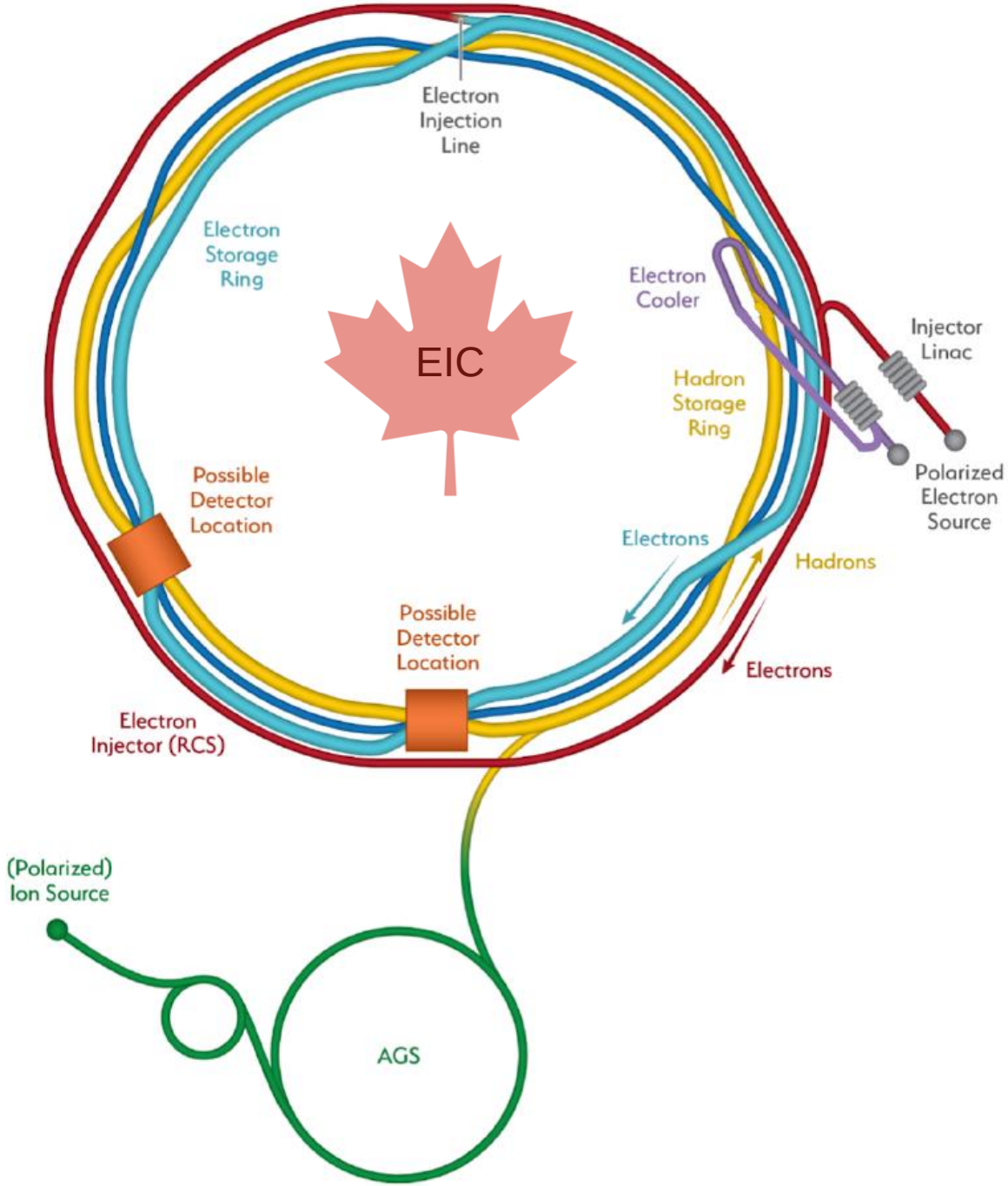
EIC Accelerator Technology Challenges

Robert Laxdal

Deputy Director, Accelerator Division

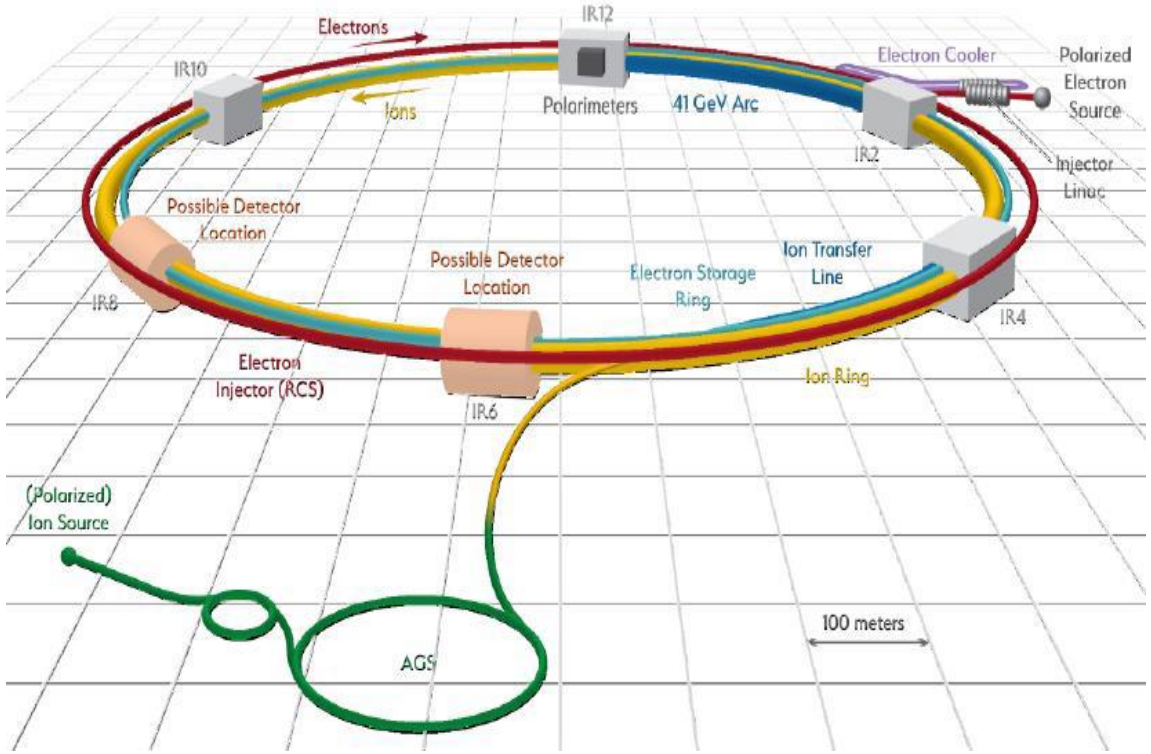
TRIUMF, Canada



TRIUMF

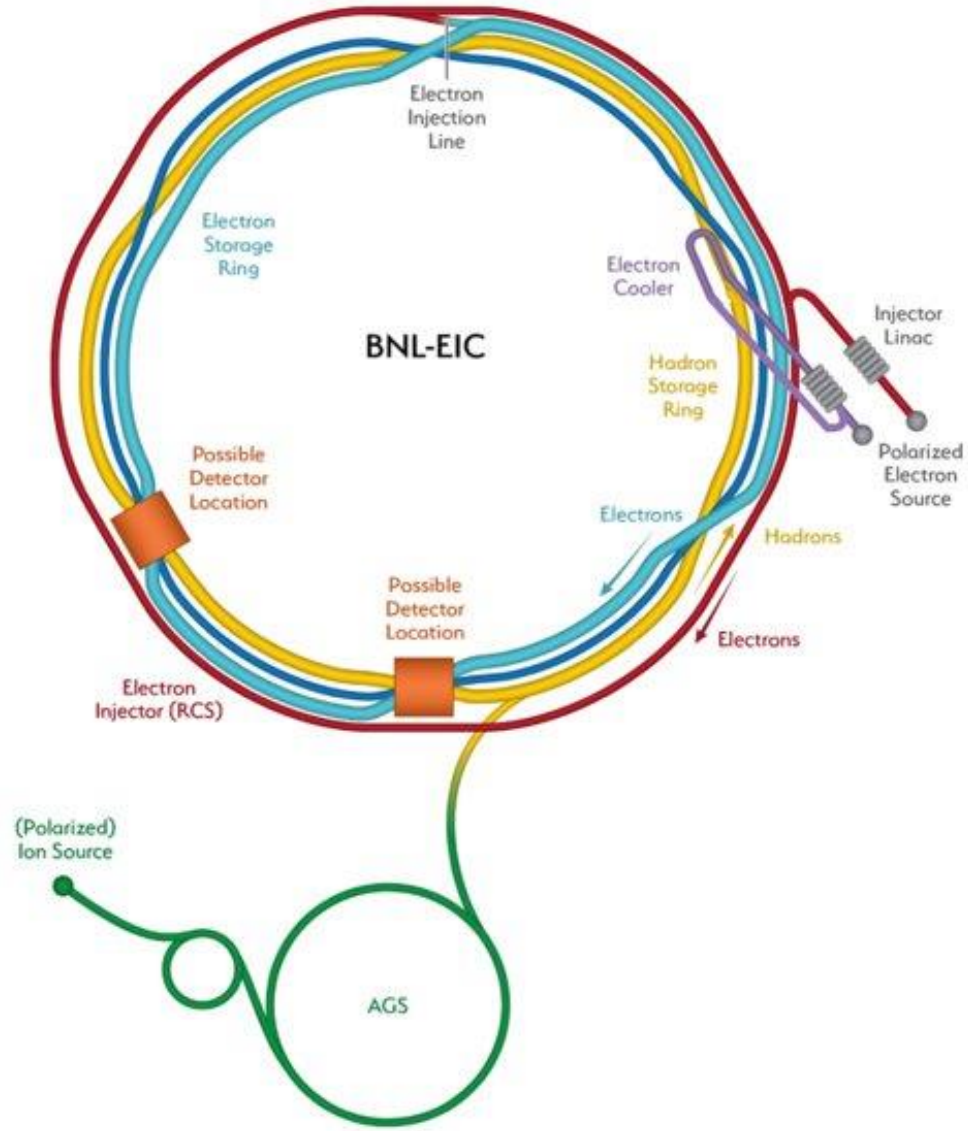
Outline

- Challenges for the design of major accelerator systems
- Canadian interest in the EIC accelerator systems



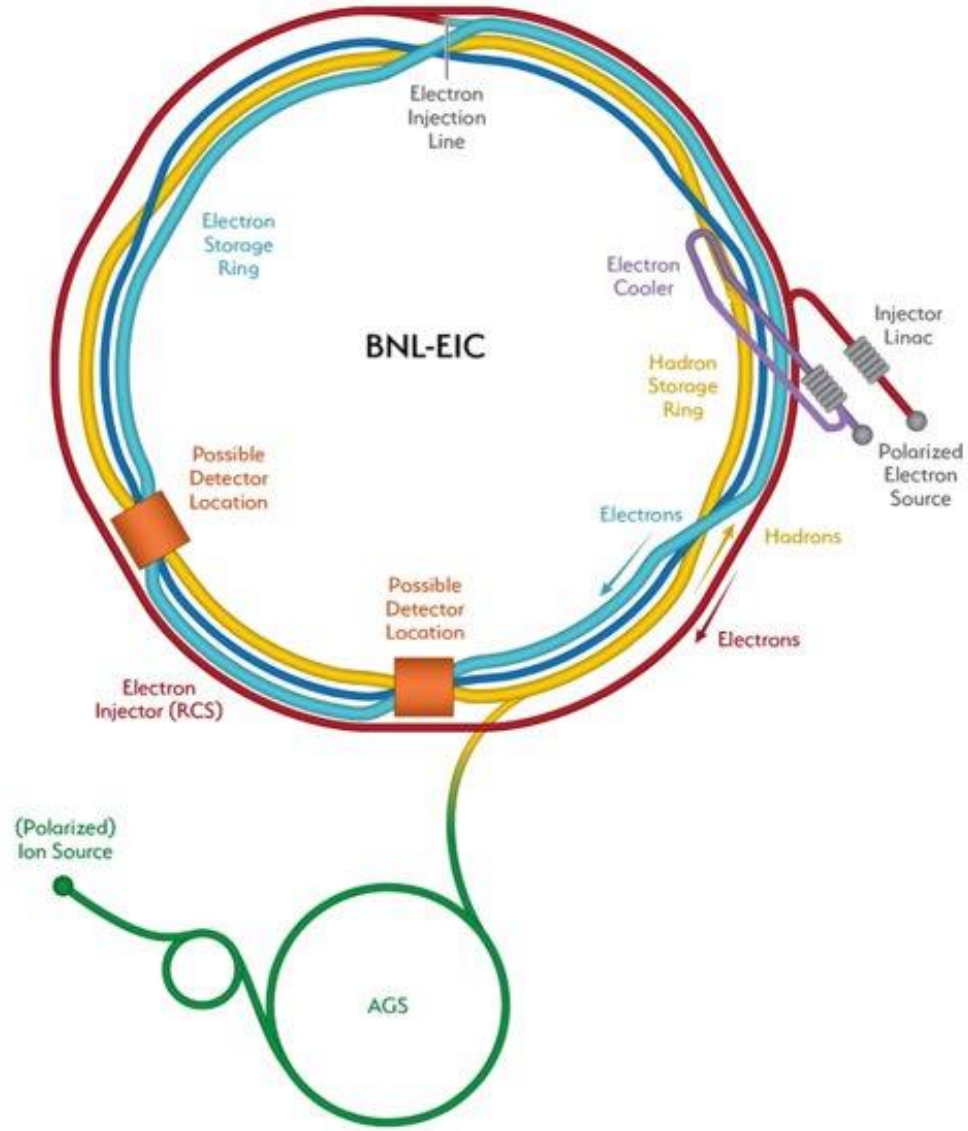
The Electron Ion Collider – the leading edge of Accelerator Technology

- The EIC will be a discovery machine – a game-changing resource for the international nuclear physics community
- The EIC is a very complex machine and requires a collaborative approach to identify and overcome the technical challenges.
- It will push the frontiers of accelerator science and technology



The Electron Ion Collider – Requirements

- High Luminosity: L= 10^{33} – 10^{34}cm^{-2}sec^{-1} over large energy range
  → Many bunches, large beam currents - small emittance
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: E_{cm} = 20 – 140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Acceptance and Good Background Conditions
- Accommodate a Second Interaction Region

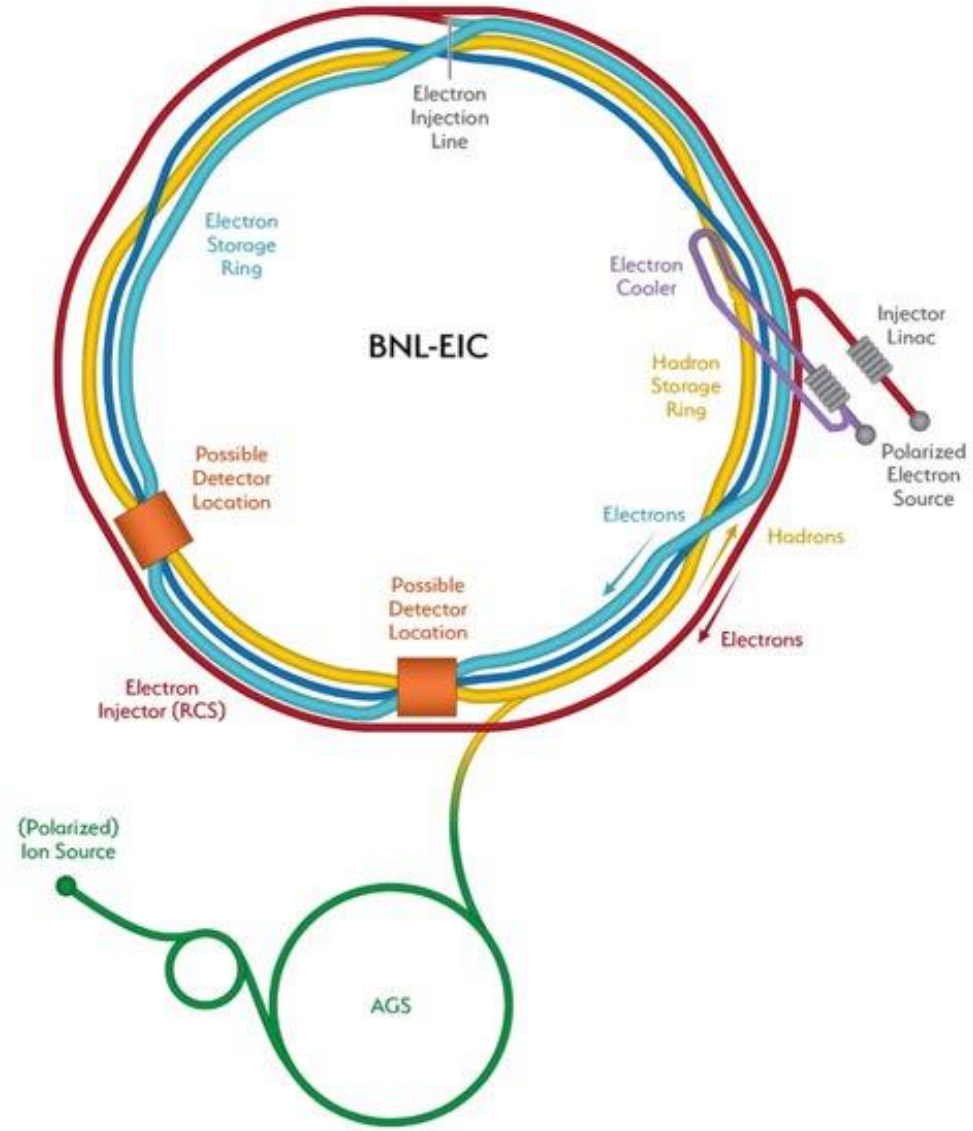


The Electron Ion Collider – Accelerator overview

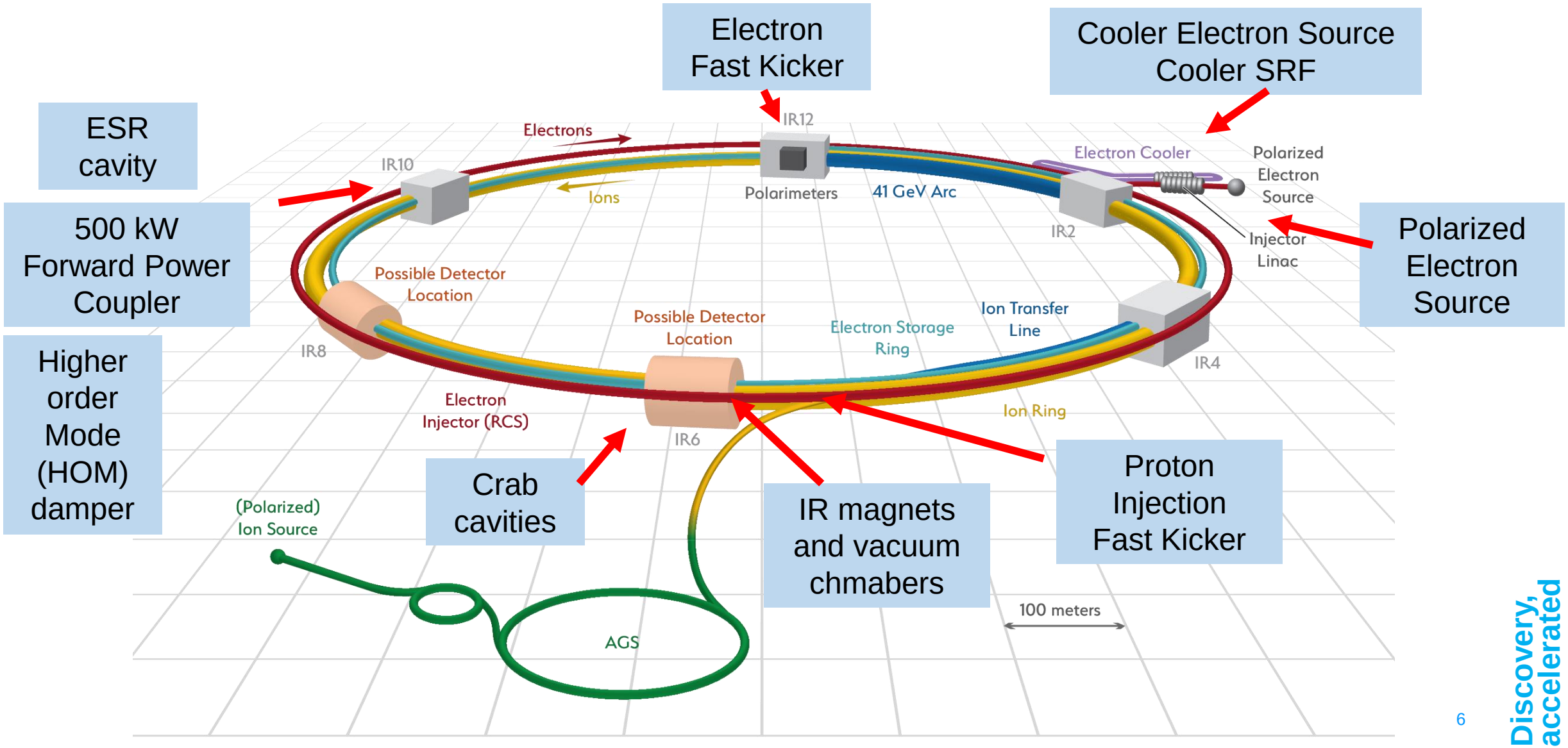
The EIC accelerator design is based on the existing RHIC Complex

Main systems of the EIC accelerator:

- Hadron storage ring 40-275 GeV (based on existing RHIC)
- Electron storage ring 2.5–18 GeV new ring in RHIC tunnel
- Electron rapid cycling synchrotron 0.4-18 GeV new in RHIC tunnel
- High luminosity interaction region(s)



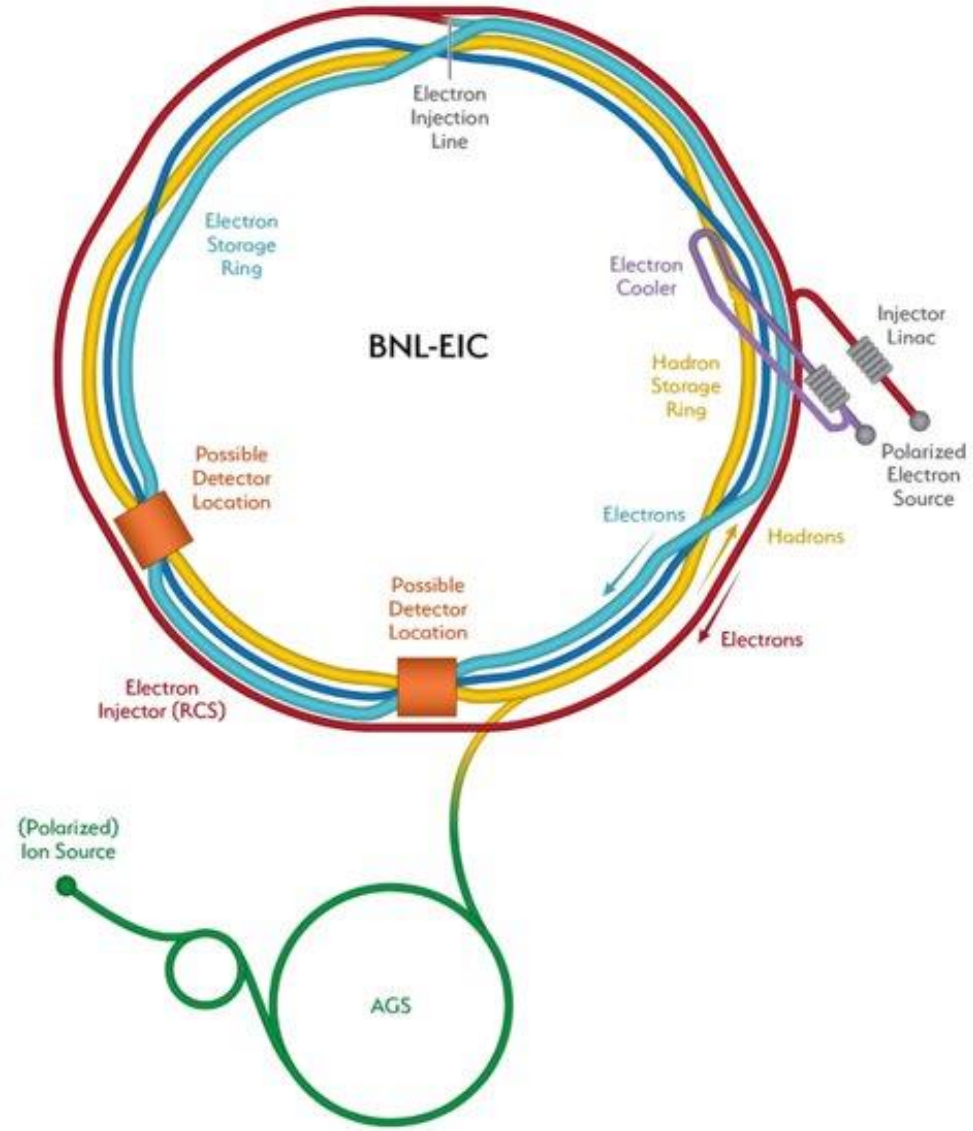
EIC Accelerator R&D scope overview



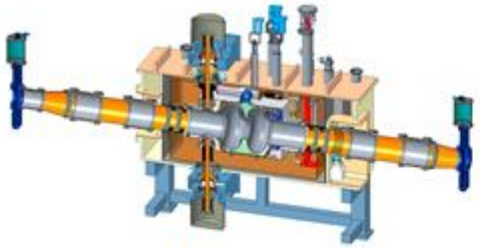
Discovery, accelerated

The Electron Ion Collider – Technical challenges

- High luminosity goals require
  - Strong hadron cooling due to Intra-beam scattering (IBS) - Coherent electron Cooling – CeC – requires a 150MeV 100mA ERL with extremely quiet beam and with sub-micron spatial accuracy
  - Crabbing at interaction zones
- Maintaining high polarization in both storage rings
- High beam current and SR loss needs advanced vacuum techniques in both HSR and ESR – resistive wall impedance and e-cloud



The Electron Ion Collider – Technical challenges - RF

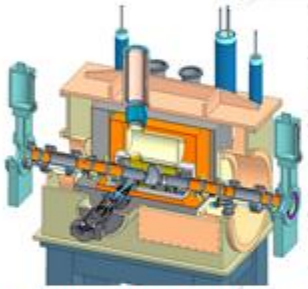


Electron - 591 MHz electron storage cavity

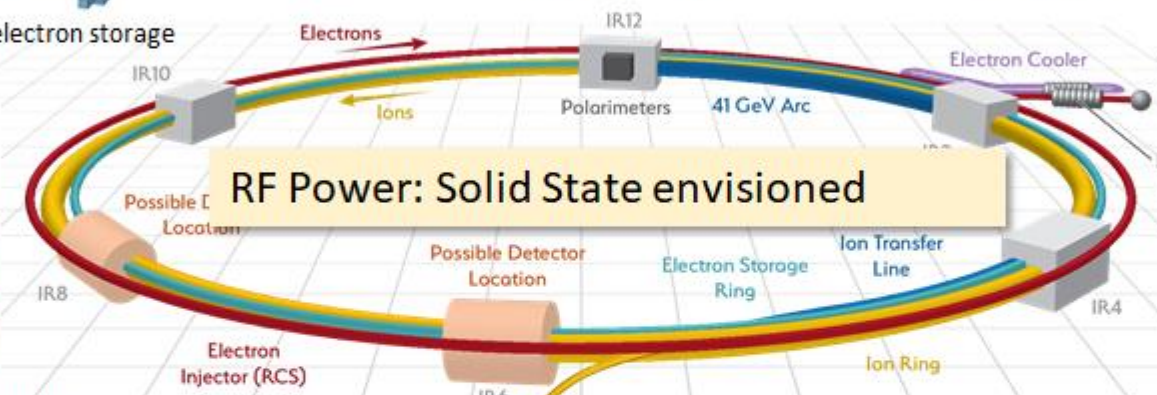
Hadron - 591 MHz bunch compression cavity

Hadron Cooling - 591 MHz acceleration cavity

Injector - 571 MHz bunch compression cavity



Electron - 1773 MHz 3rd harmonic cavity



Rapid Cycling Synchrotron - 591 MHz acceleration cavity

197MHz/394MHz Crabcavities

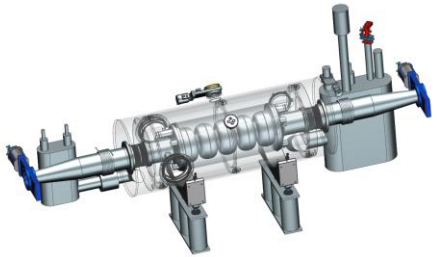
Hadron – 49.2 MHz and 98.5 MHz bunch splitter cavity

Hadron – 24.5 MHz acceleration cavity

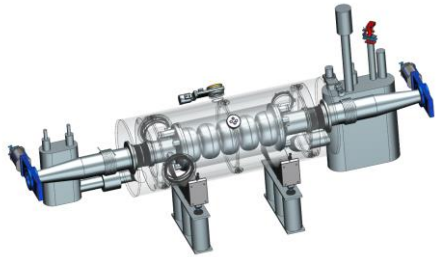
Hadron - 197 MHz bunch compression cavity

The Electron Ion Collider – Technical challenges - SRF

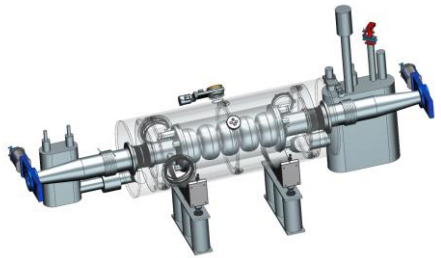
- EIC requires multiple new SRF systems. Many opportunities for new and exciting work.
- Goal of early work based at BNL and JLab is to develop understanding of systems and reduce risk.
- Requirements and designs are mature but not final. The beam and machine physics are still being optimized. SRF systems may need to be updated as the design is finalized.
- Need to leverage common designs where possible.
- Challenges in cryomodule footprint, High power rf, Fundamental power couplers, LLRF and HOM dampers



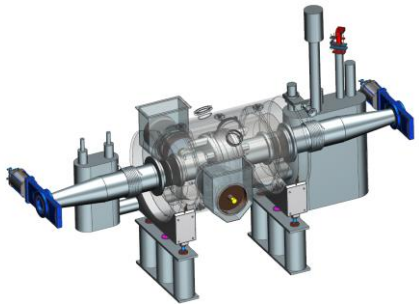
HSR - 591 MHz 5-Cell Cavity
Bunch Compression



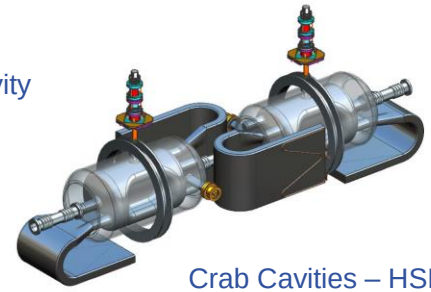
SHC- 591 MHz 5-Cell and 1773 MHz 5-Cell ERL Cavities



RCS - 591 MHz 5-Cell Cavity
Acceleration Cavity



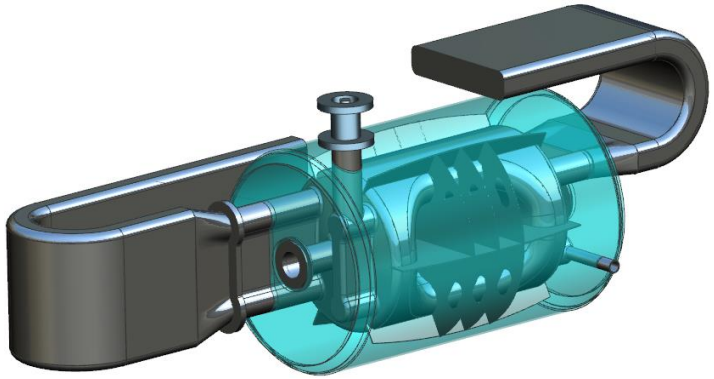
591 MHz ESR 1-Cell Cavity



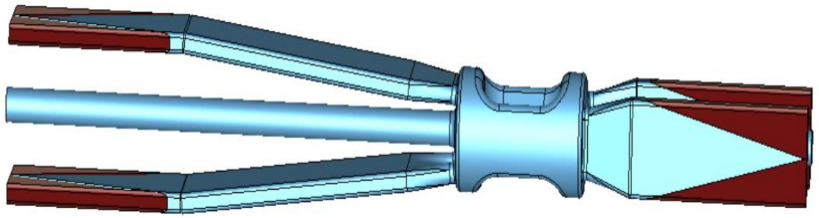
Crab Cavities – HSR & ESR

The Electron Ion Collider – Technical challenges - RF

- The Crab Cavity performance is critical to the success of the EIC
  - Large crossing angle
  - Luminosity impact ~ order of magnitude
- The requirements are challenging
  - Significant deflecting voltage ~34 MV
  - Tight impedance budgets
  - RF control requirements are beyond anything done - Phase noise should be 2 orders of magnitude lower than that of LHC.
- Hi-Lumi provides a good example of how to engage the international community in a challenging Crab cavity project

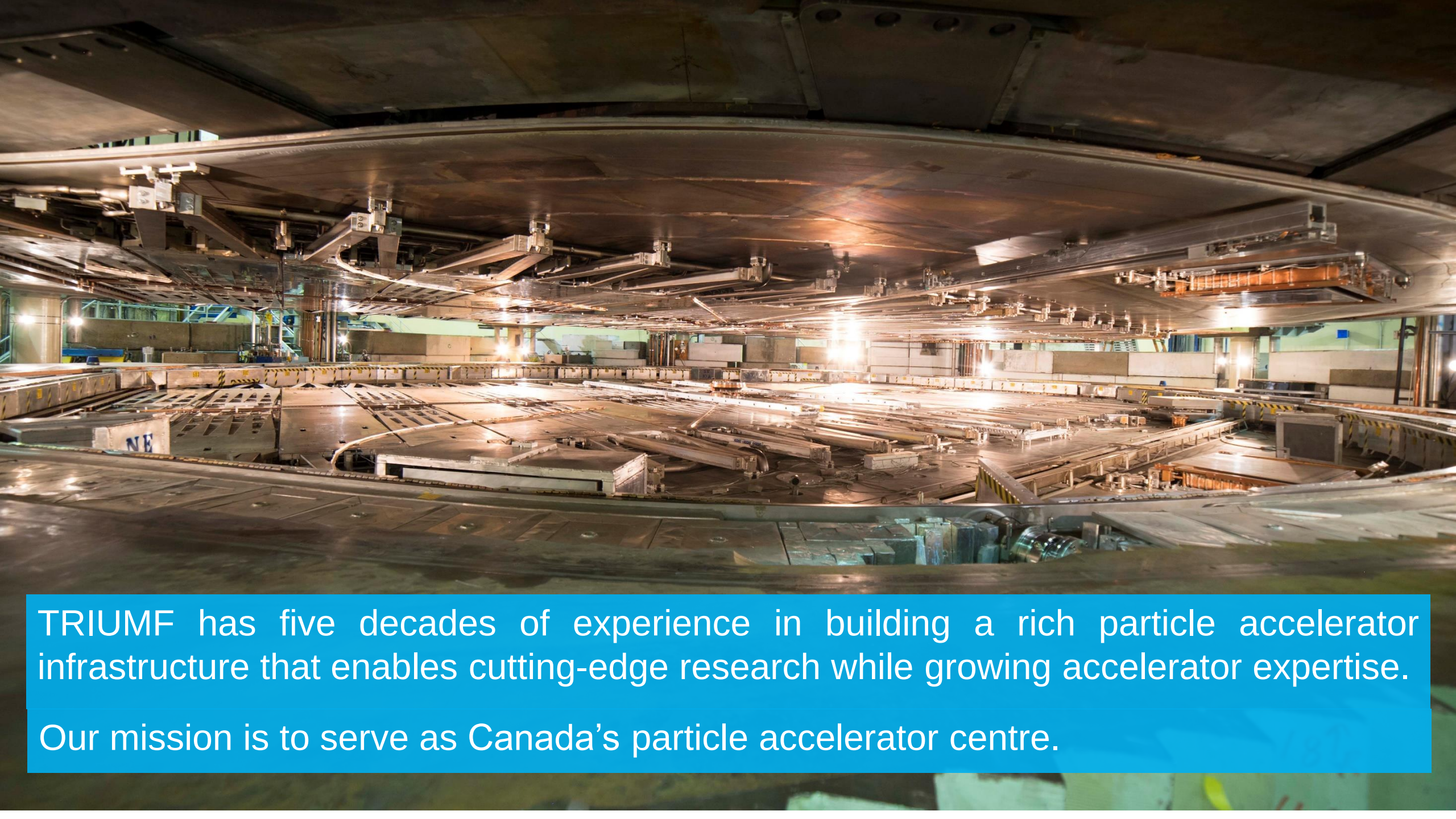


Jacketed 197 MHz Crab Cavity Variant



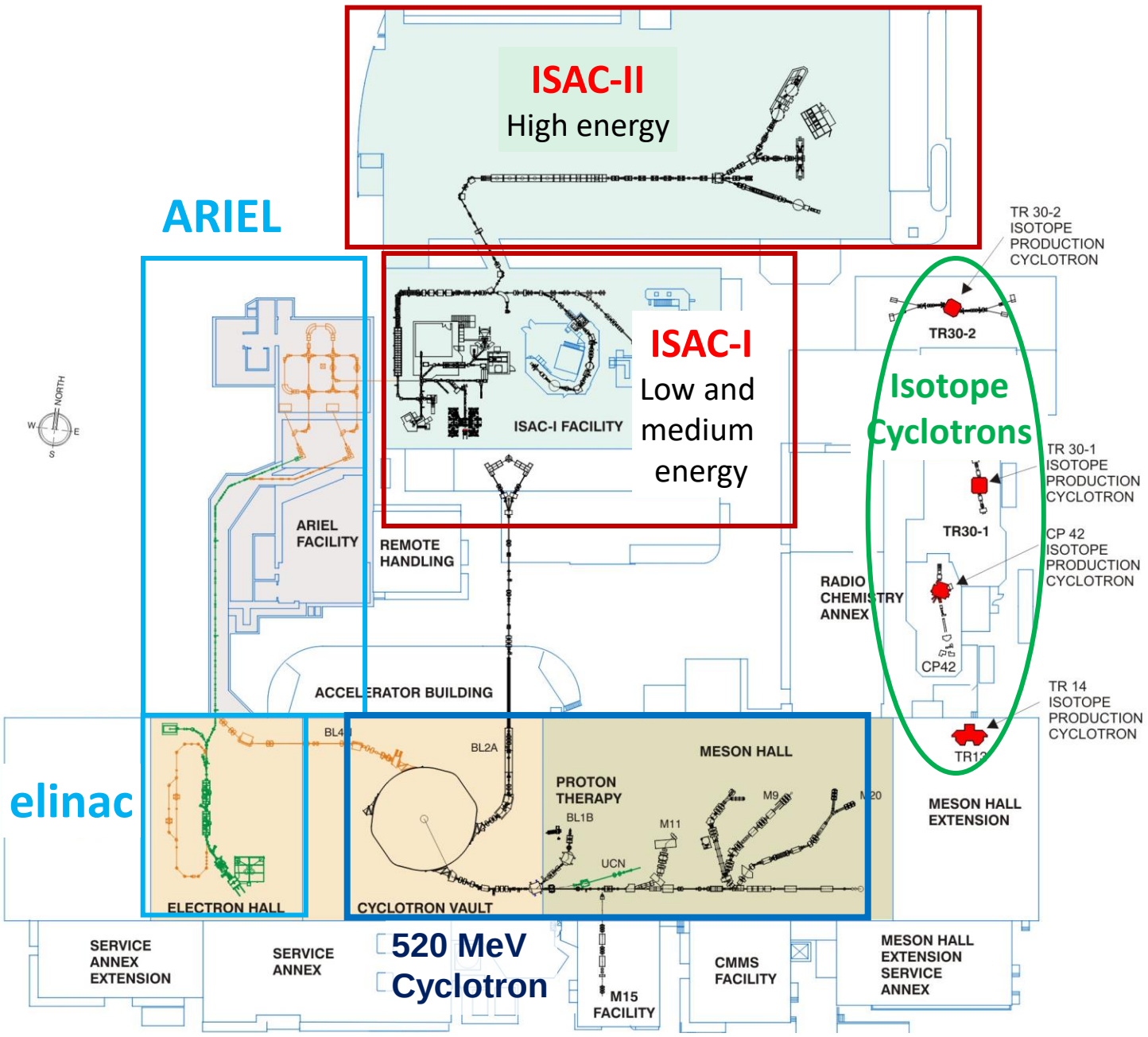
394 MHz Crab Cavity

Canada and the EIC



TRIUMF has five decades of experience in building a rich particle accelerator infrastructure that enables cutting-edge research while growing accelerator expertise.

Our mission is to serve as Canada’s particle accelerator centre.



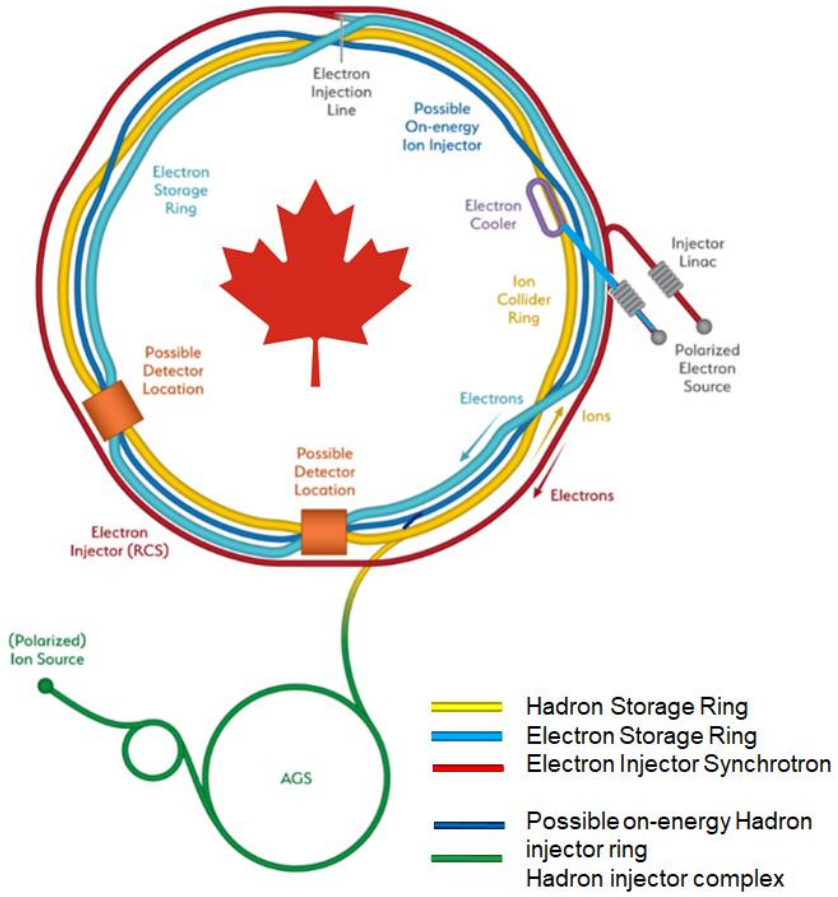
This mission is reflected in the wide variety of accelerator technologies that populate the campus.

Our strategy is to use internal projects and external collaborations as springboards to expand core competencies or gain new ones.

Rather than import technology, we typically develop it, accumulating a broad expertise within a relatively small lab.

TRIUMF and EIC accelerator

- Accelerator science at TRIUMF provides Canada with a world-class platform in beam physics and instrumentation, secondary particle production, and SRF technologies.
- TRIUMF supports the Canadian subatomic physics community to establish its scientific priorities through the five-year Long-Rang Plan via the development of a 20-year vision.
- The support for EIC is coupled to the objective to provide Canadian scientists a place at the table while engaging senior and junior accelerator scientist in a cutting-edge accelerator project.



ISAC-II Post accelerator (2001-2010)

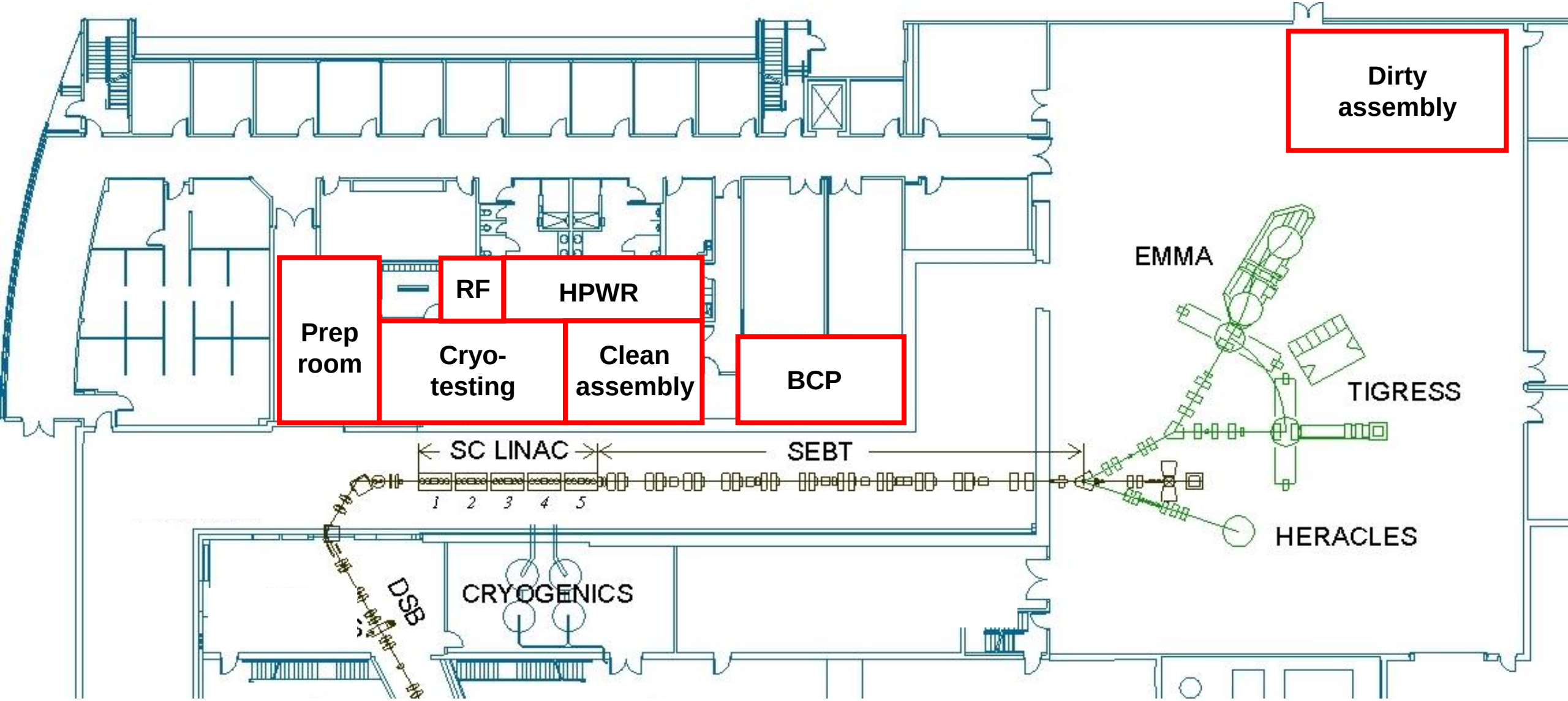
- Superconducting RF technology for heavy ions
- Cryomodule design and assembly
- Design and operation of cryogenic systems

ISAC-II Cryomodule

ARIEL e-Linac (2008-2014)

- Superconducting RF technology for electrons
- High power klystrons

SRF Facilities



TRIUMF

SRF Facilities

Dirty assembly

EMMA

Prep room

RF

HPWR

Cryo-testing

Clean assembly

BCP

SC LINAC

SEBT

1 2 3 4 5

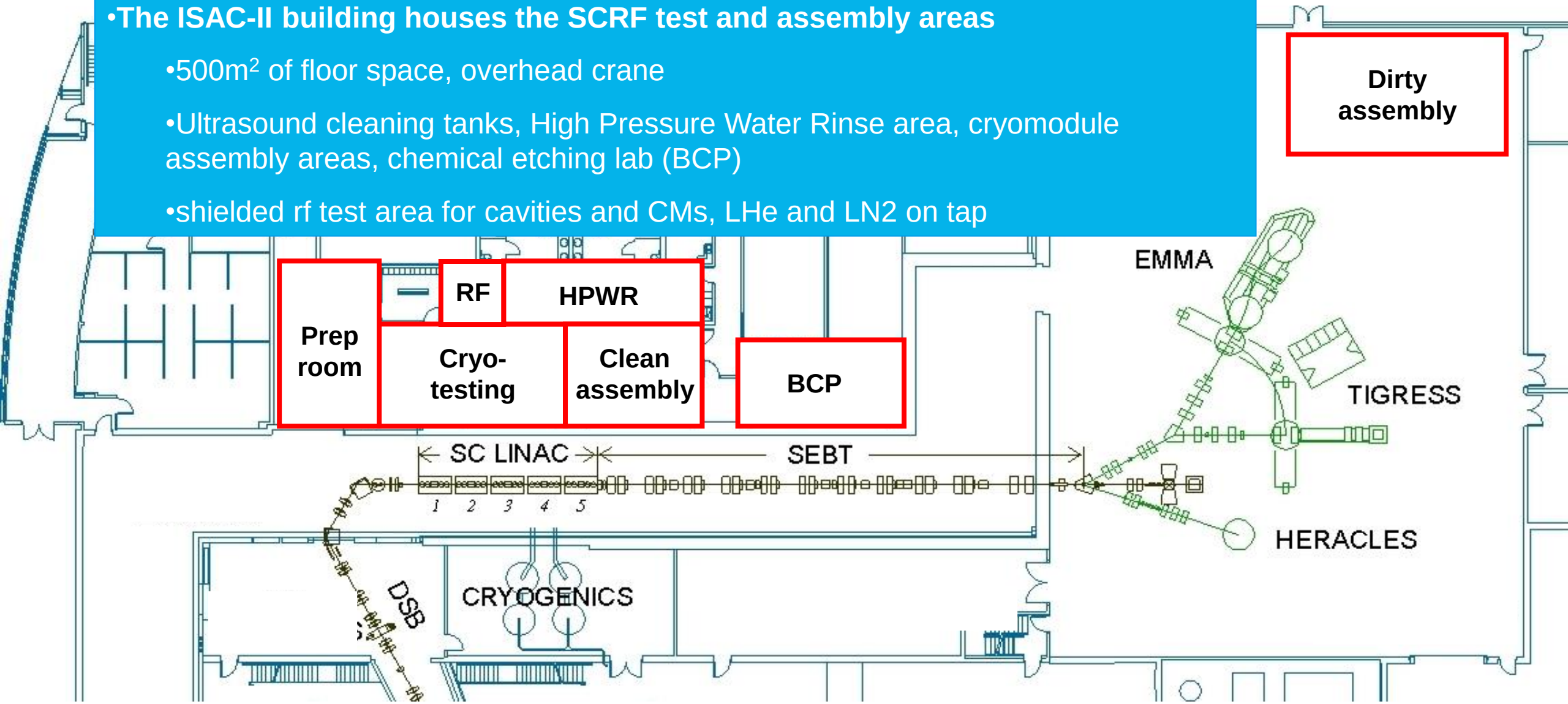
DSB

CRYOGENICS

HERACLES

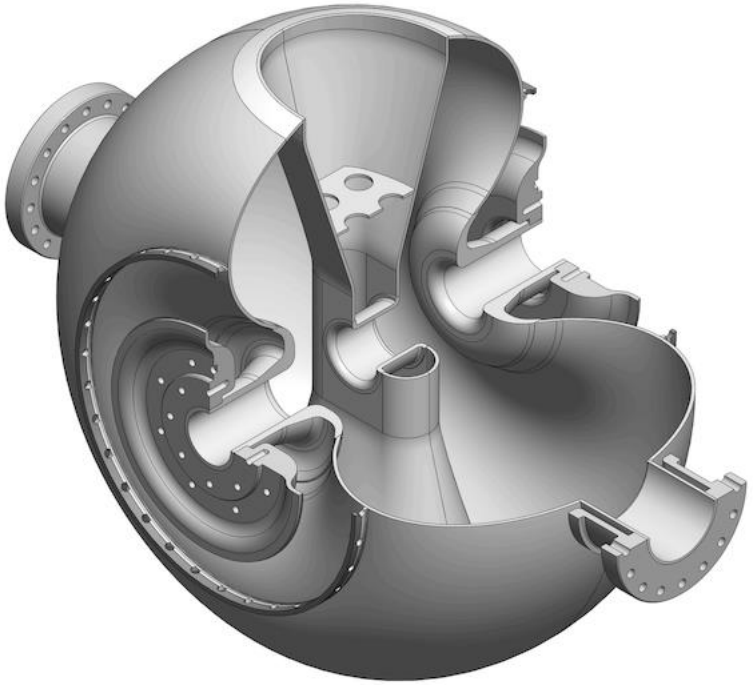
SRF Facilities

- **The ISAC-II building houses the SCRF test and assembly areas**
  - 500m^2 of floor space, overhead crane
  - Ultrasound cleaning tanks, High Pressure Water Rinse area, cryomodule assembly areas, chemical etching lab (BCP)
  - shielded rf test area for cavities and CMs, LHe and LN2 on tap



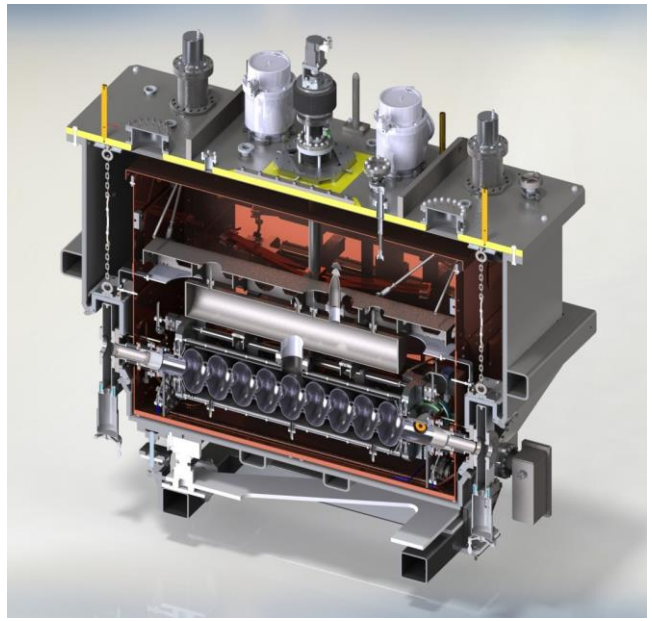
SRF Technology Development for RISP

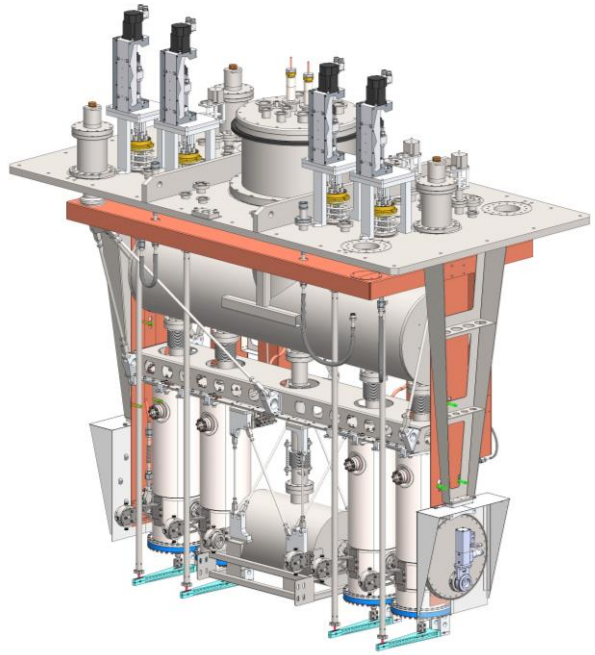
- TRIUMF has developed and successfully tested a new variant (balloon geometry) of a single spoke resonator for Hadron acceleration
- Virtually eliminates the high level multipacting that plagues standard geometries
- The cavity design and prototyping was sponsored by RISP (Korea) and is being used in their heavy ion driver linac
- TRIUMF also designed and delivered a prototype tuner and a power coupler design



TRIUMF and VECC (India)

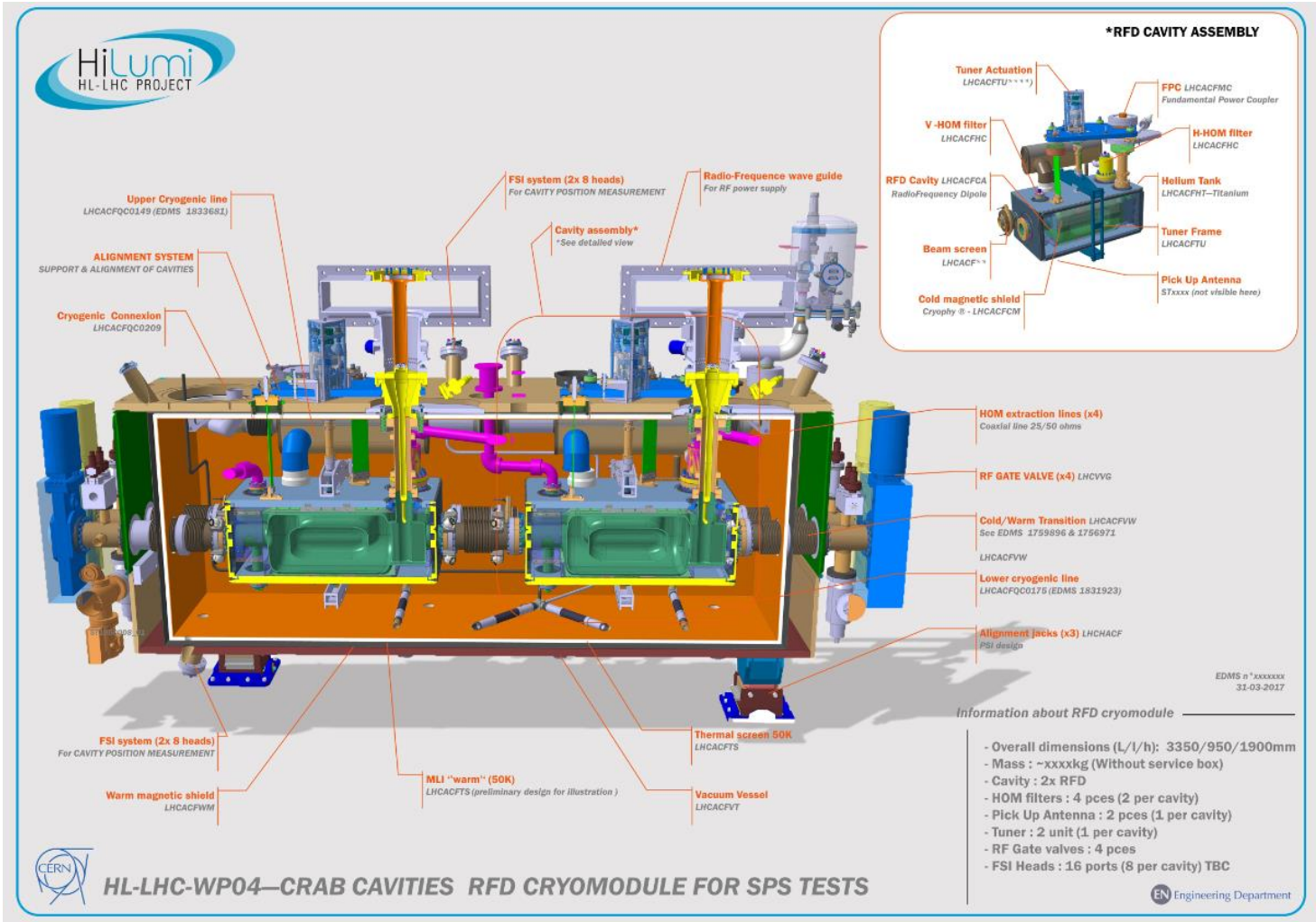
- TRIUMF and VECC have been collaborating on mutually aligned projects since 2008 – ANURIB in Kolkata and ARIEL in Vancouver
- An electron cryomodule has been shipped to VECC in 2018
- A heavy ion cryomodule has been successfully cold tested and will be shipped this year





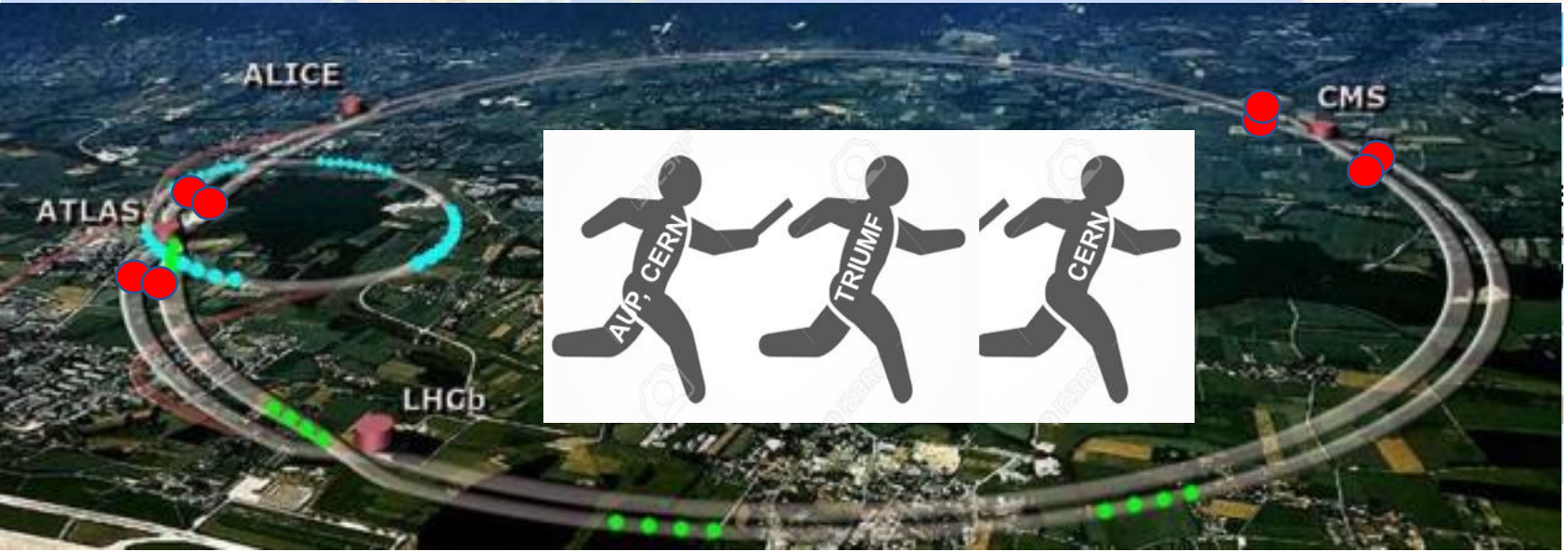
HL-LHC Crab Cavity Cryomodules

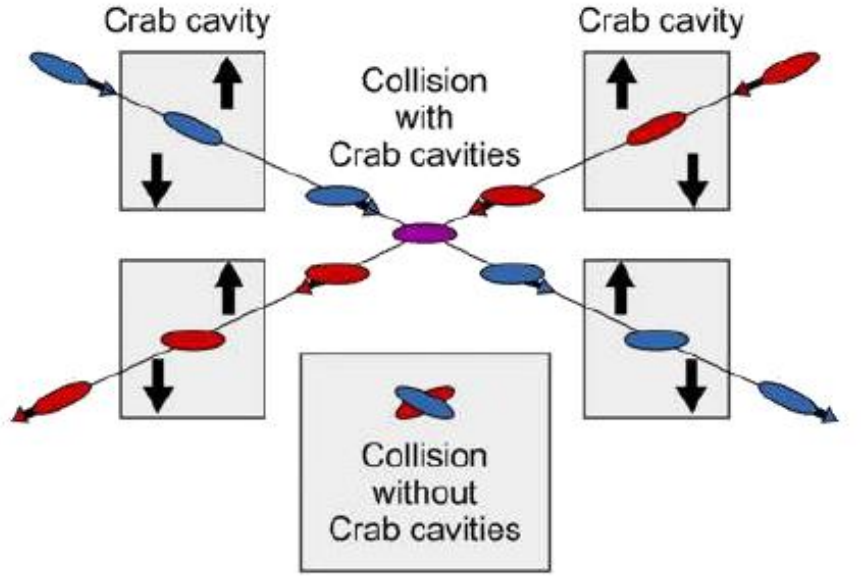
- TRIUMF to receive 10 RFD resonators produced and qualified by US DOE lab consortium (AUP), to assemble each pair of RFDs into five cryomodules
- TRIUMF to qualify the cryomodules through testing at TRIUMF before packaging and shipping to CERN
- The project supplies critical infrastructure to CERN, supporting both the HL-LHC and the Canadian IPP community



High Luminosity – Large Hadron Collider (HL-LHC)

Crab Cavities – increase luminosity by skewing the intersecting beams longitudinally at ATLAS and CMS – collaboration with CERN, Russia, UK, USA

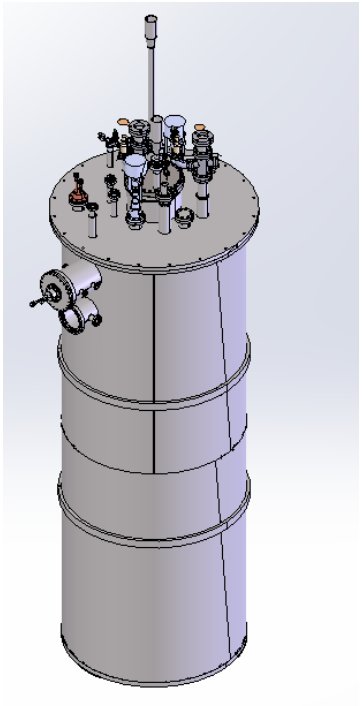


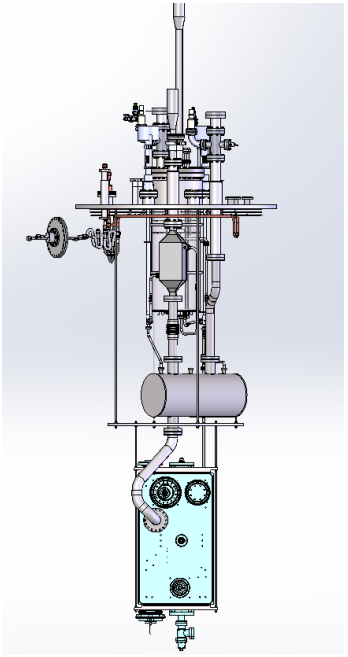


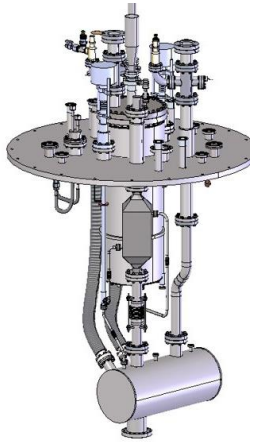
TRIUMF status - SRF infrastructure upgrade to be compatible with Hi-Lumi scope

SRF infrastructure is being upgraded to be compatible with Hi-Lumi scope.

- Clean room upgrades to reduce particulate pollution
- Testing infrastructure
  - Preparing 4k/2k insert for multi-purpose cryostat to allow testing dressed cavities at 2K in jacketed mode
  - Upgrade cavity test diagnostics
  - Upgrade 2K pumping capacity
- New Assembly fixtures in design







TRIUMF and the 2021 EIC Accelerator Partnership Workshop

- The EIC Accelerator Partnership Workshop 2021 hosted by TRIUMF was a global event with 284 registered participant from 23 countries
- The workshop Promoted Collaboration on the Electron-Ion Collider at the leading edge of Accelerator Science and Technology.

TRIUMF 2021 EIC Accelerator Partnership Workshop

26 Oct 2021, 07:00 → 29 Oct 2021, 12:30 US/Pacific

Andrei Seryi (Jefferson Lab) , Oliver Kester (TRIUMF)

Description

EIC2021, October 26-29, 2021 On-line Format

The EIC Accelerator Partnership Workshop 2021 – Promoting Collaboration on the Electron-Ion Collider – will be hosted by TRIUMF Laboratory, Canada. The virtual meeting will take place from October 26 to October 28, 2021, and will include a half-day satellite meeting on October 29. Similar to the first partnership workshop hosted by the Cockcroft Institute last year, the 2021 workshop will include sessions spread around different time zones.

With EIC project having received the CD1 approval in June 2021, and with the EIC project aiming at CD2 in about one and a half years, the EIC project team is aiming to advance the progress on defining the areas of collaboration and possible contribution from potential partners well before CD2. Therefore, unlike the 2020 workshop which included broad overview of EIC and related accelerator technology topics, the planned 2021 Accelerator Partnership Workshop will focus primarily on the areas where there are advanced technical discussions between the EIC Project and potential partners regarding collaboration and technical scope of work. We encourage all accelerator groups interested in EIC to participate in the workshop, while also encouraging the interested groups to contact the EIC project directly in parallel.

Organizing Committee

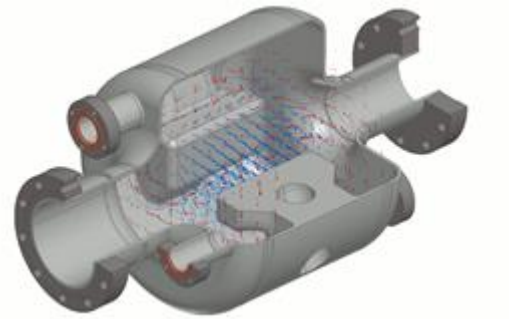
Oliver Kester (TRIUMF, Canada) Co-Chair – Local Organizing Committee (LOC)
Andrei Seryi (JLab, USA) Co-Chair, Local Organizing Committee (LOC)
Bob Laxdal (TRIUMF, Canada) - LOC
Silke Bergelt-Bruckner (TRIUMF, Canada) – LOC
Ferdinand Willeke (BNL, USA) – LOC
Graeme Burt (Cockcroft Institute, UK)
Peter Williams (Cockcroft Institute, UK)

TRIUMF and EIC accelerator

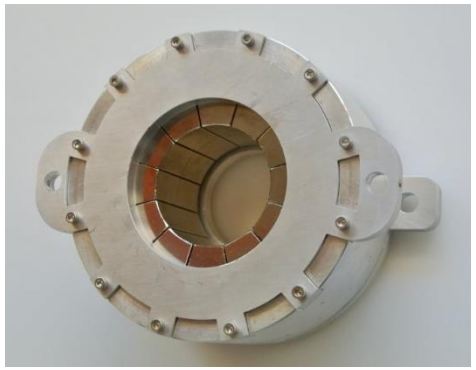
TRIUMF is well positioned to contribute Canadian `in kind' EIC accelerator technology:

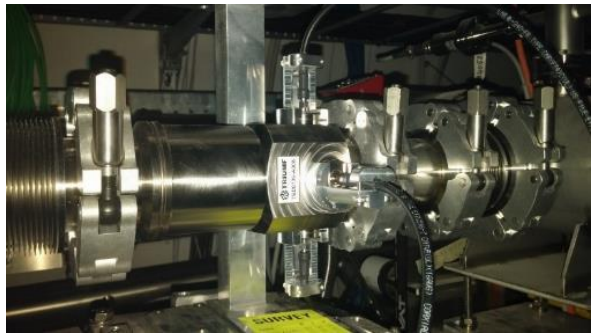
- SRF/RF: (crab and other) cavities, cryomodules, rf ancillaries
- HV kickers and Rf bunch switcher
- Beam physics investigations like for HL-LHC (FFA optics, spin)
- e-beam technology including beam instrumentation.
- Normal conducting magnets (like permanent magnet optics for e-beam lines etc.)
- high brightness electron gun

SRF cavity



Electron lens

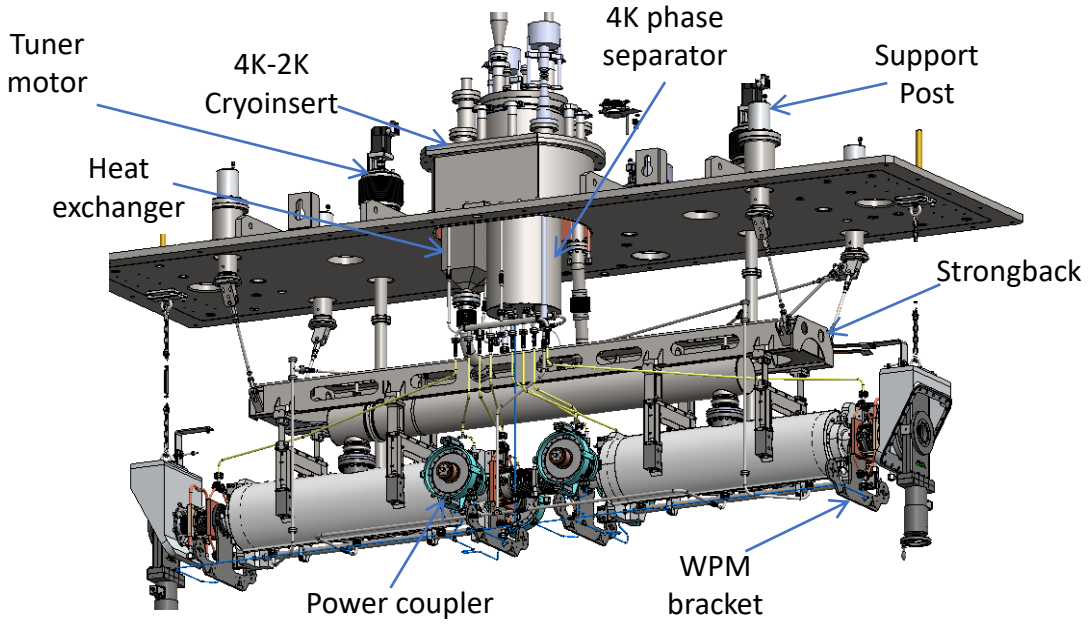


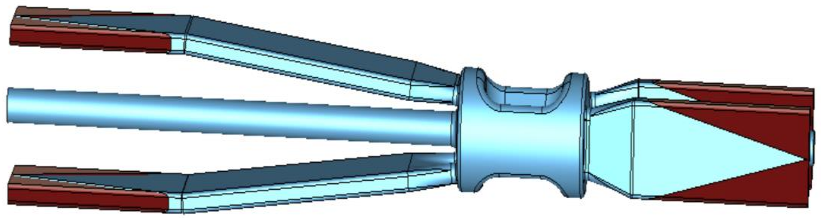


E-beam diagnostics

EIC crab cavities

- The Hi-Lumi cryomodule design borrows from the ARIEL e-Linac module developed and fabricated at TRIUMF.
- For EIC there are 200 and 400 MHz cavities planned for the crabbing.
- For EIC, the work at 200MHz is launched with a staged development and eventual prototyping
- The 400MHz crab cavity is less developed and the timelines are aligned with future CFI funding cycles – potential for early input on cavity design and eventual in-kind contributions for the modules

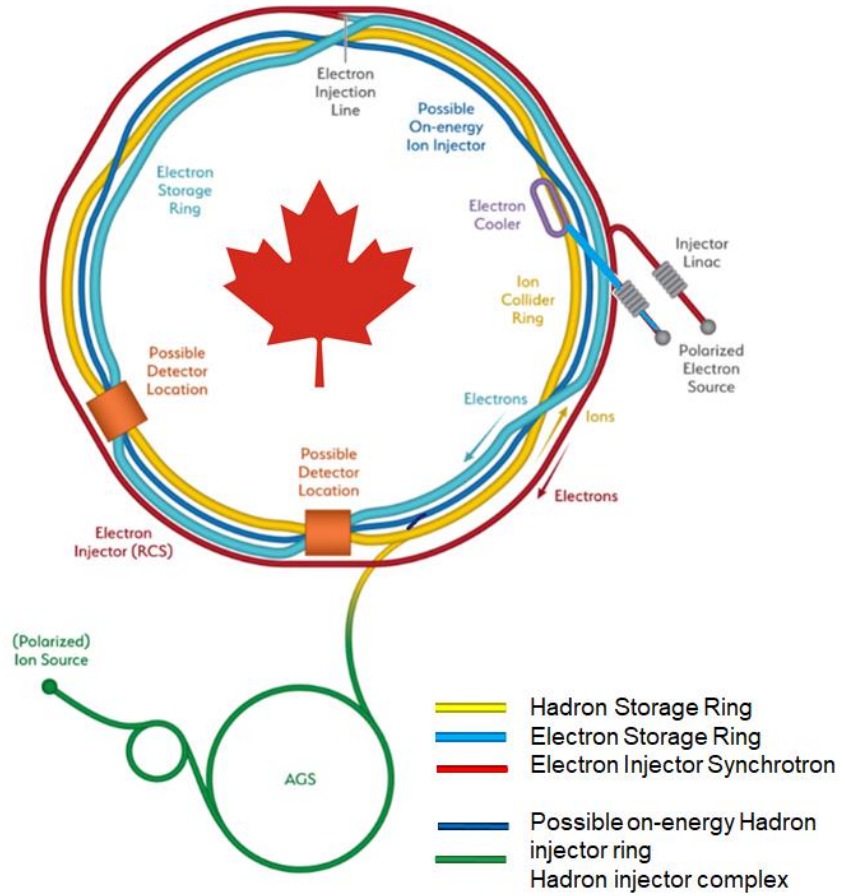




394 MHz Crab Cavity

TRIUMF and EIC accelerator

- ✓ TRIUMF supports the Canadian subatomic physics community by actively participating in funding proposals towards participation in international projects.
- ✓ Together with our scientific communities, we are developing a 5-year plan informed by a 20-year vision that includes international projects like EIC.



Discover accelerat

TRIUMF

Thank you!

Merci!

EIC will be built on strong partnership

- Italy, INFN
  - HSR vacuum chamber inserts
- Canada, TRIUMF
  - SC Crab Cavity system
  - Pulsed systems
- UK, ASTEC & Cockcroft Inst.
  - ERL components
- France, IJCLab
  - SHC ERL diagnostics
- France, CEA Saclay
  - IR SC magnets
  - SC spin rotators
- CERN, Switzerland
  - ESR SC cryomodules joint design
  - ESR high current elements joint design
- Japan, KEK
  - ESR collimation system

High level readiness of technical status
Possibly, first case for use of seed funds

High level readiness of technical status

Project is developing possibility of "Seed" funds for EIC international collaboration that can enable early start of EIC accelerator design efforts in partner countries

- Recent & tentative:
- Israel, SARAF
  - RF power amplifiers, collimators, controls
- Sweden, Uppsala Uni.
  - SSPA