Brookhaven National Laboratory

Jefferson Lab

U.S. DEPARTMENT OF ENERGY

EIC Project Overview

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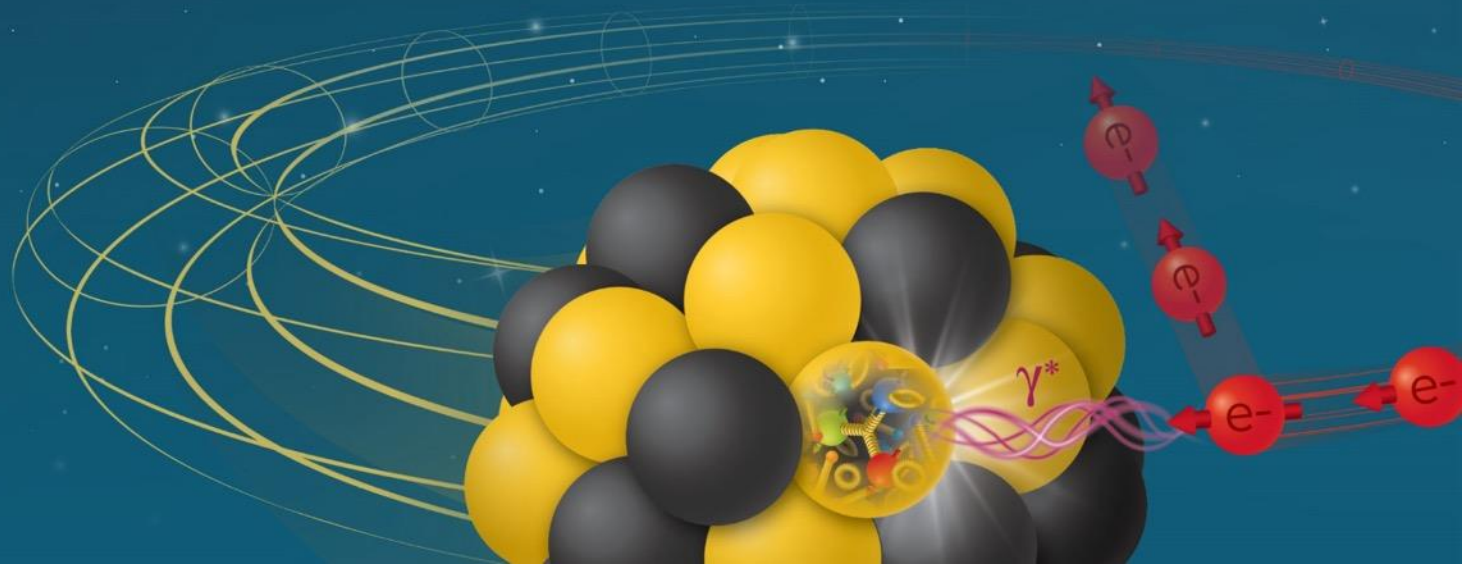
APS Group on Hadronic Physics

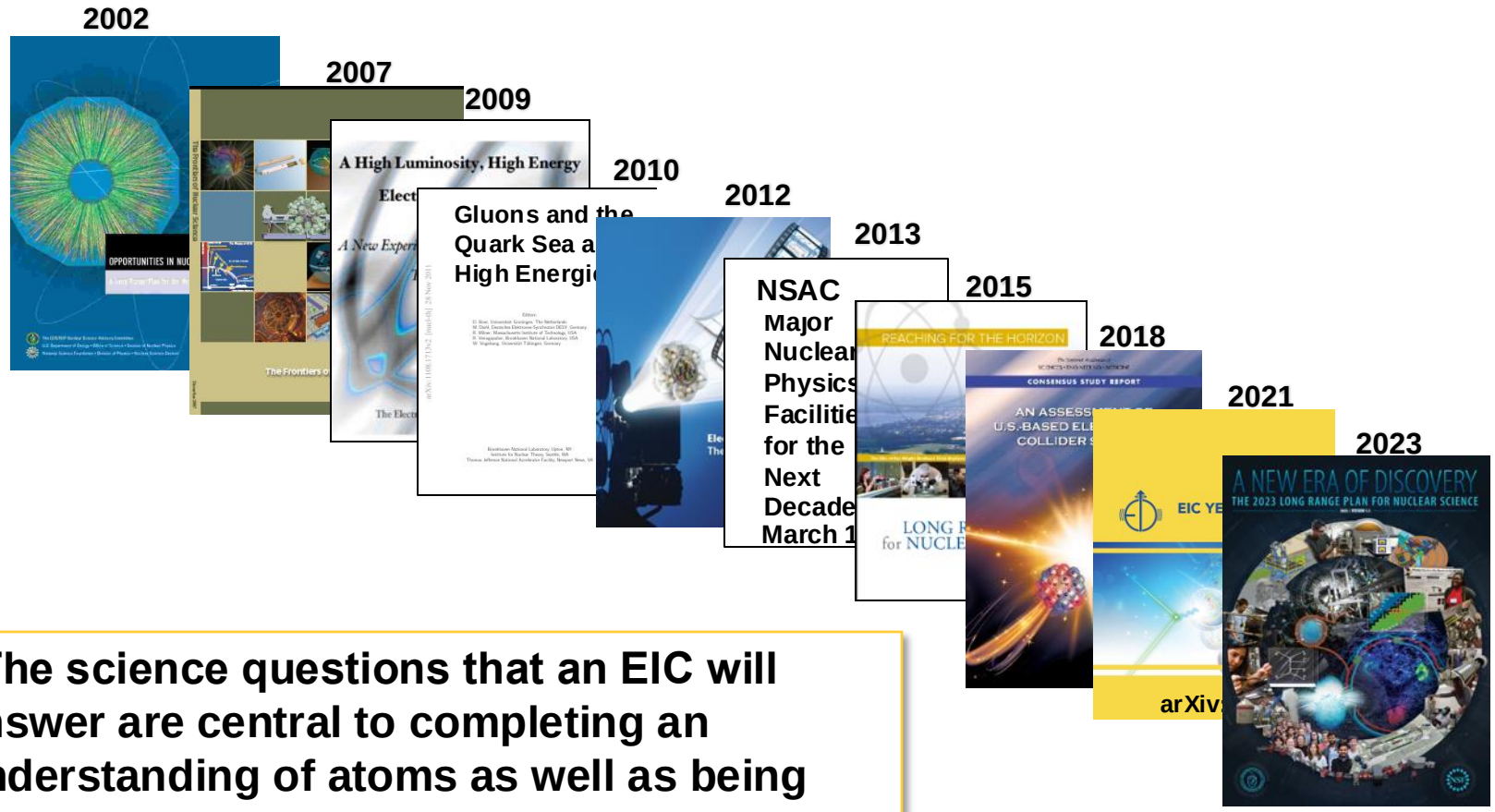
Business Meeting

March 16, 2025

Electron-Ion Collider



EIC Scientific Case Built Over Decades



"We recommend the expeditious completion of the EIC as the highest priority for facility construction." (2023)

"The science questions that an EIC will answer are central to completing an understanding of atoms as well as being integral to the agenda of nuclear physics today." (2018)

EIC will be the only operating particle collider in the U.S. and the only large collider to be built in the world in the next 20-30 years.

Compelling EIC Science (National Academy Report)

How do quarks, gluons, and orbital angular momentum contribute to proton spin?

Spin: a fundamental property of matter

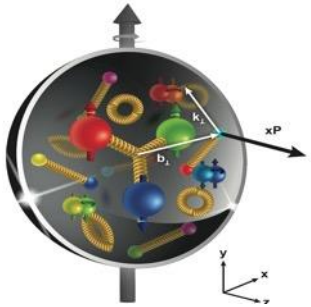
All elementary particles, but the Higgs carry spin

Spin cannot be explained by a static picture, rather the interplay between the properties and interactions of quarks and gluons inside the proton

Does the mass of visible matter emerge from quark-gluon interactions?

Atom: Binding/Mass = 0.00000001
Nucleus: Binding/Mass = 0.01
Proton: Binding/Mass = 100

The EIC will determine an important term contributing to the proton mass, the so-called “QCD trace anomaly.



How can we understand the QCD dynamics and the relation to confinement?

EIC will image quarks and gluons in 3D in space and momentum inside the nucleon & nuclei

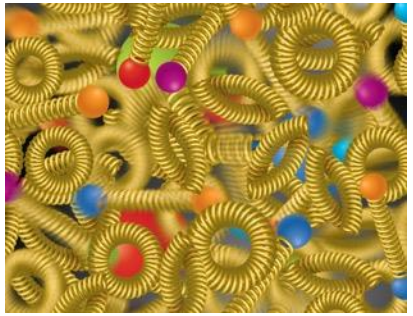
Uncover how the nucleon properties emerge from quarks and gluons and their interactions.

How do the quark-gluon interactions create nuclear binding?

Is the structure of a free and bound nucleon the same?

How do quarks and gluons, interact with a nuclear medium?

How do the confined hadronic states emerge from these quarks and gluons?



Does gluon density in nuclei saturate at high energy?

How many gluons can fit in a proton?

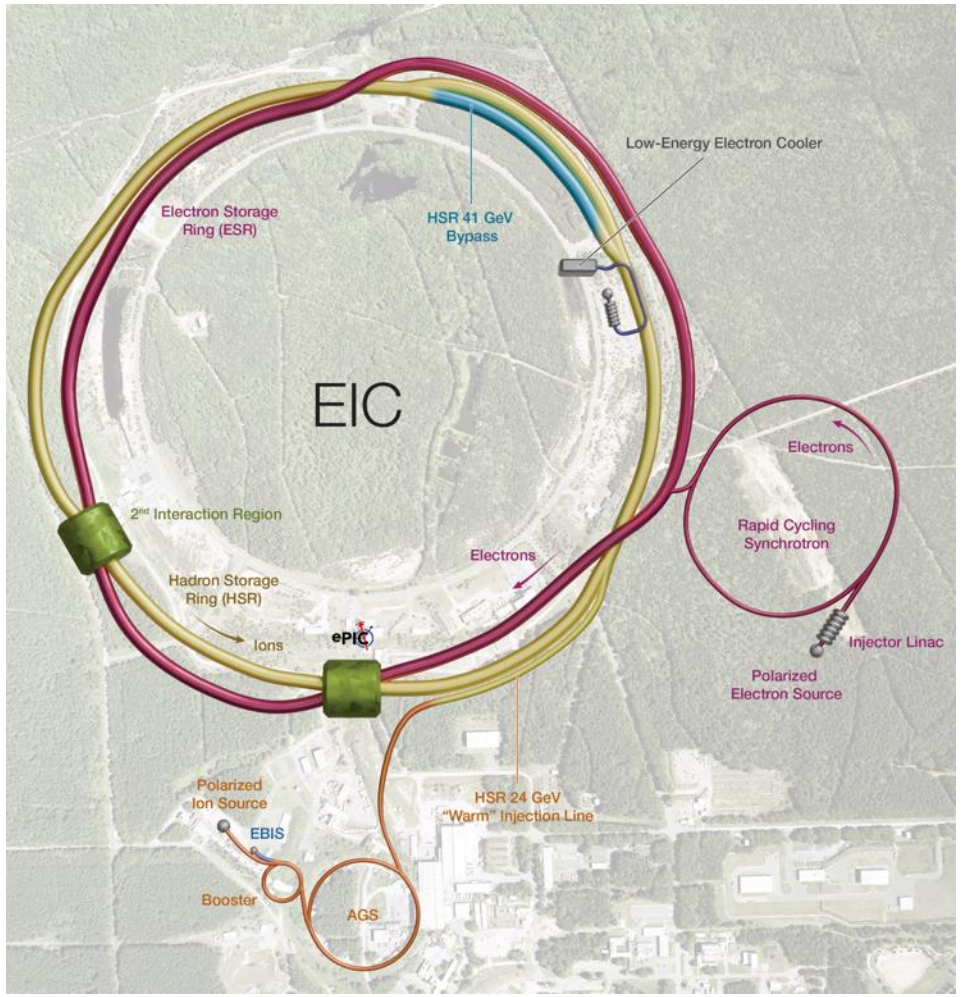
How does a dense nuclear environment affect the quarks and gluons, their correlations and interactions?

Nobel-Worthy Questions

Facility Performance

- High Luminosity: L= 10^{33} – 10^{34}cm^{-2}sec^{-1}
- 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
- Possibility to implement a Second Interaction Region (IR)

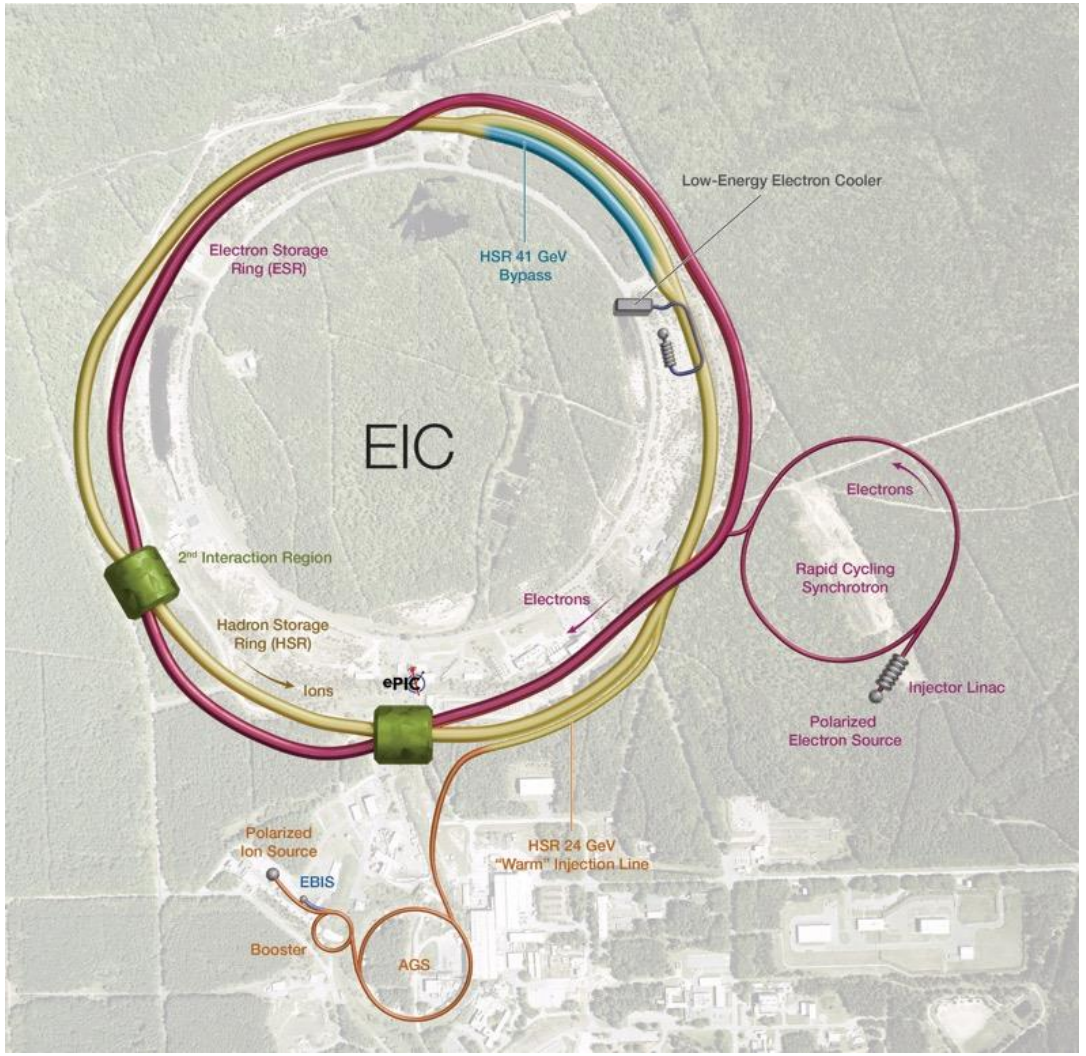
The EIC design, project scope, and performance parameters address the requirements established by the U.S. Nuclear Science Advisory Committee (NSAC) Long Range Plans (2015 & 2023) and endorsed by the U.S. National Academy of Sciences (2018).



EIC Concept and Machine Parameters

Accelerator Status:

- ✓ 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)
- NEW Electron Pre-Injector (750 MeV linac)
- NEW Electron Rapid Cycling Synchrotron (0.75 GeV – top energy)
- NEW Electron Storage Ring (5 GeV – 18 GeV)
- NEW Interaction Region(s)
- NEW Hadron Injection Cooling System



2024 Highlights

Major Project Milestones

- CD-3A LLP approved at ~$90M and initial contracts awarded! Examples:
  - Accelerator superconducting strand, $163K
  - Detector EMCal and HCal fibers, $2.3M
  - Infrastructure electrical substations, $11.2M
- CD-3B Final Design Reviews (FDRs) complete, one FDR repeated
- Requirements/interfaces for CD-3B items complete
- Project is benefiting from lessons learned on CD-3A.

Reviews, Board, and Advisory Committees

- More than 20 design reviews
- 6 Advisory Committee Meetings
- 5 Advisory Board and two Resource Review Board Meetings
- 5 Reviews of “Off-Project” Scope
- Interaction Region Superconducting Magnet Steering Group established
- Annual Director’s Review in October
- DOE CD-3B/Status Review in January

Accelerator

- New Technical Director in January
- Received and assessed Advanced Photon Source magnets at BNL and JLab
- Optimized design and scope to mitigate risk
- Electron injector modifications eliminate many risks and meet the Mission Need.
- International EIC Accelerator Collaboration established

Detector

- R&D nearly complete
- ePIC Detector technical baseline defined
- Preliminary Design Report in preparation
- Plans are developing for the EIC Science Program

Infrastructure

- $100M New York State Grant for EIC buildings in February
- 30% Detailed Design submission received in August
- 60% Detailed Design submission received in December

Significant Progress in 2024, Started Awarding Contracts for Long Lead Items.

Strong Support from Partners & Collaborators

- **New York State** committed **$100M** toward construction of EIC buildings and infrastructure.
- **EIC Accelerator Collaboration** kicked off at the International Particle Accelerator Conference with over 150 participants expressing interest in contributing to the global EIC effort.
- **UK** announced £58 million (**$75M**) for the EIC.

- **EIC Resource Review Board** Meetings in Rome in May 2024 and at BNL in Oct. 2024**.** Strong participation from **Canada, Czech Republic, France, India, Israel, Italy, Japan, Poland, South Korea, United Kingdom,** and **Taiwan.** Next meeting to be held in Prague in June 2025.

In-kind contributions are planned for the Detector (~30%) and the Accelerator (5%).

DOE CD-3B/Status Review Summary

Select DOE Independent Project Review (IPR) Committee Comments:

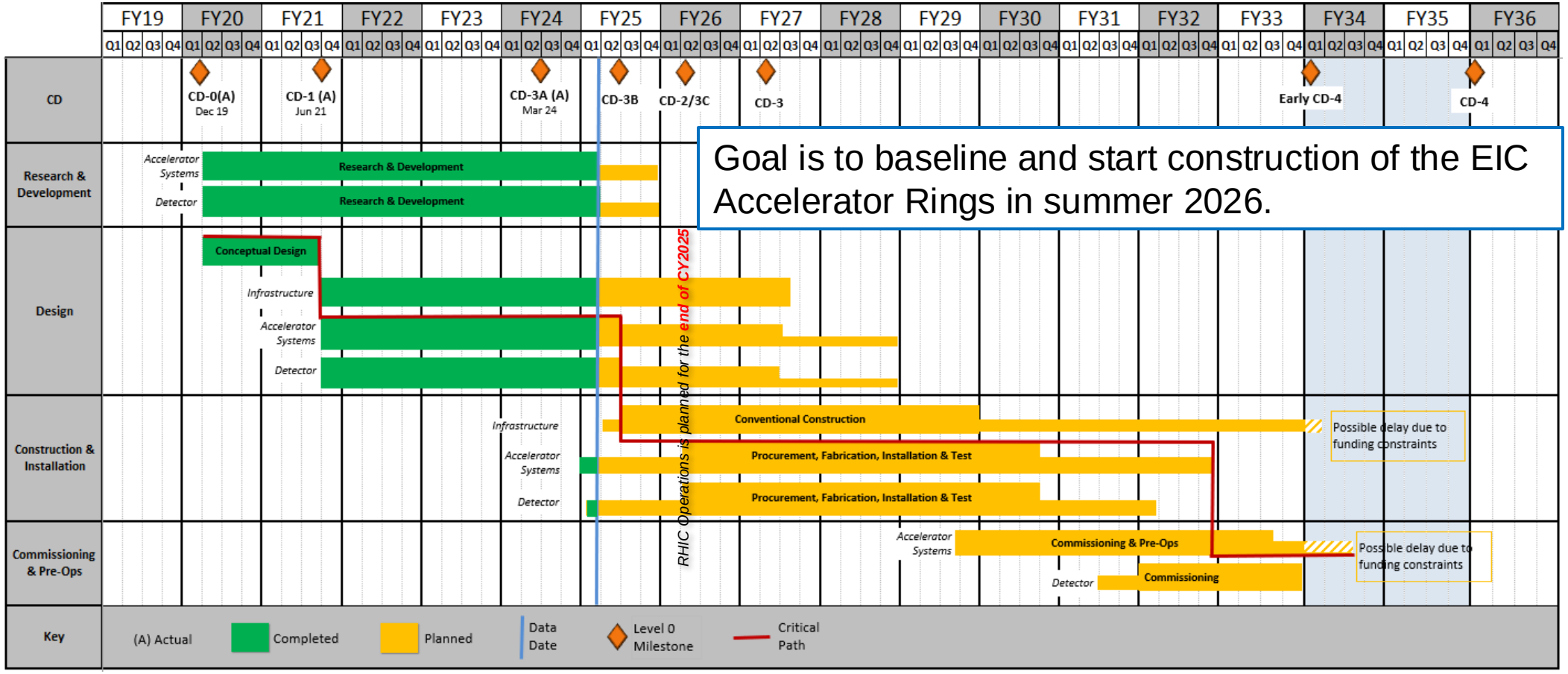
- The project team has made excellent progress since the last review. There is an experienced team in place. A new Technical Director was recently hired and has already made a positive impact on the project.
- The project has strong support from the BNL and JLab Directors. Communications between the labs are well established with bi-weekly meetings between the two lab Directors and Deputy Directors. This will be an excellent forum to facilitate constructive resolution of issues and risks as they arise.

Recommendations for EIC Project:

- **Proceed to CD-3B**
- Path to baseline
  - In advance of the next IPR, document the scope of EIC project and gain alignment with the Program Office on mission need achievement.
  - Develop details for the subproject strategy and work with the Program Office and FPD to **conduct a focused IPR in 6 months.**

EIC Reference Schedule

- EIC project is moving from R&D and design into the construction phase.



- The EIC reference schedule will be revised to delineate subprojects and to address current annual funding projections (including FY2025).

Preparation of EIC Subprojects

Requirements:

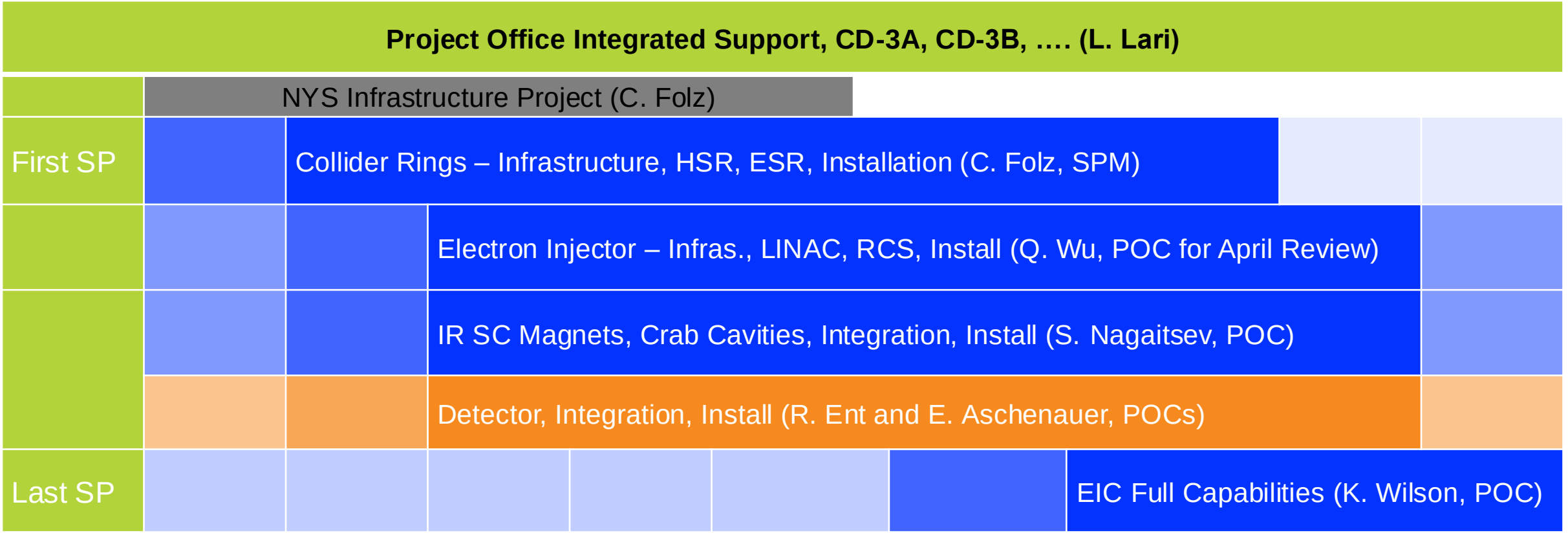
- EIC is a single, integrated line-item project.
- Subprojects have well-defined deliverables and interfaces.
- Subprojects enable start of the EIC science program.
- Subproject plans consistent with DOE annual funding guidance.

EIC Line-Item Project Scope:

Accelerator Rings – Infrastructure, HSR, ESR
Electron Injector – Infrastructure, LINAC, RCS
Interaction Region (IR) Integration – SC Magnets, Crab Cavities, Integration
Detector – ePIC including In-Kind, Integration and Installation
Start Science Program (Early Science Program)
EIC Full Capabilities

EIC Subproject Plans

- Project Office, CD-3A execution well underway
- NYS Infrastructure underway
- Accelerator Rings into construction in 2026
- IR, ePIC, E-Injector baseline quality in 2026



▲ DOE mini-IPR Jul/Aug 2025 to Assess Status, Tailoring Strategy, and Execution Plans

▲ DOE IPR in 2026 supports Critical Decision (CD) approvals

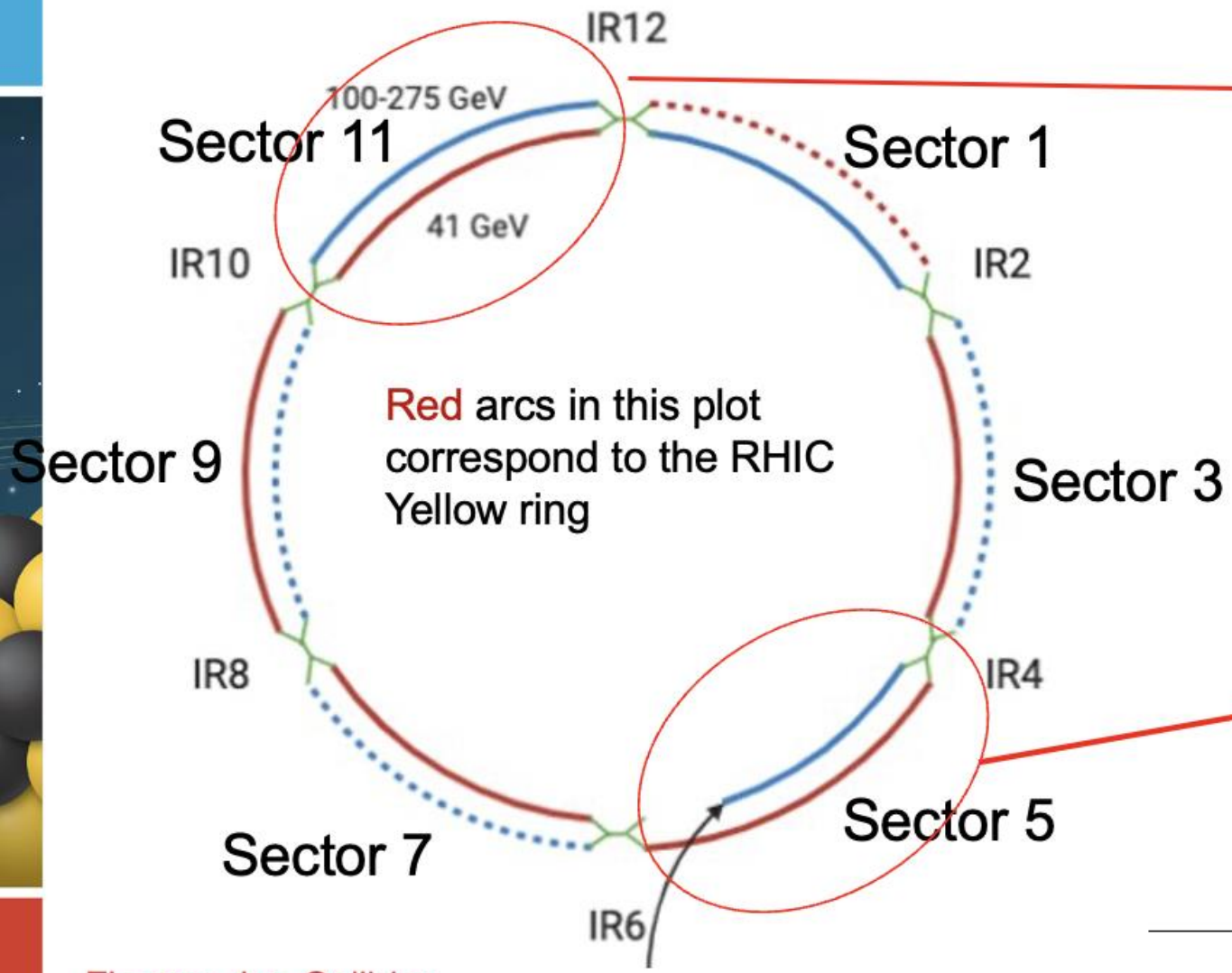
EIC Priorities for 2025 and 2026

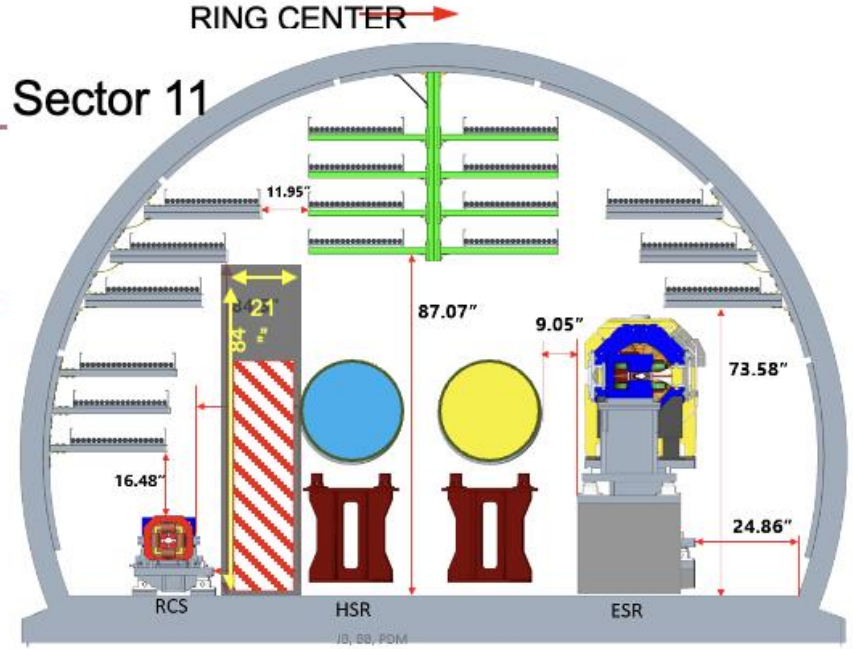
- **Priorities for 2025 include:**
  - Successfully execute the CD-3A and CD-3B long lead procurements.
  - Prepare plans for addressing the “portfolio” of EIC related scope including the Removal and Repurposing (R&R) of RHIC facilities.
  - Clarify scope of each of the proposed subprojects and prepare an initial pre-CD-2 quality performance baseline for the entire line-item project (all subprojects).
  - Conduct reviews to assess status of CD-2 preparations for each subproject and prepare the collider subproject for DOE approvals in 2026 (documentation).
- **Start R&R work after RHIC run concludes in ~December 2025.**
- **DOE reviews (IPR, ICR) required to start EIC construction will be completed in 2026:**
  - **Demonstrate ePIC Detector, Interaction Region, Electron Injector, and Full Capabilities are baseline ready; and,**
  - **Start construction of the Accelerator Rings subproject.**

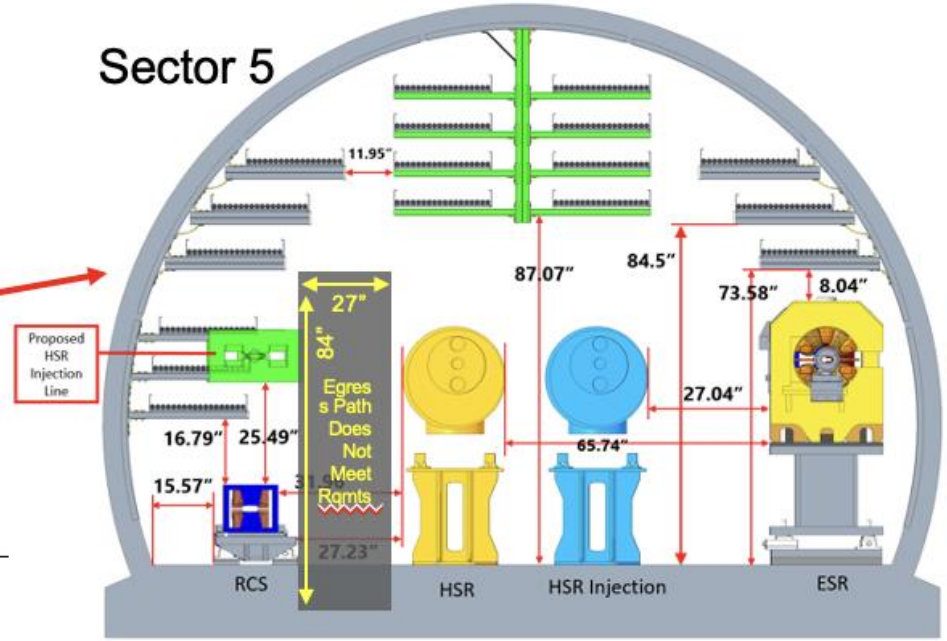
Thank you

Tunnel Layout Optimization

2024: challenges identified with the CDR layout



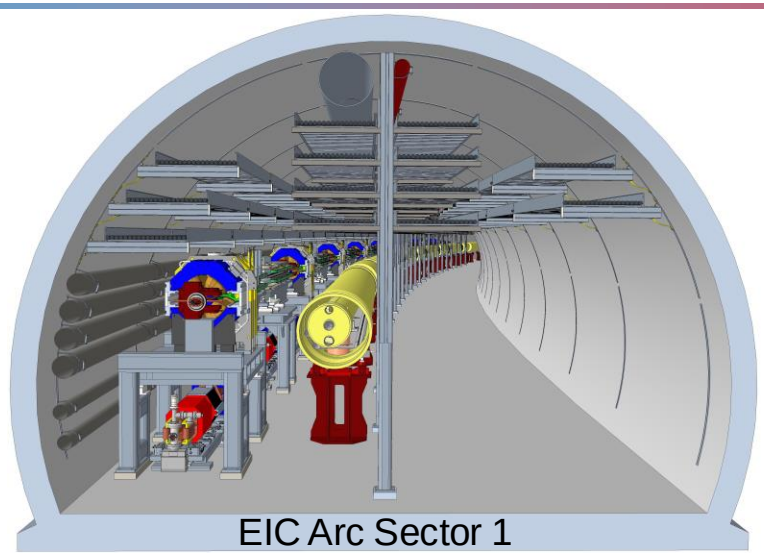




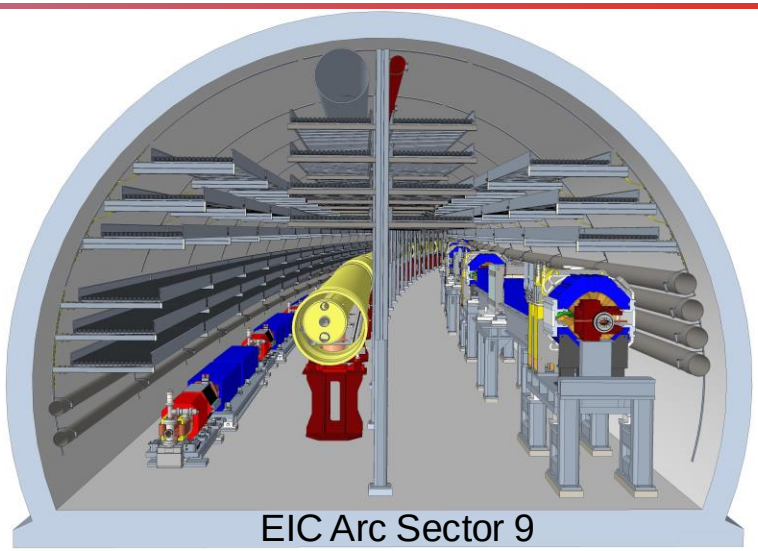
Arc Sections

Tunnel Integration Challenges:

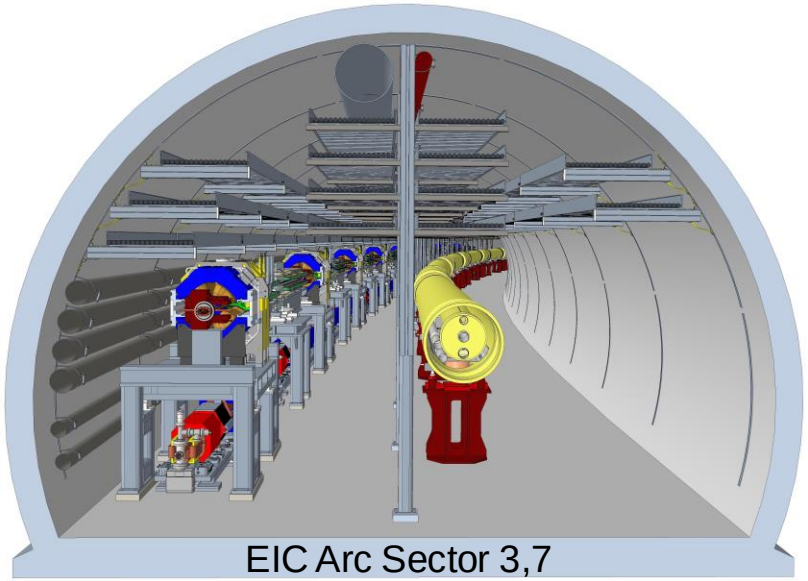
- Tight geometric constraints.
- Cable Management
- Magnet and girder Installation and maintenance.
- Fire safety and egress.



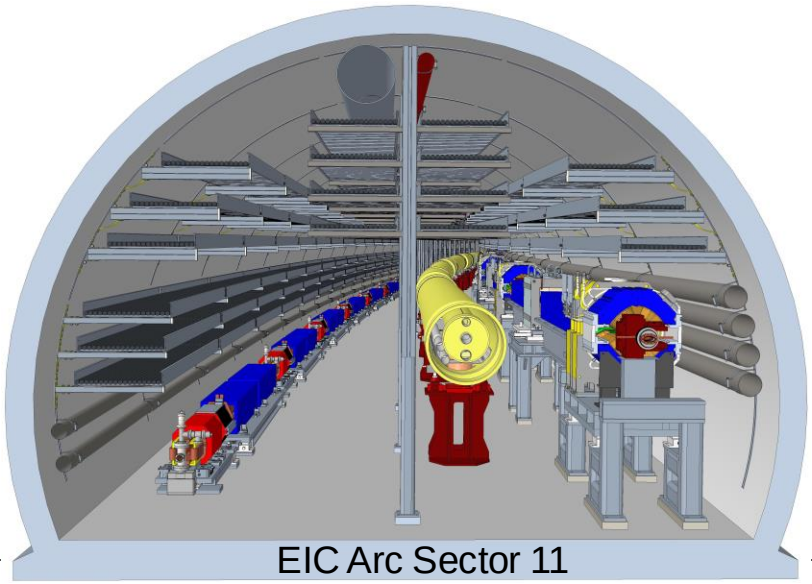
EIC Arc Sector 1



EIC Arc Sector 9

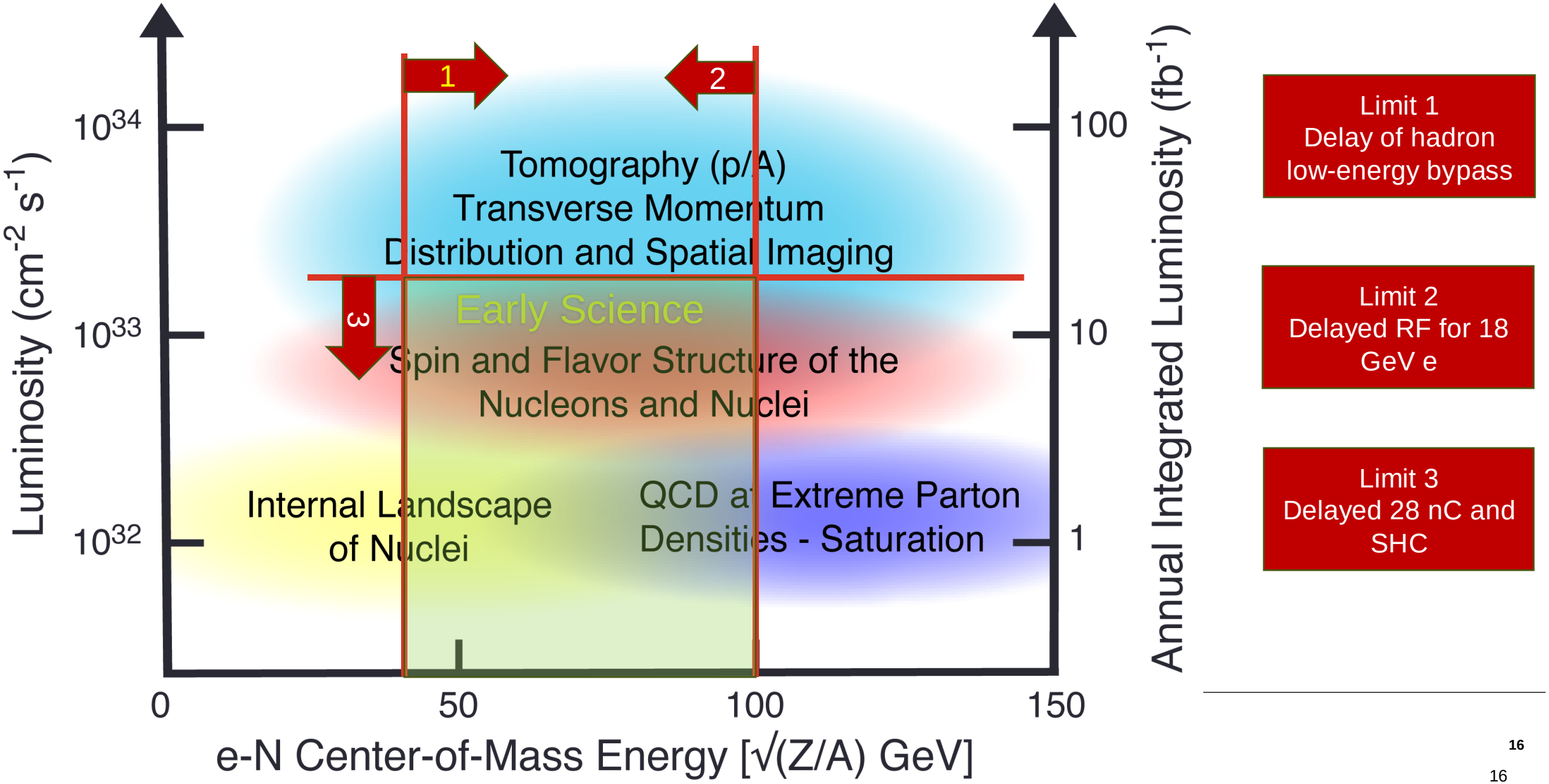


EIC Arc Sector 3,7



EIC Arc Sector 11

EIC Early Science Program Reach: Note all components of the NAS Report Science will start



Limit 1
Delay of hadron low-energy bypass

Limit 2
Delayed RF for 18 GeV e

Limit 3
Delayed 28 nC and SHC

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Planning Dates 2025 - 2026

Milestone	Date	Milestone	Date
DOE Independent Project Review (!PR)	**Jan. 7-9, 2025**	DOE RHIC R&R/Injector Operations Review	Sep/Oct 2025
Start Developing Scope of Subprojects	January 10	Accelerator Rings Scope Assessment	Sep/Oct
IR SC Magnet Steering Group Meetings in 2025	January 17	Infrastructure Construction Advisory Committee	October
Project Advisory Committee Meeting	February 11	Internal Baseline Assessments for SPs • IR and Detector SP(s) • Accelerator Rings SP • Full Capabilities SP	Sept/Oct/Nov 2025
EIC Advisory Board Meeting	February 25		
DOE CD-3B ESAAB Approval-Proposed	March/April		
Electron Injector Design and Cost Review	April 8-10	Resource Review Board Meeting (BNL)	Nov 4-5, 2025
Infrastructure Construction Advisory Committee	April 16-17	RHIC Operations Conclude	End of CY2025
Detector Advisory Committee Meeting	May/June	**RHIC Removal and Repurposing (R&R) Starts**	**January 2026**
Project Advisory Committee "Red Team" Review	June		
Resource Review Board Meeting (Prague)	June 5-6, 2025	**DOE IPR and Independent Cost Review**	**Q2FY2026**
DOE IPR Status Review (Project / 1st Subproject)	**late Jul/early Aug**		
Machine Advisory Committee Meeting	September	**DOE CD-2/3 Approval for Accelerator Rings**	**Q3FY2026**