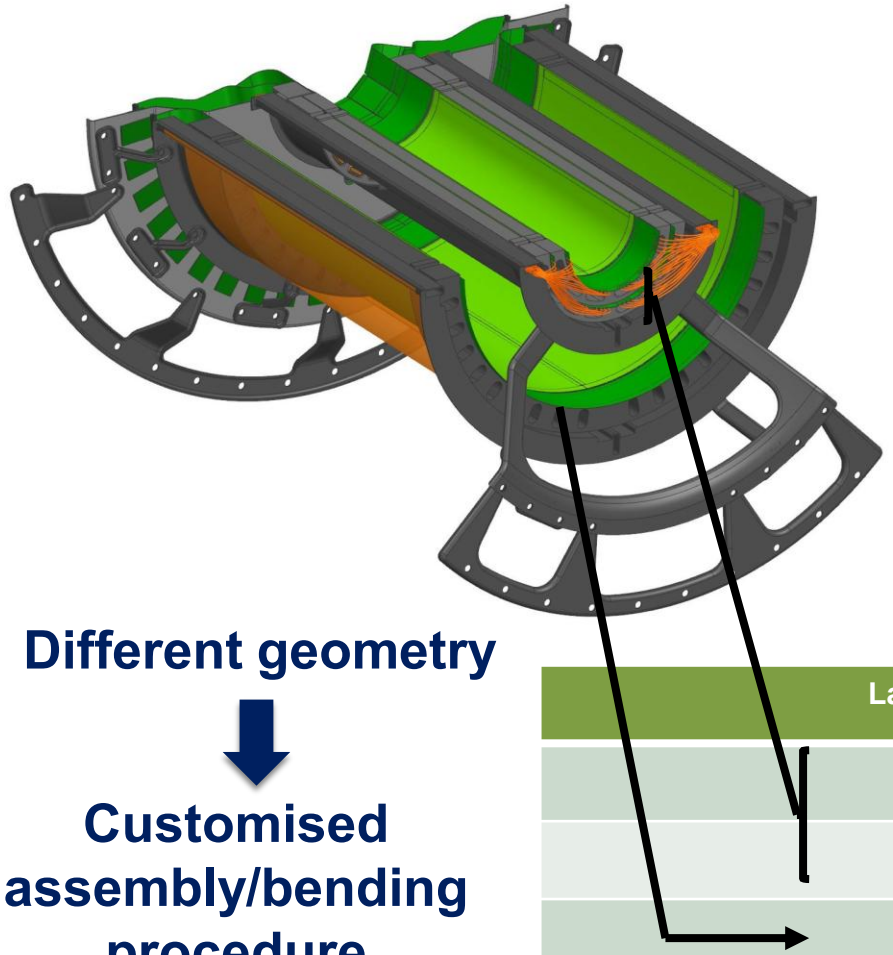
SVT half-layer bending/assembly

M.T. Camerlingo on behalf of SVT DSC (INFN Bari)

RECAP ON THE DESIGN OF INNERMOST SVT LAYERS



Different geometry

Customised assembly/bending procedure

Common key ingredients with ALICE ITS3:

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

Layer	Radii (mm)	Single sensor area (mm^2)	# of sensors for a half-layer
L0	38	266x58.7	2
L1	50	266x78.3	2
L2	126	266x97.8	4

Possible assembly strategies

Independent quarter bending

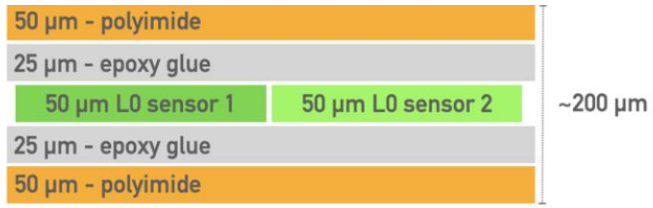
Half-layer bending could profit from ITS3 experience

Critical points:
- Mechanical supports for the bent quarters (with low-material budget)
- Alignment of bent quarters
- New assembly tools

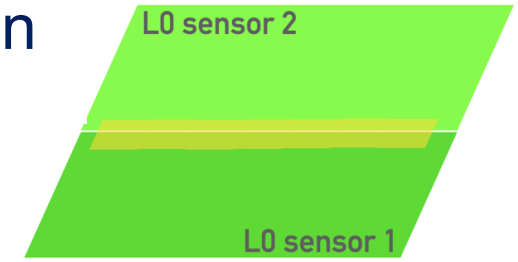
Two sensors are aligned and connected before the bending

S1. Sensor kaptonisation

kapton encapsulation of two sensors, acceptable increase of material budget



S2. Bare sensors + tape connected using a kapton tape just on one side

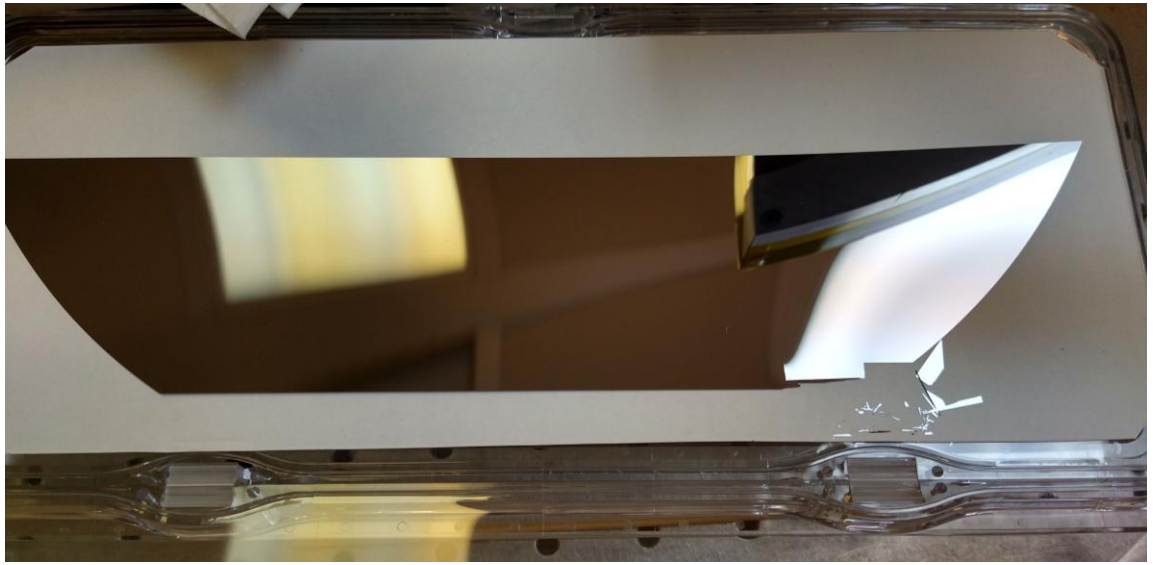


S1 and S2 were both tested using small-size dummies

S2. Bare sensors + tape: 1° step

S2 used for large-size dummies

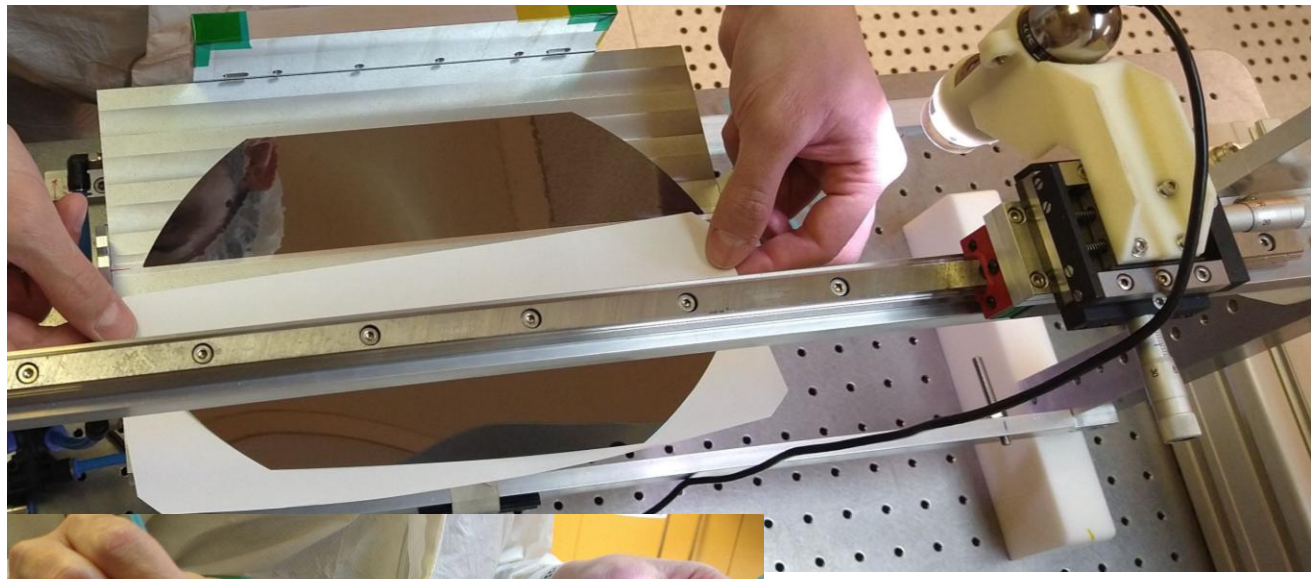
- Visual inspection and cleaning of the single sensors
- Sensor alignment
- Tape placement
- Half-layer bending
- Gluing of the local mechanical structure
- Removal of the half-layer from the mandrel
- Start of the half-barrel assembly

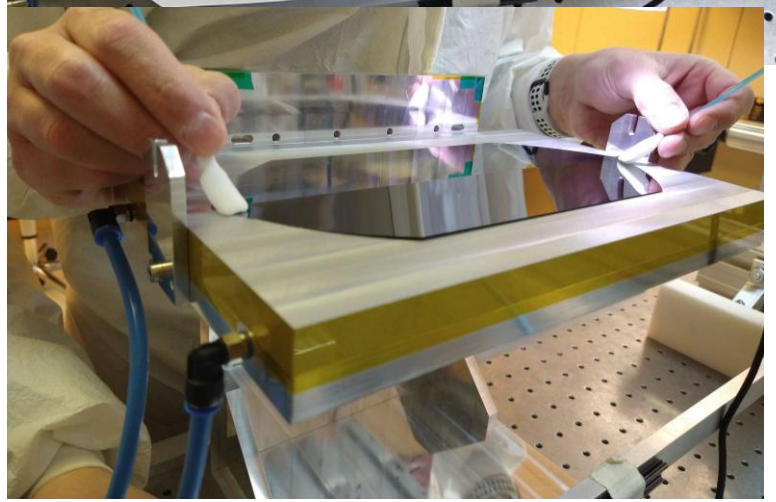


S2. Bare sensors + tape: 2° step

S2 used for large-size dummies

- Visual inspection and cleaning of the single sensors
- Sensor alignment
- Tape placement
- Half-layer bending
- Gluing of the local mechanical structure
- Removal of the half-layer from the mandrel
- Start of the half-barrel assembly



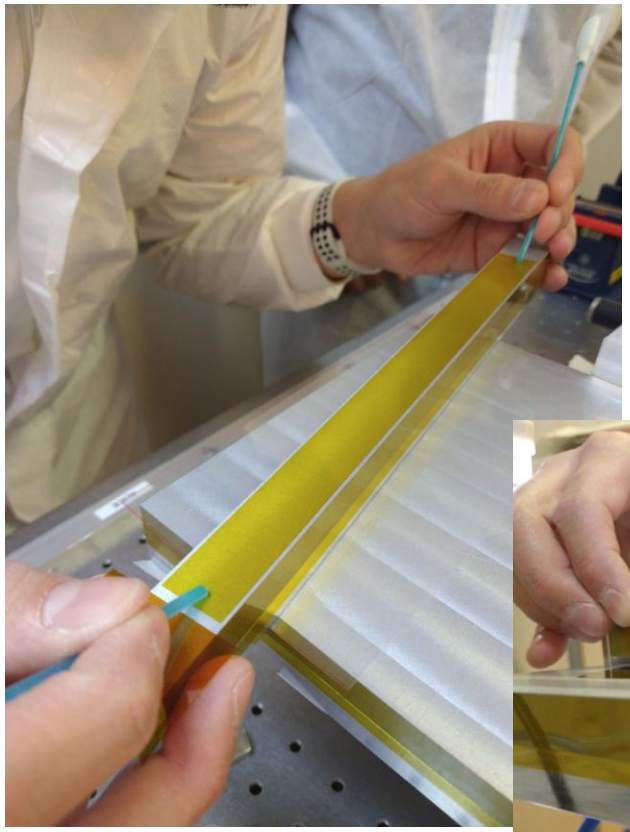


Improved tool with 2 independent vacuum surfaces

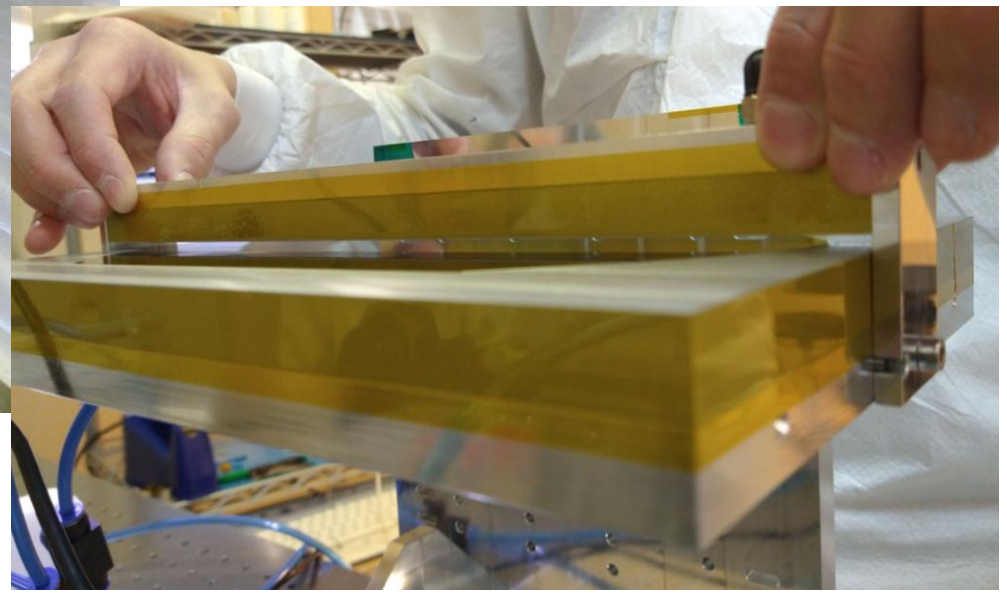
S2. Bare sensors + tape: 3° step

S2 used for large-size dummies

- Visual inspection and cleaning of the single sensors
- Sensor alignment
- Tape placement
- Half-layer bending
- Gluing of the local mechanical structure
- Removal of the half-layer from the mandrel
- Start of the half-barrel assembly



Dedicated tool with vacuum and guides to place the tape



Results of the

Alignment btw sensors (flat)

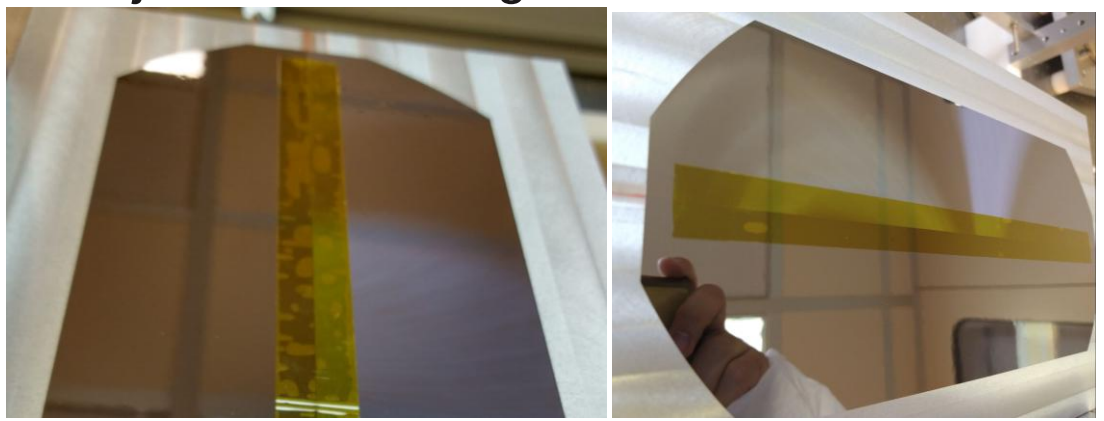
Parallelism has higher priority than pitch minimisation since a large tilt can affect the success of the bondings to FPC.

#	ID	Average pitch (μm)	Tilt angle (°)
1	**L0v1**	150	±0.021
2	**L0v2**	285	±0.008
3	**L0v3**	144	±0.006
4	**L0v4**	141	±0.002
5	**L1v1**	75.5	±0.0014
6	**L0v5**	**51.5**	±0.0004*

+ Offline measurements by analysing pictures
+ Design of accessories to reduce the number of attempts to reach the desired tilt and pitch.

Kapton tape

- Commercial tape: tesa® 51408 (or M3)
- Approximate length: ~250 mm (TBD)
- Tolerance: 1-2 mm of asymmetries in both the directions
- Air bubbles are minimised keeping the object rest for a night with vacuum ON



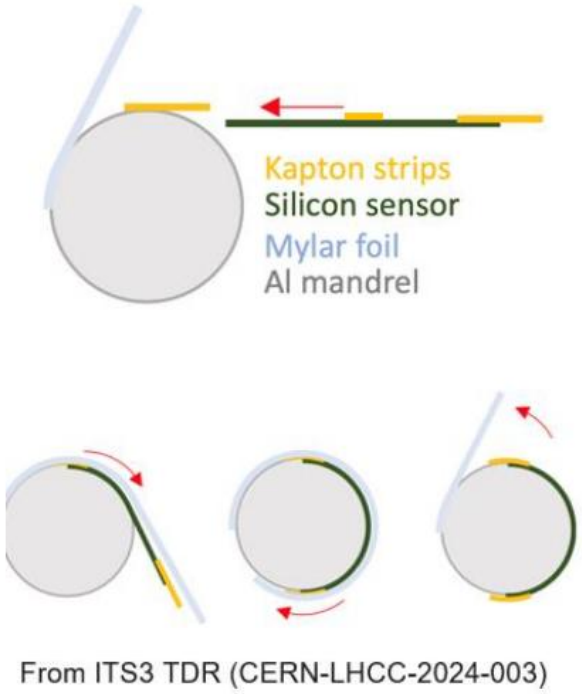
- Negligible cuspids are observed after the bending

*tilt under the resolution of dinoscope

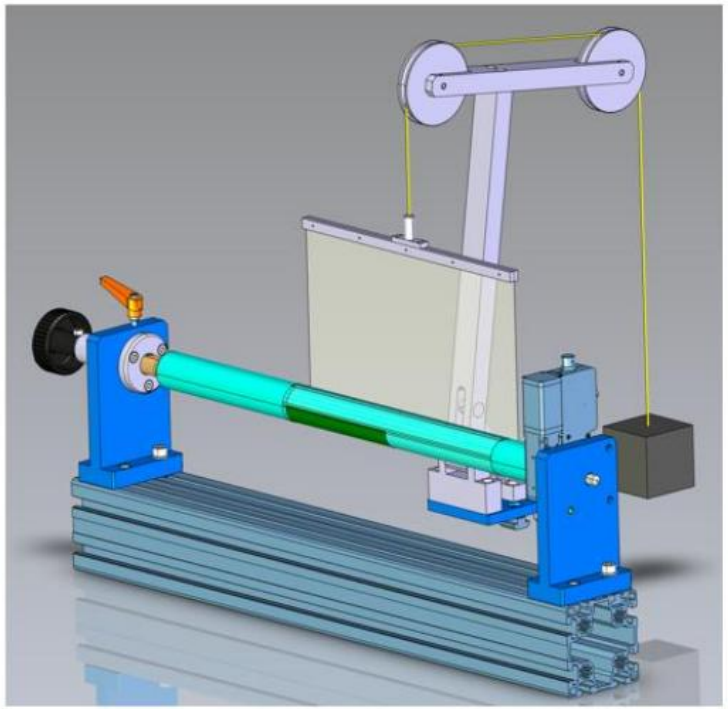
S2. Bare sensors + tape: 4° step

S2 used for large-size dummies

- Visual inspection and cleaning of the single sensors
- Sensor alignment
- Tape placement
- Half-layer bending
- Gluing of the local mechanical structure
- Removal of the half-layer from the mandrel
- Start of the half-barrel assembly



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



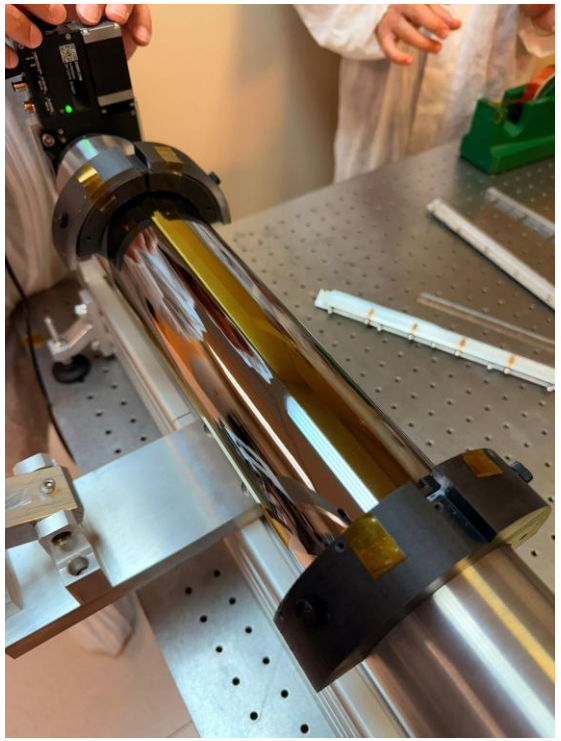
Technique developed within the ITS3 R&D

Public video: https://cernbox.cern.ch/s/wONOJ9puKAFk6IB

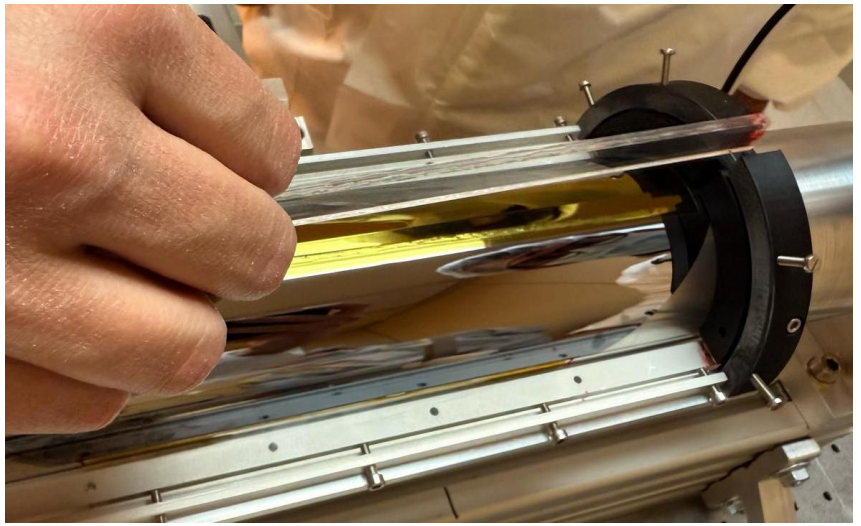
S2. Bare sensors + tape: 5° step

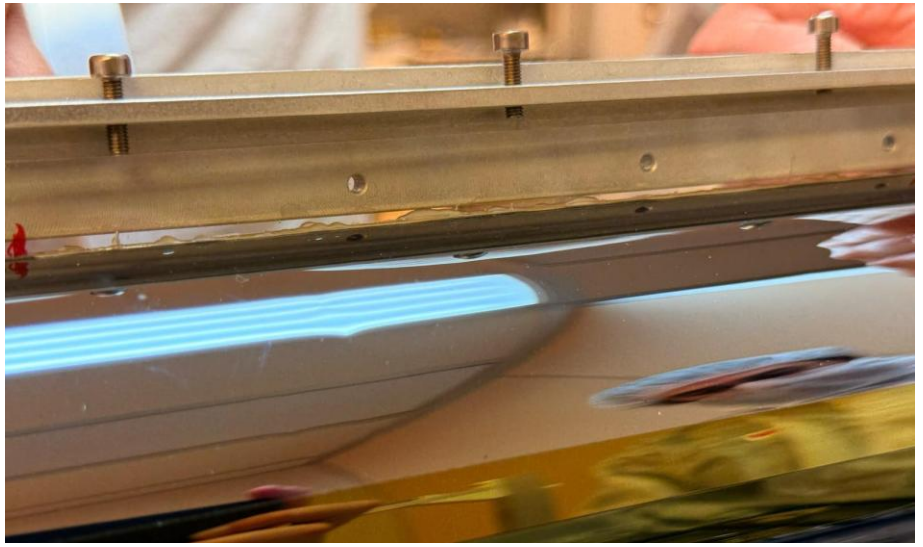
S2 used for large-size dummies

- Visual inspection and cleaning of the single sensors
- Sensor alignment
- Tape placement
- Half-layer bending
- Gluing of the local mechanical structure
- Removal of the half-layer from the mandrel
- Start of the half-barrel assembly



We are still optimising the gluing tools*



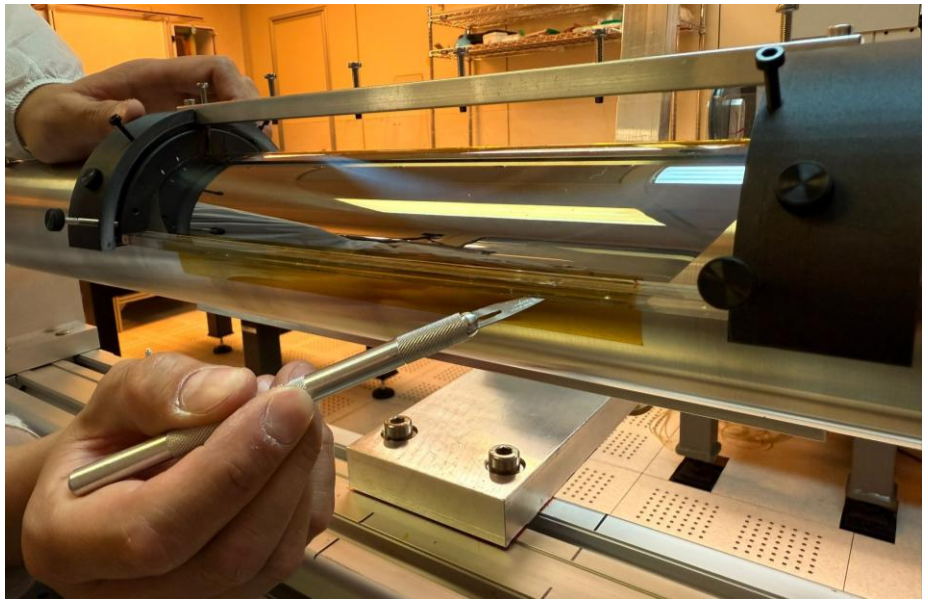


*the final ones have to fit with the presence of the FPC and wire bondings

S2. Bare sensors + tape: 6° step

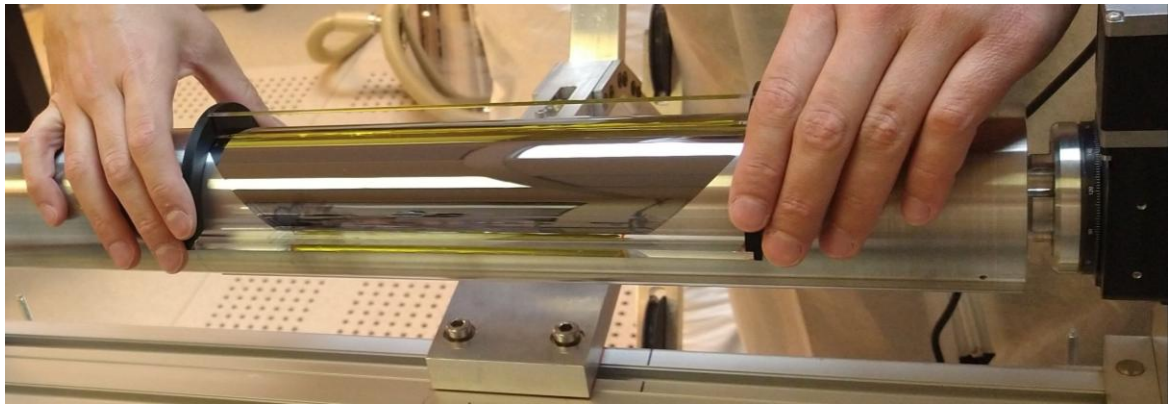
S2 used for large-size dummies

- Visual inspection and cleaning of the single sensors
- Sensor alignment
- Tape placement
- Half-layer bending
- Gluing of the local mechanical structure
- Removal of the half-layer from the mandrel
- Start of the half-barrel assembly



The removal step merges with half-barrel assembly for the prototypes with carbon foam/fibers supports (slide 16)

This removal procedure of single half-layer is possible for **temporary 3D-printed and plexiglass supports**



Summary table of half-layer attempts

Conditions:

- 2 half-moon shaped L0 (or L1);
- 3D-printed or plexiglass longerons and 3D-printed half-rings;
- mandrel produced on our workshop

#	Size	Dates	Outcome	Notes
1	**L0**	25/11/2024 26/11/2024	☹	Breakage of the second silicon piece during the Bending
2	**L0**	13/01/2025 31/01/205	☺	
3	**L0**	24/03/2025 28/03/2025	☹	A silicon piece already broken from the transport box (before tape connection)
4	**L0**	03/04/2025 10/04/2025	☺	
5	**L1**	28/04/2025 06/05/2025	☹	Both silicon pieces broke during the half-ring holder placement → gluing tool modifications: more stability and safety margin from the senso
6	**L0**	26/05/2025 03/06/2025	☺	First usage of new gluing tools for SVT

General comments and results

The full procedure takes 2.5-3 work-days for a half-layer

- 1 night : to set the kapton tape and minimise the trapped air bubble;
- 1 night : glue drying and polymerisation;

- To improve the automation of relative alignment btw two sensors (2° step):
  - At moment, it is an iterative step performed only by one technician (S. Martinadonna)
  - BEST PITCH VALUE: ~50 μm
  - Best pitch value to be established by means of tracking simulation (dead zone)

- About gluing (4° step):
  - Additional improvements on the gluing tools made after these attempts with silicon dummies and temporary supports;
  - Next validation of gluing tools at L1 radius;
  - Right amount of glue to be revised with final materials (carbon foam) of local support structures;

(Tentative) IB prototype production plan for L0-L1

JUL 2025

Prototype	Components	Goal
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
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
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

Table from Frascati meeting

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

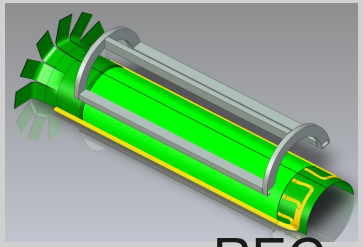
(if yes, needs for design&simulation, procurement and machining)

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

1st campaign on IBL01_P3 and 2nd campaign on IBL01_P4 of thermal tests will be performed using Pavia's climate chamber
→ In contact with the Pavia team for the transportation and test plans

Delivery dates of IBL01_P3-5 depend on availability of supports of carbon foam

Material procurement (updated)

Silicon dummy pieces	4 L0 - 4 L1	**Spares under procurements**
Heaters	2 L0 - 2 L1	Production completed: 4 L0 - 4 L1- 8 L2 Available in Bari
Pad sensors	[2 L0 - 2 L1 - (4 L2)] x 2	If two half-barrels (16 pad sensors = 16 wafers) → no spares
ER2 sensors	2 L0 - 2 L1 - (4 L2)	Only one half-barrel No spares
Support structure	**Materials**	**Components**
Carbon foam LEC  REC	**Foam procurement** - Allcomp K9 (standard density, 200-260 kg/m3) → Need to organise a joint purchase (maybe with ATLAS) - Carbon RVC Duocel (density 45 kg/m3, PPI 100) → Company in USA, but possible purchasing from Europe → A small amount is **on delivery** (thanks to Nikki-Berkley) **Foam shaping:** collecting the procedure details from CERN colleagues - Genova INFN → First objects with available POCOfoam - Berkley (Nikki) or U.K. (George) → Expressed availability - Local workshop → To be found and it requires material for attempts	Half-ring on LEC Longerons and half-ring on REC
Carbon fibre	- Carbon fleece: wet-laid non woven carbon fibre veil (8 g/cm2) - Outer shell: carbon fibre → Type of carbon fibre to be defined (Padova) **Carbon fibre production** - Producer to be identified (Padova)	Outer shell

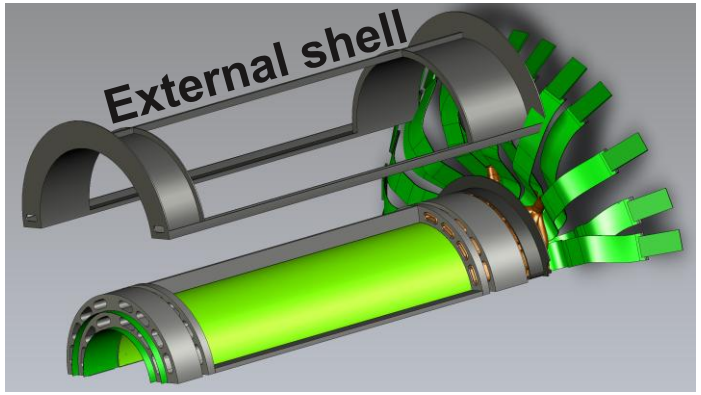
PAD and ER2 prototyping

Prototype	Components	Goal	Date
IBL012_P6/7	• 2+2+4 ER2 pad wafer L0+L1+L2 sensors (x 2 HB?) • L0+L1+L2 local support structures • gloabal support mechanics (advanced design) • FPCs (advanced design) • air distribution inlet & outlet (advanced design)	• first complete IB HB prototype w/o sensors • including test of wirebonding to FPCs • final test on HB support mechanics • possibly built 2 complete HBs (to allow HB mechanical support matching test)	2026/07
IBL012_P8	• 2+2+4 ER2 wafer L0+L1+L2 sensors • L0+L1+L2 local support structures • mechanics, FPCs, cooling (~final/advanced design)	• complete IB HB prototype w/ sensors • qualification model w/ bent sensors for cooling + powering/DAQ/DCS finalisation	2026/10

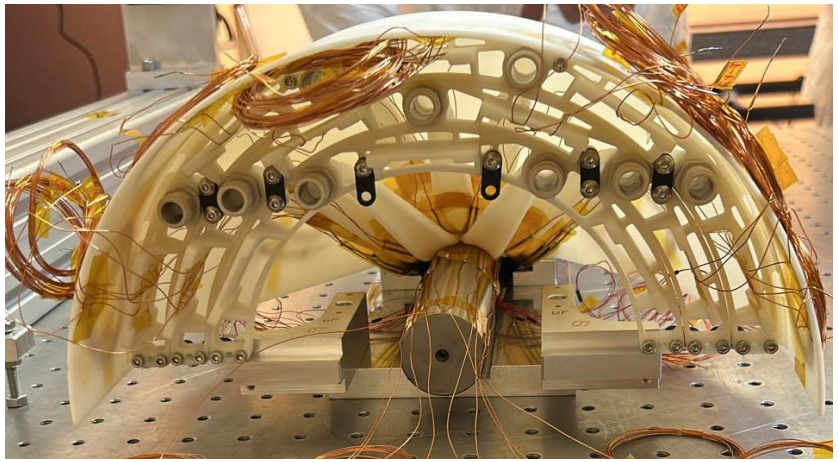
Start of the half-barrel assembly

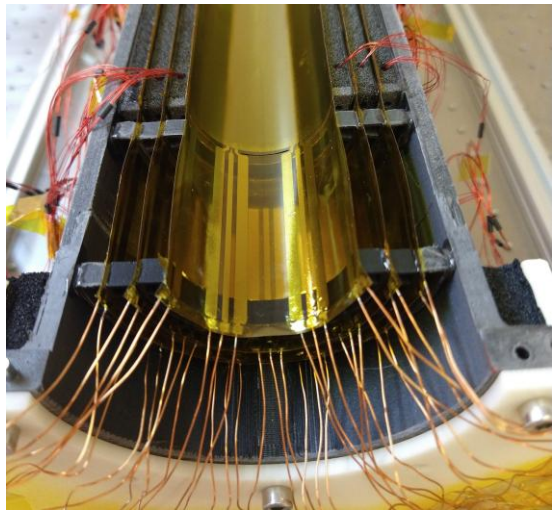
Half-layer with ultra-light supports is not self-standing mechanical configuration

- **Shell external** to the half-barrel;
- The removal from the mandrel and half-barrel assembly are merged.



The procedure is the same developed for ITS3 and used in Bari to assembly ITS3 prototypes ITS3 TDR





Half-barrel assembly procedure steps:

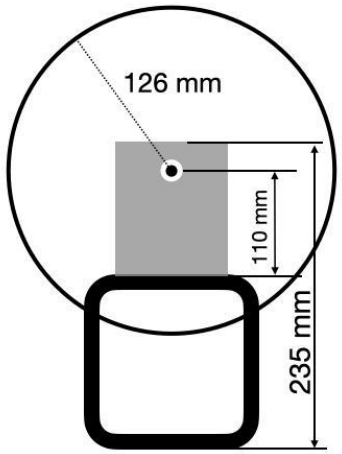
1) L1 half-layer assembly (seen before);
2) **External shell** gluing on L1;
3) {shell+L1} removal from mandrel;
4) L0 half-layer assembly;
5) {shell+L1} gluing on L0;
6) {shell+L1+L0} removal from mandrel

(Regarding ITS3-BBM6, see also ePIC Italia meeting 14 March)

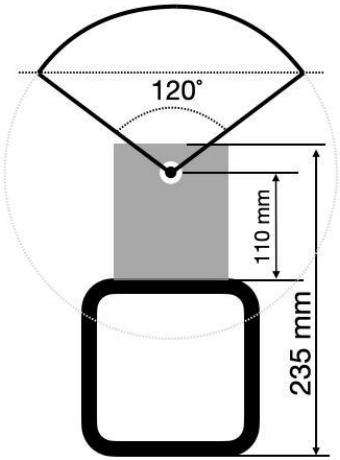
Proof of concept for a Quarter-Layer 2 bending

L2 radium (126 mm) → half-layer is covered by 4 sensors

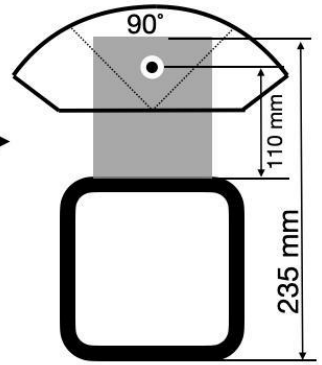
An exact scaled copy of actual bending setup for L2 is not compatible with bonding machine in Bari, but…



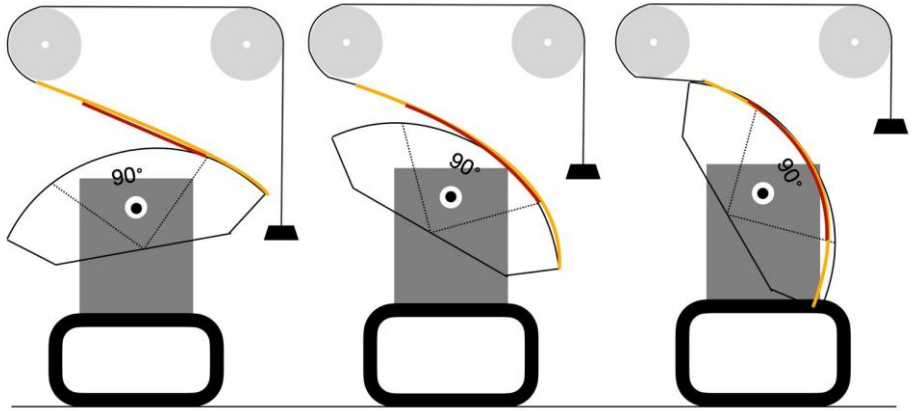
Problem!
Radius too big for the bonding machine



Reduced angular coverage



Displace the rotation axis from the center of the circumference



People are welcomed in the open discussion

CONCLUSIONS

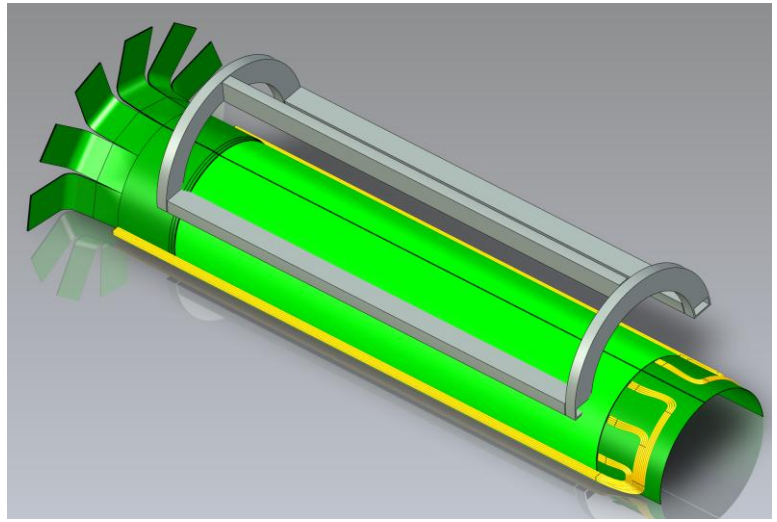
- Updates on:
  - L0-half-layer assembly → **well-mastered ☺**
  - L1-half-layer assembly → **to be verified soon using new gluing tools**
  - Procurements of the materials and final tools → **ongoing**
- Half-barrel assembly (to start) → **ITS3-like procedure**

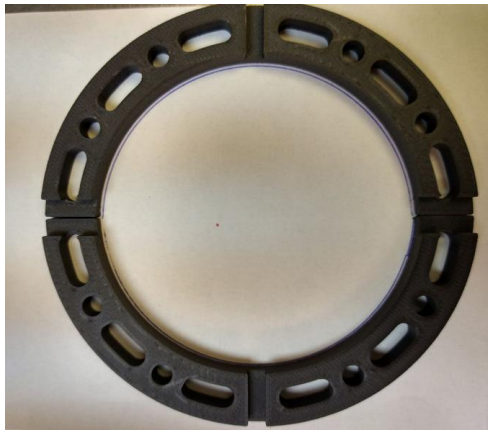
Back-up

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)



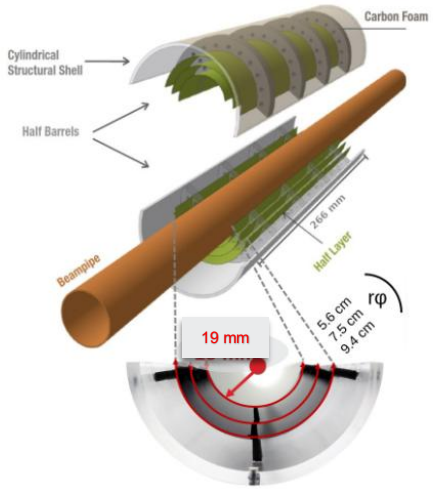


Last attempts have plexiglass longerons

A 3D-printed epoxy copy made @Bari

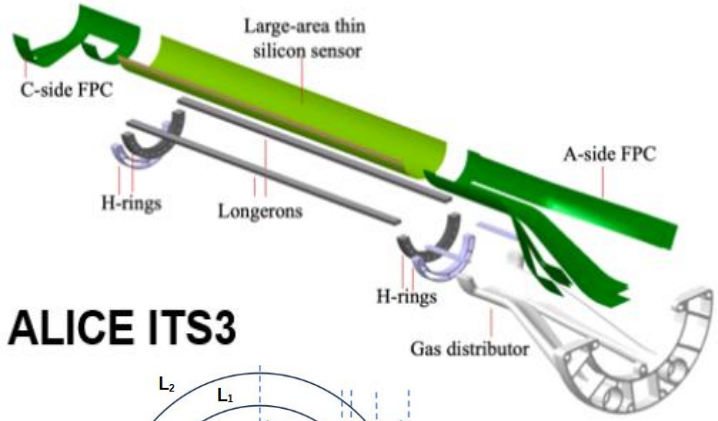
From ALICE ITS3 to ePIC SVT IB layout

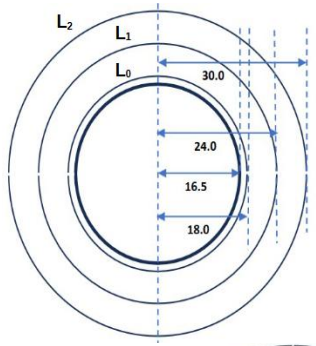
ALICE ITS3 detector as basis concept.



Common key ingredients:

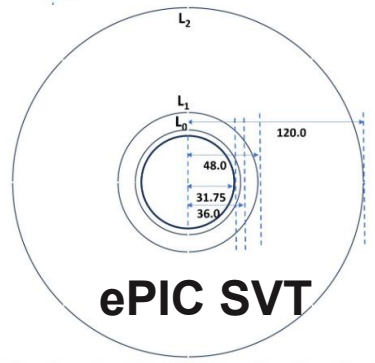
- Wafer-scale MAPS chips
  (65 nm CMOS, thickness ≤ 50 μm)
- Chips bent in cylindrical shape at target radii
- Ultra-light carbon foam structures
- Air cooling





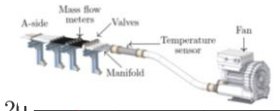
Need to adapt it to the ePIC SVT geometry:

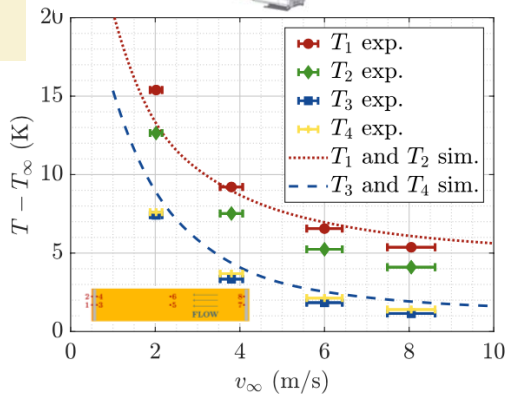
Z sensor length (mm): 266
L0 radius (mm): 38
L1 radius (mm): 50
L2 radius (mm): 126



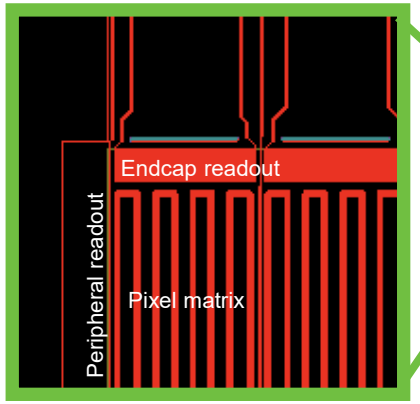
Preparation for the mechanical characterization

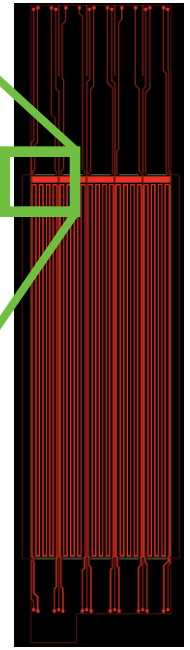
3rd campaign on IBL01_P5: «Air-based cooling performance study using a wind tunnel"

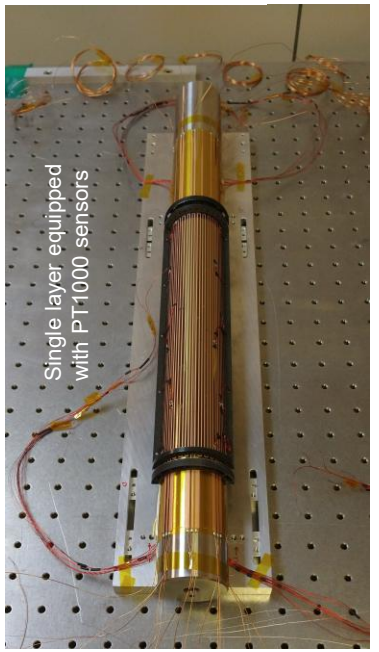




- Preliminary studies by ALICE ITS3:
  - done in ITS3 with BBM3 model
    → Results reported in the ITS3 TDR
  - ongoing on the new advanced model (ITS3-BBM6):
    - More precise sensor powering values
    - Air distribution closest to the final one
    - More precise temperature measurements (PT1000)

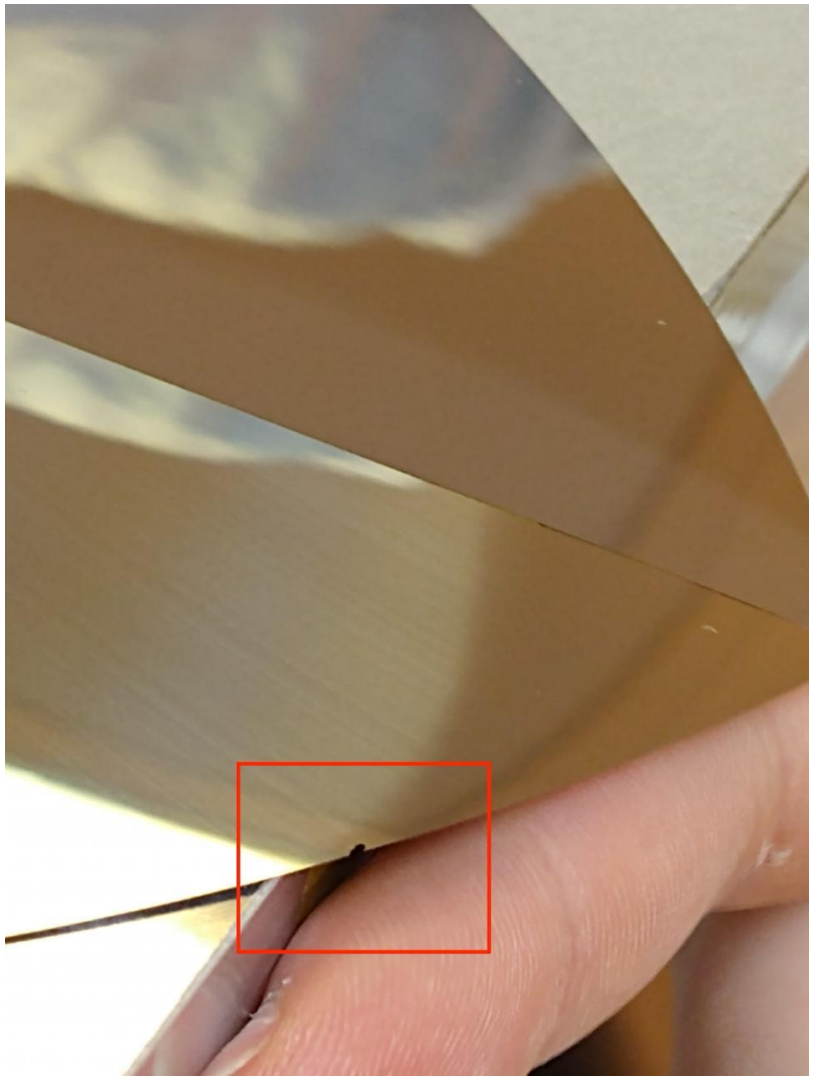




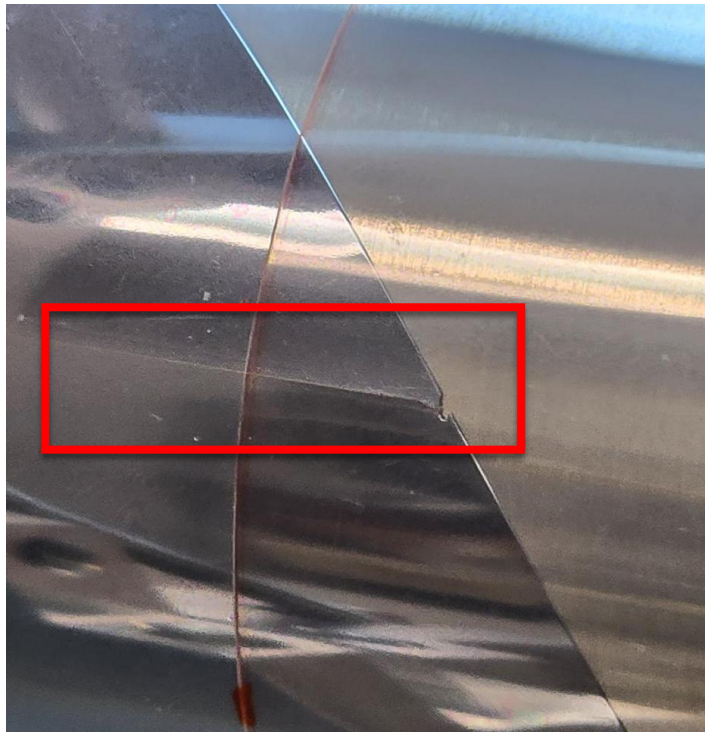


- **ITS3-BBM6** was assembled in Bari (experience acquired)
- **Similar model as and studies foreseen for the SVT**
  - Heaters under production by R. Oliveira

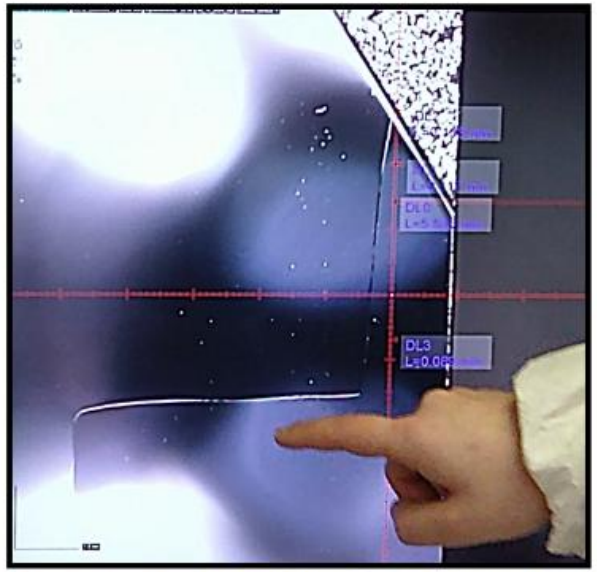
Break during the bending



The edge defect caused the break during the bending



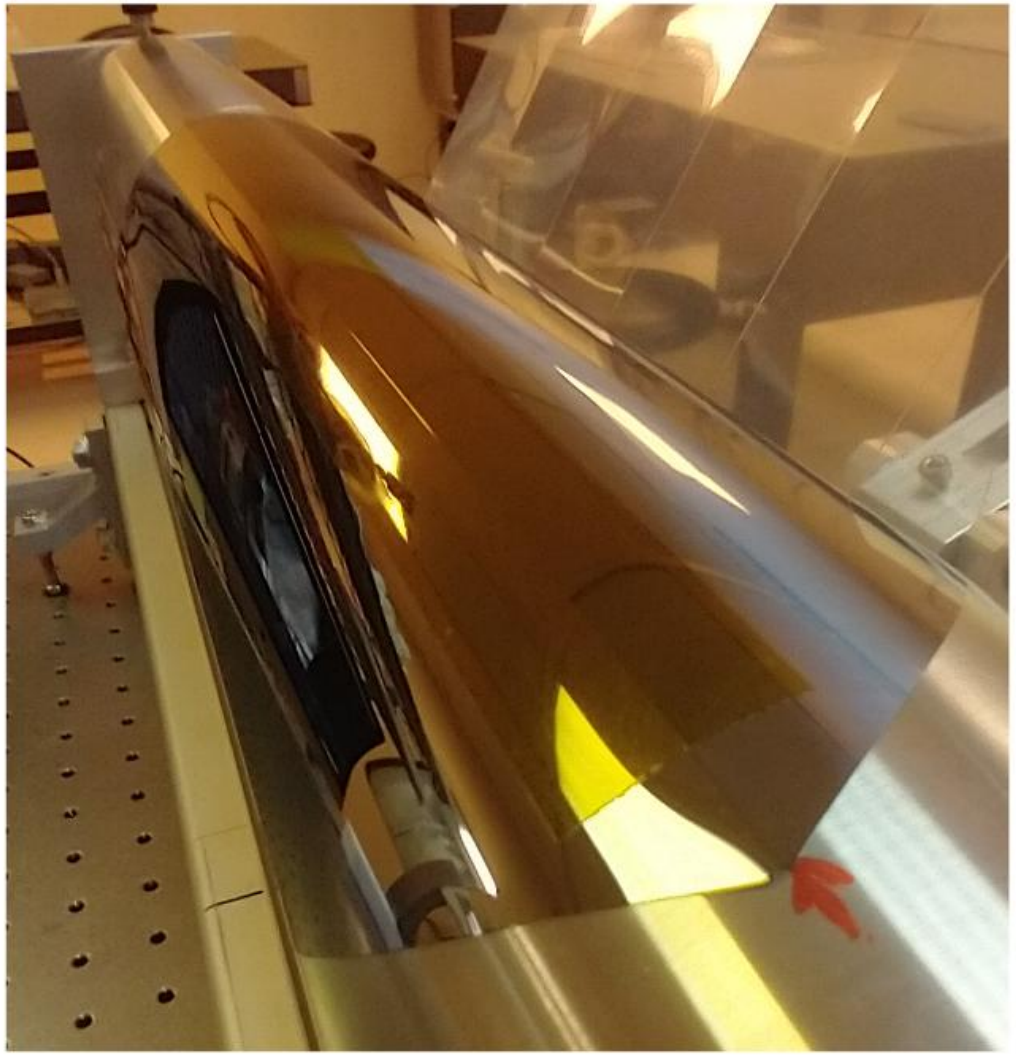
SVT-L0 Half-layer attempt n° 3: pictures



Crack stopped during bending procedures using microscope (not easily visible by eye).

Broken silicon pipe found in the same box
- Don't stack many silicons in the same box
- Visual inspection before each assembly

Discovered fracture was covered by extra kapton tape



SVT-L0 Half-layer attempt n° 3: pictures

Extra tape was not sufficient. We suspect that the discovered fracture was the source of the successive break in the picture (see detail in red box)