The Electron-Ion Collider Project

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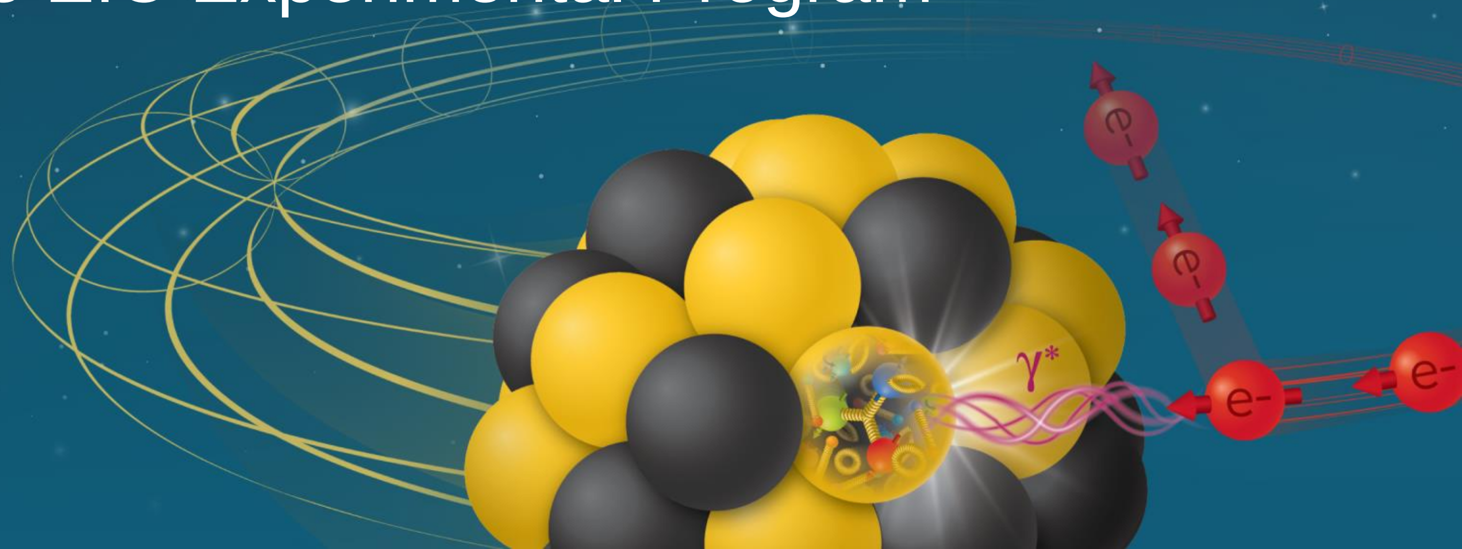
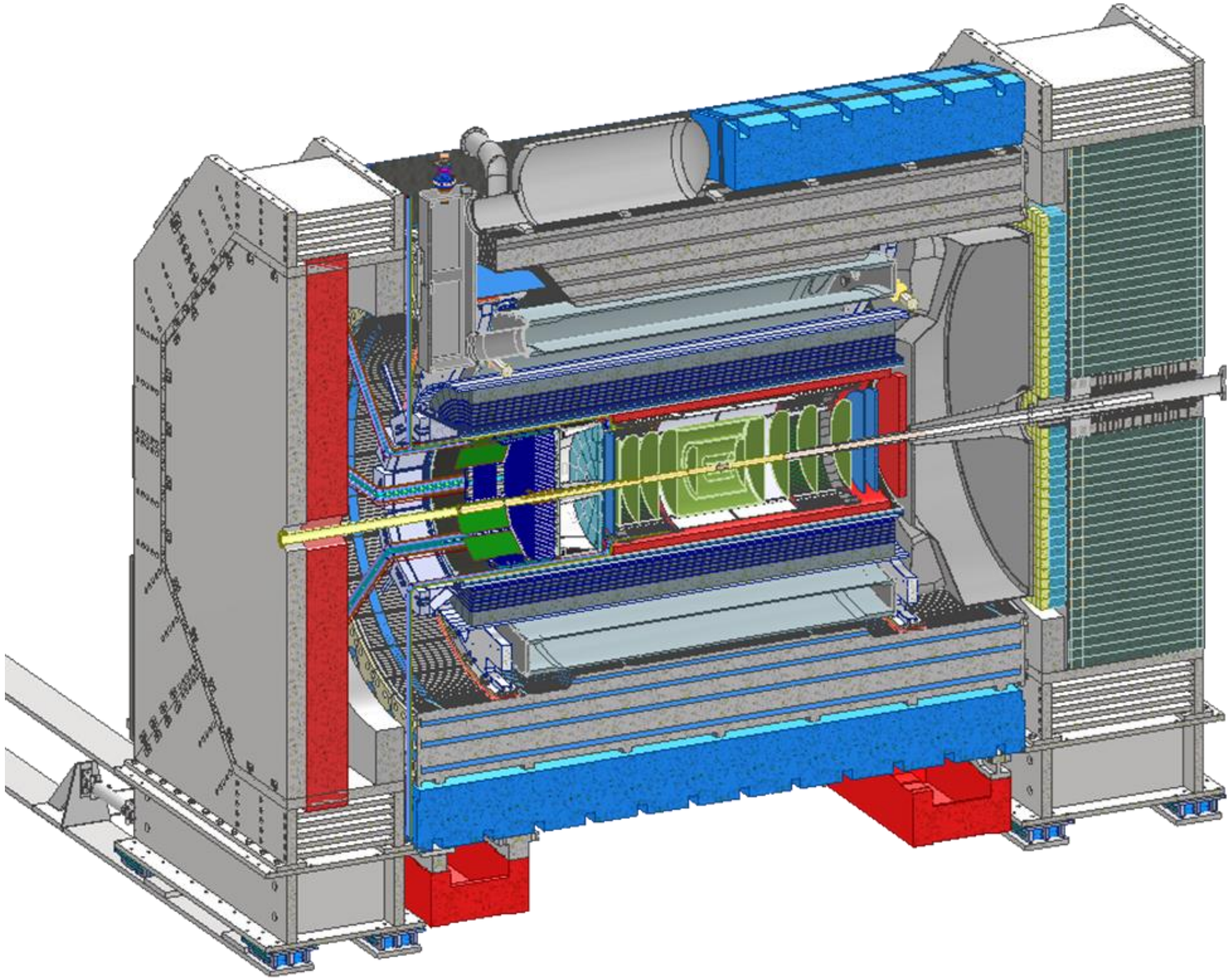
Co-Associate Directors for the EIC Experimental Program

EIC France 2024
IJCLab @ Orsay
October 9-11, 2024
Electron-Ion Collider

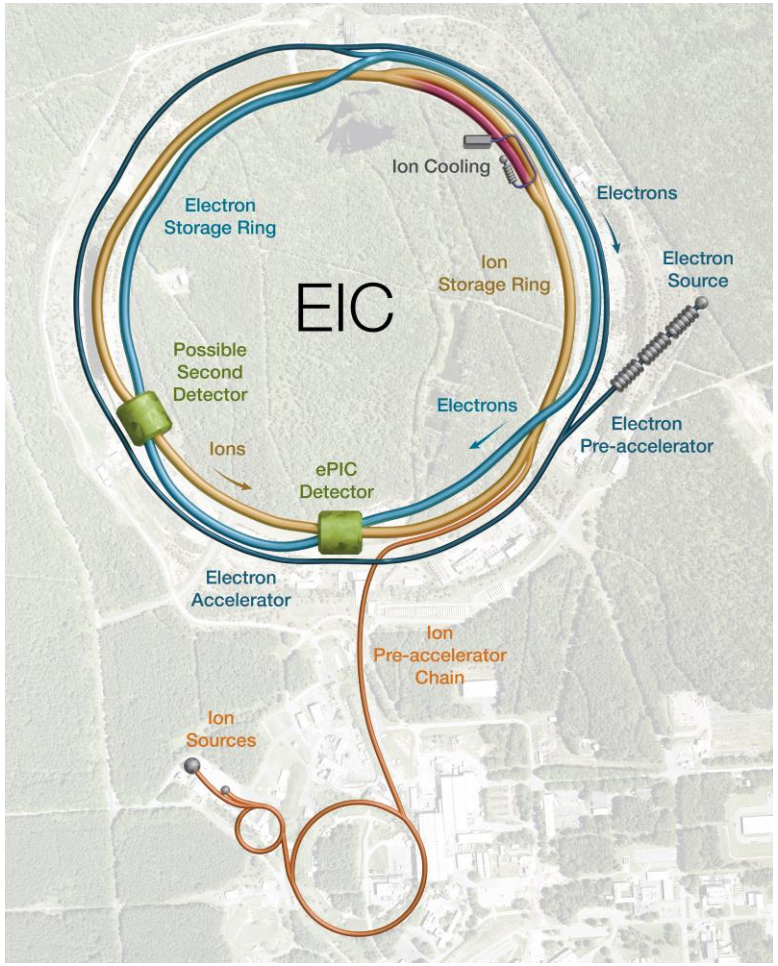


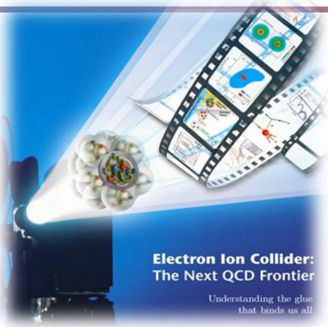
Outline

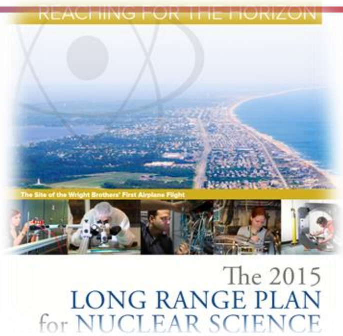
- The US-Based Electron-Ion Collider (EIC)
- EIC Project Status
  - Schedule
  - Accelerator Progress
  - Detector Progress
- The Project Organization and it's interface with the ePIC Collaboration
- The EIC: A Facility for the World
  - International Engagement
  - Cost and Expectations for In-Kind Contributions
  - Planned Contributions
- Summary

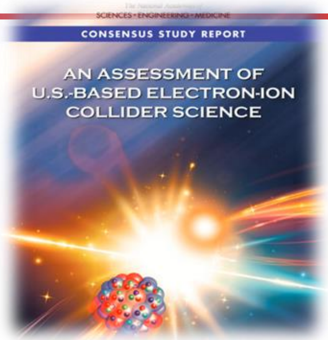


EIC Scope









Project Design Goals

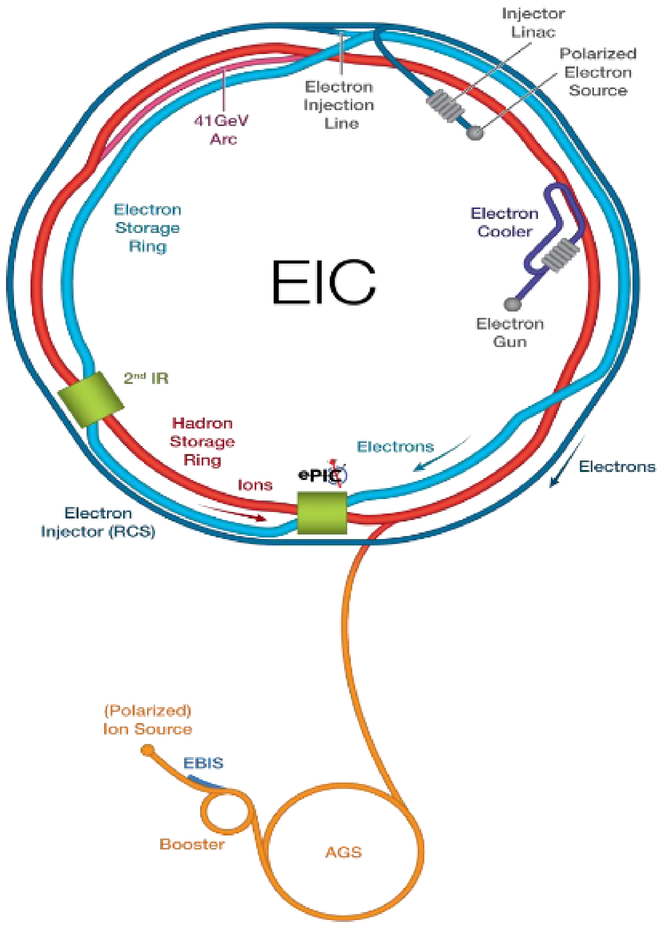
- High Luminosity: L= 10^{33} – 10^{34}cm^{-2}sec^{-1}, 10 – 100 fb^{-1}/year
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: E_{cm} = 29 – 140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Acceptance and Good Background Conditions
- Accommodate a Second Interaction Region (IR)

p/A beam → ← e beam

p: 41 GeV, 100 to 275 GeV **e: 5 GeV to 18 GeV**

From DOE/NP talk at NSAC Meeting September 8, 2024

Top Priority for New Facility Construction in the 2023 Long Range Plan: Expedient Completion of the Electron-Ion Collider

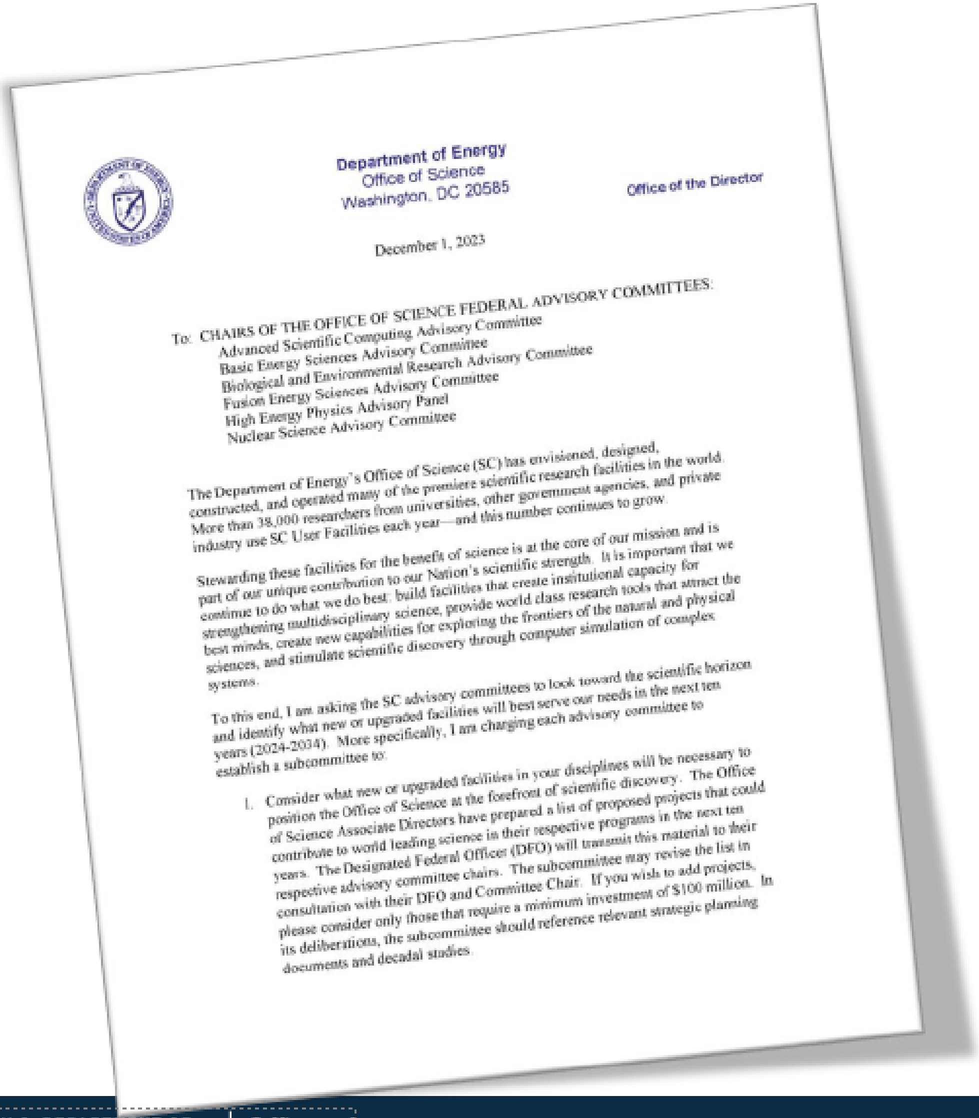


The EIC will be the most advanced accelerator in the world and the only new collider built for decades. It will maintain US leadership in accelerator physics.

Status:

- CD-3A approved March 2024
  - ~$90M in procurements to reduce technical risk
- Project continues to support preliminary engineering & design and execution of long lead procurements
- Pursuing additional long lead procurements (CD-3B) followed by CD-2

FY 2024: An Update to the Facility Plan to Advance U.S. Science & Innovation Leadership for the Next Decade+



Department of Energy
Office of Science
Washington, DC 20585

Office of the Director

December 1, 2023

To: CHAIRS OF THE OFFICE OF SCIENCE FEDERAL ADVISORY COMMITTEES:
Advanced Scientific Computing Advisory Committee
Basic Energy Sciences Advisory Committee
Biological and Environmental Research Advisory Committee
Fusion Energy Sciences Advisory Committee
High Energy Physics Advisory Panel
Nuclear Science Advisory Committee

The Department of Energy's Office of Science (SC) has envisioned, designed, constructed, and operated many of the premiere scientific research facilities in the world. More than 38,000 researchers from universities, other government agencies, and private industry use SC User Facilities each year—and this number continues to grow.

Stewarding these facilities for the benefit of science is at the core of our mission and is part of our unique contribution to our Nation's scientific strength. It is important that we continue to do what we do best: build facilities that create institutional capacity for strengthening multidisciplinary science, provide world class research tools that attract the best minds, create new capabilities for exploring the frontiers of the natural and physical sciences, and stimulate scientific discovery through computer simulation of complex systems.

To this end, I am asking the SC advisory committees to look toward the scientific horizon and identify what new or upgraded facilities will best serve our needs in the next ten years (2024-2034). More specifically, I am charging each advisory committee to establish a subcommittee to:

1. Consider what new or upgraded facilities in your disciplines will be necessary to position the Office of Science at the forefront of scientific discovery. The Office of Science Associate Directors have prepared a list of proposed projects that could contribute to world leading science in their respective programs in the next ten years. The Designated Federal Officer (DFO) will transmit this material to their respective advisory committee chairs. The subcommittee may revise the list in consultation with their DFO and Committee Chair. If you wish to add projects, please consider only those that require a minimum investment of $100 million. In its deliberations, the subcommittee should reference relevant strategic planning documents and decadal studies.

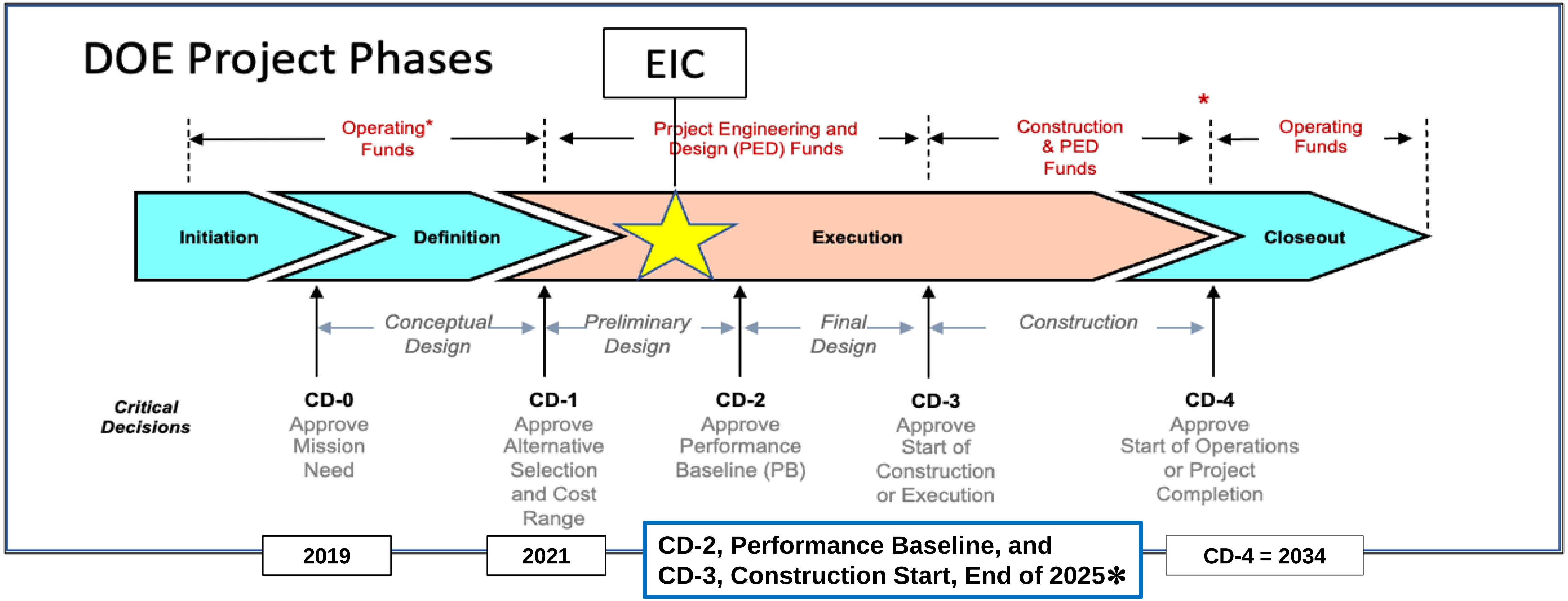
- SC Director Berhe charged each advisory committee to form subcommittee to assess list of future facilities from Associate Directors
- Assessment on:
  - The potential to contribute to world-leading science in the next decade.
  - The readiness for construction.
- Assessments completed in May 2024
- SC leadership will gather input and develop a prioritized strategy for facility investments for next decade

NSAC Facilities Charge Outcome

Major Nuclear Physics Facility	Scientific importance	Readiness for construction
Electron-Ion Collider (EIC)	(a) Absolutely central	(a) Ready to initiate
High Rigidity Spectrometer (HRS)	(b) Important	(a) Ready to initiate
Ton-scale Neutrinoless Double Beta Decay (TS-NLDBD)	(a) Absolutely central	(a) Ready to initiate
Project 8	(b) Important	(c) Mission and technical requirements not yet fully defined
FRIB Energy Upgrade (FRIB400)	(b) Important	(a) Ready to initiate
Solenoid Large Intensity Device (SoLID)	(b) Important	(a) Ready to initiate
EIC Detector II	(b) Important	(c) Mission and technical requirements not yet fully defined

- The importance of the science for each project as assessed by the Subcommittee was tied closely to the 2023 LRP
- In considering the readiness for construction the Subcommittee was guided by the current status of the project and remaining challenges, including the DOE critical decision level, if any.

DOE EIC Critical Decision Milestones & Risks



- **CD-3A, Long Lead Procurement, approved March 2024. Excellent use of IRA funding.**
- **CD-3B, Long Lead Procurement, approval planned for March 2025.**
- **CD-2, Project Performance Baseline, requires a more certain annual funding profile.**

✻ FY25 and FY26 funding will impact CD-2 and CD-3 milestone dates.

Schedule – what do the CD milestones mean?

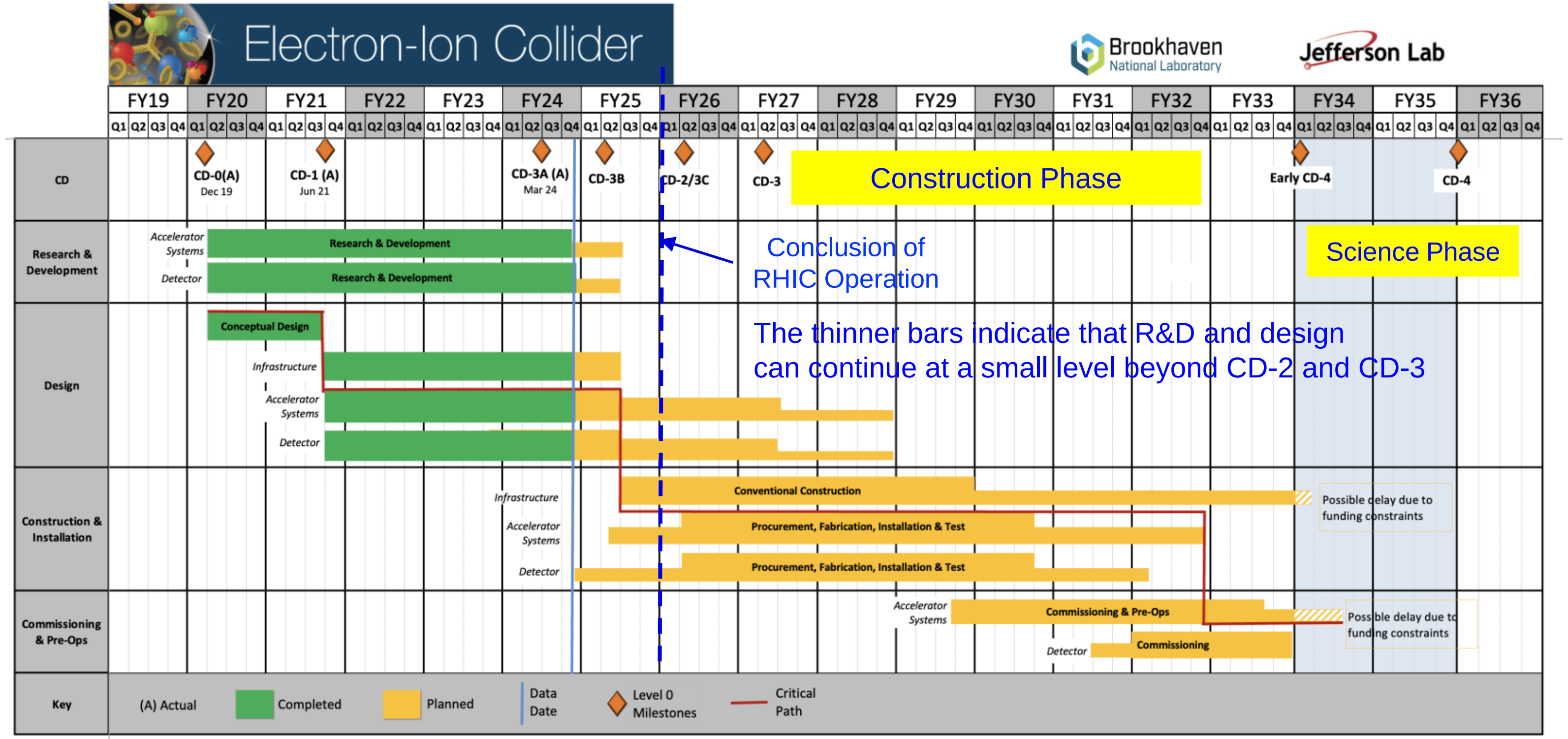
- **CD-0 – Approve mission need**: this documents that a scientific goal or a new capability, requiring material investment exists.
- **CD-1 – Approve Alternative Selection and Cost Range**: serves as a determination that the selected alternative and approach is optimized to meet the mission need defined at CD-0. What is perhaps most relevant is that CD-1 allows for release of Project Engineering and Design (PED) funds, which means the next phases of design of accelerator and detector can begin.
- **CD-2 – Approve Performance Baseline**: CD-2 is an approval of the preliminary design of the project and the baseline scope, cost, and schedule. What is most relevant is that CD-2 means there is now a definitive plan that the project will be measured against in cost, schedule and technical performance.
- **CD-3 – Approve Start of Construction**: CD-3 is an approval of the project's final design and authorizes release of funds for construction. What is most relevant is that projects can now proceed with construction related procurements and activities. CD-3 is sometimes split in CD-3A in a tailored approach to approve start construction for long-lead procurements.
- **CD-4 – Approve Start of Operations or Project Completion**: CD-4 provides recognition that the project's objectives have been met. CD-4 is sometimes split in CD-4A that allows, after agreed-upon criteria for technical success have been met, for transition into operations, and CD-4B that provides the formal closeout of the project.

EIC Schedule – best guess, dates still under discussion

CD-3A:
Approve start of long-lead procurements
CD-3A items passed final design review
All interfaces related to them are frozen
Authorization received March 28, 2024.

CD-2:
Approve prelim. design for all subdetectors
Design Maturity: >60%
Need "pre-"TDR (or draft TDR)
Baseline project in scope, cost, schedule

CD-3:
Approve final design for all subdetectors
Design Maturity: ~90%
Need full TDR



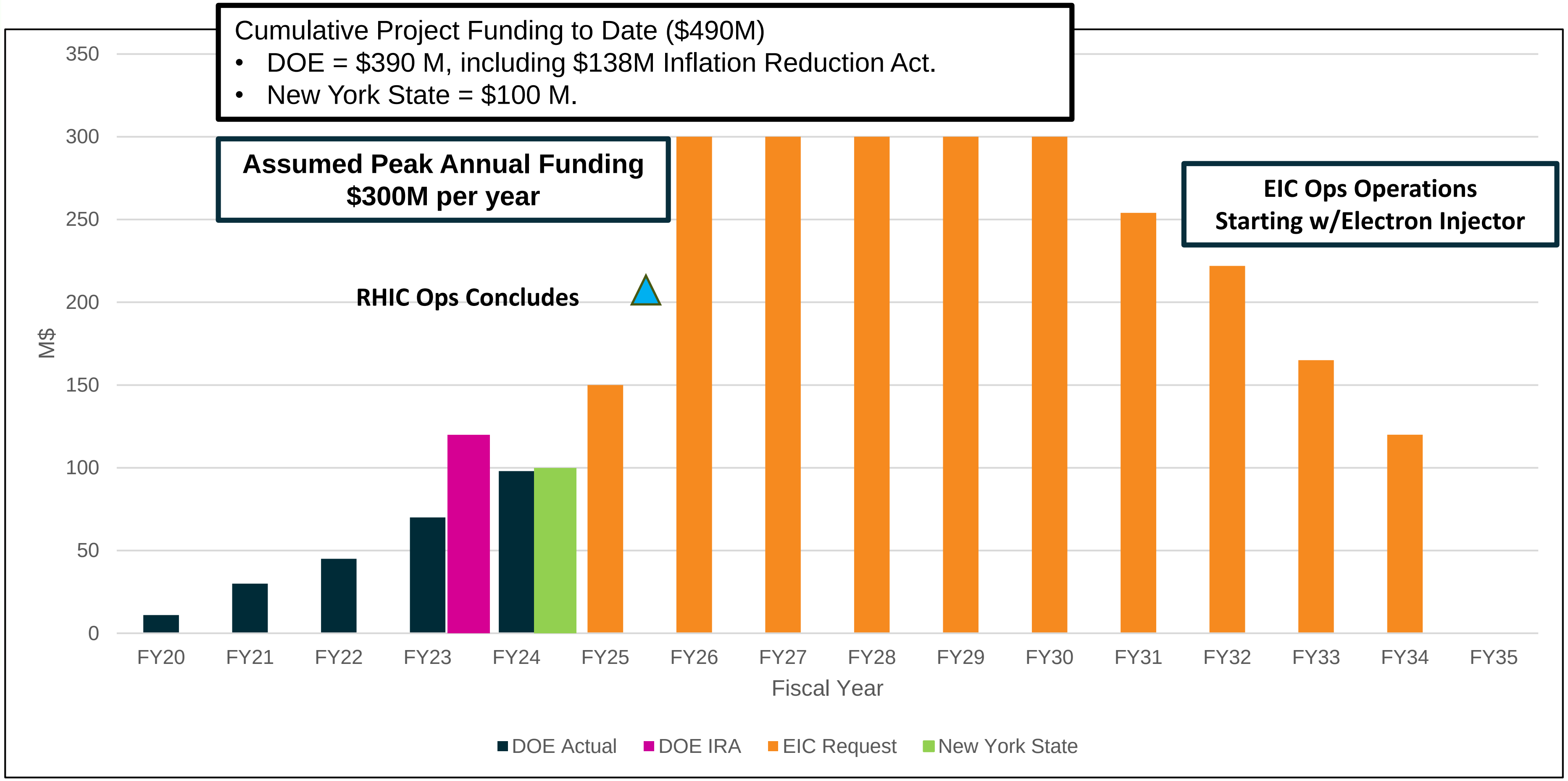
Past ("FY24") EIC Critical Decision Plan	
CD-0/Site Selection	December 2019 ✓
CD-1	June 2021 ✓
CD-3A	March 2024 ✓
CD-3B	**October 2024**
CD-2/3	**April 2025**
early CD-4	October 2032
CD-4	**October 2034**

September 2022 EIC received $138M DOE Inflation Reduction Act funding → CD-3A

Updated Project Schedule: based on the actual appropriated FY24 funding ($98M), on uncertain FY25 budget scenarios (President's Budget is ~$113M, house is ~$128M, senate is ~$138M, original EIC Project assumption was >$200M)

Updated EIC Critical Decision Plan	
CD-0/Site Selection	December 2019 ✓
CD-1	June 2021 ✓
CD-3A	March 2024 ✓
CD-3B Review	**January 7-9 2025**
CD-2/3C Review	End of 2025?
CD-3 Review	End of 2026?
early CD-4	December 2034?
CD-4	December 2036?

EIC Project Funding Plans (note that this corresponds roughly to phase-I of later)



FY2025 Funding TBD

EIC Plan: $150M
DOE Request: $113M
House: $128M
Senate: $138M

FY2026 Funding TBD

- RHIC operations concludes end of 2025.
- EIC project transitions to construction.
- Reduced RHIC operations funding maintains the injector complex and the removal/repurposing of equipment.

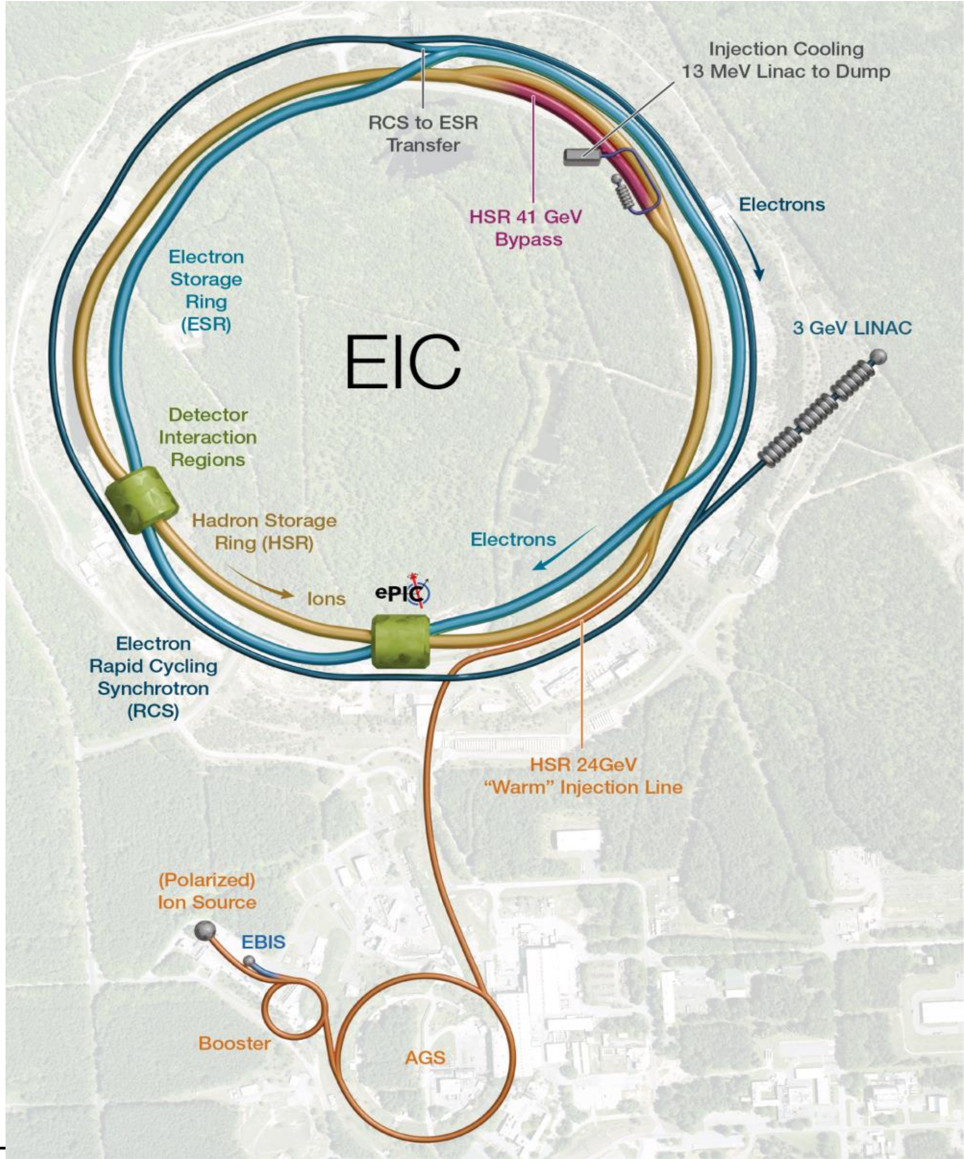
Annual Funding Plan Prior to FY25 PBR ($M)

FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	Total
11	30	183	70	98	150	300	300	300	300	300	254	222	165	120	2,803

Present EIC Accelerator Concept (Sep 2024)

Ultimate EIC Performance Parameters:

- High Luminosity: L= 10^{33} – 10^{34} $cm^{-2}sec^{-1}$
- Highly Polarized Beams: 70%
- Large Center of Mass Energy Range: Ecm = 28 – 140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Forward Acceptance and Good Background Conditions
- Possibility to Implement a Second Interaction Region (IR)



Accelerator Status at a glance:

- ✓ Polarized ion/proton source
- ✓ Ion injection and initial acceleration systems – Linac (200 MeV), Booster (1.5 GeV), AGS (25 GeV)
- UPGRADE Hadron Storage Ring (41, 100 - 275 GeV) – HSR
- NEW Electron Pre-Injector (3 GeV) – EPI
- NEW Electron Rapid Cycling Synchrotron (3 GeV – top energy) – RCS
- NEW Electron Storage Ring (5 GeV – 18 GeV) – ESR
- NEW Interaction Region(s) – IR
- NEW Strong Hadron Cooler System – SHC

Accelerator Highlight – APS magnets

- Repurposing APS magnets for EIC ESR ring
  - APS consisted of:
    - 400 quadrupoles [blue], plus a few spares
    - 280 sextupoles [yellow], plus a few spares
    - (318 dual-plane correctors –not useful for EIC)
    - (80 dipoles [red] – not useful for ESR, maybe transfer lines)
    - Recycling beam position monitors (TBD is usable in EIC)
  - ESR needs:
    - ~400 quadrupoles
    - ~320 sextupoles
    - ~400 single-plane correctors
    - ~700 dipoles

Accelerator Highlight – Electron Injector

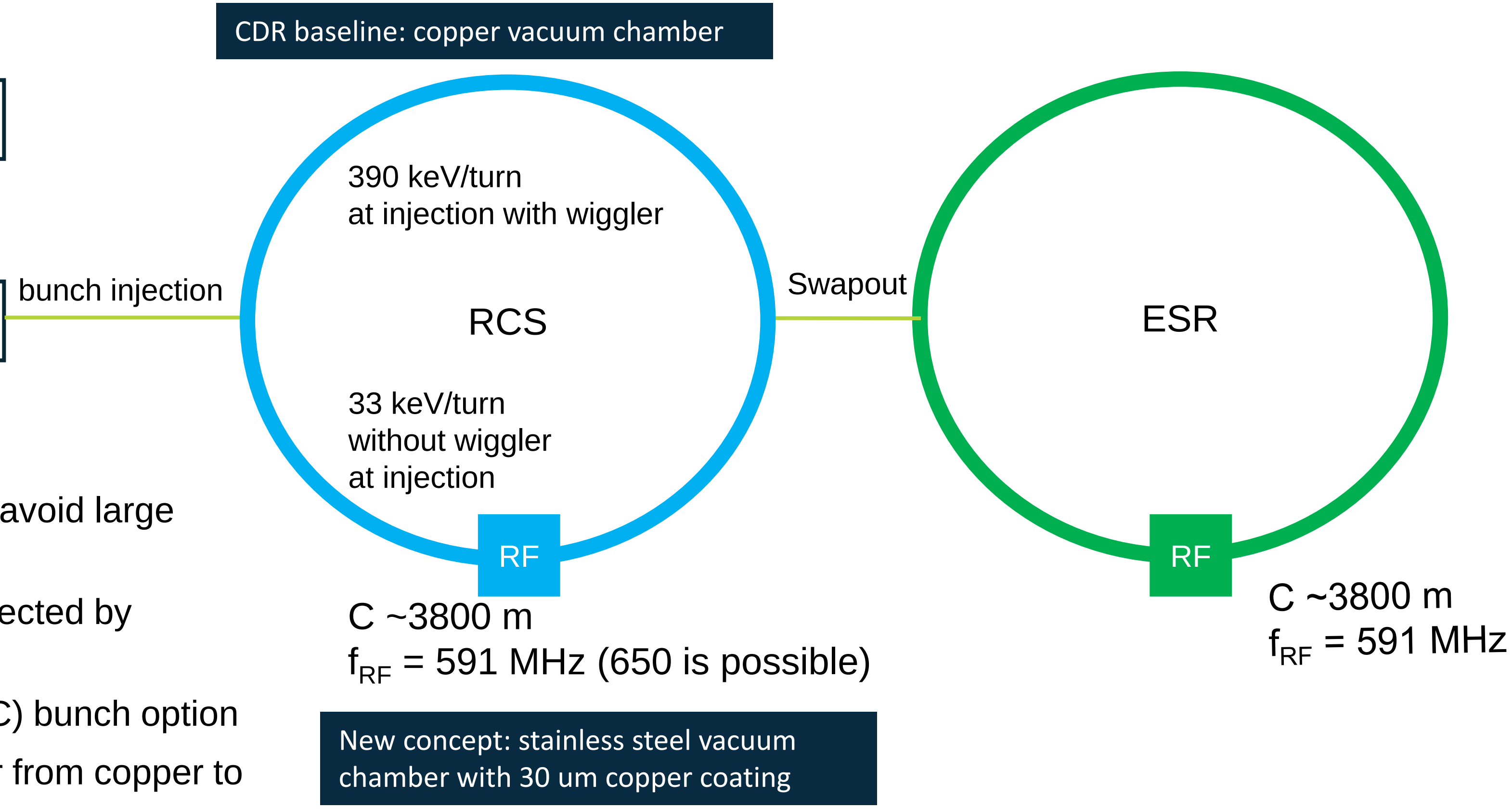
CDR baseline

400 MeV linac @ 2.8 GHz Normal conducting RF

↓

New Concept

3 GeV linac @ 1.3 GHz Superconducting RF



Improvements from baseline

- Increased RCS dipole field from 56 G to 400 G to avoid large magnetic field error at below 200 G.
- Increased RCS injection energy to avoid beam affected by ambient magnetic field from RHIC tunnel .
- Lower linac frequency to open high charge (>10nC) bunch option
- Lower eddy current by changing vacuum chamber from copper to stainless steel with copper coating
- Change accumulation scheme to avoid large bunch charge single bunch injection
- Add spin rotation option at low energy

ePIC Central Detector

Magnet

- New 1.7 T SC solenoid, 2.8 m bore diameter

Tracking

- Si Vertex Tracker MAPS wafer-level stitched sensors (ALICE ITS3)
- Si Tracker MAPS barrel and disks
- Gaseous tracker: MPGDs (μRWELL, MMG) cylindrical and planar

PID

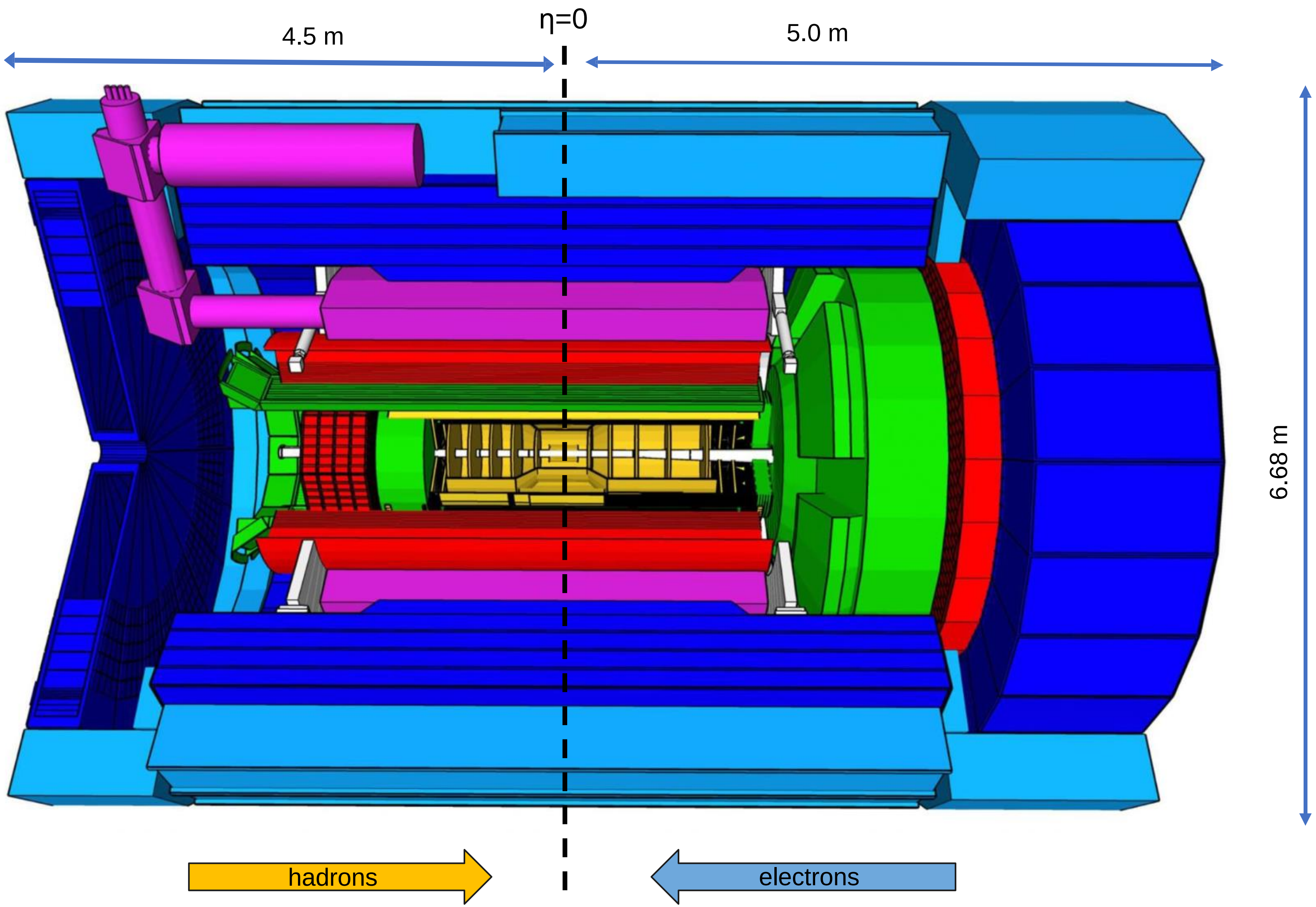
- high performance DIRC (hpDIRC)
- dual RICH (aerogel + gas) (forward)
- proximity focussing RICH (backward)
- ToF using AC-LGAD (barrel+forward)

EM Calorimetry

- imaging EMCal (barrel)
- W-powder/SciFi (forward)
- $PbWO_4$ crystals (backward)

Hadron calorimetry

- FeSc (barrel, re-used from sPHENIX)
- Steel/Scint – W/Scint (backward/forward)

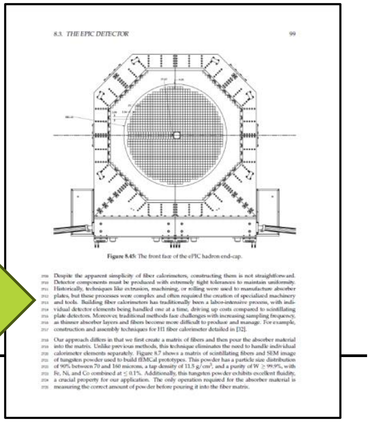


Experimental Program Progress Since CD-1

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
2022	Decision on Project Detector – baseline “ECCE”	March 2022
	Process to consolidate ECCE & ATHENA to the EIC Project Detector	Spring 2022
	ePIC Collaboration Formed – 160 institutions	July 2022
2023	ePIC Charter ratified & elected Leadership Team	February 2023
	1st Resource Review Board Meeting	April 2023
	ePIC (Central) Detector remaining technology choices made	April 2023
2024	ePIC Detector technical baselined	February 2024
	Introduction of early physics planning to ePIC Collaboration	July 2024
	Started drafting Preliminary Design Report	July 2024

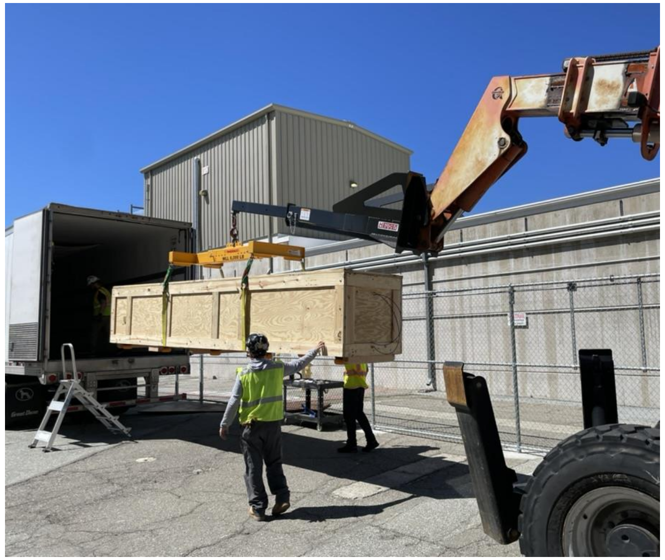
[&]Remains ongoing until formal agreements are in place – it originally led to confirmation that in-kind level assumed for the EIC detector was in range.

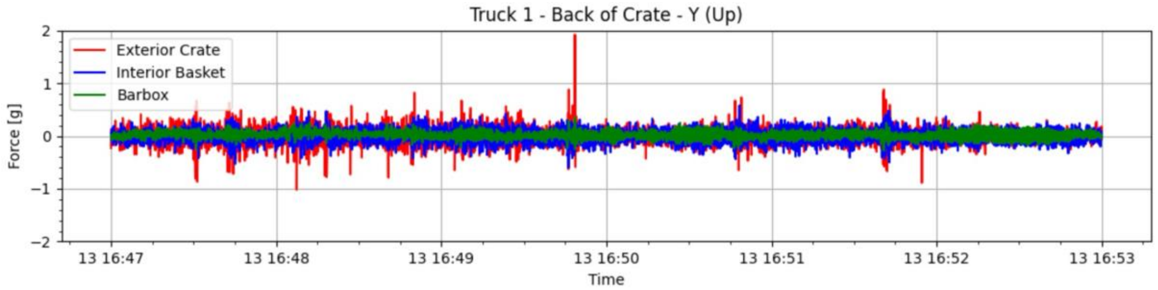
Note that the host labs also separately organized ePIC computing and software reviews in Fall 2022. 2023, and 2024.



Recent Detector Highlight

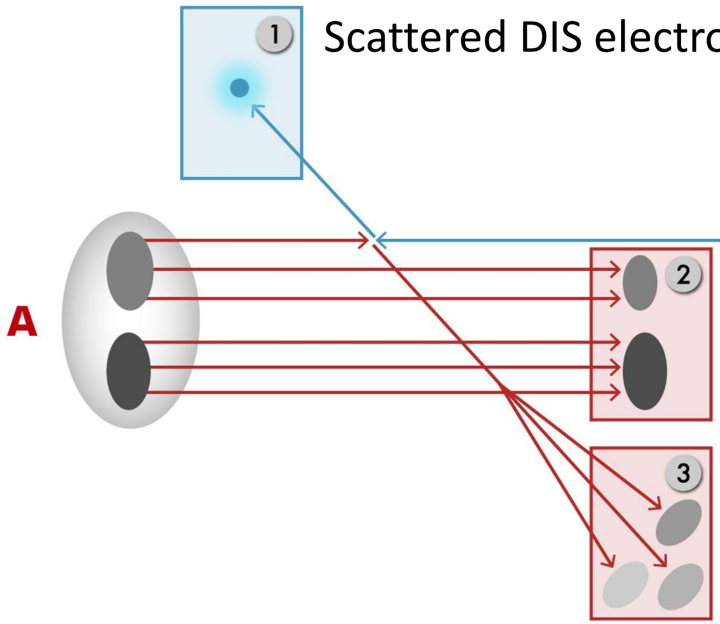
- Moved final eight ex-BABAR DIRC bar boxes from SLAC to JLab
  - Planning for this started in 2018 after successful transport of four DIRC bar boxes for use in Hall D/GlueX detector.
  - Due to SLAC safety stand downs, long COVID interruption, SLAC management and personnel transitions: 5+ years of planning…
  - The remaining eight DIRC bar boxes safely arrived at Jefferson Lab in April 2024. Shocks during trip successfully reduced to <0.5g.
  - Plan is to disassemble (unglue) DIRC bars, perform optical quality assurance, and if found okay reuse for ePIC detector, these can provide all required bars for the ePIC high-performance DIRC detector.

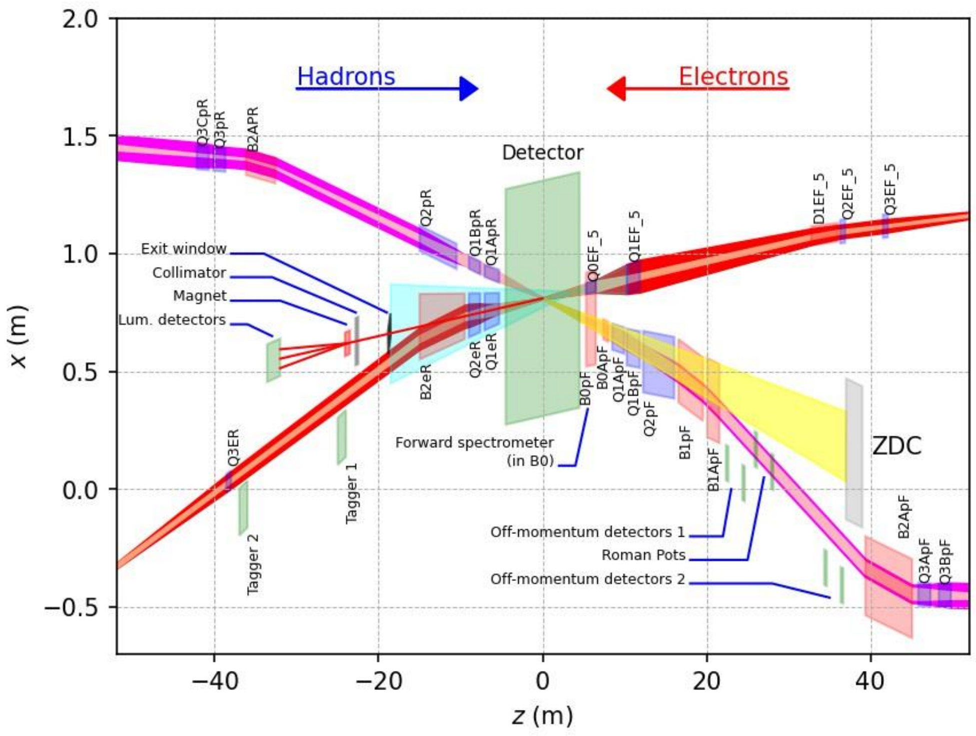




Maximizing the physics reach

The aim is to get **full acceptance** for all final state particles, and measure them with good resolution.





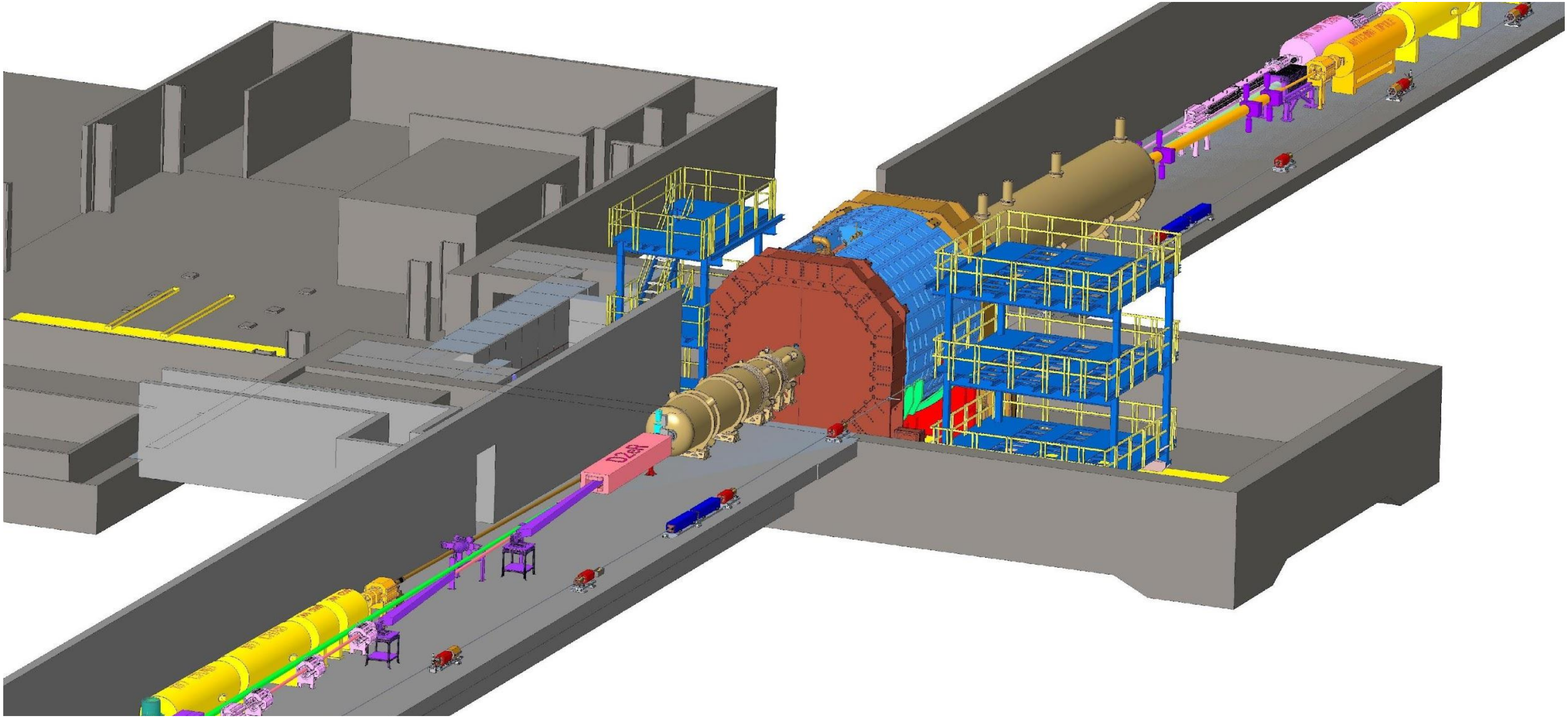
Experimental challenges:

- Beam elements limit forward acceptance.
- Central Solenoid not effective for forward.

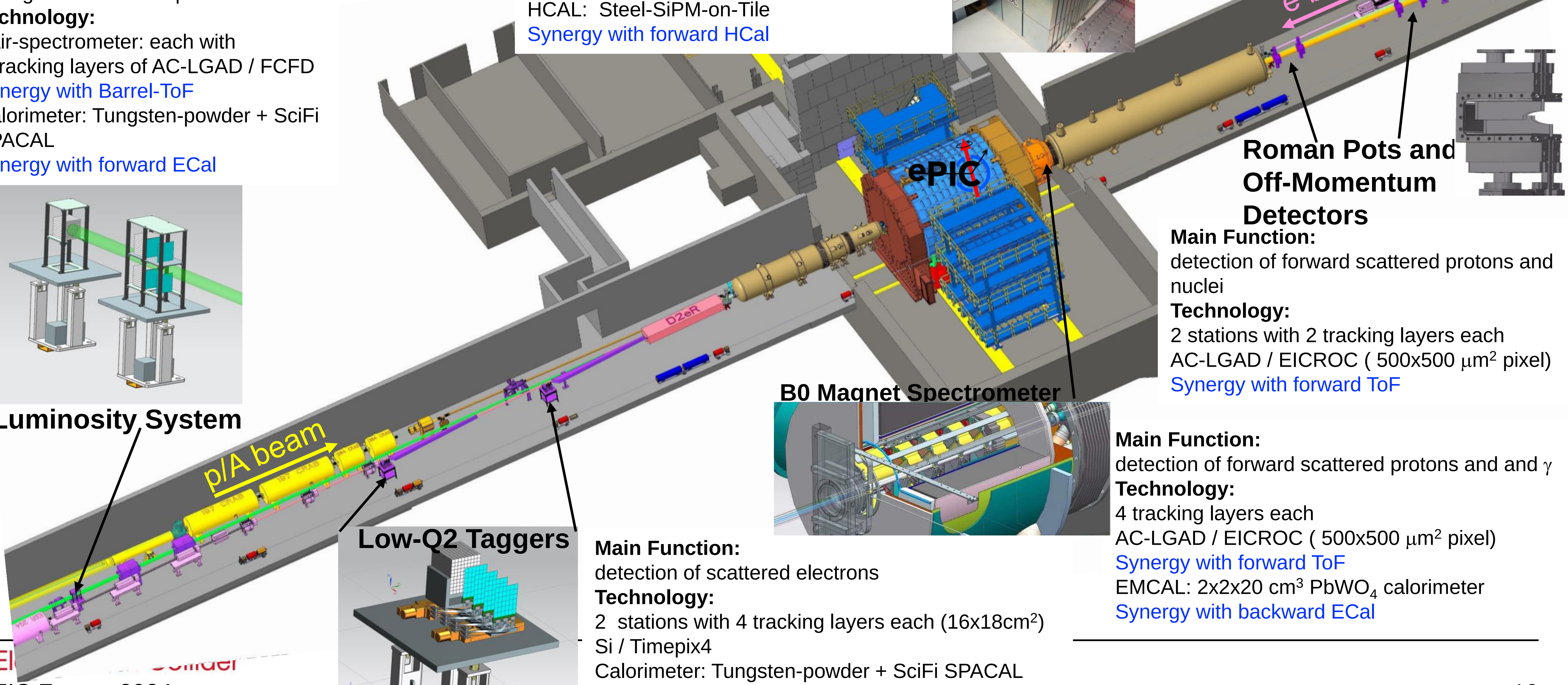
Possible to get close to full acceptance for the whole event:

- Beam crossing angle of 25mrad creates room for forward dipoles.
- Dipoles create space for detectors in the forward ion and electron direction and analyze the forward particles.

So the ePIC Detector is 90 Meters Long!



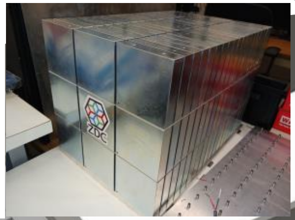
ePIC Far-Forward/Far-Backward Detectors



Luminosity System

Main Function:
measure bunch-by-bunch luminosity through Bethe-Heitler process
Technology:
Pair-spectrometer: each with
2 tracking layers of AC-LGAD / FCFD
Synergy with Barrel-ToF
Calorimeter: Tungsten-powder + SciFi SPACAL
Synergy with forward ECal

Zero Degree Calorimeter



Main Function:
detection of forward scattered neutrons and γ
Technology:
EMCAL: 2x2x20 cm^3 $PbWO_4$ calorimeter
Synergy with backward ECal
HCAL: Steel-SiPM-on-Tile
Synergy with forward HCal

Roman Pots and Off-Momentum Detectors

Main Function:
detection of forward scattered protons and nuclei
Technology:
2 stations with 2 tracking layers each
AC-LGAD / EICROC (500x500 μm^2 pixel)
Synergy with forward ToF

B0 Magnet Spectrometer

Main Function:
detection of forward scattered protons and and γ
Technology:
4 tracking layers each
AC-LGAD / EICROC (500x500 μm^2 pixel)
Synergy with forward ToF
EMCAL: 2x2x20 cm^3 $PbWO_4$ calorimeter
Synergy with backward ECal

Low-Q2 Taggers

Main Function:
detection of scattered electrons
Technology:
2 stations with 4 tracking layers each (16x18cm^2)
Si / Timepix4
Calorimeter: Tungsten-powder + SciFi SPACAL
Synergy with forward ECal

Detector Advisory Committee

DAC founded in 2020; Per the charter, 1/3 of the committee replaced every year

- This year: transition from Ed Kinney to Andy White as Chair

2020 - 2022

Edward Kinney	Boulder CO
Ewa Rondio	Warsaw
Werner Riegler	CERN
Greg Rakness	FNAL
Peter Krizan	U Ljubljana
Ana Amelia Machado	University of Campinas, Brazil
Heidi Schellman	Oregon State
Brigitte Vachon	McGill
Glenn Young	BNL
Etiennette Auffray	CERN
Andrew White	U. Texas Arlington
Chi Yang	SDU China

2023

Edward Kinney (Chair)	Boulder CO
Ken Wyllie	CERN
Petra Merkel	FNAL
Antonis Papanestis	Rutherford Appleton Laboratory
Peter Krizan	U Ljubljana
Ana Amelia Machado	University of Campinas, Brazil
Heidi Schellman	Oregon State
Brigitte Vachon	McGill
Stefano Miscetti	INFN Frascati
Etiennette Auffray	CERN
Andrew White	U. Texas Arlington
Chi Yang	SDU China

2024

Edward Kinney	Boulder CO
Ken Wyllie	CERN
Petra Merkel	FNAL
Antonis Papanestis	Rutherford Appleton Laboratory
Peter Krizan	U Ljubljana
Ana Amelia Machado	University of Campinas, Brazil
Cecillia Gerber	UIC
Brigitte Vachon	McGill
Stefano Miscetti	INFN Frascati
Roman Poeschl	IJCLab
Andrew White (Chair)	U. Texas Arlington
Eraldo Oliveri	CERN

DAC-Meetings 2024/2025:

- June 21, 2024: 8th DAC meeting - strategic advice on the planning for the construction phase of the ePIC detector
  "Congratulations on enormous progress on developing realistic designs and starting active design review cycles on different systems"
- August 28-29, 2024: 9th DAC meeting - Annual advice on detector R&D status and FY25 completion needs
- Spring 2025: 10th DAC meeting - Comprehensive look of DAC to design status and readiness for CD-2.
  → Present concept is to spread this over separate days to ease DAC availability

Detector-Related Project Meetings from September 2023 to July 2024

- September 13: Final Design Review of the SciFi for bECal & fECal
  Reviewers: Pierluigi Campana (LNF), Caroline Riedl (UIUC)
- September 14: Final Design Review of the SiPMs for ECals, HCals & dRICH
  Reviewers: Elton Smith (retired JLab), Stepan Stepanyan (JLab)
- September 25: Final Design Review of the forward HCal W & Steel
  Reviewers: Jim Mills (BNL), Felix Sefkow (DESY)
- October 5 + 6: Final Design Review of Magnet (MARCO)
  Reviewers: Gianluca Sabbi (LBNL), Ruben Fair (JLab), Vladimir Kashikin (FNAL), Bill Schneider (retired JLab)
- October 10-12: DOE CD-3A Director's Review
  Detector Reviewers: Rik Yoshida (ANL), Gabriella Carini (BNL), Luciano Musa (CERN), Tim Whitlatch (JLab)
- November 14-16: DOE CD-3A Independent Project Review
  Detector Reviewers: Andy Lankford (UC Irvine), Dave Christian (FNAL)
- December 7 + 8: 2nd Resource Review Board meeting @ CUA, Washington
- February 14: Preliminary Design Review of Auxiliary Detectors
  Reviewers: Fulvia Pilat (ORNL), Gerrit Van Nieuwenhuizen (BNL), Wolfram Zeuner (CERN), Eugene Chudakov (JLab)
- March 20 + 21: Preliminary Design Review of Tracking Detectors
  Reviewers: Andy White (UTA), Michael Begel (BNL), Maxim Titov (CEA), David Lynn (BNL), Piotr Gasik (GSI)
- May 6 + 7: 3rd Resource Review Board meeting @ Roma, Italy
- May 28: Final Design Review of the Detector Magnet Power Supply
  Reviewers: Ju Wang (ANL), Onish Kumar (JLab), Howie Pfeffer (FNAL)
- June 10 + 11: Preliminary Design Review of the Electronics/DAQ Systems, Final Design Review of the VTRx+/lpGBT components
  Reviewers: Ken Wyllie (CERN), Filippo Costa (CERN), Prashansa Mukim (BNL), Mitch Newcomer (U Penn)
- June 21: 8th Detector Advisory Committee meeting
- July 15 Preliminary Design Review of Integration, Installation and Infrastructure (Central ePIC Detector)
  Reviewers: Jim Mills (BNL), Tim Whitlatch (JLab)

Note:
Members of the DAC are sometimes integrated in sub-system design reviews as they are subject matter experts.

On we go: ePIC Detector Path to CD-3B and to CD-2/3C

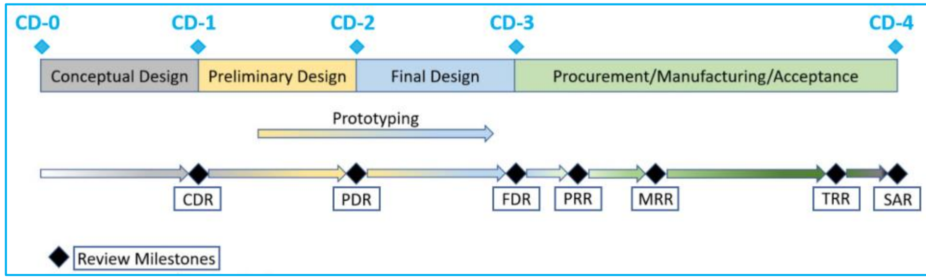
Detector Design Reviews (organized by the EIC Project):

- ✓ PDR2: IR Integration and Auxiliary Detectors – February 12, 2024 – main emphasis on baseline choices and progress
- ✓ PDR1: Tracking Detectors – 20-21 March 2024 – main emphasis on baseline tracking layout, if we are on track and plans
- ✓ PDR2: Electronics/DAQ – June 10 -11, 2024 – continuation of PDR1 to ensure we are on track and show progress
- ✓ PDR: Integration, Infrastructure and Installation – July 15, 2024 – barrel and endcaps flux return steel
- ✓ PDR2: Barrel EM Cal – **September 19th** – emphasis on mechanical design & AstroPix readiness
- ▪ PDR2: Particle Identification Detectors – **Winter** 2024/25 (late January or February 2025 for pfRICH/hpDIRC/dRICH, TOF later)
- ▪ **FDR:** Backward & Forward EM Calorimetry, Barrel & Forward HCAL – Fall 2024 → **Winter** 2024 (late January or February 2025)
- ▪ PDR2: Polarimetry – timescale TBD (but before CD-2)

FDR for any potential CD-3B scope:

- ✓ Magnet Power Supply – May 28th 2024
- ✓ VTRx+/lpGBT add ½ day to electronics/DAQ PDR2 on June 11th 2024
- ▪ Magnet Steel **October 16th 2024**

✓ BNL Off-Project Dependency review Experimental Program August 22-23, 2024



CDR = Conceptual Design Review
PDR = Preliminary Design Review
FDR = Final Design Review
PRR = Procurement Readiness Review
MRR = Manufacturing Readiness Review
TRR = Transport Readiness Review
SAR = System Acceptance Review

Detector Advisory Committee Meetings 2024/2025:

- ✓ June 21, 2024: 8th DAC meeting - strategic advice on the planning for the construction phase of the ePIC detector
- ✓ August 28-29, 2024: 9th DAC meeting - Annual advice on detector R&D status and FY25 completion needs

Spring 2025: 10th DAC meeting - Comprehensive look of DAC to design status and readiness for CD-2.

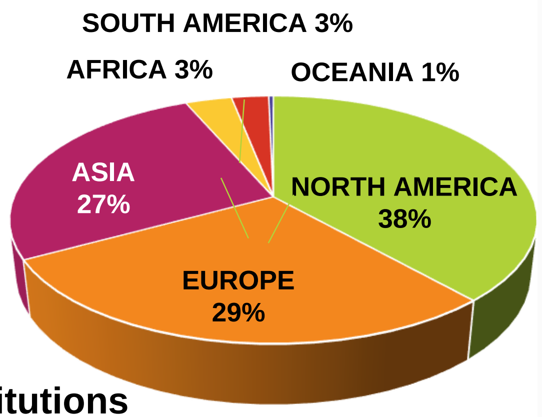
Software & Computing Reviews (organized by the host labs):

- ✓ ePIC Detector Software Infrastructure Review https://indico.bnl.gov/event/16676/ – August 22-23, 2022
- ✓ ePIC Software & Computing review by host labs https://indico.bnl.gov/event/20481/ – October 19-20, 2023
- ✓ ePIC Software & Computing review (by host labs) – **September 26-27, 2024**

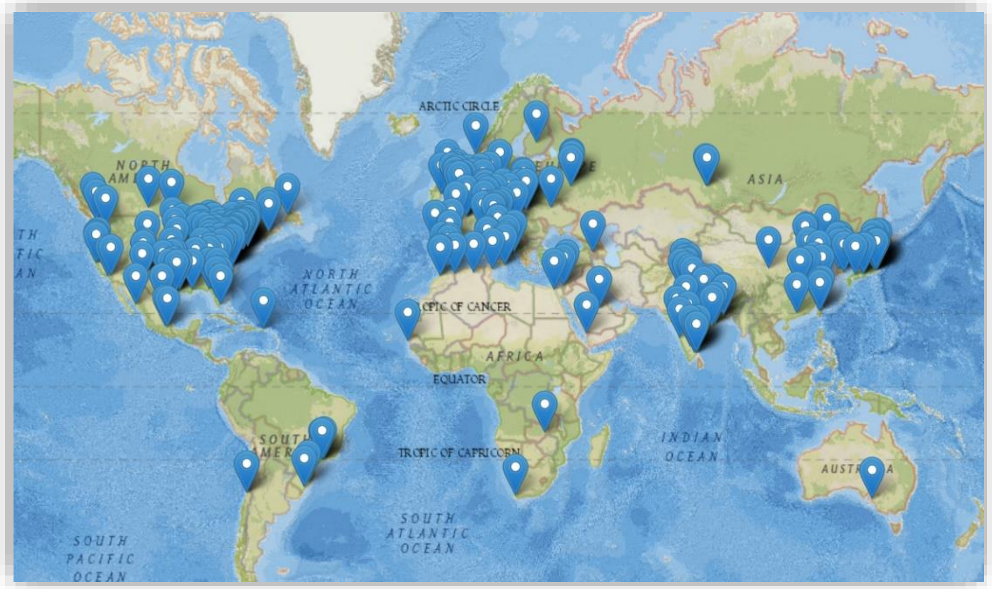
EIC Partners and Collaborators Highlights

EIC Partners (performing work and/or providing materials):
- 27 U.S. labs and universities
- 20 International labs and universities

EIC Collaborators (developing experiments, contributing expertise):
- EIC User Group: 1,546 members -- and growing
- 298 institutions worldwide (40 countries)



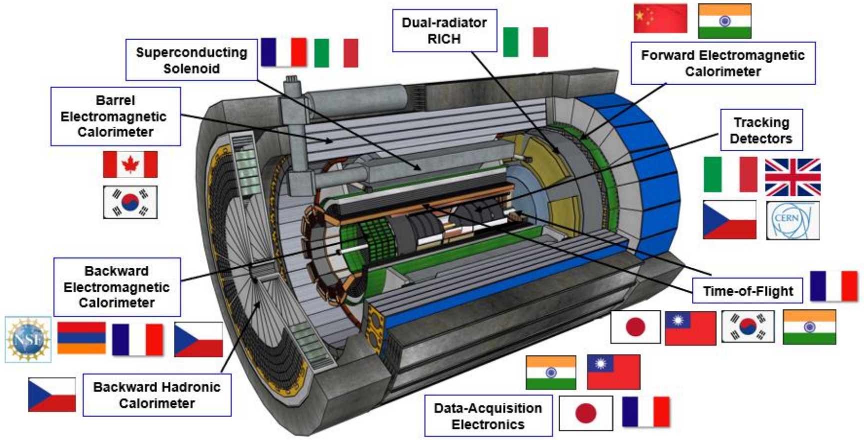
Institutions



DOE Lab Partners

Argonne National Laboratory
Brookhaven National Laboratory
Fermilab
Oak Ridge National Laboratory
Berkeley Lab – Lawrence Berkeley National Laboratory
SLAC National Accelerator Laboratory
Los Alamos National Laboratory Est. 1943
Jefferson Lab

ePIC Detector Partners



The EIC design and construction has many scientific and technical challenges, creating opportunities for worldwide collaboration.

EIC / ePIC Recent Highlights

- The US Department of Energy (DOE) and the CEA sign a "statement of interest" in the EIC project https://irfu.cea.fr/dphn/en/Phocea/Vie_des_labos/Ast/ast.php?t=fait_marquant&id_ast=5209
- U.S. DOE Under Secretary for Science and Innovation **approved the CD-3A package for $89.988M in long-lead procurements!** → includes significant scope for the detector
- In February, NYS Empire State Development Corporation executed **$100M Grant investment in EIC.** A DOE-NYS signing ceremony was held yesterday at BNL.
- **EIC Accelerator Collaboration Kick-Off**: Over 150 participants expressed interest in contributing to the global EIC effort.
- **3rd EIC Resource Review Board Meeting Held in Rome in May.** Strong participation from **Canada, Czech Republic, France, India, Israel, Italy, Japan, South Korea, United Kingdom,** and **Taiwan.**
- UK: More than £58 million will go Science and Technology Facilities Council laboratories in Daresbury and Oxfordshire, with support from universities across the UK to develop new infrastructure that will address fundamental questions on the nature of matter at the EIC https://www.gov.uk/government/news/major-funding-unveiled-for-cutting-edge-research-tools-that-could-halt-future-pandemics-and-protect-the-planet
- The education ministry in Japan announced their plans to contribute to the EIC detector construction, see https://japannews.yomiuri.co.jp/science-nature/science/20240515-186185/.
- France's National Center for Scientific Research and U.S. Department of Energy Sign 'Statement of Interest' on EIC Collaboration https://www.bnl.gov/newsroom/news.php?a=121605
- INFN Nuclear Physics scientific committee granted "experiment status" to ePIC in June 2024.

Japan News

THE JAPAN NEWS BY THE YOMIURI SHIMBUN https://japannews.yomiuri.co.jp/science-nature/science/20240515-186185/.

Note the “to join”; MEXT is in final phases before confirming

Japan to Join Electron-Ion Collider Accelerator Construction Project; Potential Boost for Quantum Computer Technology

Post | Share | Post

Yomiuri Shimbun file photo
The Education, Culture, Sports, Science and Technology Ministry building in Tokyo

The Yomiuri Shimbun
15:47 JST, May 15, 2024

Japan will participate in a U.S. project to build a large electron-ion collider (EIC), a particle accelerator capable of observing the world at the level of one trillionth of a millimeter, it has been learned.

The EIC is expected to shed new light on the physical laws governing the subatomic world and contribute to the practical application of advanced technologies such as quantum computers.

The Education, Culture, Sports, Science and Technology Ministry plans to announce soon its intention to participate in the plan, with the goal of starting operations in 2032.

The state-of-the-art EIC accelerator, a circular experimental facility about 3.8 kilometers in circumference, will be built by Brookhaven National Laboratory (BNL) in New York, part of the U.S. Department of Energy.

BNL plans to replace the existing accelerator in the basement of the building. Construction is scheduled to begin in 2026, with operations beginning in 2032.

EIC will collide electrons with nuclei at high speeds. The protons and neutrons inside the nuclei will break up into multiple particles, producing a snapshot of their internal structure.

This accelerator will make it possible to analyze the subatomic particles, which are only one trillionth of a millimeter in size, as if they were under microscopes with ultrahigh precision. By colliding high-speed particles with each other, this technology can be used to shed light on the origin of matter and reproduce the high-energy state of the early universe. It can also used to improve the breeding of agricultural crops and to measure the age of cultural assets.

EIC could lead to dramatic advances in basic science, such as understanding how matter was created in the universe.

Deepening the study of quantum mechanics, which governs the physical laws of the subatomic world, will help advance the development of quantum computers and clarify the mechanism that generates nuclear fusion energy, thus contributing to the practical application of advanced technology.

Riken, National Research and Development Agency, has a long-standing cooperative relationship with BNL, having established a research base at the laboratory in 1997.

The U.S. Department of Energy requested cooperation for the EIC’s construction from Japan in February of this year.

In constructing the EIC, which is estimated to cost between $1.7billion and $2.8 billion (about ¥270 billion to ¥440 billion), Japan will be in charge of developing the detectors and other equipment used to measure the data from the experiments.

The development cost is expected to be at least ¥4.5 billion. The education ministry plans to allocate several hundred million yen in its initial budget for the next fiscal year.

EIC Detector Work Organization

This is how we work

ELECTRON-ION COLLIDER
EXPERIMENTAL PROGRAM

Elke Aschenauer, EIC Co-Associate Director for the Experimental Program
Rolf Ent, EIC Co-Associate Director for the Experimental Program
Rahul Sharma, Chief Mechanical Engineer
Fernando Barbosa, Chief Electronics Engineer
Walt Akers, Systems Engineer
Reddy Chilakala, ES&H Detector Liaison
Joseph Zipper, QA Specialist

Tyler Lewis (BNL), Project Support
Everett Woolsey (JLab), Project Support
Christine Fragapane (JLab), Administrative Support
Anna Mendez (BNL), Administrative Support

EIC PROJECT CAMS

David Abbott (JLab)
Fernando Barbosa (JLab)
Alexander Bazilevsky (BNL)
Brian Eng (JLab)
Oleg Eyser (BNL)
Yulia Furletova (JLab)
David Gaskell (JLab)
Jeff Landgraf (BNL)
Renuka Rajput-Ghoshal (JLab)
Frank Rathmann (BNL)
Rahul Sharma (BNL)
Thomas Ullrich (BNL)
Benedikt Zihlmann (JLab)

DETECTOR EXPERTS

Arshak Asaturyan (JLab)
Alexander Jentsch (BNL)
Andrii Natochii (BNL)
Sourav Tarafdar (JLab)
Zhengqiao Zhang (BNL)

MECHANICAL ENGINEERING
Rahul Sharma (BNL)

Kevin Bailey (ANL)
Julien Bettane (IJCLab)
Dan Cacace (BNL)
Kristopher Cleveland (JLab)
Josh Crafts (CUA)
Alex Eslinger (JLab)
Elliott Fountain (ORNL)
Karim Hamdi (BNL)
Joshua Harvey (BNL)
Andreas Jung (Purdue)
Sushrut Karmarkar (Purdue)
Ron Lassiter (JLab)
Seung Joon Lee (Jlab)
Avishay Mizrahi (Tel Aviv)
Tom O'Connor (ANL)
Jonathan Smith (JLab)
Nathaniel Speece-Moyer (BNL)
John Tuozzolo (BNL)
Roland Wimmer (BNL)
Beneficial Occupancy Expert (BNL)
Cooling System Expert (BNL)

ELECTRICAL ENGINEERING
Fernando Barbosa (JLab)

Tim Camarda (BNL)
Lee Flader (BNL)
Norbert Novitzky (ORNL)
Steve Titus (JLab)
Gerard Visser (Indiana)
Electronics Engineer (JLab)
Electronics Technician (JLab)

SYSTEMS ENGINEERING
Walt Akers (JLab)

Joel Watkins (JLab)

DETECTOR MAGNET
Renuka Rajput-Ghoshal (JLab)

Christophe Berriaud (CEA)
Don Bruno(BNL)
Valerio Calvelli (CEA)
Simon Damien (CEA)
Clement Genot (CEA)
Probir Ghoshal (JLab)
Sandesh Gopinath (JLab)
François-Paul Juster (CEA)
Victor Kleymenov (CEA)
Jean-Pierre Lottin (CEA)
Lionel Quettier (CEA)
Hugo Reymond (CEA)
Michel Segreti (CEA)
Francesco Stacchi (CEA)
Eric Sun (JLab)
Robert Than (BNL)
Daniel Young (JLab)

Integrating ePIC collaboration in Project WBS

6.10 EIC Detector

- 6.10.01 Detector Management
- 6.10.02 Detect. R&D & Physics Design
- 6.10.03 Tracking
- 6.10.04 Particle Identification
- 6.10.05 Electromagn. Calorimetry
- 6.10.06 Hadronic Calorimetry
- 6.10.07 Magnets
- 6.10.08 Electronics
- 6.10.09 DAQ / Computing
- 6.10.10 Detector Infrastructure
- 6.10.11 IR Integration & Auxiliary Detectors
- 6.10.12 Detector Pre-Ops & Commiss.
- 6.10.13 Detector #2 Development
- 6.10.14 Polarimetry and Luminosity

Detector Subsystem Work Packages

need to be integrated in WBS

SPOKESPERSON'S OFFICE
J. Lajoie (ORNL), Spokesperson
S. Dalla Torre (INFN), Deputy Spokesperson

TECHNICAL COORDINATION OFFICE
Silvia Dalla Torre (INFN, interim)
Prakhar Garg (Yale), Deputy
Oskar Hartbrich (ORNL), Deputy
Matt Posik (Temple), Deputy

DSL:
Detector Subsystem Leader
DSTC:
Detector Subsystem Technical Coordinator

dRICH
DSL/DSTC: Marco Contalbrigo (INFN)

hpDIRC
DSL/DSTC: Greg Kalicy (CUA)

BACKWARD RICH
DSL/DSTC: Alexander Kiselev (BNL)

FAR FORWARD
DSL: Alex Jentsch (BNL)
DSTC (B0): Zvi Citron (Ben-Gurion)
DSTC (Roman Pots/OMD): Alex Jentsch (BNL)
Co-DSTC (ZDC): Yuji Goto (RIKEN)
Co-DSTC (ZDC): Miguel Arratia (UCR)

LUMINOSITY
Co-DSL: Nick Zachariou (York)
Co-DSL: Krzysztof Piotrzkowski (AGH Krakow)
DSTC (Pair Spectr.): Dhevan Gangadharan (Houston)

FAR BACKWARD HIGH RATE TRACKER
DSL: Jaroslav Adam (CTU)
DSTC: Simon Gardner (Glasgow)

Si TRACKERS
DSL: Ernst Sichtermann (LBL)
DSTC: Laura Gonella (Birmingham)

BACKWARDS ECAL
DSL: Tanja Horn (CUA)
DSTC: Carlos Munhoz Camacho (IJCLab)

BACKWARDS HCAL
DSL/DSTC: Leszek Kosarzewski (OSU)

BARREL ECAL
Co-DSL: Sylvester Joosten (ANL)
Co-DSL: Hwidong Yoo (Yonsei)
Deputy DSL: Maria Zurek (ANL)
DSTC (Si): Jessica Metcalfe (ANL)
DSTC (SciFi/Pb): Zisis Papandreou (Regina)

BARREL HCAL
Co-DSL: Stefan Bathe (Baruch)
Co-DSL: Megan Connors (GSU)

FORWARD ECAL
Co-DSL/DSTC: Oleg Tsai (UCLA)
Co-DSL: Huan Huang (UCLA)

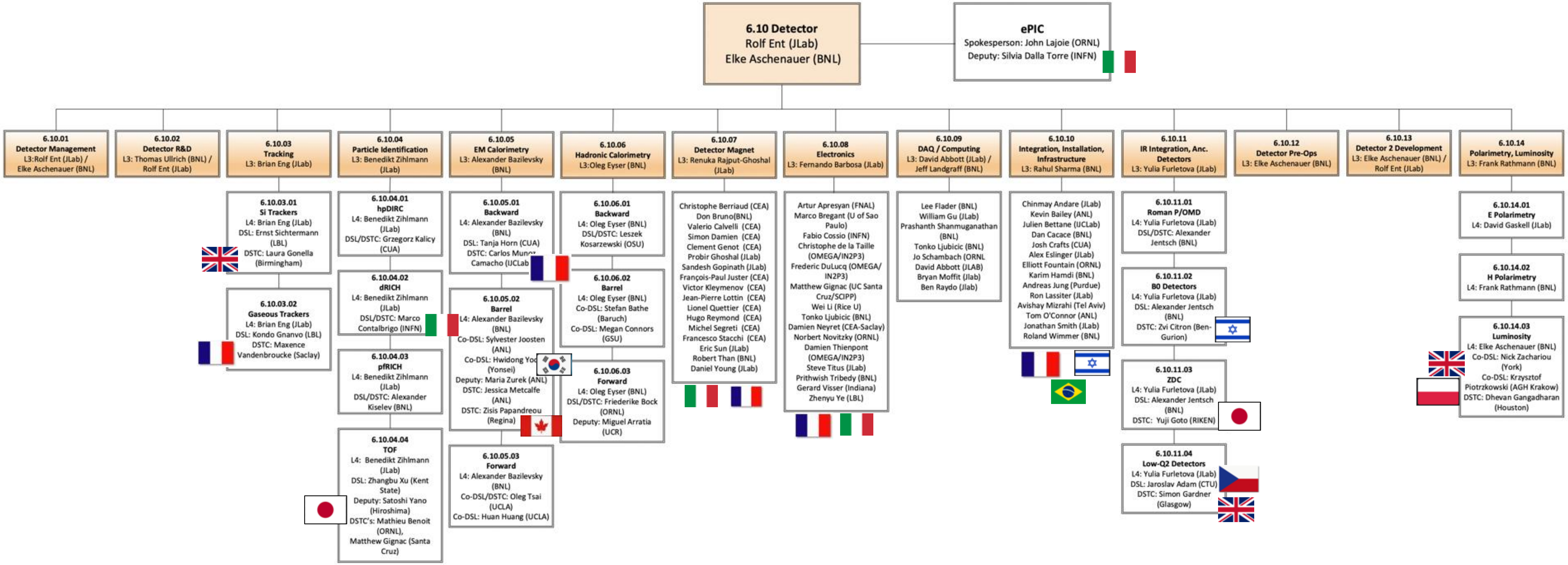
FORWARD HCAL
DSL/DSTC: Friederike Bock (ORNL)
Deputy DSL/DSTC: Miguel Arratia (UCR)

AC-LGAD TOF
DSL: Zhangbu Xu (Kent State)
Dep. DSL: Satoshi Yano (Hiroshima)
DSTC's: Mathieu Benoit (ORNL), Matthew Gignac (Santa Cruz)

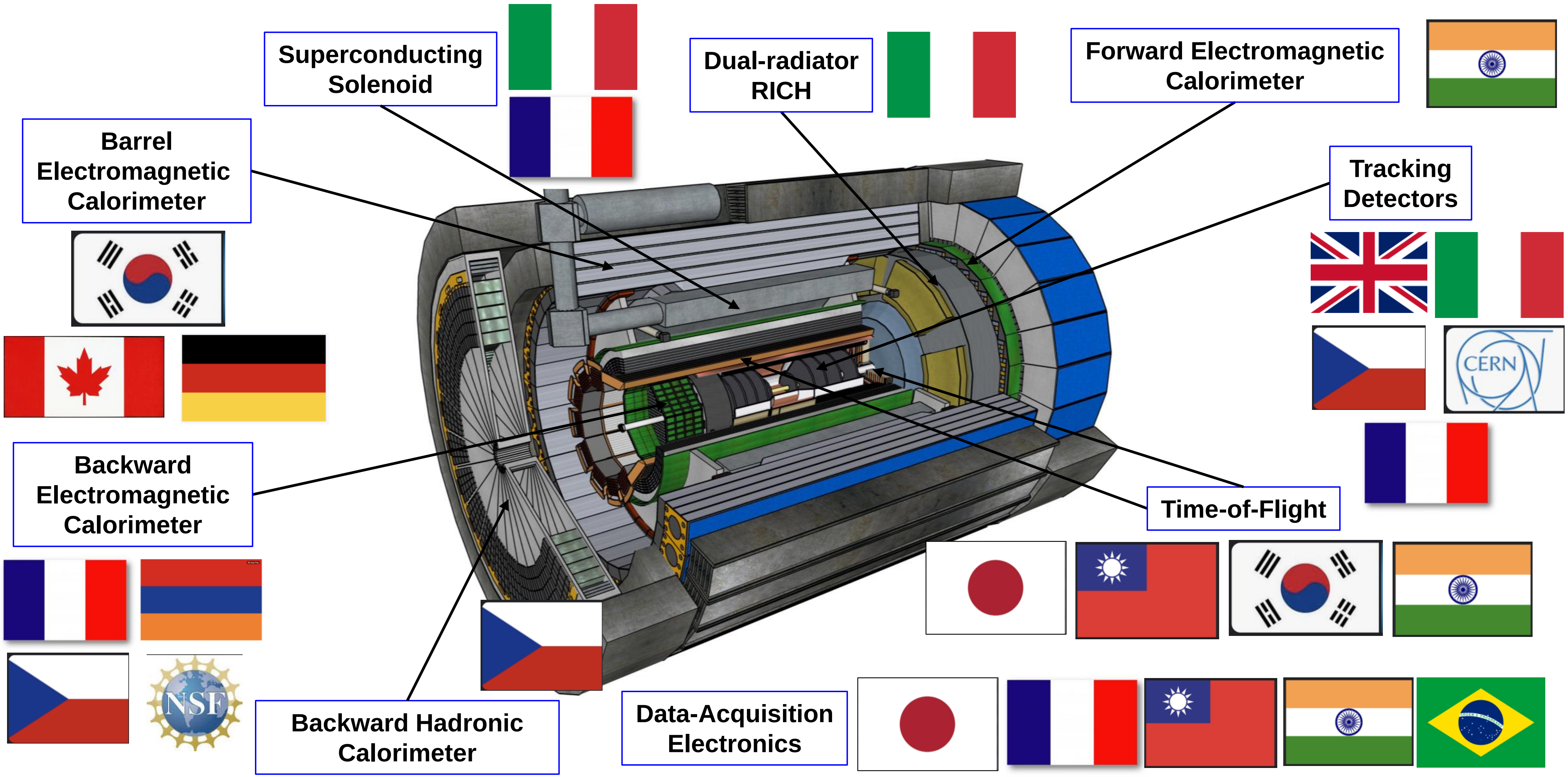
GASEOUS TRACKERS
DSL: Kondo Gnanvo (JLab)
DSTC: Maxence Vendenbroucke (Saclay)

Detector Subsystem Collaborations

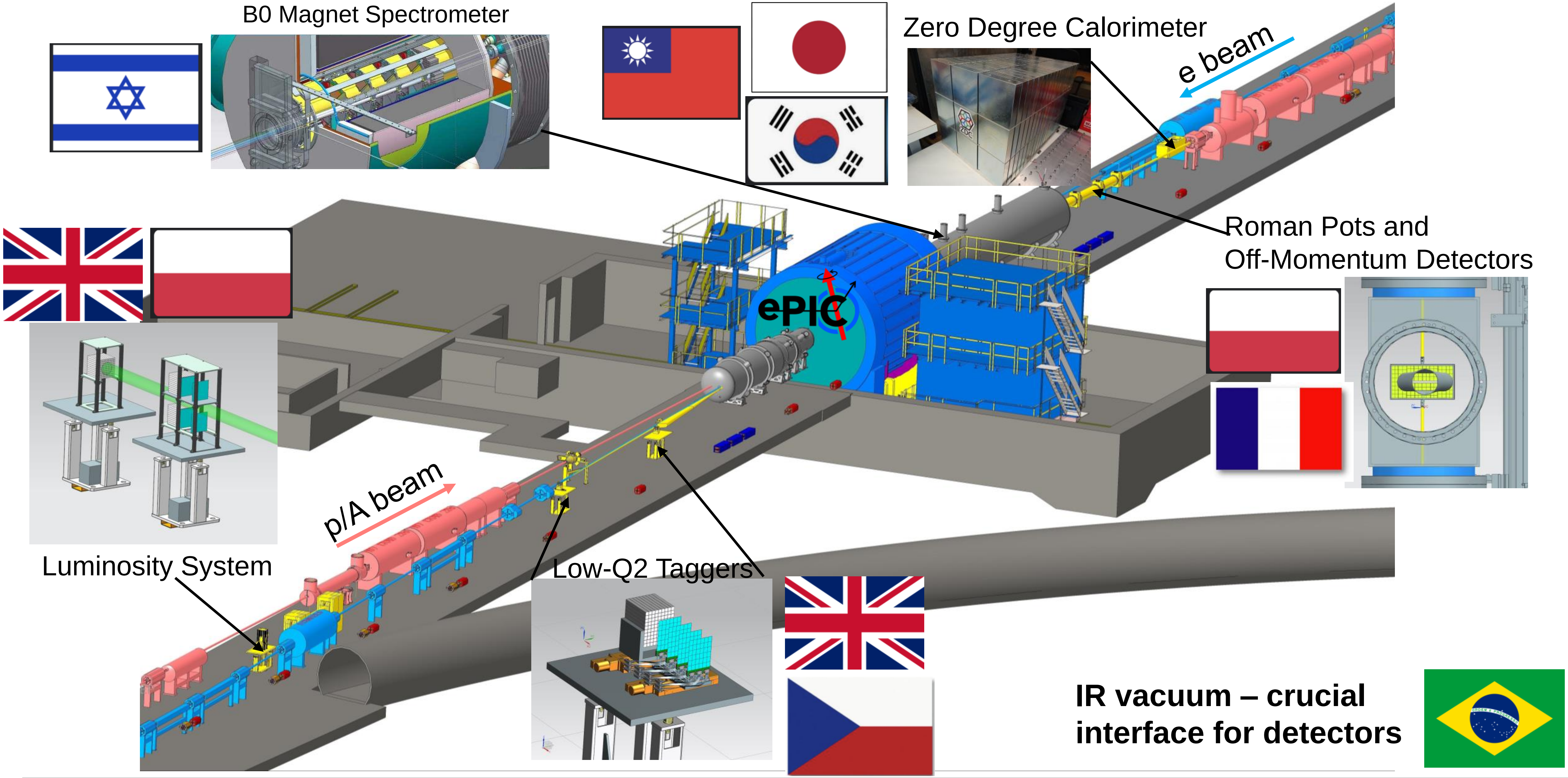
Integrating ePIC collaboration in Project WBS



Central Detector Non-DOE Interest & In-Kind



Far-Forward/Far-Backward Detectors Non-DOE Interest & In-kind

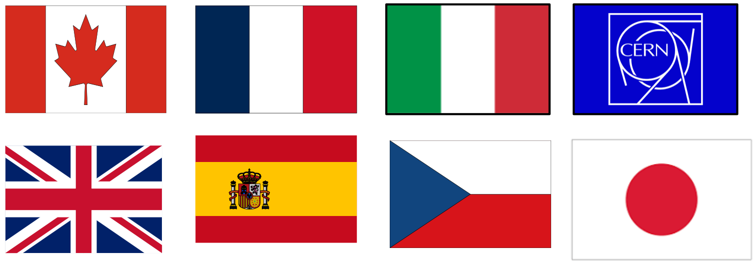


IR vacuum – crucial interface for detectors

IKC Status for Accelerator

- The IKC target for the EIC accelerator is about **5%** of the total scope approx. $50M.
- Advanced stage IKCs are now mostly for SRF scope.
- More Countries may participate in EIC accelerator IKCs in the future.

Advanced Stage Accelerator IKCs	
394 MHz Crab Cryomodules	UK + Canada
591 MHz 5-Cell Cryomodules	France
Vacuum SEY measurements	Italy INFN



Accelerator IKCs under discussion	
IR Spin Rotator Magnets	Spain
IR region Magnets	Spain
1773 MHz 5-Cell Cavity CM	UK
RF amplifiers	Spain
1.3 GHz electron injector LINAC	France CEA/ Japan KEK
Controls, Diagnostics	Czech Republic
Be vacuum pipes	CERN

Outlook to CD-2 – Detector In-Kind Contributions (IKC)

- The IKC target for the EIC detector is about 30% of the total scope approx. $100M.
- The INFN/detector iCRADA is the most advanced.

  PPDs preparations are ongoing.
- The preparation of iCRADAs – Second Phase – is starting.

First Phase of Milestones for Detector IKC

Agency	Milestone	Target Date
Italy-INFN	JLab iCRADA (for dRICH, Si/ITS3, GEM-muRwell) drafted*	✓ Apr 2024
UK	JLab iCRADA (for Si/LAS, Low-Q2, Lumi) drafted**	✓ Apr 2024
UK	BNL iCRADA (for Si/LAS) drafted	Jun 2024
Italy-INFN	JLab iCRADA (for solenoid) drafted	✓ March 2024
France-CEA	JLab iCRADA (for solenoid) drafted	✓ March 2024
France-IN2P3	JLab iCRADA (for EEEmCAL, RPs, ASICs) drafted**	✓ May 2024
France-CEA	JLab iCRADA (for MicroMegas, SALSA) drafted	✓ June 2024 → July
	PPDs preparation could start at the end of drafting the iCRADA and completed in 2025	**Mar 2025 Ready to be signed**
	CD-2 Director's Review / All ICRADA and PPDs signed	**Sep or Oct 2025**
	DOE CD-2 and Status OPA Review	**Late 2025**

STATUS:

Two iterations, complete after final check $ amount

Comments? Need to add (minor) fixes as for INFN

Resume in August, need minor fixes

Comments?

Sent in July (week ago)

Prep work started on PPD with Italy/detector and UK

** JLab iCRADA draft to start process, Si scope moves to BNL iCRADA*
***JLab iCRADA draft to start process, then may move to BNL iCRADA*

Plan to start **Second Phase** of draft iCRADAs once scope is clear and as aligned with time scales of foreign agencies, e.g., Korea, Canada, Japan, India, Israel…

Request to start on Korea to be aligned with funding proposal process. Plan to also start on Japan.

Electron-Ion Collider
EIC Advisory Board Meeting August 2 2024 13

Status: folding in
- Reuse of components enabled by explicit design (e.g., barrel HCal, cradle, DIRC bars, ….)
- In-kind contributions to PED
- Likely IKC
  - UK detector (UKRI/STFC)
  - Italy/INFN detector
  - Italy/INFN magnet
  - CEA/IN2P3 detector
- Possible IKC
  - Japan detector
  - Korea detector
  - Canada detector
  - Taiwan detector
  - NSF/MSRI

we would surpass this $100M goal.

This is coded in P6 in anticipation of further proposal confirmations and the signed formal agreements.

Project Planning Update

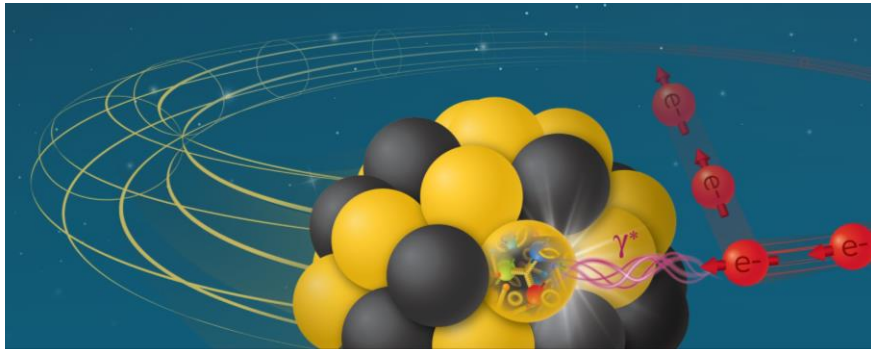
The EIC project continues to prepare plans for completing the design, construction, and commissioning of the EIC facility. These plans must satisfy the DOE approved mission need, and be based on realistic assessments of technical readiness, cost, schedule, and risk.

There are three primary project planning goals/constraints:

1. Annual project funding should not exceed $300M per year (ambitious);
2. Total Project Cost less than $3B (ambitious); and,
3. Deliver science within ten years after RHIC operations concludes (realistic).

- The annual funding limitation extends schedules and increases cost. It is possible to phase delivery of the accelerator, which is ~85% of the project scope.
- It is also possible to start the science program in less than ten years with electron-ion collisions at the conclusion of the first phase.
- The second phase would complete the full scope required to achieve the DOE approved mission need. The two phases would overlap as part of one project.

Path to Early Science



Final Performance Phase: Achieve parameters listed in the Conceptual Design Report

Early Science Phase:

5 GeV or 10 GeV polarized electron (vs 5 – 18 GeV CDR)

7 nC per electron bunch (vs 28 nC CDR)

100 – 250 GeV polarized proton (vs 41 – 275 GeV CDR)

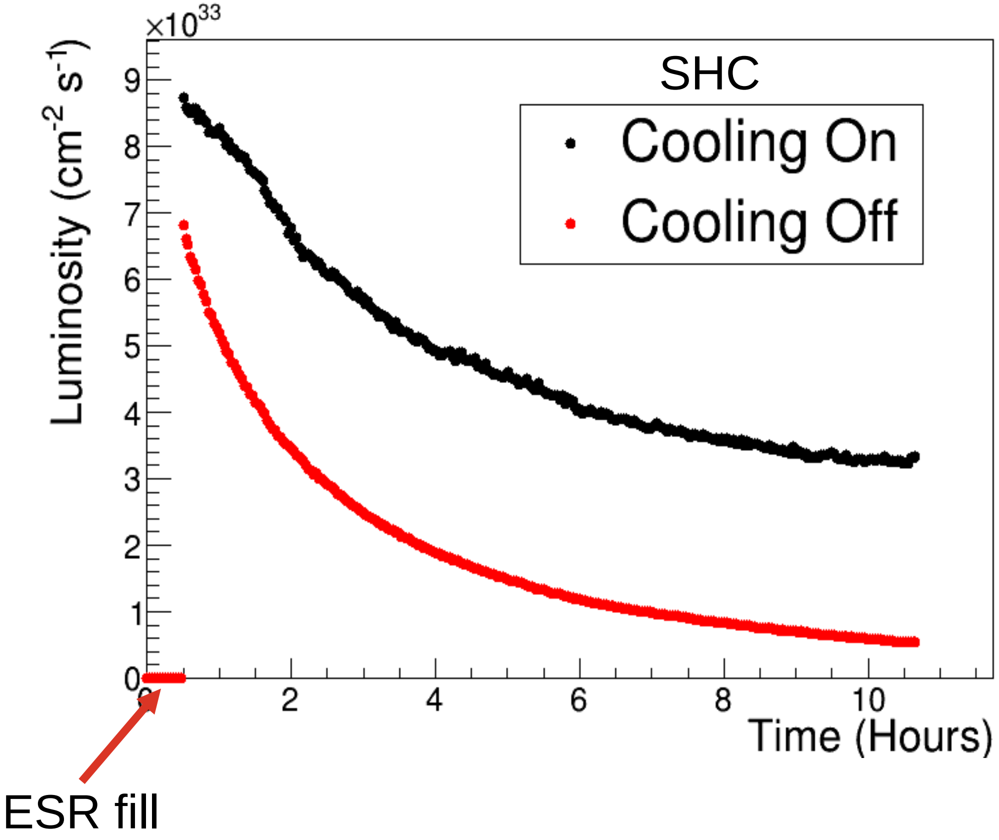
>100 GeV/u various ion

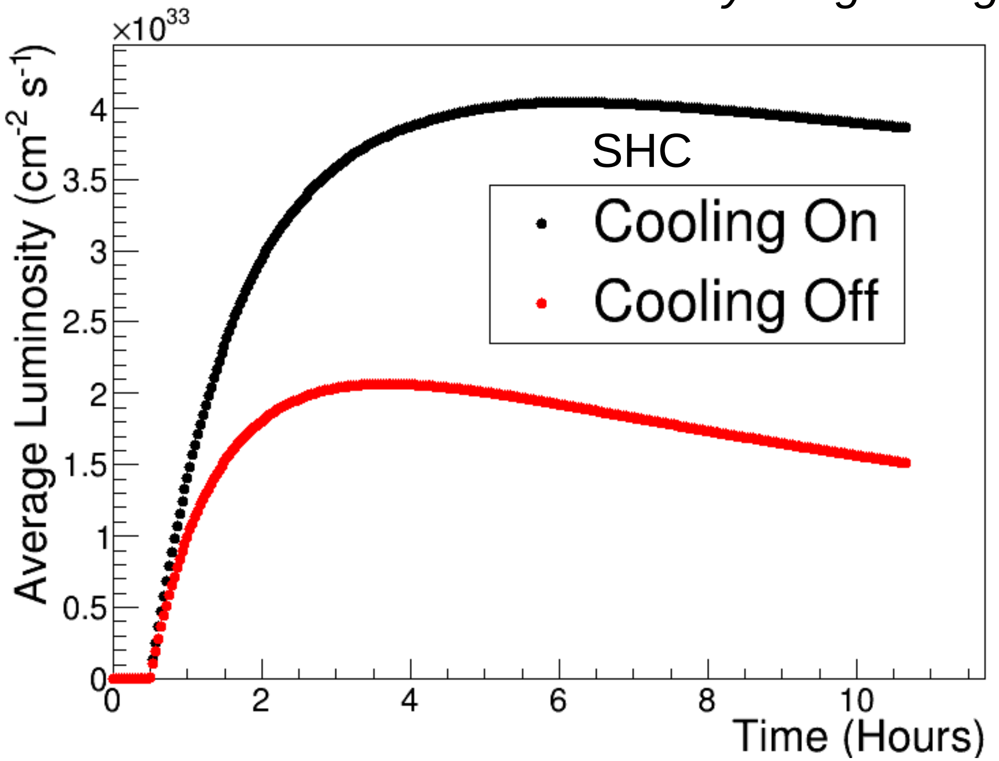
No Strong Hadron Cooling at full energy

Pre-Cooling at injection energy

Luminosities w/wo SHC for 275 GeV p on 10 GeV e (example)

Slide courtesy Sergei Nagaitsev



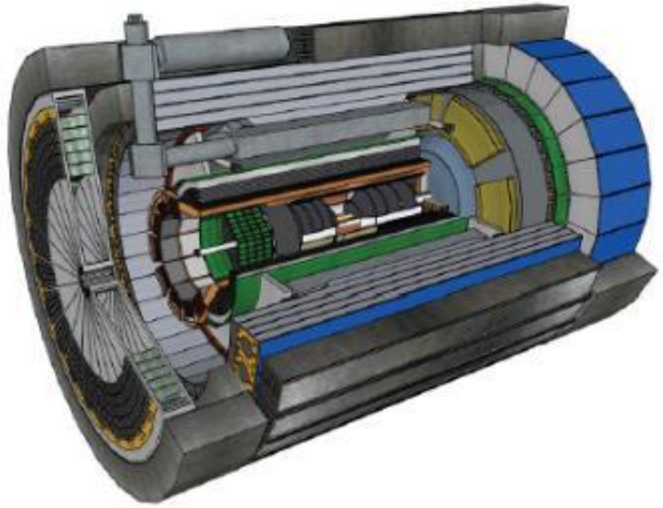


$$\text{Ave. lumi} = \frac{\text{Integral}}{\text{store length} + 2\text{ hr}}$$

- Each store starts with 30 min precooling and 30 min to fill the ESR ring (~1200 bunches);
- Total store turn-around time is assumed to be 2 hr (including precooling and the ESR fill)

EIC (Detector) Summary

- EIC is a unique, high-energy, high-luminosity, polarized beam collider that will be one of the most challenging and exciting accelerator complexes ever built -- **only new collider in the next decades.**
- DOE approved CD-3A and supports the preparation of CD-3B procurements.
- ePIC Collaboration formed and EIC Detector technically baselined
- Strong support for EIC in the scientific community and increasing international engagement.
  - EIC science has worldwide endorsement (UK/STFC Infrastructure grant, Canada Long-Range Plan, NSAC Long-Range Plan, India MegaScience Vision Plan, NuPECC recommendation, …).
  - Partners participated in preparing the EIC governance model (RRB meetings).
- Priorities for 2025/2026 include:
  - Execution of the CD-3A baseline (long-lead procurements phase-1);
  - Execution of the CD-3B baseline (long-lead procurements phase-2) once approved;
  - Strong collaboration of oversight of Project dependencies with EIC Project;
  - Complete Preliminary design (final design for select items);
  - Formalize in-kind agreements towards IKC goal; and,
  - Review of the technical, cost, schedule, and baseline towards CD-2.




QUESTIONS


BACK UP

EIC Recent Highlights

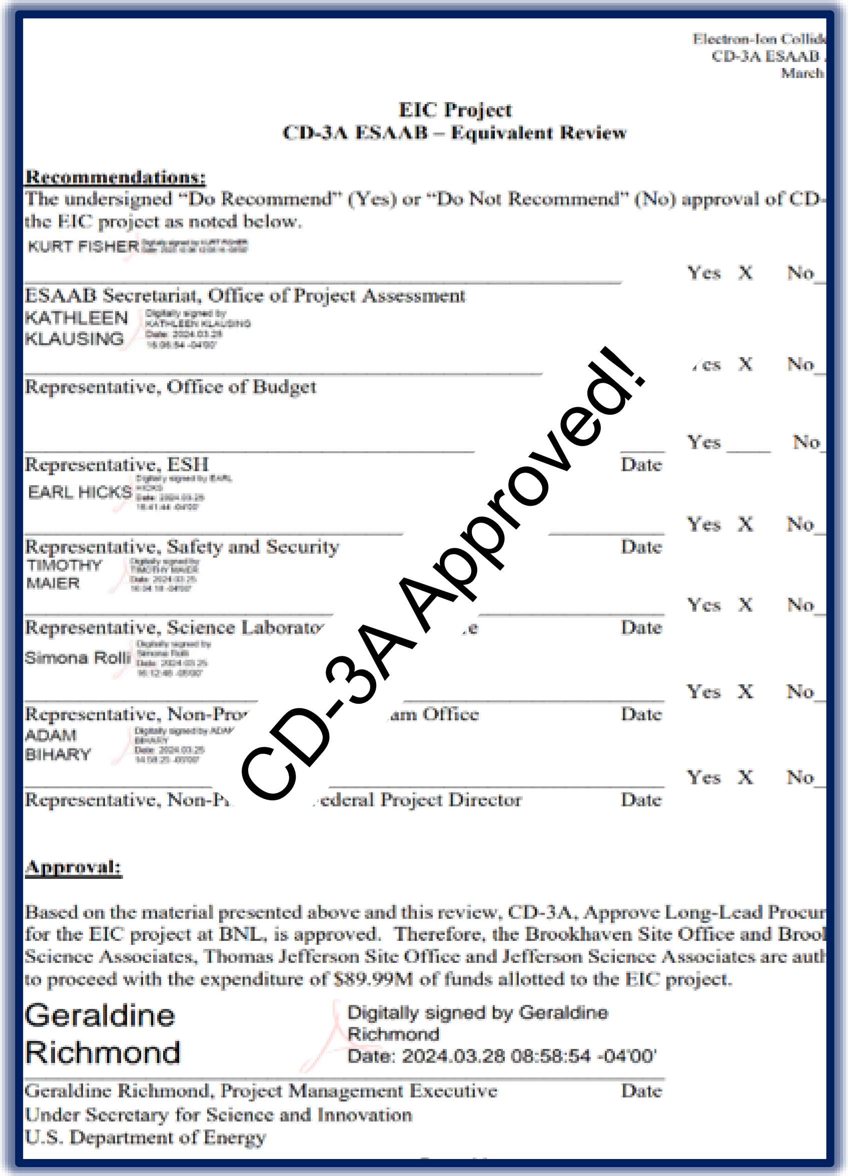
- Consolidated Appropriations Act 2024 included **$97.85M for EIC in FY2024** ($95M TEC, $2.85M for OPC). This is consistent with expectations.

- U.S. DOE Under Secretary for Science and Innovation **approved the CD-3A package for $89.988M in long-lead procurements!** This will use Inflation Reduction Act funding.

- New York State awarded a **$100M grant for constructing EIC buildings.** EIC conventional construction is underway.

- **UKRI announced support for EIC with £58.8/$74.2M** to develop new detector and accelerator and infrastructure.

- **EIC Resource Review Board (RRB) Meeting hosted by INFN on May 6-7, 2024.** Strong international participation included: Canada, Czech Republic, France, India, Israel, Italy, Japan, South Korea, United Kingdom, and Taiwan.



Electron-Ion Collide
CD-3A ESAAB
March

EIC Project
CD-3A ESAAB – Equivalent Review

Recommendations:
The undersigned "Do Recommend" (Yes) or "Do Not Recommend" (No) approval of CD-
the EIC project as noted below.

KURT FISHER — Yes X No
ESAAB Secretariat, Office of Project Assessment

KATHLEEN KLAUSING — Yes X No
Representative, Office of Budget

Yes ___ No
Representative, ESH — Date

EARL HICKS — Yes X No
Representative, Safety and Security — Date

TIMOTHY MAIER — Yes X No
Representative, Science Laborato... — Date

Simona Rolli — Yes X No
Representative, Non-Pro... am Office — Date

ADAM BIHARY — Yes X No
Representative, Non-P... ederal Project Director — Date

CD-3A Approved!

Approval:

Based on the material presented above and this review, CD-3A, Approve Long-Lead Procur
for the EIC project at BNL, is approved. Therefore, the Brookhaven Site Office and Broo
Science Associates, Thomas Jefferson Site Office and Jefferson Science Associates are auth
to proceed with the expenditure of $89.99M of funds allotted to the EIC project.

Geraldine Richmond — Digitally signed by Geraldine Richmond Date: 2024.03.28 08:58:54 -04'00'

Geraldine Richmond, Project Management Executive — Date
Under Secretary for Science and Innovation
U.S. Department of Energy

EIC Science Highlights

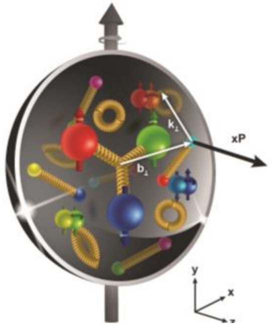
SPIN is one of the fundamental properties of matter.
All elementary particles, but the Higgs carry spin.
Spin cannot be explained by a static picture of the proton
It is the interplay between the intrinsic properties and interactions of quarks and gluons

The EIC will unravel the different contribution from the quarks, gluons and orbital angular momentum.

Does the mass of visible matter emerge from quark-gluon interactions?

Atom: Binding/Mass = 0.00000001
Nucleus: Binding/Mass = 0.01
Proton: Binding/Mass = 100

For the proton the EIC will determine an important term contributing to the proton mass, the so-called “QCD trace anomaly



How are the quarks and gluon distributed in space and momentum inside the nucleon & nuclei?

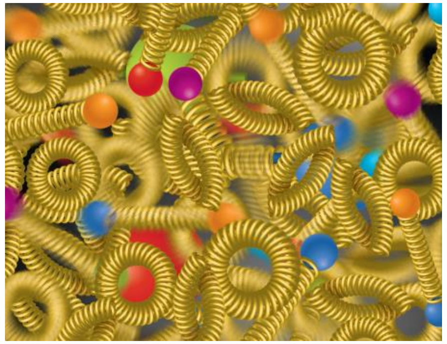
How do the nucleon properties emerge from them and their interactions?
How can we understand their dynamical origin in QCD?
What is the relation to Confinement

Is the structure of a free and bound nucleon the same?

How do quarks and gluons, interact with a nuclear medium?

How do the confined hadronic states emerge from these quarks and gluons?

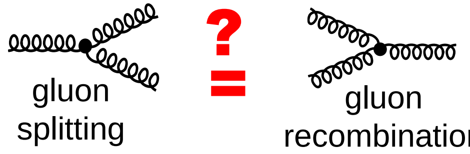
How do the quark-gluon interactions create nuclear binding?



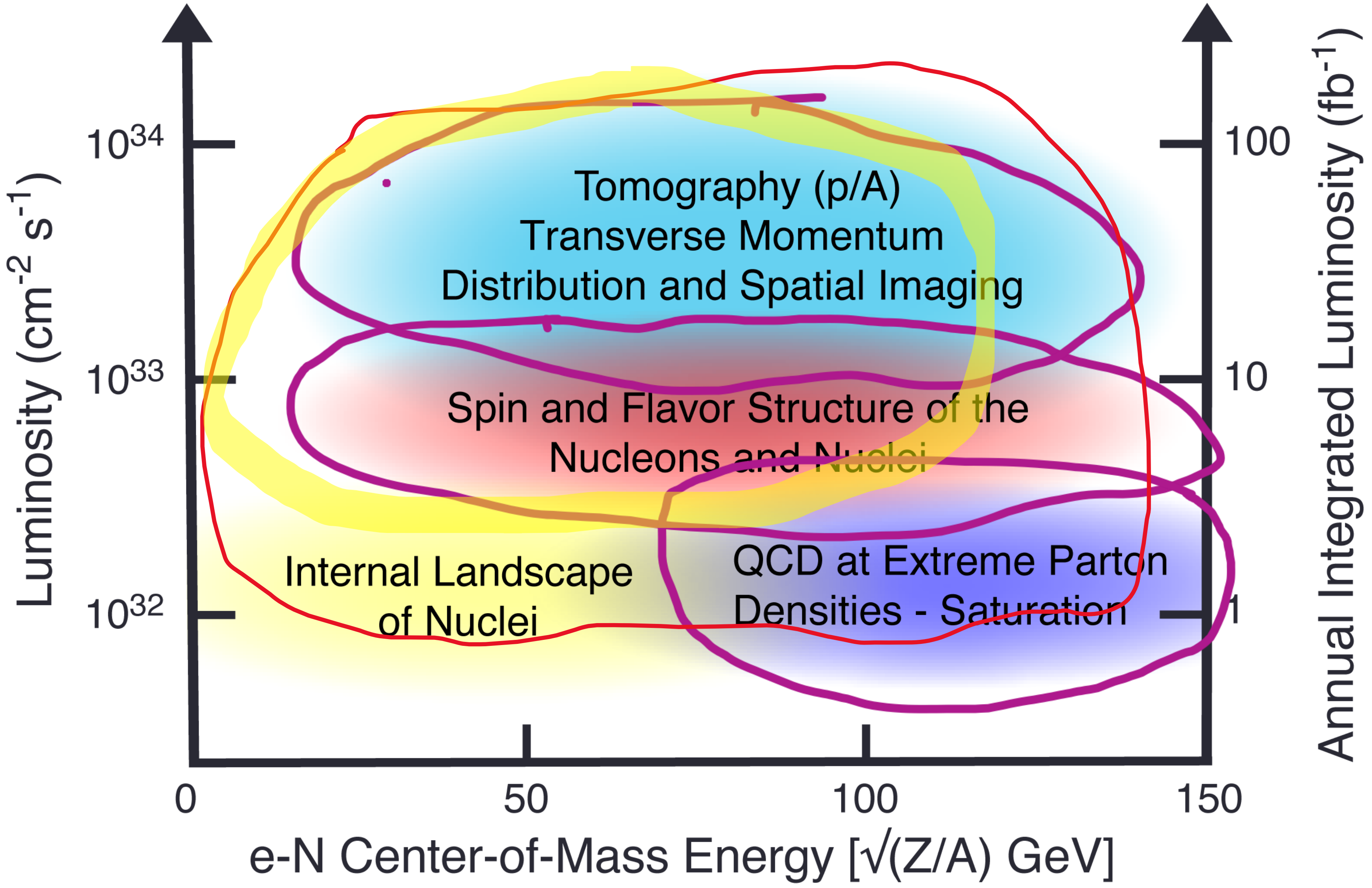
How many gluons can fit in a proton?

How does a dense nuclear environment affect the quarks and gluons, their correlations, and their interactions?

What happens to the gluon density in nuclei? Does it saturate at high energy?



EIC Science Reach



Spin

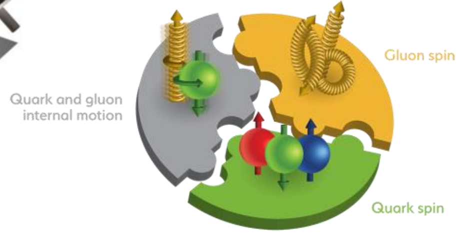
Mass

3D Imaging

Quarks, Gluons & Nuclei

Dense gluon systems

Accelerator Performance and EIC Science

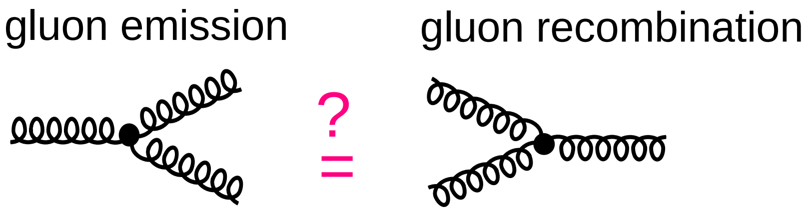


wide center-of-mass energy √s: ~20 – 140 GeV :

- map the out nucleon and nuclei structure from high to low x

polarized electron and hadron (p, He-3) beams:

- access to spin structure of nucleons and nuclei
- Spin vehicle to access the spatial and momentum structure of the nucleon in 3d
- Full specification of initial and final states to probe q-g structure of NN and NNN interaction in light nuclei

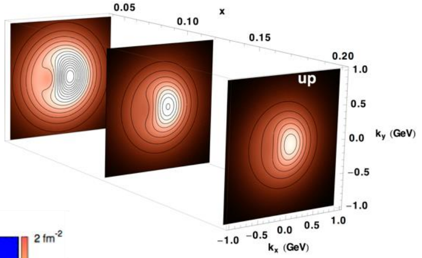


nuclear beams: d to Pb

- accessing the highest gluon densities → saturation
- quark and gluon interact with a nuclear medium

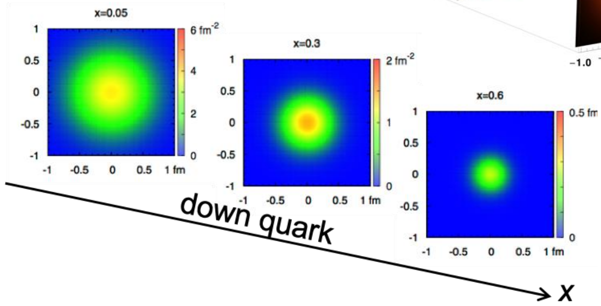
high luminosity 10^{33}-10^{34} $cm^{-2}s^{-1}$:

- mapping the spatial and momentum structure of nucleons and nuclei in 3d
- access to rare probes, i.e. Ws



large acceptance (0.2 – 1.3 GeV) through forward focusing IR magnets

- spatial imaging of nucleons and nuclei



EIC Partners and Collaborators Highlights

- **New York State** committed **$100M** toward construction of EIC buildings and infrastructure.
- **UK** announced £58 million (**$75M**) for the EIC project in March 2024.
- **In-kind contributions** developing with **Canada, France,** and **Italy**.
- **Statements of Interest** signed between DOE and **French** agencies.
- **EIC Accelerator Collaboration Kick-Off**: Over 150 participants expressed interest in contributing to the global EIC effort.

- **EIC Resource Review Board Meeting Held in Rome in May.** Strong participation from **Canada, Czech Republic, France, India, Israel, Italy, Japan, South Korea, United Kingdom,** and **Taiwan.**

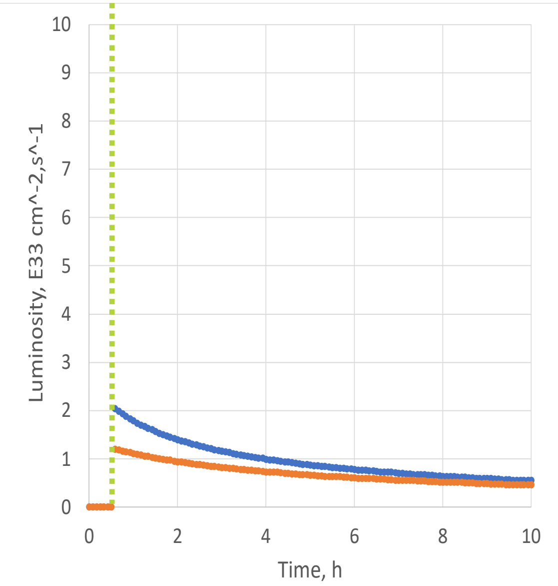
Detector Non-DOE Interest & In-Kind

Entity	Interest and Important Facts
NSF	NSF-MSRI pre-proposal submitted by 10 US universities – aims at full scope of backward EM calorimetry (eECal). Armenia, Czech, France/IN2P3 as unfunded contributors. Invited to submit proposal. Moved within NSF to consider in MPS directorate. Internal NSF review completed. Asked to resubmit this year for funding decision in late FY25.
CERN	MAPS sensor design developed by CERN/ITS-3 Group providing synergy with ALICE. Synergy of gaseous-based Cherenkov detectors and photon-sensors with ALICE & LHCb. Synergy of Forward AC-LGAD design with CMS endcap timing layer.
Armenia	Contributions, mainly labor to eECal and many EM calorimetry and particle id detectors component tests.
Canada	EIC included in 2022 Canadian Subatomic Physics Long-Range Plan; Interested in Barrel Electromagnetic Calorimetry, Electron Polarimeter and Software. Working on 2024 proposal.
China	Interested in Forward EM Calorimeter – working on NSF-China proposal.
Czech	Working with funding agency; Interested in eECal (PbWO4 crystals and glass), Silicon Vertex Tracker sensors and characterization, and collaboration on low-Q2 electron tagger.
France/IRFU	Interested in MPGD/racking and readout electronics including ASICs for MPGDs. Provided in-kind contributions to SC magnet design and interested to continue labor oversight during magnet construction.
France/IN2P3	International contribution to backward EM calorimetry (including in-kind design) and to readout electronics (in-kind design of two ASICs for AC-LGAD detectors and Calorimetry). IRFU & IN2P3 discussing together for higher-level contributions.
India	EIC included in 2023 Mega Science Vision Plan. Consortium is working with Funding agency; Interested in detector software (non-project scientific contribution), contributions to DAQ/slow controls and forward dRICH. Investigating further hardware contributions – forward EM Calorimeter, forward AC-LGAD, maintain possible links with Si groups and plants.
Italy/INFN	Commitment to EIC detector magnet construction scope. Aims at major scope of forward particle identification detector (dRICH) including ASICs development, at (part of) the Si/MAPS tracker scope, and at photo-sensor contributions as well as contributions to the μRwell. Tracker (forward disks).. EIC-Italy is a formal INFN project now with approved detector funding.
Israel	B0 Detectors (Si tracking and PbWO4)
Japan	Interested in a US-Japan agreement; Aims at full scope of Zero-Degree Calorimeter in collaboration with Taiwan/Korea. Pursuit of full scope of barrel AC-LGAD detector as EIC-Asia consortium. Contribution to DAQ/streaming. Discussions of MEXT with Ministry for ePIC detector support ongoing.
Korea	Aims at major scope for fiber-based barrel EM calorimeter, Also interest in barrel AC-LGAD and Si-based hadronic calorimetry for ZDC.as part of EIC-Asia consortium (includes also Japan,Taiwan), Si tracking detector and GEM-based detectors. Proposal submitted to MSIT.for M&S for barrel EMCal and support for labor for all interests. Beyond policy review stage.
Poland	Actively working with ministry/funding agency; Interested in detectors along the beam line (luminosity detector, Roman Pots)
Taiwan	Pursuit of full scope of barrel AC-LGAD as part of EIC-Asia consortium. LYSO-based EM calorimeter for ZDC, Also optical readout/fiber. Possible later interest in PCBs. Computing. Also investigating if AC-LGAD sensors can be produced by Taiwan industry, if so these sensors could be in-kind.
UK	STFC seed funding for UK detector R&D (3M£). Large STFC/UKRI research infrastructure proposal approved, includes the two outer barrel layers of the silicon vertex tracker, two tracking stations for the low-Q2 electron tagger, and components for the luminosity monitor. Also includes accelerator component.

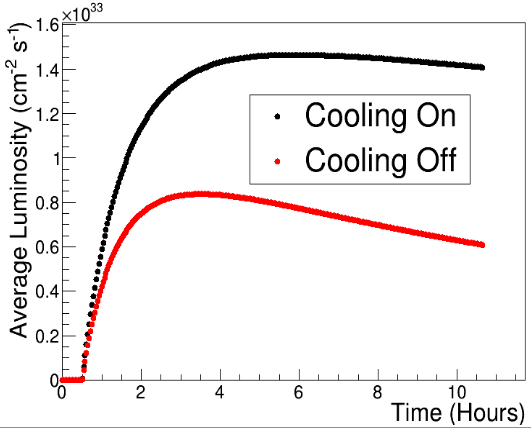
Discussion between the EIC Project and ePIC based on phasing of EIC operations

- **Phase I: Under Discussion**
  - HSR: no strong hadron cooling (SHC), add precooler, no 41-GeV bypass
  - ESR: 5-10 GeV, 7 nC max (means fewer rf cavities and amps); maybe no crabs (may require lower proton bunch intensities)
  - RCS: operates with a 7-nC (single bunch), 3 –> 5 or 10 GeV, ramps at 1 Hz
- **Phase II: Under Discussion**
  - HSR: add SHC, add 41-GeV bypass
  - ESR: add rf cavities and power to operate at 28 nC and 18 GeV;
  - RCS: upgraded to 28 nC and 3 -> 18 GeV ramps (at 1 Hz);
- **Early science program driven by:**
  - Start of EIC Science program.
  - Alignment with expected order in commissioning the collider and ramp up of performance that comes with gain of operational experience.
  - Having access to new physics results early to get high impact publications.

e-p Luminosity in EIC Phase I

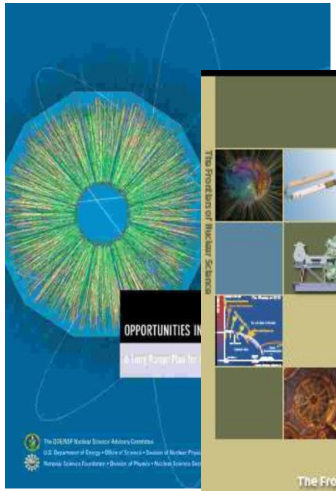


Luminosity w/wo SHC



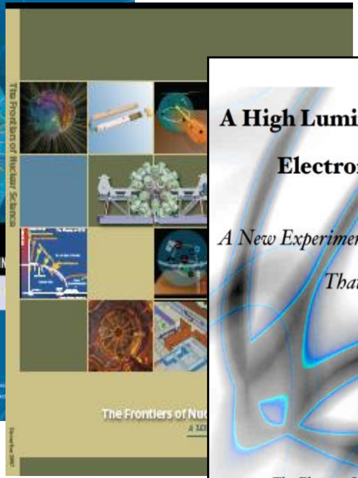
The Scientific Foundation for an EIC was Built Over Two Decades

2002



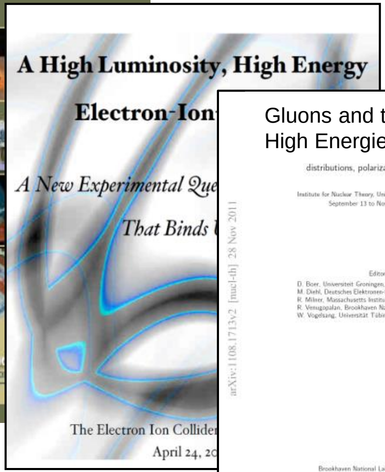
"…essential accelerator and detector R&D [for EIC] should be given very high priority in the short term."

2007



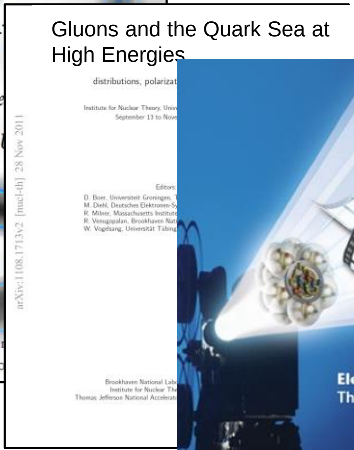
"We recommend the allocation of resources …to lay the foundation for a polarized Electron-Ion Collider…"

2009



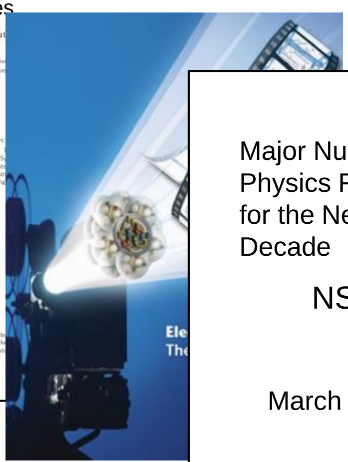
"..a new dedicated facility will be essential for answering some of the most central questions."

2010

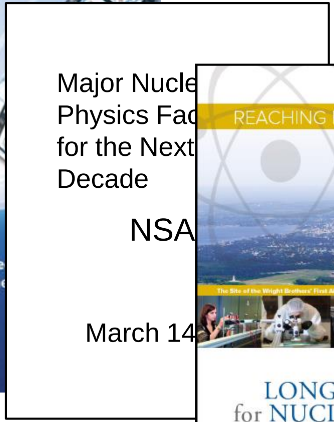


"The quantitative study of matter in this new regime [where abundant gluons dominate] requires a new experimental facility: an Electron Ion Collider.."

2012

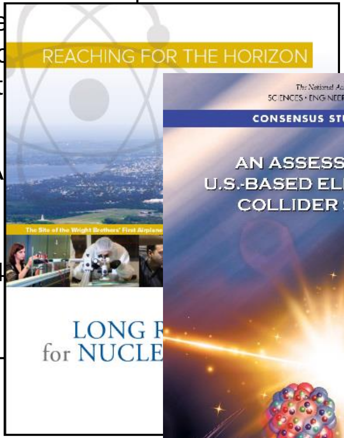


2013



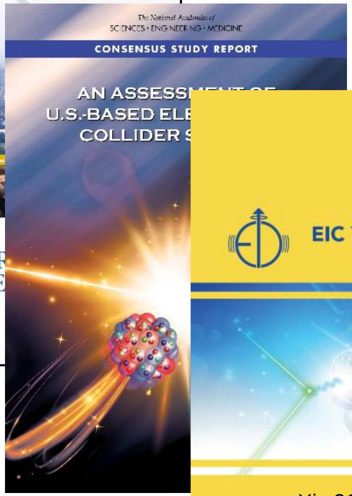
Electron-Ion Collider..*absolutely central* to the nuclear science program of the next decade.

2015



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

2018

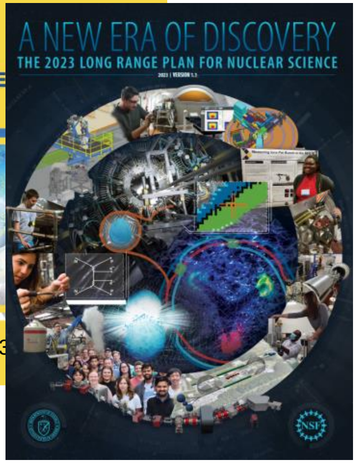


The science questions that an EIC will answer are central to completing an understanding of atoms as well as being integral to the agenda of nuclear physics today."

2021

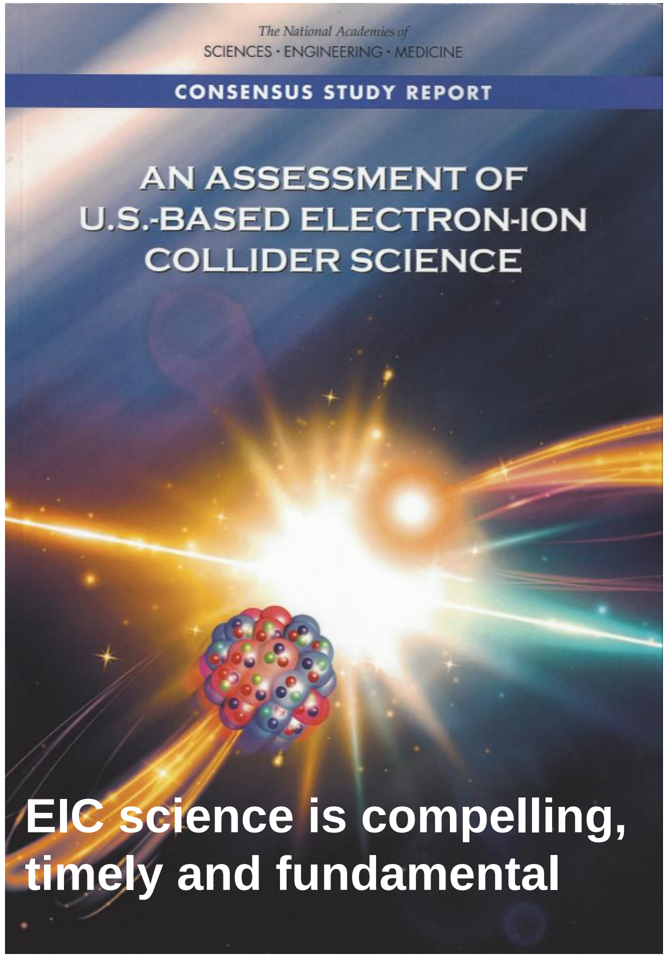
Science Requirements and Detector Concepts for the EIC – Drives the requirements of EIC detectors

2023



We recommend the expeditious completion of the EIC as the highest priority for facility construction.

EIC Science – Findings of the NAS Committee



EIC science is compelling, timely and fundamental

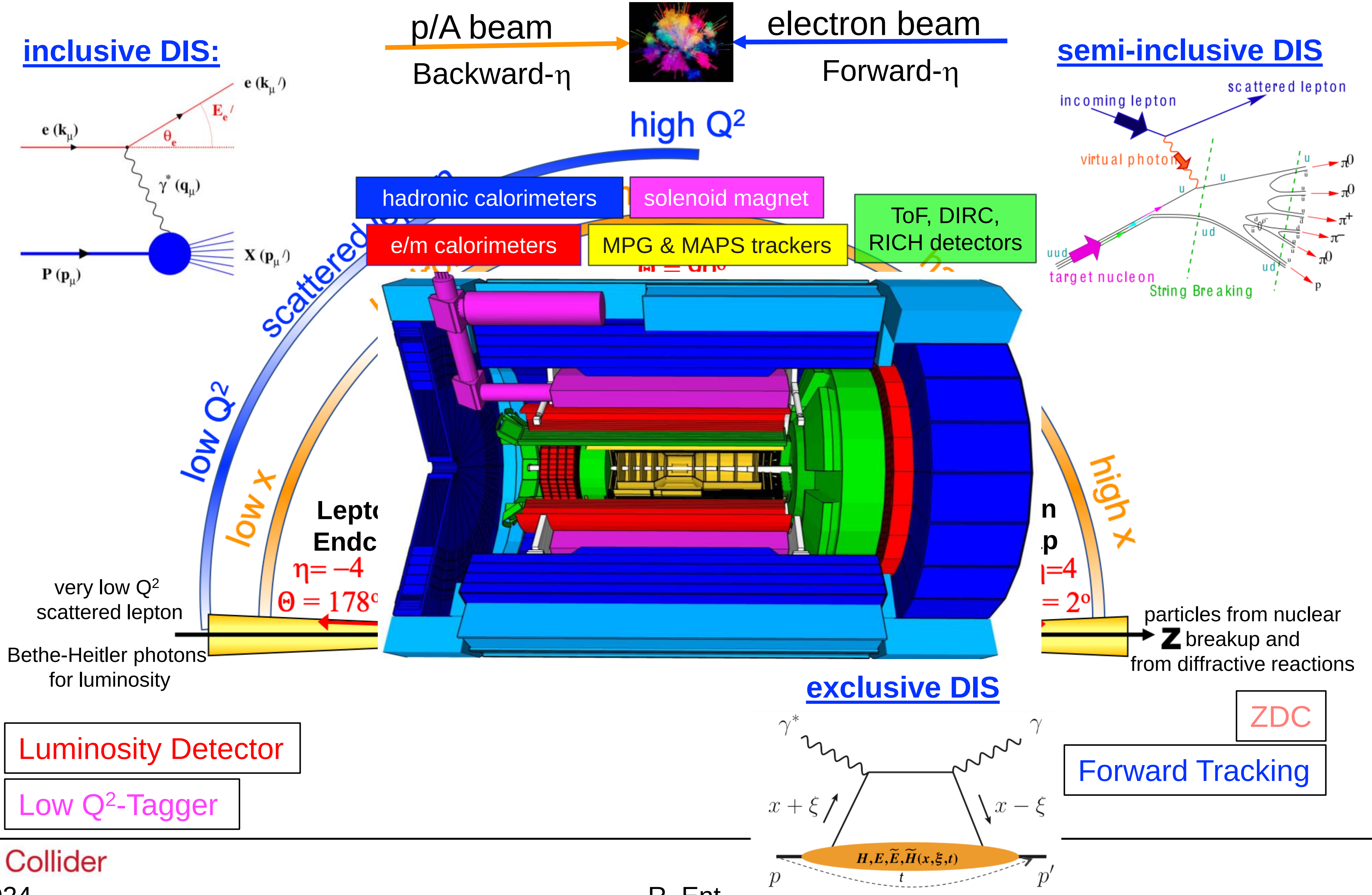
Developed by NAS committee with broad science perspective

2018 The National Academies of SCIENCES · ENGINEERING · MEDICINE

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

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

EIC General Purpose Detector: Concept



UK News

Press release

Major funding unveiled for cutting-edge research tools that could halt future pandemics and protect the planet

Researchers around the world will soon be able to access millions of the natural, historic specimens found in UK museums at the click of a button as part of a £473 million UK fund to enhance key research infrastructure.

From: Department for Science, Innovation and Technology, Science and Technology Facilities Council, UK Research and Innovation and The Rt Hon Michelle Donelan

Published 27 March 2024

More than £58 million will go towards a joint project with the United States Department of Energy to develop new infrastructure that will address fundamental questions on the nature of matter. It will be built by Science and Technology Facilities Council laboratories in Daresbury and Oxfordshire, with support from universities across the UK, before being installed at the Electron-Ion Collider (EIC) at the Brookhaven National Laboratory in New York. This new particle accelerator facility will join top infrastructure like the Large Hadron Collider, built by CERN in 2010 and stationed near Geneva, in leading major scientific breakthroughs on a global scale.

The EIC will give scientists crucial information about the forces and interactions inside protons and atomic nuclei as the smallest particles interact by colliding beams against each other. Particle accelerators have previously revolutionised our understanding of physics, leading to breakthrough discoveries such as the Higgs boson, a vital building block of our universe, as well as the development of life-saving medical technologies. UK scientists will have access to the groundbreaking new facility following their frontline role in developing this international project.

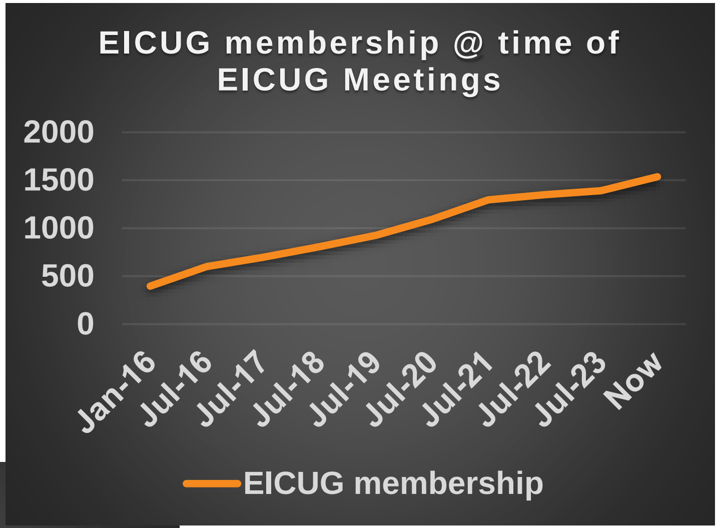
Community: EIC User Group and ePIC Collaboration

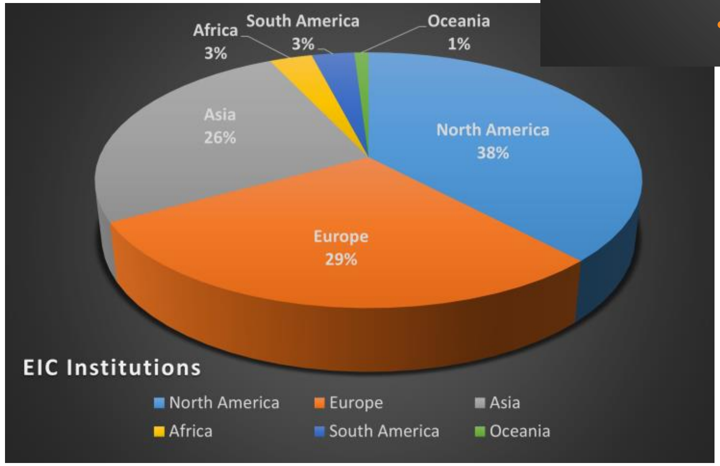
The EIC Users Group: EICUG.ORG

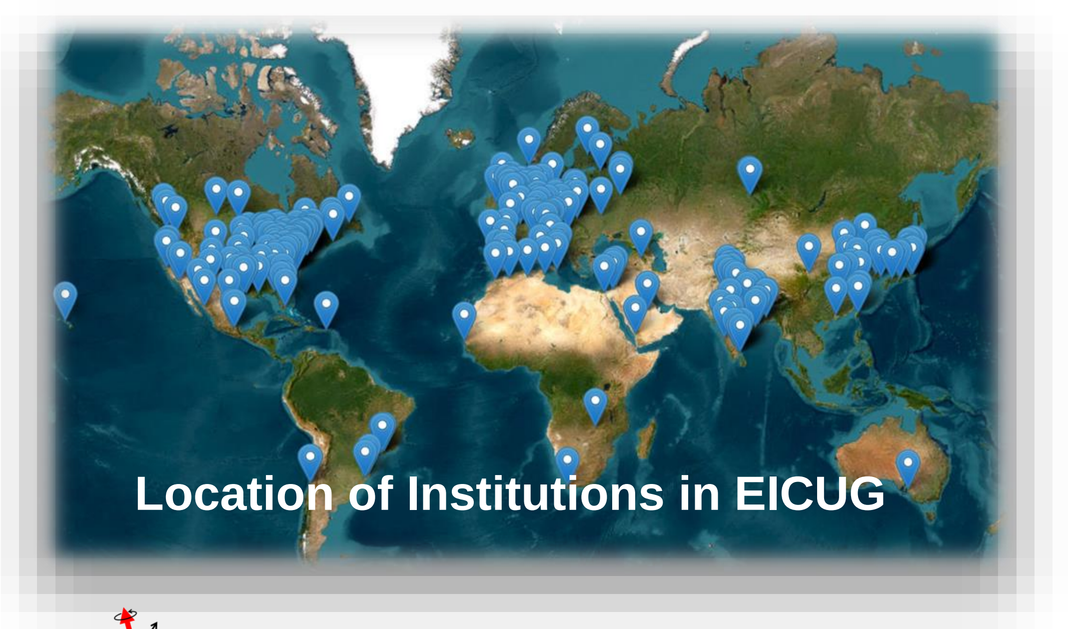
Formed in 2016 → Now

1546 users, 40 countries, 298 institutions

- Experiment 1022
- Theory 376
- Acc. Sci. 132
- Comp. Sci. 9
- Other 7







The ePIC Collaboration:

https://wiki.bnl.gov/EPIC/index.php?title=Main_Page

Formed in 2022 → Now

~850 collaborators, 25 countries, 173 institutions

Collaboration Leadership:

John Lajoie (ORNL)	*Spokesperson*
Silvia Dalla Torre (INFN Trieste)	*Deputy-Spokesperson*

ePIC in 2024 approved as CERN recognized experiment

EIC Science is Well Known and Highly Cited

- EIC White Paper that guided the EIC science written following a 10-week program at the Institute for Nuclear Theory
  - Electron-Ion Collider: The Next QCD Frontier: understanding the glue that binds us all
  - arXiV:1212.1701 & Eur. Phys. J. A 52 (2016) 9, 268 – **1691 citations (09/29/2024)**
- Year-long EIC User Group driven EIC Yellow Report activity (December 2019 – February 2021)
  - Science Requirements and Detector Concepts for the EIC – The Yellow Report set the (*initial*) EIC detector requirements.
  - Requirements further updated during proposal and follow-up processes
  - arXiv:2103.05419 & Nucl. Phys. A 1026 (2022) 122447 – **948 citations (09/29/2024)**

The EIC is a facility for the world

- Ongoing: Year-long ePIC driven activity to draft a Technical Design Report – plan to be published as were the earlier EIC White Paper and the Yellow Report.

The ePIC Detector

- Asymmetric beam energies
  - requires an asymmetric detector with electron and hadron endcap
  - tracking, particle identification, EM calorimetry and hadronic
    calorimetry functionality in all directions
  - very compact Detector, Integration will be key
- Imaging science program with protons and nuclei
  - requires specialized detectors integrated in the IR over 80 m
- Momentum resolution for EIC science
  - requires a large bore 2T magnet
    (1.7 T magnet operation point, stretch goal 2T
    that has same geometry as the BaBAR magnet).
- Highest scientific flexibility
  - requires Streaming Readout electronics model

hadronic calorimeters (HCAL)

Solenoidal Magnet

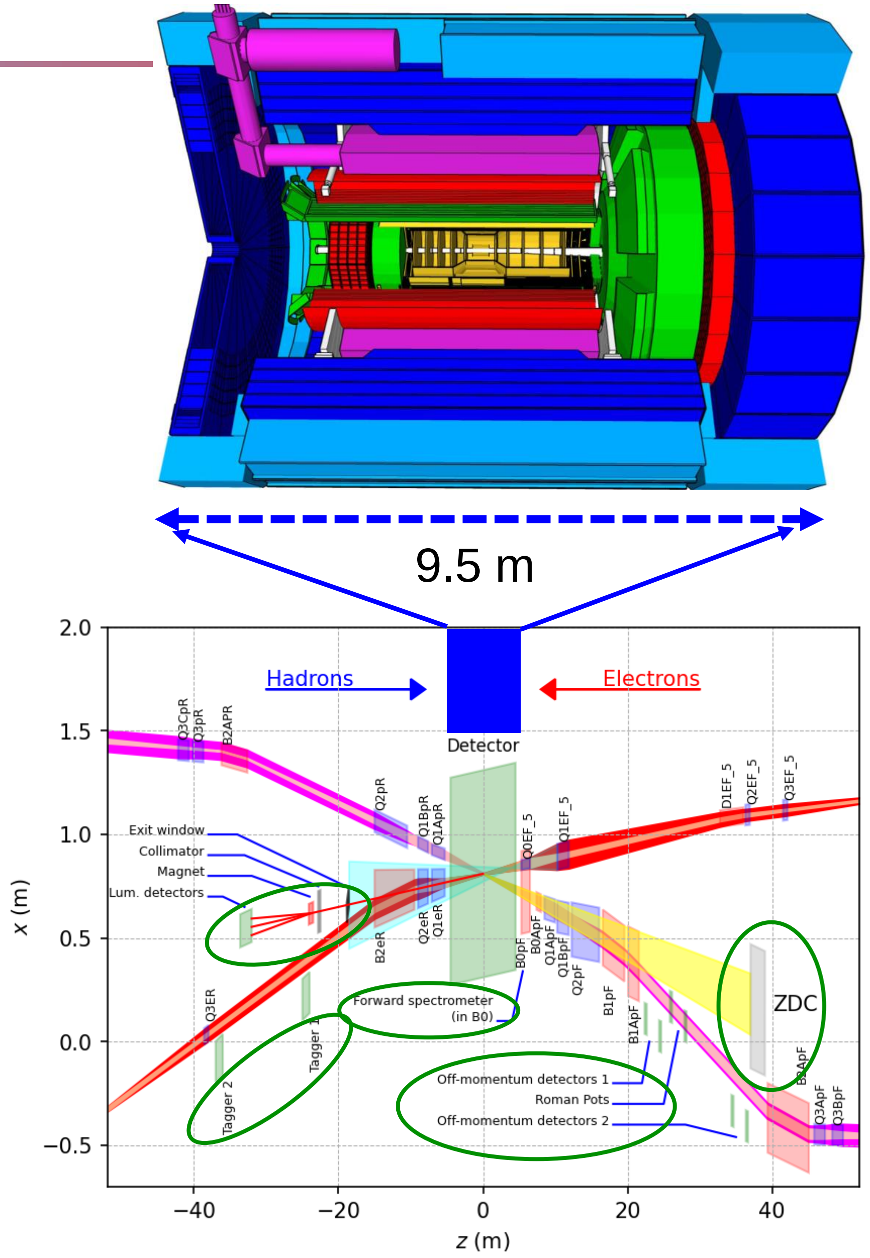
e/m calorimeters (ECal)

Time.of.Flight (ToF), DIRC, RICH detectors

MPGD trackers

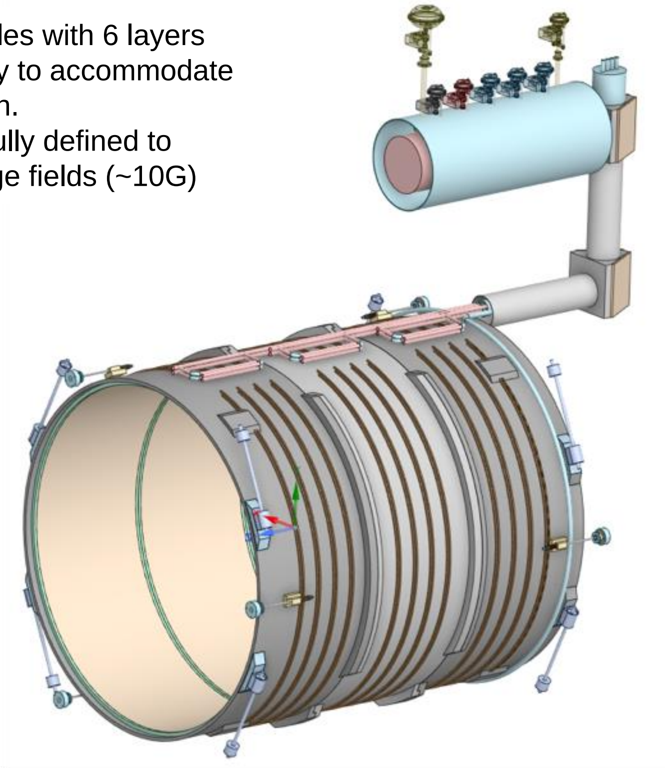
MAPS tracker

24 Subdetectors
incl. Polarimeters
+ Electronics
+ Data Acquisition



ePIC: MARCO Magnet

Coil is divided in 3 modules with 6 layers each. This is done mainly to accommodate possible conductor length.
Flux return steel layout fully defined to minimize forces and fringe fields (~10G)

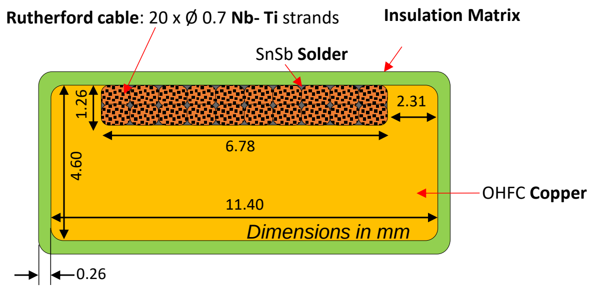


Mechanical: 2D and 3D mechanical analysis done on the overall magnet assembly, coils, mandrel and tie-rods: All stresses and displacements are well within the acceptable limits.

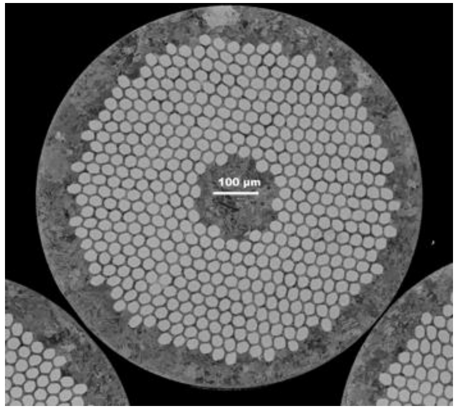
Cryogenic: Redundant cooling system is used to ensure that thermosiphon works properly

B_0	1.5 T	1.7 T	2.0 T	Units
Current	2942	3335	3924	A
T_{op}	4.7	4.7	4.7	K
B_{peak}	2.00	2.27	2.67	T
Temp. margin	3.06	2.82	2.45	K
Load line margin	59.6	54.2	46.1	%
I / Ic(T,B_{peak})	17.9	22.1	29.3	%

Robust and safe operating parameters



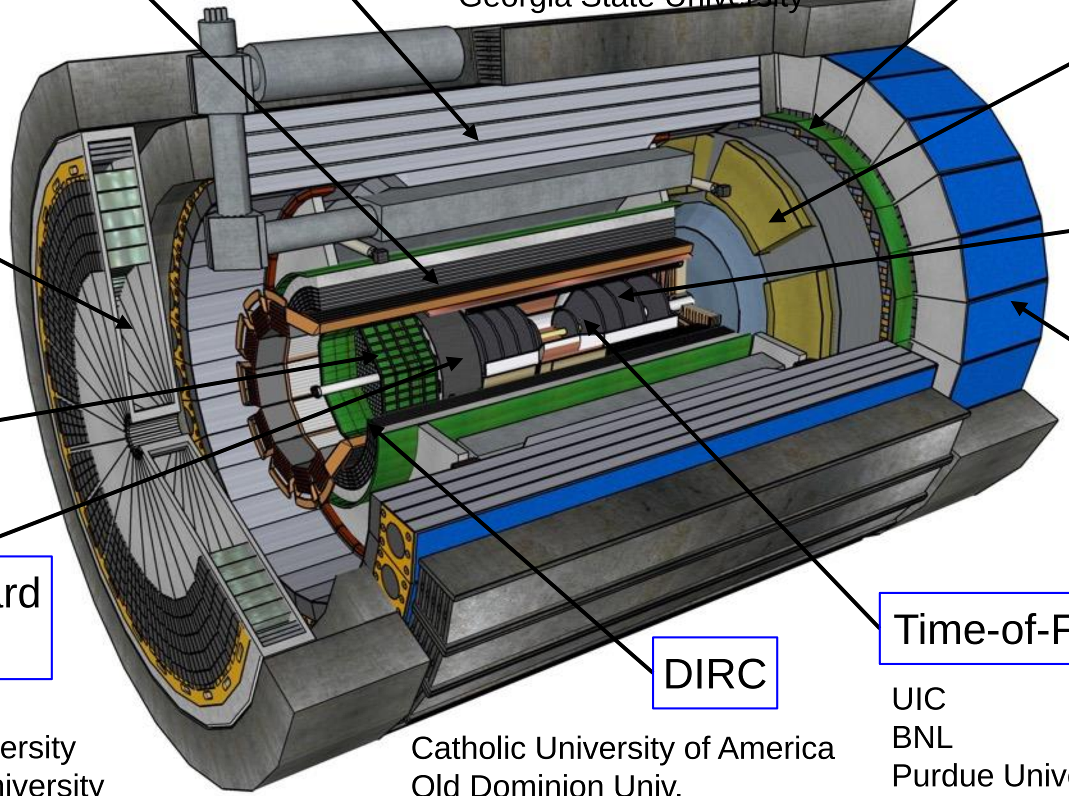
6.10.07 Magnet – strands that are sent from Luvata to Twente for sample tests, the filaments are beautifully arranged and tests confirmed specifications – These were the final quality assurance tests before starting the long-lead procurement for conductor.



Magnet Status:
- Magnet Design Report (180+ pages) – drafted and iteration ongoing
- Magnet Specification Document- 1st draft ready
- Magnet Acceptance Plan- 1st draft ready
- Inspection, Test Plan (ITP) – 1st draft ready
- Statement of Work – Have the draft from the RFI (Request For Information) of Spring 2023. Need to make further edits to the tender package.
- All documents shared with INFN and CEA/Saclay

Conductor Status:
- Order of conductor samples is in place with Luvata
- Conductor is similar to conductor used for 11.7 T MRI magnet at CEA, Saclay
- First samples received, pass visual (electron microscope) inspection
- Sent to test facility (U Twente) for sample conductor qualification; passed specifications
- Technical specifications and Statement of Work ready
- Technical Production Readiness Review ready
- RFP is launched

Detector US University Partnerships and US National Labs



Barrel Electromagnetic Calorimeter
ANL
NASA Goddard Space Flight Center
Oklahoma State University
The Ohio State University
UC Santa Cruz
University of Connecticut

Barrel Hadron Calorimeter
Baruch College, NY
Columbia University
Iowa State University
BNL
Rutgers University
University of Connecticut
Georgia State University

Forward Electromagnetic Calorimeter
Indiana University
UCLA
UCR

Dual-radiator RICH
Duke University
Temple University

Tracking Detectors
LBNL
LANL
UC Berkeley
Purdue University
Florida Institute of Technology
JLab
Temple University
BNL

Backward Hadronic Calorimeter
BNL
Rutgers University
Georgia State University
UIUC
The Ohio State University

Backward Electromagnetic Calorimeter
Abilene Christian University
Catholic University of America
Florida International University
JLab
Lehigh University
MIT
University of Kentucky
William & Mary
Ohio University

Backward RICH
BNL
Duke University
Purdue University
Temple University
Georgia State University
Yale University
Stonybrook University

DIRC
Catholic University of America
Old Dominion Univ.
SBU
JLab
University of South Carolina
Wayne State University

Time-of-Flight
UIC
BNL
Purdue University
RICE University
UC Santa Cruz
Kent State

Forward Hadron Calorimeter
ORNL
Georgia State University
Yale University
ISU
Indiana University
UCR
University of Tennessee Knoxville
Valparaiso University
UT Austin

Detector US University Partnerships and US National Labs – cont.

Data Acquisition, Slowcontrol, Quality Assurance of different components, Software

Augustana University
BNL
California Polytechnic State University, San Luis Obispo
Canisius College
Christopher Newport University
College of William and Mary
Creighton University
George Washington University
Hampton University
JLab
Lawrence Livermore National Laboratory
Mississippi State University
Morehead State University
Ohio University
ORNL
Southern Methodist University
University of California, Davis
University of Colorado Boulder
University of Illinois Urbana-Champaign
University of Massachusetts, Amherst

Detectors along the beamline

BNL
JLab
MIT
Pacific Northwest National Laboratory
Temple University
University of Houston
University of Kansas

Central Detector Non-DOE Interest & In-Kind

In-kind contribution goal: 30% of the Detector

Barrel Electromagnetic Calorimeter

Karlsruhe Institute of Technology

Yonsei University,
Gangneung-Wonju National University,
Hanyang University
Jeonbuk National University
Korea University
Kyungpook National University
University of Seoul
Pusan National University
Sungkyunkwan University
Sejong University
Hanyang University
Yonsei University

University of Regina

Superconducting Solenoid

Dual-radiator RICH

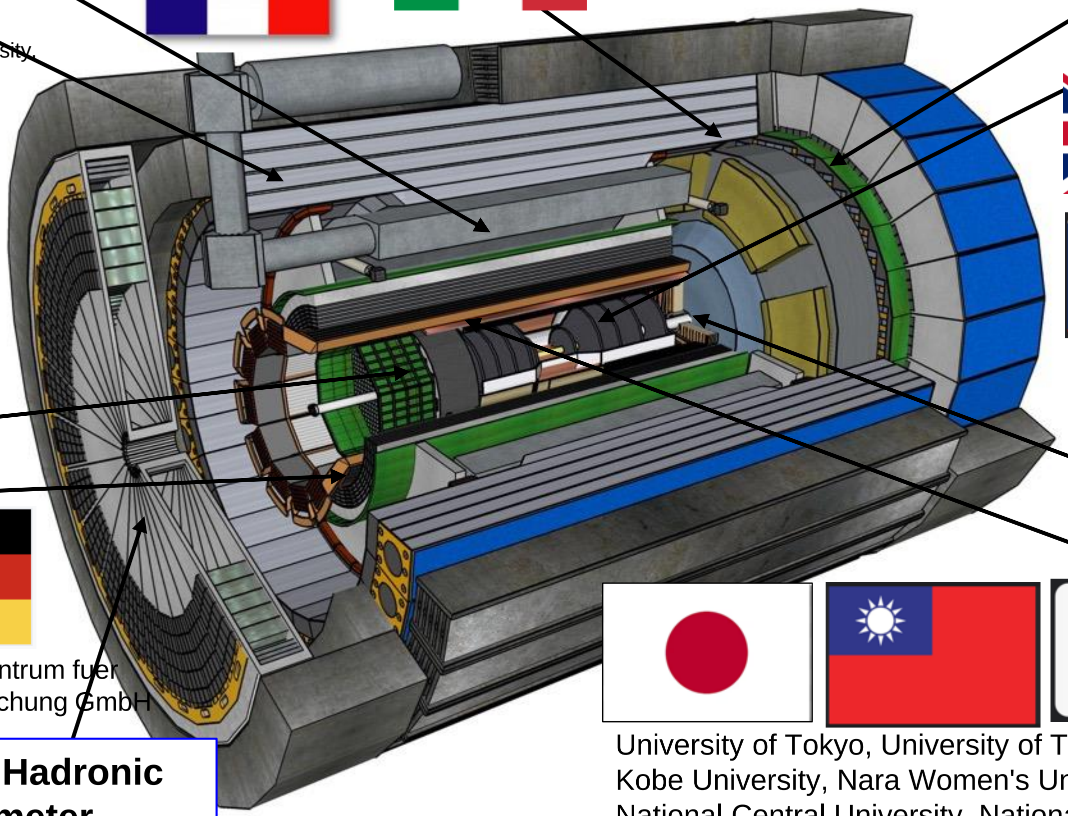
INFN Sezione di Bologna
Università di Bologna
INFN Sezione di Ferrara,
Università di Ferrara
INFN Sezione di Trieste
Universita di Trieste

Forward Electromagnetic Calorimeter

Tracking Detectors

University of Birmingham,
Daresbury Laboratory,
INFN Sezione di Bari,
Università di Bari,
Università di Foggia,
INFN Sezione di Padova,
Università di Padova,
INFN Sezione di Pavia,
INFN Sezione di Trieste,
Universita di Trieste,
Czech Technical University in Prague,
Rutherford Appleton Laboratory
University of Liverpool,
CEA-Saclay,
Seoul National University,
INFN Sezione di Roma Tor Vergata,
Universita di Roma Tor Vergata

CERN



Backward Electromagnetic Calorimeter

NSF

IJClab (Orsay)
A. Alikhanian National Laboratory, Armenia,
Charles University (CUNI), Prague

DIRC

GSI Helmholtzzentrum fuer Schwerionenforschung GmbH

Backward Hadronic Calorimeter

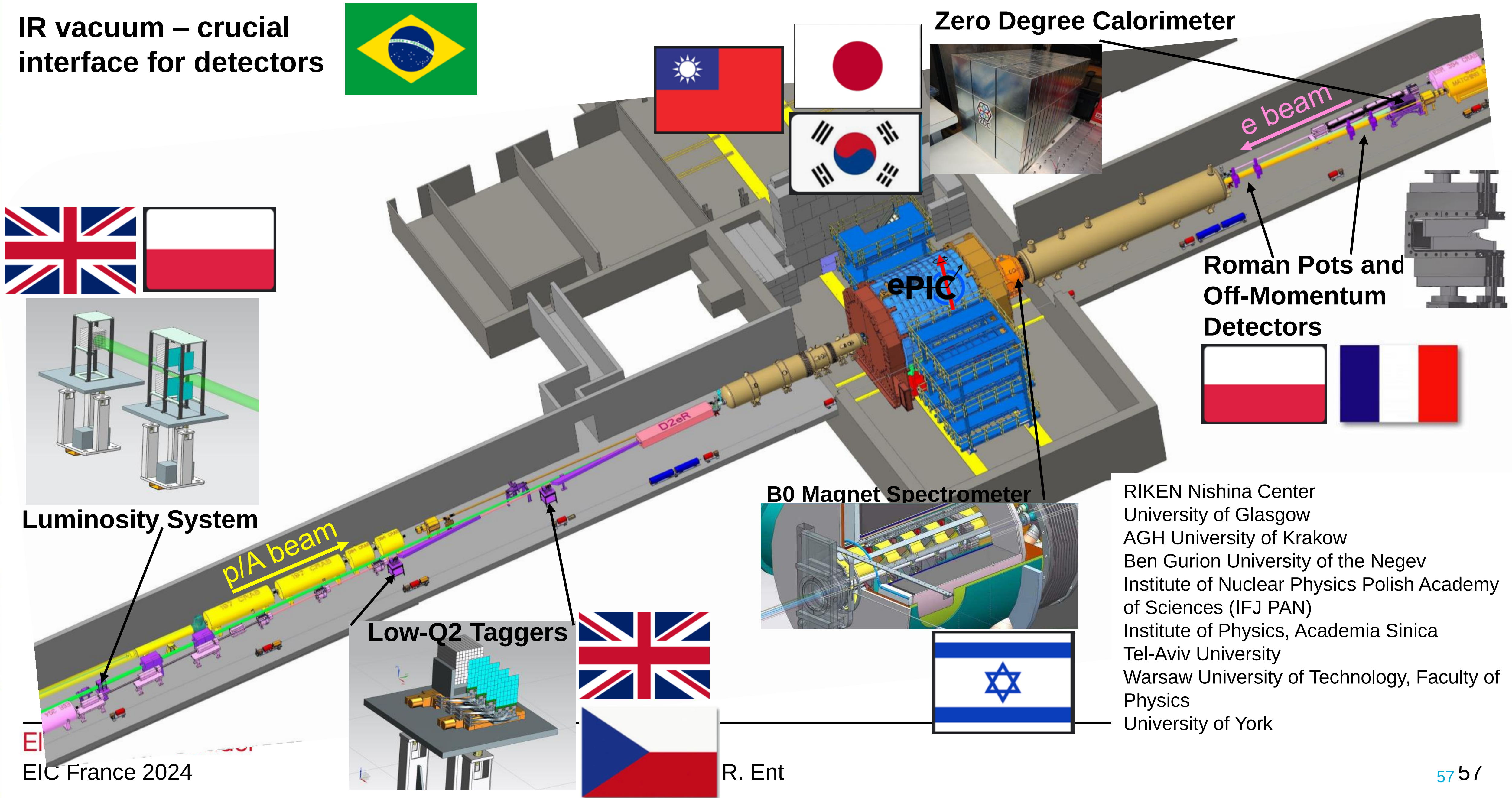
Czech Technical University in Prague,
NPI The Czech Academy of Sciences

Time-of-Flight

University of Tokyo, University of Tsukuba, Hiroshima University
Kobe University, Nara Women's University, Nihon University, Shinshu University
National Central University, National Cheng Kung University
National Taiwan University, National Tsing Hua University

Data-Acquisition Electronics

Far-Forward/Far-Backward Detectors Non-DOE Interest & In-kind



RIKEN Nishina Center
University of Glasgow
AGH University of Krakow
Ben Gurion University of the Negev
Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN)
Institute of Physics, Academia Sinica
Tel-Aviv University
Warsaw University of Technology, Faculty of Physics
University of York

US National Laboratory (Main) Involvement – not including BNL and JLab

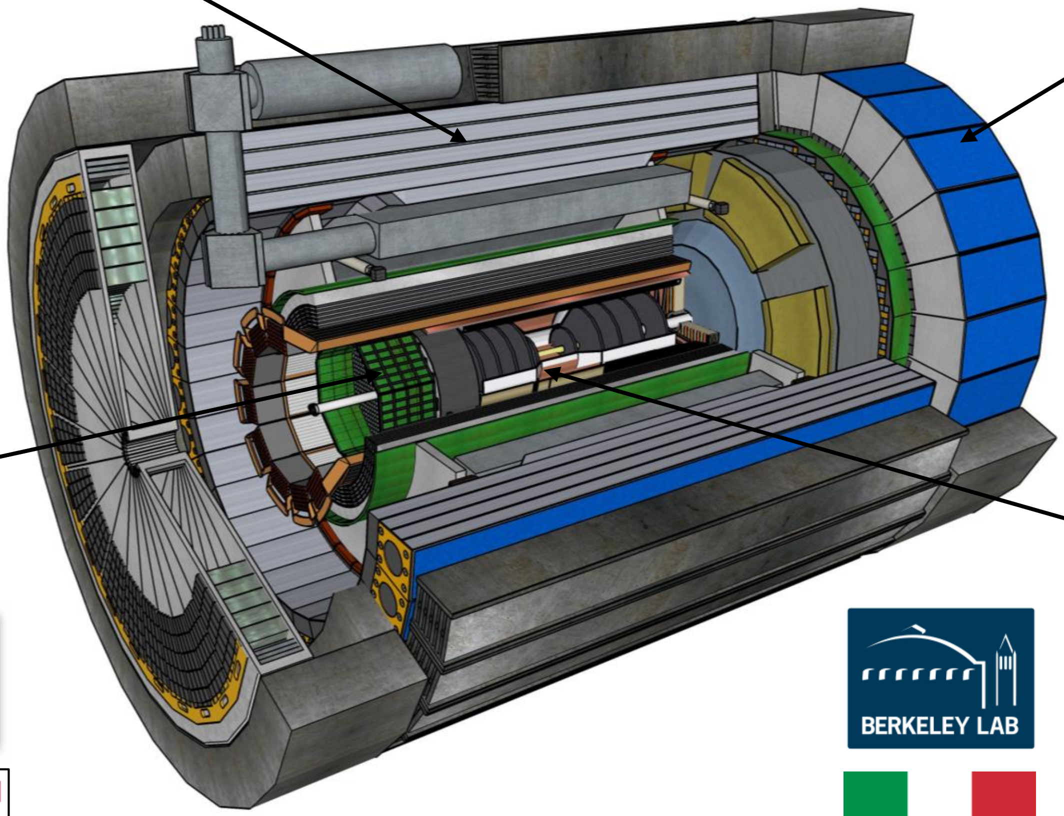
Barrel Electromagnetic Calorimeter

Argonne NATIONAL LABORATORY

Forward Hadron Calorimeter

OAK RIDGE National Laboratory

(ORNL also large involvement in DAQ/electronics)



Backward Electromagnetic Calorimeter

Silicon/MAPS Tracking Detectors

BERKELEY LAB

CERN

Los Alamos NATIONAL LABORATORY

International Engagement: Resource Review Board (RRB) Meetings

DOE and the host labs promoting the EIC as a facility “fully international in character.”

Initial RRB Co-Chairs:

- Haiyan Gao (BNL)
- Diego Bettoni (INFN)

https://www.bnl.gov/eic-rrbmeeting/

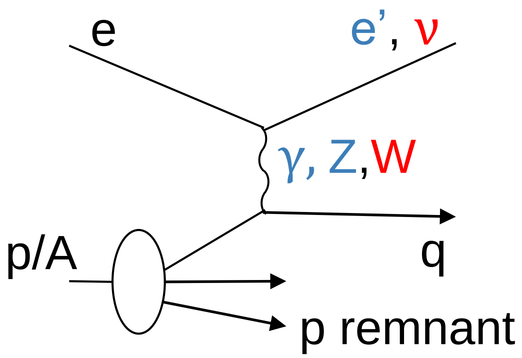
1st RRB meeting on April 3-4, 2023 at Stony Brook University.

2nd RRB meeting on December 7 + 8, 2023 at Catholic University of America.

3rd RRB meeting on May 6 + 7, 2024 in Rome hosted by INFN/Italy

4th RRB meeting will be at BNL on November 12 + 13, 2024

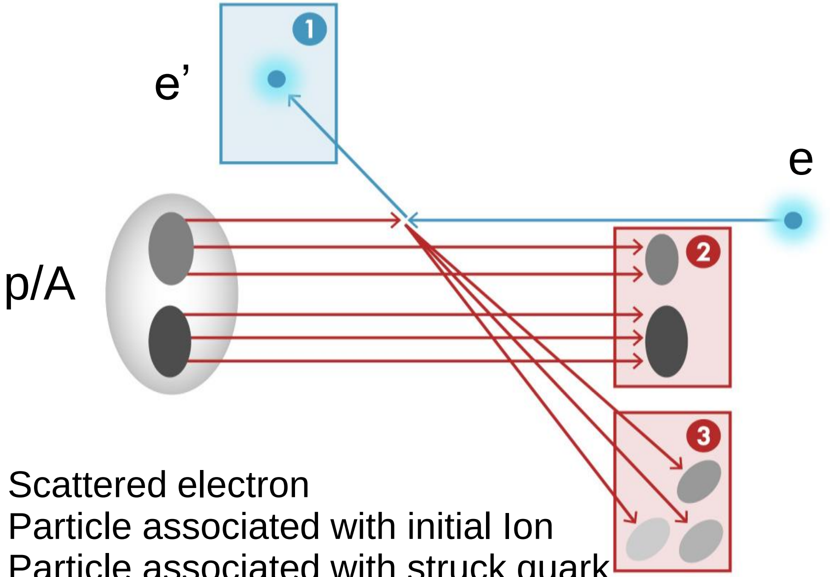
Detector Integration Challenge of the EIC



Aim of EIC is 3D nucleon and nuclear structure beyond the longitudinal description.

This makes the requirements for the machine and detector different from all previous colliders.

"Statistics" = Luminosity × Acceptance



1. Scattered electron
2. Particle associated with initial Ion
3. Particle associated with struck quark (or associated gluon)

EIC Physics demands ~100% acceptance for all final state particles (including particles associated with initial ion)

Ion remnant is particularly challenging
- not a usual concern at colliders
- at EIC integrated from the start with a highly integrated (and complex) detector and interaction region scheme.

Documented in CDR, Yellow Report, etc