Strangeness in GPDs and exclusive processes

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Physics opportunities in exclusive electroproduction
of strange mesons/baryons at high $Q^2$

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

\[ \gamma^* p \rightarrow K^{*+} + \Lambda(S_T) \]  
Quark helicity–flip GPD $E$ from recoil polarization (cf. $A_{UT}$)

\[ \begin{align*}
\gamma^* p & \rightarrow K^+ + \Lambda \\
K^+ & + \Sigma^0
\end{align*} \]  
$\Delta s, \Delta \bar{s}$, hyperon resonances

[H. Avakian et al.: $\Lambda$ polarization in the target fragmentation region, Letter of Intent to PAC 32 (2007)]
Exclusive meson production: Theory status

- $Q^2 \sim$ few GeV$^2$: Substantial higher-twist corrections
  - Finite size of $\bar{q}q$ ($\rightarrow t$-slope)
  - Experience with pion FF

- Theory predictions for absolute cross sections at JLab still uncertain
  - Leading + higher twist?
  - Modeling of GPDs?
  - NLO corrections?

→ Use “ratio” observables

$$K^*/\rho^+, \ K/\pi, \ etc.$$ 
Spin asymmetries, $t$-slopes

QCD factorization theorem
[Collins, Frankfurt, Strikman 96; ...]
Exclusive meson production: GPD spin/flavor

\[
\begin{align*}
\rho^+ n &= 2[u - d] - [\bar{u} - \bar{d}] \\
\rho^0 p &= \frac{1}{\sqrt{2}}[2u + d] + \frac{1}{\sqrt{2}}[2\bar{u} + \bar{d}] + \text{gluon} \\
\omega p &= \frac{1}{\sqrt{2}}[2u - d] + \frac{1}{\sqrt{2}}[2\bar{u} - \bar{d}] + \text{gluon} \\
K^{*+} \Lambda &= -\frac{2}{\sqrt{6}}[2u - d - s] \\
&\quad + \frac{1}{\sqrt{6}}[2\bar{u} - \bar{d} - \bar{s}] \\
K^{*+} \Sigma^0 &= -\frac{2}{\sqrt{3}}[d - s] + \frac{2}{\sqrt{3}}[\bar{d} - \bar{s}] \\
K^{*0} \Sigma^+ &= [d - s] + [\bar{d} - \bar{s}] \\
\pi^+ n &= 2[\Delta u - \Delta d] + [\Delta \bar{u} - \Delta \bar{d}] \\
\pi^0 p &= \frac{1}{\sqrt{2}}[2\Delta u + \Delta d] - \frac{1}{\sqrt{2}}[2\Delta \bar{u} + \Delta \bar{d}] \\
K^+ \Lambda &= -\frac{2}{\sqrt{6}}[2\Delta u - \Delta d - \Delta s] \\
&\quad + \frac{1}{\sqrt{6}}[\Delta \bar{u} - \Delta \bar{d} - \Delta \bar{s}] \\
K^+ \Sigma^0 &= -\frac{2}{\sqrt{2}}[\Delta d - \Delta s] - \frac{1}{\sqrt{2}}[\Delta \bar{d} - \Delta \bar{s}] \\
K^0 \Sigma^+ &= [\Delta d - \Delta s] - [\Delta \bar{d} - \Delta \bar{s}]
\end{align*}
\]

- Meson selects spin
  \[1^- \quad \rho, K^* \quad \Lambda \leftrightarrow q, \quad E\] \[0^- \quad \pi, K \quad \tilde{\Lambda} \leftrightarrow \Delta q, \quad \tilde{E}\]

- 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 \(x\)
  
  \[\rightarrow \text{Size of } \bar{s}s \text{ (higher twist)}\]
  
  \[\rightarrow \text{Transverse gluon imaging}\]

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

- Benefits from RICH?
  HERA: No kaon ID; peak in \(M^2(\pi\pi)\)

[CLAS 01 Lukashin et al.;
Theory: Frankfurt, Strikman 02]

“Clean” GPD interpretation!
$K^*+\Lambda$ production: Recoil polarization

- $\Lambda$ recoil polarization asymmetry transverse to reaction axis sensitive to quark helicity-flip GPD
  \[ E(p \rightarrow \Lambda) = 2E_u - E_d - E_s \quad \text{w. SU(3)} \]
  cf. target polarization $A_{UT}$

- Combine with target polarization (incl. longitudinal)?

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

Complements/extends measurements with transversely polarized target

[CLAS 12 GeV projected $\rho^0$; Model: Vanderhaeghen et al.]
$K^{*+}\Lambda$ production: $K^{*+}/\rho^+$ ratio

- Quark exchange only, no gluons

- Prediction for $K^{*+}/\rho^+$ ratio [Kugler et al. 07]

- Expected to be more robust than absolute cross sections

  e.g. Renormalon model of higher twist in meson production [Belitsky 04].
$K\Lambda, K\Sigma$ production: Strangeness polarization

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

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

  $\pi^0, \eta, K^0$ : 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 $\Lambda$ 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

- “Diverse” physics in hard exclusive production of strange mesons/baryons

- Need to discuss need for/benefits from RICH channel by channel

- Theory: Work on absolute cross sections in GPD approach
  \( \phi \) channel seems to offer best chances — simplest