Semi-inclusive production of pions and kaons: Exclusive channels vs. quark fragmentation

M. Diehl, W. Kugler (DESY), A. Schäfer (Regensburg), Ch. Weiss (JLab)

SIR 2005, May 18 – 20, 2005

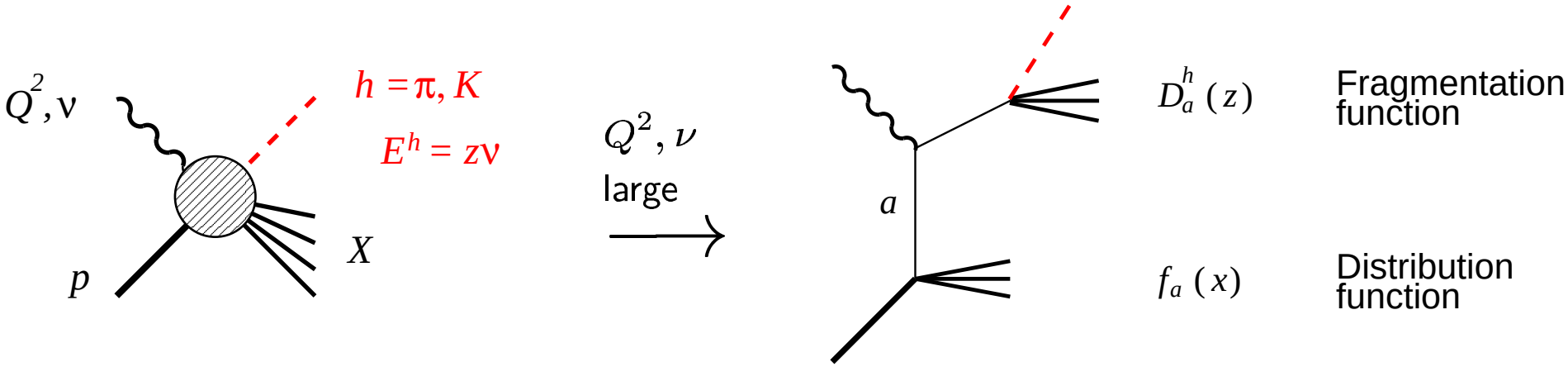
- Role of exclusive channels in semi-inclusive $\pi^{\pm 0}$, $K^{\pm 0}$ production?

$$\begin{array}{lllll} \gamma^* p & \to & \pi^+ n & \rho^0 p, \ \ \rho^+ n & \text{etc.} \\ & & K^+ \Lambda(\Sigma) & \phi p, \ \ K^{*+} n & \end{array}$$

- Systematics/uncertainties of leading–twist LO approximation for hard exclusive meson production

  Quark vs. gluon GPD's, strange vs. non-strange, . . .

- Semi-inclusive electroproduction $\gamma^* p \to \pi + X, \;\; K + X$



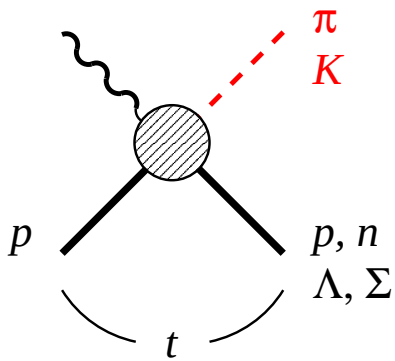
$$\frac{d\sigma^h}{dz} \propto \sum_a e_a^2 \, f_a(x) \, D_a^h(z)$$

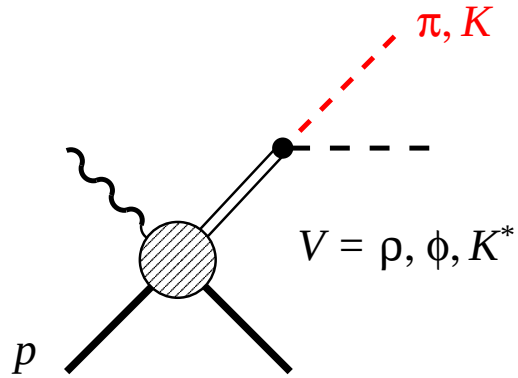
Energy distribution

  - Used to separate quark distributions in flavors, valence/sea (including spin) [HERMES, JLab]

[Frankfurt et al. 89]

- Exclusive channels in $\gamma^* p \to \pi + X, \;\; K + X$



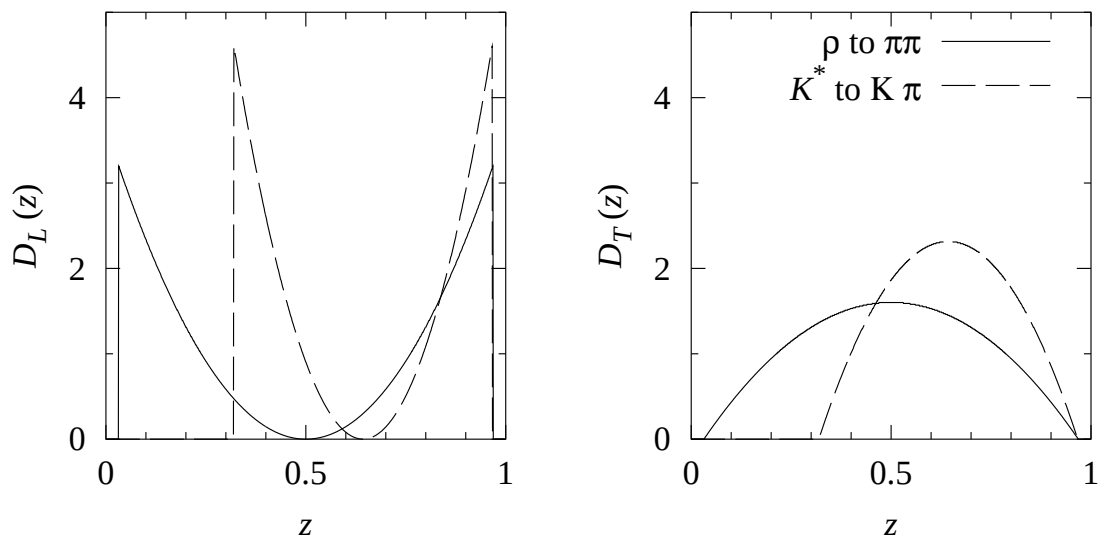


Intermediate vector meson

$$\frac{d\sigma^\pi}{dz} = \sigma^\pi \, \delta(1-z)$$

$$\frac{d\sigma^\pi}{dz} = \sigma^\rho_{L,T} \, D^{\rho\to\pi\pi}_{L,T}(z)$$

s–channel helicity conservation

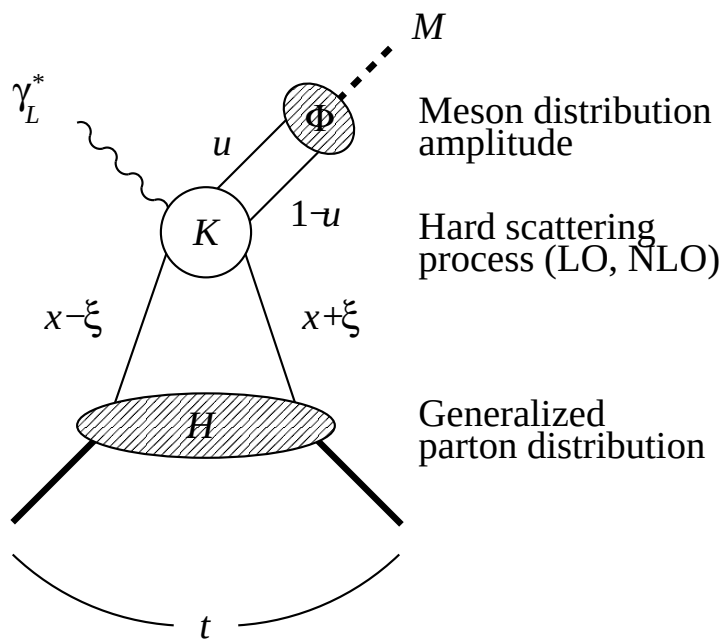


- Needed: Exclusive production cross sections

π^+, K^+	Data [JLab, HERMES]
ρ^0, ϕ	Data (L/T separation via SCHC, tested experimentally) [CLAS at JLab, HERMES]
ρ^+, K^{*+}, K^{*0}	Estimate using QCD factorization theorem for hard exclusive processes ("GPD formalism")

- Why interesting?
  - Limited photon energy $\rightarrow$ restricted phase space for fragmentation [HERMES, JLab]
  - Limit $z \rightarrow 1$ [Szczurek, Uleshchenko, Speth 00]
  - "Duality" in semi-inclusive DIS?

- QCD factorization for hard exclusive meson production
  [Brodsky et al. 94; Collins, Frankfurt, Strikman 96; Radyushkin 96]



$$\begin{aligned} \text{Amp} &= \int du\, \Phi^M(u) \\ &\times \int dx\, K(x,u,\xi;Q^2) \\ &\times H(x,\xi;t) \end{aligned}$$

- General consequences of factorization
  - $\sigma_L \propto Q^{-6}$
  - Universality (process–independence) of GPD's

- Phenomenological issues
  - GPD models: PDF parametrizations (gluons, strangeness)
    "Meson exchange" contributions
    $x \leftrightarrow t$ dependence

    [Reviews: Goeke, Polyakov, Vanderhaeghen 00; Diehl 03; Belitsky, Radyushkin 05]

  - Power (higher–twist) corrections due to
    finite transverse size of produced meson

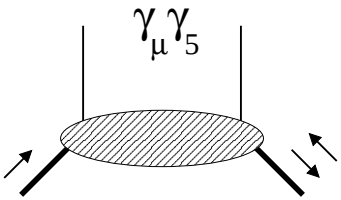
    [Small x: Frankfurt, Strikman, Koepf 95; Vanderhaeghen, Guichon 99]

  - Choice of effective QCD scale in LO

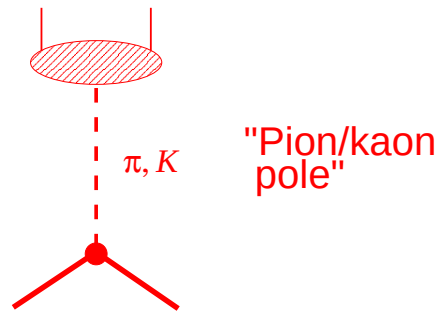
- Here: "Pure" leading–twist calculation, LO
  . . . Aim to understand systematics/uncertainties!

  [Diehl, Kugler, Schäfer, CW; in preparation]

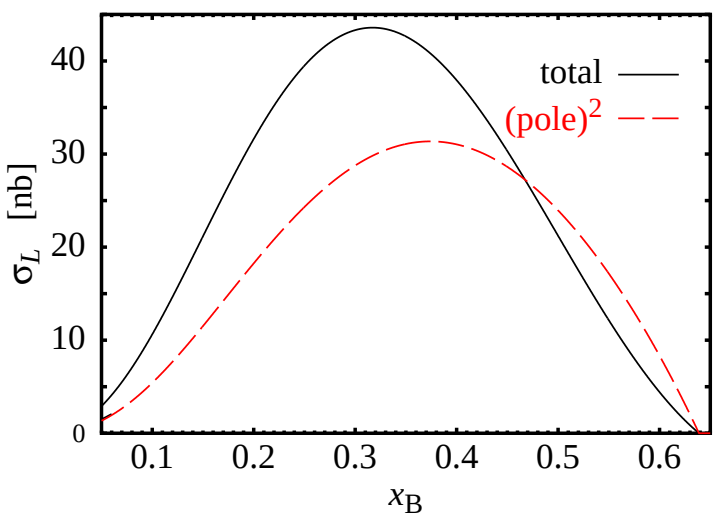
- Pseudoscalar meson production: “Pion pole” in GPD [Frankfurt et al. 99]



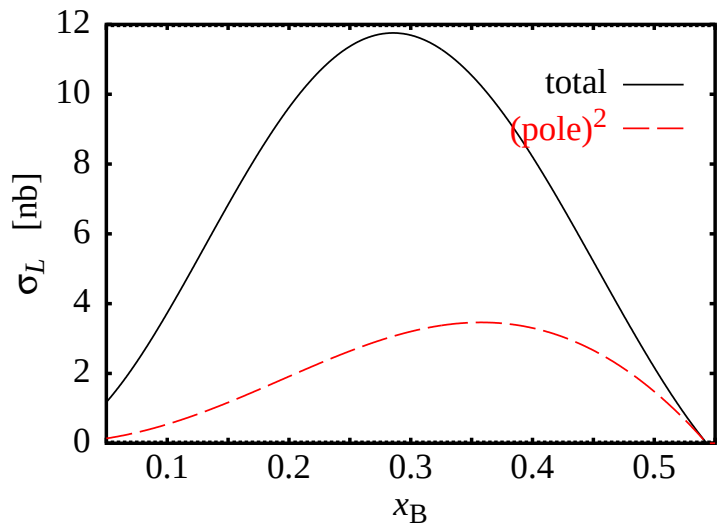
$\widetilde{H}$ axial
$\widetilde{E}$ pseudoscalar $\longleftarrow$



π^+: Pole contribution dominant

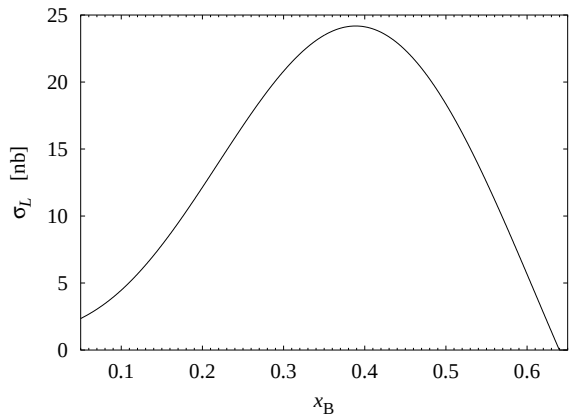


K^+: Moderate

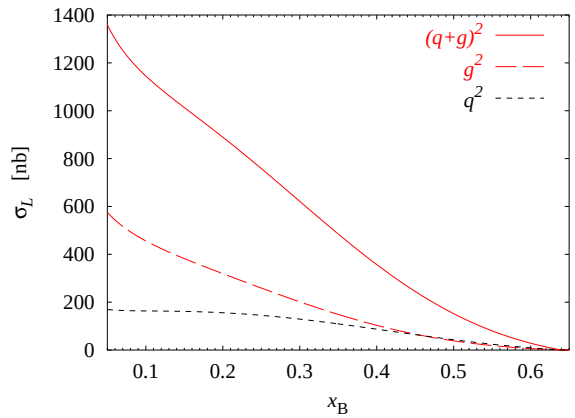


- Vector meson production: Quark vs. gluon GPD's

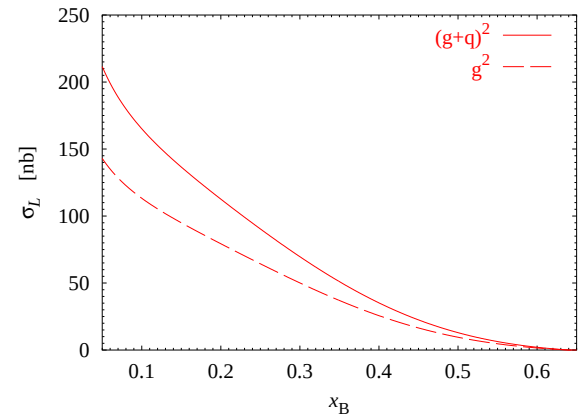
ρ^+: quarks only



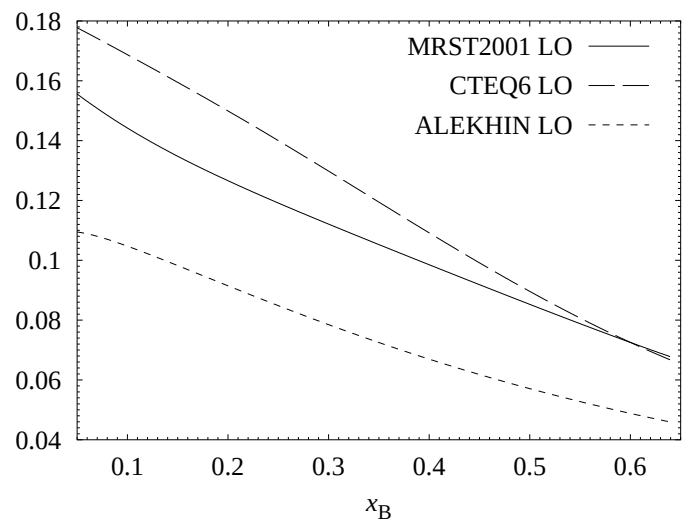
ρ^0: quarks and gluons



ϕ: gluon dominated

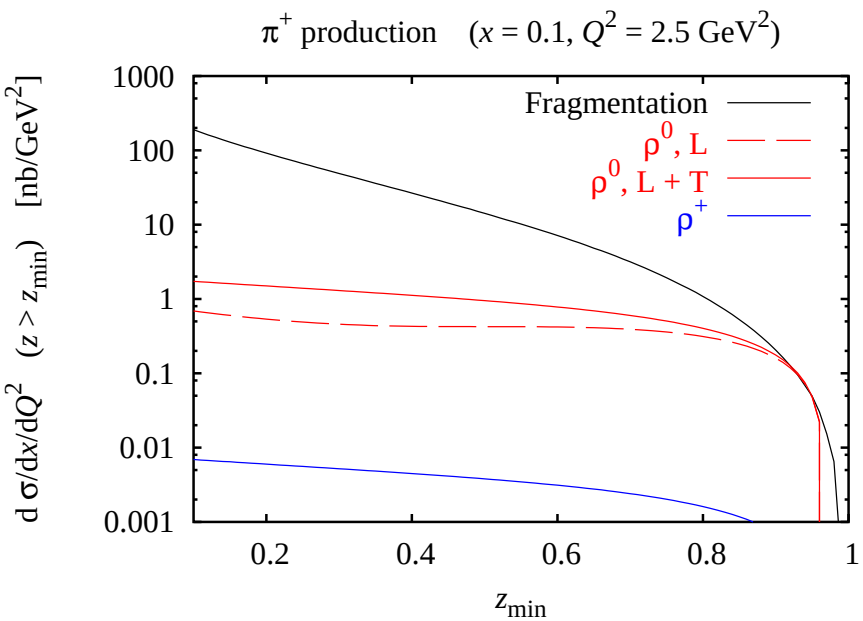


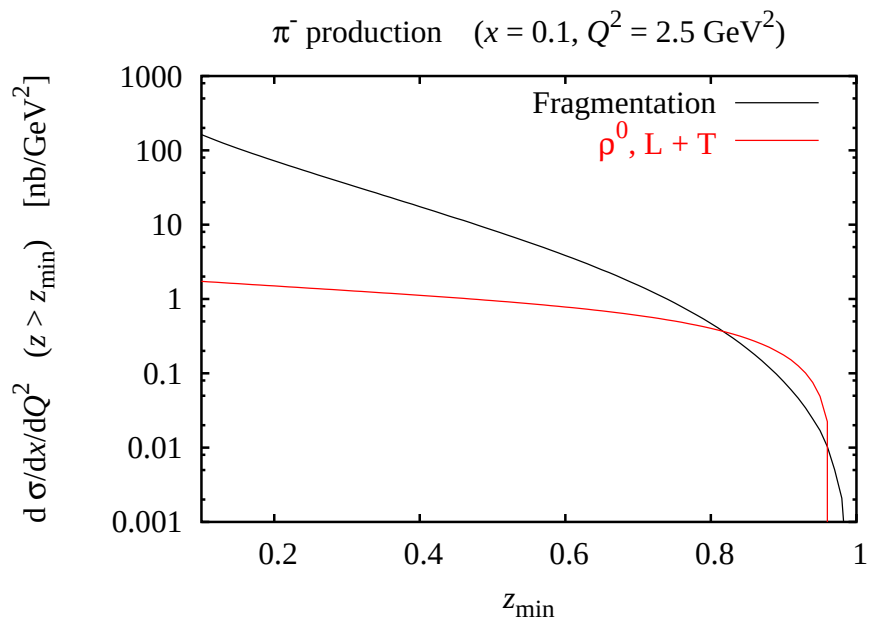
ϕ/ρ ratio



$\rightarrow$ Considerable uncertainty in leading–twist prediction due to uncertainty of gluon distribution

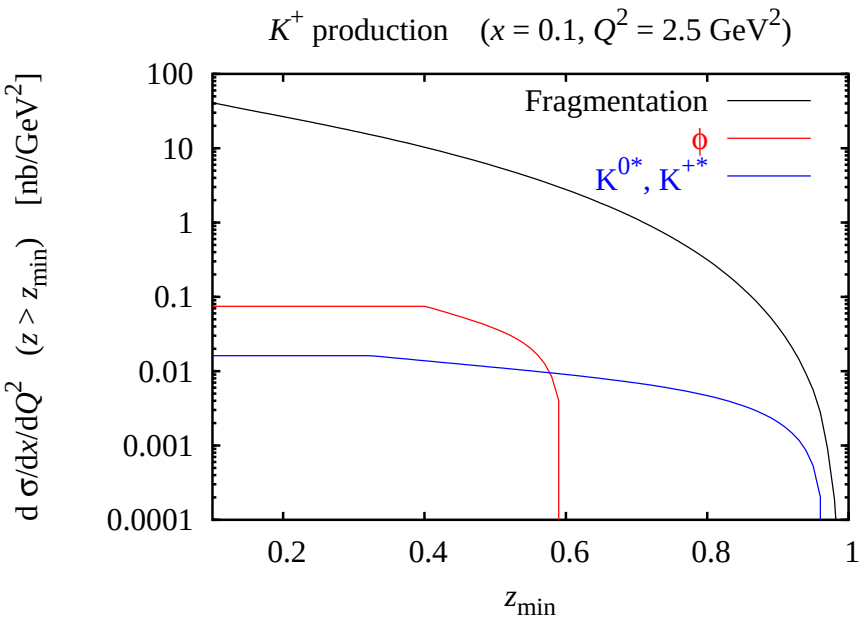
- Exclusive channels vs. quark fragmentation in $\pi^{\pm}$ production
  [Diehl, Kugler, CW, Schäfer, in progress]

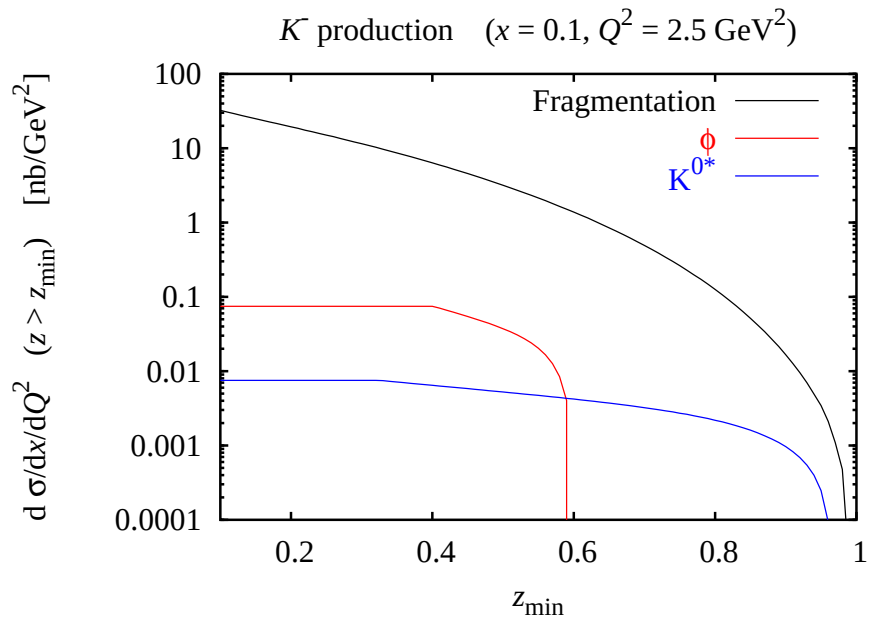




  - Dominant role of ρ^0 ("vector dominance")
  - ρ^+ negligible
  - Signs of "duality" at large z

- $K^{\pm}$ production





  - ϕ restricted to $z < 0.6$ by kinematics
  - K^* negligible
  - Duality? . . . Nothing comparable to ρ^0

- Summary and Outlook

  - Considerable uncertainty in leading–twist calculations of exclusive meson production amplitudes at fixed–target energies [JLab, HERMES]

    . . . Requires more comprehensive approach:

finite–size effects (higher twist)	$\longleftrightarrow$	effective scale	$\longleftrightarrow$	GPD models (quark and gluon)

  - Strangeness production challenges our understanding of duality in semi-inclusive DIS
    . . . no vector dominance contribution (ρ^0)