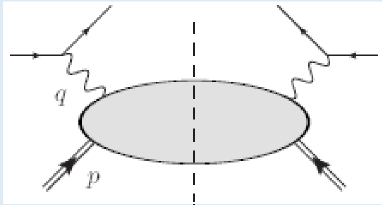
DISCUSSION

1. MOMENTUM IMAGING: AMBIGUITY IN TMC AND HT FOR SIDIS?

2. SPATIAL IMAGING: DEEP EXCLUSIVE PSEUDOSCALAR CHARGED-PION PRODUCTION – TOWARDS FLAVOR DECOMPOSITION

Rolf Ent
Jefferson Lab

DIS

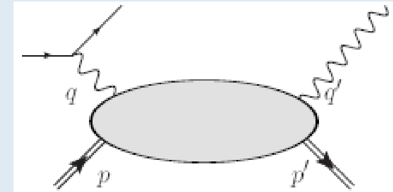


Define (p, q) as longitudinal plane:

$$p = (p_0, \vec{0}_\perp, p_z)$$
$$q = (q_0, \vec{0}_\perp, q_z)$$

$\Rightarrow$ parton fraction = Bjorken x

DVCS



Many choices possible:

$$p = (p_0, \vec{0}_\perp, p_z), \quad q = (q_0, \vec{0}_\perp, q_z)$$

or

$$p + p' = (P_0, \vec{0}_\perp, P_z), \quad q = (q_0, \vec{0}_\perp, q_z)$$

etc.

$\Rightarrow$ parton fraction $2\xi = x_B[1 + \mathcal{O}\left(\frac{t}{Q^2}\right)]$, redefinition of helicity amplitudes

- **Ambiguity is resolved by adding "kinematic" power corrections t/Q^2, m^2/Q^2**

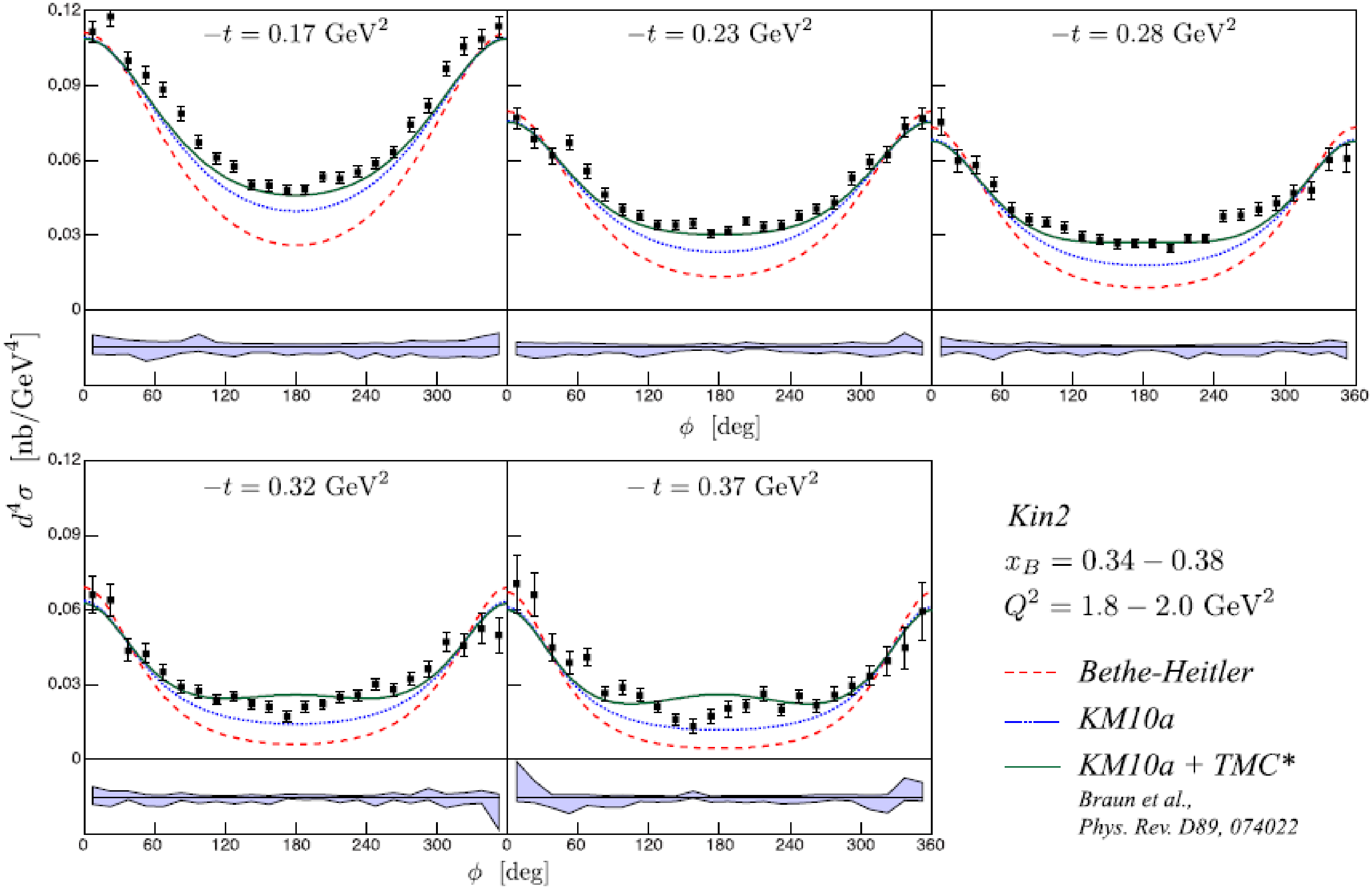
- **noncomplanarity makes separation of collinear directions ambiguous**

  — hence "leading twist approximation" ambiguous

  — related to violation of translation invariance and EM Ward identities

- **have to be repaired by adding power corrections of special type, "kinematic" PC**

DVCS cross sections: higher twist corrections



- KM10a: global fit to HERA x-sec & HERMES + CLAS spin asymmetries
  Kumericki and Mueller (2010)
- Target-mass corrections (TMC): $\sim \mathcal{O}(M^2/Q^2)$ and $\sim \mathcal{O}(t/Q^2)$
  Braun, Manashov, Mueller and Pirnay (2014)

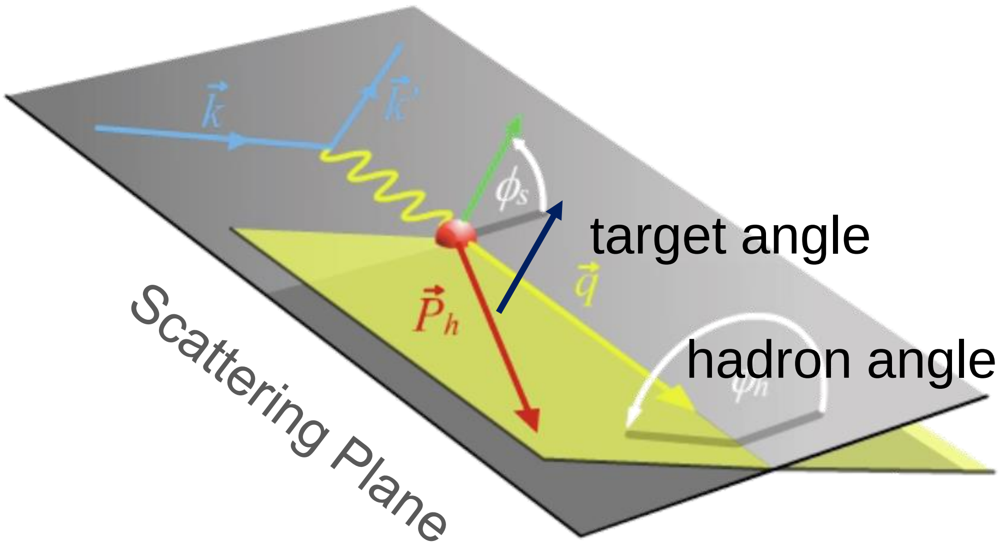
- At finite Q^2 and non-zero t, there is an ambiguity:
  1. Belitsky et al. ("BKM", 2002–2010): light-cone axis in plane (q,P)
  2. Braun et al. ("BMP", 2014): light-cone axis in plane (q,q')
     easi*er* to account for kin. corrections $\sim \mathcal{O}(M^2/Q^2)$, $\sim \mathcal{O}(t/Q^2)$

$$\left.\begin{aligned} \mathcal{F}_{++} &= \mathbb{F}_{++} + \frac{\chi}{2}\left[\mathbb{F}_{++} + \mathbb{F}_{-+}\right] - \chi_0 \mathbb{F}_{0+} \\ \mathcal{F}_{-+} &= \mathbb{F}_{-+} + \frac{\chi}{2}\left[\mathbb{F}_{++} + \mathbb{F}_{-+}\right] - \chi_0 \mathbb{F}_{0+} \\ \mathcal{F}_{0+} &= -(1+\chi)\mathbb{F}_{0+} + \chi_0\left[\mathbb{F}_{++} + \mathbb{F}_{-+}\right] \end{aligned}\right\} \xrightarrow[\mathbb{F}_{0+}=0]{\mathbb{F}_{-+}=0} \left\{\begin{aligned} \mathcal{F}_{++} &= (1+\frac{\chi}{2})\mathbb{F}_{++} \\ \mathcal{F}_{-+} &= \frac{\chi}{2}\mathbb{F}_{++} \\ \mathcal{F}_{0+} &= \chi_0 \mathbb{F}_{++} \end{aligned}\right.$$

(eg. $\chi_0 = 0.25$, $\chi = 0.06$ for $Q^2 = 2$ GeV^2, $x_B = 0.36$, $t = -0.24$ GeV^2)

So, even if one has a function without "HT" in one frame, it will have it in the other…

Discussion 1: it would seem we have the same ambiguity issues in SIDIS



- noncomplanarity makes separation of collinear directions ambiguous

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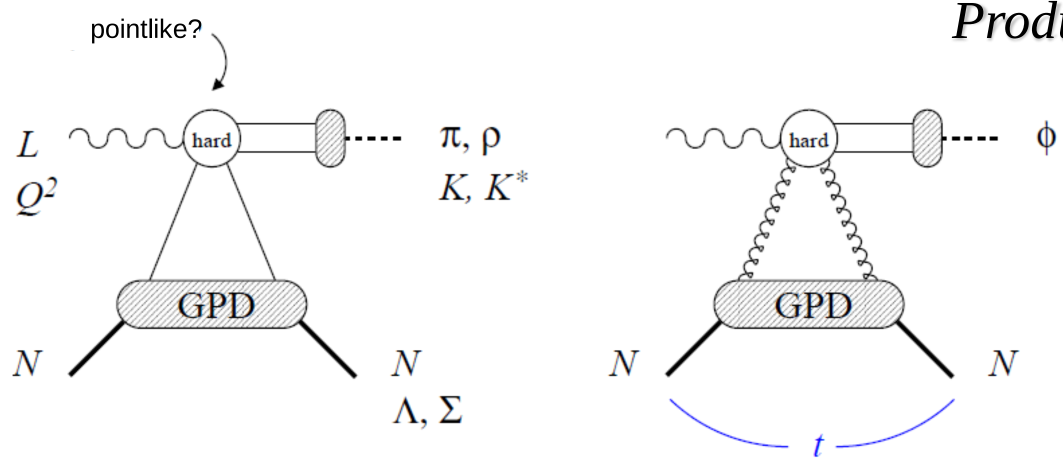
GPDs: Towards Spin/Flavor Separation

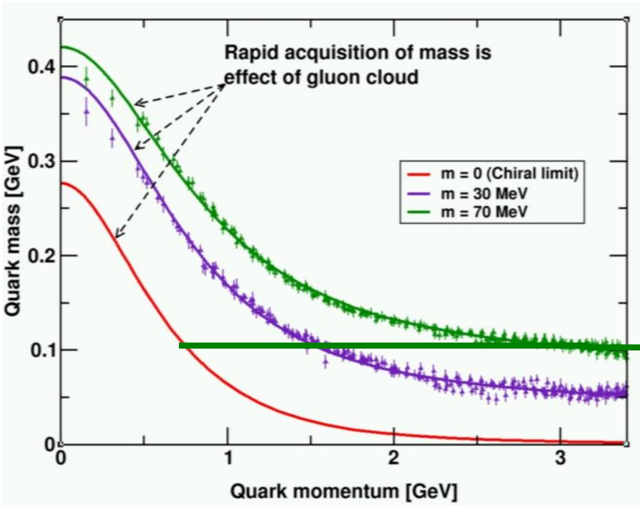
Exclusive Reactions: $\gamma^* N \rightarrow M + B$

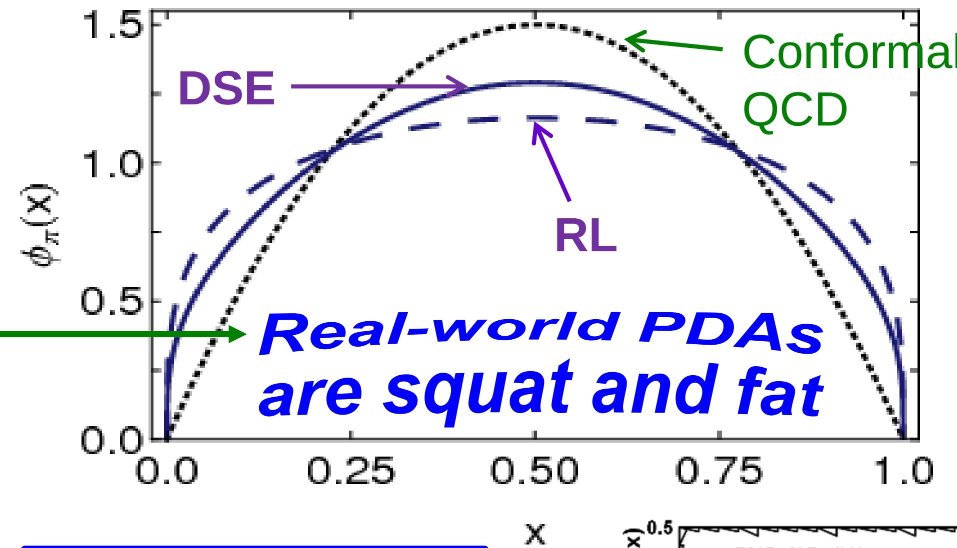
Deep Virtual Meson Production (DVMP)

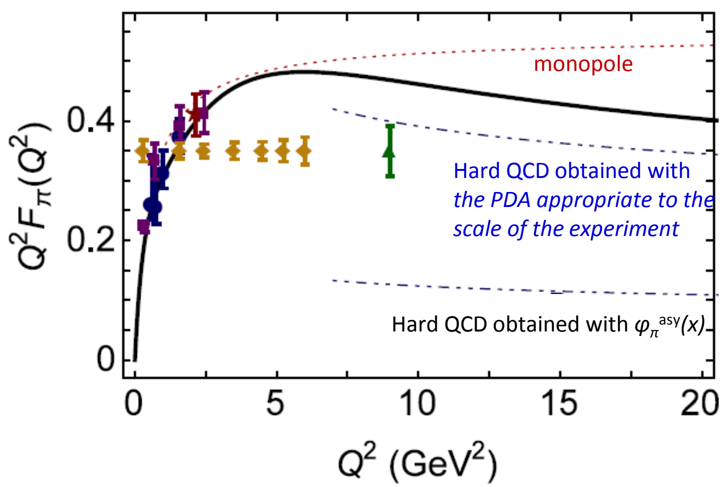


- ❑ Nucleon structure described by 4 (helicity non-flip) GPDs:
  - –*H, E* (unpolarized), $\tilde{H}$ $\tilde{E}$ (polarized)
- ❑ Quantum numbers in DVMP probe individual GPD components selectively
  - –Vector : $\rho^o/\rho+/K^*$ select *H, E*
  - –Pseudoscalar: π,η,*K* select the polarized GPDs, $\tilde{H}$ and $\tilde{E}$
- ❑ Need good understanding of reaction mechanism
  - –QCD factorisation for mesons
  - –Can be verified experimentally through L/T separated cross sections

Pion Form Factor and Structure Function





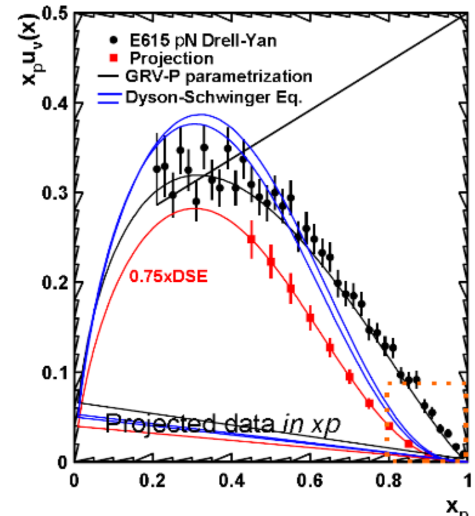


Pion FF – first quantitative access to hard scattering scaling regime?

Implications if so: two longstanding puzzles could be solved

1. Magnitude of pion form factor in hard scaling regime
2. Power of pion parton behavior at large x

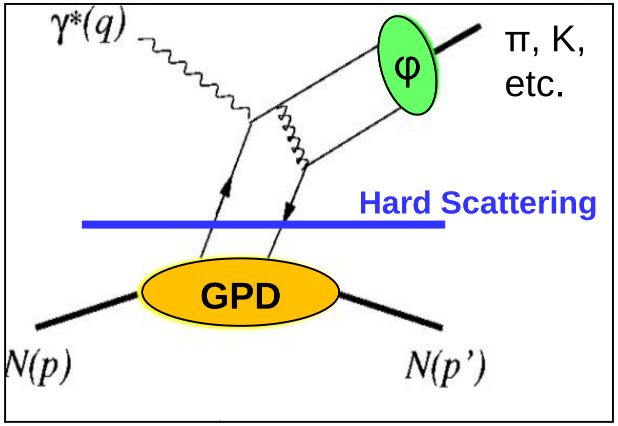
Also implications for nucleon and N form factor interpretation (not shown here).*



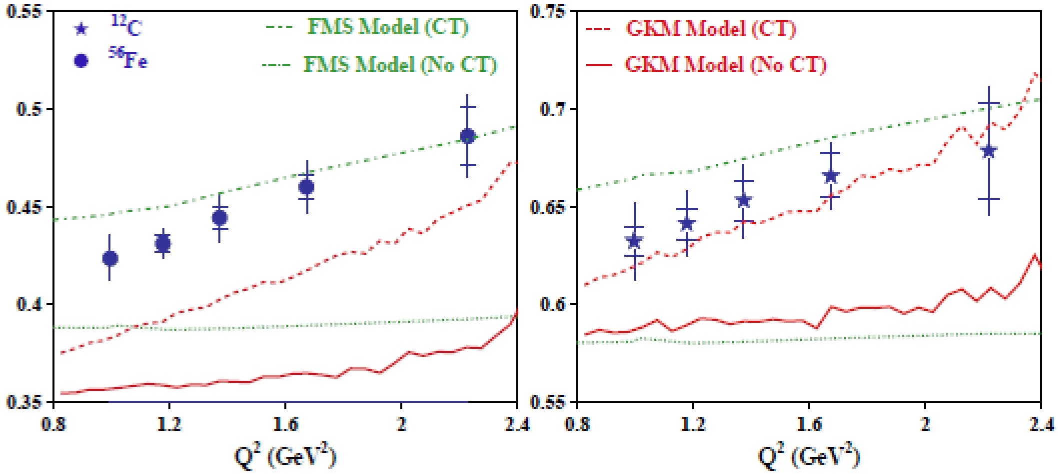
Pion SF – $(1-x)^{-1}$ or $(1-x)^{-2}$ dependence at large x?

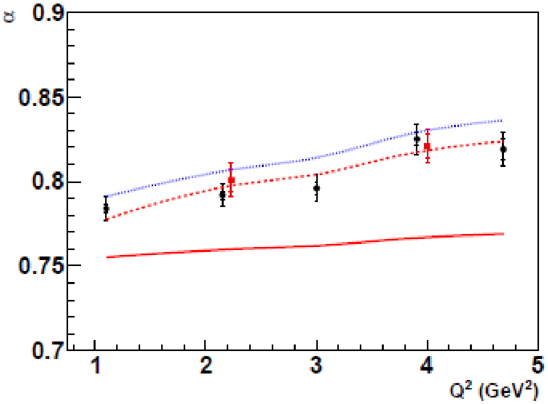
Factorization and Color Transparency

Color Transparency refers to the *vanishing* of the strong hadron-nucleus interactions for sufficiently fast hadrons. The energy scale where *the nuclear medium becomes more transparent* due to this phenomenon has now been conclusively determined.



Same factorization theorem leading to $\sigma_L \sim Q^{-6}$ leads to CT





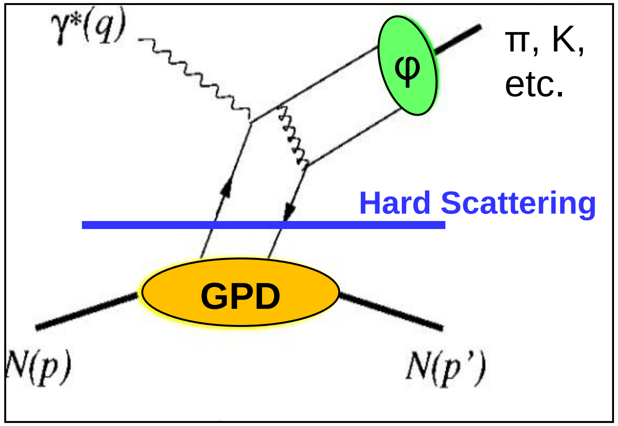
- CLAS E02-110 directly produced ρ-mesons from highly-energetic photons, and observed the nuclear medium to become more transparent at higher space-time resolution (Q^2) of the photon.

  (L. El Fassi et al., PLB 712 (2012) 326,
  (D. Dutta, K. Hafidi, M. Strikman, Prog. Part. Nucl. Phys. 69 (2013) 1)

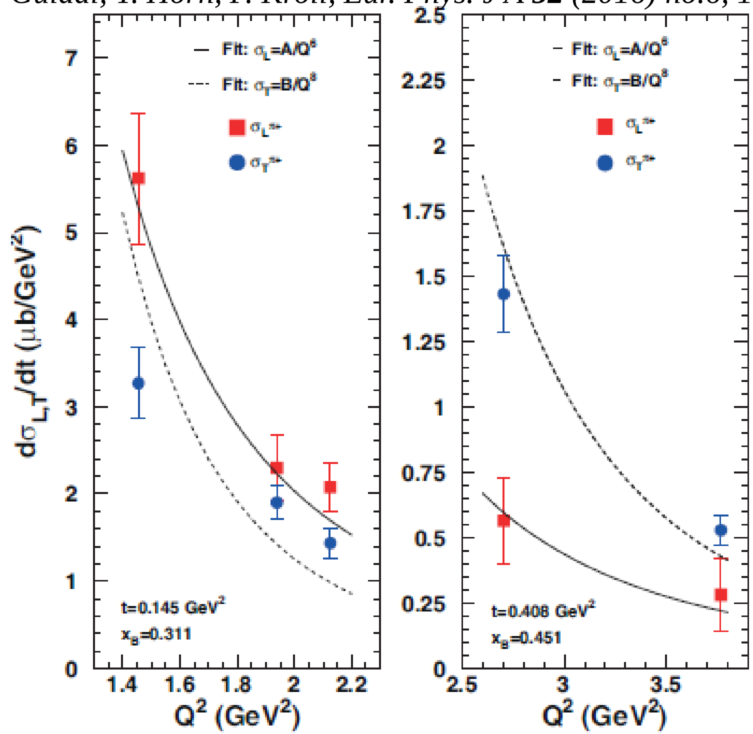
- The energy scale found is consistent and confirms the findings of a companion Hall C E01-107 experiment, that produced π-mesons rather than ρ-mesons.

  (X. Qian et al., PRC81:055209 (2010),
  B. Clasie et al, PRL99:242502 (2007))

Factorization Tests in π^+ and K^+ Electroproduction



(L. Favart, M. Guidal, T. Horn, P. Kroll, Eur. Phys. J A **52** (2016) no.6, 158)



One of the most stringent tests of factorization is the Q^2 dependence of the π and K electroproduction cross section

– σ_L scales to leading order as Q^{-6}

– σ_T scales as Q-8 so $\sigma_L >> \sigma_T$

The leading-twist, lowest order calculation of the π^+ longitudinal cross section underpredicts the data by an order of magnitude. This implies that the data are not in the region where the leading-twist result applies. That current experimental data are not in the region where the leading-twist result applies can be seen in Fig. 15 showing the Q^2 and t dependence of the separated longitudinal and transverse π^+ cross sections. The QCD scaling prediction is fitted to, and indicated by, the solid black lines and is reasonably consistent with these data. It is clear σ_T does not follow the scaling expectation illustrated by the dashed black lines and the magnitude is large. Regarding the $-t$ dependence, Fig. 15 shows that $\sigma_L > \sigma_T$ for values of $-t < 0.3$ consistent with a dominant meson pole in this region and that $d\sigma_T > d\sigma_L$ for values of $-t > 0.3$ GeV^2 providing further evidence that the leading-twist does not apply in the currently available experimental kinematics.

So where are we:

1. The Pion Form Factor is argued that it could become the first quantitative access to the hard scattering scaling regime. The "old" quantitative ~10 discrepancy between the magnitude of the data and the asymptotic form factor calculations gest resolved by the "squat and fat" real-world PDAs.
2. We seem to see hints of Color Transparency for deep exclusive charged-pion and neutral-rho measurements at moderate Q^2, a telltale signal of onset of the factorization regime.
3. The separated longitudinal cross section deep exclusive charged-pion electroproduction data arguably are consistent with $\sigma_L \sim Q^{-6}$
4. BUT: it is clear that $\sigma_L >> \sigma_T$ is not valid yet, and it is clear that the leading-twist, leading-order calculations of the π^+ longitudinal cross section still underpredicts the data by an order of magnitude, and this is not likely to disappear at $Q^2 \sim 10$ GeV^2.

So, what gives? Should we just assume that some of the factorization requirements may not be as strict and we can still can get a satisfactory GPD-based description, leading to potential for flavor separation @ EIC?