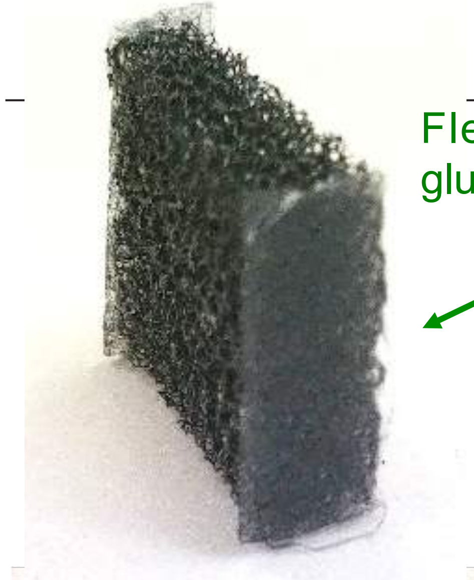
Tomography VS CAD model

Non –cylindricity → Optimize wedge geometry

From Work Package 5_C.Gargiulo

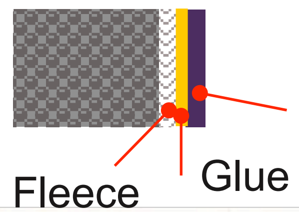
ITS3 R&D lines - Detector Integration

From Engineering model1 → Engineering model2



Fleece impregnated with glue allows for glue control

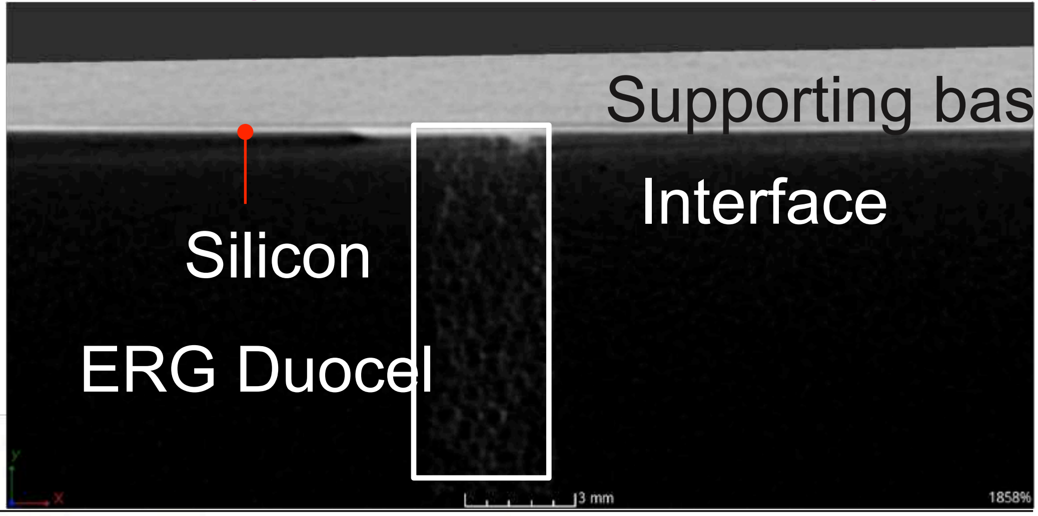
Carbon Veil (fleece)

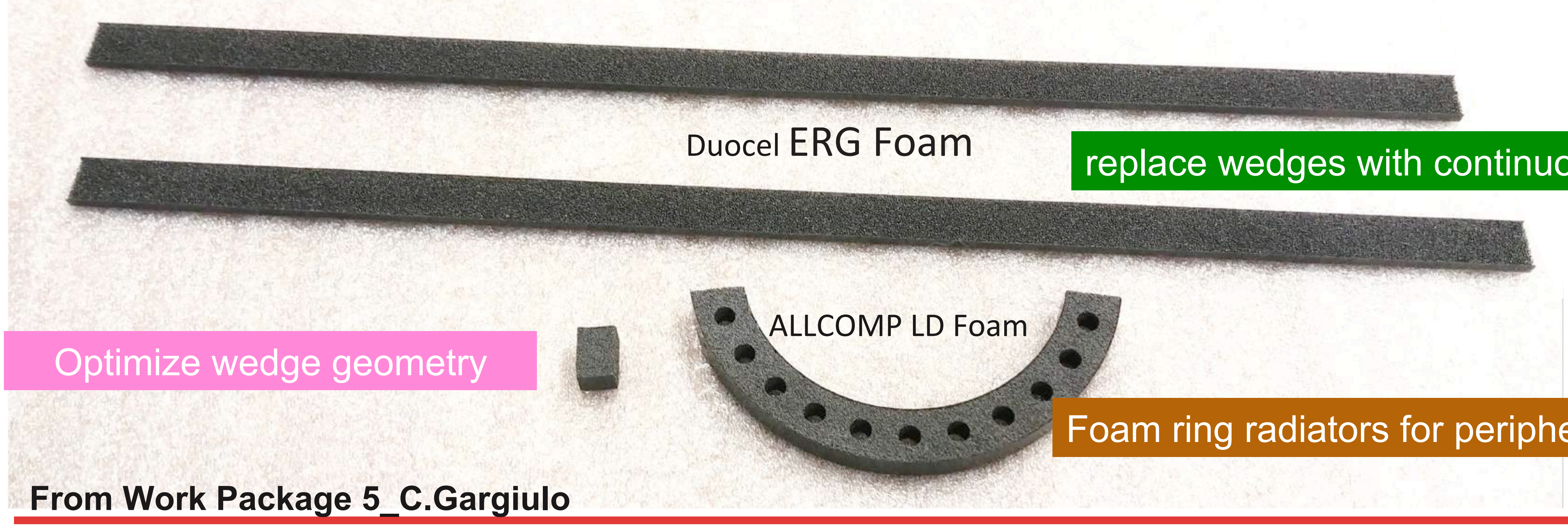


Improve carbon foam glued interface

Mould for Surface finishing

Minimized glue penetration in the foam wedge





replace wedges with continuous longeron

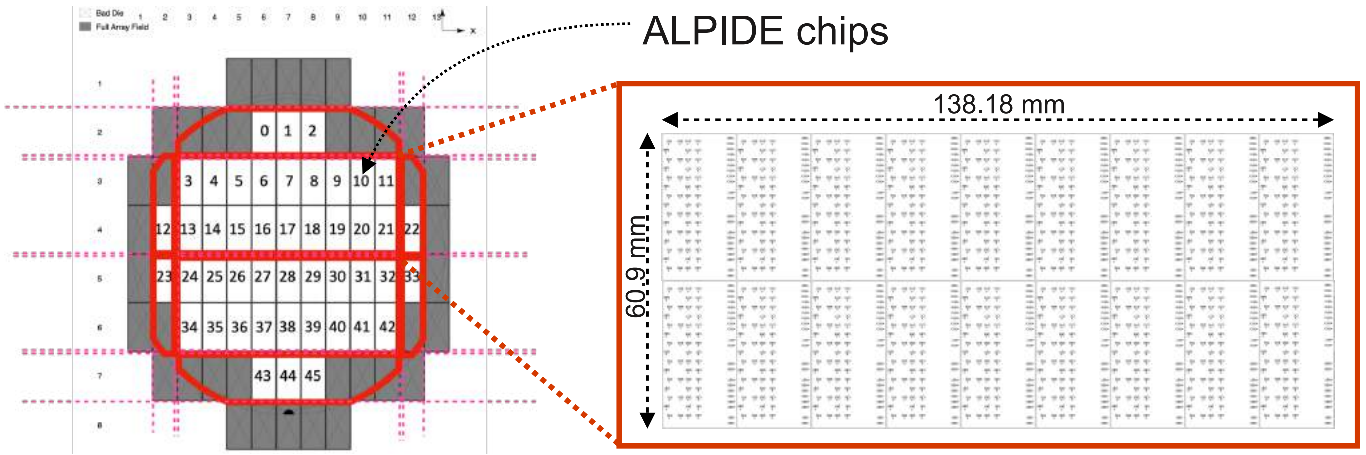
Optimize wedge geometry

Foam ring radiators for peripheral cooling

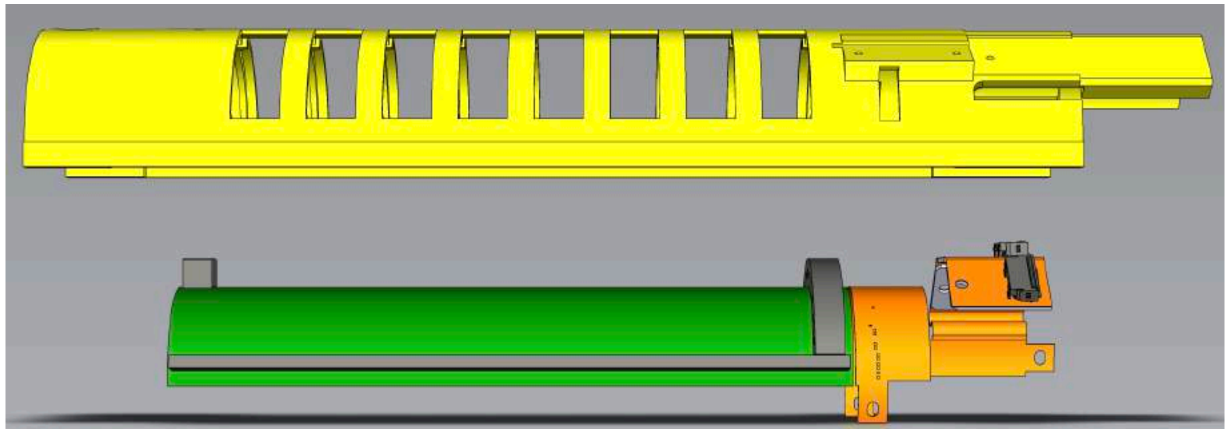
From Work Package 5_C.Gargiulo

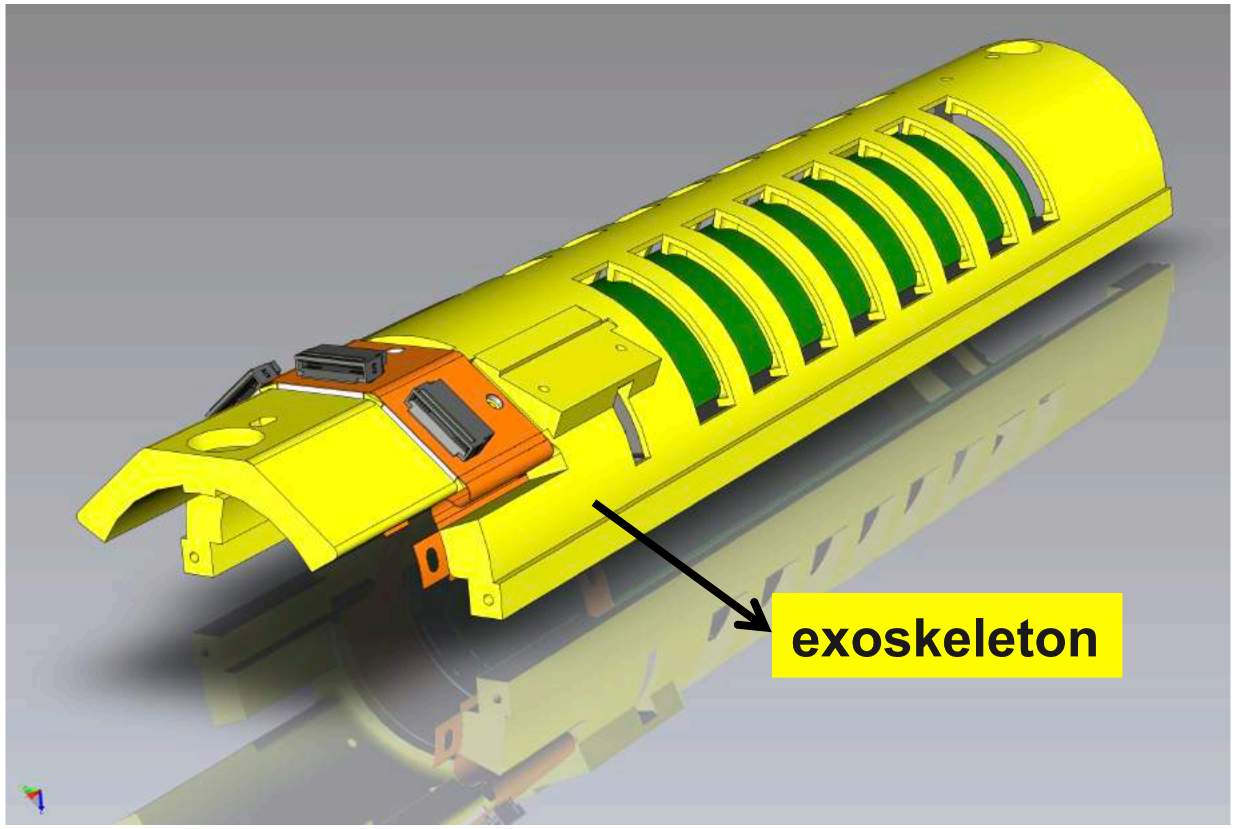
ITS3 R&D lines - Super ALPIDE-Layer interconnection

TOWARD FIRST WORKING LARGE DIMENSION SENSOR



Super-ALPIDE: 18 not diced ALPIDE chips





First prototype of bent flex

» Super-ALPIDE
  - 18 not diced ALPIDE chips
  - dimensions close to the ones for L0 sensor

» Goals
  - verify bending tools for large-size working chips
  - verify mechanical support alignment tools
  - develop wire-bonding over bent surface tools
  - develop first bent flex prototype (for powering and data streaming)
  - assemble first working large dimension bent sensor

ITS3 R&D lines - Super ALPIDE-Layer interconnection

Wire-bonding is the baseline technique for ITS3 large-area sensors

- Power/data connections on A-side (power on C-side under discussion)

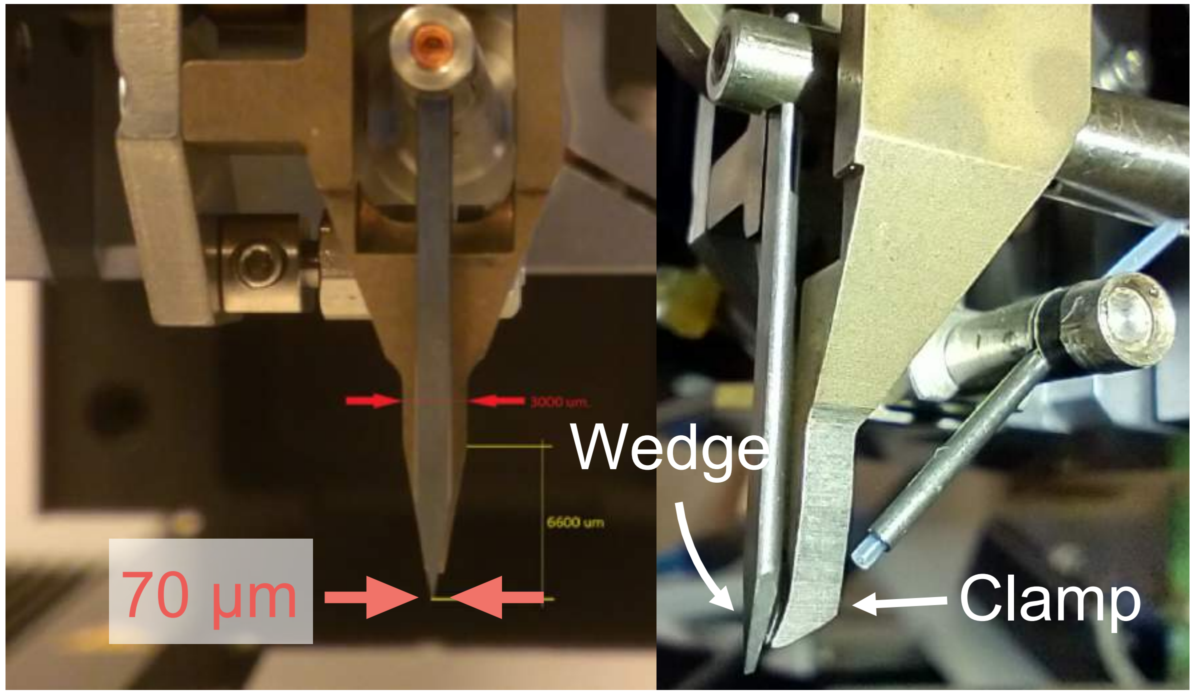
- Expected sensor pad density: down to 60µm-pitch

Wire-bonding systematic studies:

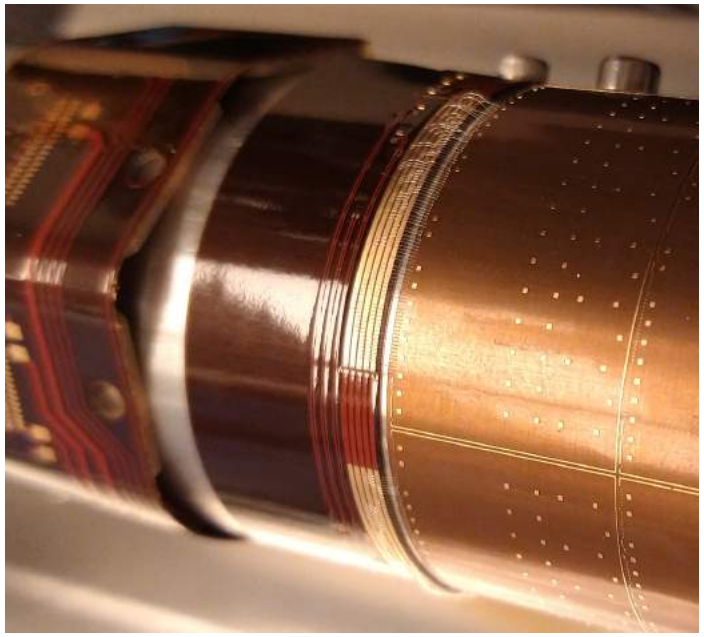
- Pull test force Vs (loop height, loop lenght)
- Different pad size and arrangements
- Different bonding heads/systems
- On flat and bent surface

ITS3 R&D lines - Super ALPIDE-Layer interconnection

Tools in Bari and already performed exercise



- The limit to the bonding density (distance between two adjacent bonding feet) is given by the width of the wedge and clamp.
- Usual wedge thickness 100 µm → In Bari 70 µm (modified for the ITS2 assembly)
- Wire thickness: 25 µm



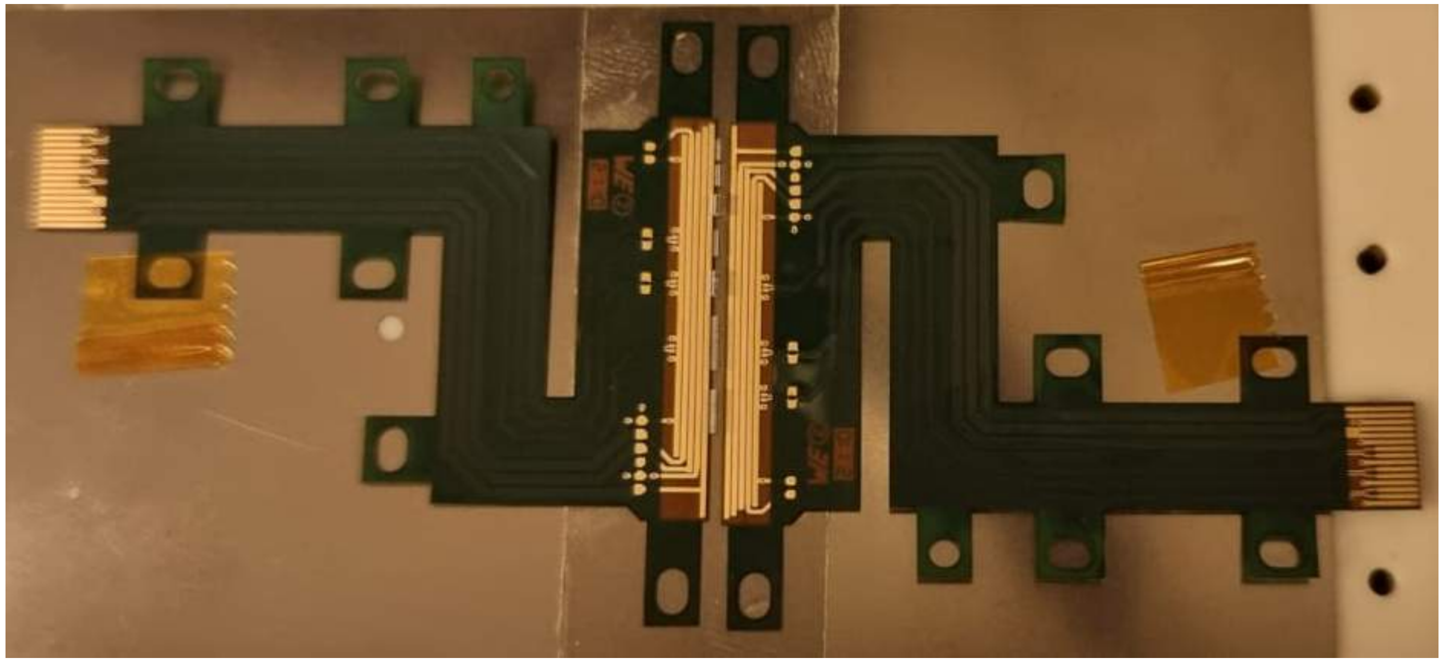
SUPER-ALPIDE edge-FPC

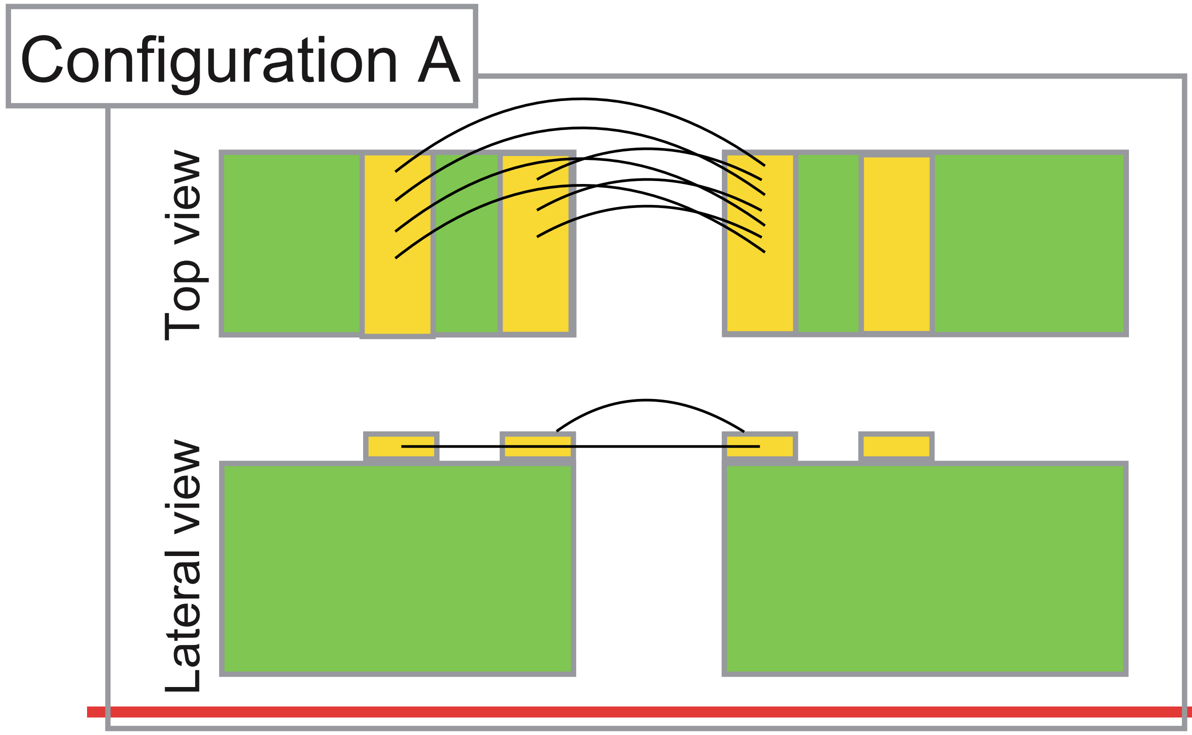
- Wires length spans between ~1 mm and ~5 mm
  - Distance between ALPIDE mini-pads and FPC border: ~1 mm
  - Distances between FPC border and long pads: ~30 µm - 4 mm
- ALPIDE mini-pads dimensions: ~90 µm x 90 µm
- Inter-pad distance, in the denser regions: ~220 µm

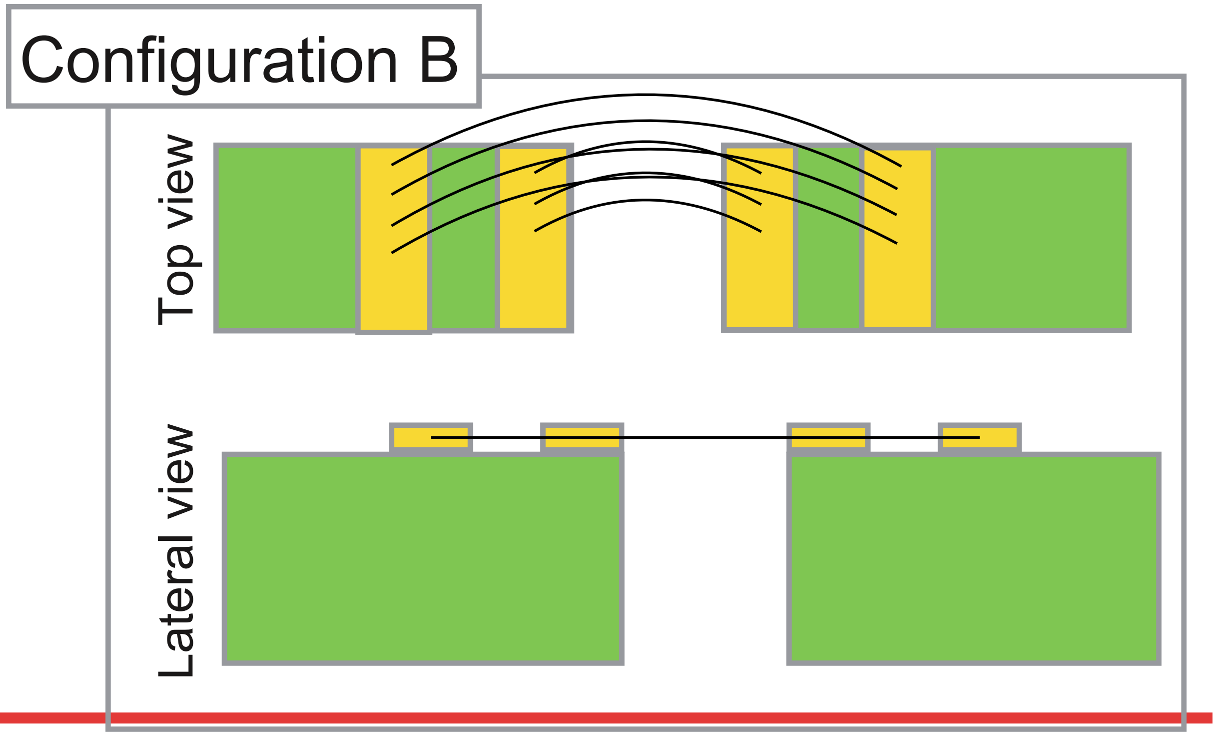
ITS3 R&D lines - Super ALPIDE-Layer interconnection

wire-bonding - 100 μm

- Setup: two single-ALPIDE FPC one facing the other, with a gap similar of ~500 μm
- Two bonding configurations:
  - A) "Deferred" : for two adjacent wires, one foot is on the same long-pad while the other is on a different long-pad
  - B) "Alternating" : for two adjacent wires, both feet are on two different long-pads
- Two inter-pad distances explored:
  - ~100 μm
  - ~80 μm

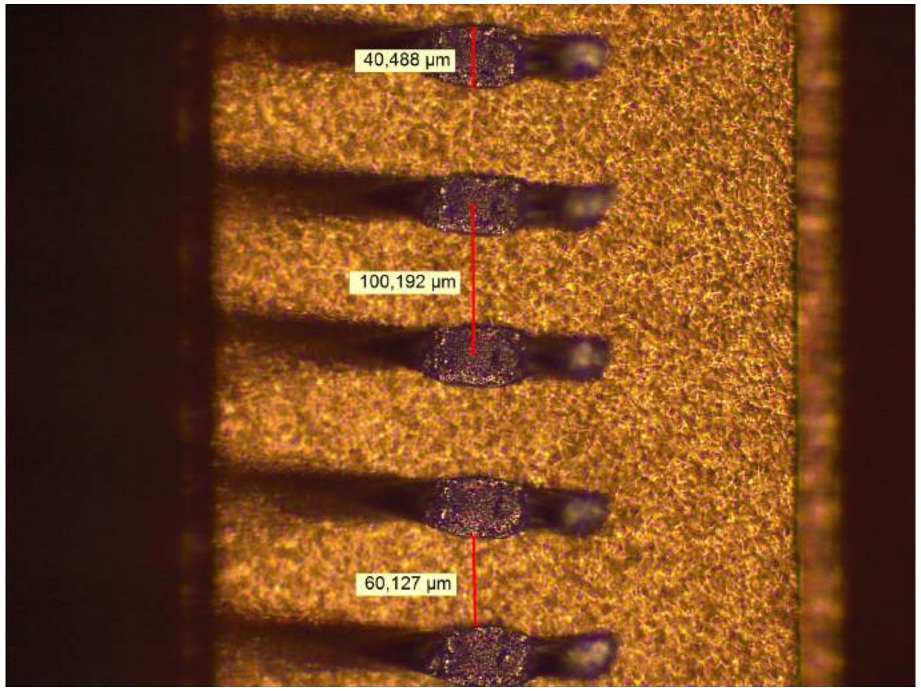



Configuration A

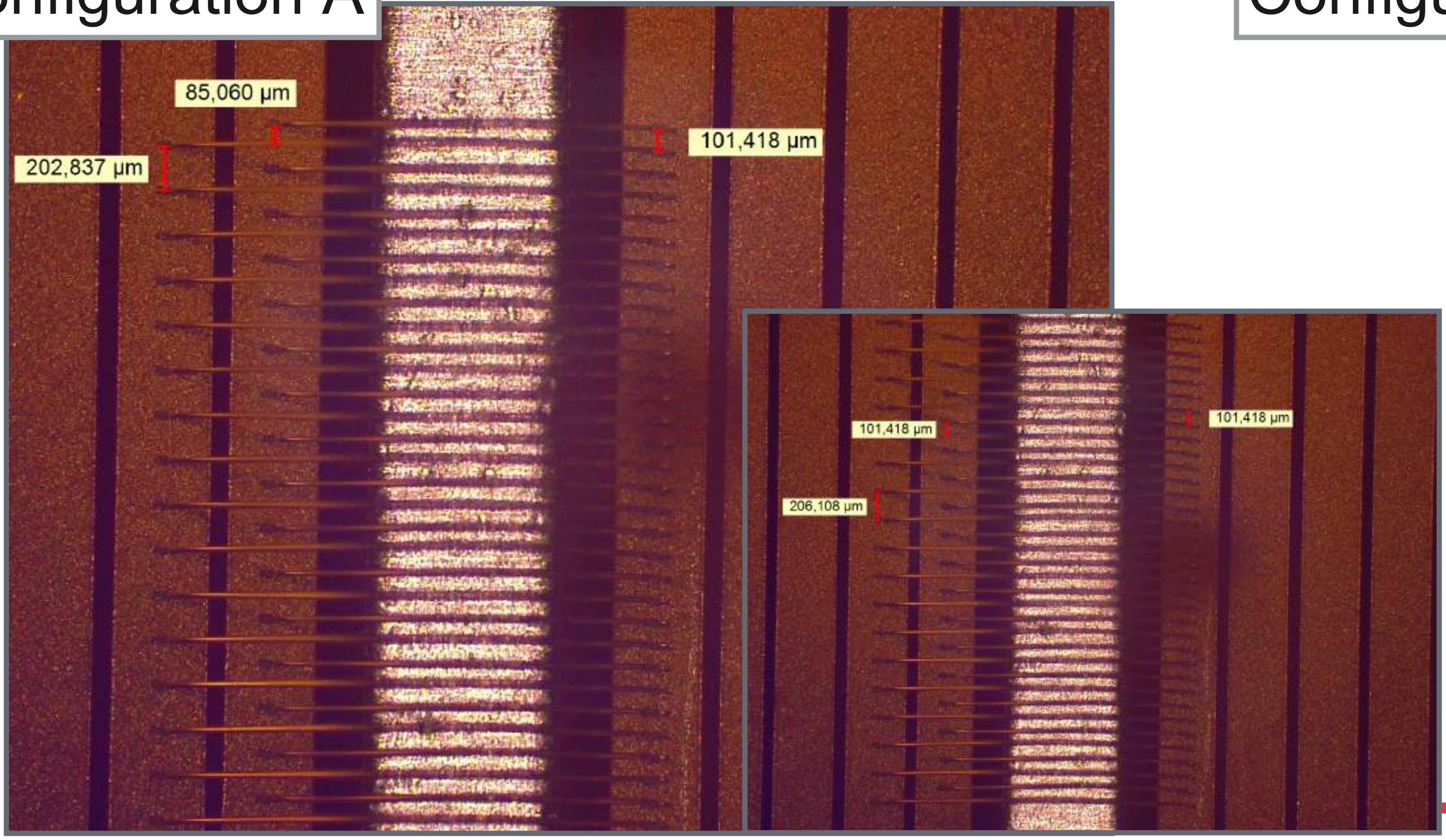

Configuration B

ITS3 R&D lines - Super ALPIDE-Layer interconnection

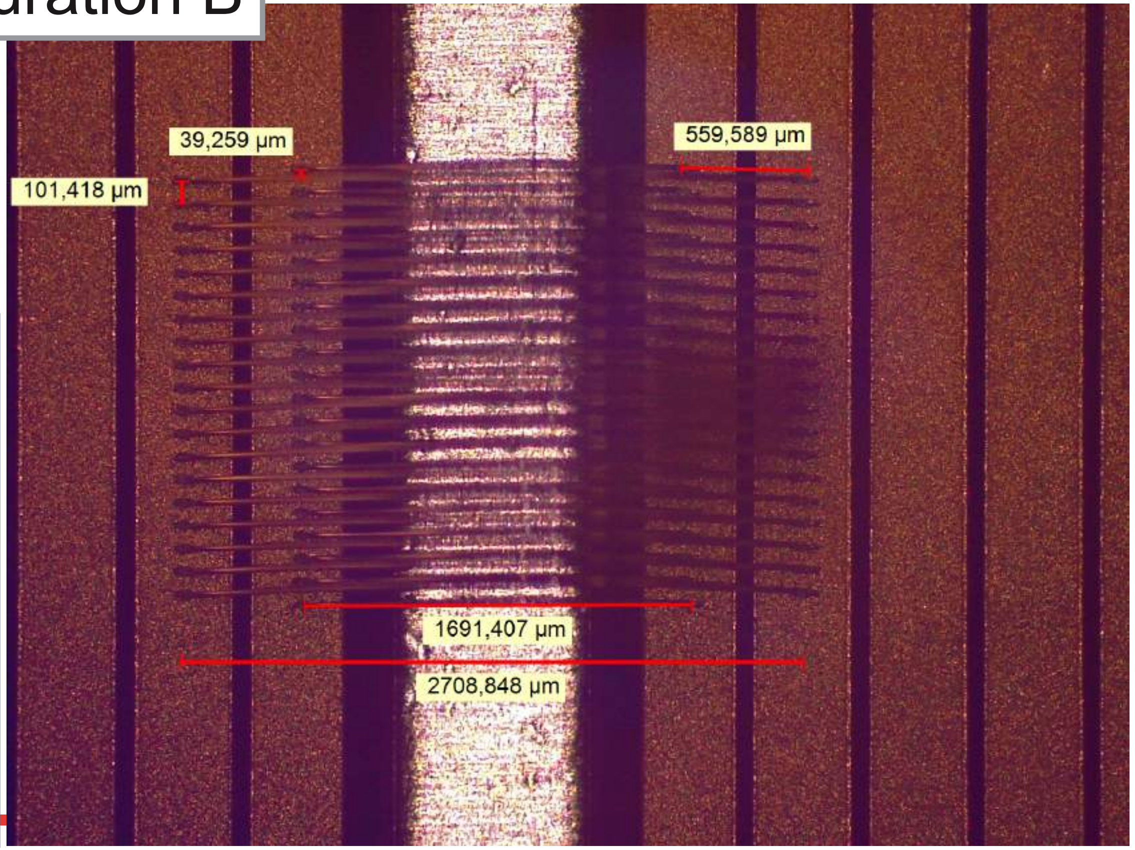
- With a wire thickness of 25 µm, a foot width of ~40 µm is expected → minimal pad dimension ~80 µm
- ~100 µm inter-pad distance can be easily achieved
- Configuration B allow to double the bonding density, but requires staggered pads



Configuration A

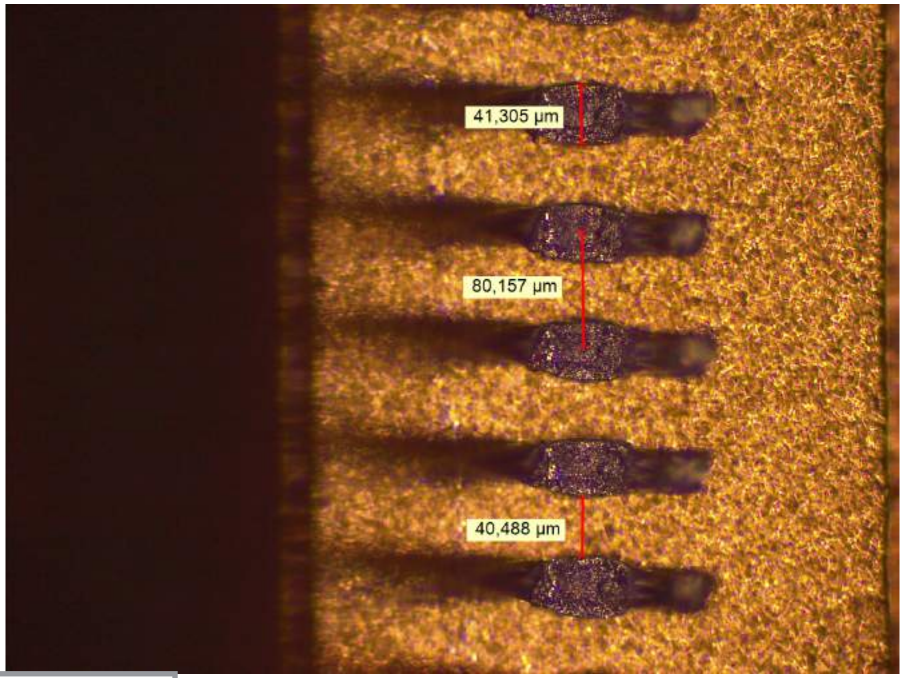


Configuration B



ITS3 R&D lines - Super ALPIDE-Layer interconnection

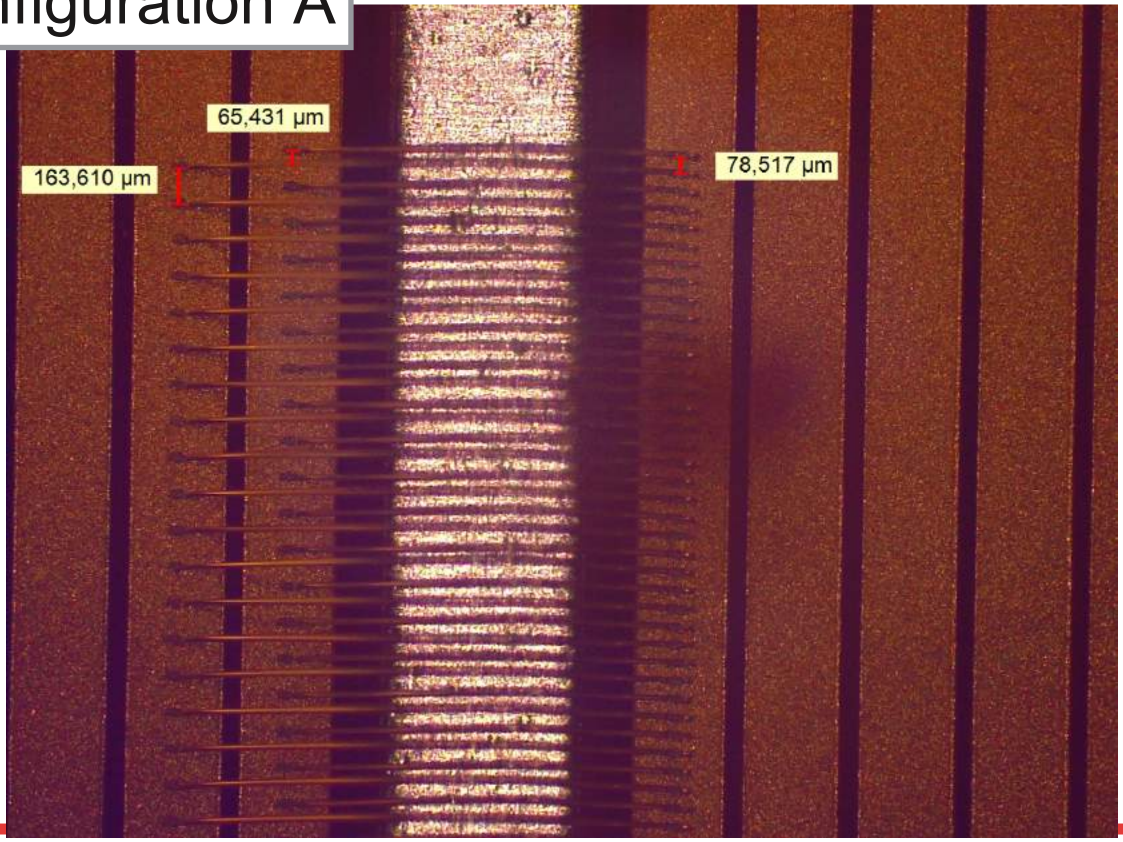
TOWARD FIRST WORKING LARGE DIMENSION SENSOR



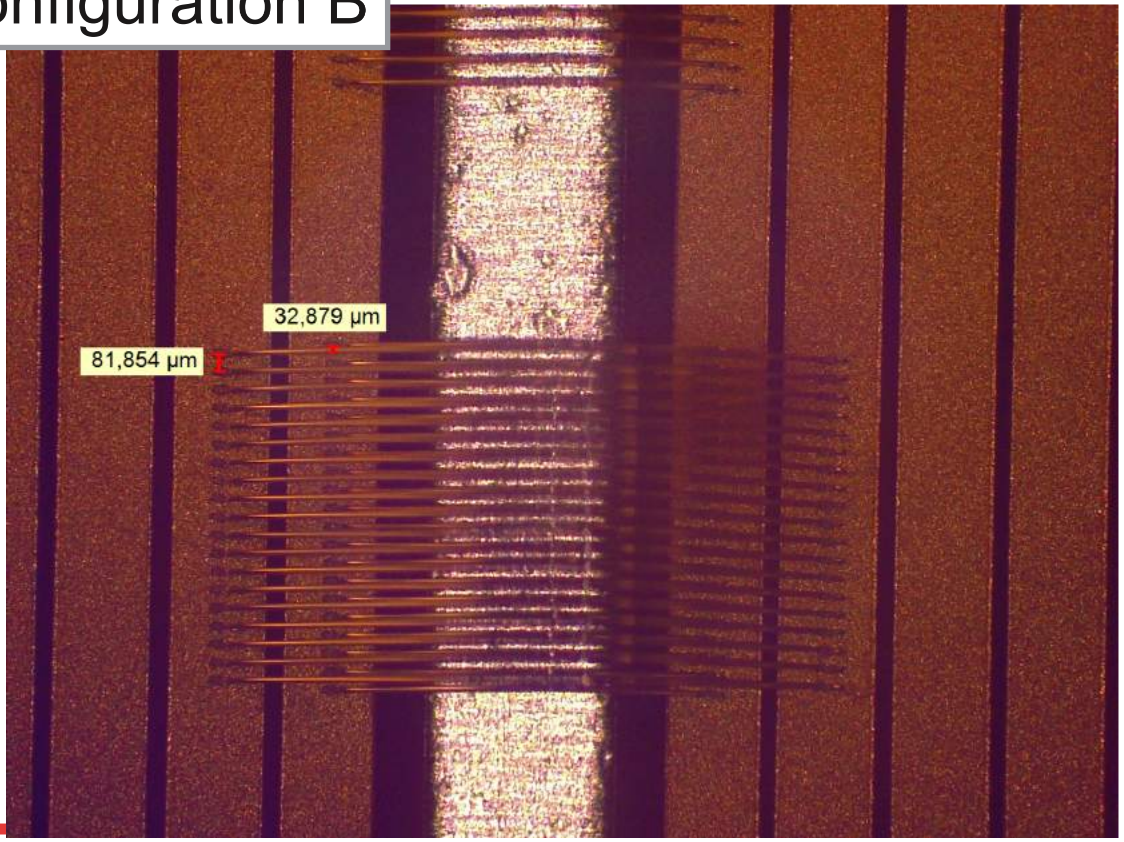
wire-bonding - 80 µm

- With a wire thickness of 25 µm, a foot width of ~40 µm is expected → minimal pad dimension ~80 µm
- ~80 µm inter-pad distance achievable
- Configuration B bring to wire distance of ~40 µm

Configuration A

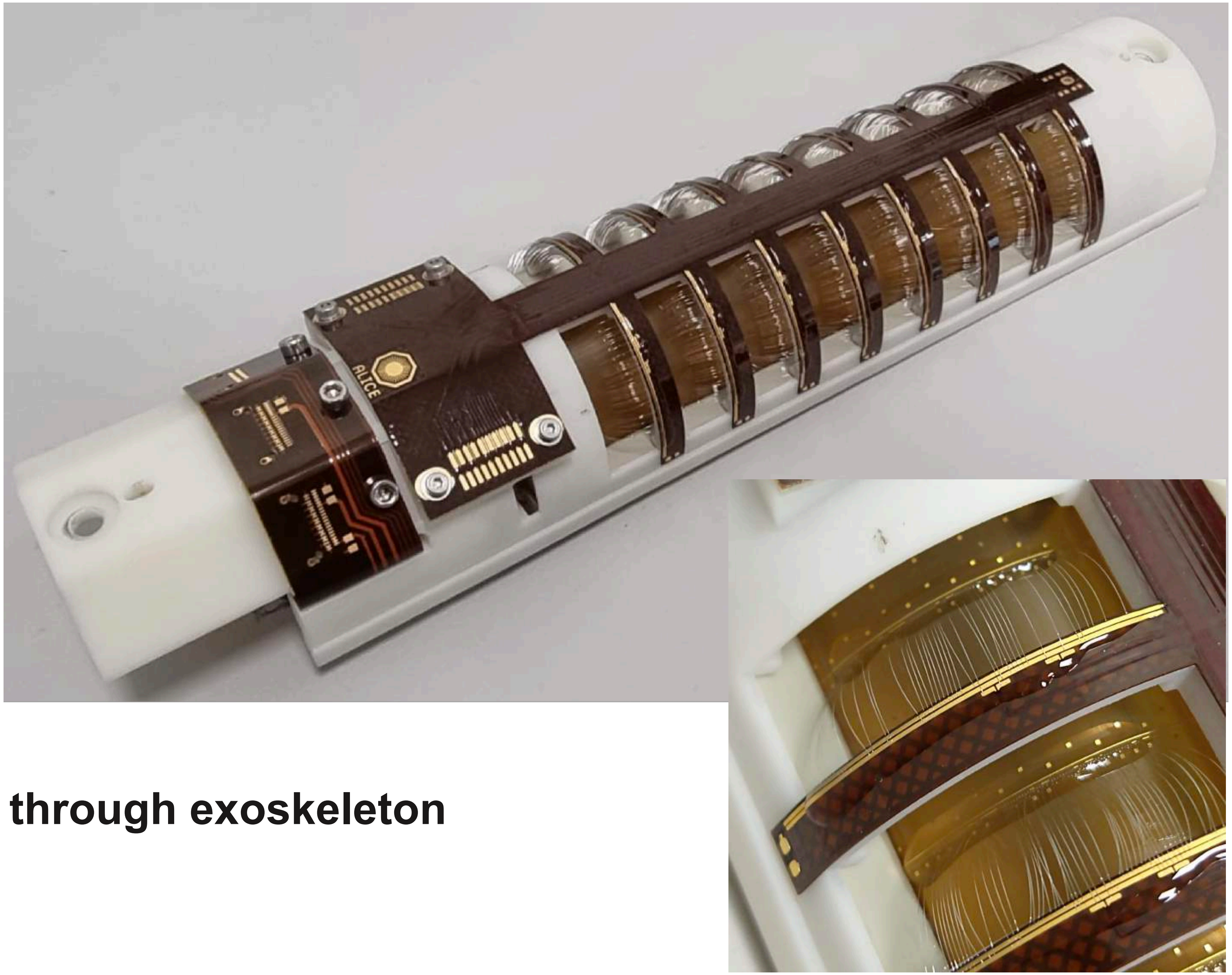


Configuration B



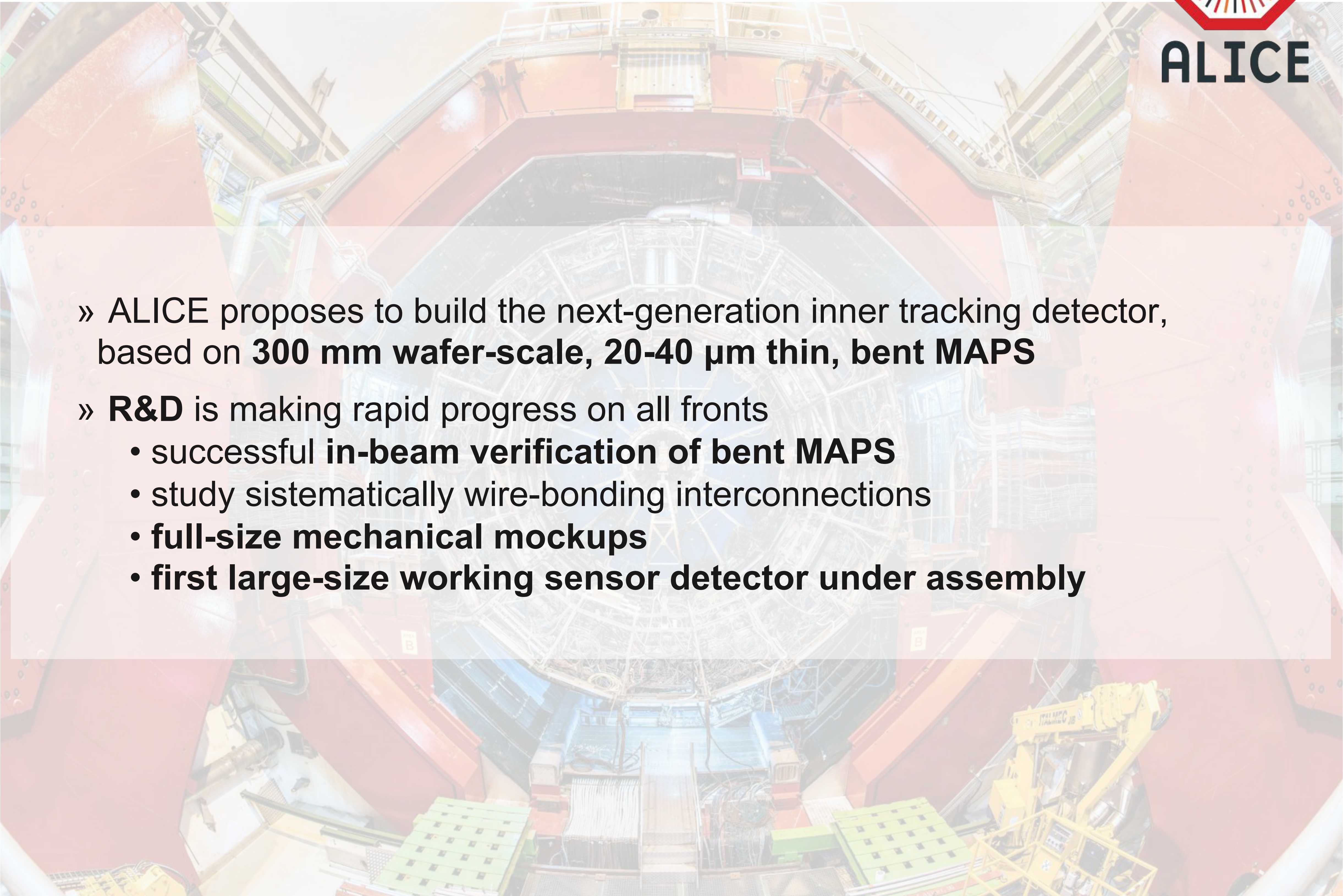
ITS3 R&D lines - Super ALPIDE

TOWARD FIRST WORKING LARGE DIMENSION SENSOR



Wire-bonding through exoskeleton

SUMMARY



- » ALICE proposes to build the next-generation inner tracking detector, based on **300 mm wafer-scale, 20-40 µm thin, bent MAPS**
- » **R&D** is making rapid progress on all fronts
  - successful **in-beam verification of bent MAPS**
  - study sistematically wire-bonding interconnections
  - **full-size mechanical mockups**
  - **first large-size working sensor detector under assembly**