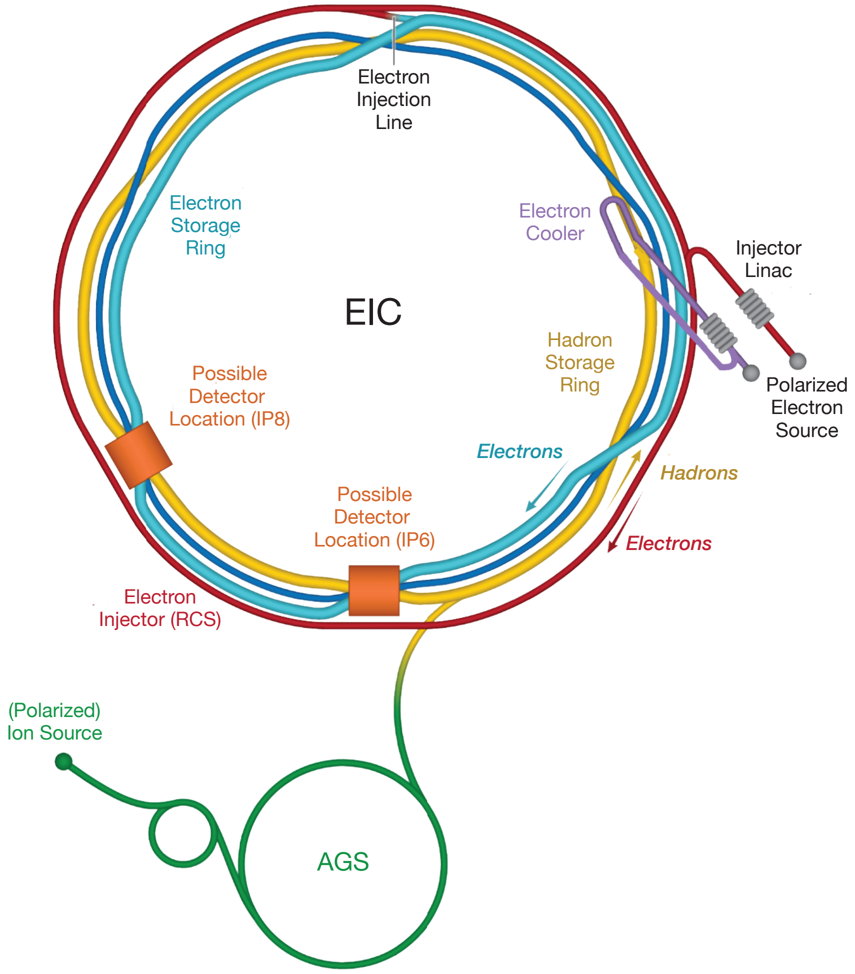
Electron-Ion Collider: Quark-Gluon Imagining in the Era of Streaming Readout and AI/ML

Markus Diefenthaler
EIC^2 at Jefferson Lab

Subject of the Talk: The Electron-Ion Collider (EIC)



Frontier accelerator facility in the U.S.

- **World's first collider of**:
  - Polarized electrons and polarized protons,
  - Polarized electrons and light ions (d, ^{3}He),
  - Electrons and heavy ions (up to Uranium).
- The EIC will enable us to embark on a **precision study of the nucleon and the nucleus at the scale of sea quarks and gluons**, over all of the kinematic range that is relevant.
- BNL and Jefferson Lab will be host laboratories for the EIC Experimental Program. Leadership roles in the EIC project are shared.

What will you hopefully get out of the talk:
- What is the EIC? Why are we working on the EIC? What is the status of the EIC project and the detector collaboration?
- What is streaming readout? How do we advance EIC science with streaming readout and AI/ML?

New Frontier in Nuclear Physics

The Electron-Ion Collider

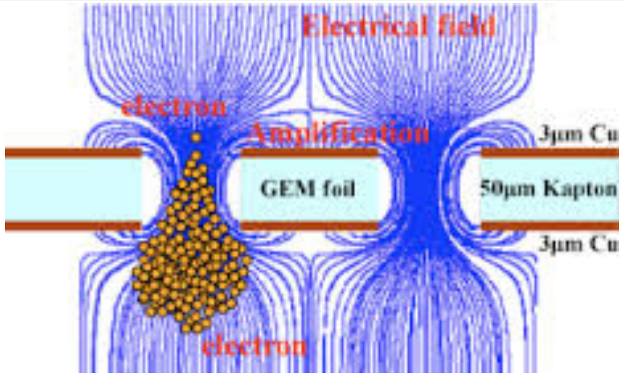
Advances in Nuclear Physics

QCD theory

$$
\begin{aligned}
\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2\,\mathrm{d}y\,\mathrm{d}q_{\mathrm{T}}^2} = {}& \frac{4\pi^2\alpha^2}{9Q^2 s} \sum_{j,j_A,j_B} e_j^2 \int \frac{\mathrm{d}^2\boldsymbol{b}_{\mathrm{T}}}{(2\pi)^2} e^{i\boldsymbol{q}_{\mathrm{T}}\cdot\boldsymbol{b}_{\mathrm{T}}} \\
& \times \int_{x_A}^{1} \frac{\mathrm{d}\xi_A}{\xi_A} f_{j_A/A}(\xi_A;\mu_{b_*})\, \tilde{C}^{\mathrm{CSS1,\ DY}}_{j/j_A}\left(\frac{x_A}{\xi_A}, b_*; \mu_{b_*}^2, \mu_{b_*}, C_2, a_s(\mu_{b_*})\right) \\
& \times \int_{x_B}^{1} \frac{\mathrm{d}\xi_B}{\xi_B} f_{j_B/B}(\xi_B;\mu_{b_*})\, \tilde{C}^{\mathrm{CSS1,\ DY}}_{\bar{j}/j_B}\left(\frac{x_B}{\xi_B}, b_*; \mu_{b_*}^2, \mu_{b_*}, C_2, a_s(\mu_{b_*})\right) \\
& \times \exp\left\{-\int_{\mu_{b_*}^2}^{\mu_Q^2} \frac{\mathrm{d}\mu'^2}{\mu'^2}\left[A_{\mathrm{CSS1}}(a_s(\mu');C_1)\ln\left(\frac{\mu_Q^2}{\mu'^2}\right) + B_{\mathrm{CSS1,\ DY}}(a_s(\mu');C_1,C_2)\right]\right\} \\
& \times \exp\left[-g^{\mathrm{CSS1}}_{j/A}(x_A,b_{\mathrm{T}};b_{\max}) - g^{\mathrm{CSS1}}_{\bar{j}/B}(x_B,b_{\mathrm{T}};b_{\max}) - g^{\mathrm{CSS1}}_{K}(b_{\mathrm{T}};b_{\max})\ln(Q^2/Q_0^2)\right] \\
& + \text{suppressed corrections.}
\end{aligned}
$$

Accelerator technologies

Detector technologies

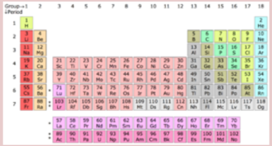
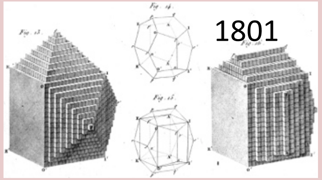
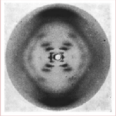
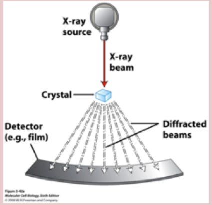
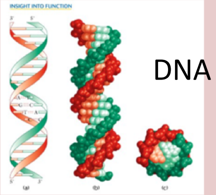
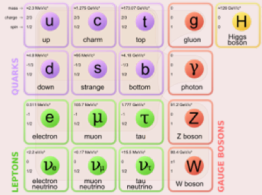
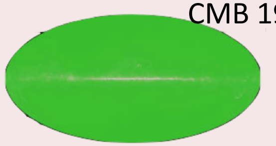
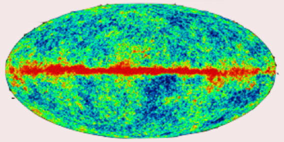
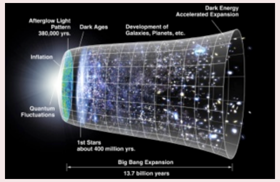
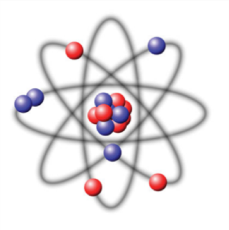
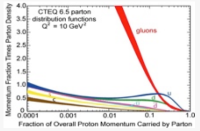
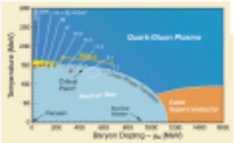
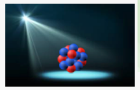
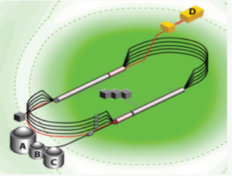
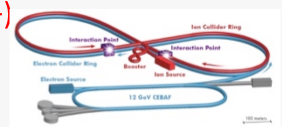


Computer technologies

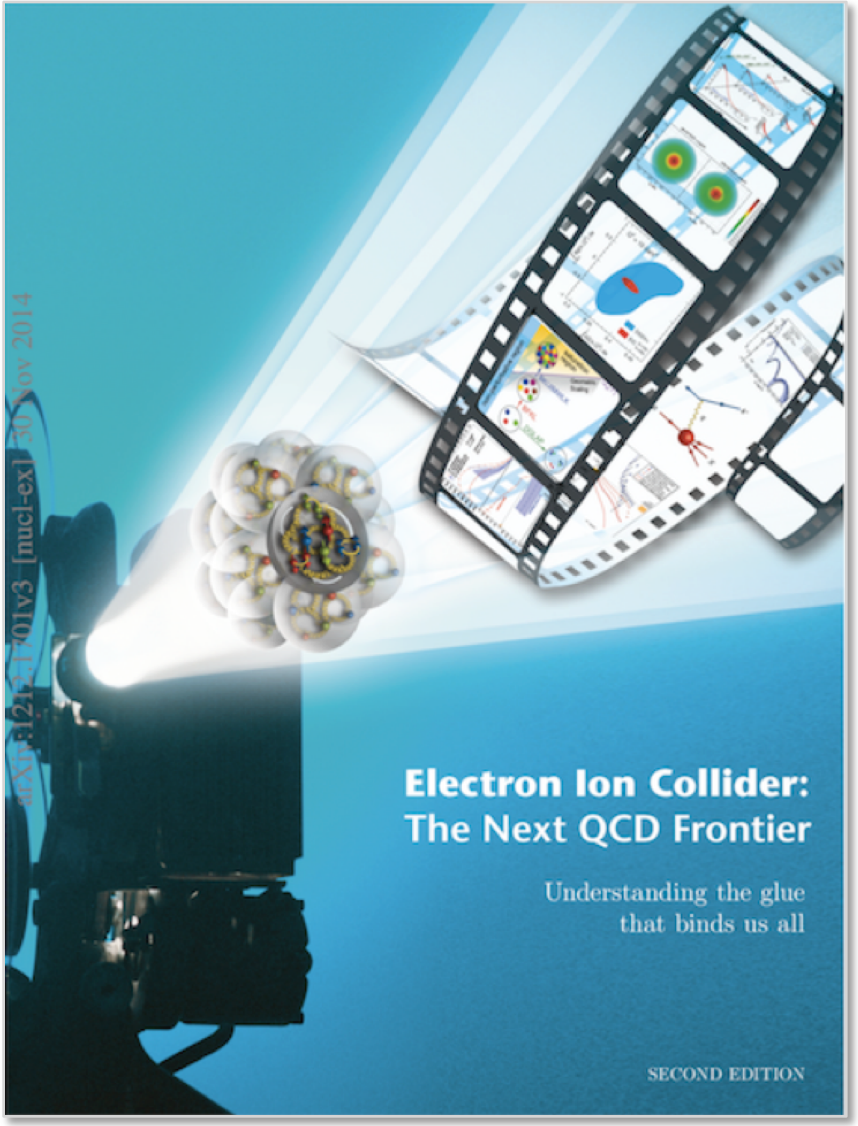
Steady advances in all of these areas mean that →

Jefferson Lab

EIC: A new frontier in science

Dynamical System	Fundamental Knowns	Unknowns	Breakthrough Structure Probes (Date)	New Sciences, New Frontiers
Solids 	Electromagnetism Atoms 	Structure  1801	X-ray Diffraction (~1920)  	Solid state physics Molecular biology  DNA
Universe 	General Relativity Standard Model 	Quantum Gravity, Dark matter, Dark energy. Structure CMB 1965 	Large Scale Surveys CMB Probes (~2000)  	Precision Observational Cosmology 
Nuclei and Nucleons 	Perturbative QCD Quarks and Gluons $\mathcal{L}_{QCD} = \overline{\psi}(i\partial\!\!\!/ - gA\!\!\!/)\psi - \frac{1}{2}\mathrm{tr}\, F_{\mu\nu}F^{\mu\nu}$	Non-perturbative QCD Structure 2017   	CEBAF12 (2018)   Electron-Ion Collider (2030+) 	Structure & Dynamics in QCD 

2012: White paper on EIC



Theme: **The glue that binds us all.**

"The quantitative study of matter in this new regime [where sea quarks and gluons dominate] requires a new experimental facility an Electron-Ion Collider…"

Focus areas of research:

- Spin and three-dimensional structure of the nucleon
- The nucleus: A laboratory for QCD

Ref.: Eur.Phys.J.A 52 (2016) 9, 268

Nobel Prizes in Physics related to role of gluons in Nuclear Physics

Hideki Yukawa (1949) “for his prediction of the existence of mesons on the basis of theoretical work on nuclear forces”
But the quark-gluon origin of the nuclear binding force remains unknown.

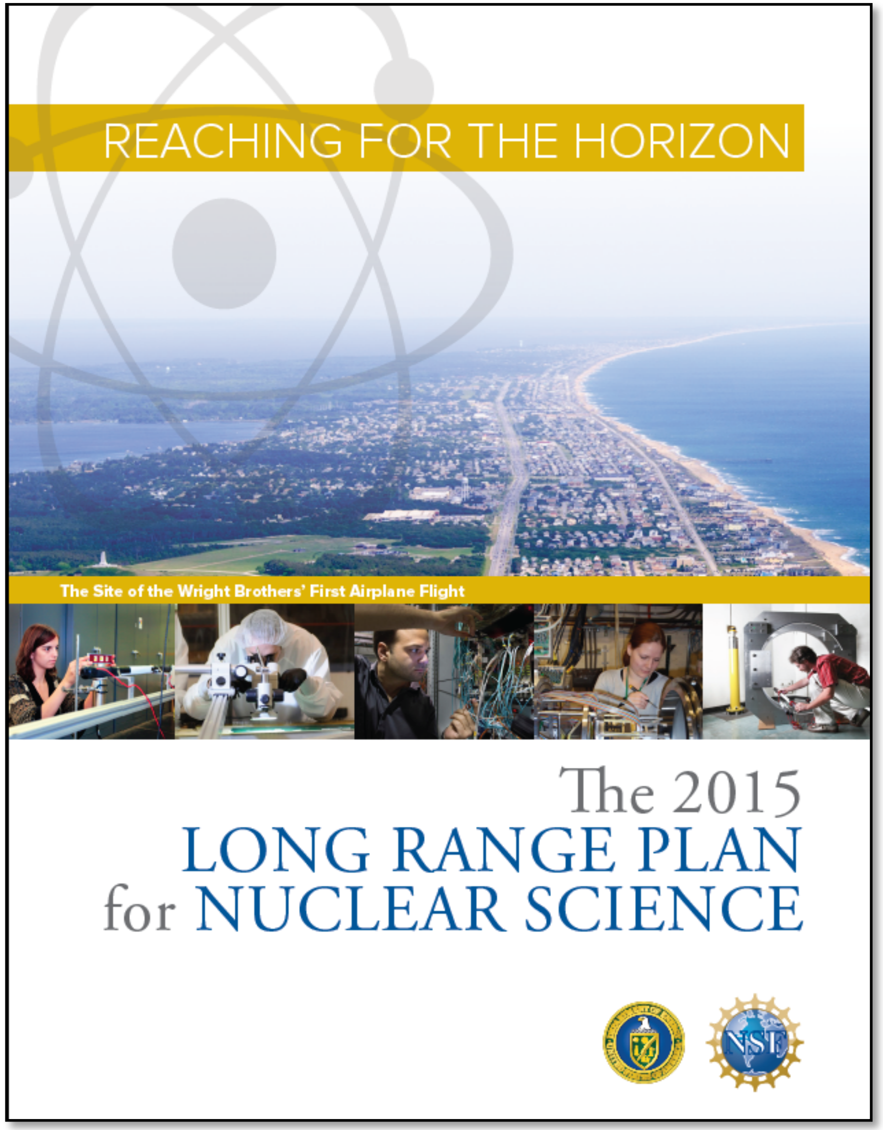
Robert Hofstadter (1961) “for his pioneering studies of electron scattering in atomic nuclei and for his thereby achieved discoveries concerning the structure of the nucleons”
But the 3D quark-gluon structure of nucleons remains unknown.

Jerome Friedman, Henry Kendall, Richard Taylor (1990) “for their pioneering investigations concerning deep inelastic scattering of electrons on protons and bound neutrons, which have been of essential importance for the development of the quark model in particle physics”
But the role of gluons in protons and bound neutrons remains unknown.

David Gross, David Politzer, Frank Wilczek (2004) “for the discovery of asymptotic freedom in the theory of the strong interaction”
But the confinement aspect of the theory remains unknown.

Yoichiro Nambu (2008) “for the discovery of the mechanism of spontaneous broken symmetry in subatomic physics ”
But how dynamical chiral symmetry breaking shapes the mass and structure of quark-gluon systems remains unknown.

2015: Nuclear Science Long-Range Plan

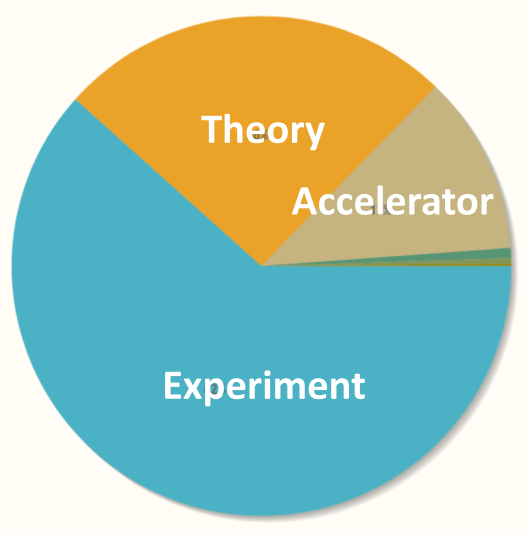


1. **The highest priority in this 2015 Plan is to capitalize on the investments made.**
   - **12 GeV** – unfold quark & gluon structure of hadrons and nuclei
   - **FRIB** – understanding of nuclei and their role in the cosmos
   - **Fundamental Symmetries Initiative** – physics beyond the SM
   - **RHIC** – properties and phases of quark and gluon matter
2. We recommend the timely development and deployment of a U.S.-led ton-scale neutrinoless double beta decay experiment.
3. **We recommend a high-energy high-luminosity polarized Electron Ion Collider as the highest priority for new facility construction following the completion of FRIB.**
4. We recommend increasing investment in small and mid-scale projects and initiatives that enable forefront research at universities and laboratories.

2016: Formation of the EIC User Group (EICUG)

EICUG in 2023

- **1382 members** from
- **269 institutions** from
- **36 countries.**



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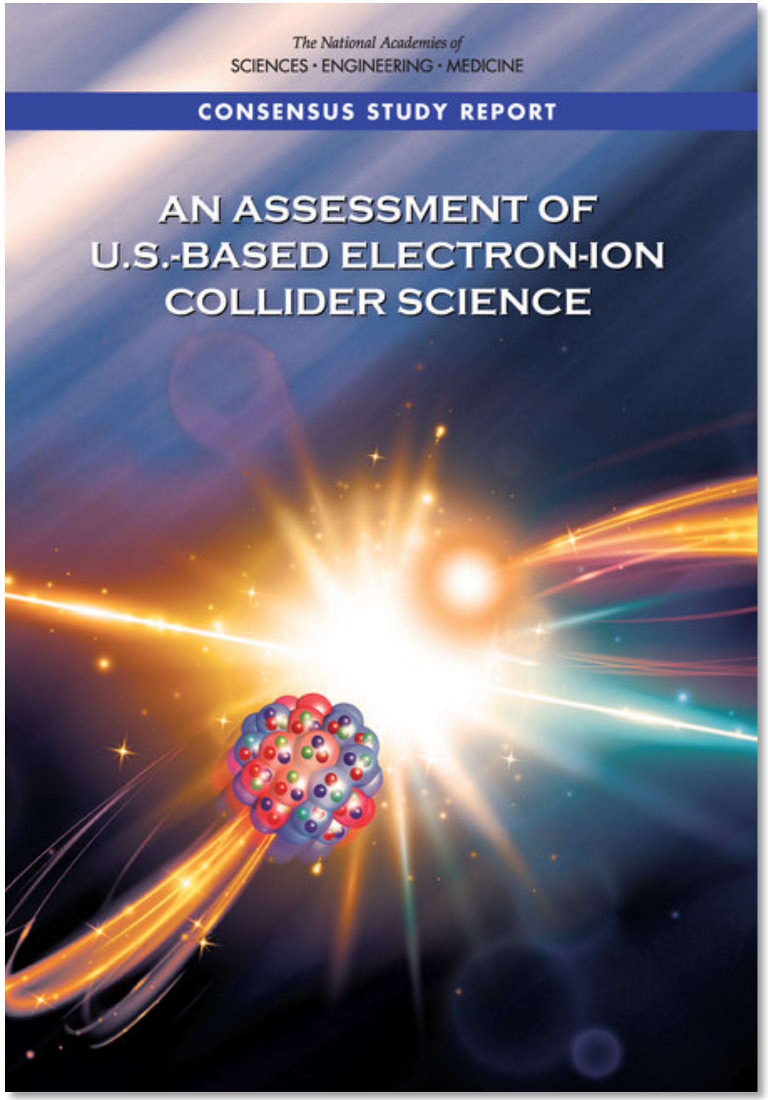
2018: Assessment of science case by National Academy of Sciences (NAS)

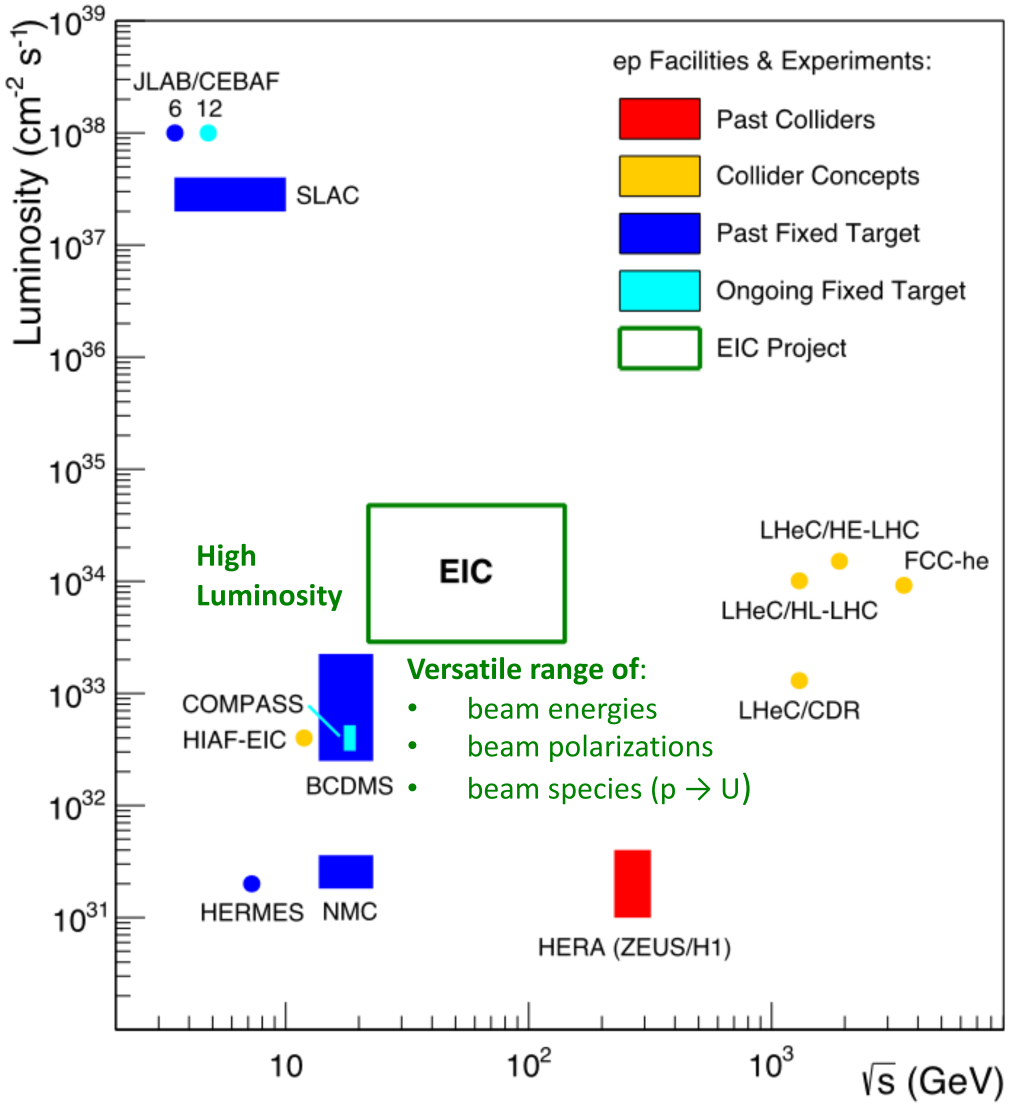


*"In summary, the committee finds **a compelling scientific case** for such a facility. The science questions that an EIC will answer are central to completing an understanding of atoms as well as being integral to the agenda of nuclear physics today.*

In addition, the development of an EIC would advance accelerator science and technology in nuclear science; it would as well benefit other fields of accelerator based science and society, from medicine through materials science to elementary particle physics."

Reference

NAS Report defines EIC science parameters



Versatile range of

- Beam energies: $\sqrt{s_{ep}}$ range ~20 to ~100 GeV upgradable to ~140 GeV
- Beam polarizations for electrons, protons and light ions (longitudinal, transverse, tensor), at least ~70% polarization
- Ion beam species: D to heaviest stable nuclei

High luminosity

- 100 to 1000 times HERA luminosity

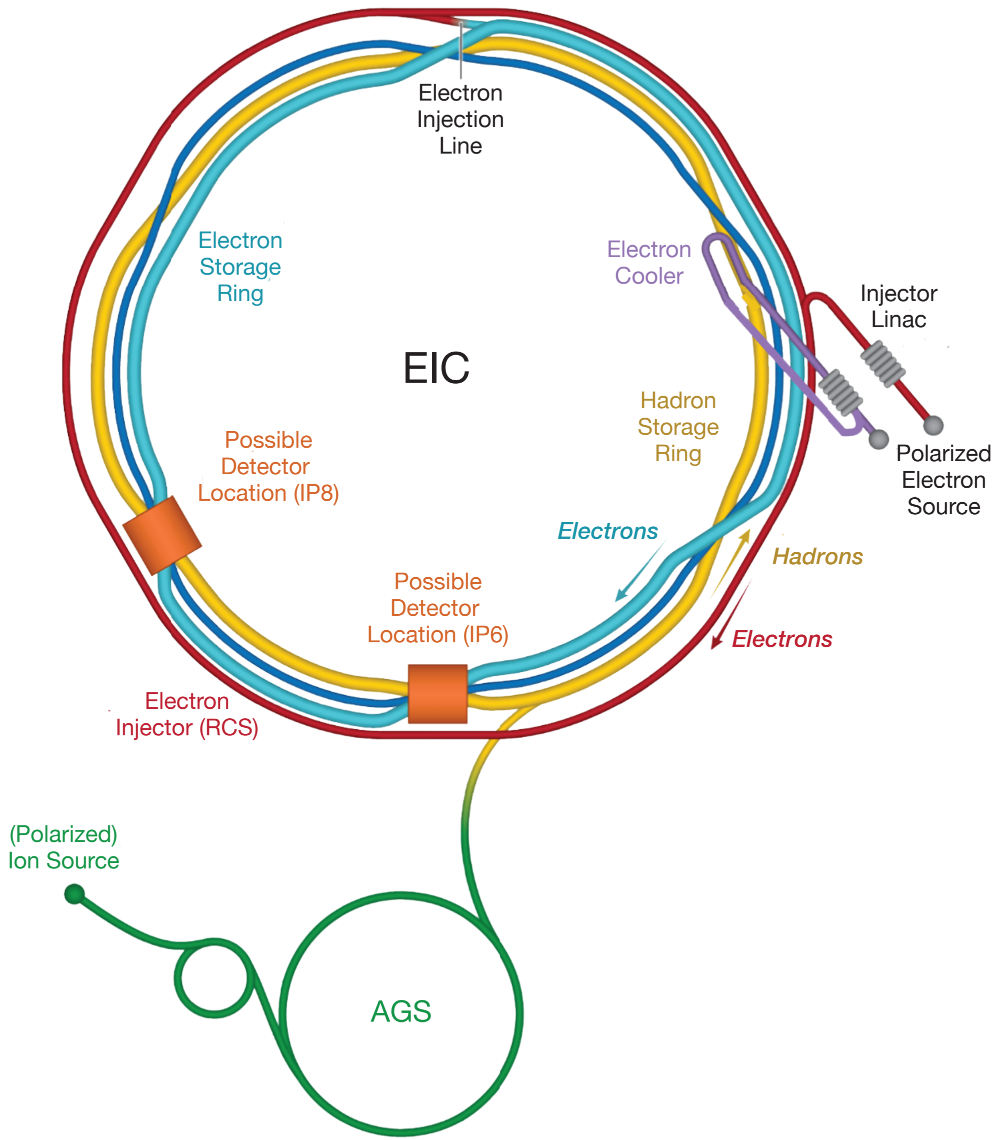
2020: Site selection between BNL (eRHIC) and Jefferson Lab (JLEIC)

Department of Energy

U.S. Department of Energy Selects Brookhaven National Laboratory to Host Major New Nuclear Physics Facility

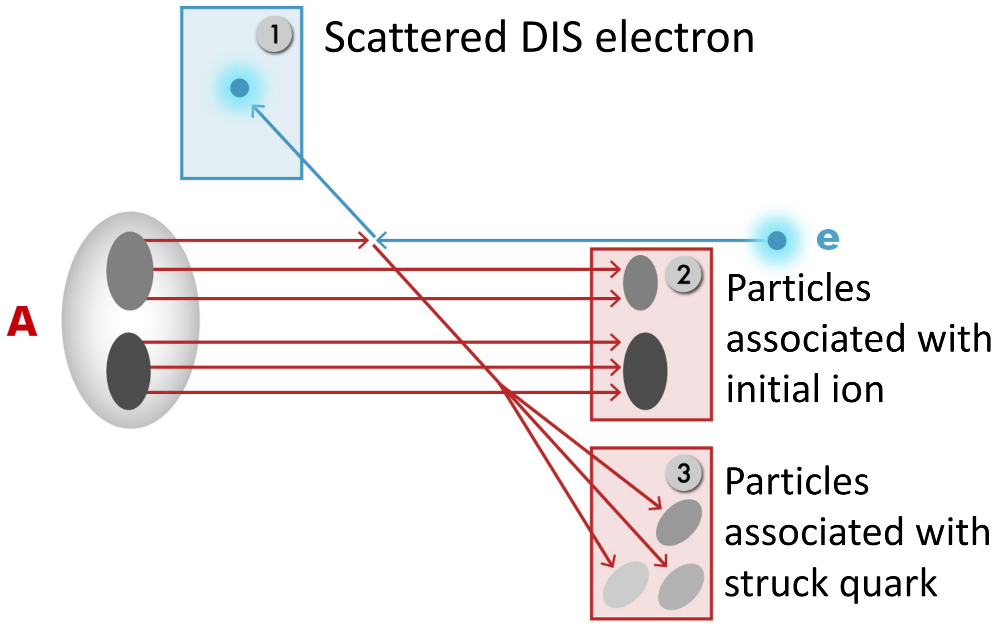
JANUARY 9, 2020

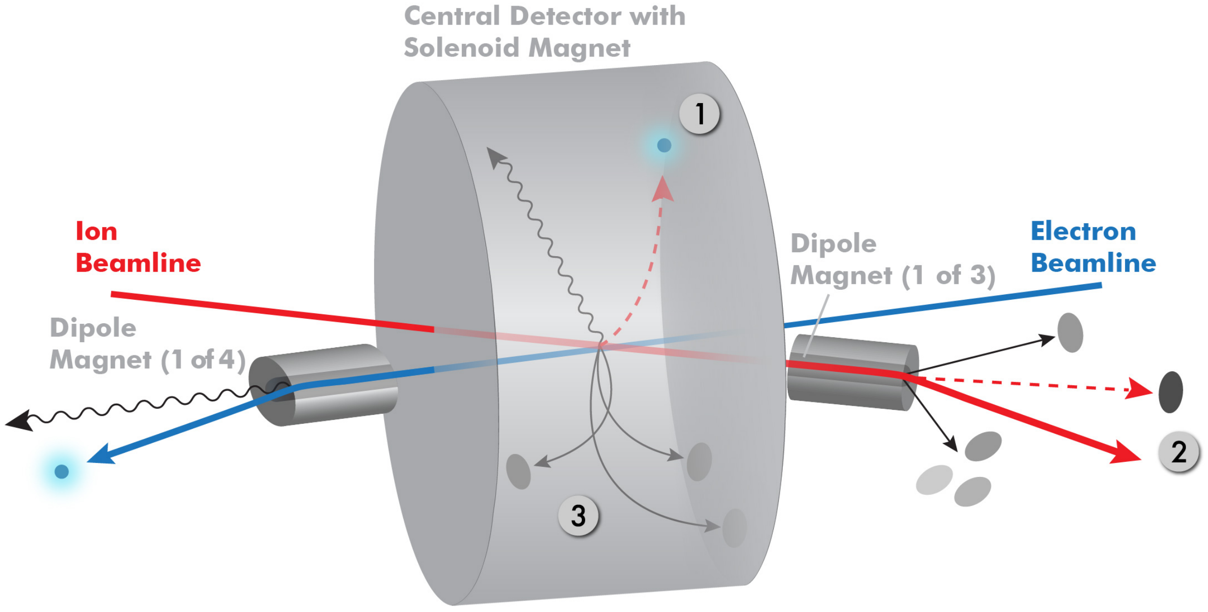
Brookhaven National Laboratory and Jefferson Lab will be host laboratories for the EIC Experimental Program. Leadership roles in the EIC project are shared.



Integrated interaction region and detector design to optimize physics reach

The aim is to get **~100% acceptance** for all final state particles, and measure them with good resolution.

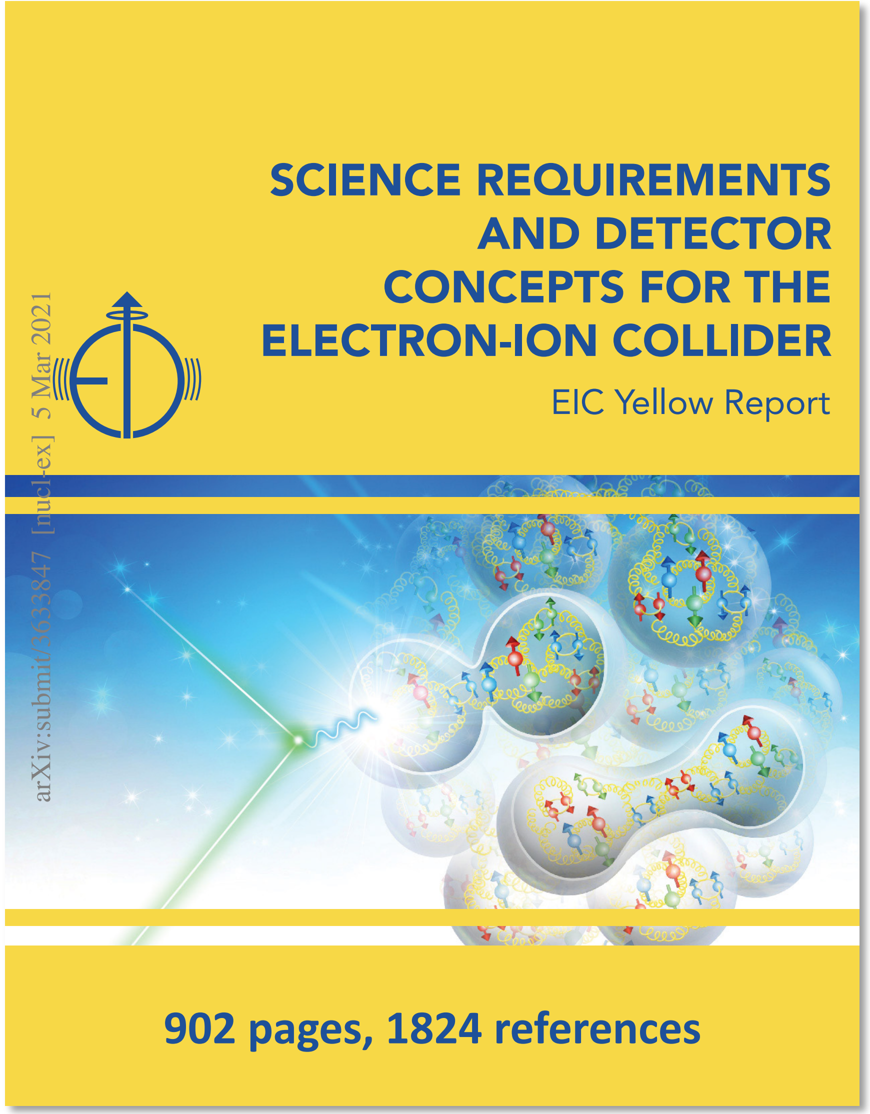




Experimental challenges:
- Beam elements limit forward acceptance.
- Central Solenoid not effective for forward.

Possible to get ~100% 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.

2021: Yellow Report Initiative by EICUG

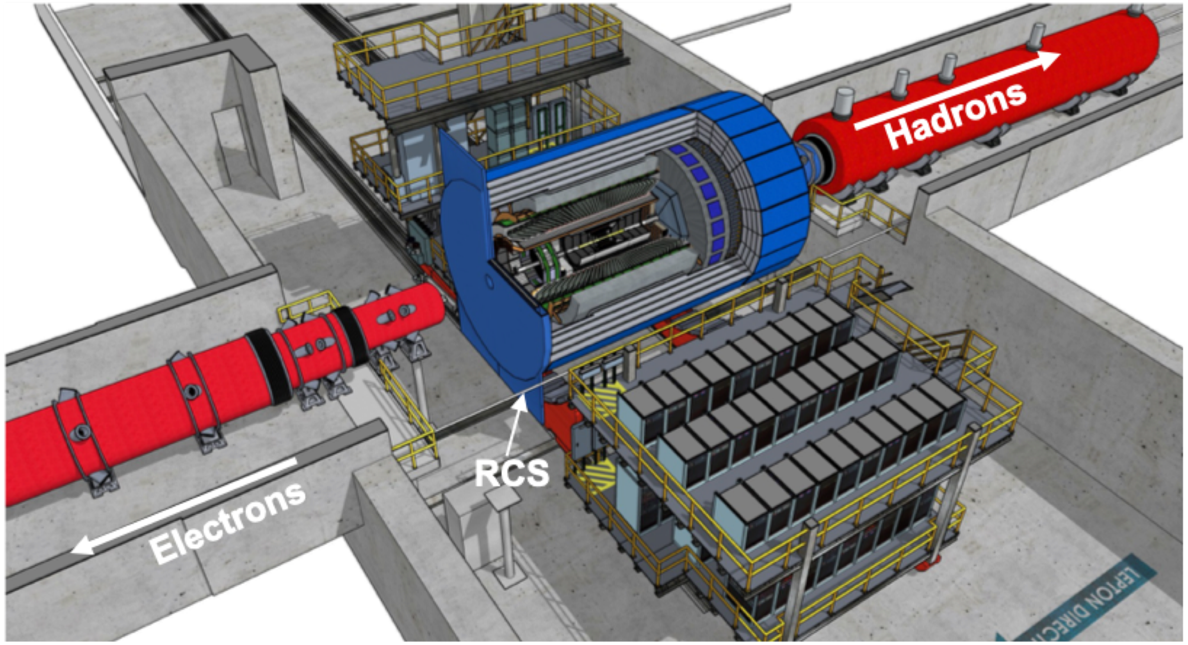


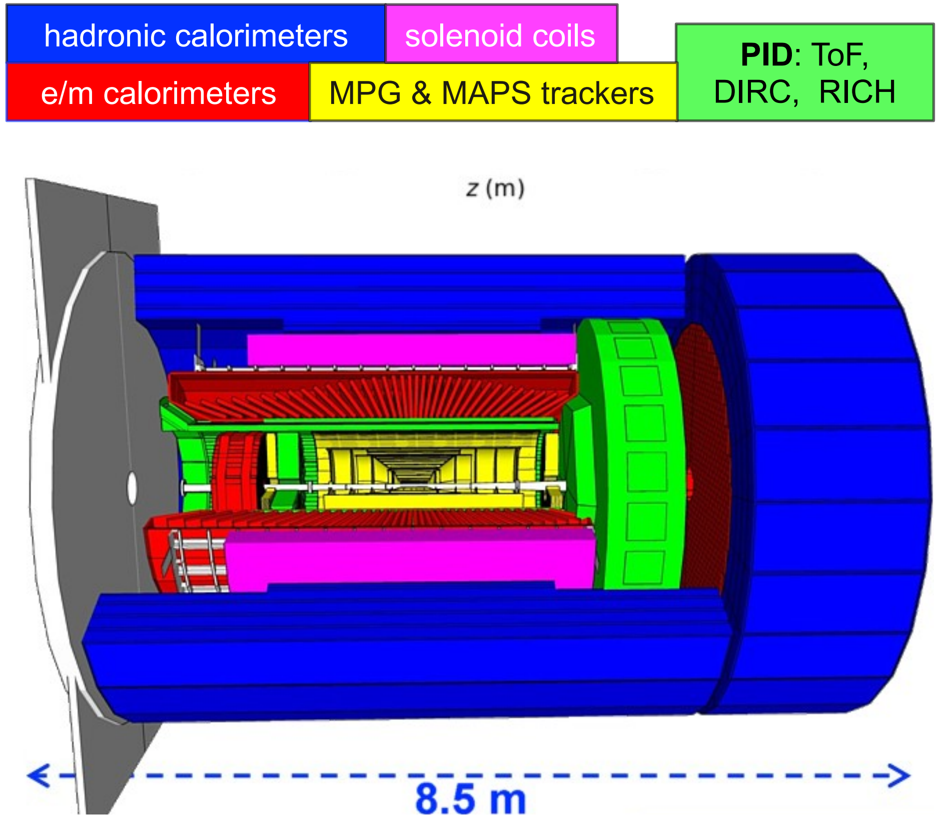
- The **EIC Yellow Report** describes the physics case, the resulting detector requirements, and the evolving detector concepts for the experimental program at the EIC.
  - Detector concepts further developed in detector collaboration proposals (ATHENA, CORE, ECCE).
- The studies leading to the EIC Yellow Report were commissioned and organized by the **EIC User Group**.
- The EIC Yellow Report has been important input to the successful DOE CD-1 review and decision.

Ref.: *Nucl.Phys.A* 1026 (2022) 122447

EIC General Purpose Detector

Integrated interaction and detector region (+/- 40 m) to get ~100% acceptance for all final state particles, and measure them with good resolution.

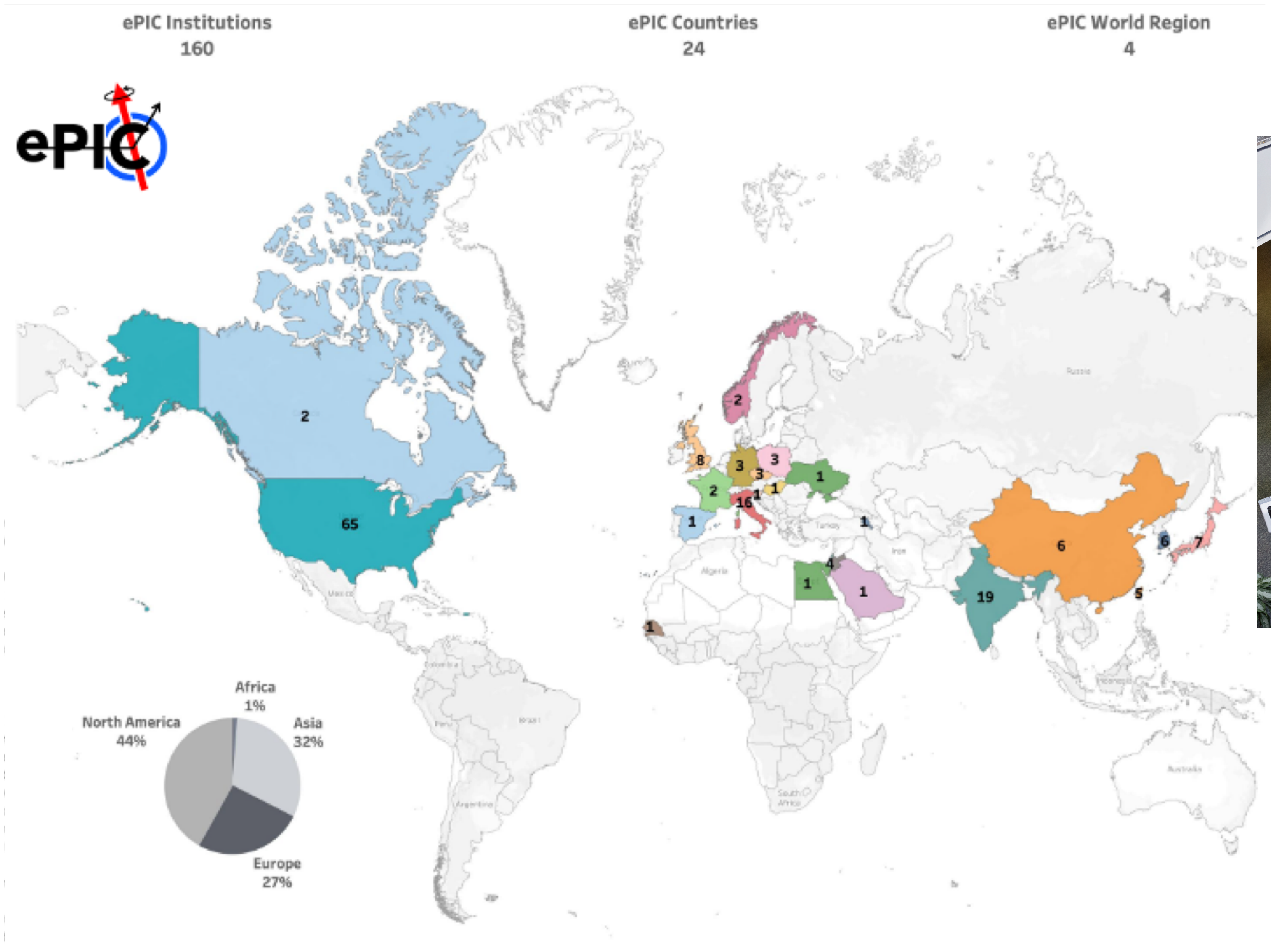




Overall detector requirements:

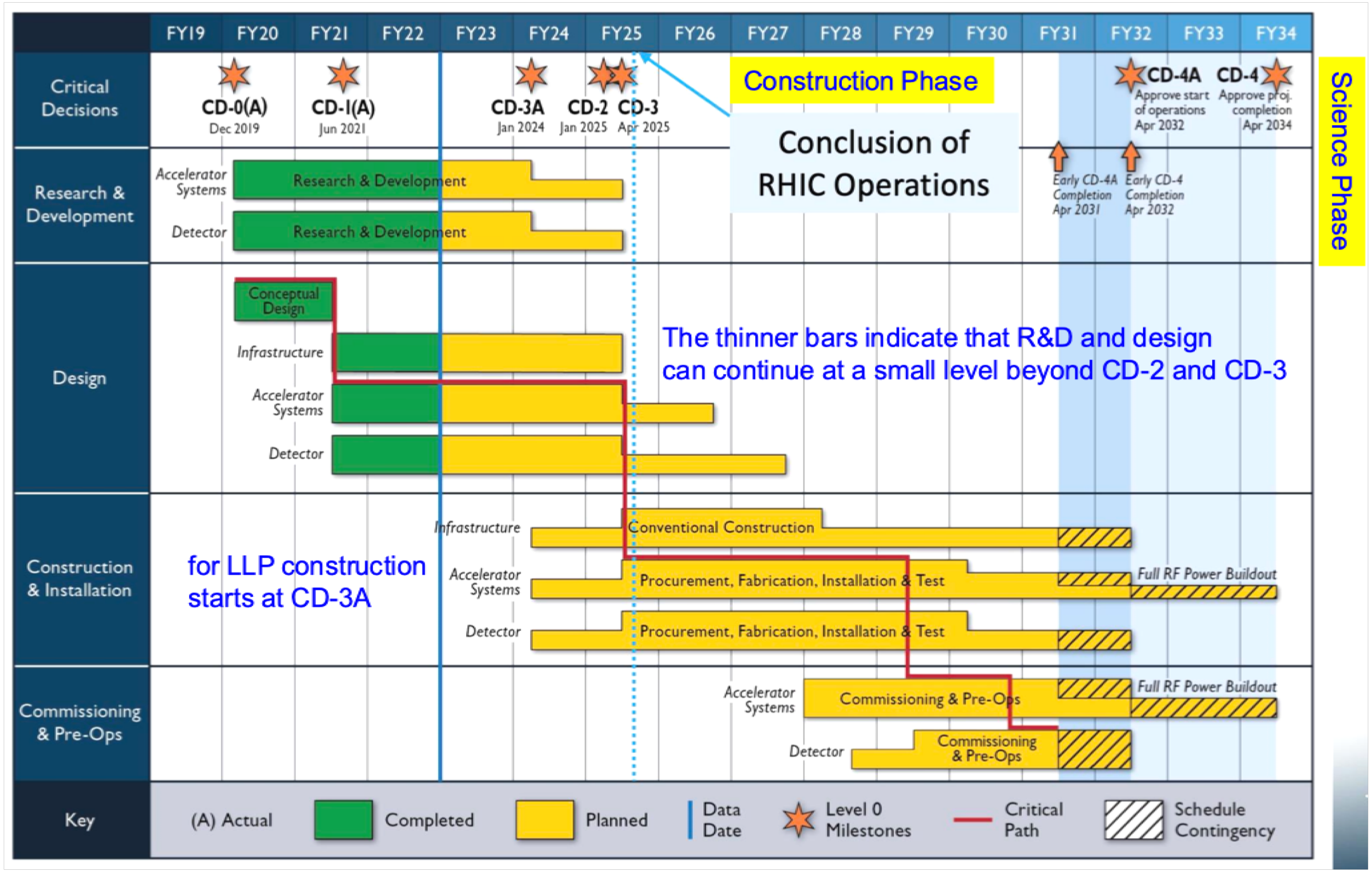
- Large rapidity (-4 < h < 4) coverage; and far beyond in far-forward detector regions.
- Large acceptance solenoid of 1.7 T (up-to 2 T).
- High control of systematics: luminosity monitor, electron and hadron polarimetry.

2022–2023: Formation of ePIC Collaboration



ePIC Collaboration Meeting at Jefferson Lab in January 2023

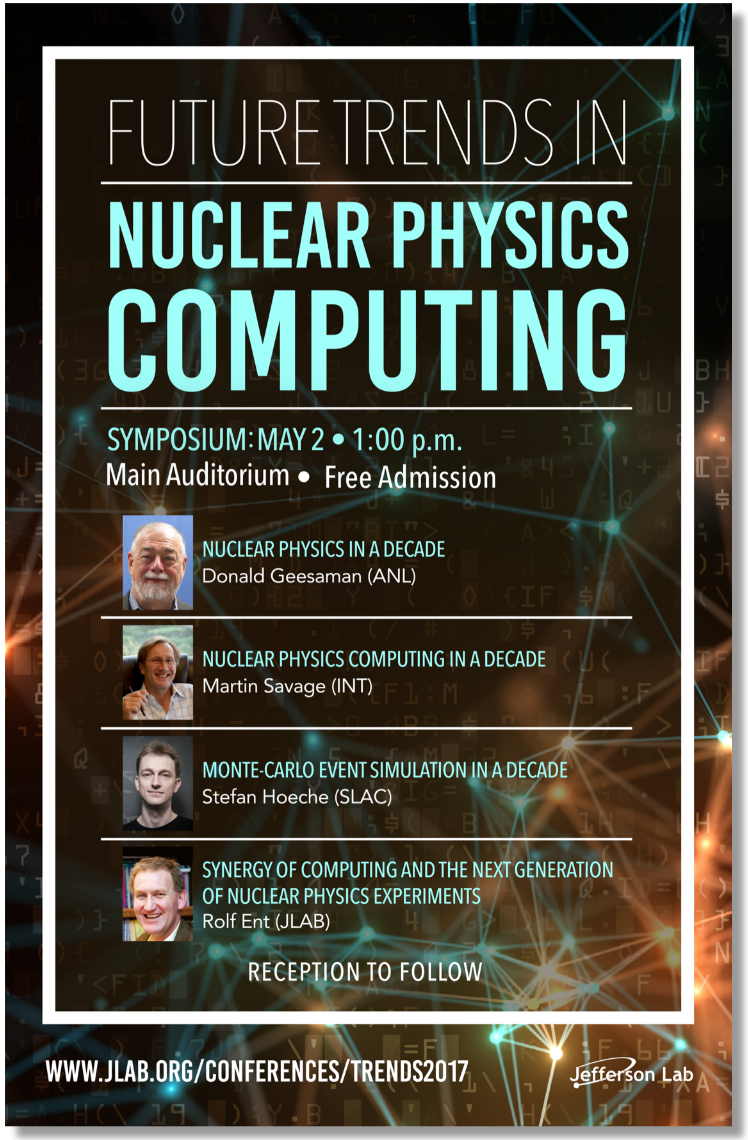
In a decade: Start of EIC Operations



After a presentation on “Breakthroughs in Detector Technology”, Ian Shipsey (Oxford) was asked about the role of software.

"***Software is the soul of the detector,***” Ian Shipsey replied in a poetic way and emphasized the **importance of great software for great science**. He added that we need to **work together**, on a global scale and with other fields, to achieve this goal.

The Role of Advanced Computing in Nuclear Physics



Future Trends in Nuclear Physics Computing

- **Recent years** Discussion about the next generation of data processing and analysis workflows that will maximize the science output.
- **One context for this discussion**
  - Workshop series on Future Trends in Nuclear Physiscs Computing

Donald Geesaman (ANL, former NSAC Chair) "*It will be **joint progress of theory and experiment** that moves us forward, not in one side alone*"

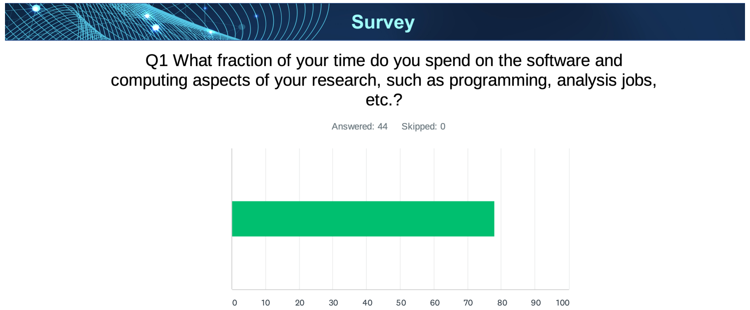
Martin Savage (INT) *"The next decade will be looked back upon as a **truly astonishing period in Nuclear Physics** and in our understanding of fundamental aspects of nature. This will be **made possible by advances in scientific computing** and in how the Nuclear Physics community organizes and collaborates, and how DOE and NSF supports this, to take full advantage of these advances."*

Jefferson Lab

Our Vision for Software & Computing at the EIC

"The purpose of computing is insight, not numbers." Richard Hamming (1962)

Software & computing are an integral part of our research:



Survey among NP Ph.D. students and postdocs in preparation of "Future Trends in NP Computing"

- **Goal** We work with a large, international community on data-intensive challenges and AI/ML and would like to ensure that scientists of all levels worldwide can participate in EIC analysis actively.
- **User-Centered Design**: To achieve this goal, we must listen to users, and then develop software.

Rapid turnaround of data for the physics analysis and to start the work on publications:

- **Goal**: Analysis-ready data from the DAQ system.
- **Compute-detector integration** with AI at the DAQ and analysis level.

One Software Stack for the EIC

How to work towards to our software & computing vision and meet the needs of the EIC community?

EIC SOFTWARE: Statement of Principles

1. **We aim to develop a diverse workforce, while also cultivating an environment of equity and inclusivity as well as a culture of belonging.**

2. **We will have an unprecedented compute-detector integration:**
   - We will have a common software stack for online and offline software, including the processing of streamed data and its time-ordered structure.
   - We aim for autonomous alignment and calibration.
   - We aim for a rapid, near-real-time turnaround of the raw data to online and offline productions.

Provisions for **streaming readout** from the start.

3. **We will leverage heterogeneous computing:**
   - We will enable distributed workflows on the computing resources of the worldwide EIC community, leveraging not only HTC but also HPC systems.
   - EIC software should be able to run on as many systems as possible, while supporting specific system characteristics, e.g., accelerators such as GPUs, where beneficial.
   - We will have a modular software design with structures robust against changes in the computing environment so that changes in underlying code can be handled without an entire overhaul of the structure.

4. **We will aim for user-centered design:**
   - We will enable scientists of all levels worldwide to actively participate in the science program of the EIC, keeping the barriers low for smaller teams.
   - EIC software will run on the systems used by the community, easily.
   - We aim for a modular development paradigm for algorithms and tools without the need for users to interface with the entire software environment.

Users should not need to know the entire toolchain to make meaningful contributions to a single component.

Statement of Principles

- Community process to define guiding principles for EIC Software.
- Guiding principles define the requirements for EIC Software.
- Endorsement by the international EIC community.

Webpage

5. **Our data formats are open, simple and self-descriptive:**
   - We will favor simple flat data structures and formats to encourage collaboration with computer, data, and other scientists outside of NP and HEP.
   - We aim for access to the EIC data to be simple and straightforward.

6. **We will have reproducible software:**
   - Data and analysis preservation will be an integral part of EIC software and the workflows of the community.
   - We aim for fully reproducible analyses that are based on reusable software and are amenable to adjustments and new interpretations.

7. **We will embrace our community:**
   - EIC software will be open source with attribution to its contributors.
   - We will use publicly available productivity tools.
   - EIC software will be accessible by the whole community.
   - We will ensure that mission critical software components are not dependent on the expertise of a single developer, but managed and maintained by a core group.
   - We will not reinvent the wheel but rather aim to build on and extend existing efforts in the wider scientific community.
   - We will support the community with active training and support sessions where experienced software developers and users interact with new users.
   - We will support the careers of scientists who dedicate their time and effort towards software development.

Focus on actual content.

8. **We will provide a production-ready software stack throughout the development:**
   - We will not separate software development from software use and support.
   - We are committed to providing a software stack for EIC science that continuously evolves and can be used to achieve all EIC milestones.
   - We will deploy metrics to evaluate and improve the quality of our software.
   - We aim to continuously evaluate, adapt/develop, validate, and integrate new software, workflow, and computing practices.

The "Statement of Principles" represent guiding principles for EIC Software. They have been endorsed by the international EIC community. For a list of endorses, see LINK.

ePIC Software for the Realization of the ePIC Experiment

Our software design is based on **lessons learned in the worldwide NP and HEP community** and a **decision-making process** involving the whole community. We will continue to work with the worldwide NP and HEP community.

Modular Simulation, Reconstruction, and Analysis Toolkit using tools from the NP-HEP community

MC Event Generators — Detector Simulations in Geant4 — Readout Simulation (Digitization) — Reconstruction in JANA2 — Physics Analyses

Edm4eic data model based on edm4hep and podio.
Geometry Description and Detector Interface using DD4hep.

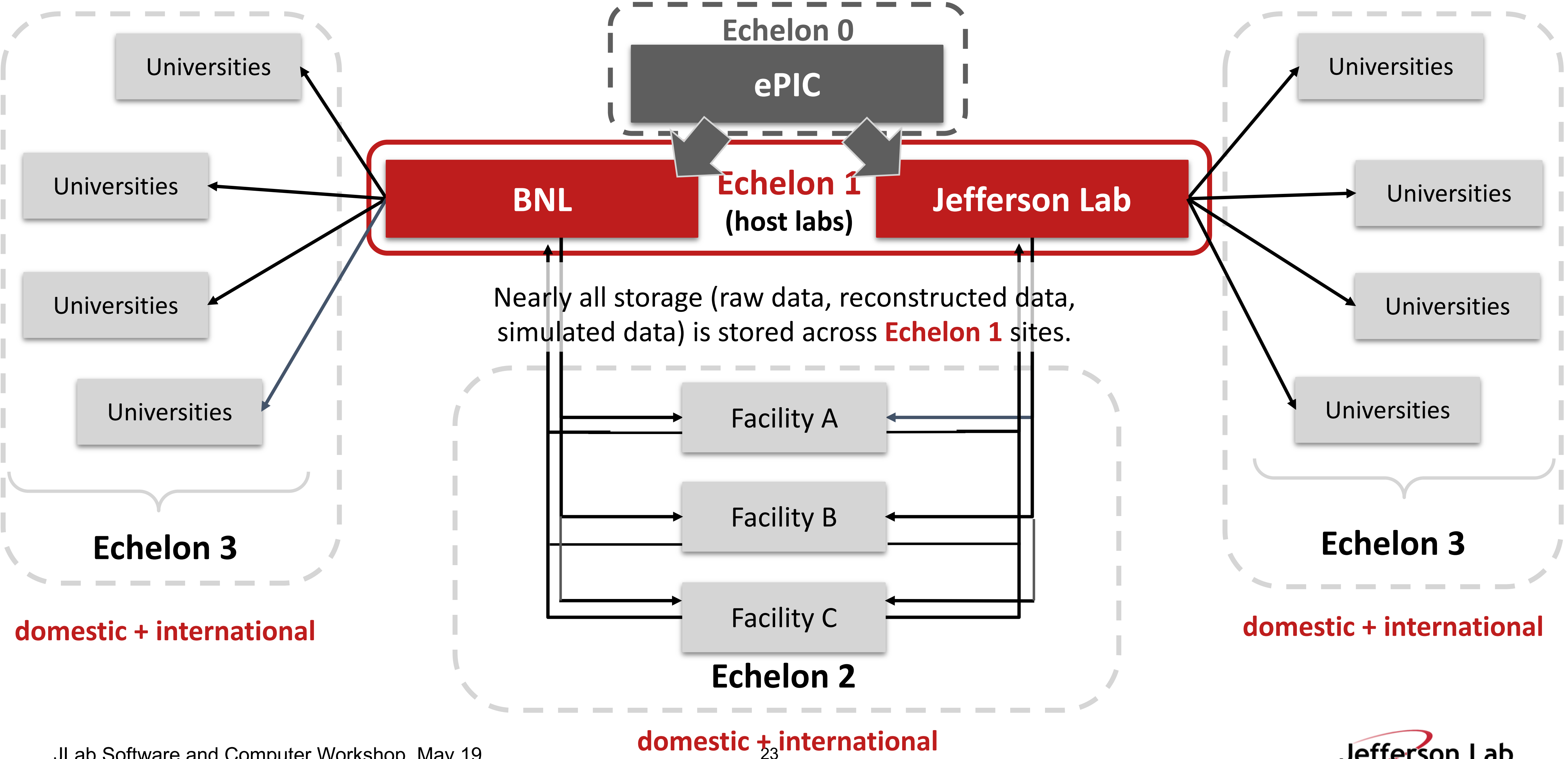
Continuous Integration for Detector and Physics Benchmarks and Reproducibility

We are providing a production-ready software stack throughout the development:

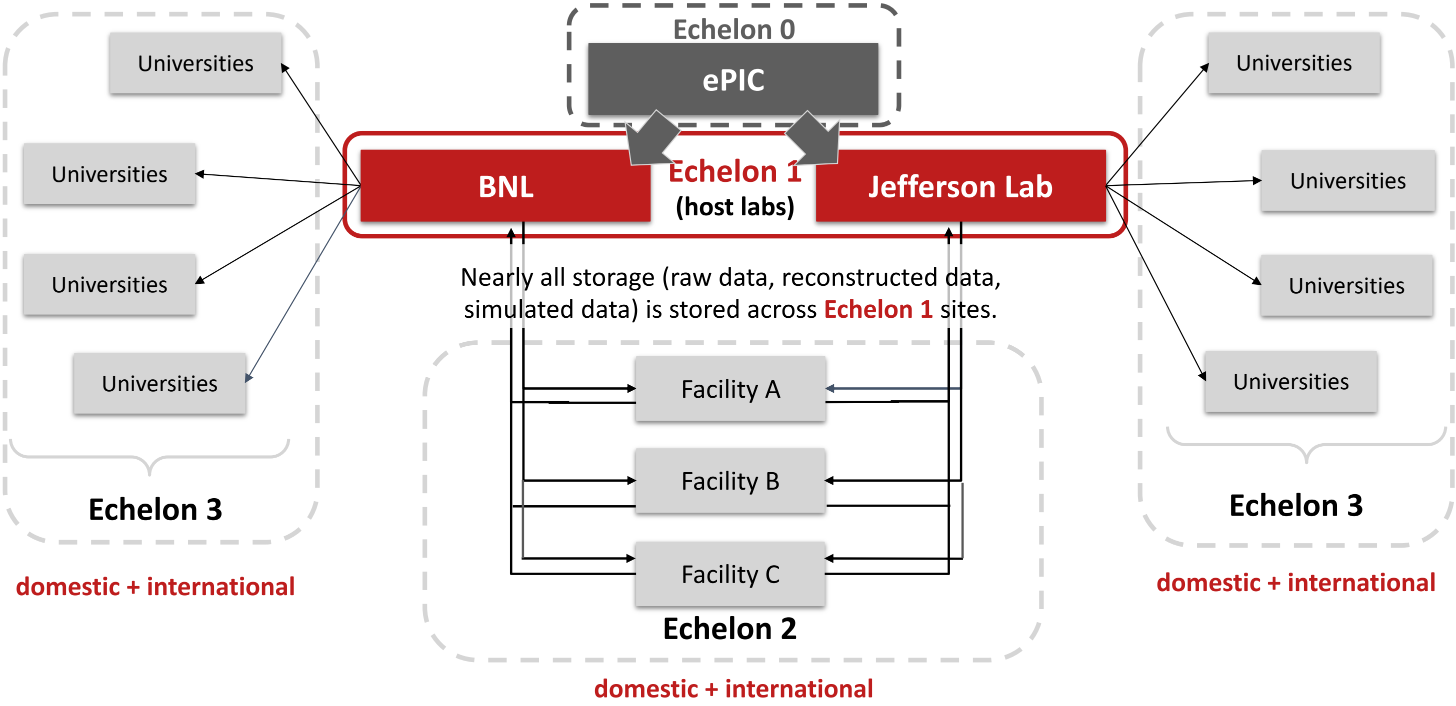
- **Milestone**: Software enabled first large-scale simulation campaign for ePIC.

We have a good foundation to meet the near-term and long-term software needs for ePIC.

Distributed Computing Model



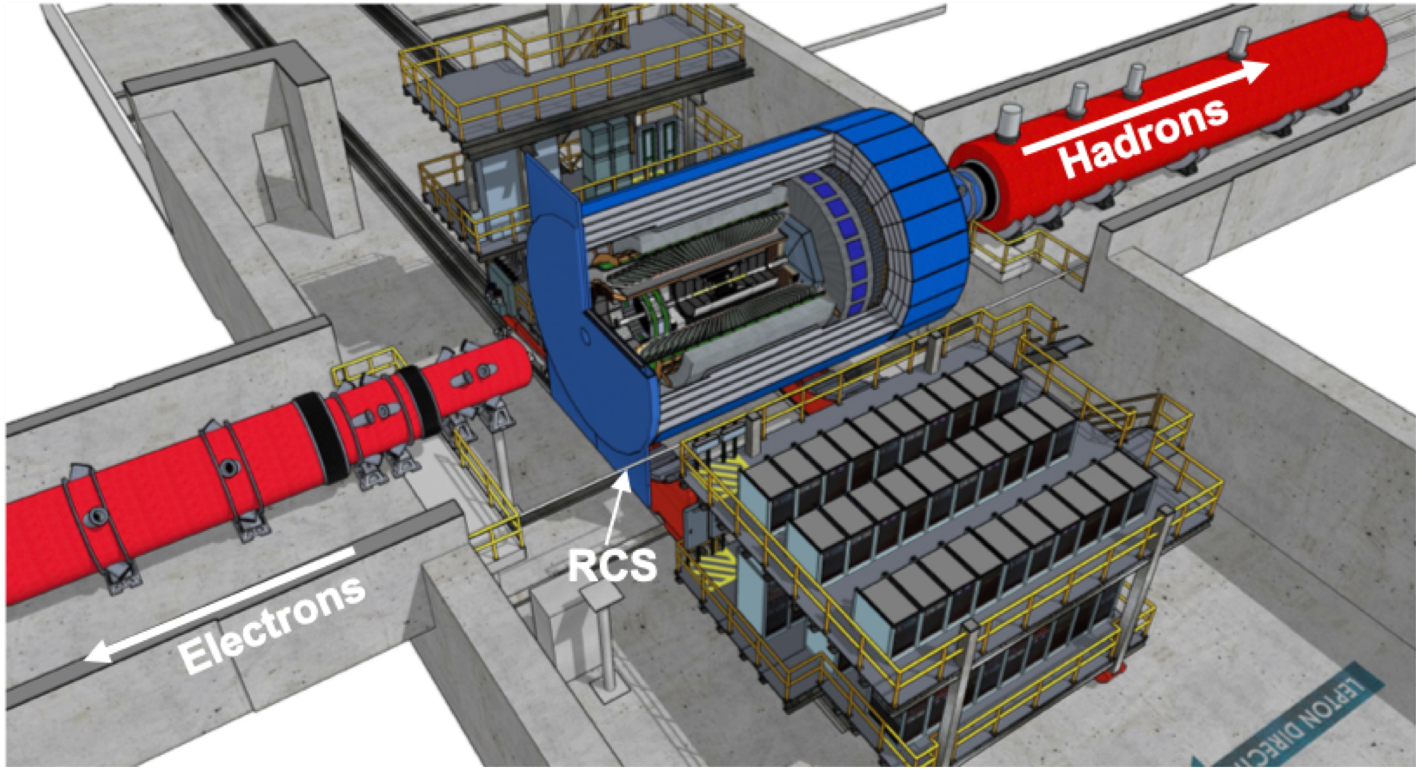
Distributed Computing Model in Use



- Key components of the EIC model were developed and implemented during the detector collaboration proposal phase in 2021.
- BNL and Jefferson Lab have supported the computational needs for the proposals and for ePIC.
- **Lessons learned** on needs for federated authentication, scientific data management, and data and analysis preservation.

Optimize Physics Reach

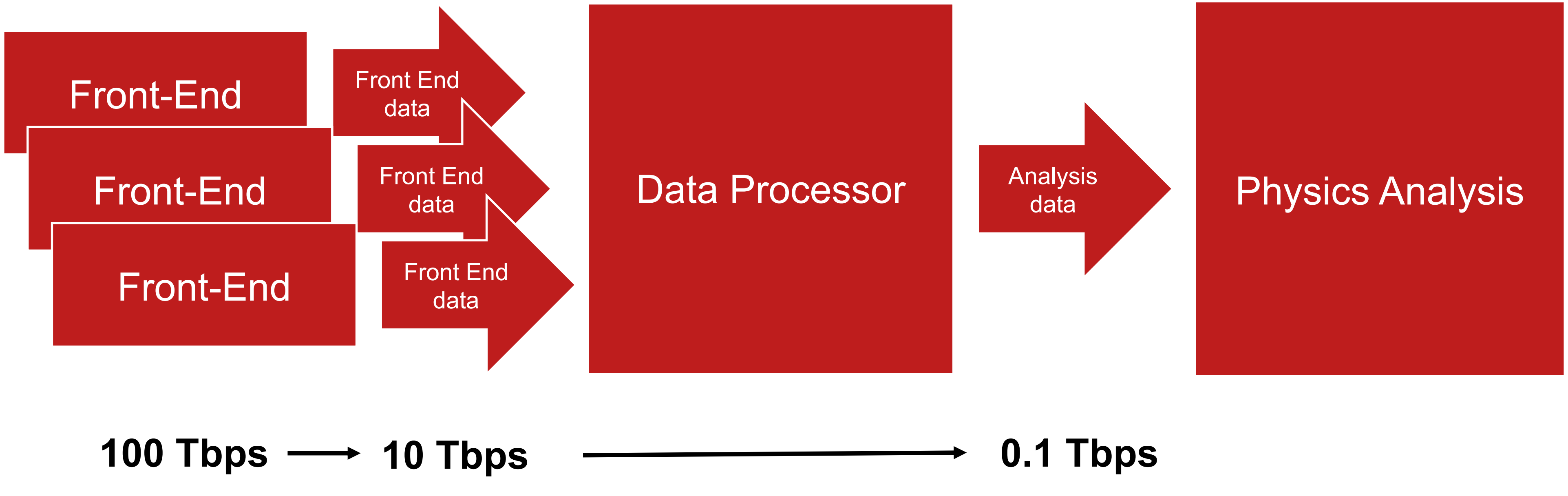
Integrated interaction and detector region (+/- 40 m)
Get ~100% acceptance for all final state particles, and measure them with good resolution. All particles count!



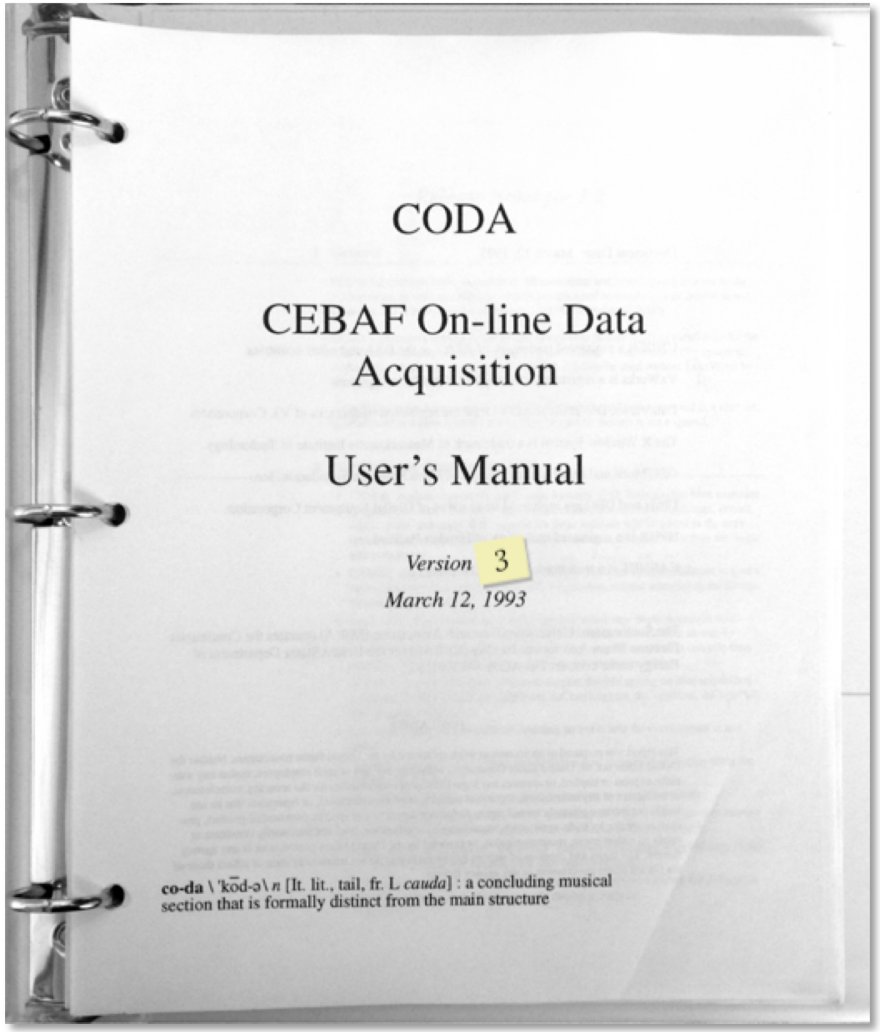
Compute-Detector Integration
Extend integrated interaction and detector region into detector readout (electronics), data acquisition, data processing and reconstruction, and physics analysis.

Compute-Detector Integration to Maximize Science

- **Problem** Data for physics analyses and the resulting publications available after O(1year) due to complexity of NP experiments (and their organization).
  - Alignment and calibration of detector as well as reconstruction and validation of events time-consuming.
- **Goal** Rapid turnaround of data for physics analyses.
- **Solution** Compute-detector integration using:
  - AI/ML for autonomous alignment and calibration as well as reconstruction in near real time,
  - Streaming readout for continuous data flow and heterogeneous computing for acceleration.



CODA: Trigger-based readout system



Based upon assumptions in traditional DAQ design

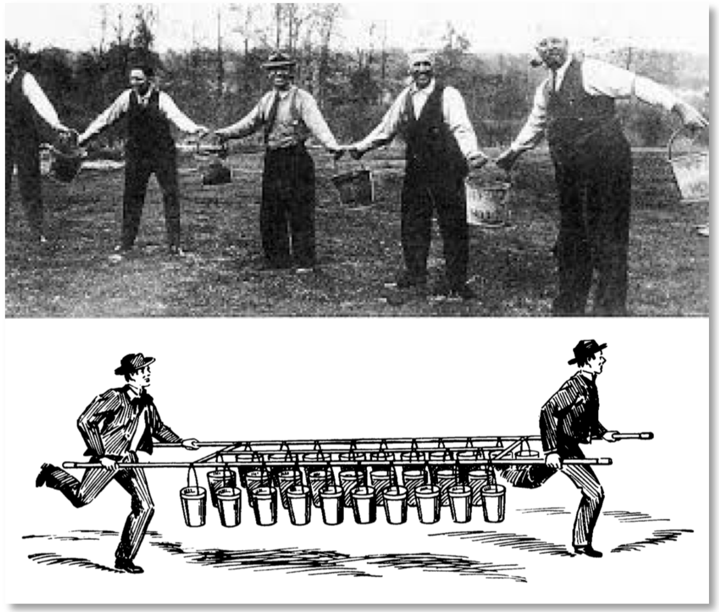
- The data rate from a detector is impossible to capture with an affordable data acquisition system without a trigger to reduce event rates.
- Even if the untriggered data rate could be captured, it would be impossible to store.
- Even if it could be stored the full dataset would represent a data volume that would require impractically large computing resources to process.

With computing advances Assumptions no longer valid

Limitation in trigger-based readout systems

- Bias to low-energy particles.
- Do not deal well with event-pileup.
- Not an ideal for complex, general-purpose detectors.

Alternative readout mode: Streaming



Traditional trigger-based readout

- data is digitized into buffers
- trigger starts readout
- parts of events are transported to an event builder where they are assembled into events
- at each stage the flow of data is controlled by *back pressure*
- data is organized sequentially by events

Streaming readout

- data is read continuously from all channels
- validation checks at source reject noise and suppress empty channels
- data then flows unimpeded in parallel channels to storage or a local compute resource
- data flow is controlled at source
- data is organized in multiple dimensions by channel and time

Streaming Readout: Trigger-less data acquisition

Definition of Streaming Readout

- Data is digitized at a fixed rate with thresholds and zero suppression applied locally.
- Data is read out in continuous parallel streams that are encoded with information about when and where the data was taken.
- Event building, filtering, monitoring, and other processing is deferred until the data is at rest in tiered storage.

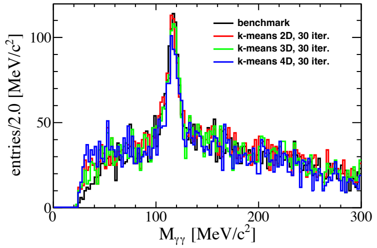
Advantages of Streaming Readout

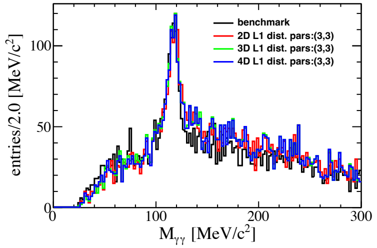
- simplification of readout (no custom trigger hardware and firmware)
- trigger-less readout:
    - beneficial for experiments that are limited by event-pileup or overlapping signals from different events
    - beam time is expensive so data mining or taking generic datasets shared between experiments is becoming popular: loosen triggers to store as much as possible
    - include all detectors, not only the fast ones, in the event selection
- opportunity to streamline workflows
- take advantage of other emerging technologies

On-Beam Validation of Streaming Readout at Jefferson Lab

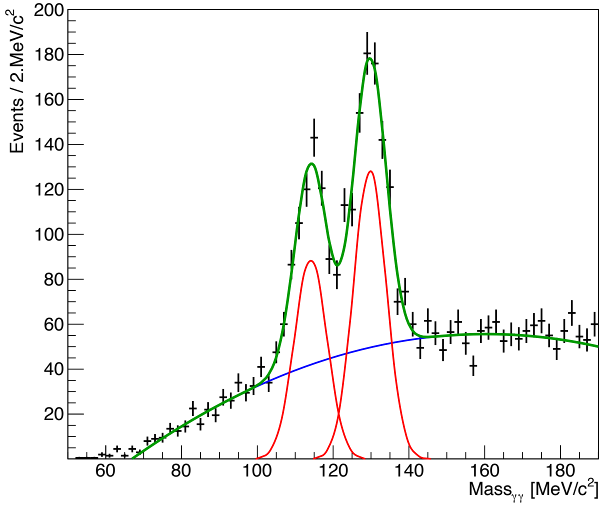
Tests included AI-supported real-time tagging and selection algorithms (*Eur.Phys.J.Plus* 137 (2022) 8, 958)

- Standard operation of **Hall-B CLAS12** with high-intensity electron-beam
- Streaming readout of forward tagger calorimeter and hodoscope
- Measurement of inclusive π^0 hadronproduction



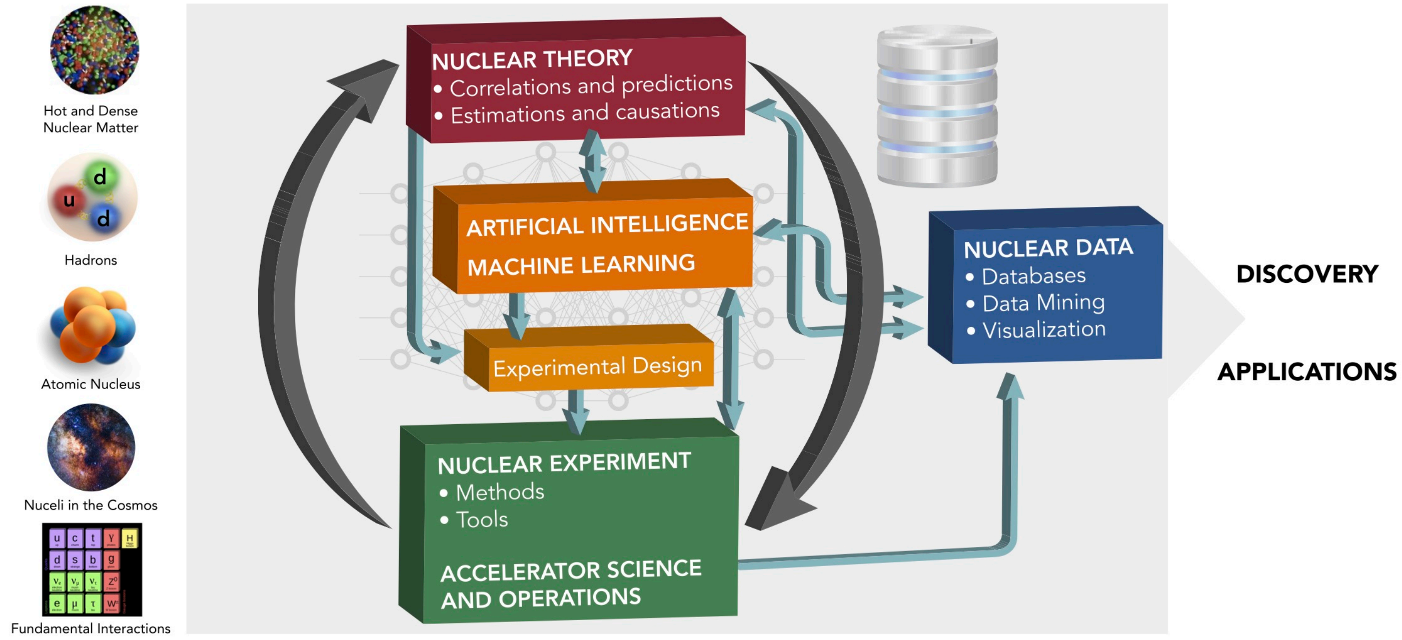


- Prototype of EIC PbWO4 crystal EMCAL in **Hall-D Pair Spectrometer**
- Calorimeter energy resolution of SRQ compatible with triggered DAQ.



Jefferson Lab

AI/ML in Nuclear Physics



NP is a highly distributed scientific field, utilizing various data types across different scales, making it **ideal for AI/ML applications** (Colloquium Article).

Tremendous interest and activity in AI/ML in NP:

- NP researchers already have the talent and many of the tools required for the AI/ML revolution.
- NP addresses challenges that are not addressed in current technologies.
- NP presents data sets that expose limitations of cutting edge methods.
- **Cross collaboration**: To solve the many complex programs in the field and facilitate discoveries strong collaborations between NP, data science, and industry would be beneficial for all parties.
- **Education** is key to increase the level of AI-literacy – research programs and curricula in data science can help to attract students.

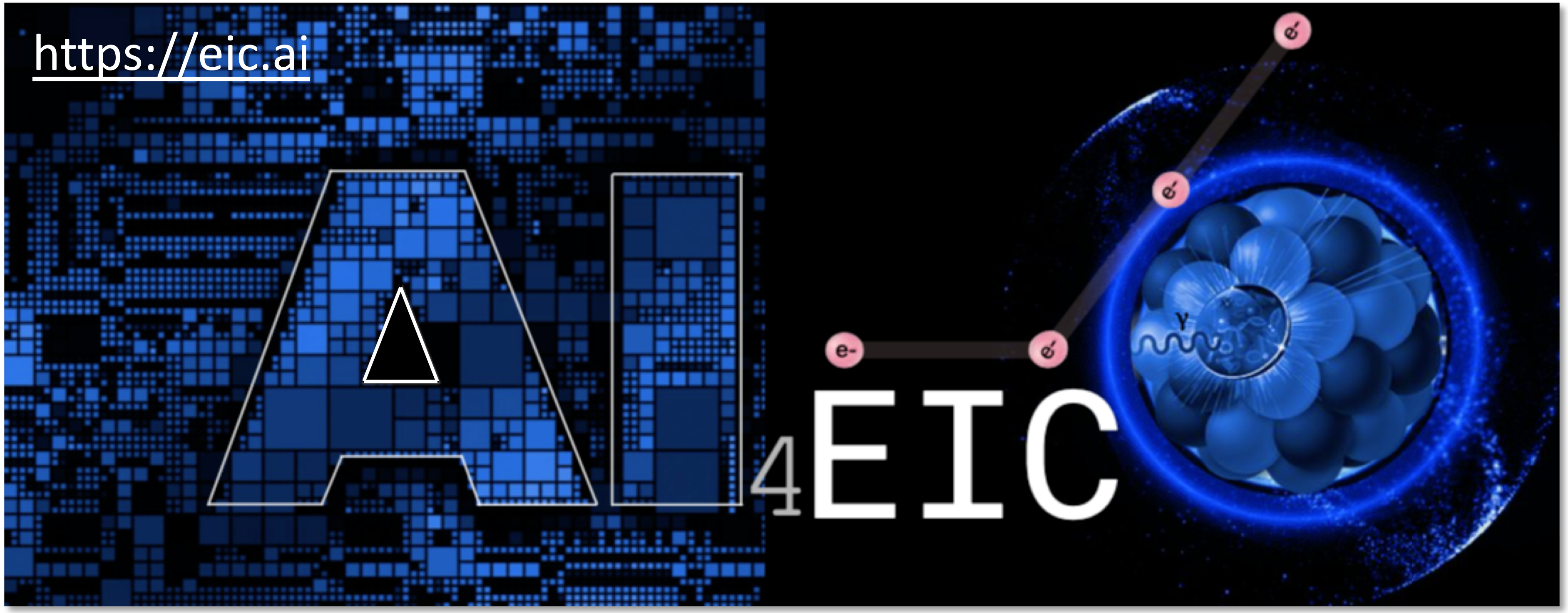
AI4EIC

AI/ML already has an **important presence in EIC** with many prototypes, e.g., for detector optimization or reconstruction methods using ML.

- Overview: **Colloquium: Machine learning in NP**
- **AI4EIC 2021 and 2022 workshops** with 200+ participants each

To explore and develop the full potential of **AI/ML for the EIC**, we as a community need to **move from prototyping to production** and add promising AI/ML solutions into our workflows.

- Promising candidate: Detector optimization using ML.



Software & Computing is Ultimately About Science

We need to work together on great software for great science, on a global scale and with other fields:

User-Centered Design:

- We will **enable scientists of all levels worldwide** to actively participate in the EIC science program, keeping the barriers low for smaller teams.
- We will engage the international community in our design and development.

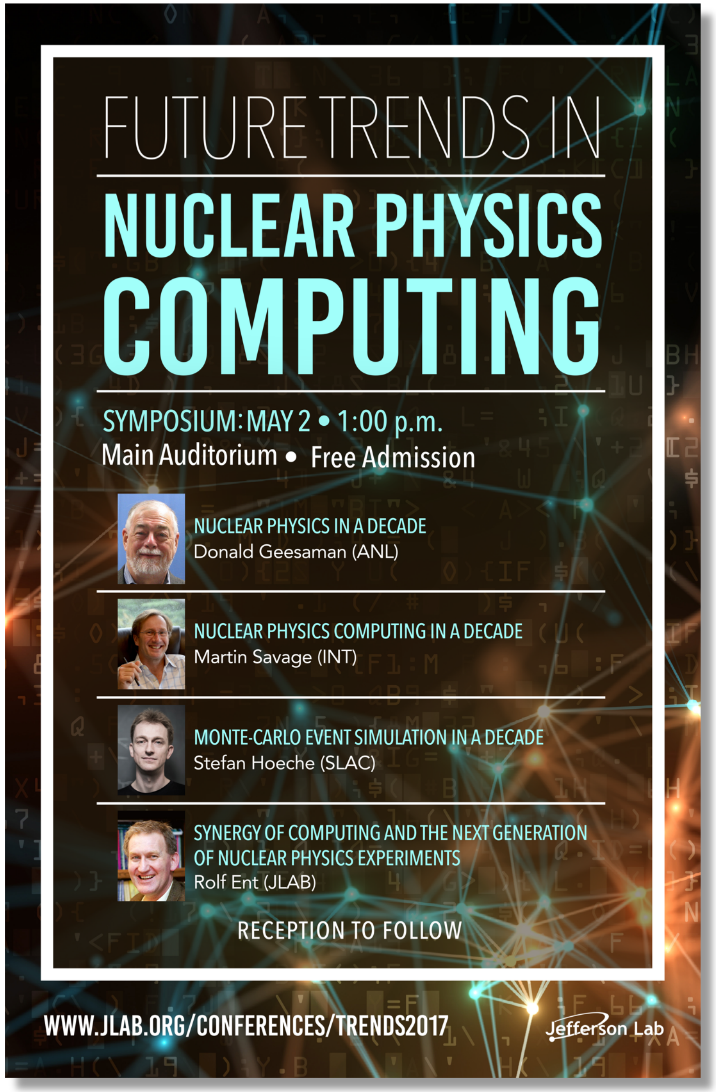
Next-Generation Simulations and Analysis Tools for High-Precision Measurements:

- We will collaborate with the international community on the **accurate modeling of physics and background processes** as well as their interplay with the ePIC detector.
- We will **collaborate with the international community** on data science for the EIC.

Data and Analysis Preservation:

- The success of the EIC science program depends on **fully reproducible, re-usable, and re-interpretable analyses**.
- We will make steady progress with **data and analysis preservation**, building on the experience and expertise of the international community.

Future Trends



Details on https://www.jlab.org/FTNPC

Donald Geesaman (ANL, former NSAC Chair) *"It will be **joint progress of theory and experiment** that moves us forward, not in one side alone."*

Obvious path

- Sharing data early with theory.

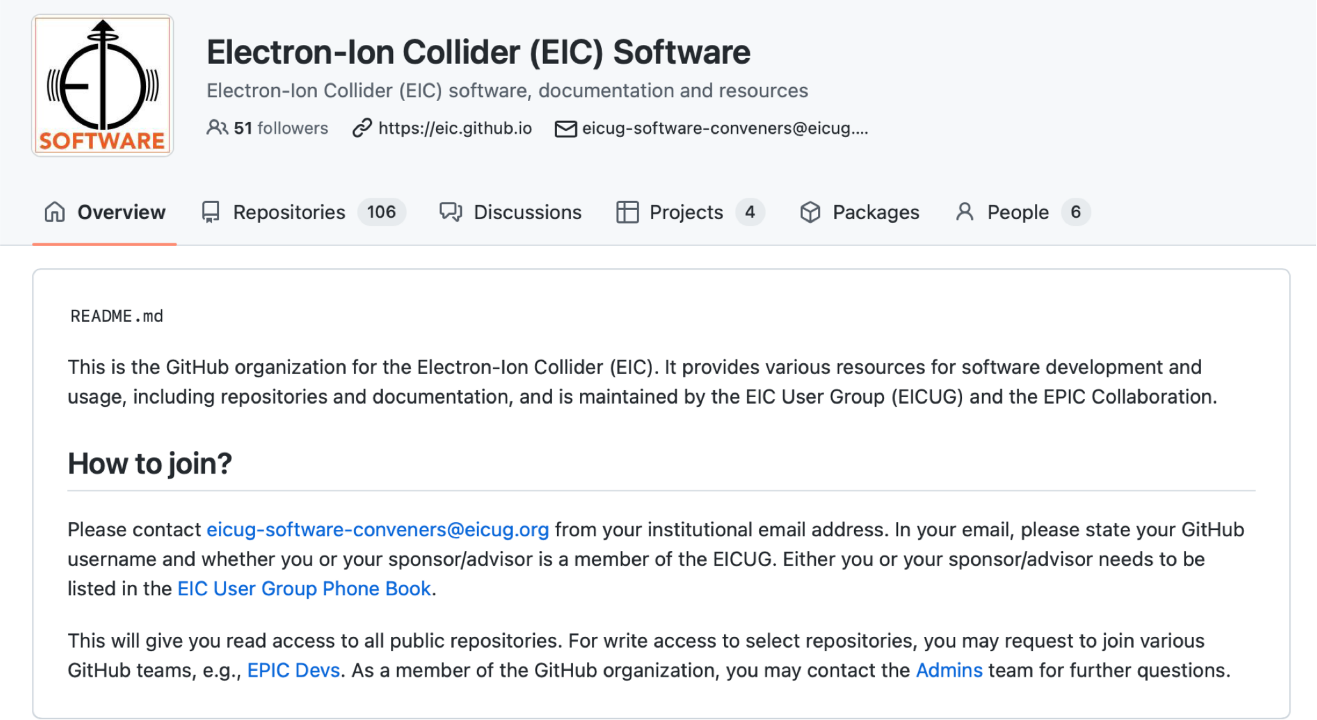
Martin Savage (INT) *"The next decade will be looked back upon as a **truly astonishing period in Nuclear Physics** and in our understanding of fundamental aspects of nature. This will be **made possible by advances in scientific computing** and in how the Nuclear Physics community organizes and collaborates, and how DOE and NSF supports this, to take full advantage of these advances."*

We can make a difference

- AI/ML for autonomous control and experimentation is a tremendous opportunity.
- Streaming readout using AI/ML as a new paradigm for seamless data processing from DAQ to analysis.

How to get involved

- **Mailing lists for announcements**:
  - https://lists.bnl.gov/mailman/listinfo/eic-projdet-compsw-l
  - https://lists.bnl.gov/mailman/listinfo/eic-projdet-simqa-l
- **Mattermost for discussions**: https://eic.cloud.mattermost.com/
- **GitHub for software development**: https://github.com/eic


Electron-Ion Collider (EIC) Software

Electron-Ion Collider (EIC) software, documentation and resources

51 followers https://eic.github.io eicug-software-conveners@eicug....

Overview | Repositories 106 | Discussions | Projects 4 | Packages | People 6

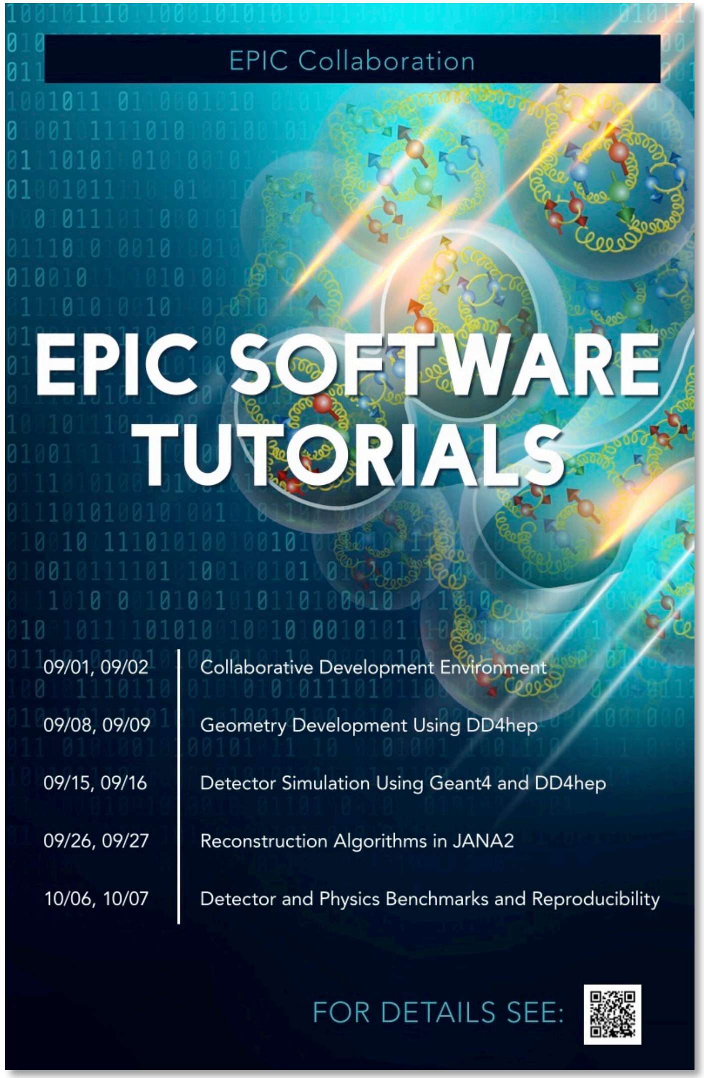
README.md

This is the GitHub organization for the Electron-Ion Collider (EIC). It provides various resources for software development and usage, including repositories and documentation, and is maintained by the EIC User Group (EICUG) and the EPIC Collaboration.

How to join?

Please contact eicug-software-conveners@eicug.org from your institutional email address. In your email, please state your GitHub username and whether you or your sponsor/advisor is a member of the EICUG. Either you or your sponsor/advisor needs to be listed in the EIC User Group Phone Book.

This will give you read access to all public repositories. For write access to select repositories, you may request to join various GitHub teams, e.g., EPIC Devs. As a member of the GitHub organization, you may contact the Admins team for further questions.

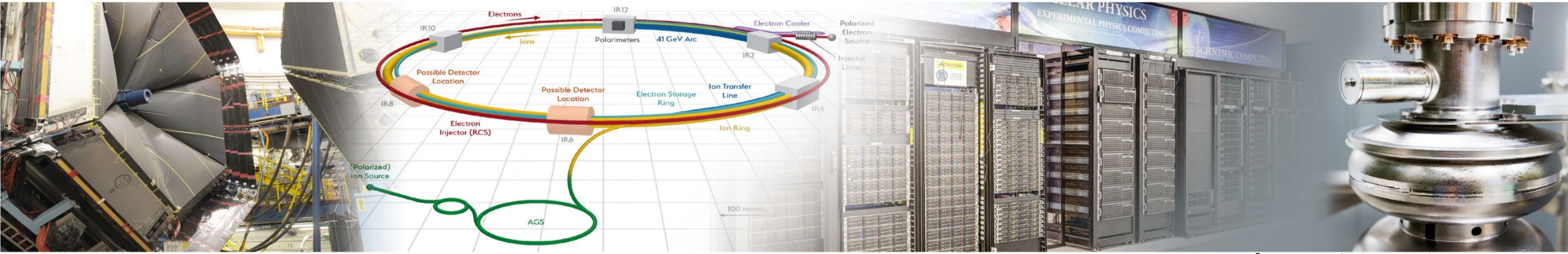


https://indico.bnl.gov/category/443/

Summary

Electron-Ion Collider: Quark-Gluon Imagining in the Era of Streaming Readout and AI/ML

Jefferson Lab's Science and Technology Vision



Nuclear Physics at CEBAF

Vibrant 12 GeV research program, operating >30 weeks/yr, supporting 1,700 annual users

MOLLER Project & SoLID proposal

Future opportunities in fixed-target, high-luminosity complementary to EIC

Theory and computation supporting NP goals

Electron-Ion Collider

Partnering with BNL in the management, design, and construction of the Electron-Ion Collider Project

Leadership in EIC scientific program

Computational Science & Technology

Vision for world-leading computational program

Developing concept of a High Performance Data Facility focused on the unique challenges and opportunities for data-intensive applications and near real-time computing needs

Computational Nuclear Physics

Accelerator Science & Technology

Accelerator component production for DOE/SC projects, including LCLS-II and LCLS-II-HE at SLAC, and SNS-PPU at ORNL

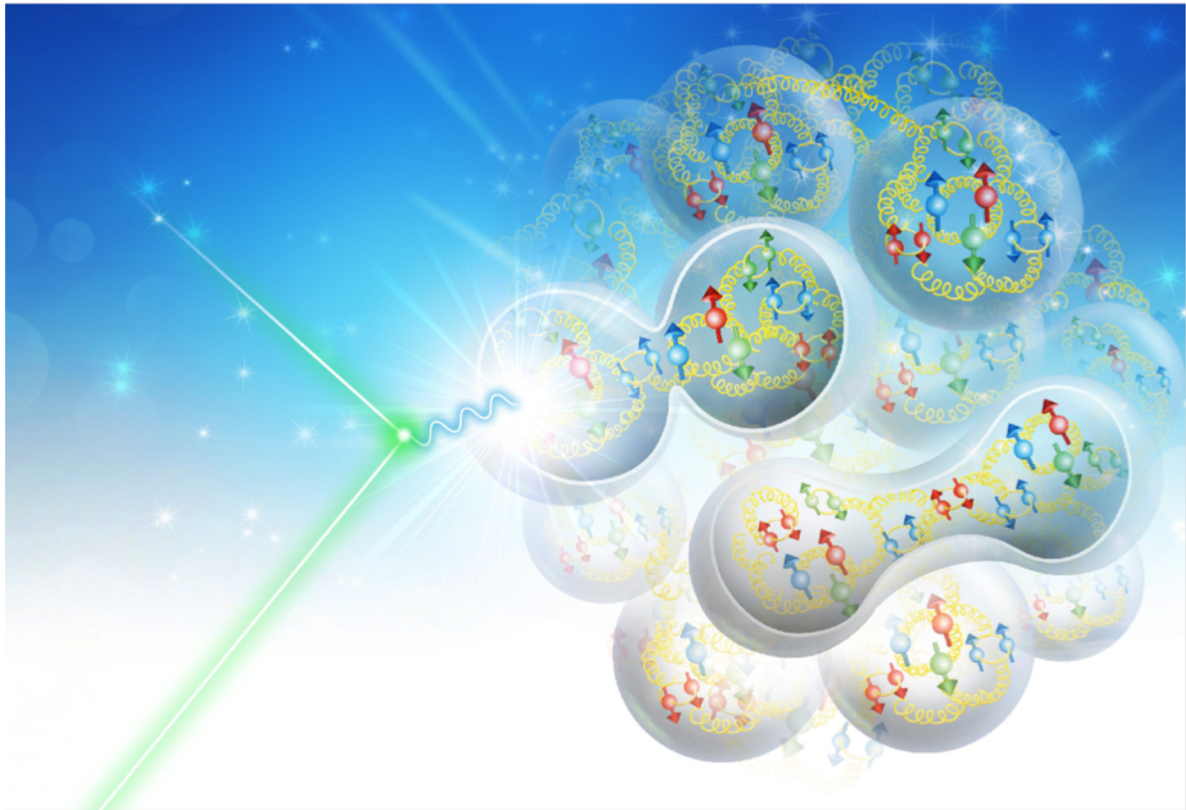
R&D in accelerators, detectors, isotopes

Electron-Ion Collider: Quark-Gluon Imagining in the Era of Streaming Readout and AI/ML

Markus Diefenthaler

mdiefent@jlab.org

- The EIC will enable us to embark on a **precision study of the nucleon and the nucleus at the scale of sea quarks and gluons**.
- Software & Computing will be an integral part of EIC science. "***Software is the soul of the detector***".
- In synergy with the computing for the 12 GeV CEBAF science program, we are working to **accelerate science**:
  - AI/ML and heterogenous computing for next-generation simulations.
  - Seamless data processing from DAQ to analysis using streaming readout and AI/ML.
    - Rapid turnaround of data to start work on publications.



STRONG INTERACTIONS

A podcast about exploring a new frontier in nuclear physics at the upcoming Electron Ion Collider, by Maria Zurek and Markus Diefenthaler.

Stories straight from the heart of matter.

https://www.stronginteractions.org