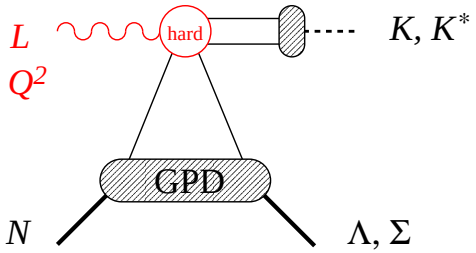
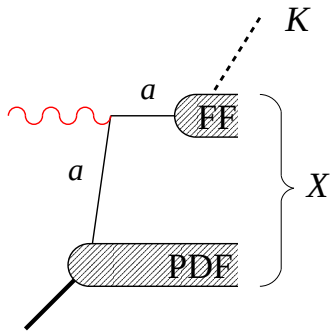
# Physics opportunities in kaon production

C. Weiss (JLab), CLAS12 RICH WG Meeting, 07–Aug–08




- Exclusive
  - Gluon GPD in $\phi N$ $(K^+K^-)$
  - $H \leftrightarrow E$ separation in $K^*\Lambda$ with recoil polarization [LOI PAC 32 (2007)]
  - Spin structure in $K\Lambda, K\Sigma$

  [Summary: Strikman, CW arXiv:0804.0456]




- Semi–inclusive
  - $\Delta s, \Delta\bar{s}$ from $K^+, K^-$
  - $K^-$ as pure "non-valence" probe
  - Sivers effect in $K$ production

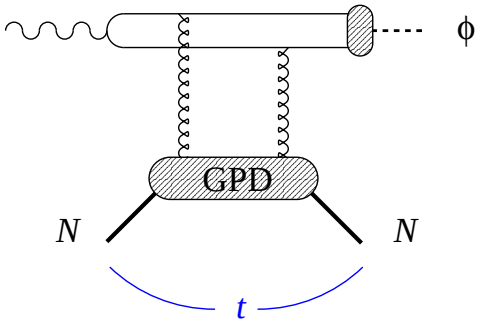
# Theory status: Exclusive, semi–inclusive

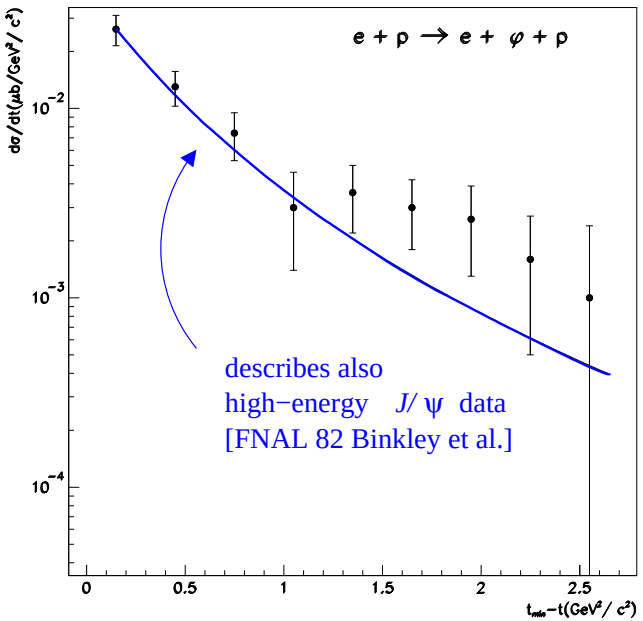
- Exclusive
  - QCD factorization theorem; clear operator structure of GPD $\rightarrow$ Lattice, models
  - Higher twist substantial $\rightarrow$ study/test reaction mechanism
  - GPD information from ratio observables (very channel–specific)

- Semi–inclusive, $p_T$ integrated
  - Simple QCD factorization PDF $\times$ FF . . . is it applicable at 6/12 GeV?
  - Formalism developed in NLO $\rightarrow$ global analysis

- Semi–inclusive, $p_T$ dependent
  - "True" QCD factorization likely complicated (soft factors);
    operator structure of TMDs?
  - Phenomenology based on naive factorization;
    primitive dynamical models
  - Correspondence with pQCD mechanism at $p_T \gg 1$ GeV$^2$ [$\rightarrow$ EIC]

# Exclusive $\phi$: Gluon GPD



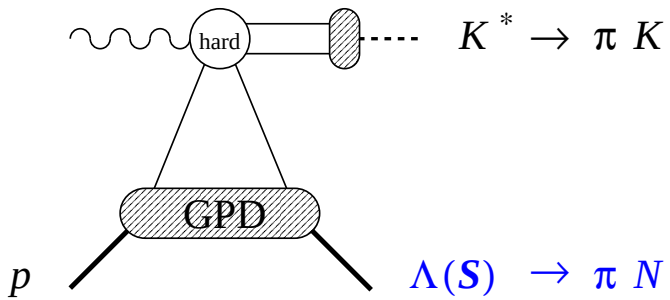

[CLAS 01 Lukashin et al.;
Theory: Frankfurt, Strikman 02]

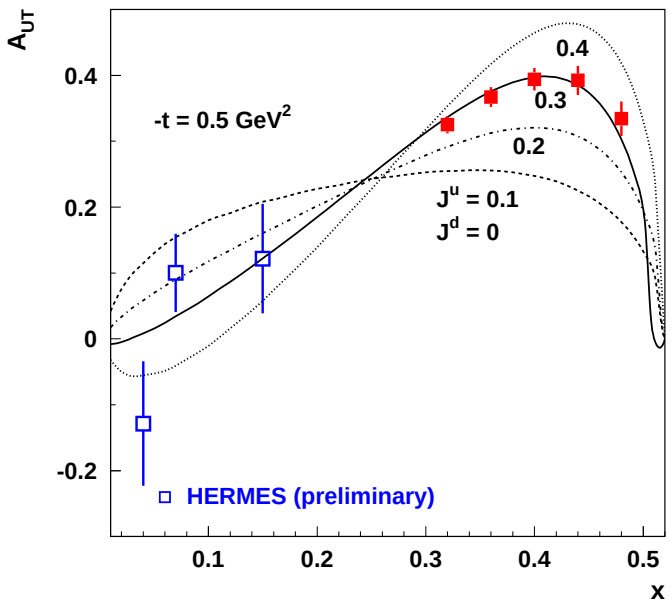
- Clean probe of gluon ($g \gg \bar{s}, s$) even at JLab energies
- Interesting observable: $t$–distribution, change with $Q^2$ and $x$

  $\rightarrow$ Size of $\bar{s}s$ (higher twist)
  $\rightarrow$ Transverse gluon imaging
- $L/T$ separation from $\phi \rightarrow K^+K^-$ decay + SCHC
- Benefits from RICH?
  HERA: No kaon ID; peak in $M^2(+-)$

"Clean" GPD interpretation!

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




[CLAS 12 GeV projected $\rho^0$; Model: Vanderhaeghen et al.]

- $\Lambda$ recoil polarization asymmetry transverse to reaction axis sensitive to quark helicity–flip GPD

  $E(p \to \Lambda) = 2E_u - E_d - E_s$ w. SU(3)

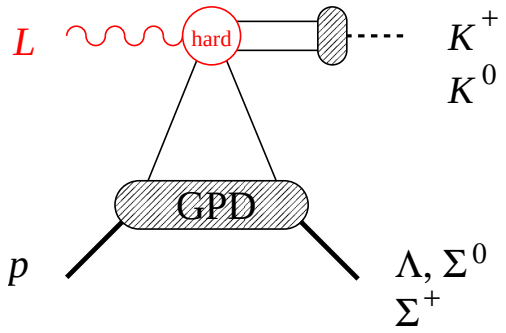
  cf. target polarization $A_{UT}$

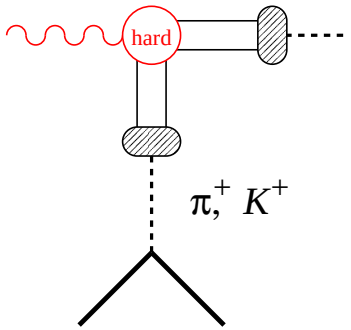
- Combine with target polarization (incl. longitudinal)?

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

Complements/extends measurements with transversely polarized target

# Exclusive $K\Lambda, K\Sigma$: Strangeness polarization




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

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

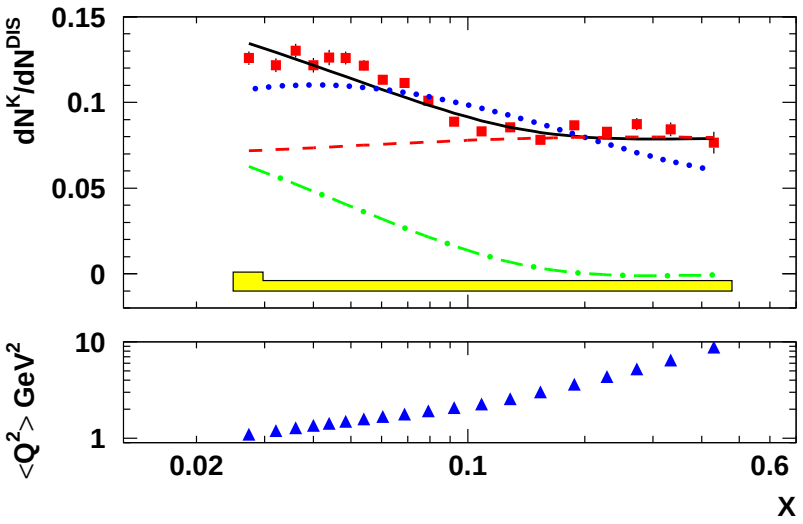
  $\pi^0, \eta, K^0$ : Pole term zero/small,
  access to $\Delta d/\Delta u, \ \Delta s/\Delta u$
  through cross section ratios
  [Eides, Frankfurt, Strikman 99]

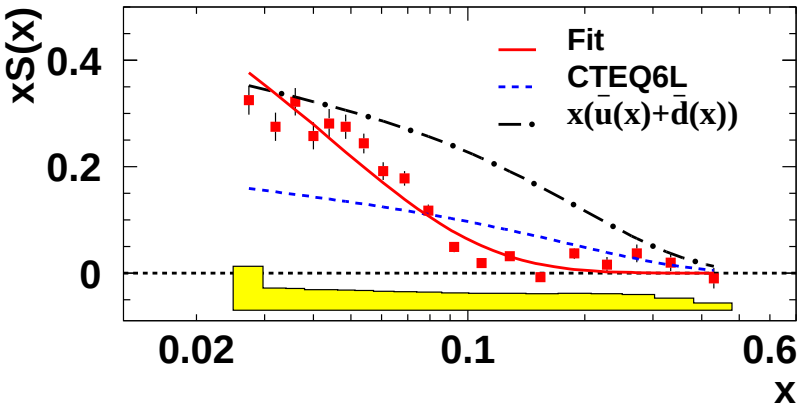
- SU(3) in meson wave functions?

- $L/T$ by Rosenbluth separation

- Also interesting: High–$t$ meson production
  . . . Reaction mechanism?

# Semi-inclusive: $s, \bar{s}$ from $K^+, K^-$




- Semi–inlcusive $K^+, K^-$ major source of information on $s(x), \bar{s}(x)$ + polarization
- HERMES: $s + \bar{s} \ll \bar{u} + \bar{d}$ at $x > 0.1$

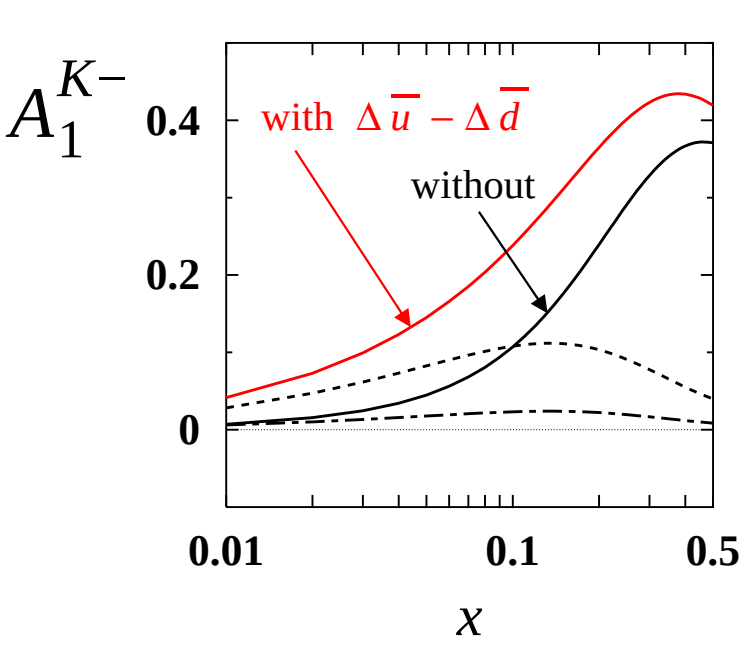
  $\rightarrow$ non-perurbative origin of sea cf. asymmetry $\bar{d} - \bar{u}$

  $\rightarrow$ nucleon structure

  [Airapetian et al. 0803.2993]

- $\Delta s, \Delta \bar{s}$ small . . . can we measure significant non-zero polarization?

# Semi–inclusive: $K^-$ as pure "non-valence" probe




[Dressler, Goeke, Polyakov, CW, EPJC14:147 (2000)]

- $K^- = \bar{u}s$ . . . no valence flavors!

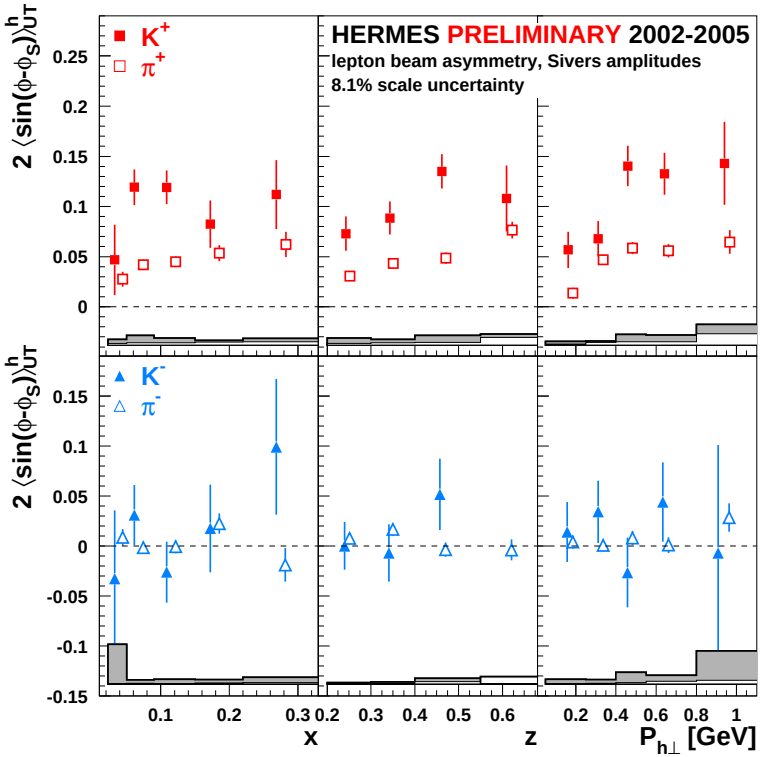
  $\rightarrow$ "Pure" probe of sea

  $\rightarrow$ Avoid $u$–quark dominance

- $A_1^{K-}$ most sensitive to $\Delta\bar{u} - \Delta\bar{d}$ in SIDIS (compared to $\pi^+, \pi^-, K^+$)

Estimate based on outdated PDFs and FFs. . . should be repeated with current parametrizations . . . no time!

# Semi–inclusive: Sivers effect in $K^+, K^-$




[HERMES: M. Diefenthaler, 0706.2242]

- HERMES: Sizable Sivers asymmetry observed in $K^+$

  $\rightarrow$ Reaction mechanism . . . does factorization work?

  $\rightarrow$ If yes: Large Sivers function for sea quarks . . . very interesting for nucleon structure

  $\rightarrow$ How about $K^-$ ?

# Connections, extensions

- Exlcusive $\Lambda$ production is limiting case of target fragmentation in DIS

  $\rightarrow$ Fracture functions [Trentadue, Veneziano 94; DeFlorian, Sassot et al., . . . ]

  $\rightarrow$ Correlations between current/target jets

  . . . Unexplored field!

- Hard exclusive processes with resonance excitation
  e.g. $\gamma_L^* p \rightarrow K^+ \Lambda^*(1405)$

  $\rightarrow$ Transition induced by well–defined QCD operator

  $\rightarrow$ New information about resonance structure

# Summary

- Exclusive: Need to discuss need for/benefits from RICH channel by channel . . . no "summary" statement

- Semi–inclusive: Clear benefits;
  should be relatively easy to quantify

# Exclusive meson production: GPD spin/flavor

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

[from Diehl, Kugler, Schäfer, CW 05]

- Meson selects spin

  $1^-$ $\quad \rho, K^* \quad H \leftrightarrow q, \quad E$

  $0^-$ $\quad \pi, K \quad \tilde{H} \leftrightarrow \Delta q, \quad \tilde{E}$

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

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

  $\to$ Extract information on proton GPDs

- SU(3) for meson wavefunctions?