Progress on

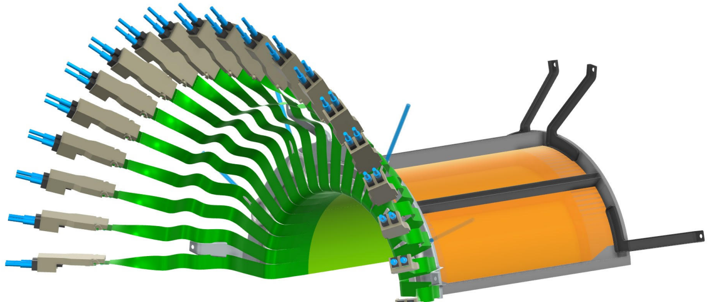
SVT IB prototyping

On behalf of INFN SVT-IB team

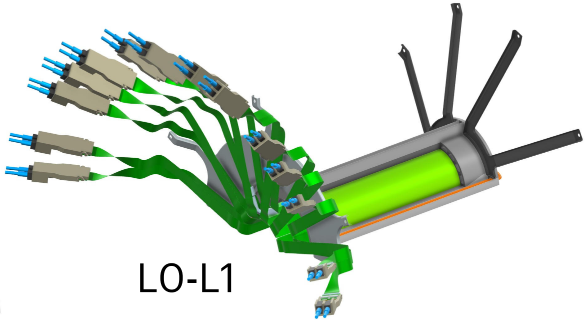
Bari, Padova, Pavia, Trieste, TIFPA

Outline

- L0-L1 half-barrel prototyping
- L2 half-barrel assembly procedure
- Global mechanics prototyping and integration
- FPC design and characterization
- Thermo-mechanical studies



L2



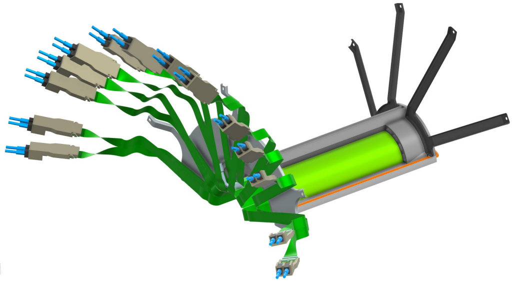
L0-L1

SVT winter work fest
15-19 December 2025, Oxford
https://indico.bnl.gov/event/30334/overview

Incremental Preliminary Design and
Safety of the ePIC MAPS Tracker
27-29 February 2026, Online
https://indico.bnl.gov/event/30868/

Progress on SVT IB prototyping

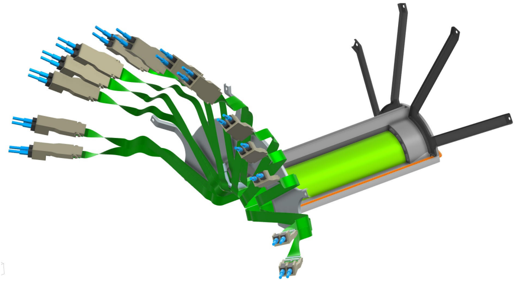
L0-L1 half-barrel prototyping (@Bari)



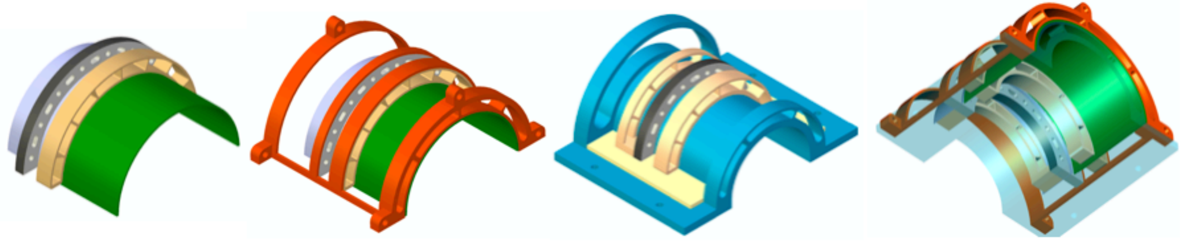
Sensors alignment and joining	☑
Joint sensors bending	☑
FPC to sensors interconnection	⟳
Local support structures gluing	⟳
Services integration in layer	⟳
L0-L1 half-barrel assembly	⟳
L0-L1 half-barrel integration to L2	⟳

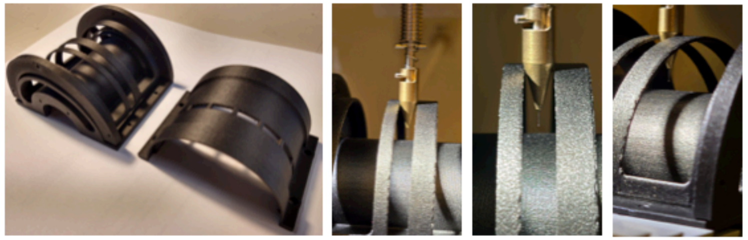
Progress on SVT IB prototyping

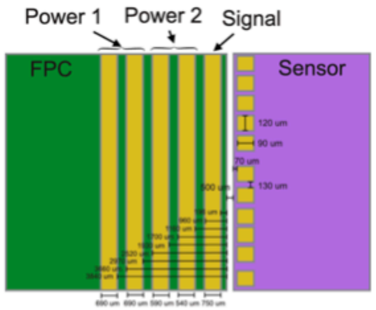
L0-L1 half-barrel prototyping (@Bari)

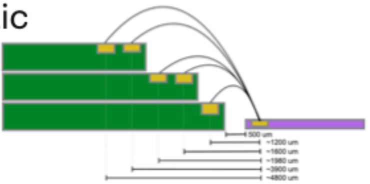


- **Sensors alignment and joining** ✓
- **Joint sensors bending** ✓
- **FPC to sensors interconnection** ↻
- **Local support structures gluing** ↻
- **Services integration in layer** ↻
- **L0-L1 half-barrel assembly** ↻
- **L0-L1 half-barrel integration to L2** ↻





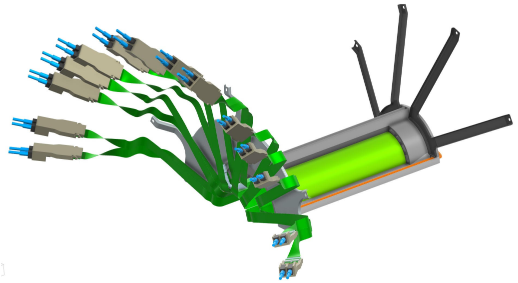




- Definition of best loop shapes and semi-automatic procedure for wire-bonding over bent surface
- Assessment of wire-bond pull-force variation following extended air-flow exposure
- Done in the context of ITS3 but valid for SVT-IB

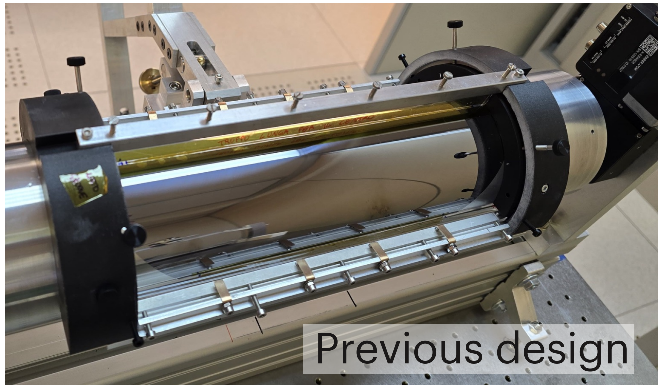
Progress on SVT IB prototyping

L0-L1 half-barrel prototyping (@Bari)

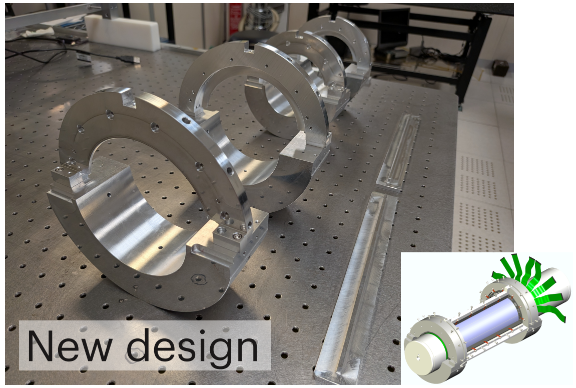


- **Sensors alignment and joining** ✓
- **Joint sensors bending** ✓
- **FPC to sensors interconnection** ↻
- **Local support structures gluing** ↻
- **Services integration in layer** ↻
- **L0-L1 half-barrel assembly** ↻
- **L0-L1 half-barrel integration to L2** ↻

- New design compatible with FPC on LEC and REC sides
- Production completed → Functionality to be verified

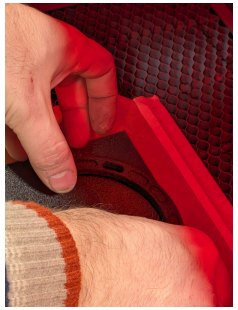


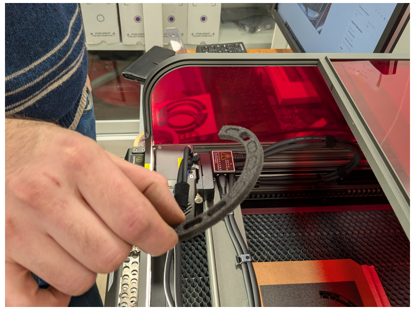
Previous design



New design

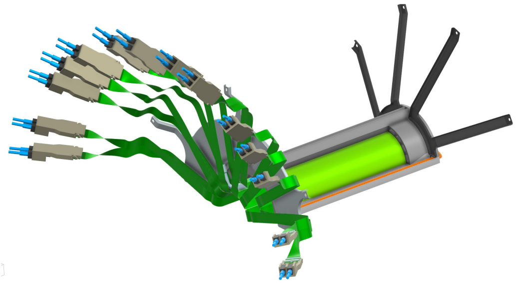
- Exploring precise carbon foam cut using a low-power laser





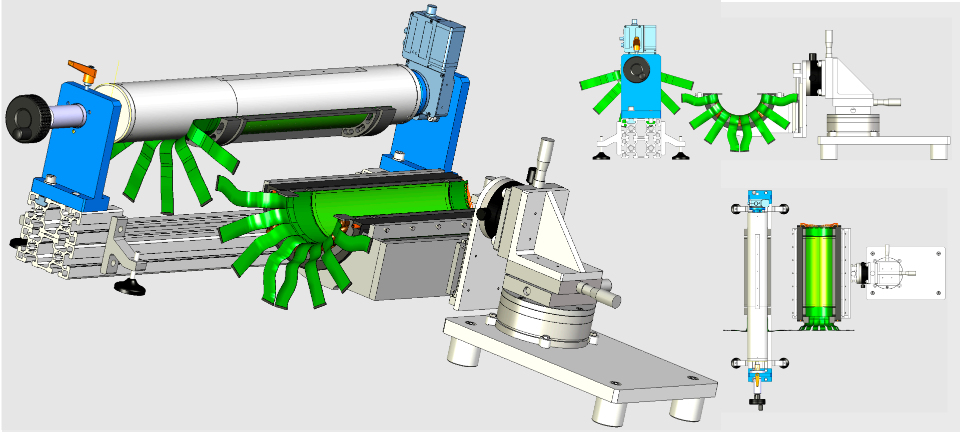
Progress on SVT IB prototyping

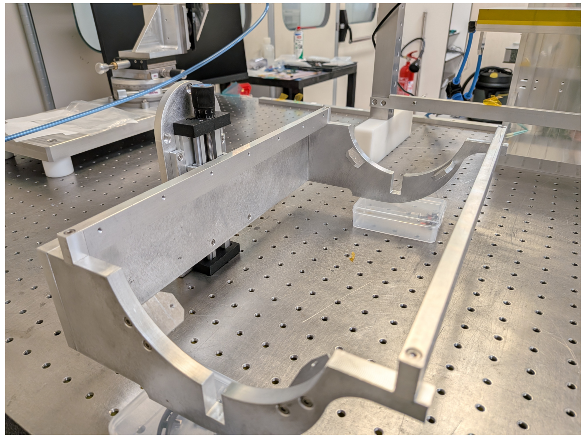
L0-L1 half-barrel prototyping (@Bari)



- **Sensors alignment and joining** ✓
- **Joint sensors bending** ✓
- **FPC to sensors interconnection** ↻
- **Local support structures gluing** ↻
- **Services integration in layer** ↻
- **L0-L1 half-barrel assembly** ↻
- **L0-L1 half-barrel integration to L2** ↻

- Layer-to-layer or layer-to-shell gluing tool for precise alignment
- Production competed → Functionality to be verified





Progress on SVT IB prototyping

L0-L1 half-barrel prototyping (@Bari)

Prototype	Components	Goal	Delivery target date
IB-HB01-M1	L0/L1 sensors: blank silicon pieces LSS: 3d printed L1COS: NOT needed, LSS self-supporting FPC: NOT included	Finalize half-barrel assembly tooling and procedures	Completed in November 2025
WB-M01	L0/L1 sensors: MOSS fraction (length to fit the ITS3 L1 radius) LSS ans L1COS: 3d printed in one single object FPC: re-shaped sample of SVT FPC from Padova	Study the eventual possible of continuous air-flow over the wire-bonding	April 2026
IB-HB01-M1.2	L0/L1 sensors: (half-mooned) blank silicon pieces LSS: carbon foam (PocoFOAM, no fleece) L1COS: 3d printed FPC: NOT included	First assembly with carbon foam LSS + Preliminary studies in climate chamber	Mid May 2026
IB-HB01-M2	L0/L1 sensors: blank silicon pieces LSS: carbon foam (ERG Duocel everywhere, w/ fleece) L1COS: carbon fiber composite FPC: NOT included	Temperature induced mechanical stress in climate chamber	June 2026
IB-HB01-M3	L0/L1 sensors: heaters + PT1000 sensors LSS: carbon foam (ERG Duocel + Alcomp K9 SD, w/ fleece) L1COS: 3d printed FPC: NOT included	Air-flow cooling effectiveness in a wind tunnel	July 2026

New entry: to speed up first advances on thermal chamber test

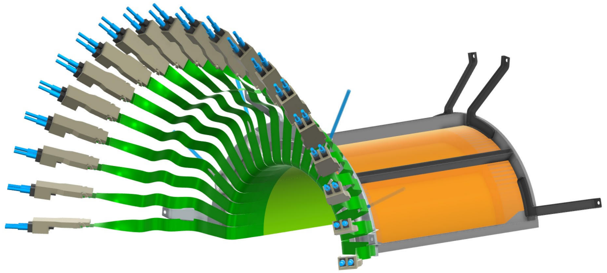
Delayed due to missing L1COS in carbon fiber
→ More in following slide

Delayed due to missing Allcomp K9 carbon foam → Good news from Nikki!

Legend
LSS = Local Support Structures | L1COS = L1 Cylindrical Outer Shell

Progress on SVT IB prototyping

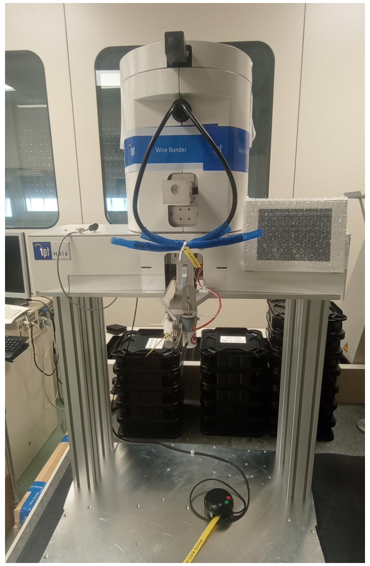
L2 half-barrel assembly procedure (@ Padova)

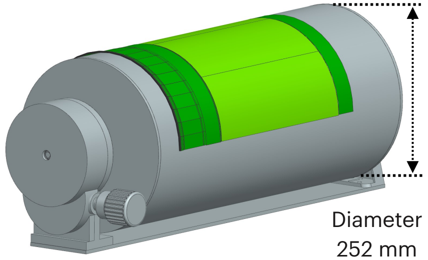


- Commitment to build L2 half-barrel agreed with INFN and SVT project
- Padova team focusing on the L2 assembly procedure and tooling
  - Bari, focusing on L0-L1, will equip for L2 assembly in a later stage
  - Padova, will equip for L0-L1 assembly in a later stage

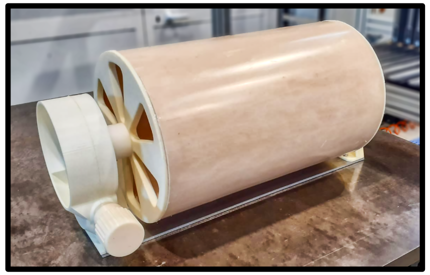
Wire wedge bonding machine

- Movements integrated in the head (custom build)
- Machine delivered! (mid-April) → Under installation





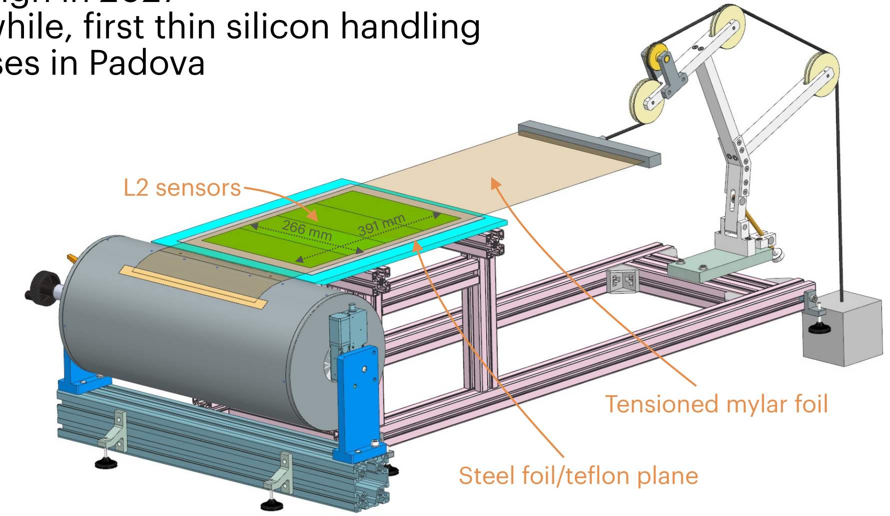
Diameter 252 mm



L2 mandrel 3D printed mockup

L2 assembly tooling

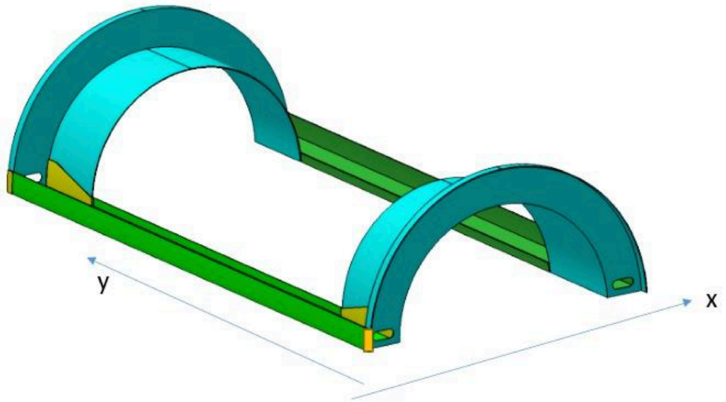
- Ideas on tooling/procedures for sensors alignment/bending developed
- Under revision following analysis of L0–L1 procedures during a visit to Bari
- Expected to be ready by the end of the year, to start prototyping campaign in 2027
- Meanwhile, first thin silicon handling exercises in Padova



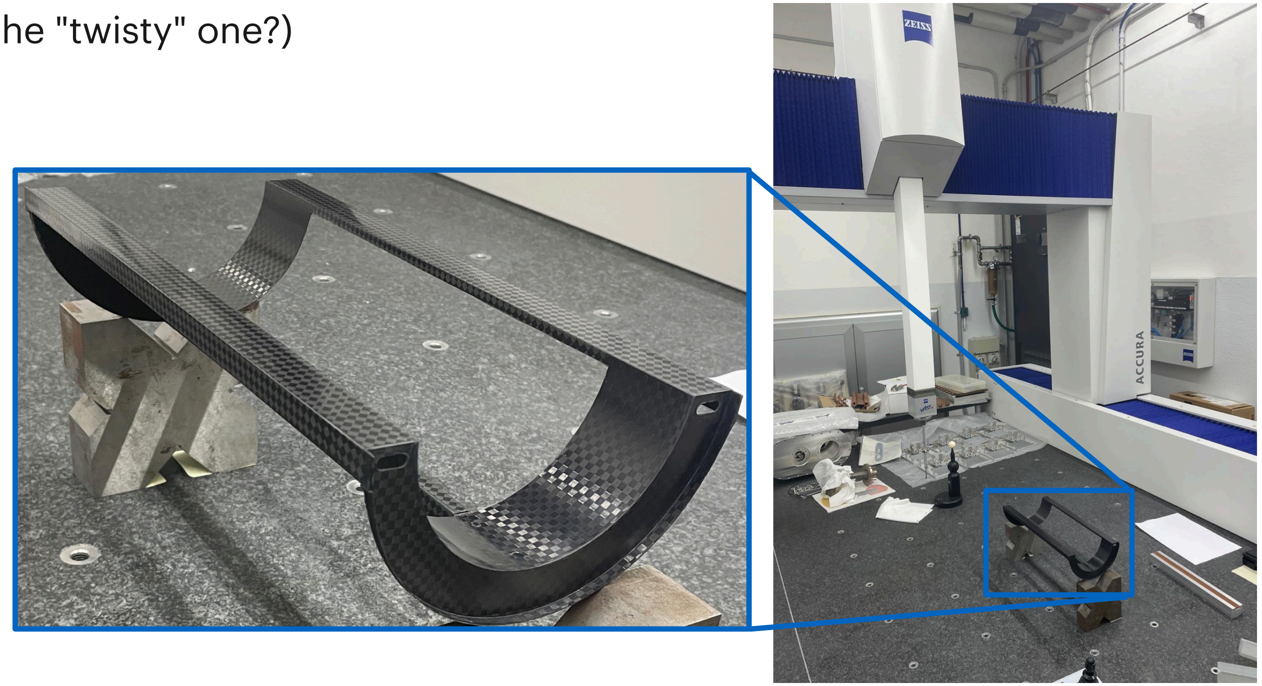
Progress on SVT IB prototyping

Global mechanics prototyping and integration (@Padova)

- SVT-IB global mechanics in advance status of design
  - First sample of L1 external shell in CCF received → Structure very “twisty”, looking for solution
    - Performing more measurements to identify required modifications (thicker longerons/half rings, full cylinder “à la ITS3”, spiral bands, cantilever design…)
    - Impact on prototype campaign programme:
      - move on using 3D-printed L1COS for M1.2 and M3
      - wait for a new version in CCF for M2 if modifications can be implemented in a short timeline (or try anyway the "twisty" one?)



Thickness < 0.5 mm but in the yellow regions

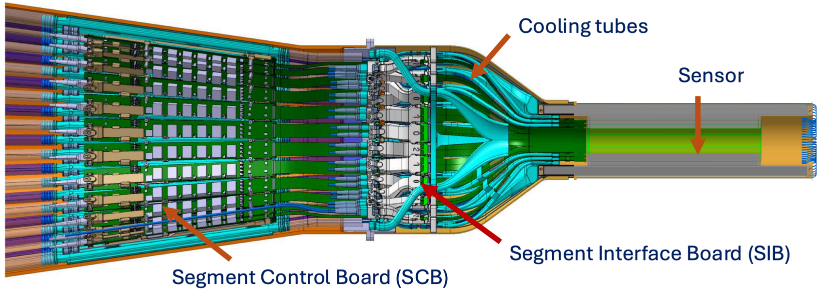


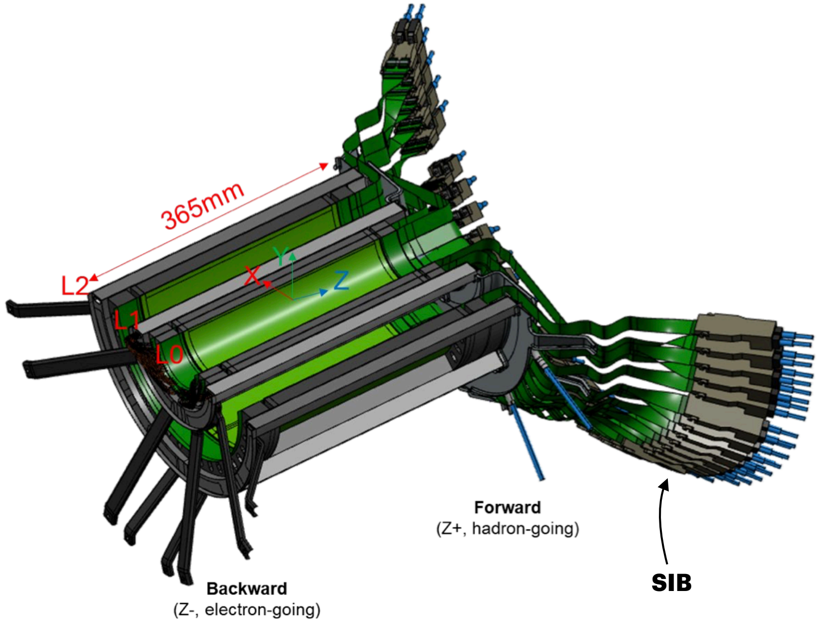
Progress on SVT IB prototyping

Global mechanics prototyping and integration (@Padova)

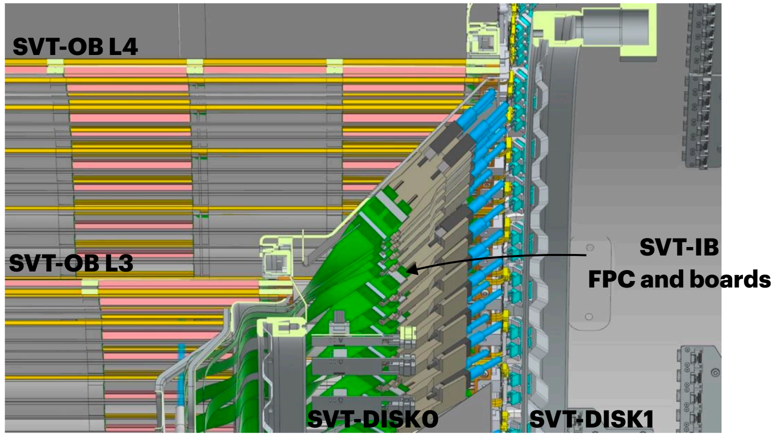
- SVT-IB global mechanics in advance status of design
  - First sample of L1 external shell in CCF received → Structure very “twisty”, looking for solution
- Significant effort spent in integration
  - Readout and powering chains, same of the ITS3, foresee FPCs and off-detector boards (SIB/SCB)
  - SIB (integrating optical transceiver) connected to sensors through FPC limited in length by signal attenuation (~30-40 cm) → difficult integration in the small available volume in front of the disks (hadron-going side)

ITS3 Readout and powering system



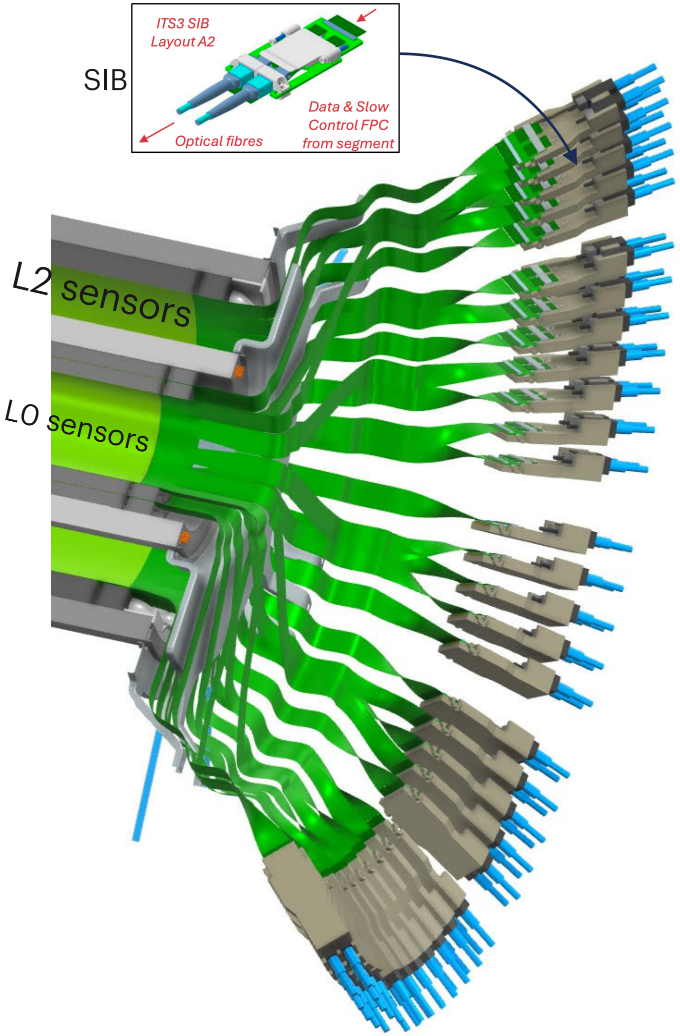


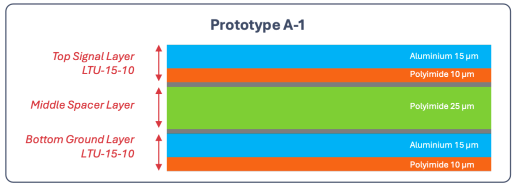
SIB integration in between Disk0 and Disk1

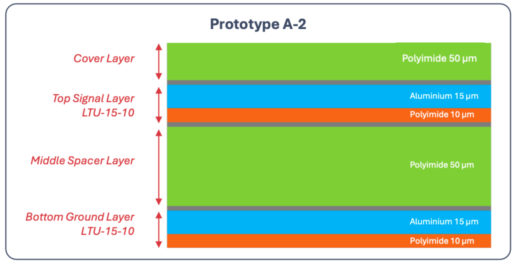


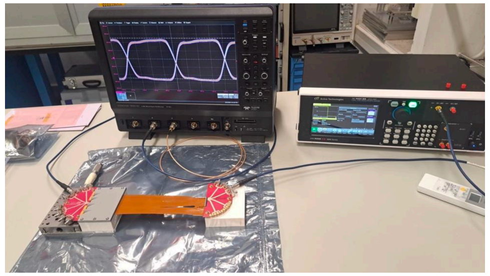
Progress on SVT IB prototyping

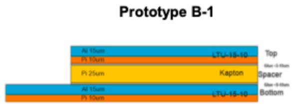
FPC design and characterization (@ Trieste)

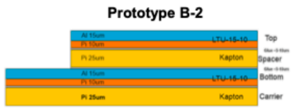


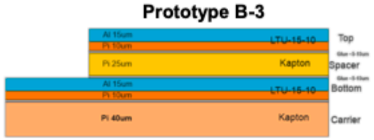








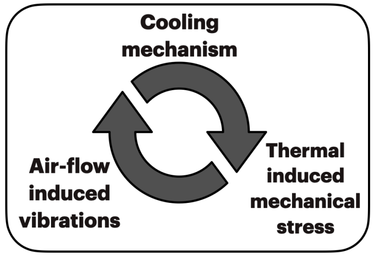




- Signal FPC from sensors to SIB
  - Two layer FPC, straight differential lines (data links and slow control) + ground plane, wire bonding pads, ~30-40 cm long
  - “standard” aluminum-polyimide based technology from LTU
- Prototypes A to investigate electrical properties
  - Two versions:
    A1 without cover layer and 25 µm middle spacer layer
    A2 with cover layer and 50 µm middle spacer layer
  - 5 test samples of each variant (18 cm length) and further sub-variants with nominal (100 Ohm) and ±10% trace width
  - Basic setup for signal integrity measurement available and working to acquire all needed instruments for full suite of tests (Eye-diagram, BERT, S-parameters, TDR)
- Prototypes B to test bending and bonding
  - Difference between versions:
    Presence/absence of bottom polyamide carrier
    Thickness of bottom polyimide carrier layer
  - 5 test samples for each prototype
- Prototypes A/B ordered → Shipped, en route to Trieste

Progress on SVT IB prototyping

Thermo-mechanical studies



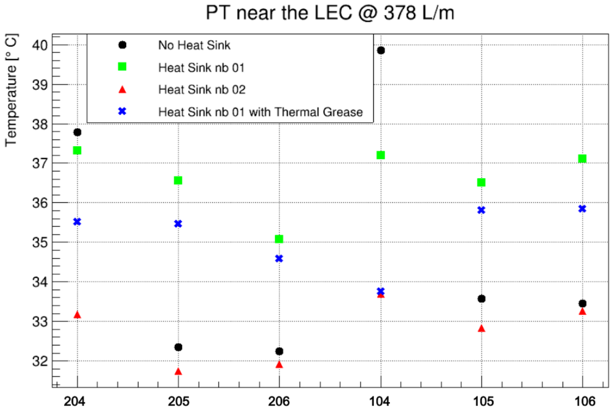
Cooling mechanism

Air-flow induced vibrations

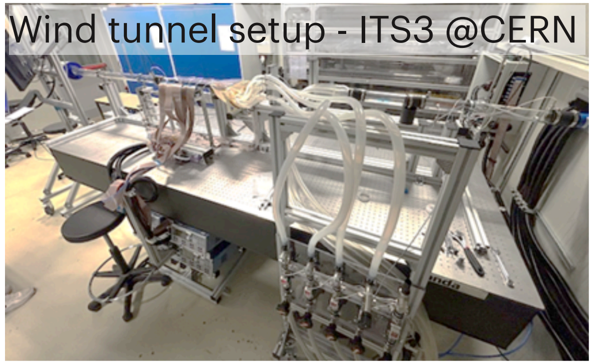
Thermal induced mechanical stress

Cooling mechanism

- Detector cooling based on **two mechanisms**:
  - **Air-flow** over the sensor surface (full detector) → Important to model air-ducts
  - **Conduction** between sensor integrated electronics (LEC) and high conductivity carbon foam (Half-ring) → Important to choose the proper material



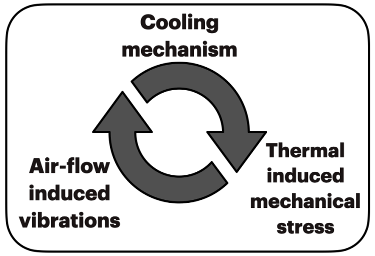
- **Preliminary** cooling studies (@Padova) progressing from planar tests with 3D-printed aluminum half-rings to an evolved bent setup using fiberglass with copper traces and aluminum/CFOAM HTC half-rings for comparison → Target June.


Wind tunnel setup - ITS3 @CERN

- **Advances prototype** (HB01-M3, @Bari) equipping heaters with improved power dissipation distribution and reference carbon foam materials for local support structures and most refined air-ducts design to be included in (close to) final configuration air cooling system (wind tunnel) → Target July

Progress on SVT IB prototyping

Thermo-mechanical studies



Cooling mechanism

Air-flow induced vibrations

Thermal induced mechanical stress

Thermal induced mechanical stress

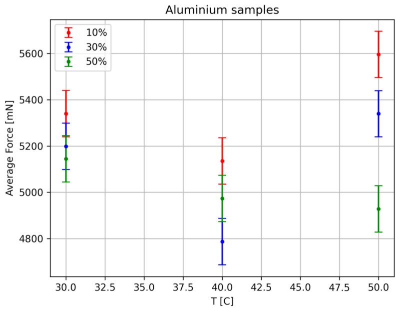
A **climate chamber** is intended to be used for mechanical stress studies induced by:

- Repetitive power cycles of the sensors during the years of operation → Non destructive controlled temperature/ humidity cycles
- Heating during the beam pipe bake out → Destructive thermal cycles to asses the max sustainable temperature

Two chambers available:

- Genviro 030LC - small volume (@Pavia)
- ACS DY110C - large volume (@Bari)

Same chambers used to perform aging measurements for other components like kapton adhesive tape (@Bari and @Pavia), through peeling force measurements

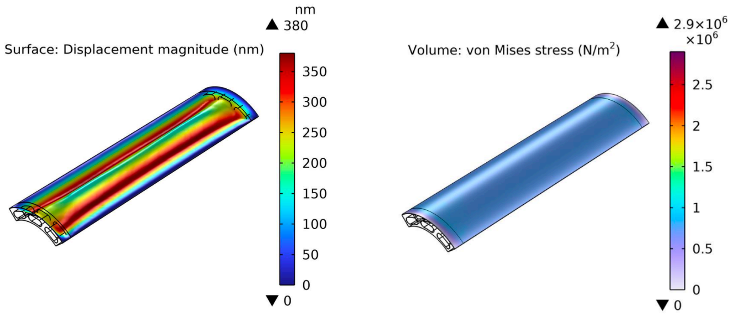


Air-flow induced vibrations

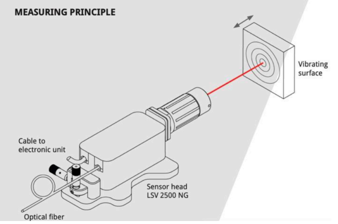
@TIFPA

Aeroelastic simulation for a quarter of layer:

- (CFD+FSI*) with turbulence modeled using RANS-SST, different inlet/outlet pressure conditions, and inlet air velocity at 8 m/s
- Ansys-Fluent for LES** to estimate pressure fluctuations and aerodynamic load on layers



Measurements to be performed using **interferometric system** (@University of Trento), a wind tunnel and dedicated SVT-IB prototypes



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*Computational Fluid Dynamics + Fluid–Structure Interaction

** Large Eddy Simulation

Progress on SVT IB prototyping

Summary

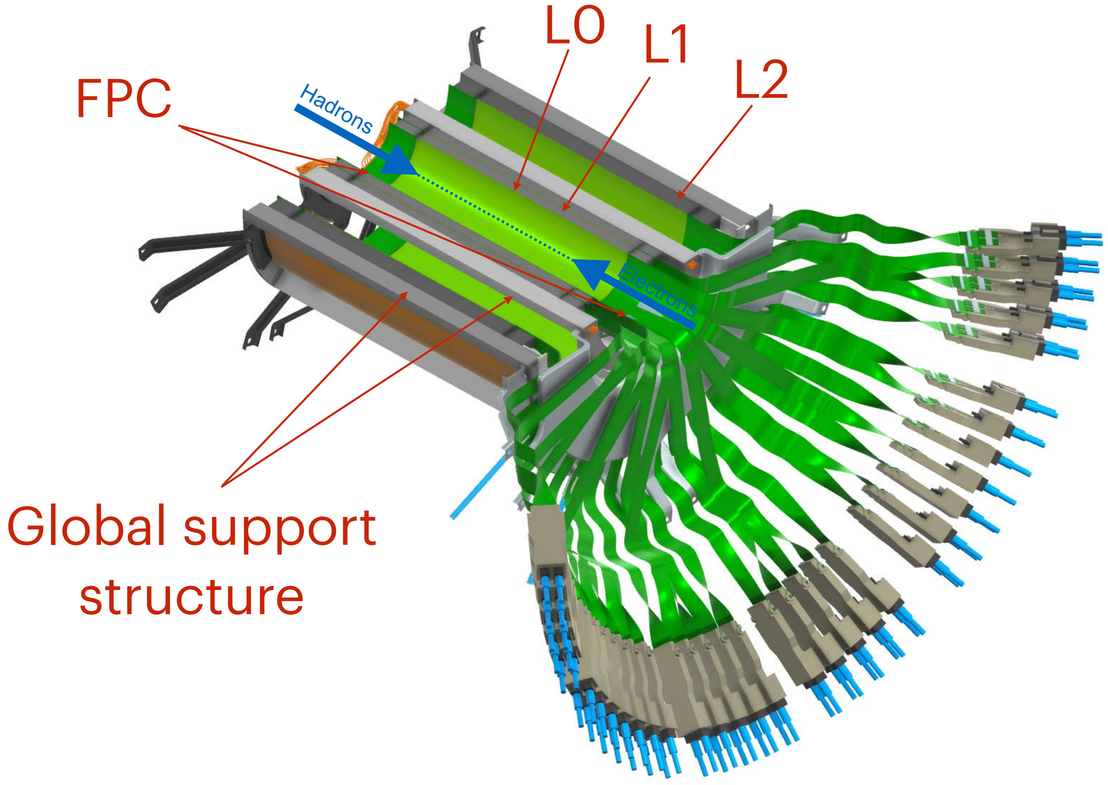
- L0-L1 half-barrel assembly
  - Tooling design and production in advance status
  - Defined prototyping campaign for 2026
  - Delay due to material procurement (CFC external shell, K9 carbon foam)
- L2 half-barrel assembly
  - Initial idea for bending under revision after comparison with L0-L1 tooling
  - Setup ready by end of the year
- Global mechanics prototyping and integration
  - First prototype (L1 external shell) received and found “twisty” → Working on solution
- FPC design and characterization
  - Qualification setup ready for basic check, under completion for full qualification
  - Prototypes for multiple verification produced
- Thermo-mechanical studies
  - Simulations and multiple setups for cooling system verification ongoing or under preparation
  - Thermal induced stress to be arranged using climatic chamber
  - Vibrational effect of air flow by ongoing simulation campaign and under definition setup for measurement

Extra material

Extra material - SVT IB concept

Basic ingredients:

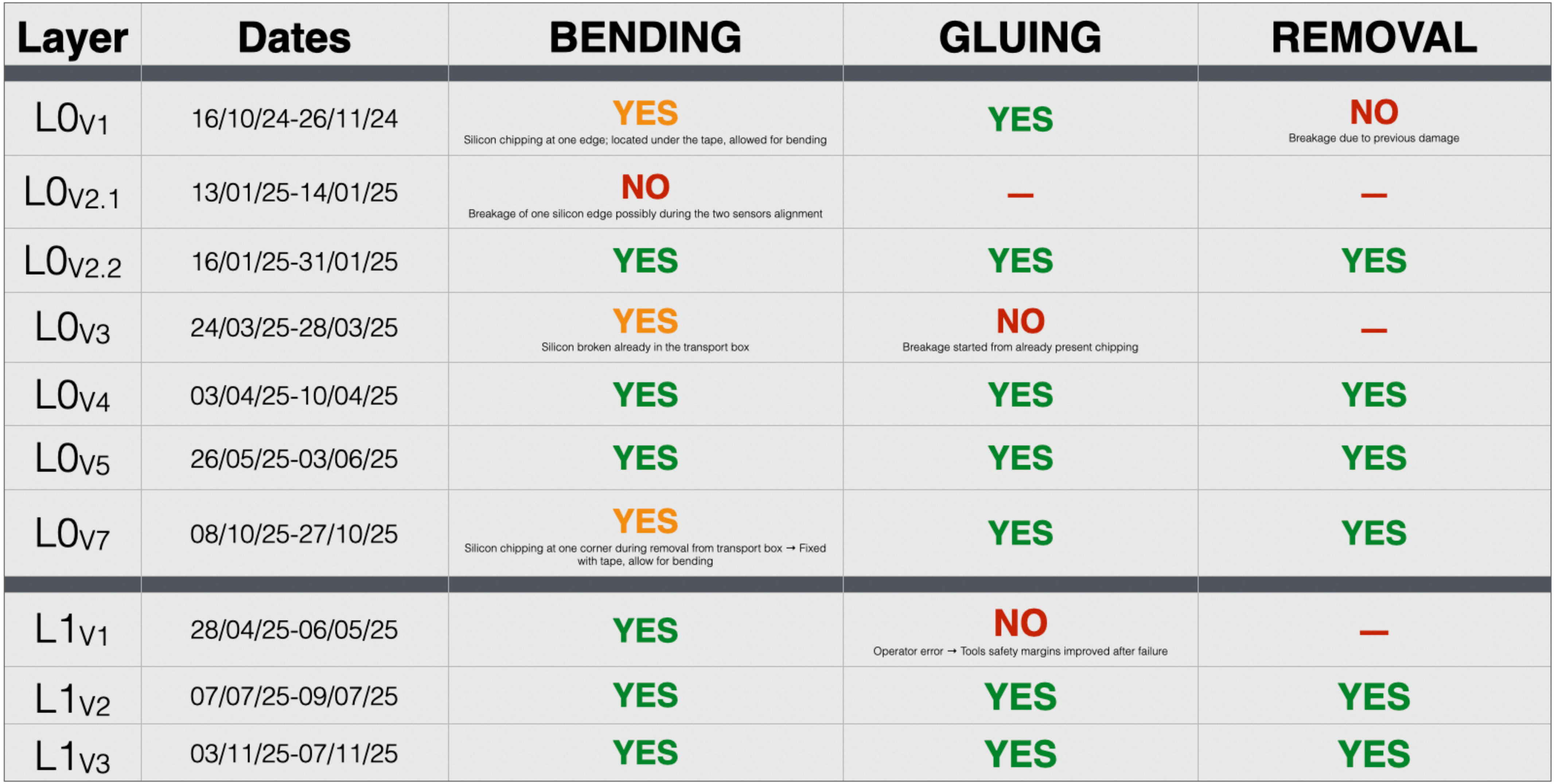
- Wafer-scale MAPS chips (ITS3 65 nm CMOS, thickness ≤ 50 μm)
- Chips bent in semi-cylindrical shape at target radii
- Ultra-light carbon foam/fiber structures
- Air cooling



Layer	Radii (mm)	Single sensor area (mm^2)	# of sensors for a half-layer
L0	38	266 x 58.7	2
L1	50	266 x 78.3	2
L2	126	266 x 97.8	4

Extra material - Progress on SVT IB prototyping

L0-L1 half-barrel prototyping (@Bari)



Layer	Dates	BENDING	GLUING	REMOVAL
$L0_{v1}$	16/10/24-26/11/24	YES Silicon chipping at one edge; located under the tape, allowed for bending	YES	NO Breakage due to previous damage
$L0_{v2.1}$	13/01/25-14/01/25	NO Breakage of one silicon edge possibly during the two sensors alignment	–	–
$L0_{v2.2}$	16/01/25-31/01/25	YES	YES	YES
$L0_{v3}$	24/03/25-28/03/25	YES Silicon broken already in the transport box	NO Breakage started from already present chipping	–
$L0_{v4}$	03/04/25-10/04/25	YES	YES	YES
$L0_{v5}$	26/05/25-03/06/25	YES	YES	YES
$L0_{v7}$	08/10/25-27/10/25	YES Silicon chipping at one corner during removal from transport box → Fixed with tape, allow for bending	YES	YES
$L1_{v1}$	28/04/25-06/05/25	YES	NO Operator error → Tools safety margins improved after failure	–
$L1_{v2}$	07/07/25-09/07/25	YES	YES	YES
$L1_{v3}$	03/11/25-07/11/25	YES	YES	YES

Used for **IB-HB01-M0** ($L0_{v5}$)

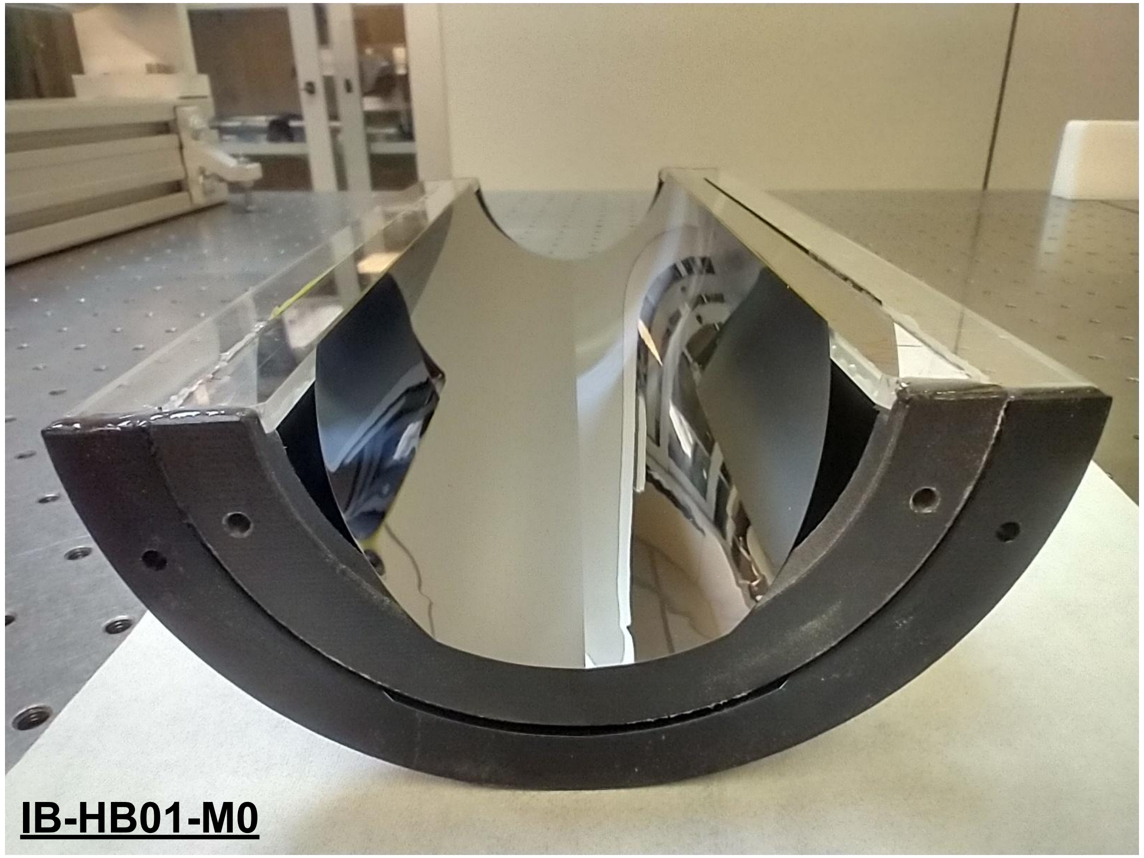
Used for **IB-HB01-M1** ($L0_{v7}$)

Used for **IB-HB01-M0** ($L1_{v2}$)

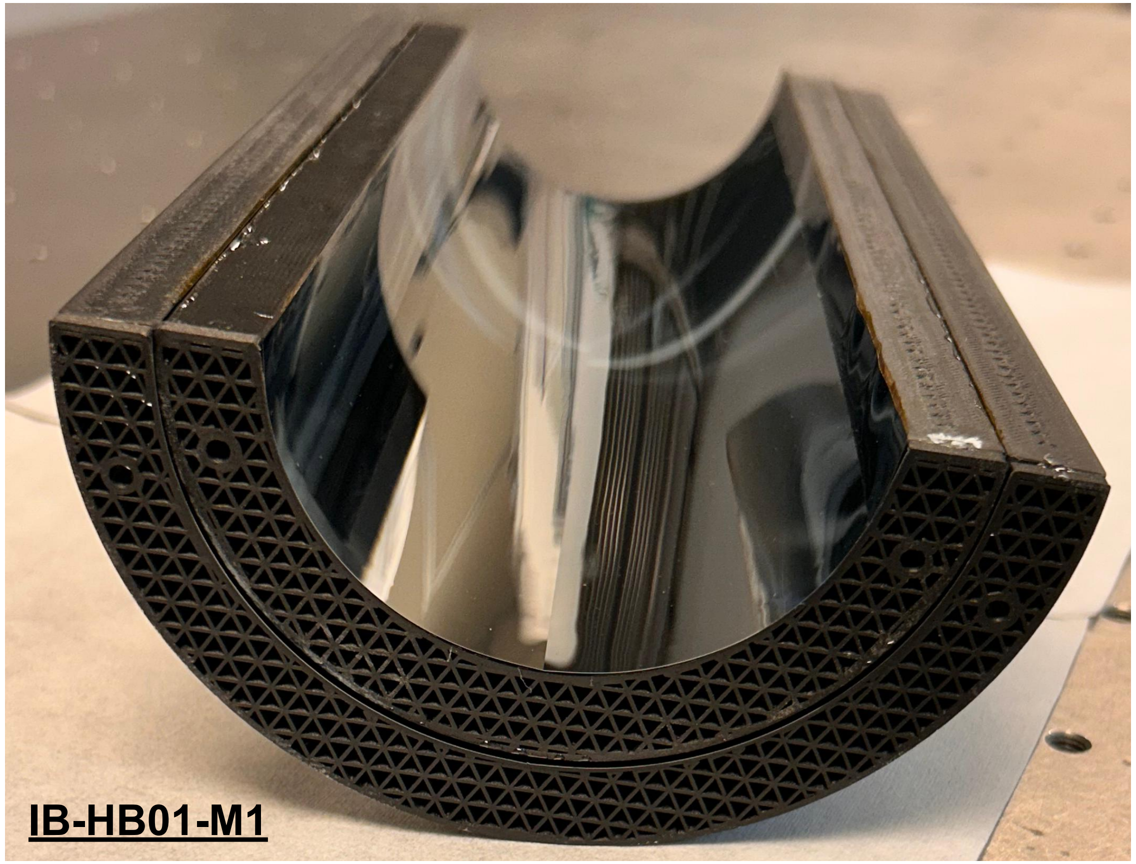
Used for **IB-HB01-M1** ($L1_{v3}$)

Extra material - Progress on SVT IB prototyping

L0-L1 half-barrel prototyping (@Bari)


IB-HB01-M0

First L0-L1 bare half-barrel prototype


IB-HB01-M1

Second L0-L1 bare half-barrel prototype

Extra material

Extra material - Progress on SVT IB prototyping

L0-L1 half-barrel prototyping (@Bari)

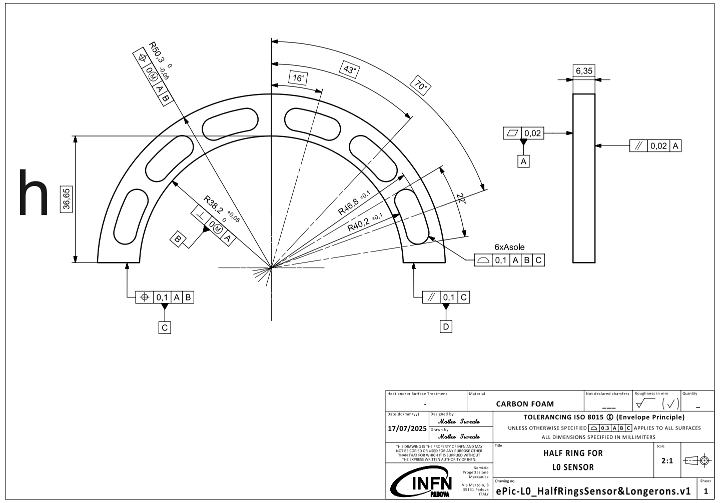
Prototype	Components	Goal	Target date
IB-HB012-M1	•2+2+4 ER2 pad L0+L1+L2 sensors •L0+L1+L2 local support structures in carbon foam (both ERG and Allcomp) •L0+L1+L2 FPCs •L0+L1+L2 air-ducts •Outer support shell to L1 and to L2 3d printed •IB global support mechanics 3d printed	• First compete integration including wire-bonding • Possible assembly of 2 HBs to allow mechanical matching	To be completed by September 2026
IB-HB012-M2	•2+2+4 ER2 L0+L1+L2 sensors •L0+L1+L2 local support structures in carbon foam (both ERG and Allcomp) •L0+L1+L2 FPCs •L0+L1+L2 air-ducts •IB global support mechanics 3d printed	• Qualification model integrating actual sensors for full system (cooling, powering, DAQ, DCS) characterization	To be completed by October 2026

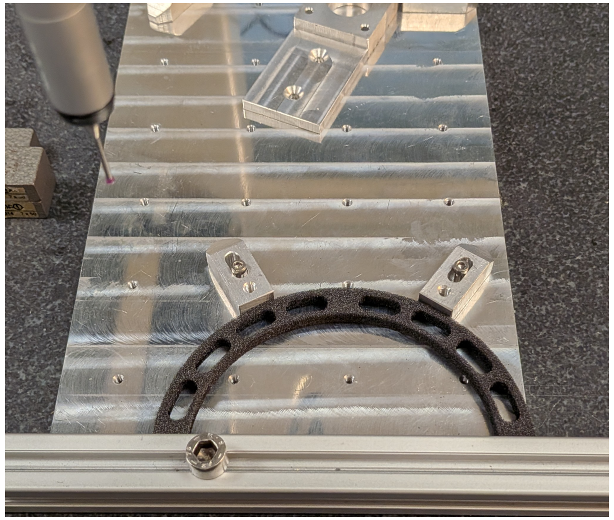
Extra material - Carbon foam laser cut

Duocel® RVC Foam Panel, 100 PPI, 3% relative density, 6.000”±0.06" x 6.000"±0.06" x 0.250"±0.01"

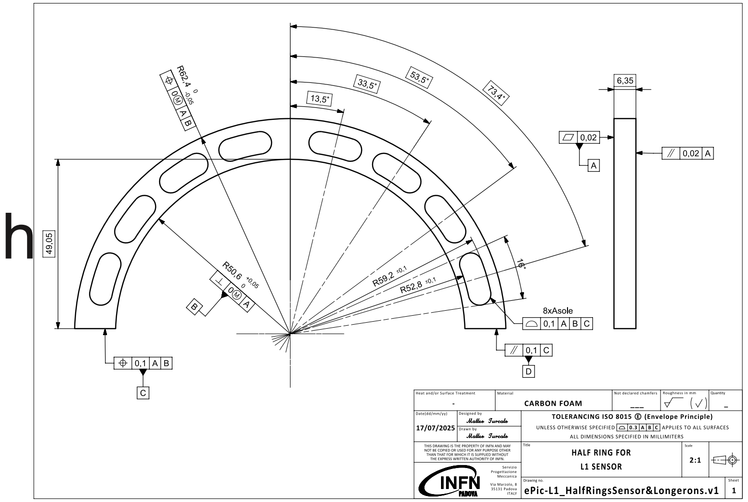
Extra material - Carbon foam laser cut

Duocel® RVC Foam Panel, 100 PPI, 3% relative density, 6.000”±0.06" x 6.000"±0.06" x 0.250"±0.01"





Measurements performed using the Mitutoyo CNC CMM touch-trigger probe, fixing the object under measurement using a double side adhesive tape (differently from the picture), to minimize any deformation.



	Internal diameter (mm)	External diameter (mm)	Distance between center of circumferences (in the laying plane)	Distance h (look in the table previous slide)
Disegno L0	38,2 ± 0,05	50,3 ± 0,05	0,0	36,65
HR-L0 #1	38,260	50,113	0,112	36,704
HR-L0 #2	38,316	50,165	0,248	36,635
Disegno L1	50,60 ± 0,05	62,40 ± 0,05	0,0	49,05
HR-L1 #1	50,648 ± 0,045	62,214 ± 0,085	0,095	49,065
HR-L1 #2	50,700	62,244	0,138	49,08

Extra material - Prototype campaign 2025-2026

WB-M01

ASSEMBLY PARAMETERS	
GOAL	Study the eventual reduction of bonding strength of continuous air-flow over the wire-bonding
Structures to be assembled	ITS3 L1 bonding region
Completion target date	April 2026

- Sensor and wires breakage during the first assembly attempt
- New attempt:
  - FPC prepared and bent
  - MOSS bent
  - Wire-bonding ongoing
- Next steps
  - Pull-force measurements for initial sample
  - Gluing to support structures and removal from mandrel
    - Trying to improve the quality of the support structures

Extra material - Prototype campaign 2025-2026

IB-HB01-M1.2 | IB-HB01-M2 | IB-HB01-M3

ASSEMBLY PARAMETERS	
GOAL	First assembly with carbon foam LSS + Preliminary studies in climate chamber
Structures to be assembled	L0 layer + L1 layer + L0/L1 half-barrel
Completion target date	Mid-May 2026

REQUIRED COMPONENTS AVAILABILITY		
Silicon pieces	TO BE CHECKED	x2 L0/L1 half-moon shaped blank silicon pieces
FPCs	NOT REQUIRED	—
Local Support Structures (LSS)	AVAILABLE	Carbon foam PocoFOAM, w/o fleece
Air ducts	NOT REQUIRED	—
L1 Cylindrical Outer Shell (L1COS)	CAN BE PRINTED	3d printed: material available and design under completion

Extra material - Prototype campaign 2025-2026

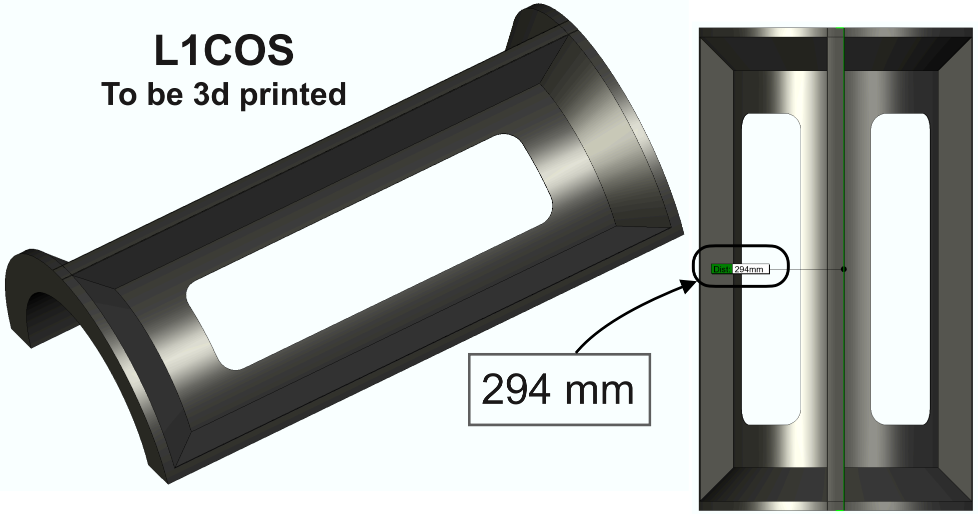
IB-HB01-M1.2 | IB-HB01-M2 | IB-HB01-M3

PocoFOAM half-rings and longerons

(Mechanically shaped in Genova)

L1COS

To be 3d printed

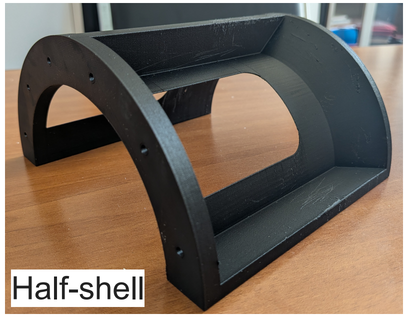


Size of climate chamber in Pavia

Larghezza : 320 mm

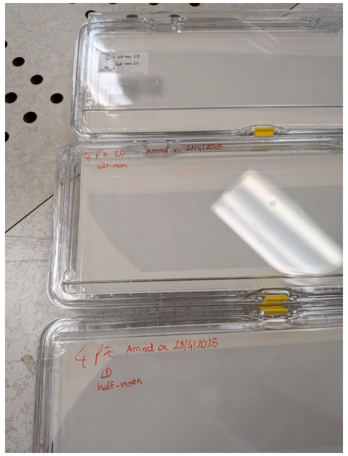
Profondità : 270 mm

Altezza : 270 mm



Available blank silicon pieces

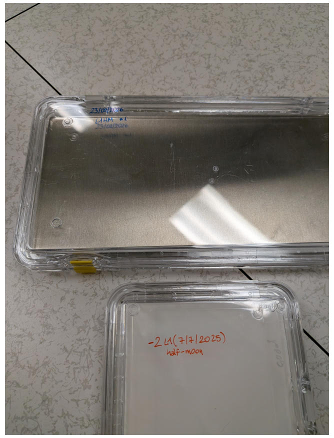
(half-moon shaped)



4x HM-L0 + 4x HM-L1

4x HM-L0

4x HM-L0



1x HM-L1

??x HM-L1

Extra material - Prototype campaign 2025-2026

IB-HB01-M1.2 | IB-HB01-M2 | IB-HB01-M3

ASSEMBLY PARAMETERS	
GOAL	Temperature induced mechanical stress in climate chamber
Structures to be assembled	L0 layer + L1 layer + L0/L1 half-barrel
Completion target date	June 2026

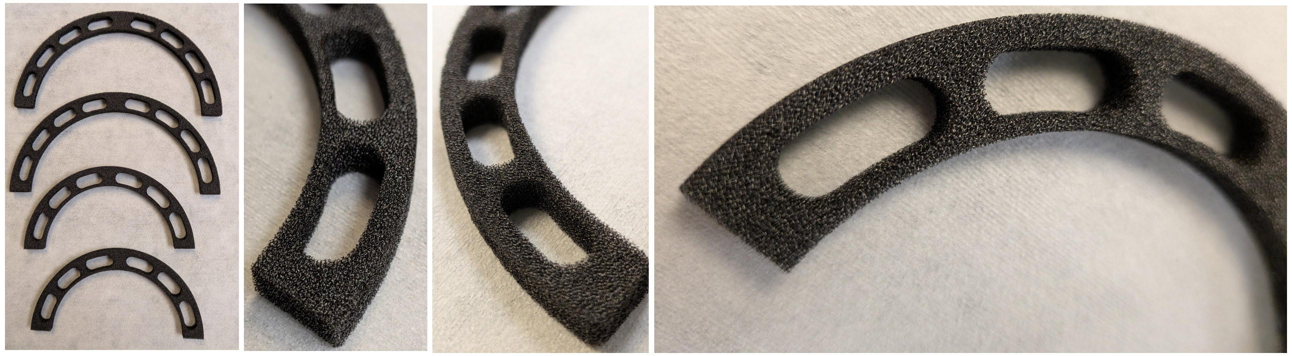
REQUIRED COMPONENTS AVAILABILITY		
Silicon pieces	AVAILABLE	x2 L0/L1 blank silicon pieces + no spares
FPCs	NOT REQUIRED	—
Local Support Structures (LSS)	TO BE COMPLETED	ERG Duocel available Half-ring ready (laser cut), longerons to be shaped Fleece gluing tool under completion
Air ducts	NOT REQUIRED	—
L1 Cylindrical Outer Shell (L1COS)	TO BE PRODUCED	Carbon fiber composite one received in Padova but too large elasticity → Finding the way to reinforce it

Extra material - Prototype campaign 2025-2026

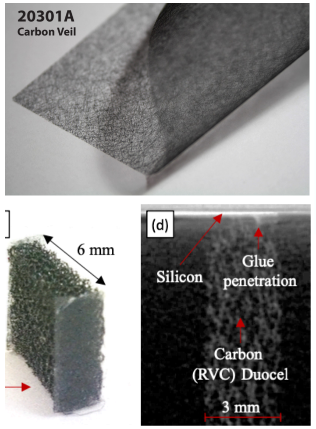
IB-HB01-M1.2 | **IB-HB01-M2** | IB-HB01-M3

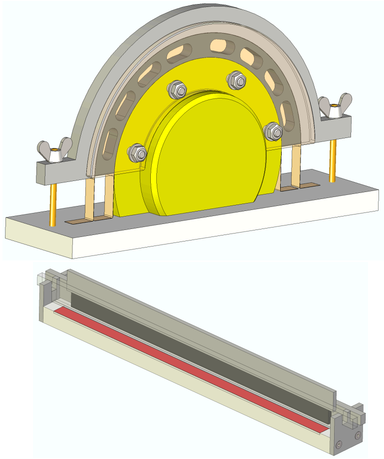
ERG Duocel half-rings for L0 and L1

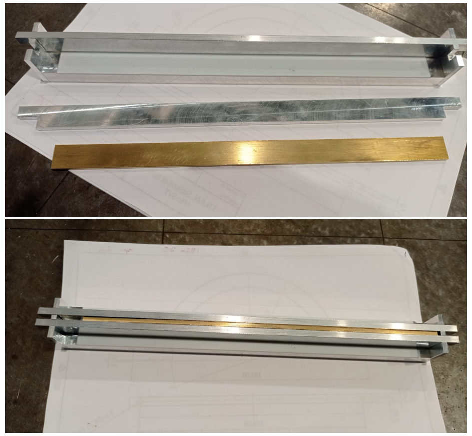
(Laser cut, without fleece)



Carbon fleece and gluing tools

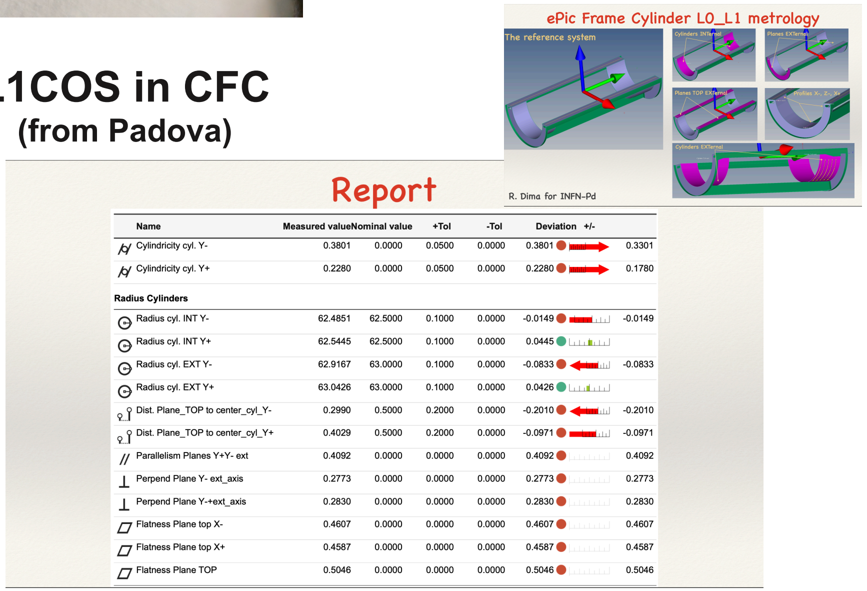






L1COS in CFC

(from Padova)



ePic Frame Cylinder L0_L1 metrology

R. Dima for INFN-Pd

Report

Name	Measured value	Nominal value	+Tol	-Tol	Deviation	+/-	
Cylindricity cyl. Y-	0.3801	0.0000	0.0500	0.0000	0.3801 ●	→	0.3301
Cylindricity cyl. Y+	0.2280	0.0000	0.0500	0.0000	0.2280 ●	→	0.1780
Radius Cylinders							
Radius cyl. INT Y-	62.4851	62.5000	0.1000	0.0000	-0.0149 ●		-0.0149
Radius cyl. INT Y+	62.5445	62.5000	0.1000	0.0000	0.0445 ●		
Radius cyl. EXT Y-	62.9167	63.0000	0.1000	0.0000	-0.0833 ●	←	-0.0833
Radius cyl. EXT Y+	63.0426	63.0000	0.1000	0.0000	0.0426 ●		
Dist. Plane_TOP to center_cyl_Y-	0.2990	0.5000	0.2000	0.0000	-0.2010 ●	←	-0.2010
Dist. Plane_TOP to center_cyl_Y+	0.4029	0.5000	0.2000	0.0000	-0.0971 ●		-0.0971
Parallelism Planes Y+Y- ext	0.4092	0.0000	0.0000	0.0000	0.4092 ●		0.4092
Perpend Plane Y- ext_axis	0.2773	0.0000	0.0000	0.0000	0.2773 ●		0.2773
Perpend Plane Y-+ext_axis	0.2830	0.0000	0.0000	0.0000	0.2830 ●		0.2830
Flatness Plane top X-	0.4607	0.0000	0.0000	0.0000	0.4607 ●		0.4607
Flatness Plane top X+	0.4587	0.0000	0.0000	0.0000	0.4587 ●		0.4587
Flatness Plane TOP	0.5046	0.0000	0.0000	0.0000	0.5046 ●		0.5046

Extra material - Prototype campaign 2025-2026

IB-HB01-M1.2 | IB-HB01-M2 | IB-HB01-M3

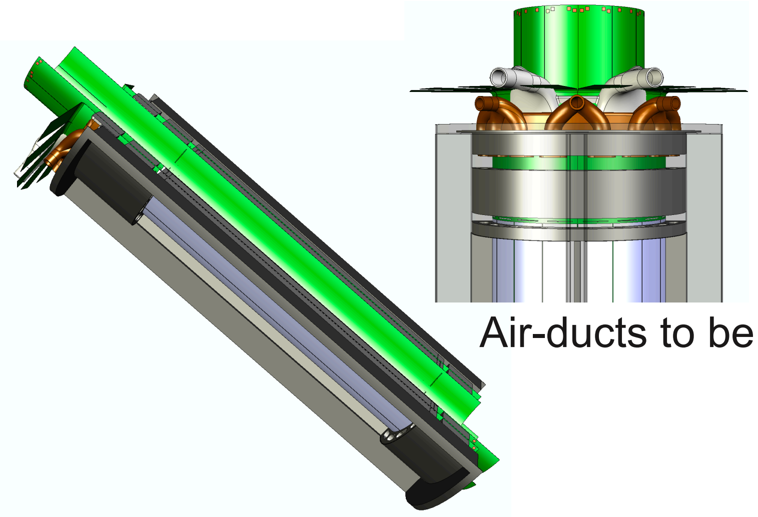
ASSEMBLY PARAMETERS	
GOAL	Air-flow cooling effectiveness in a wind tunnel
Structures to be assembled	L0 layer + L1 layer + L0/L1 half-barrel
Completion target date	July 2026

REQUIRED COMPONENTS AVAILABILITY		
Silicon pieces	AVAILABLE	x2 L0/L1 haters + PT1000 sensors
FPCs	NOT REQUIRED	—
Local Support Structures (LSS)	TO BE PRODUCED	ERG Duocel available, Alcomp K9 SD under procurement Half-ring and longerons to be shaped (laser cut for K9 at the limit) Fleece gluing tool under completion
Air ducts	TO BE PRINTED	Design still progressing in the Padova model
L1 Cylindrical Outer Shell (L1COS)	TO BE PRODUCED	3d printed: material and design available

Extra material - Prototype campaign 2025-2026

IB-HB01-M1.2 | IB-HB01-M2 | IB-HB01-M3

Model CAD integration



Air-ducts to be fixed

Temperature sensors

Amount and location

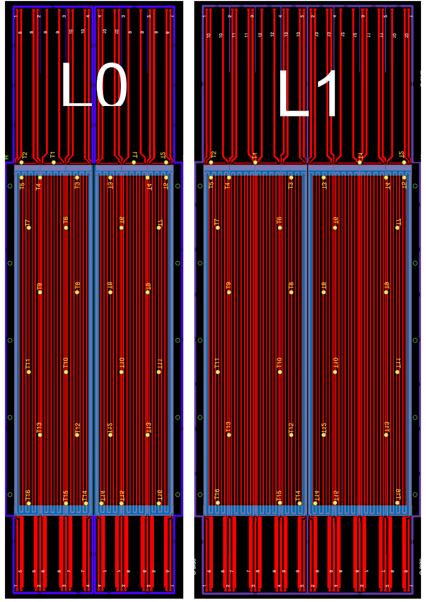
Sensors PT1000 (2952-P1K0.161.6W.Y.010-ND) :
- available 100 pieces

In ITS3-BBM6:
- 16 PT1000 per silicon

In the SVT-IB HBM3 prototype we should have:
- 32 PT1000 per layer → 64 PT1000 for L0-L1

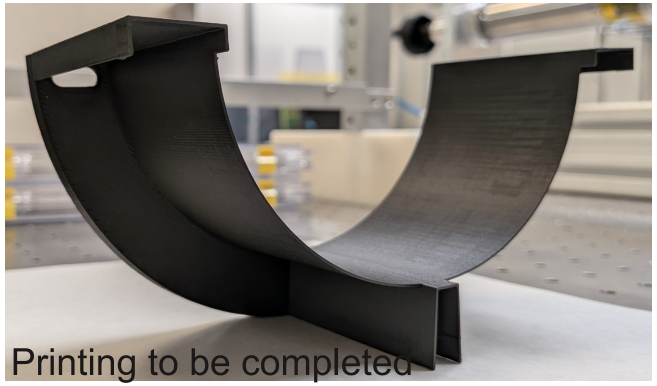
This is a large number of P1000 to be read together
→ We could install them and choose the ones to read, depending on the capability of the readout system.

Assuming similar locations
of PT1000 as in ITS3-BBM6 →



L1COS 3d printed

Printing in multiple parts and following gluing



Printing to be completed

LSS gluing tools compatible with FPC presence

Production completed, functionality to be verified