Electron-Ion Collider Progress and Plans

Jim Yeck, EIC Project Director November 2, 2022

Electron-Ion Collider





ENERGY Office of Science

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





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

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

Both designs use DOE's significant investments in infrastructure





EIC Double Ring Design Based on Existing RHIC Facility RHIC Operations Concludes in 2025

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RHIC Infrastructure



Completing RHIC Ops Mission

- 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

- **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



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

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EIC Conceptual Design



Electron-Ion Collider Scope



EIC Machine Design Overview

Leverages RHIC: maintained and operating at peak performance

Hadron Storage Ring (RHIC Rings) 40-275 GeV - modified

- 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

- \circ large beam current, 2.5 A
- o S.C. RF cavities
- \circ Need to inject polarized bunches

Electron Rapid Cycling Synchrotron 0.4-18GeV - new

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- o **1-2 Hz**
- Spin transparent due to high periodicity

High Luminosity Interaction Region(s) - new

- \circ L = 10³⁴ cm⁻²s⁻¹
- Superconducting magnets
- 25 mrad Crossing angle with crab cavities
- Spin Rotators (longitudinal spin)

BNL/TJNAF Special Partnership



- BNL/JLab partnership established in early 2020
- Serve together as hosts for the EIC experimental program

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Integrated project scope responsibilities defined

EIC Project Organization



EIC Project – BNL/JLab, Boards, Advisory Committees



- DOE, together with BNL and JLab, envision an EIC facility that is "fully international in character."
- EIC Advisory Board provides oversight and advice on the construction of the facility, focusing on the accelerator (BNL, TJNAF, LBNL, ANL, TRIUMF, IN2P3, CEA, STFC, INFN).
- EIC Project Advisory Committee provides advice on the successful delivery of the DOE Project (management, scope, schedule, cost, and performance).
- EIC RRB to provide oversight of the experiments, 1st meeting planned for 2023.

DOE Funding Plan



DOE ONP New Funds RHIC Ops Funds Directed to EIC New York State Other DOE Funds - IRA Funding Changes from V3

- Inflation Reduction Act funding of \$138.24M is a game changer and mitigates risk of slower than optimum ramp of new funding to the \$150M/year needed.
- Possibility of significant package of long lead procurement items (CD-3A) helping to mitigate risks including procurement, supply chain, inflation and schedule.

EIC Reference Schedule - V3



The EIC User Group: https://eicug.github.io/

Formed in 2016, Currently:

- 1361 collaborators,
- 36 countries,
- 267 institutions

International Participation Growing

EICUG membership @ time of EICUG Meetings





Annual EICUG meeting

2016 UC Berkeley, CA 2016 Argonne, IL 2017 Trieste, Italy 2018 CUA, Washington, DC 2019 Paris, France 2020 Miami, FL 2021 VUU, VA & UCR, CA 2022 Stony Brook U, NY 2023 Warsaw, Poland



Experimental Program Preparation

- Year-long EIC User Group driven EIC Yellow Report activity
 - $\circ~$ Science Requirements and Detector Concepts for the EIC
 - arXiv:2103.05419 361 citations (09/17/22)
 - Appeared as one volume in Nucl. Phys. A 1026 (2022) 122447
- Establishes the requirements of the EIC detectors



BNL and TJNAF Jointly Leading Efforts Towards Experimental Program

2020	Call for Expressions of Interest (EOI) https://www.bnl.gov/eic/EOI.php	May 2020
	EOI Responses Submitted	November 2020
	Assessment of EOI Responses	On-going
2021	Call for Collaboration Proposals for Detectors https://www.bnl.gov/eic/CFC.php	March 2021
	BNL/TJNAF Proposal Evaluation Committee	Spring 2021
	Collaboration Proposals for Detectors Submitted	December 2021
\checkmark	Decision on Project Detector – "ECCE"	March 2022
	Guide process to joint "Detector-1" Collaboration	Spring 2022
	EPIC Collaboration* Formed – 160 institutions	July 2022
aut	*Merger of two large ATHENA and ECCE proposals	Electron-Ion Collider

Reference Schedule for 2nd IR and Detector



International Boards

- EIC Advisory Board
 - Includes leaders of international and domestic partner institutions
 - BNL Director welcoming new members interested in contributing to the EIC accelerator facility
- Resource Review Board (RRB) for the EIC experiments
 - Similar to the LHC RRBs, includes funding agency reps

- EIC RRB pre-planning meeting October 12-13, 2022
- 1st EIC RRB meeting is April 3-4, 2023
- ePIC collaboration forming now

Collaboration Topics with DOE Laboratories: Accelerator

- ANL
 - RCS Quadrupole and sextupole preliminary engineering design, <u>status: in progress</u>
 - Prototype and first article cavity processing (TJ), <u>status: under discussion</u>
- LBNL:
 - o Beam dynamics, status: in progress
 - Superconducting cable production, design (and possibly production) of superconducting dipole magnets, <u>status</u>: agreement in principle, details to be worked out

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- SLAC:
 - o Beam dynamics, IR design, status: in progress
- FNAL
 - Beam dynamics (ESR polarization), <u>status: in progress</u>
 - Design of collared s.c. IR magnet, <u>status:</u> under discussion
 - Design s.c. cavity (of 5-cell?), <u>status</u>: preliminary discussion
 - o RCS dipoles & ESR quads design (TJ), status: under discussion
- ORNL
 - Polarization and Beam dynamics (TJ), <u>status</u>: in progress
 - EIC instrumentation, status: under discussion

Collaboration Topics with International Partners: Accelerator

- Italy / INFN:
 - o Beam screens for HSR, prototyping, design, manufacturing,

status: agreement in principle; EIC L2&L3 ready to finalize the scope of work

- Canada / TRIUMF:
 - Crab cavity system, 394 MHz, design, prototype, manufacturing (TJ), <u>status:</u> agreement in principle; EIC L2&L3 are ready to finalize the scope of work
 - Pulsed devices, status: agreement in principle, details to be worked out
- France / CEA Saclay:
 - SC spin rotator solenoids, status: under discussion
- France / IJCLAB:
 - ERL diagnostics, <u>status</u>: under discussion
- UK / CI, JAI, Daresbury Lab, ...
 - Crab cavity system phase stabilization, status: under discussion
 - o ERL (TJ), status: under discussion
- CERN:

 Joint work working groups on variety of FCCee-EIC topics, SRF, polarization, impedances, feedbacks, etc., <u>status</u>: in progress

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DOE Project Phases



Formal Process of DOE Gateway Reviews

• CD-0, Mission Need √

• CD-1, Alternative Selection and Cost Range \checkmark

Partner and collaboration engagement needed to establish the baseline

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- CD-2, Performance Baseline
- CD-3a, Long Lead Procurement

Summary

- DOE Inflation Reduction Act funding is a game changer shift from progress constrained by availability of early DOE funding to technical progress determined by ability to advance the design, hiring, partnering, collaboration, and procurement – bringing on people!
- Priority is to secure DOE CD-2/3a in early 2024 and CD-3 before RHIC concludes operations in 2025.
 - CD-3a, Long Lead Procurement Approval, key factor in mitigating risk and determining overall project schedule and cost.
 - CD-2, Performance Baseline Approval, establishes Total Project Cost, schedule, performance, and annual funding profile.
- Excellent progress defining the EIC project detector, ePIC, and establishing the collaboration responsible for the experiment.
- Engage now in the world-wide effort to build a collider facility and detectors designed to meet EIC performance and science goals.

Backup Slides



Project leadership experience – Ingredients to success

- ✓ Facility is a priority of the science community!
 - ✓ 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



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A Brief Timeline

- EICUG Yellow Report (2020-21)
- Call for proposals issued jointly by BNL and JLab in March 2021
 - Proposals due Dec. 1, 2021
 - ATHENA, CORE and ECCE proposals submitted
- Public DPAP meetings Dec. 13-15, 2021
 - Presentations from proto-collaborations
 - Panel-assigned homework questions
- Second DPAP session Jan. 19-21, 2022
- DPAP closeout March 8th, 2022
 - Final report available March 21st, 2022
 - ECCE proposal chosen as basis for Detector-1 reference design
- Spring/Summer 2022 ATHENA and ECCE form joint leadership team
 - Joint WG's formed and consolidation process undertaken
 - Coordination with EIC project on development of technical design
- Collaboration formation process started July, 2022
 - First IB Meeting July 18th
 - Charter writing committee formed and active DE&I built in from start!
- First "Detector-1" / ePIC Collaboration meeting July 26-29, 2022

EIC Project Detector

- To be sited at IP6 (25mr crossing angle)
- Addresses EIC science program as outlined in the EIC white paper and NAS report
- Must be ready for Day-1 EIC operations
- Working towards pre-TDR and CD-2/3A



ECCE and ATHENA Consolidation



Key conceptual differences – bore size and magnetic field!

The ePIC Collaboration



160+ institutions24 countries

500+ participants

A truly global pursuit for a new experiment at the EIC!

The ePIC Collaboration



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Collaboration Formation Timeline

- April: Formation of joint working groups and start of technological consolidation process
- June: Collaboration roster established via institutional survey
- July:
 - Name selection via members vote,
 - Collaboration council establishment and interim chairs appointment,
 - Collaboration formation meeting @ Stony Brook University (July 26th-28th).
- August: Formation of charter committee
- October:
 - 6th: Draft bylaws sent to collaboration,
 - 14th: Collaboration council meeting to discuss draft bylaws,
- Late October Early November:
 - Comments and feedback collection of draft bylaws,
 - Final bylaws circulated to collaboration members,
 - Vote and adoption of collaboration bylaws.
- Late November: Collaboration leadership election and appointment of formal roles as defined by bylaws.