

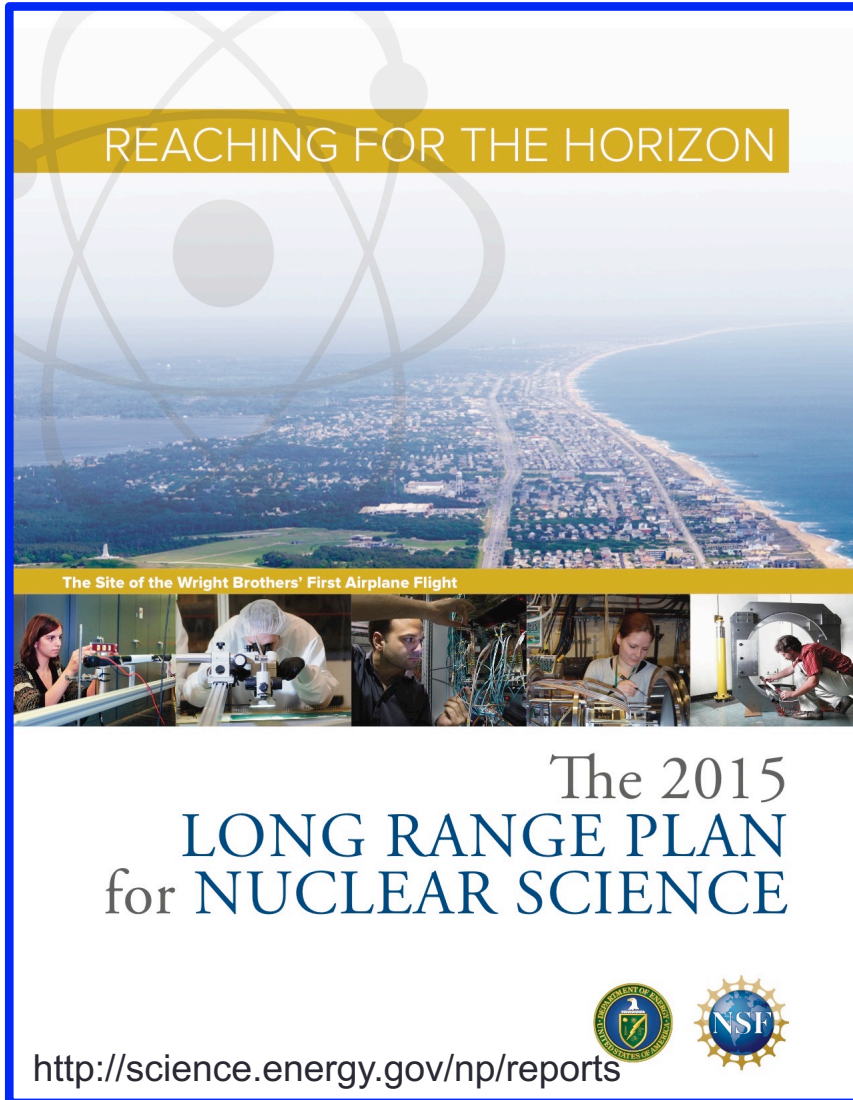


Overview of the EIC & Goals of This meeting

Outline of this talk:

- Recent events: before and after QEIC-1
- **Initiating** a discussion for EIC India: what next





REACHING FOR THE HORIZON

The Site of the Wright Brothers' First Airplane Flight

The 2015
LONG RANGE PLAN
for NUCLEAR SCIENCE

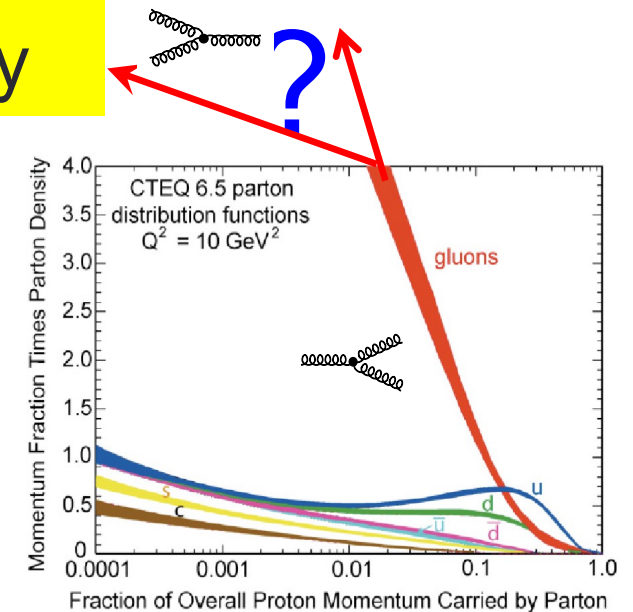
<http://science.energy.gov/np/reports>

Gluons, the carriers of the strong force, bind the quarks together inside nucleons and nuclei and generate nearly all of the visible mass in the universe. Despite their importance, fundamental questions remain about the role of gluons in nucleons and nuclei. These questions can only be answered with a powerful new electron ion collider (EIC), providing unprecedented precision and versatility. The realization of this instrument is enabled by recent advances in accelerator technology.

RECOMMENDATION:

We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

Slide from
January, 4, 2020, QEIC-I, IIT Bombay





The Electron Ion Collider

For e-N collisions at the EIC:

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

For

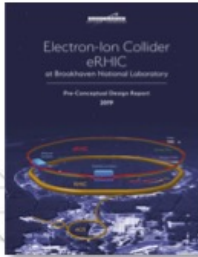
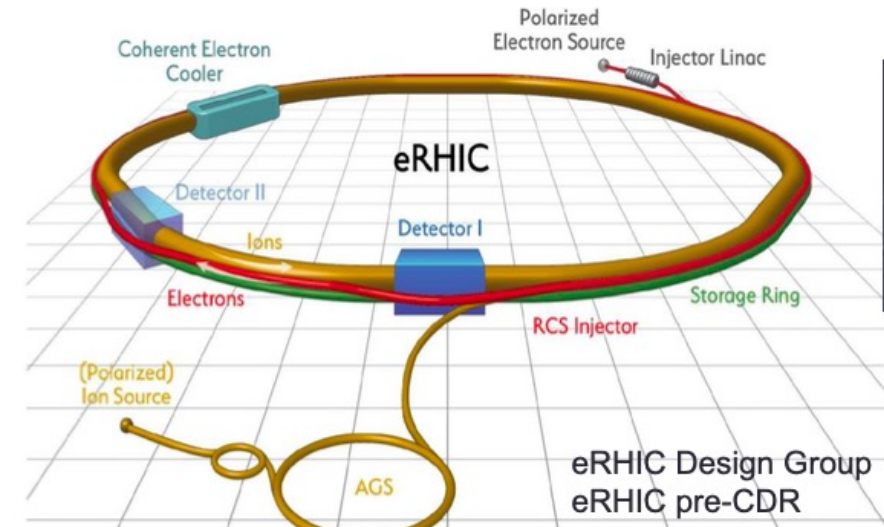
Slide from

January 4, 2020, QEIC-I, IIT Bombay

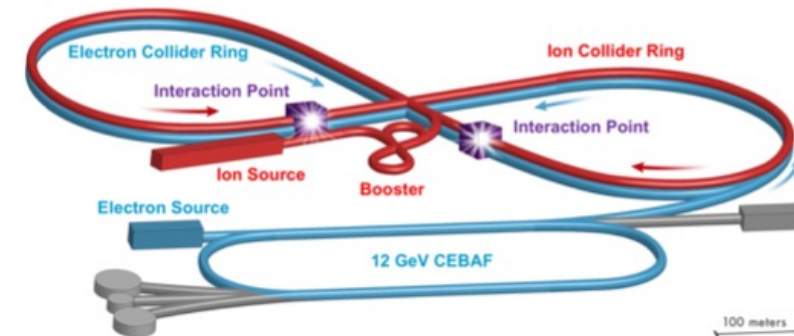
- ✓ Variable center of mass energy

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

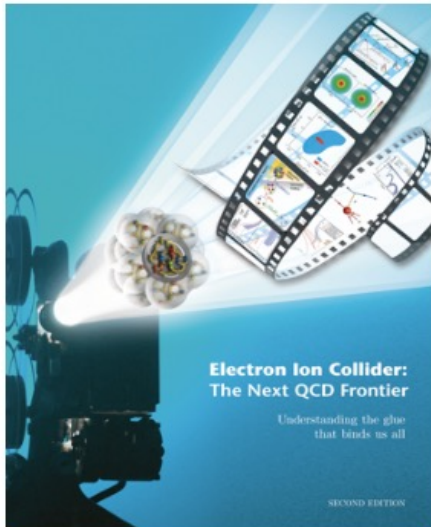
Both designs use DOE's
significant investments in
infrastructure



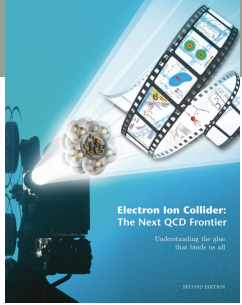
RHIC→EIC



Rolf Ent, Jefferson Lab, CEBAF12→ EIC



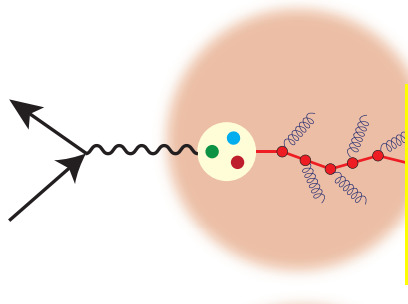
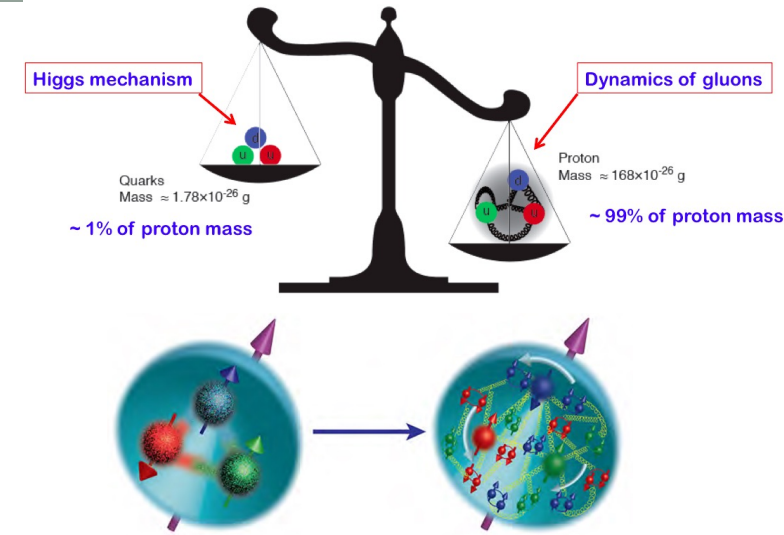
1212.1701.v3
A. Accardi et al
Eur. Phys. J. A, 52 9(2016)



EIC Physics at-a-Glance

Eur. Phys. J. A 52 (2016) 9, 268 arXiv:1212.1701 (nucl-ex)

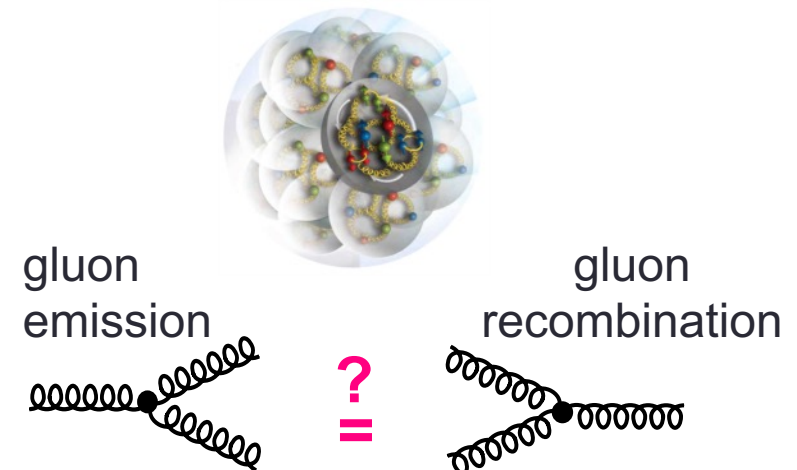
How are the sea quarks and gluons, and their spins, **distributed in space and momentum** inside the nucleon? How do the **nucleon properties (mass & spin) emerge** from their interactions?



How do color-charged quarks and gluons, and colorless jets, the **confined hadronic** jets? How do the **binding?**

Slide from
January, 4, 2020, QEIC-I, IIT Bombay

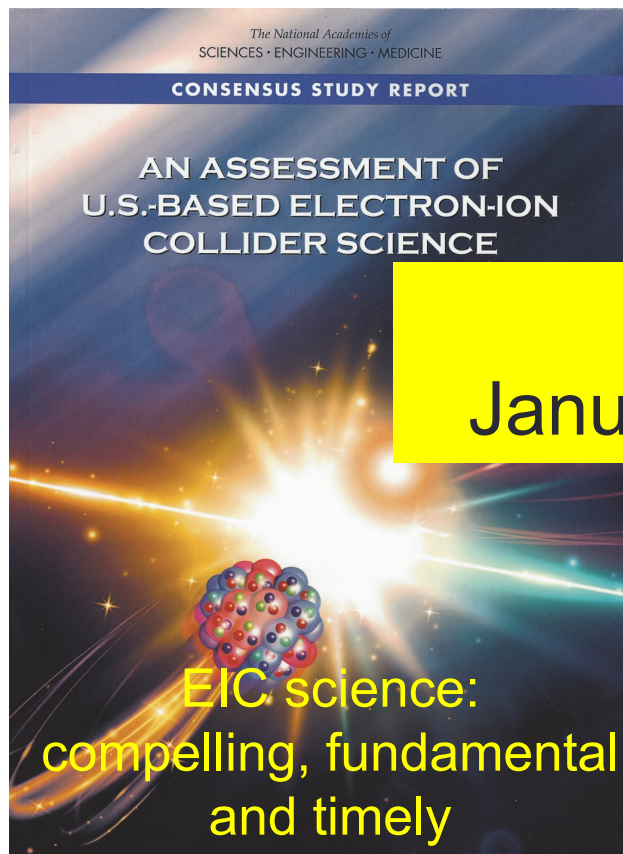
How does a **dense nuclear environment affect** the quark- and gluon- distributions? What happens to the **gluon density in nuclei**? Does it **saturate at high energy**, giving rise to a **gluonic matter with universal properties** in all nuclei, even the proton?





National Academy of Science, Engineering and Medicine

Assessment July 2018

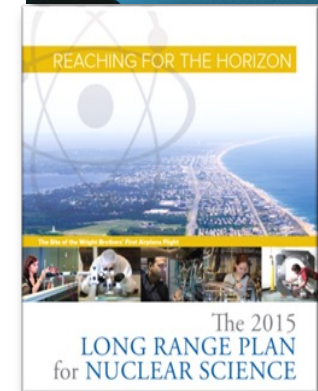
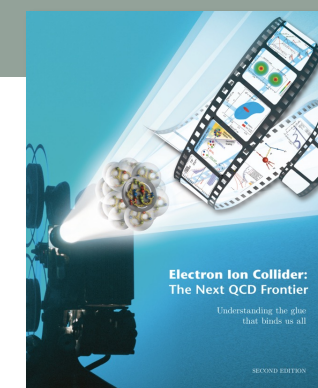


Physics of EIC

- Emergence of Spin
- Emergence of Mass
- Physics of high-density gluon fields

Slide from
January 4, 2020, QEIC-I, IIT Bombay

- a factor ~ 100 -1000 times HERA
- Broad range in **center-of-mass energy**: ~ 20 -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

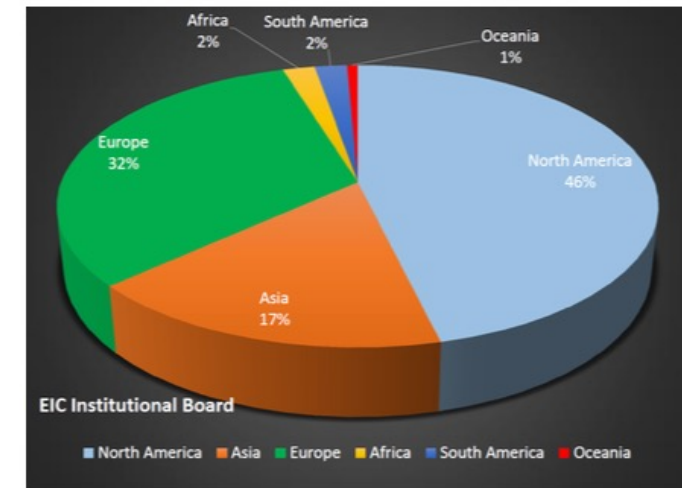


The EIC Users Group: EICUG.ORG

Formally established in 2016
~950 Ph.D. Members from 30 countries, 189 institutions



New:
[Center for Frontiers in Nuclear Science](#) (at Stony Brook/BNL)
[EIC²](#) at Jefferson Laboratory



EICUG Structures in place and active.
EIC UG Steering Committee, Institutional Board, Speaker's Committee

Slide from
January 4, 2020, QEIC-I, IIT Bombay

Year long workshops: Yellow Reports for detector design

Annual meetings: Stony Brook (2014), Berkeley (2015), ANL (2016), **Trieste (2017)**, CAU (2018), **Paris (2019)**, [FIU \(2020\)](#), **Warsaw (2021)**

Week following QEIC-I (Jan. 4-7, 2020)

→ A phase transition occurred in the EIC

January 9, 2020, I was on an overnight train to Sholapur when BNL's ALD Berndt Mueller called me to say that:

- EIC received DoE's "CD0" on Dec. 19, 2019
- BNL will be the site of the Electron Ion Collider
- EIC to be realized in partnership with Jefferson Lab

EIC gained momentum despite COVID



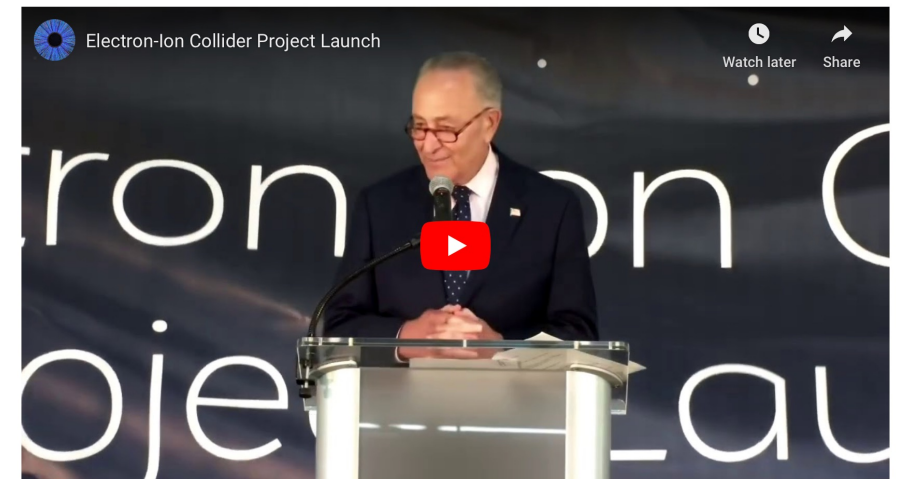
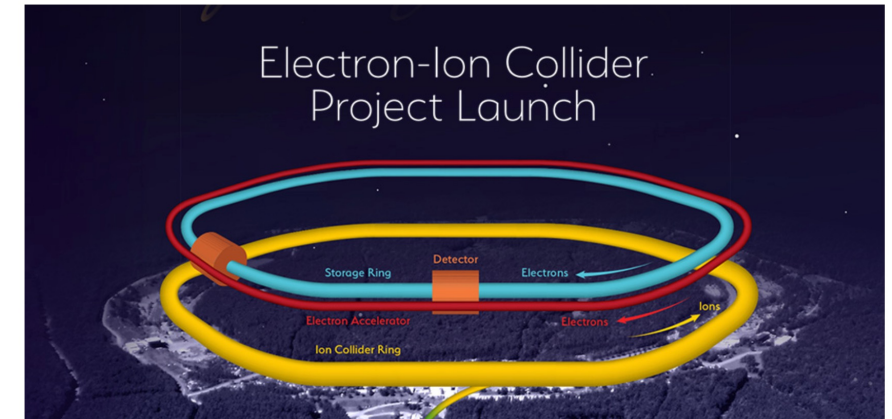
<https://www.bnl.gov/newsroom/news.php?a=117399>



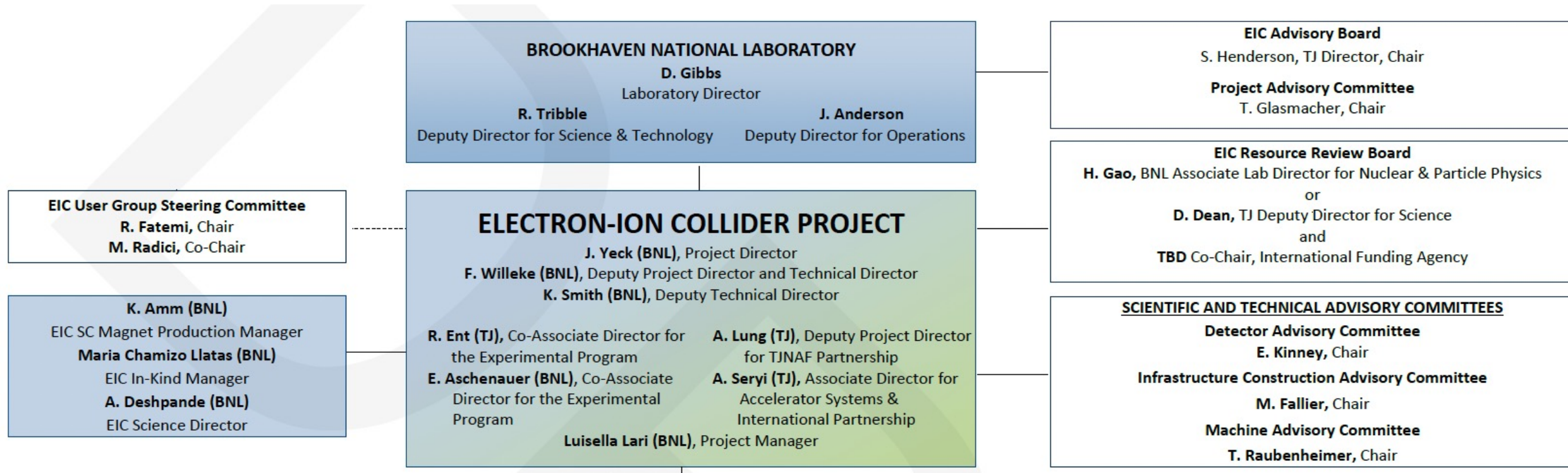
Key Partners Mark Launch of Electron-Ion Collider Project

State-of-the-art facility and partnership among DOE, NYS, Brookhaven Lab, and Jefferson Lab will open a new frontier in nuclear physics, a field essential to our understanding of the visible universe with applications in national security, human health, and more

September 18, 2020



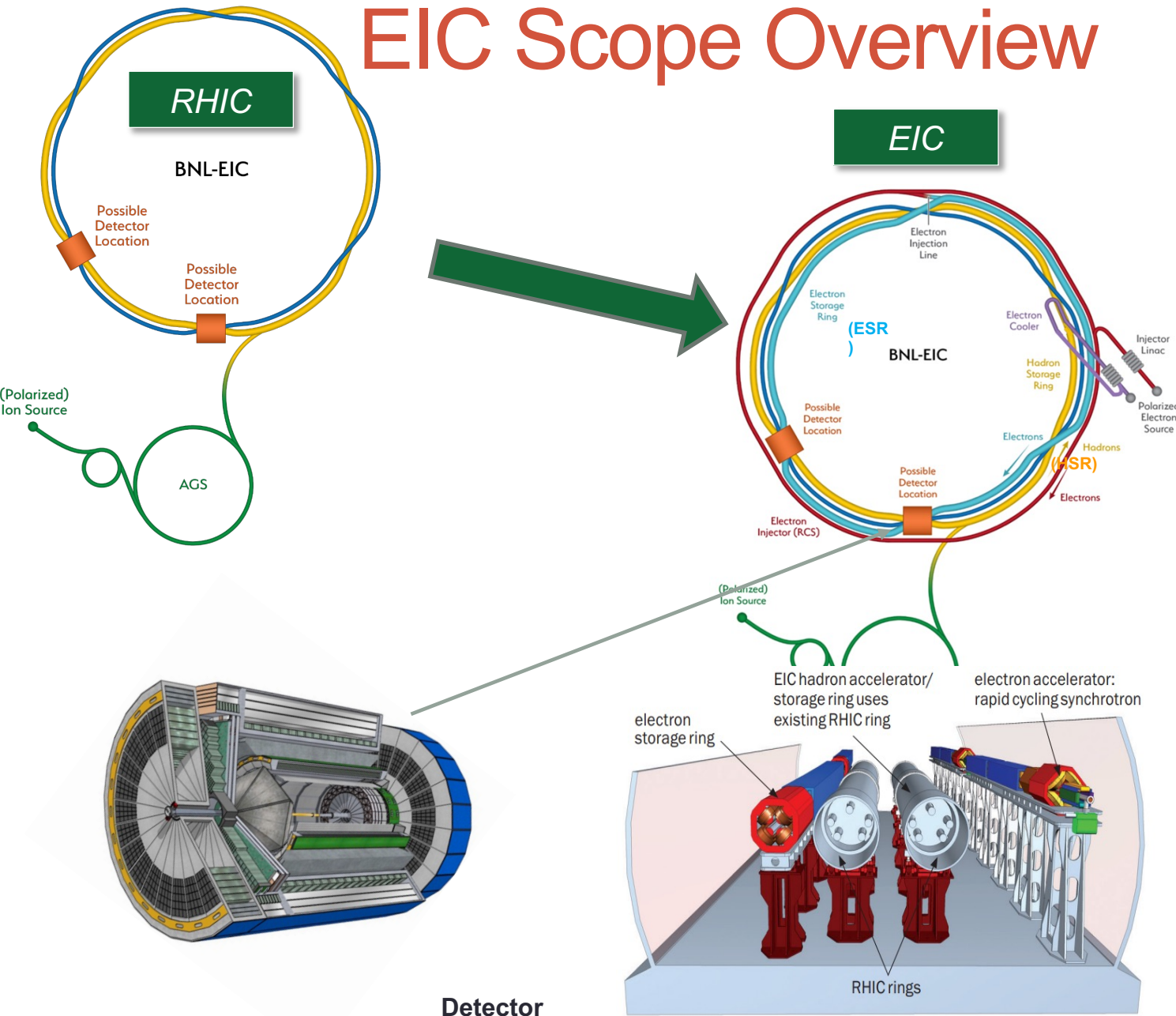
Replay of Electron-Ion Collider project launch event at Brookhaven Lab, September 18, 2020



- 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
- EIC Project Advisory Committee provides advice on the successful delivery of the DOE EIC Project (management, scope, schedule, cost, and performance)
- **EIC RRB to provide oversight of the experiments**

EIC Scope Overview

Facilities modified, construct new accelerators and detector(s).

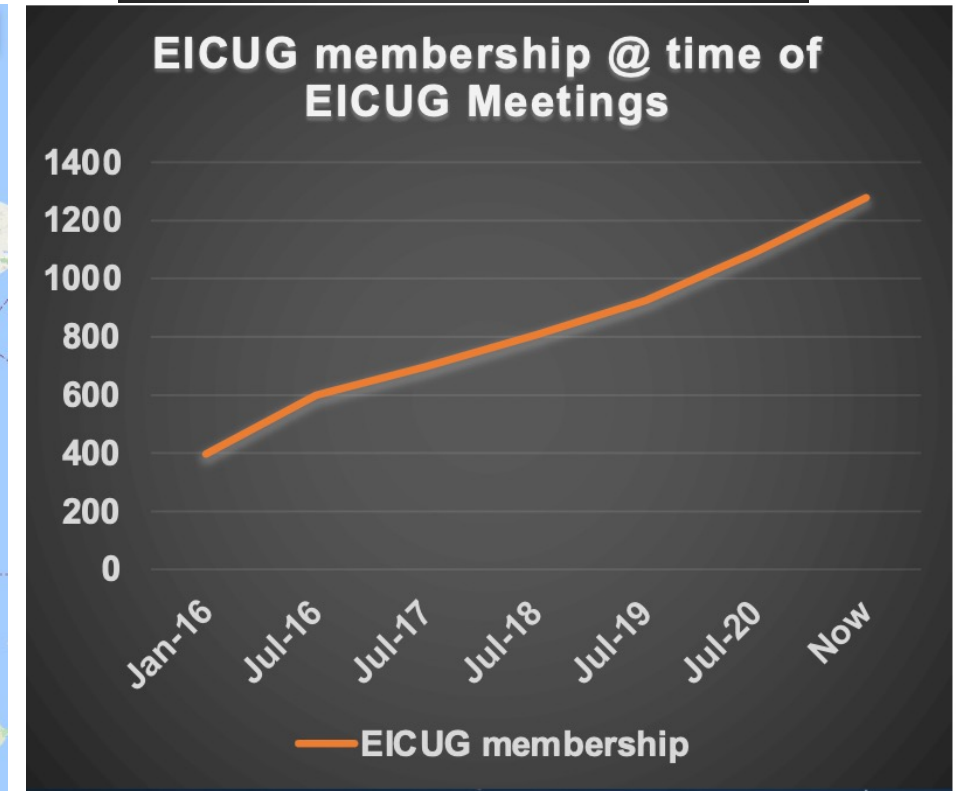
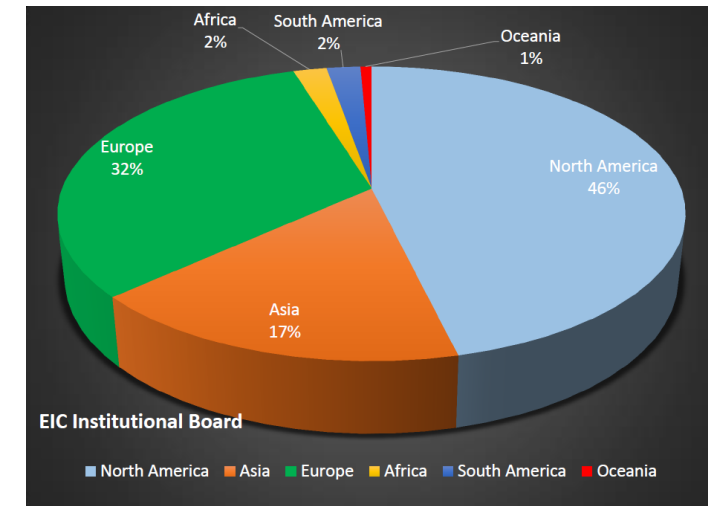


New systems include:

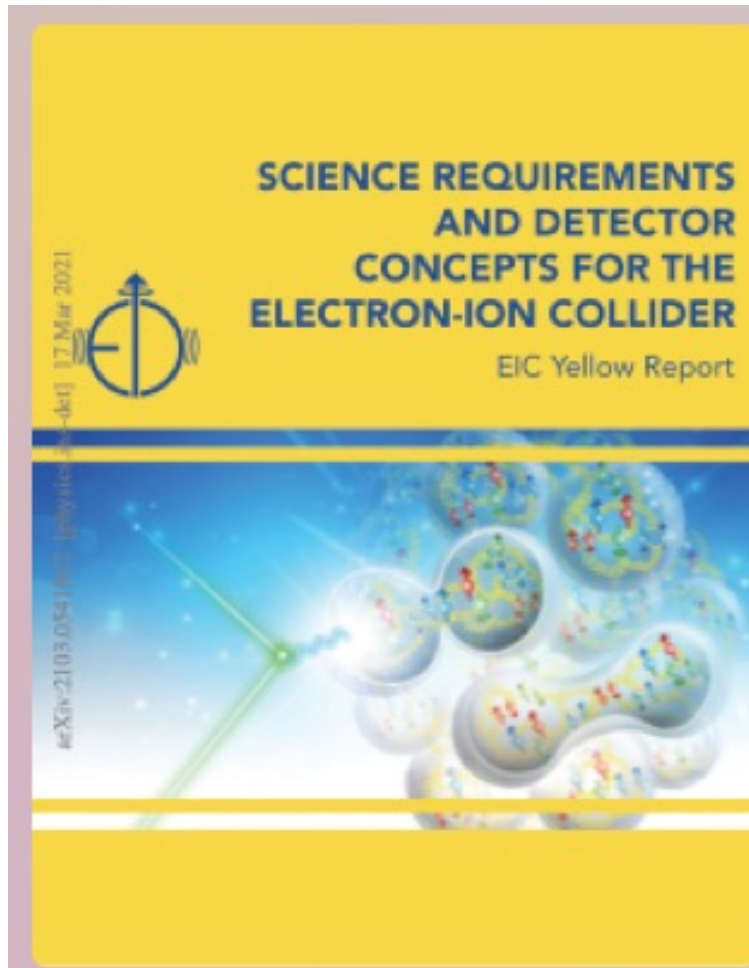
- Polarized electron source,
- Injector linac,
- Electron cooler complex,
- Rapid Cycling Synchrotron(RCS),
- Electron storage ring (ESR),
- **Interaction region (IR) with 1 detector**
- Capability for implementing 2 IRs
- Infrastructure improvements.

The Global EIC Users Group: EICUG.ORG

Formally established in 2016, now we have:
~1350 Ph.D. Members from ~36 countries, 266 institutions
EICUG is continuously growing
with world-wide participation

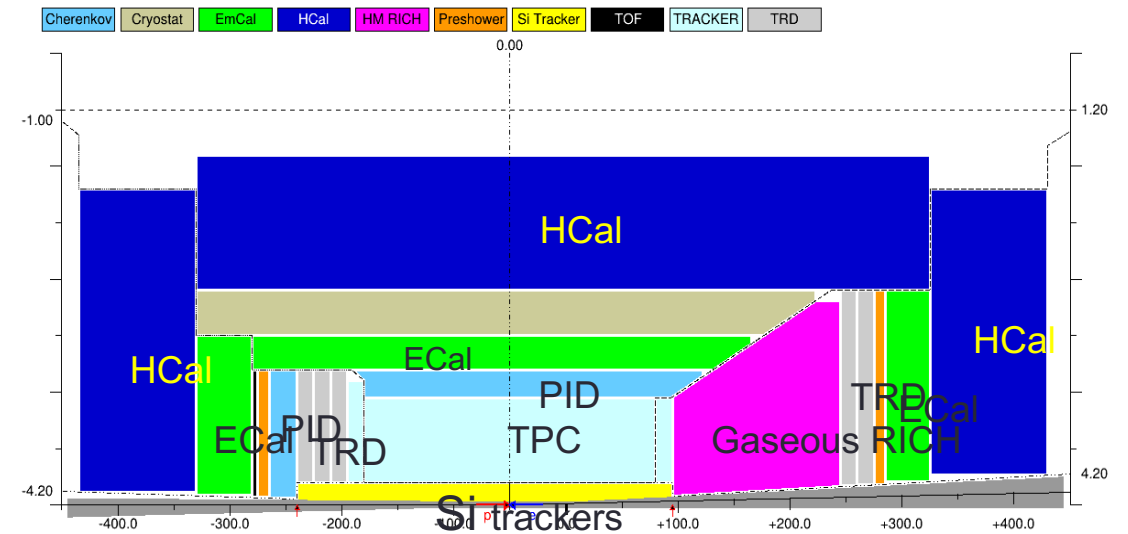
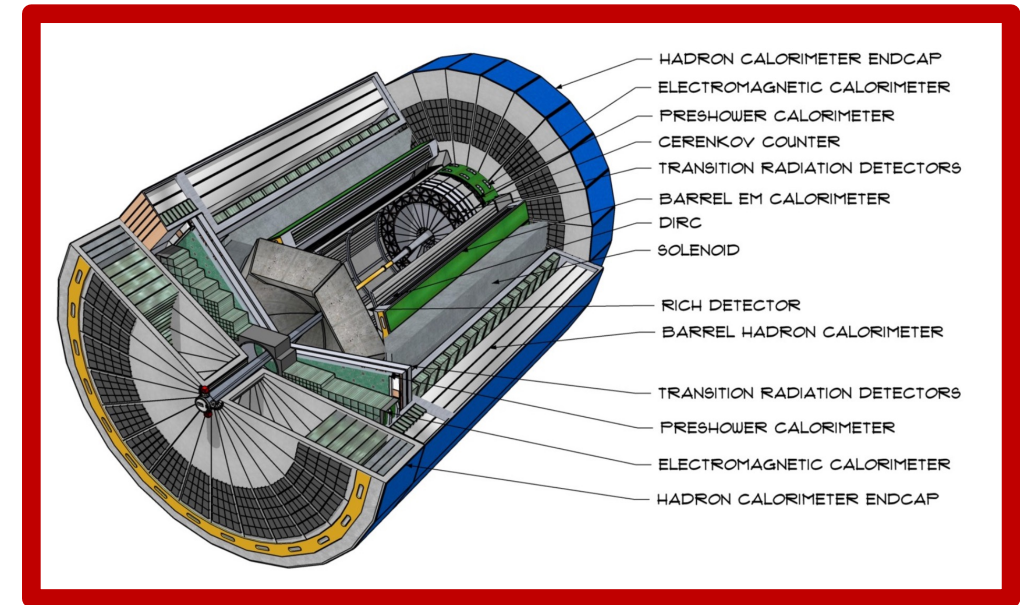


EICUG led “reference” detector design 2019-2021 “Yellow Report”



902 pages
415 authors
151 institutions

120 MB

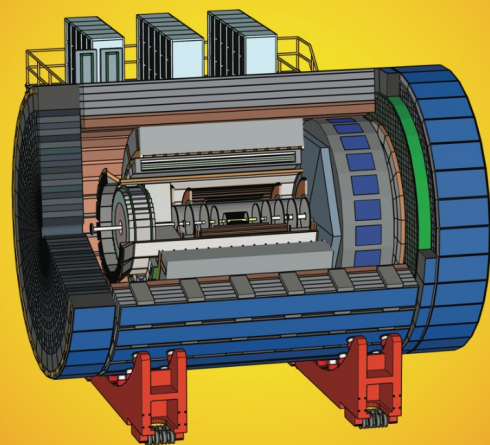


The three proposals: reviewed by an external panel

EIC Advisory Panel's recommendation on April 8, 2022

ATHENA Detector Proposal

A Totally Hermetic
Electron Nucleus Apparatus
proposed for IP6 at the Electron-Ion Collider



The ATHENA Collaboration
December 1, 2021

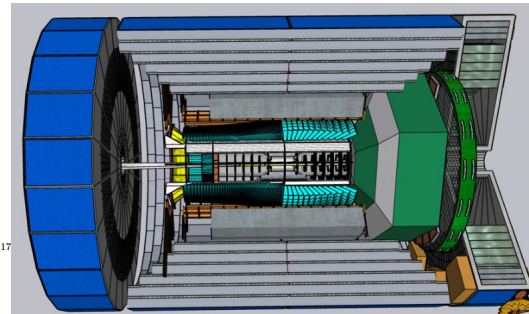
CORE - a COMPact detectoR for the EIC

R. Alarcon,¹ M. Baker,² V. Baturin,³ P. Brindza,³ S. Bueltmann,² M. Bukhari,⁴
R. Capobianco,⁵ E. Christy,² S. Diehl,^{5,6} M. Dugger,¹ R. Dupré,⁷ R. Dzhygadlo,⁸
K. Flood,⁹ K. Gnanvo,² L. Guo,¹⁰ T. Hayward,⁵ M. Hattawy,³ M. Hoballah,⁷
M. Hohlmann,¹¹ C. E. Hyde,¹² Y. Ilieva,¹² W. W. Jacobs,¹³ K. Joo,⁵ G. Kalicy,¹⁴
A. Kim,⁵ V. Kubarovsky,² A. Lehmann,¹⁵ W. Li,¹⁶ D. Marchand,⁷ H. Marukyan,¹⁷
M. J. Murray,¹⁸ H. E. Montgomery,² V. Morozov,¹⁹ I. Mostafaezhad,⁹
A. Movsisyan,¹⁷ E. Munevar,²⁰ C. Muñoz Camacho,⁷ P. Nadel-Turonski,¹⁶
S. Nicolai,⁷ K. Peters,⁸ A. Prokudin,^{2,21} J. Richards,⁵ B. G. Ritchie,¹ U. Shrestha,⁵
B. Schmookler,¹⁰ G. Schnell,²² C. Schwarz,⁸ J. Schwenning,⁸ P. Schweitzer,⁵
P. Simmerling,⁵ H. Szumila-Vance,² S. Tripathi,²³ N. Trotta,⁵ G. Varner,²³
A. Vossen,²⁴ E. Voutier,⁷ N. Wickramaarachchi,¹⁴ and N. Zachariou²⁵

¹Arizona State University, Tempe Arizona 85287

²Thomas Jefferson National Accelerator Laboratory, Newport News VA 23606

³Old Dominion University, Norfolk Virginia 92599



²¹Penn State University Berks, Reading Pennsylvania 19610

²²University of the Basque Country UPV/EHU & Ikerbasque, Bilbao, Spain

²³University of Hawaii, Honolulu Hawaii 96822

²⁴Duke University, Durham North Carolina 27708

²⁵University of York, Heslington, York, YO10 5DD, UK

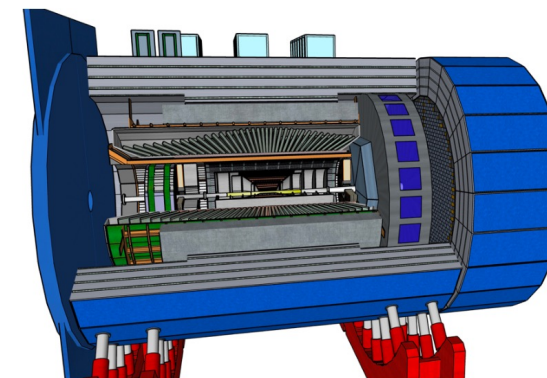
(Dated: December 1, 2021)

^a chyde@odu.edu

^b turonski@jlab.org



EIC Comprehensive Chromodynamics Experiment
Collaboration Detector Proposal



A state of the art detector capable of fully exploiting the science potential of the EIC, realized through the reuse of select instrumentation and infrastructure, to be ready by project CD-4A

December 1, 2021

Detector Proposal Advisory Panel →

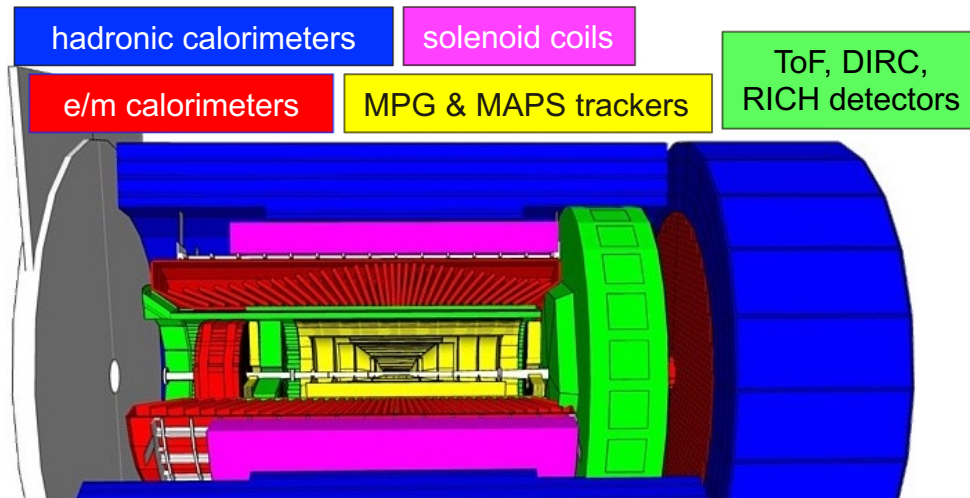
All three proposals received high marks & concluded that both ATHENA and ECCE satisfied the requirements

Recommended ECCE as the “reference detector”: lower risk and cost

- ATHENA, ECCE – collaborator overlap – neither large enough to become Detector 1
- Strongly encouraged the proto-collaborations to merge and build the **Project Detector** starting from ECCE’s reference design

As of July 2022: (ATHENA + ECCE) : Electron Proton Ion Collider (**EPIC**) Detector Collaboration formed → working together to realize the EIC science → Dec.12, 2022, EPIC Charter was approved → elections will be held soon.

DPAP: Enthusiastically supported the idea of a **second detector for the 2nd IR**

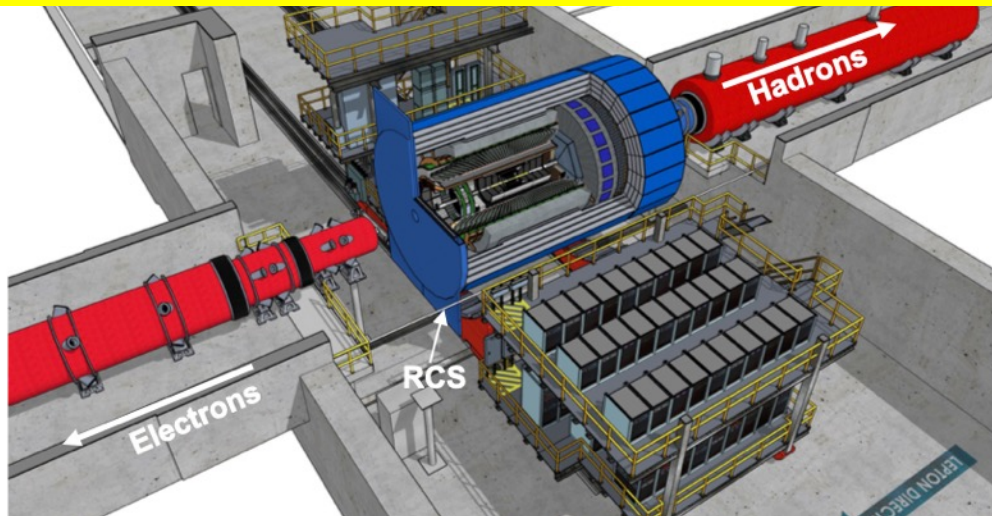


EIC Management team working with the EICUG to realize EPIC

Detector requirements:

- ❑ Large rapidity ($-4 < \eta < 4$) coverage; and far beyond
 - Large acceptance for diffraction, tagging, neutrons from nuclear breakup: critical for physics program
 - Integration into IR from the beginning critical

December 12, 2022: EPIC Charter was Approved
A detector collaboration has been formed



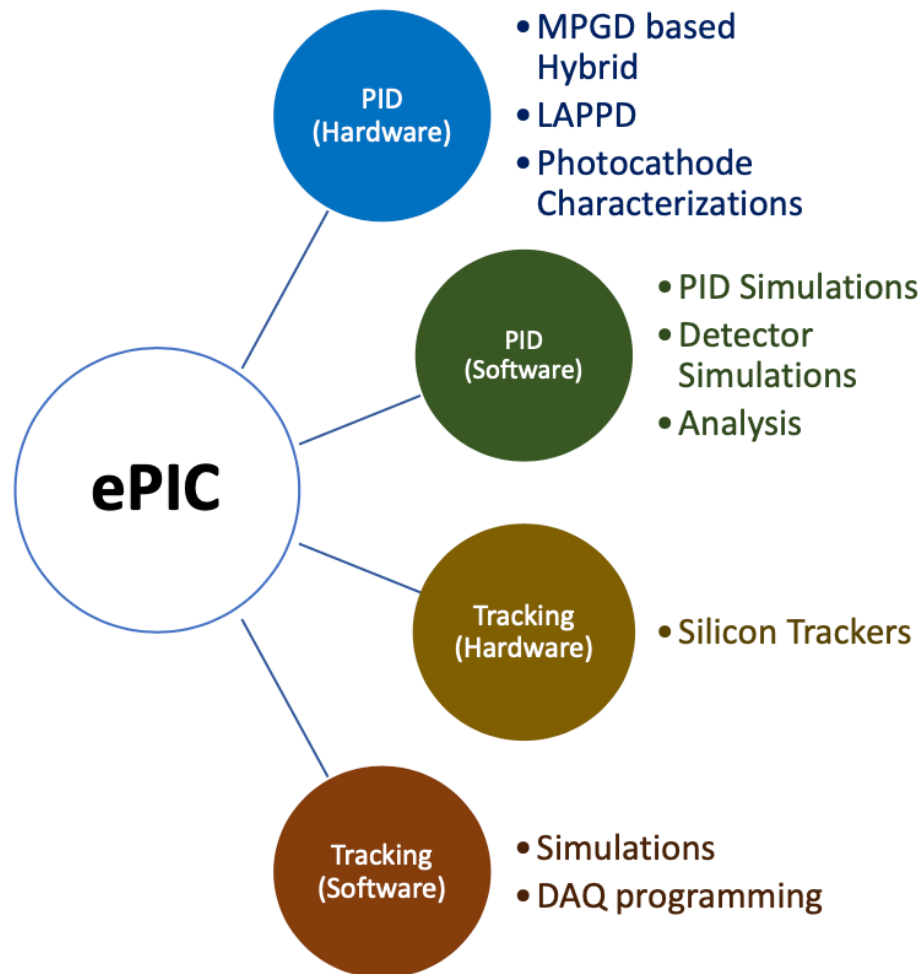
- ❑ Electromagnetic and Hadronic Calorimetry
 - equal coverage of tracking and EM-calorimetry
- ❑ High performance PID to separate e , π , K , p on track level
 - good e/h separation critical for scattered electron ID
- ❑ Maximum scientific flexibility
 - Streaming DAQ → integrating AI/ML
- ❑ Excellent control of systematics
 - luminosity monitor, electron & hadron Polarimetry

The Indian context and potential impact:

Slowly, steadily but assuredly, the Indian interest & involvement in the EIC related activities has grown.

Started with theory (Asmita M., Rohini G.) and lattice QCD (Nilmani M.) and now a strong young group of experimentalists (many in this audience) led & organized with the help from Bedanga M. et al.

Indian Interests in EPIC:



U. Of Goa, Panjab B., MNIT and RMRCK

- TRK, MPGD/TRK, MPGD/PID
- Tracker and PID

NISER & BHU

- Laboratory for Photon Detection
 - Installing & enhancing photon detection
 - Collaborate on photocathode coating and characterization
 - New scientists hired at NISER

NISER:

- Silicon Lab. Initiative: scientists, engineers
- Current effort on ALICE → EPIC

ATHENA did not get selected should NOT affect you or any one of us interested in the EIC

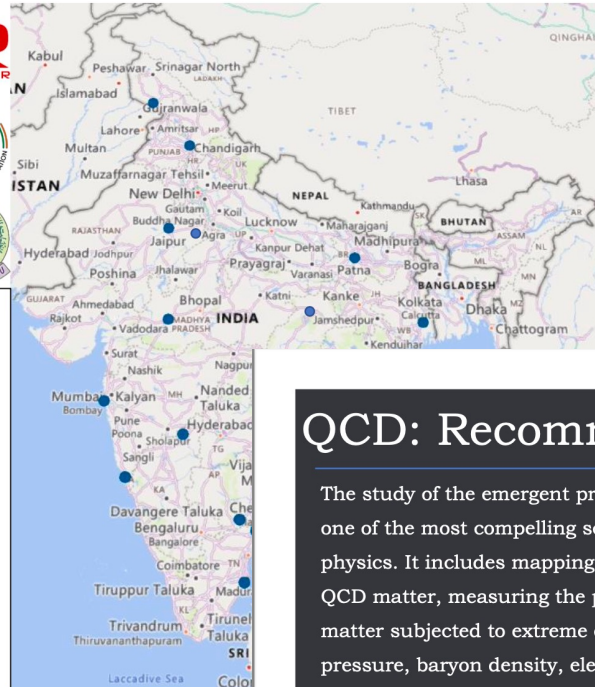
Indian Scientific interests – I assume – are the same, so we are here to see how best to incorporate all your interests, passions, and resources in to the EIC project – including EPIC detector.

THIS IS MEETING IS ABOUT HOW
BEST TO DO THIS

Indian Institutes interested in EIC



- 18 Institutes from all around India have shown interest.
- Interests in Software as well as in hardware activities.
 - Vertex tracking detectors and PID detectors.
 - Physics simulations related to the above detector systems, dominantly related to heavy flavor production.
 - Detector Simulation.



04-11-2022

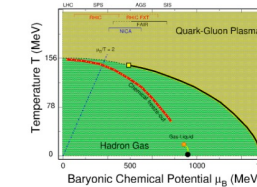
Dr. S. S. Dasgupta, NISER, Bhubaneswar

Indian long-range plan – Mega Science Vision 2035 – Nuclear Physics

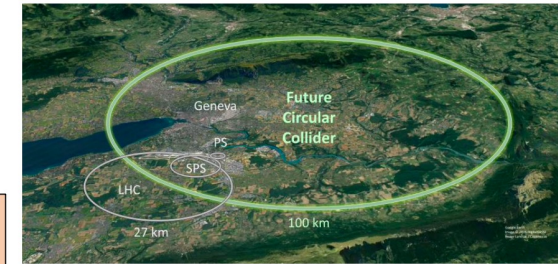
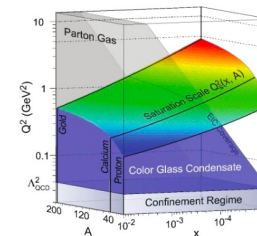
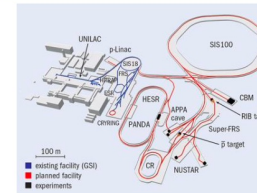
QCD: Recommendations

The study of the emergent properties of QCD matter is one of the most compelling science problems in nuclear physics. It includes mapping the phase diagram of the QCD matter subjected to extreme conditions of temperature, pressure, baryon density, electromagnetic fields and angular momentum, finding out the partonic content of a nucleus and the fundamental mechanisms behind the properties of nucleons, such as its mass and spin.

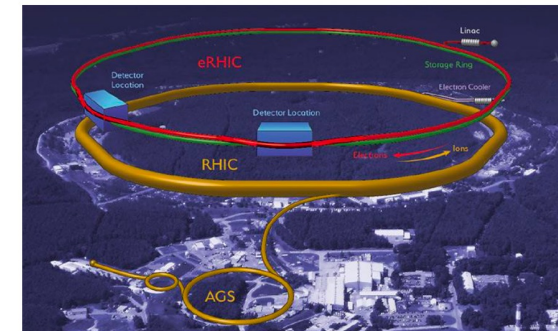
We recommend continued participation in heavy-ion programs at LHC, RHIC and FAIR, the collision energies of which, only when taken together, allow to map the QCD phase diagram. While the CBM experiment, which is under construction at FAIR, should be the focus for the high-energy nuclear collisions in the near future, we also recommend participation in the upcoming Electron-Ion Collider experiments to address the fundamental questions in nuclear physics.



What are the phase structures of Quantum Chromodynamic (QCD) matter?



How do the strong interactions amongst quarks and gluons inside the nucleons result in confinement and collectively result in their properties such as mass and spin?



How does a nucleus look in terms of its partonic content? Does the gluon density saturate to gluonic matter of universal properties?

My observation:

(Details n S. Datta's presentation in recent past and many private discussions)

EIC India willing to be involved in designing and commissioning the EPIC: Do whatever studies needed, with collaborators

Large trained community working in QCD that is willing to be re-oriented and focus on EIC.

Significant software expertise already super useful for EIC Users Group, ATHENA and ECCE proposals

Main hardware interest: Particle Identification (with technologies and experience gained in experimental involvements/collaborations) and (Si tracking).

Today, this week, and near future

- EIC Science and **Detector status/Opportunities** (Elke Aschenauer)
- **Details** of EIC-Indian interests: (Shuddha's Das)
- EIC-India's various **software contributions and potentials** (Markus Diefenthaler)
- A short window for discussion
- Discussion on **preparation of a document** to go to Govt. Of India for requesting funding for Indian activities. (B. Mohanty) → Lets try to get *specific*
- Continually enhance and support **Indian's theoretical interests** in the EIC

This week:

- We visit and re-visit all interests & issues (theory and experiment)
- Discussion in the context of the EPIC detector going forward
- Help each other any way we can to make both EPIC, EIC and EIC-India successful.