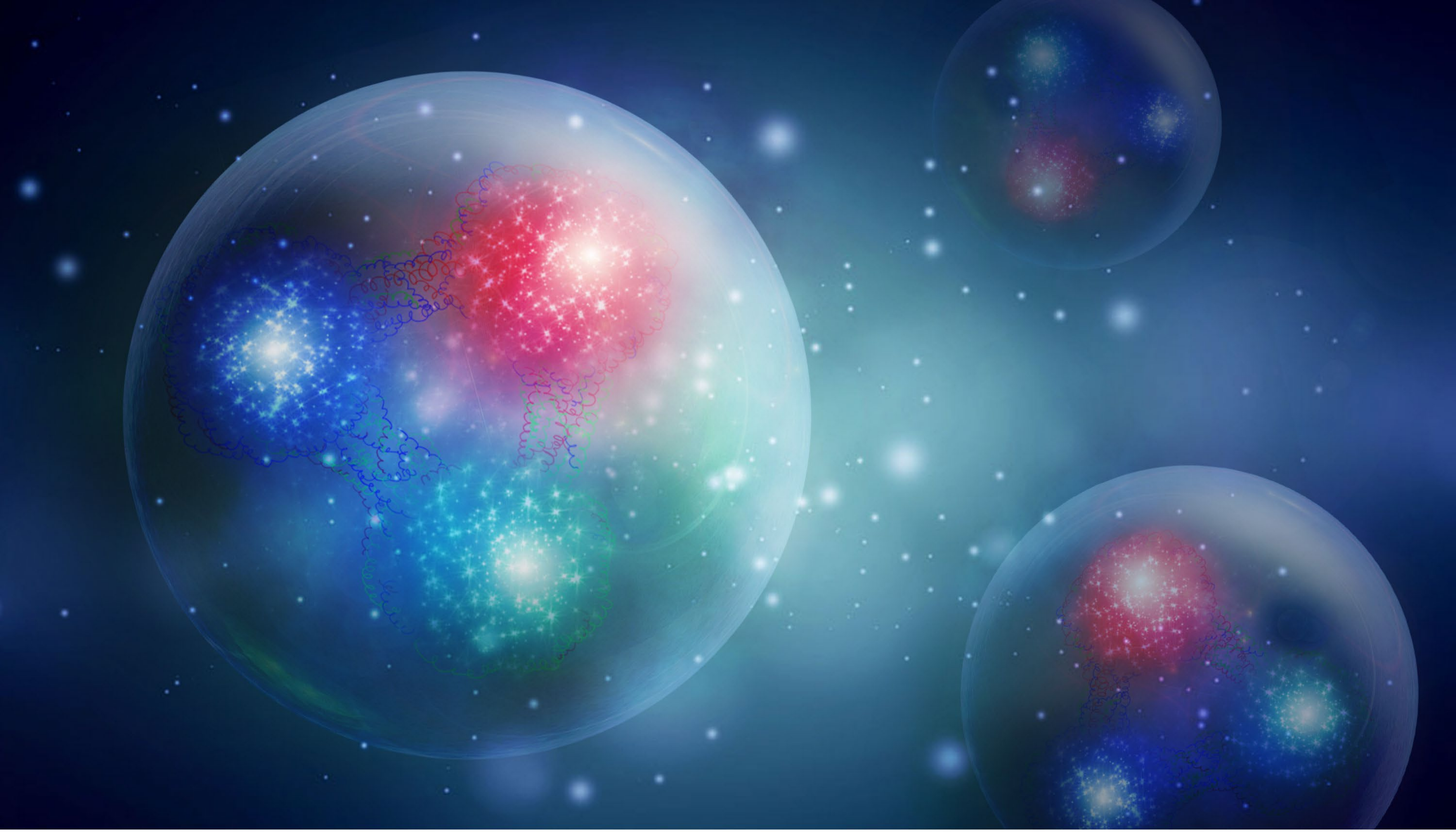


Electron-Ion Collider

NNPSS Lectures 2017 (Day 2) Rik Yoshida, Jefferson Lab

Plan for the Lectures

Day 1:

- Prologue
- Some History
- Deep Inelastic Scattering and Parton Distributions (I)

Day 2:

- **DIS and PDF (II)**
- **Beyond parton distributions.**

Day 3:

- EIC accelerator and detector realizations
- Other facilities and EIC physics topics.
- EIC and physics topic at other facilities.
- EIC and the future of Nuclear Physics.
- Epilogue

DEEP INELASTIC SCATTERING AND PARTON DISTRIBUTION (II).

Quarks and Gluons as partons

$u(x)$: up quark distribution
$\bar{u}(x)$: up anti-quark distribution
etc.

Momentum has to add up to 1 ("momentum sum rule")

$$\int x[u(x)+\bar{u}(x)+d(x)+\bar{d}(x)+s(x)+\bar{s}(x)+\ldots.]dx = 1$$

Quantum numbers of the nucleon has to be right

So for a proton:

$$\int[u(x)-\bar{u}(x)]dx=2 \qquad \int[d(x)-\bar{d}(x)]dx=1$$

$$\int[s(x)-\bar{s}(x)+\ldots\ldots]dx=0$$

$e^- p$ Neutral Current (NC) cross-section:

We'll come back to these →

Has to do with long. photon. Only large at largest y

Has to do with Z_0 exchange: small for $Q \ll M_Z$

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ F_2(x,Q^2) - y^2 F_L(x,Q^2) + Y_- xF_3(x,Q^2)\right]$$

$Y_\pm = 1 \pm (1-y)$

$y = Q^2/xs$ $\quad 0 \le y \le 1$ "inelasticity"

So for now:

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4} Y_+ F_2(x,Q^2)$$

quark charge

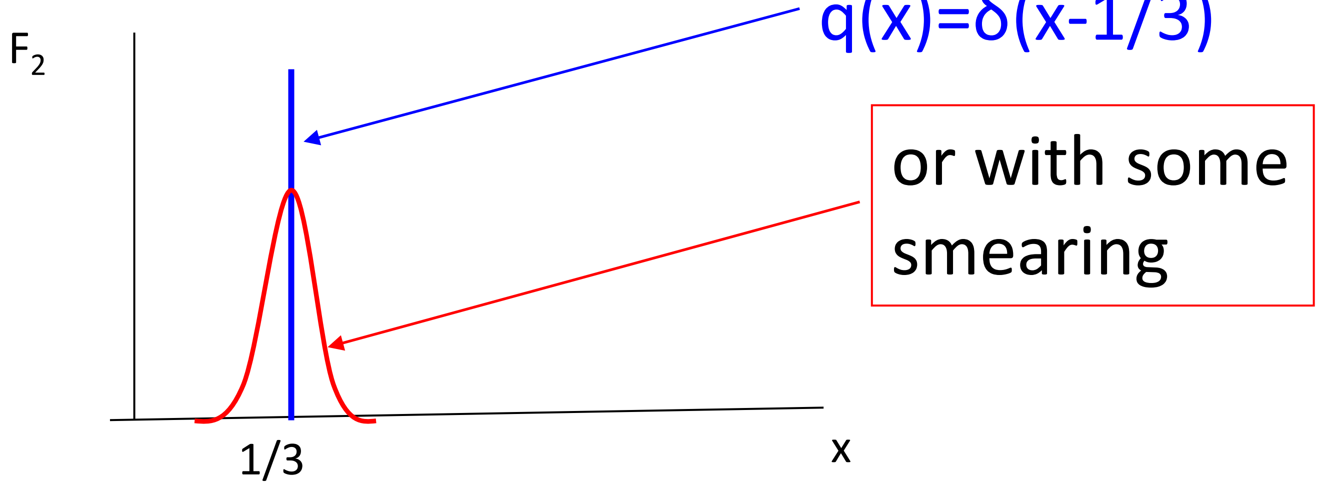
$$F_2 = x\sum(q + \bar{q})\, e_q^2 + \text{Z-exchange}$$

quark and anti-quark distributions

IF, proton was made of 3 quarks each with 1/3 of proton's momentum:

$$F_2 = x\sum(q(x) + \bar{q}(x))\, e_q^2$$

no anti-quark!

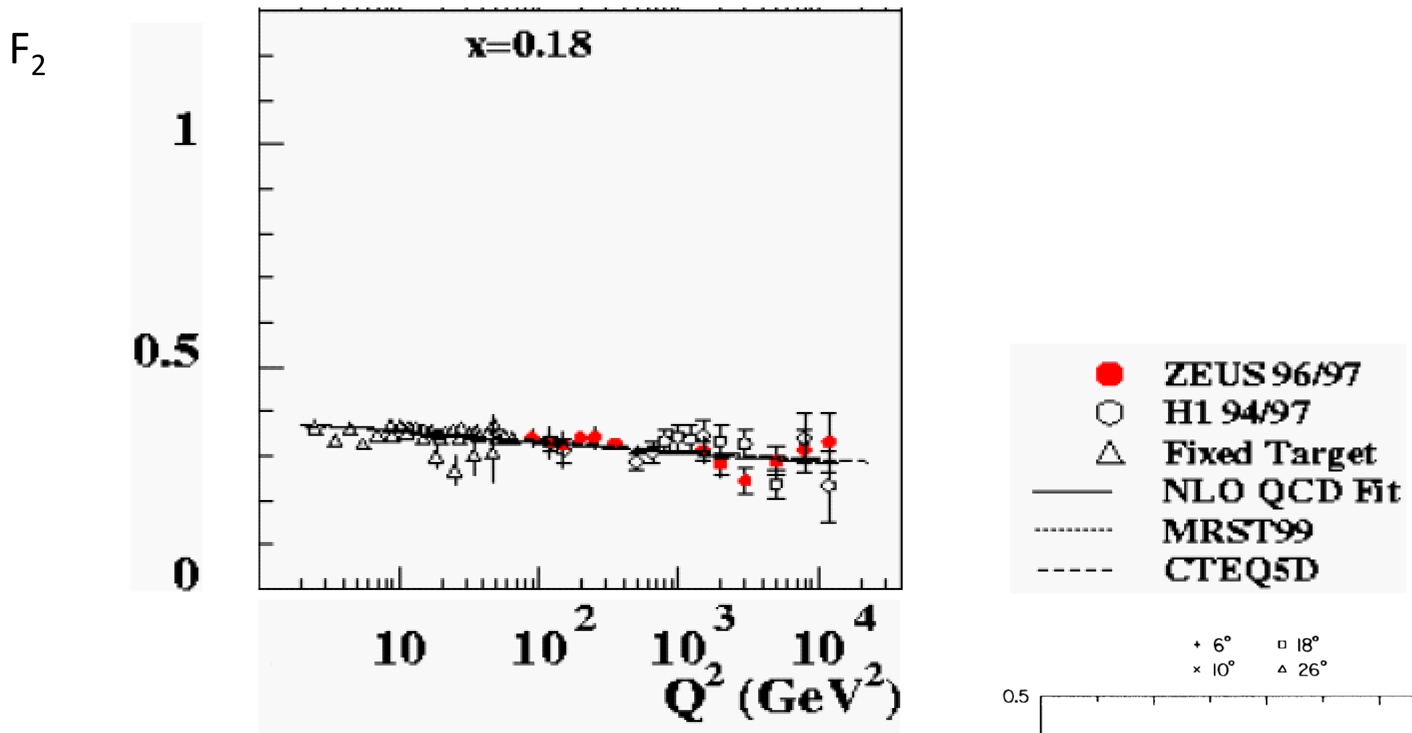


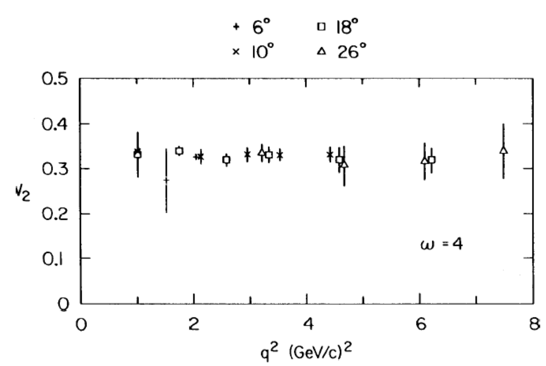
The partons are point-like and incoherent then Q^2 shouldn't matter.

→ Bjorken scaling: F_2 has no Q^2 dependence.

Let's look at some data→

Proton Structure Function F_2





Seems to be…. NOT

So far:

$F_2 \sim \sum(q+\bar{q}) \approx S$ (sea quarks)   measured directly in NC DIS

Scaling violations

$dF_2/d\ln Q^2 \sim \alpha_s \bullet g$ Scaling violations gives gluons (times α_s).   DGLAP equations.

What about valence quarks?

$\sum(q-\bar{q}) = u_v + d_v$ can we determine them separately?

Can we decouple α_s and g ?

Return to Neutral Current (NC) cross-section:

Now write out the e^+p and e^-p separately

(keep ignoring F_L for now..)

$Y_\pm = 1 \pm (1-y)$

$$\frac{d^2\sigma(e^\pm p)}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\,[Y_+ F_2(x,Q^2) \mp Y_- xF_3(x,Q^2)]$$

$xF_3 = \sum(q(x,Q^2) - \bar{q}(x,Q^2))\, xB_q$ ~The valence quarks!

$$B_q = -2e_q a_q a_e \chi_Z + 4 v_q a_q v_e a_e \chi_Z^2$$

$$\chi_Z = \frac{1}{\sin 2\theta_W}\left(\frac{Q^2}{M_Z^2 + Q^2}\right)$$

Keeps xF_3 small if $Q < M_Z$

Return to Neutral Current (NC) cross-section:

Now write out the e^+p and e^-p separately

(keep ignoring F_L for now..)

$Y_\pm = 1 \pm (1-y)$

$$\frac{d^2\sigma(e^\pm p)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ F_2(x,Q^2) \mp Y_- xF_3(x,Q^2)\right]$$

$$xF_3 = \sum(q(x,Q^2)-\bar{q}(x,Q^2))\, xB_q$$ ~The valence quarks!

$$B_q = \underbrace{-2e_q a_q a_e \chi_Z}_{\gamma\text{-Z interference}} + \underbrace{4 v_q a_q v_e a_e \chi_Z^2}_{\text{Z-exchange}}$$

e_q: electric charge of a quark

$a_q v_q$: axial-vector and vector couplings of a quark

$a_e v_e$: axial-vector and vector couplings of an electron

Return to Neutral Current (NC) cross-section:

Now write out the e^+p and e^-p separately

(keep ignoring F_L for now..)

$$Y_\pm = 1 \pm (1-y)$$

$$\frac{d^2\sigma(e^\pm p)}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+ F_2(x,Q^2) \mp Y_- xF_3(x,Q^2)\right]$$

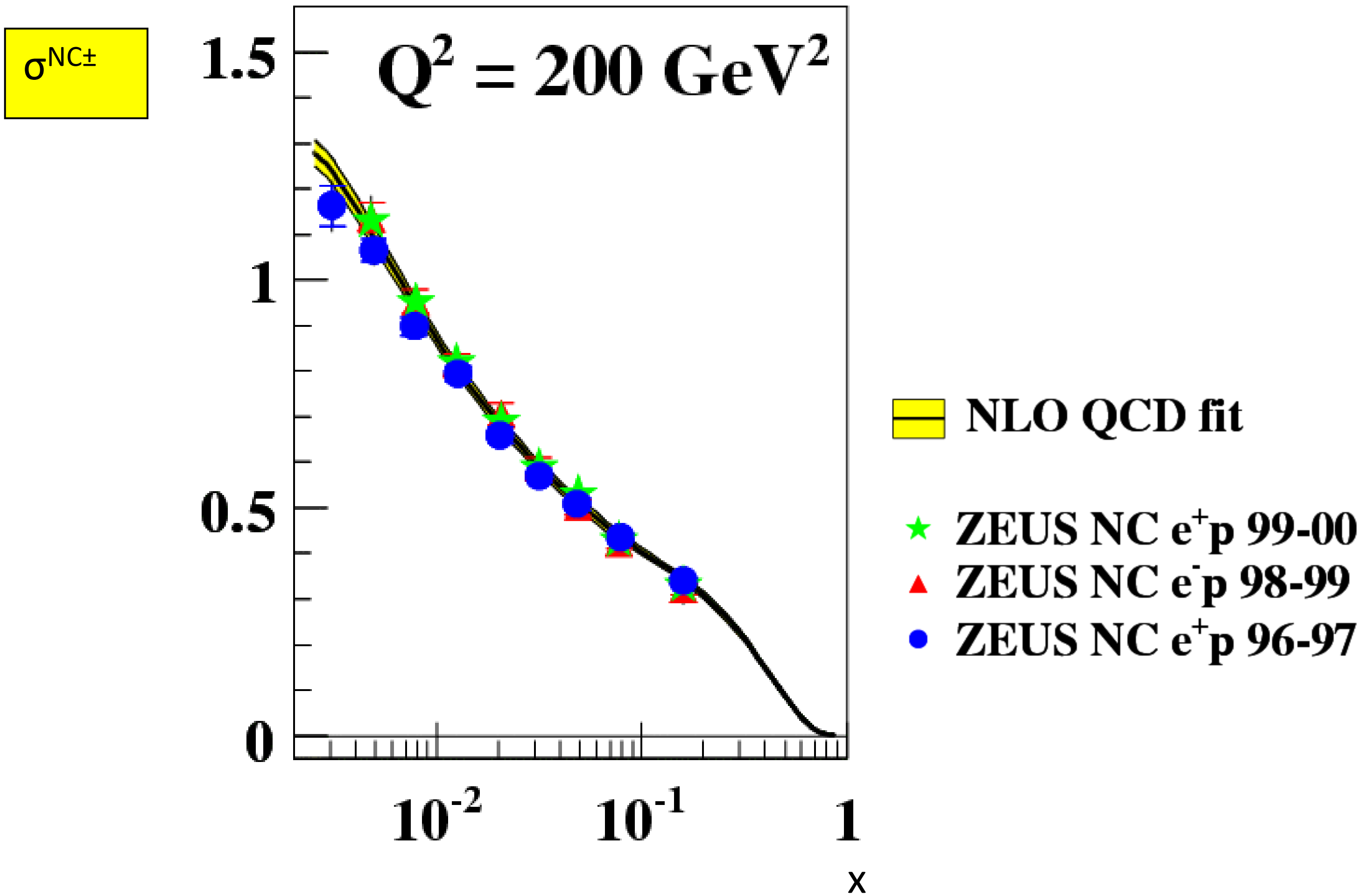
$$xF_3 = \sum(q(x,Q^2)-\bar{q}(x,Q^2))\, xB_q$$ ~The valence quarks!

Let's look at the "reduced NC cross-section"

$$\sigma^{NC\pm} = F_2(x,Q^2) \mp (Y-/Y+) \bullet xF3(x,Q^2)$$

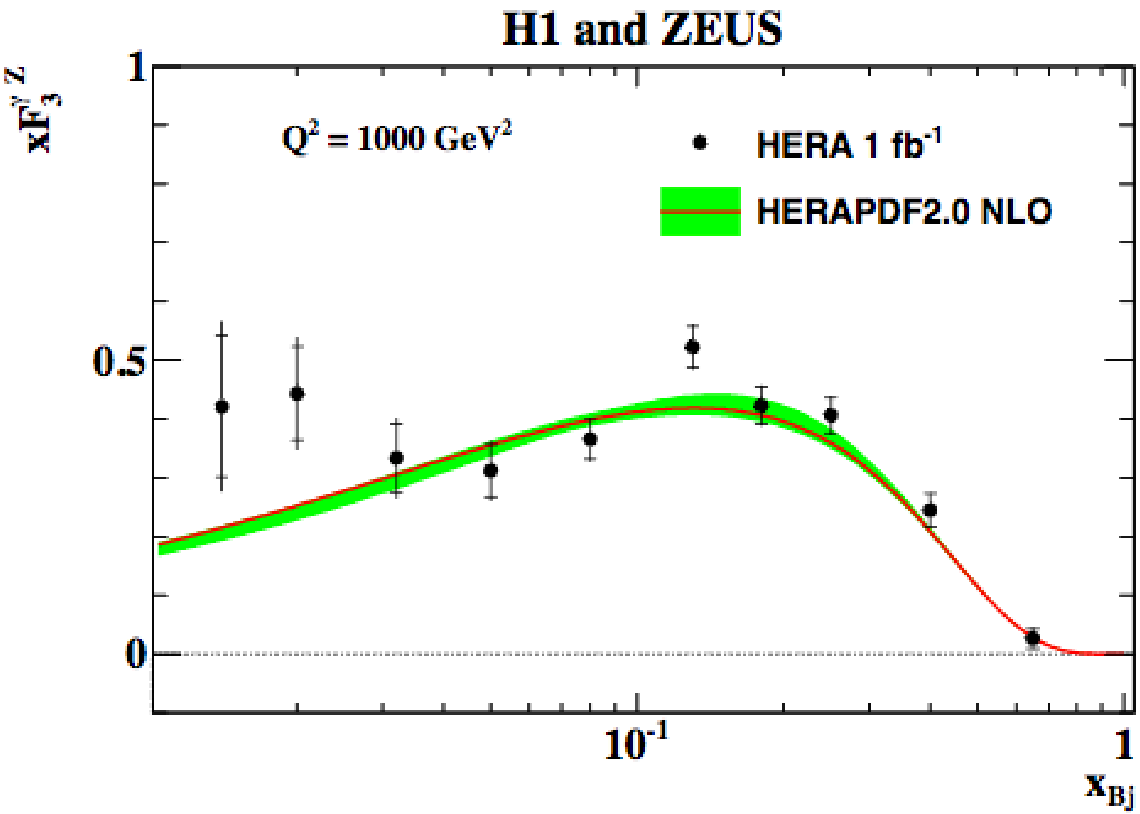
Note the change of sign from e^+p to e^-p

Reduced Neutral Current Cross-section

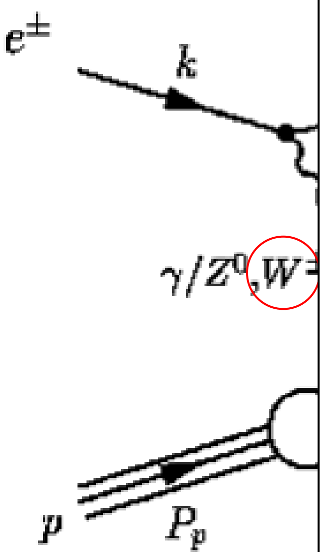


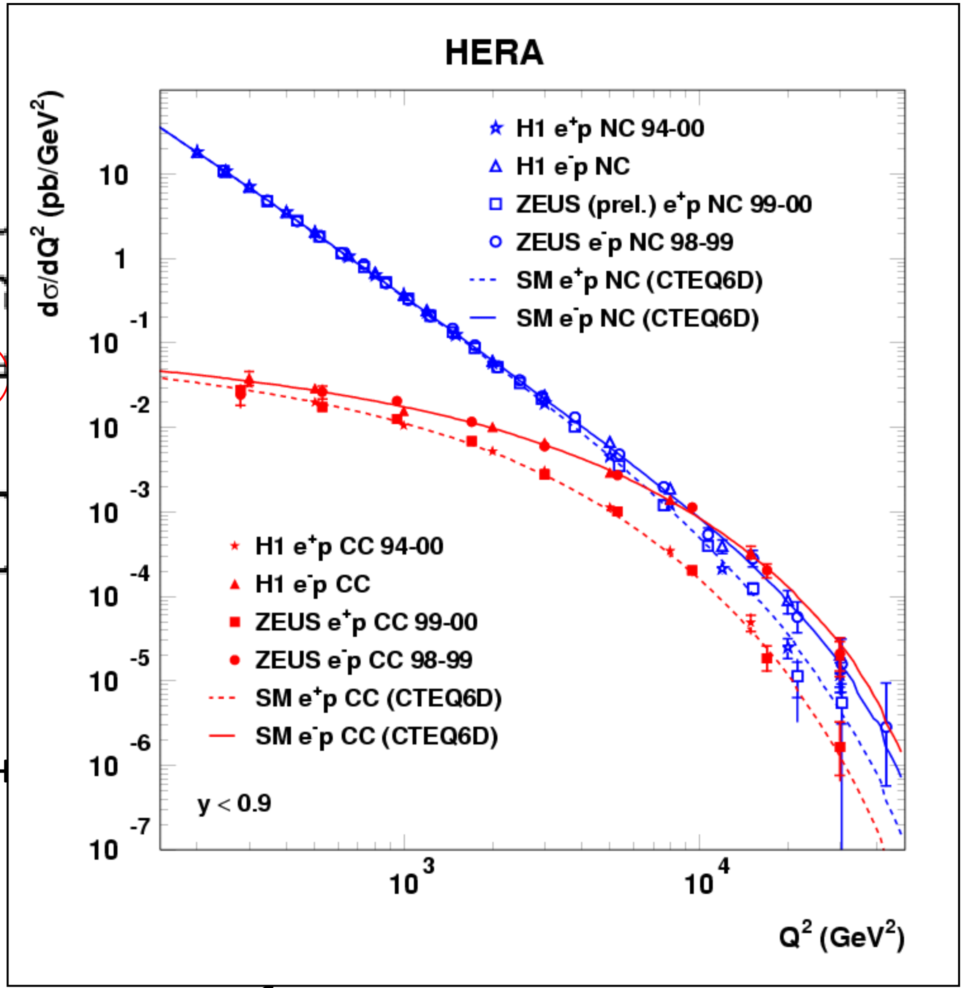
Measurements are at relatively high x

Final result from HERA



Charged Current Cross-Sections





$$\left[\frac{M_W^2}{M_W^2+Q^2}\right]^2\sigma^{CC\pm}$$

σ^{CC+}

σ^{CC-}

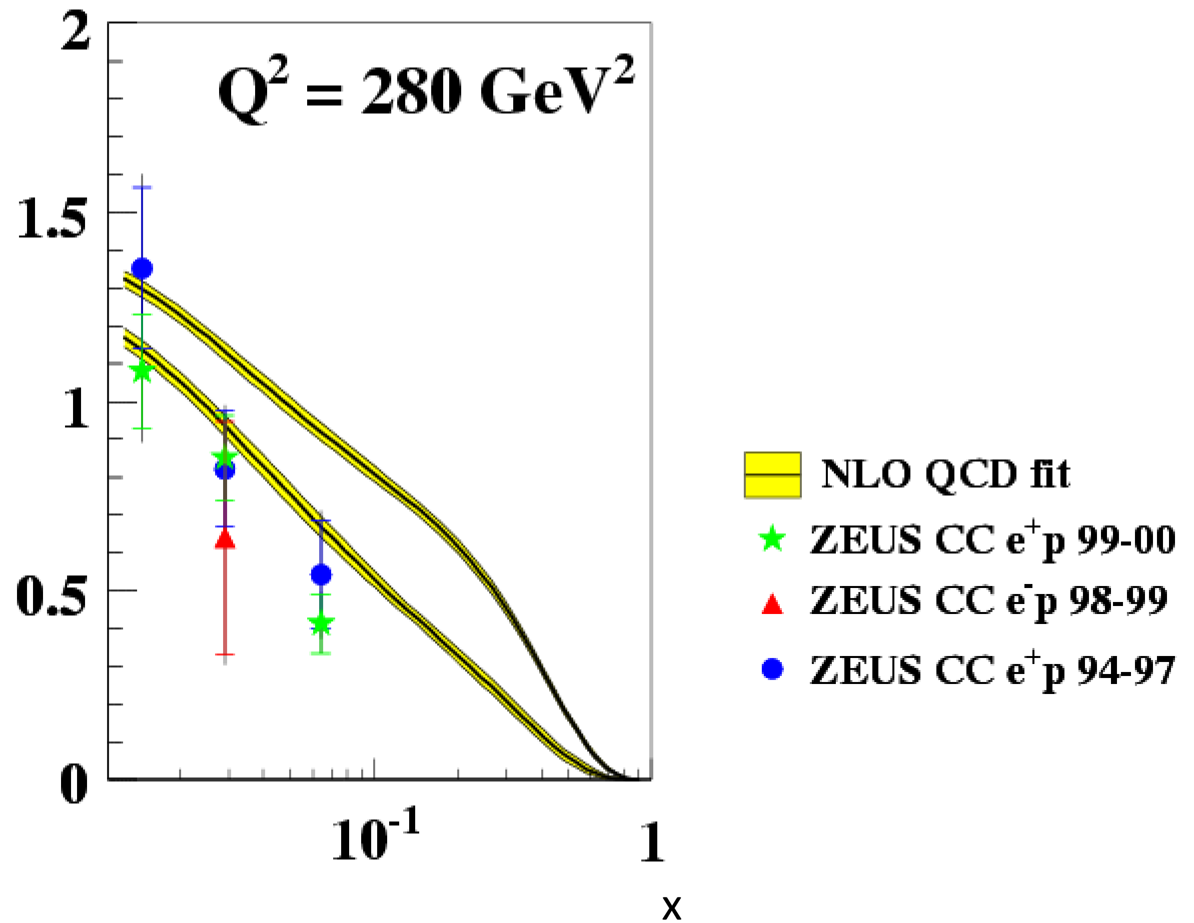
charm

Reduced Charged-Current Cross-Section

$\sigma^{CC\pm}$

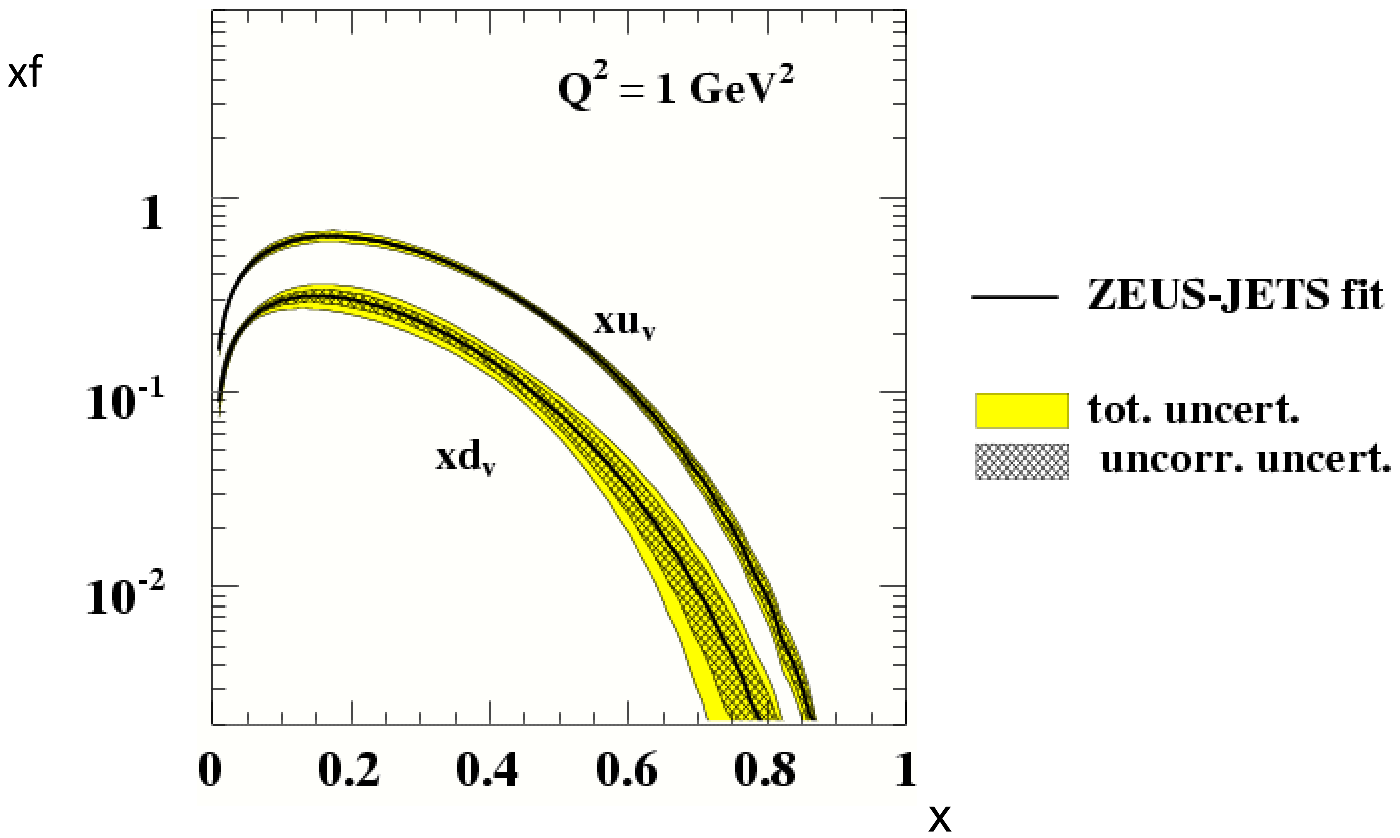
$\sigma^{CC+} \sim d$

$\sigma^{CC-} \sim u$



Now let's look at the valence quarks from the QCD fits →

Valence PDFs

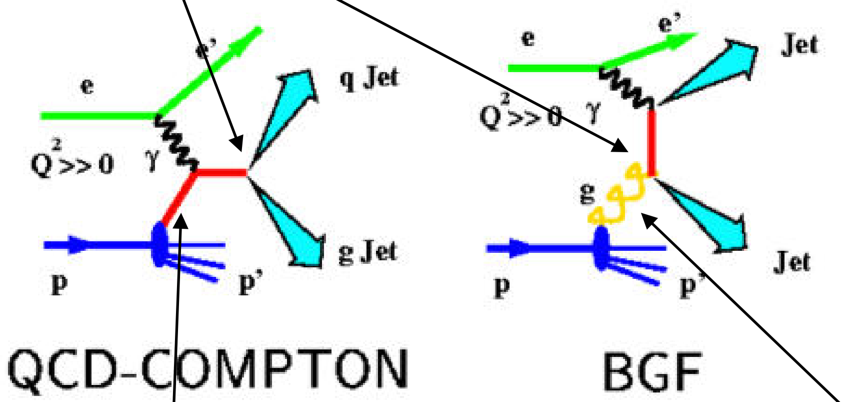


The momenta from valence quarks are producing gluons and sea quarks at low x

Jet production in DIS (HERA)

Sensitive to α_s

$\sigma_{jet} \sim \alpha_s \bullet f(x)$



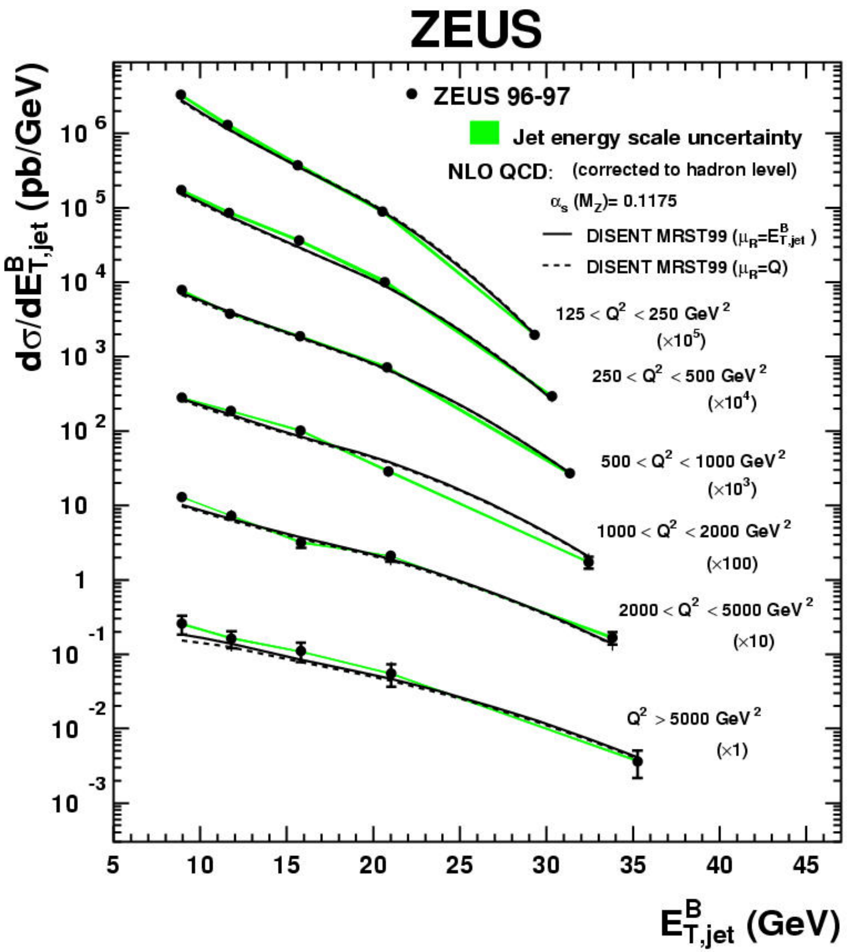
Sensitive to quarks
$\sim 10^{-2} < x < \sim 10^{-1}$

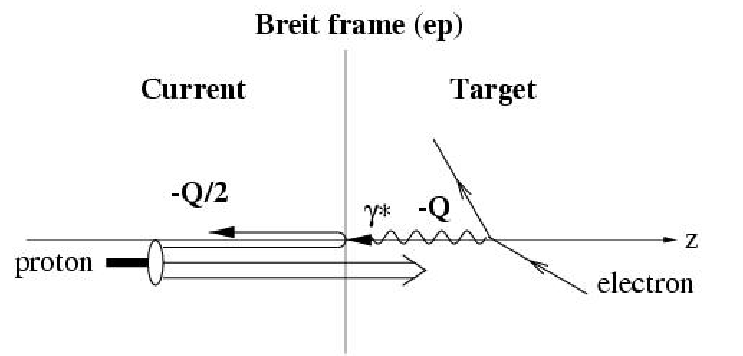
Same range as NC and CC

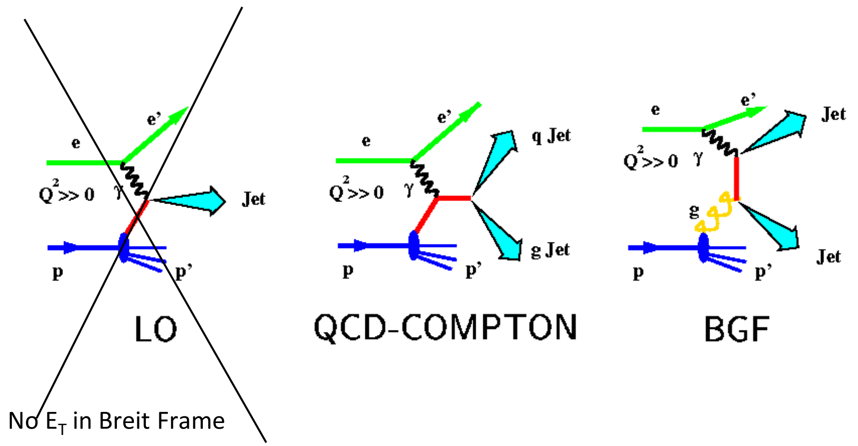
Sensitive to gluon
$\sim 10^{-3} < x < \sim 10^{-2}$

complementary
to gluon from F_2

Jet measurements in Breit frame

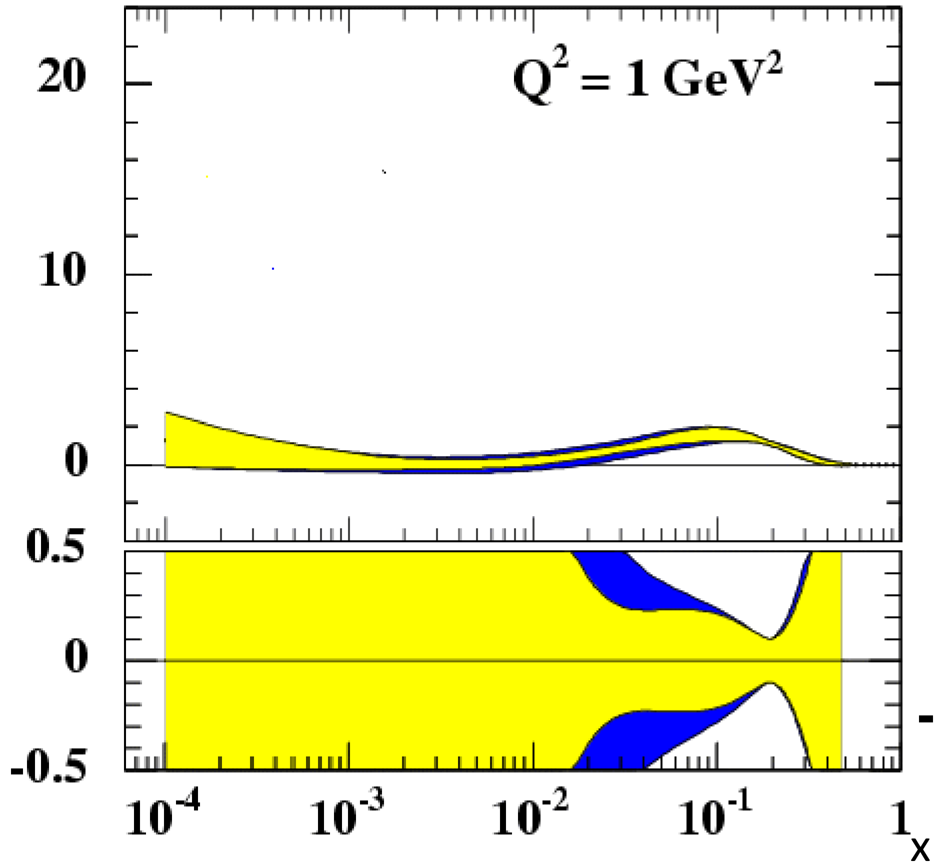


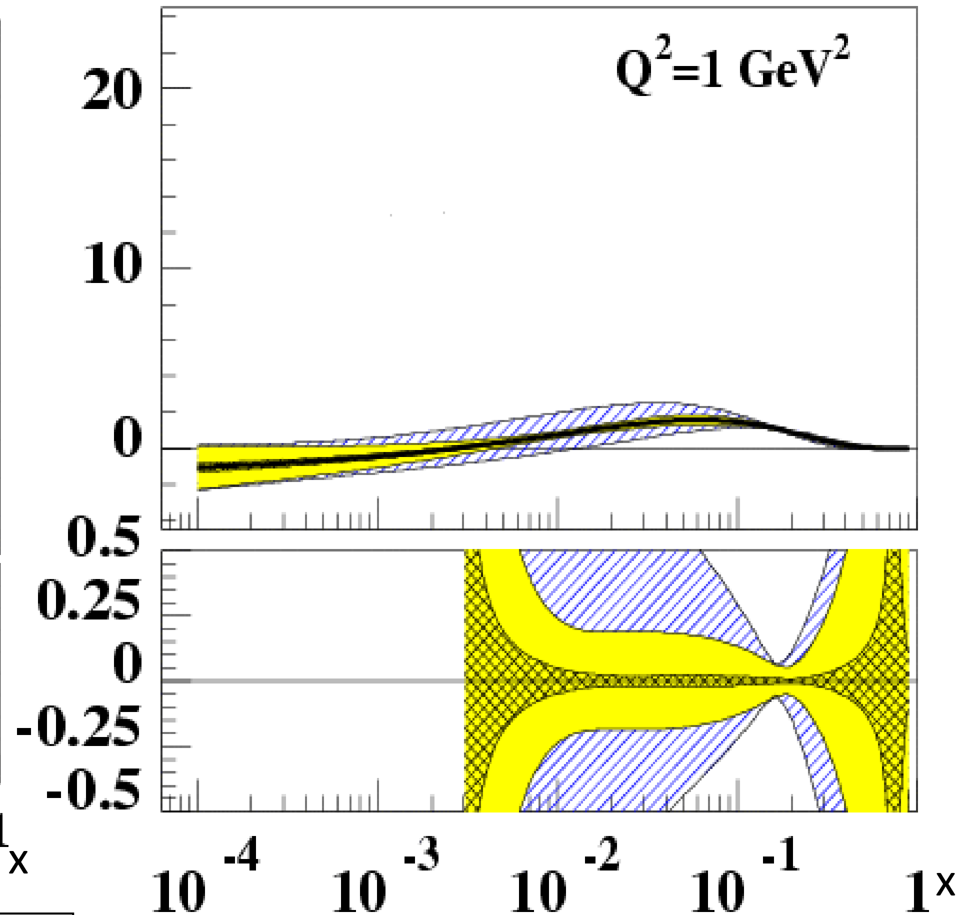




Jet production cross-section used in QCD fit →

Gluon distributions

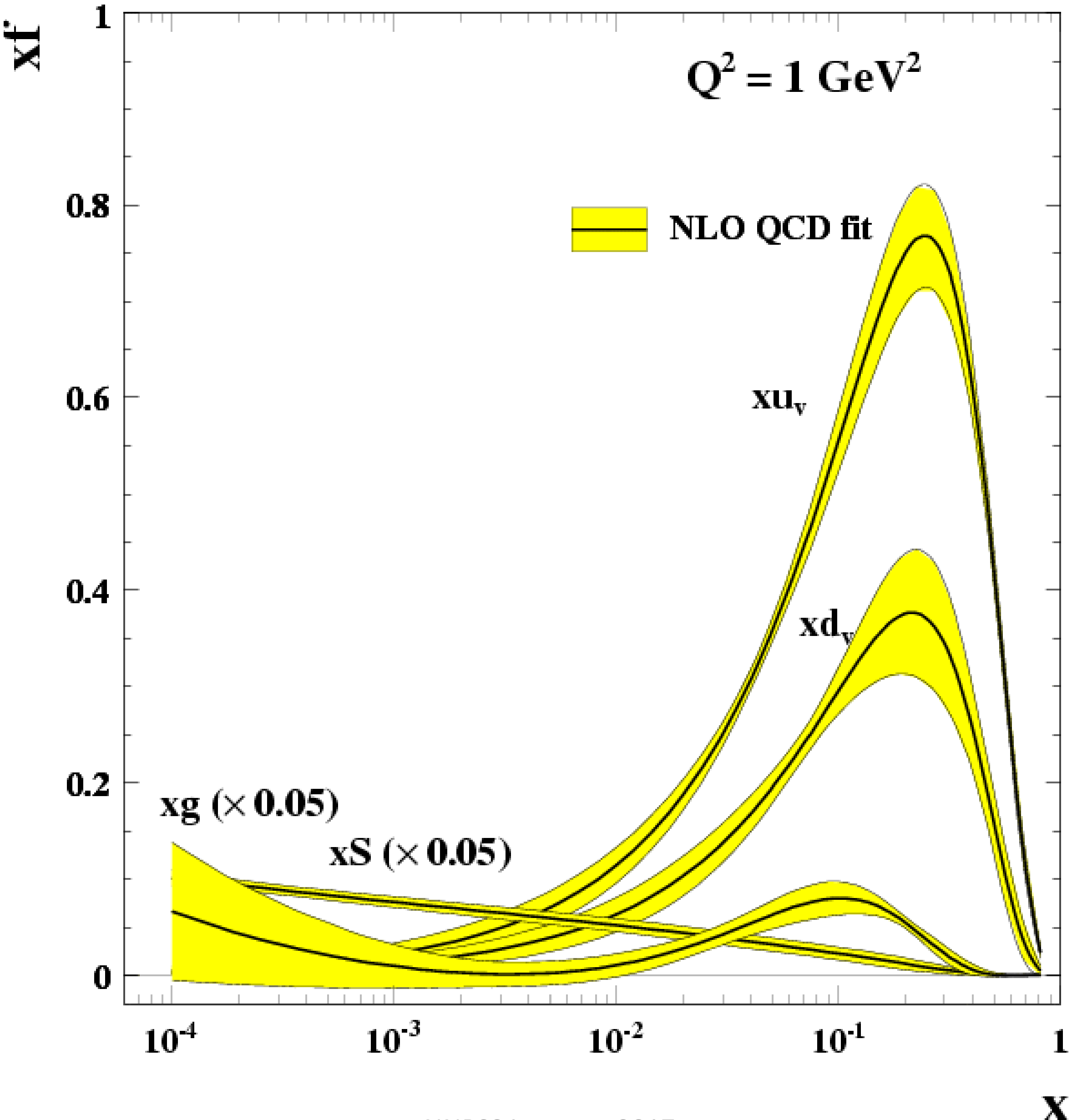




Using only HERA (ZEUS) data including NC,CC and jets

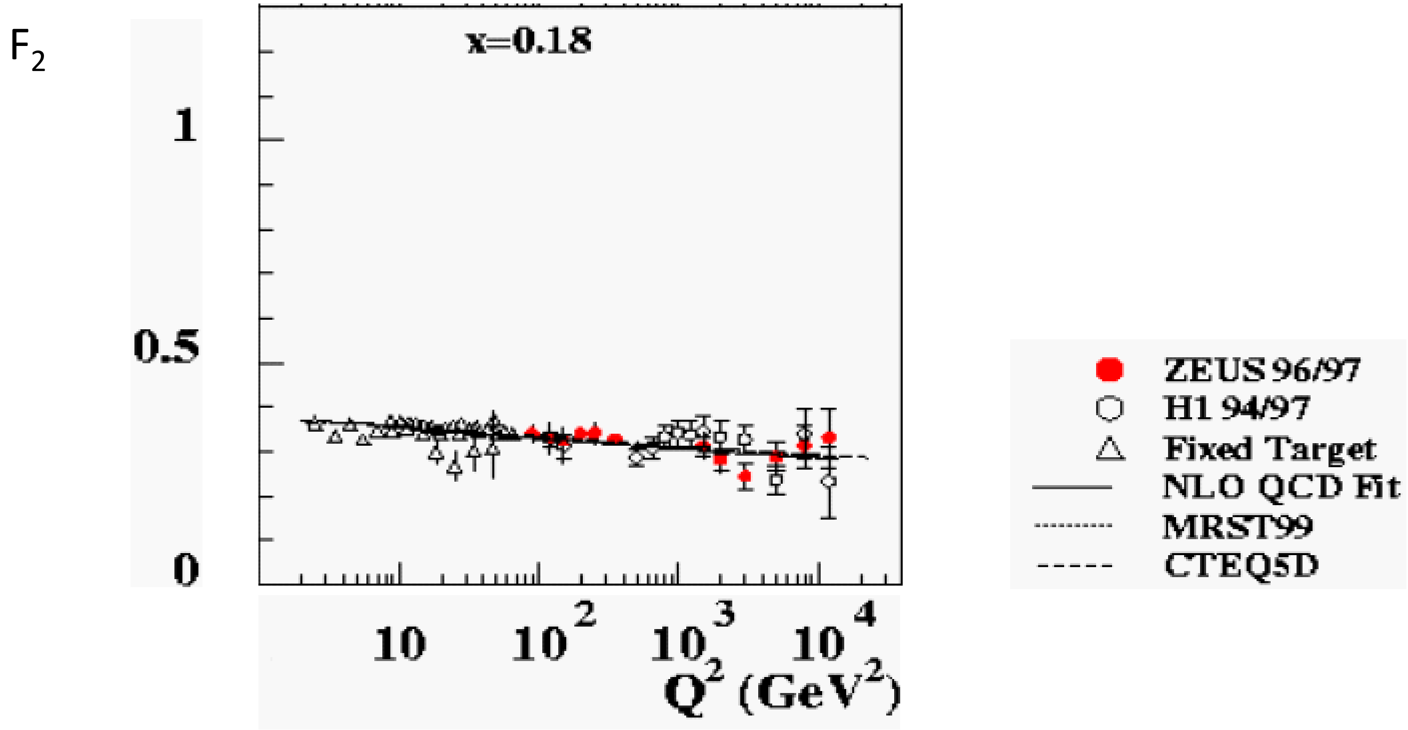
Using HERA (ZEUS) F_2 data and FNAL, CERN fixed tgt

Finally…



xf
1
0.8
0.6
0.4
0.2
0
Q² = 1 GeV²
NLO QCD fit
xu_v
xd_v
xg (× 0.05)
xS (× 0.05)
10⁻⁴
10⁻³
10⁻²
10⁻¹
1
x

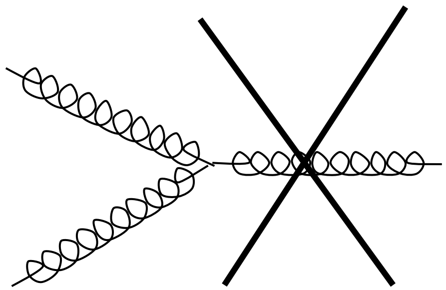
Proton Structure Function F_2



Now we understand what is happening here.

Some remarks about DGLAP equations:

The “incoherence” of the original parton model is preserved. i.e. a parton doesn’t know anything about its neighbor.



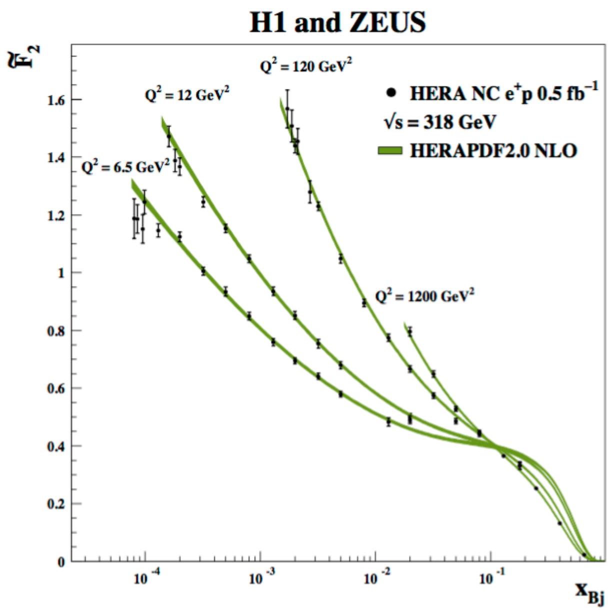
never happens

The “process independent” partons also survive.

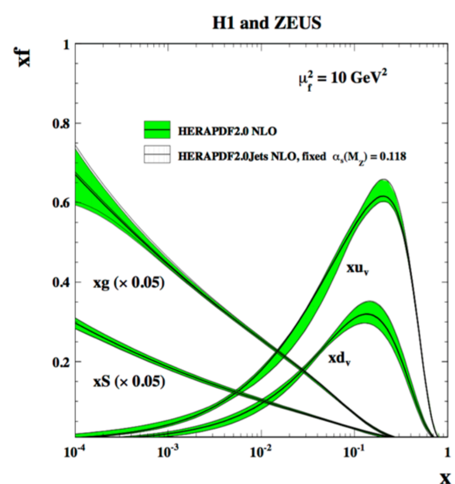
But now parton densities must be “evolved” in Q^2.

What does this mean? →

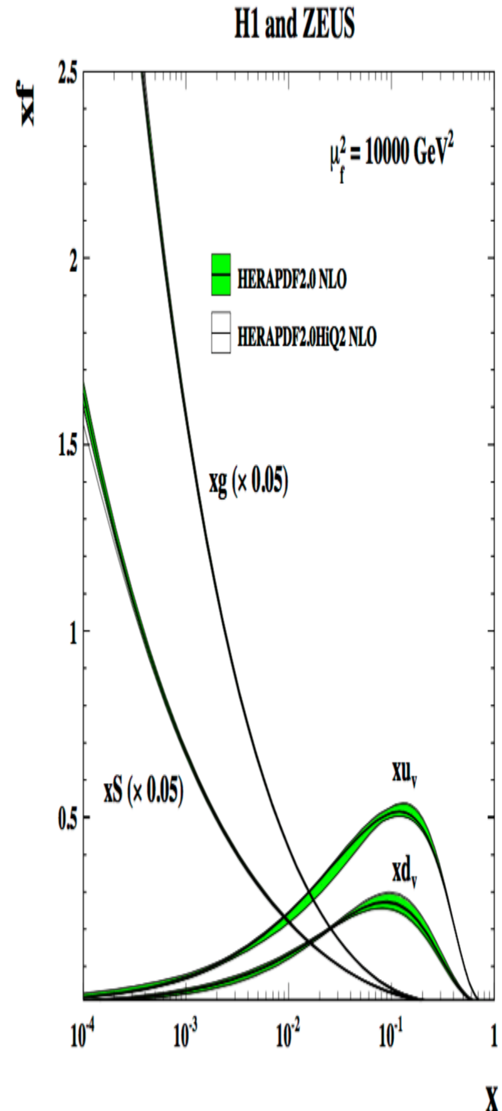
How this works



do a fit to get q_f and g



Q^2 (or μ^2) evolution



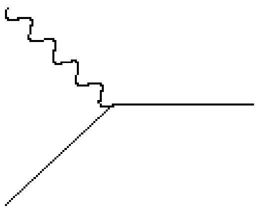
Structure function F_L

Longitudinal cross-section

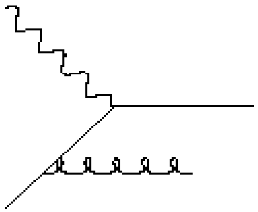
- F_L corresponds to absorption of longitudinally polarized virtual photon.

$$F_L = (Q^2/4\pi^2\alpha)\,\sigma_L$$

- Spin 1/2 quarks (with no transverse momentum) cannot absorb a longitudinally polarized boson.



LO: $k_T = 0$, $F_L = 0$



NLO: $k_T \neq 0$, $F_L \neq 0$

$$F_L = \frac{\alpha_s}{4\pi} x^2 \int_x^1 \frac{dz}{z^3}\left[\frac{16}{3} F_2 + 8 \sum e_q^2 \left(1 - \frac{x}{z}\right) zg\right]$$

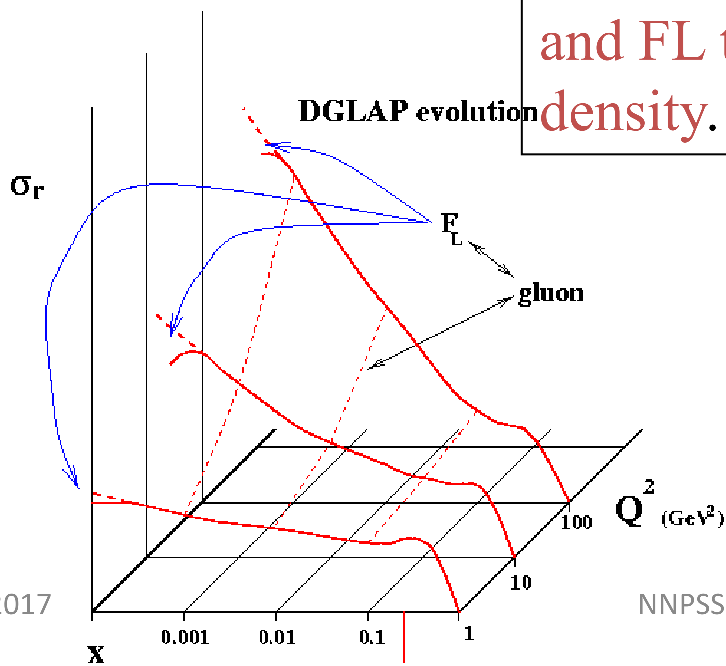
- At higher orders, quarks have transverse momentum (k_T), and therefore $F_L \neq 0$.
- F_L is related to the gluon density in the proton.

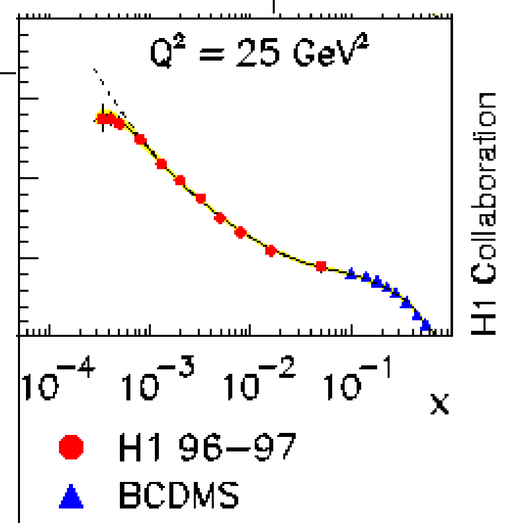
$$\frac{d\sigma^2}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4}(Y_+ F_2 - y^2 F_L \pm Y_- x F_3)$$

$y = Q^2/xs$: need to measure at different $\sqrt{s}$ to get F_L (or indeed F_2, in principle).

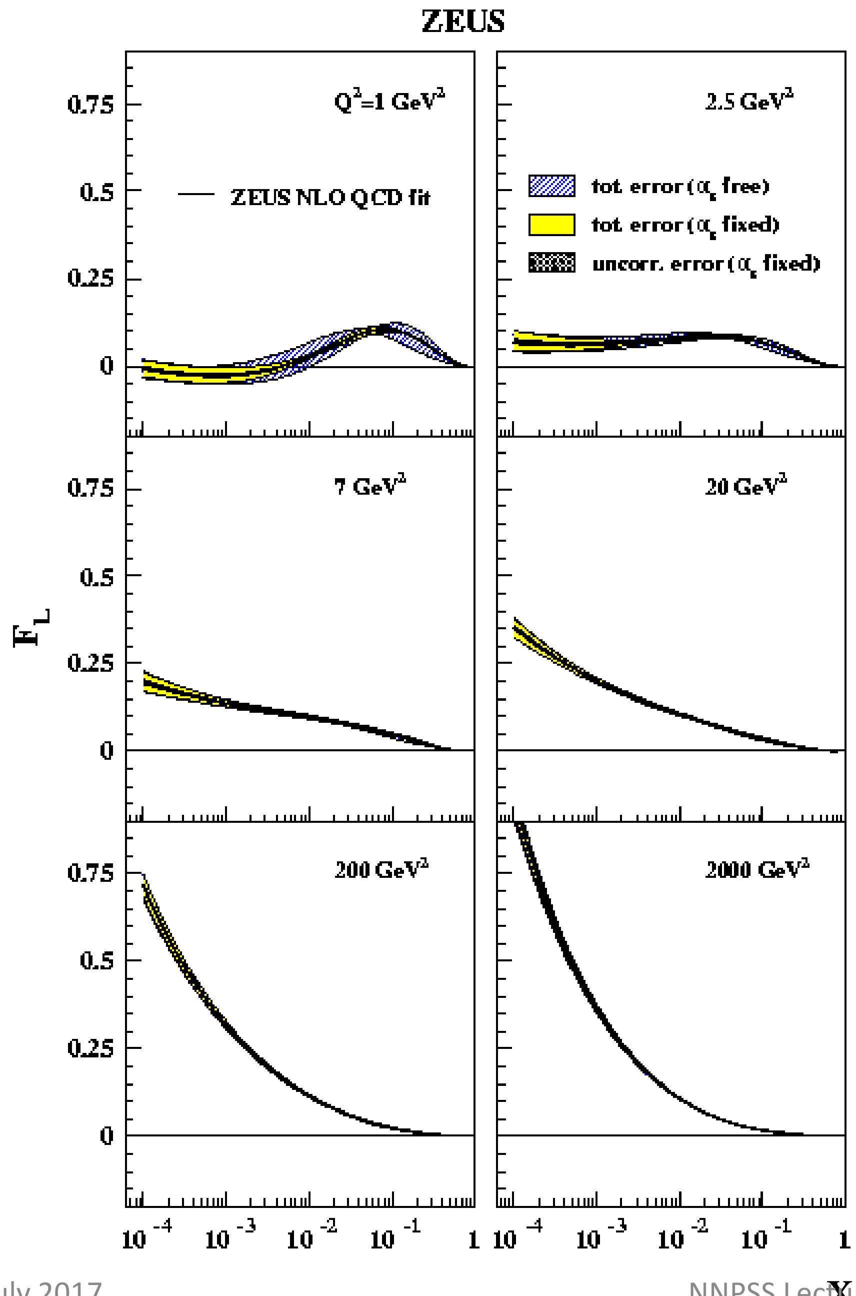
But...

QCD predicts a relationship between scaling violations and FL through the gluon density.





← increasing y

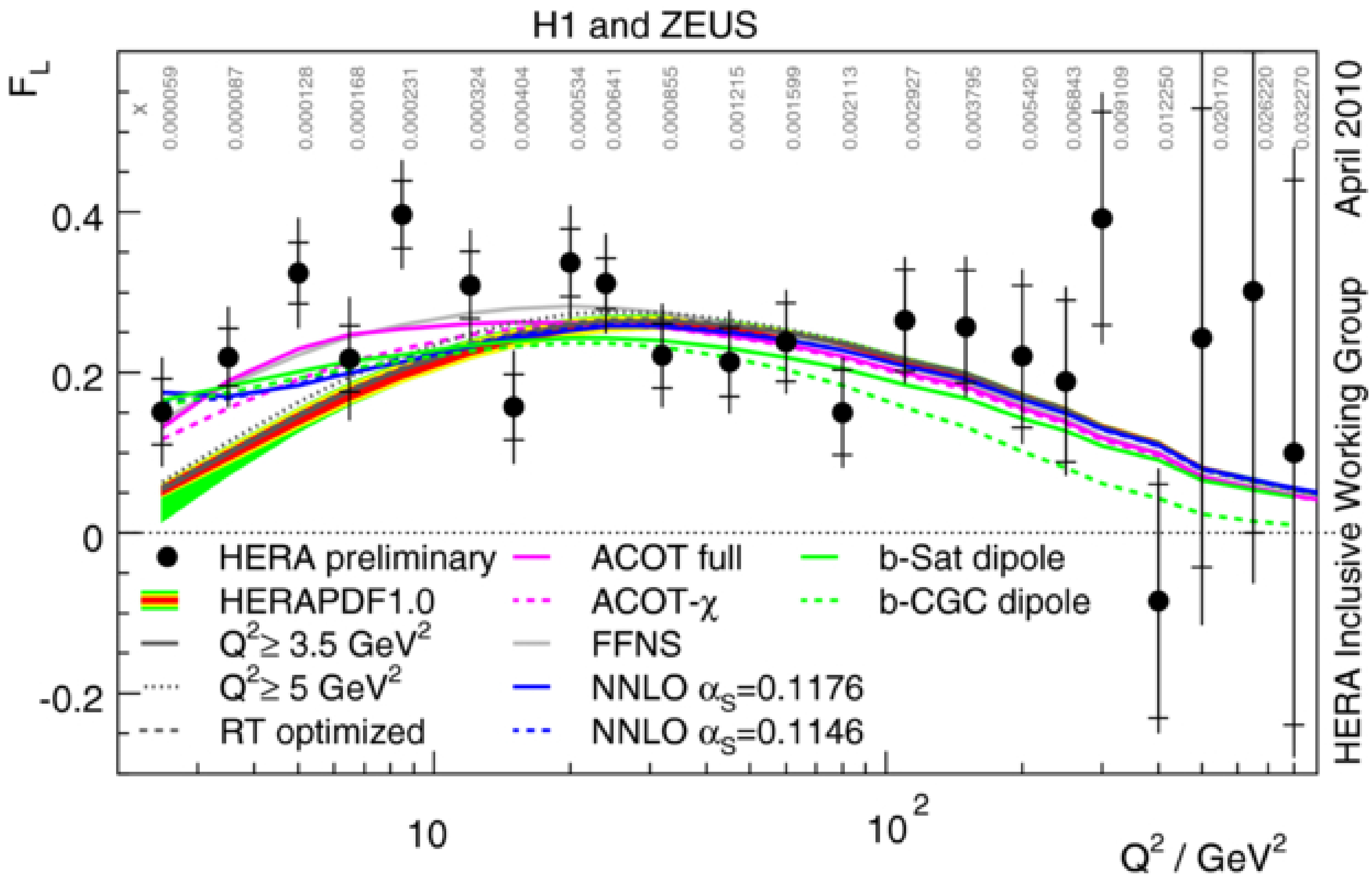


You can determine F_L from a NLO DGLAP fit to NC cross-section.

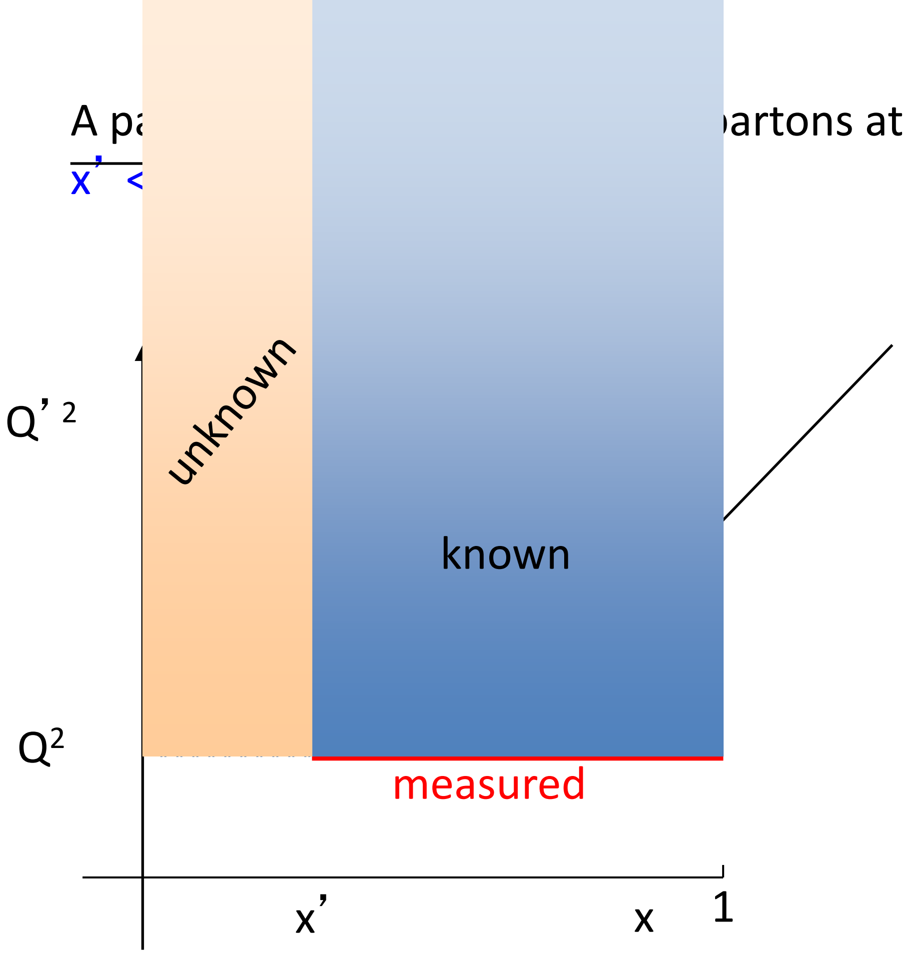
Indeed, we also only determine F_2 the same way, in principle:

$$\frac{d\sigma^2}{dx dQ^2} = \frac{2\pi\alpha^2}{xQ^4}(Y_+ F_2 - y^2 F_L \pm Y_- xF_3)$$

We measure this only


H1 and ZEUS
F_L
x
0.000059
0.000087
0.000128
0.000168
0.000231
0.000324
0.000404
0.000534
0.000641
0.000855
0.001215
0.001599
0.002113
0.002927
0.003795
0.005420
0.006843
0.009109
0.012250
0.020170
0.026220
0.032270
0.4
0.2
0
-0.2
HERA preliminary
HERAPDF1.0
Q²≥ 3.5 GeV²
Q²≥ 5 GeV²
RT optimized
ACOT full
ACOT-χ
FFNS
NNLO α_S=0.1176
NNLO α_S=0.1146
b-Sat dipole
b-CGC dipole
10
10²
Q² / GeV²
HERA Inclusive Working Group
April 2010

A pa … artons at
x' < …



In fact, any parton at $x > x'$ at Q^2 is a source.

To know the parton density at x', Q'^2 it's necessary (and sufficient) to know the parton density in the range: $x' \leq x \leq 1$ at some lower Q^2.

If you know the partons in range $x' \leq x \leq 1$ at some Q^2, then you know the partons in the range $x' \leq x \leq 1$ for all $Q'^2 > Q^2$.

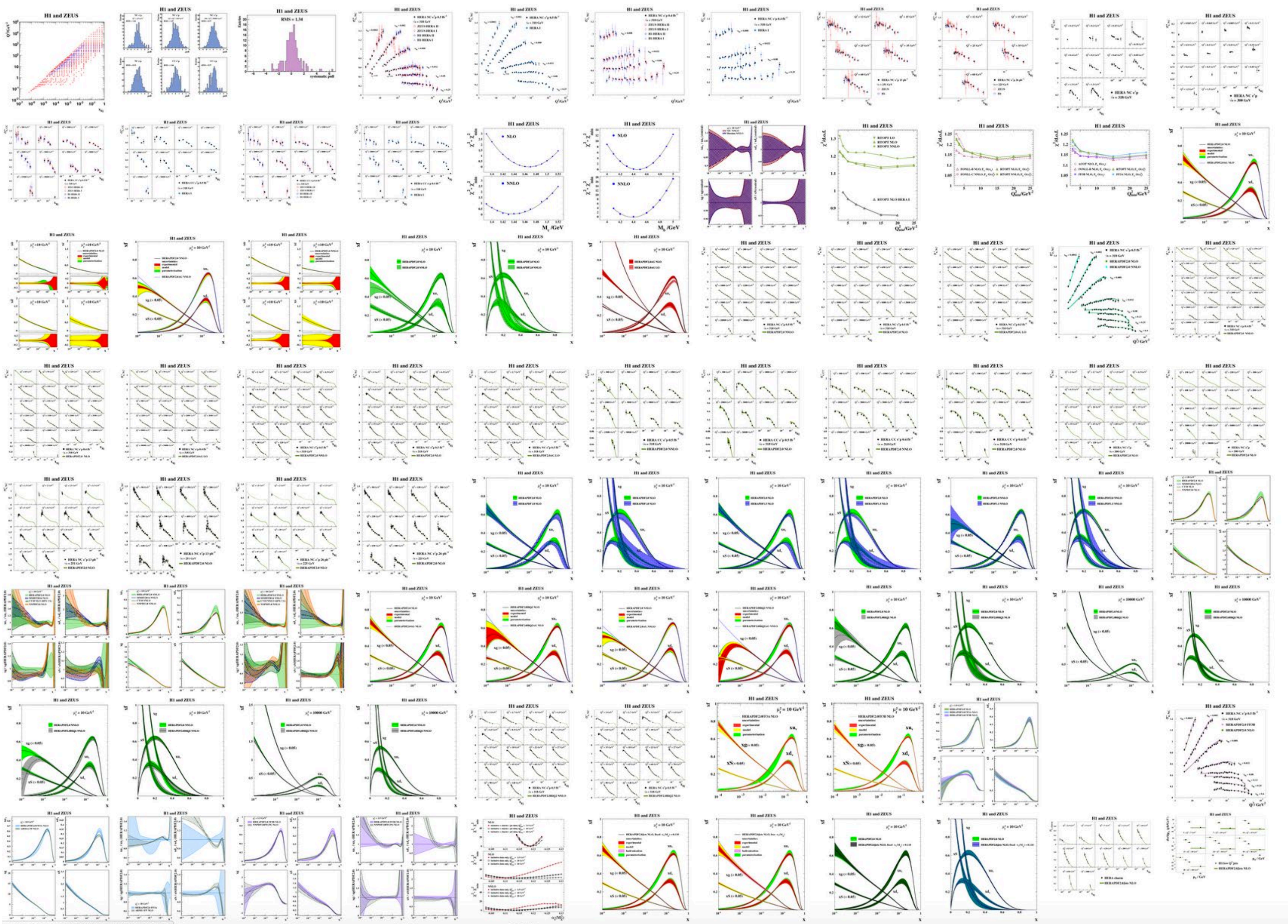
Some remarks I

- We've just gone through an informal tour of QCD-improved parton model and its application to data from ep Deep Inelastic Scattering.
- Some health warnings:
  - Most of what I talked about is a leading-order picture. In practice, most things are done at least to next-to-leading order. At NLO, the interpretation of the results are not as straight-forward.
  - Many people worry about whether we are not missing something fundamentally with the picture of DGLAP equations.
    - Much of the data are at very low x: DGLAP is a $\ln Q^2$ approximation. Why aren't $\ln(1/x)$ terms important…or are they? → BFKL equations.
    - The density of the partons, especially that of the gluons is getting very high. When and where should we worry about "shadowing", "gluon recombination" etc.
    - The idea of incoherence of partons may be breaking down in some kinematic regions: phenomenon of "hard diffraction" is difficult to understand in terms of partons without correlations to each other.
    - We'll cover some of this in the next section.

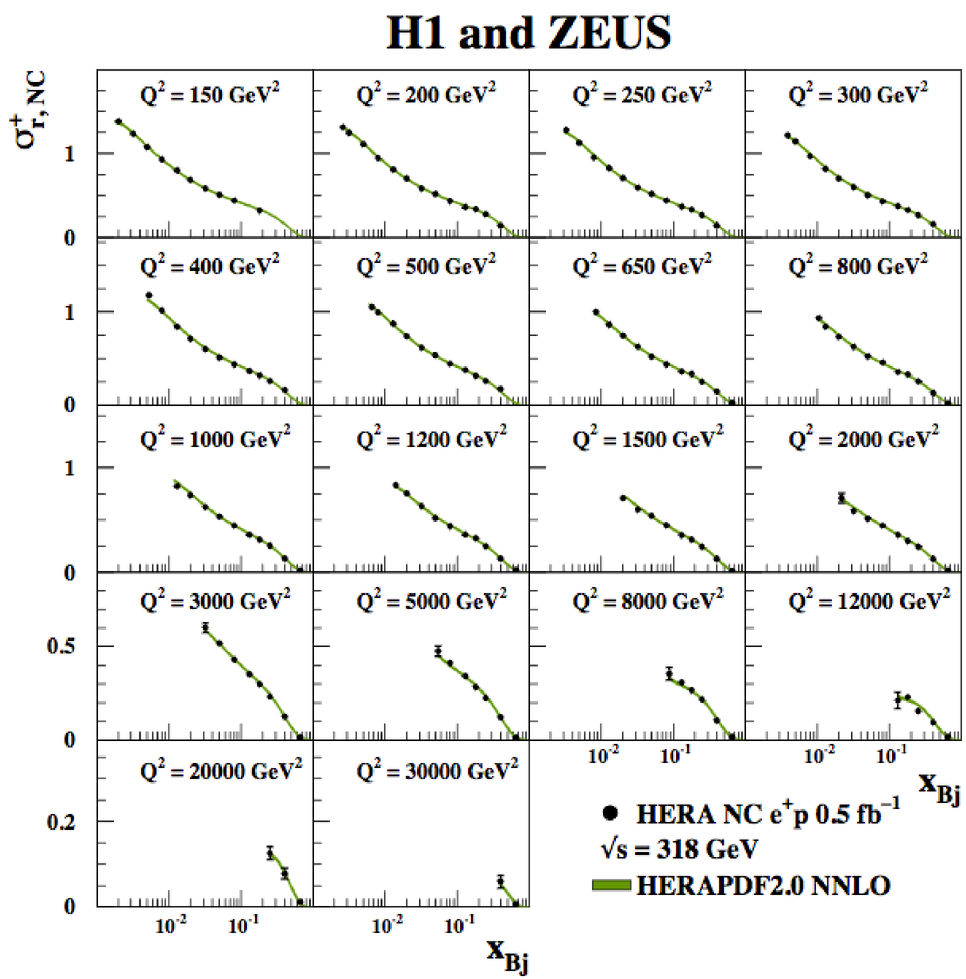
Some remarks II

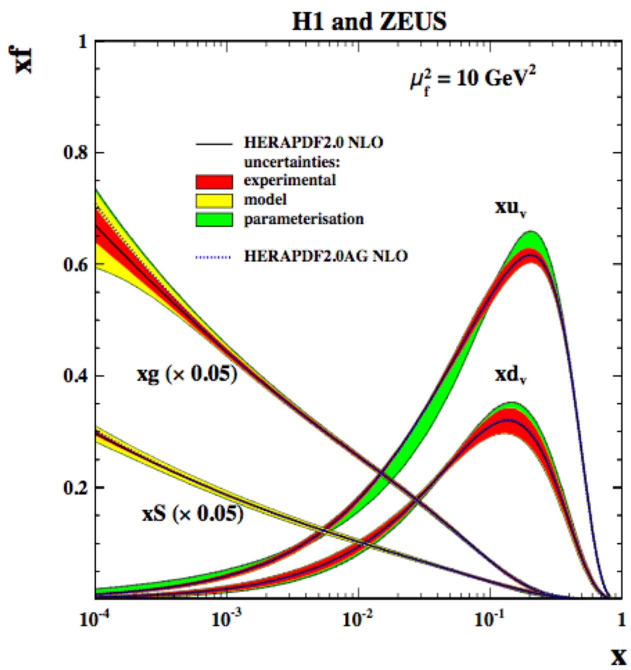
- Thanks to Claire Gwenlan for preparing some of the plots animation for me.
- However, the data used were relatively old.
- Final HERA (combined H1 and ZEUS) structure function data are summarized in the publication: **Eur.Phys.J. C75 (2015) no.12, 580**

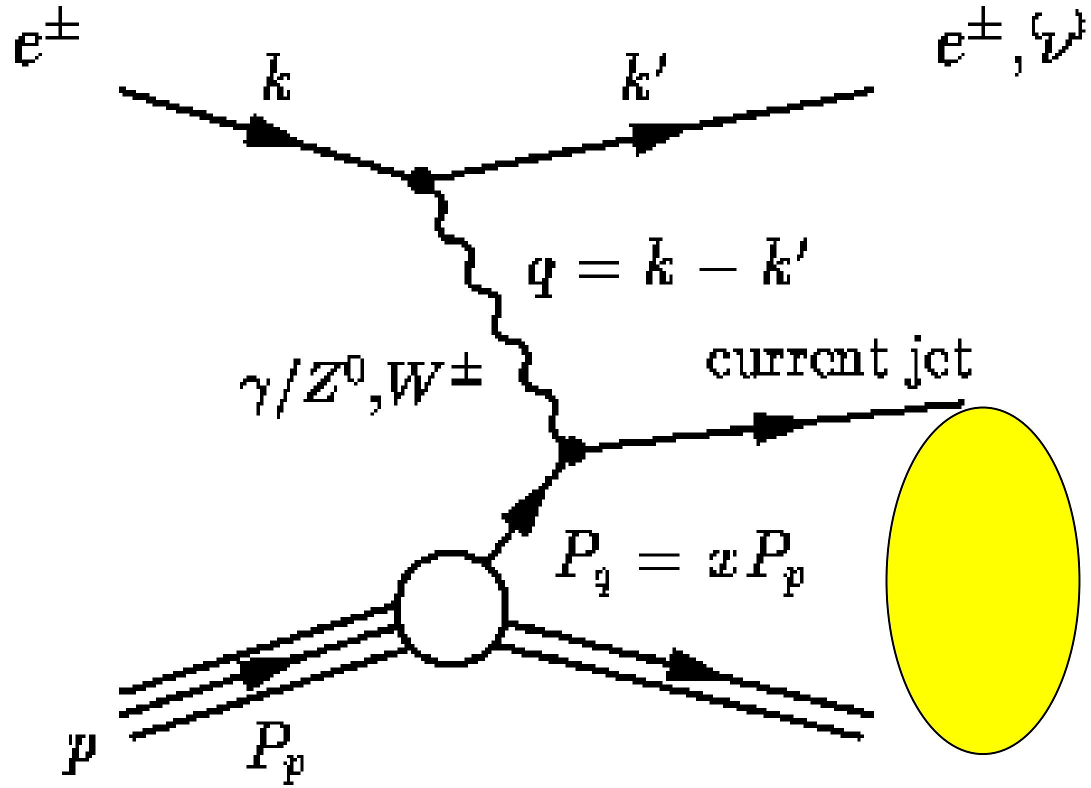
Final St. Fcn. Results from HERA



A small portion of the data.

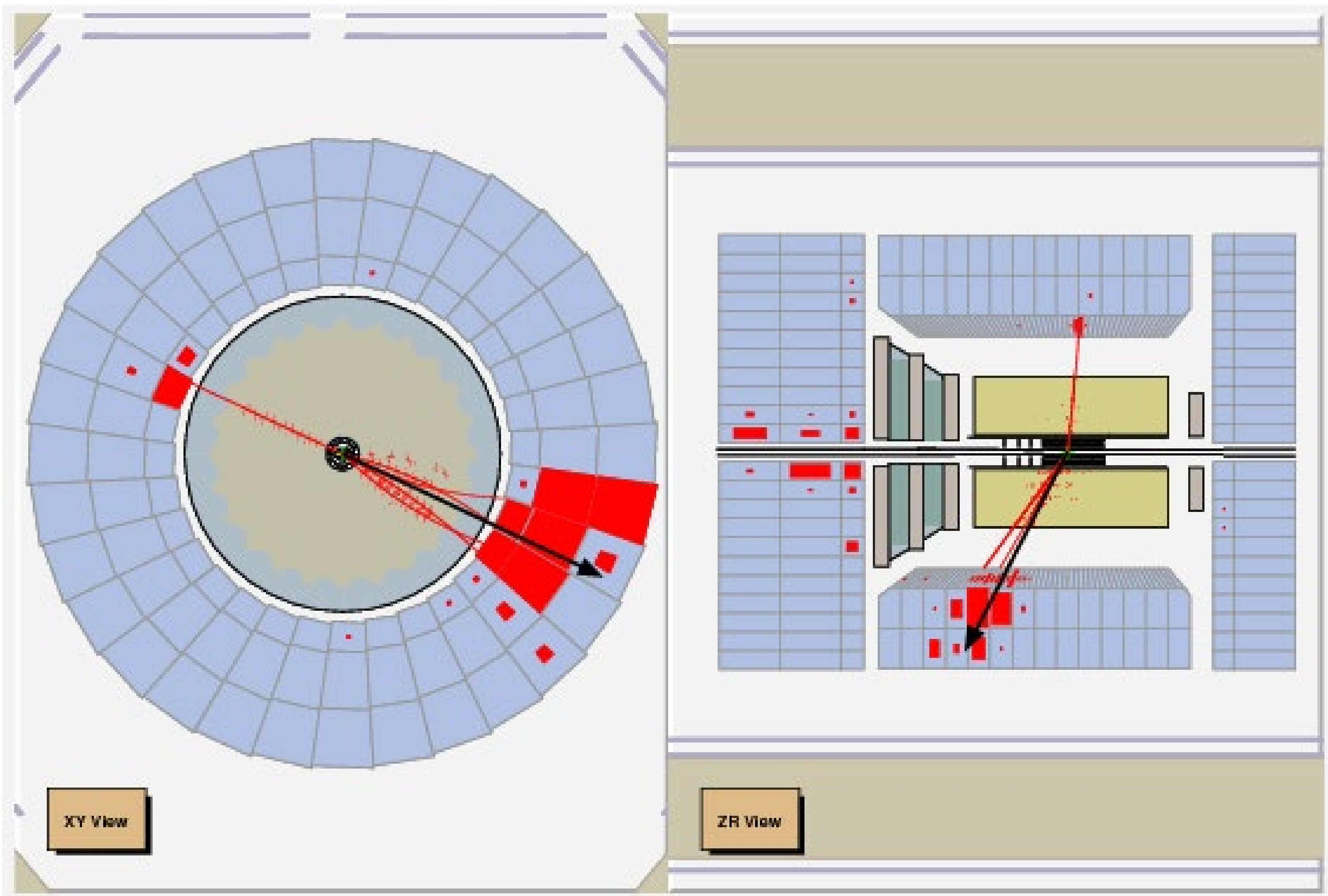






color
connection
leads to
particles
in "gap".

DIS Event in the ZEUS Detector



NEXT

- We learned about parton distribution functions of the proton.
- Things are similar for polarized PDFs and Fragmentation Functions.
- Did we learn something about the proton?
- What is missing?

Now we enter areas without too many answers

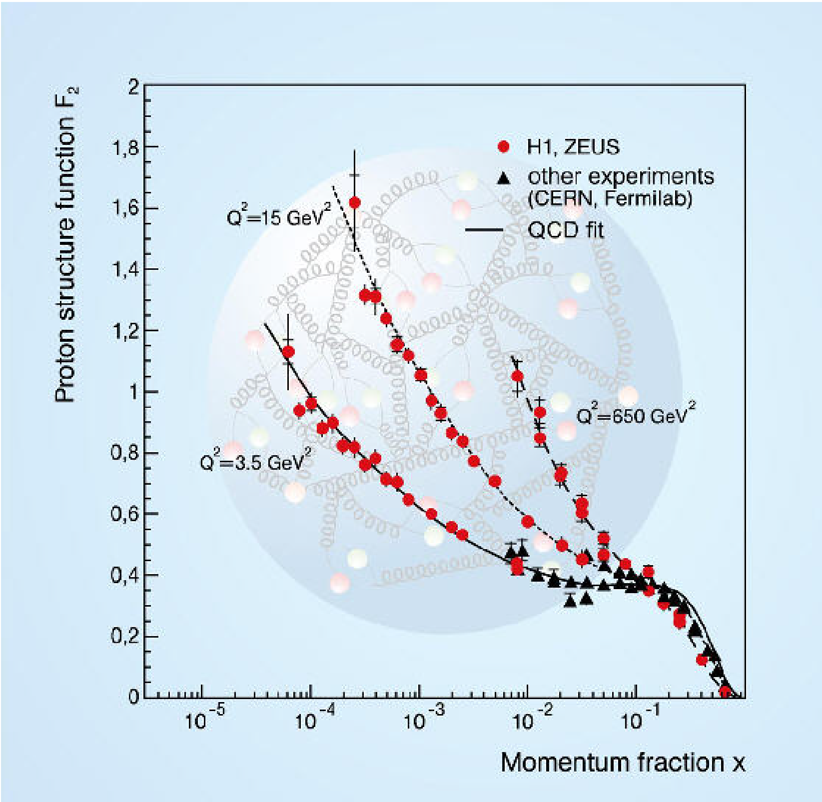
BEYOND PARTON DISTRIBUTIONS

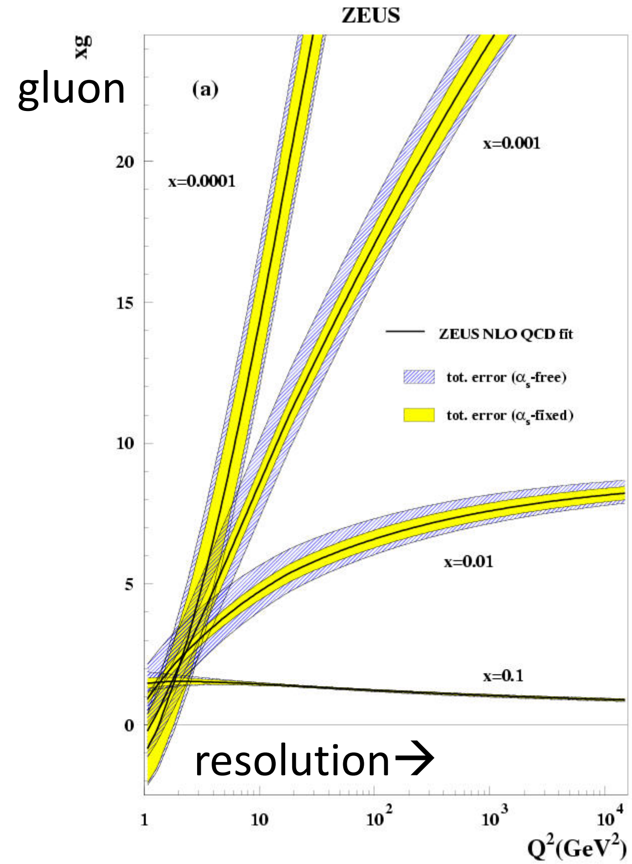
Where we are…

- We were interested in how protons and neutrons (nucleons) and hadrons “work”.
  - How do they acquire their characteristics.
    - Intrinsic characteristics such as mass, spin arise.
    - Interactions with other hadrons.
    - Bindint into nuclei. How does that lead to the characteristics of the nuclei.
- We’ve found out that nucleons (all hadrons) are made of quarks and gluons.
- We’ve extracted proton pdf’s (longitudinal distributions)
- We’ve verified the perturbative QCD describe the evolution of pdf’s.
- It seems like we should be able to answer some of the initial questions in terms of quarks, gluons and pQCD… But..
- In the last two lectures, we talked about answers. Now we talk about questions..
  - Part I: Is all really well? Are we sure the this pQCD+pdf edifice is correct?
  - Part II: How do we move ahead beyond pdf’s and start to answer some of those questions.

PART I: DIFFRACTION, BFKL, SATURATION

Triumph of perturbative QCD



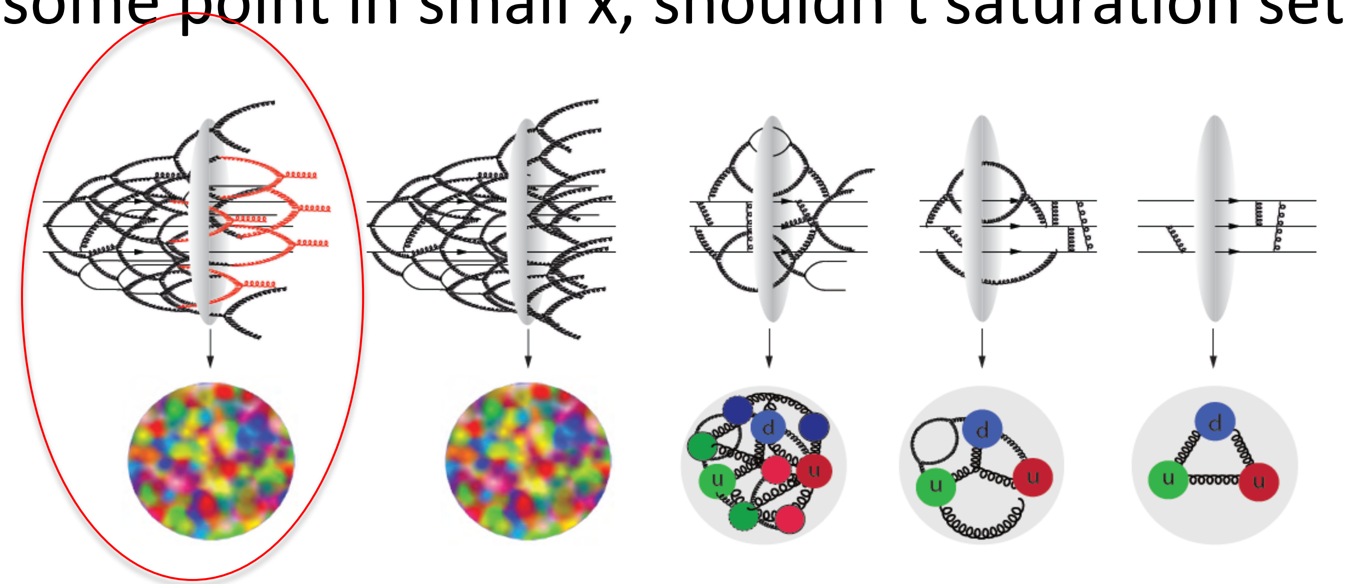


A part of Wilczek's comments upon the Nobel Prize announcement

proposed specific experimental tests of our ideas. In the fourth paper some technical objections to the theory were cleared up, and in the fifth and sixth papers further experimental consequences, regarding the pointwise evolution of structure functions, were derived. The most dramatic of these, that protons viewed at ever higher resolution would appear more and more as field energy (soft glue), was only clearly verified at HERA twenty years later.

Beyond DGLAP: BFKL and Saturation

- DGLAP is an expansion in $\alpha_s(\ln Q^2)$. Terms proportional to $\alpha_s \ln(1/x)$ are neglected.
- If x < 0.001 then should DGLAP still work?
- ln (1/x) evolution is called BFKL.
- At some point in small x, shouldn't saturation set in?



From 1991 HERA Workshop proceedings

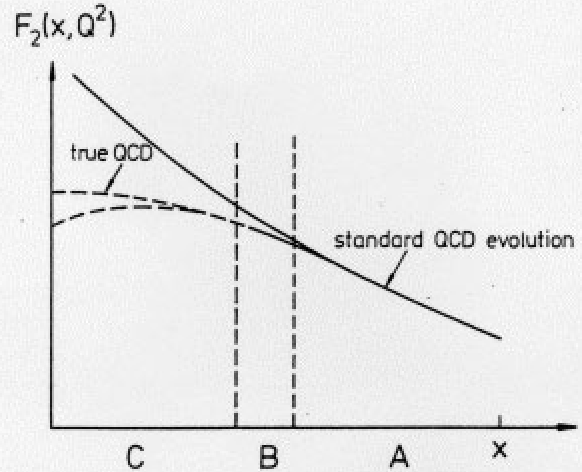
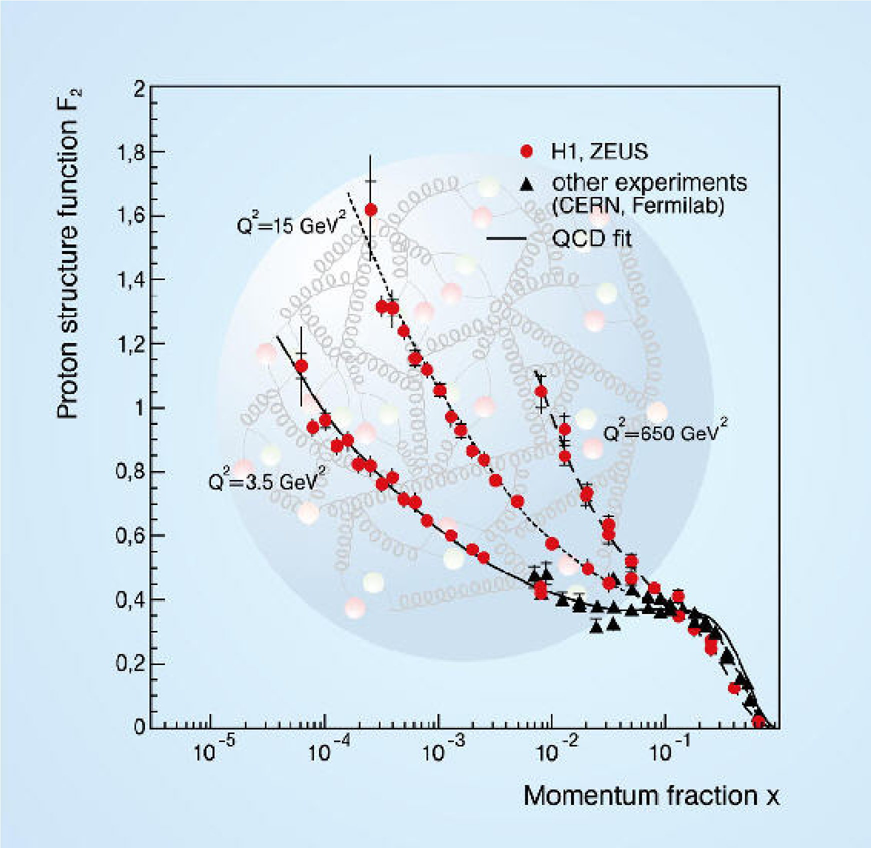
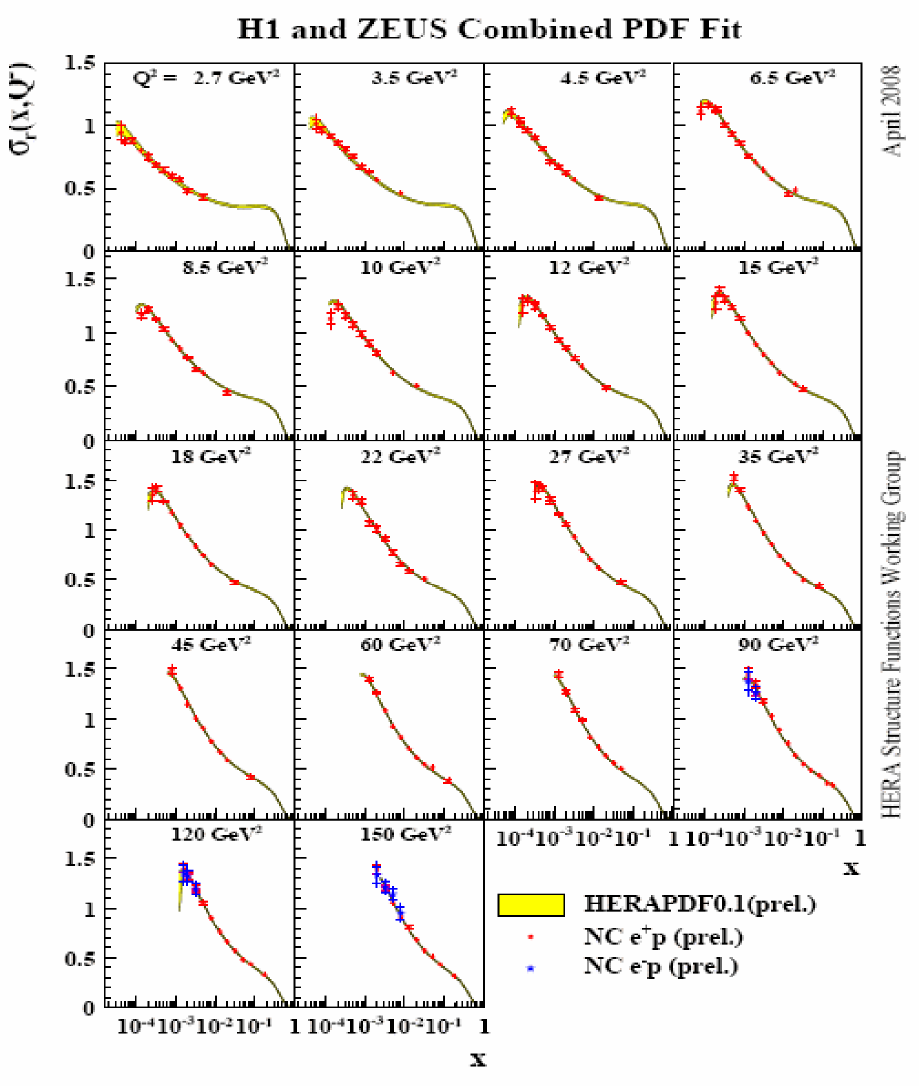


Figure 2: *Small-x behavior of the structure function: standard QCD evolution versus "true QCD" evolution. A is the perturbative region, B the transition region, C the nonperturbative region.*

A: Standard pQCD
B: Modified by GLR (saturation)
C: non-perturbative region.

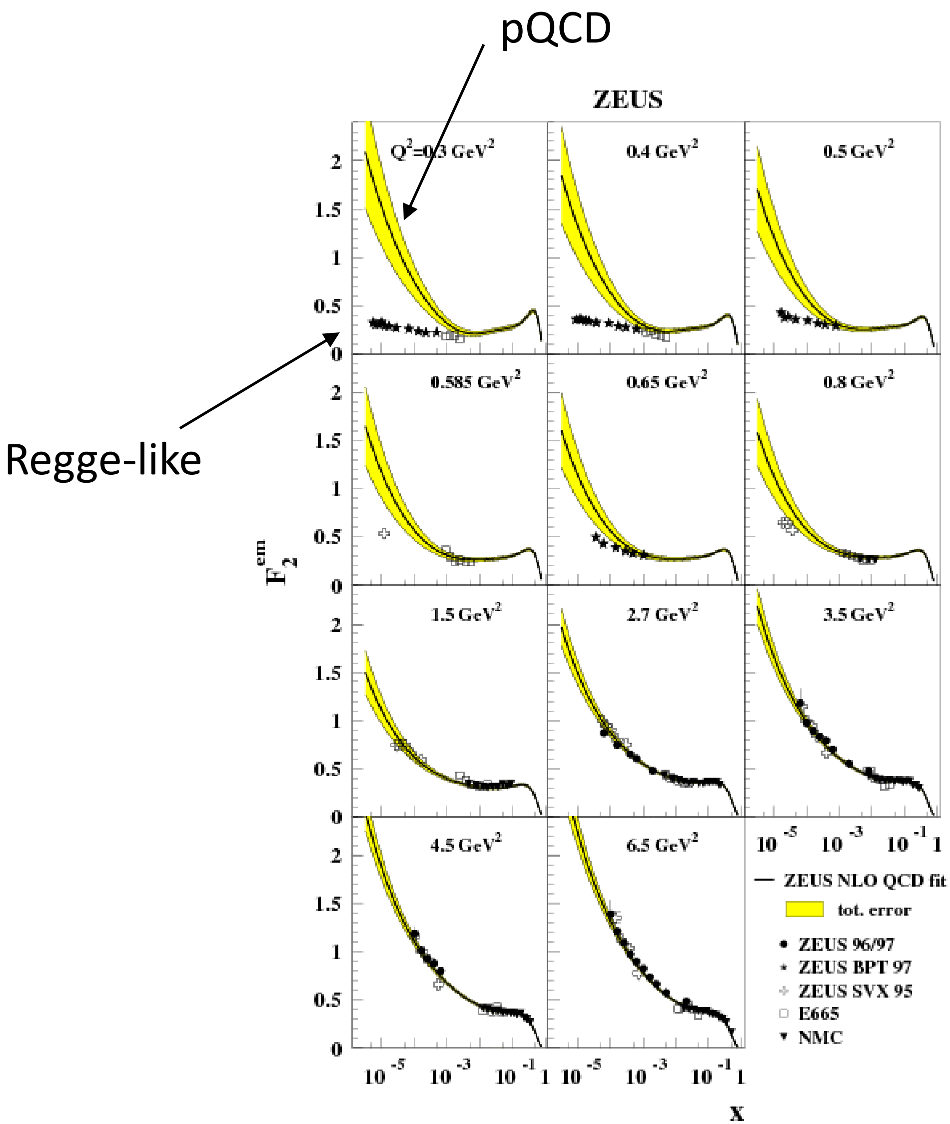


- In early 1990's when we started to measure the F2 structure function at HERA, most of the experimentalists thought of gluon saturation as visibly changing the behaviour of F2 at low-x (for a fixed Q2).
- DGLAP fits achieved excellent fits to the data, and precision PDFs began to be extracted.
- There seemed to be no "need" for low-x theory. We did not find a smoking gun for BFKL, much less saturation.
- This remains the view of many HERA experimentalists today.



Recent HERAPDF0.1 fit

Remarkably good fit to very precise data using DGLAP alone.



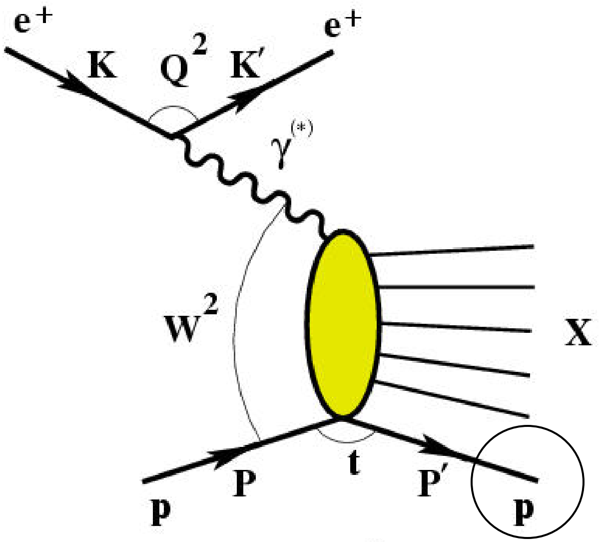
The only visible failure of DGLAP happens at low-Q^2 below 1 GeV^2.

This seems reasonable as a limit of perturbation theory.

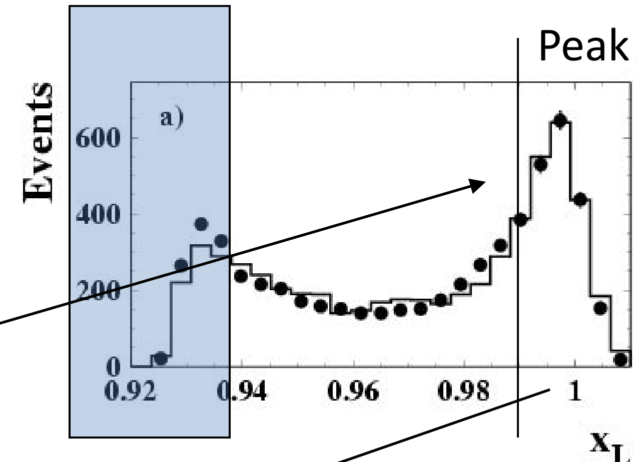
(Note, however but the failures begin at low-x)

Diffraction

Has the hadronic proton completely vanished
(only manifestation in the parton densities) ?

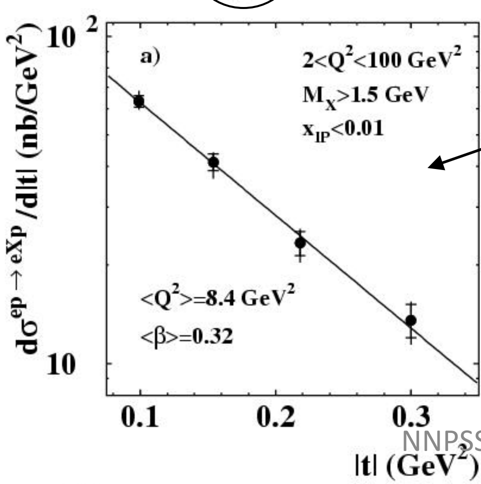


Look for leading protons in the final state



Peak!

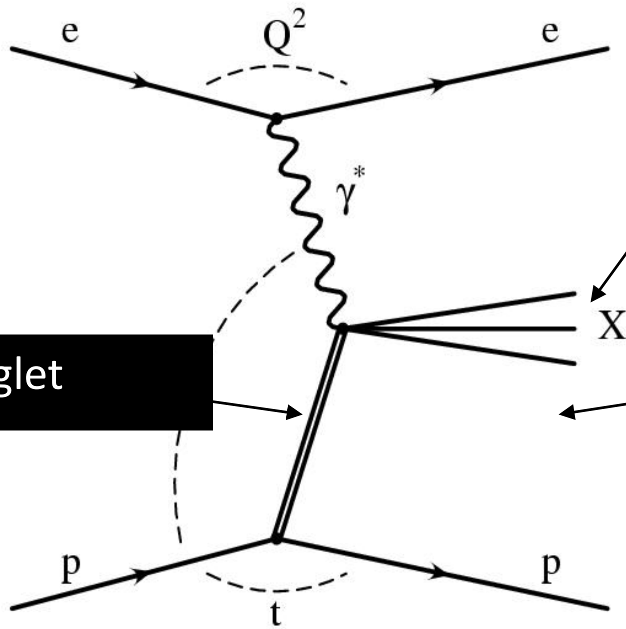
carries most of the beam momentum



t is small

If proton carries most
of the beam momentum
and t is small →

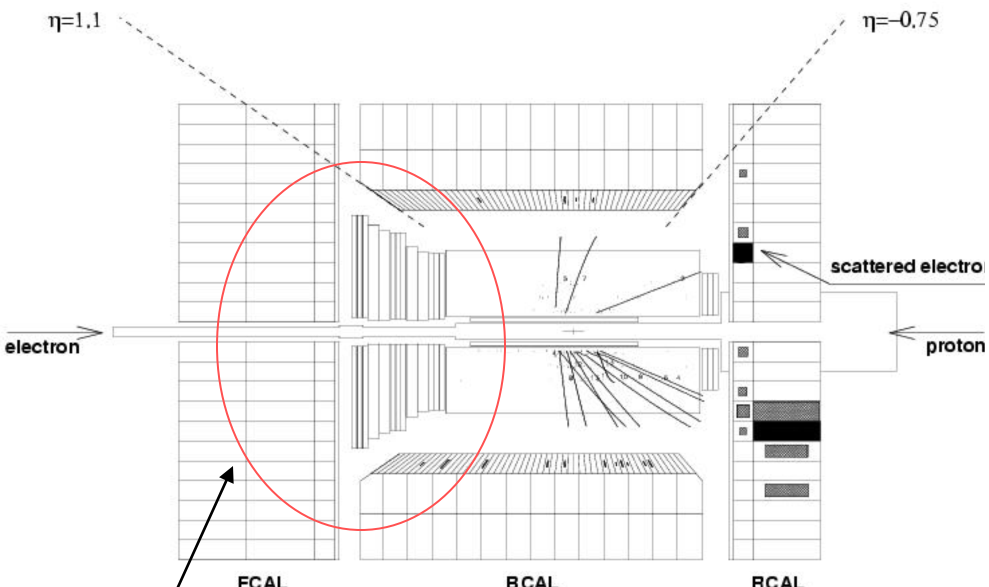
...then



Mass of X, Mx, must be small with respect to W

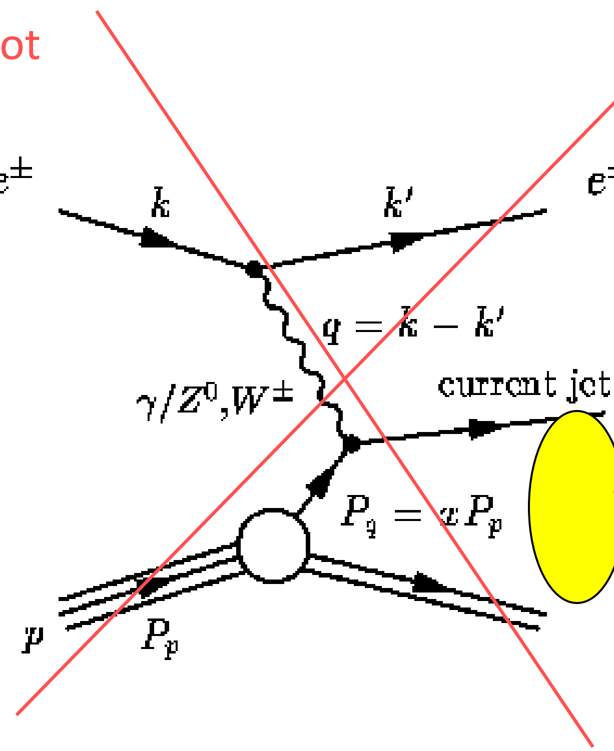
X is far away in rapidity from the proton→ a rapidity gap

color singlet

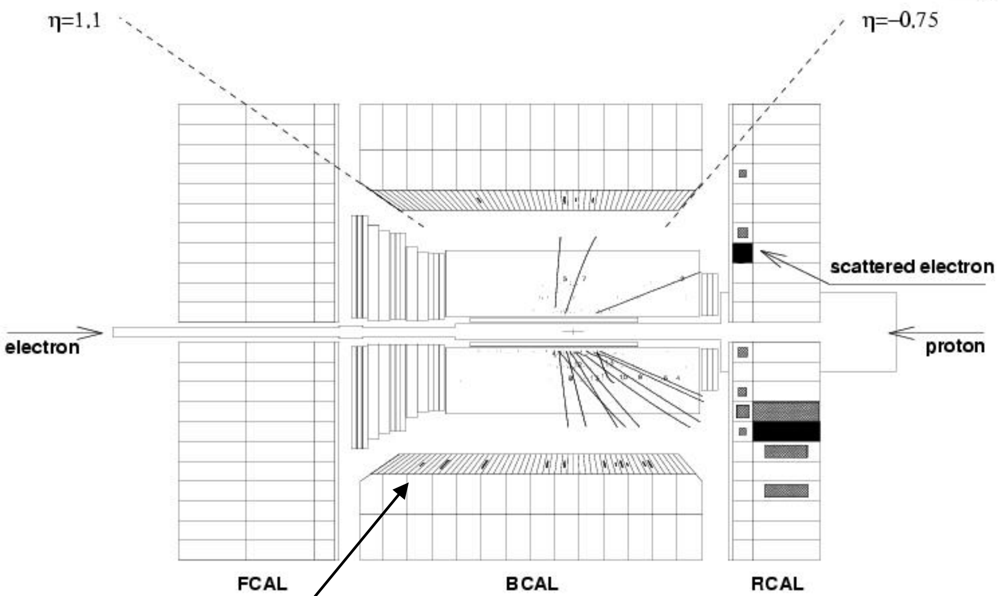


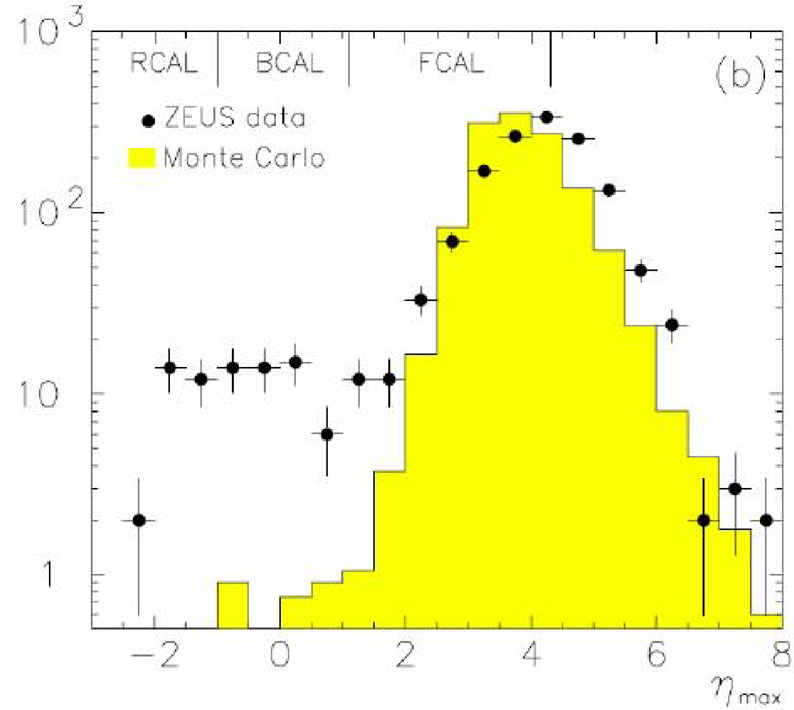
No particles in the proton direction

Not



color connection leads to particles in “gap”.

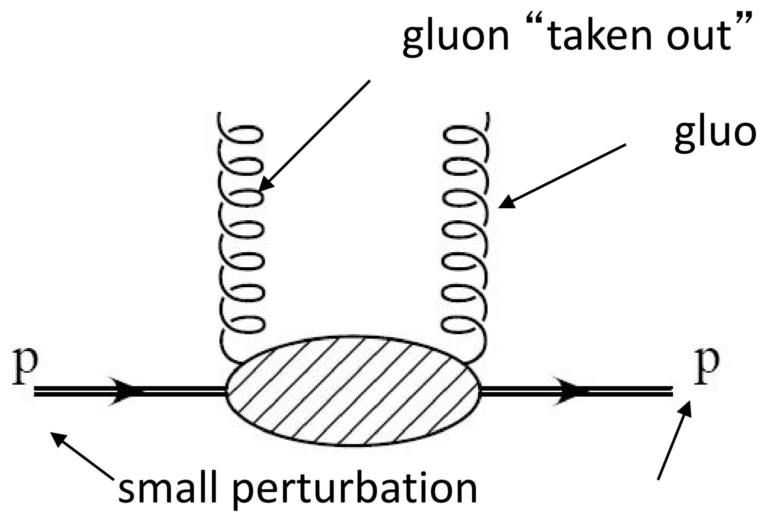




η_{max}, the most forward energy deposit

~10% of DIS events are “rapidity gap” events

In the simplest interpretation 2 gluons in a color singlet state are exchanged:



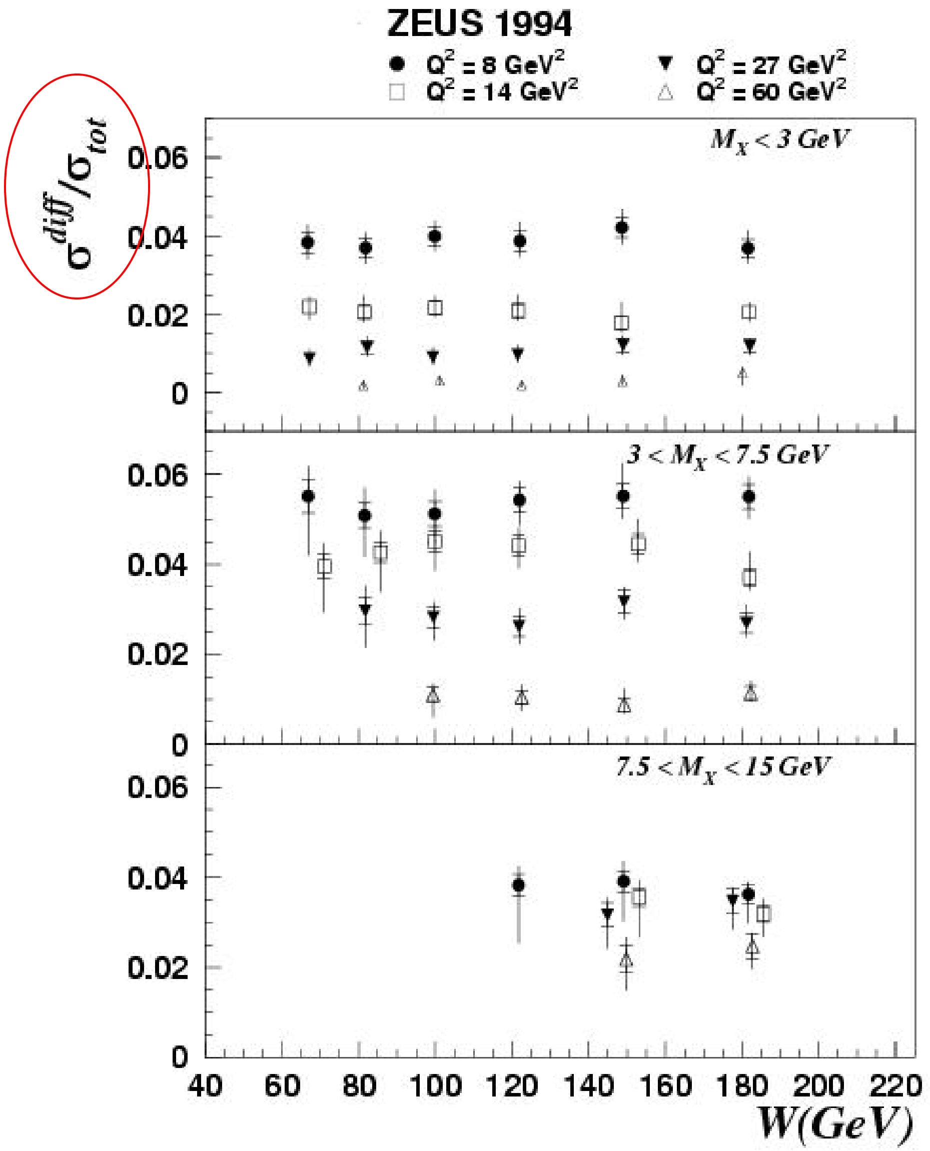
Proton stays intact: this process carries information about the proton wave function.

Here, proton is behaving as a hadron!

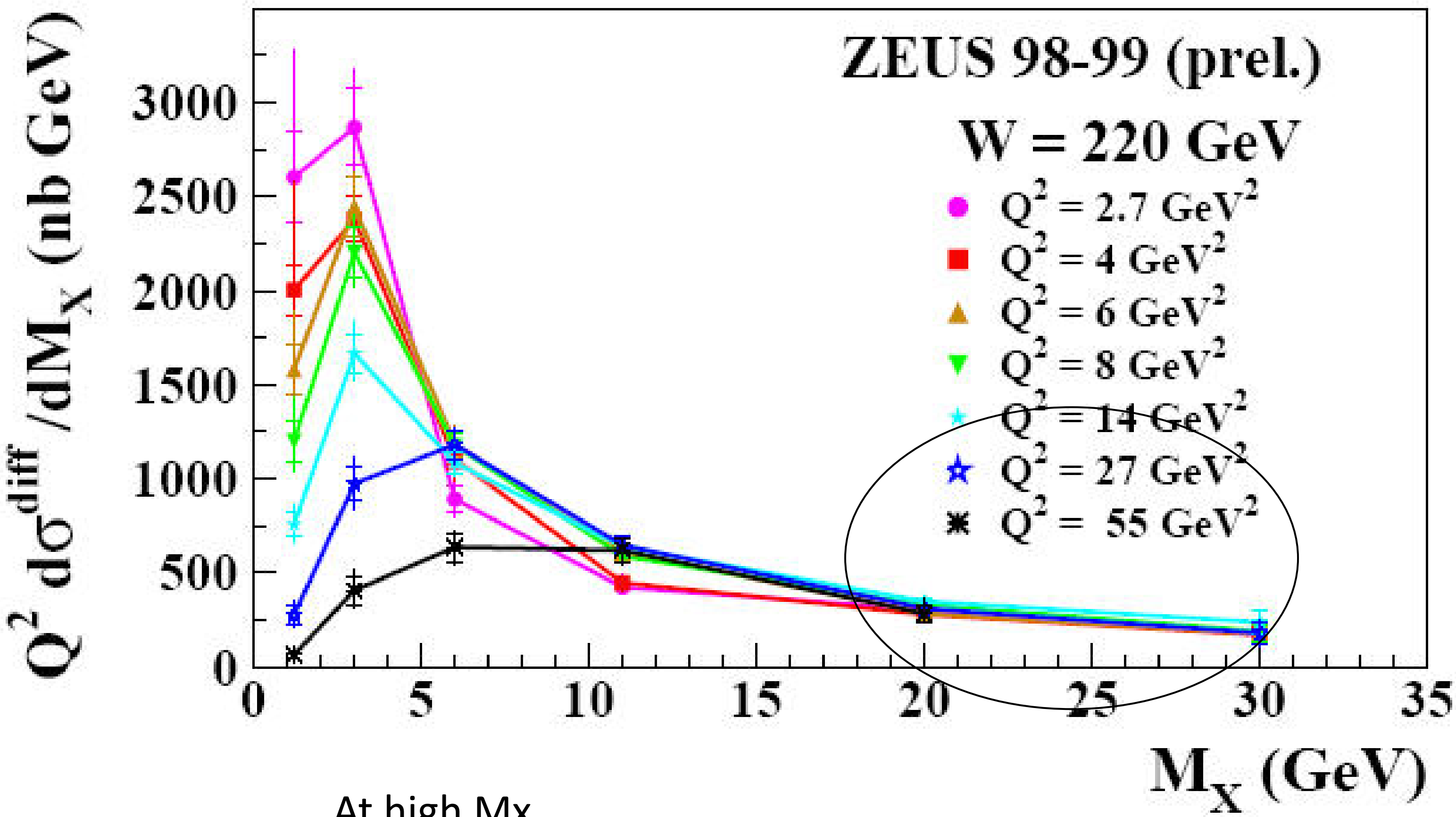
This is "diffraction" familiar from hadronic physics: however, with some peculiarities

- Sizable part of F_2 even at high Q^2 (~10% at 30 GeV^2). → High Q^2 means interpretable in terms of pQCD(?)
- Ratio to total cross section is flat with W (or x). How is this possible? If
  - σ_{tot} ~ gluon density
  - σ_{diff}~(gluon density)^2

  (Naively…)



ZEUS



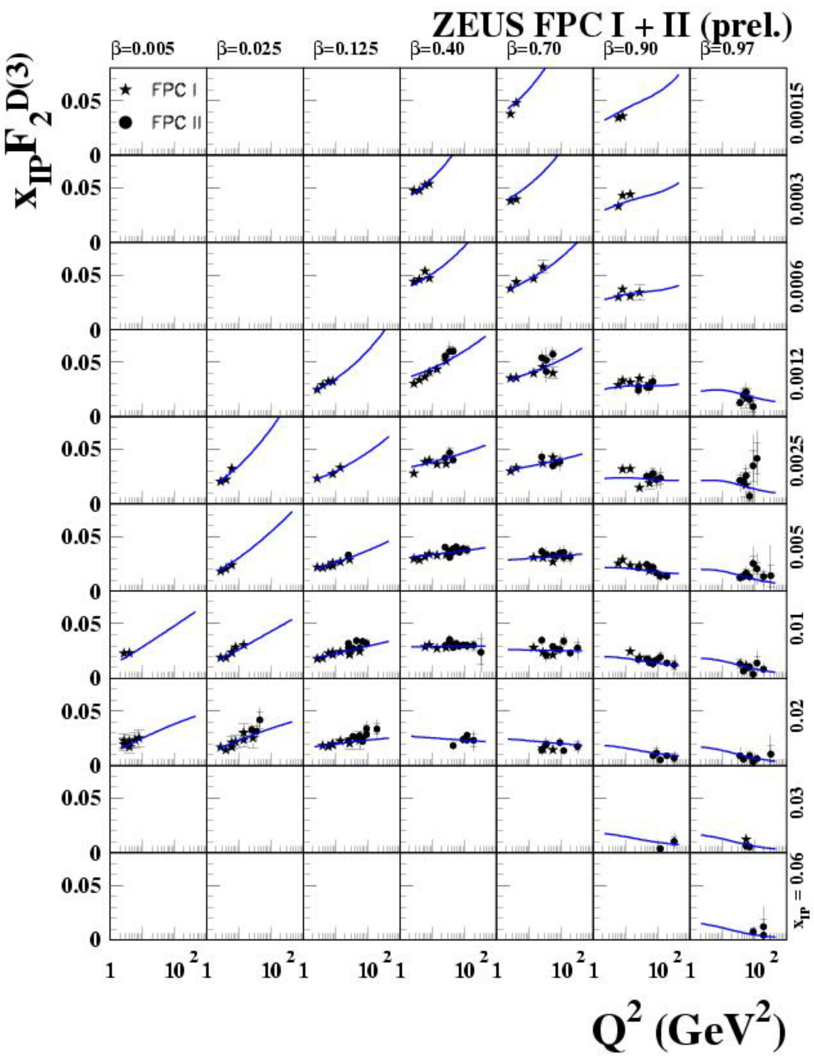
At high Mx, diffractive DIS is not vanishing at high Q^2.—"leading twist" in pQCD language.

Proton as a hadron

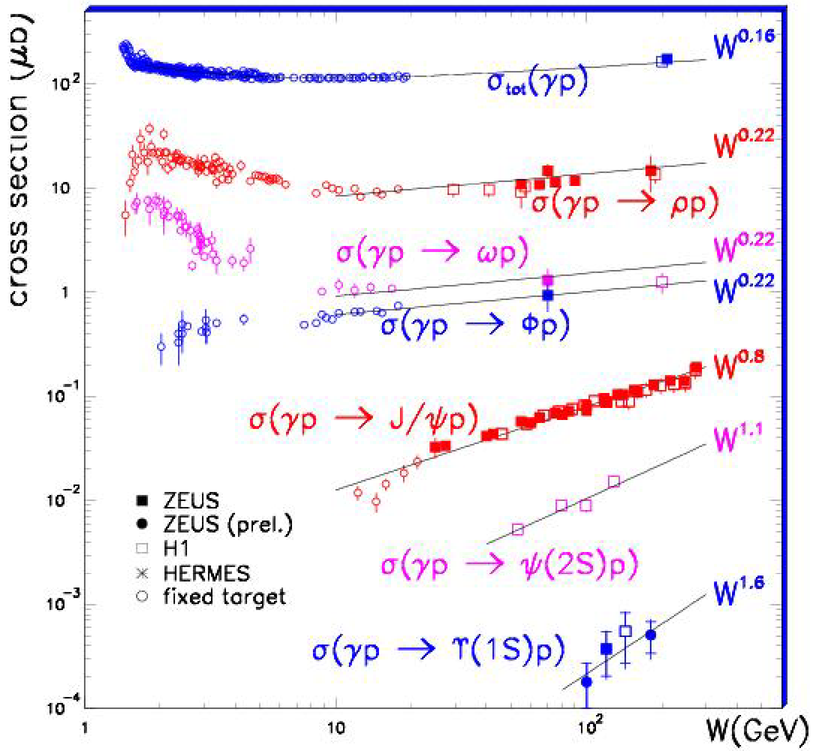
- In DIS diffraction we have:
  - A phenomenon that is clearly related to the hadronic nature of the proton—i.e. that of confined color.
  - that exists at 10% level at high Q2—where perturbative QCD should be usable.
  - that does not conform to the expectation from the hadronic phenomenology.
  - that does not conform to the naïve expectation of 2 gluon exchange.
- Plenty of mysteries:
  - We observe protons as hadrons clearly in the kinematic region where asymptotic freedom+partons appears to give a good description of data.
  - Do we, then, truly understand the evolution of partons in the proton—especially at low x?
  - Is diffractive DIS the opportunity to finally begin to unravel confinement from a perturbative point of view?

A lot of high precision data from HERA exists→

Diffractive DIS cross-section



Elastic VM production



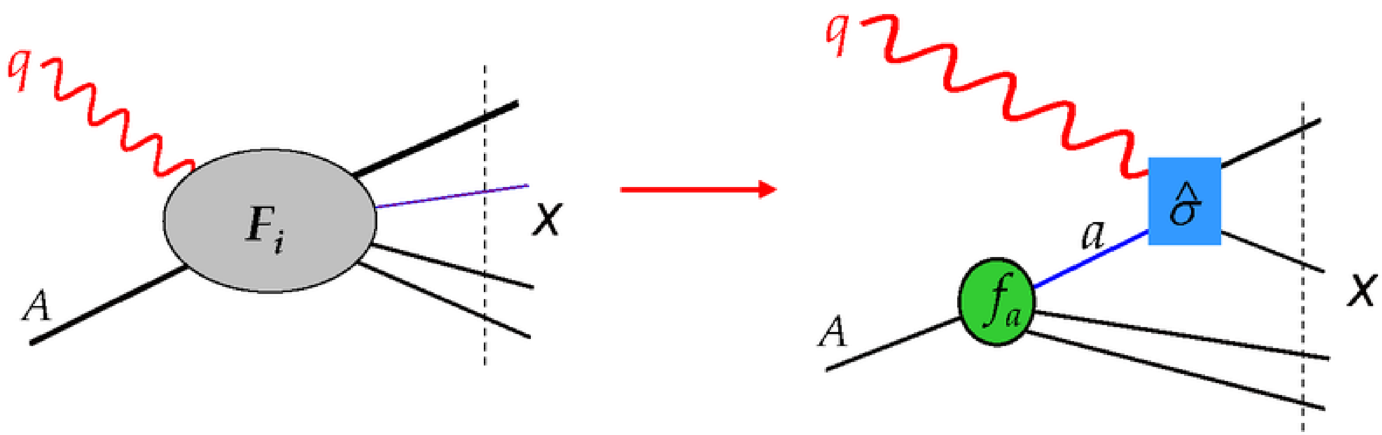
So far, no true understanding of this phenomenon

PART II: TOWARDS 3D STRUCTURES OF THE NUCLEI AND NUCLEON

What are we missing?

- We discovered that (nearly) massless quarks and gluons make up the nucleon and that QCD governs their interactions.
- We had hoped to find out how quarks and gluons and their interactions give rise to the characteristics of the nucleons.
  - Spin
  - Mass
  - Bulk
- We also hoped that we would be able to find out how NN interactions work in terms of QCD.
  - How nuclear forces arise.
  - How nuclear characteristics come about
- We were able to do this kind of things with EM and atoms.
- So far we have failed..

What longitudinal factorization did

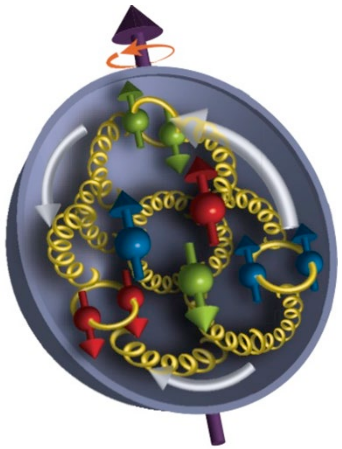


$$\lim_{Q^2 \to \text{large},\, x\,\text{fixed}} F_i(x, Q^2) = f_a \otimes \hat{\sigma}$$

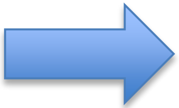
Function only of x (i.e. longitudinal momentum)

Our quarks and gluons as constituents of the proton only exist longitudinally.

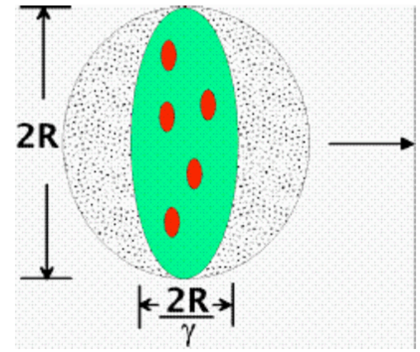
Limits of Longitudinal Information



infinite
momentum
frame



What we know



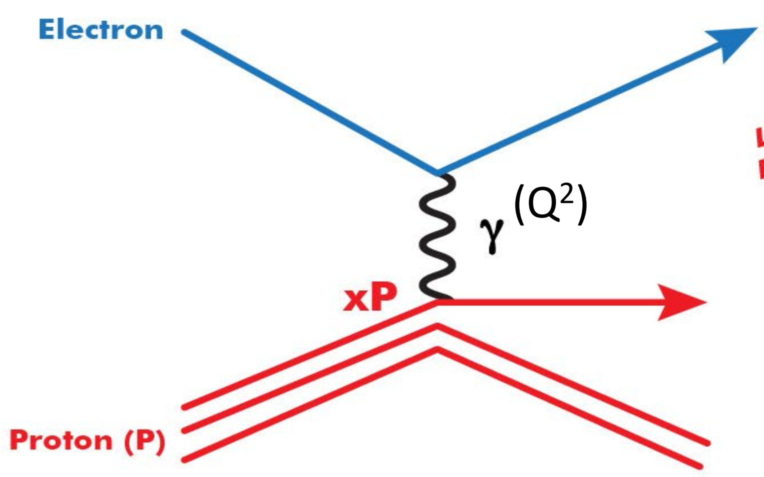
What is the quark and gluon structure of the proton?
-orbital motion?
-color charge distribution?
-how does the mass come about?
-origin of nucleon-nucleon interaction?

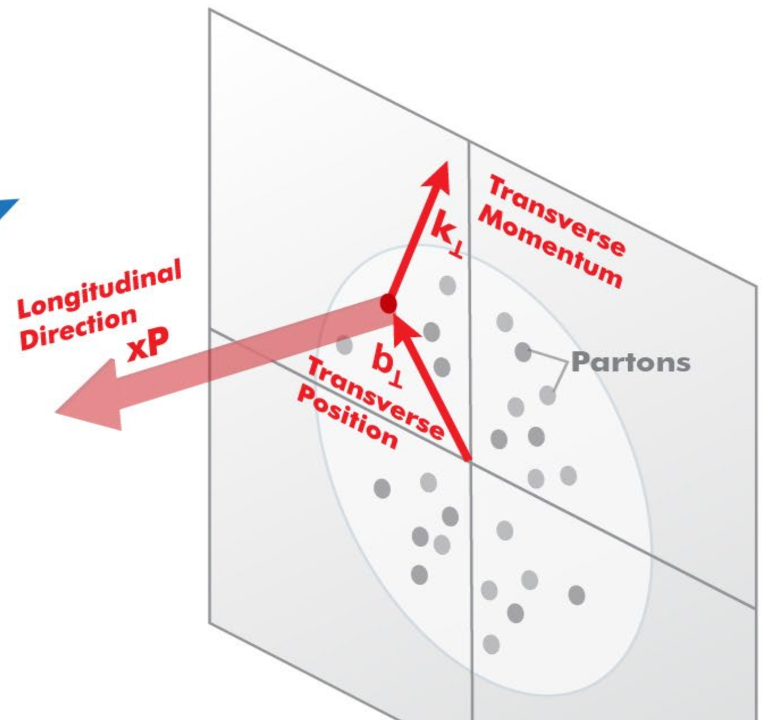
Parton frozen transversely. Framework does not incorporate any transverse information.

But this was the only way to define quark-gluon structure of proton in pQCD.

Progress in pQCD Theory (~1980-~2010)

Factorization II





Parton Distribution Functions:
Longitudinal only—
No way to interpret nucleon partonic structure in rest frame

→

3D (Transverse) Structure
TMD's, GPD's—
Now we know what to measure to understand the 3D structure of nucleons

Transverse Momentum Dependent Distributions (TMD): k_t
Generalized Parton Distributions (GPD): b_t

3D Imaging of Quarks and Gluons

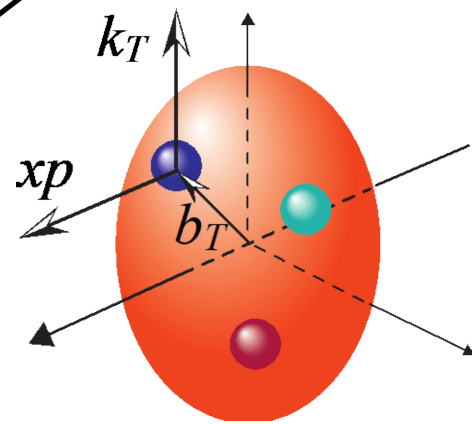
$W(x,b_T,k_T)$

Momentum space

$\int d^2b_T$

$\int d^2k_T$

Coordinate space

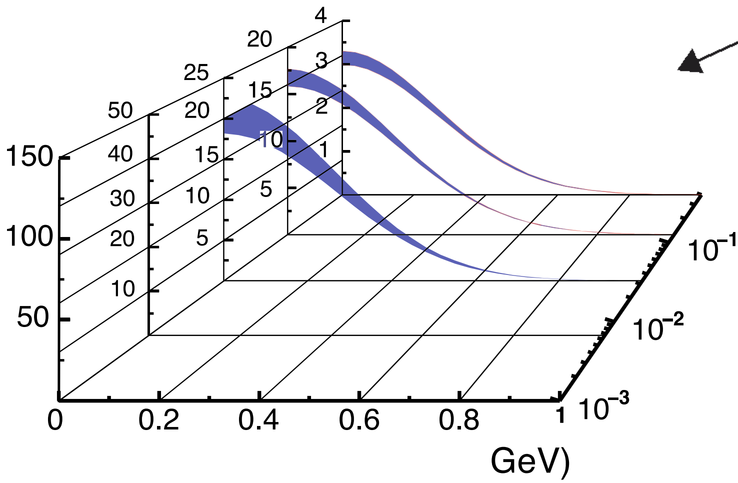


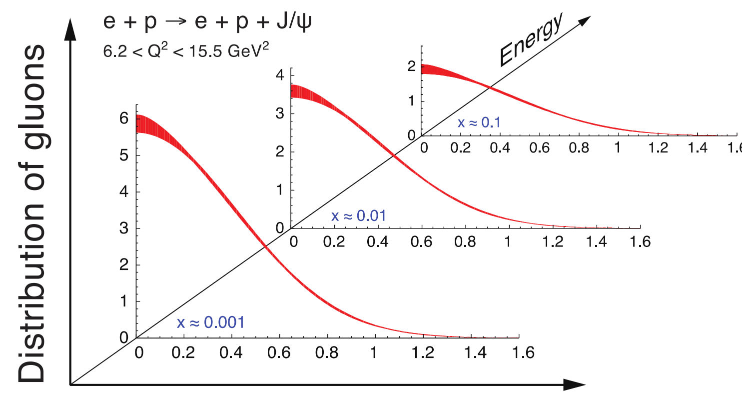
$f(x,k_T)$

$f(x,b_T)$

Quarks

Gluons





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

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

3D Imaging of Quarks and Gluons

$W(x,b_T,k_T)$

Momentum space

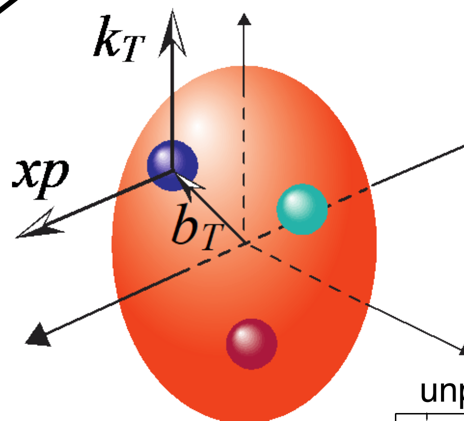
$\int d^2b_T$

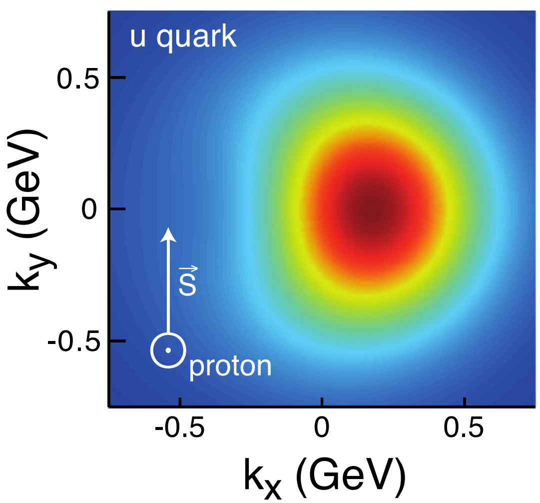
$f(x,k_T)$

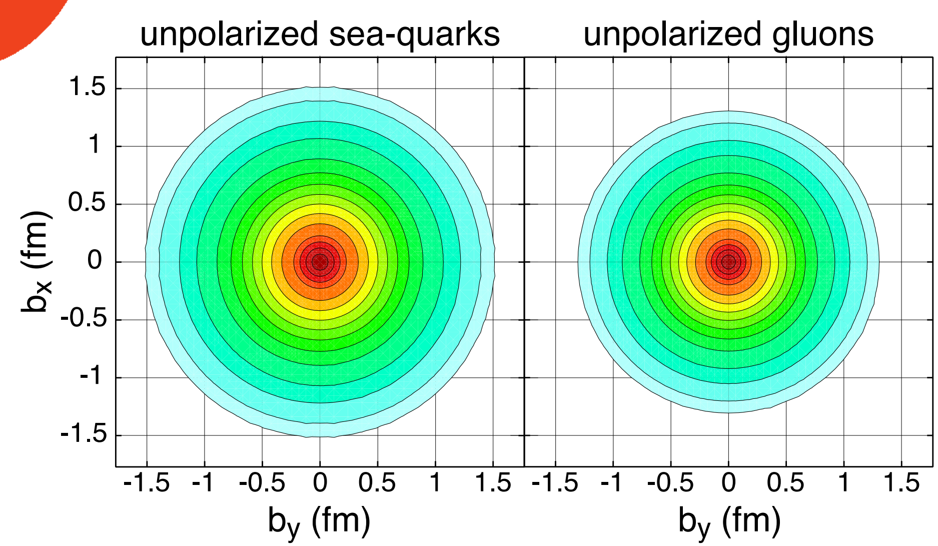
Coordinate space

$\int d^2k_T$

$f(x,b_T)$

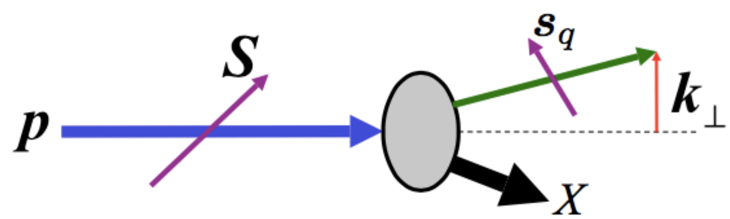






Position $r \bullet p$ → Orbital Motion of Partons

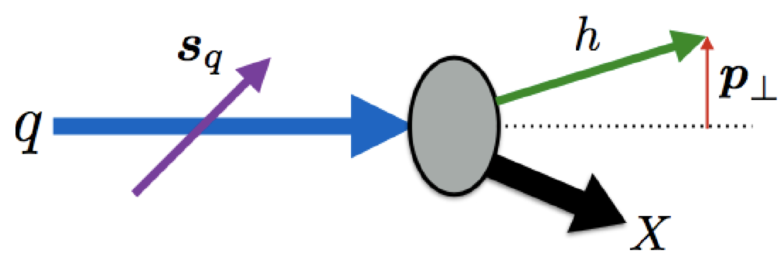
Some TMD examples



$\boldsymbol{S} \cdot (\boldsymbol{p} \times \boldsymbol{k}_\perp)$ "Sivers effect"

$\boldsymbol{s}_q \cdot (\boldsymbol{p} \times \boldsymbol{k}_\perp)$ "Boer-Mulders effect"

$\boldsymbol{S} \cdot \boldsymbol{s}_q$

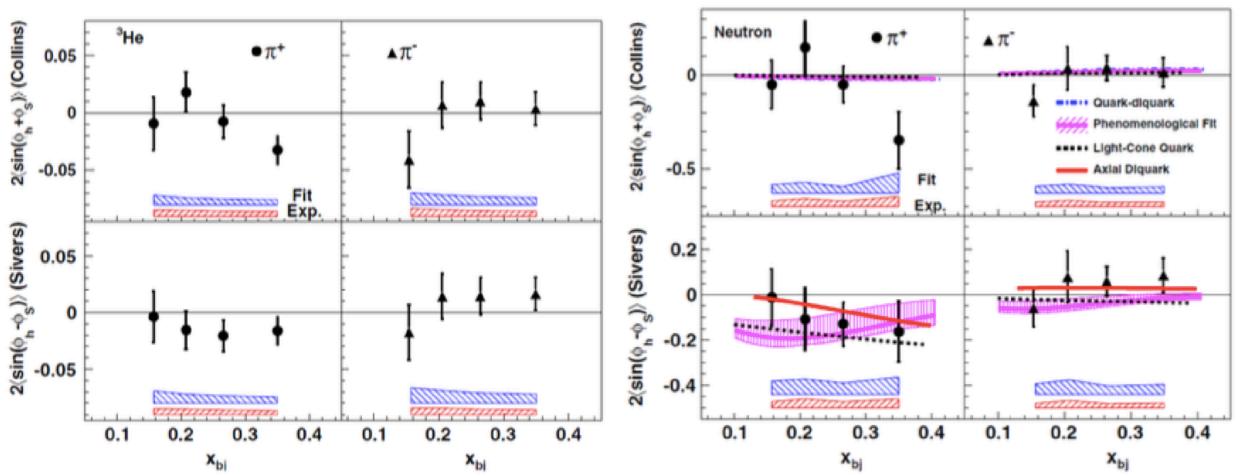


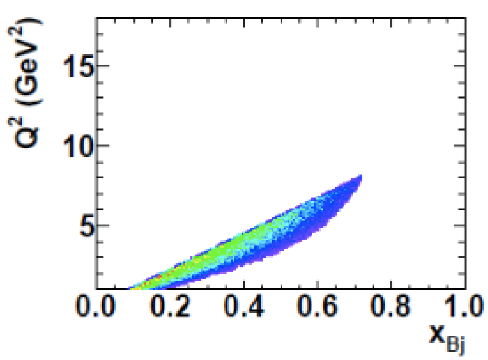
$\boldsymbol{s}_q \cdot (\boldsymbol{p}_q \times \boldsymbol{p}_\perp)$ "Collins effect"

Courtesy of M. Anselmino

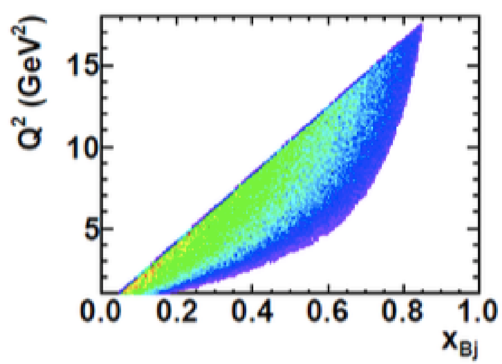
JLab Program on TMDs and GPDs

Collins and Sivers effects: ***PRL 107, 072003 (2011)***





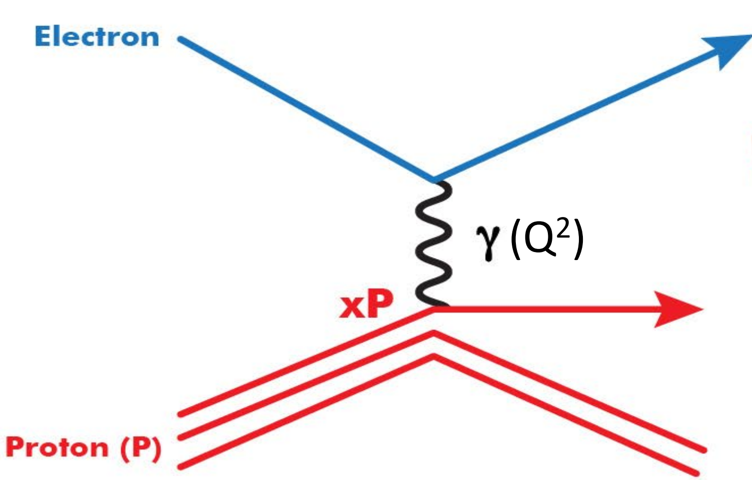
JLAB 12

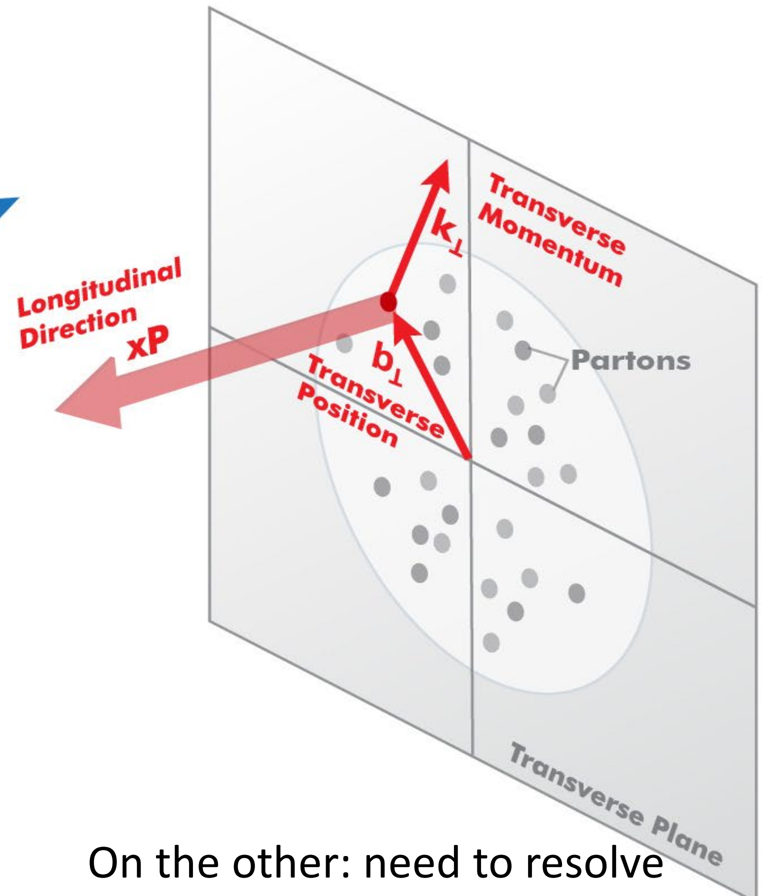


THE NEXT LEAP FORWARD: EIC

Experimental Challenge of the EIC

$Q^2 = sxy, \quad s = 4E_eE_p$





On one hand: need high beam energies to resolve partons in nucleons.
Q^2 needs to be up to ~1000 GeV^2

On the other: need to resolve quantities (k_t, b_t) of order a few hundred MeV in the proton. Limits proton beam energy. High Lumi needed.

Electron-Ion Collider: Cannot be HERA or LHeC: proton energy (TeV) too high

Understanding the Nucleon at the Next Level

<u>Nucleon: A many-body system with challenging characteristics</u>

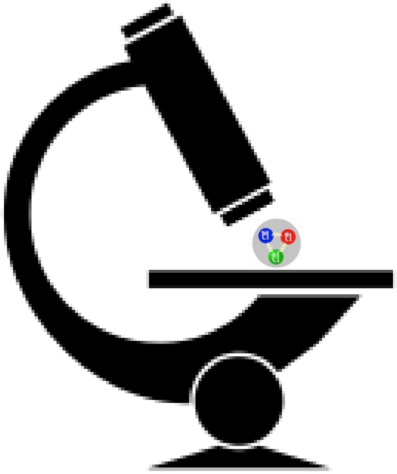
Relativistic ($M_{proton} >> M_{quark}$)

Strongly Coupled (QCD)

Quantum Mechanical (Superposition of configurations)

Measure in the Multi-Body regime:
- Region of quantum fluctuation + non-perturbative effects → dynamical origin of mass, spin.

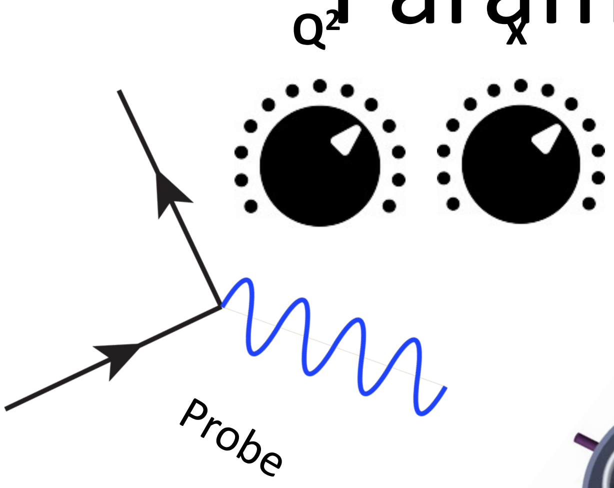
For the first time, get (almost?) all relevant information about quark-gluon structure of the nucleon

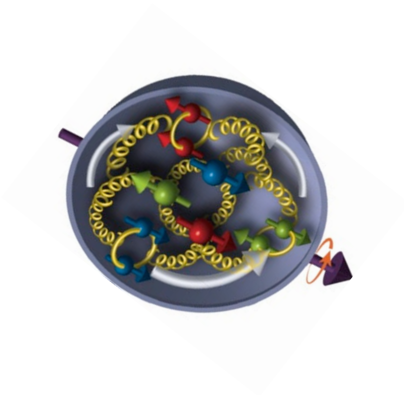


Designing EIC → Designing the right probe

- Resolution appropriate for quarks and gluons
- Ability to project out relevant Q.M. configurations

Parameters of the Probe

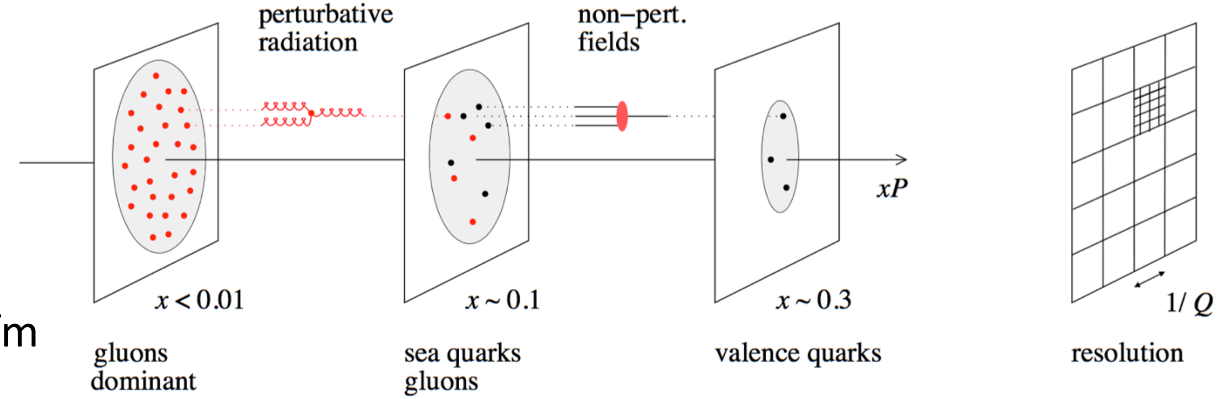




Ability to change **x** projects out different configurations where different dynamics dominate

Ability to change **Q²** changes the resolution scale

$Q^2 = 400\ GeV^2 \Rightarrow 1/Q = .01\ fm$

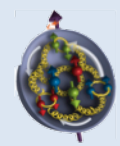


Where EIC Needs to be in x (nucleon)

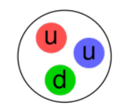
Saturation Regime: Needs to be Accessed via Ions (see later)

Collective Regime

Many-body Regime



Few-body Regime



10^{-4} — 10^{-3} — 10^{-2} — 10^{-1} — 1 — X (for proton)

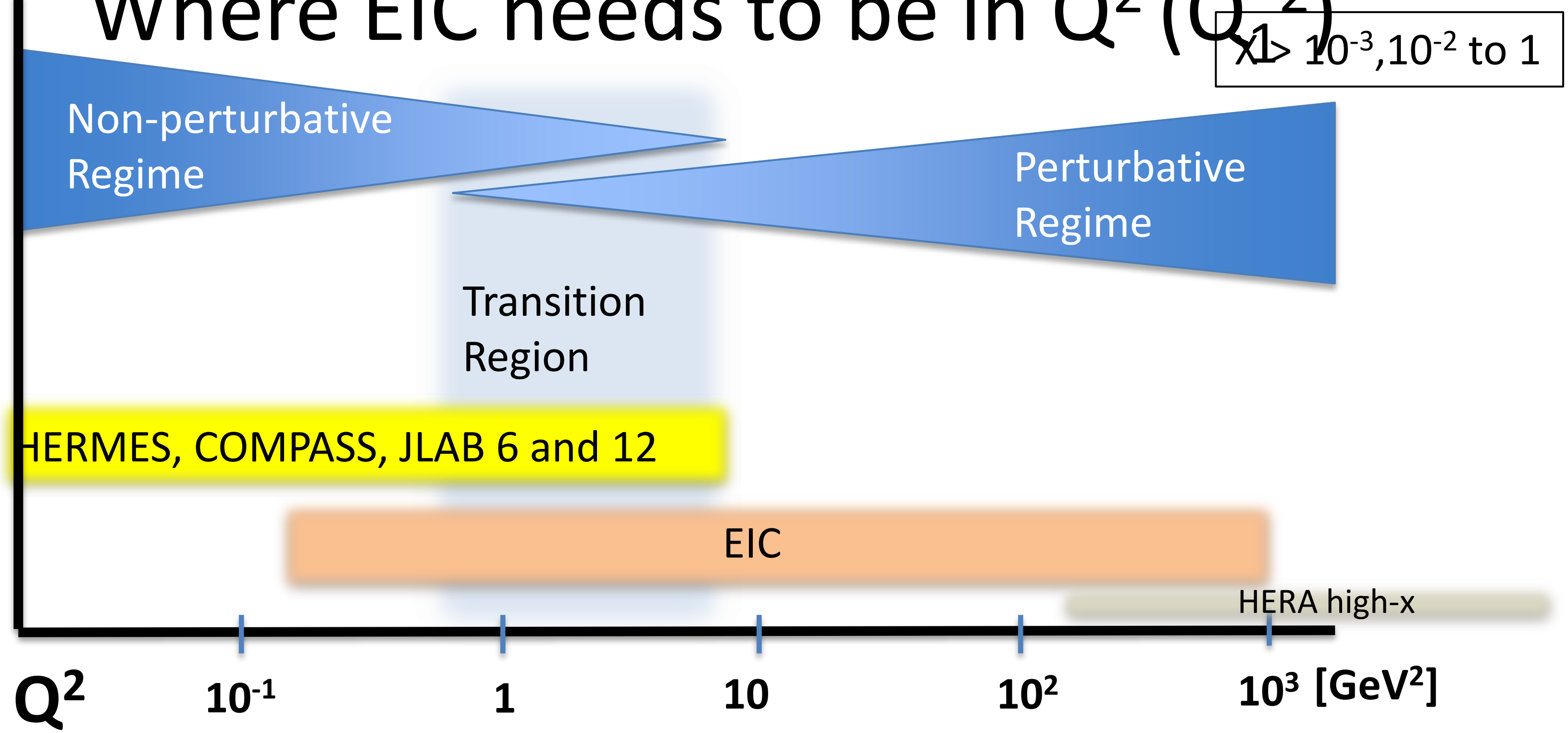
QCD Radiation Dominated (Studied at HERA)

Hadron Structure Dominated

Main interest for EIC Nucleon/Nuclear Program

Spin,TMD, GPD…

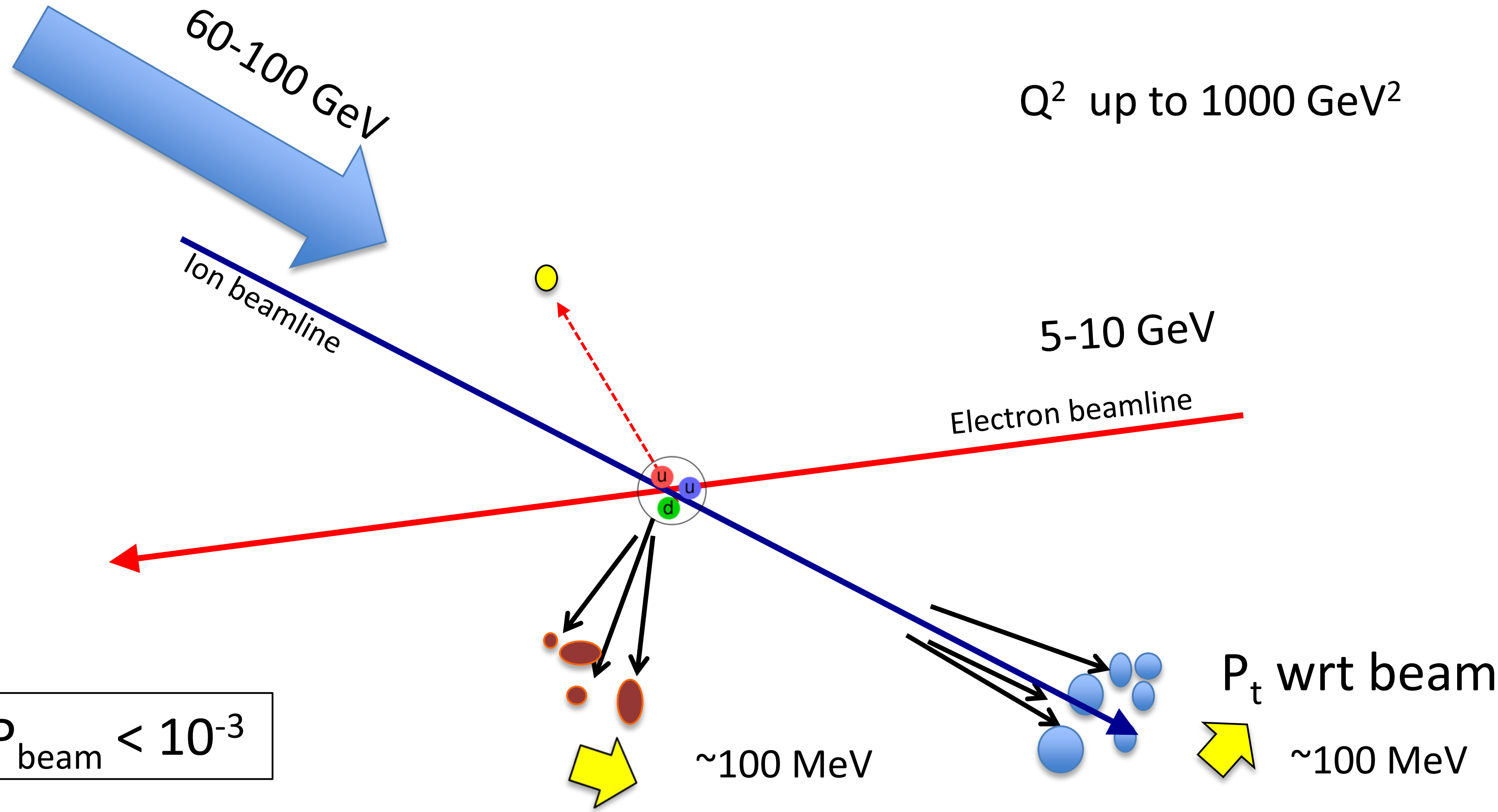
Where EIC needs to be in Q^2 (Q_1^2)



- Include non-perturbative, perturbative and transition regimes
- Provide long evolution length and up to Q^2 of ~1000 GeV^2 (~.005 fm)
- Overlap with existing measurements

Disentangle Pert./Non-pert., Leading Twist/Higher Twist

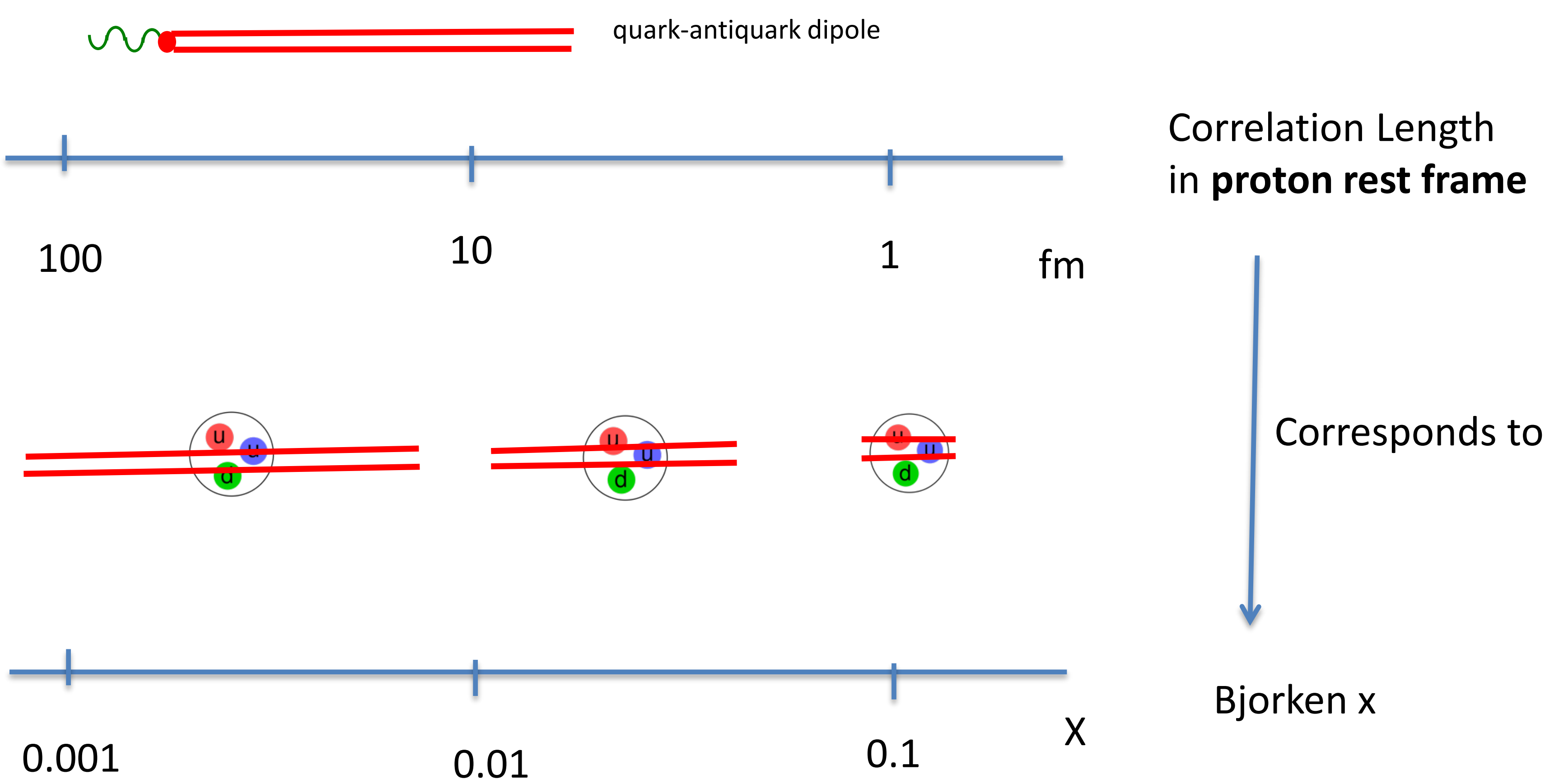
Measuring k_t and b_t



$P_t/P_{beam} < 10^{-3}$

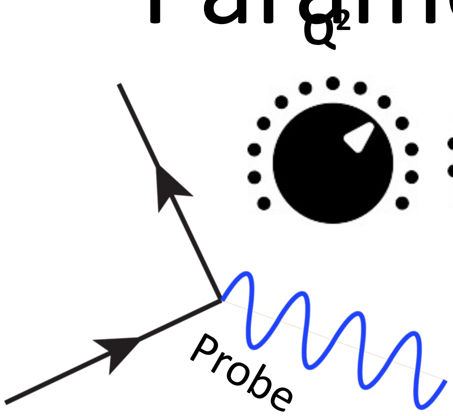
P_t wrt scattering plane.
+ particle ID

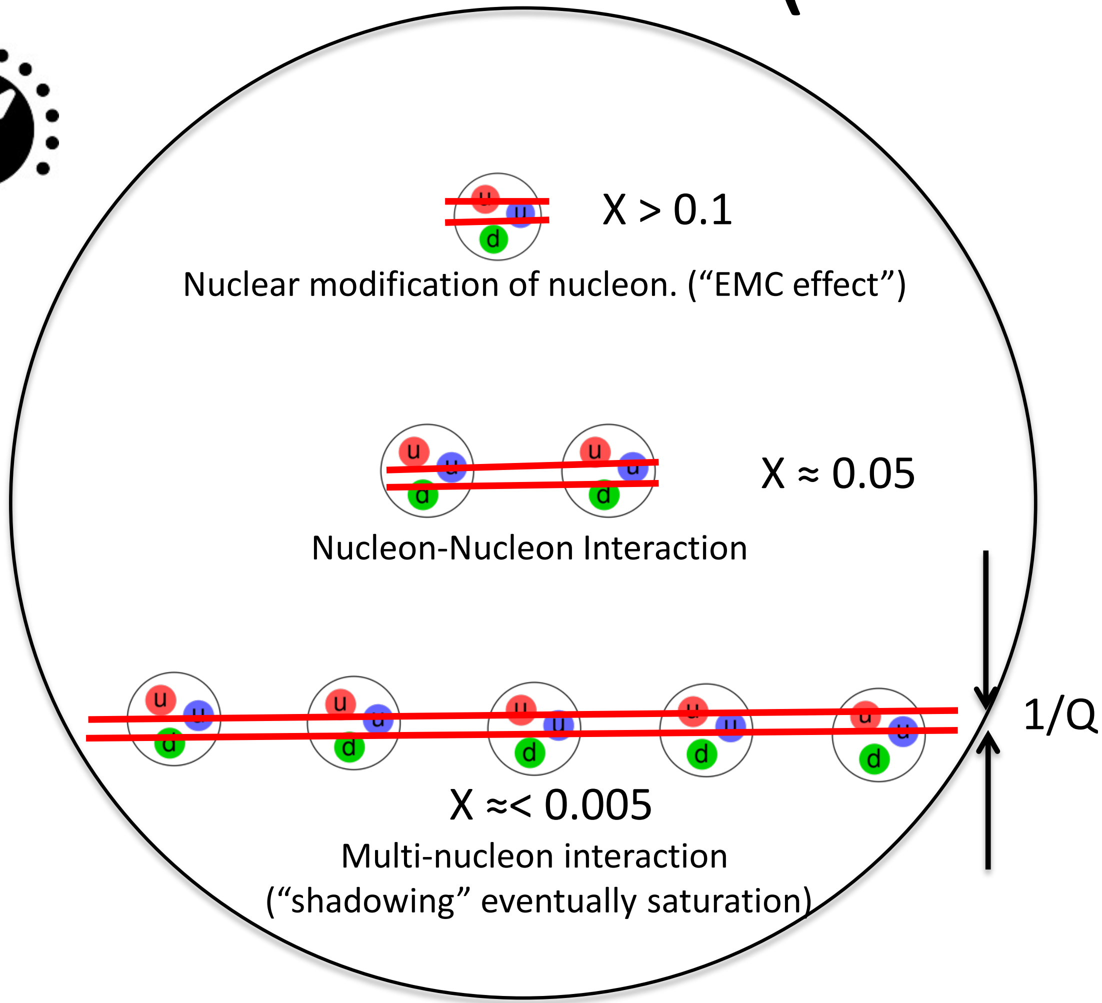
Bjorken x and length scale



In the proton rest frame, dipole lifetime (x < 0.1) extends far beyond the proton charge radius

Parameters of the Probe (Nuclei)

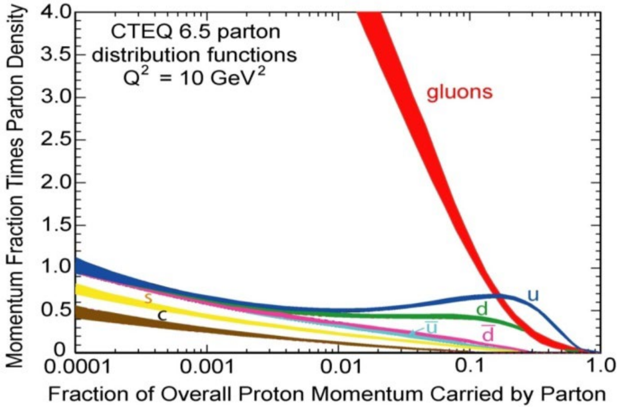




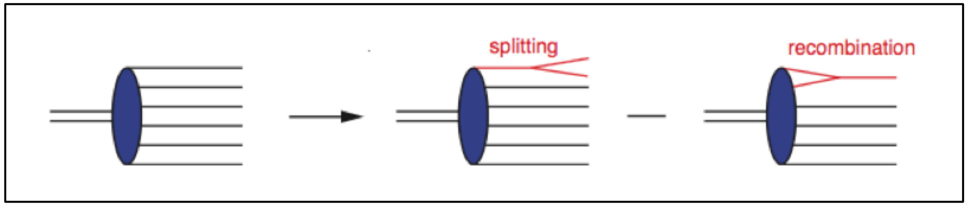
Probing the nucleon interaction in the nuclei (note this is different from correlation measurements)

Note: the x range for nuclear exploration is similar to the nucleon exploration

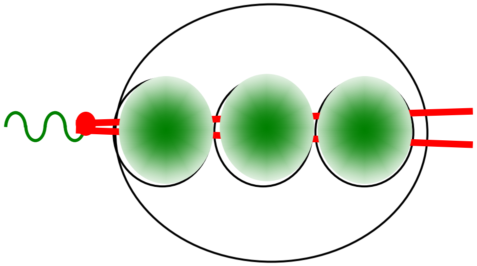
QCD at Extremes: Parton Saturation



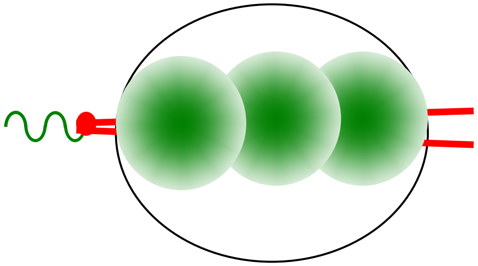
HERA discovered a dramatic rise in the number of gluons carrying a small fractional longitudinal momentum of the proton (i.e. small-x).



This cannot go on forever as x becomes smaller and smaller: parton recombination must balance parton splitting.
i.e. Saturation—unobserved at HERA for a proton. (expected at extreme low x)

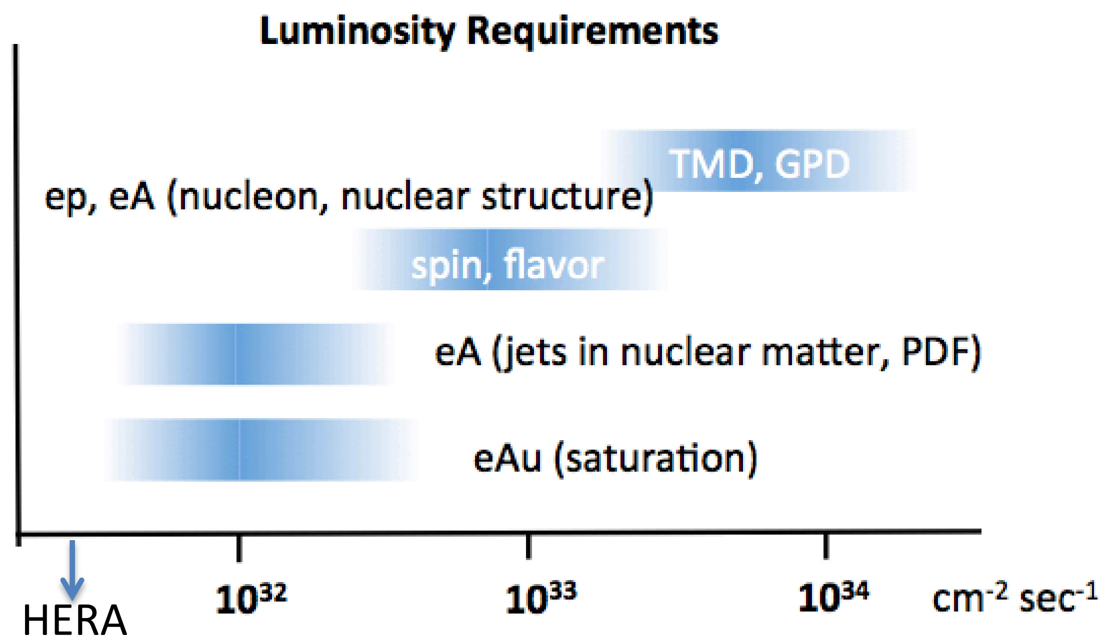


In nuclei, the interaction probability enhanced by $A^{1/3}$



Will nuclei saturate faster as color leaks out of nucleons?

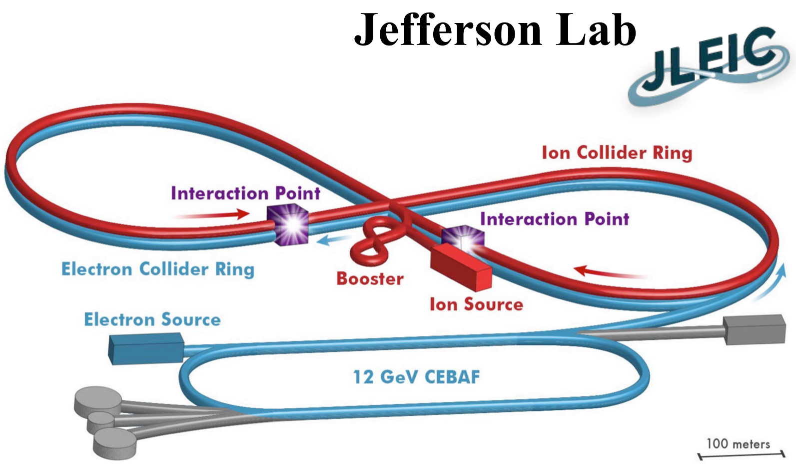
Luminosity/Polarization Needed

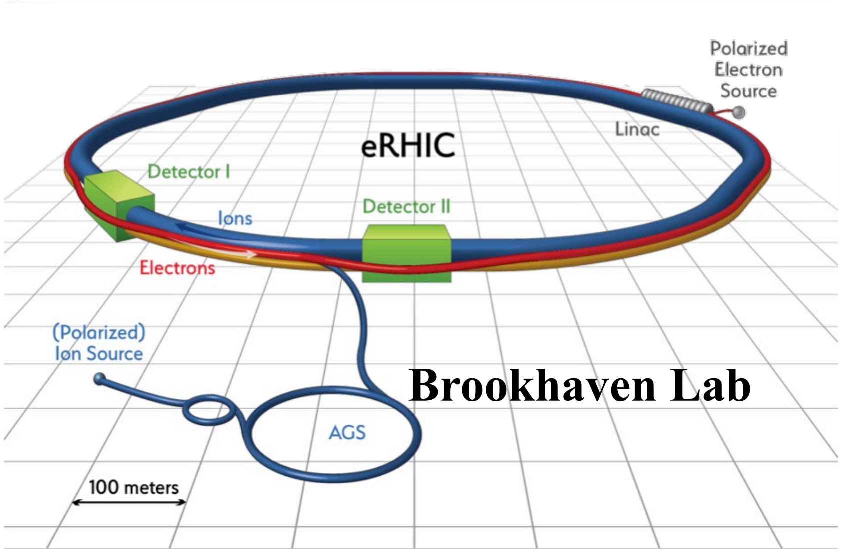


Central mission of EIC (nuclear and nucleon structure) requires high luminosity and polarization (>70%).

EIC Parameters

- US EIC Machine design aims from the EIC Whitepaper
  - Highly polarized (~70%) electron and nucleon beams.
  - Ion beams from deuterons to the heaviest nuclei (uranium or lead).
  - Variable center of mass energies from ~20 - ~ 100 GeV, upgradable to ~140 GeV.
  - High luminosity: ~$10^{33\text{-}34}$ cm^{-2} s^{-1}
  - Possibility of having more than one interaction region.
- Two proposed realization plans
  - Jefferson Lab: building on the existing 12 GeV CEBAF. JLEIC Design.
  - BNL: building on the existing RHIC. eRHIC Design.
  - Recent review of acc. R&D
- Similar performances, cost according to LRP assessment.
- US EIC will likely be down-selected from one of these proposals.





End of Day 2

Day 3:

- EIC accelerator and detector realizations
- Other facilities and EIC physics topics.
- EIC and physics topic at other facilities.
- EIC and the future of Nuclear Physics.
- Epilogue