Center for Frontiers in Nuclear Science

Brief History of the EIC Project

Abhay Deshpande

Week 4, INT 18-3, U. of Washington

Grateful for many plots, pictures & comments I received from a large number of people.
Special thanks to Rolf Ent, Richard Milner, Berndt Mueller, Mark Strikman, Raju Venugopalan, Rik Yoshida.
This talk is an updated version of Richard Milner's 2016 talk at the EICUG that we prepared together

Stony Brook University

BROOKHAVEN NATIONAL LABORATORY

Center for Frontiers in Nuclear Science

Outline of this talk based on the time line...

- Before the beginning ~1995/96
- The early ideas in the US ~2000/**02**
- US EIC takes shape 2005/**07**: ideas gel, community is formed
- Hectic and frenzy of activity (2013/**15 →2018**) → EIC: verge of reality

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Before the beginning: mid-1990's

Its mainly a European idea….

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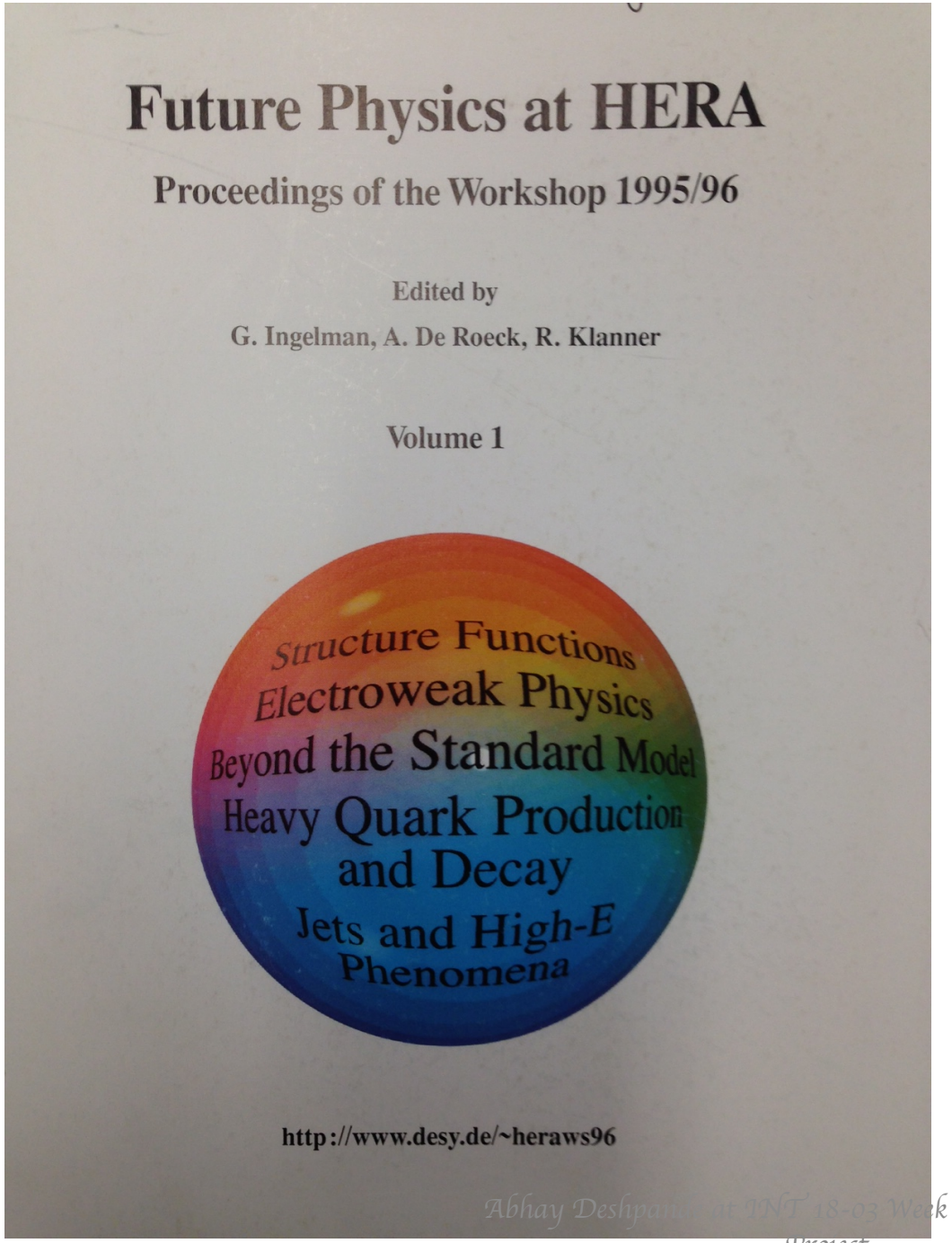
Ideas for a polarized electron-proton and electron-nucleus collider were first discussed in the mid 1990s….

Motivated by the results from the 2nd generation fixed target experiments (@SLAC, @CERN)

and

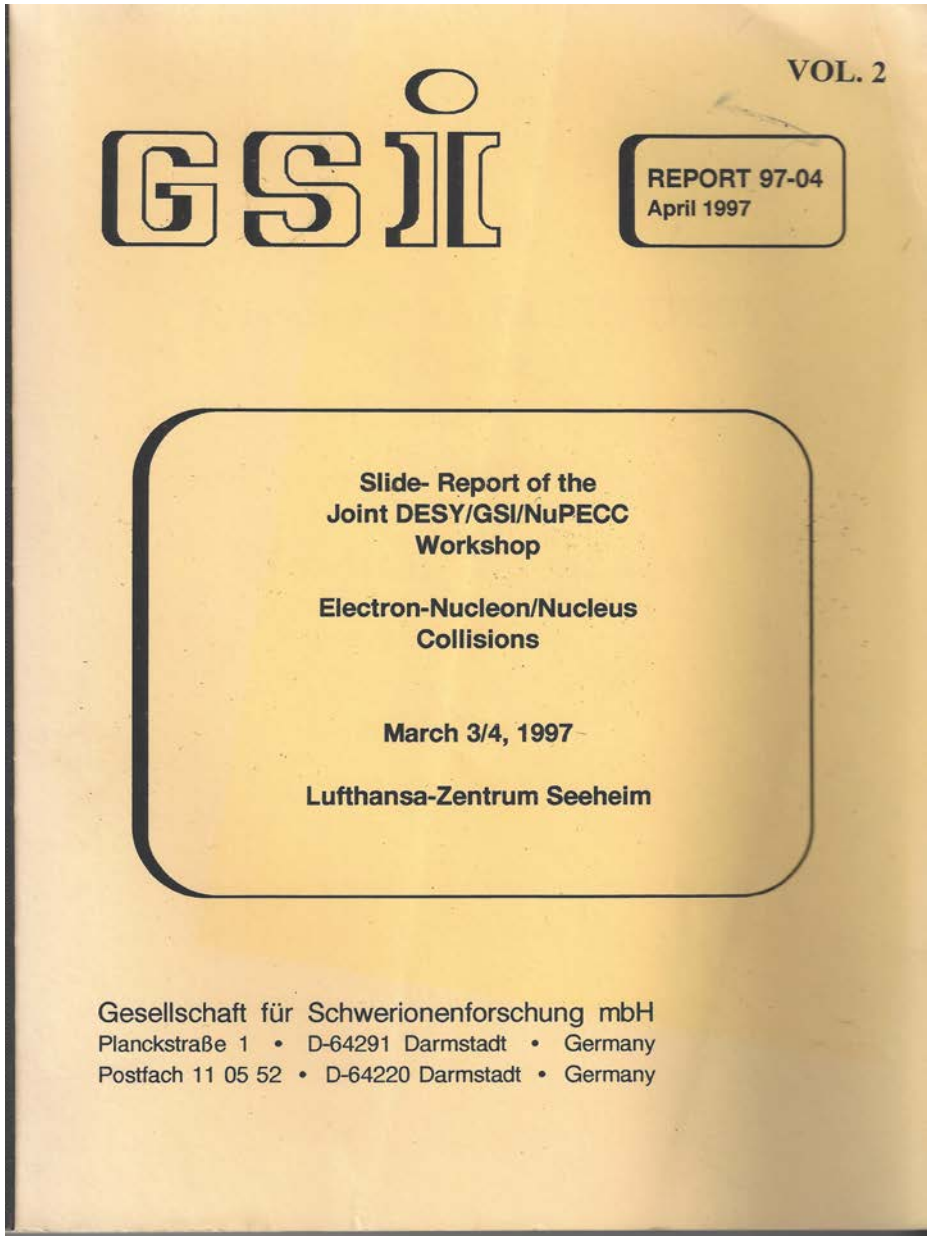
the successful start of HERA the first DIS collider....



Polarized and nuclear beams considered in the HERA proton ring

First exploratory workshops conducted 1995-1996.

$X < 0.005$



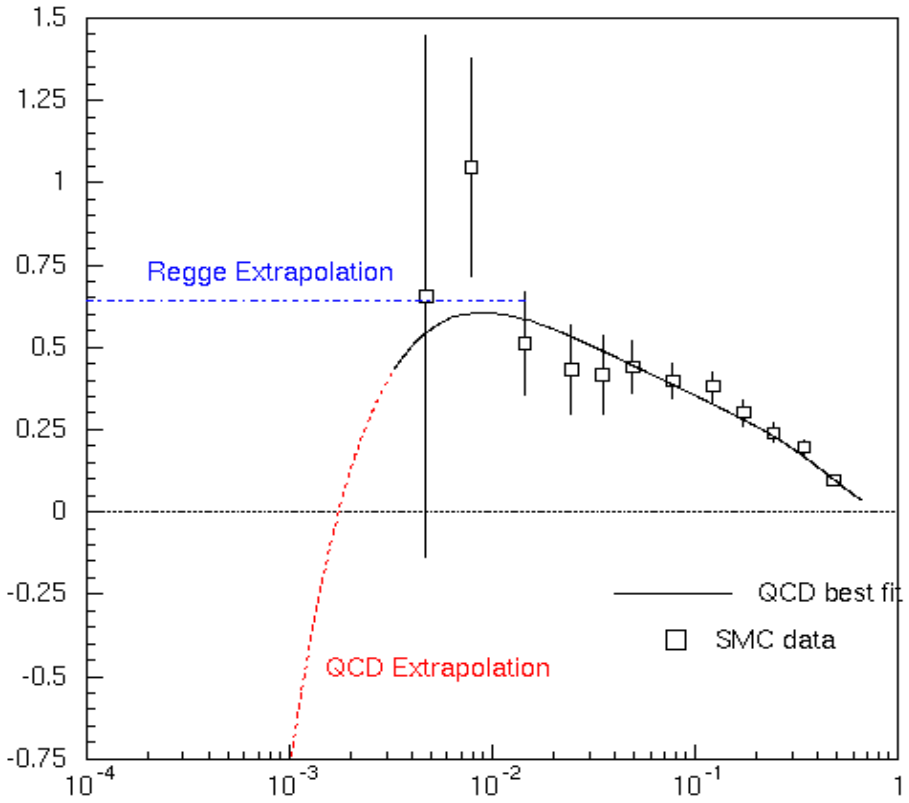
Early study of great value focused on GSI upgrade possibilities

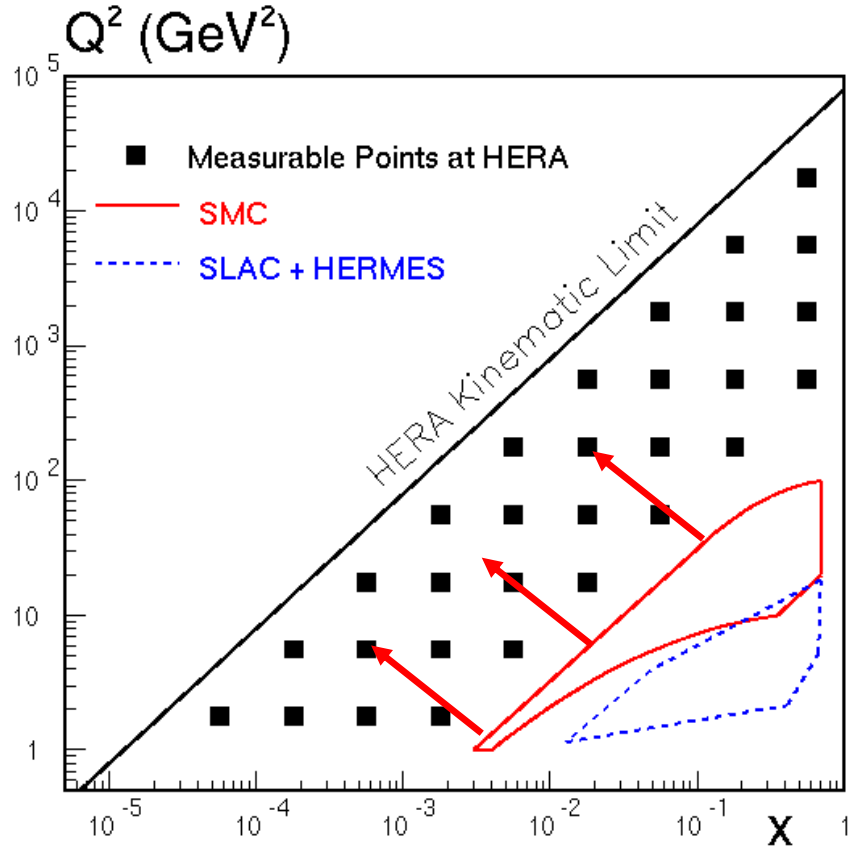
$x > 0.005$

Dietrich Von Harrach – At least the one who used to communicate with us as we worked on the COMPASS proposal.

Low x behavior of $g_1(p)$!

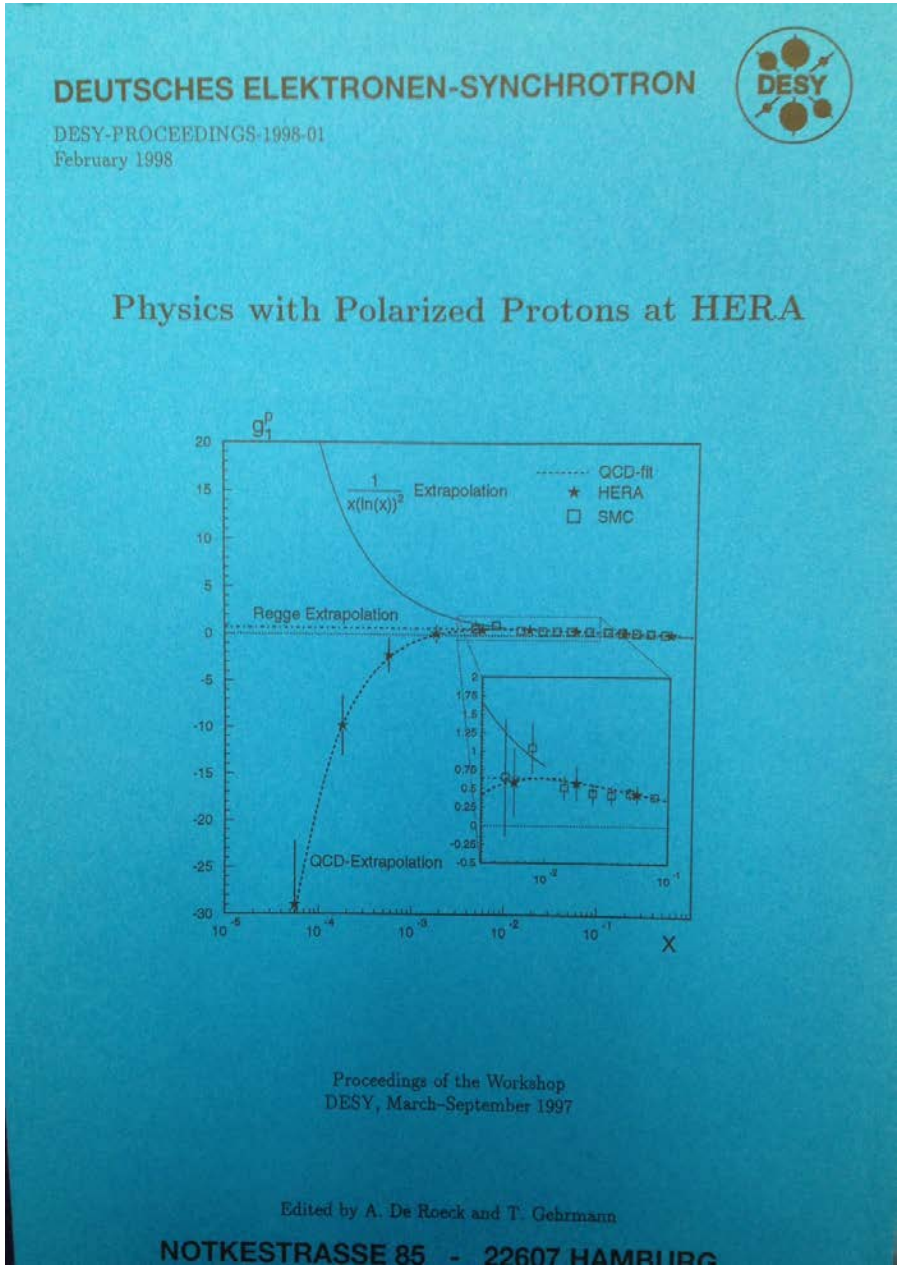
A. Deshpande & V. W. Hughes
~1995 SMC (internal) analysis meeting





$$\textbf{Regge}: \quad g_1(x \to 0) \sim x^{-\alpha}; \quad 0 < \alpha < 0.5$$

Clear need for
low x measurements!



Encouraged by
B. Wiik, R. Klanner (DESY),
&
A. Caldwell, F. Sciulli (Columbia)

The Yale group (A.D., V. Hughes & S. Dhawan) joined ZEUS and together with **A. De Roeck** & J. Feltesse (H1) and theorist **T. Gehrmann** ran the 1999 workshop on Physics with Polarized Proton Beams at HERA.

Accelerator Experts: D. Barber, G. Hoffstaedter & M. Vogt
External advisors: Mei Bai & Thomas Roser

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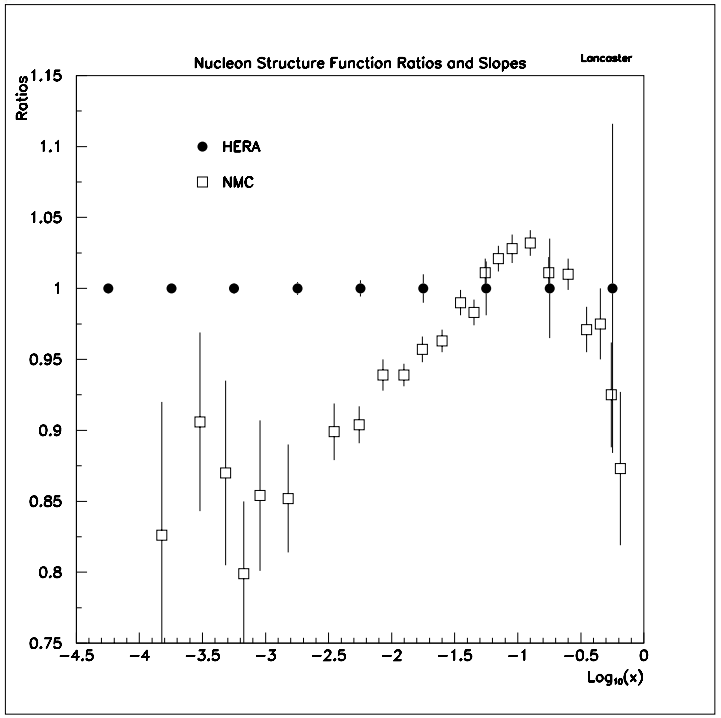
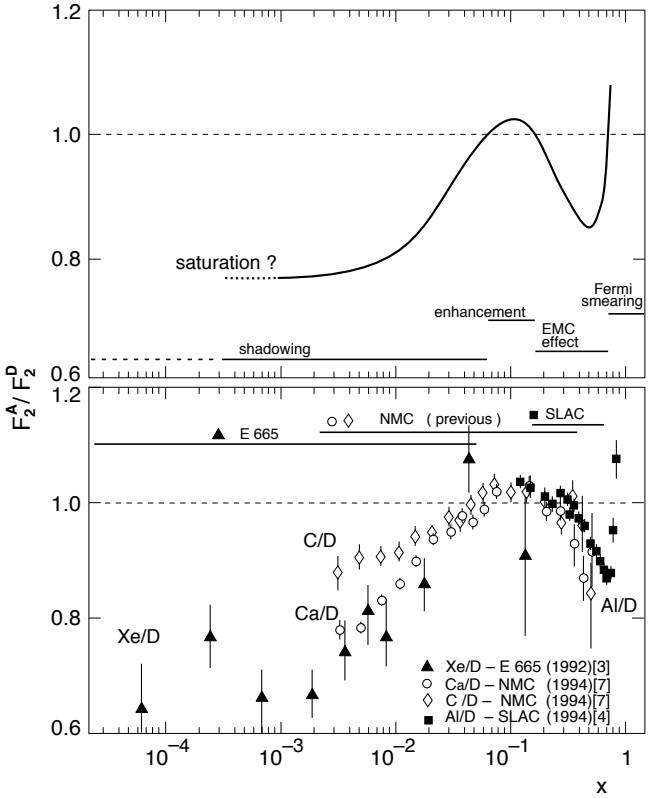


Nuclear beams in HERA

M.Arneodo[a], A.Bialas[b], M.W.Krasny[c], T.Sloan[d] and M. Strikman[e]

Università di Torino, I-10125 and INFN Cosenza, Italy
Institute of Physics, Jagellonian University, Cracow, Poland
LPNHE, Universités Paris VI and VII, IN2P3 CNRS, Paris, France
School of Physics and Chemistry, University of Lancaster, Lancaster LA1 4YB, UK
Pennsylvania State University, University Park, PA 16802, USA

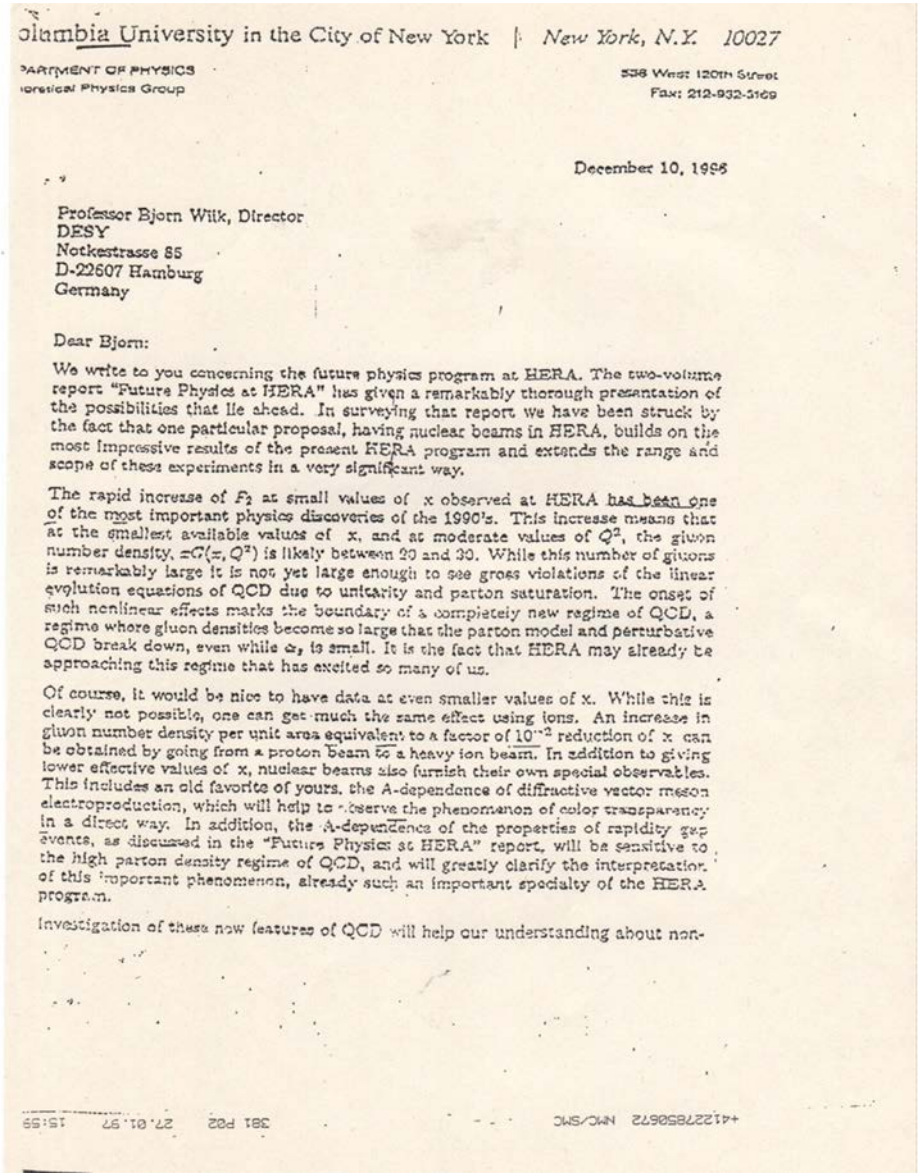
Abstract: A study has been made of the physics interest and feasibility of experiments with nuclear beams in HERA. It is shown that such experiments widen considerably the horizon for probing QCD compared to that from free nucleon targets. In addition there is some sensitivity to physics beyond the standard model. Hence the option to include circulating nuclear beams in HERA allows a wide range of physics processes to be studied and understood.



Nuclear Beams in HERA

Letter to Director Wiik
From
Bjorken, McLerran and Mueller
Page 2 with their signatures could not be found

Courtesy: Mark Strikman



olumbia University in the City of New York | New York, N.Y. 10027

PARTMENT OF PHYSICS
oretical Physics Group

538 West 120th Street
Fax: 212-932-5169

December 10, 1996

Professor Bjorn Wiik, Director
DESY
Notkestrasse 85
D-22607 Hamburg
Germany

Dear Bjorn:

We write to you concerning the future physics program at HERA. The two-volume report "Future Physics at HERA" has given a remarkably thorough presentation of the possibilities that lie ahead. In surveying that report we have been struck by the fact that one particular proposal, having nuclear beams in HERA, builds on the most impressive results of the present HERA program and extends the range and scope of these experiments in a very significant way.

The rapid increase of F_2 at small values of x observed at HERA has been one of the most important physics discoveries of the 1990's. This increase means that at the smallest available values of x, and at moderate values of Q^2, the gluon number density, $xG(x,Q^2)$ is likely between 20 and 30. While this number of gluons is remarkably large it is not yet large enough to see gross violations of the linear evolution equations of QCD due to unitarity and parton saturation. The onset of such nonlinear effects marks the boundary of a completely new regime of QCD, a regime where gluon densities become so large that the parton model and perturbative QCD break down, even while α_s is small. It is the fact that HERA may already be approaching this regime that has excited so many of us.

Of course, it would be nice to have data at even smaller values of x. While this is clearly not possible, one can get much the same effect using ions. An increase in gluon number density per unit area equivalent to a factor of 10^{-2} reduction of x can be obtained by going from a proton beam to a heavy ion beam. In addition to giving lower effective values of x, nuclear beams also furnish their own special observables. This includes an old favorite of yours, the A-dependence of diffractive vector meson electroproduction, which will help to observe the phenomenon of color transparency in a direct way. In addition, the A-dependence of the properties of rapidity gap events, as discussed in the "Future Physics at HERA" report, will be sensitive to the high parton density regime of QCD, and will greatly clarify the interpretation of this important phenomenon, already such an important specialty of the HERA program.

Investigation of these new features of QCD will help our understanding about non-

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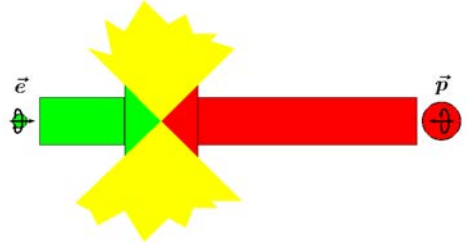
Viewed as nuclei @HERA's **competition** with polarized HERA

Vernon Hughes then got a letter from Bjorken suggesting polarized HERA was at least as important and interesting.

Not sure that letter exists in Hughes' collection of correspondences

Bjorken later indicated to Vernon that *he was unaware that only one of the programs could be done.*



AT DESY:

A strong physics motivation to go to low x and high Q^2 with spin variables was developed

- HERA Existed….. Polarized electrons existed…. Accelerator Physicists working on e and p beams existed…
- Nuclear beams (with limited number of species) could be accelerated..
- H1 and ZEUS detector existed along with collaborators…
- HERMES polarized DIS community existed…

Polarized Proton Beam was the ONLY missing item…!
The preliminary cost as I remember was ~$30M DM…
We e-p/e-A communities were **divided**: were told only ONE (either polarized protons or nuclei) would be possible before 2007
Deep physics/intellectual connection between e-p and e-A did not exist

DESY directorate has other things on its mind….

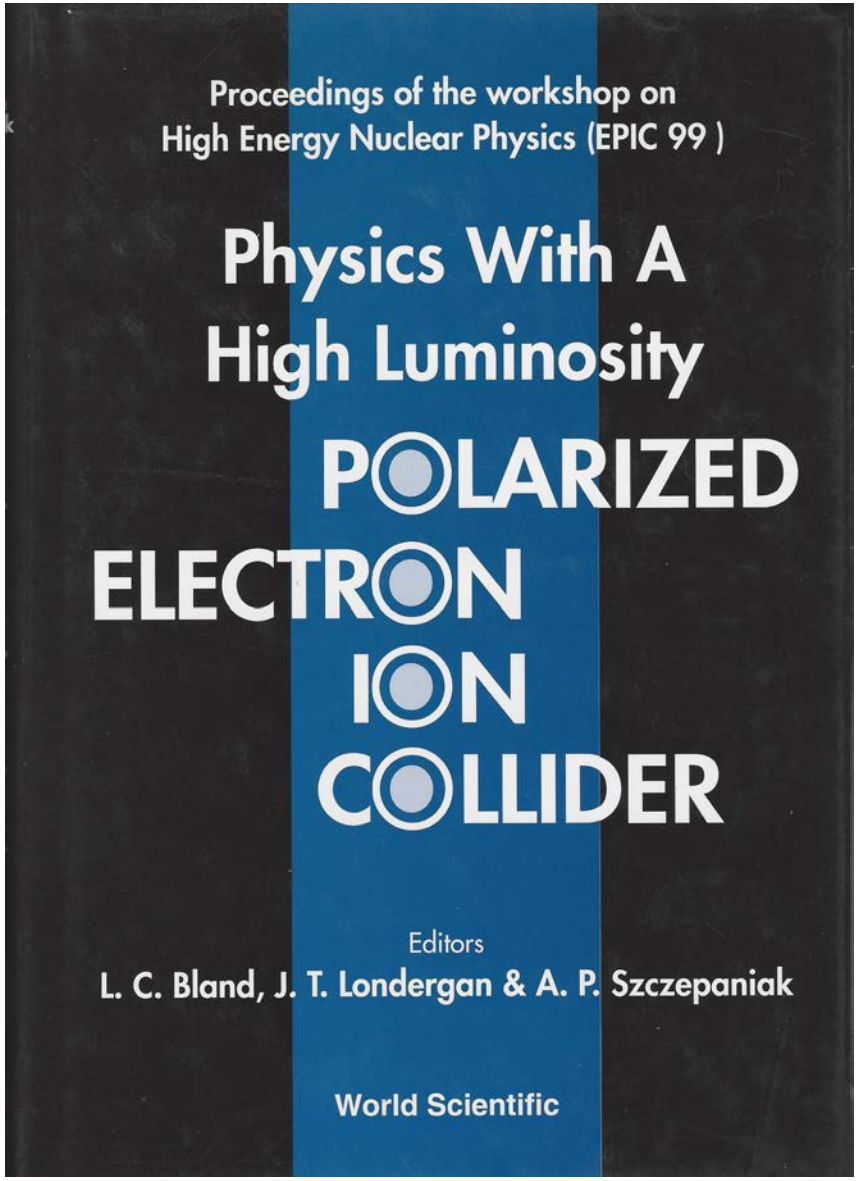
In search of new possibilities immigrants ~~sailed~~ flew to ~~India~~... US

Late 1990s and early 2000

One indigenous effort, and two migrants:

- IUCF
- MIT Bates
- eRHIC

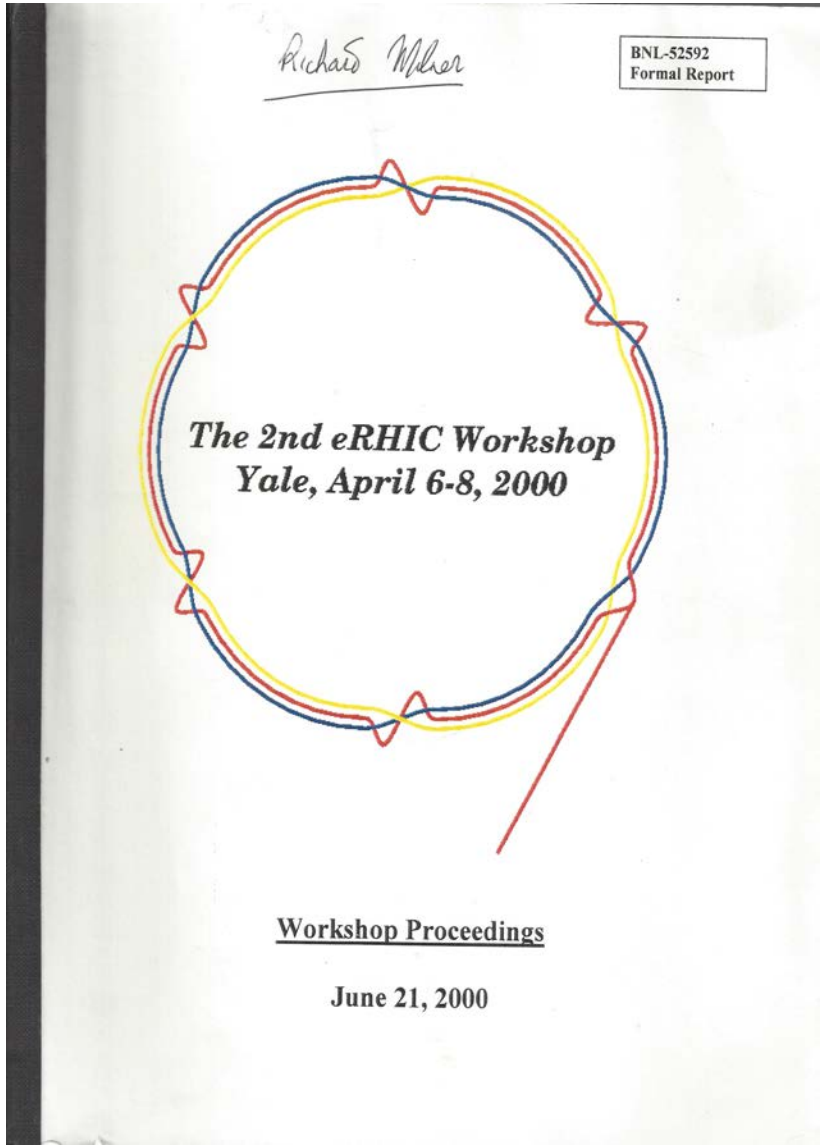
Development of polarized proton beams at RHIC



EPIC 99

At end of the 1990's some medium energy nuclear physics labs in U.S. were coming to a close. They identified a low energy **E**lectron **P**olarized **I**on **C**ollider as a promising future avenue.

IUCF – One of them @ Indiana U.



The Yale group organized a first workshop fully focused on polarized eRHIC:

A.D., Vernon Hughes,

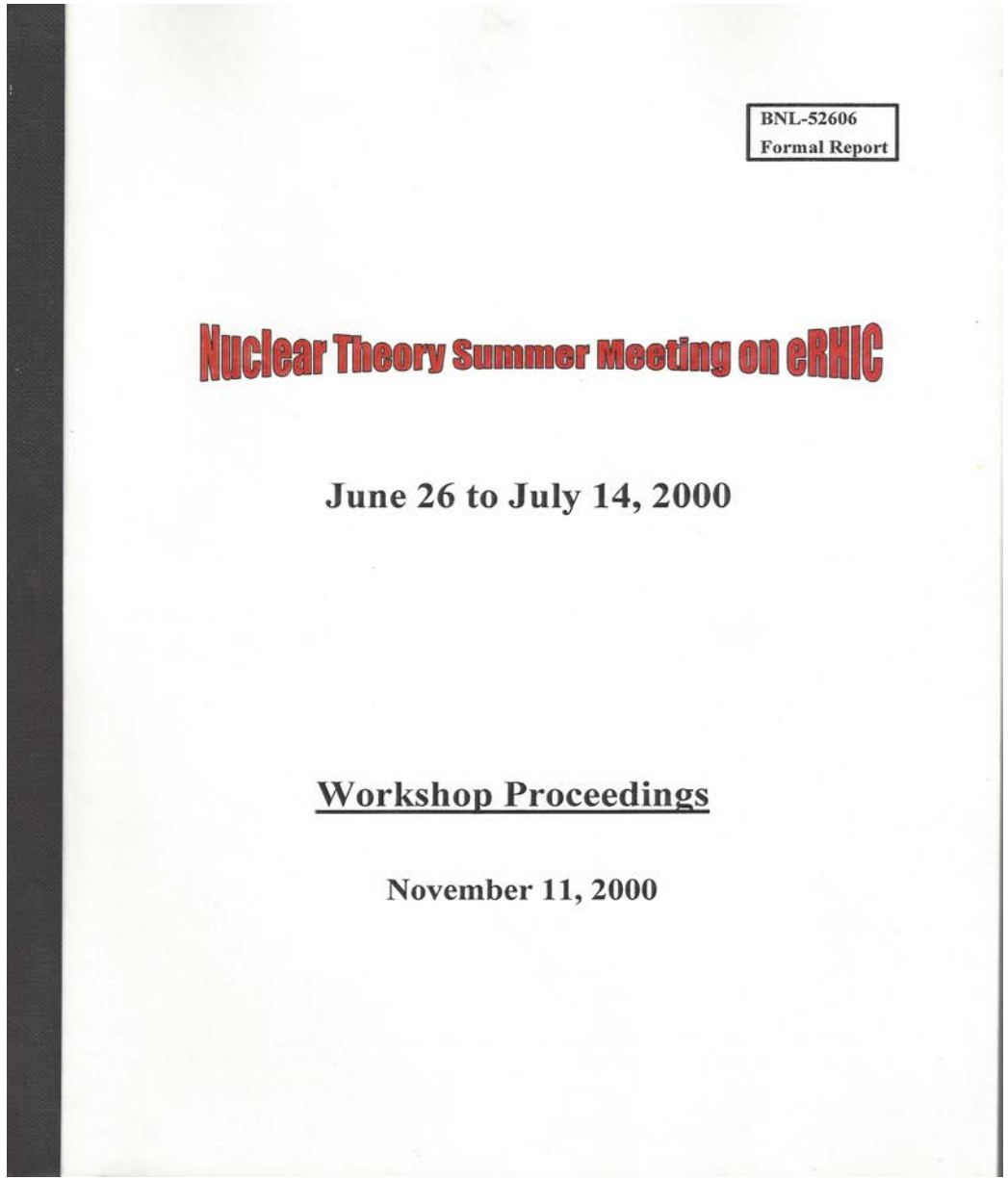
+ George Igo (UCLA)

+ A. De Roeck (DESY/CERN)

Encouraged by G. Garvey, P. Paul and others,

identify eRHIC as a particularly promising avenue

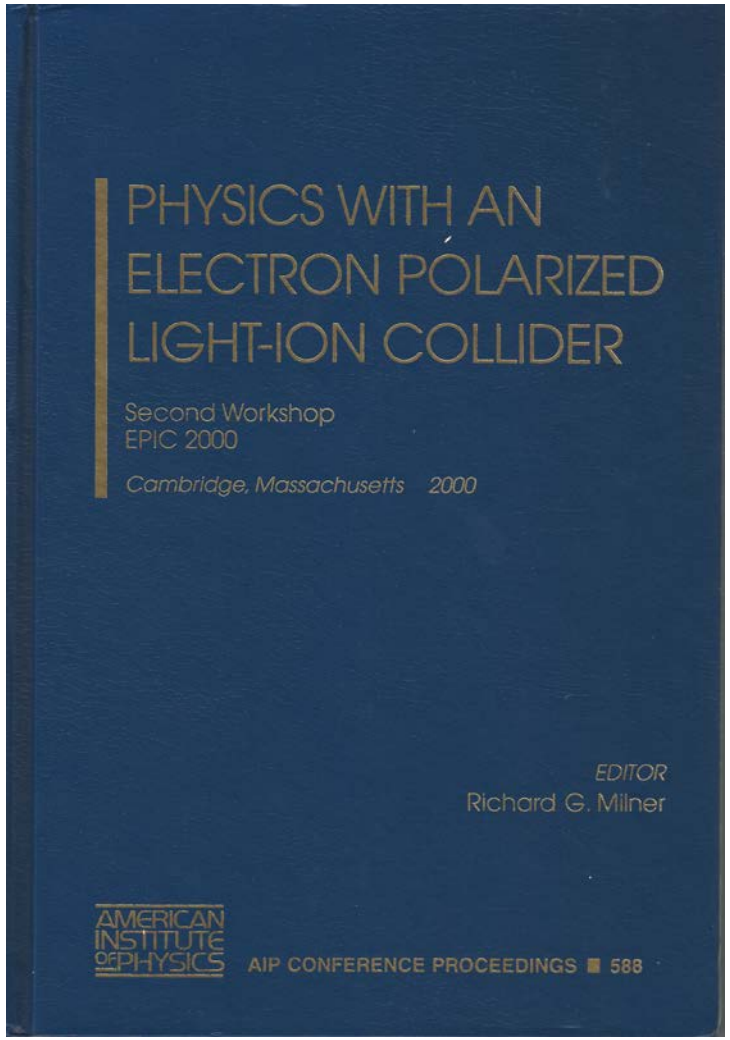
(Roser et al. showed polarization at RHIC was possible)

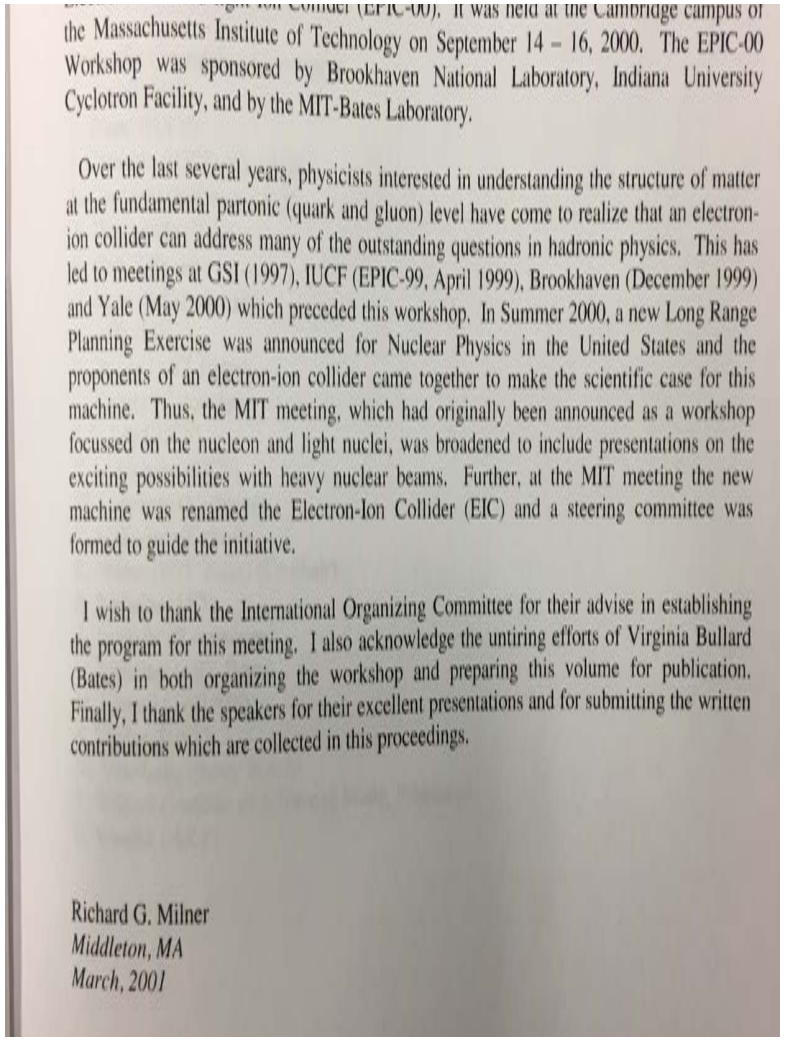


Larry McLerran, Raju Venugopalan et al. at BNL led the workshop on Nuclei in eRHIC with some discussion of polarized protons by A. D. & Richard Milner

While not the highest of energies hoped for (in comparison with HERA), it was the first time, that **polarized proton, and nuclear beam proponents worked together.**

At MIT-Bates





...Collider (EPIC-00). It was held at the Cambridge campus of the Massachusetts Institute of Technology on September 14 – 16, 2000. The EPIC-00 Workshop was sponsored by Brookhaven National Laboratory, Indiana University Cyclotron Facility, and by the MIT-Bates Laboratory.

Over the last several years, physicists interested in understanding the structure of matter at the fundamental partonic (quark and gluon) level have come to realize that an electron-ion collider can address many of the outstanding questions in hadronic physics. This has led to meetings at GSI (1997), IUCF (EPIC-99, April 1999), Brookhaven (December 1999) and Yale (May 2000) which preceded this workshop. In Summer 2000, a new Long Range Planning Exercise was announced for Nuclear Physics in the United States and the proponents of an electron-ion collider came together to make the scientific case for this machine. Thus, the MIT meeting, which had originally been announced as a workshop focussed on the nucleon and light nuclei, was broadened to include presentations on the exciting possibilities with heavy nuclear beams. Further, at the MIT meeting the new machine was renamed the Electron-Ion Collider (EIC) and a steering committee was formed to guide the initiative.

I wish to thank the International Organizing Committee for their advise in establishing the program for this meeting. I also acknowledge the untiring efforts of Virginia Bullard (Bates) in both organizing the workshop and preparing this volume for publication. Finally, I thank the speakers for their excellent presentations and for submitting the written contributions which are collected in this proceedings.

Richard G. Milner
Middleton, MA
March, 2001

Scientific Organizing Committee:

A.Bruell (MIT)
L. Bland (IUCF)
J. Cameron (IUCF, Co-Chair)
A. Deshpande (Yale)
R. Holt (ANL)
N. Isgur (Jefferson Lab)
R. Jaffe (MIT)
K. Jacobs (MIT-Bates)
E. Kinney (Colorado)
S. Y. Lee (IUCF)
T. Londergan (IUCF)
W. Lorenzon (Michigan)
R. McKeown (Caltech)
R. Milner (MIT, Co-Chair)
R. Redwine (MIT)
A. Schaefer (Regensburg)
C. Tschalaer (MIT-Bates)
M. Vetterli (IUCF)
S. Vigdor (IUCF)
W. Vogelsang (Stony Brook)
F. Wilczek (IAS, Princeton)
W. Wissink (IUCF)

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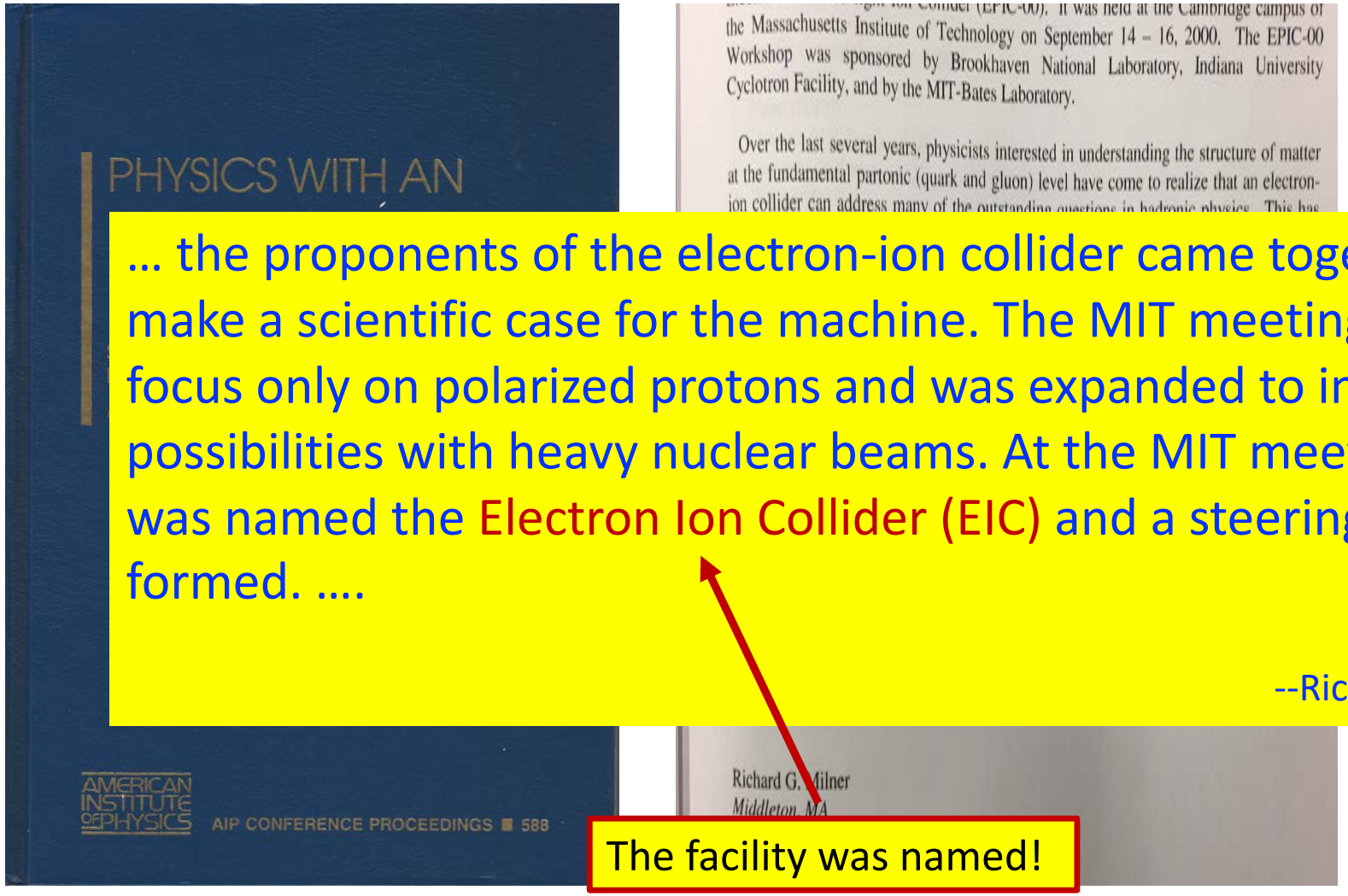
At MIT-Bates



… the proponents of the electron-ion collider came together and agreed to make a scientific case for the machine. The MIT meeting originally planned to focus only on polarized protons and was expanded to include exciting possibilities with heavy nuclear beams. At the MIT meeting, the new machine was named the Electron Ion Collider (EIC) and a steering committee was formed. ….

--Richard Milner (Co-Chair)

The facility was named!

Scientific Organizing Committee:

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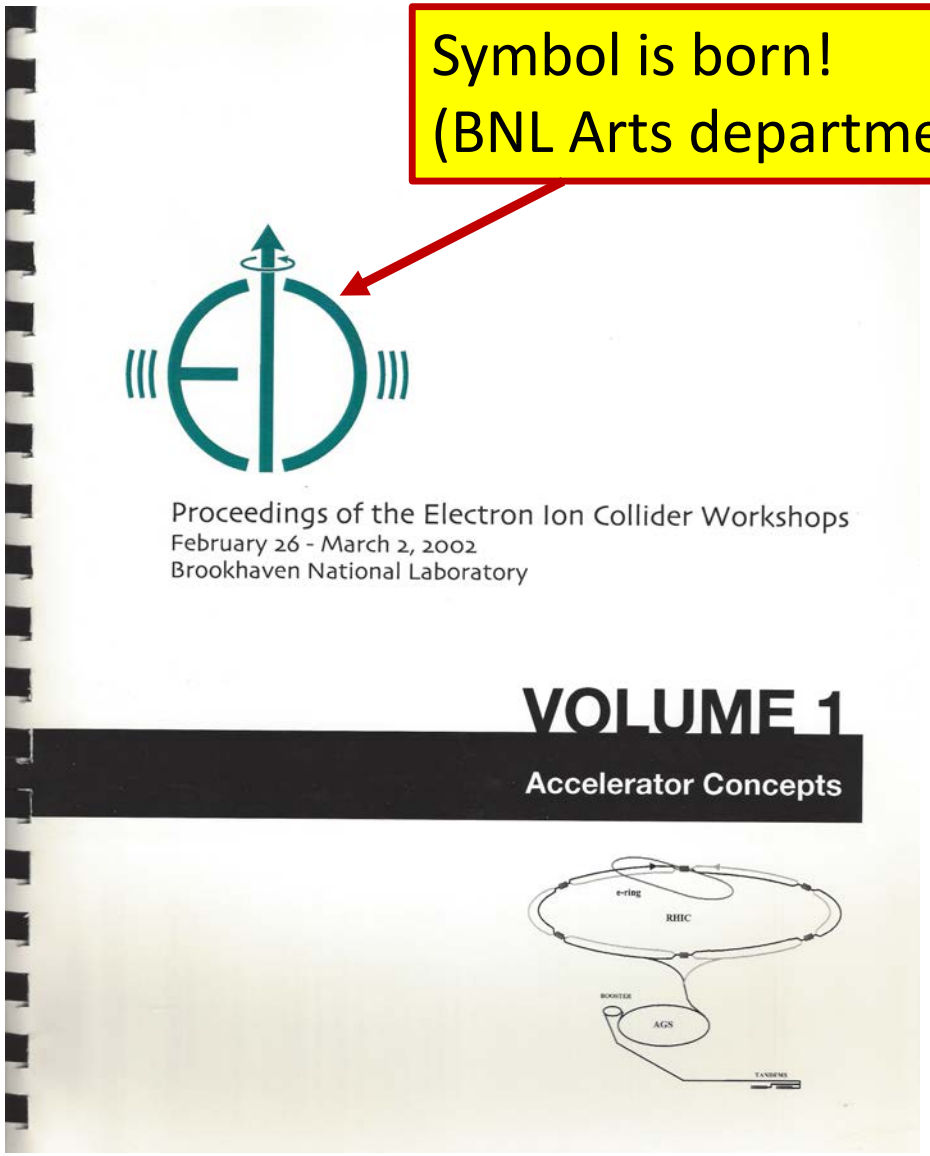
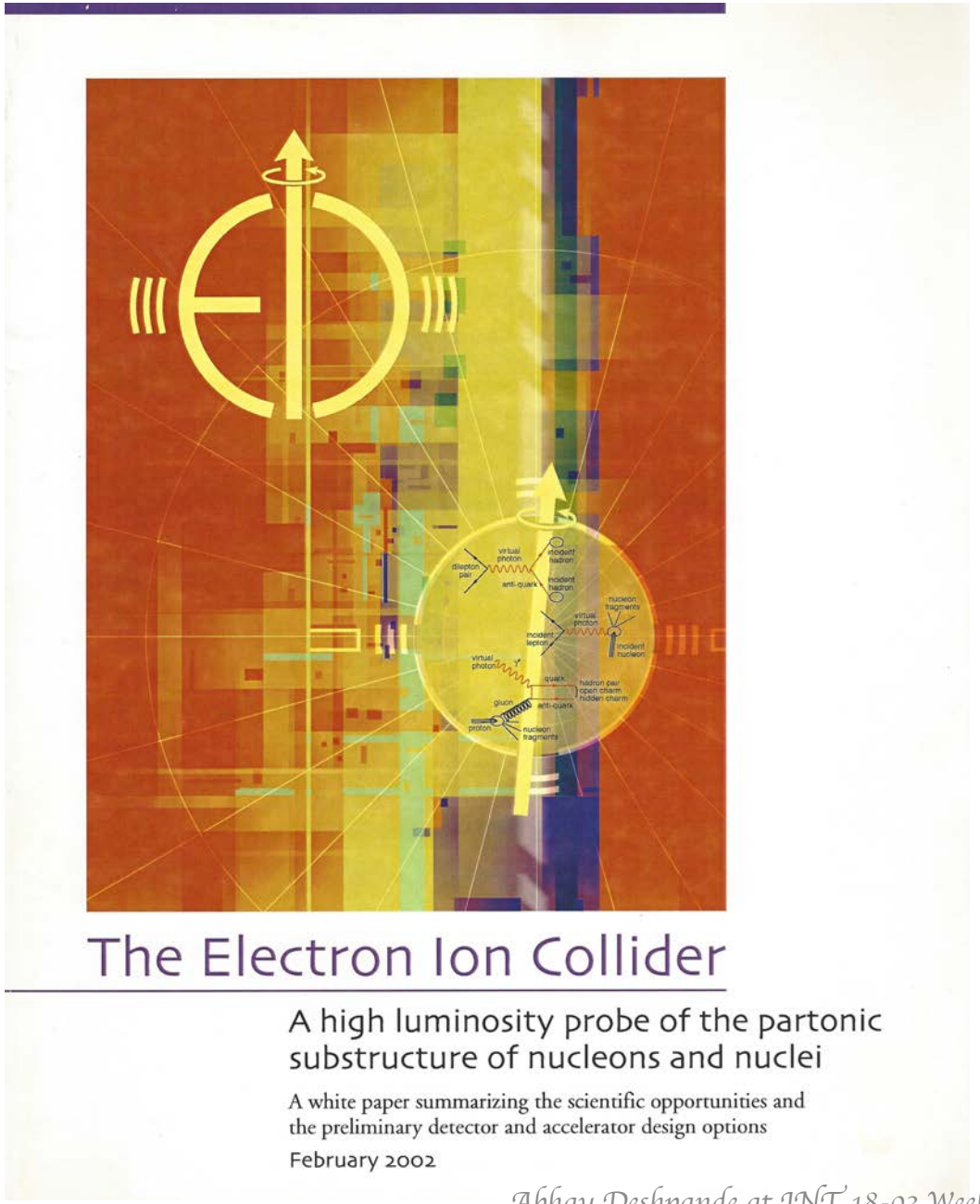
W. Wissink (IUCF)



By 2001-2003

BNL & RIKEN-BNL Research Center became the focus of EIC activities

AD, R. Venugopalan, W. Vogelsang et al. locally supported by L. McLerran, T.D. Lee, P. Paul (Acting D. Director for Science & Technology), and G. Garvey (on Sabbatical)



Preparation for the 2002 Long Range Plan

White Paper prepared/edited by:

A. Deshpande, R. Milner & R. Venugopalan

Institutions:

BNL, Budker Institute, CERN, U. of Colorado (Boulder), FNAL, UIUC, Indiana U., LBNL, Los Alamos, MIT, INP Poland, U. of Paris VI, Penn State, Regensburg, RIKEN-BNL, Saclay, Triumf, Yale

Actively **Supported by:**

G. Garvey (Los Alamos) & Peter Paul

(Acting Director BNL Dep. Director) & T. D. Lee (RBRC/Columbia)

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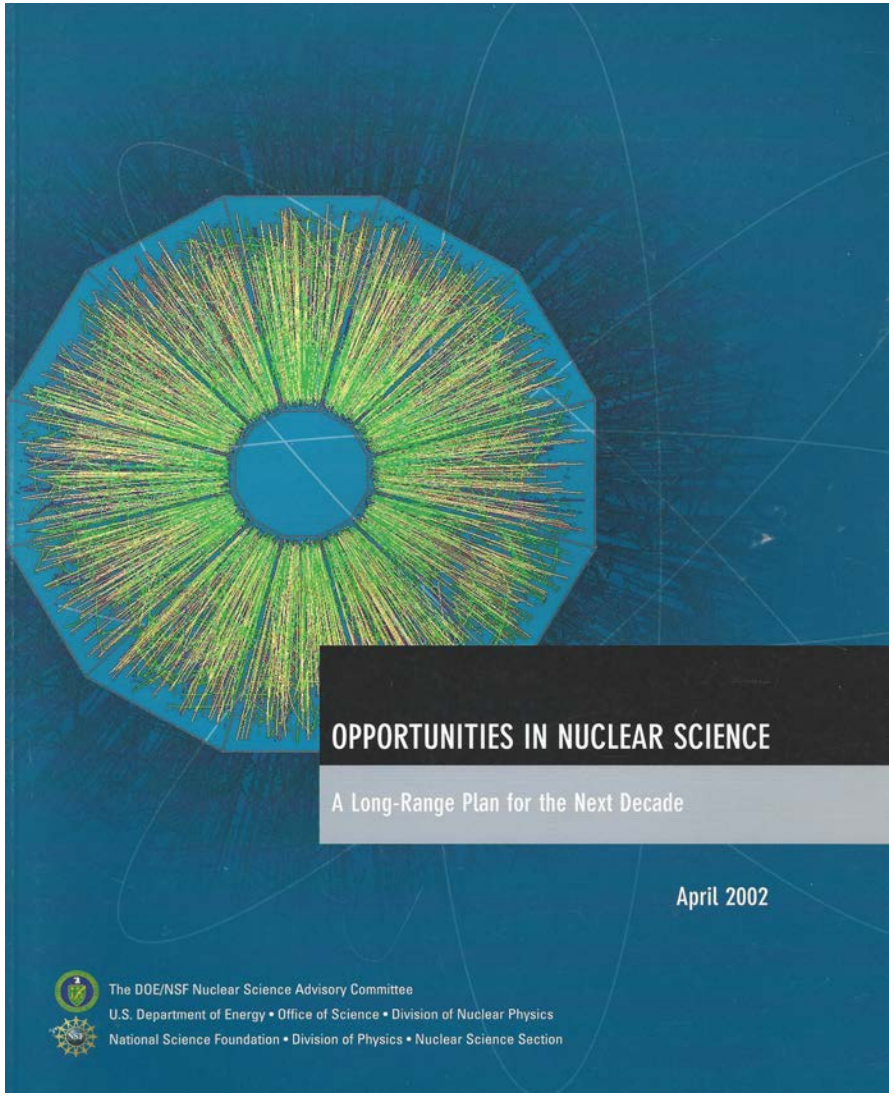
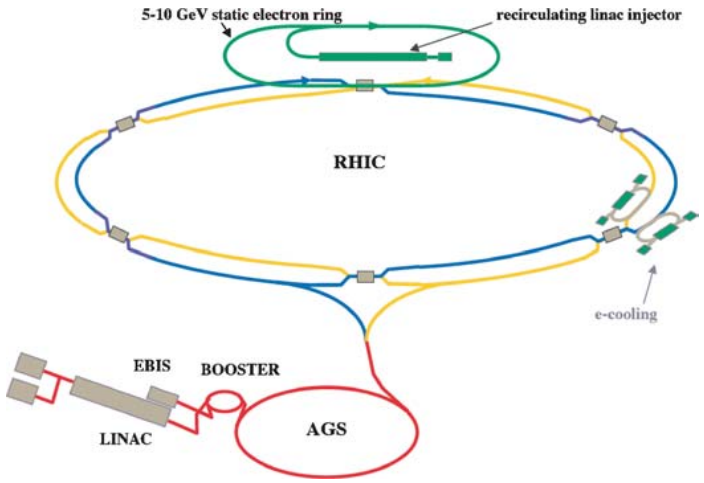
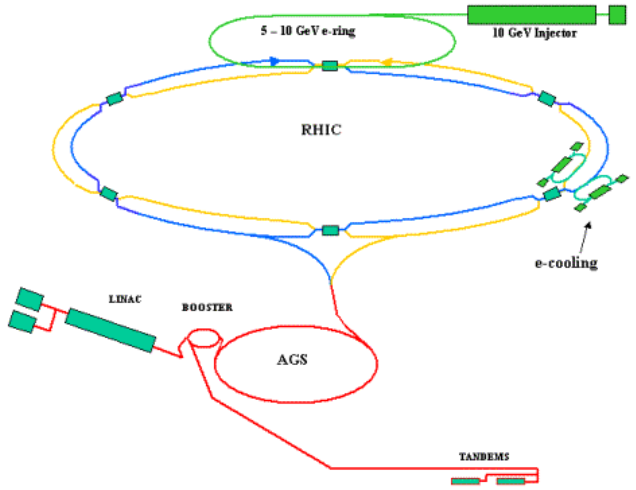
NSAC 2002 Long Range Plan: First Recognition

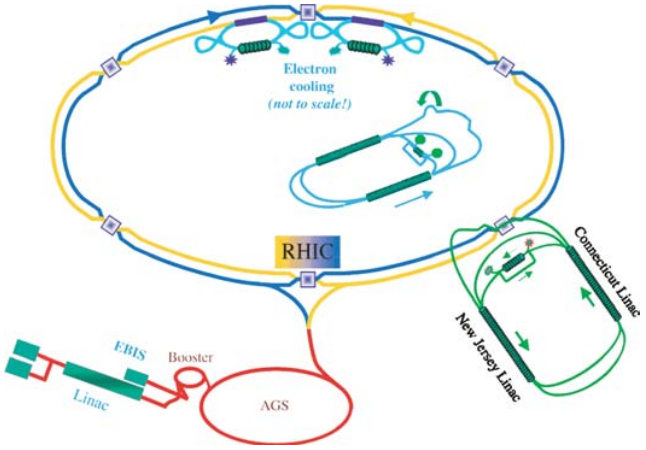


The Electron-Ion Collider is a new accelerator concept that has been proposed to extend our understanding of the structure of matter in terms of its quark and gluon constituents.
Two classes of machine design for the EIC have been considered: a ring-ring option where both electron and ion beams circulate in storage rings, and a ring-linac option where a linear electron beam incident on a stored ion beam.

There is a strong consensus among nuclear scientists to pursue R&D over the next three years to address a number of EIC design issues. In parallel, the scientific case for the EIC will be significantly refined.







EIC = eRHIC Then….

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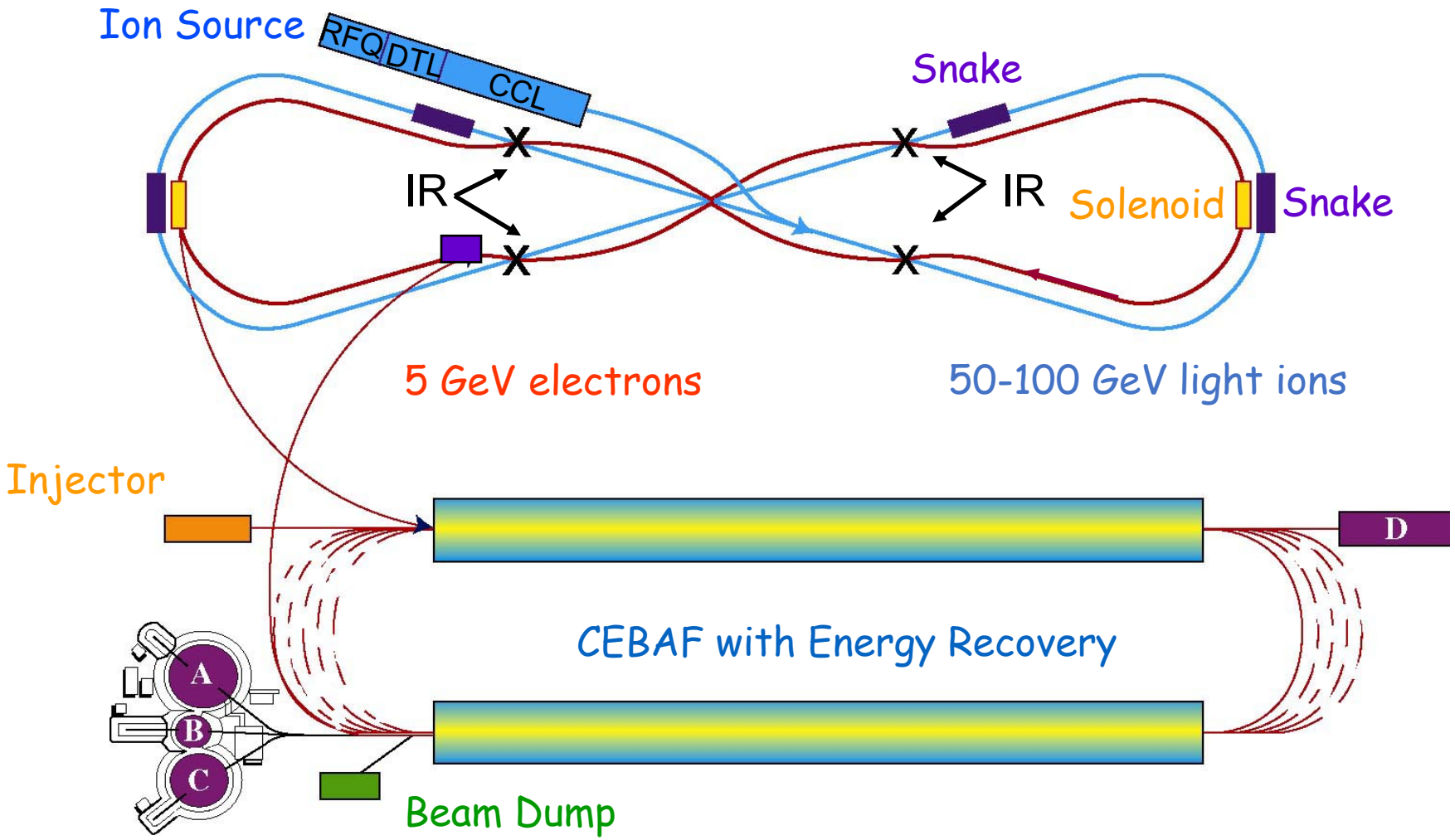
I think I witnessed the birth of JLEIC...

Pre-Resolution, in the town meetings, 2001/2002

- BNL presented eRHIC and Jlab presented a 24 GeV upgrade of the 12 GeV. The resulting discussion centered round the "collider", not the 24 GeV fixed target experiment.

- Swapan Chattopaddhyay turned to Lia Merminga and asked why don't we think of a collider too…?

JLAB/ELIC Layout Superfast development : March 2003!



One accelerating & one decelerating pass through CEBAF

NSAC Subcommittee Evaluation March 03: 1 Science, 3 for Readiness

From this time onwards EIC in the US context meant either eRHIC or MEIC (now JLEIC)

A single project!

What was the science program at the time?

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Scientific Frontiers for the EIC (eRHIC & ELIC)

- **Nucleon Structure:** polarized & unpolarized e-p/n scattering

  -- Role of quarks and gluons in the nucleon: unpolarized quark & gluon distributions

  -- Spin structure: polarized quark & gluon distributions

  -- Correlation between partons ➔ hard exclusive processes leading to Generalized Parton Distributions (GPD's)

- **Nuclear structure:** unpolarized e-A scattering

  -- Role of quarks and gluons in nuclei

  -- e-p vs. e-A physics in comparison

- **Hadronization in nucleons and nuclei & effect of nuclear media**

  -- How do partons knocked out of nucleon in DIS evolve in to colorless hadrons?

- **Partonic matter under extreme conditions**

  -- e-A vs. e-p scattering; study as a function of A

Note: Science case surprisingly close to what we talk about these days.

But no mention of "imaging", although implicit in it.

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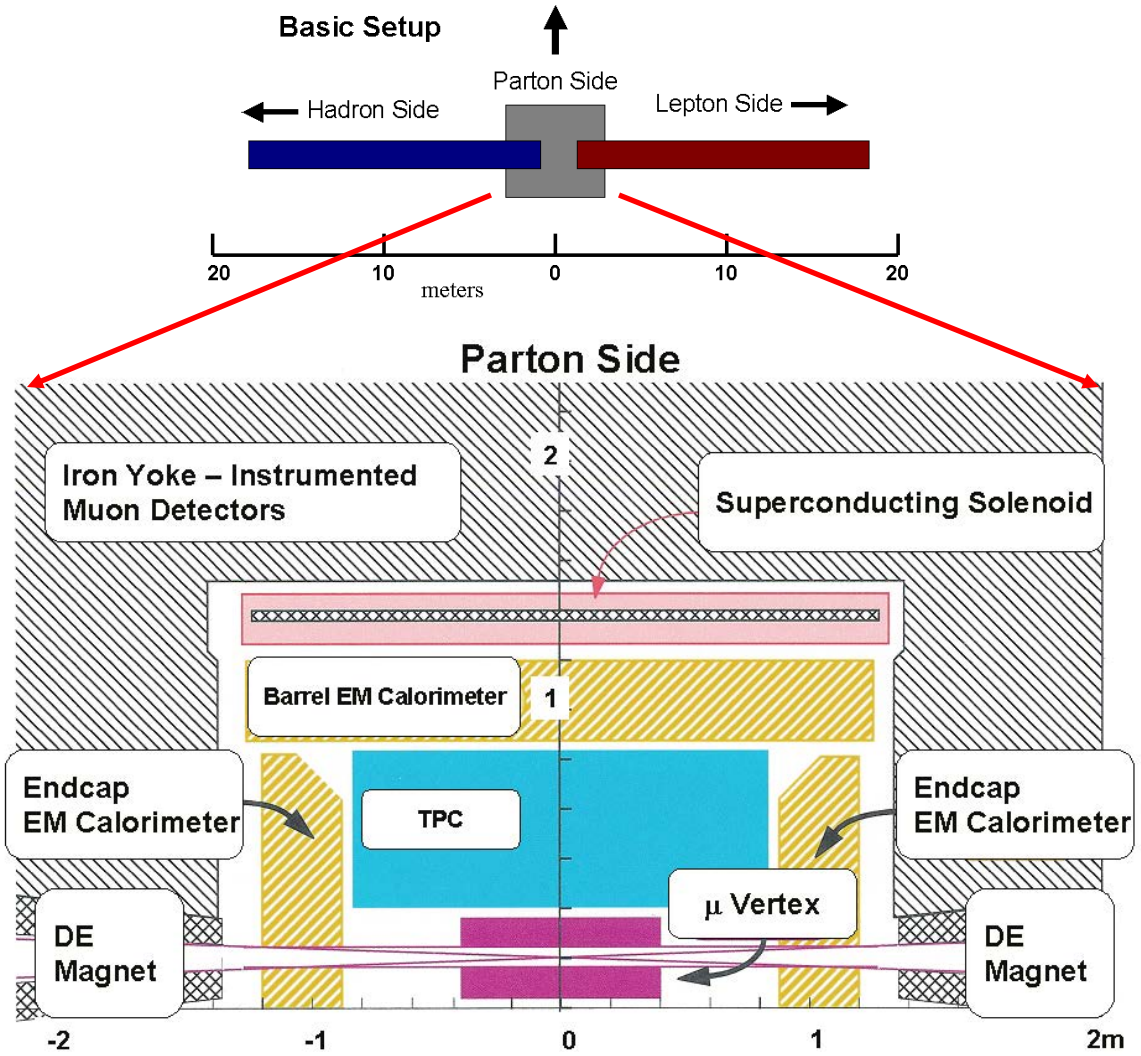
Detector Design (I)… others expected



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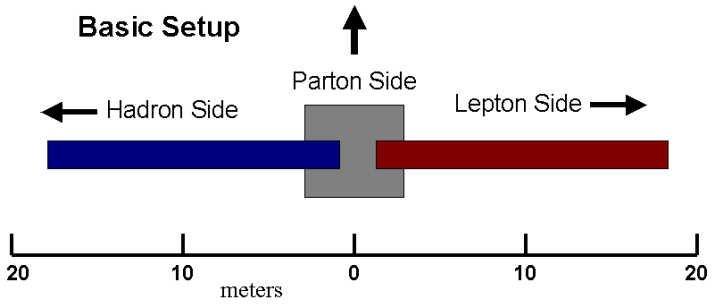
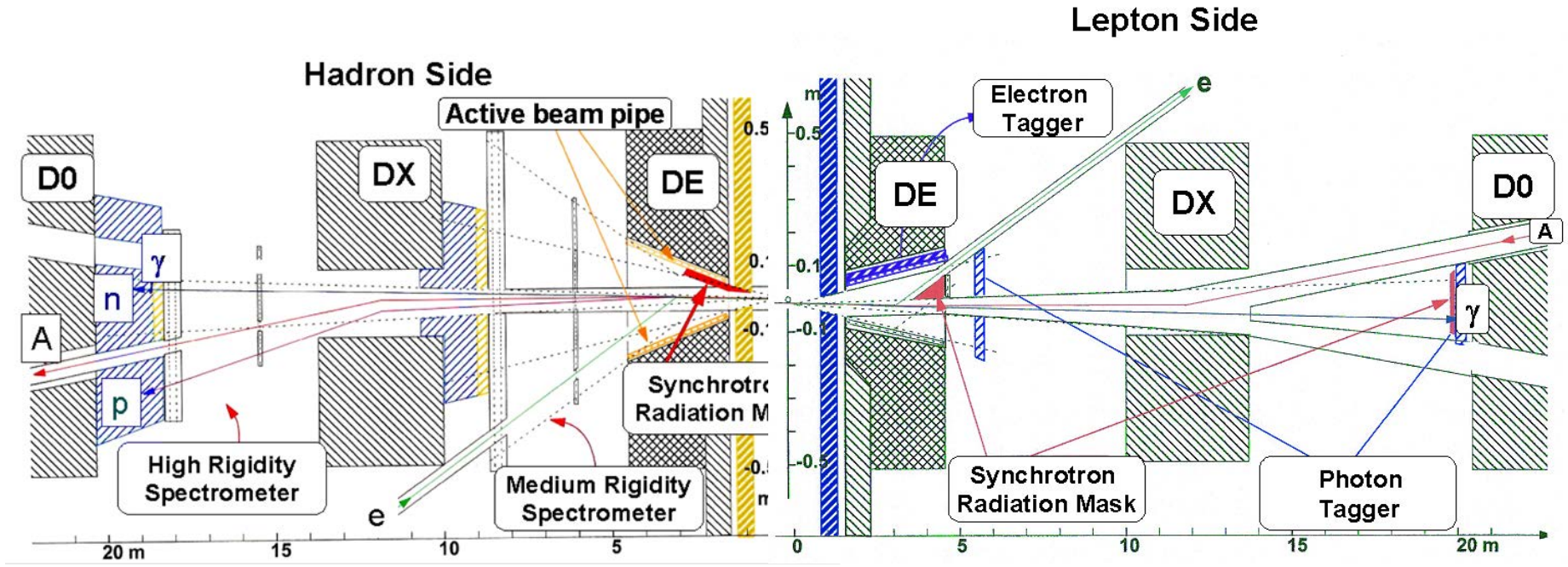
Detector Design (I)… others expected





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A New Experiment for the HERA Collider
Expression of Interest

ZEUS, H1 and Hermes collaborators make a final last push for polarized protons and/or nuclei

April 16, 2003

H. Abramowicz[1], I. Abt[2], L. Adamczyk[3], M. Arneodo[4], J. Bracinik[2], I. Brock[5], A. Bruell[6], A. Caldwell[2,18], S. Chekanov[7], J. Chwastowski[8], J. Ciborowski[9], W. Dabrowski[3], R. Devenish[10], Y. Eisenberg[11], P. Ermolov[12], A. Eskreys[8], J. Figiel[8], L. K. Gladilin[12], I. Grabowska-Bold[3], G. Grindhammer[2], G. Gustafson[13], T. Haas[14], K. Hafidi[7], D. Hasell[6], R. J. Holt[7], G. Ingelman[15], H. E. Jackson[7], L. Jönsson[13], H. Jung[13], U. Karshon[11], C. Kiesling[2], E. Kinney[16], D. Kisielewska[3], A. Kotanski[17], H. Kowalski[14], A. Levy[1], X. Liu[2], L. Lönnblad[13], O. Lukina[12], S. Magill[7], N. Makins[19], M. Merkin[12], R. Milner[6], B. Naroska[20], J. Peng[19], D. Potterveld[7], A. Proskuryakov[12], M. Przybycien[3], P. E. Reimer[7], J. Repond[7], S. Schlenstedt[21], W. Schmidke[18], U. Schneekloth[14], V. Shekelyan[2], T. Sjöstrand[13], W. Slominski[17], L. Stanco[22], R. Stroili[22], J. Whitmore[23], R. Yoshida[7], L. Zawiejski[8], N. Zotov[12]

- Nuclear beams up to **calcium** technically feasible
- Polarized nucleon technically very challenging
- **HERA stopped in June 2007**

Paper originally planned: AD, V. Hughes, J. Kuti & W. Vogelsang on Nucleon Spin.

Delayed and then we sadly lost Vernon Hughes.

Advent of EIC as a concept and recognition in the NSAC LRP 2002, led to:

Annu. Rev. Nucl. Part. Sci. 2005. 55:165–228
doi: 10.1146/annurev.nucl.54.070103.181218

STUDY OF THE FUNDAMENTAL STRUCTURE OF MATTER WITH AN ELECTRON-ION COLLIDER

Abhay Deshpande,[1] Richard Milner,[2] Raju Venugopalan,[3] and Werner Vogelsang[4]

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[2]*Physics Department and Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139; email: milner@mit.edu*
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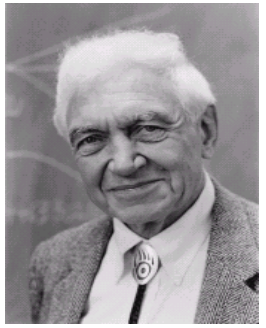
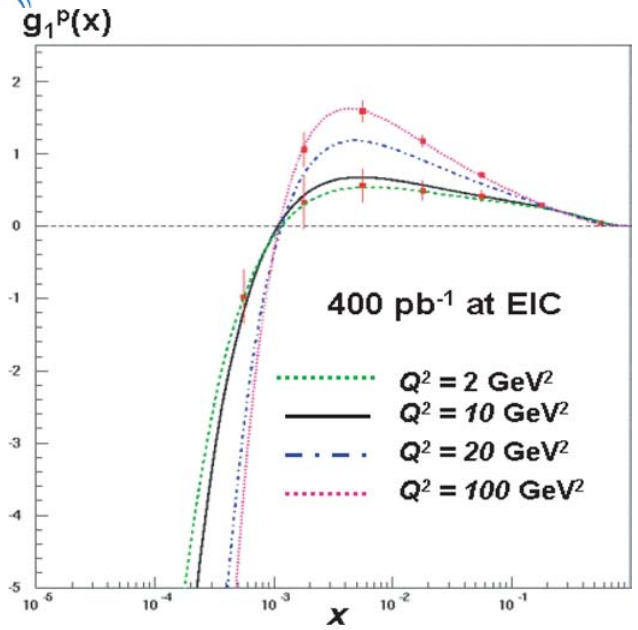
[4]*Physics Department and RIKEN-BNL Research Center, Brookhaven National Laboratory, Upton, New York 11973; email: vogelsan@quark.phy.bnl.gov*

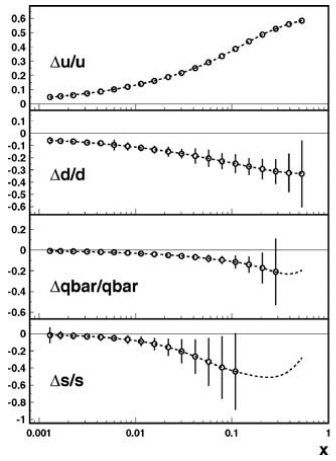
This review is dedicated to the memory of Professor Vernon W. Hughes.

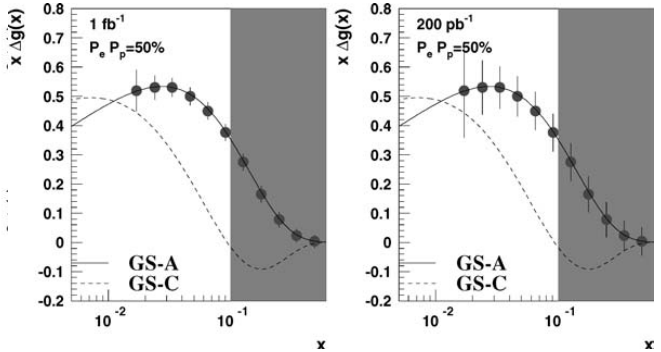
Key Words Quantum Chromodynamics, DIS structure functions, Polarized ep Scattering, Nucleon Spin, DIS off Nuclei, Saturation, Color Glass Condensate, EIC, eRHIC

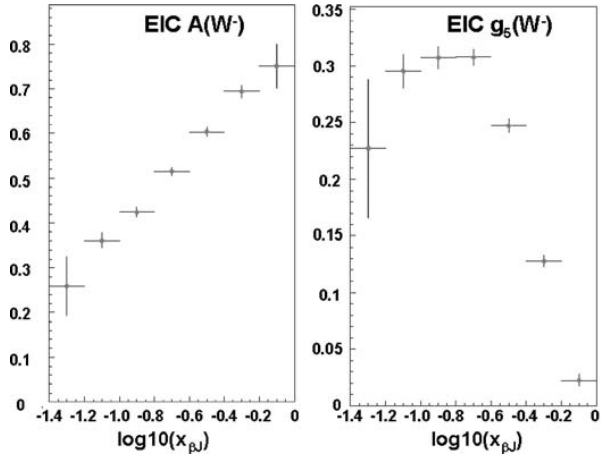
■ **Abstract** We present an overview of the scientific opportunities that would be offered by a high-energy electron-ion collider. We discuss the relevant physics of polarized and unpolarized electron-proton collisions and of electron-nucleus collisions. We also describe the current accelerator and detector plans for a future electron-ion collider.

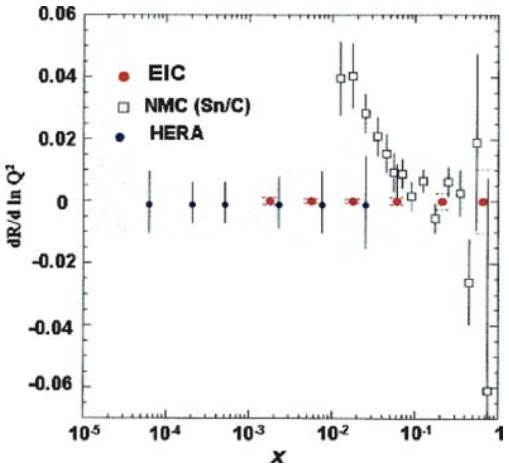


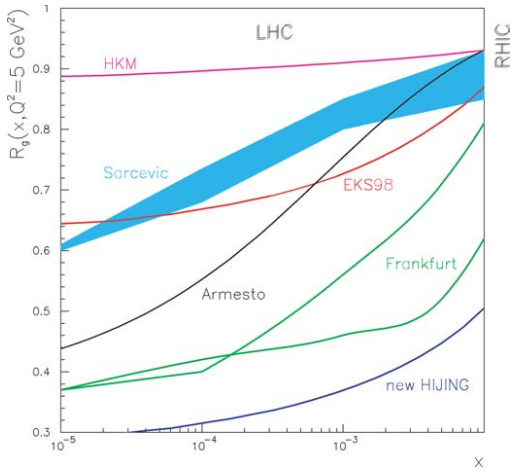

$g_1^p(x)$
400 pb^{-1} at EIC
Q^2 = 2 GeV^2
Q^2 = 10 GeV^2
Q^2 = 20 GeV^2
Q^2 = 100 GeV^2
x

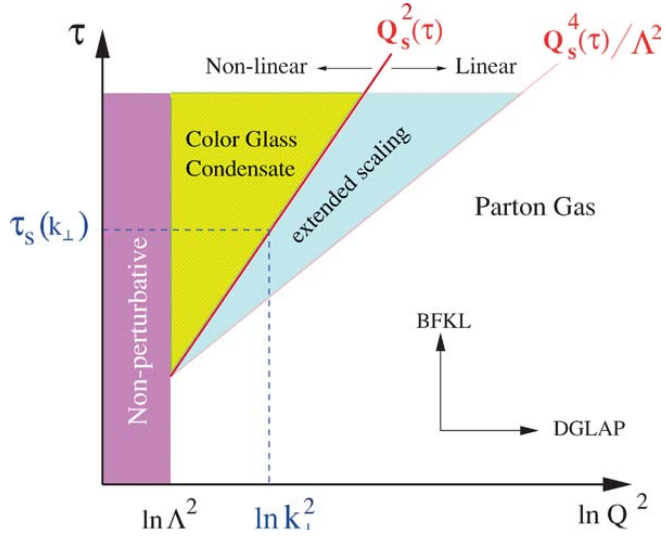

Δu/u
Δd/d
Δqbar/qbar
Δs/s
x

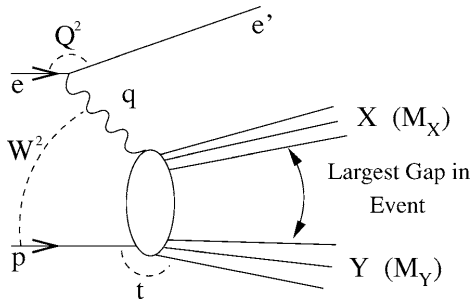

1 fb^{-1}
P$_e$ P$_p$=50%
200 pb^{-1}
P$_e$ P$_p$=50%
x Δg(x)
GS-A
GS-C
x

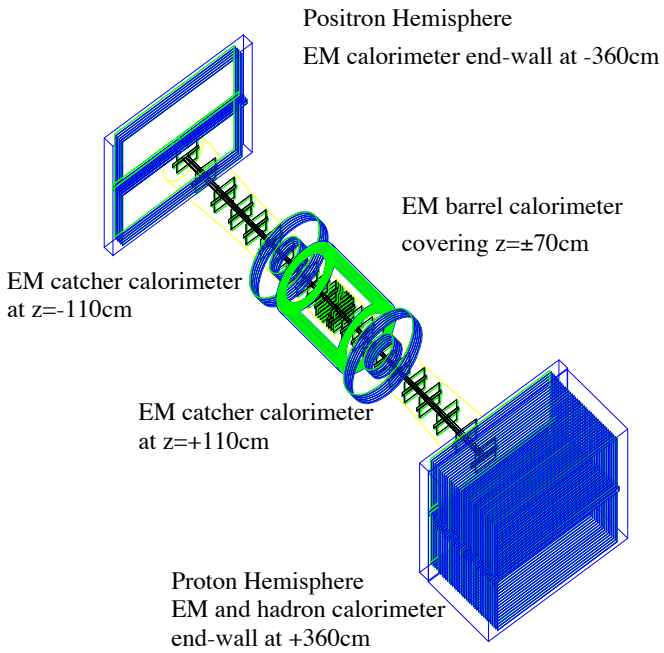

EIC A(W$^-$)
EIC g$_5$(W$^-$)
log10(x$_{βJ}$)
log10(x$_{βJ}$)

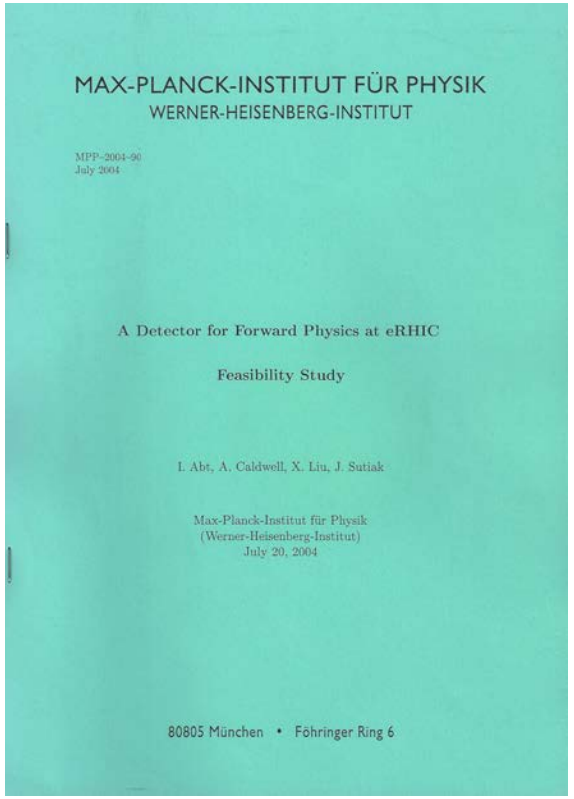

EIC
NMC (Sn/C)
HERA
dR/d ln Q^2
x


LHC
RHIC
HKM
Sarcevic
EKS98
Armesto
Frankfurt
new HIJING
R$_g$(x,Q^2=5 GeV^2)
x


τ
Q$_s^2$(τ)
Q$_s^4$(τ)/Λ^2
Non-linear
Linear
Color Glass Condensate
extended scaling
Parton Gas
τ$_s$(k$_⊥$)
Non-perturbative
BFKL
DGLAP
ln Λ^2
ln k$_⊥^2$
ln Q^2


e
e'
Q^2
q
W^2
X (M$_X$)
Largest Gap in Event
p
Y (M$_Y$)
t




MAX-PLANCK-INSTITUT FÜR PHYSIK
WERNER-HEISENBERG-INSTITUT

MPP-2004-90
July 2004

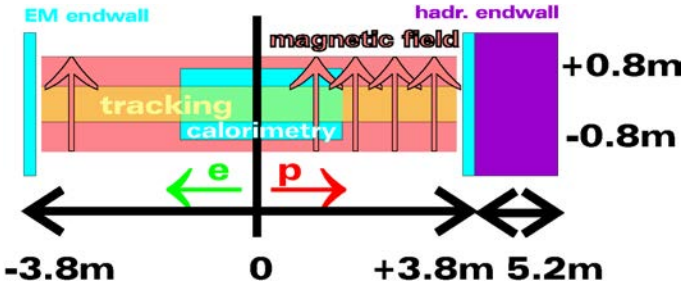
A Detector for Forward Physics at eRHIC

Feasibility Study

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

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)
July 20, 2004

80805 München • Föhringer Ring 6



Novel detector ideas presented for eRHIC based on the experience at HERA
by
I. Abt, A. Caldwell, X. Liu and J. Sutiak (MPI)

Center for Frontiers in Nuclear Science

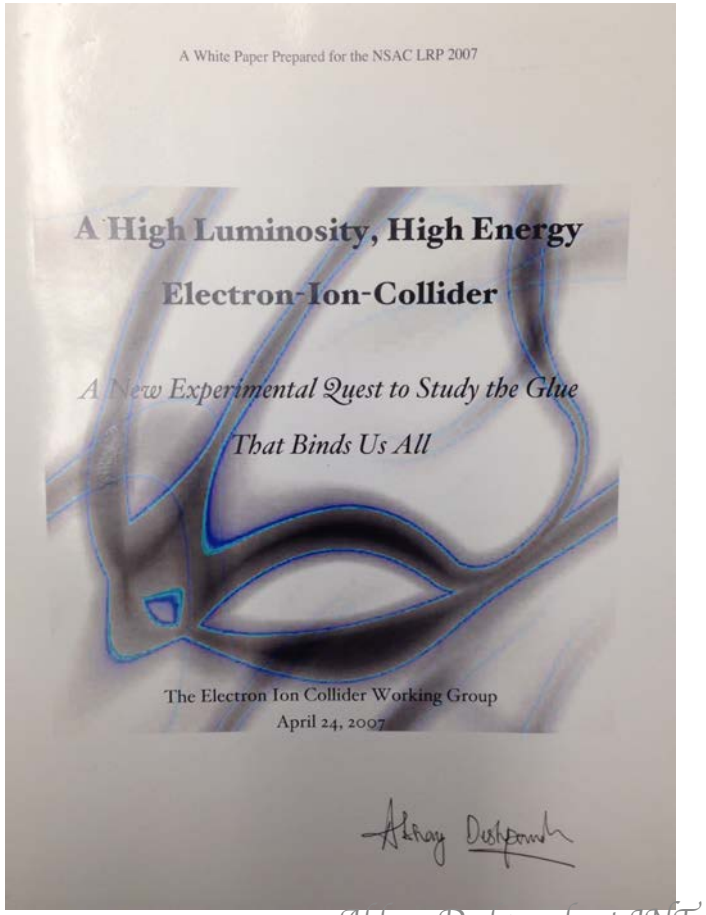
2007 Long Range Plan approaches…

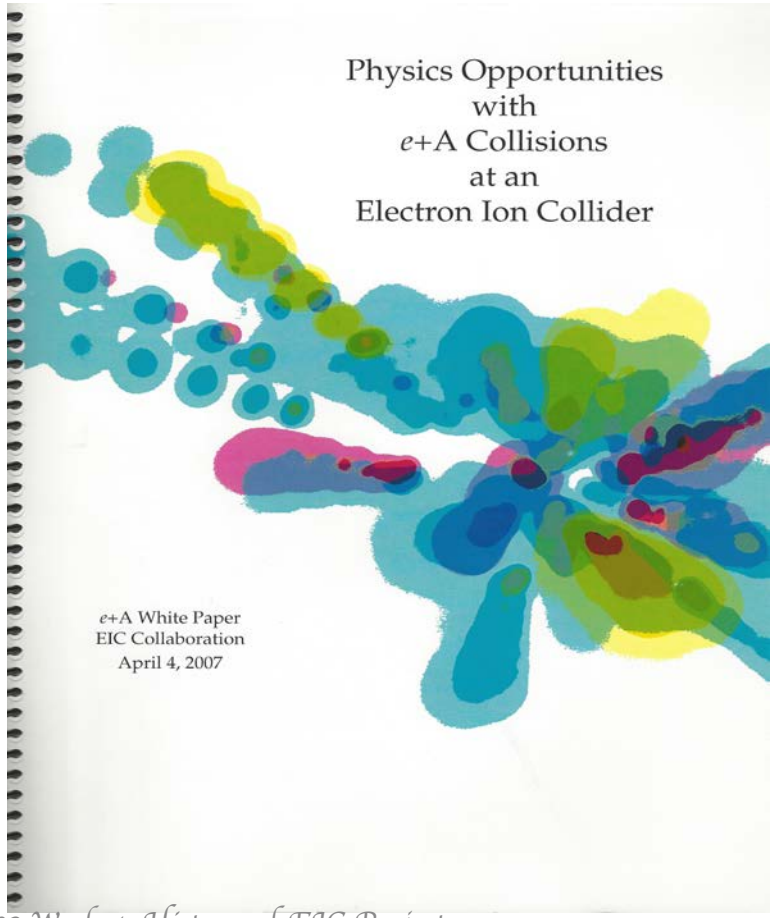
Nothing like a Long Range Plan to focus one's mind….

Center for Frontiers in Nuclear Science

Institution List for EIC Working Group Institutes 2007 LRP

ANL, BARC/india, BNL, Buenos Aires, UCLA, CERN, U. Colorado, Columbia, DESY, Glasgow, Hampton U., UIUC, Iowa State, Jlab, U. Kyoto, LBNL, Los Alamos, U. Mass (A), MIT, MPI Munich, U. of Michigan, NMSU, ODU, Penn State, RIKEN, RIKEN-BNL, SINS Poland, Stony Brook, Tel Aviv, TJNAF





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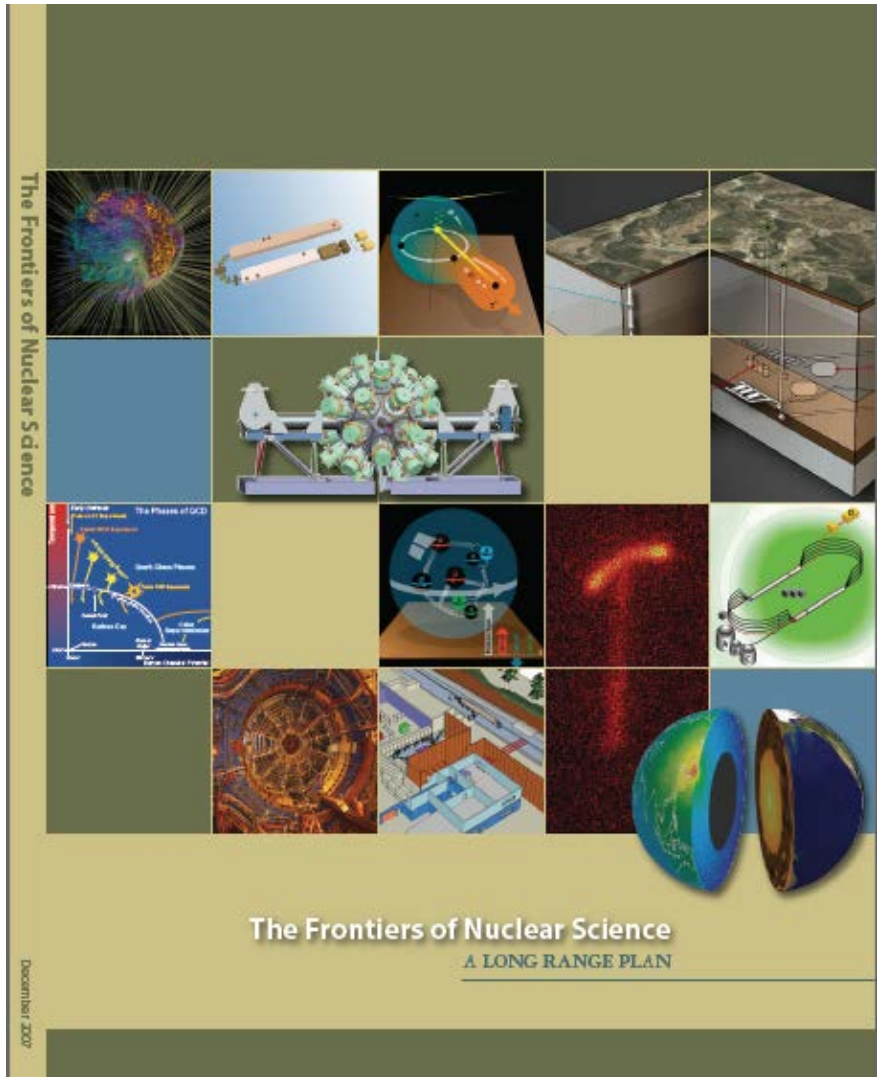
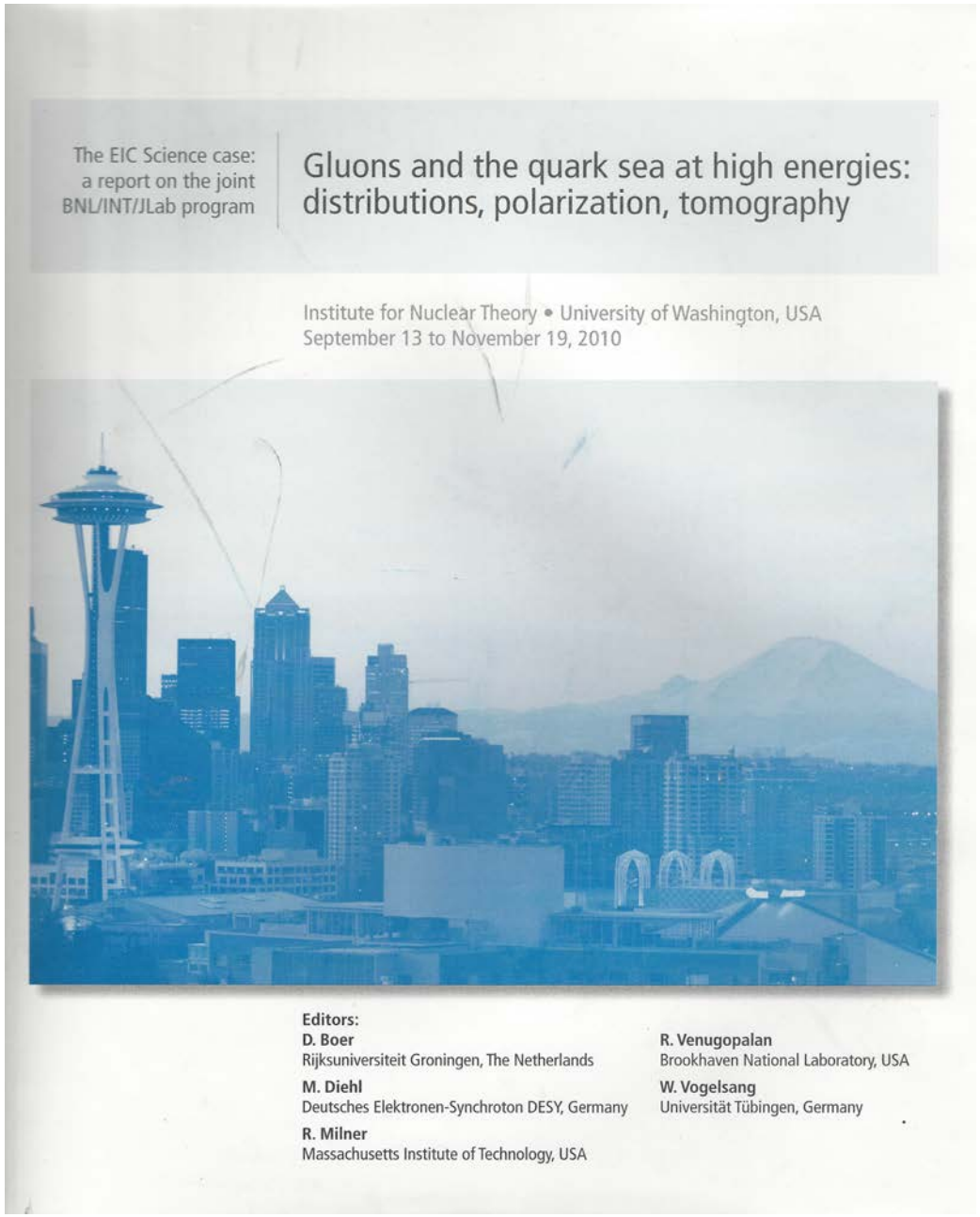
NSAC 2007 Long Range Plan

"An **Electron-Ion Collider (EIC)** with polarized beams has been **embraced by the U.S. nuclear science community** as embodying the vision for **reaching the next QCD frontier**. EIC would provide unique capabilities for the study of QCD well beyond those available at existing facilities worldwide and complementary to those planned for the next generation of accelerators in Europe and Asia. In support of this new direction:

We recommend the allocation of resources to develop accelerator and detector technology necessary to lay the foundation for a polarized Electron Ion Collider. The EIC would explore the new QCD frontier of strong color fields in nuclei and precisely image the gluons in the proton."





INT program 2010

Organizers:

D. Boer, M. Diehl, R. Milner, R. Venugopalan, W. Vogelsang

Broad community input and participation. A document containing 500+ pages and 160+ writers summarized the entire gamut of EIC physics.

Identified the most compelling measurements to **make the case for the EIC**: Golden, Silver, Bronz. (not appreciated by all but) very convincing to the outsiders , the broader community of our sincere effort. – *Important understated lesson*

Center for Frontiers in Nuclear Science

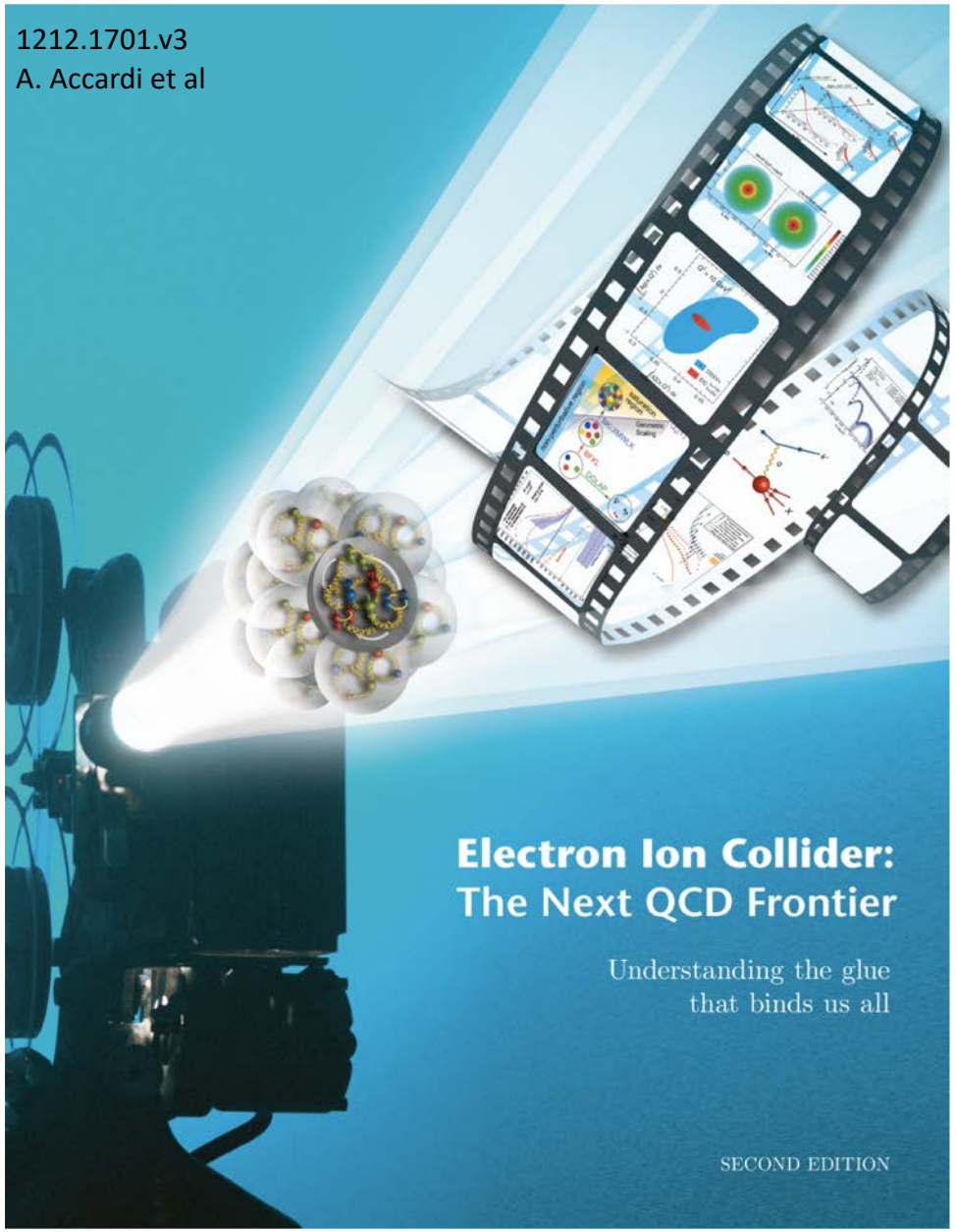
March 2013 NSAC Subcommittee on Major Nuclear Physics Facilities for the Next Decade

EIC Science Rating : **A or 1**

The subcommittee ranked the EIC as "Absolutely Central in its ability to contribute to world-leading science in the next decade"

EIC Construction Readiness Rating: **B or 2 for eRHIC**

"Significant scientific/engineering challenges to resolve before initial construction"



EIC White Paper for LRP 2015

In 2012 R. McKeown and S. Vigdor appointed a group:

A. Accardi et al. 1212.1701.v3

Ed: AD, Jianwei Qiu & Zein-Eddine Meziani

Pre-LRP QCD Town Meeting Temple University:

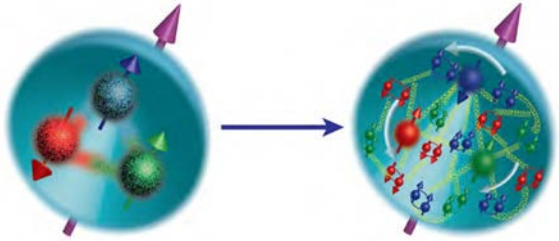
Hot & Cold QCD Working Groups *unanimously* declared EIC to be the most desired future facility for US Nuclear Science – September 2014

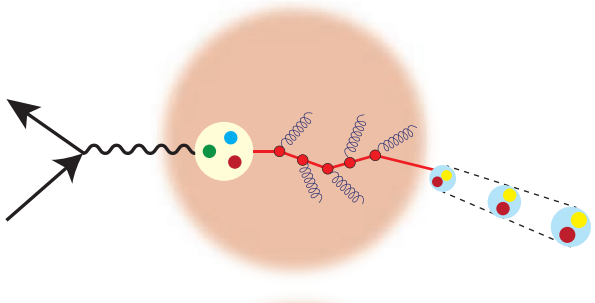
Center for Frontiers in Nuclear Science

A new facility is needed to investigate, with precision, the dynamics of gluons & sea quarks and their role in the structure of visible matter

How are the sea quarks and gluons, and their spins, distributed in space and momentum inside the nucleon?

How do the nucleon properties emerge from them and their interactions?





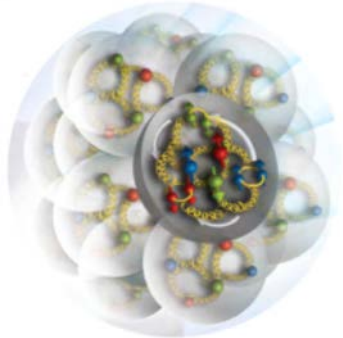
How do color-charged quarks and gluons, and colorless jets, interact with a nuclear medium?

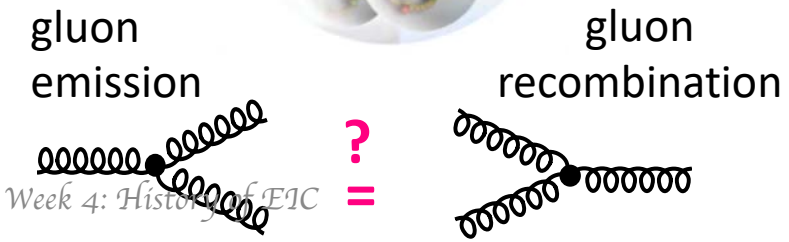
How do the confined hadronic states emerge from these quarks and gluons?

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?





NSAC 2015 Long Range Plan

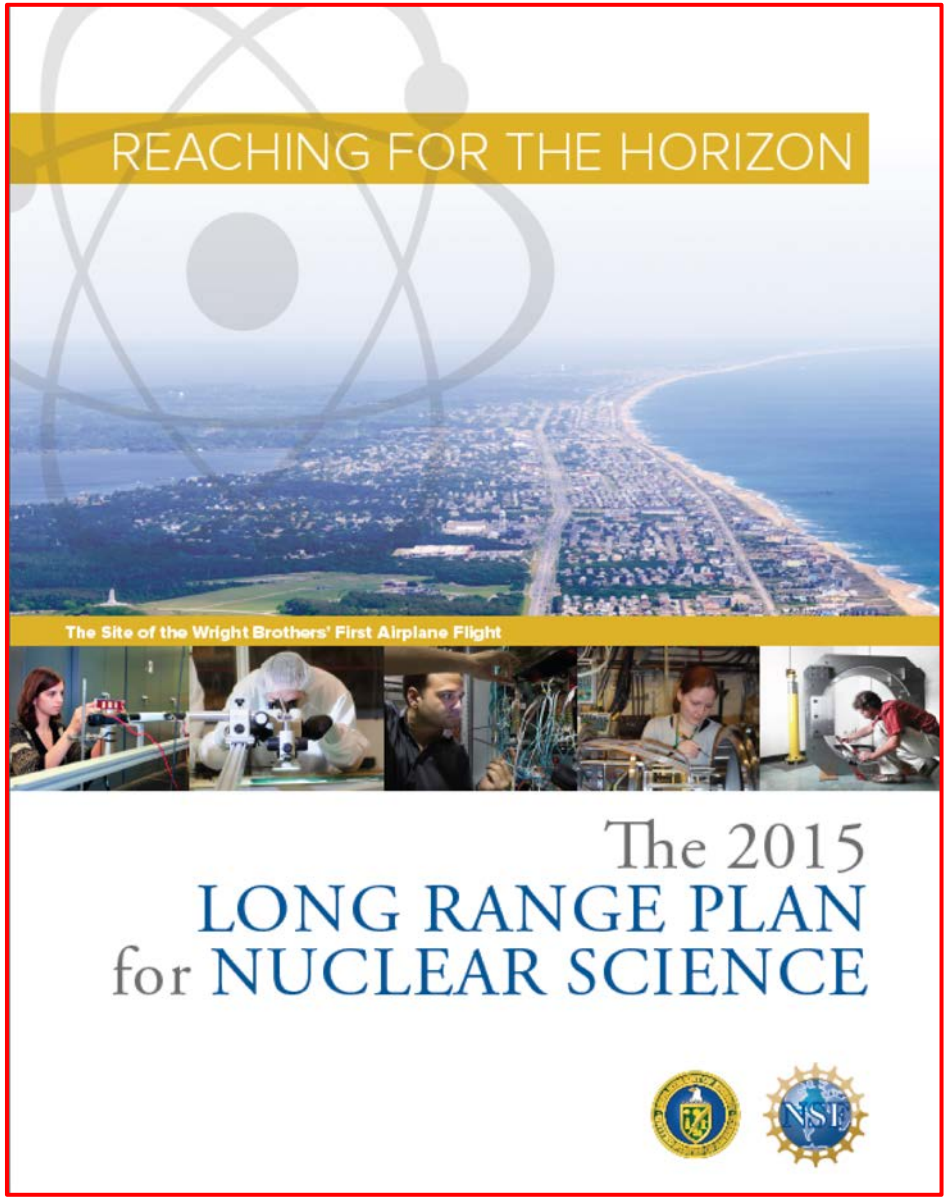
science.energy.gov/np/nsac/

RECOMMENDATION III

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

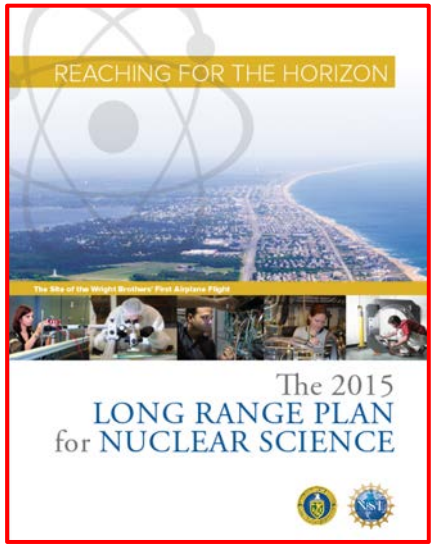
We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB.

The EIC will, for the first time, precisely image gluons in nucleons and nuclei. It will definitively reveal the origin of the nucleon spin and will explore a new quantum chromodynamics (QCD) frontier of ultra-dense gluon fields, with the potential to discover a new form of gluon matter predicted to be common to all nuclei. This science will be made possible by the EIC's unique capabilities for collisions of polarized electrons with polarized protons, polarized light ions, and heavy nuclei at high luminosity.



Center for Frontiers in Nuclear Science

The Vision...



The vision of an EIC was already a powerful one in the 2007 Long Range Plan. The case is made even more compelling by recent discoveries. This facility can lead to the convergence of the present world-leading QCD programs at CEBAF and RHIC in a single facility. This vision for the future was expressed in the 2013 NSAC report on the implementation of the 2007 Long Range Plan with the field growing towards two major facilities, one to study the quarks and gluons in strongly interacting matter and a second, FRIB, primarily to study nuclei in their many forms. Realizing the EIC will keep the U.S. on the cutting edge of nuclear and accelerator science.

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The US Electron Ion Collider

Two options of realization

For e-N collisions at the EIC:

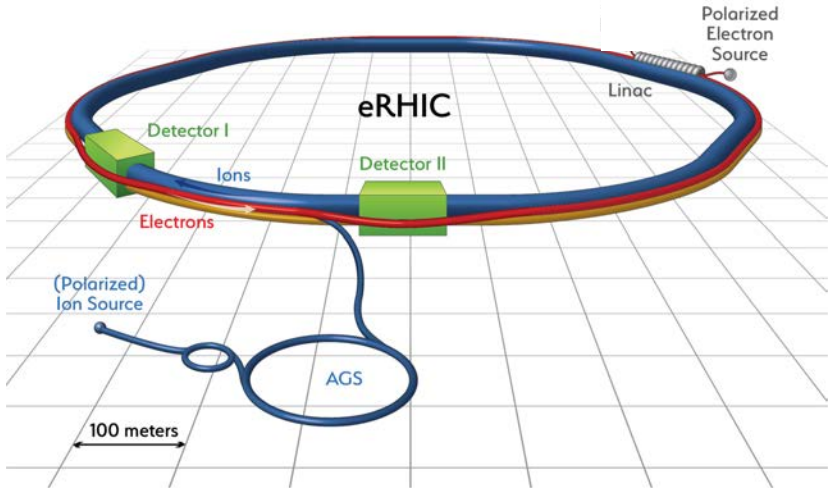
- ✓ Polarized beams: e, p, d/^{3}He
- ✓ e beam 5-10(20) GeV
- ✓ Luminosity L_{ep} ~ $10^{33\text{-}34}$ $cm^{-2}sec^{-1}$
  100-1000 times HERA
- ✓ 20-100 (140) GeV Variable CoM

For e-A collisions at the EIC:

- ✓ **Wide range in nuclei**
- ✓ Luminosity per nucleon same as e-p
- ✓ Variable center of mass energy

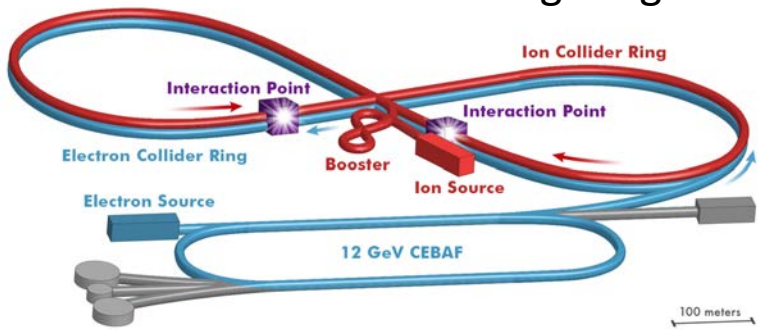
World's first
Polarized electron-proton/light ion
and electron-Nucleus collider

Both designs use DOE's significant investments in infrastructure



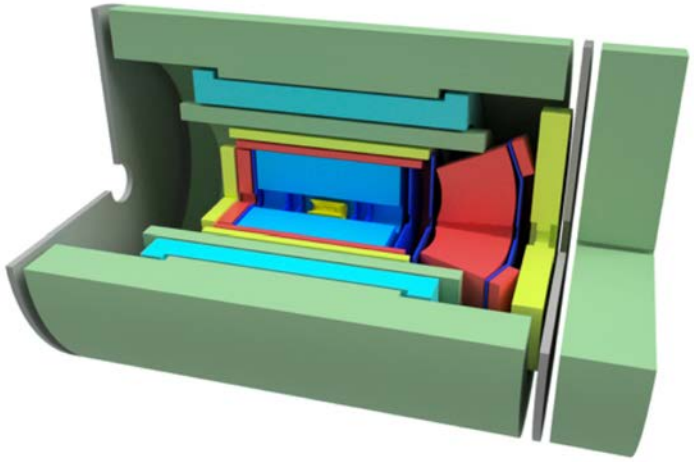
Not to scale

Ring-Ring

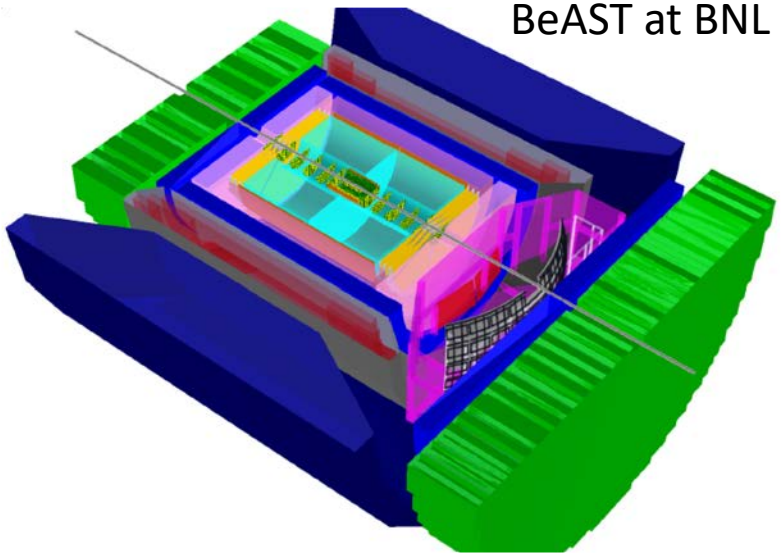


EIC Detector Concepts

EIC Day 1 detector, with BaBar Solenoid

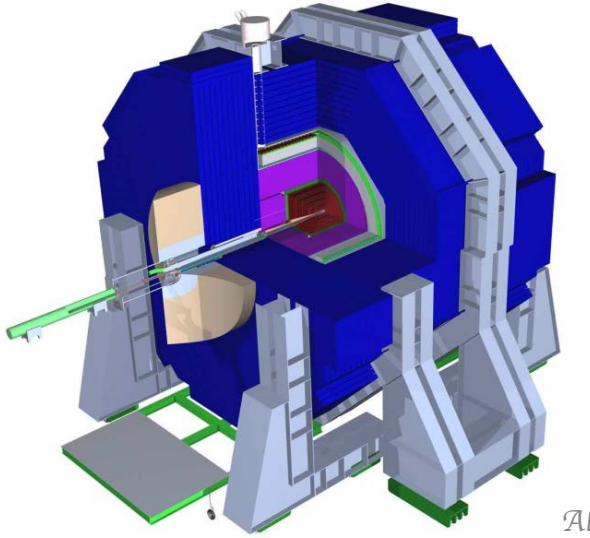


BeAST at BNL

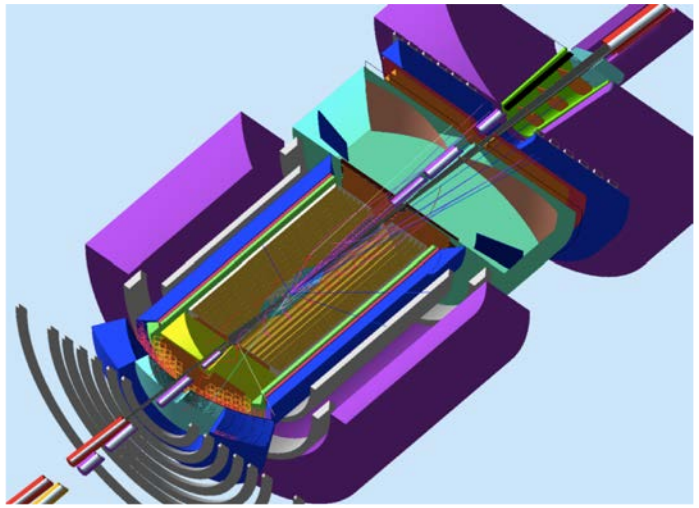


Detector R&D Program (~1M/yr) Managed by BNL for the DOE. (Thomas Ullrich)

ANL's: "SiEIC Detector" Si-tracker &
Precision calorimetry: particle flow detector

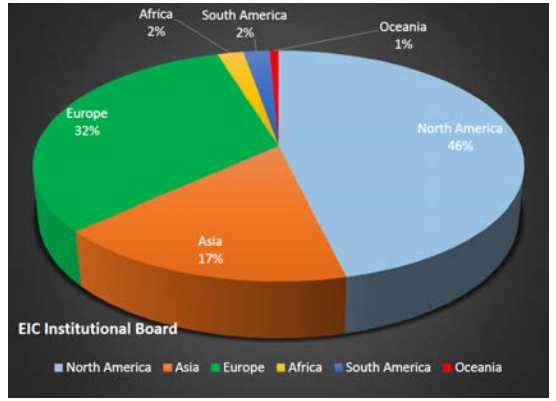


JLEIC Detector Concept, with CLEO Solenoid



The EIC Users Group: EICUG.ORG

826 collaborators, 30 countries, 176 institutions... (October 2018)



EICUG Structures in place and active.

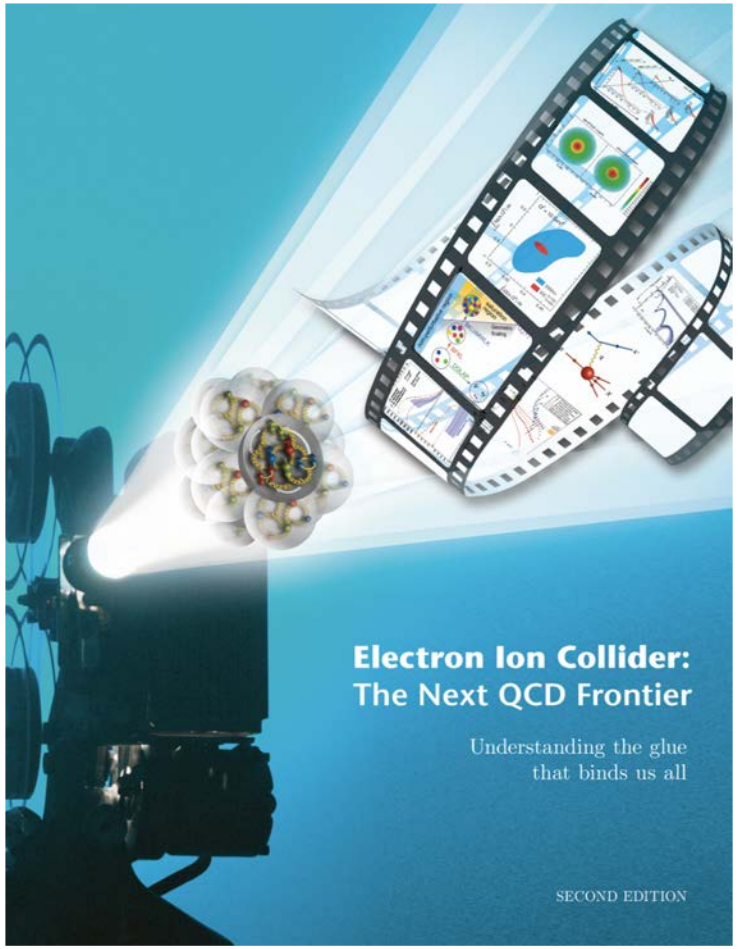
EIC UG Steering Committee
EIC UG Institutional Board
EIC UG Speaker's Committee

Task forces on:
-- Beam polarimetry
-- Luminosity measurement
-- Background studies
-- IR Design

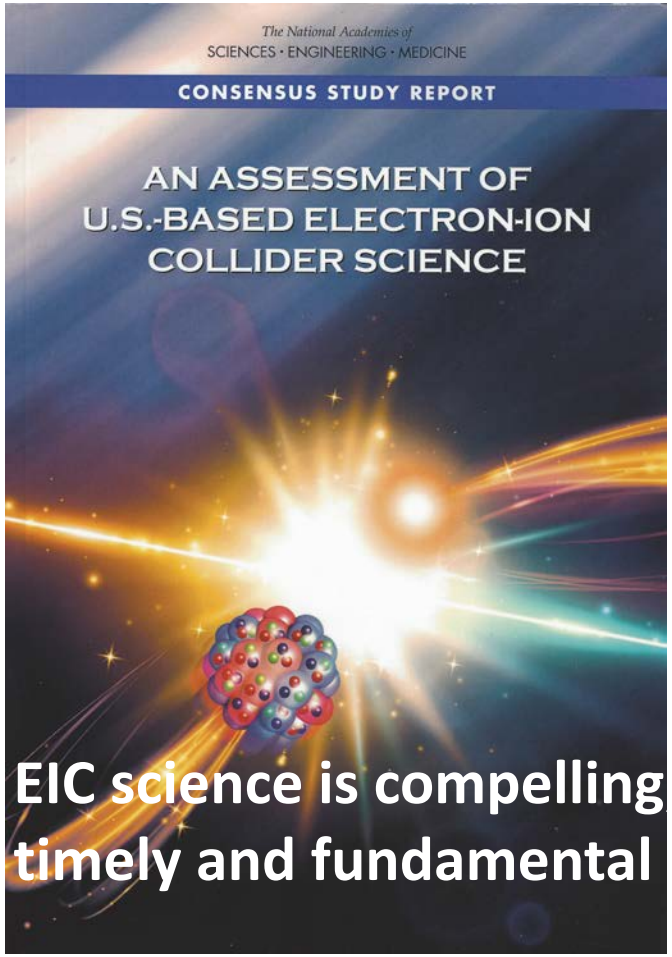
Annual meetings: Stony Brook (2014), Berkeley (2015), ANL (2016), Trieste (2017), CAU (2018), **Paris 2019**

Center for Frontiers in Nuclear Science

EIC Physics Case: Strongly Endorsed by the National Academy of Science Subcommittee

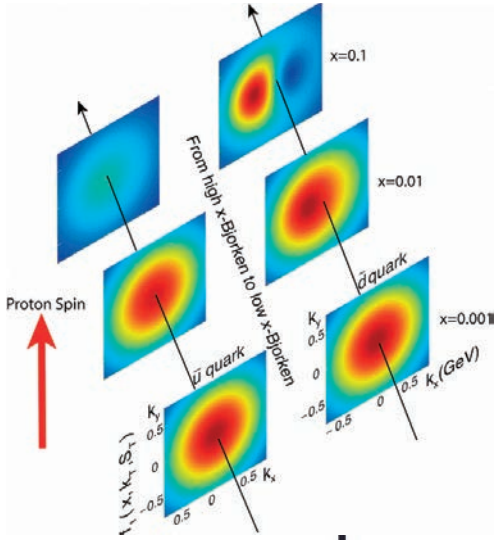


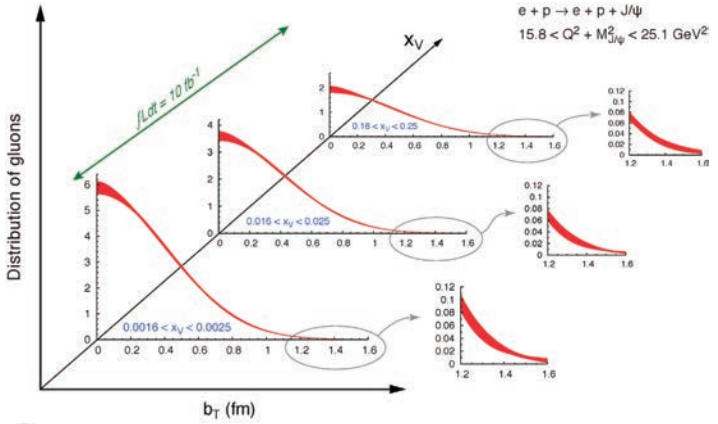
Developed by US QCD community over two decades

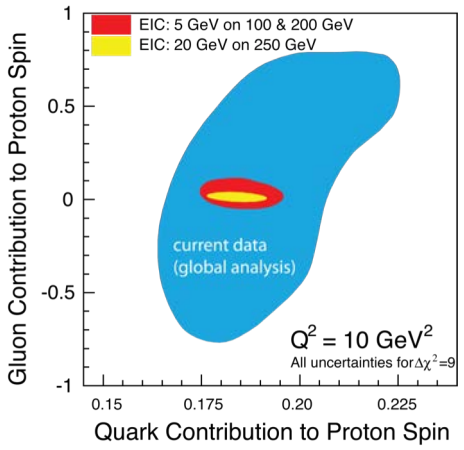


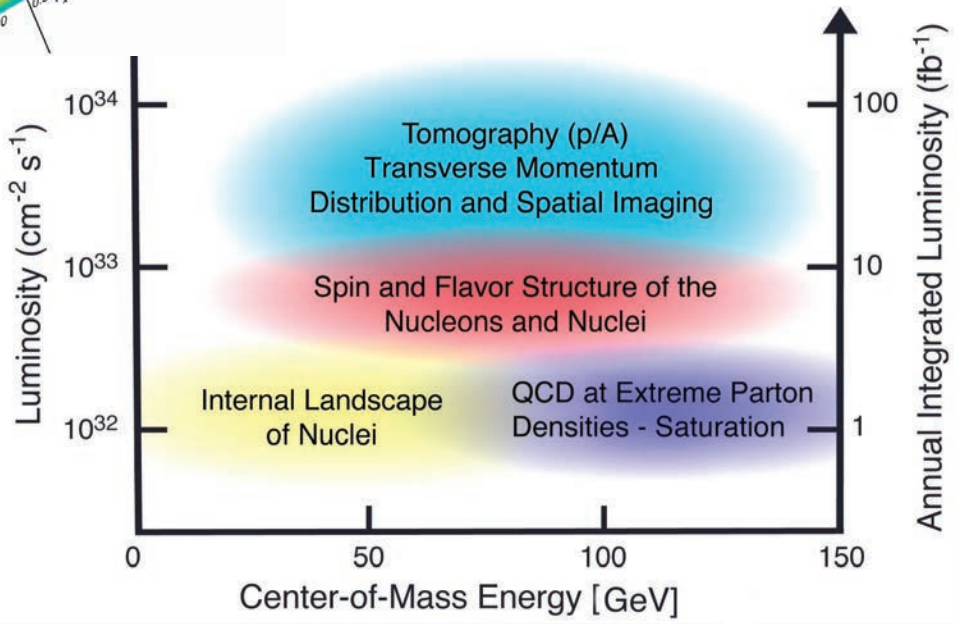
Developed by NAS committee with broad science perspective

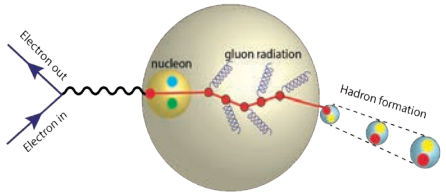
Center for Frontiers in Nuclear Science

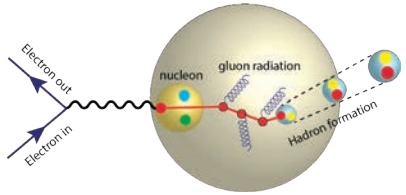


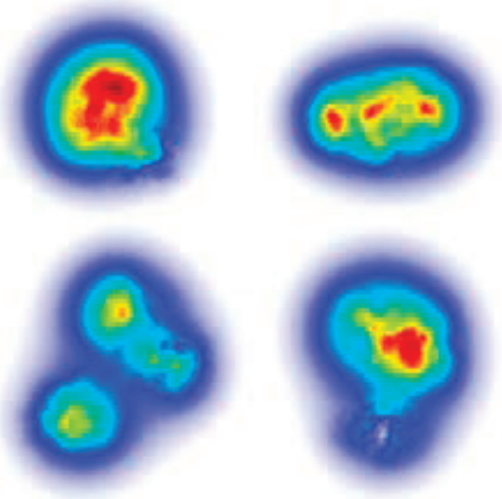








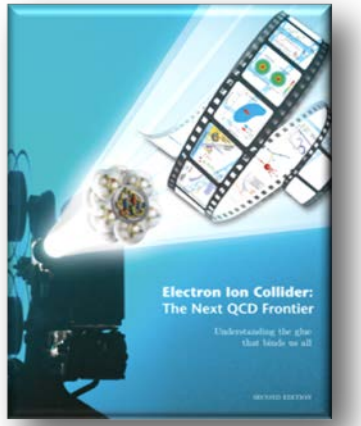


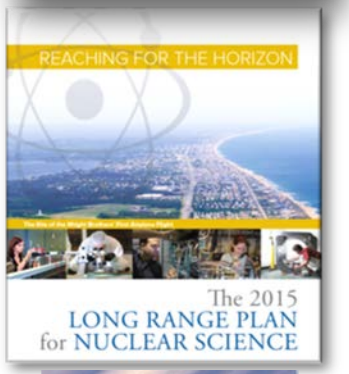


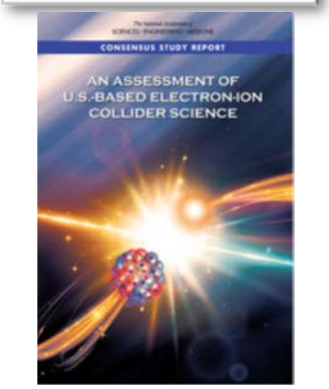
NAS REPORT ON EIC REQUIREMENTS

In order to definitively answer the compelling scientific questions elaborated in Chapter 2, including the origin of the mass and spin of the nucleon and probing the role of gluons in nuclei, a new accelerator facility is required, an electron-ion collider (EIC) with unprecedented capabilities beyond previous electron scattering programs. An EIC must enable the following:

- Extensive center-of-mass energy range, from ~20-~100 GeV, upgradable to ~140 GeV, to map the transition in nuclear properties from a dilute gas of quarks and gluons to saturated gluonic matter.
- Ion beams from deuterons to the heaviest stable nuclei.
- Luminosity on the order of 100 to 1,000 times higher than the earlier electron-proton collider Hadron-Electron Ring Accelerator (HERA) at Deutsches Elektronen-Synchrotron (DESY), to allow unprecedented three-dimensional (3D) imaging of the gluon and sea quark distributions in nucleons and nuclei.
- Spin-polarized (~70 percent at a minimum) electron and proton/light-ion beams to explore the correlations of gluon and sea quark distributions with the overall nucleon spin. Polarized colliding beams have been achieved before only at HERA (with electrons and positrons only) and Relativistic Heavy Ion Collider (RHIC; with protons only).

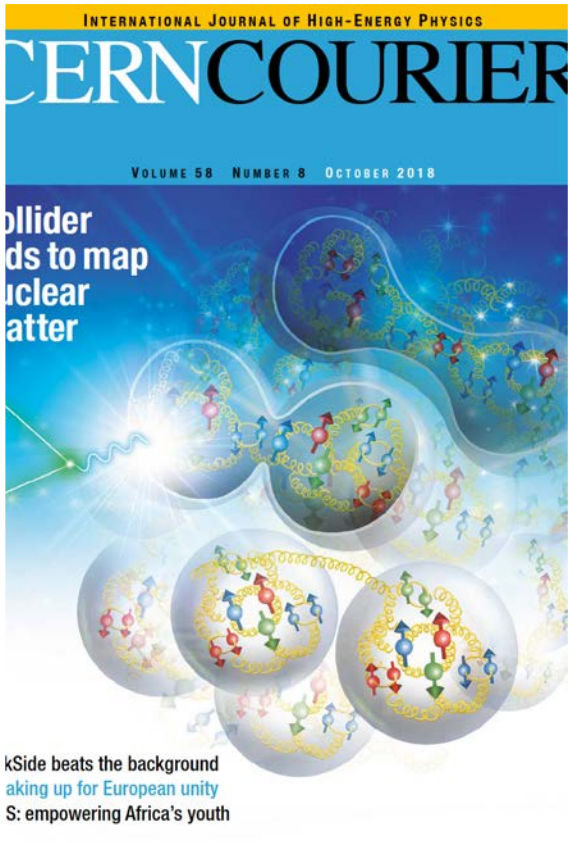






NAS Study endorses machine parameters suggested by the 2012 White Paper and 2015 NSAC Long Range Plan

Rolf Ent, Thomas Ullrich, Raju Venugopalan
Scientific American (2015), **Just before LRP2015**
Translated and published in 4 different languages



Elke Aschenauer
Rolf Ent (October 2018)
With NAS report

The Glue That Binds Us

Center for Frontiers in Nuclear Science

History ends and future begins...

- Ideas of EIC have roots in Europe… they have flourished in the US with the involvement of scientists around the world

- Narrowly focused e-h machines, failed. The US EIC is different: it has polarized beams, e-p, e-A, high luminosity and attempting to catch all the collision fragments….– it hence has the highest chance of success.
  - Accelerator challenges : Research Opportunities
  - Detector/IR integration: challenging and innovative

- Theory, experimental ideas and accelerator: all ready together to reap the harvest

- This workshop should explore new physics ideas, and deepen the existing one, for the facility enthusiastically supported by the EIC Users, broader US Nuclear Science Community and the committee setup by the National Academy