Hard exclusive processes and GPDs with EIC

Ch. Weiss (JLab), EIC Collaboration Meeting, MIT, Apr. 5–7, 2007

- Hard exclusive processes and GPDs

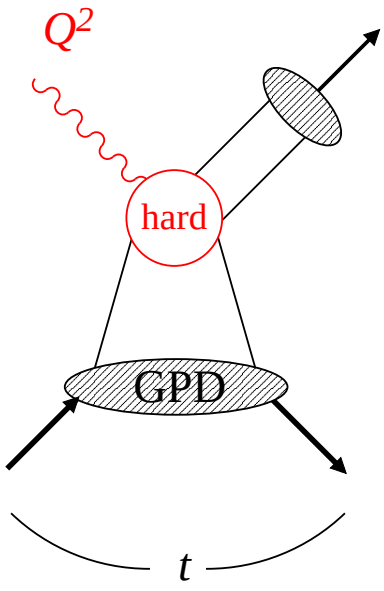
  QCD factorization, transverse nucleon imaging

- Exclusive measurements in ep/eA with EIC

diffractive:	transverse gluon imaging	J/ψ, ρ^0, γ (DVCS)
non–diffractive:	quark spin/flavor structure	$\pi, K, \rho^+, \ldots$

cf. Joint INT/JLab/BNL Workshop "Hard exclusive processes with JLab 12 GeV and a future EIC," U. Maryland, Oct. 29–30, 2006
+ White Paper, in preparation

Hard exclusive processes: Factorization

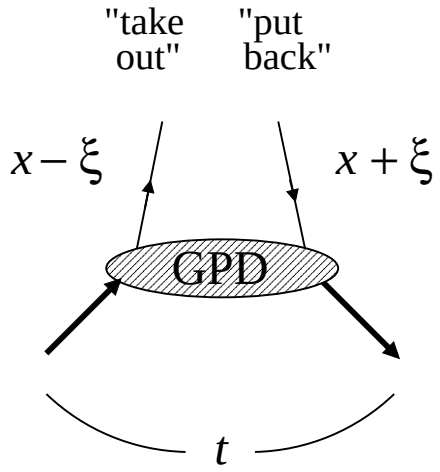


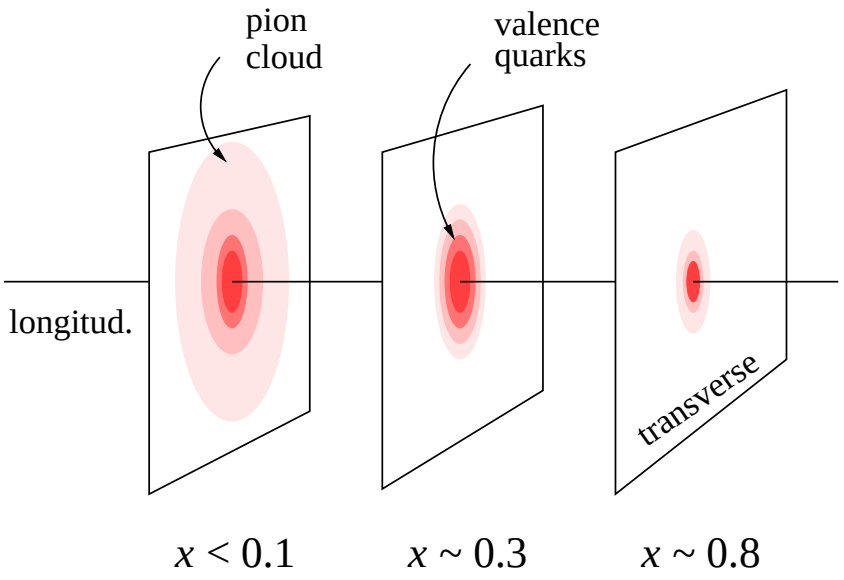
$$\begin{array}{lcll} \gamma^* p & \to & \gamma + p & \text{DVCS} \\ \gamma_L^* p & \to & M + p & \text{Meson productn} \\ & & J/\psi + p & \text{Heavy } Q\bar{Q} \\ & & & (\to \text{gluon GPD}) \end{array}$$

- Meson produced in hard reaction with single quark/gluon in target
- QCD factorization (hard $\leftrightarrow$ soft) cf. inclusive DIS
- GPDs universal characteristics of nucleon (process–independent)
- Experimental challenge: Small cross sections at high Q^2 Recoil detection

[D. Müller et al. 94, Brodsky et al. 94; Collins et al. 96; Radyushkin 96, Ji 96, . . .]

GPDs and nucleon structure





- Unify concepts of parton density and elastic form factor

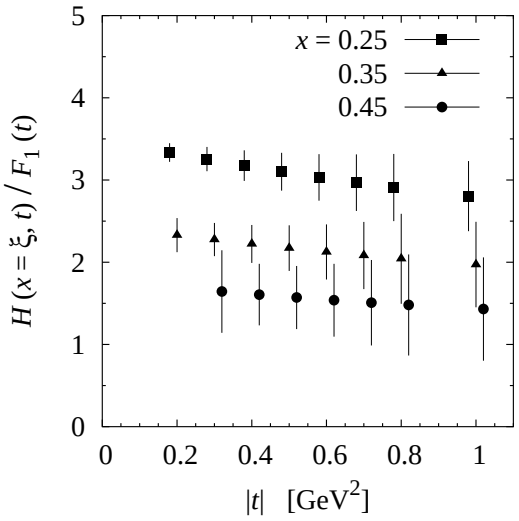
- Describe correlation of longitudinal momentum and transverse position of quarks/gluons

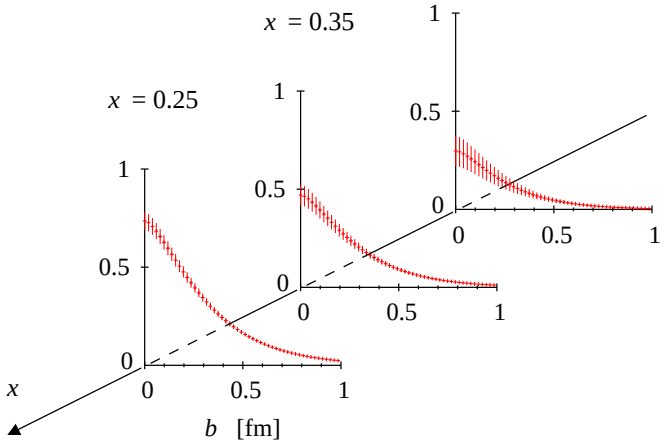
  $\rightarrow$ Transverse quark/gluon imaging of nucleon ("tomography")
  [Burkardt 00; Diehl 02]

- Moments (x–integrals) related to fundamental static properties:
  J_q quark angular momentum [Ji 96]

  $\rightarrow$ Lattice

GPD program with JLab 12 GeV





[CLAS 12 GeV]

- Aim: Comprehensive mapping of quark GPDs in valence region $0.15 < x < 0.6$
- Incorporates PDF/form factor data
- DVCS: Measurements of beam/target spin asymmetries and absolute cross sections

  Hall A 6 GeV DVCS cross sections consistent with scaling at $Q^2 \sim$ 1-2 GeV^2
- Meson production: Cross section ratios provide additional information about spin/flavor separation

[Details: 12 GeV CDR, White Paper]

Hard exclusive processes at collider energies

$W^{\gamma^* p} > 10$ GeV

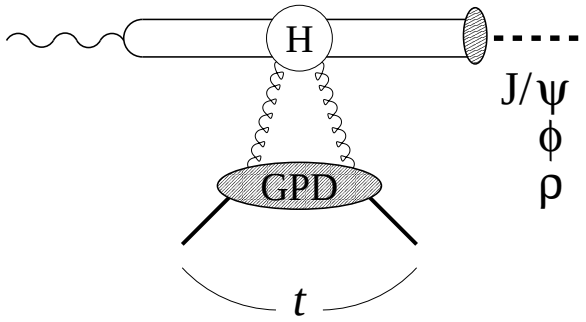
- "Diffractive" channels: J/ψ, ϕ, ρ^0, γ (DVCS)
  - Cross sections grow with energy
  - Probe gluon and singlet quark GPDs
  - Need to be studied together!

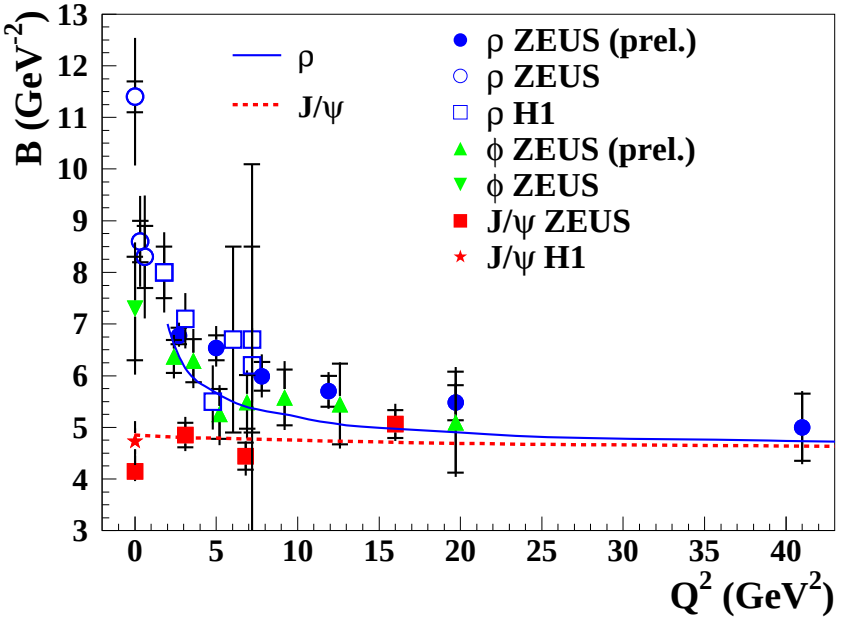
"Transverse gluon imaging of nucleon"

- "Non-diffractive" channels: π, η, K, $\rho^+, \ldots$
  - Cross sections small, do not grow with energy
  - Probe spin/flavor/charge non-singlet GPDs
  - Comparisons between different channels

"Spin/flavor structure of nucleon"

Diffractive channels: HERA results





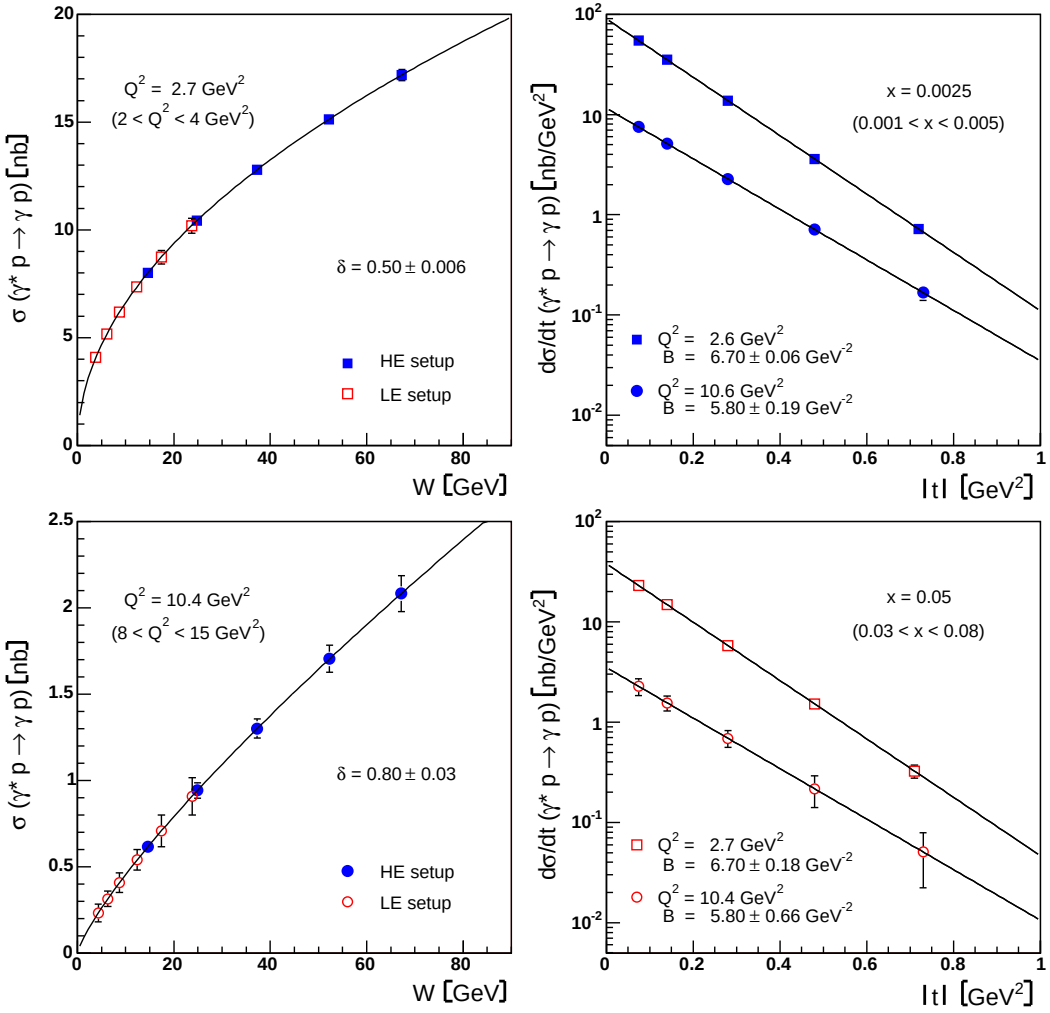
[Levy; Frankfurt, Strikman, CW 05]

- LO QCD factorization $\leftrightarrow$ Dipole picture
  Gluon GPD $\leftrightarrow$ Color dipole moment

- Measurements of diffractive channels $(J/\psi,\, \phi,\, \rho,\, \gamma)$ have confirmed applicability of QCD factorization:
  - Energy dependence changes with Q^2
  - t–slopes universal at high Q^2
  - Flavor relations $\phi : \rho$

- Transverse gluonic size of nucleon
  . . . essential input for small–x physics!

Diffractive channels: EIC projections

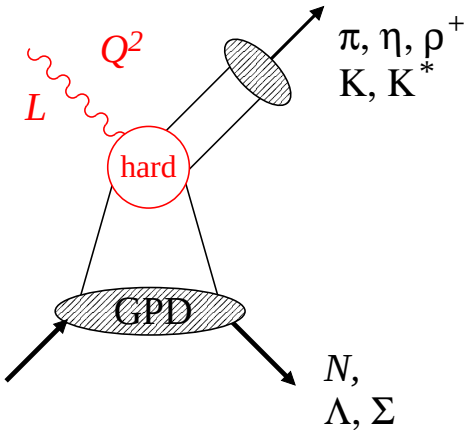


[DVCS with eRHIC HE/LE, $530/180\,\mathrm{pb}^{-1}$
A. Sandacz, GPD White Paper (2007)]

- Aim: Transverse gluon/singlet quark imaging of nucleon over wide range $10^{-3} < x < 10^{-1}$
- Requirements:
  - $Q^2 \sim$ 10–20 GeV^2: Factorization
  - Wide Q^2–range: Leading/higher twist, QCD evolution
  - Wide W–range: x–dependence, overlap with fixed–target
  - Luminosity: Differential measurements in W, Q^2, t

Feasible with high–luminosity EIC; need to work out details

Non-diffractive channels: Options for EIC



- Aim: Probe spin/flavor structure of quark GPDs by model–independent comparison of channels

π^0/η	$\Delta u/\Delta d$, meson wavefns
ρ^+/K^*	SU(3) symmetry of quark GPDs (u, d, s)
π^+/π^0	Pion pole vs. non-pole in GPD

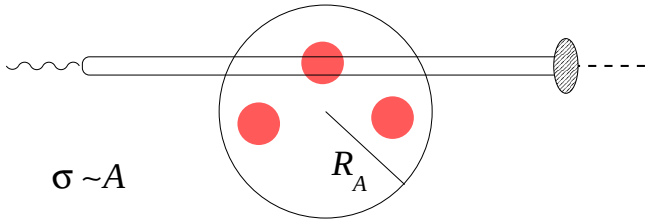
- QCD factorization: Needs $Q^2 \sim$ 10-20 GeV^2, L/T separation

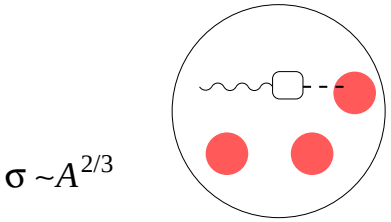
- Significantly smaller cross sections than diffractive channels ($\sim 1/100$), but less statistics needed than for imaging

- Also possible $N \to N\pi, N \to \Delta$ GPDs: New information on chiral dynamics and resonance structure

Many possibilities; need simulations for specific goals!

Hard exclusive processes with nuclei





coherence length $\longleftrightarrow$ nuclear radius

- QCD factorization $\leftrightarrow$ Color Transparency
- Nuclei offer unique possibilities for
  - Testing reaction mechanism
  - Exploring longitudinal direction
- Use leverage in x, Q^2 provided by collider
- Detector/IR requirements:
  Forward detectors for nuclear fragments

Unique option for EIC; needs further study!

Summary

- A high–luminosity EIC offers unique opportunities for studying nucleon structure and small–x dynamics through hard exclusive processes and GPDs:
  - Diffractive channels: Transverse gluon/quark imaging
    . . . certainly feasible; need to work out details
  - Non-diffractive channels: Spin/flavor structure of nucleon
    . . . many possibilities; need simulations for specific goals
  - Nuclear targets: Color transparency . . . unique, needs further study

- "Big picture:" GPDs/hard exclusive processes essential component of small–x physics $\longrightarrow$ saturation, diffraction in pp, . . .

  [Frankfurt, Strikman, CW, ARNPS 55, 403 (2005)
  Frankfurt, Hyde, Strikman, CW, PRD 75, 054009 (2007)]