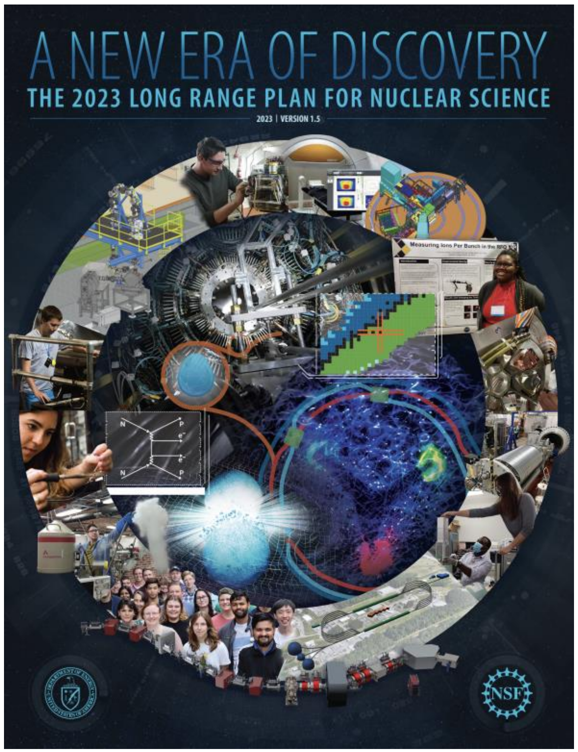
Scientific Origins of the Electron Ion Collider

My personal story with apologies for omissions and incompleteness



- **Origins of EIC**
- **Timeline of Evolution of the Science Case**
- **Outlook**

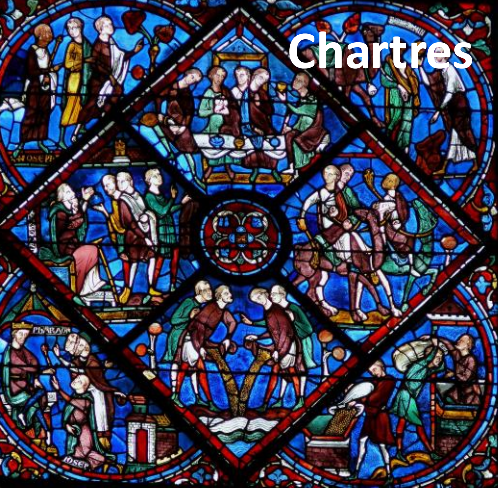
We recommend the expeditious completion of the EIC as the highest priority for facility construction.

Source of the Amazon the World's Largest River

- Subject of speculation for centuries
- Current understanding: headwaters of three different Peruvian rivers
  - the Marańón
  - the Apurímac
  - the Mantaro

that rise high (~ 17,000 ft) in the Andes.

- Downstream tributaries that join are essential.



Large Human Endeavors

Building Gothic Cathedrals

- Constructed in N. Europe in 11th to 13th centuries from stone, wood, iron and stained glass.
- Tallest buildings in Europe since Roman times.
- $ 1 billion class projects.
- Took decades to centuries, e.g. Cologne cathedral took 600 years (1248-1560, 1814-1880).
- Required highly skilled workforce: masons, carvers, carpenters, glass workers, laborers,…

Quantum Chromodynamics

- **1961**

  Particle zoo organized in terms of the eightfold way by Gell-Mann and Ne'eman

- **1963**

  Quarks proposed by Gell-Mann and Zweig

- **1968**

  Pointlike quarks discovered experimentally at SLAC by Friedman, Kendall and Taylor

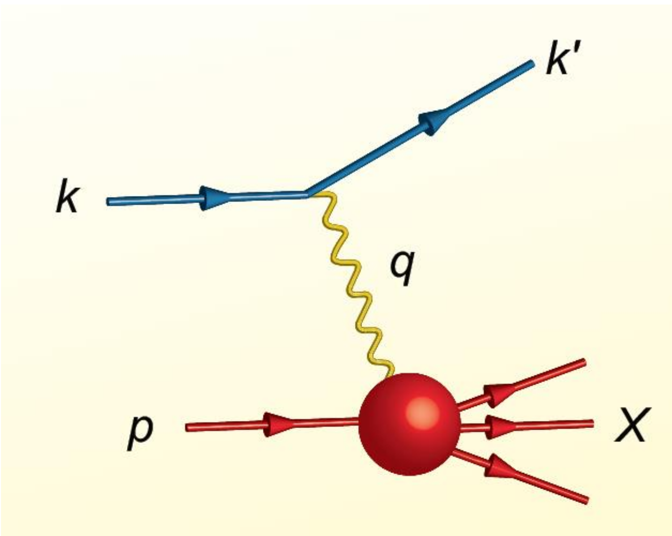
- **1973**

  - color as source of the strong field developed into QCD by Frisch, Leutwyler and Gell-Mann

  - asymptotic freedom discovered by Gross, Politzer and Wilczek

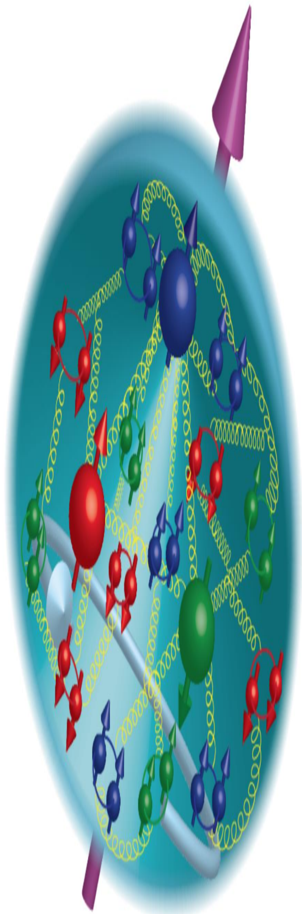
- **1974** November Revolution

Proton Viewed in High Energy Electron Scattering: Longitudinal Dimension



Lorentz Invariants

- $E^2_{CM} = (p+k)^2$
- $Q^2 = -(k-k')^2$
- $x = Q^2/(2p\bullet q)$



- Viewed from boosted frame, length contracted by

$$\gamma_{Breit} = \sqrt{1 + \frac{Q^2}{4M^2}}$$

- Internal motion of the proton's constituents is slowed down by time dilation – the instantaneous charge distribution of the proton is seen.
- In boosted frame x is understood as the longitudinal momentum fraction

valence quarks: $0.1 < x < 1$

sea quarks: $x < 0.1$

J. Bjorken, SLAC-PUB-0571 March 1969

The structure of the proton ~ 1985

- Structure and dynamics understood in terms of quarks: gluons assumed to carry half of the proton's momentum but essentially `invisible'
- Theoretical QCD inspired models based on quarks and confinement, e.g. the MIT bag model
- EMC Effect => quark momentum modified in the nucleus
- Violation of Gottfried Sum Rule => flavor asymmetry of the sea established
- Lattice QCD in its infancy

Polarized lepton beams

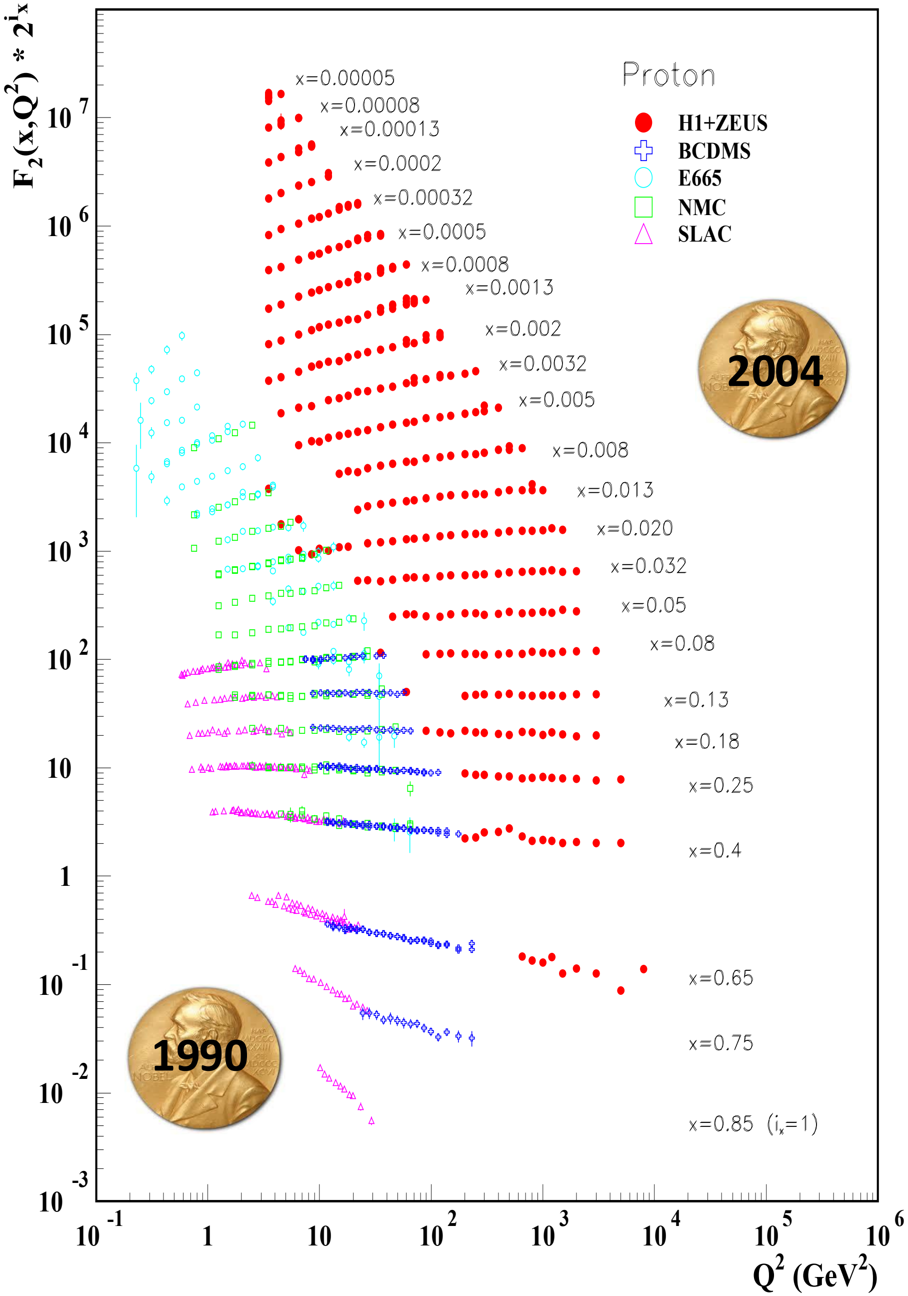
- In ~ 1987 available beams included
  - low intensity, highly polarized muon beams
  - high intensity, low polarization electron beams
- Interest in studying the spin structure of the nucleon drove the polarized electron beam technology in a major way
- At SLAC, ~ 80% polarized electron beams were developed for E122 – direct evidence for Z^0 in parity violating electron scattering.
- At DESY, HERMES drove the development of ~65% polarized electron/positron beams using the Sokolov-Ternov effect
- Precision beam polarimetry was developed

HERMES originated in 1987 from a number of sources

- EMC spin results => quarks carry only a fraction of the proton's spin
- Significant development in polarized internal gas target technology
- HERA had the potential for longitudinally polarized electron/positron beams
- Common interests of scientists in Europe and North America
- Seek to understand proton structure in terms of the quarks (and gluons) of QCD
- Desire to be technically innovative
- Initial focus was on inclusive electron detection but quickly added hadron particle id.

Importance of HERA Collider

- While proposed as a discovery machine, it ended up being a QCD machine of enormous consequence
- Rise of $F_2(x,Q^2)$ with Q^2 at low x
- Observation of high fraction (~15%) of diffraction events in DIS
- Search for gluon saturation
- Limitations: no polarized proton beams, low luminosity

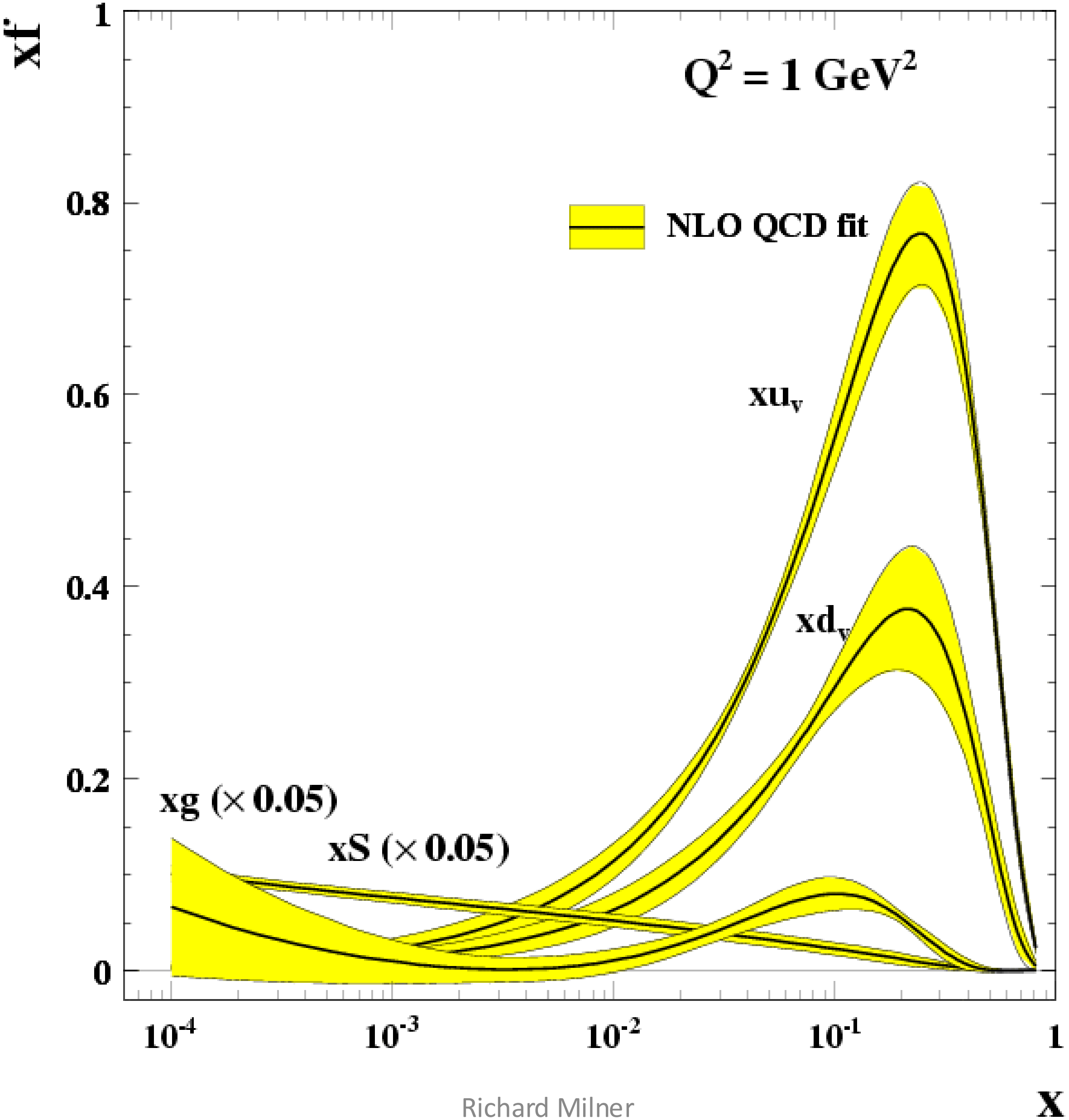


Quark Structure of Proton from High-Energy Lepton Scattering

e-p cross section ≈ $\sigma_{Mott} \bullet F_2(x,Q^2)$

- Snap shots of the charged structure of the proton taken in the boosted frame
- *1/Q* spatial resolution
- *1/x* shutter speed
- QCD prescribes evolution with Q^2 which connects quarks and gluons

Low x rise of the gluons!



R. Yoshida
C. Gwenlan

Theory 1990-2010

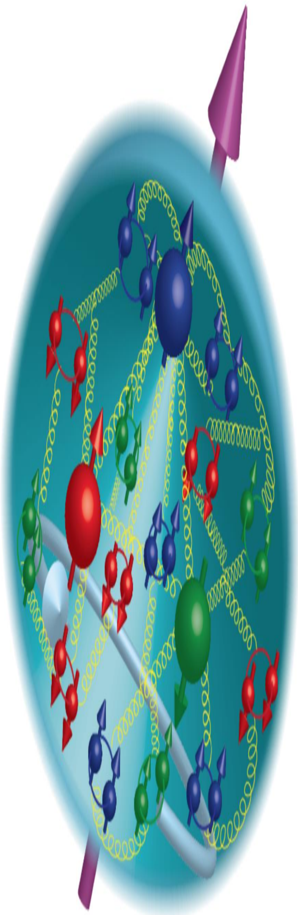
- Realization that one could access transverse structure in high energy lepton scattering
- Generalized Parton Distributions and Transverse Momentum Distributions
- Experimentally, one needs a high energy scattering event where the target was left intact.
- Deeply Virtual Compton Scattering

X. Ji, PRL **78**, 610 (1997)

- Gluon saturation at low *x*: development of the chiral glass condensate

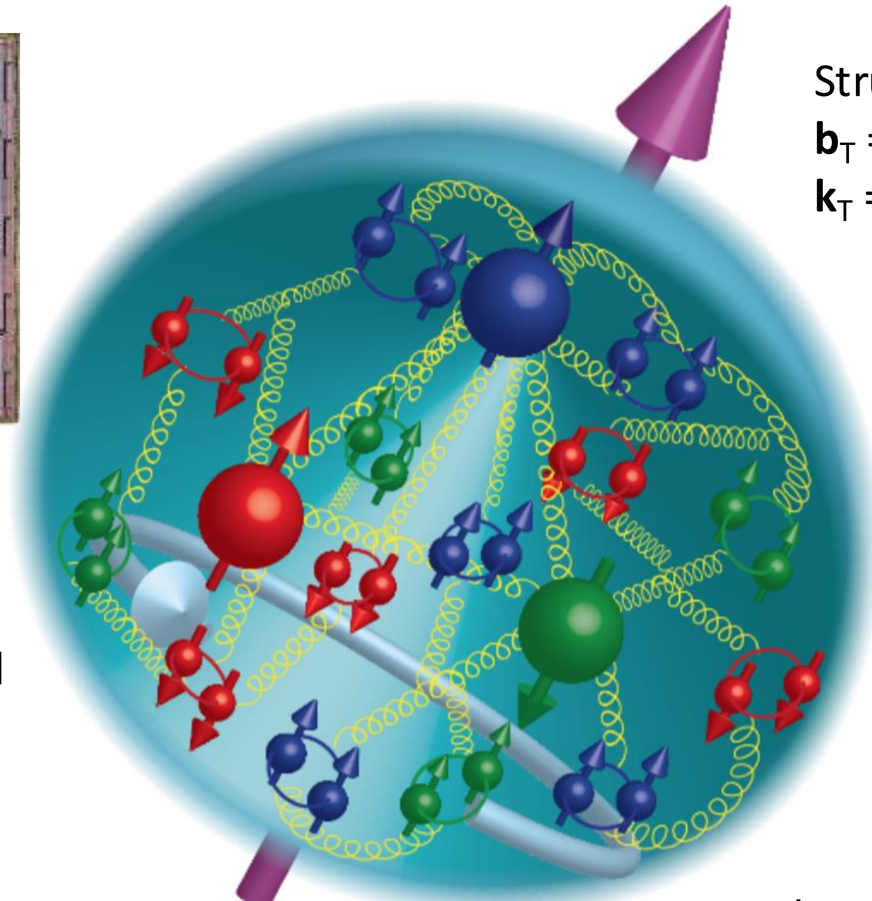
L. McLerran and R. Venugopalan, Phys. Rev. D **50**, 2225 (1994)

Proton Viewed in High Energy Electron Scattering: 1 Longitudinal Dimension



Proton Tomography: 2 New Dimensions Transverse to Longitudinal Momentum

Structure mapped in terms of
$\mathbf{b}_T$ = transverse position
$\mathbf{k}_T$ = transverse momentum



Nuclei!

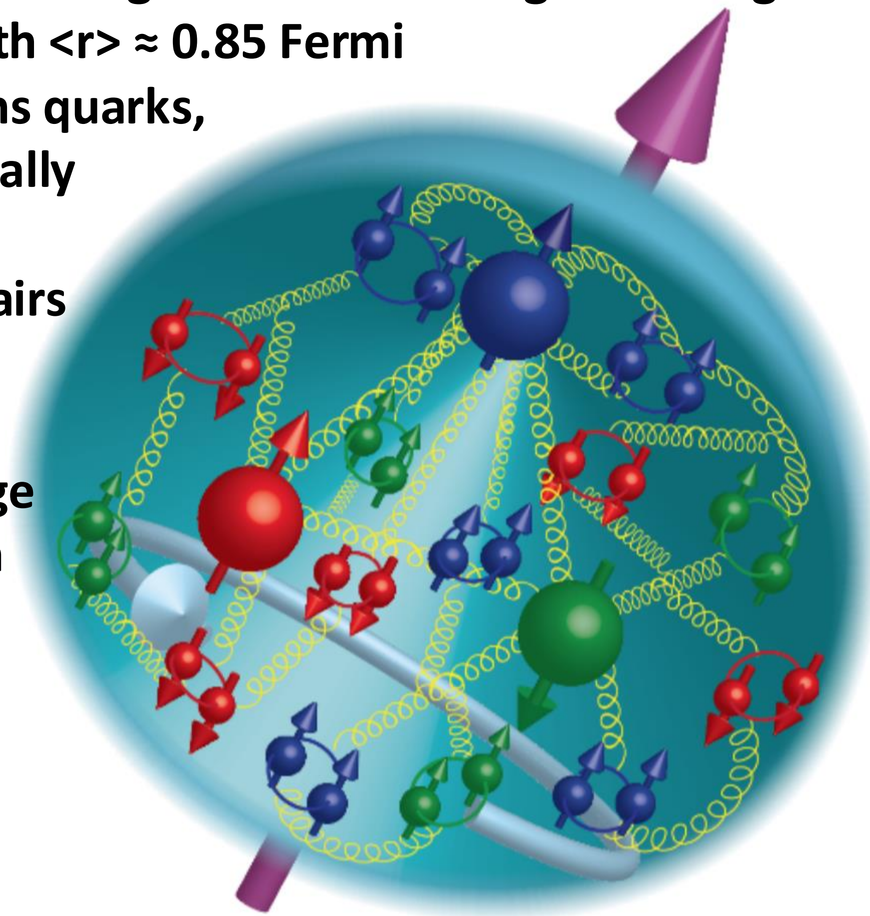
Goal:
Unprecedented
21st Century Imaging
of Hadronic Matter

Direction of longitudinal momentum normal to plane of slide

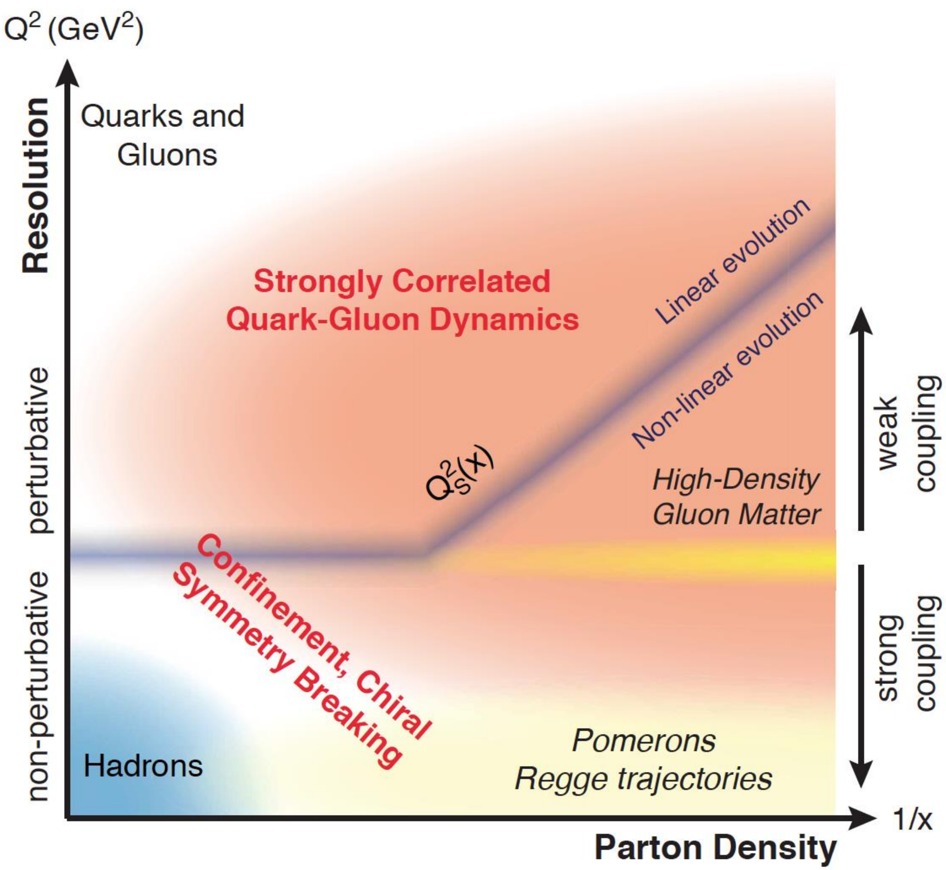
Valence Quarks: JLab 12 GeV
Sea Quarks and Gluons: EIC

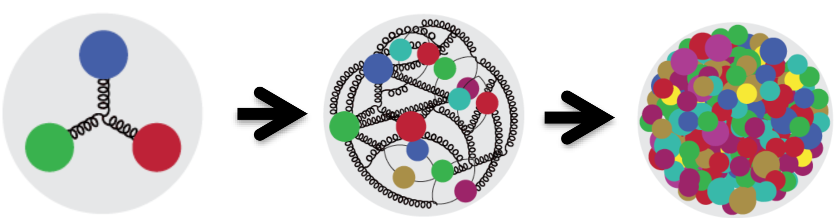
21st Century View of the Fundamental Structure of the Proton

- **Elastic electron scattering determines charge and magnetism of nucleon**
- **Approx. sphere with <r> ≈ 0.85 Fermi**
- **The proton contains quarks, as well as dynamically generated quark-antiquark pairs and gluons.**
- **The proton spin and mass have large contributions from the quark-gluon dynamics.**

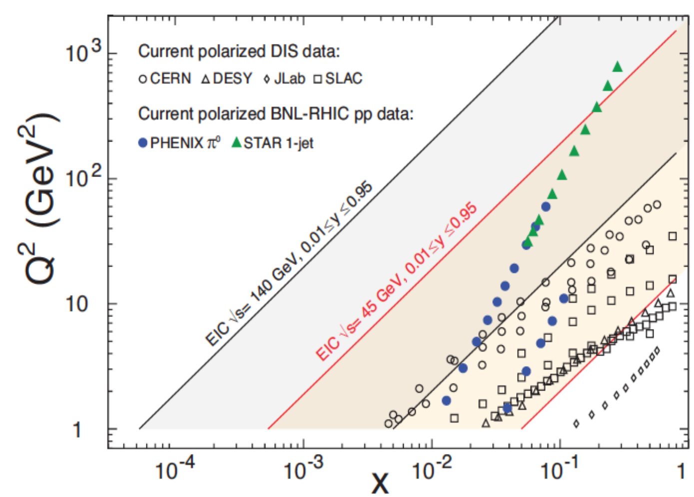


QCD Exploration

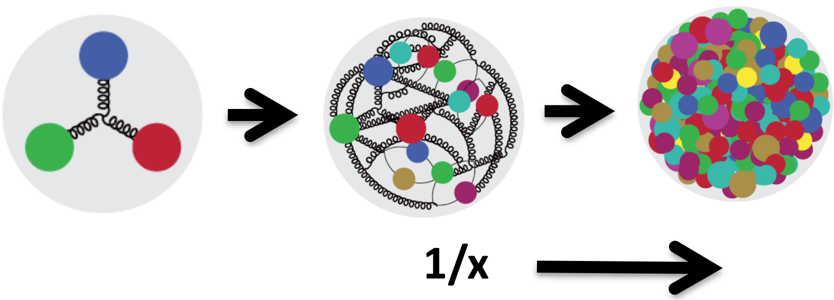




- Desire to explore the QCD landscape over a wide range in *x* and Q^2.
- Study high-density gluon matter
- Different coupling regimes
- Nuclei are *terra incognita*
- Study modifications of gluons in nuclear environment complementing heavy ion programs at RHIC and LHC

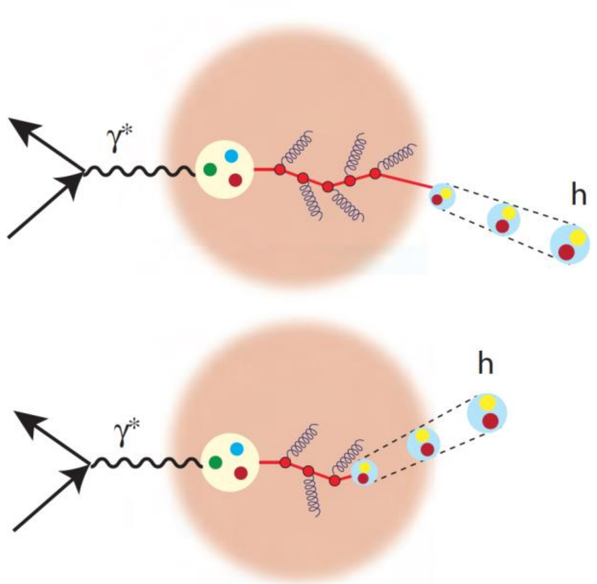


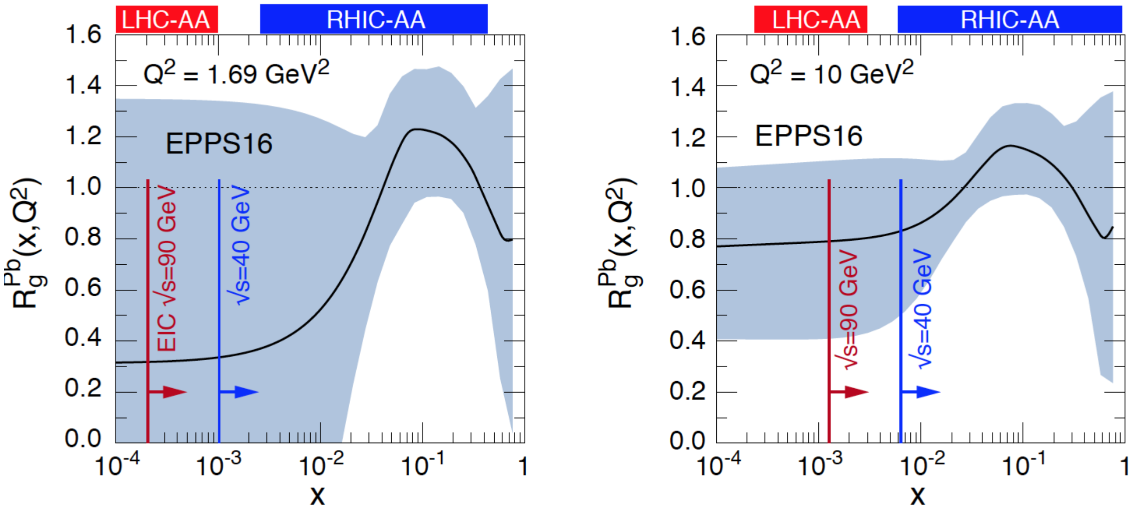
QCD Dynamics in Nuclei



- Hadronization: the process that connects QCD with experiment
- Nuclear PDFs
- Color neutralization and propagation
- Diffraction: no net color exchange

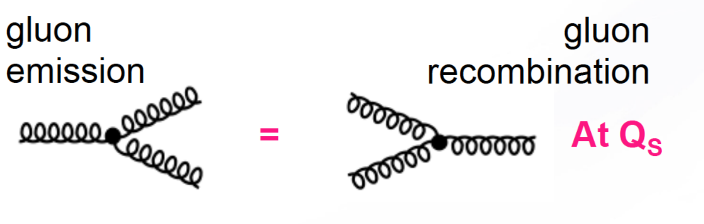
Hadronization

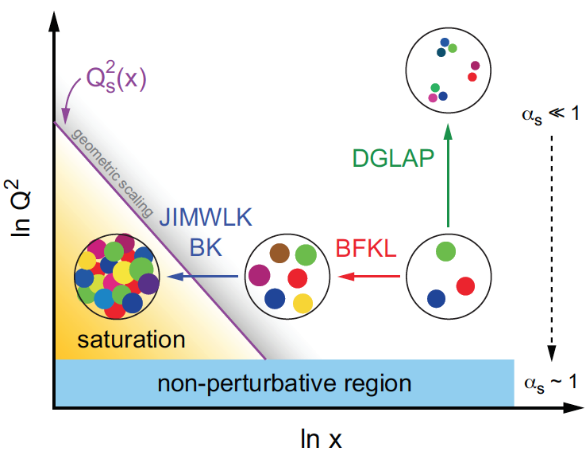




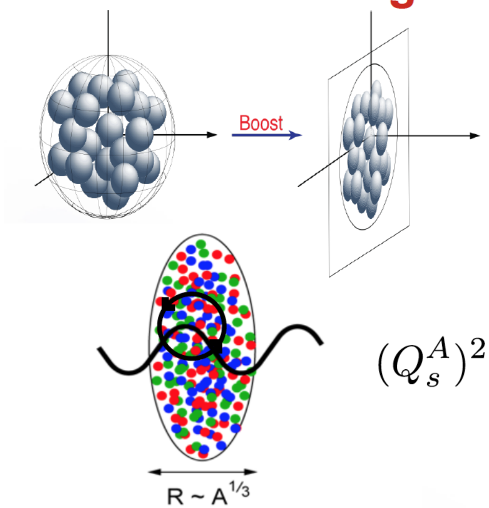
What tames the low-x rise of the gluons?

- New evolution equations at low x and moderate Q^2
- **Saturation scale $Q_s(x)$** where gluon emission and recombination become comparable





Advantage of nucleus



$$(Q_s^A)^2 \approx c Q_0^2 \left[\frac{A}{x}\right]^{1/3}$$

$L \sim (2m_N x)^{-1} > 2 R_A \sim A^{1/3}$

- First observation of gluon recombination effects in nuclei
- Is this a universal property?
- What is the new effective theory in this regime?

Mid-1990's

- **1995**

  - ZEUS and H1 taking data

  - HERMES and CEBAF begin taking data

  - SMC taking data at CERN

- **March 1997**

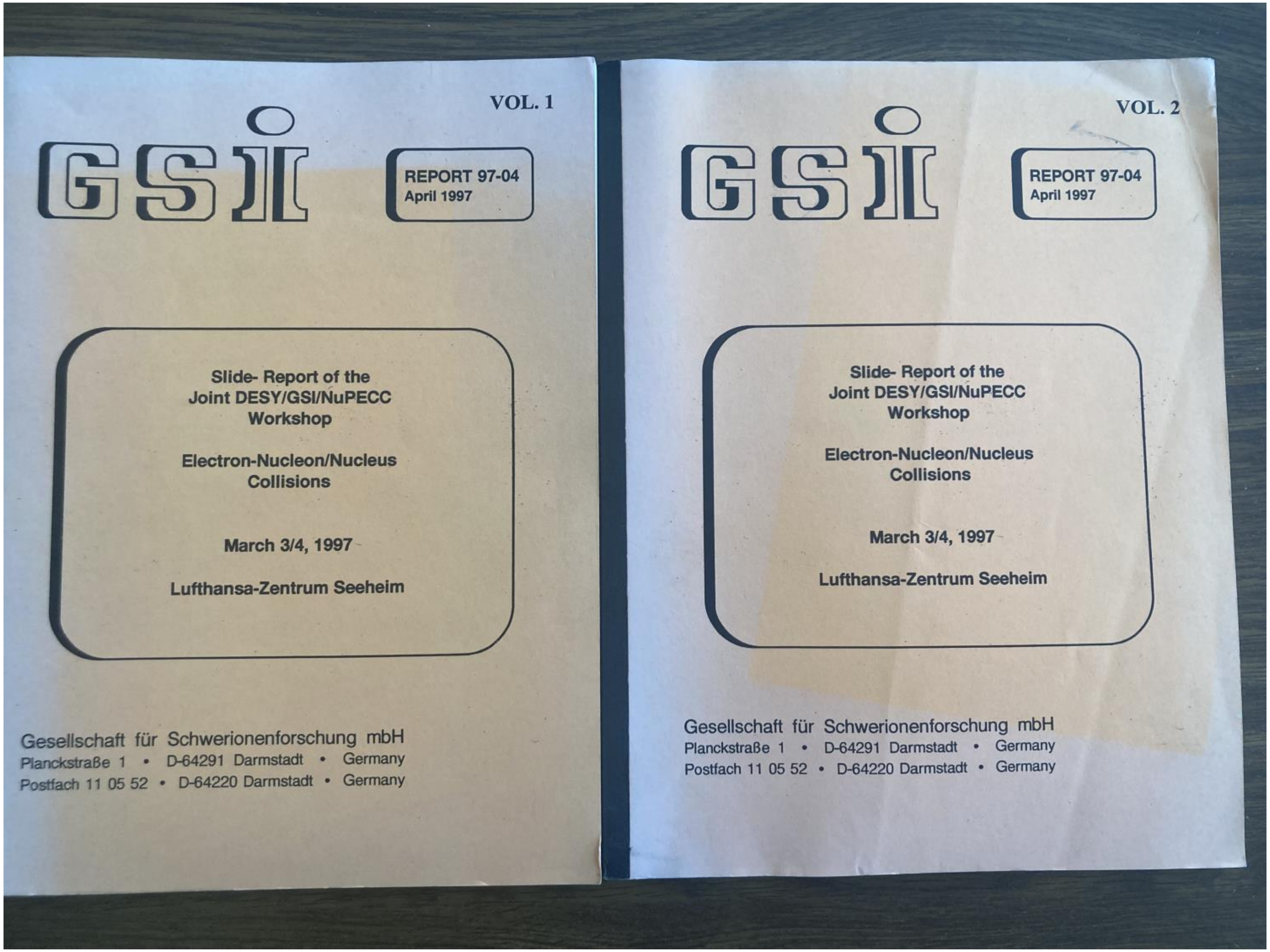
  DESY/GSI NuPECC meeting at Seeheim, Germany

  - electron-nucleus collisions at HERA

  - new electron-nucleus collider; E_{cm} ~20-30 GeV

  - 20 GeV linac ELFE

Earliest Headstream for EIC?



Low energy facilities at universities in the US were being phased out

- **Indiana University Cyclotron Facility**

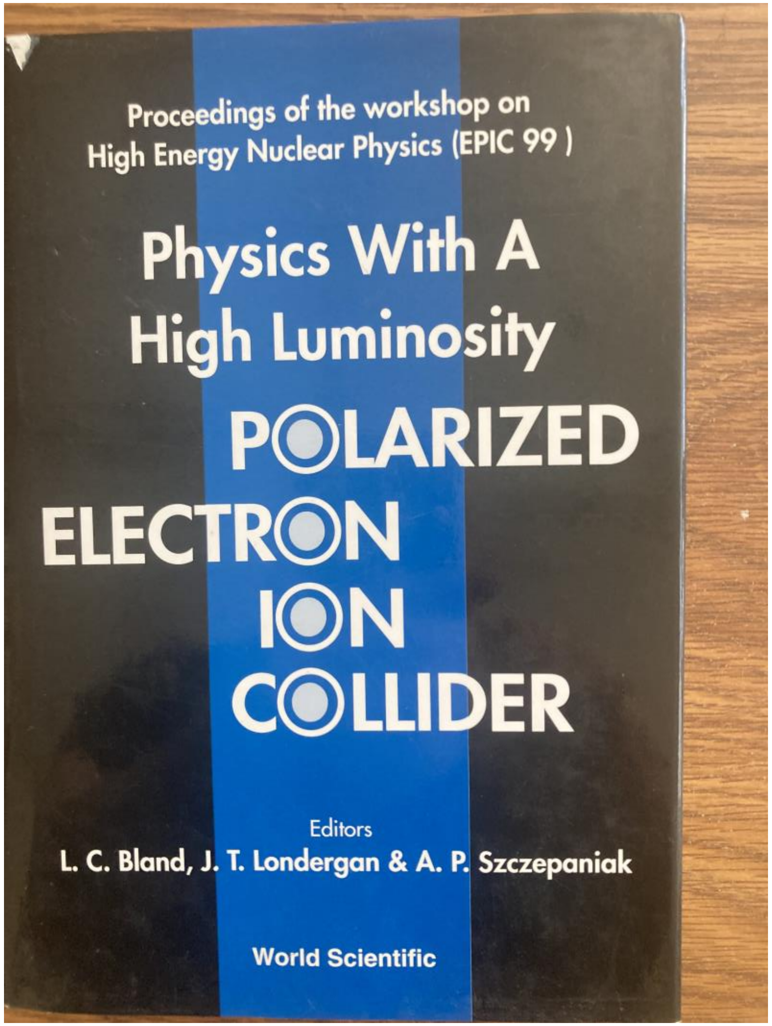
John Cameron, Tim Londergan and colleagues developed a concept for a low high electron-proton collider: (EPIC) workshop in April 1999.

- **MIT-Bates Linear Accelerator Center**

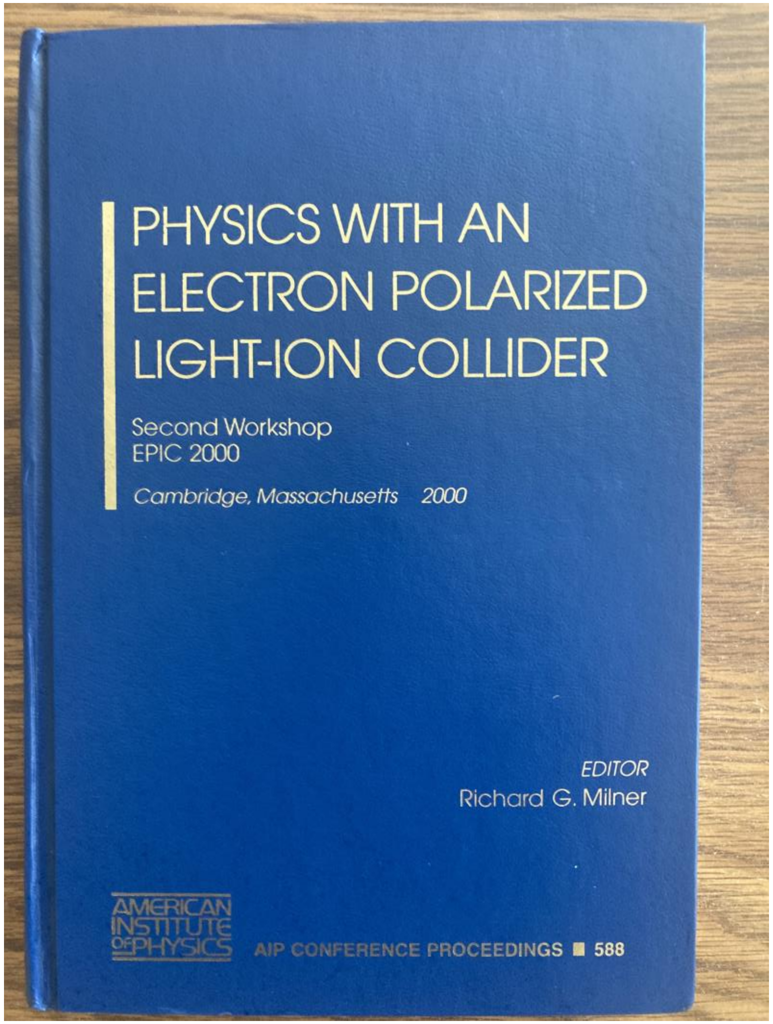
Manouchehr Farkhondeh, Chris Tschalaer and RM became interested in EPIC and hosted a workshop at MIT in September 2000.

Headstreams for EIC

IUCF, Indiana April 1999



MIT, August 2000



Brookhaven National Laboratory Headstream for EIC

- **December 1999 BNL**

Abhay Deshpande, Gerry Garvey, Vernon Hughes, Larry McLerran, Peter Paul, Raju Venugopalan held a workshop at BNL on eRHIC.

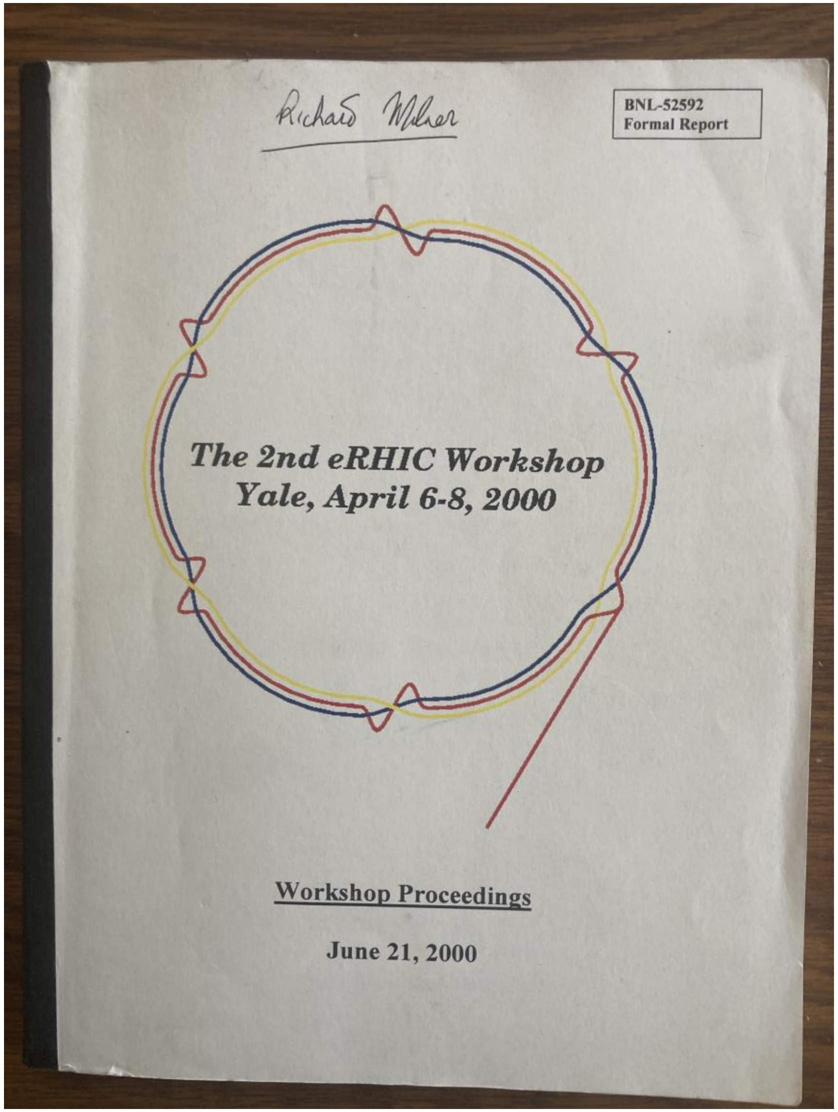
- **April 2000 Yale University**

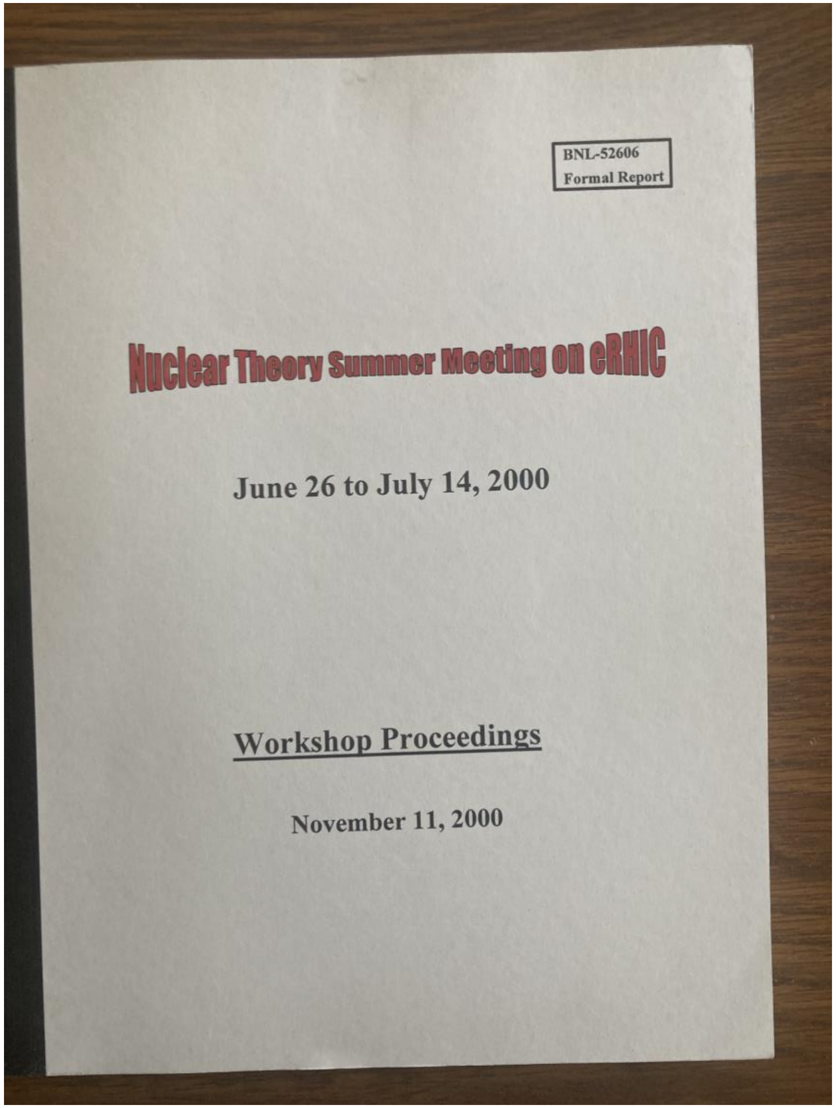
Second eRHIC workshop at Yale.

- **March 2001 Santa Fe, NM**

EPIC and eRHIC united to make a case for eRHIC at the 2002 US Nuclear Physics Long Range Planning Exercise.

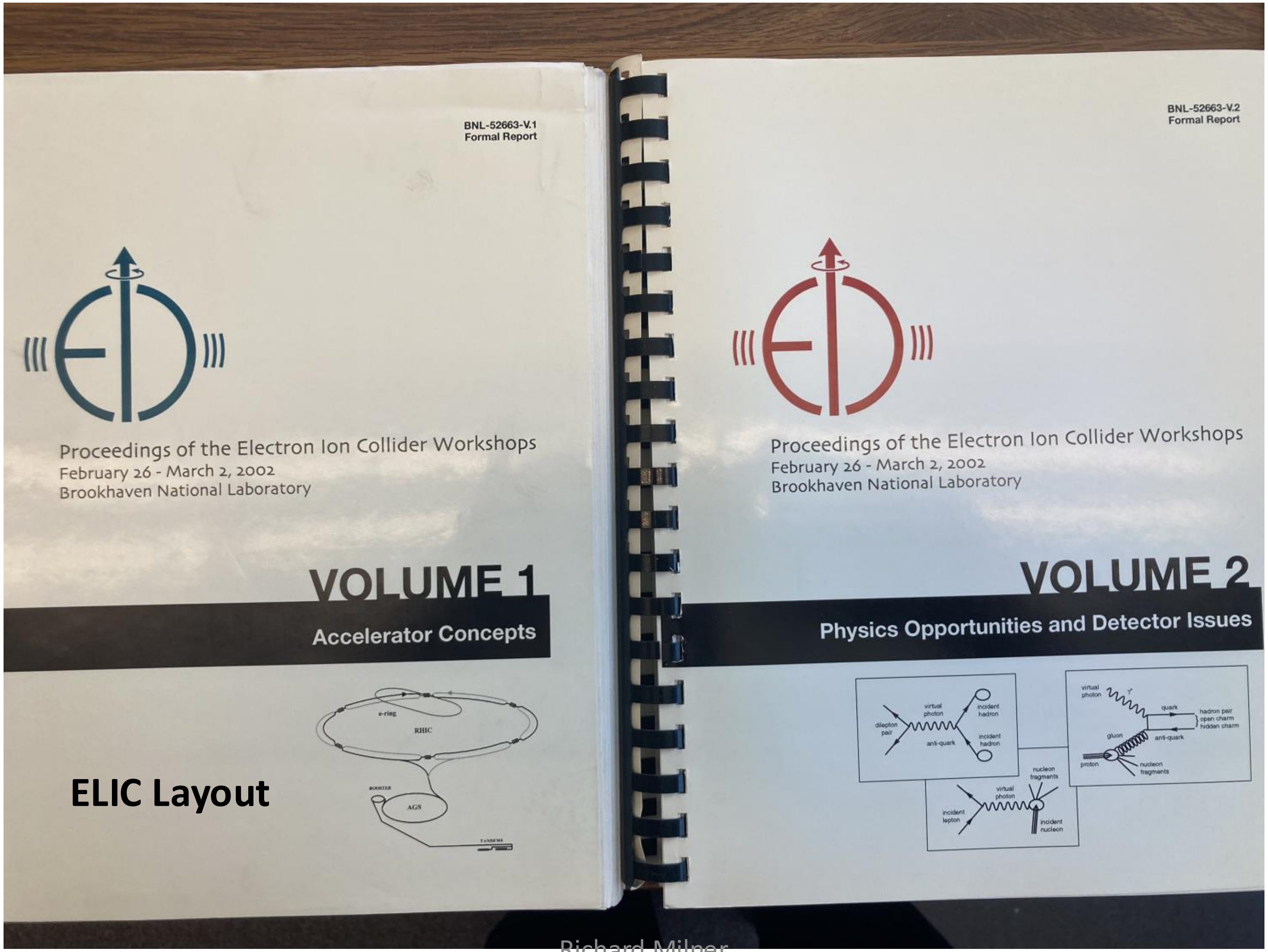
The current builds





Electron-Ion Collider is Born!

BNL Feb 26 – March 2, 2002



First Formal Proposal February 2002

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3

1.2 The Electron Ion Collider (EIC)

The Electron Ion Collider is proposed as a means to obtain experimental answers to all of these questions. The design requirements are shaped by three decades of experimental work carried out with stationary or fixed targets at high-energy physics facilities such as SLAC, CERN, DESY, and Fermilab. In addition, a significant amount of effort was expended at DESY to investigate future polarized electron – proton (e - p) and unpolarized electron - ion (e - A) options. The inherent limitations of these facilities points to the need for a facility with the following characteristics:

- Collider geometry where electron beams collide with beams of protons or light and heavy nuclei,
- Wide range of collision energies (from E_{cm}/nucleon = 15 GeV to 100 GeV),
- High luminosity $L = 10^{33}$ cm^{-2} s^{-1} per nucleon,
- Polarization of electron and proton spins, and
- Preferably, two interaction regions with dedicated, nearly hermetic, detectors.

The Electron Ion Collider

A high luminosity probe of the partonic substructure of nucleons and nuclei

A white paper summarizing the scientific opportunities and the preliminary detector and accelerator design options

February 2002

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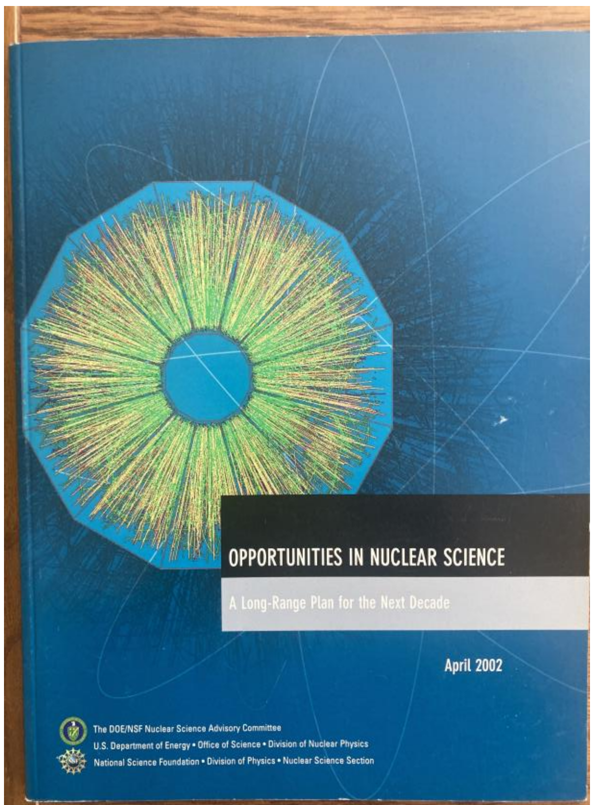
NSAC 2002 Long Range Plan

- Met in Santa Fe in March 2001
- Secret science ballot ranked eRHIC science highly
- Community sense was positive



NSAC Long-Range Plan Working Group

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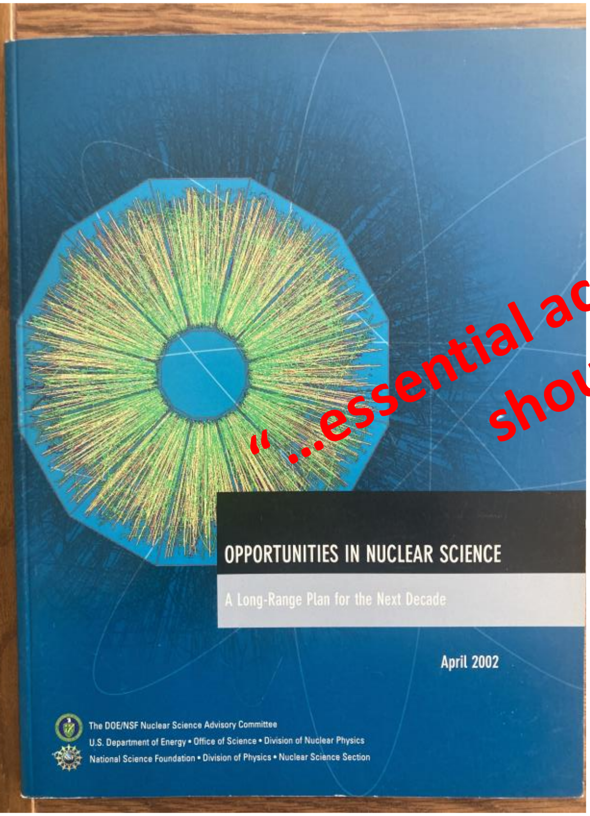

"...essential accelerator and detector R&D [for EIC] should be given very high priority in the short term."

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HERA III Not Realized

Meanwhile, back at DESY, then the world center of high-energy electron-proton scattering, there was a concerted effort to make the case for a post-2007 HERA-III era, where nuclear beams would be accelerated and collided with the 27 GeV electron beam and the interactions studied in the existing H1 and ZEUS detectors. Ferdinand Willeke led the accelerator effort to collide nuclei up to calcium and the estimated cost was DM 50 million. However, the German high energy physics community had little interest in HERA III and rather chose to focus on the LHC at CERN. Thus, HERA running came to an end in 2007. Subsequently, several of the leaders of the HERA-III project, including Max Klein, originated LHeC, the high-energy electron-ion collider project at CERN.

When one door closes, another door opens.

Jefferson Lab enters the picture!

- At the Santa Fe meeting, there were presentations on eRHIC and on CEBAF energy upgrades. The idea to use the CEBAF linac as an injector into an injector for a future collider came up.
- After the 2002 LRP Exercise, there was a strong push from BNL Management and their PAC to engage the broader electromagnetic physics community.

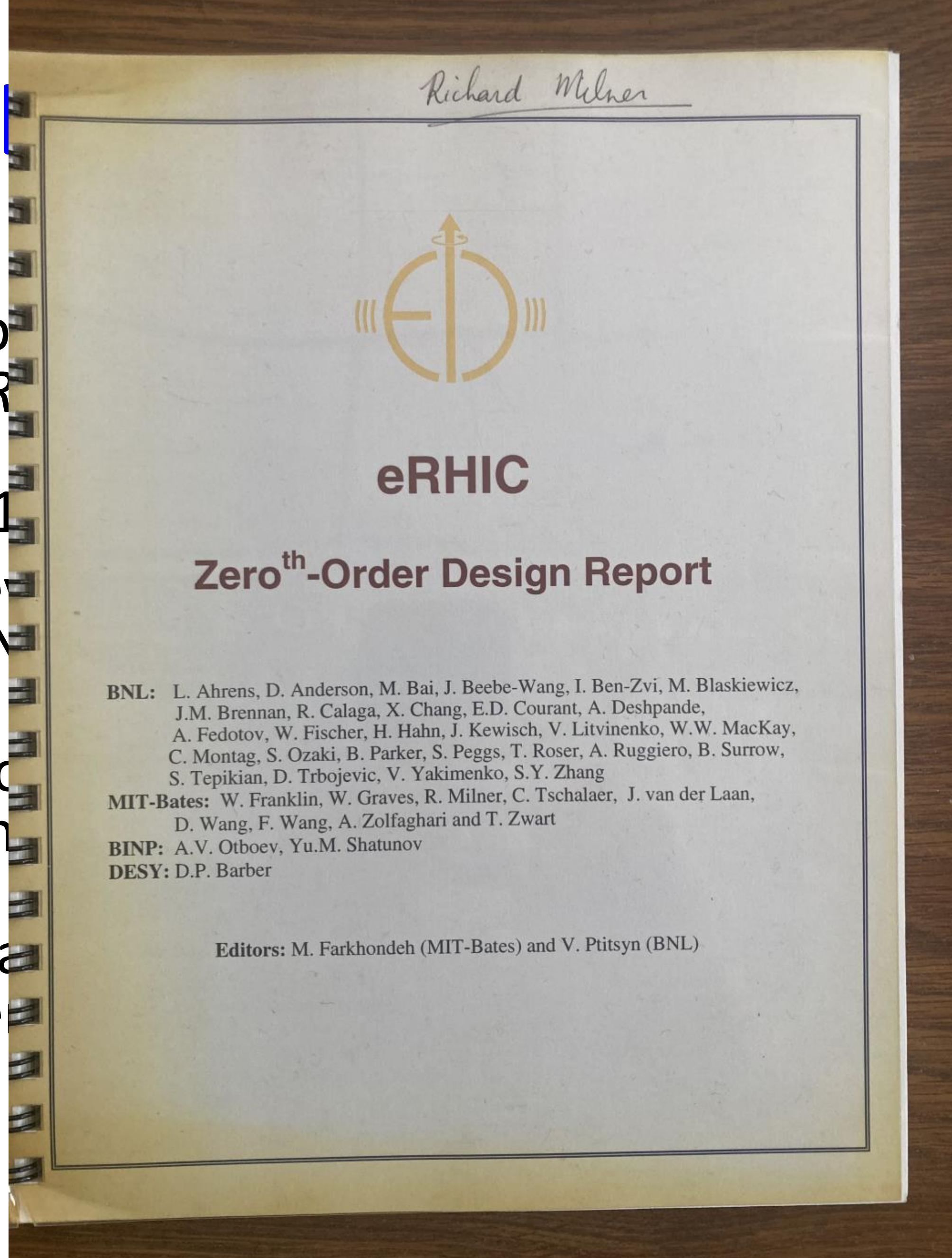
If this is so important for QCD why isn't Jefferson Lab interested?"

- Rolf Ent played a leadership role in the science case from the beginning.
- The strong accelerator group at CEBAF developed a novel and compelling figure-eight ring-ring design.
- This was introduced at the Second EIC Workshop which took place at Jefferson Lab in March 2004.

EIC Accelerator Design

- In 2004, the first EIC accelerator conceptual design was developed by a Bates-BNL collaboration, the so-called *Zeroth order Ring-Ring eRHIC Design*, coordinated by Manouchehr Farkhondeh and Vadim Ptitsyn. The maximum luminosity in this design was 10^{32} $cm^{-2}s^{-1}$.
- After the development of the initial eRHIC ring-ring concept in 2004, the BNL eRHIC machine design group focused for about a decade on an electron linac colliding with the RHIC ion beam. While this concept had the possibility of attaining higher collision luminosity than the ring-ring concept, it demanded enormously high currents of polarized electrons as well as very ambitious hadron cooling mechanisms. This drove ambitious R&D for over a decade at BNL.
- Jefferson Lab developed a design **ELIC** which used CEBAF as an injector into a figure eight storage ring. This design was very stable over more than a decade.

BN ign



- In 2004, the n was developed b alled *Zeroth order Ring-R* nouchehr Farkhondeh ninosity in this design was 1
- After the de ng concept in 2004, the BN ed for about a decade on a C ion beam. While this co higher collision lum demanded enormously s well as very ambitious ha e ambitious R&D for ove

Learning from HERA

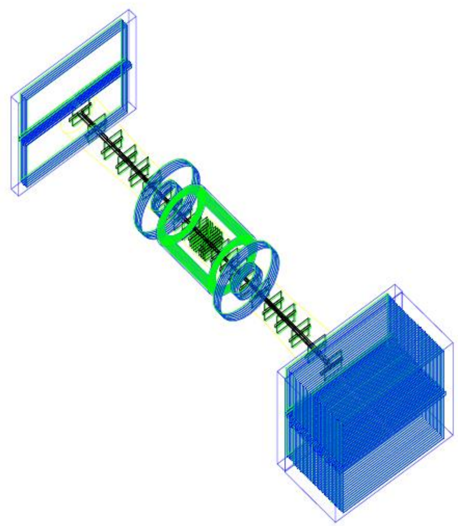
A Detector for Forward Physics at eRHIC

Feasibility Study

I. Abt, A. Caldwell, X. Liu, J. Sutiak

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

July 20, 2004



Learning from HERA

3.1 Summary of measurements

In summary, the following measurements are seen as the highlights of the proposed program:

- The high precision measurement of F_2 at low x from $Q^2 = 0.05$ GeV^2 to $Q^2 = 5$ GeV^2 to better understand the observed transition of the cross sections from hadronic to partonic behavior.
- The measurement of the longitudinal structure function, F_L, particularly at Q^2 values below 10 GeV^2, where present theoretical and experimental uncertainties are very large.
- The measurement of forward jets and forward particle production up to pseudorapidities of at least $\eta = 4$ to test in a direct way our understanding of parton branching in strong interactions and to see the onset of collective phenomena. Acceptance for forward jets will also allow the measurement of F_2 to $x = 1$ at moderate Q^2.
- The measurement of diffractive and exclusive reactions (VM production and DVCS) over the full W range, and to values of $|t| \leq 1.5$ GeV^2, with no proton dissociation background, to perform a three dimensional mapping of the proton and perform first extractions of generalized parton distributions.

All of the above measurements should be performed with protons and with at least two nuclear targets to search for the gluon condensate, and understand nuclear effects in parton distributions.

EIC Collaboration (EICC)

- In April 2007 in an EIC meeting at MIT, the EIC Collaboration (EICC) was formed with three goals:

(1) to develop the most compelling science case for a high luminosity, high energy electron-ion collider (EIC) independent of where it may be sited;

(2) to work with accelerator physicists, especially at BNL and JLab, to develop the optimal EIC accelerator design;

(3) to design and realize through a R&D program the most optimal suite of detectors for the EIC.

- The following EICC Steering Committee was established:

Allen Caldwell (MPI Munich), Abhay Deshpande (Stony Brook) (Co-Chair),

Rolf Ent (JLab), Gerry Garvey (LANL), Emlyn Hughes (Caltech), Ken'ichi Imai (Kyoto U.), Peter Jacobs (LBNL), Lia Merminga (JLab), Richard Milner (MIT) (Co-Chair),

Peter Paul (BNL), Jen-Chieh Peng (U. Illinois), and Thomas Roser (BNL).

- EICC was active through the 2010 Long Range Planning Exercise and held meetings at BNL, JLab, U Maryland, MIT, Washington DC, Stony Brook U, Hampton U, GSI, LBNL,

Electron-Ion Collider Collaboration

Home | Organisation | Institutions | Timeline | Mailing Lists | Calendar | Events

Accelerators
Documentation
Meetings
Conference/Seminar Presentations
News

Welcome | EIC Science | EIC Goals | EIC Activities | EIC Meetings

The Electron-Ion Collider Collaboration

Welcome

This is the home page of the Electron-Ion Collider Collaboration (EICC). EICC consists of more than 100 physicists from over 20 laboratories and universities from around the world who are working to realize a powerful new facility in the United States with the aim of studying the particles (gluons) which bind all the observable matter in the world around us. This new facility, known as the Electron-Ion Collider (EIC), would collide intense beams of spin-polarized electrons with intense beams of both polarized nucleons and unpolarized nuclei from deuterium to uranium. Large, new detectors are being designed to detect the high-energy scattered particles as well as the low-energy debris as a means to definitively understand how the matter we are all made of is bound together.

Welcome | EIC Science | EIC Goals | EIC Activities | EIC Meetings

https://web.mit.edu/eicc/

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EICC Charter

The Electron-Ion Collider Collaboration has been formed for the following purposes and goals:

1. to develop the most compelling science case for a high-luminosity, high-energy, electron-ion collider (EIC) independent of where it may be sited;
2. to work with accelerator physicists, especially at BNL and JLab, to develop the optimal EIC accelerator design; and
3. to design and realize through an R&D program the most optimal suite of detectors for the EIC.

Membership

The EICC membership is open to any one who will work on achieving the goals of the EICC. Any physicists interested in joining should contact Abhay Deshpande at abhay@bnl.gov or Richard Milner at milner@mit.edu.

Charter | Membership | Governance | International Advisory | Working Groups and Convenors | Meetings and Communication

Governance

The EIC Collaboration is governed by an EICC Steering Committee, broadly representative of the collaborating institutes with two co-chairs who will act as contact persons/spokespersons of the collaboration.

The purpose of the Steering Committee is:

- To oversee the coordination of the three central activities of the EICC
- To work with all parties towards timely realization of EIC
- To ensure that the Collaboration is appropriately represented at all meetings, conferences, and relevant discussions.

The Steering Committee is appointed by the EIC Collaboration, and will be renewed ~annually. The present members of the Steering Committee are:

- Antje Bruell, Jlab
- Abhay Deshpande, Stony Brook, RBRC (Co-Chair/Spokesperson)
- Rolf Ent, JLab
- Charles Hyde, ODU/UBP, France
- Peter Jacobs, LBL
- Richard Milner, MIT (Co-Chair/Spokesperson)
- Thomas Ulrich, BNL
- Raju Venugopalan, BNL
- Werner Vogelsang, BNL

International Advisory Committee

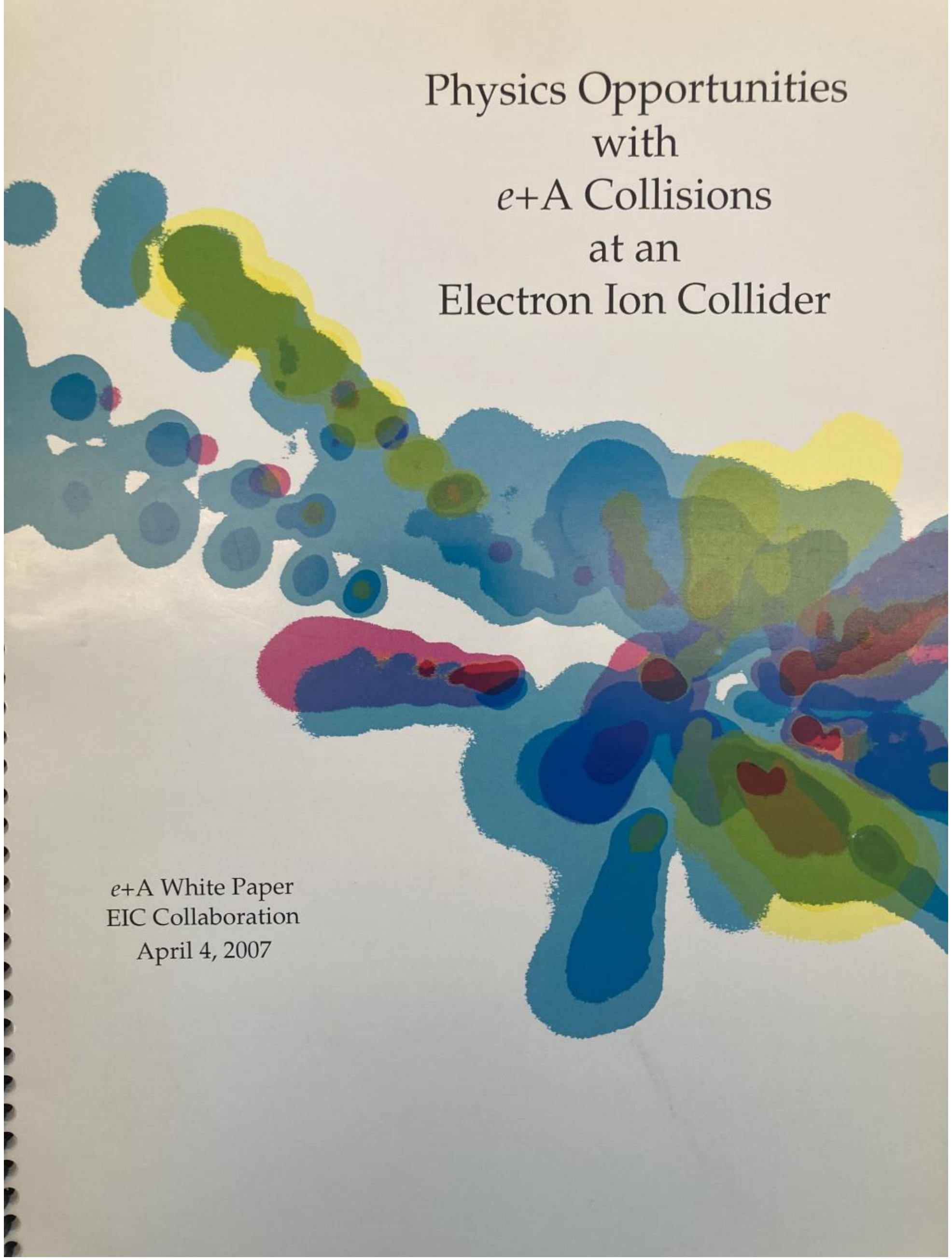
The members of the International Advisory Committee are:

- Jochen Bartels (DESY)
- Allen Caldwell (MPI, Munich)
- Albert De Roeck (CERN)
- Walter Henning (ANL, Chair)
- Dave Hertzog (UIUC)
- Xiangdong Ji (U. Maryland)
- Robert Klanner (U. Hamburg)
- Alfred Mueller (Columbia U.)
- Katsunobu Oide (KEK)
- Naohito Saito (KEK,J-PARC)
- Uli Wienands (SLAC)

Working Groups and Convenors

The activities of the Collaboration are divided into several working groups. The convenors of the various working groups are:

- ep Physics
  - Antje Bruell, JLab
  - Ernst Sichtermann, LBL
  - Werner Vogelsang, BNL
  - Christian Weiss, JLab
- eA Physics
  - Vadim Guzey, JLab
  - Dave Morrison, BNL
  - Thomas Ullrich, BNL
  - Raju Venugopalan, BNL
- Detector
  - Elke Aschenauer, JLab
  - Edward Kinney, U. Colorado
  - Bernd Surrow, MIT
- Electron Beam Polarimetry
  - Sasha Bazilevsky, BNL
  - Wolfgang Lorenzon, U. Michigan


Physics Opportunities
with
e+A Collisions
at an
Electron Ion Collider
e+A White Paper
EIC Collaboration
April 4, 2007

2007 Long Range Plan

In April 2007, the resolution meeting of the U.S. Long Range Plan took place in Galveston, Texas and discussions were led by Robert Tribble. This was preceded by Town Meetings in the different sub-fields. The principal EIC proponents at the Galveston meeting were Abhay Deshpande, Rolf Ent, Richard Milner and Thomas Ullrich. **A strong recommendation to pursue EIC R&D together with a dedicated chapter on the science in the report** meant that the forward momentum for the EIC project continued. Steven Vigdor played a significant role in writing the most effective case for EIC in the 2007 long range plan document.

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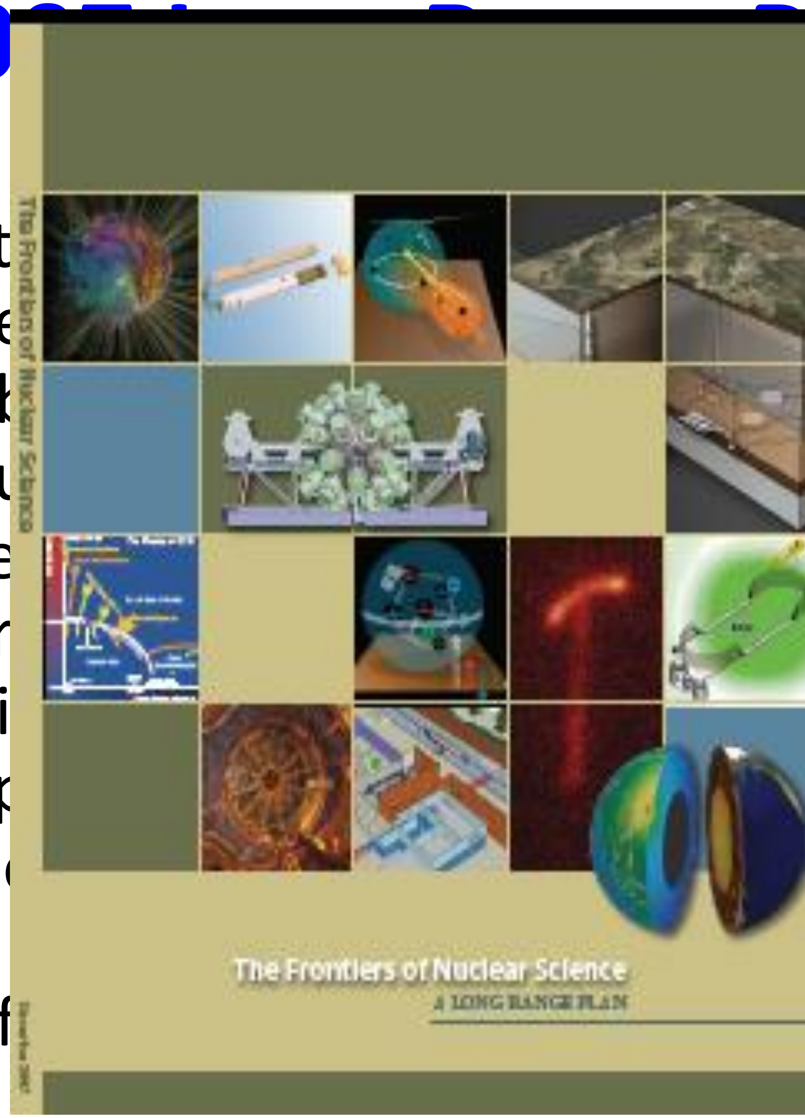

In April 2007, t … e U.S. Long Range
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Richard Milner … ng
recommendati … her with a
dedicated chap … port meant that
the forward m … t continued.
Steven Vigdor … riting the most
effective case f … e plan document.

INT Workshop Fall 2010

Following the 2007 U.S. Long Range planning exercise, an intensive ten-week workshop took place in fall 2010 at the Institute for Nuclear Theory at the University of Washington Seattle. The purpose was to bring together the world's experts in QCD to make a comprehensive and broad study of the EIC science case with the aim of then writing a succinct and compelling summary paper for the subsequent U.S. long range planning exercise. Thus, a 538 page proceedings from the INT workshop was published in August 2011.

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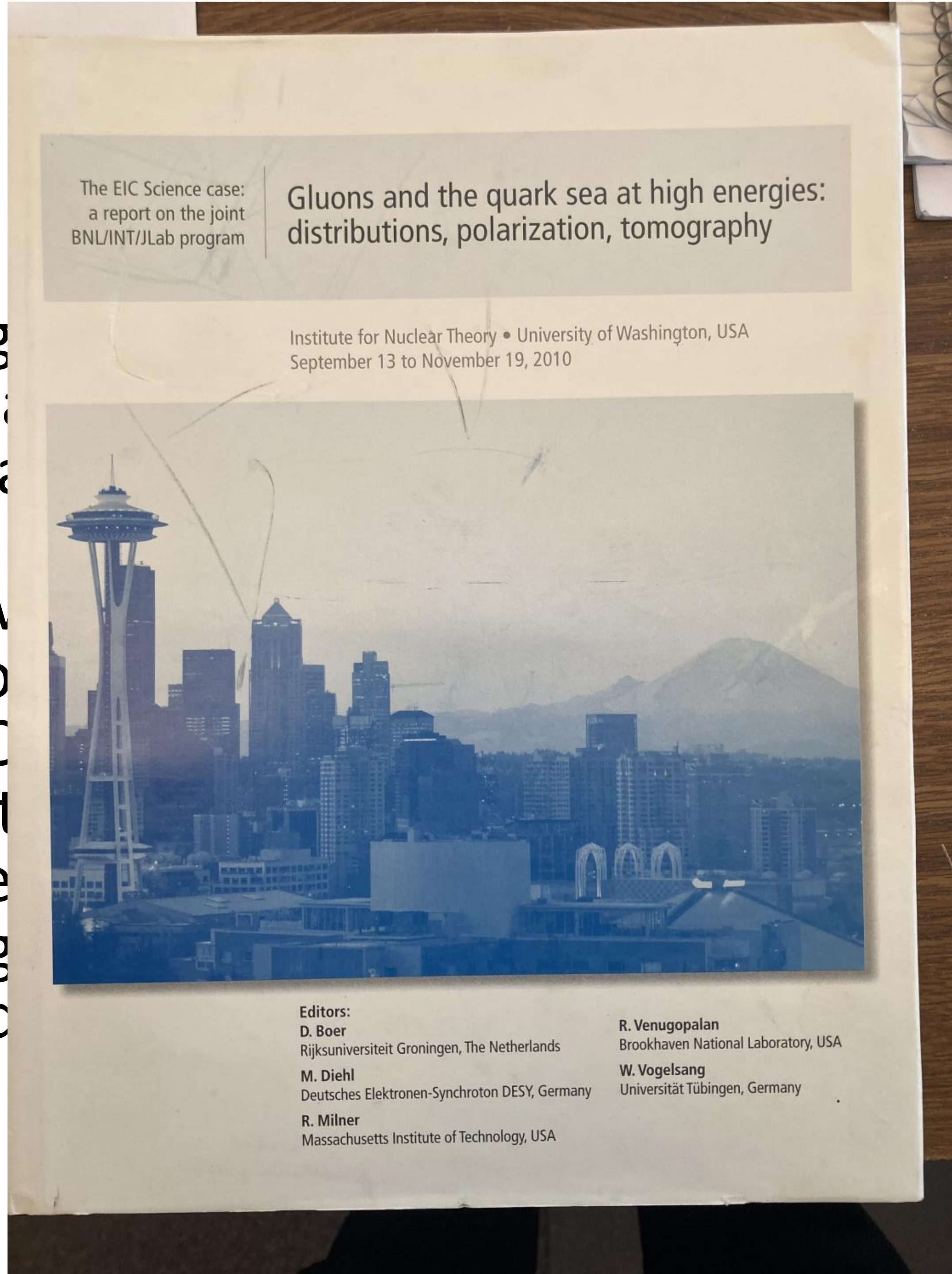
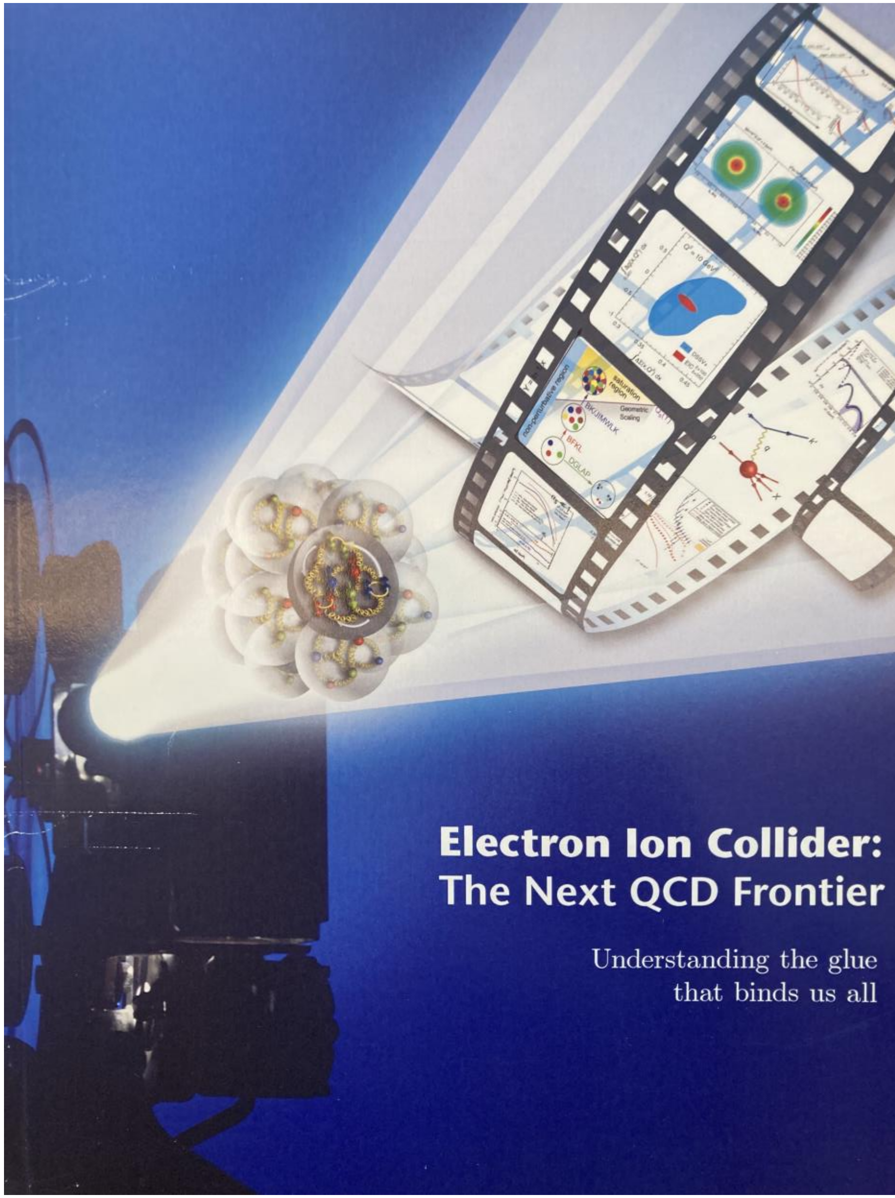


EIC White Paper and 2015 Long Range Plan

Subsequently, Brookhaven National Laboratory and Jefferson Laboratory, with Steven Vigdor (and later Berndt Mueller) and Bob McKeown together playing an important leadership role, led the writing of the EIC White Paper, which was first published in 2012, and revised in 2014. Abhay Deshpande, Jian-Wei Qiu and Zein-Eddine Meziani were the lead editors of the EIC White Paper. This EIC White Paper presented the science case which was reviewed in the 2015 U.S. Long Range planning exercise.

In September 2014, a town meeting of the entire U.S. QCD community took place at Temple University in Philadelphia. The EIC was endorsed unanimously as the highest priority for new construction, after existing commitments were fulfilled. In April 2015, the Long Range Planning resolution meeting took place at Kitty Hawk, North Carolina led by Donald Geesaman. **It unanimously endorsed the Electron-Ion Collider as the next facility to study QCD, after completion of existing commitments.** Thus, an initiative which began in the mid-1990s by those intent on understanding the fundamental quark and gluon structure of matter using lepton scattering, had finally become the top priority for future construction for the U.S. nuclear physics community.



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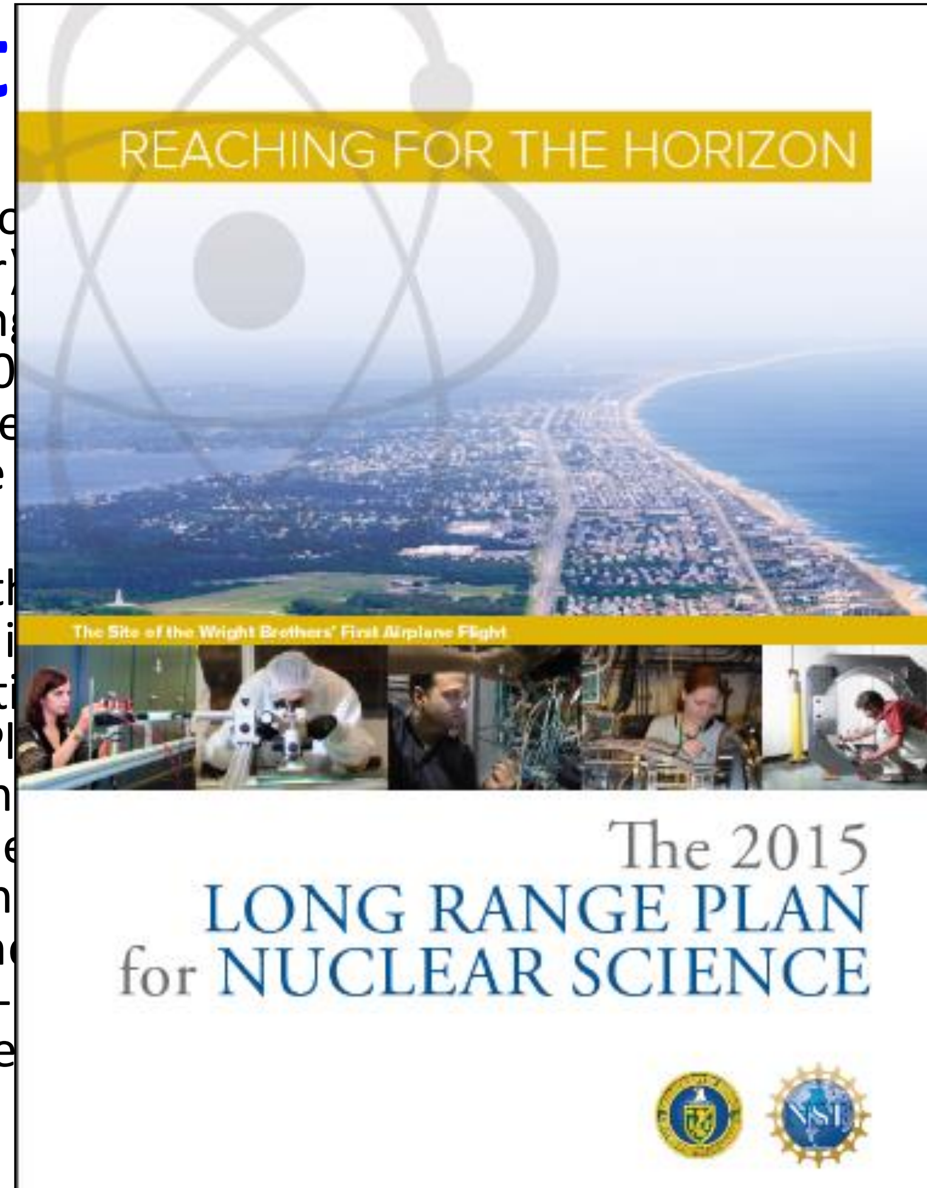

National Academy of Sciences Evaluation of EIC Science Case

- In 2017 and 2018, a committee appointed by the U.S. National Academy of Sciences and Engineering evaluated the science case for EIC. The committee, chaired by Ani Aprahamian and Gordon Baym, released a report in July 2018 that favorably endorsed the science case for EIC and emphasized the strategic importance for the U.S. of the accelerator science technology associated with EIC realization.
- The U.S. National Academy of Sciences judged the physics case to be

“**compelling, fundamental and timely**.”

Na ... ces
Eva ... ase

- In 2017 ... the U.S. Nationa ... ng evaluate ... nittee, chaired ... n, released a report ... the science ... tegic importa ... ence technolo...
- The U.S. ... d the physics ...

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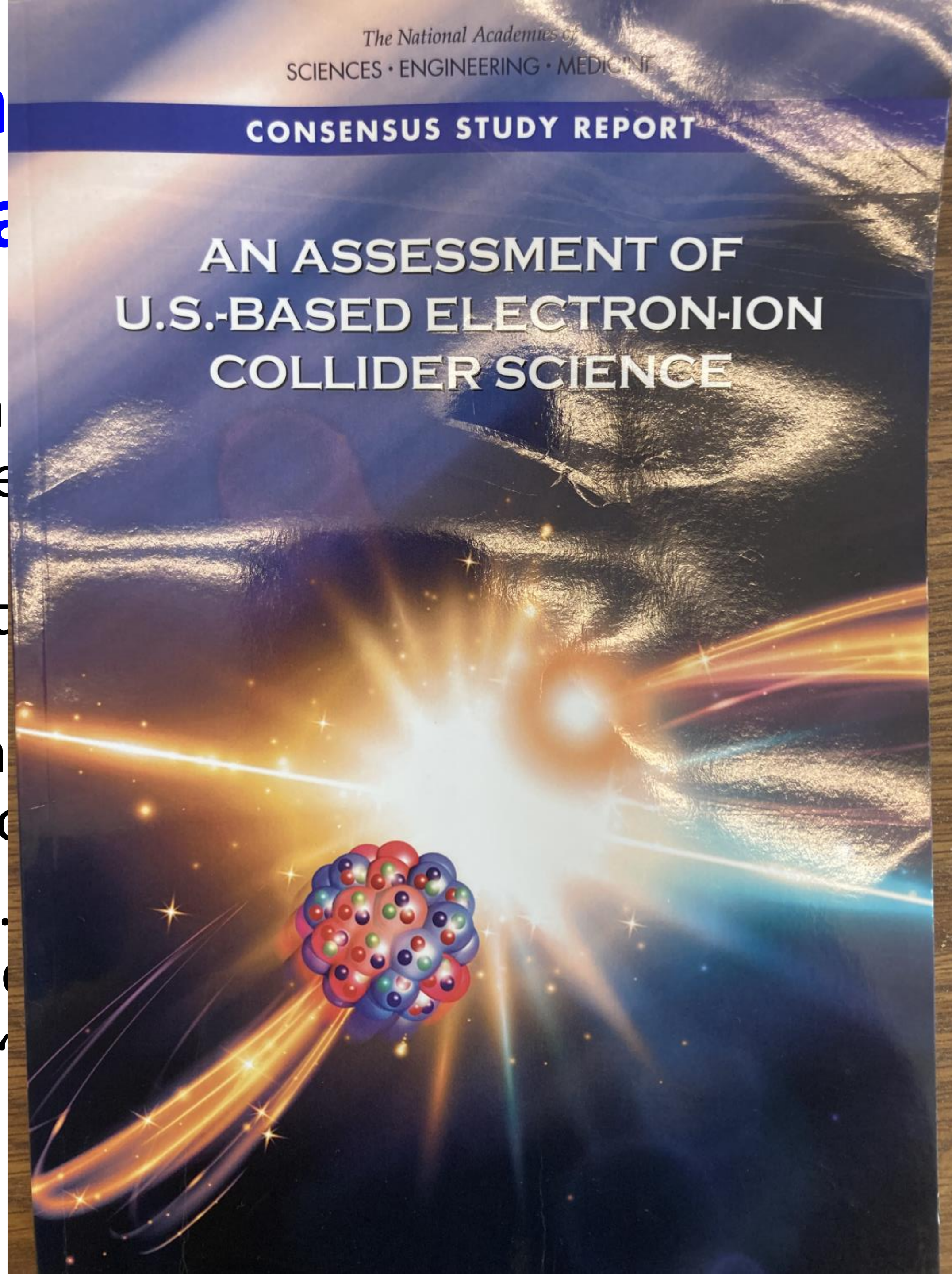
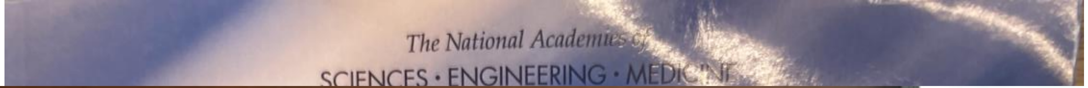




EICUG Annual Meeting 2018

EIC Users Group Founded

In 2016 the EIC User Group was founded with the aim of promoting the science and technical case for EIC, independent of the siting.

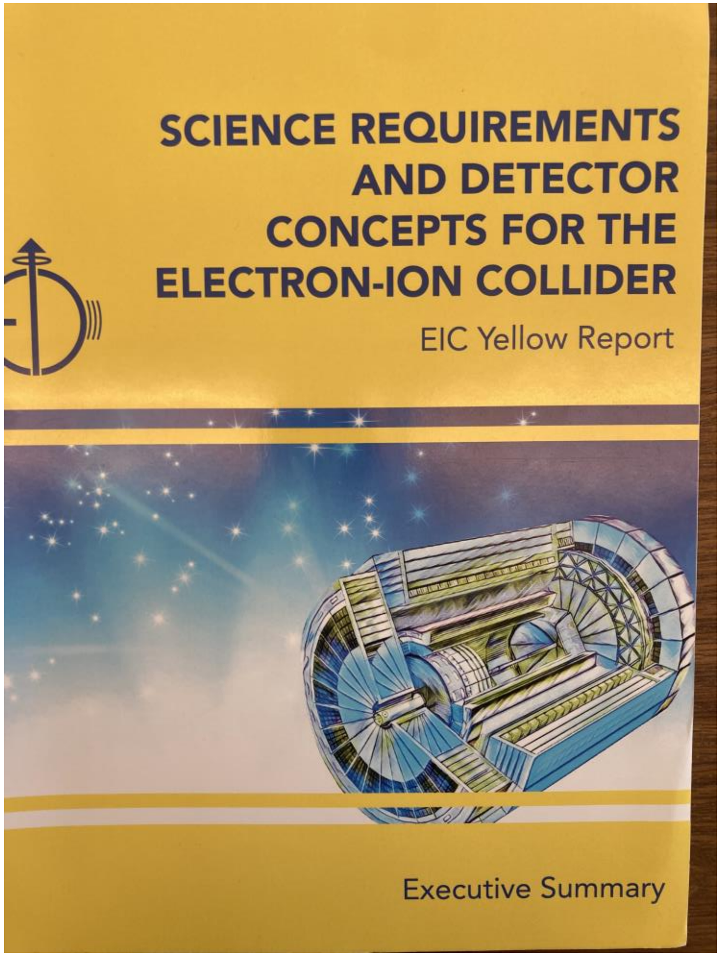
By 2026, this has over 1558 members from more than 310 institutions in 41 countries across the globe.

U.S. Governments Commits to EIC Construction

- December 2019: U.S. Department of Energy grants Critical Decision Zero: “mission need” for EIC
- January 2020: U.S. Department of Energy launched EIC construction
- EIC would be realized around the existing RHIC complex at BNL
- Jefferson Lab a major partner with BNL in EIC
- January 2021: U.S. Department of Energy grants Critical Decision One

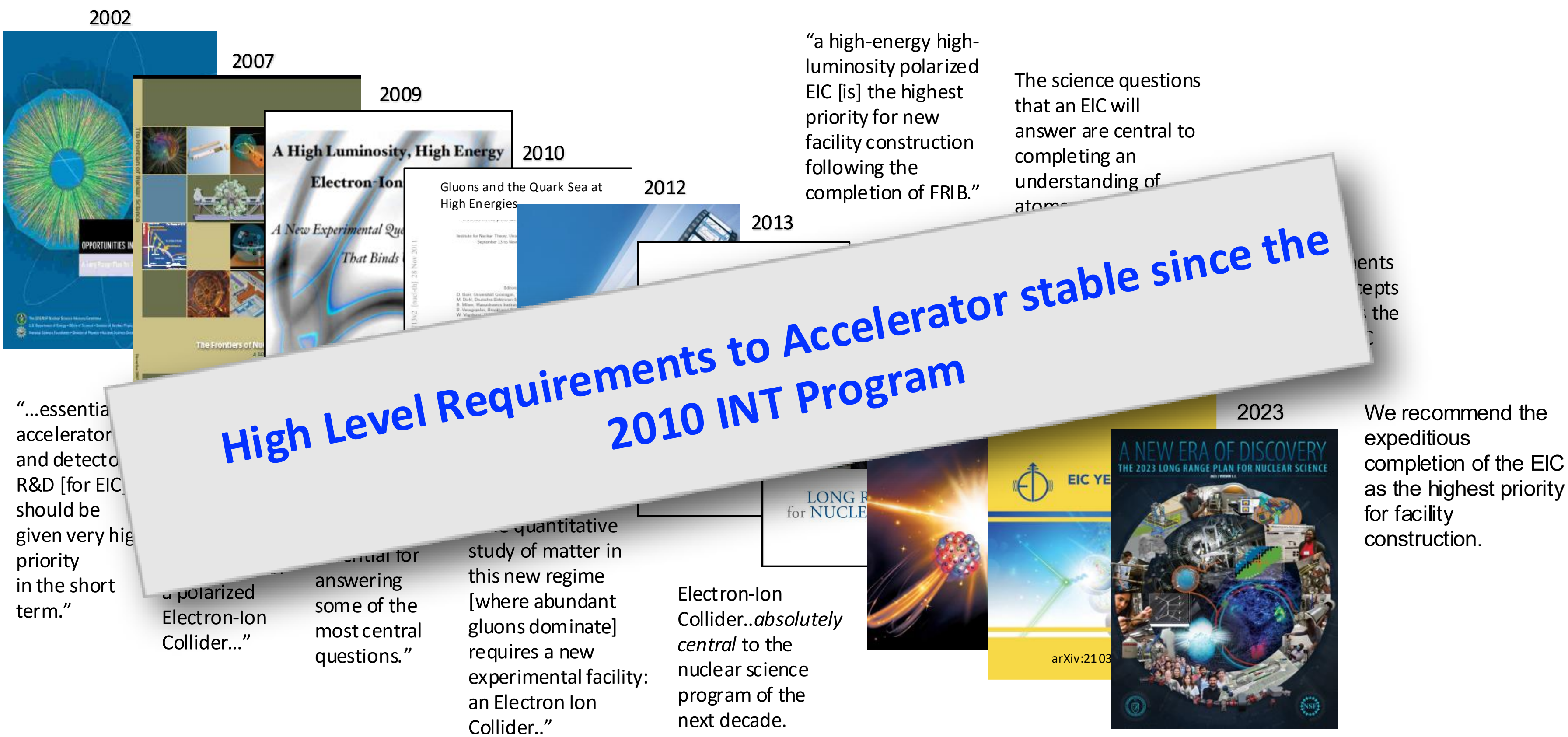
EIC Yellow Report

December 2019 – March 2021



- Organizational in-person meeting at MIT, December 2019.
- Subsequently developed in a series of remote meetings organized around the world at the height of the pandemic.

The Scientific Foundation for the EIC was Built Over Two Decades



EIC: 21st Century QCD Laboratory

- To explore the fundamental structure and dynamics of the matter in the visible world

$$\mathcal{L}_{QCD} = \sum_{j=1}^{n_f} \bar{\psi}_j \left(iD_\mu \gamma^\mu - m_j \right) \psi_j - \frac{1}{4} \mathrm{Tr}\, G^{\mu\nu} G_{\mu\nu}$$

- Interactions arise through fundamental symmetry principles
- Properties of the visible universe emerge through complex structure of the QCD vacuum
- The proton is a highly relativistic system described by QCD, a fully relativistic quantum field theory.
- Lattice QCD is an increasingly powerful means to carry out *ab initio* QCD calculations of hadron structure in the rest frame.
- The goal of the EIC is to provide us with an understanding of the internal structure of the proton and more complex atomic nuclei that is comparable to our knowledge of the electronic structure of atoms themselves, which lies at the heart of modern technologies.

Large Reach of EIC in x and Q^2

with greatly increased luminosity

inclusive, semi-inclusive, exclusive

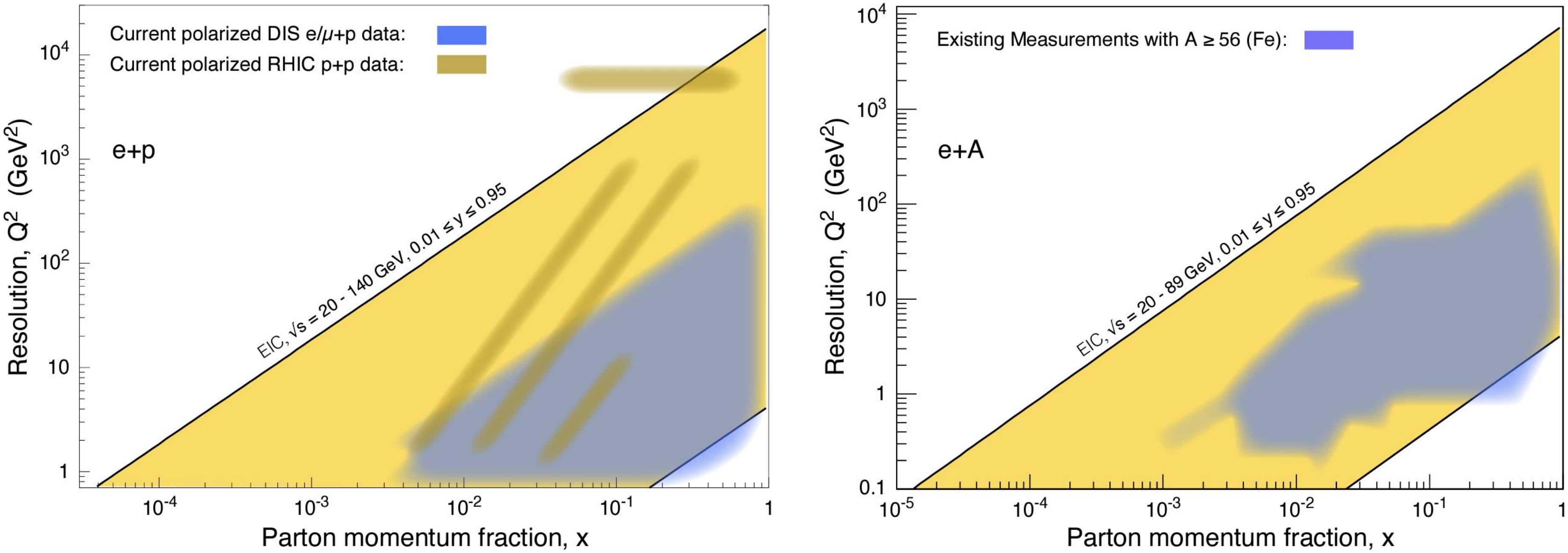
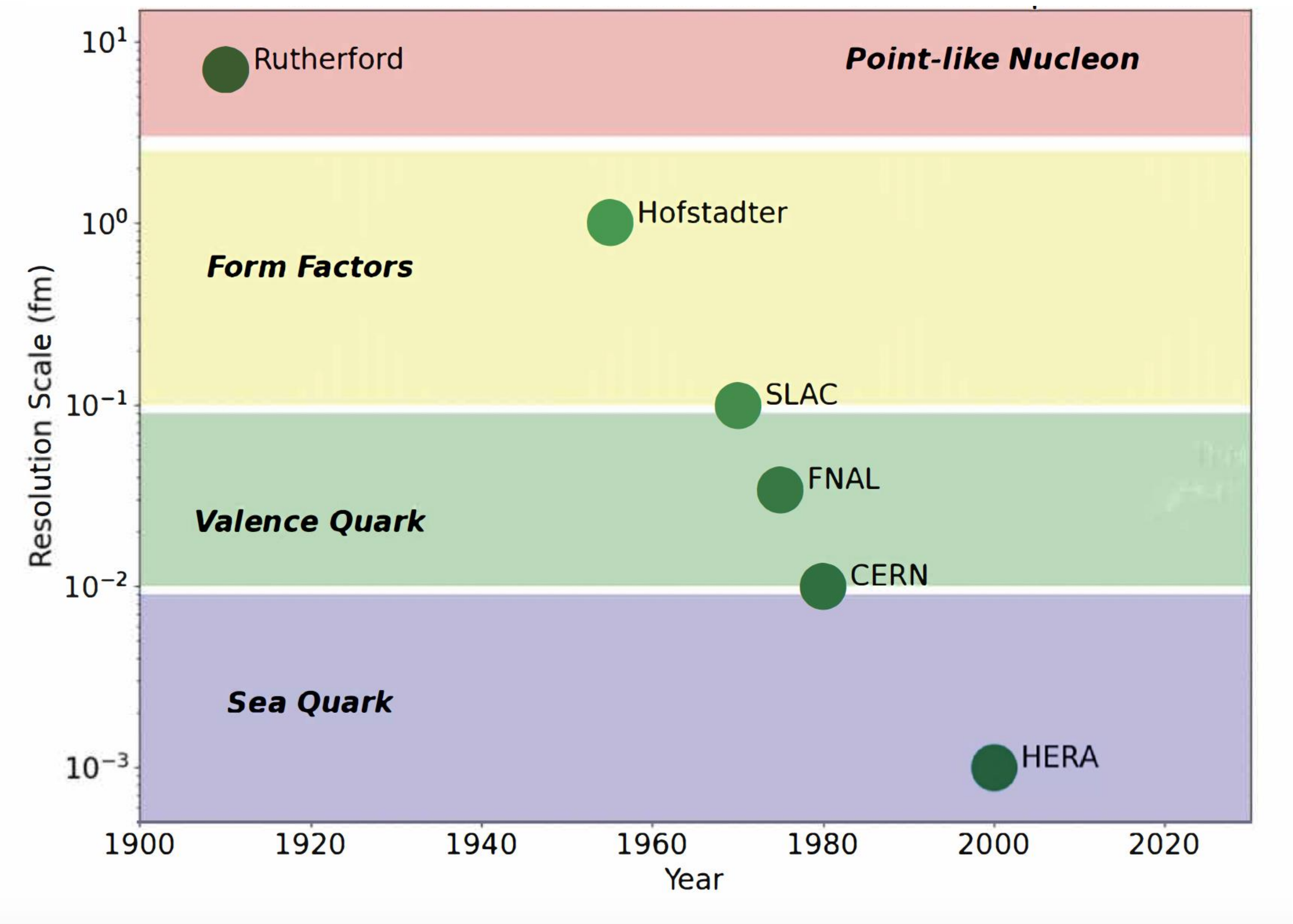
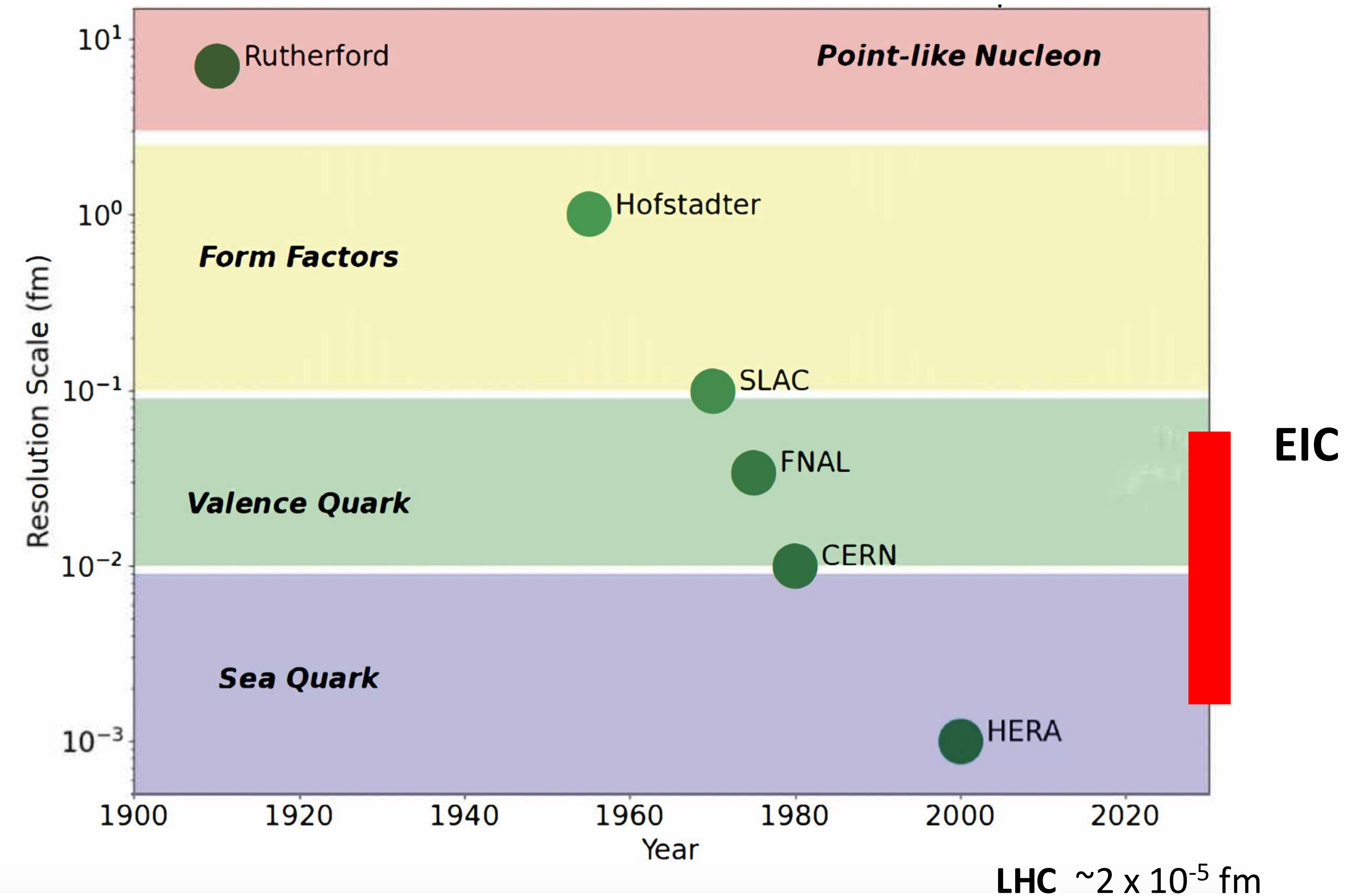


Figure 2.1: Left: The x-Q^2 range covered by the EIC (yellow) in comparison with past and existing polarized $e/\mu+p$ experiments at CERN, DESY, JLab and SLAC, and $p+p$ experiments at RHIC. Right: The x-Q^2 range for e+A collisions for ions larger than iron (yellow) compared to existing world data.

EIC is NOT a high energy frontier machine



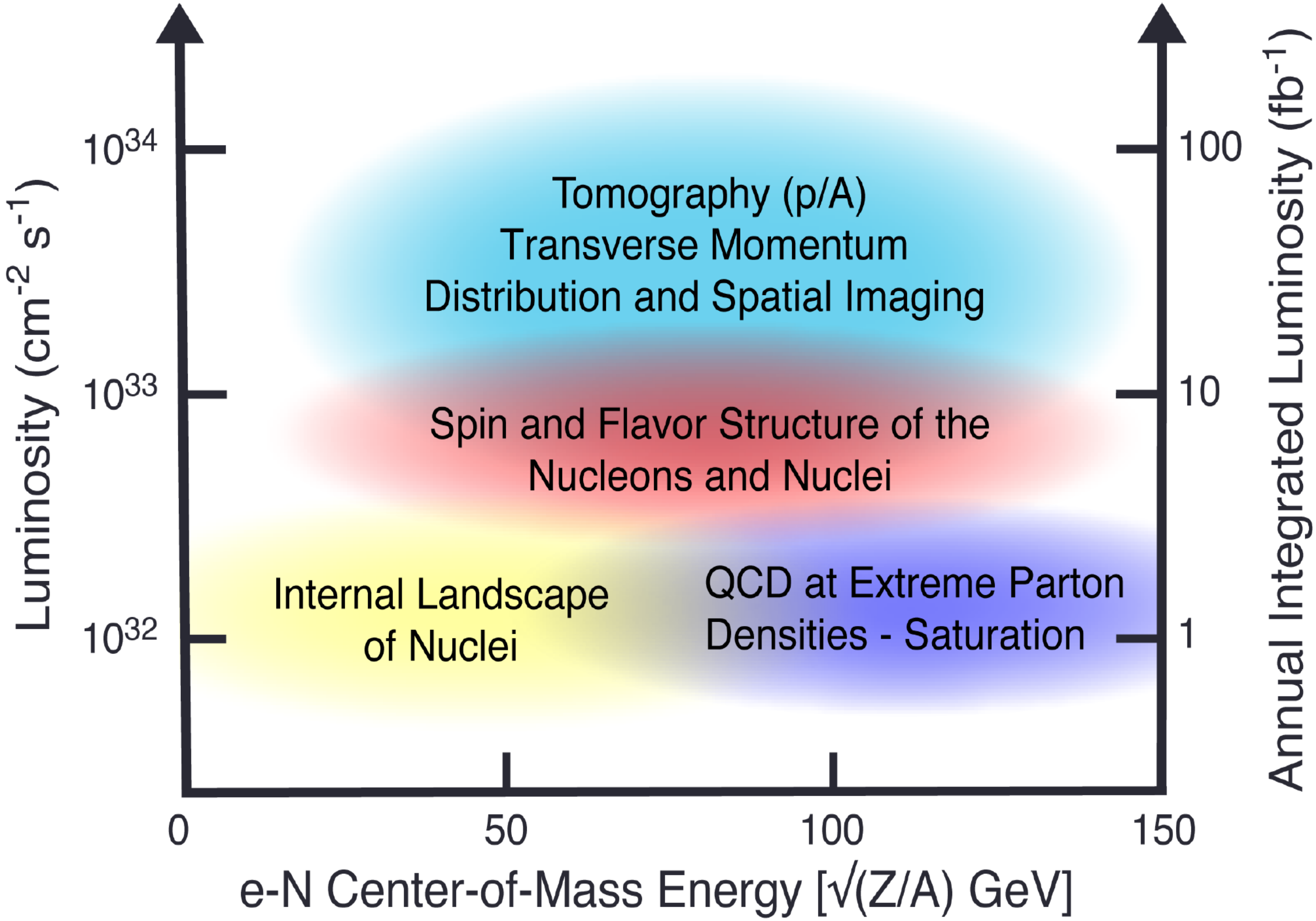
EIC is NOT a high energy frontier machine

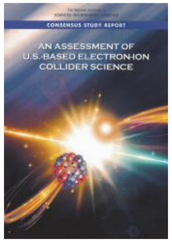


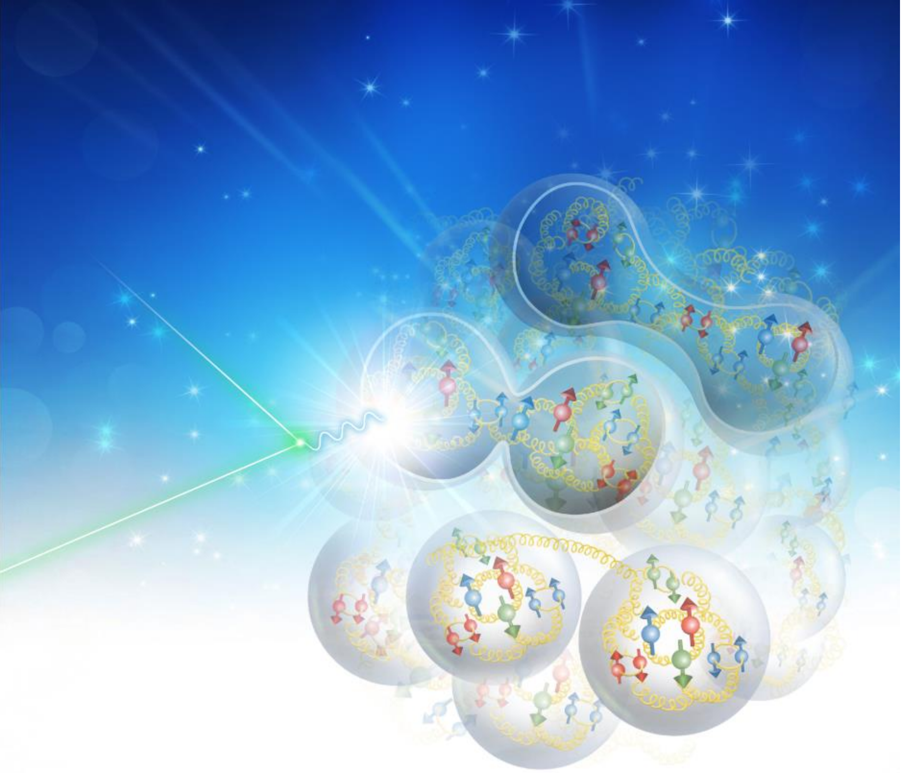
LHC ~2 x 10^{-5} fm

Collider Specifications from Science

First drafted by Abhay, Rolf and RM at EICC meeting in Darmstadt in 2009.

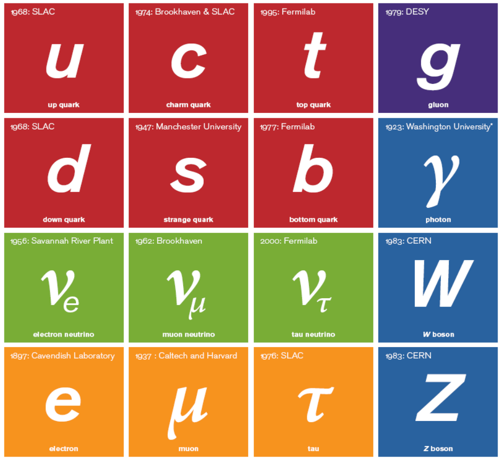


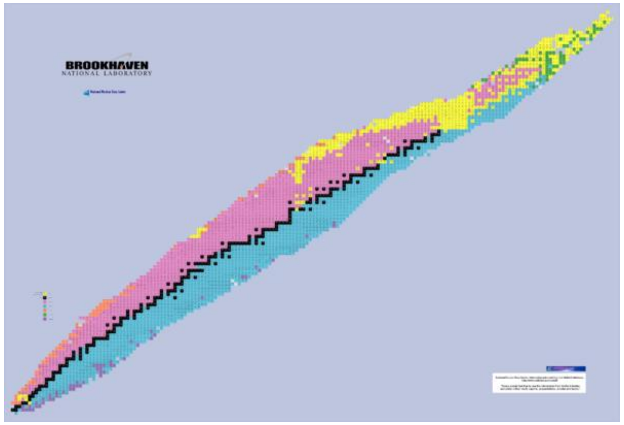




Understanding The Nucleus

- Reality: experiments deal with hadrons
- How do we relate the successful hadronic description of the nucleus to the fundamental quarks and gluons?
- How does the nucleon with its structure and properties emerge from quarks and gluons of QCD?
- What role does QCD play in the structure and properties of nuclei?





In closing

- EIC is the unique accelerator required to advance the frontiers of our understanding of the fundamental structure of matter in the twenty first century:
    - first double-polarized e-p collider
    - first e-A collider.
- It is the first machine designed to probe the complex quantum world of the quarks and gluons of QCD.
- It originated ~ 2000 from within the U.S. nuclear physics research community motivated by the desire to make a substantial advance in the study of the fundamental structure of matter.
- Theoretical developments were essential to developing the convincing science case for a billion dollar class machine.
- The 2010 INT program was pivotal in creating the EIC White Paper that led to the 2015 Long Range Plan recommendation, the successful NAS evaluation and decision by DOE to begin construction in 2020.
- Going forward to realization, a healthy U.S. nuclear physics research community is essential to harvest the considerable investments in the Electron-Ion Collider, the ePIC detector and other scientific instrumentation. **There will be surprises!**

In closing

- EIC is the unique accelerat … frontiers of our understanding of the fundamental structu … first century:
  - first double-polarize
  - first e-A collider.
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- Going forward to realizatio … hysics research community is essential to harvest the co … the Electron-Ion Collider, the ePIC detector and other sc … **here will be surprises!**