DIS 2018

XXVI International Workshop on Deep Inelastic Scattering and Related Subjects

16-20 April 2018 Kobe, Japan

Discussion for European Strategy Update for Particle Physics (ESUPP)
April 17, 2018

QCD Theory

(Addressed in the above facilities)

Dual roles of QCD theory

Advantages of the DIS facilities

Uniqueness of what these DIS facilities could contribute

Jianwei Qiu

Theory Center, Jefferson Lab

Acknowledgement: Thanks to all of you who communicated to me with valuable suggestions and comments

Theory Center

Jefferson Lab
EXPLORING THE NATURE OF MATTER

Dual Roles of QCD Theory

- QCD has been extremely successful in interpreting the vast data from high energy scattering experiments
  - ✧ QCD factorization – controllable approximation
  - ✧ Our ability to calculate the short-distance hard parts
  - ✧ Extraction of the universal PDFs

➡ *A critical service role for the search of new physics*

(Not to comment on the capability of these facilities in search for BSM)!

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- Other than many successful stories from the asymptotic regime, and a limited success of lattice QCD calculations, we just started to explore the most interesting dynamics of QCD:
  - ✧ QCD at high temperature and high density
    – *Relativistic heavy ion theory and experimental programs*

To be covered by Nestor Armestor

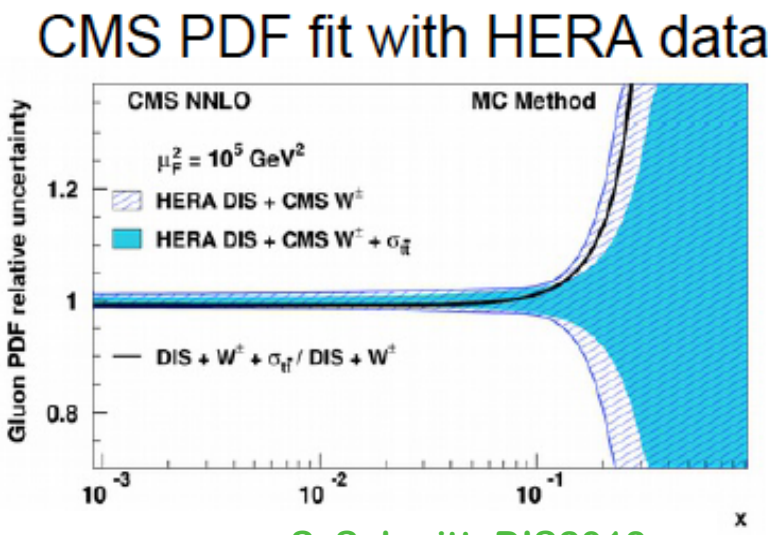
  - ✧ Emergent phenomena from strong interacting regime of QCD
    – *QCD may have as many lessons to teach us in hadronic matter as QED does for condensed matter*

G. Sterman

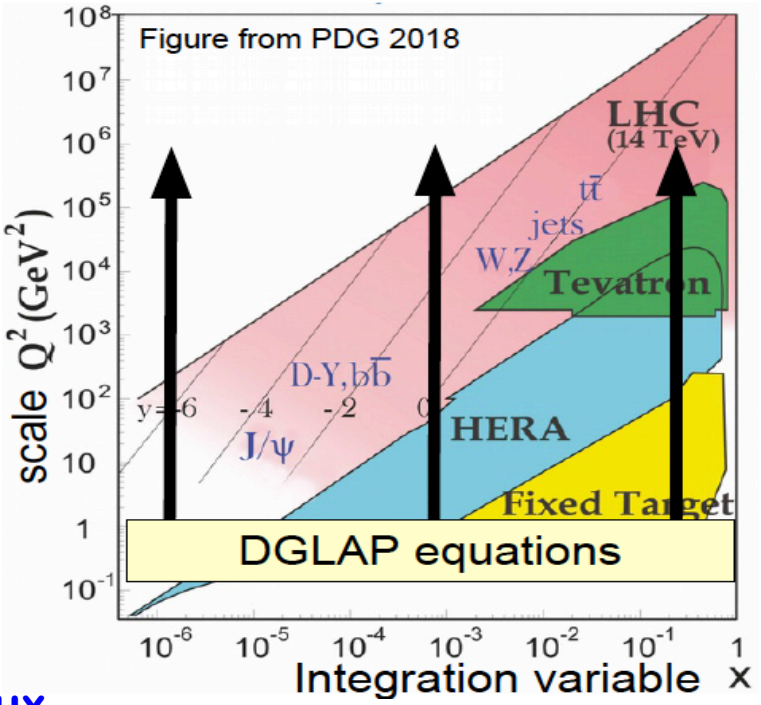
→ *A required role for understanding the building blocks of all atomic nuclei, making up us and the visible world*

Help search for new physics

- **Large PDF uncertainty at large x:**



S. Schmitt, DIS2018



- ✧ **Large uncertainty in partonic flux**
- ✧ **Uncertainty in searching for BSM at high scale**

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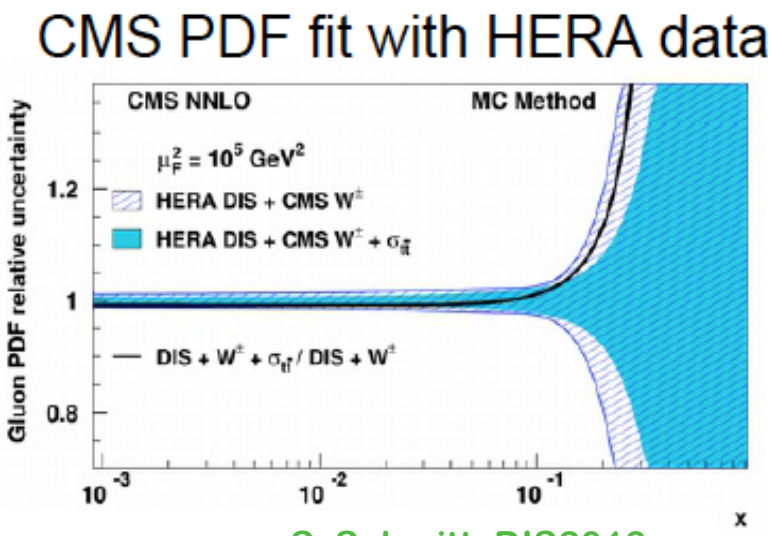

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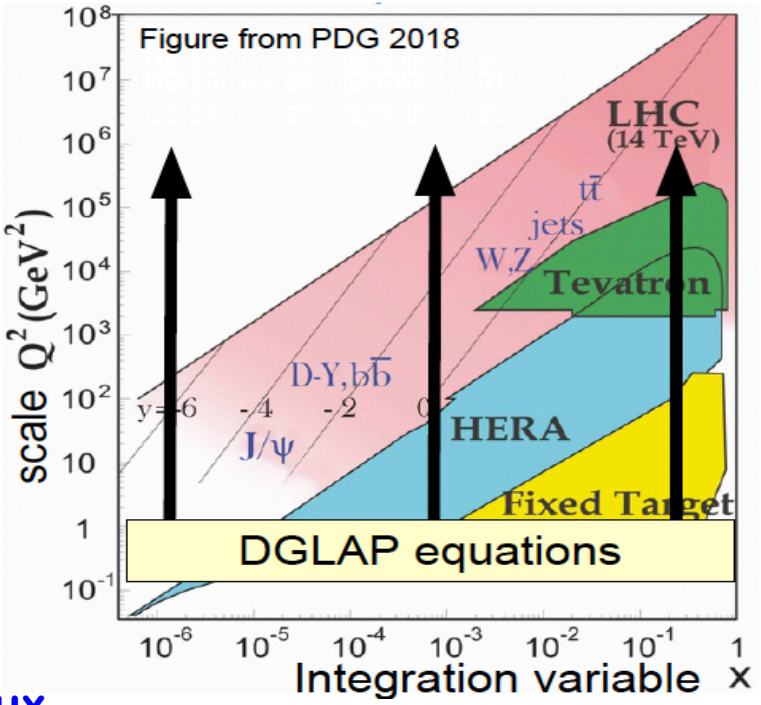

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- **DIS facilities provide the "clean" information on PDFs:**

DGLAP is a linear differential-integral equation, only sensitive to the x-region larger than the probed x

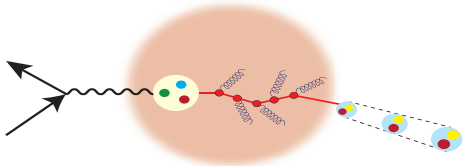
- ✧ Need good reach to large-x region
- ✧ Need large level-arm in Q^2

See talk by Claire Gwenlan
WG7, Wed (4/18) @3:10pm

Both US-EIC and LHeC have a good reach in Q^2, US-EIC covers larger-x

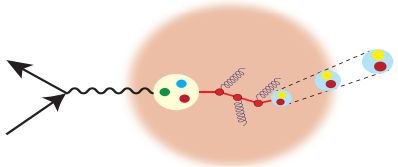
Explore emergent phenomena of QCD

❑ Emergence of hadrons – eA:



✧ **US-EIC:**

- Nuclei as femtometer sized detectors
- "right" energy to have color neutralization taken place inside/outside the medium



✧ **LHeC:**

- Color neutralization takes place outside
- Jet transverse structure = boosted hadronization

These two facilities, so as other higher energy ones, are complementary

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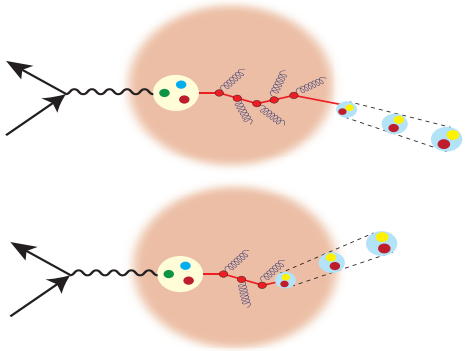

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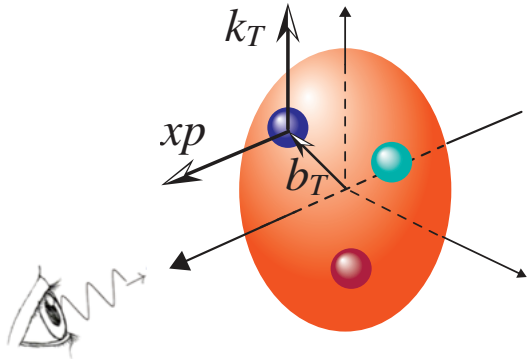
❑ Hadron's 3D structure – ep:

✧ **Minimum requirement:**

Cross sections with two-momentum scales observed

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

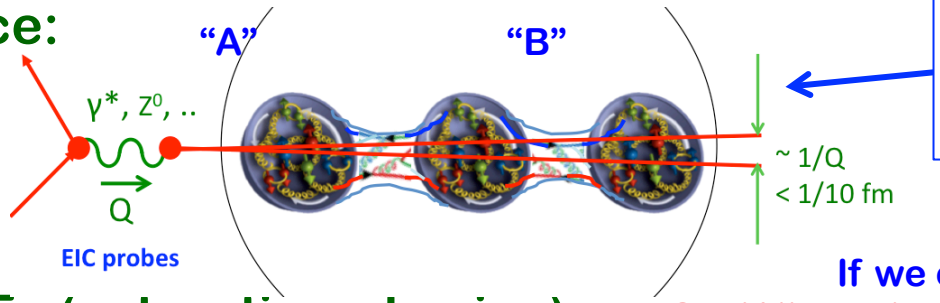
- Hard scale: Q_1 localizes the probe
- "Soft" scale: Q_2 sensitive to the structure ~ a few hundreds MeV



✧ **Too higher collision energy ➡ more shower ➡ larger $\langle p_T \rangle$**
➡ dilute correlation ➡ less sensitive to confined motion!

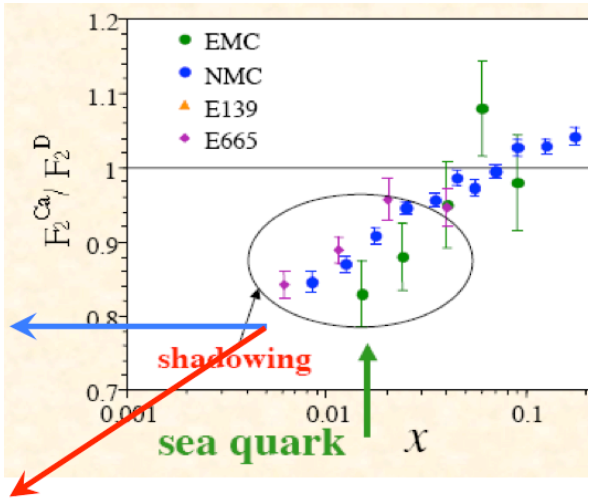
Explore emergent phenomena of QCD

- **Nuclear force: (eA)**



Hadron rest frame view
Physics is frame independent

- **Nuclear PDFs (saturation physics):**



If we only see quarks and gluons,

Q: What does a nucleus look like?

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

Explore emergent phenomena of QCD

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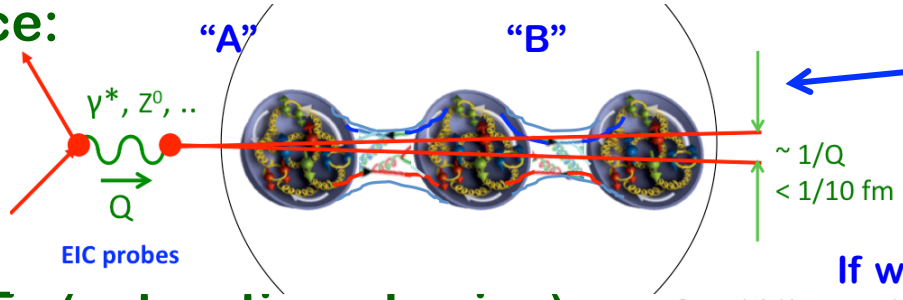

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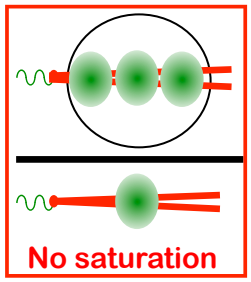
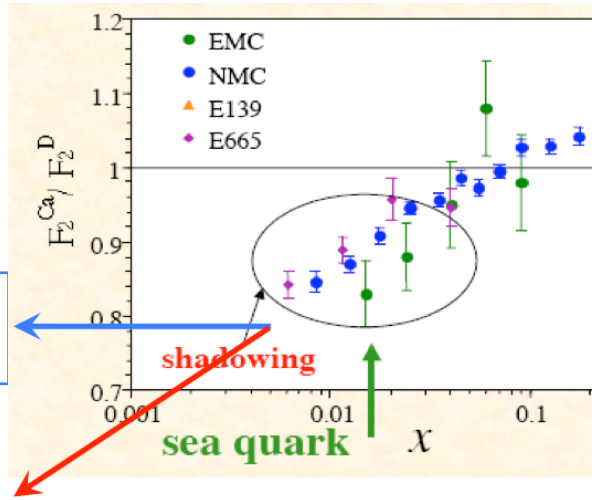


Coherent collision effect!



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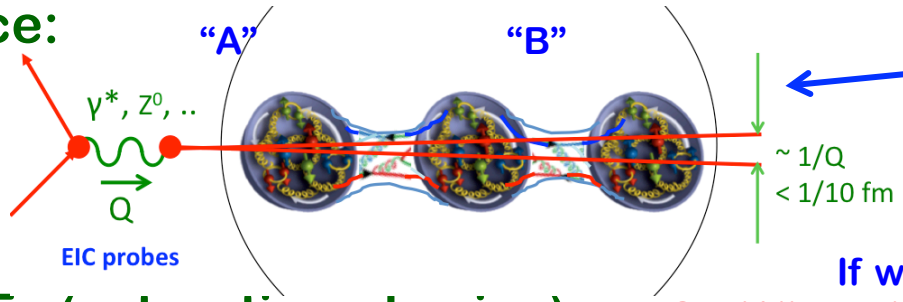

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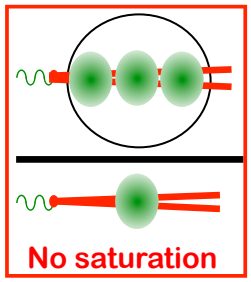

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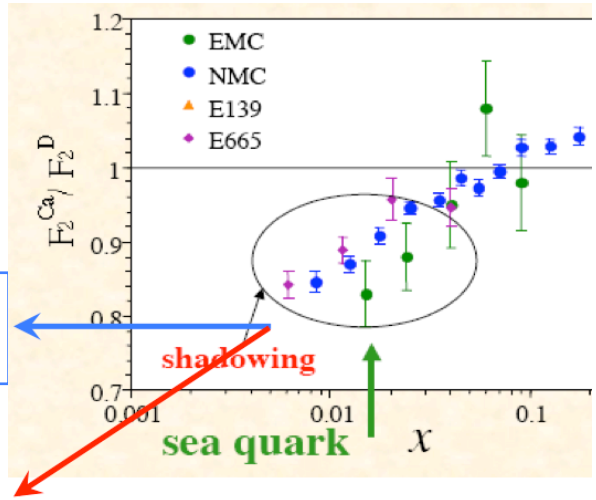

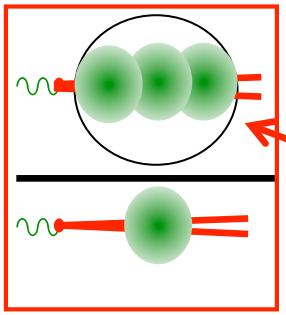

Color interactions between nucleons

Nucleus as a bigger proton

- **US-EIC:**
  Cover the transition region
- **LHeC + higher E:**
  Deep into saturation region!

Explore emergent phenomena of QCD

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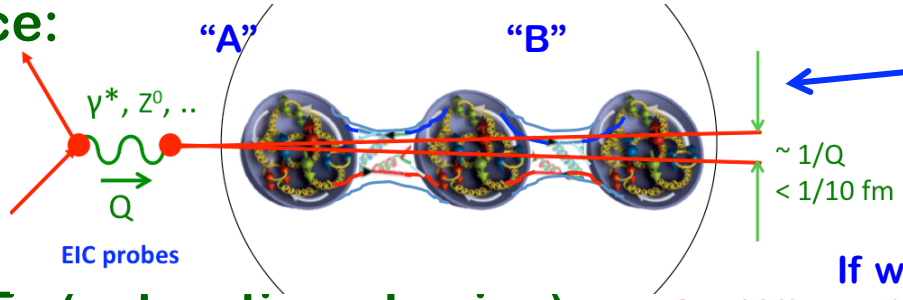

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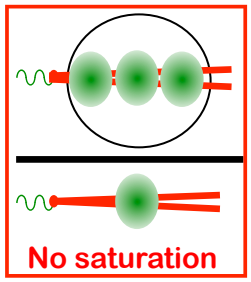

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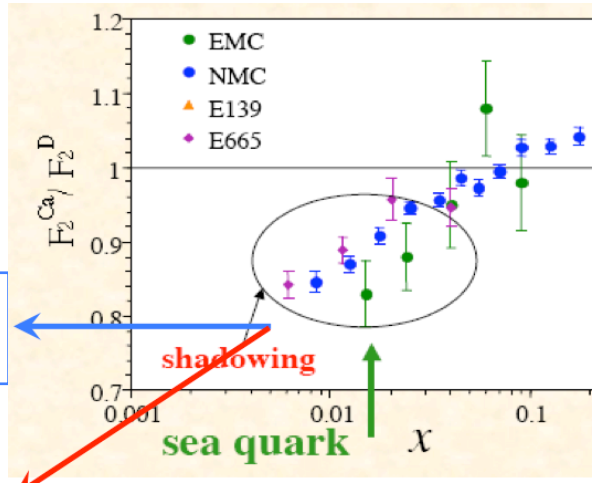

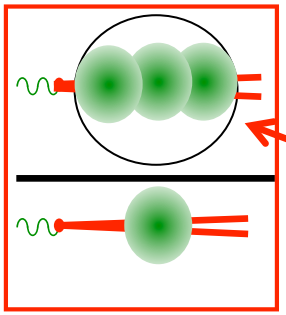

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Q: Physics at x → 0, √s → ∞ ?

Higher energy machines introduce opportunities into new phenomina: strongly interacting many body, condensate, …

$$\sigma^{\gamma p}, \sigma^{\gamma^* p}, \sigma^{\gamma A}, \sigma^{\gamma^* A}$$

US-EIC is not designed for this!

A few more thoughts …

- US-EIC is a QCD machine covering the transition regime from parton dynamics to many body strongly interacting physics
- US-EIC is a good machine for emergence phenomena, hadron structures, quauntum correlations, fluctuations, …
- LHeC is a machine complementary in physics with US-EIC, is capable of exploring much lower x regime, and related QCD phenomena, and has the potential to probe the physics of BSM that HERA was not able to do, with unique advantage of DIS kinematics/environment
- The innovative idea of accelerating the electron to go to very high energy is very exciting
- If facilities achieve a new decade in energy reach, the distinction between QCD and electroweak physics will be narrowed, and lessons from and analysis developed for QCD in the past few decades will become relevant to the Standard Model as a whole