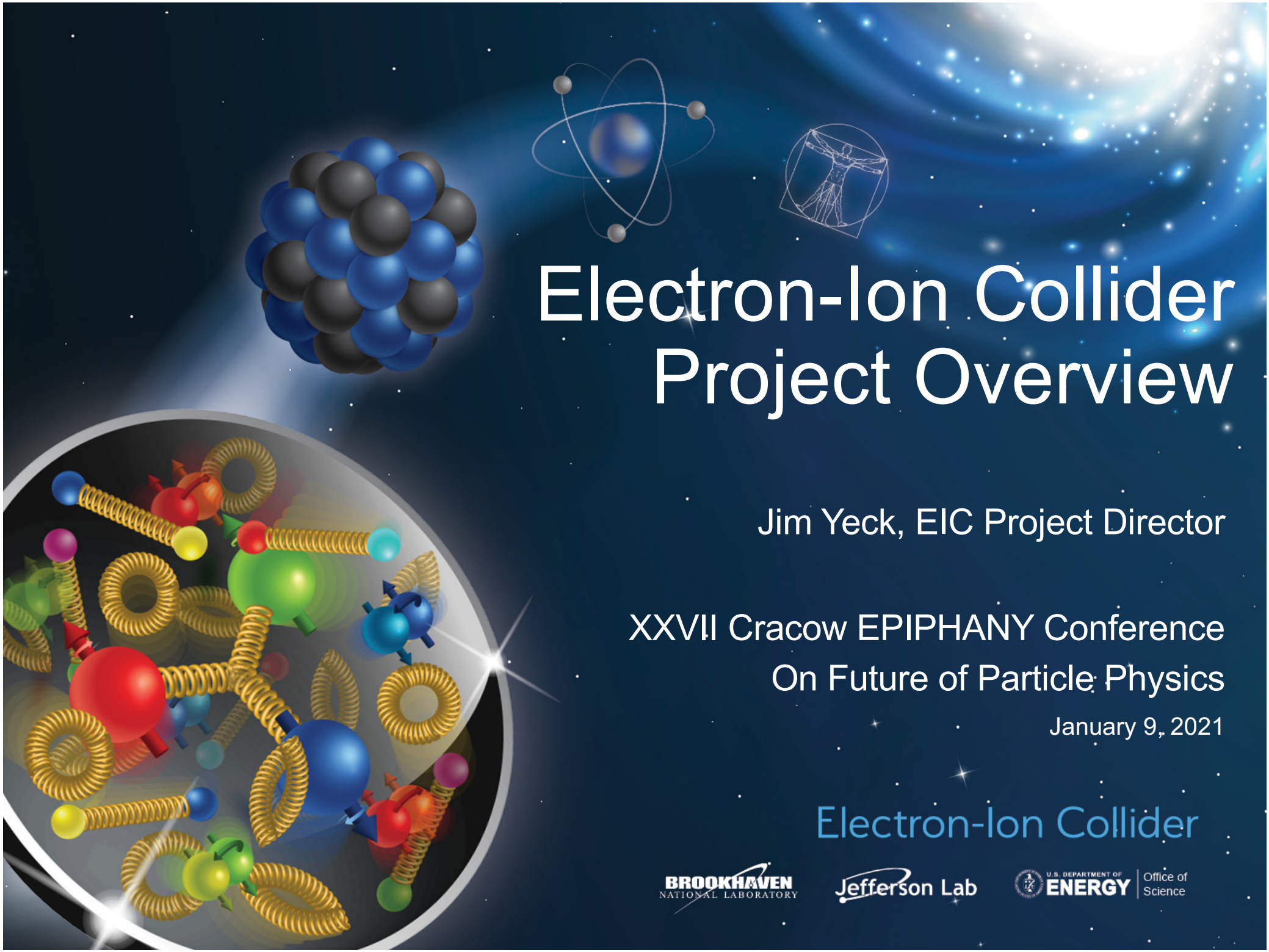


Electron-Ion Collider Project Overview

Jim Yeck, EIC Project Director

XXVII Cracow EPIPHANY Conference
On Future of Particle Physics

January 9, 2021

Electron-Ion Collider

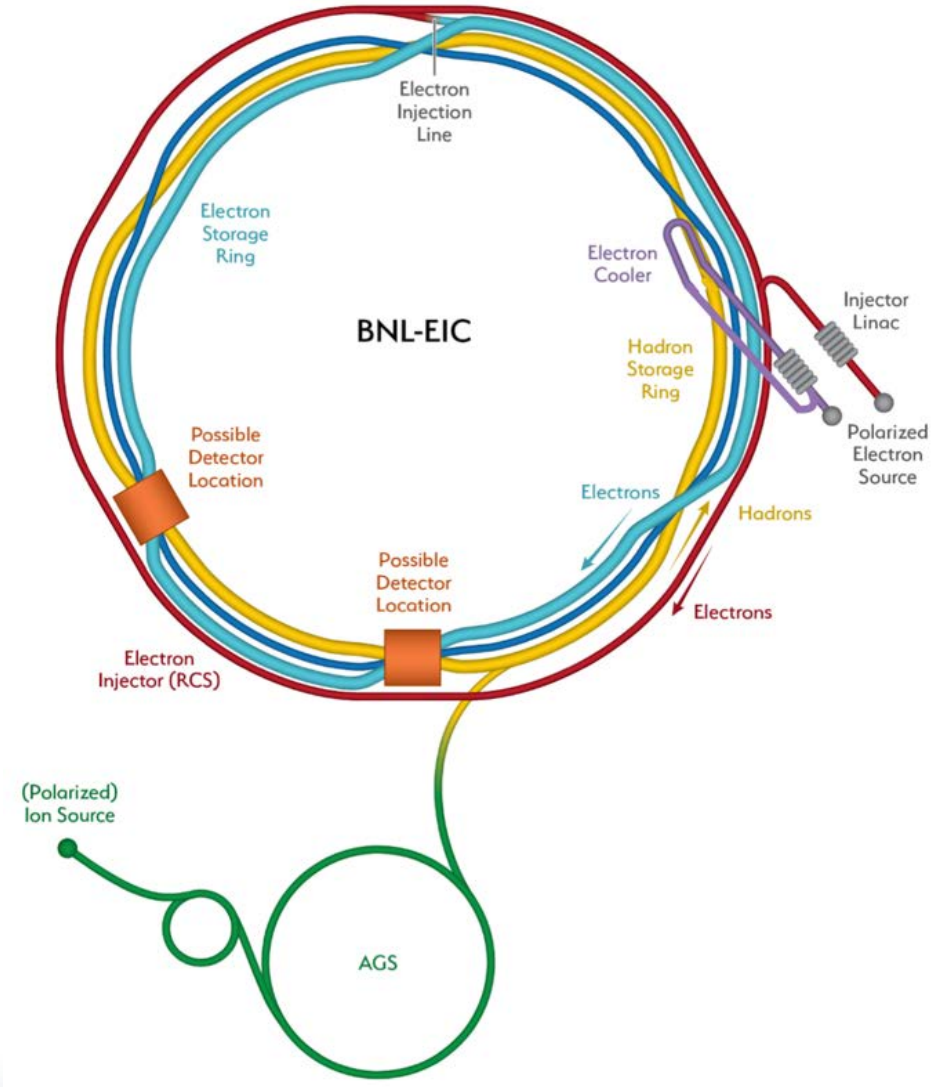
BROOKHAVEN NATIONAL LABORATORY

Jefferson Lab

U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

- Science Goals, Users, Requirements
- BNL/TJNAF Partnership
- Project Organization
- Current Scope
- Plans for the Experimental Program
- Schedule, Funding
- Results of Recent Reviews
- Challenges and Opportunities
- Summary



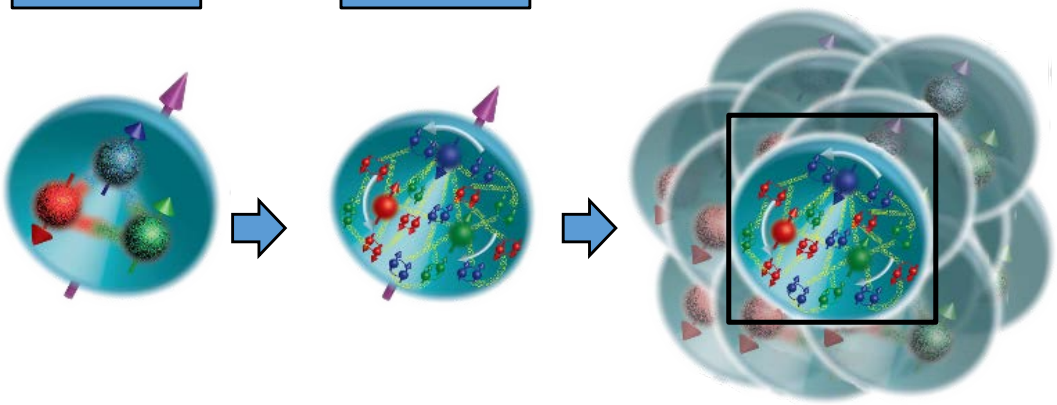
EIC Science

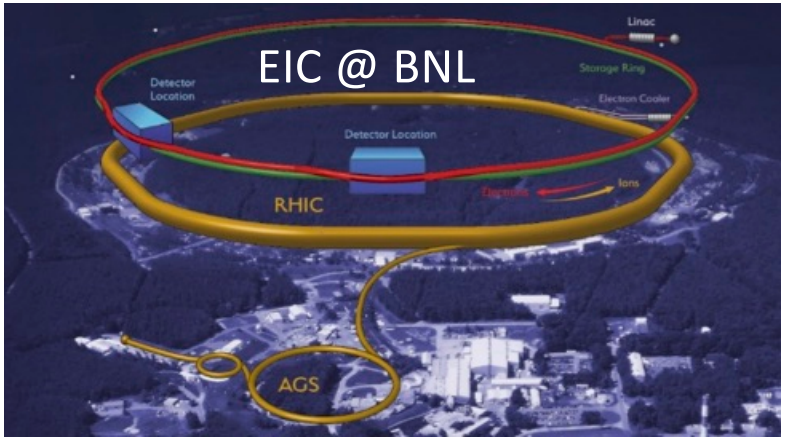
Science: The EIC will, for the first time, provide a complete view of the nucleus:

The Proton (1975)

The Proton (2015)

The Proton in a nucleus





The EIC will revolutionize our understanding of the inner workings of the nucleus by providing us with detailed knowledge of the internal structure of the proton and more complex atomic nuclei that is comparable to our knowledge of the electronic structure of atoms.

The EIC will be a discovery machine, providing answers to long-elusive mysteries of matter related to our understanding the origin of mass, structure, and binding of atomic nuclei that make up the entire visible universe.

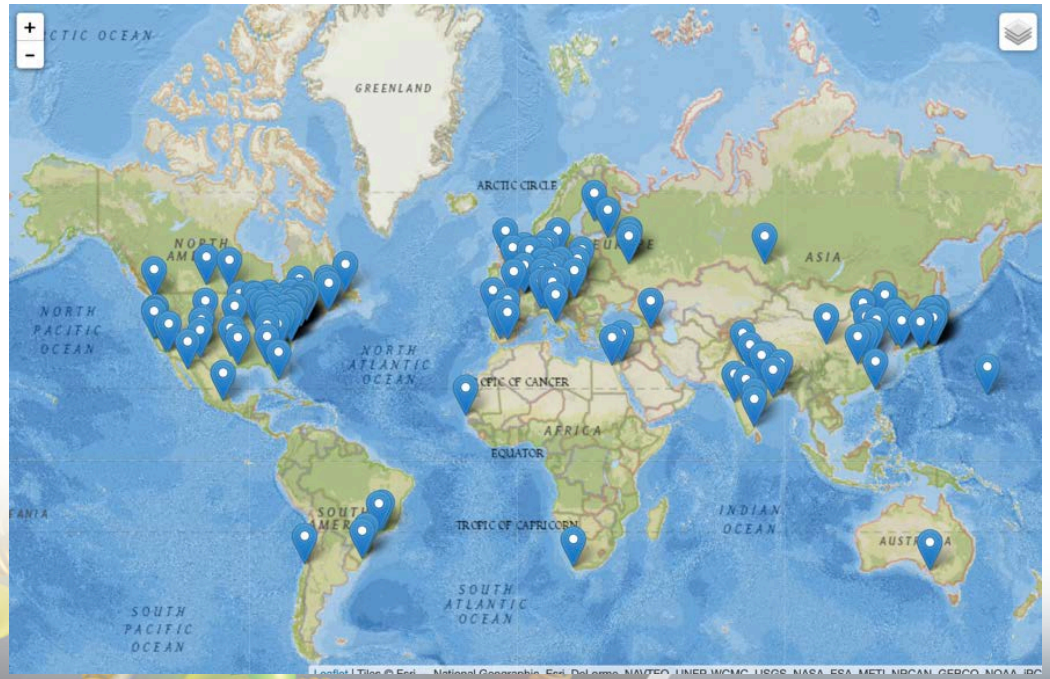
The EIC project will work closely with domestic and international partners to deliver the EIC construction project and then begin EIC operations.

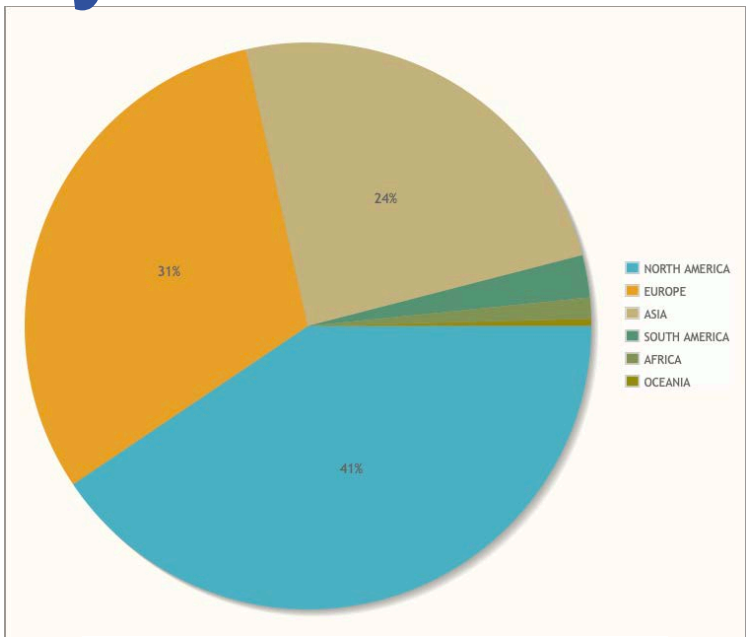
EIC User Community

EIC Users Group Formed in 2016
EICUG.ORG

Status November 2020:

- Collaborators 1230
- Institutions 248
- Countries 34





Annual EICUG Meetings

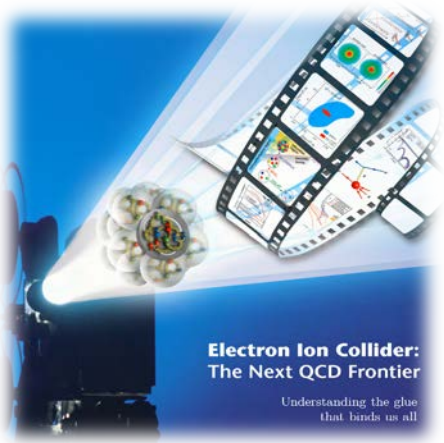
2016	UC Berkeley
2016	Argonne
2017	Trieste, Italy
2018	Washington, DC
2019	Paris, France
2020	Miami
2021	TBD
2022	Warsaw, Poland

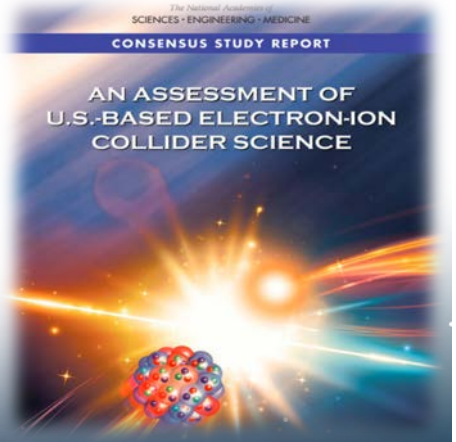
EIC Requirements

Project Design Goals

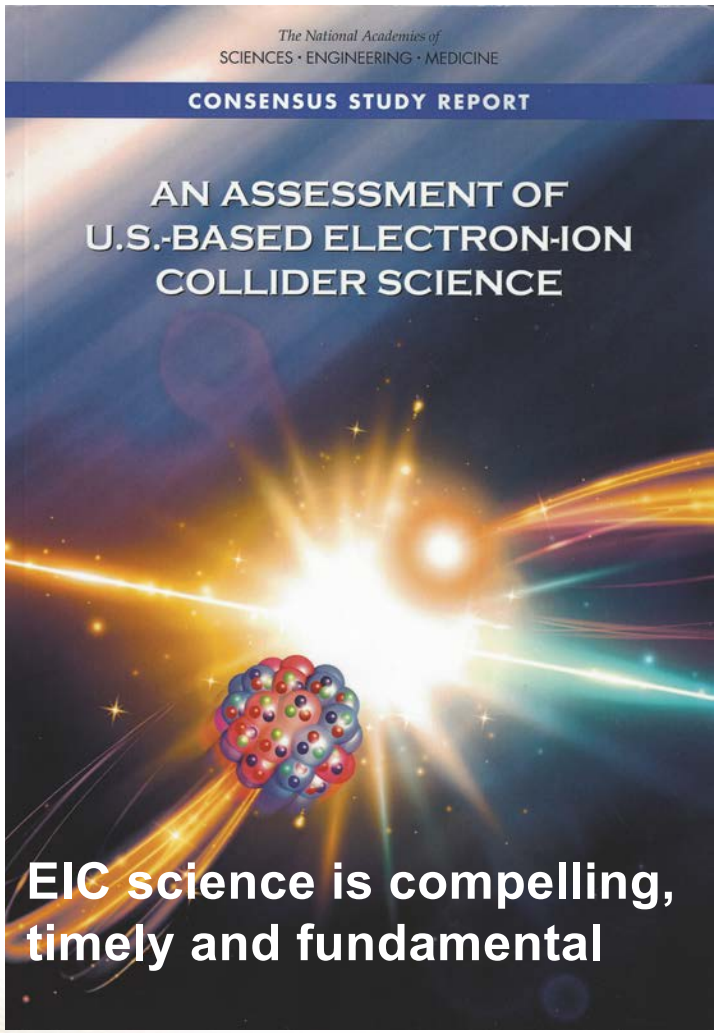
- High Luminosity: $L = 10^{33} – 10^{34} cm^{-2} sec^{-1}$, 10 – 100 fb^{-1}/year
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: E_{cm} = 20 – 140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Acceptance and Good Background Conditions
- Accommodate a Second Interaction Region (IR)

Conceptual design scope and expected performance meets or exceed Nuclear Science Advisory Committee (NSAC) Long Range Plan (2015) and the EIC White Paper requirements endorsed by the National Academy of Sciences (NAS) (2018)





EIC Science



Developed by NAS committee with broad science perspective

- **Finding 1:** An EIC can uniquely address three profound questions about nucleons — neutrons and protons — and how they are assembled to form the nuclei of atoms:
  - How does the **mass** of the nucleon arise?
  - How does the **spin** of the nucleon arise?
  - What are the **emergent properties** of dense systems of gluons?

- **Finding 2:** These three high-priority science questions can be answered by an EIC with **highly polarized beams** of electrons and ions, with sufficiently **high luminosity** and sufficient, and **variable**, center-of-mass **energy**.

EIC Recent History

Event	Date
DOE Mission Need Statement Approved	January 22, 2019
DOE Independent Cost Review	July 2019
DOE Electron Ion Collider Site Assessment	October 2019
Critical Decision – 0 (CD-0) Approved	December 19, 2019
DOE Site Selection Announced	January 9, 2020
BNL TJNAF Partnership Agreement	May 7, 2020
DOE Office of Science Status Review	September 9-11, 2020
Independent EIC Conceptual Design Review	November 16-18, 2020
BNL Director's Review	December 8-10, 2020
DOE Critical Decision-1 (CD-1) Review	***January 26-28, 2021***
CD-1 Approval Target Date	*April 2021*

BNL TJNAF Partnership

- BNL-TJNAF Partnering Agreement Approved- May 7, 2020
- The EIC Project Leadership Team captures project delivery experience from BNL and TJNAF
- EIC Project Executive Management Team (EMT) Established:
  Elke Aschenauer, Rolf Ent, Diane Hatton, Allison Lung, Andrei Seryi, Ferdinand Willeke, and Jim Yeck
- Abhay Deshpande, EIC Science Director, participates in the EMT meeting as an ex-officio member, providing an additional connection to the User community.

BNL Visit to TJNAF – Feb 28, 2020

ELECTRON ION COLLIDER PROJECT

J. Yeck (BNL), Project Director
F. Willeke (BNL), Deputy Project Director and Technical Director

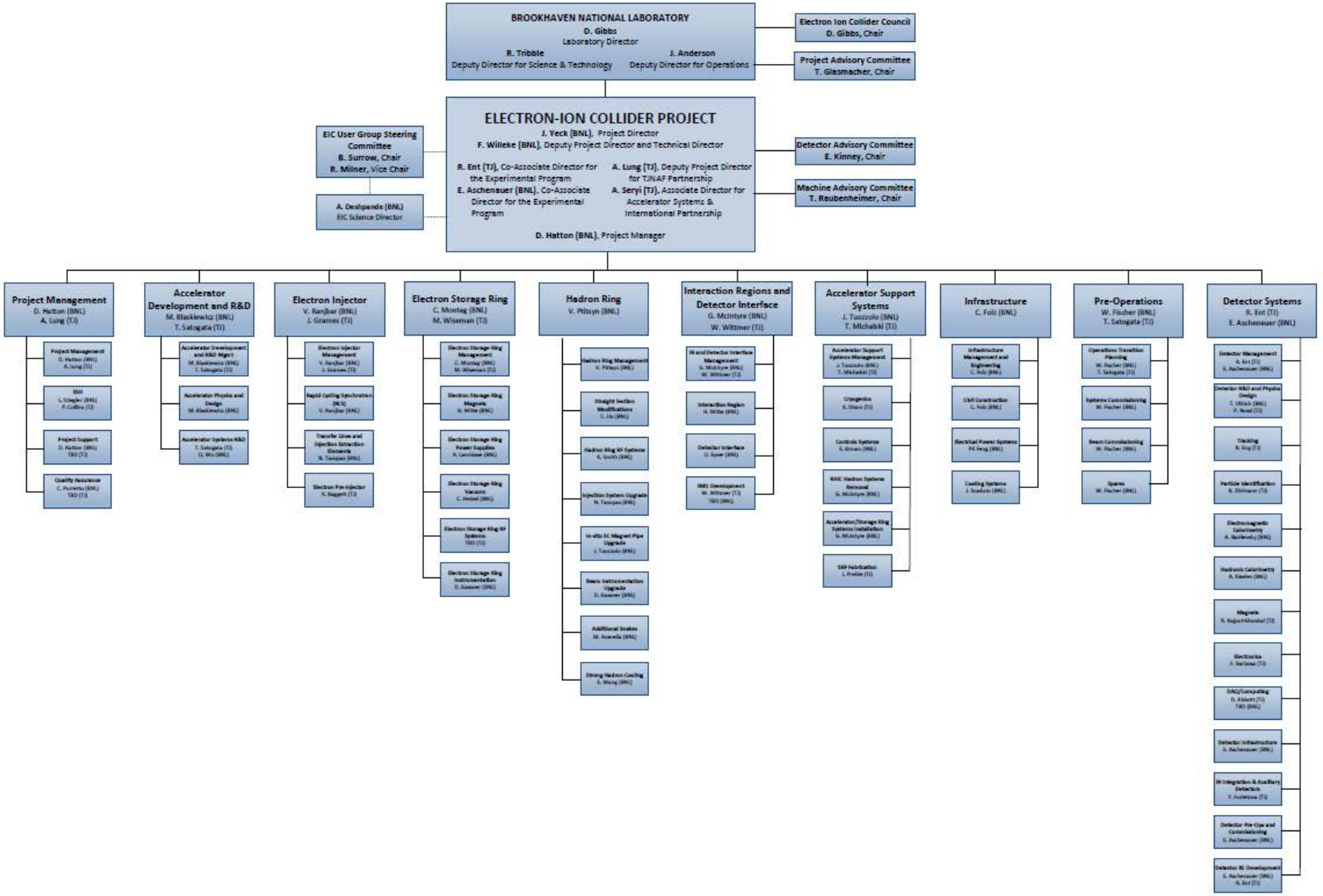
R. Ent (TJ), Co-Associate Director for the Experimental Program
E. Aschenauer (BNL), Co-Associate Director for the Experimental Program
A. Lung (TJ), Deputy Project Director for TJNAF Partnership
A. Seryi (TJ), Associate Director for Accelerator Systems & International Partnership
D. Hatton (BNL), Project Manager

Project Organization

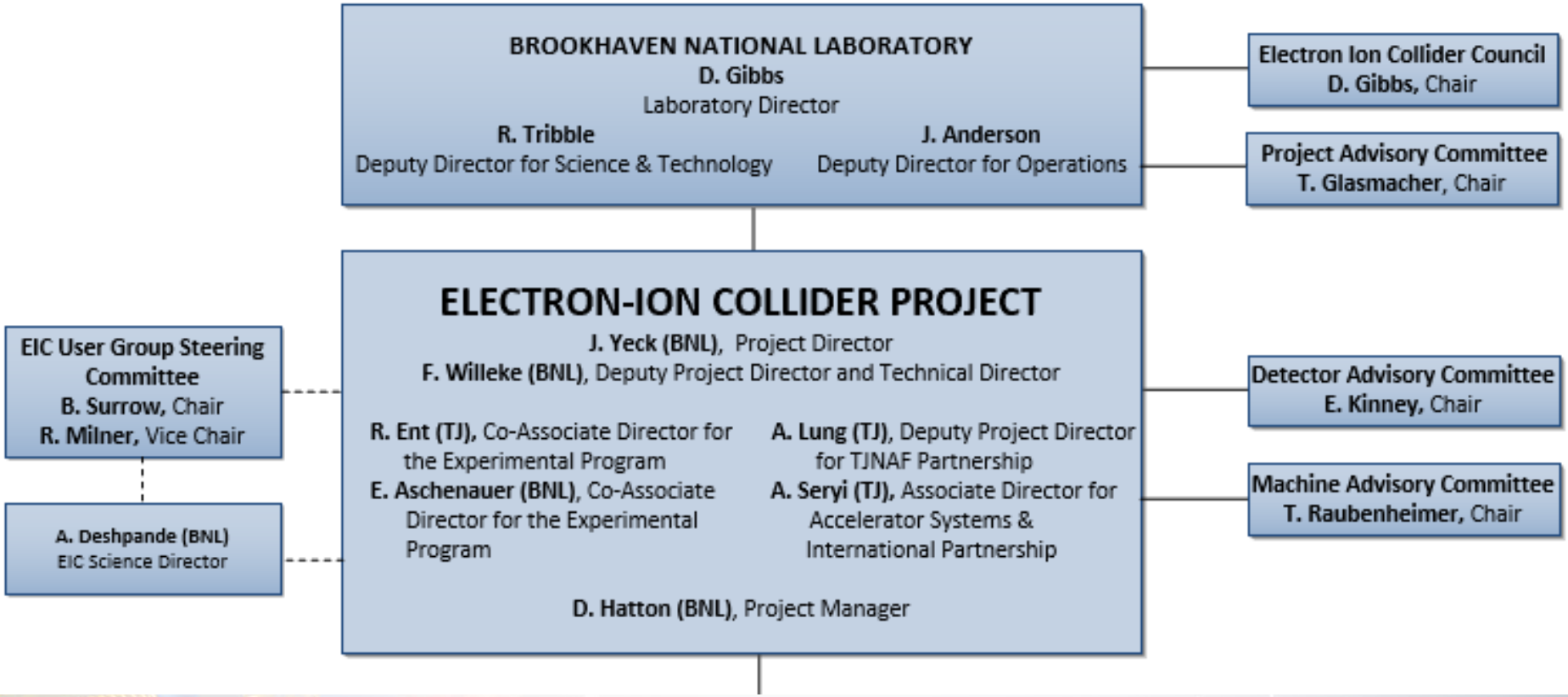
- BNL/TJNAF Partnership
  - BNL and TJNAF partnering agreement signed in May 2020
  - EIC Council, chaired by BNL Director, established in June. TJNAF Director is a founding member. Concept based on recent DOE Office of Science projects including LCLS-II and Exascale.
  - Executive Management Team integrates BNL and TJNAF project leadership roles. Weekly and ad hoc meetings.

- BNL and TJNAF worked together to clarify mandates and membership for the standing advisory committees
  - Machine Advisory Committee: 1st Meeting Aug 26, 2020
  - Project Advisory Committee: Meetings Aug 27, Dec 1, 2020
  - Detector Advisory Committee: Meetings Sep 28-29, Dec 18, 2020

EIC Project Organization

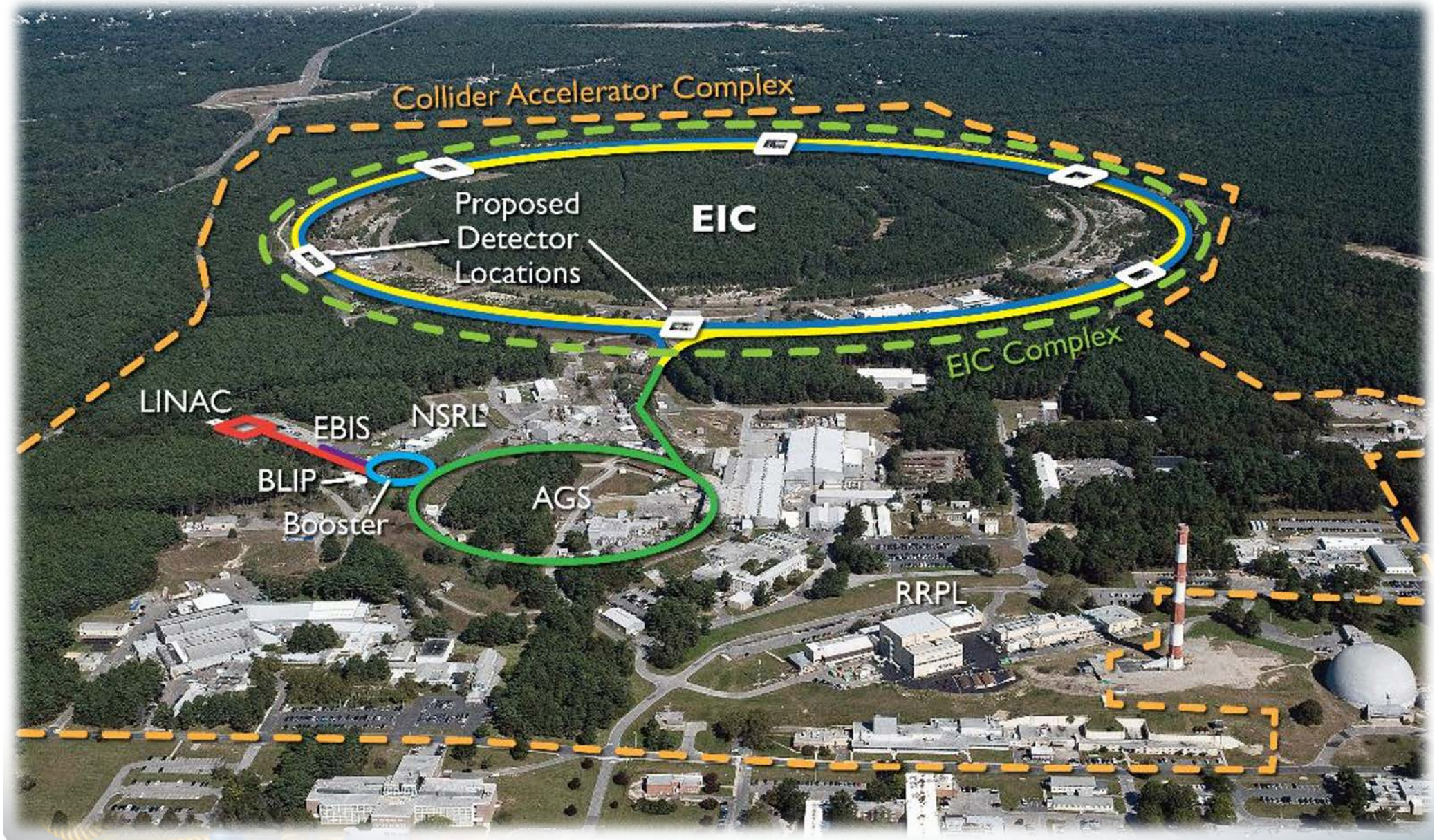


Project Leadership, Committees, and Users

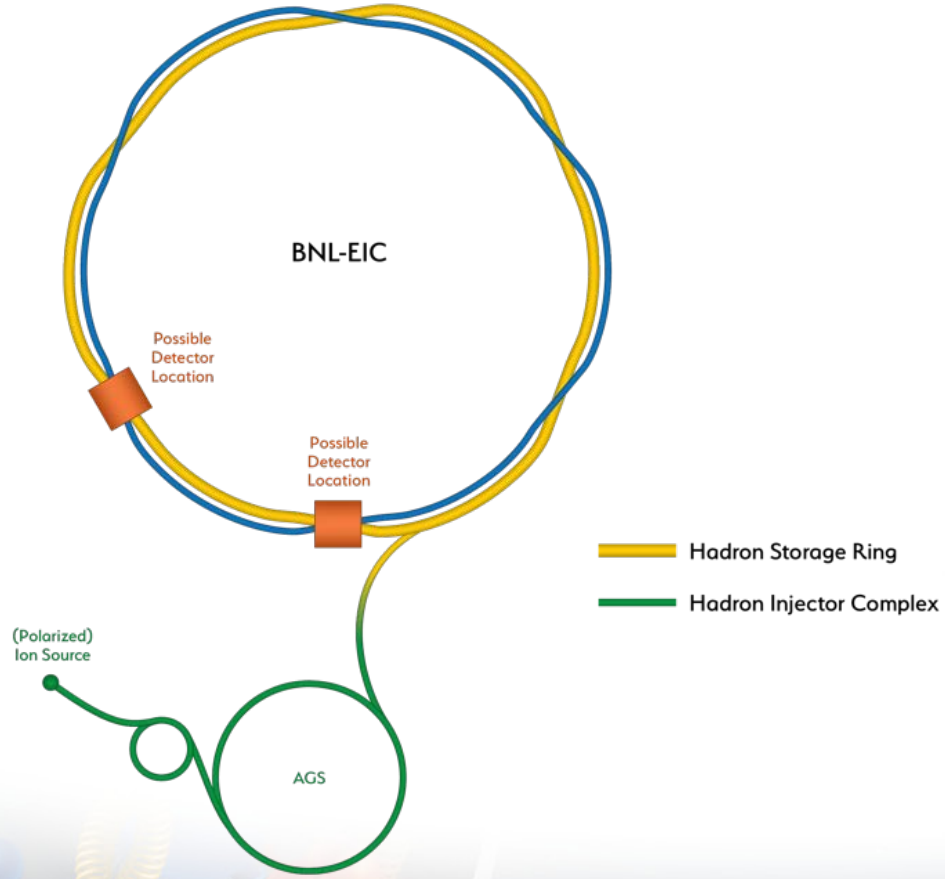


EIC Partnership Plans

- Actively promoting a culture of interdisciplinary and multi-institutional collaboration for both the accelerator and experimental program
- International and domestic partners are being pursued and bi-lateral meetings with potential partners are well underway to discuss opportunities in the accelerator and experimental areas
- Accelerator Partnership Activities (Assuming ~5-10% In-kind)
  - Workshop October 7-9 Hosted by Cockcroft Institute, UK – *Promoting Collaboration on the Electron-Ion Collider*
  - In-kind contributions to the accelerator design and hardware are being pursued
- Detector Partnership Activities (Assuming ~30% In-kind for project detector)
  - Expressions of Interest (EoI) for potential cooperation on EIC experimental equipment submitted following a call in May: https://www.bnl.gov/eic/EOI.php
  - Call for proposals for detector(s) planned for March 2021
- DOE Office of Nuclear Physics organizes regular meetings with international funding agencies. The next meeting is planned for late February.

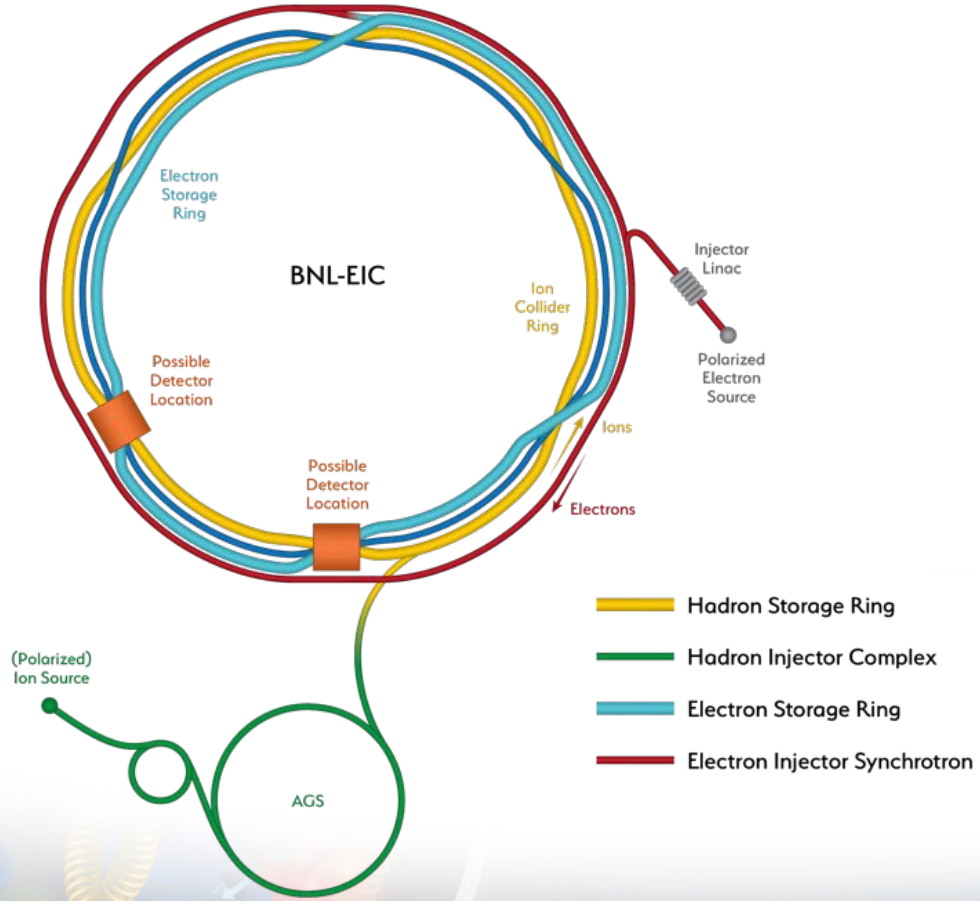

Collider Accelerator Complex
Proposed
Detector
Locations
EIC
EIC Complex
LINAC
EBIS
NSRL
BLIP
Booster
AGS
RRPL

Relativistic Heavy Ion Collider (RHIC) Transformed into an Electron-Ion Collider



- Existing RHIC accelerator complex with blue and yellow hadron storage rings

Relativistic Heavy Ion Collider (RHIC) Transformed into an Electron-Ion Collider

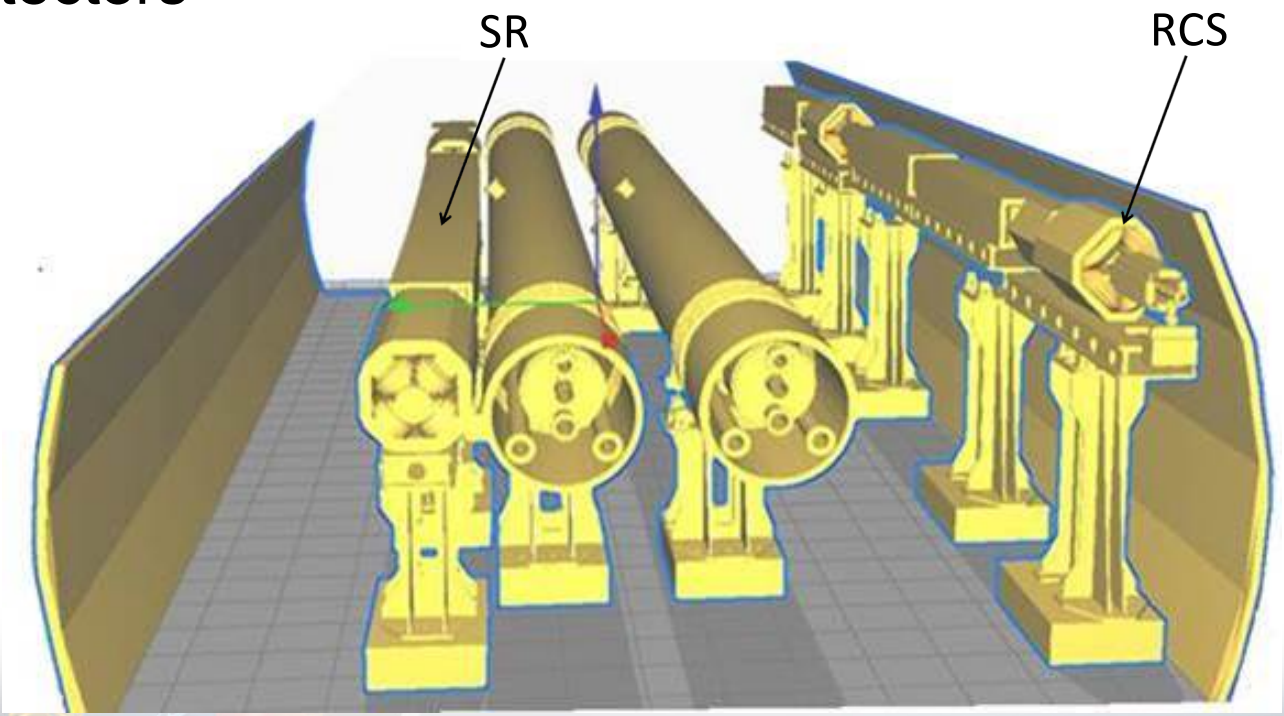


- Add electron storage ring
- Add an electron injector complex with Rapid Cycling Synchrotron
- Strong hadron cooling completes the facility

EIC in the RHIC Tunnel

- Rapid Cycling Synchrotron (RCS) for electrons and Electron Storage Ring (SR) fit into the existing RHIC tunnel

- Two existing detector halls available for interaction regions and detectors



Experimental Program Preparation

EIC User Community Yellow Report – Kicked off in December 2019

- 4 workshops to advance the state of the documented physics studies and detector concepts in preparation for the realization of the EIC
- 4th and final workshop November 19-21, draft Yellow Report available for CD-1

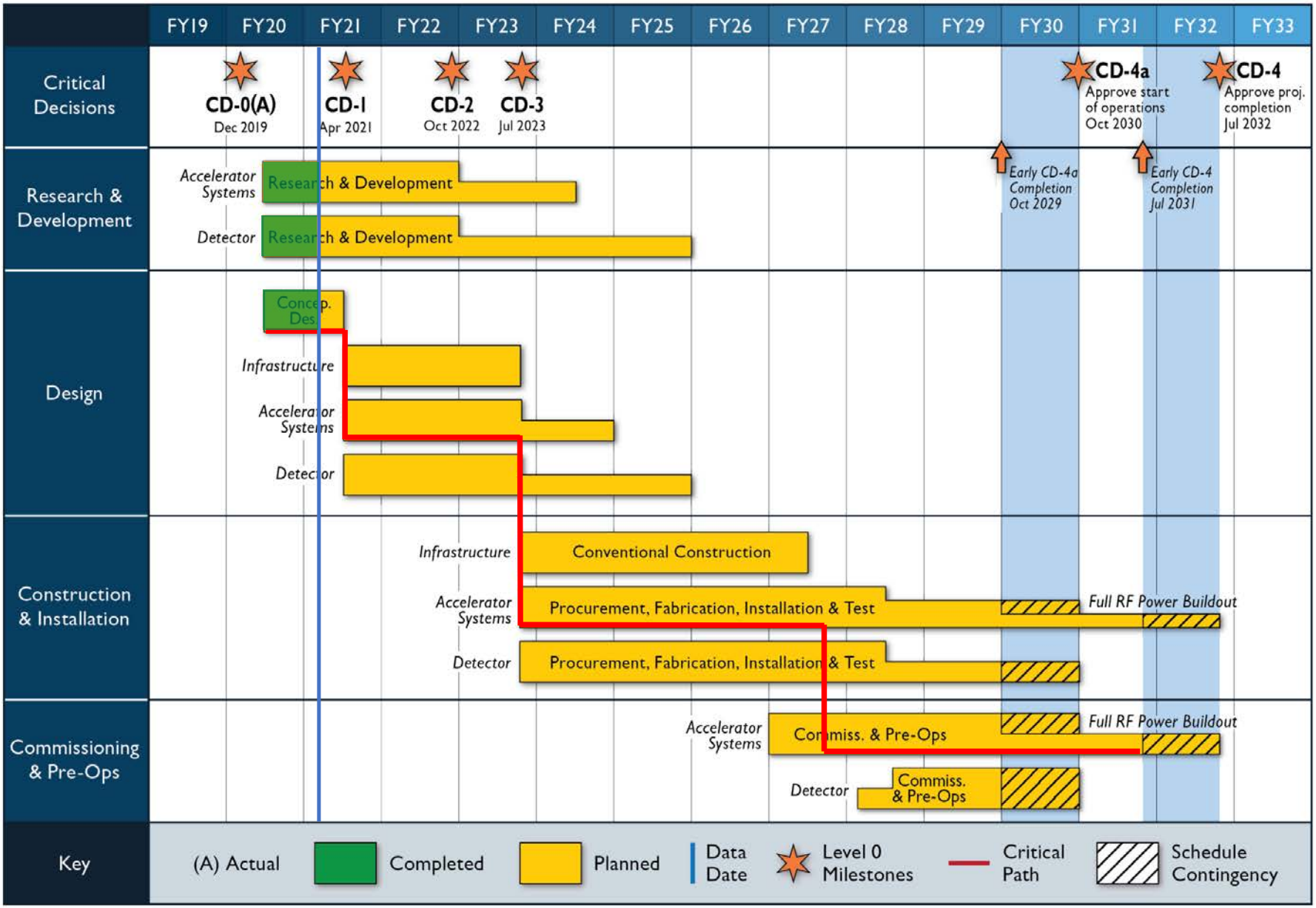
BNL and TJNAF Jointly Leading Process for Defining Detector(s)	
Call for Expressions of Interest (EOI) for "Potential Cooperation on the EIC Experimental Program"	May 2020
EOI Responses	November 2020
Assessment of EOI Responses	On-going
Call for Detector Proposals	March 2021
BNL/TJNAF Program Advisory Committee Established	Summer 2021
Detector Proposals Submitted	December 2021
Decision on Detector(s)	Early 2022

2nd Detector and IR Planning

EIC facility will be capable of supporting a science program that includes two detectors/interaction regions

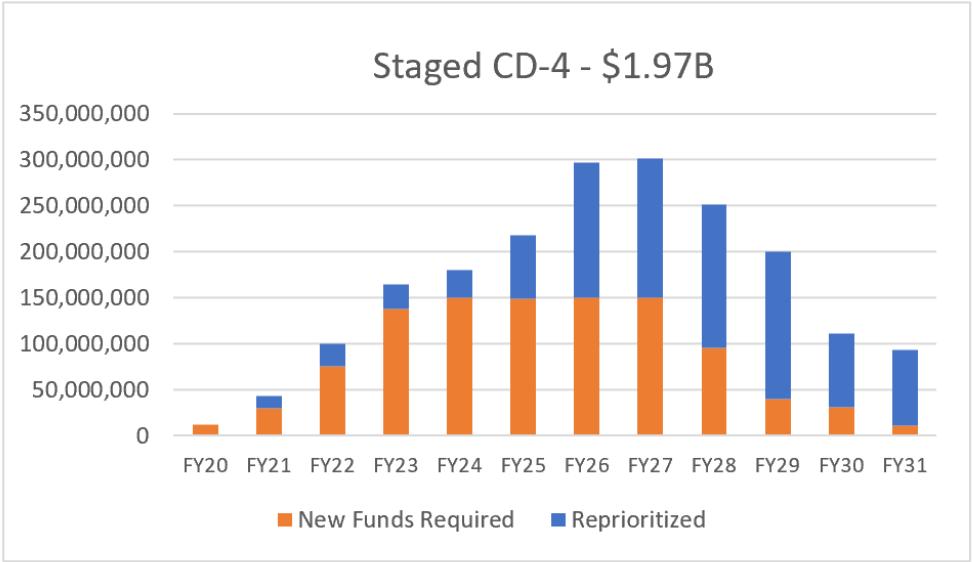
- EIC project scope/budgets support one IR and one detector
- EIC project planning will ensure the viability of a 2nd IR and detector
- Stakeholders agree that a 2nd IR and detector with a similar timeline as the EIC project detector is desirable, and routes to making this possible will be explored
  - Dedicated session on the 2nd IR during Yellow Report Workshop in November
  - Topical week-long workshop on 2nd IR concepts in February 2021

Schedule


FY19
FY20
FY21
FY22
FY23
FY24
FY25
FY26
FY27
FY28
FY29
FY30
FY31
FY32
FY33
Critical Decisions
CD-0(A)
Dec 2019
CD-1
Apr 2021
CD-2
Oct 2022
CD-3
Jul 2023
CD-4a
Approve start of operations
Oct 2030
CD-4
Approve proj. completion
Jul 2032
Research & Development
Accelerator Systems
Research & Development
Detector
Research & Development
Early CD-4a Completion Oct 2029
Early CD-4 Completion Jul 2031
Design
Concep. Des.
Infrastructure
Accelerator Systems
Detector
Construction & Installation
Infrastructure
Conventional Construction
Accelerator Systems
Procurement, Fabrication, Installation & Test
Full RF Power Buildout
Detector
Procurement, Fabrication, Installation & Test
Commissioning & Pre-Ops
Accelerator Systems
Commiss. & Pre-Ops
Full RF Power Buildout
Detector
Commiss. & Pre-Ops
Key
(A) Actual
Completed
Planned
Data Date
Level 0 Milestones
Critical Path
Schedule Contingency

Reference Funding Profile

Fiscal Year	FY 20	FY 21	FY 22	FY 23	FY 24	FY 25	FY 26	FY 27	FY 28	FY 29	FY 30	FY 31	Total ($M)
OPC	$10	$18	$9	$3									$40
TEC PED	$1	$25	$91	$120	$95	$30							$129
TEC Construction				$41	$86	$189	$294	$271	$216	$172	$102	$85	$1,456
Pre-Ops							$3	$30	$35	$29	$10	$8	$115
Total Project Cost ($M)	**$11**	**$43**	**$100**	**$164**	**$181**	**$219**	**$297**	**$301**	**$251**	**$201**	**$112**	**$93**	**$1,973**



- New Funds and Reprioritized Funds
- Project Funding Profile Set at CD-2
- FY2021 Budget TBD (Continuing Resolution). DOE ONP Supports Schedule for CD-1

- $100M Investment by New York State for Conventional Construction

EIC Conceptual Design Review – November 2020

- Conceptual design of the EIC collider and reference detector likely to meet its performance goals and is of sufficient quality and maturity to provide a sound basis to start the preliminary engineering design.
- One of the largest challenges of the EIC baseline design is the inclusion of a single detector system to cover the entire suite of facility science goals. Timely progress towards a conceptual design is important [from the current Reference Design/Generic Detector].
- EIC team is encouraged to establish a central system integration function.

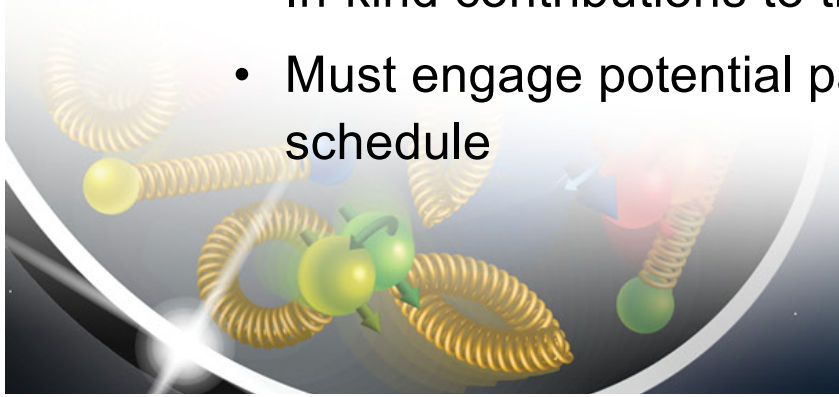
Committee recognized numerous technical challenges and provided detailed comments and recommendations.

Post Critical Decison-1 Timeline

Accelerator Technical Reviews	Spring/Summer 2021
Call for Detector Proposals	March 2021
Start Preliminary Design	April 2021
Detector Proposals	September 2021
Selection of Detector(s)	December 2021
In-kind Deliverables - Agreements	Spring 2022
Start Earned Value Tracking	March 2022
Goal for CD-2 Approval	October 2022
Goal for CD-3 Approval	July 2023

EIC Challenges and Opportunities

- Affordability – EIC is very large project for DOE Office of Nuclear Physics (NP) and Office of Science (SC)
  - Requires reprioritization of RHIC operations funding to EIC and new funding
  - Significant ramp up of project funding (annual doubling) starting in FY2021 is required to maintain timeline for Critical Decisions
  - Most cost-effective project follows closely to a technically driven schedule
- Partner Engagement – Expectations and Implementation
  - International and domestic engagement highly desirable and widely expected
  - In-kind contributions to the accelerator and experiment(s) will be pursued
  - Must engage potential partners now given the EIC technically driven schedule



EIC Challenges and Opportunities

- TJNAF Partnership – Non-traditional, breaking new ground
  - EIC Executive Management Team (Level 1) and TJNAF personnel in Level 2 management roles establish TJNAF as a full intellectual partner in the leadership of the project.
  - BNL and TJNAF jointly hosting the EIC experiments.
  - TJNAF responsibilities for project scope need to be further clarified
- COVID-19 Impacts – Immediate and long-term implications
  - Current EIC activities are primarily planning and design work which can be carried out remotely
  - There are short term impacts on efficiency, but the project is ready for CD-1
  - Long term Indirect impacts may be more significant, e.g., aligning with RHIC operations plans, uncertain fiscal context, design efficiency, R&D efficiency

Summary

- Preliminary Project Plans Established
  - Strong foundation in place: organization, scope definition, conceptual design and performance parameters, cost & schedule
  - BNL/TJNAF partnership defined
    - High-level TJNAF responsibilities identified, scope deliverables to be finalized after CD-1 review
    - BNL and TJNAF jointly leading the process for defining detector(s)
  - Pursuing broad collaboration and partnership in the EIC
- Engage in the EIC Now
  - Project Baseline (CD-2) in ~2 years
  - Construction Start in ~ 3 years
  - Science in ~10 years