Deeply Virtual Compton Scattering

– my own understandings –

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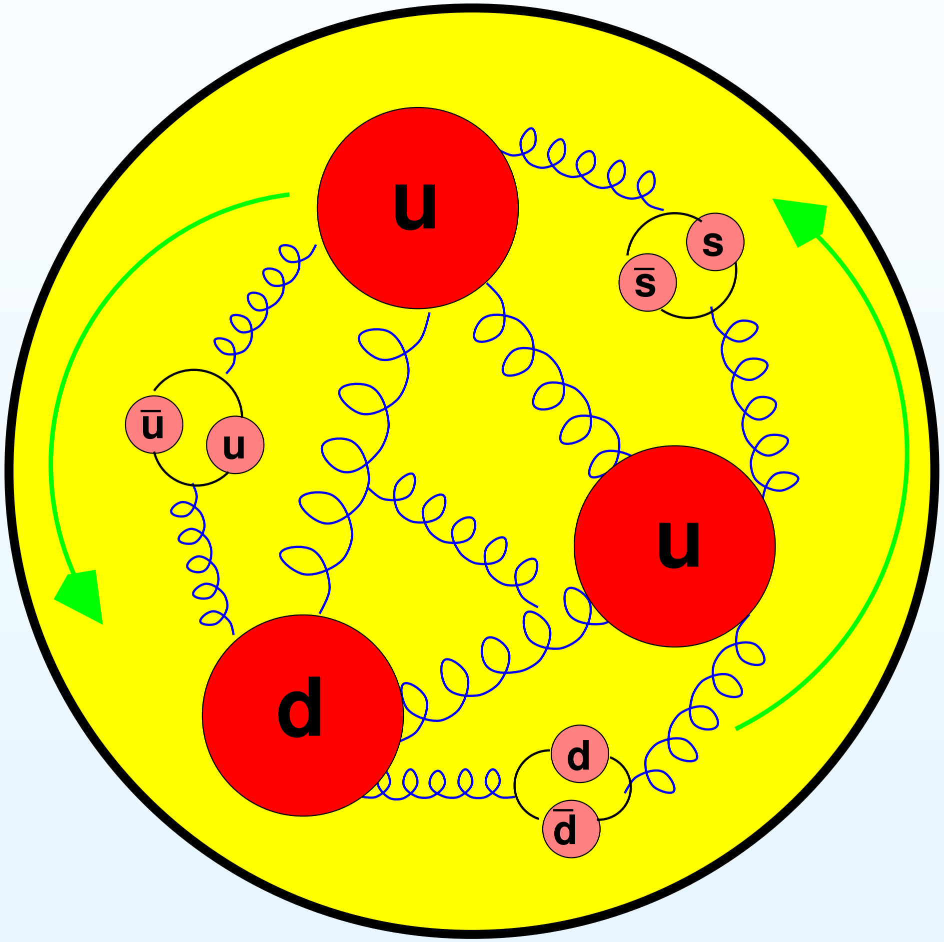
- Physics Background
  - Quark-Gluon Structure of the Nucleon
  - Generalized Parton Distributions
  - Deeply Virtual Compton Scattering
- How to perform a DVCS analysis
  - Knowledge about HERMES
  - An example – TTSA extraction
  - My analysis code ...

Nucleon Structure



History

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  – *Stern, Nobel Prize in Physics 1943*

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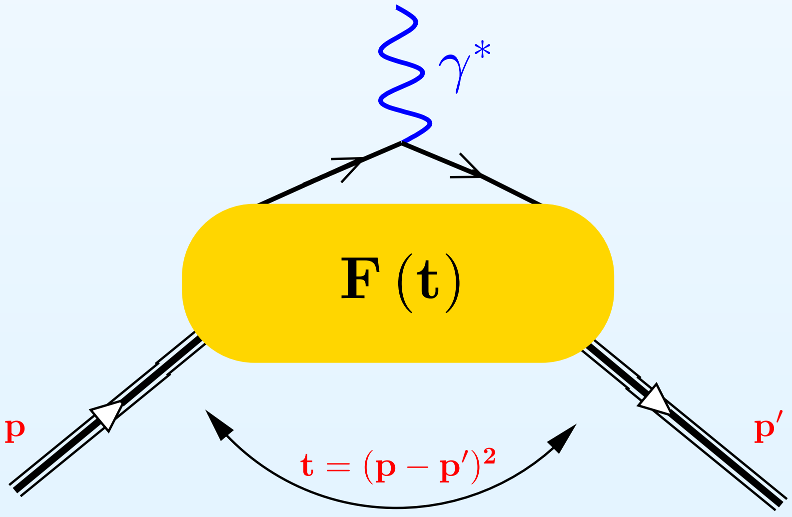
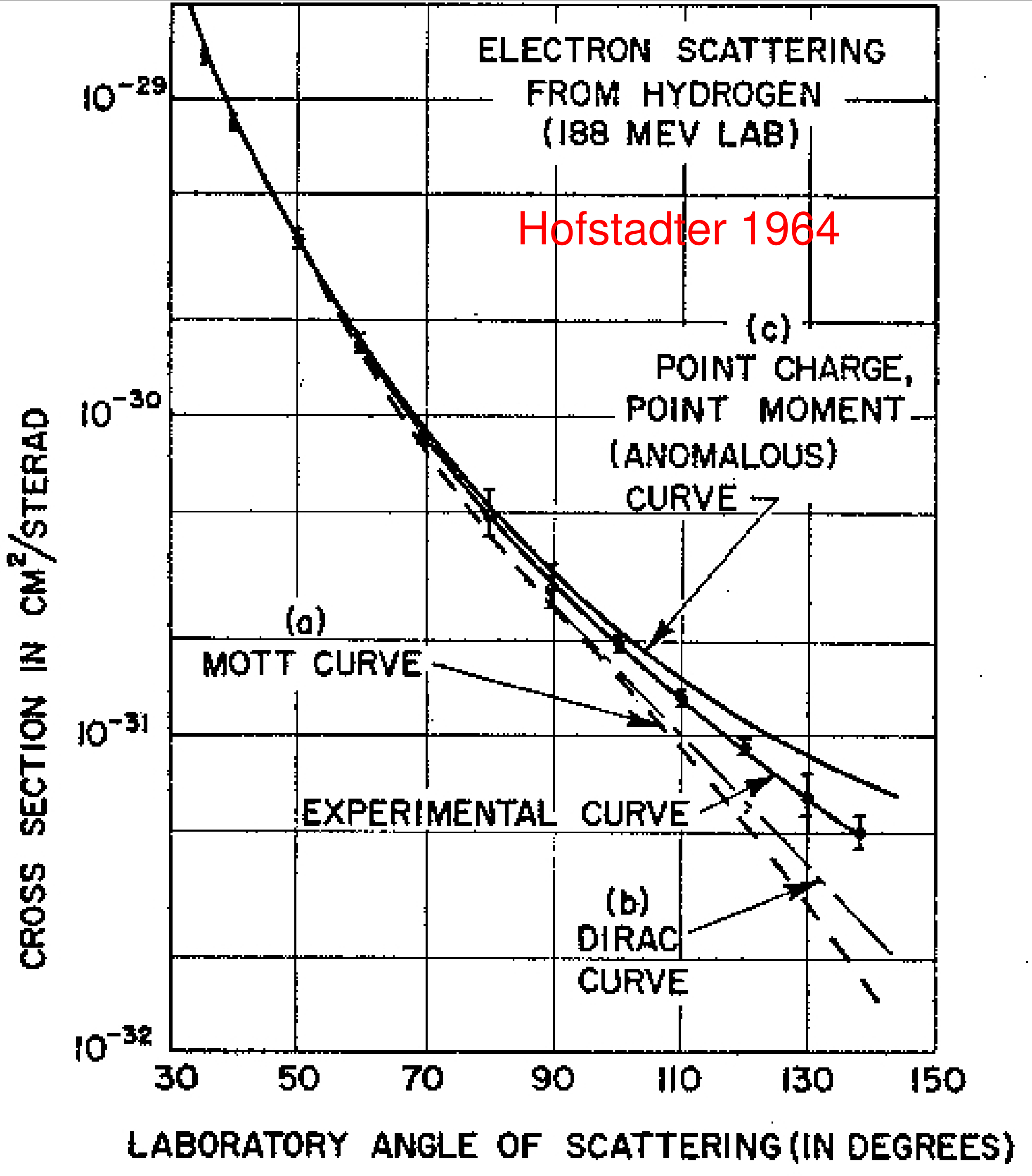
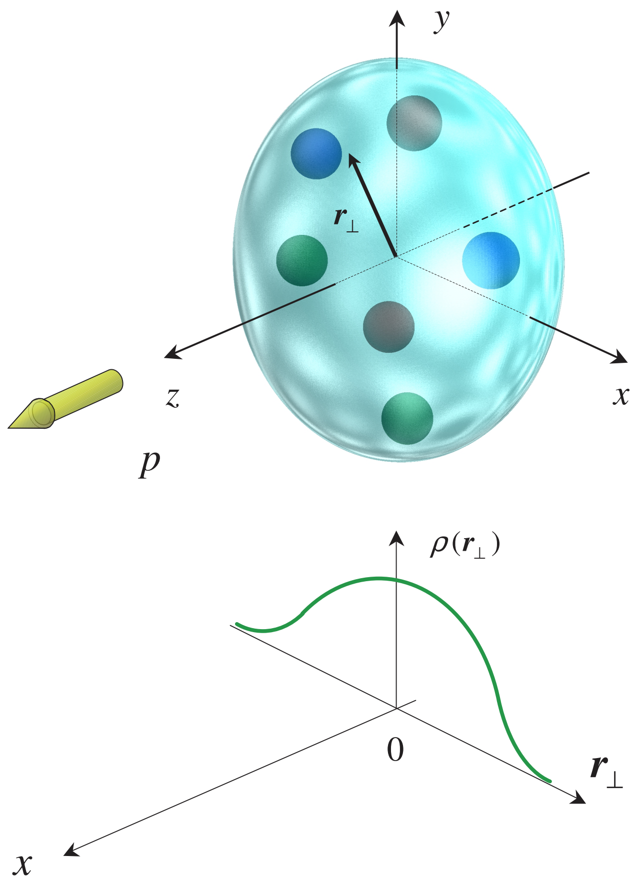
  – *Hofstadter, Nobel Prize in Physics 1961*.




ELECTRON SCATTERING
FROM HYDROGEN
(188 MEV LAB)
Hofstadter 1964
(c)
POINT CHARGE,
POINT MOMENT
(ANOMALOUS)
CURVE
(a)
MOTT CURVE
EXPERIMENTAL CURVE
(b)
DIRAC
CURVE
10^-29
10^-30
10^-31
10^-32
CROSS SECTION IN CM²/STERAD
30
50
70
90
110
130
150
LABORATORY ANGLE OF SCATTERING (IN DEGREES)

FFs characterize charge and magnetization distributions in the impact parameter space (transverse plane in the IMF).



$$F(-\vec{\Delta}_\perp^2) = \int d^2\vec{r}_\perp \cdot e^{-i\vec{\Delta}_\perp \cdot \vec{r}_\perp} \cdot \rho(\vec{r}_\perp)$$

History

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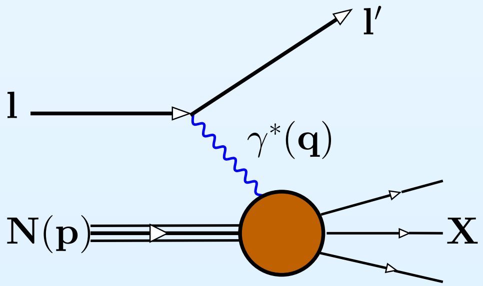
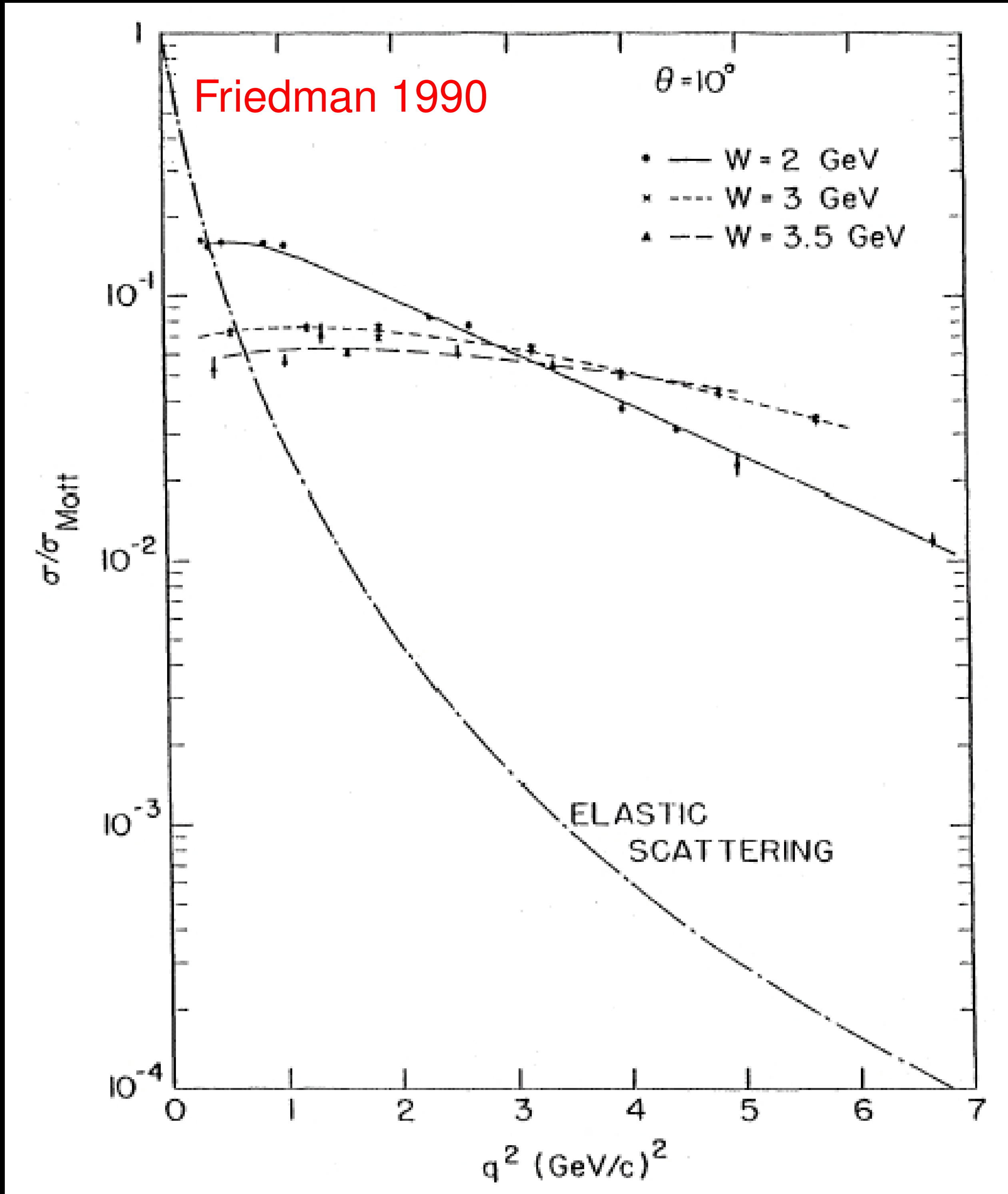
  – *Stern, Nobel Prize in Physics 1943*
- Measurements of nucleon EM form factors in elastic electron scattering off the nucleon in the 1960's demonstrated for the first time that the nucleon has a spatial extension of about 1 fm.
  – *Hofstadter, Nobel Prize in Physics 1961*.
- Measurements of nucleon structure functions in inclusive DIS in the 1970's discovered the existence of point-like constituents in the nucleon and asymptotic freedom of the strong force.
  – *Friedman, Kendall, Taylor, Nobel Prize in Physics 1990*
  – *Gross, Politzer, Wilczek, Nobel Prize in Physics 2004*



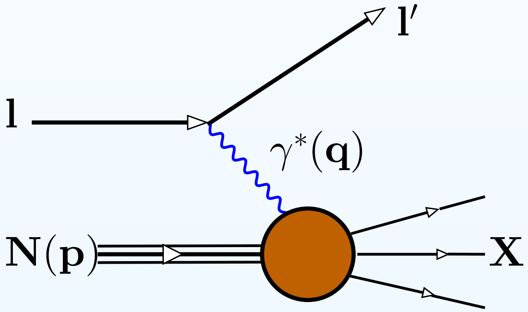
$$\begin{aligned} Q^2 &\equiv -q^2 = -(l - l')^2 \\ \nu &\equiv l_0 - l'_0 \\ W^2 &\equiv (p+q)^2 = m_p^2 + 2m_p\nu - Q^2 \\ x_B &\equiv Q^2/2pq = Q^2/2m_p\nu \end{aligned}$$

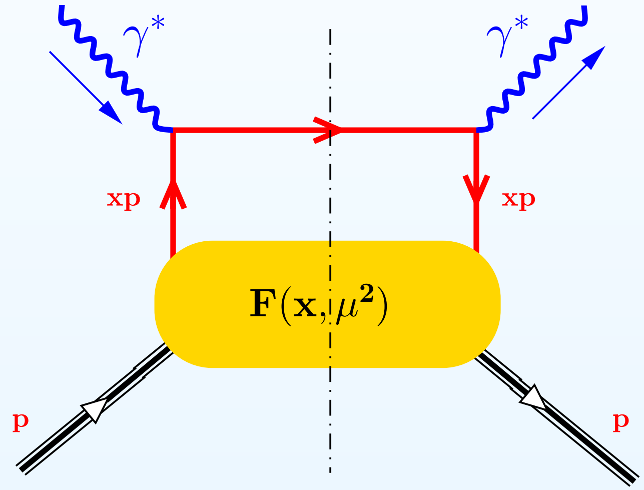

Friedman 1990
θ = 10°
W = 2 GeV
W = 3 GeV
W = 3.5 GeV
ELASTIC SCATTERING
σ/σ_Mott
q² (GeV/c)²

Parton Distribution Functions

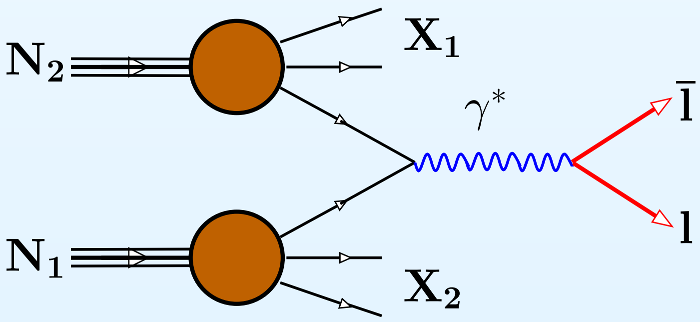
- According to factorized theorem, PDFs enter into a global description of inclusive DIS (a), Drell-Yan process (b), ...

(a)

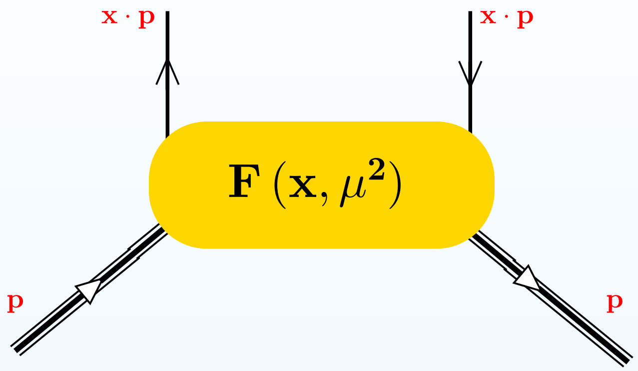




(b)



Parton Distribution Functions



F: defined through ME $\langle P,S|\mathcal{O}_{q/g}|P,S\rangle$

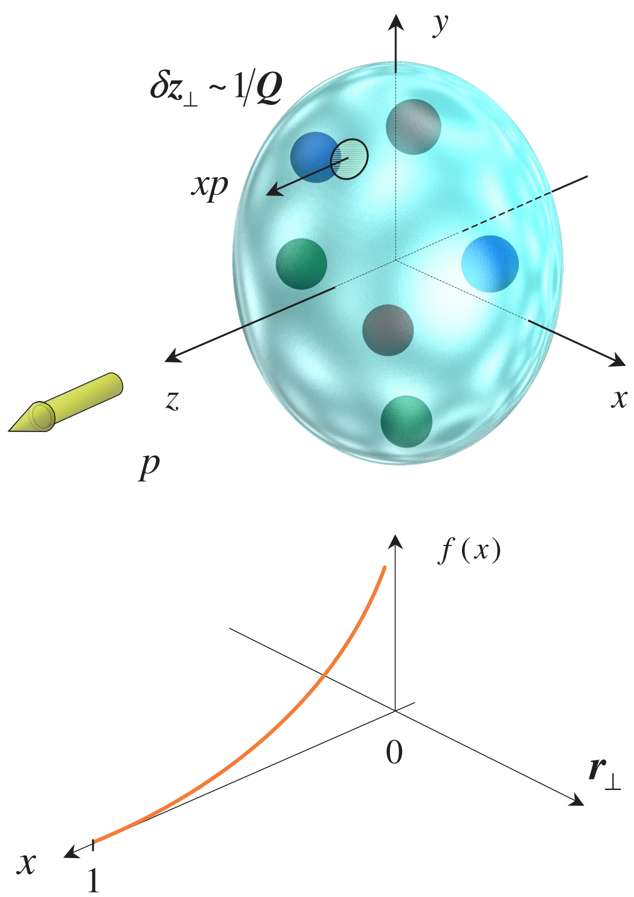
x: longitudinal momentum fraction

μ^2: renormalization scale

- PDFs for a spin-$\frac{1}{2}$ nucleon at twist-two level:

unpolarized	longitudinally polarized
$q(x) = \overrightarrow{q}(x) + \overleftarrow{q}(x)$	$\Delta q(x) = \overrightarrow{q}(x) - \overleftarrow{q}(x)$
$g(x) = \overrightarrow{g}(x) + \overleftarrow{g}(x)$	$\Delta g(x) = \overrightarrow{g}(x) - \overleftarrow{g}(x)$

PDFs characterize longitudinal momentum distributions (IMF)

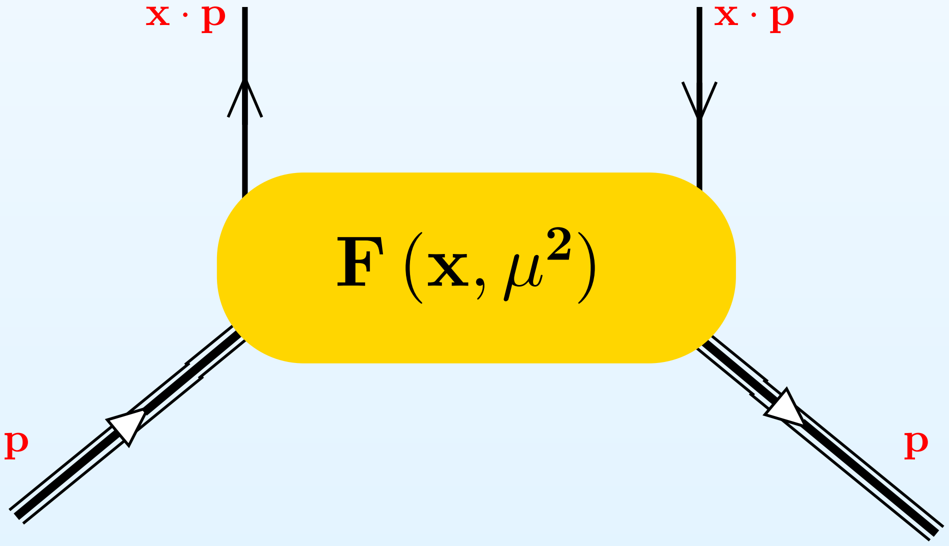


x – longitudinal momentum fraction

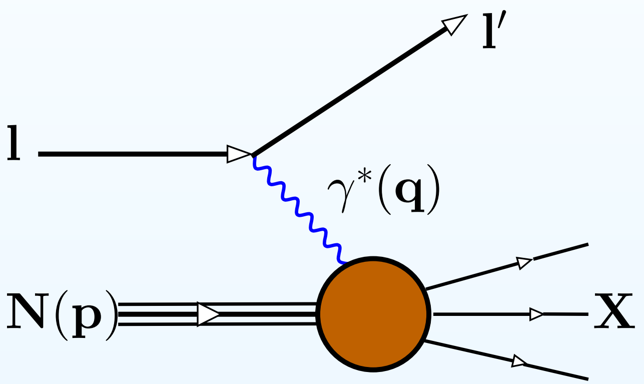
Parton Distribution Functions

- According to factorized theorem, PDFs enter into a global description of inclusive DIS, Drell-Yan process, ...
- PDFs characterize longitudinal momentum distributions of partons within the nucleon (IMF):
  - unpolarized PDFs:

$$q(x) = \frac{\overleftarrow{q}(x) + \overrightarrow{q}(x)}{2}, \qquad g(x) = \frac{\overleftarrow{g}(x) + \overrightarrow{g}(x)}{2};$$

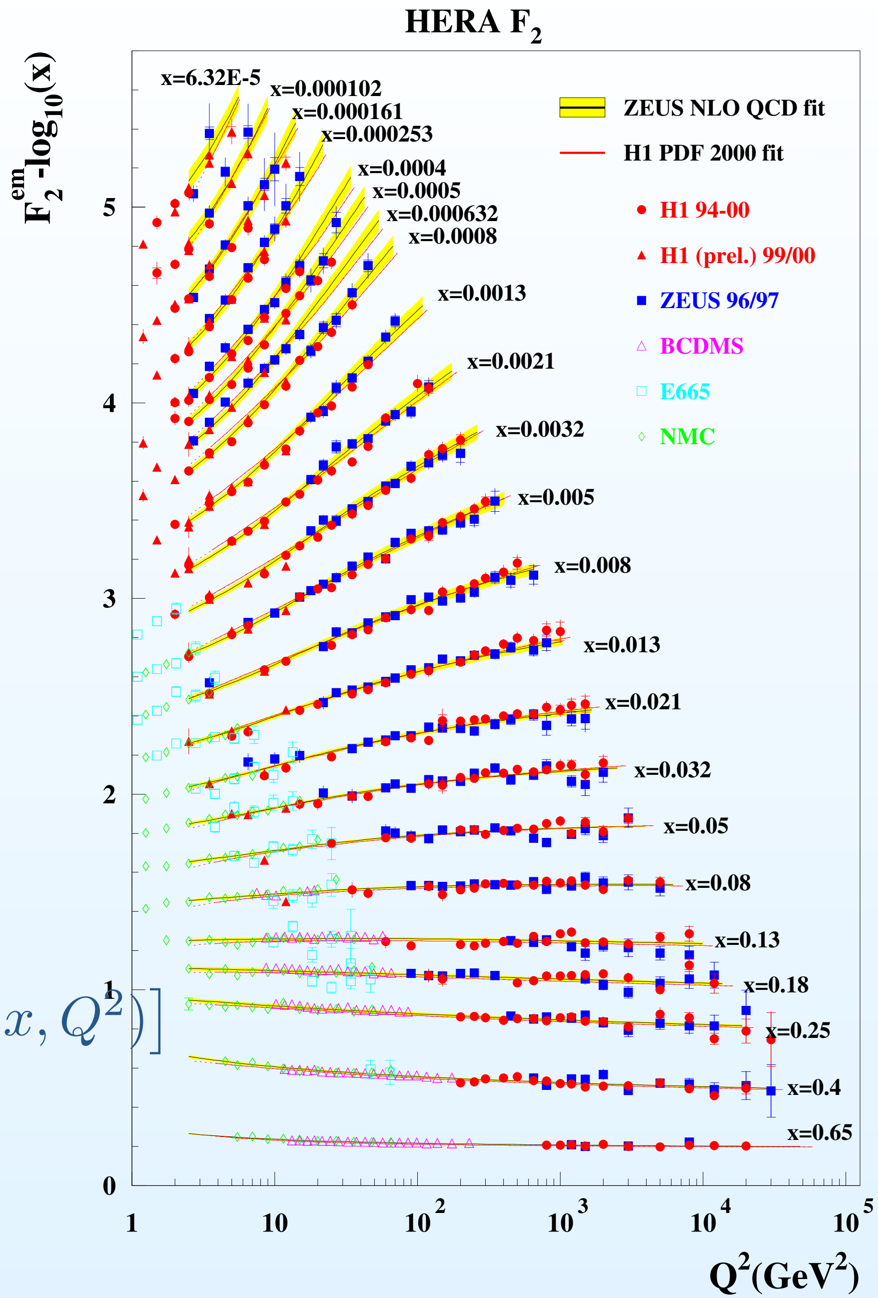


Parton Distribution Functions

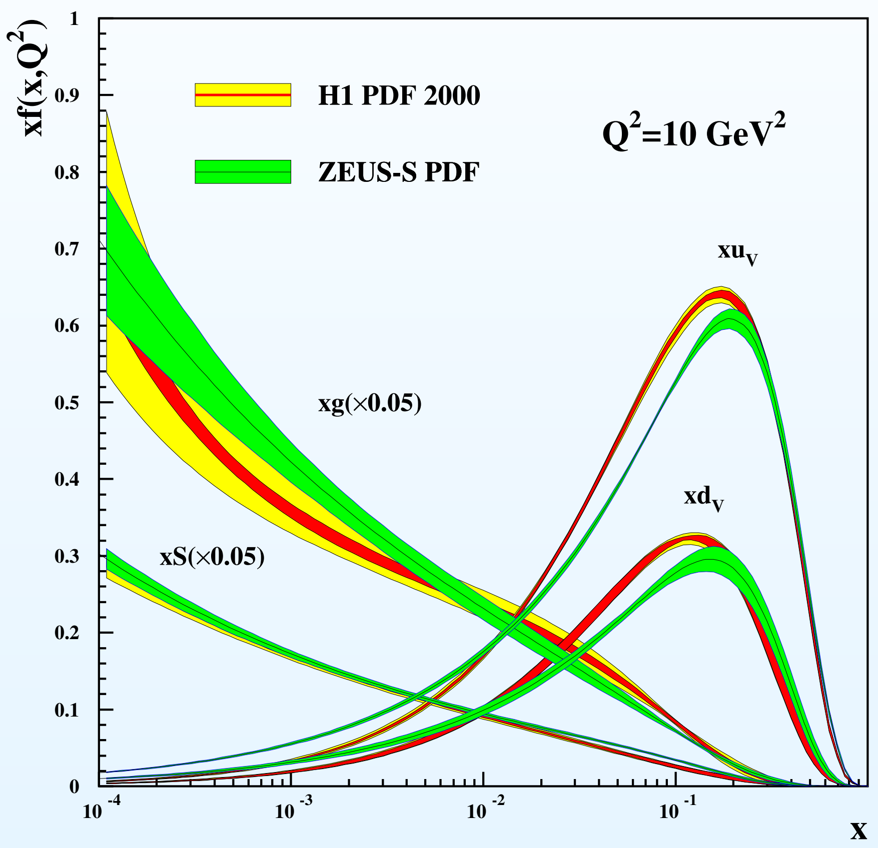


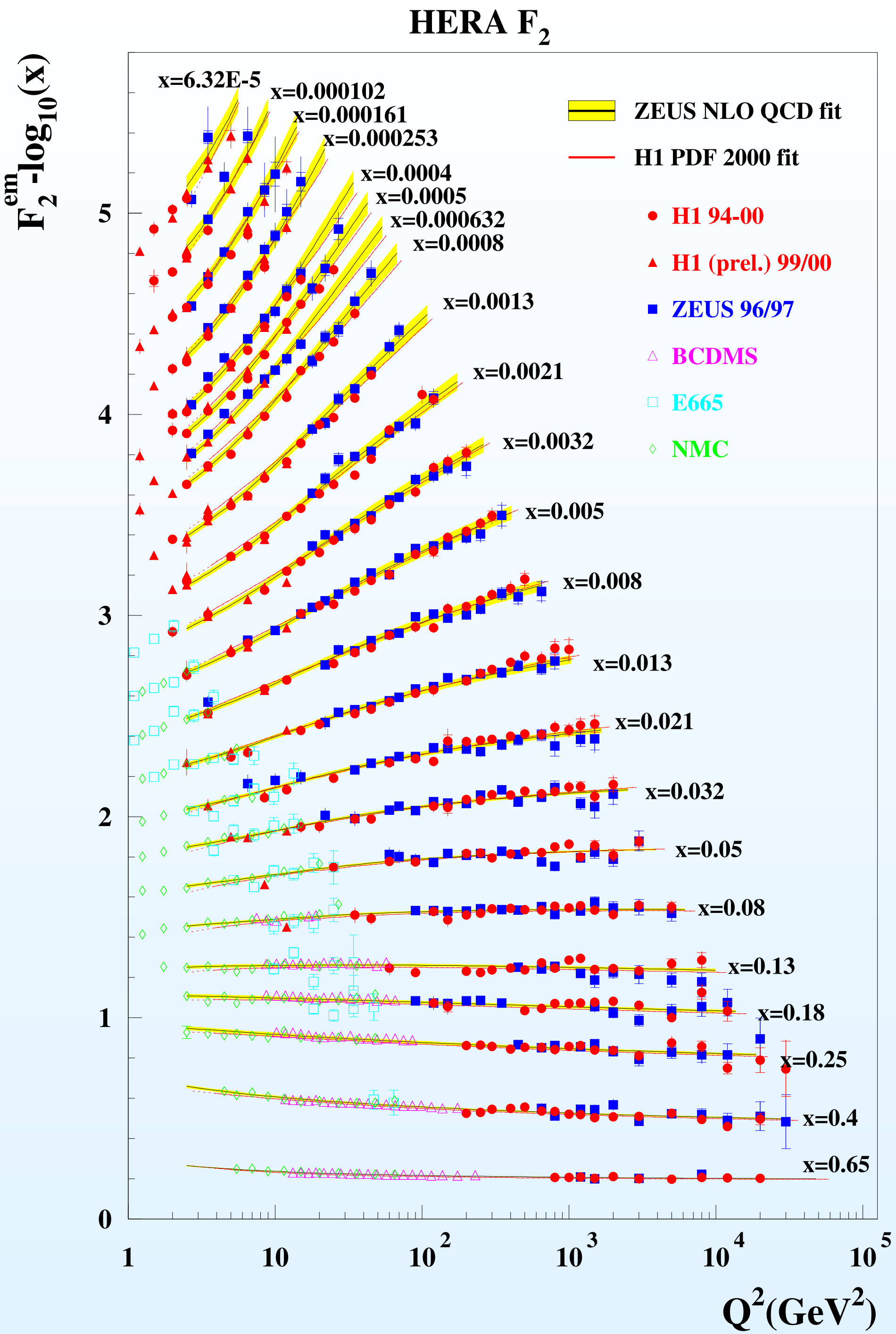
$$Q^2 \equiv -q^2$$
$$x_B \equiv Q^2/2p \cdot q$$

$$F_2(x,Q^2) \stackrel{LO}{=} x \sum e_q^2 \cdot \left[q(x,Q^2) + \bar{q}(x,Q^2) \right]$$



Parton Distribution Functions

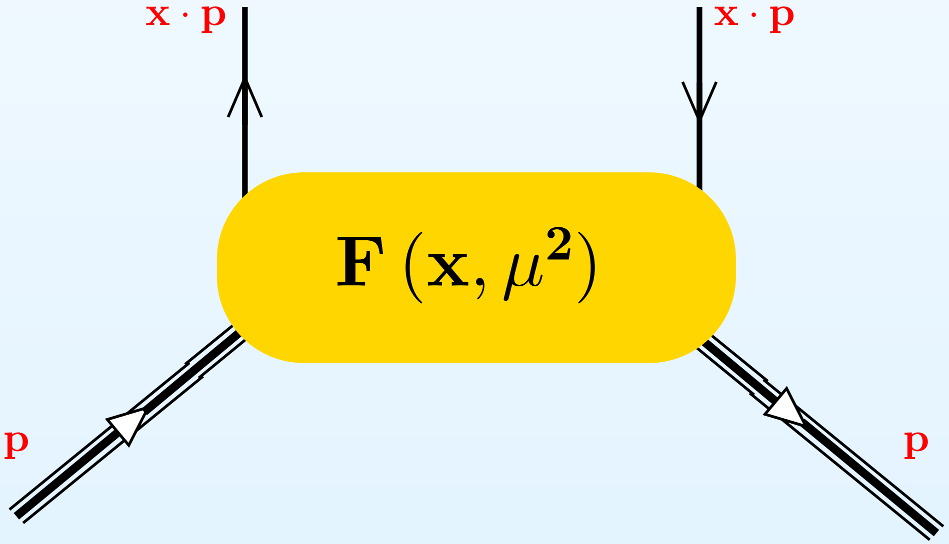




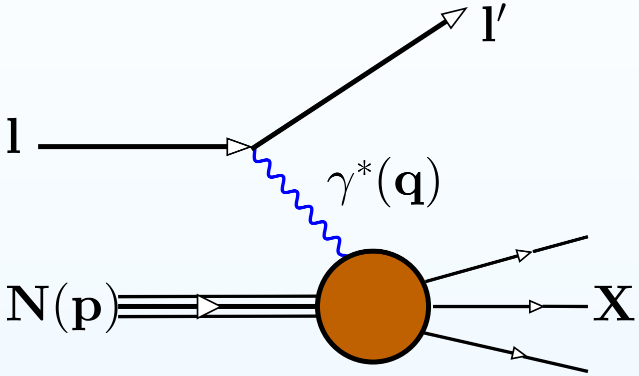
Parton Distribution Functions

- According to factorized theorem, PDFs enter into a global description of inclusive DIS, Drell-Yan process, ...
- PDFs characterize longitudinal momentum distributions of partons within the nucleon (IMF):
    - helicity-dependent PDFs:

$$\Delta q(x) = \frac{\overleftarrow{q}(x) - \overrightarrow{q}(x)}{2}, \quad \Delta g(x) = \frac{\overleftarrow{g}(x) - \overrightarrow{g}(x)}{2}.$$



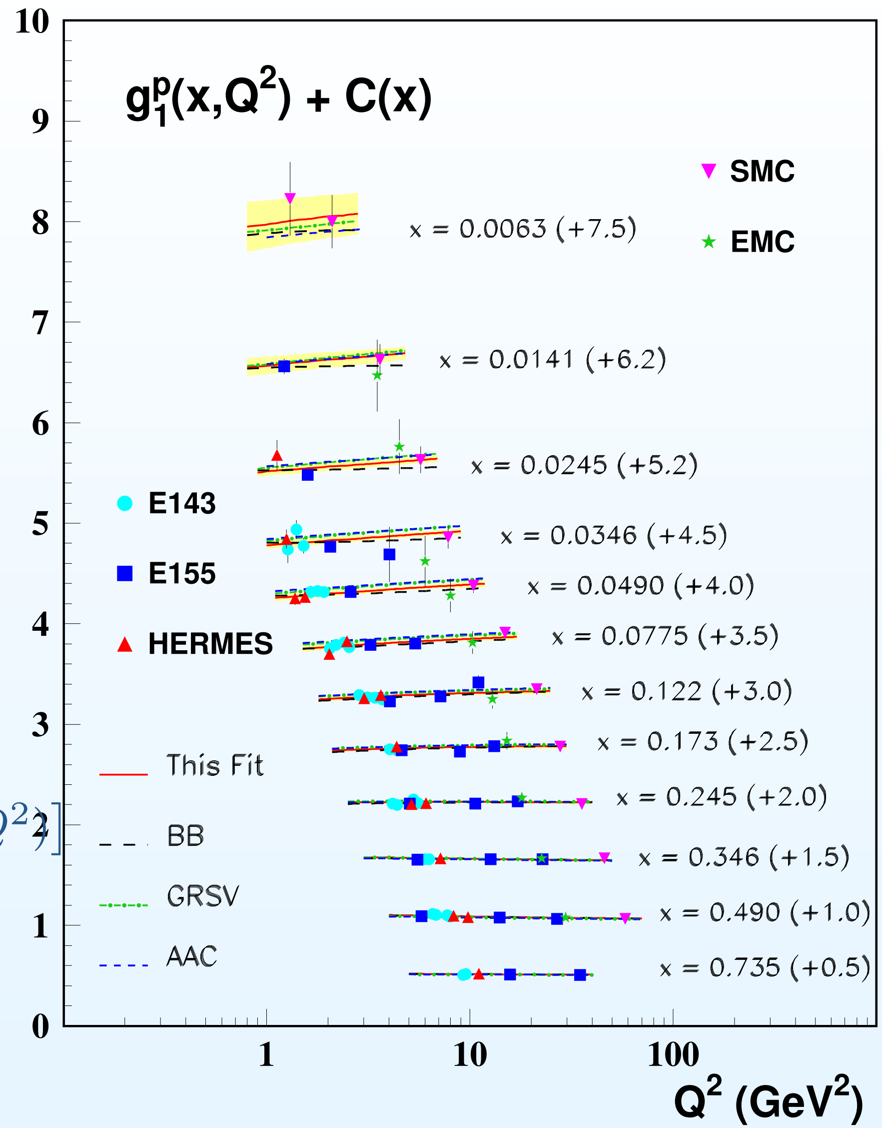
Parton Distribution Functions



$Q^2 \equiv -q^2$

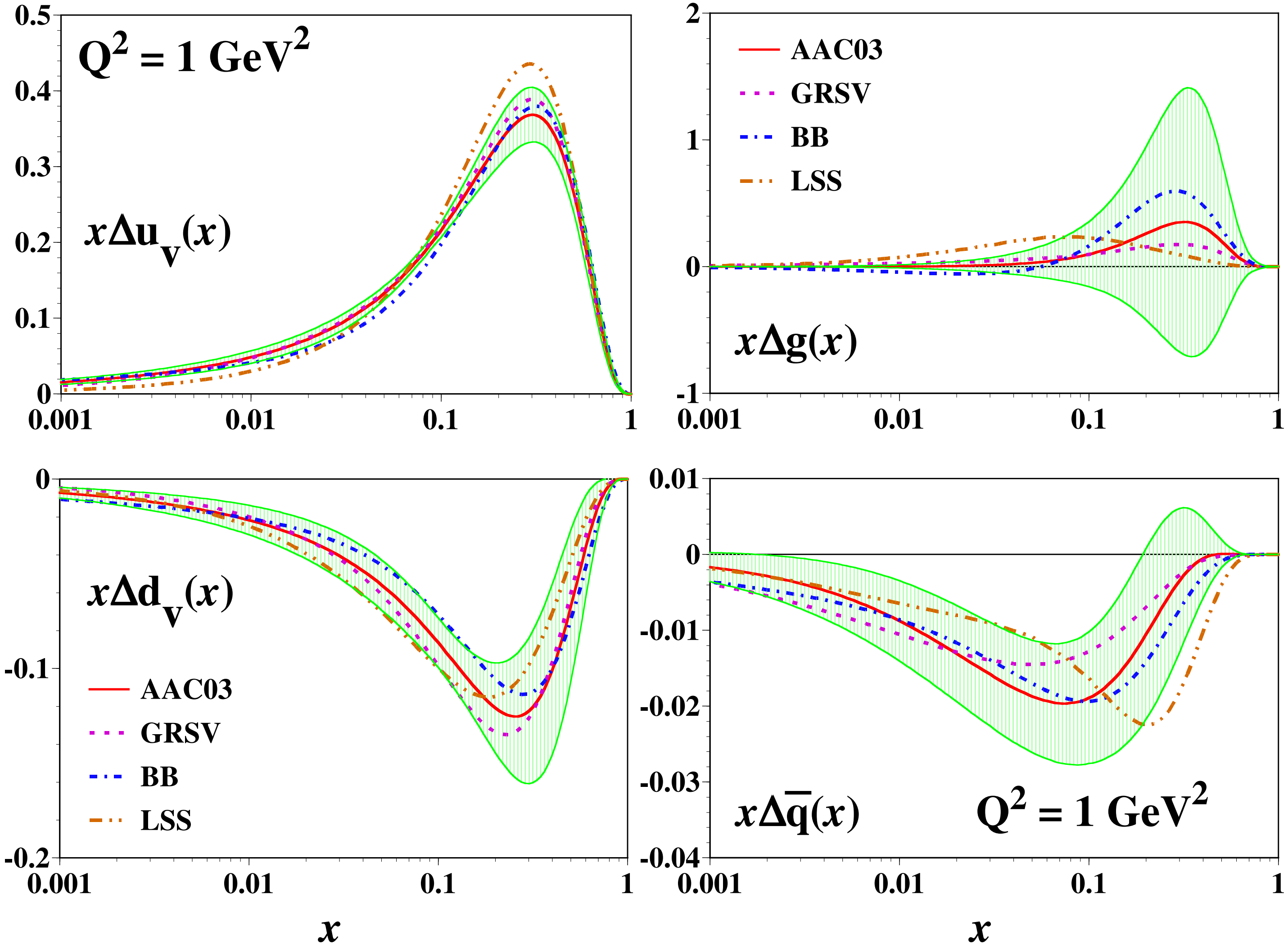
$x_B \equiv Q^2/2p \cdot q$

$$g_1(x,Q^2) \stackrel{LO}{=} \sum e_q^2 \cdot [\Delta q(x,Q^2) + \Delta\bar{q}(x,Q^2)]$$



Hirai et al., 2003

$$\Delta q(x) = \overrightarrow{q}(x) - \overleftarrow{q}(x) \qquad \Delta g(x) = \overrightarrow{g}(x) - \overleftarrow{g}(x)$$



Nucleon Spin Structure

$$\Delta\Sigma = \sum_q \int_{-1}^{1} dx\, \Delta_q(x) \sim 20 - 35\%$$

$\Longrightarrow$ Where is the rest of the nucleon spin?