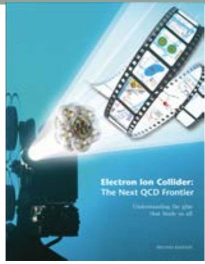
Center for Frontiers in Nuclear Science

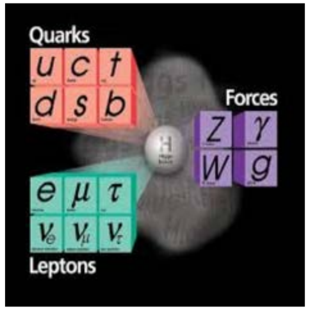


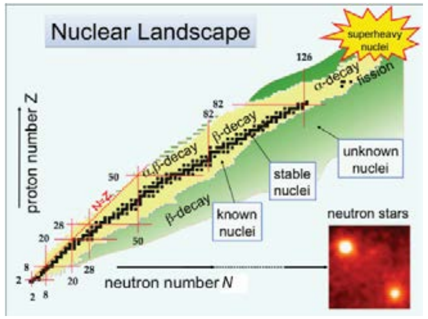
Electron Ion Collider: The next QCD frontier

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





Stony Brook University

Abhay Deshpande

BROOKHAVEN NATIONAL LABORATORY

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:

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

(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

Non-linear Structure of QCD has Fundamental Consequences

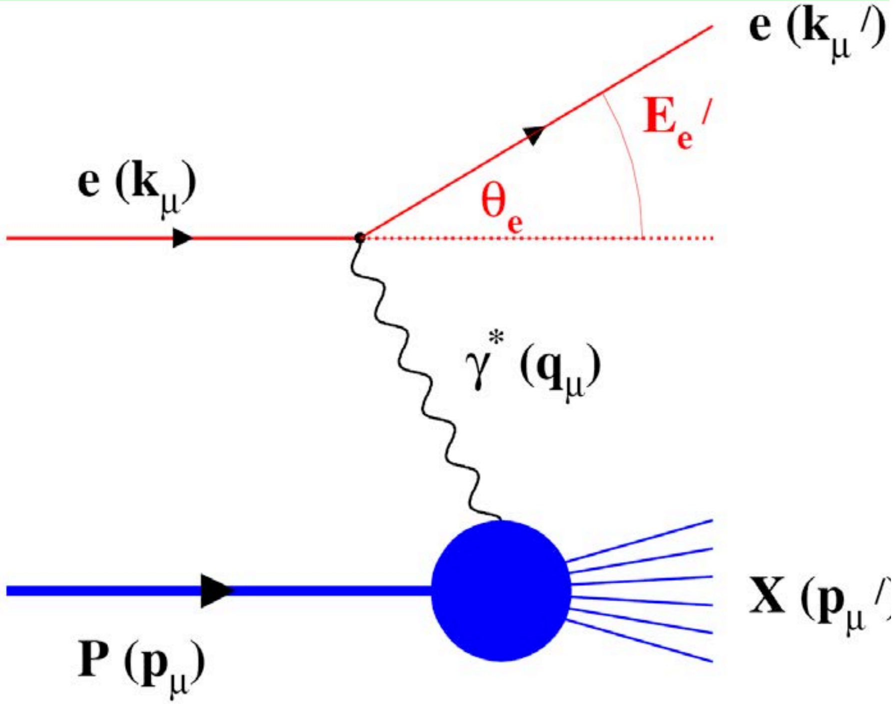
Emergence of spin, mass & confinement, gluon fields

- Quark (Color) confinement:
  - Unique property of the strong interaction
  - Consequence of nonlinear gluon self-interactions
  - Clues: deconfinement in QGP @ LHC/RHIC & fragmentation/hadronization @ EIC
- Strong Quark-Gluon Interactions:
  - Confined motion of quarks and gluons – Transverse Momentum Dependent Parton Distributions (TMDs): *Measured at an EIC, and used in others including LHC*
  - Confined spatial correlations of quark and gluon distributions – Generalized Parton Distributions (GPDs): *Measured at an EIC, and used elsewhere*
- 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?
  - *To be measured in light ion and asymmetric collisions at LHC/RHIC and at the EIC*
  - *Initial State of Heavy Ion Collisions*

LHC/RHIC & EIC are all essential for the deeper understanding of QCD

Deep Inelastic Scattering: Precision & Control

Kinematics:



Inclusive events: e+p/A → e'+X

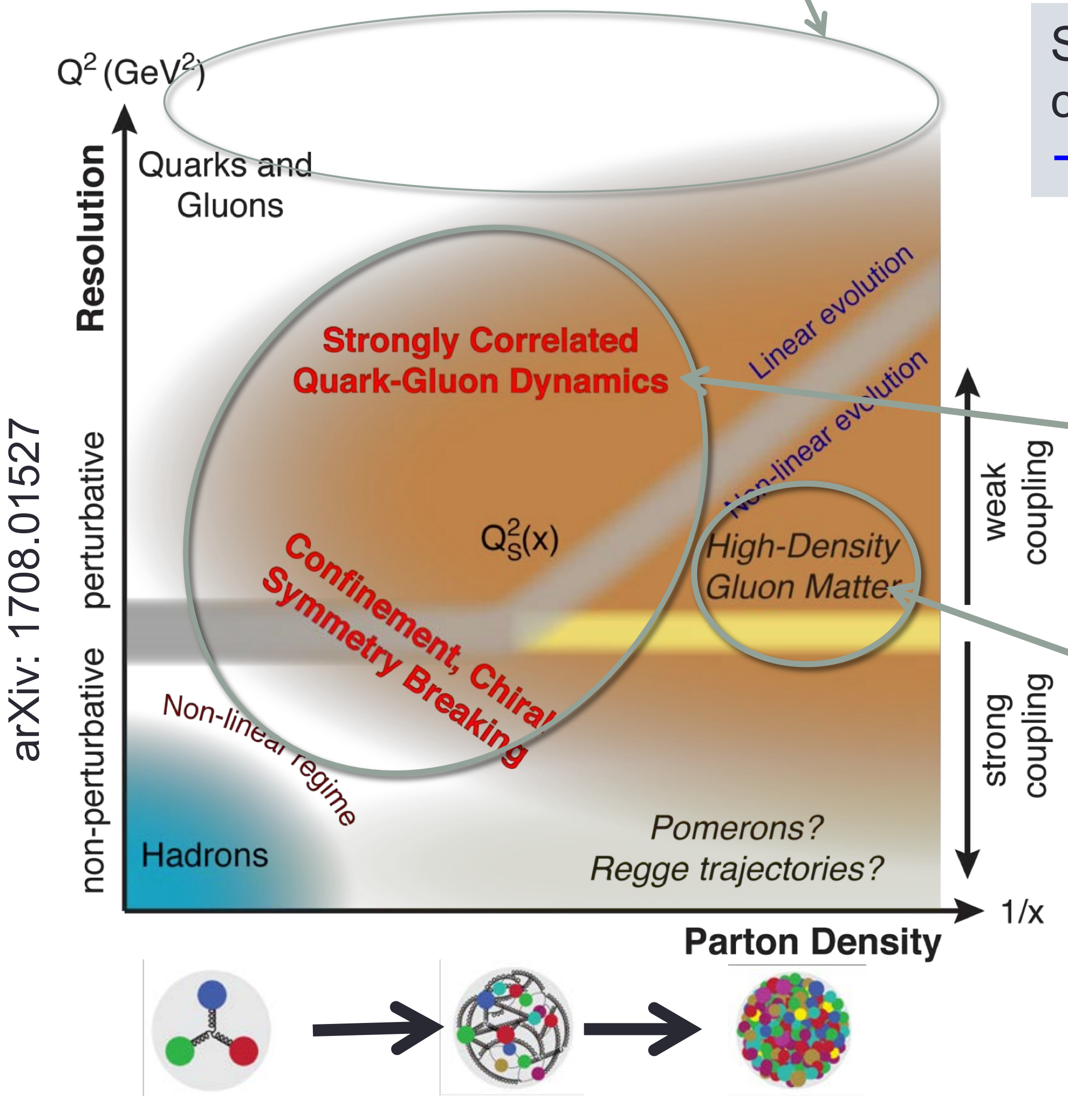
Semi-Inclusive events: e+p/A → e'+h(π,K,p,jet)+X

Exclusive events: e+p/A → e'+ p'/A'+ h(π,K,p,jet)

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

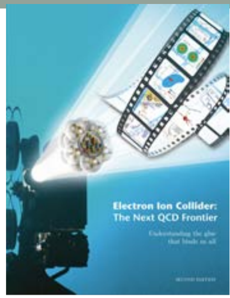
Emergent Dynamics in QCD

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

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



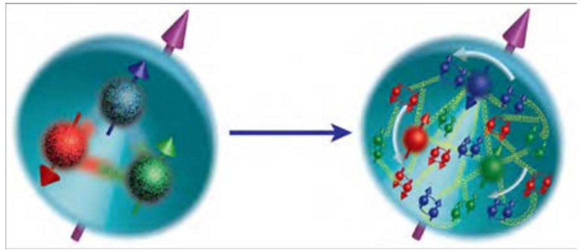
A new facility is needed to investigate, with precision, the dynamics of gluons & sea quarks and their role in the structure of visible matter

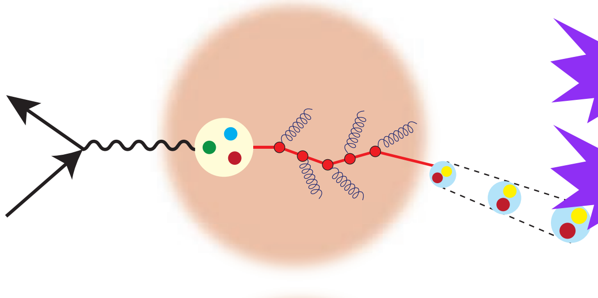
PID

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

PID

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





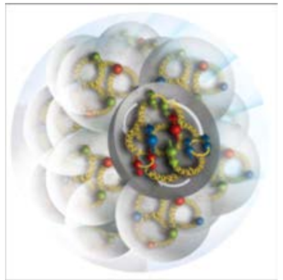
PID

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

PID

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

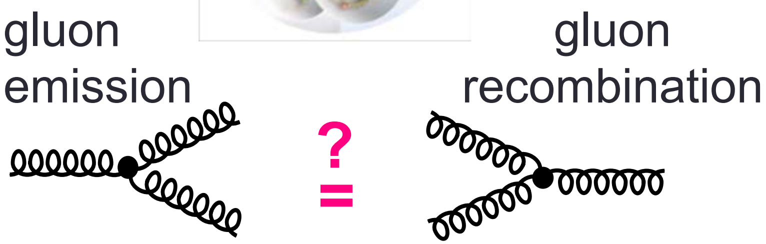
How do the quark-gluon interactions create nuclear binding?



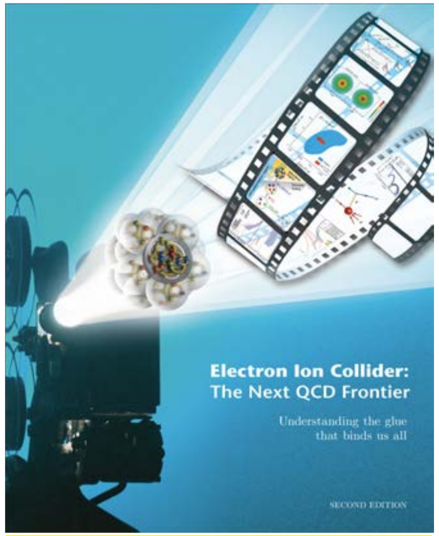
PID

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



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

For e-N collisions at the EIC:

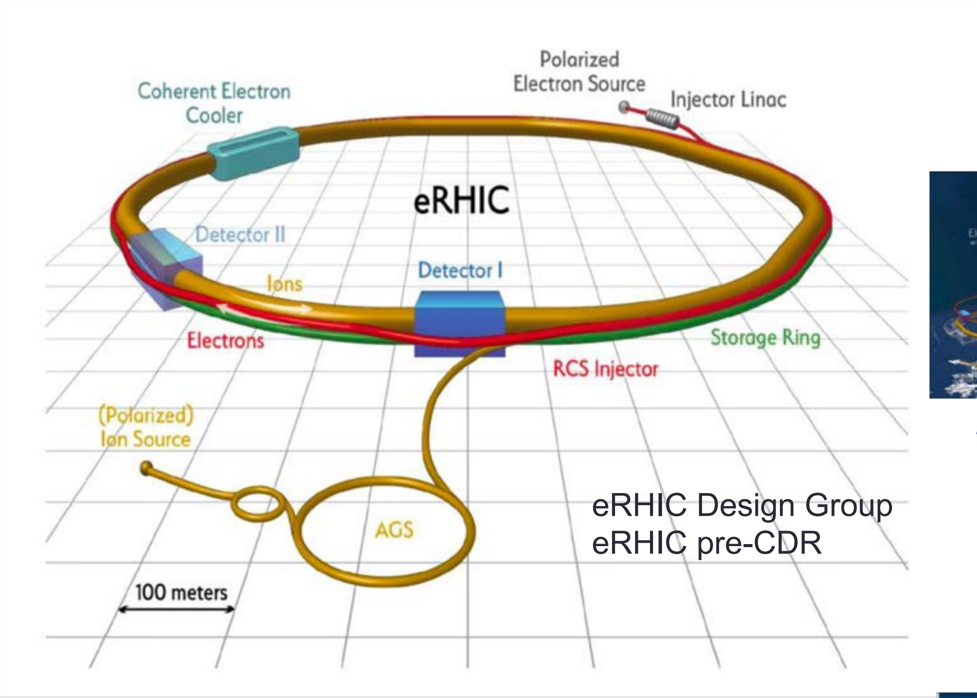
- ✓ Polarized beams: e, p, d/^{3}He
- ✓ e beam 5-10(20) GeV
- ✓ Luminosity L_{ep} ~ 10^{33-34} cm^{-2}sec^{-1}
  100-1000 times HERA
- ✓ 20-100 (140) GeV Variable CoM

For e-A collisions at the EIC:

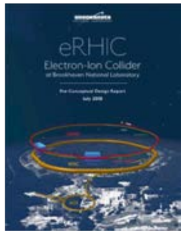
- ✓ **Wide range in nuclei**
- ✓ Luminosity per nucleon same as e-p
- ✓ Variable center of mass energy

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

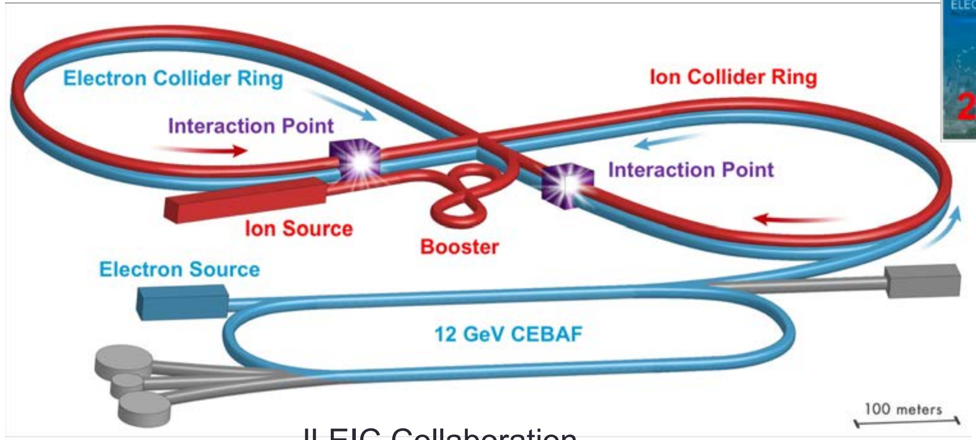
Both designs use DOE's significant investments in infrastructure

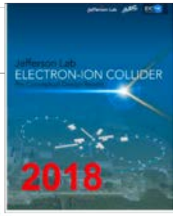


eRHIC Design Group
eRHIC pre-CDR



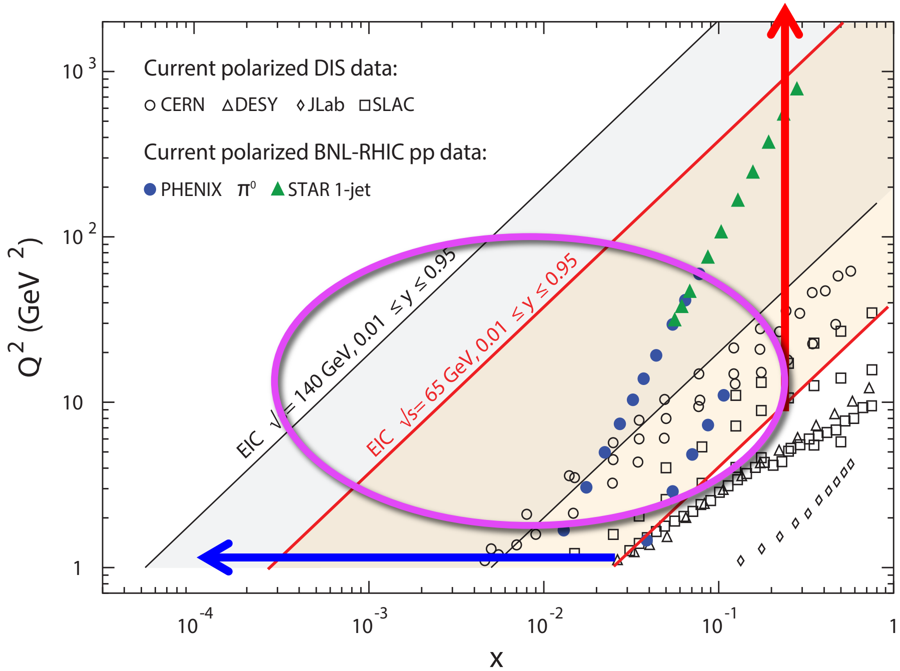
2018





JLEIC Collaboration
JLEIC Pre-CDR about to be finalized

EIC: Kinematic reach & properties

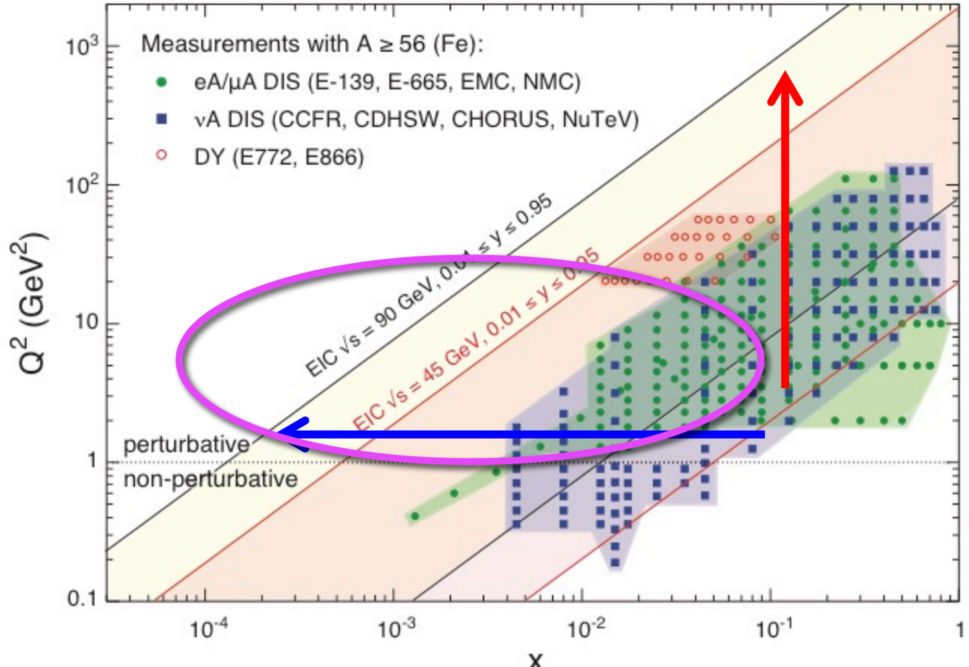


For e-N collisions at the EIC:

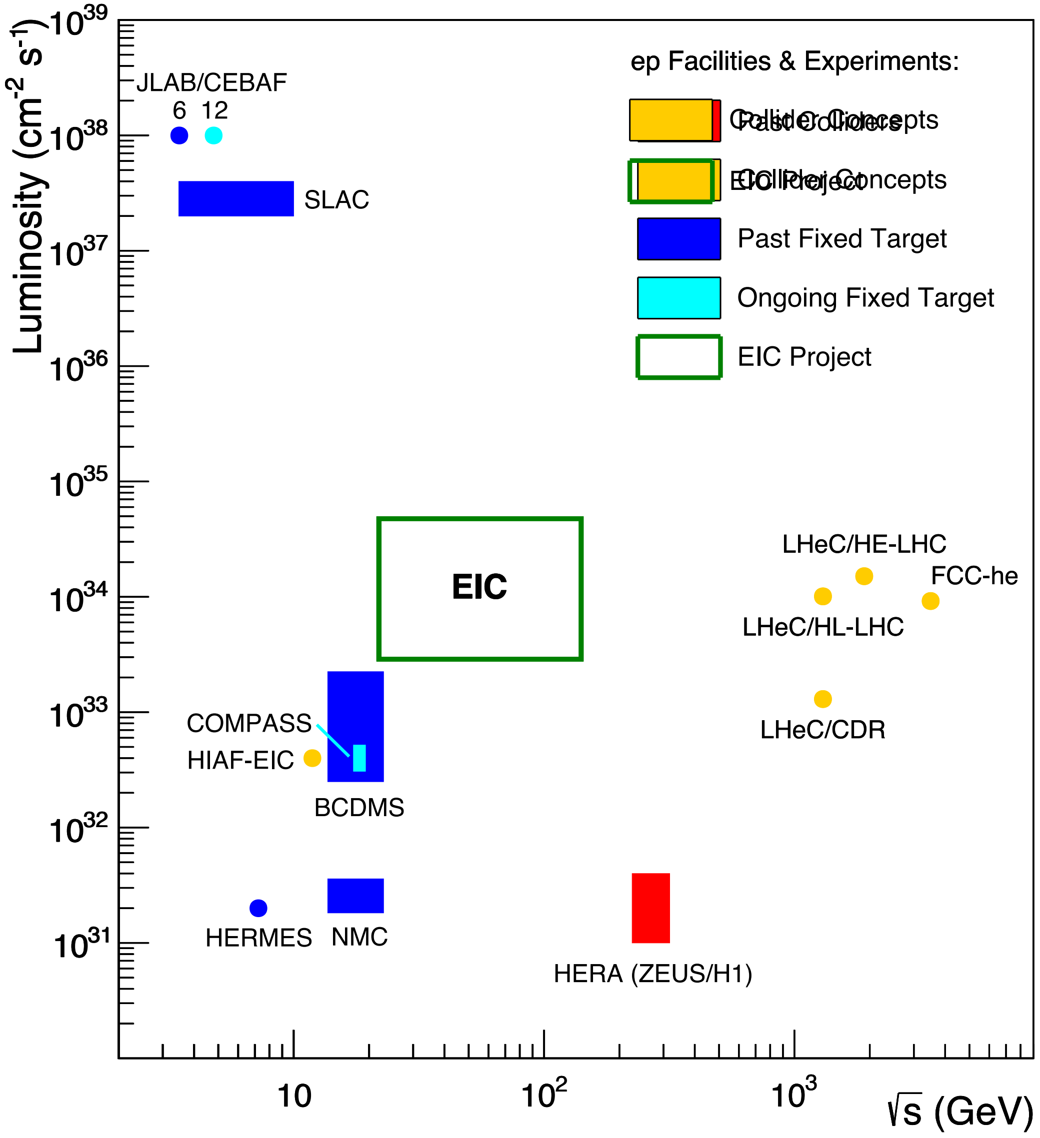
- ✓ **Polarized** beams: e, p, d/^{3}He
- ✓ Variable center of mass energy
- ✓ Wide Q^2 range → evolution
- ✓ Wide x range → spanning valence to low-x physics

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.

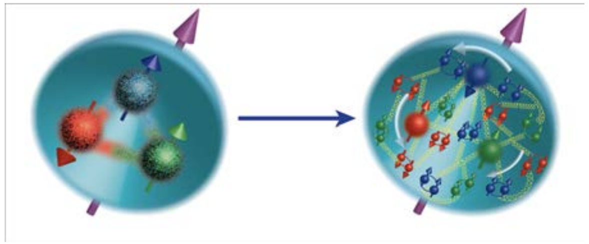
However, if we ask for:

- high luminosity & wide reach in √s
- polarized lepton & hadron beams
- nuclear beams

EIC stands out as unique facility …

Proton as a laboratory for QCD

3D structure of hadrons in momentum and position space….



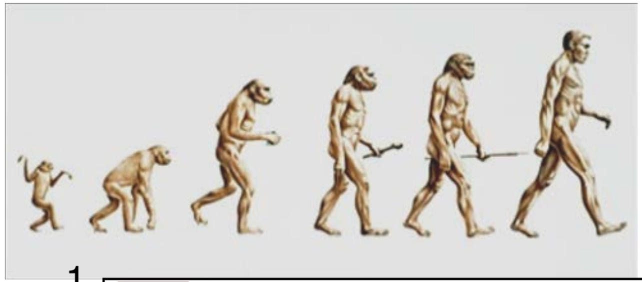
Understanding of Nucleon Spin

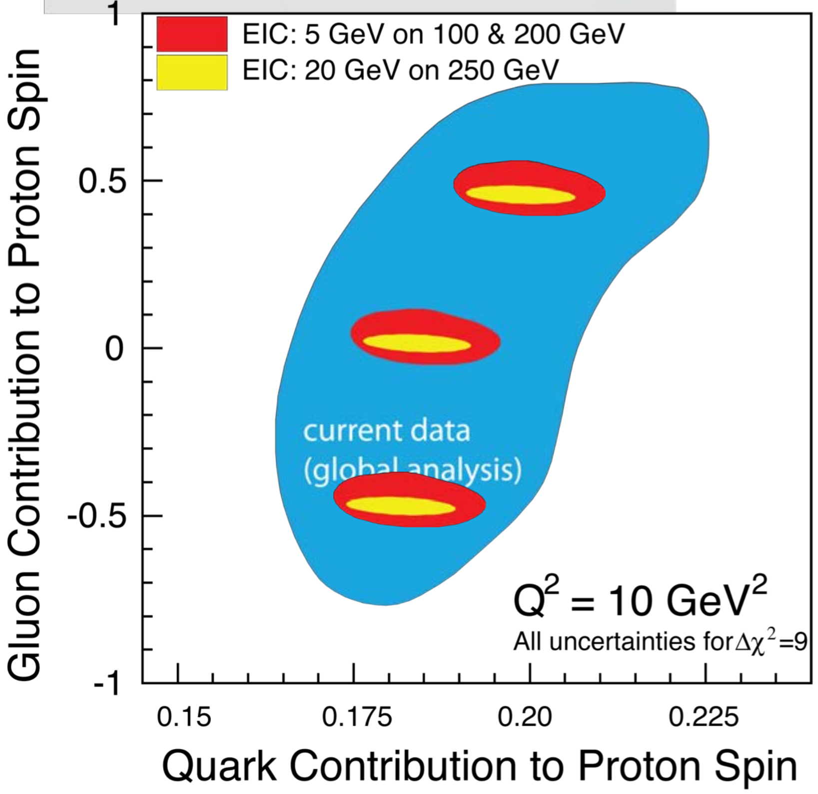
PID

$$\frac{1}{2} = \left[\frac{1}{2}\Delta\Sigma + L_Q\right] + \left[\Delta g + L_G\right]$$

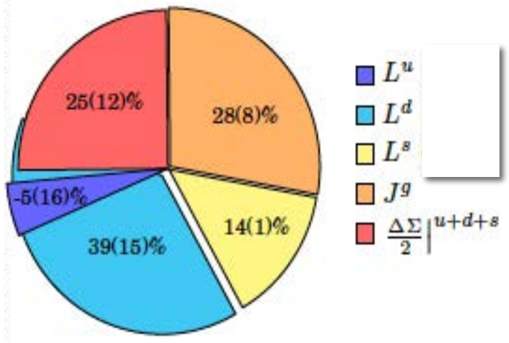
$\Delta\Sigma/2$ = Quark contribution to Proton Spin
L_Q = Quark Orbital Ang. Mom
Δg = Gluon contribution to Proton Spin
L_G = Gluon Orbital Ang. Mom

Precision in $\Delta\Sigma$ and Δg ➔ A clear idea Of the magnitude of L_Q+L_G

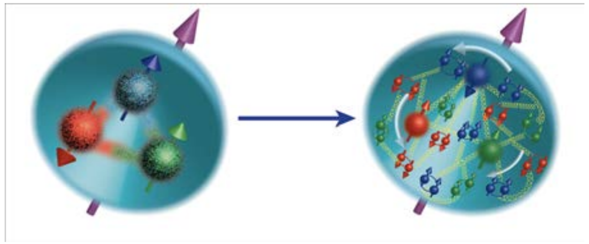




Spin and Lattice: Recent Activities



- **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:** χQCD Collaboration, PRD91, 014505, 2015



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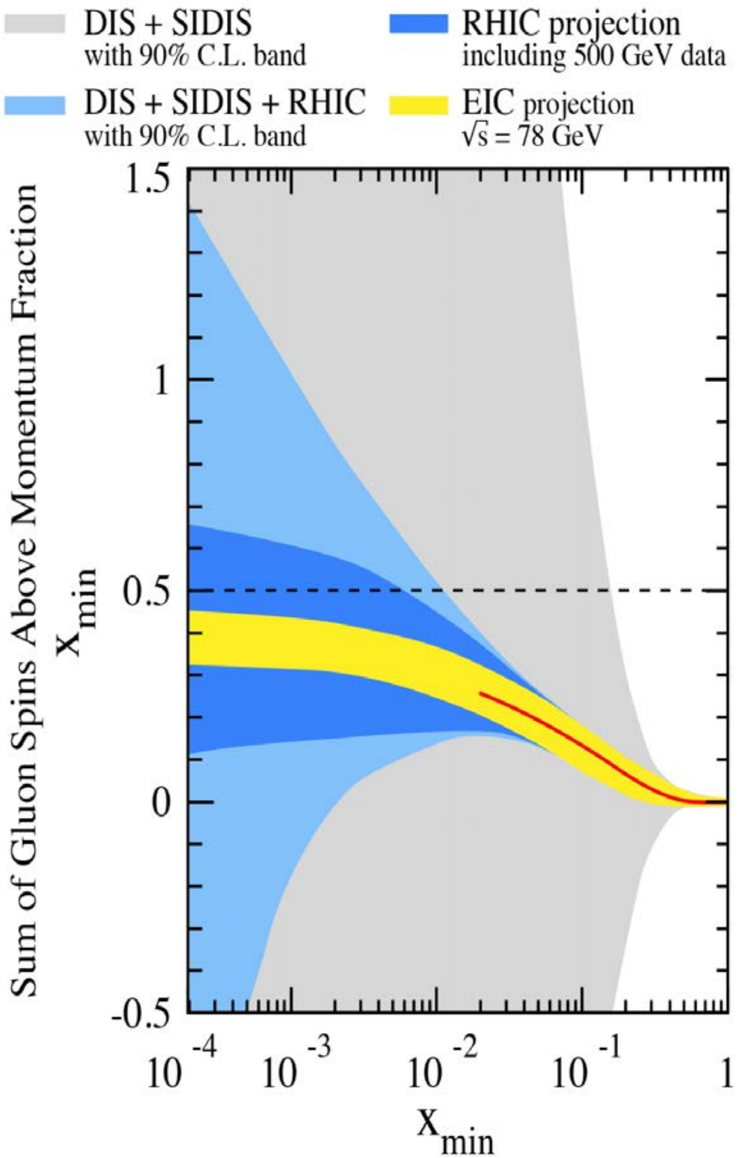

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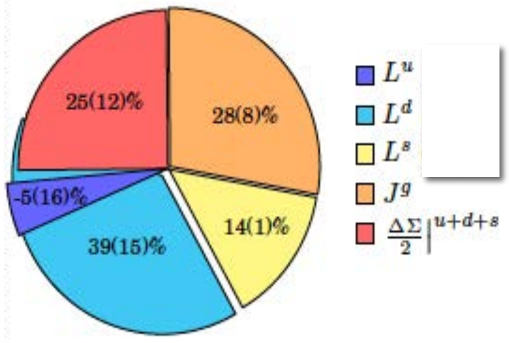

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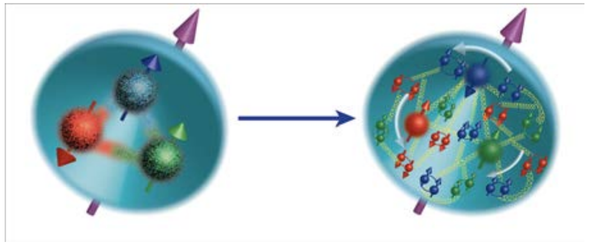

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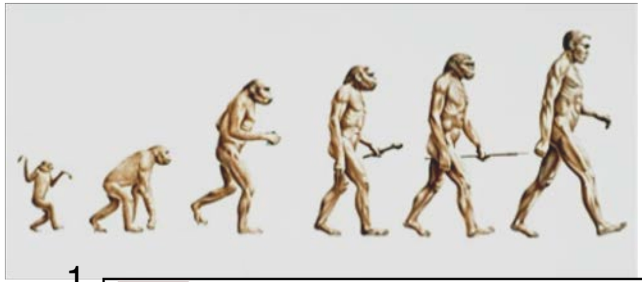

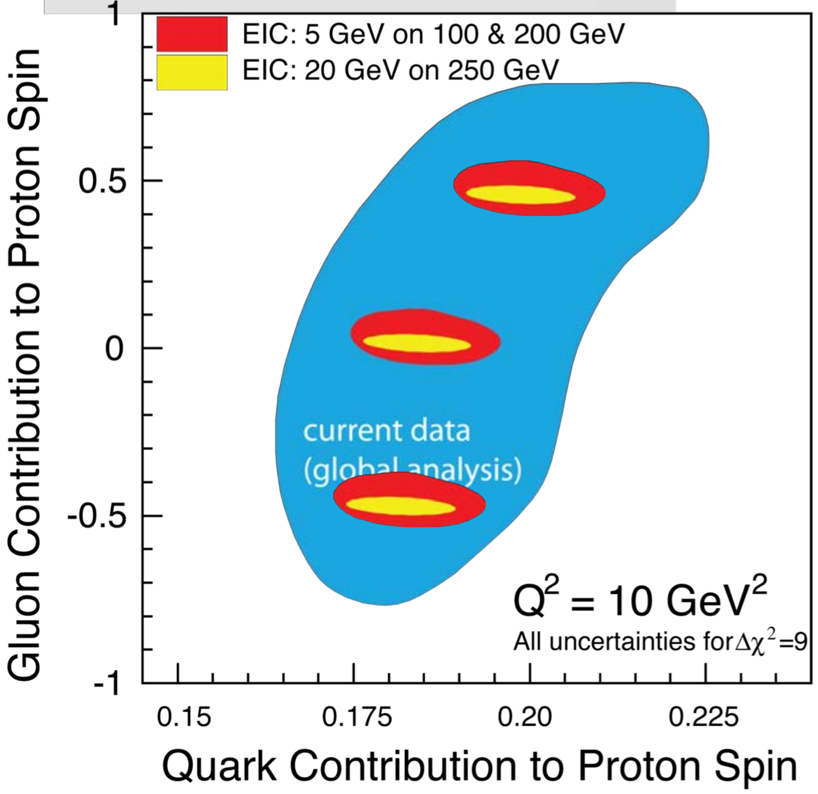

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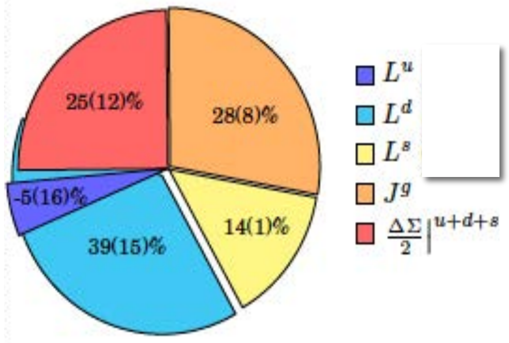

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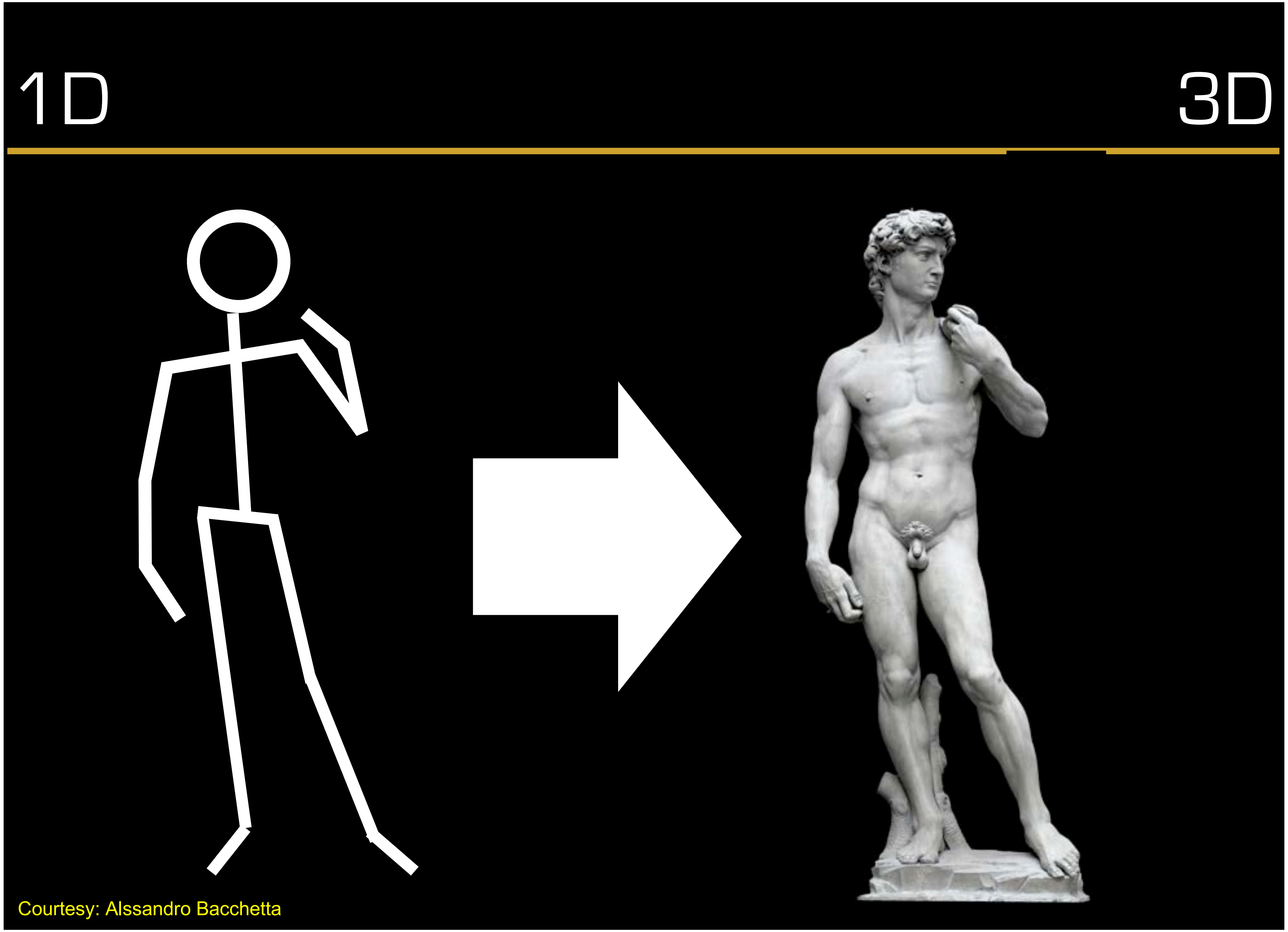
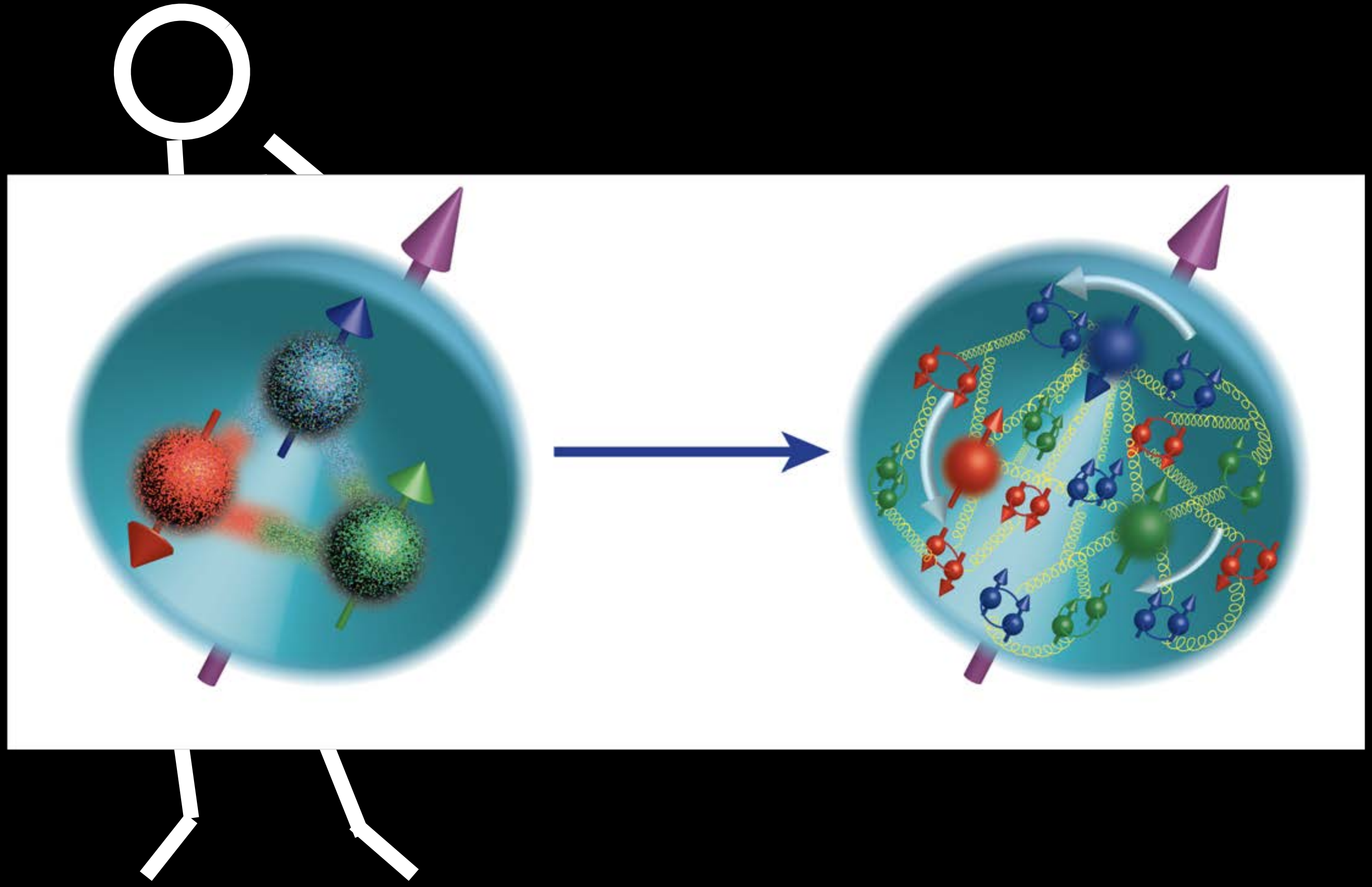

1D
3D
Courtesy: Alssandro Bacchetta

1D 3D



Courtesy: Alssandro Bacchetta

3-Dimensional Imaging Quarks and Gluons

PID

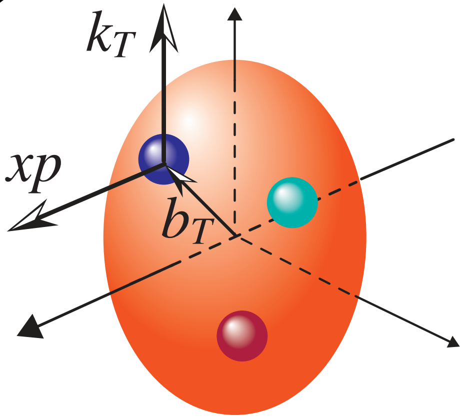
Wigner functions $W(x,b_T,k_T)$

offer unprecedented insight into confinement and chiral symmetry breaking.

$W(x,b_T,k_T)$

Momentum space $\int d^2b_T$ → $f(x,k_T)$

$\int d^2k_T$ ***Coordinate space*** → $f(x,b_T)$



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

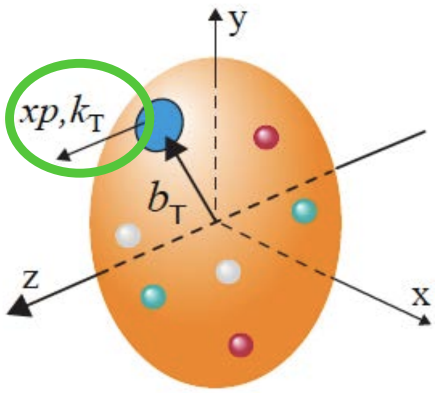
Spin-dependent 2D coordinate space (transverse) + 1D (longitudinal momentum) images from exclusive scattering
→ **GPDs**

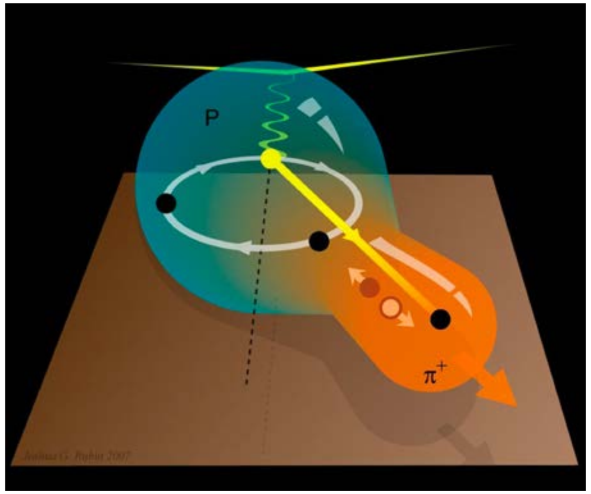
Position and momentum → Orbital motion of quarks and gluons

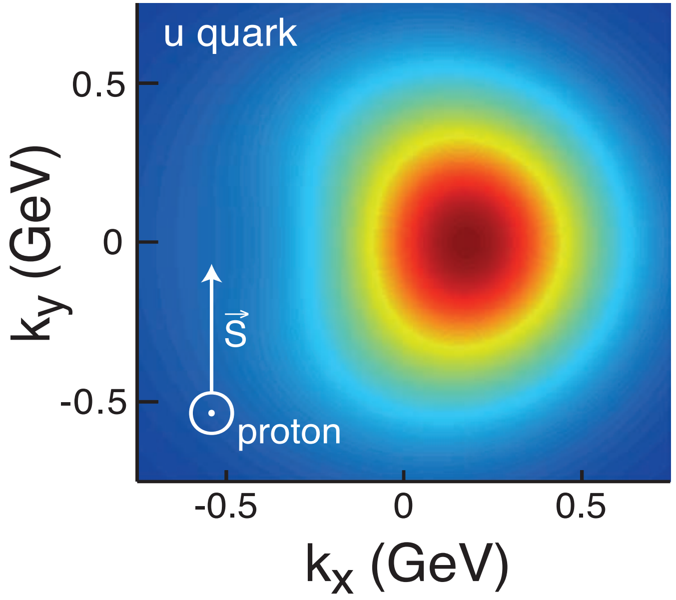
Measurement of Transverse Momentum Distribution

Semi-Inclusive Deep Inelastic Scattering

PID



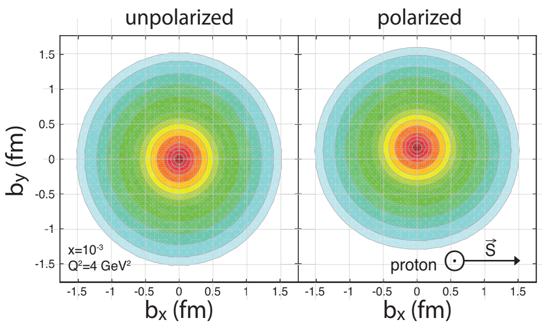




- Naturally, two scales:
  - high Q – localized probe
    To "see" quarks and gluons
  - Low p_T – sensitive to confining scale
    To "see" their confined motion
  - *Theory – QCD TMD factorization*

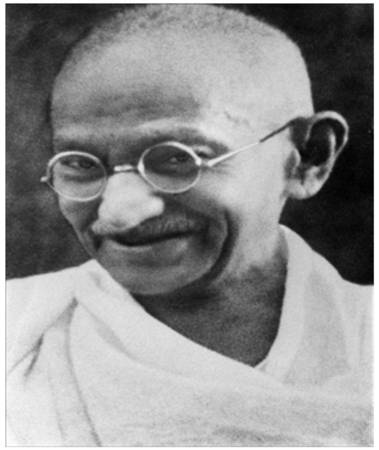
Spatial Imaging of quarks & gluons

Generalized Parton Distributions



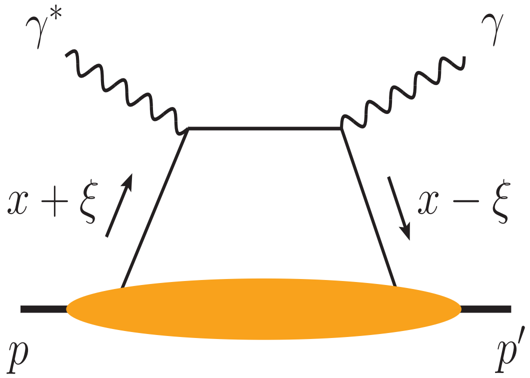
Historically, investigations of nucleon structure and dynamics involved breaking the nucleon…. (exploration of internal structure!)

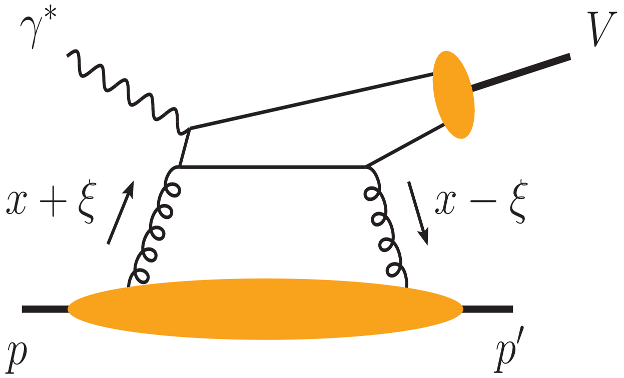
To get to the **orbital motion** of quarks and gluons we need **non-violent collisions**



Exclusive measurements → measure "everything"

Quarks Motion





Gluons: Only @ Collider

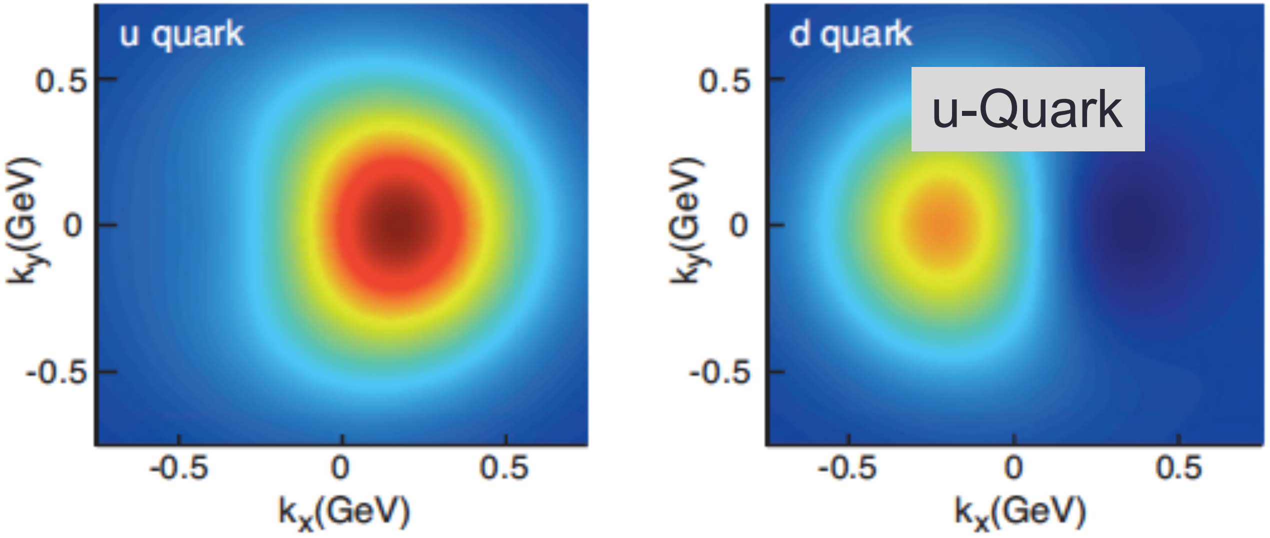
Deeply Virtual Compton Scattering
Measure all three final states
e + **p** → e'+ **p'**+ γ

Fourier transform of momentum transferred=(p-p') → Spatial distribution

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

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

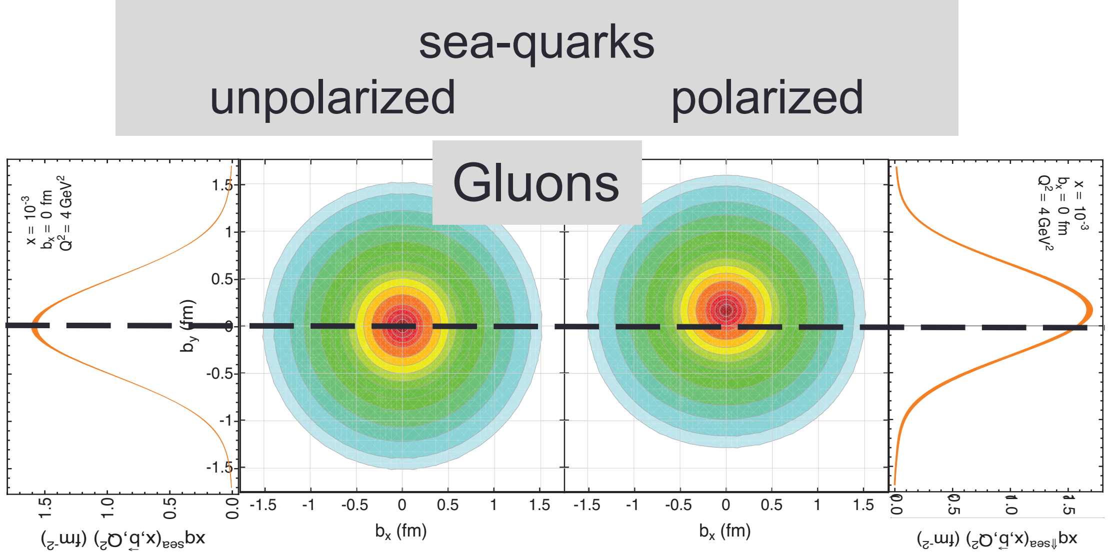
Transverse Momentum Distributions



PID

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

Transverse Position Distributions



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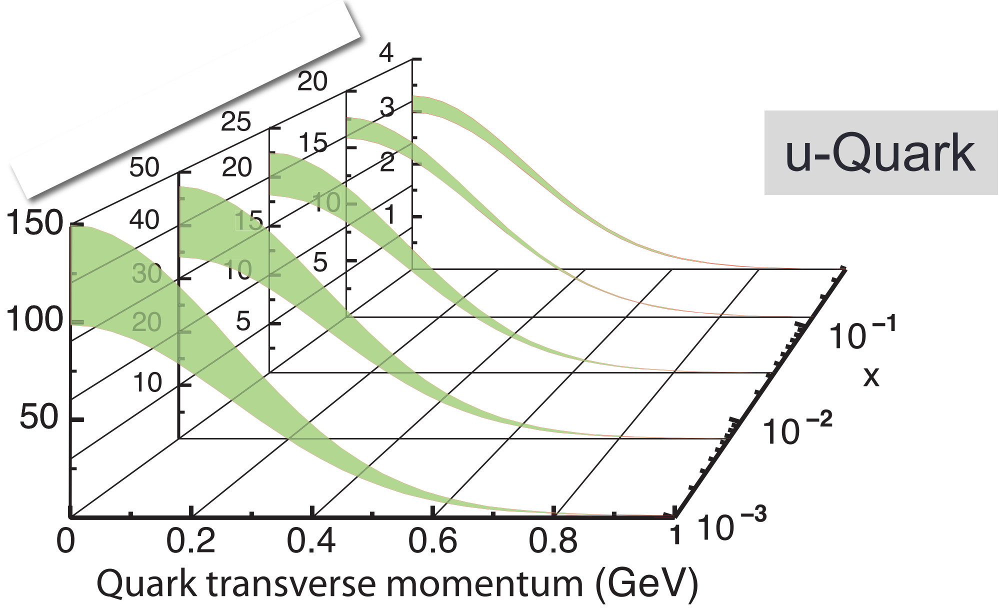

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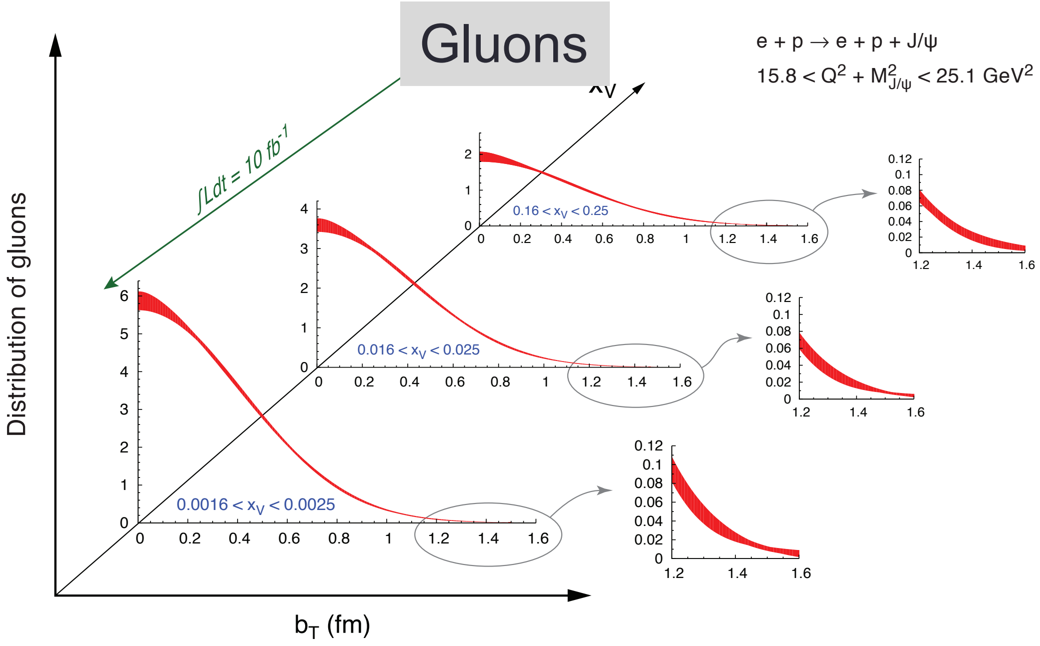
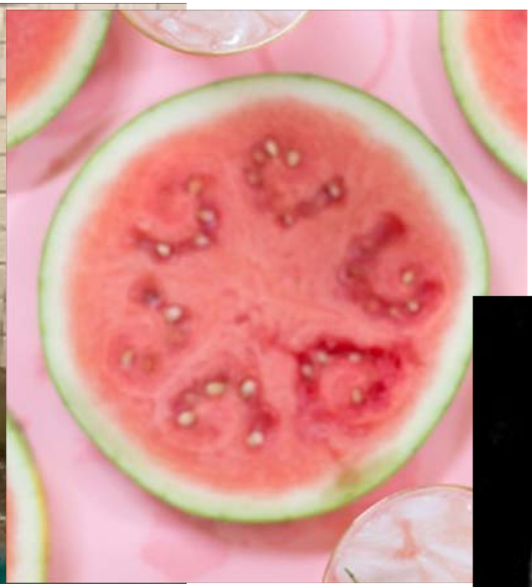


Study of internal structure of a watermelon:

A-A (RHIC)

1) Violent collision of melons



2) Cutting the watermelon with a knife

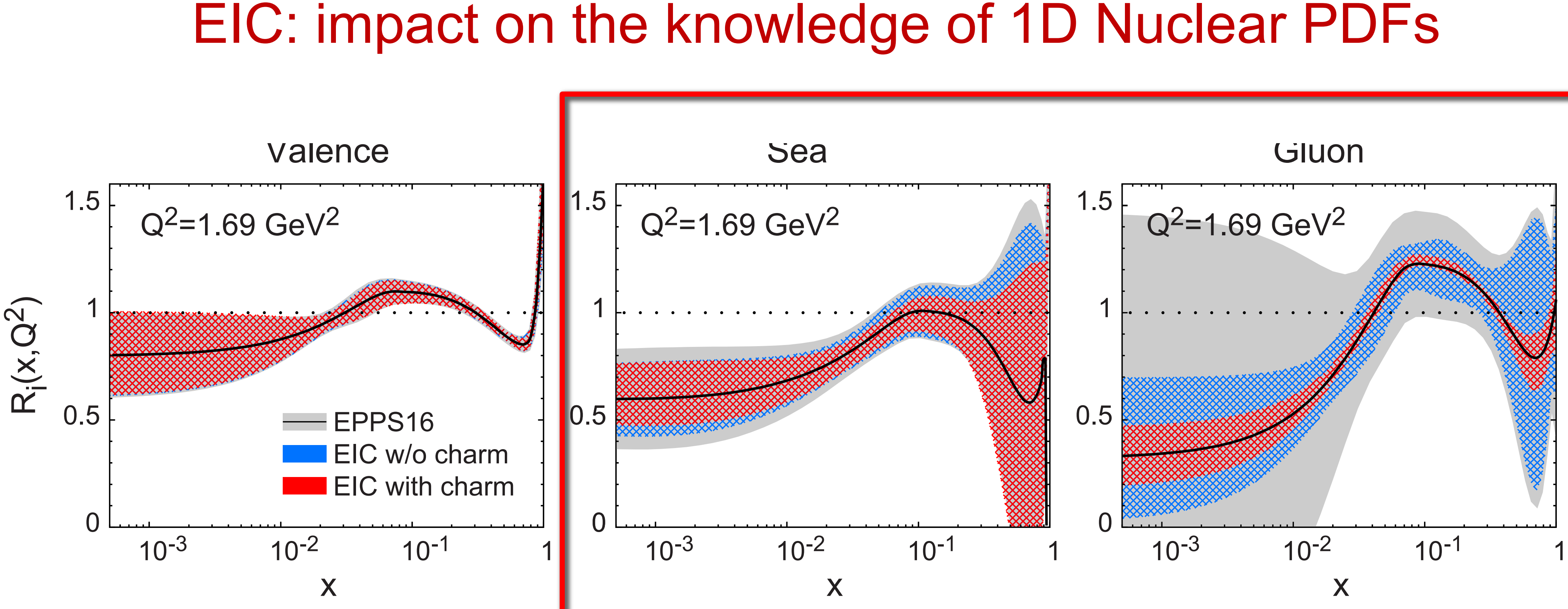
Violent DIS e-A (EIC)

3) MRI of a watermelon

Non-Violent e-A (EIC)

Use of Nuclei as a Laboratory for QCD :

EIC: impact on the knowledge of 1D Nuclear PDFs

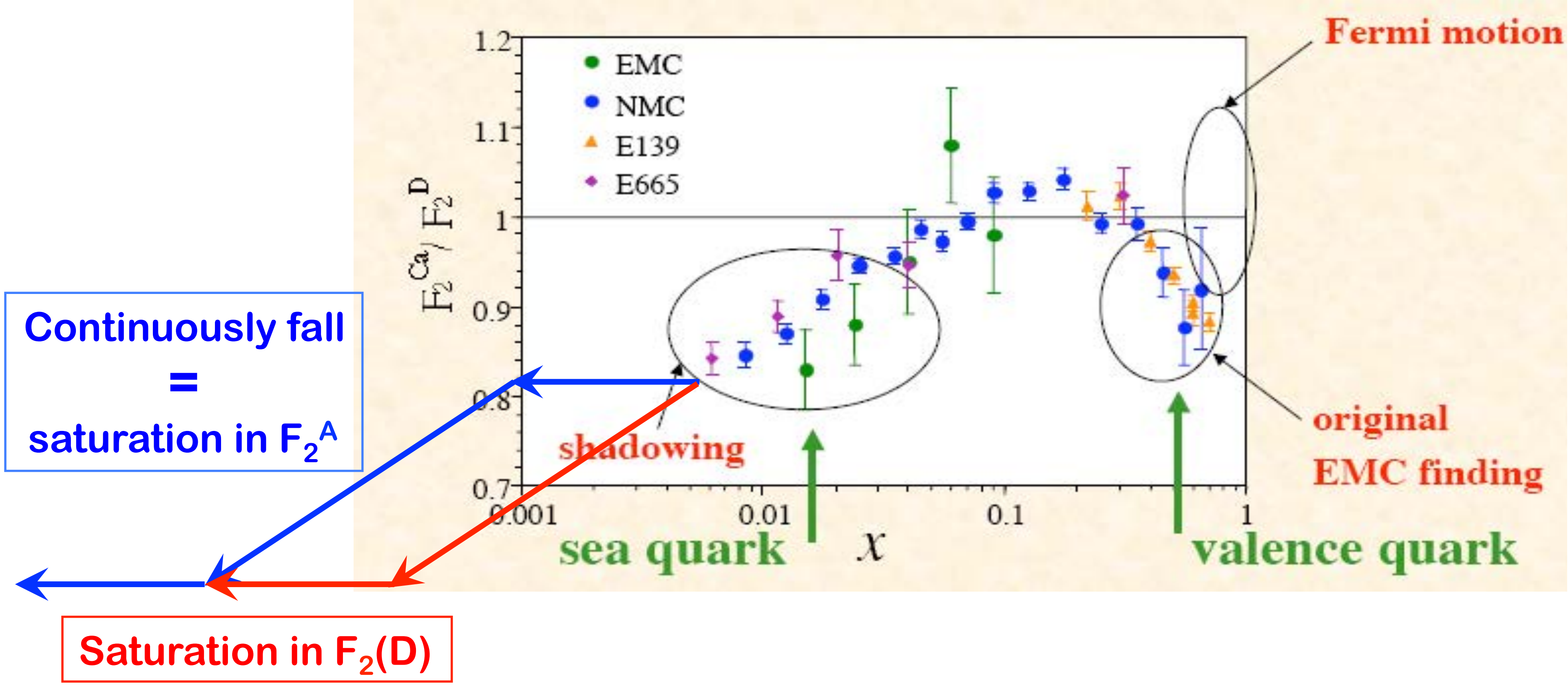


Ratio of Parton Distribution Functions of Pb over Proton:

- Without EIC, large uncertainties in **nuclear sea quarks and gluons** ➔EIC will significantly reduce uncertainties
- Complementary to RHIC and LHC pA data. Provides information on initial state for heavy ion collisions.
- Does the nucleus behave like a proton at low-x? ➔ such color correlations relevant to the understanding of astronomical objects

❑ Ratio of F_2: EMC effect, Shadowing and Saturation:

An easy measurement (early program)



❑ Questions:

Will the suppression/shadowing continue fall as x decreases?

Could nucleus behaves as a large proton at small-x?

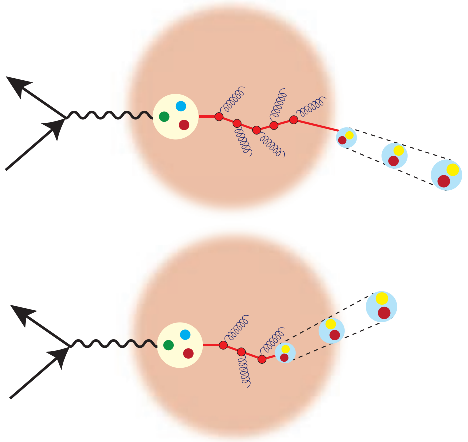
Range of color correlation – could impact the center of neutron stars!

Emergence of Hadrons from Partons

Nucleus as a Femtometer sized filter

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

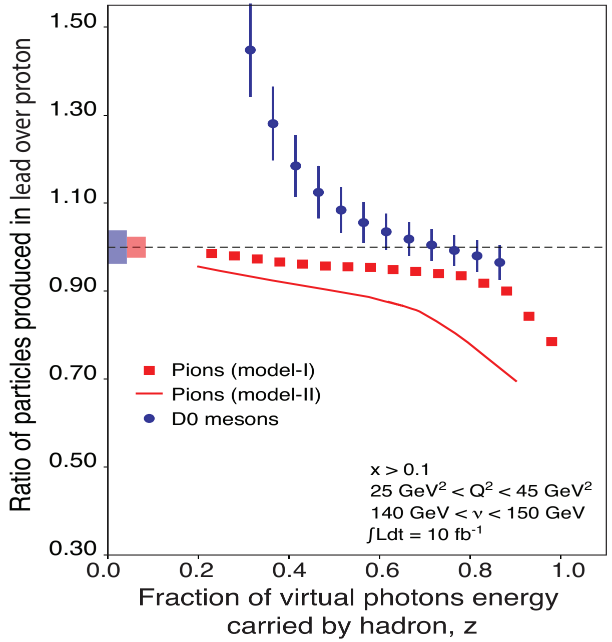
$$\nu = \frac{Q^2}{2mx}$$



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

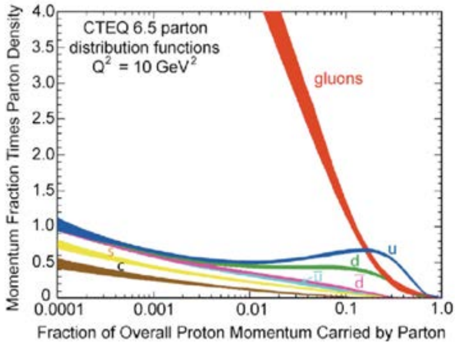
(colored) Quark passing through cold QCD matter emerges as color-neutral hadron ➔ Clues to color-confinement?

Energy loss by light vs. heavy quarks:

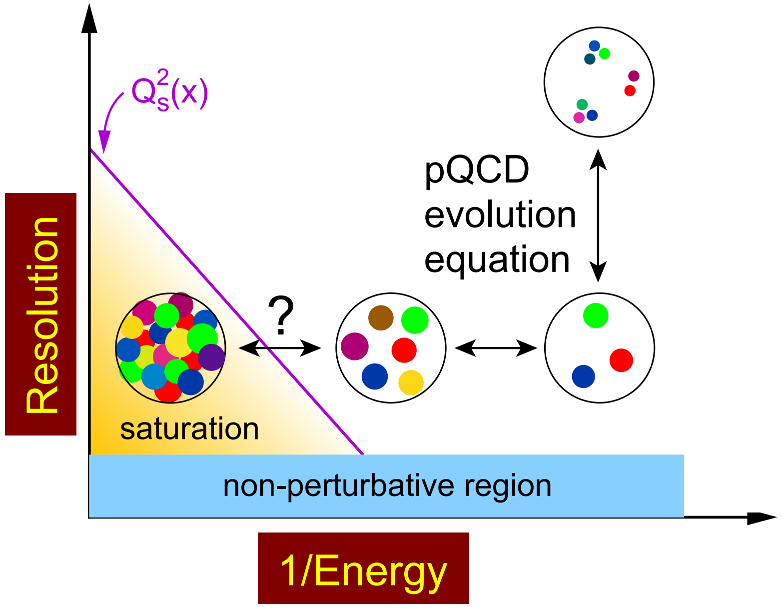


Identify π vs. D^0 (charm) mesons in e-A collisions:
Understand energy loss of light vs. heavy quarks traversing the cold nuclear matter:
Connect to energy loss in Hot QCD

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



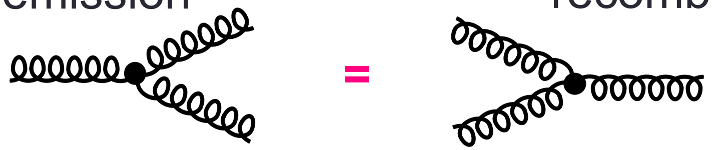
What do we learn from low-x studies?



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

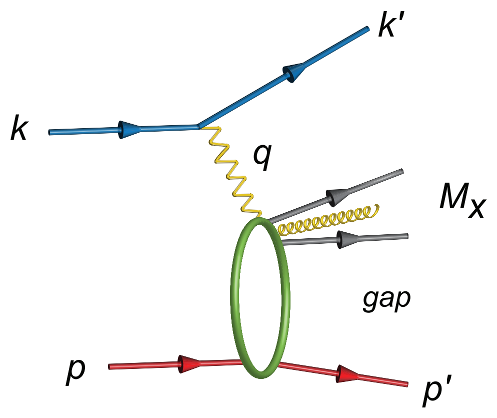
gluon emission = gluon recombination At Q_S



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?

Saturation/CGC: What to measure?

Many ways to get to gluon distribution in nuclei, but diffraction most sensitive:



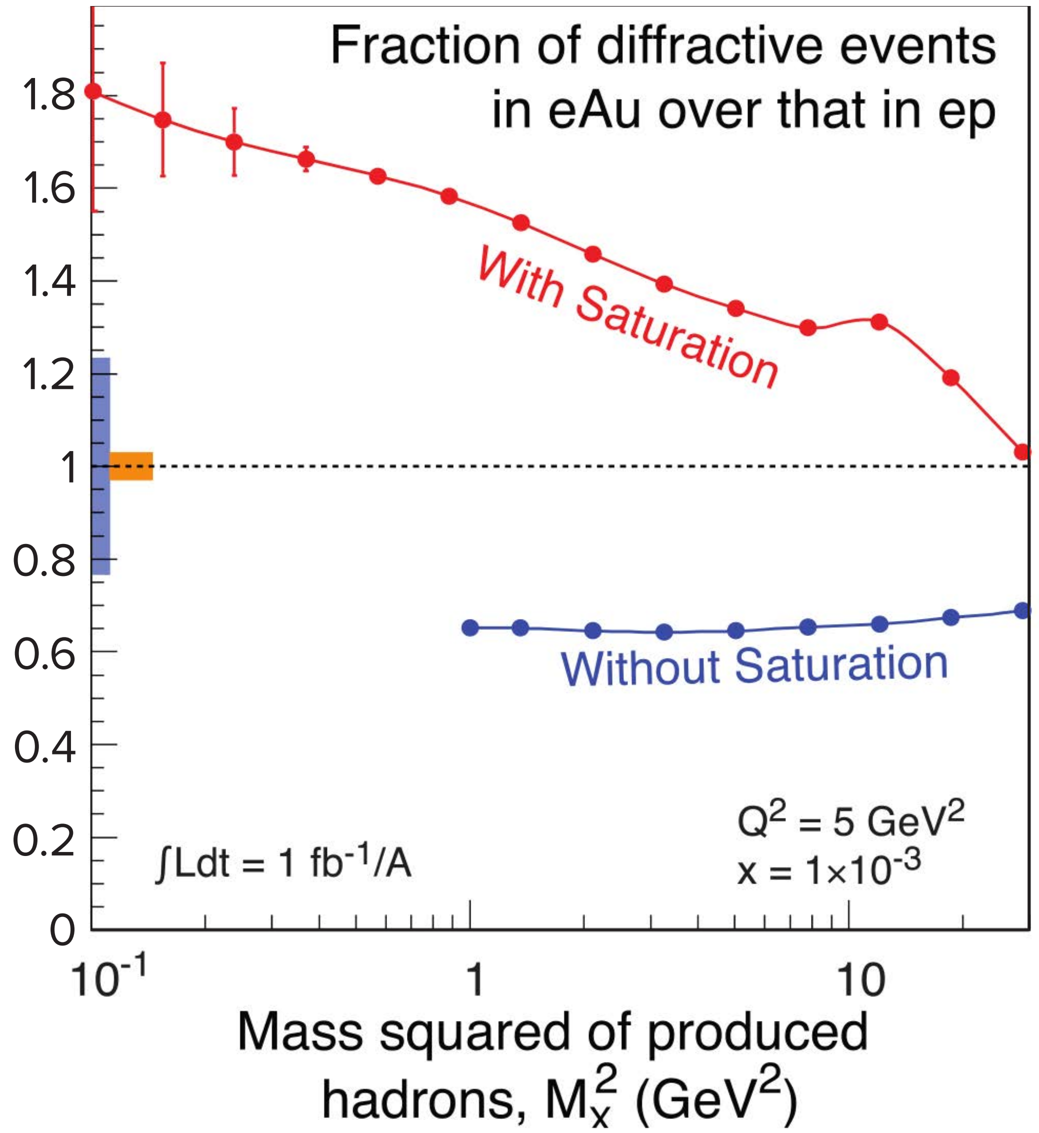
$$\sigma_{\text{diff}} \propto [g(x, Q^2)]^2$$

At HERA

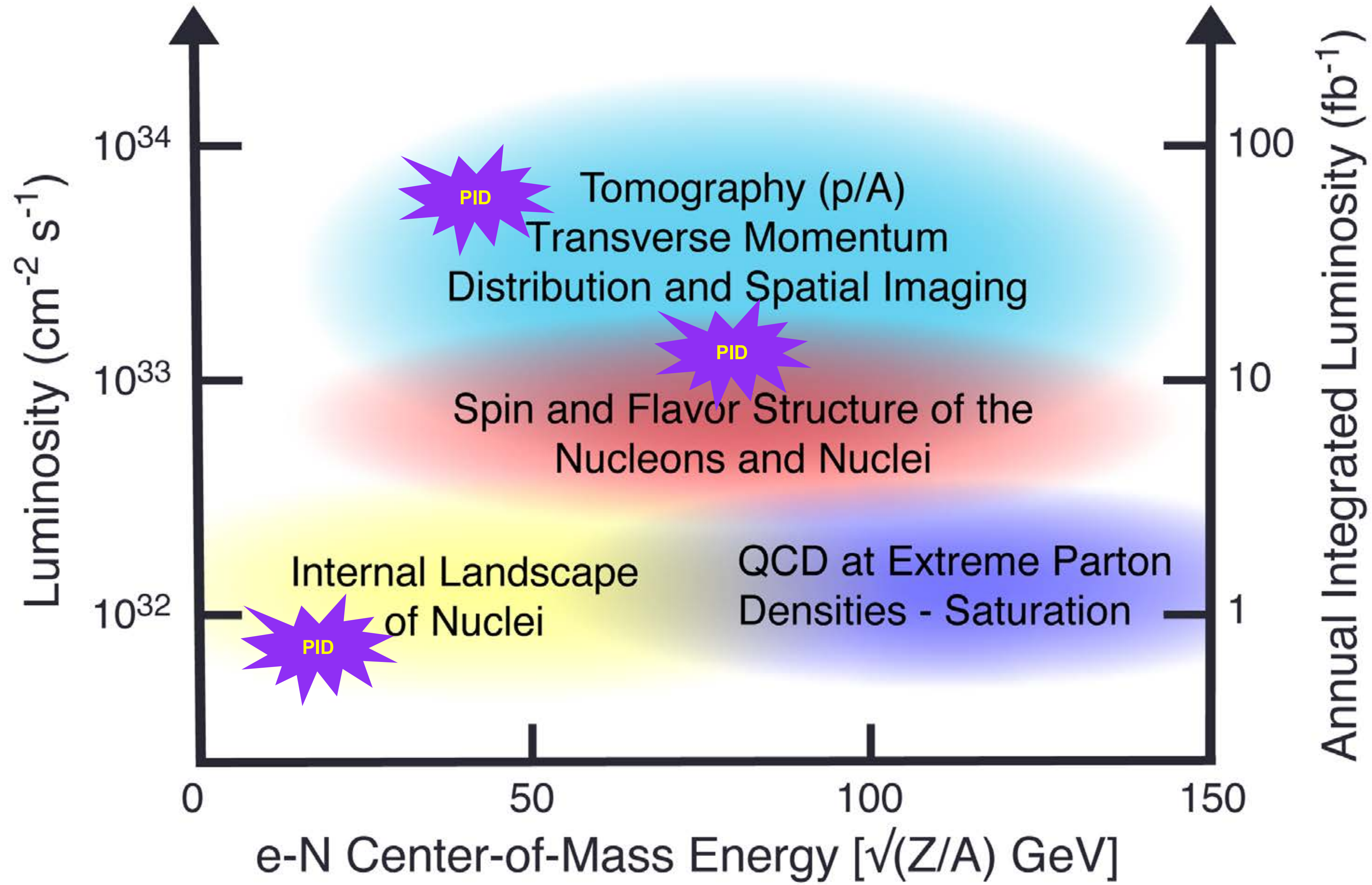
ep: 10-15% diffractive

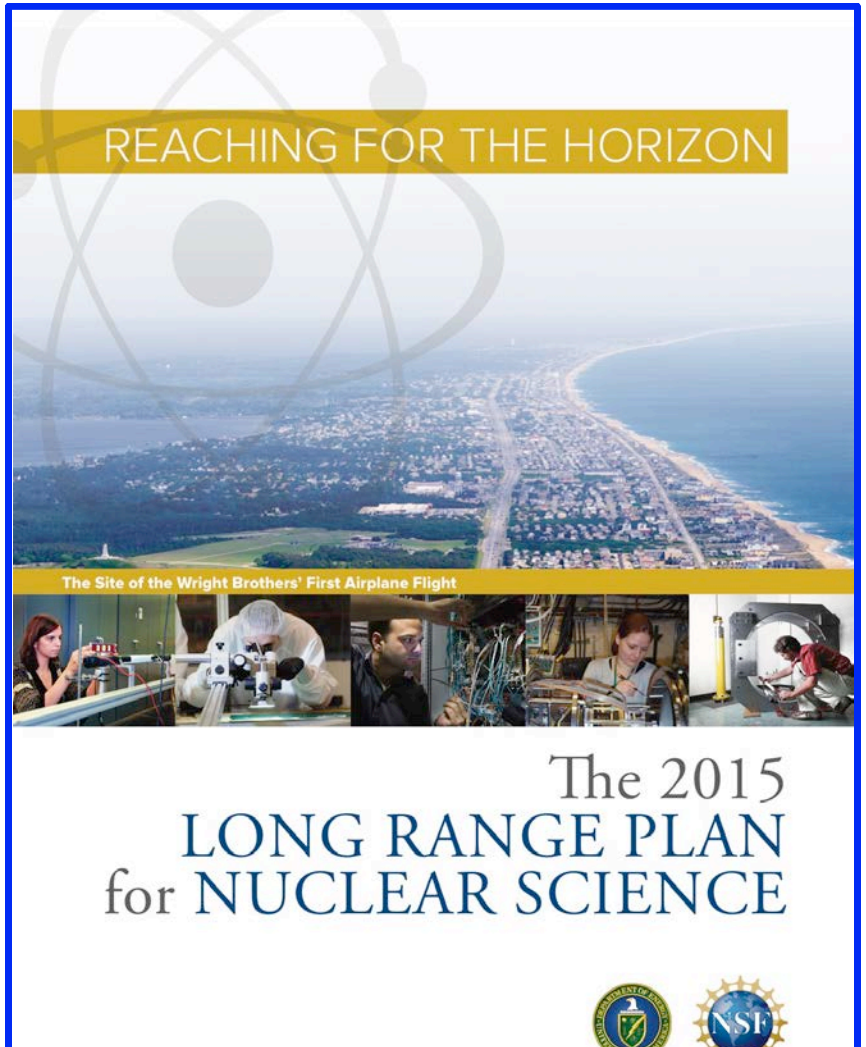
At EIC eA, if Saturation/CGC

eA: 25-30% diffractive



Summary: EIC Physics: CM vs. Luminosity vs. Integrated luminosity





http://science.energy.gov/np/reports

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 soonr

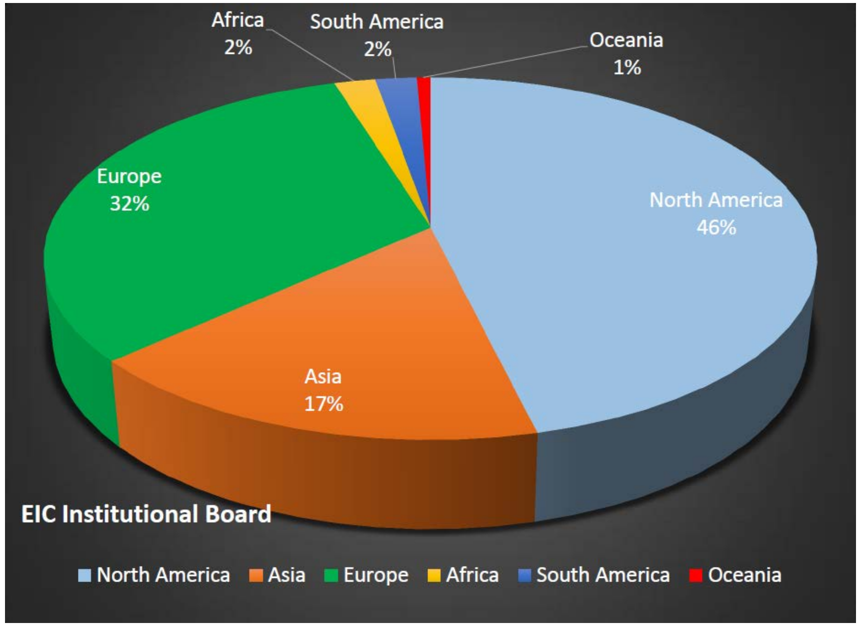
Since FY 2017

EIC Accelerator R&D already assigned $7m/yr

The EIC Users Group: EICUG.ORG

Formally established in 2016
826 Ph.D. Members from 30 countries, 176 institutions
(Significant interest (32%) from Europe)

New:
Center for Frontiers in Nuclear Science (at Stony Brook/BNL)
EIC² at Jefferson Laboratory



EICUG Structures in place and active.

EIC UG Steering Committee (w/ European Representative)
EIC UG Institutional Board
EIC UG Speaker's Committee (w/European Rep.)

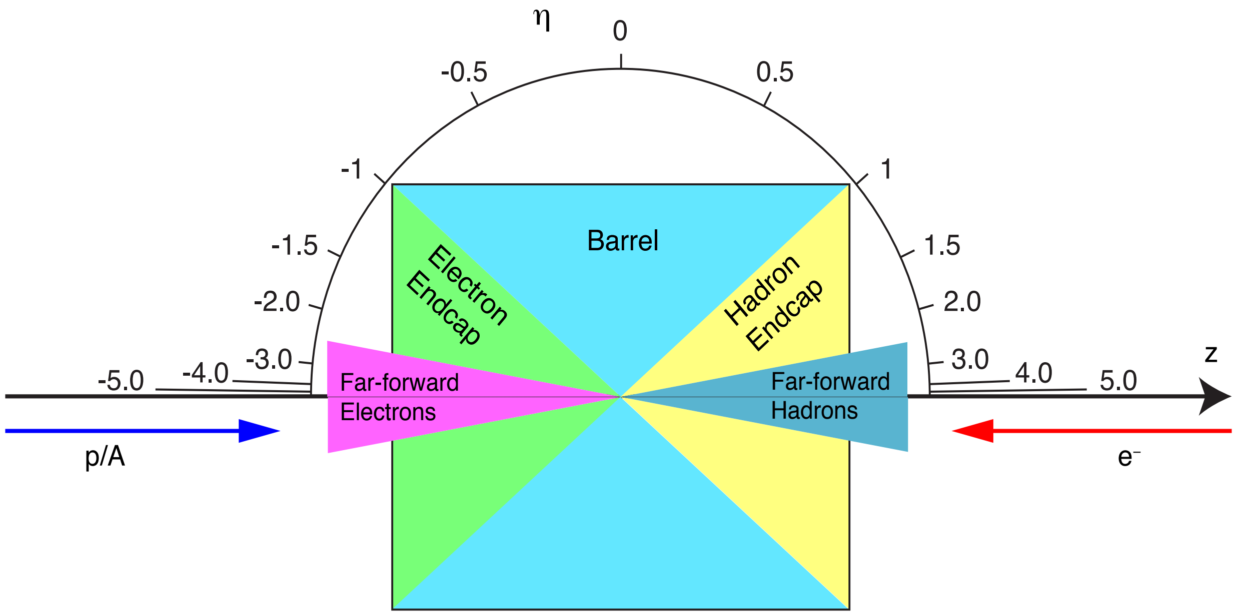
Task forces on:
-- Beam polarimetry
-- Luminosity measurement
-- Background studies
-- IR Design

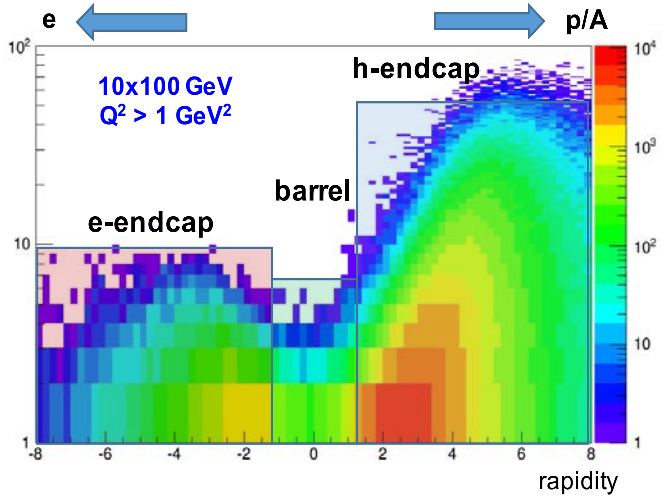
Annual meetings: Stony Brook (2014), Berkeley (2015), **ANL (2016)**, **Trieste (2017)**, **CAU (2018)**, **Paris (2019)**

Requirement are mostly site-independent with some slight differences in the forward region (IR integration)

In Short:

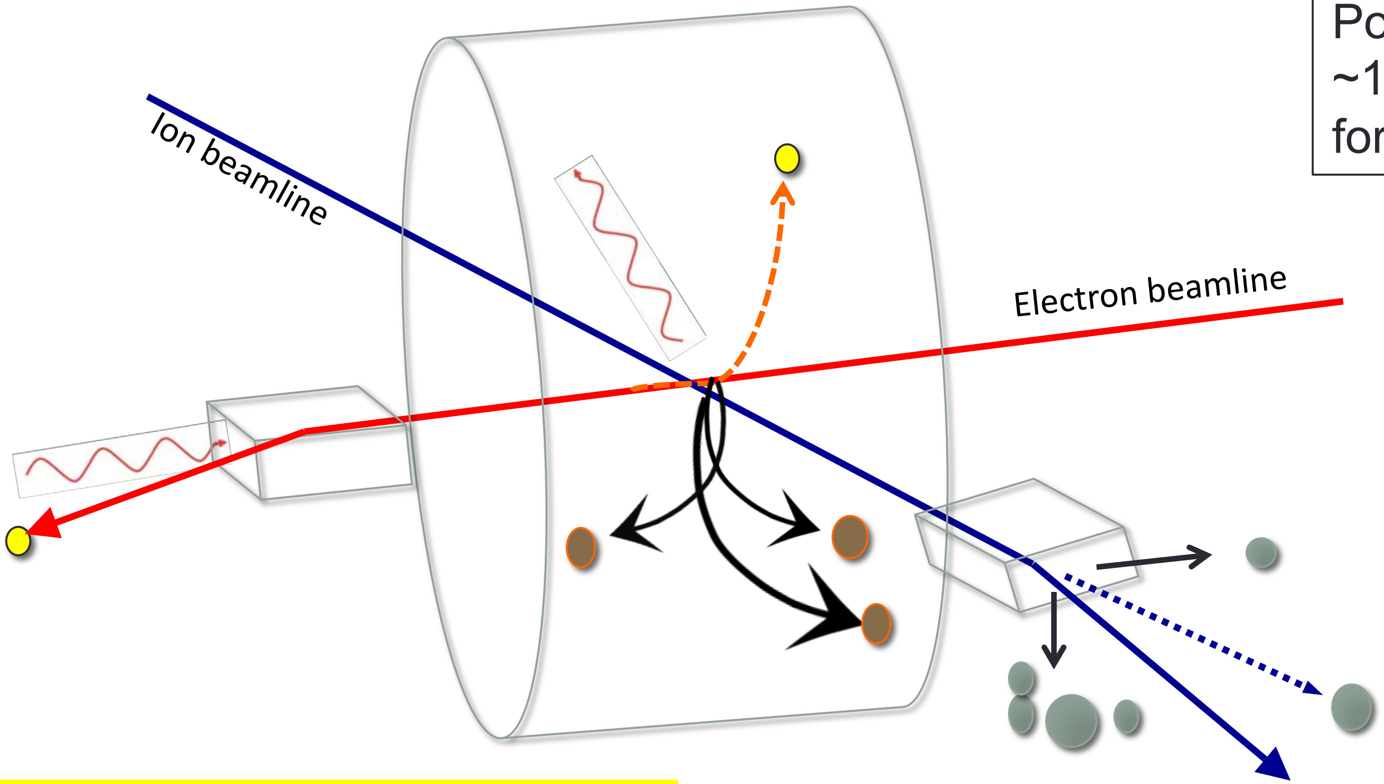
- Hermetic detector, low mass inner tracking, good PID (e and π/K/p) in wide range, calorimetry
- Moderate radiation hardness requirements, low pile-up, low multiplicity





Detector integration with the Interaction Region

Lessons learned from HERA



Possible to get ~100% acceptance for the whole event

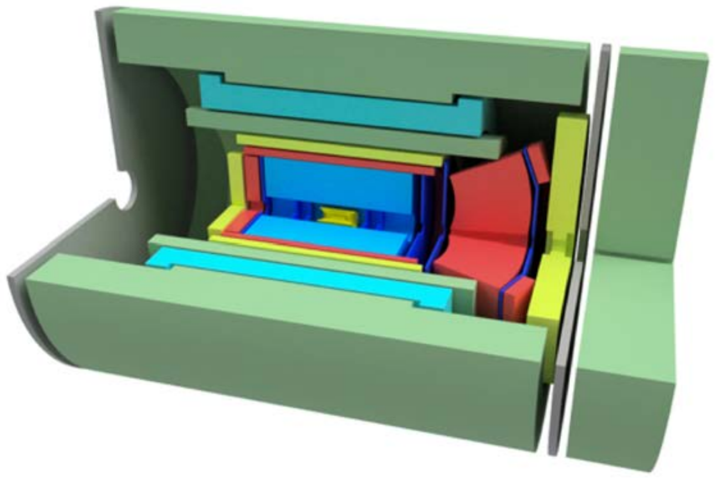
Total acceptance detector (and IR)

Figure Courtesey: Rik Yoshida

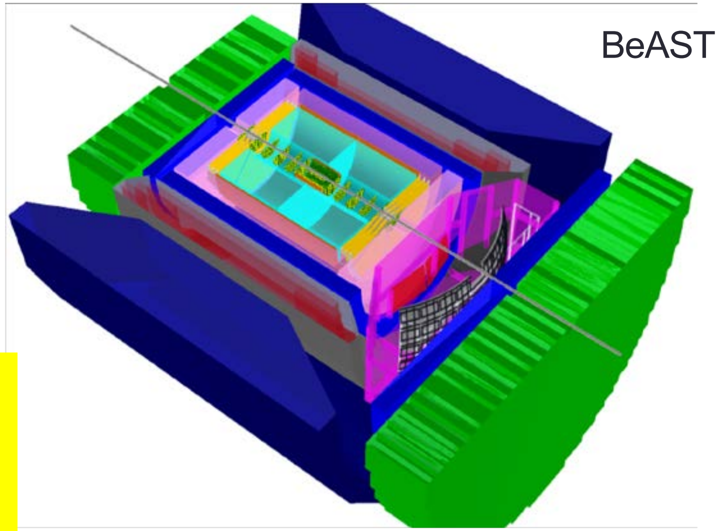
Crossing angles:
eRHIC: 10-22 mrad
JLEIC : 40-50 mrad

EIC Detector Concepts, others expected to emerge

EIC Day 1 detector, with BaBar Solenoid

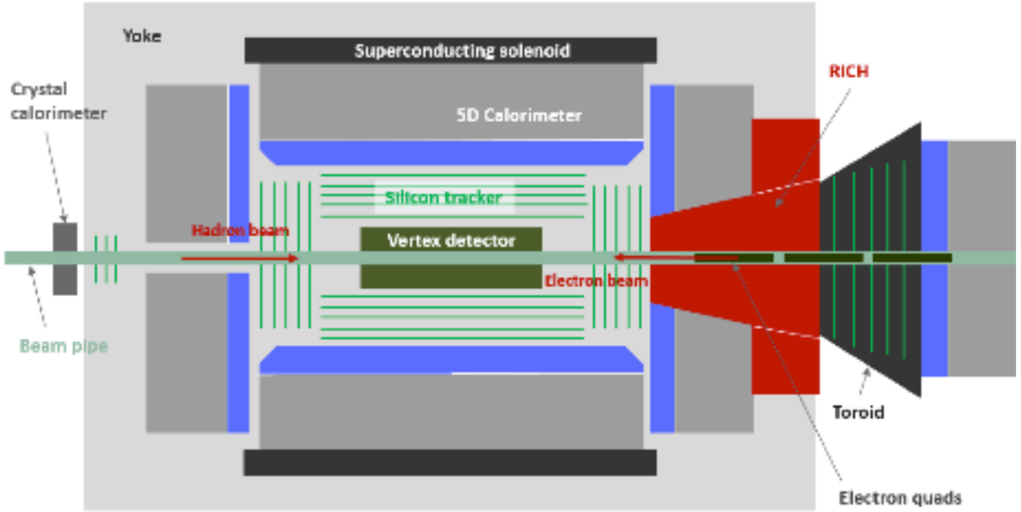


BeAST at BNL

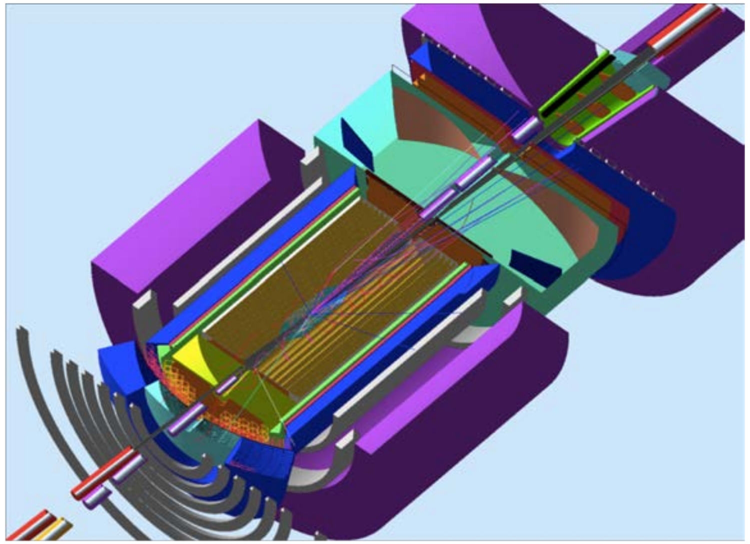


Ample opportunity and need for additional contributors and collaborators

TOPSiDE: Time Optimized PID Silicon Detector for EIC



JLEIC Detector Concept, with CLEO Solenoid

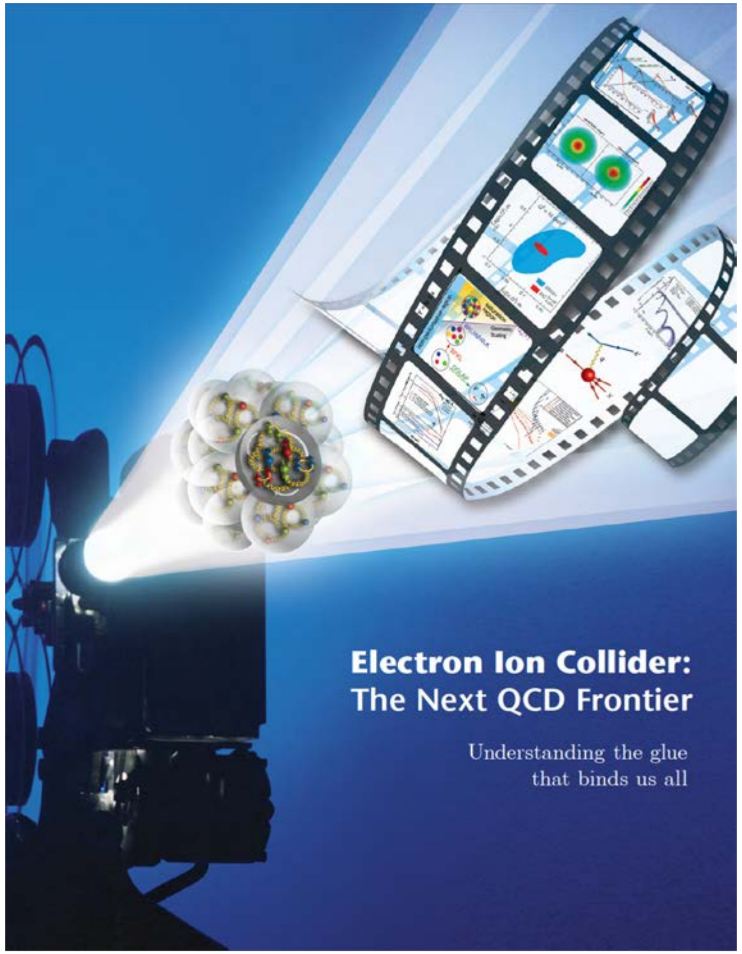


Statement of Task from the Office of Science (DOE/NSF) to the

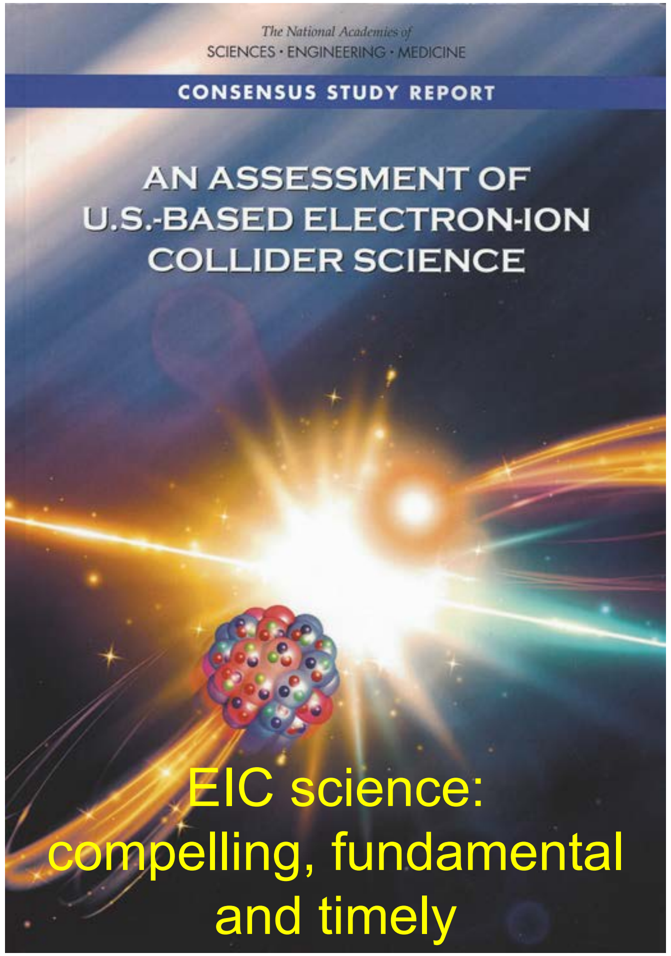
National Academy of Science, Engineering & Medicine (NAS)

The committee will assess the scientific justification for a U.S. domestic electron ion collider facility, taking into account current international plans and existing domestic facility infrastructure. In preparing its report, the committee will address the role that such a facility could play in the future of nuclear physics, considering the field broadly, but placing emphasis on its potential scientific impact on quantum chromodynamics.

EIC Science Endorsed Unanimously by the NAS



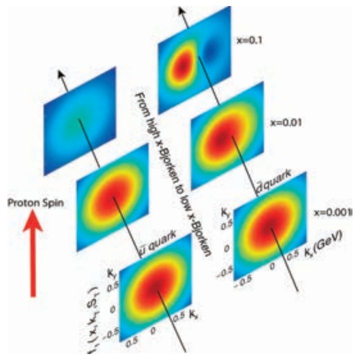
Developed by US QCD community over two decades



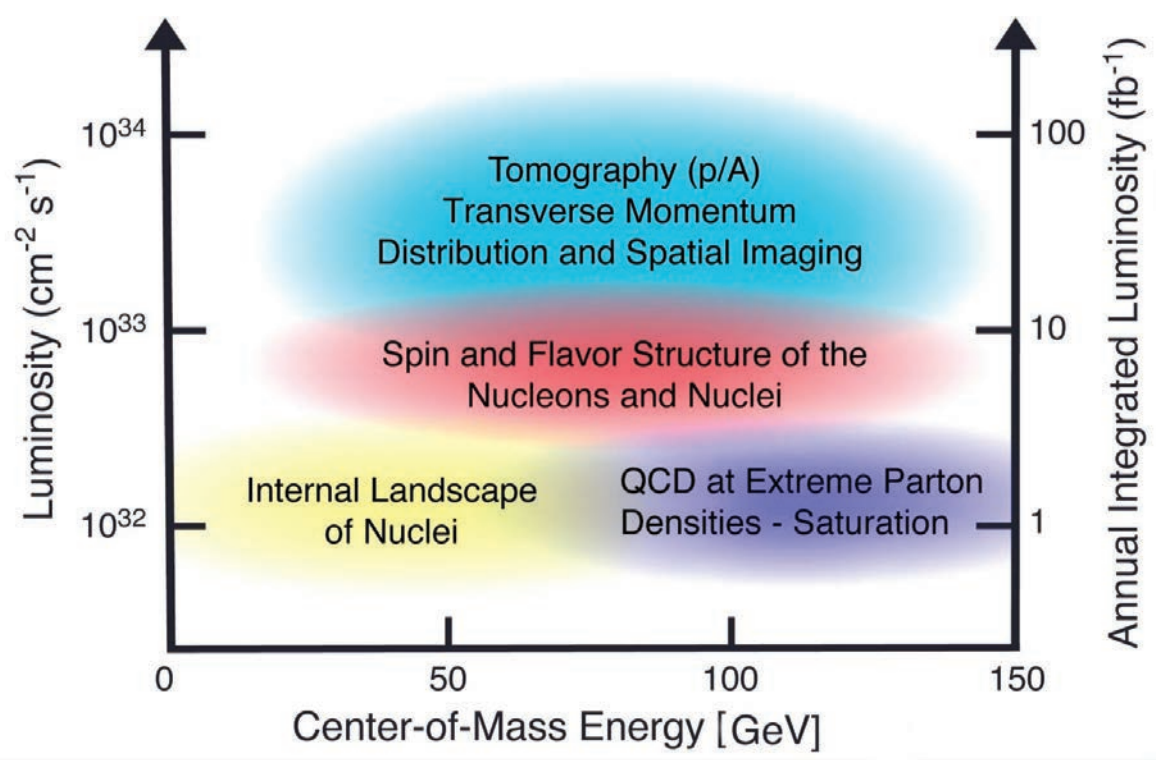
A consensus report July 26, 2018

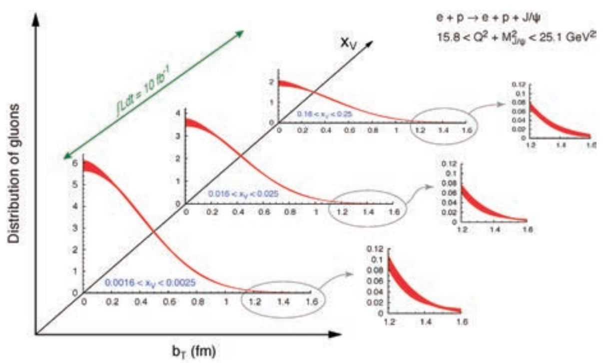
Developed by NAS with broad science perspective

EIC science and required luminosity

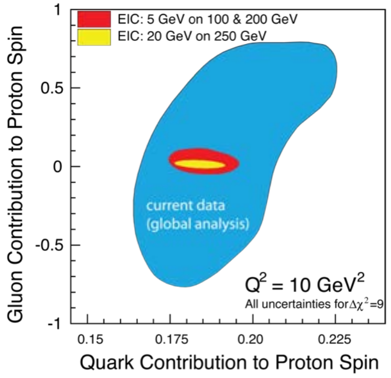


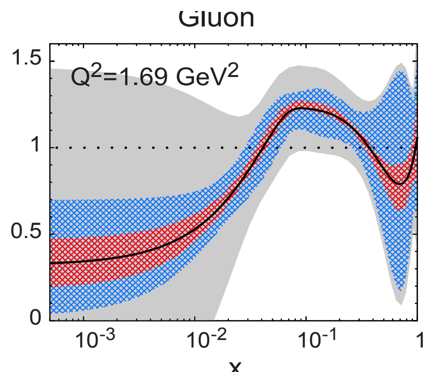
2+1D imaging of quarks and gluons, dynamics, and emergence of spin & mass

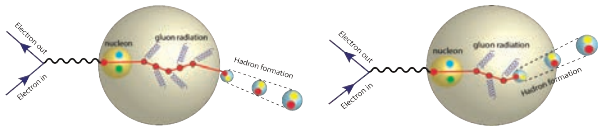




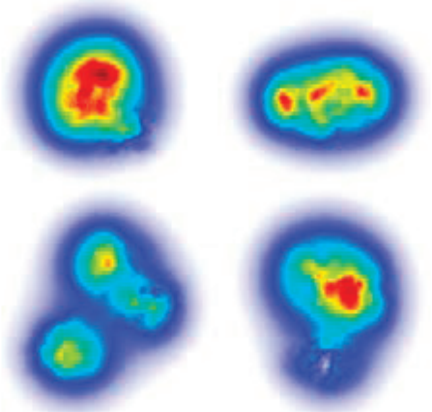
Gluon imaging in nucleons



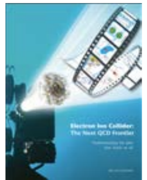


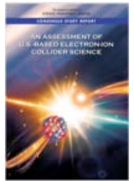


Color propagation, neutralization in nuclei & hadronization



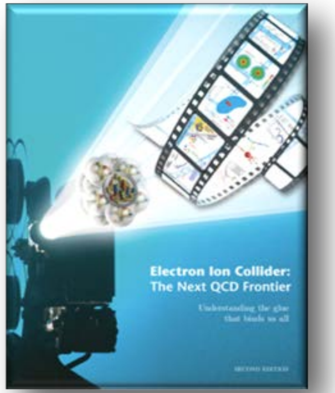
Gluons at high energy in nuclei:
(Gluon imaging in nuclei)

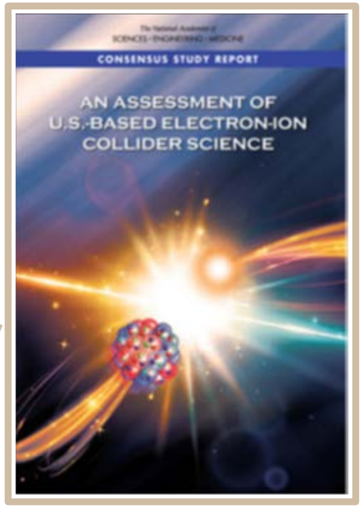




In order to definitively answer the compelling scientific questions elaborated in Chapter 2, including the origin of the mass and spin of the nucleon and probing the role of gluons in nuclei, a new accelerator facility is required, an electron-ion collider (EIC) with unprecedented capabilities beyond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

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





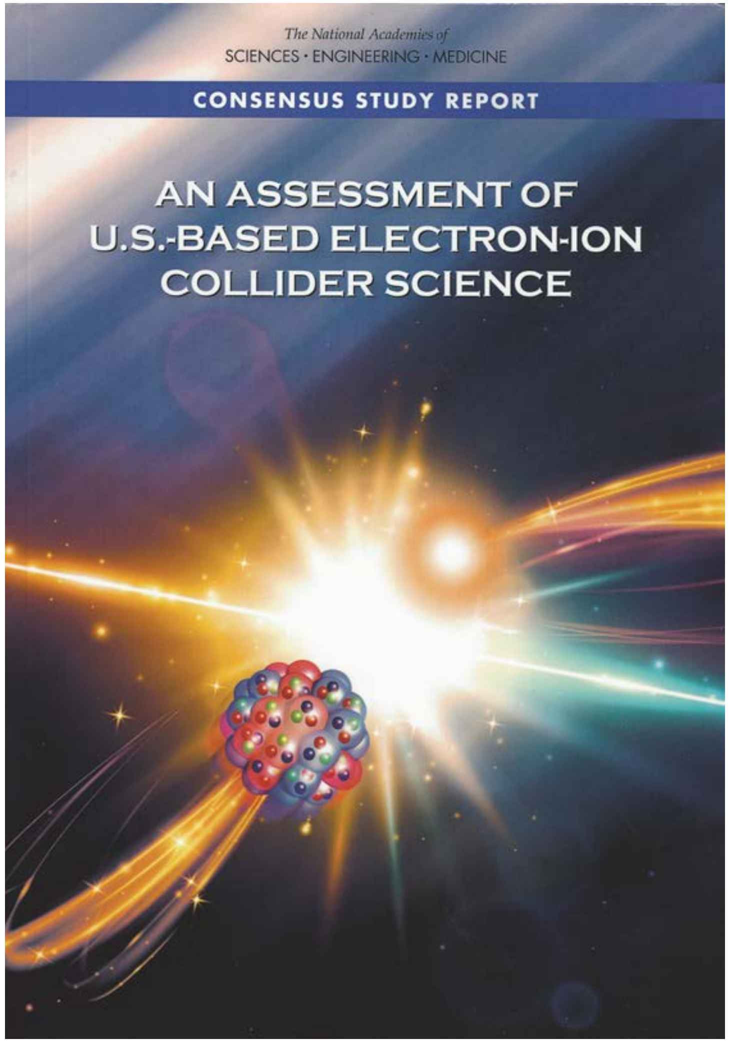
NAS Study endorses machine parameters suggested by the 2012 White Paper and 2015 NSAC Long Range Plan

National Academy's Findings

- **Finding 1**: An EIC can uniquely address three profound questions about nucleons—neutrons and protons—and how they are assembled to form the nuclei of atoms:
  - How does the mass of the nucleon arise?
  - How does the spin of the nucleon arise?
  - What are the emergent properties of dense systems of gluons?
- **Finding 2:** These three high-priority science questions can be answered by an EIC with highly polarized beams of electrons and ions, with sufficiently high luminosity and sufficient, and variable, center-of-mass energy.
- **Finding 3**: An EIC would be a unique facility in the world and would maintain U.S. leadership in nuclear physics.
- **Finding 4:** An EIC would maintain U.S. leadership in the accelerator science and technology of colliders and help to maintain scientific leadership more broadly.
- **Finding 5:** Taking advantage of existing accelerator infrastructure and accelerator expertise would make development of an EIC cost effective and would potentially reduce risk.

National Academy's Findings

- **Finding 6:** The current accelerator R&D program supported by DOE is crucial to addressing outstanding design challenges.
- **Finding 7**: To realize fully the scientific opportunities an EIC would enable, a theory program will be required to predict and interpret the experimental results within the context of QCD, and furthermore, to glean the fundamental insights into QCD that an EIC can reveal.
- **Finding 8**: The U.S. nuclear science community has been thorough and thoughtful in its planning for the future, taking into account both science priorities and budgetary realities. Its 2015 Long Range Plan identifies the construction of a high-luminosity polarized EIC as the highest priority for new facility construction following the completion of the Facility for Rare Isotope Beams (FRIB) at Michigan State University.
- **Finding 9:** The broader impacts of building an EIC in the United States are significant in related fields of science, including in particular the accelerator science and technology of colliders and workforce development.



Consensus Study Report on the US based Electron Ion Collider

Summary:

The science questions that an EIC will answer *are central* to completing an understanding of atoms as well as being integral to the agenda of nuclear physics today. In addition, the development of an EIC would *advance accelerator science and technology* in nuclear science; it would as well *benefit other fields of accelerator based science and society*, from medicine through materials science to elementary particle physics

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
	CD-0 Approve Mission Need	CD-1 Approve Preliminary Baseline Range	CD-2 Approve Performance Baseline	CD-3 Approve Start of Construction	CD-4 Approve Start of Operations or Project Closeout

Expected Soon (2019)

Technical feasibility (~2029)

CD-0	CD-1	CD-2	CD-3	CD-4
Actions Authorized by Critical Decision Approval				
• Proceed with conceptual design using program funds • Request PED funding	• Allow expenditure of PED funds for design	• Establish baseline budget for construction • Continue design • Request construction funding	• Approve expenditure of funds for construction	• Allow start of operations or project closeout

PED: Project Engineering & Design

EIC support, outreach and other news

European High Energy Physics Strategic Planning:

Rolf Ent (Jlab), Rik Yoshida(Jlab) and Abhay Deshpande (SBU/BNL) went to CERN in October 2018 to meet with Eckhard Elsen (CERN's Research and Technology Director)

- Very well informed about the US EIC status, very supportive, suggested strong involvement and input on EIC in the European High Energy Strategy Planning activity (ongoing now)
- EICUG presenting a science paper (led by its European contingent), and an accelerator design paper led by BNL and Jlab together
- EIC at the Plenary session of ECFA meeting November 2018

Recent success in funding of EIC as part of the Hadron studies (Hadron2020) in European Nuclear Physics $Eu 12M (Saclay, INFN and others) over 3 years

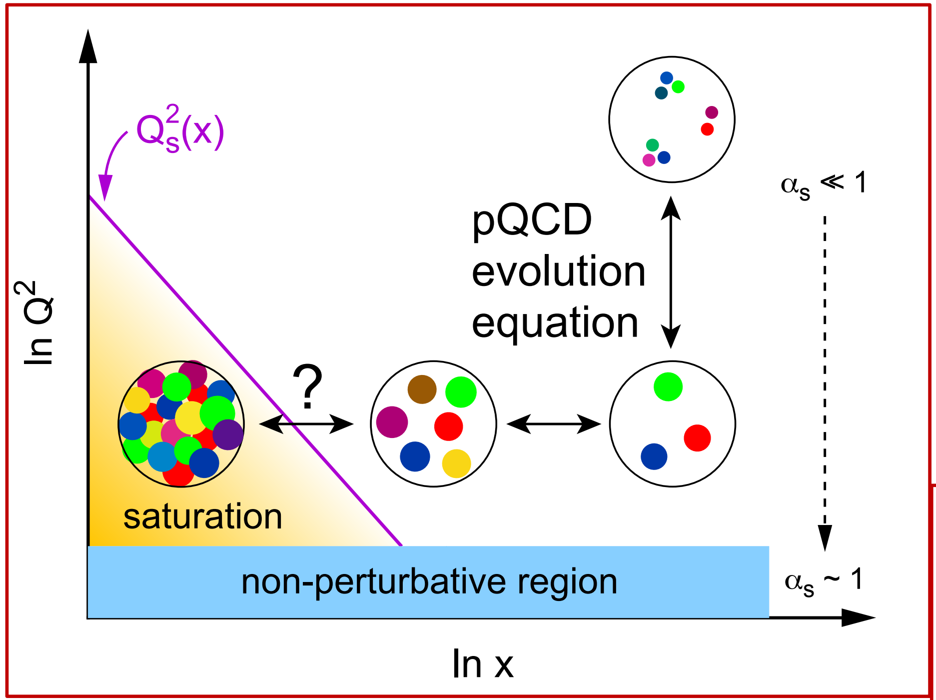
A Consortium of 5 California Universities and 3 national labs supported by UC Chancellor's office for EIC in addition to contributions from the States of New York and Virginia.

Summary:

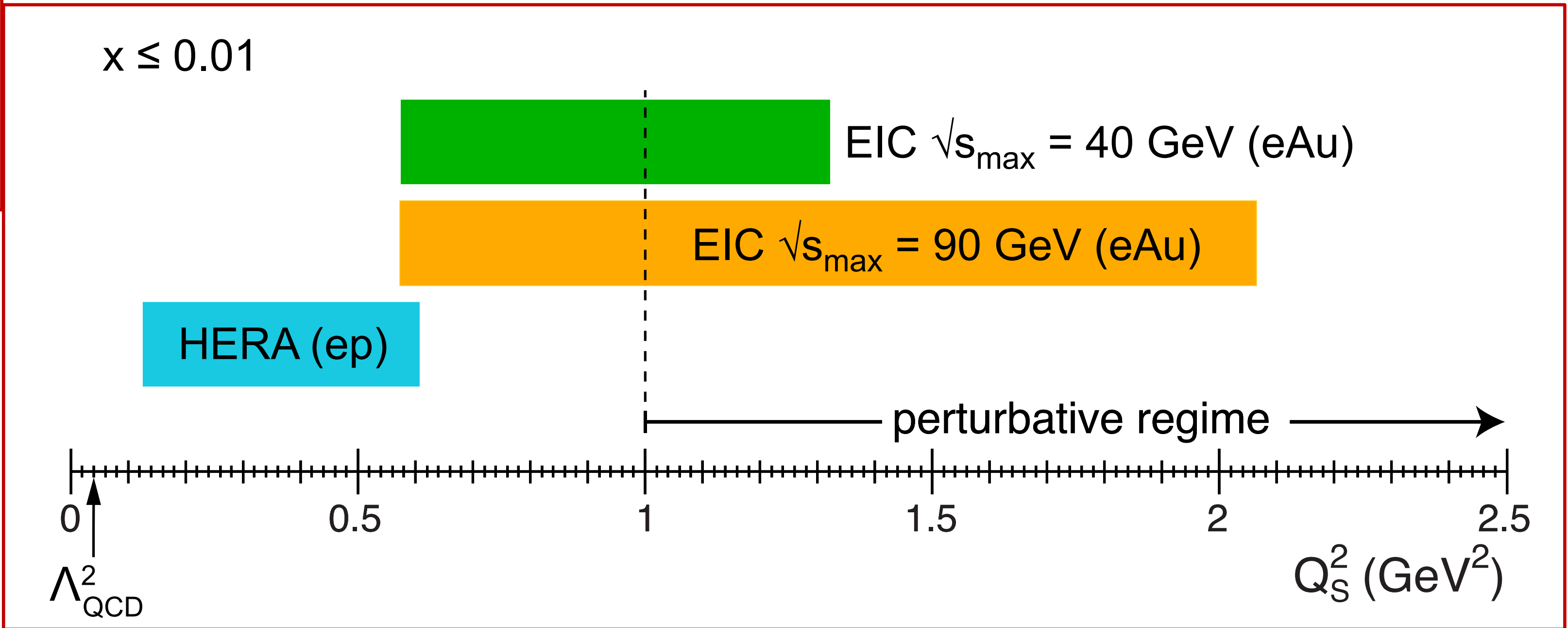
- Science of EIC: Gluons that bind us all… understanding their role in QCD
- The US EIC project has significant momentum on all fronts right now:
  - National Academy's positive evaluation → Science compelling, fundamental and timely
  - EIC Users Group is energized, active and enthusiast: organized
    - EICUG led working groups on polarimetry, luminosity measurement, IR design evolving
  - Funding agencies taking note of the momentum: not just in the US but also internationally
- The science of EIC, technical designs (eRHIC and JLEIC) moving forward
  - Pre-CDRs prepared by BNL (eRHIC) and Jlab (under preparation) : machine & IR designs
  - CFNS, EIC^2 Centers established in the US to help EIC Users before research money becomes available
- **CD0 for the EIC project very near. – We are waiting…**

Thank you.

Advantage of the nucleus over proton



Accessible range of saturation scale $Q_s{}^2$ at the EIC with e+A collisions.
arXiv:1708.01527



State of the art Accelerator Technology for EIC

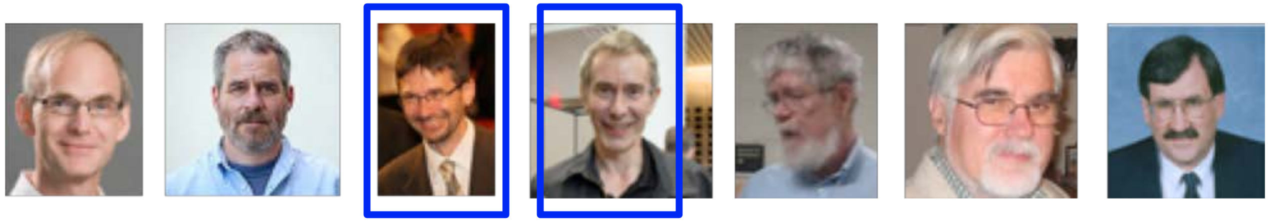
EIC will be one of the most complex collider accelerators ever be built. It will push the envelope on many fronts including high degree of beam polarization, high luminosity, beam cooling, beam dynamics, crab cavities on for both beams, and interaction region with complex magnets integrated with the detectors.

- **Beam cooling: Absolutely needed** to achieve the high collisions luminosity ~ 10^{33-34} $cm^{-2}sec^{-1}$
  - High current multi-pass energy recovery linac (ERL)
  - High current unpolarized electron injectors for the ERL
- **Interaction Region:**
  - **Magnets:** challenging magnet designs to meet the required high fields and field free regions
  - **Crab Cavities: M**aximize collisions rates. No experience yet for crab cavities in hadron beams (R&D @ CERN)
- **Storage Ring Magnets:** Challenging high field storage ring magnets needed
- **Polarized electron source:** High bunch charges for ring-ring concept
- **Simulation Codes**: Benchmarking the realistic EIC simulation tools against available data

*Ample opportunity for joint accelerator research and development initiatives with Jlab/BNL and other labs around the world. (**Details in US EIC Accelerator Paper planned to be submitted to ESPP process next month).***

EIC detector R&D effort

- Laboratory Directed Research & Development Programs (LDRDs) at BNL, JLAB, ANL
- R&D at Belle-II and Panda has some overlap with EIC
- CERN/LHC
  - R&D for phase-I upgrades ended, phase-II focus on radiation hardness and rate
  - R&D on key common with EIC challenges (PID, EMCal) :→ Opportunity?
- Generic EIC Detector R&D Program (See here)
  - Managed since 2011 by BNL, in association with JLab and DOE NP
  - Funded by DOE NP, through RHIC operations
  - Program non site specific and explicitly open to international participation
  - 13 (non-US – mostly European) of the 46 institutions have benefited and now European Contingent of EICUGs have successfully acquired European funding (Strong2020: NextDIS)
  - Standing EIC Detector Advisory Committee with internationally recognized detector experts



Current: Marcel Demarteau (ANL, Chair), Carl Haber (LBNL), **Peter Krizan (Ljubljana), Ian Shipsey (Oxford)**, Rick Van Berg (UPenn), Jerry Va'vra (SLAC), Glenn Young (JLab)

Path forward for the EIC:

Predictions are especially difficult when it comes to the future

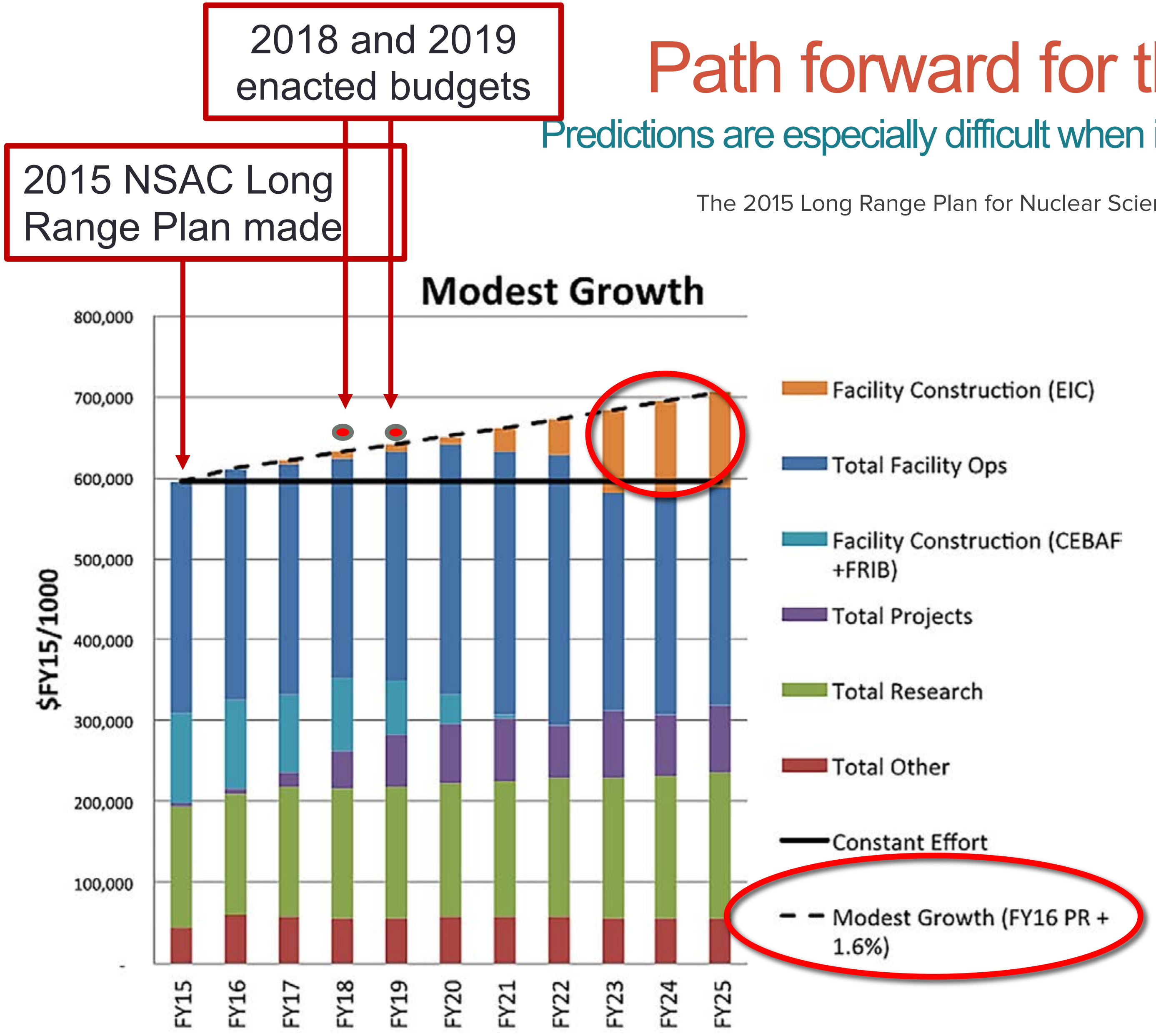


Figure 10.4: *DOE budget in FY 2015 dollars for the Modest Growth scenario.*

- Strong endorsement by the NAS (July 2018)
- BNL and JLab working together with the US DOE towards realizing the project.
- Technically driven schedule: the future
  - CD0 (critical decision process of the US DOE) in near future
  - EIC-Proposal's Technical & Cost review → Site selection → CD1-3
  - According to NSAC LRP 2015 major construction funds ("CD3") ~2023
  - *Earliest First* collisions in 2029/30