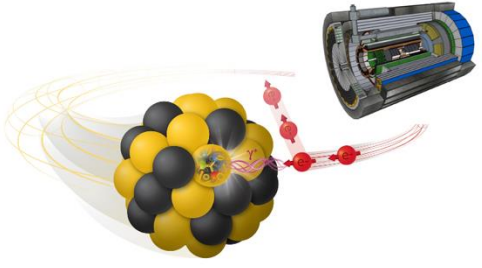


The ePIC SVT barrel

design and first prototyping activities

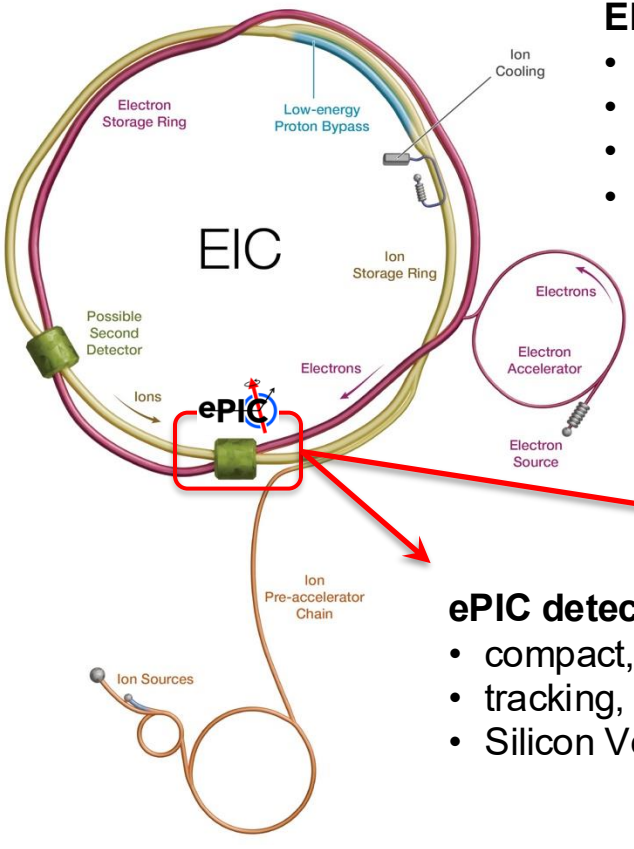
Domenico Elia *(INFN Bari, Italy)*

for the ePIC Collaboration

Outline

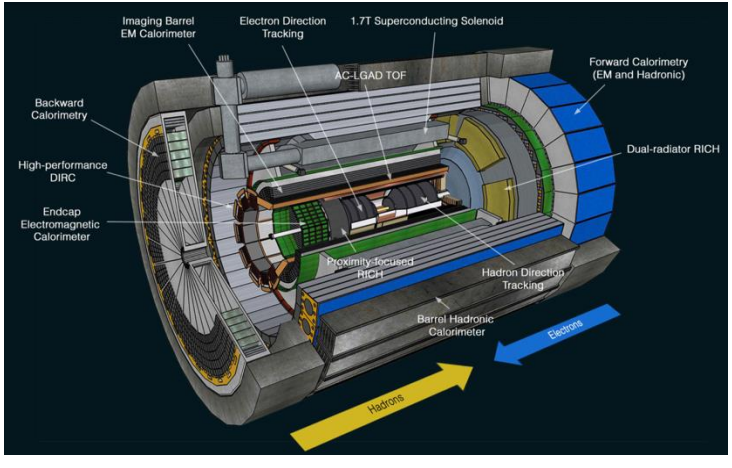
- The ePIC detector at the EIC
- The ePIC Silicon Vertex Tracker:
  - ✓ physics goals and requirements
  - ✓ detector overview
- Focus on SVT (Inner & Outer) Barrel layers:
  - ✓ detector design and technological choices
  - ✓ ongoing R&D and prototyping activities
  - ✓ milestones and project timeline
- Summary

The ePIC detector at the EIC



EIC machine:

- high luminosity, L ~ 10^{33} – 10^{34} $cm^{-2}s^{-1}$
- broad center-of-mass energy range, $\sqrt{s}$ = 29 –140 GeV
- highly polarized beams (electrons & protons, light ions), ~70%
- heavy ions up to Uranium



ePIC detector:

- compact, only ~9 m in length
- tracking, PID, calorimetry
- Silicon Vertex Tracker (SVT) at core, ~8m^2

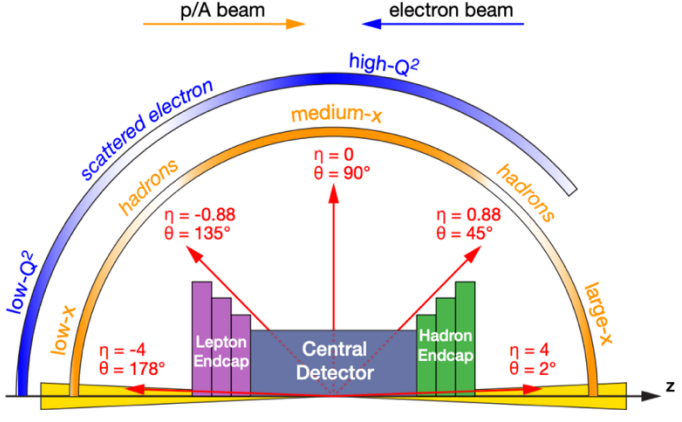
See talk by S. Dalla Torre on Monday

The ePIC Silicon Vertex Tracker

Physics goals and requirements:

- precise tracking and vertexing for EIC science programme (Yellow Report)
  - ✓ measure trajectories of scattered electron and charged hadrons in e-p/A collisions
    - → large acceptance, high-granularity, low-mass well-integrated Silicon Vertex Tracker
      - high spatial resolution $20\mu m/p_T \oplus 5\mu m$
      - excellent momentum resolution $0.05\%p_T \oplus 0.5\%$

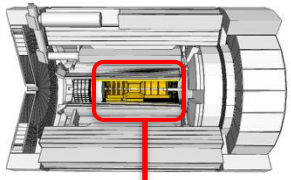
Rapidity Range	Momentum Resolution	Spatial Resolution
Backward (-3.5 to -2.5)	~0.10% × p ⊕ 2.0%	~30/p_T μm ⊕ 40 μm
Backward (-2.5 to -1.0)	~0.05% × p ⊕ 1.0%	~30/p_T μm ⊕ 20 μm
Barrel (-1.0 to 1.0)	~0.05% × p ⊕ 0.5%	~20/p_T μm ⊕ 5 μm
Forward (1.0 to 2.5)	~0.05% × p ⊕ 1.0%	~30/p_T μm ⊕ 20 μm
Forward (2.5 to 3.5)	~0.10% × p ⊕ 2.0%	~30/p_T μm ⊕ 40 μm



The ePIC Silicon Vertex Tracker

Detector overview:

~ 8 m² of silicon sensors!



Inner Barrel (IB)
- 3 layers: L0, L1, L2
- radii of ~38, 50, 120 mm
- length of 27 cm
- X/X_0 ~ 0.07% per layer

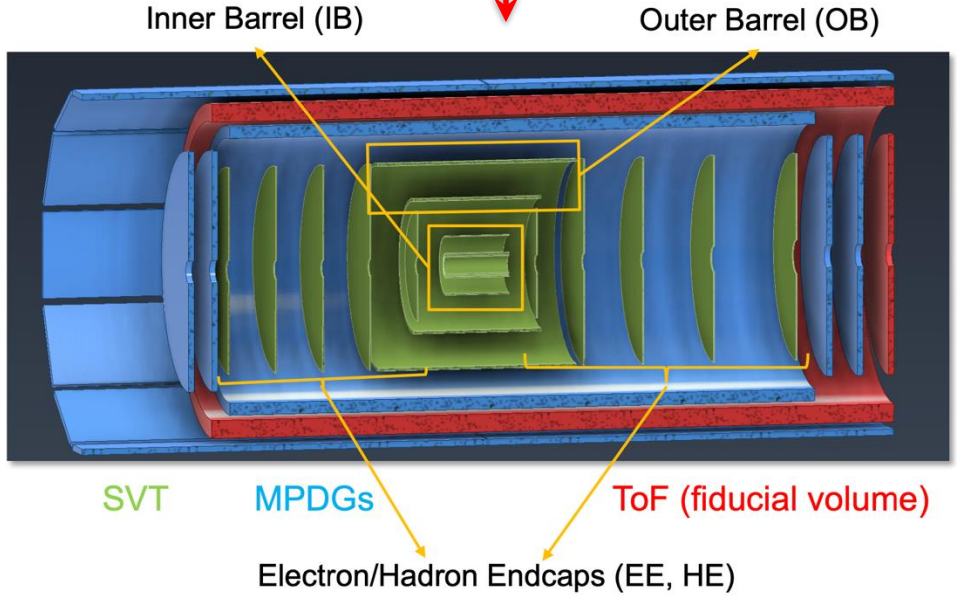
bent, thin, wafer-scale MOSAIX MAPS

Outer Barrel (OB)
- 2 layers: L3, L4
- radii of ~27 and 42 cm
- X/X_0 ~0.25% and ~0.55% per layer

conventional staves with EIC-LAS MAPS

Electron/Hadron Endcaps (EE, HE)
- 2 arrays with 5 disks each
- X/X_0 ~0.25% per disk

conventional structure with EIC-LAS MAPS



Lengths L2 → L4 increase so as to project back to z = 0; disk radii adjust accordingly

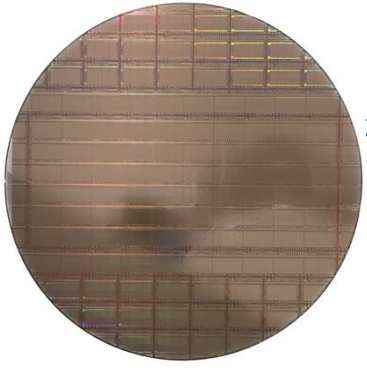
The ePIC Silicon Vertex Tracker

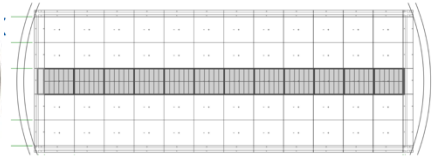
Detector design and technological choices

Focus on SVT barrel layers

Detector design and technological choices:

Inner Barrel (SVT IB)





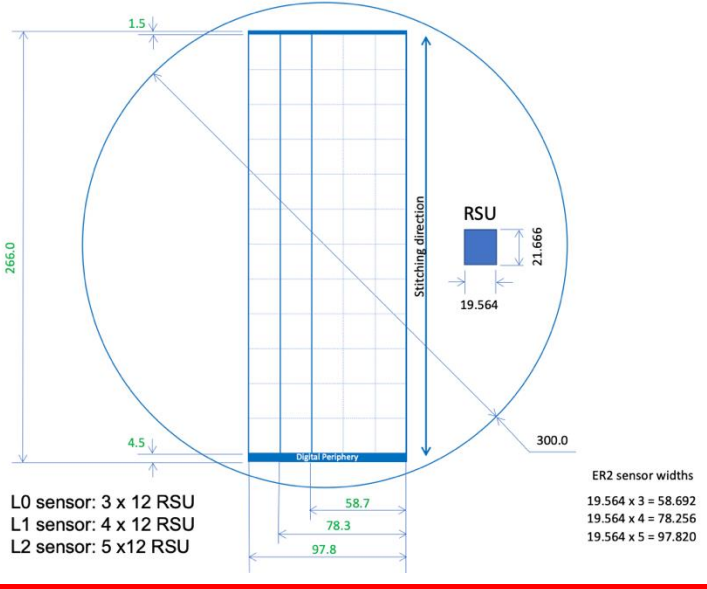
- **silicon sensor technology**:
  - ✓ MAPS in 65 nm CMOS imaging technology
- main advantages:
  - ✓ high granularity and low power → high spatial resolution, air cooling
  - ✓ stitching on 300 mm wafers for large area sensors → increased detector active area, reduced material budget → ultra-thin (~40 μm) and bent silicon layers
  - ✓ collaboration with ALICE ITS3 → reduced risk and cost of sensor development
- use ITS3 sensor (MOSAIX) for the SVT IB:
  - ✓ wafer scale, low power sensor → enabling the design of truly cylindrical vertex layers with 0.07% X_0 material budget

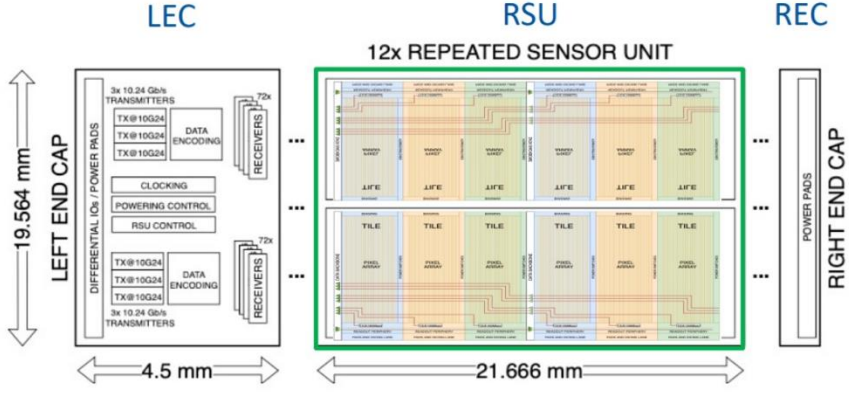
Focus on SVT barrel layers

Detector design and technological choices:
Inner Barrel (SVT IB)

Pixel size: ~ 20 x 22 μm^2
Frame duration: 2 to 5 μs
Data link: 10.24 Gbps

- **MOSAIX** complex circuit designed, led by ITS3 team at CERN





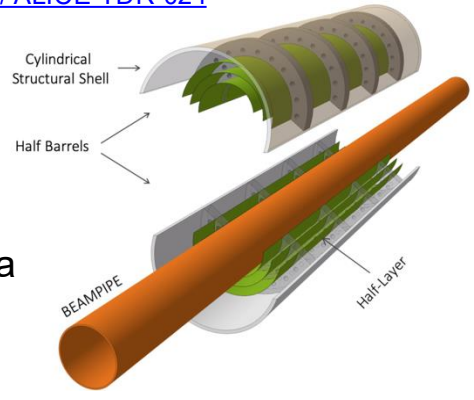
Main features:
- Powering and readout only from endcaps
- High-speed links (up to 10.24 Gbps)
- Granular power segmentation (144 switches/Segment)
- Long edge probing pads for power nets

Focus on SVT barrel layers

Detector design and technological choices:

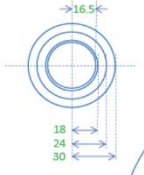
Inner Barrel (SVT IB)

ALICE ITS3
CERN-LHCC-2024-003 / ALICE-TDR-021

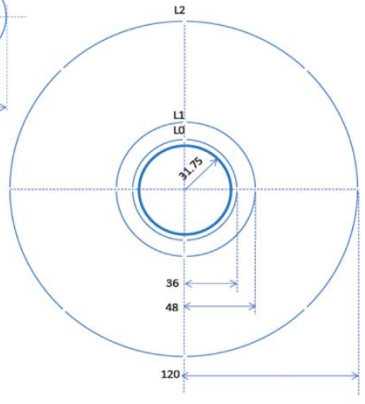


- **detector concept**:
  - ✓ adapt ITS3 design concept to the ePIC SVT larger radii
    - → mimimal mechanical support, air cooling, no services in activa area

ALICE – ITS3



ePIC – SVT



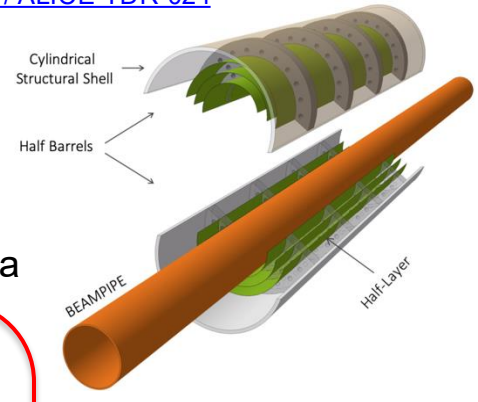
- ✓ 3 layers of thin, bent, wafer-scale sensors
- ✓ uses same MOSAIX sensor as ALICE ITS3
  - L0: 3 x 12 RSUs (4 each) → R ~ 36 mm (x2 wrt ITS3 L0)
  - L1: 4 x 12 RSUs (4 each) → R ~ 48 mm (x2 wrt ITS3 L1)
  - L2: 5 x 12 RSUs (8 each) → R ~ 120 mm (x4 wrt ITS3 L2)
- ✓ due to the beam pipe geometry, and the need for full disk acceptance, services need to be routed along service cones

Focus on SVT barrel layers

Detector design and technological choices:

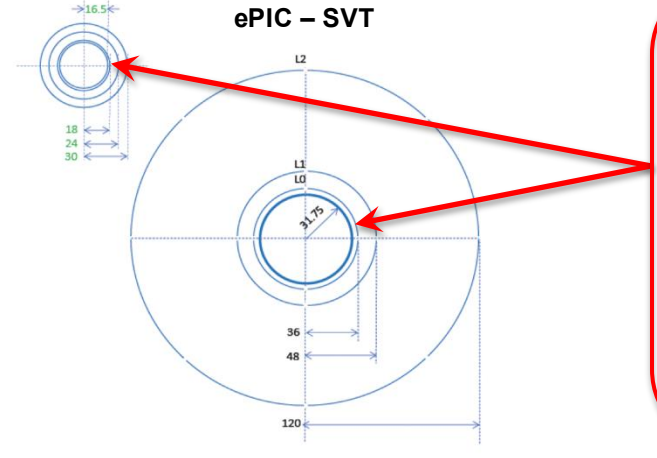
Inner Barrel (SVT IB)

ALICE ITS3
CERN-LHCC-2024-003 / ALICE-TDR-021

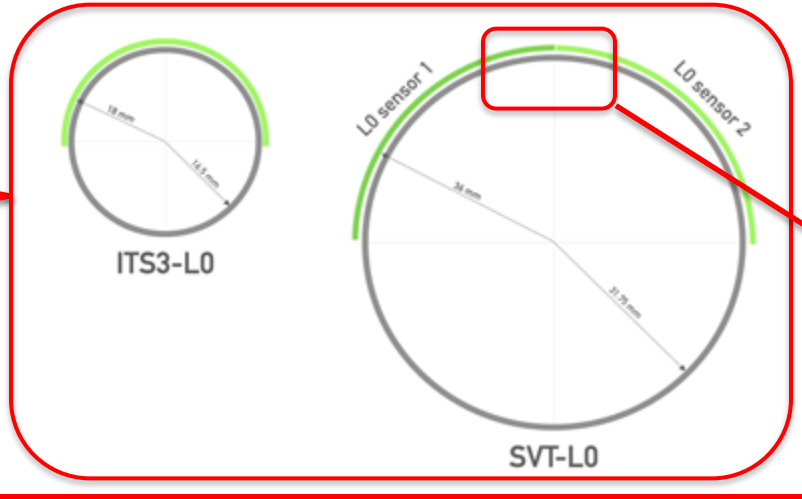


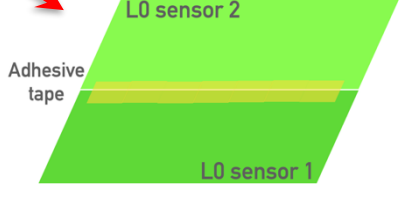
- **detector concept**:
  - ✓ adapt ITS3 design concept to the ePIC SVT larger radii
    - → mimimal mechanical support, air cooling, no services in activa area

ALICE – ITS3



ePIC – SVT



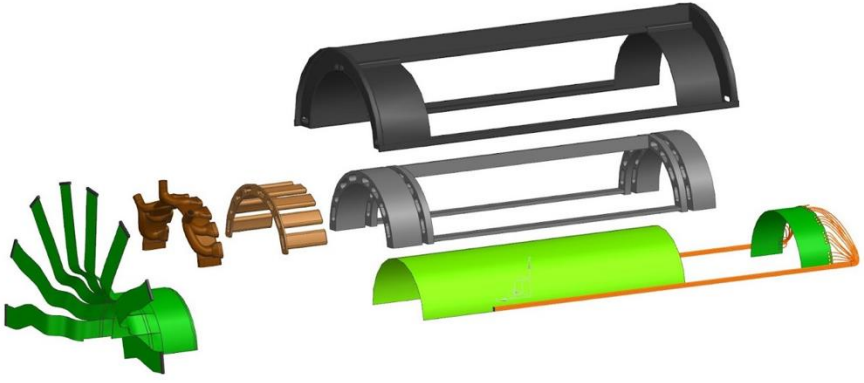


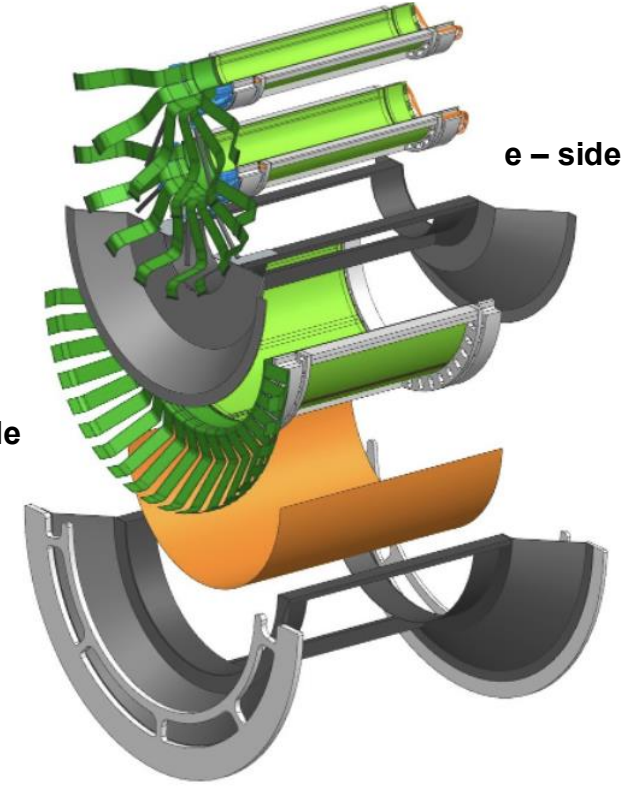
Focus on SVT barrel layers

Detector design and technological choices:

Inner Barrel (SVT IB)

- **mechanical support and services**:
  - ✓ design advanced, aim to minimize material budget
    - → materials: carbon fiber composites, carbon foams
    - → optimized service routing on h-side cones





Focus on SVT barrel layers

Detector design and technological choices:

Outer Barrel (SVT OB)

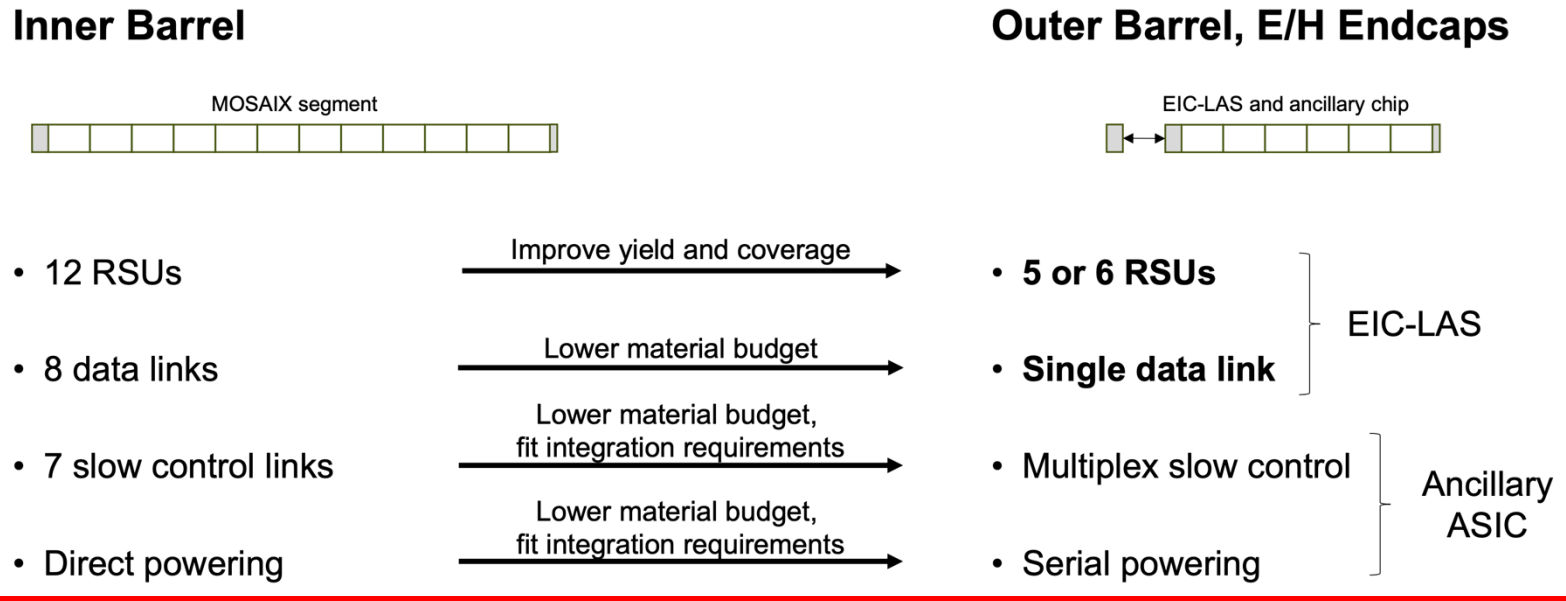
- silicon sensors: **MOSAIX → EIC-LAS**
  - ✓ SVT OB layers (and endcap discs) will cover ~8 m^2
    - → requires a sensor design optimized for yield, high acceptance, large area coverage
  - ✓ EIC-LAS sensor will be based off of the MOSAIX design
    - → EIC-LAS will be thinned and stitched, but not wafer-scale
  - ✓ MOSAIX modifications kept to a minimum
    - → based on reduced risk and time/resource availability
    - → no changes to pixel matrix
  - ✓ low-material powering, biasing & slow control for the EIC-LAS is essential and will be provided with a single **Ancillary ASIC**

Focus on SVT barrel layers

Detector design and technological choices:

Outer Barrel (SVT OB)

- silicon sensors: **MOSAIX → EIC-LAS + Ancillary ASIC**

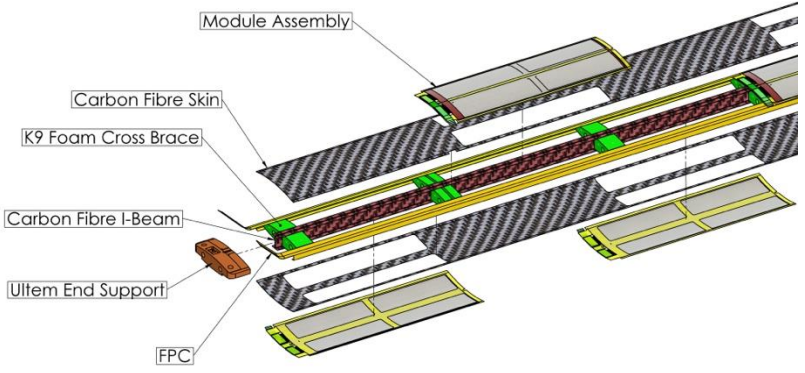


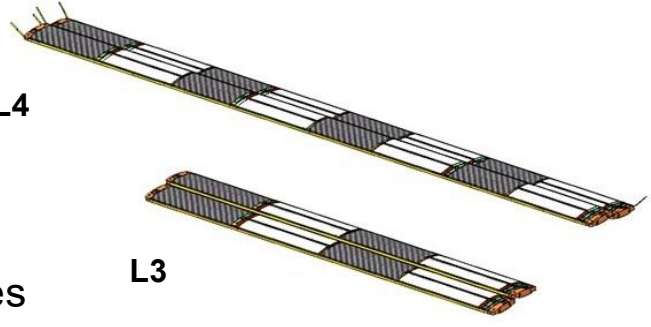
Focus on SVT barrel layers

Detector design and technological choices:

Outer Barrel (SVT OB)

- **detector concept**:
  - ✓ two layers (L3-L4) segmented into staves
  - ✓ each stave has modules on both facings
    - L3 (4 x 6 RSU long EIC-LAS) → R ~ 270 mm
    - L4 (8 x 5 RSU long EIC-LAS) → R ~ 440 mm
  - ✓ modules in alternating top/bottom arrangement
    - → active areas provide overlap for tracks from vertex
    - → 2 LAS side-by-side + 2 AncASICs on common carrier
    - → glued on openings in stave skin
  - ✓ stave connect mechanically at both ends to half-cones





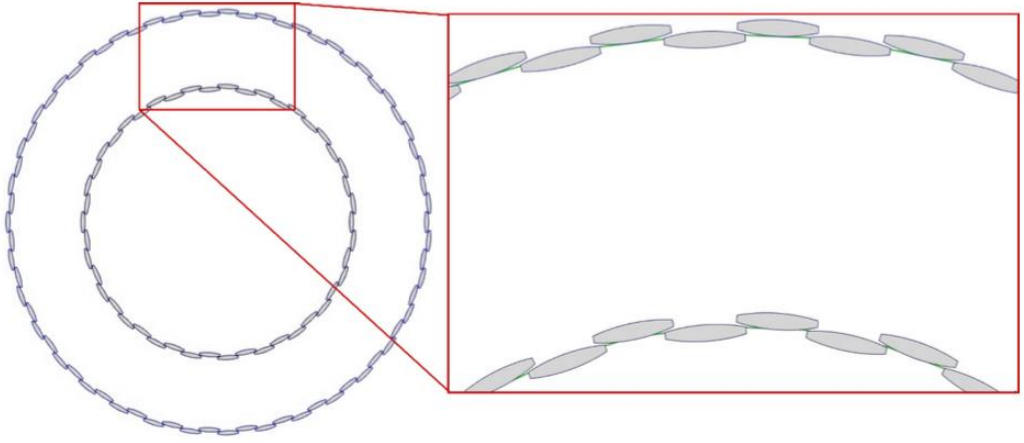
Focus on SVT barrel layers

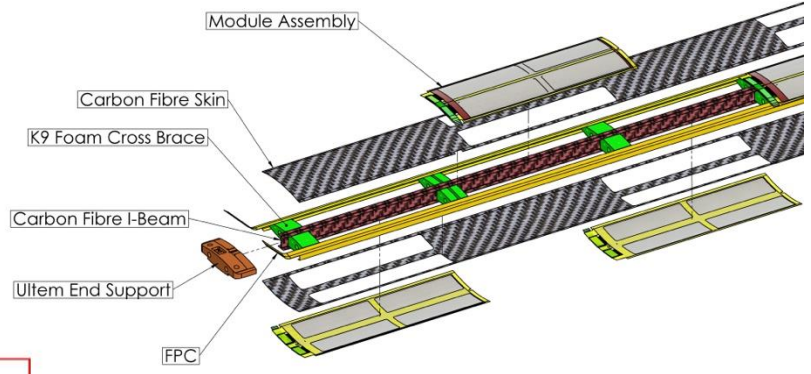
Detector design and technological choices:

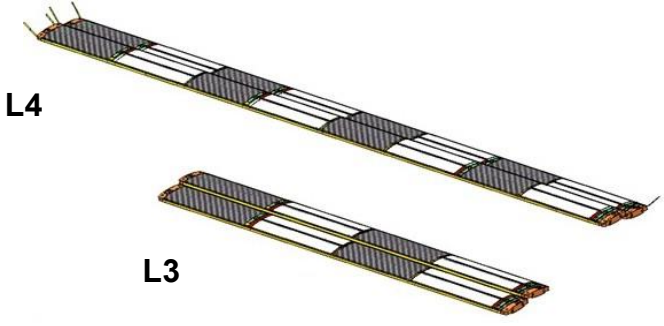
Outer Barrel (SVT OB)

- **detector concept**:
  - ✓ current design: curved silicon modules

    → evaluate layout benefits vs manufacturing challenges (eg bonding/interconnection)







The ePIC Silicon Vertex Tracker

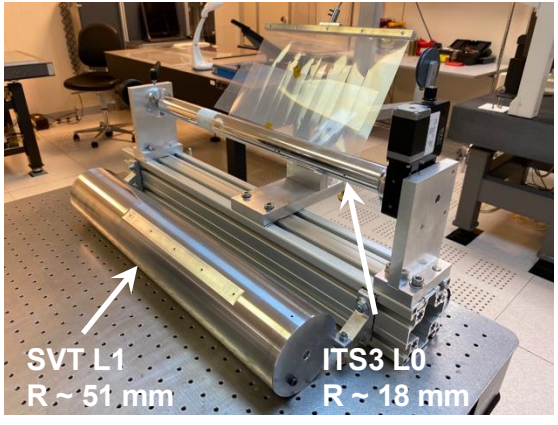
Ongoing R&D and prototyping activities

Focus on SVT barrel layers

Ongoing R&D and prototyping activities:

Inner Barrel (SVT IB)

- sensor bending procedure partly inherited from ITS3
  - ✓ dedicated setup and tool design/development needed
    - → mainly due to larger dimensions / 2-sensors Half-Layer
    - → specific development for sensor connection by adhesive kapton tape → single bending for L0/L1 HLs “à-la ITS3”

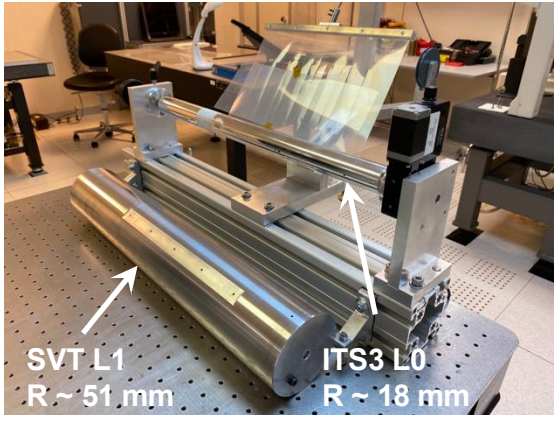


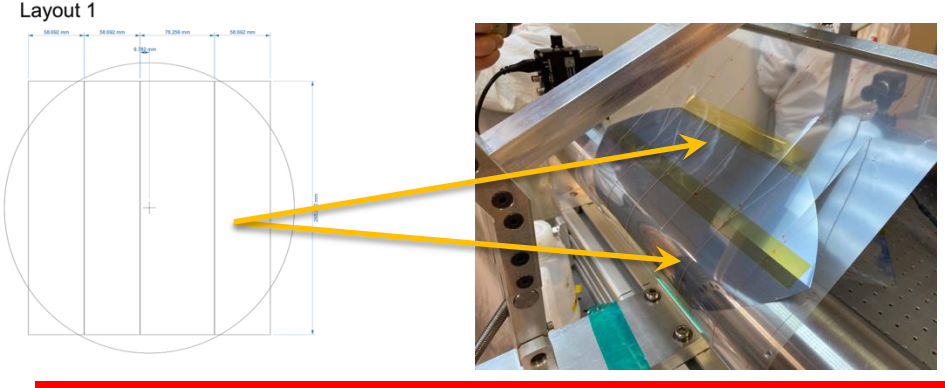
Focus on SVT barrel layers

Ongoing R&D and prototyping activities:

Inner Barrel (SVT IB)

- sensor bending procedure partly inherited from ITS3
  - ✓ dedicated setup and tool design/development needed
    - → mainly due to larger dimensions / 2-sensors Half-Layer
    - → specific development for sensor connection by adhesive kapton tape → single bending for L0/L1 HLs “à-la ITS3”





- ✓ sensor connection procedure validated using incomplete-shape dummies

→ bent sensor-couples suitable for validating glueing/assembly procedures using preliminary local support mechanics

Focus on SVT barrel layers

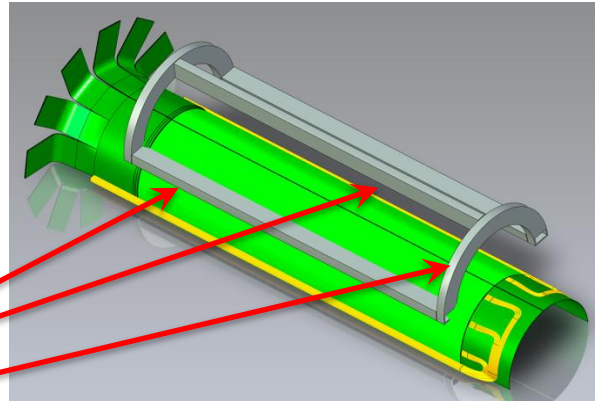
Ongoing R&D and prototyping activities:

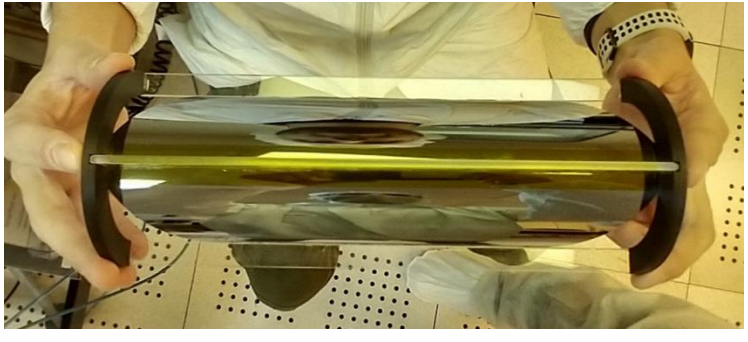
Inner Barrel (SVT IB)

- gluing to local support structure
  - ✓ single light support structure (3-D printed, epoxy)
    - → able to self-supporting sensors of a single half-layer
    - → obtained by gluing 2 half-rings + 3 longerons

for final support:

- low density carbon foam for the **longerons**
- high density carbon foam for the **half-rings**





Focus on SVT barrel layers

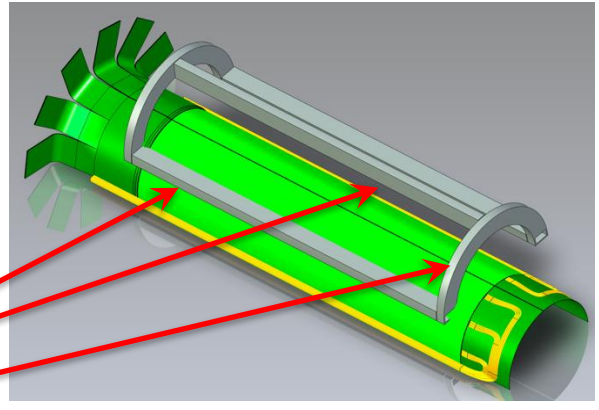
Ongoing R&D and prototyping activities:

Inner Barrel (SVT IB)

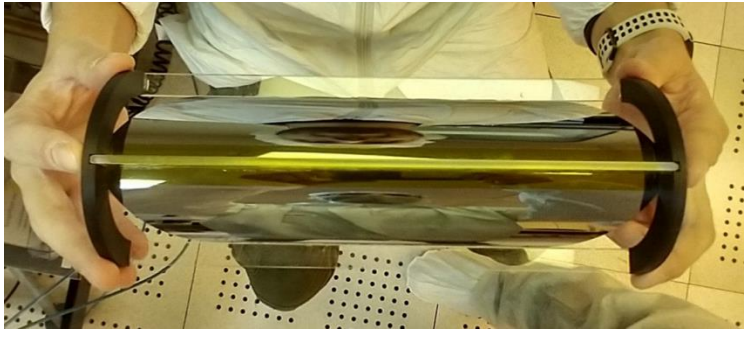
- gluing to local support structure
  - ✓ single light support structure (3-D printed, epoxy)
    - → able to self-supporting sensors of a single half-layer
    - → obtained by gluing 2 half-rings + 3 longerons

for final support:

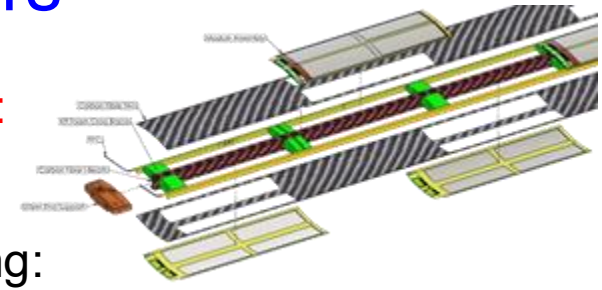
- low density carbon foam for the **longerons**
- high density carbon foam for the **half-rings**



- next steps
  - ✓ Half-Barrel with basic support (validate assembly)
  - ✓ HB with carbon foam support (thermal chamber test)
  - ✓ full “thermo-mechanical” prototype by end 2025
    - → dummy sensors + heaters (suitable for cooling studies)

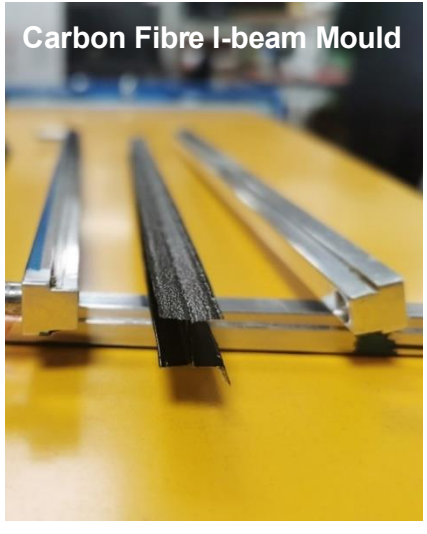


Focus on SVT barrel layers



Ongoing R&D and prototyping activities:
Outer Barrel (SVT OB)

- prototype stave components & tooling:
  - ✓ hand-cut carbon fibre top/bottom skins (2 layers (90/0) of K13C2U/EX1515)
  - ✓ pure Kapton FPC mock-ups
  - ✓ SLA 3D-printed Stave End Supports
  - ✓ production intent I-beam and K9 foam blocks

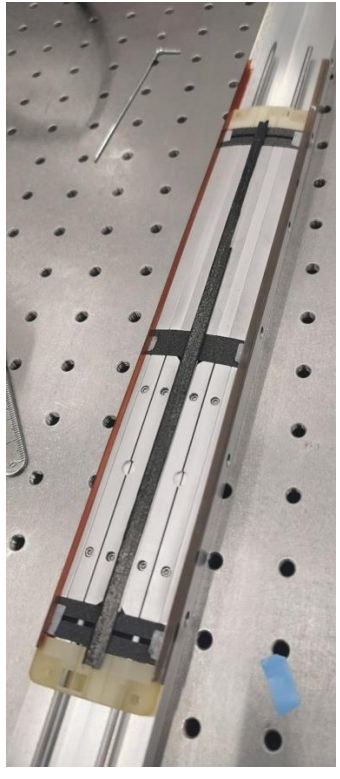


Focus on SVT barrel layers

Ongoing R&D and prototyping activities:

Outer Barrel (SVT OB)

- first quarter stave assembly:
  - ✓ no noticeable twist in stave
  - ✓ internal tooling awkward to remove
  - ✓ end supports deformed → to be reinforced

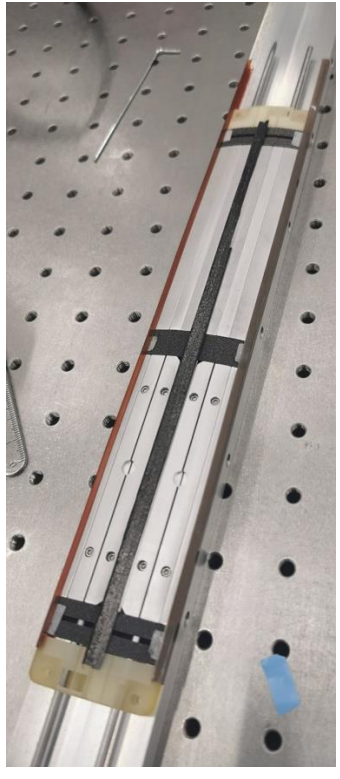


Focus on SVT barrel layers

Ongoing R&D and prototyping activities:

Outer Barrel (SVT OB)

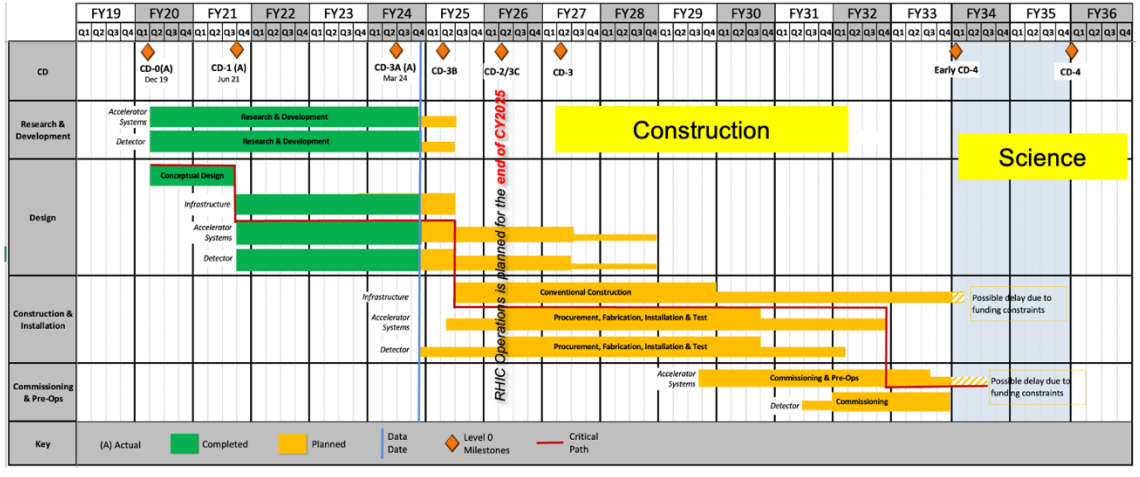
- first quarter stave assembly:
  - ✓ no noticeable twist in stave
  - ✓ internal tooling awkward to remove
  - ✓ end supports deformed → to be reinforced
- next steps
  - ✓ build more quarter staves (robust end pieces etc.)
  - ✓ test V2 quarter length stave on vibration table and compare with FEA
  - ✓ prototype an FPC with representative Al quantity
  - ✓ measure stave deformation with heat generation & internal pressure



Focus on SVT barrel layers

Current milestones and project timeline:

- align with EIC Project reference schedule:



Sensor availability constraints:

- ✓ ER2 for IB HL: ~Q4 2025 (for prototyping activity)
- ✓ ER3 for IB HL: ~Q1 2027
- ✓ EIC-LAS for OB: ~Q4 2027

- ✓ SVT construction start in 2027
- ✓ IB half-barrels and OB staves delivery to EIC site in 2030

Summary

- ePIC is a compact detector with stringent tracking and vertexing requirements dictated by the EIC Science programme
- The ePIC SVT is a large acceptance, high granularity, ultra-thin, MAPS based detector designed to meet these requirements
- Sensor design is currently benefitting from ALICE ITS3 development and collaboration (MOSAIX), will extend to EIC-LAS design for OB/disks
- SVT layout and design optimizations are being finalized, mechanical and thermal prototyping is ongoing
- SVT construction completed ~ early 2030s to match starting collisions in EIC!

Summary

- ePIC is a compact detector with stringent tracking and vertexing requirements dictated by the EIC Science programme

Thank You!

- SVT layout and design optimizations are being finalized, mechanical and thermal prototyping is ongoing
- SVT construction completed ~ early 2030s to match starting collisions in EIC!