Impressions from the 2021 EIC Accelerator Partnership Workshop

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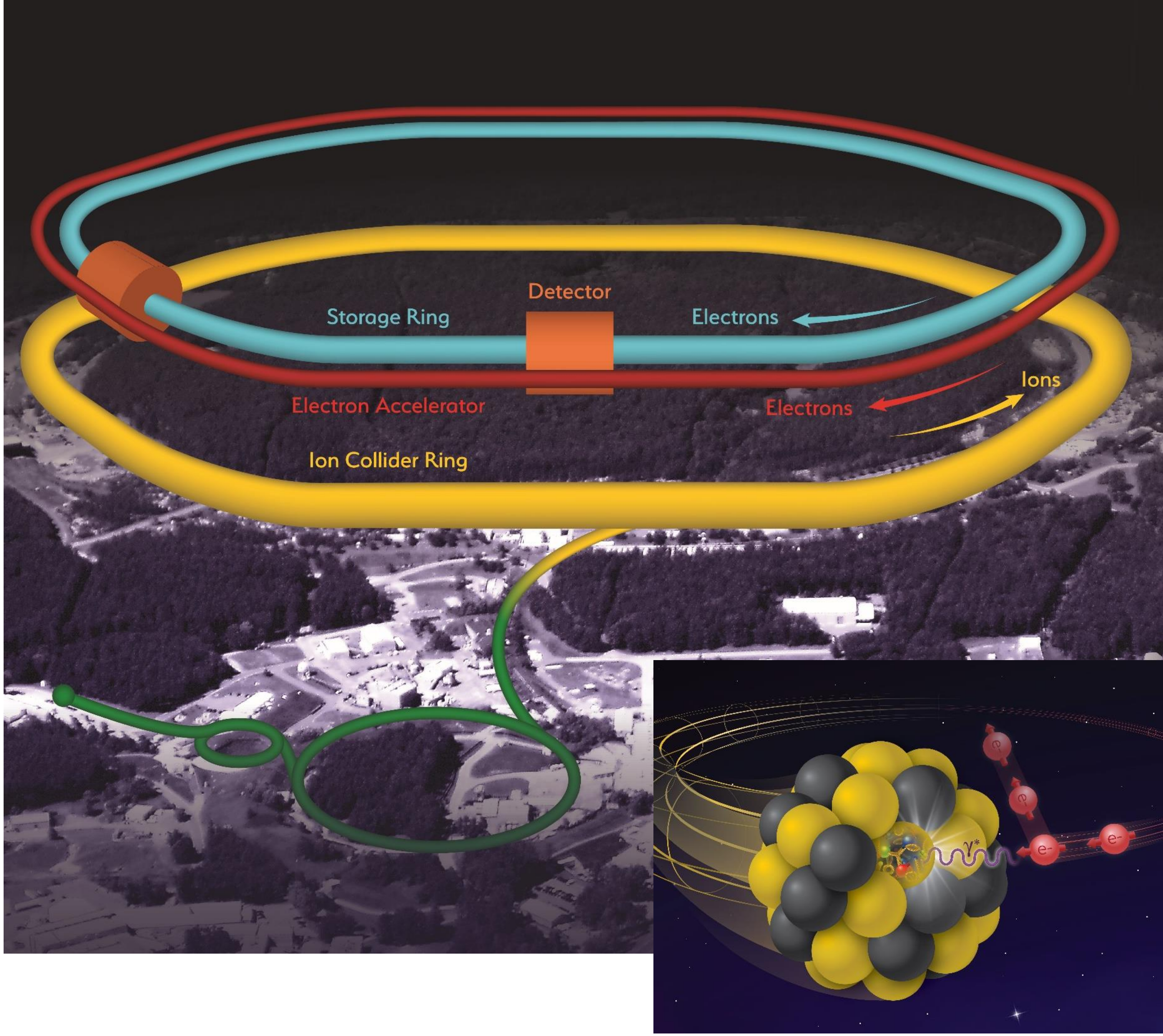

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The Electron Ion Collider – leading edge of Accelerator Technology

EIC is a very complex machine and requires a collaborative approach to identify and overcome the technical challenges

BNL and JLab seek engagement of international and domestic partners in these efforts → this workshop!

Challenges:

- 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 → Collaboration investigates an IR based on Nb_3Sn

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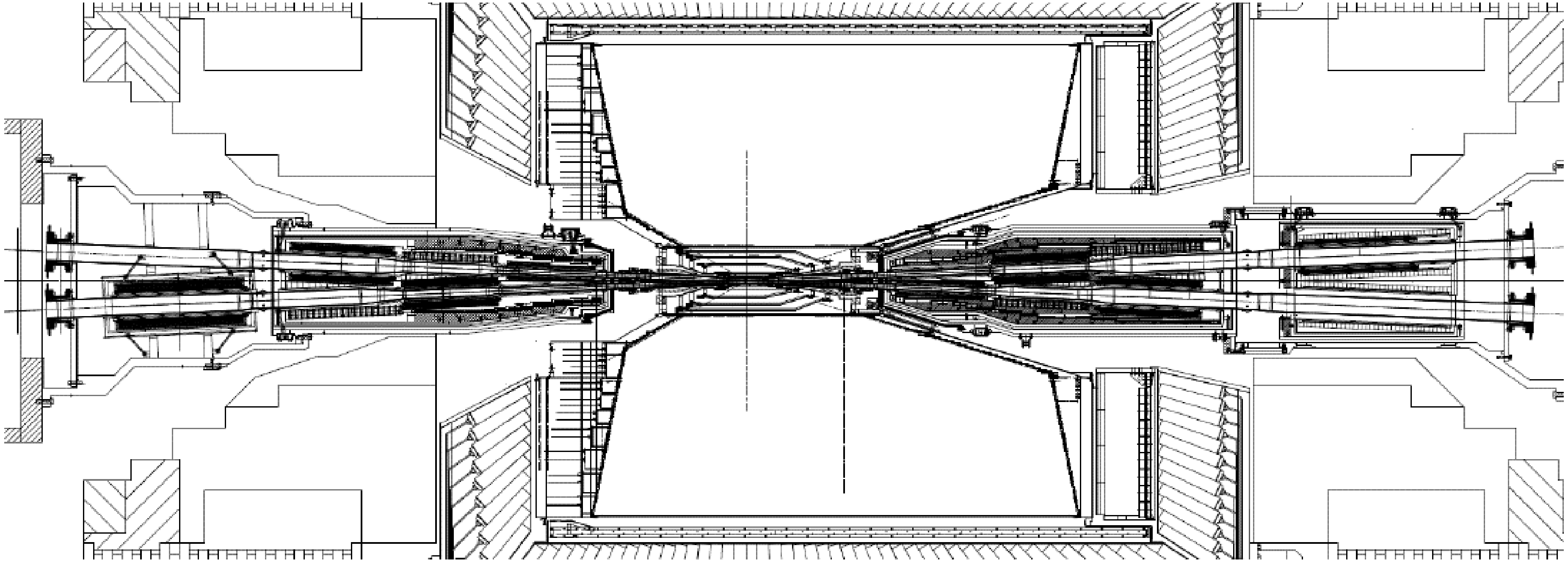
2021 EIC Accelerator Partnership Workshop participation

- The workshop saw 284 registered participants from 23 countries
  Between 60 and 100 participants in each session
- Topics we explored (contribution from):
  - IR SC magnets and spin rotators (BNL, KEK, Jlab, INFN, CERN)
  - Second IR based on Nb_3Sn option (Jlab, CERN, FNAL, LBNL)
  - HSR and ESR vacuum system (BNL, CERN, INFN, KEK, ANL, MAX-IV,CNPEM)
  - Lessons from SuperKEKB (KEK and U of Hawaii)
  - Crab Cavities (Jlab, ODU, TRIUMF, BNL, CERN, STFC, U of Uppsala, FNAL)
  - ESR high current elements (CERN, BNL, ESRF)
  - ESR SRF and CM (BNL, SLAC, Stanford U, CERN, ESS, Euclid Techlabs)
  - Machine Detector Interface (MDI), First and Second IR (BNL, Jlab, U of Hawaii, PAL, LBNL)

Impressions from the sessions: IR SC magnets

- IR1 has challenging geometric constraints – SC IR magnets and spin rotator solenoids
  all magnets in NbTi, forward direction 2K, rear direction 4K
- Beams share magnet aperture → combined function magnets, large aperture → space constraints require 2K
- CCT (Canted Cosine Theta) winding pattern resolves several issues → reduced conductor stress, excellent field quality
  need to be proven mechanically (quit some experience at LBNL)
- IR2 – Nb_3Sn magnets, which allow higher gradients, shorter L*, higher luminosity – compact IR
  → driving development of Nb_3Sn magnets and lessons learned from the US program on Nb_3Sn magnets

- Just to visualize the complexity of an IR
  → SuperKEKB



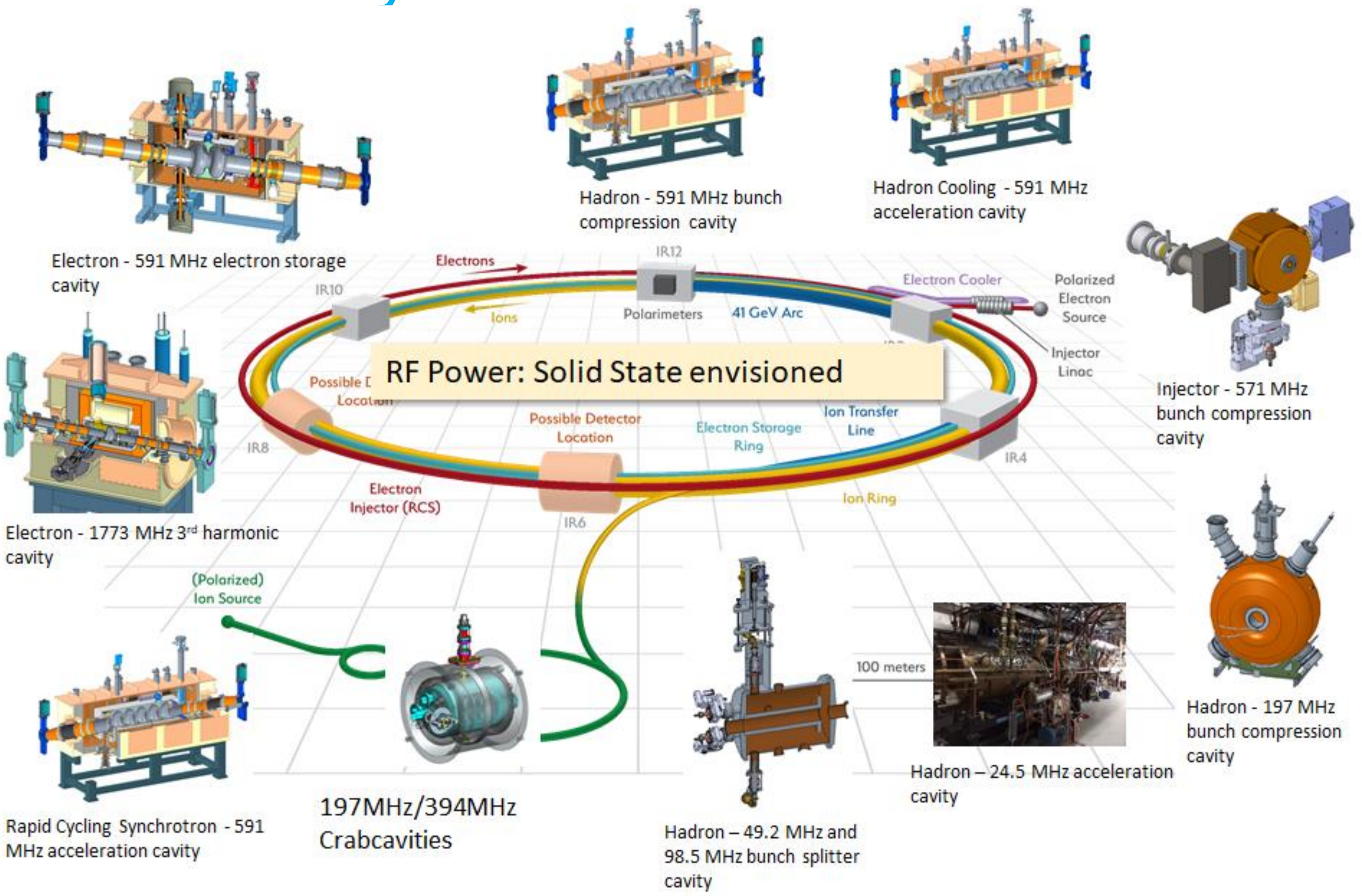
Impressions from the sessions: HSR and ESR vacuum systems and high current systems

- Electron cloud and vacuum stability (e- ionize residual gas and are a second source of ion flux to the wall - desorption
- Electron and photo stimulated desorption – lower on porous substrate
  → C-coating in cold sections, significant coating experience at CERN
  → investigation of resistive wall impedance
- Dealing with synchrotron radiation (9 MW)
- High intensity, short bunches and short bunch spacing – large resistive wall heating
  Vacuum upgrade of the hadron ring
- Impedance modeling is essential, important lessons from synchrotron light sources (ESRF, MAX-IV,…)
  → impedance minimization in close collaboration with mechanical engineers essential
- Careful design beam screens with minimal impact on the apertures – combined with cryosorbers or NEG in warm sections

- Interesting the contribution from SLAC about the pre-injector (high achievable gradients, distributed coupling structure and enhancement of rf-parameters for cryogenics temperatures)

The EIC rf-systems

- Significant portfolio of different systems
- Normal and super-conducting



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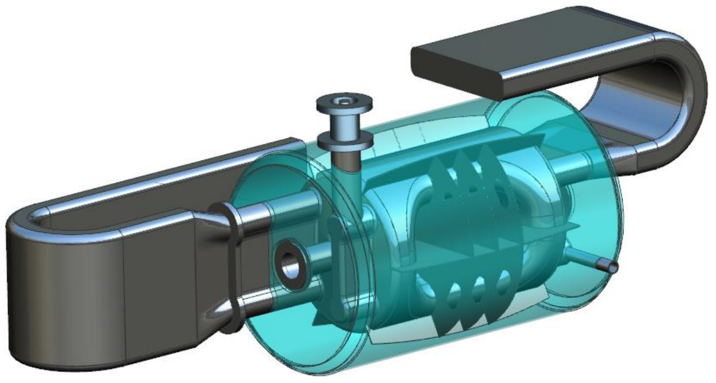
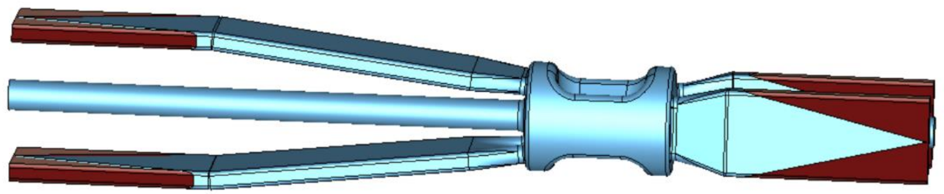
Impressions from the sessions: EIC crab cavities



Jacketed 197 MHz Crab Cavity Variant

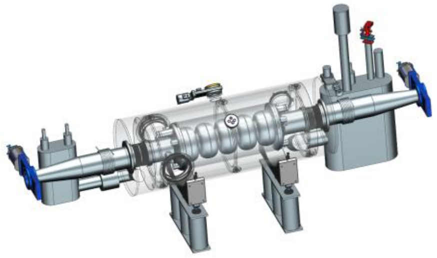


394 MHz Crab Cavity

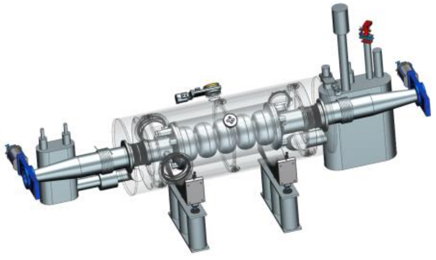
- The Crab Cavity performance is critical to the success of the EIC
  - Large crossing angle
  - Luminosity impact ~ order of magnitude
- The requirements are challenging
  - Significant deflecting voltage ~34 MV
  - Tight impedance budgets
  - RF control requirements are beyond anything done - Phase 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

Impressions from the sessions: SRF and cryomodules

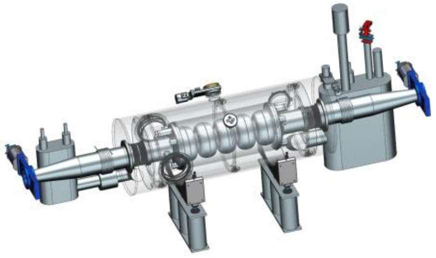
- EIC requires multiple new SRF systems (cavity, power, and control). Many opportunities for new and exciting work.
- Goal of early work based at BNL and JLab is to develop understanding of systems and reduce risk.
- Requirements and designs are mature but not final. The beam and machine physics are 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



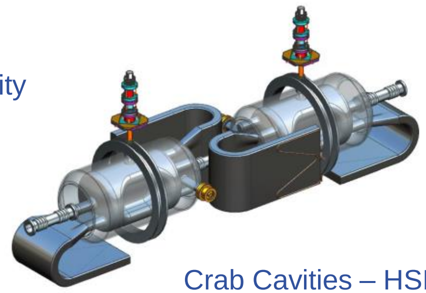
HSR - 591 MHz 5-Cell Cavity
Bunch Compression



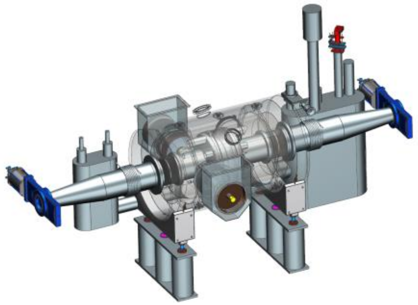
SHC- 591 MHz 5-Cell and 1773 MHz 5-Cell ERL Cavities



RCS - 591 MHz 5-Cell Cavity
Acceleration Cavity



Crab Cavities – HSR & ESR



591 MHz ESR 1-Cell Cavity

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Impressions from the sessions: Machine Detector Interface

- The EIC will feature powerful beams: 10x the stored energy of RHIC, 2x SuperKEKB target stored energy with 1/2 the bunches
- Collimators are even more critical - accomplish 2 main missions:
  a) Beam cleaning to reduce radiation & backgrounds form lost particles and
  b) machine protection from accidental beam loses (CCs, kickers, instabilities, …)
- Synchrotron Radiation management - Heat extraction (ANSYS simulation)

- 5-7 collimators in both rings + absorbers and masks
  Simulation studies with FLUKA and tracking codes

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Lot’s of lessons from SuperKEKB (to learn!)

- Collimator beam power and damages
  Narrow aperture to reduce beam background at detector, but limit on max. bunch current
- Beam-beam blow-up
  chromatic coupling, multi bunch effects, head-tail?
  I wonder why are the long range beam-beam wire correctors explored at CERN not in discussion for EIC?
- Quality and amount of beam injected from the linac (quite common)
  strict on parameter fluctuation of beam from the linac (energy spread, pointing stability, beam current …)
- Feedback gain of bunch feedback system – can inject noise and might cause dipole motion of the beam
- Beam background at the detector Belle II
  Movable collimators – cut beam tails, tungsten shielding to stop showers from the final focus quads
- Beam losses (or aborts) by pressure bursts – dynamic vacuum effects, collision of the circulating beam with dust particles, etc.

And more ….

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My overall impression

- The selected focused areas are all very important for the EIC project and the project team is really benefitting from presentation from experts from other labs.
- A follow up on collaboration on these topic will be very useful and timely for CD2.
- I'm fascinated by the advances in the different areas, the community is not afraid to explore new ideas!
- Yes, there are a lot of challenges, but there are many labs working on solutions to overcome these challenges and support the EIC project.

- I want to congratulate BNL and Jlab for the significant advances and the strong collaboration that has been established to realize this outstanding nuclear physics facility.

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Thank you!

Merci!

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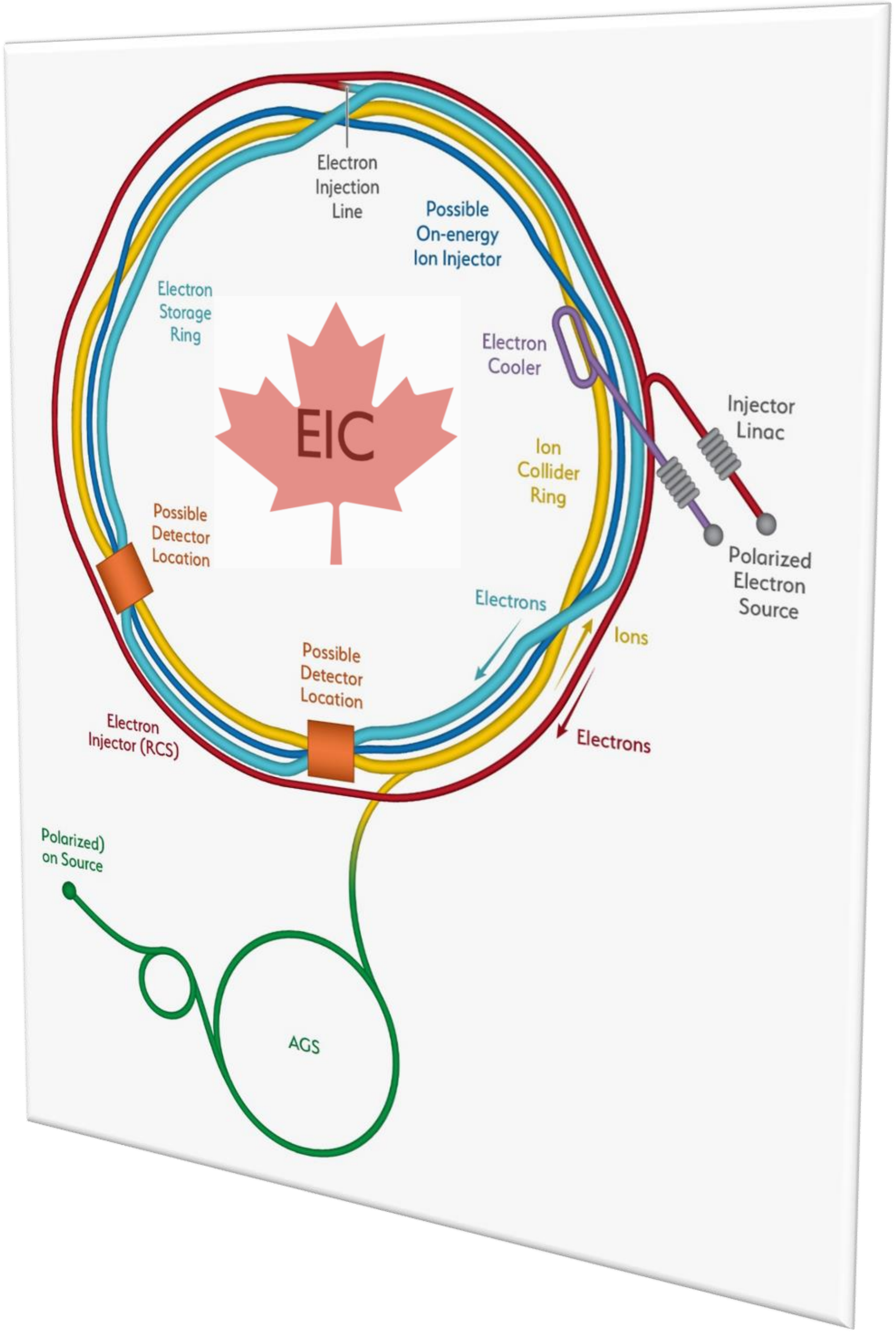

Discovery, accelerated