Canada’s Involvement in the Electron Ion Collider

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Collaborators:

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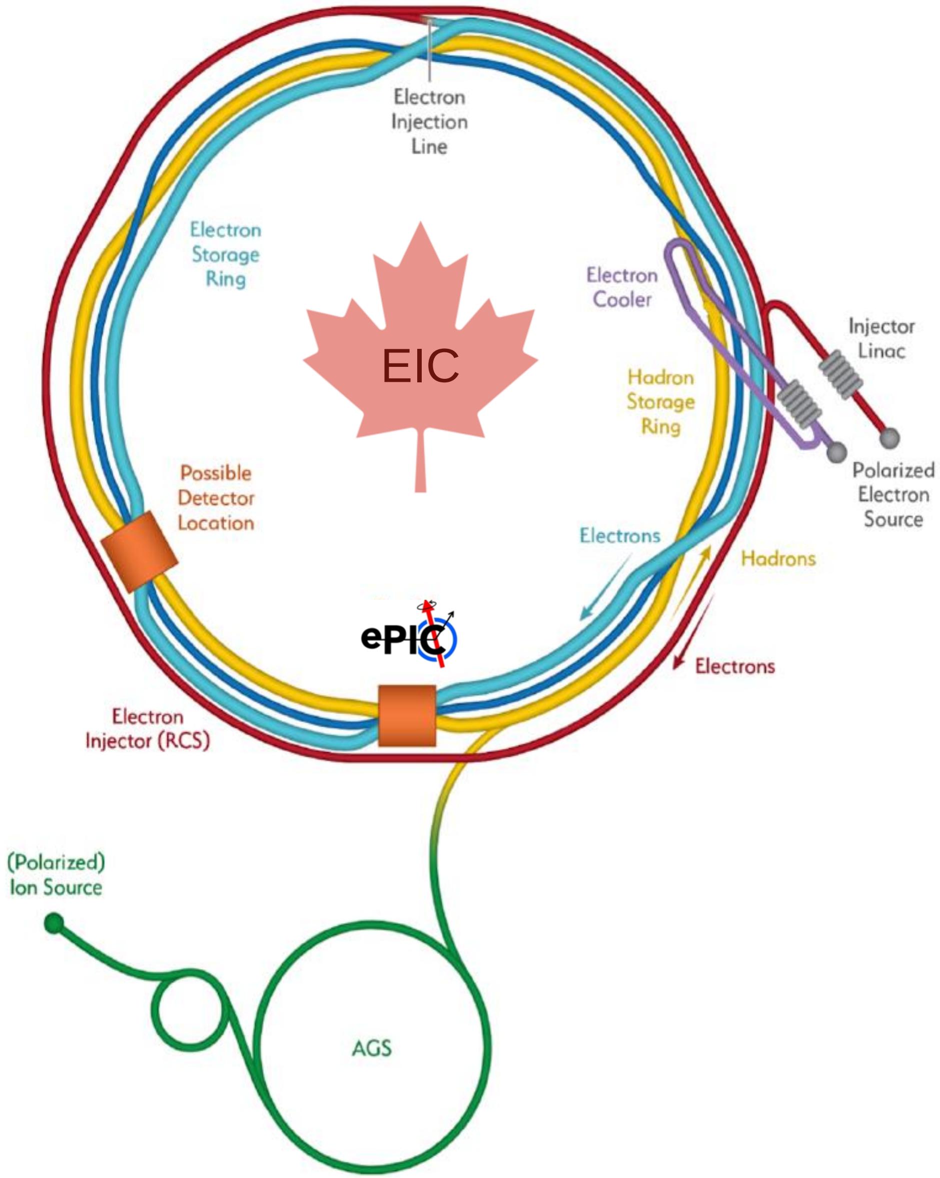
U. Manitoba: W. Deconinck, M. Gericke, S. Longo, J. Mammei,

U. Regina: G. Huber, Z. Papandreou, A. Teymurazyan

Mt Allison: D. Hornidge

UVic: T. Junginger

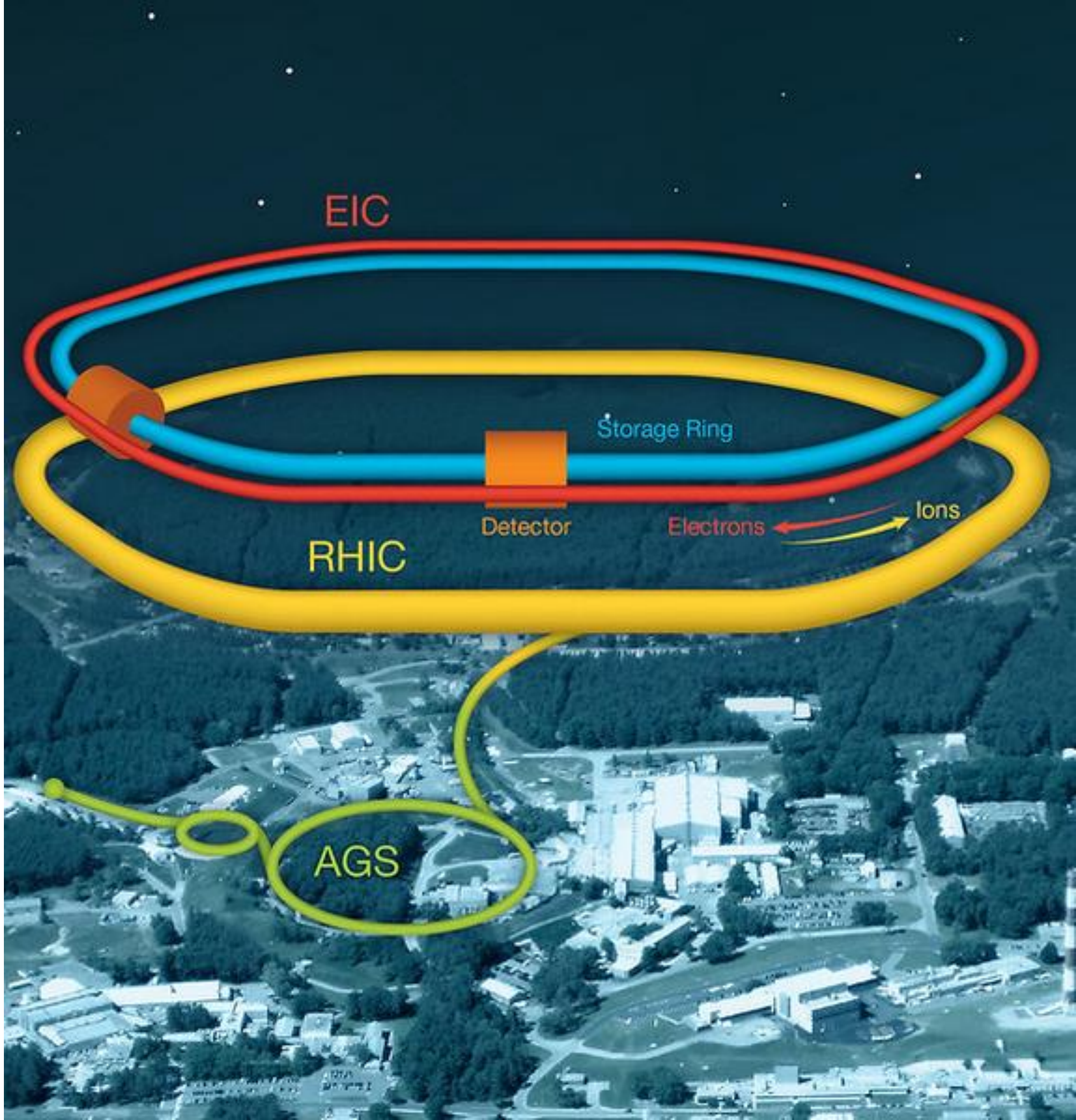


Electron Ion Collider

The EIC at Brookhaven will be the next international discovery machine.

The EIC accelerator design is based on the existing RHIC Complex

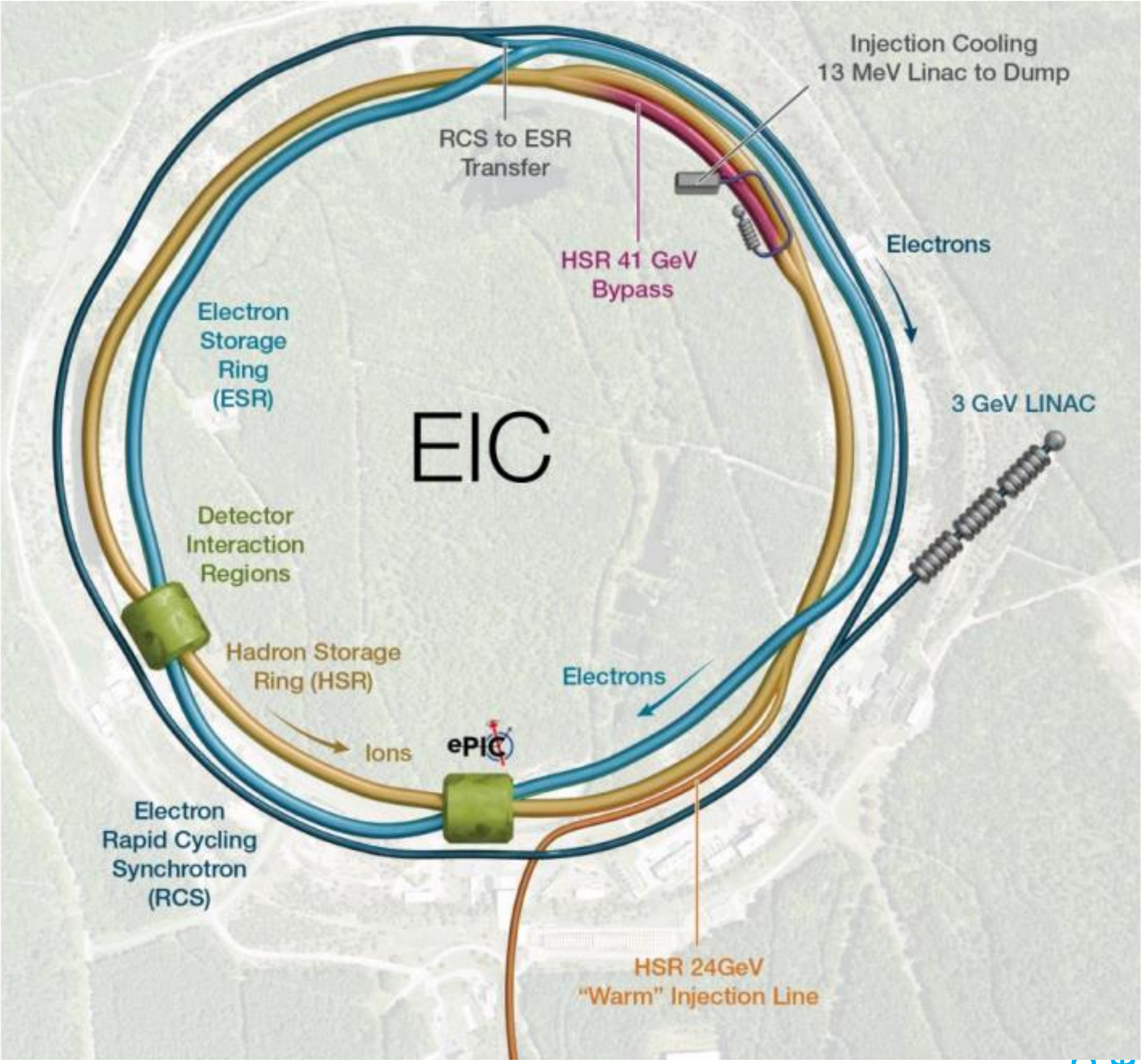
- Hadron storage ring 40-275 GeV (based on existing RHIC)
- New 3 GeV SRF e-Linac
- New Electron rapid cycling synchrotron 3 - 18 GeV in RHIC tunnel
- New electron storage ring 5 – 18 GeV ring in RHIC tunnel
- High luminosity interaction region and new detector ePIC



EIC Challenges

The Electron Ion Collider is the most challenging and complex collider project to date

- Constrained by existing tunnel, hadron source and infrastructure
- Broad energy range, radial off-set of hadrons to match synchronism with electrons
- High currents and polarization in both electrons and hadrons
- Crab cavities
  - Very tight phase and amplitude noise requirements
- Hadron cooling



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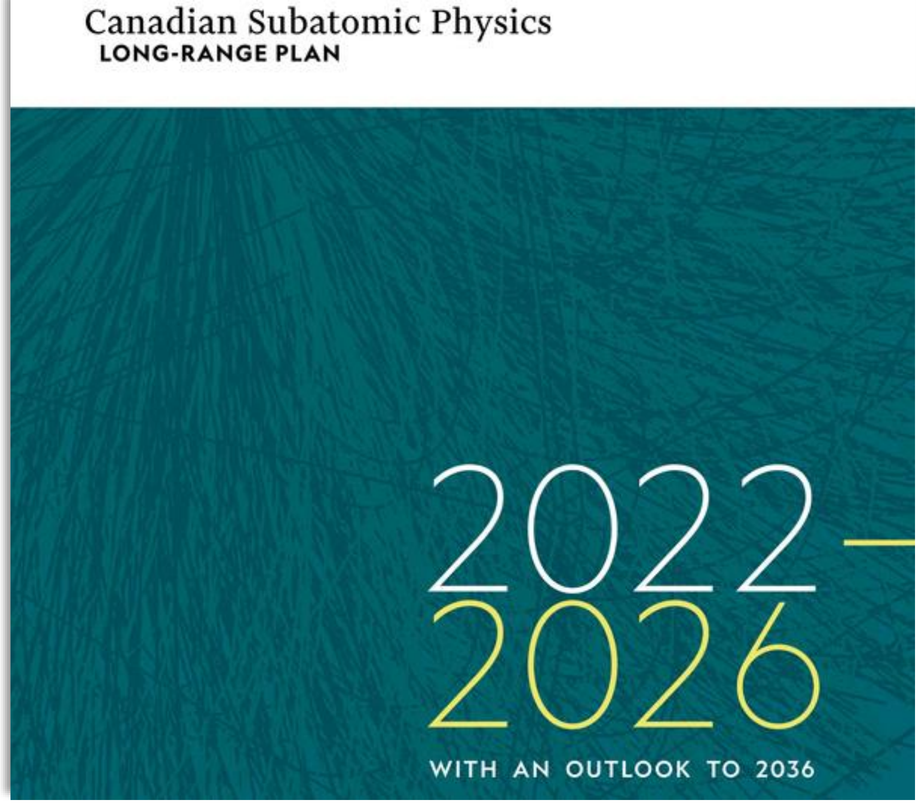
Canada and EIC

- The Canadian subatomic physics community is strongly supporting participation in the EIC program. In the 2022–2026 Canadian Subatomic Physics Long Range Plan, the community named the EIC as a “flagship program with broad outcomes.”
- A Canadian collaboration with EIC Canada, TRIUMF and University partners is pursuing a CFI proposal in the 2025 IF competition.
- The proposal leverages technical know-how at TRIUMF and partnering universities, engages Canadian industry in cutting edge accelerator technology while training next generation HQP.



Discovery, accelerated

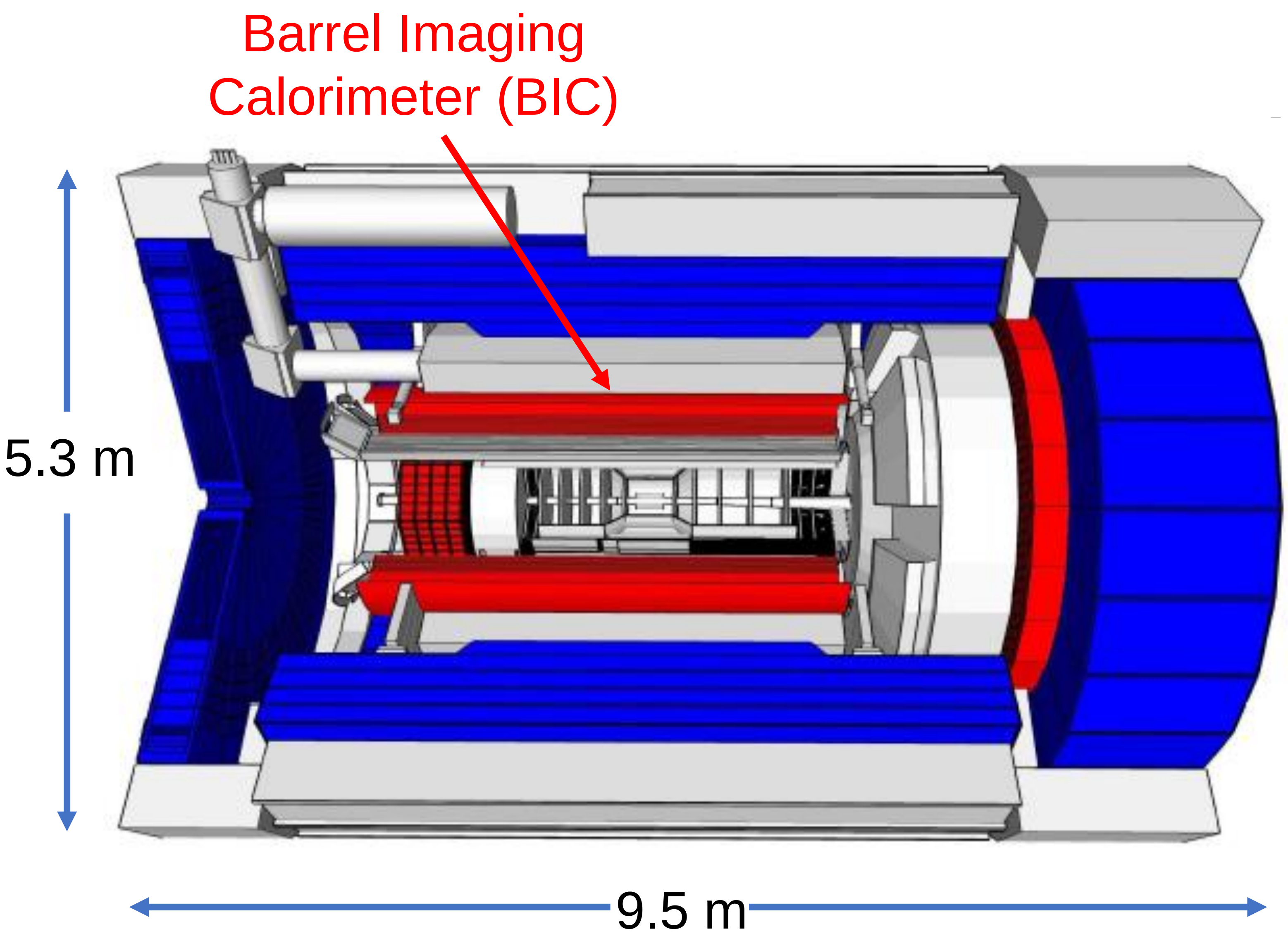
A Canadian contribution to EIC

- Discussions with EIC have identified two potential deliverables for in kind contributions from Canada
  - 394 MHz crab cavities for the hadron ring – led by TRIUMF and UVic
  - Barrel Imaging Calorimeter subsystem of the ePIC detector – led by the U. of Regina and the U. of Manitoba

Barrel Imaging Calorimeter

The ePIC Detector

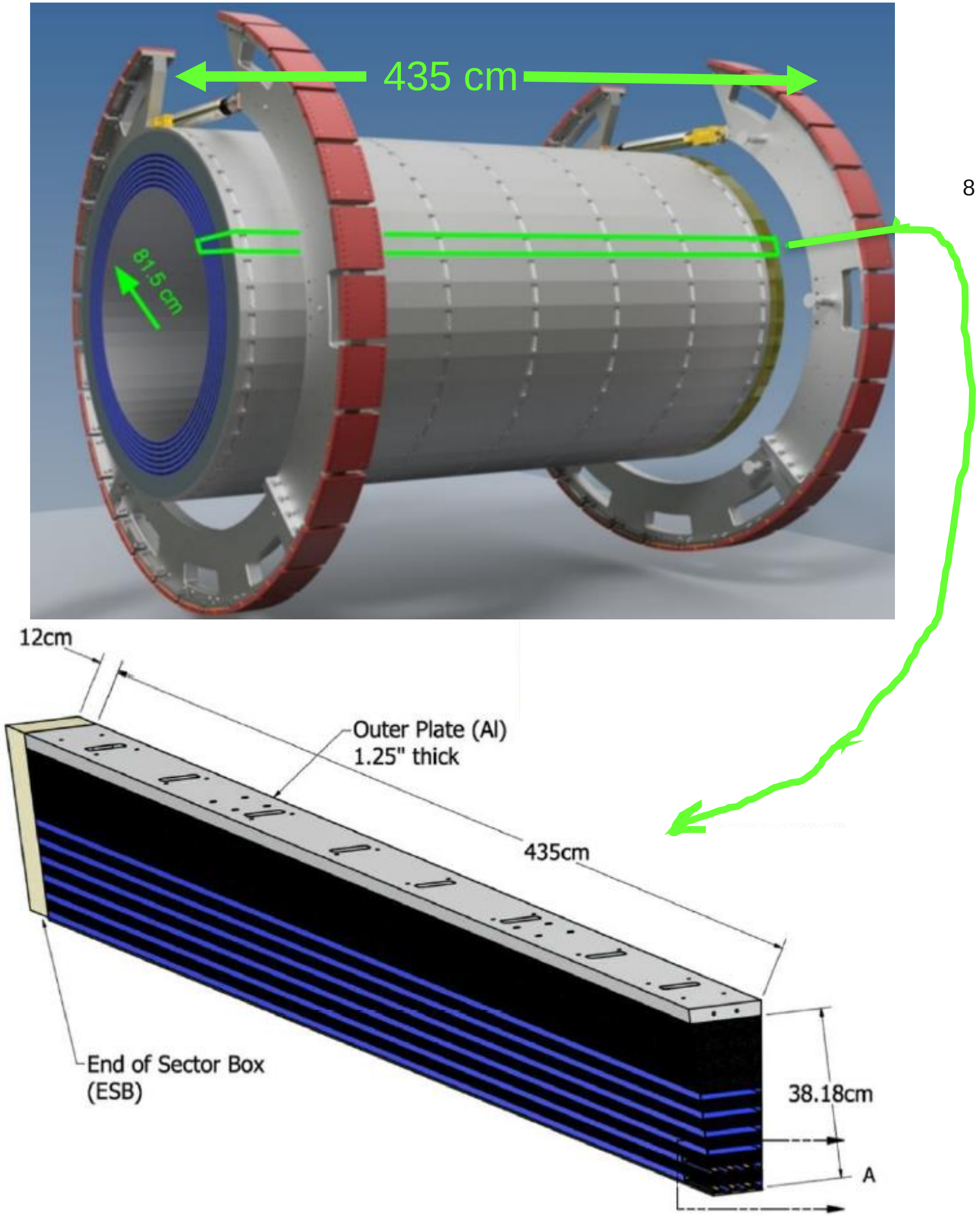
- EIC baseline scope has a single detector at the south collision point – the ePIC detector
- BIC is an innovative particle-imaging hybrid calorimeter that interleaves lead-scintillating-fiber calorimetry matrices (for neutral-particle energy measurement) to an advanced silicon-based tracker (for submillimeter charged-particle tracking precision).



Tuesday DNP T1-6 10:15AM `The Barrel Imaging Calorimeter for the ePIC Experiment at EIC', Tegan Beattie

Barrel Imaging Calorimeter

- Canadian contributions will support the Barrel Imaging Calorimeter (BIC)
- BIC is comprised of 48 sectors each sector consisting of 12 Pb/ScFi calorimetry layers and 4 tracking layers (AstroPix)
- End of Sector Boxes (ESB) (two per sector) contain light guides and silicon photomultipliers (SiPMs) to convert optical light into electrical signals.
- Canadian contributions include:
  - Construction of 96 end-of-sector boxes (ESB) each box with 60 optical light guides and SiPMs (5 per Pb/ScFi layer)
  - Training towards scintillating fiber and lead sheet sampling calorimeter (Pb/ScFi layers) – 12 per sector
- Design faces considerable challenges due to limited available space



HSR 394MHz Crab Cavities

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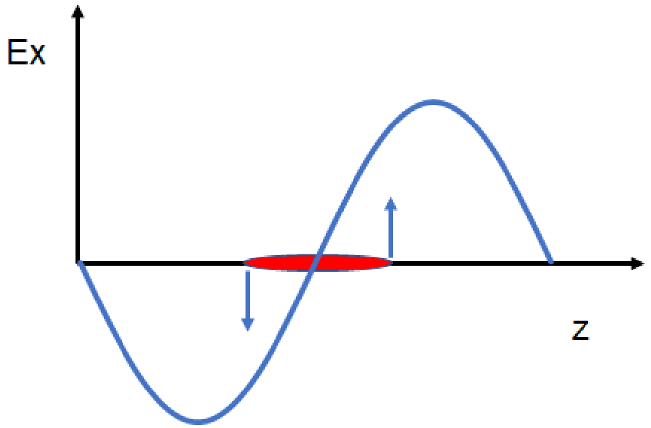
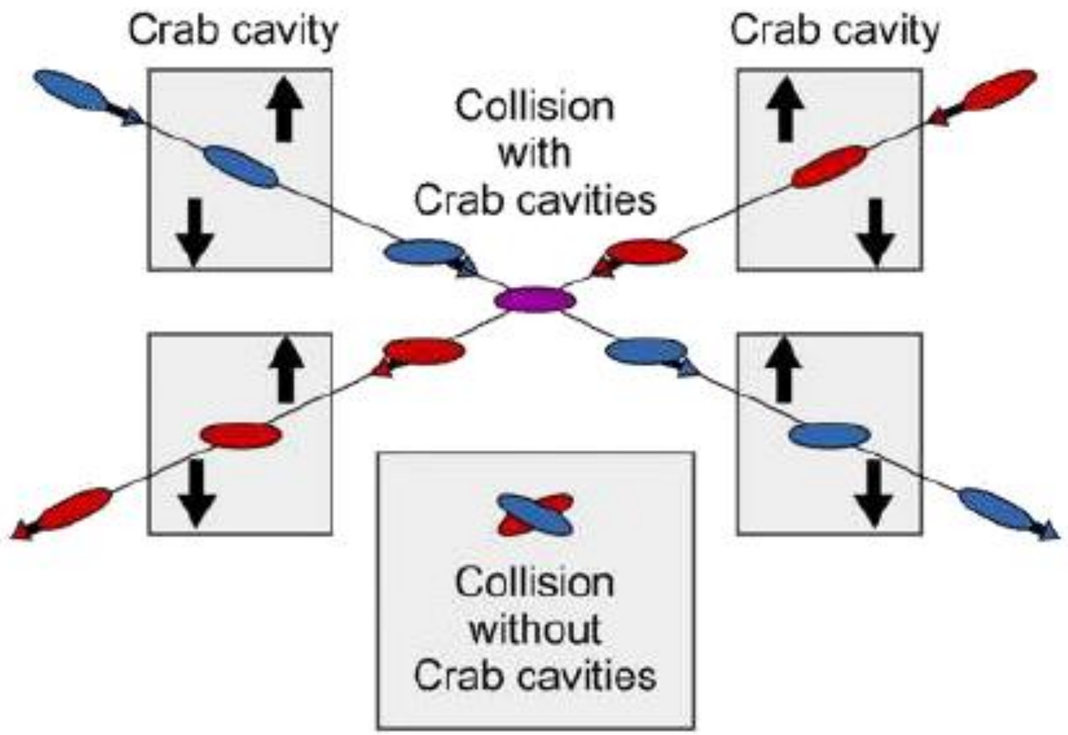
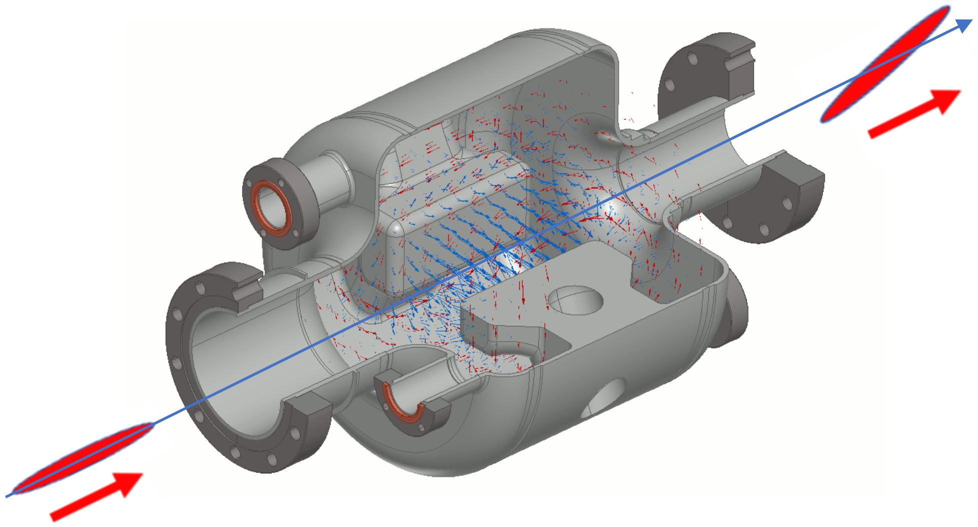
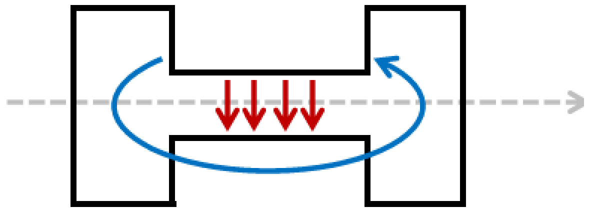
What is a crab cavity?

- A crab cavity is designed to produce a deflecting (rather than accelerating) electro-magnetic rf field.
- A charged particle bunch passing through the cavity at the zero-crossing will experience a transverse skewing (crabbing)
- This skewing compensates for the crossing angle at the collision point and increases the probability of collision (luminosity)









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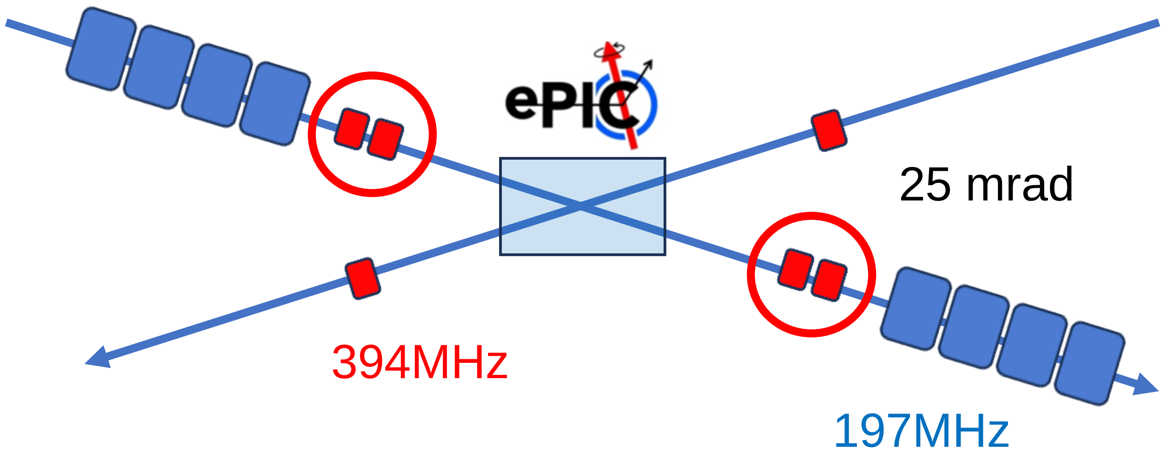
EIC Crab Cavities

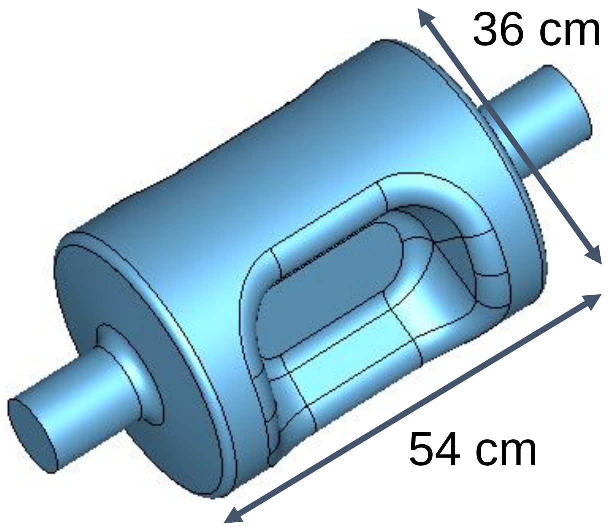
- The EIC requires crab cavities on both the hadron storage ring (HSR) and the electron storage ring (ESR)
- HSR – long bunch, high rigidity
  - requires eight 197MHz crab cavities and four 394MHz cavities to linearize the deflection
- ESR – short bunch, low rigidity
  - requires two 394 MHz cavities
- The performance of the crab cavities is critical to the success of EIC – they increase luminosity by a factor of 10
- Canadian contribution includes the 394 MHz hadron ring crab cryomodules

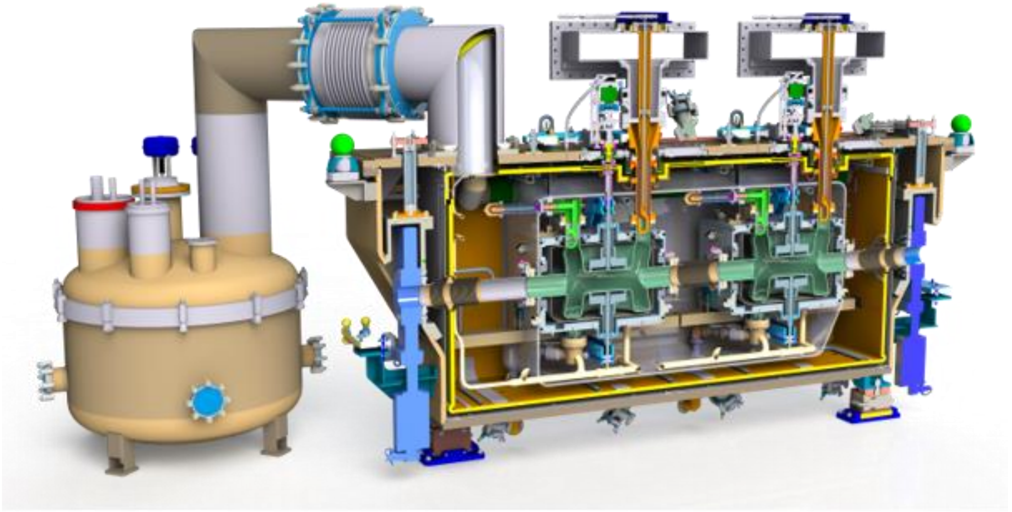
	Voltage/cavity Vt (MV)		No. of cavities	
System	HSR	ESR	HSR	ESR
197 MHz	8.5	-	8	-
394 MHz	2.4	2.9	4	2



Challenge 1: Large crossing angle -> high voltage -> SRF technology

- Given the high crossing angle (25mrad) and limited space strong deflecting voltages are required
- This precludes the use of normal conducting structures as the dissipated power would be too high (~1 MW for RT vs a few Watts for SRF)
- The cavities will be made from Niobium (Tc=9.2K) and operated at 2K
- The cavities will be housed in cryomodules for thermal isolation





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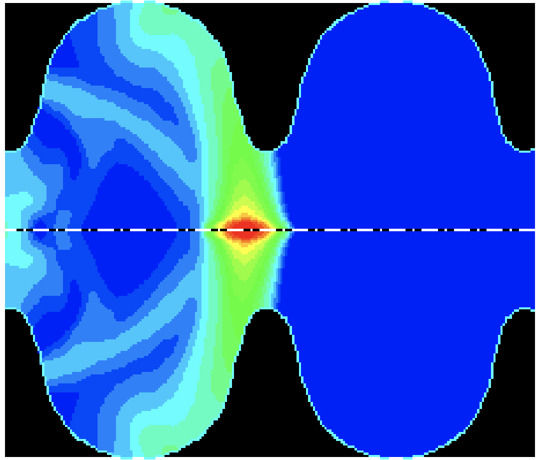
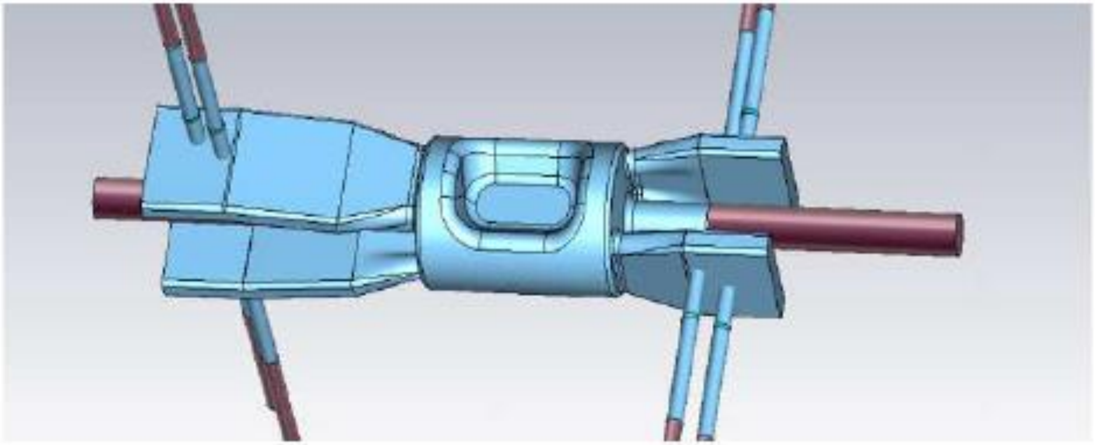
Challenge 2: High beam current and short bunches -> HOM excitation

- High intensity charged particles passing through an rf cavity can excite additional rf field modes in addition to the fundamental crabbing mode

- In EIC these higher order modes (HOMs) represent considerable power (10s of kW in e-ring) that must be removed from the cavity and delivered to an external load – under study at TRIUMF





394 MHz Crab Cavity with waveguide HOM extraction to damped loads

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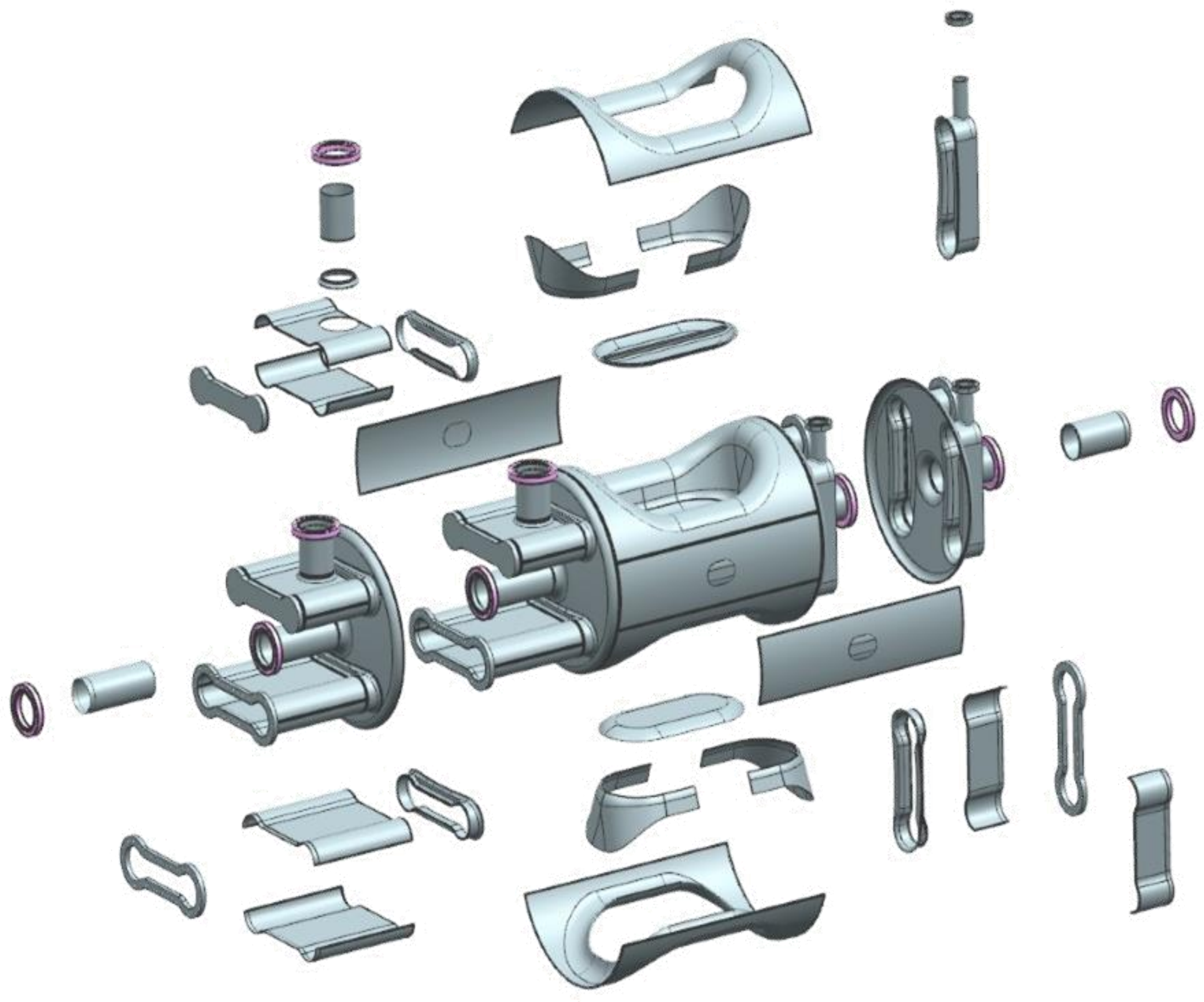
Challenge 3: Complex cavity shape

- Crab cavities have complex shapes further complicated by additional ports and waveguides for HOM extraction
- Requires many unique forming/machining and electron beam welding steps



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Scope for EIC crab contribution

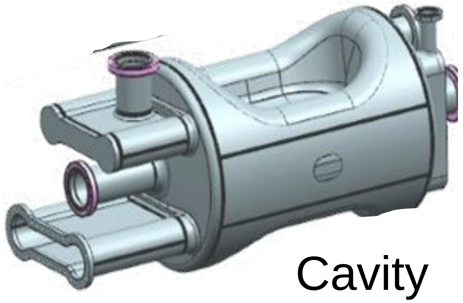
TRUMF/UVic propose to deliver scope on the 394 MHz crab cavity system for the HSR.

SRF Cavity package: (4)

- Cavity design including HOM mitigation schemes
- Niobium cavity fabrication plus jacket
- Fundamental Power Couplers (FPC) and HOM mitigation schemes (waveguide or coupler).
- Rf tuner

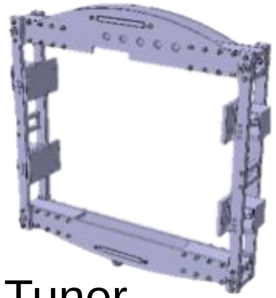
Cryomodule package: (2)

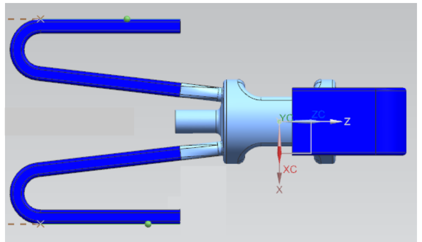
- Outer vacuum chamber (OVC)
- thermal shield, mu-metal
- cryogenic piping
- fabricated in industry
- assembled and qualified at TRIUMF.

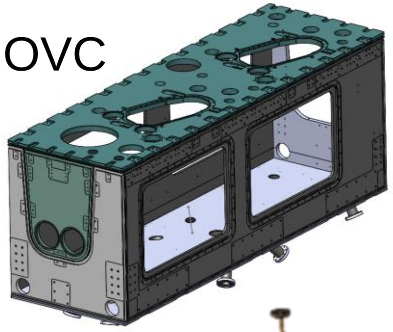

Cavity

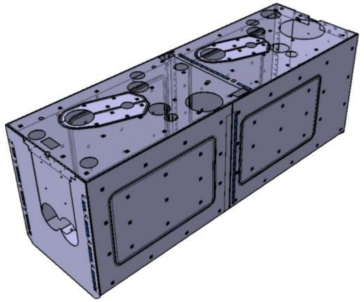

Jacketing

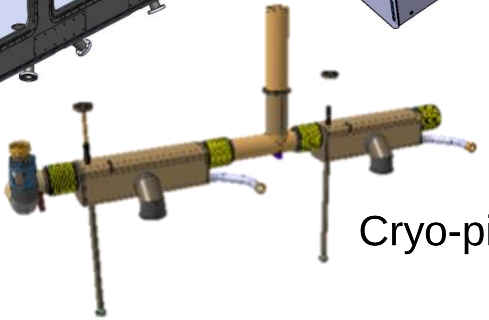

FPC


Tuner


HOM mitigation


OVC


Thermal screen and mu metal


Cryo-piping


Assembly

CFI project

INNOVATION
Canada Foundation for Innovation / Fondation canadienne pour l'innovation

Project number **45702**
Innovation Fund 2025 Stream 1 (open)
Proposal

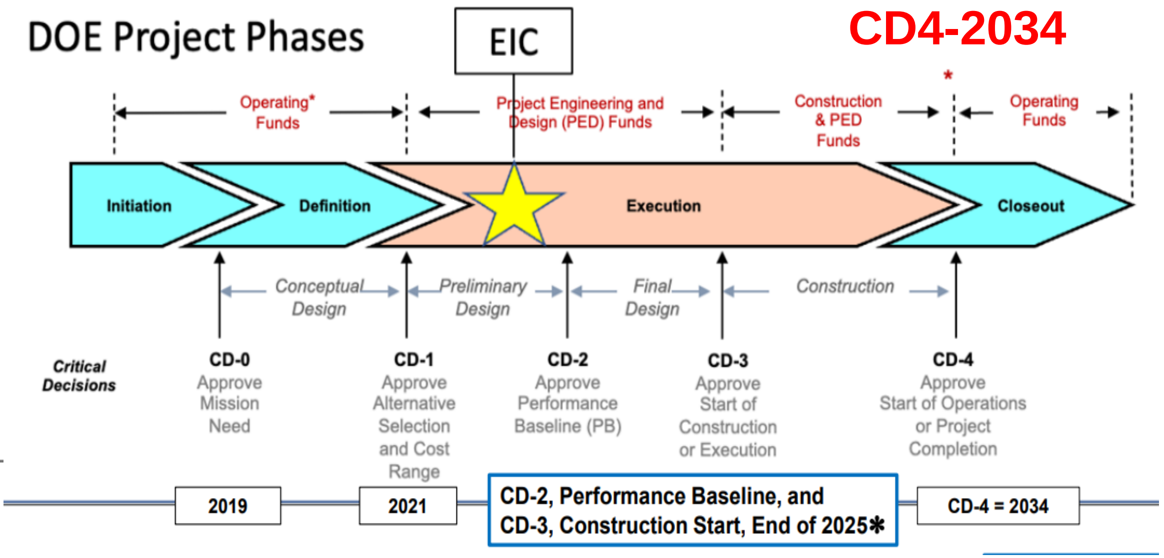
Project information

Project title	Enabling High Intensity Collisions and High Granularity Detectors for the Electron-Ion Collider
Applicant institution	University of Manitoba
Collaborating institutions	Mount Allison University, University of Regina, University of Victoria
Team leader(s)	Deconinck, Wouter Papandreou, Zisis

Project funding

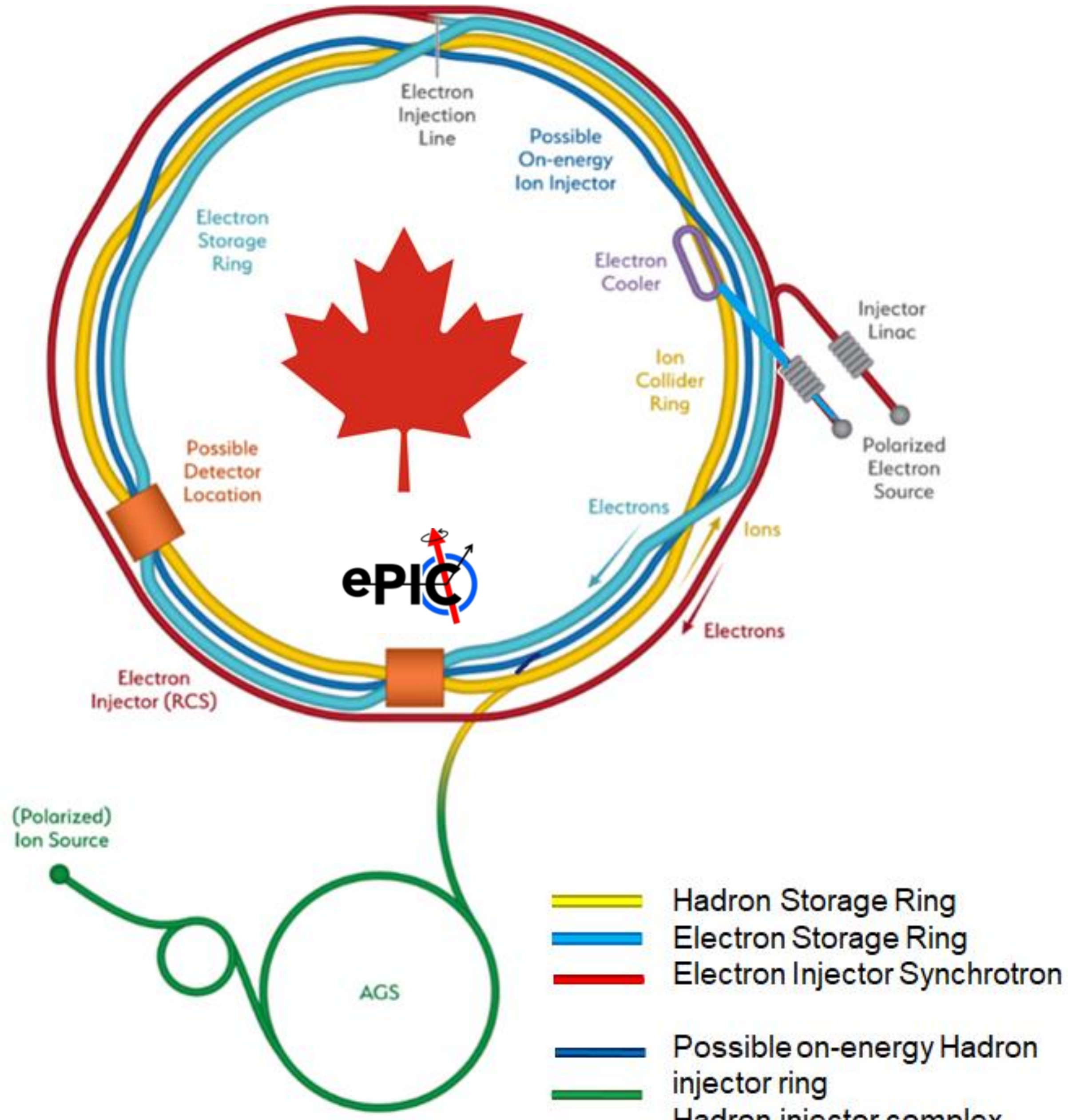
Total project cost	$31,740,678
Amount requested from the CFI	$5,270,000
Percentage of the total project cost requested from the CFI (maximum 40%):	16.6%

Project planning to baseline (CD-2) at end of 2025



Summary

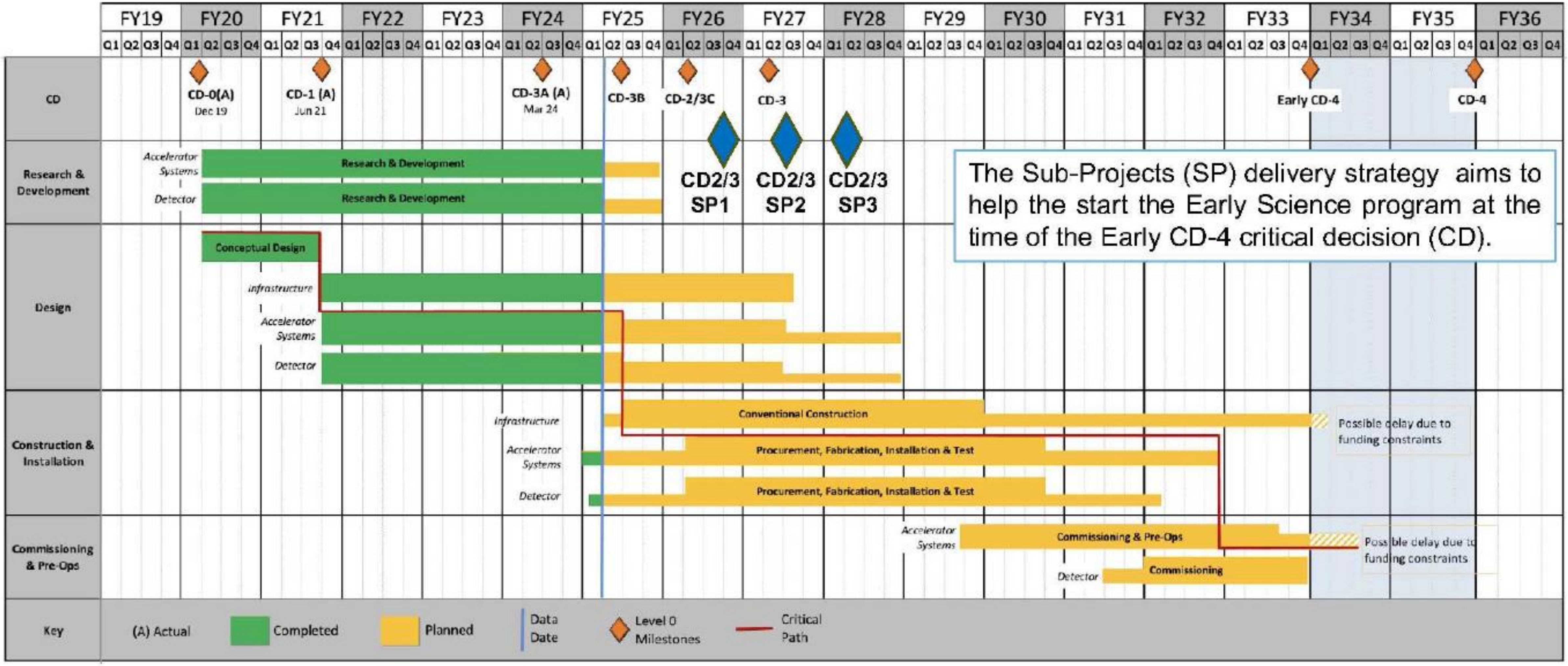
- ✓ The proposal will deliver critical elements to the EIC within the accelerator and the detector
- ✓ The technical scope offers unique challenges in design, fabrication, assembly and testing with excellent opportunities for HQP training
- ✓ The project supports both the EIC and the CINP community while leveraging and augmenting Canada's core competence in cutting edge accelerator and detector technology and offering opportunity to Canadian industry
- ✓ Collaborators and students are welcome!



Thank you!

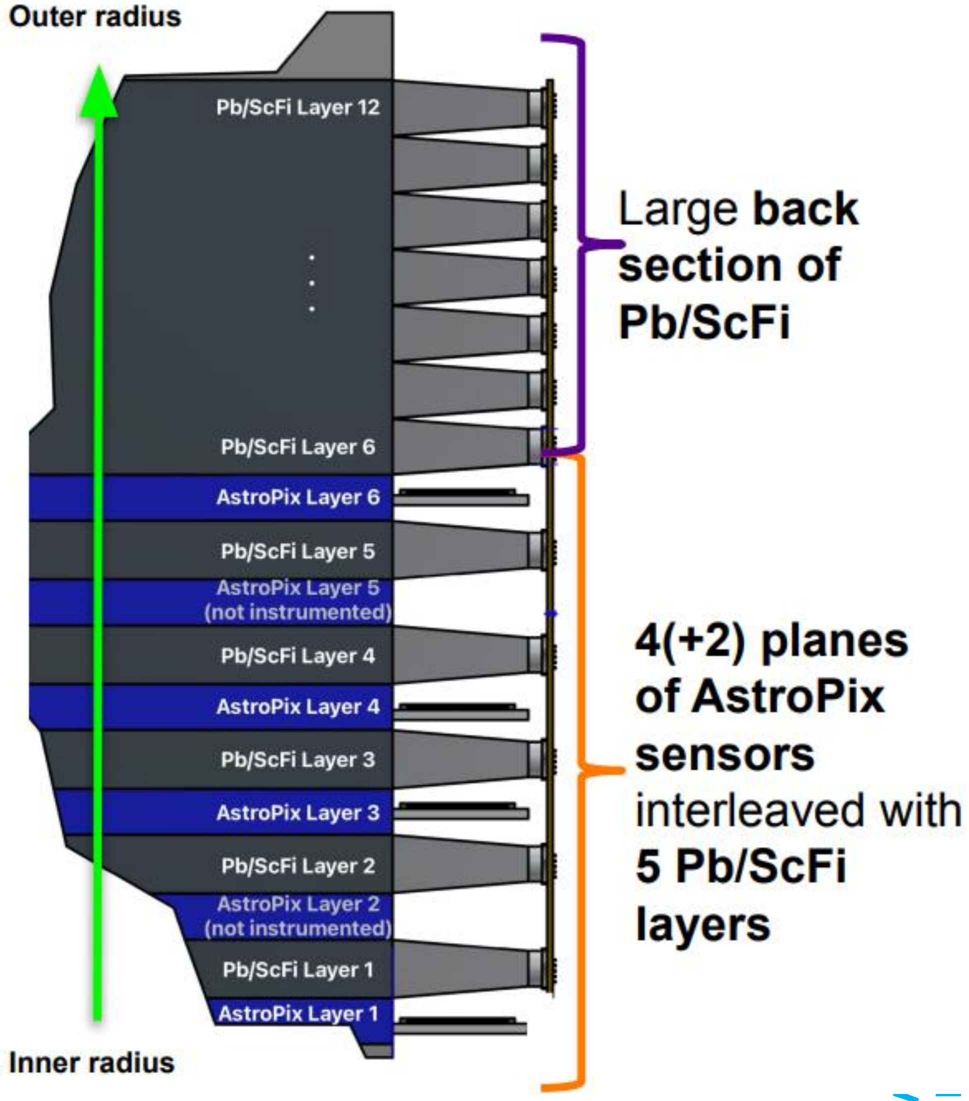
Merci!

EIC Timeline



BIC End of Sector (ESB) Boxes

- Each of the 96 ESBs contain 60 optical light guides and optical silicon interfaces coupled to silicon photomultipliers (SiPM), AstroPix End-of-Tray Cards (ETCs), field-programmable gate array (FPGA) boards to combine SiPM and ETC signals into streaming readout
- ESBs require cooling to stabilize the SiPMs and remove heat from ETCs
- All components will be surrounded by a light-tight enclosure
- Design faces considerable challenges for installation and future maintenance due to limited space, particularly in the electron-going direction and inner radius of the BIC.



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