DIS 2018
XXVI International Workshop on Deep Inelastic Scattering and Related Subjects
16-20 April 2018 Kobe, Japan

Overview of EIC Physics Goals

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Theory Center, Jefferson Lab

WG7: Future of DIS at DIS 2018, April 17, 2018

Acknowledgement: Much of the physics presented here are based on the work of EIC White Paper Writing Committee put together by BNL and JLab managements, …

Eternal Questions we have been asking …

- Where did we come from?

Global Time: →

How did hadrons are emerged from the energy, the quarks and gluons?

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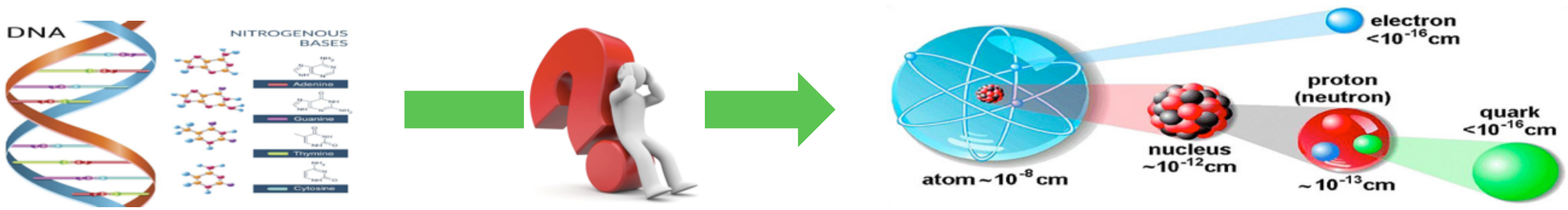

What is the internal structure and dynamics of hadrons?

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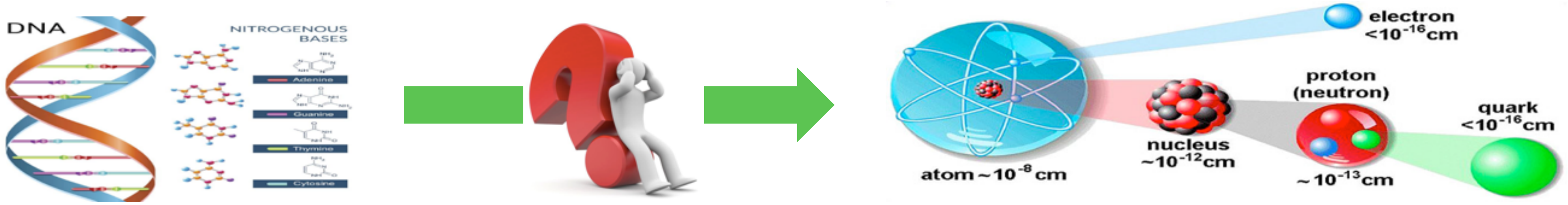
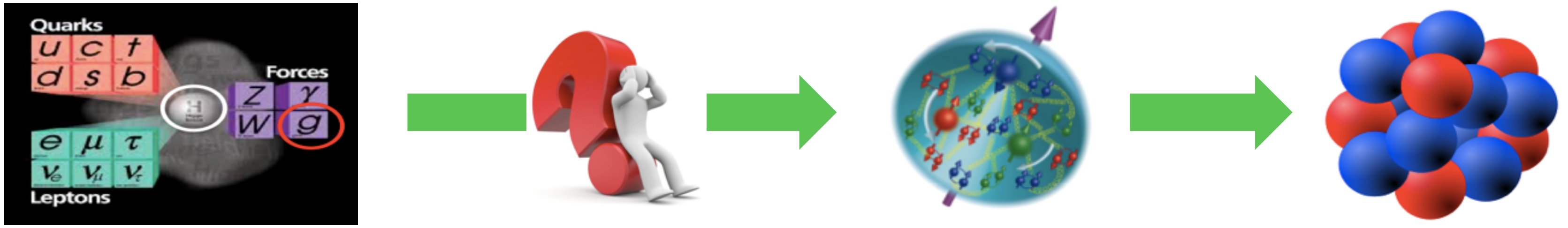


What is the internal structure and dynamics of hadrons?

- What holds us together?



How does the glue bind us all?

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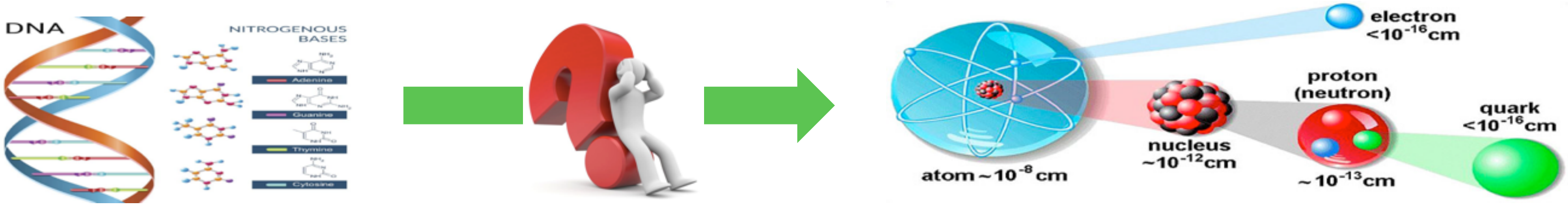

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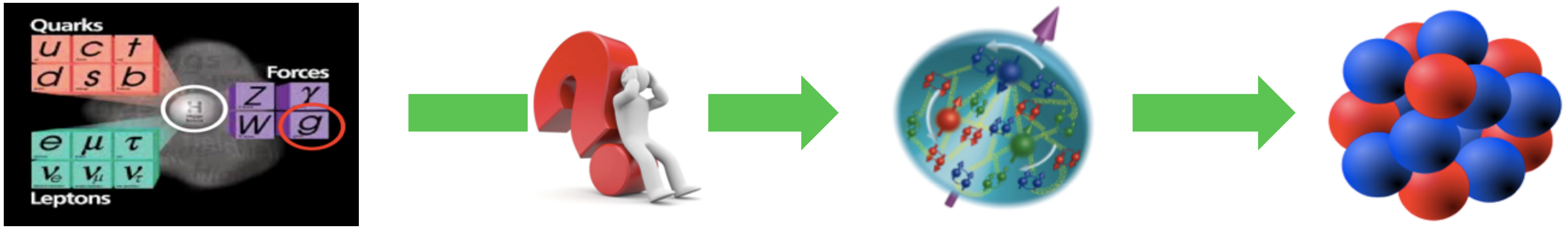
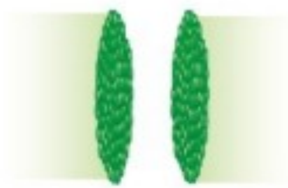


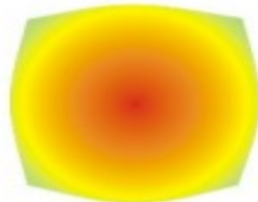
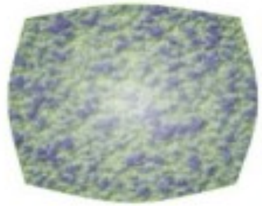
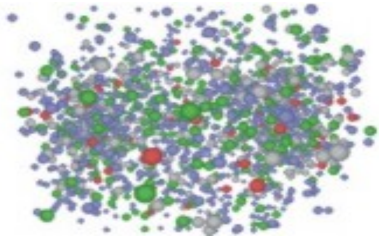
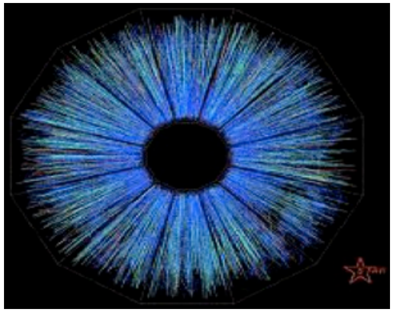
How does the glue bind us all?

Goals of EIC: to help search for answers of these questions in various stages!

Going back in time?

- Relativistic heavy-ion collisions - RHIC:



Lorentz contraction | Near collision | Quark-gluon plasma | Hadronization | Freeze-out | Seen in the detector

Visible!

"Seeing" the unseen

Visible!

A virtual journey of the visible matter!

A virtual journey of the visible matter

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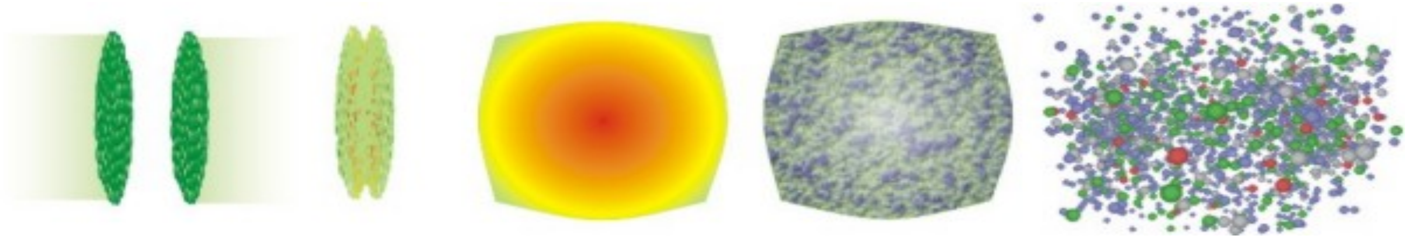

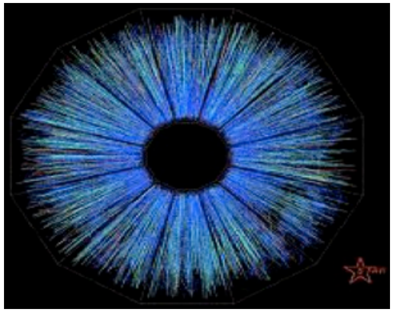

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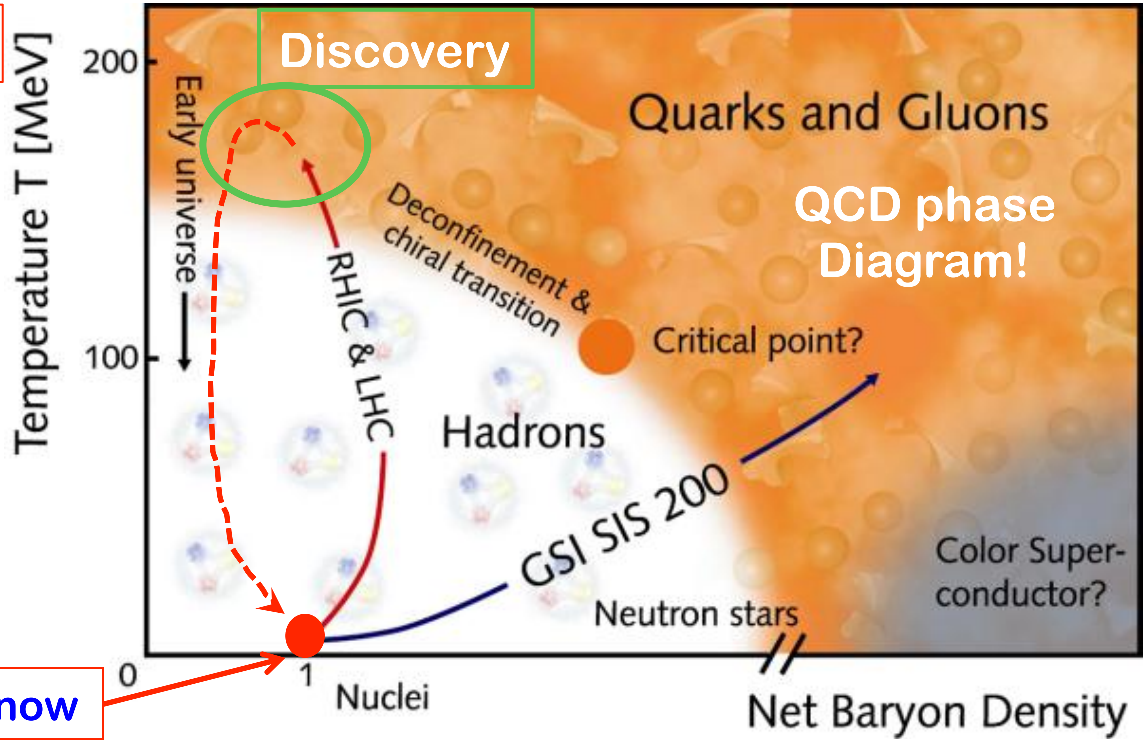

Where we are now

A virtual journey of the visible matter

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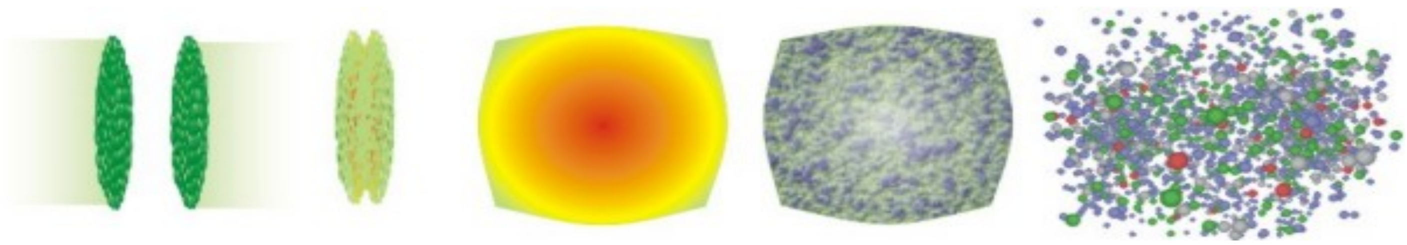

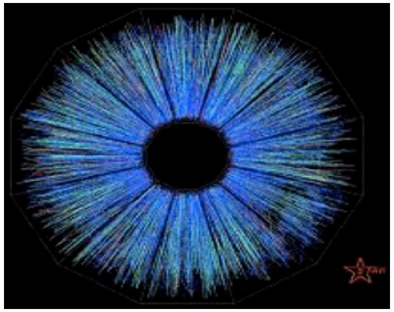

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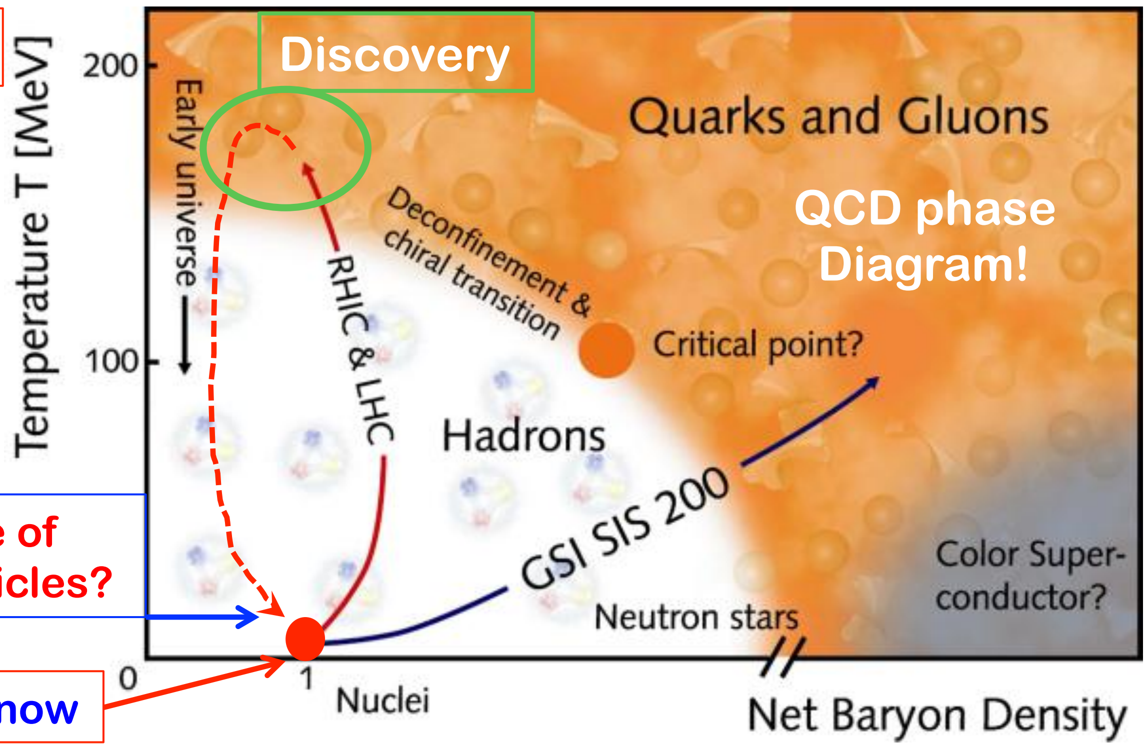

Emergence of hadronic particles?

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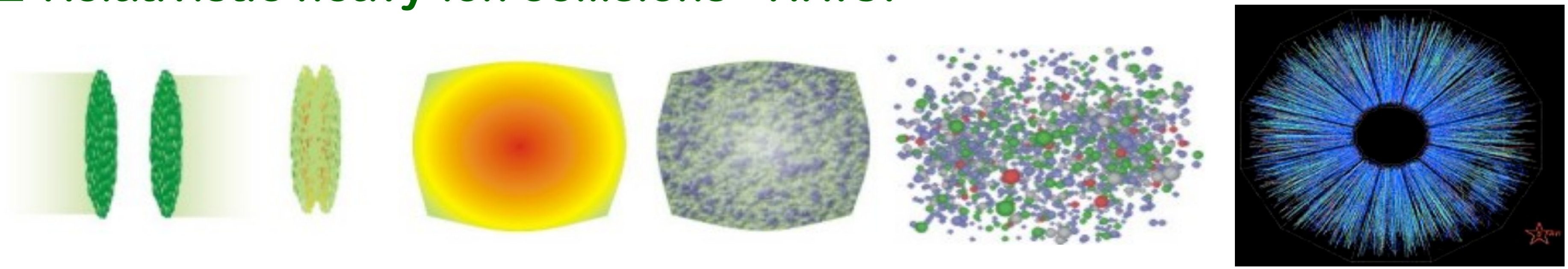

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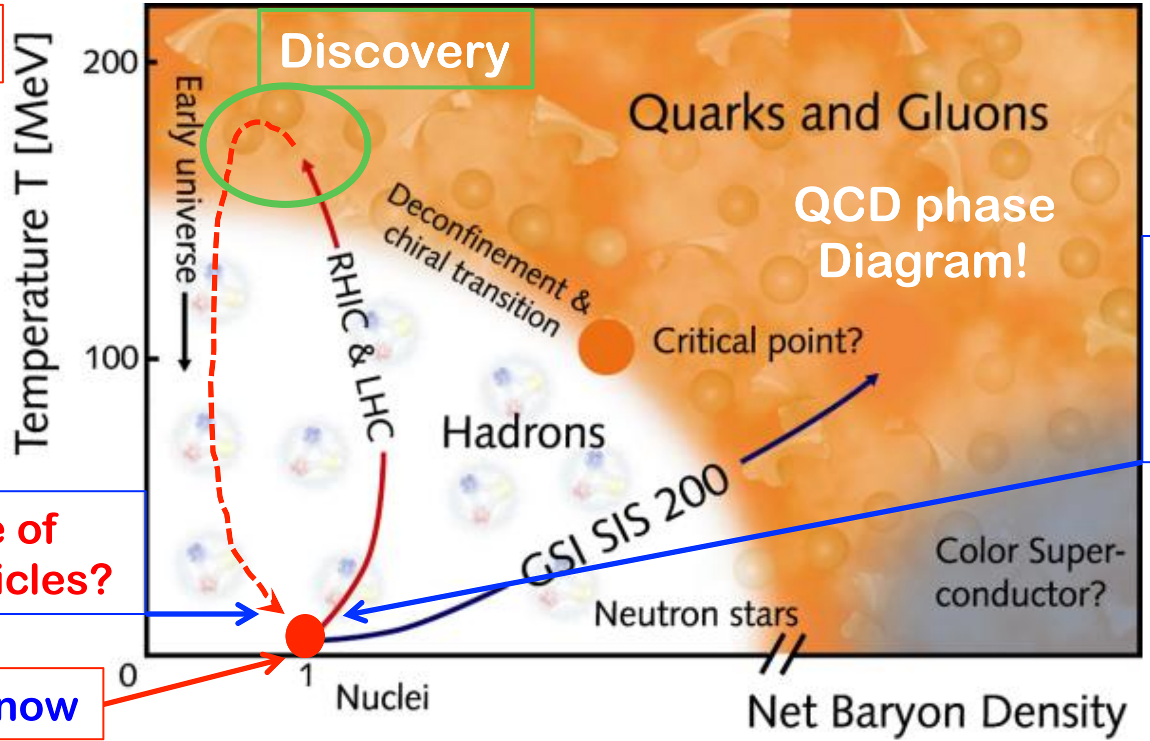


Structure of hadrons?
= initial conditions of RHIC?

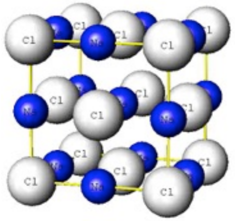
Emergence of hadronic particles?

Where we are now

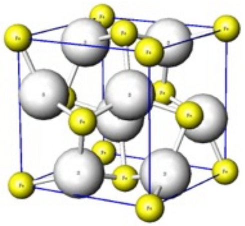
Hadron's partonic structure in QCD

- Structure – "a still picture"

Crystal Structure:

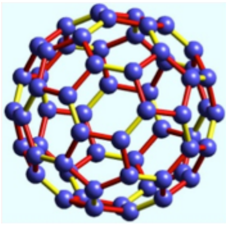


NaCl,
B1 type structure



FeS2,
C2, pyrite type structure

Nano-material:



Fullerene, C60

Motion of nuclei is much slower than the speed of light!

Hadron’s partonic structure in QCD

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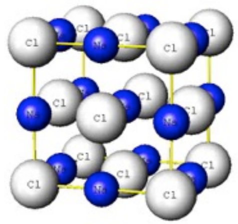

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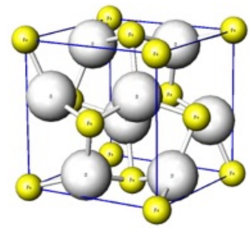

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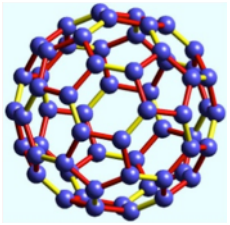

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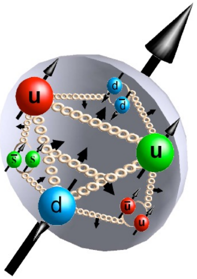

Motion of quarks/gluons is relativistic!

Partonic Structure:

Quantum “probabilities” $\langle P, S|\mathcal{O}(\overline{\psi}, \psi, A^{\mu})|P, S\rangle$

None of these matrix elements is a direct physical observable in QCD – color confinement!

Hadron's partonic structure in QCD

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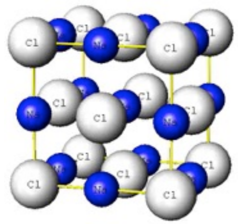

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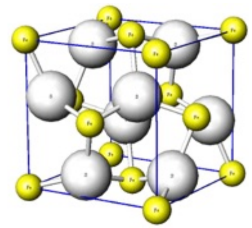

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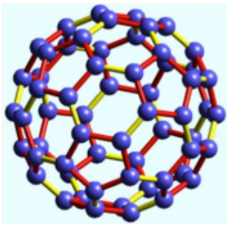

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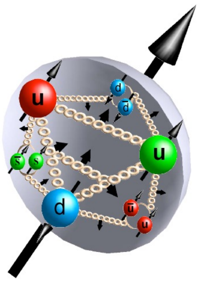

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- **Accessible hadron's partonic structure?**

= Universal quantum matrix elements of quarks and/or gluons

1) can be related to good physical cross sections of hadron(s) *with controllable approximation*,

2) can be calculated in lattice QCD, …

Intellectual challenge!

- **The challenge:**

  No modern detector has been able to see quarks and gluons in isolation!

- **Answer to the challenge:**

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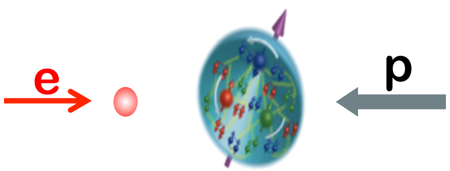
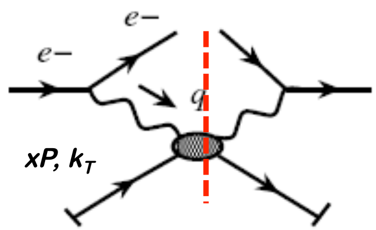


Color entanglement
Approximation

$\sigma_{\rm tot}^{\rm DIS}$:



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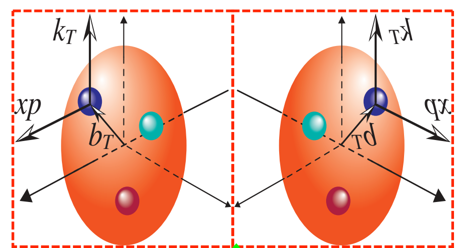

$+ \; O\left(\frac{1}{QR}\right)$

Physical
Observable

Controllable
Probe

Quantum Probabilities
Structure

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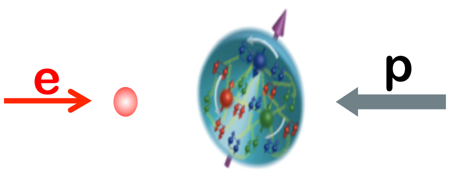

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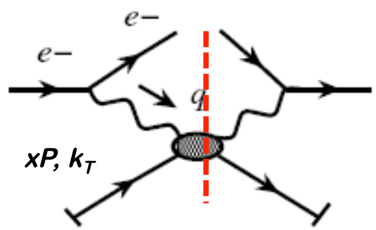

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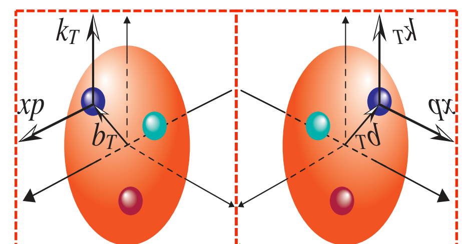


$$+ \, O\left(\frac{1}{QR}\right)$$

Physical Observable | **Controllable Probe** | **Quantum Probabilities Structure**

Experimental tools:

Jets – *Footprints of energetic quarks and gluons*

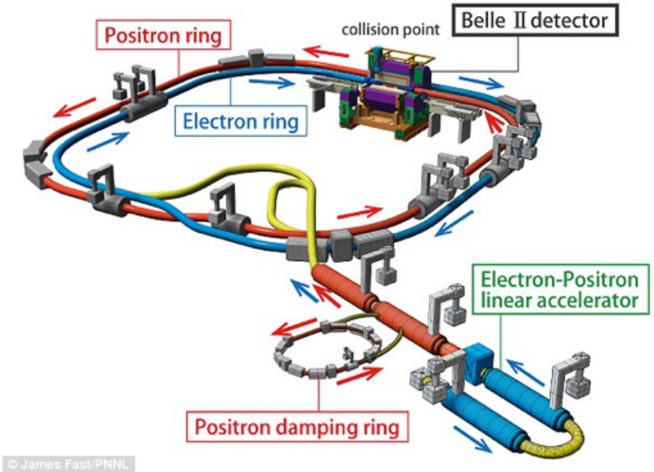
Quarks – *Need an EM probe to "see" their existence, …*

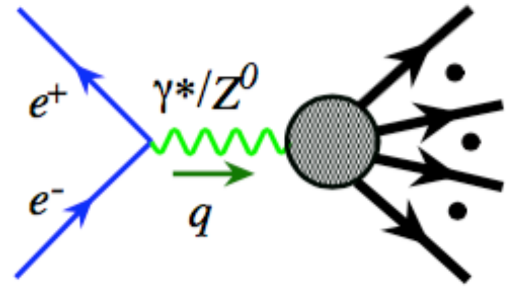
Gluons – *Varying the probe's resolution to "see" their effect, …*

Need probes with sub-femtometer resolution, and "see" the gluons!

Hard probes from high energy collisions

- Lepton-lepton collisions:





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- ✧ Hadrons are emerged from energy
- ✧ Not ideal for studying hadron structure

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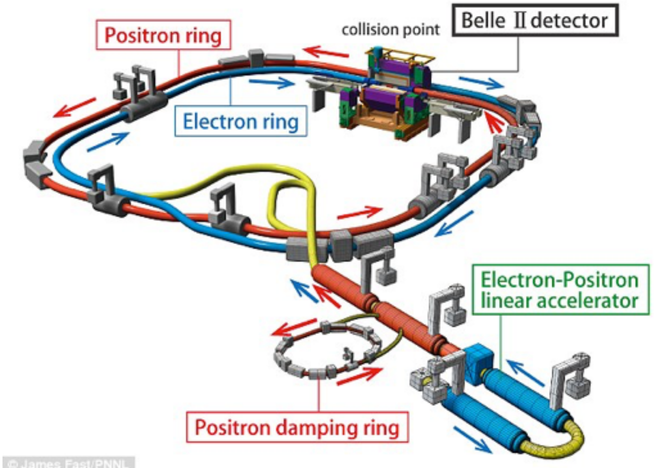

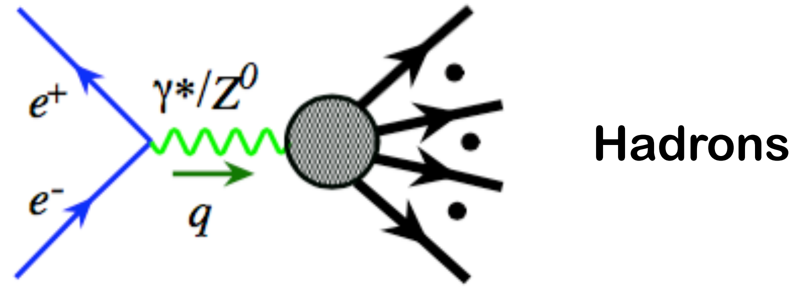

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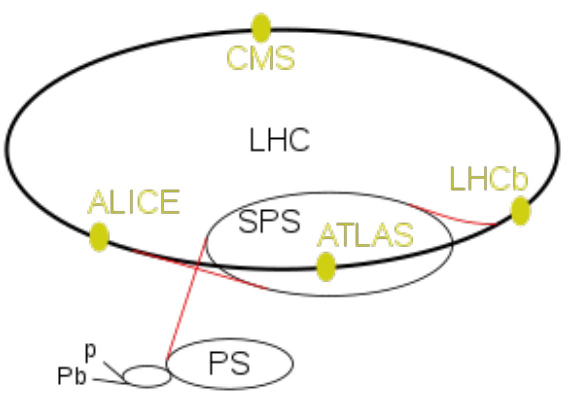

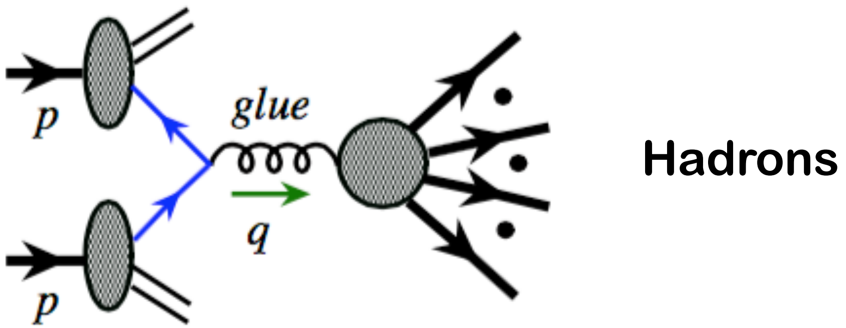

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✧ Initial hadrons broken – collision effect, …

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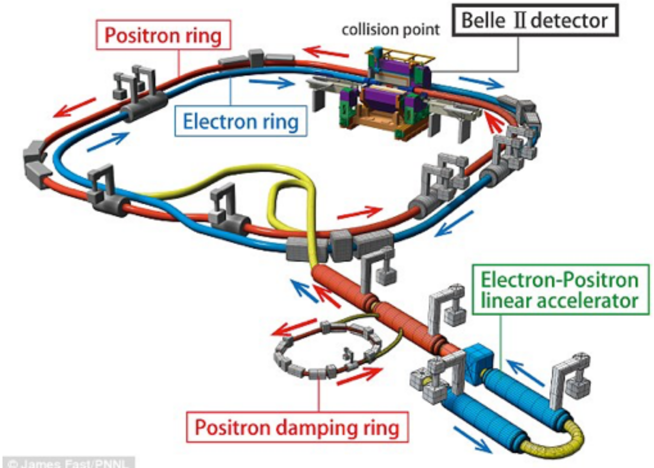

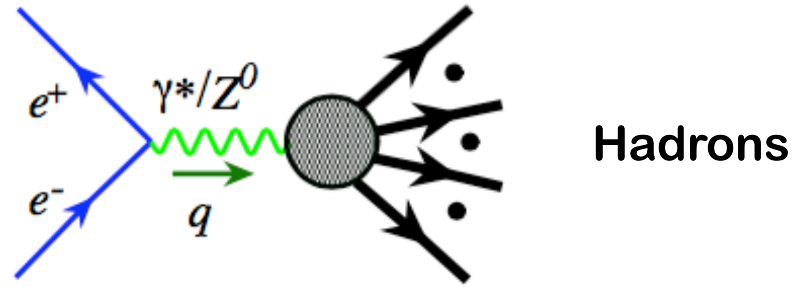

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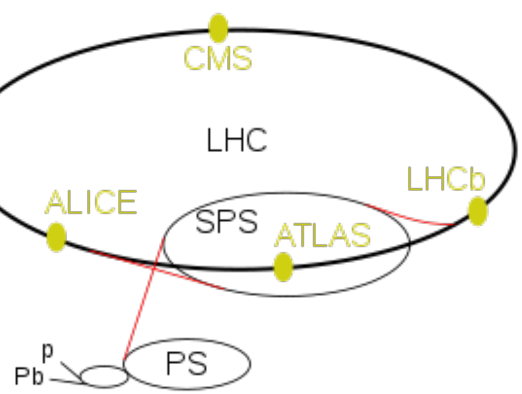

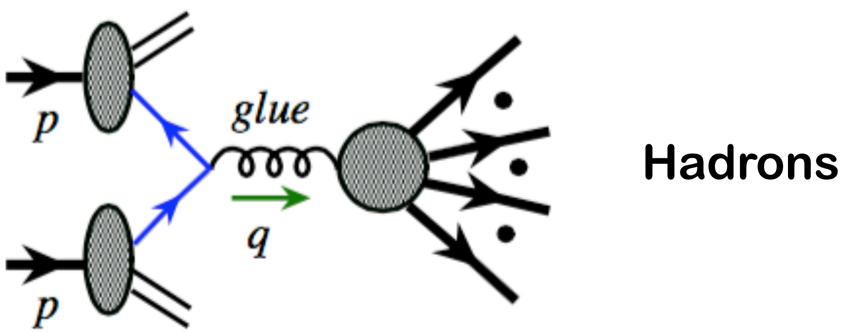

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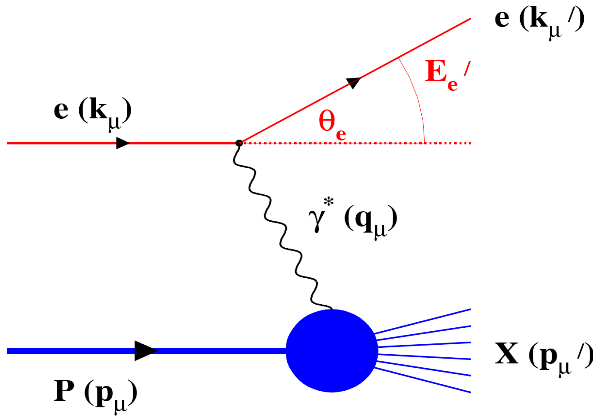
❑ **Lepton-hadron collisions:**

Hard collision without breaking the initial-state hadron – spatial imaging, …

Why a lepton-hadron facility is special?

- Many complementary probes at one facility:



Q^2 → Measure of resolution

y → Measure of inelasticity

x → Measure of momentum fraction of the struck quark in a proton

$Q^2 = S \times x \times y$

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Detect only the scattered lepton in the detector

(Modern Rutherford experiment!)

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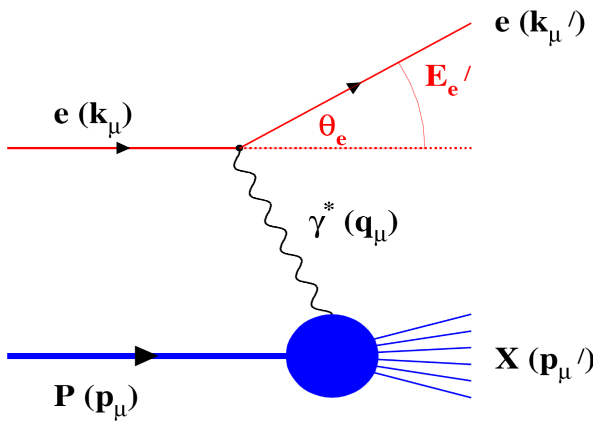

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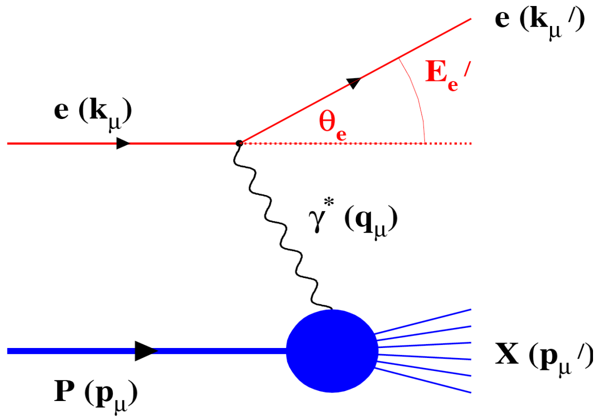

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Detect every things including scattered proton/nucleus (or its fragments)

(Initial hadron is NOT broken – tomography! – almost impossible for h-h collisions)

The Electron-Ion Collider (EIC) – the Future!

- A sharpest "CT" – "imagine" quark/gluon structure without breaking the hadron
  - – "cat-scan" the nucleon and nuclei with a better than 1/10 fm resolution
  - – "see" proton "radius" of quark/gluon density comparing with the radius of EM charge density

➡ *To discover color confining radius, hints on confining mechanism!*

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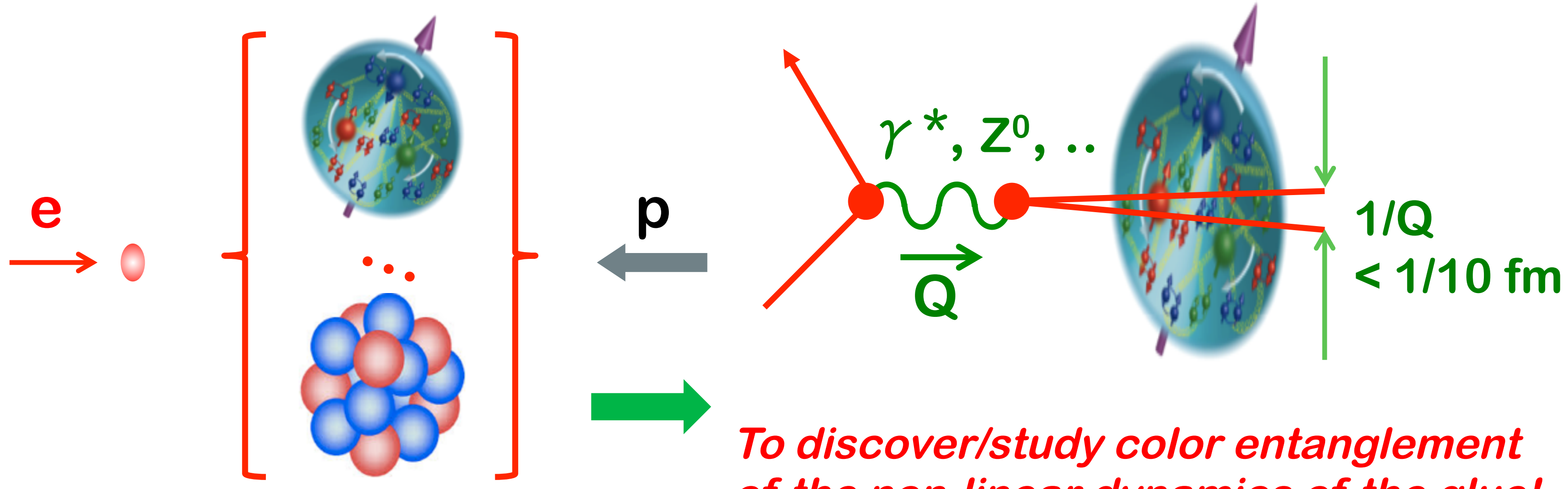
- A giant "Microscope" – "see" quarks and gluons by breaking the hadron



➡ *To discover/study color entanglement of the non-linear dynamics of the glue!*

EIC: the World Wide Interest

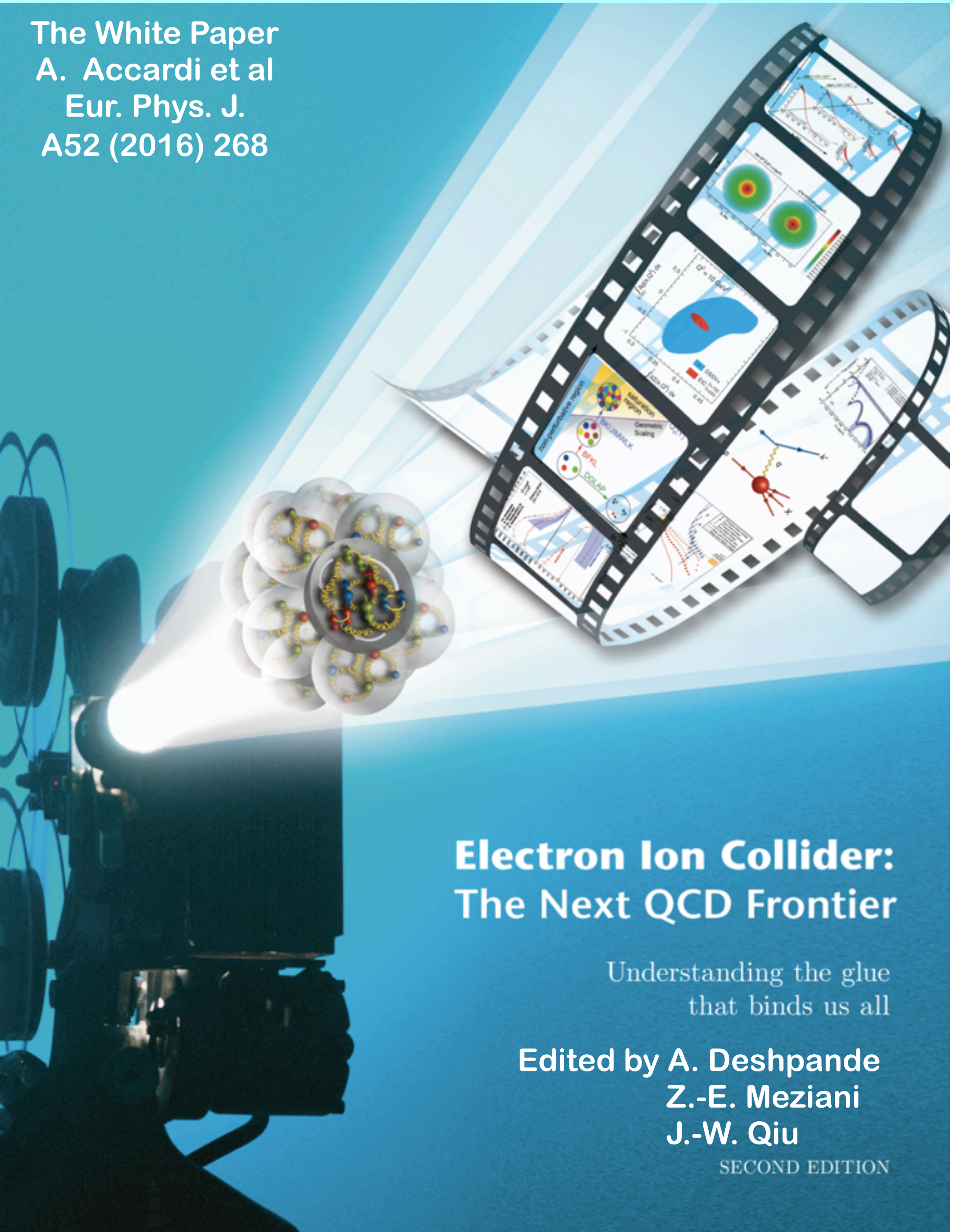
	HERA@DESY	LHeC@CERN	eRHIC@BNL	JLEIC@JLab	HIAF@CAS	ENC@GSI
E_{CM} (GeV)	320	800-1300	45-175	12-140	12 → 65	14
proton x_{min}	1×10^{-5}	5×10^{-7}	3×10^{-5}	5×10^{-5}	$7 \times 10^{-3} \rightarrow 3 \times 10^{-4}$	5×10^{-3}
ion	p	p to Pb	p to U	p to Pb	p to U	p to ~ ^{40}Ca
polarization	-	-	p, ^{3}He	p, d, ^{3}He (^{6}Li)	p, d, ^{3}He	p,d
L [cm^{-2} s^{-1}]	2×10^{31}	10^{33}	10^{33-34}	10^{33-34}	$10^{32-33} \rightarrow 10^{35}$	10^{32}
IP	2	1	2+	2+	1	1
Year	1992-2007	2022 (?)	2022	Post-12 GeV	2019 → 2030	upgrade to FAIR

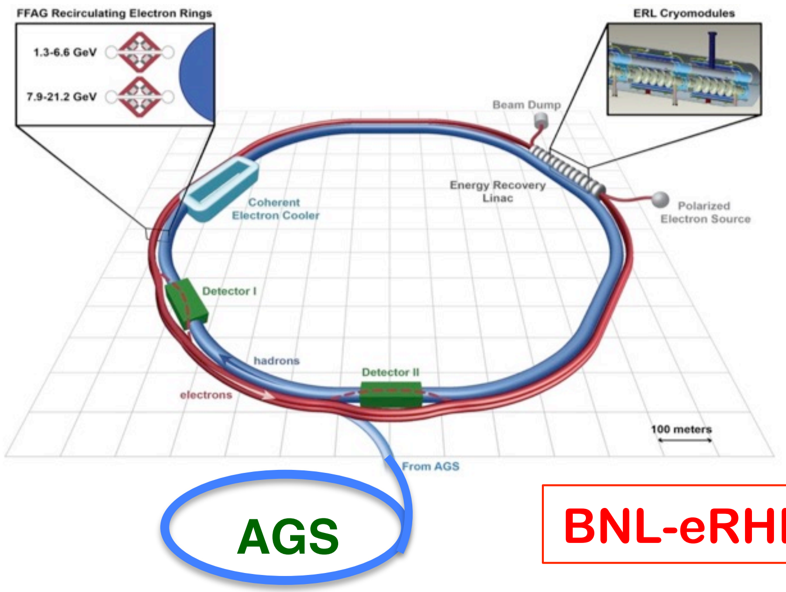
The past (HERA@DESY)

Possible future (LHeC@CERN – ENC@GSI)

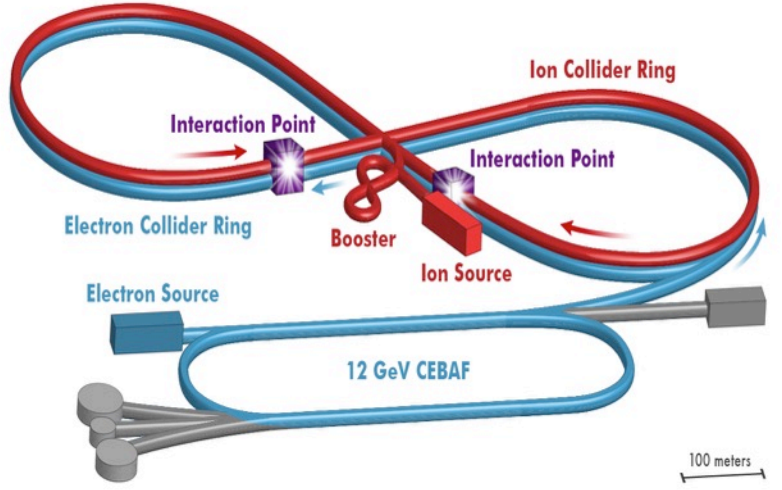
US EIC – Two Options of Realization

The White Paper
A. Accardi et al
Eur. Phys. J.
A52 (2016) 268



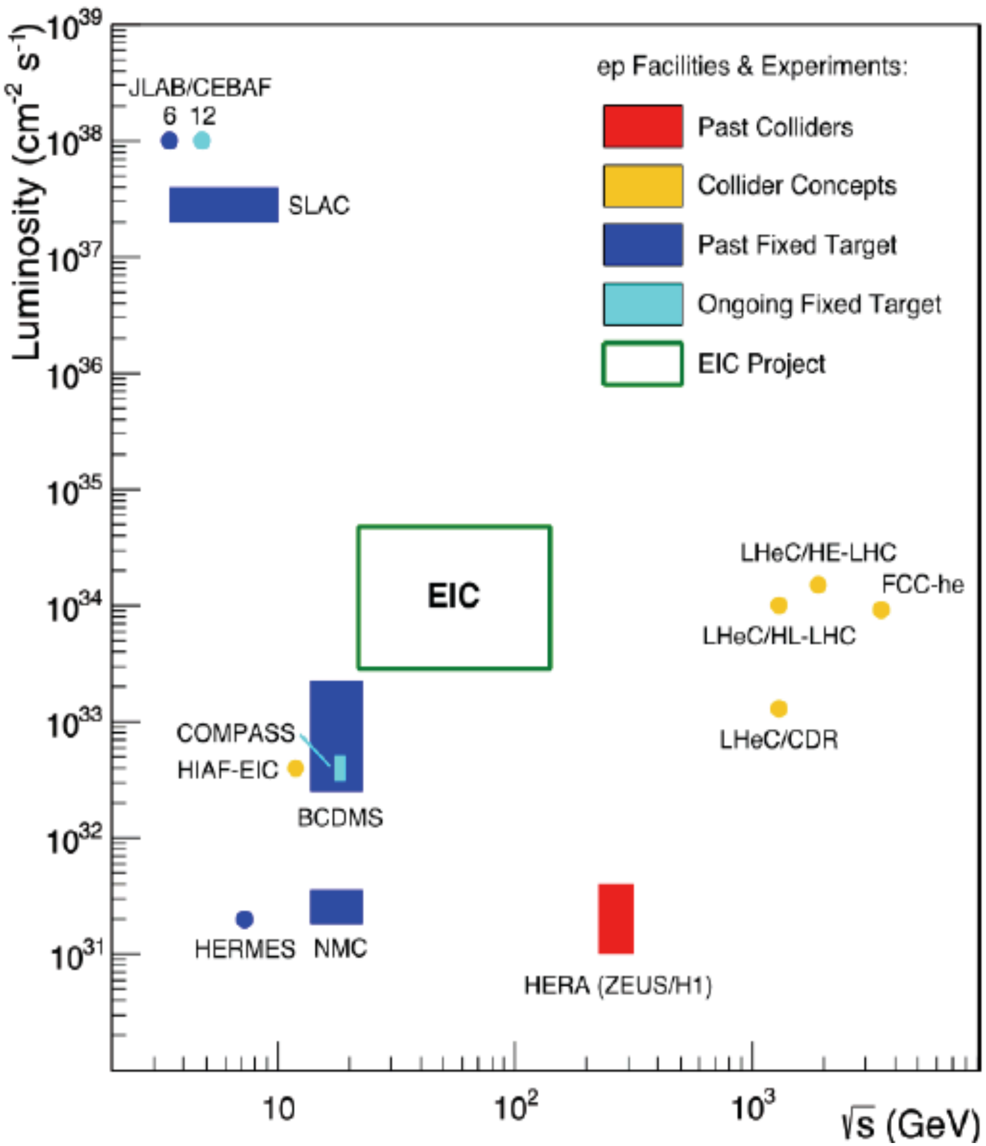


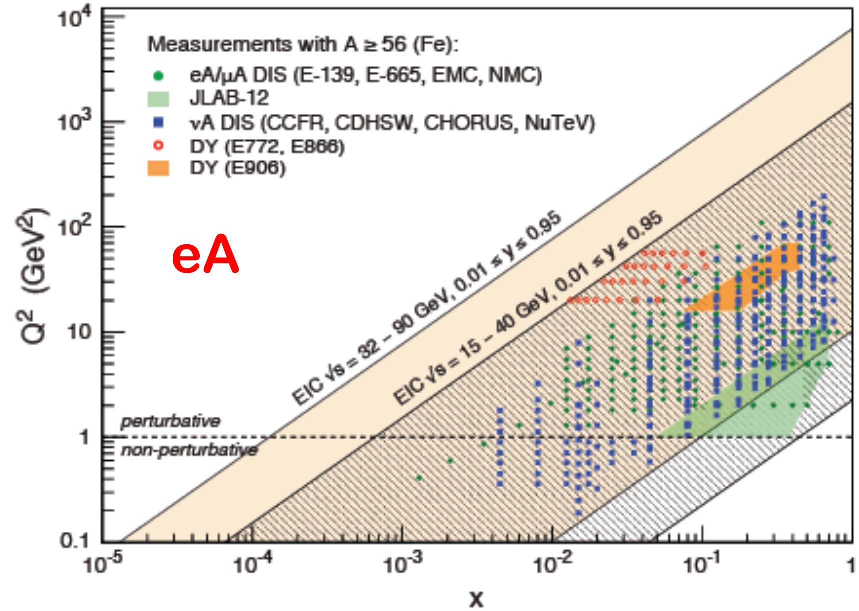
BNL-eRHIC

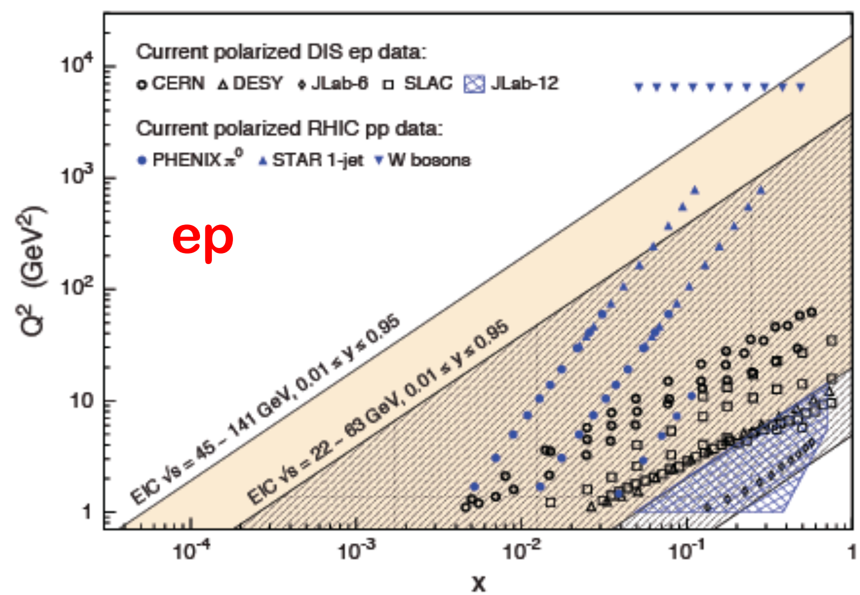


JLab-JLEIC

US EIC – Luminosity & kinematics coverage







US-EIC – can do what HERA could not do

- **Quantum imaging:**
  - **HERA discovered: 15% of e-p events is diffractive – Proton not broken!**
  - **US-EIC: 100-1000 times luminosity – *Critical for 3D tomography!***

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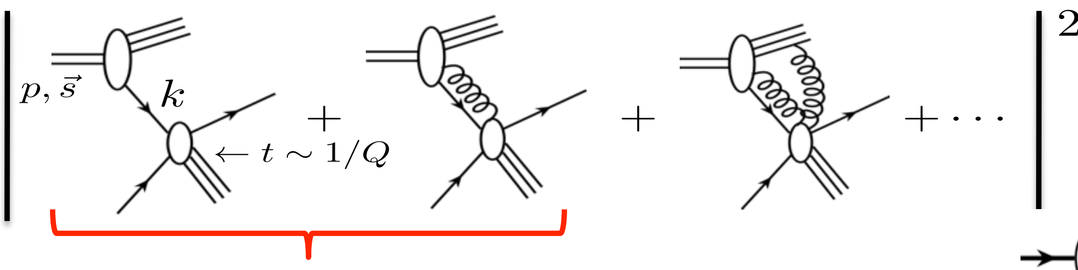
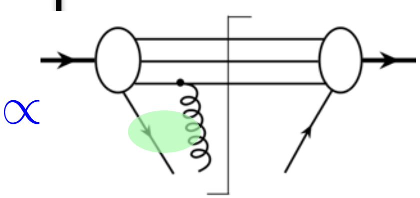
  - ✧ **US-EIC: 100-1000 times luminosity – *Critical for 3D tomography!***
- **Quantum interference & entanglement:**
  - ✧ **US-EIC: Highly polarized beams – *Origin of hadron property: Spin, …***
    Direct access to chromo-quantum interference!

$\sigma(Q, \vec{s}) \propto$



$\sigma(s) - \sigma(-s)$ ➡ **Quantum interference** ➡ $T^{(3)}(x, x) \propto$



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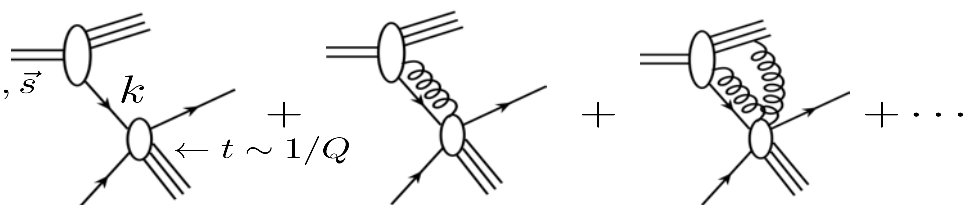
$\sigma(Q, \vec{s}) \propto \Big| \ldots \Big|^2$



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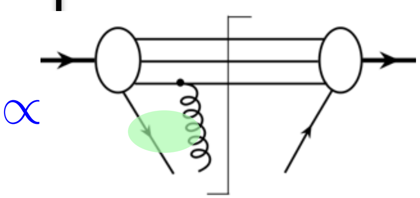


- **Nonlinear quantum dynamics:**
  - ✧ US-EIC: Light-to-heavy nuclear beams – *Origin of nuclear force, …*
    Catch the transition from chromo-quantum fluctuation
    to chromo-condensate of gluons, …
    Emergence of hadrons (femtometer size detector!),
    – "a new controllable knob" – Atomic weight of nuclei

US EIC – Deliverables & Opportunities

Why existing facilities, even with upgrades, cannot do the same?

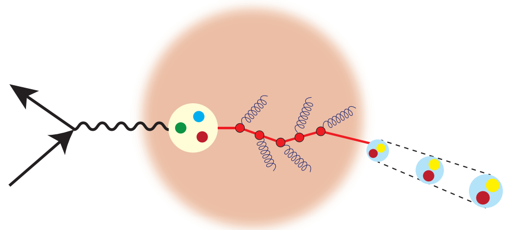
- ✧ Emergence of hadrons
- ✧ Hadron properties:
  mass, spin, …
- ✧ Hadron's 3D partonic structure:
  confined motion, spatial distribution,
  color correlation, fluctuation,
  saturation, …
- ✧ Quantum correlation between
  hadron properties and parton dynamics, …

…

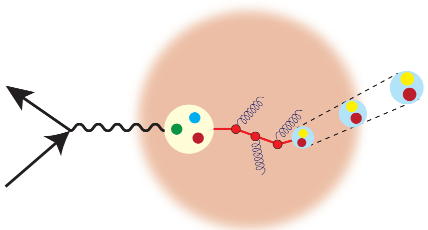
Due to the time, only a few examples to be presented in this talk!

Emergence of Hadrons from quarks & gluons

❑ Femtometer sized detector:



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

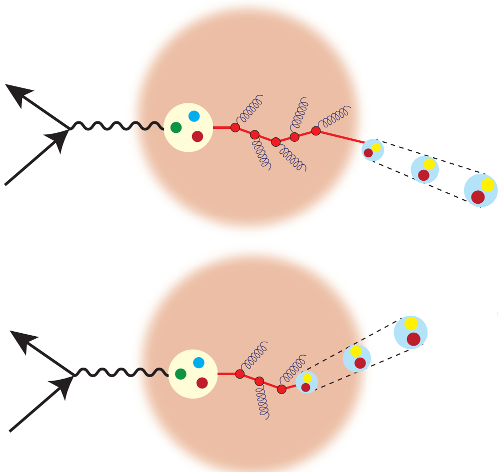


Control of ν and medium length!

Mass dependence of hadronization

Emergence of Hadrons from quarks & gluons

❑ **Femtometer sized detector:**



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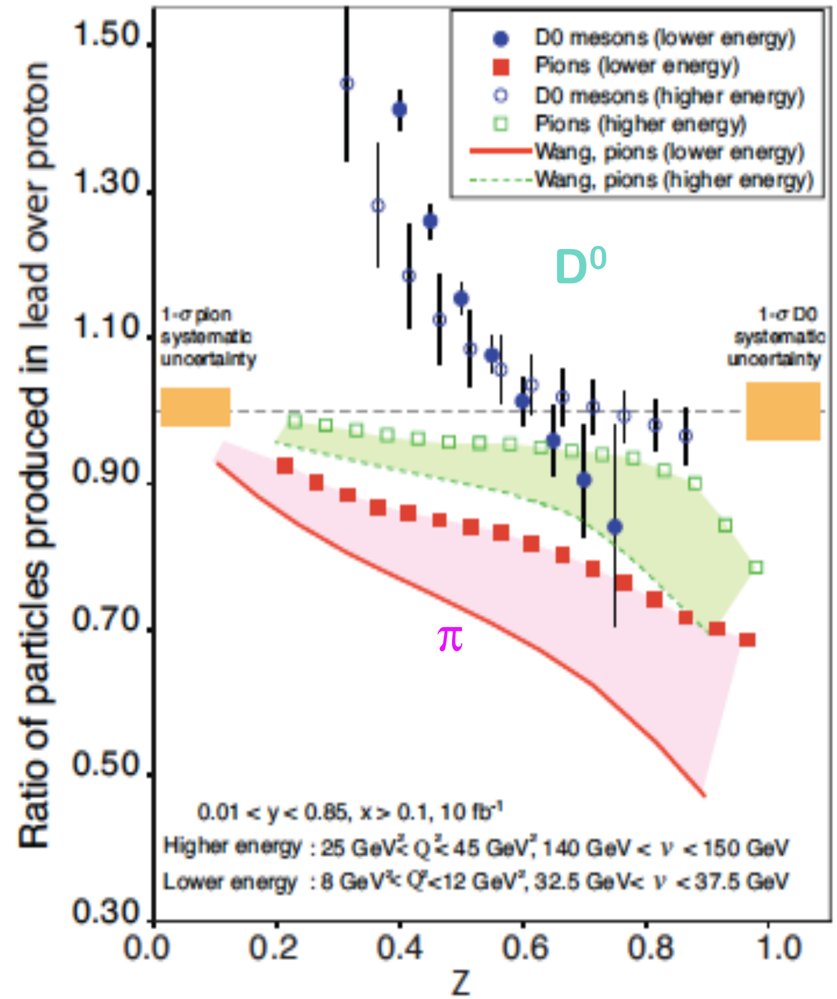

Need the collider energy of EIC and its control on parton kinematics

Emergence of Hadrons from quarks & gluons

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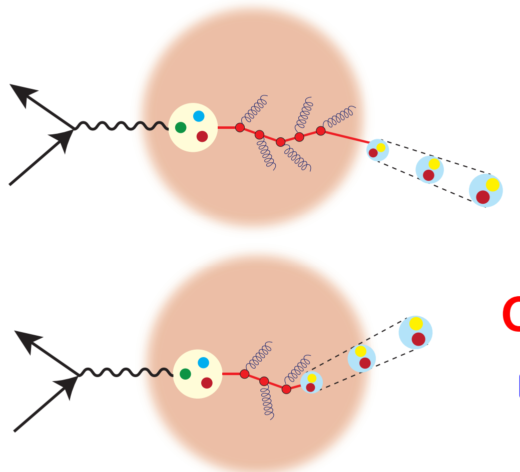

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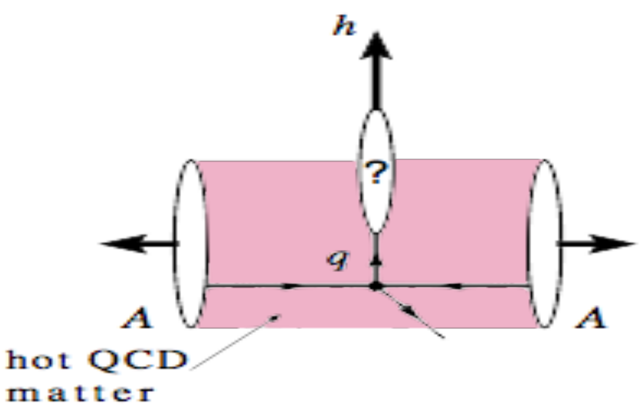
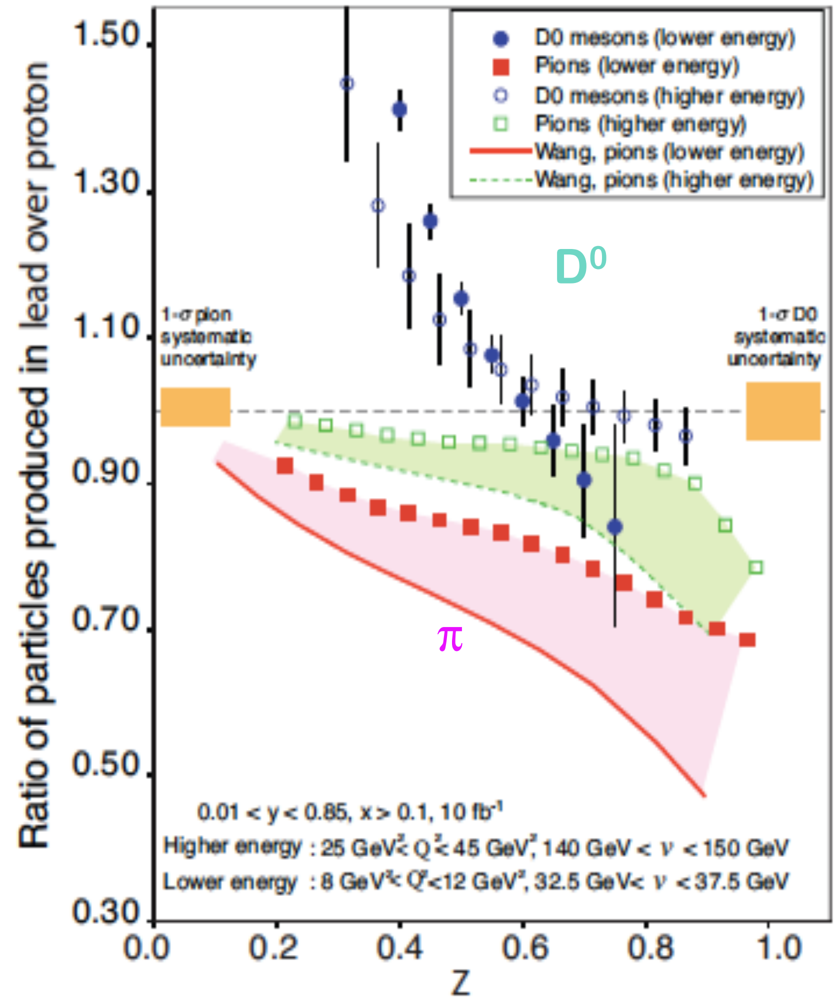
Control of ν and medium length!

Mass dependence of hadronization

❑ Apply to heavy-ion collisions:





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

Hadron Properties: Mass & Spin, …

- **Mass – intrinsic to a particle:**

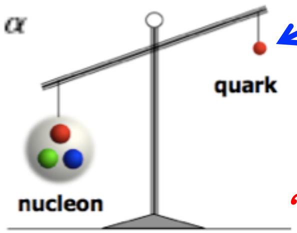
  = Energy of the particle when it is at the rest

  ✧ **QCD energy-momentum tensor in terms of quarks and gluons**

$$T^{\mu\nu} = \frac{1}{2}\,\overline{\psi} i \overleftrightarrow{D}^{(\mu}\gamma^{\nu)}\psi + \frac{1}{4}\,g^{\mu\nu}F^2 - F^{\mu\alpha}F^{\nu}{}_{\alpha}$$

  ✧ **Proton mass:**

$$m = \frac{\langle p|\int d^3x\, T^{00}\,|p\rangle}{\langle p|p\rangle} \sim \text{GeV}$$



Higgs Mech.

m_q ~ 10 MeV

m_N ~ 1000 MeV

"Mass without mass"

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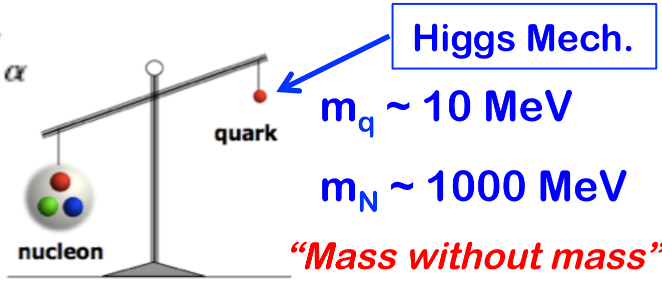


$m_q \sim 10$ MeV

$m_N \sim 1000$ MeV

"Mass without mass"

❑ Spin – intrinsic to a particle:

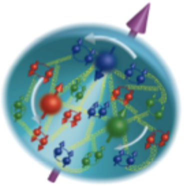
= Angular momentum of the particle when it is at the rest

✧ QCD angular momentum density in terms of energy-momentum tensor

$$M^{\alpha\mu\nu} = T^{\alpha\nu}x^{\mu} - T^{\alpha\mu}x^{\nu} \qquad J^i = \frac{1}{2}\epsilon^{ijk}\int d^3x M^{0jk}$$

✧ Proton spin:

$$S(\mu) = \sum \langle P,S|\hat{J}^z_f(\mu)|P,S\rangle = \frac{1}{2}$$



EMC found:

$$\sum_q(\Delta q + \Delta\bar{q}) \sim 0.12 \pm 0.17$$

"Proton spin puzzle"

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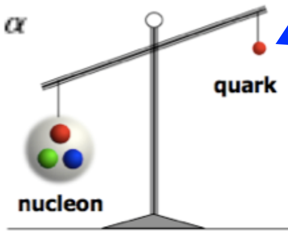

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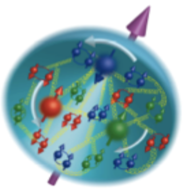

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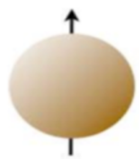
"Proton spin puzzle"

If we do not understand proton mass & spin, we do not understand QCD!

The Proton Spin

- **The sum rule:** $$S(\mu) = \sum_f \langle P, S | \hat{J}_f^z(\mu) | P, S \rangle = \frac{1}{2} \equiv J_q(\mu) + J_g(\mu)$$
  - Infinite possibilities of decompositions – connection to observables?
  - Intrinsic properties + dynamical motion and interactions
- **An incomplete story:**

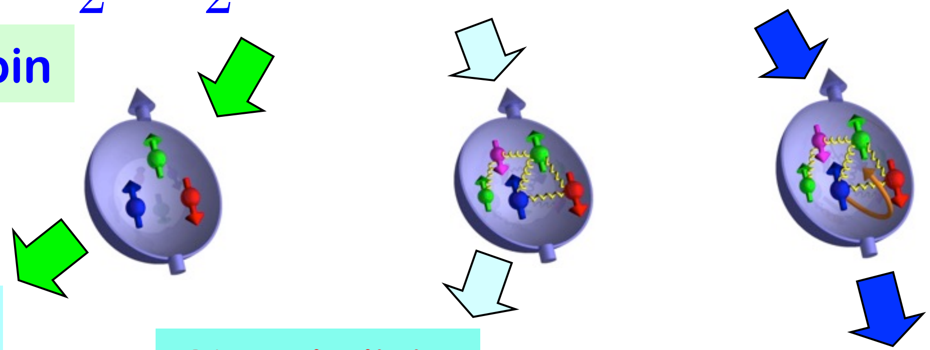
See H. Gao's Plenary Talk



Proton Spin

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + (L_q + L_g)$$

Jaffe-Manohar, 90
Ji, 96, …



Quark helicity
Best known

$$\frac{1}{2}\int dx \left(\Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s}\right)$$
$$\sim 30\%$$

Gluon helicity
Start to know

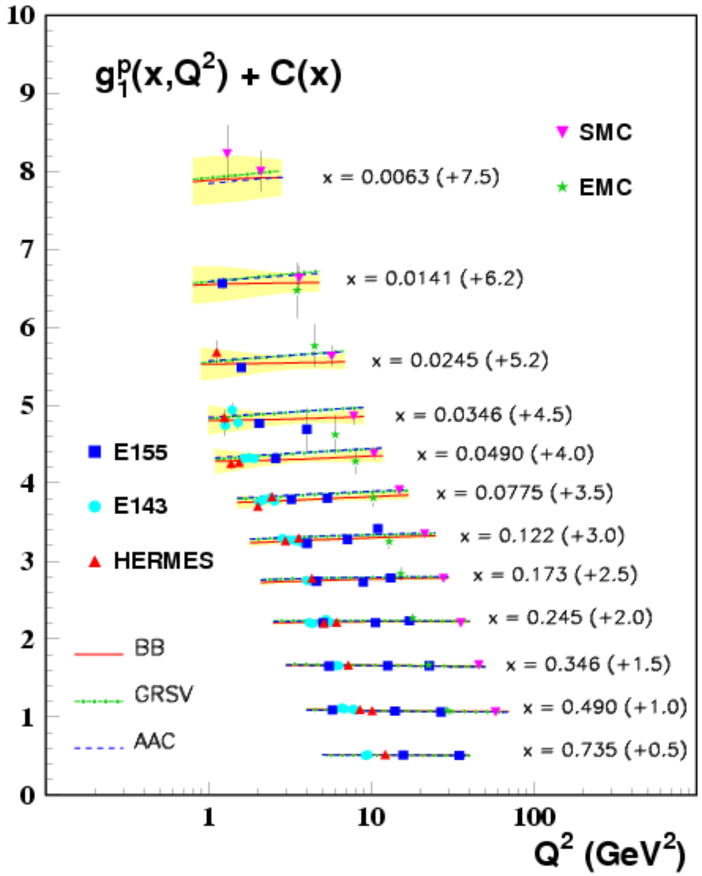
$$\Delta G = \int dx \Delta g(x)$$
$$\sim 40\% (\text{with RHIC data})$$

Orbital Angular Momentum of quarks and gluons
Little known

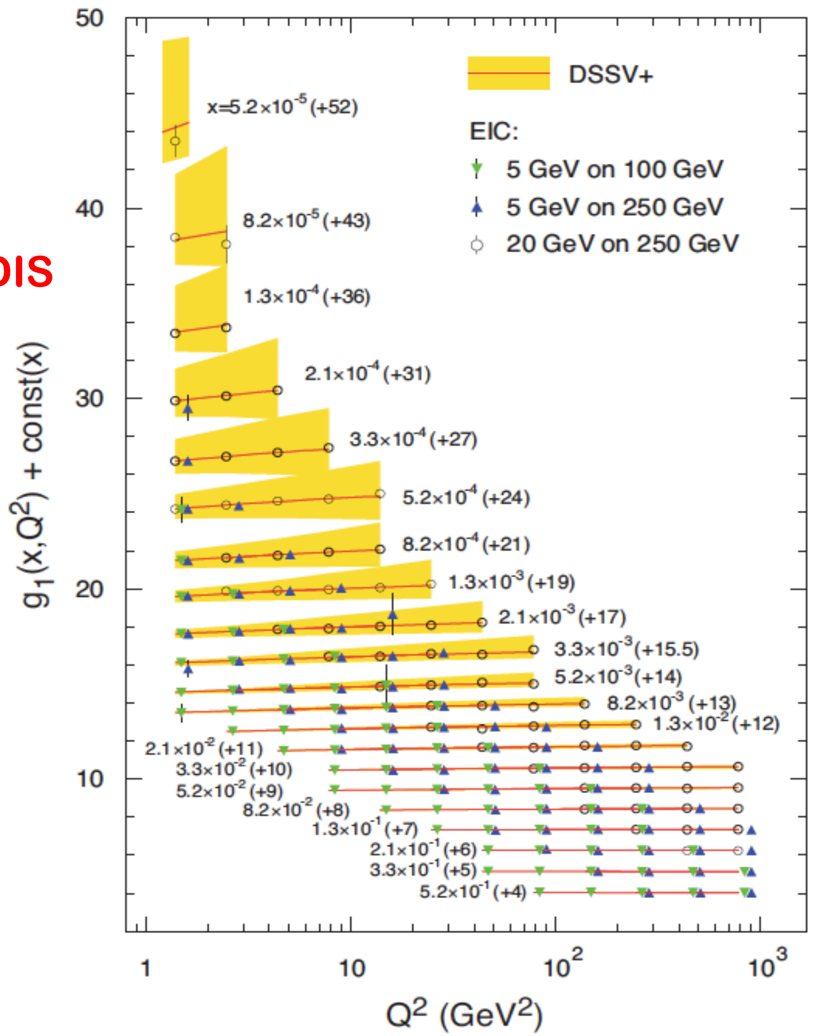
Net effect of partons' transverse motion?

The Proton Spin

- The power & precision of EIC:



Polarized DIS at EIC



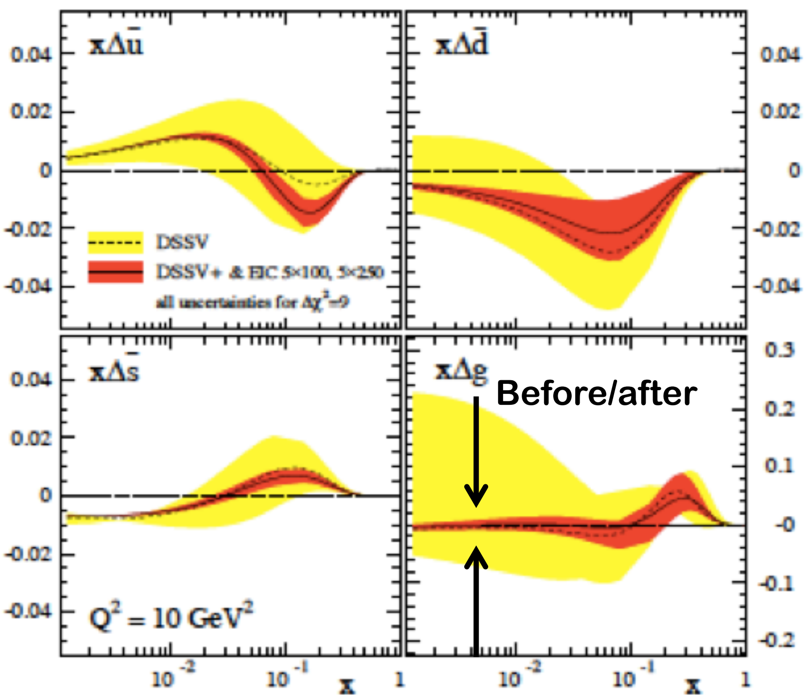
- Reach out the glue:

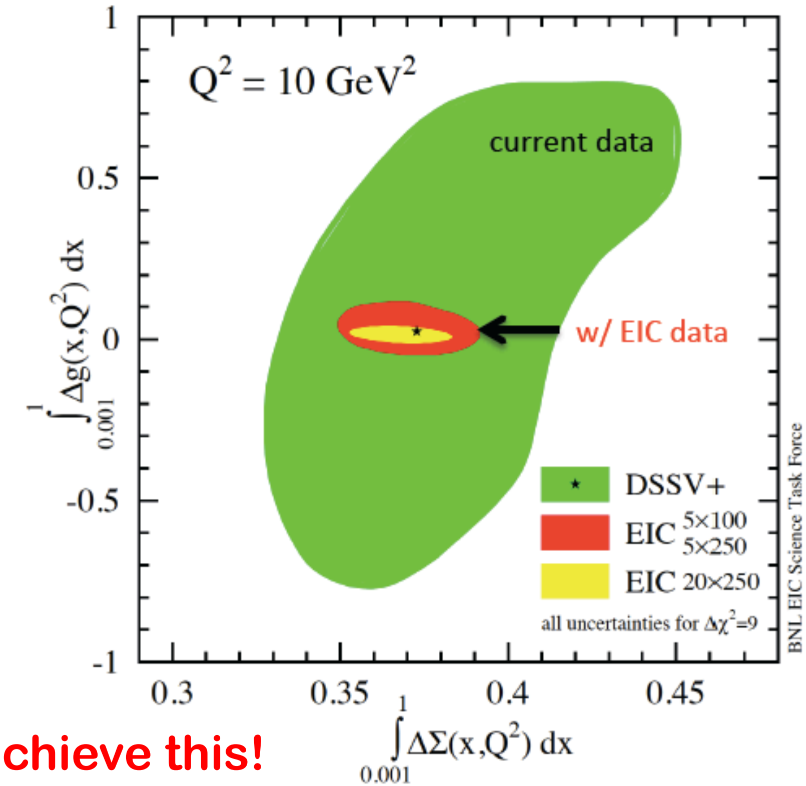
$$\frac{dg_1(x,Q^2)}{d\ln Q^2} = \frac{\alpha_s}{2\pi} P_{qg} \otimes \Delta g(x,Q^2) + \cdots$$

The Proton Spin

❑ **One-year of running at EIC:**

Wider Q^2 and x range including low x at EIC!





No other machine in the world can achieve this!

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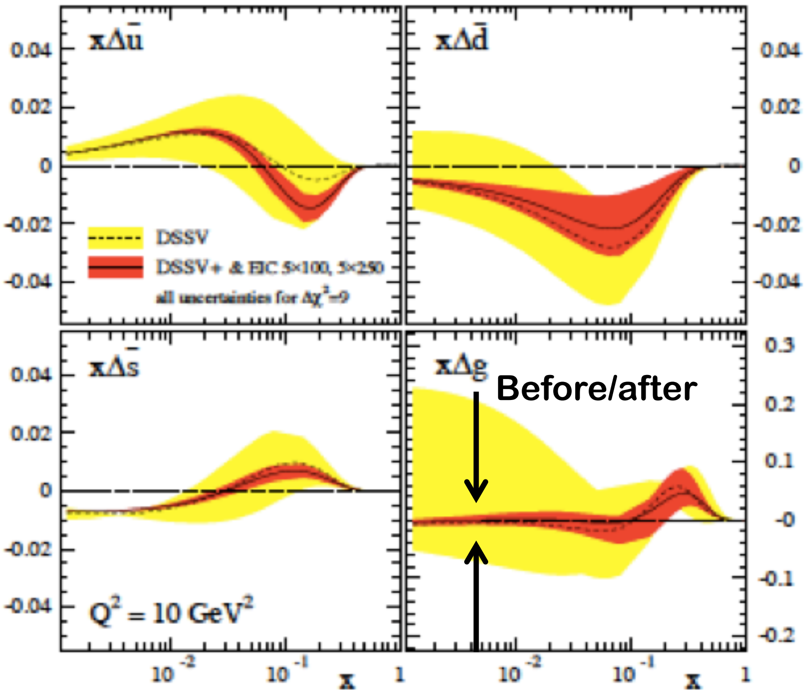

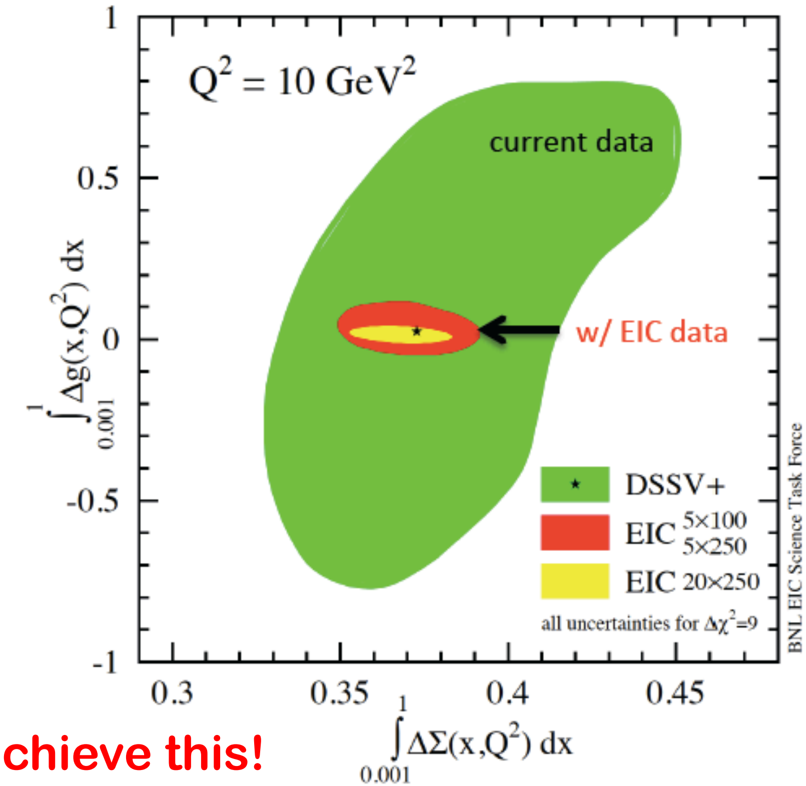

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❑ **Ultimate solution to the proton spin puzzle:**

✧ ***Precision measurement of Δg(x) – extend to smaller x regime***

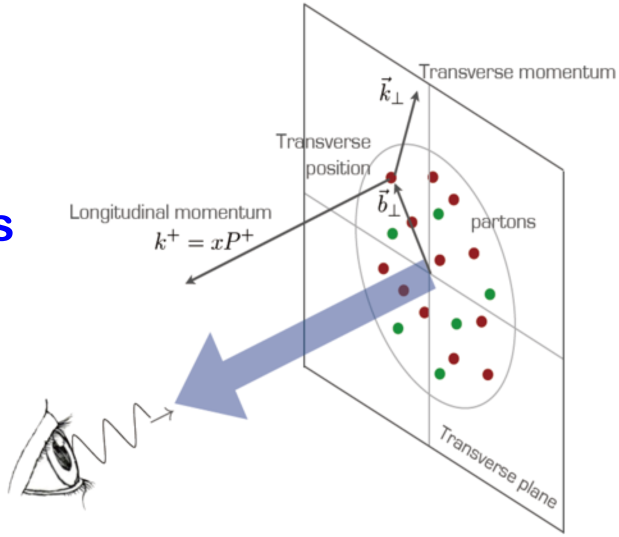
✧ ***Orbital angular momentum contribution – measurement of TMDs & GPDs!***

Hadron's 3D partonic structure

- **Cross sections with two-momentum scales observed:**

$$Q_1 \gg Q_2 \sim 1/R \sim \Lambda_{\rm QCD}$$

  - ✧ **Hard scale:** Q_1 **localizes the probe particle nature of quarks/gluons**
  - ✧ **"Soft" scale:** Q_2 **could be more sensitive to the structure, e.g., confined motion**



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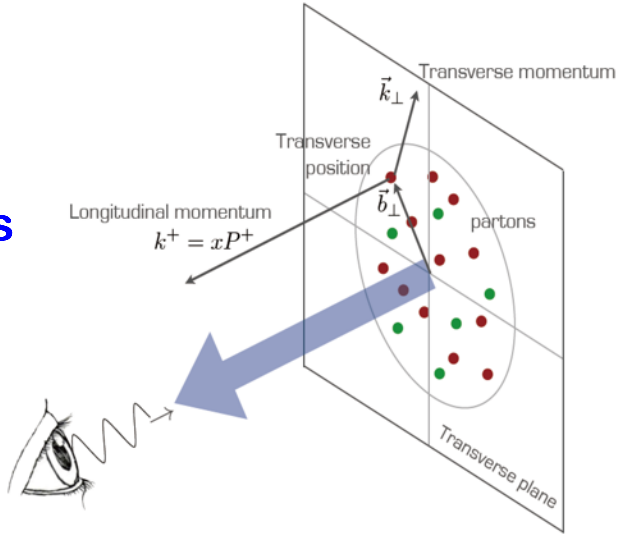
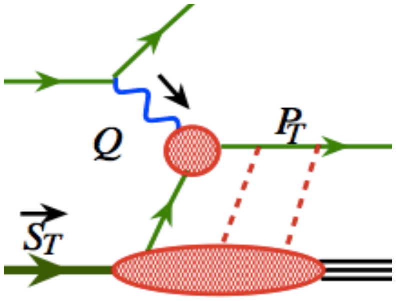


- Two-scale observables at the EIC:
  - ✧ Semi-inclusive DIS:

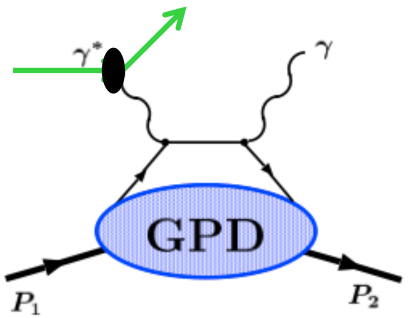


+ …

SIDIS: $Q \gg P_T$

Parton's confined motion encoded into TMDs

  - ✧ Exclusive DIS:



+ …

DVCS: $Q^2 \gg |t|$

Parton's spatial imaging from Fourier transform of GPDs' t-dependence

Theory is solid – unified description

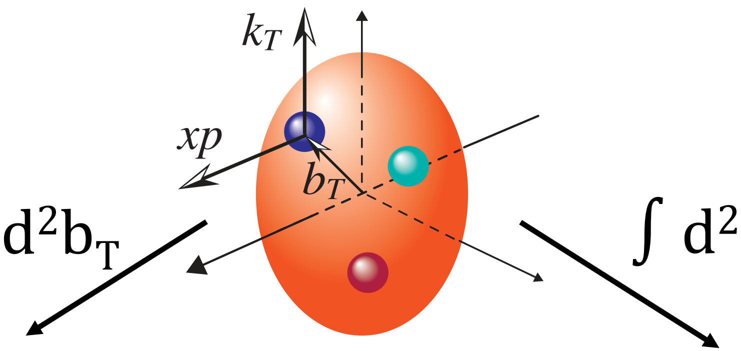
- **Wigner distributions in 5D (or GTMDs):**

Momentum Space | *Coordinate Space*

TMDs | *GPDs*

Confined motion | **Spatial distribution**

$\int d^2 b_T$



$\int d^2 k_T$

$f(x,k_T)$ **Two-scales observables** $f(x,b_T)$

- **TMDs & SIDIS as an example:**

  - **Low P_{hT} (P_{hT} << Q) – TMD factorization:**

$$\sigma_{\text{SIDIS}}(Q, P_{h\perp}, x_B, z_h) = \hat{H}(Q) \otimes \Phi_f(x, k_\perp) \otimes \mathcal{D}_{f\to h}(z, p_\perp) \otimes \mathcal{S}(k_{s\perp}) + \mathcal{O}\left[\frac{P_{h\perp}}{Q}\right]$$

  - **High P_{hT} (P_{hT} ~ Q) – Collinear factorization:**

$$\sigma_{\text{SIDIS}}(Q, P_{h\perp}, x_B, z_h) = \hat{H}(Q, P_{h\perp}, \alpha_s) \otimes \phi_f \otimes D_{f\to h} + \mathcal{O}\left(\frac{1}{P_{h\perp}}, \frac{1}{Q}\right)$$

  - **P_{hT} Integrated - Collinear factorization:**

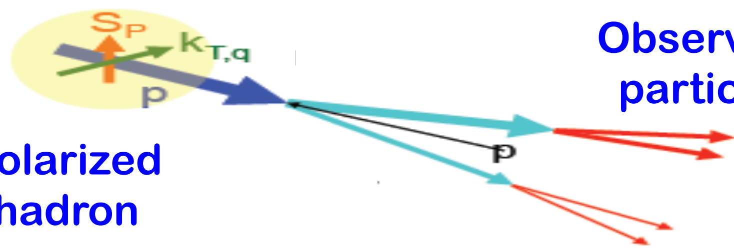
$$\sigma_{\text{SIDIS}}(Q, x_B, z_h) = \tilde{H}(Q, \alpha_s) \otimes \phi_f \otimes D_{f\to h} + \mathcal{O}\left(\frac{1}{Q}\right)$$

  - **Very high P_{hT} >> Q – Collinear factorization:**

$$\sigma_{\text{SIDIS}}(Q, P_{h\perp}, x_B, z_h) = \sum_{abc} \hat{H}_{ab\to c} \otimes \phi_{\gamma\to a} \otimes \phi_b \otimes D_{c\to h} + \mathcal{O}\left(\frac{1}{Q}, \frac{Q}{P_{h\perp}}\right)$$

Confined motion of quarks & gluons

- Quantum correlation between hadron spin and parton motion:



Observed particle

Polarized hadron

Sivers effect – Sivers function

Hadron spin influences parton's transverse motion

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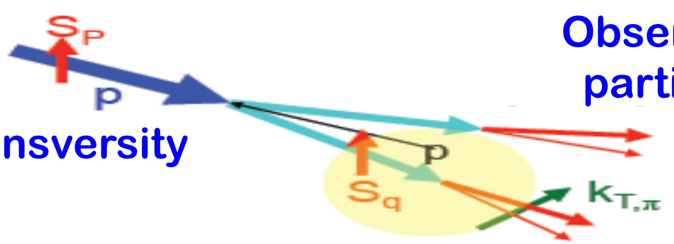

Observed particle

Transversity

Collins effect – Collins function

Parton's transverse polarization influences its hadronization

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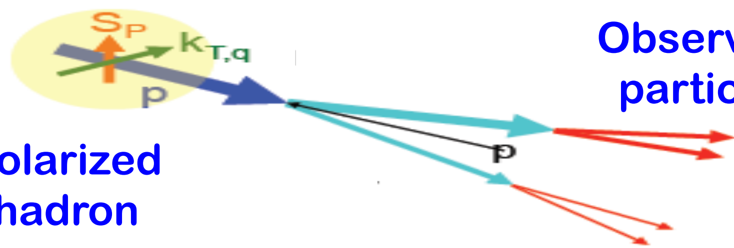

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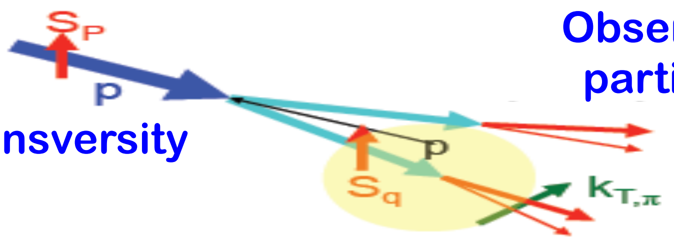
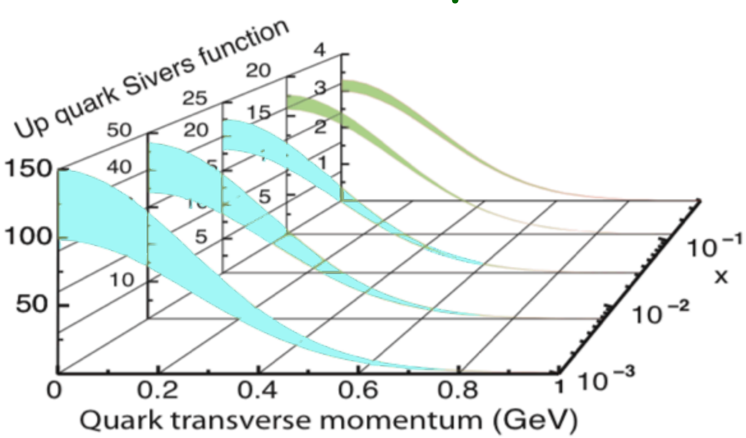
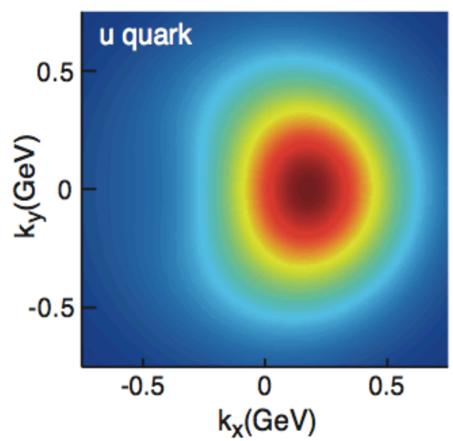


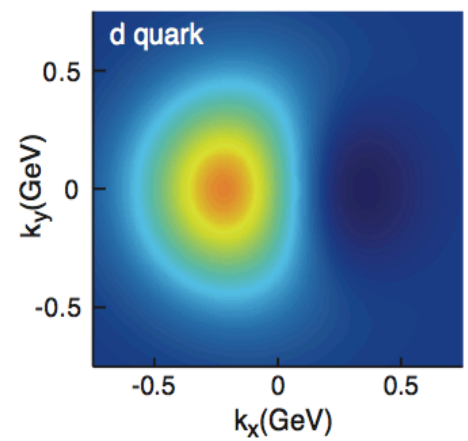
Collins effect – Collins function

Parton's transverse polarization influences its hadronization

- **TMDs and their separation at EIC:**



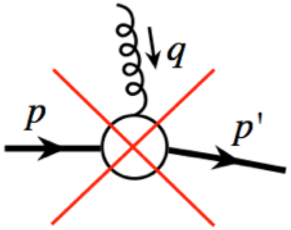




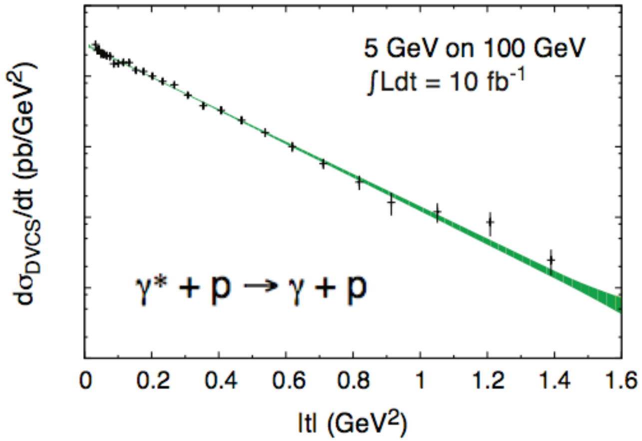
Spatial imaging of quarks & gluons

- No color elastic nucleon form factor!

  ➡ *Spatial distribution of quark/gluon densities – GPDs*



- DVCS at EIC:

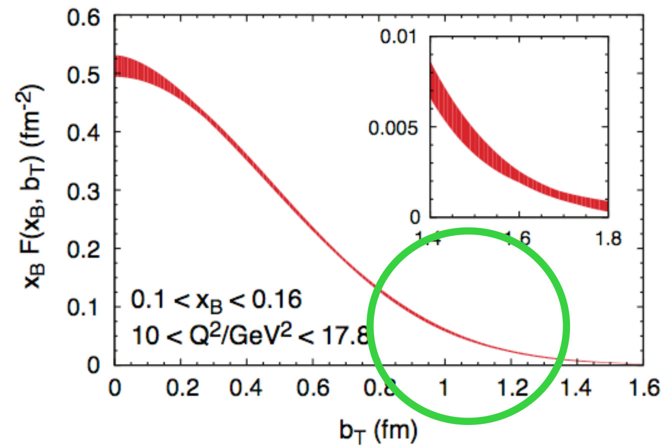


Factorization

➡ GPDs ➡

F.T.

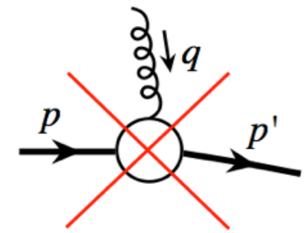
Proton radius of quarks (x)!



Spatial imaging of quarks & gluons

- No color elastic nucleon form factor!

  ➡ *Spatial distribution of quark/gluon densities – GPDs*



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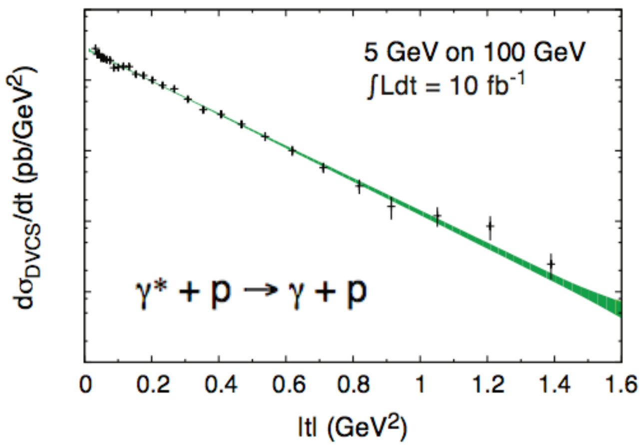

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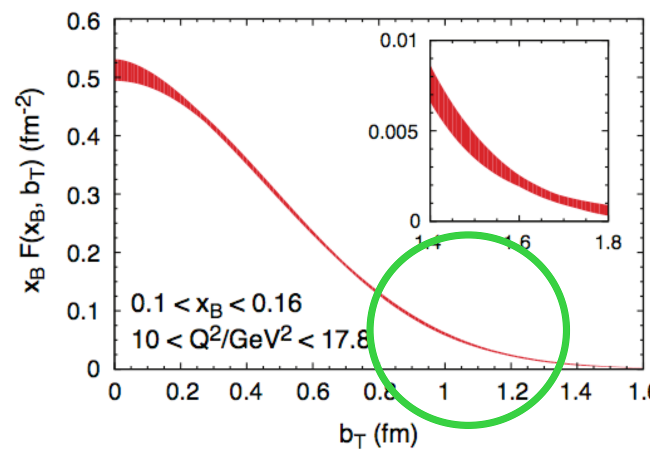
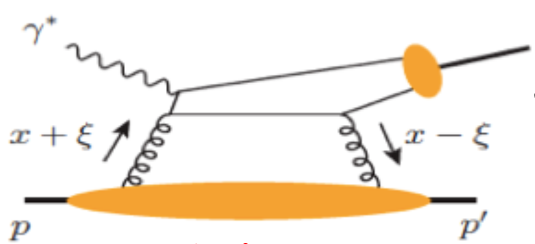


- "Seeing" the glue at EIC:



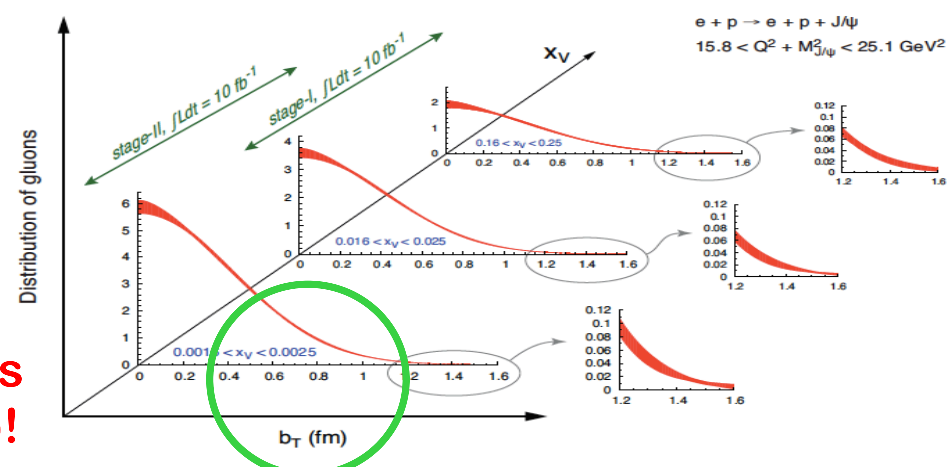
J/Ψ, Φ, …

t-dep

➡

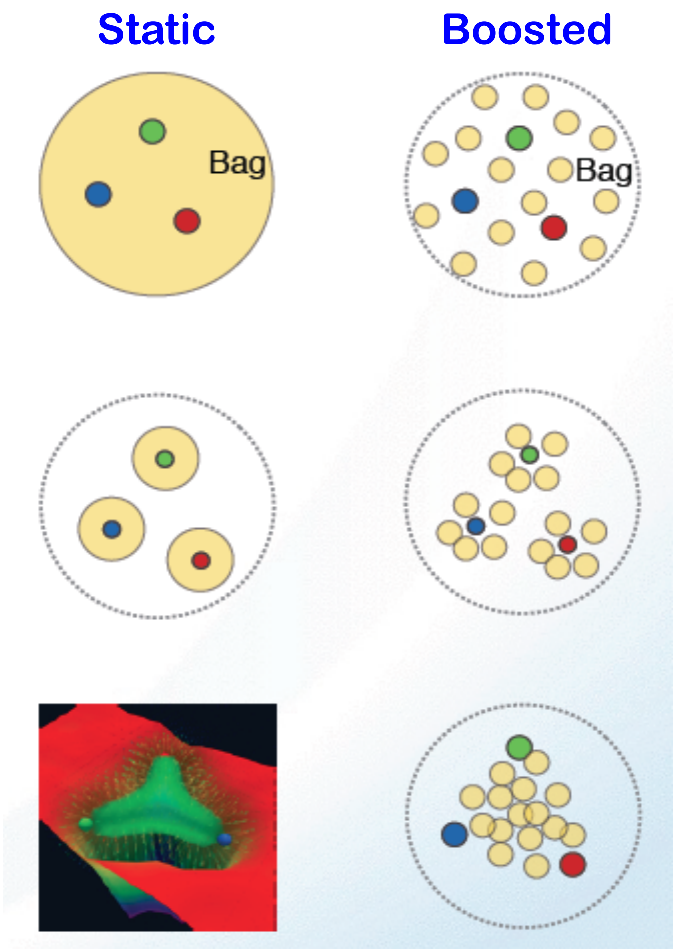
Only possible at EIC!

Proton radius of gluons (x)!



Why 3D nucleon structure?

❑ Spatial distributions of quarks and gluons:



Bag Model:
Gluon field distribution is wider than the fast moving quarks.
Gluon radius > Charge Radius

Constituent Quark Model:
Gluons and sea quarks hide inside massive quarks.
Gluon radius ~ Charge Radius

Lattice Gauge theory (with slow moving quarks):
Gluons more concentrated inside the quarks
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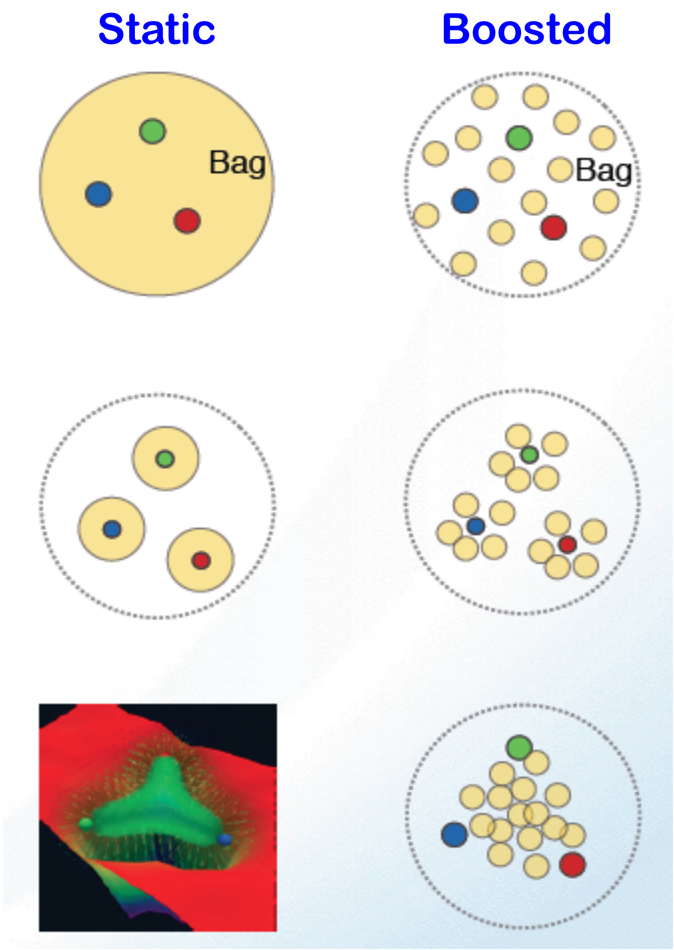

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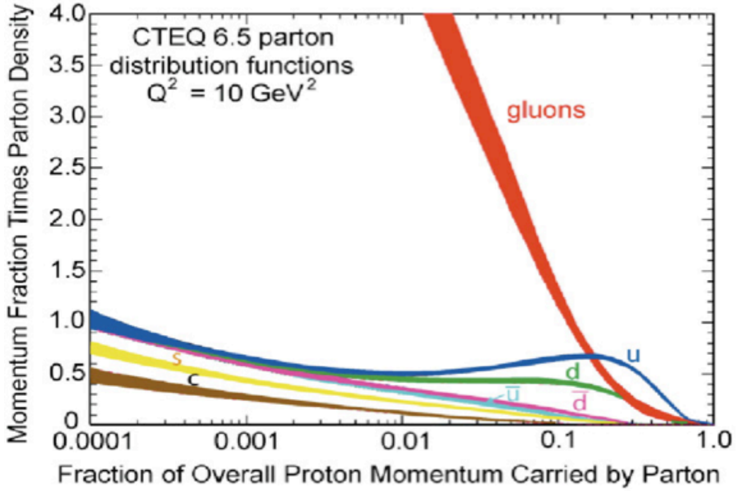
Gluon radius < Charge Radius

3D confined motion (TMDs) + spatial distribution (GPDs)
Hints on the color confining mechanism
Relation between charge radius, quark radius (x), and gluon radius (x)?

Another HERA discovery

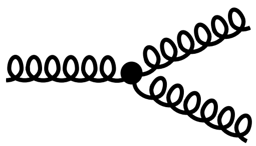
- Run away gluon density at small-x?



What causes the low-x rise?

gluon radiation

– non-linear gluon interaction



What could tame the low-x rise?

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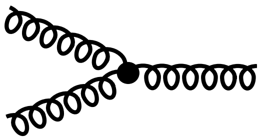

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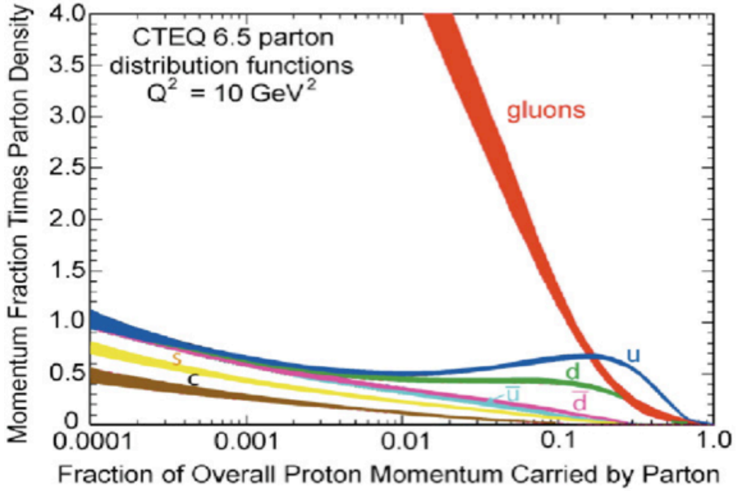

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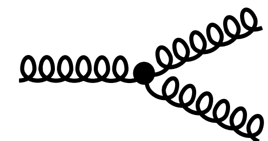

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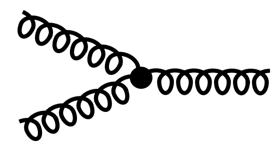
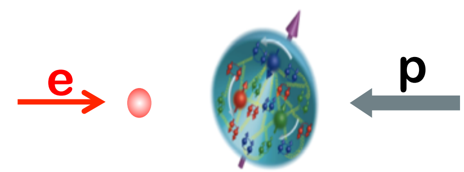
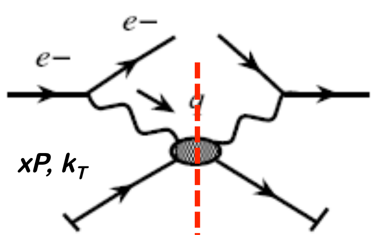


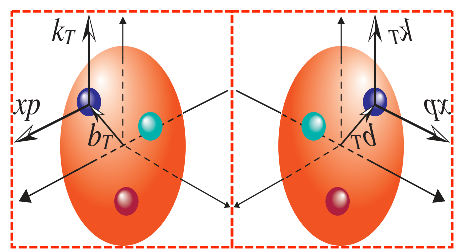
- Color entanglement enhanced at small-x:



$\sigma_{\rm tot}^{\rm DIS}$:



$\otimes$



+

+ ...

$\mathcal{O}(1/QR)$

$$= \sum_f \hat{C}_f \otimes \Phi_f + \mathcal{O}\left(Q_s^2/Q^2\right) + \mathcal{O}\left(Q_s^4/Q^4\right) + \ldots$$

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Color entangled or correlated between two active partons

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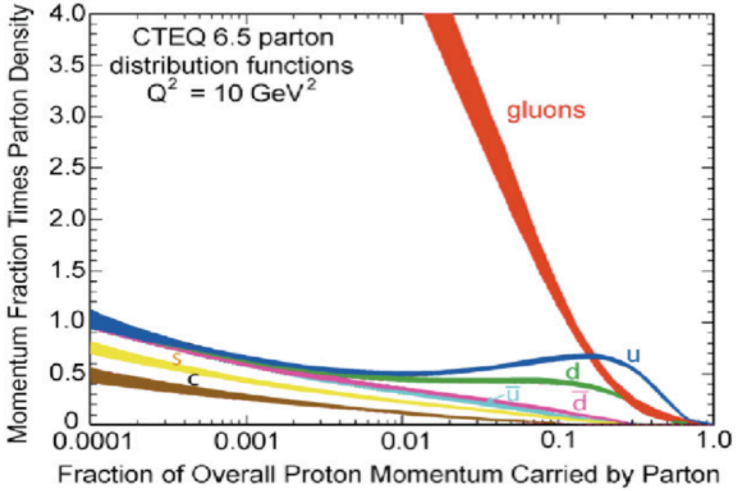

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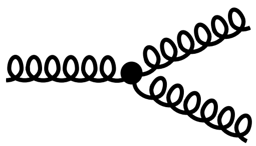

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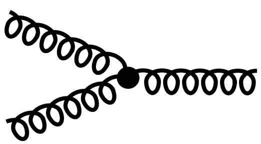

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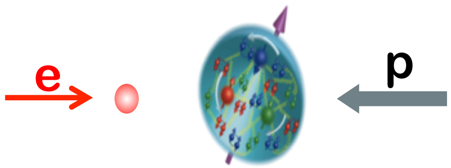

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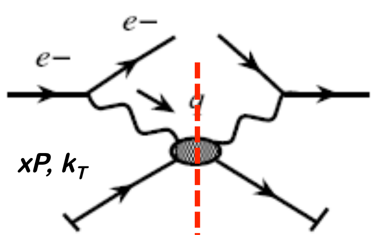

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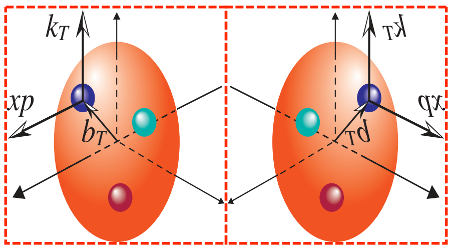
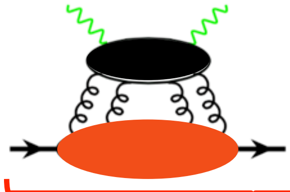


+



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$Q_s^2 \propto$ parton density

Color entangled or correlated between two active partons

- **Saturation:**

Counting single parton is meaningless if every term is equally important!

→ *Color Glass Condensate (CGC)*

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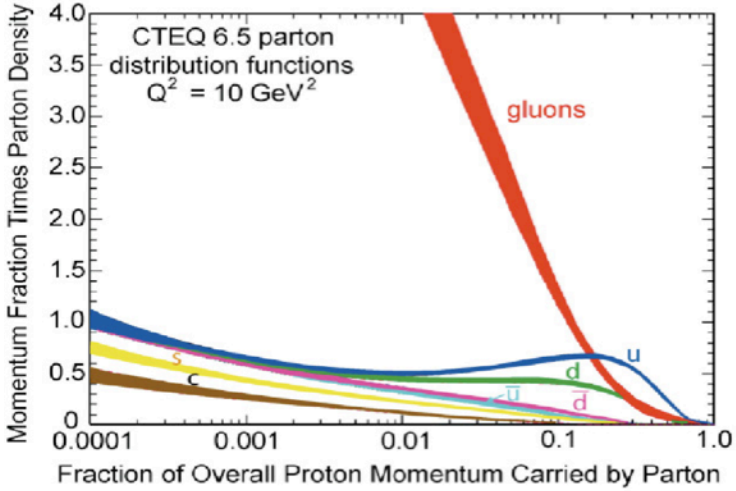

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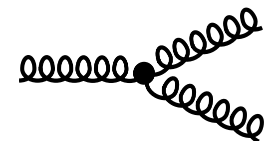

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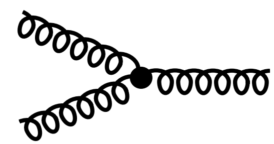

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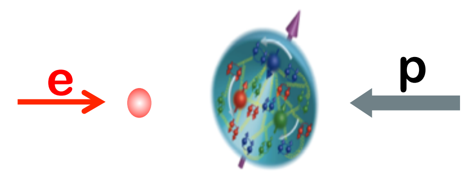

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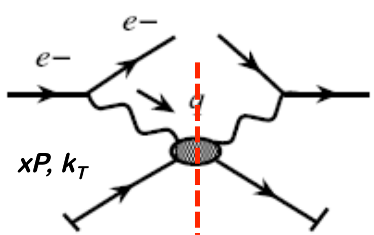

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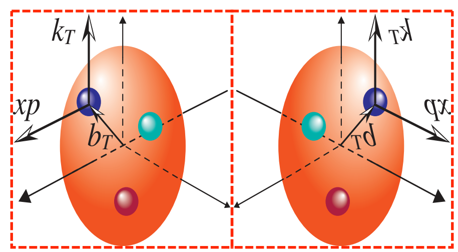

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$\mathcal{O}(1/QR)$

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Color entangled or correlated between two active partons

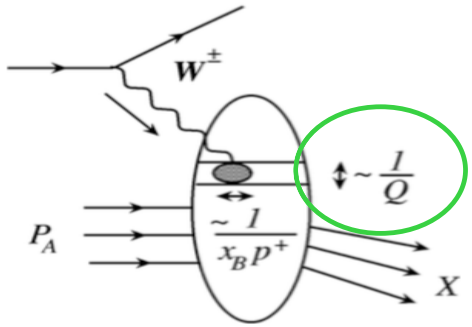
- Saturation:

is a part of QCD!
Where to find it?

Expectation: $x=10^{-5}$ in a proton at $Q^2=5\ \mathrm{GeV}^2$

Can a large nucleus help!

❑ **The hard probe at small-x is NOT localized:**



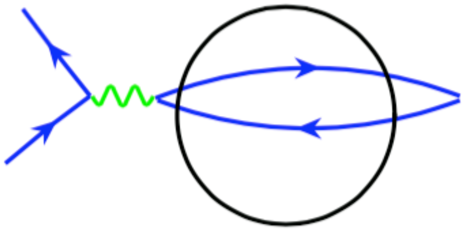
c.m. frame

Longitudinal probing size

> Lorentz contracted nucleon, if

$$\frac{1}{xp} > 2R_A \frac{m}{p} \quad \text{or} \quad x \lesssim 0.01$$

Hadron rest frame



Hard probe can "see" gluons from all nucleons at the same impact parameter, coherently!

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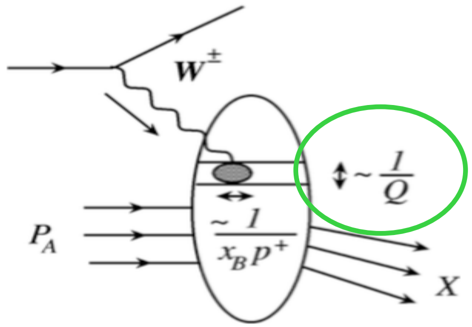

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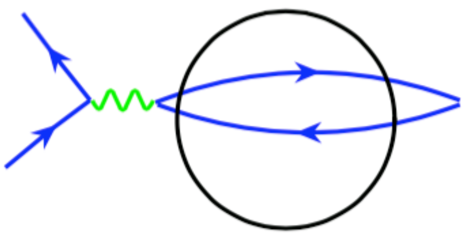

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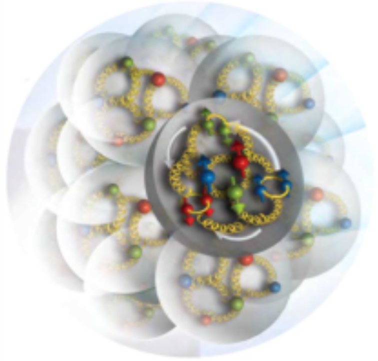
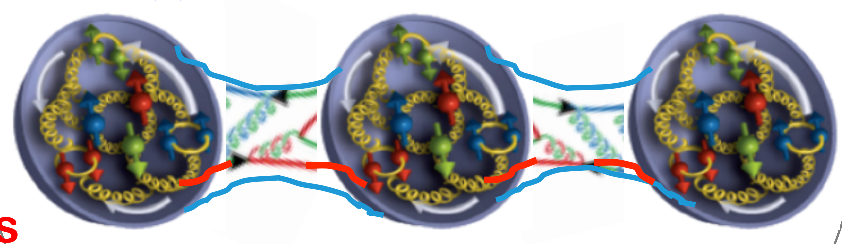
- Help explore the nature of nuclear force!



If we only see quarks and gluons, …

What does a nucleus look like?



Does the color of "A" know the color of "B"?

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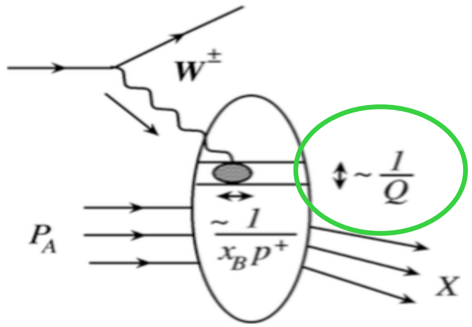

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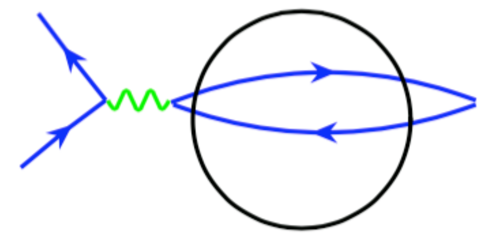

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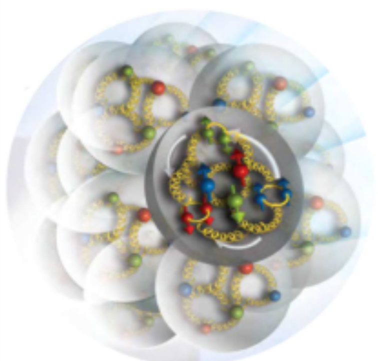
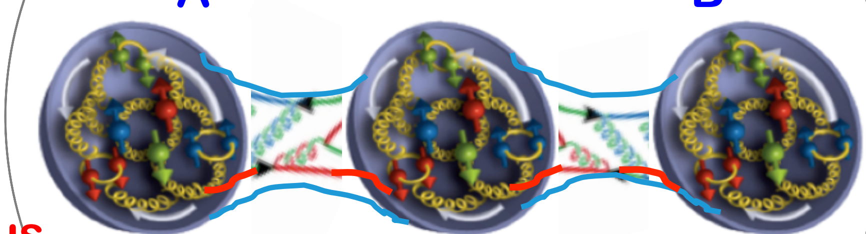


If we only see quarks and gluons, ...

"A" "B"



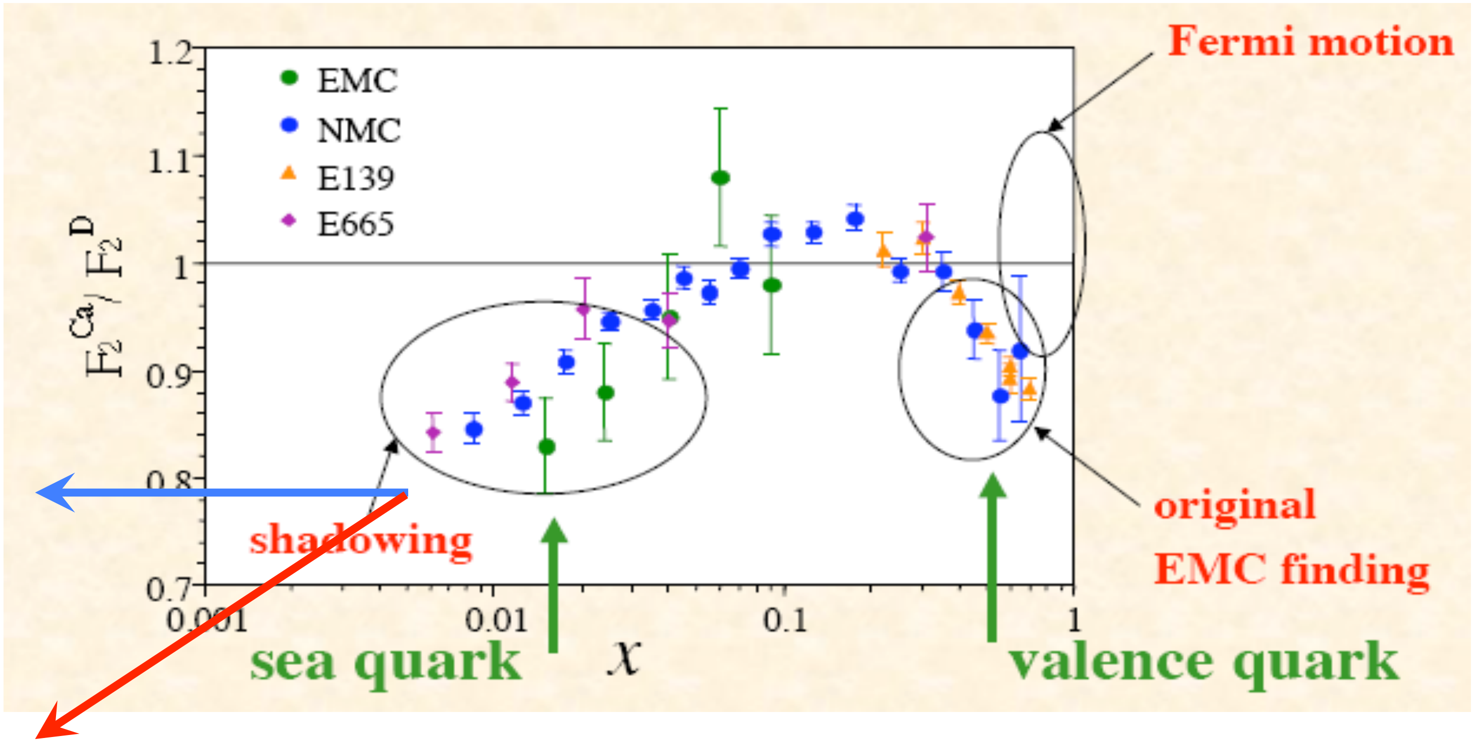
What does a nucleus look like?

Does the color of "A" know the color of "B"?

- ✧ NO → Observed nuclear effect is a coherent collision effort
- ✧ YES → Nucleus could act like a bigger proton at small-x, and could reaching the saturation sooner!

EIC can tell!

Role of color for nuclear force?



- A simple question:

  Will the suppression/shadowing continue to fall as x decreases?

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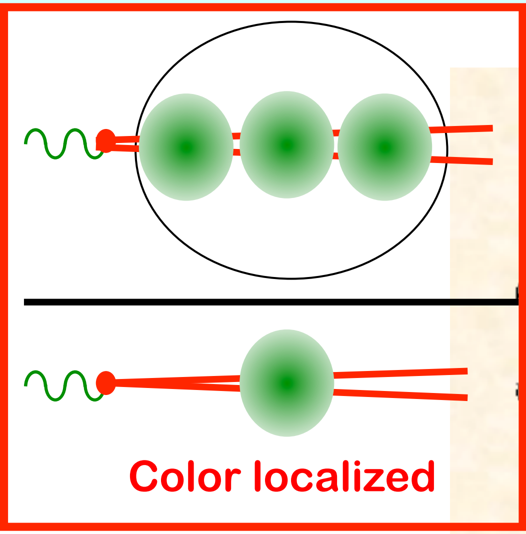

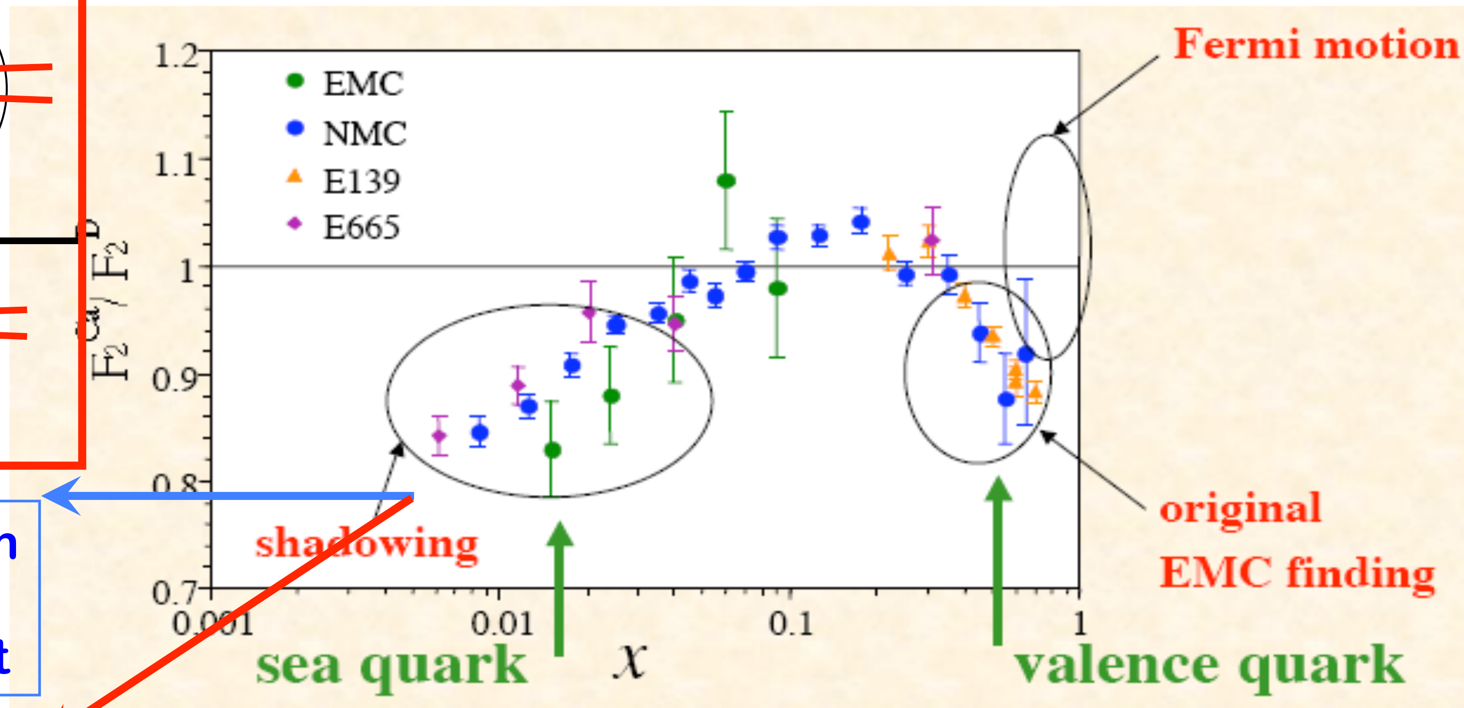

No saturation in nucleon
Collision effect

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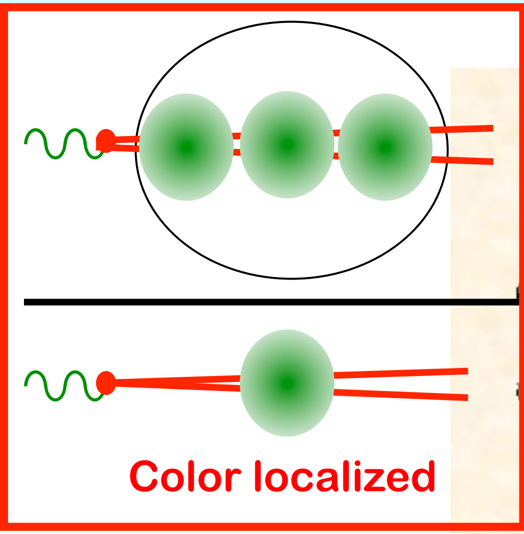
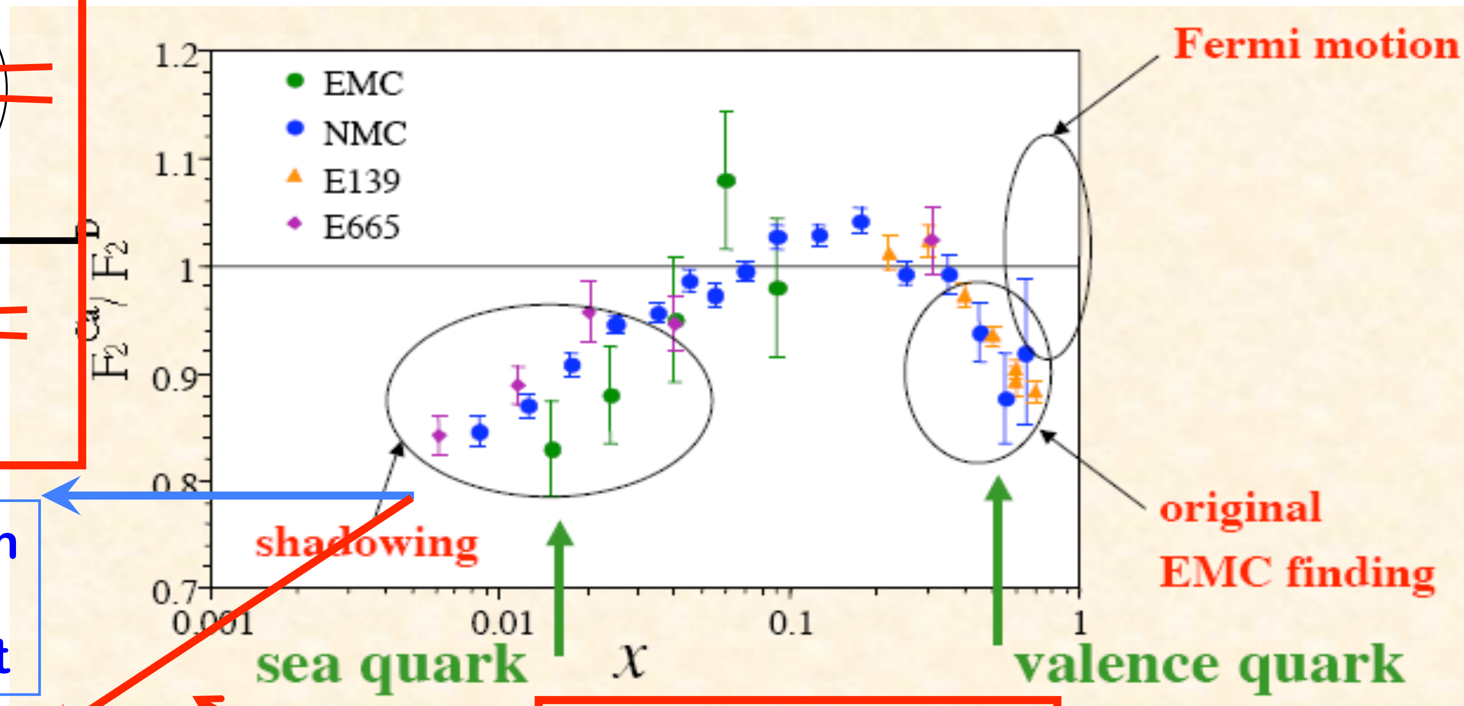
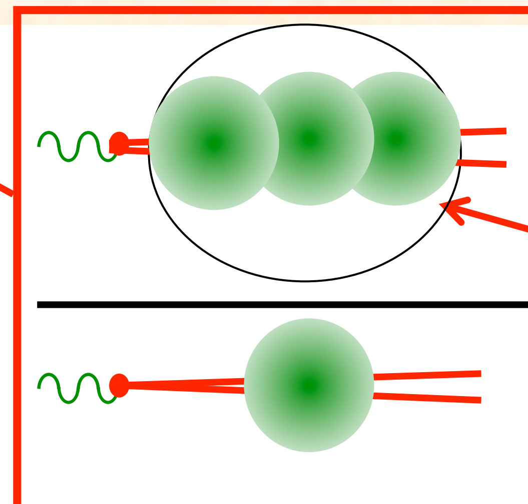
Role of color for nuclear force?





No saturation in nucleon Collision effect

Nucleus as a bigger proton



Color leaks outside nucleons Soft gluon radius is larger

- ❑ A simple question:

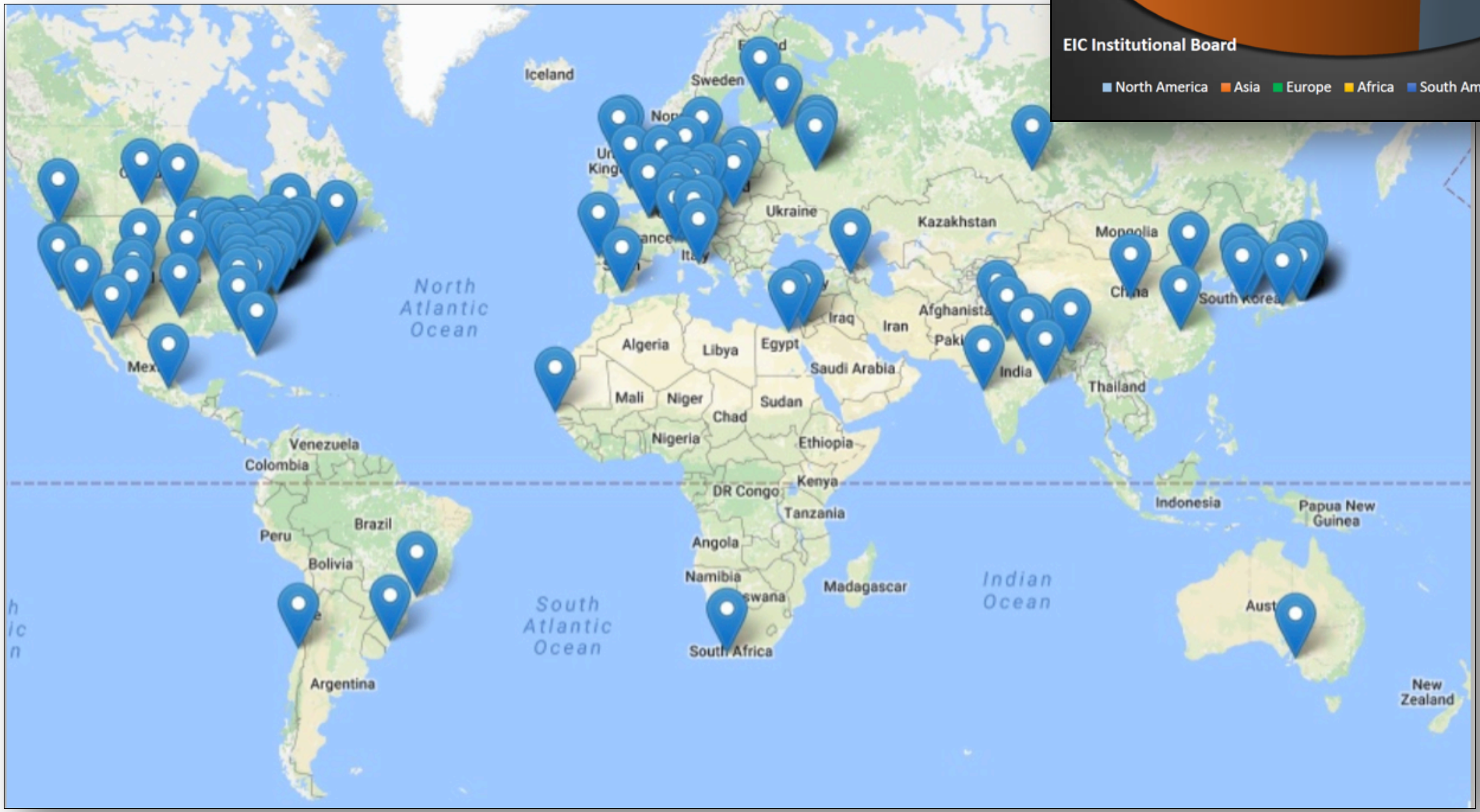
  Will the suppression/shadowing continue to fall as x decreases?

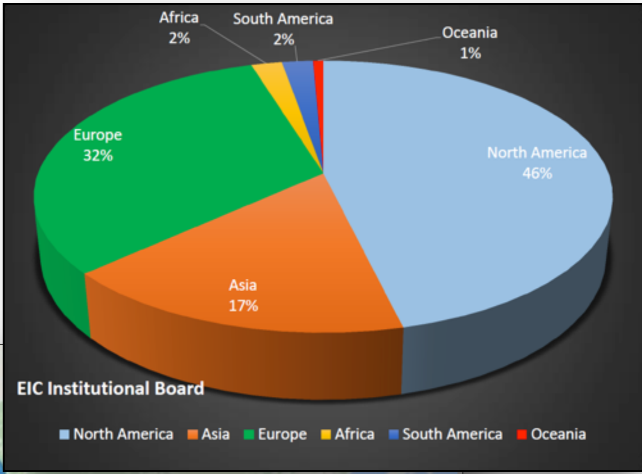
US EIC – An International Effort

❑ EIC Users Group – *EICUG.ORG*:

732 collaborators, 29 countries, (no students included yet!)
169 institutions… (growing, …)

Map of institution's locations





Summary and outlook

- EIC is a ultimate QCD machine:
  1) to discover and explore the quark/gluon structure and properties of hadrons and nuclei,
  2) to search for hints and clues of color confinement, and
  3) to measure the color fluctuation and color neutralization

- EIC is a tomographic machine for nucleons/nuclei (1/10 fm resolution) – necessarily for exploring nuclear femtography

- EIC could study major Nuclear Science issues that other existing facilities, even with upgrades, cannot do

- US-EIC designs explore the polarization and intensity frontier, as well as the frontier of new accelerator/detector technology

- US-EIC is sitting at a sweet spot for rich QCD dynamics – capable of taking us to the next frontier of Nuclear Science!

Thanks!

U.S. - based Electron-Ion Collider

- **NSAC 2007 Long-Range Plan:**

  "An Electron-Ion Collider (EIC) with polarized beams has been embraced by the U.S. nuclear science community as embodying the vision for reaching the next QCD frontier."

- **NSAC Facilities Subcommittee (2013):**

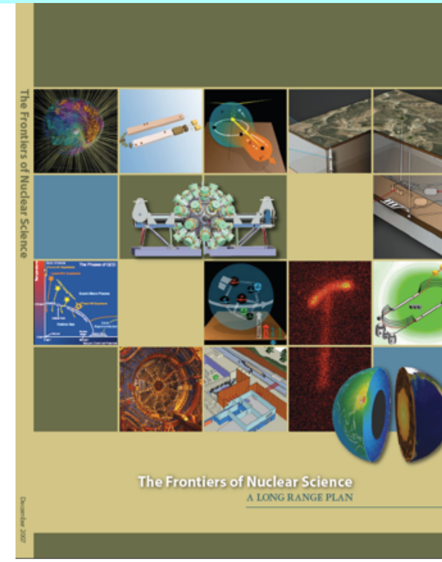
  "The Subcommittee ranks an EIC as Absolutely Central in its ability to contribute to world-leading science in the next decade."

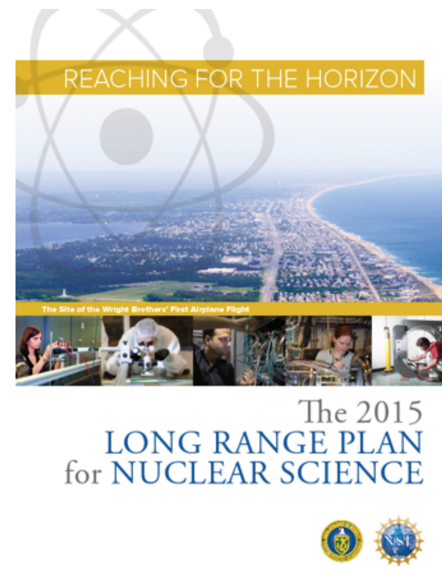
- **NSAC 2015 Long-Range Plan:**

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

- **Under review of National Academy of Science:**

  Expect to have the committee report this year soon!





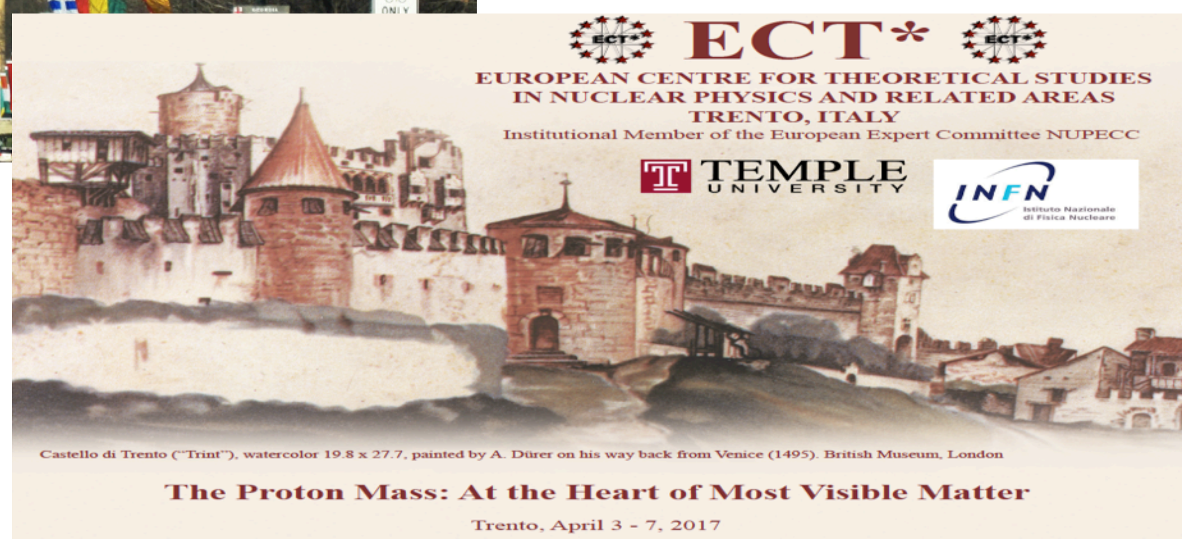
The Proton Mass

- **Three-pronged approach to explore the origin of hadron mass**
  - ✧ **Lattice QCD**
  - ✧ **Mass decomposition – roles of the constituents**
  - ✧ **Model calculation – approximated analytical approach**

https://phys.cst.temple.edu/meziani
/proton-mass-workshop-2016/

http://www.ectstar.eu/node/2218

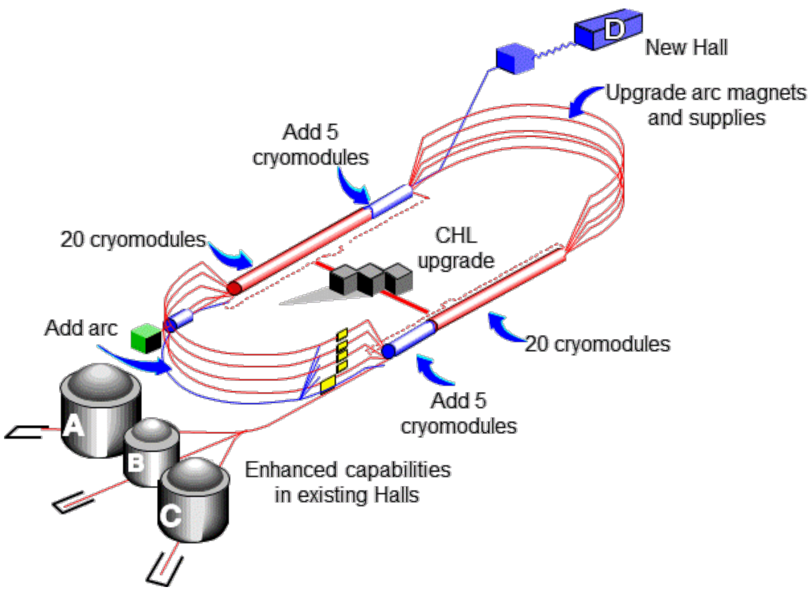
A true international effort!



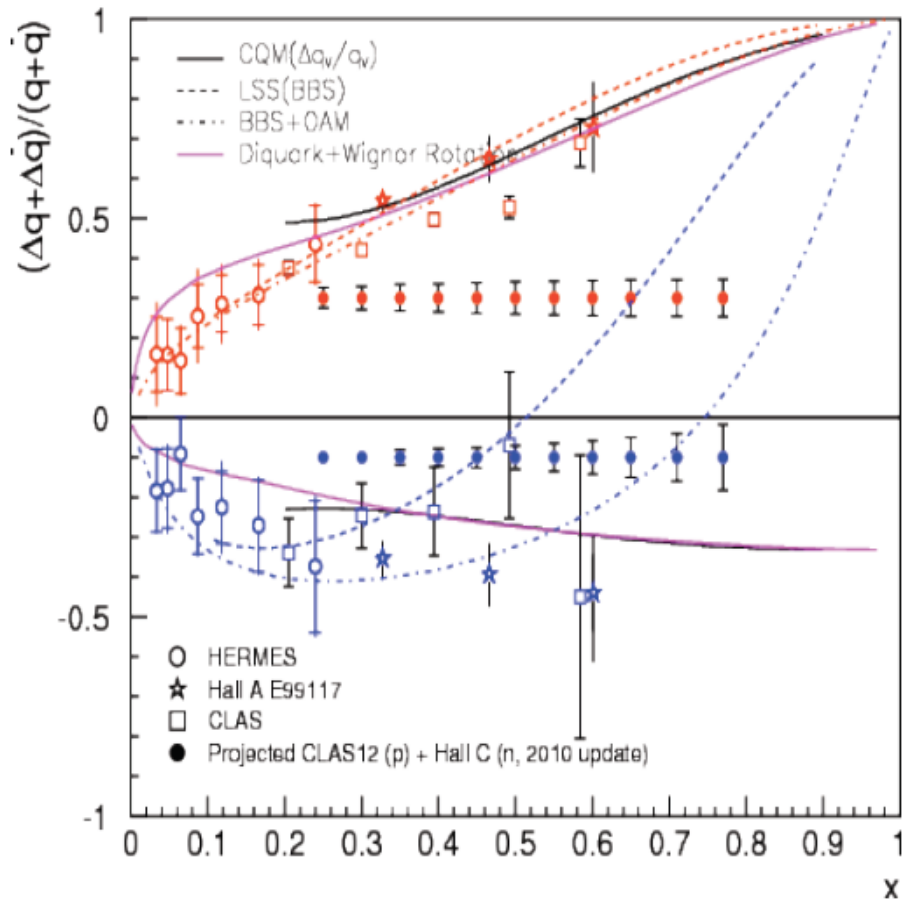
The Proton Spin

- ❑ **JLab 12GeV – upgrade project just completed:**

**12 GeV CEBAF Upgrade Project
is just complete, and
all 4-Halls are taking data**



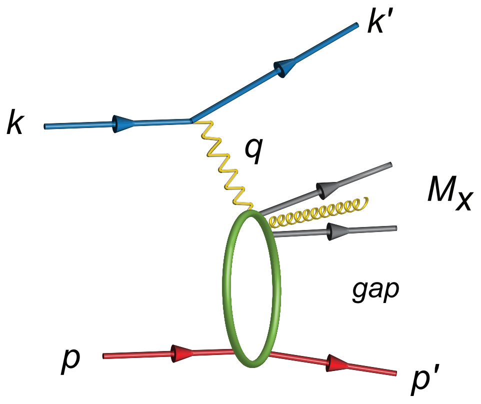
CLAS12



**Plus many more JLab experiments,
COMPASS, Fermilab-fixed target expts
…**

Best signature for gluon saturation

❑ **Diffractive cross section:**



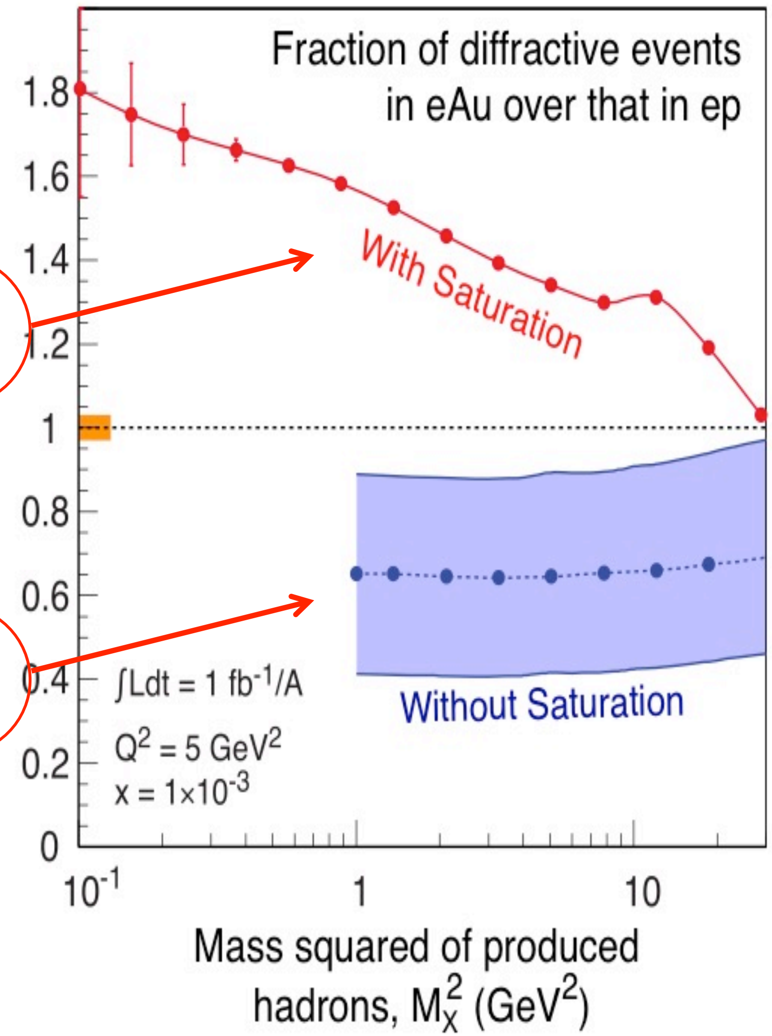
– off a coherent obj.

$$\frac{1}{\sigma_{\rm tot}^{eA}}\frac{d\sigma^{eA}_{diff}}{dM_x^2}\Bigg/\frac{1}{\sigma_{\rm tot}^{ep}}\frac{d\sigma^{ep}_{diff}}{dM_x^2} \sim \frac{25-30\%}{10-15\%} > 1$$

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

– off a single hard, local interaction

$$\frac{1}{\sigma_{\rm tot}^{eA}}\frac{d\sigma^{eA}_{diff}}{dM_x^2}\Bigg/\frac{1}{\sigma_{\rm tot}^{ep}}\frac{d\sigma^{ep}_{diff}}{dM_x^2} \sim \left[\frac{g^p(x)}{g^A(x)}\right]_{\rm tot}\left[\frac{g^A(x)}{g^p(x)}\right]^2_{\rm diff} < 1$$



At HERA

ep: 10-15% diffractive

At EIC eA, if Saturation/CGC

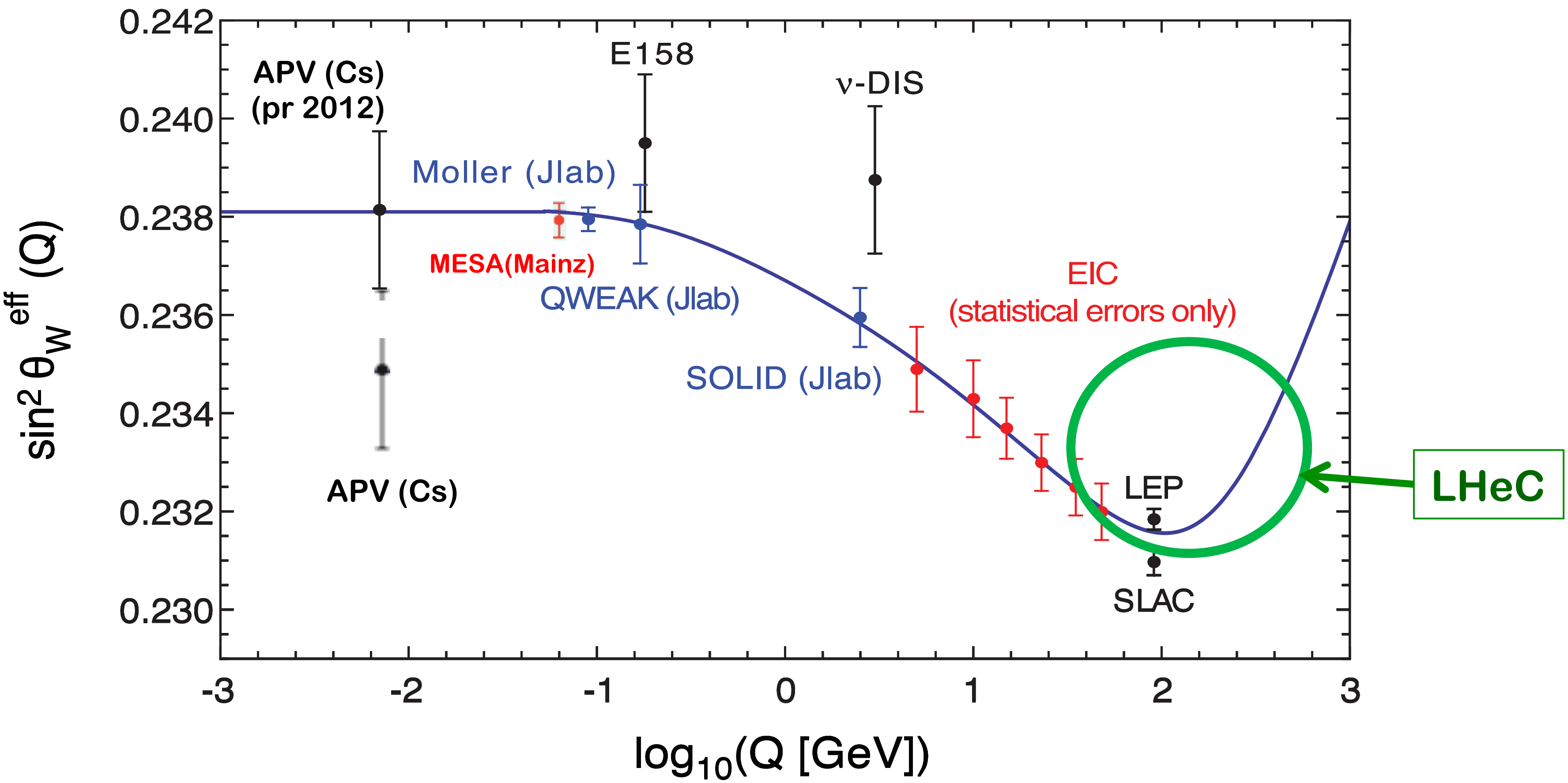
eA: 25-30% diffractive

Early work – E665 @ FNAL:

Nuclear shadowing, diffractive scattering and low momentum protons in μ Xe interactions at 490 GeV Z. Phys. C 65, 225–244 (1995)

Electroweak physics at EIC

❑ Running of weak interaction – high luminosity:



✧ **Fills in the region that has never been measured**

✧ ***have a real impact on testing the running of weak interaction***