Tracking Systems Overview and Requirements

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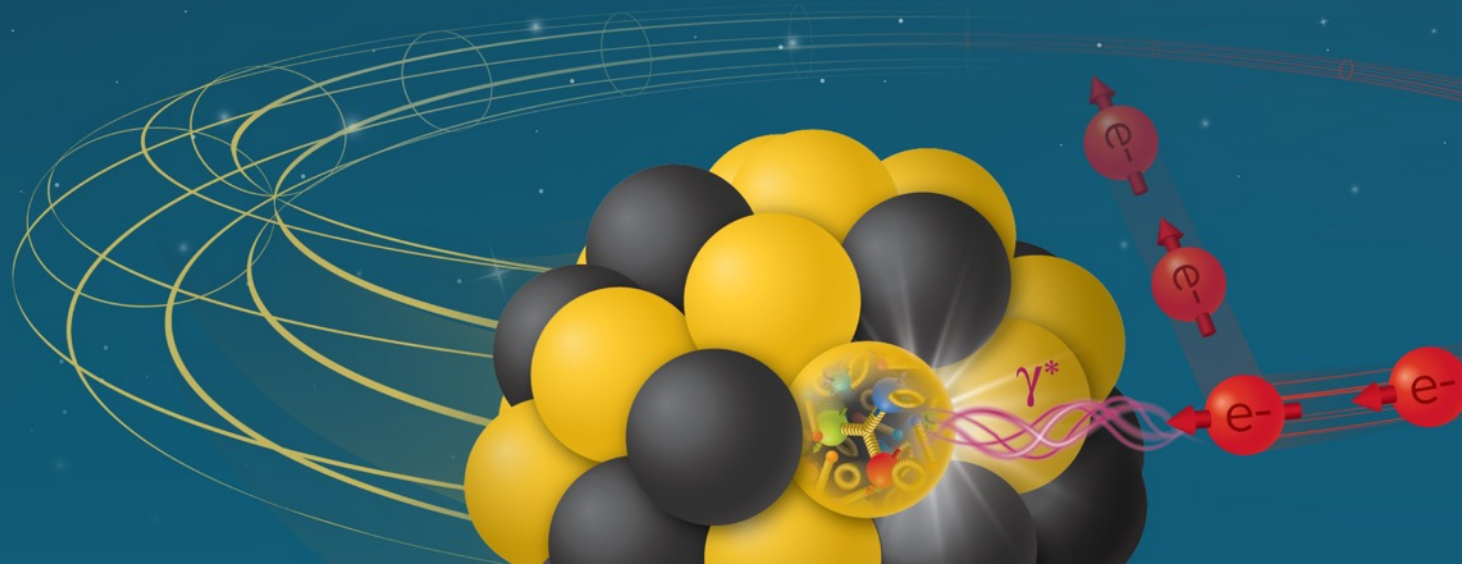
Incremental Design and Safety Review
of the EIC Tracking Detectors
March 20-21, 2024

Electron-Ion Collider



Charge Questions Addressed

1. Are the technical performance requirements appropriately defined and complete for this stage of the project?
2. Are the plans for achieving detector performance and construction sufficiently developed and documented for the present phase of the project?
3. Are the current designs and plans for detector, electronics readout, and services sufficiently developed to achieve the performance requirements?
4. Are plans in place to mitigate risk of cost increases, schedule delays, and technical problems?
5. Are the fabrication and assembly plans for the various tracking detector systems consistent with the overall project and detector schedule?
6. Are the plans for detector integration in the EIC detector appropriately developed for the present phase of the project?
7. Have ES&H and QA considerations been adequately incorporated into the designs at their present stage?

Outline

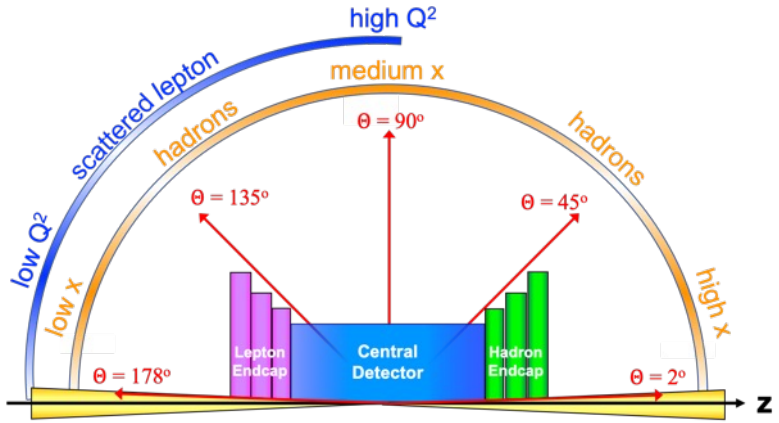
- Requirements
- Interfaces
- Tracking Detector Layout
- Risks
- Safety
- Summary

Requirements

Charge 1

- https://eic.jlab.org/Requirements/index.html
- Based physics in Yellow Report

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

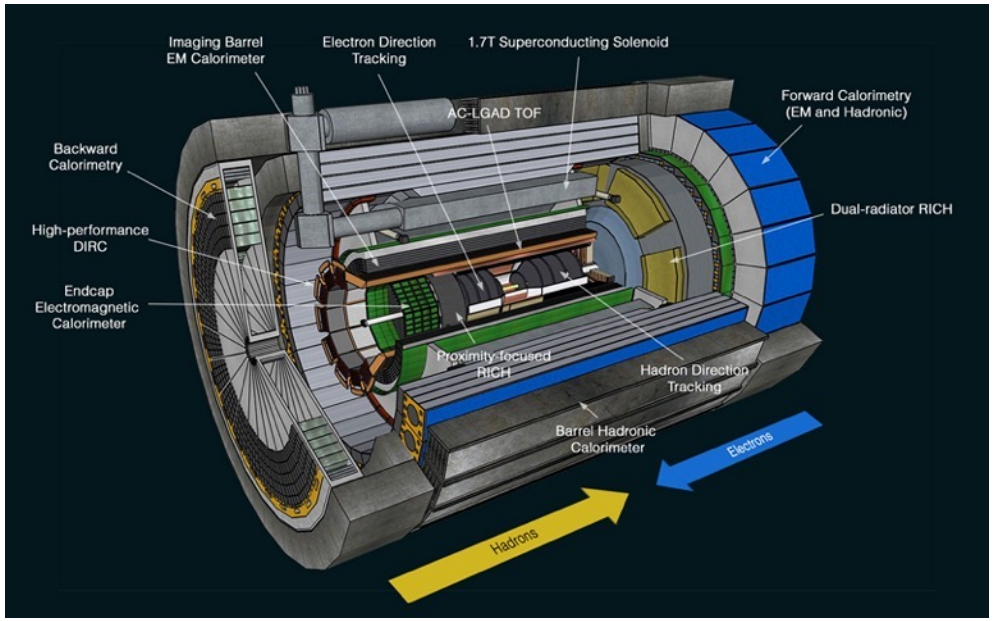


Interfaces

Charge 1

- https://eic.jlab.org/Interfaces/Interfaces.html

  - Outer barrel limited by DIRC
  - Disks limited by pfRICH/AC-LGAD
  - Inner Barrel first vertex layer 5mm from beampipe



Tracking Systems
Interfaces associated with the tracking systems located in the forward, barrel, and backward sections of the central detector.

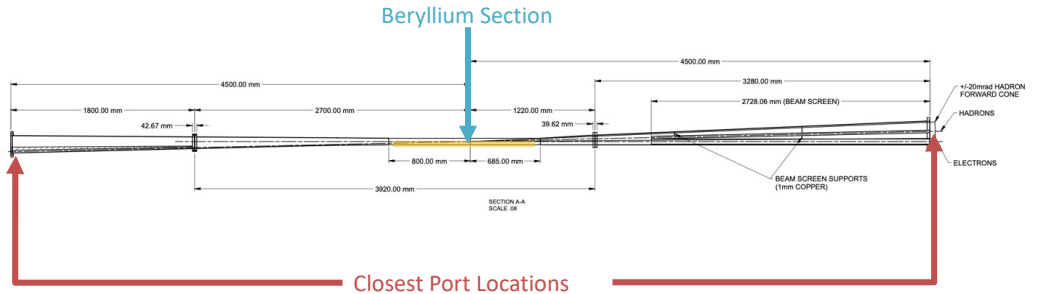
DET-TRAK : Tracking Systems (WBS 6.10.03)

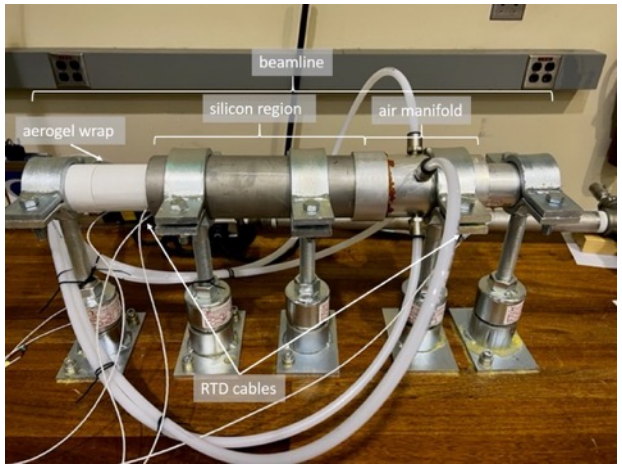
InterfaceID	Type	RelatedSystemID	InterfaceName	Description
I-DET-TRAK-BAR.1	STRUCT	DET-INF-STRUCT	Support Structure	A single structural support system will support the silicon detectors and the micro-pattern gaseous detectors within the DIRC detector.
I-DET-TRAK-BAR.2	STRUCT	DET-PID-BAR-DIRC	Weight Distributed	The weight of the barrel tracking systems will be transferred to the DIRC support system.
I-DET-TRAK-BAR.3	SPACE	DET-PID-BAR-TOF	Exterior Space Constraint	The maximum size of the tracking system is limited to the interior radius of the barrel time of flight detector.
I-DET-TRAK-BAR.4	SPACE	DET-PID-BCK-RICH	Backward Space Constraint	The maximum backward location for the tracking system is limited by the position of the RICH (Modular or Proximity Focusing).
I-DET-TRAK-BAR.5	SPACE	DET-PID-FWD-TOF	Forward Space Constraint	The maximum forward location for the tracking system is limited by the position of the AC LGAD Time of Flight Detector.
I-DET-TRAK-BAR.6	SPACE	IR-VAC	Interior Space Constraint	The interior radius of the tracking detectors is governed by the size of the beamline.
I-DET-TRAK-BAR.7	SPACE	DET-INF-SPACE	Service Pathway	Services to this detector (power, signal, cooling) will be delivered through conduits within the DIRC support system.
I-DET-TRAK-BAR.8	ENV	IR-VAC	Heat Tolerance	The silicon is in close proximity with the beamline. During bakeout the heat will need to be removed to prevent damage to the silicon.
I-DET-TRAK-BAR.9	COOL	DET-INF-COOL	Heat Rejection	Air, liquid or other cooling technology will be required for the tracking detectors.
I-DET-TRAK-BAR.10	ELEC	DET-ELEC	Low Voltage	DC power will be provided from the electronics racks to support electronics in the detector.
I-DET-TRAK-BAR.11	ELEC	DET-ELEC	Bias Voltage	DC power will be provided from the electronics racks to support electronics in the silicon photomultipliers.
I-DET-TRAK-BAR.12	ELEC	DET-ELEC	High Voltage	DC power will be provided from the electronics racks to support silicon sensors and gas detectors.
I-DET-TRAK-BAR.13	GAS/ FLUID	DET-INF-GAS	Ionization Gas	Gas will need to be provided to the trackers for detector operation.
I-DET-TRAK-BAR.14	CONTROL	DET-COMP-ONLINE	Slow Controls	A network connection will be provided from the DAQ system to the barrel tracking system's slow controls interface.
I-DET-TRAK-BAR.15	DATA	DET-COMP-ONLINE	Data Transfer and Control Interface	A fiber connection will be provided from the DAQ system to the barrel tracking system's readout board to perform configuration, control, and data acquisition.
I-DET-TRAK-BAR.16	DATA	DET-COMP-ONLINE	Timing Interface	A fiber connection will be provided from the DAQ system to the barrel tracking system's readout board for timing synchronization.
I-DET-TRAK-BAR.17	DATA	DET-COMP-ONLINE	Data Acquisition	Cables required to transfer data from the detector to the online data acquisition system.

Interfaces – Beam Pipe

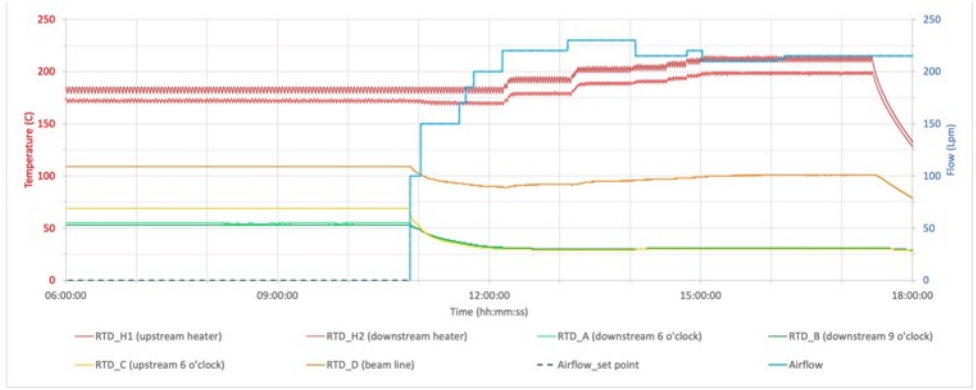
Charge 1

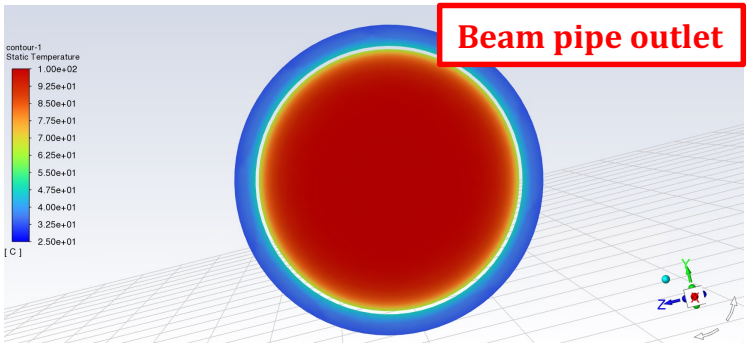
- Unique beampipe
  - Tapered beampipe, tracking detectors must be installed prior to beampipe installation in central detector
  - Beampipe exposed to ambient prior to installation
  - Need min 100°C in beampipe to break H_2O bonds
    - Silicon detector limited to <50°C due to CTE of materials
    - Additional details in Nicole's talk





Only covers 1 m of 3 m beryllium section

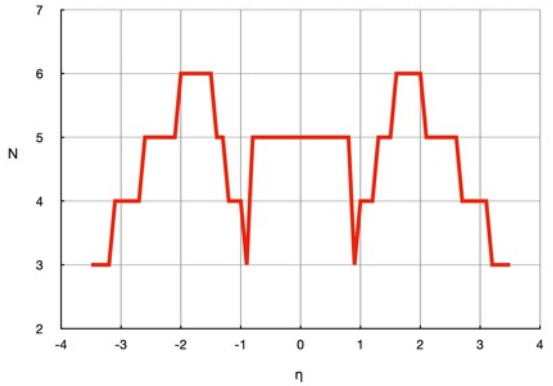


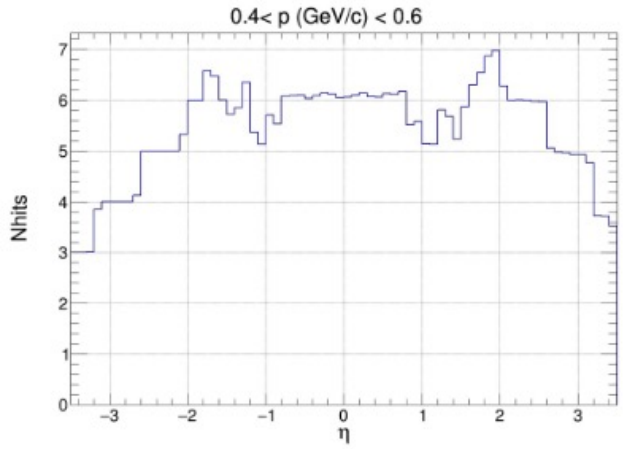


Tracking Detector Layout Modifications

Charge 2, 3

- Low number of hits in certain rapidity ranges
  - Need more planes
  - Red = Si Only, fast simulation
  - Blue = Previous layout, full simulation

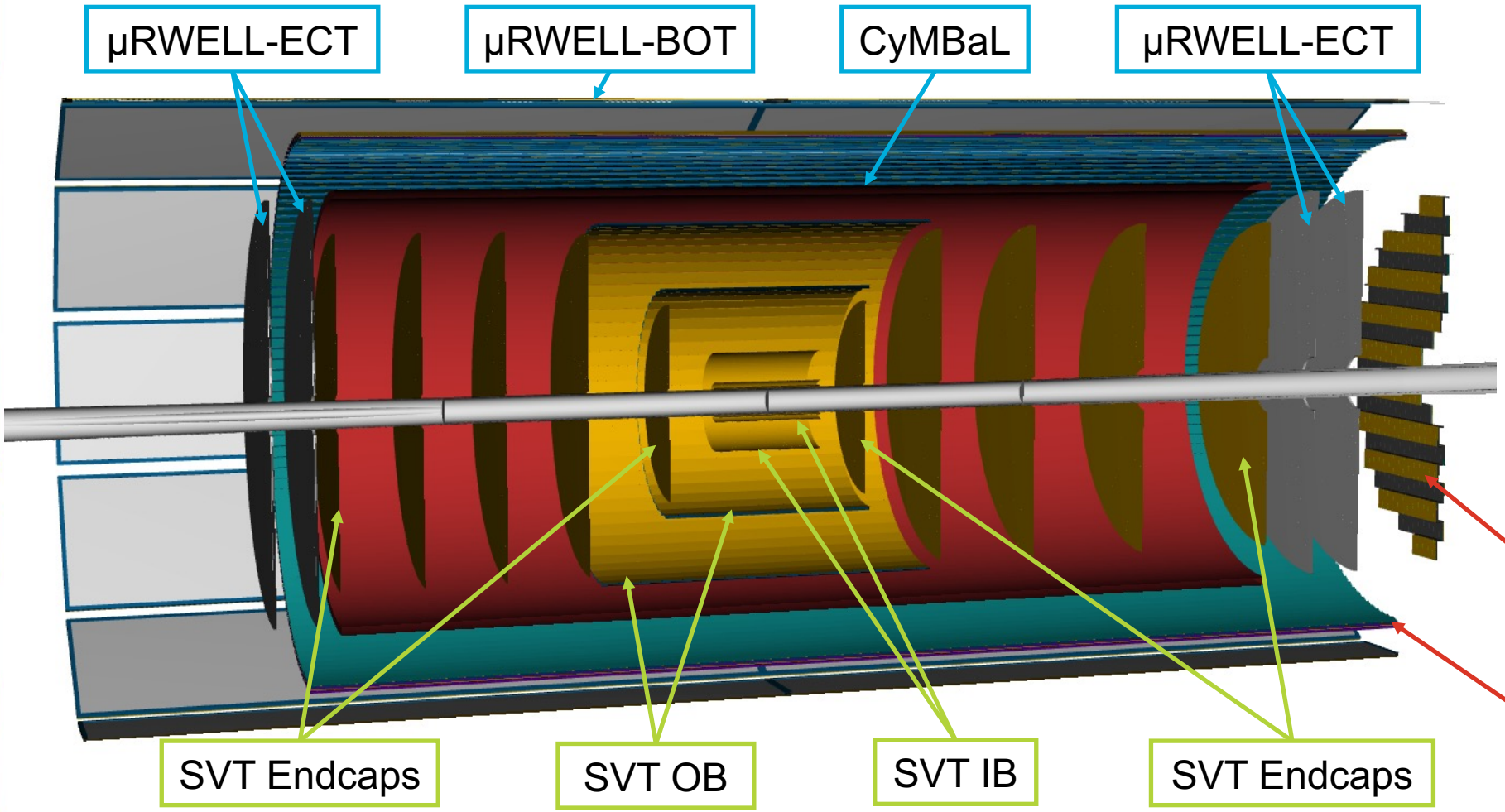




- Solve impact from 5 (2) μs MAPS frame accumulation time
  - Need enough hits from faster detectors to form a tracklet with a good pointing resolution, e.g. MPGDs
  - Need to utilize ToF and maybe Barrel-ECal AstroPix as possible
    - Note: Barrel ToF has good time resolution but not spatial resolution

- Current layout finalized in Spring 2023

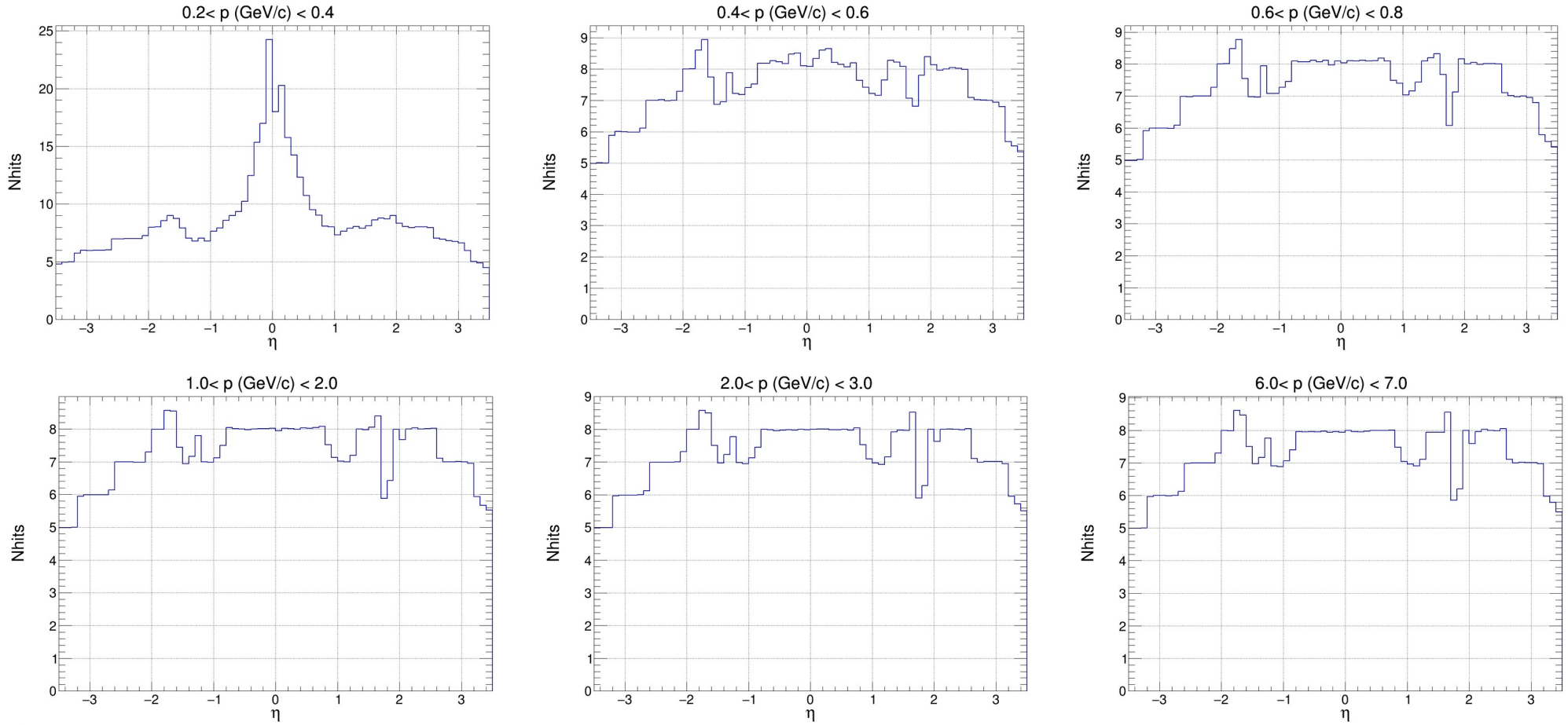
Overall Tracking Layout



- MPGD
  - BOT Length: 340 cm
  - BOT Radius: 72.5 cm
- Silicon
  - Outer Length: 84 cm
  - Outer Radius: 42 cm
- AC-LGAD
  - ToF: Part of PID

Simulation – Nhits vs η

- Only tracking detectors included, will improve further once calorimeters included which should remove dip at rapidity ±1, details in Matt's talk



Silicon

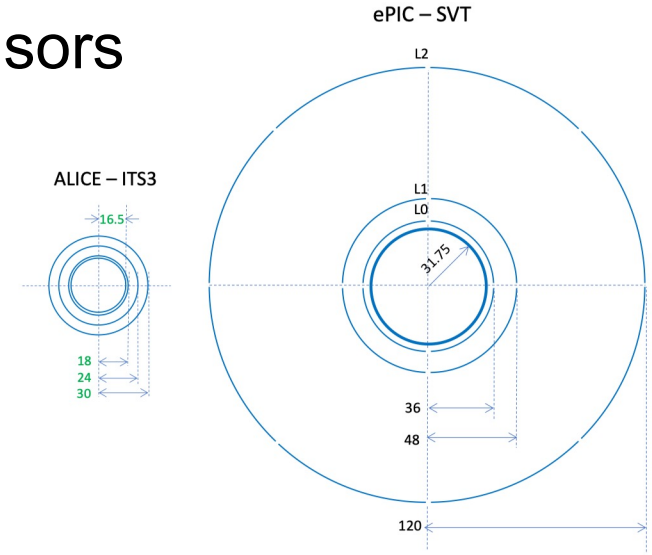
- MAPS (monolithic active pixel sensors) in 65 nm CMOS technology, developed with ALICE ITS3 collaboration, details in Laura's talk
  - Inner Barrel: Directly use ITS3 wafer scale sensor
  - Outer Barrel: EIC Large Area Sensor (LAS), modification of ITS3 sensor

- EIC Project, ePIC SVT Collaboration and CERN ALICE/ITS3 meeting in Q2 23
  - Path forward on collaboration (draft completed at BNL legal)
  - EIC has hired 2 engineers to work directly with ALICE team on sensor development

Silicon – Inner and Outer Barrel

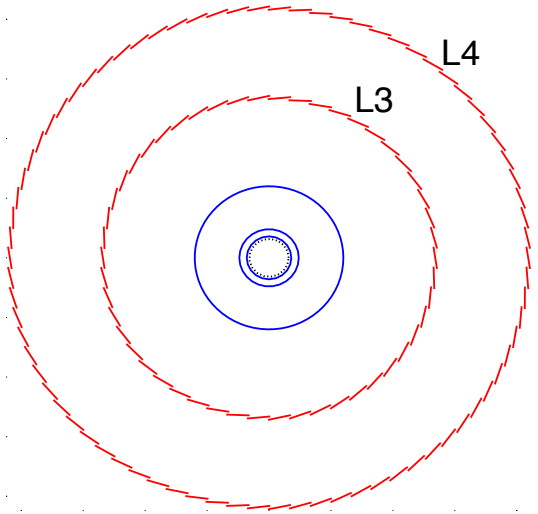
- Inner: three layers of thin, bent, wafer scale ITS3 based sensors
- ITS3 concept adapted to ePIC radii, details in Ernst's talk
- X/X0 % = 0.05

Layer	Radius (mm)	Length (mm)	Sensors
L0	36	270	4
L1	48	270	4
L2	120	270	8



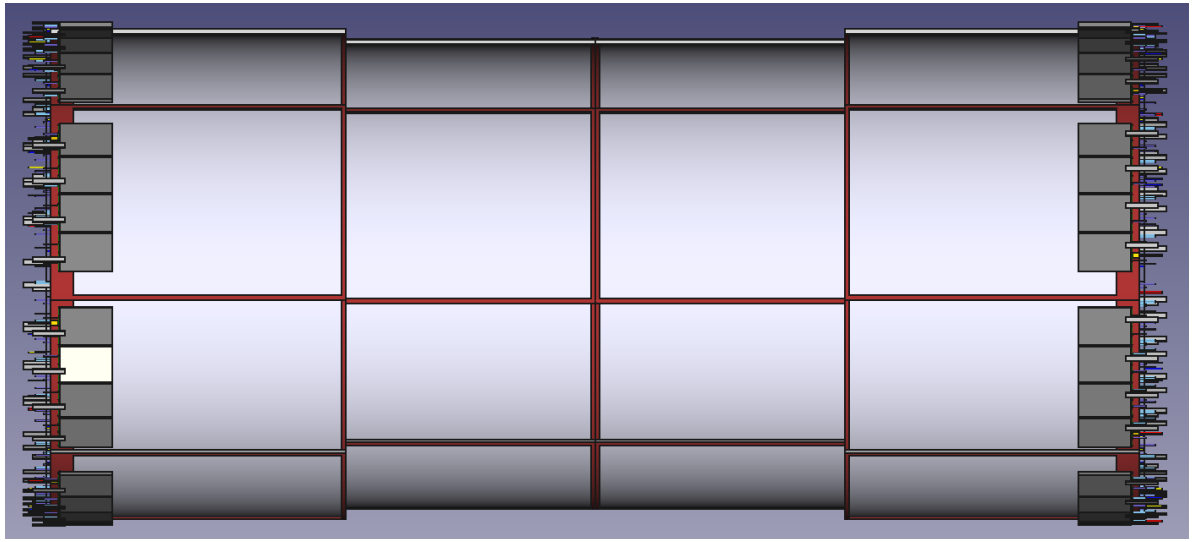
- Outer: Traditional stave design

Layer	Radius (mm)	Length (mm)	X/X0%
L3	270	540	0.25
L4	420	840	0.55

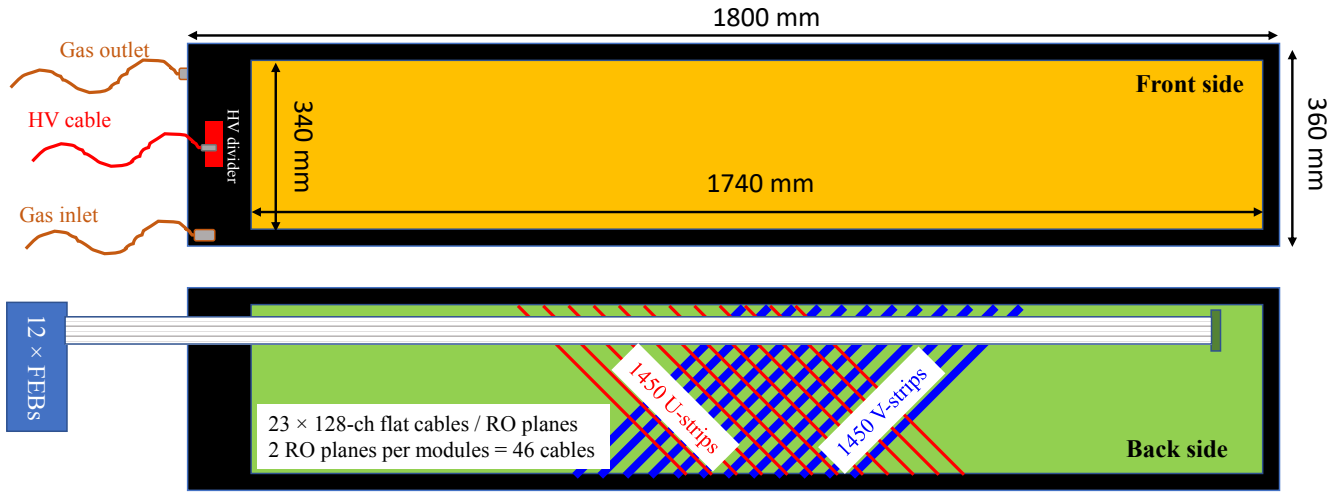


Outer Barrel – MPGD

- CyMBaL
  - Additional Tracking Points
- Single Tile
  - 65 x 46 cm
  - Simplifies production
  - More details in Francesco's talk

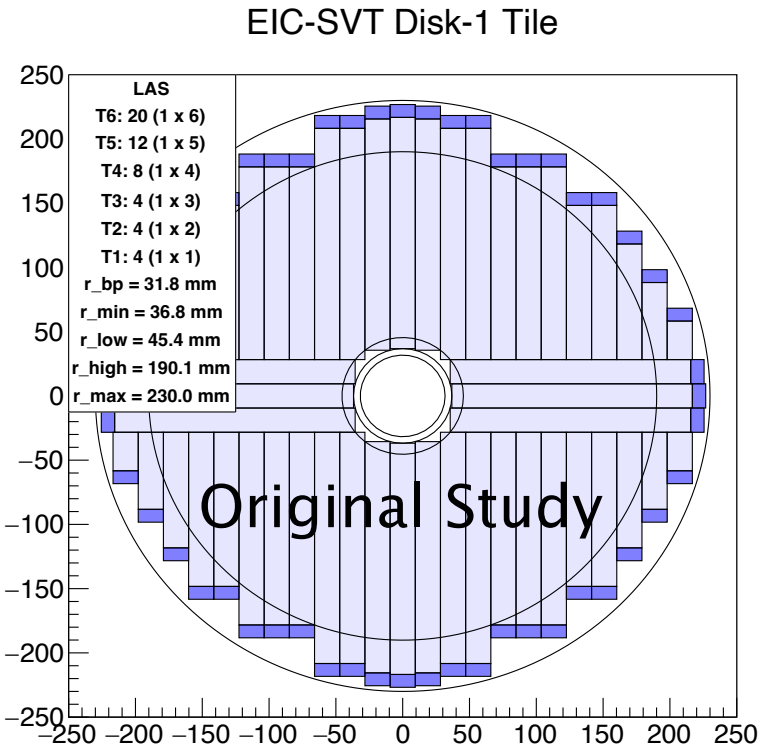


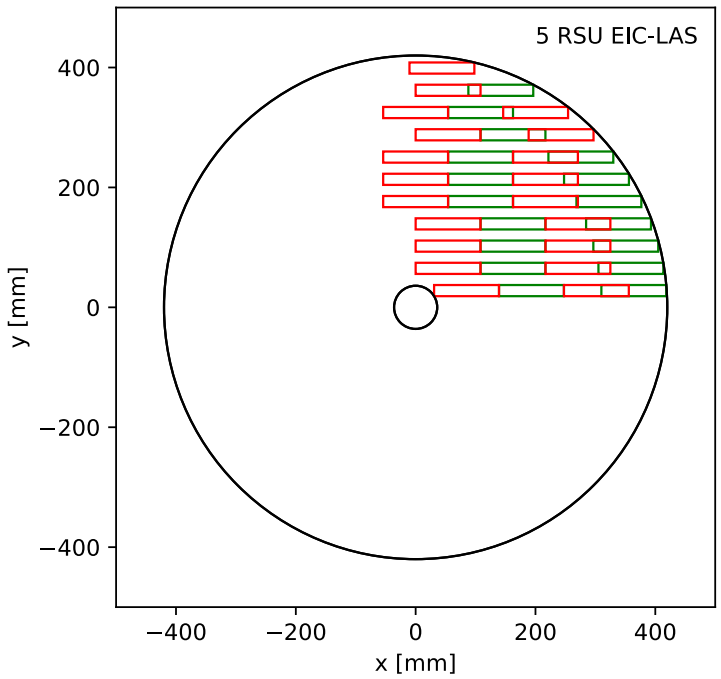
- µRWELL-BOT
  - Provides hits for DIRC
- Single module design
  - 24 modules in total
  - More details in Kondo's talk

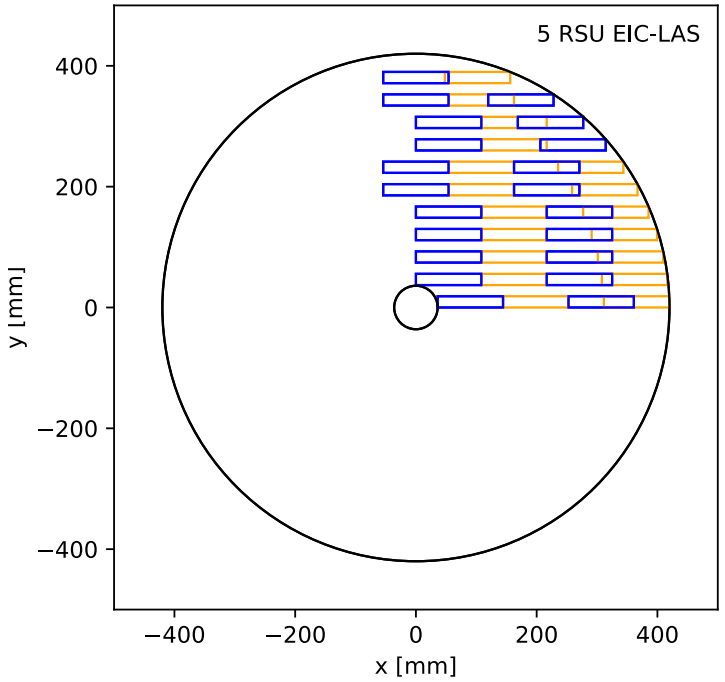


Forward / Backward Disks – Silicon

- Foundry rule/limitation, need to limit number of sizes (2-3 total)
  - Direct outcome from meeting with ALICE
  - More details in Ernst's talk

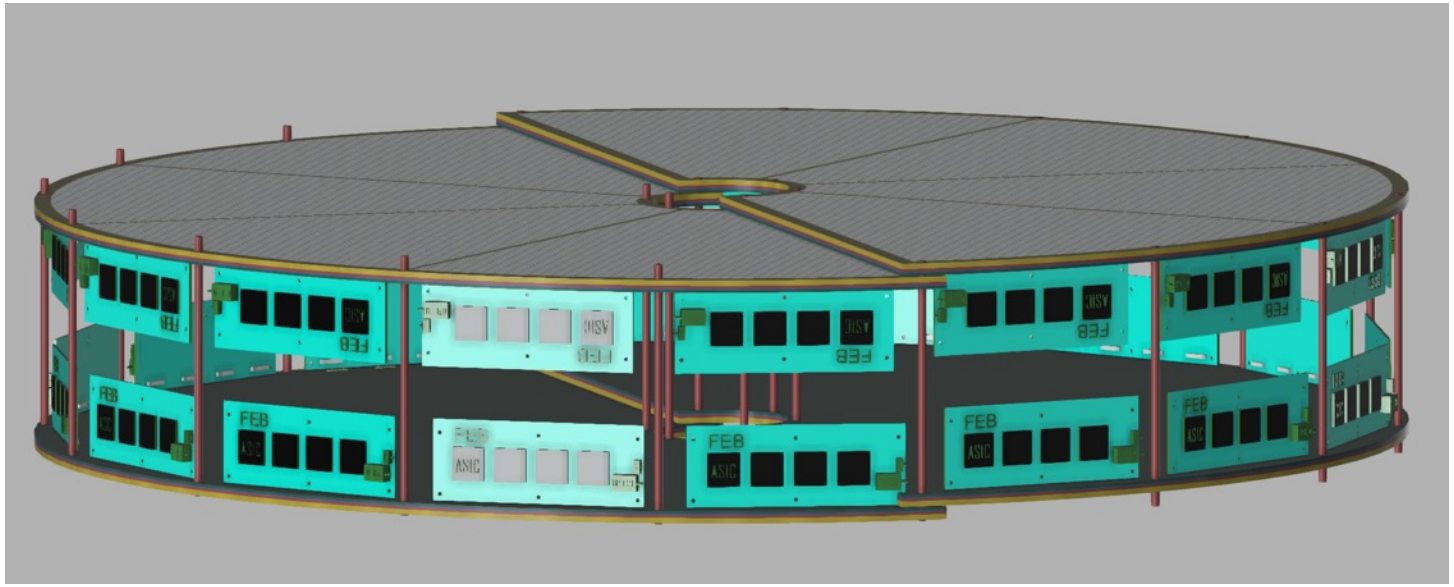


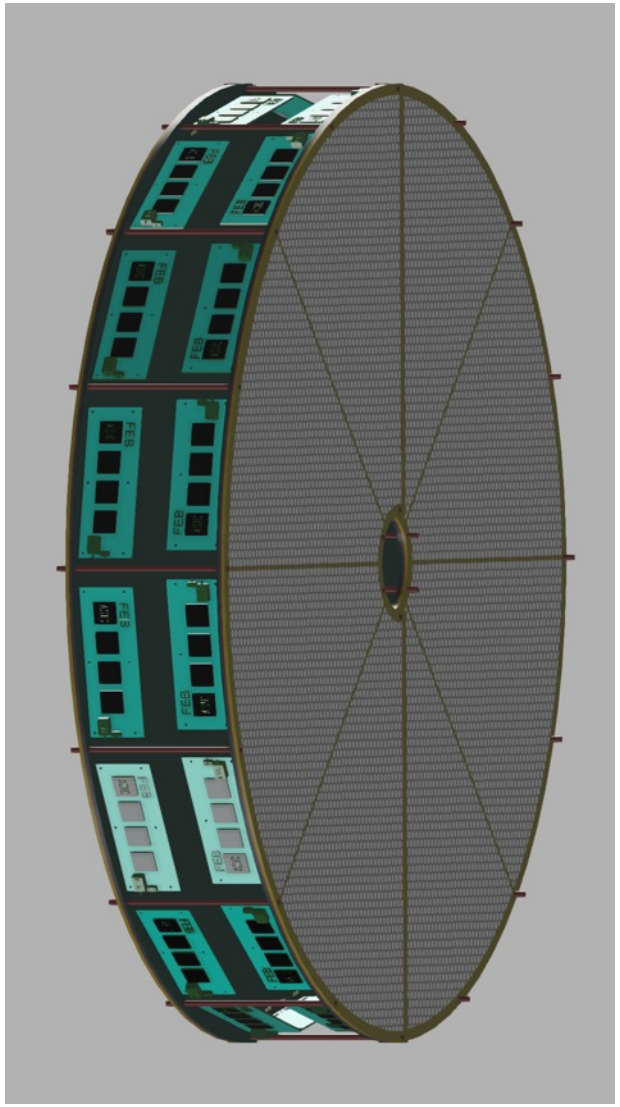




Forward / Backward Disks – MPGD

- μRWELL-ECT
  - 4 disks in total (8 half-disks)
  - Diameter ~100 cm with 2 cm overlap
  - More details in Annalisa's talk

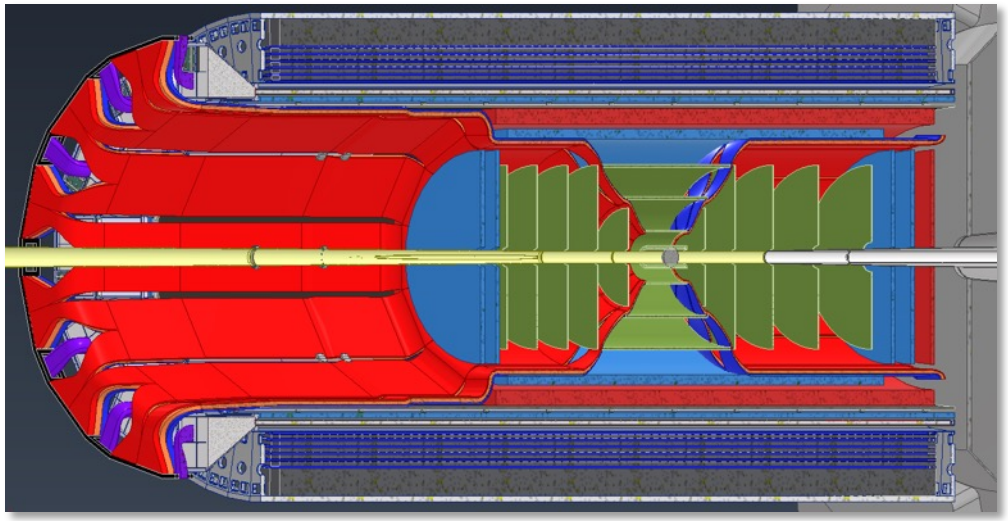


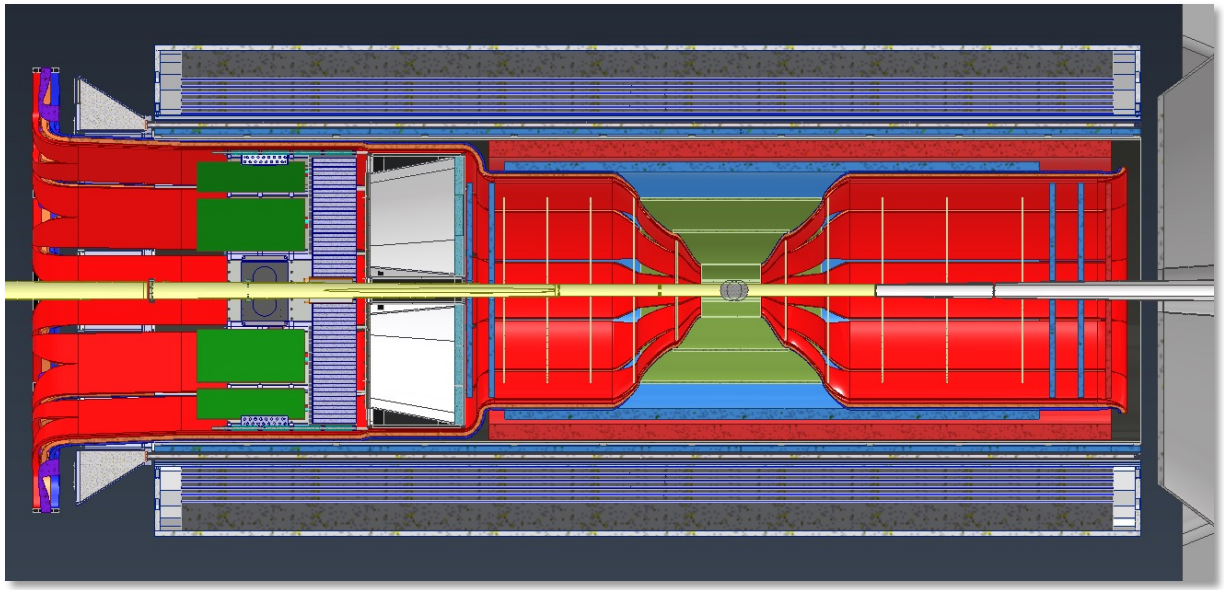


Services

Charge 3

- Service volume increases as get further from Interaction Point
  - More details in Roland's talk
- RED = power
- BLUE = cooling/gas
- ORANGE = signal

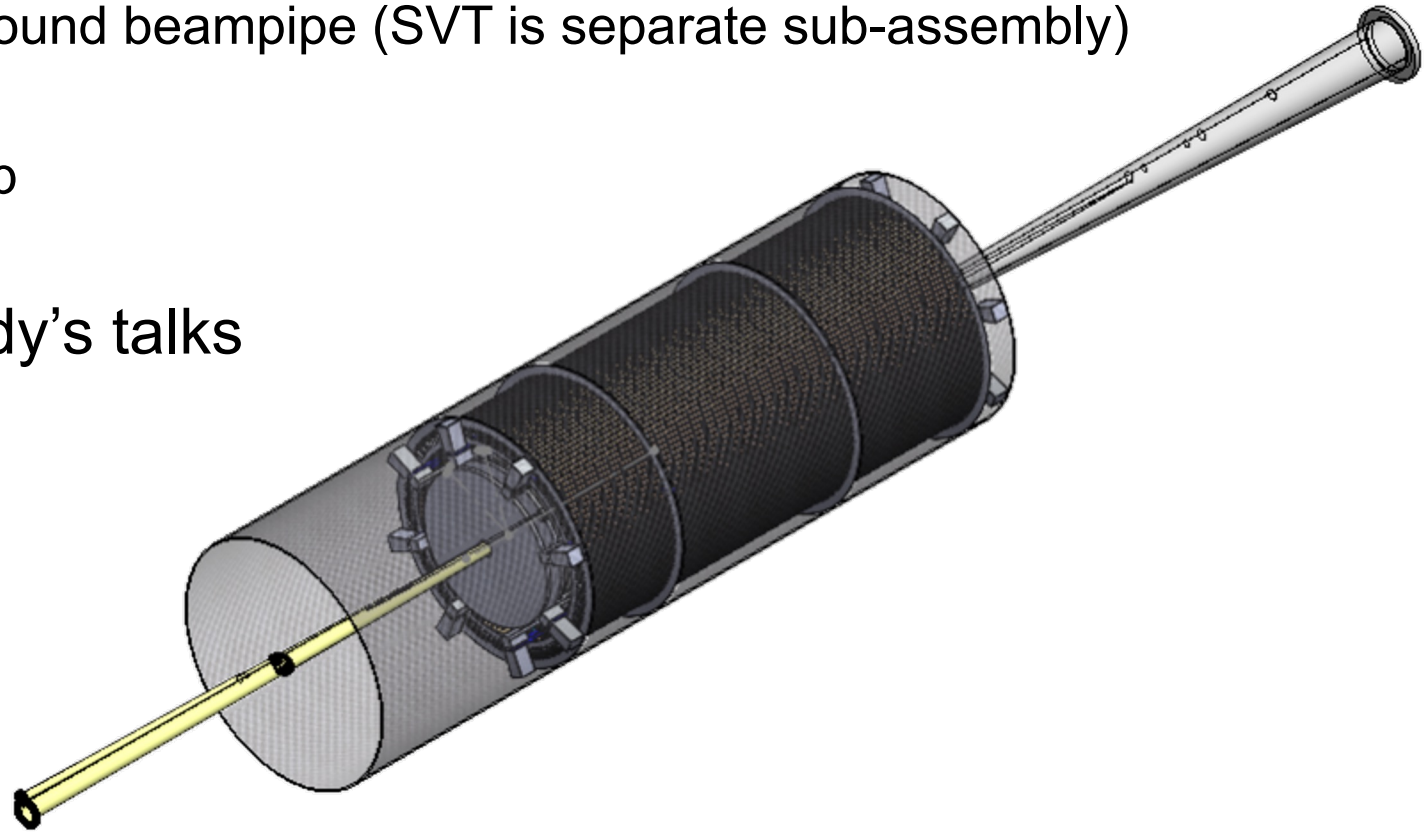




Integration

Charge 6

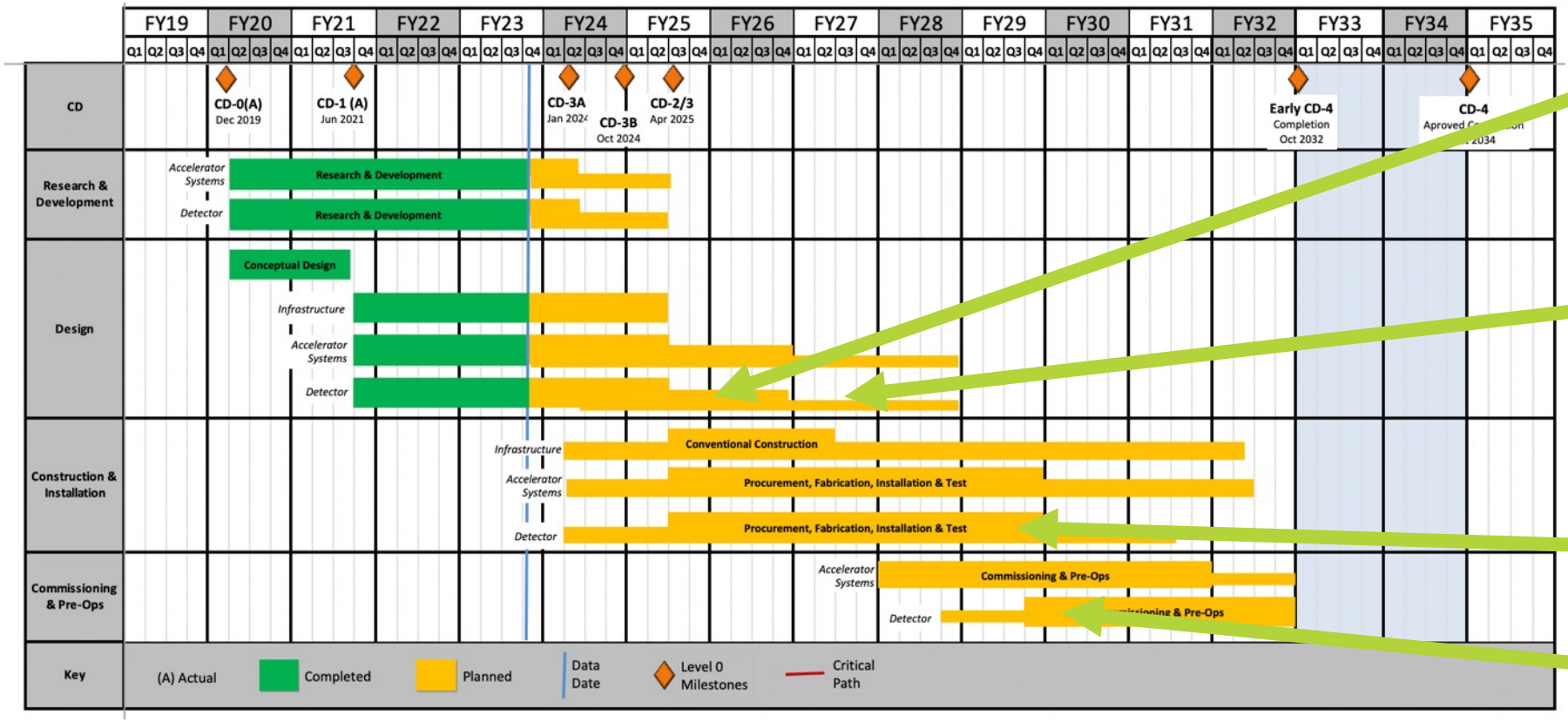
- Assembled in stages
  - µRWELL-BOT together with hpDIRC
  - CyMBaL with TOF
  - Silicon barrels and disk clamshell around beampipe (SVT is separate sub-assembly)
  - TOF assembly slides over SVT
  - µRWELL-ECT are added as last step
- More details in Roland's and Andy's talks



Cost / Schedule

Charge 5

- Cost / Schedule is based on engineering estimates from detector experts



- Inner Barrel Silicon (ITS3)
  - 2024-2026
- Outer Barrel/Disk Silicon (LAS)
  - 2025-2027
- Stave/Disk Construction Complete
  - Q4 29
- Ready for integration
  - Q2 30

Risks

Charge 4

- Currently for the silicon trackers there is a planned engineering run during R&D with the production run taking place during PED
- Benefit from ALICE ER1 and ER2 runs and that the EIC runs would be based on the final ER3 design
- However, if unforeseen issues arise another engineering run for the sensors might be needed
  - The risk register has a proposed risk (ID RT-6-10-014) if a second engineering run is needed which would use contingency

- CD-3A Director's Review comment:
  "Upfront discussion of risks of R&D not coming to a favorable conclusion, and mitigation plans in this case, should be more clearly documented and presented. Where appropriate, for example for the tracking detector, more detailed plans should be developed."
  - Silicon detectors have external dependency on ITS3 sensors

- See later talk for alternative layout discussion

Safety

Charge 7

- Generally the tracking WBS is in the design phase and and such doesn't have any safety issues

- However, there are a few test stands being developed which follow their institution's safety protocols
  - Protocols include required training
  - LBNL testing carbon foam cooling: ISM, documented in Work Planning & Control
  - JLAB testing beampipe bake-out: ISM, Task List and ePAS (JLab-PR-725)

- Equipment going in the BNL Experimental Hall must follow NEC/NFPA 70E, 2021 and electrical safety guidelines: DOE-HDBK-1092-2013
  - Defines voltage hazards, cable type requirements, circuit protection, etc
  - Equipment must be NRTL listed or approved by BNL Electrical Equipment Inspection program

Summary

- Recent design change to address performance issues, which has been incorporated into the ePIC collaboration's latest models
- Cost and schedule developed with input from ePIC collaborators and ALICE/ITS3 efforts
  - Scope change request for additional personnel based on discussions from CERN visit in progress.
- Tracking WBS is in the final design stage no major ES&H issues
  - Test stands follow the relevant institution's policies.
- Proposed risk added to register for additional engineering runs of silicon sensors