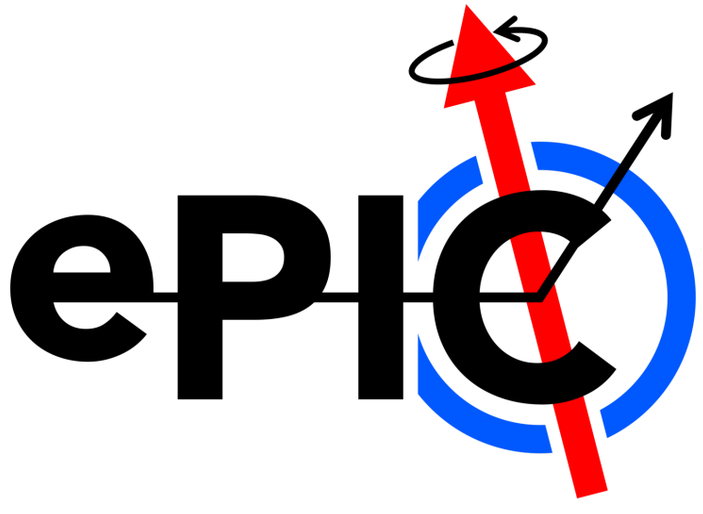


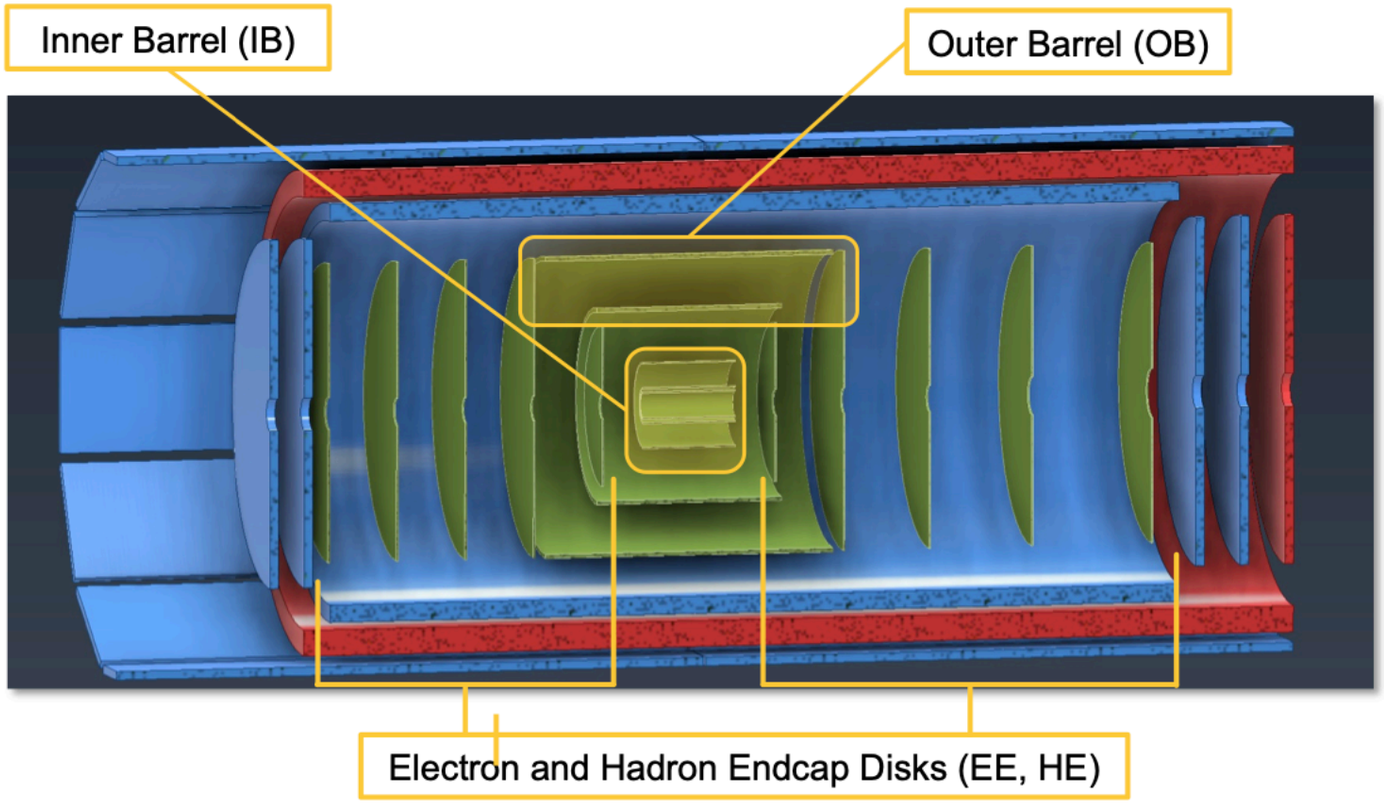
SVT-IB activities update

SVT Concept

- **Inner Barrel (IB)**
  - Three layers, L0, L1, L2,
  - Radii of 36, 41, 120 mm
  - Length of 27 cm
  - X/X_0 ~ 0.05% per layer
  - Curved, thinned, wafer-scale sensor

- **Outer Barrel (OB)**
  - Two layers, L3, L4
  - Radii of 27 and 42 cm
  - X/X_0 ~0.25% and ~0.55%
  - More conventional structure w. staves

- **Electron/Hadron Endcaps (EE, HE)**
  - Two arrays with five disks
  - X/X_0 ~0.25% per disk
  - More conventional structure



- **Lengths for L2—L4 increase so as to project back to z = 0; disk radii adjust accordingly**

SVT IB layout and concept

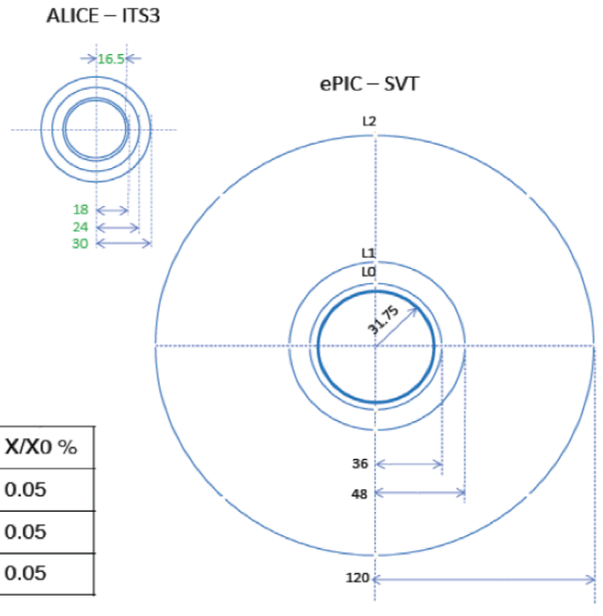
Basic assumptions:

- use the ALICE ITS3 wafer-scale sensor
- adapt ITS3 detector concept to the (larger) ePIC radii

→ mechanics, services and cooling of the SVT IB need specific development

ePIC SVT Inner Barrel (IB) layers

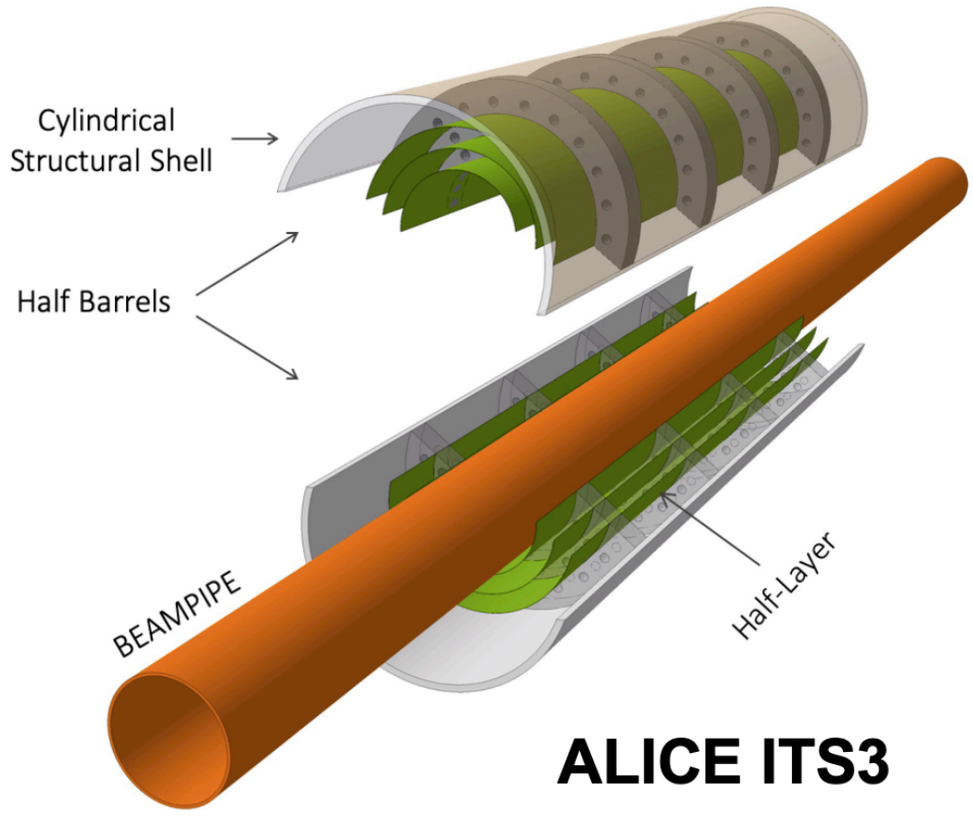
- Re-use ITS3 wafer-scale sensor
  - L0: 3x12 RSU + endcaps
  - L1: 4x12 RSU + endcaps
  - L2: 5x12 RSU + endcaps



- Number of sensors per layer
  - L0: 4
  - L1: 4
  - L2: 8

ePIC SVT IB	r [mm]	l [mm]	X/X0 %
L0	36	270	0.05
L1	48	270	0.05
L2	120	270	0.05

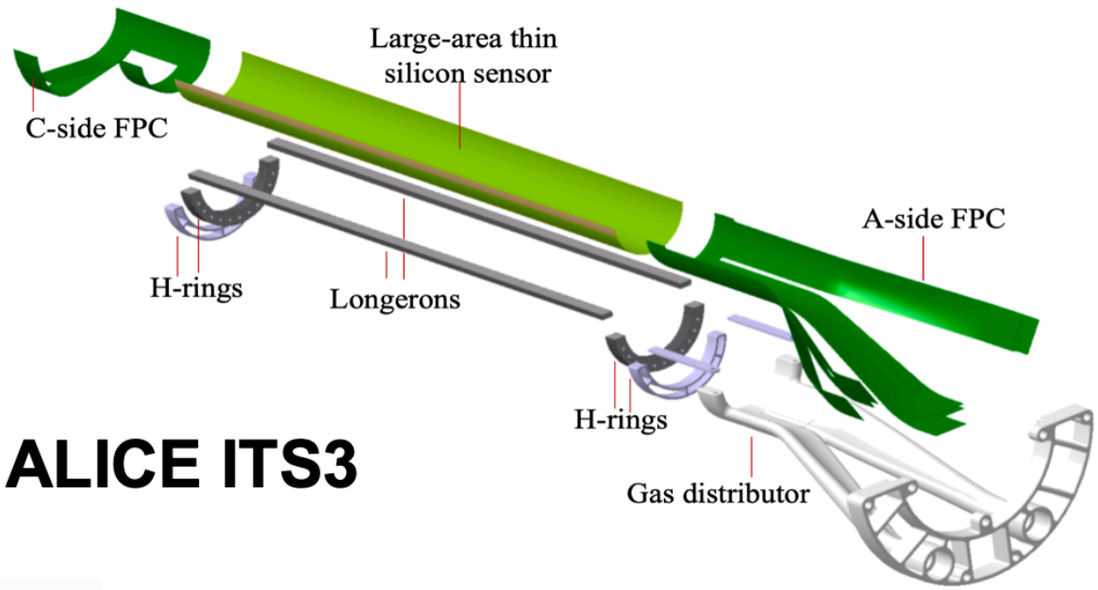
Laura Conella | ePIC SVT kickoff meeting | 9 June 2023 13



SVT IB layout and concept

ALICE ITS3 concept:

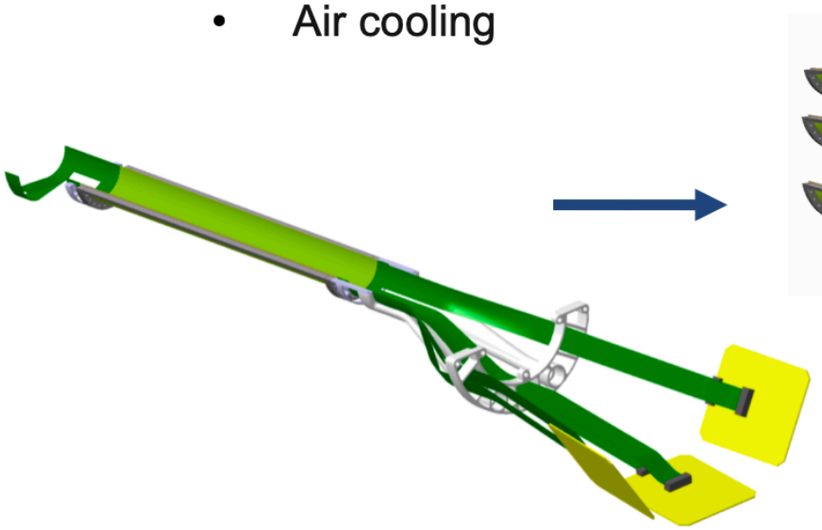
- half-layer is the basic building block
- 3 half-layers will be assembled in a half-barrel

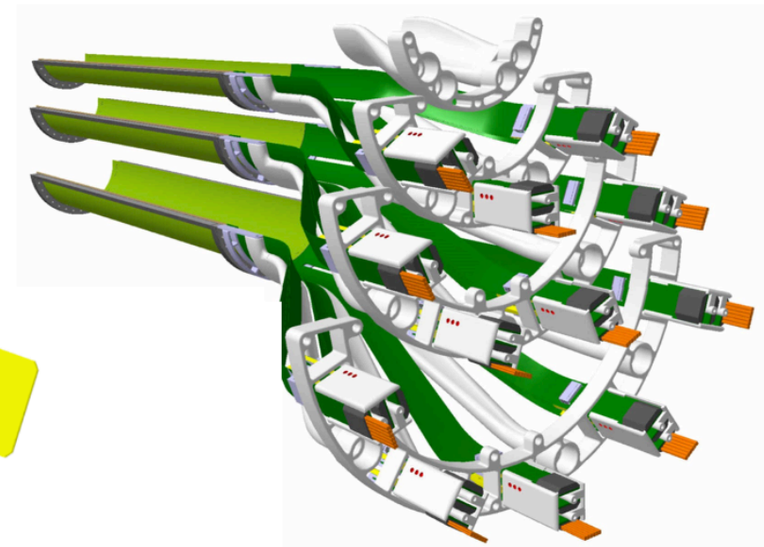


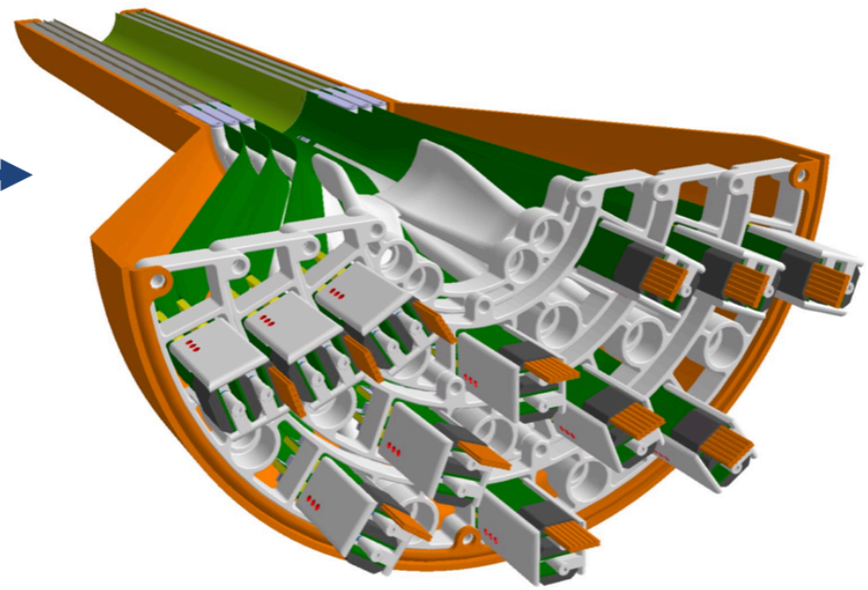
ALICE ITS3

key ingredients:

- Wafer-scale chips (up to ~27x10 cm, ≤ 50 µm thick)
- Chips bent in cylindrical shape at target radii
- Ultra-light carbon foam structures
- Air cooling







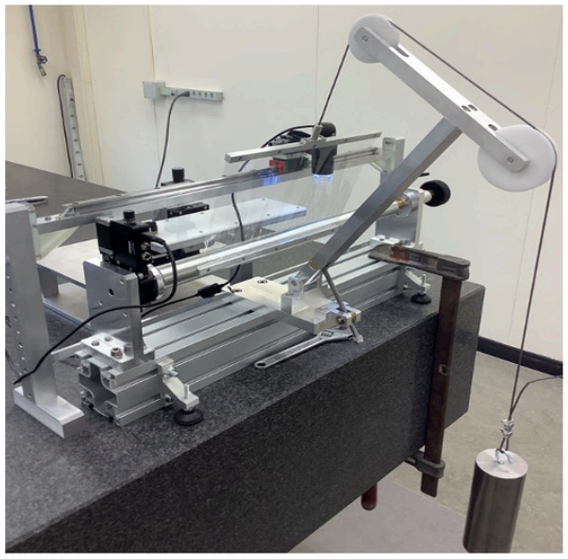
SVT IB interested institutions

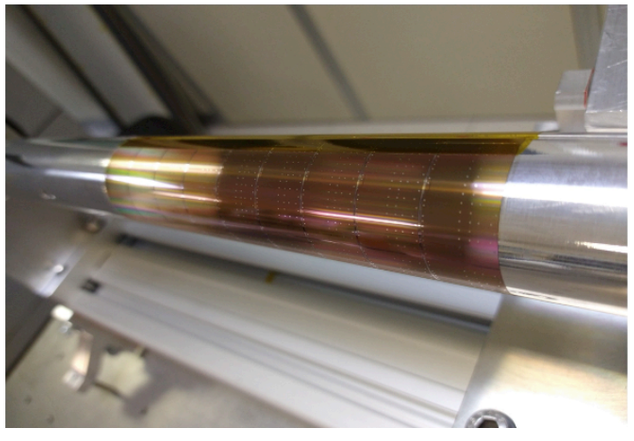
- integrated design of the 3 innermost layers including mechanics, cooling, readout and powering, up to the electrical/optical interface:
  - ✓ develop bending procedure, eg L0 (similar for L1)
  - ✓ extend to L2 considering additional issues
  - ✓ design L0/L1 and L2 support structures
  - ✓ integration of the cooling needs
  - ✓ development of the edge FPC(s)
- choice of the cooling:
  - ✓ simulation studies with ANSYS
- thermo-mechanical prototypes:
  - ✓ build prototypes for both L0/L1 and L2
  - ✓ perform dedicated tests of prototypes in wind tunnel
  - ✓ test of embedded silicon thermal properties in a thermal chamber
- support structure within the subsystem to keep everything together
  - ✓ connection of L0/L1 to L2
  - ✓ explore needs for a (light) supporting external shell (to L2)

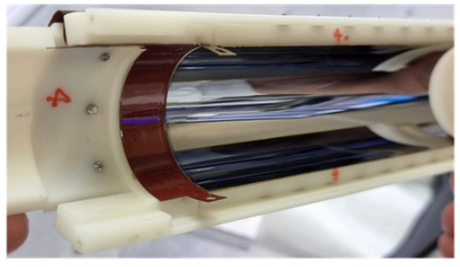
SVT IB interested institutions

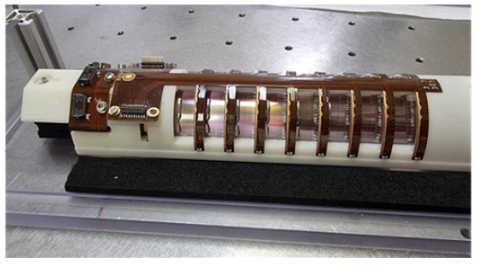
INFN (DE for Bari, Padova, Pavia, Trieste)

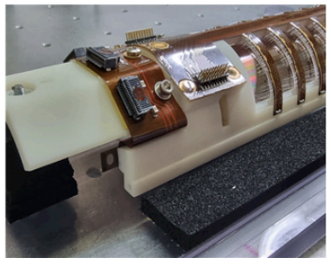
- **Focus on L0/L1**
- **Mechanics/conceptual design of the IB innermost layers:**
  - ✓ definition of the bending and assembly procedure
  - ✓ development of the layer support structure
  - ✓ explore interconnection to sensors
- **Cooling:**
  - ✓ build dedicated prototype same as for mechanics studies (suitable for wind tunnel tests)
  - ✓ test of thermal properties for embedded silicon in a thermal chamber
- **Workforce (FTE in 2024):**
  - ✓ Research: ~2-3
  - ✓ Mech Eng & CAD: ~0.5
  - ✓ Mech Tech: ~0.5











SVT IB layout and concept

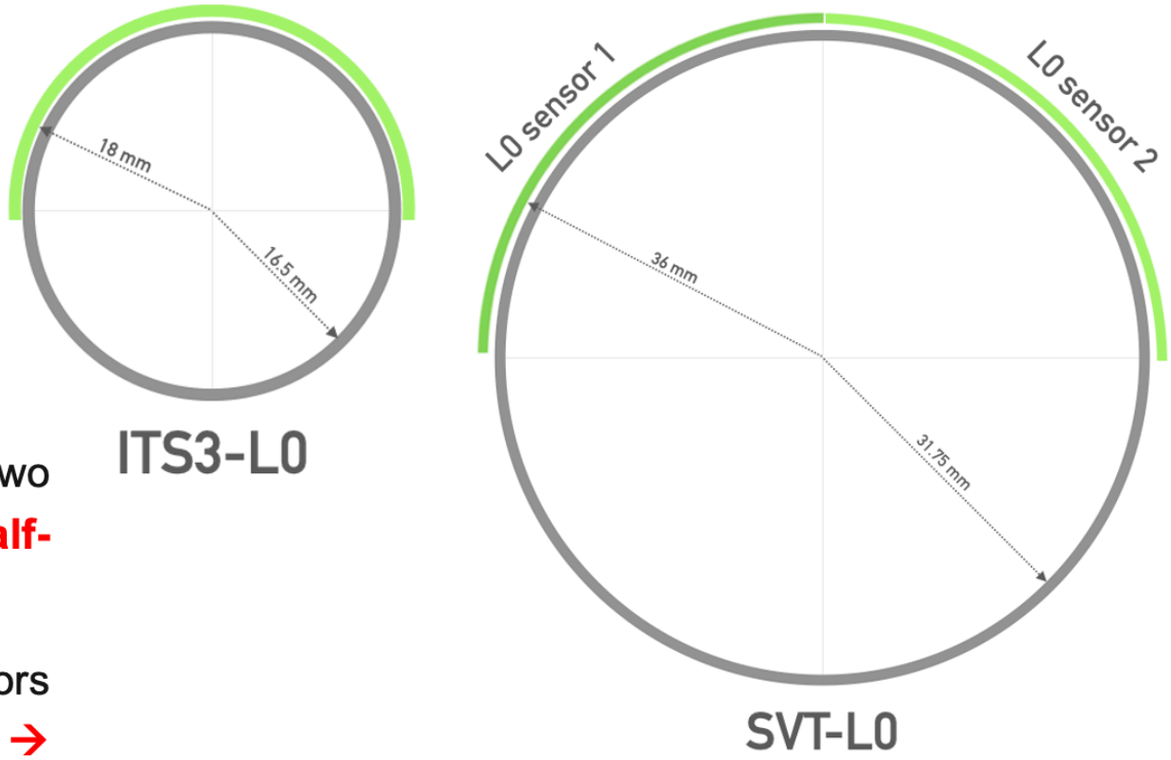
Towards SVT IB concept:

- integrated design of the 3 innermost layers including mechanics, cooling, readout and powering, up to the electrical/optical interface:
  - ✓ develop bending procedure, eg L0 (similar for L1):

Main differences & challenges wrt ITS3:

- x2 larger radius (18 → 36 mm)*
- need to bend 2 sensors for each half-layer

  * will increase to ~19/~38 mm with ITS3 ER2/3 sensors



Possible strategies:

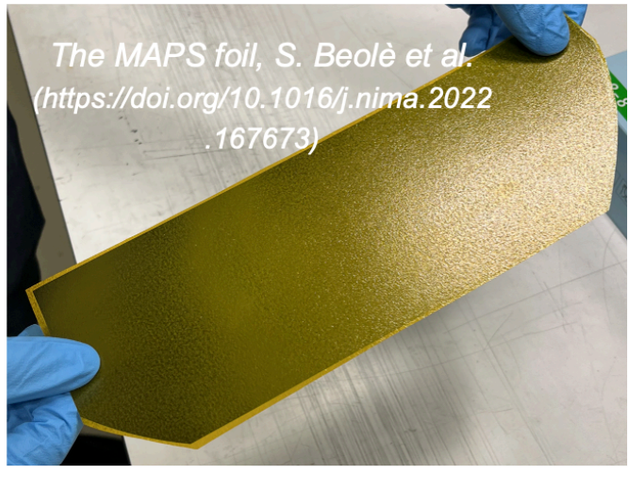
1. **embedding (2 sensors):** try to exploit "embedding" the two sensors in kapton foils and bend them as a single object → **half-layer based assembly**
2. **independent bending:** bend each of the two sensors separately and glue them on independent support structures → **quarter-of-layer based assembly**

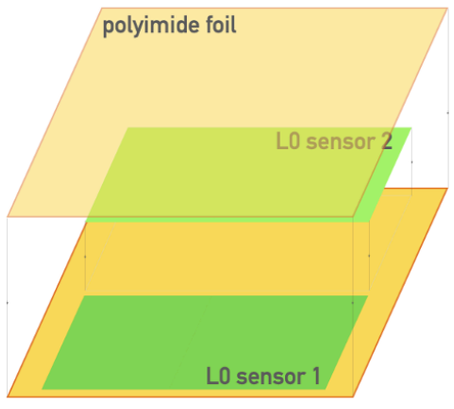
SVT IB layout and concept

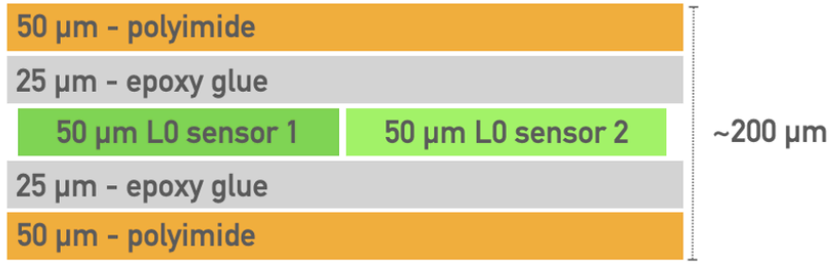
Towards SVT IB concept:

- integrated design of the 3 innermost layers including mechanics, cooling, readout and powering, up to the electrical/optical interface:
  - ✓ develop bending procedure, eg L0 (similar for L1):

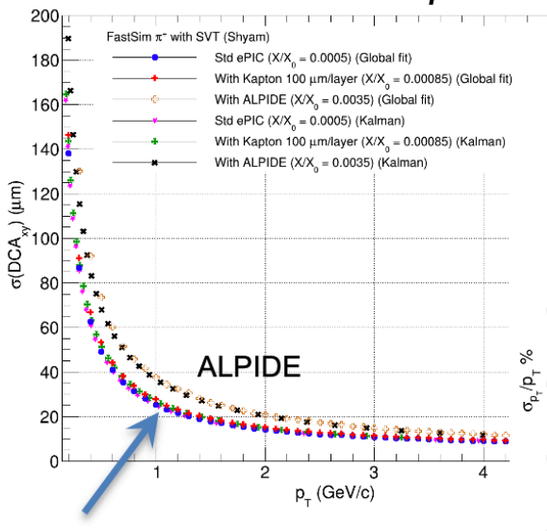
Embedding (2 sensors)

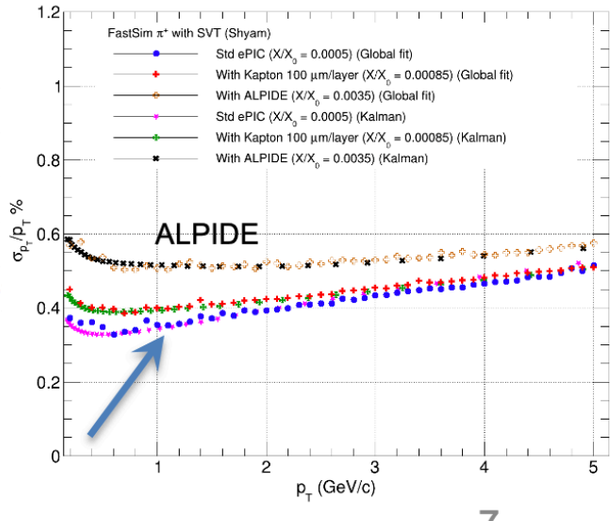






Limited effect of the additional material budget due to kapton foils (S. Kumar et al.)





65 nm MAPS w/ and w/o kapton

SVT IB layout and concept

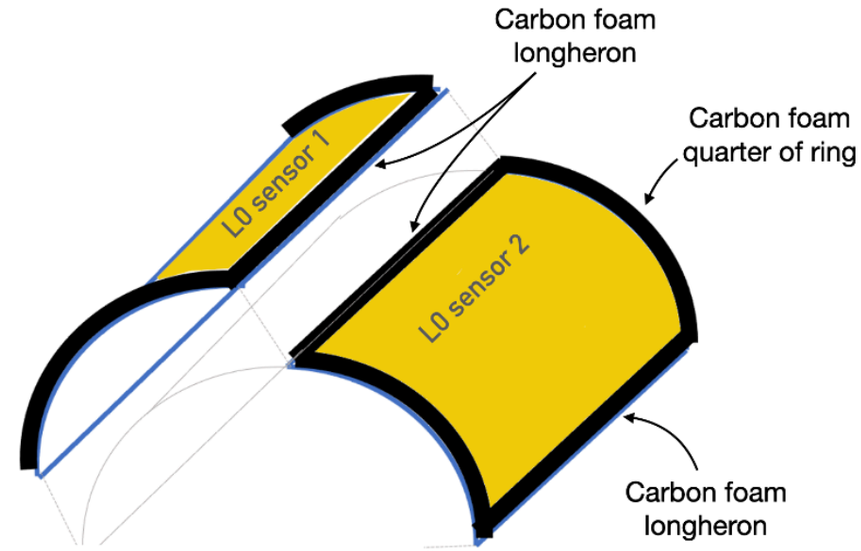
Towards SVT IB concept:

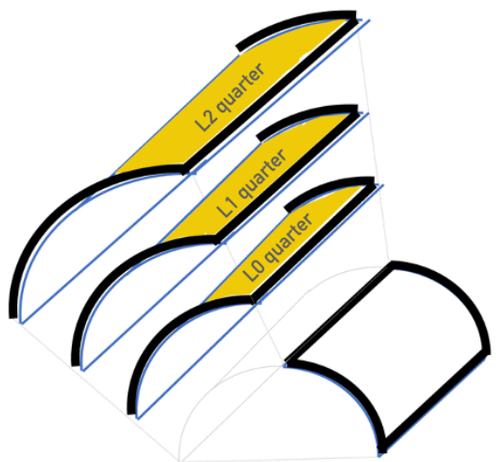
- integrated design of the 3 innermost layers including mechanics, cooling, readout and powering, up to the electrical/optical interface:
  - ✓ develop bending procedure, eg L0 (similar for L1):

Independent (single sensor) bending strategy

- avoids complications connected to embedding
- introduces further steps and potential issues on positioning procedure and mechanical stability of the bent sensors
- implies that the full IB (or maybe L0+L1) would be built in mechanically independent quarters to be precisely positioned together in the subsequent final assembly*

*This basically follows the same strategy used by ITS3 for bending the single sensors (kept on the mandrel by adhesive tape) and assemblying the detector (glueing from outermost to innermost) → the assemby of SVT IB will proceed in quarters of layers and not (as for ITS3) in half-layers





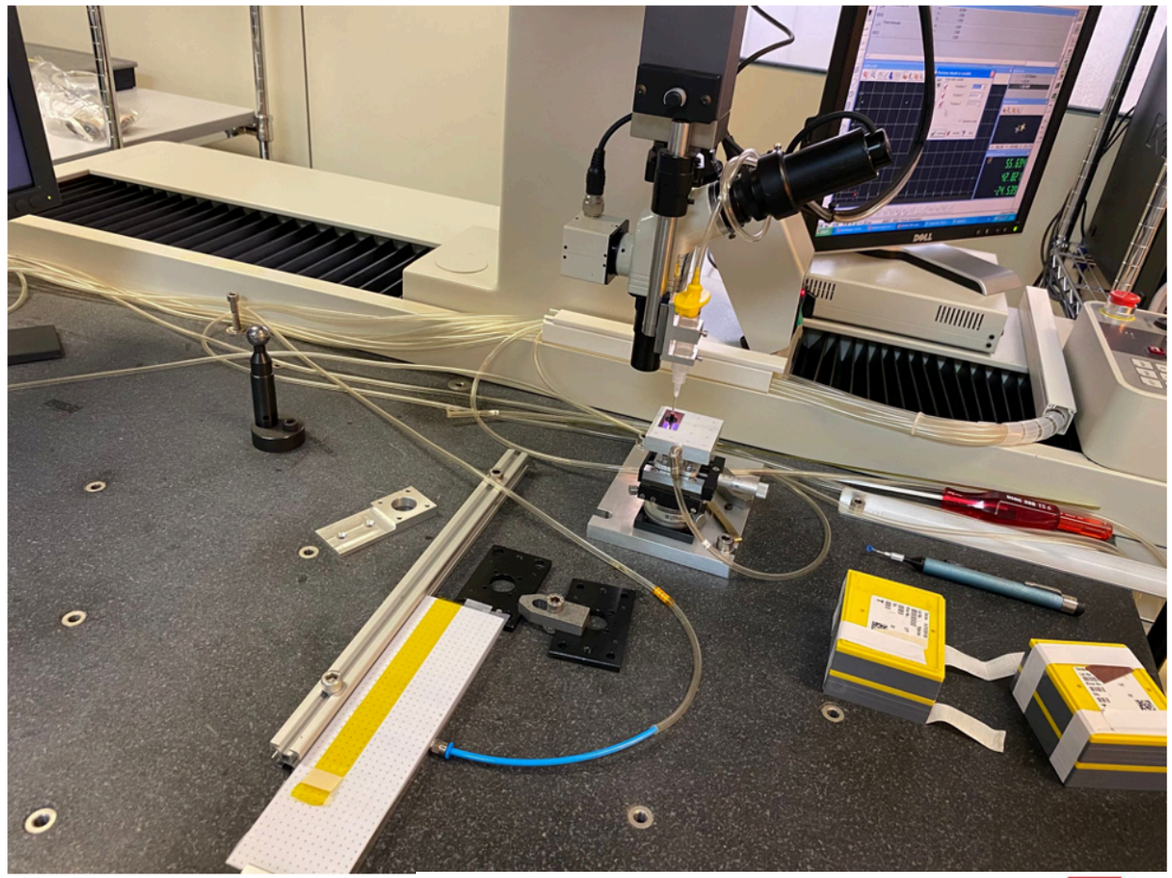
SVT IB INFN activities

Sensor encapsulation and bending

First tests performed in clean room @INFN Bari:

- sensor encapsulation in kapton adhesive tape
- encapsulated sensor bending

Mitutoyo machine equipped with alignment vacuum tool

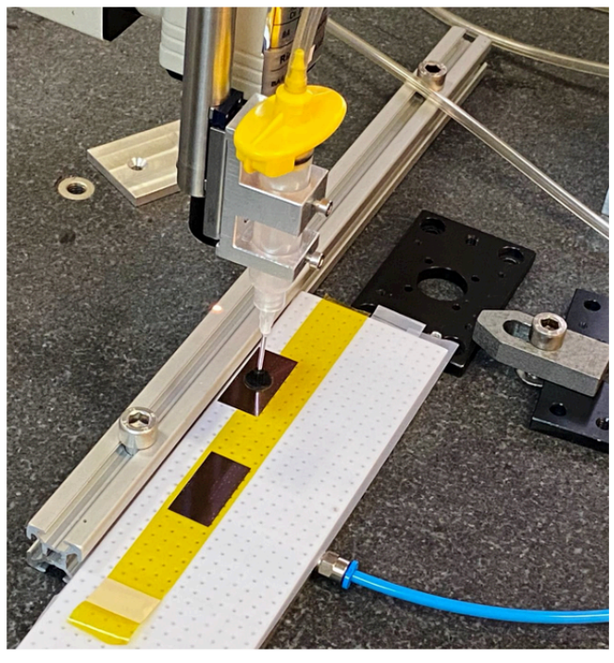


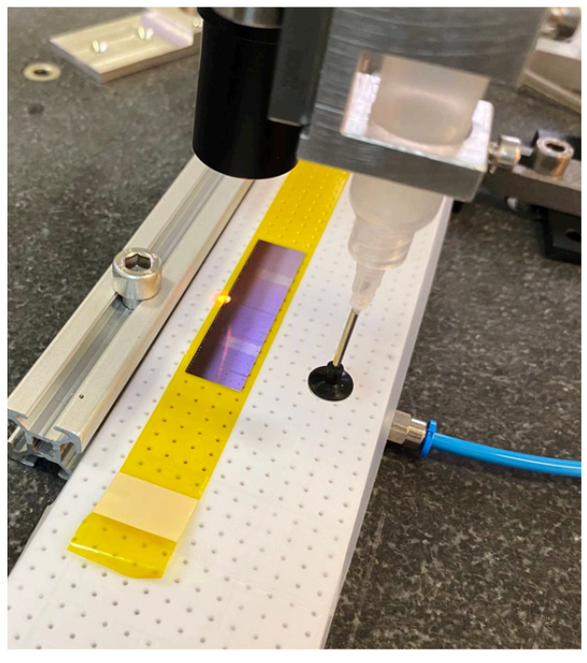
Synergy with ITS3/ALICE 3

SVT IB INFN activities

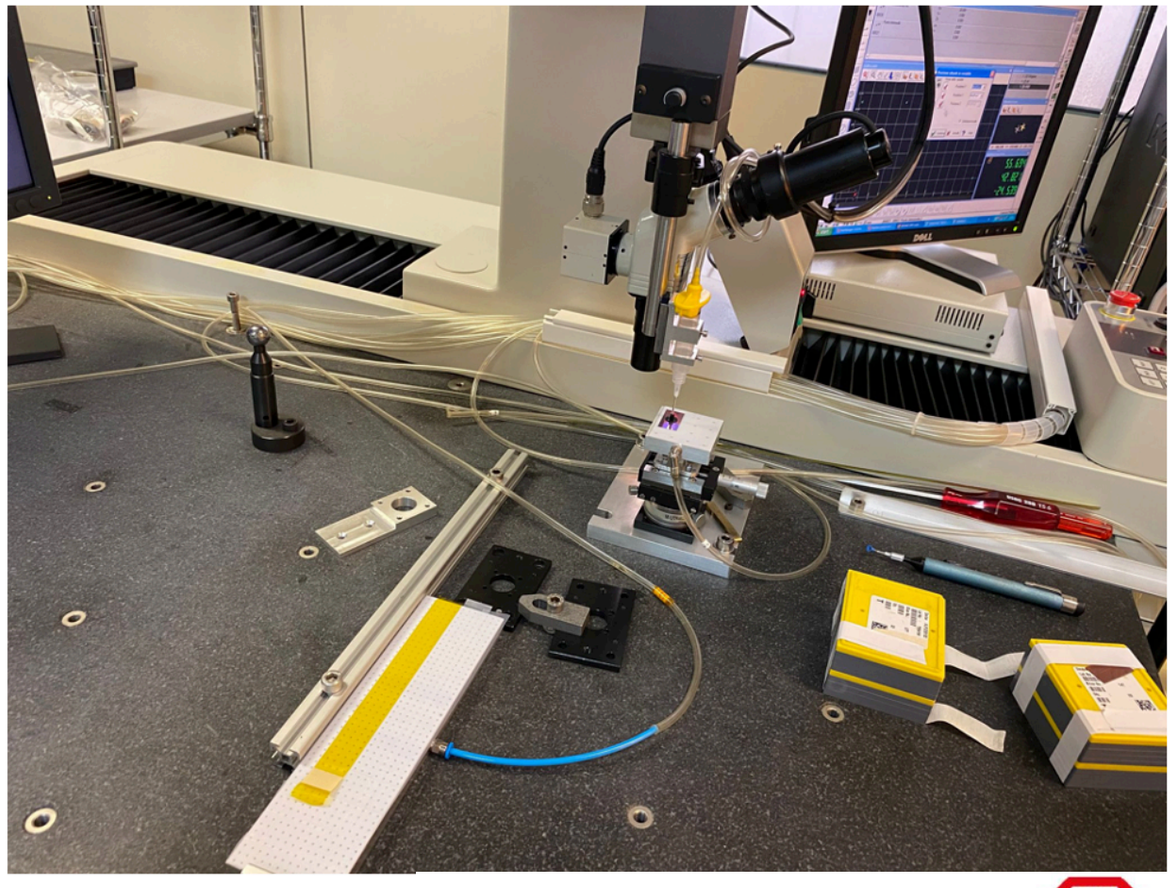
Sensor encapsulation and bending

- sensor encapsulation in kapton adhesive tape
  - ✓ available material:
  - **kapton tape** (20 mm width, 40 μm thickness)
  - **ALPIDE sensors** (15 mm x 30 mm, 100 μm thickness, not working samples)
  - ✓ precise positioning of the sensors on kapton:





Mitutoyo machine equipped with alignment vacuum tool



Synergy with ITS3/ALICE 3

SVT IB INFN activities

Sensor encapsulation and bending

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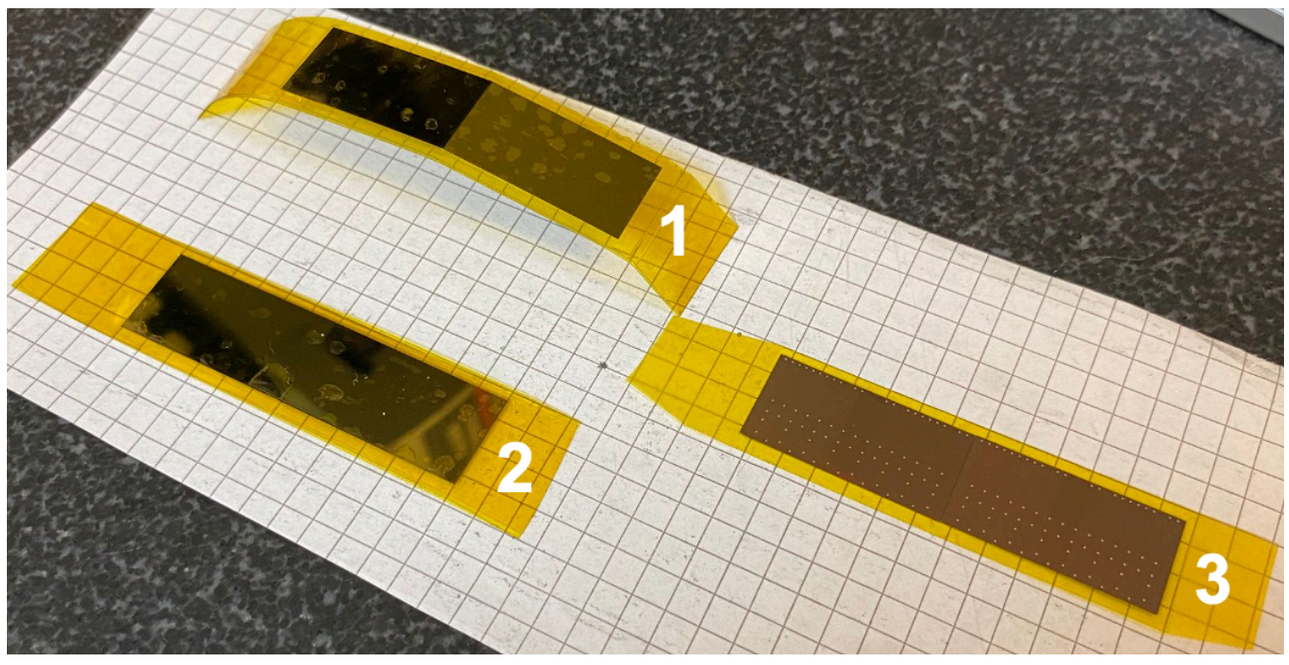


Three different samples:

- **S1**:
  - encapsulated sensors
  - top kaption positioning by hand
- **S2**:
  - encapsulated sensors
  - top kaption by dedicated tool
- **S3**:
  - single kapton layer (kapton on one side of the sensors only)

Synergy with ITS3/ALICE 3

SVT IB INFN activities

Sensor encapsulation and bending

- encapsulated sensor bending:
  - ✓ using the setup developed for ITS3 bending
  - ✓ the mandrel had the radius of the innermost ITS3 layer (R ~18mm)
  - ✓ main aim: (re-)excercising the procedure, checking behavious of the encapsulated samples

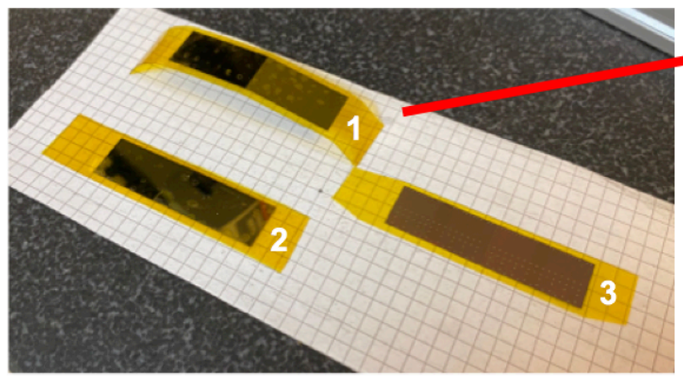
Synergy with ITS3/ALICE 3

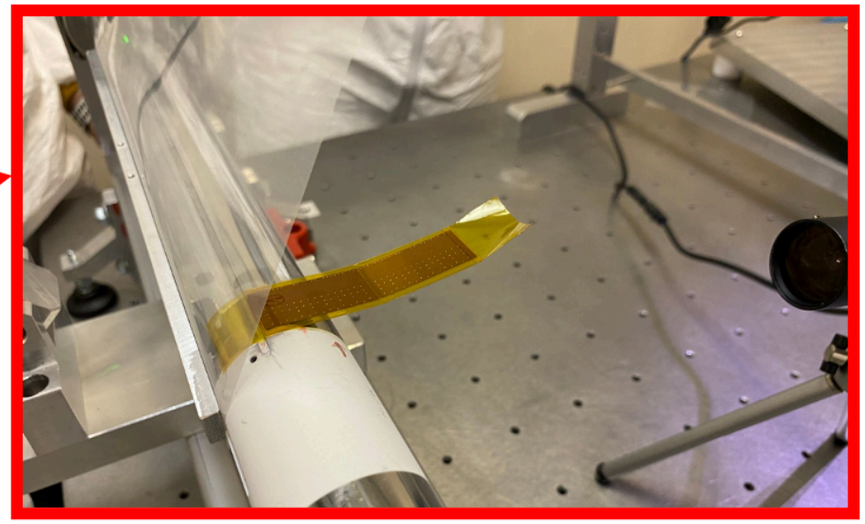
SVT IB INFN activities

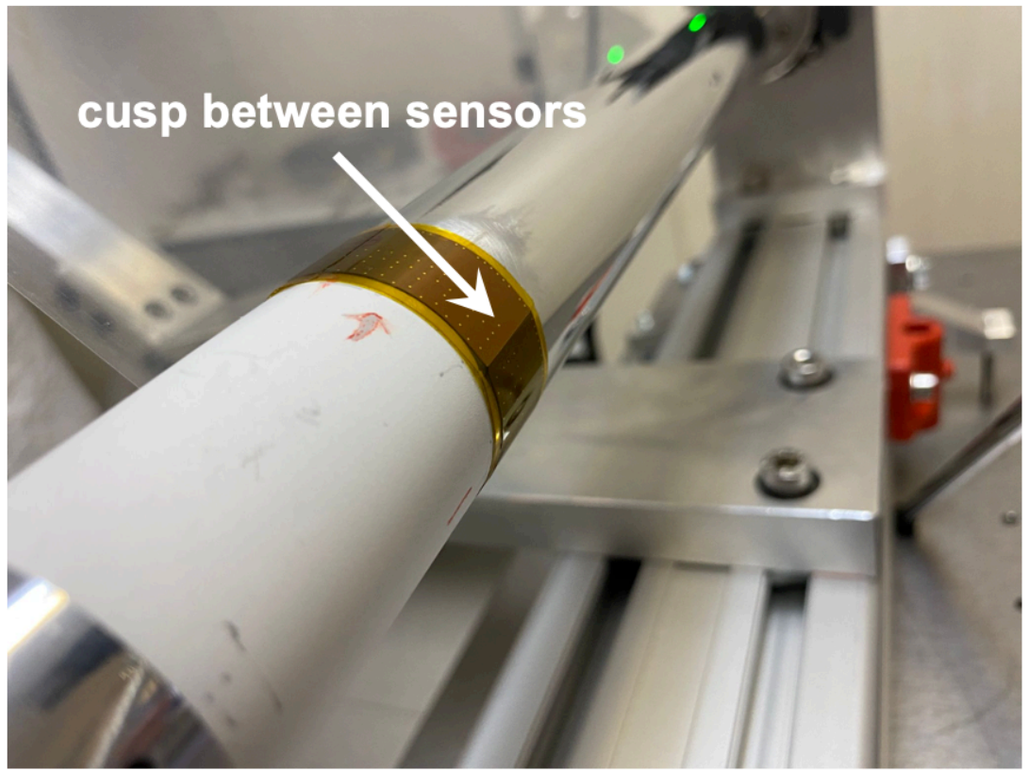
Sensor encapsulation and bending

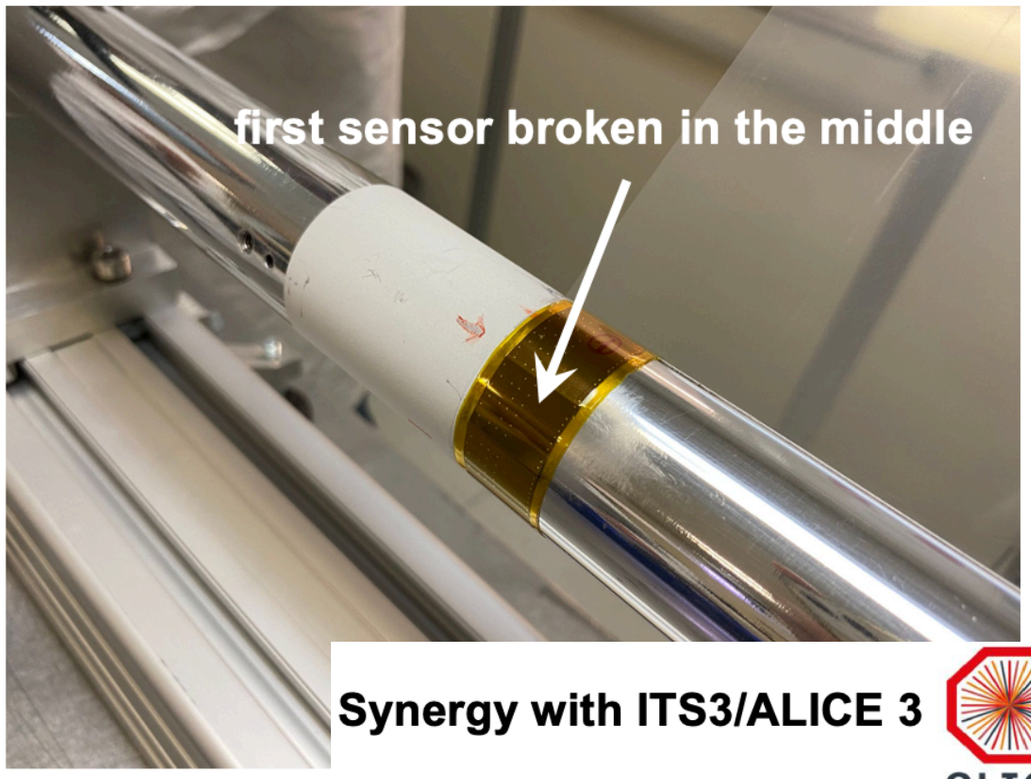
- encapsulated sensor bending:

S1:
- encapsulated sensors
- top kaption positioning by hand









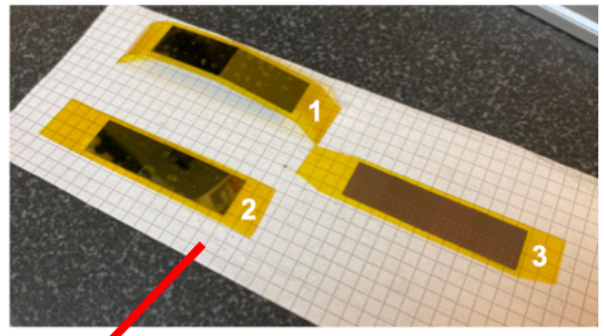
Synergy with ITS3/ALICE 3

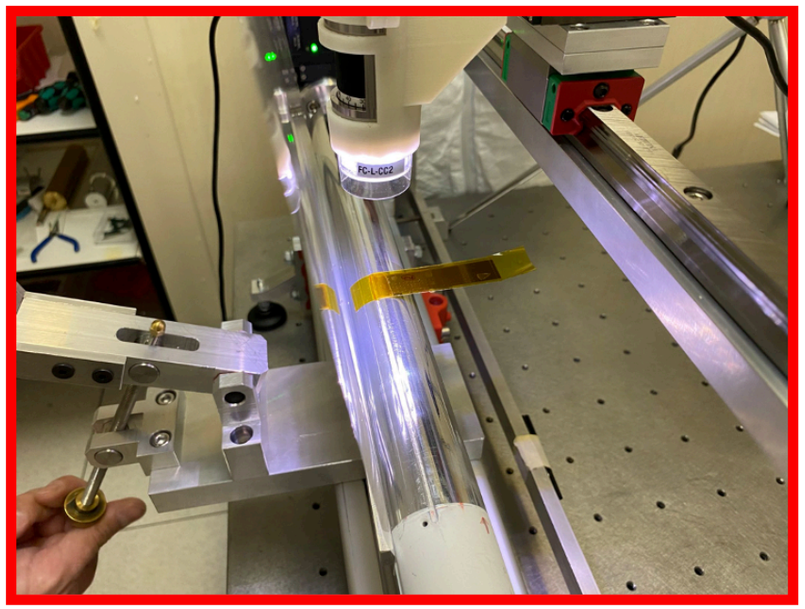
SVT IB INFN activities

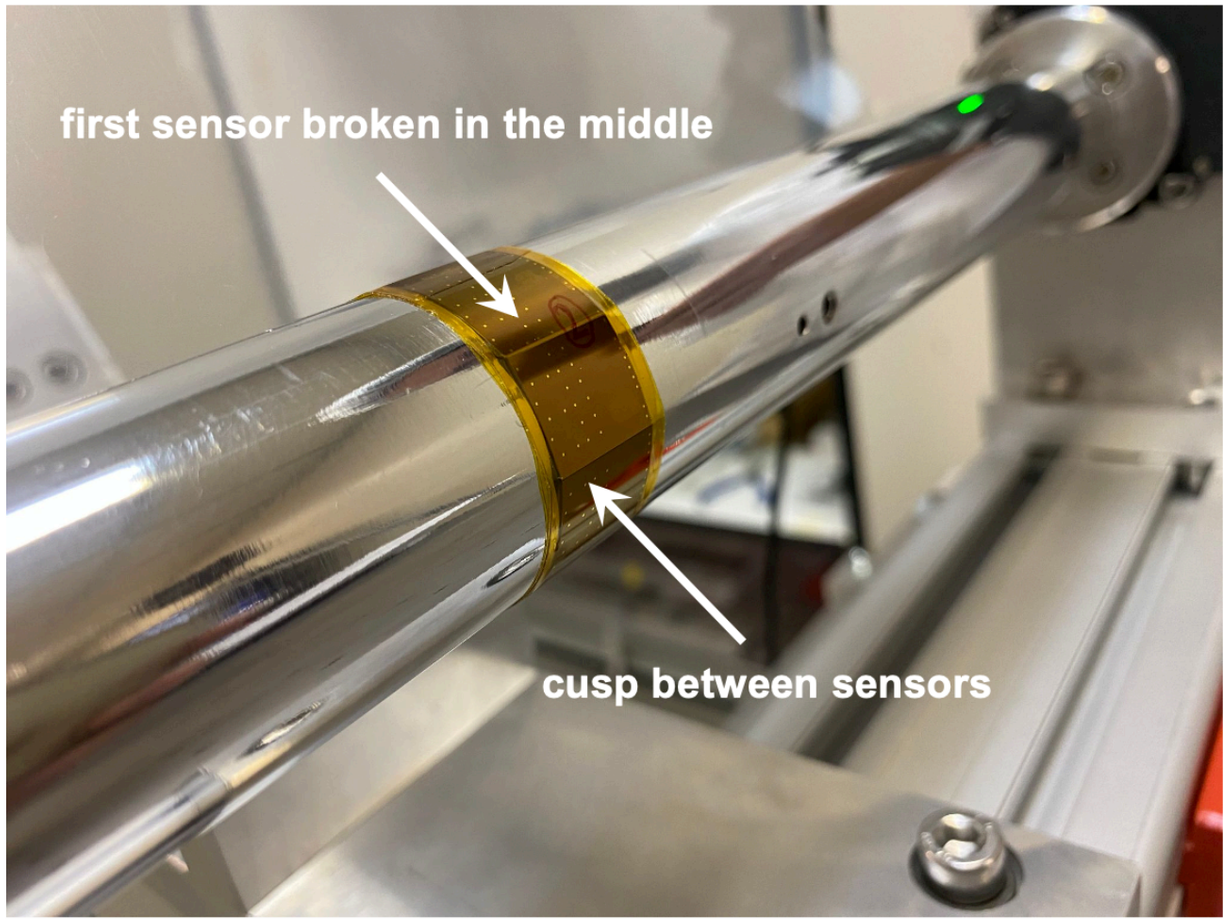
Sensor encapsulation and bending

- encapsulated sensor bending:

S2:
- encapsulated sensors
- top kaption positioning by dedicated tool







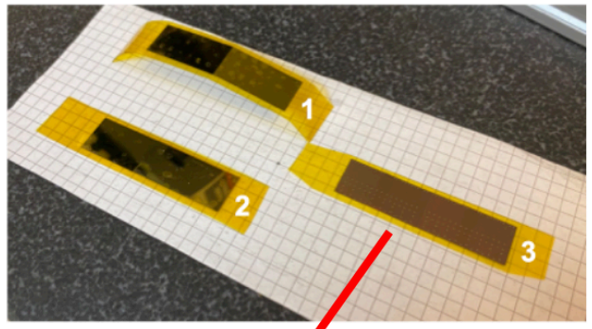
Synergy with ITS3/ALICE 3

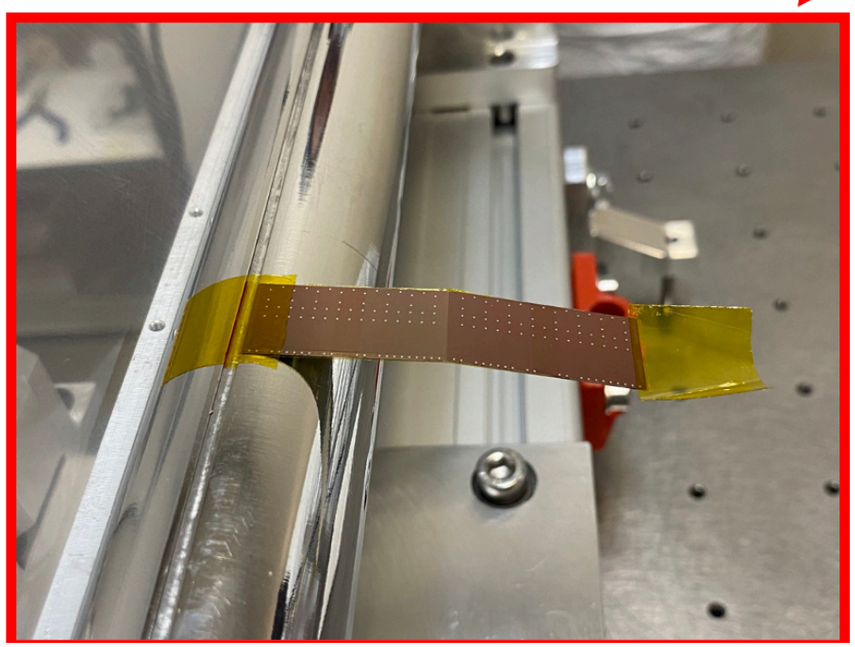
SVT IB INFN activities

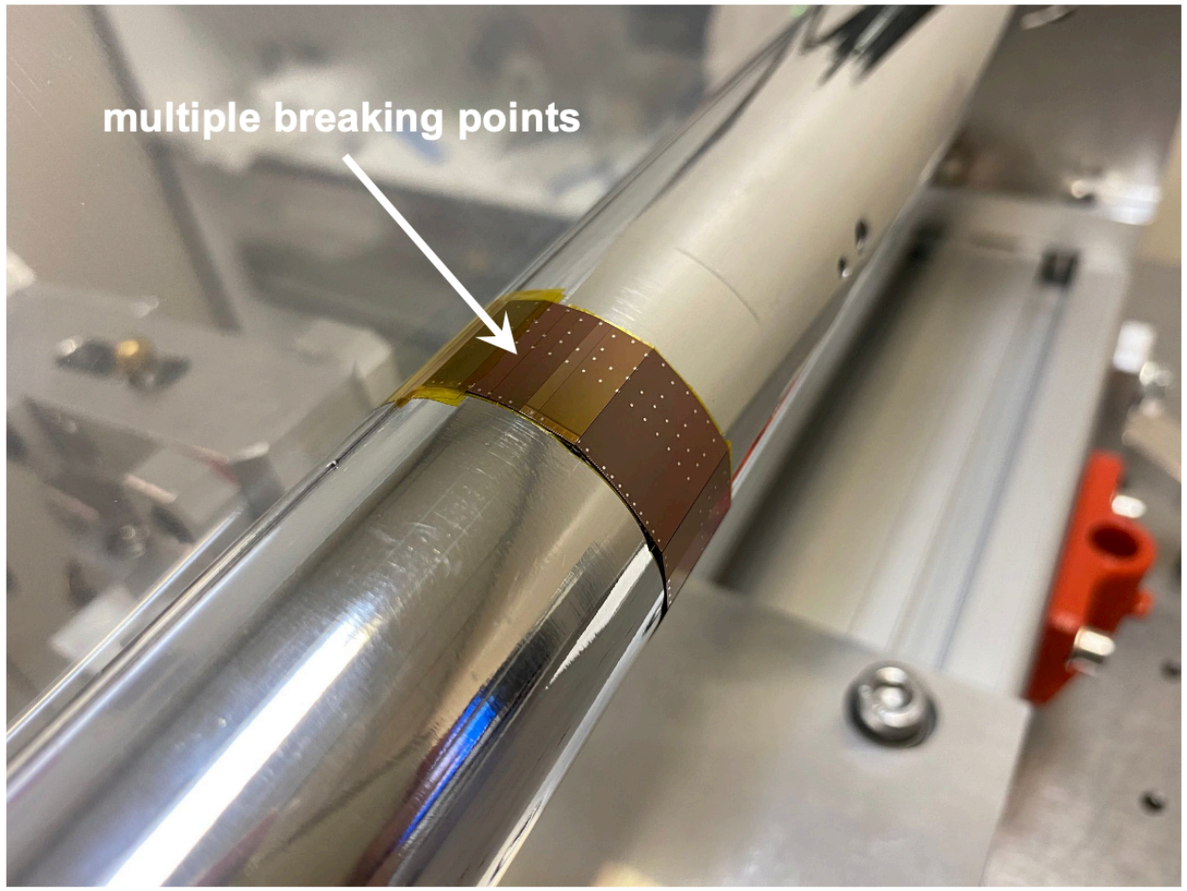
Sensor encapsulation and bending

- encapsulated sensor bending:

S3:
- single kapton sample







Synergy with ITS3/ALICE 3

SVT IB INFN activities

Sensor encapsulation and bending

First tests performed in clean room @INFN Bari:

- sensor encapsulation in kapton adhesive tape
- encapsulated sensor bending

Conclusions:

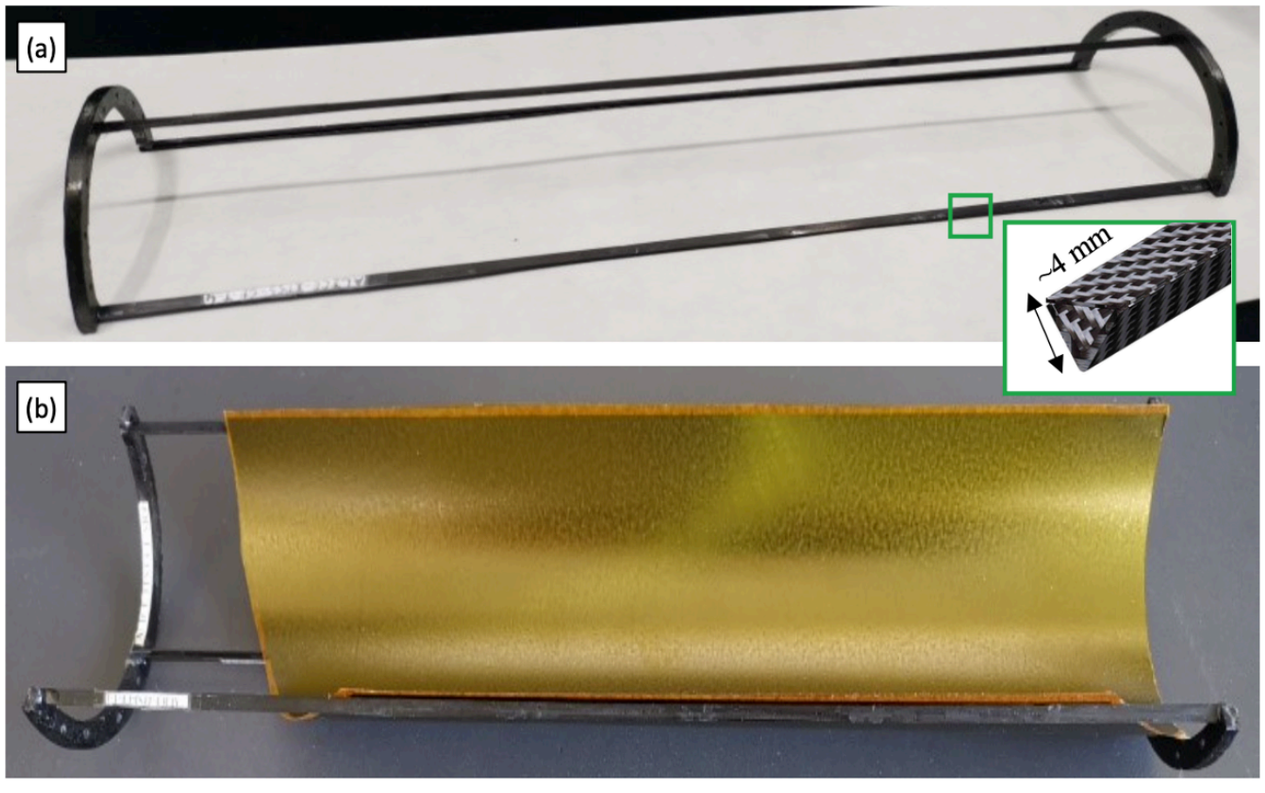
- encapsulation:
  - ✓ excercised precise positioning of kapton and sensors (precisions ~10 μm)
  - ✓ better ideas of additional tooling needed for large sensors / kapton foils → design ongoing
- bending:
  - ✓ (re-)excercised bending procedure used for ITS3 superALPIDE prototypes
  - ✓ understood additional tooling needed (both for ITS3 and SVT)
  - ✓ need SVT dedicated setup (including new mandrel) → design/fabrication/procurements ongoing
  - ✓ 100 μm sensors too thick for bending tests (independent of the encapsulation)
    - → need to switch to larger and thinner sensors (and larger adhesive kapton foils)
    - → ongoing, connected to procurements for thermo-mechanical prototypes (see Georg)

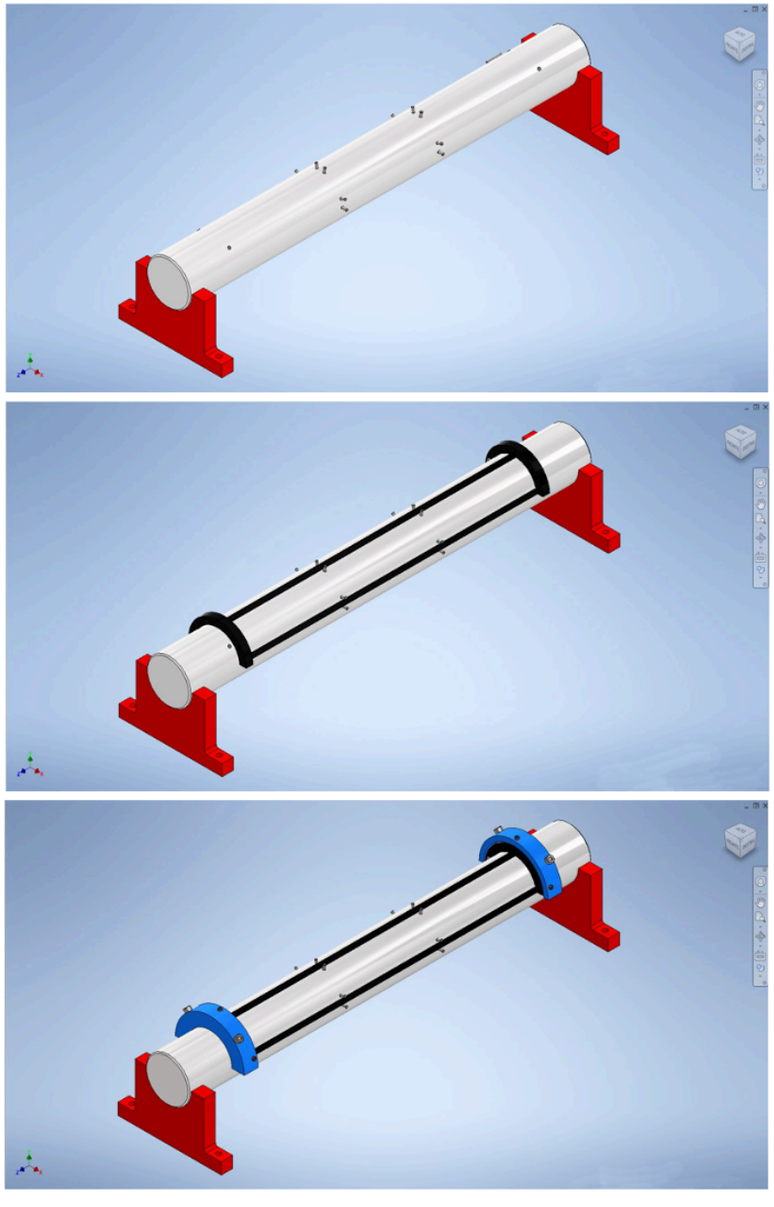
Local support structures

First design and printing of a light support structure:

- obtained by glueing 2 half-rings and 3 longerons

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

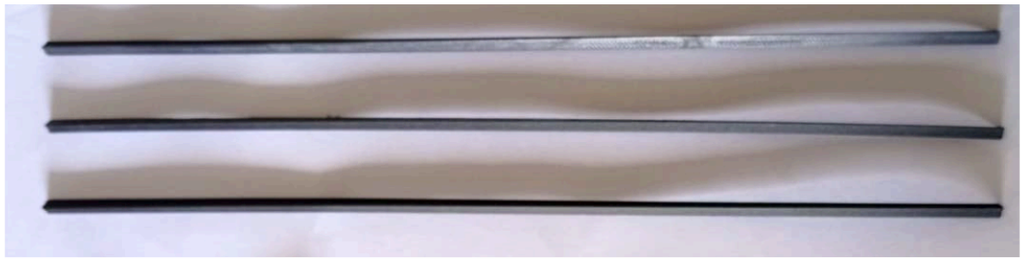


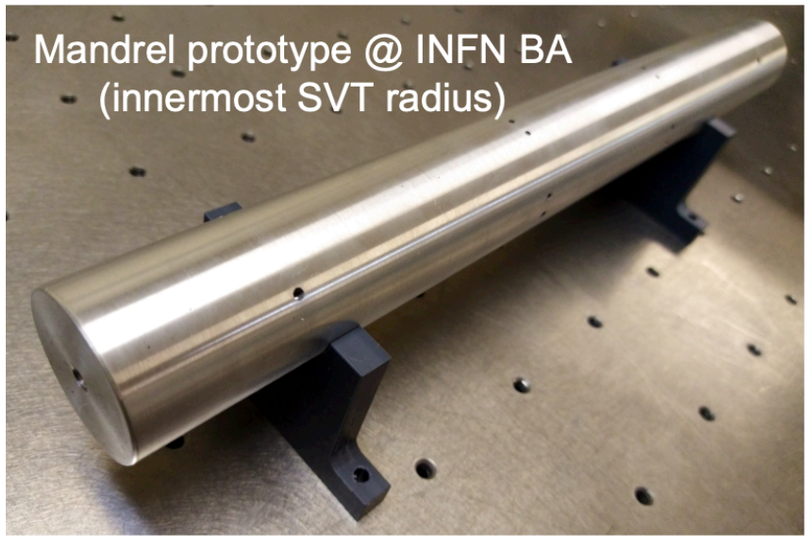


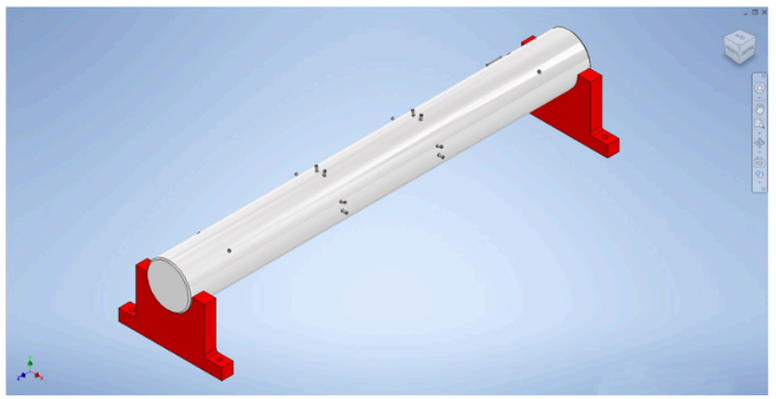
Local support structures

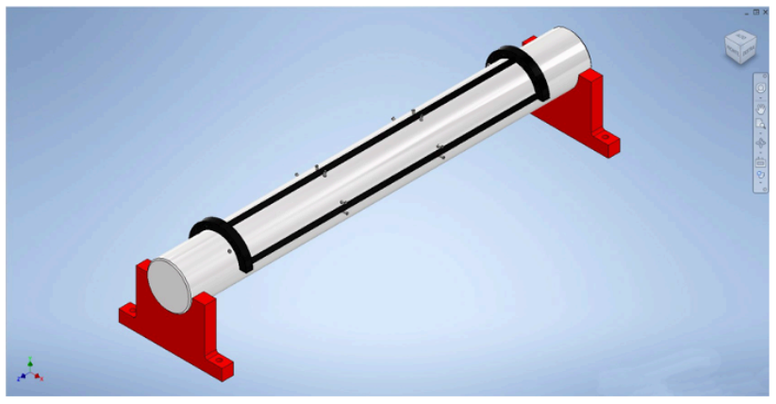
First design and printing of a light support structure:

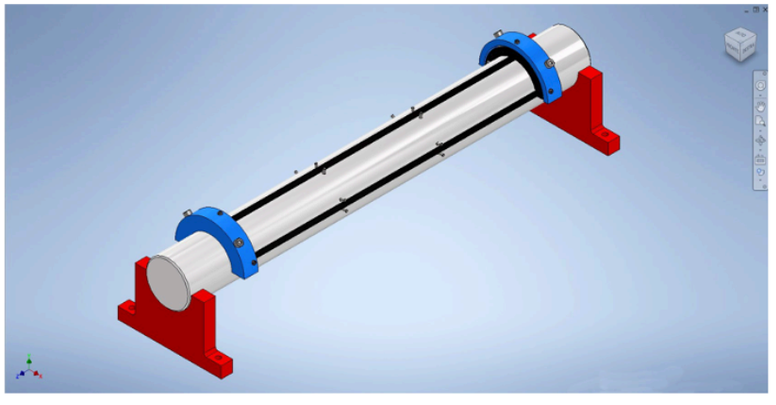
- obtained by glueing 2 half-rings and 3 longerons
- 3-D printed in carbon addicted material
- (partially) in carbon foam for prototype assembly?











SVT IB INFN activities

Summary activities in Bari

Finalize bending tool design/production and layer assembly procedure

- material needs for R&D
  - ✓ naked silicon (common order to DISCO for IB, OB and DISKS) → ongoing
  - ✓ adhesive polyimide kapton foils (60 x 100 cm^2, 13 μm thick) → order submitted
  - ✓ 3-D printed support structures → design refinement ongoing, produced @ INFN BA
- dedicated SVT tooling and bending setup
  - ✓ tools for precise sensor/kapton positioning being modified → design ongoing
  - ✓ bending setup being duplicated → design+production @ INFN BA + procurements ongoing
  - ✓ mandrel → investigating high-quality prodution by a local agency (being tested, also for ITS3)

SVT IB INFN activities

Summary activities in Bari

Finalize bending tool design/production and layer assembly procedure

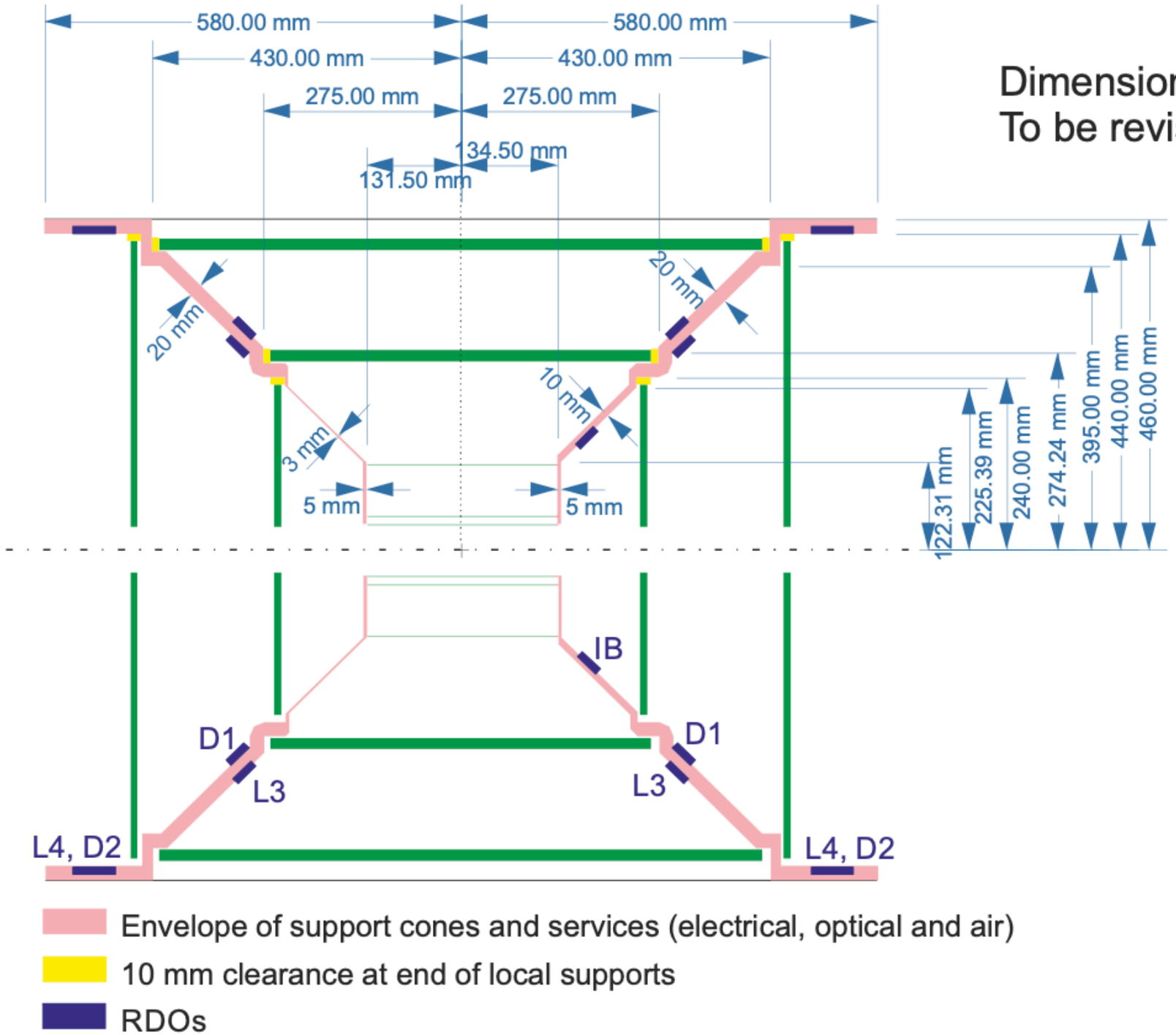
- material needs for R&D
  - ✓ naked silicon (common order to DISCO for IB, OB and DISKS) → ongoing
  - ✓ adhesive polyimide kapton foils (60 x 100 cm^2, 13 μm thick) → order submitted
  - ✓ 3-D printed support structures → design refinement ongoing, produced @ INFN BA
- dedicated SVT tooling and bending setup
  - ✓ tools for precise sensor/kapton positioning being modified → design ongoing
  - ✓ bending setup being duplicated → design+production @ INFN BA + procurements ongoing
  - ✓ mandrel → investigating high-quality prodution by a local agency (being tested, also for ITS3)

Towards prototype assembly:

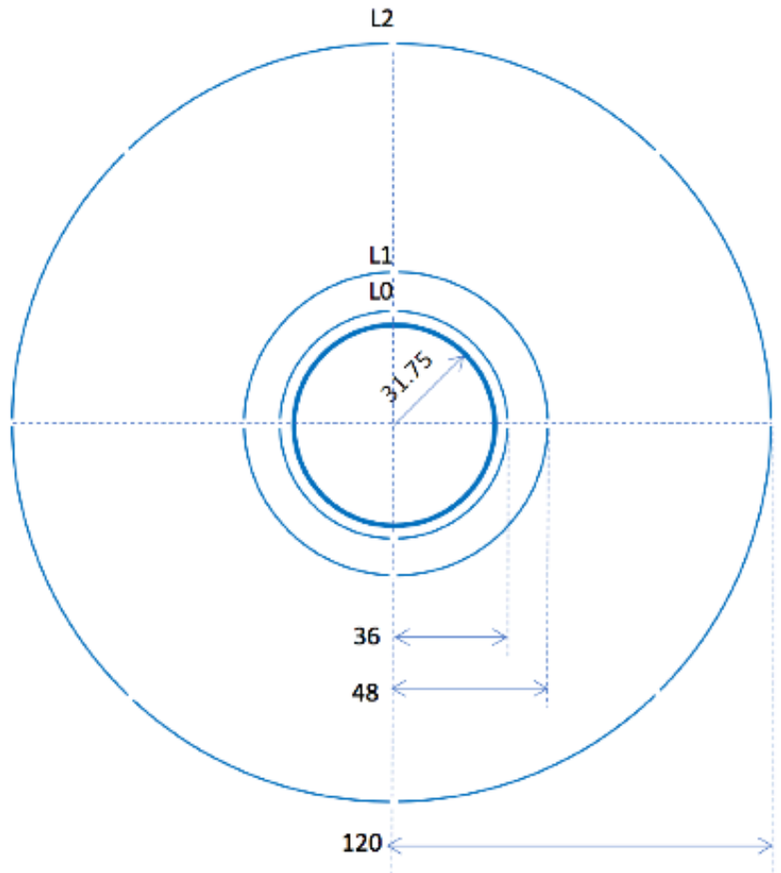
- final goal:
  - ✓ single layer: heaters/encapsulated silicon supported by local mechanics
  - ✓ L0 and L1 layers connected by global mechanics
- material needs for prototype assembly:
  - ✓ encapsulated silicon/heaters → ongoing with CERN (in common for IB, OB and DISKS)
  - ✓ machined carbon foam → to be explored

SVT IB INFN activities

IB global mechanics/integration - Background info



Dimensions indicative only!
To be revised after proper design



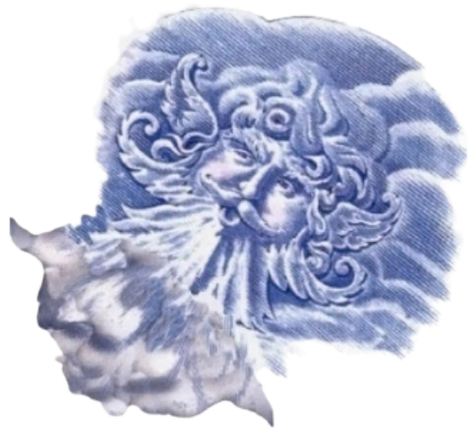
Envelope of support cones and services (electrical, optical and air)

10 mm clearance at end of local supports

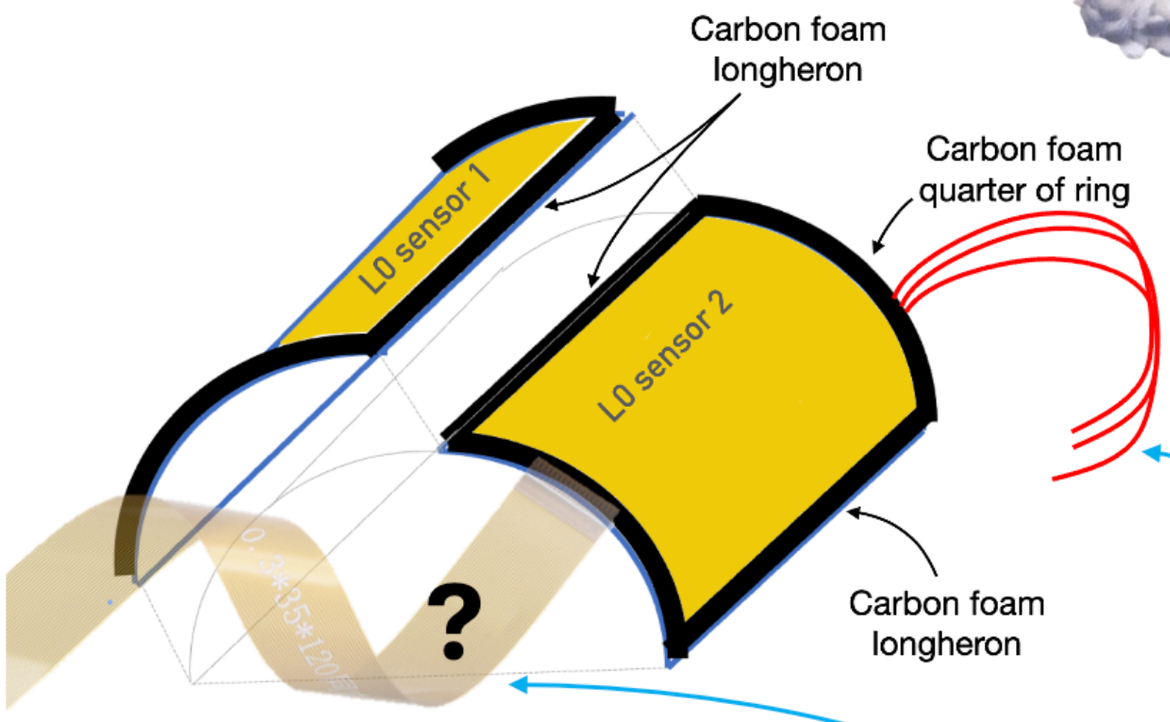
RDOs

IB global mechanics/integration - Basic ideas

@INFN PD



Cooling: a first idea on air distribution on the layers



e-side

cables or FPC's?

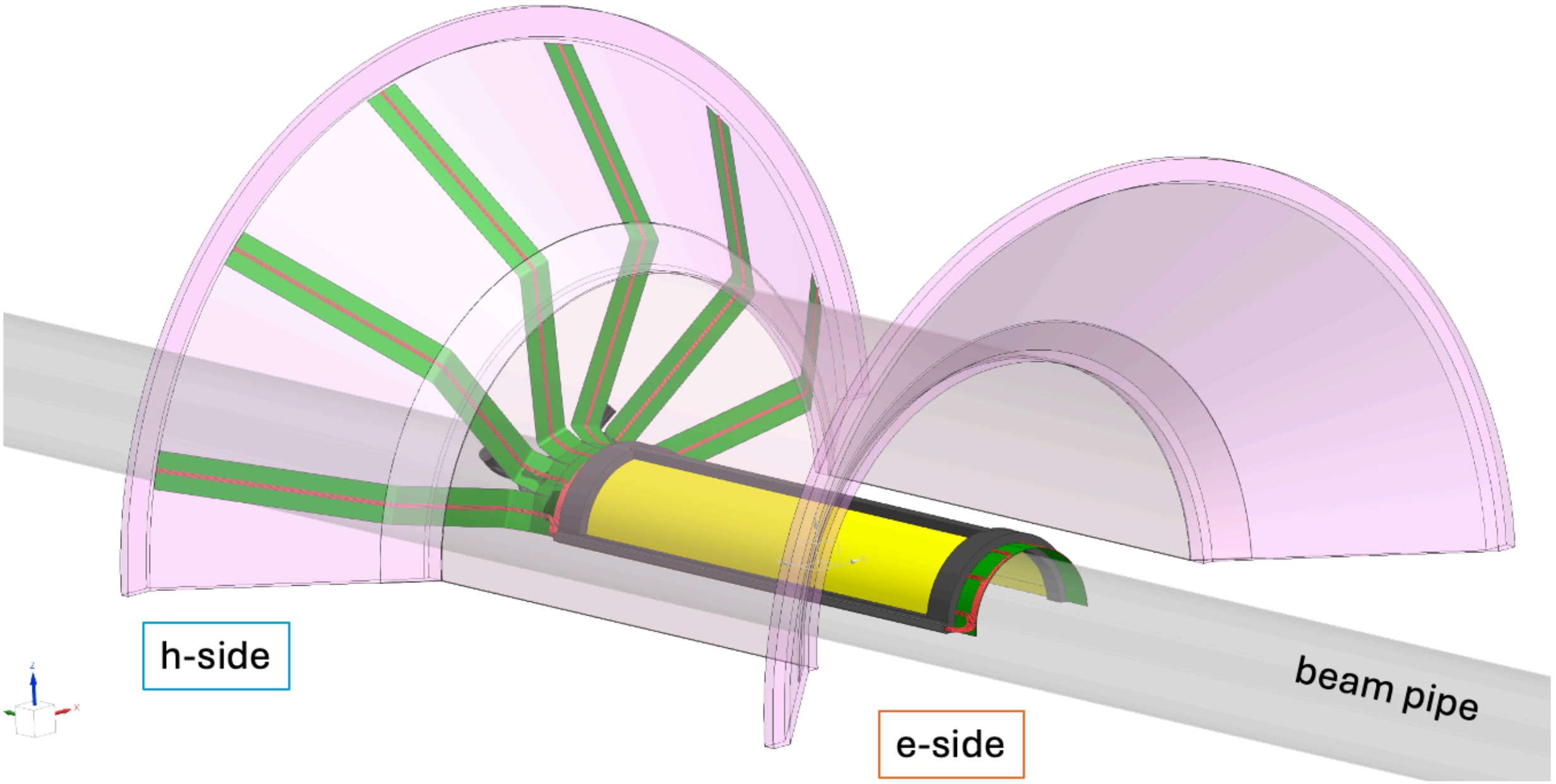
we tried with the first hypothesis as a placeholder, to figure out the possible routing – one cable per phase/ground

h-side

FPC's ITS3-inspired, but with mandatory differences, to be updated along the way…

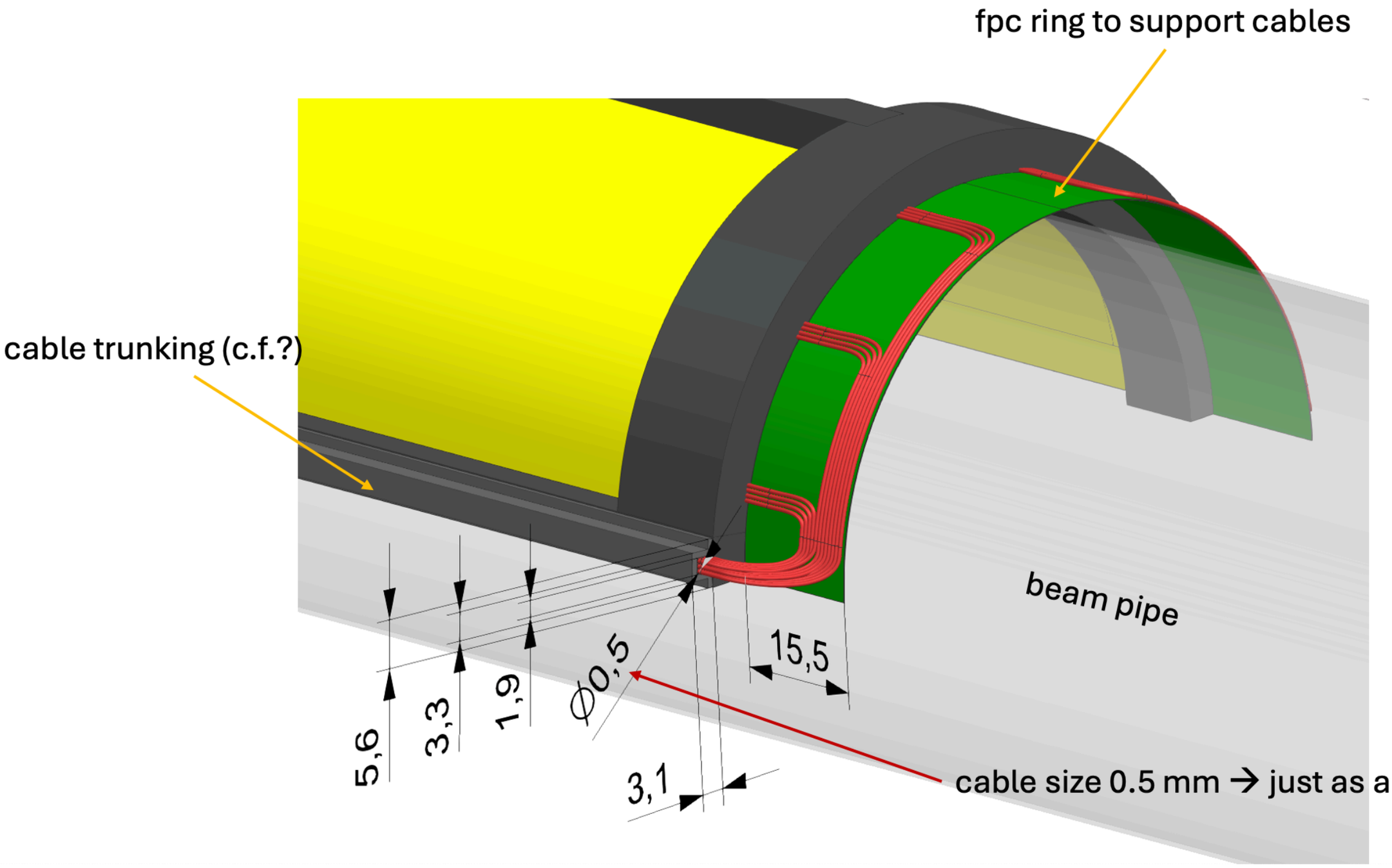
SVT IB INFN activities

IB global mechanics/integration - General view



SVT IB INFN activities

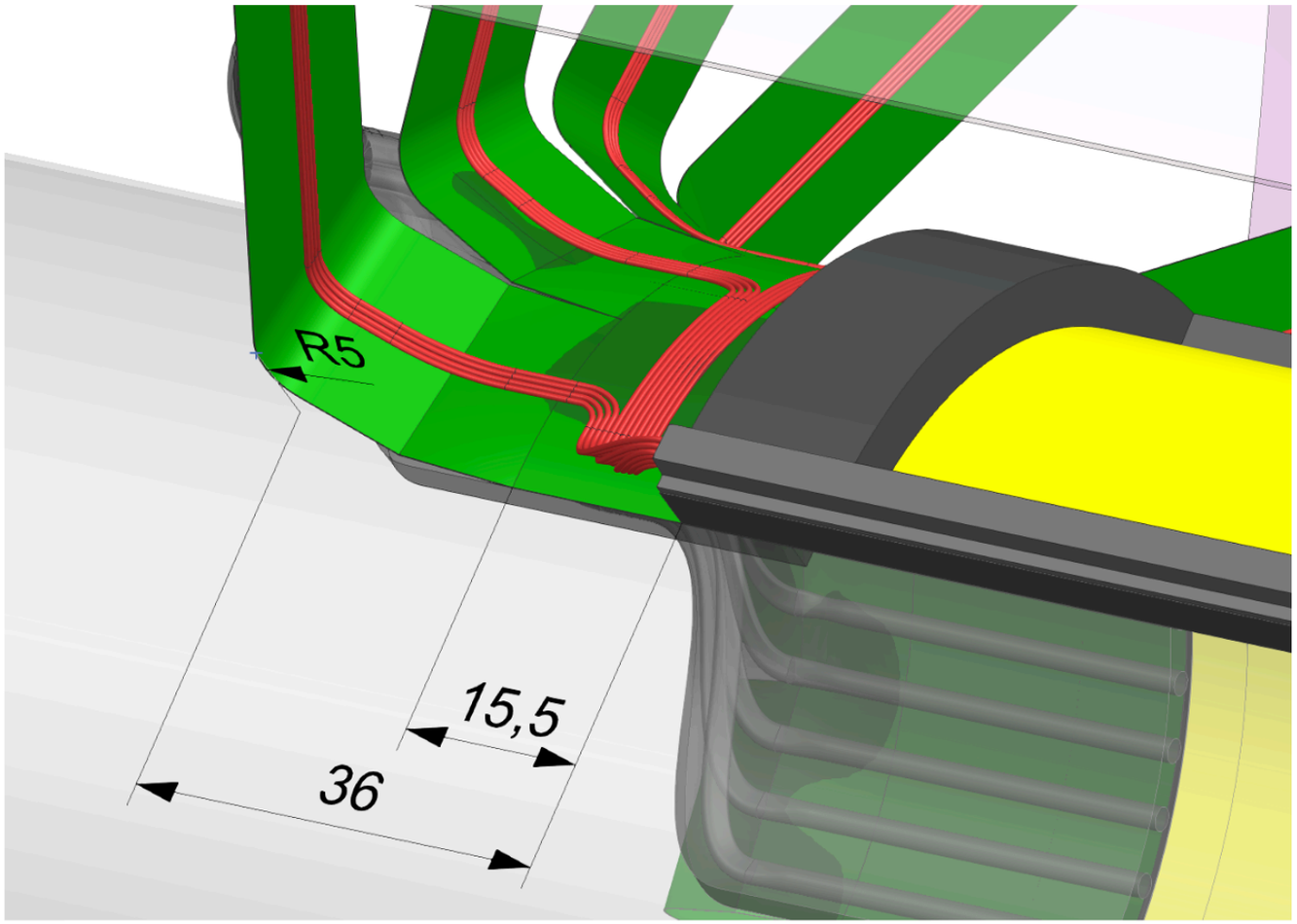
IB global mechanics/integration - e-side view

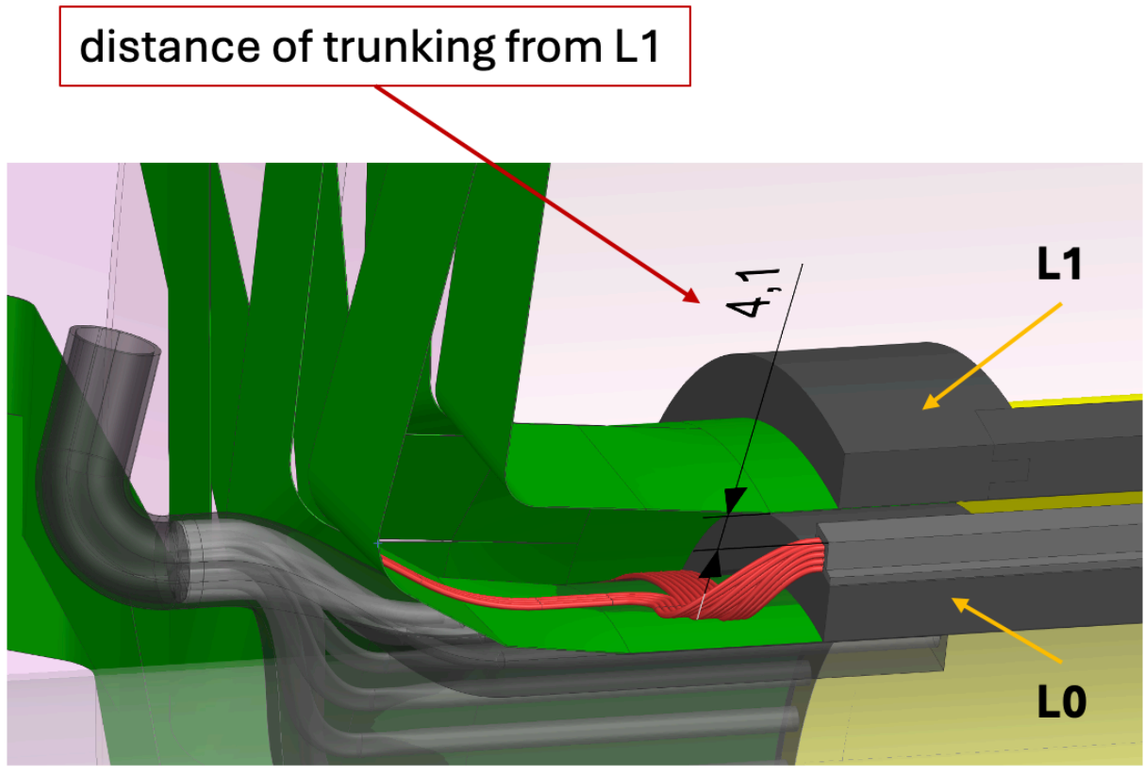


SVT IB INFN activities

IB global mechanics/integration - h-side view

- fpc bending radius 5 mm
- overall extension from support edge: 36 mm

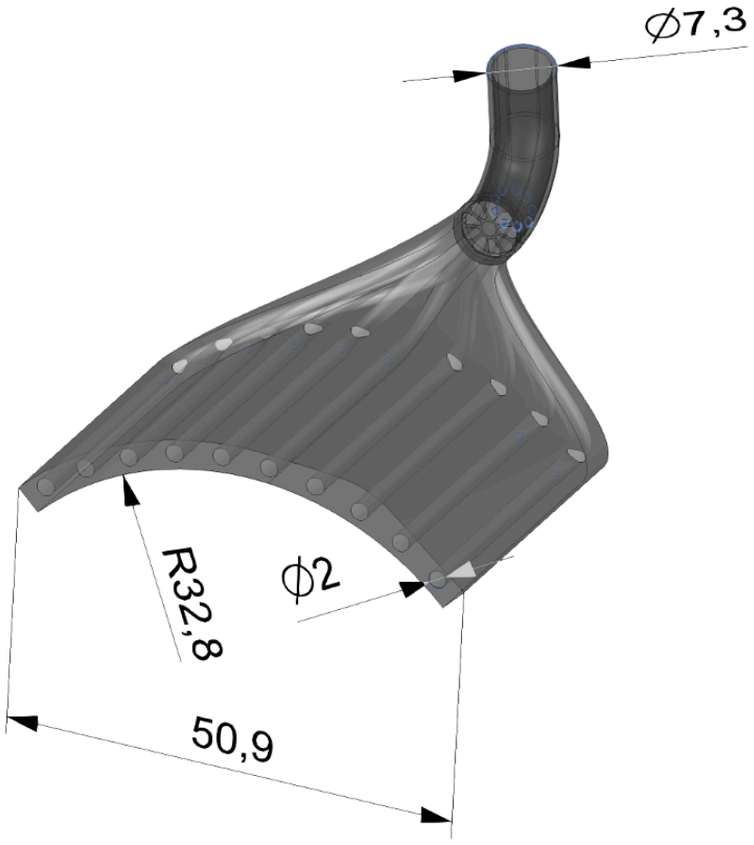


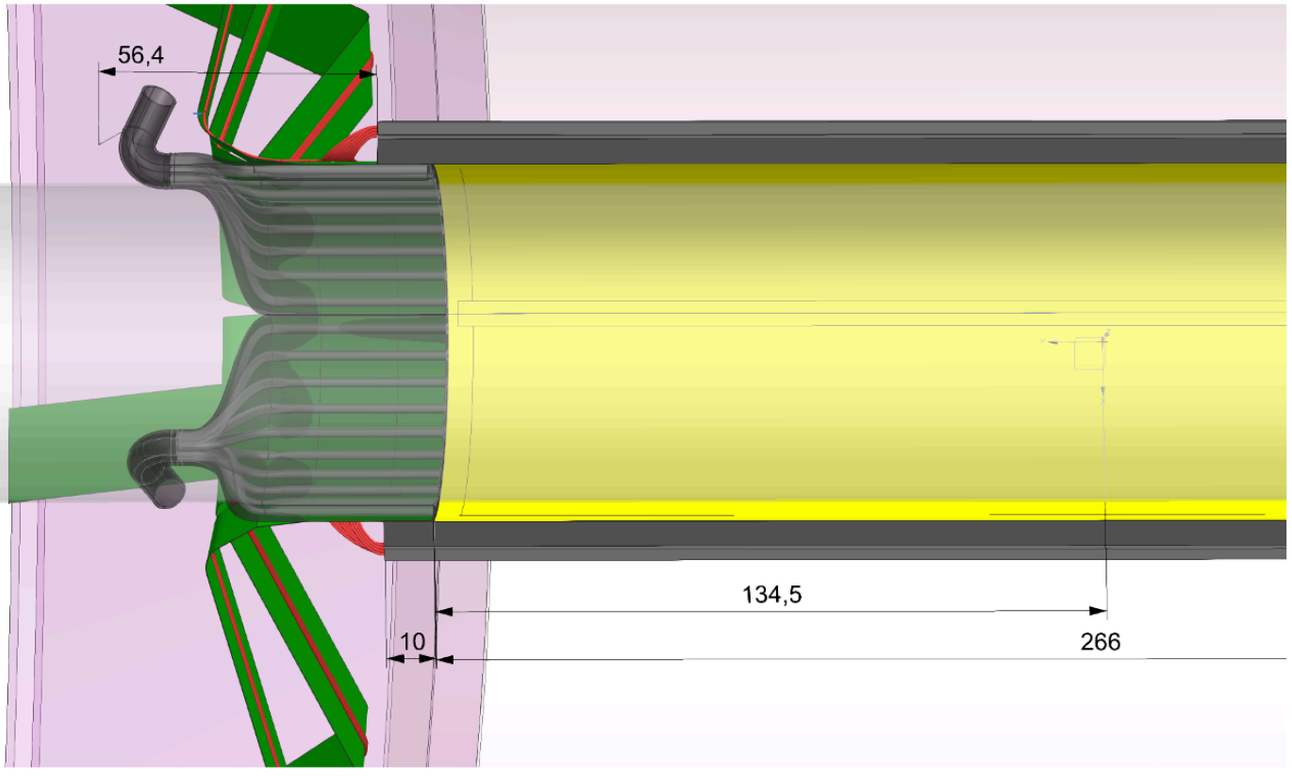


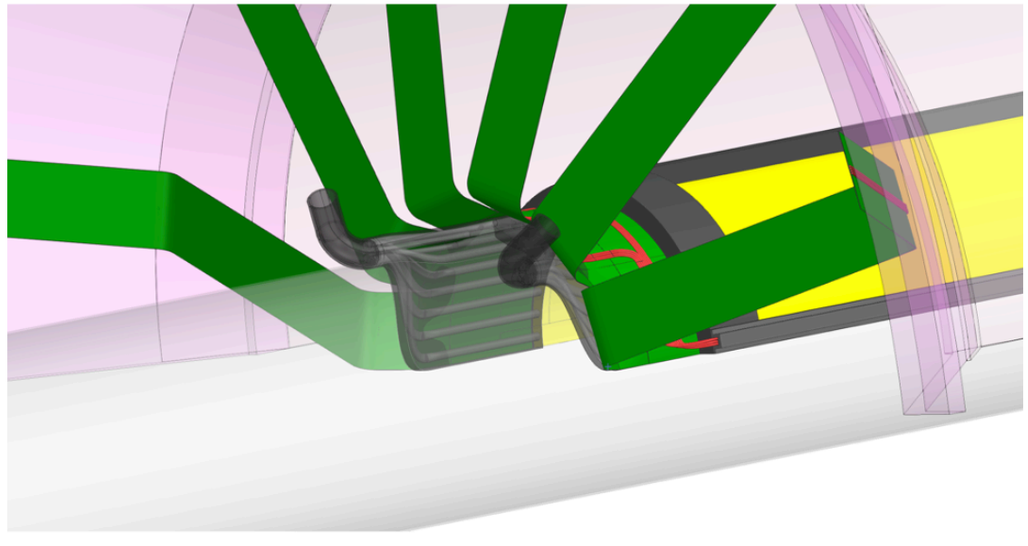
SVT IB INFN activities

IB global mechanics/integration - Air collector

- Designed to flow air between BP and L0
  - not the main plan, but easier to implement and… “who knows”
  - collector between L0 and L1 **w.i.p.** (need to fit among fpc, cables)
- Designed with a 3D print procedure in mind
  - if the case a first mock-up in e.g. PLA doable in Padova – carbon fiber 3d printing also available (Bari)
- Separate lines matching holes on the support for better uniformity







SVT IB INFN activities

Summary activities in Padova

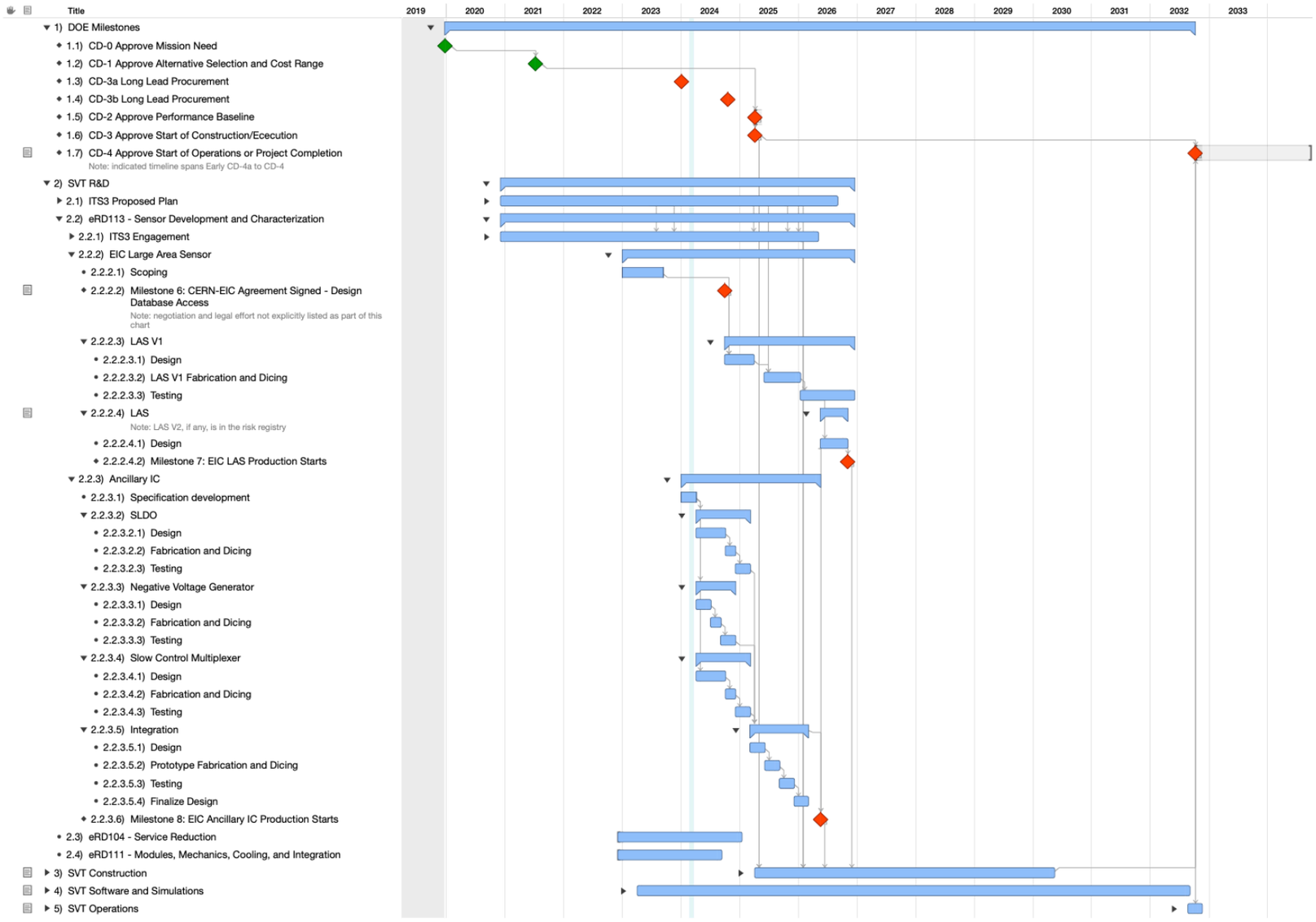
- Update on the different designs of cables e-side/h-side
  - the routing details significantly depending on the size of cables
  - In our hypothesis L2 has 80 lines to be routed, 40 each side, need probably a dedicated modification of the support – maybe easier-to-handle cables, like flat ones?

- First design hypothesis for the air flow collector
  - Could be needed between BP and L0?
  - L0-L1 in progress – L2-external shell?

- A feedback on air distribution effectiveness could come from ANSYS simulation – started a discussion on a simplified simulation to be updated concurrently with the design updates
  - clearly to be validated with measurements on a mock-up

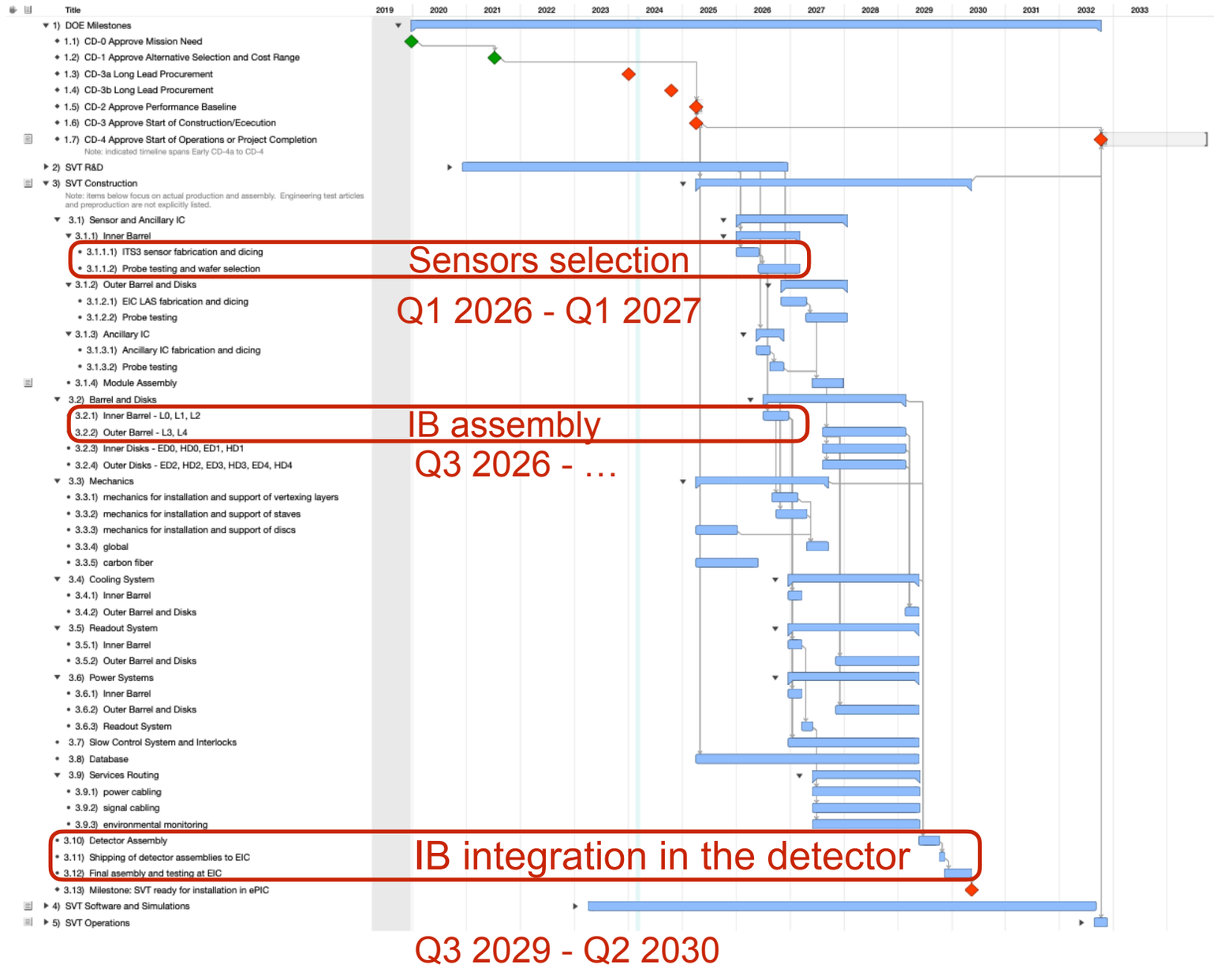
SVT IB Timeline

- Sensor development:
  - ITS3 wafer scale sensor development (ER2, ER3) for IB 2024 – 2026,
  - EIC-LAS development for OB and Disks complete and ready for production start in calendar Q4 2026,
- Ancillary IC development for EIC-LAS complete and ready for production start in calendar Q2 2026.



SVT IB Timeline

- Construction:
  - Engineering test articles following R&D in 2025—2026,
  - Pre-production phase of about 1 year for IB; 2 years for OB,
  - Production and QA through calendar Q2 2029 followed by assembly,
  - Current plan is shipment of surveyed and assembled half barrels and disks to BNL in calendar Q4 2029,
  - Final assembly and testing at BNL through calendar Q1 and Q2 2030, prior to installation in ePIC.
- SVT schedule is compatible with Project requirements, being finalized.

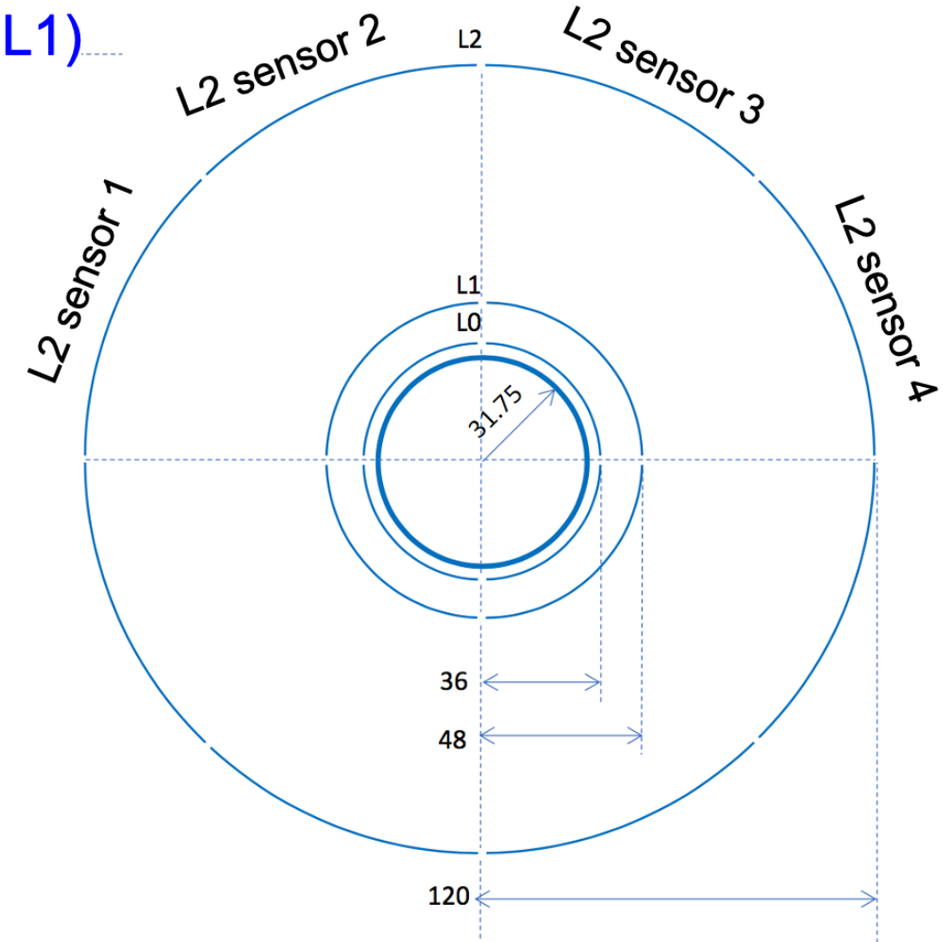


Backup

Backup

Towards SVT IB concept:

- integrated design of the 3 innermost layers including mechanics, cooling, readout and powering, up to the electrical/optical interface:
  - ✓ develop bending procedure, eg L0 (similar for L1)
  - ✓ extend to L2 considering additional issues:



Bending procedure:

- 4 sensors for each half-layer
- embedding all 4 or just 2 sensors, as well as independent (single sensor) bending, to be evaluated in connection with the next point

L2 specific issues and required development:

- L2 radius quite large (~120 mm) and far away from L1 (~70 mm, compared to L1-L0 ~6 mm)
- need to define mechanical connection to L1
- also aspects connected to cooling (in a much larger volume) will be completely different wrt L0/L1 (and to ITS3) and will require dedicated solutions

Further activities/plans

Ongoing @ LBNL

- working on beam pipe bake out studies
- plan to start some general cooling studies

Ongoing @ MIT

- plan to start simulation studies for IB mechanical properties, focus on L2
- contribute to the design of the IB geometry, support structure and cooling

Preliminary discussions on IB FPC with WP3 (Marcello)

→ Updates for the next round IB report