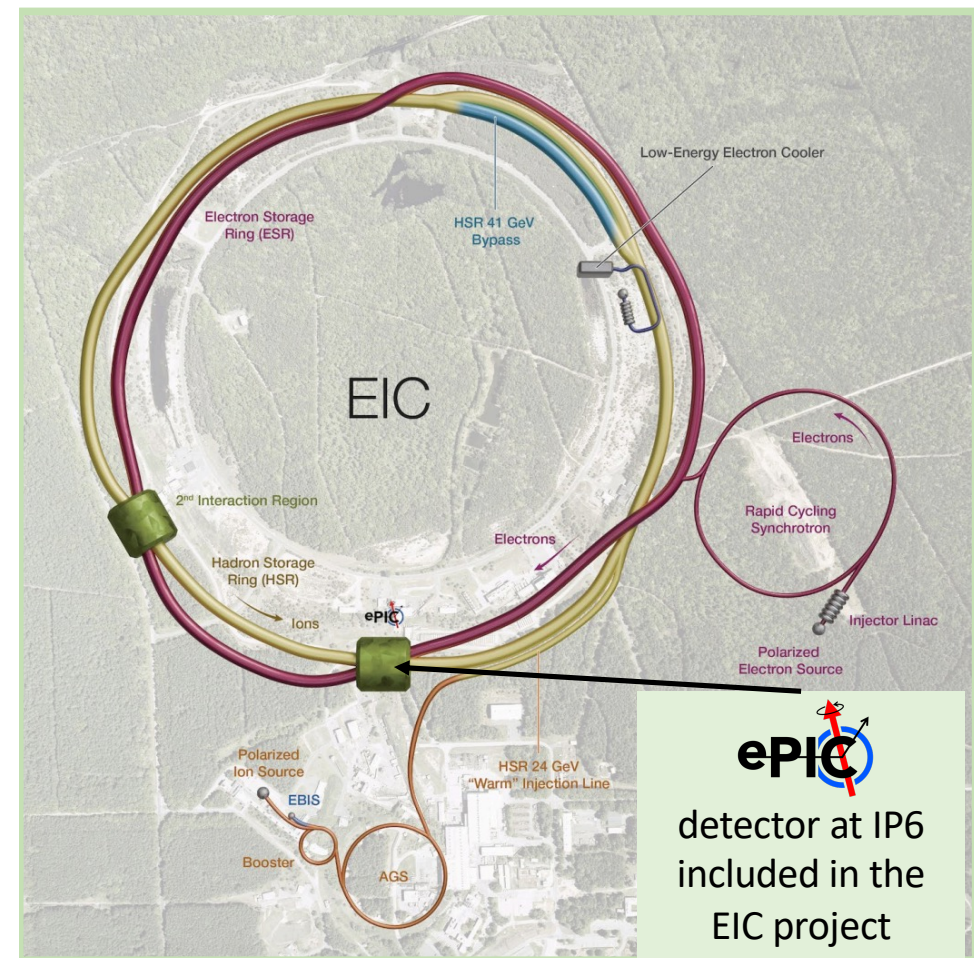
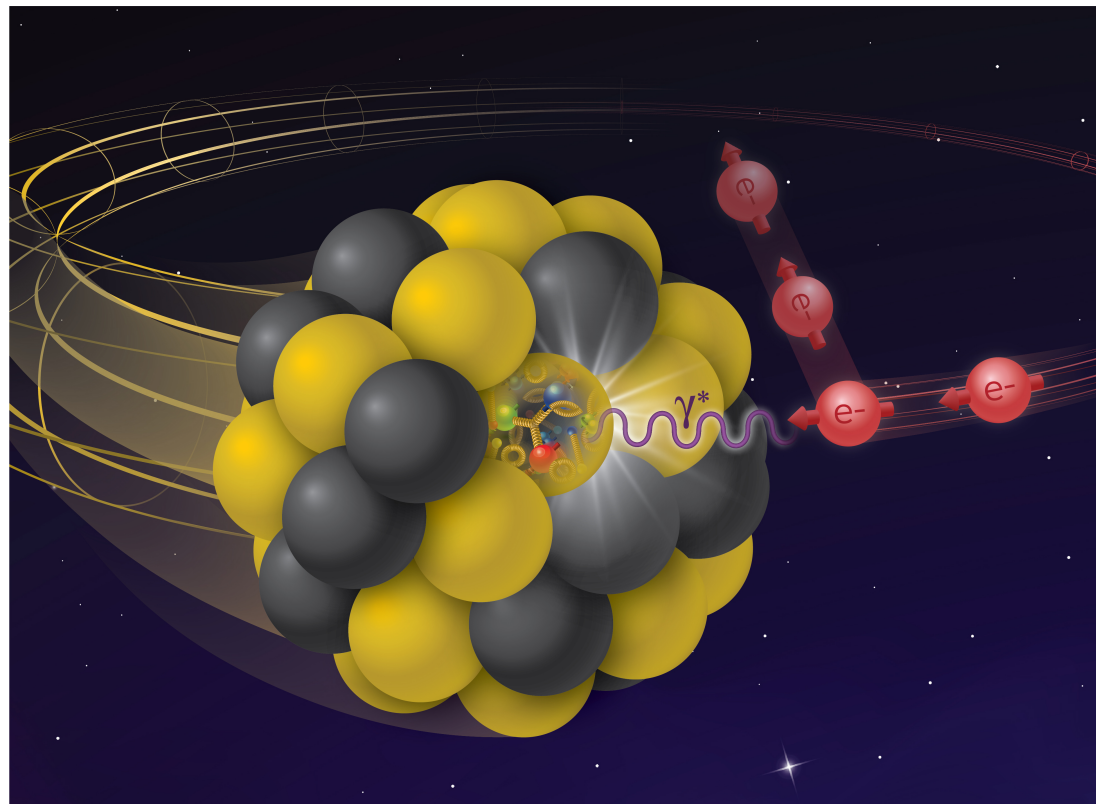


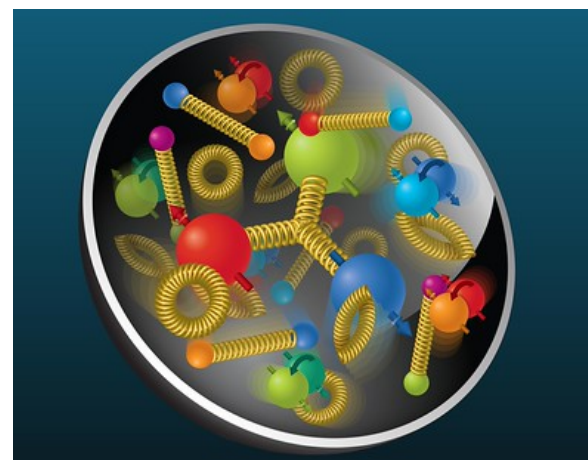
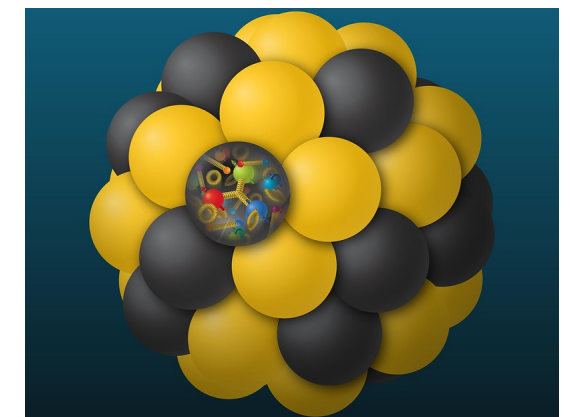
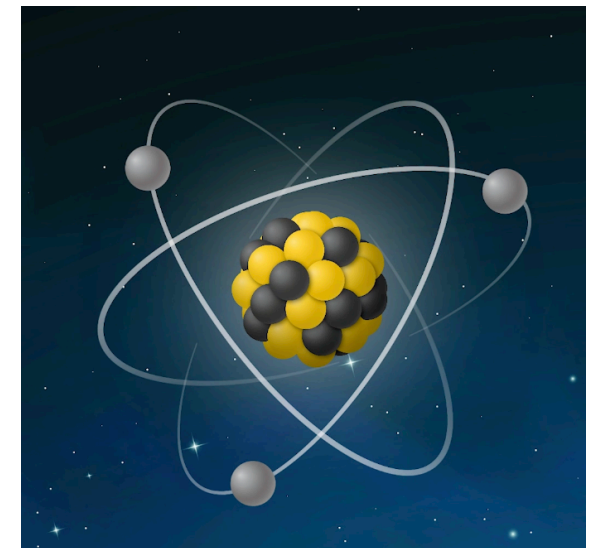
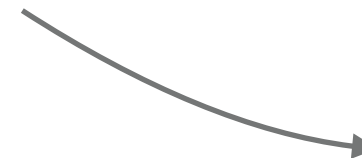
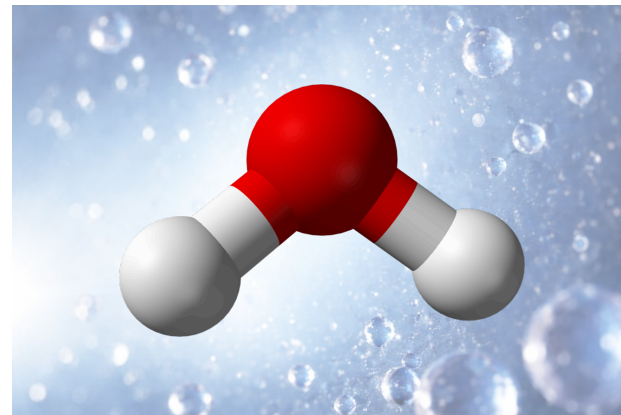


Physics at the **E**lectron **I**on **C**ollider

Anna Staśto

Penn State University

What is structure of matter ?



Looking through more and more powerful microscope one can explore Universe at femtoscales

$$1 \text{ fm} = 10^{-15} \text{ m}$$

Big question: what is structure of matter ?

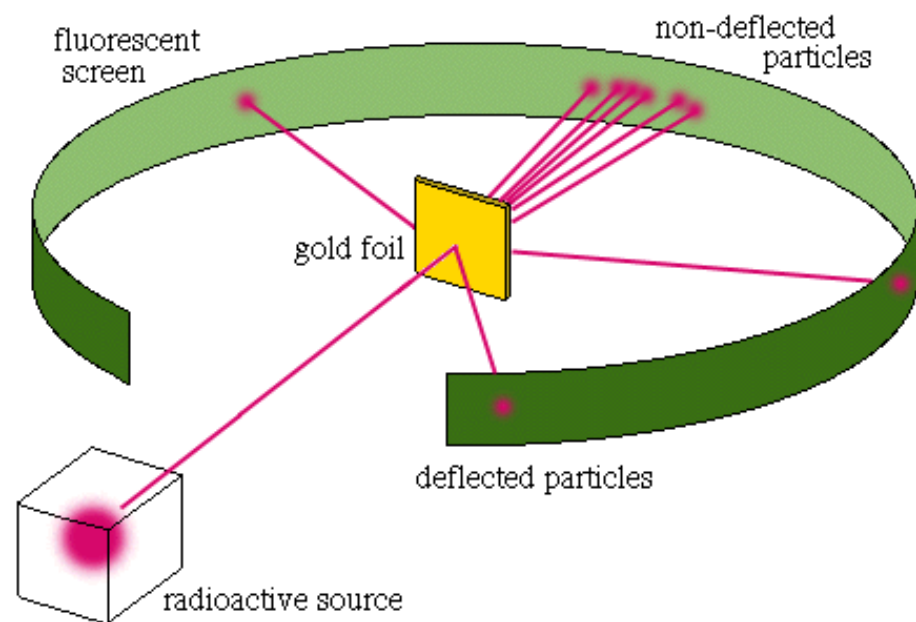
How is the visible matter formed from the smallest elementary building blocks: **quarks** and **gluons** ?

Exploring structure of matter: scattering experiments

Can explore structure of matter by performing **scattering experiments**

Geiger-Marsden experiment 1909

Scattering of alpha particles off the gold foil.
Observation of large angle scattering.



Rutherford model 1911

Atomic structure: positively charged
small nucleus

LXXIX. *The Scattering of α and β Particles by Matter and the Structure of the Atom.* By Professor E. RUTHERFORD, F.R.S., University of Manchester*.

traversed. The observations, however, of Geiger and Marsden† on the scattering of α rays indicate that some of the α particles must suffer a deflexion of more than a right angle at a single encounter. They found, for example, that

It seems reasonable to suppose that the deflexion through a large angle is due to a single atomic encounter, for the chance of a second encounter of a kind to produce a large deflexion must in most cases be exceedingly small. A simple calculation shows that the atom must be a seat of an intense electric field in order to produce such a large deflexion at a single encounter.

Nucleon size

Hofstadter experiments in 1950-1957

Electron scattering off nuclei, determining the charge and shape of nuclei, and measuring the finite size of protons.

Energy of electrons 188 MeV

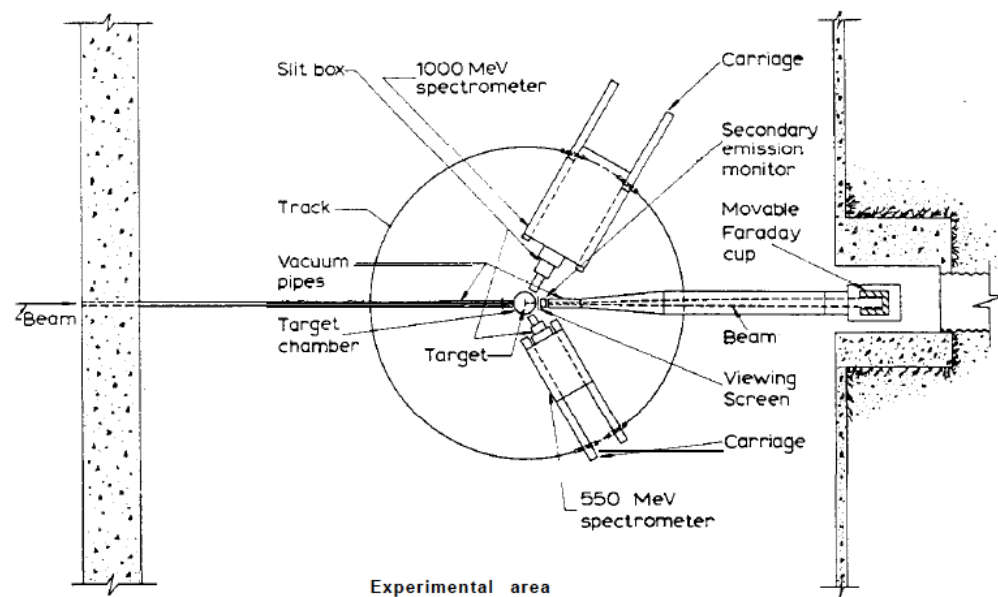
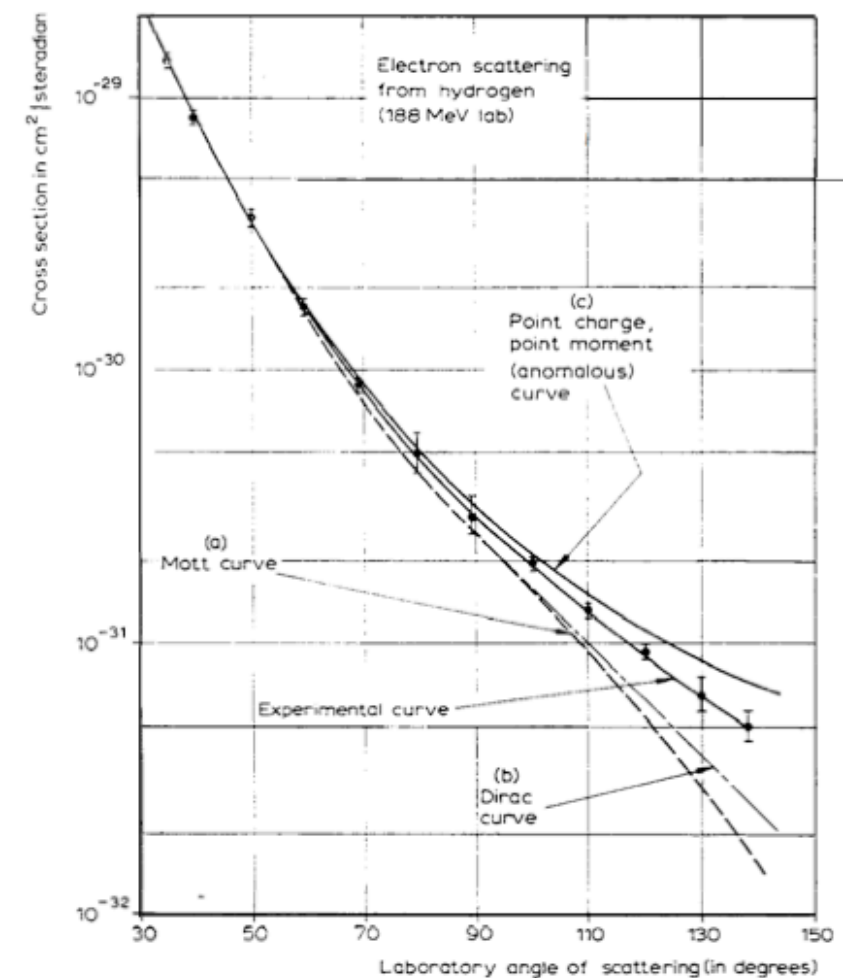


Fig. 2. This figure shows a schematic diagram of a modern electron-scattering experimental area. The track on which the spectrometers roll has an approximate radius of 13.5 feet.

ELECTRON-SCATTERING METHOD



Current experimental value
(measured with electrons):

$$R_p = 0.87 \text{ fm}$$

$$1 \text{ fm} = 10^{-13} \text{ cm}$$

First observation of proton structure

VOLUME 23, NUMBER 16

PHYSICAL REVIEW LETTERS

20 OCTOBER 1969

OBSERVED BEHAVIOR OF HIGHLY INELASTIC ELECTRON-PROTON SCATTERING

M. Breidenbach, J. I. Friedman, and H. W. Kendall

Department of Physics and Laboratory for Nuclear Science,*
Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

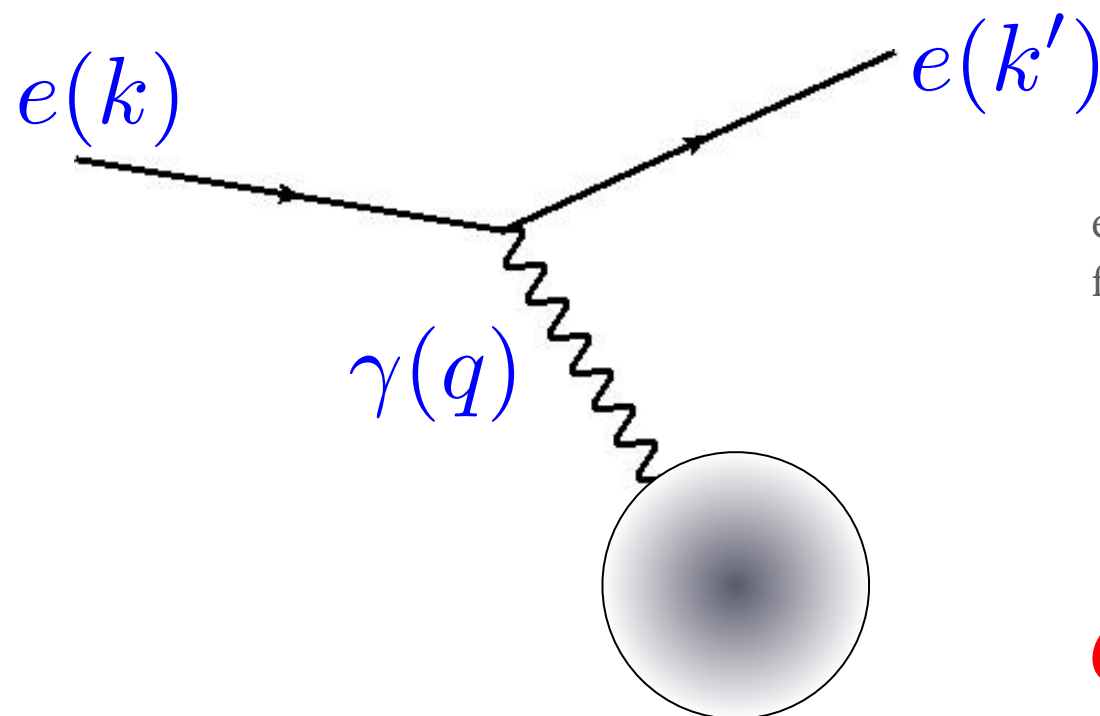
and

E. D. Bloom, D. H. Coward, H. DeStaebler, J. Drees, L. W. Mo, and R. E. Taylor

Stanford Linear Accelerator Center,† Stanford, California 94305

(Received 22 August 1969)

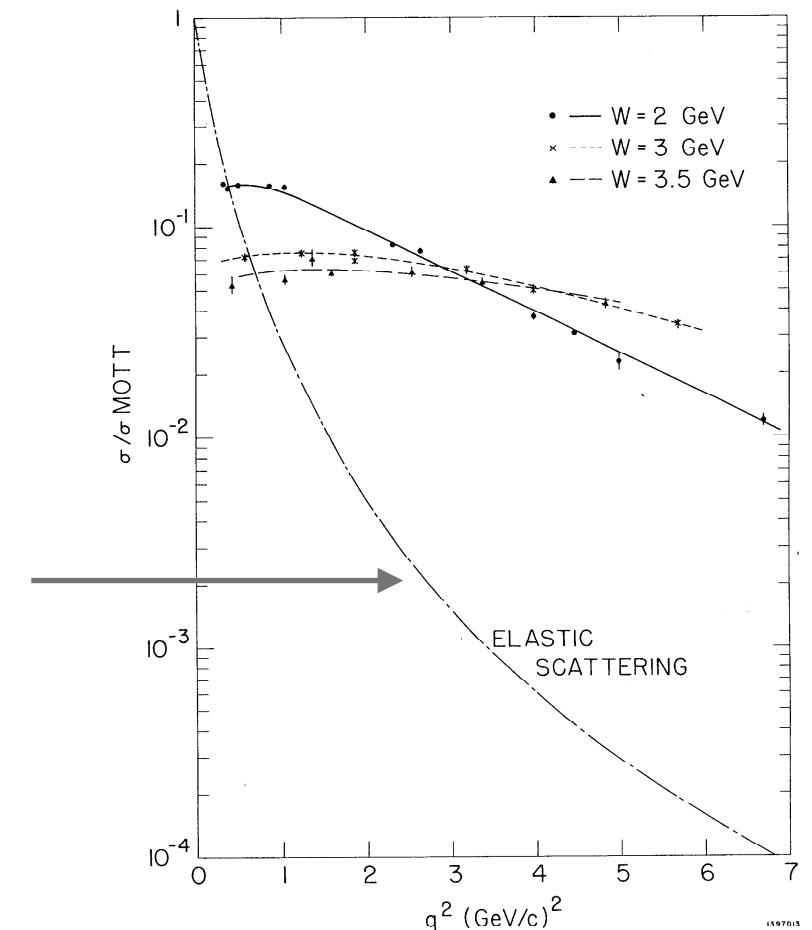
20 GeV electron beam scattering off protons



elastic scattering
form factor included

$$Q^2 = -q^2$$

resolving power of interaction



First observation of proton structure

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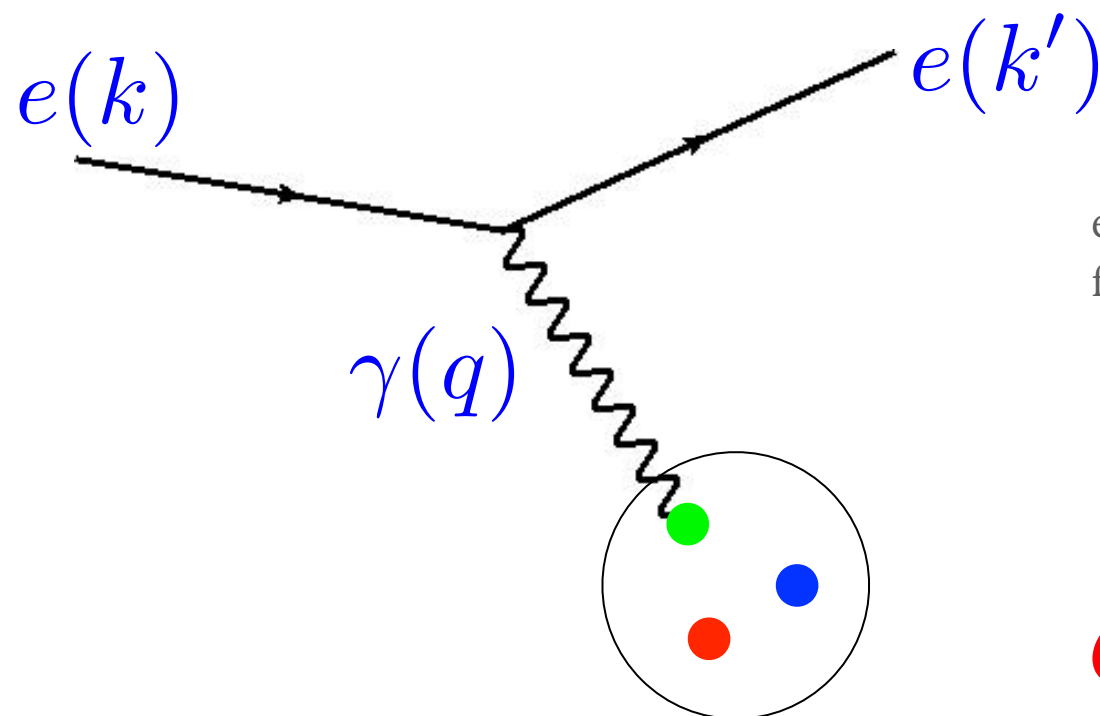
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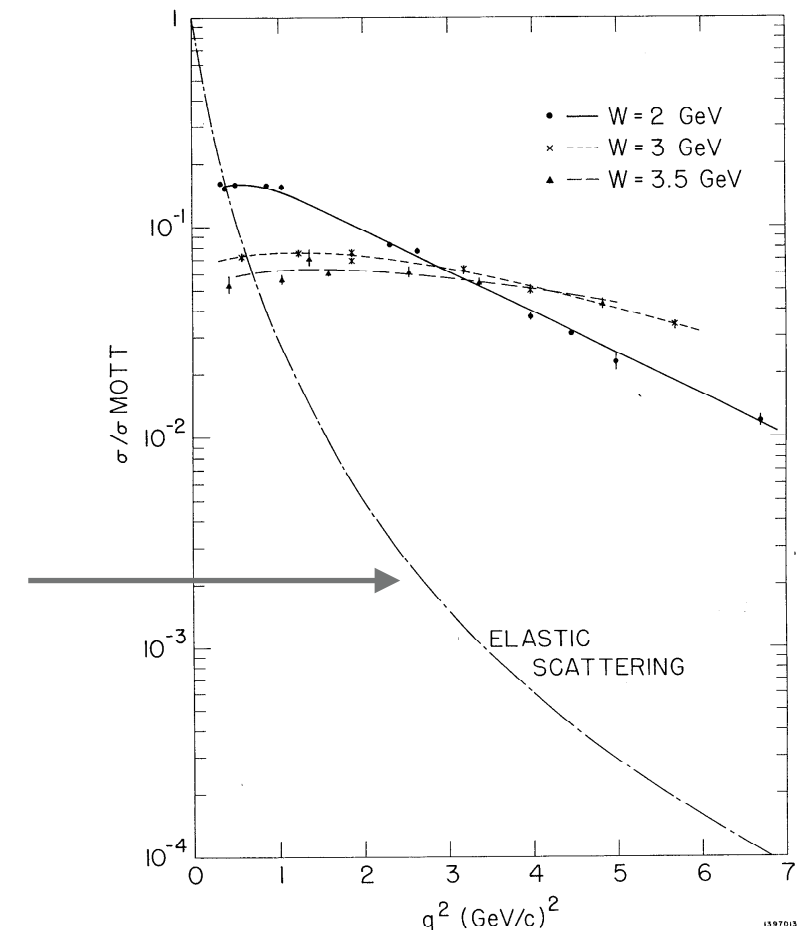
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20 GeV electron beam scattering off protons



$$Q^2 = -q^2$$

resolving power of interaction

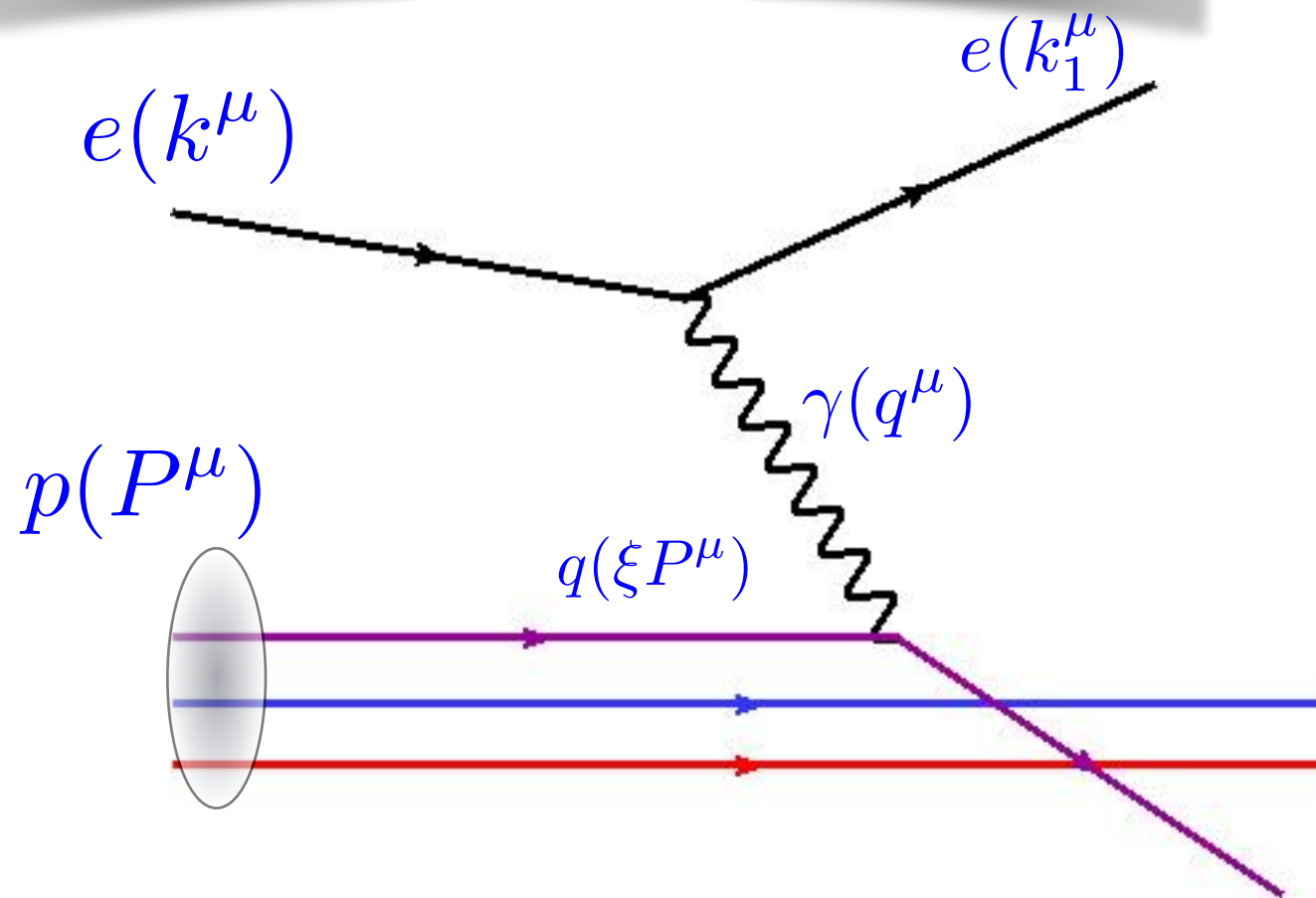


Deep Inelastic Scattering

Inelastic scattering off proton



Elastic scattering off parton
(quark)

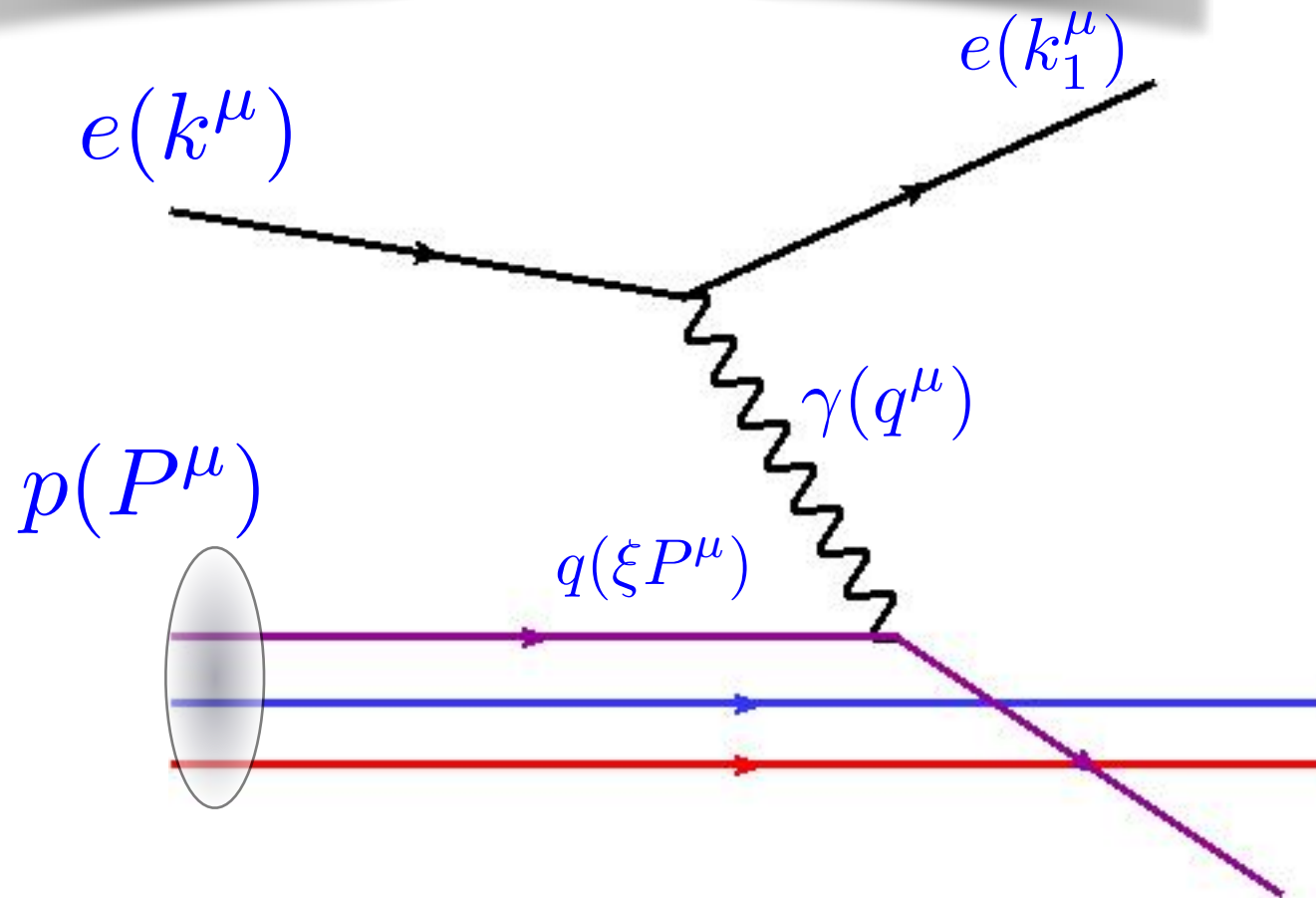


Deep Inelastic Scattering

Inelastic scattering off proton



Elastic scattering off parton
(quark)



Q^2

Photon virtuality :
resolving power

x

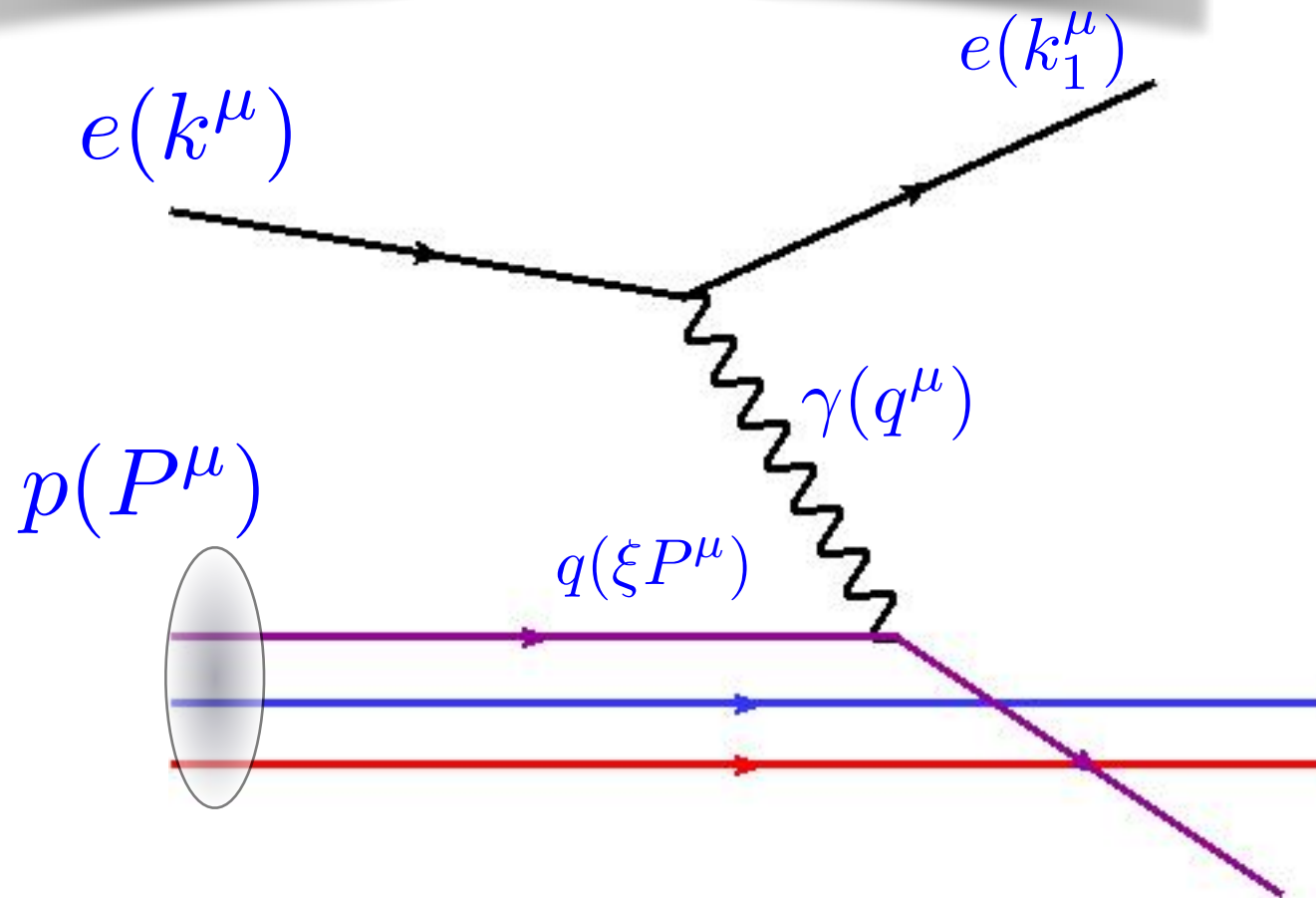
Bjorken x

Deep Inelastic Scattering

Inelastic scattering off proton



Elastic scattering off parton
(quark)



Q^2

Photon virtuality :
resolving power

x

Bjorken x

x has the interpretation of the longitudinal momentum fraction of the proton carried by the struck quark (in the frame where proton is fast)

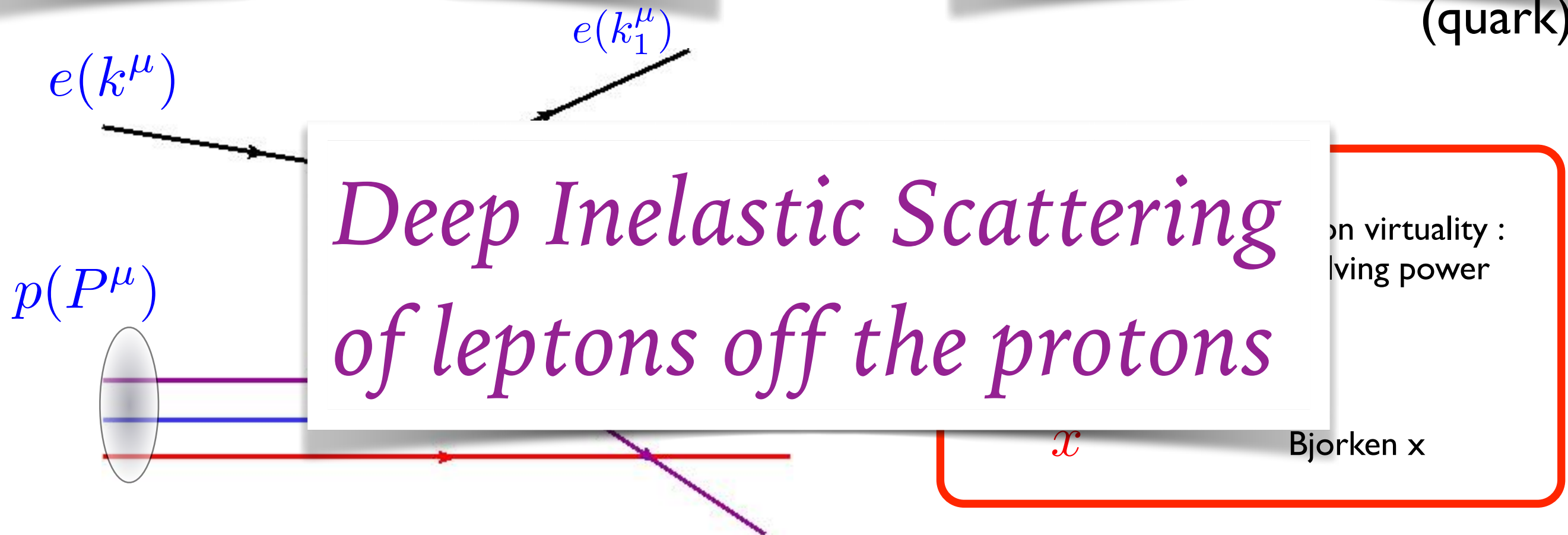
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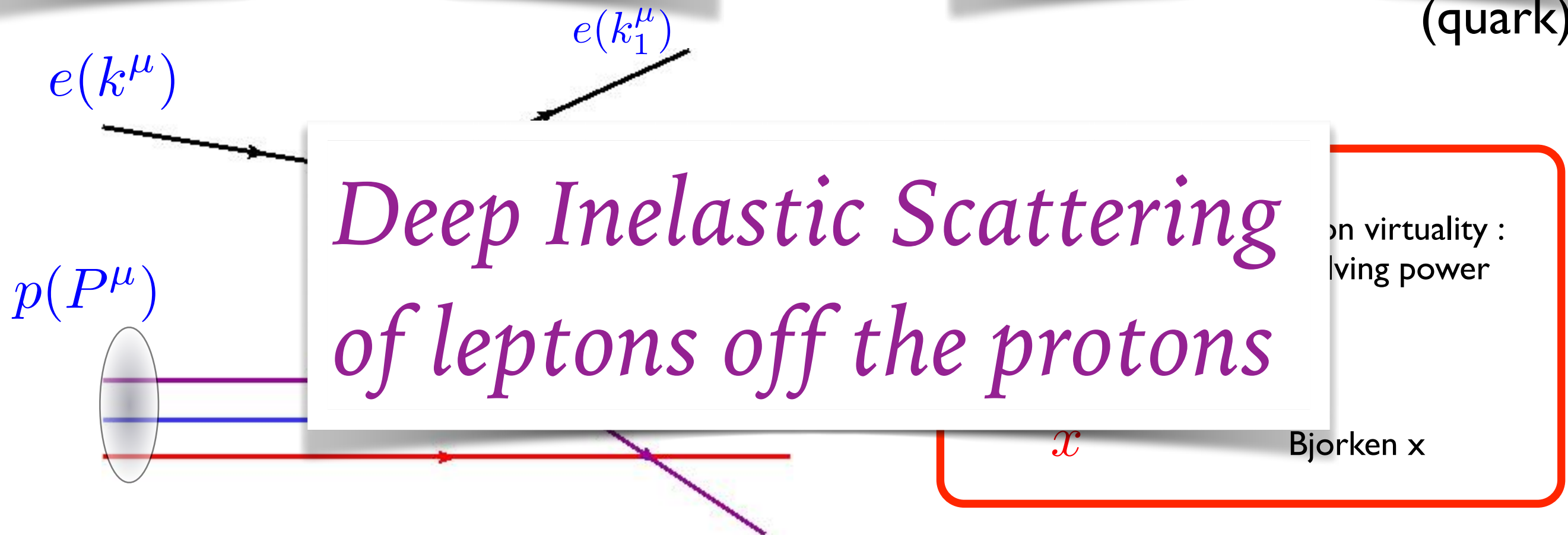
Deep Inelastic Scattering

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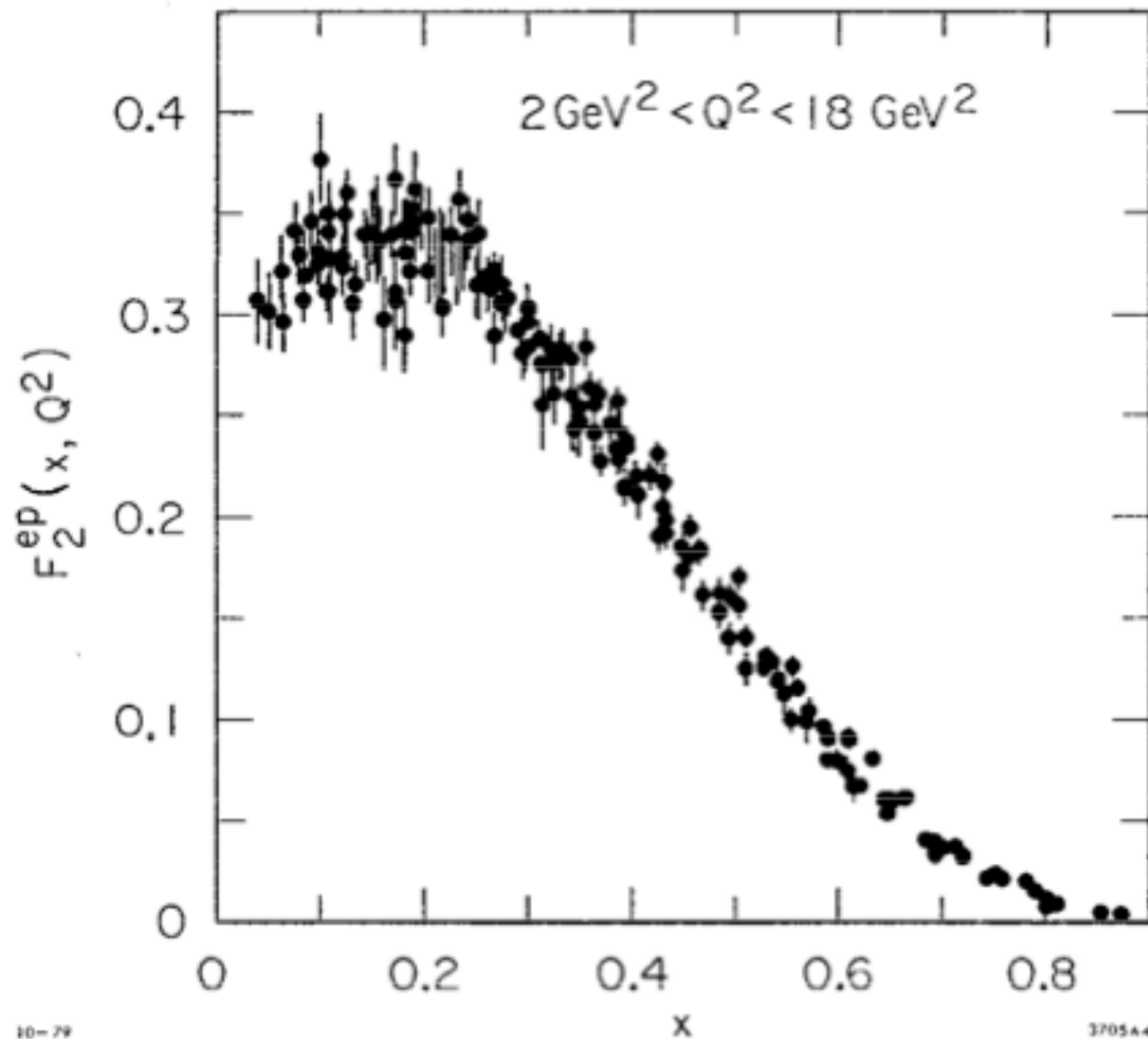
(quark)



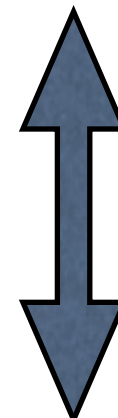
x has the interpretation of the longitudinal momentum fraction of the proton carried by the struck quark (in the frame where proton is fast)

High energy $\longleftrightarrow$ low x

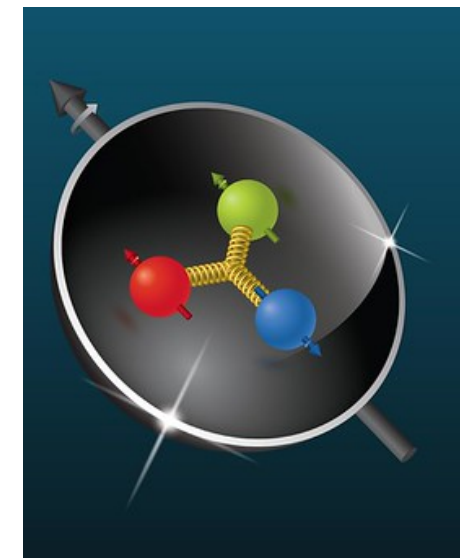
Revealing proton structure



Measured cross section



Momentum distribution of
partons inside the proton



Exploring proton structure at high energy

DESY - Hamburg
HERA Collider
1992-2007

The only electron(positron)-proton
collider ever built



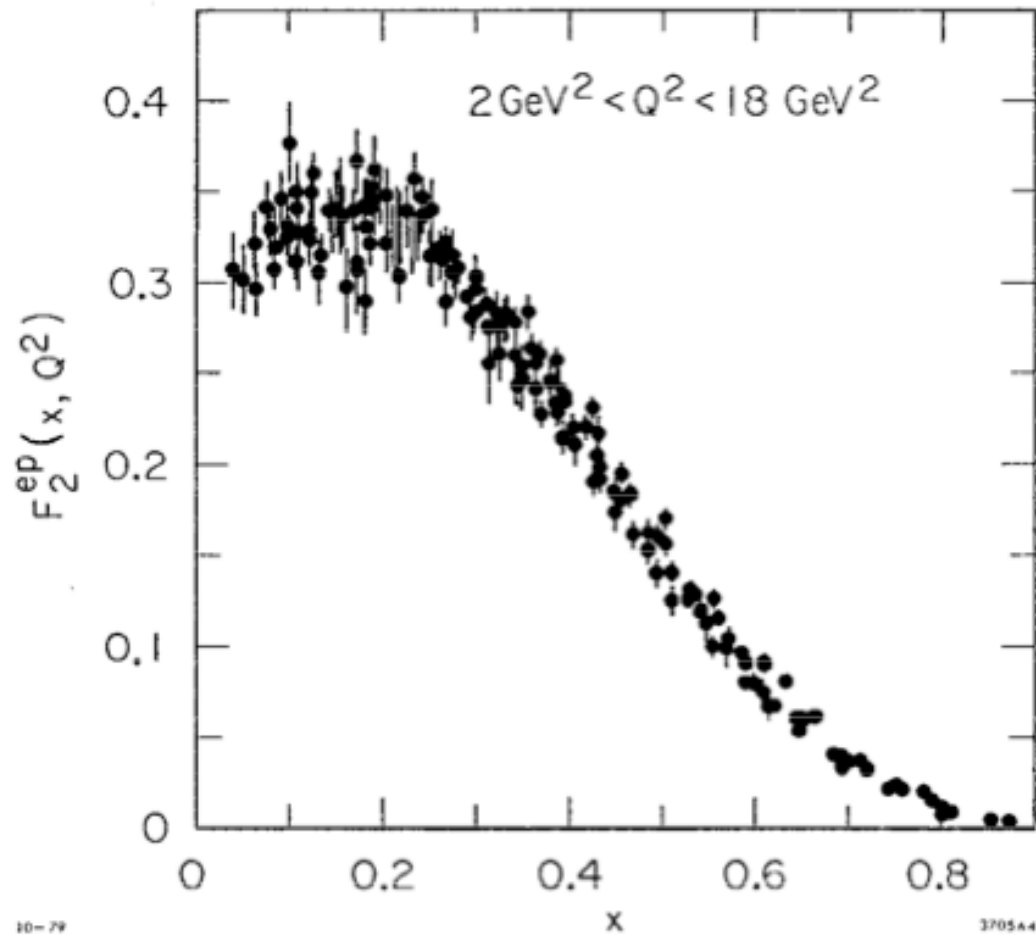
Center of mass energy:

$$E_{\text{cm}} = 320 \text{ GeV}$$

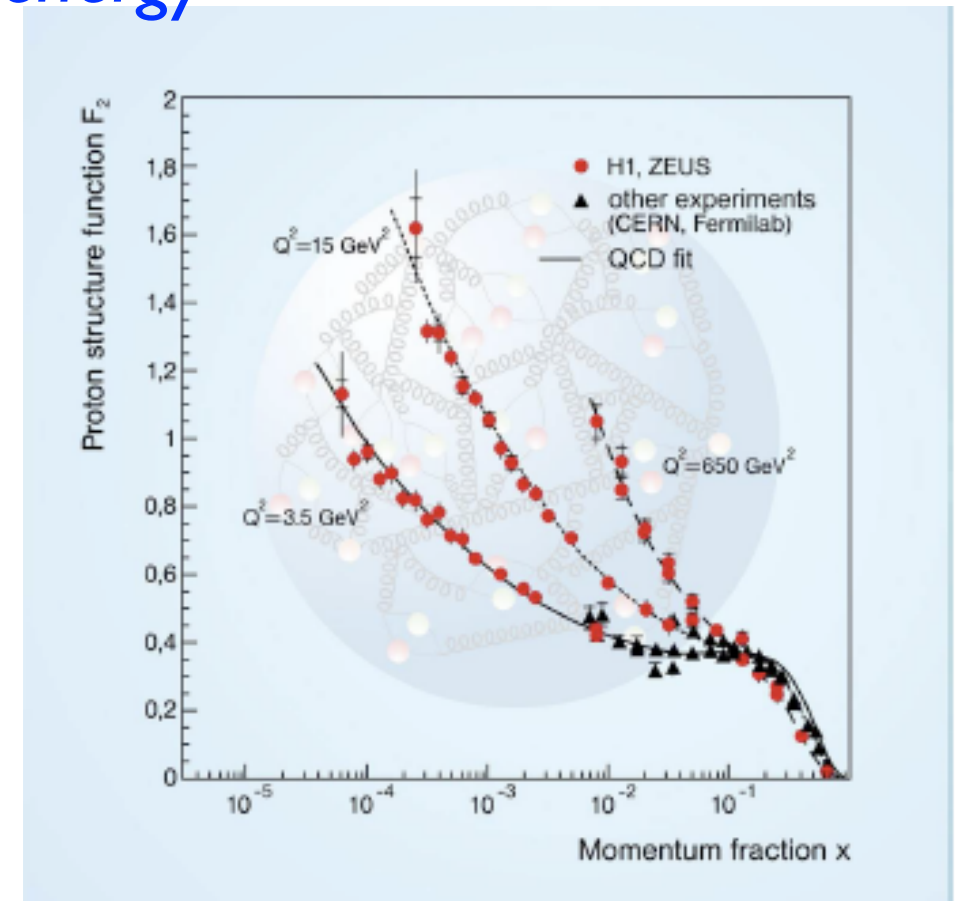
equivalent to 50 TeV electron beam on a fixed proton
target...about 2500 times more than at SLAC

Measurements of proton structure function

low energy

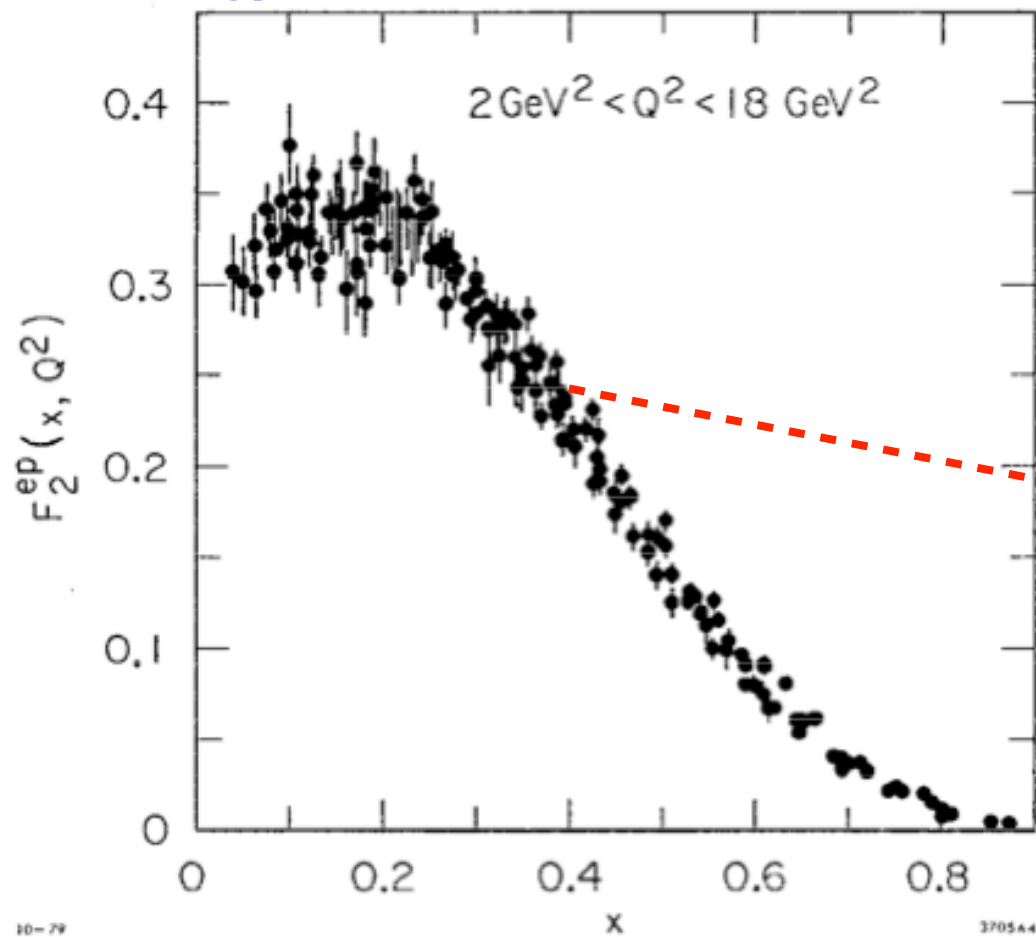


high energy

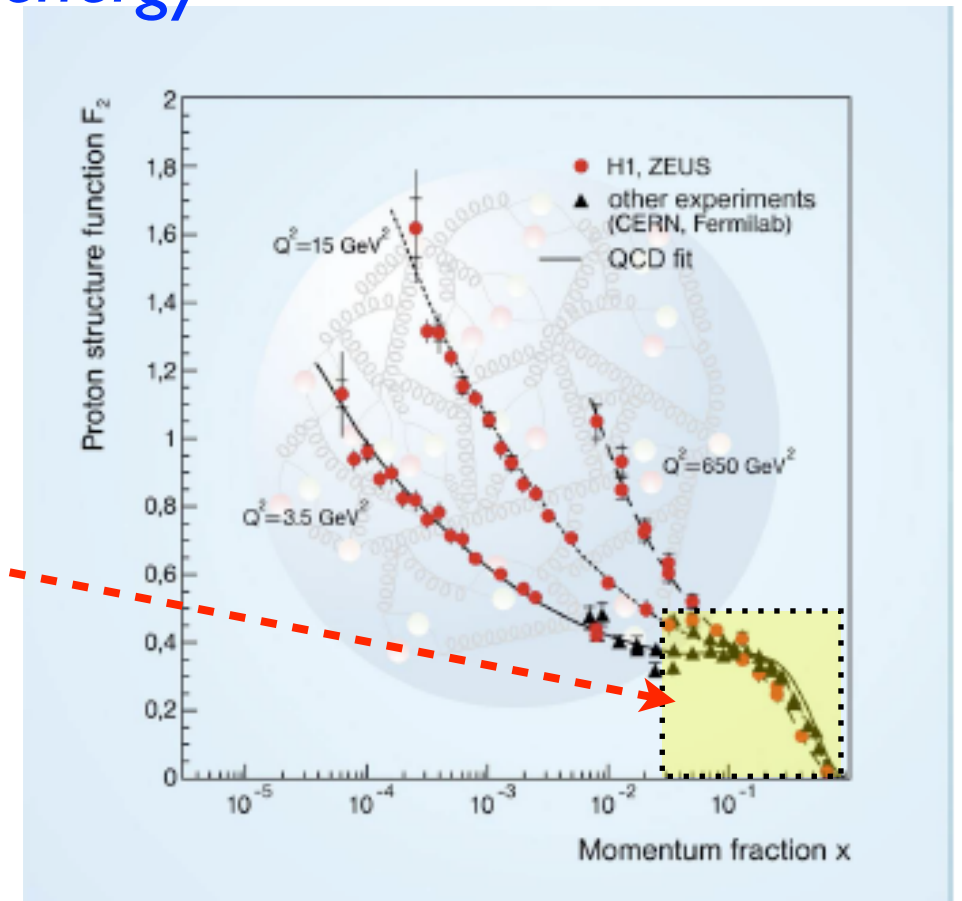


Measurements of proton structure function

low energy

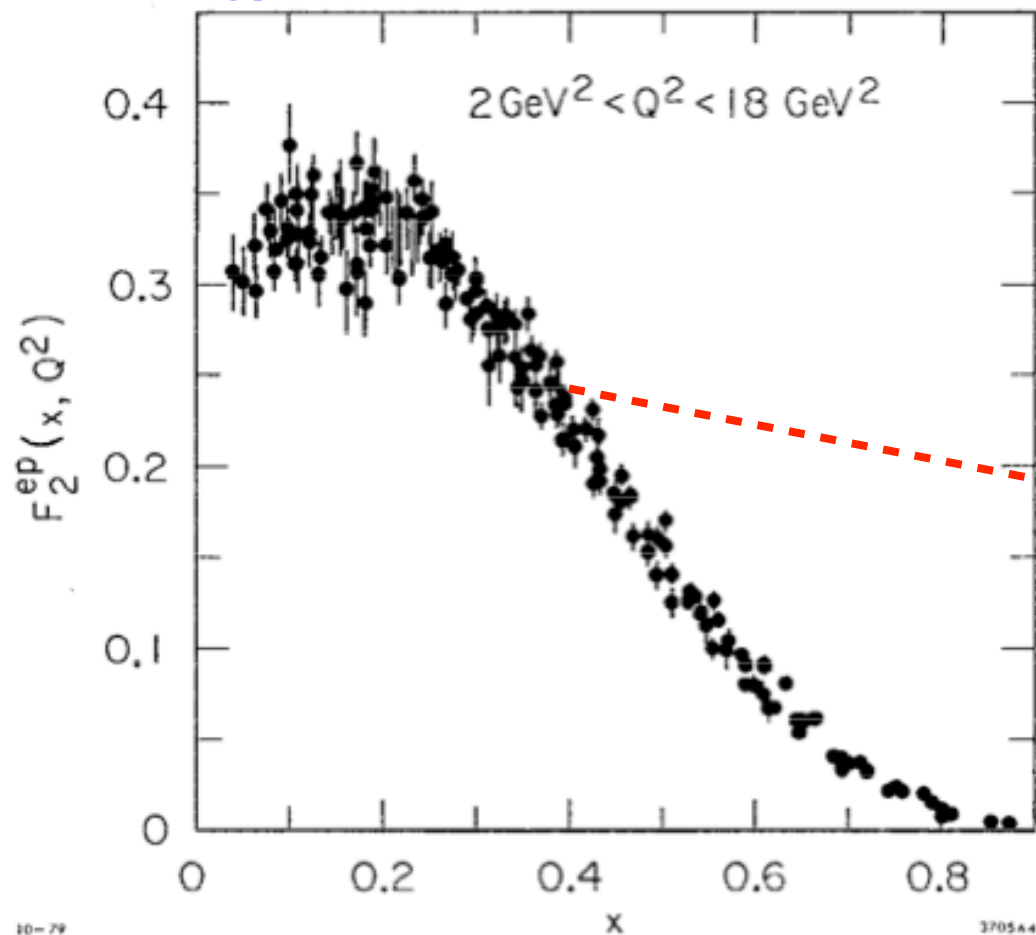


high energy

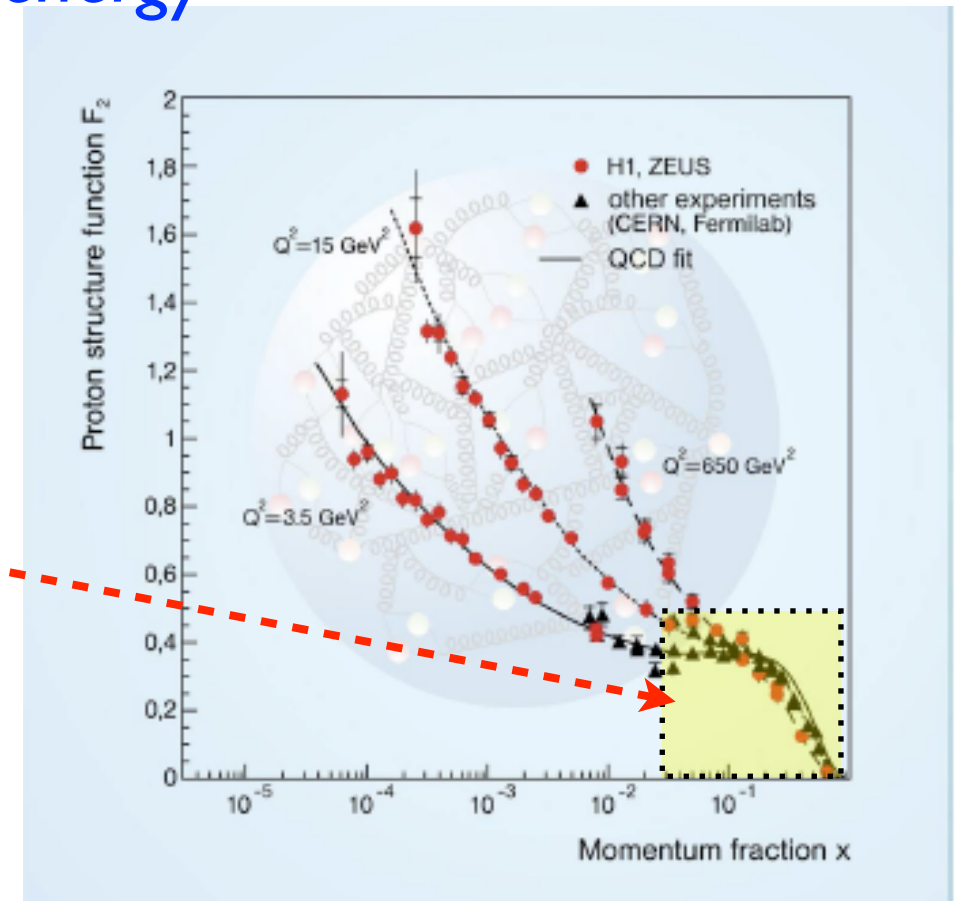


Measurements of proton structure function

low energy



high energy

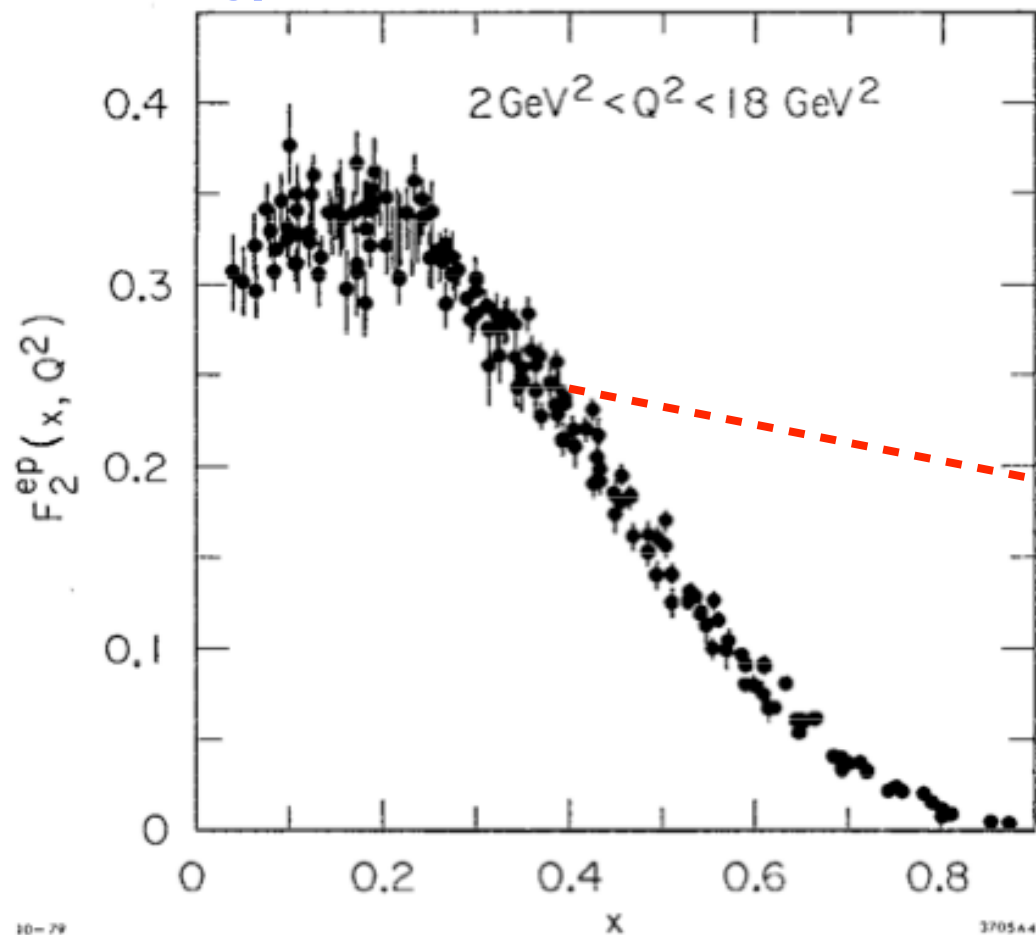


Cross section increases:

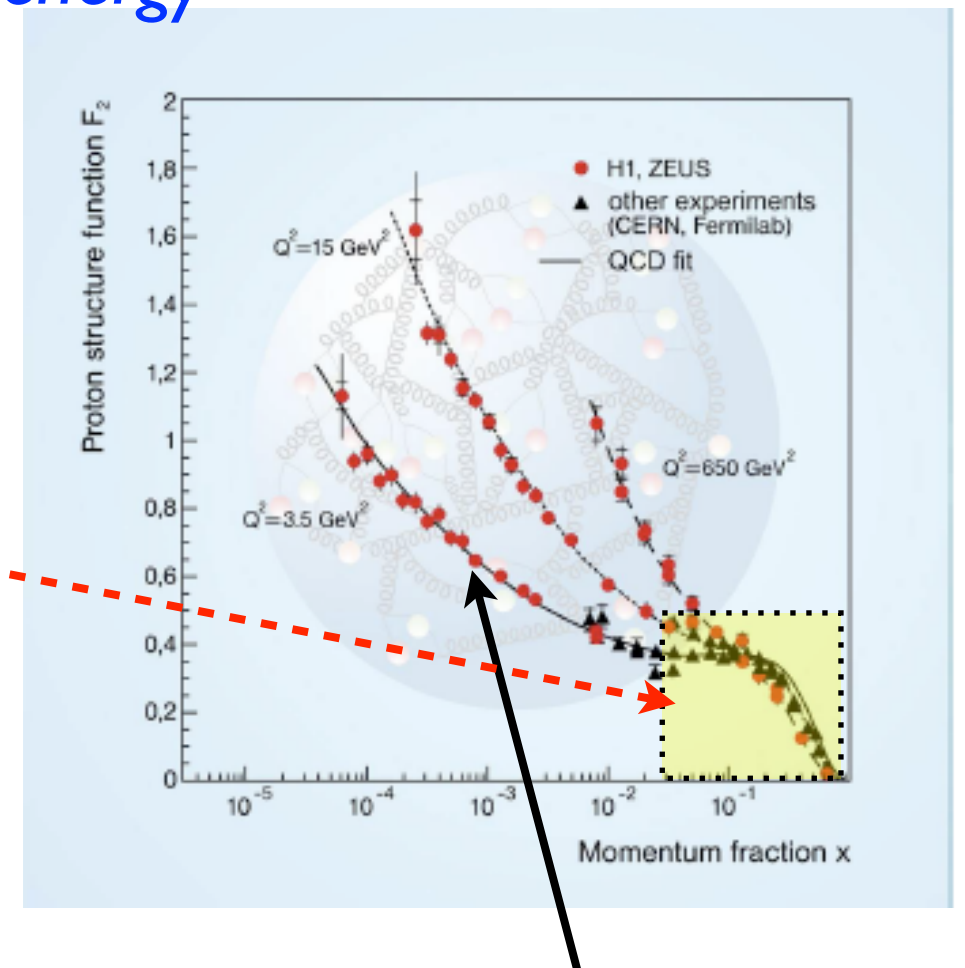
- with decreasing x
- with increasing scale Q

Measurements of proton structure function

low energy



high energy



Where does this rise come from?

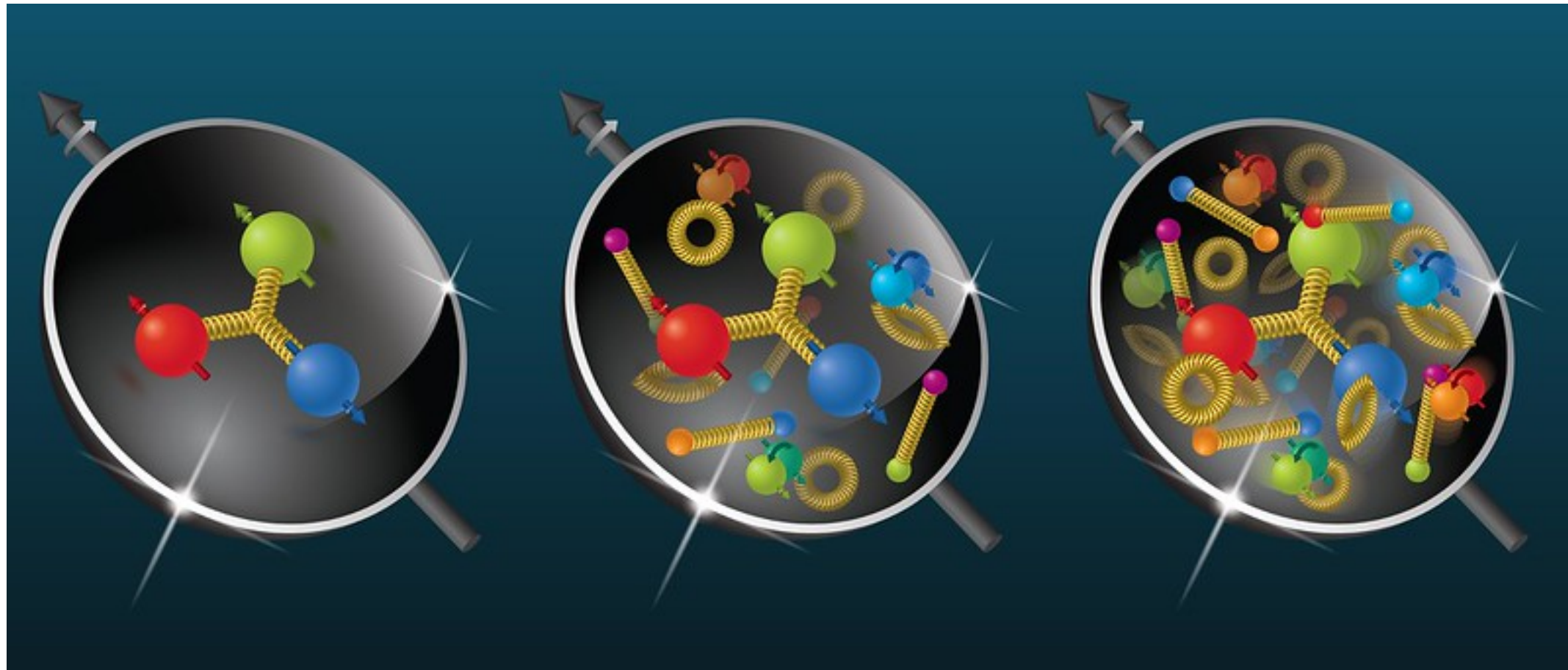
Cross section increases:

- with decreasing x
- with increasing scale Q

Answer:

Quantum Chromodynamics
(QCD) radiation

Proton probed at increasing energy



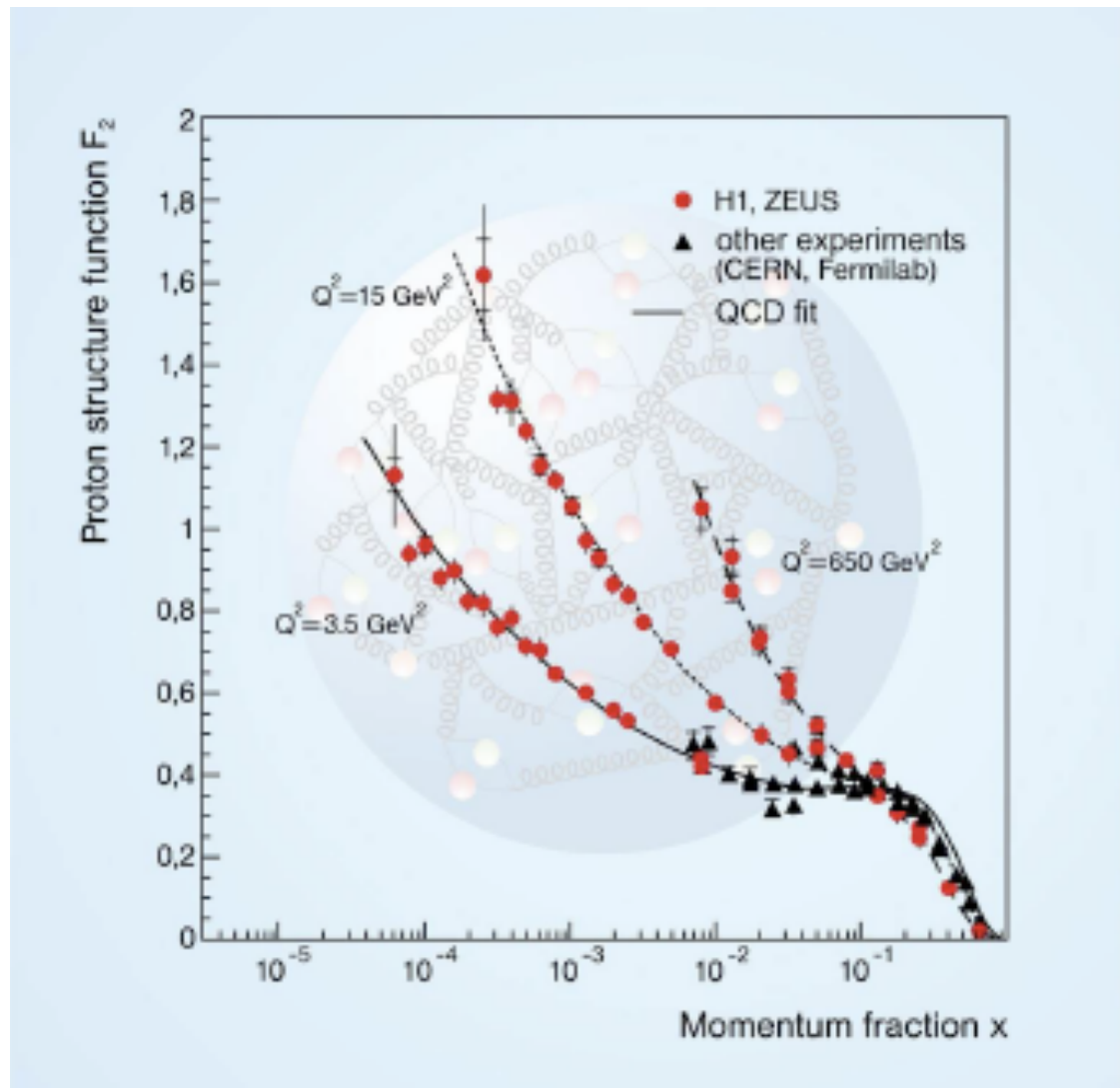
Energy (or $1/x$)

As energy is increased more quarks are resolved due to the parton splitting

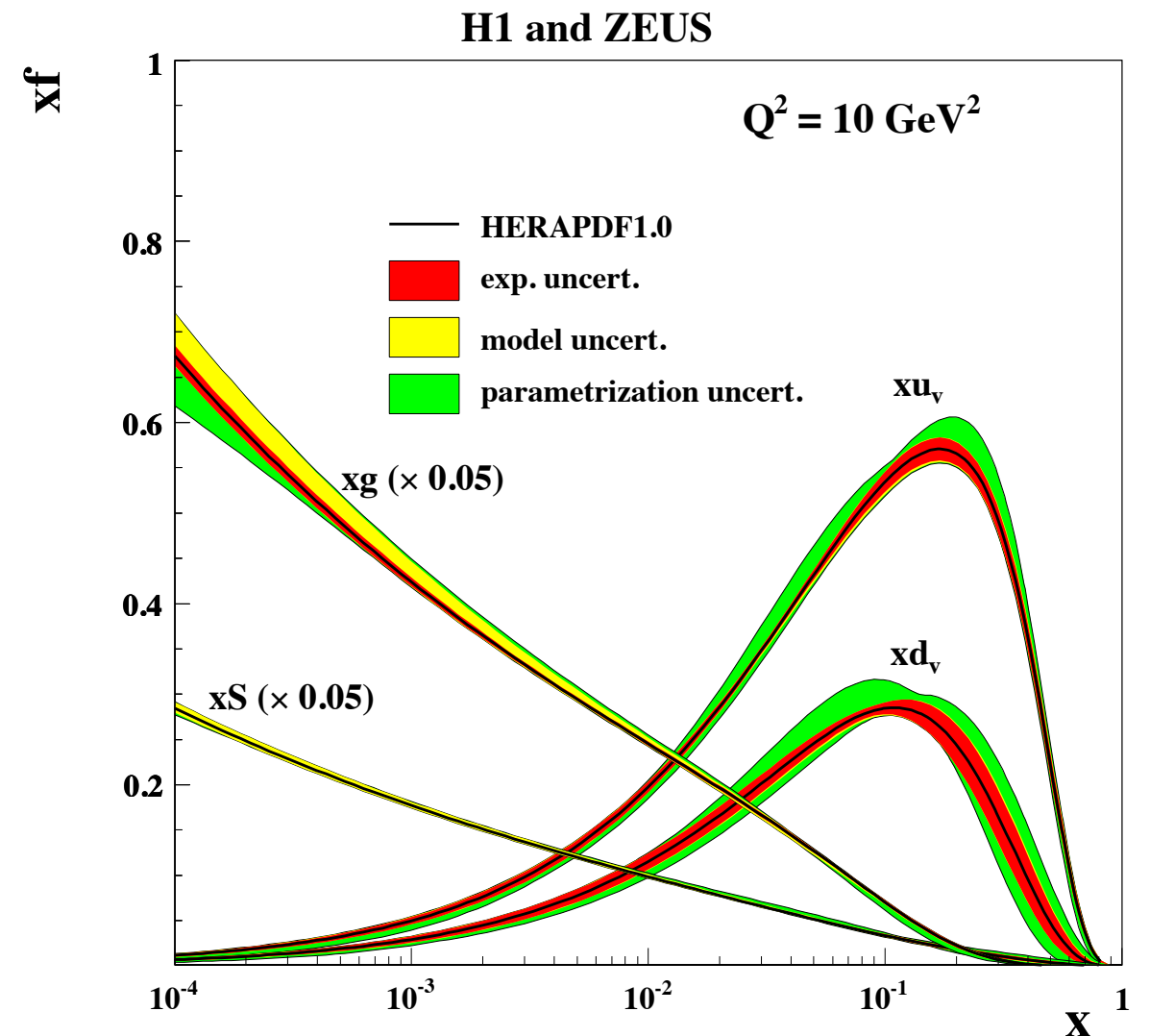
Proton: very complex system of **quarks** and **gluons** (carriers of strong force)

At higher energies gluon density dominates

Cross section vs parton density



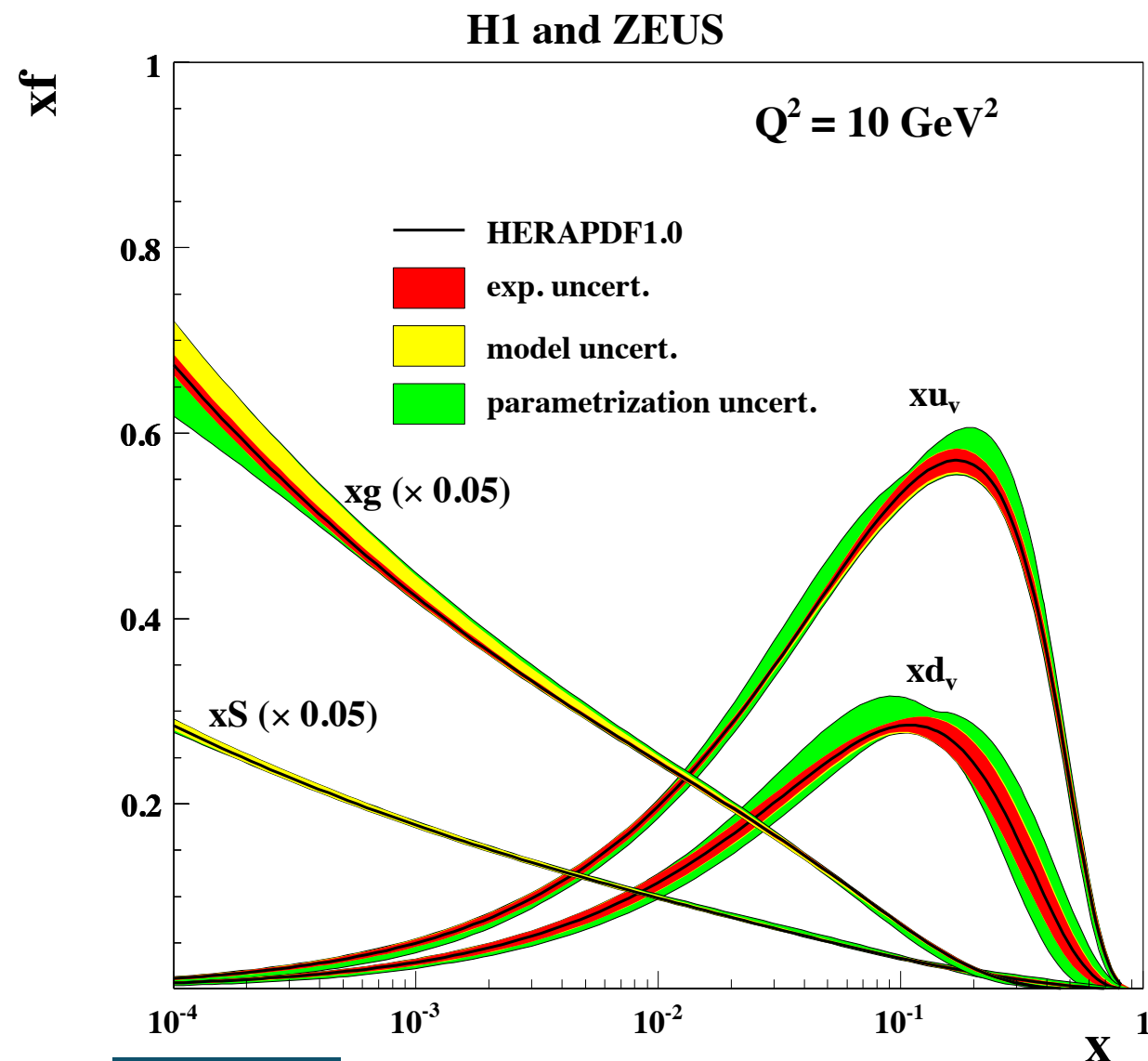
cross section



parton density

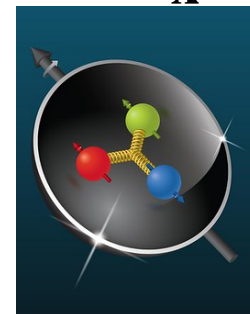
Data demonstrate the growth of the **gluon** and **sea quark** distributions with decreasing x

Parton densities

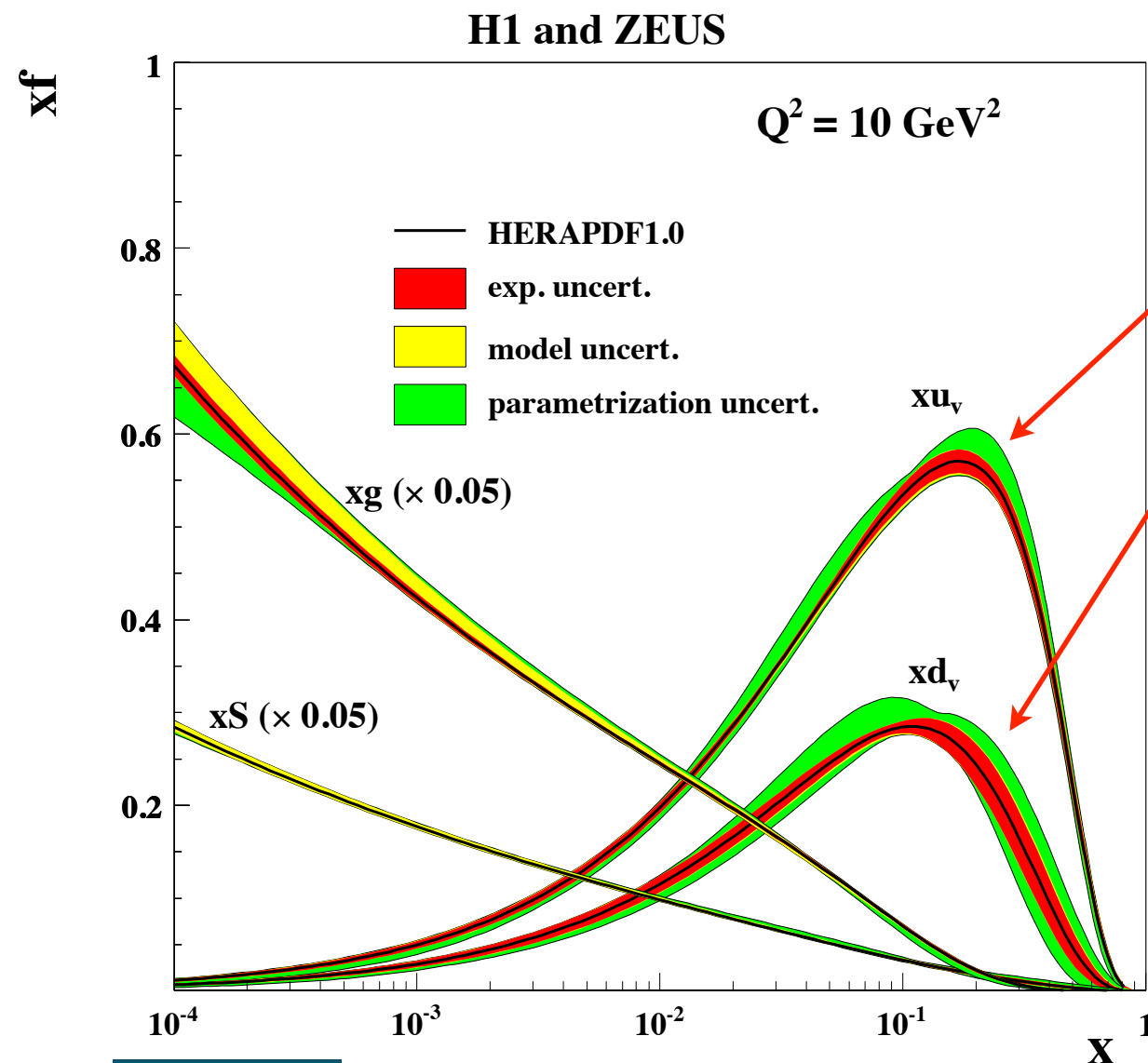


Gluon density increases rapidly with x and with Q

Gluons dominate over the quark density



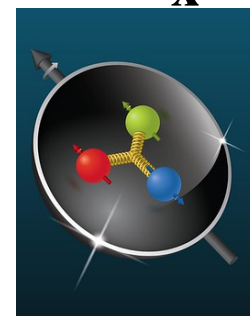
Parton densities



valence quarks

Gluon density increases rapidly with x and with Q

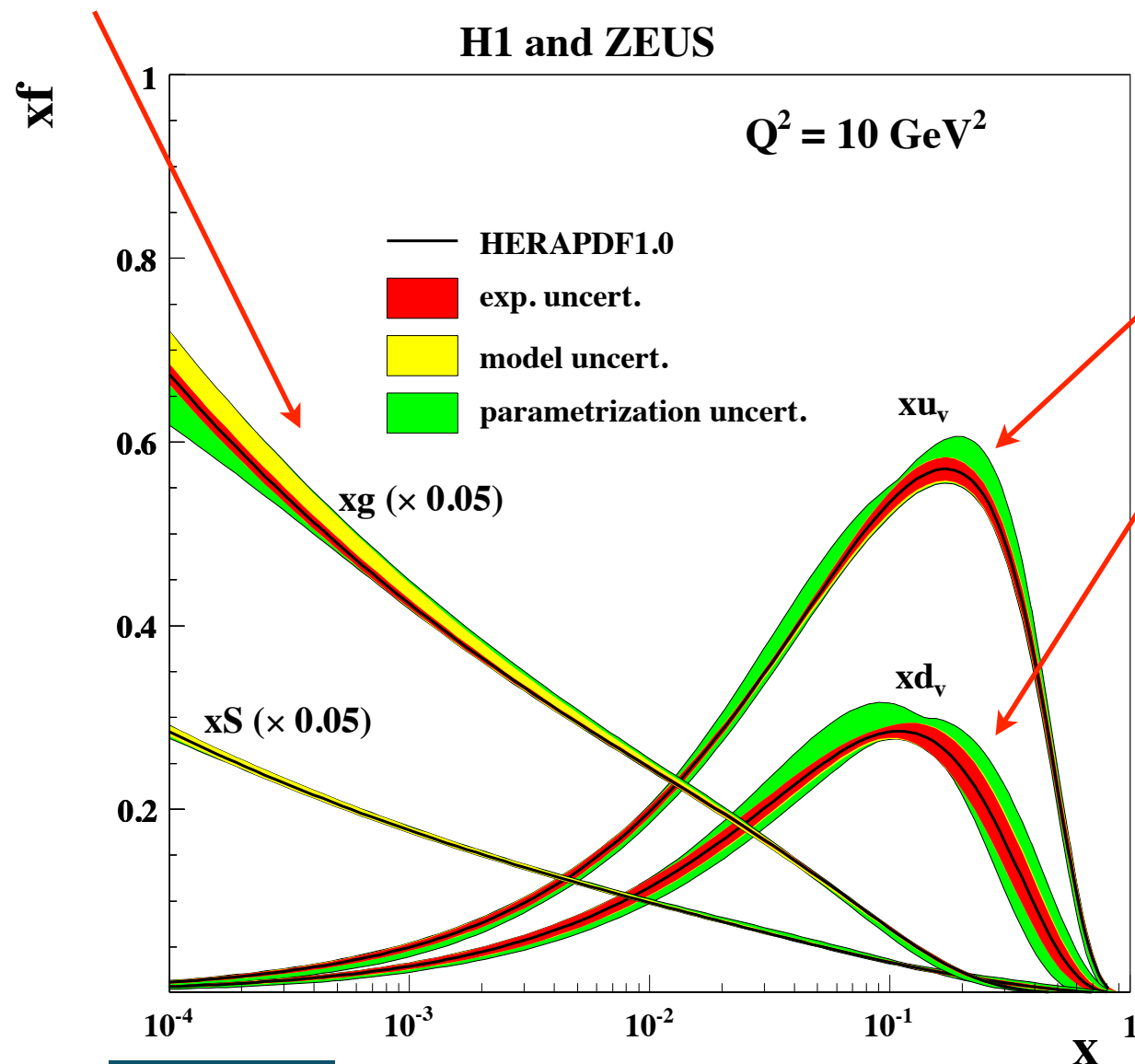
Gluons dominate over the quark density



Parton densities

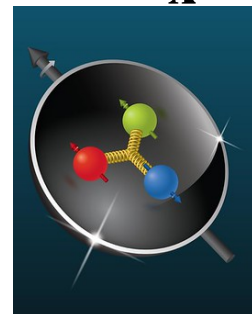
gluons

valence quarks



Gluon density increases rapidly with x and with Q

Gluons dominate over the quark density

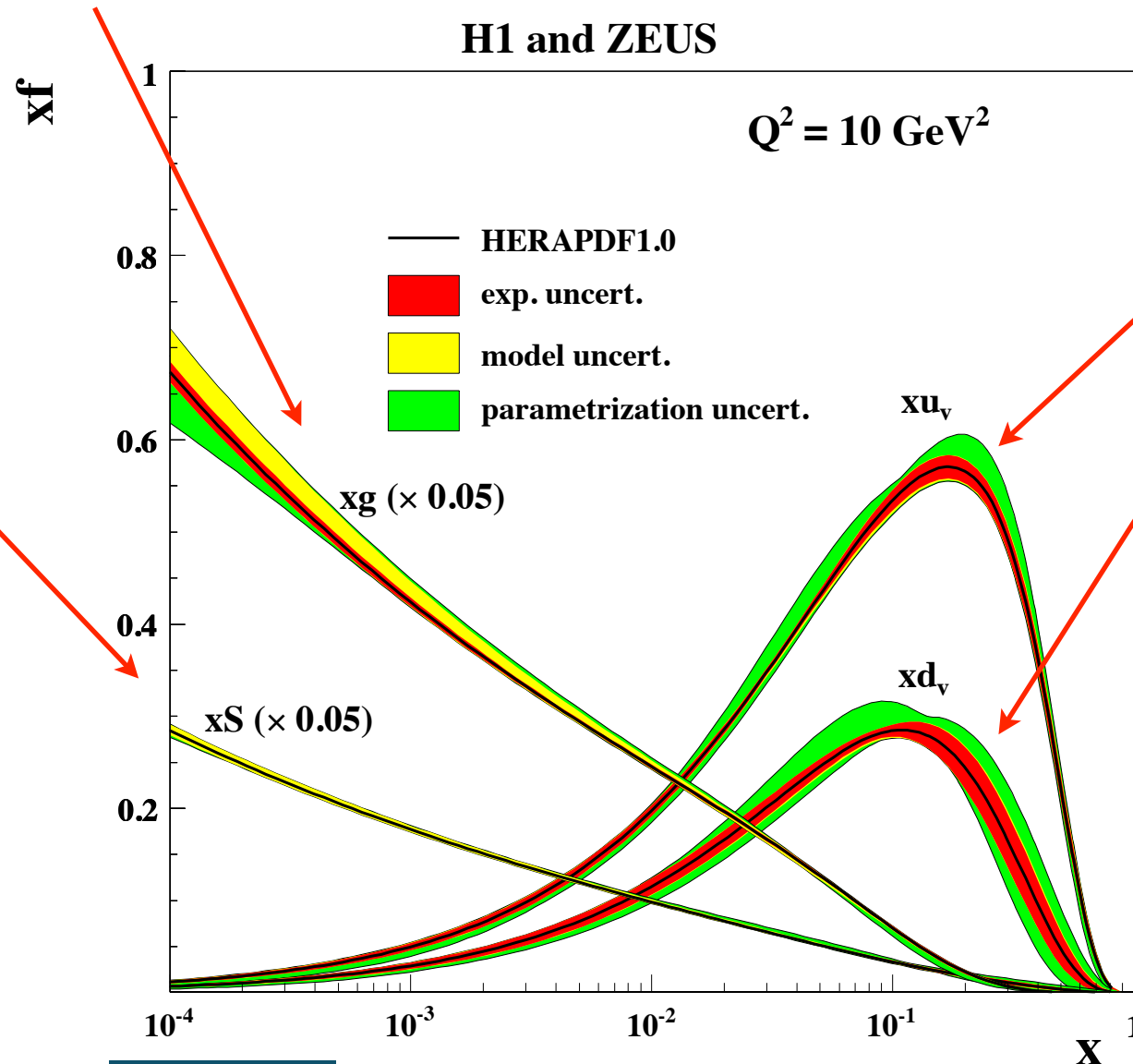


Parton densities

gluons

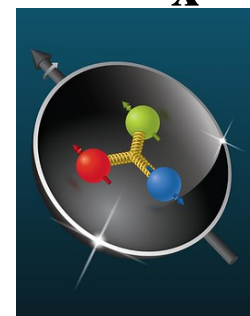
valence quarks

sea quarks



Gluon density increases rapidly with x and with Q

Gluons dominate over the quark density

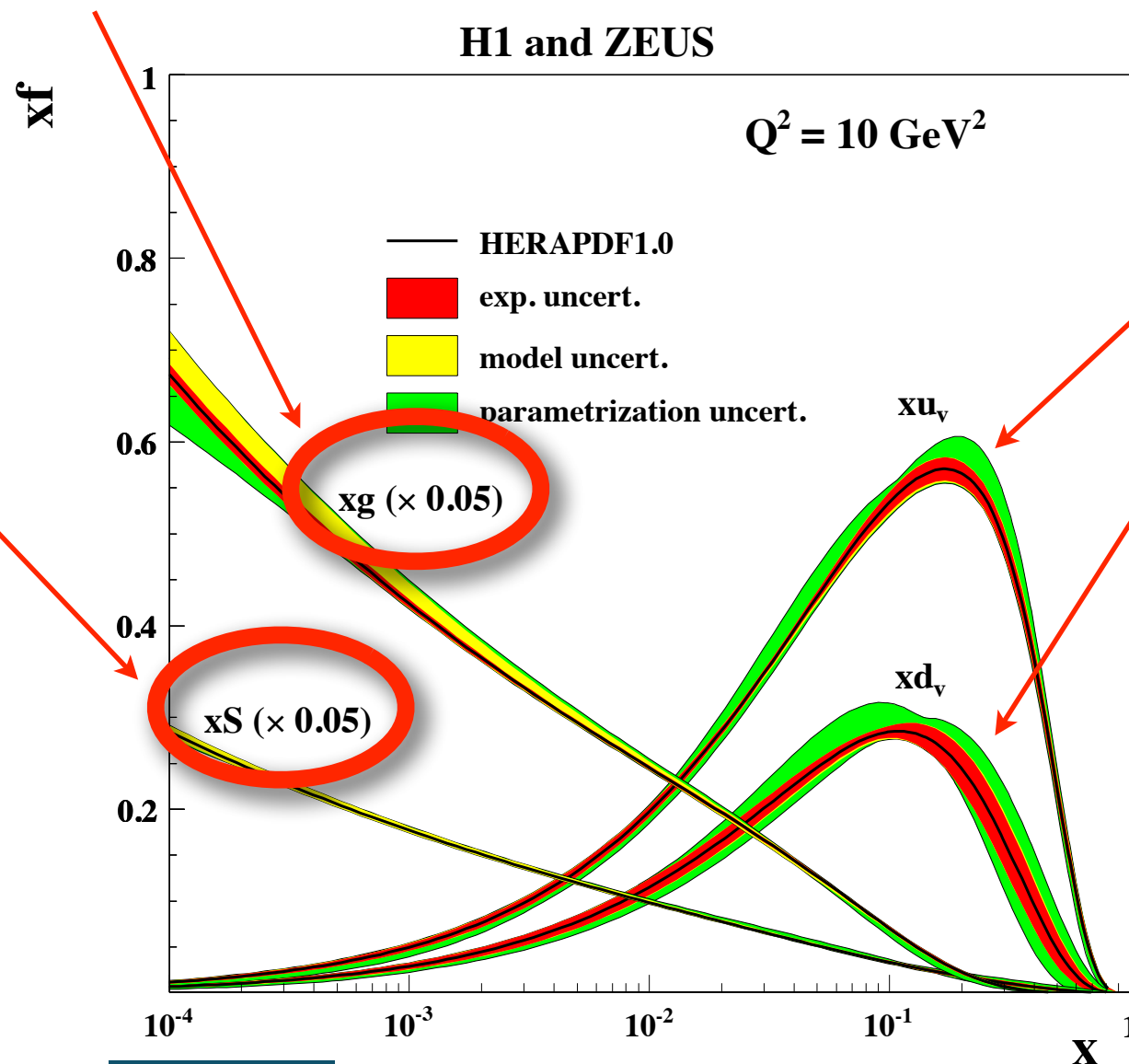


Parton densities

gluons

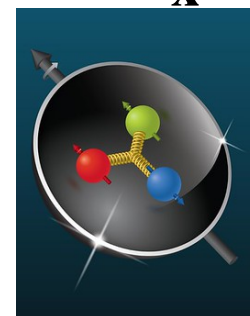
valence quarks

sea quarks

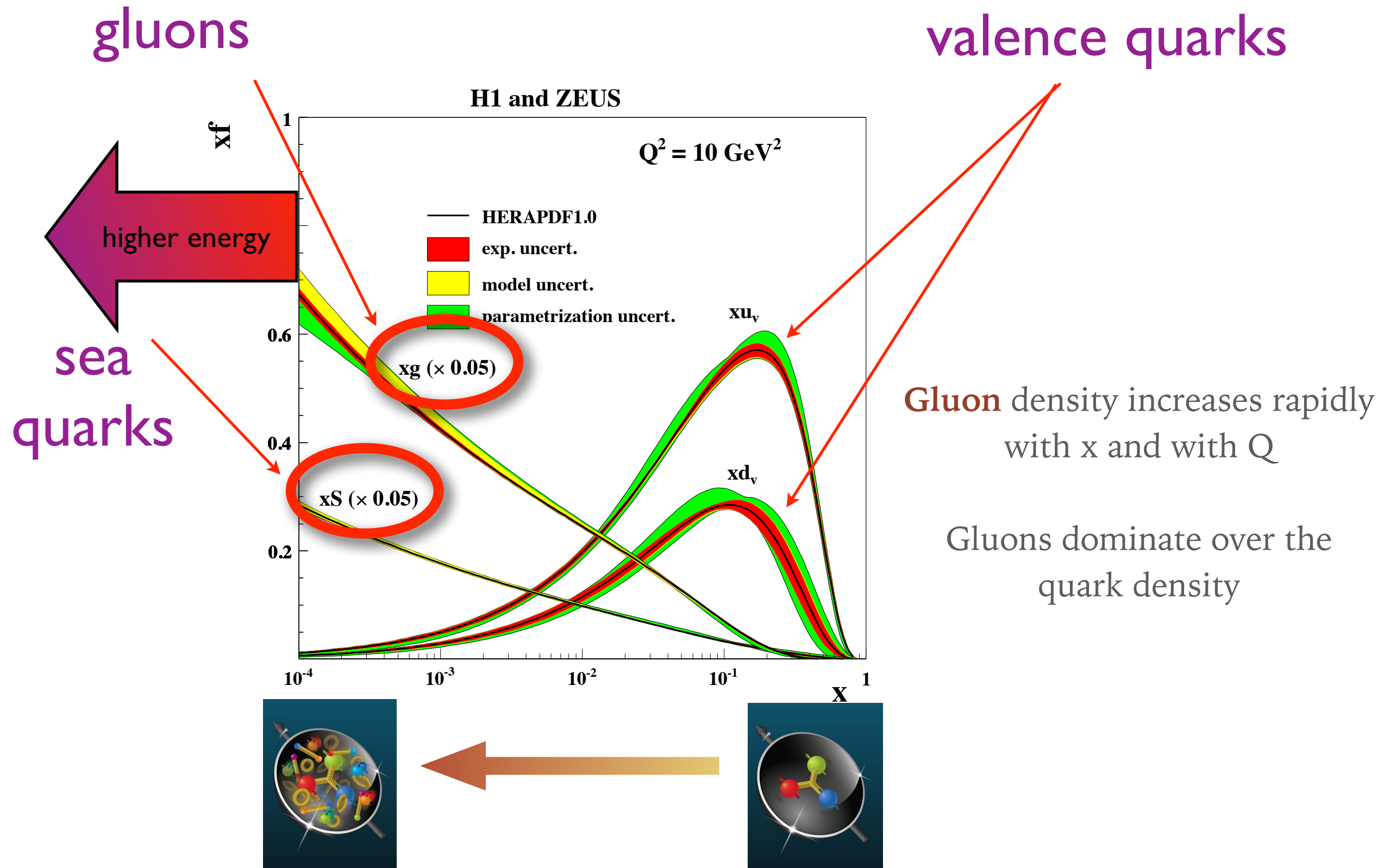


Gluon density increases rapidly with x and with Q

Gluons dominate over the quark density

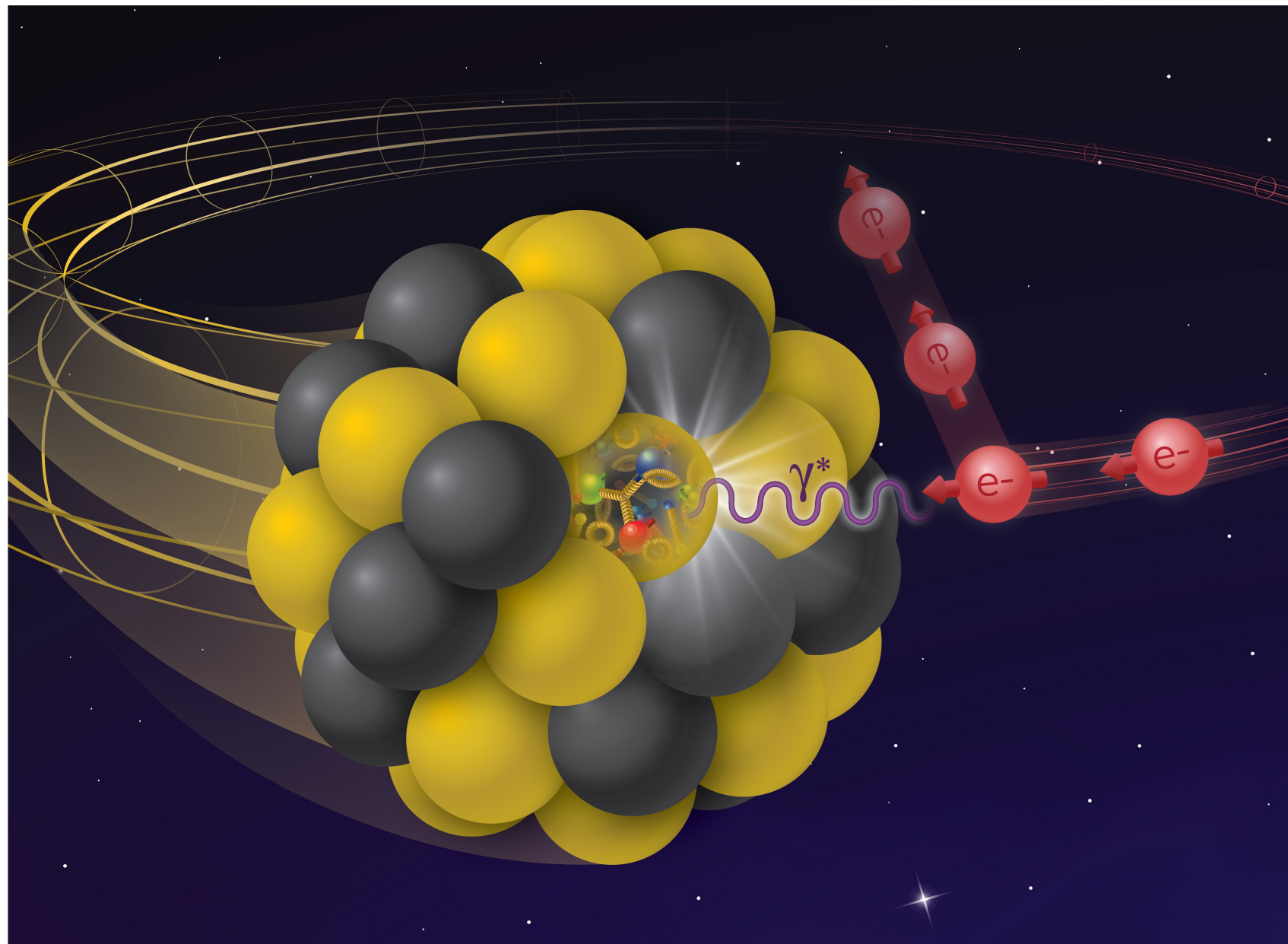


Parton densities

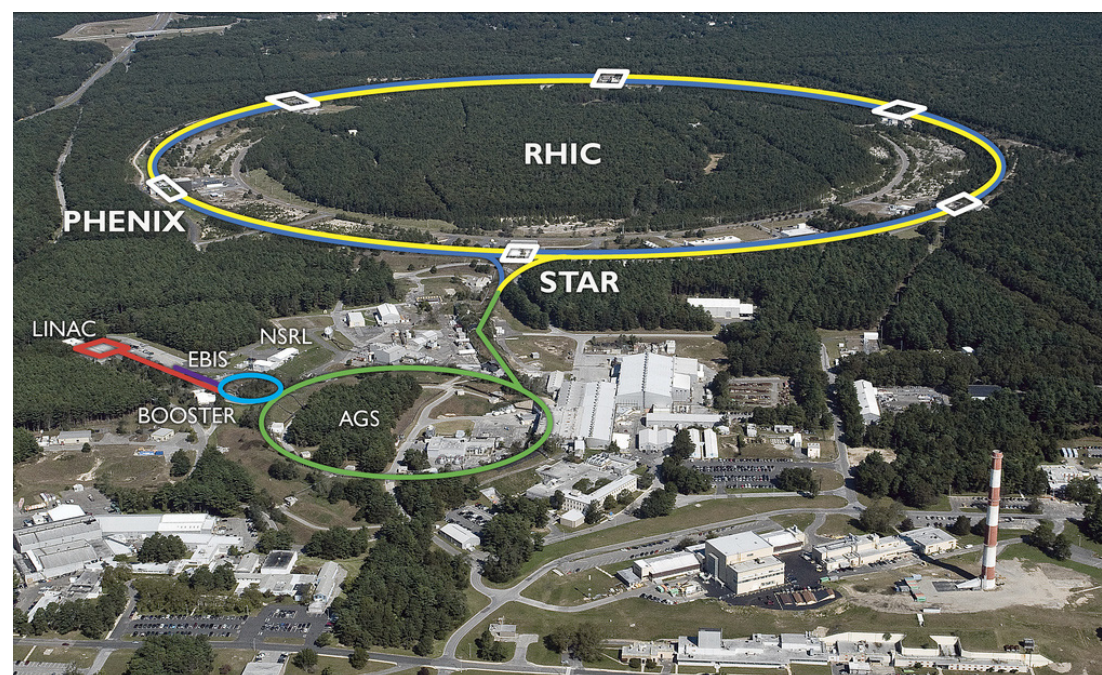
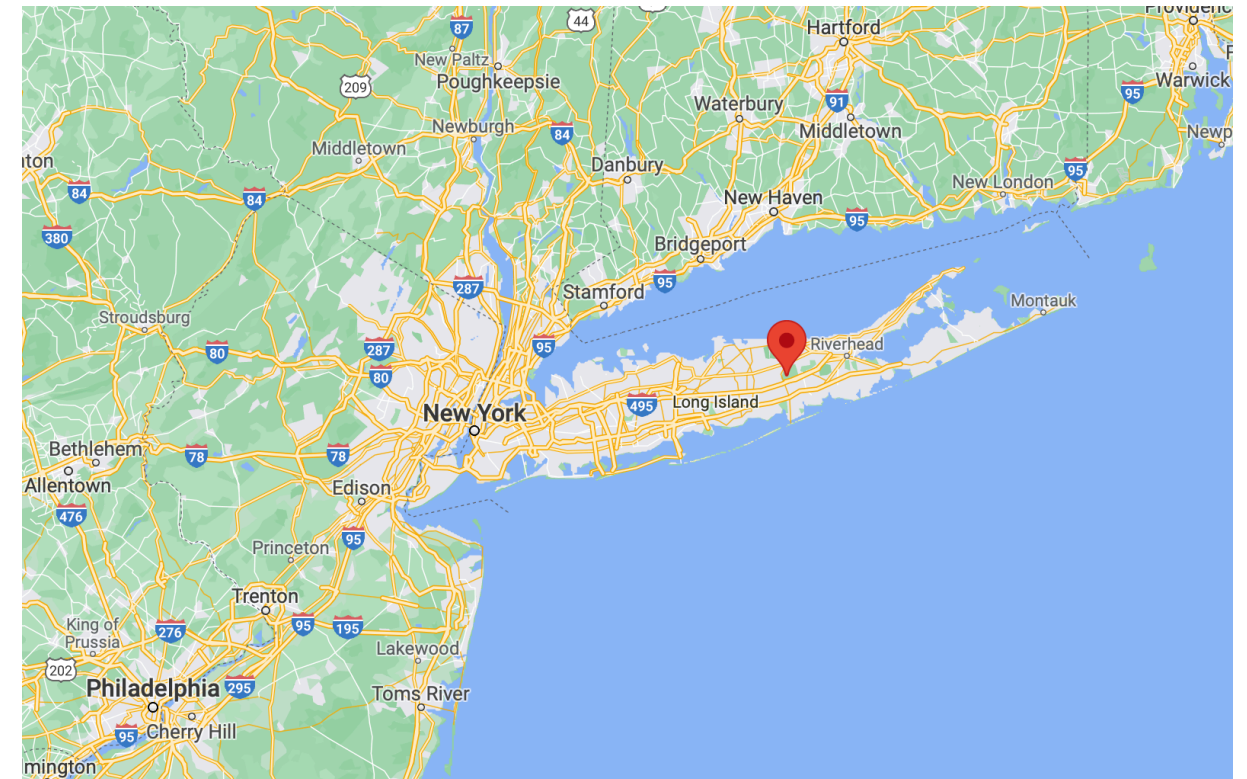


Electron–nucleus collisions as probe of nuclear structure

Electron-proton/nucleus experiments best way to explore **proton** and **nuclear structure** and many aspects of strong interactions



Electron Ion Collider (EIC)

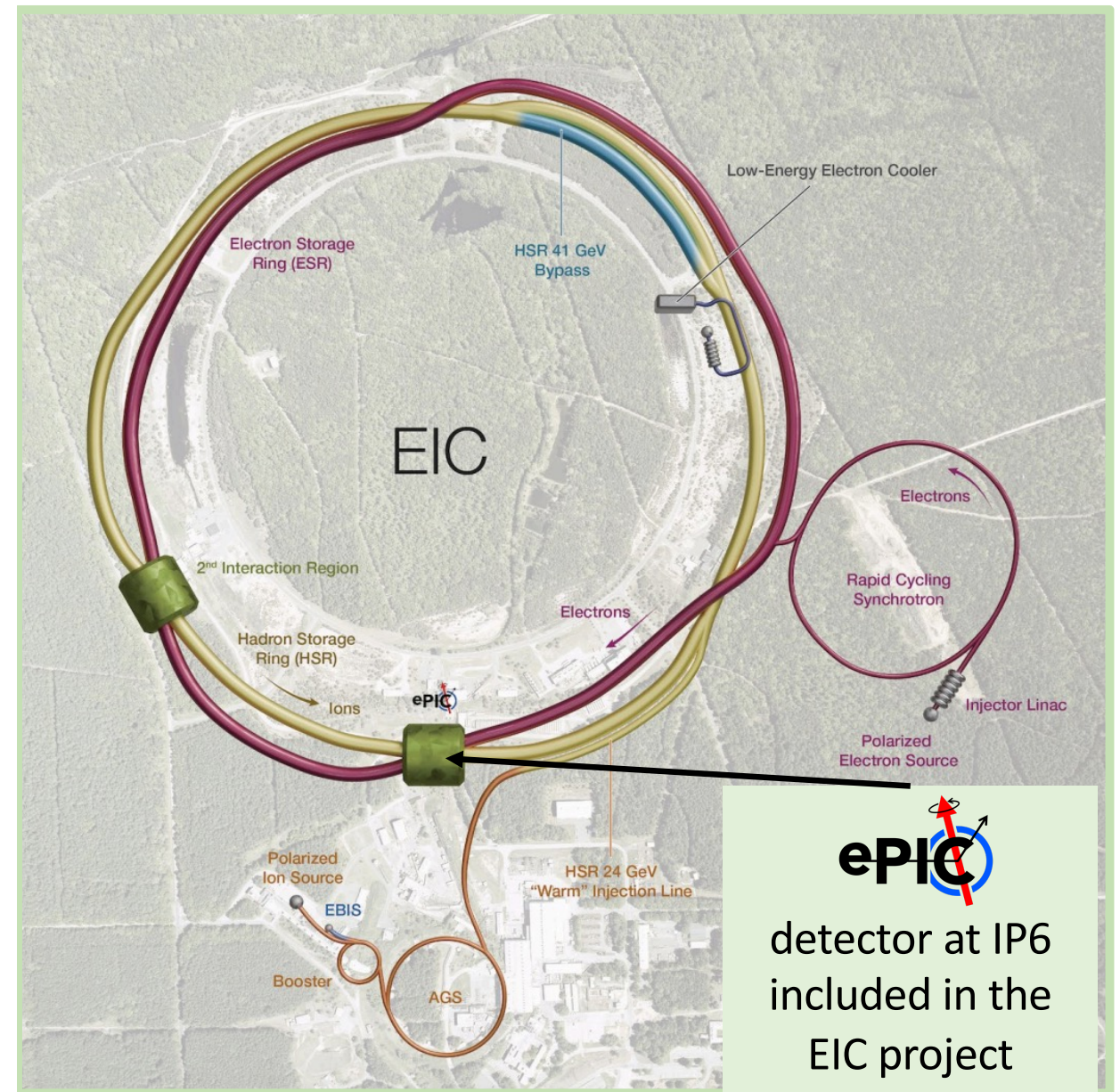


Use existing RHIC complex at Brookhaven National Laboratory for hadron beams and add the electron ring. Partnership between BNL and Jefferson Lab.

Electron Ion Collider (EIC)

EIC main features:

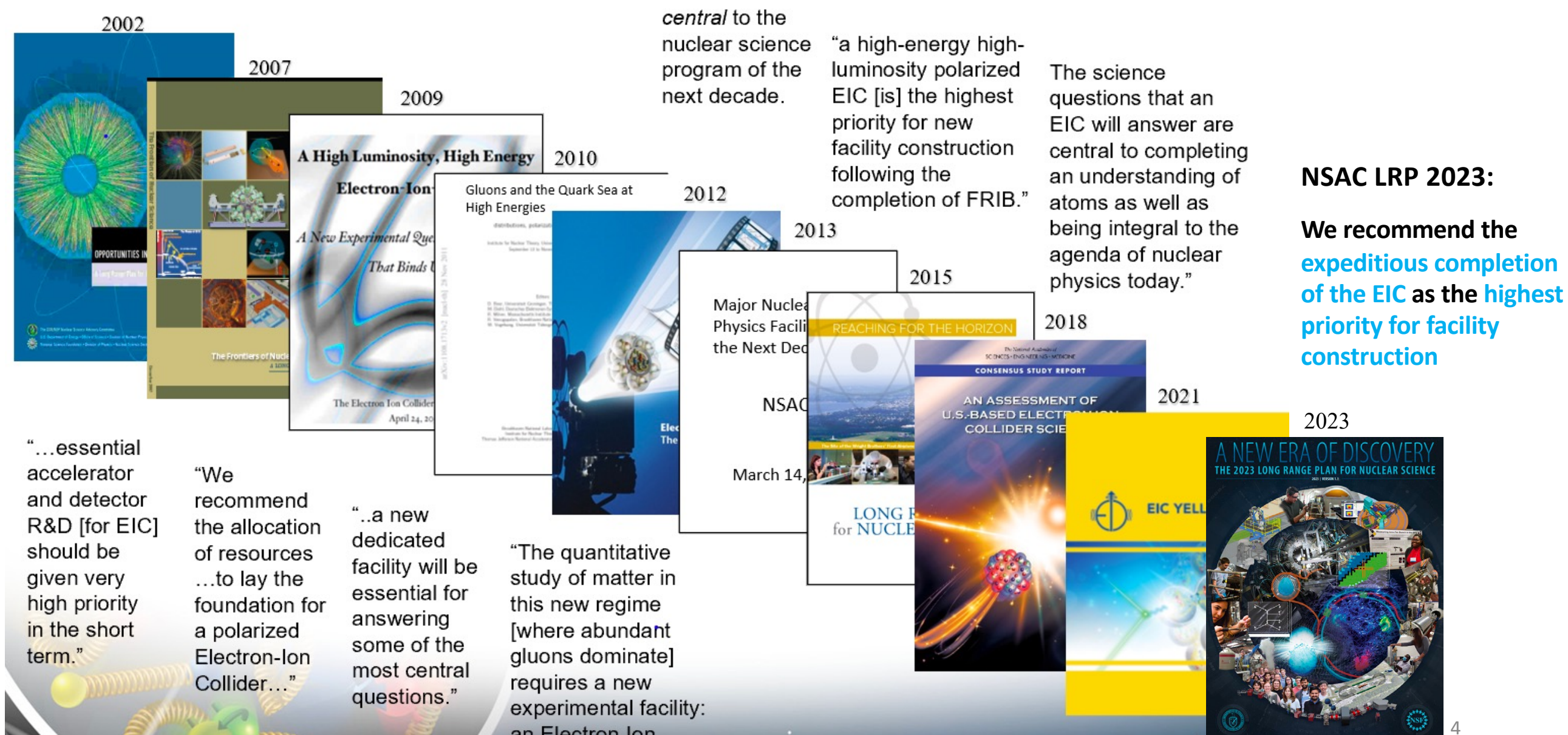
- **High luminosity** $10^{33} - 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ (100-1000 times more than HERA) allowing for high statistics
- **Variable** center of mass energies 20 -140 GeV
- Beams with different A: from **light nuclei (proton)** to the **heaviest nuclei (uranium)**
- **Polarized** electron and proton beams. Possibility of polarized light ions.
- Up to **two interaction** regions



World's first polarized electron-proton/light ion and electron-nucleus collider

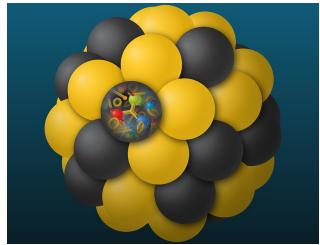
EIC project history

> 20 years long pathway!

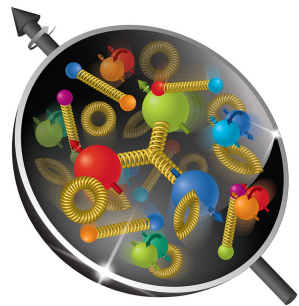


Slide from Salvatore Fazio

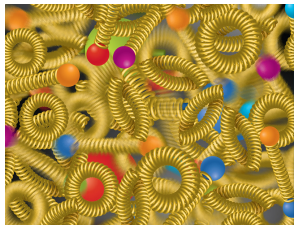
Physics Questions to be explored at EIC



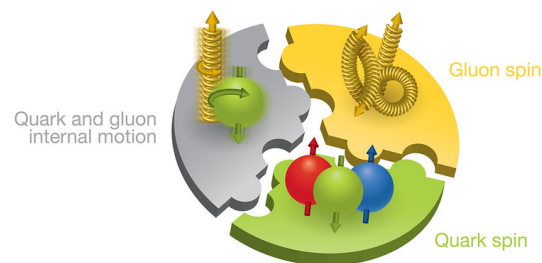
How do the quark-gluon interactions create **nuclear binding**?



How are partons inside the nucleon **distributed** ?



Does gluon density in a nucleus **saturate** at **high energies** ?



How quark and gluon spins and their orbital angular momentum combine in the proton **spin** ?

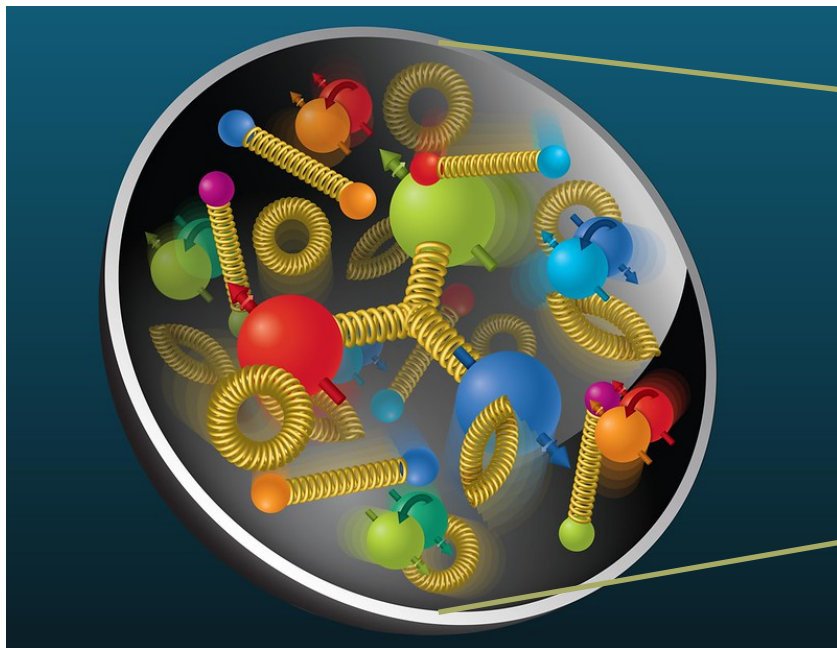


How does visible **mass** emerge from partons and their underlying interactions?

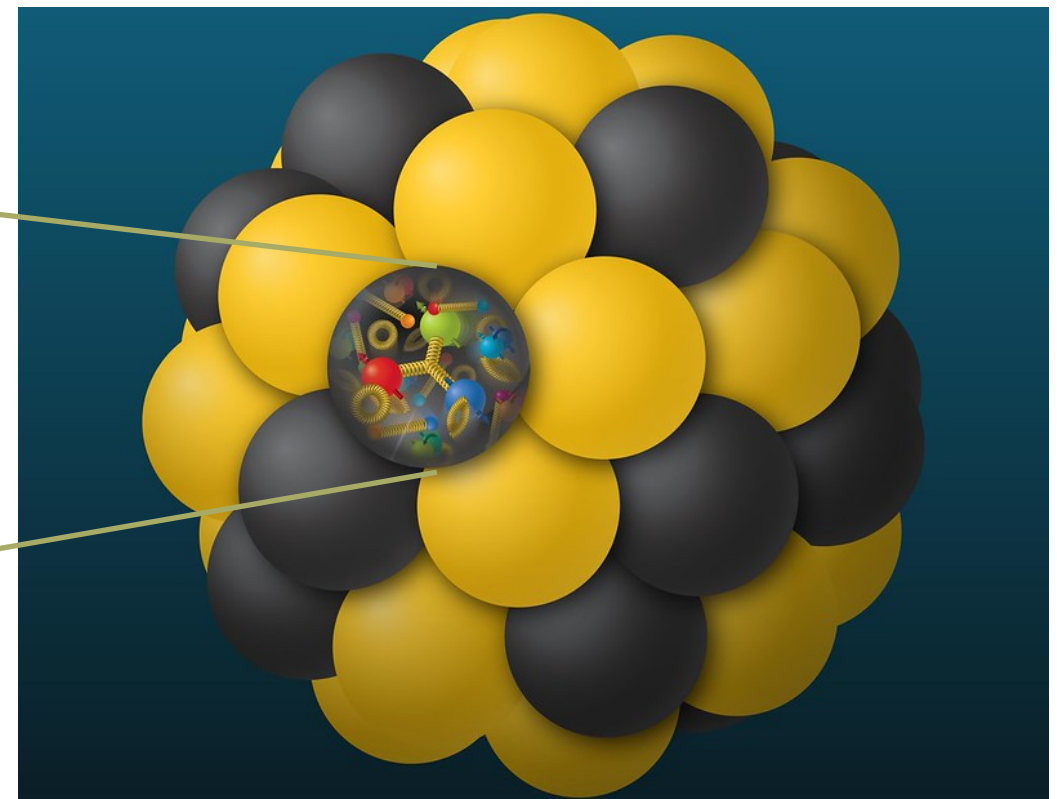
Nuclear structure

How quarks and gluon distributions get modified in nuclei?

How this interaction creates nuclear binding?



free proton



bound proton in a nucleus

Nuclear structure

Nuclear ratio:

$$R_{F_2}^A(x, Q^2) = \frac{F_2^A(x, Q^2)}{A F_2^{\text{nucleon}}(x, Q^2)}$$

Ratio of cross section on a nucleus to the proton (scaled by mass number A)

Nuclear effects: $R^A \neq 1$

Nuclear structure

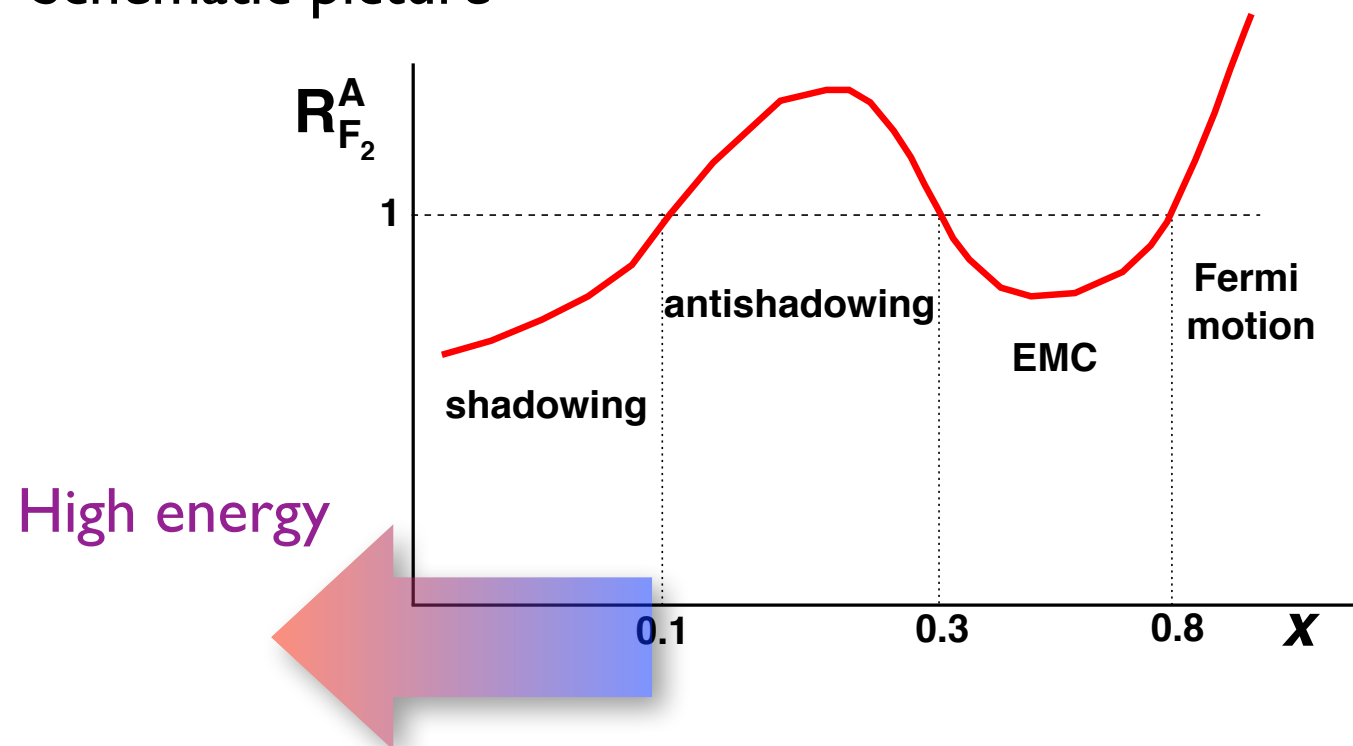
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Ratio of cross section on a nucleus to the proton (scaled by mass number A)

Nuclear effects: $R^A \neq 1$

Schematic picture



Nuclear structure

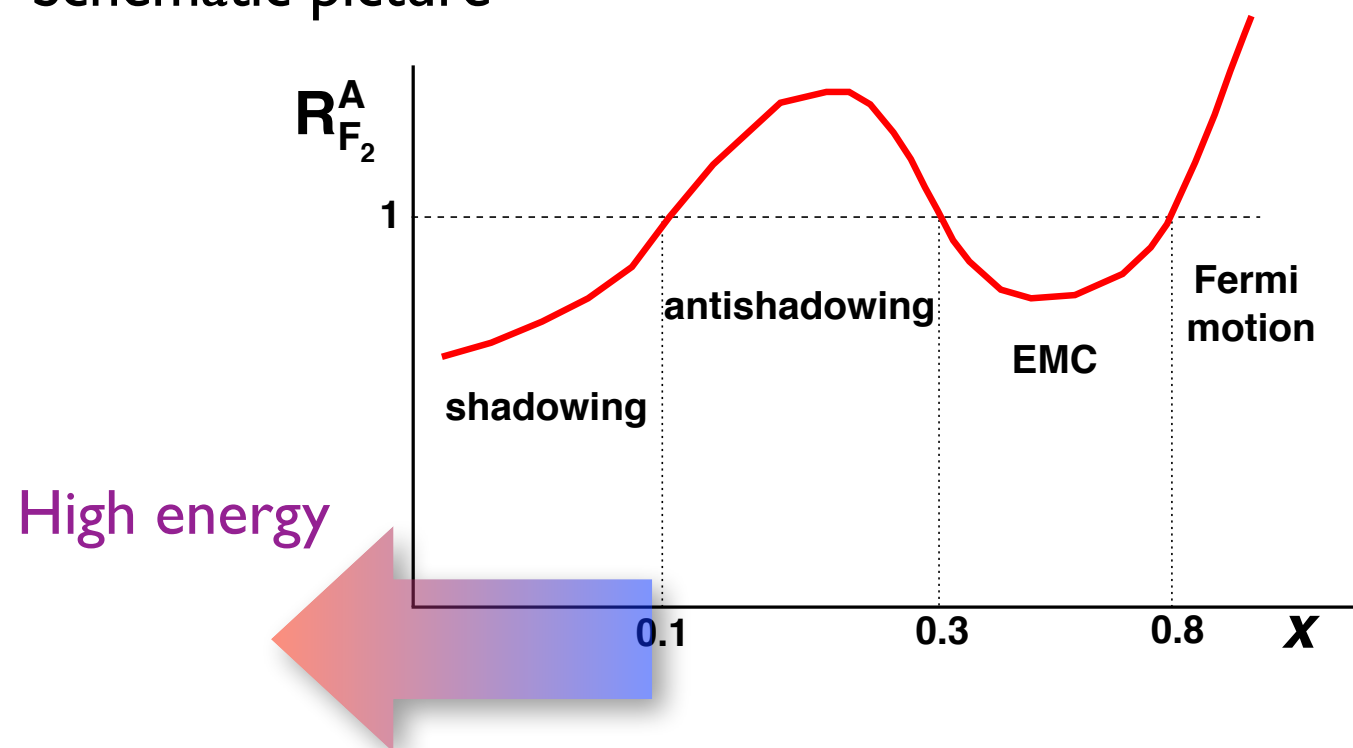
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Ratio of cross section on a nucleus to the proton (scaled by mass number A)

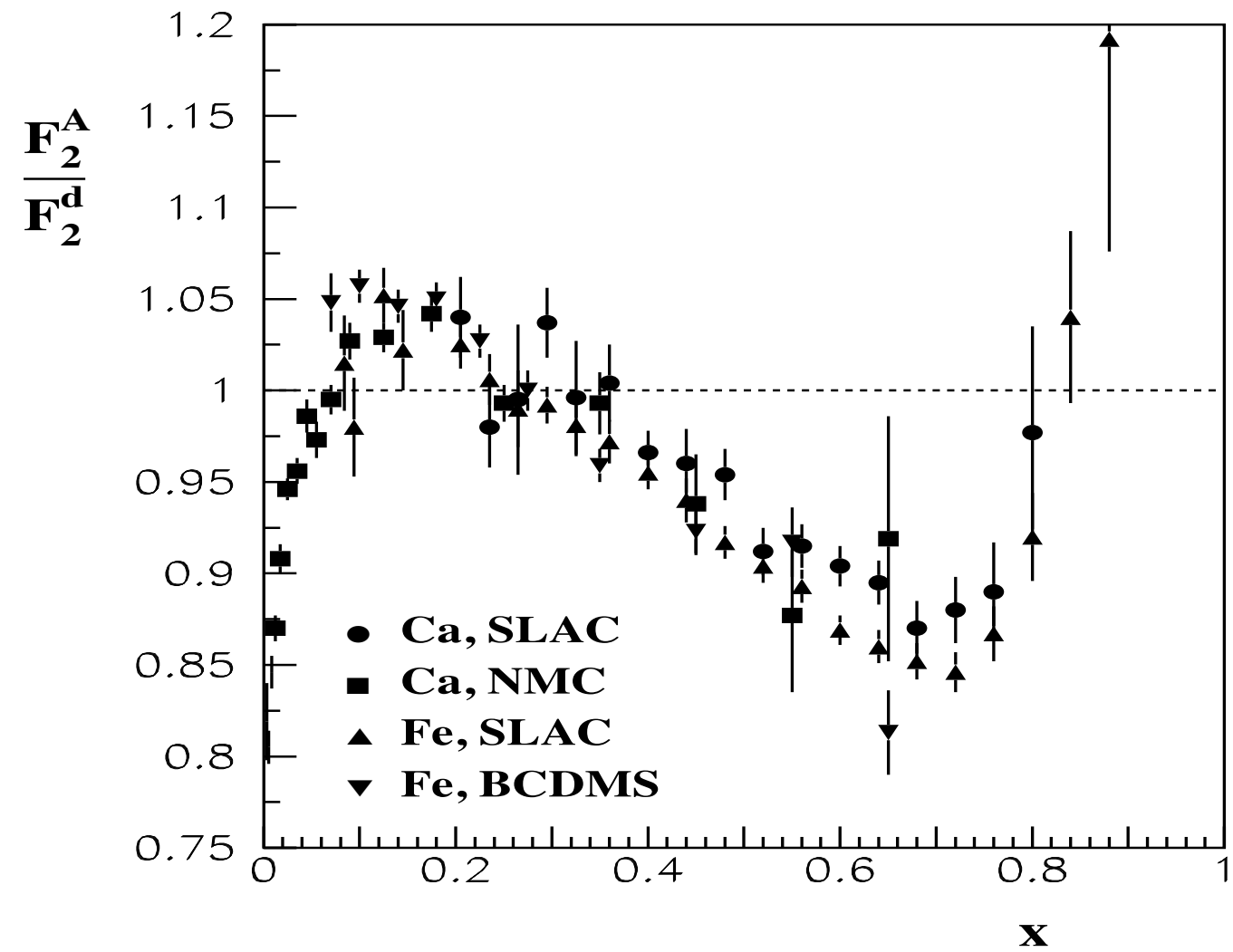
Nuclear effects: $R^A \neq 1$

Schematic picture



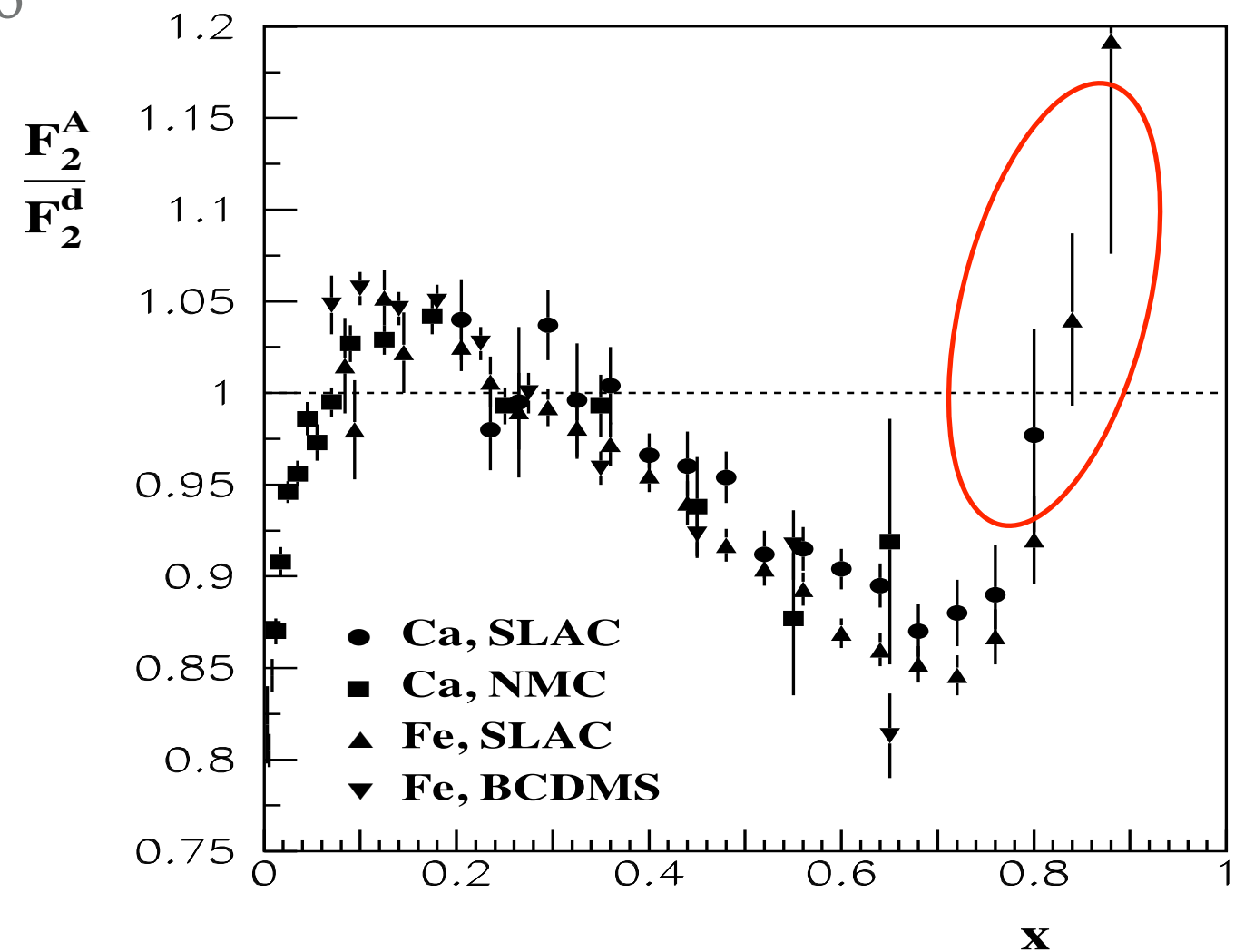
- Fermi motion
 $x \geq 0.8$
- EMC region
 $0.25 - 0.3 \leq x \leq 0.8$
- Antishadowing region
 $0.1 \leq x \leq 0.25 - 0.3$
- Shadowing region
 $x \leq 0.1$

Nuclear structure



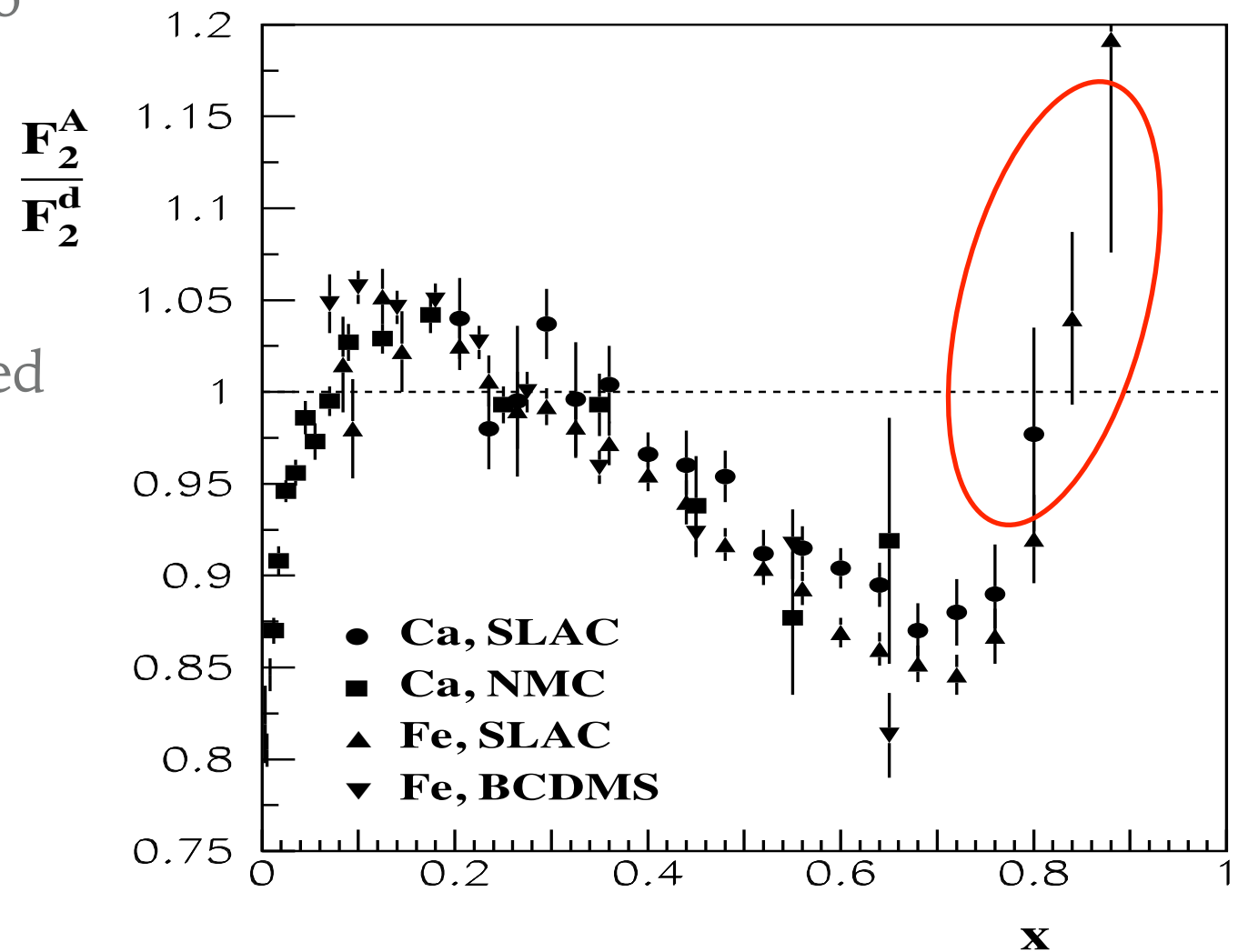
Nuclear structure

- ◆ Fermi motion: ratio >1 for $x > 0.8$. Due to motion of bound nucleons inside the nucleus.



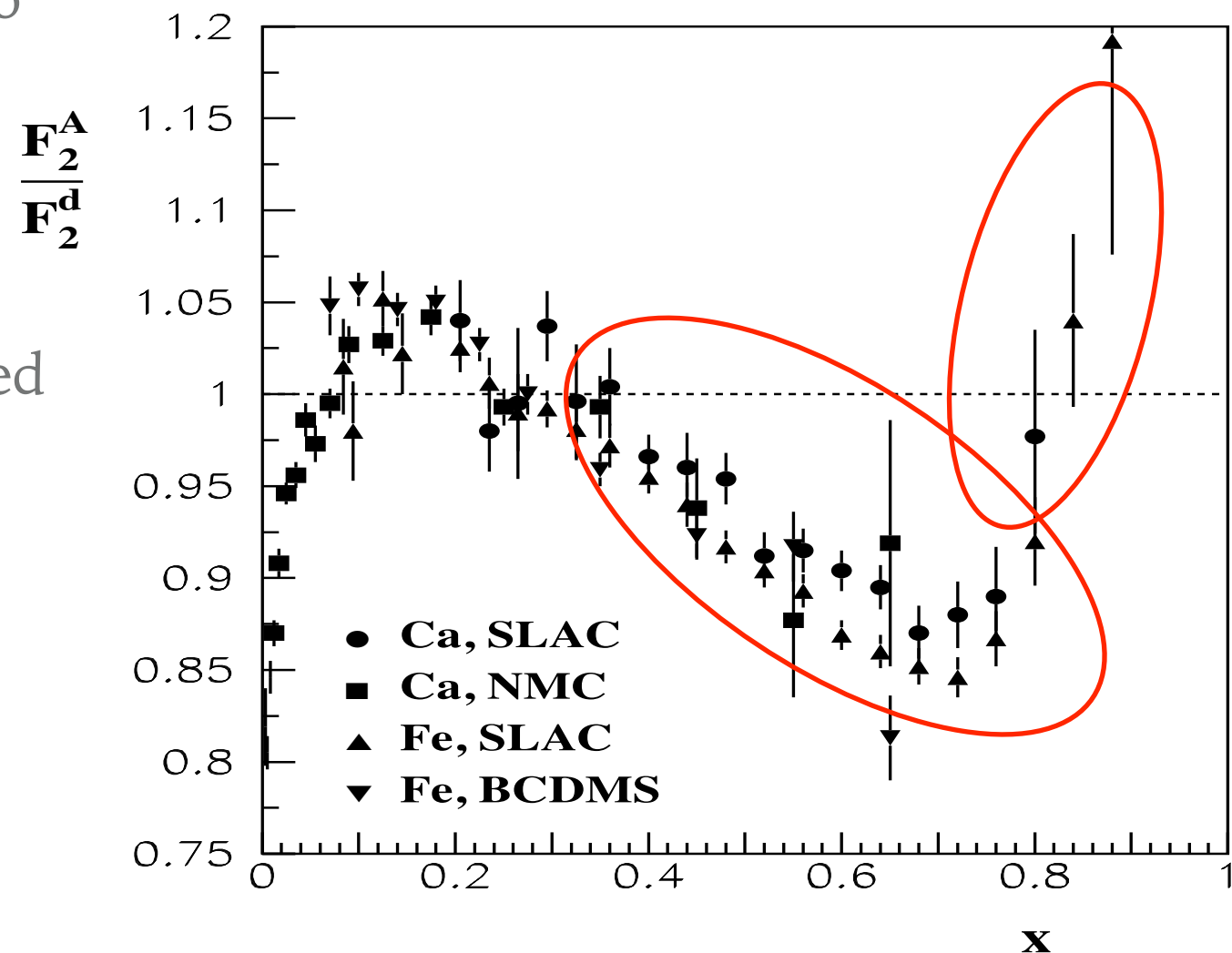
Nuclear structure

- ◆ Fermi motion: ratio >1 for $x > 0.8$. Due to motion of bound nucleons inside the nucleus.
- ◆ EMC region: EMC collaboration discovered large deviation of the ratio from 1 in the region of $0.3 < x < 0.8$. Usually referred as the EMC effect.

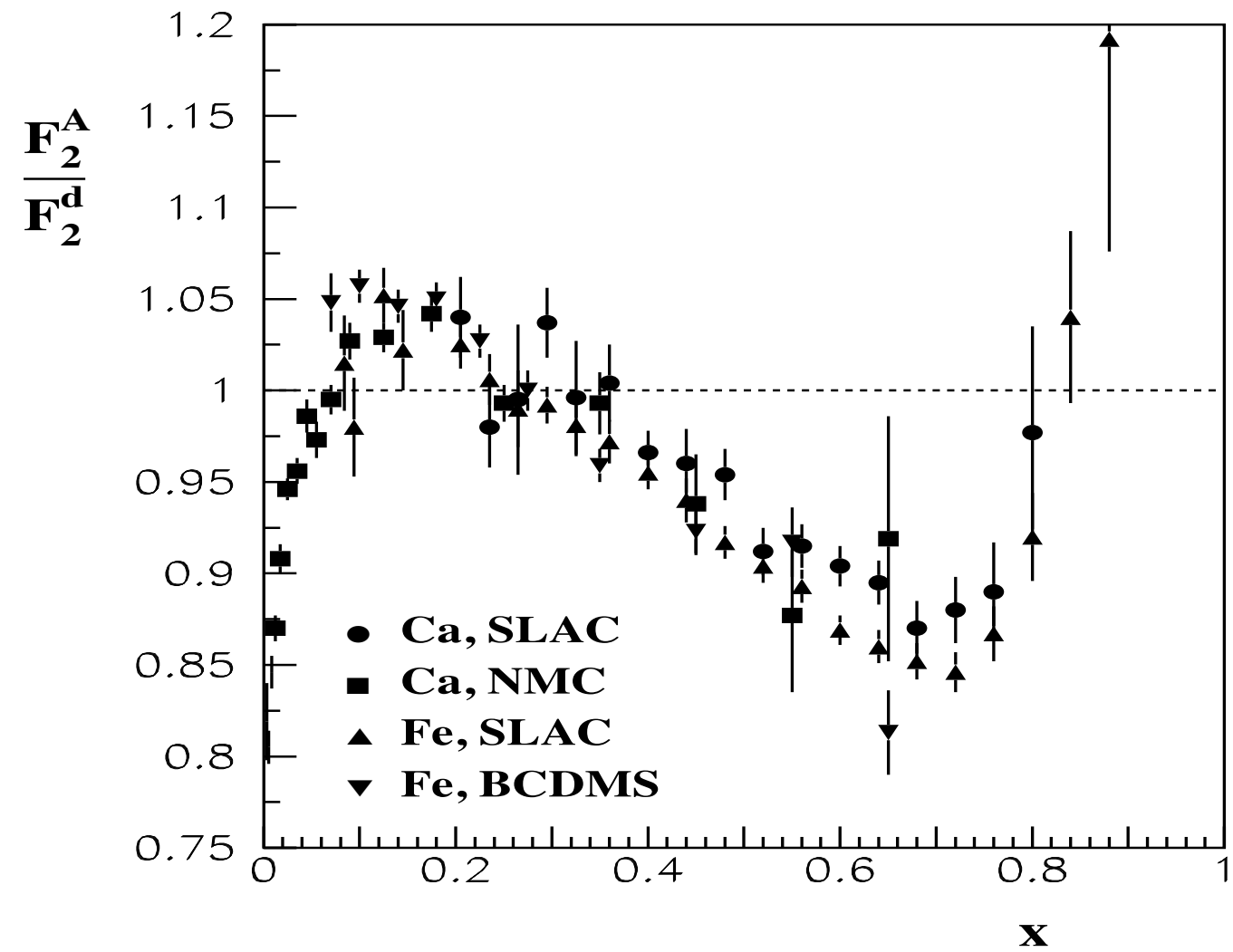


Nuclear structure

- ◆ Fermi motion: ratio >1 for $x > 0.8$. Due to motion of bound nucleons inside the nucleus.
- ◆ EMC region: EMC collaboration discovered large deviation of the ratio from 1 in the region of $0.3 < x < 0.8$. Usually referred as the EMC effect.
- ◆ Possible explanation: Short range correlations between nucleons, most nucleons are not modified but some experiencing SRC are modified (about 20%).

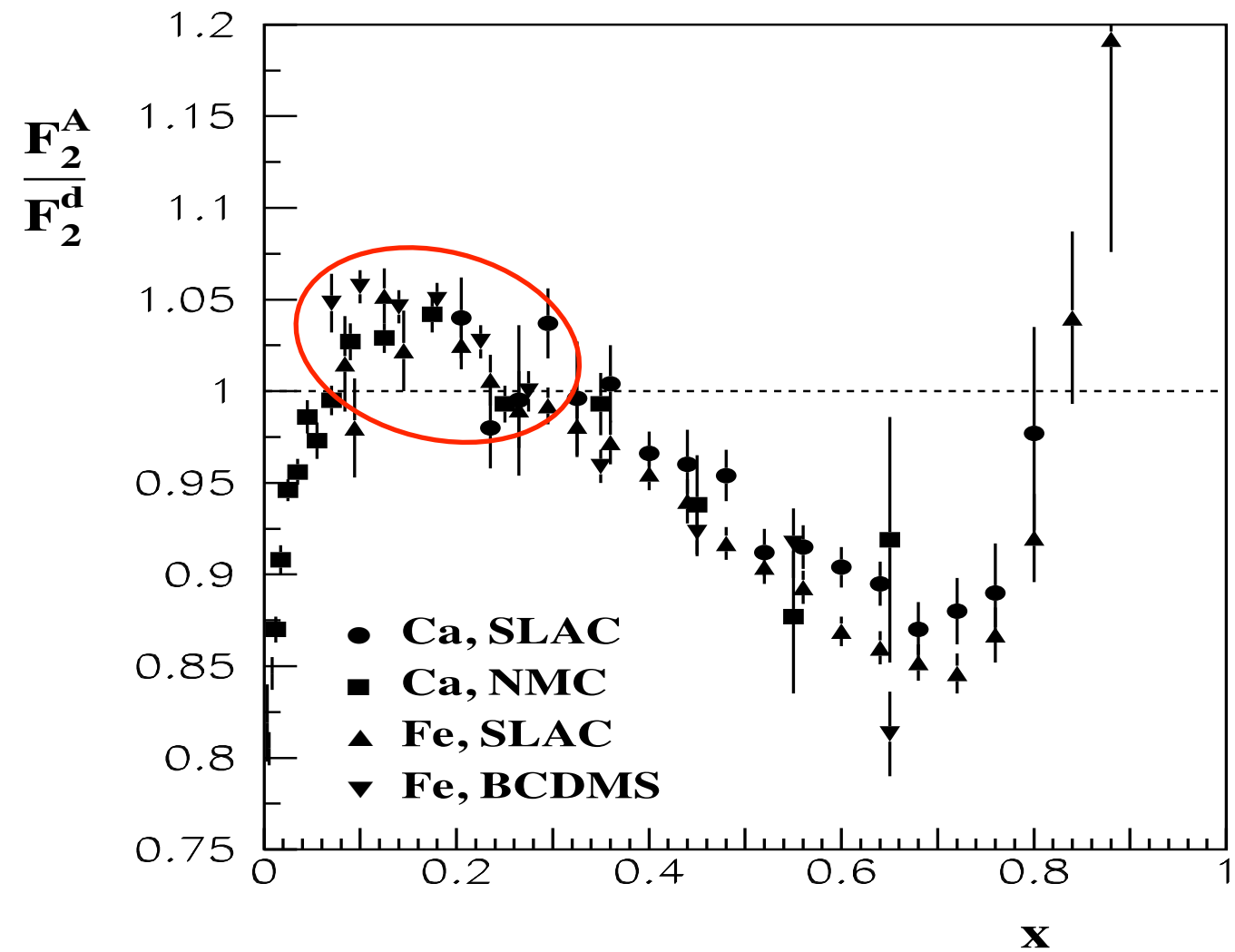


Nuclear structure



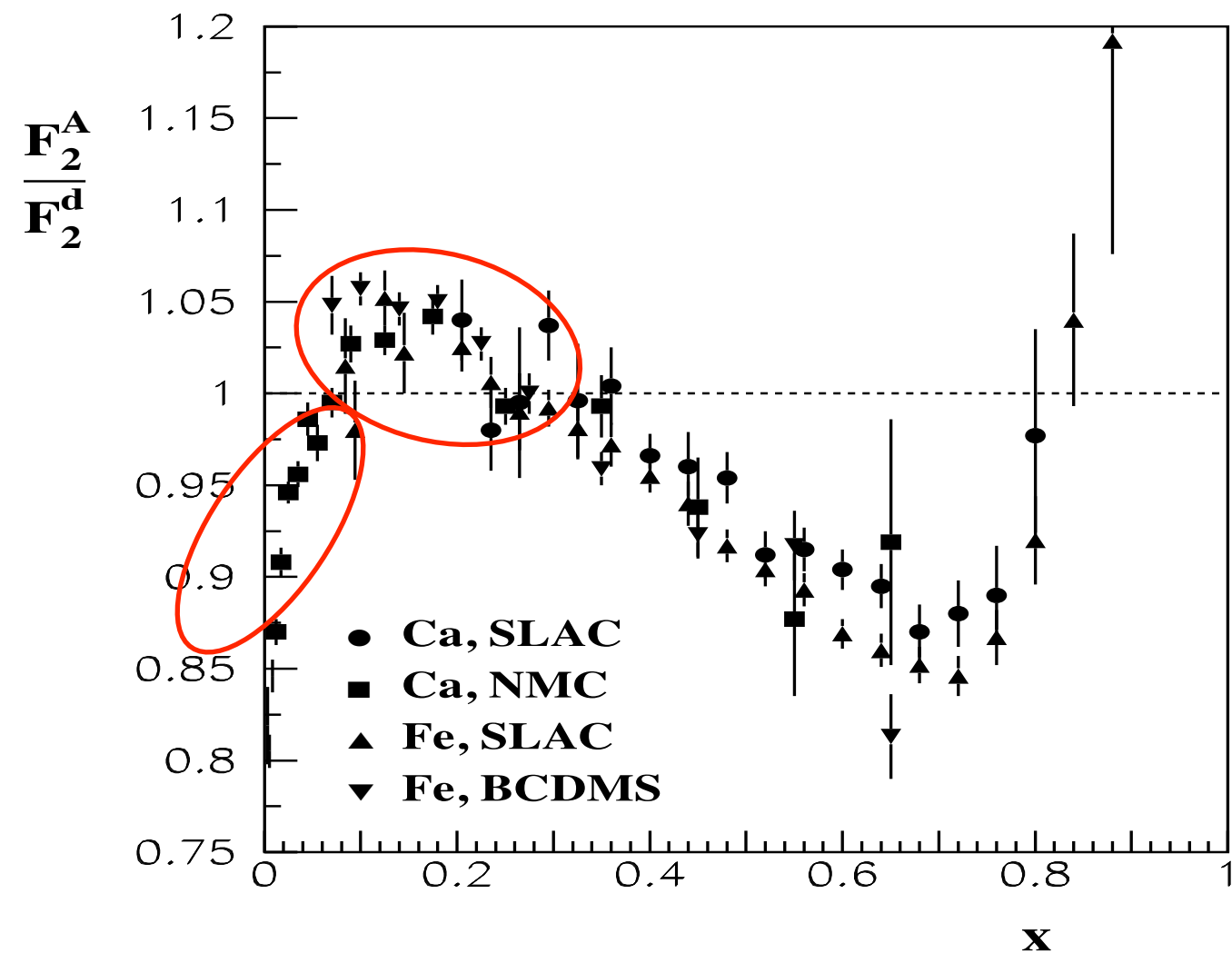
Nuclear structure

- ◆ Antishadowing: Ratio > 1 for $0.1 < x < 0.3$. Momentum sum rule (?)



Nuclear structure

- ◆ Antishadowing: Ratio > 1 for $0.1 < x < 0.3$. Momentum sum rule (?)
- ◆ Shadowing: ratio < 1 for small x , $x < 0.1$.

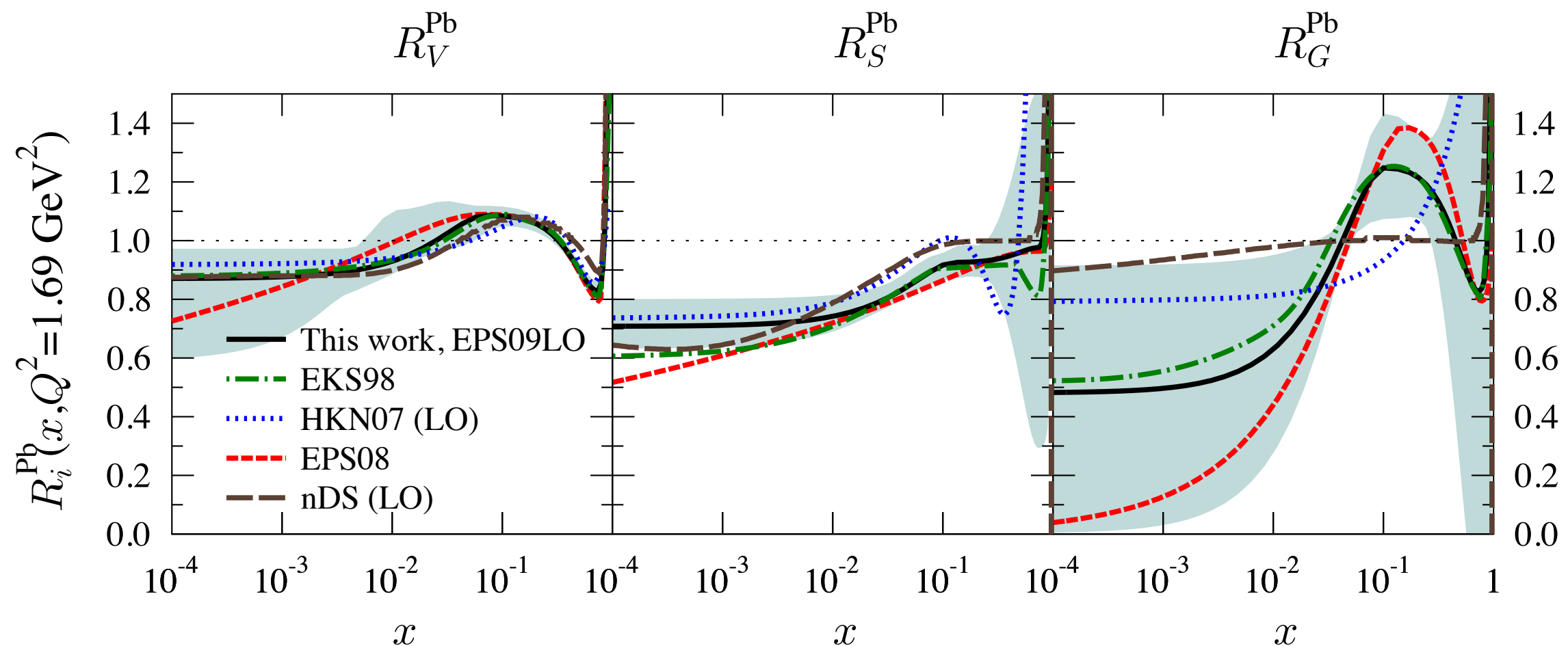


Nuclear structure

Nuclear **ratio** for parton densities

$$R_f^A(x, Q^2) = \frac{f^A(x, Q^2)}{A f^p(x, Q^2)}$$

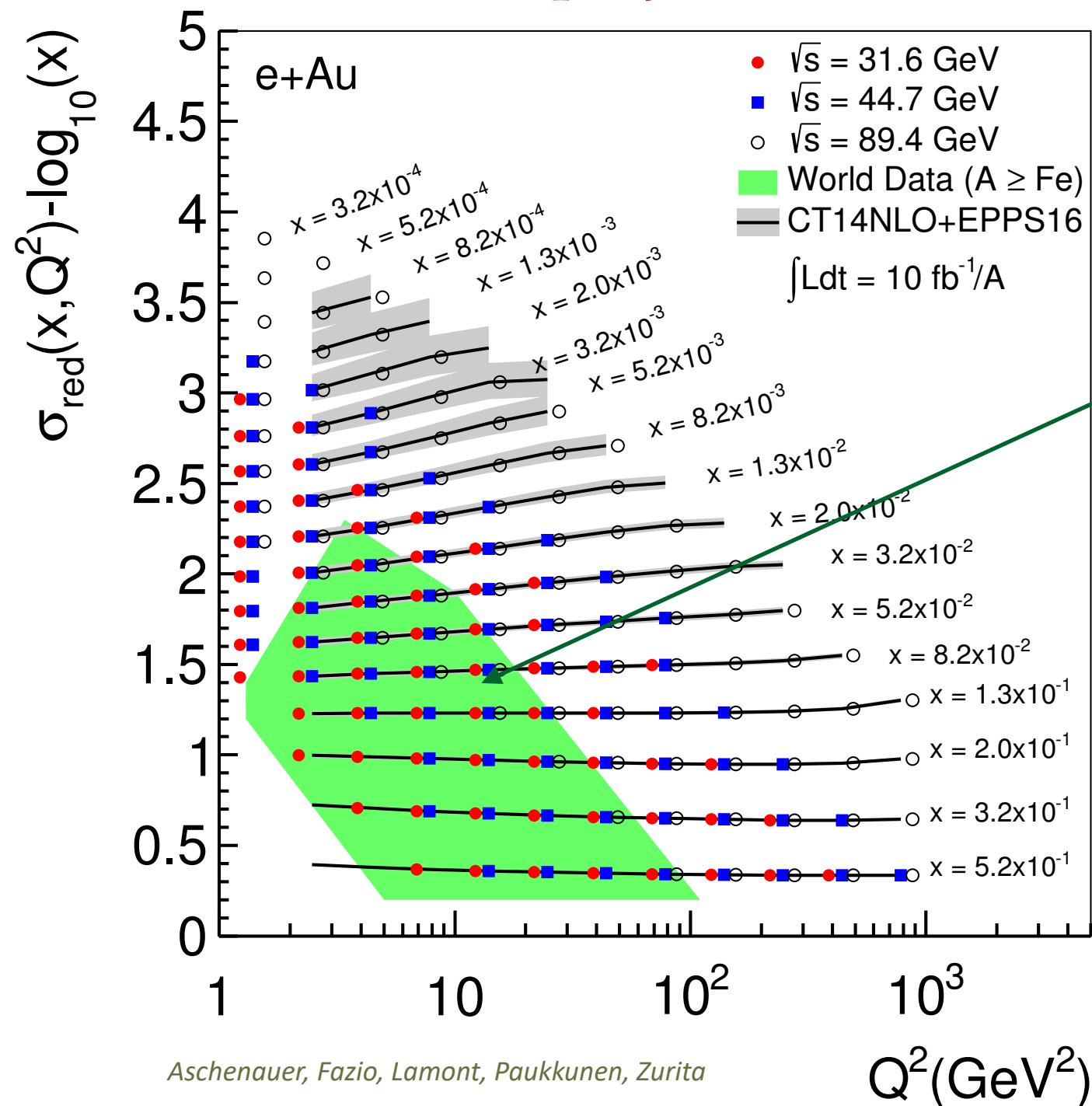
Nuclear effects: $R^A \neq 1$



Large uncertainties, particularly at low x : need more accurate data

Global nuclear structure: structure functions

Simulated(projected) data

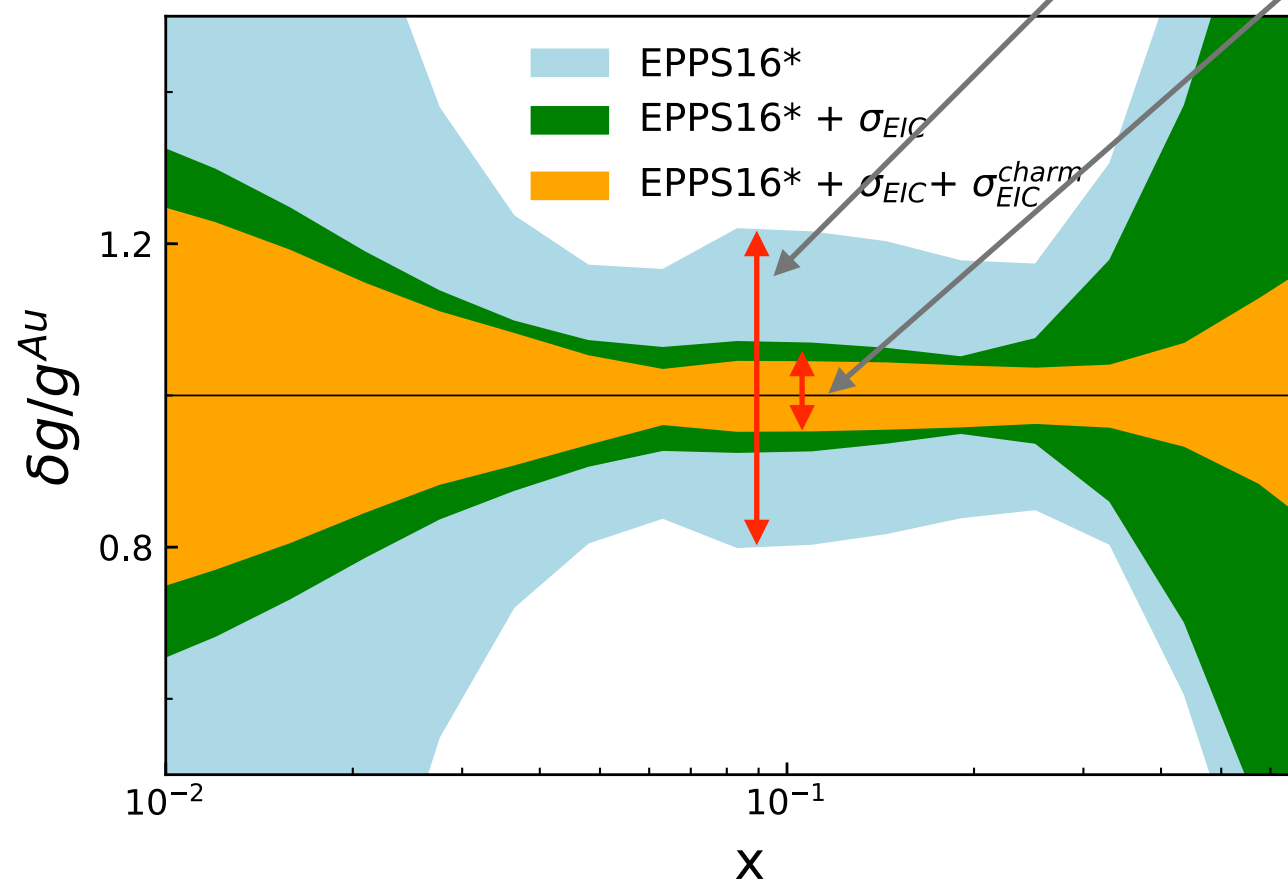


- Large extension of the **previously** covered kinematical region
- **Precision** measurements of the reduced cross section
- Errors **much smaller** than the **uncertainties** of theoretical predictions

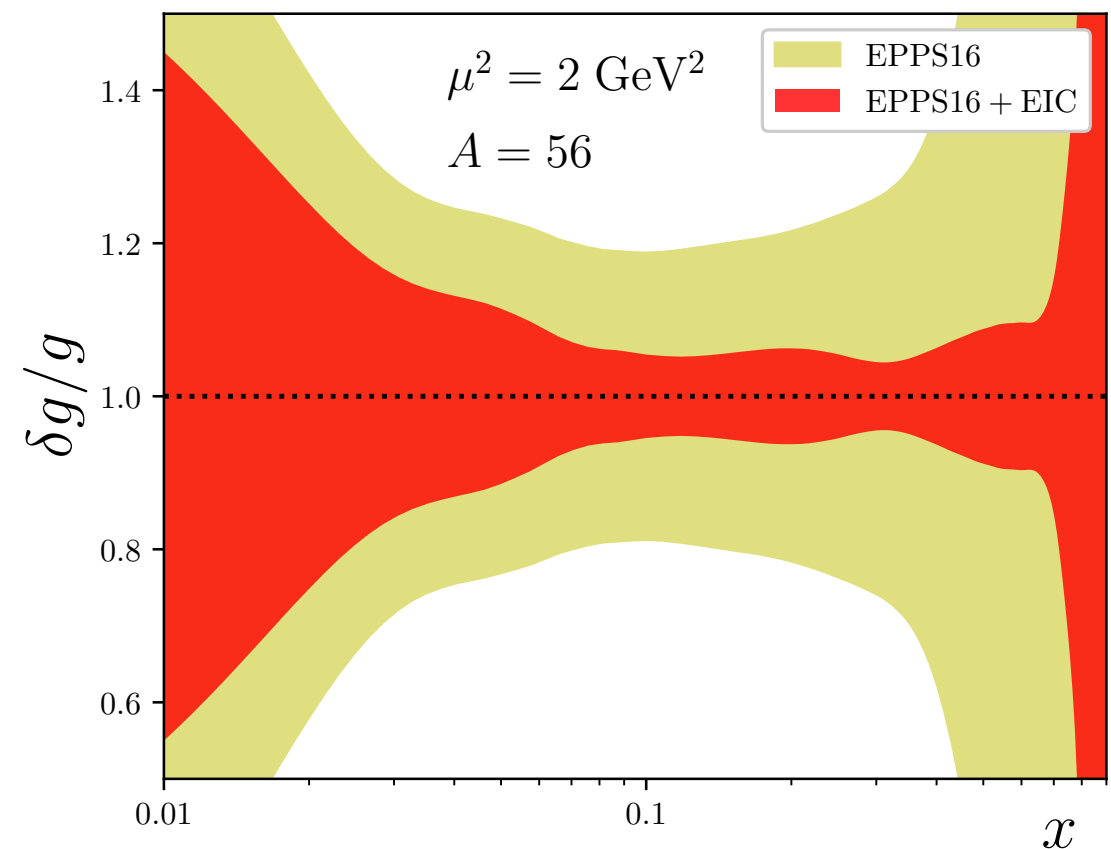
Potential of EIC to constrain the gluons in nuclei

Relative uncertainty of the gluon distribution: before and after including EIC projections

Au

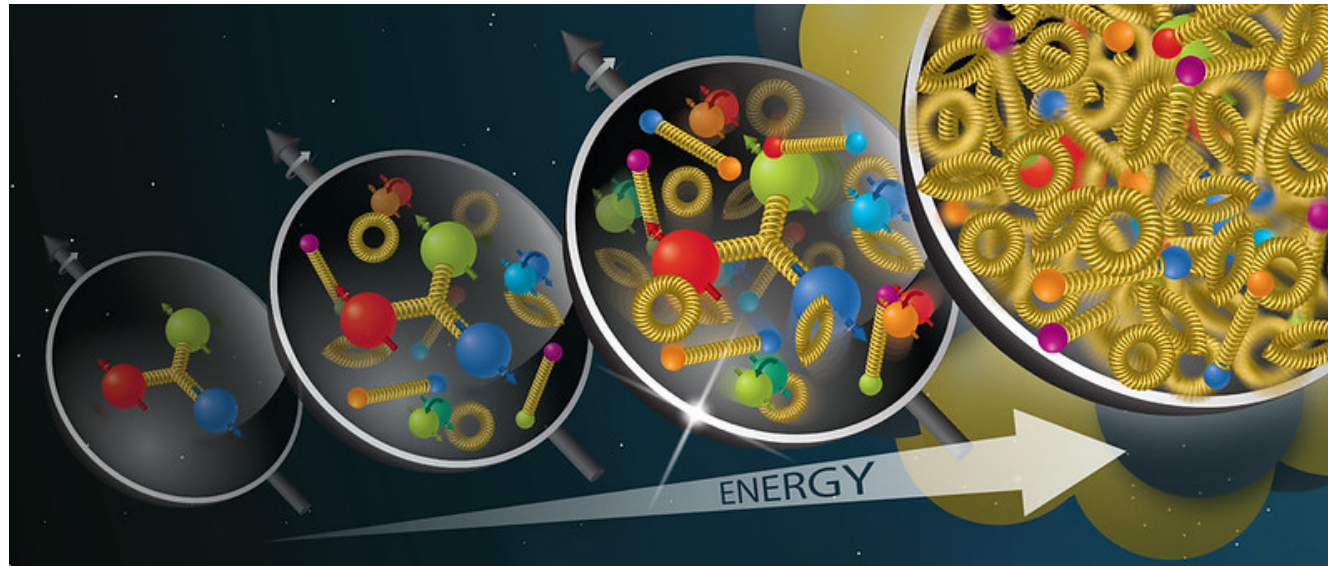


Fe



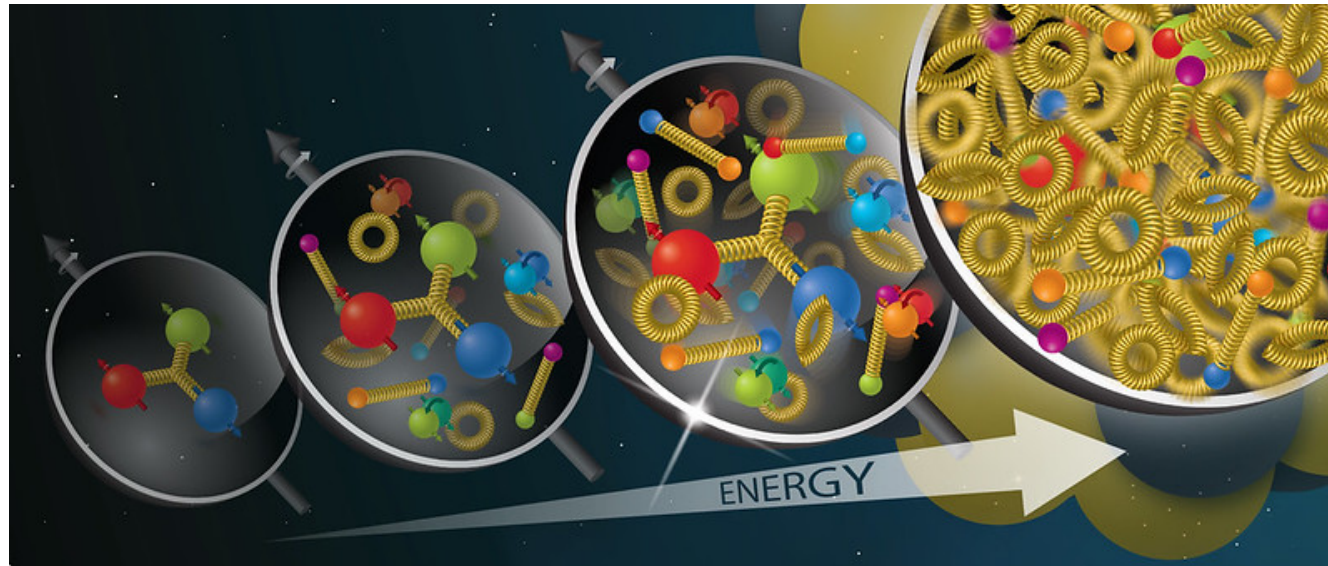
Large reduction of uncertainties for the gluon distributions in nuclei from EIC

Saturation of partons in nuclei

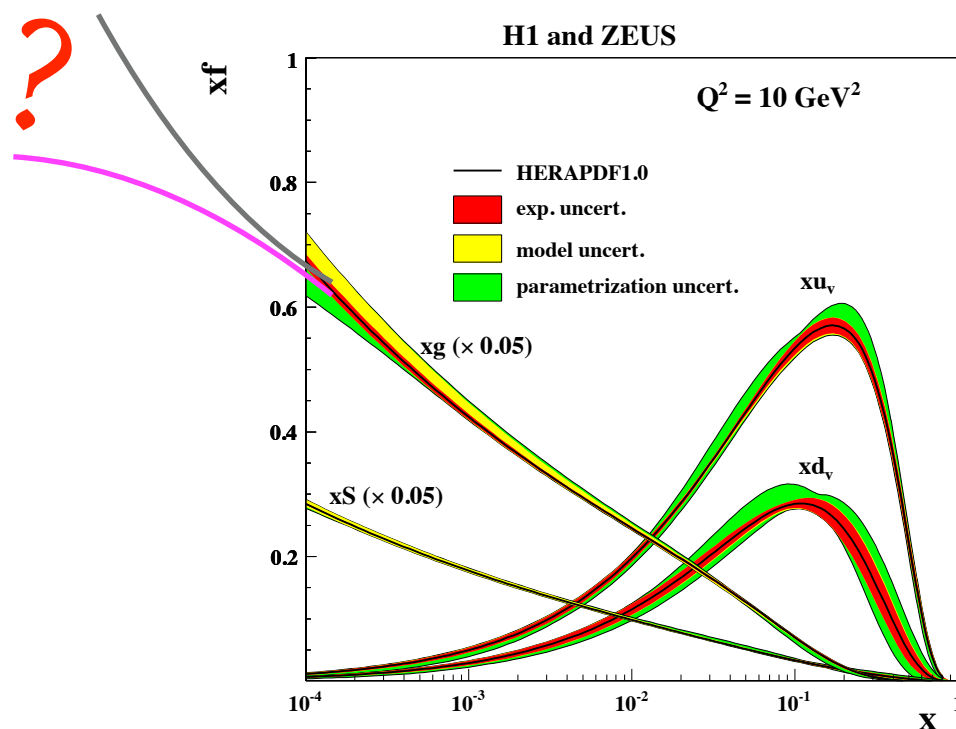


QCD at high energy (low x) and/or high density target (large nucleus, A) predicts **saturation** of gluons: taming of the growth due to the recombination.

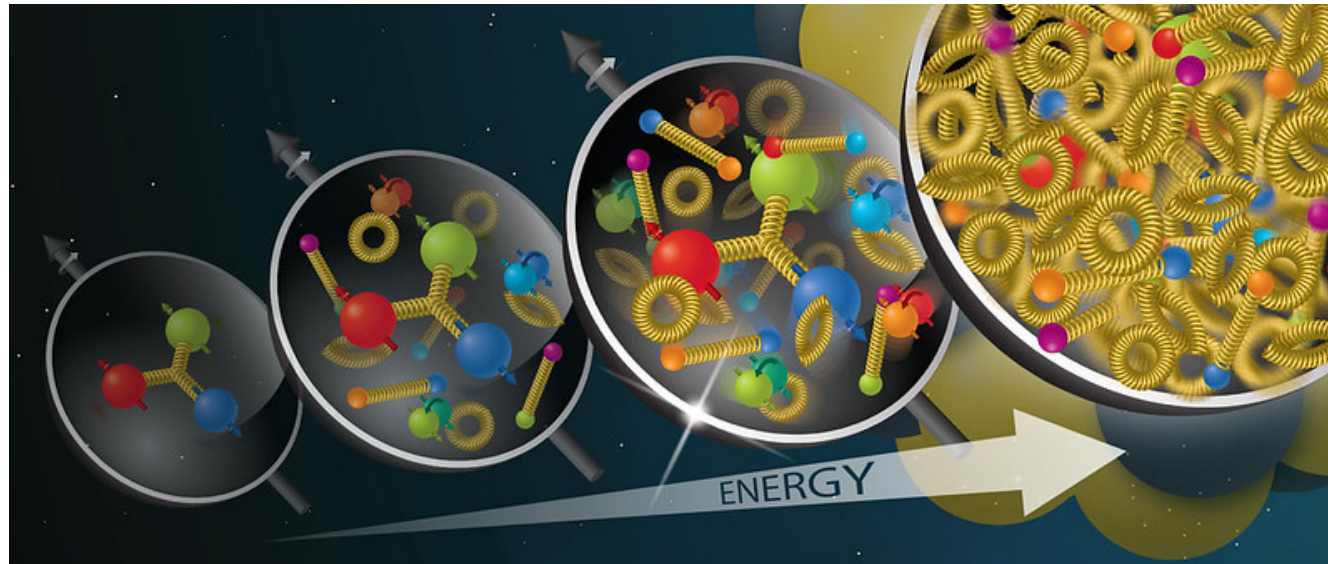
Saturation of partons in nuclei



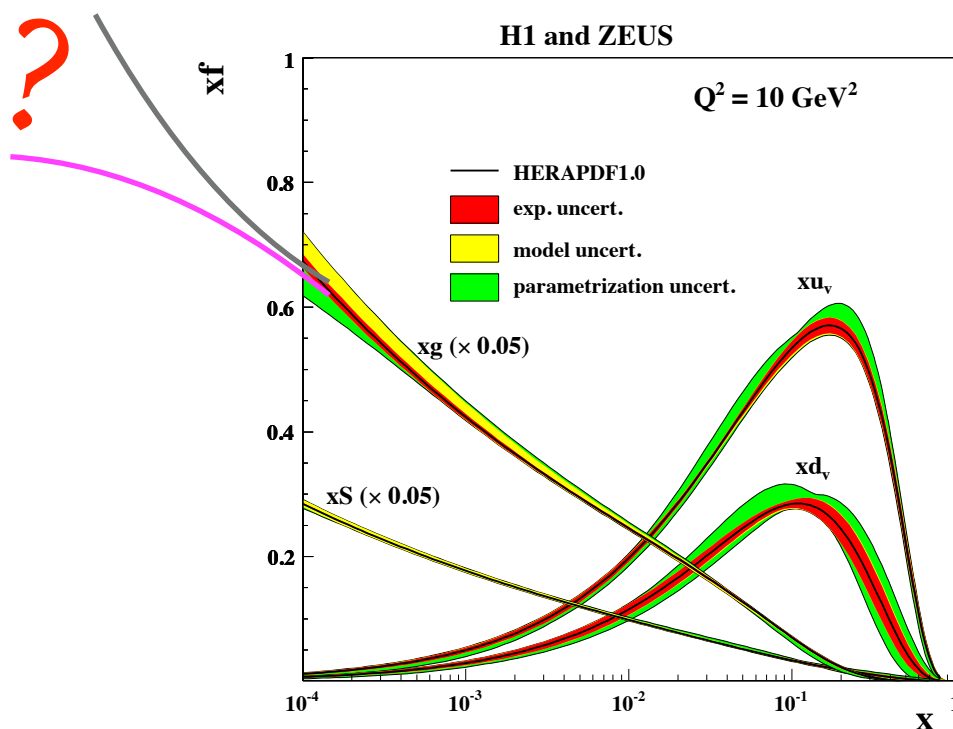
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$Q_s(x, A)$
Saturation
scale

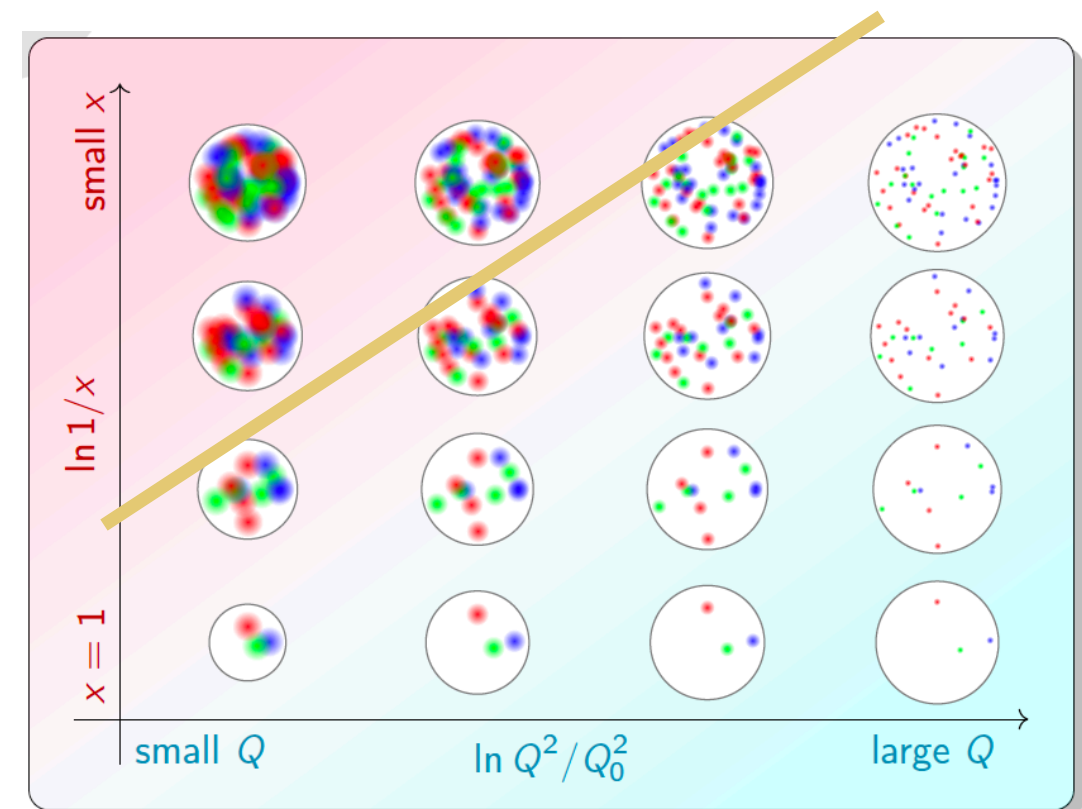
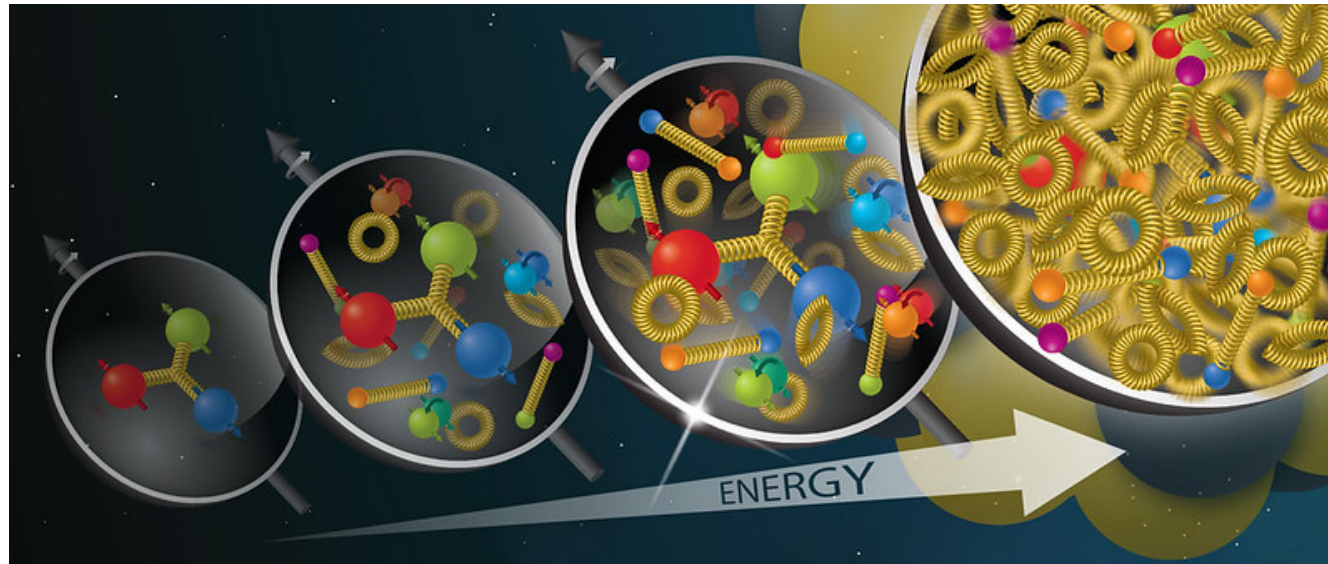
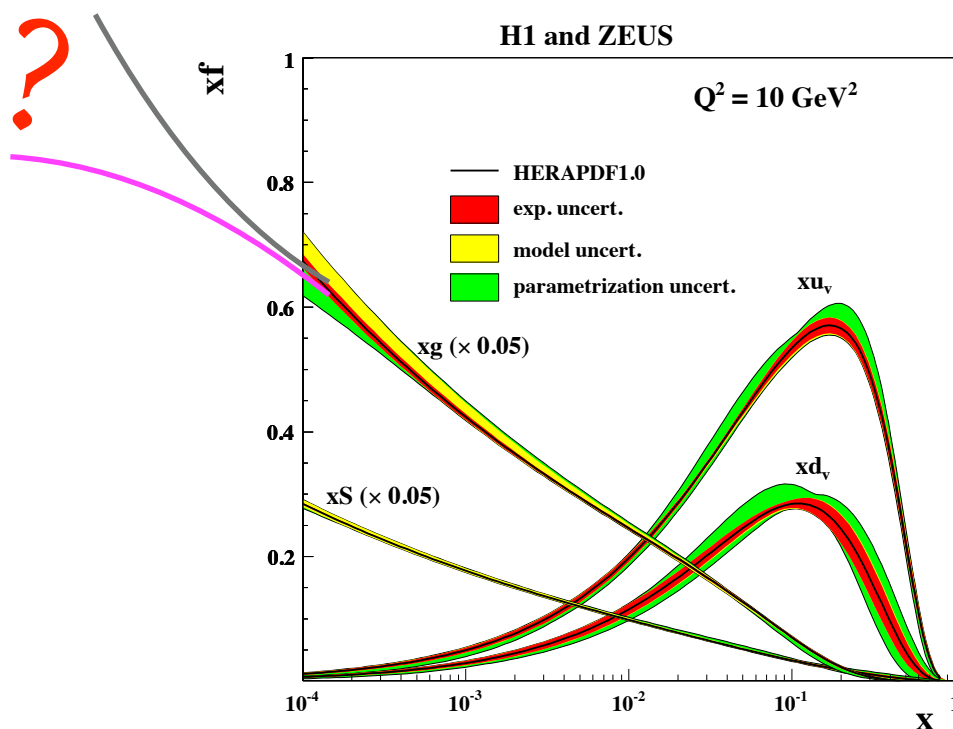


Image credit: David Zaslavsky

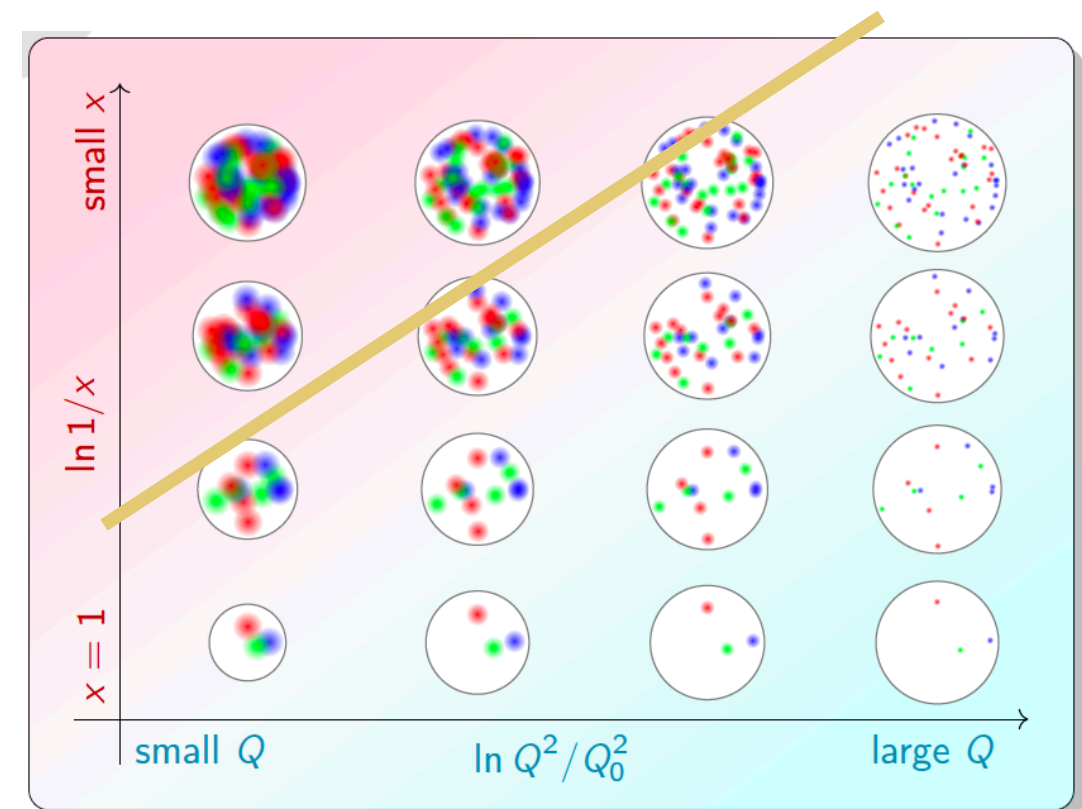
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QCD at high energy (low x) and/or high density target (large nucleus, A) predicts **saturation** of gluons: taming of the growth due to the recombination.



$Q_s(x, A)$
Saturation
scale



Question: when (at what x) does this happen ?
EIC can test this prediction in nuclei.

Image credit: David Zaslavsky

Spin

Fundamental **quantum** property of particles: intrinsic angular momentum

Spin

Fundamental **quantum** property of particles: intrinsic angular momentum

Proton: spin $1/2$ Quarks: spin $1/2$

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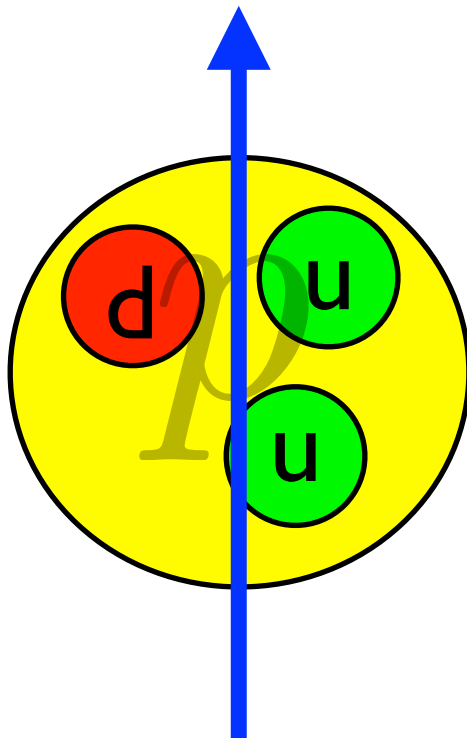
Proton has complex structure. How does its spin emerge?

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Hypothesis: two quarks spin parallel, one quark spin anti-parallel

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Problem solved....Is it ? Not so fast...

**A MEASUREMENT OF THE SPIN ASYMMETRY
AND DETERMINATION OF THE STRUCTURE FUNCTION g_1
IN DEEP INELASTIC MUON-PROTON SCATTERING**

European Muon Collaboration

Aachen, CERN, Freiburg, Heidelberg, Lancaster, LAPP (Annecy), Liverpool, Marseille, Mons, Oxford,
Rutherford, Sheffield, Turin, Uppsala, Warsaw, Wuppertal, Yale

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D. LANSKE ^l, F. LETTENSTRÖM ^o, T. LINDQVIST ^o, J. LOKEN ^h, M. MATTHEWS ^e,
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L. ROPELEWSKI ^{b,1}, D. SALMON ^{a,9}, A. SANDACZ ^{b,10}, T. SCHRÖDER ^m, K.P. SCHÜLER ^e,
K. SCHULTZE ^l, T.-A. SHIBATA ^p, T. SLOAN ^g, A. STAIANO ^{p,14}, H. STIER ^m, J. STOCK ^m,
G.N. TAYLOR ^{h,15}, J.C. THOMPSON ⁱ, T. WALCHER ^{p,16}, S. WHEELER ^{a,7}, W.S.C. WILLIAMS ^h,
S.J. WIMPENNY ^{e,17}, R. WINDMOLDERS ^q, W.J. WOMERSLEY ^{h,18} and K. ZIEMONS ^l

EMC and spin crisis

Polarized muon - proton scattering



Measuring asymmetry (difference between cross sections of parallel and antiparallel orientations of projectile and target spins divided by the sum)

$$A = \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}}$$

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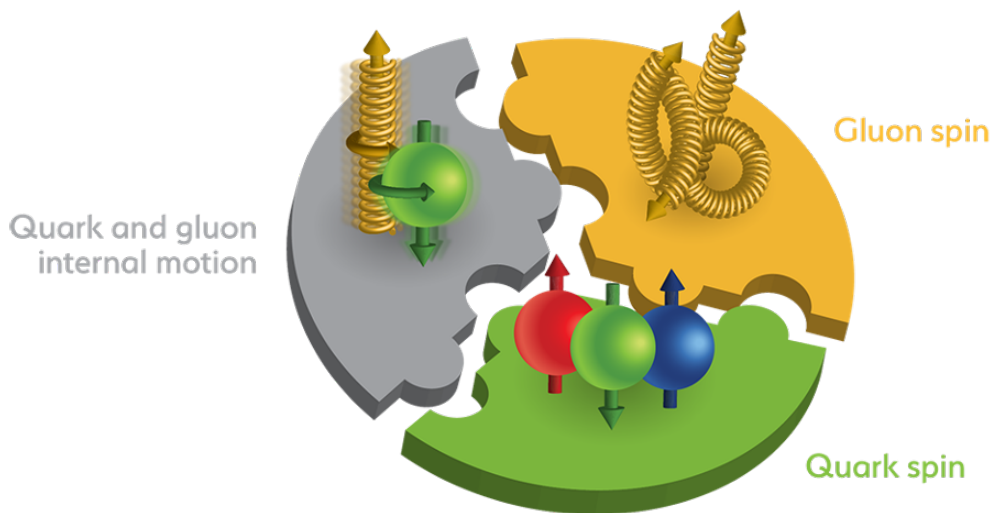
$$A = \frac{\sigma^{\uparrow\downarrow} - \sigma^{\uparrow\uparrow}}{\sigma^{\uparrow\downarrow} + \sigma^{\uparrow\uparrow}}$$

Result:

In addition, the result implies that, in the scaling limit, a rather small fraction of the spin of the proton is carried by the spin of the quarks.

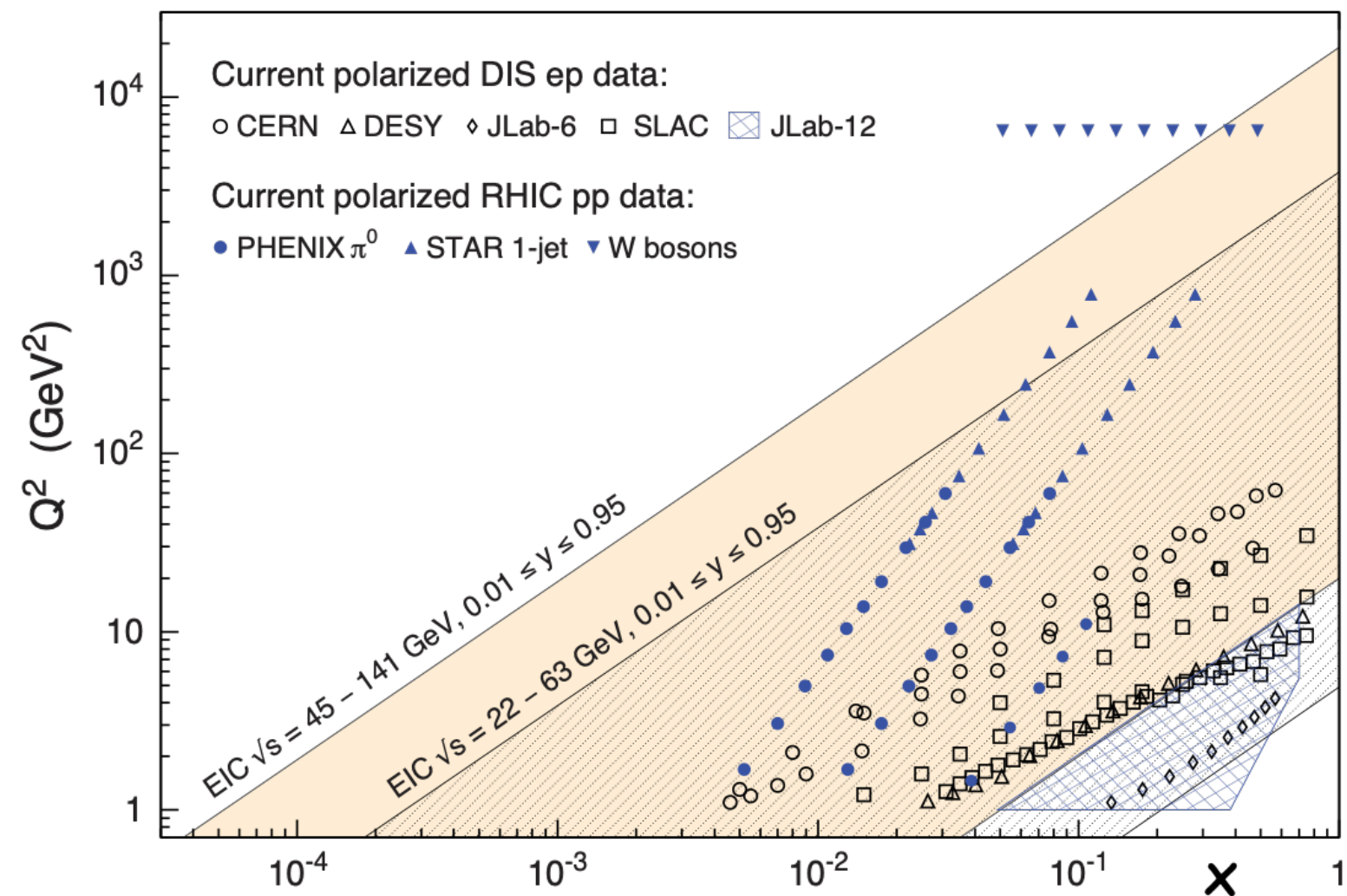


Proton spin at EIC



EIC extends range in (x, Q^2) by 1-2 orders of magnitude for polarized measurements.

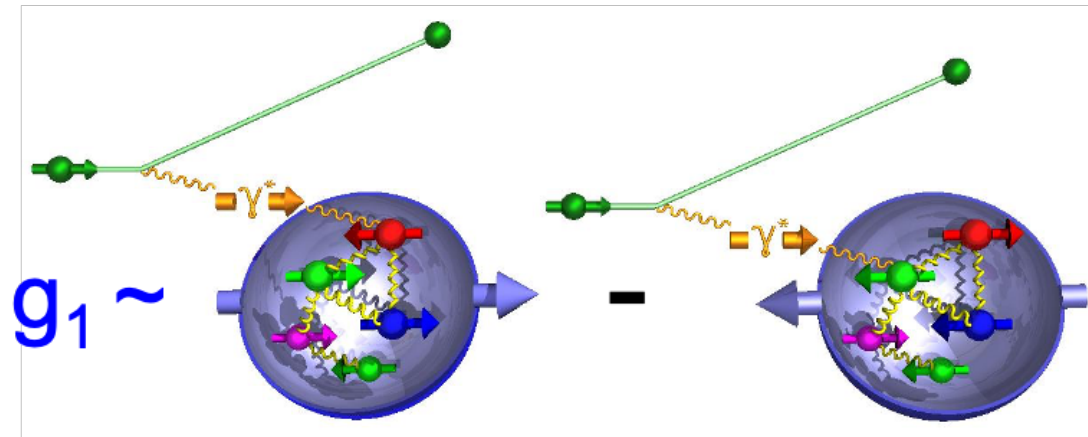
EIC kinematic plane vs current polarized data



Possibilities:

- precision measurement of **structure function g_1**
- **gluon** contribution to proton spin
- **quark** contribution
- **strange** quark contribution also accessible
- **polarized deuterons** allow for measurement of g_1 in a neutron

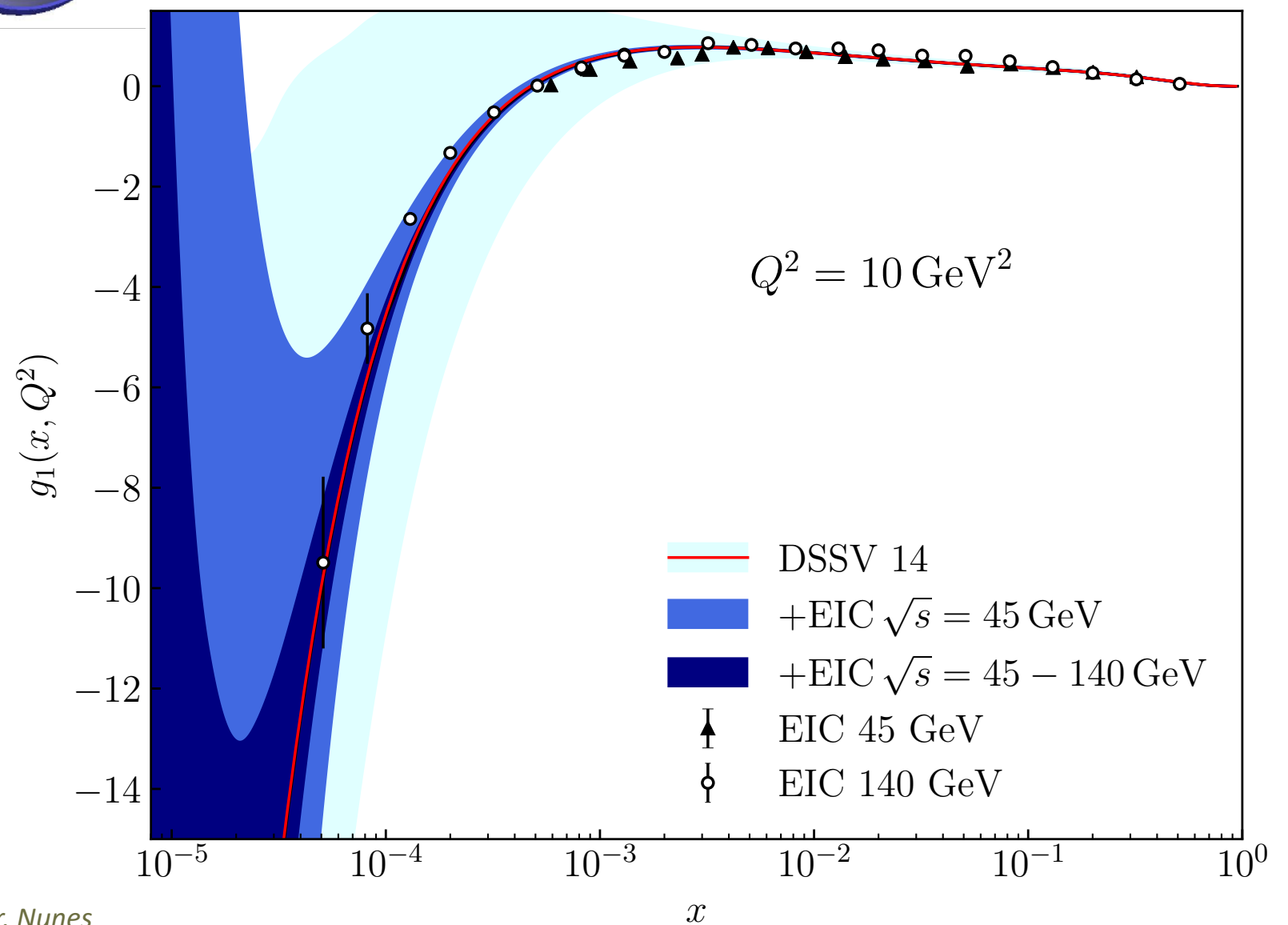
Proton spin



$$\frac{1}{2} \left[\frac{d^2\sigma^{\rightarrow\rightarrow}}{dx dQ^2} - \frac{d^2\sigma^{\rightarrow\leftarrow}}{dx dQ^2} \right] \simeq \frac{4\pi\alpha^2}{Q^4} y(2-y) g_1(x, Q^2)$$

Current **uncertainties** for g_1 as a function of x for fixed Q^2

EIC projections leads to greatly reduced **uncertainties**



Borsa, Lucero, Sassot, Aschenauer, Nunes

What is the origin of mass ?

Standard model of particle physics: leptons, quarks, bosons

mass →	$\approx 2.3 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 173.07 \text{ GeV}/c^2$	0	$\approx 126 \text{ GeV}/c^2$
charge →	$2/3$	$2/3$	$2/3$	0	0
spin →	$1/2$	$1/2$	$1/2$	1	0
	u up	c charm	t top	g gluon	H Higgs boson
QUARKS	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
	$-1/3$	$-1/3$	$-1/3$	0	
	$1/2$	$1/2$	$1/2$	1	
	d down	s strange	b bottom	γ photon	
LEPTONS	$0.511 \text{ MeV}/c^2$	$105.7 \text{ MeV}/c^2$	$1.777 \text{ GeV}/c^2$	$91.2 \text{ GeV}/c^2$	
	-1	-1	-1	0	
	$1/2$	$1/2$	$1/2$	1	
	e electron	μ muon	τ tau	Z Z boson	
	$< 2.2 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$80.4 \text{ GeV}/c^2$	
	0	0	0	± 1	
	$1/2$	$1/2$	$1/2$	1	
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
					GAUGE BOSONS

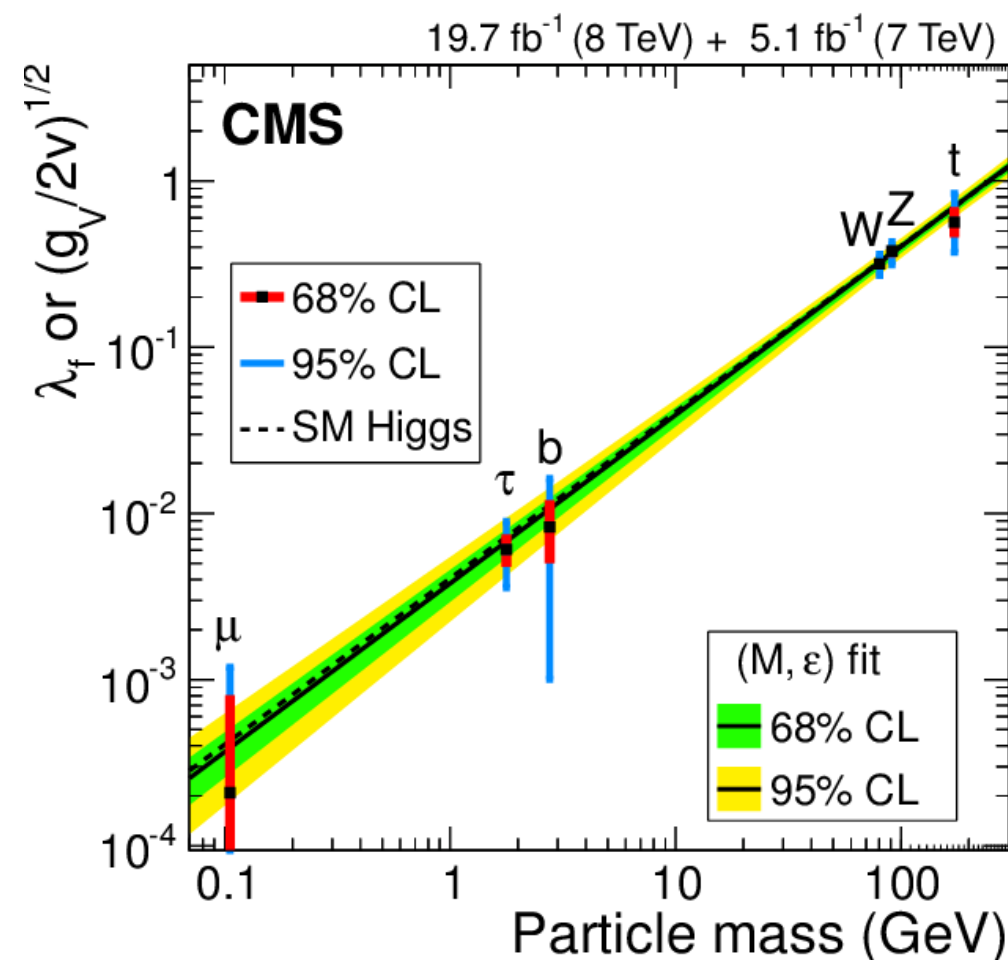
Source: Wikipedia

Higgs mechanism

Higgs, Brout, Englert

Higgs mechanism with spontaneous symmetry breaking responsible for the masses of W, Z, electron, muon, tau, quarks

Generation of elementary masses via interactions with Higgs field.



Coupling of Higgs vs mass

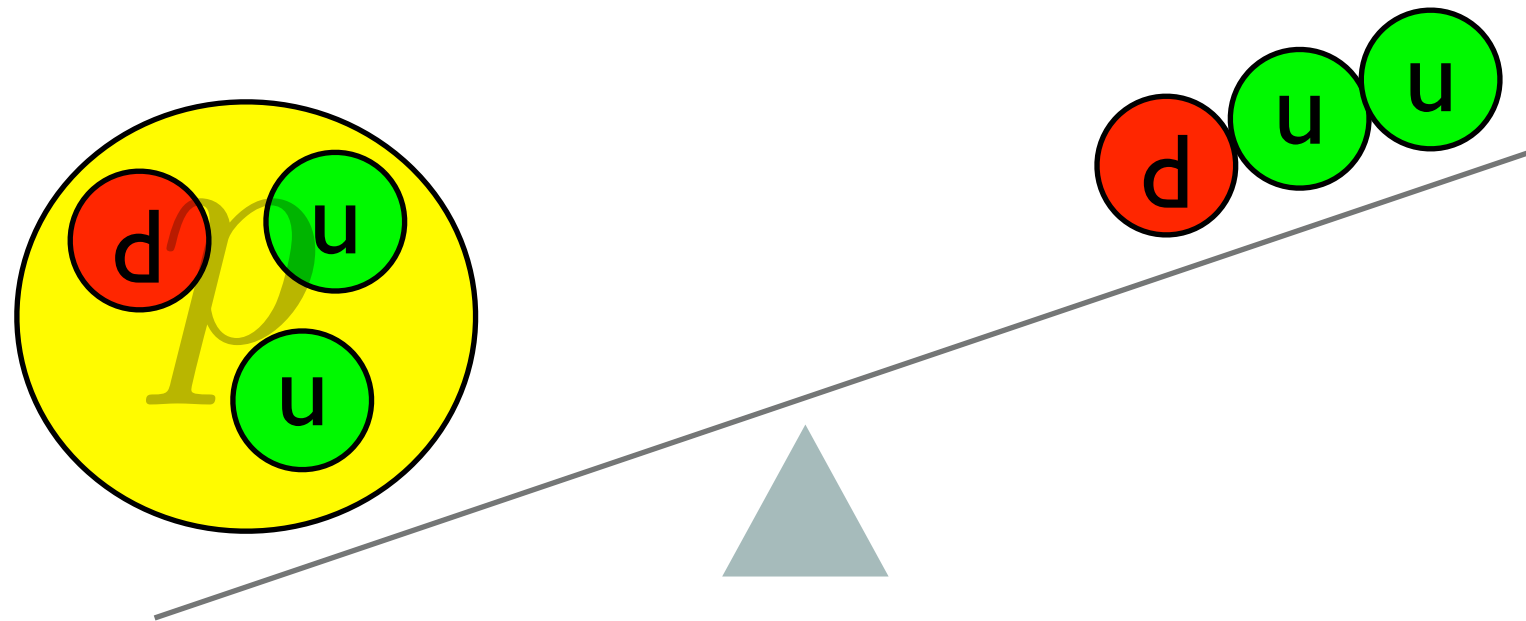
Mass of the proton

Mass of proton

$$m_p = 938.272 \text{ MeV}/c^2$$

Masses of quarks in the proton

$$m_u + m_u + m_d \simeq 10 \text{ MeV}/c^2$$



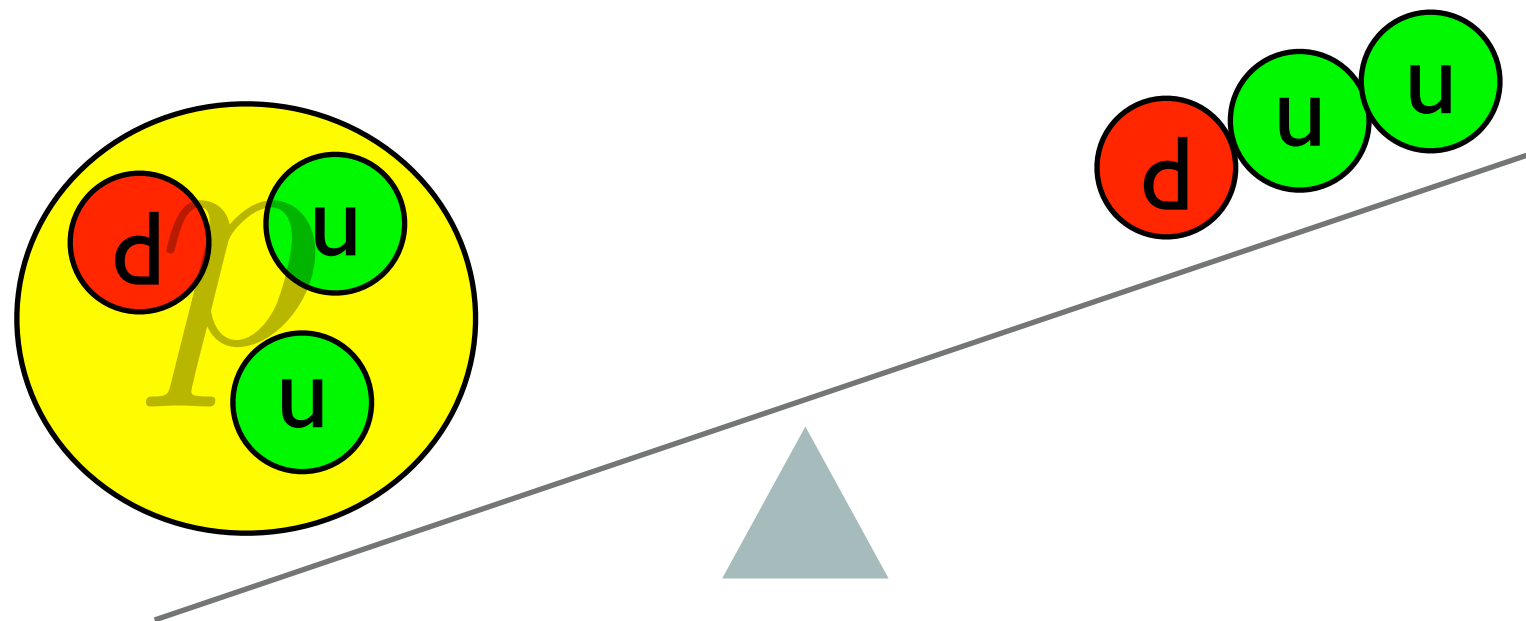
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Sum of masses of quarks is only about 1% of the mass of the proton. Higgs mechanism is not a dominant mechanism for the generation of the mass of the proton.

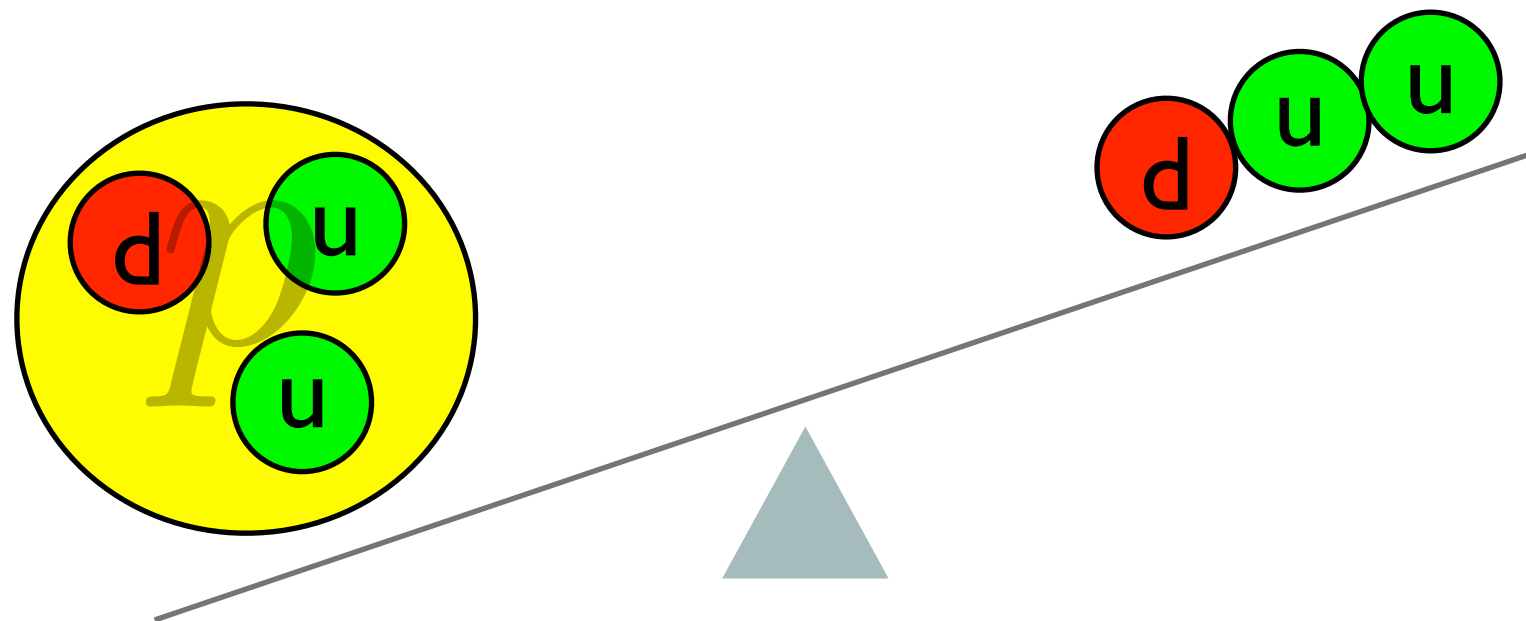
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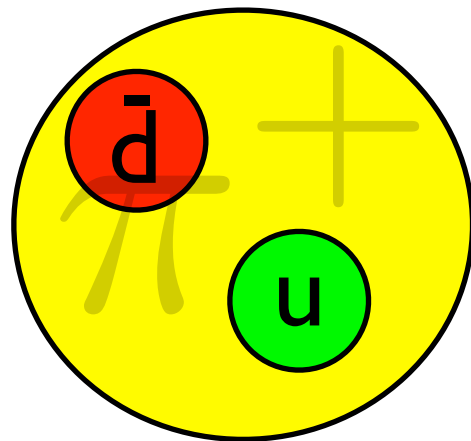


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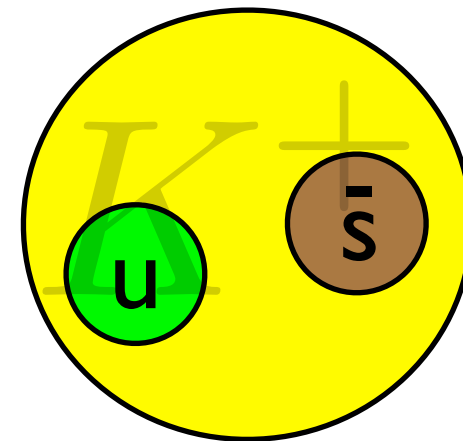
Proton and neutron mass, and hence most (in 99%, or so) of the visible mass in the Universe is generated by strong force, by QCD interaction.

How EIC will explore mass generation?

Example:



Pions: Higgs mechanism not contributing much since only down and up quarks

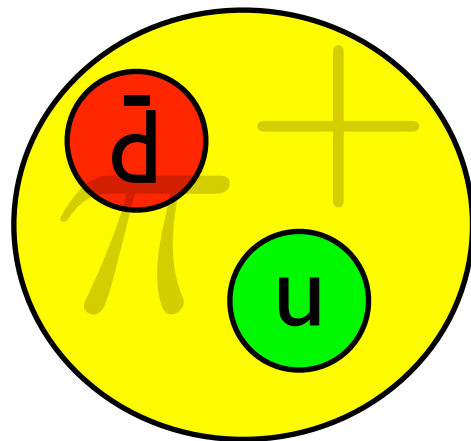


Kaons: Higgs mechanism contributing more to the mass, since strange quark is heavier

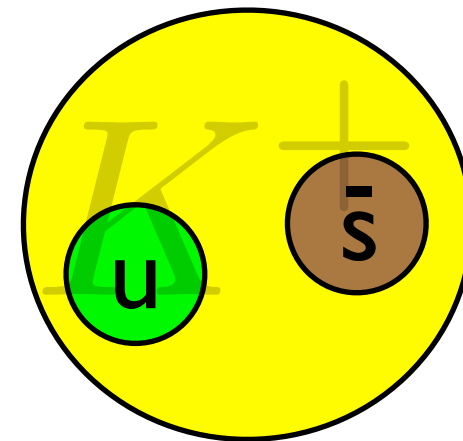
Comparing pion and kaon structure functions and form factors in wide range of scales

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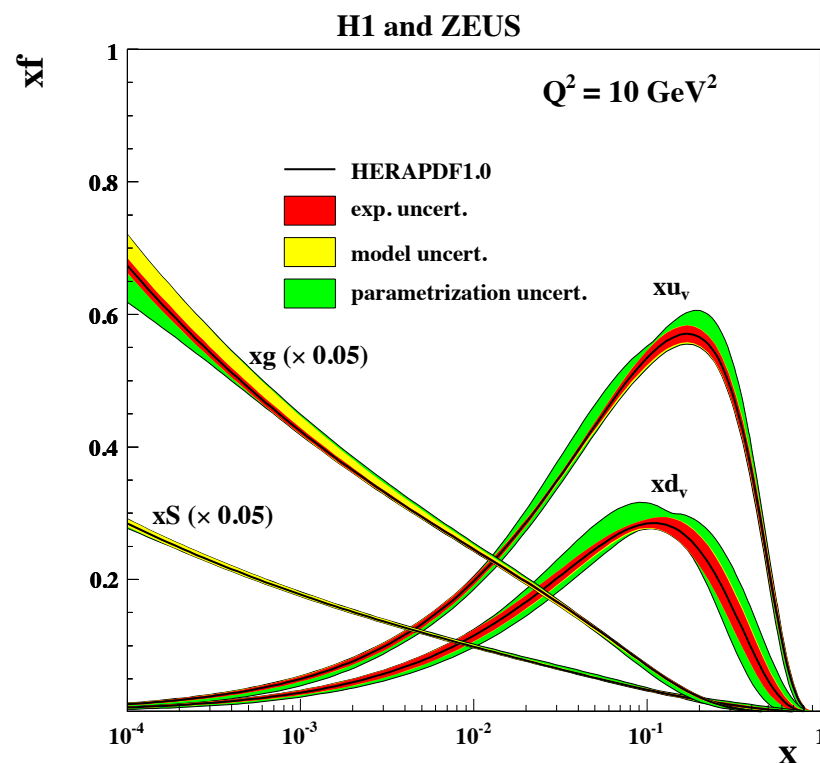


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Comparing pion and kaon structure functions and form factors in wide range of scales

Precise measurements of the J/ψ production in ep

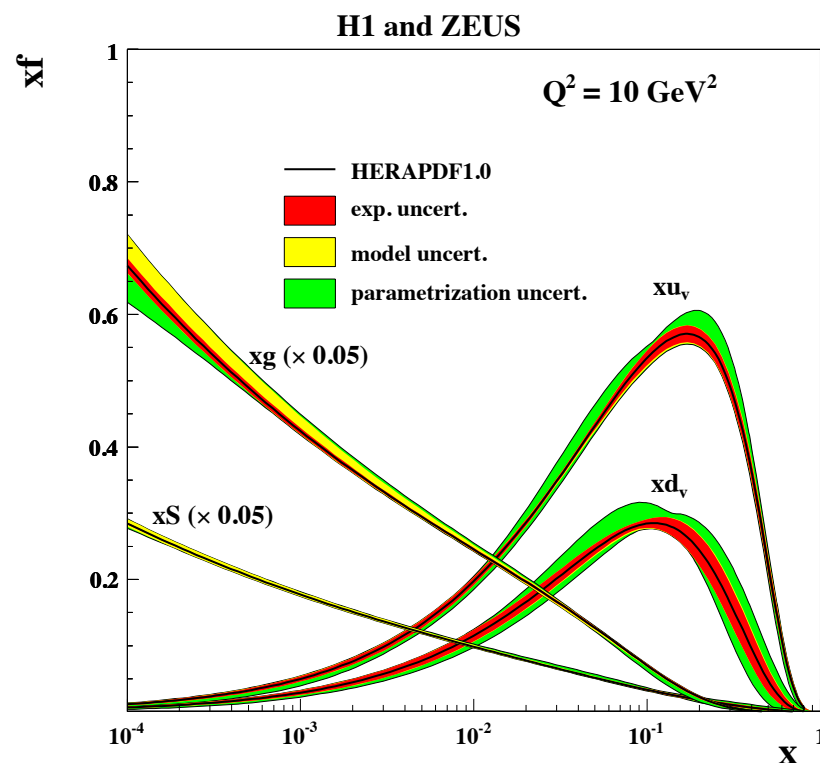
Imaging with EIC: nucleon / nuclear tomography



Parton distributions tell us about the **integrated** densities of partons in the hadron.

They only have information about x distribution

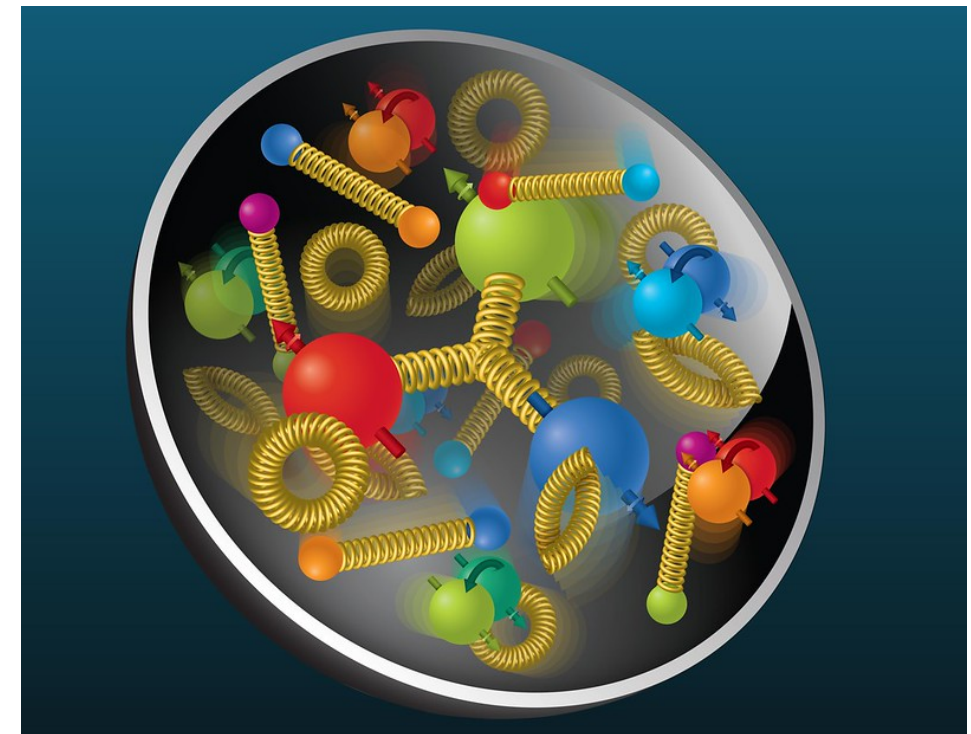
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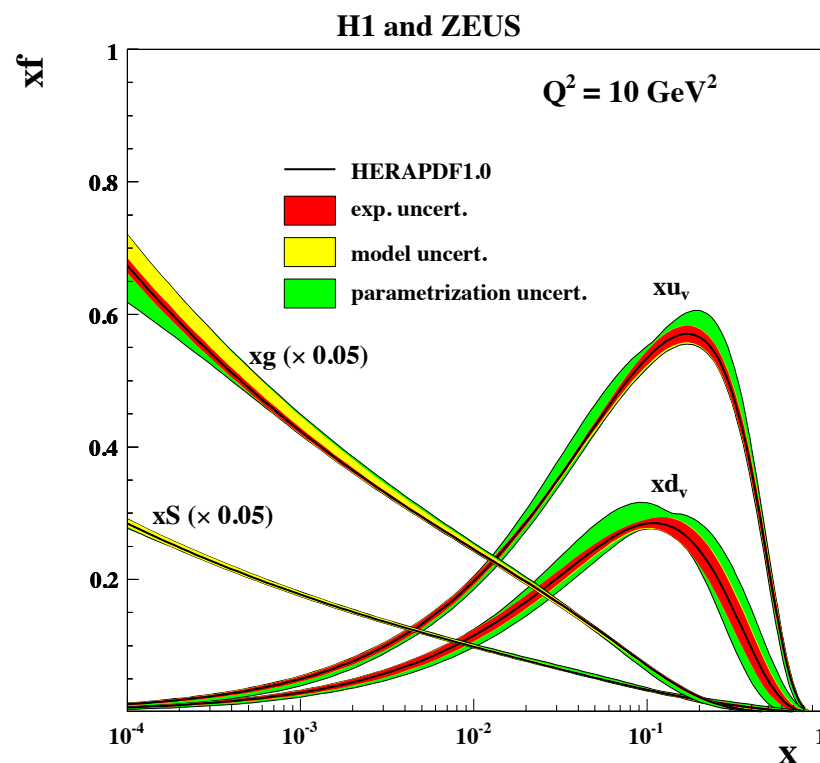
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What about the spatial distribution?



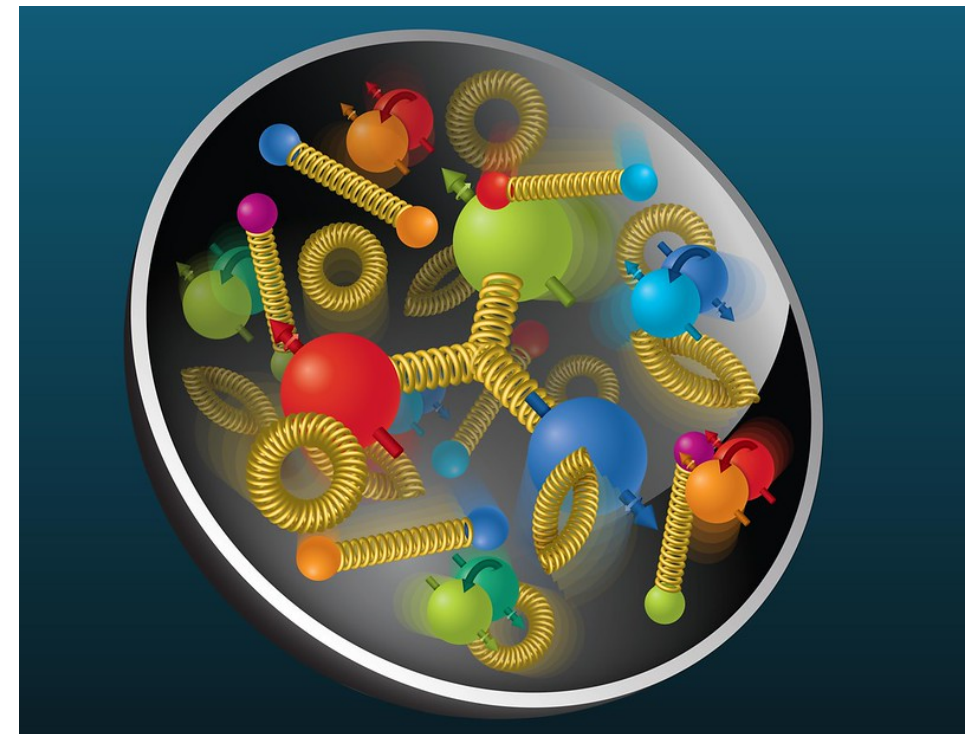
Imaging with EIC: nucleon / nuclear tomography



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They only have information about x distribution

What about the spatial distribution?



Process that can tell us more shape: **diffraction**

Diffraction

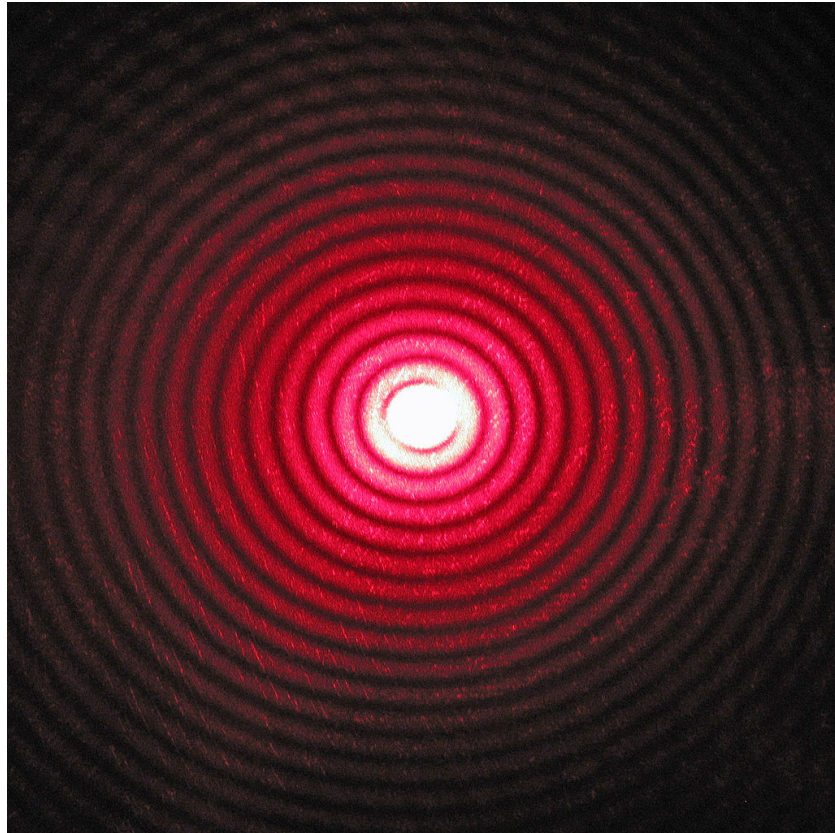
Diffraction : occurs when a wave (for example light) encounters an obstacle or an opening.



Source: Wikipedia
Author: Verbcatcher

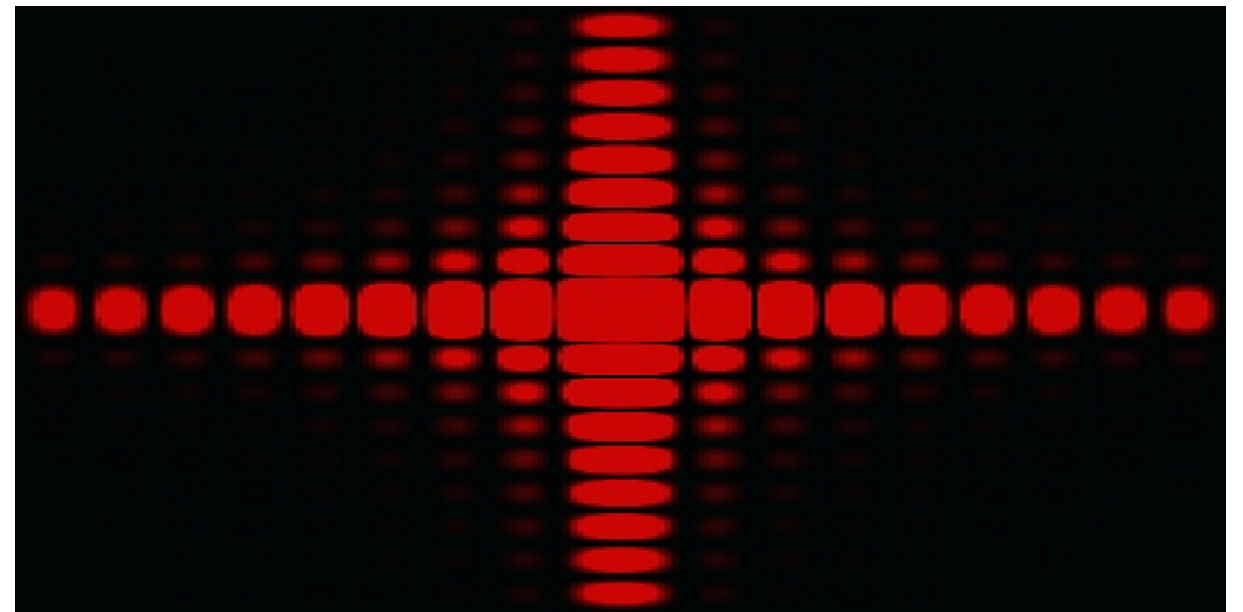
Water waves passing through small entrance

Diffraction patterns



Source: Wikipedia
Author: Wisky

Circular aperture



Source: Wikipedia
Author: Epzcaw

Rectangular aperture

The diffraction pattern (far away from obstacle) is a Fourier transform of the apertured field.

Diffraction pattern

Diffraction : occurs when a wave (for example light) encounters an obstacle or an opening.

Diffraction pattern (far away from obstacle) is a Fourier transform of the apertured field.

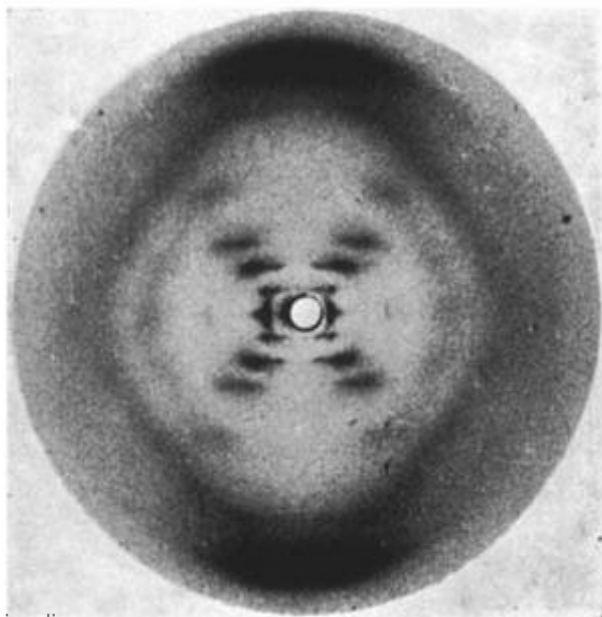
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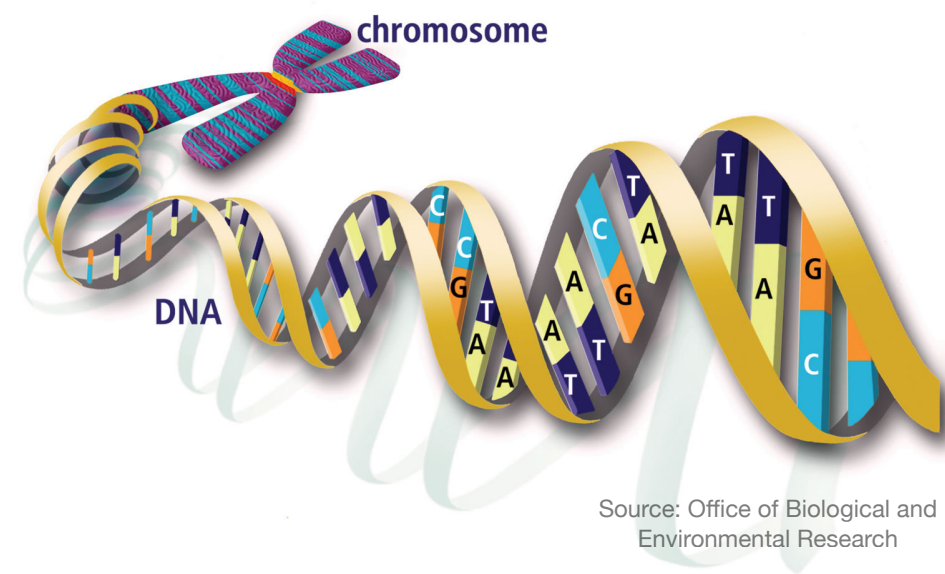
Photo 51

Gosling-Franklin



Source: Wikipedia

Watson-Crick



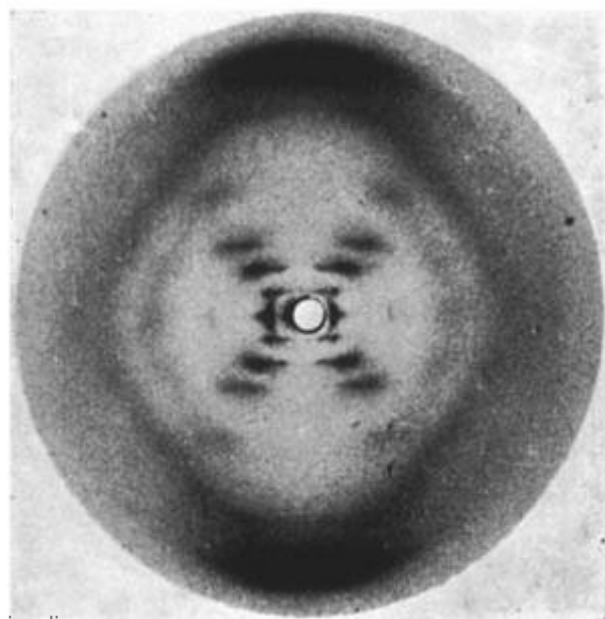
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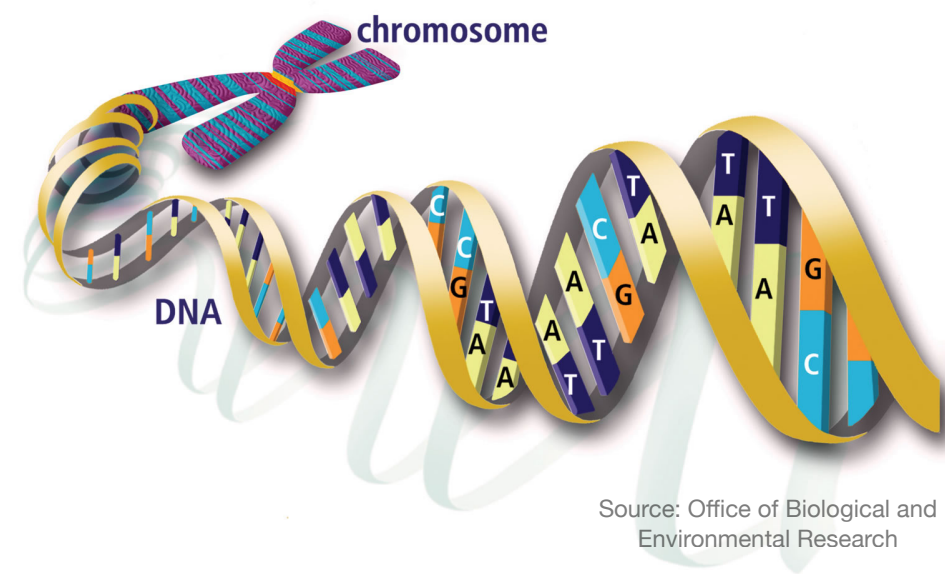
Photo 51

Gosling-Franklin



Source: Wikipedia

Watson-Crick



Diffraction can provide **very** detailed information about the structure of an object.

The object cannot be destroyed in this process.

Inclusive DIS vs diffraction

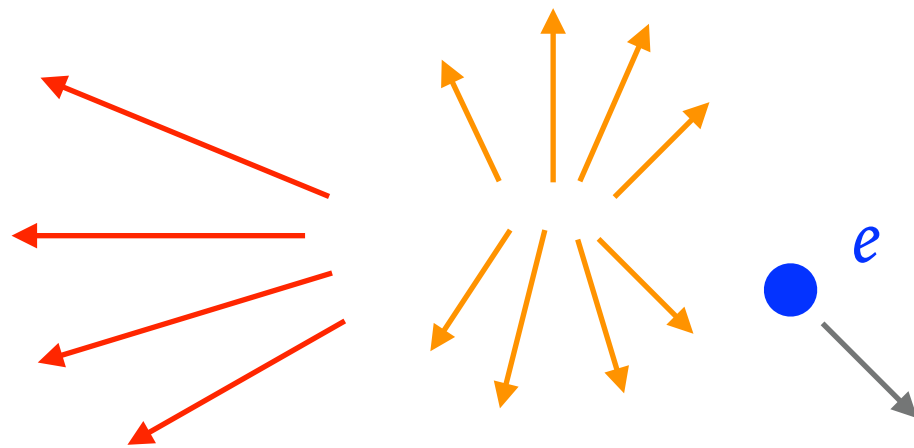
Inclusive DIS vs diffraction

Electron - hadron(nucleus) scattering (like at EIC)



Inclusive DIS vs diffraction

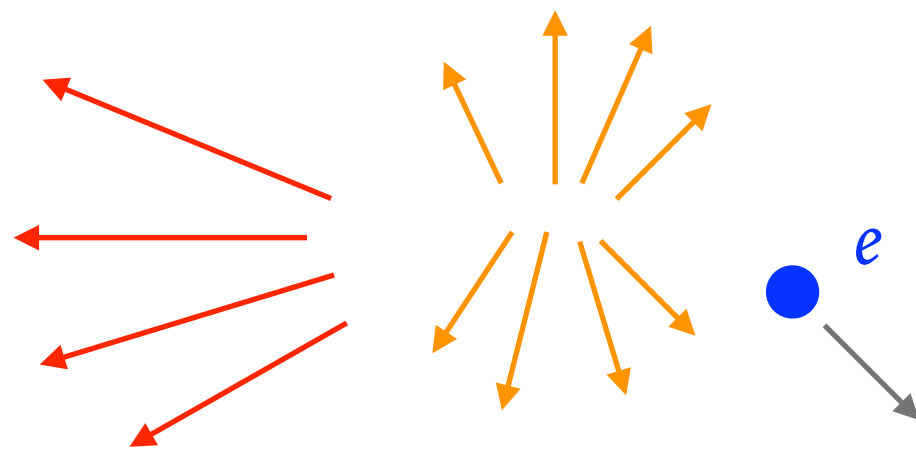
Electron - hadron(nucleus) scattering (like at EIC)



Proton is fragmented (inelastic process)

Inclusive DIS vs diffraction

Electron - hadron(nucleus) scattering (like at EIC)



Proton is fragmented (inelastic process)

lepton

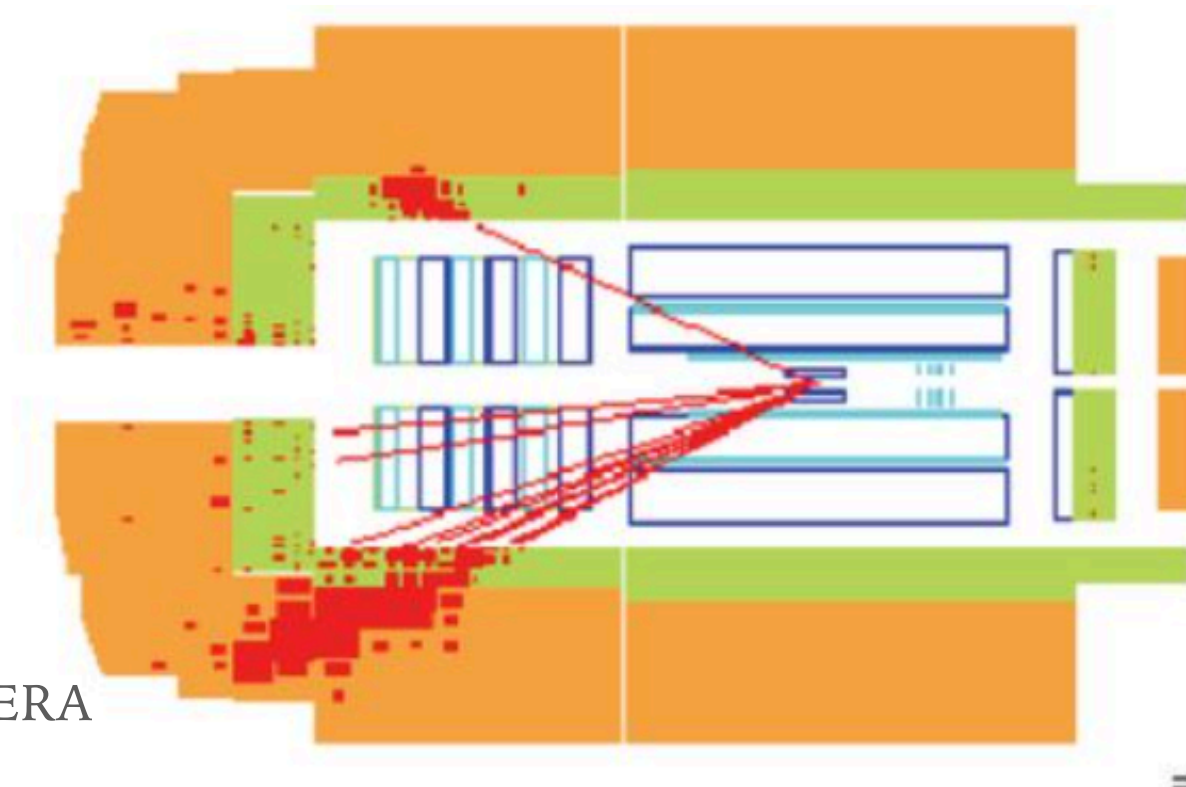


Image from HERA

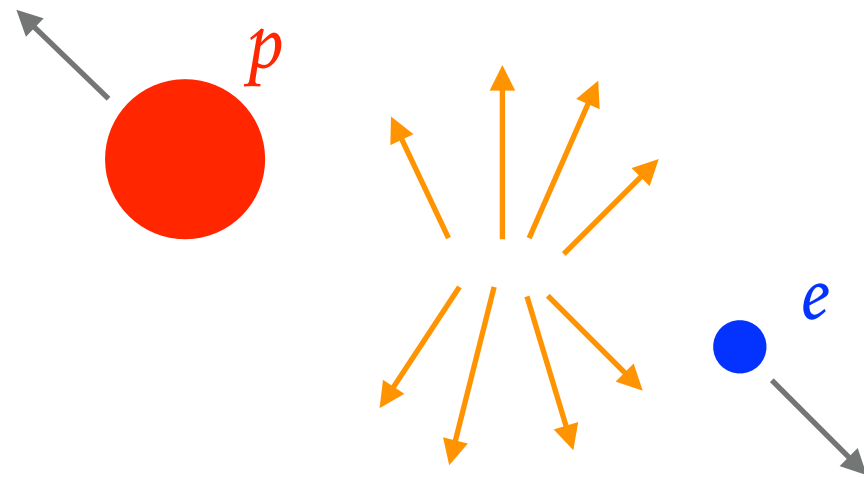
proton



Diffraction event

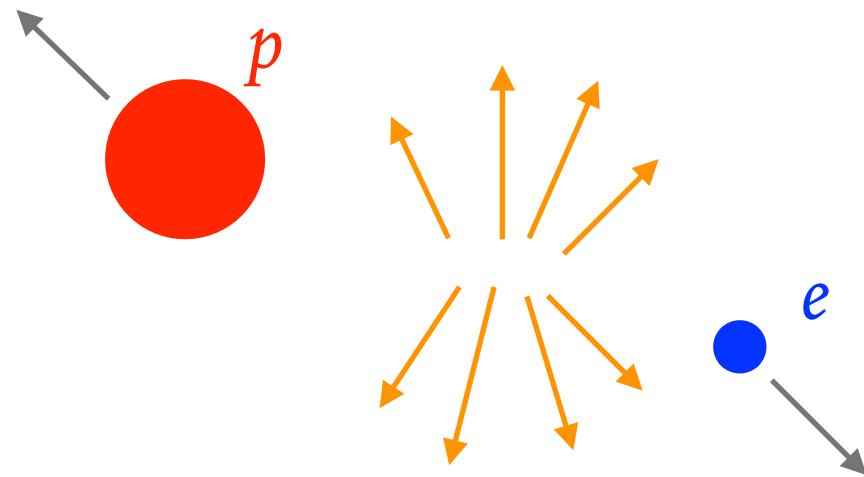
Diffractive event

Electron - hadron(nucleus) scattering (like at EIC)



Diffractive event

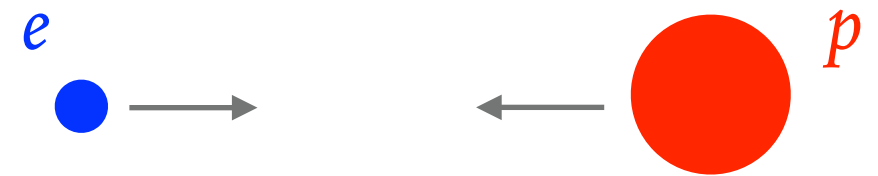
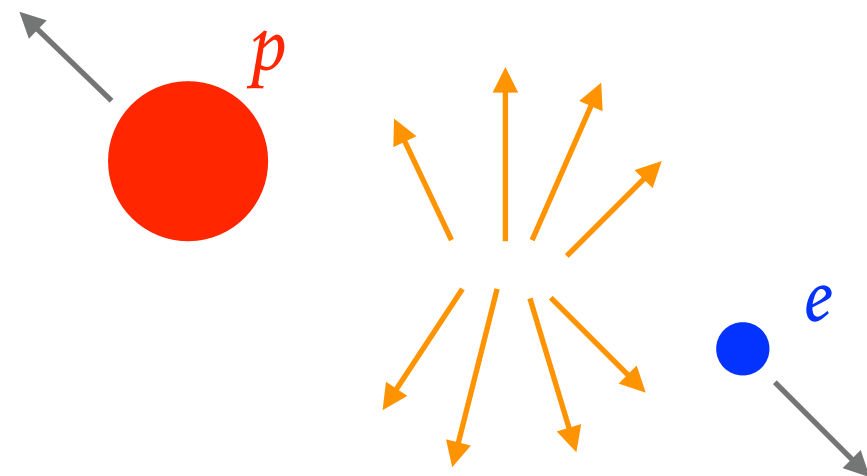
Electron - hadron(nucleus) scattering (like at EIC)



Target (proton) is intact despite
undergoing violent collision
Possible hadronic activity in central region

Diffractive event

Electron - hadron(nucleus) scattering (like at EIC)



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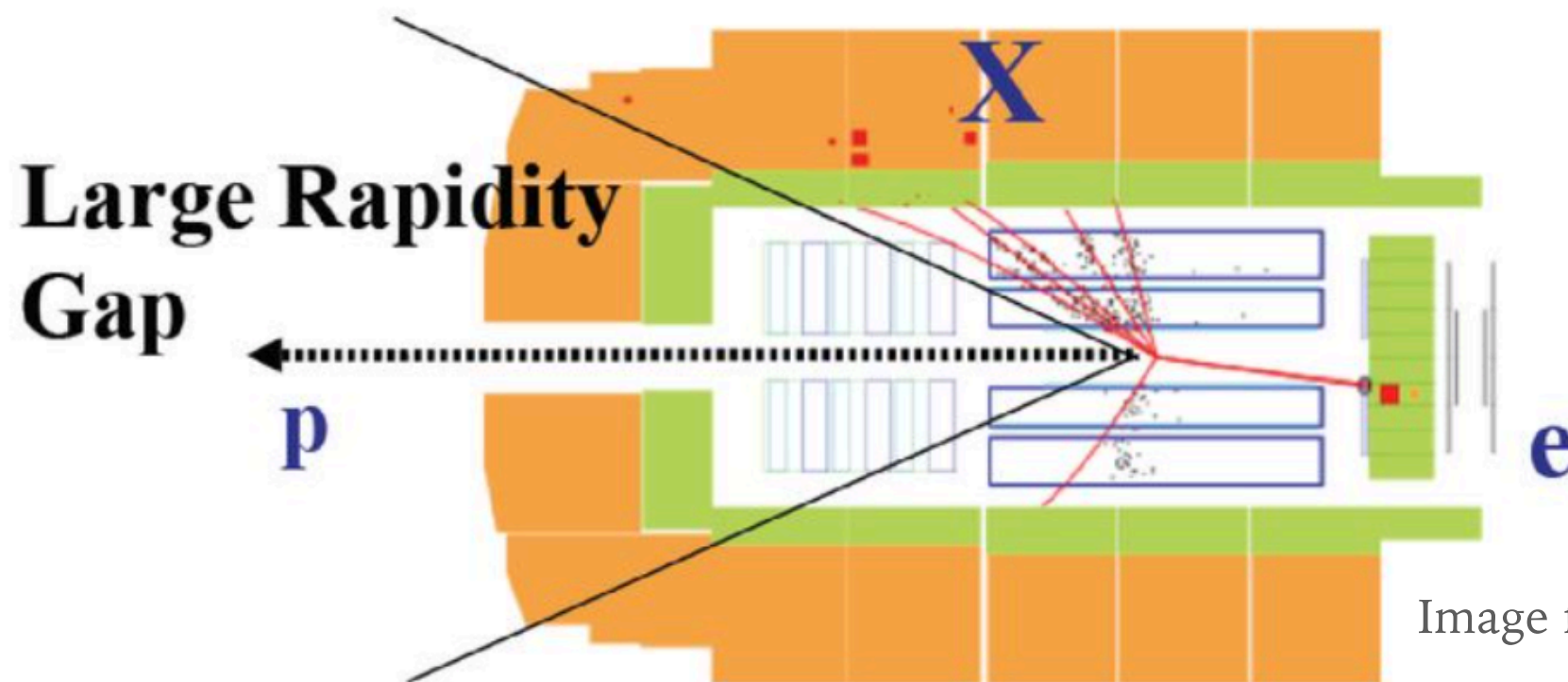


Image from HERA

At HERA collider about 10% events were diffractive

Diffractive exclusive production at EIC: proton imaging

Diffractive **exclusive** vector meson production, for example

J/ψ

Diffractive exclusive production at EIC: proton imaging

Diffractive **exclusive** vector meson production, for example

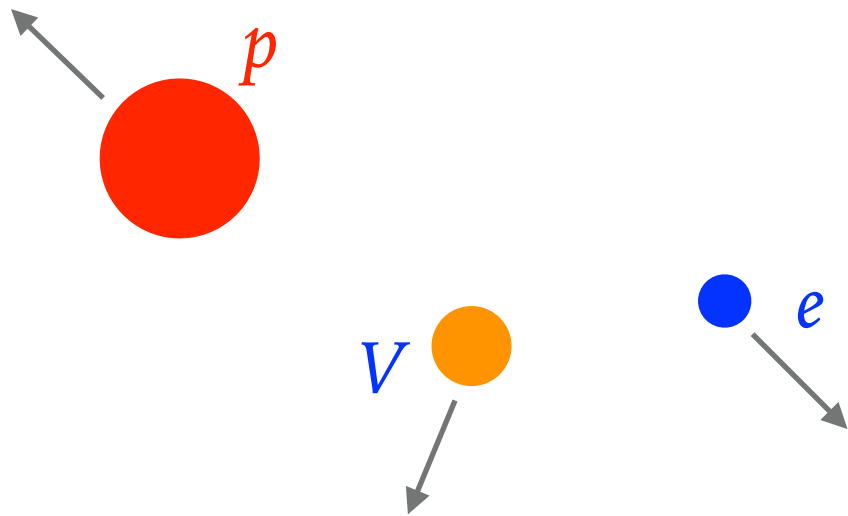
J/ψ



Diffractive exclusive production at EIC: proton imaging

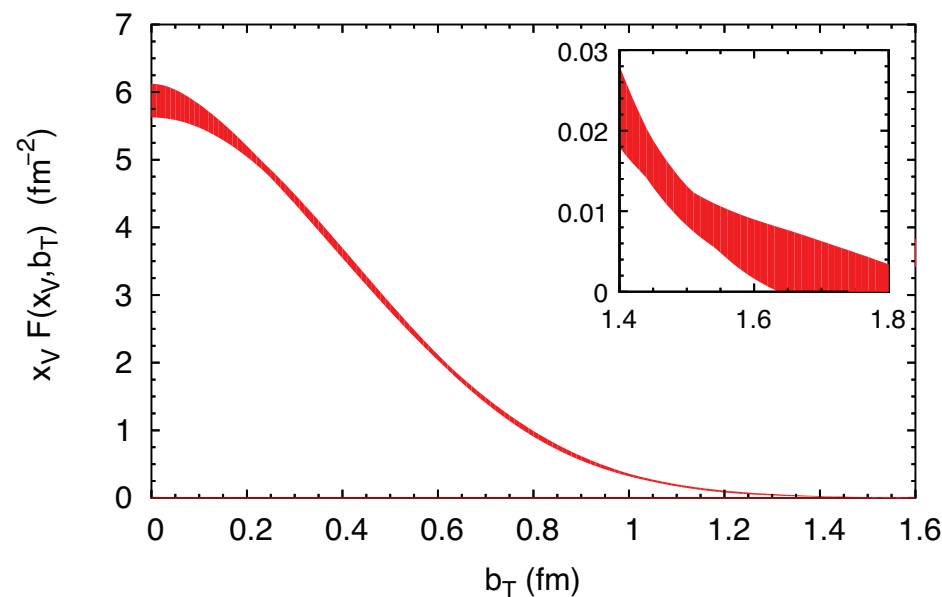
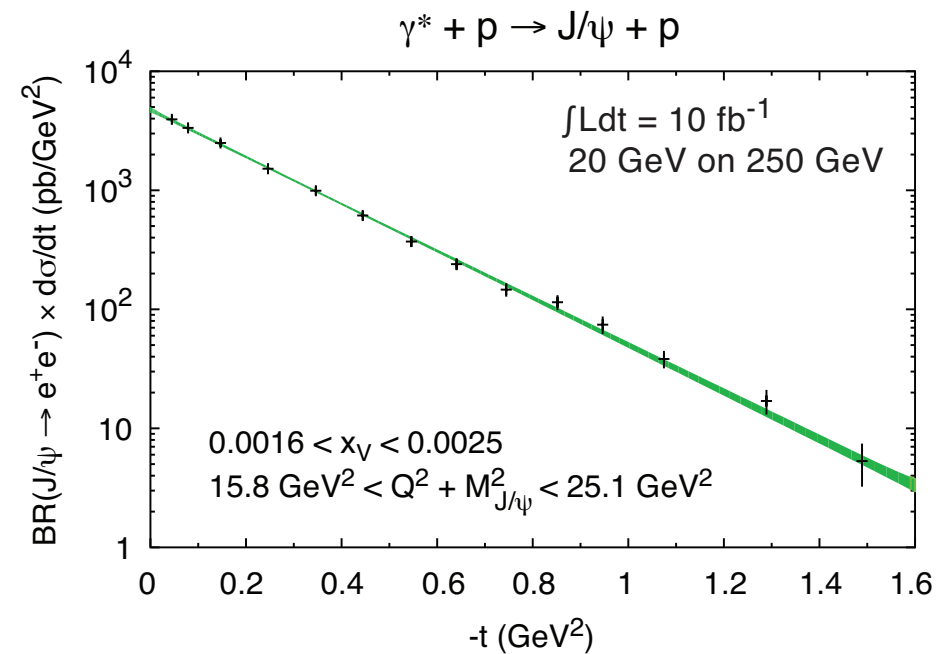
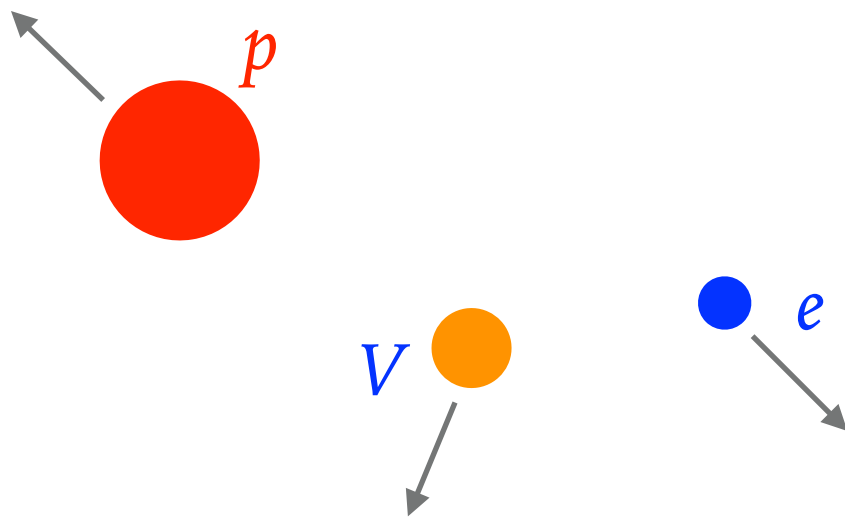
Diffractive **exclusive** vector meson production, for example

J/ψ



Diffractive exclusive production at EIC: proton imaging

Diffractive **exclusive** vector meson production, for example J/ψ

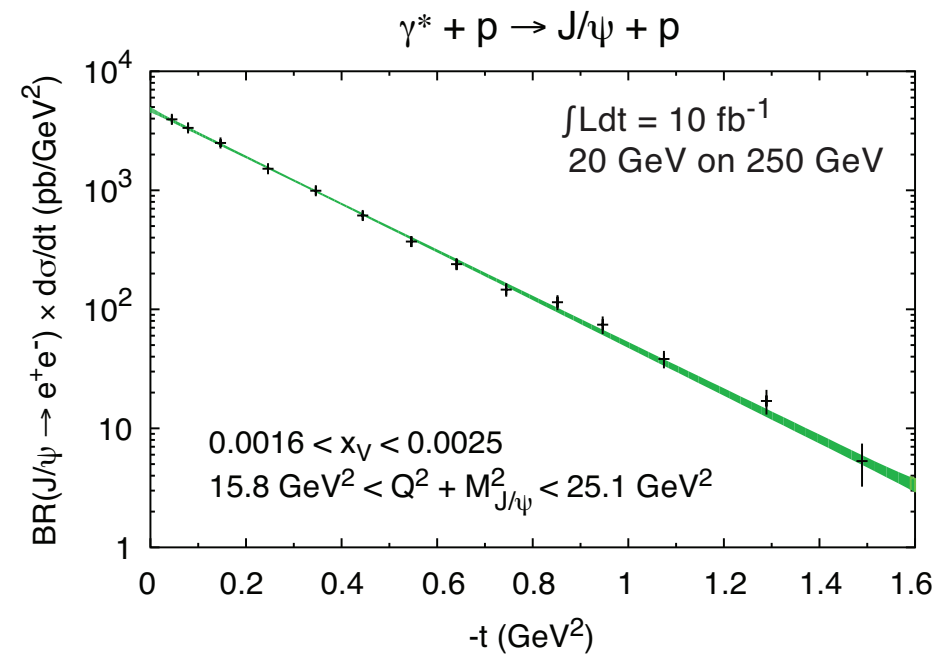
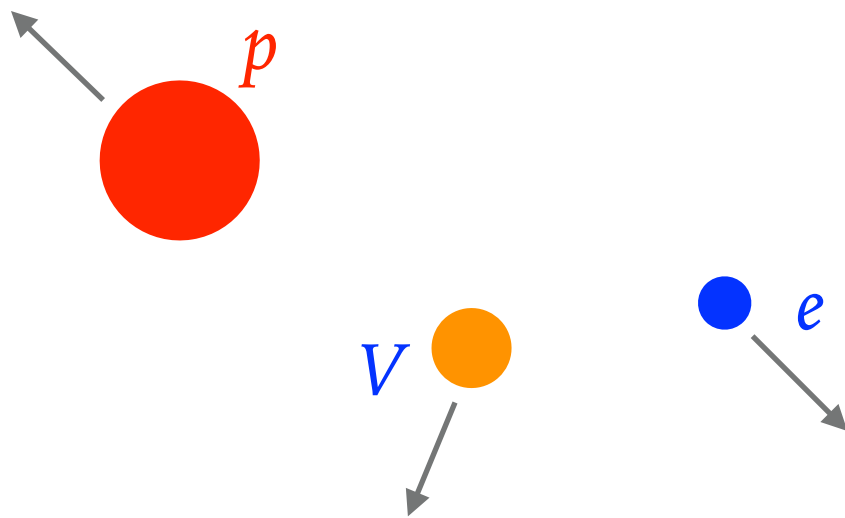


EIC, White paper

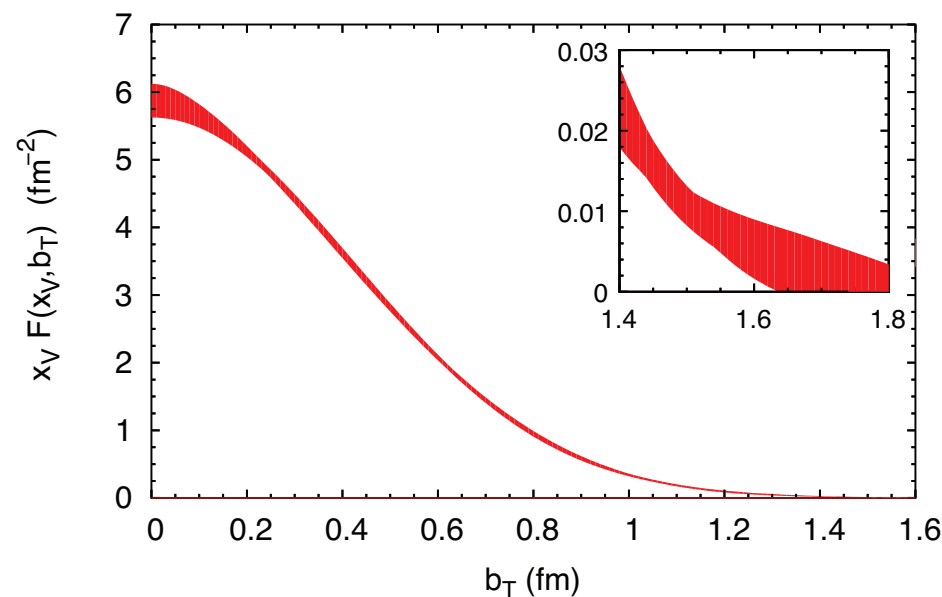
Diffractive exclusive production at EIC: proton imaging

Diffractive **exclusive** vector meson production, for example

J/ψ



Measured observable as a function of the momentum transfer (or scattering angle of the scattered proton)

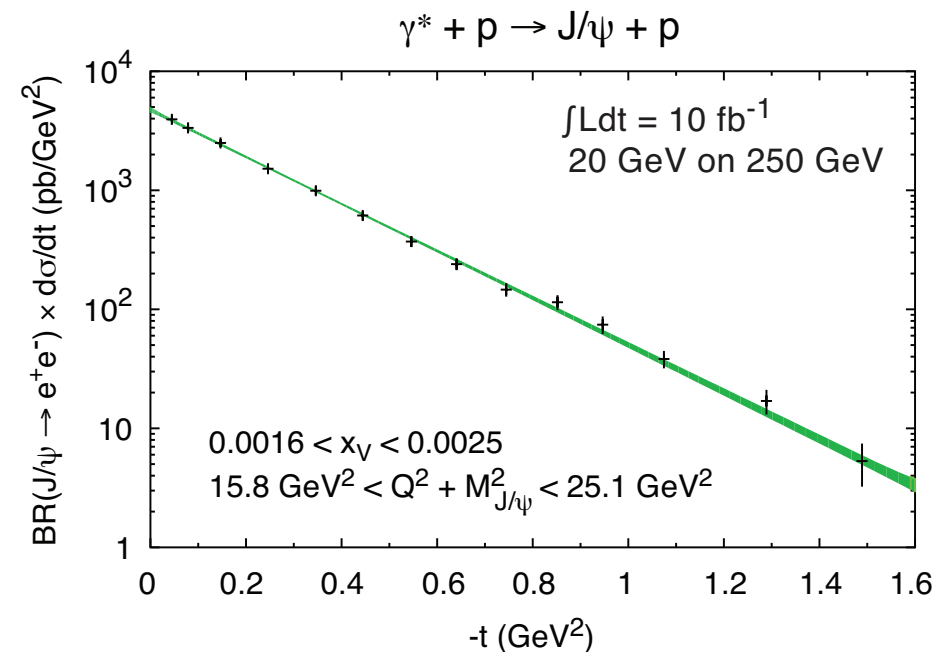
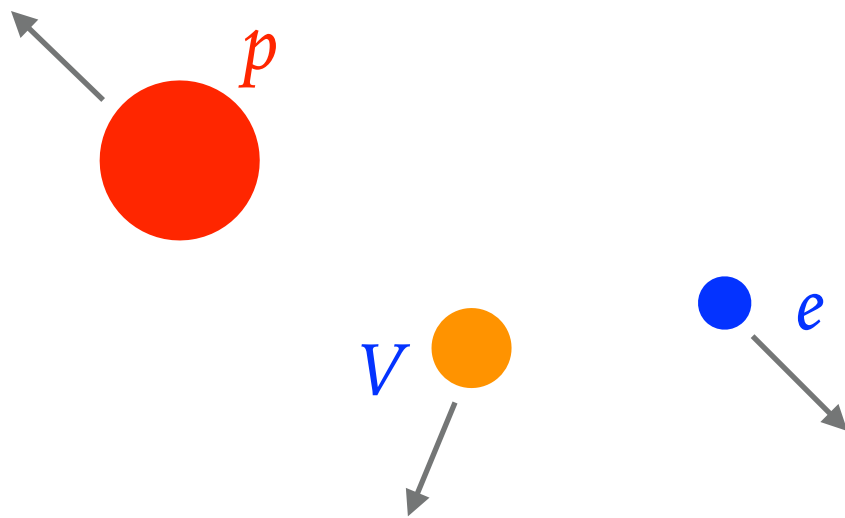


EIC, White paper

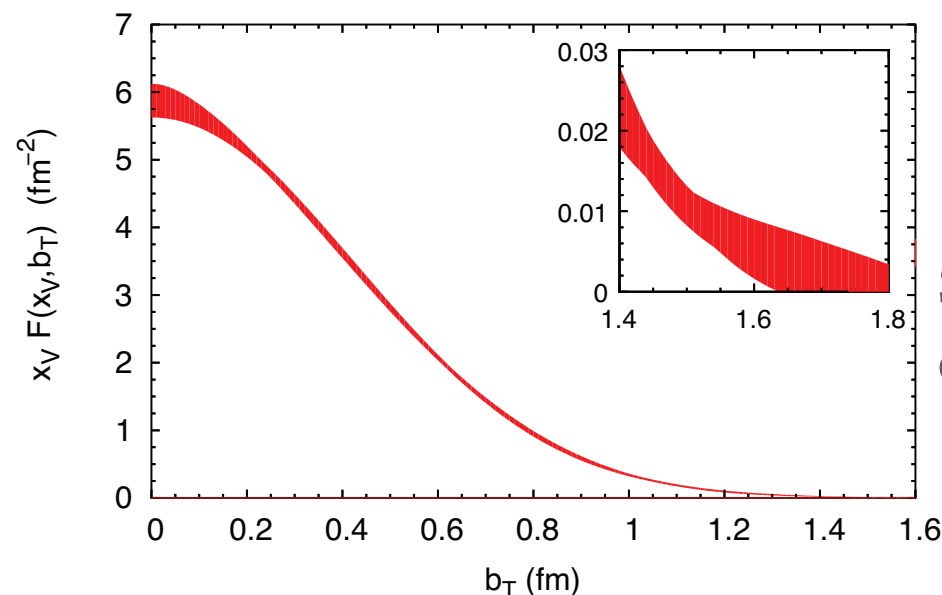
Diffractive exclusive production at EIC: proton imaging

Diffractive **exclusive** vector meson production, for example

J/ψ



Measured observable as a function of the momentum transfer (or scattering angle of the scattered proton)



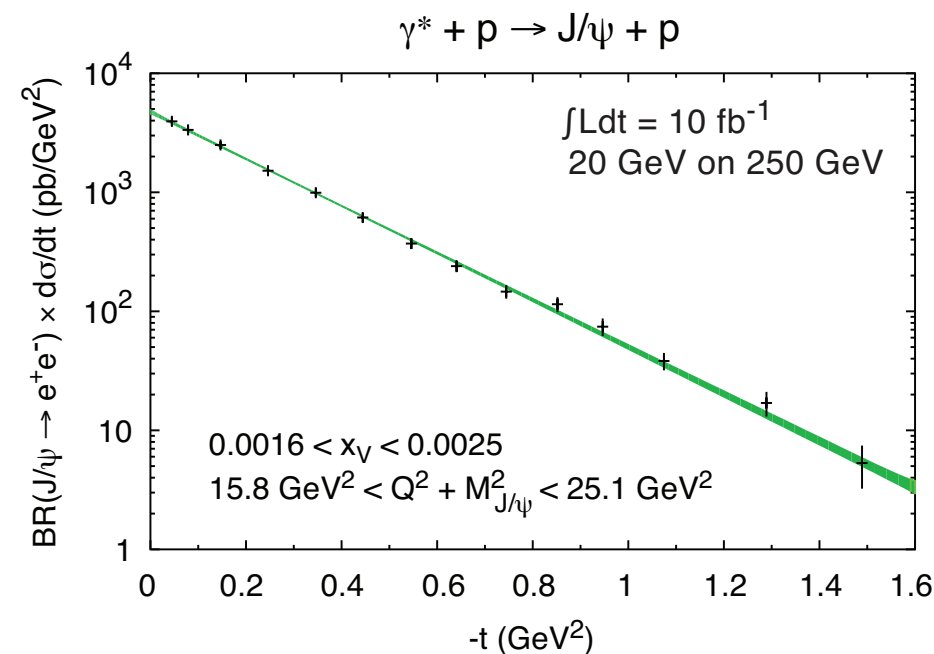
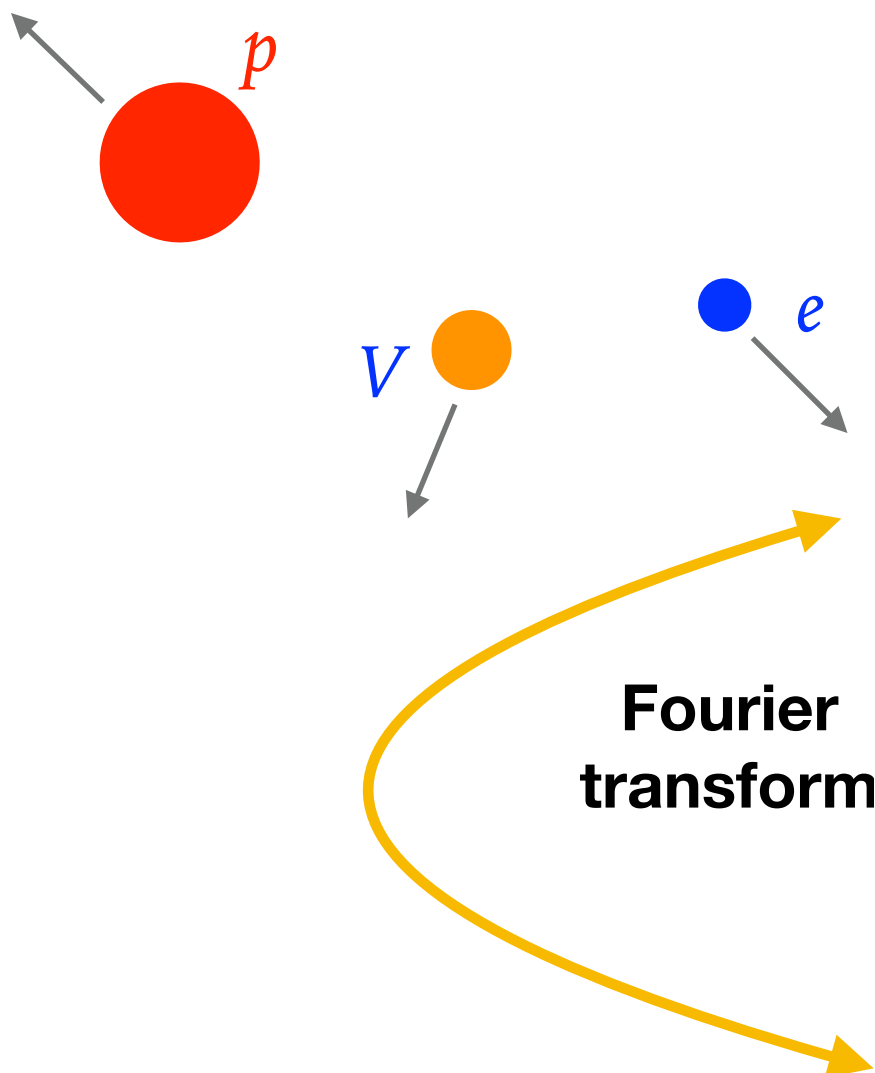
Spatial distribution of **gluon** density in the proton

EIC, White paper

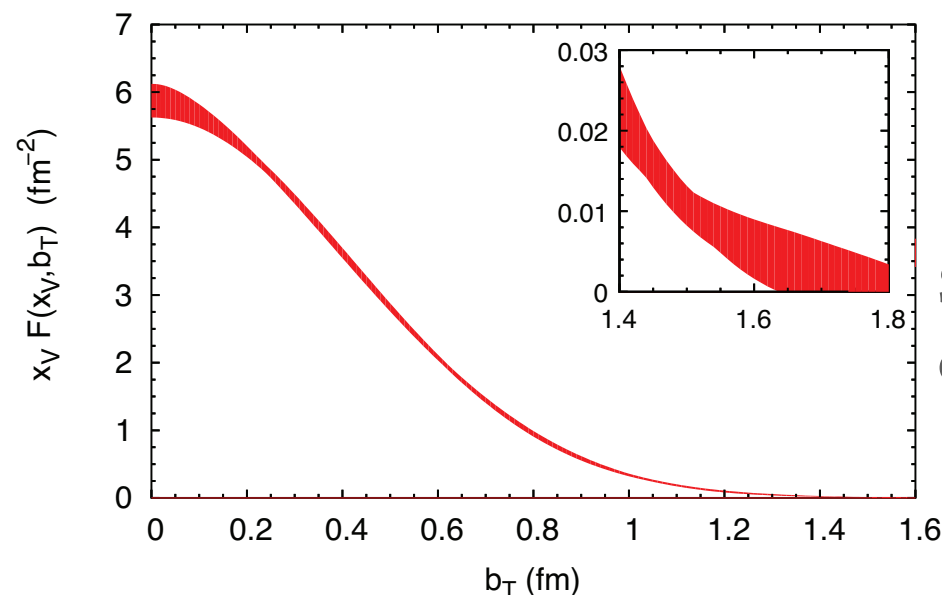
Diffractive exclusive production at EIC: proton imaging

Diffractive exclusive vector meson production, for example

J/ψ



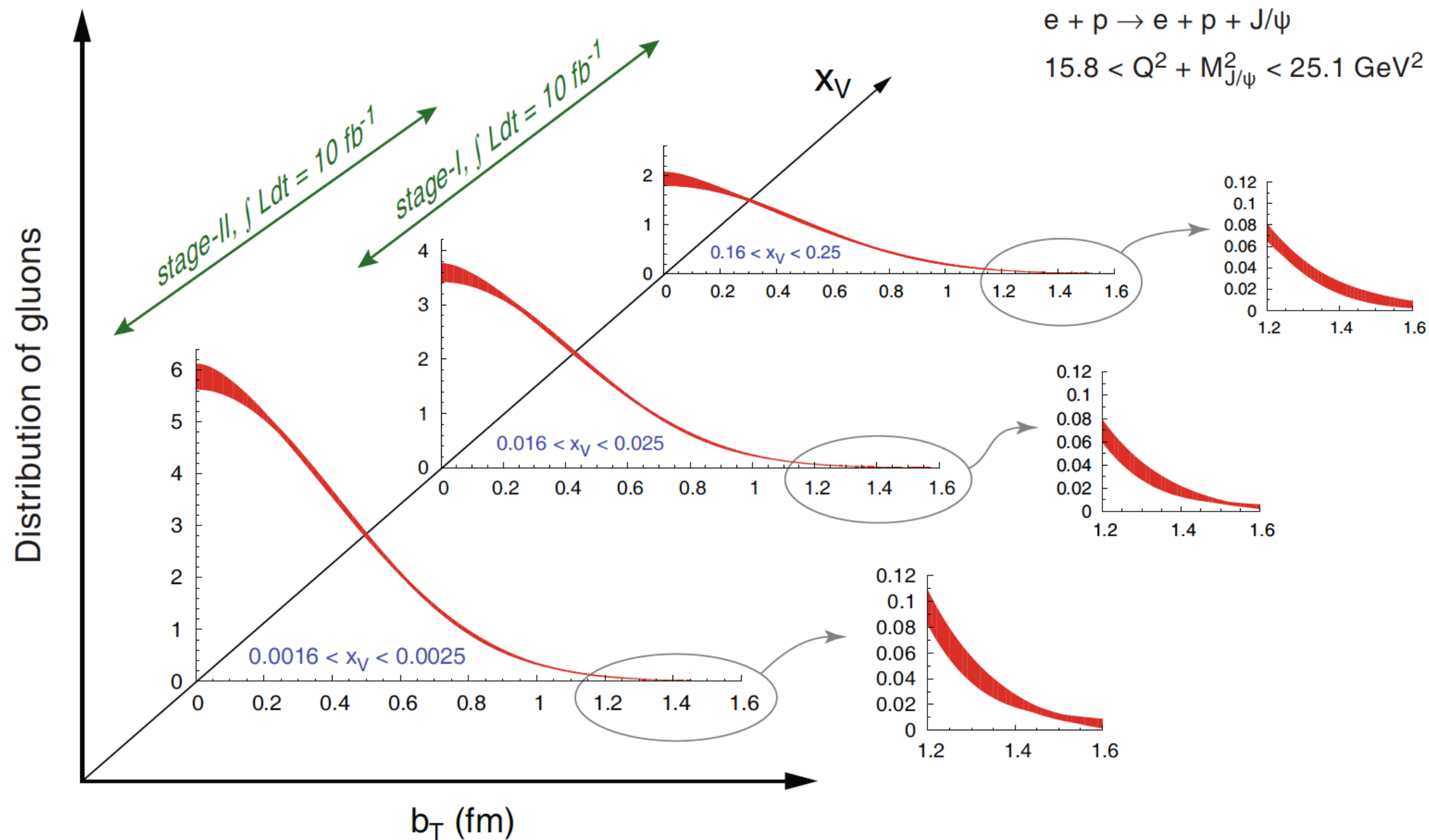
Measured observable as a function of the momentum transfer (or scattering angle of the scattered proton)



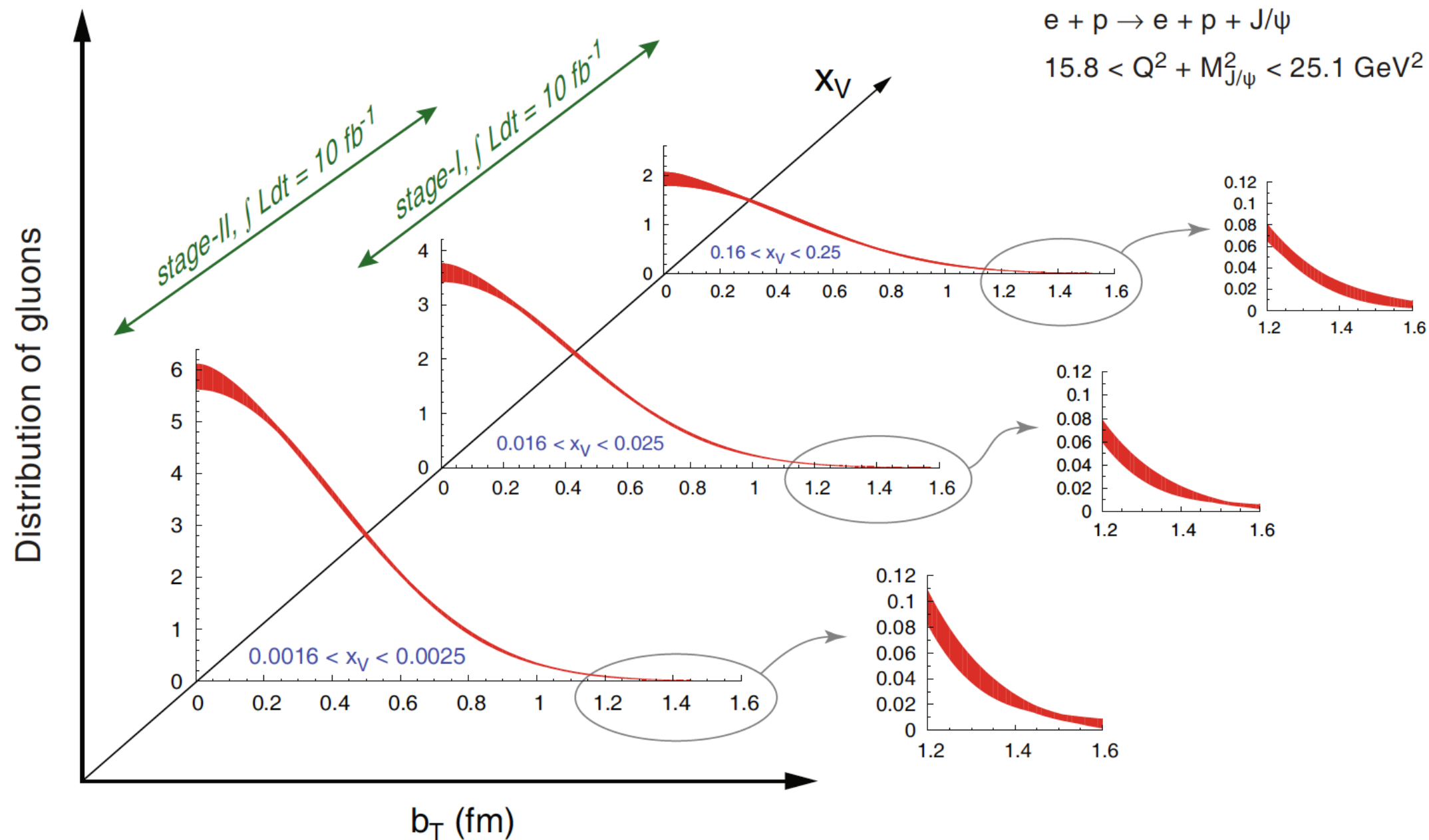
Spatial distribution of gluon density in the proton

EIC, White paper

Profile function from elastic vector meson production



Profile function from elastic vector meson production



Evolution of the spatial distribution of gluons with x

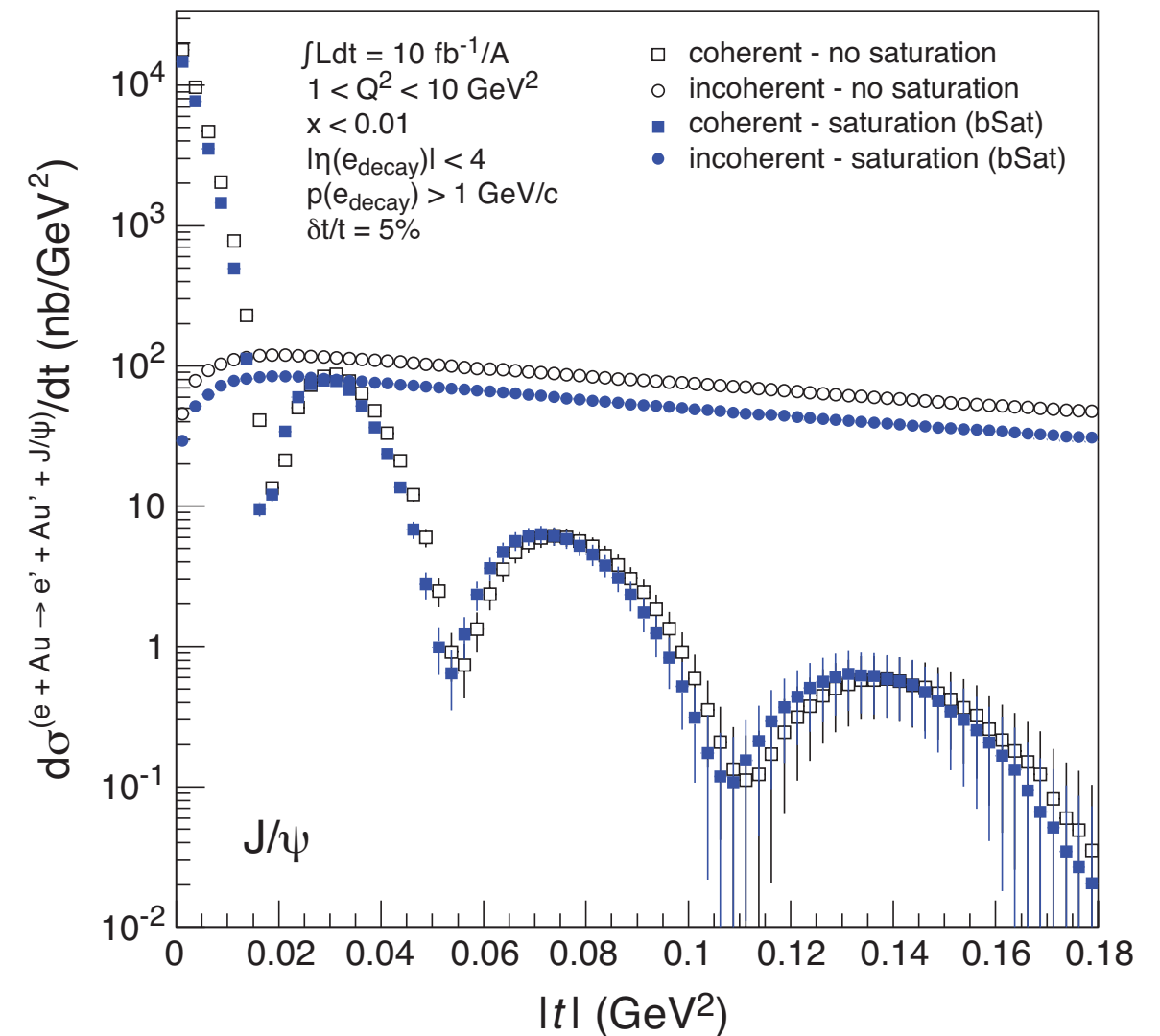
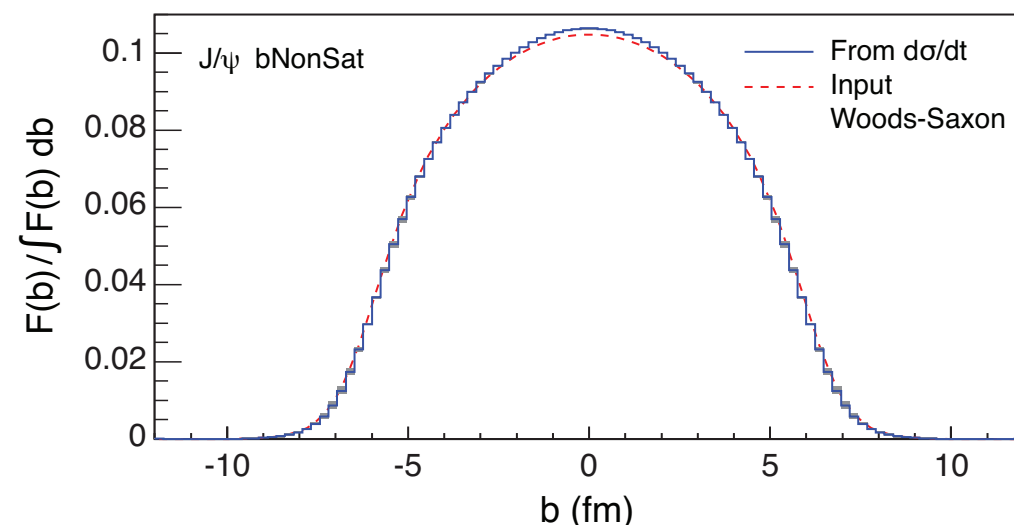
Elastic vector meson production at EIC : eA

EIC, White paper

Nuclear target: Au

$$e + Au \rightarrow e + Au + J/\psi$$

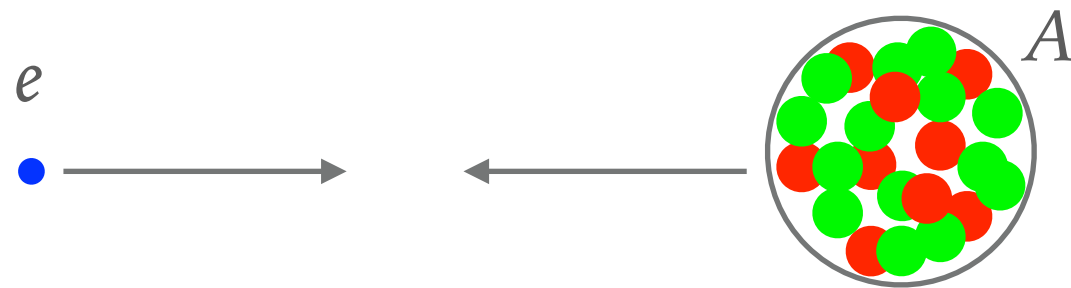
Characteristic 'dips' in t-distribution



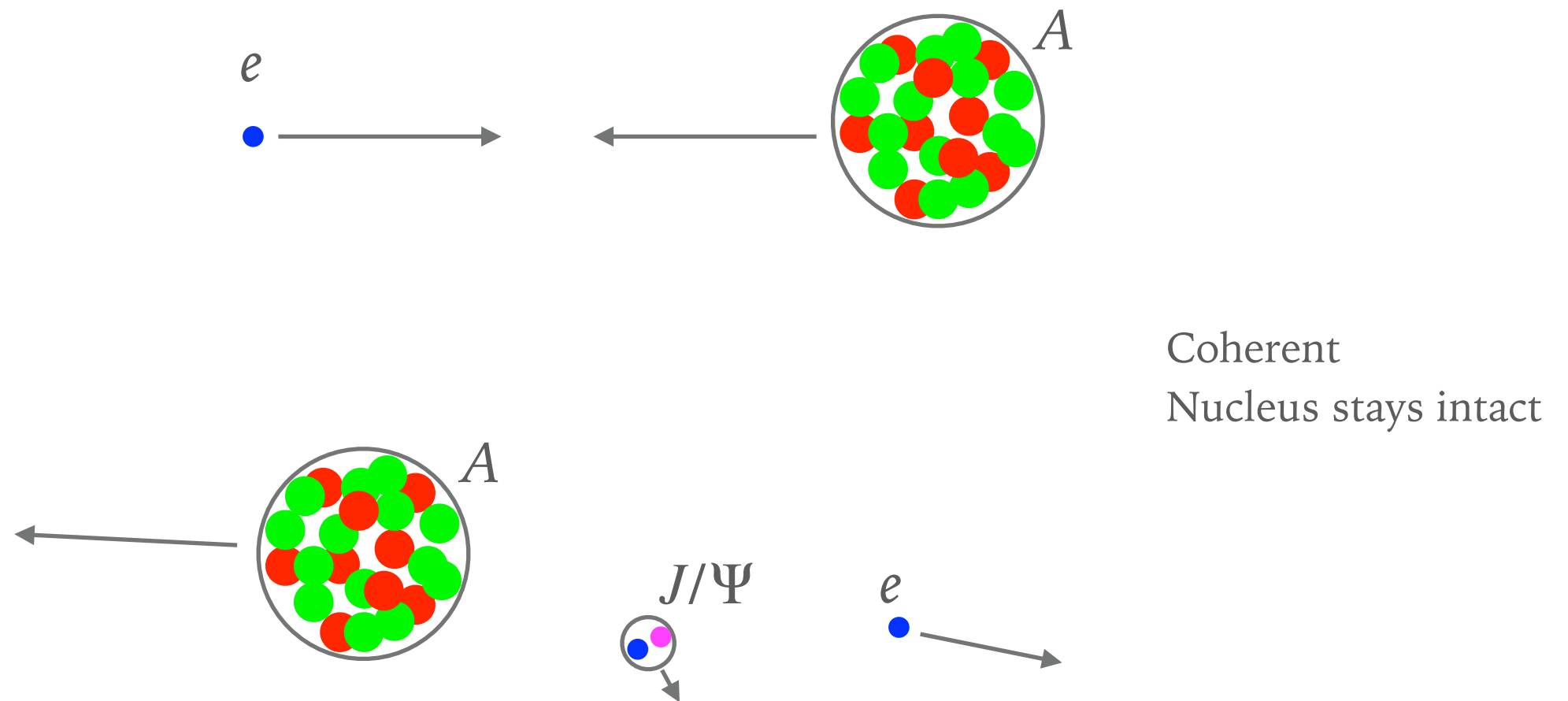
$$F(b) = \int_0^\infty \frac{q dq}{2\pi} J_0(qb) \sqrt{\frac{d\sigma_{\text{coherent}}}{dt}}$$

$$t = -q^2$$

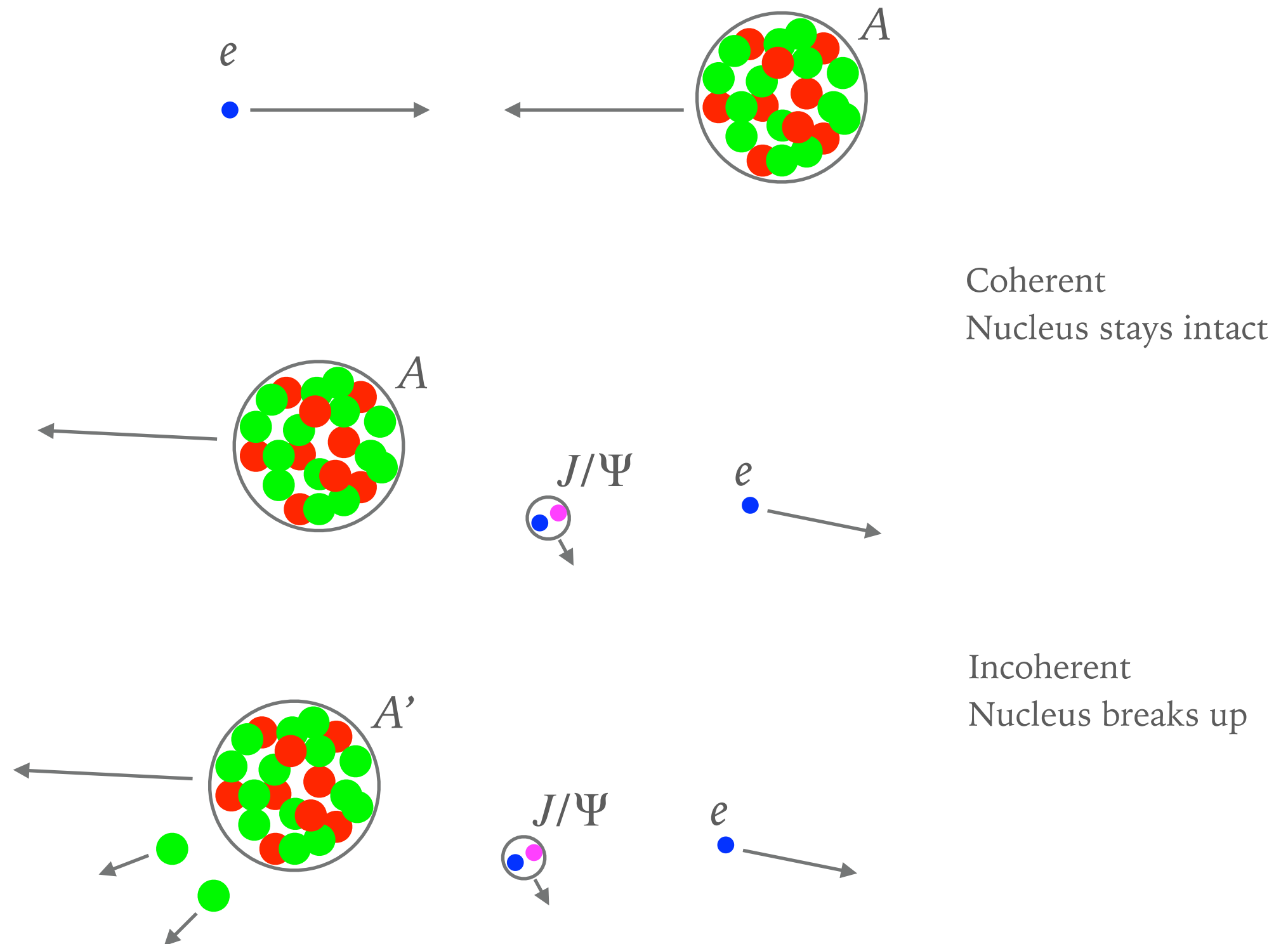
Coherent vs incoherent



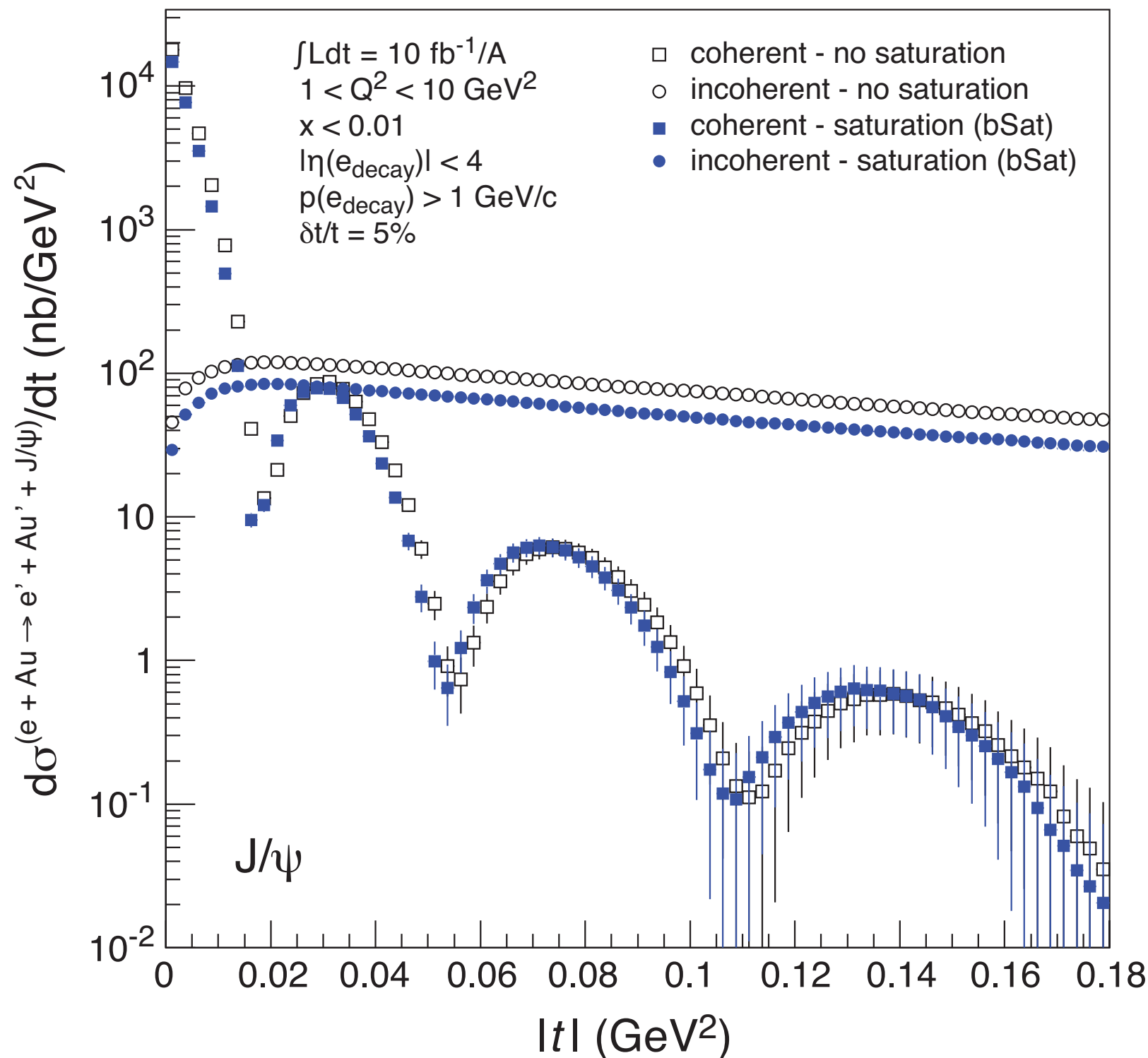
Coherent vs incoherent



Coherent vs incoherent



Coherent vs incoherent



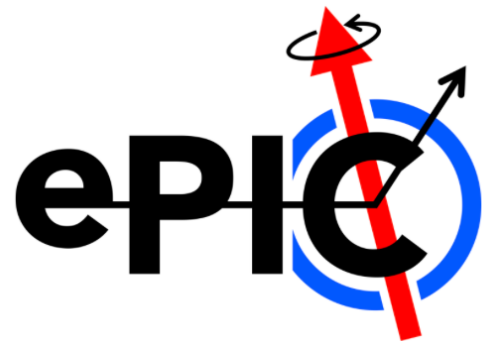
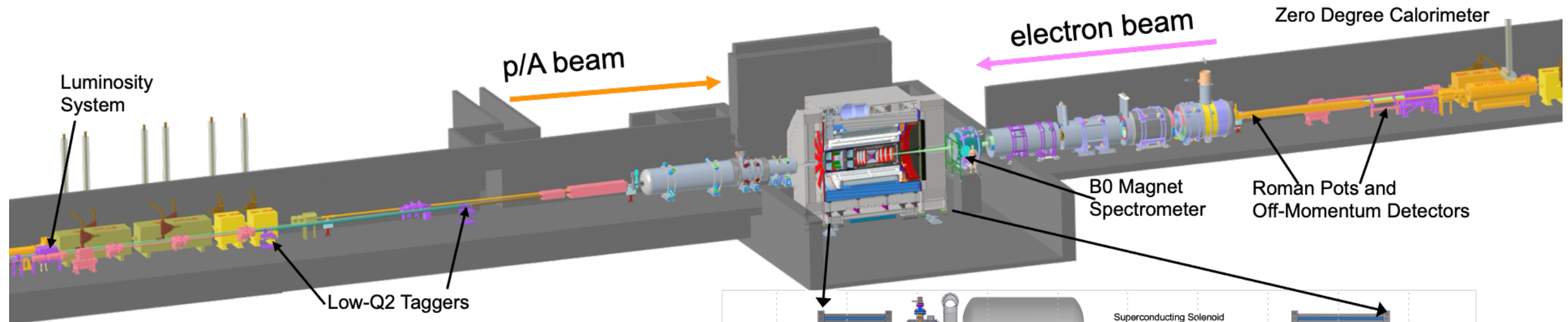
Coherent:

Depends on the shape of the source, average distribution

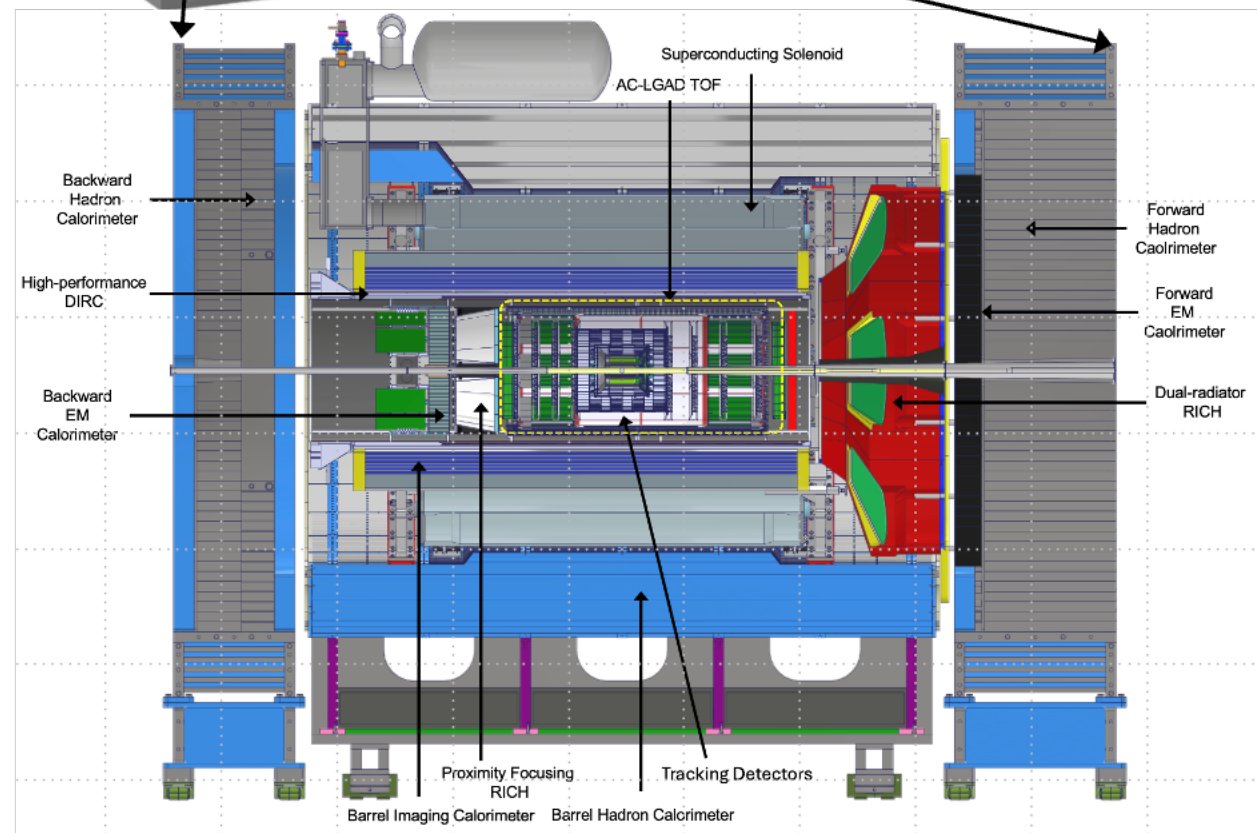
Incoherent:

Provides information about the fluctuations or lumpiness of the source

How to measure all of it ? Detector design



26 subsystems over ± 40 m
to measure particle momenta, energy and
particle type
Needs: tracking, particle identification, EM
and hadronic calorimetry over an
extremely wide acceptance

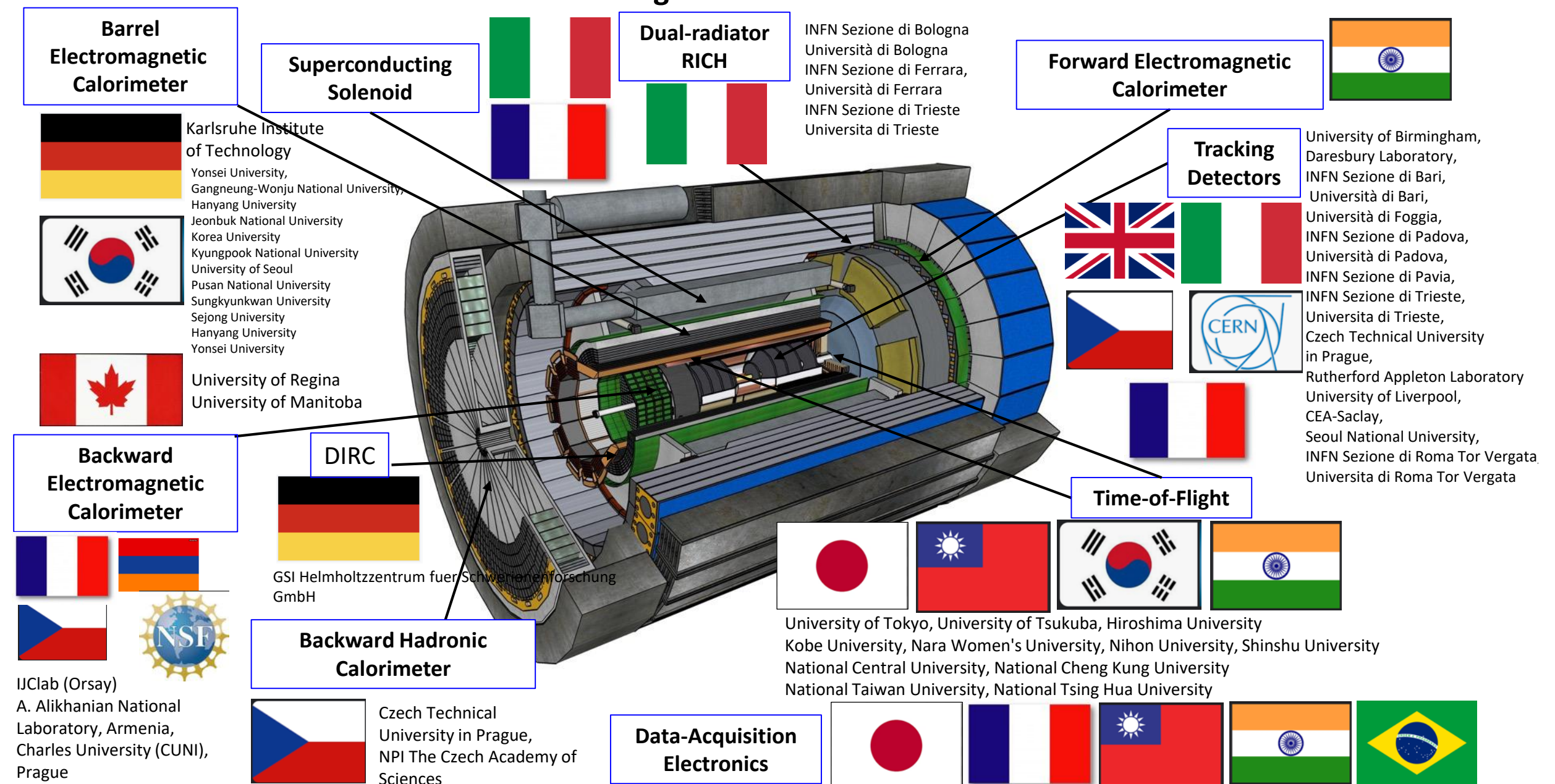


Central detector: international contributions

Central Detector Non-DOE Interest & In-Kind

Courtesy of E-C. Aschenauer

In-kind contribution goal: 30% of the Detector

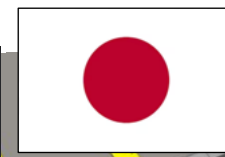


Far-Forward / Far-backward detector: international contributions

Far-Forward/Far-Backward Detectors Non-DOE Interest & In-Kind

Courtesy of E-C. Aschenauer

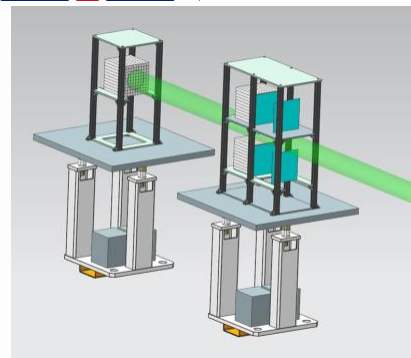
IR vacuum – crucial interface for detectors



Zero Degree Calorimeter

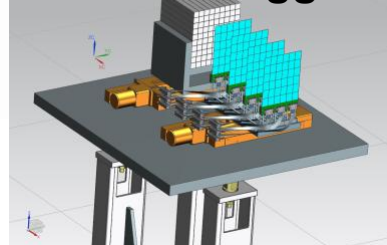


Roman Pots and Off-Momentum Detectors

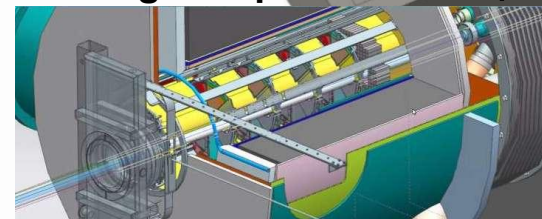


Luminosity System

Low-Q2 Taggers



B0 Magnet Spectrometer

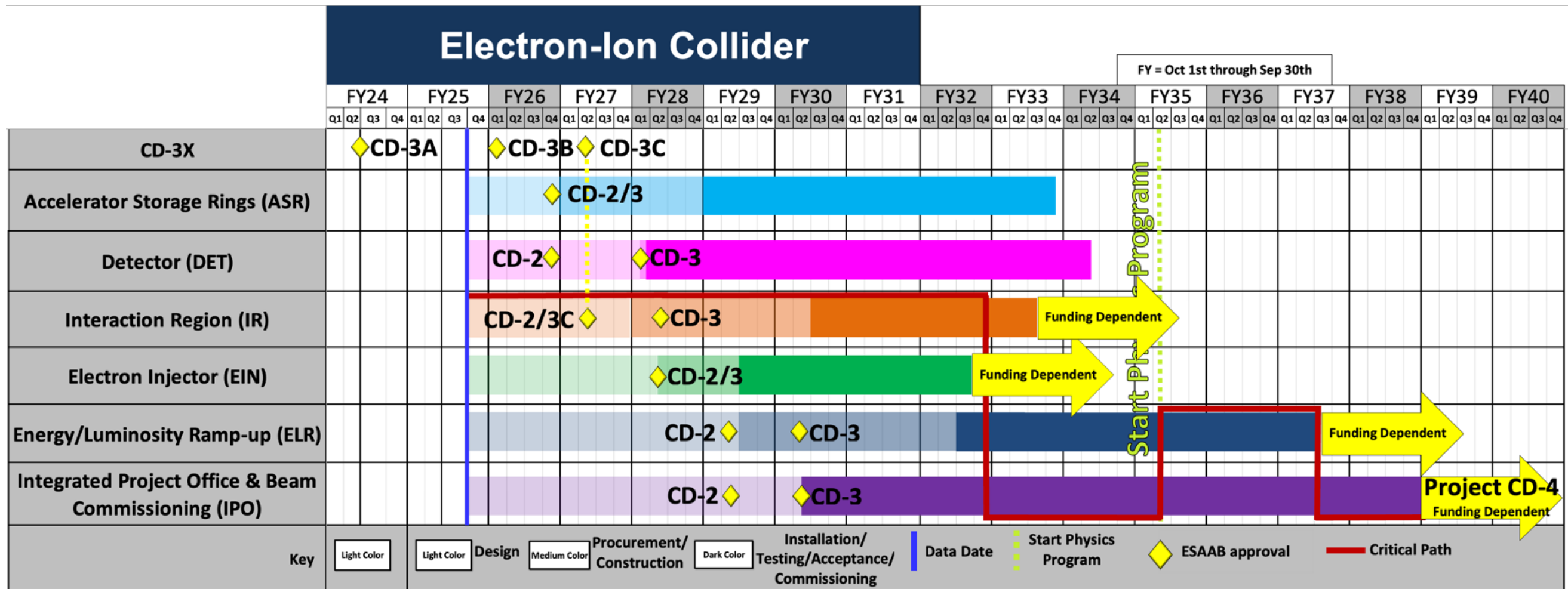


RIKEN Nishina Center
University of Glasgow
AGH University of Krakow
Ben Gurion University of the Negev
Institute of Nuclear Physics Polish Academy of Sciences (IFJ PAN)
Institute of Physics, Academia Sinica
Tel-Aviv University
Warsaw University of Technology, Faculty of Physics
University of York

slide from Janusz Chwastowski

Timeline

High level schedule

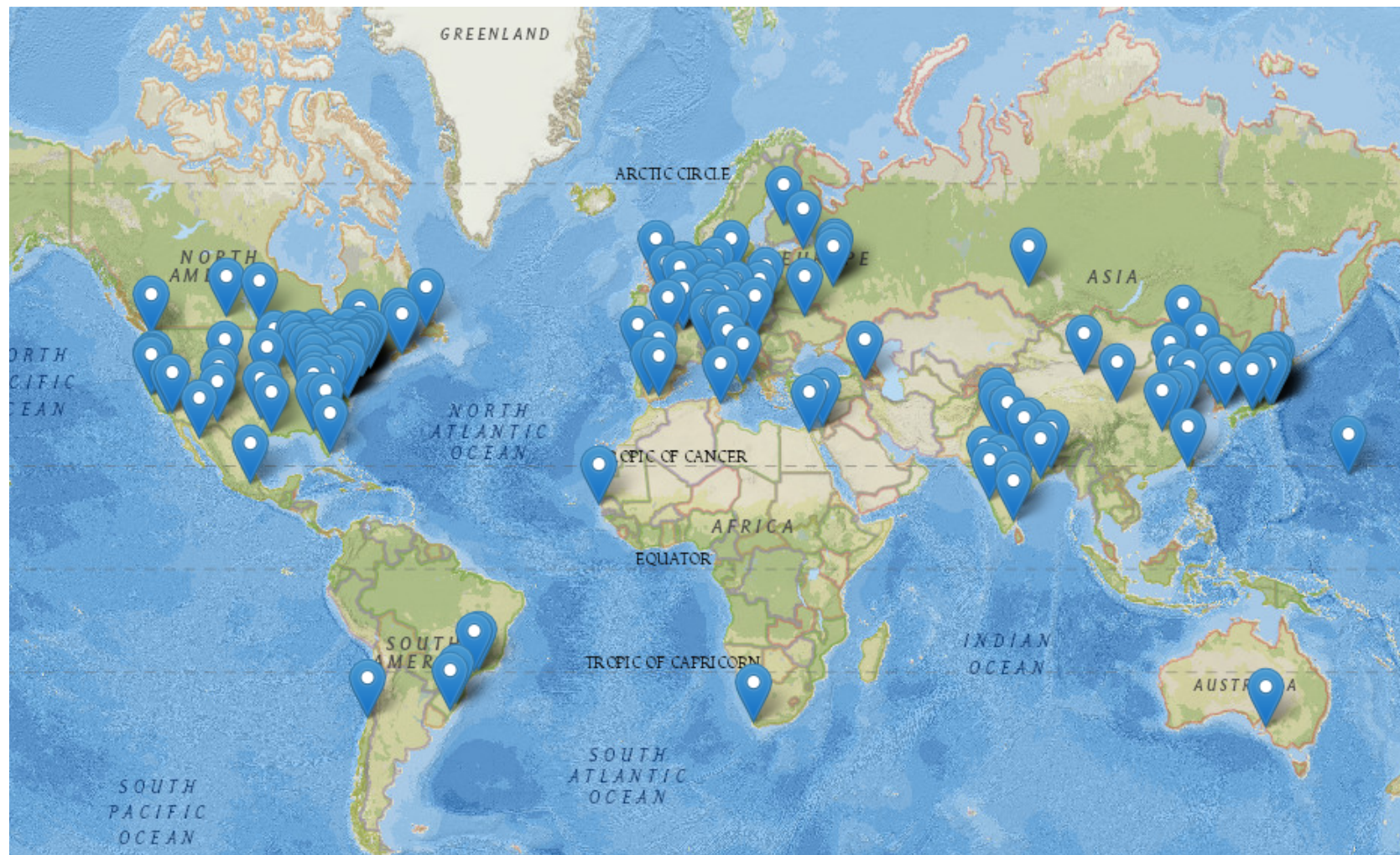


Commissioning and first science in about a decade

RHIC is scheduled to complete running in early February 2026

EIC Users Group

The **Electron-Ion Collider User Group (EICUG)** is an international affiliation of scientists dedicated to developing and promoting the scientific, technological, and educational goals and motivations for a new high energy **Electron-Ion Collider**.



1563 members

1038 experimentalists

384 theorists

124 accelerator scientists

9 computer scientists

5 support

3 other

310 institutions

41 countries

<https://www.eicug.org/index.html>

Status as of January 17, 2026

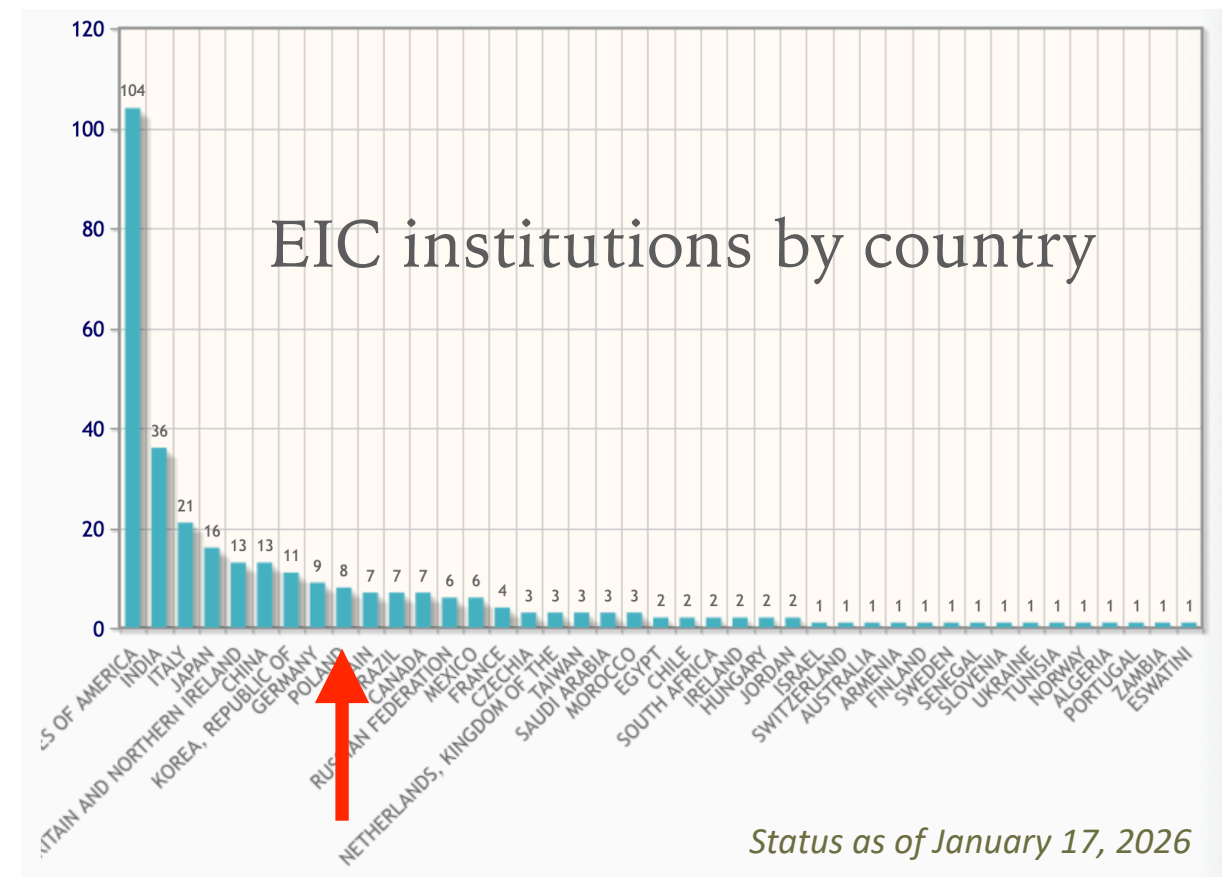
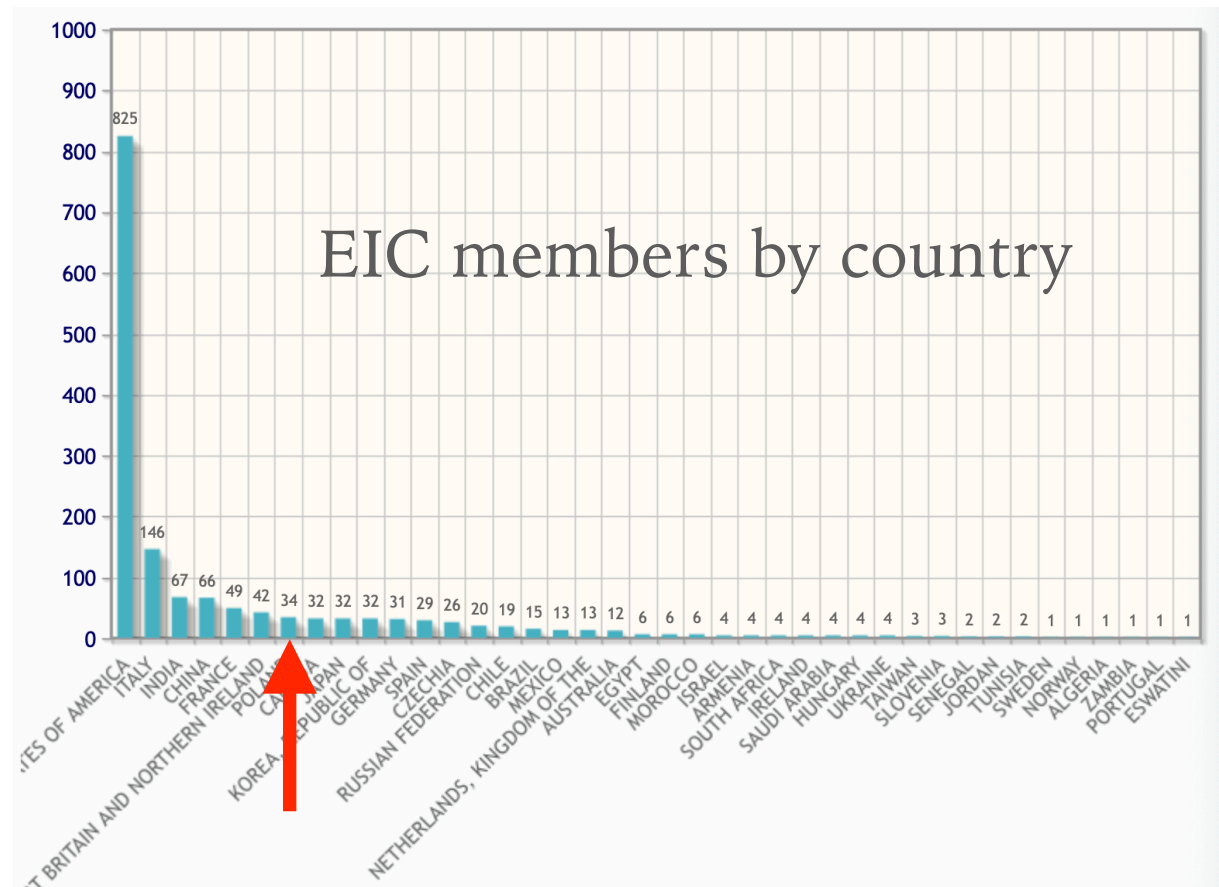
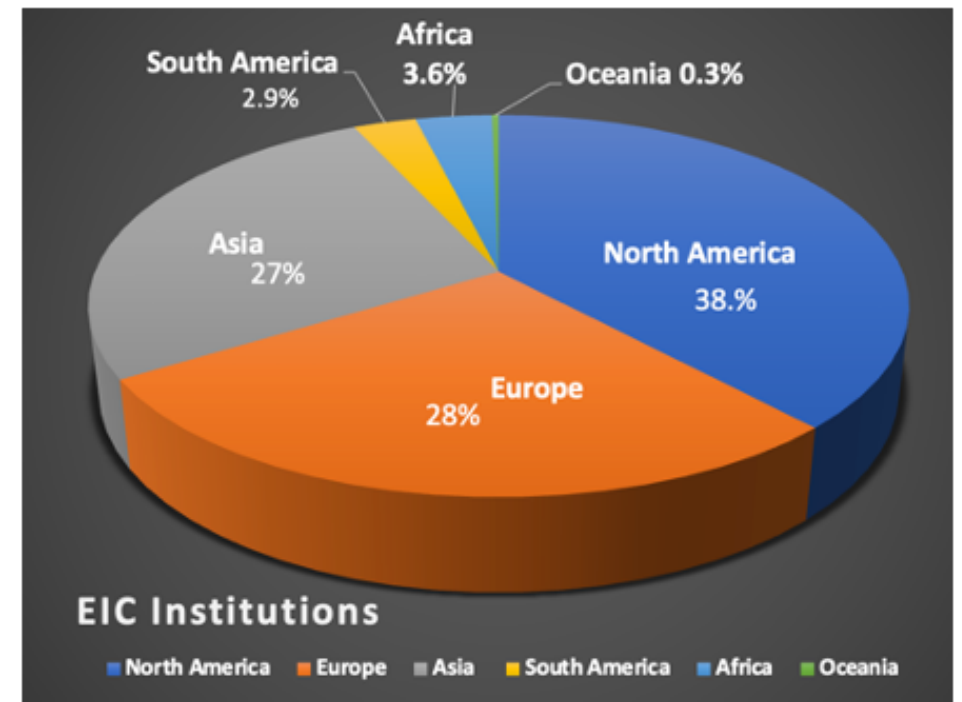
EIC Users Group

EIC is international at its core

Over 60% institutions are outside US

In 2023, annual meeting was in Warsaw, Poland

Strong community and still growing !



Status as of January 17, 2026

Summary

Electron Ion Collider : high energy, high luminosity, polarized, electron-proton and electron-ion collider, funded by Department of Energy, will be built in about a decade and start operating in 2030's

- **Precision tool** which will address most profound unanswered questions (nucleon and nuclear structure, hadron imaging, spin...)
- One of the most **challenging** and **versatile** accelerator complexes ever built
- EIC is a project with strong **international** engagement
- **ePIC** collaboration: 1st detector collaboration formed
- **2nd** detector: under consideration, needs additional funding

Please join and contribute! Everybody is welcome: engineers, designers, technicians, administrators, theorists, experimentalists, accelerator physicists...

Especially early career scientists: postdocs, undergraduate and graduate students...

<https://www.bnl.gov/eic/>

<https://www.eicug.org/index.html>