Generalized parton distributions of nucleons and nuclei

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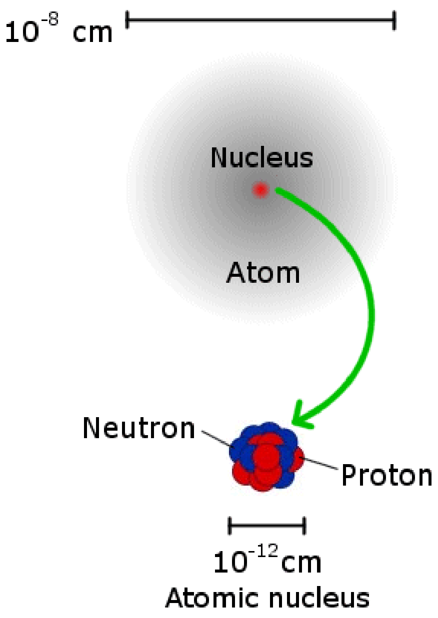
Outline

- Electron scattering and microscopic structure of hadrons
- Generalized Parton Distributions (GPDs)
  - definitions, properties, interpretation
  - dual parameterization and comparison to DVCS data
- Future measurements of GPDs
- Summary

Introduction

Protons and neutrons (nucleons) are basic building blocks of atomic nuclei.

The strong interactions between protons and neutrons determine the properties of atomic nuclei, which form all the variety of Matter around us.

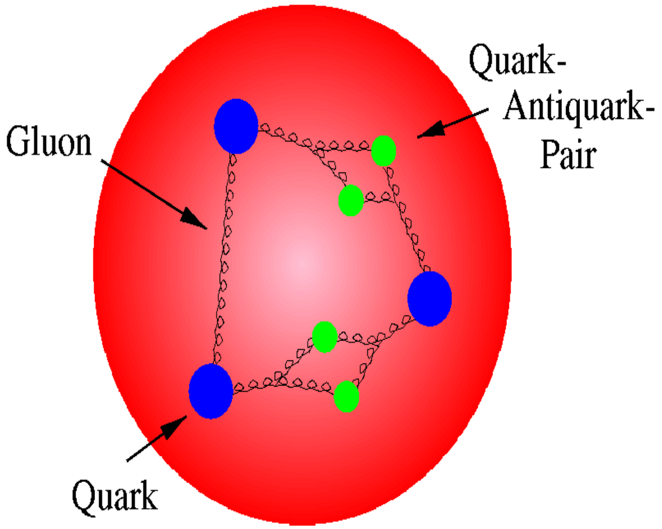


The strong interactions also govern nuclear reactions, such as those which shaped the early Universe, fuel suns and take place in nuclear reactors.

Introduction

The modern theory of the strong interactions is Quantum Chromodynamics, a quantum field theory whose fundamental d.o.f. are quarks and gluons.

It is a key objective of nuclear physics to understand the structure of the nucleon in terms of quarks and gluons.



Nucleon in QCD

Introduction

One of the most powerful tools in unraveling the hadron structure is high-energy electron scattering.

Historically, such experiments provided two crucial insights.

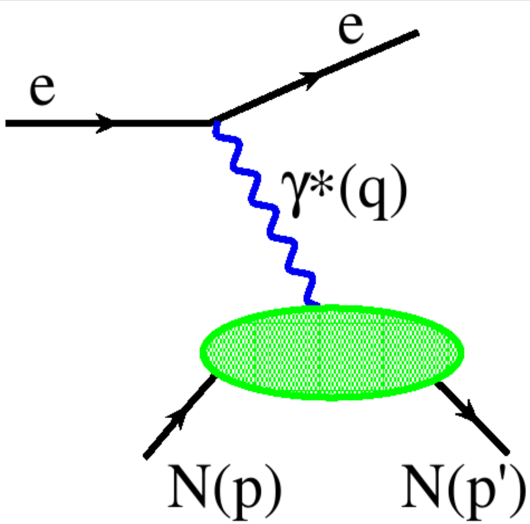
1) Elastic electron scattering established the extended nature of the proton, proton size ~ 10^{-13} cm.

R. Hofstadter, Nobel Prize 1961

2) Deep-Inelastic scattering (DIS) discovered the existence of quasi-free point-like objects (quarks) inside the nucleon, which eventually paved the way to establish QCD.

Friedman, Kendall, Taylor, Nobel Prize 1990
Gross, Politzer, Wilczek, Nobel Prize 2004

Elastic scattering



$$\langle N(p')|J^\mu(0)|N(p)\rangle = \bar{u}(p')\left[F_1(q^2)\gamma^\mu + F_2(q^2)\frac{i\sigma^{\mu\nu}q_\nu}{2m_N}\right]u(p)$$

Dirac form factor

Pauli form factor

$$F_1^p(0) = 1$$
$$F_1^n(0) = 0$$

$$F_2^p(0) = \kappa^p = 1.79$$
$$F_2^n(0) = \kappa^n = -1.91$$

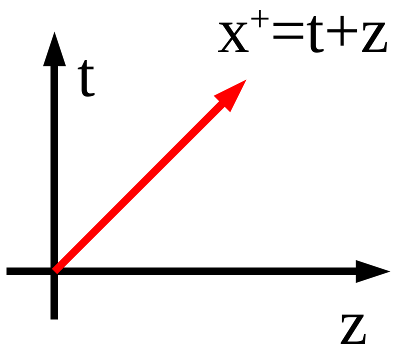
Sachs form factors

$$G_E(q^2) = F_1(q^2) + \frac{q^2}{4m_N^2}F_2(q^2)$$
$$G_M(q^2) = F_1(q^2) + F_2(q^2)$$

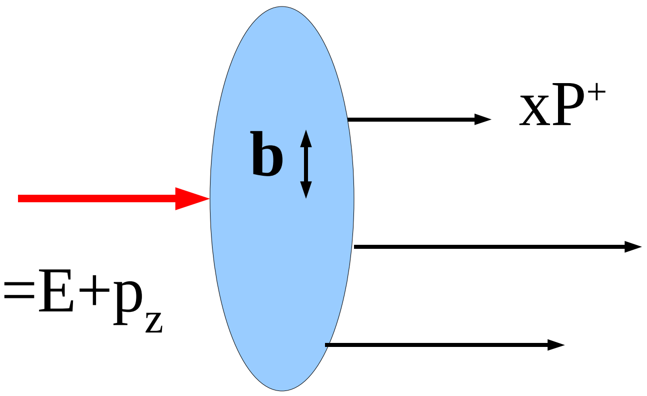
Elastic scattering

Interpretation of elastic form factors in the infinite momentum frame

For the interpretation in terms of partons (quarks and gluons), it is convenient to consider a very fast moving nucleon.



The nucleon is a superposition of long-lived and non-interacting (due to Lorentz time-dilation) partons.

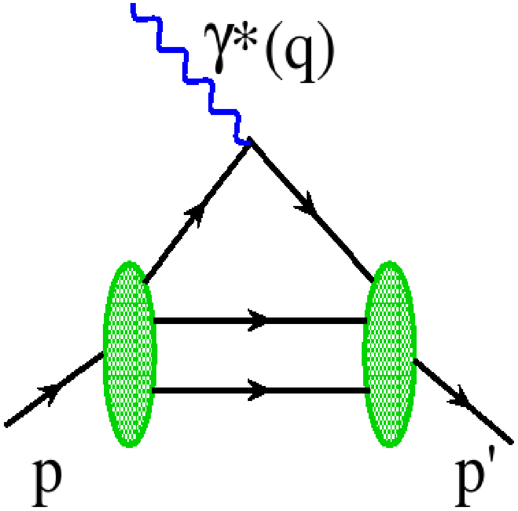


x is fraction of P^+

b is distance from transverse C.M.

$$\mathbf{R}_\perp = \sum_i x_i \mathbf{b}_i$$

Elastic scattering



$q^2=-\mathbf{q}^2$

$$F_1(q^2) = \sum_q e_q \int d^2\mathbf{b} e^{i\mathbf{q}\cdot\mathbf{b}} \int_0^1 dx\, H^q(x,\mathbf{b})$$

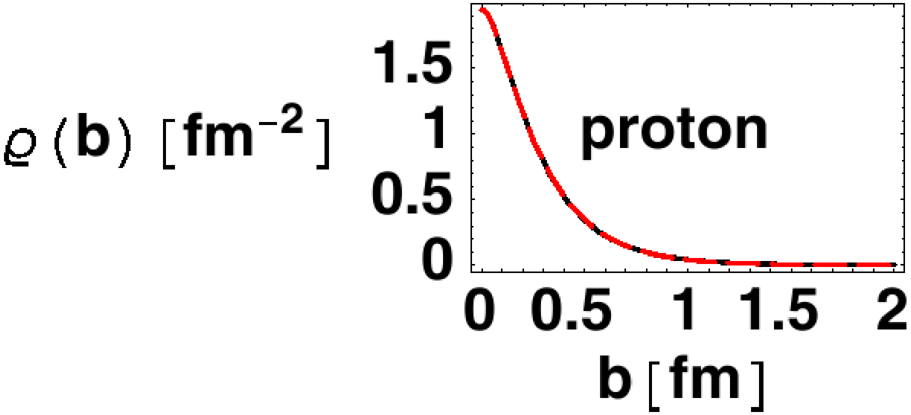
Probability to find a quark with light-cone fraction x and at transverse distance **b** in the nucleon

Elastic form factors measure transverse distribution of valence quarks, information about their longitudinal distribution is washed out.

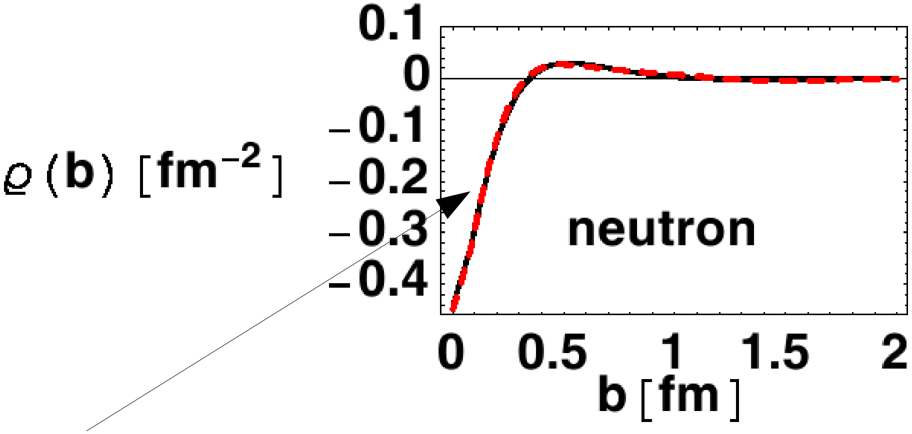
Elastic scattering

$$\rho(\mathbf{b}) = \sum_q e_q \int_0^1 dx\, H^q(x, \mathbf{b}) = \int \frac{d^2\mathbf{q}}{(2\pi)^2} e^{-i\mathbf{q}\cdot\mathbf{b}} F_1(q^2)$$

G. Miller, 2007



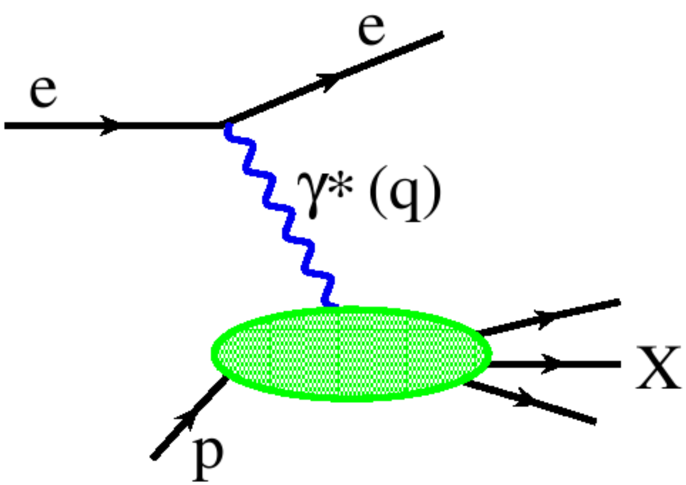
Charge distribution in the transverse plane of a fast moving nucleon.



Surprise: central charge density of the neutron is negative!

Contradicts conventional pion cloud picture.

Deep-Inelastic scattering



$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{4\pi\alpha_{\rm em}^2}{xQ^4}\left[(1-y)F_2(x,Q^2) + y^2 x\,F_1(x,Q^2)\right]$$

Unpolarized structure functions

$$q^2 = -Q^2$$
$$W^2 = (p+q)^2$$
} large

$$x_B = \frac{Q^2}{2p\cdot q}$$
fixed

} Bjorken kinematic limit

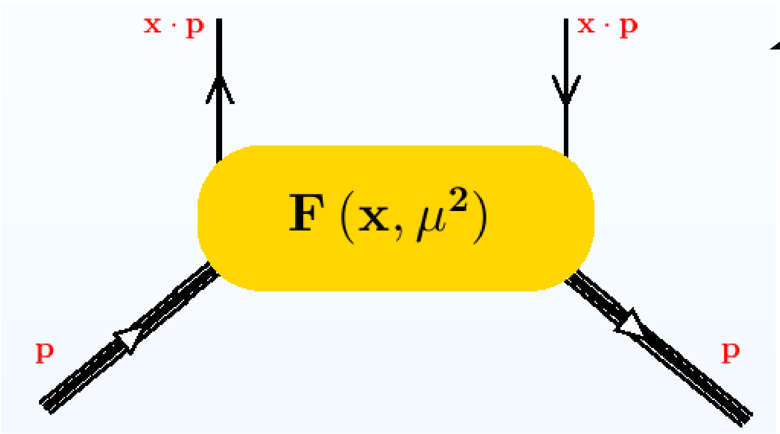
Deep-Inelastic scattering

In the Bjorken limit, $\alpha_S(Q^2)$ is small (asymptotic freedom) and one can use the perturbation theory to prove the factorization theorem:

$$F_2(x,Q^2) = \sum_{i=q,\bar{q},g} \int_0^1 \frac{dz}{z} C^i\left(\frac{x}{z}, \frac{Q^2}{\mu^2}\right) \phi_i(z,\mu^2)$$

Perturbative coefficient function

Non-perturbative parton distribution functions (PDFs) defined via matrix elements of parton operators between nucleon states with equal momenta



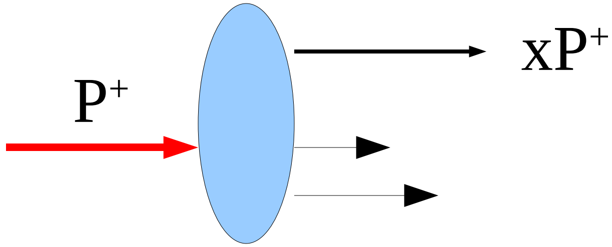
p -- nucleon momentum

x -- longit. momentum fraction

μ^2 -- factorization scale

Deep-Inelastic scattering

Interpretation in the infinite momentum frame:



Parton distributions are probabilities to find a parton with the light-cone fraction x of the nucleon P^+ momentum.

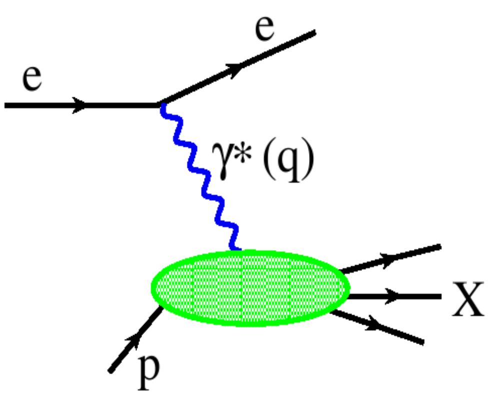
Fast moving nucleon with $P^+=E+p_z$

Q^2 is the resolution of the “microscope”

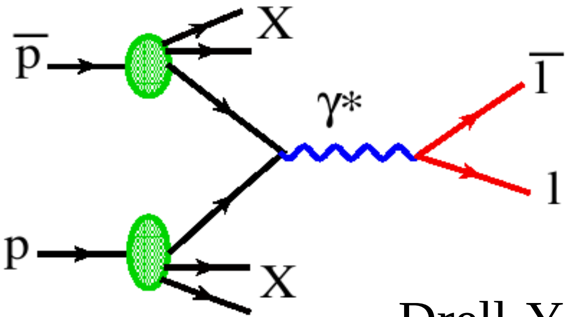
Information about the transverse position of the parton is integrated out.

Deep-Inelastic scattering

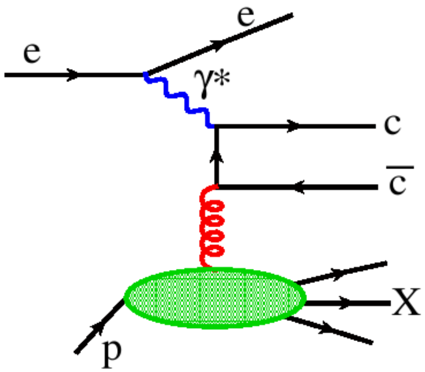
The power of the factorization theorem is that the same quark and gluon PDFs can be accessed in different processes as long as there is large scale, which guarantees validity of factorization.



Inclusive DIS



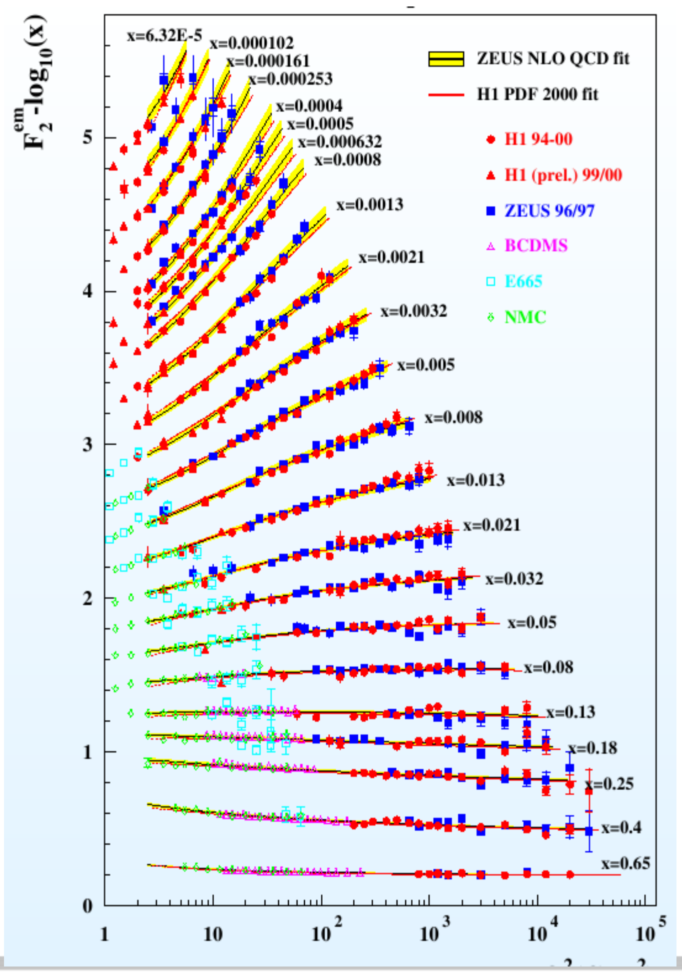
Drell-Yan process

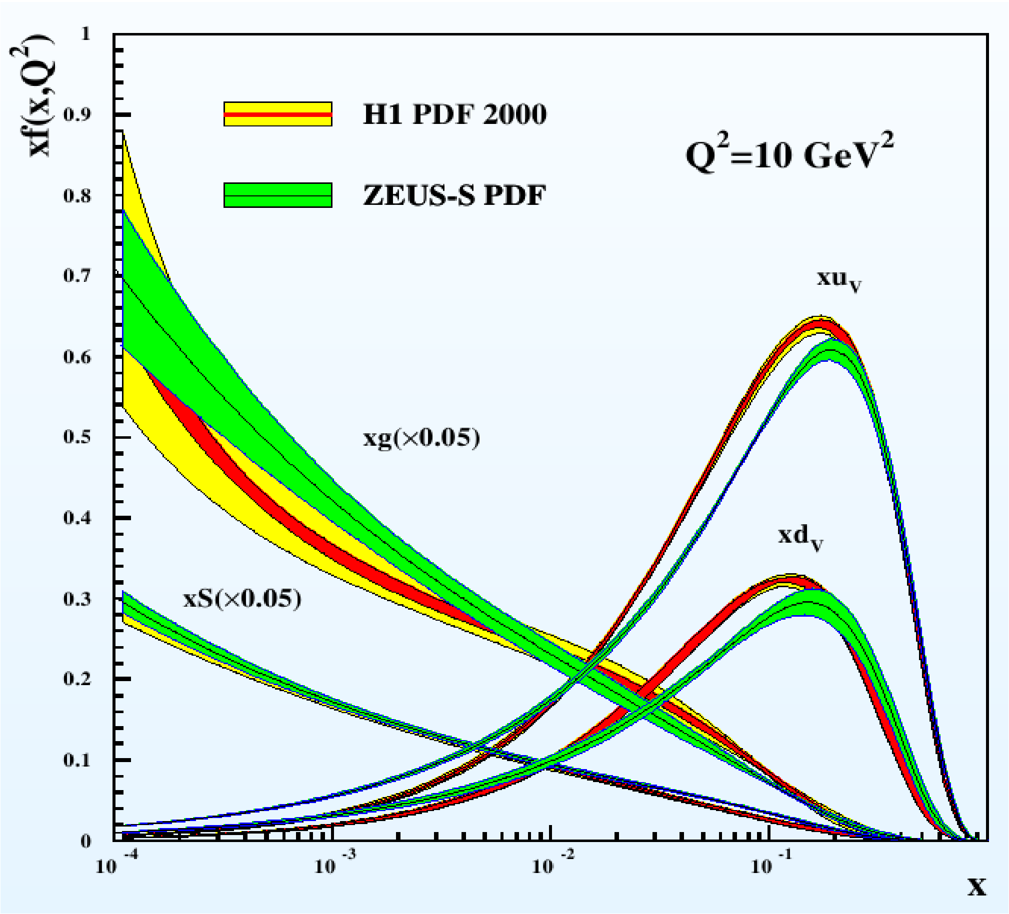


Inclusive charm production, sensitive to gluons

Deep-Inelastic scattering

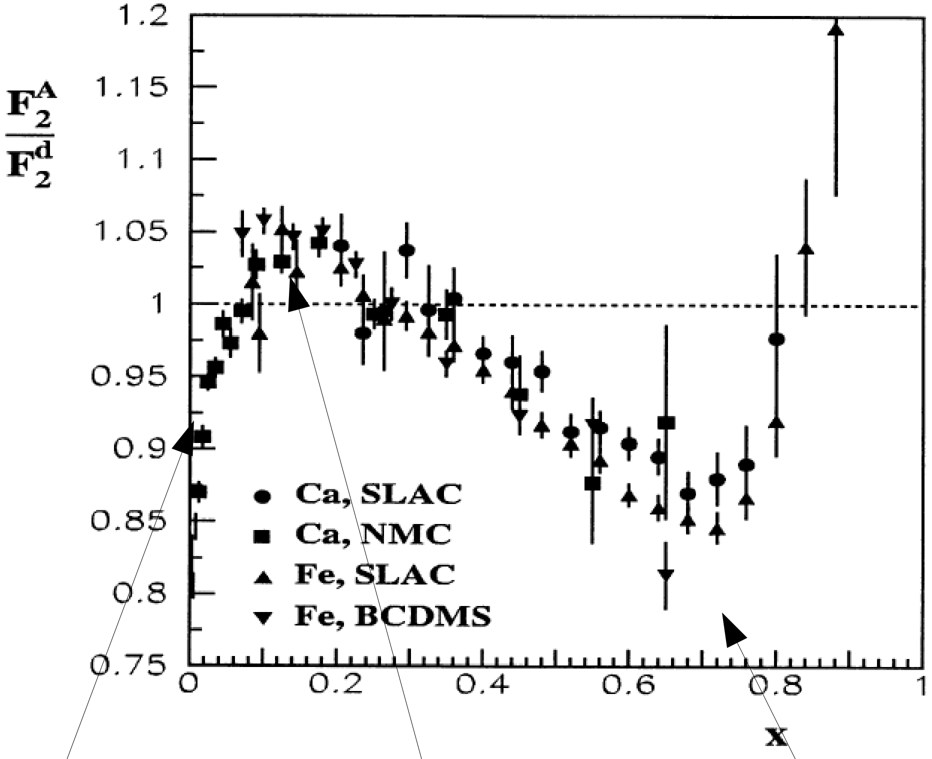
A huge amount of data on DIS off nucleons and nuclei have been collected and analyzed in terms of PDFs:





Deep-Inelastic scattering off nuclei

Ratio of the nuclear to deuteron inclusive structure functions:



PDFs are modified by nuclear matter!

shadowing antishadowing EMC-effect (No accepted explanation!)

II. Generalized Parton Distributions

Generalized Parton Distributions

Traditionally, elastic form factors and parton distribution functions (PDFs) were considered totally unrelated:

Elastic form factors give information on the charge and magnetization distributions in the transverse plane;

PDFs describe the distribution of partons in the longitudinal direction.

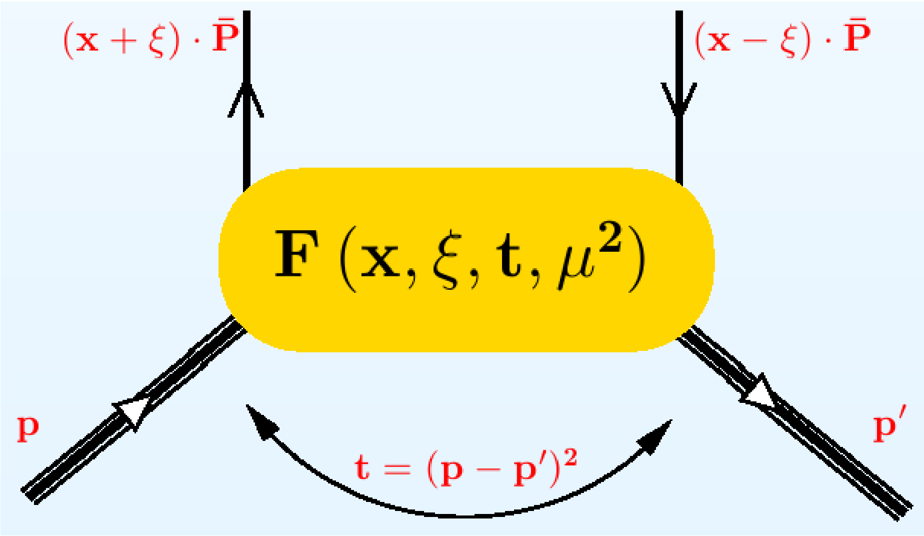
Generalized Parton Distributions encode information on the distribution of partons both in the transverse plane and in the longitudinal direction

→ natural extension and continuation of studies of the hadron structure.

Definition of GPDs

The nucleon (spin-1/2) has four quark and gluon GPDs. Like usual PDFs, GPDs are non-perturbative functions defined via the matrix elements of well-defined parton operators:

$$F^q = \frac{1}{2}\int \frac{dz^-}{2\pi} e^{ix\bar{P}^+z^-} \langle p'|\bar{q}(-\frac{1}{2}z)\gamma^+ q(\frac{1}{2}z)|p\rangle|_{z^+=0,\mathbf{z}=0}$$
$$= \frac{1}{2\bar{P}^+}\left[H^q(x,\xi,t,\mu^2)\bar{u}(p')\gamma^+u(p) + E^q(x,\xi,t,\mu^2)\bar{u}(p')\frac{i\sigma^{+\alpha}\Delta_\alpha}{2m_N}u(p)\right]$$



$\Delta = p' - p$

$t = (p' - p)^2$

$\bar{P}^+ = (p' + p)/2$

$x \pm \xi$ -- long. mom. fractions

μ^2 -- factorization scale

$\xi = x_B/(2 - x_B)$ -- fixed

Basic properties of GPDs

For the rest of the talk, I will consider only quark GPDs H and E.
In general, PDFs are correlation functions and not probabilities.

Forward limit (p=p', t=0)

$$H^q(x,0,0,\mu^2) = q(x,\mu^2)$$
$$E^q(x,0,0,\mu^2) \quad \text{decouple}$$

Connection to elastic FFs

$$\int_0^1 dx\, H^q(x,\xi,t,\mu^2) = F_1^q(t)$$
$$\int_0^1 dx\, E^q(x,\xi,t,\mu^2) = F_2^q(t)$$

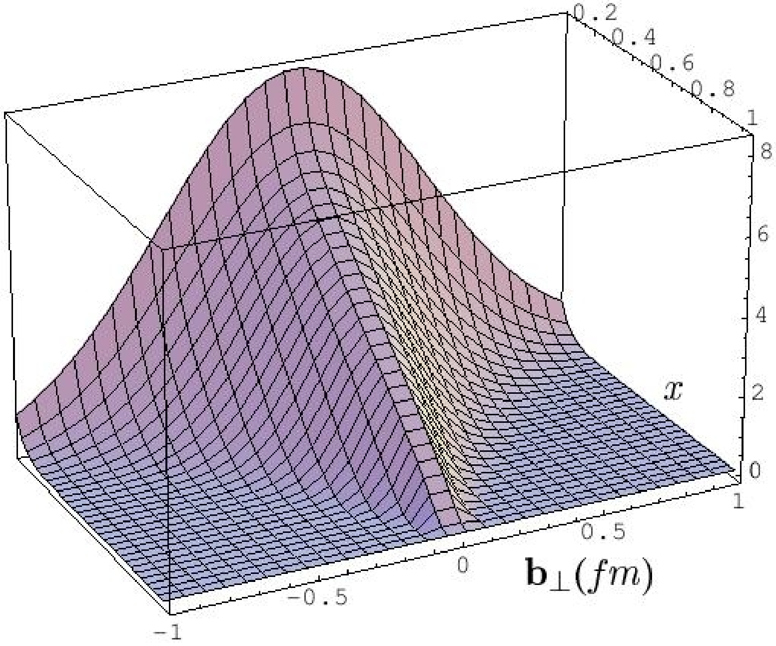
Additional properties of GPDs:

- Polynomiality – consequence of Lorentz invariance
- Positivity – consequence of unitarity

Interpretation

Consider the limit ξ=0 (t=-**q**²). The partons carry equal long. fractions x and GPDs have probabilistic interpretation in the mixed x-**b** represent.

M. Burkardt, 2003



u-quark

$$q(x,\mathbf{b}) = \int \frac{d^2\mathbf{q}}{(2\pi)^2} e^{-i\mathbf{b}\cdot\mathbf{q}} H^q(x,\xi=0,t=-\mathbf{q}^2,\mu^2)$$

Probability to find a quark with the light-cone fraction x and at a transverse distance **b**.

Important feature: correlation between x and **b** (between x and t).
E.g. the transverse width → 0 as x → 1.

GPDs and spin sum rule

Considering matrix elements of the QCD energy-momentum tensor, one can derive the relation between GPDs H and E and the total angular momentum of the target carried by quarks and gluons:

$$\frac{1}{2}\int_0^1 dx\, x\, \left[H^q(x,\xi,t=0,\mu^2) + E^q(x,\xi,t=0,\mu^2)\right] = J^q(\mu^2)$$

$$\frac{1}{2}\int_0^1 dx\, x\, \left[H^g(x,\xi,t=0,\mu^2) + E^g(x,\xi,t=0,\mu^2)\right] = J^g(\mu^2)$$

$$\sum_q J^q + J^g = \frac{1}{2}$$

X. Ji, 1997

Decomposition into spin and orbital contributions

$$J^q = S^q + L^q$$

$$J^g = \Delta G + L^g$$

$$S^q = \frac{1}{2}\int_0^1 dx\, \Delta q(x,\mu^2)$$

$$\Delta G = \int_0^1 dx\, \Delta g(x,\mu^2)$$

Polarized PDFs

GPDs and spin sum rule

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

Polarized PDFs Δq(x) and Δg(x) is the probability to find the parton polarized along the direction the nucleon polarization minus the probability to find it polarized in the opposite direction.

$\Delta\Sigma = \sum_q S^q = 0.33 \pm 0.03 \pm 0.05$ → Inclusive and semi-inclusive DIS by EMC and Hermes

$\Delta G \approx 0$ → Polarized pp at RHIC

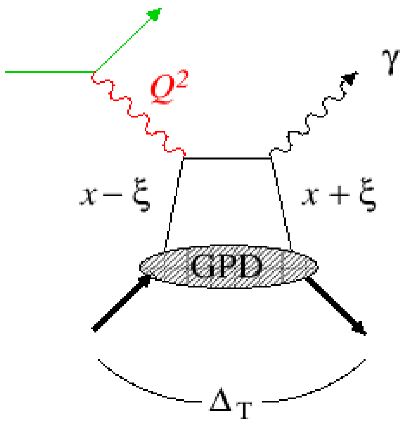
Proton spin puzzle: Since $\Delta\Sigma + \Delta G < 1$, where is all proton spin?

Possible answer: In the quark angular momentum, A.W. Thomas, 2008

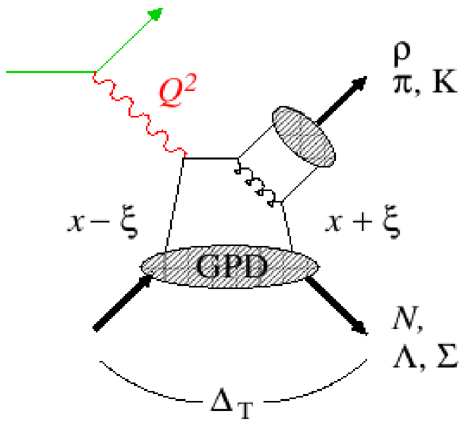
GPDs will help solve the riddle by accessing J^q

Measurements of GPDs

The new QCD factorization theorems at the amplitude level allow to access GPDs in various hard (large scale) exclusive (all final-state particles are detected) reactions.



) Deeply virtual Compton scattering



(e) Deeply virtual meson production

$$\mathcal{A}_{\rm DVCS}(\xi,t,Q^2) \propto \sum_q e_q^2 \int_0^1 dx\, \frac{2x}{x^2-\xi^2} H^q(x,\xi,t,Q^2) + \text{other GPDs}$$

Perturbative

GPDs

Accessing GPDs

It is difficult to extract GPDs from the data (like has been done for usual PDFs) because:

- Physical observables involve convolution of GPDs and information on the longitudinal fraction x is washed out.

- GPDs are more complicated than PDFs since the former are functions of 4 variables instead of 2.

- Unlike inclusive cross sections, exclusive ones are much smaller and harder to measure. We don't (won't) have the luxury of a broad kinematic coverage.

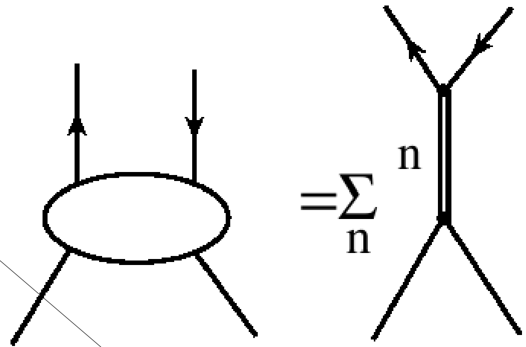
→ need to model/parameterize GPDs

Dual parameterization

Polyakov, Shuvaev, 2002

The dual parameterization of nucleon GPDs H and E is an analog of the partial wave decomposition of scattering amplitude in NR QM in the t-channel.

It is an expansion in terms of the relative orbital momentum and eigenfunctions of the QCD evolution operator:



$$H^q(x,\xi,t,\mu^2) = \sum_{\substack{n=1 \\ \text{odd}}}^{\infty} \sum_{\substack{l=0 \\ \text{even}}}^{n+1} B^i_{nl}(t,\mu^2)\,\theta(\xi-|x|)\left(1-\frac{x^2}{\xi^2}\right) C^{3/2}_n\left(\frac{x}{\xi}\right) P_l\left(\frac{1}{\xi}\right)$$

$$E^q(x,\xi,t,\mu^2) = \sum_{\substack{n=1 \\ \text{odd}}}^{\infty} \sum_{\substack{l=0 \\ \text{even}}}^{n+1} C^i_{nl}(t,\mu^2)\,\theta(\xi-|x|)\left(1-\frac{x^2}{\xi^2}\right) C^{3/2}_n\left(\frac{x}{\xi}\right) P_l\left(\frac{1}{\xi}\right)$$

generalized form factors with known QCD evolution

Gegenbauer polynomials

Legendre polyn.

Dual parameterization

Introduce generating functions:

$$B^q_{n\,n+1-k}(t,\mu^2) = \int_0^1 dx\, x^n Q^q_k(x,t,\mu^2)$$

$$C^q_{n\,n+1-k}(t,\mu^2) = \int_0^1 dx\, x^n R^q_k(x,t,\mu^2)$$

The generating functions Q_0 and R_0 related to forward distributions (in the t=0 limit):

$$Q^q_0(x,0,\mu^2) = q(x,\mu^2) + \bar{q}(x,\mu^2) - \frac{x}{2}\int_x^1 \frac{dz}{z^2}\left[q(z,\mu^2)+\bar{q}(z,\mu^2)\right]$$

$$R^q_0(x,0,\mu^2) = e^q(x,\mu^2) + \bar{e}^q(x,\mu^2) - \frac{x}{2}\int_x^1 \frac{dz}{z^2}\left[e^q(z,\mu^2)+\bar{e}^q(z,\mu^2)\right]$$

well-known

unknown, but easy to model; contain information on J^q

Dual parameterization

Resulting GPDs H and E:

Small parameter, which allows to expand around the forward distributions

$$H^q(x,\xi,t,\mu^2) = \sum_{\substack{k=0\\ \text{even}}}^{\infty} \Big[\frac{\xi^k}{2}\Big(H^{q\,(k)}(x,\xi,t,\mu^2) - H^{q\,(k)}(-x,\xi,t,\mu^2)\Big)$$

$$+\left(1-\frac{x^2}{\xi^2}\right)\theta\left(\xi-|x|\right)\sum_{\substack{l=1\\ \text{odd}}}^{k-3} C^{3/2}_{k-l-2}\left(\frac{x}{\xi}\right) P_l\left(\frac{1}{\xi}\right)\int_0^1 dy\, y^{k-l-2}\, Q^q_k(y,t,\mu^2)\Big]$$

$$H^{q\,(k)}(x,\xi,t,\mu^2) = \frac{1}{\pi}\int_0^1 \frac{dy}{y}\left[\left(1-y\frac{\partial}{\partial y}\right) Q^q_k(y,t,\mu^2)\right]\int_{-1}^1 ds \frac{x_s^{1-k}}{\sqrt{2x_s - x_s^2 - \xi^2}}\theta(2x_s - x_s^2 - \xi$$

$$-\lim_{y\to 0} Q^q_k(y,t,\mu^2)\int_{-1}^1 ds \frac{x_s^{1-k}}{\sqrt{2x_s - x_s^2 - \xi^2}}\theta(2x_s - x_s^2 - \xi^2)$$

$$x_s = 2\frac{x-s\xi}{(1-s^2)y}$$

Minimal model of dual parameterization

Keep only the leading (Q_0 and R_0) and subleading (Q_2 and R_2) generating functions

Guzey, Teckentrup, 2006

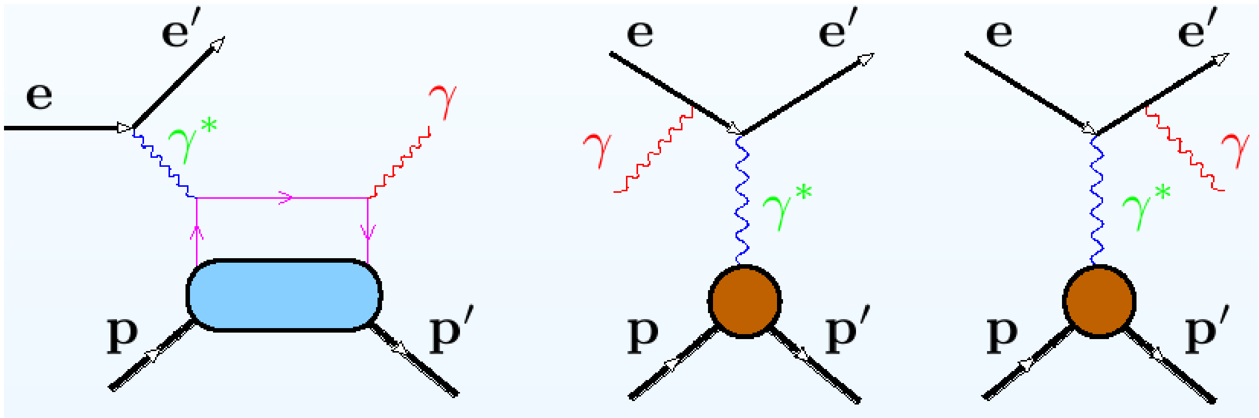
→ essentially model-independent predictions for H and E

Main features of the minimal model of the dual parameterization

- works best at small ξ ($\xi<0.005$ at HERA; $\xi<0.1$ at Hermes)
- GPDs have simple leading-order QCD evolution: great help when comparing to experimental data
- dependence on J^q enters via the forward distributions $e^q(x)$
- t-dependence is modeled separately. We include correlations between x and t (lesson from impact parameter representation)
- can be systematically improved

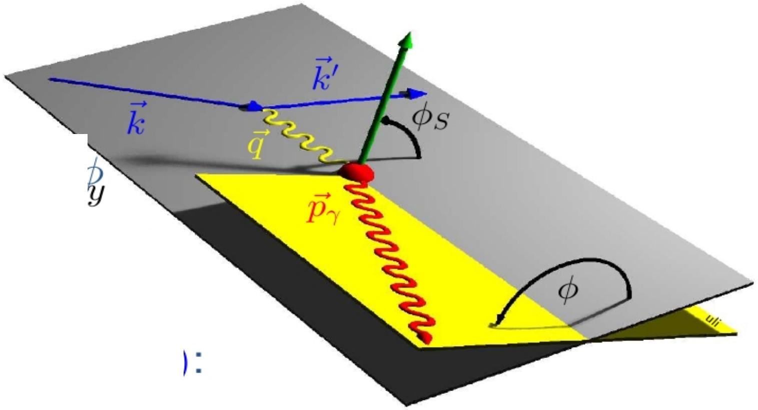
Comparison to DVCS observables

To date, all experimental information on GPDs has been obtained from Deeply Virtual Compton Scattering (DVCS).
DVCS amplitude interferes with the purely EM Bethe-Heitler (BH) one:



BH is calculable in terms of nucleon elastic FFs F_1 and F_2

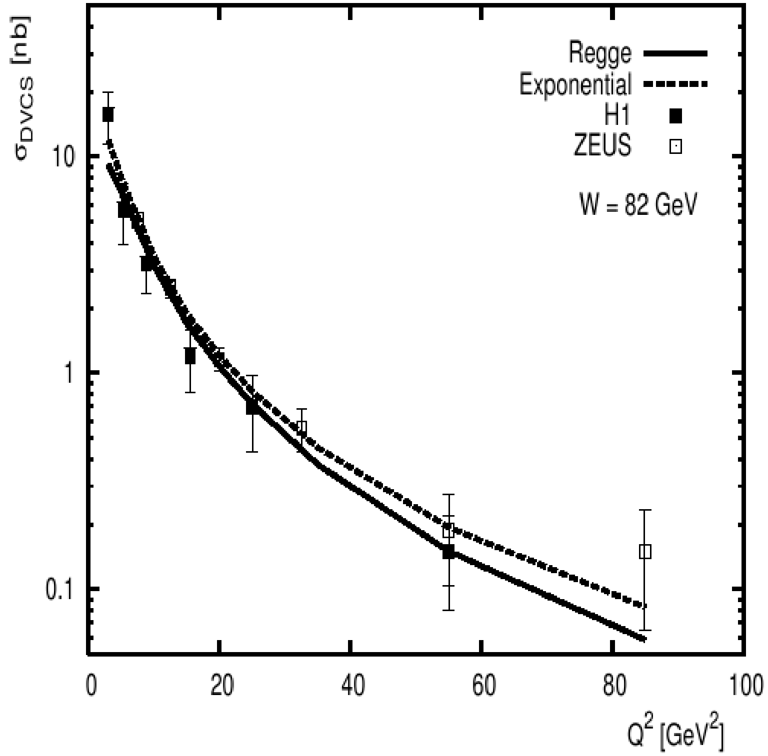
In the kinematics of Hermes and JLab, weak DVCS is accessed through its interference with BH by measuring the angular dependence

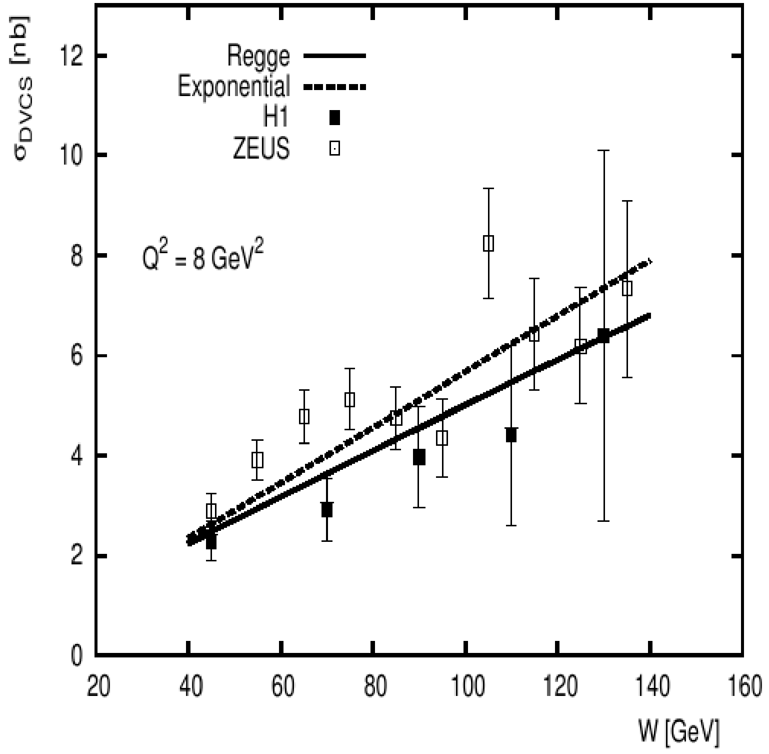


Comparison to DVCS observables

The DVCS cross section at the photon level, dominated by the GPD H (small BH subtracted)

H1, 2005 and ZEUS, 2003 (HERA)





Dual parameterization with non-factorized (Regge) and factorized (Exponential) t-dependence of GPDs

Guzey, Teckentrup, 2006

Comparison to DVCS observables

Beam-spin DVCS asymmetry $A_{LU}(\varphi)$

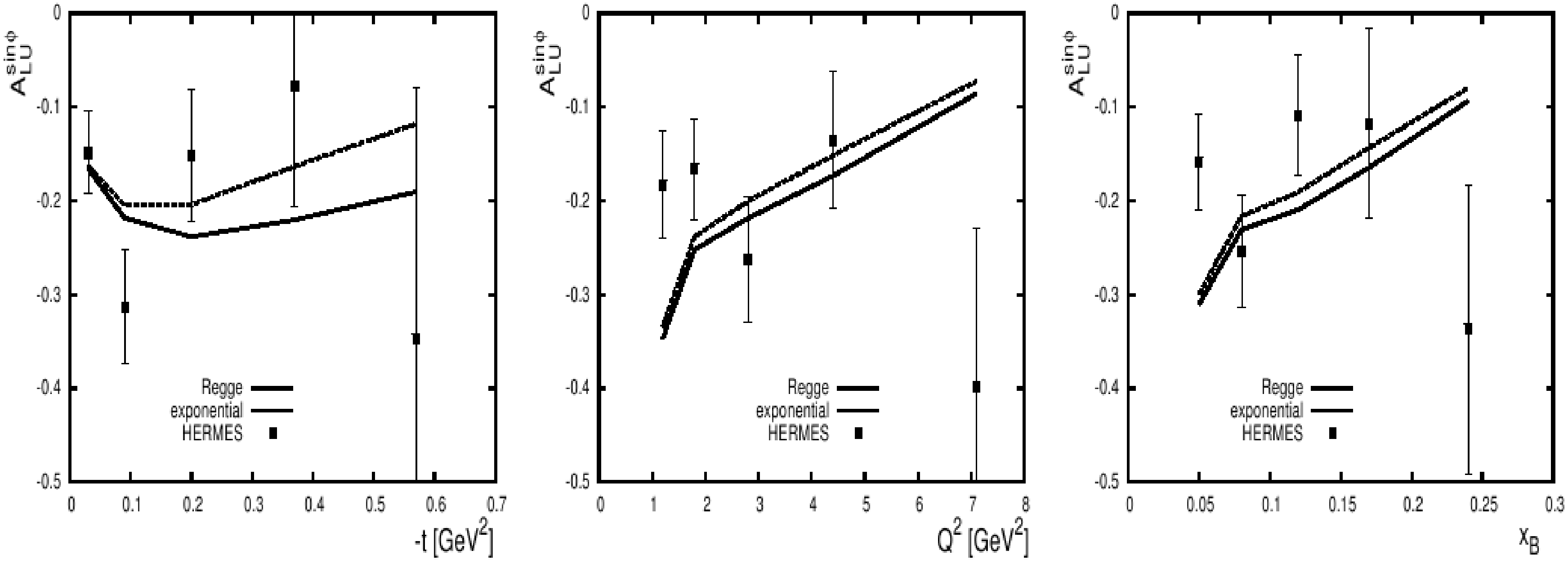
(polarized beam and unpolarized proton target)

Sensitive mostly to the GPD H

$$\vec{e}\, p \to e\, p\, \gamma$$

$$\frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = A_{\rm LU}^{\sin\phi} \sin\phi$$

Hermes, 2004 (F. Ellinghaus, PhD)



Dual parameterization with $J^q=0$

(insensitive to E)

Guzey, Teckentrup, 2006

Comparison to DVCS observables

Beam-spin DVCS asymmetry $A_{LU}(\varphi)$ at Jefferson Lab (CLAS)

E=4.25 GeV, Q^2=1.25 GeV^2, x_B=0.19, t=-0.19 GeV^2

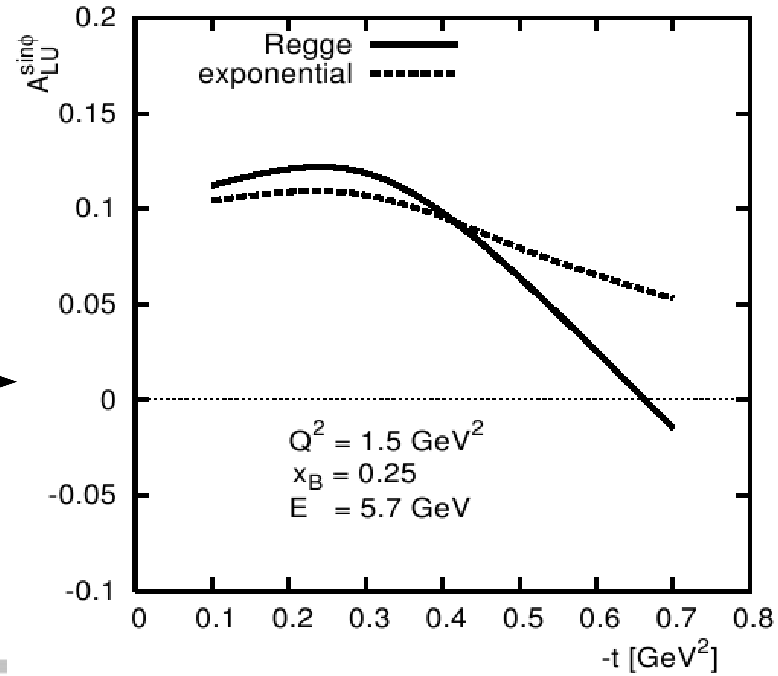
$$A_{LU}^{\sin\phi} = 0.15 \ldots 0.17\,, \quad \text{exponential } t - \text{dependence}$$

$$A_{LU}^{\sin\phi} = 0.18 \ldots 0.20\,, \quad \text{Regge } t - \text{dependence}$$

$$A_{LU}^{\sin\phi} = 0.202 \pm 0.028\,, \quad \text{CLAS (Stepanyan, 2001)}$$

Dual parameterization with $0 < J^u < 0.4$

Current JLab beam energy



Comparison to DVCS observables

Transversely-polarized proton target

DVCS asymmetry $A_{UT}(\varphi,\varphi_S)$

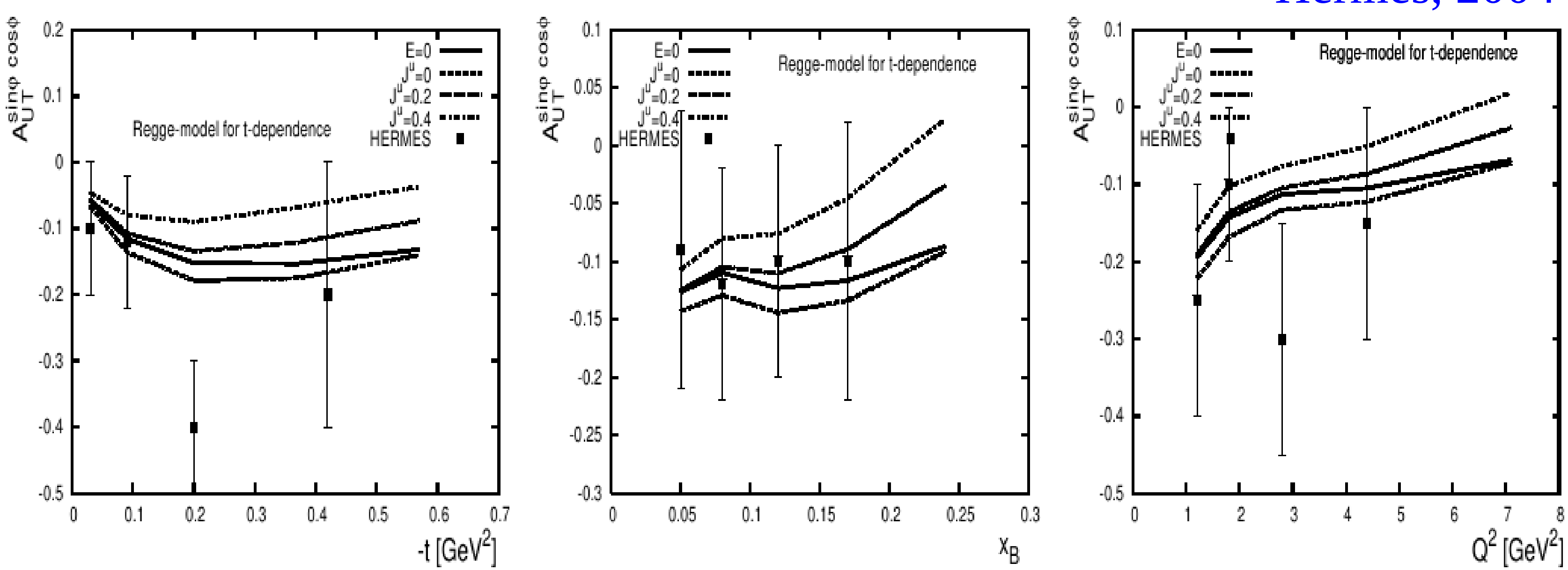
(unpolarized beam)

Sensitive both to the GPD H and E

$$e\,p^{\Uparrow} \rightarrow e\,p\,\gamma$$

$$\frac{d\sigma(\phi,\phi_S) - d\sigma(\phi,\phi_S)}{d\sigma(\phi,\phi_S) + d\sigma(\phi,\phi_S)} = A_{UT}^{\sin(\phi-\phi_S)\cos\phi} \sin(\phi-\phi_S)\cos\phi + \cdots$$

Hermes, 2004-2006

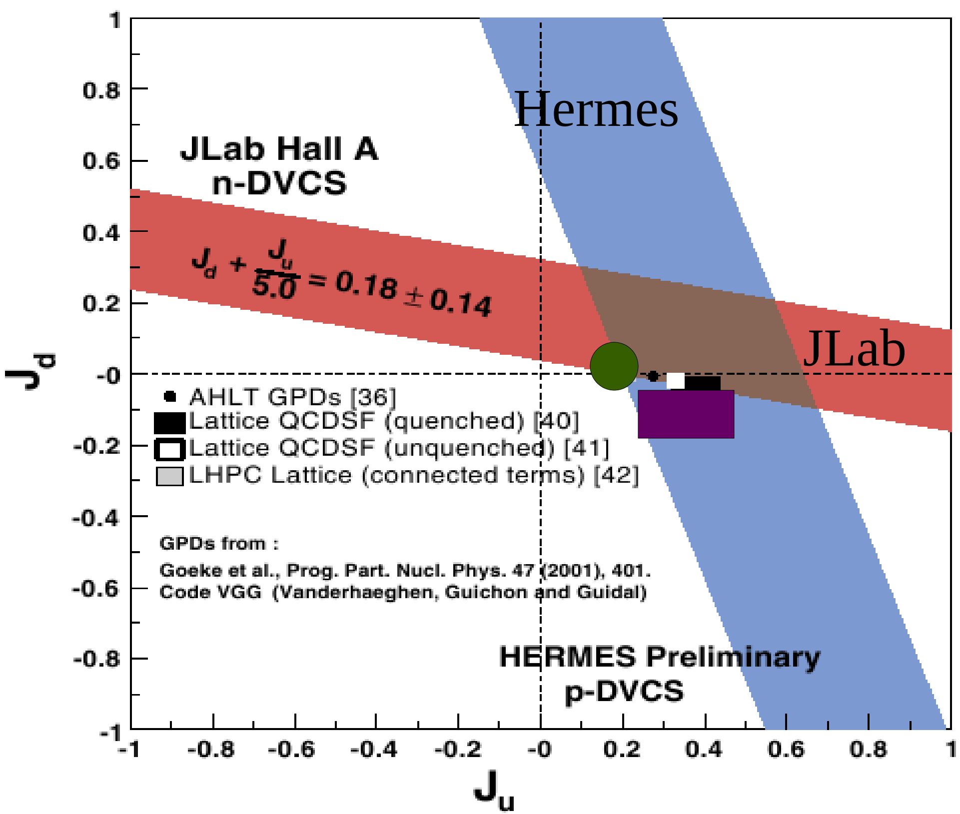


Dual parameterization, sensitivity to J^u

Guzey, Teckentrup, 2006

Constraints on J^q

DVCS off transversely polarized proton (sensitive to J^u) and off unpolarized neutron [deuteron] (sensitive to J^d).



Z. Ye (Hermes), 2006

M. Mazouz (JLab Hall A), 2007

A.W.Thomas, 2008

Lattice QCD,

M. Goekeler et al. (QCDSF), 2004

Ph. Hagler (LHPC), 2007

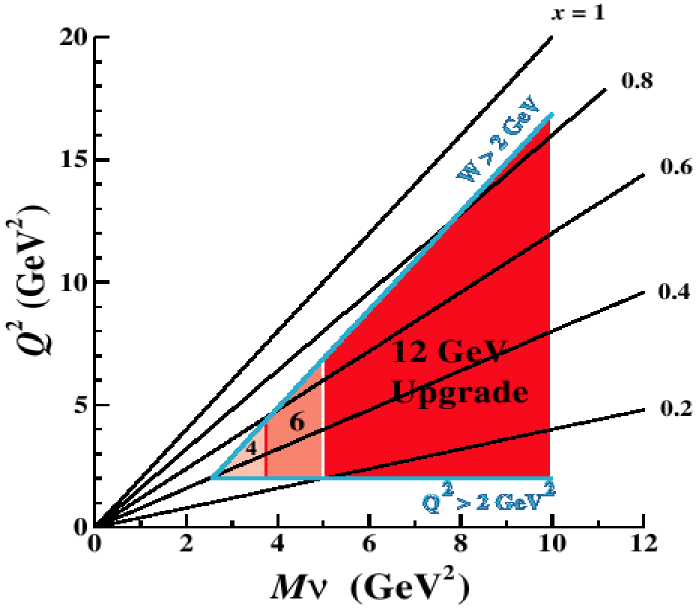
Dual parameterization

Guzey, Teckentrup, 2006

III. Future measurements of GPDs

GPDs at JLab at 6 and 12 GeV

Mapping the valence quark GPDs of the nucleon over a wide kinematic range is a key objective of the physics program at Jefferson Lab at the present 6 GeV electron beam and future upgrade to 12 GeV.



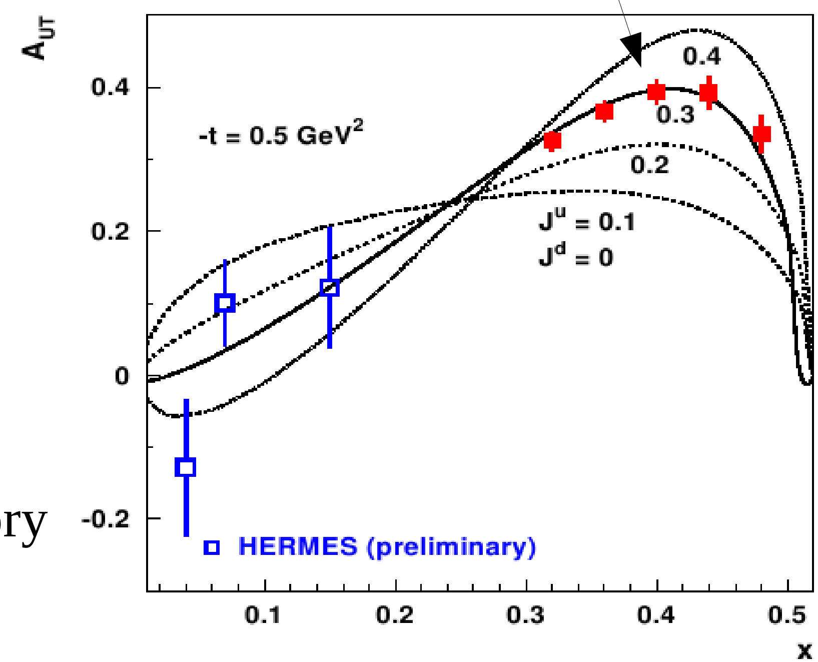
The combination of high beam intensity with large-acceptance detectors allows for precision measurements of such “rare” exclusive processes as DVCS and meson production.

GPDs at JLab at 6 and 12 GeV

There will be measured various beam and target-spin observables (asymmetries) in DVCS and meson production, which will emphasize different quark GPDs (E^q, H^q, $\tilde{H}^q$, $\tilde{E}^q$) of the nucleon:

- A_{LU} is sensitive to H
- A_{UL} is sensitive to $\tilde{H}$
- A_{UT} is sensitive to H and E

Projected experimental errors



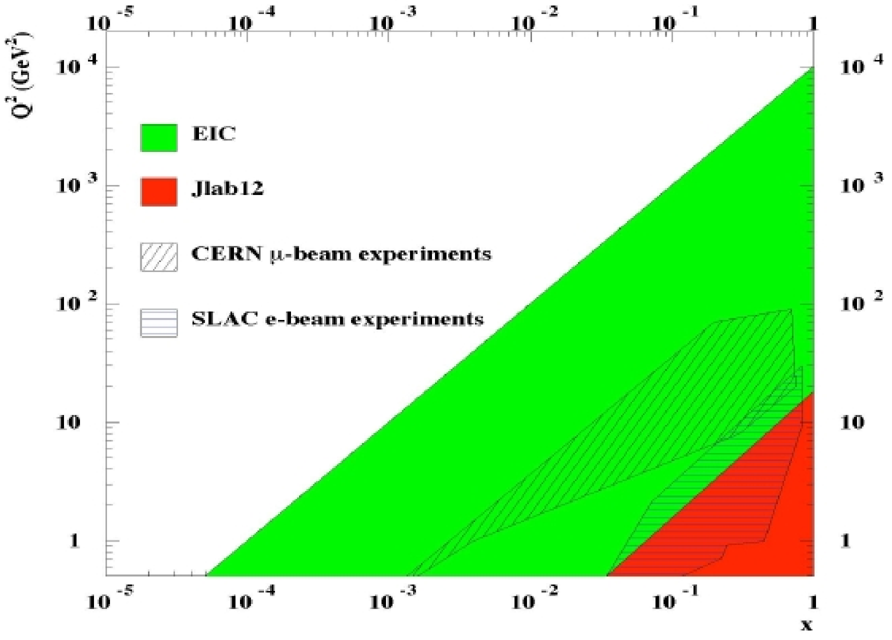
Transverse target asymmetry at 12 GeV

$$e\,p^{\Uparrow} \rightarrow e\,p\,\rho^0$$

Curves are theory predictions

GPDs at the future EIC

The future high-intensity Electron-Ion Collider (EIC) will study QCD at the "small-x regime", i.e. in the regime dominated by QCD radiation of sea quarks and gluons.

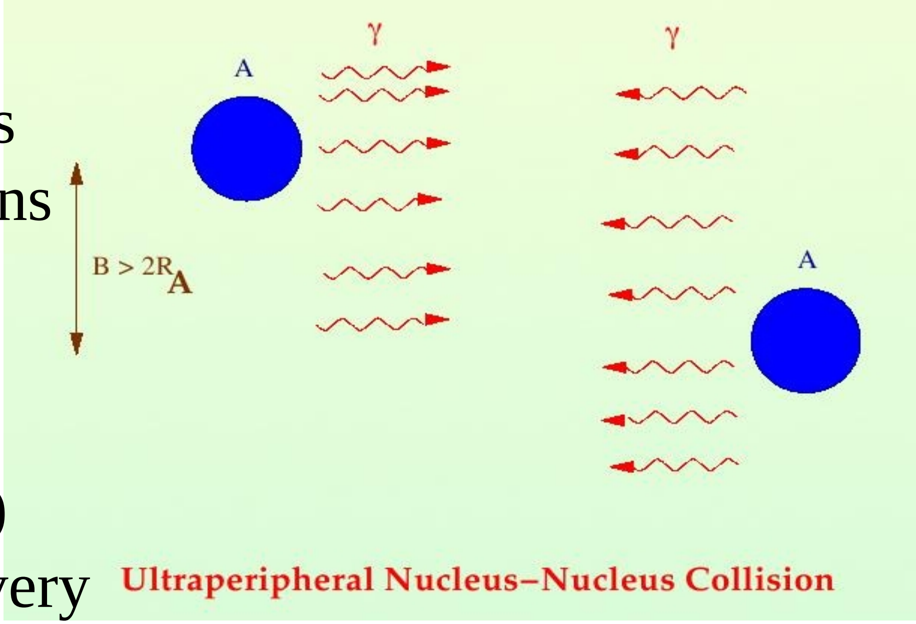


Physics topics at EIC include:

- gluon parton distributions in proton and nuclei
- polarized proton structure function (polarized gluon distribution ΔG)
- proton and nucleus sea quark and gluon Generalized Parton distributions accessed in DVCS and meson production (both diffractive and non-diffractive channels).

Note: The dual parameterization suits very well small-x!

GPDs at the LHC

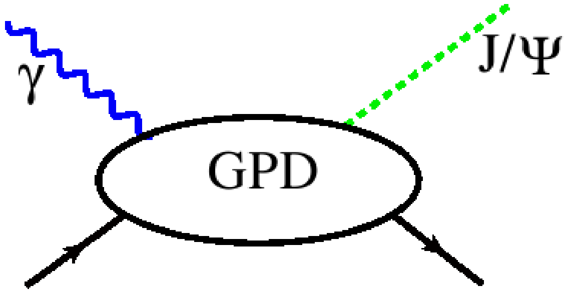


There is an exciting possibility to study nucleon and nuclear gluon GPDs in ultra-peripheral AA and Ap collisions at the Large Hadron Collider (LHC) in a few years!

A fast moving nucleus (with charge Z) emits flux of quasi-real photons with very large energy, E_{LAB}=1000 TeV!

The photon interacts with the other nucleus (nucleon) and probes gluon distributions (usual and generalized).

Example:



Frankfurt, Guzey, Strikman, Zhalov, 2003
and in K. Henken et al., Phys. Rept. 458 (2008)

Summary

• Theoretical and experimental studies of hard exclusive reactions with nucleons and nuclei are a natural continuation and extension of studies of the hadronic structure using high-energy elastic and Deep-Inelastic electron scattering.

• New QCD factorization theorems and the formalism of Generalized Parton Distributions provide the unifying theoretical framework which allows to access the 3D parton structure of the target.

•The dual parameterization of GPDs is a convenient and reliable model for GPDs that provides a good description of DVCS observables.

• Experiments at Jefferson Lab at 6 GeV and12 GeV and at the future Electron-Ion collider will be able to map GPDs over a wide range of kinematics, accessing both valence quark, sea quark and gluon GPDs. The LHC will allow to stidy gluon GPDs down to $x{\sim}10^{-5}$.

Back-up slides

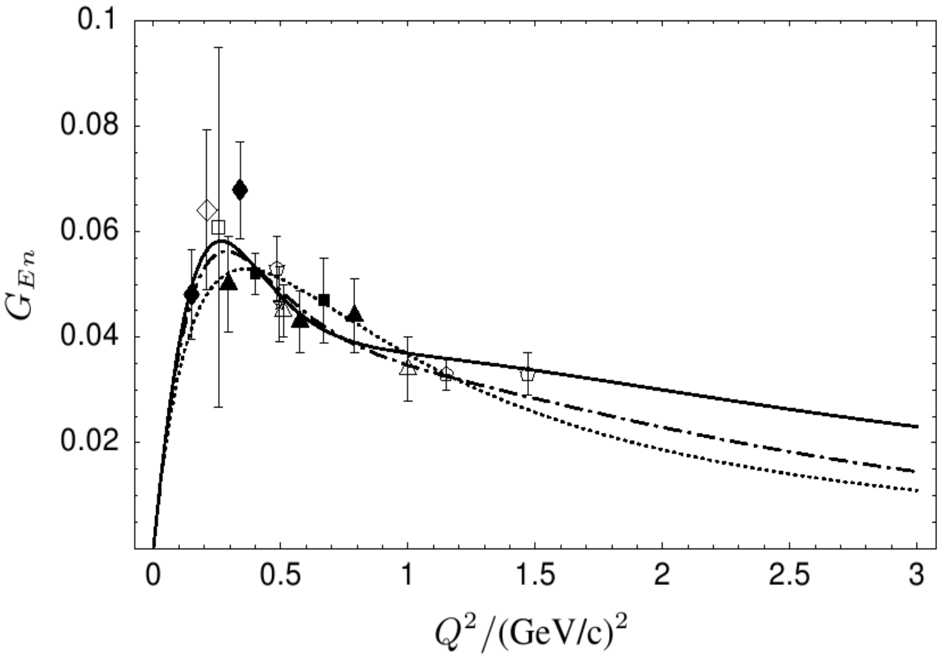
Elastic scattering

Interpretation of elastic form factors in Breit frame ($q^0=0$)

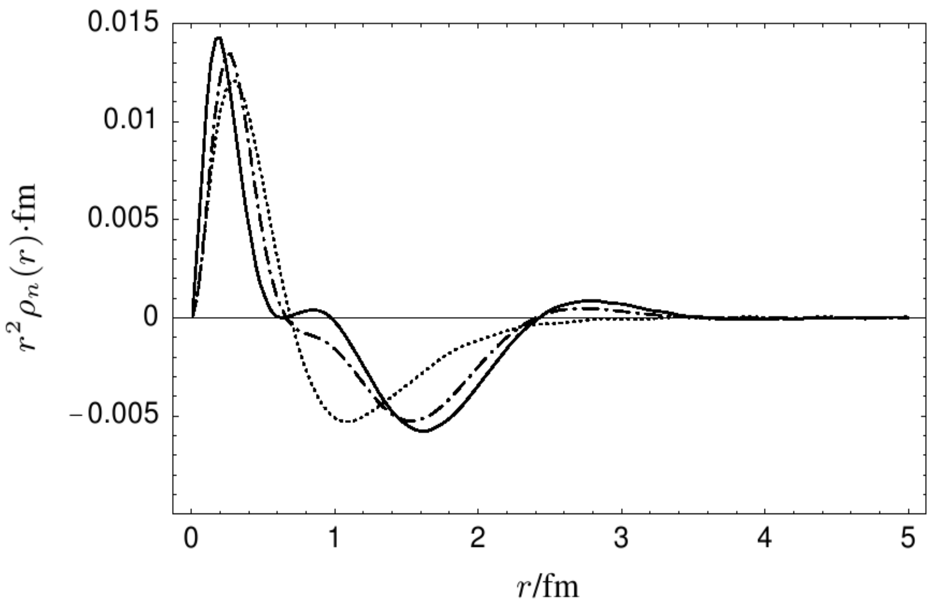
$$\langle N_{s'}(p')|J^0(0)|N_s(p)\rangle = 2m_N\delta_{ss'}\, G_E(q^2)$$
$$\langle N_{s'}(p')|\vec{J}(0)|N_s(p)\rangle = \chi^\dagger_{s'}\, i\vec{\sigma}\times\vec{q}\,\chi_s\, G_M(q^2)$$

$$\longrightarrow \quad \rho(r) = \int \frac{d^3q}{(2\pi)^3} e^{-i\vec{q}\cdot\vec{r}}\, \frac{m_N}{E}\, G_E(q^2)$$

J. Friedrich, T.Walcher, 2003



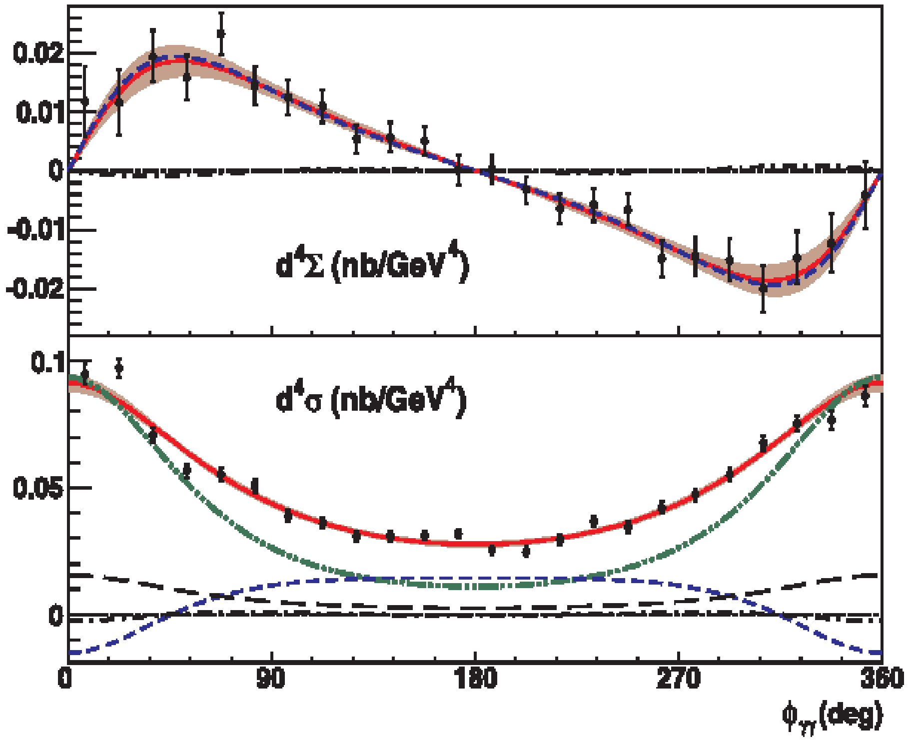
Neutron 3D charge density



Three key experimental results

1) Leading-twist dominance in the DVCS cross section, i.e. the GPD formalism is applicable at rather low Q^2 (Jefferson Lab kinematics)

C. Munoz Camacho *et al*. (JLab Hall A), 2006



Q^2=2.3 GeV^2, t=-0.28 GeV^2, x_B=0.36

$$\vec{e}\,p \to e\,p\,\gamma$$

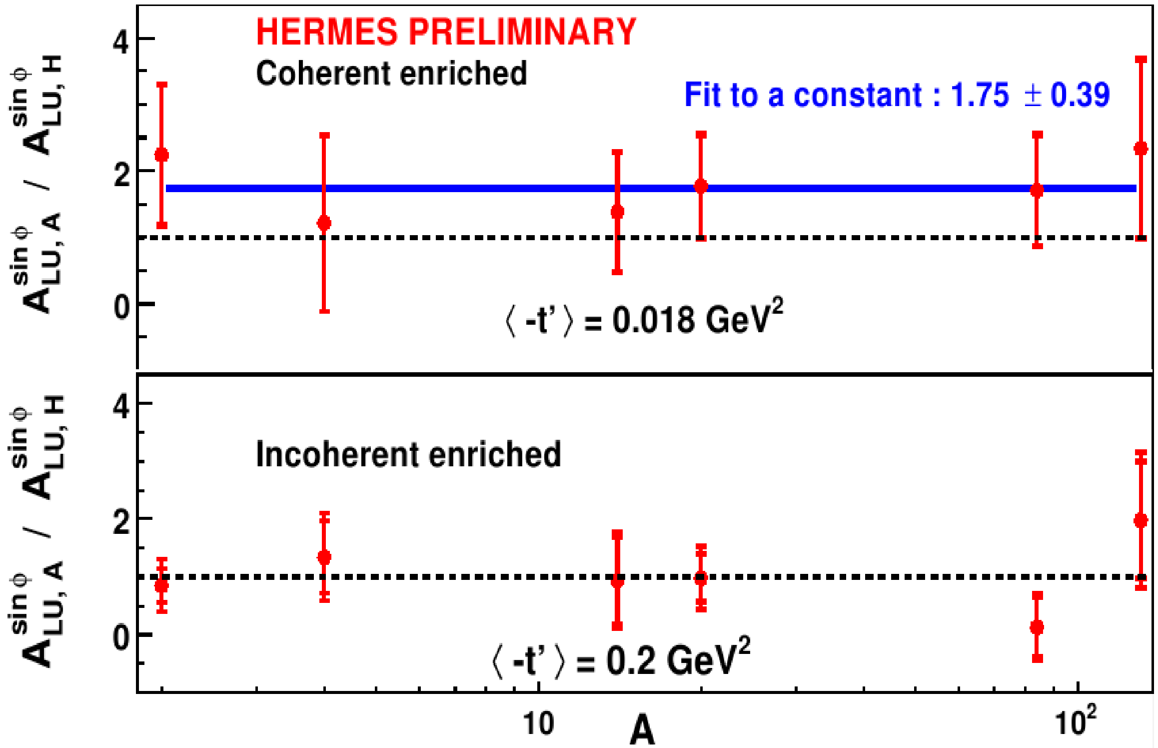
$$\frac{d^4\Sigma}{d^4\Phi} = \frac{1}{2}\left[\frac{d^4\sigma^+}{d^4\Phi} - \frac{d^4\sigma^-}{d^4\Phi}\right]$$

$$\frac{d^4\sigma}{d^4\Phi} = \frac{1}{2}\left[\frac{d^4\sigma^+}{d^4\Phi} + \frac{d^4\sigma^-}{d^4\Phi}\right]$$

$$d^4\Phi = dQ^2\, dx_B\, dt\, d\phi$$

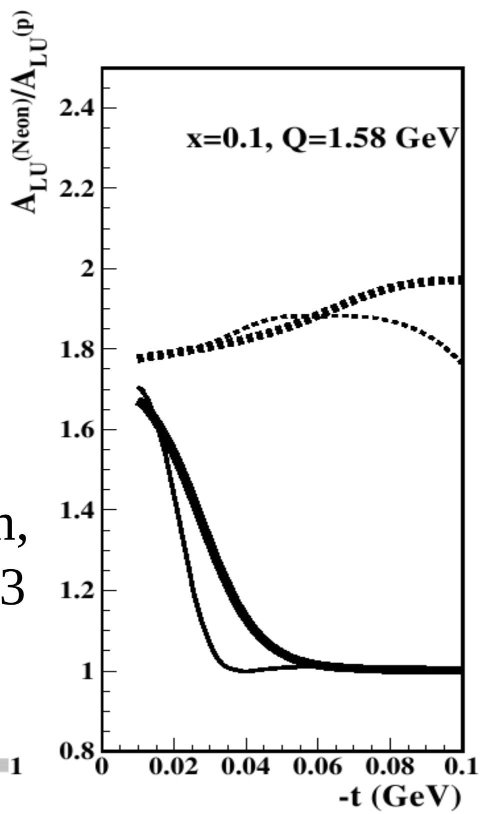
Three key experimental results

3) First measurement of DVCS off nuclear targets (Hermes, 2006)



$$\vec{e}\, A \to e\, A\, \gamma$$

$$\frac{d\sigma^+ - d\sigma^-}{d\sigma^+ + d\sigma^-} = A_{LU}^{\sin\phi} \sin\phi$$

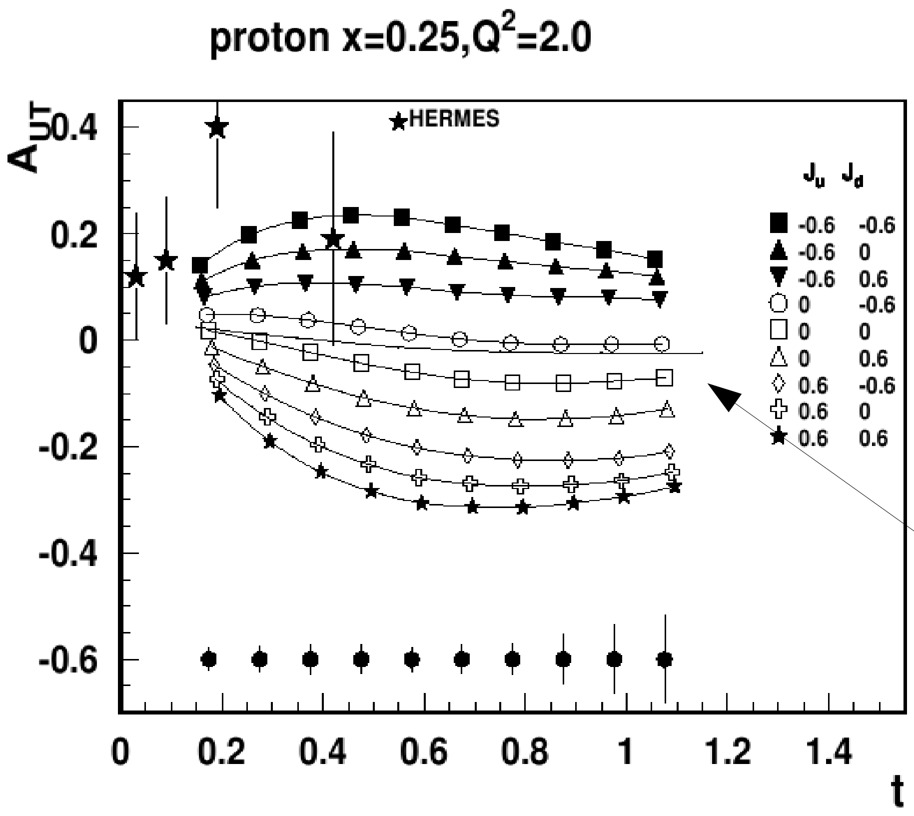


Consistent with prediction, Guzey and Strikman, 2003

New Hermes results to be released in April 2008.

Jefferson Lab at 6 GeV

A new measurement of DVCS off the transversely polarized proton target at Hall B with the will significantly improve accuracy of determination of J^u and J^d



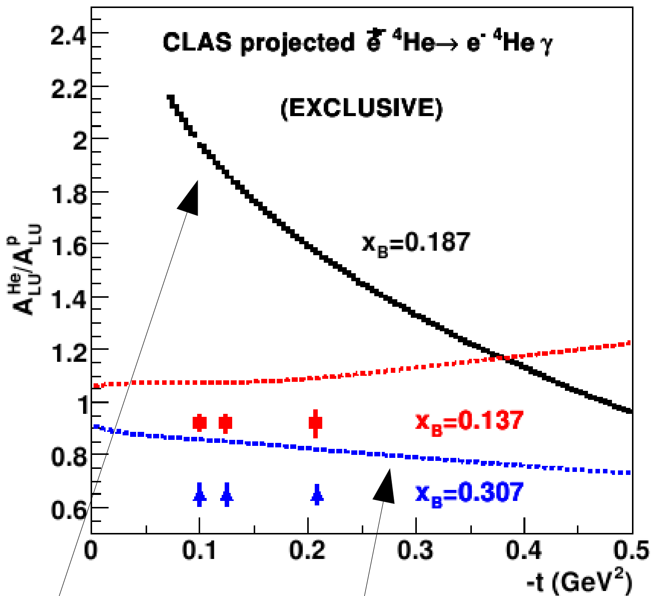
H. Avakian *et al.*,
proposal PR-08-021 (2008)

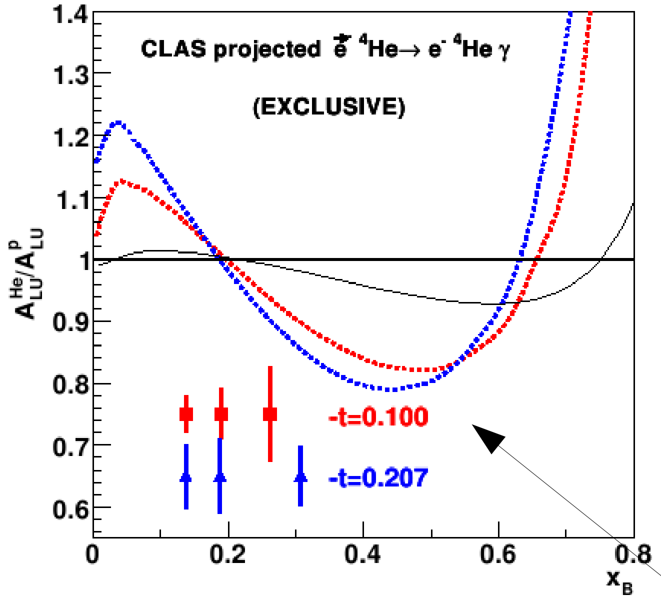
Dual parameterization predictions

Jefferson Lab at 6 GeV

For the first time, a dedicated experiment at Hall B will measure DVCS off the nucleus of ^{4}He (recoiled nucleus will be detected using BoNuS detector). This will greatly improve Hermes results.

K. Hafidi et al., proposal PR-08-024 (2008)





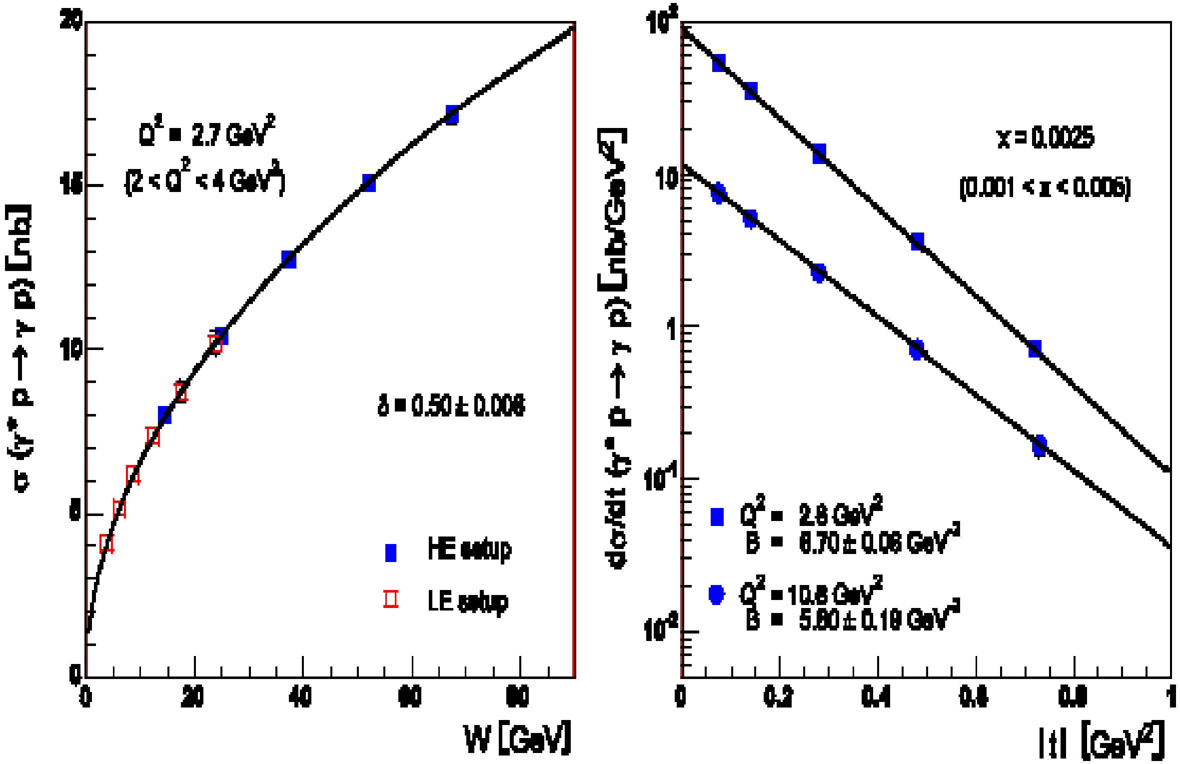
Guzey, Strikman, 2003

Liuti *et al.*, 2005

Off-forward EMC effect

DVCS at EIC

DVCS on the proton at the EIC.



HE – high-energy set-up, 10-GeV electrons on 250-GeV protons
LE – low-energy set-up, 5 on 50 GeV