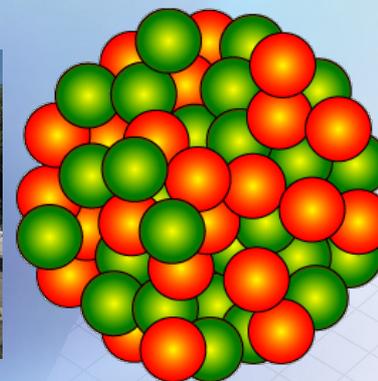
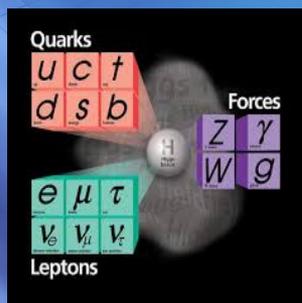
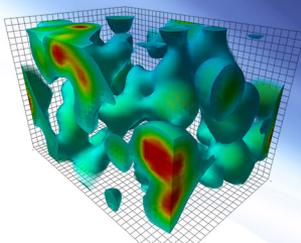


arXiv 1212.1701.v3
Eur. Phys. J. A52, 9 (2016)

Electron Ion Collider: The next QCD frontier

*Understanding the **Glue** that Binds Us All*

This talk is based on the work of a large number of scientists, excited about the EIC science and involved in the EIC project, now organized as the EIC Users Group



Abhay Deshpande

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

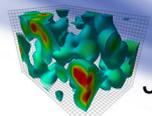
Detector R&D money ~1.3M/yr since 2011; significant increase anticipated soon.

Anticipated Now:

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

Why an Electron Ion Collider

- ❖ ***Interactions and structure are inseparable in nuclear matter:***
 - ◇ 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***
 - ◇ 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 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.



QCD: The Holy Grail of Quantum Field Theories

- QCD : “nearly perfect” theory that explains nature’s strong interactions, is a fundamental quantum theory of quarks and gluon fields
- QCD is rich with symmetries

$$SU(3)_C \times \boxed{SU(3)_L \times SU(3)_R} \times \boxed{U(1)_A \times U(1)_B}$$

(1) (2) (3)

(1) Gauge “color” symmetry : unbroken but confined

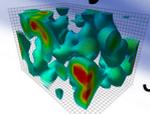
(2) Global “chiral” flavor symmetry: exact for massless quarks

(3) Baryon number and axial charge (massless quarks) conservation

(4) Scale invariance for massless quarks and gluon fields

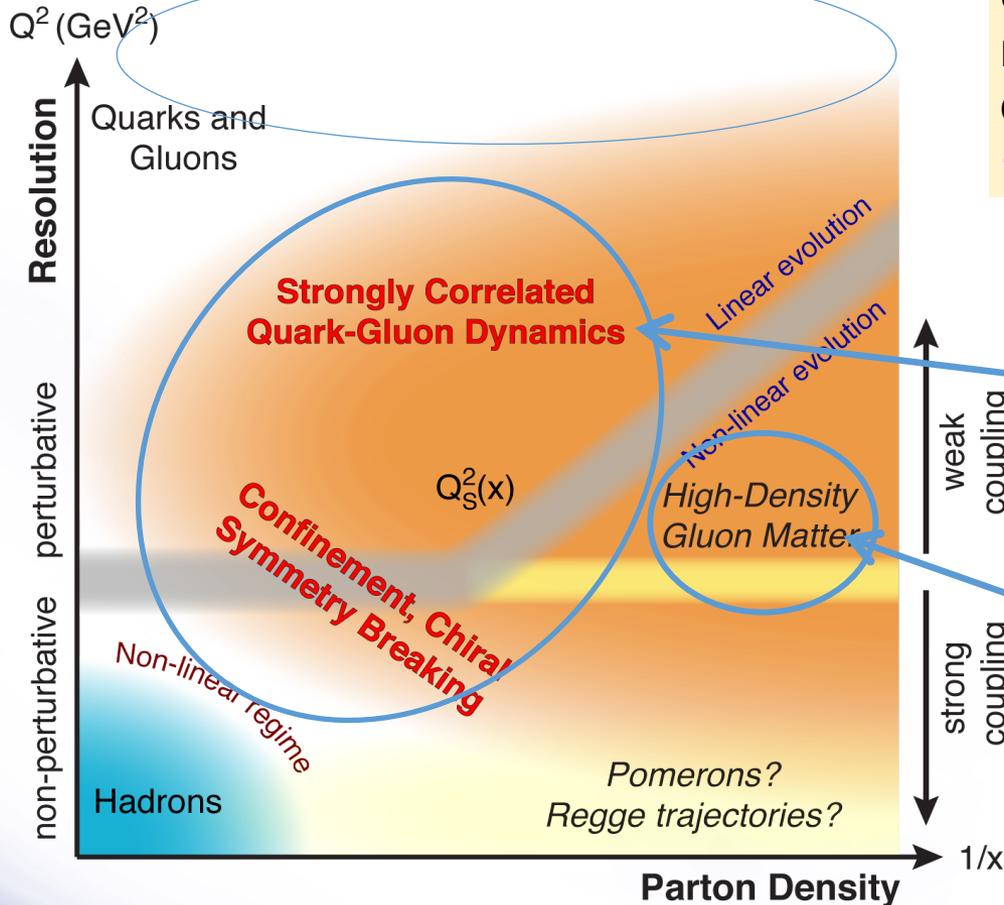
(5) Discrete C, P & T symmetries

- Chiral, Axial, Scale & P&T symmetries broken by quantum effects: Most of the visible matter in the Universe emerges as a result
- Inherent in QCD are the deepest aspects of relativistic quantum field theories: (confinement, asymptotic freedom, anomalies, spontaneous breaking of chiral symmetry) → all depend on non-linear dynamics in QCD



QCD Landscape explored by EIC

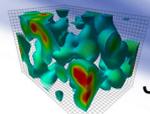
QCD at high resolution (Q^2) — weakly correlated quarks and gluons are well-described



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

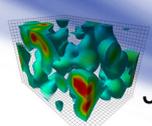
EIC systematically explores correlations in this region.

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



Non-linear Structure of QCD: Fundamental Consequences

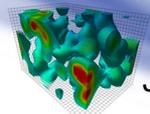
- Quark (Color) confinement:
 - Consequence of nonlinear **gluon self-interactions**
 - Unique property of the strong interaction
- Strong **Quark-Gluon** Interactions:
 - **Confined motion** of quarks and gluons – Transverse Momentum Dependent Parton Distributions (TMDs)
 - **Confined spatial correlations** of quark and gluon distributions – Generalized Parton Distributions (GPDs)
- Ultra-dense color (**gluon**) fields:
 - Is there a universal many-body structure due to ultra-dense color fields at the core of **all** hadrons and nuclei?



Emergent Dynamics in QCD

*Without gluons, there would be no nucleons,
no atomic nuclei... no visible world!*

- Massless gluons & almost massless quarks, *through their interactions*, generate most of the mass of the nucleons
- Gluons carry ~50% of the proton's momentum, a significant fraction of the nucleon's spin, and are essential for the dynamics of confined partons
- Properties of hadrons are **emergent phenomena** resulting not only from the equation of motion but are also inextricably tied to the properties of the QCD vacuum. Striking examples besides confinement are spontaneous symmetry breaking and anomalies
- The nucleon-nucleon forces emerge from quark-gluon interactions: how this happens remains a mystery

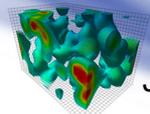


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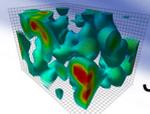
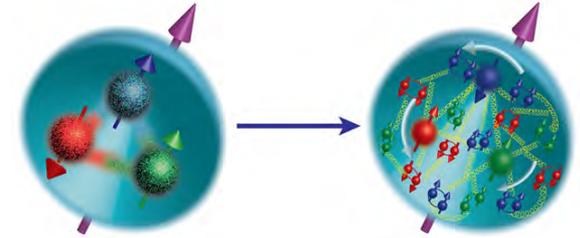
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Experimental insight and guidance crucial for complete understanding of *how* hadrons & nuclei emerge from quarks and gluons



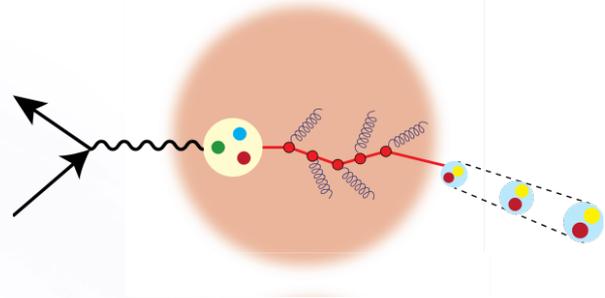
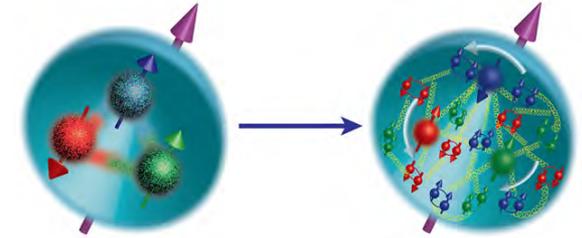
A new facility is needed to investigate, with precision, the dynamics of gluons & sea quarks and their role in the structure of visible matter

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

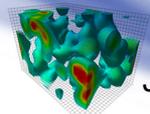


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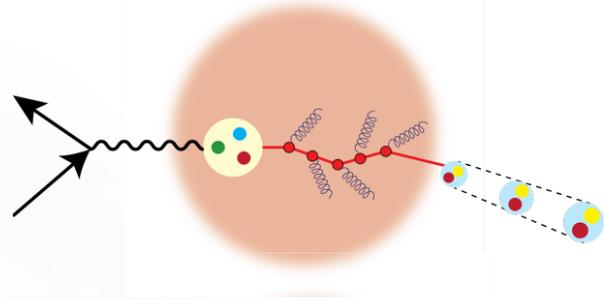
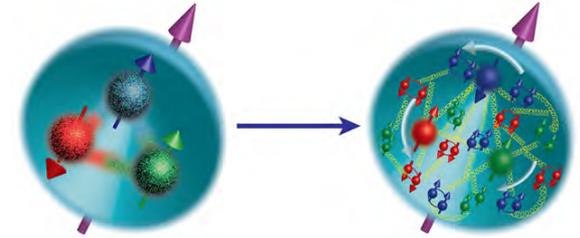


How do color-charged quarks and gluons, and colorless jets, **interact with a nuclear medium**?
How do the **confined hadronic states emerge** from these quarks and gluons?
How do the quark-gluon **interactions create nuclear binding**?



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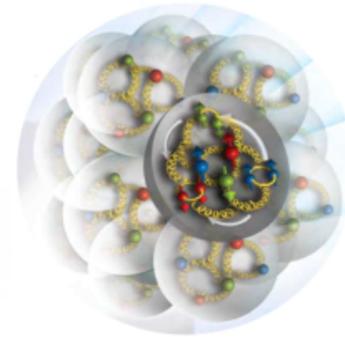
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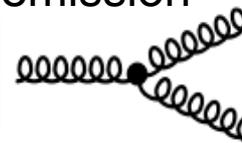
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How does a **dense nuclear environment affect** the quarks and gluons, their correlations, and their interactions?

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?



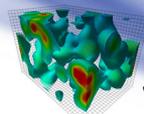
gluon emission



gluon recombination

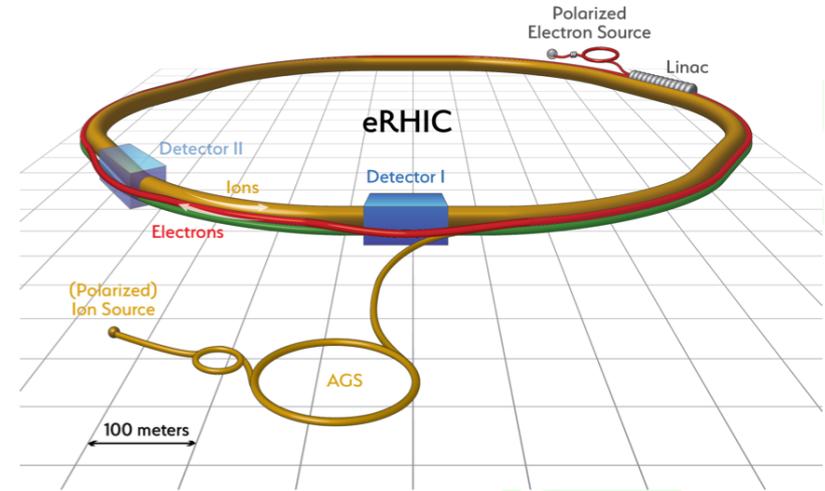


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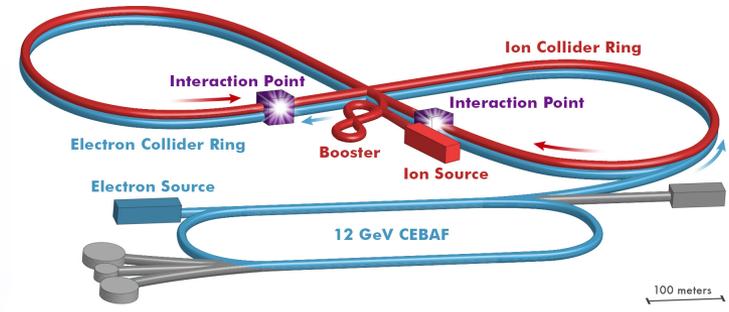


The Electron Ion Collider

Two options of realization!



Not to scale



**Electron Ion Collider:
The Next QCD Frontier**

Understanding the glue
that binds us all

1212.1701.v3
A. Accardi et al Eur. Phys. J. A, 52 9(2016)

SECOND EDITION

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

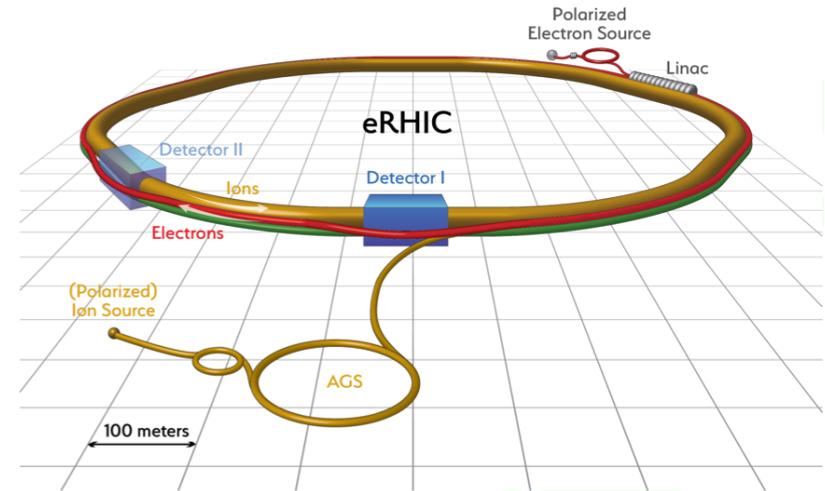
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- ✓ Wide range in nuclei
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- ✓ Variable center of mass energy

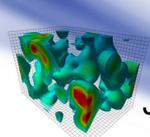
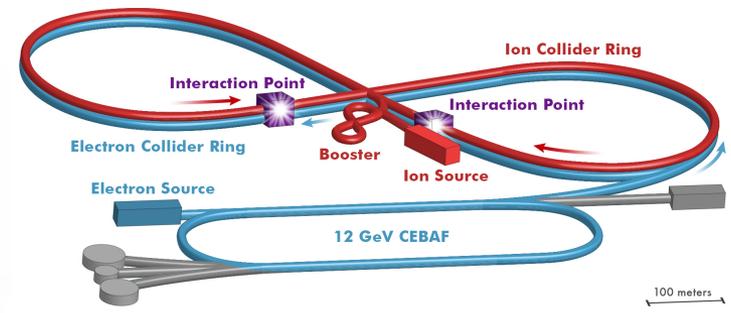
World's first

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

Both designs use DOE's significant
investments in infrastructure



Not to scale



The Electron Ion Collider

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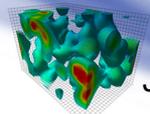
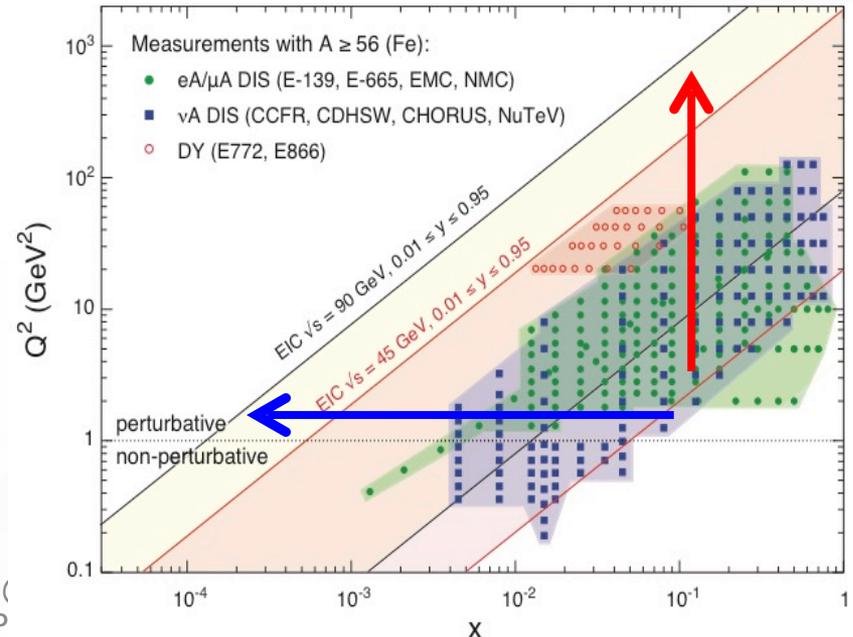
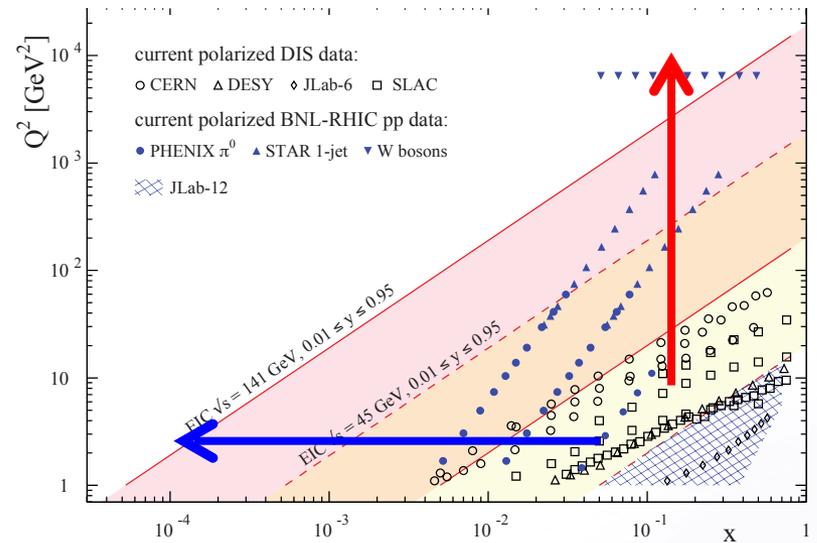
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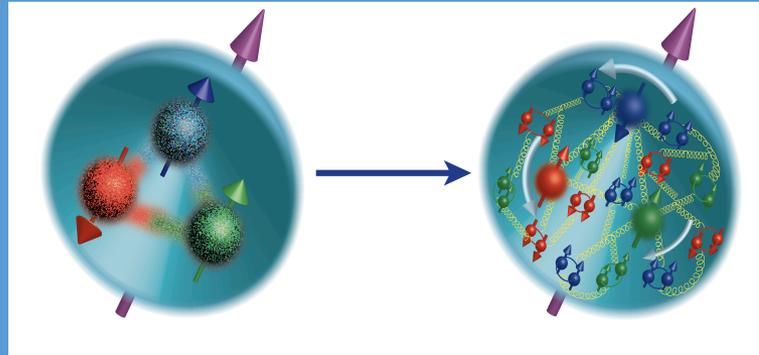
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A. Accardi et al Eur. Phys. J. A, 52 9(2016)

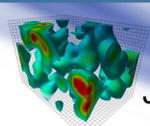


The world's first polarized electron-proton collider

Polarized proton as a laboratory for QCD



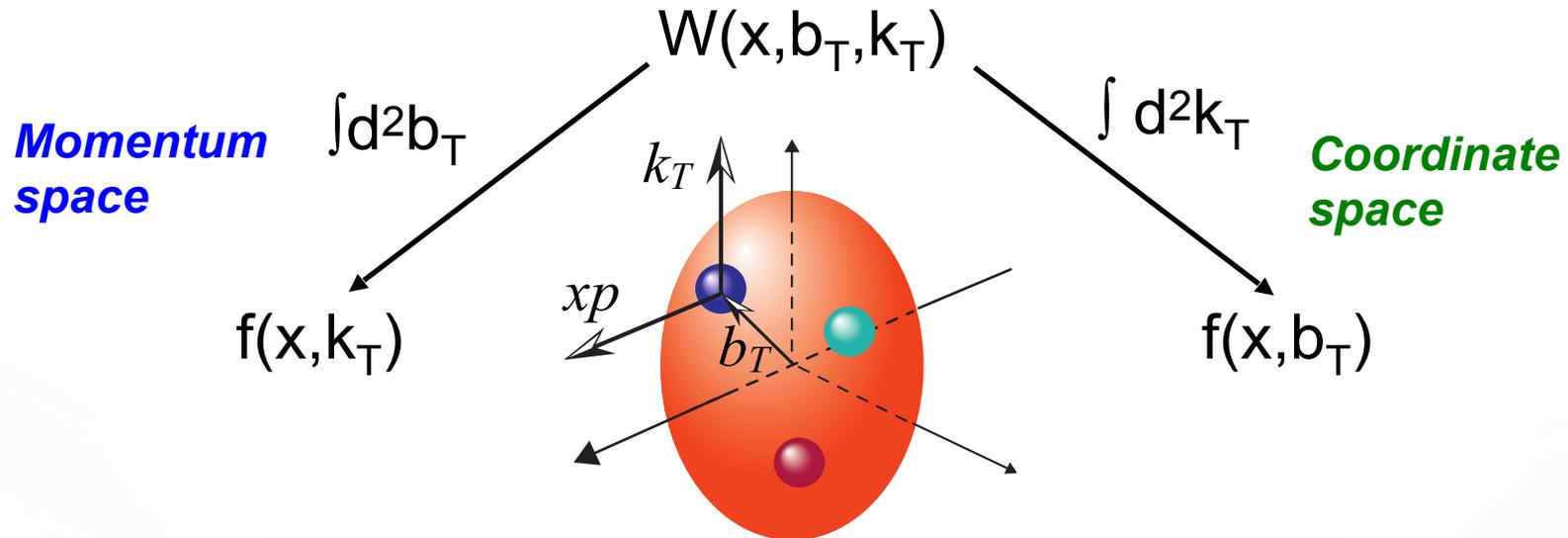
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3-Dimensional Imaging Quarks and Gluons

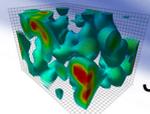
Wigner functions $W(x, b_T, k_T)$

offer unprecedented insight into confinement and chiral symmetry breaking.



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

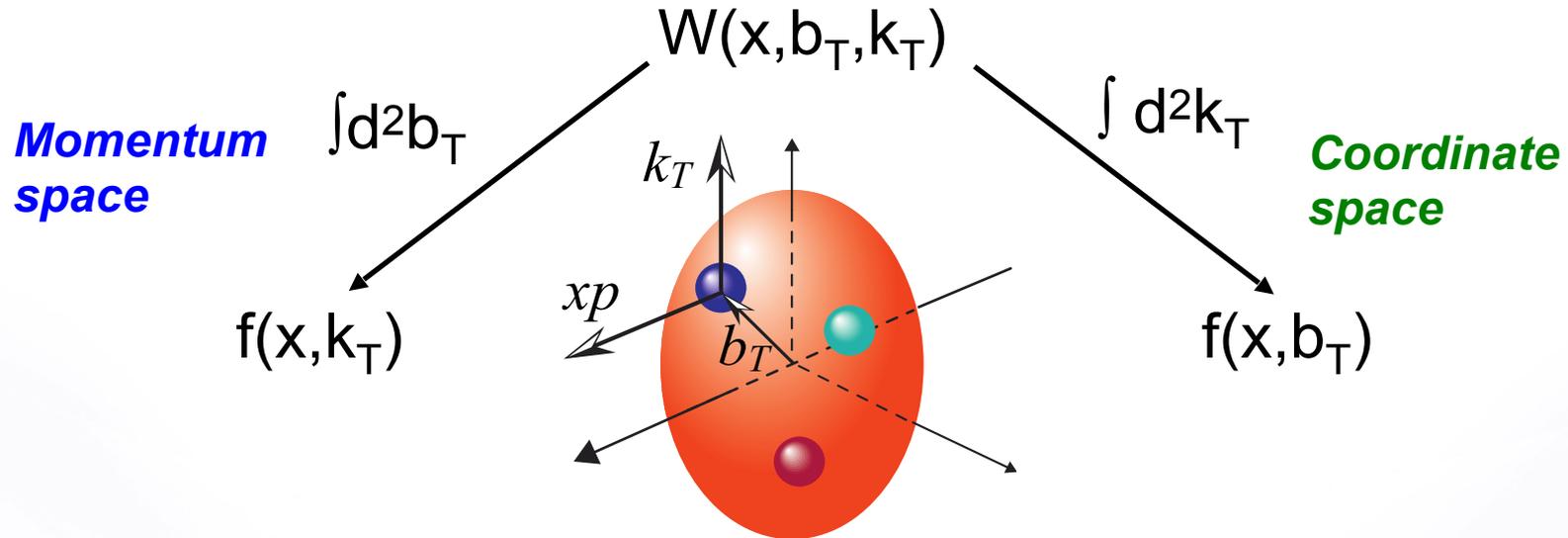
Spin-dependent 2D **coordinate space** (transverse) + 1D (longitudinal momentum) images from exclusive scattering
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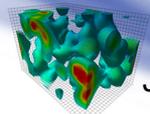
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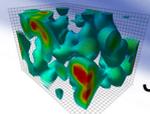
Position and momentum → Orbital motion of quarks and gluons



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

Spin-dependent 3D **momentum space**
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Spin-dependent 2D **coordinate space**
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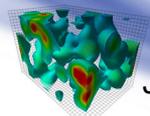
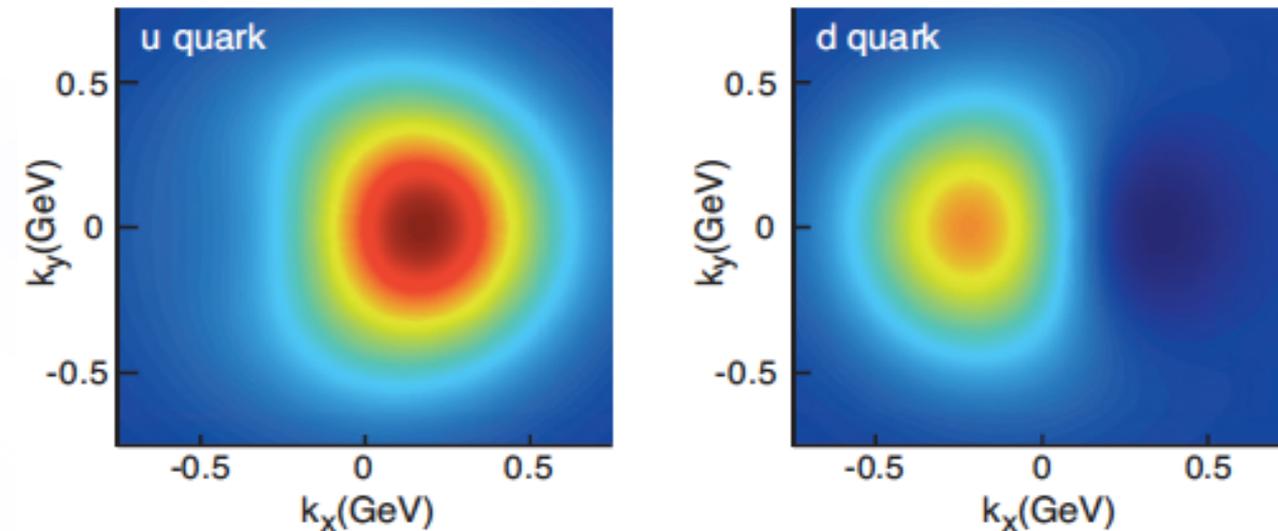


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Transverse Momentum Distributions

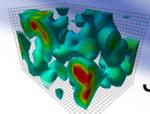
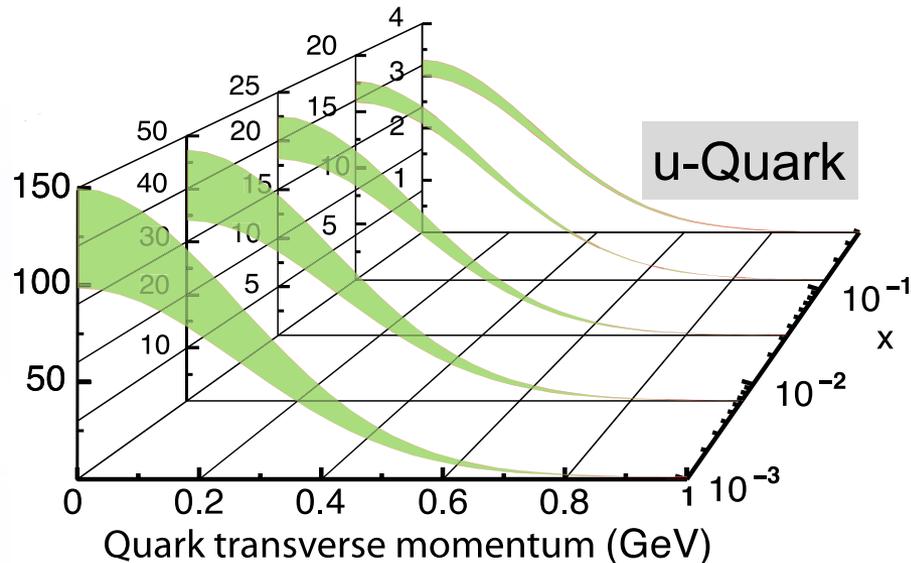


2+1 D partonic image of the proton with the EIC

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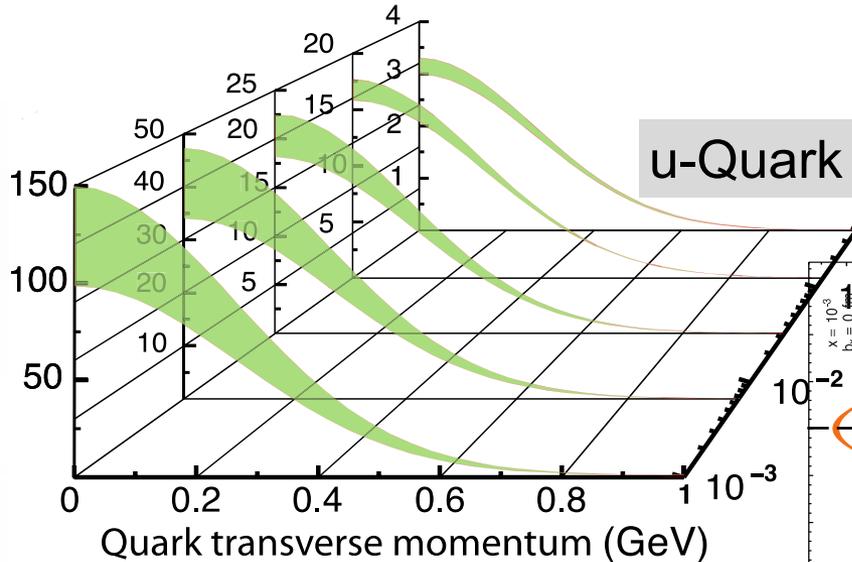
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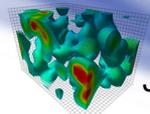
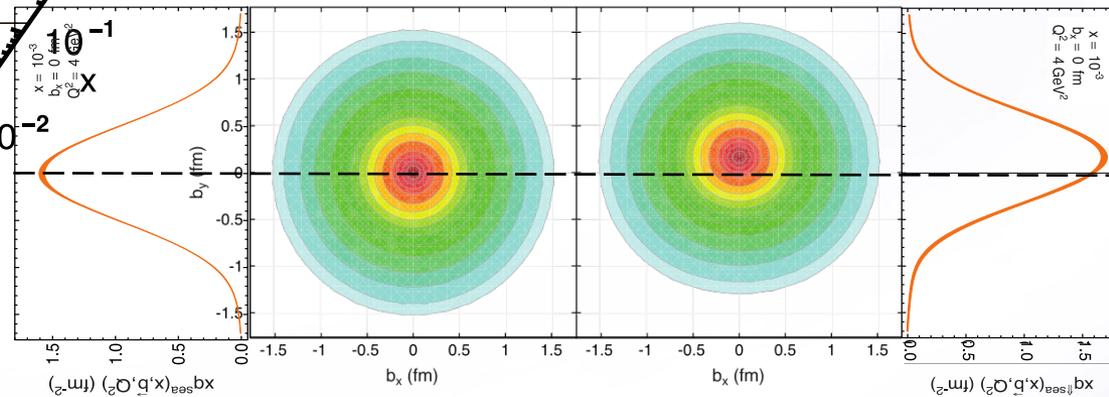
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Transverse Momentum Distributions

Transverse Position Distributions



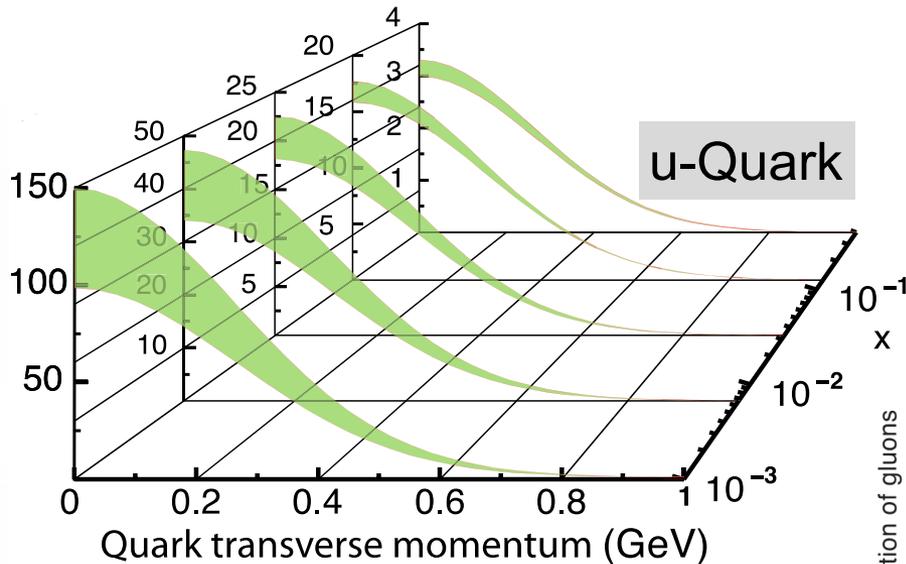
sea-quarks
unpolarized polarized



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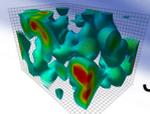
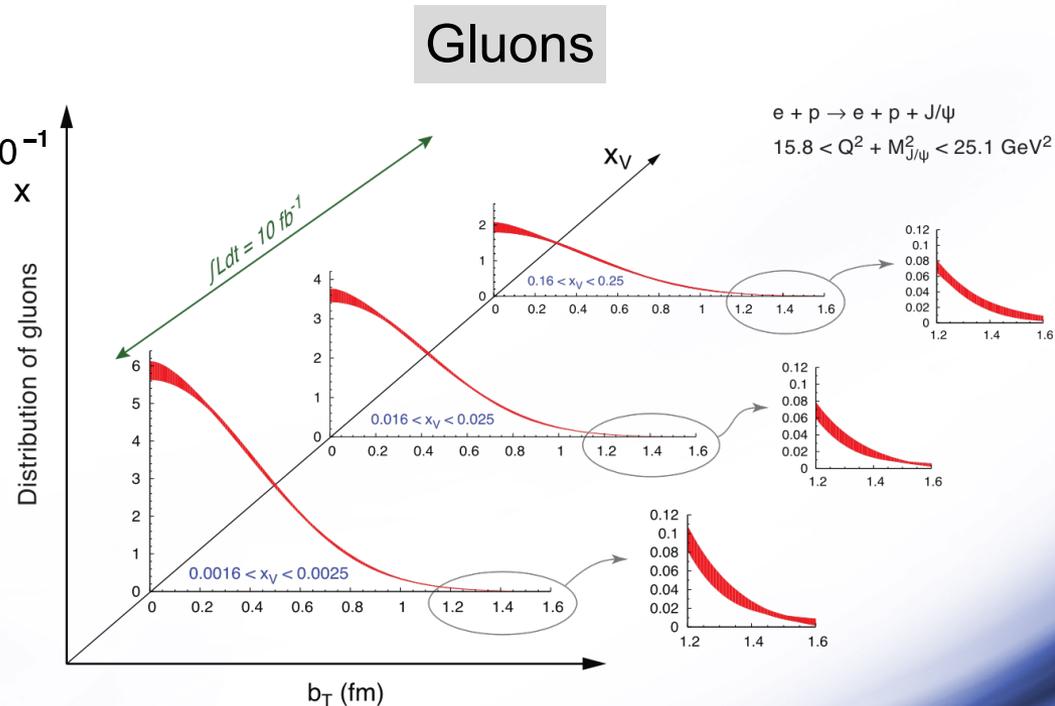
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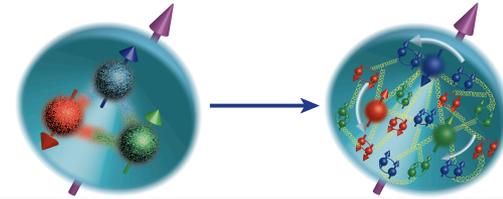


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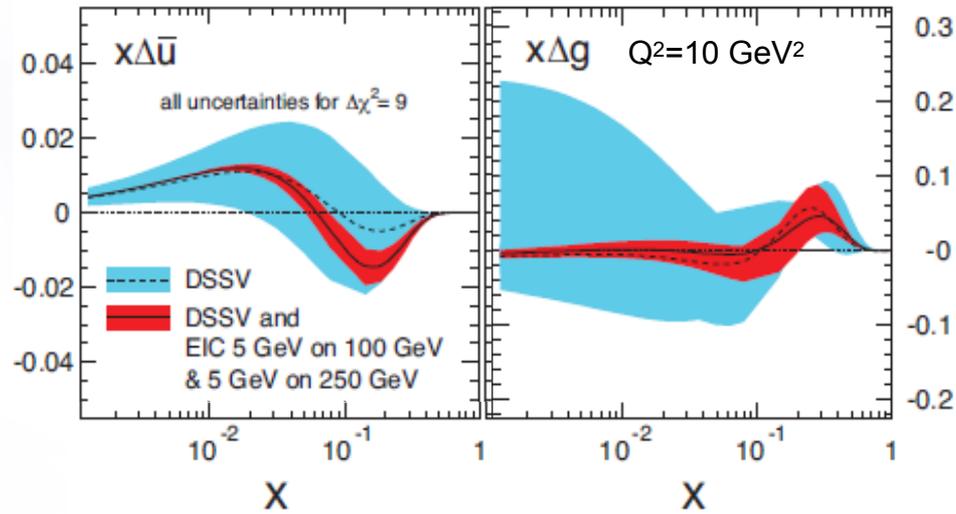
Understanding Nucleon Spin



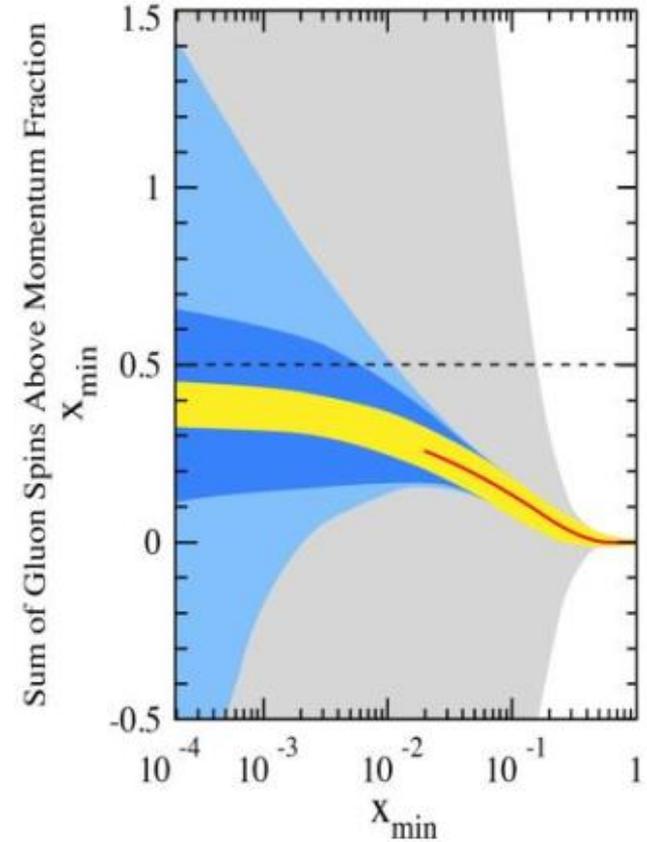
“Helicity sum rule”

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

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 $\sum L_q + L_g$



DIS + SIDIS with 90% C.L. band
 DIS + SIDIS + RHIC with 90% C.L. band
 RHIC projection including 500 GeV data
 EIC projection $\sqrt{s} = 78$ GeV



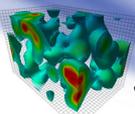
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 Yi-Bo Yang et al. PRL 118, 102001 (2017)
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χ QCD Collaboration, PRD91, 014505, 2015

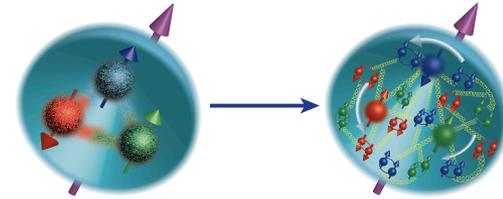
abhay.deshpande@stonybrook

EIC at CAP Congress



June 14, 2018

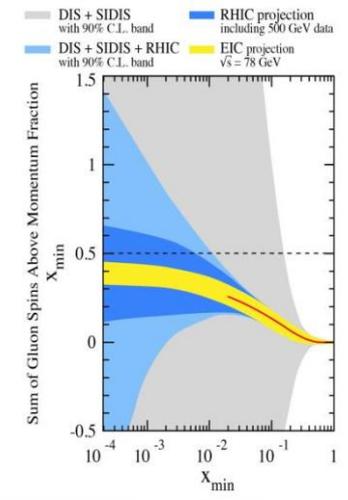
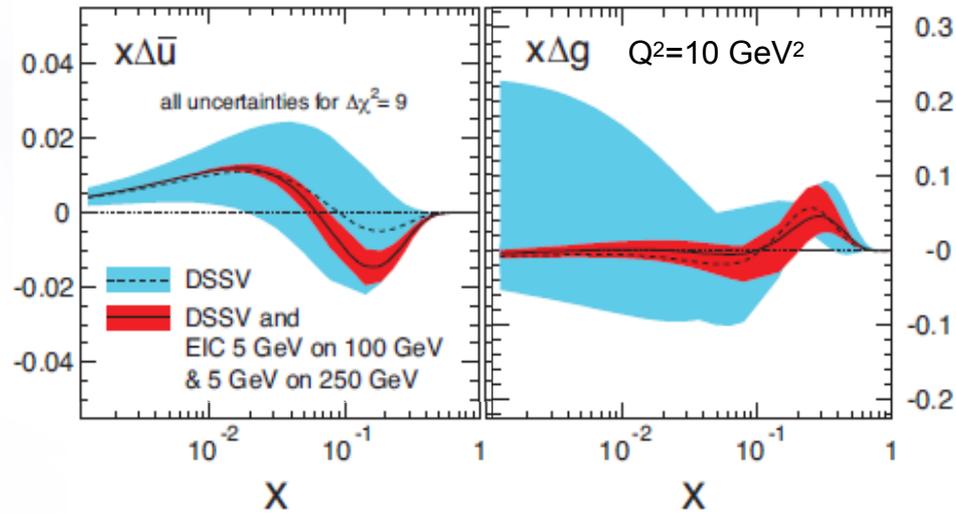
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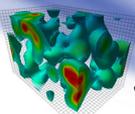
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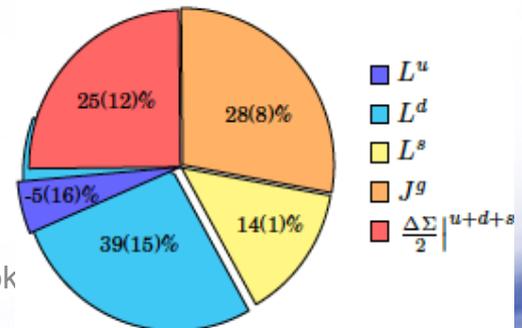
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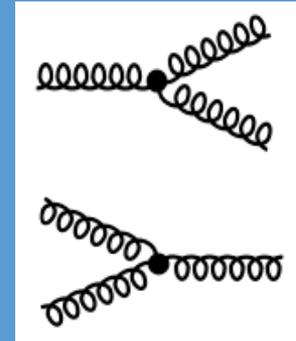
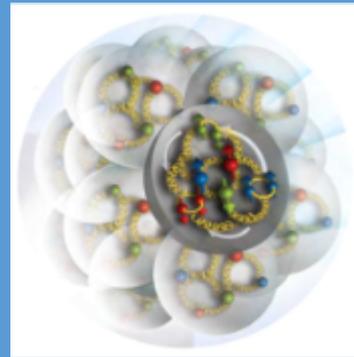
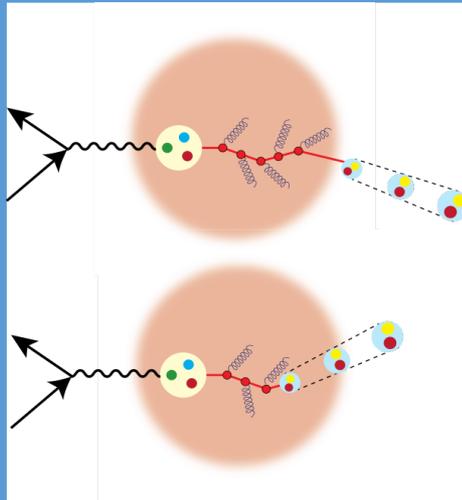
abhay.deshpande@stonybrook
 EIC at CAP Congress



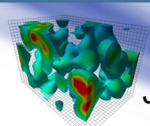
June 14, 2018

The world's first electron-nucleus collider

The Nucleus as a laboratory for QCD



- 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 does the quark-gluon interaction *create nuclear binding*?

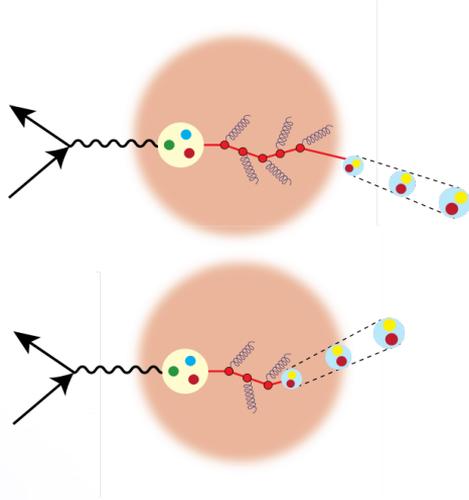


Emergence of Hadrons from Partons

Nucleus as a Femtometer sized analyzer

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

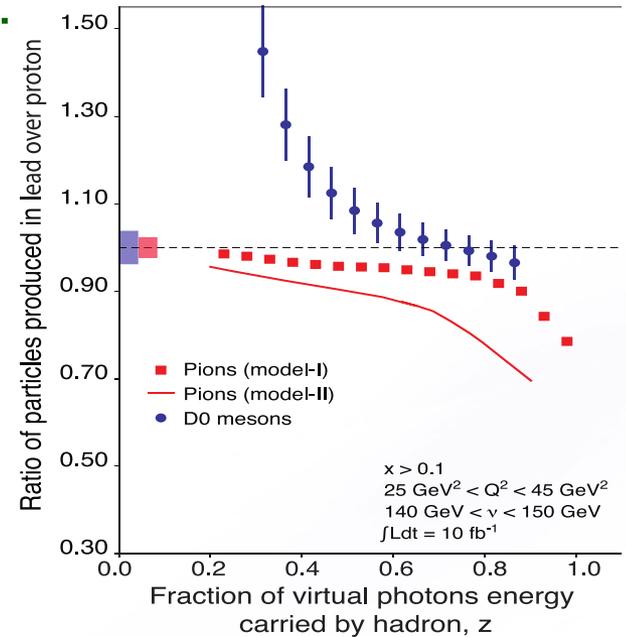
$$\nu = \frac{Q^2}{2mx}$$



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

Colored quark emerges as color neutral hadron → What is the impact of colored media on confinement?

Energy loss by light vs. heavy quarks:



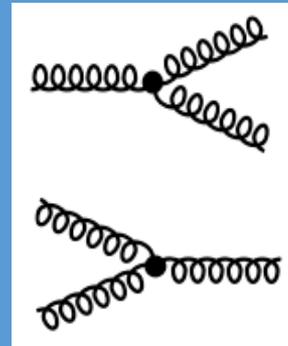
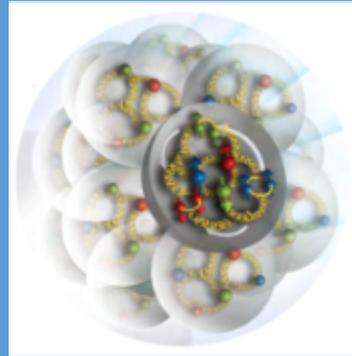
Identify light vs. charm hadrons in e-A:
Understand energy loss of light vs. heavy quarks in cold nuclear matter.
Provides insight into energy loss in the Quark-Gluon Plasma

DIS at collider energies enables control of parton/event kinematics

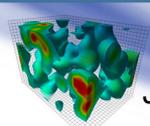


The world's first electron-nucleus collider

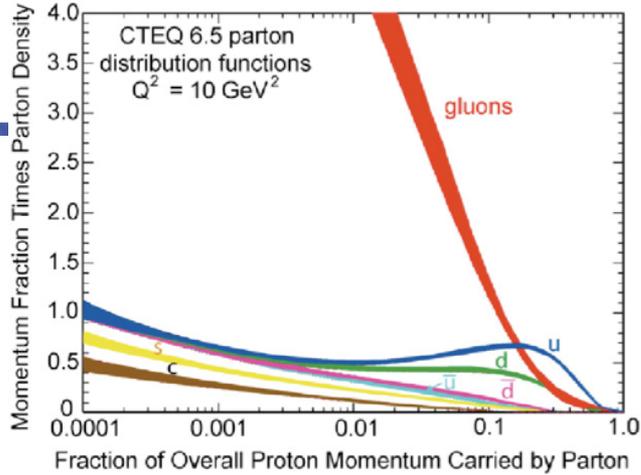
The Nucleus as a laboratory for QCD



- 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?

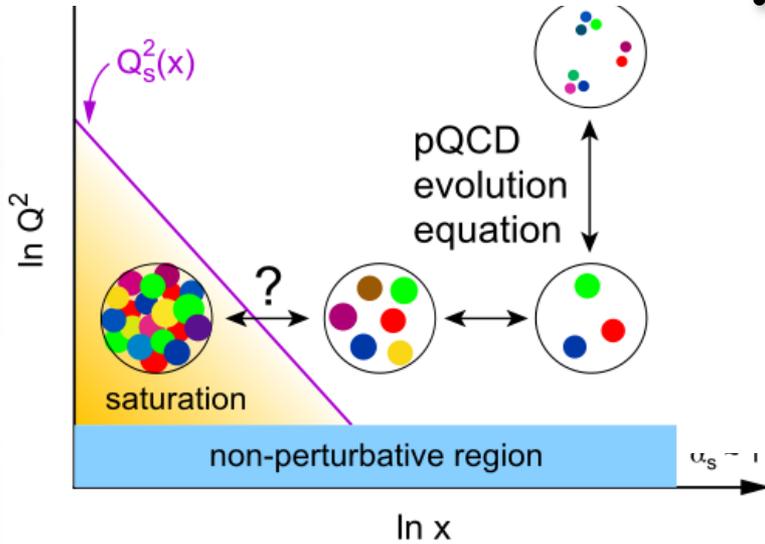


Gluon saturation at low-x

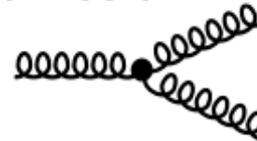


What tames the low-x rise?

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

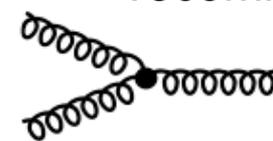


gluon emission

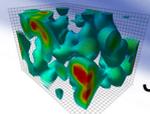


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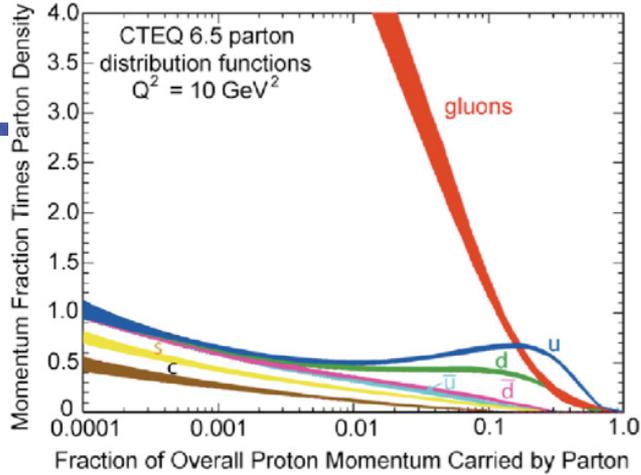
gluon recombination



At Q_s

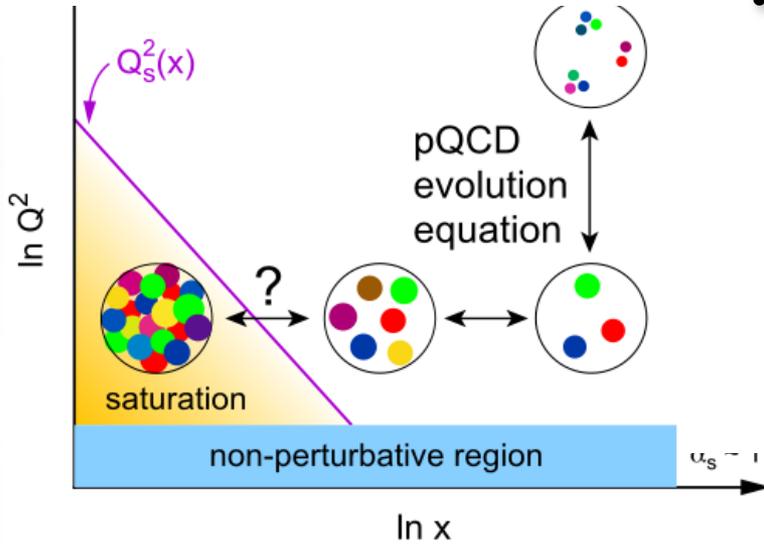


Gluon saturation at low-x

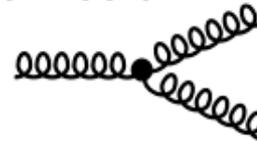


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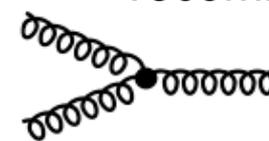


gluon emission



=

gluon recombination



At Q_s

First observation of gluon recombination effects in nuclei:

→ leading to a **collective gluonic system**

First observation of gluon recombination in different nuclei

→

Is this a **universal property**?

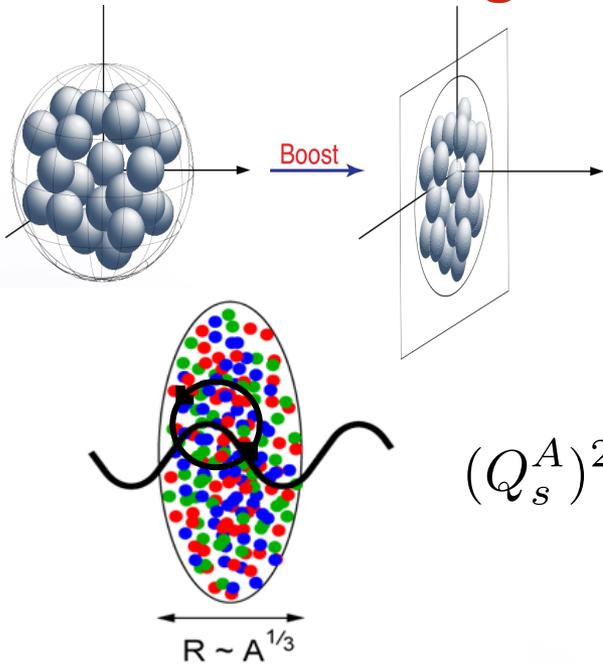
What is the new effective theory in this regime?



How to explore/study this new phase of matter?

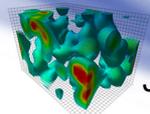
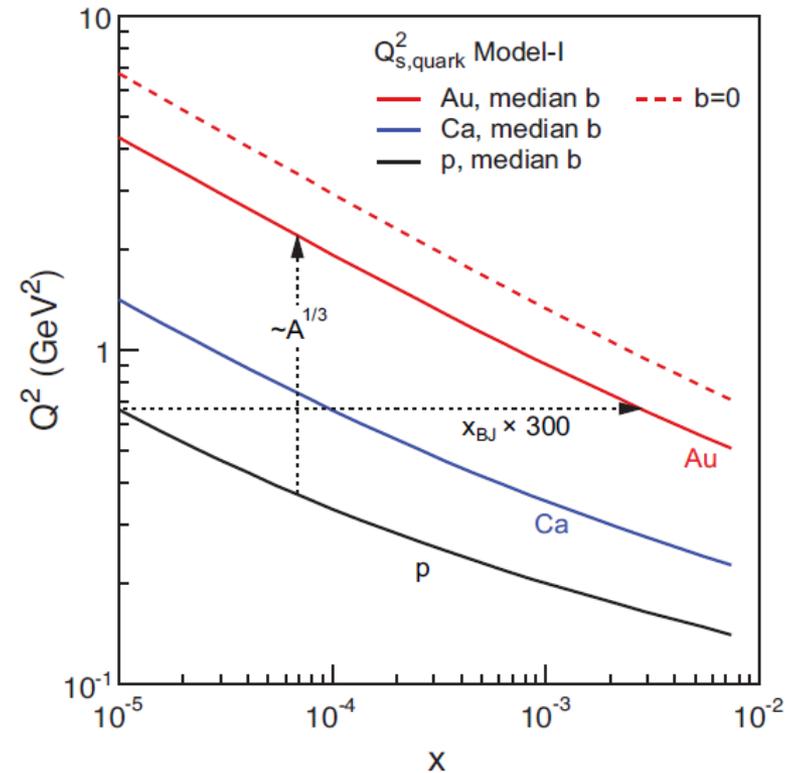
(multi-TeV) e-p collider (LHeC) OR [a \(multi-10s GeV\) e-A collider](#)

Advantage of nucleus →



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

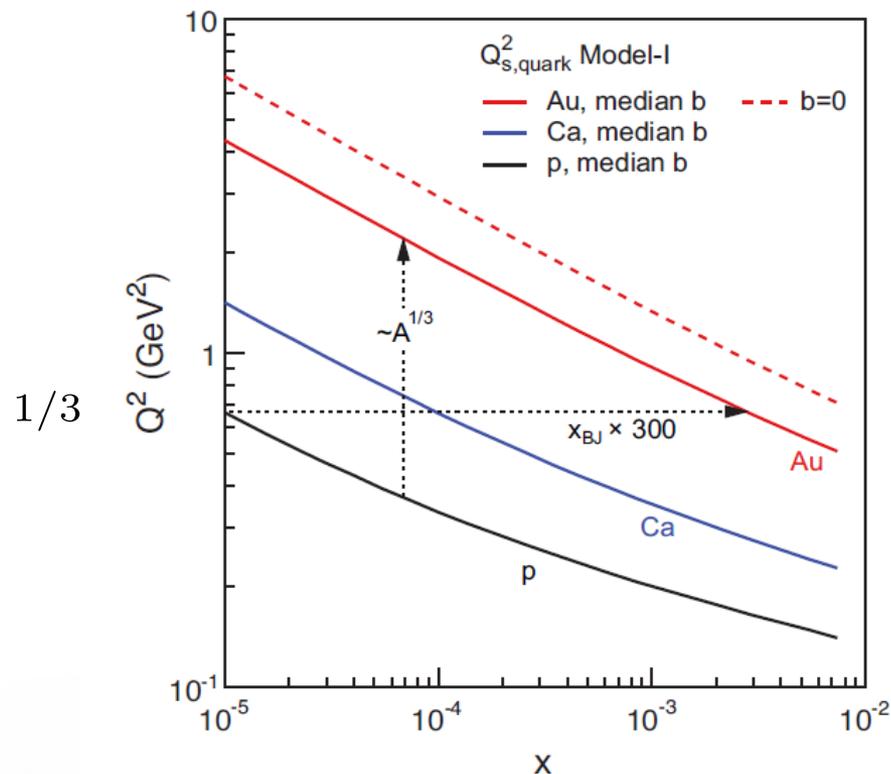
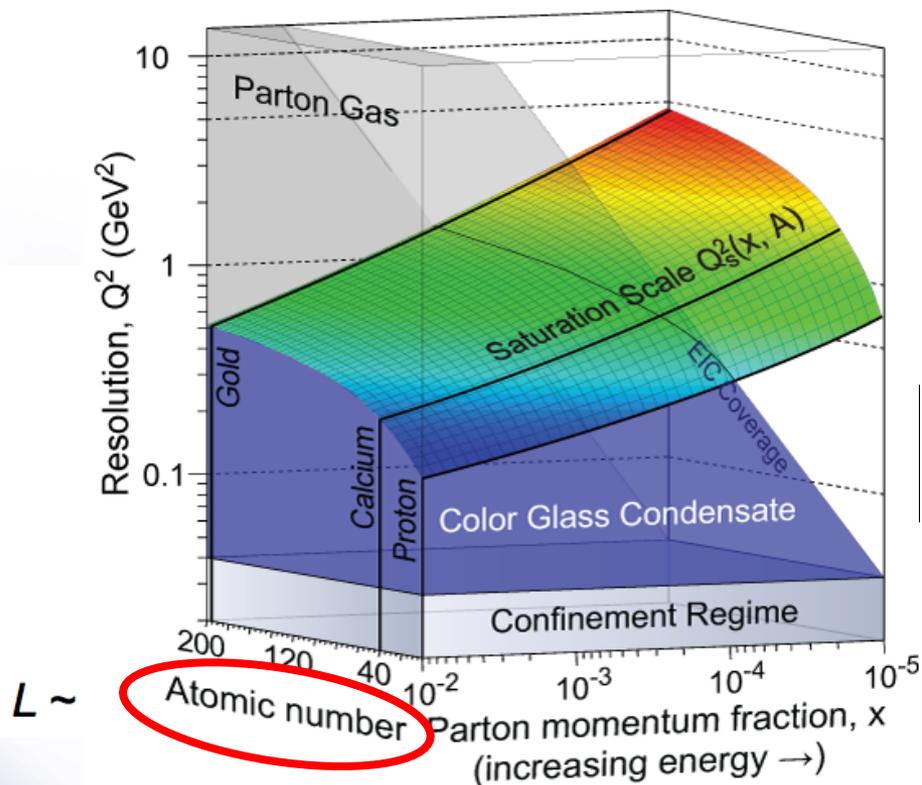
$$L \sim (2m_N x)^{-1} > 2 R_A \sim A^{1/3}$$



How to explore/study this new phase of matter?

(multi-TeV) e-p collider (LHeC) OR [a \(multi-10s GeV\) e-A collider](#)

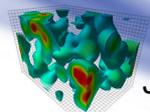
Advantage of nucleus →



Enhancement of Q_s with A :

Saturation regime reached at significantly lower energy

(read: "cost") in nuclei

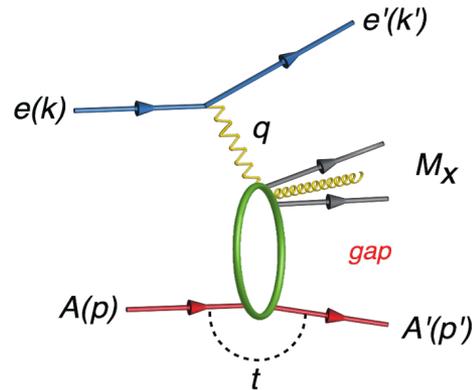


Diffraction for the 21st Century

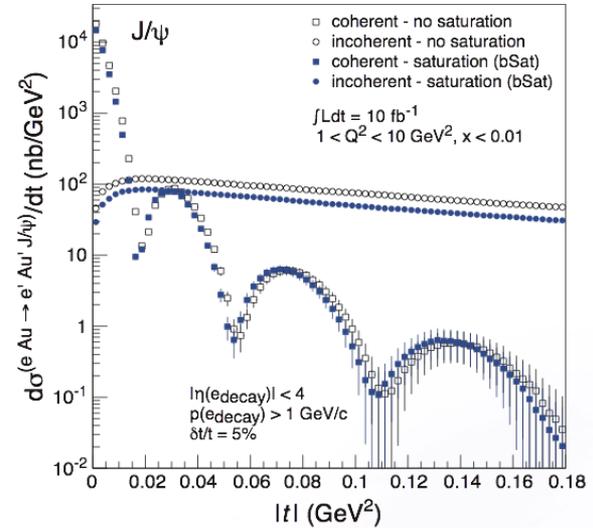
Diffraction cross-sections have strong discovery potential:

High sensitivity to gluon density in linear regime: $\sigma \sim [g(x, Q^2)]^2$

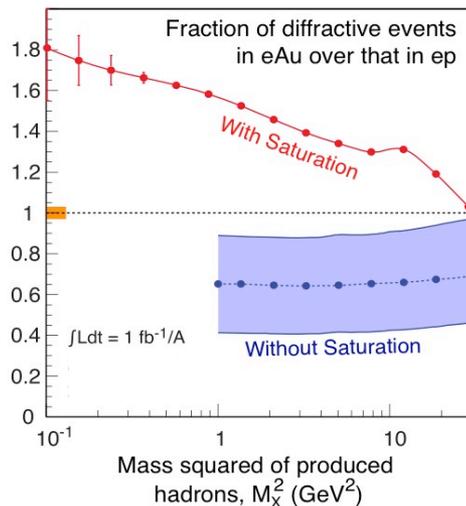
Dramatic changes in cross-sections with onset of non-linear strong color fields



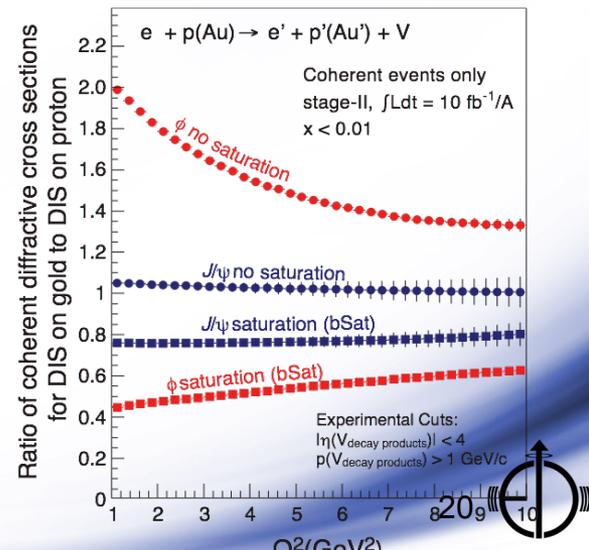
Extracting the gluon distribution $\rho(b_T)$ of nuclei via Fourier transformation of $d\sigma/dt$ in diffractive J/ψ production



Probing gluon saturation through measuring $\sigma_{diff}/\sigma_{tot}$



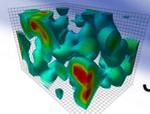
Probing Q^2 dependence of gluon saturation in diffractive vector meson production



ide@stonybrook.edu

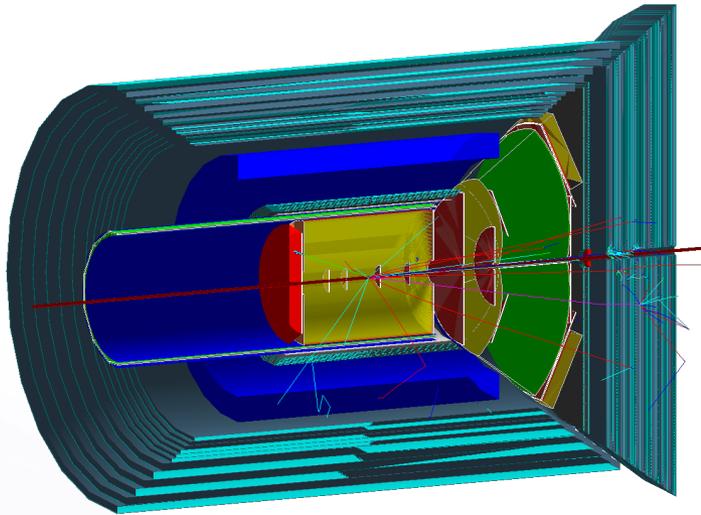
EIC at CAP Congress

June 14, 2018

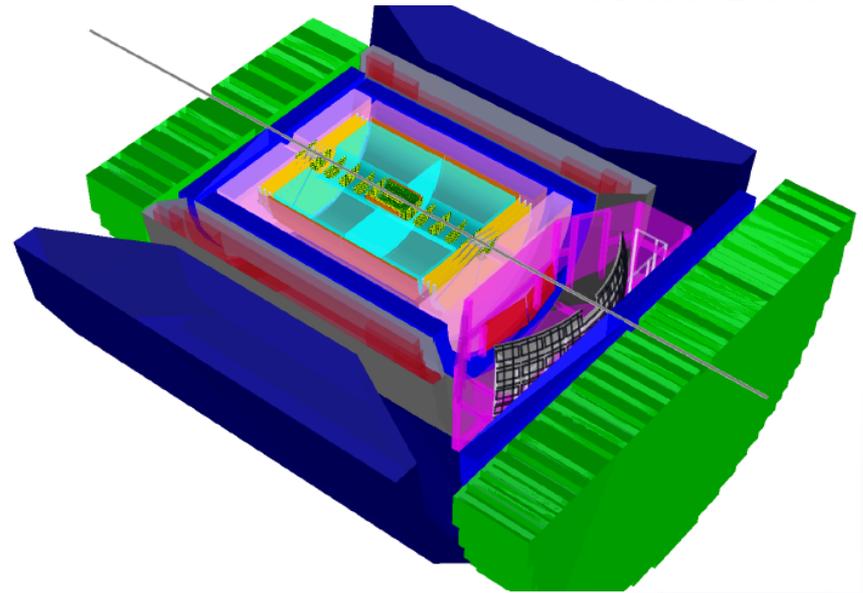


EIC Detector Concepts

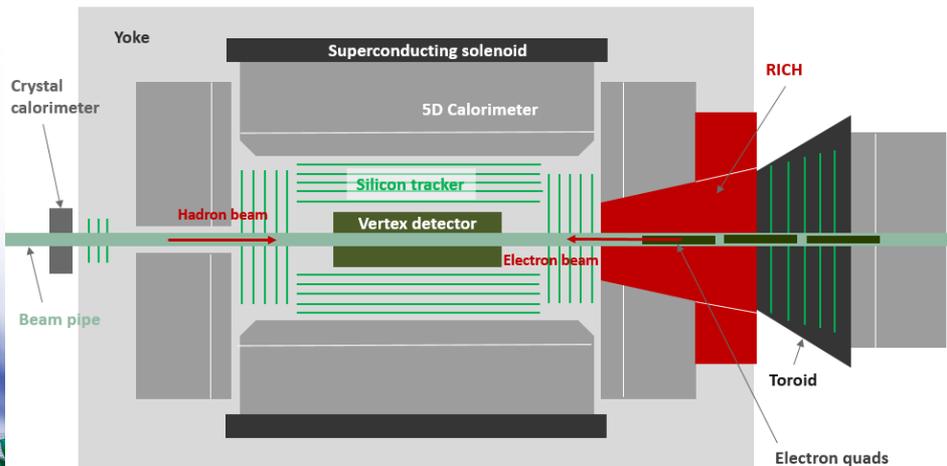
“eRHIC Day 1 Detector”



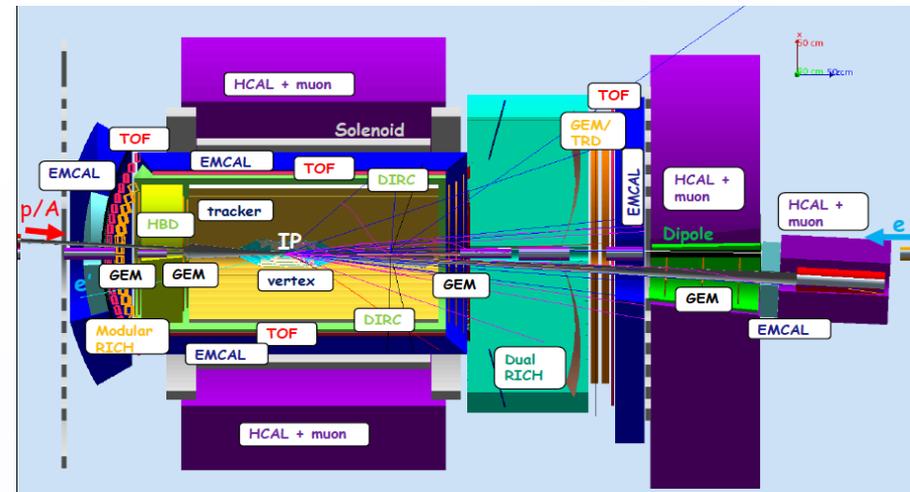
eRHIC Detector



TOPSiDE by ANL



JLEIC Detector

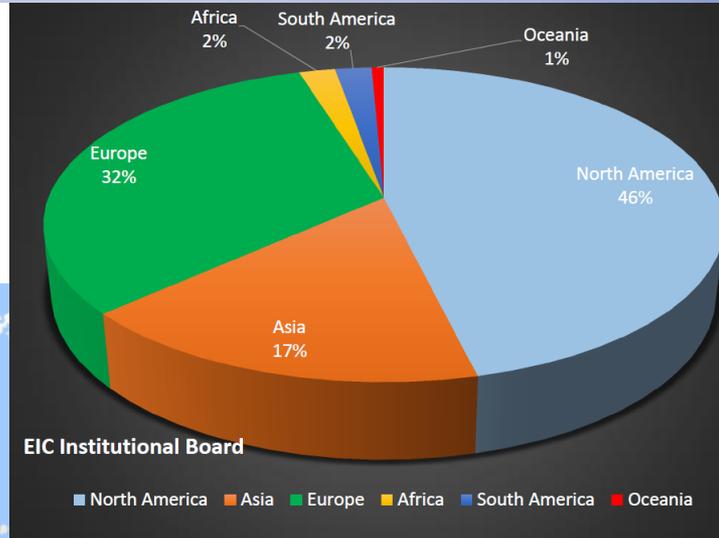


The EIC Users Group: EICUG.ORG

(no students included as of yet)

788 collaborators, 29 countries, 169 institutions... (June, 2018)

Map of institution's locations

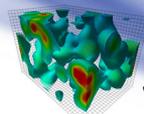
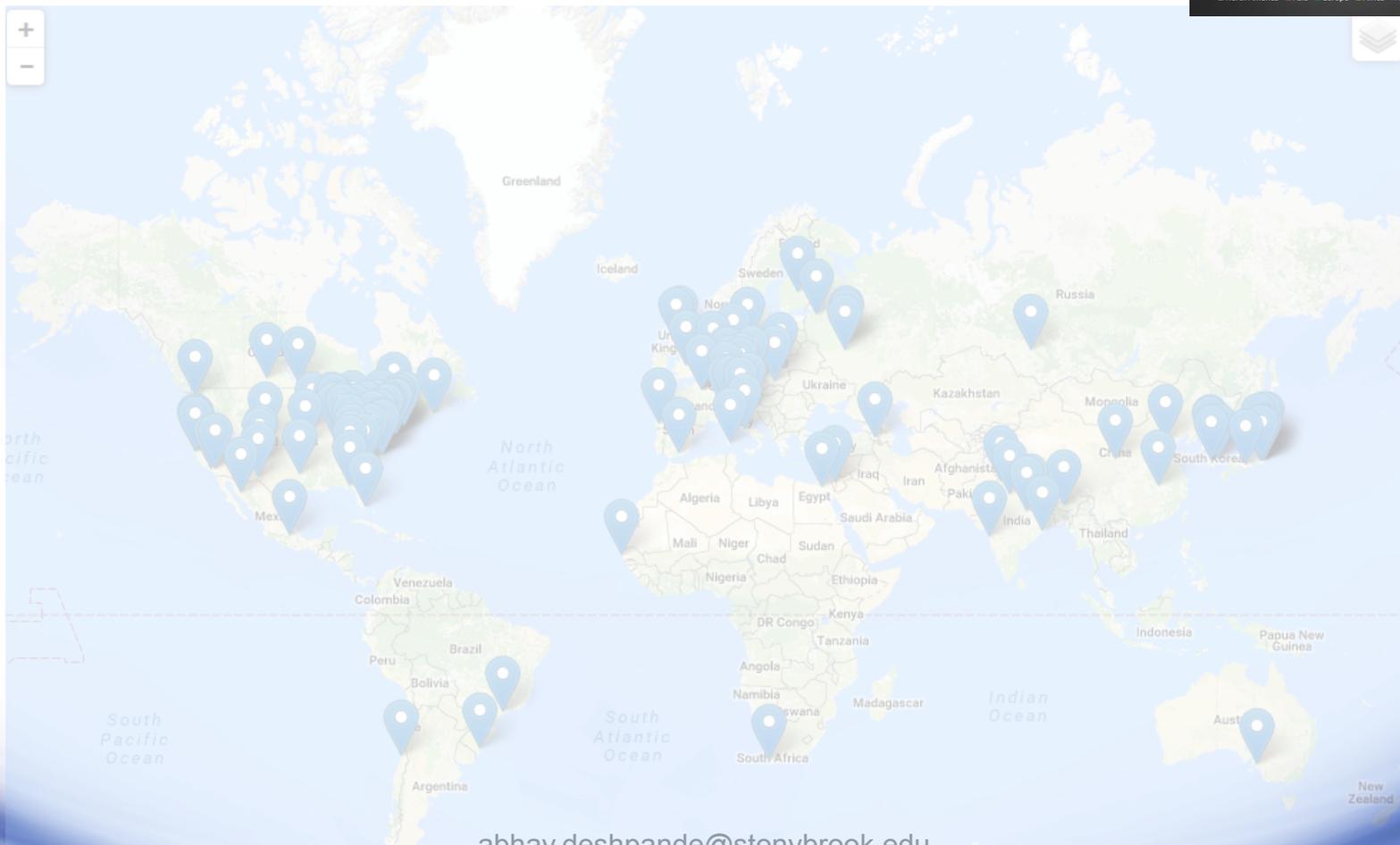
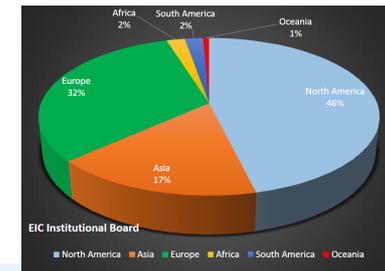


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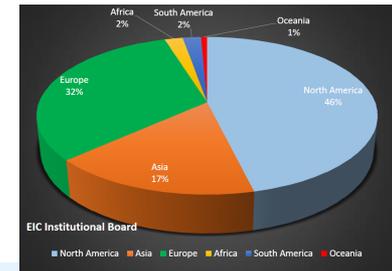


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Map of institution's locations



- Established, enthusiastic and active
- Setting up working groups for polarimetry, luminosity measurements, interaction region design, software use
- New physics ideas initiated with new influx of people....

Next meeting:

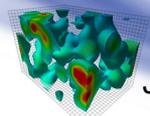
Catholic American University, Washington DC, July 29-Aug 2

<https://www.jlab.org/conferences/eicugm18/>



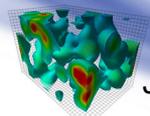
Path forward for the EIC:

- DOE requested a science review conducted by a panel appointed by the National Academy of Science (NAS)
 - Expect report by ~July 2018 (?)
- Positive NAS review will trigger the DOE's CD process
 - CD0 (“critical need for science”) FY19 after NAS report
 - CD1 after EIC design technical/cost review & site selection (FY20-FY21)
 - Major Construction funds (“CD3”) earliest by FY23”
 - Assuming 1.6% sustained increase over inflation of the next several years (Long Range Plan) as discussed in the US LRP



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. $\text{Sin}^2\Theta_W$)
- 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 2016
Ecole Polytechnique, Palaiseau, France
<http://poetic6.sciencesconf.org/>



INSTITUTE FOR NUCLEAR THEORY
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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)
May 5, 2017
Majumder, J. Putschke, L. Ruan

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

Chiral Signatures of R-process Nuclei (INT-17-3)
August 18, 2017
D. Kasen, G. Martinez-Pinedo, B. D.

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

ECT*
EUROPEAN CENTRE FOR THEORETICAL STUDIES
NUCLEAR PHYSICS AND RELATED AREAS

International Advisory Committee

Speakers

Moderator

Local Organizers

The Proton Mass: At the Heart of Most Visible Matter

From Tuesday, 3 April 2017 - 09:00 to Friday, 7 April 2017 - 13:30

Workshops

- NAC
- Links
- Safety

EICUG MEETING – July 18-22 TRIESTE 2017

Hosting Institution: INFN, Sezione di Trieste in cooperation with Trieste University

Workshops

- Hadron Mass
- Lattice QCD Nov 14 - 18, 2016: POETIC 7 Conference
- Hadron Mass Nov 17, 2016: Joint CTEQ Meeting and POETIC 7 Conference
- Nov 18, 2016: CTEQ Business Meeting

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-Salazar, C.A. Reduzinski, S.R. Klein, T. Lappi, M. Strikman

SIGN 2017: International Workshop on the Sign Problem in QCD and Beyond (INT-17-64W)
March 20 - 24, 2017
J. Carlson, S. Chandrasekharan, K. Dasgupta, 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. Pascau, W. Detmold, J. Qiu, W. Vogelwang

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

Programs related to EIC

Highly Active EIC Community has evolved

EICUG MEETING – July 18-22 TRIESTE 2017

Hosting Institution: INFN, Sezione di Trieste in cooperation with Trieste University

BROOKHAVEN **Jefferson Lab**

2018 Programs

Nuclear ab-Initio Theories and Neutrino Physics (INT-18-1a)
February 26 - March 30, 2018
C. Barberi, 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-18-1c)
October 1 - November 16, 2018
M. Alex, Y. Kovchegov, C. Marquet, A. Prokudin



Canadian participation: A warm welcome

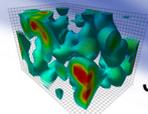
Five institutions already involved!

- Dalhousie University
 - Swadhin Taneja
- McGill University.
 - Thomas Brunner, Charles Gale, Sangyong Jeon, Ken Ragan,
- Mount Allison University
 - David Hornidge, Philippe Martel
- U. of Manitoba
 - Michael Gerrick, Juliet Mammei, Wim Van Oers
- U. of Regina
 - Zafar Ahemed, Mauricio Barbi, Garth Huber, Zicis Papandreou

Varied expertise & history: Nucleon Spin, GPD theory, Phenomenology, DIS at high energy (ZEUS), Current Jlab experiments

There is opportunity and need for many more!

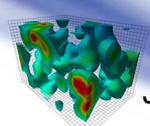
Detector R&D, Experiment design, theoretical investigations, *accelerator connections to BNL and JLab*



Summary

- The EIC will profoundly impact our understanding of QCD and its dynamics
→ the **structure of nucleons and nuclei** in terms of **sea quarks & gluons**
 - The EIC will enable **imaging** and provide **unprecedented kinematic reach** into **yet unexplored regions of phase spaces in QCD** with its high luminosity/energy, nuclei & beam polarization
- ⇒ **High potential for discovery within QCD with broad impact beyond**

- Outstanding questions raised by the science at BNL, CEBAF and CERN, and other hadron physics facilities around the world have **naturally led to the EIC Science & design parameters**
 - ❖ **World wide interest** in collaborating on the EIC
- Accelerator scientists at BNL and JLab together with international accelerator scientists are providing the intellectual and technical leadership to realize this frontier accelerator facility.



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**Canadian Participation in the Scientific Activities
Most Welcome & Essential**

abhay.deshpande@stonybrook.edu

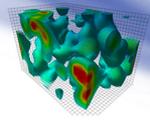
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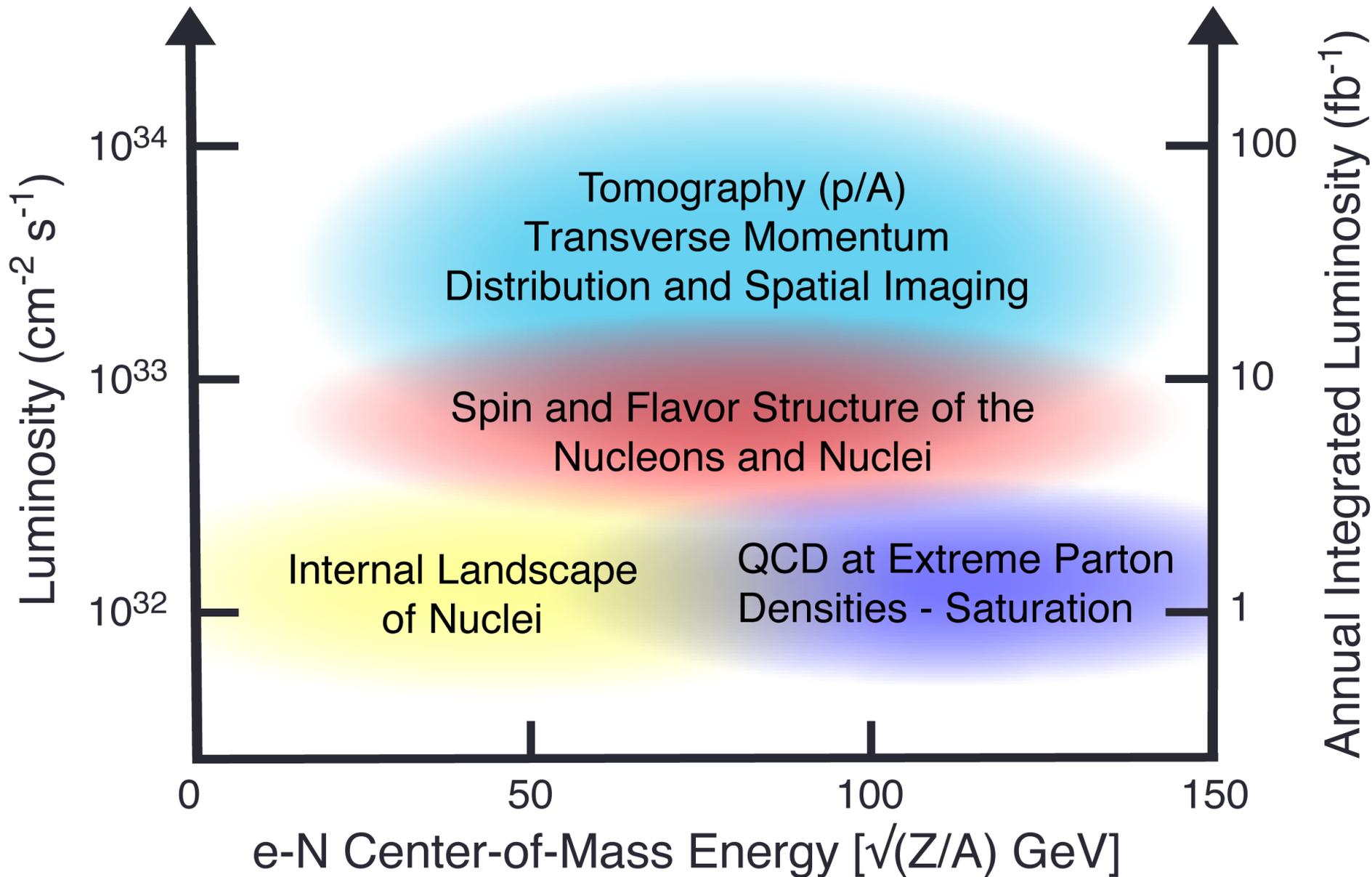
26



Thank you!



EIC Physics: CM & Luminosity



Gluon Saturation in Nuclei: The Oomph

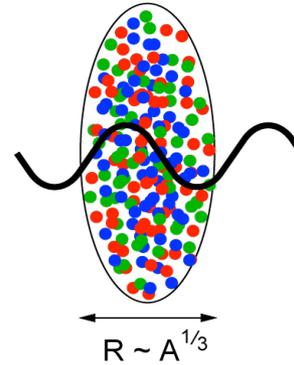
Probes interact over distances

$$L \sim (2m_N x)^{-1}$$

Probe interacts coherently with

all nucleons for

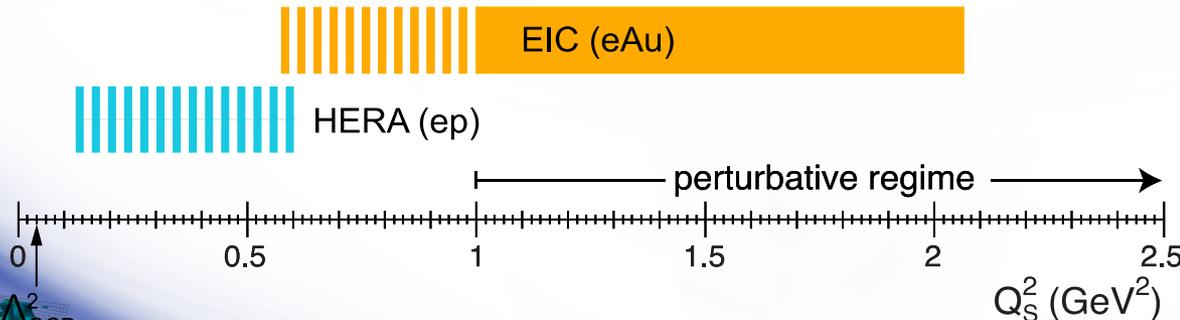
$$L > 2 R_A \sim A^{1/3}$$



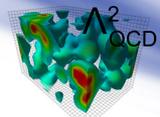
$$(Q_s^A)^2 \approx c Q_0^2 \left(\frac{A}{x} \right)^{1/3}$$

Enhancement of Q_s with A : saturation regime reached at significantly lower energy in nuclei (and lower cost)

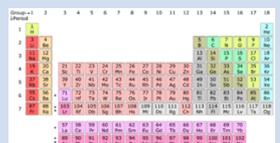
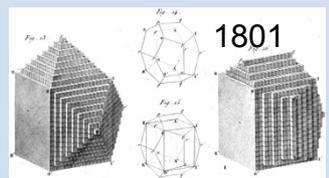
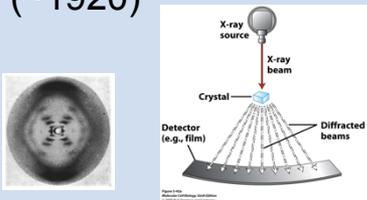
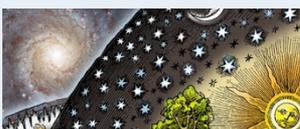
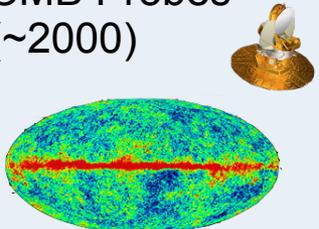
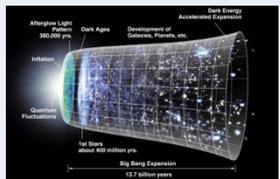
$$x \leq 0.01$$



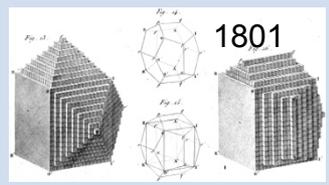
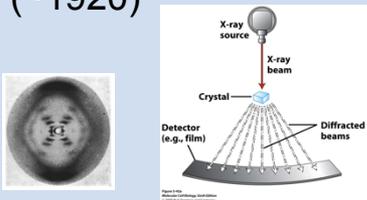
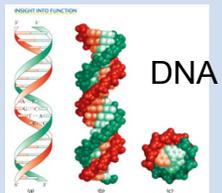
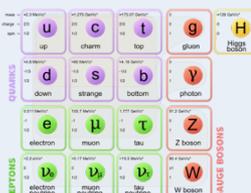
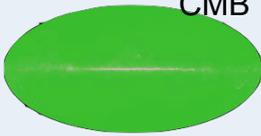
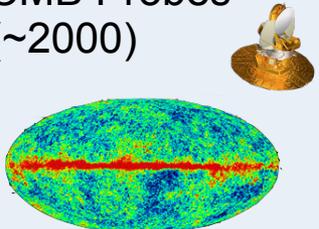
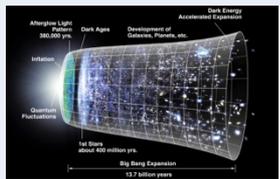
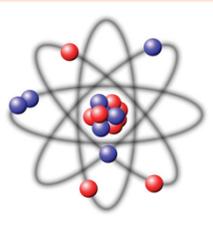
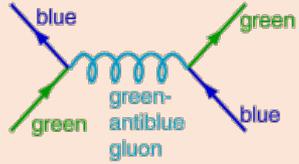
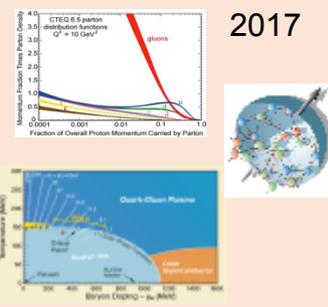
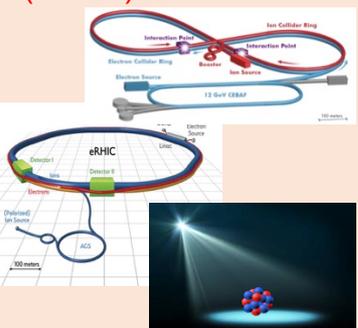
Nucleus serves as **amplifier** of the saturation scale



EIC: A Portal to a New Frontier

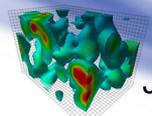
Dynamical System	Fundamental Knowns	Unknowns	Breakthrough Structure Probes (Date)	New Sciences, New Frontiers
<p>Solids</p> 	<p>Electromagnetism Atoms</p> 	<p>Structure</p>  <p>1801</p>	<p>X-ray Diffraction (~1920)</p> 	<p>Solid state physics Molecular biology</p>  <p>DNA</p>
<p>Universe</p> 	<p>General Relativity Standard Model</p> 	<p>Quantum Gravity, Dark matter, Dark energy. Structure</p>  <p>CMB 1965</p>	<p>Large Scale Surveys CMB Probes (~2000)</p> 	<p>Precision Observational Cosmology</p> 

EIC: A Portal to a New Frontier

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<p>Nuclei and Nucleons</p> 	<p>Perturbative QCD Quarks and Gluons</p> $\mathcal{L}_{\text{QCD}} = \bar{\psi}(i\partial - g\mathcal{A})\psi - \frac{1}{2}\text{tr} F_{\mu\nu}F^{\mu\nu}$ 	<p>Non-perturbative QCD Structure</p>  <p>2017</p>	<p>Electron-Ion Collider (2025+)</p> 	<p>Structure & Dynamics in QCD</p> 

Connections to other areas of physics

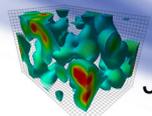
- Explorations of the stringy dynamics of hadrons led to the string theory of Gravity. A weakly coupled regime of 10-d **gravity** is conjectured to be dual to strongly coupled 4-d QCD-like theory. *Further profound connections may emerge from deeper investigations of the QCD landscape.*
- The dynamics 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.*



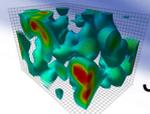
Charge to the National Academy

The committee will assess the scientific justification for the US domestic electron ion collider facility. In particular the committee will address the following questions:

- ◇ What is the merit and significance of the science? What is its importance in the overall context of research in nuclear physics and physical sciences in general?
- ◇ Capabilities of other facilities, existing and planned, domestic and international? What would be the unique scientific role of the US EIC complementary to existing and planned facilities?
- ◇ What are the benefits of the US leadership in nuclear physics?
- ◇ What are the benefits to other fields of science and to society?



- **Funded by Simon's Foundation and NY State & supported by Stony Brook University and BNL**
- All members of EIC Users Group are welcome to participate
- **Workshops in 2018:**
 - Light ion beams at the EIC, Ghent Belgium, (February 2018)
 - Pre-DIS workshop on EIC and its connections to other areas, Kobe, (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 (October 2018)
 - Inaugural meeting of the Center (November 2018)
- **Other:**
 - 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 starting in 2019.
- If you want to participate: Please contact me ([Abhay Deshpande](#))



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

