Bending and assembly of the L0 and L1 layers

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on behalf of the SVT-IB INFN and UniBA team

* INFN Bari

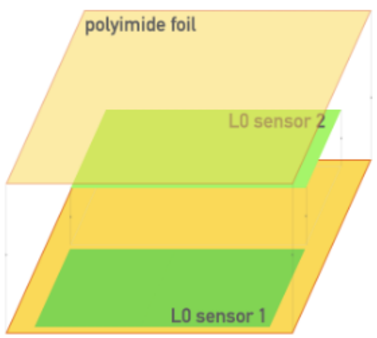
Contents

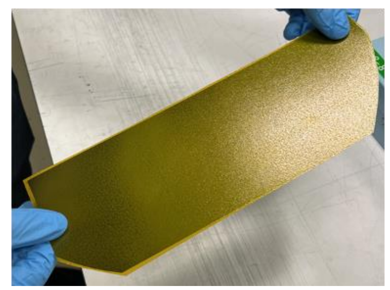
- Connection of two L0/L1 sensors
  - Alignment of two sensors
  - Kapton tape placement
- Half-layer bending
  - ITS3-like bending approach
- One-shot gluing of the “minimal” mechanical structure
- ITS3 activities preparatory to SVT prototyping
- Protype campaign
  - Finalisation of the production bending setup
  - Timetable

General half-layer assembly strategies

SENSOR PREPARATION : two possible strategies

Embedding strategy

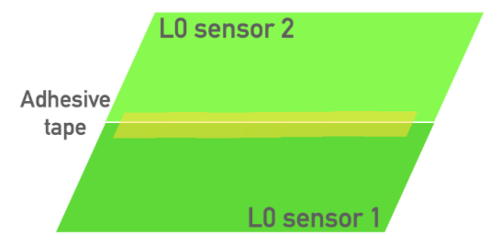


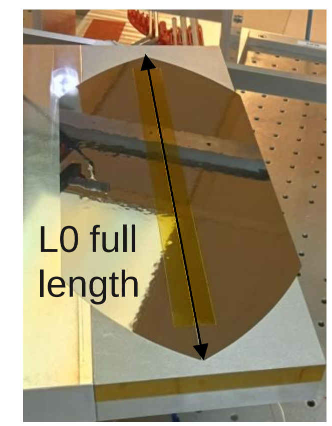


- R&D started within ITS3, but a dedicated one is required (thermal and pressure stress on the sensor during the gluing, air bubbles, access to the soldering pads)

- Investigations on single ALPIDEs presented during previous SVT workfest of 2024 Summer joint EICUG/ePIC meeting

Bare+tape strategy

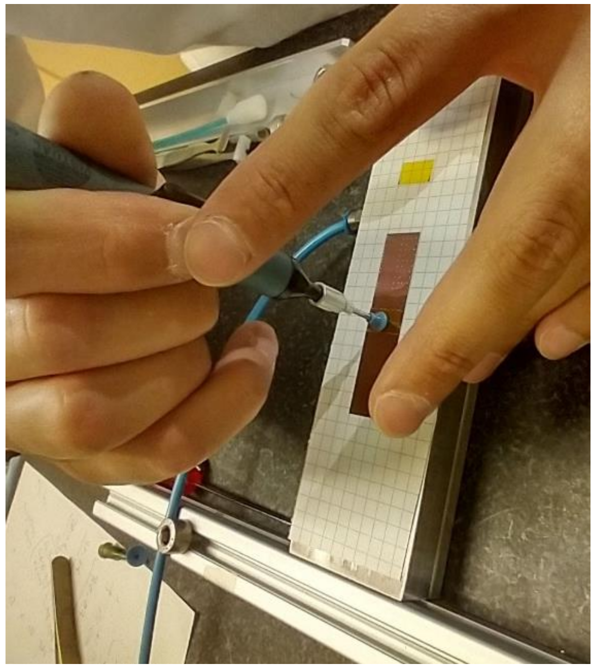


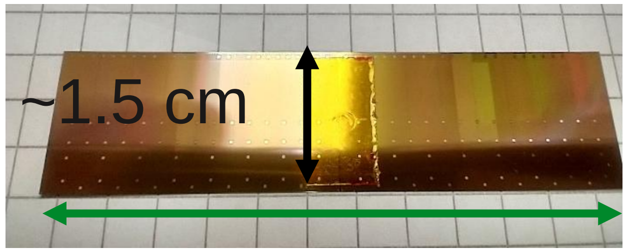


- Reduced amount of kapton
- the most reasonable solution to investigate locally
- **Ongoing studies of its feasibility,** presented today

Moving from small-size to half-moon L0

Preliminary tests using small size sensors





~7 cm

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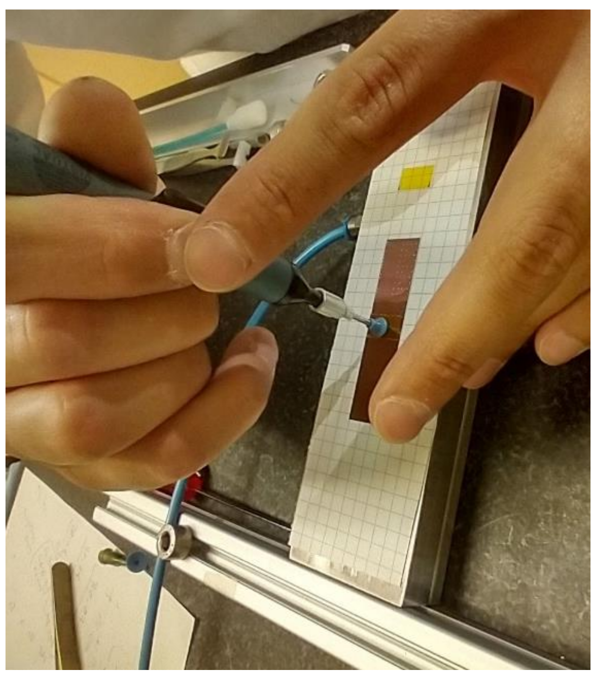
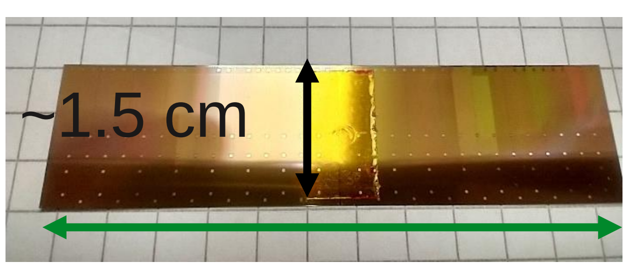
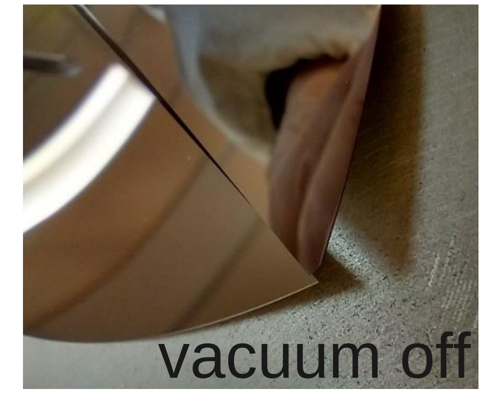




~7 cm

New tests using final size silicon pieces

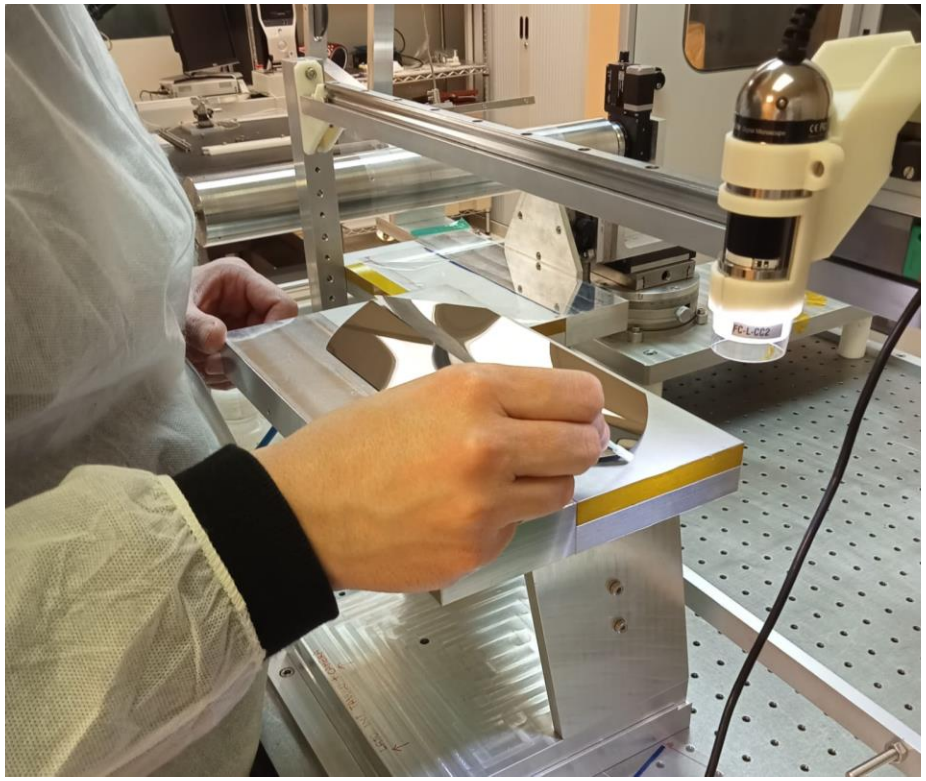


Handling of L1/L0 size silicons requires:

- Extension of the ITS3 handling tools to hold two sensors
- Usage of new handling tools + dinoscope (instead of the Mitutoyo machine)
- Dealing with banana-shaped objects when the vacuum is released, Their thickness is 50 µm.

Bare+Tape strategy - Sensor alignment

1. Relative alignment by eyes reaching sensor pitch O(100 µm) **on a single vacuum porous surface**



The final setup will include a new handling tool with two independent vacuum surfaces → smaller pitches

Need of additional tools to handling the sensor after the tape connection

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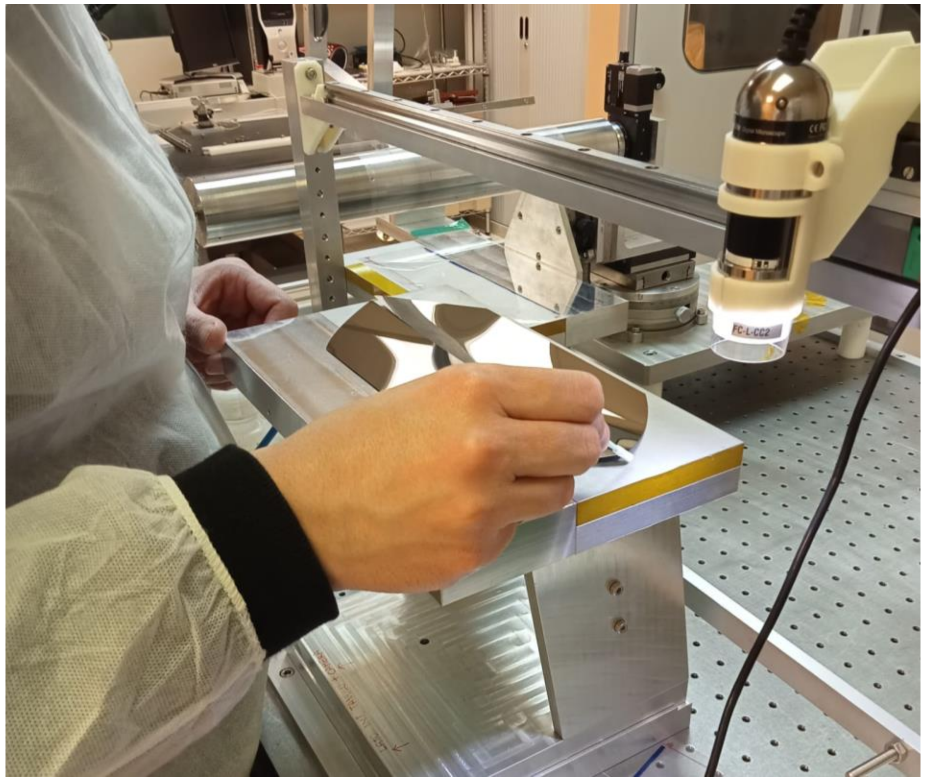

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Need of additional tools to handling the sensor after the tape connection

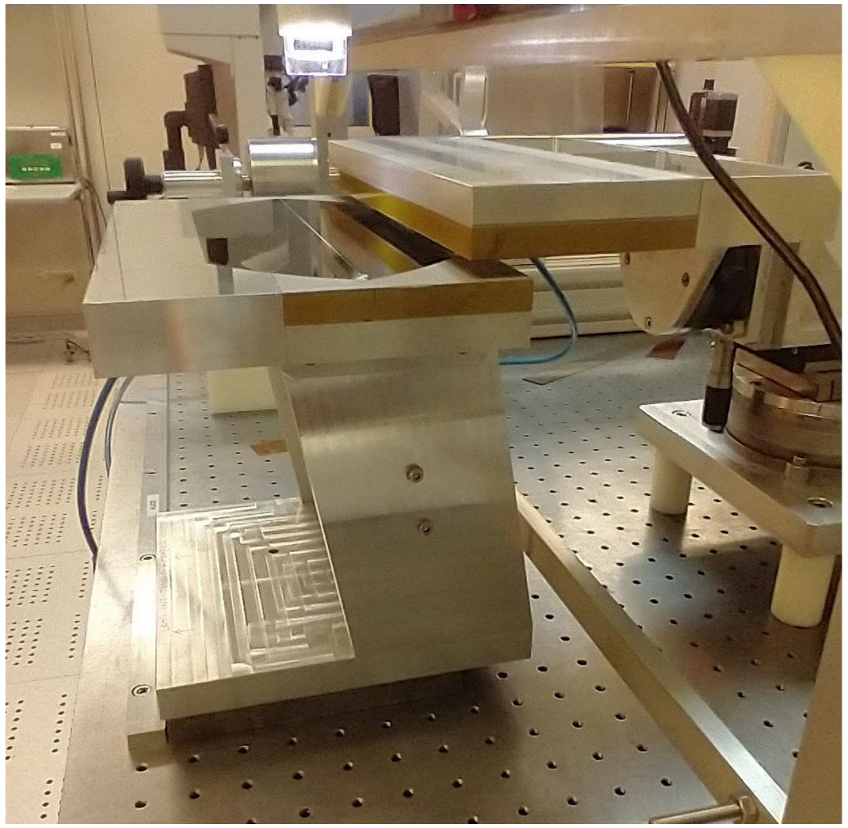
2. Alignment quality verified through dinoscope measurements

three trials up to now

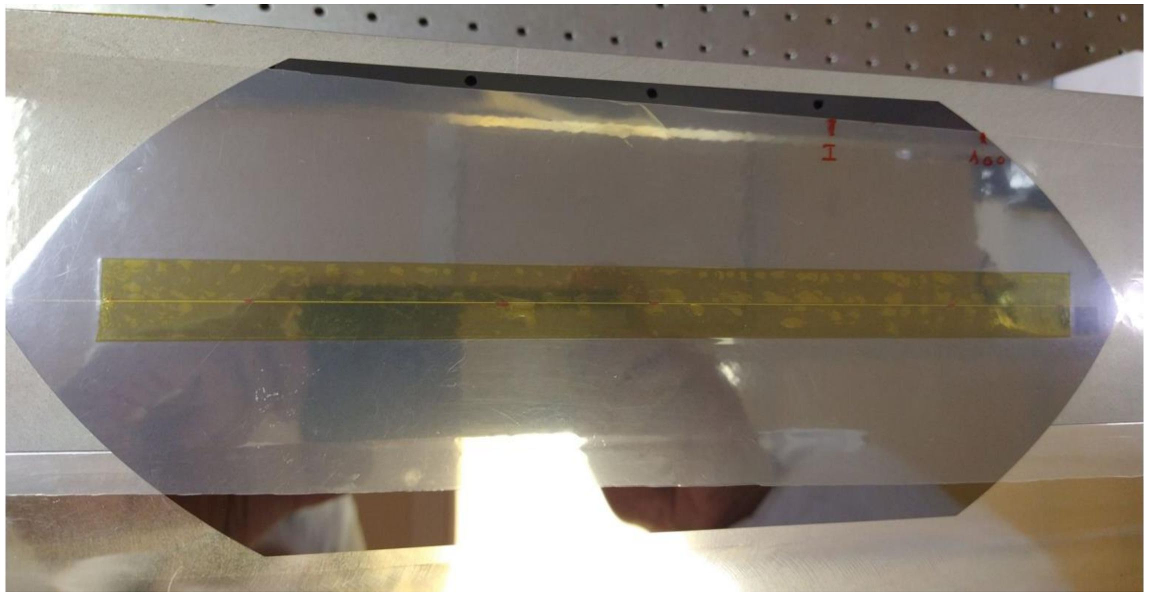
	Average pitch (µm)	Tilt angle (°)
Trial 1	150	±0.021°
Trial 2	285	±0.008°
Trial 3	144	±0.006°

Bare+Tape strategy - Sensor alignment

3. Sensor connection using a commercial kapton tape (tot. thickness ~60-70 um)



Tape placement



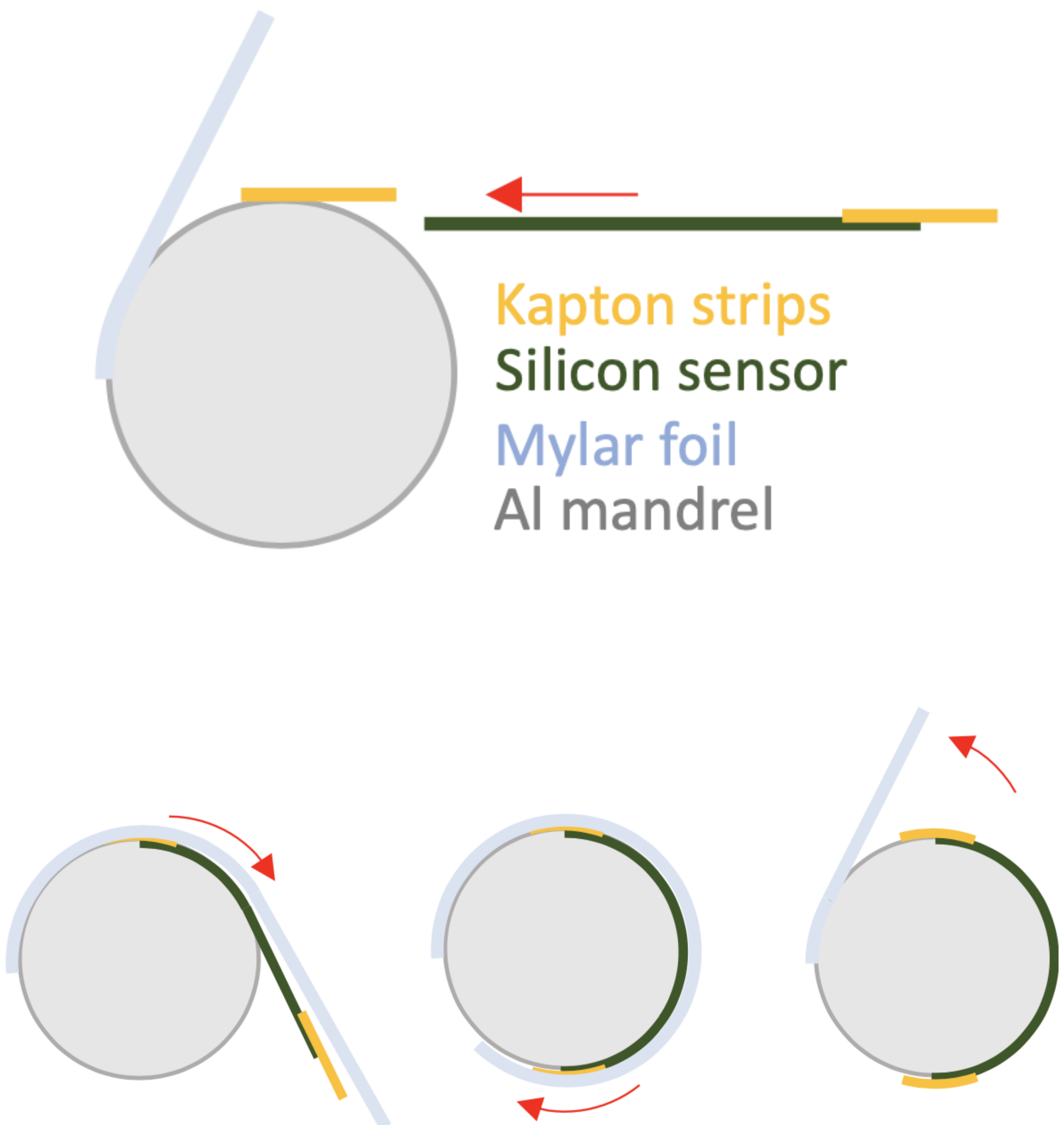
vacuum on + mylar foil to remove the trapped air/bubbles under the tape

After treatment, no visible bubbles

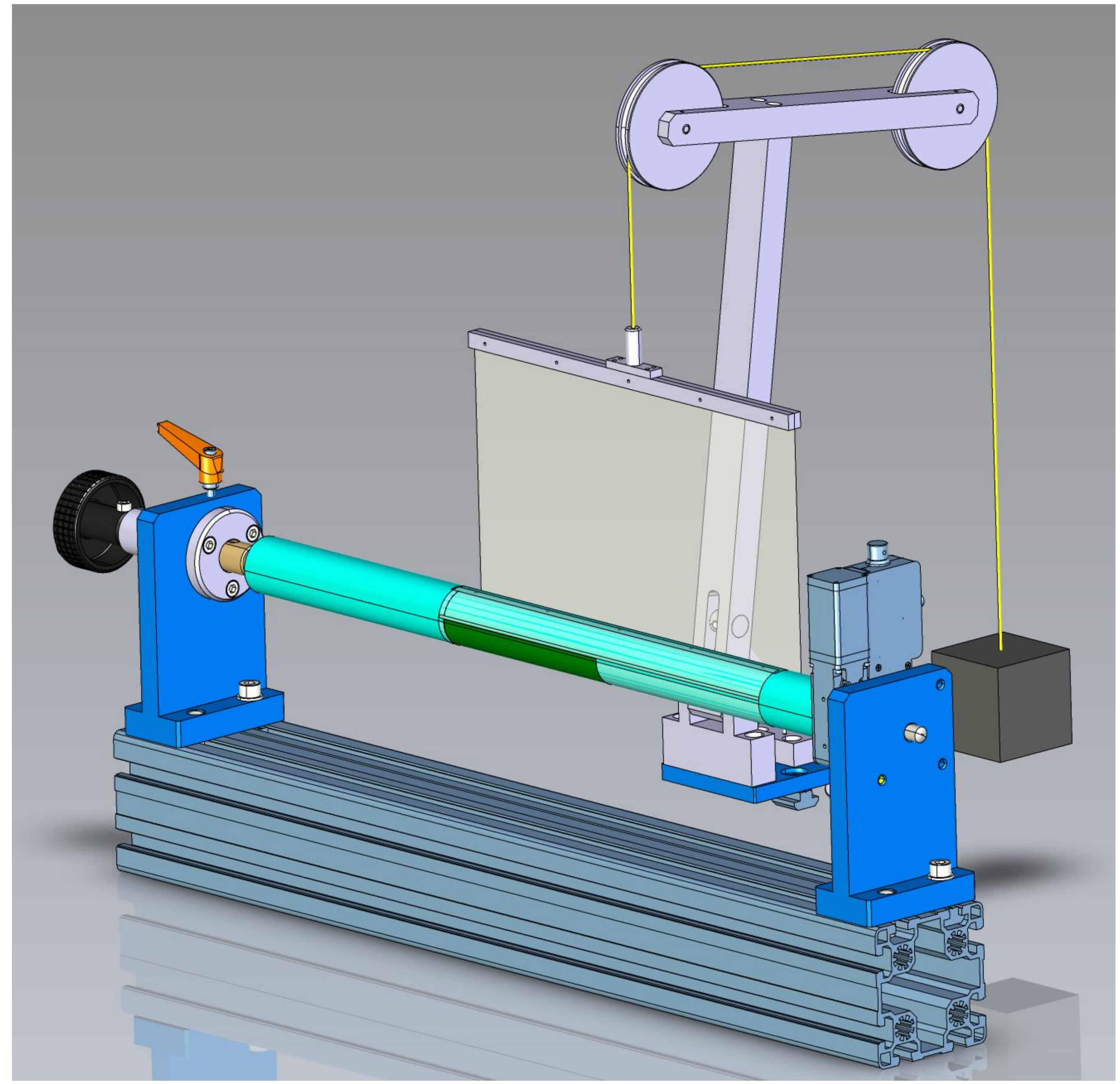
→ connected pair ready for bending

ITS3 silicon sensor bending technique

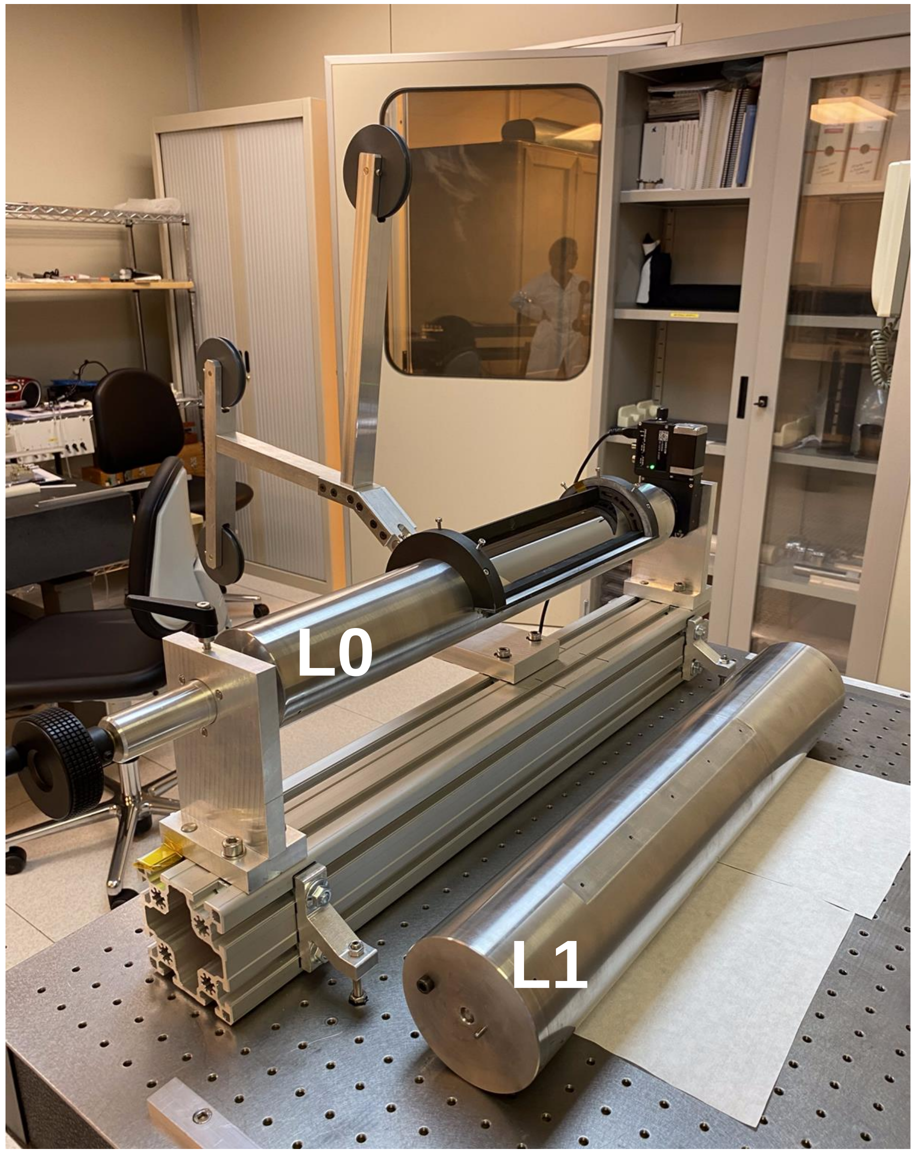
Technique developed within the ITS3 R&D



From ITS3 TDR (CERN-LHCC-2024-003)

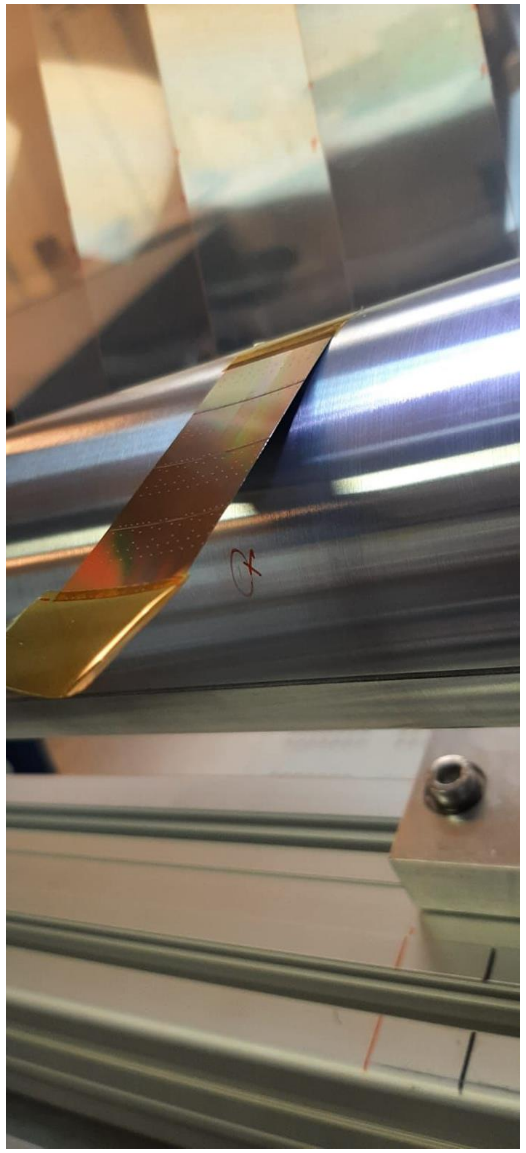


SVT-IB bending setup for preparatory studies @INFN Bari



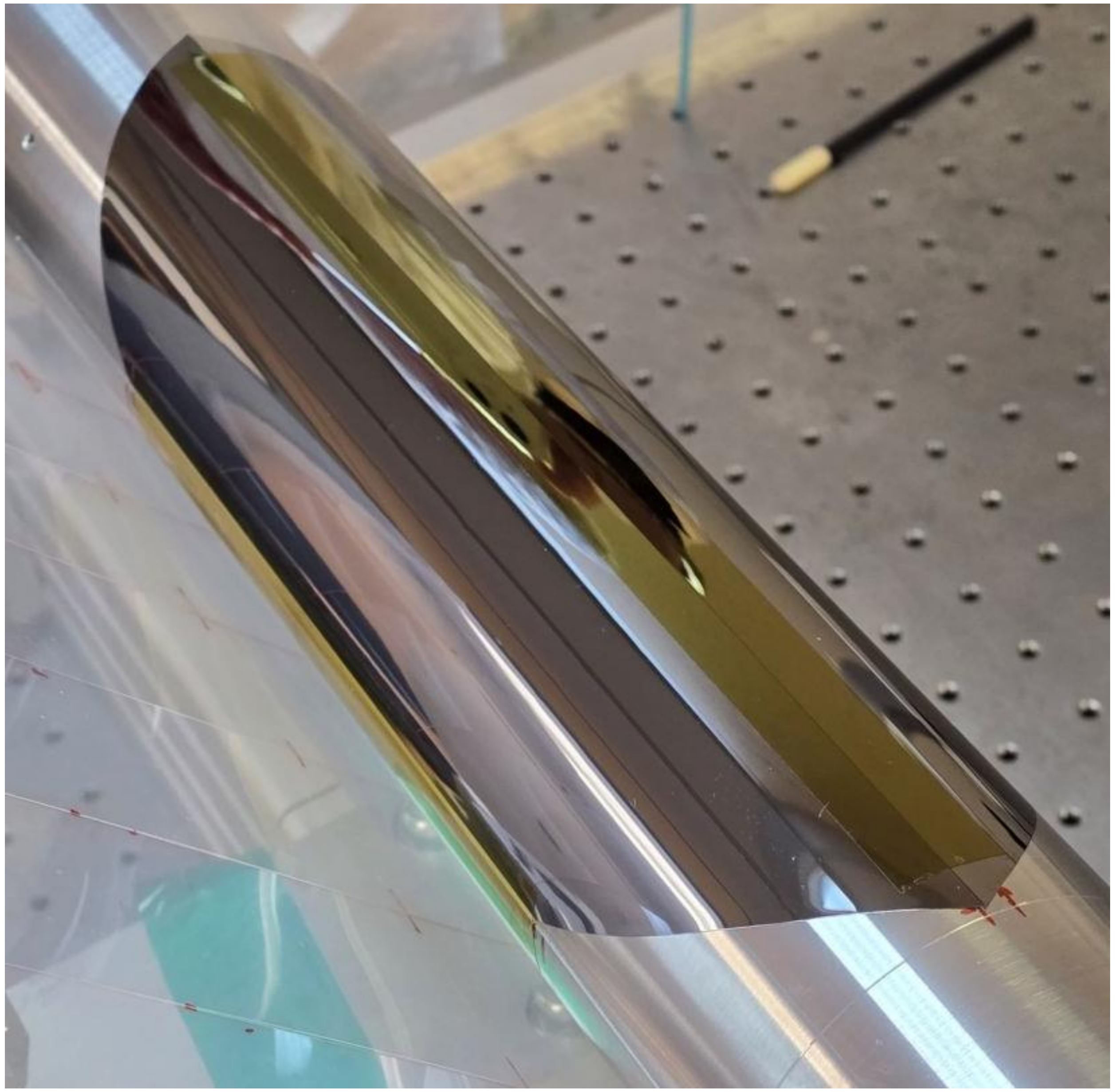
Mandrels for L0 and L1 layers made by the INFN Bari mechanics workshop.

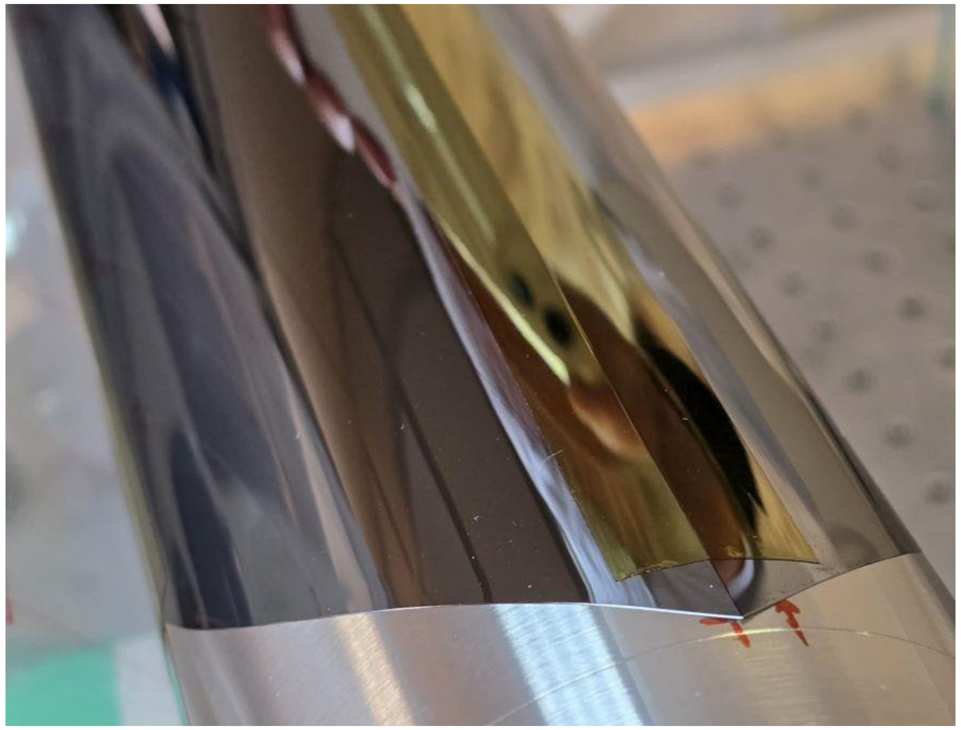
- Visual check to spot local surface defects.
- small-size sensors were bent on the defects.



➡ **No severe defects, good quality enough to start the studies on the "large-size" dummies**

Results of the last half-layer bending trial

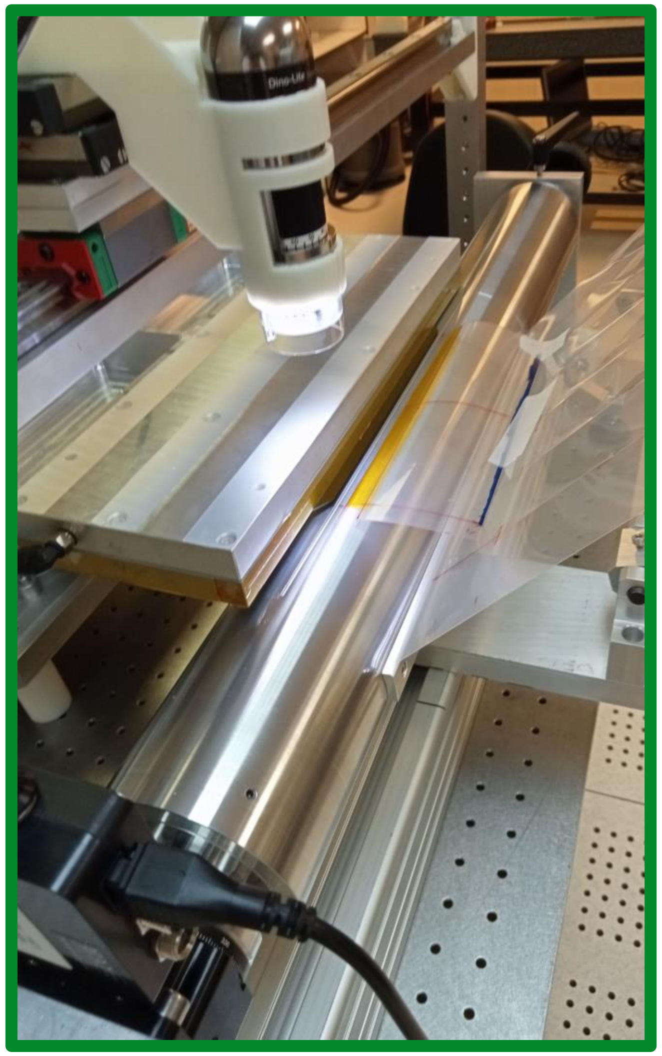




It proceeded smoothly

No significant cuspid was observed

Details on the half-layer bending procedure



Mastered the sensor connection and **placement close to mandrel**

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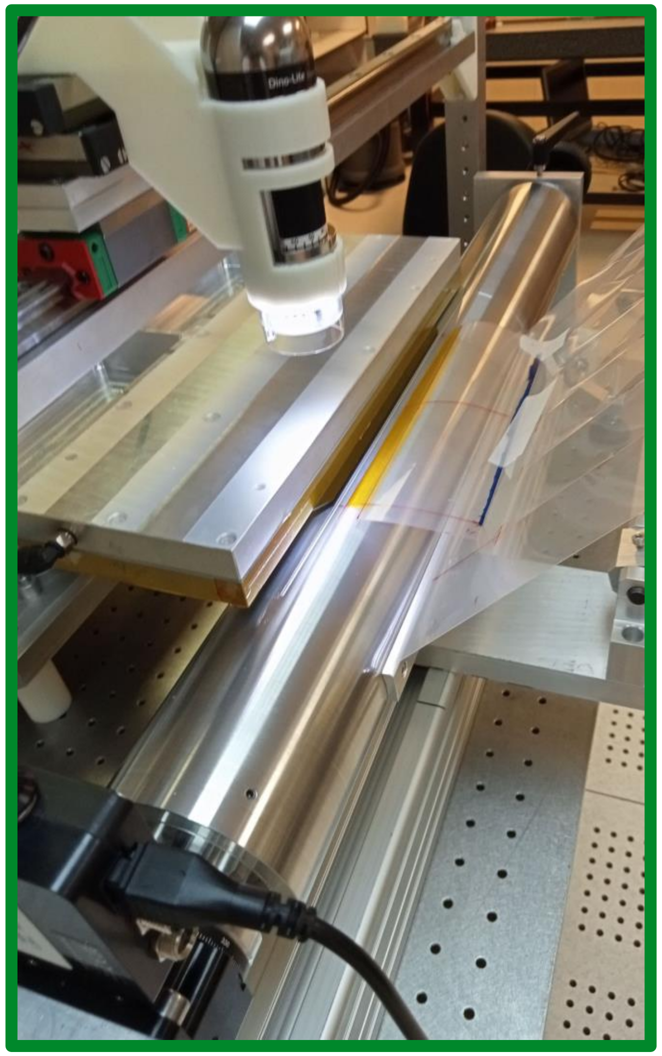

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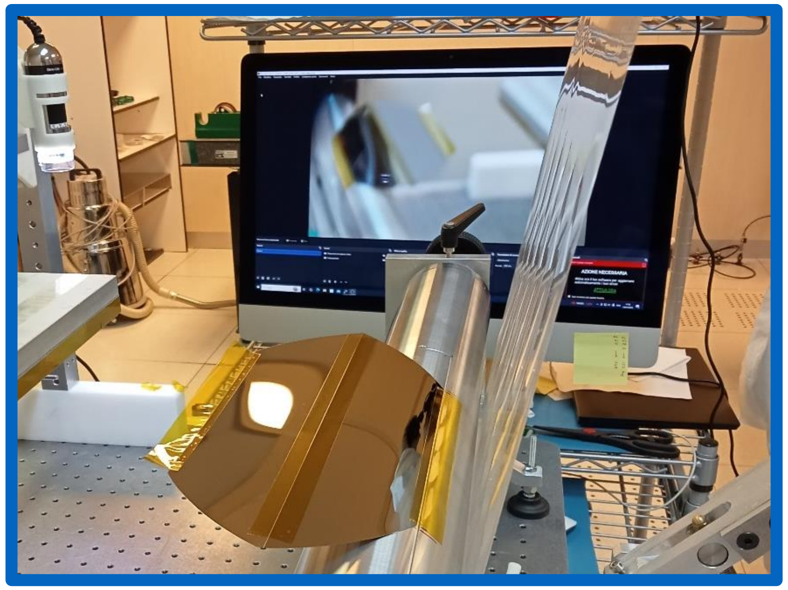

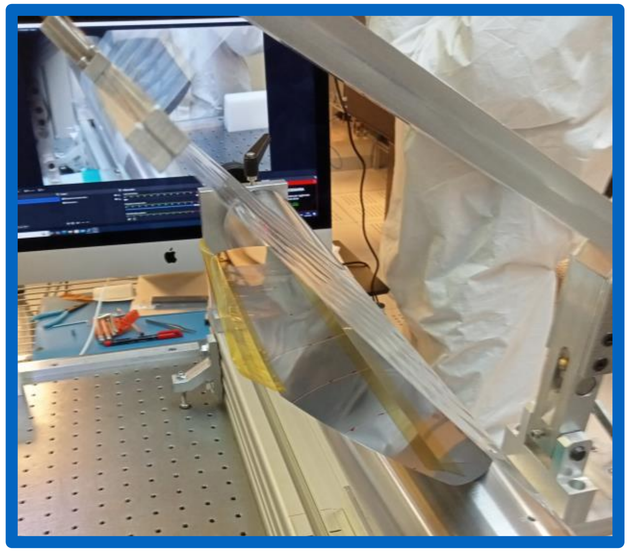

The trials confirmed that we do not require additional holding tools for the **beginning of the bending**

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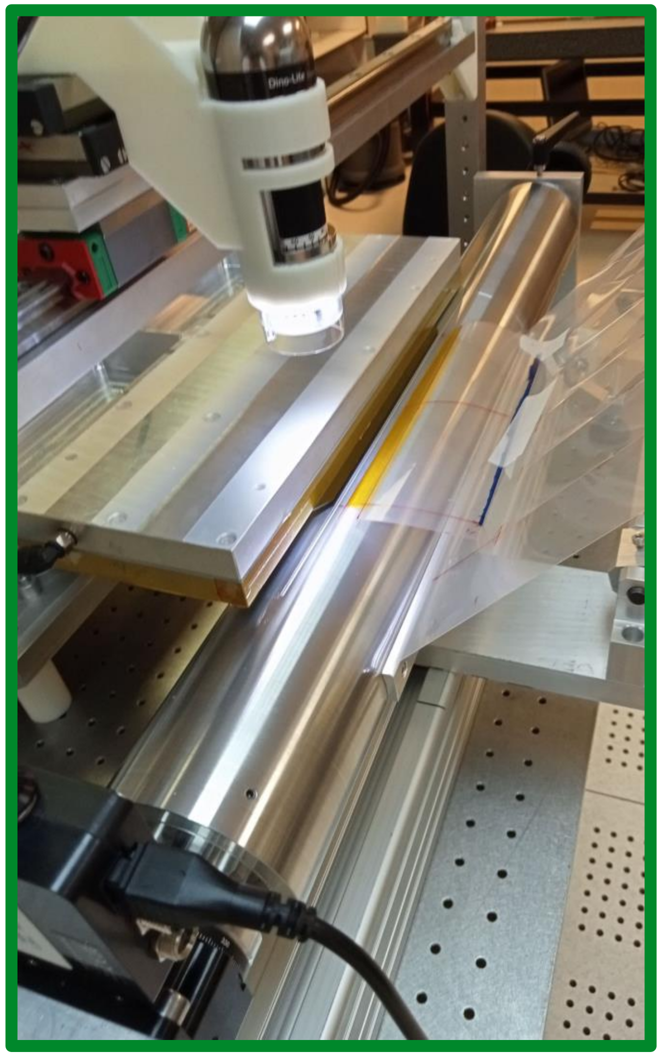

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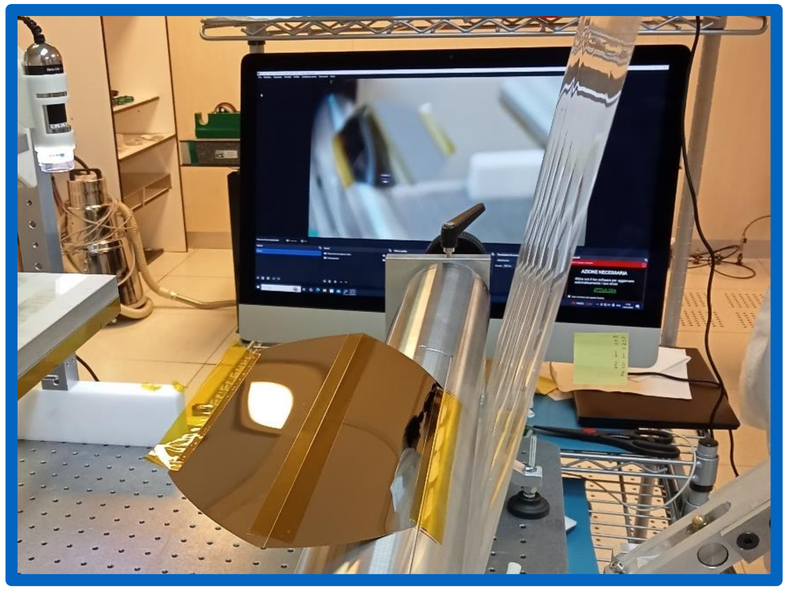

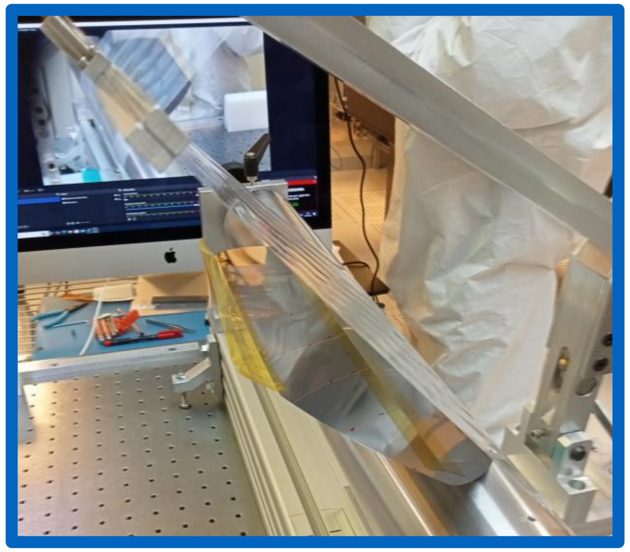

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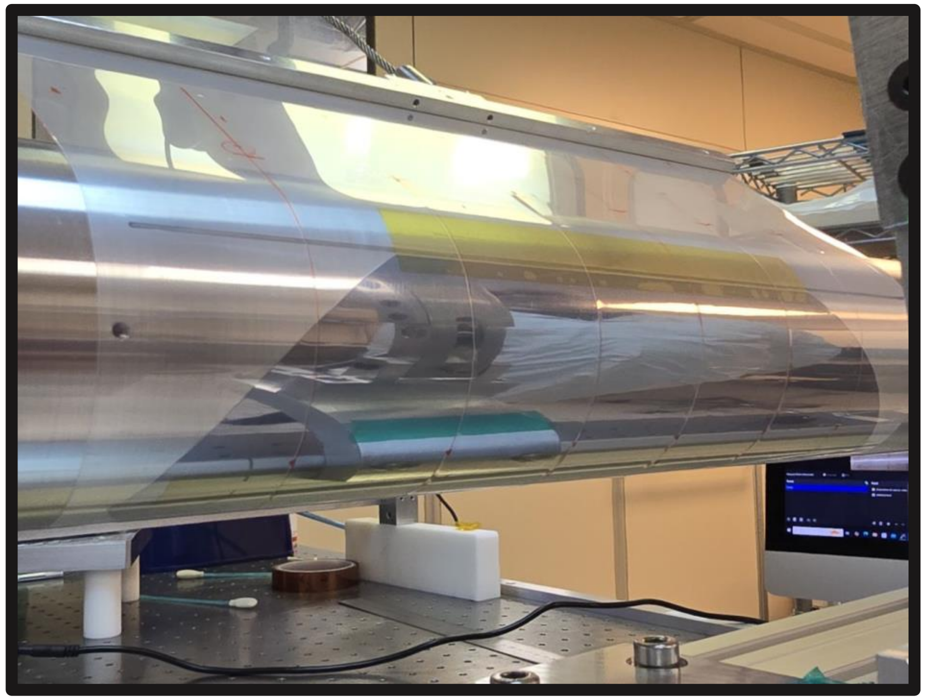
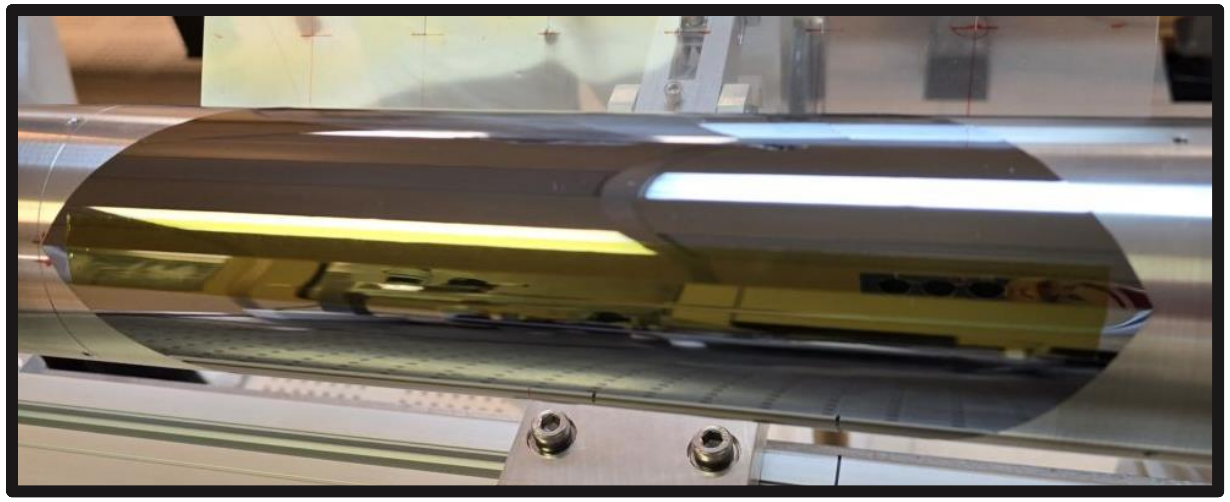




After the mylar release:

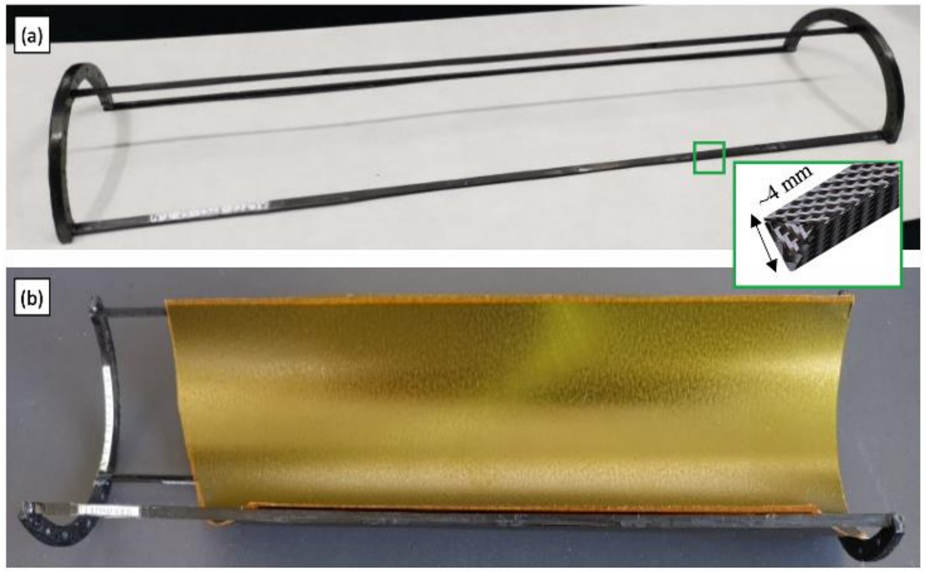
- the uncontrained corners are not breaking starting points;
- **No significant cuspid**

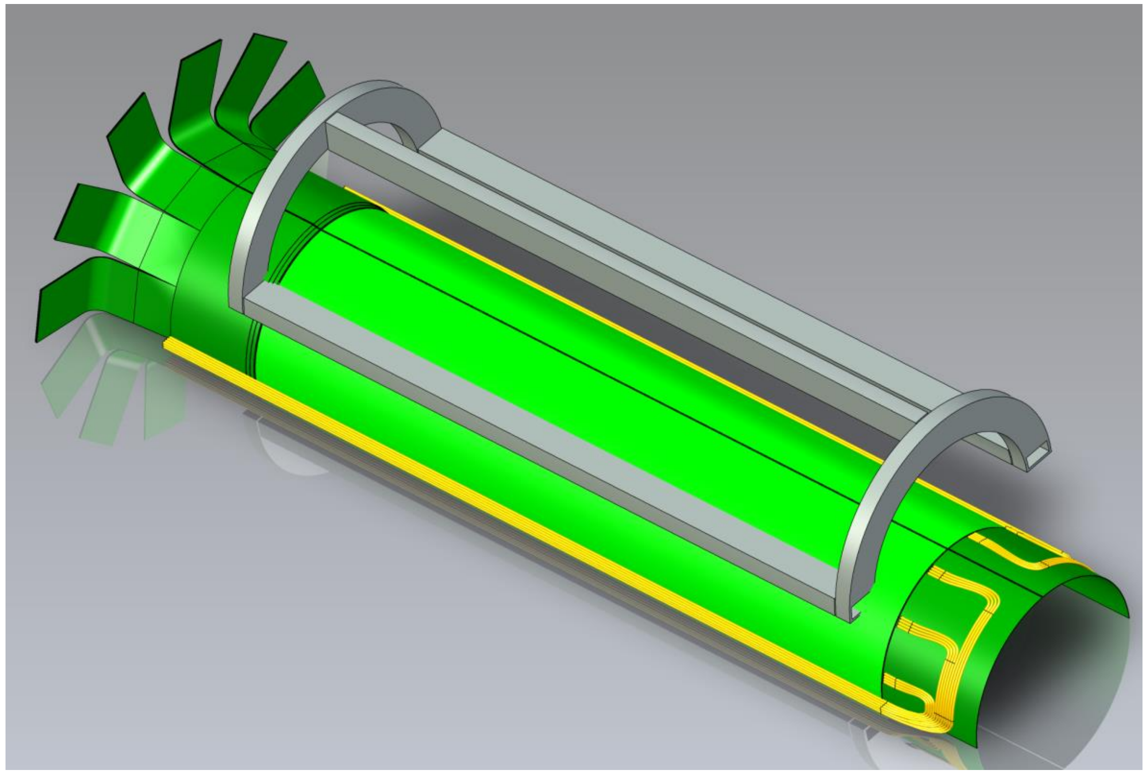
Local support structures

Single light support structures:

- able to self-supporting the sensors of a single half-layer → Required to avoid a shell externally to L1 (needs still to be verified for cooling)
- obtained by gluing two half-rings and three longerons
- made of combination of carbon foam (for half-rings) and carbon fiber (for longerons)

G. Feofilov et al., **ITS3 WP4** 10 October 2023



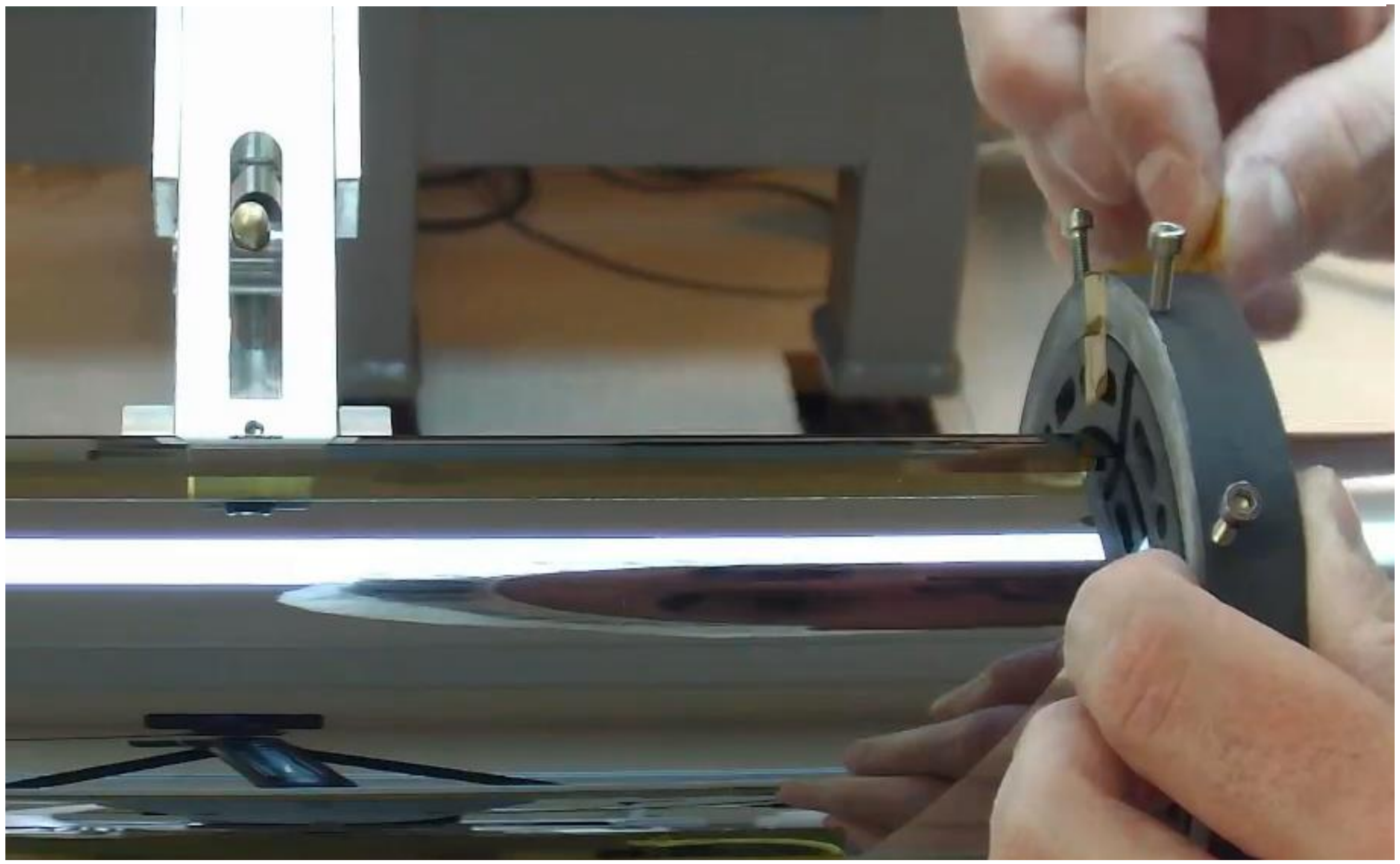


A 3D-printed epoxy copy made @Bari

One-shot gluing of the “minimal” mechanical structure

The insertion of the longerons inside half-rings required one-shot gluing

A. 1st half-ring + alignment tool



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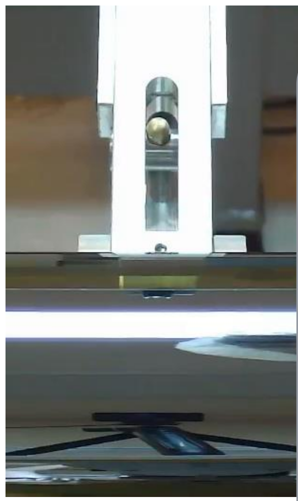
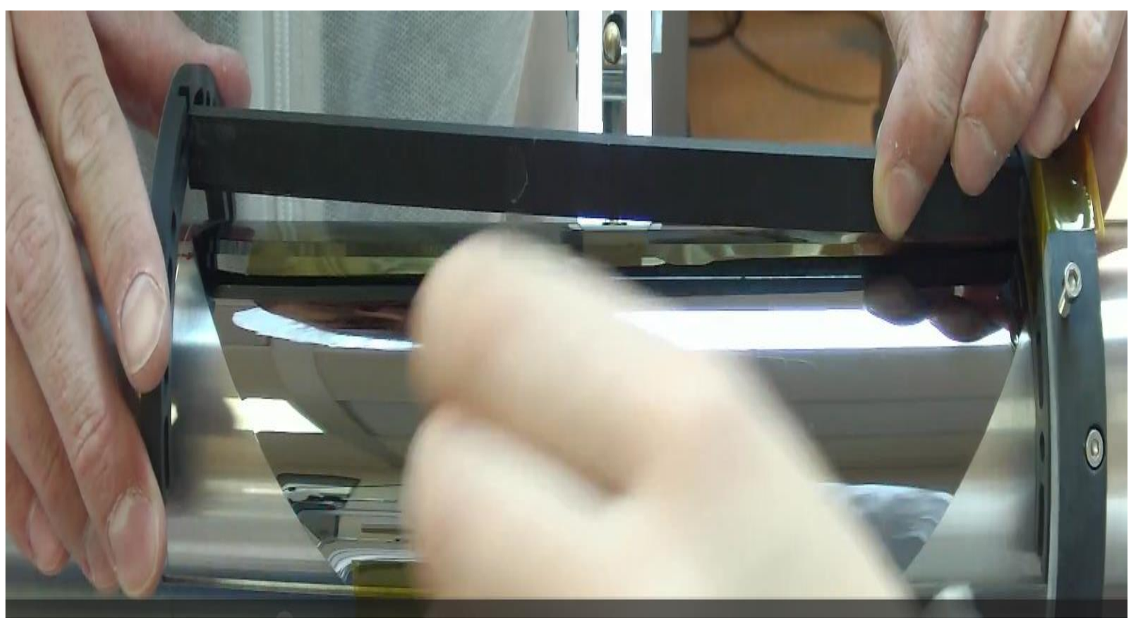
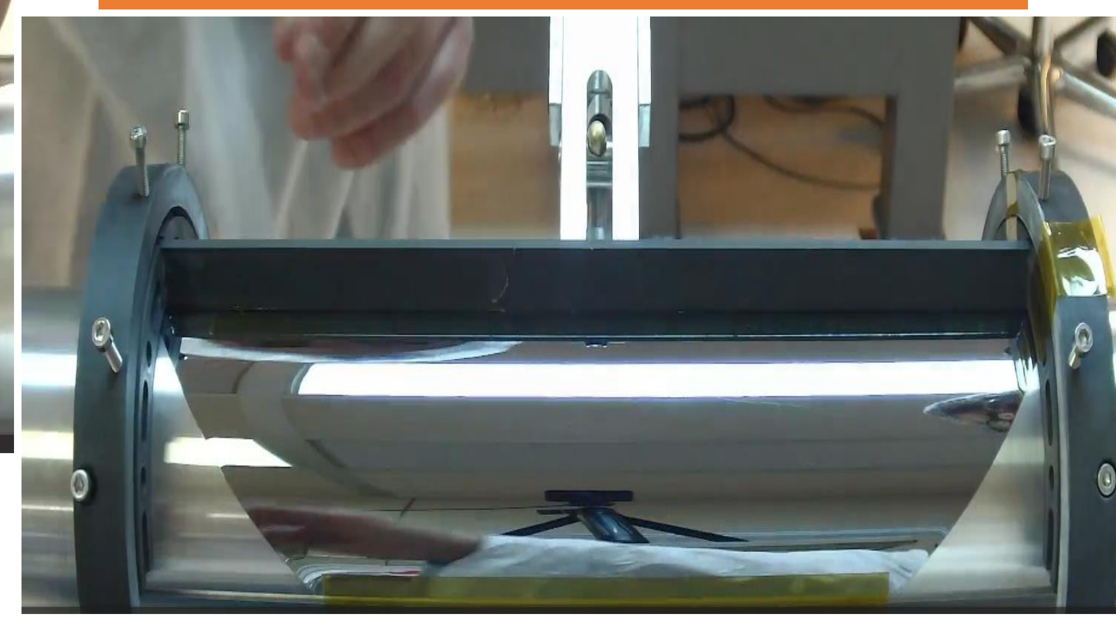


B. Glue (Araldite 2011) under the central longeron, placed over the tape, and insertion into the slots on the half-rings



Insertion of 2nd half-ring

Insertion of 2nd alignment tool



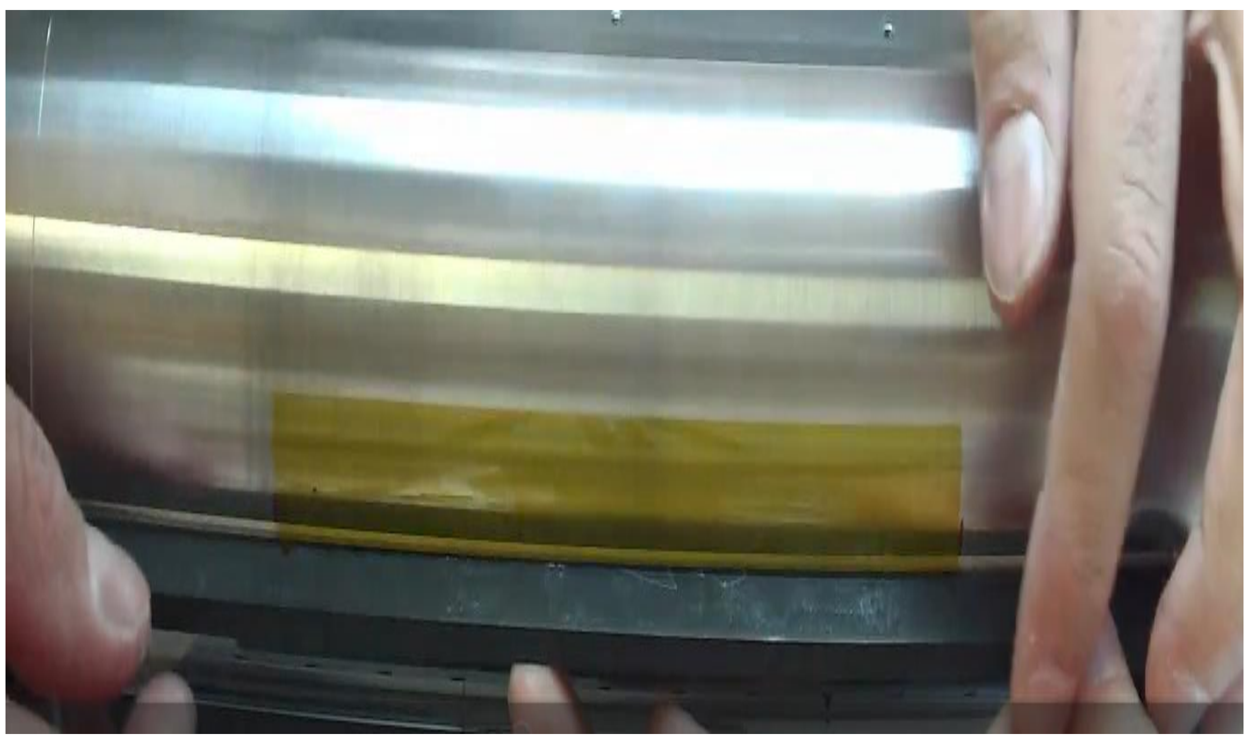
One-shot gluing of the “minimal” mechanical structure

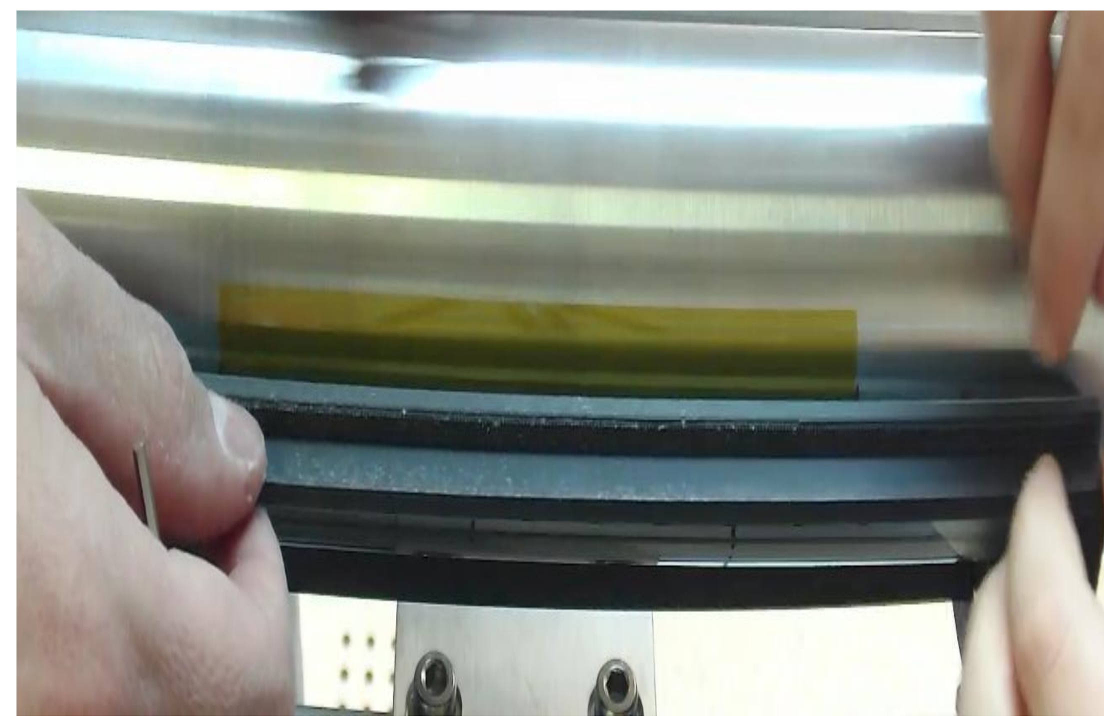
The insertion of the longerons inside half-rings required one-shot gluing

A. 1st half-ring + alignment tool

B. Glue (Araldite 2011) under the central longeron, placed over the tape, and insertion into the slots on the half-rings

C. 180° Rotation of the mandrel, glue under the lateral longeron, placed over the tape, insertion into the slots on the half-rings. + alignment tool during curing





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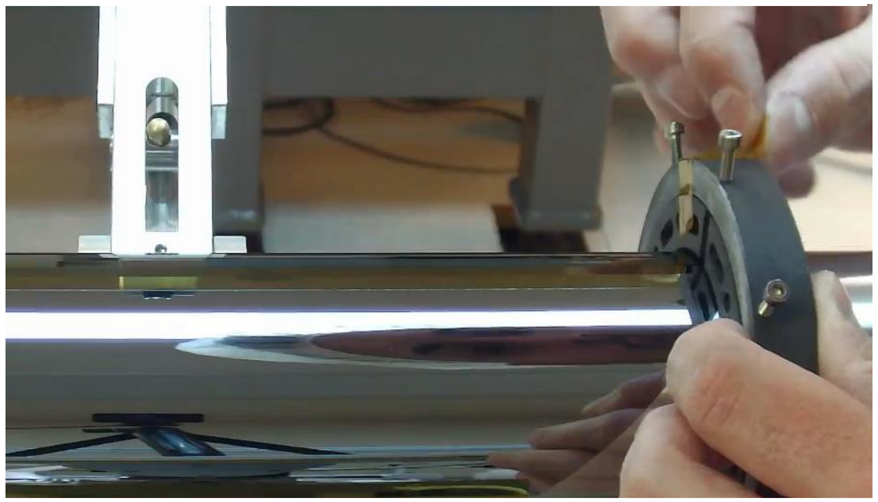

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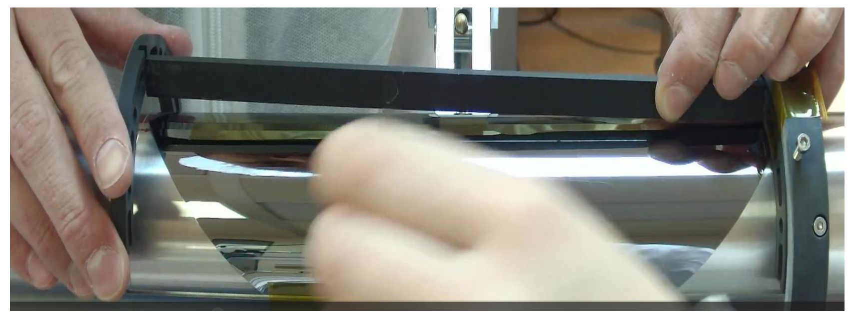
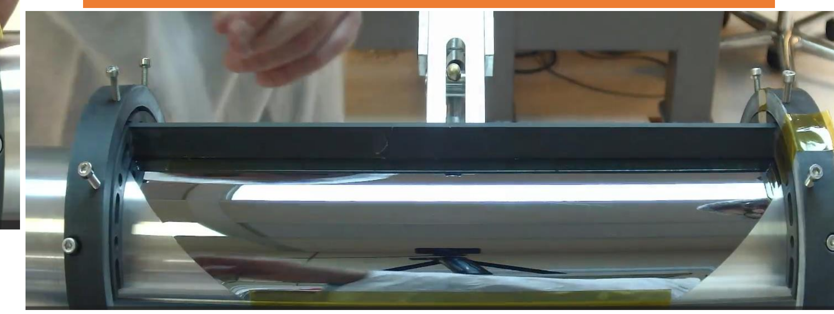
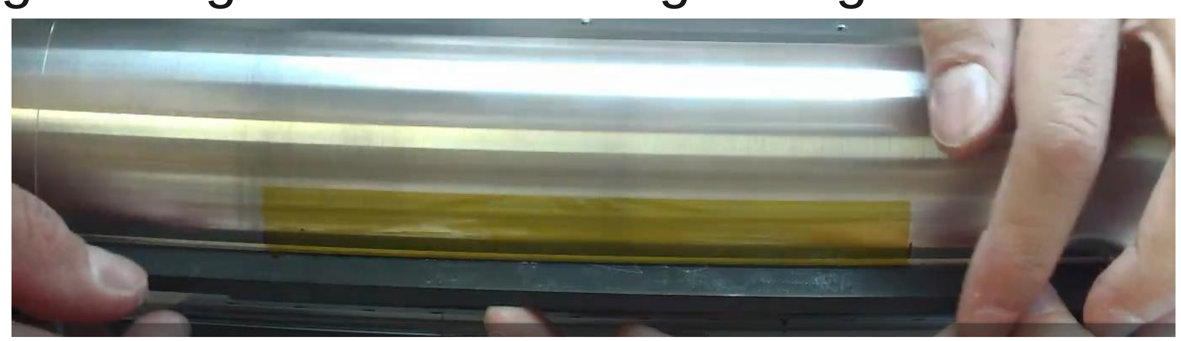


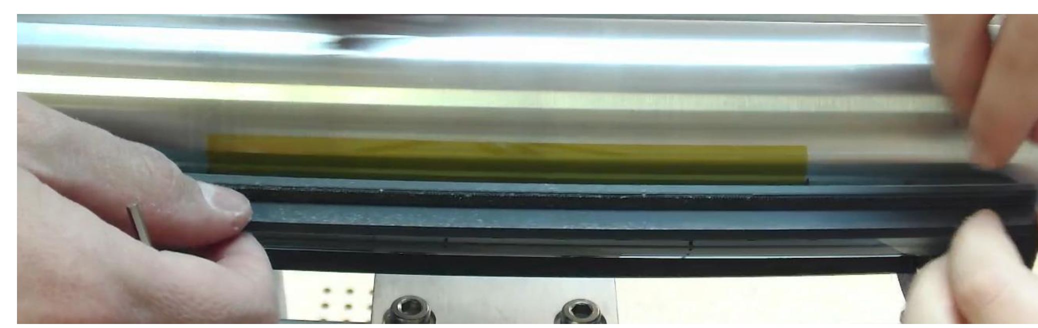
Insertion of 2nd half-ring

Insertion of 2nd alignment tool



C. Glue under the lateral longeron, placed over the tape, insertion into the slots on the half-rings. + alignment tool during curing



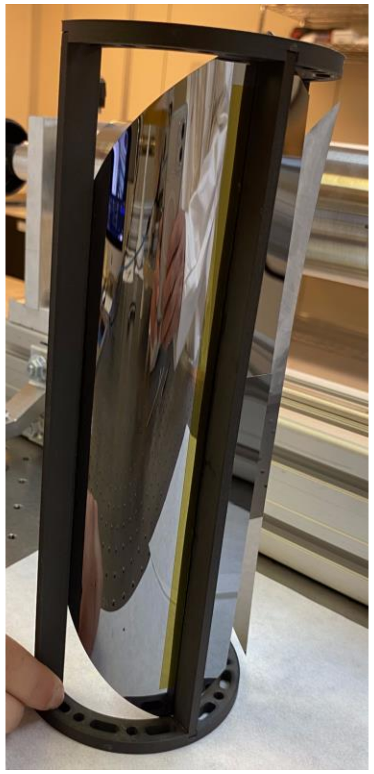


- Longeron alignment cases will be modified to uniformally press the long side of the longeron; after the 1° trial, the 3D-printed longerons should be made shorter than the design dimension

One-shot gluing of the "minimal" mechanical structure: RESULTS

CAVEATs:
- due to the half-moon shape, the half rings were not glued to the sensors just to longerons;
- A silicon dummy had already a fracture before the gluing and release from the mandrel (slide 30 in back-up).

Even if the final break of the fractured silicon during the release, we learned:



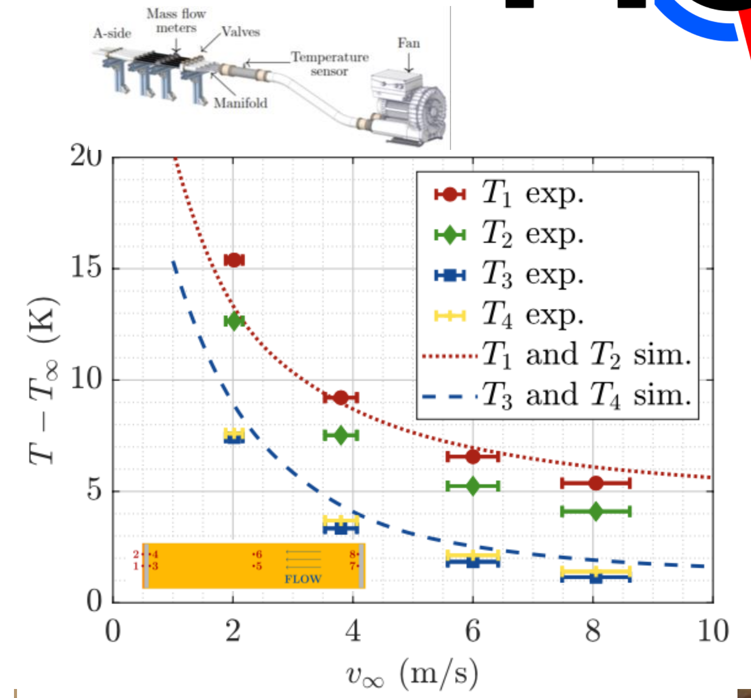
1. **3D-printed structure can sustain the bending sensors** without folds; ☺
2. No problematics seemed to show from the central longeron putting **pressure on the cuspid** (but we wait the repetition without break) ☺
3. Better understanding of gluing tool requirements, and **procedure for the release of the L0/L1 half-layers from mandrel** ☺

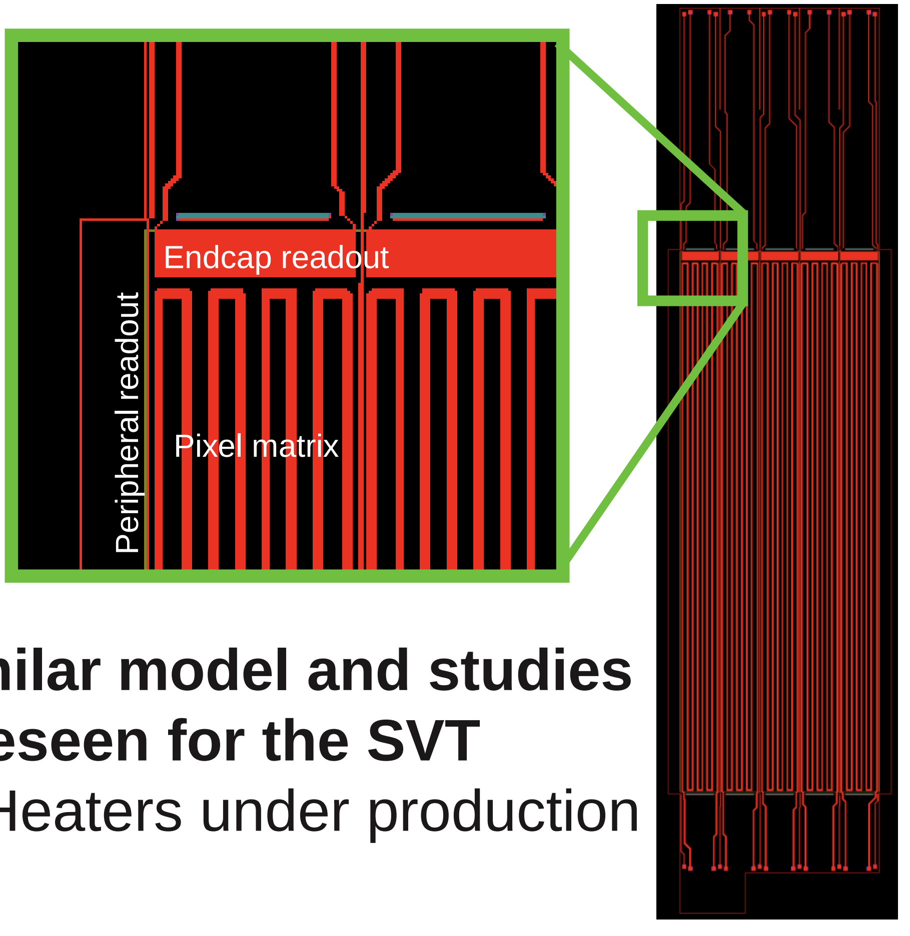
ITS3 activities preparatory to SVT prototyping

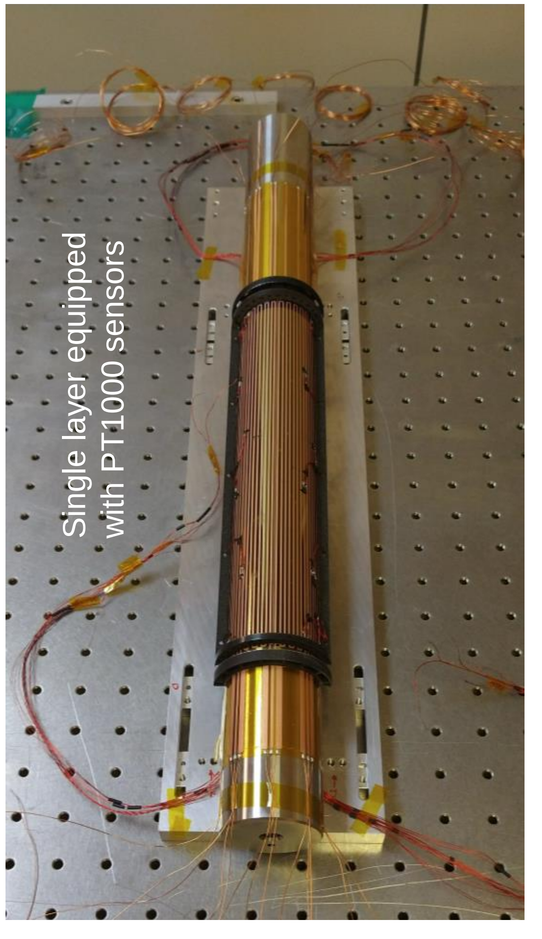
- Air-based cooling performance study using a wind tunnel

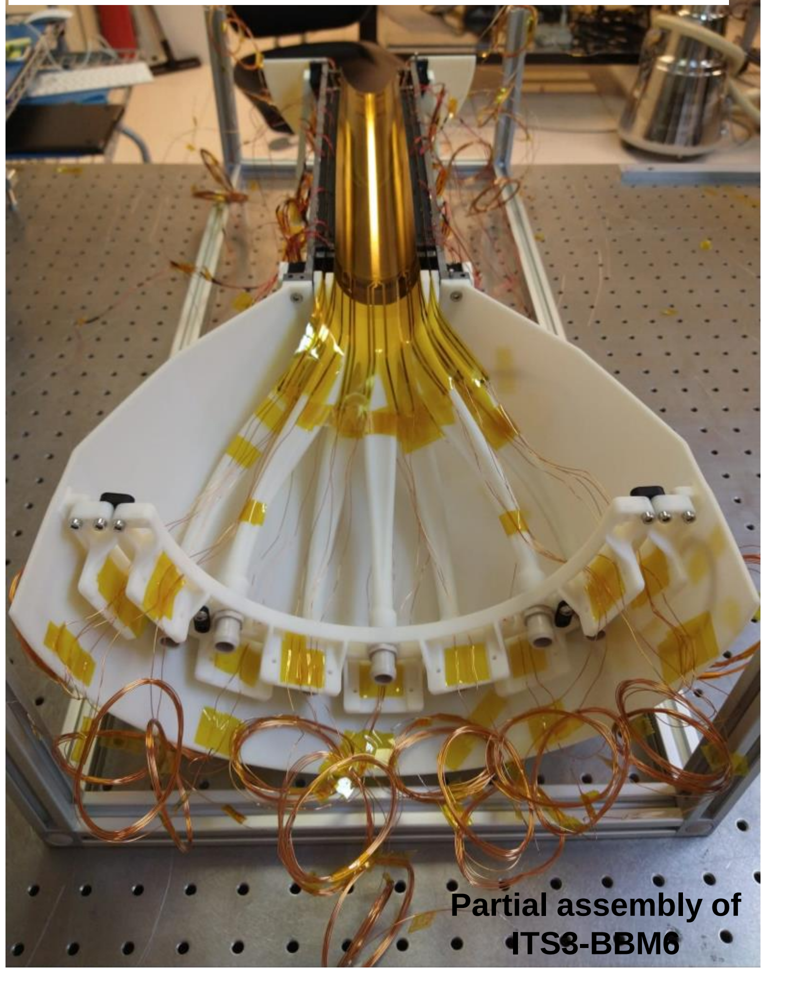
- Preliminary study done in ITS3 with BBM3 model
  → Results reported in the [ITS3 TDR]

- New advanced model (ITS3-BBM6):
  - More precise sensor powering values
  - Air distribution closest to the final one
  - More precise temperature measurements









- **Similar model and studies foreseen for the SVT**
  - Heaters under production

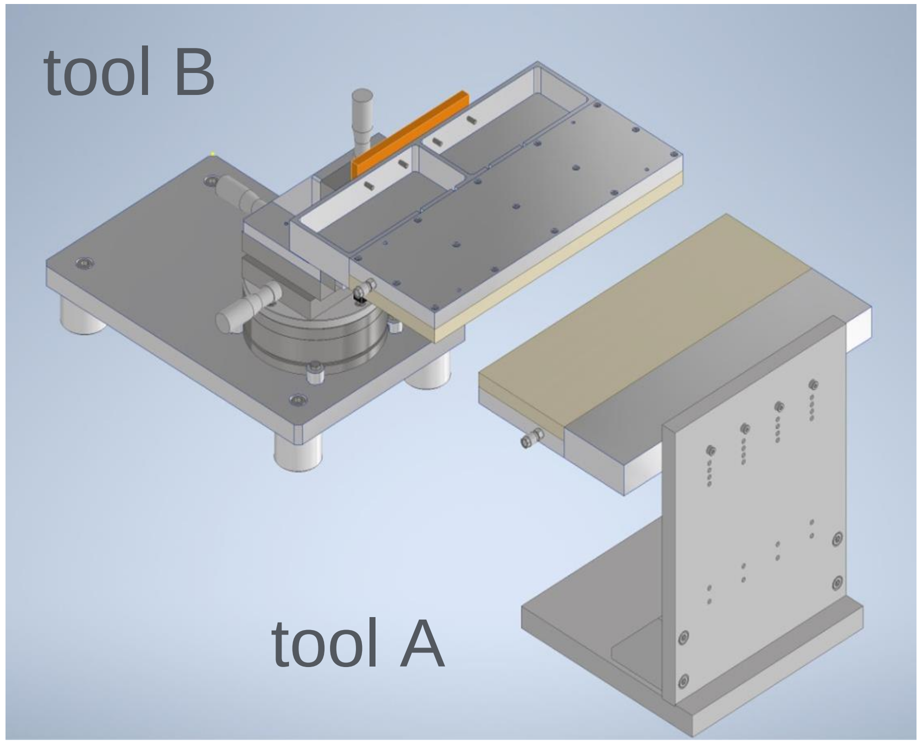
Updates of the design of the setup for the final production

- Handling tool A with adjustable heights + two vacuum sectors in a single surface that can contain two L1 sensors; To be produce ✓

- Additional tool to handle the tape-connected sensors; Preliminary design

- Cases that uniformly press the lateral longerons during the gluing; Preliminary design

- Optimization of the release procedure of the L0/L1 half-layer from the mandrel; To be validated



- Final design of the mandrels to be finalised according to the results of the ongoing studies.
    - We are already in contact with Gigotti company for the mandrel production

(Tentative) IB prototype production plan for L0-L1

	Prototype	Components	Goal
MAR 2025	IBL01_P1 (half-layer)	• 2 naked silicon L1 sensors • L1 local support structure (3-D printed) • outer support shell (machined in PEEK)	• finalize half-layer assembly procedure
	IBL01_P2 (half-barrel)	• IBL01_P1 + • 2 naked silicon L0 sensors • L0 local support structure (3-D printed)	• finalize half-barrel assembly procedure
JUL 2025	IBL01_P3 (half-layer)	• 2 naked silicon L1 sensors • L1 local support structure (carbon foam) • outer support shell (carbon fiber, to be defined)	• thermal chamber test
	IBL01_P4 (half-barrel)	• IBL01_P3 + • 2 naked silicon L0 sensors • L0 local support structure (carbon foam)	• thermal chamber test
OCT 2025	IBL01_P5 (half-barrel)	• 2+2 silicon L0+L1 **sensors with heaters from CERN** • L0+L1 local support structures (carbon foam) • outer support shell (carbon fiber, to be defined) • **air distribution inlet et outlet** (to be designed) • PT1000 sensors (to be glued on heater surface)	• wind tunnel test

They require dummy silicon sensors from DISCO; to validate 2-sensor connection and bending, to design local support structure, external shell etc

In addition to DISCO dummies, they require:
- carbon foam local support (procurement and machining TBD)
- carbon fiber outer support shell TBD

(if yes, needs for design&simulation, procurement and machining)

IBL01_P5 requires:
- dummy silicon sensors with heaters
- air-cooling mechanism verification
- Possible preliminary FPC (mechanical) prototype to check volumes, transport etc)
- transport issues to wind tunnel facility

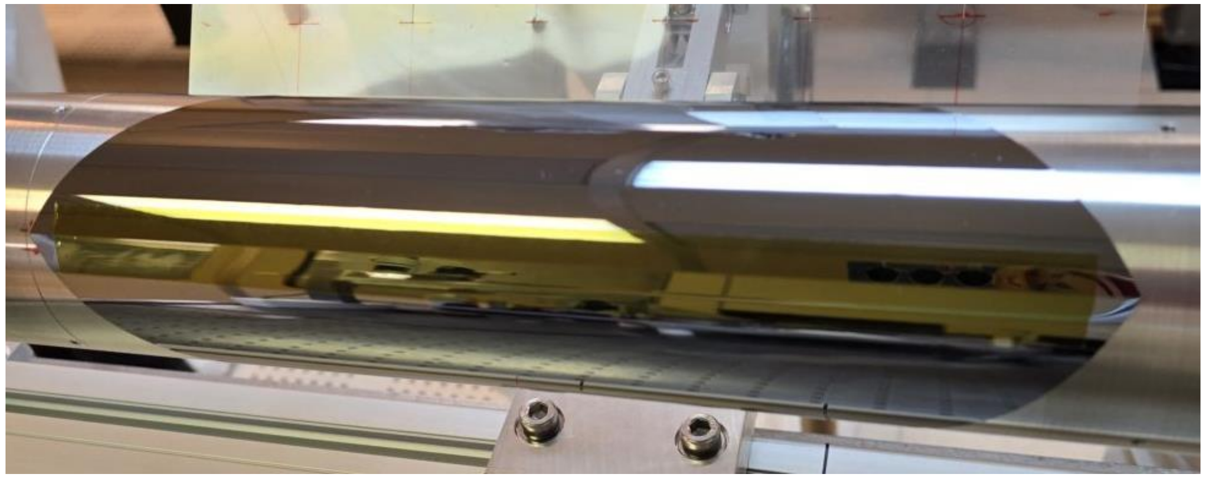
Conclusions and future plans

Activities are still ongoing.

Three half-bending trials were carried out using L0 half-moon dummies
- to state the procedure for SVT IB L0/L1;
- to understand if additional tools are required w.r.t. ITS3 setup.

LAST TRIAL is very promising !!!

Observations:
- final pitch between the two sensors is expected to be within [50,100] µm;
- At moment, the most delicate actions are to handle the tape-connected sensors and the object release from the mandrel after the gluing.

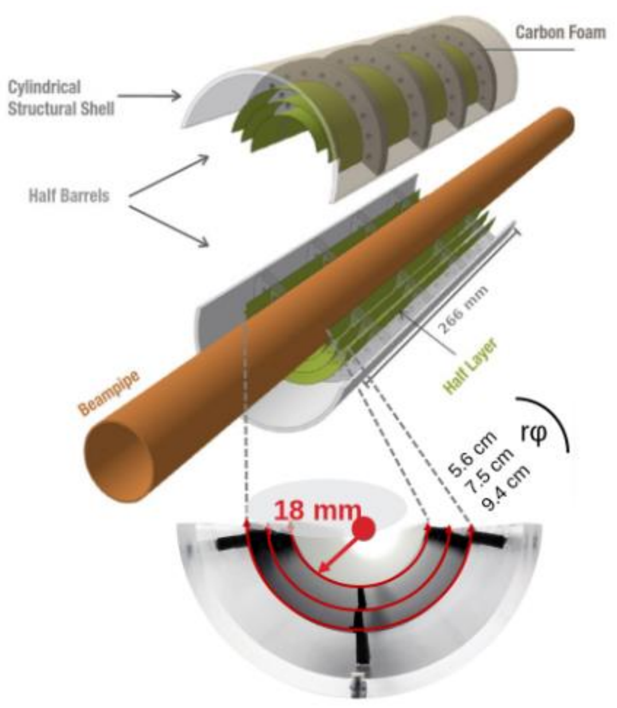


The schedule is tight but we will use the built-up experience on ITS3 BBM6 to deliver prototypes for thermal chamber and wind tunnel tests after summer 2025

Backup

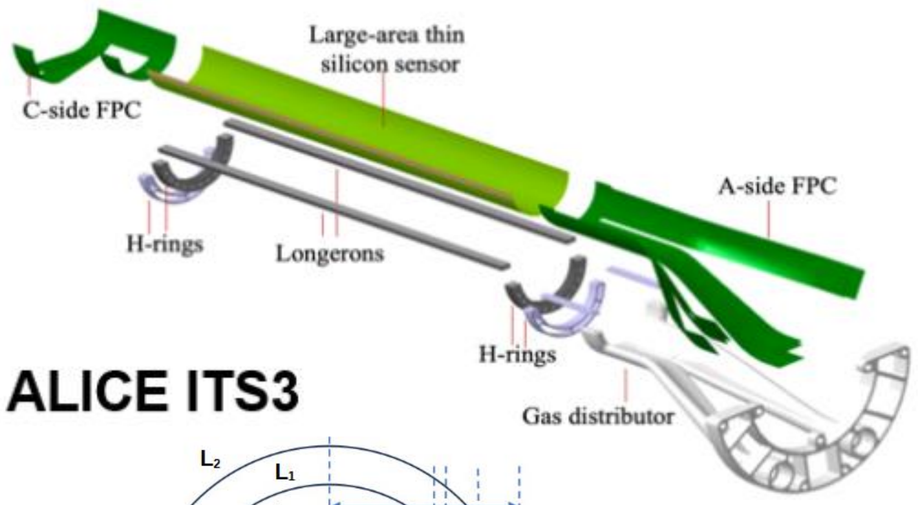
From ALICE ITS3 to ePIC SVT IB layout

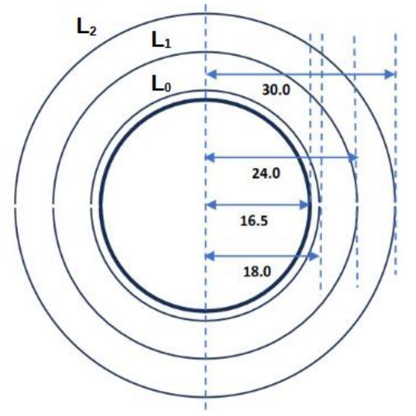
ALICE ITS3 detector as basis concept.



Common key ingredients:

- ❑ Wafer-scale MAPS chips (65 nm CMOS, thickness ≤ 50 µm)
- ❑ Chips bent in cylindrical shape at target radii
- ❑ Ultra-light carbon foam structures
- ❑ Air cooling

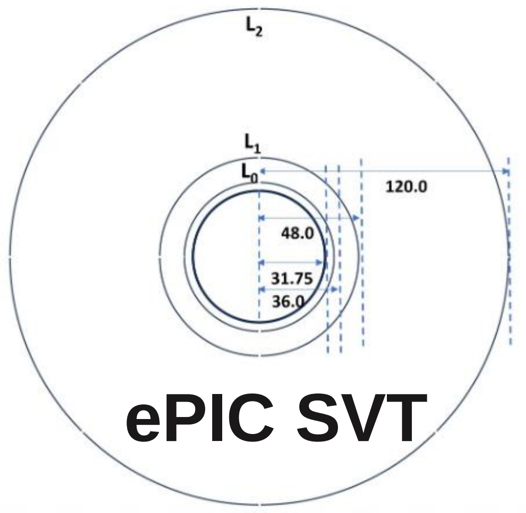




Need to adapt it to the ePIC SVT geometry:

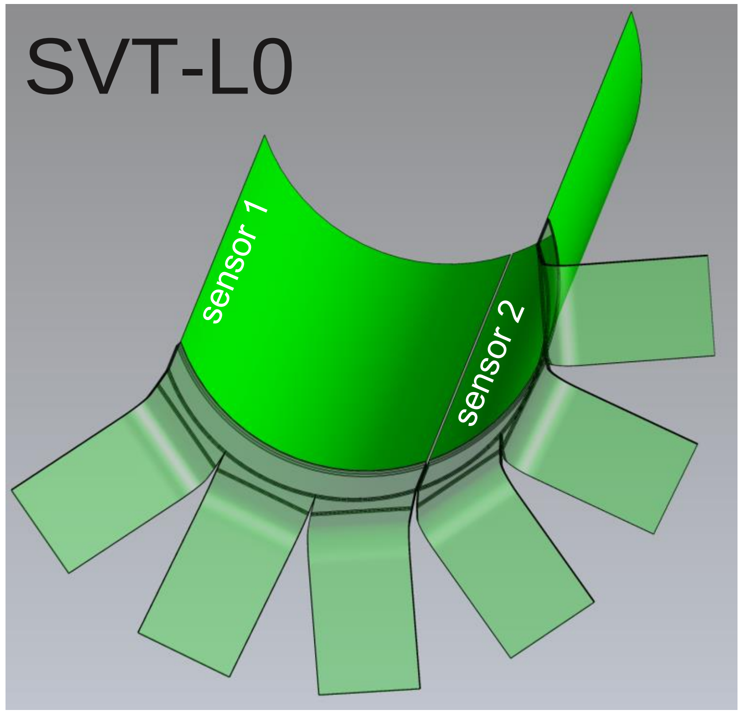
Z sensor length (mm): 270

L0 radius (mm): 38
L1 radius (mm): 50.4
L2 radius (mm): 126



1. Silicon sensor bending technique

In SVT, # of sensors per half-layer:
- two in L0 and L1,
- four in L2.



Two alternative approaches for half-layer assembly:

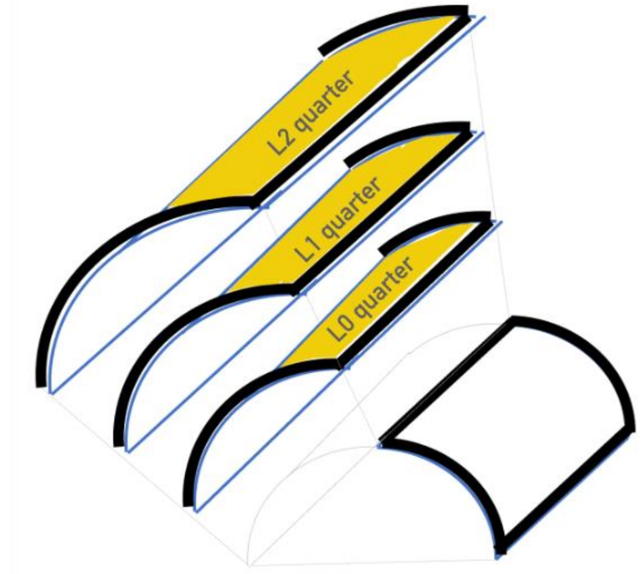
Single object bending

The two sensors are aligned, “connected” and bent as single object (à la ITS3).

Pros. - tools already developed, reduced sensor separation, better alignment

Cons. - bending more difficult, (potentially) slightly larger material budget

Independent bending

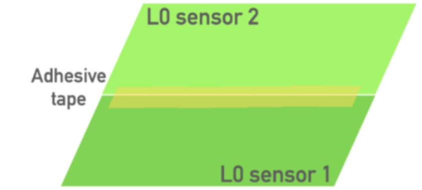


1. Silicon sensor bending technique

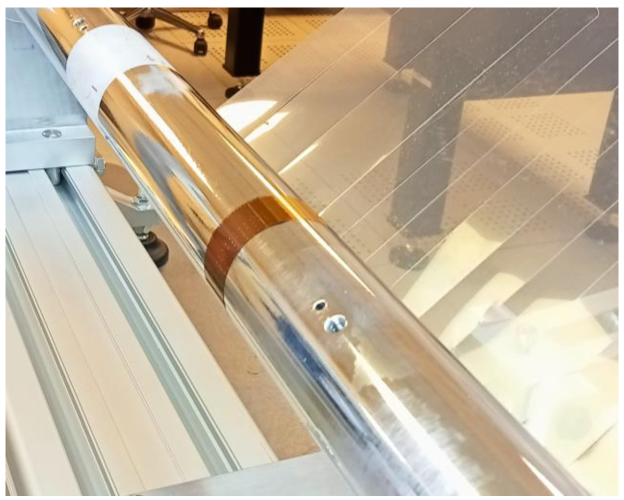
Single object bending

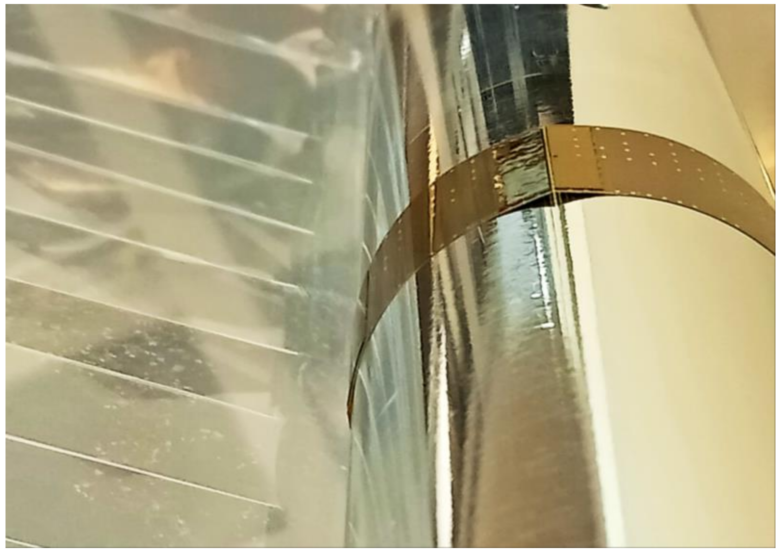
Test conditions:
- 50 µm ALPIDE sensors (30 mm x 15 mm)
- bending radius 18 mm
- adhesive tape thickness: from 12 µm to ~60 µm

Bare+tape strategy



- Reduced amount of kapton
- Feasibility to be verified





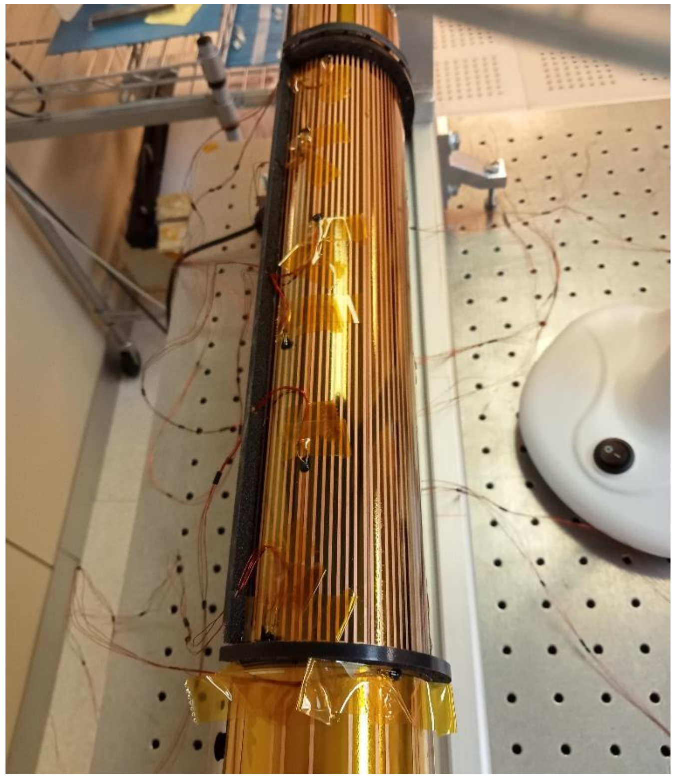
Attempt	Adhesive tape thickness	Result	Note
#1	12 µm	breakage	Close to tape-to-mandrel edge
#2	12 µm	success	Cusp at sensors junction
#3	40 µm	success	Reduced cusp
#4	60 µm	breakage	Cusp not reduced wrt 40 µm Breakage (probably) due to already stressed silicon

4. ITS3 activities preparatory to SVT prototyping

Man-power of the SVT activities is in parallel involved in the ITS3 half-barrel prototype for thermal/cooling tests

1. Bending of the dummies encapsulated inside polyimide-copper heaters

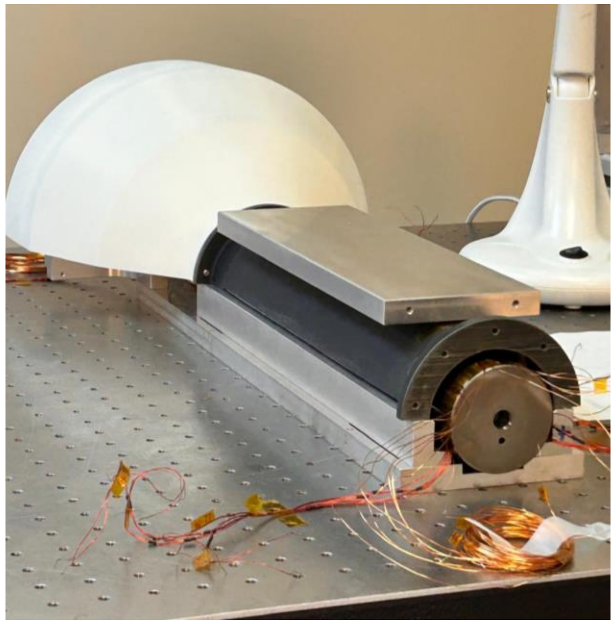
2. Gluing local structure in carbon foam

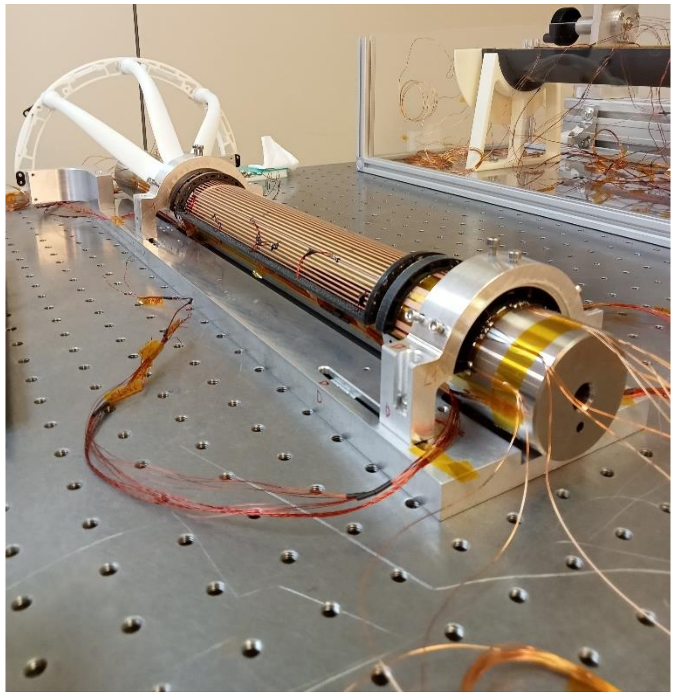


3. Gluing PT1000 using epoxies 50-3150 FR glue;

4. Soldering power cables

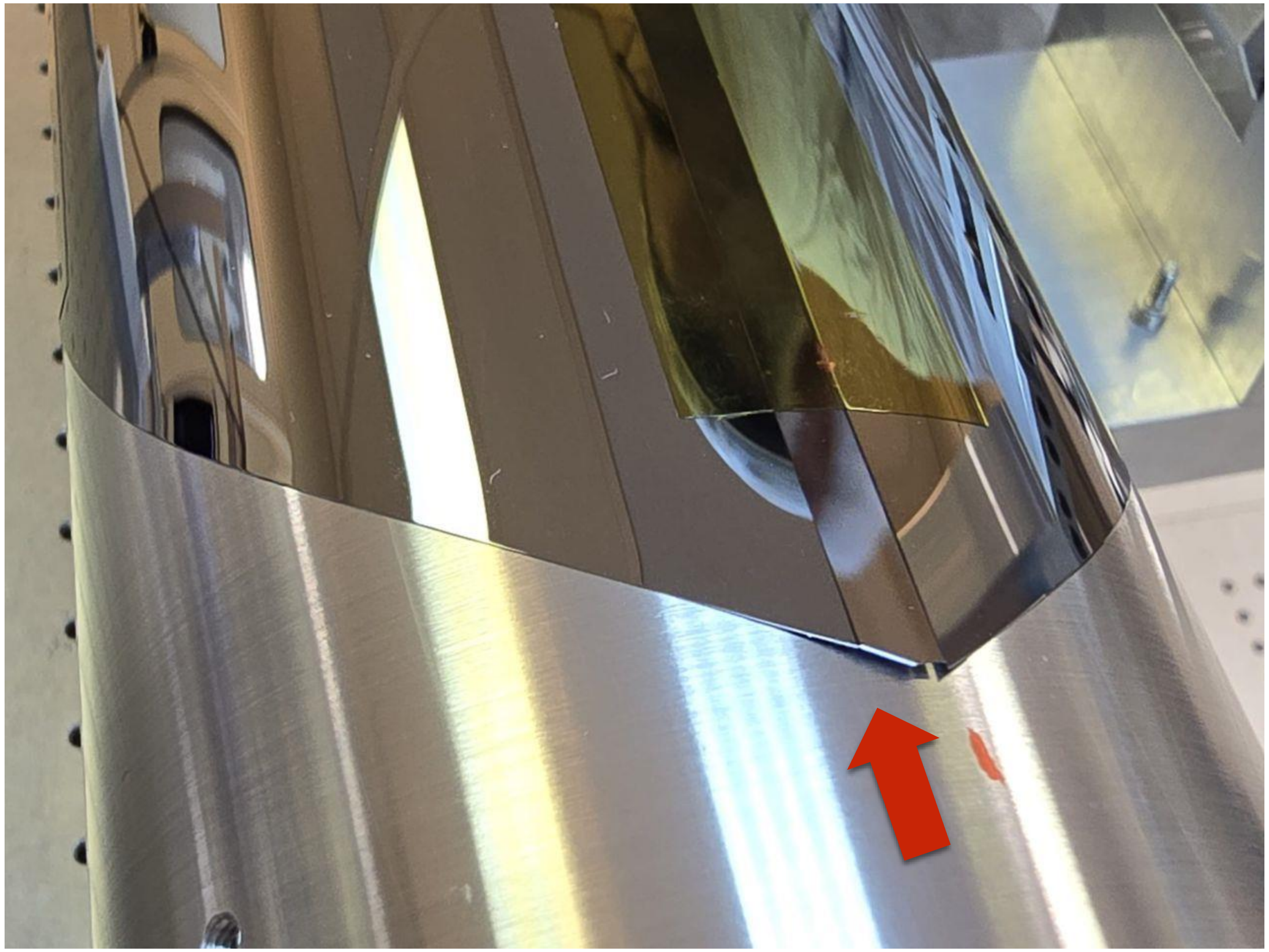
5. Gluing air cooling structure





6. Final gluing/assembly

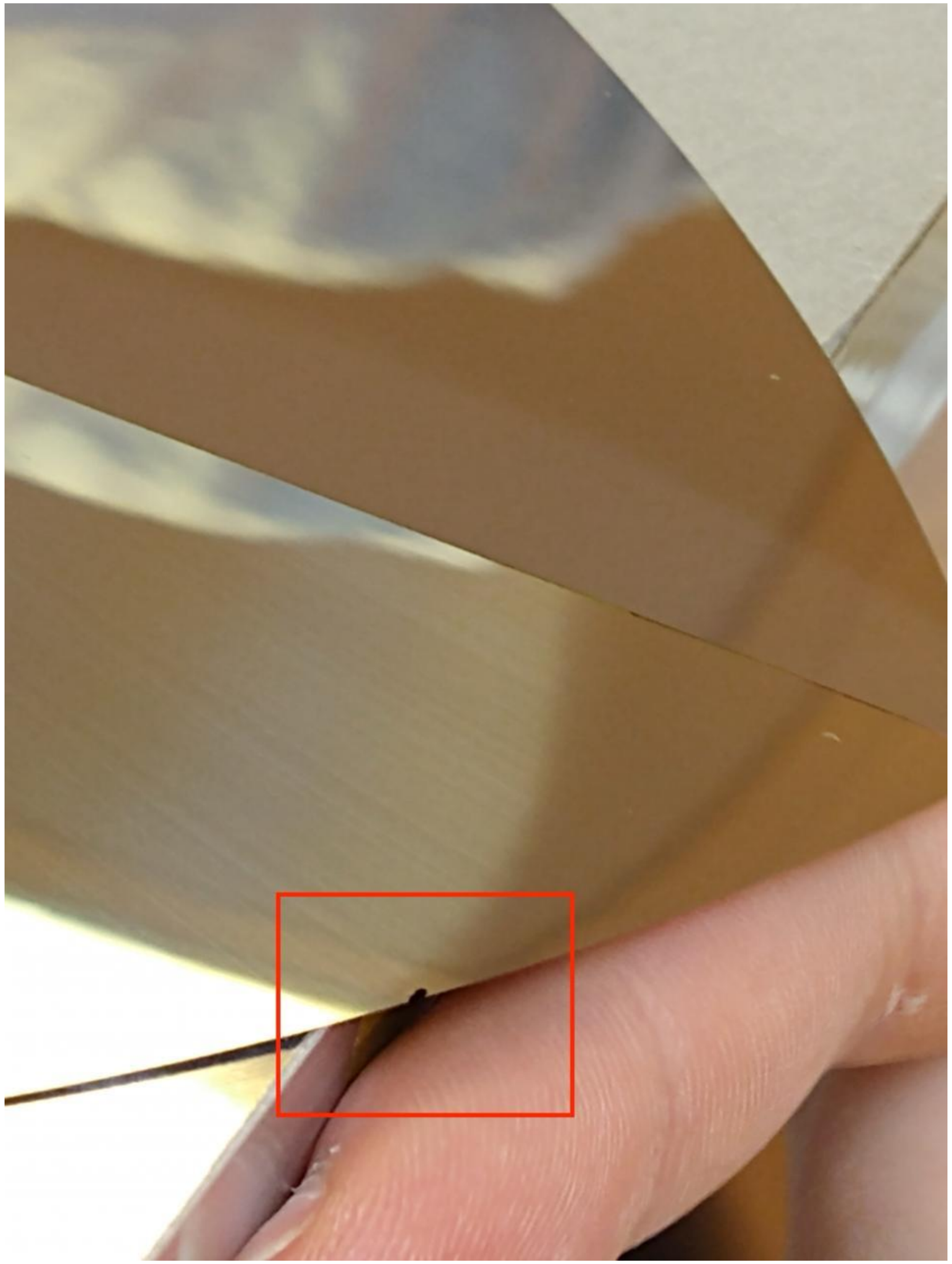
Break during the 1nd trial



Break during the bending;

It was under the tape, then we could glue the local structure

Break during the 2nd trial



The edge defect caused the
break during the bending