Search for BSM at the EIC
CFNS Workshop, July 22-24, 2025

Brookhaven National Laboratory

U.S. DEPARTMENT of ENERGY

Early Science at the EIC

Abhay Deshpande

Associate Laboratory Director, Nuclear and Particle Physics

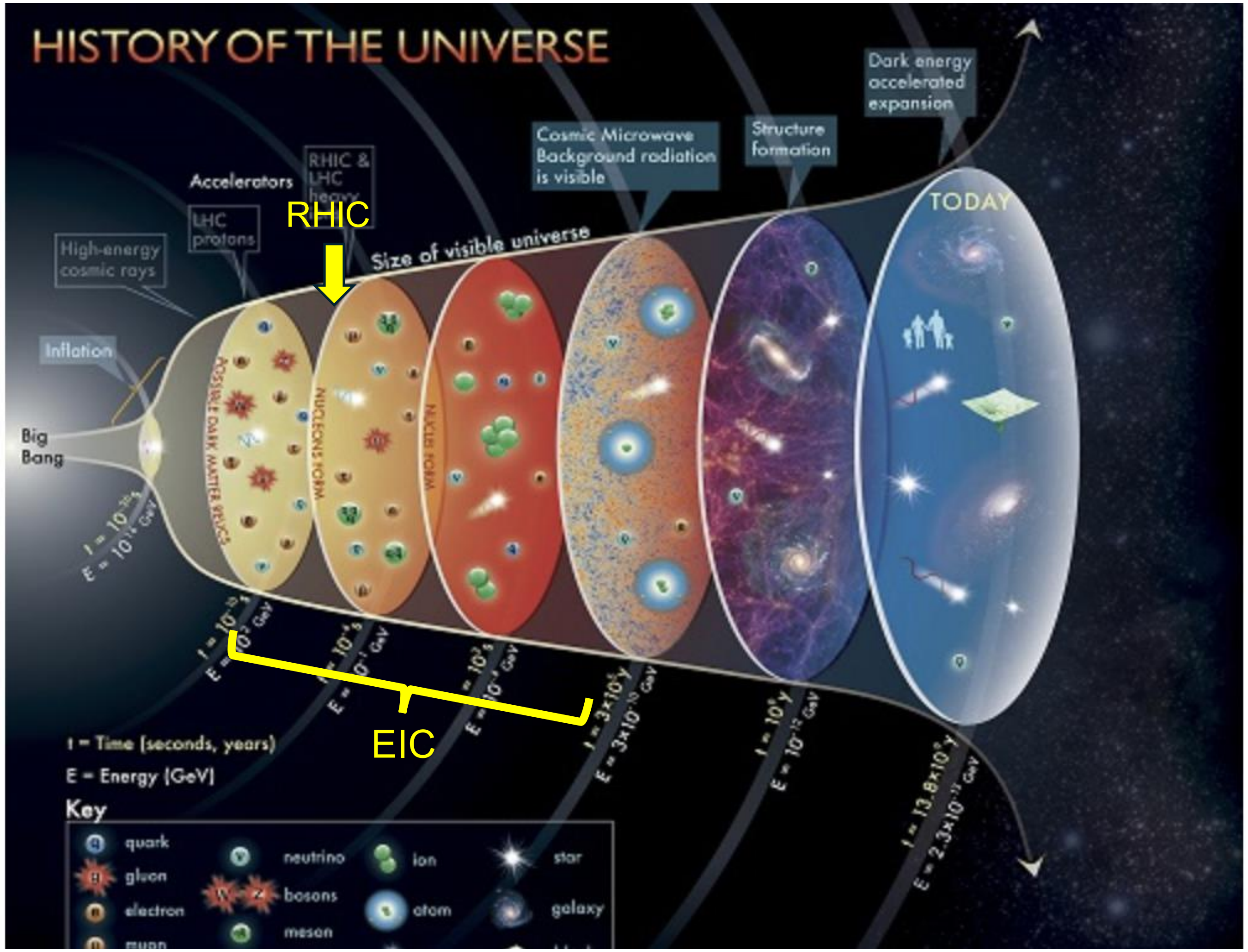
EIC Science Director

July 24, 2025

RHIC & EIC

Facilities with complementary scientific missions

- To study Quark Gluon Plasma and its properties – early universe
- How do the quarks and gluons interact and form protons, neutrons and all the nuclei (the visible universe)
    - Understanding the origin of proton's spin, mass, and critical role of gluons .



Two accelerator facilities (current & future) colliding different particles but with a common vision to understand the origin & emergence of the visible matter universe

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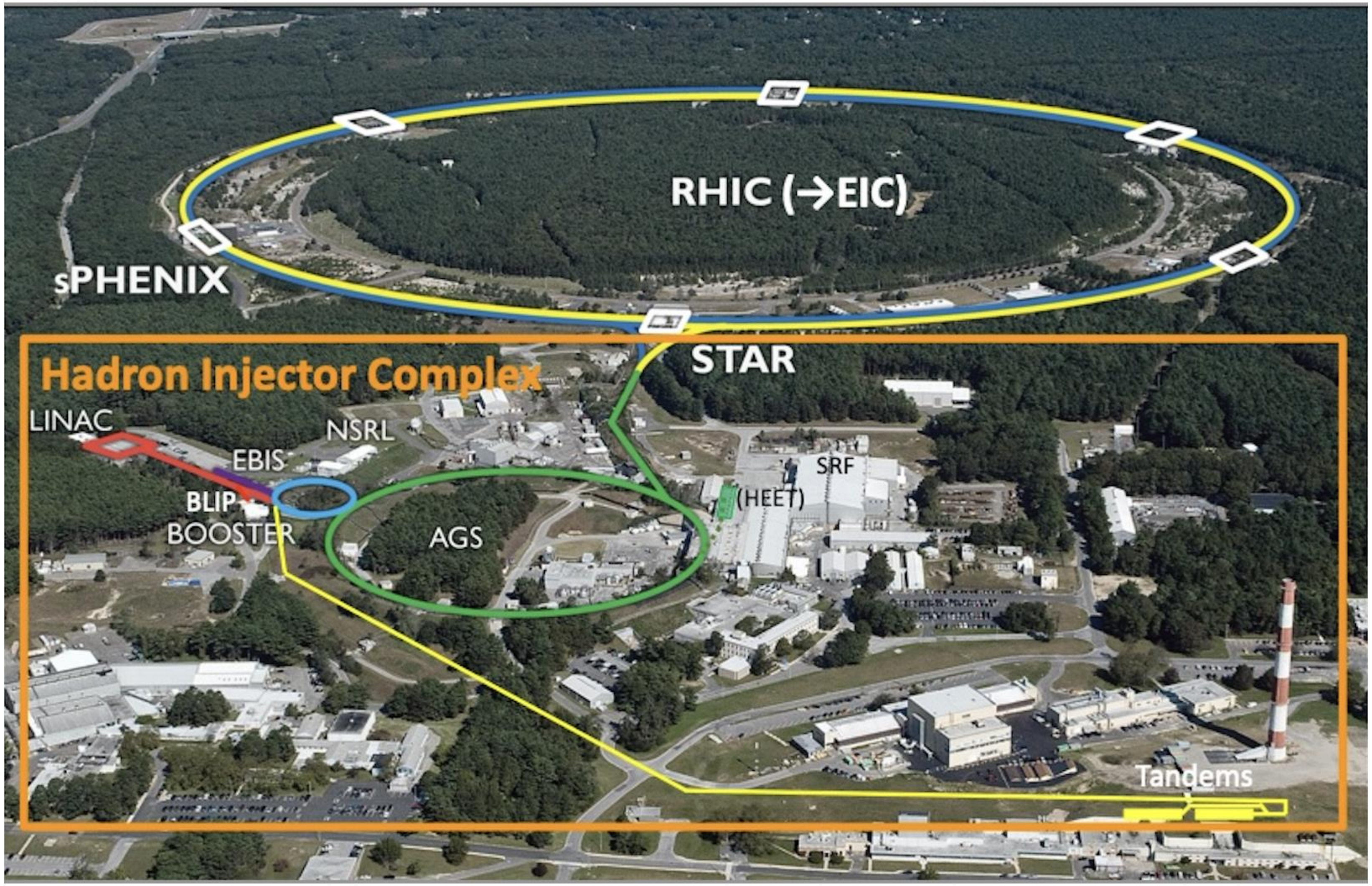
Relativistic Heavy Ion Collider (RHIC)

Basic scientific research woven with direct benefits to society

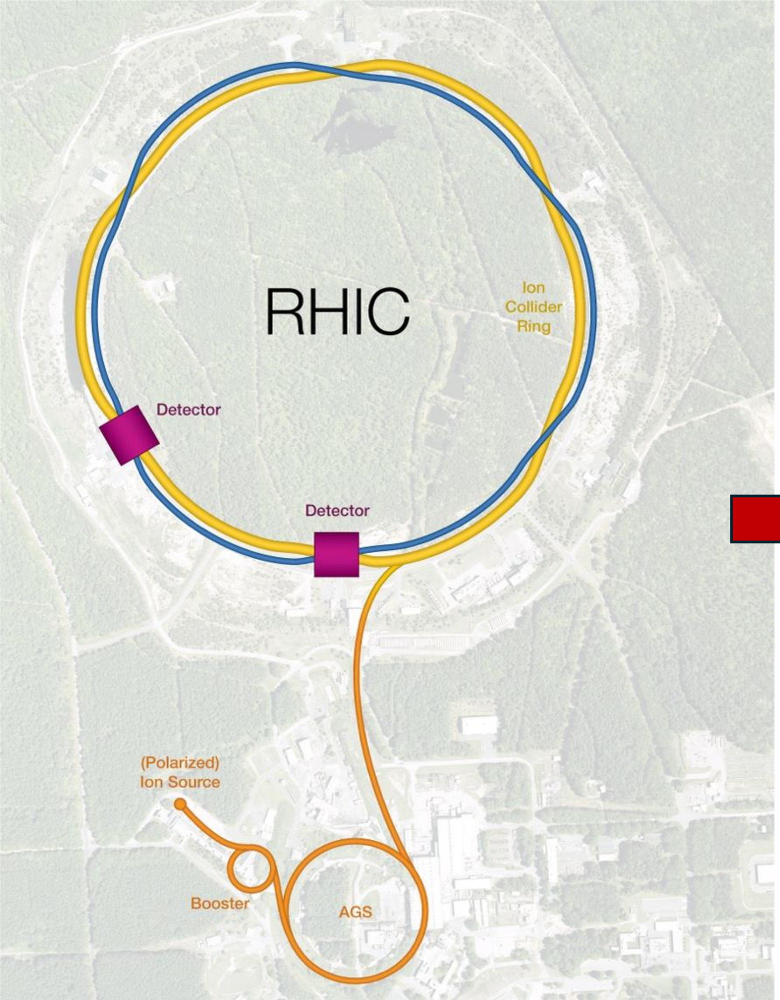
Uniquely flexible and only hadron collider in US for exploration of Quark Gluon Plasma and proton (spin) structure

Injectors also used for application programs:

- **LINAC**: Brookhaven Linac Isotope Producer: (medical and other Isotope production)
- **Booster** NASA Space Radiation Lab for space radiation studies
- **Tandem** for industrial/academic users
- **R&D for future facilities and application** sources, beam cooling, polarized beams, …



Transition from RHIC to Electron Ion Collider (EIC) in 2026

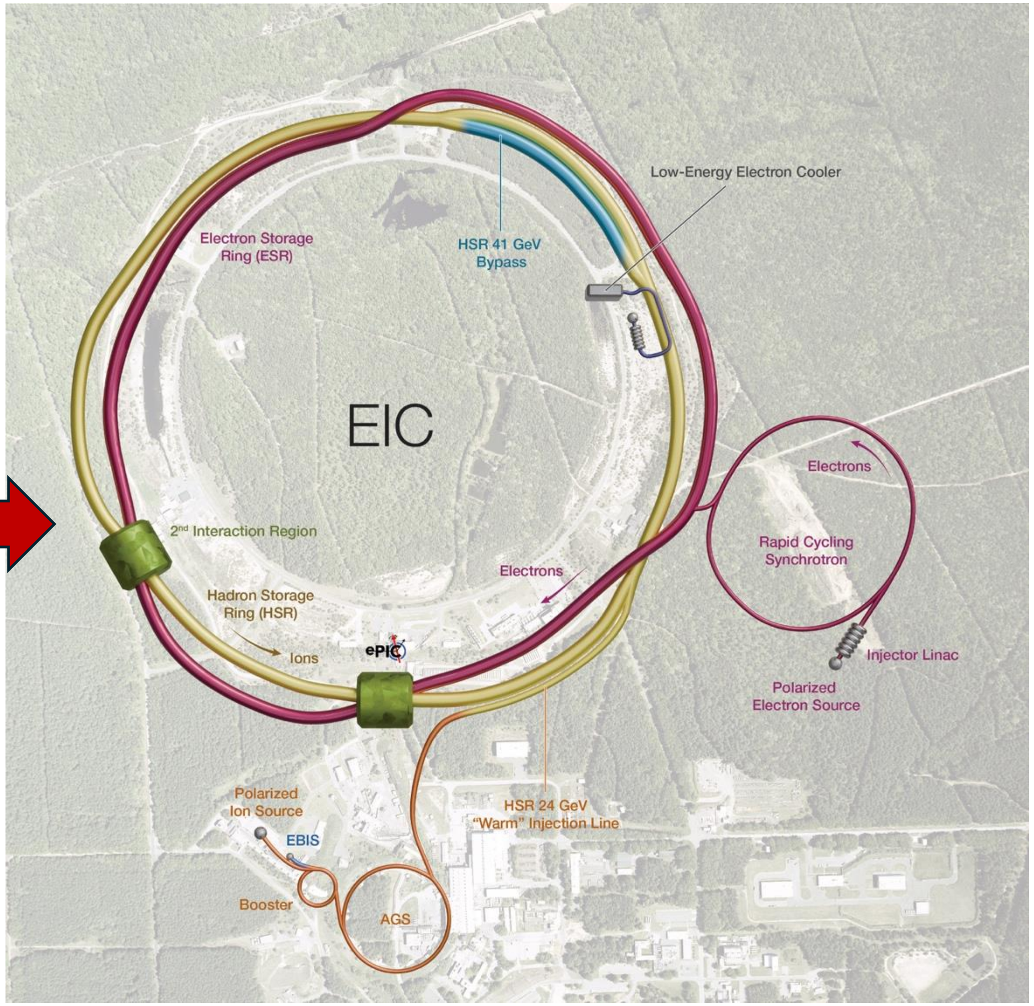


Re-Use the existing tunnel

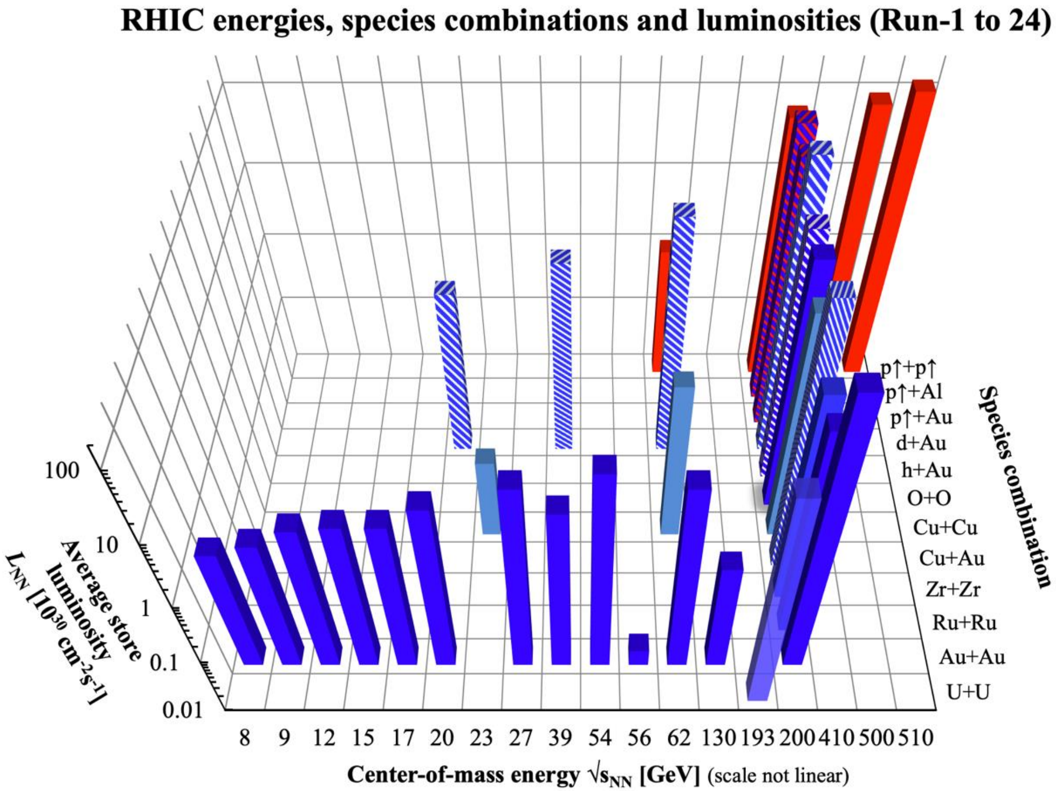
Minimal modification to the hadron beam complex (yellow)

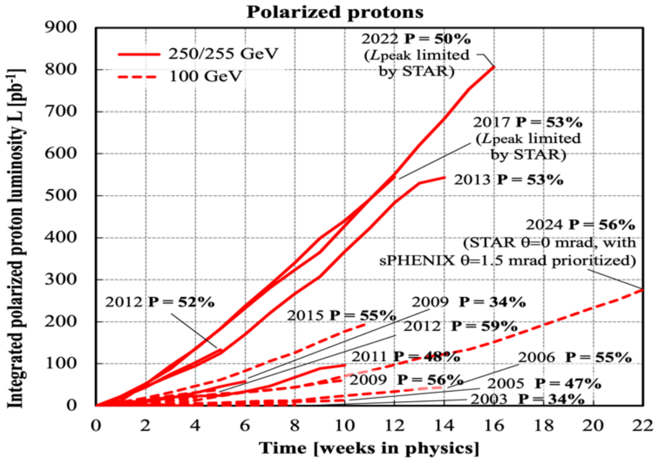
New electron beam facility

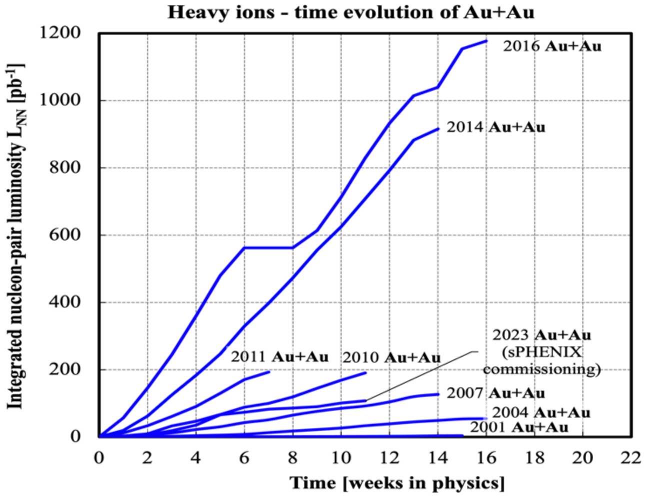
Build on the ~$2B investment

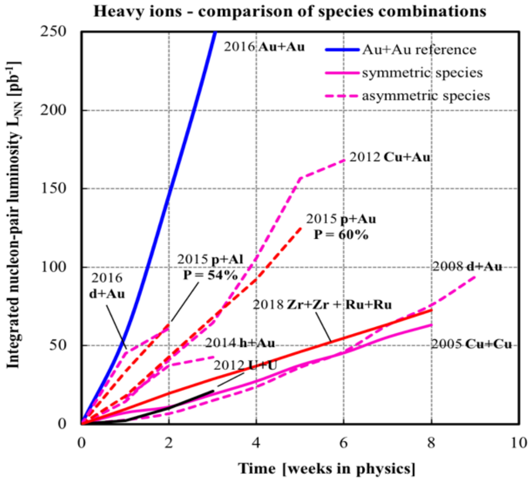


The Most Versatile Collider Ever Built





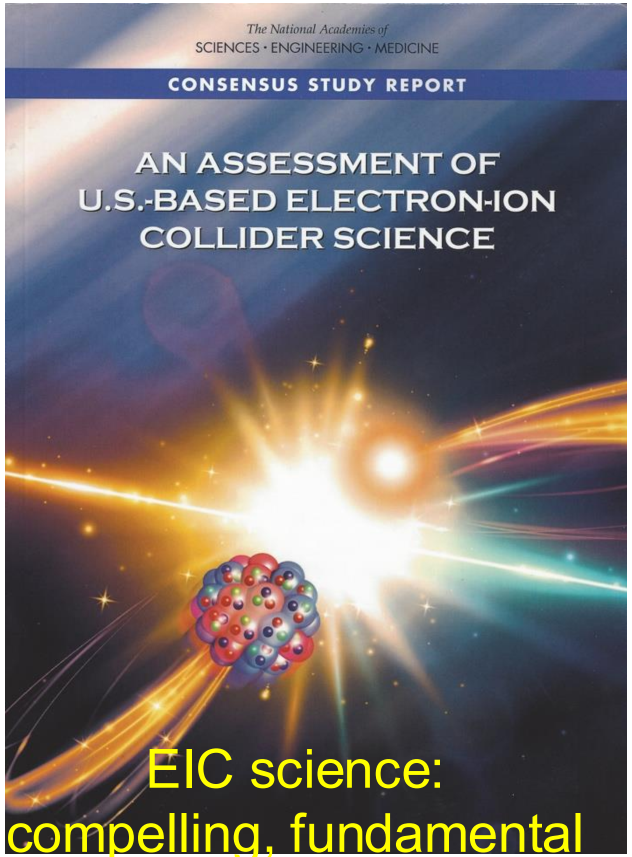




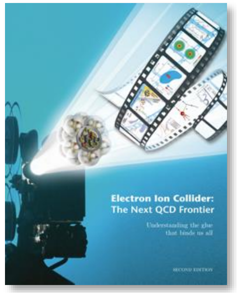
Vision:
The Electron Ion Collider

BNL is fully committed the common vision of realizing a high-luminosity, high-energy polarized electron ion collider, as early as it is fiscally and technically possible

National Academy's Assessment, July 2018



EIC science:
compelling, fundamental
and timely



Electron Ion Collider Science:

Origin of nucleon spin & 3D imaging of partons

Understanding the origin of mass of the visible universe

Intense gluon fields ➔ novel gluonic matter?

Machine Design Parameters:

High luminosity: up to 10^{33}-10^{34} $cm^{-2}sec^{-1}$

- a factor ~100-1000 times HERA

Broad range in center-of-mass energy: ~20-100 GeV upgradable to 140 GeV

Polarized beams e-, p, and light ion beams with flexible spin patterns/orientation

Broad range in hadron species: protons…. Uranium

Up to two detectors well-integrated detector(s) into the machine lattice

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 at 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)

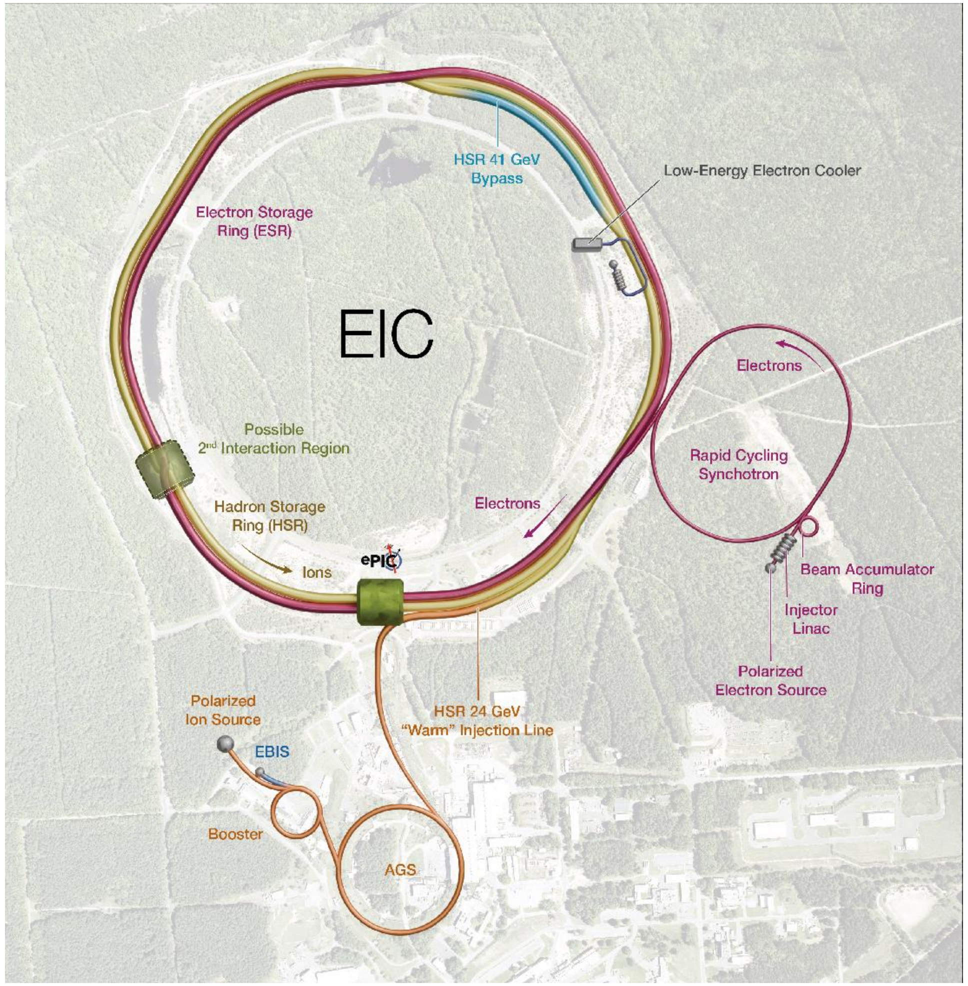
NEW Beam Accumulation Ring (750 MeV) – BAR

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 Cooling System



Protons: ~40 – 275 GeV
Electrons: 5 – 18 GeV

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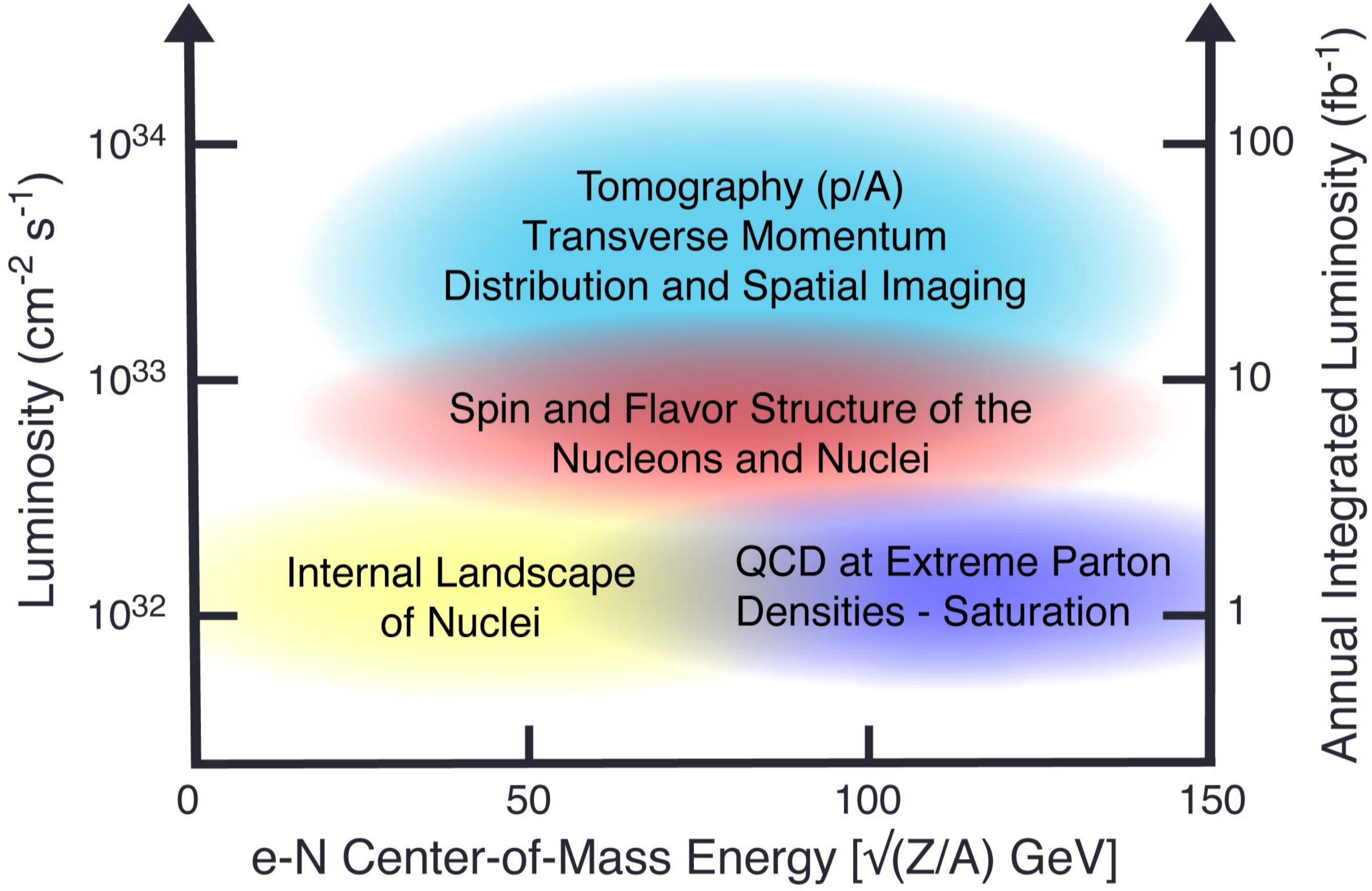
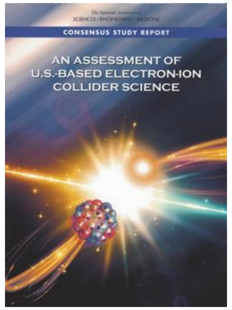
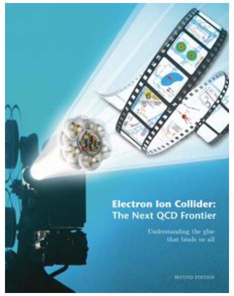
Summary: EIC Physics:
CM vs. Luminosity vs. Integrated luminosity







EIC Project Delivery Organization

BOARDS AND COMMITTEES

EIC ADVISORY BOARD INSTITUTIONS	**K. Sawyer (JLAB), Chair** ANL, CERN, FNAL, IN2P3, INFN,IRFU-Saclay, JLAB, LBNL, ORNL, TRIUMF, STFC
RESOURCE REVIEW BOARD FUNDING AGENCIES	**A. Deshpande (BNL)/D. Dean (JLAB), Co-Chair** **D. Bettoni (INFN), Co-Chair**
PROJECT ADVISORY COMMITTEE	**T. Glasmacher (MSU), Chair**

BROOKHAVEN NATIONAL LABORATORY

J. Hewett
Laboratory Director

J. Hill
Deputy Director for Science & Technology

A. Emrick
Deputy Director for Operations

EIC PORTFOLIO COORDINATION

INTERIM EIC PORTFOLIO COORDINATOR — **E. Johnson**

EIC SCIENCE & TECHNOLOGY COLLABORATIONS

BNL EIC SCIENCE DIRECTOR	**A. Deshpande (SBU/BNL)**
USER GROUP STEERING COMMITTEE	**O. Hen (MIT)** **M. Radici (INFN)**
ePIC COLLABORATION	**J. Lajoie (ORNL)** **S. Dalla Torre (INFN)**
EIC ACCELERATOR COLLABORATION	**T. Pieloni (EPFL)** **A. Seryi (JLAB)**

ADVISORY COMMITTEES & STEERING GROUP

MACHINE ADVISORY COMMITTEE	**T. Raubenheimer (SLAC), Chair**
DETECTOR ADVISORY COMMITTEE	**A. White (U. of Texas), Chair**
INFRASTRUCTURE CONSTRUCTION ADVISORY COMMITTEE	**M. Fallier (BNL Retired), Chair**
IR SUPERCONDUCTING MAGNETS STEERING GROUP	**G. Apollinari, (FNAL), Chair**

ELECTRON-ION COLLIDER PROJECT

J. Yeck
PROJECT DIRECTOR

EIC PROJECT MANAGER	**L. Lari**
TECHNICAL DIRECTOR	**S. Nagaitsev**
DEPUTY TECHNICAL DIRECTOR	**K. Smith**
INTERIM DEPUTY PROJECT DIRECTOR-JLAB	**K. Wilson**
CO-ASSOCIATE DIRECTOR EXPERIMENTAL PGM-JLAB	**R. Ent**
CO-ASSOCIATE DIRECTOR EXPERIMENTAL PGM-BNL	**E. Aschenauer**
ASSOCIATE DIRECTOR FOR INFRASTRUCTURE	**C. Folz**
IR SC MAGNET PRODUCTION MANAGER	**B. Wahl**
ENVIRONMENTAL SAFETY & HEALTH MANAGER	**C. Schaefer**
CHIEF OF STAFF	**A. Petrone**
EXECUTIVE ADMINISTRATION	**C. Hoffman**

PROJECT SUPPORT OFFICE

L. Lari
DIRECTOR

K. Krug
DEPUTY DIRECTOR

PROCUREMENT OFFICE	**K. Kirkendall/M. Laney**
PERFORMANCE OFFICE	**K. Krug**
RISK MANAGER	**I. Sourikova**
FINANCIAL OFFICE	**H. Turbush**
SAFETY OFFICE	**C. Schaefer/ W. Rainey**
QUALITY OFFICE	**C. Porretto/J. Harris**
IN-KIND CONTRIBUTIONS SUPPORT OFFICE	**P. Berrutti**

TECHNICAL INTEGRATION OFFICE

S. Nagaitsev
DIRECTOR

DEPUTY TECHNICAL DIRECTOR	**K. Smith**
CHIEF SYSTEM ENGINEER	**T. Russo**
CHIEF ENGINEER	**J. Tuozzolo**
PROJECT ENGINEER	**K. Wilson**

PROJECT ADVISORS

J. Yeck

SENIOR ADVISOR	**F. Willeke**
SUPPORT ACTIVITIES COORDINATOR	**D. Lissauer**
PROJECT REPORTING AND ASSURANCE MANAGER AND ADVISOR	**C. Lavelle** (50%)

Subprojects

6.01	**6.02**	**6.03**	**6.04**	**6.05**	**6.06**	**6.07**
CD-3A/B CIVIL CONSTRUCTION WITH NYS FUNDS	ACCELERATOR STORAGE RINGS (ASR) SUBPROJECT	DETECTOR SUBPROJECT	INTERACTION REGIONS (IR) SUBPROJECT	ELECTRON INJECTOR (EIN) SUBPROJECT	ENERGY & LUMINOSITY RAMP-UP (ELR) SUBPROJECT	PROJECT MANAGEMENT AND GLOBAL SERVICES (PMG) SUBPROJECT
L. Lari	**C. Folz**	**E. Aschenauer & R. Ent**	**S. Nagaitsev**	**Q. WU**	**K. Wilson**	**L. Lari**
POINT OF CONTACT	SUBPROJECT MANAGER	POINT OF CONTACT	POINT OF CONTACT	POINT OF CONTACT	POINT OF CONTACT	SUBPROJECT MANAGER

- Leadership of subprojects superimposed on the existing EIC project organization
- Significant technical scope in Infrastructure, Accelerator Systems, RF, Cryogenics delivered in multiple subprojects.
- Stronger technical integration effort will be required.

EIC Project Delivery Requirements

Requirements:

EIC is a single, integrated line-item project.

Subprojects have well-defined deliverables, interfaces, and KPPs.

Subprojects enable start of the EIC science program.

Subproject plans are consistent with DOE annual funding guidance.

EIC Line-Item Project Scope:

Accelerator Storage Rings
Electron Injector
Interaction Region (IR) Integration – SC Magnets, RF Crab Cavities
Detector (ePIC)
Start Science Program
Energy and Luminosity Ramp-up (CD-4)

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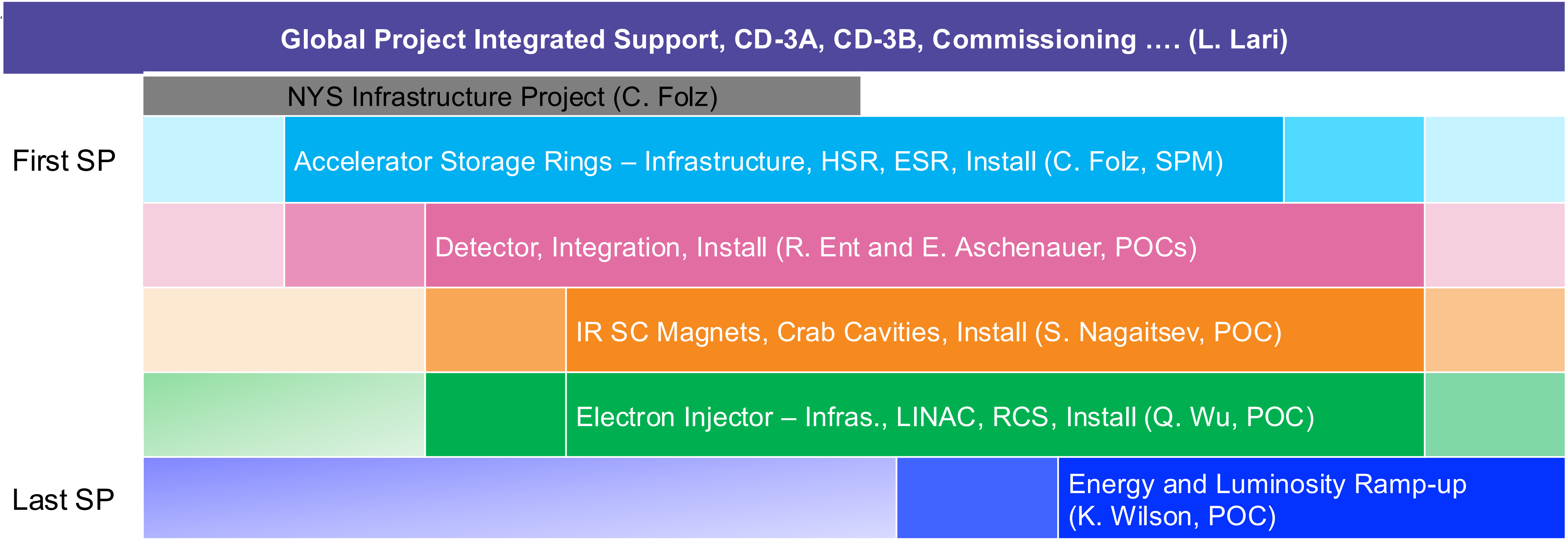
Project Delivery Strategy

Project Delivery Strategy: Deliver the full EIC facility scope as part of the line-item construction project using subprojects and the phased completion of the EIC project scope. The strategy enables the start of the EIC science program during collider commissioning and for the concurrent completion of the full capability required



EIC Construction Project

CD-3x & NYS Scope	**CD-3A, Long Lead Procurement**	3A: ~40% scope in ASR; ~6% IR; 54% in DET
	CD-3B, Long Lead Procurement	3B: ~75% scope in ASR; 25% DET
	NYS Civil Construction Project	Site Preparation work and construction of Service Buildings and support systems related to the ASR subproject.
Initial Science Program Scope	**Accelerator Storage Rings (ASR)**	Hadron Storage Ring Modifications, Electron Storage Ring (10 GeV) and related infrastructure.
	Detector (DET)	ePIC Detector including SC magnet, detector systems, and integration and installation.
	Interaction Region (IR)	Interaction Region including the SC magnets and 197 MHz crab cavities.
	Electron Injectors (EIN)	Electron Injectors (LINAC, BAR & RCS @ 10 GeV) and related infrastructure.
Full Scope	**Energy and Luminosity Ramp-up (ELR)**	Accelerator scope required to increase Energy (18GeV e-, RCS SRF & Cryo, 394 MHz crab cavities, 41 GeV by-pass, ESR and HSR RF amplifiers, etc.)
PM & CX	**Project Management and Global Services (PMG)**	Project and Technical integration support to entire project and integration and beam commissioning.

In-Kind Contribution Plan: 5% or more of the accelerator scope and 30% of the detector scope. New accelerator opportunities.

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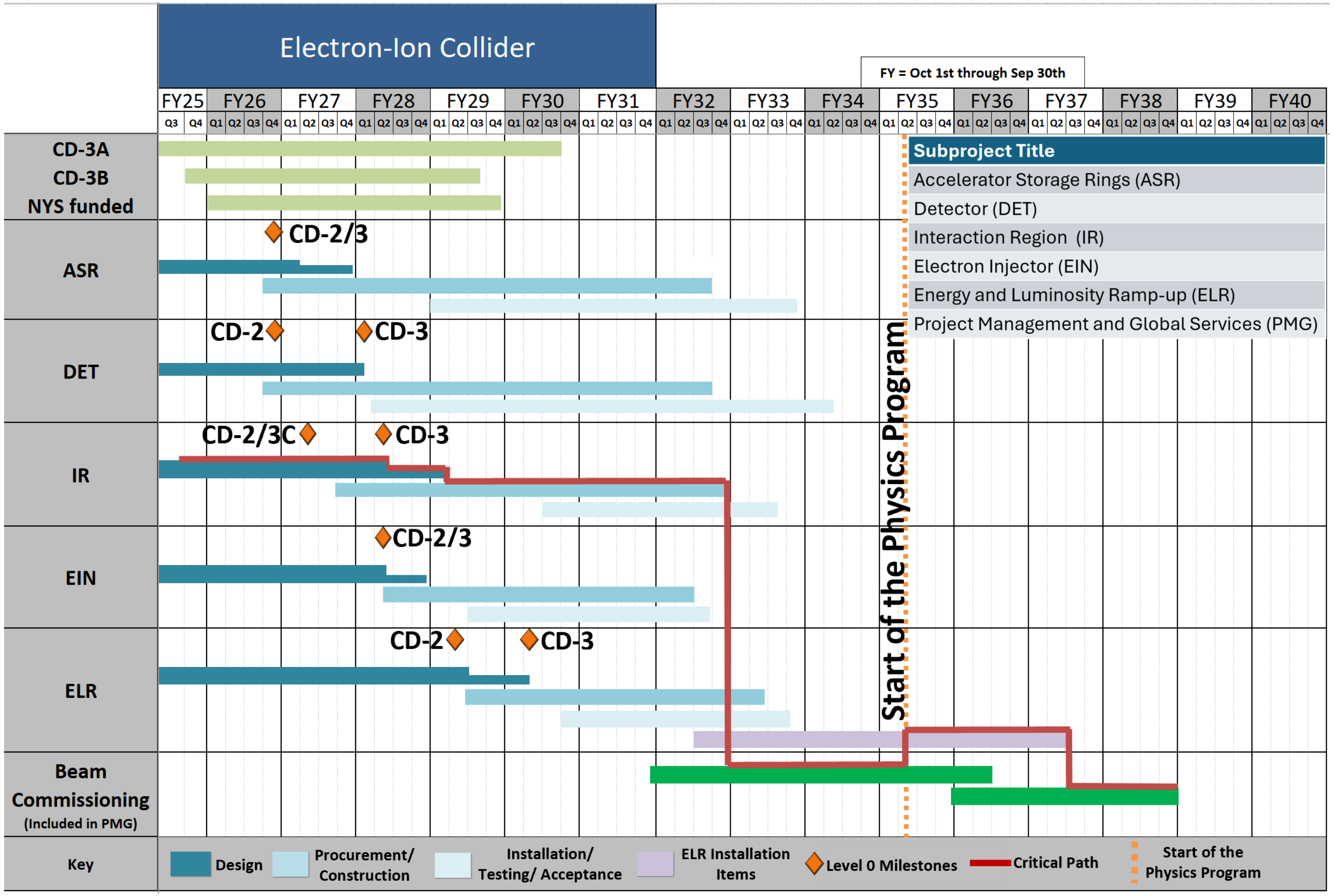
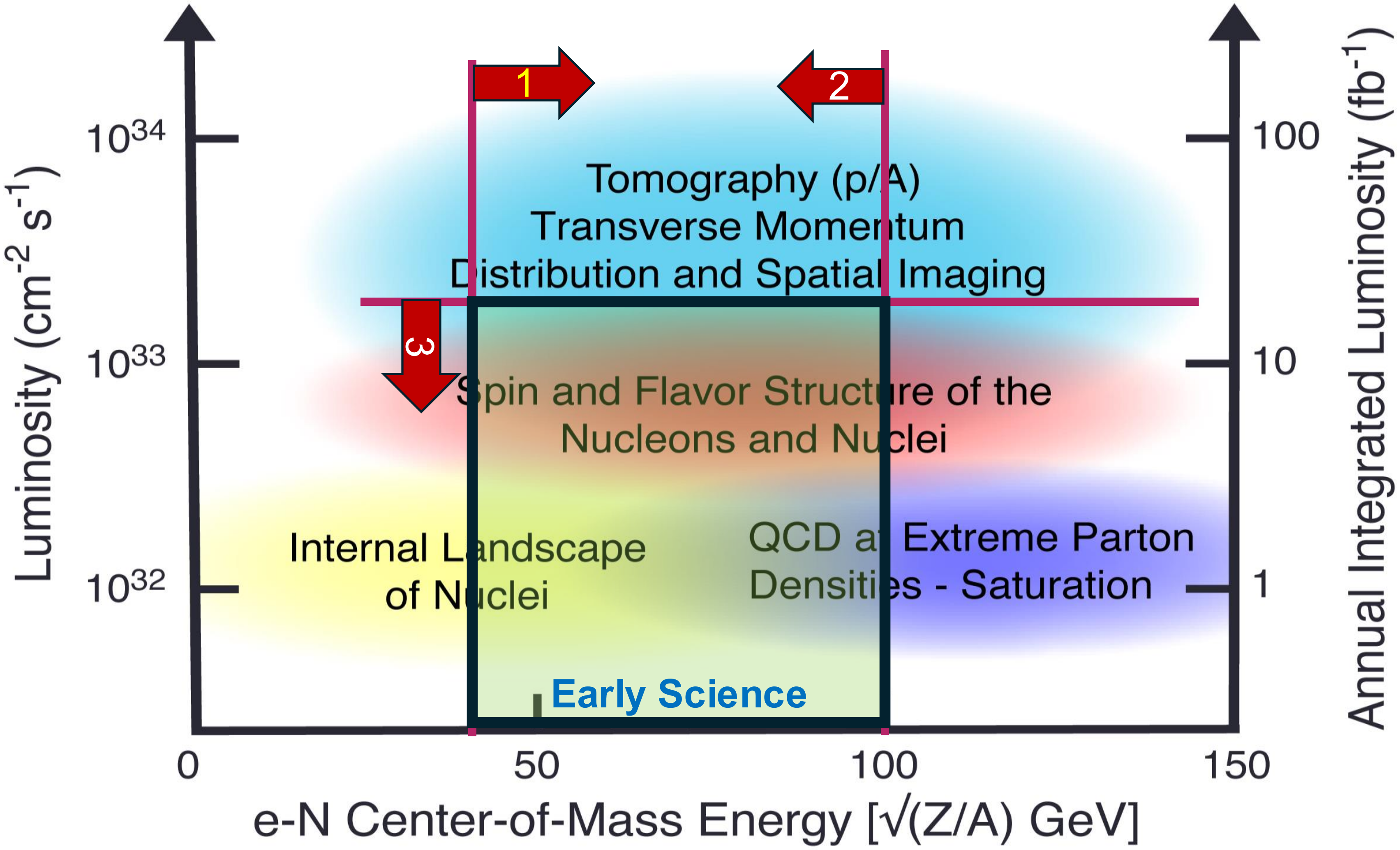
EIC Reference Schedule - Subprojects



EIC Early Science Program Reach:

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
low energy hadron
beam cooling

All Colliders Ramp Up

No collider turns on at the design beam parameters. The ramp up from safe set of parameters to the design parameters can take up to five years. RHIC, LHC, HERA, Tevatron, LEP – all are examples of this.

Project and collaboration will work out the details, but dictated by accelerator needs and safety considerations

A guiding principle: Each of the early years should bring in some new machine component or capability that allows new physics to begin.

Year 1: 10 GeV electrons x 115 GeV/u heavy ion beams (Ru or Cu)

- Highest early energy of electron (with polarization setup requirements)
- Choice of Heavy dictated by the beam path centered in the magnet
- Unprecedented nuclear DIS at the highest energy could begin

Years 2 and beyond….

Year 2: Commission proton polarization, improve e-polarization

- 10 GeV polarized electrons x 130 GeV/u Deuterons
- 10 GeV polarized electrons x 130 GeV/u transverse polarized protons
- D-PDFs, transverse momentum distributions in protons

Year 3: Commission hadron spin rotators: longitudinal proton polarization

- Possibility to have polarized e on transverse and longitudinal polarized protons
- Longitudinal spin structure of proton, Delta-G, from scaling violations, jets, α_s

Year 4: Commission hadron ring for non-centered nuclei

- 10 GeV electrons on 100 GeV/u Au and any other nucleus if Au succeeds
- 10 GeV polarized e on 250 GeV polarized protons (transverse & longitudinal)

Years 5 and beyond….

Year 5: Commission polarized 166 GeV He-3

- First measurements of neutron spin structure function, first Bjorken
- Any e-A collision

Years 4 and 5: Add additional RF power etc. to reach the 18 GeV for e to reach 140 GeV in e-p Center of Mass.

Year 6: Commission ESR and HSR for max energy and beam currents

- Possible 18 GeV polarized e on 275 GeV polarized protons

Year 7: introduce and commission 41 GeV bye pass

- Possible 5 GeV e x 41 GeV transverse polarized protons

Comment on the selection of beam parameters:

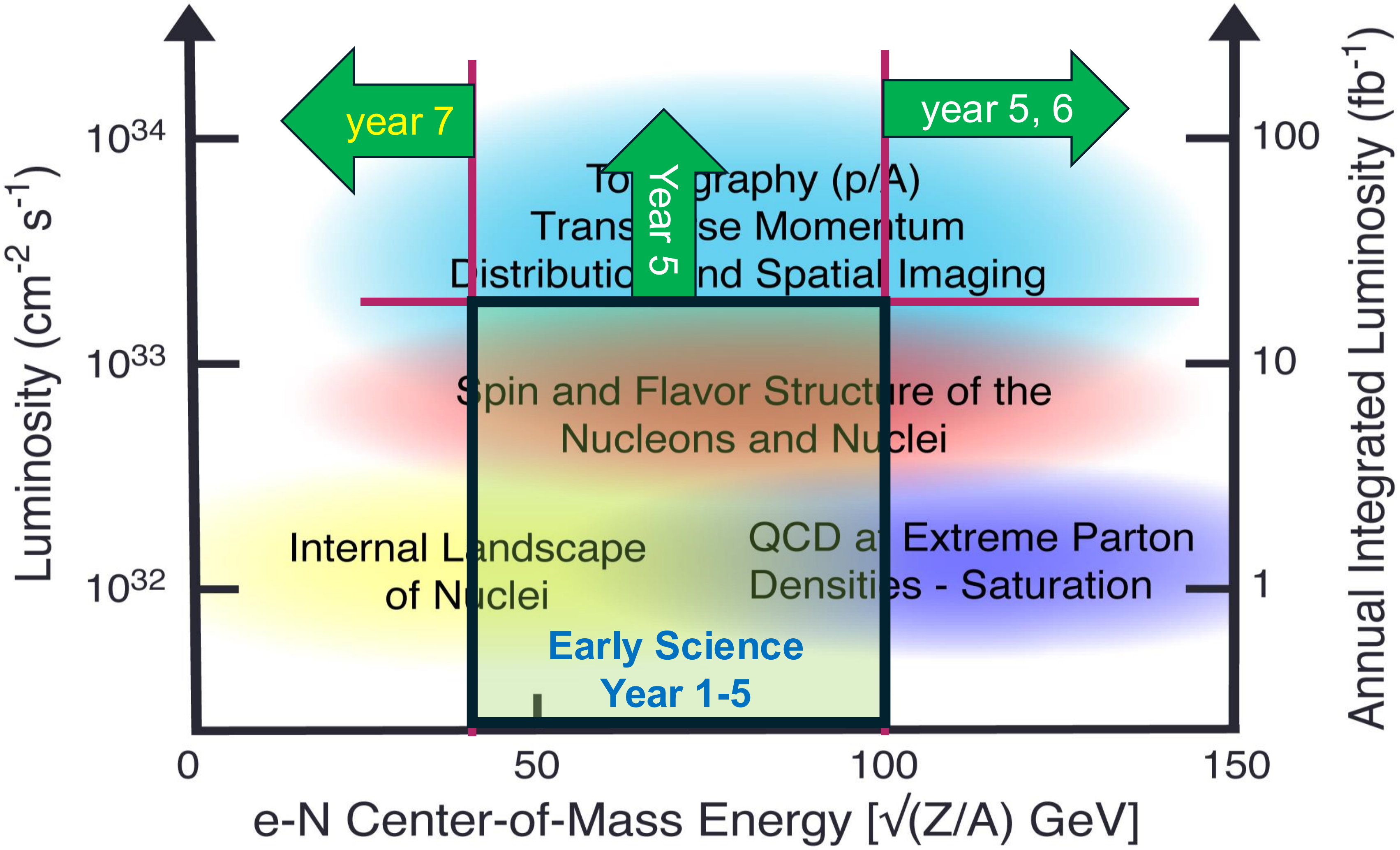
Beam parameter dictated by the desire to have safe early operation, while accelerator operators learn to run a high current machine

Low luminosity earlier, beams easiest to center in beam pipe minimal energy variations etc. all stem from the safety considerations both for the machine elements and the detector elements (particularly those closest to the beam)

I still feel giving us a possibility of having one new experimental feature every year would enable exciting physics every year in the first few years (and later, when maximum parameters are realized)

Early Science to Full EIC capability

Transition over 6-7 years with early science



Year 5
Delayed 28 nC and low energy hadron beam cooling

Year 5, 6
Delayed RF for 18 GeV e

Year 7
Delay of hadron low-energy bypass

John Lajoie

Early Science Charge

- The collaboration has received a charge from Abhay Deshpande and David Dean to develop a document that summarizes EIC Early Science.
- Supports the EIC project plan
- Report requested by May 1, 2026
  - Consistent with our publication plan
- Next Early Science workshop in early 2026

Physics Analysis Readiness Workshop will be held September 17-18th in London.

More in the Physics Analysis Coordination talk.

Jefferson Lab | Brookhaven National Laboratory

June 13, 2025

Subject: ePIC Collaboration: Early Science Document

John Lajoie and Silvia Dalla Torre
Spokespeople, ePIC Collaboration

Dear John, Silvia and the ePIC Collaboration,

As the EIC construction plan becomes more mature, it is apparent that there will be a period of about five years when there will be collisions at the ePIC and early data could be recorded. The EIC Project team has released their expectations for the beam parameters (polarization, luminosity, energy and nuclear species) and their ramp-up during that early operating phase. We are writing to you – the ePIC collaboration - to develop a short document summarizing the science that would be possible from those early data.

Based on the early commissioning beam parameters released by the EIC project [1,2], the ePIC collaboration should summarize for the broader nuclear physics community, the funding agencies, and for the Labs, what exciting scientific results would be possible from this perid. The results in the document should be based on the most recent understanding of the ePIC detector including the acceptances, efficiencies of each detector subsystem, and off-line reconstruction capabilities the collaboration has developed so far. We believe this document will also serve to help in the preparation of the ePIC TDR currently under preparation by the collaboration with the EIC Project, as input to CD2/3 milestone for the EIC. Beyond the physics of interest, we think that this ePIC early physics document would also be useful to demonstrate the collaboration's engagement and getting prepared for physics at the EIC and capture the status of ePIC collaboration's activities at this stage. We are happy to support this activity through in-person or hybrid workshops or topical meetings should they be needed.

We recognize that this is an additional exercise for the ePIC community. At the same time, many previous such exercises (like the Yellow Report) were focused on full EIC machine capability. This report should focus on the science that could be produced before the ramp up to the full EIC machine capability.

We suggest that the collaboration prepares this report by May 1, 2026.

to add notes

Thank you!