Electron-Ion Collider Project Update

Jim Yeck EIC Project Director

IEEE 23rd Real Time Conference August 2, 2022

Electron-Ion Collider



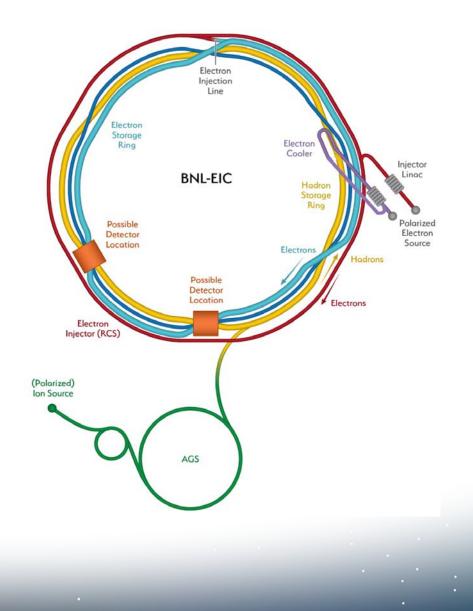


ENERGY Office of Science

Outline

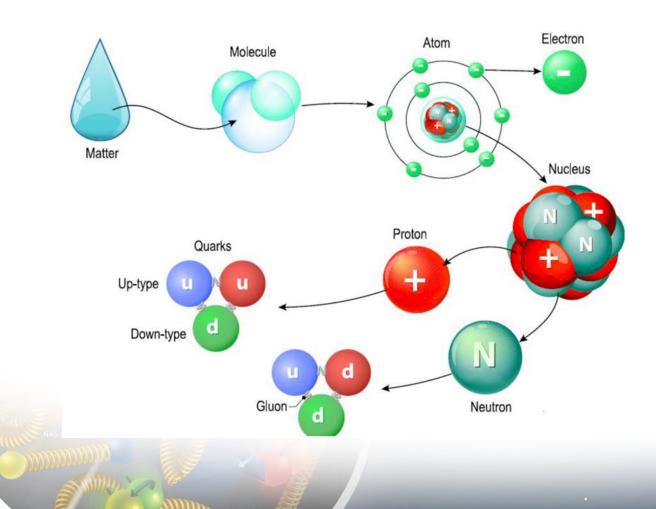
• EIC Science Requirements

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



Quest for the fundamental structure of matter

3





What's in there?

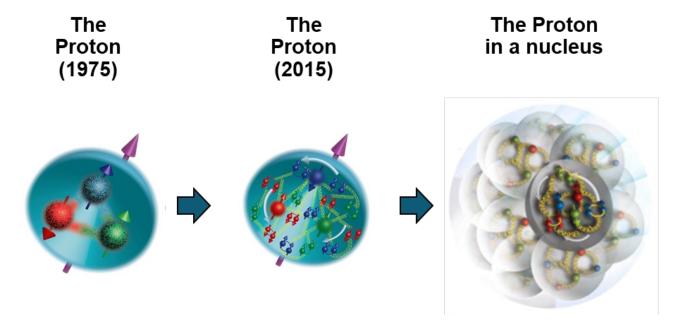
What are we made up of?

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



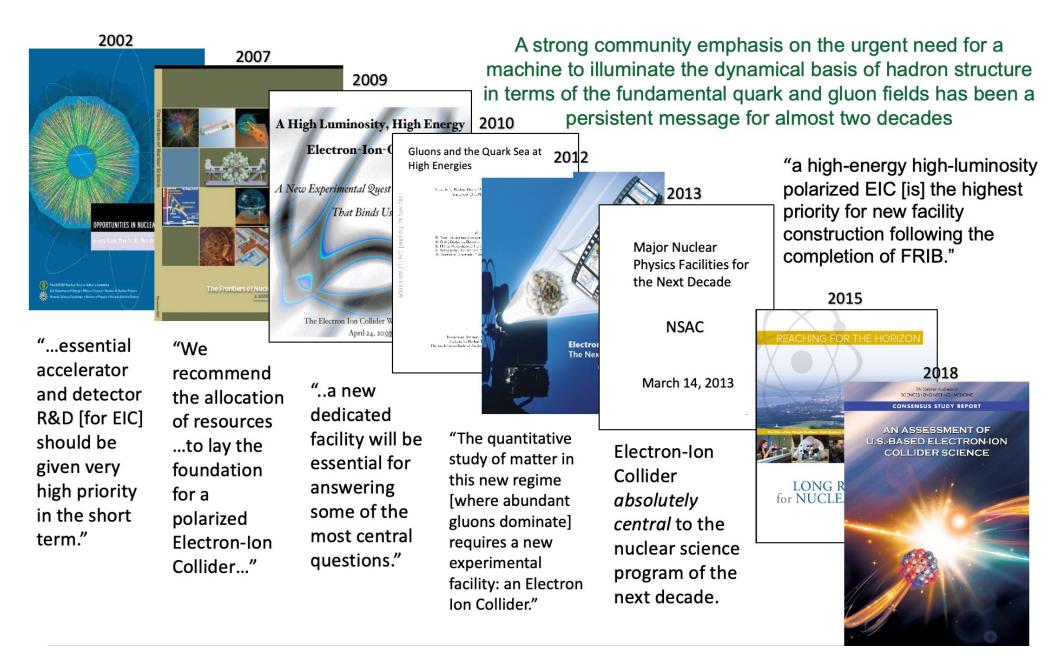
The EIC, a discovery machine, will enable the definitive study of the role of gluons and quarks in nucleons and nuclei. It will provide precise images of the gluon/quark structure of the polarized proton, unravel the mysteries of the origin of nucleon mass and spin, and explore the physics of gluons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

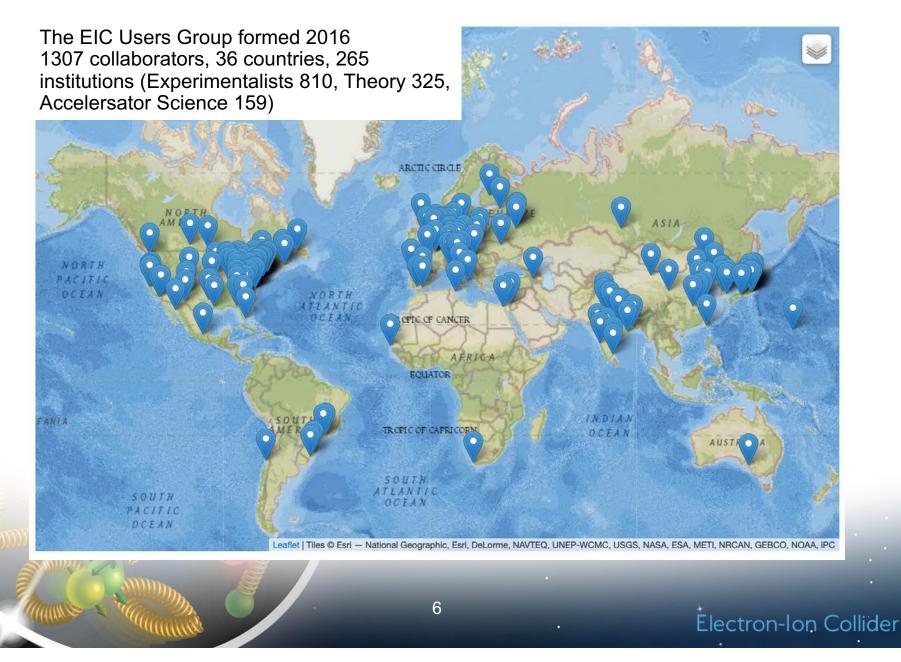
The EIC project is working closely with domestic and international partners to deliver the EIC.

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Science Case



World-wide interest in EIC science



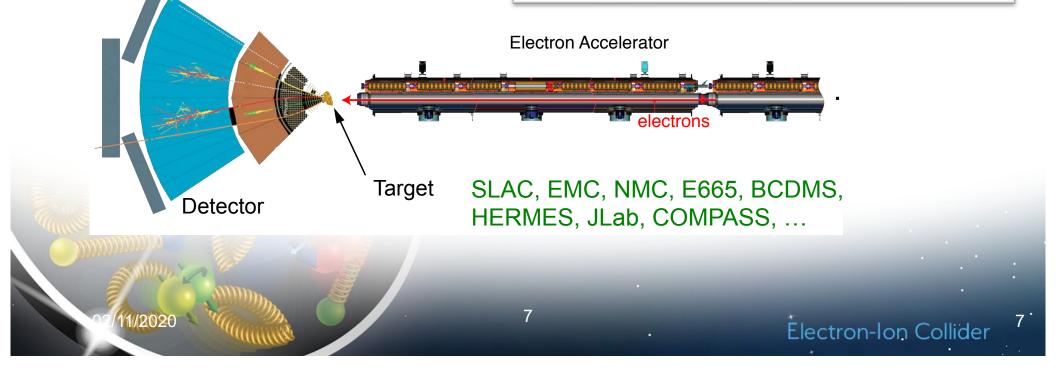
Studying smaller

and smaller

Light Microscope Wave ength: 380-740 nm Resolution: > 200 nm

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

Electron Microscope Wave length: 380-740 nm Resolution: > 200 nm Probe Probe



US DOE Nuclear Physics Facilities



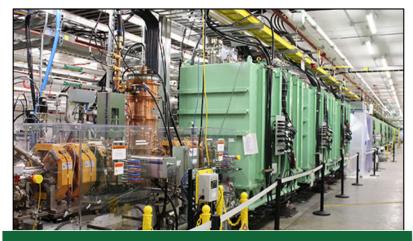
Relativistic Heavy Ion Collider



Continuous Electron Beam Accelerator Facility



Argonne Tandem Linac System



Facility for Rare Isotope Beams

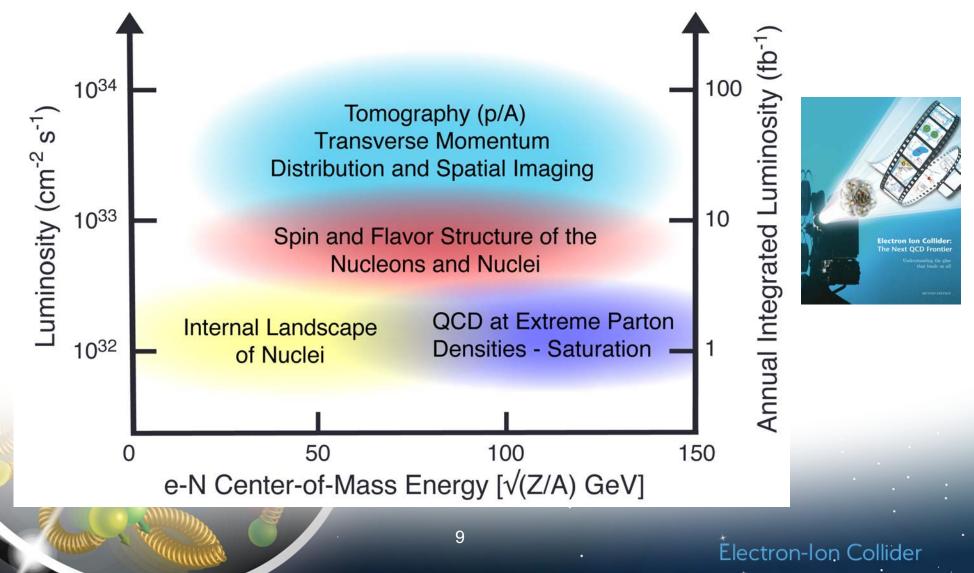
Electron-Ion Collider

"Microscopes" of Varying Resolving Power – T. Hallman

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EIC Physics

Center of Mass vs. Luminosity/Integrated Luminosity



Project Requirements

Project Design Goals

- High Luminosity: L= 10³³ 10³⁴cm⁻²sec⁻¹, 10 100 fb⁻¹/year
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: $E_{cm} = 20 140 \text{ GeV}$
- 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)



The 2015 LONG RANGE PLAN for NUCLEAR SCIENCE





AN ASSESSMENT OF U.S.-BASED ELECTRON-ION COLLIDER SCIENCE

Electron-Ion Collider Concepts

For e-N collisions at the EIC:

 ✓ Polarized beams: e, p, d/³He
 ✓ e beam 5-10(20) GeV
 ✓ Luminosity L_{ep} ~ 10³³⁻³⁴ cm⁻²sec⁻¹ 100-1000 times HERA
 ✓ 20-100 (140) GeV Variable CoM

For e-A collisions at the EIC:

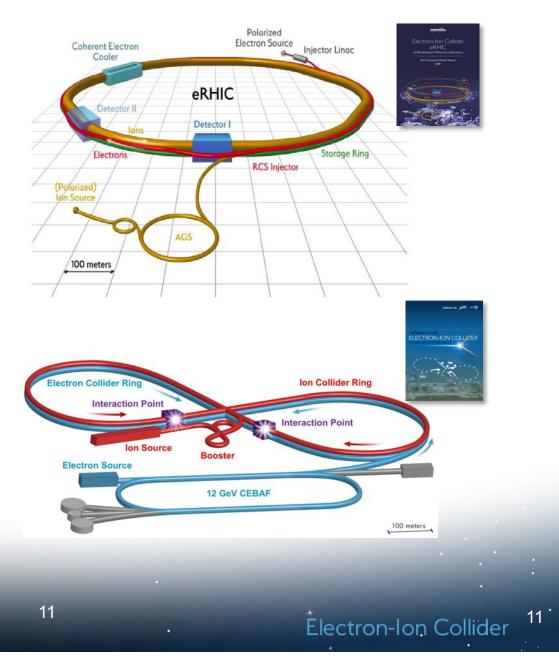
- ✓ Wide range in nuclei
- ✓ Luminosity per nucleon same as e-p
- ✓ Variable center of mass energy

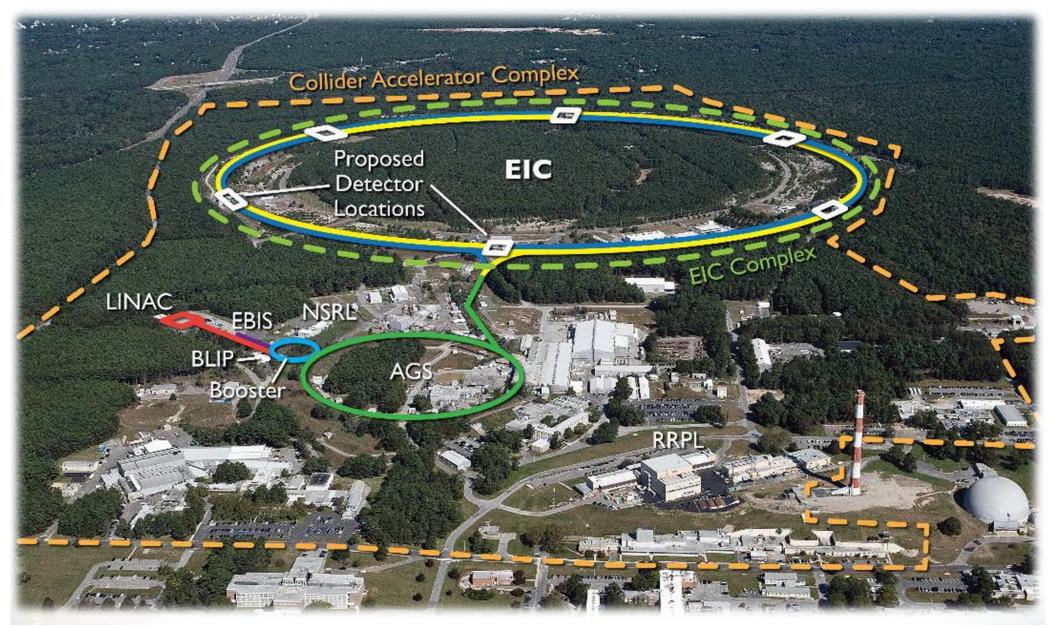
World's first

11/2020

Polarized electron-proton/light ion and electron-Nucleus collider

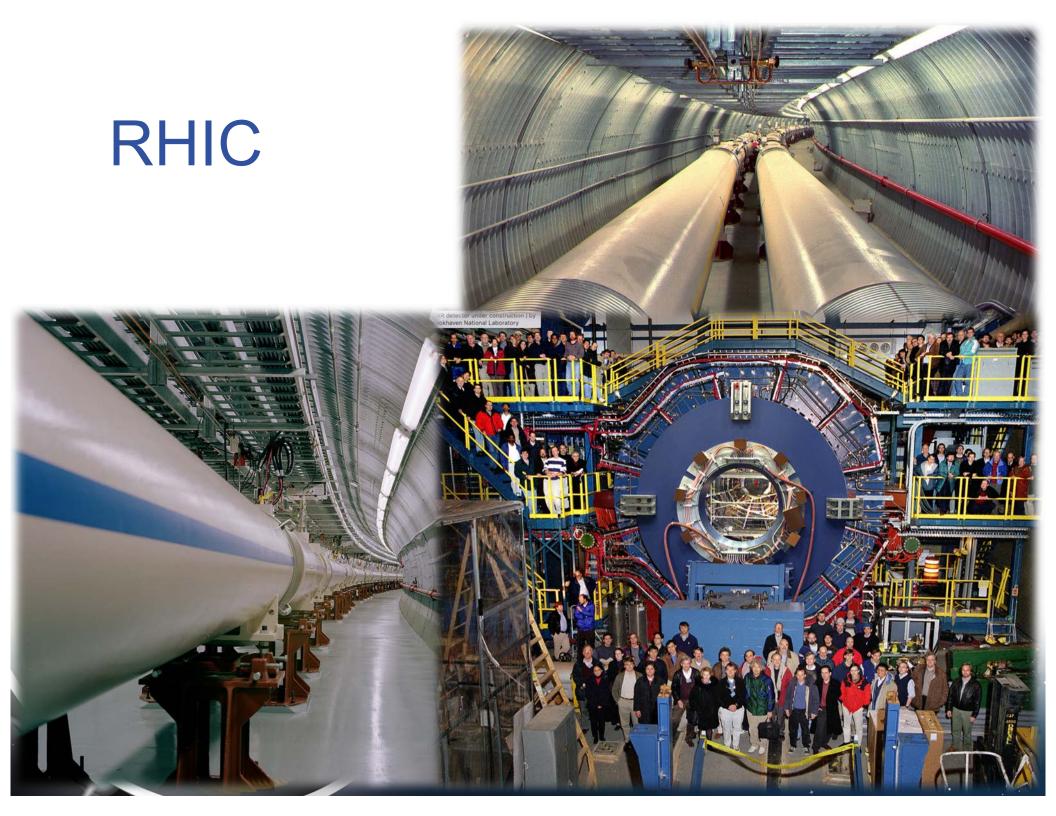
Both designs use DOE's significant investments in infrastructure





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

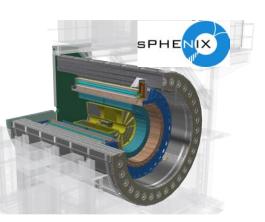
Munnik



Completing RHIC Mission with sPHENIX and STAR

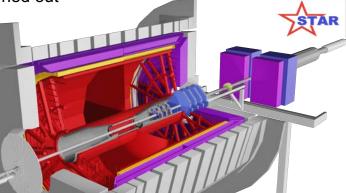
- sPHENIX will use energetic probes (jets, heavy quarks) to study quark-gluon plasma on different length scales with unprecedented precision
 - How the structureless "perfect" fluid emerges from the underlying interactions of quarks and gluons at high temperature
- State-of-the-art collider detector 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



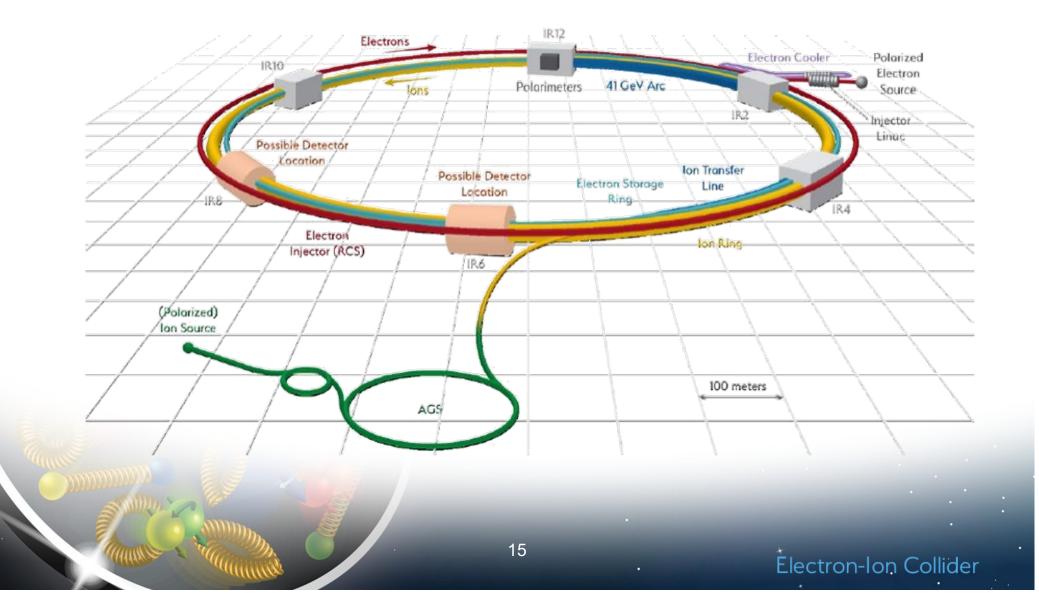


Electron-Ion Collider

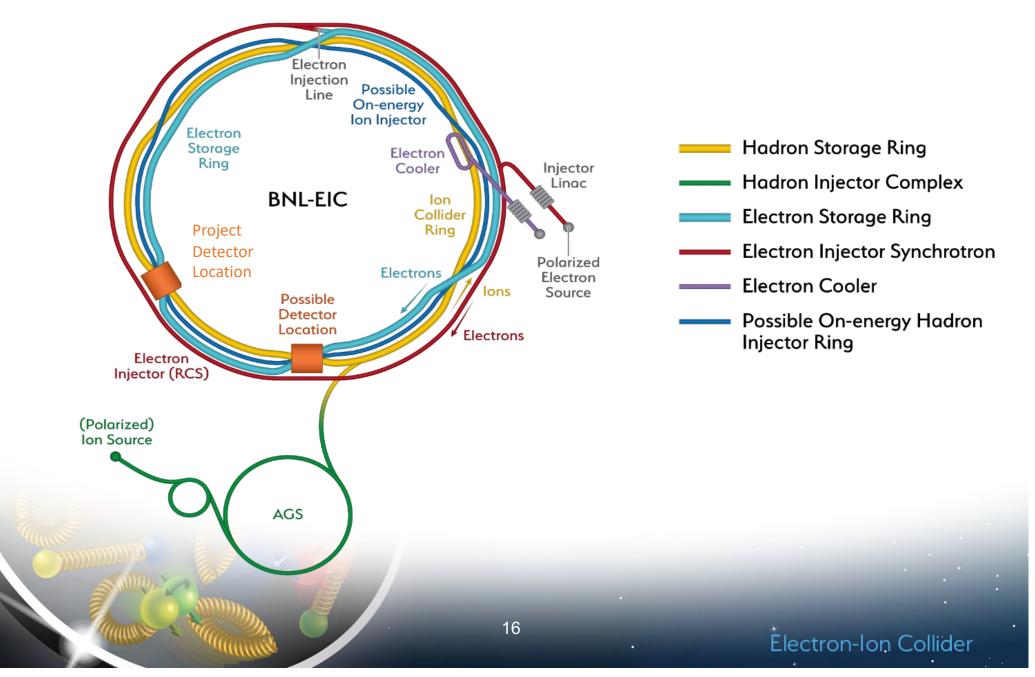
RHIC data taking scheduled for 2023–2025 sPHENIX upgrade and STAR with forward upgrade will fully utilize the enhanced (~50 times Au+Au design) luminosity of RHIC

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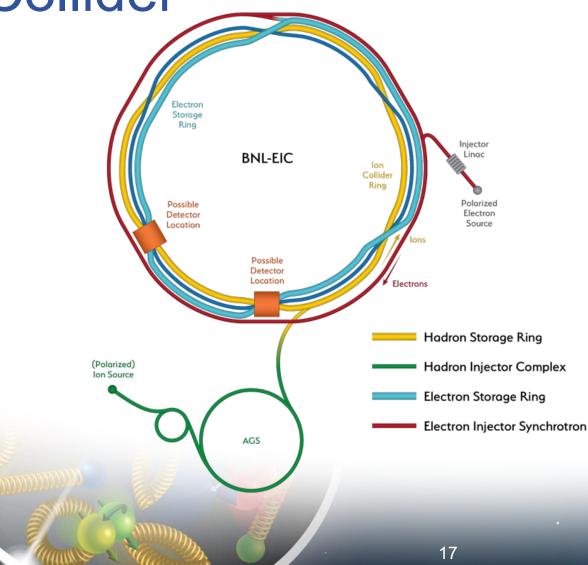
EIC Conceptual Design



Electron-Ion Collider Scope



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)
- o bright vertical beam emittance 1.5 nm
- strong cooling (coherent electron cooling)

Electron storage ring 2.5–18 GeV (new)

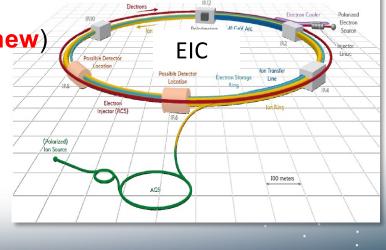
- o many bunches,
- large beam current, 2.5 A → 9 MW S.R. power
- o S.C. RF cavities
- Need to inject polarized bunches

Electron rapid cycling synchrotron 0.4-18GeV (new)

- o **1-2 Hz**
- Spin transparent due to high periodicity
- High luminosity interaction region(s) (new)
 - \circ L = 10³⁴ cm⁻² s⁻¹
 - Superconducting magnets
 - 25 mrad Crossing angle with crab cavities
 - Spin Rotators (longitudinal spin)
 - Forward hadron instrumentation

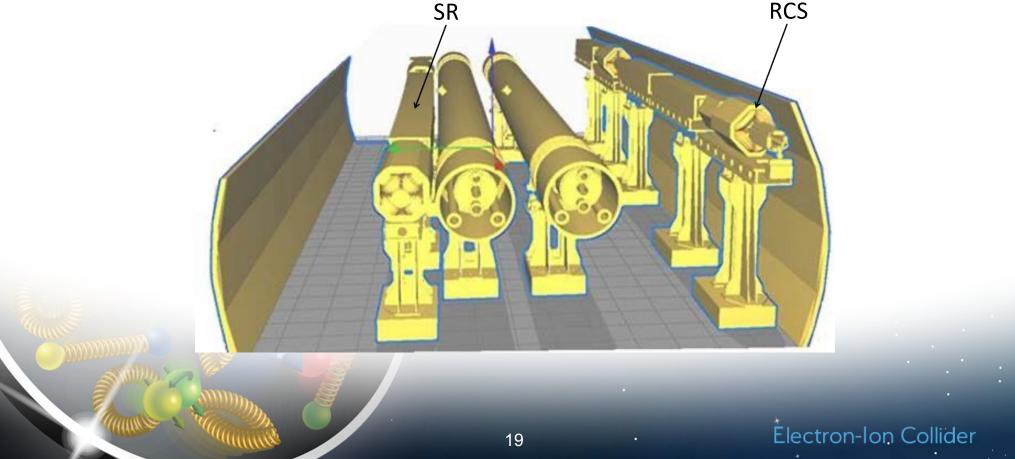




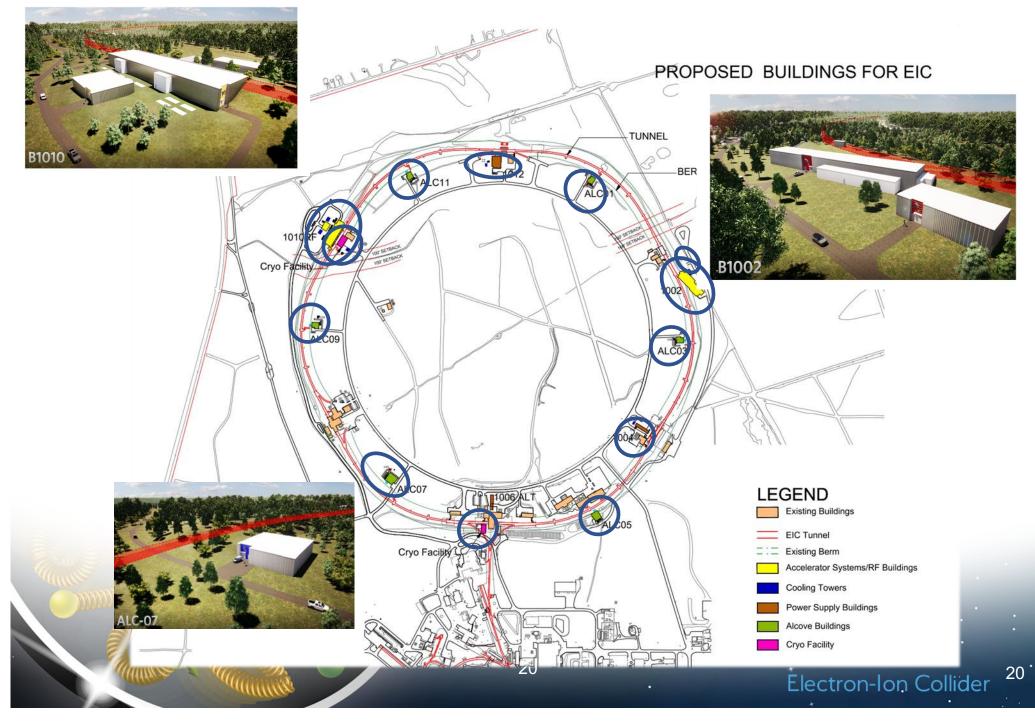


EIC Machine in the RHIC Tunnel

- 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



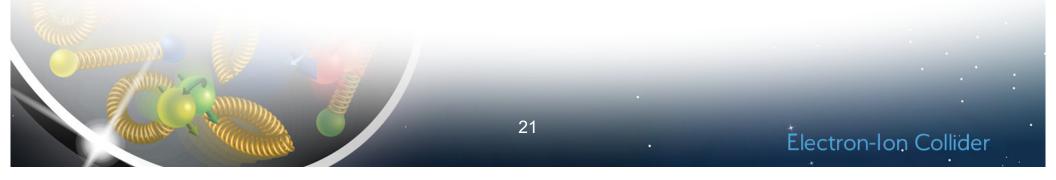
EIC Proposed Site Plan: Buildings



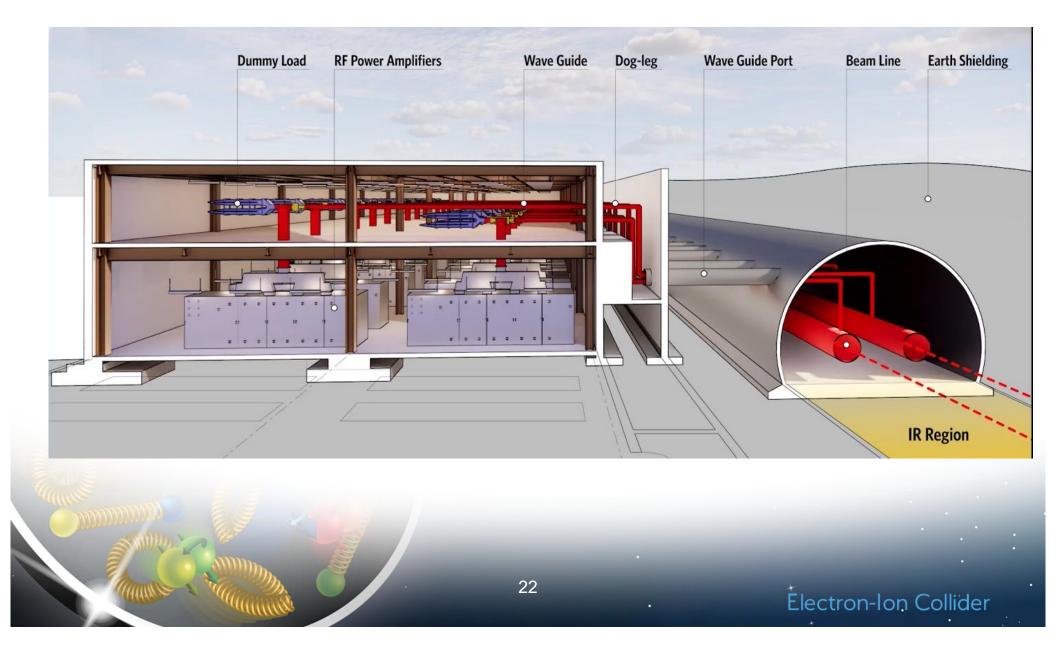
Electron Injection Support Building



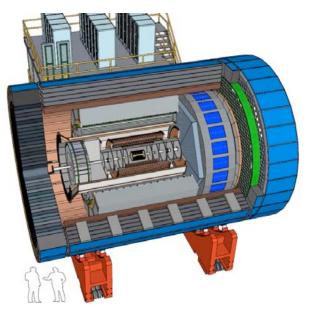
 1002H EIC Injection LINAC Building ≈ 50,000 SF

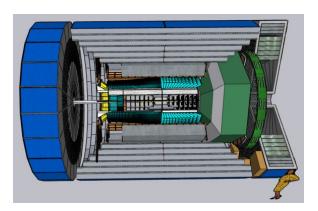


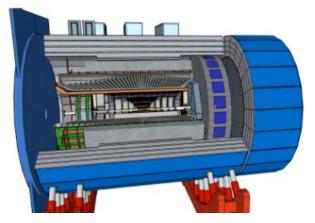
RF Support Buildings



EIC Detector Proposals







100 institutions

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

20 institutions

23

96 institutions

20 msu	
CO	RE
Location	IP8
Detector Length	8 meter
Magnet Field	3 Tesla
Magnet Bore	2.0 meter

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

Magnet 2.8 meter

Electron-Ion Collider

Bore

EIC Proto-Collaborations

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

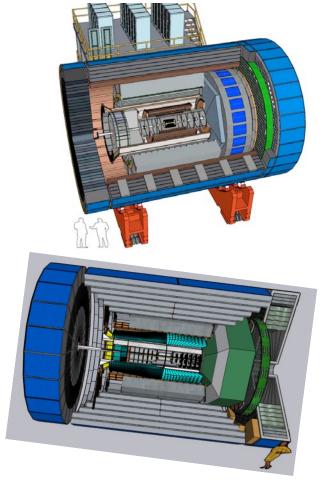
- Focus on becoming the "project detector"@IP6
- New 3 T magnet and the YR Reference Detector
- Leadership: S. Dalla Torre (INFN Trieste, B. Surrow (Temple)
- ~100 collaborating institutions from Armenia, Canada, China, Czech, France, Germany, Italy, India, Poland, Romania, UK

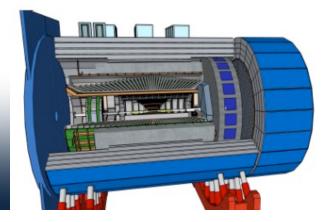
CORE (<u>https://eic.jlab.org/core/</u>)

- 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

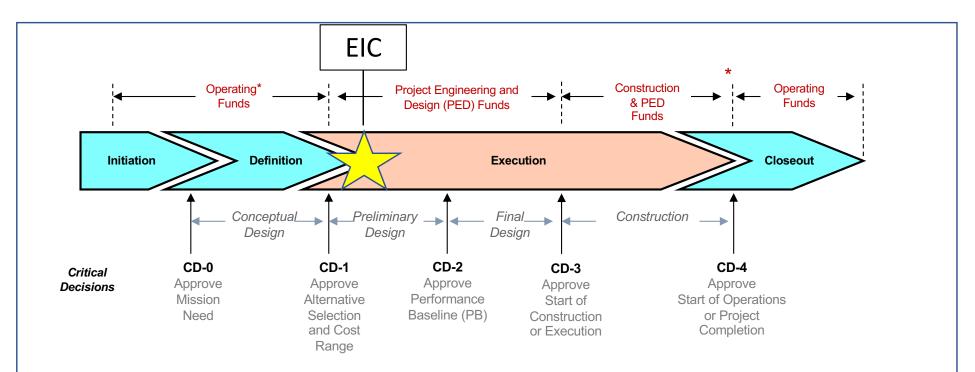




Project Detector Selection

- 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

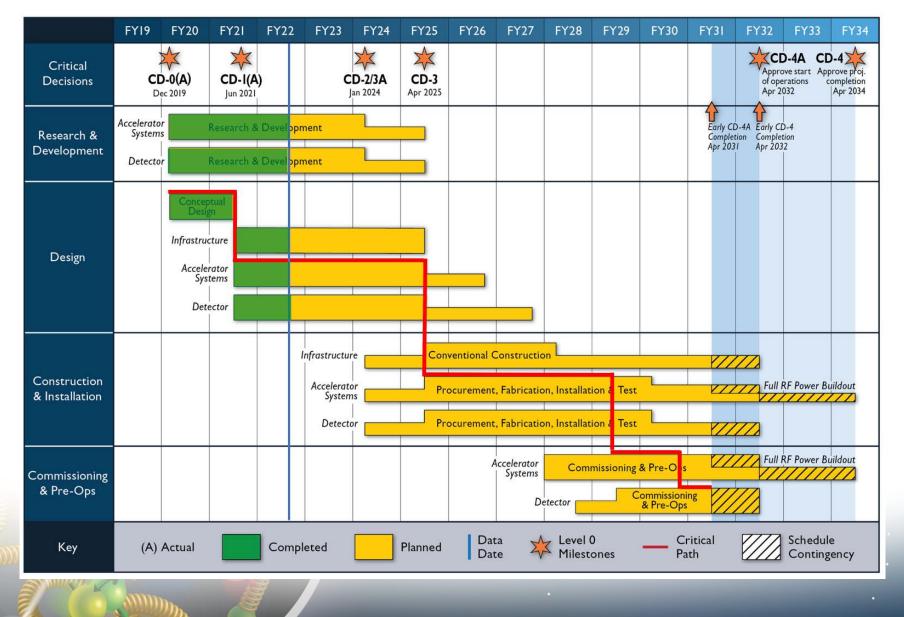
- CD-0, Mission Need
- CD-1, Alternative Selection and Cost Range
- CD-2, Performance Baseline
- CD-3a, Long Lead Procurement

EIC Project Recent History

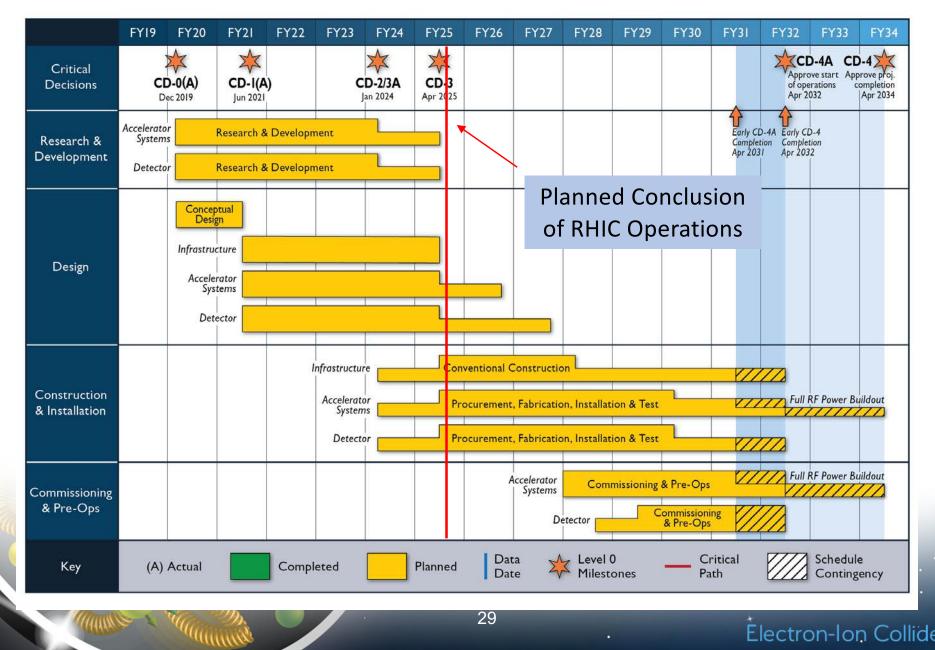
Event	Date
Mission Need Statement Approved	January 22, 2019
CD-0, Mission Need Approved	December 19, 2019
DOE Site Selection Announced	January 9, 2020
BNL - TJNAF Partnership Agreement Approved	May 2020
Conceptual Design Review	November 2020
DOE Independent Cost Review (ICR)	January 2021
CD-1, Alternative Selection and Cost Range, Approved	June 29, 2021
DOE FY2022 Budget Uncertainties, Potential DOE Infrastru	cture 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

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EIC Schedule



RHIC to EIC Transition



Primavera P6 Schedule

-	Add ID	Article Name				eRHIC - Fu	Dotail Schedule Finish	Total Cost		001 2000	0000 000-	0005	2027 20	28-Apr-19 19:12 28 2029 203		
	Adivity ID	Activity Name				Dur Start	Finish	Iotal Cost	The second se		2023 2024 Y23 FY24	2025 2026 FY25 FY26		28 2029 203 FY29 FY30		
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	ER_195000	Ray tracing with SynRad and ANSYS ana			at the second state	500 30-Sep-20		\$504,904.05								
	ER_195010 ER 195020	Development of various cross sections, in Welding and tooling development includi	the second s		id mid curved si	500 30-Sep-20 500 30-Sep-20	the second s	\$904,476.02 \$882,668.68					~73	300 ac	stiviti.	20
	ER 195030	Development of RF shielded bellows inclu		otorrabsorber		500 30-Sep-20		\$684,205.78					-70		, (V ()	53
	ER 195040	Development of SR masks including prok				500 30-Sep-20		\$315,641.17								
		2 Datector Interface Vacuum Systems				500 30-Sep-20		\$2,163,832.18								
	ER_197000	Ray tracing with SynRad and ANSYS ana				500 30-Sep-20		\$384,040.05								
	ER_197010 ER_197020	Development of large aperture RF shields Development of adjustable collimator	ed bellows includ	ang prototype (Mos	st material cost li	500 30-Sep-20 500 30-Sep-20	29-Sep-22 29-Sep-22	\$447,548.17 \$413,078.92	_							
	ER 197020	Prototype detector chamber and weld dev	elopment for ber	vilum chamber		500 30-Sep-20		\$659,702.15								
	ER 197040	Development of support and bake out sys				500 30-Sep-20	the second se	\$259,462.90								
	ADE-6.02.03.10 C					875 02-Jan-20		\$9,070,177.36								
	IC_EW_1000 IC_EW_1001	Simulation and design of gun and test equi	ipment			250 02-Jan-20 250 02-Jan-20	30-Dec-20 30-Dec-20	\$2,025,729.04	8							
	IC_EW_1001	design of gun and test eqipment gun-upgrade design				250 02-Jan-20 250 02-Jan-20	30-Dec-20 30-Dec-20	\$1,756,708.05 \$253,360.00								
	IC EW 1012	Installation of gun and test egipment				250 02-Jan-22	30-Dec-22	\$1,237,978.16								
	IC_EW_1004	Procurement, Internal coll for magnetize	5			250 31-Dec-20	30-Dec-21	\$526,152.90								
	IC_EW_1005	Procurement, HV ps 600 kV				250 31-Dec-20	30-Dec-21	\$789,229.35								
	IC_EW_1006	Procurement, solenoid for gun				250 31-Dec-20	30-Dec-21	\$52,615.29								
	IC_EW_1007 IC_EW_1008	Procurement, magnets for low enrgy bean Procurement addit equipment	n transport			250 31-Dec-20	30-Dec-21	\$63,138.35								
		Prostantian and Anno 1911				250 31-Dec-20 250 31-Dec-20	30-Dec-21 30-Dec-21	\$105,230.58 \$63,138.35								
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DOE CD-2 in January 2024



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)
- Cost and Schedule Scrutiny Meetings
- Project Detector Meetings
- DOE OPA Status Review Confirm CD-2/3A Plans
- Preliminary Design and Director's Reviews
- DOE CD 2/3A OPA Review and ICR
- DOE CD 2/3A ESAAB Approval

Electron-Ion Collider

June 28, 29, 30 2022

July - August 2022

Fall 2022

June 2023

January 2023

October 2023

January 2024

BNL/TJNAF Special Partnership

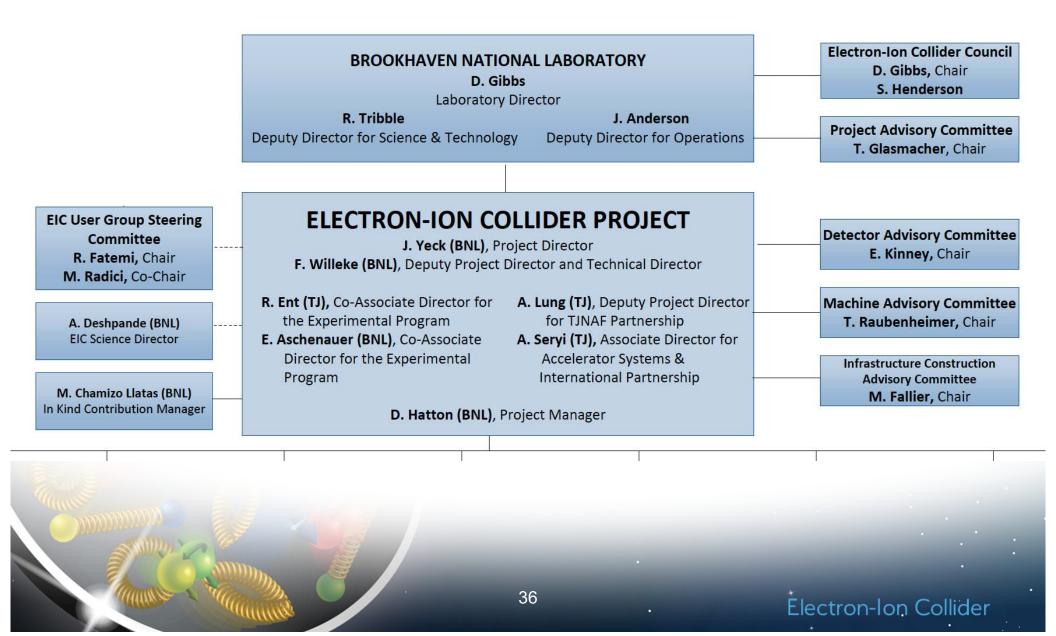


- BNL/JLab partnership established in early 2020
- Serve together as hosts for the EIC experimental program
- Integrated project scope responsibilities defined

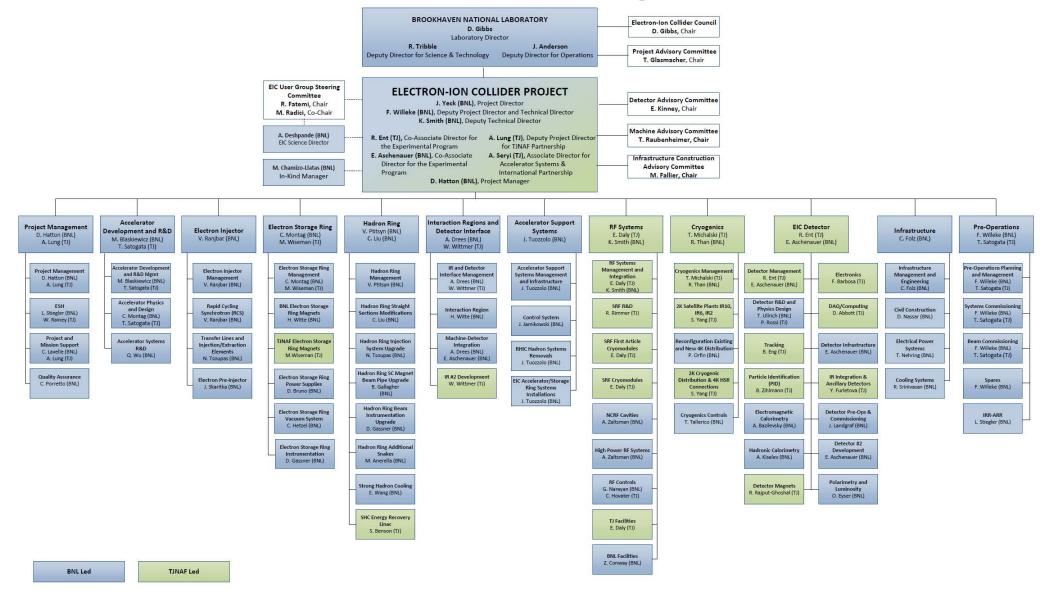
BNL/TJNAF

- 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

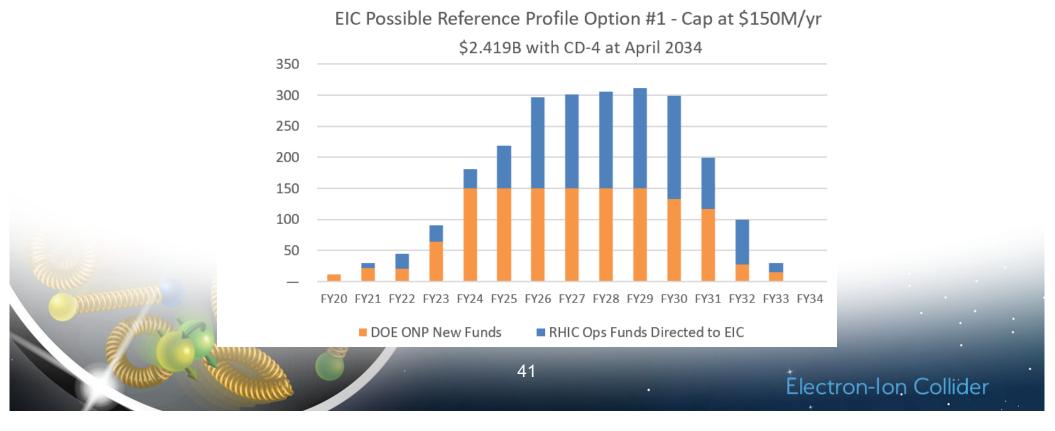
- EIC Council (BNL and TJNAF Directors) will become the "EIC Advisory Board" with international and domestic partners joining
 - Solicited input from leaders of international and domestic labs at Council meetings in April and June
 - BNL Director inviting new members
 - EIC Advisory Board meeting in 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						
	L	ow End	(\$M)	Hig	h End	(\$M)		
Total Estimated Cost (TEC)								
PED			\$280)		\$367		
Construction			\$1,118	3		\$1,466		
TEC Contingency			\$159)		\$733		
Subtotal TEC			\$1,558	3		\$2,566		
Other Project Cost (OPC)								
OPC			\$128	3		\$167		
OPC Contingency			\$14	1		\$67		
Subtotal OPC			\$142	2		\$234		
Total Project Cost (TPC)(\$M)			\$1,700)		\$2,800		
Optimum Annual Funding	ined Peak	•	FY2022 Revised Fundin	\$45M in 2 Funding d Annual g Profile 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!
 - \checkmark Strong funding agency commitments and host role
 - \checkmark Project leaders viewed as enabling success of others
 - ✓ Establish realistic goals "Experience over hope"
 - \checkmark Credibility through openness and transparency
 - \checkmark 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!

PROJECT LEADERSHIP INSTITUTE



Electron-Ion Collider

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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!





