George Washington University

Department of Physics

April 13, 2017

Exploring the fundamental properties of matter with an Electron-Ion Collider

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Theory Center, Jefferson Lab

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, …

Theory Center

Jefferson Lab
EXPLORING THE NATURE OF MATTER

Eternal Questions

People have long asked

Where did we come from?

The Big Bang theory?

What is the world made of?

Basic building blocks?

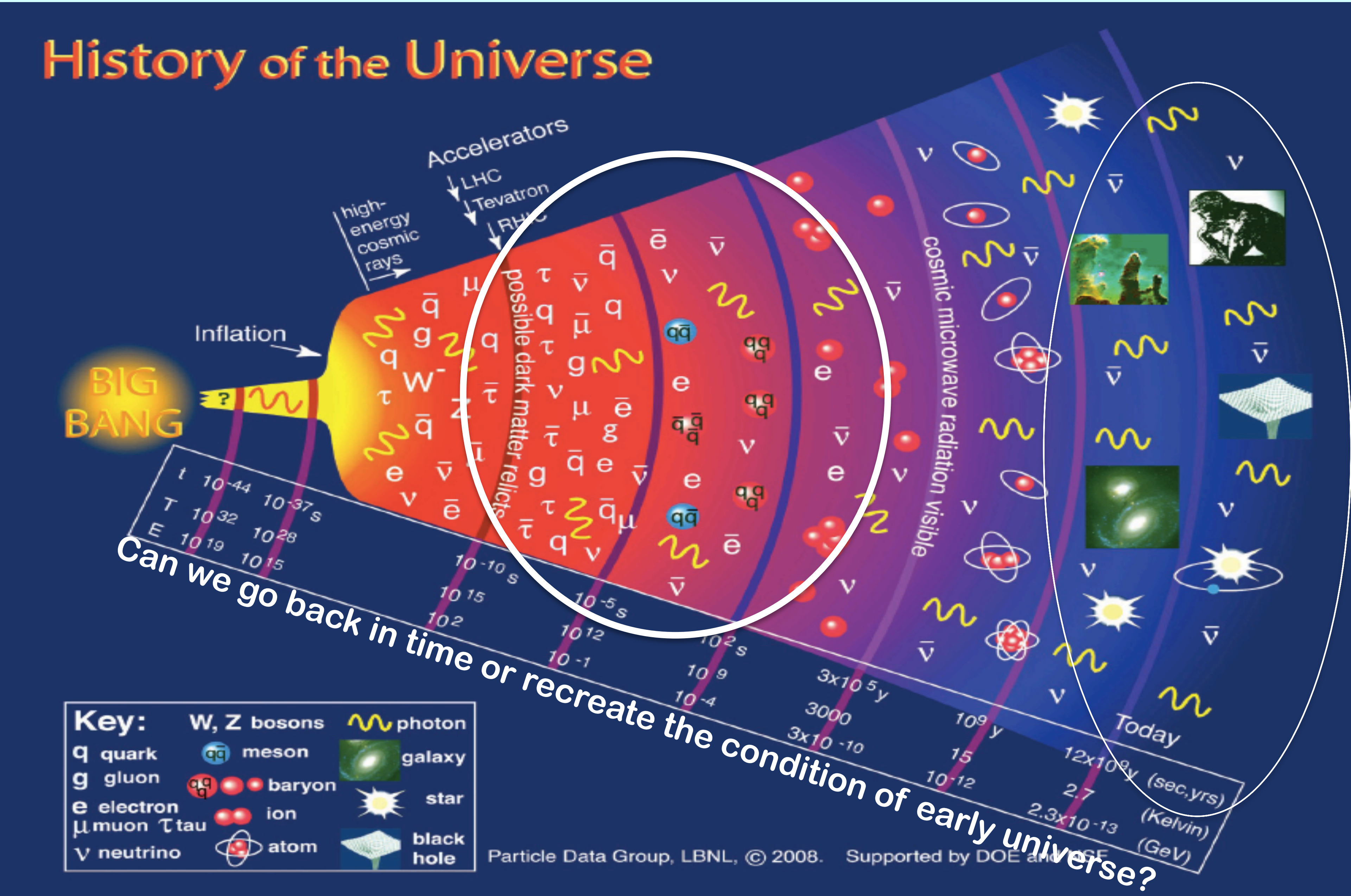
What holds it together?

Fundamental forces?

Where are we going to?

The future?

Where did we come from?



Can we go back in time or recreate the condition of early universe?

Going back in time?

Expansion of the universe

Little Bang in the Laboratory

Create a matter (QGP) with similar temperature and energy density

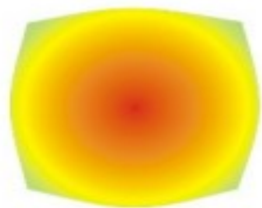
Relativistic heavy-ion collisions – the little bang

❑ A Virtual Journey of Visible Matter:

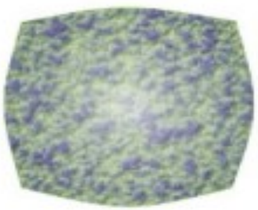
Lorentz contraction

Visible!

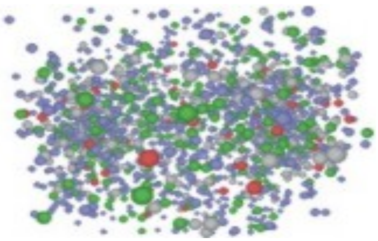
Near collision



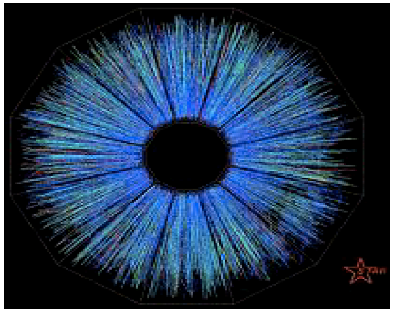
Quark-gluon plasma



Hadronization



Freeze-out

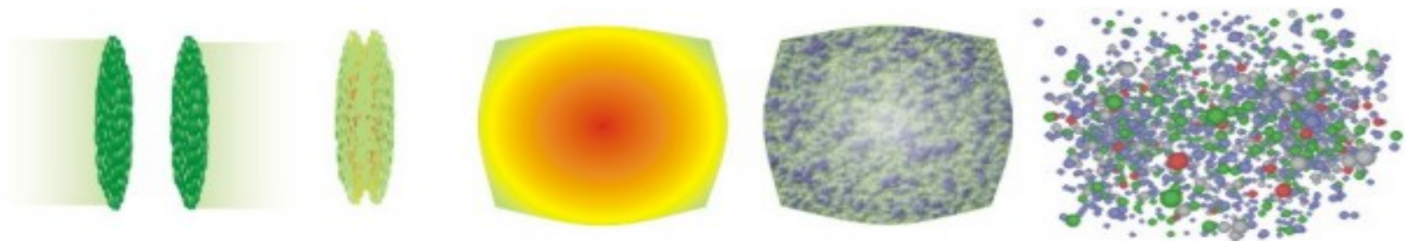


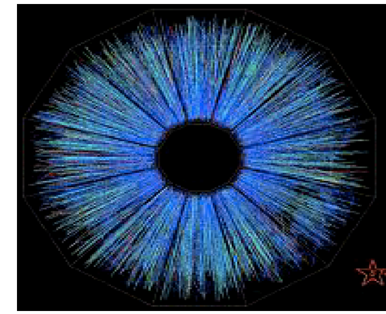
Seen in the detector

Visible!

Relativistic heavy-ion collisions – the little bang

❑ **A Virtual Journey of Visible Matter:**

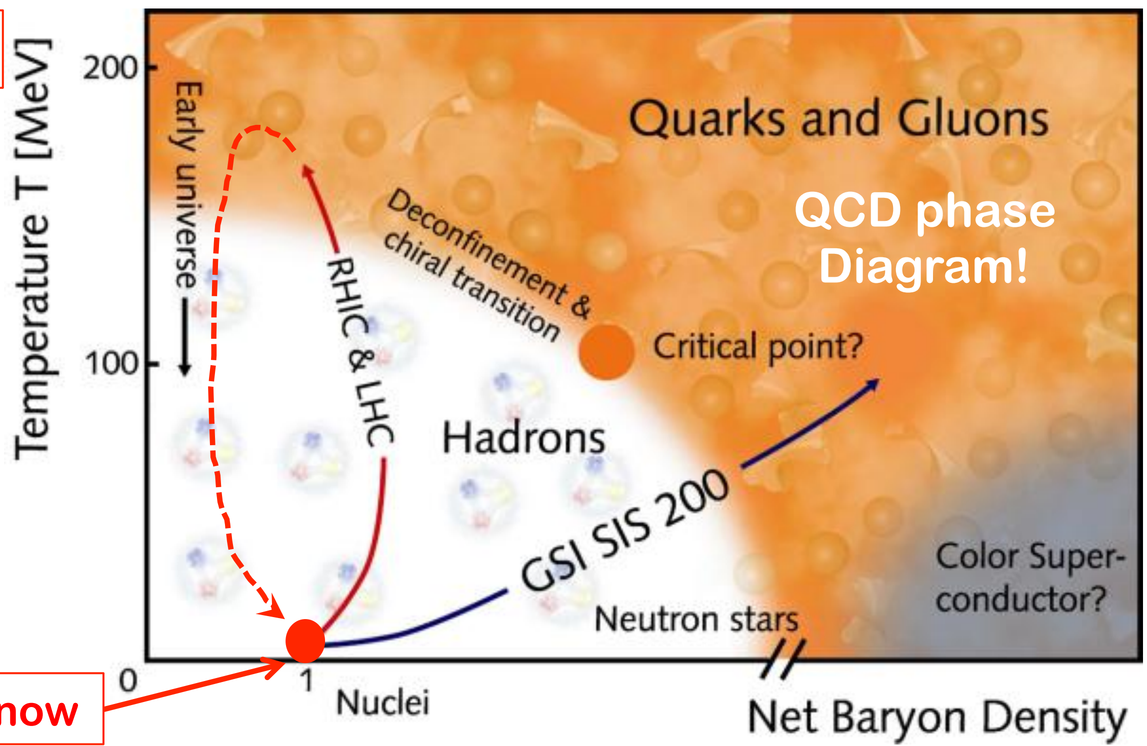




Lorentz contraction | Near collision | Quark-gluon plasma | Hadronization | Freeze-out | Seen in the detector

Visible!

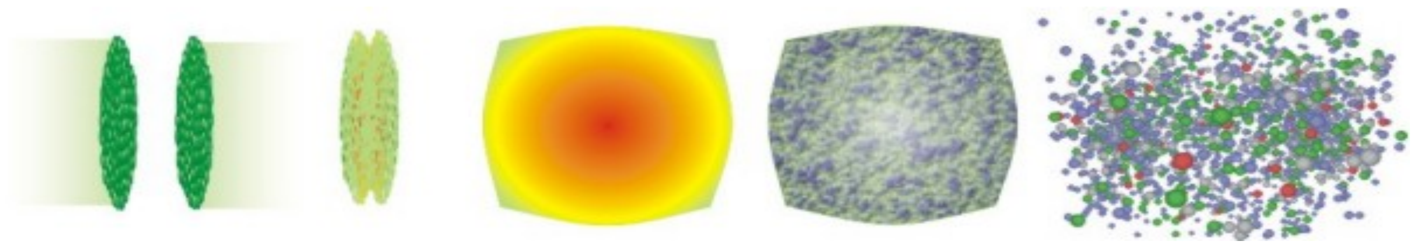
Visible!

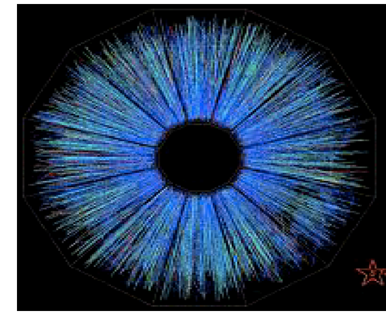


Where we are now

Relativistic heavy-ion collisions – the little bang

❑ A Virtual Journey of Visible Matter:





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

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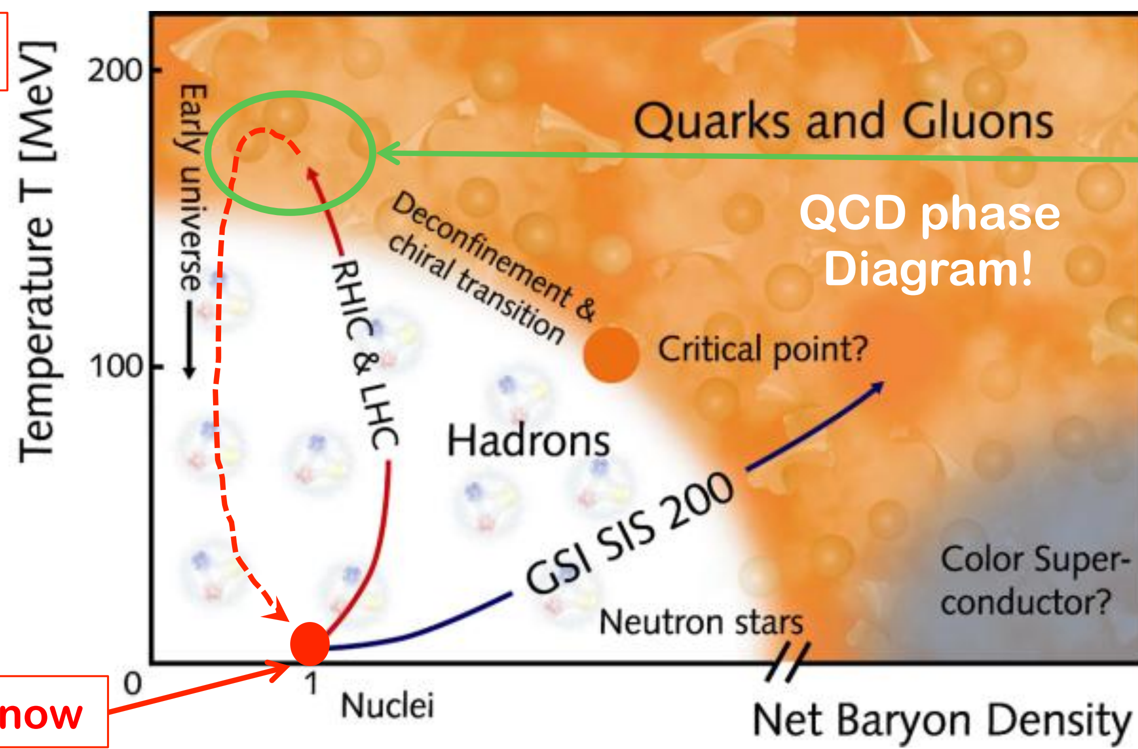
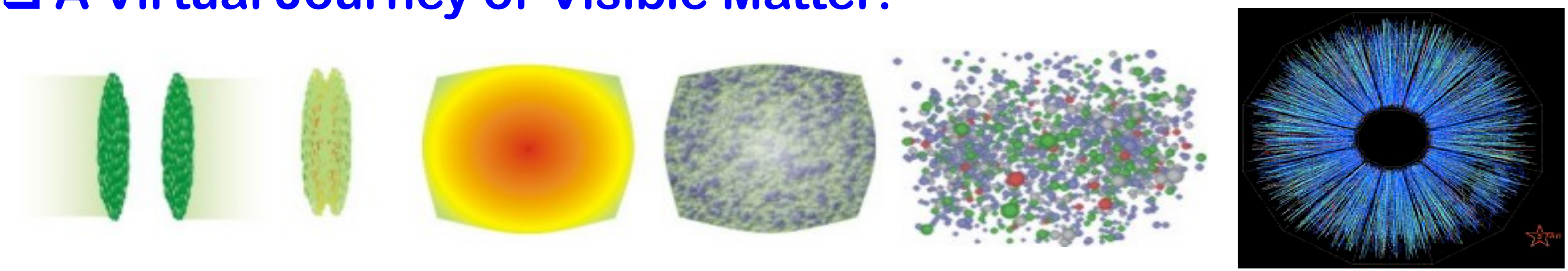


Where we are now

Discovery:
A nearly perfect quantum fluid (NOT a gas!) at 4 trillion degrees Celsius,
Not, at 10^{-5} K like ^{6}Li

Relativistic heavy-ion collisions – the little bang

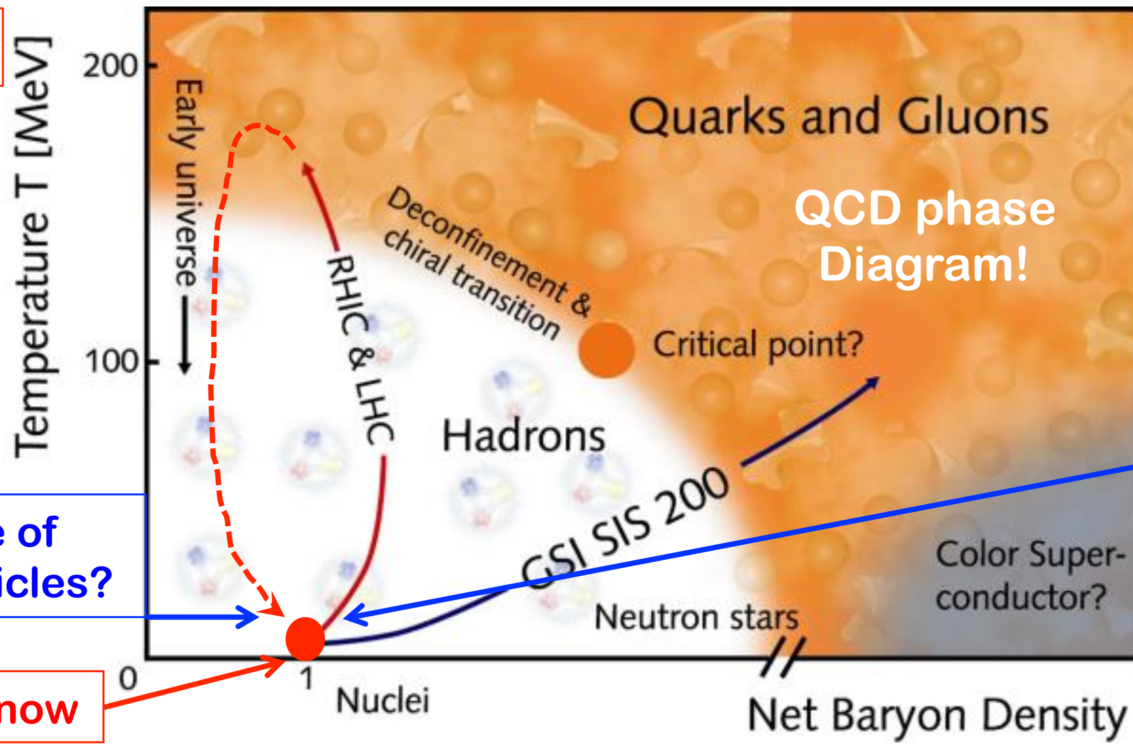
❑ A Virtual Journey of Visible Matter:



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

Visible!

Visible!

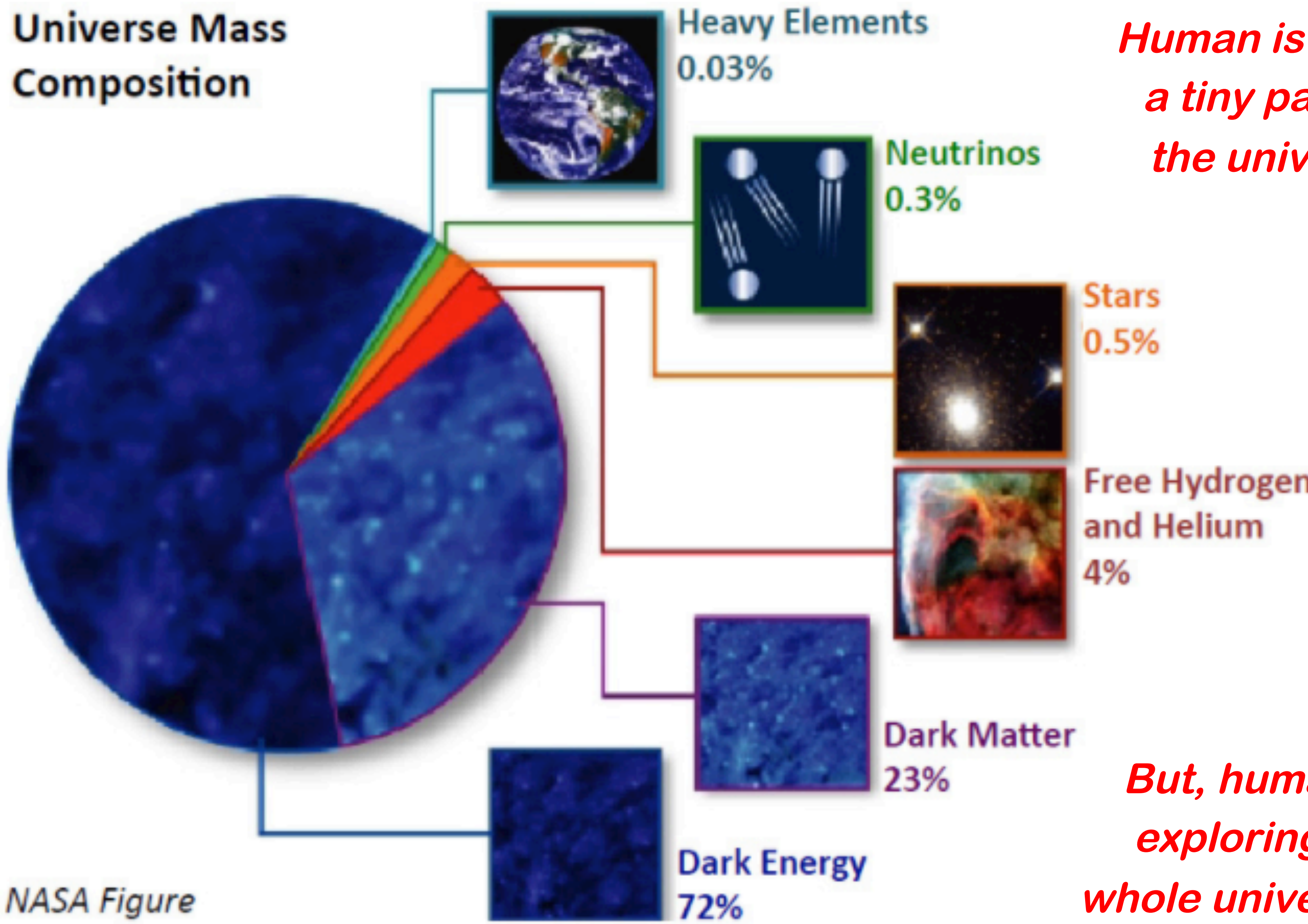


Structure of hadrons? = initial conditions of RHIC?

Emergence of hadronic particles?

Where we are now

What the world is made of?



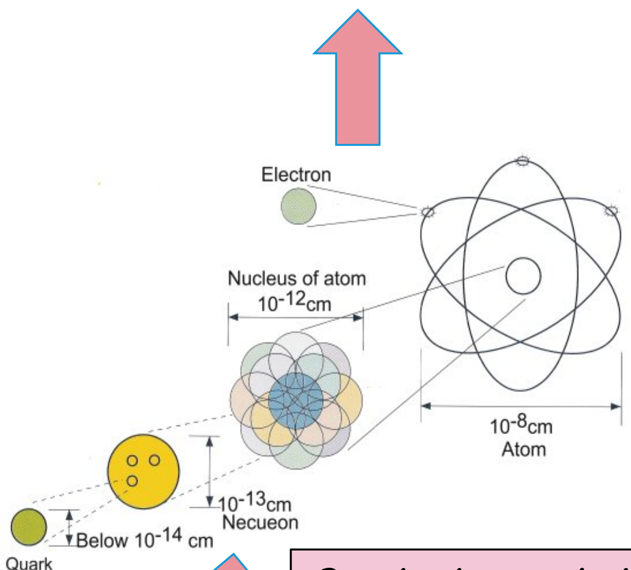
Human is only a tiny part of the universe

But, human is exploring the whole universe!

What hold it together?

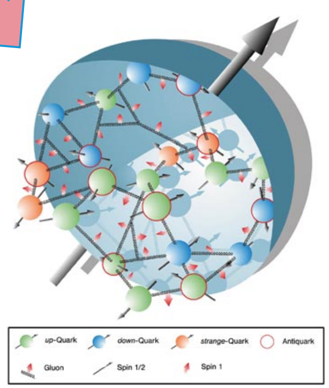
- Force, distance, complexity:

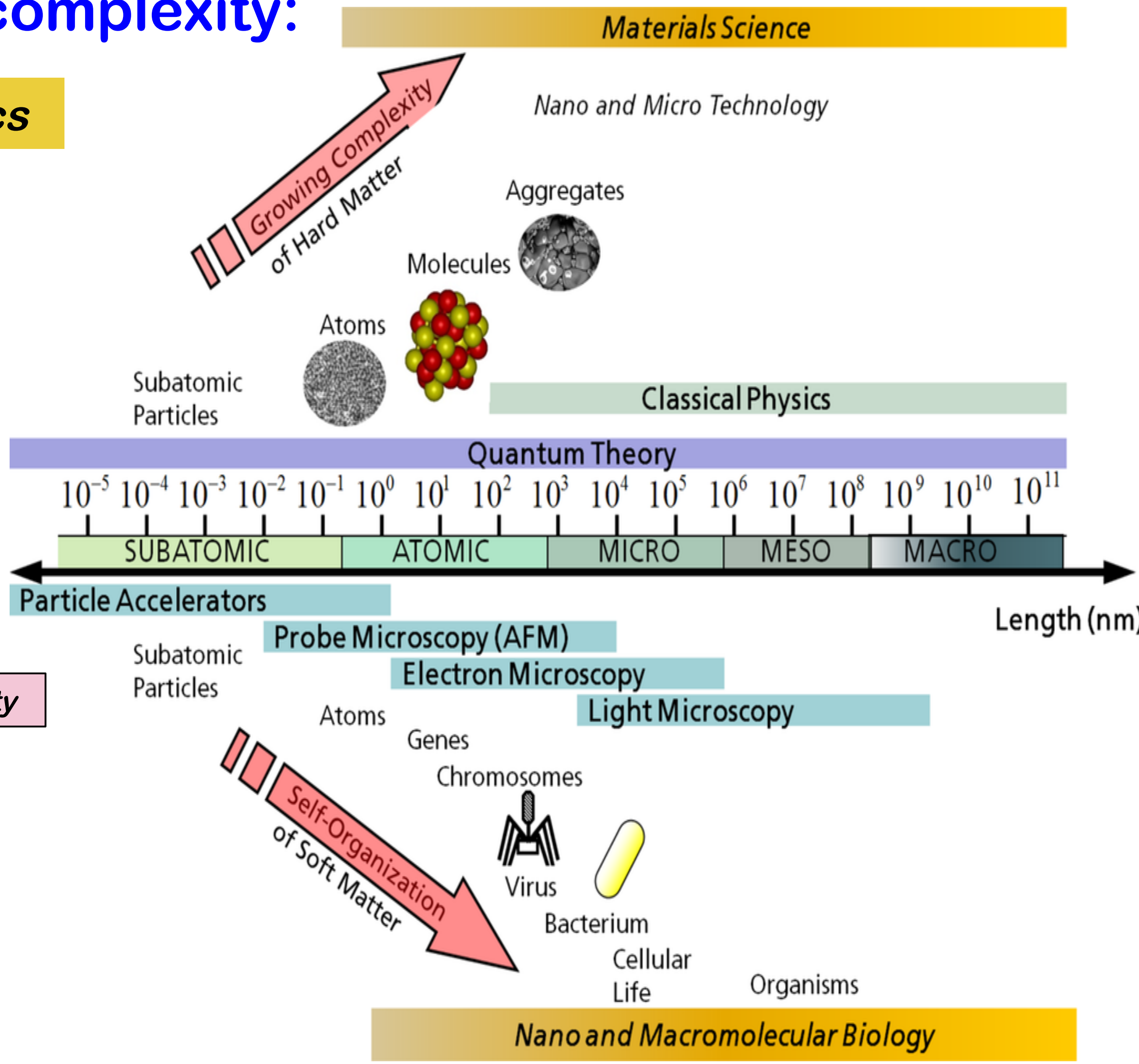
Particle & Nuclear Physics



Growing in complexity

Nucleon: Proton, or Neutron

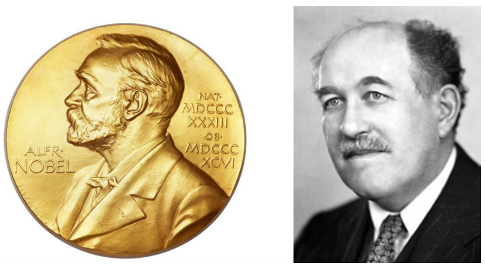




Nucleon – building block of all atomic matter

❑ Nucleon has internal structure:

1933: Proton's magnetic moment



Nobel Prize In Physics 1943

Otto Stern

"for … and for his discovery of the magnetic moment of the proton".

$$g \neq 2$$

1960: Elastic e-p scattering

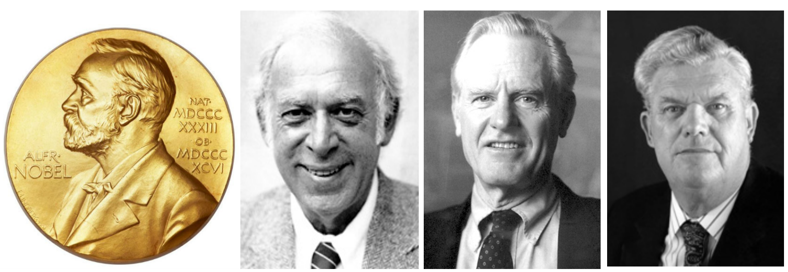
Nobel Prize In Physics 1961

Robert Hofstadter

"for … and for his thereby achieved discoveries concerning the structure of the nucleons"

$$\text{Form factors} \rightarrow \text{Charge distributions}$$

1969: Deep inelastic e-p scattering



Nobel Prize in Physics 1990

Jerome I. Friedman, Henry W. Kendall, Richard E. Taylor

"for their pioneering investigations concerning deep inelastic scattering of electrons on protons …".

QCD landscape of nucleon

Color Confinement **Asymptotic freedom**

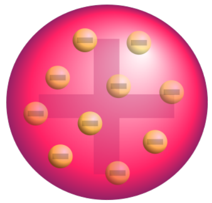
200 MeV (1 fm) **2 GeV (1/10 fm)**

Need subatomic probes!

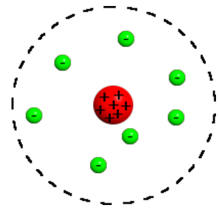
Seeing the unseen

❑ Rutherford's experiment – atomic structure (100 years ago):

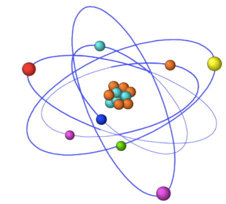
Atom:



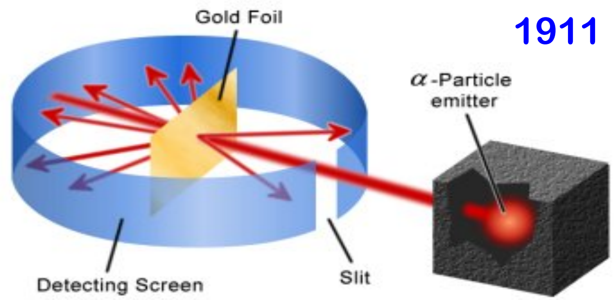
J.J. Thomson's
plum-pudding model



Rutherford's
planetary model



Modern model
Quantum orbitals



Discovery of nucleus
A localized
charge/force center
A vast
"open" space

Discovery of
Quantum Mechanics,
and
the Quantum World!

❑ Completely changed our "view" of the visible world:

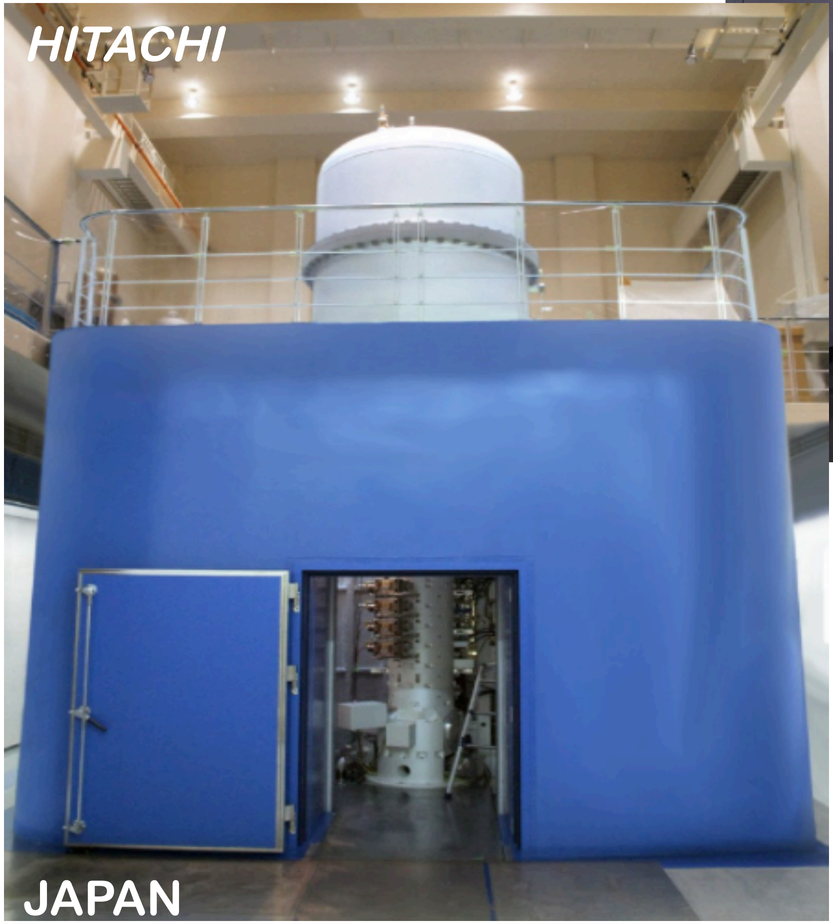
- ✧ Mass by "tiny" nuclei – *less than 1 trillionth in volume of an atom*
- ✧ Motion by quantum probability – *the quantum world!*

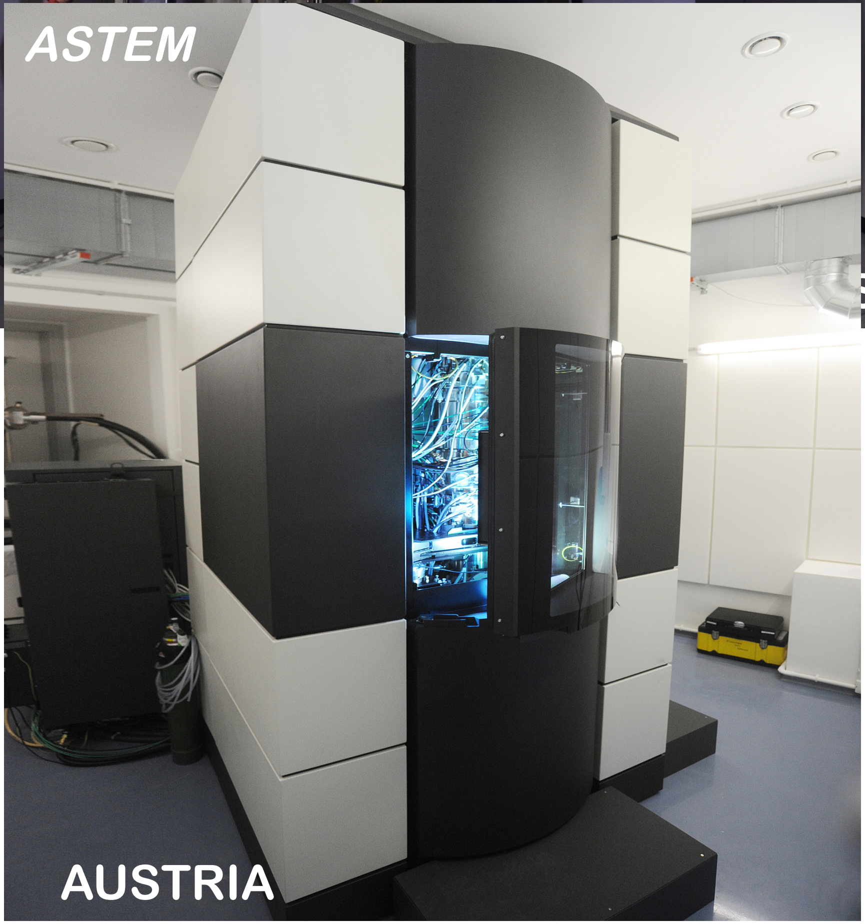
❑ Provided infinite opportunities to improve things around us:

- ✧ Gas, Liquid, Solid, Nano materials, Quantum computing, …

Seeing the unseen

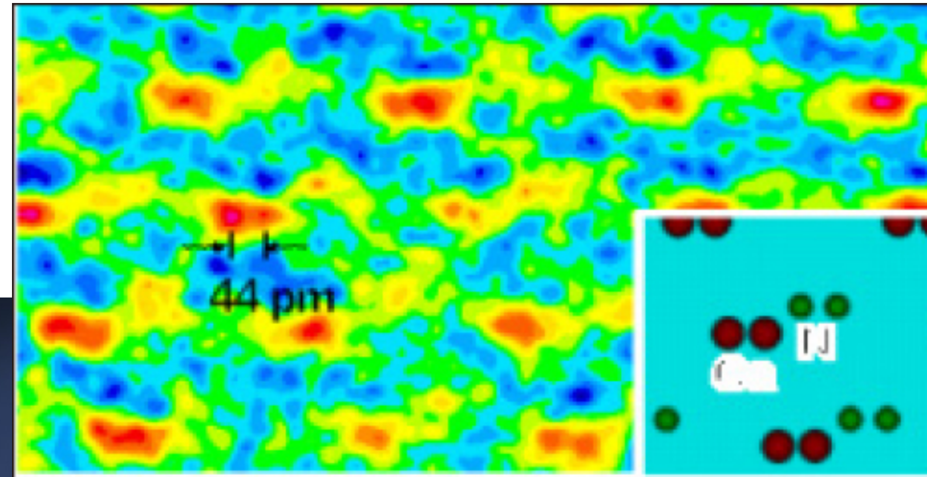
- ❑ **Electron Microscope:**





Seeing the unseen

- Electron Microscope:



Low-pass filtered image Atomic positions

Crystals of gallium nitride (GaN), used in blue light-emitting diodes, as seen through the electron microscope. Pairs of red gallium atoms were observed 44 picometers apart, showing how structures and electromagnetic fields can be observed and measured at an atomic level.

Half size of an atom!

Seeing the unseen

❑ CAT (Computer Assisted Tomography) Scan:

Allan M. Cormack

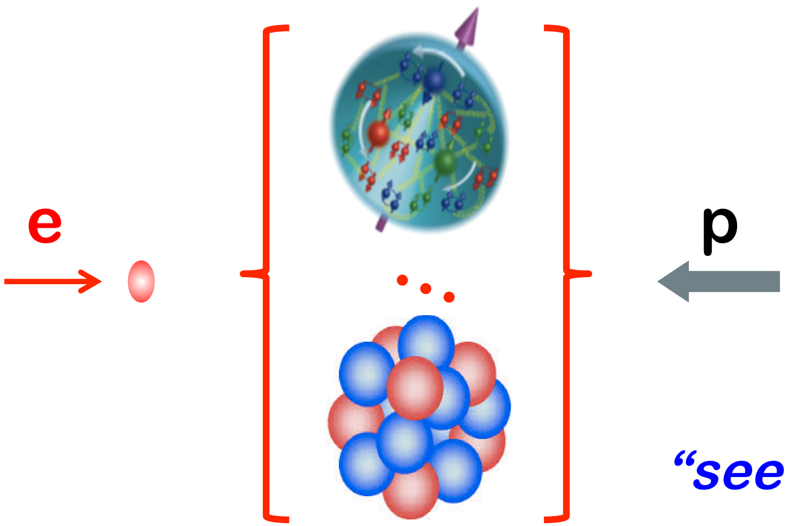
Godfrey N. Hounsfield

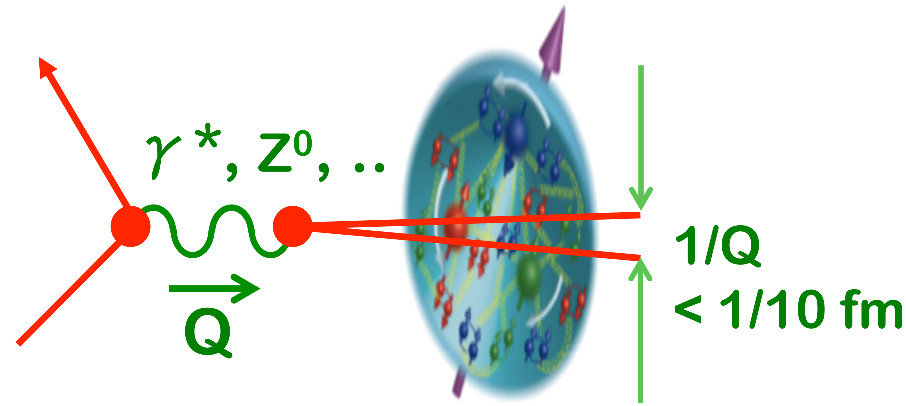
The Nobel Prize in Physiology or Medicine 1979

"for the development of computer assisted tomography"

Electron-Ion Collider (EIC)

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





"see" the non-linear dynamics of the glue!

- ❑ A sharpest "CT" – "imagine" quark/gluon without breaking the hadron
  - "cat-scan" the nucleon and nuclei with better than 1/10 fm resolution
  - "see" the proton "radius" of quark density and gluon density: vs. the charge radius?

Unprecedented Intellectual Challenge!

- **Facts:**
  - ✧ We measure/detect leptons and hadrons
  - ✧ No modern detector has been able to see quarks and gluons in isolation!
- **The challenge:**

  How to probe the quark-gluon dynamics, quantify the hadron structure, study the emergence of hadrons, …, if we cannot see quarks and gluons?
- **Answer to the challenge:**

  Theory advances:

  QCD factorization – matching the quarks/gluons to hadrons with controllable approximations!

  Experimental breakthroughs:

  Energy, luminosity and measurement – Unprecedented resolution, event rates, and precision probes, especially EM probes, …

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

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

  Jets – *Footprints of energetic quarks and gluons*

EIC: the World Wide Interest

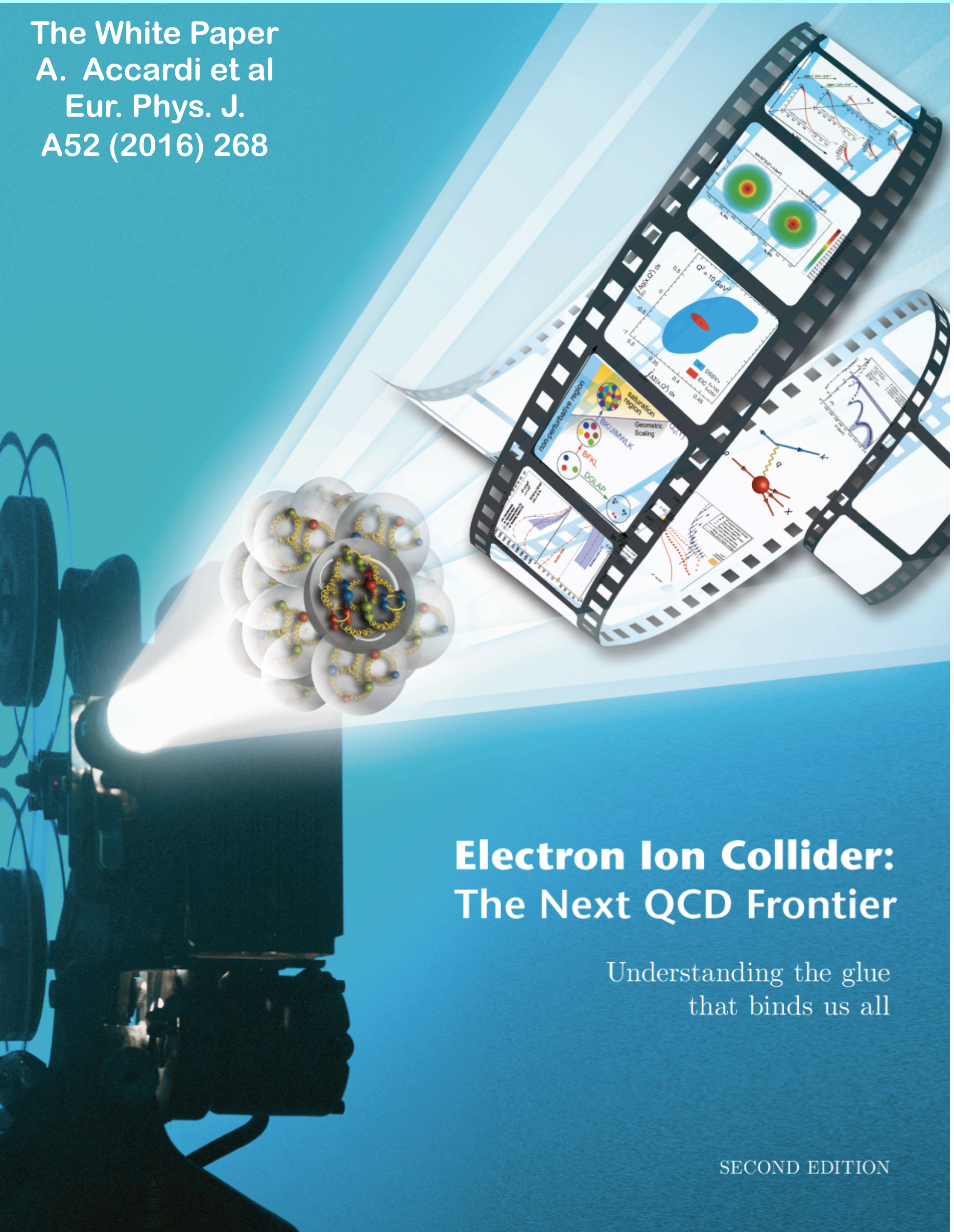
	HERA@DESY	LHeC@CERN	eRHIC@BNL	JLEIC@JLab	HIAF@CAS	ENC@GSI
E_{CM} (GeV)	320	800-1300	45-175	12-140	12 → 65	14
proton x_{min}	1×10^{-5}	5×10^{-7}	3×10^{-5}	5×10^{-5}	$7 \times 10^{-3} \rightarrow 3 \times 10^{-4}$	5×10^{-3}
ion	p	p to Pb	p to U	p to Pb	p to U	p to ~ ^{40}Ca
polarization	-	-	p, ^{3}He	p, 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

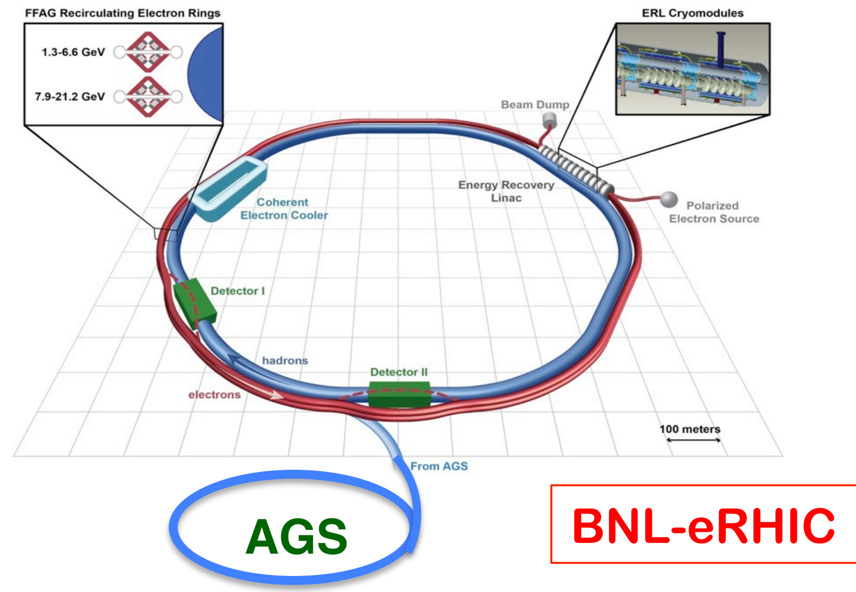
The past (HERA@DESY)

Possible future (LHeC@CERN – ENC@GSI)

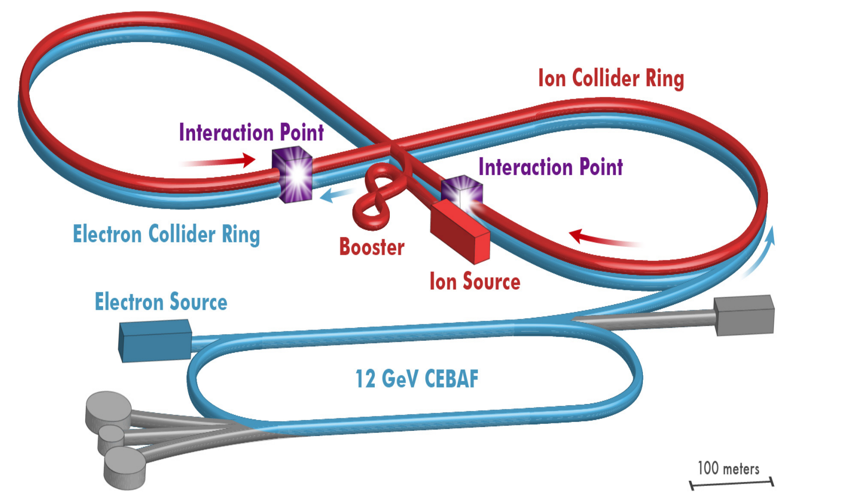
US EIC – two options of realization

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





BNL-eRHIC



JLab-JLEIC

U.S. - based Electron-Ion Collider

❑ NSAC 2007 Long-Range Plan:

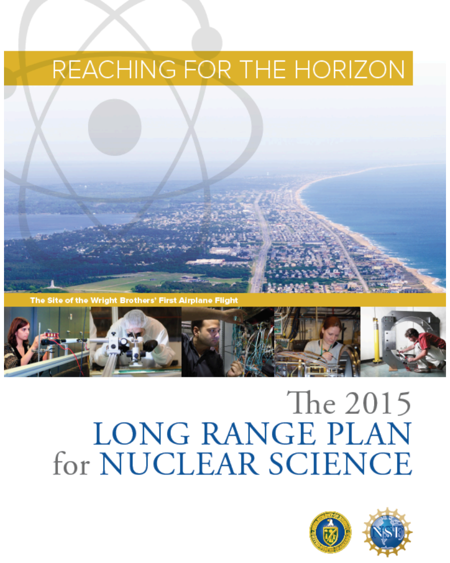
"An **Electron-Ion Collider (EIC)** with **polarized** beams has been **embraced by the U.S. nuclear science community** as embodying the vision for **reaching the next QCD frontier**."

❑ 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**."



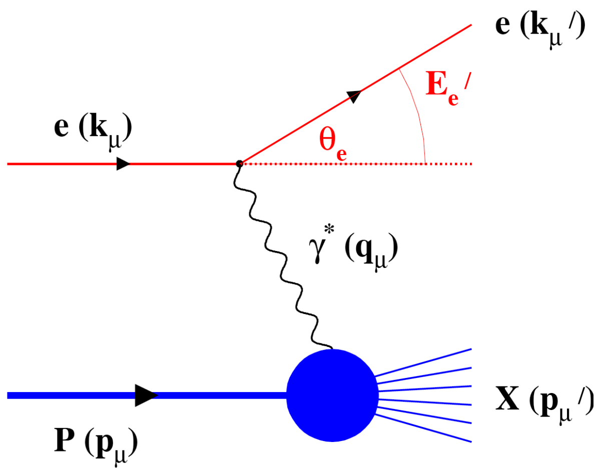
❑ Under review of National Academy of Science:

Next committee meeting: April 19-21

Expect to have the committee report late this year!

Many complementary probes at one facility

- High energy and luminosity Lepton-hadron facility:



Q^2 → Measure of resolution

y → Measure of inelasticity

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

$Q^2 = S \times y$

Inclusive events: e+p/A → e'+X

Detect only the scattered lepton in the detector

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

Detect the scattered lepton in coincidence with identified hadrons/jets

(Initial hadron is broken – confined motion!)

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

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

(Initial hadron is NOT broken – tomography!)

US EIC

"Big" questions/puzzles about QCD, …

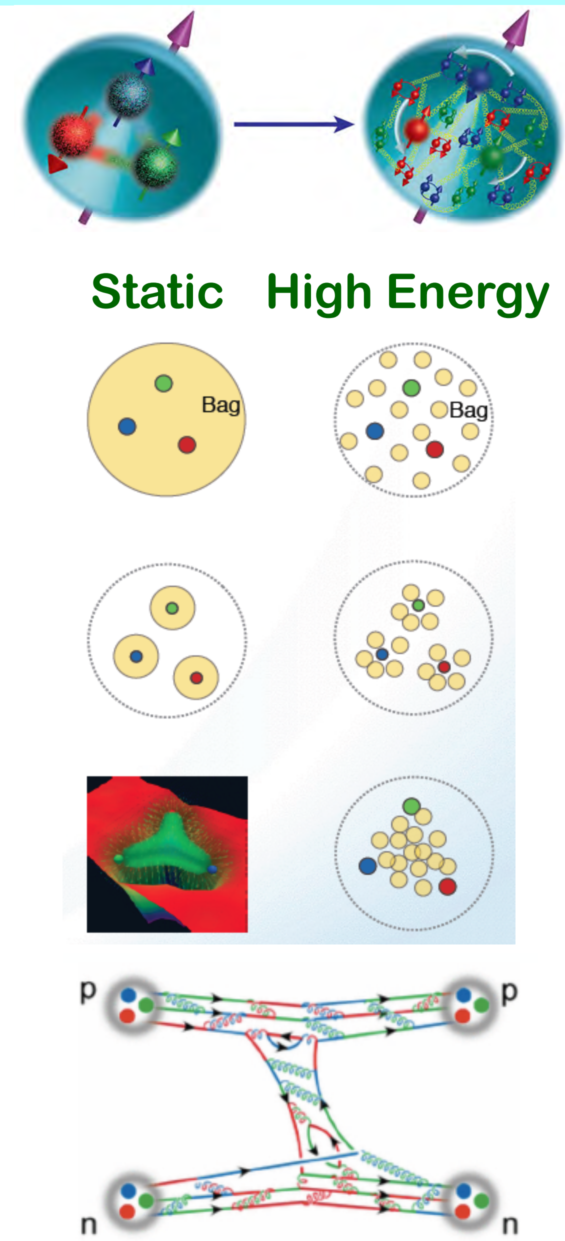
The key deliverables & opportunities

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

“Big” questions/puzzles about QCD, …

- ❑ **How quarks and gluons are confined inside the hadrons – 3D structure?**
  - ✧ Can we develop analytical tools to connect hadron structure and properties at low energy to their parton descriptions at high energy?!

    Hadron mass, spin, confined parton motion, …
    Proton radius: EM charge, quarks, gluons, …
    Nuclear force from QCD, …
  - ✧ Can lattice QCD and EFT help?



"Big" questions/puzzles about QCD, ...

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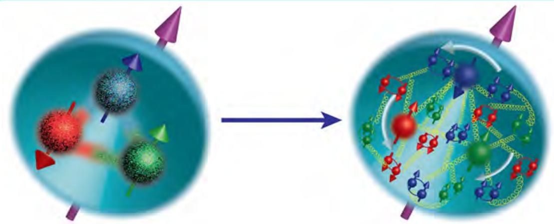
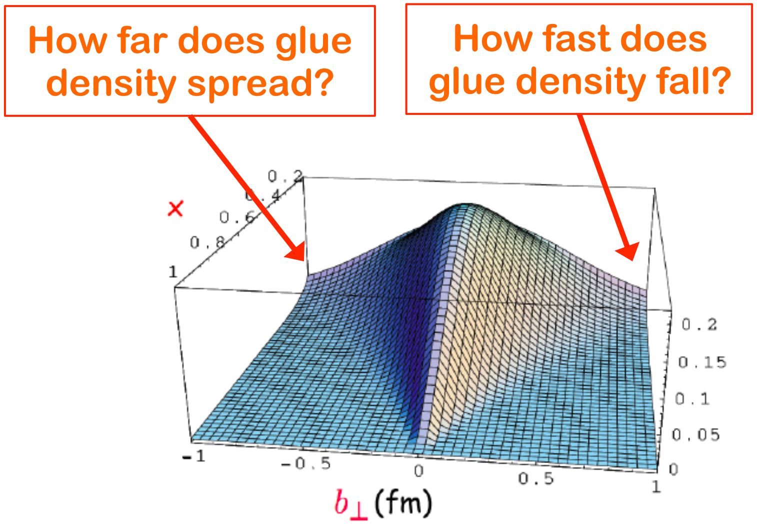
    Hadron mass, spin, confined parton motion, ...
    Proton radius: EM charge, quarks, gluons, ...
    Nuclear force from QCD, ...
  - ✧ Can lattice QCD and EFT help?
- How does the glue fill out hadron's inner space – 3D glue distribution?
  - ✧ Can we develop better probes to go beyond the current accuracy?!

    Glue distribution in proton, and in ions,
    Color confinement radius, ...
    Initial condition for HI collision,
    The physics and role of the momentum "x", ...



Glue tomography
toward small-x

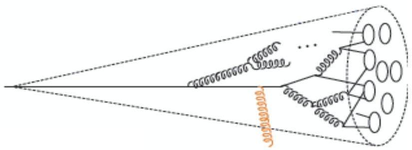


Only possible at EIC

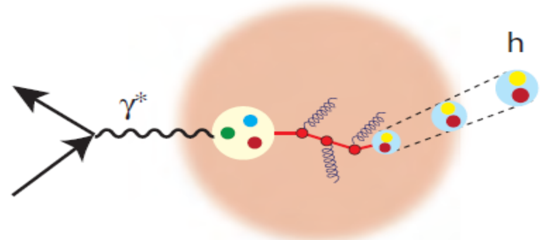
"Big" questions/puzzles about QCD, ...

- ❑ **How hadrons are emerged from the color charge(s)?**
  - ✧ Can we develop analytical tools to "see" the evolution of the color/jet and to predict the jet structure and the emergence of hadrons?!

    Control of the partonic kinematics?
    Hadronization mechanism?



Jet structure

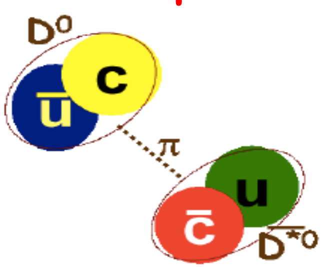


Nucleus as a "vertex detector" at a femtometer scale

- ❑ **How to understand the family of hadrons?**
  - ✧ Can we see gluonic excitations in hadron spectrum?
  - ✧ Can we understand the newly observed hadronic particles, XYZ, …?
  - ✧ XYZ particles at future ep + eA, …

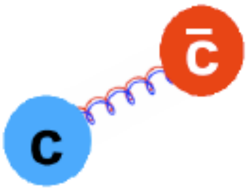
Not covered here!

A new particle explosion?



$D^0 - \bar{D}^{*0}$ "molecule"

diquark-diantiquark



$q\bar{q}$-gluon "hybrid"

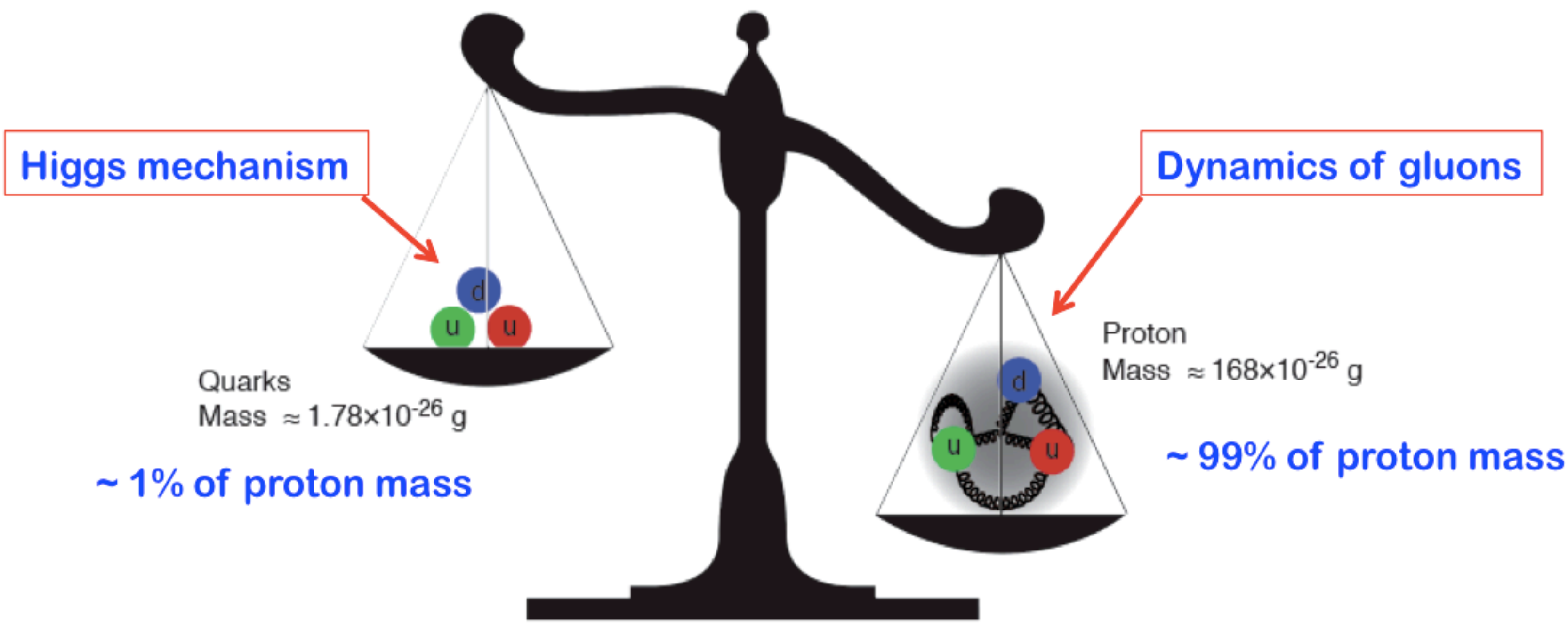
Pentaquarks?

How to answer the "big" questions?

- **How does QCD generate the nucleon mass?**

  "… The vast majority of the nucleon's mass is due to quantum fluctuations of quark-antiquark pairs, the gluons, and the energy associated with quarks moving around at close to the speed of light. …" *The 2015 Long Range Plan for Nuclear Science*

- **Higgs mechanism is not relevant to hadron mass!**



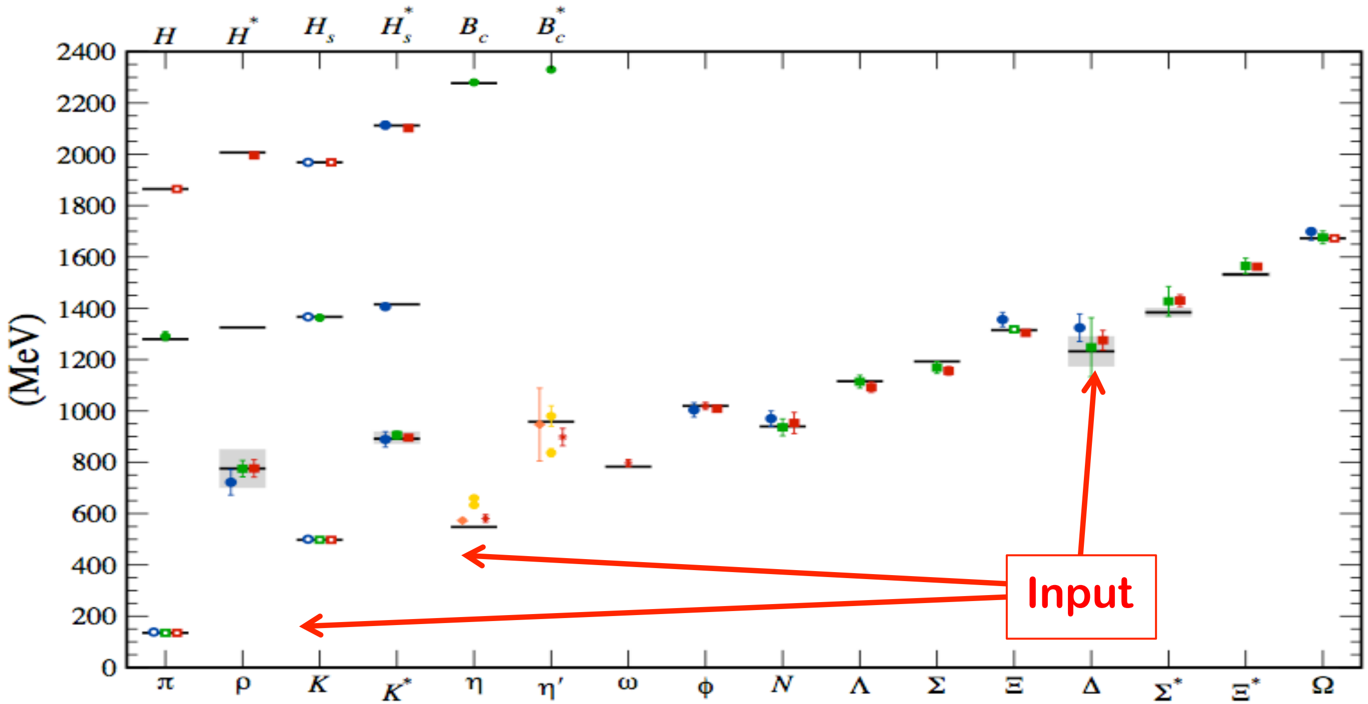
"Mass without mass!"

How to answer the "big" questions?

- ❑ **How does QCD generate the nucleon mass?**

"… The vast majority of the nucleon's mass is due to quantum fluctuations of quark-antiquark pairs, the gluons, and the energy associated with quarks moving around at close to the speed of light. …" *The 2015 Long Range Plan for Nuclear Science*

- ❑ **Hadron mass from Lattice QCD calculation:**



How does QCD generate this? The role of quarks vs that of gluons?

If we do not understand proton mass, we do not understand QCD

How to answer the "big" questions?

❑ **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/

How to answer the "big" questions?

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

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

How to answer the “big” questions?

❑ How does QCD generate the nucleon mass?

“… The vast majority of the nucleon’s mass is due to quantum fluctuations of quark-antiquark pairs, the gluons, and the energy associated with quarks moving around at close to the speed of light. …” *The 2015 Long Range Plan for Nuclear Science*

❑ Role of quarks and gluons?

✧ QCD energy-momentum tensor:

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

✧ Mass = energy of the hadron when it is at the rest

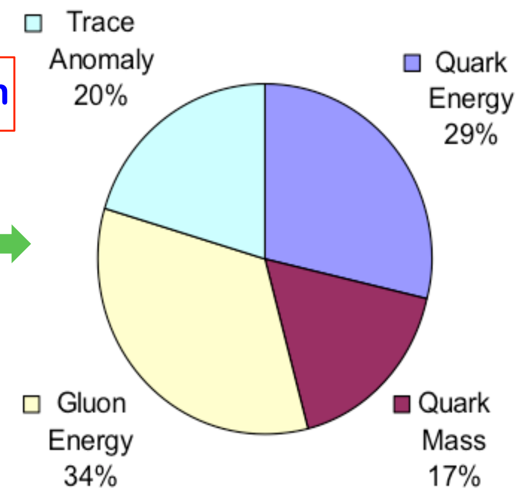
$$m = \frac{\langle p|\int d^3x\, T^{00}\,|p\rangle}{\langle p|p\rangle} \sim \mathrm{GeV}$$

when proton is at rest!

Relativistic motion | χ Symmetry Breaking | Quantum fluctuation

$$m = E_q + E_g + \chi_{m_q} + T_g$$

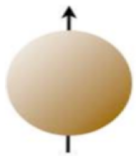
Quark Energy | Gluon Energy | Quark Mass | Trace Anomaly



Decomposition is not unique!

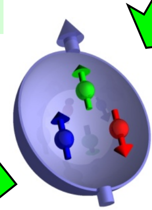
How to answer the “big” questions?

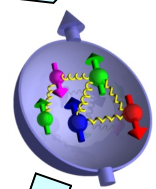
❑ **How does QCD generate the nucleon’s spin?**

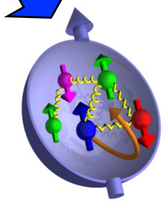


$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + (L_q + L_g) = \sum \langle P, S|\hat{J}^z_f(\mu)|P, S\rangle$$

Proton Spin







Quark helicity
Best known

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

$$\sim 30\%$$

Spin “puzzle”

Gluon helicity
Start to know

$$\Delta G = \int dx \Delta g(x)$$

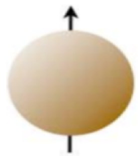
$$\sim 20\% (\text{with RHIC data})$$

Orbital Angular Momentum
of quarks and gluons
Little known

If we do not understand proton spin, we do not understand QCD

How to answer the "big" questions?

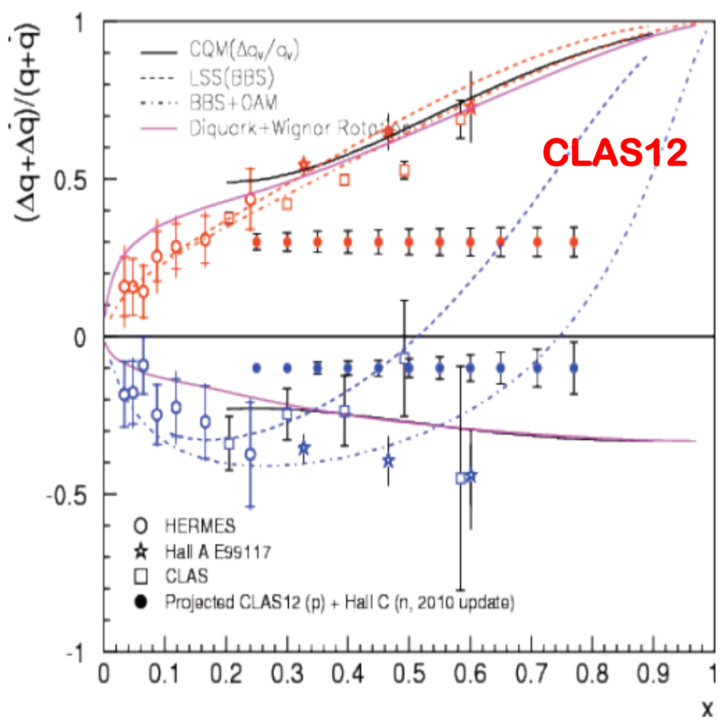
- ❑ **How does QCD generate the nucleon's spin?**

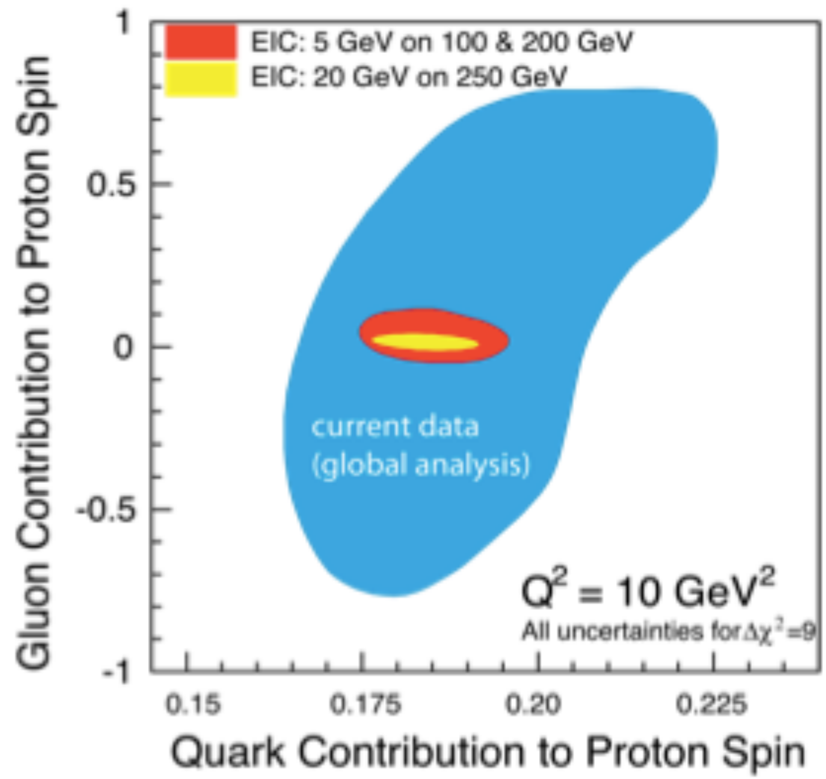


Proton Spin

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

- ❑ **What can JLab12 and EIC do?**

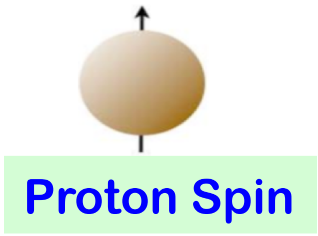




Plus many more JLab12 experiments – flavor

How to answer the "big" questions?

- How does QCD generate the nucleon's **spin**?



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

To understand the proton spin,
fully, we need to understand
the position and confined motion of
quarks and gluons in QCD

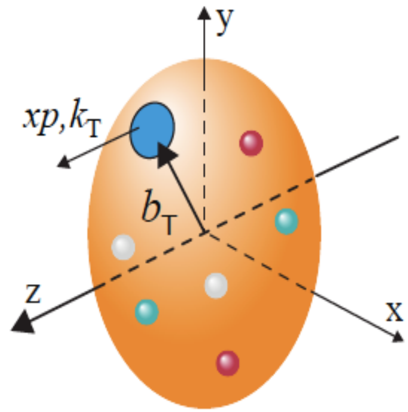
➡ **GPDs, TMDs, GTMDs, …**

Need "probes"
for two-scale observables!

Two-momentum-scale observables

- Cross sections with two-momentum scales observed:

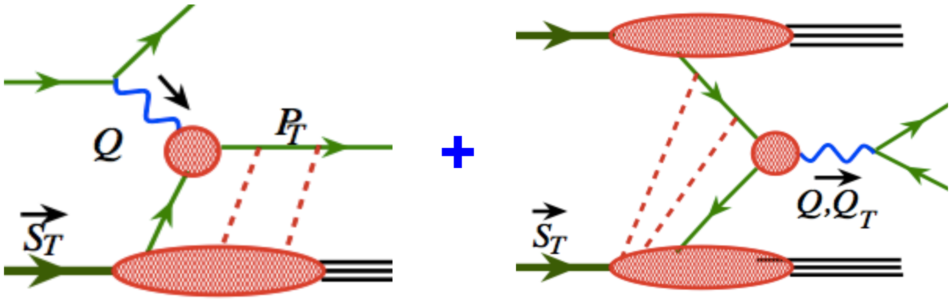
$$Q_1 \gg Q_2 \sim 1/R \sim \Lambda_{\mathrm{QCD}}$$



✧ Hard scale: Q_1 localizes the probe to see the quark or gluon d.o.f.

✧ "Soft" scale: Q_2 could be more sensitive to hadron structure, e.g., confined motion

- Two-scale observables with the hadron broken:



\+ Two-jet momentum imbalance in SIDIS, …

SIDIS: Q>>P_T DY: Q>>P_T

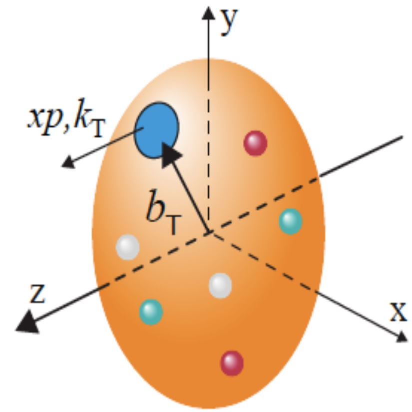
✧ Natural observables with TWO very different scales

✧ TMD factorization: partons' confined motion is encoded into TMDs

Two-momentum-scale observables

❑ Cross sections with two-momentum scales observed:

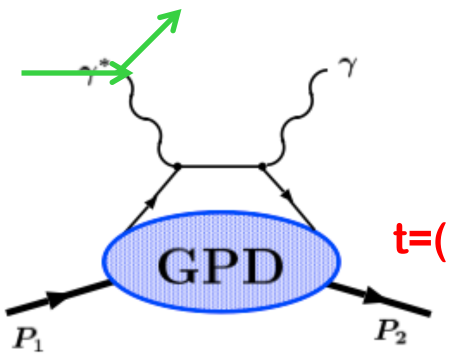
$$Q_1 \gg Q_2 \sim 1/R \sim \Lambda_{\rm QCD}$$



✧ Hard scale: Q_1 localizes the probe to see the quark or gluon d.o.f.

✧ "Soft" scale: Q_2 could be more sensitive to hadron structure, e.g., confined motion

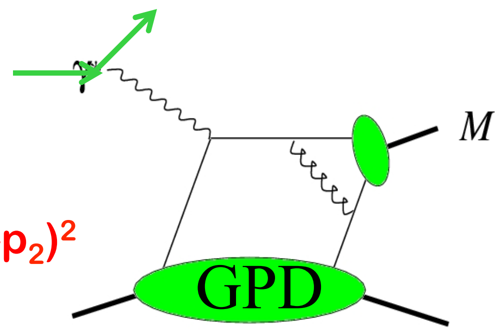
❑ Two-scale observables with the hadron unbroken:



DVCS: $Q^2 >> |t|$

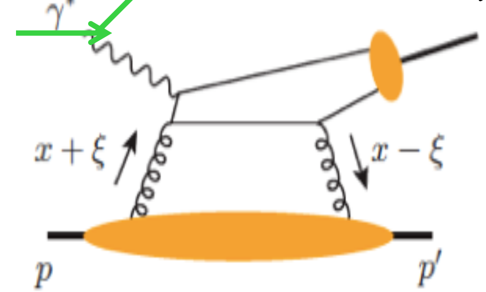
\+

$t=(p_1-p_2)^2$



DVEM: $Q^2 >> |t|$

\+



EHMP: $Q^2 >> |t|$

\+ …

✧ Natural observables with TWO very different scales

✧ GPDs: Fourier Transform of t-dependence gives spatial b_T-dependence

How to answer the "big" questions?

❑ 3D boosted partonic structure:

Momentum Space

TMDs

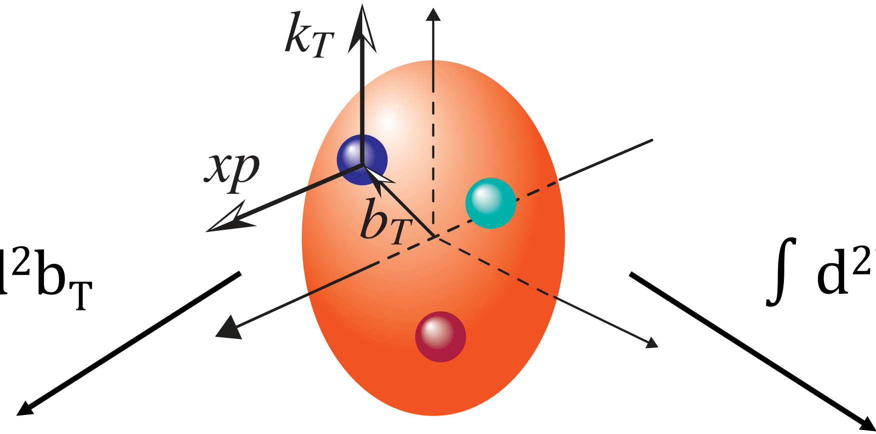
Confined motion

Coordinate Space

GPDs

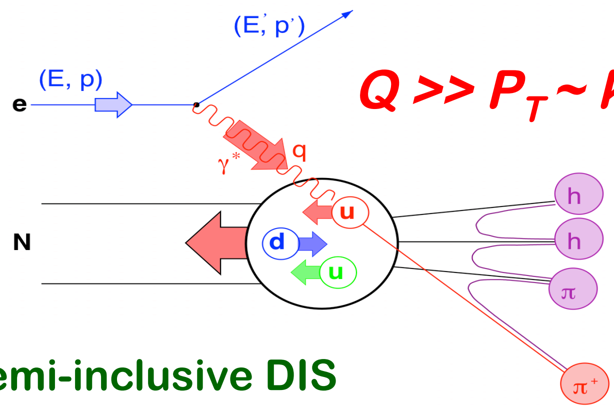
Spatial distribution

$\int d^2b_T$ $\qquad$ $\int d^2k_T$



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

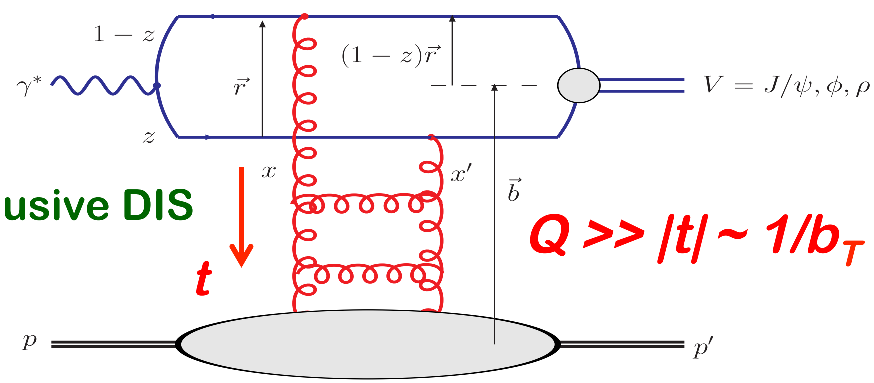
3D momentum space images $\qquad$ **2+1D coordinate space images**



$Q >> P_T \sim k_T$

Semi-inclusive DIS

Exclusive DIS



$Q >> |t| \sim 1/b_T$

JLab12 – valence quarks, EIC – sea quarks and gluons

How to answer the "big" questions?

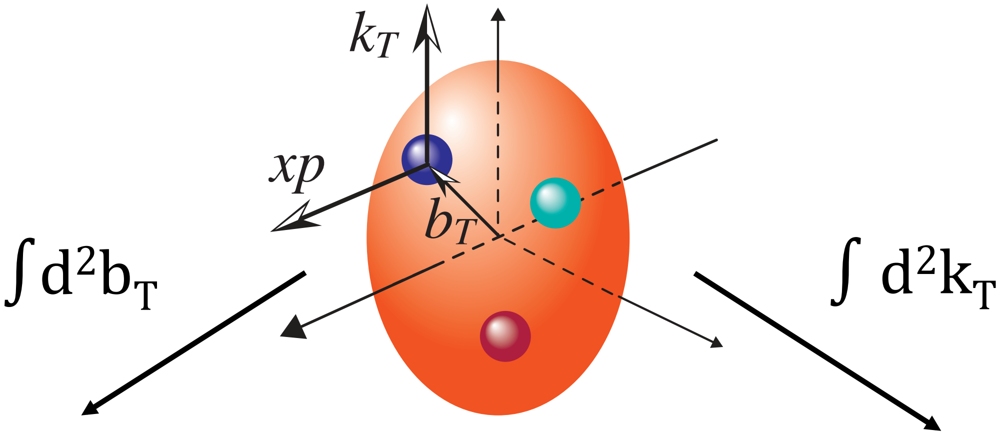
- 3D boosted partonic structure:

Momentum Space

TMDs

Coordinate Space

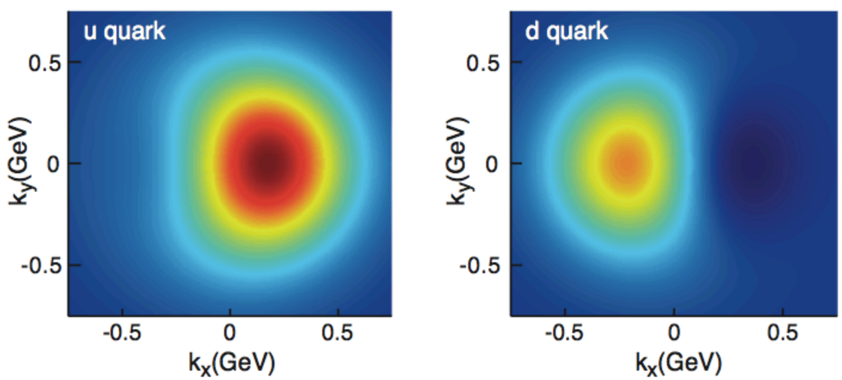
GPDs



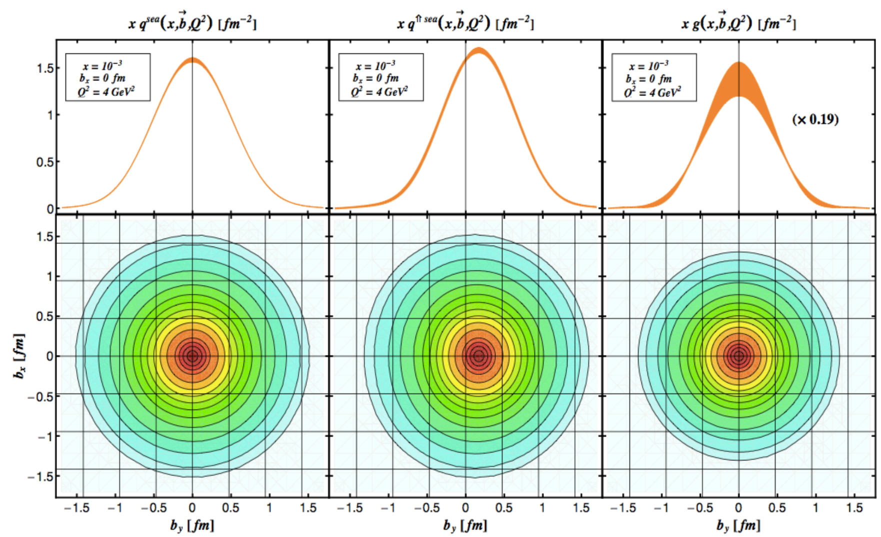
$f(x,k_T)$ | EIC white paper: arXiv:1212.1701 | $f(x,b_T)$

Sivers Function

Imaging



Density distribution of an unpolarized quark in a proton moving in z direction and polarized in y-direction



Spatial density distributions – "radius"

How to answer the "big" questions?

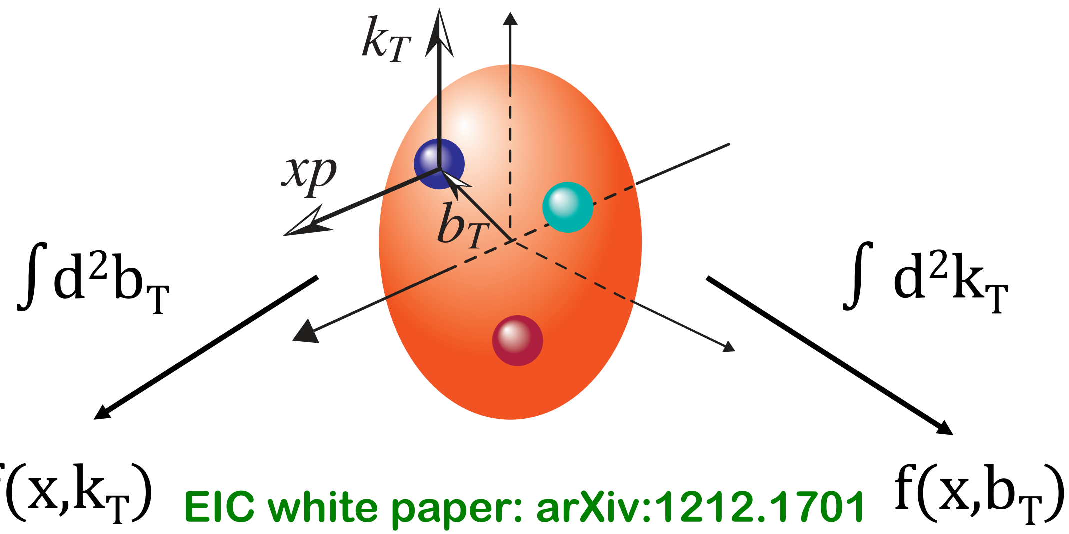
❑ **3D boosted partonic structure:**

Momentum Space

TMDs

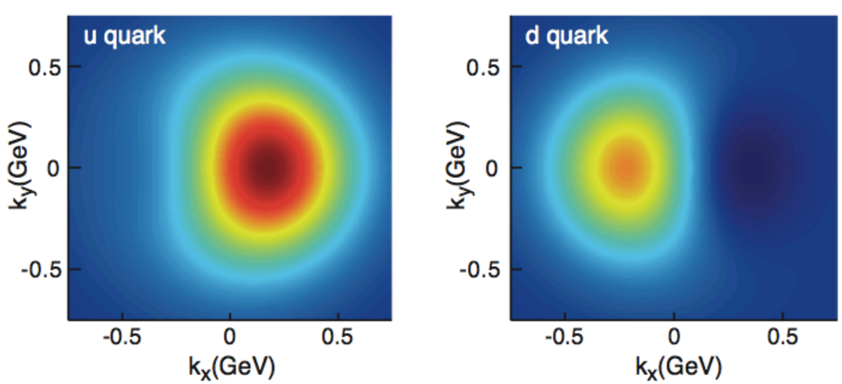
Coordinate Space

GPDs

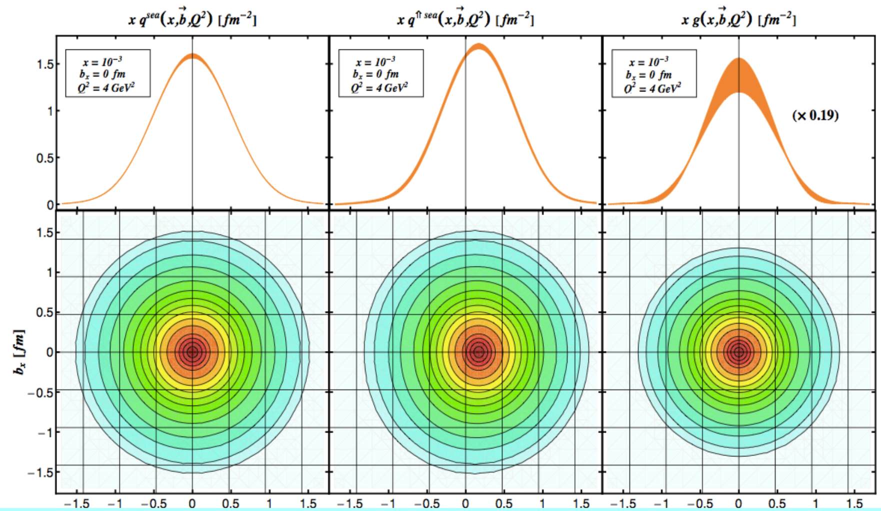


EIC white paper: arXiv:1212.1701

Sivers Function



Imaging



Position r x Momentum p → Orbital Motion of Partons

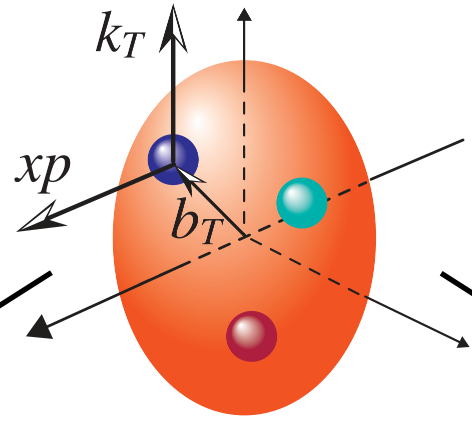
How to answer the “big” questions?

- 3D boosted partonic structure:

Momentum Space

TMDs

$\int d^2b_T$



Coordinate Space

GPDs

$\int d^2k_T$

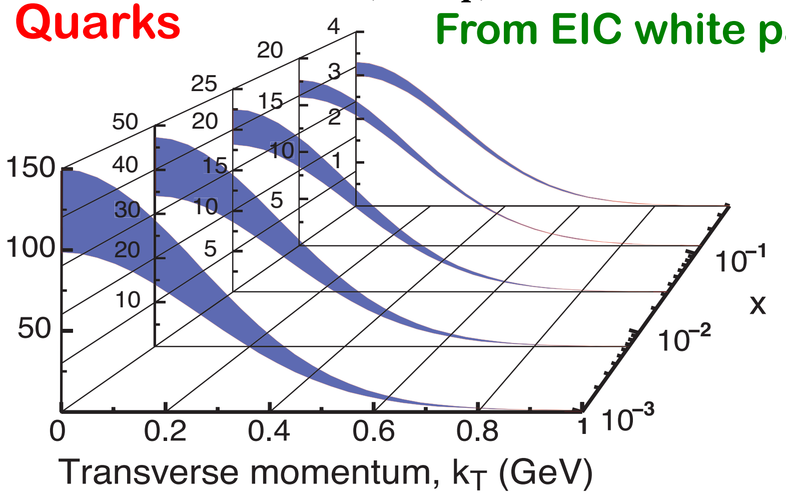
$f(x,k_T)$

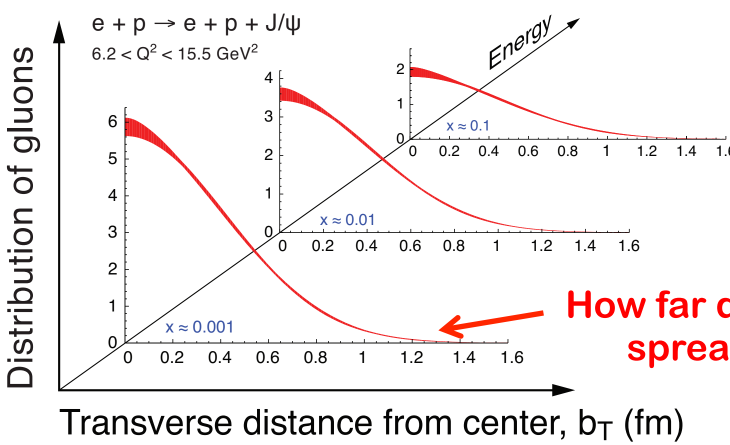
$f(x,b_T)$

Quarks

From EIC white paper: arXiv:1212.1701

Gluons



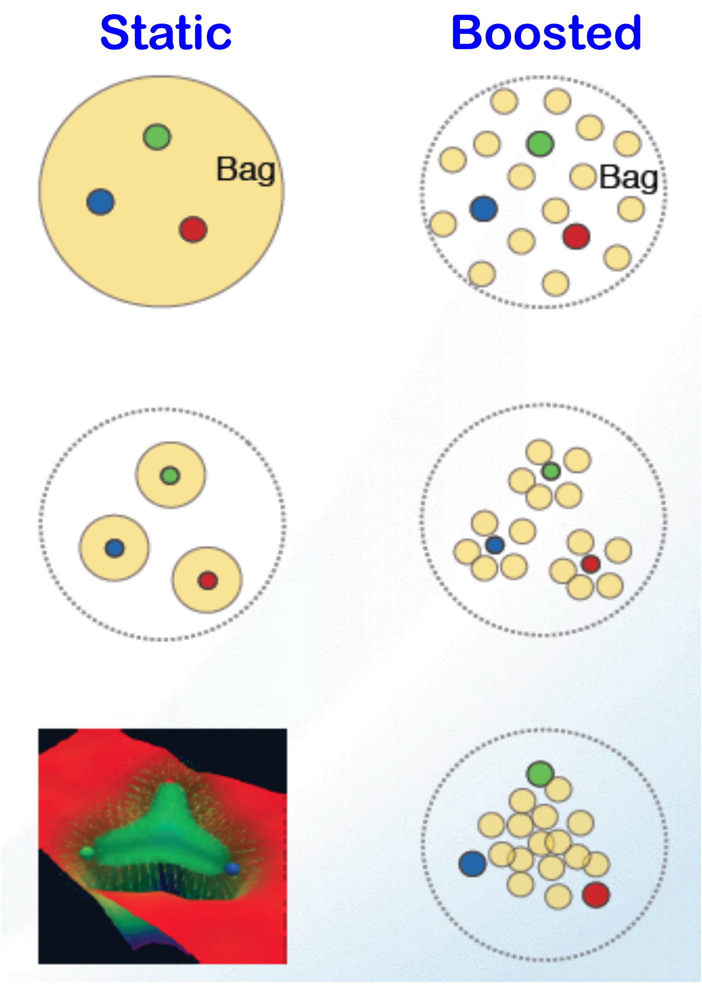


How far does it spread?

Role of momentum fraction -“x”, and nature of pion cloud?

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
Gluon radius < Charge Radius

3D Confined Motion (TMDs) + Spatial Distribution (GPDs)

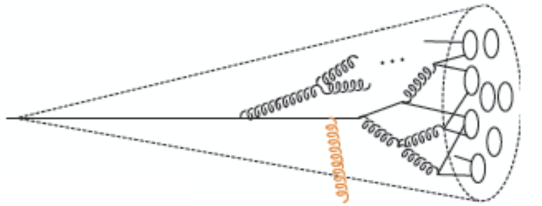
Relation between charge radius, quark radius (x), and gluon radius (x)?

Emergence of hadrons/Jets – A puzzle

- ❑ **Emergence of hadrons:**

  How do hadrons emerge from a created quark or gluon?
  How is the color of quark or gluon neutralized?

Jet substructure

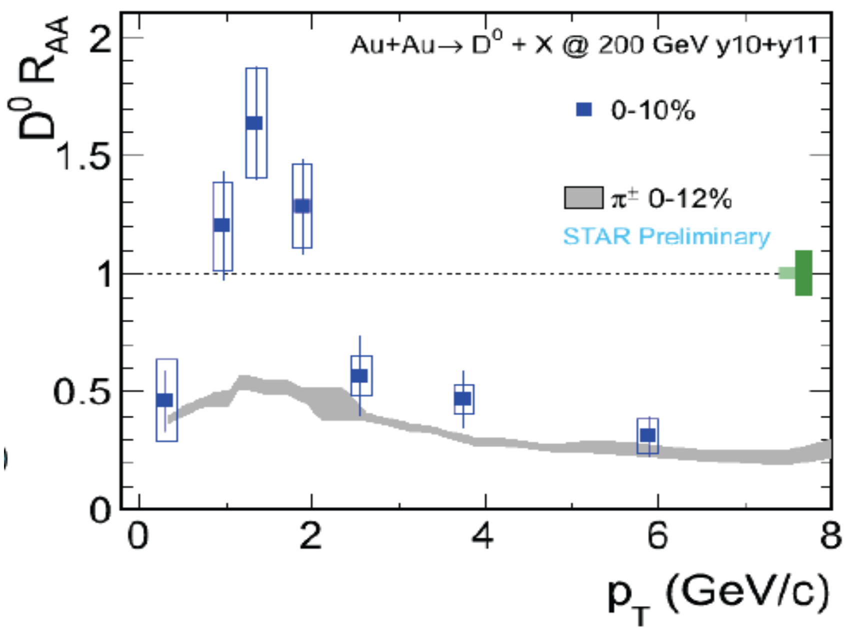


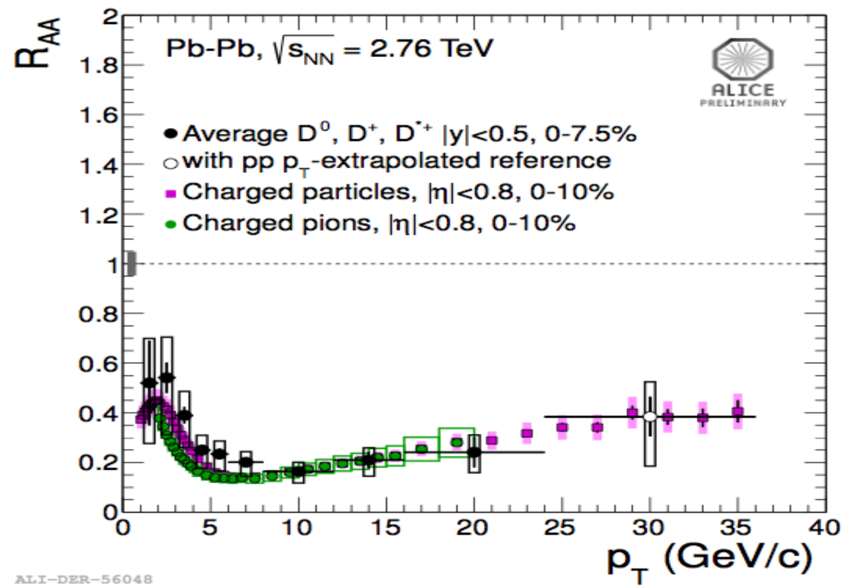
Boosted hadronization

- ❑ **Need a femtometer detector or "scope":**

  Nucleus, a laboratory for QCD
  A "vertex" detector: Evolution of hadronization

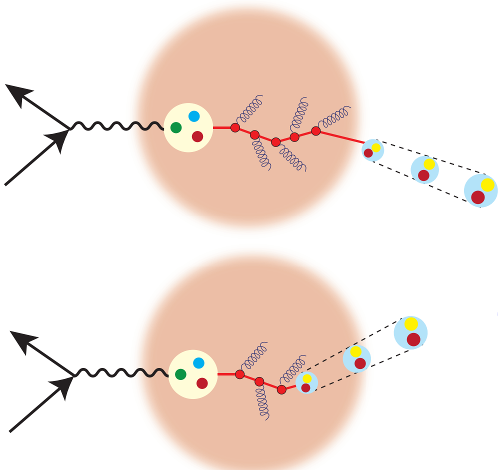
- ❑ **Strong suppression of heavy flavors in AA collisions:**





How to answer the "big" questions?

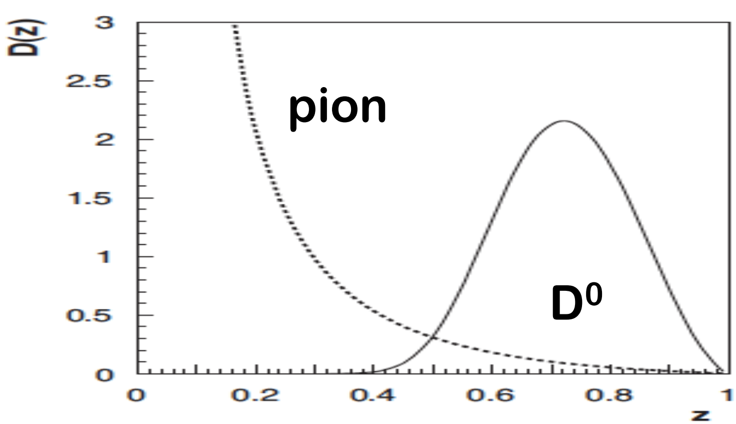
- ❑ **Emergence of a hadron?**

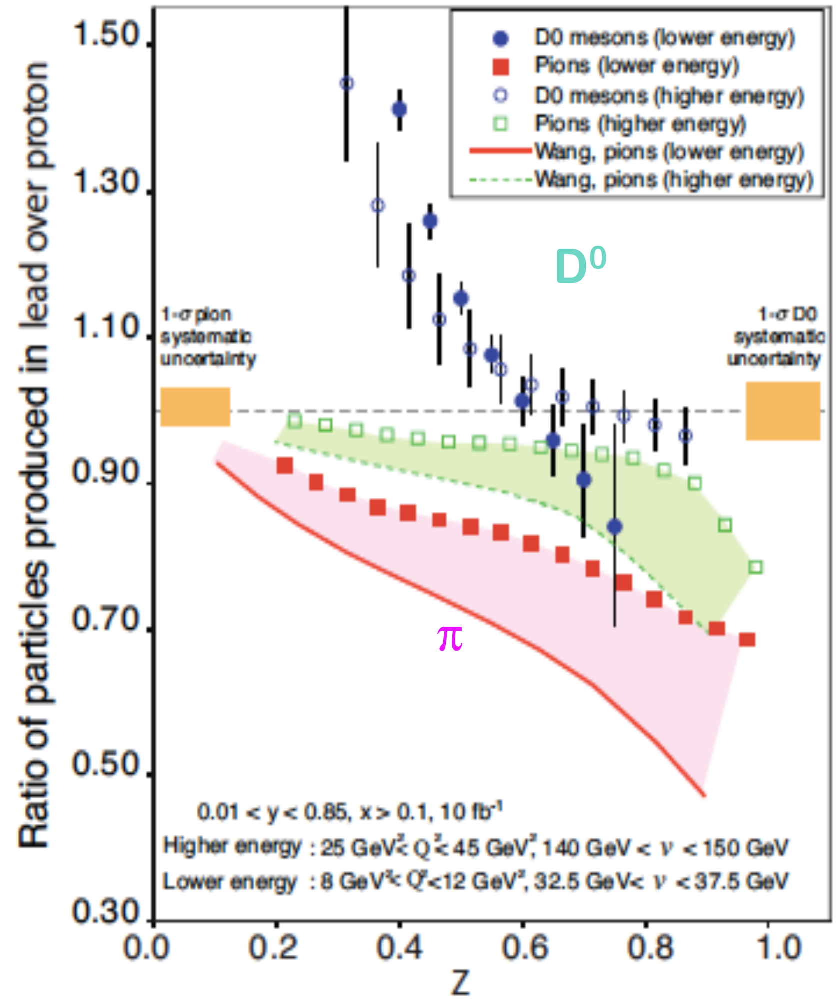


$$\nu = \frac{Q^2}{2mx}$$

Control of ν and medium length!

- ❑ **Heavy quark energy loss:**
  - **Mass dependence of fragmentation**

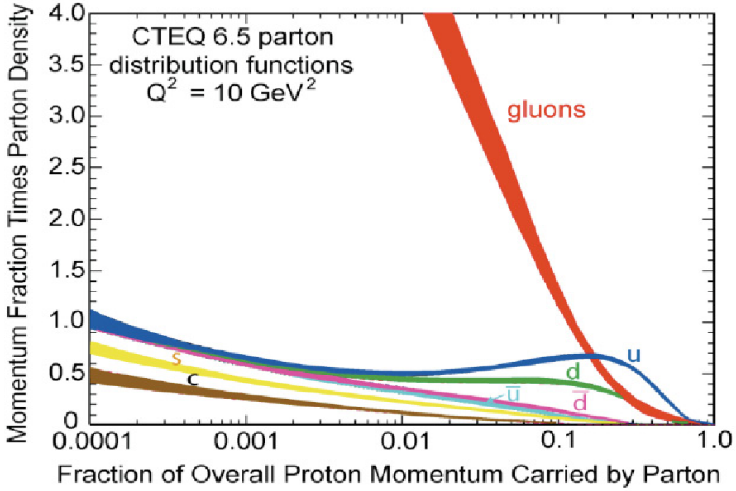




Need the collider energy of EIC and its control on parton kinematics

How to answer the "big" questions?

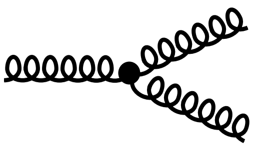
- Run away gluon density at small x?



What causes the low-x rise?

gluon radiation

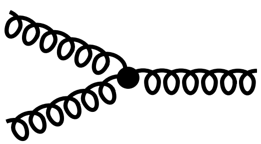
– non-linear gluon interaction



What tames the low-x rise?

gluon recombination

– non-linear gluon interaction



- QCD vs. QED:

QCD – gluon in a proton:

$$Q^2 \frac{d}{dQ^2} xG(x, Q^2) \approx \frac{\alpha_s N_c}{\pi} \int_x^1 \frac{dx'}{x'} x' G(x', Q^2)$$

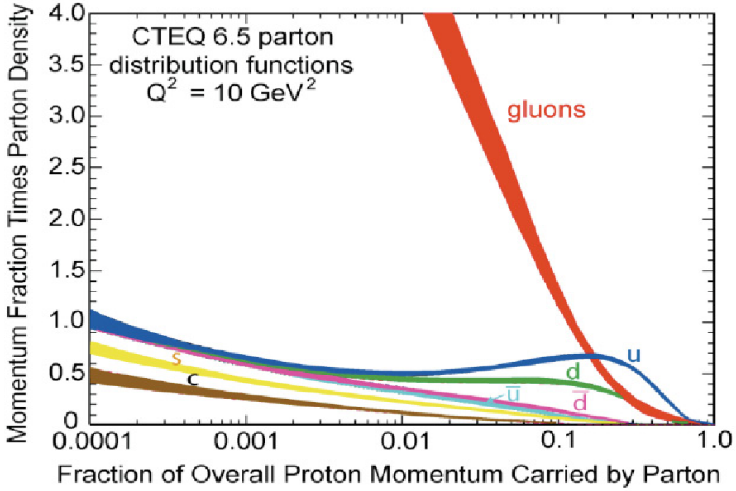
QED – photon in a positronium:

$$Q^2 \frac{d}{dQ^2} x\phi_\gamma(x, Q^2) \approx \frac{\alpha_{em}}{\pi} \left[-\frac{2}{3} x\phi_\gamma(x, Q^2) + \int_x^1 \frac{dx'}{x'} x' [\phi_{e^+}(x', Q^2) + \phi_{e^-}(x', Q^2)] \right]$$

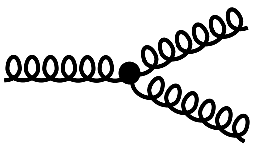
- At very small-x, proton is "black", positronium is still transparent!
- Recombination of large numbers of glue could lead to saturation phenomena

How to answer the "big" questions?

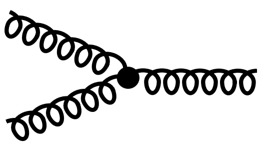
- Run away gluon density at small x?



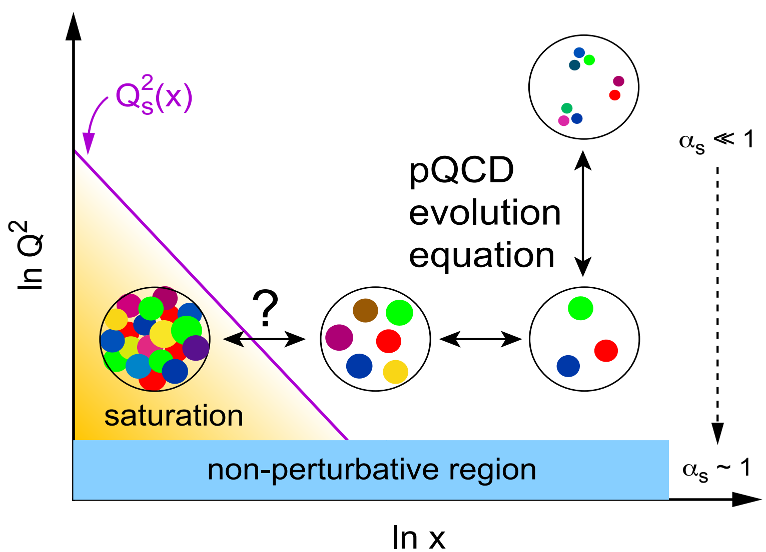
What causes the low-x rise?
gluon radiation
– non-linear gluon interaction



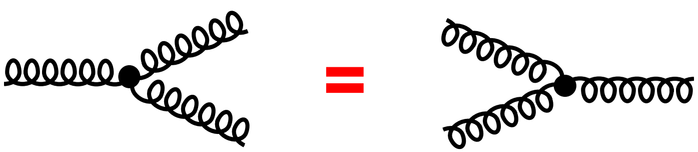
What tames the low-x rise?
gluon recombination
– non-linear gluon interaction



- Particle vs. wave feature:



Gluon saturation – Color Glass Condensate
Radiation = Recombination



at Q_s

Leading to a collective gluonic system?

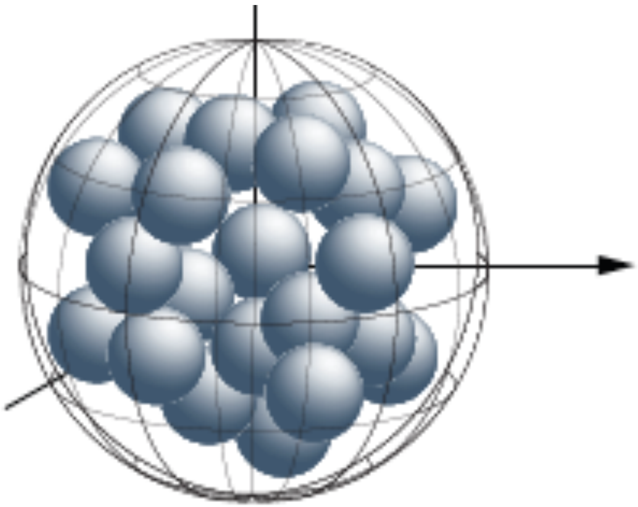
with a universal property of QCD?

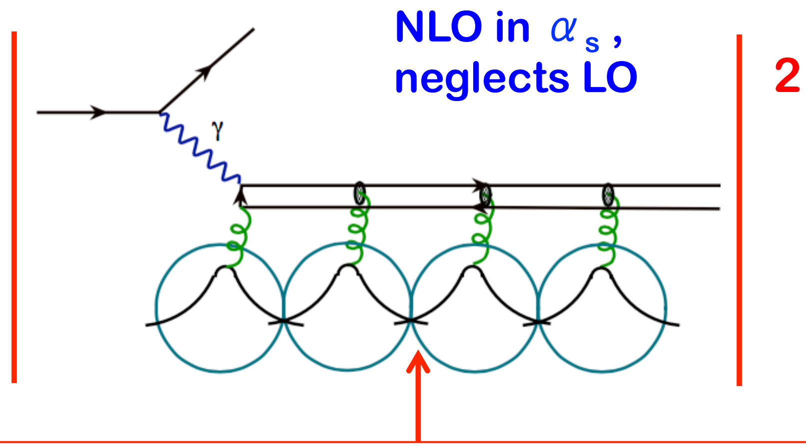
new effective theory QCD – CGC?

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

Nuclear landscape – color confining radius

❑ If we only see quarks and gluons, …





Could there be overlap of color between nucleons?

✧ If color is localized inside the nucleon, using a large nucleus does not change gluon dynamics inside nucleon

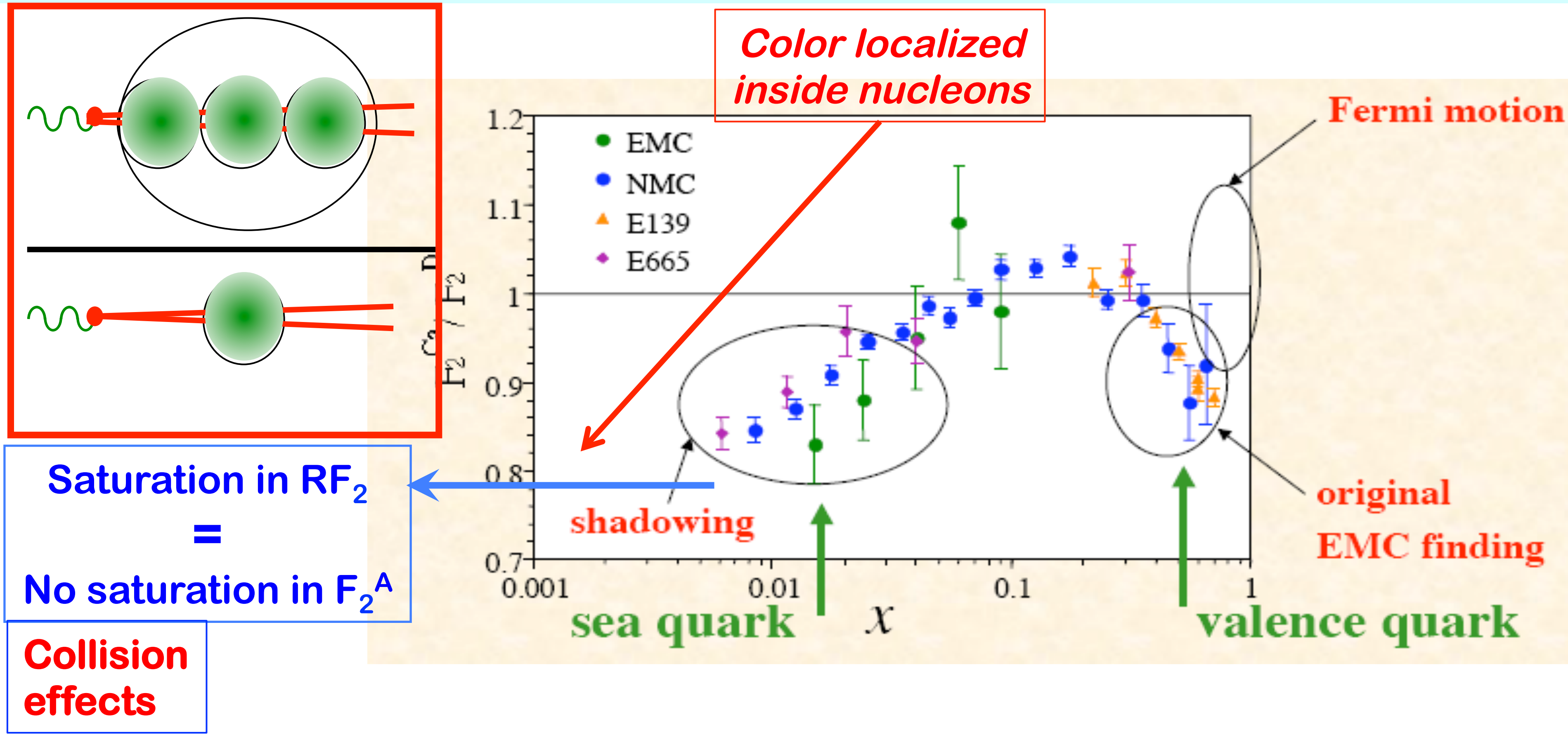
– *no advantage for seeing the gluon saturation,*

– *but, provides an opportunity to study QCD multiple scattering*

✧ If color leaks outside of the nucleon inside a large nucleus, color interaction between nucleons modifies the nuclear landscape

– *large nucleus could have an advantage for discovering the universal properties of the gluon saturation "earlier"*

Color confining radius?



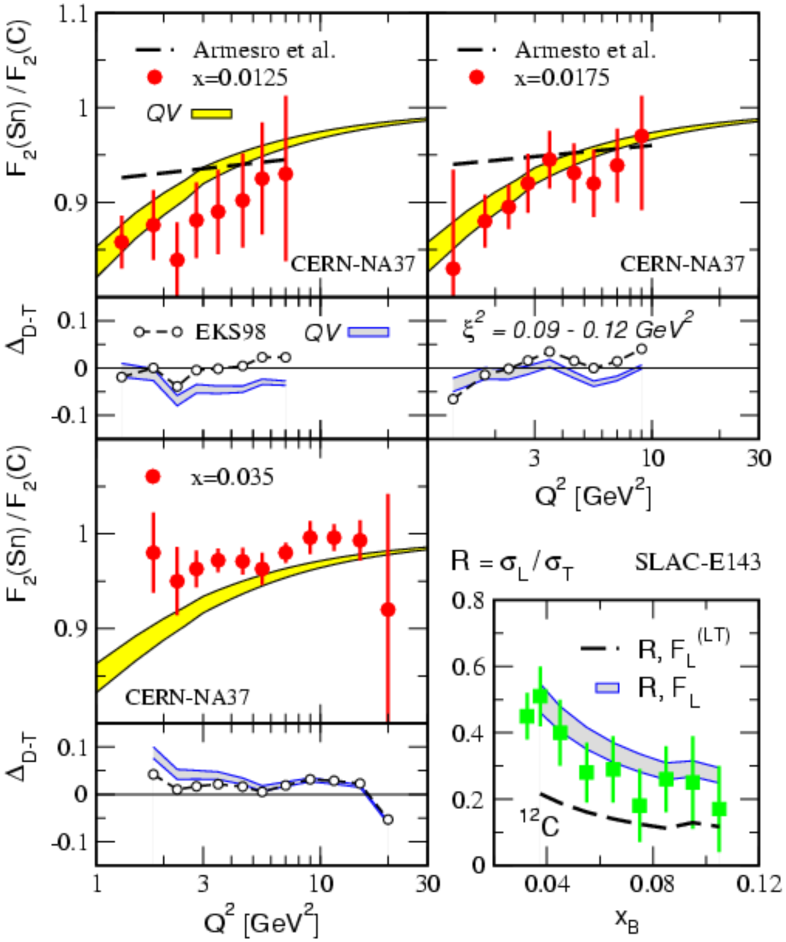
- ❑ **A simple question:**

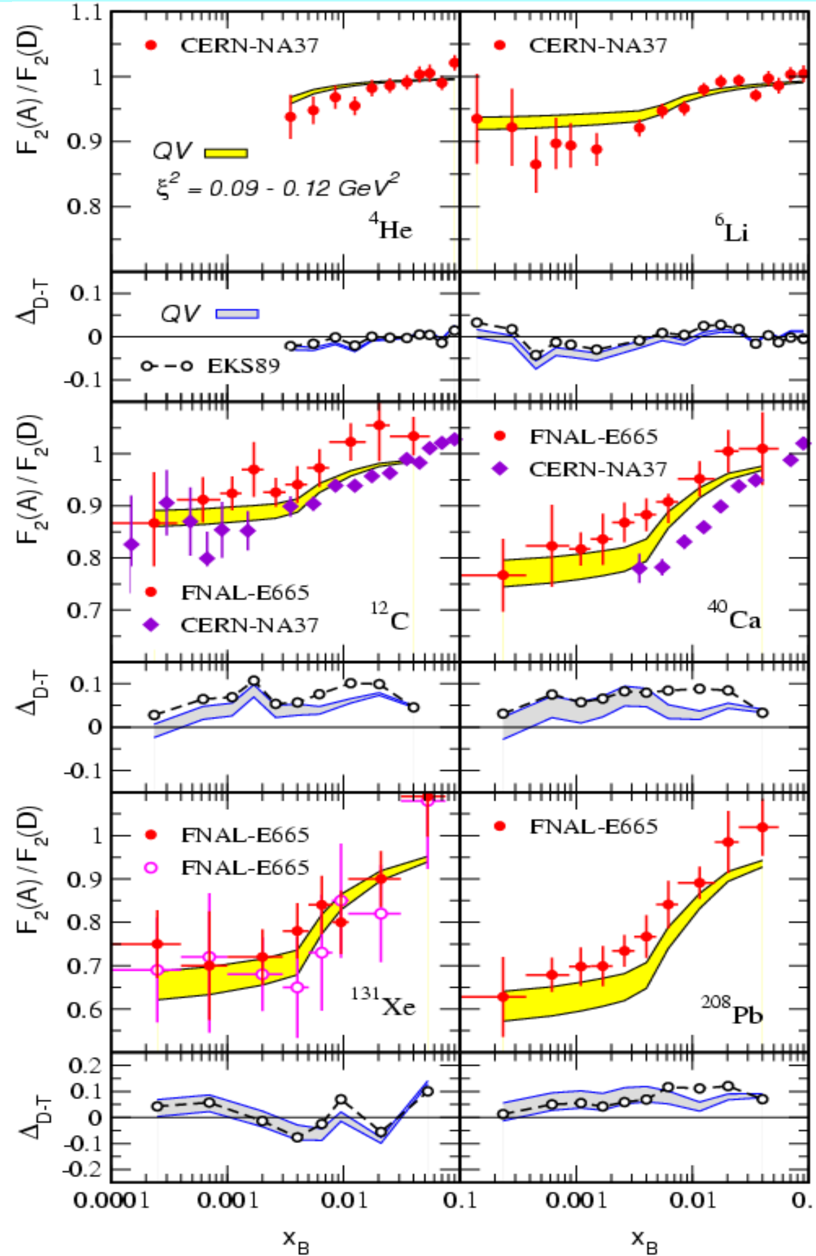
  Will the suppression/shadowing continue to fall as x decreases?

DIS on a large nucleus

- If the color is localized inside nucleon, … Qiu, Vitev, PRL2004

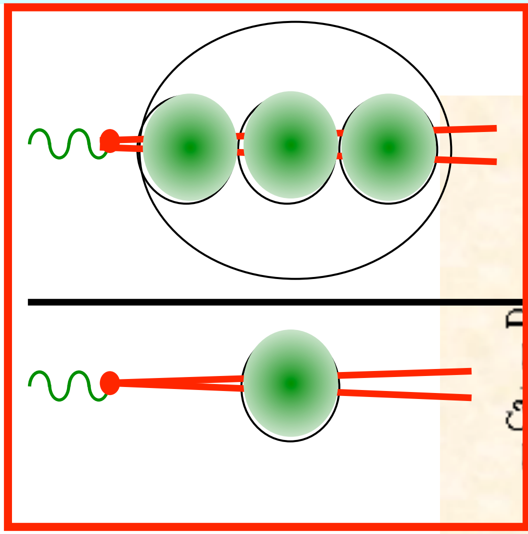
$\xi^2 = 0.09 - 0.12\ \mathrm{GeV}^2$



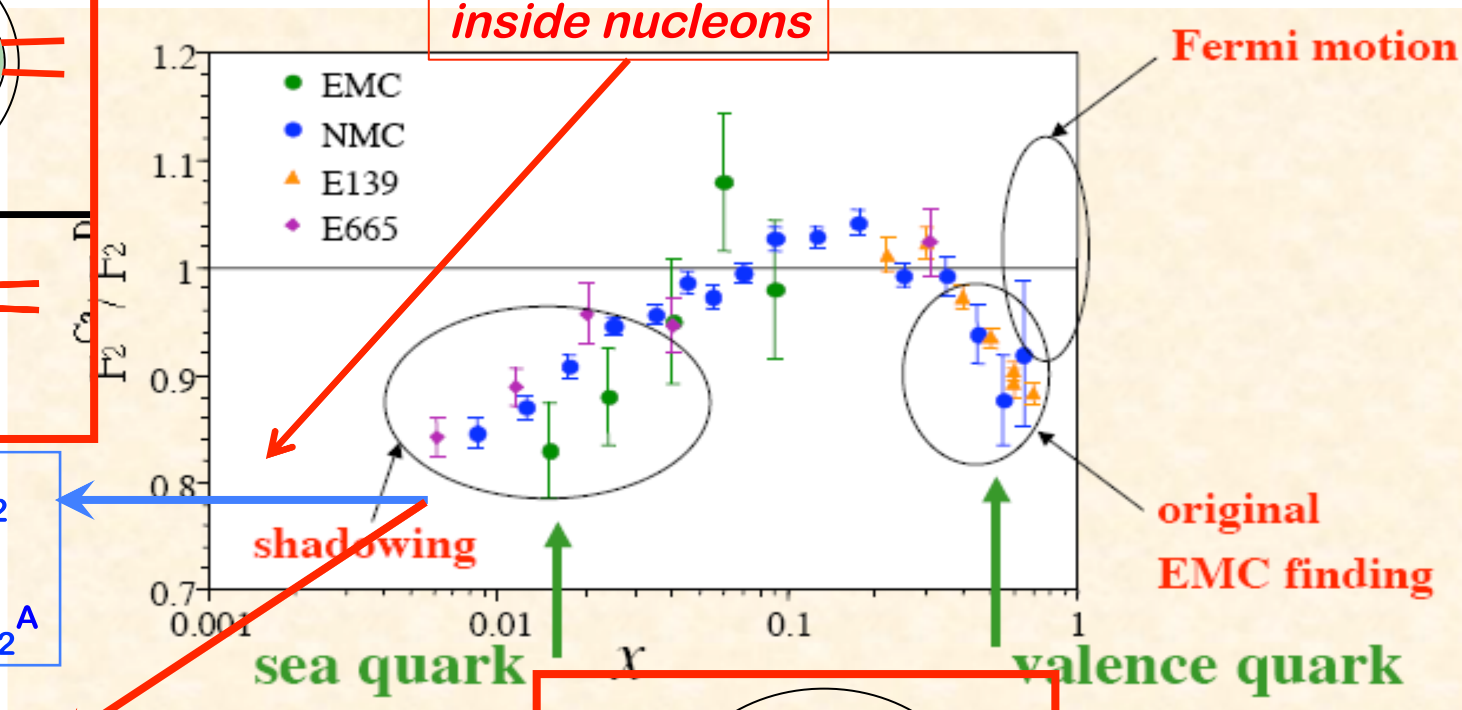


One number for all x_B, Q, and A dependence !

Color confining radius?



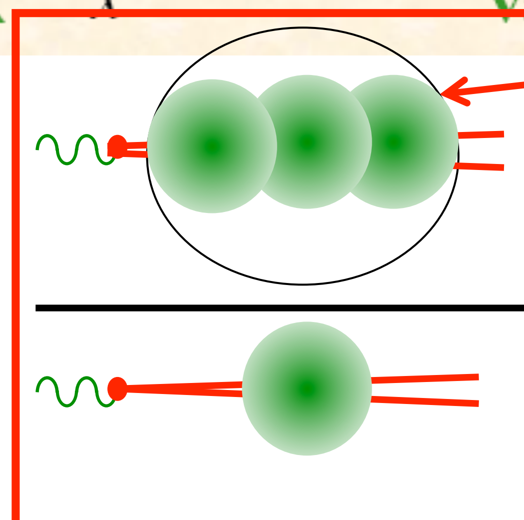
Color localized inside nucleons



Saturation in RF_2
=
No saturation in F_2^A

Collision effects

Saturation in nucleon



Color leaks outside nucleons
Soft gluon radius is larger

- **A simple question:**

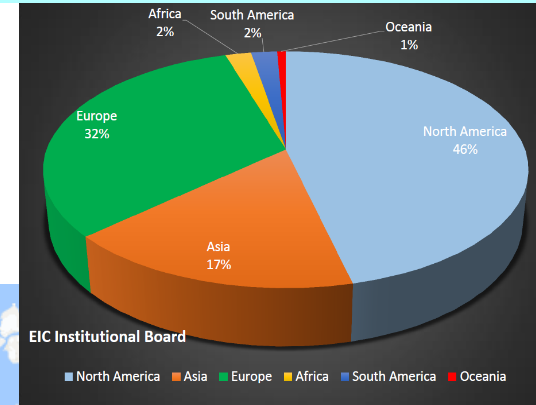
Will the suppression/shadowing continue to fall as x decreases?

The EIC Users Group: *EICUG.ORG*

(no students included as of yet)

670 collaborators, 28 countries, 150 institutions… (December, 2016)

Map of institution's locations



The EIC Users Meeting at Stony Brook, June 2014:

→ *http://skipper.physics.sunysb.edu/~eicug/meeting1/SBU.html*

The EIC UG Meeting at University of Berkeley, January 6-9, 2016

http://skipper.physics.sunysb.edu/~eicug/meeting2/UCB2016.html

Recent EICUG Argonne National Laboratory July 7-10, 2016

http://eic2016.phy.anl.gov

Remote/Internet: meeting: March 16th : For NAS Review preparation

Next meeting:

July 18-22, 2017 Trieste, Italy

- **Registration opening by April 30**

EICUG MEETING – July 18-22
TRIESTE

INFN

UNIVERSITÀ
DEGLI STUDI DI TRIESTE

eicug2017.ts.infn.it

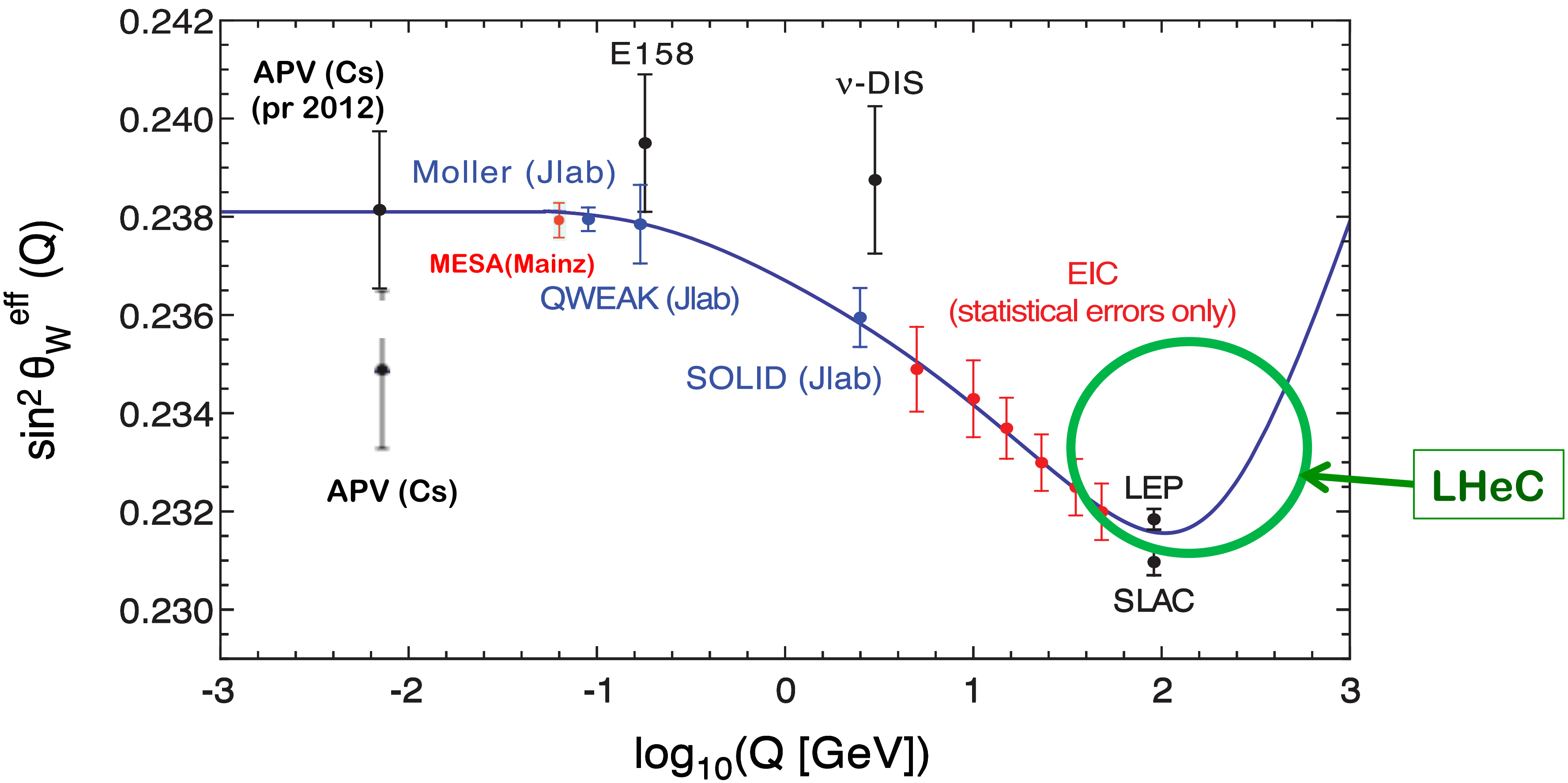
Summary

- 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 and nuclei with a resolution better than 1/10 fm
- EIC designs explore the polarization and intensity frontier, as well as the frontier of new accelerator/detector technology
- EIC@US is sitting at a sweet spot for rich QCD dynamics – capable of taking us to the next QCD frontier

Thanks!

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***