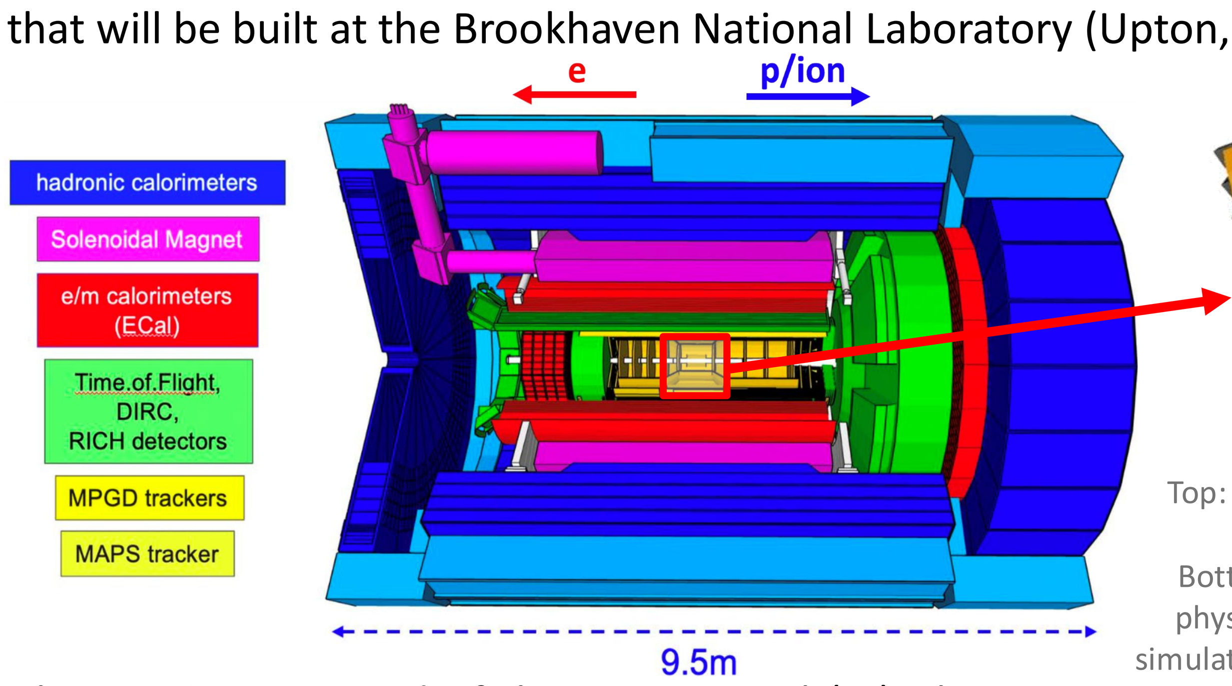
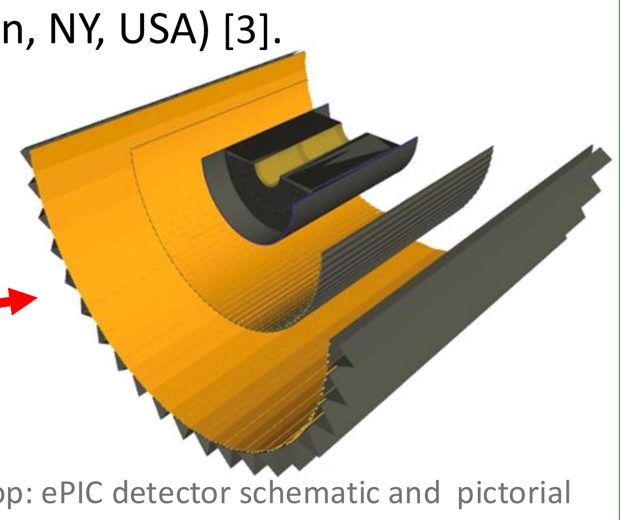
The ePIC Silicon Vertex Tracker IB-OB: design and thermal-mechanical simulations.

S. Ciarlantini[1,3] for the ePIC SVT detector subsystem collaboration
[1]University of Padua, Centro di Ateneo di Studi e Attività Spaziali CISAS "Giuseppe Colombo", Via Venezia 15, 35131 Padova, Italy
[3]Istituto Nazionale di Fisica Nucleare, sezione di Padova, via Marzolo 8, 35131 Padova, Italy

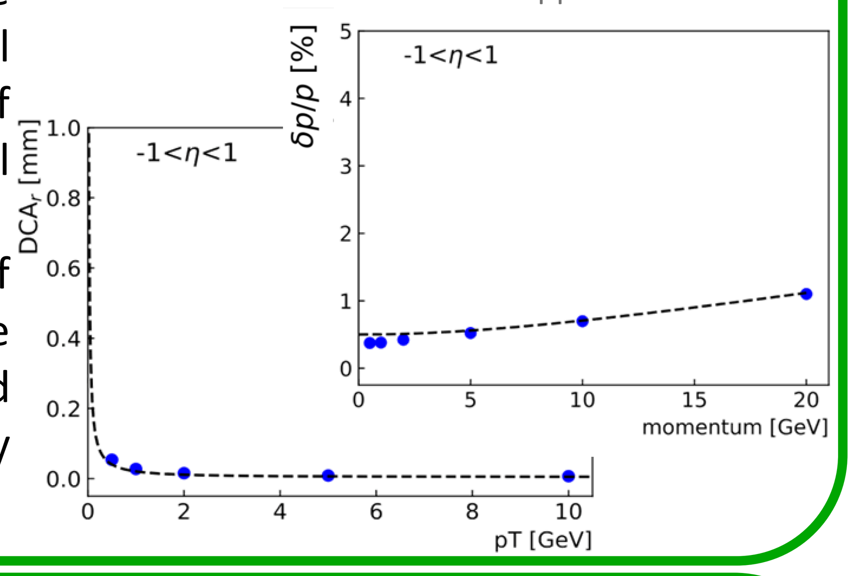
Silicon Vertex Tracker

The Silicon Vertex Tracker (SVT) is the innermost subsystem of the future ePIC (electron-Proton-Ion Collider collaboration) detector [1,2]. It is designed to meet the performance required by the physics program at EIC (Electron-Ion Collider), the new accelerator facility that will be built at the Brookhaven National Laboratory (Upton, NY, USA) [3].





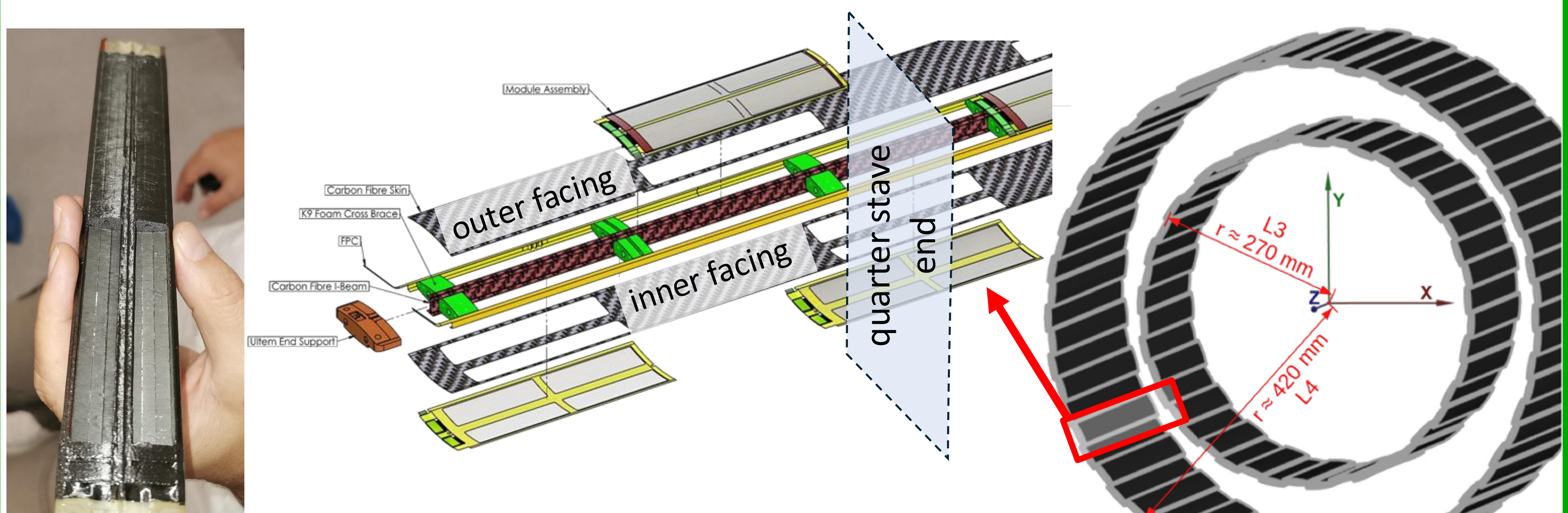
Top: ePIC detector schematic and pictorial view of IB and OB half-barrel.
Bottom: required performances from the physics working group compared to a fast simulation of transverse momentum resolution and distance of closest approach of tracks.



The SVT is composed of the Inner Barrel (IB), the Outer Barrel (OB), covering the central pseudorapidity range, and the two groups of endcap disks (not discussed here), for a total active area of approximately 8.5 m^2.
The role of the SVT is to perform the tracking of charged particles and the localization of the primary collision vertexes and of the displaced decay vertexes of hadrons containing heavy quarks.

Outer Barrel

The Outer Barrel (OB) high precision position measurements with large lever arm deliver the required momentum resolution and acceptance at intermediate pseudorapidity.



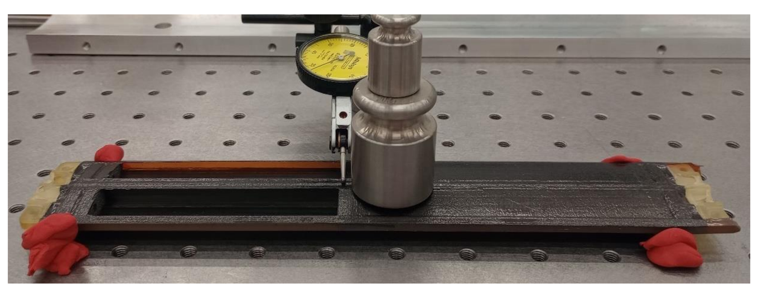
Quarter-stave prototype (left), stave structure (middle) and OB design (right).

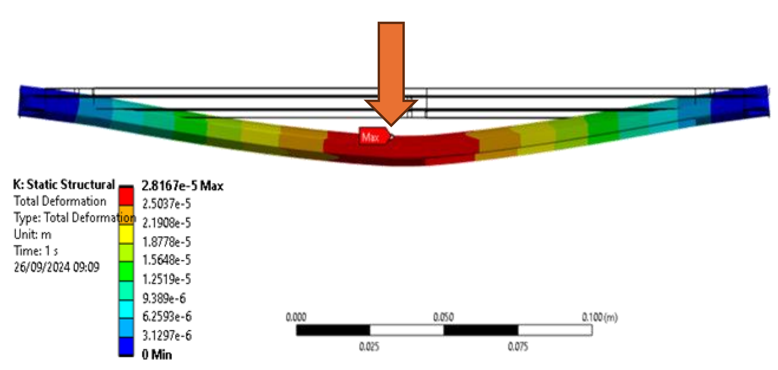
OB structure

OB is composed by two active layers L3 - L4, each segmented in staves assembled into a tiled/turbine like barrel structure. L3 and L4 will have four and two modules per facing respectively, for a material budget of 0.25% X/X_0 and 0.55% X/X_0. The OB will be equipped with a modified version of the ALICE ITS3 sensor called the EIC Large Area Sensor (LAS), thinned down to 50 µm and optimized for high yield, low cost, and large area coverage.

Mechanical FEA and Test

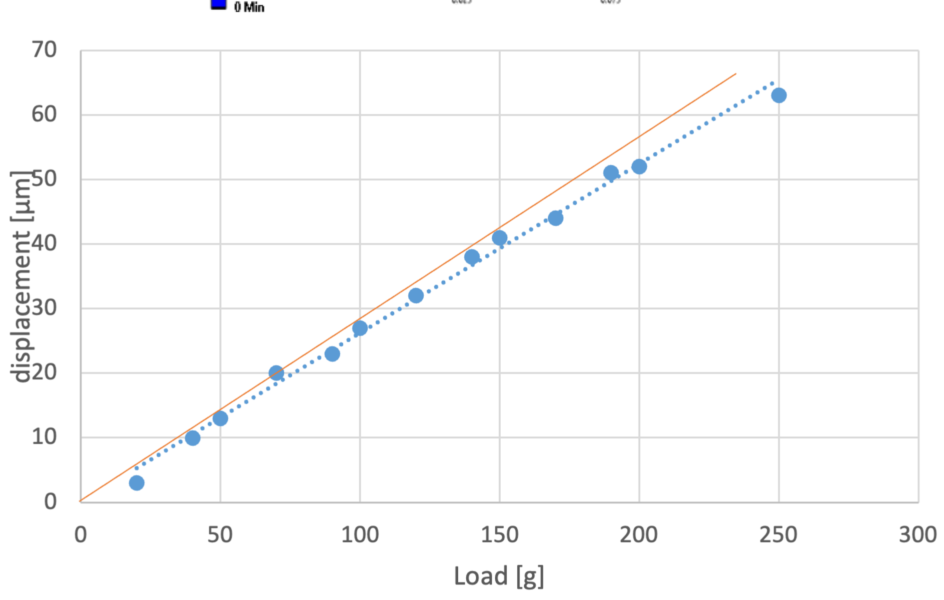
Two L4 quarter staves protypes have been produced, comprehensive of the carbon fiber top/bottom skins, pure Kapton FPC mock-ups and SLA 3D printed stave end supports. They show no noticeable twists, but reinforcements will be needed to avoid supports end deformation.





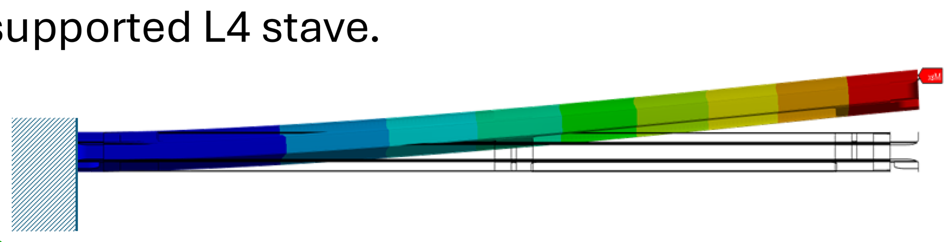
Picture of three-point bending test (left) and FEA with 0.981 N vertical load (right)

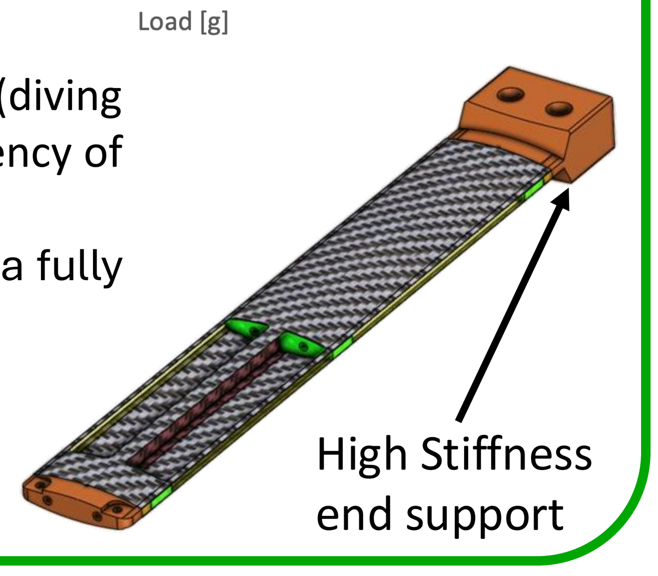
The prototypes have been tested with a three-point bending test.
The deformation of the center is measured as a function of the load placed upon it. The comparison plot is shown on the right: the results (blue dot) and FEA (orange line) are in good agreement.



Vibrational FEA

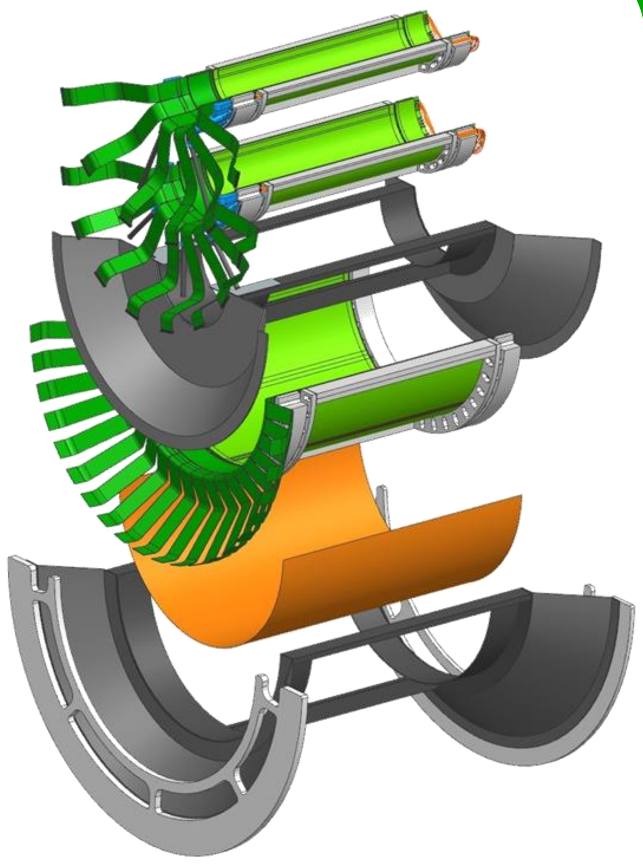
The ANSYS Modal model is performed on a cantilevered (diving board) quarter-stave without sensors: the FEA gives a frequency of 97 Hz for the first mode.
This configuration gives similar magnitude frequencies of a fully supported L4 stave.





Inner Barrel

The Inner Barrel (IB) is composed by three active layers: L0 - L1 - L2. The IB is designed to provide precise vertex reconstruction with asymptotic resolution better than 10 µm, and contributing to momentum measurement.



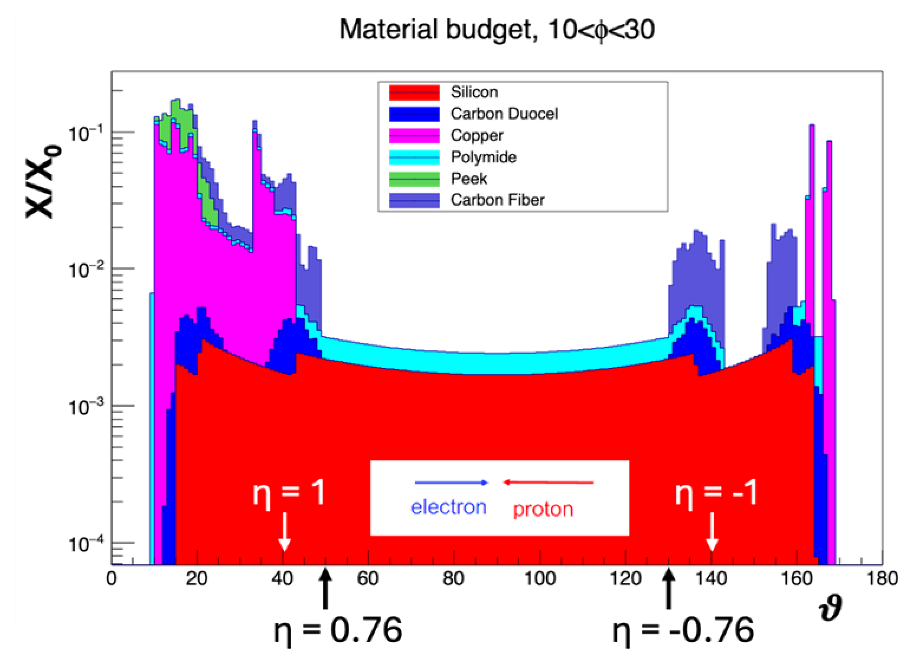
CAD exploded view of IB support with cables and sensors.

IB structure

The current IB design foresees a cylindrical frame structure: each half-layer will consist of the sensors, a local carbon foam support structure and two sets of FPCs/cables for powering data and control transmission. The IB will use the ALICE ITS3 [4] MAPS sensor MOSAIX fabricated in 65nm commercial CMOS technology and thinned to 50 µm. It is composed of twelve independent chips (Repeated Sensor Units, RSUs) stitched together. MOSAIX has a pixel size of 21x23 µm^2 and a power consumption of 40 mW/cm^2.
The sensors will be placed one next to the other and bent in a cylindrical shape radii of 37.5, 50 and 125 mm for L0, L1 and L2, respectively.

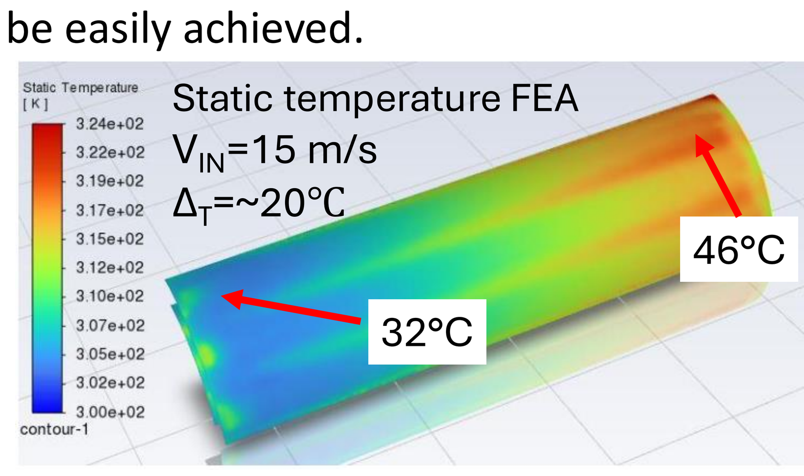
Material budget

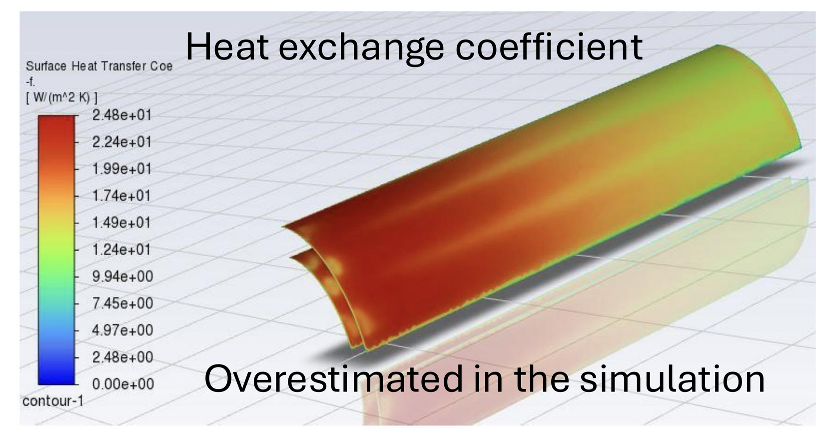
Material budget simulation plot is shown on the left. For pseudorapidity η in [-1, 1] only sensors are present targeting the material budget to X/X_0 = 0.07%, elsewhere copper (likely to be replaced with aluminum) cables and services increase X/X_0. CFC thickness is kept at the upper safe estimate value of 1 mm.



Thermal FEA

Simulation of the thermal load is ongoing for the quarter-barrel L0-L1 without the Left Endcap (power and data transfer, on wafer). Turbulence (critical for proper cooling) can not be easily achieved.

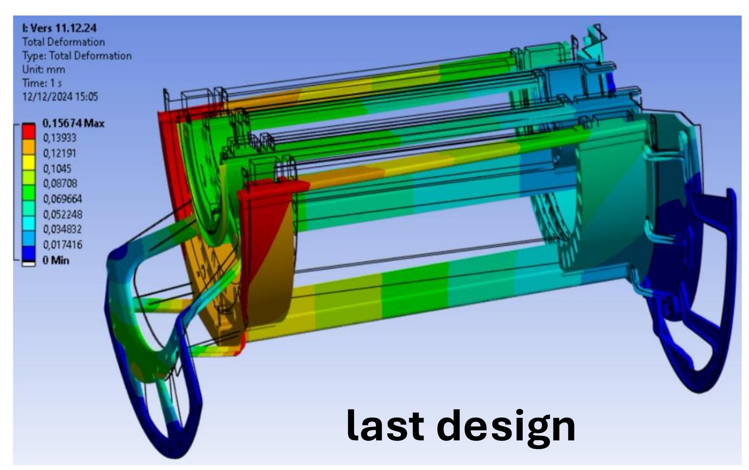


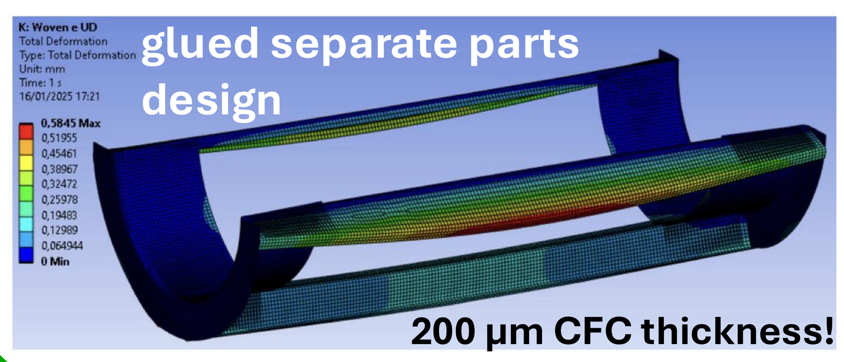


Air flow cooling and possible addition of other cooling elements are still under investigation. Measurements on mock-up with thermal load are needed to confirm the preliminary evaluation of cooling effectiveness.

Mechanical FEA

Mechanical load simulations with a load safety factor of 1.5 are ongoing.
L2 deformation results are extrapolated by L0-L1.
Last support design simulations results show an enhanced deformation on e-side arms.





If support is made of separated parts glued together, the deformation is 600 µm on edges, due to copper cables, not affecting the sensor region. In this case CFC thickness of 200 µm is considered.

Outlook

Inner Barrel

- **MOSAIX**: Tests of MOSAIX sensors more ePIC-oriented (timing, fake hit rate).
- **Mechanical and thermal load simulation:** Implementation of design details and complete crosscheck of FEA on mock-up and first prototype with dummy thermal load.
- **Mechanical support:** Definition of materials and of design parameters to match required performances of mechanical stability and material budget. Production of prototypes at end of the 2025.

Outer Barrel

- **Stave Tests:** Continue the quarter-staves production including I-beam and K9 foam blocks and start of flow tests. Update drawings for remaining mold parts for full stave & manufacture.
- **Vibrational Tests:** Test quarter length stave on vibration table to compare with FEA.
- **Mechanical Tests:** Measure stave deformation with heat generation and internal pressure.
- **Thermal Tests**: Study temperature with air flow adding dummy ancillary ASIC (AncASIC).

[1] S. Dalla Torre , "The ePIC (electron-Proton and Ion Collider) detector at the EIC (Electron Ion Collider)". CERN Detector Seminar 2024 https://indico.cern.ch/event/1418391/
[2] Gonella, L. "Development of a Silicon Vertex and Tracking Detector for the Electron-Ion Collider." The 32nd International Workshop on Vertex Detectors. 2024.
[3] Khalek, R. Abdul, et al. "Science requirements and detector concepts for the electron-ion collider: EIC yellow report." Nuclear Physics A 1026 (2022): 122447.
[4] The ALICE collaboration, "Technical Design report for the ALICE Inner Tracking System 3 - ITS3 ; A bent wafer-scale monolithic pixel detector", CERN, CERN-LHCC-2024-003, ALICE-TDR-021, Geneva, 2024, https://cds.cern.ch/record/2890181