EIC Silicon Tracker R&D

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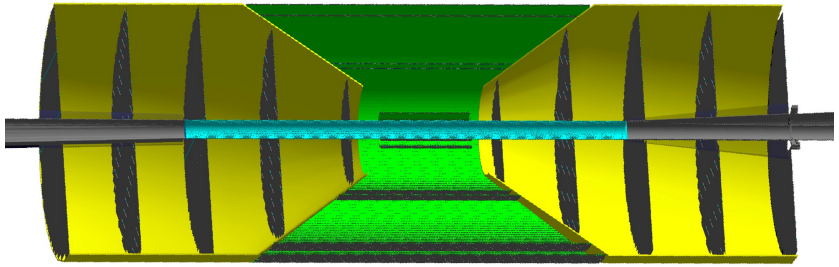
RNC Group Meeting

June 23, 2022

EIC Detector: Tracking Requirements

- Wide kinematic coverage
- Good momentum resolution
- High-precision primary vertex determination
- Secondary vertex separation capability

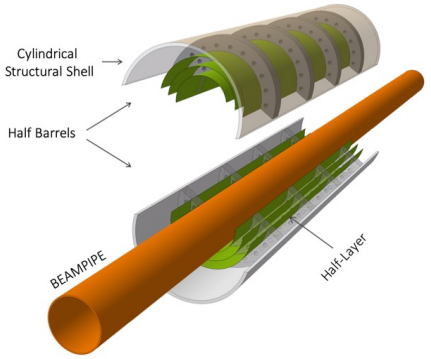


All-Silicon Tracking Detector example: arXiv:2102.08337

- **Needs detector with:**
  - **high granularity & low material budget**

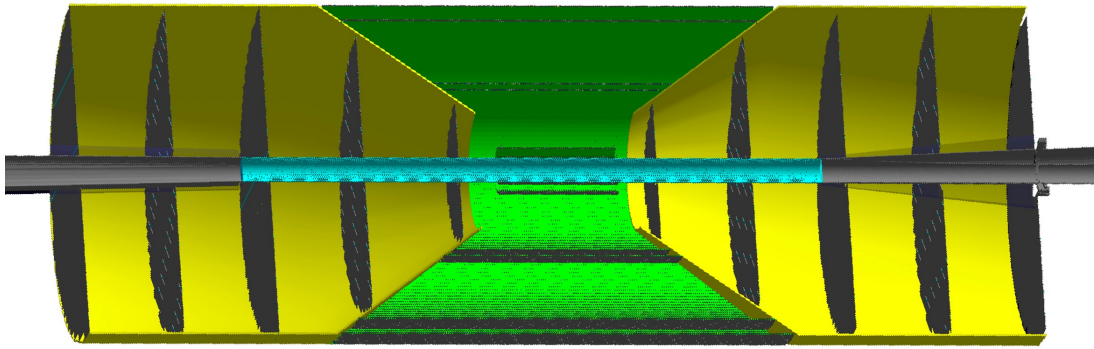
R&D Predecessors: eRD16 & 25 → MAPS technology chosen

Towards an EIC Detector 1 Concept



Based on ALICE ITS3 sensor technology (65 nm)

- 3 innermost layers (vertexing)
- 2-3 intermediate layers (sagitta)
- 4-6 silicon discs (forward & backward)



ALICE ITS3 ~0.12 m^2, EIC silicon ~10 m^2

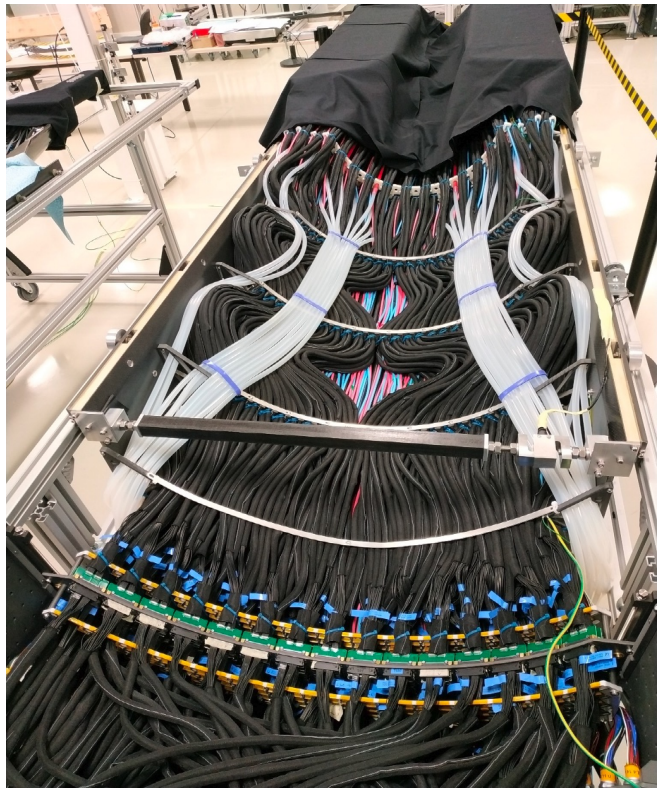
- Wafer-scale not suitable for staves & discs
- Forked sensor design → optimize for large area coverage & yield

Current EIC Tracking R&D

- eRD104: Services reduction
  - Powering & readout
- eRD111: Forming modules from stitched sensors
  - Optimizing the module size & design to meet mechanical requirements and take advantage of the new sensor design
- ***eRD111: Staves & Discs***
  - ***Conceptual designs***
- ***eRD111: Mechanics, integration, & cooling***
  - ***Support structures, study of air cooling***

R&D: Material Budget

- Mass minimization is key, especially in electron-going (backward) direction
  - Base design:
    - 0.24% X/X_0 per layer for discs
    - 0.55% X/X_0 for staves
- eRD104
  - Power & data services reduction
- eRD111
  - Staves & Discs layout options, air cooling

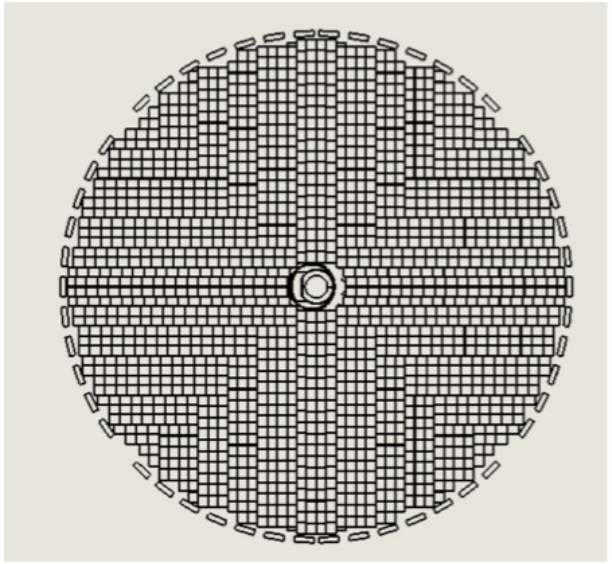


eRD111 Overall Plan

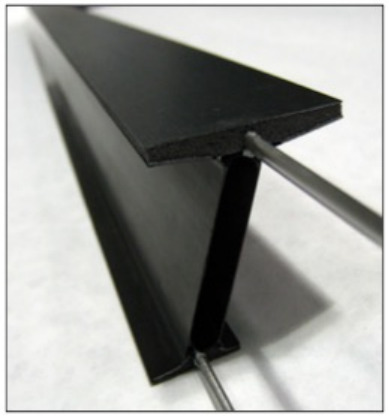
- Forming modules from stitched sensors (INFN Trieste, INFN Bari, Daresbury, Lancaster, Liverpool, Birmingham)
  - Options & optimizations
- Stave & disc construction (LBNL, LANL)
  - Conceptual design options
  - Cooling studies
- Additional infrastructure including mechanics & cooling (LBNL, LANL, JLAB)
  - Up-to-date CAD models
  - Conceptual designs

eRD111: Staves & Discs

- Disc concept → Flexible & challenging
  - Plates, staves, etc.
  - Different disc diameters
  - Different inner hole openings
- Stave concepts
  - Truss, I-beam
- Iteration with module group
  - Module sizes/options
  - Buildability & tooling

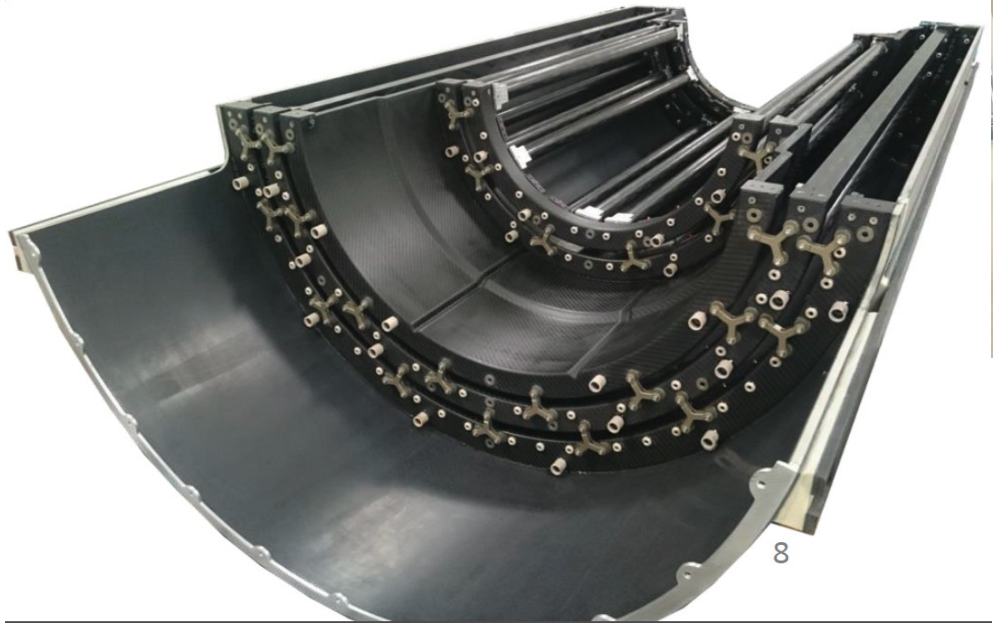


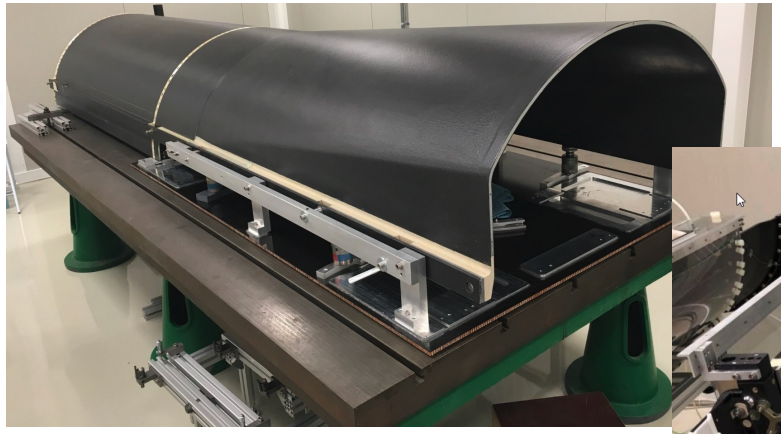
Air cooling options will be studied for both

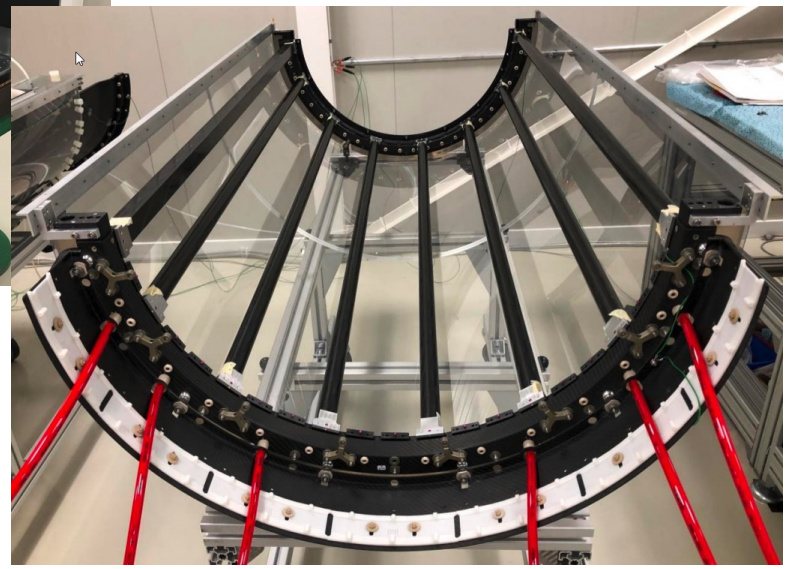


eRD111: Mechanics/Integration

- Detector mechanical structure & assembly/insertion mechanisms
  - Iterate with overall project needs/constraints
  - CAD models







Support structure examples from ALICE ITS2

eRD111: Milestones

New milestone dates (to be verified, estimates are my own)
Based on start date of June 1, 2022

Milestone Description	Date
Report on baseline stave designs	10/2022
Report on baseline disc designs	12/2022
Report on simple disc & stave models	06/2023
Up-to-date silicon tracking CAD models	12/2022
Report on mechanics conceptual design	01/2023
FY22 R&D report	03/2023

- LBNL is planning to work on stave/disc construction & additional infrastructure (mechanics & cooling) from the eRD111 plan

eRD111: Time

- To meet these milestones, LBNL has requested money to cover engineer & technician time, as well as for materials

	Engineer	Technician	Staff	Postdoc	Student
Hours	480	220	800	780	200

- Time split between ~2 staff, ~2 postdocs

eRD111: Stave Designs

Milestone Description	Date
Report on baseline stave designs • Stiffness & vibrational requirements for staves & discs • Examine stave options (ITS like, I-beam, etc.) • Develop options based on potential reticle sizes	10/2022

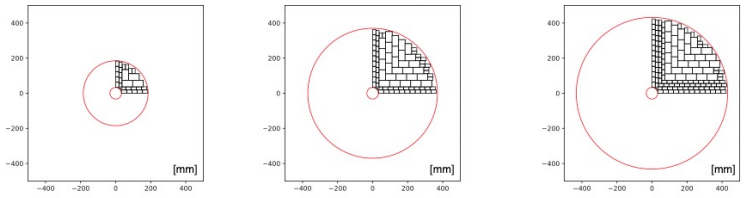
- Stiffness & vibrational requirements
  - What has been studied by ITS3 already? What do we know from our own simulations ?
- Stave options
  - ITS-like (truss), I-beam (ATLAS), something else?
    - Benefits & drawbacks (material budget, stiffness, etc.). Information gathering
- Stave configurations based on likely reticle size
  - Layout options to meet the lengths (being discussed for Detector 1. Up to 60 cm?)

eRD111: Disc Designs

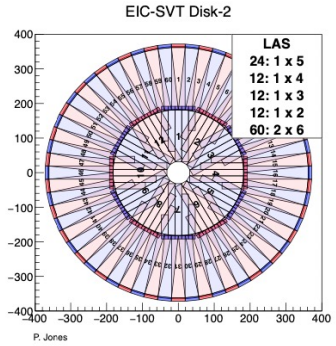
Milestone Description	Date
Report on baseline stave designs	10/2022
Report on baseline disc designs • Stiffness & vibrational requirements for staves & discs • Examine disc options (stave based, plate based, etc.) • Develop options based on potential reticle sizes	12/2022

- Disc options
  - Stave based, plate based, etc.
    - Benefits & drawbacks (material budget, stiffness, etc.)
    - Cooling?
  - Some layout options have already been attempted (Ernst & others)
    - Further optimizations, simulations to study dead area/overlap

Example studies of best way to tile disks



Work by Ernst Sichtermann



Work by Peter Jones

eRD111: Mechanical/Cooling

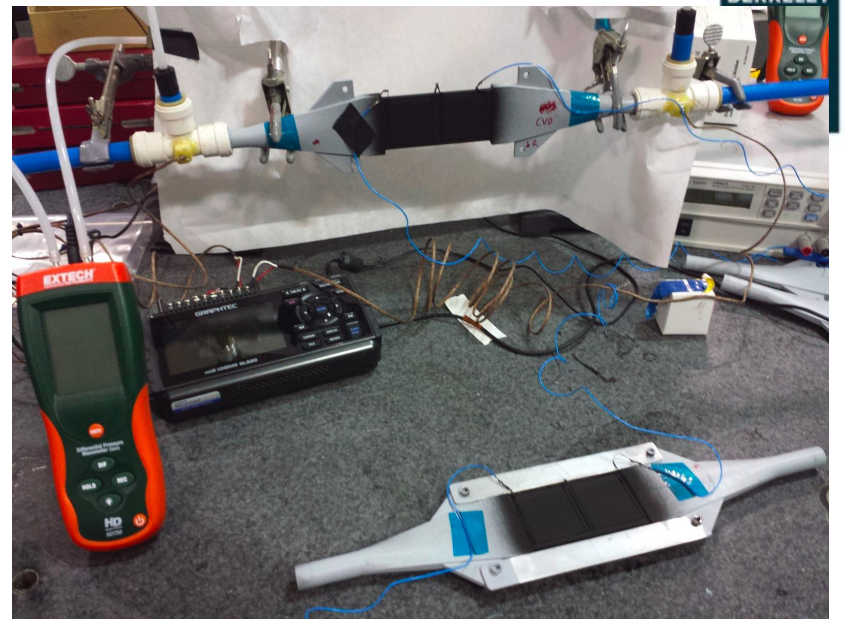
Milestone Description	Date
Report on baseline stave designs	10/2022
Report on baseline disc designs	12/2022
Report on simple disc & stave models • FEA analysis of stave & disc designs • Fabricate & test simple disc & stave mechanical models (mechanical properties, cooling)	06/2023
Up-to-date silicon tracking CAD models	01/2023

eRD111: Mechanical/Cooling

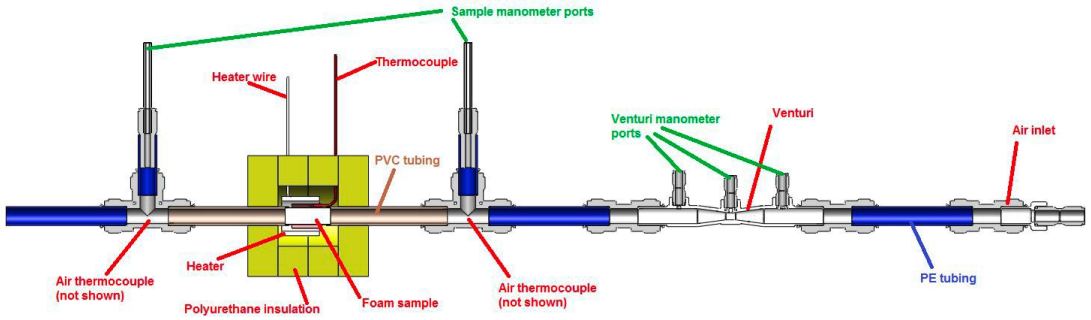
Milestone Description	Date
Report on mechanics conceptual design • Review carbon foam studies for cooling options • Integrate cooling options into stave/disc prototype designs • Develop conceptual designs other mechanical structure/support pieces • FEA analysis of shells & cones	03/2023

- Previous LBNL LDRD on air cooling with carbon foam
  - Structure still exists, needs some technician/engineer time for set-up
  - Planned as a summer project using ITS3 power estimates & carbon foam selection

Summer mechanical project



- Start with previous engineering LDRD
  - Measuring ΔT & ΔP
- 1 postdoc, 1 graduate student, 1-2 undergrads
- ~1 day technician/engineer time for setup
- Repeat previous measurements to familiarize ourselves with setup
- Next: more realistic power consumption, different foams, different thicknesses, etc.



Summer software work

- More detailed layout of staves & discs
  - How do the dead areas affect performance?
  - What if we have some overlap?
  - What if we have to liquid cool things?
  - How long can we actually build these?
- Studies on the material budget
  - 0.55% for staves is probably pessimistic – how much can we (reasonably!) reduce that?
  - Kapton embedded silicon?
  - Different foam choices & thicknesses
- What pressure & vibration can staves & discs withstand?

Involvement with ITS3

- Chip testing
  - 88” cyclotron for radiation effects, other test beams in the US (FNAL, SLAC, JLAB)?
    - ALPIDE telescope exists at LANL
- UC Berkeley Postdoc at CERN starting on DPTS test beam analysis
- Possibility for LBNL Postdoc to work on WP1, physics/simulations

- 2 UC Berkeley people at CERN
  - Participated in DPTS test beam

Summary

- eRD111
  - Stave/Disc concepts, mechanics/cooling
  - Some cooling test setups exist and can be re-used
  - Some initial work has already started
    - Information gathering, stave/disc layout options
  - Still needed:
    - Workforce: postdoc for simulations/CAD work, postdoc for hardware supervision (starting in fall)
    - Engineer workshop/discussion – go through tracker configuration in detail

- ITS3
  - Chip testing, test beam analysis, physics/simulations?
  - Members at CERN provide good opportunity for LBNL involvement