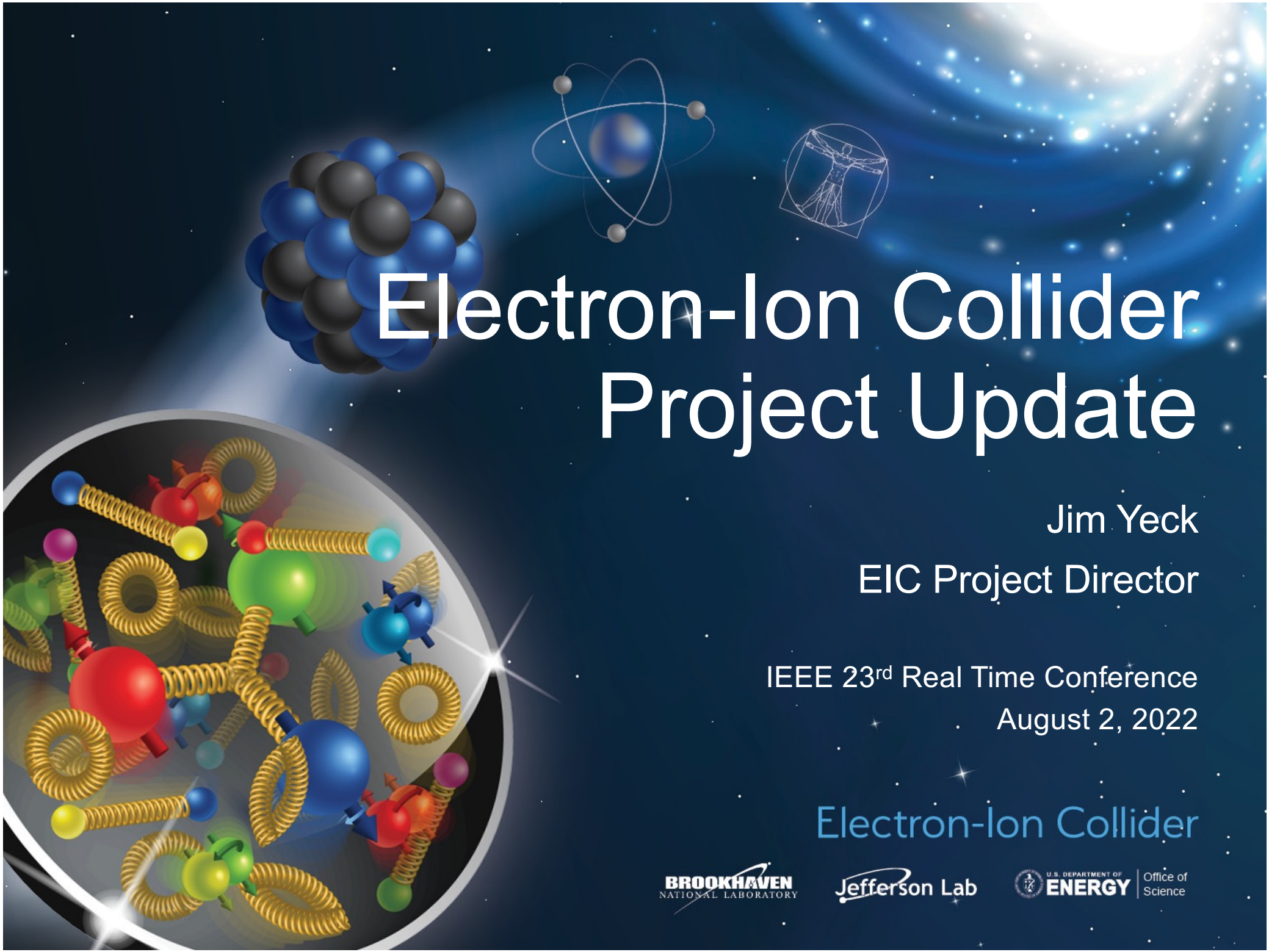


Electron-Ion Collider Project Update

Jim Yeck

EIC Project Director

IEEE 23rd Real Time Conference

August 2, 2022

Electron-Ion Collider

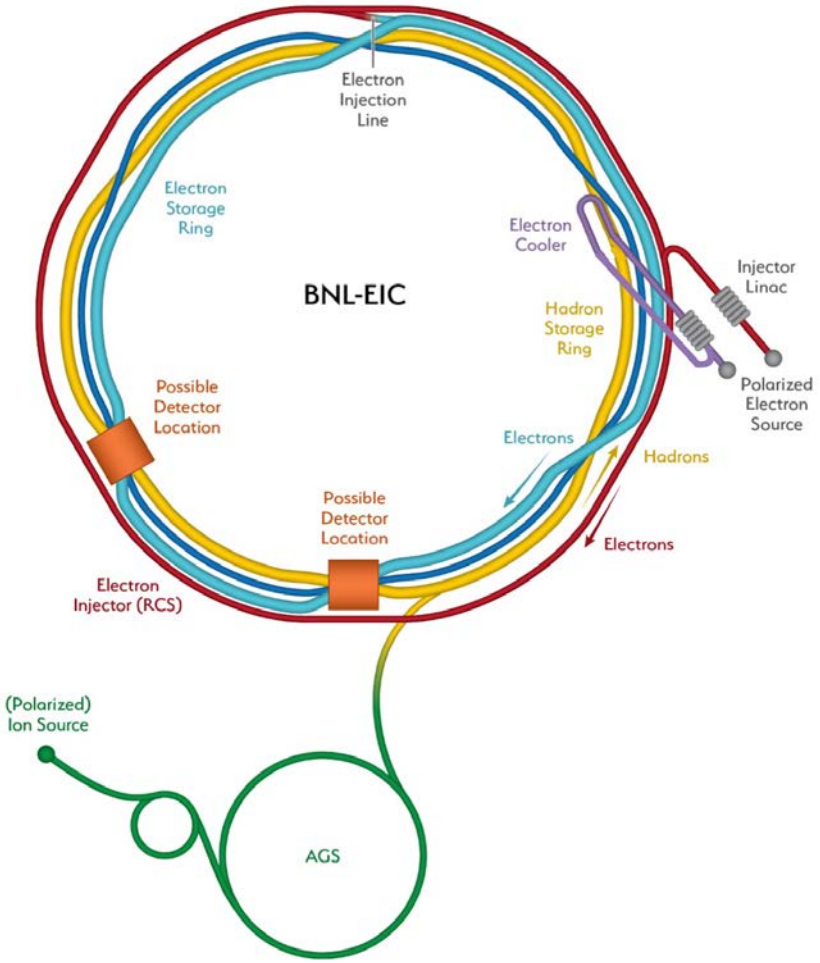
BROOKHAVEN NATIONAL LABORATORY

Jefferson Lab

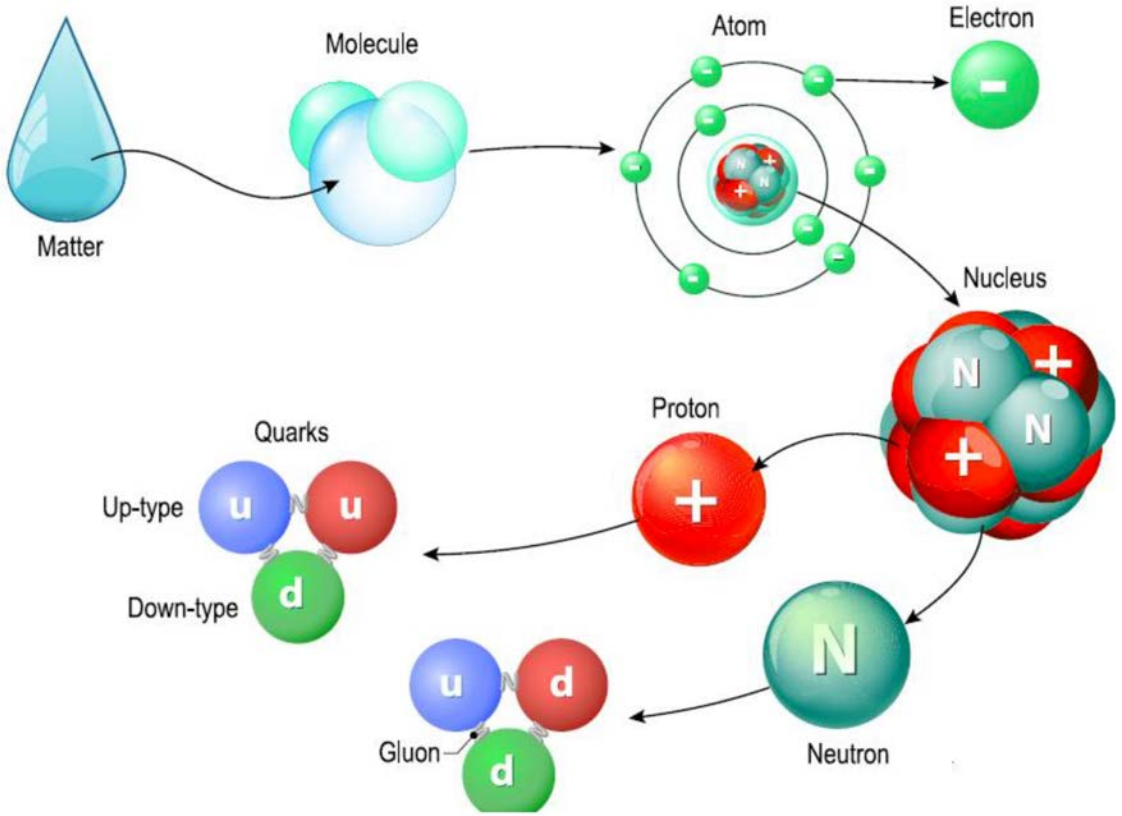
U.S. DEPARTMENT OF ENERGY | Office of Science

Outline

- EIC Science Requirements
  - Science
  - Instrumentation
  - Facility Design
- Project Planning
  - Schedule
  - Organization
  - Partnerships
- Positioning for Success
  - Challenges
  - Ingredients to Success
- Summary



Quest for the fundamental structure of matter



What's in there?

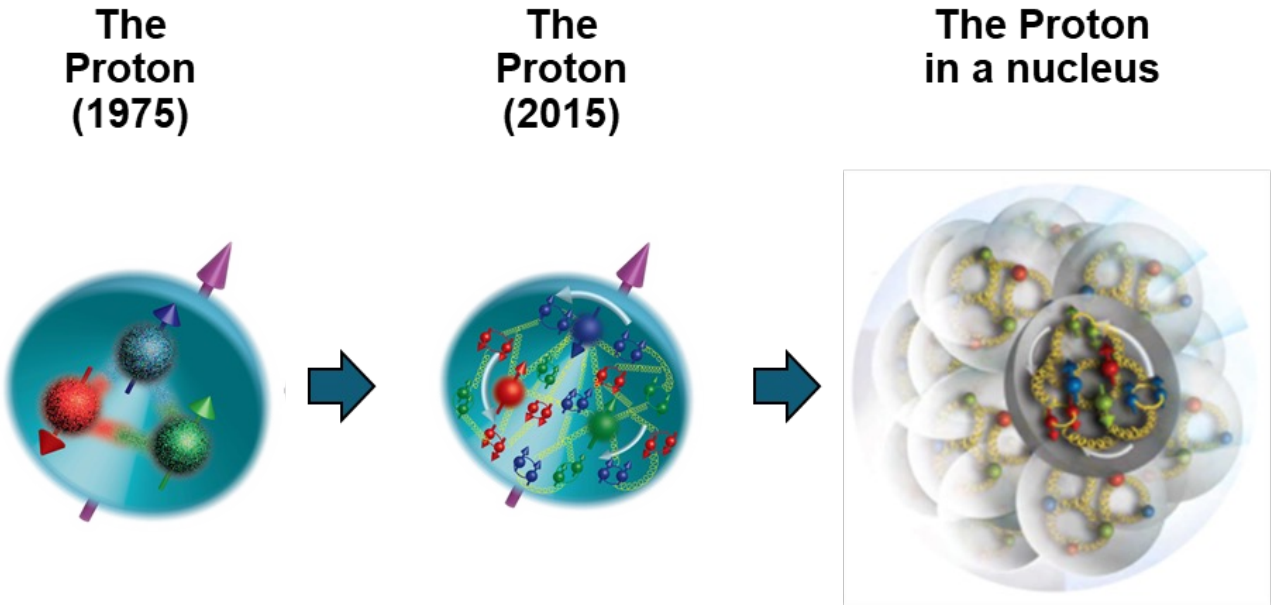
What are we made up of?

What is the "smallest"?

What is "fundamental" that can't be divided further?

EIC Science

Uncovering the Structure of Visible Matter at the Electron-Ion Collider



The EIC, a discovery machine, will enable the definitive study of the role of gluons and quarks in nucleons and nuclei. It will provide precise images of the gluon/quark structure of the polarized proton, unravel the mysteries of the origin of nucleon mass and spin, and explore the physics of gluons at high density.

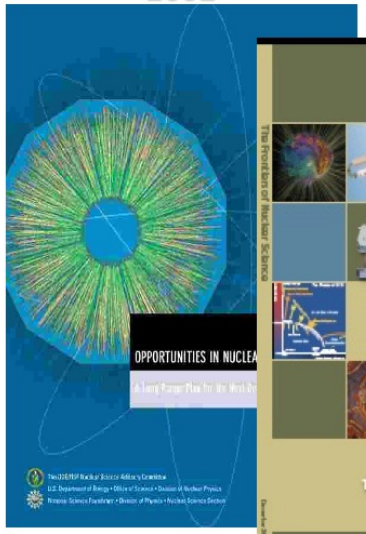
The innovations required to design, construct, and operate the EIC will have impacts beyond nuclear physics in accelerator science, particle physics, medicine, isotopes, materials, energy, and computing.

The EIC project is working closely with domestic and international partners to deliver the EIC.

Science Case

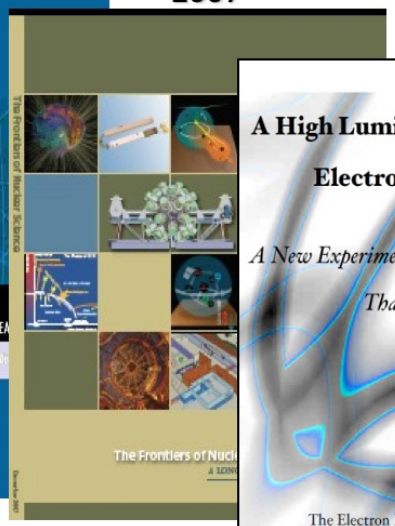
A strong community emphasis on the urgent need for a machine to illuminate the dynamical basis of hadron structure in terms of the fundamental quark and gluon fields has been a persistent message for almost two decades

2002



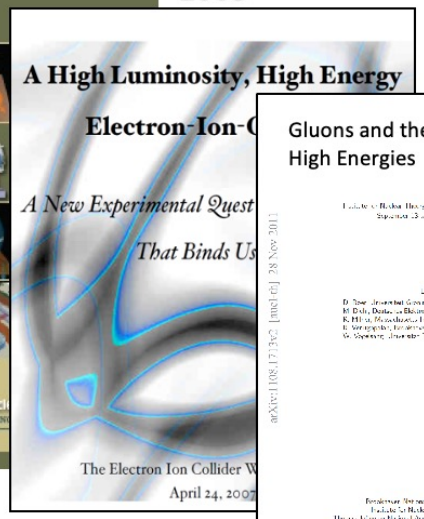
"…essential accelerator and detector R&D [for EIC] should be given very high priority in the short term."

2007



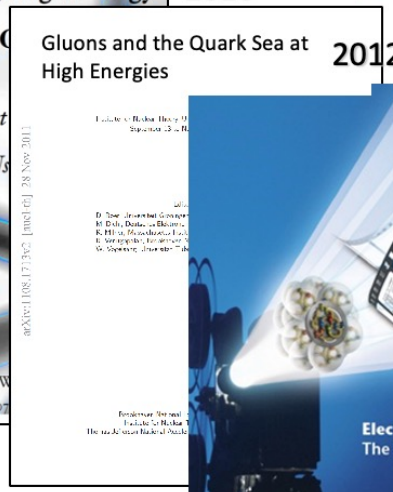
"We recommend the allocation of resources …to lay the foundation for a polarized Electron-Ion Collider…"

2009

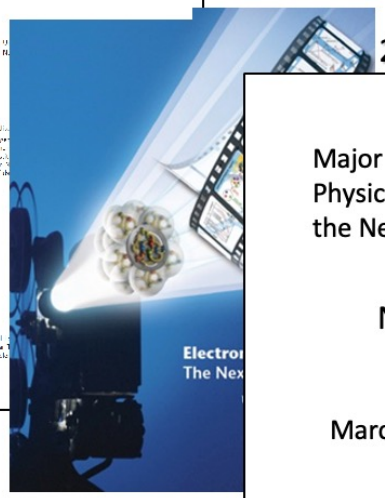


"..a new dedicated facility will be essential for answering some of the most central questions."

2010

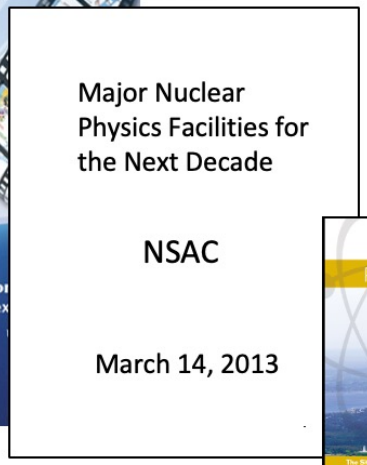


2012



"The quantitative study of matter in this new regime [where abundant gluons dominate] requires a new experimental facility: an Electron Ion Collider."

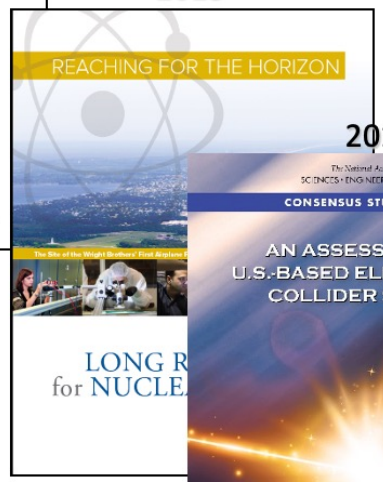
2013



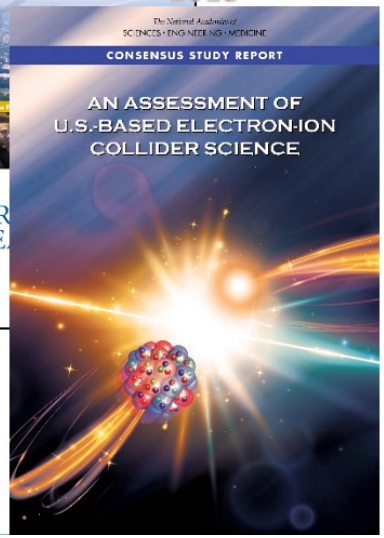
Electron-Ion Collider *absolutely central* to the nuclear science program of the next decade.

"a high-energy high-luminosity polarized EIC [is] the highest priority for new facility construction following the completion of FRIB."

2015

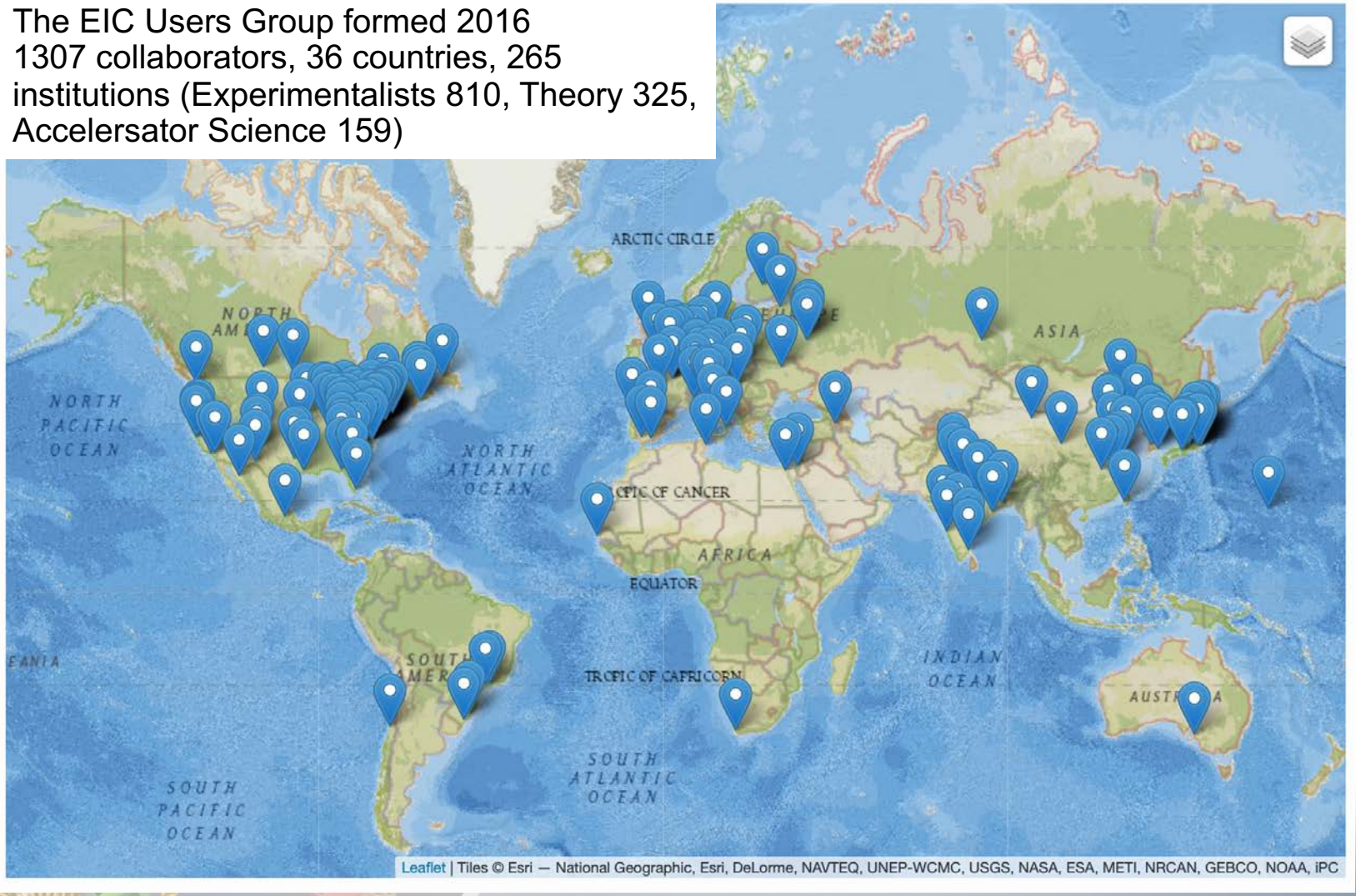


2018



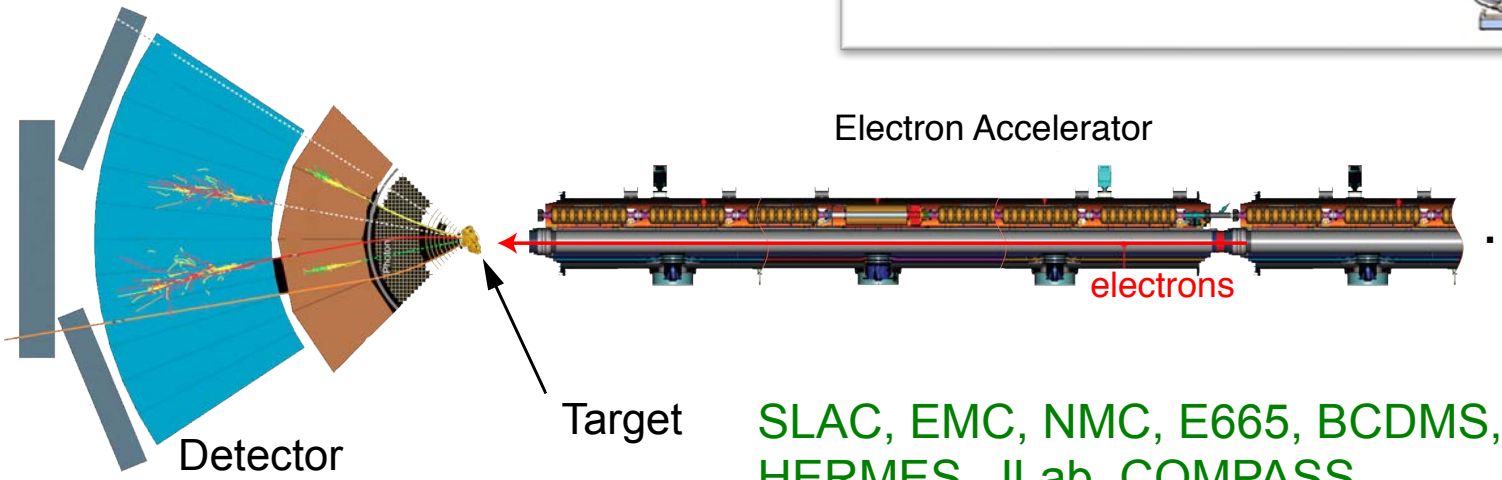
World-wide interest in EIC science

The EIC Users Group formed 2016
1307 collaborators, 36 countries, 265 institutions (Experimentalists 810, Theory 325, Accelersator Science 159)

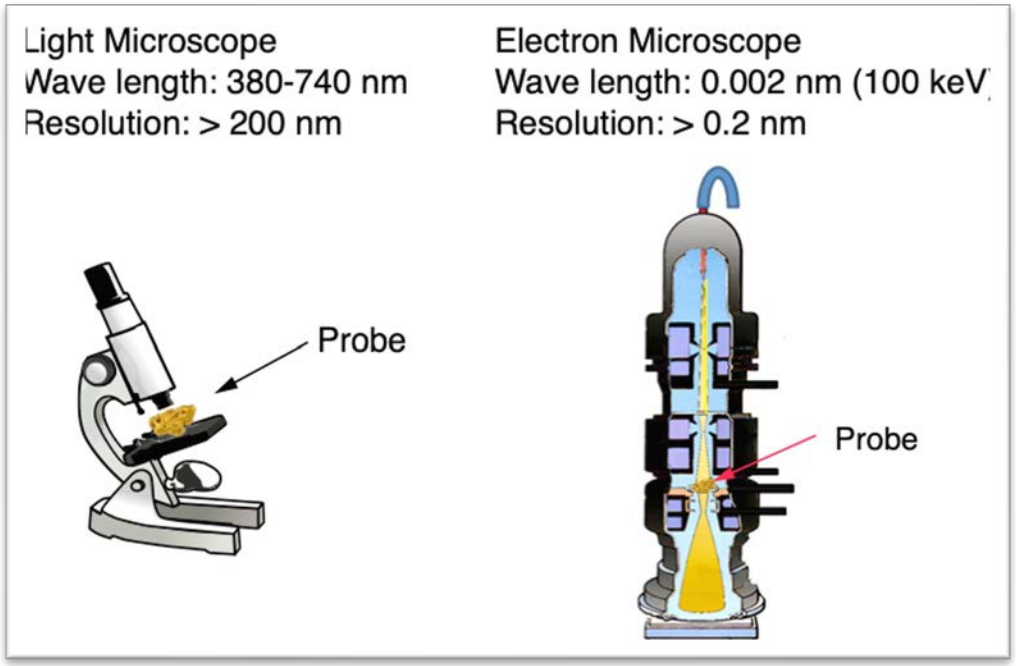


Studying smaller and smaller things…

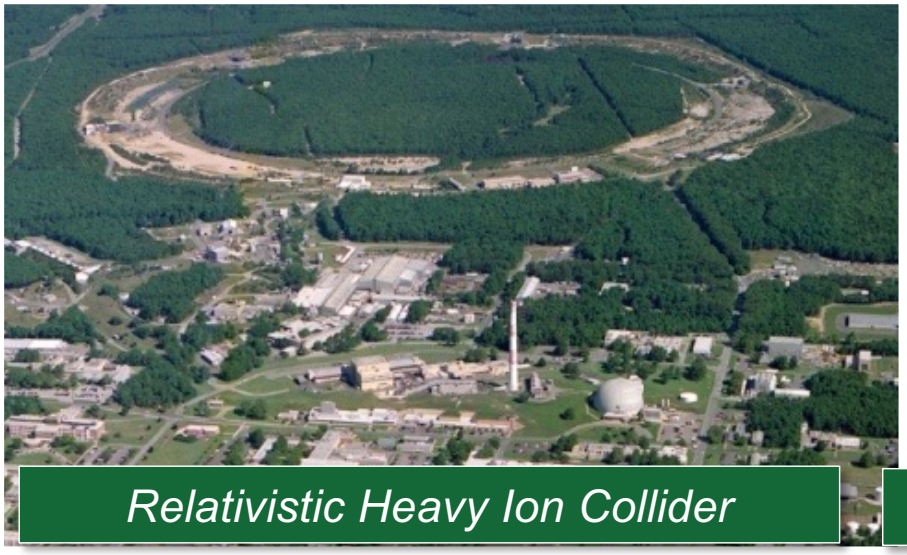
Fixed Target Particle Accelerator Experiments
Wave length: 0.01 fm (20 GeV)
Resolution: ~ 0.1 fm



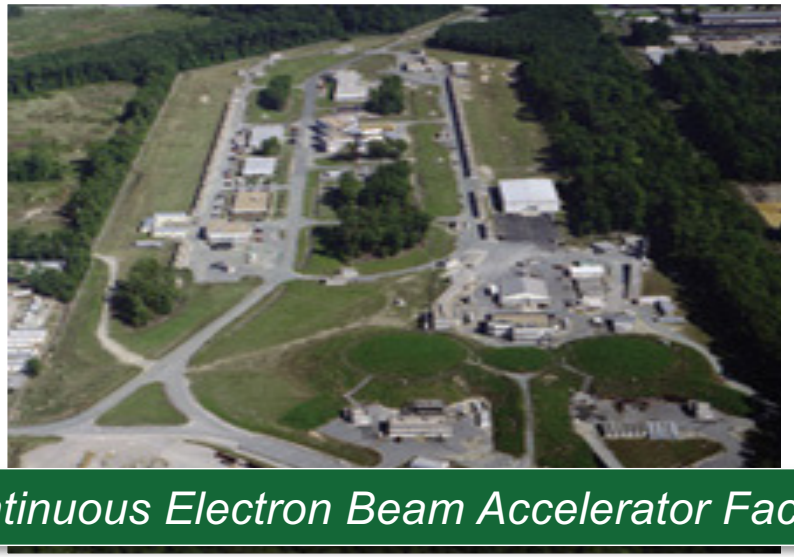
SLAC, EMC, NMC, E665, BCDMS, HERMES, JLab, COMPASS, …



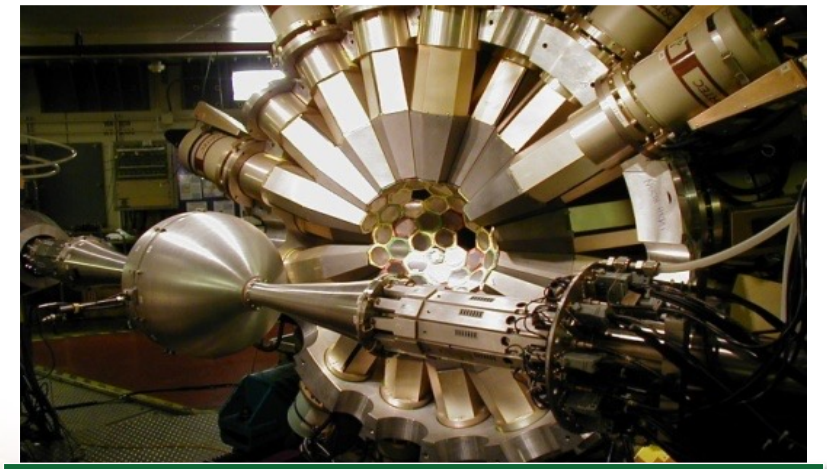
US DOE Nuclear Physics Facilities



Relativistic Heavy Ion Collider



Continuous Electron Beam Accelerator Facility



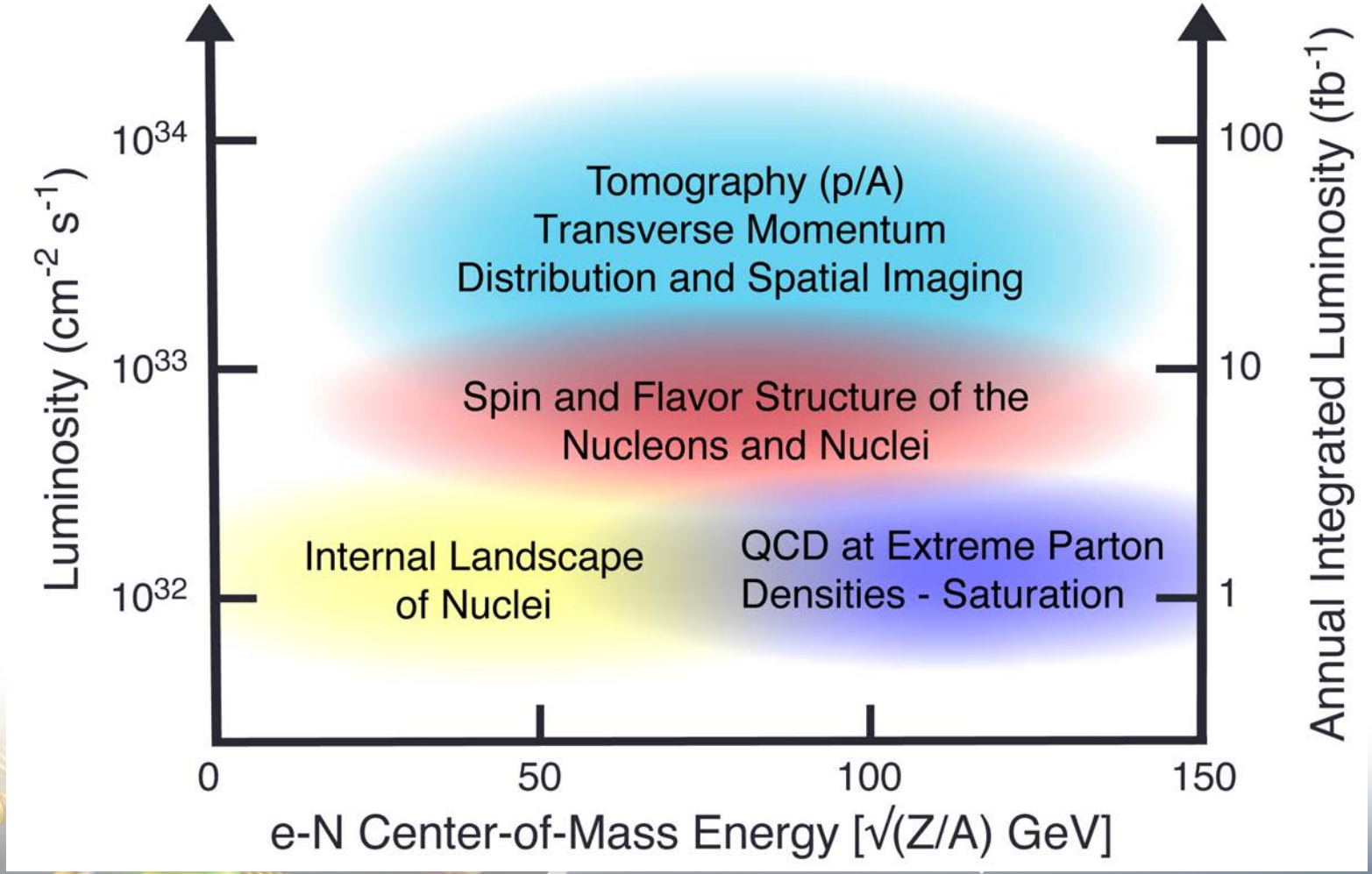
Argonne Tandem Linac System

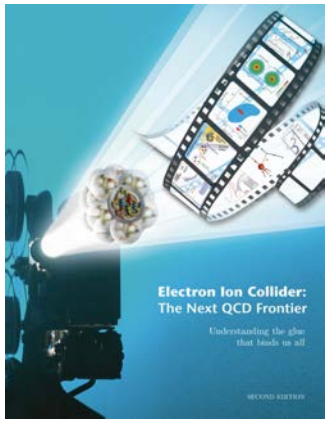
Facility for Rare Isotope Beams

"Microscopes" of Varying Resolving Power – T. Hallman

EIC Physics

Center of Mass vs. Luminosity/Integrated Luminosity

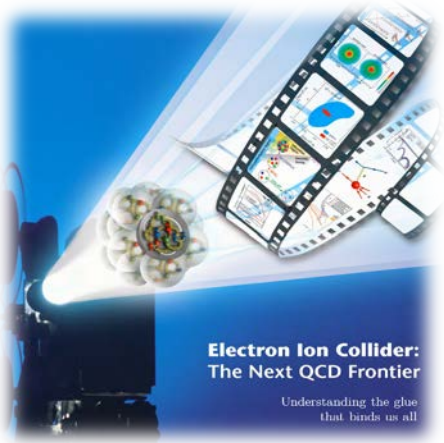


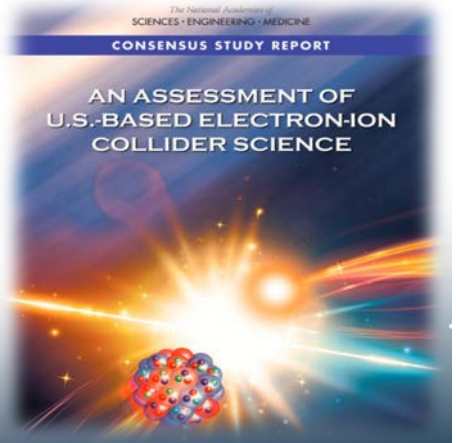


Project Requirements

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 NSAC Long Range Plan (2015) and the EIC White Paper requirements endorsed by NAS (2018)

Electron-Ion Collider Concepts

For e-N collisions at the EIC:

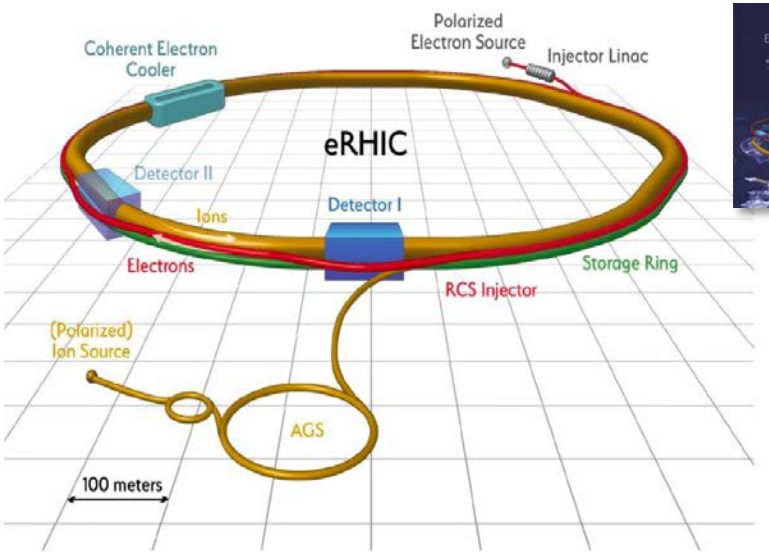
- ✓ Polarized beams: e, p, d/^{3}He
- ✓ e beam 5-10(20) GeV
- ✓ Luminosity L_{ep} ~ $10^{33\text{-}34}$ $cm^{-2}sec^{-1}$
  100-1000 times HERA
- ✓ 20-100 (140) GeV Variable CoM

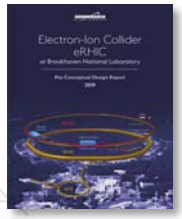
For e-A collisions at the EIC:

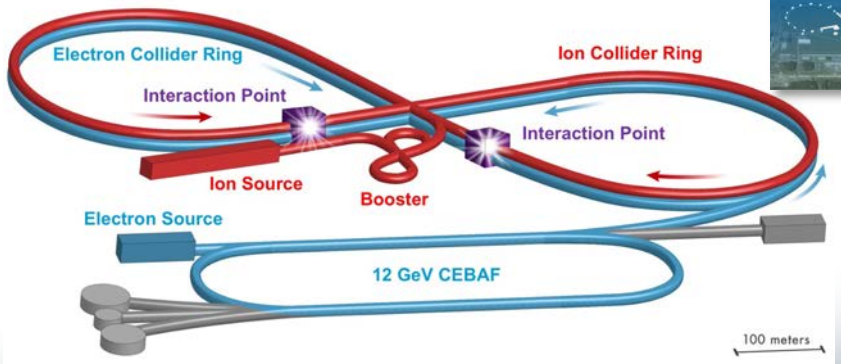
- ✓ **Wide range in nuclei**
- ✓ Luminosity per nucleon same as e-p
- ✓ Variable center of mass energy

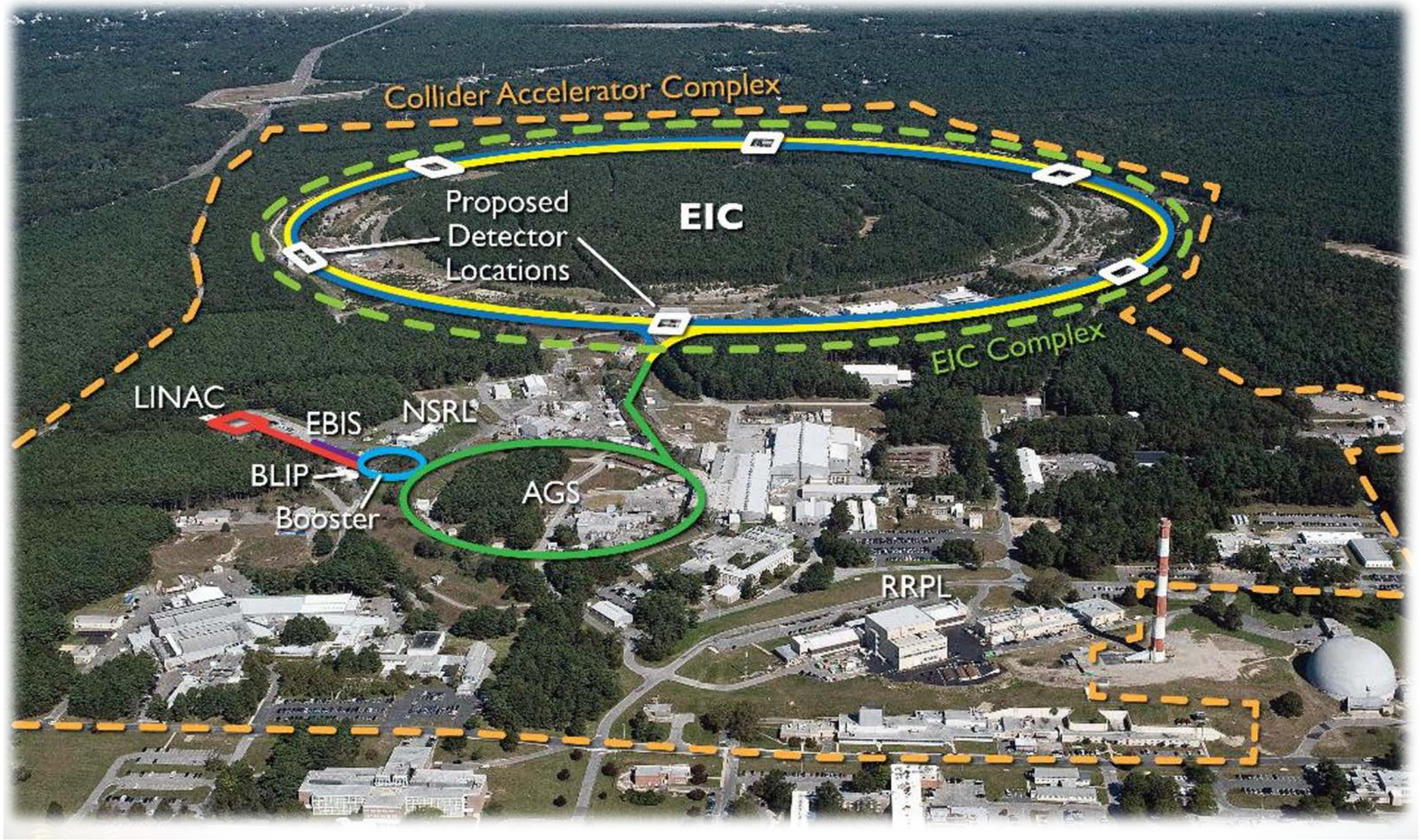
World's first
Polarized electron-proton/light ion
and electron-Nucleus collider

Both designs use DOE's significant investments in infrastructure



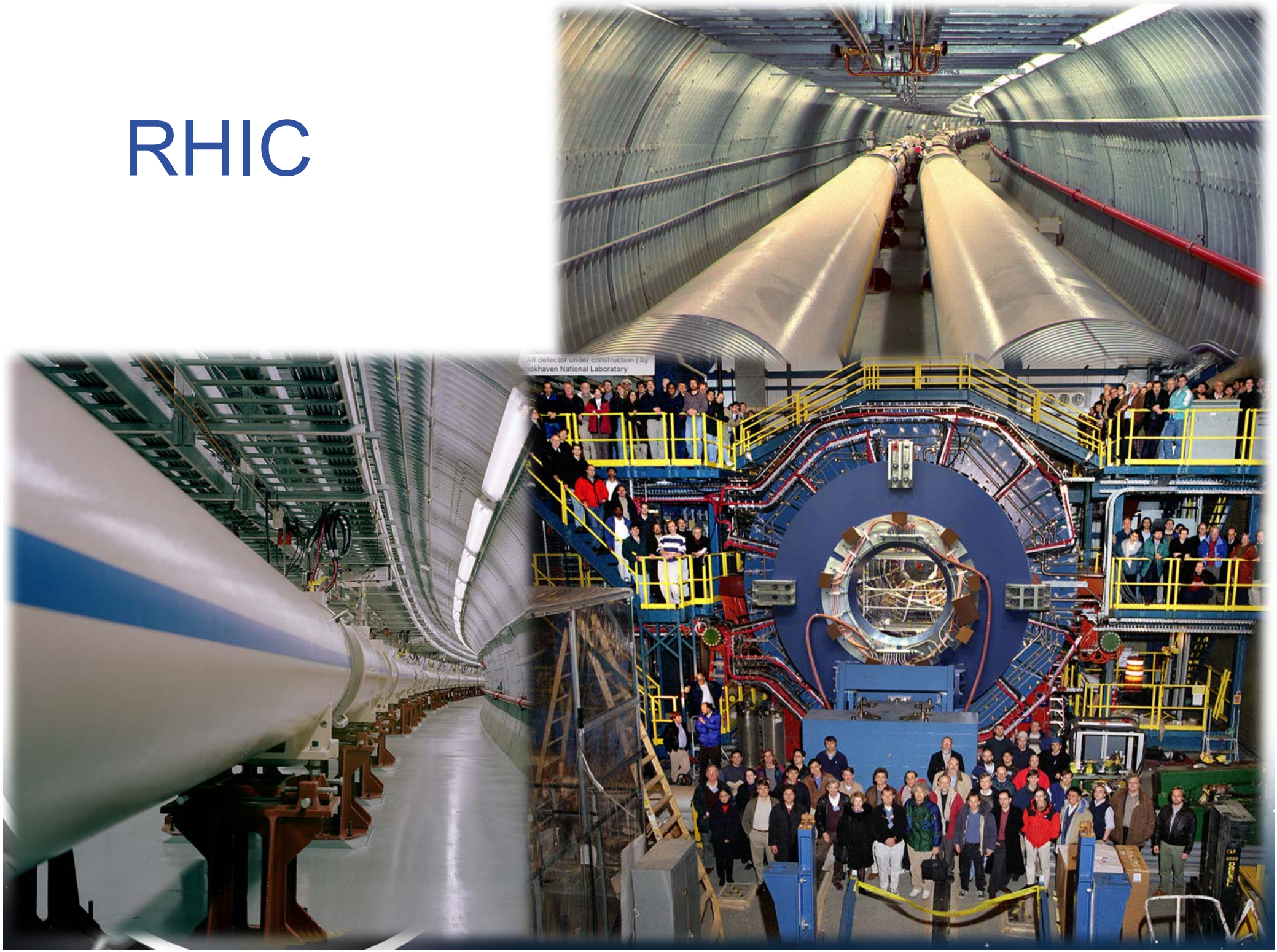






Double Ring Design Based on Existing Relativistic Heavy Ion Collider Facility at Brookhaven National Laboratory

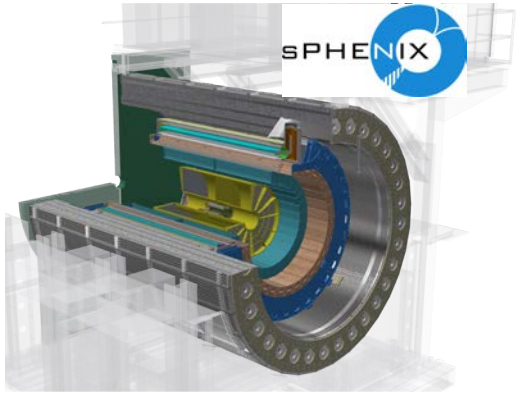
RHIC


AR detector under construction | by
ookhaven National Laboratory

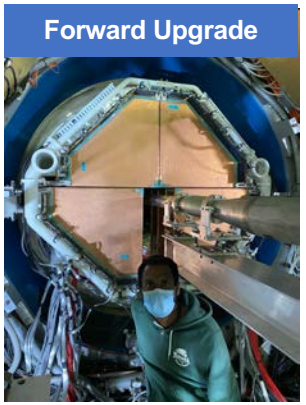
Completing RHIC Mission with sPHENIX and STAR

- sPHENIX will use energetic probes (jets, heavy quarks) to study quark-gluon plasma on different length scales with unprecedented precision
  - How the structureless "perfect" fluid emerges from the underlying interactions of quarks and gluons at high temperature
- State-of-the-art collider detector using technology developed for LHC by ONP and OHEP
- sPHENIX magnet and its hadron calorimeter will be part of the EIC project detector

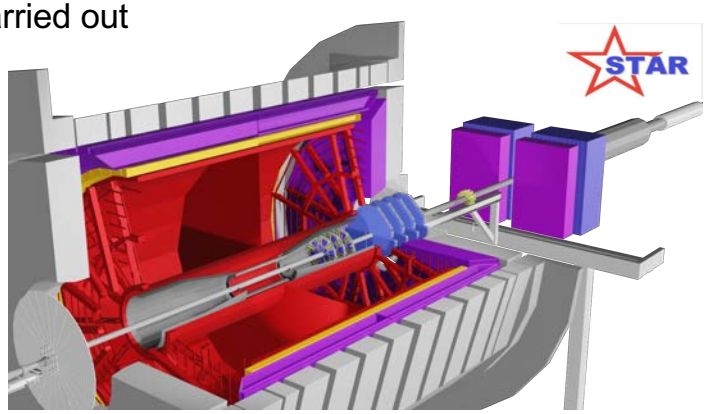
Magnet & Calorimeter



- STAR with forward upgraded detectors ran successfully in Run 2022
  - 3-D tomography (like Magnetic Resonance Imaging) of the nucleon uncovers new information
  - STAR exploits such 3-D parton dynamics in ways complementary to the EIC, where precision tomography of the nucleon and nuclei will be carried out



Forward Upgrade

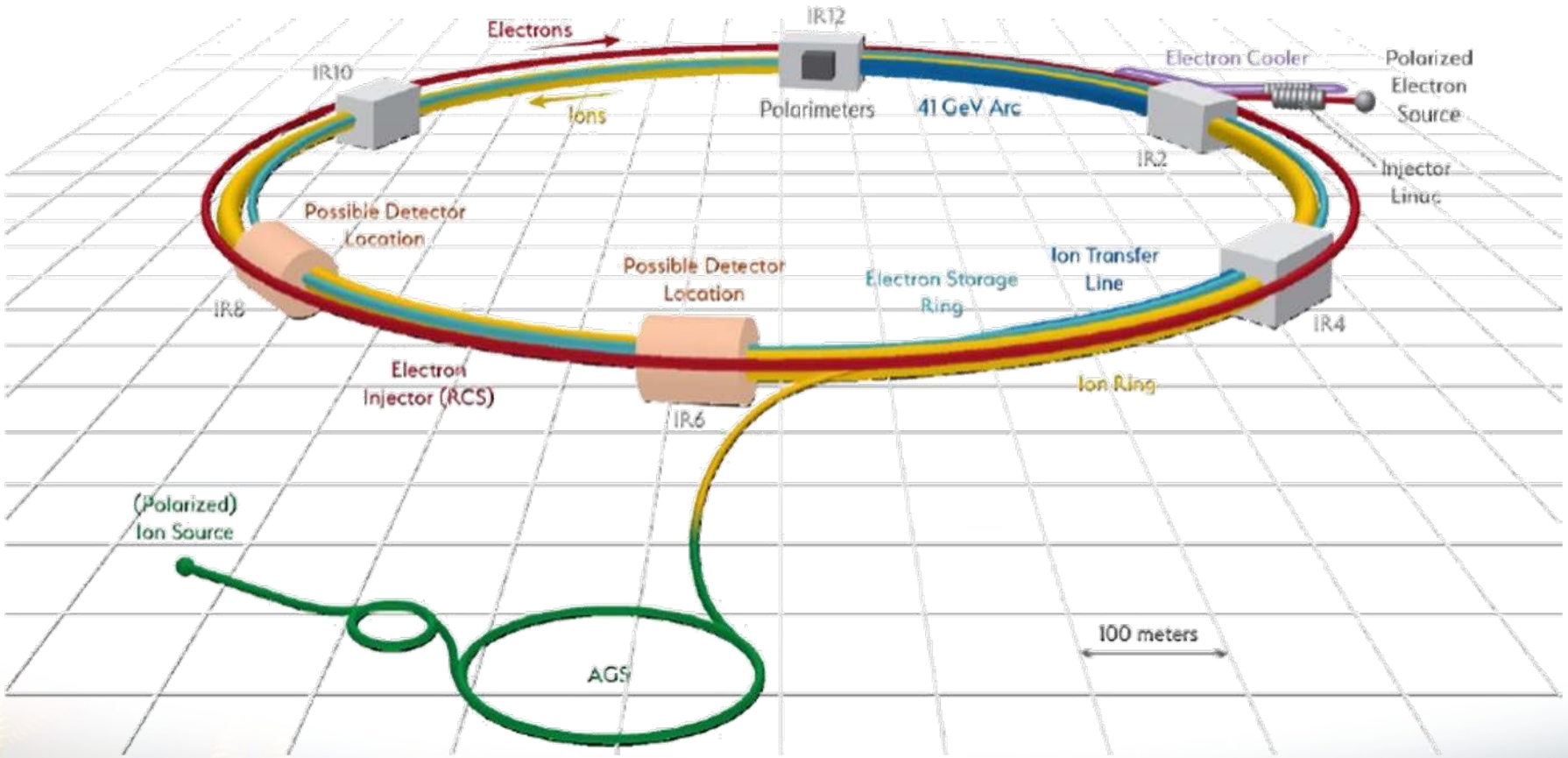


RHIC data taking scheduled for 2023–2025

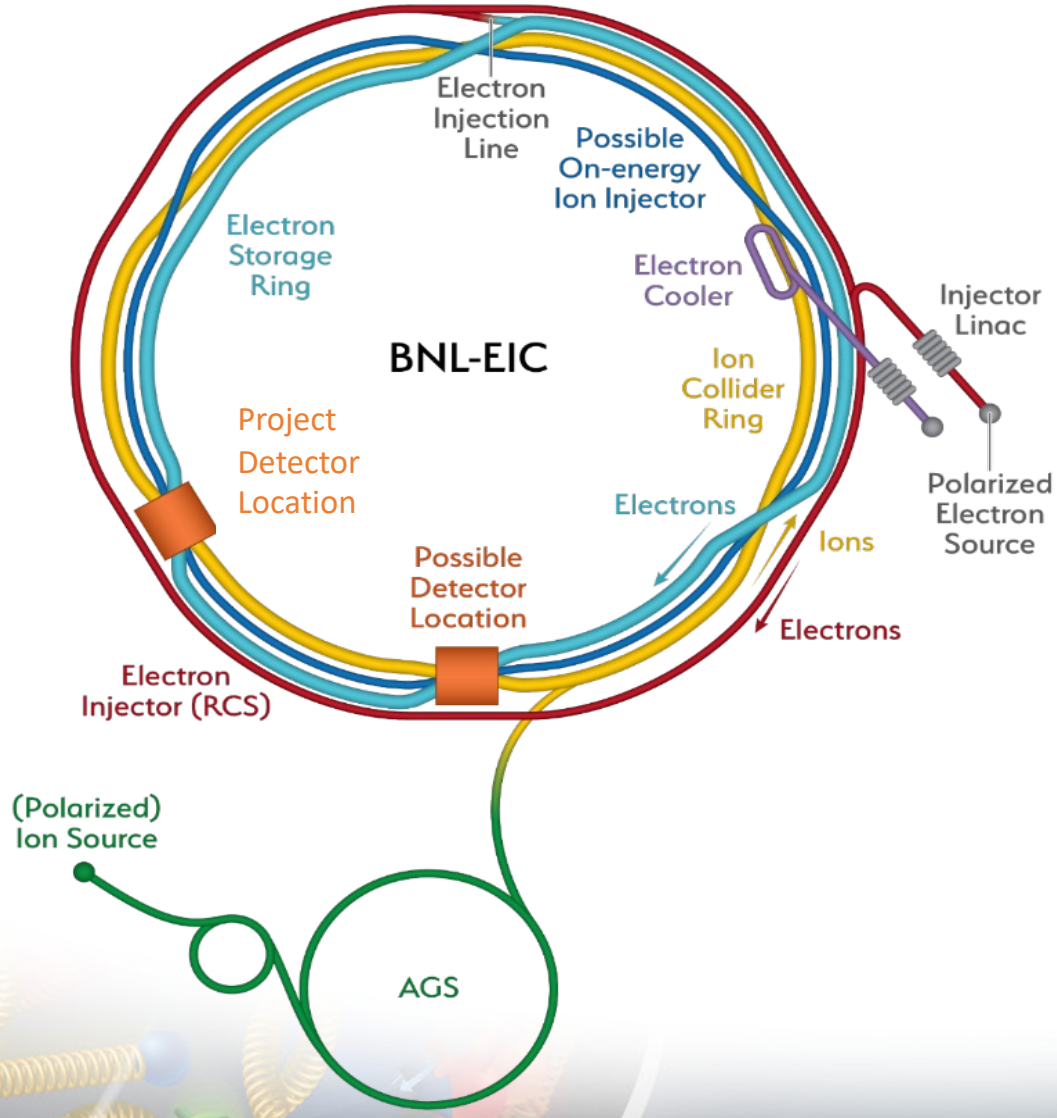
sPHENIX upgrade and STAR with forward upgrade will fully utilize the enhanced (~50 times Au+Au design) luminosity of RHIC

14

EIC Conceptual Design

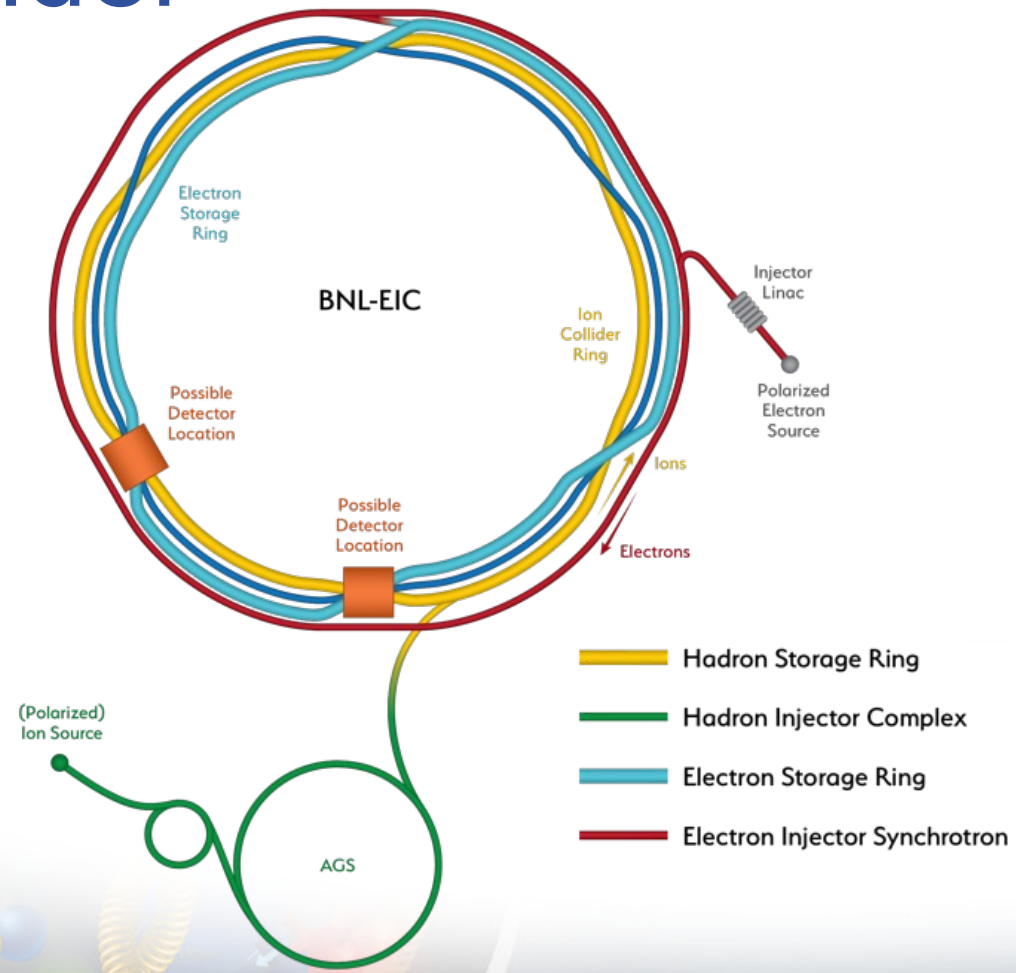


Electron-Ion Collider Scope



- Hadron Storage Ring
- Hadron Injector Complex
- Electron Storage Ring
- Electron Injector Synchrotron
- Electron Cooler
- Possible On-energy Hadron Injector Ring

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



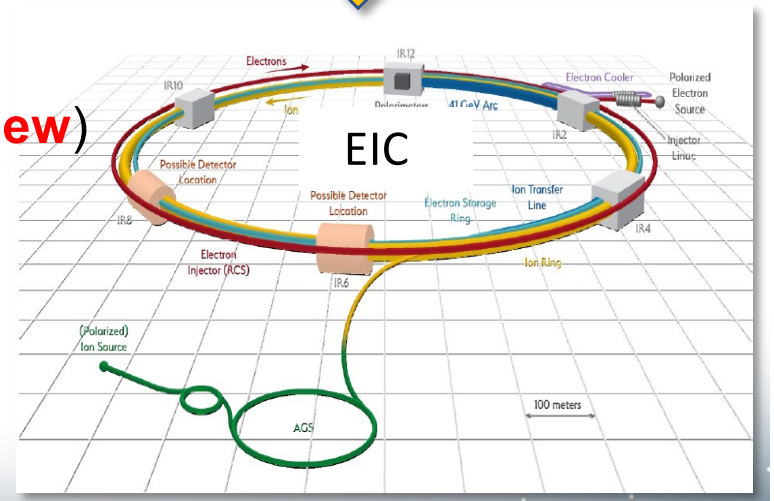
- Hadron Storage Ring
- Electron Injector Complex with Rapid Cycling Synchrotron
- Electron Storage Ring
- Strong hadron cooling completes the facility

EIC Design Overview

Design based on **existing RHIC Complex**
RHIC is well maintained, operating at its peak

- **Hadron storage Ring (RHIC Rings) 40-275 GeV**

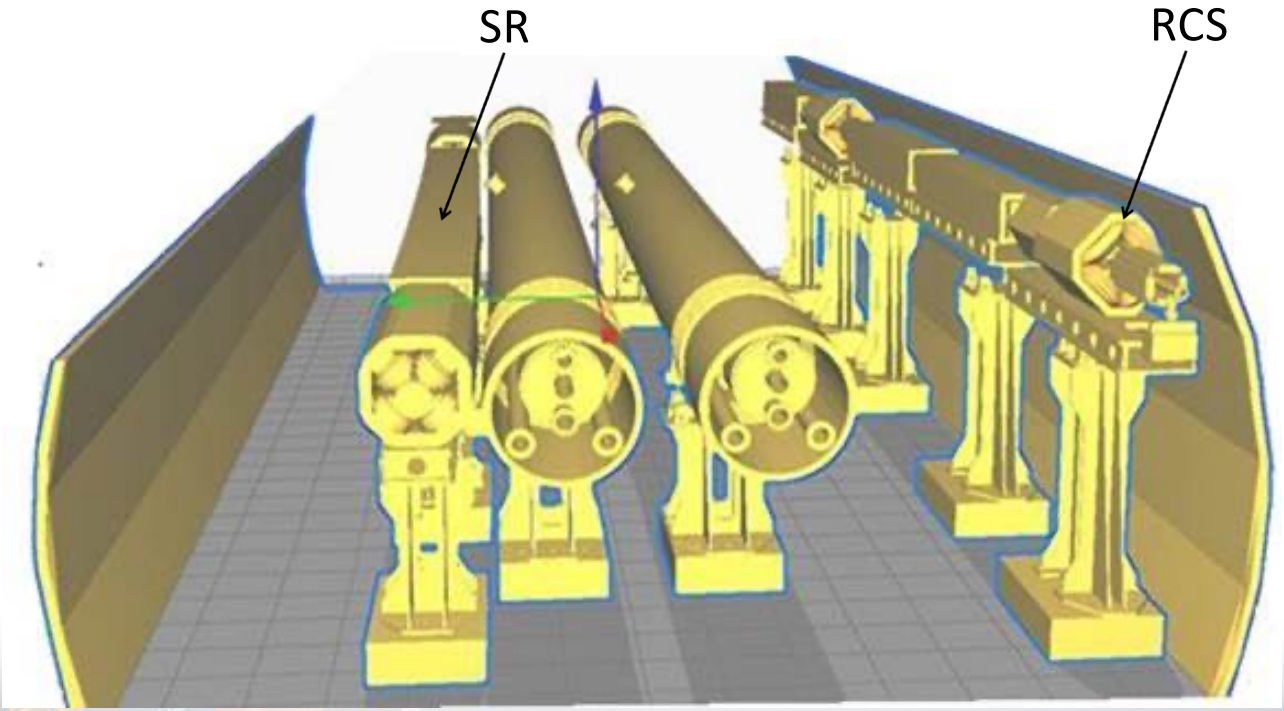
(existing)
  - 1160 bunches, 1A beam current (3x RHIC)
  - bright vertical beam emittance 1.5 nm
  - strong cooling (coherent electron cooling)
- **Electron storage ring 2.5–18 GeV** (**new**)
  - many bunches,
  - large beam current, 2.5 A ➔ 9 MW S.R. power
  - S.C. RF cavities
  - Need to inject polarized bunches
- **Electron rapid cycling synchrotron 0.4- 18GeV** (**new**)
  - 1-2 Hz
  - Spin transparent due to high periodicity
- **High luminosity interaction region(s)** (**new**)
  - L = $10^{34}cm^{-2}s^{-1}$
  - Superconducting magnets
  - 25 mrad Crossing angle with crab cavities
  - Spin Rotators (longitudinal spin)
  - Forward hadron instrumentation



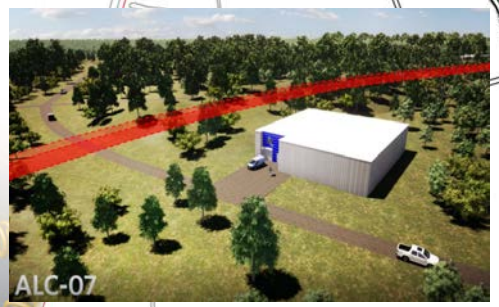
EIC Machine in the RHIC Tunnel

- 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



EIC Proposed Site Plan: Buildings



PROPOSED BUILDINGS FOR EIC

TUNNEL

BER

ALC11

ALC01

1010 RF

Cryo Facility

100' SETBACK

100' SETBACK

100' SETBACK

100' SETBACK

1002

ALC09

ALC03

1004

ALC07

1006 ALT

ALC05

Cryo Facility

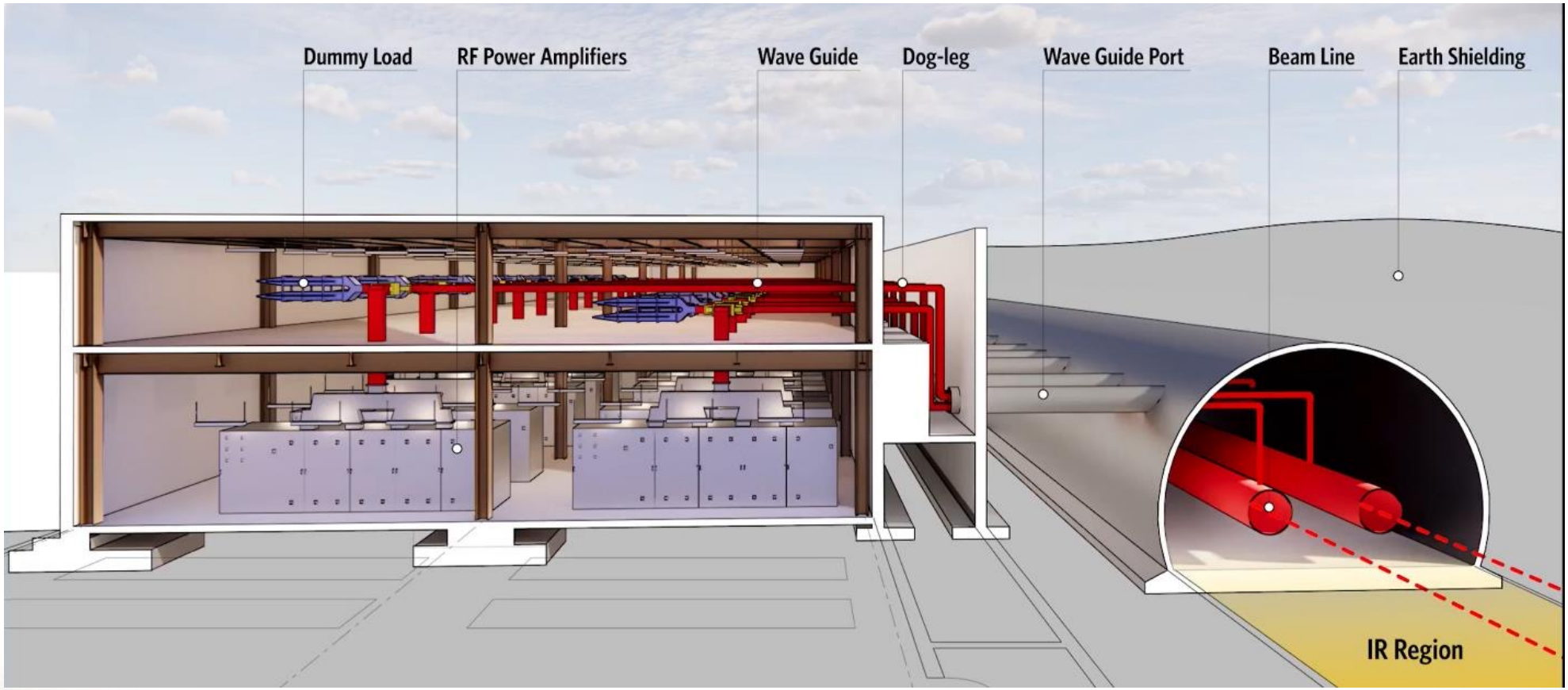
LEGEND

- Existing Buildings
- EIC Tunnel
- Existing Berm
- Accelerator Systems/RF Buildings
- Cooling Towers
- Power Supply Buildings
- Alcove Buildings
- Cryo Facility

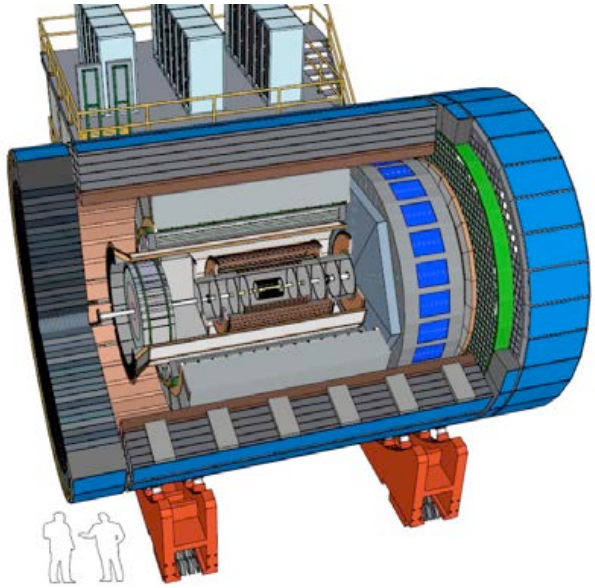
Electron Injection Support Building

- 1002H EIC Injection LINAC Building ≈ 50,000 SF

RF Support Buildings

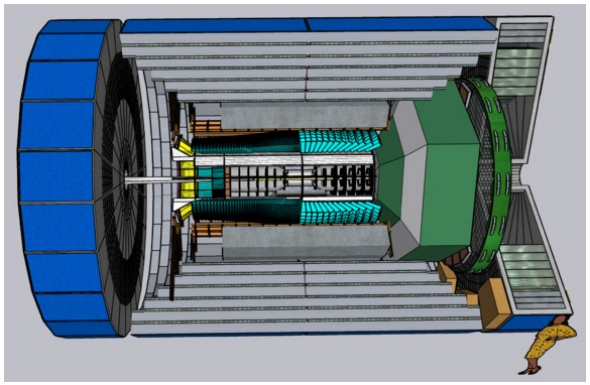


EIC Detector Proposals



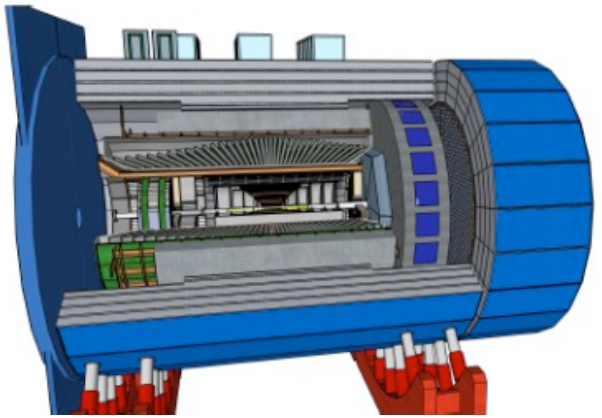
100 institutions

ATHENA	
Location	IP6
Detector Length	9.5 meter
Magnet Field	3 Tesla
Magnet Bore	3.2 meter



20 institutions

CORE	
Location	IP8
Detector Length	8 meter
Magnet Field	3 Tesla
Magnet Bore	2.0 meter



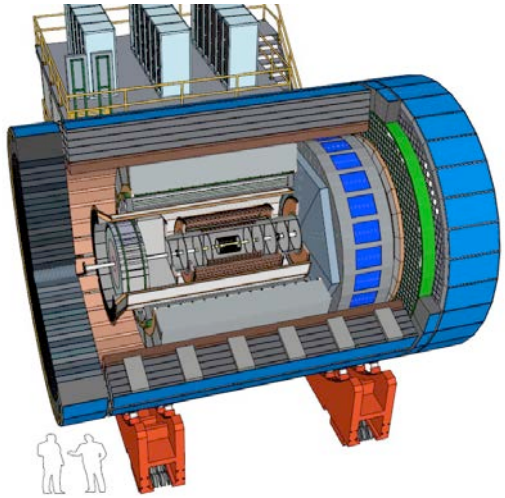
96 institutions

ECCE	
Location	IP6 (or IP8)
Detector Length	9.1 meter
Magnet Field	1.5 Tesla
Magnet Bore	2.8 meter

EIC Proto-Collaborations

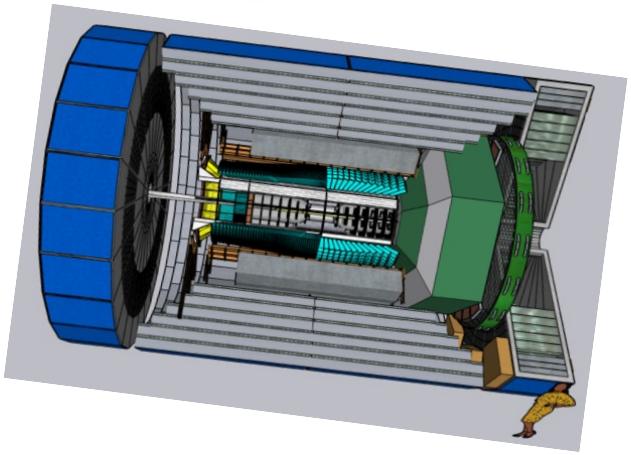
ATHENA (https://sites.temple.edu/eicatip6/)

- Focus on becoming the “project detector”@IP6
- New 3 T magnet and the YR Reference Detector
- Leadership: S. Dalla Torre (INFN Trieste, B. Surrow (Temple)
- ~100 collaborating institutions from Armenia, Canada, China, Czech, France, Germany, Italy, India, Poland, Romania, UK



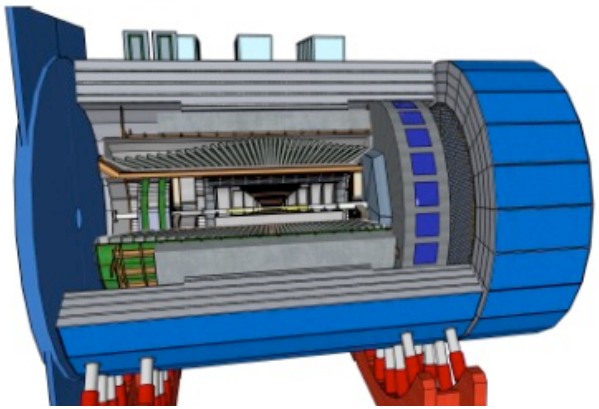
CORE (https://eic.jlab.org/core/)

- An EIC Detector proposal based on a new 2-2.5 T compact magnet for the 2nd EIC detector @ IP8
- Contacts: Ch. Hyde (ODU) and P. Nadel-Turonski (SBU)
- Smaller-scale effort, ~20-30 active collaborators



ECCE (https://www.ecce-eic.org)

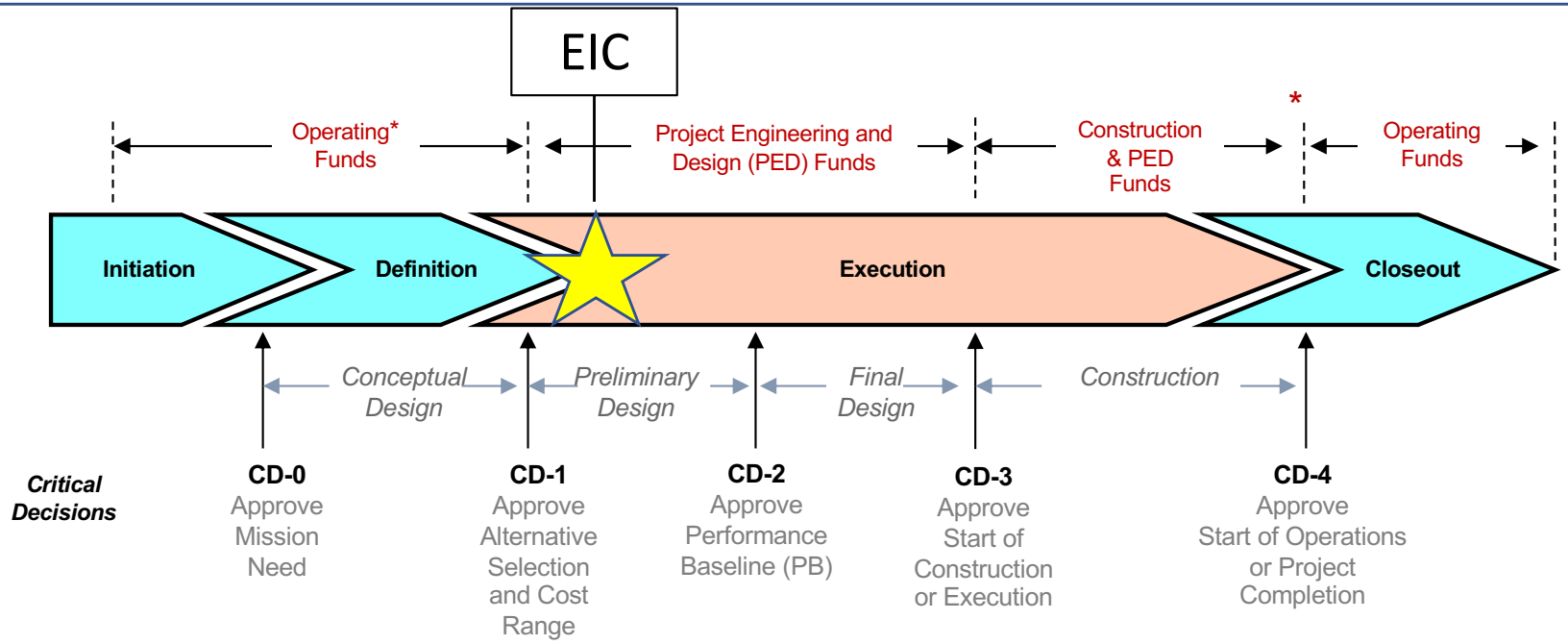
- Project detector @IP6 or the 2nd EIC detector @ IP8 using existing 1.5T “Babar” solenoid
- Leadership: O. Hen (MIT), T. Horn (CUA), J. Lajoie (Iowa State)
- ~80 collaborating institutions from Armenia, Canada, Chile, Croatia, China, Czech, France, Germany, Israel, Japan, Senegal, Korea, Russia, Slovenia, Taiwan, UK



Project Detector Selection

- Two-year long process complete
  - Call for Expression of Interest for potential cooperation on experimental equipment in 2020
  - Call for Collaboration Proposals for Detectors at the Electron-Ion Collider in 2021
  - Detector Proposal Advisory Panel (DPAP) Recommendations in March 2022
- ECCE and ATHENA leadership working together to address DPAP recommendations
  - Leadership team encouraging participation of additional groups
  - By-Laws, Institutional Board, and elected leadership "spokesperson" before the end of this year
  - Detector recently named "EPIC!"

DOE Project Planning Process



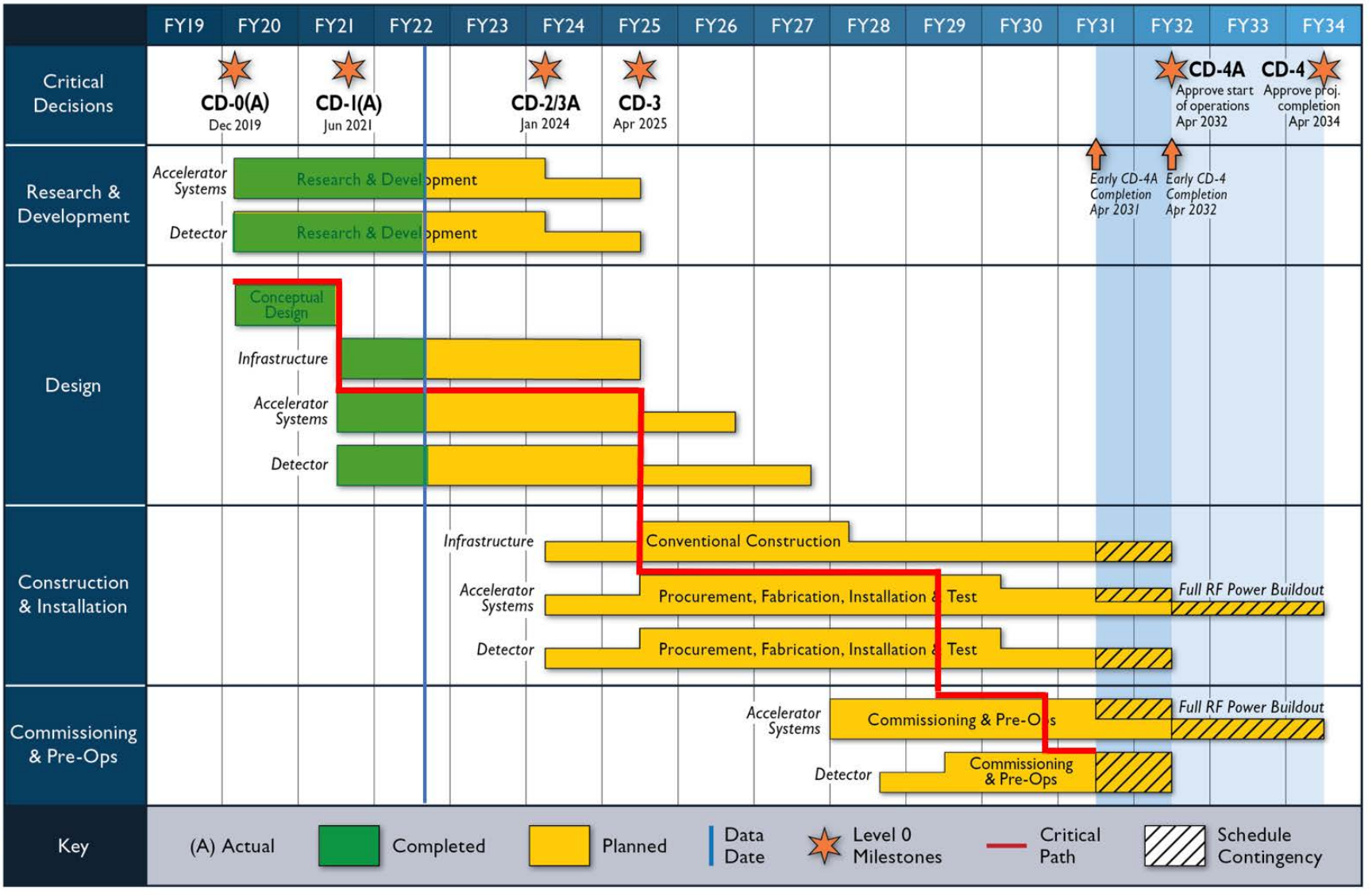
Formal Process of Gateway Reviews

- CD-0, Mission Need
- CD-1, Alternative Selection and Cost Range
- CD-2, Performance Baseline
- CD-3a, Long Lead Procurement

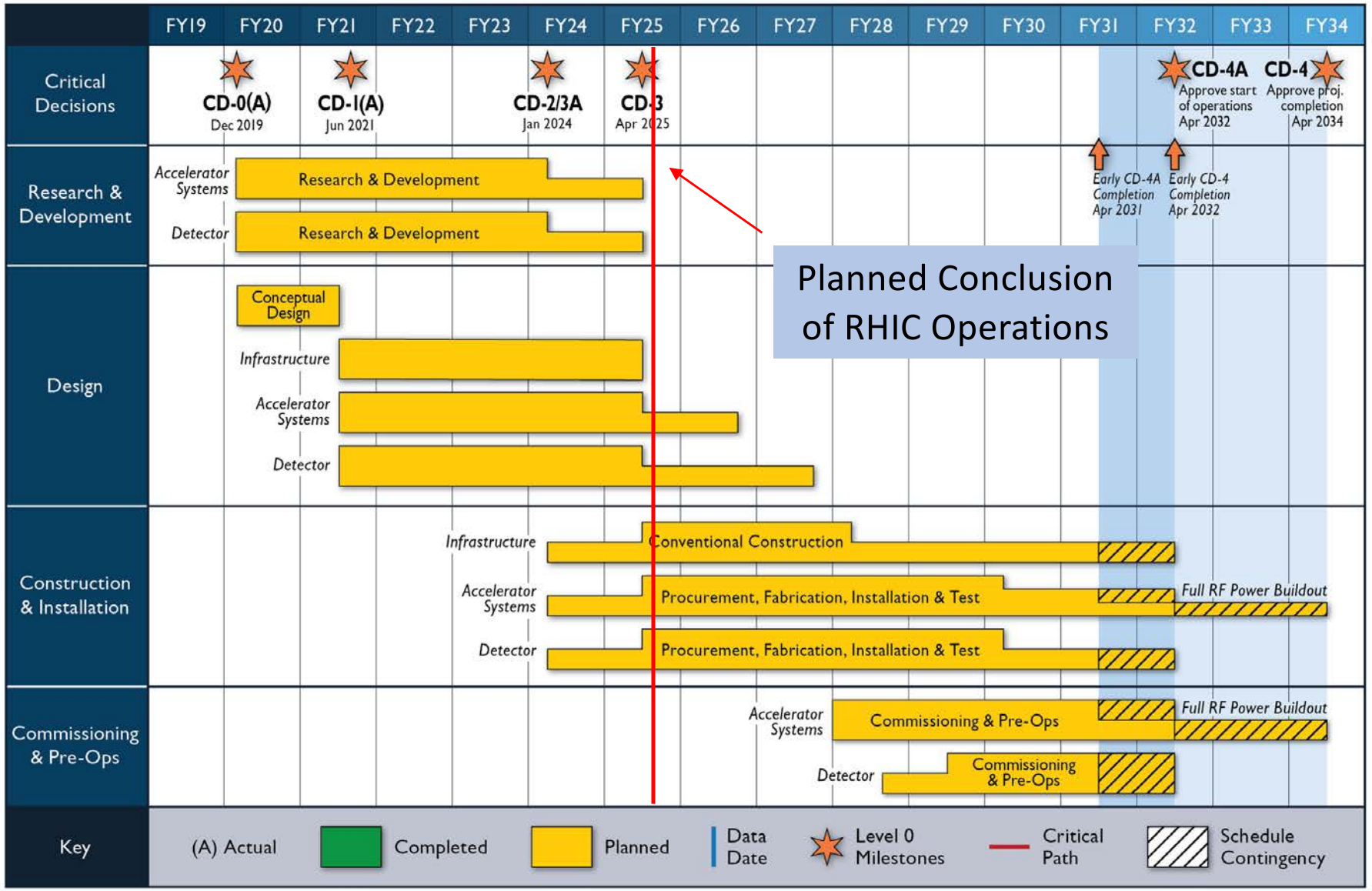
EIC Project Recent History

Event	Date
Mission Need Statement Approved	January 22, 2019
CD-0, Mission Need Approved	**December 19, 2019**
DOE Site Selection Announced	January 9, 2020
BNL - TJNAF Partnership Agreement Approved	May 2020
Conceptual Design Review	November 2020
DOE Independent Cost Review (ICR)	January 2021
CD-1, Alternative Selection and Cost Range, Approved	**June 29, 2021**
DOE FY2022 Budget Uncertainties, Potential DOE Infrastructure Funding…	
DOE EIC FY2022 Budget Approved at $45M	March 2022
Detector Proposal Advisory Panel Report	March 21, 2022
CD-2/3A, Baseline/Long Lead Procurement	***January 2024***

EIC Schedule

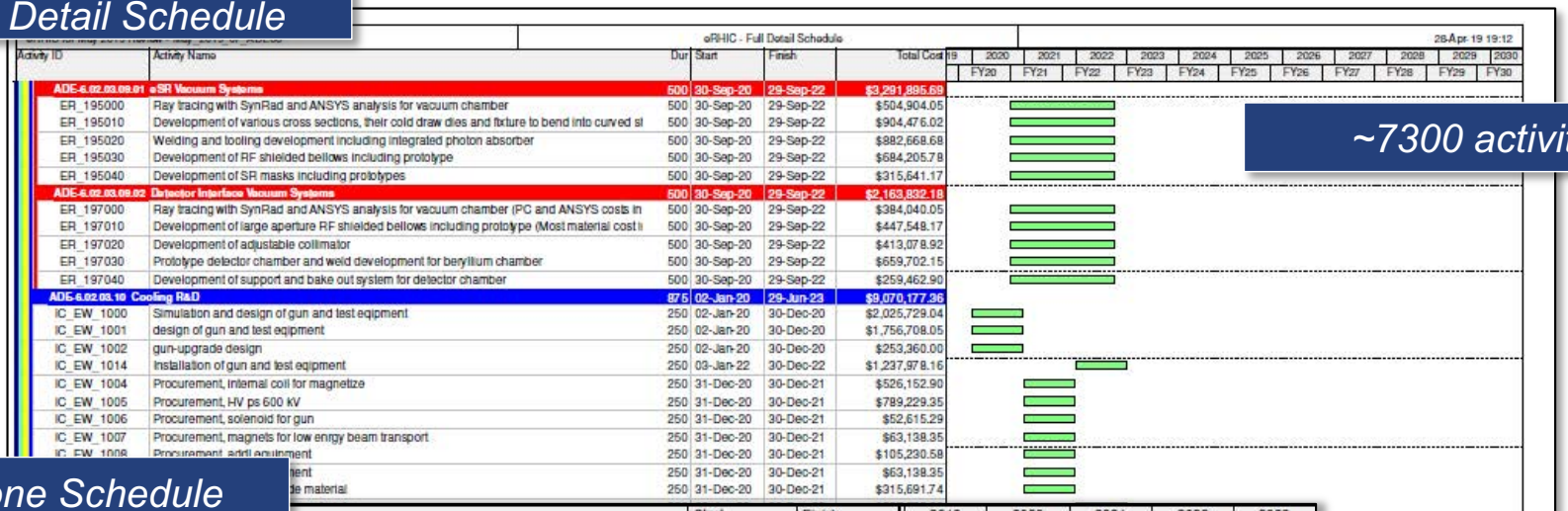


RHIC to EIC Transition



Primavera P6 Schedule

Detail Schedule



~7300 activities

Milestone Schedule

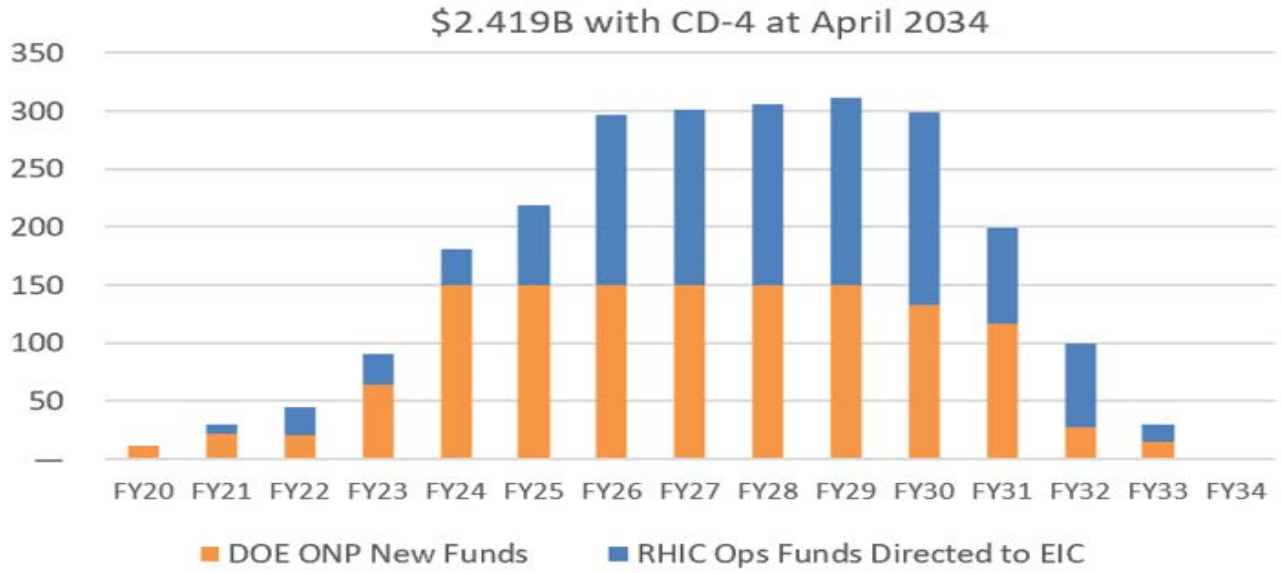
		Start	Finish
Level 1 Milestones			
A_010	CD-0 – Approve Mission Need (FY19Q1)		30-Sep-19*
A_025	Project Start (1/2/20)	02-Jan-20*	
A_030	CD-1 – Approve Alternative Selection and Cost Range (FY20Q4)	30-Sep-20*	
A_040	CD-2/3A– Approve Performance Baseline/Approve Long Lead Procurements (LLP) (FY22Q3)	30-Jun-22*	
A_050	CD-3 – Approve Start of Construction (FY23Q4)		29-Sep-23*
A_060	Early Completion (June 2029)		29-Jun-29*
A_070	CD-4 – Approve Start of Operations or Project Completion (FY30Q3)		28-Jun-30*
Level 2 Milestones			
B_0010	Start Conceptual Design	02-Jan-20	
B_0020	St		
B_0030	C		
B_0040	St		
B_0050	C		
B_0060	C		
B_0070	St		

FY Resource Hours by WBS

Activity Name	Start	Finish	Budgeted Units	Budgeted Cost	2020	2021	2022	2023						
					FY20	FY21	FY22	FY23						
Total	02-Jan-20	29-Jun-29	827772457	$1,467,616,914.98	1139466	1119560	4524962	14875360	20					
WBS: ADE06.01 Project Management	02-Jan-20	29-Dec-28	14220927	$87,692,069.62	670100	996505	1338421	1540087	1796210	2302110	2995610	1835216	674100	72568
Administrative_Low	02-Jan-20	29-Dec-28	119630	$9,530,453.64	6380	9740	14520	14080	18480	19360	19360	8360	8360	990
Administrative_Med	01-Oct-20	29-Sep-28	73260	$7,062,924.80		3520	5720	9240	14080	14080	14080	6820	5720	
ES&H Engineer_Low	01-Oct-21	29-Sep-28	10560	$1,449,009.02			1760	1760	1760	1760	1760	880	880	
IT Professional (Network-Bus Support)_Med	02-Jan-20	29-Sep-28	5940	$912,894.21	440	880	880	880	880	880	880	110	110	
Group Manager_Low	02-Jan-20	29-Sep-28	49280	$7,705,356.37	3960	4840	5280	7040	7040	7040	7040	3520	3520	
Group Manager_Med	02-Jan-20	29-Sep-28	13310	$2,388,070.58	660	880	3520	1760	1760	1760	1760	880	330	
Group Manager_High	02-Jan-20	29-Dec-28	25690	$5,544,278.87	660	880	3360	3520	3520	3520	3520	3080	1980	1650
Division Manager_Low	02-Jan-20	29-Dec-28	14690	$5,391,753.62	660	1600	1760	1760	1760	1760	1760	1320	1320	990
QA Professional_Low	01-Oct-21	29-Sep-28	14960	$1,465,653.90			880	1760	1760	3520	3520	1760	1760	
QA Professional_Med	02-Jan-20	29-Sep-28	12320	$1,717,530.00	880	880	1760	1760	1760	1760	1760	880	880	
Scientist_Med	01-Oct-24	29-Sep-28	5280	$905,476.03						1760	1760	880	880	
Project Management Specialist_RC	02-Jan-20	29-Sep-28	38720	$7,847,310.10	1760	5280	5280	5280	5280	5280	5280	2640	2640	
Electric_No Escalation_NonLabor	02-Jan-20	29-Sep-28	2229800	$2,229,800.00	43000	117800	184000	228000	274000	392000	558000	345000	90000	

30

DOE CD-2 in January 2024



• Mission Need Approval	January 22, 2019
• Critical Decision 0	December 19, 2019
• Site Selection Announced	January 9, 2020
• CD-1 Approval	June 29, 2021
• Project Detector Design Selected	March 8, 2022

Schedule: CD-2/3A = January 2024; CD-3 = April 2025; Project Completion = 2034
RHIC operations conclude and EIC tunnel work starts in June 2025

Cost: CD-1 cost range of $1.7B-$2.8B

Perspective on DOE CD-2/3A

- Priority is to secure CD-2/3A, Project Performance Baseline/Long Lead Procurement (LLP), at the earliest achievable date that funding permits
  - Enables a more secure funding plan
  - LLP authority improves overall schedule and supply chain risks
  - Optimum alignment with conclusion of RHIC OPS and ONP redirection plans
  - Promotes engagement of users, international partners, NSF, and DOE.
- Funding increase in FY2023 is essential for timely CD-2/3A
  - Increase pace of technical progress and restore momentum lost after CD-1
  - Increase design maturity and viability of CD-2/3A goals
  - Improve accuracy of cost and schedule uncertainty estimates, reduce risk
  - Bolster stakeholder confidence in EIC construction schedules
  - Strengthen partner engagement and secure commitments
- DOE CD-2/3A reviews will be requested when ready, following:
  - Preliminary Design Review – assessment of design maturity and technical risk
  - “Director’s Review” – comprehensive assessment of mgmt., TPC, CD-4, etc.
  - DOE Federal Project Director assessment of readiness to proceed

CD-2/3A Planning Dates

- DOE OPA Status Review (Remote) — October 19-21, 2021(A)
- Funding Discussion at DOE ONP (In-Person) — April 26, 2022 (A)
- FPD Status Update at BNL (Hybrid) — June 28, 29, 30 2022
- Cost and Schedule Scrutiny Meetings — July - August 2022
- Project Detector Meetings — Fall 2022
- DOE OPA Status Review - Confirm CD-2/3A Plans — January 2023
- Preliminary Design and Director's Reviews — June 2023
- DOE CD 2/3A OPA Review and ICR — October 2023
- DOE CD 2/3A ESAAB Approval — January 2024

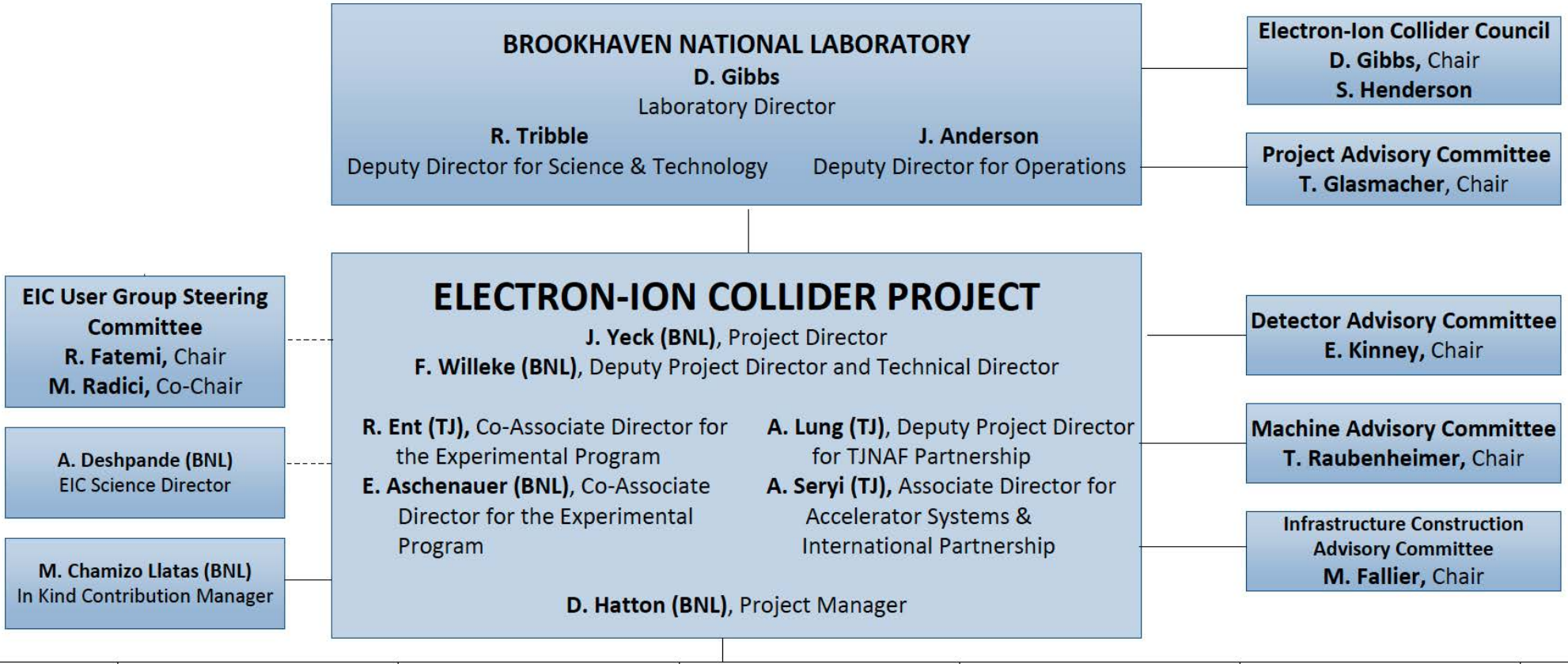
BNL/TJNAF Special Partnership

- BNL/JLab partnership established in early 2020
- Serve together as hosts for the EIC experimental program
- Integrated project scope responsibilities defined

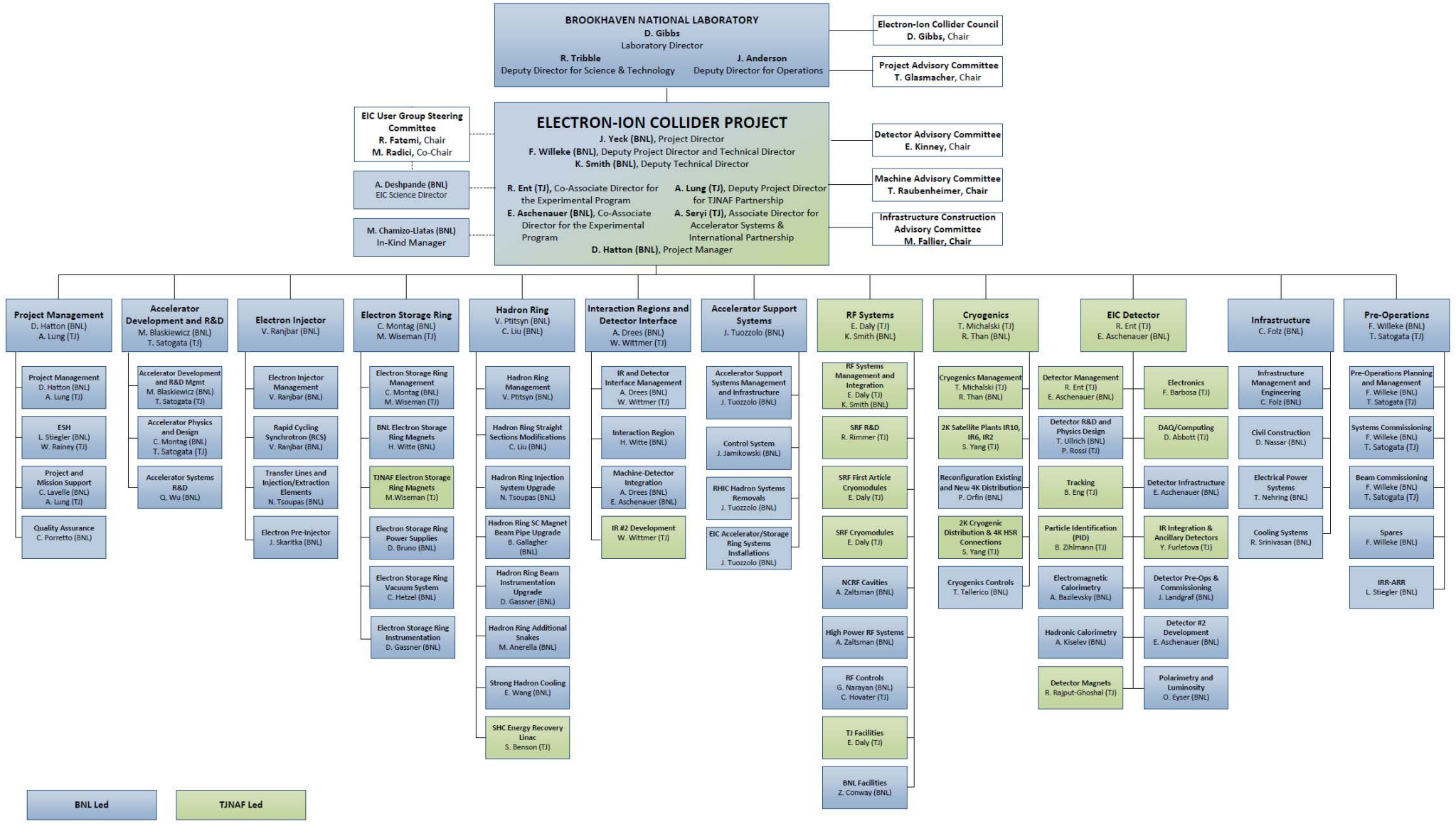
BNL/TJNAF

- Integrated project leadership team
  - Extensive project experience
  - Joint ownership of project strategies and plans
- TJNAF project scope
  - Scope aligned with expertise, interests, and project needs
  - ~$500M plus partner project
- BNL and TJNAF host the EIC experimental program
  - Co-Associate Directors for the EIC Experimental Program supported by BNL NPP ALD and TJNAF Deputy Director
  - TJNAF to administer EIC generic detector R&D program in support of Detector 2 and upgrade paths for Detector 1

EIC Project Organization



TJ/BNL Scope Integration



Partnerships

- Joint BNL/TJNAF Team Promoting World-Wide Partnerships
- New York State
  - Empire State Development (ESD) Corporation will provide $100M for EIC infrastructure
  - Critical path infrastructure work can commence with the availability of the NYS funding
- DOE Labs and Universities
- Industry

International Engagement

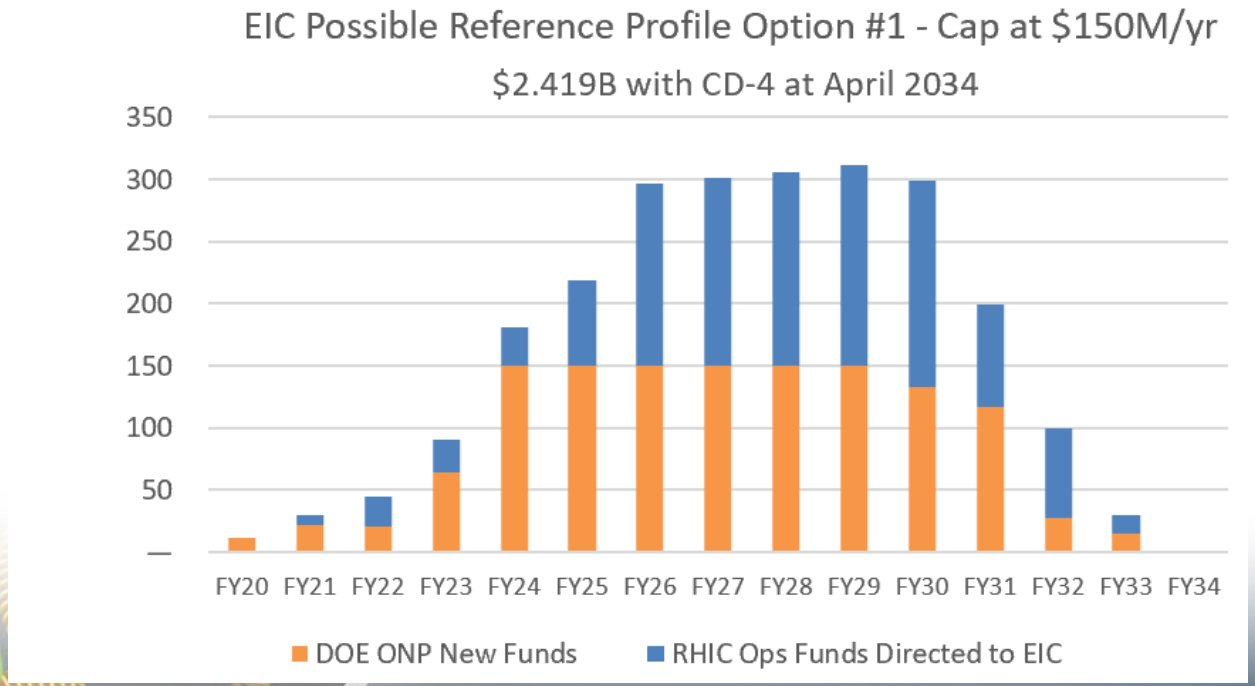
- EIC Council (BNL and TJNAF Directors) will become the “EIC Advisory Board” with international and domestic partners joining
  - Solicited input from leaders of international and domestic labs at Council meetings in April and June
  - BNL Director inviting new members
  - EIC Advisory Board meeting in the fall
  - TRIUMF and INFN ready to proceed with bi-lateral agreements for initial design work on accelerator design topics
- Ready to take steps to establish a Resource Review Board (RRB) for the EIC experiments
  - Preparatory discussion meeting in late September/October
  - 1st RRB meeting planned for Spring 2023
  - Assuming a single MoU for the project detector capturing contributions by all participating institutions

Funding Updates Since CD-1

- FY20 Actual **$11M** (TEC $1M, OPC $10M)
- FY21 Plan $43M, Actual **$30M** (TEC $5M, OPC $25M)
  - Full speed ahead to CD-1
  - Hiring Hold, Prioritized R&D and Design Work
- FY22 Plan $100M, Actual **$44.8M** (TEC $20M, OPC $25M)
  - President's Budget at $30M
  - House Mark at $15M, Senate Mark at $30M, Infrastructure Bill - ?
- FY23 Plan $100M
  - President's Budget TEC $30M, OPC $15M?
  - House Mark TEC $35M, OPC = ? ($15M – $35M)
  - Senate Mark TEC $50M,, OPC = ? ($20M - $40M)
- Assumptions needed to proceed…
  - **$90M in FY2023**

Planning Scenario

- FY2023 funding at $90M would enable the project to mature the EIC design, start long-lead procurements (CD-3A), and prepare for CD-3 prior to June 2025, the planned conclusion of RHIC operations.

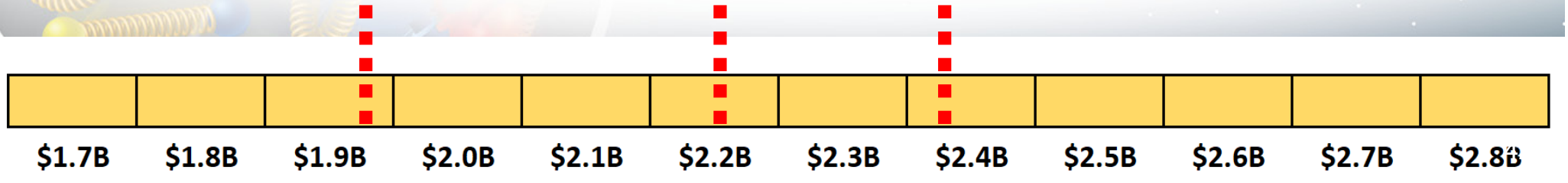


	Range	
	Low End ($M)	High End ($M)
Total Estimated Cost (TEC)		
PED	$280	$367
Construction	$1,118	$1,466
TEC Contingency	$159	$733
Subtotal TEC	$1,558	$2,566
Other Project Cost (OPC)		
OPC	$128	$167
OPC Contingency	$14	$67
Subtotal OPC	$142	$234
Total Project Cost (TPC)($M)	$1,700	$2,800

Scenario 1
- Pre-CD-1 Profile
- Technically Driven Schedule
- Optimum Annual Funding Profile

Scenario 2
- CD-1 Approval Profile
- Constrained Peak Funding Profile
- 40% Contingency

Scenario 3
- Actual $45M in FY2022 Funding
- Revised Annual Funding Profile
- $90M in FY2023



Project Challenges

- Construction Funding Ramp-Up (50% vs >100% per year)
  - Funding profile and construction project affordability
  - Partner engagement and motivation of in-kind contributions
- Accelerator Science and Technology
  - Complex machine with high performance goals (luminosity, polarization, reliability, etc.) requiring a collaborative approach
  - BNL and JLab working to engage international and domestic partners in these efforts
- Infrastructure Schedule w/ NYS Support ($100M)
  - Initial pacing scope for the project with significant NYS funding
  - Requires EIC technical teams to deliver timely requirements
- Project Detector Plans
  - Excellent progress leveraging Advisory Panel recommendations
  - Working to support an inclusive collaboration and institutional responsibilities, scope, cost & schedule for CD-2/3A

Positioning the EIC Project for Success

- EIC Project Advisory Committee preparing a report on lessons learned and conditions needed for success based on recent and contemporary projects
  - PAC Chair, Thomas Glasmacher, MSU FRIB Director
  - PAC members provided additional input and provided direction on next steps
- Next steps
  - PAC subcommittee interviewing stakeholders and performing “gap analysis”
  - Recommendations on actions needed to position the EIC project for success

Project leadership experience – Ingredients to success

- ✓ **Facility is a priority of the science community!**
- ✓ **Strong funding agency commitments and host role**
- ✓ **Project leaders viewed as enabling success of others**
- ✓ **Establish realistic goals – "Experience over hope"**
- ✓ **Credibility through openness and transparency**
- ✓ **Collective ownership of problems and solutions**
- ✓ **Populate organization with critical experience**
- ✓ **Success requires energy and enthusiasm!**

Project leaders who prioritize on schedule performance and exhibit behaviour that is consistent with a "project culture" are likely to be successful!

PLI PROJECT LEADERSHIP INSTITUTE

U.S. DEPARTMENT OF ENERGY

Summary

- Excellent Progress
  - Project foundation in place: established partnership and organization, defined scope, conceptual design, preliminary performance parameters, cost & schedule range, and planning documentation
  - BNL and TJNAF actively pursuing broader collaboration and partnership in the EIC
  - Clear path forward on the project detector
- Preparing for CD-2/3A
- EIC facility rapidly moving from planning to reality!


Thank You!
Electron-Ion Collider
BROOKHAVEN NATIONAL LABORATORY
Jefferson Lab
U.S. DEPARTMENT OF ENERGY
Office of Science