Brookhaven National Laboratory
Jefferson Lab
U.S. DEPARTMENT OF ENERGY

EIC Collider Status

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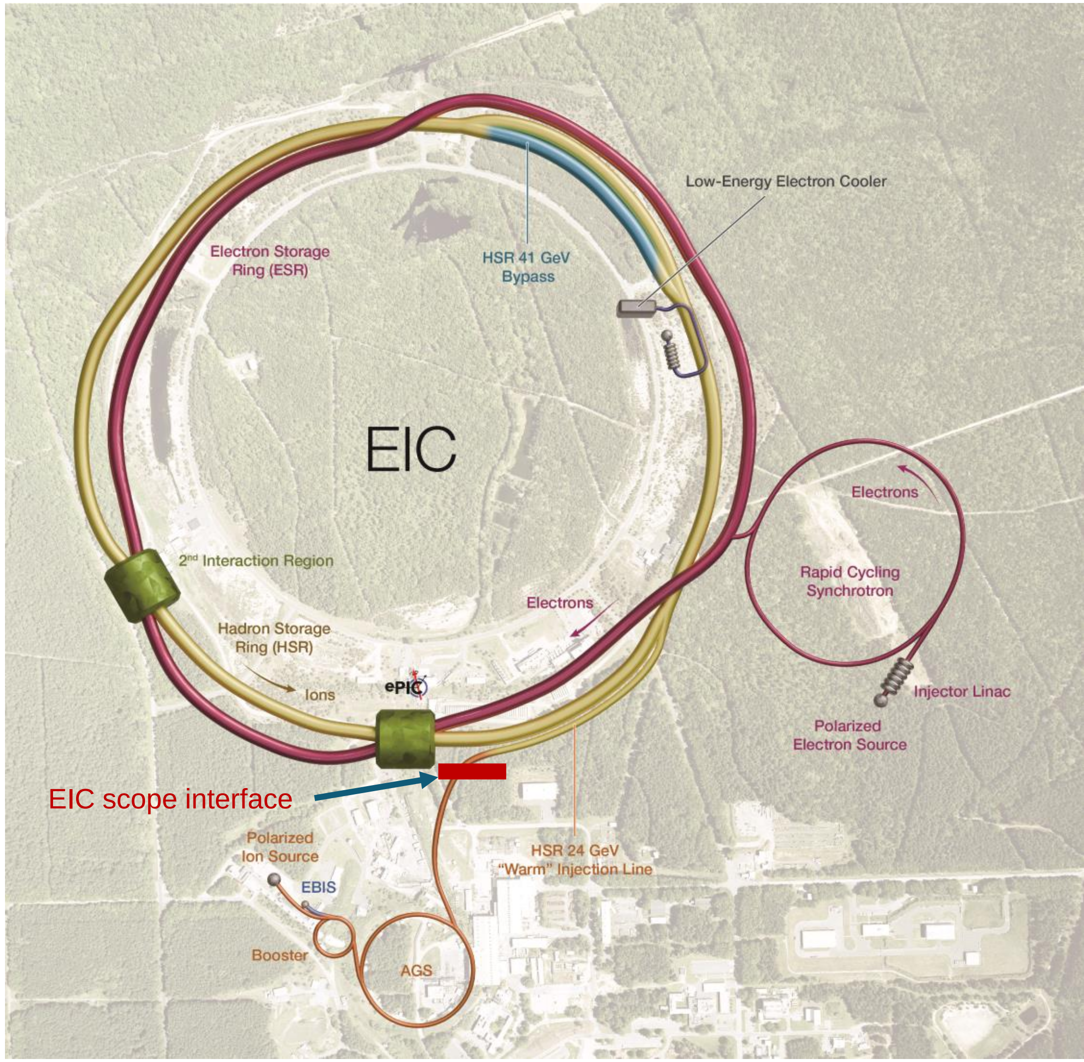
ePIC Collaboration Meeting

January 20, 2025
Electron-Ion Collider

Outline

- Key Message
- Project Requirements, Design Goals, Assumptions, and Community Expectations
- Subprojects
- Design Status and Progress
  - Strategy for reusing RHIC
  - Strategy for Hadron Cooling
  - Strategy for RCS
- IR design progress
- Summary



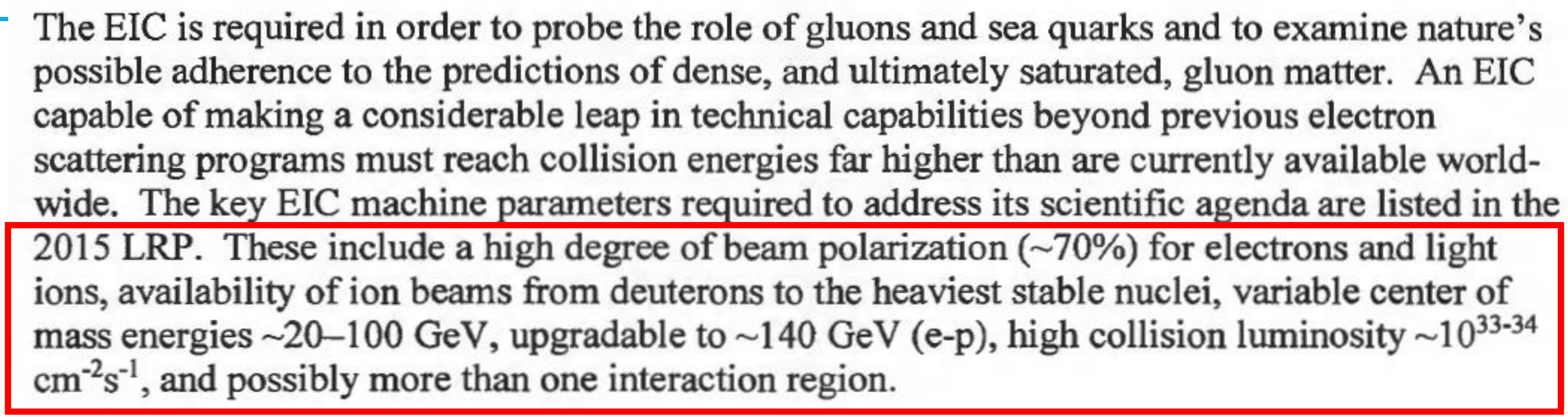
EIC scope interface

Key Takeaway Messages

- In 2024, the project made several key EIC design decisions. They will lead to formal Project Scope changes after the Technical Change Control Board (TCCB) and the CCB processes.
  1. Reuse the entire Yellow RHIC ring, delay the 41-GeV bypass (a Blue RHIC arc).
  2. Implement a new room-temperature Hadron Storage Ring (HSR) injection line.
  3. Drop Strong Hadron Cooling (SHC), add Low-Energy Cooling (LEC).
  4. Move the Rapid Cycling Synchrotron (RCS) out of the collider tunnel.
  5. Delay the 28 nC/bunch and the 18 GeV capability implementation (ESR and RCS).
- These design decisions resolve uncertainties, challenges, and risks to EIC performance, safety, and future operation and maintenance.
- Today, there are no more technical scope uncertainties related to the EIC performance and Key Performance Parameters (KPPs).
  - There are of course remaining risks, which we will continue to mitigate and properly manage.
- We understand what we need to build to deliver EIC!

Project Requirements and Design Goals

The DOE CD-0 Mission-Need Statement (MNS) 2019

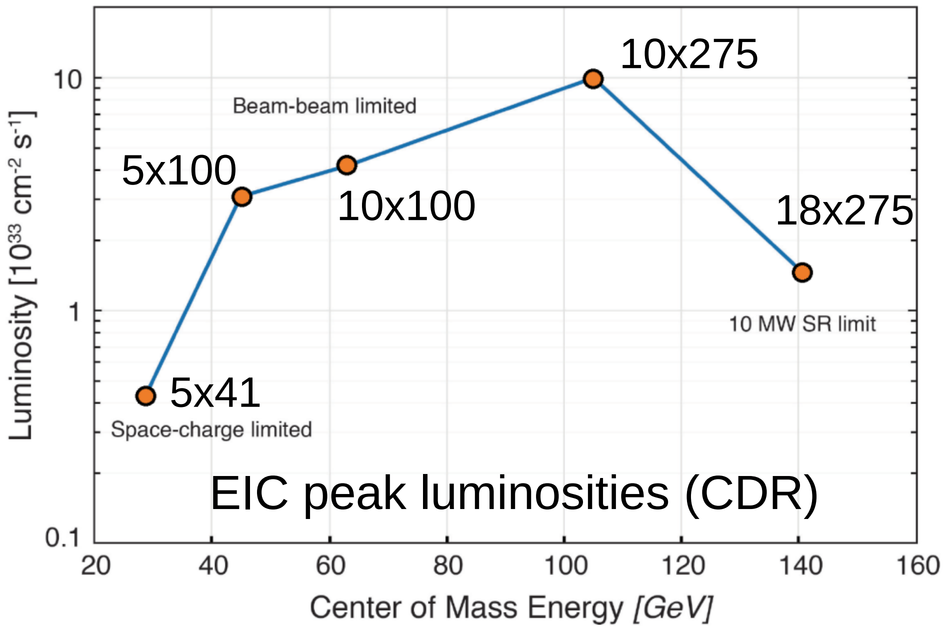


The EIC is required in order to probe the role of gluons and sea quarks and to examine nature's possible adherence to the predictions of dense, and ultimately saturated, gluon matter. An EIC capable of making a considerable leap in technical capabilities beyond previous electron scattering programs must reach collision energies far higher than are currently available world-wide. The key EIC machine parameters required to address its scientific agenda are listed in the 2015 LRP. These include a high degree of beam polarization (~70%) for electrons and light ions, availability of ion beams from deuterons to the heaviest stable nuclei, variable center of mass energies ~20–100 GeV, upgradable to ~140 GeV (e-p), high collision luminosity ~$10^{33\text{-}34}$ $\text{cm}^{-2}\text{s}^{-1}$, and possibly more than one interaction region.

$$E_{COM} \approx 2\sqrt{E_e E_h}$$

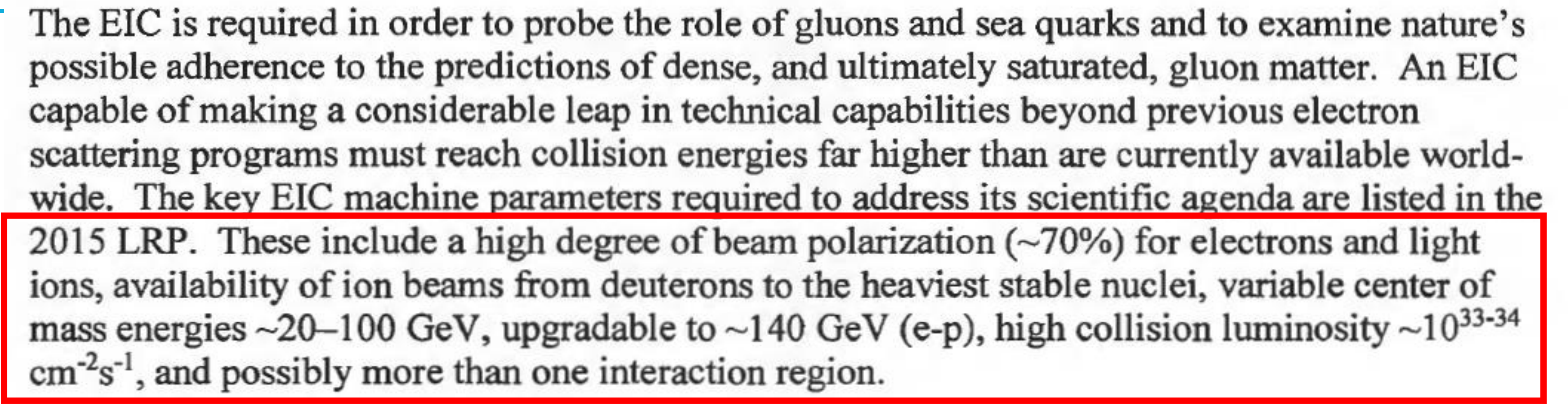
Bunch charges: 28 nC (10 GeV, e) and 11 nC (275 GeV, p)

$$L = \frac{N_e N_p}{4\pi\sigma_h\sigma_v} N_b f_0 \approx 1\times10^{34}\ \text{cm}^{-2}\text{s}^{-1} \qquad N_b = 1160;\ f_0 = 78.3\ \text{kHz}$$



EIC peak luminosities (CDR)

The DOE CD-0 Mission-Need Statement (MNS) 2019



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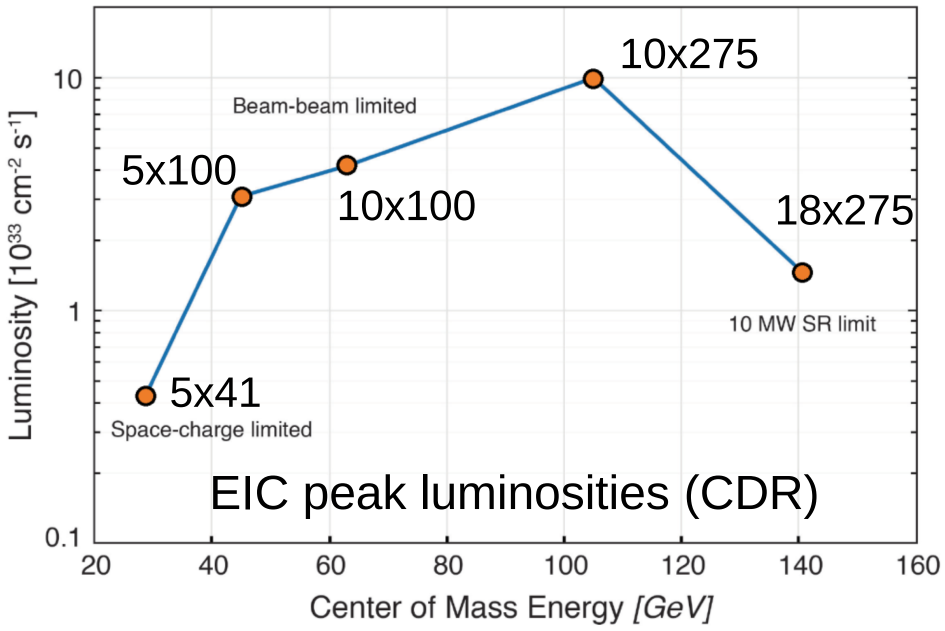
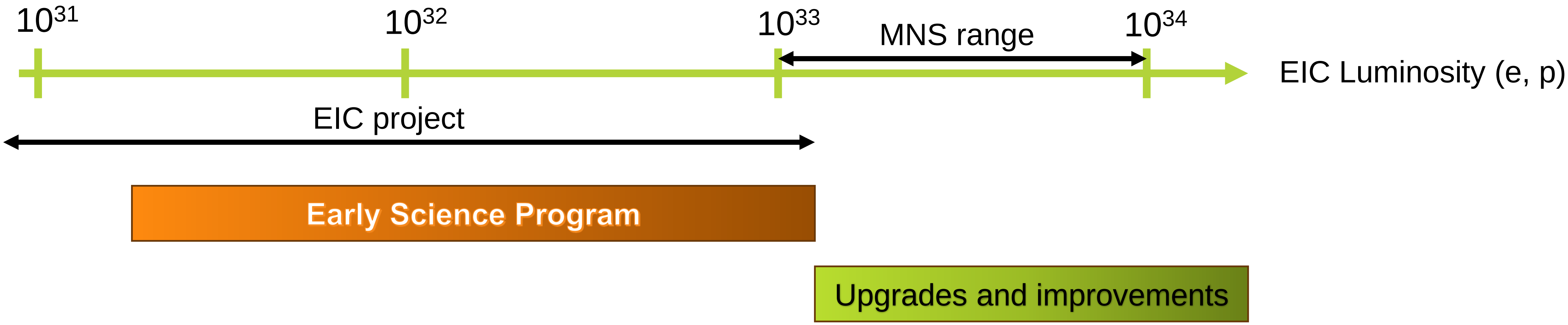
$$E_{COM} \approx 2\sqrt{E_e E_h}$$

The 2021 Conceptual Design Report describes a path to EIC ultimate performance which interprets the MNS in a broadest way ($10^{33\text{-}34}$ cm^{-2} s^{-1}).



EIC peak luminosities (CDR)

Proposed EIC Performance Goals



10^{31} 10^{32} 10^{33} 10^{34}

MNS range

EIC Luminosity (e, p)

EIC project

Early Science Program

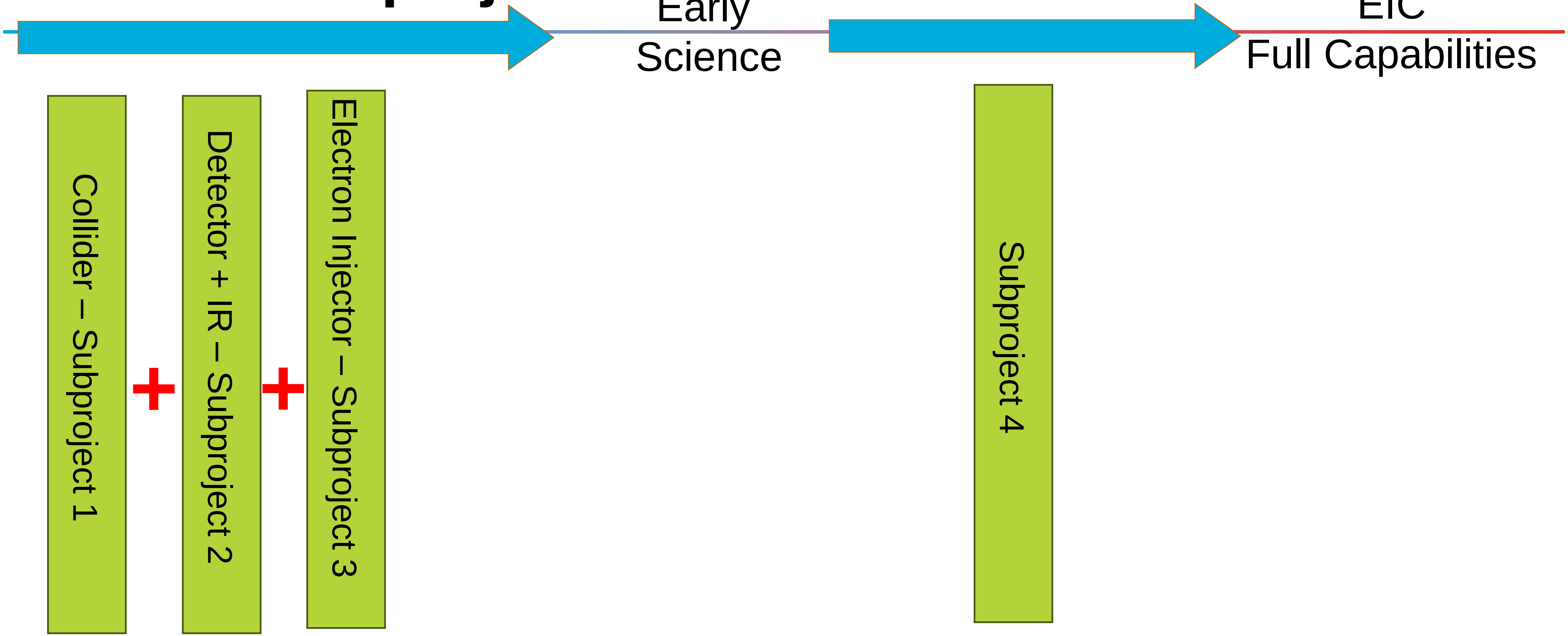
Upgrades and improvements

We are proposing to focus on delivering EIC performance, which meets the MNS for the range of Center of Mass energies from 40 GeV – 100 GeV, and peak luminosity of 10^{33} $cm^{-2}s^{-1}$ or above. Ultimate EIC performance would leverage upgrades and improvements.

Proposed Scope Meets the MNS and Early Science Goals

- Center of Mass (COM) energy range: 40 GeV – 100 GeV
  - Upgradeable to extend COM energy range: ~20 GeV - 140 GeV
- Luminosity greater than 10^{33} $cm^{-2}sec^{-1}$ over this COM energy range
- HSR delivered to operate from 100 GeV – 275 GeV with LEC to achieve luminosity goal, polarized protons (>60%) from the existing Alternating Gradient Synchrotron (AGS).
  - No SHC
  - Upgradeable to reach 41-GeV (bypass line installation) for lowest COM collision energy
- Electron Storage Ring (ESR) delivered to operate at 5 GeV and 10 GeV, 1160 bunches, 7 nC each, but designed to 28 nC/bunch and 18 GeV. Polarization >70%.
  - Upgradeable to 18 GeV for highest COM collision energy and 28 nC/bunch charge swap-out for highest luminosity
- Interaction Region (IR) Superconducting (SC) magnets close to the Conceptual Design Report (CDR)
- The electron injector is optimized to deliver high-polarization bunches (7 nC/bunch @ 1 Hz) at 5 and 10 GeV, designed to 28 nC/bunch @ 1 Hz and 18 GeV.
  - Upgradeable to 18 GeV and to 28 nC/bunch per second

EIC and Subprojects



Early Science

EIC Full Capabilities

Collider – Subproject 1

+

Detector + IR – Subproject 2

+

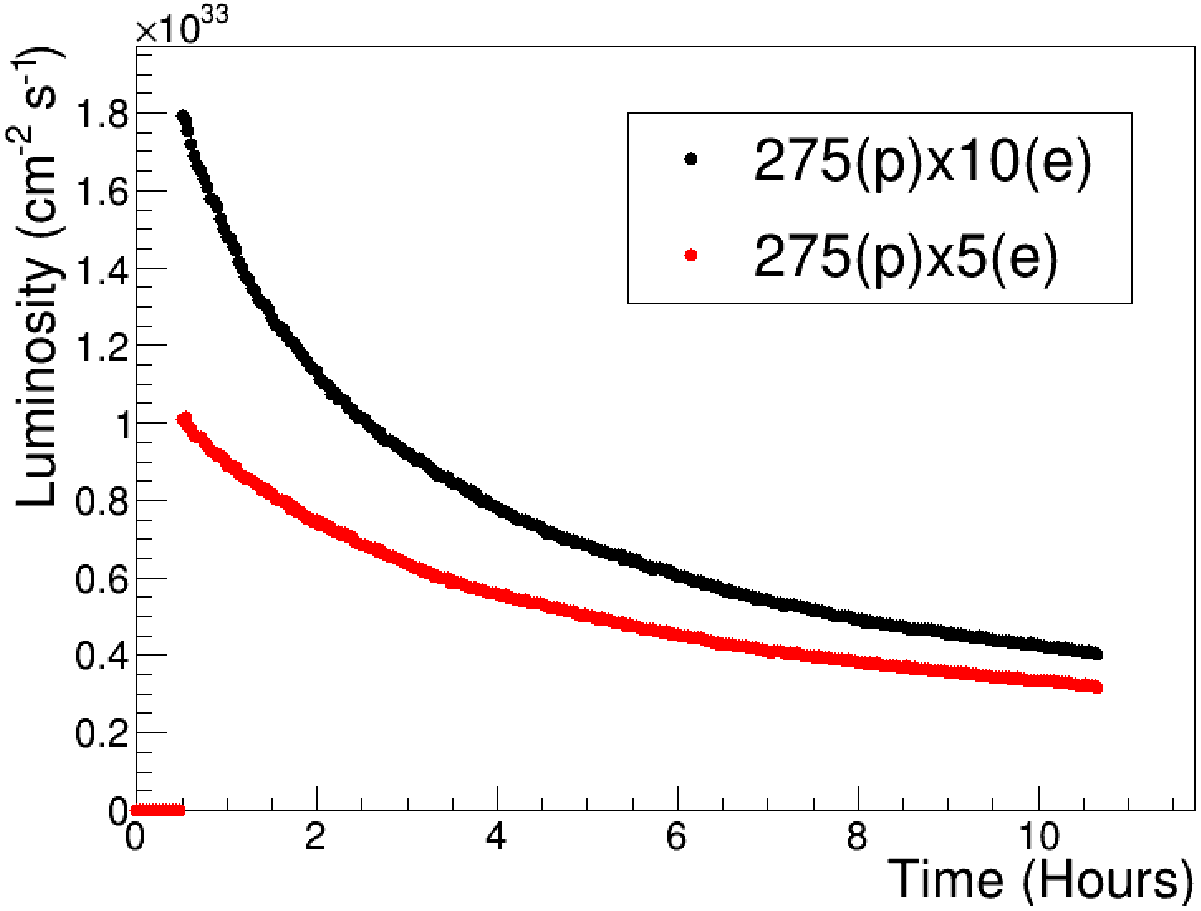
Electron Injector – Subproject 3

Subproject 4

All the scope needed for early science program

All the scope needed to reach full EIC capabilities

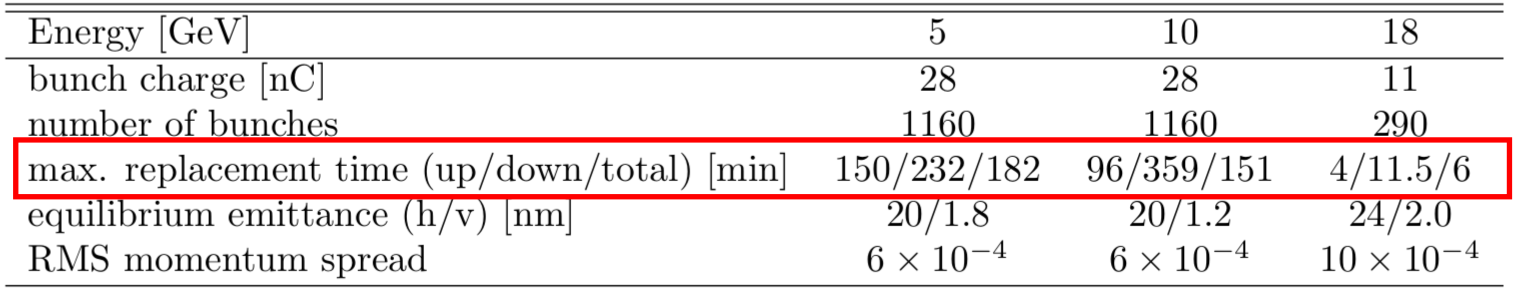
Projected e-p Luminosities for the Proposed Scope



First 30 mins. are taken by filling
the ESR and turning on detector.

- 7 nC electron bunch charge (reduced from 28 nC)
- Nominal 11 nC proton bunch charge for 275x10 (as in CDR)
    - Reduced 5.5 nC proton bunches for 275x5
- Constant proton beam IP divergencies are maintained throughout the store. by gradual increase of proton IP beta-functions as the beam emittance increases.
- The electron IP beta-functions are adjusted accordingly to match electron and proton transverse beam size.
- Compare to HERA peak luminosity of $5\times10^{31}\text{cm}^{-2}\text{sec}^{-1}$

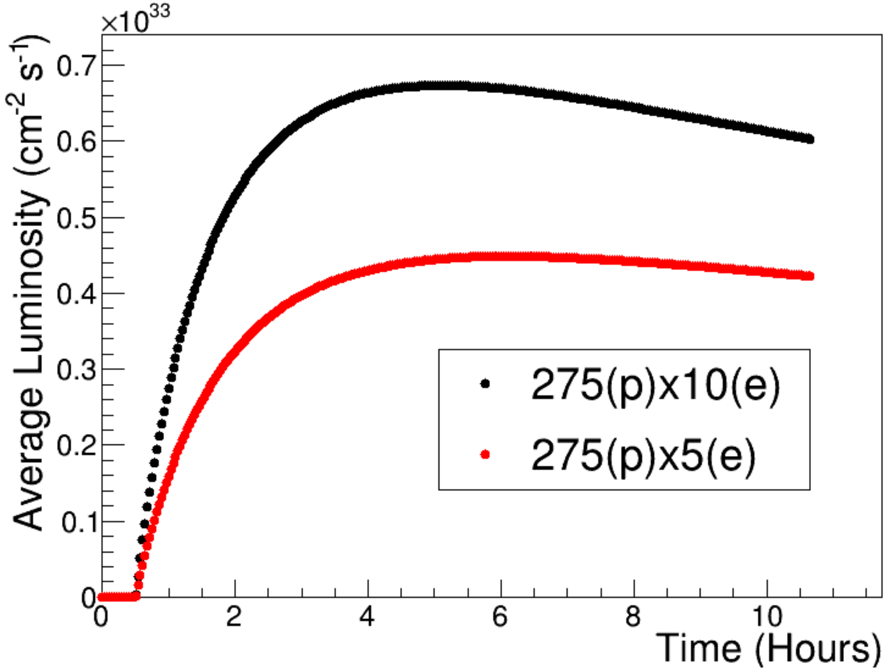
Average Luminosity and Optimal Store Length



Energy [GeV]	5	10	18
bunch charge [nC]	28	28	11
number of bunches	1160	1160	290
max. replacement time (up/down/total) [min]	150/232/182	96/359/151	4/11.5/6
equilibrium emittance (h/v) [nm]	20/1.8	20/1.2	24/2.0
RMS momentum spread	6×10^{-4}	6×10^{-4}	10×10^{-4}

Maximum replacement times (= max. allowable storage times in ESR) are based on the 85% injected polarization and 70% time-averaged polarization

	275x10	**275x5**
Optimal store length	~5h	~6h
Average luminosity, x10^{33}, cm^{-2},s^{-1}	~0.7	~0.4



- Each store starts with 30 mins. to fill the ESR ring (~1200 bunches, 1 bunch per second);
- In addition, we assume a two-hour turnaround time for filling hadrons, precooling (30 mins.), and ramping.

$$\text{Ave. lumi} = \frac{\text{Integral}}{\text{store length} + 2.5\text{ hr}}$$

Critical EIC Accelerator Technology Areas

- Hadron Beam Cooling
- Beam Polarization
  - High polarization for both beams from source to collisions
  - Swap-out injection for electron bunches (at 1 Hz) to maintain high polarization
- Crab cavities
  - Large-size, complex geometries;
  - Very tight phase and amplitude noise requirements
- IR magnets (large aperture, 2K SC magnets)

Design Status and Progress

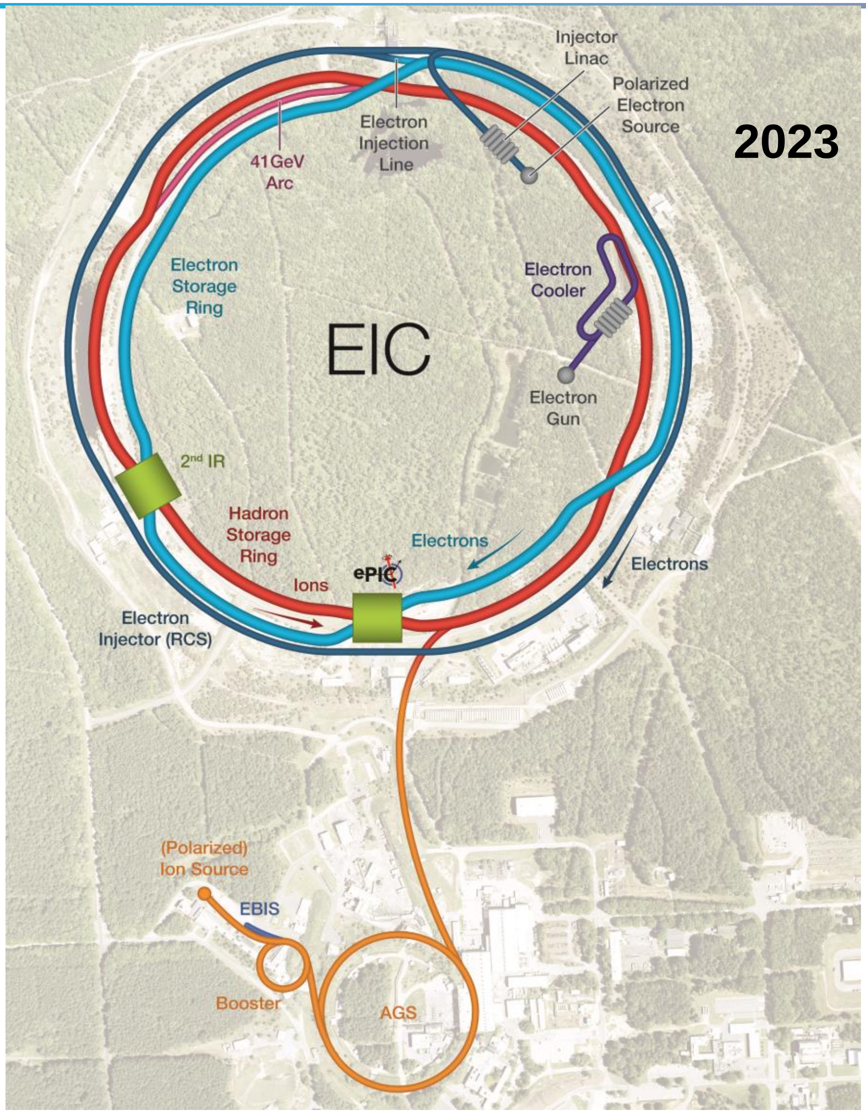
In 2024, the project made several key EIC design decisions. They will lead to formal Project Scope changes after the TCCB and the CCB processes.

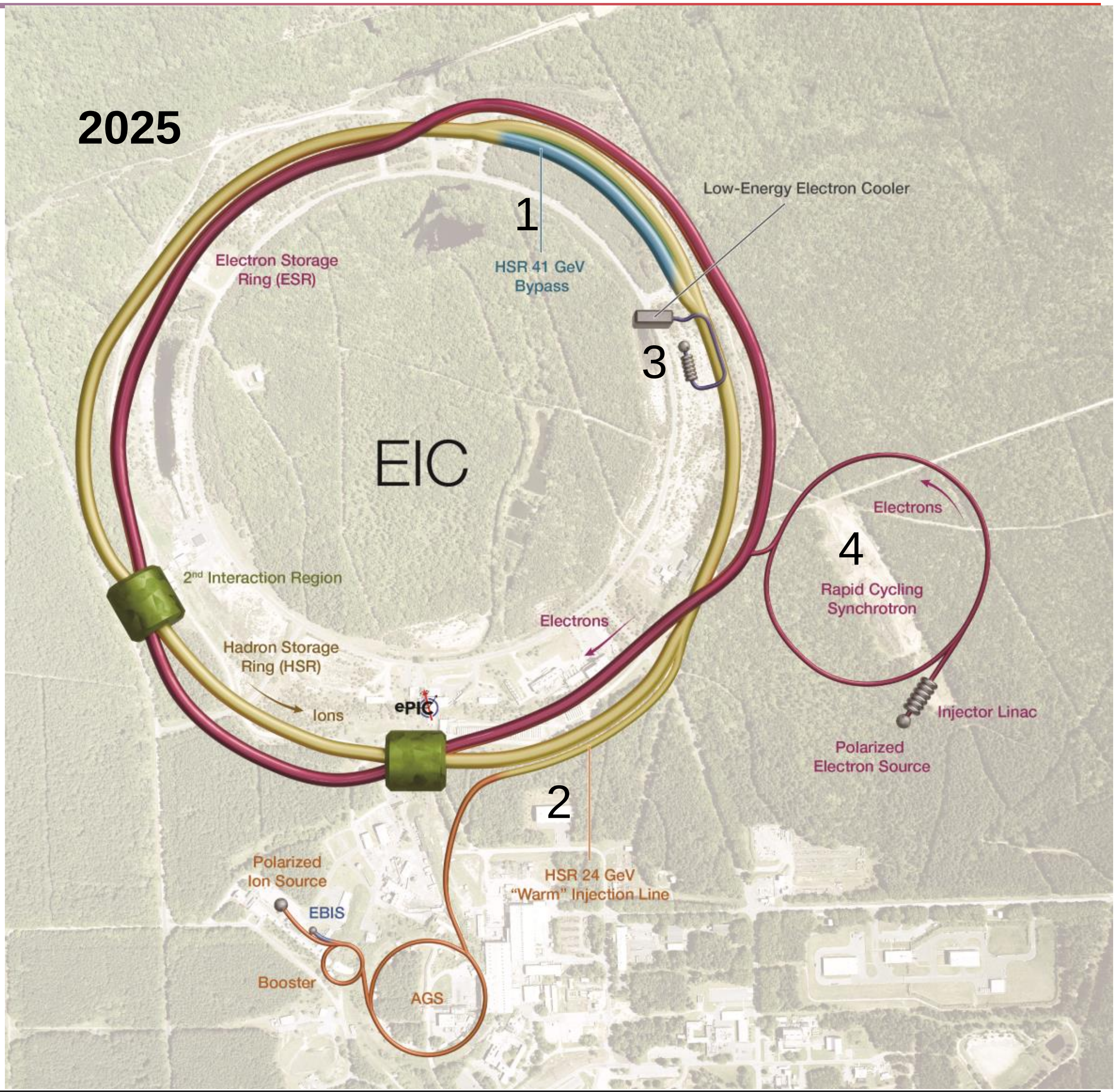
1. Reuse the entire Yellow RHIC ring, delay the 41-GeV bypass (a Blue RHIC arc)
2. Implement a new room-temperature HSR injection line
3. Drop SHC, add LEC
4. Move RCS out of the collider tunnel
5. Delay the 28 nC/bunch and the 18 GeV capability implementation (ESR and RCS)

These design decisions resolve uncertainties, challenges and risks to EIC performance, safety, and future operation and maintenance.

There is no change to the EIC cost objective.

Can You Spot the 4 Design Changes?





Strategy for Reusing RHIC Rings and Tunnel

Design Change #1: The 41-GeV Bypass

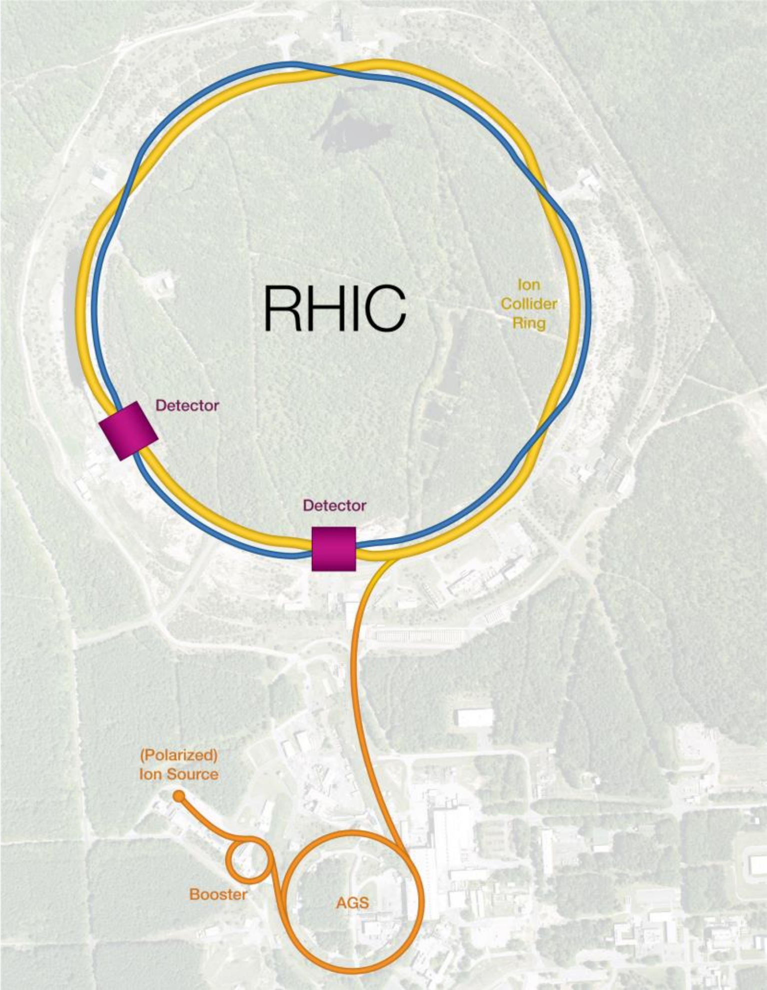
Design Change #2: The HSR Injection Line

Relativistic Heavy Ion Collider (RHIC)

- Existing tunnel and infrastructure
- Two SC storage rings
    - 3.8km circumference
- Energy up to 255 GeV protons, or 100 GeV/n gold
- 110 bunches/beam
- Ion species from protons to uranium

- 60% proton polarization – world’s only polarized proton collider
    - Needs to be upgraded to 70% (outside of KPPs)
- Exceeded design luminosity by a factor of 44
- 6 interaction regions, 2 detectors
- In operation since 2001; operations will end in 2025

EIC is based on the existing RHIC facility



Electron-Ion Collider

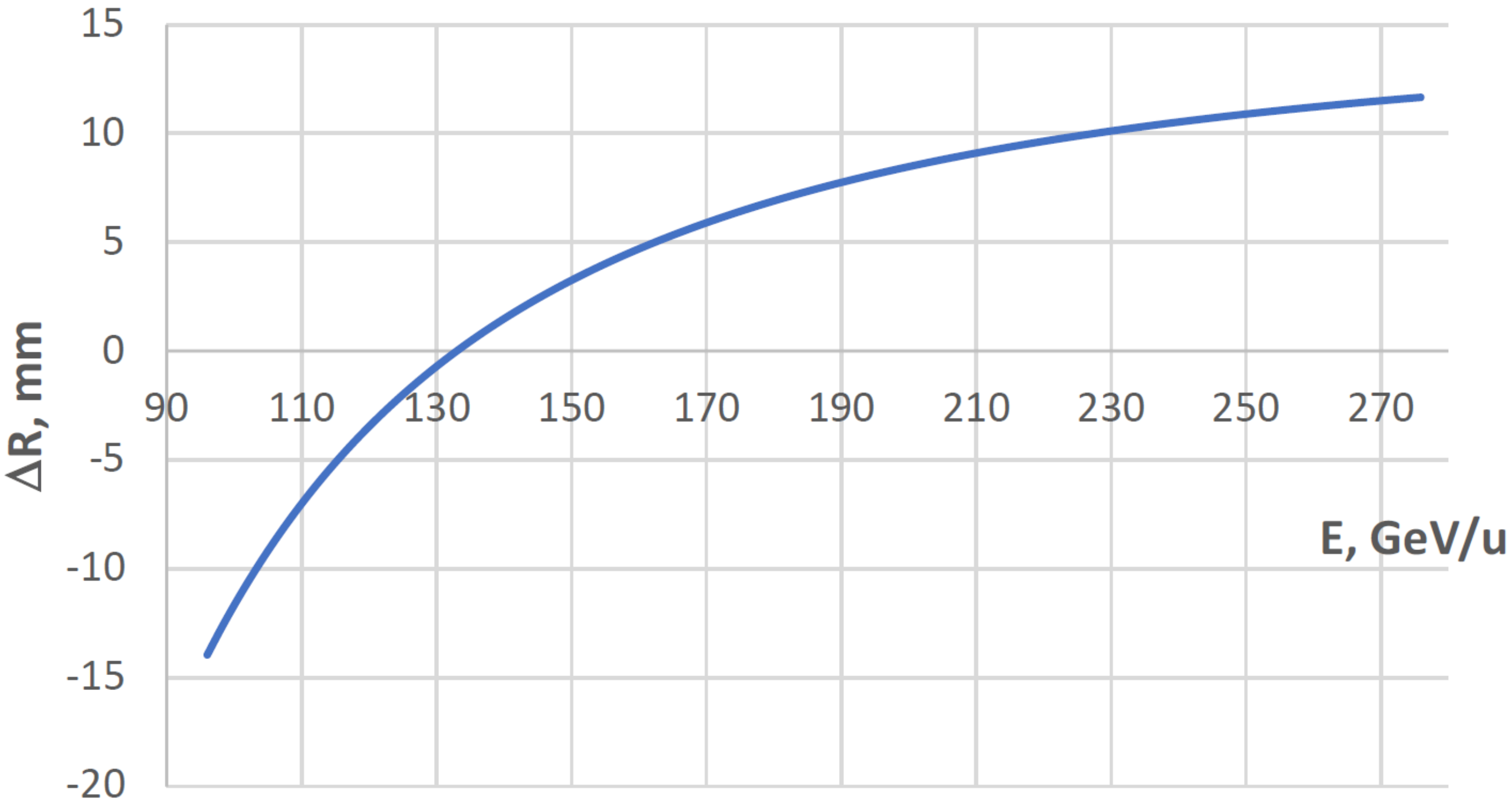
From RHIC to HSR

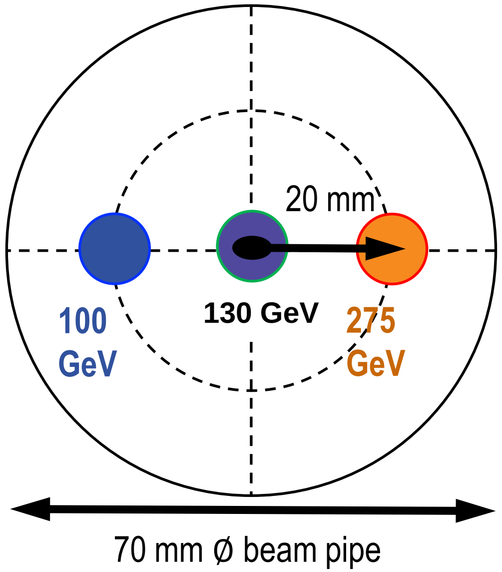
Tripled beam current, shorter bunch length, shorter bunch distance, ‘flat’ beams with small vertical emittance

- EIC Hadron Storage Ring (HSR) to be composed of existing arcs of the Yellow RHIC ring (remove unused magnets)
- Insert sleeves coated with copper and amorphous carbon into superconducting magnet beam pipes to improve conductivity and reduce secondary electron yield (-> electron cloud)
- Add new RF cavities
- Add hadron cooling to create ‘flat’ bunches
- Add crab cavities, new IR SC magnets
- Add a collimation system

CD3A -- Actively Cooled Beam Screen Material procurement

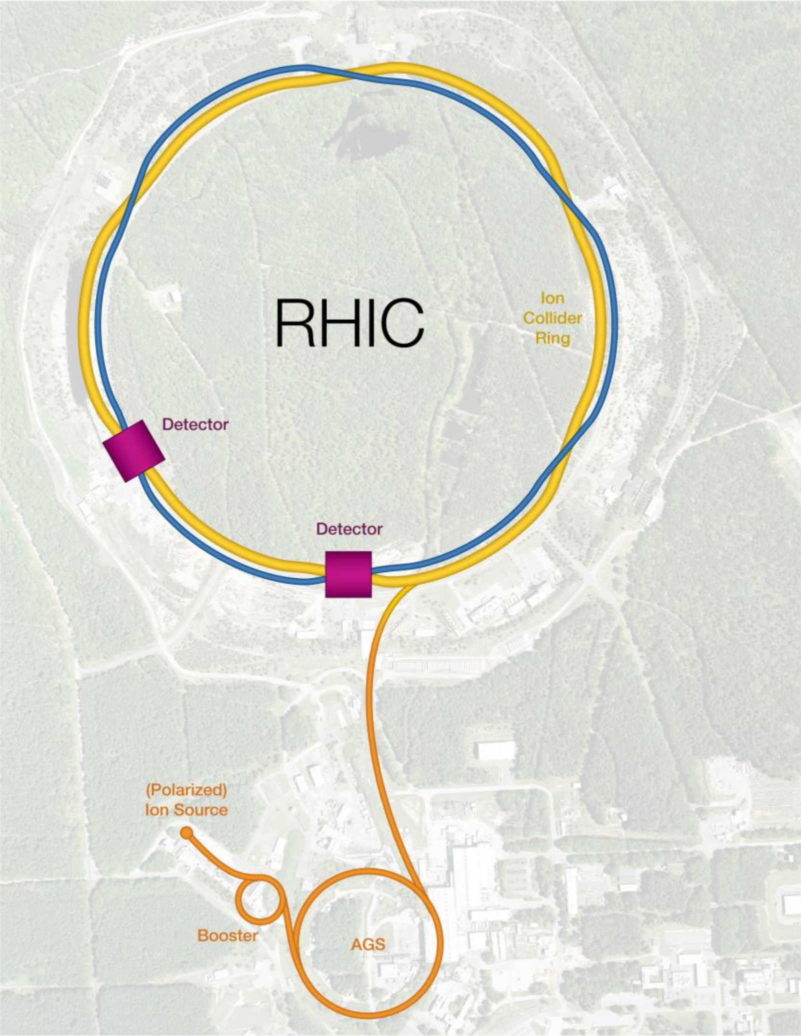
Beam Energy and Average Orbit Radius in the HSR



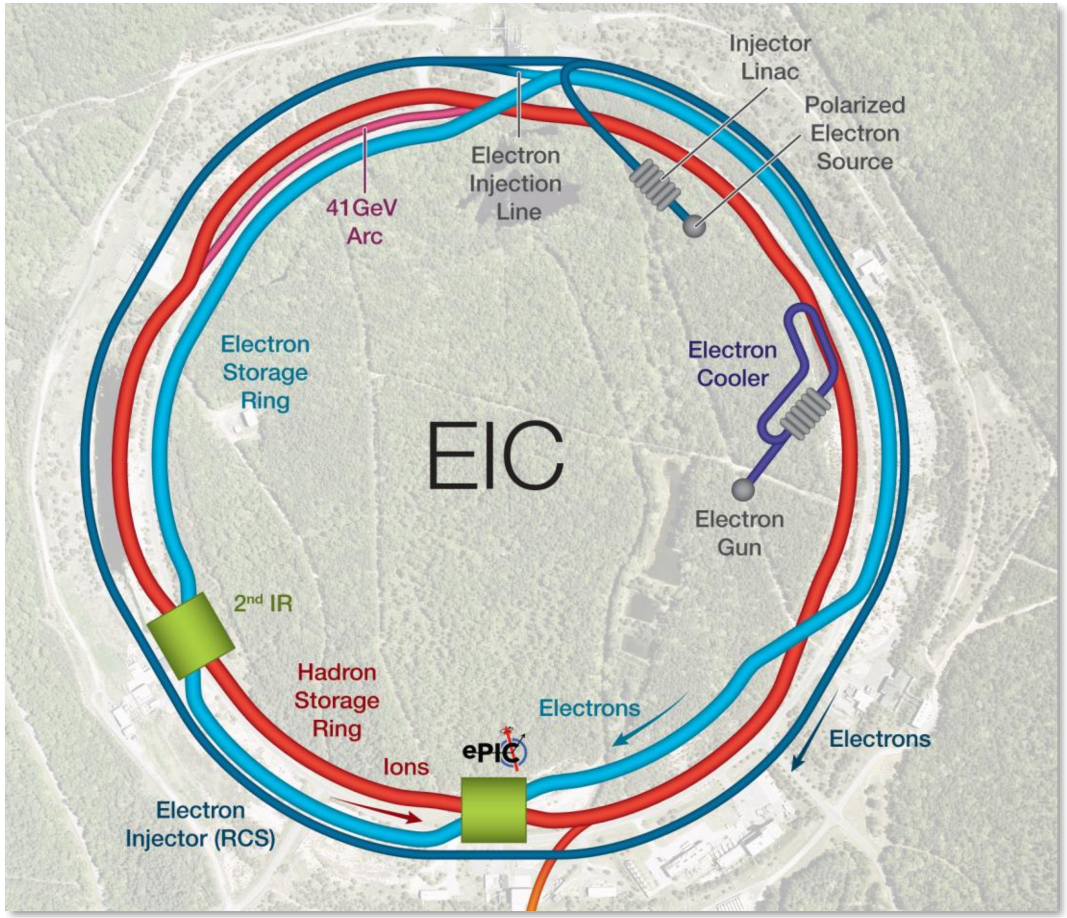


Since the electron revolution frequency is fixed, the hadron orbit must be adjusted with energy to keep the collisions in synch.

RHIC Tunnel Reuse

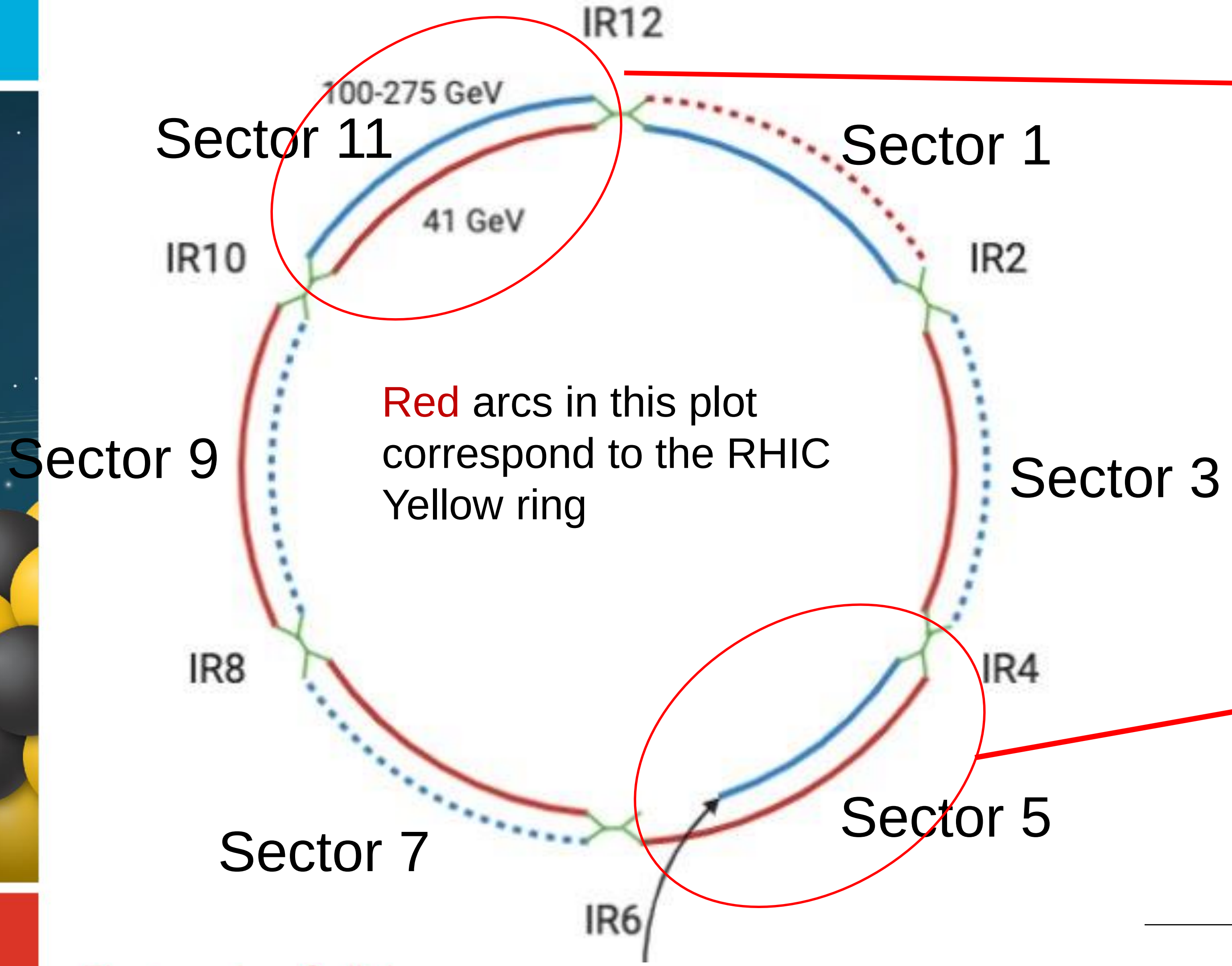


CDR concept (2021)

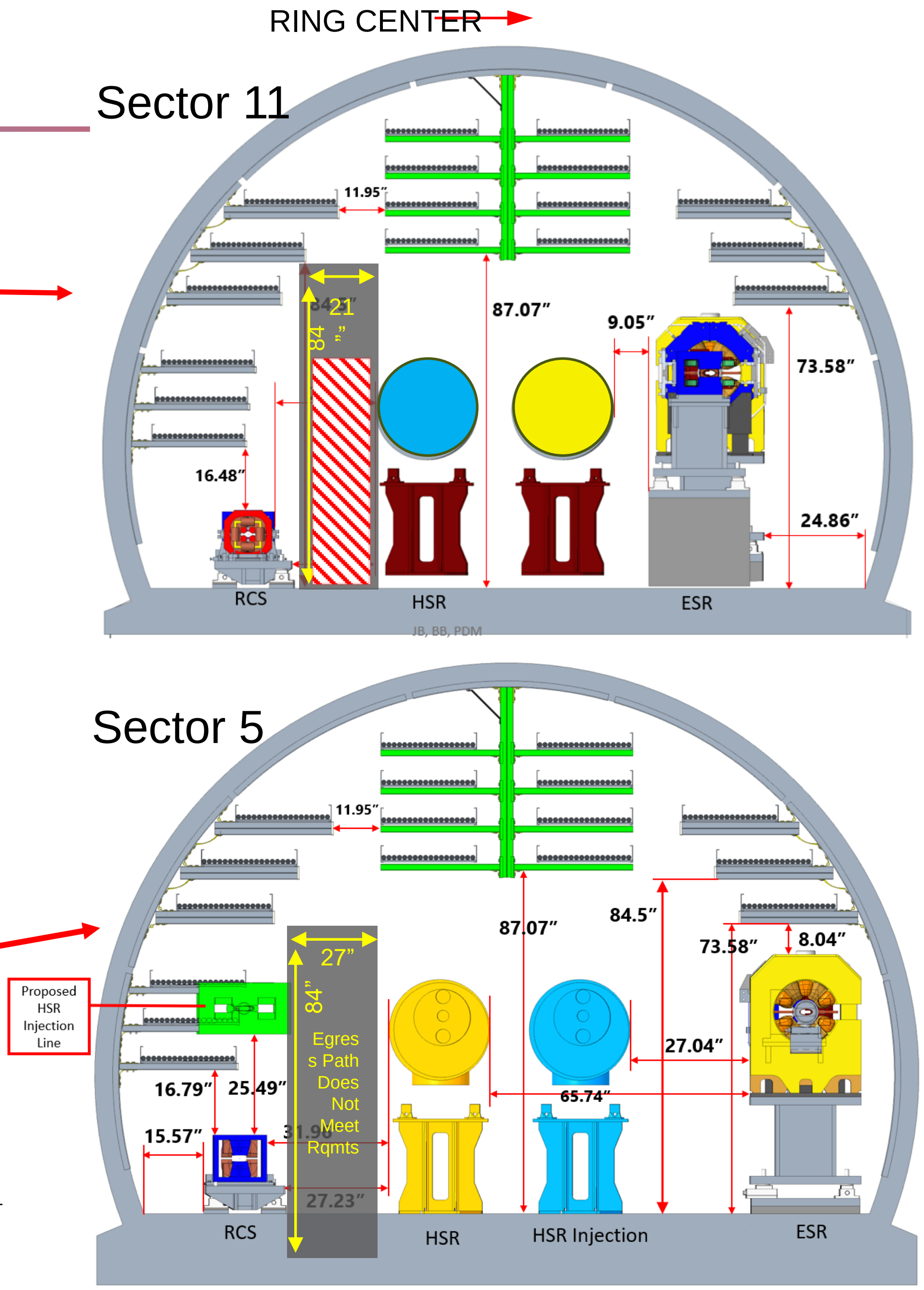


Tunnel Layout Optimization

2024: challenges identified with the CDR layout



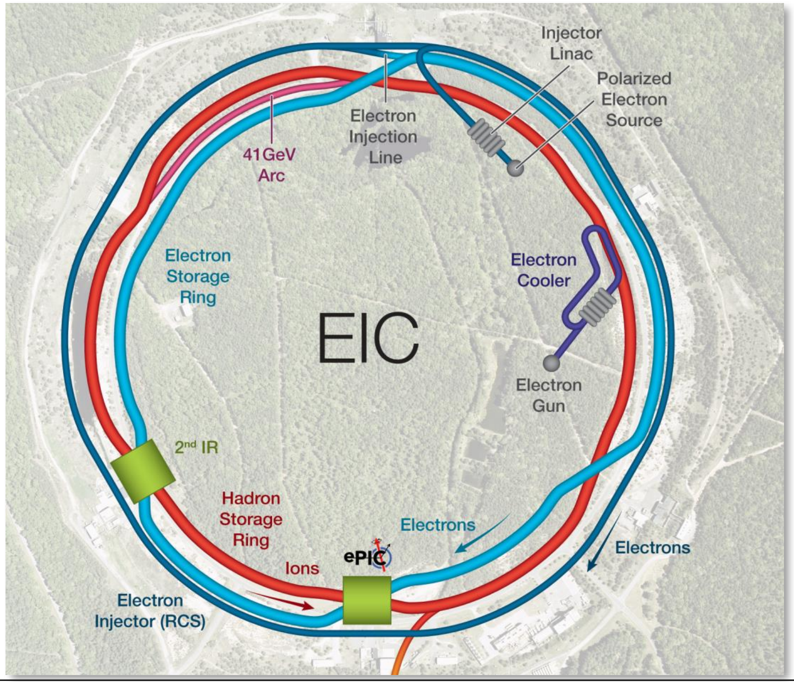
Red arcs in this plot correspond to the RHIC Yellow ring



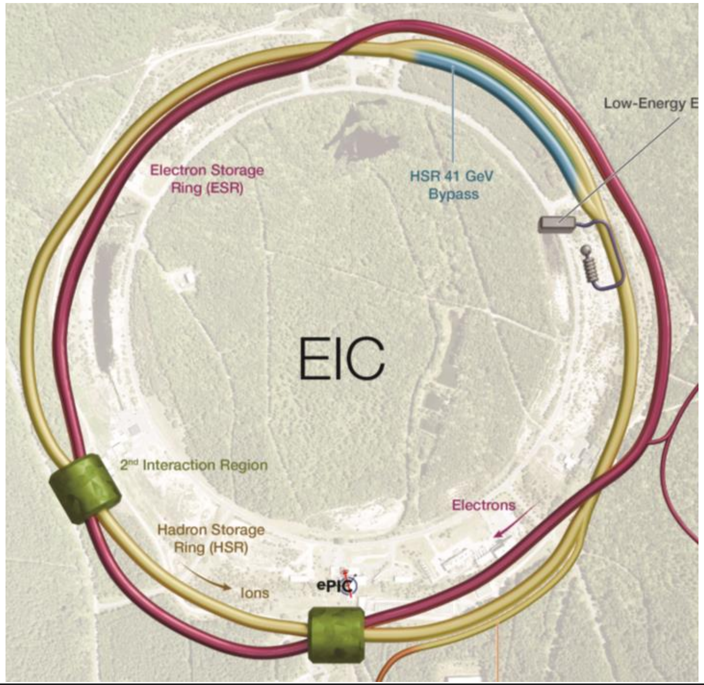
Optimization for Sector 11 and Sector 5

- Sector 11: Use the entire ‘Yellow’ RHIC ring for the HSR; remove unused Blue arcs.
  - The 41-GeV bypass, made of Blue magnets, will be installed in Sector 1 in Sub-project 4.
- Sector 5: add a new room-temperature HSR injection line; remove Blue magnets.

CDR concept (until Apr 2024 MAC)

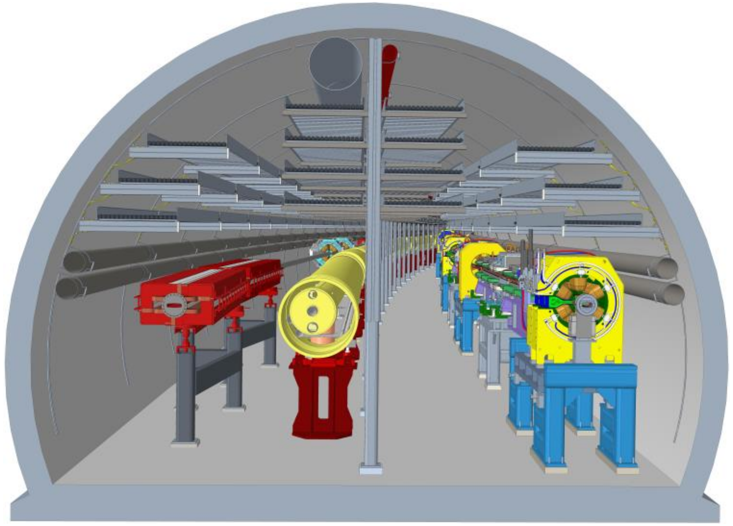


Concept now (2025)

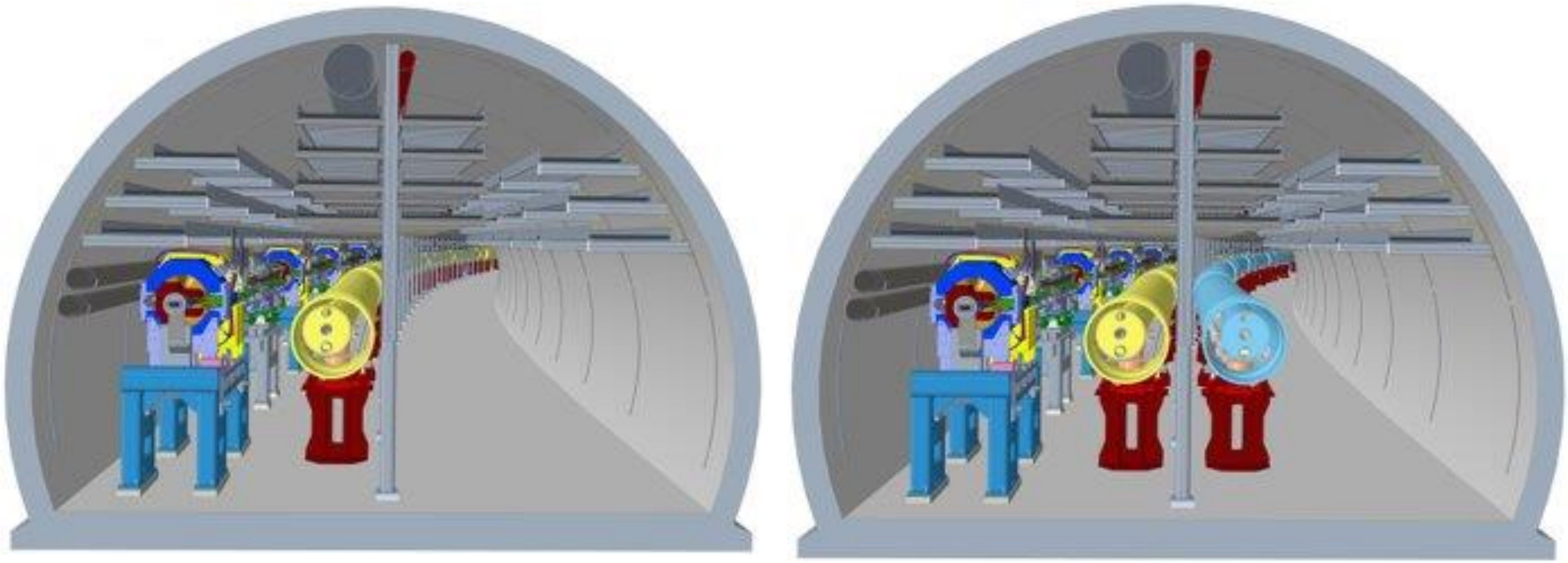


Sectors 1 and 5 now

Sector 5 with a new HSR injection line



Sector 1 without and with the 41-GeV bypass line

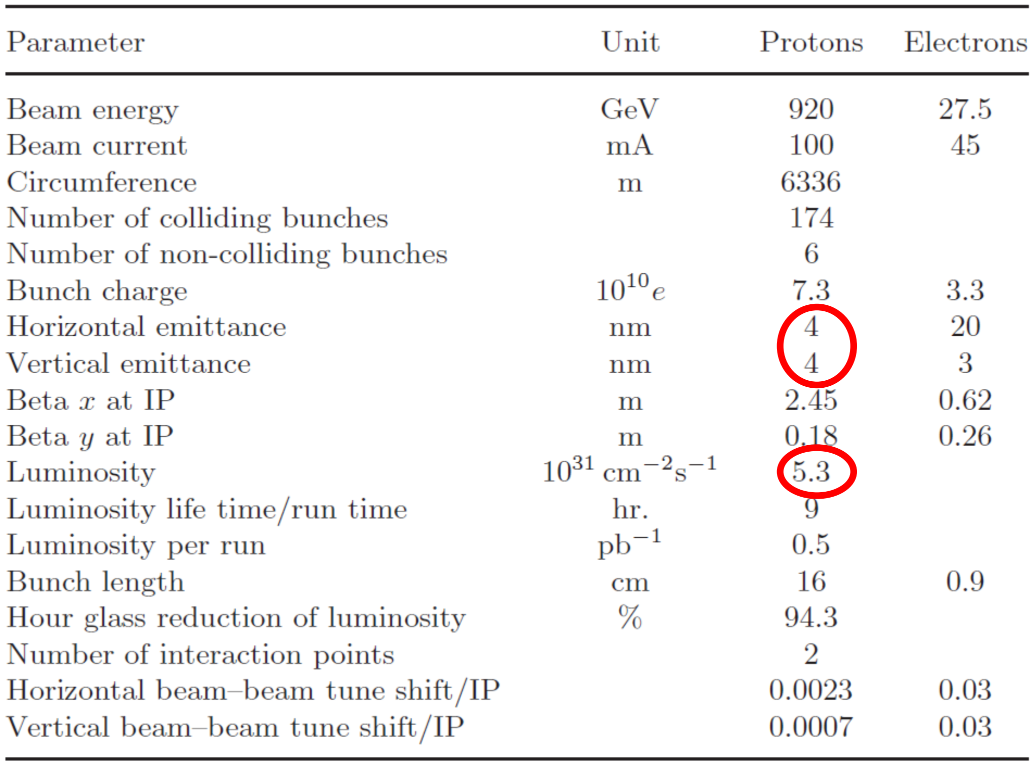


Strategy for Hadron Cooling

Design Change #3: Low Energy Electron Cooling

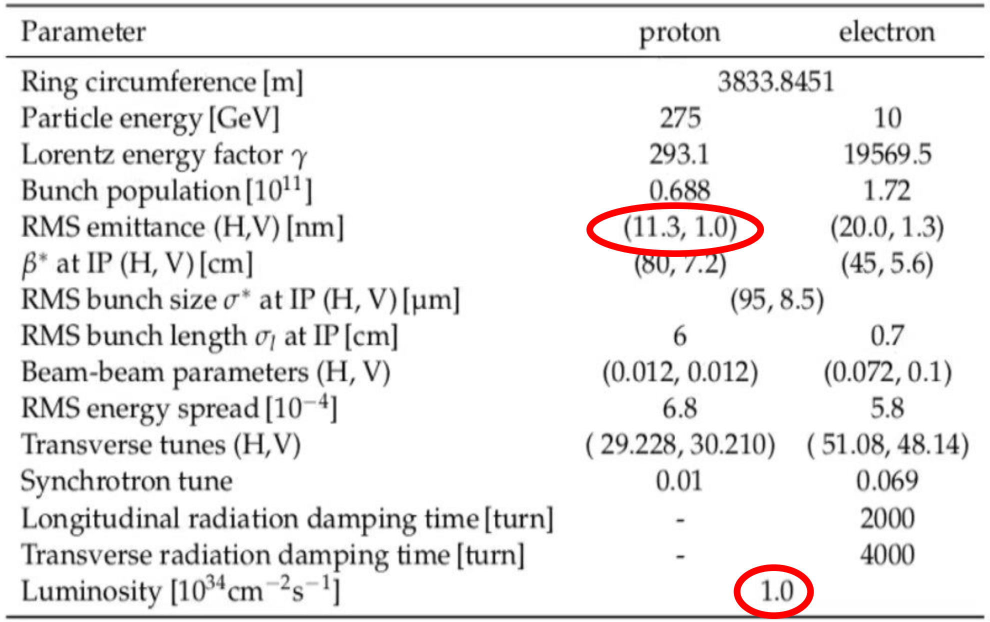
Why is beam cooling so important for the EIC?

Table 1. HERA main parameters (as achieved in routine operations).



Parameter	Unit	Protons	Electrons
Beam energy	GeV	920	27.5
Beam current	mA	100	45
Circumference	m	6336	
Number of colliding bunches		174	
Number of non-colliding bunches		6	
Bunch charge	$10^{10}e$	7.3	3.3
Horizontal emittance	nm	4	20
Vertical emittance	nm	4	3
Beta x at IP	m	2.45	0.62
Beta y at IP	m	0.18	0.26
Luminosity	10^{31} cm^{-2}s^{-1}	5.3	
Luminosity life time/run time	hr.	9	
Luminosity per run	pb^{-1}	0.5	
Bunch length	cm	16	0.9
Hour glass reduction of luminosity	%	94.3	
Number of interaction points		2	
Horizontal beam–beam tune shift/IP		0.0023	0.03
Vertical beam–beam tune shift/IP		0.0007	0.03

EIC main parameters



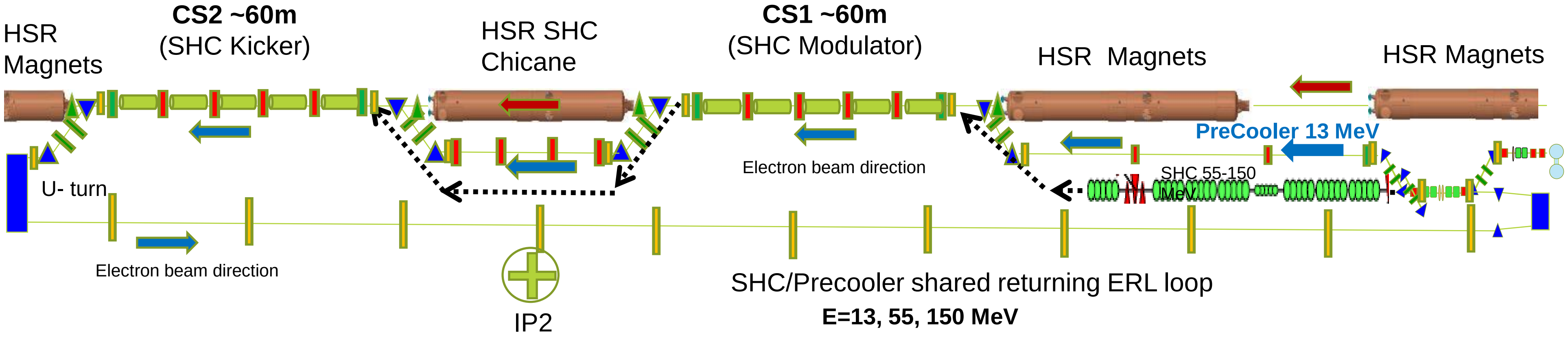
Parameter	proton	electron
Ring circumference [m]	3833.8451	
Particle energy [GeV]	275	10
Lorentz energy factor γ	293.1	19569.5
Bunch population [10^{11}]	0.688	1.72
RMS emittance (H,V) [nm]	(11.3, 1.0)	(20.0, 1.3)
β^* at IP (H, V) [cm]	(80, 7.2)	(45, 5.6)
RMS bunch size σ^* at IP (H, V) [μm]	(95, 8.5)	
RMS bunch length σ_l at IP [cm]	6	0.7
Beam-beam parameters (H, V)	(0.012, 0.012)	(0.072, 0.1)
RMS energy spread [10^{-4}]	6.8	5.8
Transverse tunes (H,V)	(29.228, 30.210)	(51.08, 48.14)
Synchrotron tune	0.01	0.069
Longitudinal radiation damping time [turn]	-	2000
Transverse radiation damping time [turn]	-	4000
Luminosity [10^{34}cm^{-2}s^{-1}]	1.0	

$$L = \frac{N_e N_p}{4\pi\sigma_h\sigma_v} N_b f_0 \approx 1\times10^{34}\ \text{cm}^{-2}\text{s}^{-1} \qquad N_b = 1160;\ f_0 = 78.3\ \text{kHz}$$

- Compared to HERA, the EIC design implements two new critical ideas:
  1. Flat proton bunches at collisions (to match the electron beam dimensions) – this helps with the peak luminosity.
  2. Continuous proton beam cooling during collisions to maintain matched beam dimensions – this helps with the average luminosity.

SHC: Background Info

- 2021: The EIC CDR focuses on SHC as a preferred alternative to (1) create flat bunches and (2) maintain emittance during collisions.
- 2023: We realize that SHC is too slow to create flat bunches at collision energy. Added a low-energy electron cooler (13 MeV) at injection, combined with SHC-CEC.

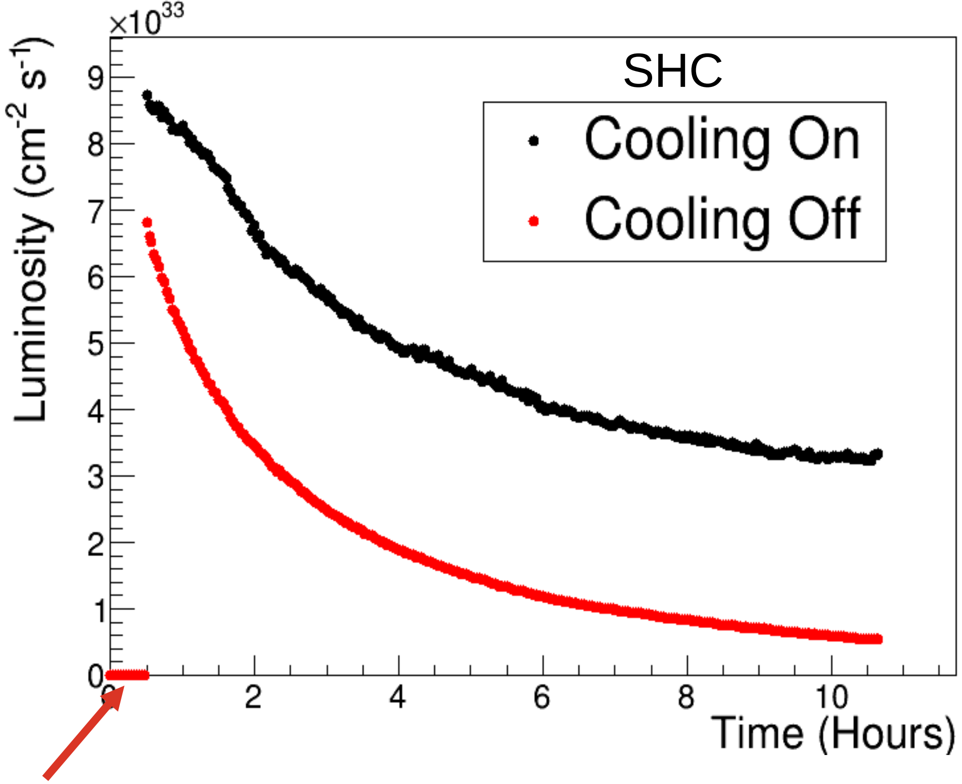


- 2024: SHC has remaining unresolved technical challenges. We developed a detailed luminosity model with and without SHC at collisions. Model assumes flat bunches, created by a low-energy electron cooler.

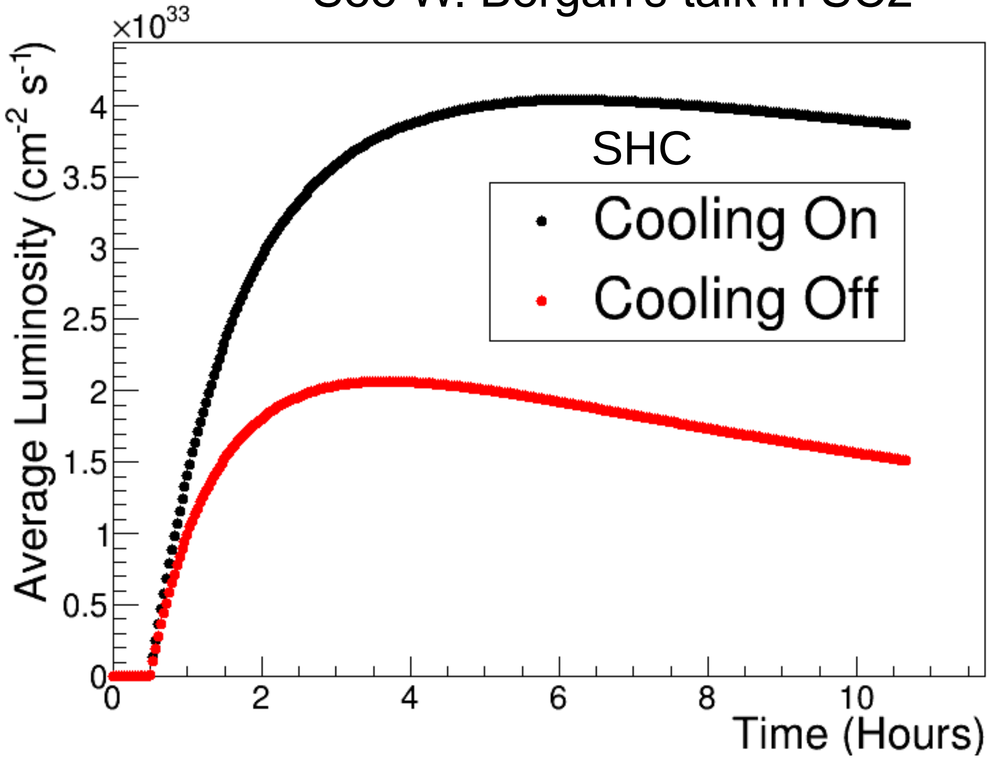
Luminosities w/wo SHC for 275 GeV p on 10 GeV e (example)

Starting collisions with "flat" proton bunches and 28-nC e bunches

See W. Bergan's talk in SC2



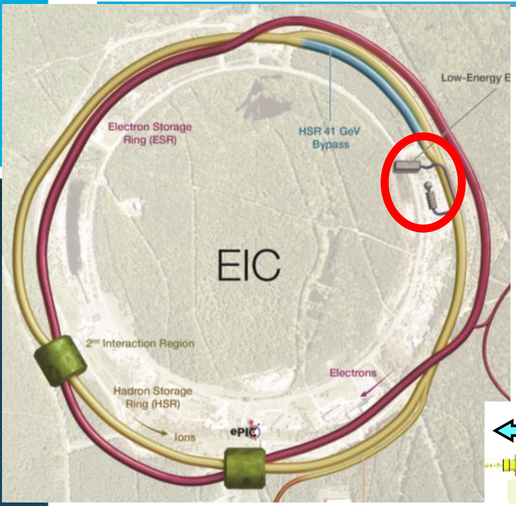
ESR fill



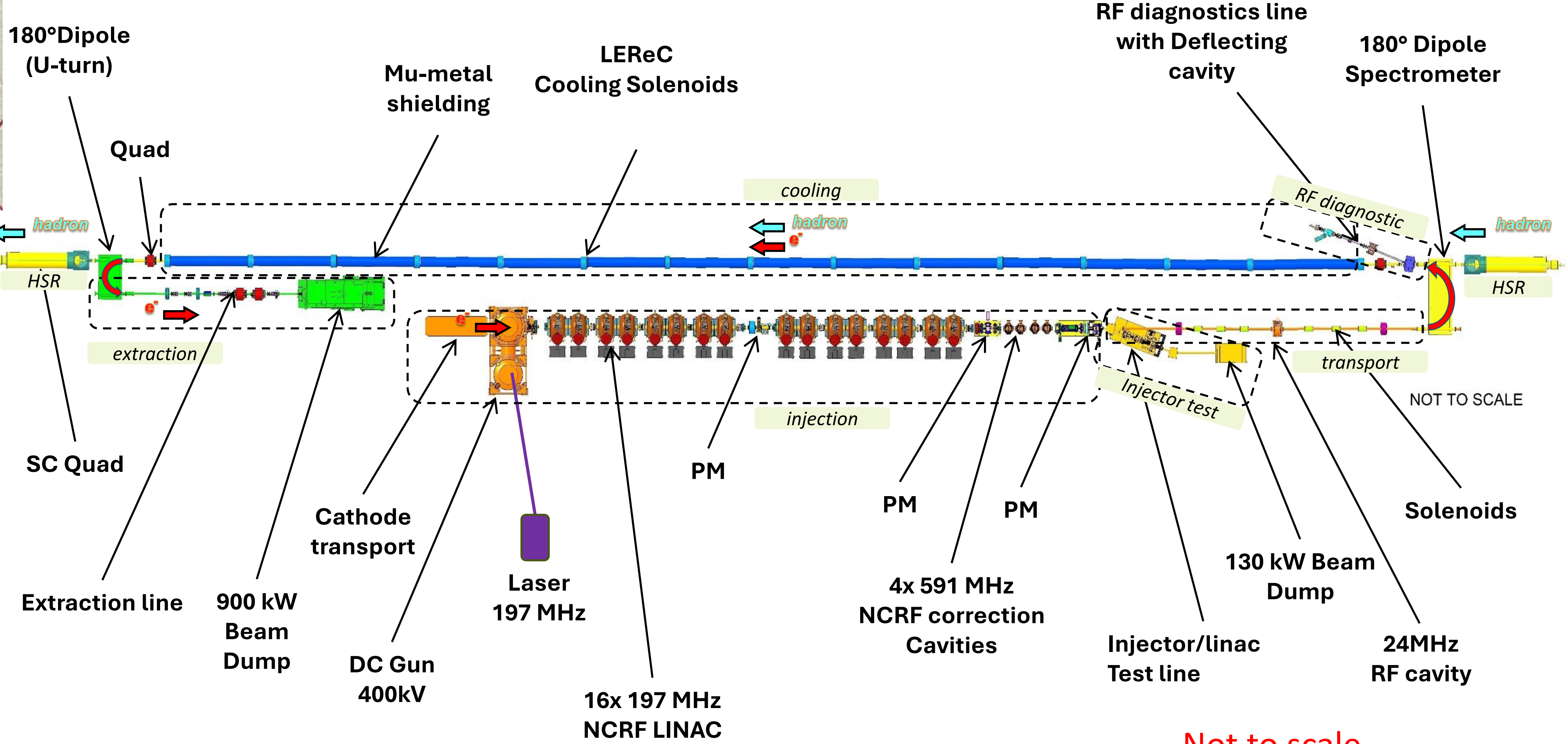
$$\text{Ave. lumi} = \frac{\text{Integral}}{\text{store length} + 2.5\ \text{hr}}$$

- Each store starts with 30 mins. precooling and 30 mins. to fill the ESR ring (~1200 bunches);
- In addition, we assume a two-hour turnaround time for filling hadrons, precooling, and ramping.

Producing ‘Flat’ Proton Bunches



See A. Fedotov’s talk in SC2



180°Dipole (U-turn)

Quad

Mu-metal shielding

LEReC Cooling Solenoids

RF diagnostics line with Deflecting cavity

180° Dipole Spectrometer

SC Quad

Extraction line

900 kW Beam Dump

Cathode transport

DC Gun 400kV

Laser 197 MHz

16x 197 MHz NCRF LINAC

PM

PM

4x 591 MHz NCRF correction Cavities

PM

Injector/linac Test line

130 kW Beam Dump

24MHz RF cavity

Solenoids

IR2 layout (all within the existing RHIC Tunnel)

Not to scale

Strategy for Hadron Cooling

- The SHC-related risk was identified as ‘HIGH’.
- To mitigate this risk, we are adding an injection electron cooler for hadrons (at 25 GeV/u) to create ‘flat’ bunches. This is a proven and tested technology. We propose to remove the SHC system from the project baseline.
  - The average luminosity would drop by a factor of two per our model, but the proposed KPPs and the MNS goals can still be met even without the SHC system.
- This downgrades the hadron cooling risk from HIGH (SHC) to LOW (Injection cooler).
- The High-Energy Cooling technology development will continue as an off-project R&D program, supported by the EIC Accelerator Collaboration.

Strategy for the Electron Injector

Design Change #4: RCS Outside the RHIC/EIC Tunnel

Electron Injector Functions

- The EIC design calls for an on-axis swap-out injection of polarized electron bunches into the ESR (see C. Montag’s talk SC2)
    - All ESR bunches to be exchanged frequently for 70% average polarization
    - Polarized electron source already exists, 85% polarization, ~11 nC bunch charge & long cathode lifetimes.
    - Rapid Cycling Synchrotron (1 Hz): special lattice & beam optics suppress depolarizing resonances.
    - Frequent swap-out injection of bunches with high initial polarization of 85%
- The Electron Injector functions
    1. Provide 7 nC (ultimately 28-nC) in a single bunch per 1 second
        - filling 1160 ESR bunches in 20 minutes (one bunch per second)
    2. Accelerate up to 10 (18) GeV with a 1-Hz cycle rat
    3. Preserve the initial polarization during acceleration (~85% min).
    4. Prepare bunch emittances to match that of the ESR, before bunch transfer

Typically, this would require an extra ring (e.g., LEP, APS, ALS-U, etc.).

An ‘Ideal’ Electron Injector

1. A full-energy linac (5, 10, 18 GeV) – preserves polarization!
2. Followed by a fixed-energy accumulation ring (preserves polarization), similar to the ESR, to prepare bunches for ‘swap-out’ injection

…However, such a linac (18 GeV -> ~ 1 km long) and an 18 GeV storage ring would be costly. Thus, to reduce the costs, the project has initially made a decision to use a low energy linac and thus, accumulate and accelerate in an RCS (rapid cycling synchrotron).

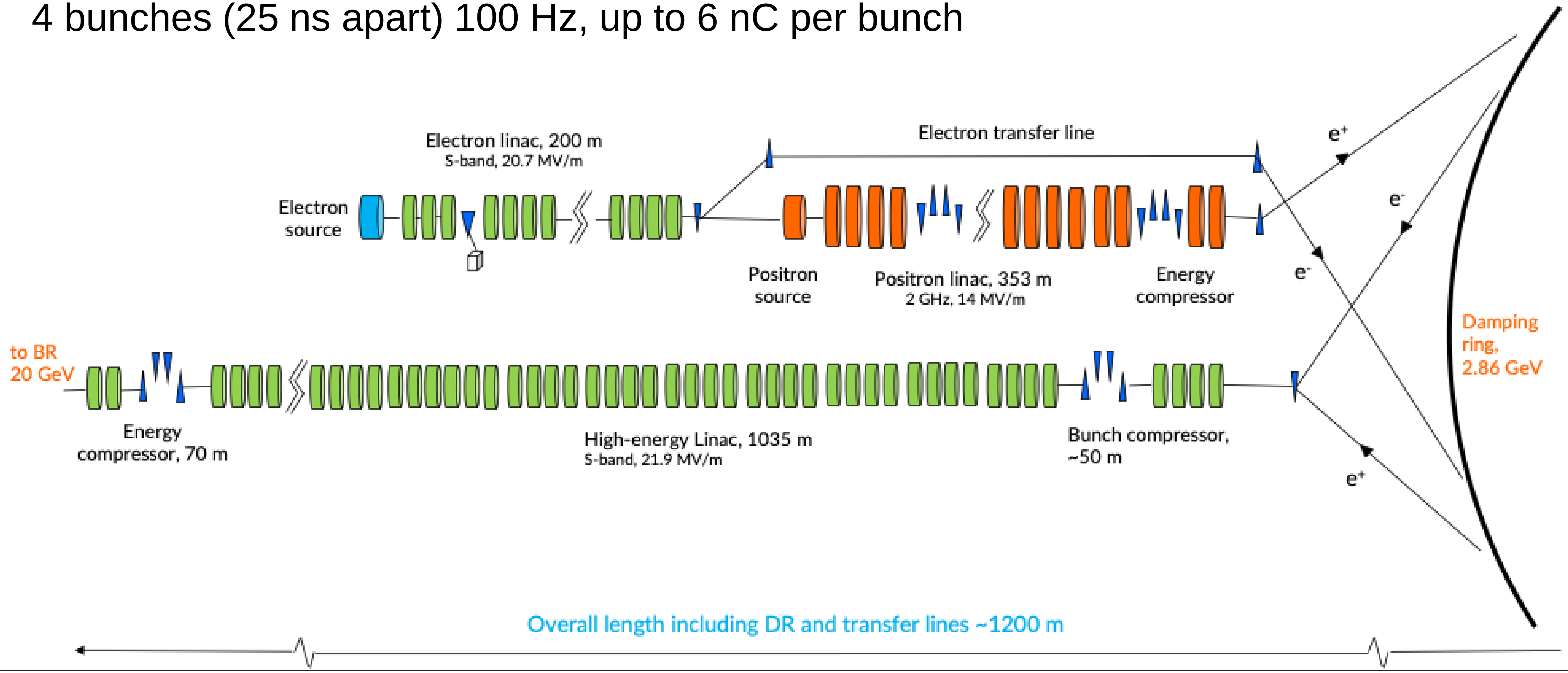
Notice that modern light sources with swap-out injection have a linac and two rings:

APS-U: Linac, Accumulator, Booster

ALS-U: Linac, Booster, Accumulator

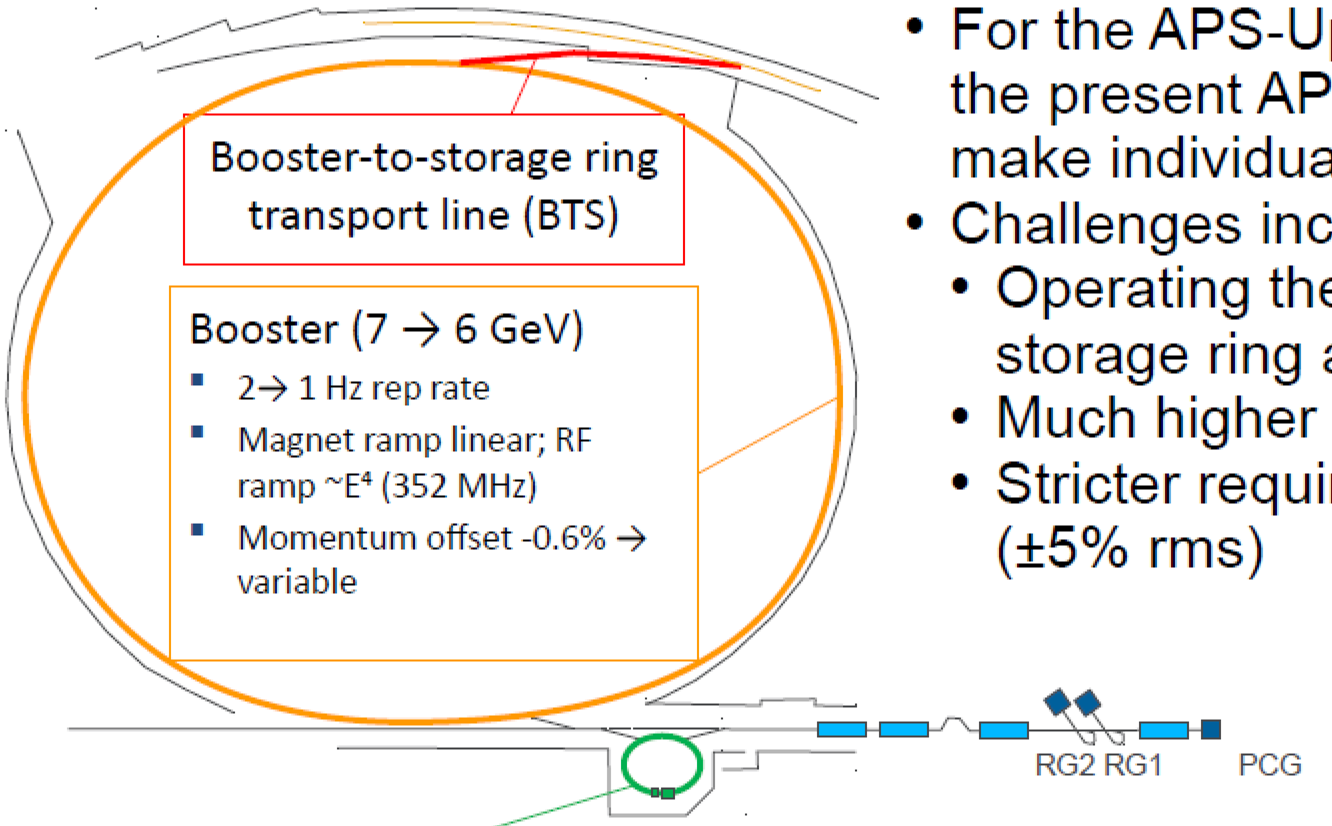
FCC Injector (concept)

- Copper linac
- 4 ASs for module
- 4 bunches (25 ns apart) 100 Hz, up to 6 nC per bunch



APS → APS-U injector chain

- For the APS-Upgrade, it was decided to leave the present APS injector chain in place and make individual improvements where needed.
- Challenges include:
  - Operating the booster synchrotron and storage ring at different rf frequencies
  - Much higher charge per bunch (up to 16 nC)
  - Stricter requirement for charge stability (±5% rms)

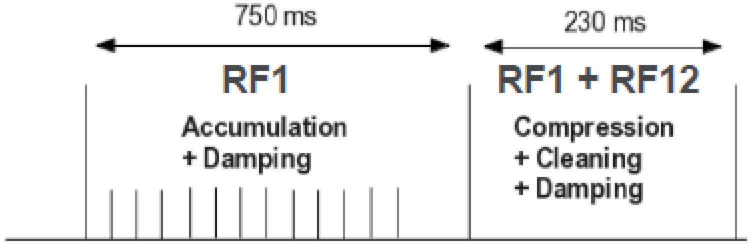


Booster-to-storage ring transport line (BTS)

Booster (7 → 6 GeV)
- 2→ 1 Hz rep rate
- Magnet ramp linear; RF ramp ~E^4 (352 MHz)
- Momentum offset -0.6% → variable

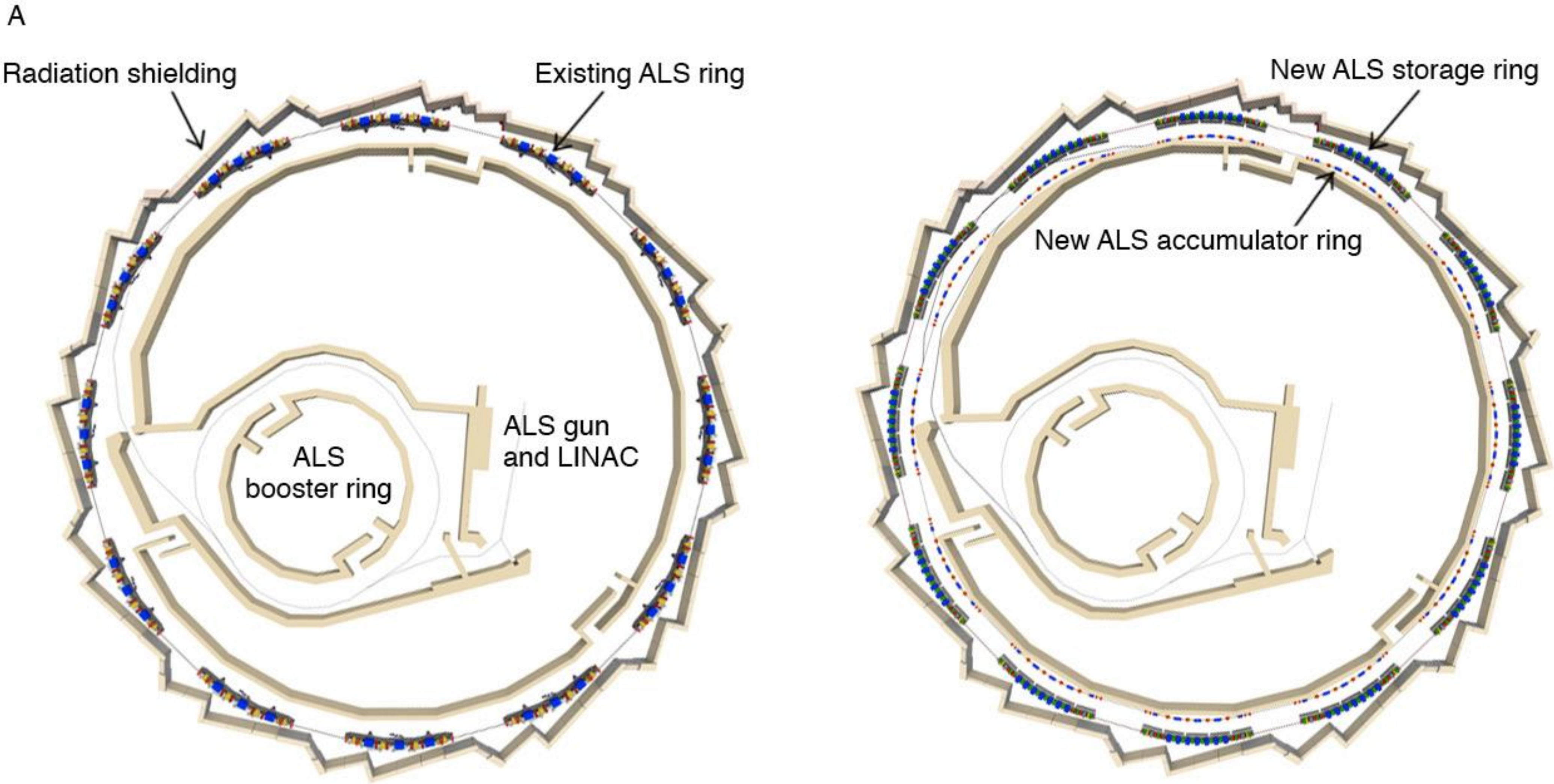
Particle accumulator ring (PAR) (425 → 475 MeV)
- Single bunch; 2 → 1-Hz rep rate
- Captures linac pulses in RF1 (9.8 MHz); compresses damped beam in RF12 (117 MHz)

Linac (425 → 475 MeV)
- 1 nC/pulse; 30 Hz rep rate
- Thermionic RF guns: RG1, RG2 (1 hot spare)

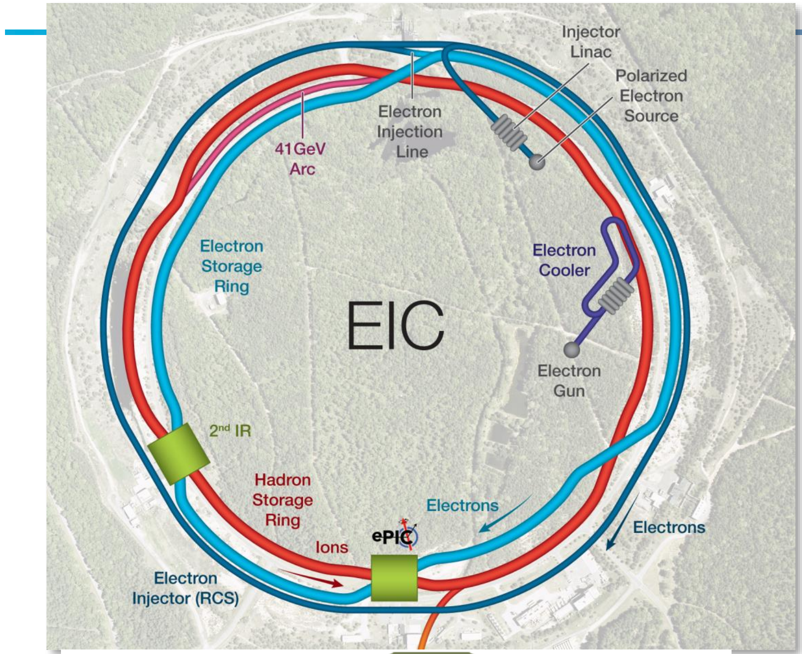


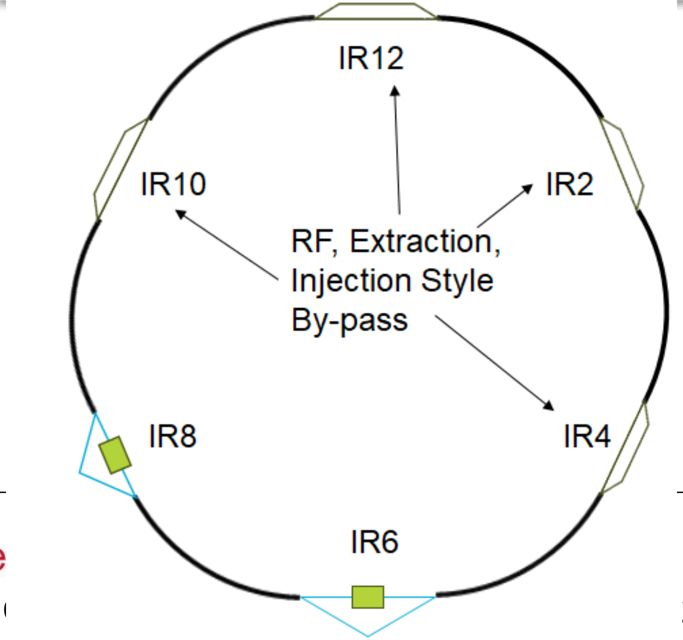
PAR cycle

ALS-U Concept



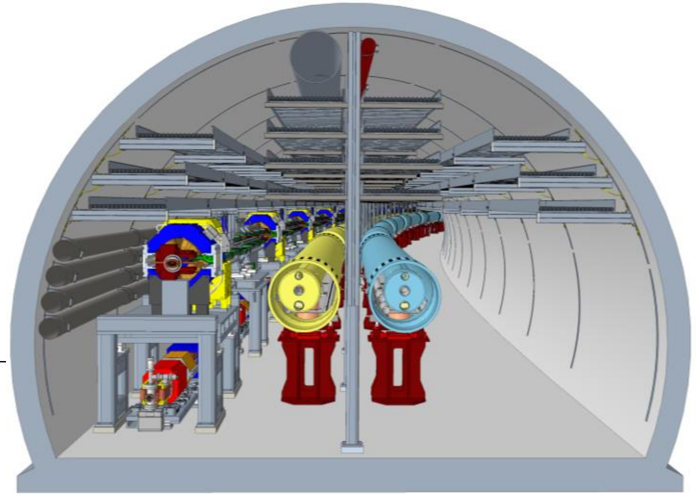
The EIC CDR (2021) Concept: 400 MeV linac + RCS (0.4 -> 18 GeV)





RCS Performance risks:

1. Magnetic (dipole) fields at injection are too low (~50 G).
    - Magnetic shielding requirements not well understood
2. No synchrotron radiation damping at injection because of low beam energy.
    - Beam accumulation is challenging.
3. Bunches are unstable because of high charge, long ring circumference, and low energy.
4. The RCS placement into the existing RHIC tunnel is leading to a highly non-optimal design. Also, presents a challenge to installation and future EIC operations (maintenance and servicing of the RCS)



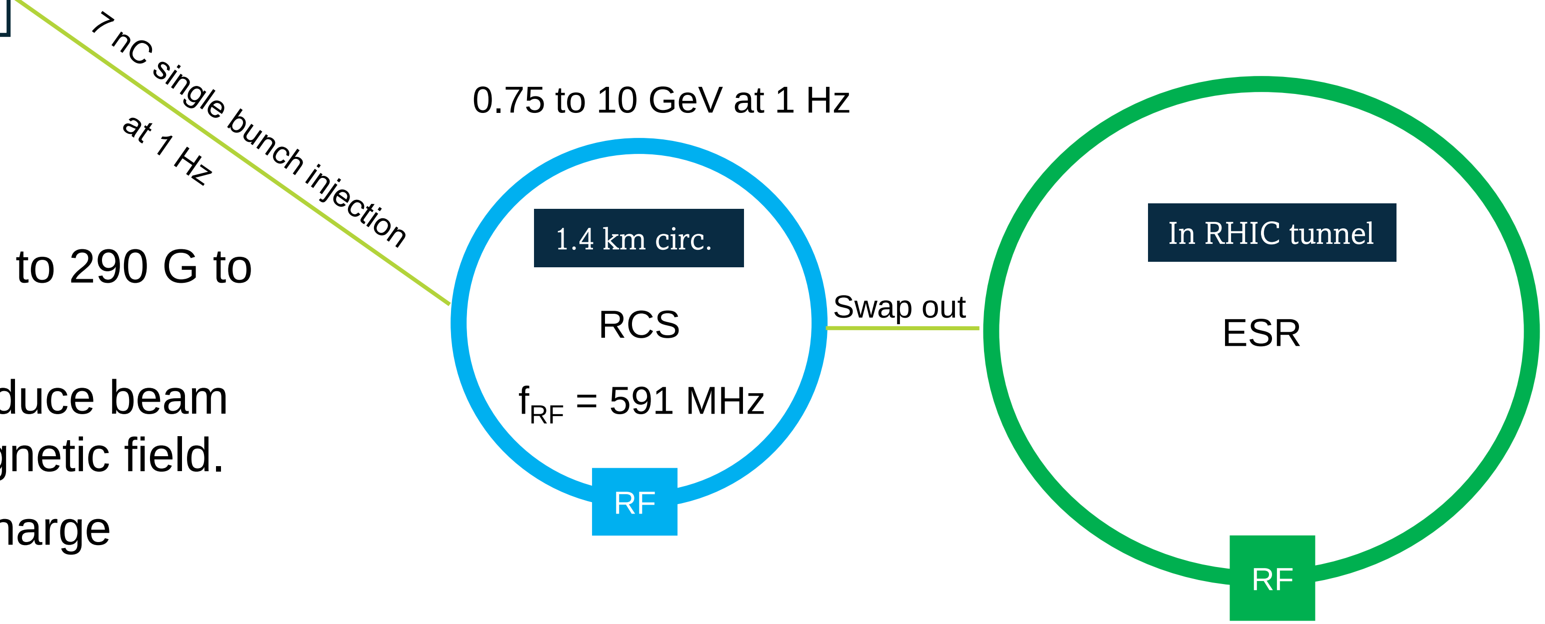
RCS Decision Timeline

- Director’s Review (Oct. 2023): Identified many RCS design challenges
- EIC MAC (April 2024): Supported the change of injection energy to 3 GeV
  - This mitigated some risks and challenges, but not all.
- June 2024: EIC adopts a new 3-GeV injector linac (SRF, 1.3 GHz).
  - External review, chaired by John Galambos (SNS)
- Beam stability and beam accumulation challenges persist.
- More tunnel installation challenges identified.
  - RF cavities require large vertical clearance.
- Oct. 2024: EIC Director’s Review questions our costs and linac design choices.
- Nov. 2024: EIC Performance retreats – we make the decision to remove the RCS from the RHIC tunnel.
- Dec. 2024: Document “Decision and Rationale for Removing the EIC RCS from the RHIC/EIC Tunnel” posted.

New Concept of the Electron Injector

New Concept

750 MeV linac @ 1.3 GHz Superconducting RF



7 nC single bunch injection at 1 Hz

0.75 to 10 GeV at 1 Hz

1.4 km circ.

RCS

f_{RF} = 591 MHz

RF

Swap out

In RHIC tunnel

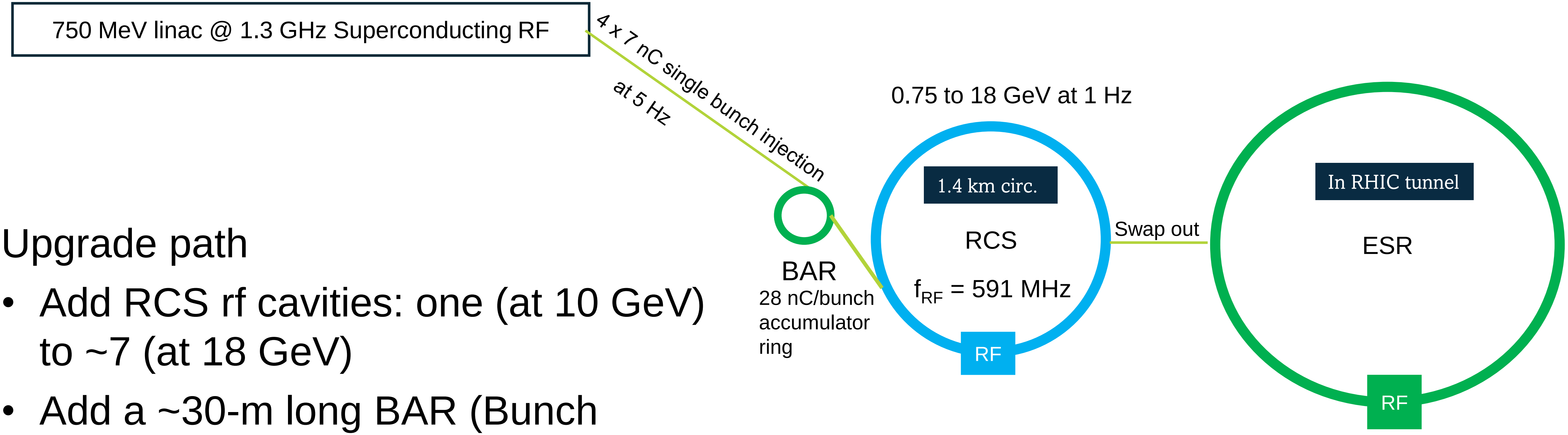
ESR

RF

Improvements from baseline

- Increased RCS dipole field from 56 G to 290 G to avoid low-field magnets.
- Increased RCS injection energy to reduce beam affected by eddy current induced magnetic field.
- Lower linac frequency to open high charge (>10nC) bunch option
- Add spin rotation option at low energy
- RCS is upgradeable to 18 GeV and 28 nC/bunch

Electron Injector upgrade path



750 MeV linac @ 1.3 GHz Superconducting RF

4 x 7 nC single bunch injection

at 5 Hz

0.75 to 18 GeV at 1 Hz

BAR
28 nC/bunch
accumulator
ring

1.4 km circ.

RCS

f_{RF} = 591 MHz

RF

Swap out

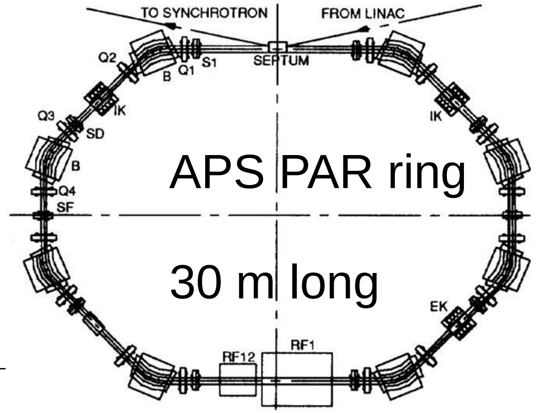
In RHIC tunnel

ESR

RF

Upgrade path

- Add RCS rf cavities: one (at 10 GeV) to ~7 (at 18 GeV)
- Add a ~30-m long BAR (Bunch Accumulation Ring) to accumulate 4 x 7-nC bunches = 28 nC/bunch

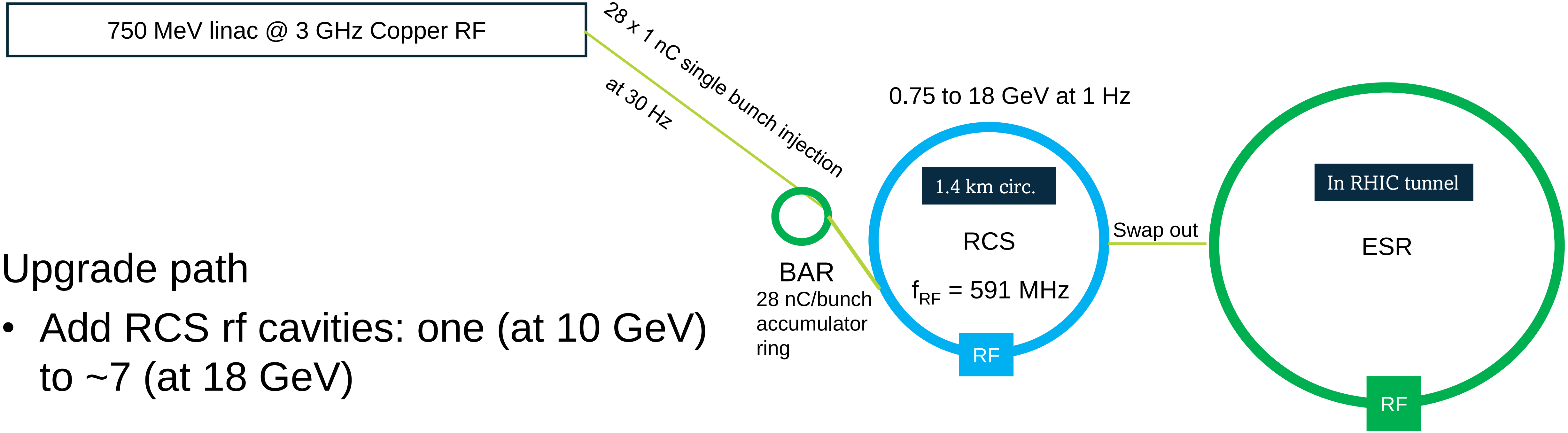


APS PAR ring

30 m long

Figure 3
Plan view of the PAR

Electron Injector (alternative concept)



750 MeV linac @ 3 GHz Copper RF

28 x 1 nC single bunch injection

at 30 Hz

BAR

28 nC/bunch accumulator ring

0.75 to 18 GeV at 1 Hz

1.4 km circ.

RCS

f_{RF} = 591 MHz

RF

Swap out

In RHIC tunnel

ESR

RF

Upgrade path

- Add RCS rf cavities: one (at 10 GeV) to ~7 (at 18 GeV)

The down-select between SRF and Copper linac will be made before Apr 2025

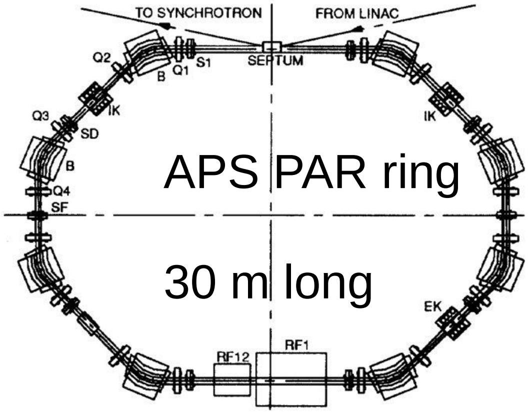


Figure 3
Plan view of the PAR

Present EIC Concept (2025)

Ultimate EIC Performance Parameters:

- High Luminosity: L= 10^{33} – 10^{34}cm^{-2}sec^{-1}
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: Ecm = 28 – 140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Forward Acceptance and Low-Background Conditions
- Possibility to Implement a Second Interaction Region (IR)

Accelerator Status in a glance:

✓ Polarized ion/proton source

✓ Ion injection and initial acceleration systems – Linac (200 MeV), Booster (1.5 GeV), AGS (25 GeV)

UPGRADE Hadron Storage Ring (40-275 GeV) – HSR

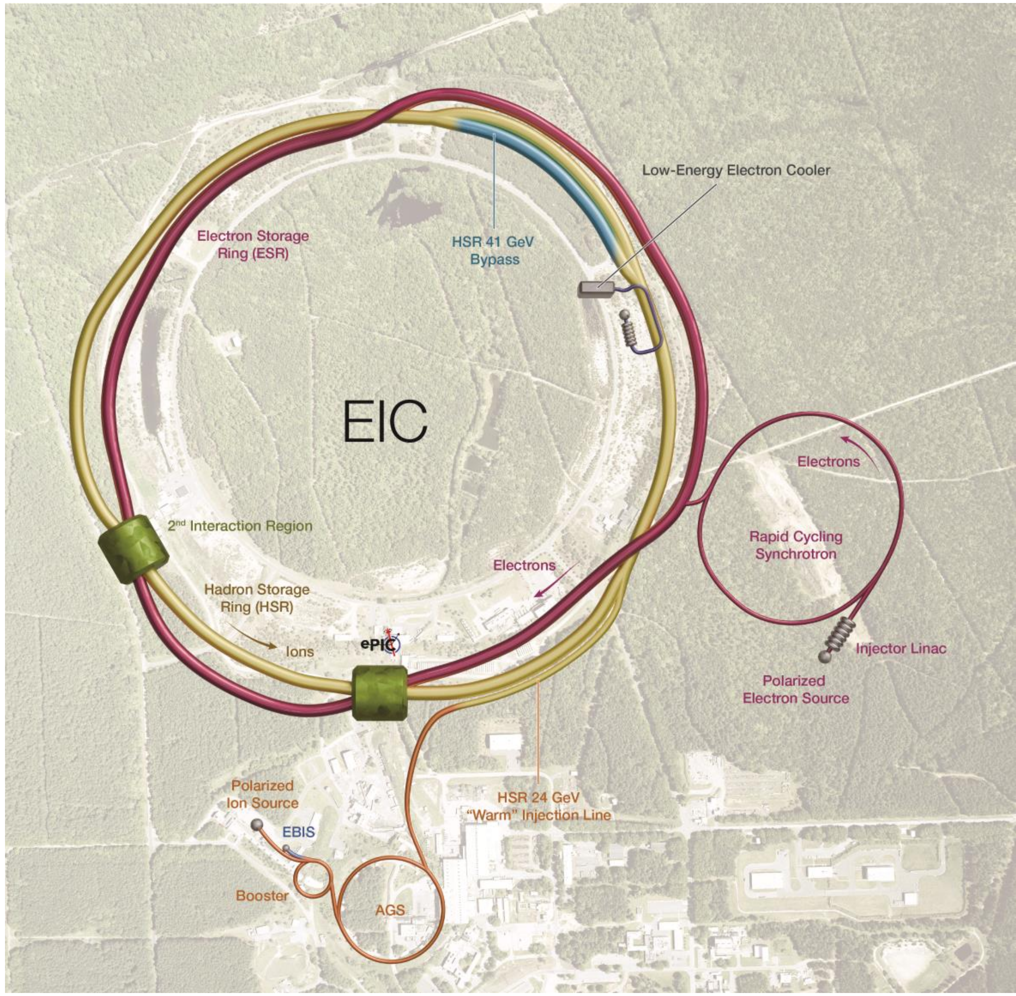
NEW Electron Pre-Injector (750 MeV linac) – EPI

NEW Electron Rapid Cycling Synchrotron (0.75 GeV – top energy) – RCS

NEW Electron Storage Ring (5 GeV – 18 GeV) – ESR

NEW Interaction Region(s) – IR

NEW Hadron Injection Cooling System



Summary of Proposed Major Design Changes

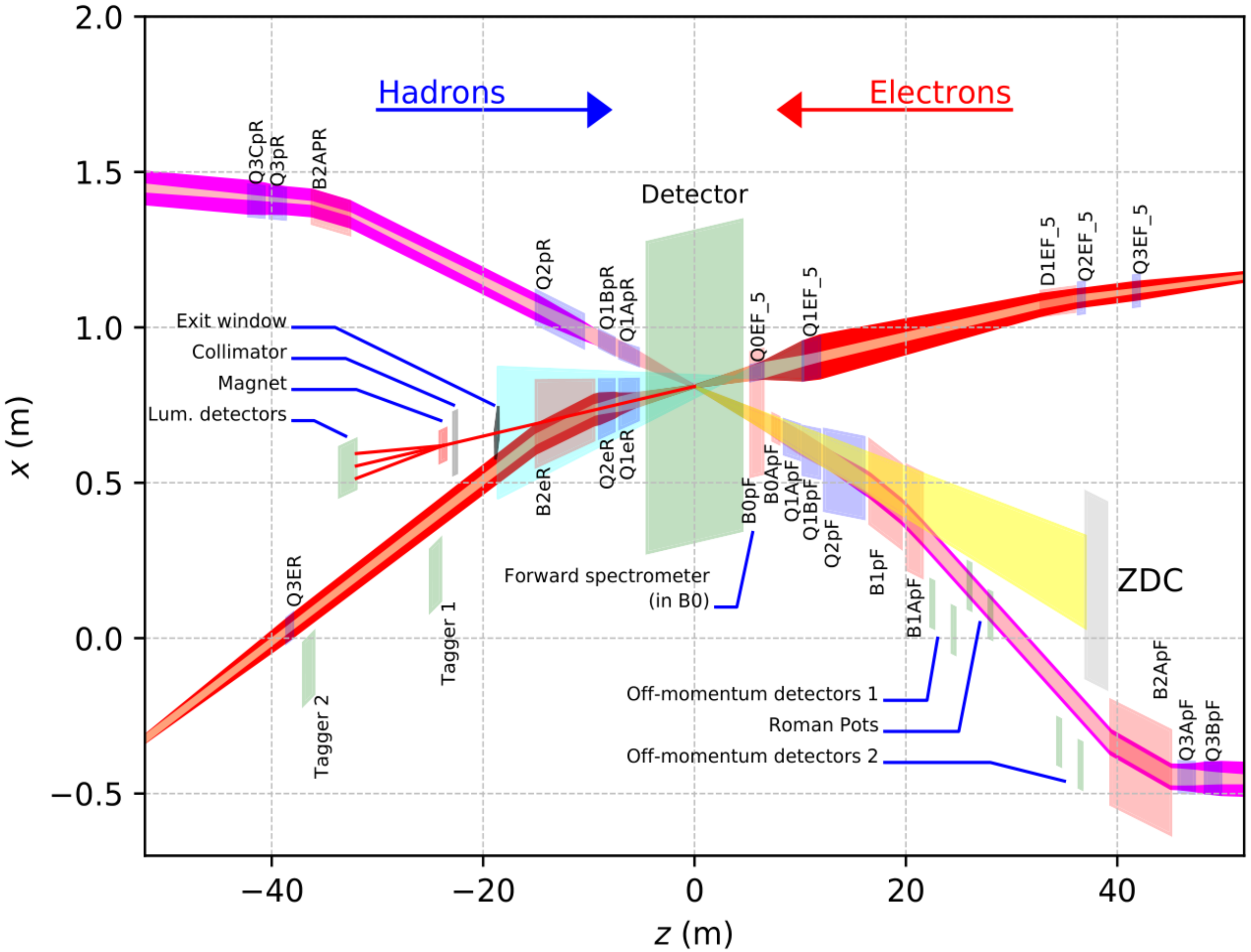
1. Reuse all Yellow ring, delay the 41-GeV bypass (savings: $)
2. Implement a new room-temperature HSR injection line (savings: $)
3. Drop SHC, add LEC (savings: $$)
4. Move RCS out of the collider tunnel (in progress)

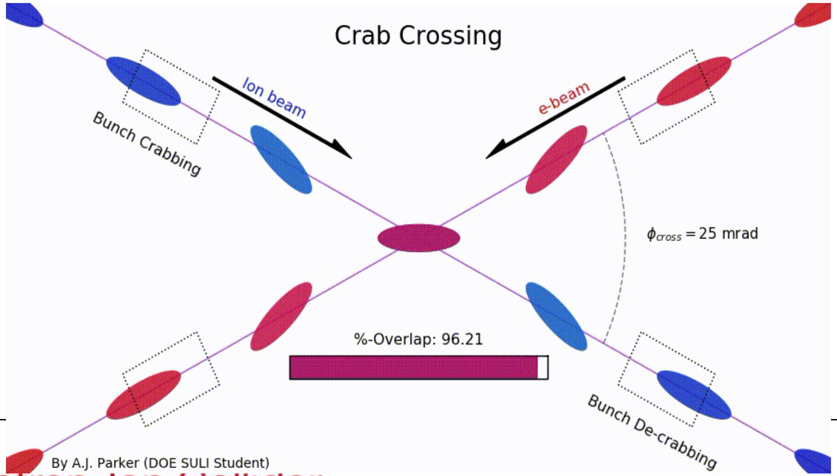
5. Delay 28 nC/bunch and 18 GeV capability implementation

EIC IR6 Layout

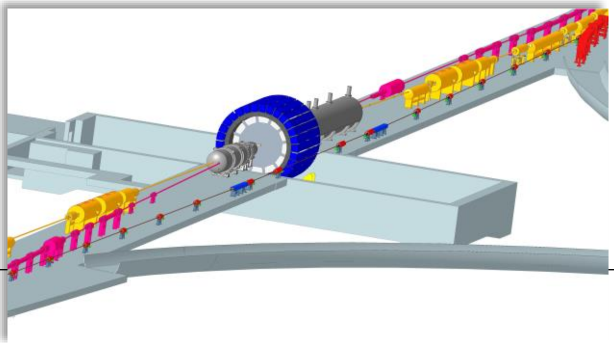
High Luminosity:
- 25 mrad crossing angle
- Small β* for high luminosity with limited IR chromaticity contributions
- Large final focus quadrupole aperture

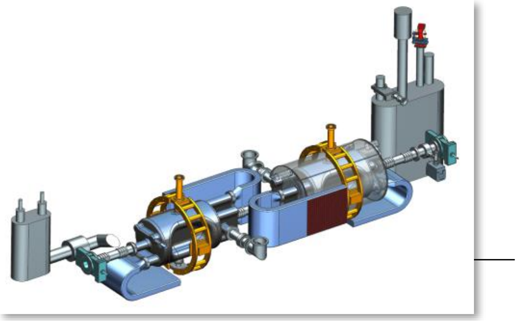
Machine Detector Interface
- Large detector acceptance
- Forward spectrometer
- No magnets within - 4.5 / +5 m from IP
- Space for luminosity detector, neutron detector, “Roman Pots”





By A.J. Parker (DOE SULI Student)





EIC Near-detector IR Layout

High luminosity:

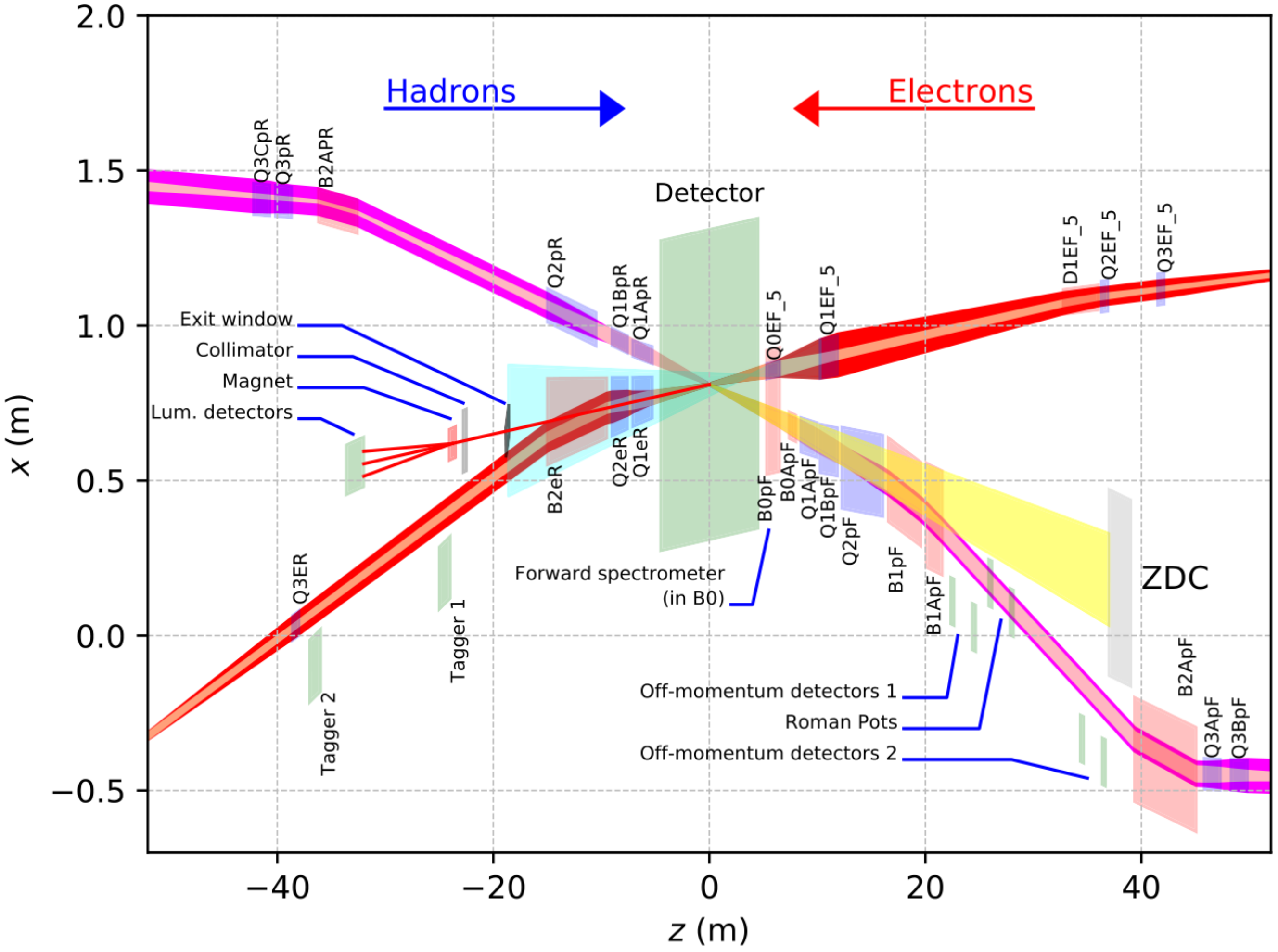
- Small β* for high luminosity
- Limited IR chromaticity contributions
- Large final focus quadrupole aperture

Physics requirements:

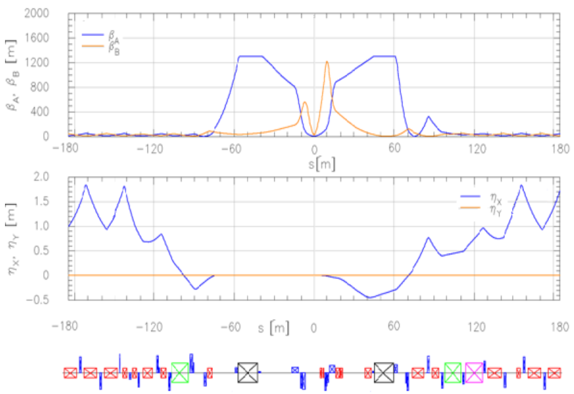
- Large detector acceptance for forward-scattered particles, and safe passing of synchrotron radiation fan – even larger magnet apertures
- Forward spectrometer
- No machine elements within +/- 4.5m from the IP
- Space for luminosity detector, neutron detector, “Roman Pots”

Multi-stage separation:

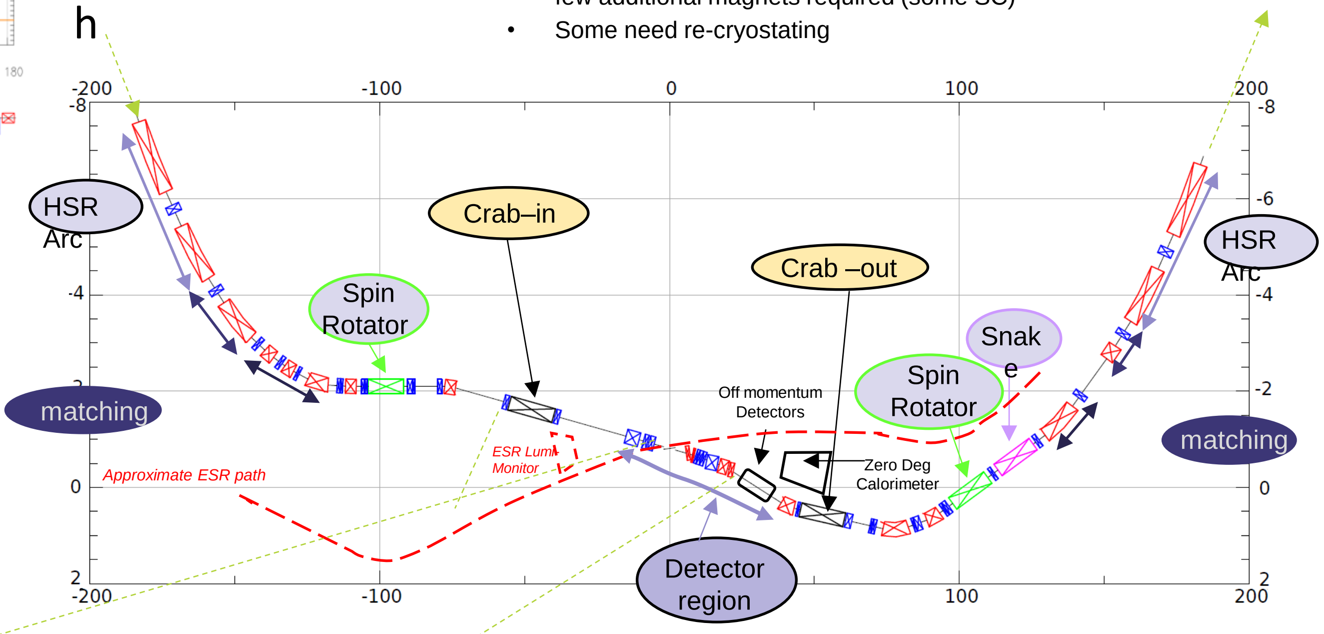
- Electrons from protons – 25 mrad crossing angle
- Protons from neutrons – separator dipole
- Electrons from Bethe-Heitler photons for luminosity monitoring – separator dipole

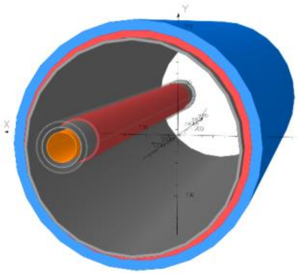


HSR layout at IR6



- Forward and rear hadron lattice matched into RHIC
  - Snake at correct angle
  - Beta = 1300m at crab cavities
    - Hor. phase advance 90º
  - Matching Magnets
    - Mostly repurposed RHIC magnets
    - few additional magnets required (some SC)
    - Some need re-cryostating

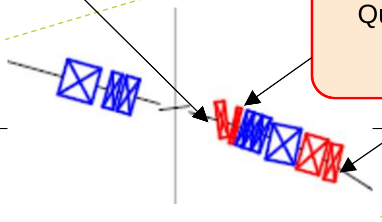




B0pF spectrometer

Nov 2021 layout

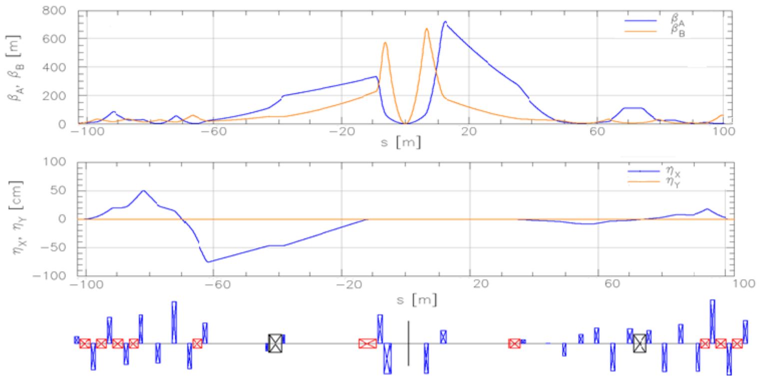
3 Dipoles and 3 Quadrupoles in one shared cryostat

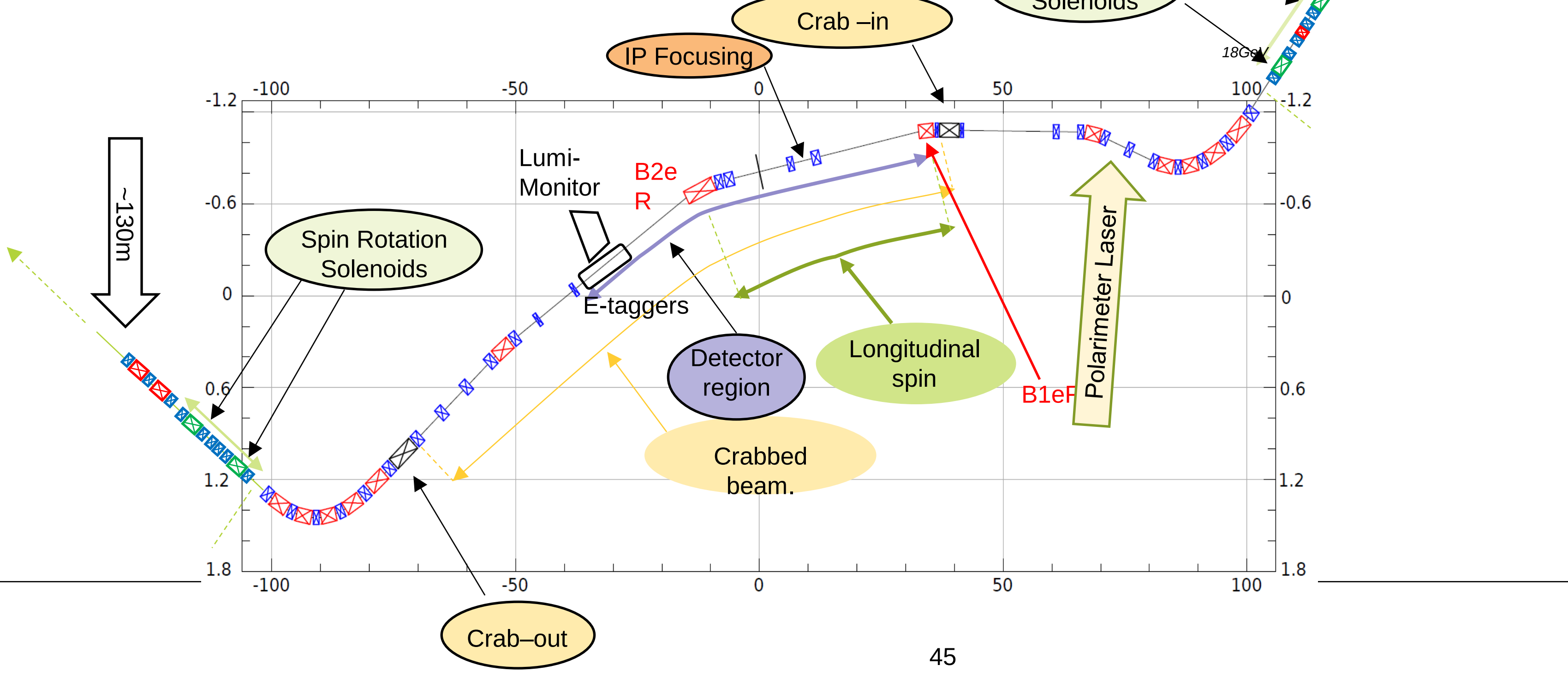


ESR layout at IR6

Design to:

- Provide room for detector components
- Mitigate synchrotron radiation issues
- Provide longitudinal spin (new spin rotators)
- Match into the arcs
- Provide conditions for crabbing
- Allow 3 rings and beam elements





Summary

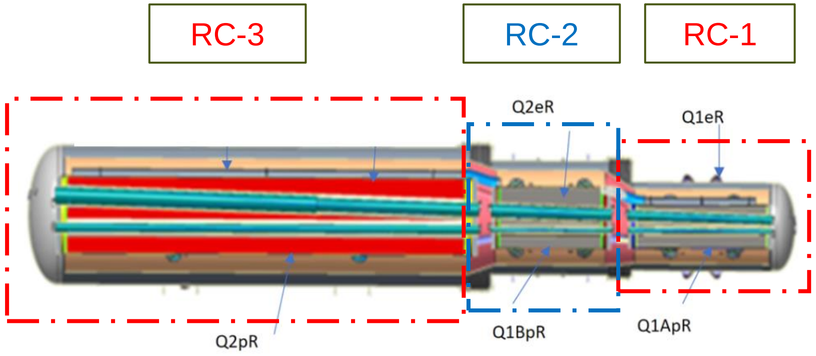
- **All EIC design elements are progressing well!**
- **Some project scope** is well developed, designs are mature, **ready to be executed as Long-lead procurements**
- We made several project design decisions to increase the design maturity and decrease risks.
  - There is no change to the current preliminary performance parametrs and no change to the EIC cost objective.
- We understand what we need to build to deliver EIC!

Backup Slides

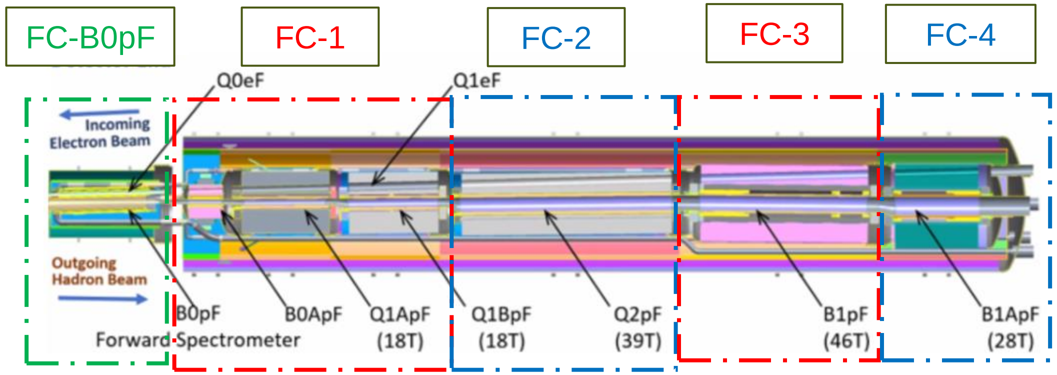
Direct Wind Magnets (current plan)

9 Total

Magnet Designation	Magnet Type	Pole Tip Field (T)	Aperture R [mm]	Possible Other Manufacturers	IR Location (Cryostat)	Comments
Q1ApR	Quad (CCT)	2.0	26-28	Consensus is NO (best to leverage SMD's experience)	Rear Cryostat #1	~
Q1eR	Quad (CCT)	0.78	66-79			~
Q1BpR	Quad (Serpentine)	2.2	28		Rear Cryostat #2	~
Q2eR	Quad (Serpentine)	0.9	83-94			~
Q2pR	Quad (Serpentine)	1.84	54		Rear Cryostat #3	~
B0ApF	Dipole (CCT)	3.3	43		Forward Cryostat #1	~
Q1eF	Quad (Serpentine)	0.5	63			~
B0pF	Dipole/Quad (Serpentine)	1.3	320		B0pF Cryostat	Cryostat outlined in green below
Q0eF	Quad (Serpentine)	0.4	48			



Detector Here



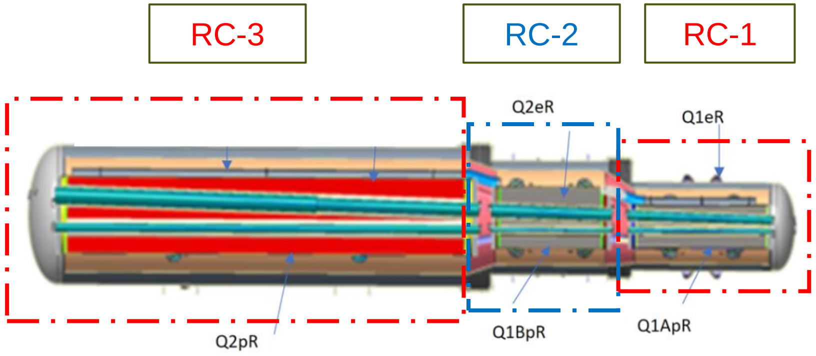
CCT = Canted Cosine Theta

Cable Magnets (current plan)

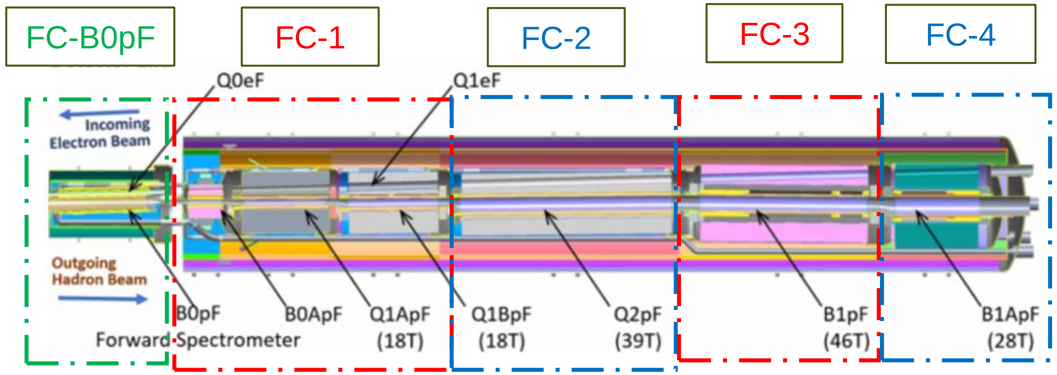
5 Total
(see note)

Magnet Designation	Magnet Type	Pole Tip Field (T)	Aperture R [mm]	Possible Other Manufacturer	Candidate for DW or B&K	IR Location (Cryostat)	Comments
Q1ApF	Quad	4.07	56	Industry/FNAL?	DW or B&K (Q1ABpF)	Forward Cryostat #1	Q1ABpF DW short prototype underway (see following slides)
Q1BpF	Quad	5.2	78	Industry/FNAL?			
Q2pF	Quad	5.4	131	FNAL (see comments)	DW or B&K	Forward Cryostat #2	Discussions underway with FNAL to design FC-2 with Q2pF
B1pF	Dipole	3.4	135	Industry	DW	Forward Cryostat #3	Full size prototype underway (see following slides)
B1ApF	Dipole	2.7	168	Industry	DW	Forward Cryostat #4	~

Note: B2pF Matching magnet covered in following slide (also a “Cable” magnet)



Detector Here



Spin Rotator & Matching Magnet

Quantity	Magnet Type	Pole Tip Field (T)	Inner Radius [mm]	Possible Manufacturer	IR Location	Comments
2	Spin Rotator - Long	8.5	50	Saclay	Rear IR	Same magnets used in “Forward”
2	Spin Rotator - Short	8.5	50	Saclay		
2	Spin Rotator - Long	8.5	50	Saclay	Forward IR	Same magnets used in “Rear”
2	Spin Rotator - Short	8.5	50	Saclay		
1	B2pF (Matching Magnet)	6.2	50	LBNL	Forward IR	Cable Magnet using B&K design Currently under contract with LBNL