

Standing In For a Last Minute Cancellation of a Planned Talk

Abhay Deshpande

WG-7, DIS 2018 Kobe, April, 2018

Charge given: Give an overview of the EIC



Many things that need to be said about EIC in the US have been said in WG-7

Tuesday

Physics:

- Jianwei Qiu
- Rolf Ent

Machine:

- Elke Aschenauer
- Vasily Morozov

Detectors/IR:

- Elke Aschenauer
- Vasily Morozov
- Jose Repond
- Itaru Nakagawa

EIC in the context of European Strategy

- Bernd Surrow for the EICUG

Wednesday

Physics:

- Chu xiaoxuan
- Michael Lomnitz
- Jorge Andres Lopez
- Charles Hyde
- Yulia Ferletova
- Vasily Morozov

EIC Detector R&D Review:

- Yordanka Ilieva

Polarization:

- Elke Aschenauer
- Eric Voutier

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All essential parts of the EIC project are spread over these days and talks: Decided to bring some essential elements together, and emphasize some of the aspects of the program that I thought would be useful for non-US potential collaborators

EIC in the context of European Strategy

- Bernd Surrow for the EICUG

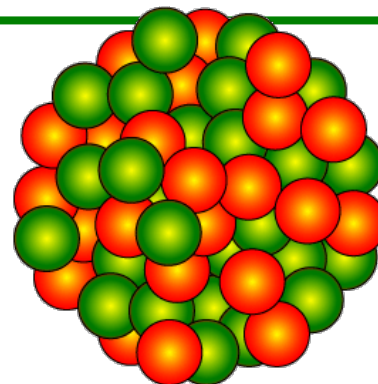
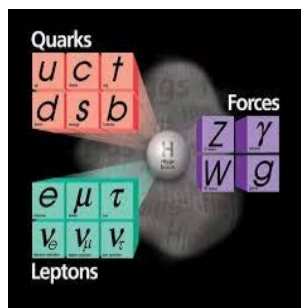
- Eric Voutier



Electron Ion Collider: Science and Status

Understanding the Glue that Binds Us All

Why the EIC? → “Gluon Imaging”
To understand the role of gluons in binding
quarks & gluons into Nucleons and Nuclei

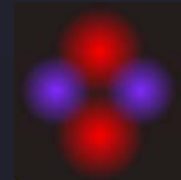
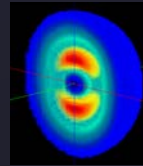
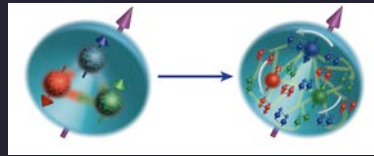


21st Century Nuclear Science:

Probing nuclear matter in all its forms & exploring their potential for applications

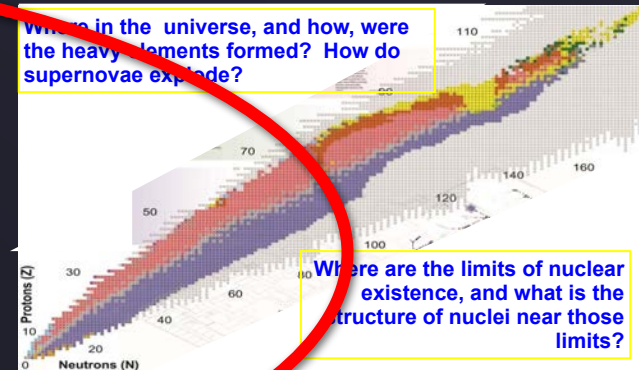
The Standard Model of Particle Interactions
Three Generations of Matter

	I	II	III	
Quarks	u	c	t	Force Carriers
	d	s	b	
	e	μ	τ	
Leptons	ν_e	ν_μ	ν_τ	Force Carriers
	e	μ	τ	
	ν_e	ν_μ	ν_τ	

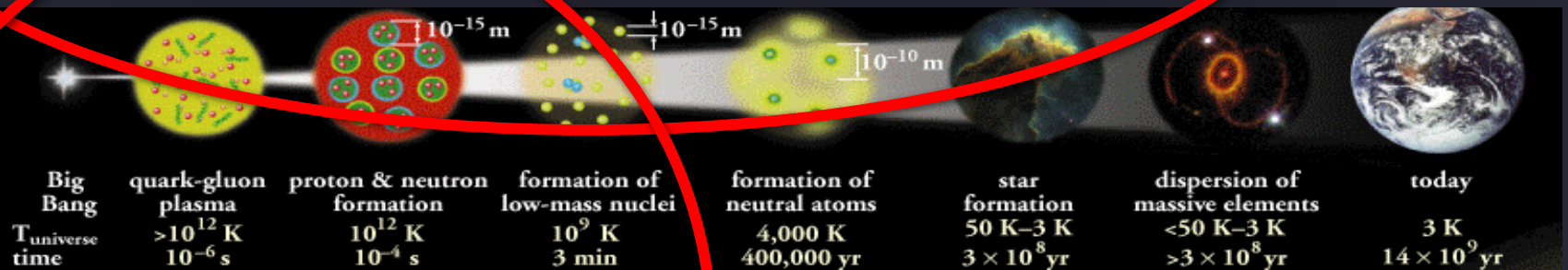


How are the properties of protons and neutrons, and the force between them, built up from quarks, antiquarks and gluons? What is the mechanism by which these fundamental particles materialize as nucleons?

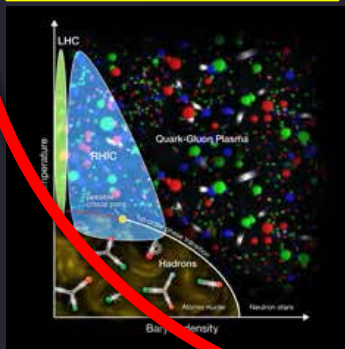
Where in the universe, and how, were the heavy elements formed? How do supernovae explode?



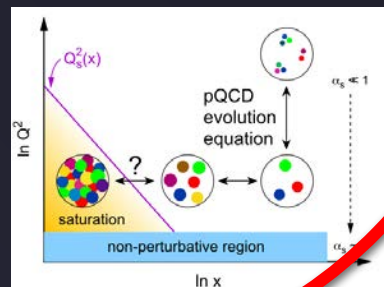
Where are the limits of nuclear existence, and what is the structure of nuclei near those limits?



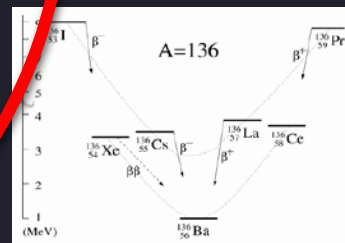
What is the nature of the different phases of nuclear matter through which the universe has evolved?



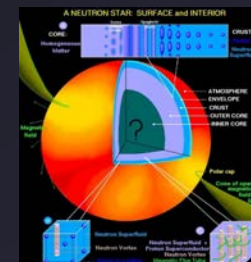
Do nucleons and all nuclei, viewed at near light speed, appear as walls of gluons with universal properties?



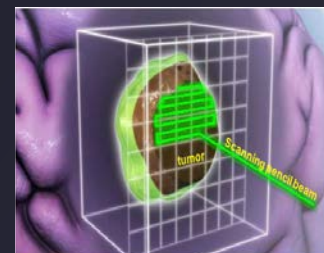
How can the properties of nuclei be used to reveal the fundamental processes that produced an imbalance between matter and antimatter in our universe?



How are the nuclear building blocks manifested in the internal structure of compact stellar objects, like neutron stars?

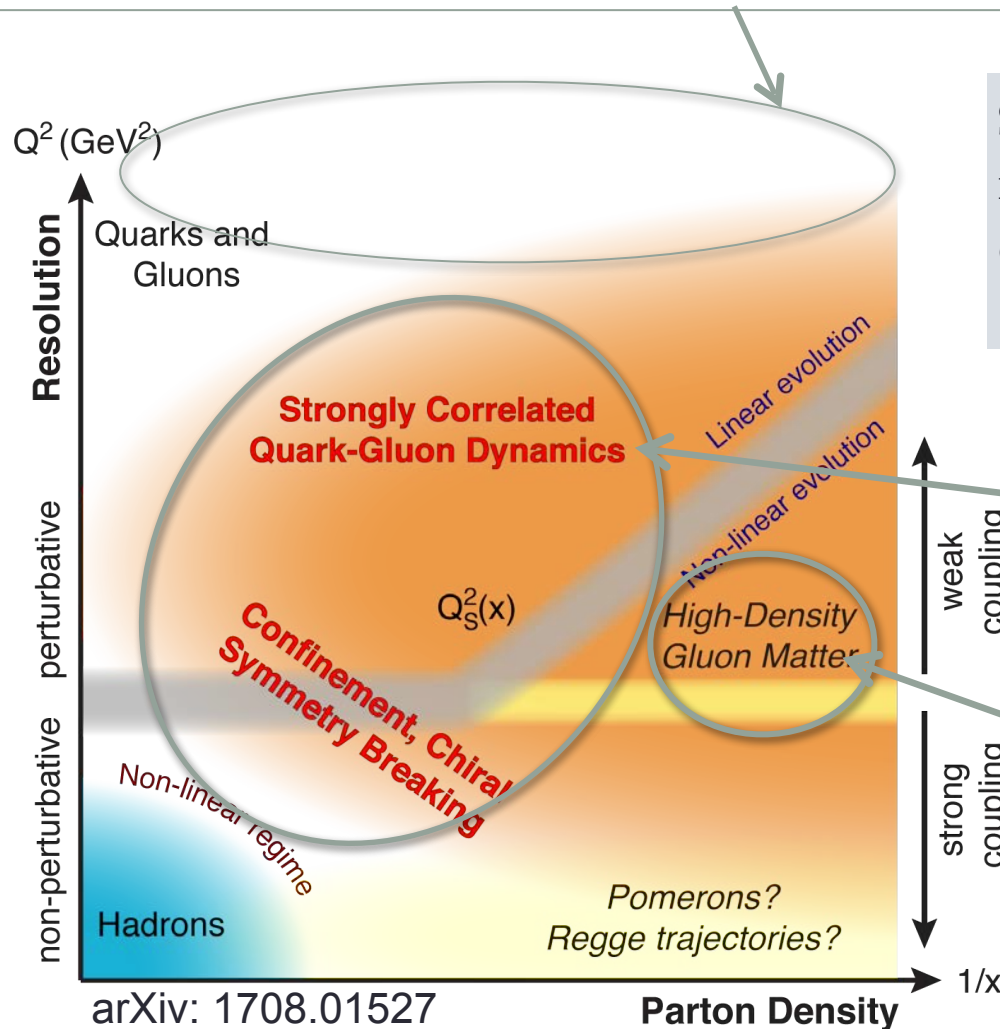


How can technologies developed for basic nuclear physics research be adapted to address society's needs?



QCD Landscape to be explored by EIC

QCD at high resolution (Q^2) —weakly correlated quarks and gluons are well-described



Strong QCD dynamics creates many-body correlations between quarks and gluons
 → hadron structure emerges

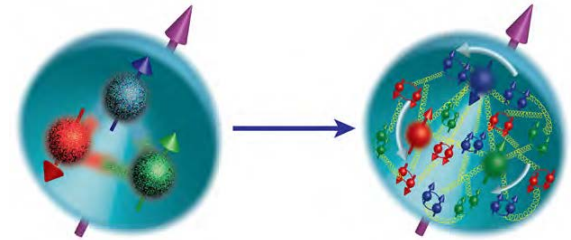
EIC will systematically explore correlations in this region.

An exciting opportunity:
 Observation by EIC of a new regime in QCD of weakly coupled high density matter

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?

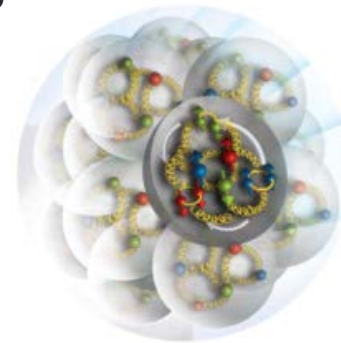
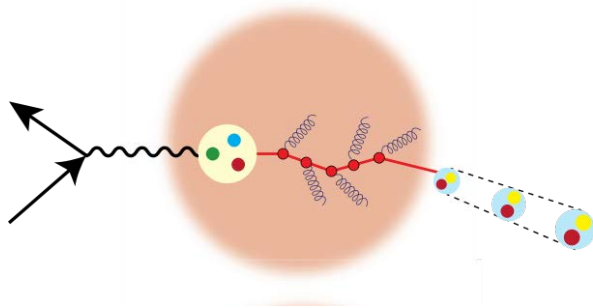
How do the **nucleon properties emerge** from them and their interactions?



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**?



gluon
emission

?

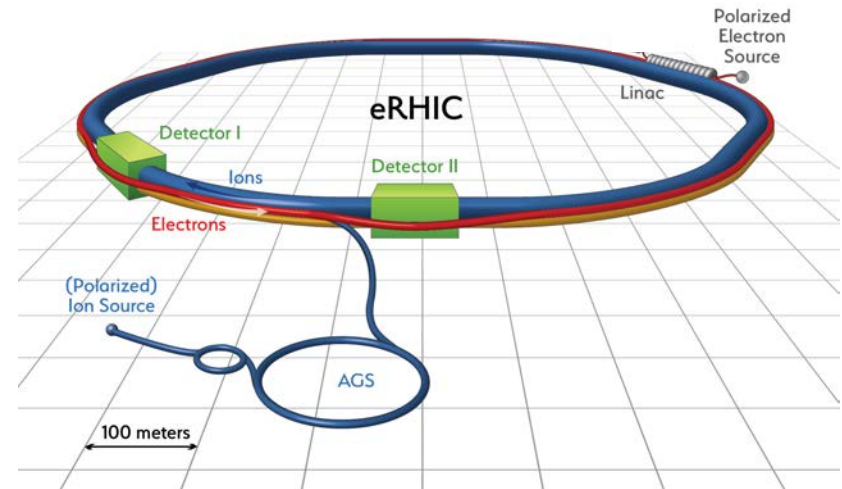
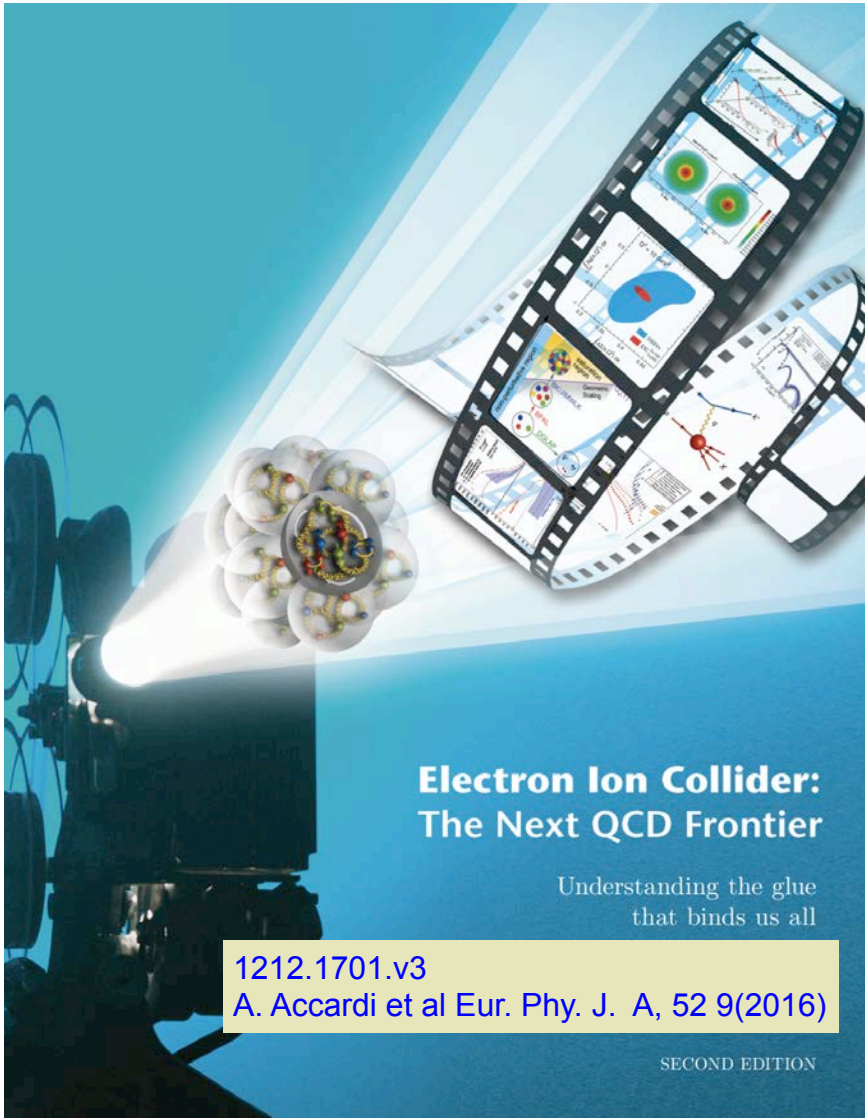
gluon
recombination

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

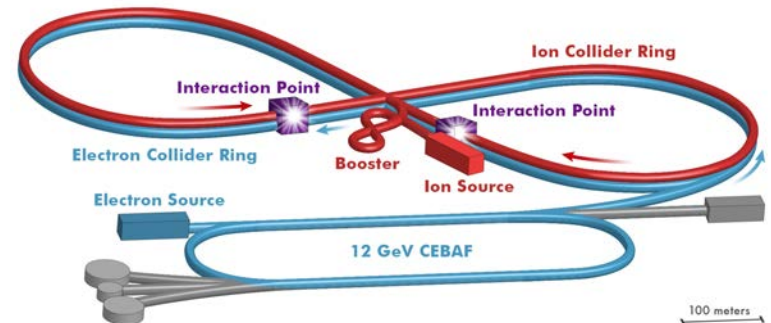
What happens to the **gluon density in nuclei**? Does it **saturate at high energy**, giving rise to a **gluonic matter with universal properties** in all nuclei, even the proton?

The Electron Ion Collider

Two options of realization!

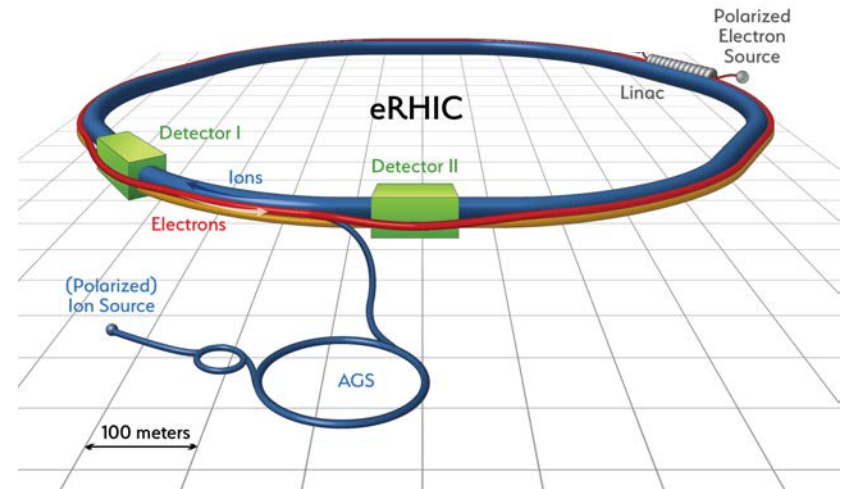
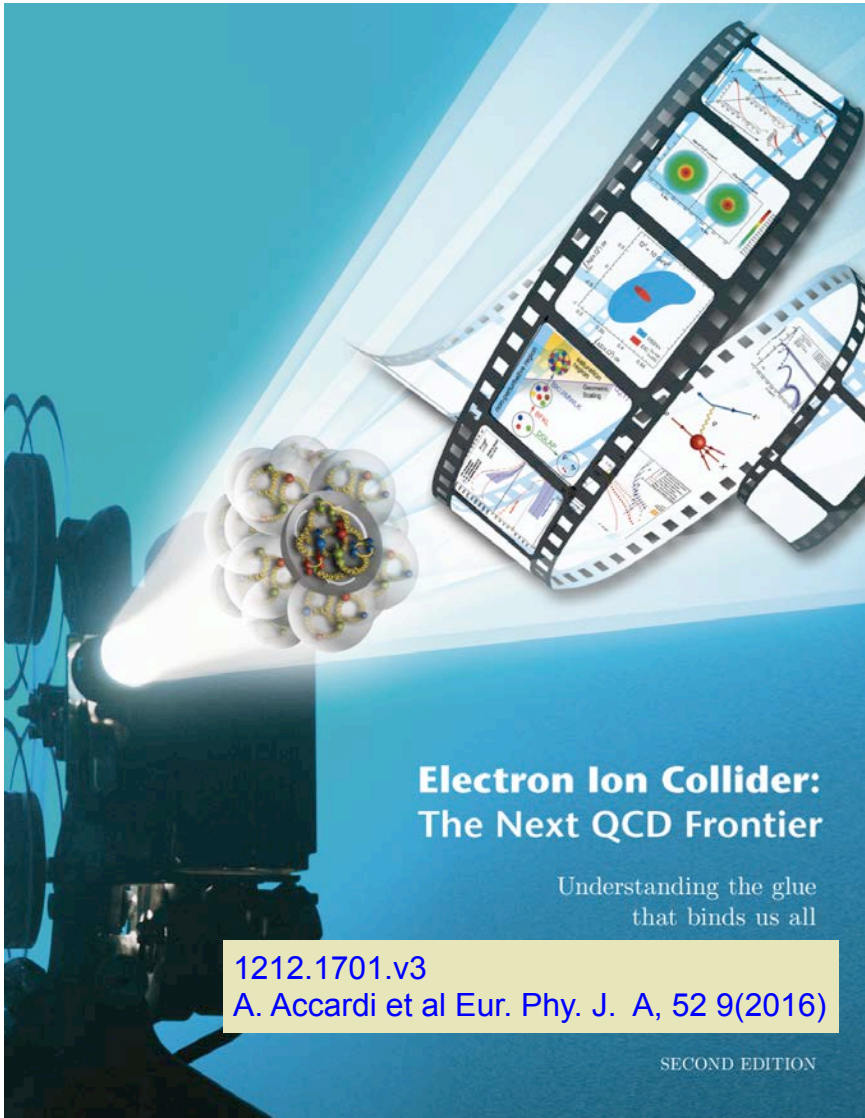


Not to scale

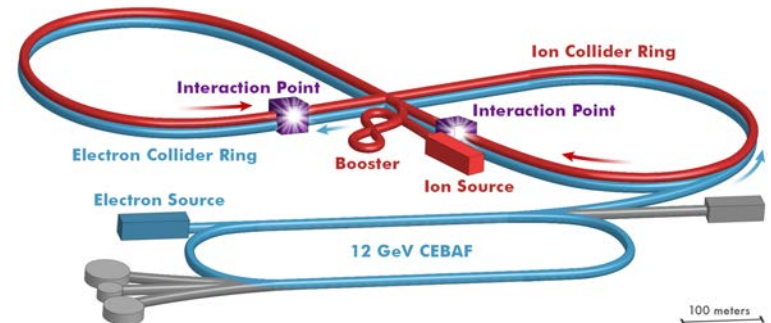


The Electron Ion Collider

Two options of realization!



Not to scale



The Electron Ion Collider

Two options of realization!

For e-N collisions at the EIC:

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

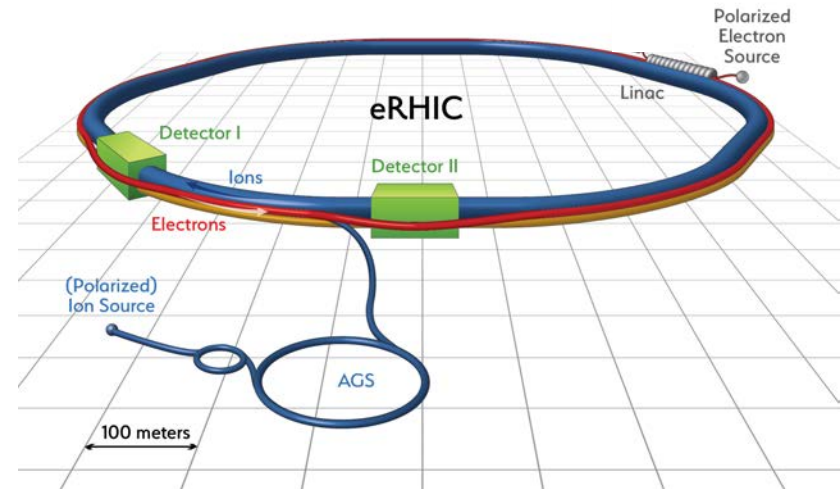
For e-A collisions at the EIC:

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

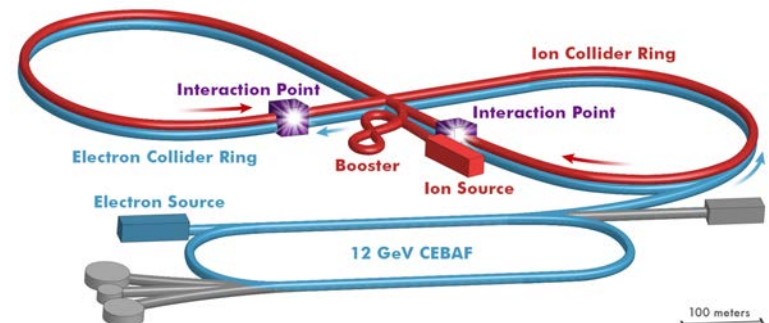
World's first

Polarized electron-proton/light ion
and electron-Nucleus collider

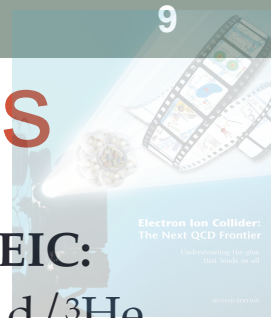
Both designs use DOE's significant
investments in infrastructure



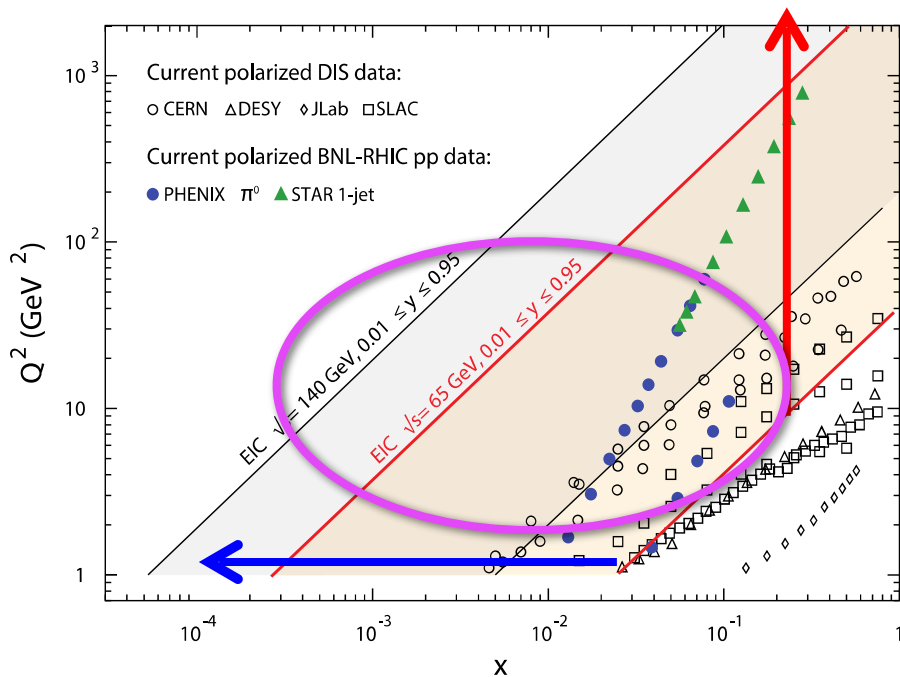
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EIC: Kinematic reach & properties



Electron Ion Collider
The Next QCD Frontier

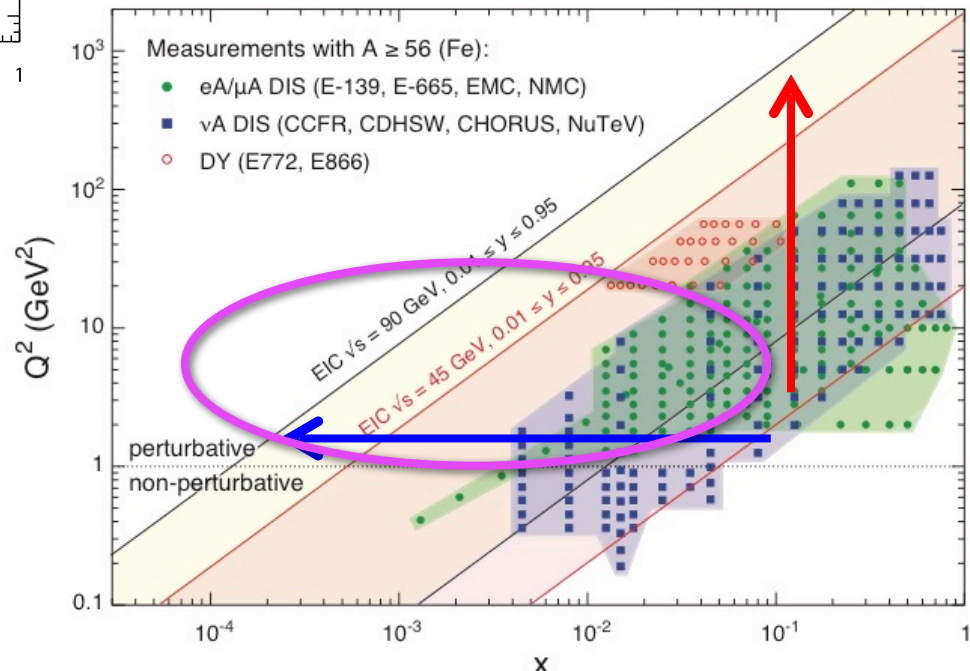


For e-N collisions at the EIC:

- ✓ Polarized beams: e, p, d/ ^3He
- ✓ Variable center of mass energy
- ✓ Wide Q^2 range → evolution
- ✓ Wide x range → spanning valence to low-x physics

For e-A collisions at the EIC:

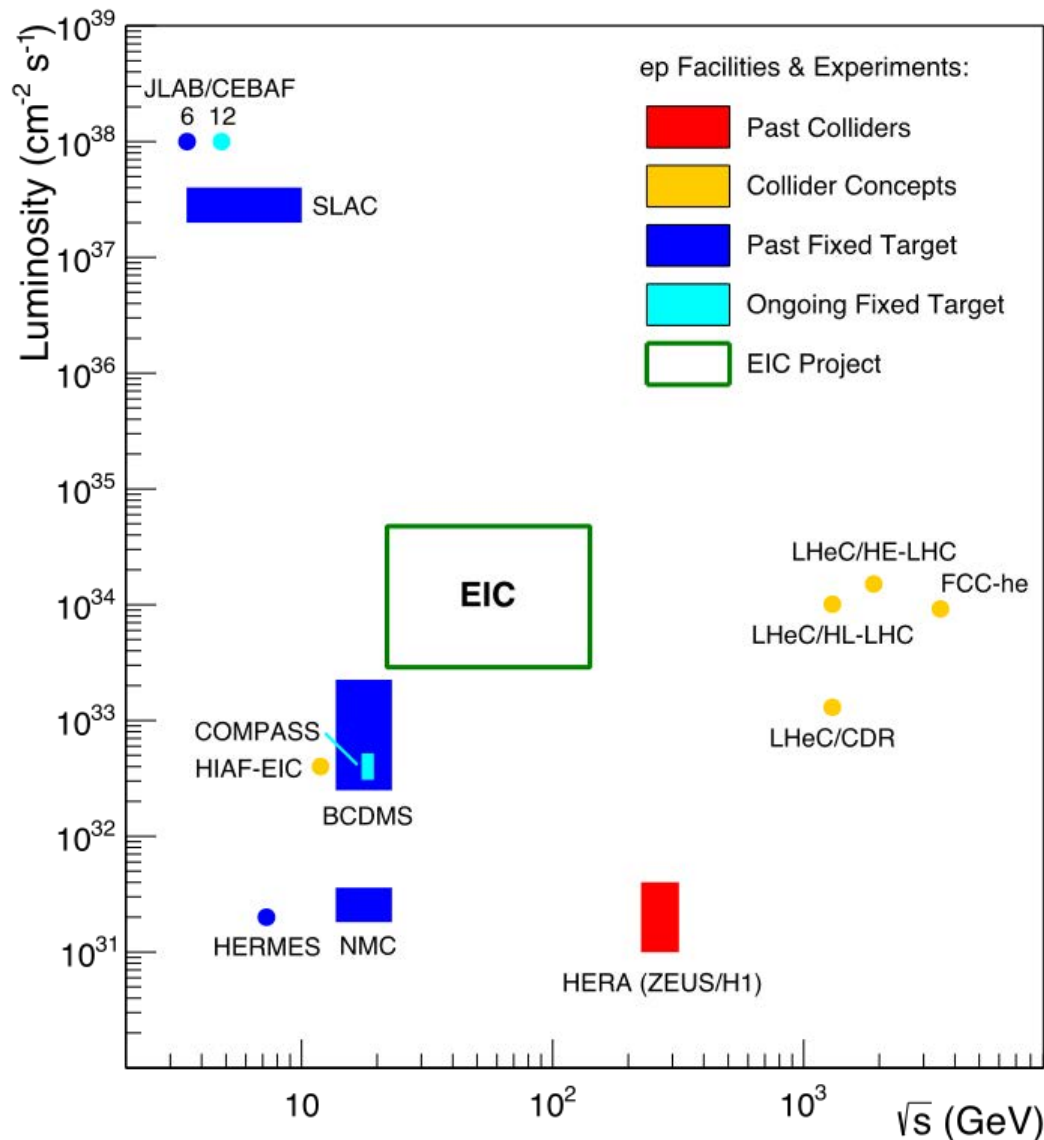
- ✓ Wide range in nuclei
- ✓ Lum. per nucleon same as e-p
- ✓ Variable center of mass energy
- ✓ Wide x range (evolution)
- ✓ Wide x region (reach high gluon densities)



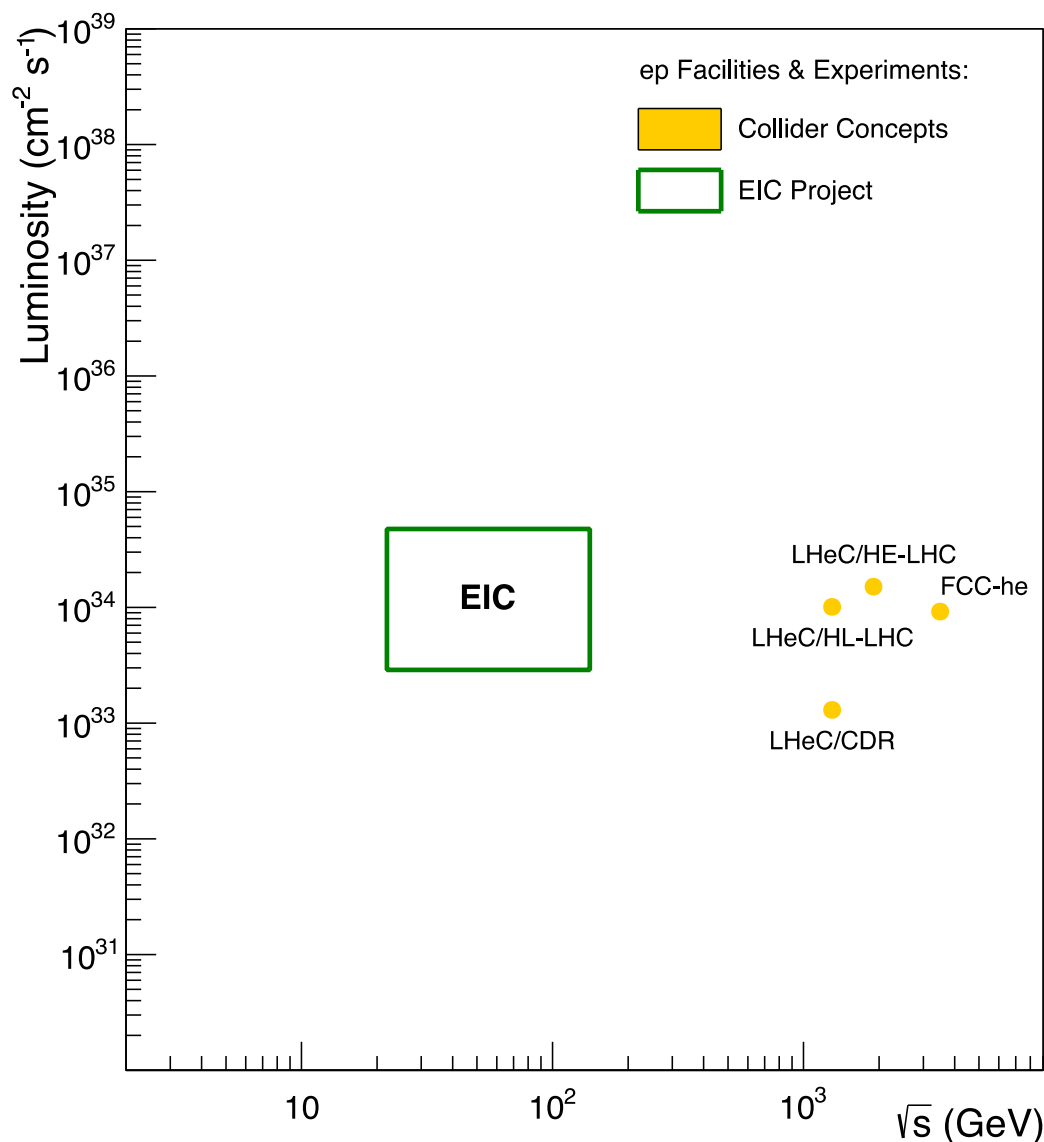
Uniqueness of EIC among all DIS Facilities

All DIS facilities in the world.

However,
if we ask for:



Uniqueness of EIC among all DIS Facilities

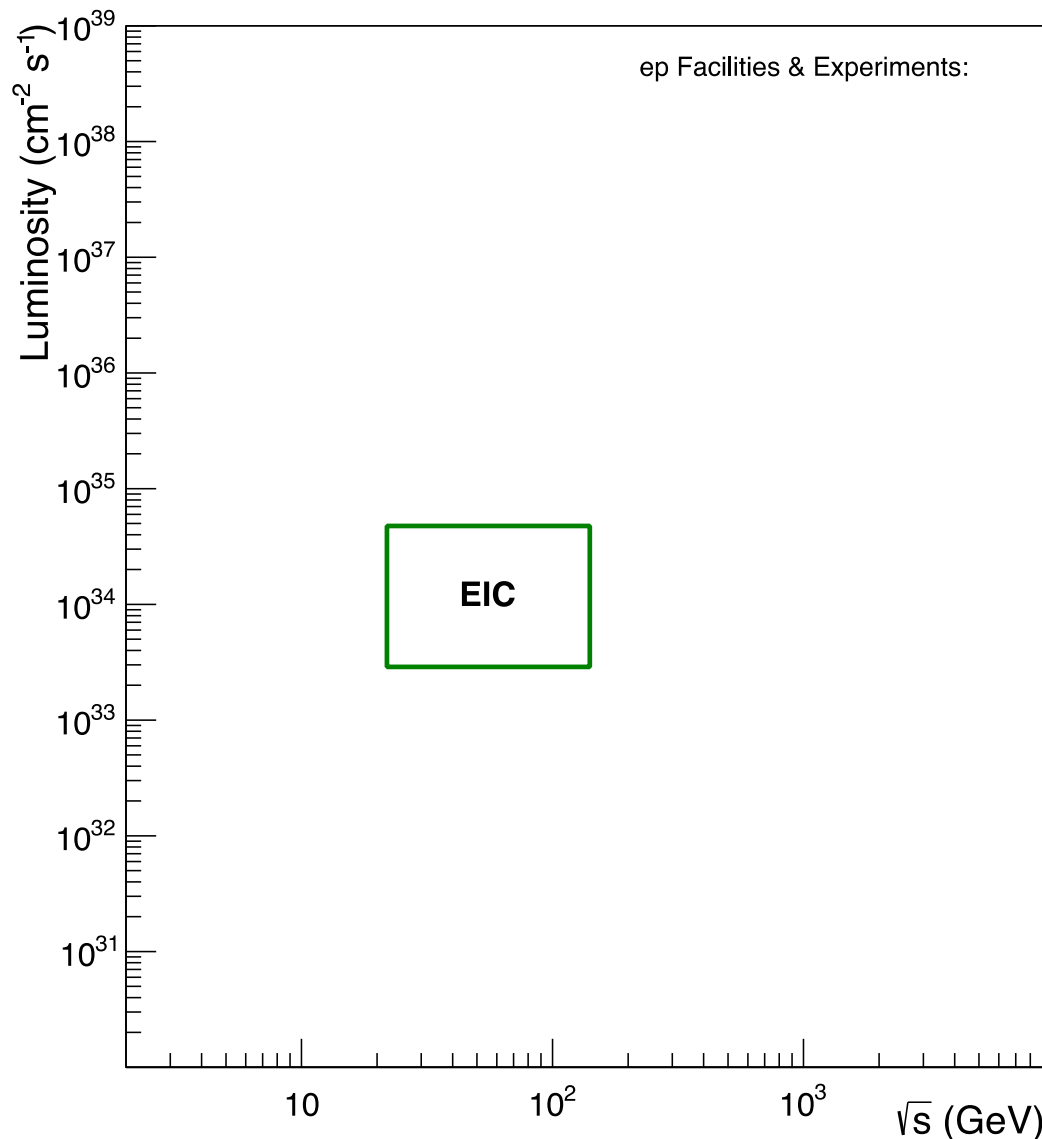


All DIS facilities in the world.

However,
if we ask for:

- high luminosity & wide reach in \sqrt{s}

Uniqueness of EIC among all DIS Facilities



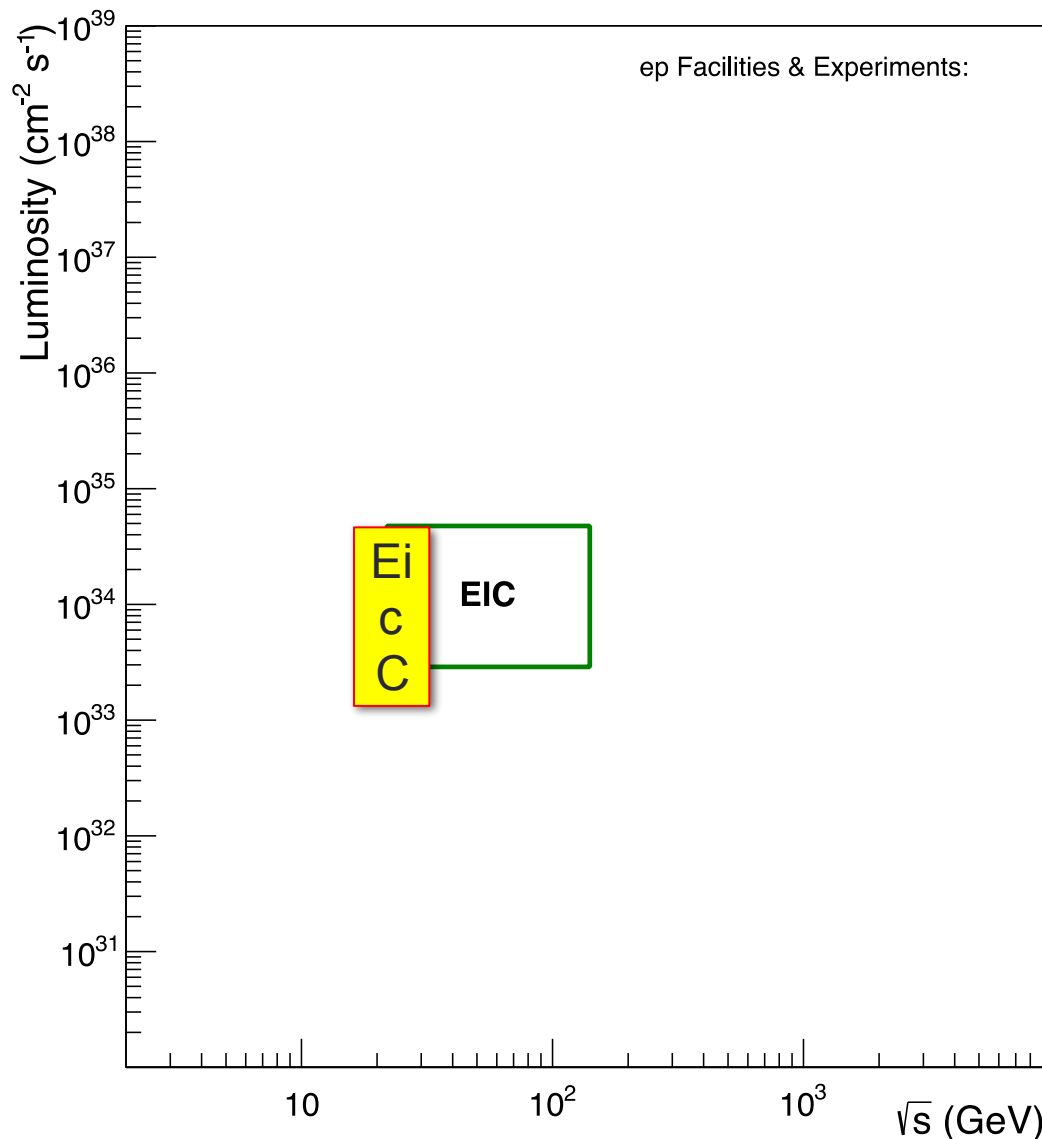
All DIS facilities in the world.

However,
if we ask for:

- high luminosity & wide reach in \sqrt{s}
- polarized lepton & hadron beams
- nuclear beams

EIC stands out as unique facility ...

Uniqueness of EIC among all DIS Facilities



All DIS facilities in the world.

However,
if we ask for:

- high luminosity & wide reach in \sqrt{s}
- polarized lepton & hadron beams
- nuclear beams

EIC stands out as unique facility ...

Proton: A Laboratory For QCD

Semi-Inclusive DIS → Transverse Momentum Distributions

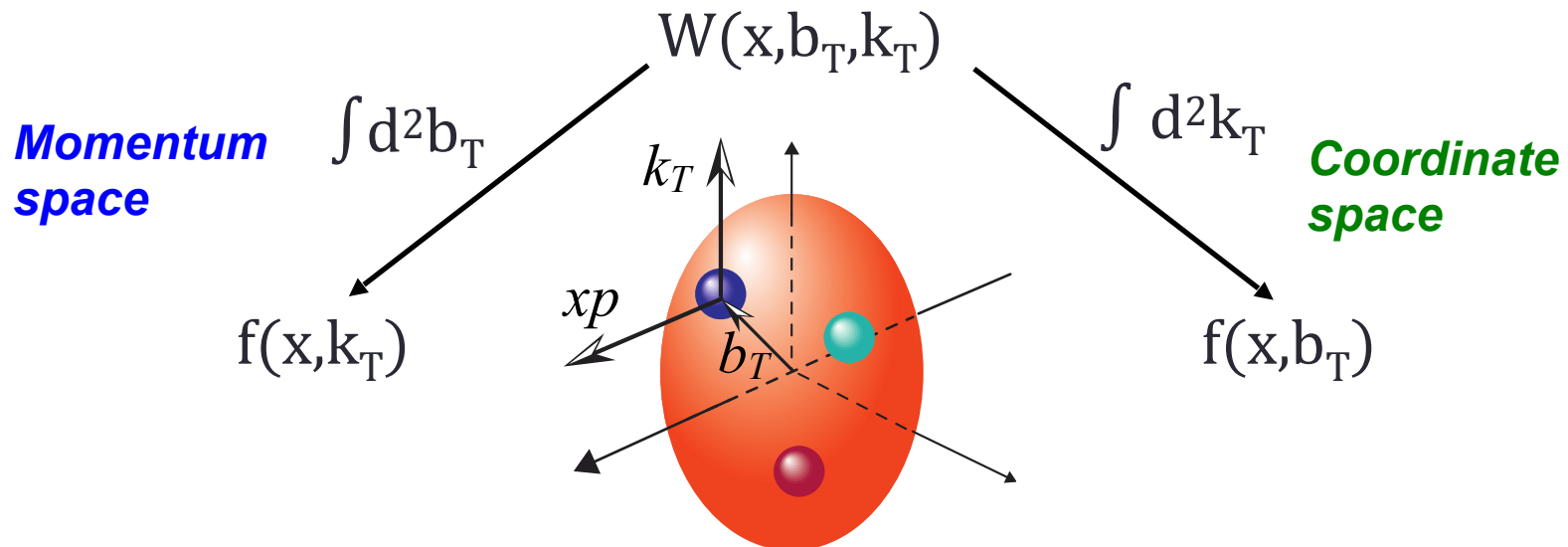
Deeply Virtual Compton Scattering & Deeply Virtual Vector Meson production → Generalized Parton Distributions → Spatial distribution of quarks and gluons

Precision determination of nucleon spin sum rule

3-Dimensional Imaging Quarks and Gluons

Wigner functions $W(x, b_T, k_T)$

offer unprecedented insight into confinement and chiral symmetry breaking.



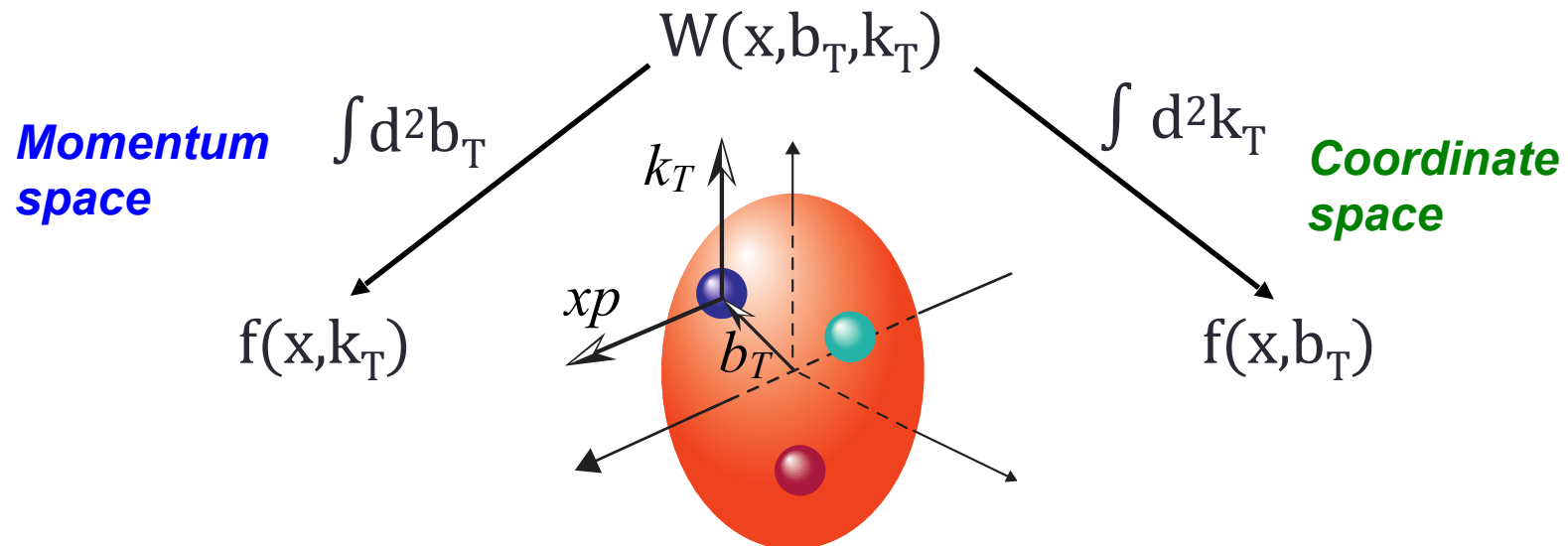
Spin-dependent 3D **momentum space** images from semi-inclusive scattering
 → **TMDs**

Spin-dependent 2D **coordinate space** (transverse) + 1D (longitudinal momentum) images from exclusive scattering
 → **GPDs**

3-Dimensional Imaging Quarks and Gluons

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Spin-dependent 3D **momentum space** images from semi-inclusive scattering
 → **TMDs**

Spin-dependent 2D **coordinate space** (transverse) + 1D (longitudinal momentum) images from exclusive scattering
 → **GPDs**

Position and momentum → Orbital motion of quarks and gluons

2+1 D partonic image of the proton with the EIC

Spin-dependent 3D **momentum space**
images from semi-inclusive scattering

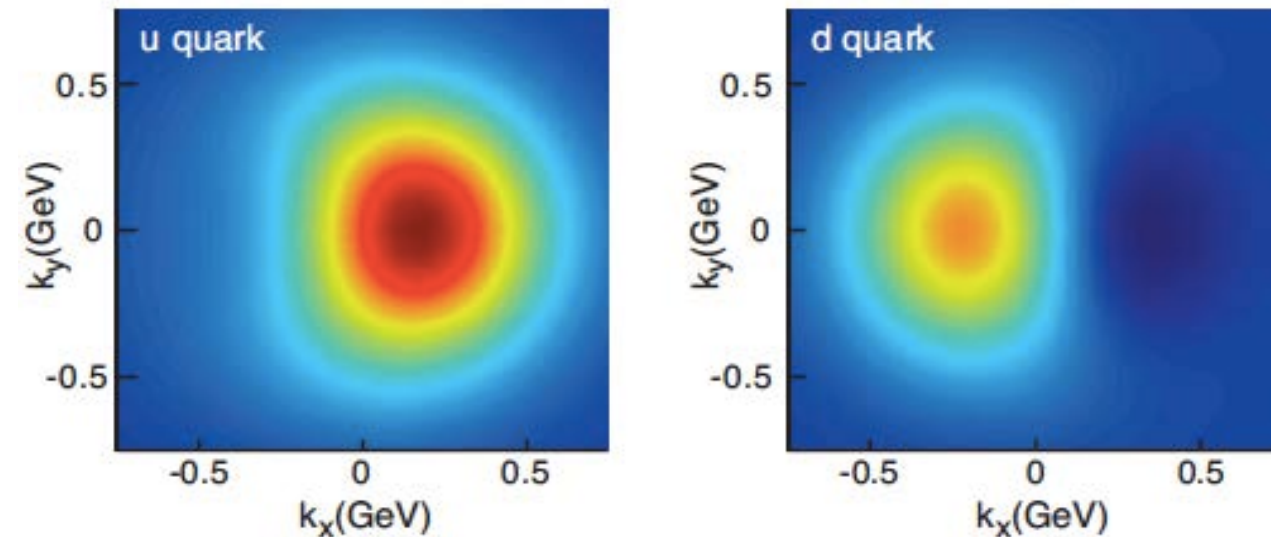
Spin-dependent 2D **coordinate space**
(transverse) + 1D (longitudinal momentum)
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Transverse **Momentum** Distributions

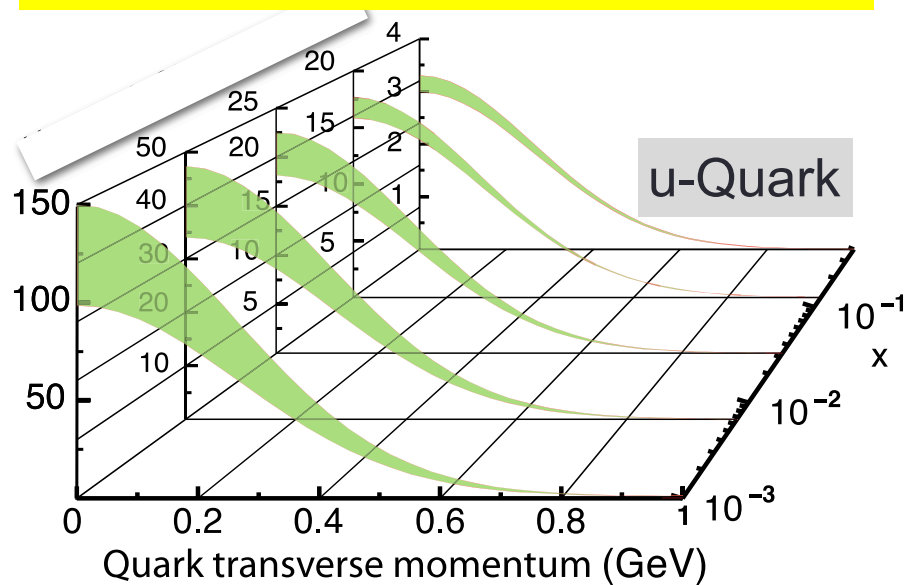


2+1 D partonic image of the proton with the EIC

Spin-dependent 3D **momentum space**
images from semi-inclusive scattering

Spin-dependent 2D **coordinate space**
(transverse) + 1D (longitudinal momentum)
images from exclusive scattering

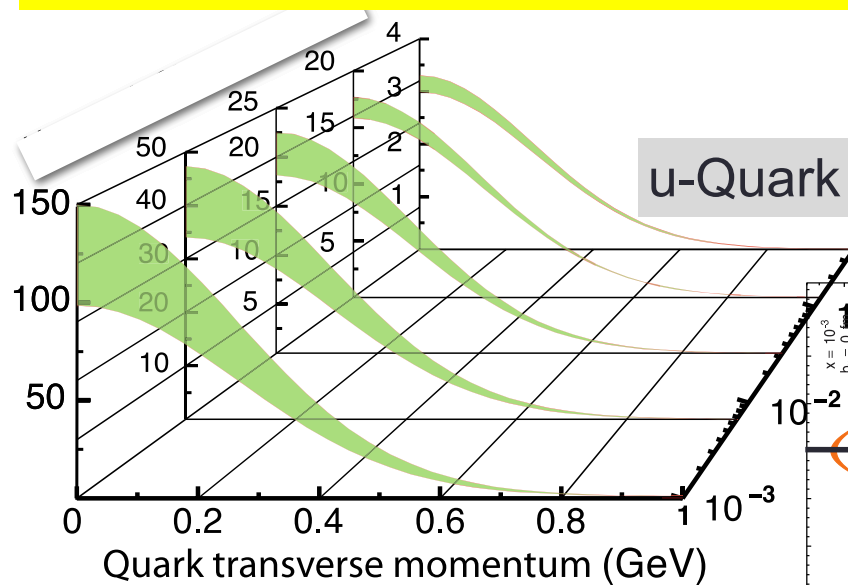
Transverse **Momentum** Distributions



2+1 D partonic image of the proton with the EIC

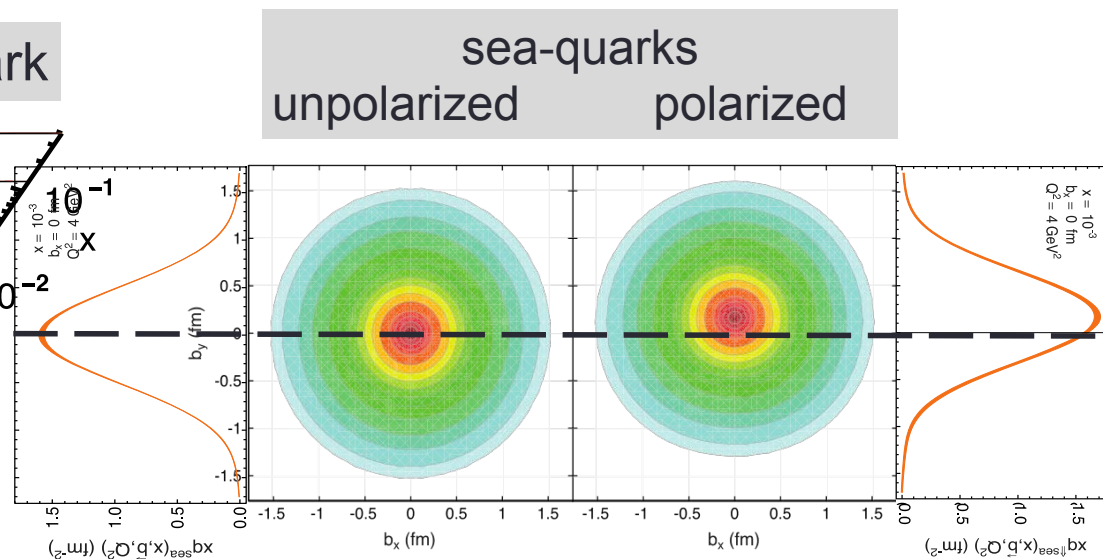
Spin-dependent 3D **momentum space**
images from semi-inclusive scattering

Transverse Momentum Distributions



Spin-dependent 2D **coordinate space**
(transverse) + 1D (longitudinal momentum)
images from exclusive scattering

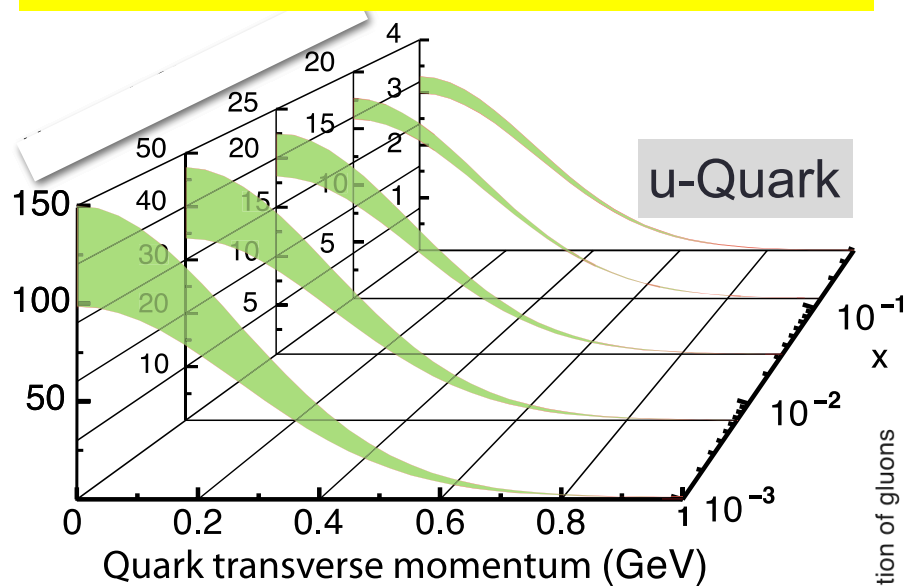
Transverse Position Distributions



2+1 D partonic image of the proton with the EIC

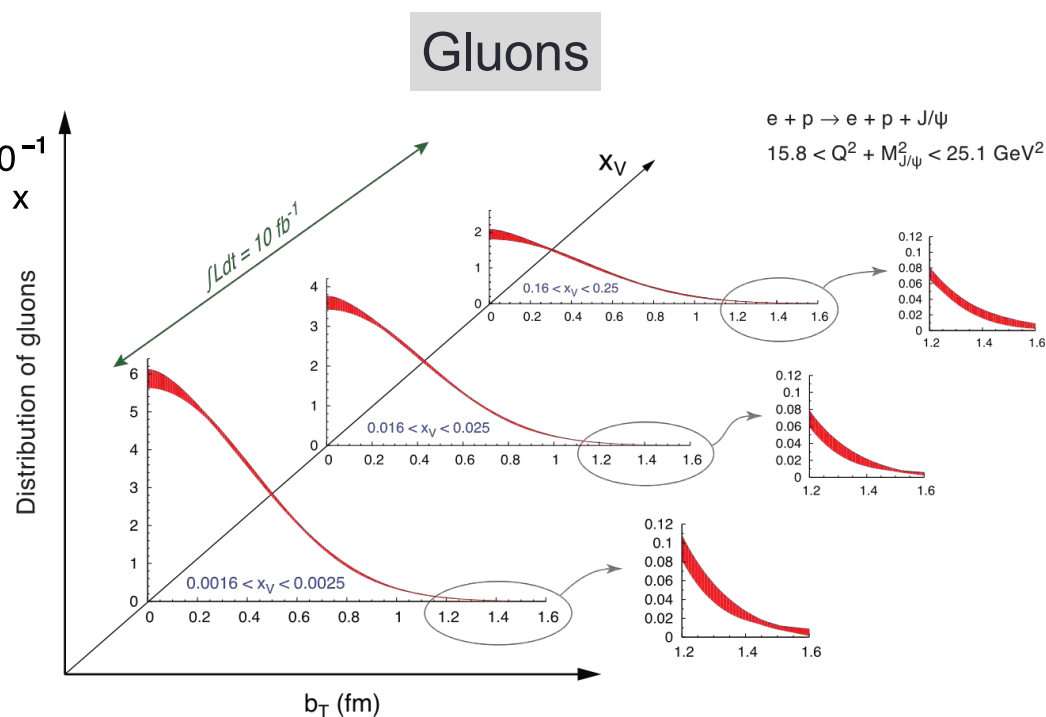
Spin-dependent 3D **momentum space** images from semi-inclusive scattering

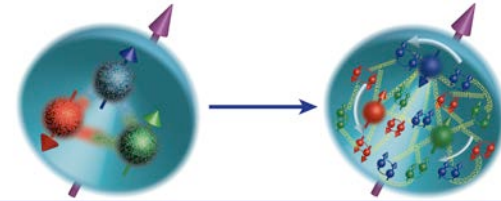
Transverse Momentum Distributions



Spin-dependent 2D **coordinate space** (transverse) + 1D (longitudinal momentum) images from exclusive scattering

Transverse Position Distributions



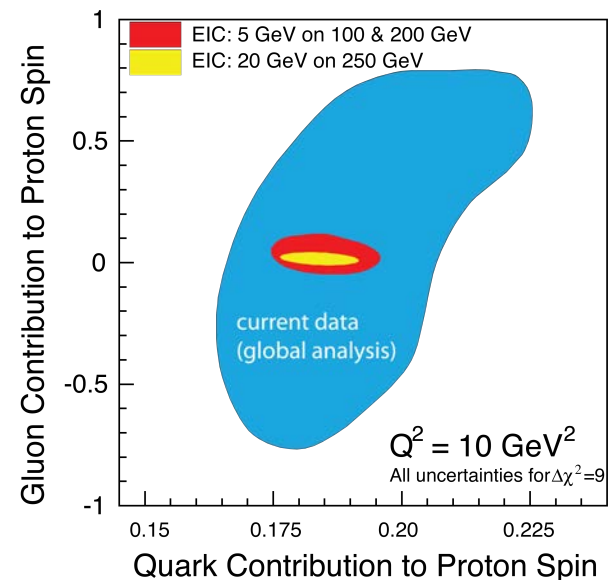
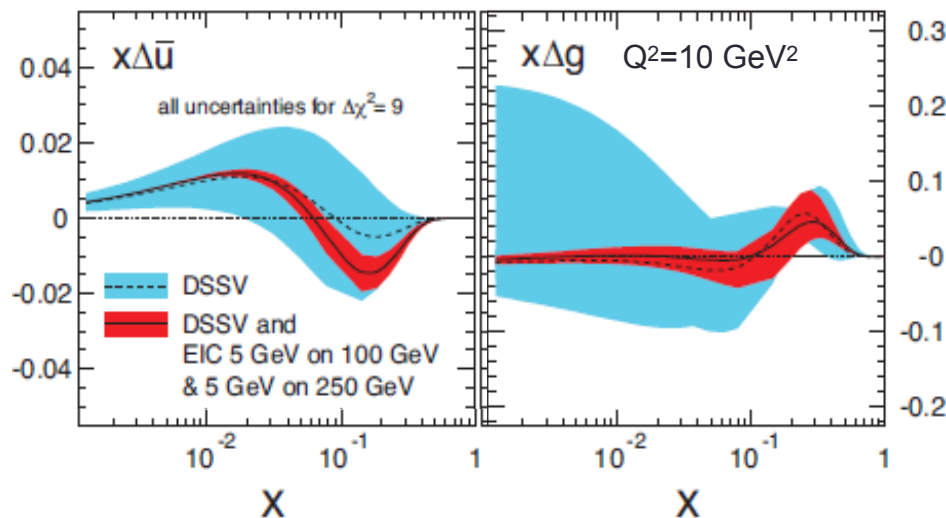


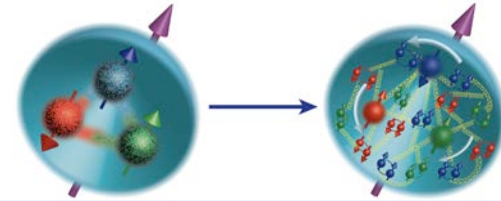
Understanding Nucleon Spin

“Helicity sum rule”

$$\frac{1}{2}\hbar = \underbrace{\frac{1}{2}\Delta\Sigma}_{\text{quark contribution}} + \underbrace{\Delta G}_{\text{gluon contribution}} + \underbrace{\sum_q L_q^z + L_g^z}_{\text{orbital angular momentum}}$$

EIC projected measurements:
precise determination of polarized PDFs of quark sea and gluons → precision ΔG and $\Delta\Sigma$
→ A clear idea of the magnitude of $\Sigma L_q + L_g$



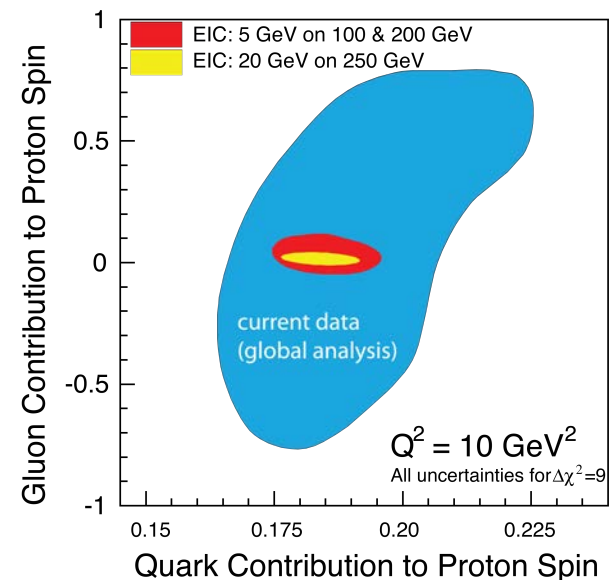
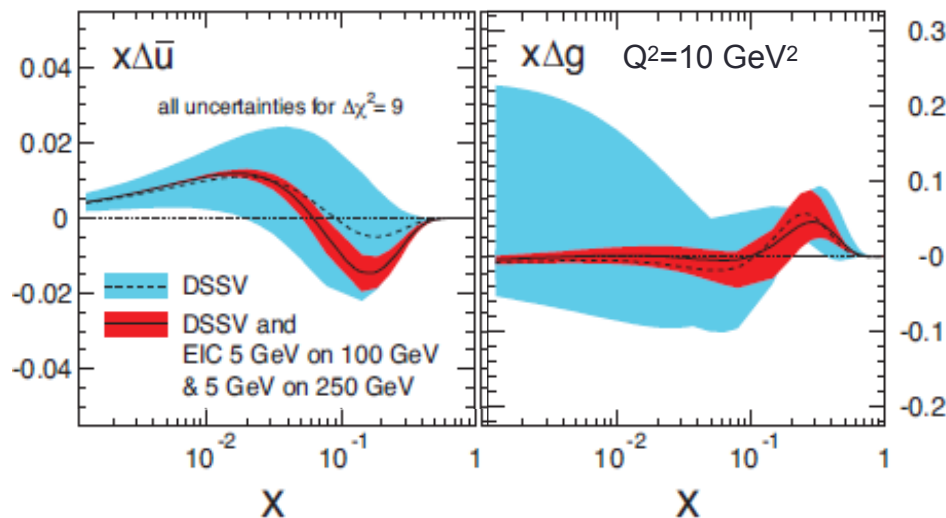


Understanding Nucleon Spin

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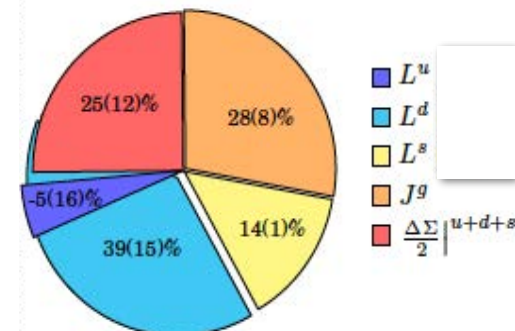
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Spin and Lattice: Recent Activities

- Gluon's spin contribution on Lattice: $S_G = 0.5(0.1)$
Yi-Bo Yang et al. PRL **118**, 102001 (2017)
- J_q calculated on Lattice QCD:
 χ QCD Collaboration, PRD91, 014505, 2015



Nucleus as a laboratory for QCD

Distributions

Energy loss and interactions

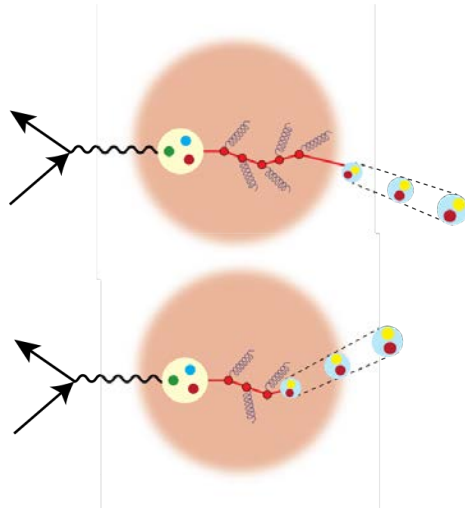
High parton density matter?

Emergence of Hadrons from Partons

Nucleus as a Femtometer sized filter

Unprecedented ν , the virtual photon energy range @ EIC : precision & control

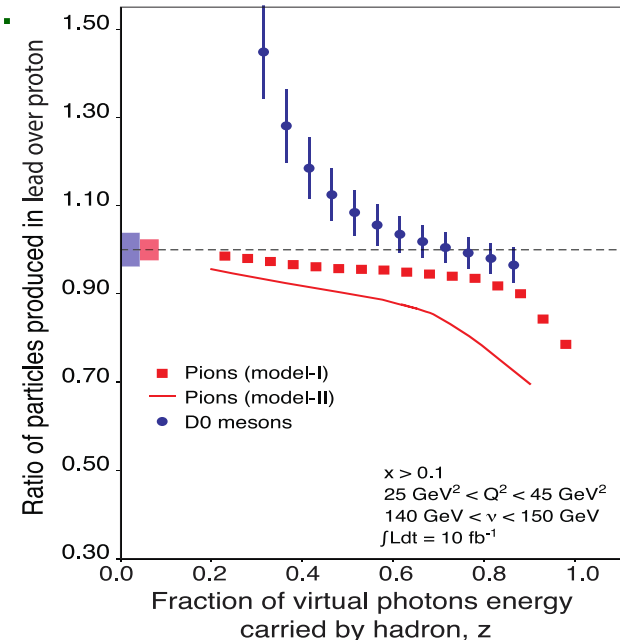
$$\nu = \frac{Q^2}{2mx}$$



Control of ν by selecting kinematics;
Also under control the nuclear size.

(colored) Quark passing through cold QCD matter emerges as color-neutral hadron →
Clues to color-confinement?

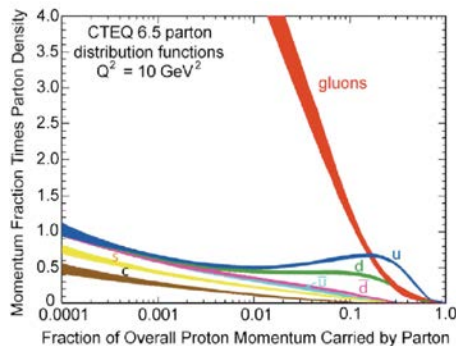
Energy loss by light vs. heavy quarks:



Identify π vs. D^0 (**charm**) mesons in e-A collisions: Understand energy loss of light vs. heavy quarks traversing the cold nuclear matter:

Connect to energy loss in Hot QCD

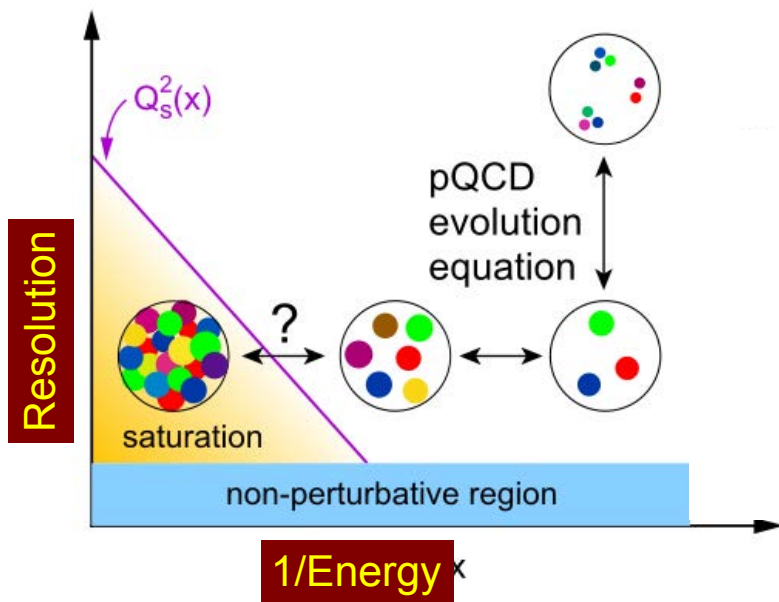
Need the collider energy of EIC and its control on parton kinematics



What do we learn from low-x studies?

What tames the low-x rise?

- New evolution eqn.s @ low x & moderate Q^2
- Saturation Scale $Q_s(x)$ where gluon emission and recombination comparable



gluon
emission

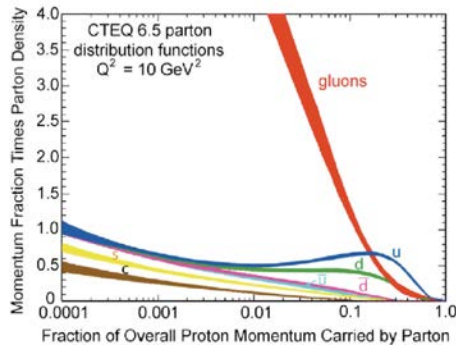


=

gluon
recombination



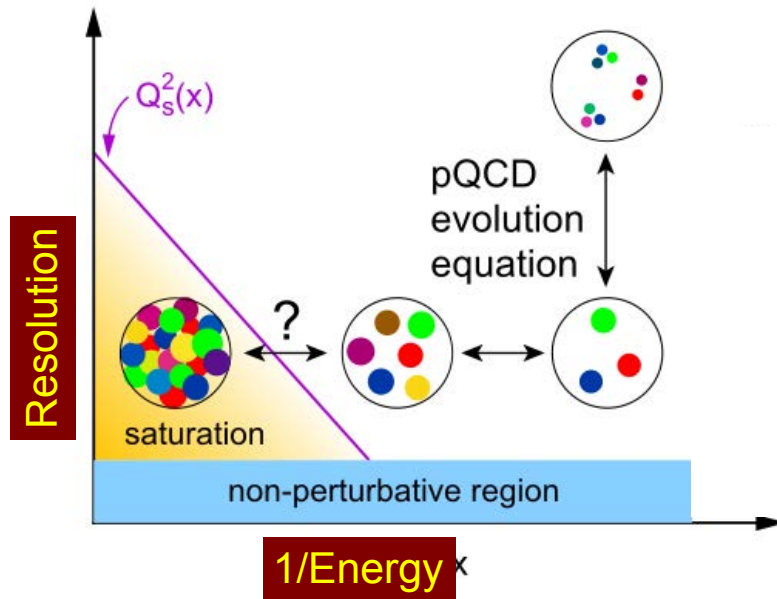
At Q_s



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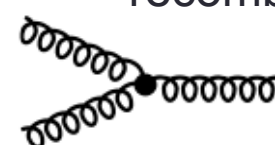


gluon
emission



=

gluon
recombination



At Q_s

First observation of gluon recombination effects in nuclei:

→ leading to a collective gluonic system!

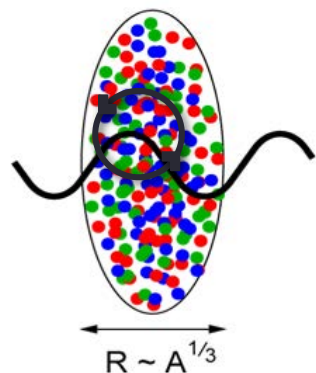
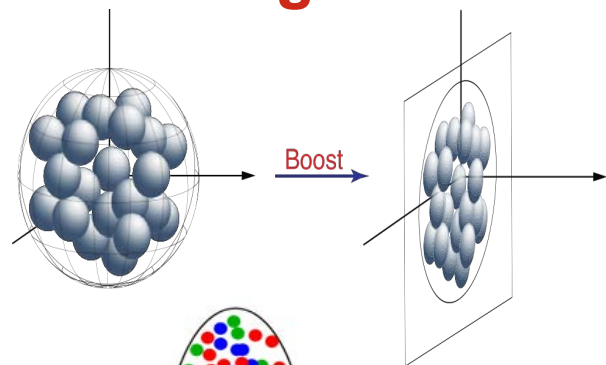
First observation of g-g recombination in different nuclei

Is this a universal property?

Is the Color Glass Condensate the correct effective theory?

How to explore/study this new phase of matter?
 (multi-TeV) e-p collider OR a (multi-10s GeV) e-A collider

Advantage of nucleus →



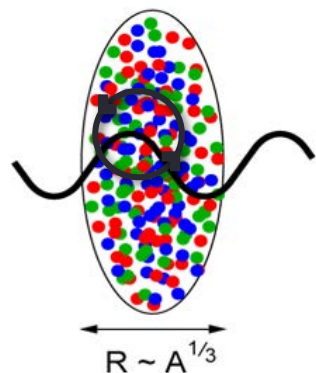
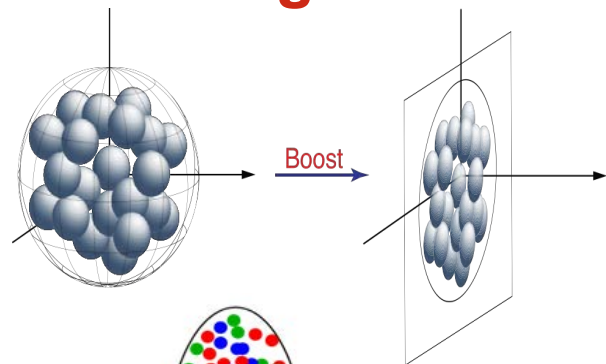
$$(Q_s^A)^2 \approx c Q_0^2 \left[\frac{A}{x} \right]^{1/3}$$

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

How to explore/study this new phase of matter?

(multi-TeV) e-p collider **OR** a (multi-10s GeV) e-A collider

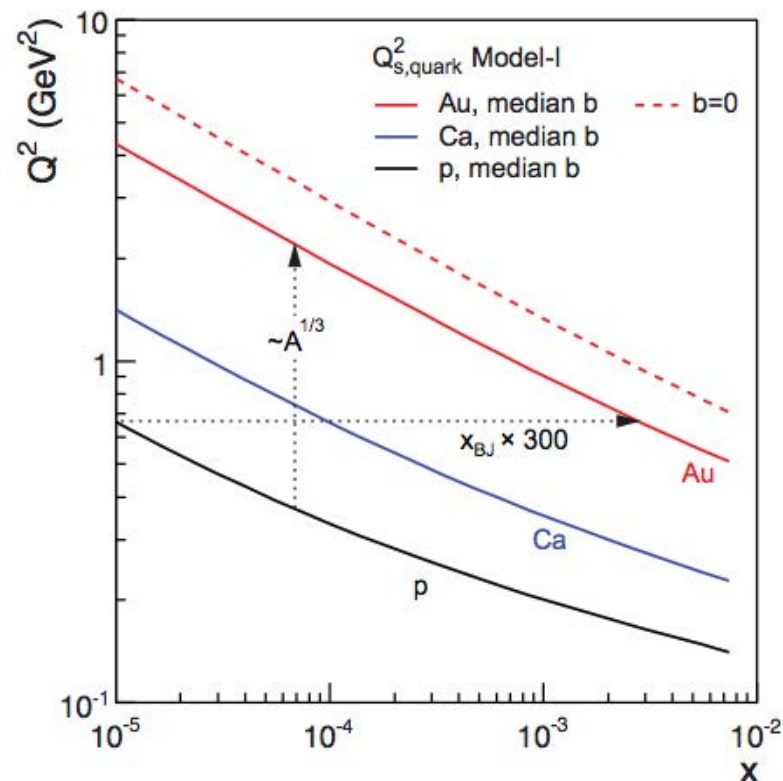
Advantage of nucleus →



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

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

Teaney, Kowalski
Kovchegov et al.

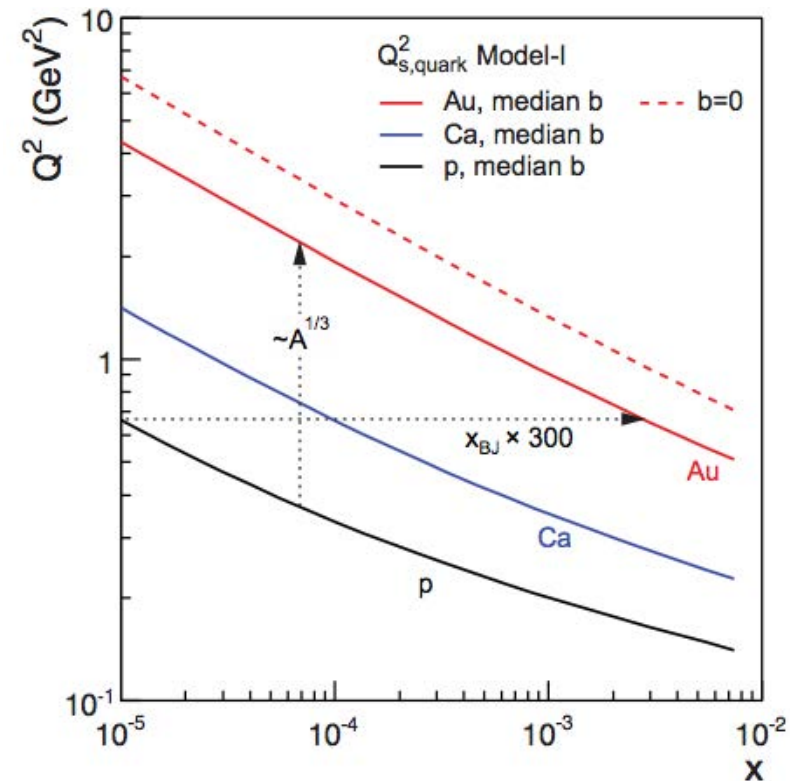
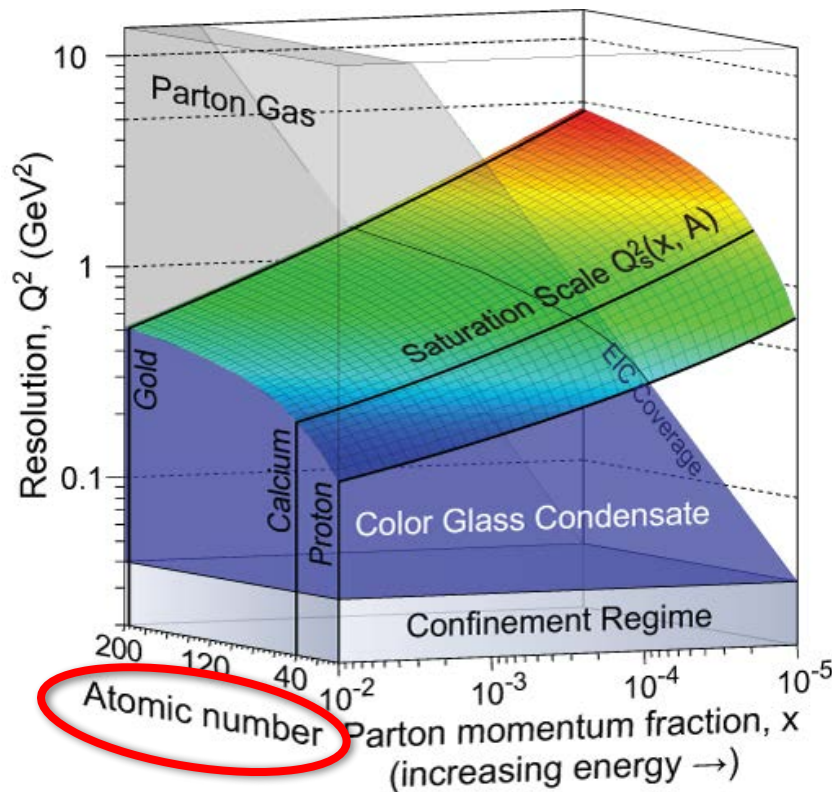


How to explore/study this new phase of matter?

(multi-TeV) e-p collider **OR** a (multi-10s GeV) e-A collider

Advantage of nucleus →

Teaney, Kowalski
Kovchegov et al.

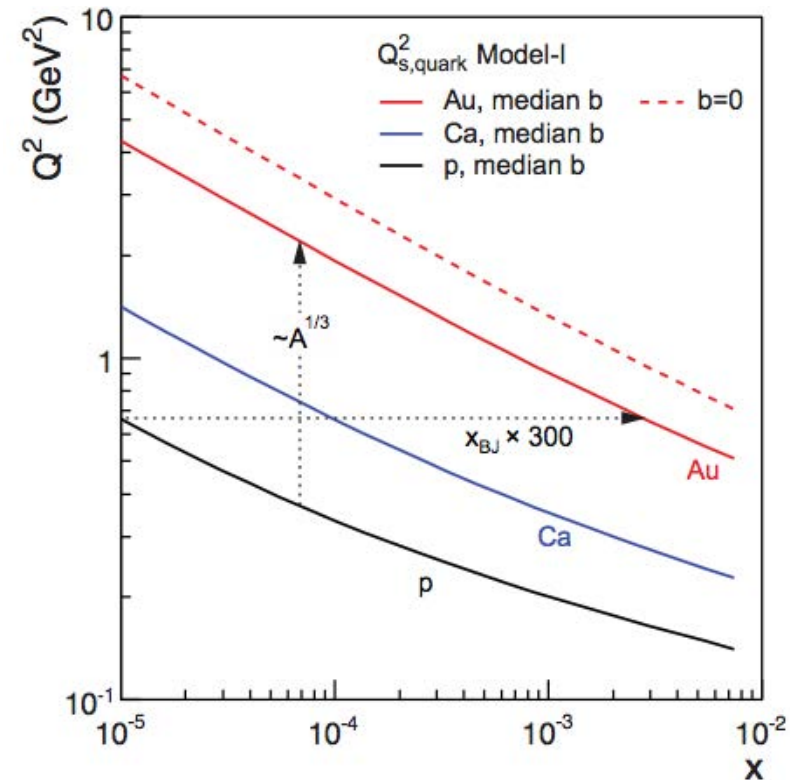
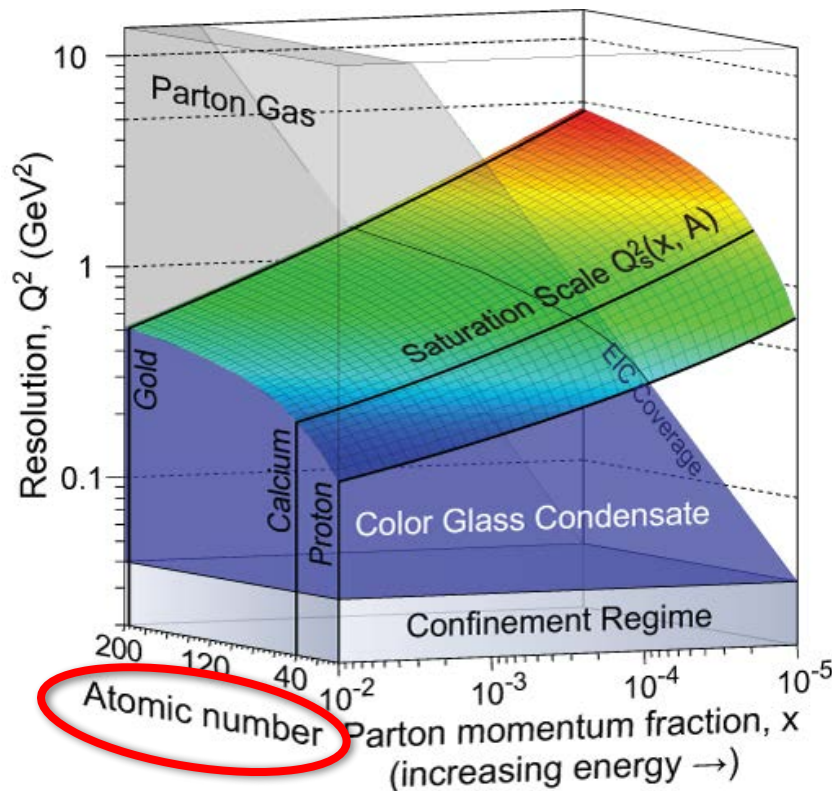


How to explore/study this new phase of matter?

(multi-TeV) e-p collider **OR** a (multi-10s GeV) e-A collider

Advantage of nucleus →

Teaney, Kowalski
Kovchegov et al.



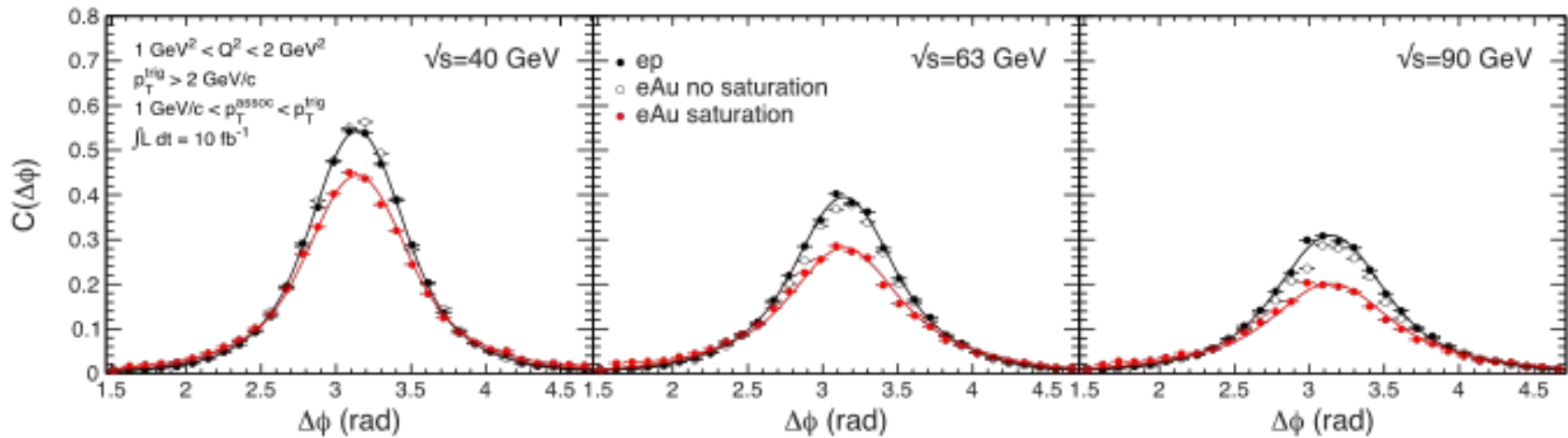
Enhancement of Q_s with A :
Saturation regime reached at significantly lower energy (read: "cost") in nuclei

Exp. Signal for Saturation

Di-hadron Correlations: $e + A \rightarrow e' + h_1 + h_2 + X$



arXiv: 1708.01527

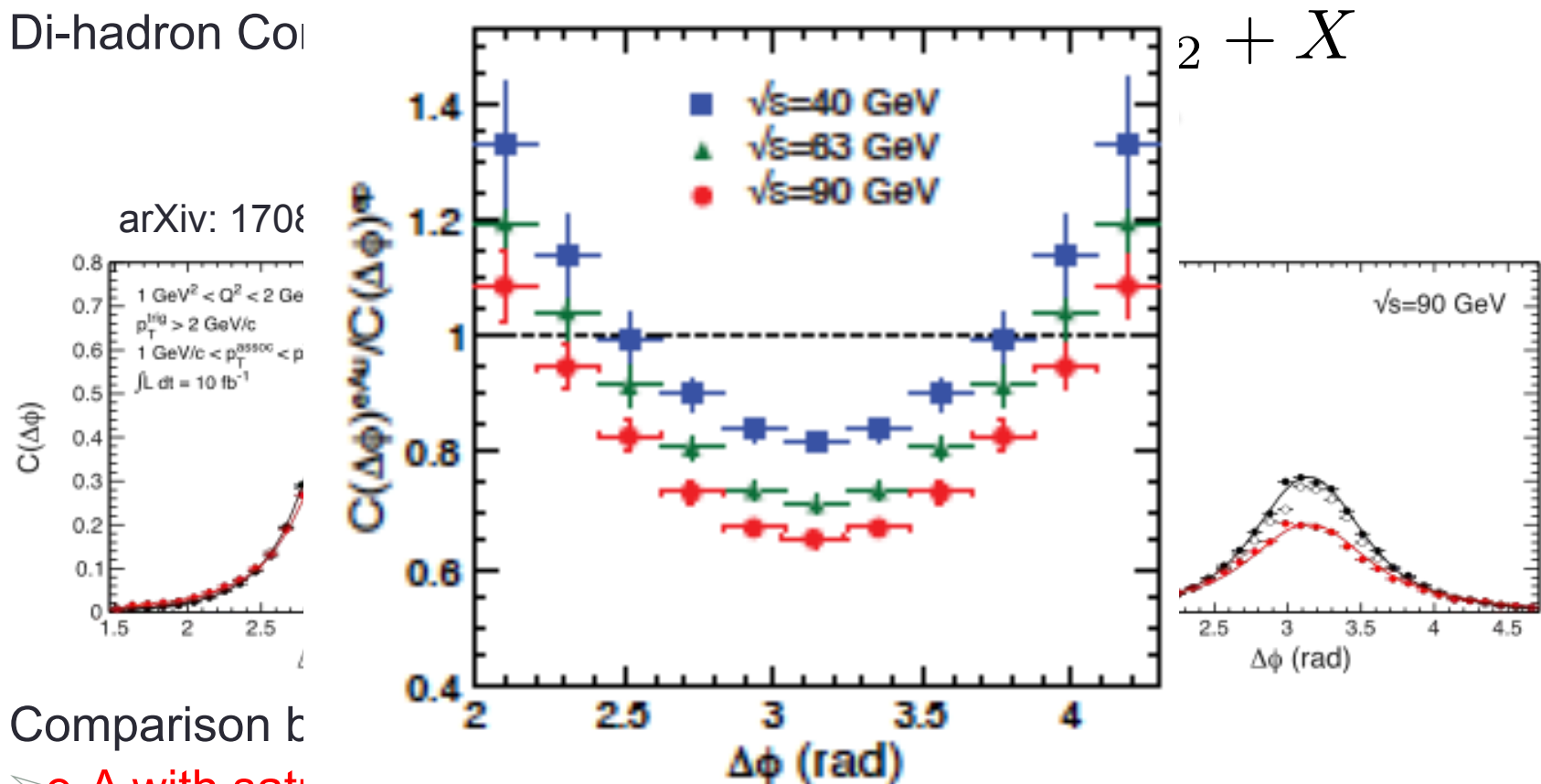


Comparison between

- e-A with saturation (red filled),
- e-p non-saturation (**black full points**), and
- e-A non-Saturation model (black-hollow points)

Exp. Signal for Saturation

Di-hadron Correlation

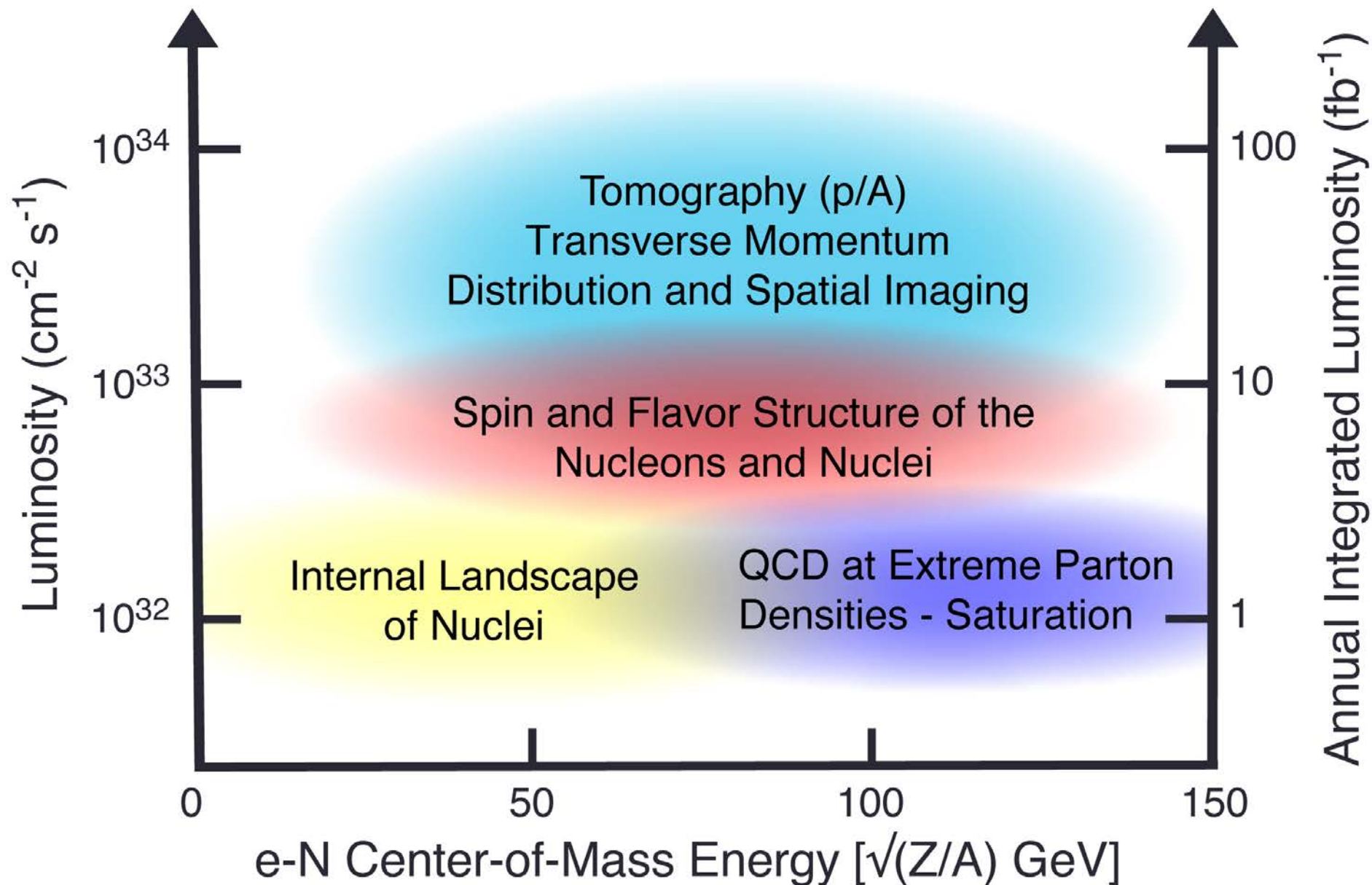


Comparison between

- e-A with saturation (red filled),
- e-p non-saturation (**black full points**), and
- e-A non-Saturation model (black-hollow points)

Summary: EIC Physics:

CM vs. Luminosity vs. Integrated luminosity



Detector Strategy And Design

Detector + IR integrated approach

Detector:

- As much of the 4p acceptance as possible
- Wide pseudo-rapidity coverage
- Low material budget
- High momentum resolution
- Reliable particle ID
- Good $\pi/K/p$ separation over a broad p range
- Spatial vertex resolution to distinguish between primary, secondary vertices

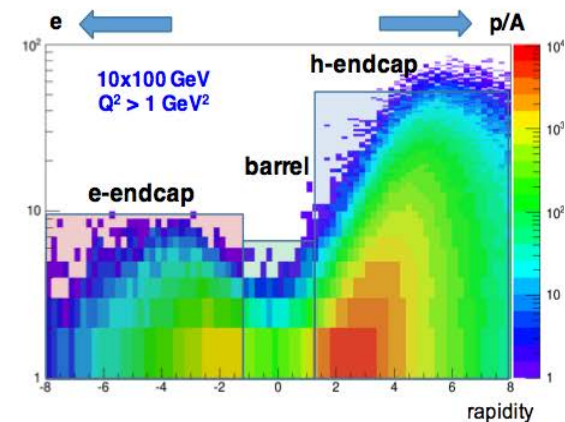
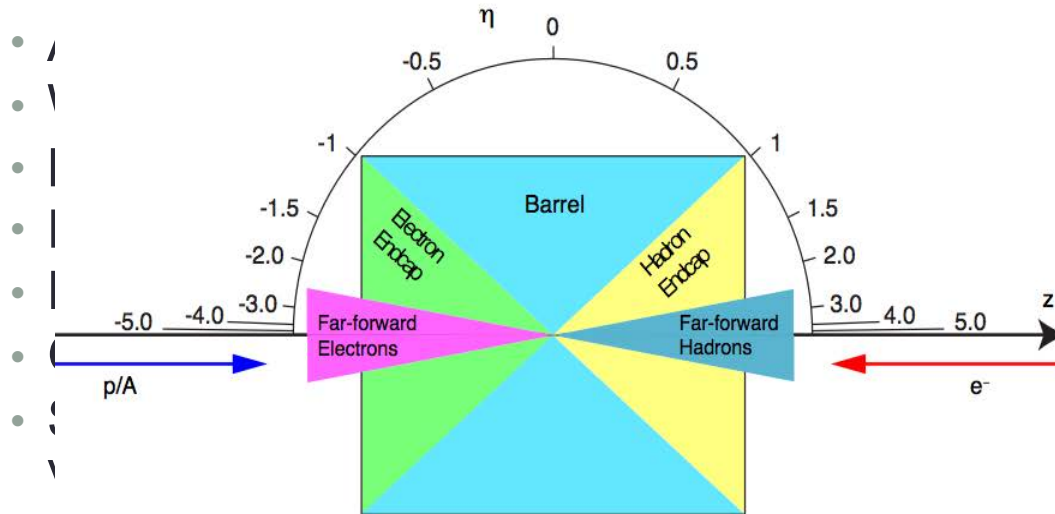
Close to beam-pipe Detectors for

- Recoil protons
- Low- Q^2 electrons
- Neutrons in hadron going direction (ZDCs)

Luminosity and polarization measurement

Detector + IR integrated approach

Detector:



Close to beam-pipe Detectors for

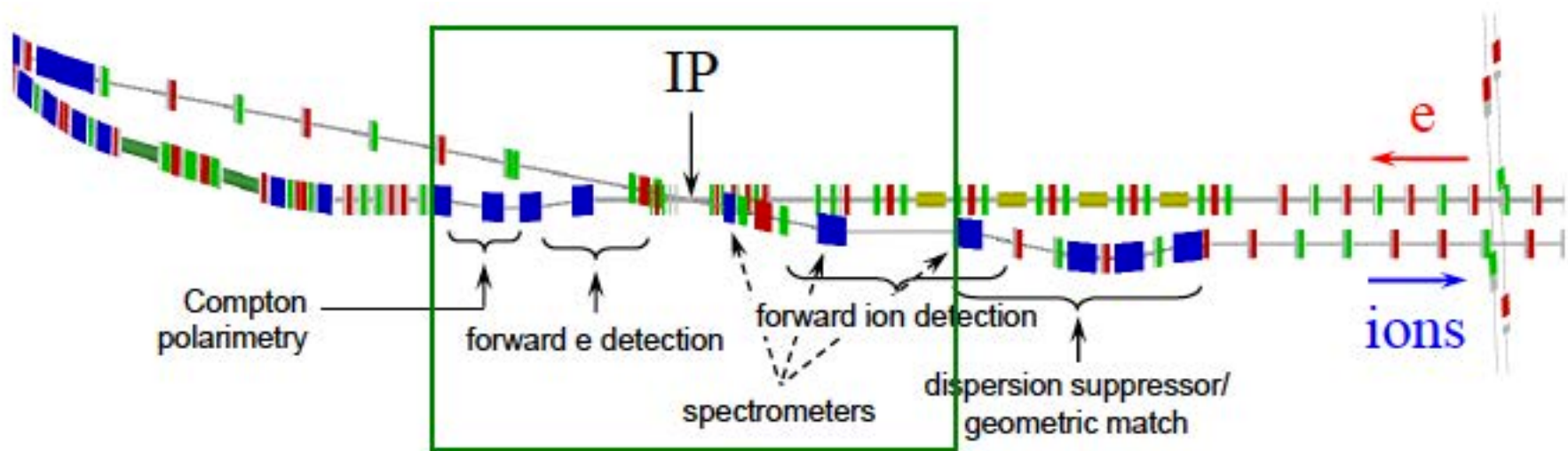
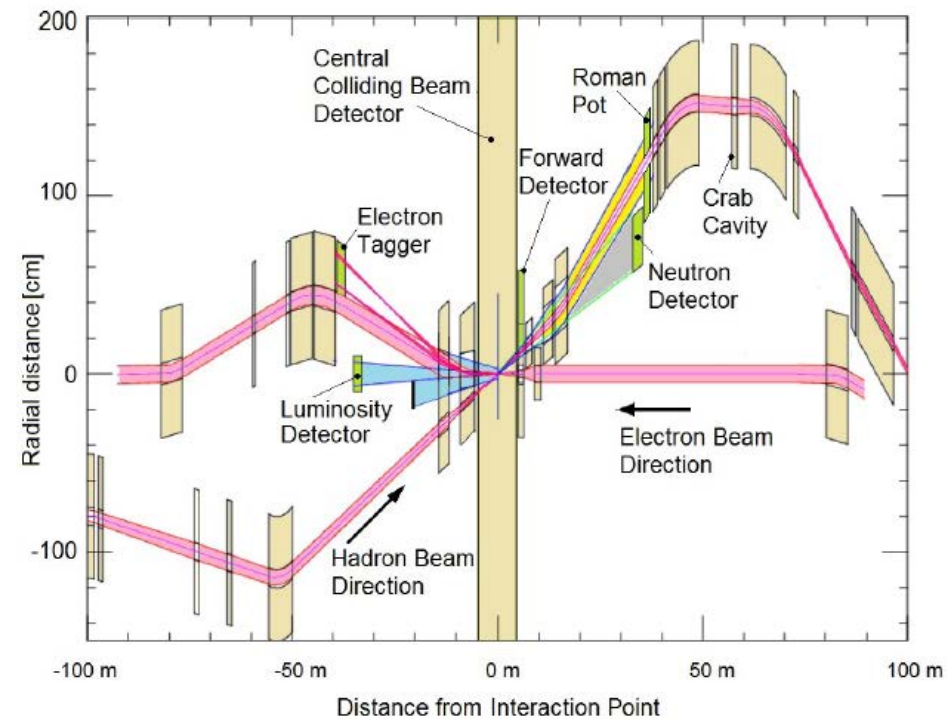
- Recoil protons
- Low- Q^2 electrons
- Neutrons in hadron going direction (ZDCs)

Luminosity and polarization measurement

IR Designs

eRHIC
Elke Aschenauer

JLEIC
Vasily Morozov



Measurements for EIC Physics

Inclusive DIS in ep/eA

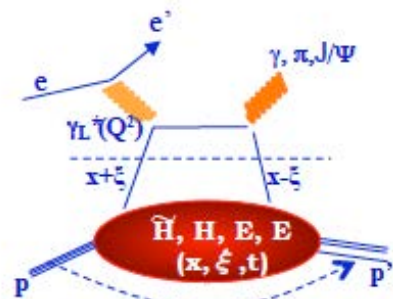
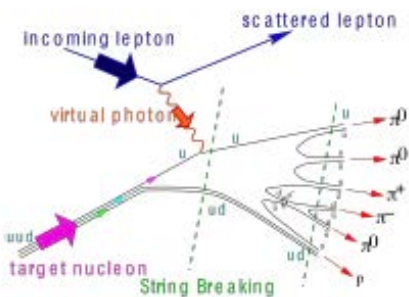
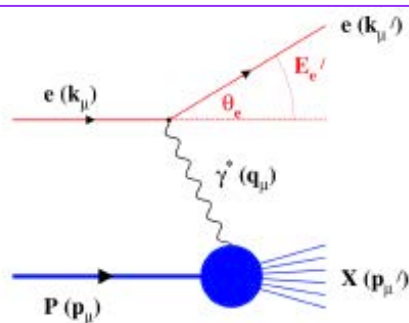
- Physics: Structure function measurements F_2 , F_L , g_1
 - PID & excellent energy/angular resolution for scattered electron

Semi-Inclusive DIS in ep/eA

- TMD, flavor separated (π, K, p) , cross sections, helicity PDFs, Frag. Func., di-hadron correlations...
 - Excellent PID for (p, K, p) over wide range in momentum & pseudorapidity
 - Full azimuthal acceptance for γ^* , wide p_t coverage for TMD's
 - Vertex resolution for heavy quark physics

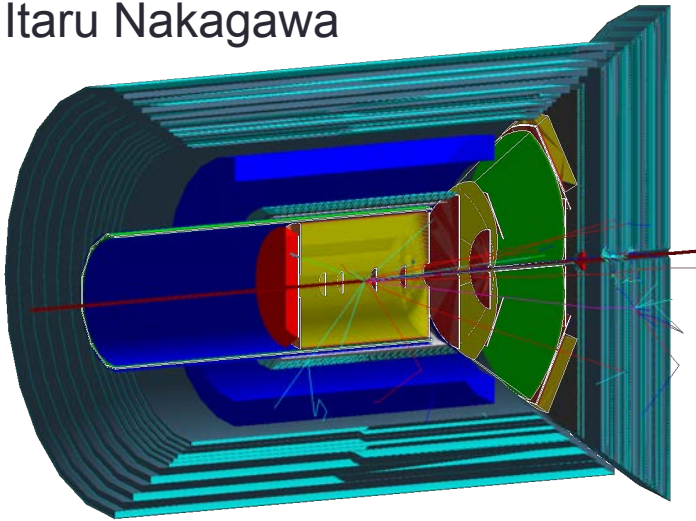
Exclusive DIS in ep/eA

- DVCS, DVVM (for GPDs, Imaging)
 - Establish exclusivity: large rapidity, reconstruct full event
 - High resolution, wide coverage in t at the Roman Pots
 - eA: identify/veto nuclear break up, measure impact parameter
 - Neutron acceptance in ZDCs

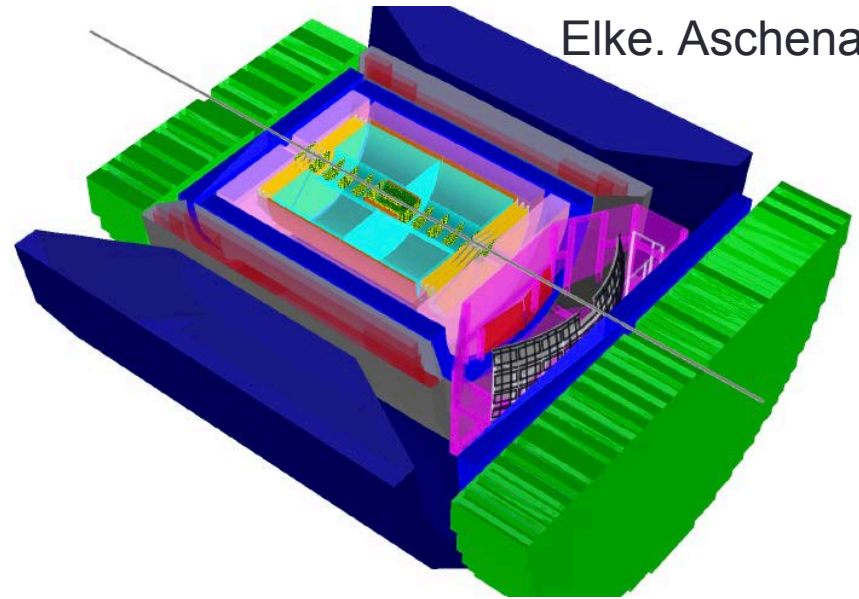


EIC Detector Concepts

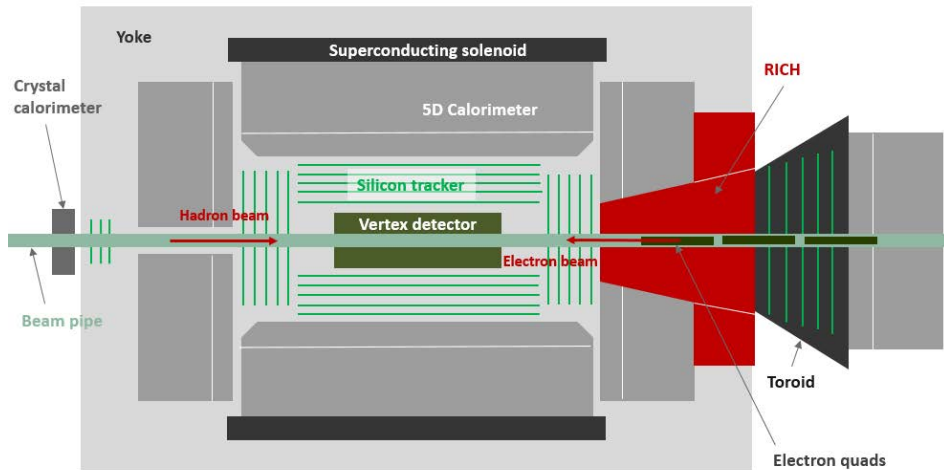
“eRHIC Day 1 Detector”
Itaru Nakagawa



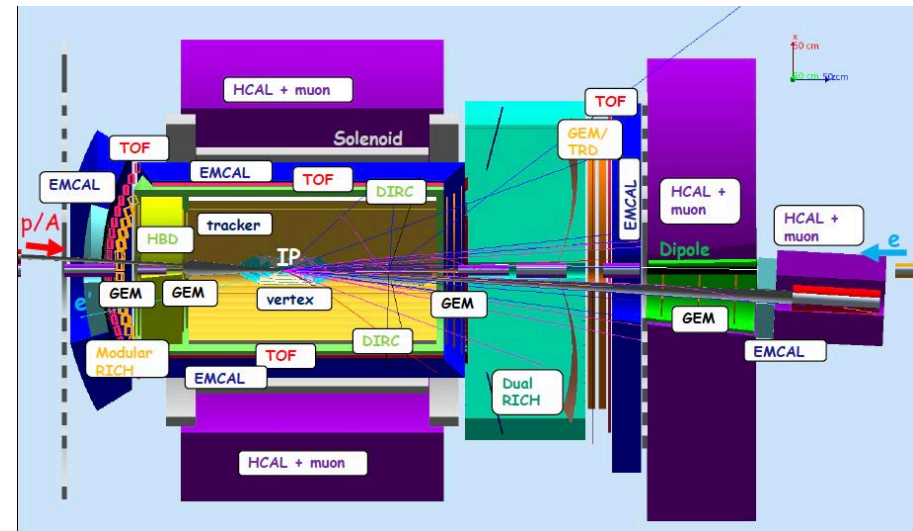
eRHIC Detector
Elke. Aschenauer



TOPSiDE by ANL
Jose Repond



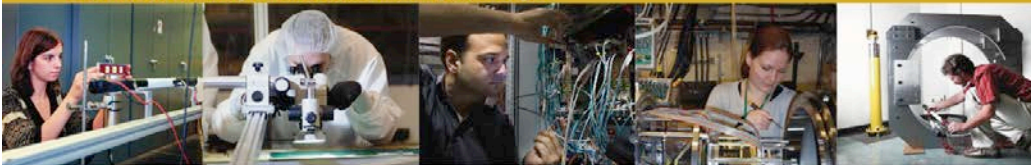
JLEIC Detector, Yulia Ferletova



STATUS OF US EIC

REACHING FOR THE HORIZON

The Site of the Wright Brothers' First Airplane Flight



The 2015 LONG RANGE PLAN for NUCLEAR SCIENCE



RECOMMENDATION:

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

Initiatives:

Theory

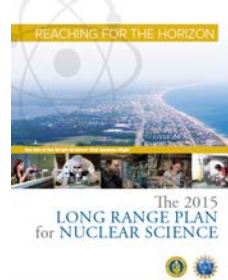
Detector & Accelerator R&D

Detector R&D money ~1.3M/yr since 2011; significant increase anticipated soon.

Anticipated Now:

NEW Money for EIC Accelerator R&D already assigned \$7m/yr

NSAC LRP 2015: (EIC)



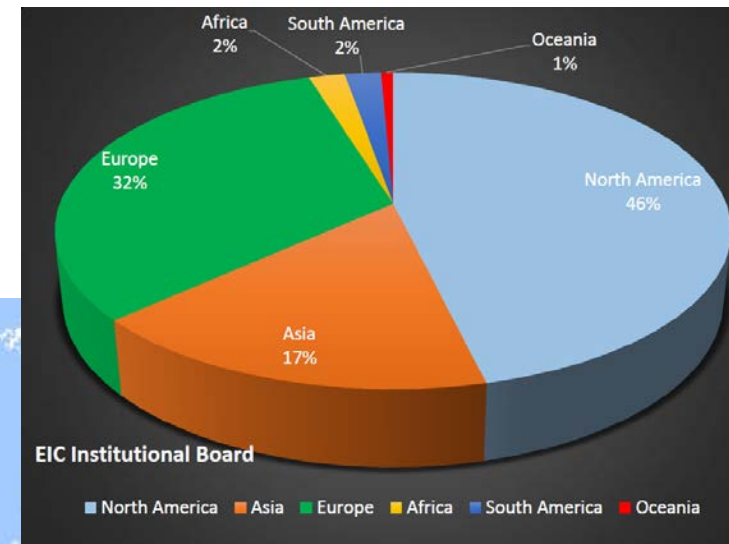
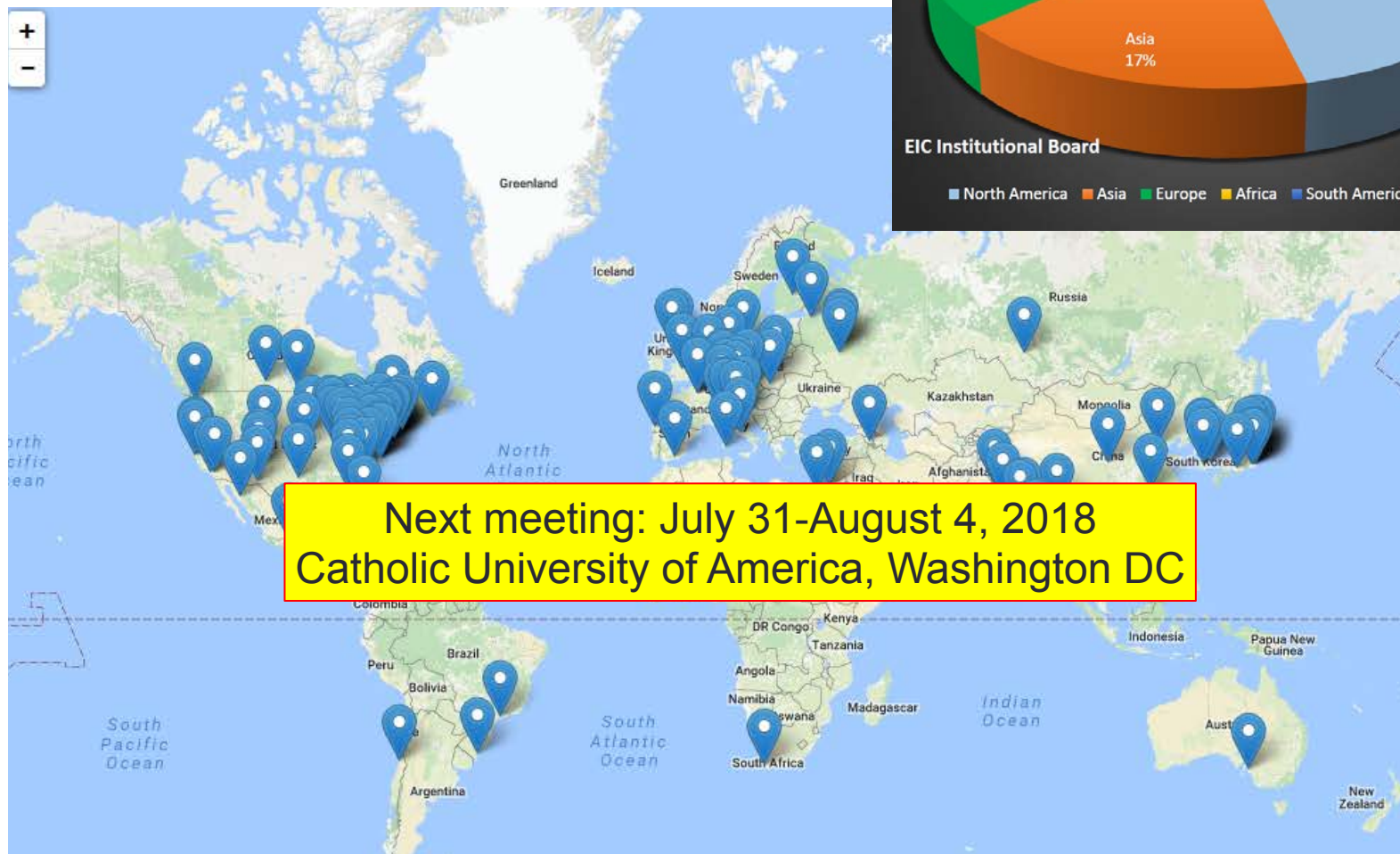
- “*This facility can lead to the convergence of the present world-leading QCD programs at CEBAF and RHIC in a single facility. This vision for the future was expressed in the 2013 NSAC report on the implementation of the 2007 Long Range Plan with the field growing towards two major facilities, one to study the quarks and gluons in strongly interacting matter and a second, FRIB, primarily to study nuclei in their many forms.*”
- Expect significant fractions of current RHIC users and Jlab users to come together to work on the EIC (where-ever it gets built) → A conservative number for official users of this facility ~ 1500 – 2000 assuming participation from a broad group of international users, included.
- Expect to develop at least two final detector concepts/collaborations, based on the sizes US NP community is used to (and extrapolating to ~2028).

The EIC Users Group: EICUG.ORG

(no students included as of yet)

731 collaborators, 29 countries, 169 institutions... (January 2018)

Map of institution's locations





CFNS activities in 2018

<http://www.stonybrook.edu/cfns/>

- **Funded by Simon's Foundation and New York State**
- An initiative supported by Stony Brook University and BNL
- **All members of EIC Users Group are welcome to participate & lead the Center's activities**
- **Physics topics/Workshops:**
 - Pre-DIS workshop on EIC and its connections to other areas (April 2018)
 - GPD measurements at the EIC (Workshop in June, 2018)
 - Short Range Nuclear correlations EIC at FRIB (September 2018)
 - Entropy Entanglement and connections to Confinement (September 2018)
 - Ultrahigh energy gamma rays and EIC (TBD 2018)
 - Inaugural meeting of the Center (November 2018)
- Bi-Monthly Seminars on Blue Jeans (see web pages)
- Post doctoral fellow program launched
- Visitor program to start in Summer 2018
- A EIC QCD summer school planned 1st one in 2019.
- If you want to participate: Please contact me ([Abhay Deshpande](#))



Center for EIC at Jefferson Lab

<https://www.eiccenter.org/eic-center-jefferson-lab>

EIC Center at Jefferson Lab (EIC²@Jlab) is organized to advance and promote the science program at a future EIC facility. Particular emphasis is on the close connection of EIC science to the current 12 GeV CEBAF program.

Consolidates and connects EIC Physics and detector development activities at/ around Jlab including:

- Weekly meetings, hosting and organizing adhoc meetings, keeping documentation on EIC and JLEIC
- LDRD projects, EIC Detector R&D funded activities, HUGS Summer School, local hosting of visitors and planning of EICUG activities
- Graduate student and post doctoral fellow program
- Participation & activities coordinated by Rik Yoshida

New Users → New Physics → Lots of activities

- Jet studies at the EIC:
 - Systematic investigations of general issues in jet-finding at an EIC
 - Understanding of “micro-jets” – jets with only few hadrons
 - Understanding the jet structure modifications in nuclei vs. protons
 - Energy loss in cold QCD matter (Nuclei) vs. hot QCD matter at RHIC and LHC
- Precision measurements of the “initial state” for collisions leading to the QGP being studied at RHIC and LHC
- Precision PDF measurements in proton, neutron & photons at the EIC:
 - Study the free neutron PDFs through tagging and on-shell extrapolation
 - Study the gluon PDFs at large Bjorken x through evolution and open-charm production
 - Study of gluons TMDs
 - Study the potential impact on Higgs studies in the High-Luminosity LHC era
 - Study the impact of TMDs @ EIC on W-production at the LHC
 - Polarized and unpolarized photon PDFs
- Measurements of PDFs in pions and kaons through the Sullivan process
 - Theoretical studies of the equivalence of near-off-shell and on-shell pions and kaons
 - Study the extraction of, and expected differences of, quark and gluon PDFs in pions, kaons and nucleons, and the relation to their physical masses
- Nucleon structure with electroweak probes, and precision BSM physics (i.e. $\sin^2\Theta_W$)
- Heavy quark & quarkonia production with 100-1000 times HERA luminosity
- In view of new discoveries of multi-quark XYZ states: what could EIC contribute?



New Users → New Physics → Lots of activities

POETIC VI
6th International Conference on
Physics Opportunities at an Electron-Ion Collider
7-11 September 2015
Ecole Polytechnique, Palaiseau, France
<http://poetic6.sciencecast.org/>

PHYSICS
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INSTITUTE FOR NUCLEAR THEORY
Home | Contact | Search | Site Map

Programs & Workshops

► **2017 Programs**

Toward Predictive Theories of Nuclear Reactions Across the Isotopic Chart (INT-17-1a)
March 31, 2017
H. Elster, K.D. Launey, D. Lee

Spectroscopy of QGP Properties with Jets and Heavy Quarks (INT-17-1b)
April 8, 2017
Majumder, J. Putschke, L. Ruan

Double-beta Decay (INT-17-2a)
April 14, 2017
Wilson, V. Cirigliano

Stellar Signatures of R-process Nucleosynthesis (INT-17-2b)
April 18, 2017
D. Kasen, G. Martinez-Pinedo, B.C.

Programs related to EIC

Spin and Momentum Tomography of Hadrons and Nuclei (INT-17-3)
August 28 - September 29, 2017
Ciofi, K. Hafid, Z.-E. Meziani, B. Pasquini

► **2017 Workshops**

Probing QCD in Photon-Nucleus Interactions at RHIC and LHC: the Path to EIC (INT-17-65W)
February 13 - 17, 2017
J.D. Tapia Takane, S.A. Bass, S.R. Klein, T. Lappi, M. Stenlund

SIGN 2017: International Workshop on the Sign Problem in QCD and Beyond (INT-17-64W)
March 20 - 24, 2017
J. Carlson, S. Chandra Sekharian, K. Damle, C. Gattringer, D. Kaplan, U.-J. Wiese

Lattice QCD Input for Neutrinoless Double- β Decay (INT-17-67W)
July 6 - 7, 2017
Z. Davoudi, W. Detmold, A. Nicholson, M. J. Savage

The Flavor Structure of Nucleon Sea (INT-17-68W)
October 2 - 13, 2017
C. Pasca, W. Detmold, J. Liu, W. Vogelsang

Neutron-Antineutron Oscillations: Appearance, Disappearance, and Baryogenesis (INT-17-69W)
October 23 - 27, 2017
K. Babu, Z. Berezhiani, Y. Kamyskhov, B. Kerbikov

► **2018 Programs**

Nuclear ab-initio Theories and Neutrino Physics (INT-18-1a)
February 26 - March 30, 2018
C. Barbieri, O. Benhar, A. Galindo-Uribarri, A. Lovato, J. Menéndez

Multi-Scale Problems Using Effective Field Theories (INT-18-1b)
May 7 - June 1, 2018
E. Braaten, N. Brambilla, T. Schäfer, A. Vairo

Probing Nucleons and Nuclei in High Energy Collisions (INT-18-2)
October 1 - November 16, 2018
Y. Ma, Y. Kovchegov, C. Marquet, A. Prokudin

The Proton Mass
At the heart of most visible matter.
Temple University, March 28-29, 2016

Joint CTEQ Meeting and POETIC
(7th International Conference on Physics Opportunities at an Electron-Ion Collider)
Temple University
November 14-18, 2016

EICUG MEETING - TRIESTE 2017
July 18-22, 2017
Hosting Institution: INFN, Sezione di Trieste
in cooperation with Trieste University

Highly Active EIC Community has evolved

in view of new discoveries of multi-quark

Critical Decision Process DOE

PROJECT ACQUISITION PROCESS AND CRITICAL DECISIONS						
Project Planning Phase		Project Execution Phase			Mission	
Preconceptual Planning	Conceptual Design	Preliminary Design	Final Design	Construction	Operations	
<i>i</i> CD-0 Approve Mission Need		<i>i</i> CD-1 Approve Preliminary Baseline Range	<i>i</i> CD-2 Approve Performance Baseline	<i>i</i> CD-3 Approve Start of Construction	<i>i</i> CD-4 Approve Start of Operations or Project Closeout	

CD-0	CD-1	CD-2	CD-3	CD-4
Actions Authorized by Critical Decision Approval				
<ul style="list-style-type: none"> • Proceed with conceptual design using program funds • Request PED funding 	<ul style="list-style-type: none"> • Allow expenditure of PED funds for design 	<ul style="list-style-type: none"> • Establish baseline budget for construction • Continue design • Request construction funding 	<ul style="list-style-type: none"> • Approve expenditure of funds for construction 	<ul style="list-style-type: none"> • Allow start of operations or project closeout

Path forward for the EIC:

- DOE sanctioned a science Review by National Academy of Science of EIC
 - Expect report by **June/July 2018 (?)**
- Positive NAS review will trigger the DOE's CD process
 - CD0 (acceptance of the critical need for science by DOE) FY19
 - EIC-Proposal's Technical & Cost review → FY20 (site selection)(/)
 - CD1 requires site selection
 - **Major Construction funds ("CD3") by 2022/23"**
 - Assuming 1.6% sustained increase over inflation of the next several years (Long Range Plan)
 - Consistent with the past 10 years of NP funding increases in the US

Concluding thoughts & perspective:

The EIC will profoundly impact our understanding of QCD:

- ◇ *The bridge between sea quark/gluons to Nuclei* by Imaging of quarks and gluons in 3D in nucleons and nuclei

EIC: Pushes the boundaries of our knowledge on Accelerator Science

- ❖ A “magnet” of the best and “brightest” of the accelerator scientists

EIC Users Group: eicug.org → Seeds for Detector Collaborations

Positive National Academy Science report (June/July 2018?)

→ Critical Decision process of the DOE to start → 1st collisions ~10 years

BNL + Jlab are moving together with the EIC Users to realize the US EIC and its physics program.

Exciting times for scientists and particularly for young researchers who will be in “the driver’s seat at the EIC”

THANK YOU

Thanks to many of my EIC Collaborators and Enthusiasts who led many of the studies presented in this talk

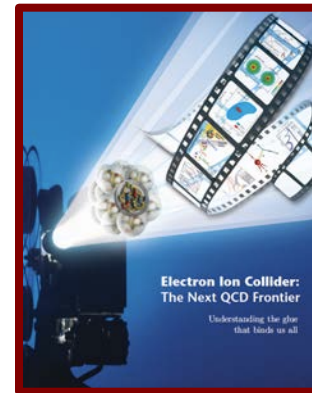
See: [arXiv:1108.1713](https://arxiv.org/abs/1108.1713), D. Boer et al.

Without the EIC White Paper Writing Group the EIC White Paper would not have existed.

Special thanks to Dr. Jianwei Qiu and Prof. Zein-Eddine Meziani, my Co-Editors for the EIC White Paper

See: [arXiv:1212.1701.v3](https://arxiv.org/abs/1212.1701), A. Accardi et al.

[Eur. Phys. J. A 52, 9 \(2016\)](#)



The eRHIC and JLEIC machine design teams

Also gratefully acknowledge recent input from: M. Diefenthaler, R. Ent, R. Milner, R. Yoshida

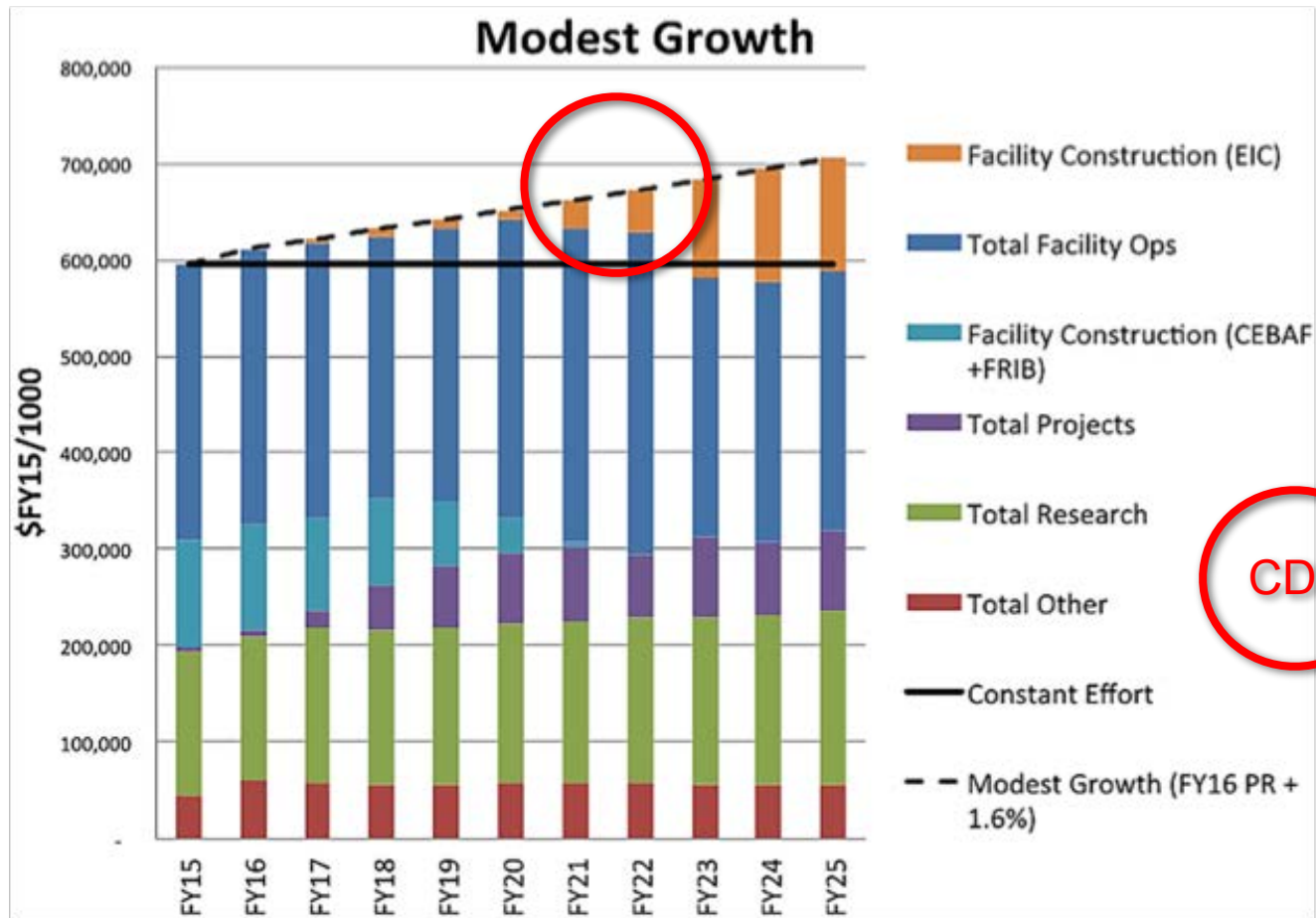
INT Program Approved: 2018

A 7-week program "Probing Nucleons and Nuclei in High Energy Collisions" dedicated to the physics of the Electron Ion Collider has been approved by the Institute for Nuclear Theory in Seattle with the tentative dates of **October 1 - November 16, 2018**. The topics to be covered include Spin and Three-Dimensional Structure of the Nucleon (GPDs, TMDs, longitudinal spin) and QCD in a Nucleus (small-x physics and saturation, connections to heavy ions, large-x physics in a nucleus).

The program organizers will be [Yoshitaka Hatta, Yuri Kovchegov, Cyrille Marquet, and Alexei Prokudin](#). They plan to have ample discussion time and lectures aimed at young researchers. Both **theorists and experimentalists** are welcome to participate in the program. Young researchers, women and underrepresented minorities are strongly encouraged to apply.

Assumption: “Modest Growth” →
1.6% growth/year above constant effort

The 2015 Long Range Plan for Nuclear Science



Not much
time!

CD3

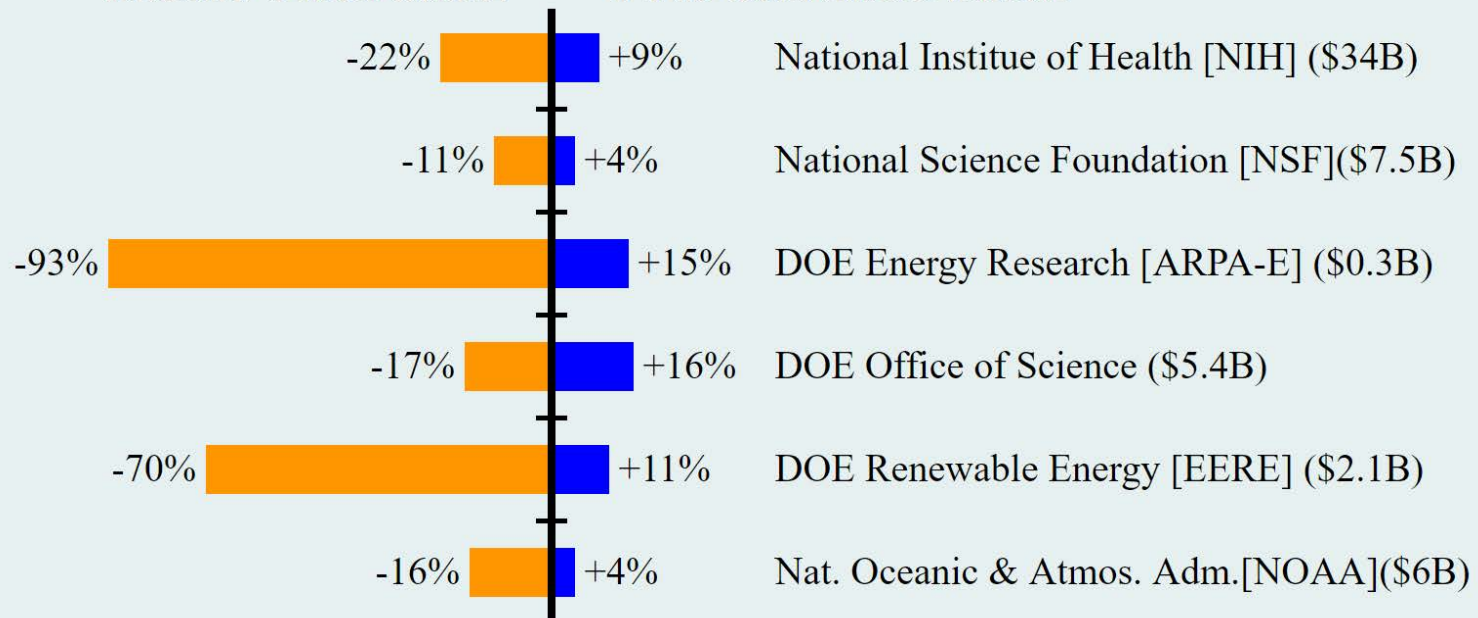
Figure 10.4: DOE budget in FY 2015 dollars for the Modest Growth scenario.

March 2018 Status of US Funding

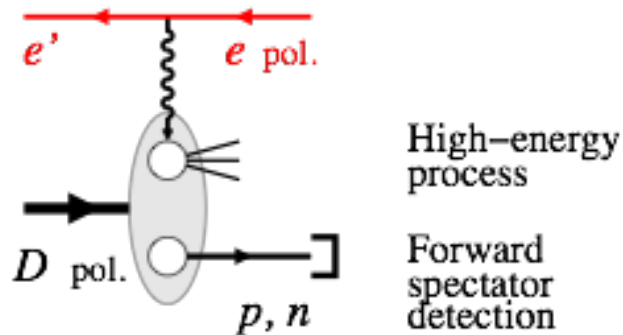
Science & Education Budgets

TRUMP PROPOSAL

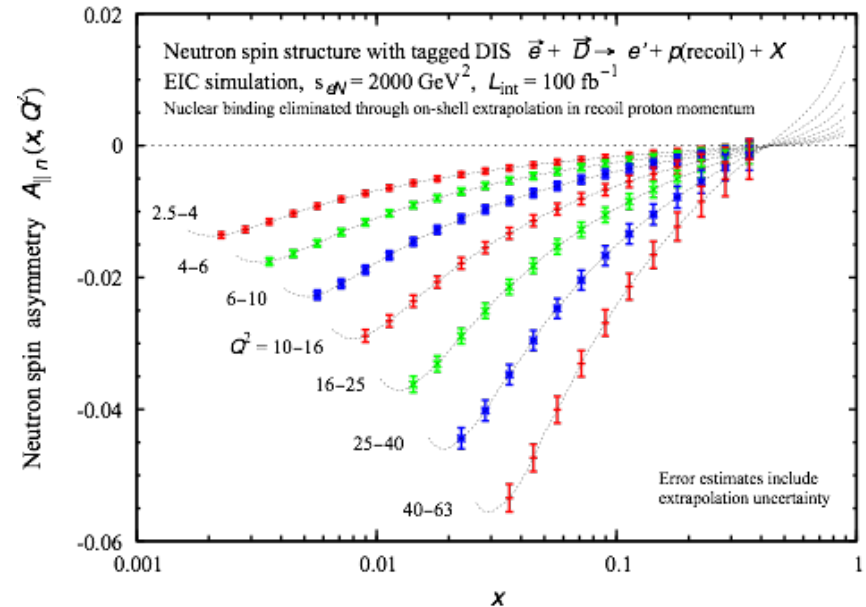
FY18 OMNIBUS DEAL



Nuclear binding



- Measurement of the kinematics of the spectator nucleon indicator of the strength and (hence) the nature of its *binding* with the in-play nucleon(s):
 → quark-gluon origin of the nuclear binding



Tag the recoil proton:
 Study the neutron's q-g spin structure function.
Also for other few body nuclei

Neutron Spin Structure

Why an Electron Ion Collider

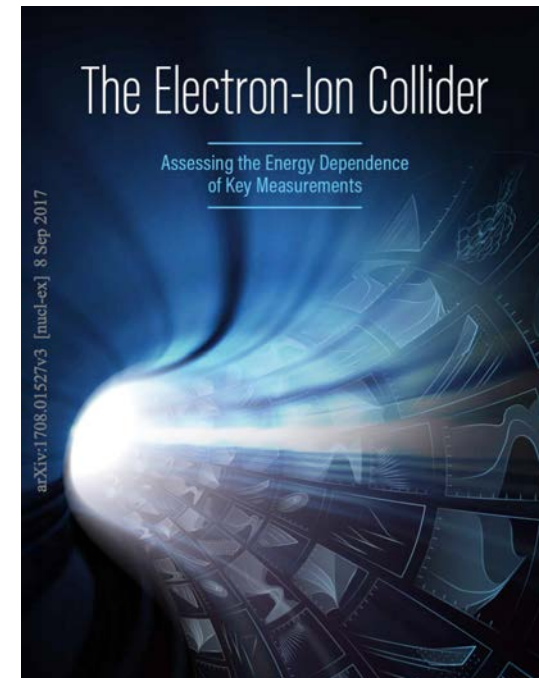
- **Interactions and structure are inseparable in nuclear matter:** Nuclear matter is made of quarks that are bound by gluons that also bind themselves. Unlike with the more familiar atomic and molecular matter, the **interactions and structures are inseparable**, and the **observed properties** of nucleons and nuclei, such as mass & spin, **emerge** out of this complex system.
- **Gaining understanding of this dynamic matter → transformational:** Gaining **detailed knowledge** of this astonishing dynamical system at the heart of our world **could be transformational**, and as **dramatic as** the understanding of the atomic and molecular structure of matter led to new frontiers, new sciences and new technologies.
- **The Electron Ion Collider is the right tool:** A new US-based facility, high-energy, high-luminosity Electron Ion collider (EIC), capable of a versatile range of beam energies, polarizations, and species, is **required to precisely image the quarks and gluons and their interactions in situ**, to explore the **new QCD frontier of strong color fields** in nuclei – to *understand* how matter at its most fundamental level is made.

Connections to other areas of physics

- Explorations of the stringy dynamics of hadrons led to the string theory of Gravity. A weakly coupled regime of 10-d **gravity** is conjectured to be dual to strongly coupled 4-d QCD-like theory. *Further profound connections may emerge from deeper investigations of the QCD landscape.*
- The dynamics of strongly coupled **cold atom gases** and QCD (non-Abelian gauge fields but also strong nuclear fields) show strikingly common features. Cold atom scientists are actively engaged in engineering cold atoms simulators of gauge field mechanism.
- Strong connections have emerged between studies of **strongly correlated condensed matter systems** and QCD: *topological effects arising from chiral anomaly*
- **Strong field QED** explores the breakdown of the QED vacuum and its nonlinear optical response in e^+e^- pair creation. *Reaching this regime is a major goal in developing high powered lasers.*

Advantages of (high) energy:

- Precision measurement of proton spin
- Spatial imaging of quarks and gluons
- Charged current interactions as probe of nucleon structure
- Nuclear Structure function
- Gluon saturation studies in nuclei
 - Di-hadron suppression
 - Diffraction
- Physics with Jets:
 - Hadronization, parton shower evolution in strong color fields, dijets, diffractive dijets, photon structure, gluon helicity....



arXiv:1708.01527
E. Aschenauer et al.