MAPS-based tracking and vertexing for the Electron-Ion Collider

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EIC vertex and tracking detector: from requirements to technology choice

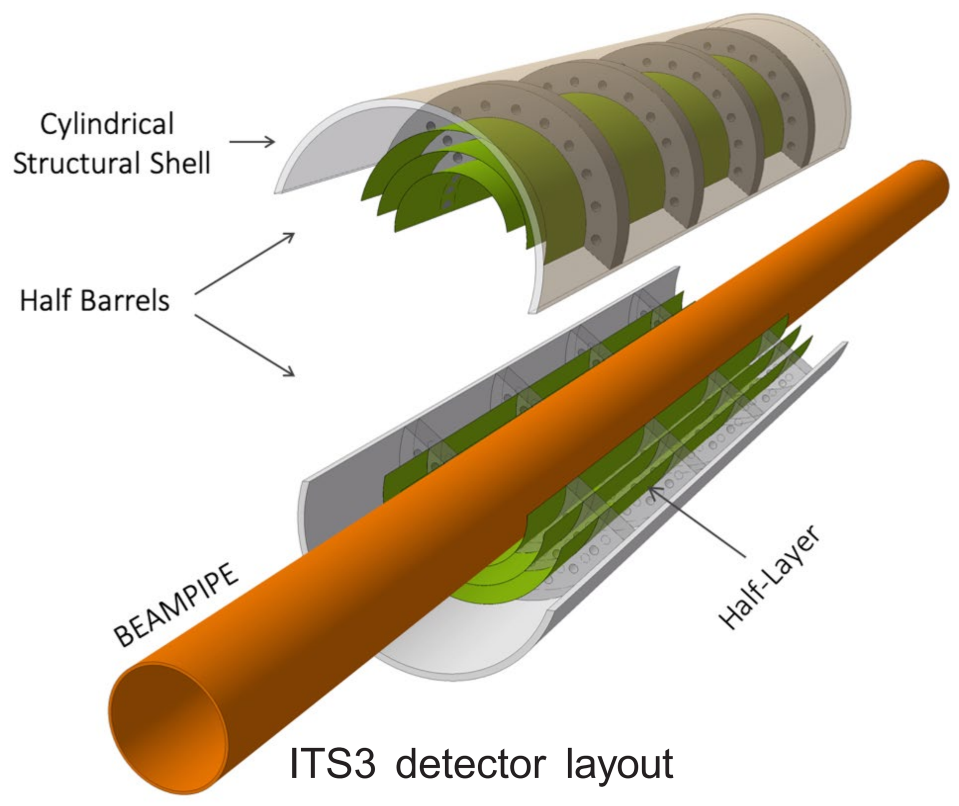
Requirements of an EIC vertex and tracking detector: • Wide kinematic coverage • Good momentum resolution • High-precision primary vertex determination • Secondary vertex separation capability → **Well integrated, large acceptance** detector featuring **high granularity and low material budget**.

Detector requirements

- Spatial resolution:
  - **$\leq$ 5 μm** in tracking layers and disks
  - **~ 3 μm** in the vertex layers
- Material budget:
  - **<0.8/0.3% X/X_0** per layer/disk
  - **< 0.1% X/X_0** per vertex layer
- Power consumption 20 - 40 mW/cm^2
- Integration time 2 μs

65 nm MAPS for the EIC

- New MAPS generation developed by ALICE ITS3 collaboration
- Target specifications for the sensor:
  - Pixel pitch **~ 20 μm**
  - Power consumption **~ 20 mW/cm^2** (50% reduction wrt ALPIDE)
  - Integration time ~ 200 ns
- ITS3 detector layout with **0.05% X/X_0** → adopted for EIC vertex layer.
  - Wafer-scale (up to **~ 28 x 10 cm^2**), thin sensor (**20 - 40 μm**), bent around beam pipe
  - **Air cooling**, carbon foam rings and cylindrical structural shell, no electrical services in active area



ITS3 detector layout
(https://cds.cern.ch/record/2703140/)

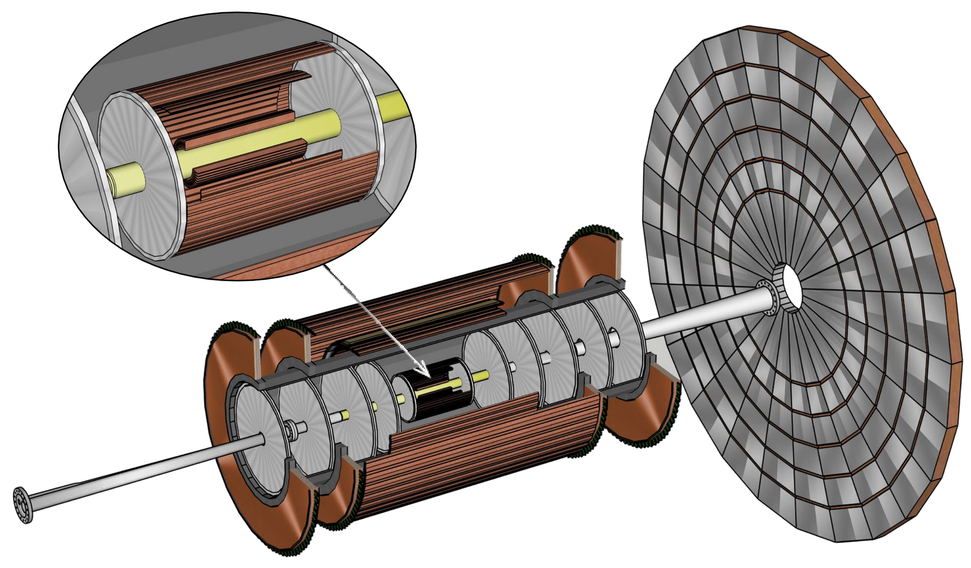
- Dedicated EIC development for tracking layers and disks
  - Optimised ITS3 sensor size for high yield, low cost, large area coverage
  - Baseline stave concept: **0.55% X/X_0**
  - Baseline disk concept: **0.24% X/X_0**

ATHENA vertex and tracking detector

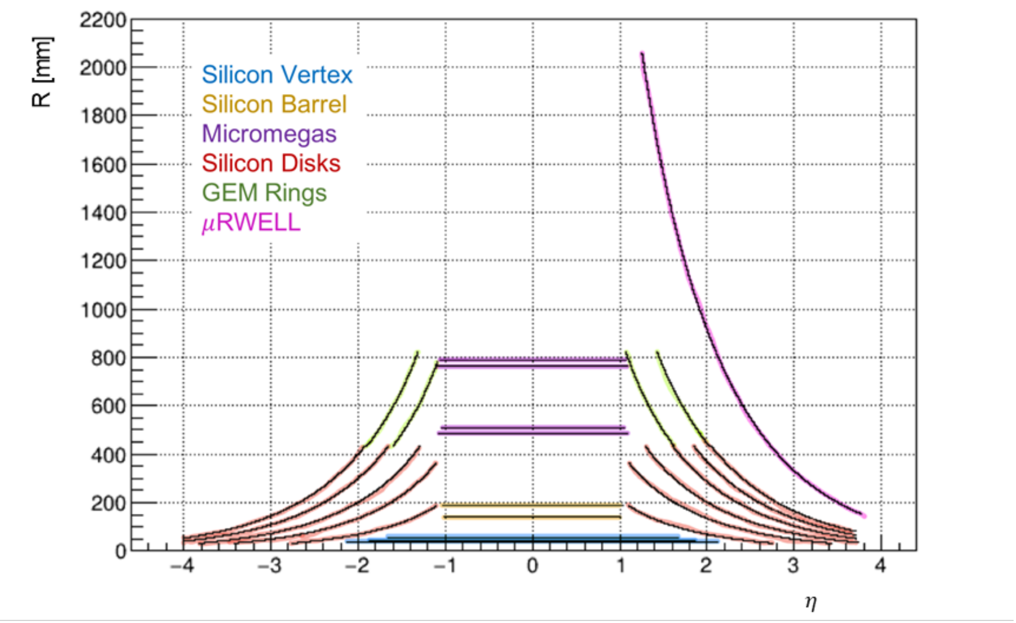
- **65 nm MAPS** near the interaction point complemented by MPGD technologies at larger radii.
  - 3 ultra-low mass MAPS layers for vertexing
  - 2 MAPS layers for sagitta measurements
  - 6 MAPS forward disks (hadron-going)
  - 5 MAPS backward disks (electron-going)

Layers	Radius (cm)	Length (cm)
L0, L1, L2	~ 3.5 – 6.0	~ 28
L3, L4	~ 13 – 18	~ 35 – 48
disks	**In/out R (cm)**	**z distance (cm)**
6 forward	~ 3.5 - 43	~ 25 – 165
5 backward	~ 3.5 – 43	~ 25 – 145

- Full coverage of the available space → tracking acceptance of **-3.8 < η < 3.75**.
- **Low material budget** tracking with **sufficient redundancy** over a **large lever arm** → critical to achieve the required momentum resolution.



ATHENA baseline hybrid tracking system

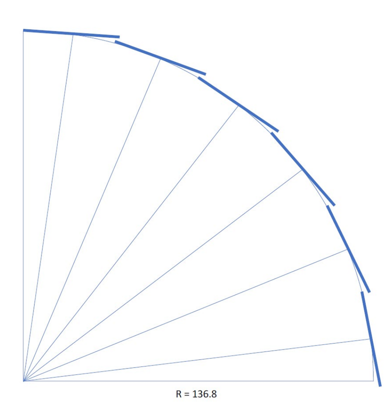


Tracking material surfaces as a function of pseudorapidity

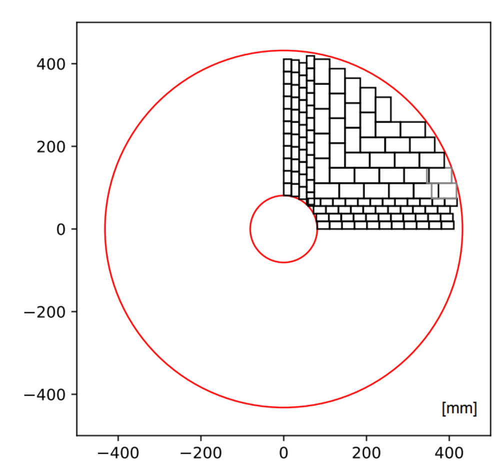
EIC Silicon R&D

- The **EIC Silicon Consortium** formed in 2020 to develop a vertex and tracking detector for EIC
  - Based on MAPS sensors (65 nm CMOS) and associated detector technologies
  - Larger group of participants from EIC Users Group, not tied to a specific collaboration
  - Now working in close collaboration with the EIC Detector-1 Tracking Working Group
- **Sensor development and characterization** within the ALICE ITS3 framework
  - Sensor yields to be evaluated after ITS3 stitched sensor characterization
  - EIC-specific stitching plan to maximize yield and wafer-area usage
  - Possibility to optimize the sensor operations to EIC-specific detector design
- **Services reduction via optimsed powering and readout schemes** (eRD104 project)
  - Radiation tolerant DC-DC converters, or Serial powering with on-die or hybrid power regulation
  - On-detector data regulation through FPGA, receive over twinax/FPC, transmit over fiber
- **Detector development** (eRD111 project)
  - Module concept:
    - Adapt vertex layers to EIC radii – lengths
    - Integrate sensor with light supports/bus for staves/disks
  - Stave and disk concepts
    - Segmentation options for improved yield / lower cost
    - Tiling options for maximum coverage
    - Module production and integration in large area segments
  - Mechanics and Cooling
    - Air cooling on carbon foam structure under investigation

L3 segmentation options: 2-reticle wide sensors

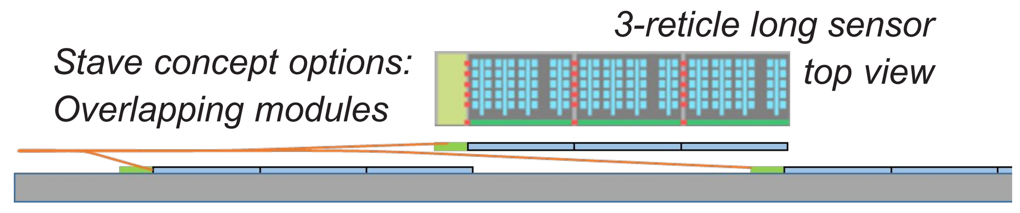


disk tiling options: 2 module variants



Stave concept options: Overlapping modules

3-reticle long sensor top view



Conclusions

Challenging vertexing and tracking requirements necessary for physics goals at the EIC. 65 nm MAPS offers the best solution: large-area stitched sensor developed within the ALICE ITS project can be adapted to EIC needs. R&D ongoing within the EIC SC to develop detector concept and infrastructure