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U.S. DEPARTMENT OF ENERGY

The EIC Detector Selection process; and the Path to a Possible Second Detector

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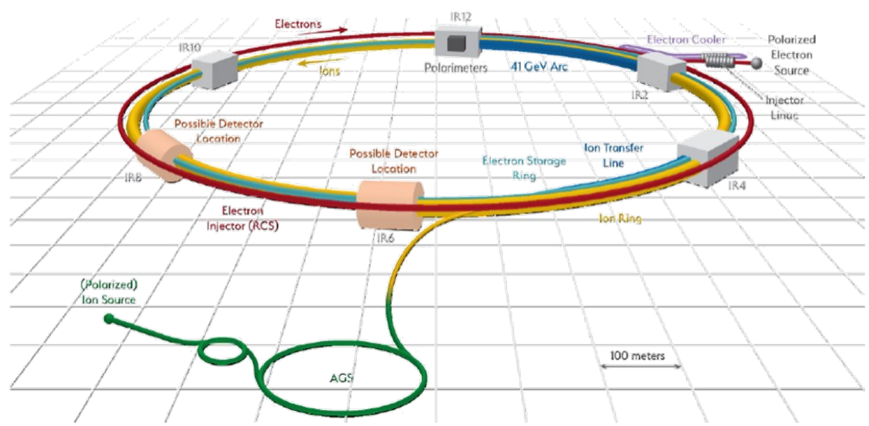
Perceiving the Emergence of Hadron Mass through Amber@CERN

The Electron-Ion Collider

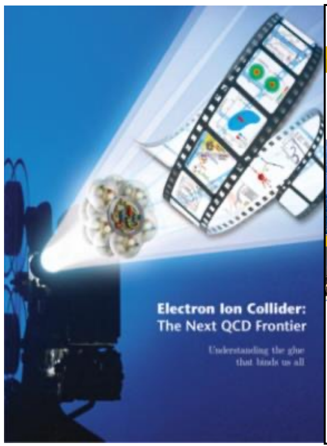
Project Design Goals

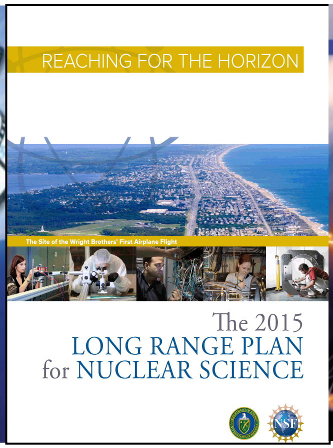
- High Luminosity: L= 10^{33}–10^{34} $cm^{-2}sec^{-1}$, 10–100 fb^{-1}/year
- Highly Polarized Beams: ~70%
- Large Center of Mass Energy Range: E_{cm} = 20–140 GeV
- Large Ion Species Range: protons – Uranium
- Large Detector Acceptance and Good Background Conditions
- Accommodate a Second Interaction Region (IR)

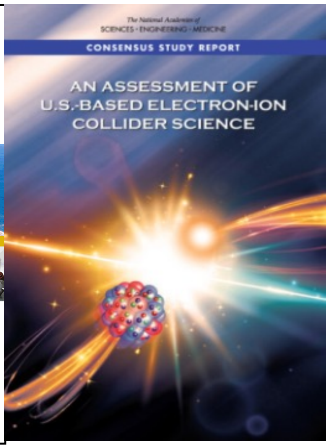
Conceptual design scope and expected performance meet or exceed NSAC Long Range Plan (2015) and the EIC White Paper requirements endorsed by NAS (2018)



Double Ring Design Based on Existing RHIC Facility







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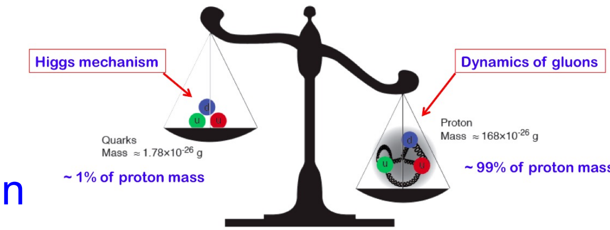
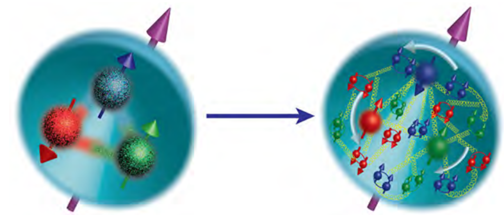
Major milestones: CD-0 December 2019; DOE EIC site (BNL) selection on Jan 9, 2020; CD-1 June 2021; EIC project detector reference design selection March 2022

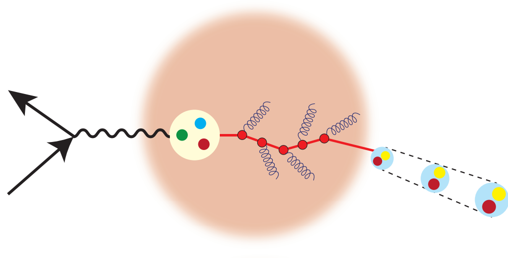
EIC Physics at-a-Glance



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?





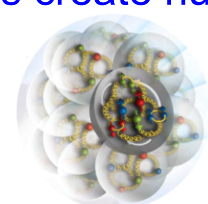
How do color-charged quarks and gluons, and colorless jets, interact with a nuclear medium?

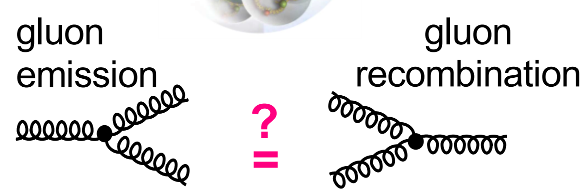
How do the confined hadronic states emerge from these quarks and gluons?

How do the quark-gluon interactions create nuclear binding?

How 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, giving rise to a gluonic matter with universal properties in all nuclei, even the proton?



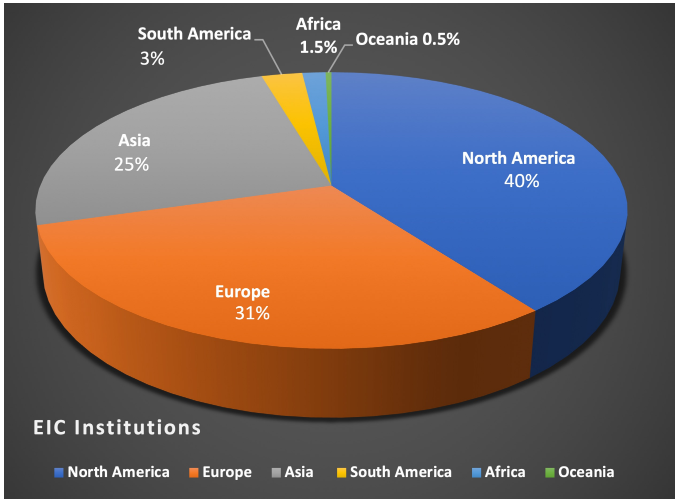


World-Wide Interest in EIC Physics

The EIC Users Group: EICUG.ORG

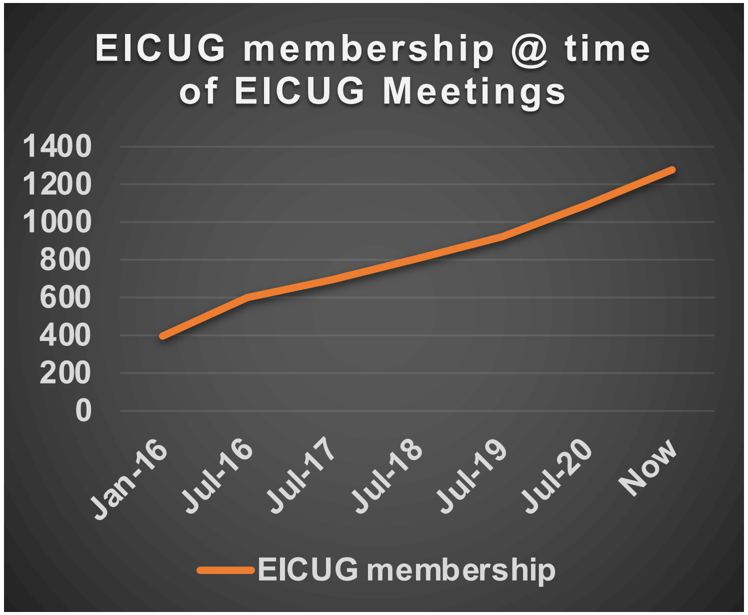
Formed in 2016, Current Status

1307 collaborators, 36 countries, 265 institutions
(Experimentalists 810, Theory 325, Acc. Sci. 159)



- EICUG has continuously grown since its formation, notably after CD-0 and site-selection
- Growth will continue as EIC project moves into construction

Location of Institutions

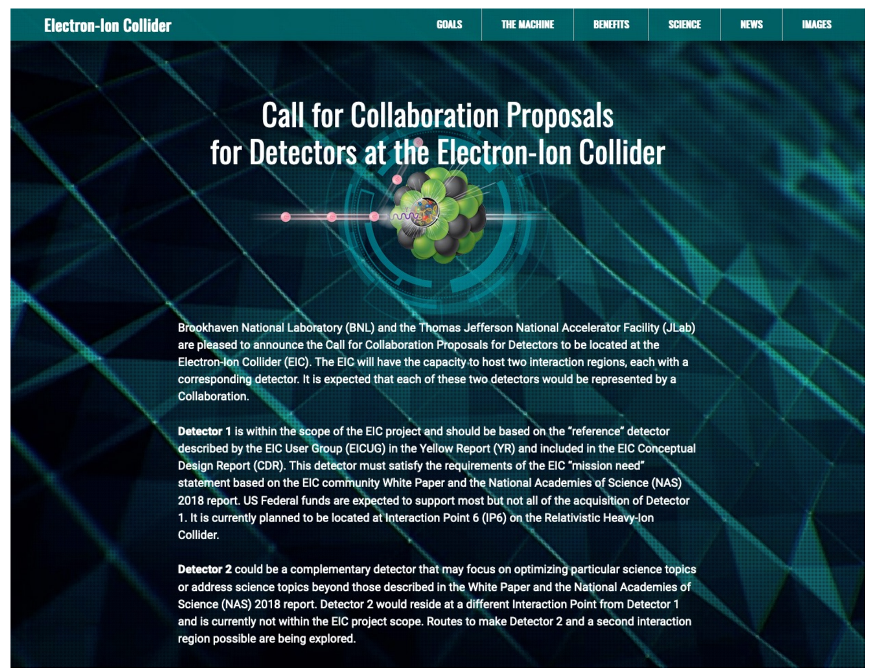


Yellow Report

"Yellow report" laying out physics case, detector requirements, and evolving detector concepts arXiv:2103.05419

Call for Proposals

Issued jointly by BNL and JLab in March 2021 with input from DOE and the EIC User Group.
Proposals due December 1, 2021



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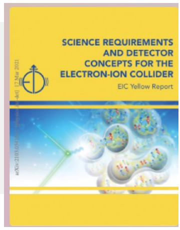
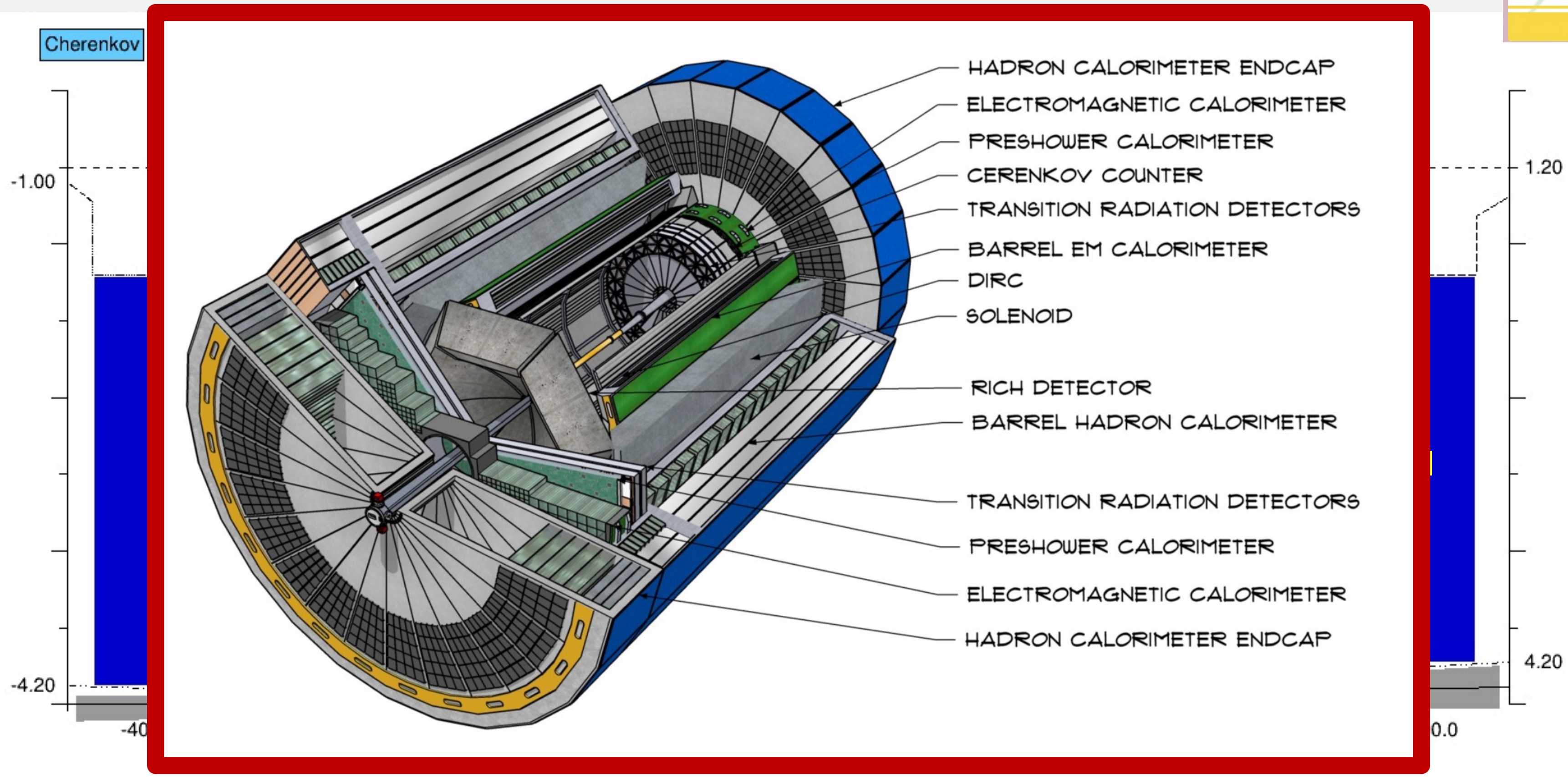
Concept DETECTOR

This detector concept was included in the EIC CDR prepared for the CD1 Review





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EIC Detector Proposal Advisory Panel

A scientific-technical committee of renowned and independent experts to evaluate the proposals was jointly appointed by BNL and JLab.

Patricia McBride, co-chair	FNAL
Rolf Heuer, co-chair	CERN, Former CERN Director General
Sergio Bertolucci	INFN Sezione di Bologna, Former CERN Research Dir.
Daniela Bortoletto	Oxford Univ.
Markus Diehl	DESY
Ed Kinney	U. Colorado EIC DAC Chair
Fabienne Kunne	Paris-Saclay
Andy Lankford	UC Irvine
Naohito Saito	KEK, Former J-PARC Director
Brigitte Vachon	McGill Univ. EIC DAC Member
Tom Ludlam, Scientific Secretary	BNL

Charge to the Advisory Panel

The primary goal of the EIC Detector Proposal Advisory Panel is to advise BNL and JLab on how to realize an optimal set of experimental equipment at the EIC utilizing the resources and expertise of the EIC user community. This advice should address the following:

- The first priority is to identify the optimal approach to realize a detector system, designated Detector 1, to be primarily funded by the EIC project and capable of addressing the science case in the EIC White Paper and NAS Report.

- The second priority is to assess options for an alternate detector system, designated Detector 2, possibly addressing science beyond the White Paper and NAS Report and/or enabling some complementarity to Detector 1. Such a second detector could be envisioned to be realized up to 3-5 years after Detector 1. Currently, the EIC project scope does not include the construction of Detector 2 or the accelerator components needed for the second interaction region.

Charge to the Advisory Panel

Based on the proposals submitted, the Panel should evaluate the scientific merit, the expected scientific performance, technical risk, cost, and schedule of the experiment proposed as well as the availability of resources. We welcome guidance and advice on the following topics:

- What are the strengths and weaknesses of the submitted collaboration proposals for detectors at the EIC, including the criteria listed above?
- How can the resources and expertise of the EIC user community be best utilized?
- Comment on the complementary science reach of two potential EIC detectors to be located at Interaction Points 6 (IP6) and 8 (IP8).

To aid the Panel in its assessment, the EIC Project Detector Advisory Committee (DAC) will provide an independent evaluation of each of the detector proposals, based on the DAC's expertise in detector technologies and related cost and risk assessment.

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EIC Project Detector Advisory Committee (DAC)

Name	Institition	Expertise
Edward Kinney	Univ. of Colorado, Boulder	EIC Science, general
Ewa Rondio	NCBJ, Warsaw	EIC Science, general
Werner Riegler	CERN	Integration
Greg Rakness	Fermilab	Integration
Peter Krizan	Univ. Ljubljana	Particle Identification
Ana Amelia Machado	Univ. of Campinas, Brazil	Particle Identification, Sensors
Heidi Schellman	Oregon State Univ.	Computing
Brigitte Vachon	McGill Univ.	Electronics
Glenn Young	BNL	Calorimetry
Etiennette Auffray	CERN	Calorimetry
Andrew White	U. Texas, Arlington	Tracking
Chi Yang	SDU, China	Tracking

This Committee was expanded for this process to include James Fast (JLab) and Cathy Lavelle (BNL) to provide additional expertise on project issues and cost assessments

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Timeline for Proposal Evaluation

December 1, 2021 Proposals submitted: ATHENA, ECCE, CORE
Proposals distributed to Advisory Panel and DAC members

December 13-15, 2021   First public Advisory Panel meeting (3 days, Virtual)

- Presentations from proto-collaborations
- Panel discussion of DAC evaluation
- Panel developed homework questions for collaborations to address at January meeting

January 19-21, 2022   Second 3-day Advisory Panel meeting (executive sessions)

- Responses to homework and further input from DAC
- Panel began Report writing

March 8, 2022   Public closeout on panel's recommendations

March 21, 2022.   Panel final report released and available at

https://www.bnl.gov/dpapanelmeeting/index.php

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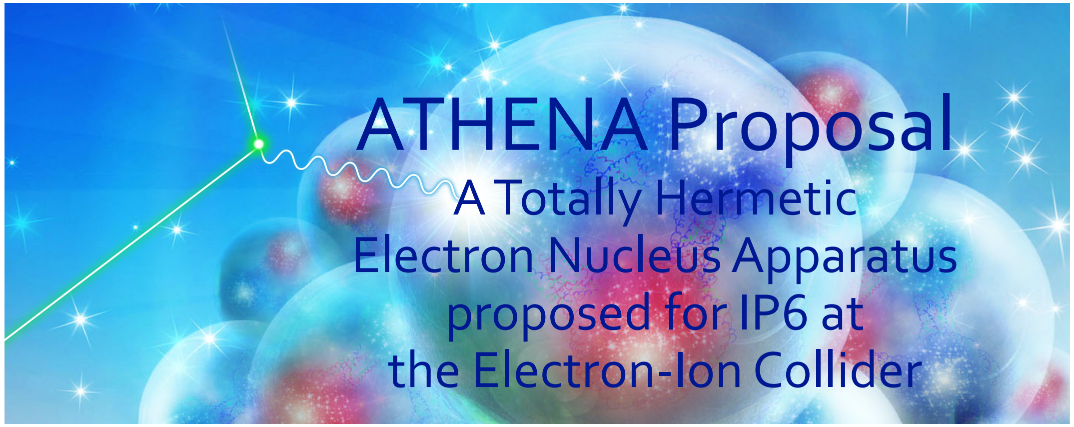
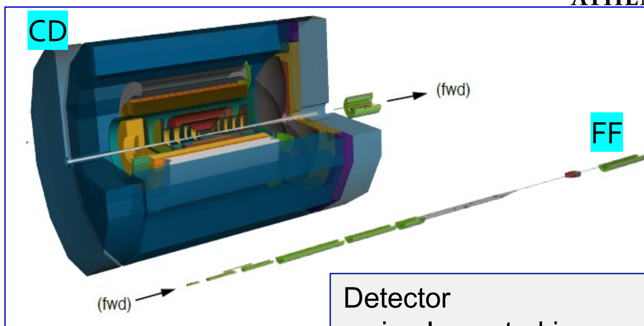


What characterizes ATHENA: **DETECTOR**

- INCLUDES
  - **CENTRAL DETECTOR** (CD)
  - **Far Forward** (FF) & **Far Backward** (FB) subdetectors

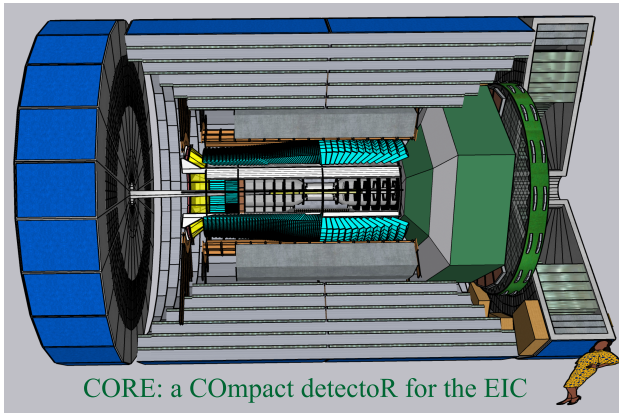


Detector as implemented in GEANT4 the FullSim

- **ATHENA DETECTOR matches ALL REQUIREMENTs** for EIC physics program by
  - Light, large-bore 3-T solenoid
  - Fully exploiting the IP6 potentialities (longitudinal and transversal space)
  - Careful choice of technologies, **several innovations since CDR/YR "reference"**
  - acceptance and hermeticity in CD:
    - ✓ careful integration of support structures and detector services to minimize gaps

- **Robust and realistic Detector**
  - careful balance between cutting-edge and mature technologies
  - Largely newly-built detectors that guarantee reliability over 10 y and more
  - Detector and support/services principle allowing for assembly/maintenance interventions

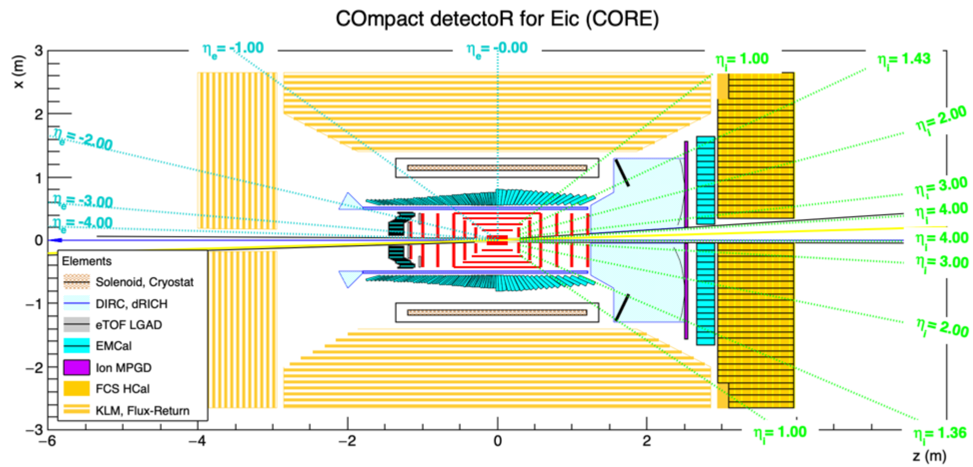
Included part in this talk, part in Thomas Ullrich's talk (tomorrow)



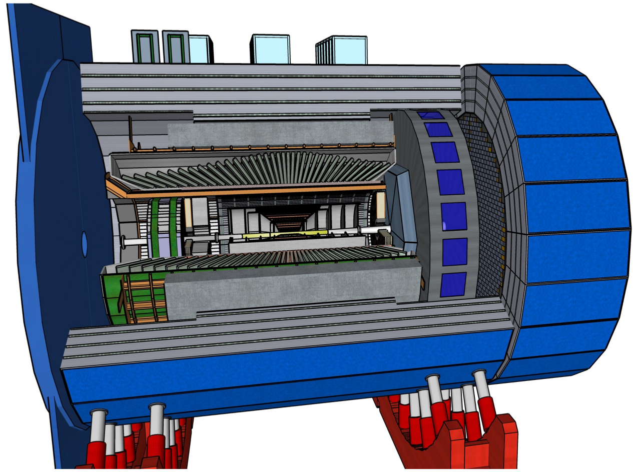
COmpact detectoR for the Eic (CORE)

CORE design philosophy

- A short 3 T solenoid enables high-resolution tracking and a higher luminosity
  - Synergetic with an IR with a 2nd focus, which provides the best far-forward acceptance at the lowest β^*
- A compact core of subsystems around a high-resolution all-silicon tracker inside a spacious flux return, makes the detector cost-effective and provides ample space for supports and services.
- In particular, the compact core makes it affordable to use the best possible EM calorimetry in the barrel, enabling new physics (*e.g.,* tomography of nuclei).

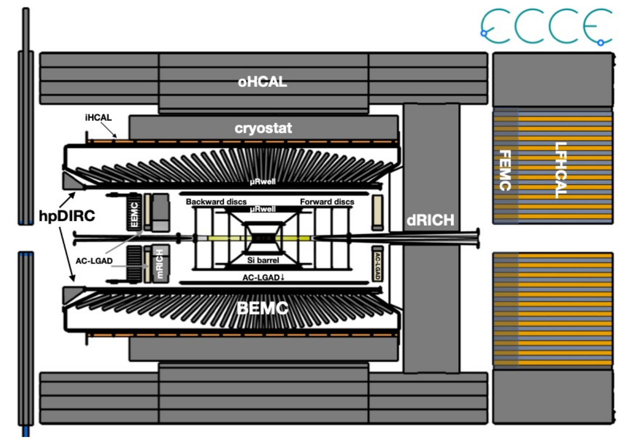


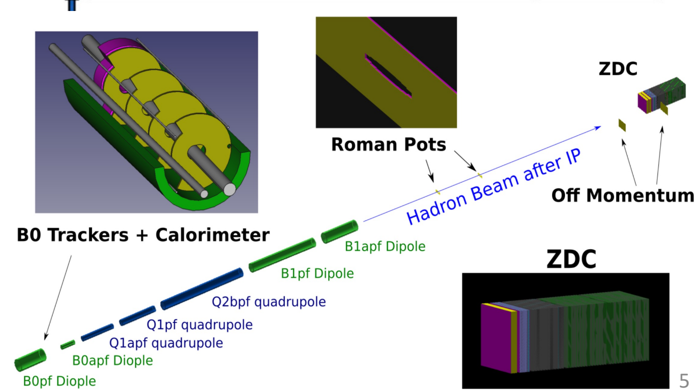
- CORE is a fully hermetic detector with 4π tracking, calorimetry, and PID.
- Since EIC jets generally have low energies and multiplicities, and are best reconstructed from the individual particles, the KLM in the barrel and electron endcap of CORE emphasizes measurement of the position of neutral hadrons and identification of muons.



EIC Comprehensive Chromodynamics Experiment (ECCE)

- Integrated design for physics performance:
  - AI optimized tracking,
  - Excellent calorimetry ($PbWO_4$; SciGlass; …),
  - Comprehensive PID (TOF + Cerenkov + Calo),
  - Reuse BaBar Magnet & sPHENIX HCal,
  - Optimized far-forward / back detectors.
- Established physics reach with Geant4 simulations
- Low-risk design to ensure on-time on-budget project completion:
  - Use advanced yet low-risk technologies,
  - Minimize number of technologies,
  - Magnet design contingency.





Conclusions from DPAP

- **The panel finds that ECCE and ATHENA fulfill all requirements for a Detector 1.**
  - ECCE has several advantages, in particular reduced risk and cost, and qualifies best for Detector 1.
  - CORE presented a more conceptual design and given the tight timeline for CD2/3a would generate a schedule risk for the EIC Project as Detector 1.
- **The panel supports the case for a second EIC detector**
  - DOE resources to start a Detector 2 project will most likely be delayed for several years, or the resources would have to found from other sources. There is significant international participation in the proto-collaborations, however, the panel found the overall resources were insufficient to proceed with a second detector effort at this time.
- **The EIC's project planning for Detector 1 should incorporate a period for integrating new collaborators and re-optimizing experiment conceptual design in advance of CD-2.**

Physics Performance; Detector Concept and Feasibility; Electronics, DAQ, Offline; Infrastructure, Magnet, and Machine Detector Interface; Management and Collaboration

Recommendations from DPAP

- “The panel unanimously recommends ECCE as Detector 1. The proto-collaboration is urged to openly accept additional collaborators and quickly consolidate its design so that the Project Detector can advance to CD2/3a in a timely way.”

- “The panel supports the case for a second EIC detector, however, given the current funding and available resources, the committee finds that a decision on Detector 2 should be delayed until the resources and schedule for the Project detector (Detector 1) are more fully realized.”

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A Key Point from DPAP

"In order to ensure that the EIC has a maximally optimal Detector 1, the proto-collaboration for a concept selected for Detector 1 must be open to: (1) integrating new collaborators in a manner that enables them to make contributions that impact the capabilities and success of the experiment in significant ways, including some new collaborating individuals and groups into positions of responsibility and leadership; and (2) integrating new experimental concepts and technologies that improve physics capabilities without introducing inappropriate risk."

Strength of Collaborations

"The three proto-collaborations are led by experienced, strong leadership teams. ATHENA and ECCE also have expert and experienced international collaborators, as demonstrated by the well-developed state of the proposed conceptual designs prepared in a relatively short period of time, and by the organization of the effort to produce these designs and of the proposals. This accomplishment is truly impressive."

Development following DPAP recommendations

- Meetings with each Proto-collaboration shortly after the closeout
  - Lab management, EIC Project reps
  - Opportunity for questions, discussions

- Subsequent meeting with the three Proto-collaborations together as part of the EICUG Steering Committee meeting on March 24, 2022

- Priority goal is to establish collaboration for project detector and consolidate the design – ongoing and being coordinated by the project team

- A joint leadership team has formed between ATHENA and ECCE with detector and physics working groups

- Detector 1 General Meeting took place April 29th, 2022: https://indico.bnl.gov/event/15371/

- EIC User Group annual meeting July 27-31, 2022, at Stony Brook (hybrid)

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Path towards a possible second EIC detector

- From DPAP report: "…it is essential to have two detectors with a sufficient degree of complementarity in layout and detector technologies. This requires a well-chosen balance between optimization as general-purpose detector versus partial specialization and the ability to cross check the other detector for a broad range of measurements. The design of a second detector should be chosen with these criteria in mind. The time required for its design and construction may offer opportunities for benefiting from technological progress. "

- Opportunities for pursuing detector 2* - DOE Office of Nuclear Physics plans to support generic EIC detector R&D in FY 2022, very positive development!

- US Nuclear Science Advisory Committee (NSAC) is expected to receive a charge from the DOE and NSF in July 2022 on the NSAC Long Range Plan for Nuclear Science

- The top priority is to build the EIC and the project detector/Detector 1

*EICUG Steering Committee has worked on a brochure on the benefits of two detectors

Summary

- EIC is the next QCD frontier with compelling science
- A strong international EIC user community continues to grow
- Major progress has been made with the EIC project in the last year
  - CD-1 approval in June 2021
  - EIC project detector reference design was selected in March 2022
  - Next major milestone for the EIC: CD2/3a
- The EIC community presented a strong case for a second EIC detector, supported by the DPAP; pursuing a path forward towards the 2nd detector with the highest priority on the project detector

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