Bending and assembly activities for SVT IB

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Sezione di Bari

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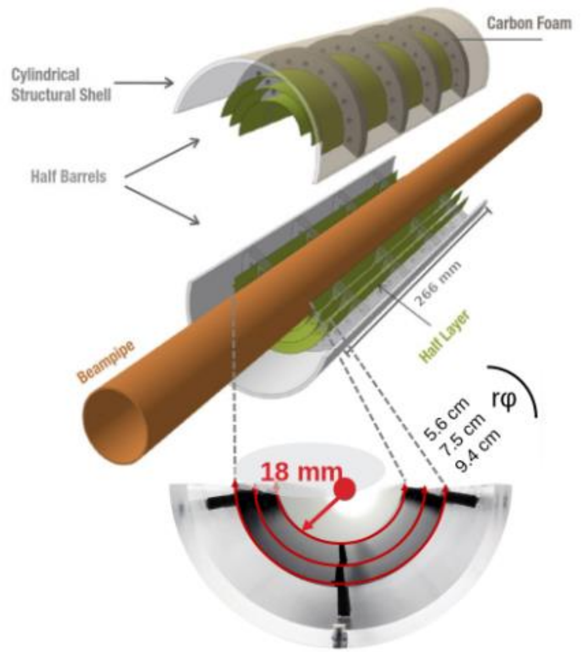
- Sensor bending and detector assembly challenges in SVT
- Recent tests in clean room to define the final procedures
- Next steps

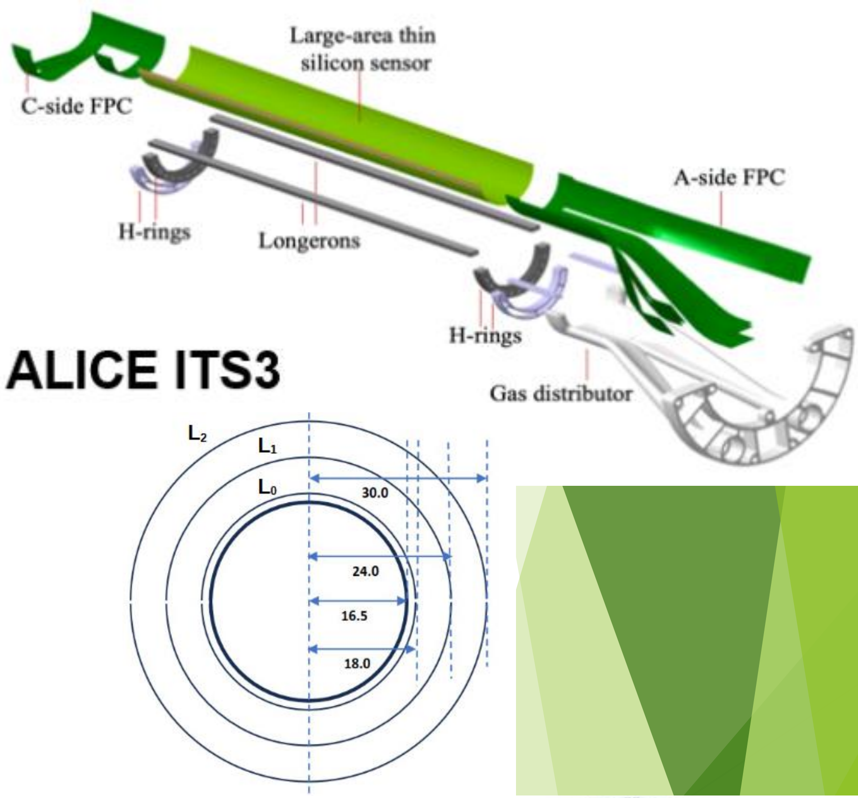
From ALICE ITS3 to ePIC SVT IB layout

ALICE ITS3 detector as basis concept.



Common key ingredients:

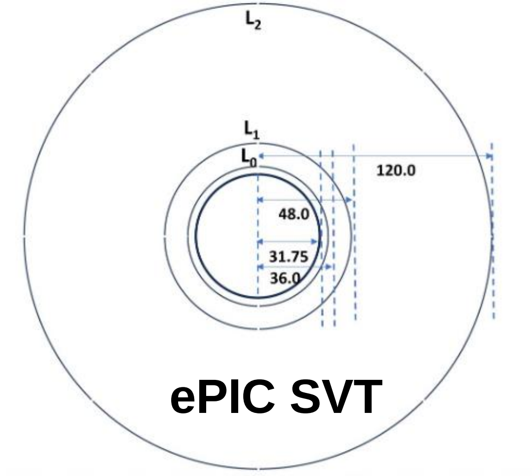
- ❑ Wafer-scale MAPS chips (65 nm CMOS, thickness ≤ 50 µm)
- ❑ Chips bent in cylindrical shape at target radii
- ❑ Ultra-light carbon foam structures
- ❑ Air cooling



Need to adapt it to the ePIC SVT geometry:

Z sensor length (mm): 270

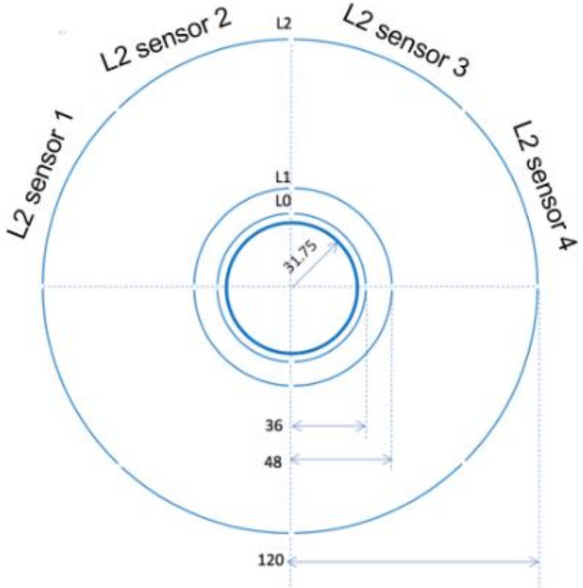
L0 radius (mm): 38
L1 radius (mm): 50.4
L2 radius (mm): 126



Mechanics of the 3 innermost SVT layers

Mechanical challenges:

- Development of bending procedures
  - **specific to L0,L1**: Two sensors in each half-layer
  - specific to L2: Four sensors in each half-layer



- Mechanical support structure
  - Mechanical connection between L1 and L2 (~70 mm)
  - Definition of cooling volumes (possibly exploited as mechanical support, too)
  - Exploring needs for («light») supporting shell external to L2, and an additional shell between L1 and L2.

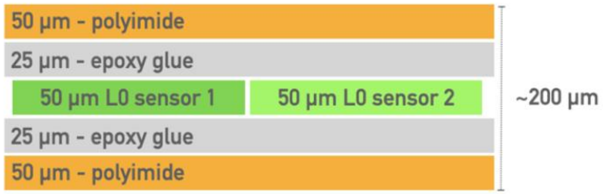
L0, L1 bending procedure

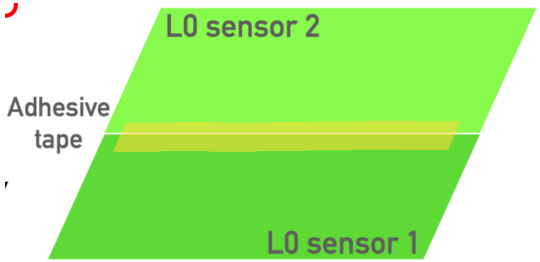
Half bending

Two sensors 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 tape just on one side



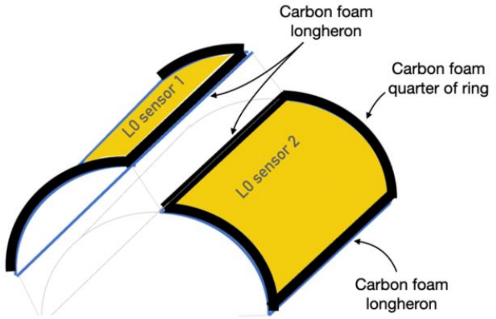


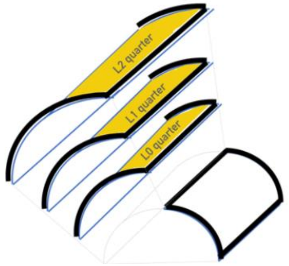
S1 and S2 Pros: Assembly procedure and most of the tools equal to ITS3 (just scaling)

S1 Cons: new R&D on kaptonisation procedure (thermal and pressure stress on the sensor during the gluing, air bubbles if adhesive kapton sheets are chosen);
Access to the soldering pads (Proposed solution from Cern MPT workshop)

Independent quarter bending

Still not investigated in details,





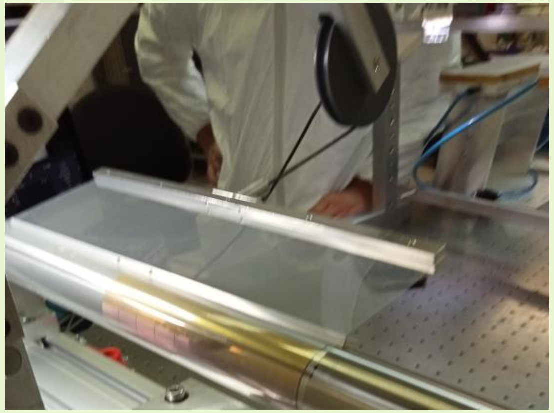
because it needs:

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

super-ALPIDE dummy assembly

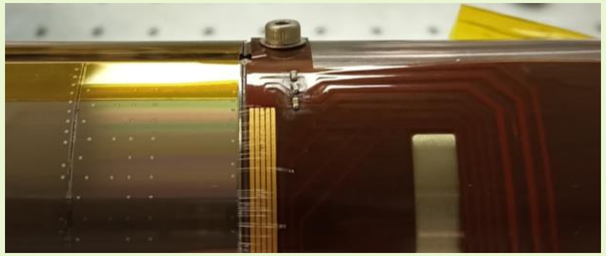
In the scenario of «half bending», the super-ALPIDE is also a good preparatory work for SVT IB since it has several common steps

Sensor bending



- ❑ Sensor transfer (vacuum tools)
- ❑ Kapton tape placement on the sensor edge/mylar sheet edge
- ❑ Alignment procedure to place the sensor on the mandrel (sensor edge is the mobile reference)
- ❑ Bending lead by mylar sheet, constrained by a pulley

Wire bonding



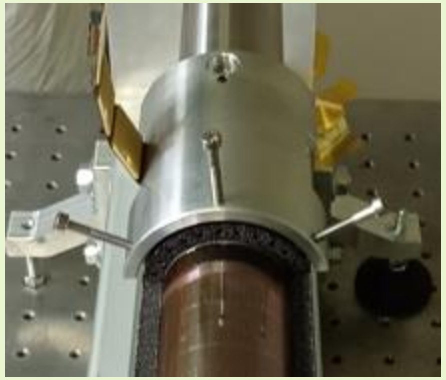
Ultrasonic wire bonding tecnique, applied btw:

- ❑ Sensor and edge-FPC

On curved surface at different azimuthal angle

Inter-layer mechanical support gluing

Carbon foam struts and half-rings



Delicate procedure, be aware of

- ❑ wire-bondings btw sensor and edge-FPC are already made before the gluing
- ❑ Not cover with glue the soldering pads for the bondings btw sensor and the guide tools

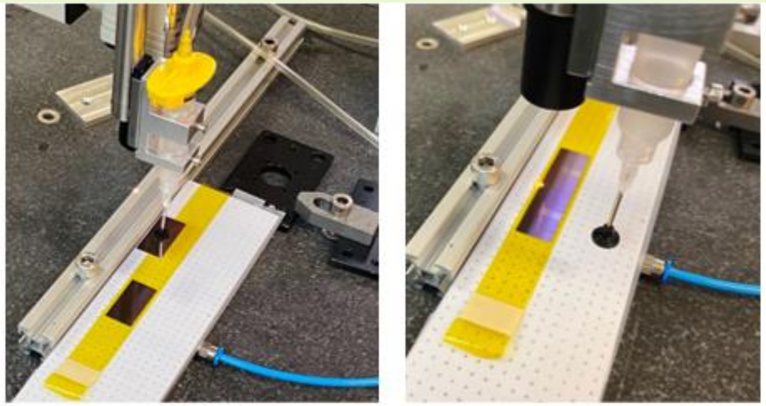
Half bending S1: **Sensor kaptonisation**

kapton gluing/kaptonisation is an established procedure in PCB manufacture

Caveat: First trials made with :

- ~100 µm thick ALPIDE, with area (15x30 mm^2) and smaller mandrel radius (~ 18 mm)
- adhesive kapton tape (20 mm width, 40 µm thickness)

Precise placement of the sensors on (bottom) kapton



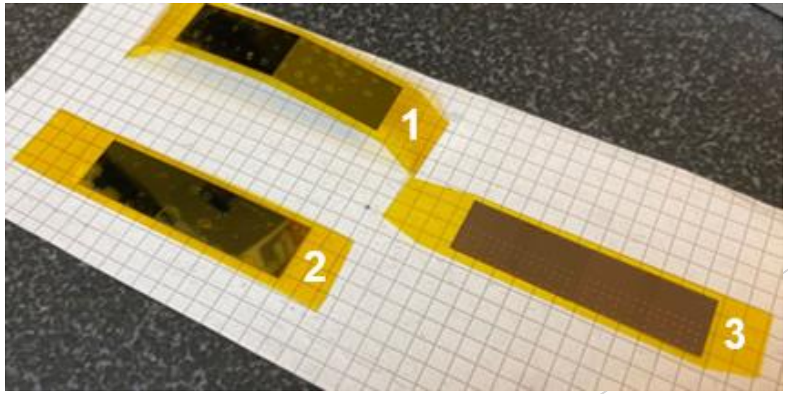
using a Mitutoyo machine equipped with alignment vacuum tool, distance btw sensors ~50 µm

Three samples

enc-K1: encapsulated sensors (i.e. kapton on both sides), top kapton tape positioned by hand

enc-K2: encapsulated sensors (i.e. kapton on both sides), top kapton tape positioned by

single-K3: only bottom kapton on the sensor side



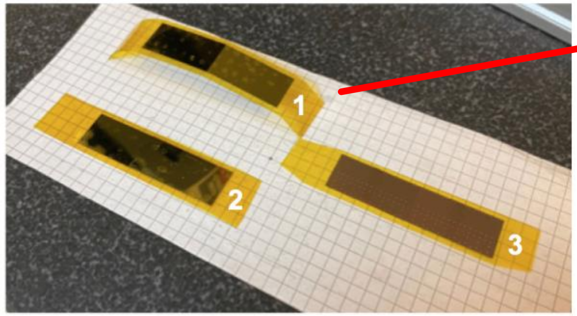
Sensor encapsulation and bending

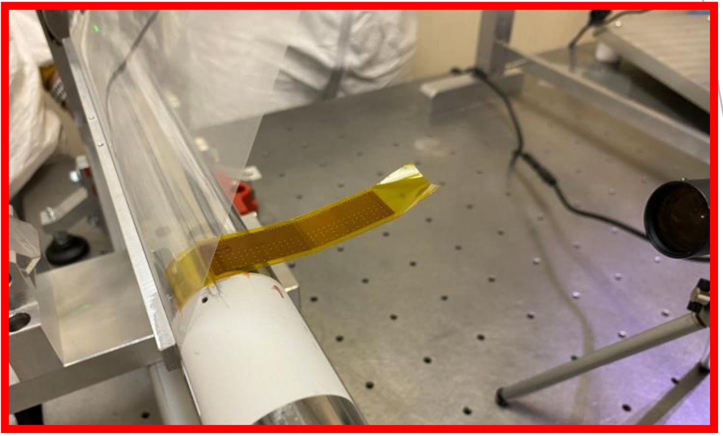
- encapsulated sensor bending:

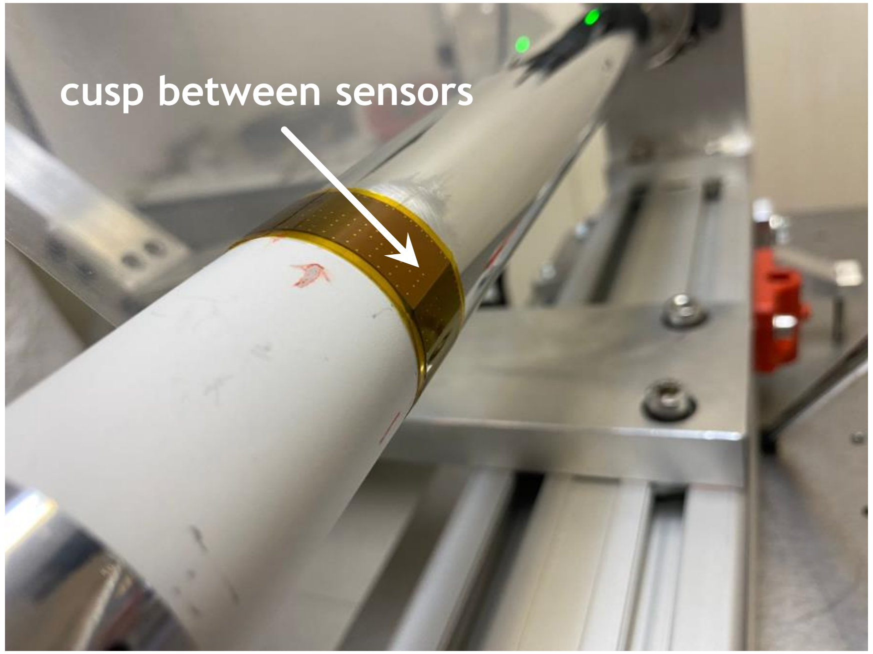
enc-K1 :

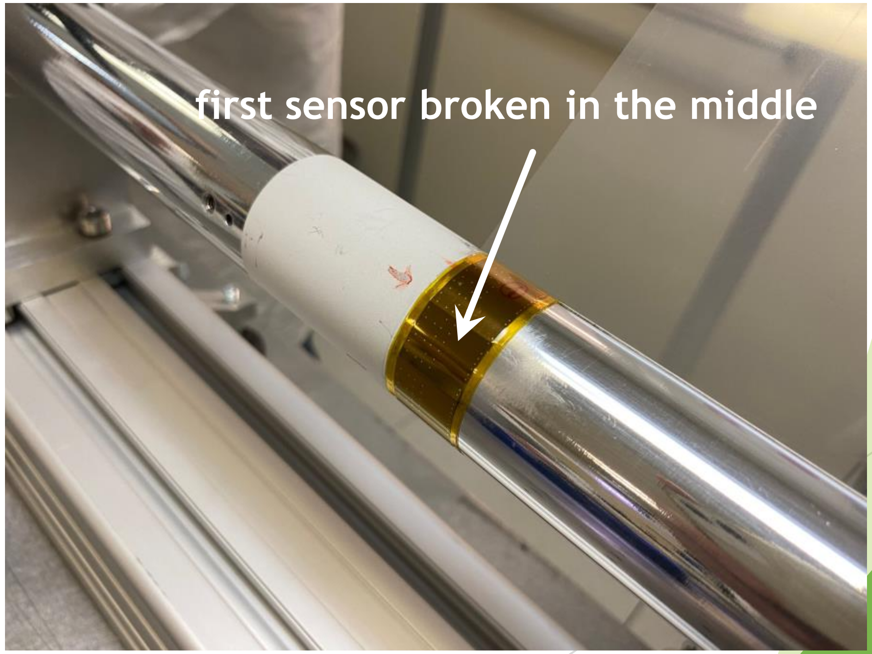
☐ encapsulated sensors

☐ top kapton positioning by hand







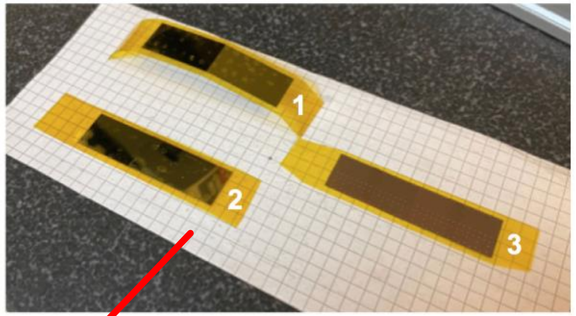


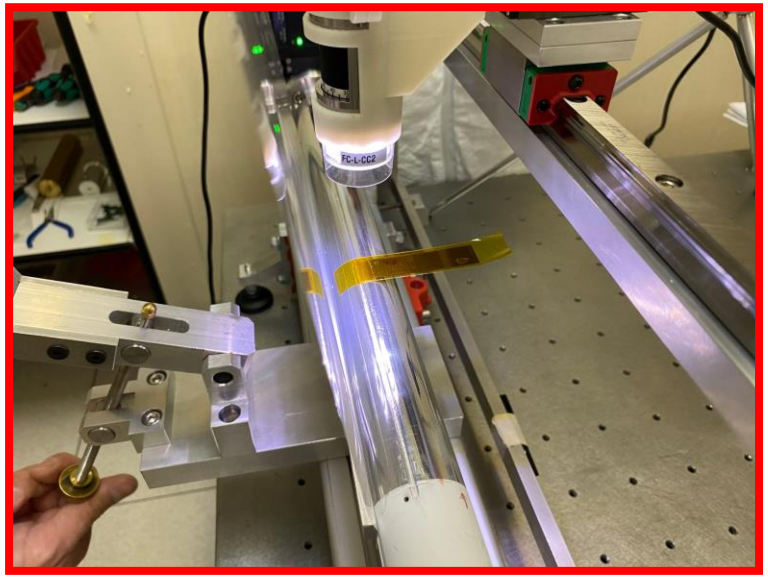
Sensor encapsulation and bending

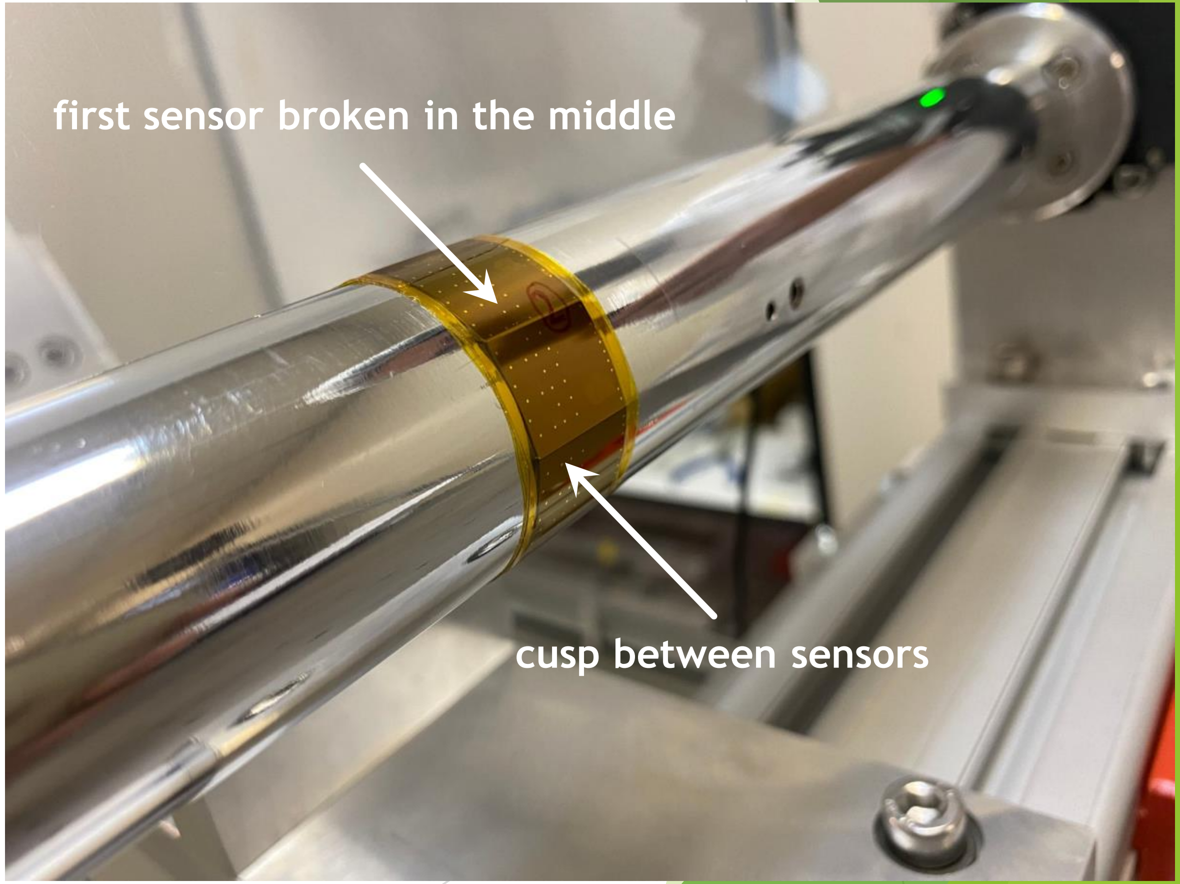
- encapsulated sensor bending:

enc-K2 :

- ☐ encapsulated sensors
- ☐ top kapton positioning by a dedicated tool






first sensor broken in the middle

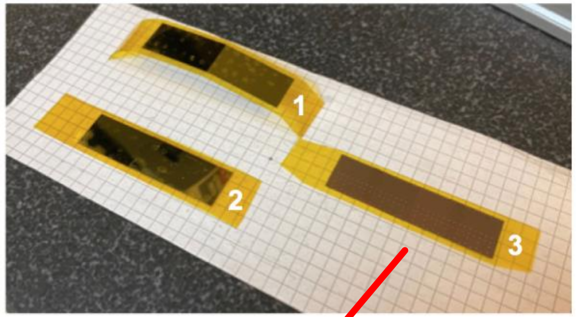
cusp between sensors

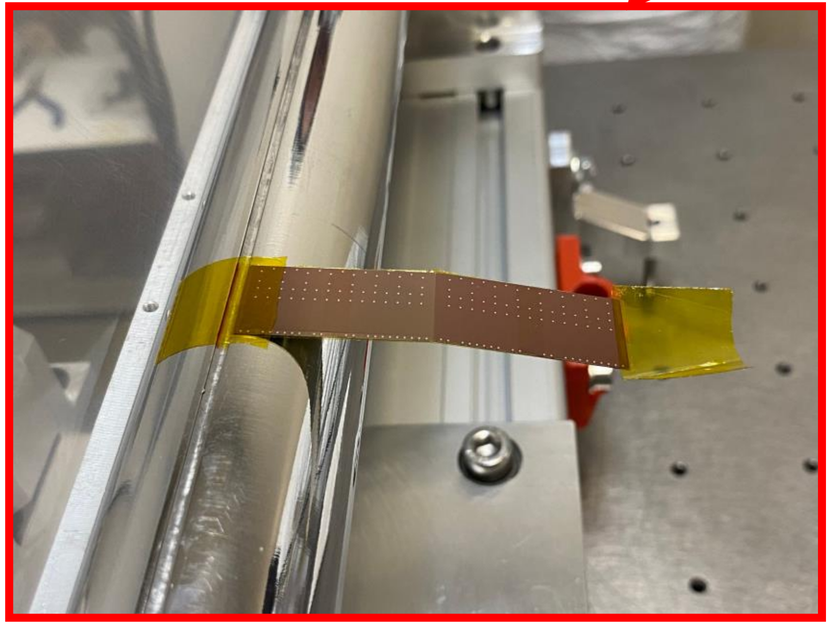
Sensor encapsulation and bending

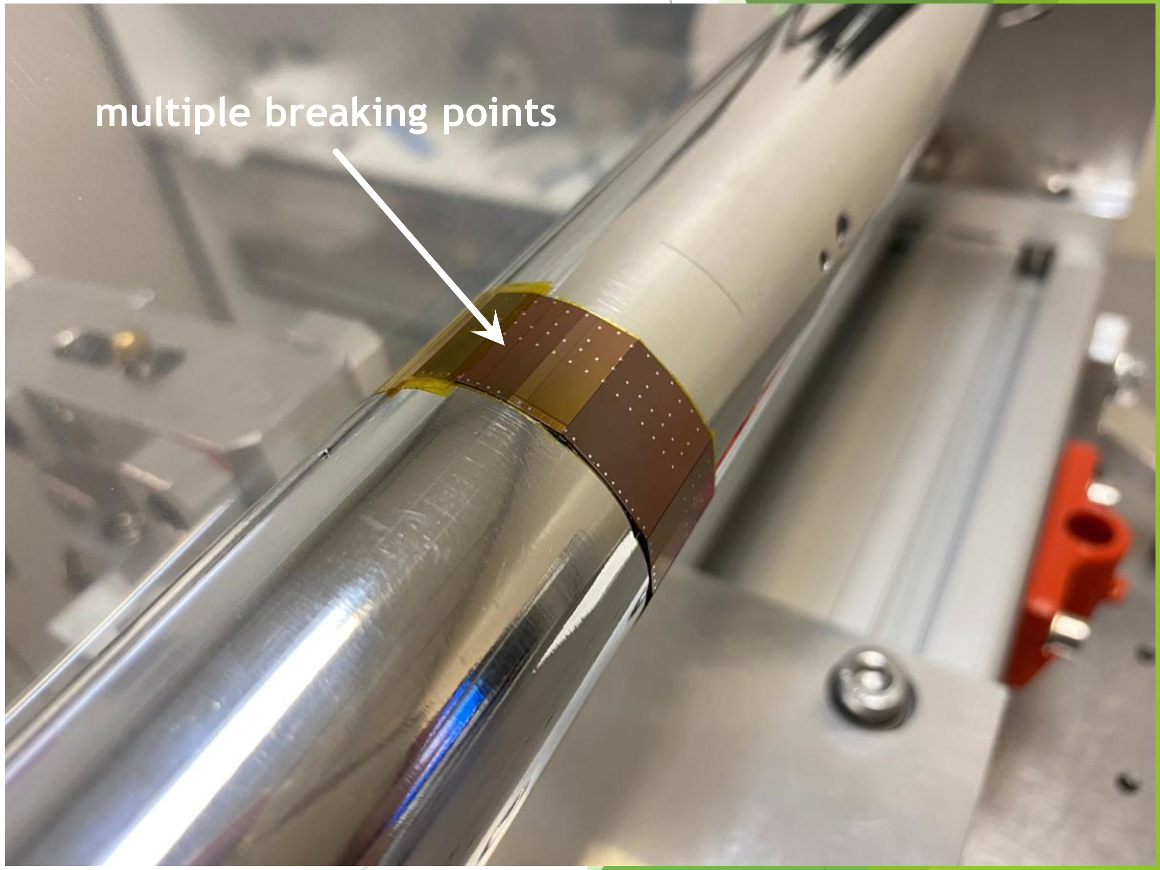
- Semi-encapsulated sensor bending:

Single-K3:

☐ kapton tape only on the sensor side







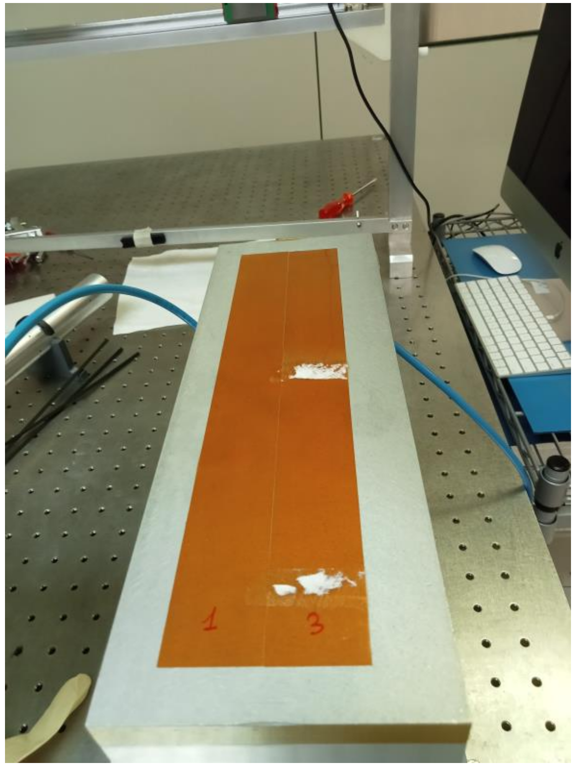
Sensor encapsulation and bending summary

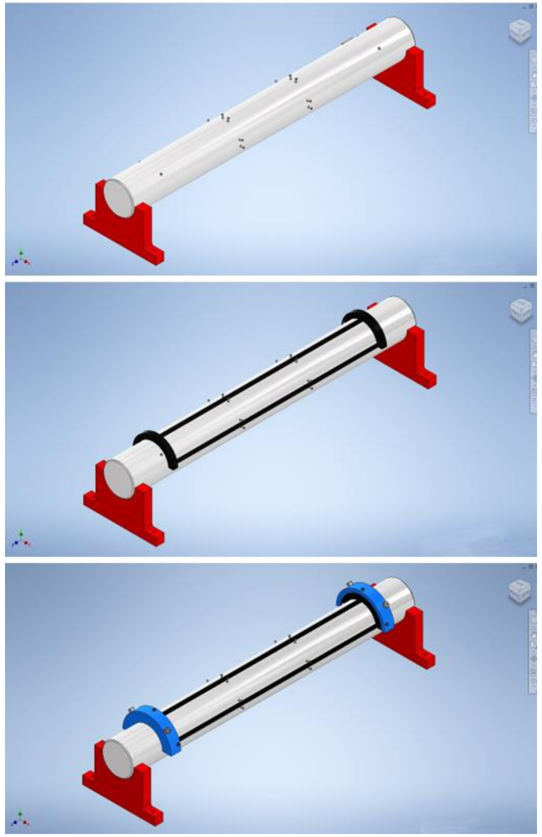
Results of the first tests performed in clean room @INFN Bari:

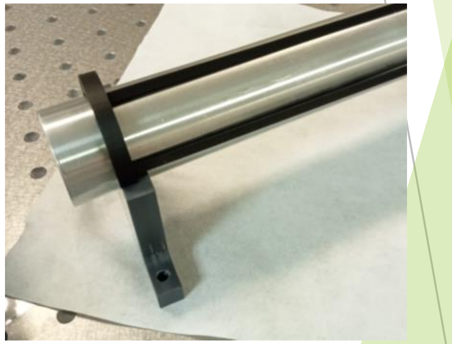
- ☐ sensor encapsulation in kapton adhesive tape (or kaptonisation) :
  - ✓ excercised precise positioning of kapton and sensors (precisions ~10 µm)
  - ✓ better ideas of additional tooling needed for large sensors / kapton foils
    → design ongoing
- ☐ encapsulated sensor bending:
  - ✓ (re-)excercised 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)

Next steps

- Half bending S2 (already started): Definition of the procedure with kapton foils with 50 µm thickness to mimic the objects that we want to bend and keep bent.





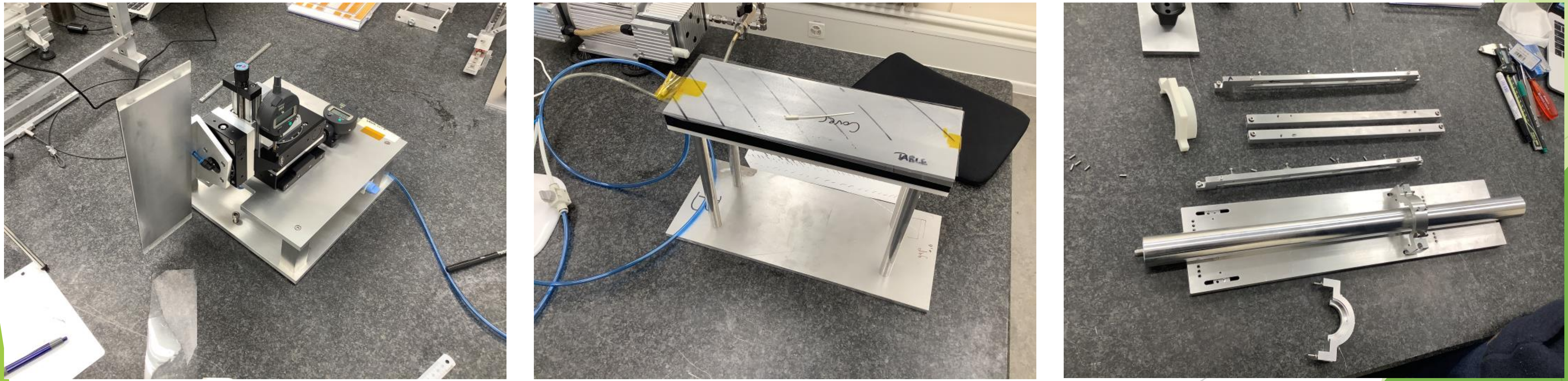


- Delivery of the SVT material in Bari
  - ❑ DISCO sensor dummies
  - ❑ Assembly tools with scaled dimensions w.r.t ITS3 setup (next slide)

IB preliminary assembly concept

First steps towards developing SVT IB concept:

- ❑ preliminary SVT dedicated assembly setup @INFN
  - ❑ most of the components already available (procurements + local production)
  - ❑ external contact for high-quality mandrel already in place
- ❑ some tools need specific (re-)design to be tested and validated
  - ❑ on real-size components (silicon dummies being produced → see next slides)
  - ❑ for 2-sensor bending in half-barrel assembly procedure



(Tentative) IB prototype production plan for L0-L1

	Prototype	Components	Goal
OCT 2024	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
NOV 2024	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
DIC 2024	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 distributor (if yes, to be designed/produced)
- Possible preliminary FPC (mechanical) prototype to check volumes, transport etc)
- transport issues to wind tunnel facility

IB prototype production plan

On the critical path:

- ☐ dummy silicon sensor available:
  - ☐ P1-2: validate bending, then half-layer and -barrel assemblies
  - ☐ P1-4: asses if local support structure can made half-layer/barrel self-standing (no external shell)
- ☐ carbon foam:
  - ☐ procurement and machining need to be defined
  - ☐ P3-5: asses if local support structure can made half-layer/barrel self-standing (no external shell)
- ☐ simulation:
  - ☐ manpower needs to be defined
  - ☐ P1-5: understand if outer supporting shell is thermally needed (confine volumes)
  - ☐ P1-5: understand if outer supporting shell is mechanically needed
- ☐ carbon fiber shell(s)
  - ☐ if needed (see previous points), procurement and machining need to be defined
- ☐ L2 prototyping
  - ☐ needs to be planned and eventually matched to L0-L1 prototypes

Towards SVT IB …

All the SVT IB team is working :

- to finalise the integrated design of 3 innermost layers including mechanics, cooling, readout and powering, up to the electrical/optical interfaces
- to realize the thermo-mechanical prototypes
- to finalise the mechanical structure within to mount everything

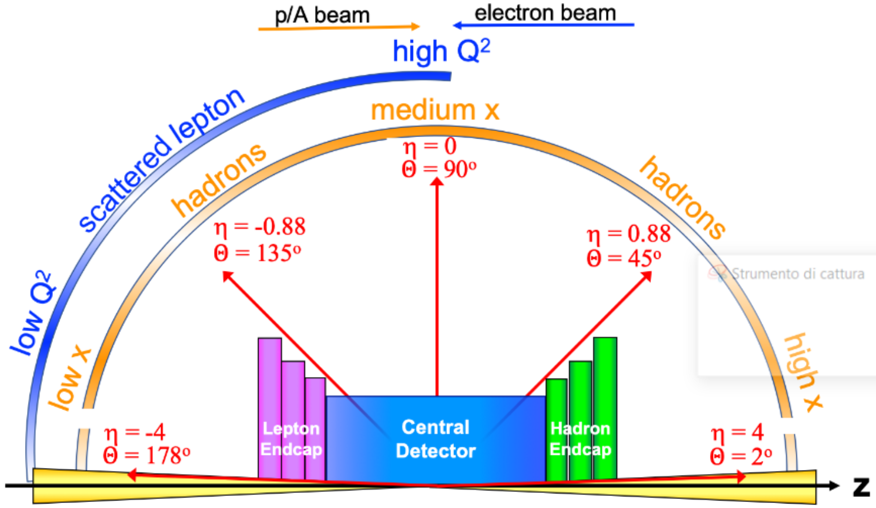
INFN Bari:

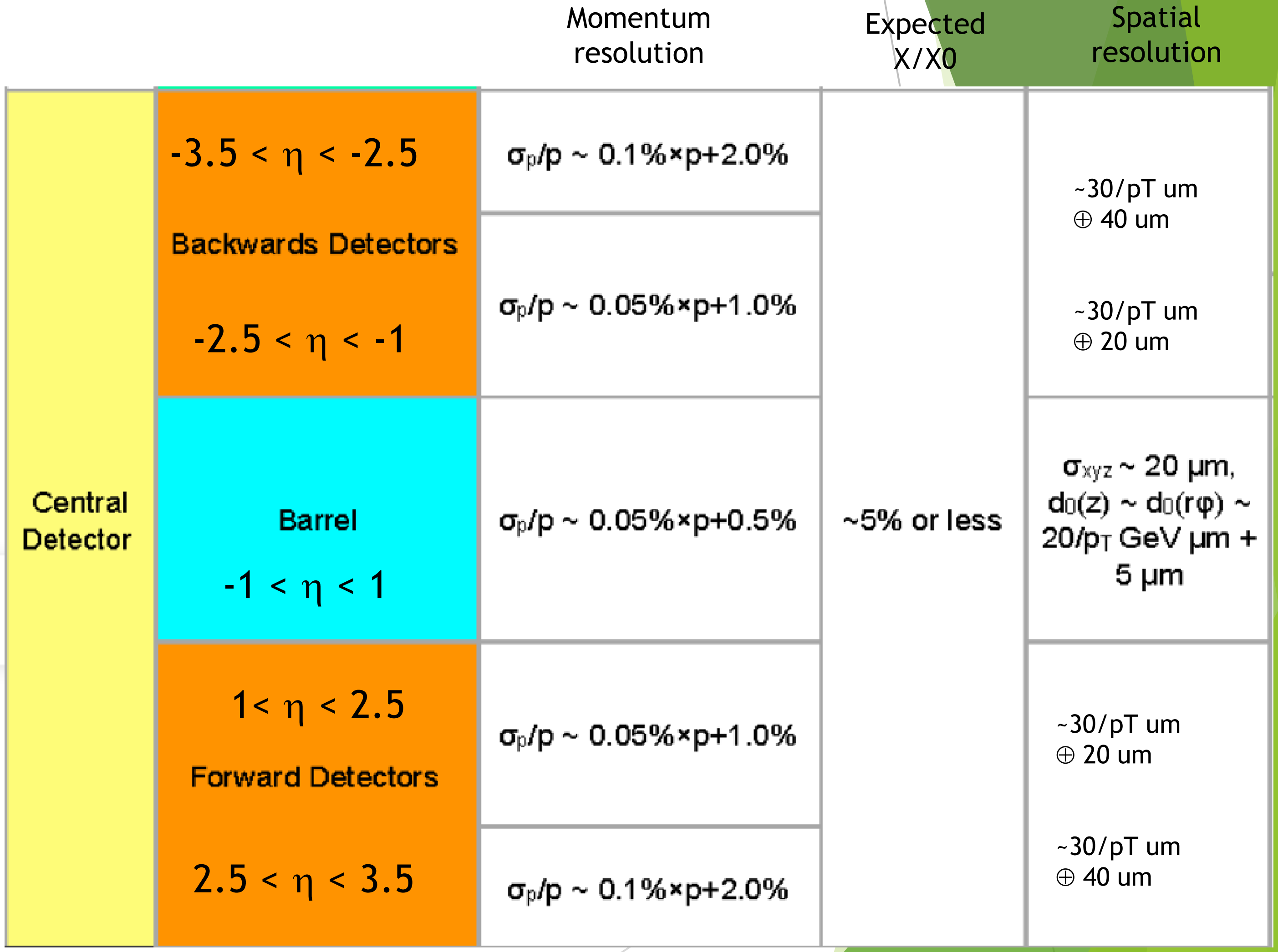
- performed the first test and required the setup to equip the laboratory for the assembly of half-barrel SVT L0 an L1 dummies;
- Plans to firstly investigate the half-barrel assembly procedure after aligning the sensors with a tape (+ a possible structural shell external to L1)

Back-up

Physics performance requirements

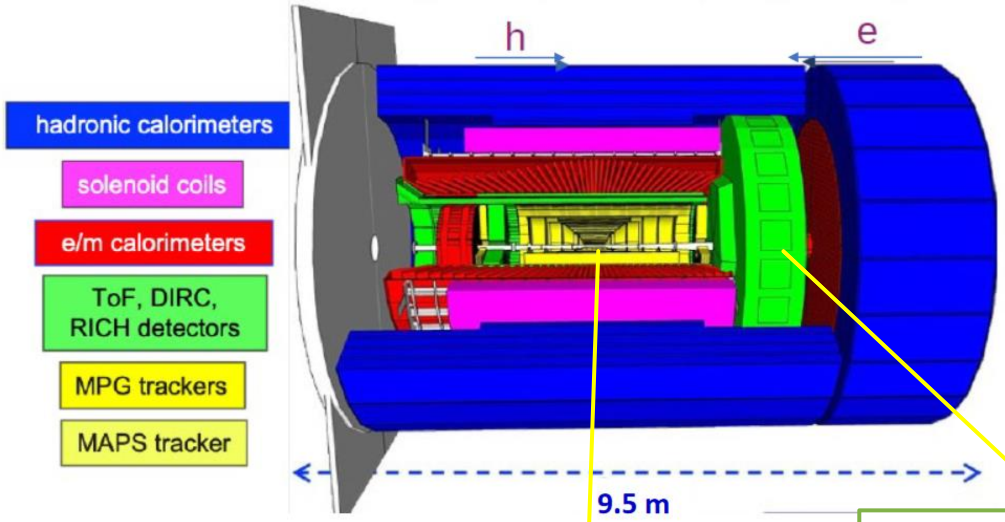
List of EIC Detector Requirements (updated Nov 2023) from Yellow Report





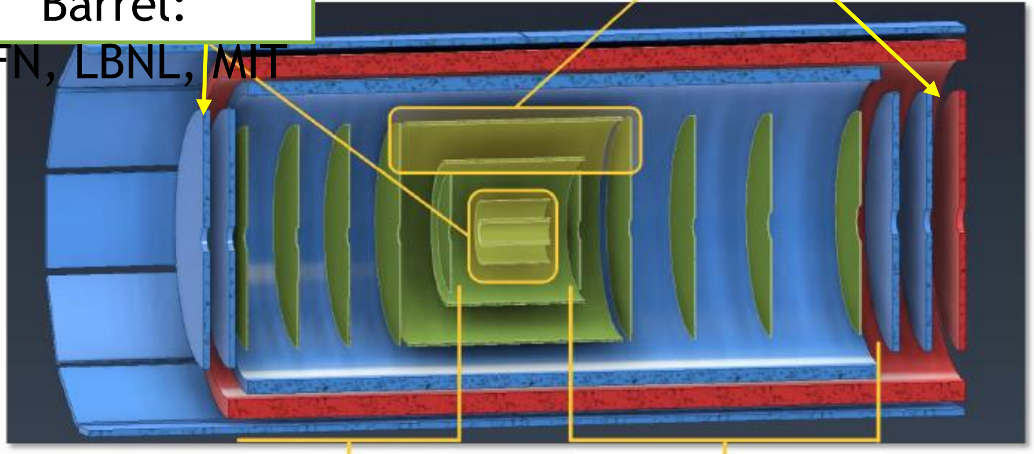
		Momentum resolution	Expected X/X0	Spatial resolution
Central Detector	$-3.5 < \eta < -2.5$ **Backwards Detectors**	$\sigma_p/p \sim 0.1\% \times p + 2.0\%$	~5% or less	$\sim 30/pT$ um $\oplus$ 40 um
	$-2.5 < \eta < -1$	$\sigma_p/p \sim 0.05\% \times p + 1.0\%$		$\sim 30/pT$ um $\oplus$ 20 um
	Barrel $-1 < \eta < 1$	$\sigma_p/p \sim 0.05\% \times p + 0.5\%$		$\sigma_{xyz} \sim 20$ μm, $d_0(z) \sim d_0(r\varphi) \sim 20/p_T$ GeV μm + 5 μm
	$1 < \eta < 2.5$ **Forward Detectors**	$\sigma_p/p \sim 0.05\% \times p + 1.0\%$		$\sim 30/pT$ um $\oplus$ 20 um
	$2.5 < \eta < 3.5$	$\sigma_p/p \sim 0.1\% \times p + 2.0\%$		$\sim 30/pT$ um $\oplus$ 40 um

Tracking system layout



SVT Inner Barrel: INFN, LBNL, MIT

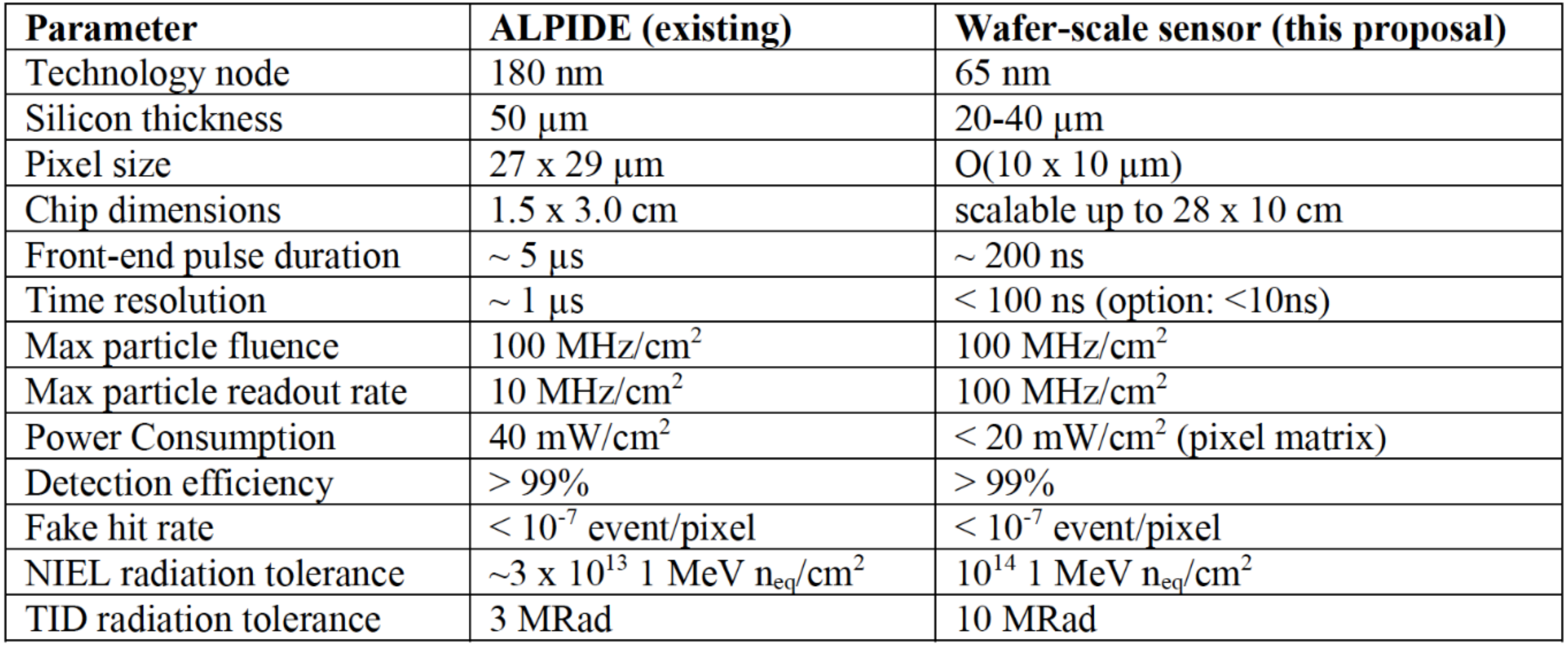
SVT Inner L2 and Outer Barrel: UK group



SVT Disks: LANL, LBNL+UCB, Purdue

MAPS

Similar sensor structure possible as in ALPIDE able to operate at HL-LHC (EIC) luminosity for ITS3 (SVT)



Parameter	**ALPIDE (existing)**	**Wafer-scale sensor (this proposal)**
Technology node	180 nm	65 nm
Silicon thickness	50 μm	20-40 μm
Pixel size	27 x 29 μm	O(10 x 10 μm)
Chip dimensions	1.5 x 3.0 cm	scalable up to 28 x 10 cm
Front-end pulse duration	~ 5 μs	~ 200 ns
Time resolution	~ 1 μs	< 100 ns (option: <10ns)
Max particle fluence	100 MHz/cm^2	100 MHz/cm^2
Max particle readout rate	10 MHz/cm^2	100 MHz/cm^2
Power Consumption	40 mW/cm^2	< 20 mW/cm^2 (pixel matrix)
Detection efficiency	> 99%	> 99%
Fake hit rate	< 10^{-7} event/pixel	< 10^{-7} event/pixel
NIEL radiation tolerance	~3 x 10^{13} 1 MeV n_{eq}/cm^2	10^{14} 1 MeV n_{eq}/cm^2
TID radiation tolerance	3 MRad	10 MRad

M. Mager | ITS3 kickoff | 04.12.2019 |

(ALICE ITS3) MAPS

Technology: 65 nm CMOS; **Chip size**: scalable up to 28x10 cm^2;

Pitch: O(20 um) pitch; **Pixel matrix power consumption**: < 20 mW/cm^2;

Sensor material budget: 0.05% X/X_0 per layer; **Time resolution** < 100 ns