

Exclusive electroproduction of strangeness

Ch. Weiss (JLab), ECT* Workshop “Strangeness/ Λ ”, 27–31 Oct 2008

- Theory introduction

- Reaction mechanism: QCD factorization
- Generalized parton distributions: Concept, nucleon structure

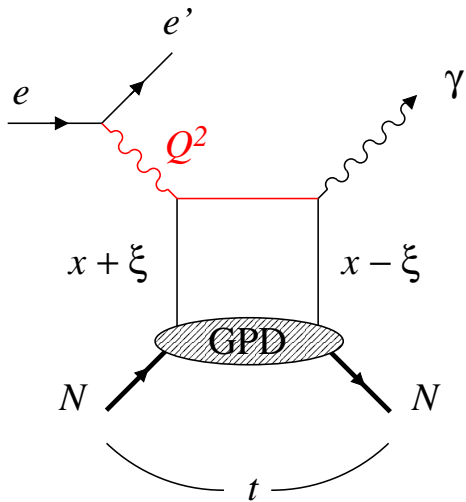
- Measurements with JLab at 6 & 12 GeV → Presentation by K. Joo

$\gamma^* N \rightarrow \phi + N$ Gluon GPD, “transverse imaging”

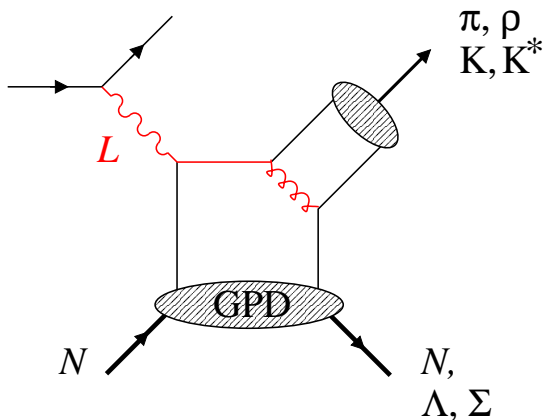
$\gamma^* p \rightarrow K^{*+} + \Lambda(\mathbf{S}_T)$ Quark helicity-flip GPD E from
recoil polarization (cf. A_{UT})

$\gamma^* p \rightarrow \begin{matrix} K^+ + \Lambda \\ K^+ + \Sigma^0 \end{matrix}$ $\Delta_s, \Delta_{\bar{s}}$, hyperon resonances

Exclusive processes in eN : Factorization



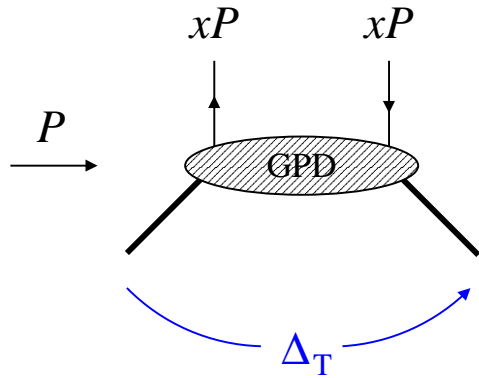
- Photon/meson produced in reaction with single parton in target
- Generalized parton distribution $H(x, \xi; t)$
 - combines aspects of PDF and elastic FF
 - universal, process-independent!



- Factorization = short-distance dominance
Finite-size corrections?

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

GPDs: Transverse spatial distribution

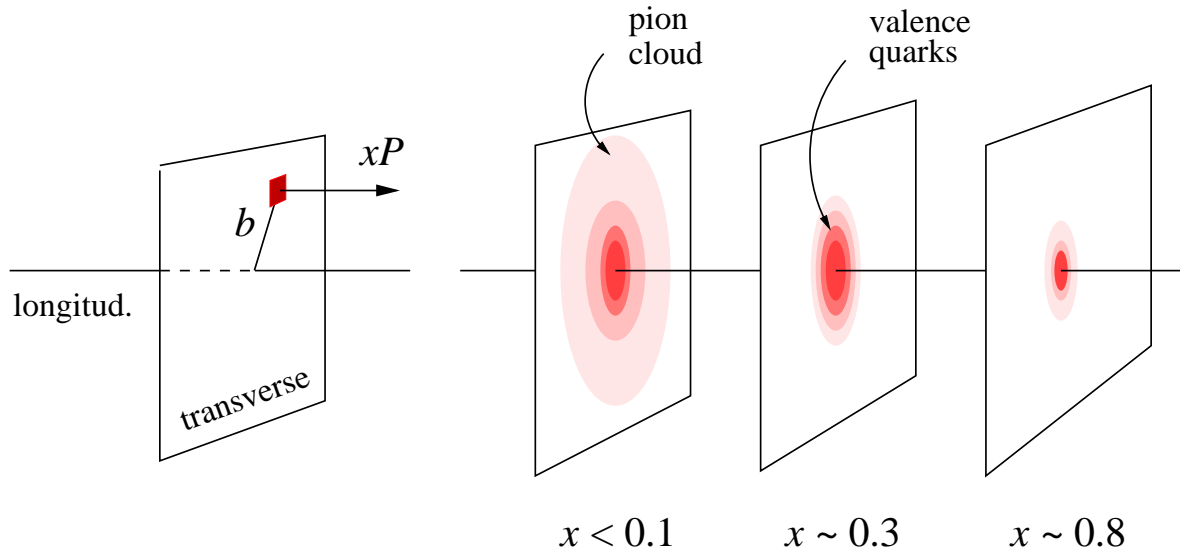


- Transverse coordinate representation ($\xi = 0$)

$$H(x, -\Delta_T^2) = \int d^2b e^{-i\Delta_T b} f(x, b)$$

FF of partons
with mom. xP

transverse spatial
distribution

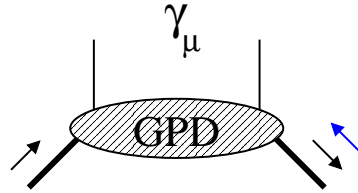


- “Tomographic” image of nucleon at fixed x

- Nucleon structure!
Valence quarks
“pion cloud”
gluons . . .

GPDs: Polarization

Quarks unpolarized:

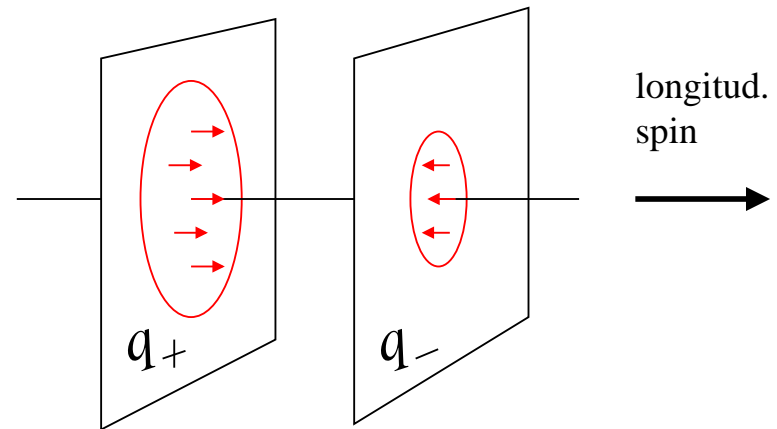
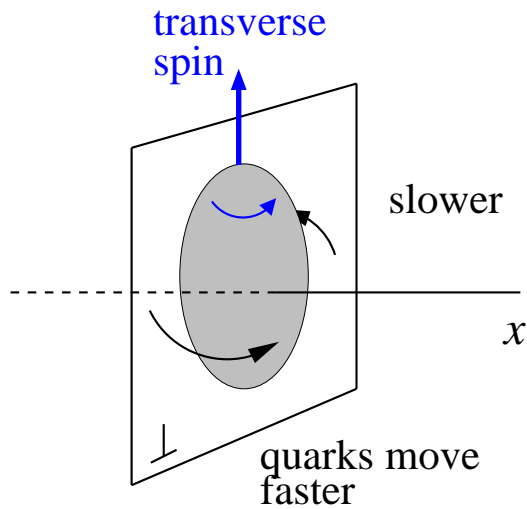


$$= \begin{matrix} H, & E \\ \text{Dirac} & \text{Pauli} \end{matrix} \quad (+ \text{Transversity})$$

polarized:

$$\gamma_\mu \gamma_5$$

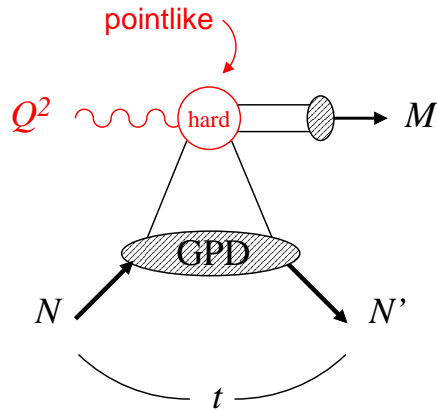
$$\begin{matrix} \tilde{H}, & \tilde{E} \\ \text{axial} & \text{pseudoscalar} \end{matrix}$$



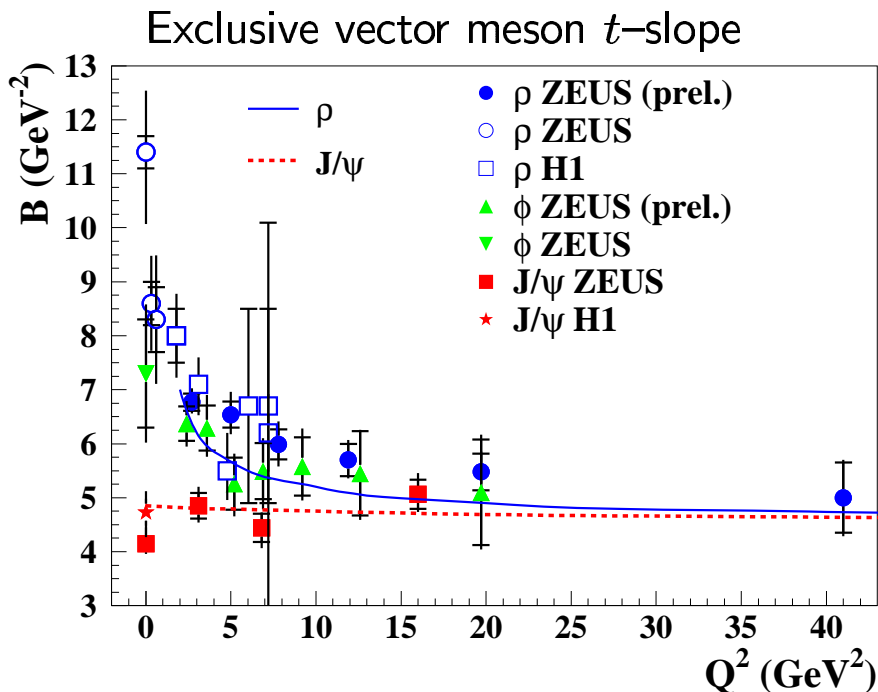
E : Distortion of quark longitudinal motion by transverse spin [Burkardt 03]

$H \pm \tilde{H}$: Spatial distribution of quark helicity

Meson production: Reaction mechanism



- $Q^2 \rightarrow \infty$: Meson produced in pointlike configuration
 - t -slope independent of Q^2
 - Seen in HERA vector meson data!



- $Q^2 \sim \text{few GeV}^2$: Substantial finite-size corrections (higher twist)
 - Dynamical models w. intrinsic k_T [Frankfurt et al. 96; Vanderhaeghen et al. 98; Kroll, Goloskokov 05]
 - Analyze cross section ratios

Meson production: GPD spin/flavor

$\rho^+ n$	$2[u - d] - [\bar{u} - \bar{d}]$
$\rho^0 p$	$\frac{1}{\sqrt{2}}[2u + d] + \frac{1}{\sqrt{2}}[2\bar{u} + \bar{d}] + \text{gluon}$
ωp	$\frac{1}{\sqrt{2}}[2u - d] + \frac{1}{\sqrt{2}}[2\bar{u} - \bar{d}] + \text{gluon}$
$K^{*+} \Lambda$	$-\frac{2}{\sqrt{6}}[2u - d - s]$ $+\frac{1}{\sqrt{6}}[2\bar{u} - \bar{d} - \bar{s}]$
$K^{*+} \Sigma^0$	$-\frac{2}{\sqrt{2}}[d - s] + \frac{2}{\sqrt{2}}[\bar{d} - \bar{s}]$
$K^{*0} \Sigma^+$	$[d - s] + [\bar{d} - \bar{s}]$
$\pi^+ n$	$2[\Delta u - \Delta d] + [\Delta \bar{u} - \Delta \bar{d}]$
$\pi^0 p$	$\frac{1}{\sqrt{2}}[2\Delta u + \Delta d] - \frac{1}{\sqrt{2}}[2\Delta \bar{u} + \Delta \bar{d}]$
$K^+ \Lambda$	$-\frac{2}{\sqrt{6}}[2\Delta u - \Delta d - \Delta s]$ $-\frac{1}{\sqrt{6}}[2\Delta \bar{u} - \Delta \bar{d} - \Delta \bar{s}]$
$K^+ \Sigma^0$	$-\frac{2}{\sqrt{2}}[\Delta^d - \Delta^s] - \frac{1}{\sqrt{2}}[\Delta \bar{d} - \Delta \bar{s}]$
$K^0 \Sigma^+$	$[\Delta d - \Delta s] - [\Delta \bar{d} - \Delta \bar{s}]$

- Meson selects spin

$$\begin{array}{ll} 1^- & \rho, K^* \quad H \leftrightarrow q, \quad E \\ 0^- & \pi, K \quad \tilde{H} \leftrightarrow \Delta q, \quad \tilde{E} \end{array}$$

- SU(3) flavor symmetry relates $p \rightarrow \Lambda$ transition GPDs to “usual” GPDs in proton

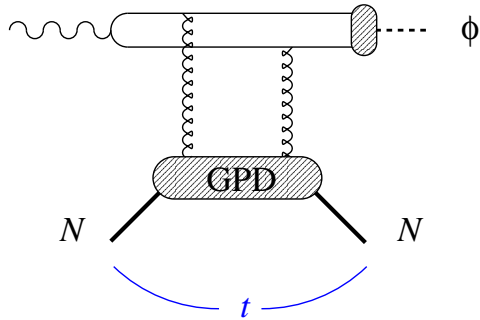
$$\langle \Lambda | \bar{s}u | p \rangle = -\frac{1}{\sqrt{6}} \langle p | 2\bar{u}u - \bar{d}d - \bar{s}s | p \rangle$$

→ Extract information on proton GPDs

- SU(3) for meson wavefunctions?

[from Diehl, Kugler, Schäfer, CW 05]

ϕ production: Gluon GPD

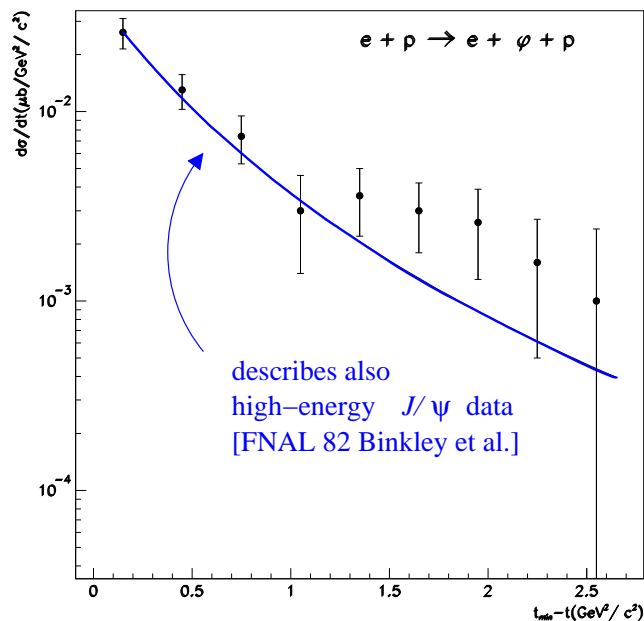


- Clean probe of gluon ($g \gg \bar{s}, s$) even at JLab energies

- Interesting observable: t -distribution, change with Q^2 and x

- Size of $\bar{s}s$ (higher twist)
- Transverse gluon imaging

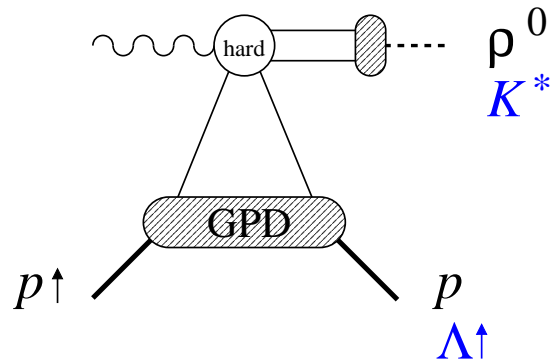
- L/T separation from $\phi \rightarrow K^+K^-$ decay + SCHC



[CLAS 01 Lukashin et al.;
see also Santoro et al. 08
Theory: Frankfurt, Strikman 02]

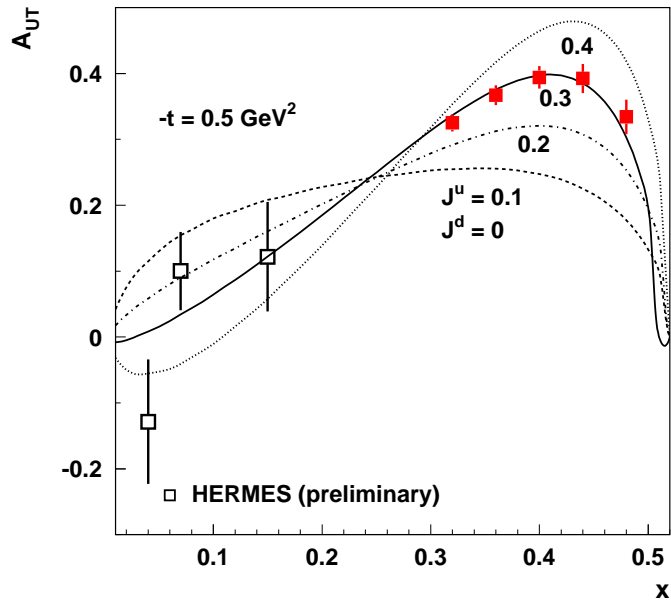
“Clean” GPD interpretation!

$K^{*+}\Lambda$ production: Recoil polarization



- Transverse target spin asymmetry in $\gamma_L^* p \rightarrow \rho^0 p$ probes hel-flip GPD E

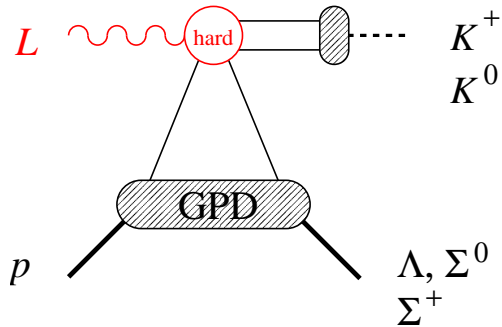
$$\frac{\sigma_{\uparrow} - \sigma_{\downarrow}}{\sigma_{\uparrow} + \sigma_{\downarrow}} \propto \frac{\text{Im}(\mathcal{H}\mathcal{E}^*)}{|\mathcal{H}|^2 + \text{corr.}}$$



[CLAS 12 GeV projected ρ^0
Model: Vanderhaeghen et al.]

- Alt: Transverse recoil polarization in $\gamma_L^* p \rightarrow K^* \Lambda$
 $SU(3)$ symmetry: $\langle \Lambda | \dots | p \rangle \rightarrow \langle p | \dots | p \rangle$
- L/T separation from $K^* \rightarrow K\pi$ decay + SCHC
- Also interesting: $K^{*+}\Lambda/\rho^+n$ ratio:
Finite-size effects cancel

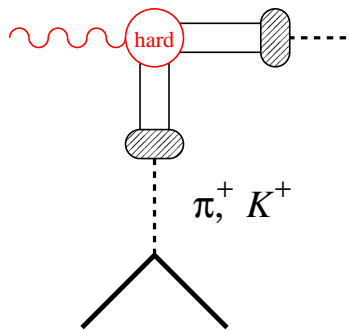
$K\Lambda, K\Sigma$ production: Strangeness polarization



- π, η, η', K probe “polarized” GPDs
 $\tilde{H} \leftrightarrow \Delta q, \tilde{E}$

π^+, K^+ : Pole term in \tilde{E} prominent
 (cf. π/K form factor measurements)

π^0, η, K^0 : Pole term zero/small,
 access to $\Delta d/\Delta u, \Delta s/\Delta u$
 through cross section ratios
[\[Eides, Frankfurt, Strikman 99\]](#)



- SU(3) in meson wave functions?
- L/T by Rosenbluth separation
- Also interesting: High- t meson production
 . . . Reaction mechanism?

Connections and extensions

- Exclusive Λ production is limiting case of **target fragmentation** in DIS
 - Fracture functions [Trentadue, Veneziano 94; DeFlorian, Sassot et al., . . .]
 - Correlations between current/target jets
 - . . . Unexplored field!

- Hard exclusive processes with **resonance excitation**
e.g. $\gamma_L^* p \rightarrow K^+ \Lambda^*(1405)$
 - Transition induced by well-defined QCD operator
 - New information about resonance structure

Summary

- Hard exclusive meson production can probe individual spin/flavor components of GPDs
- Absolute cross sections at $Q^2 \sim \text{few GeV}^2$ show significant finite-size effects
 - Well-understood at small x ;
phenomenolog. models w. finite k_T
 - JLab energies: Needs more work
- “Ratio observables” provide restricted information on GPDs; experimentally favorable