Update on SIDIS-TMD Experiment E12-09-017

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On behalf of **P. Bosted** (William & Mary)

- Brief review of motivation
- Results of Parameter Fit
- To-Do List

E12-09-017:
Precision $(e,e'\pi^{\pm})$,$(e,e'K^{\pm})$ cross sections at low $P_{h\perp}$

- Precision measurements to test the assumptions in factorization of SIDIS
- Explore assumptions of favored/disfavored fragmentation of different flavor quarks
- Look for target mass effects
- Higher twist effects
- Complementary to Hall B SIDIS measurements

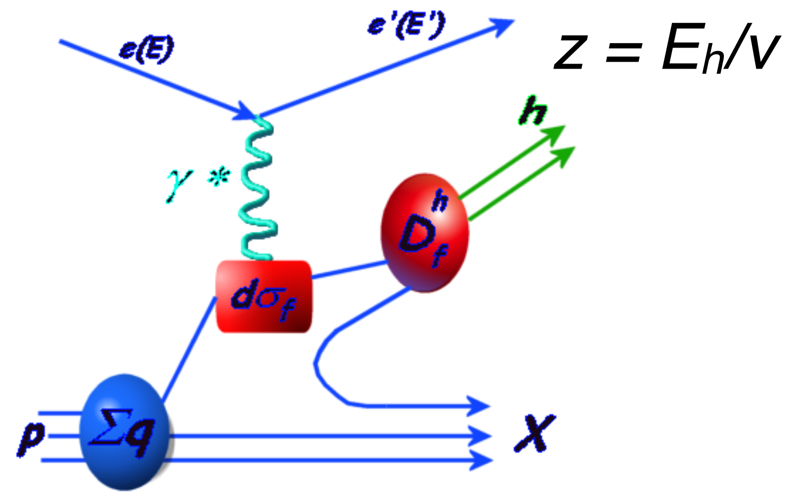
Do parton distributions and fragmentation functions factorize at Jefferson Lab energies?

Flavor Decomposition of SIDIS

$$\frac{1}{\sigma_{(e,e')}}\frac{d\sigma}{dz}(ep \rightarrow hX) = \frac{\sum_q e_q^2 f_q(x) D_q^h(z)}{\sum_q e_q^2(x) f_q(x)}$$

$f_q(x)$: parton distribution function

$D_q^h(z)$: fragmentation function



$M_x^2 = W'^2 \sim M^2 + Q^2 (1/x - 1)(1 - z)$

- Leading-Order (LO) QCD
- after integration over $p_{h\perp}$ and Φ_h
- NLO: gluon radiation mixes x and z dependences
- Target-Mass corrections at large z
- ln(1-z) corrections at large z

With p_T and k_T dependences, some kind of convolution is necessary to obtain final $P_{h\perp}$

Kinematic Plan at 11 GeV

- W^2 = 5.08 GeV^2 and larger (up to 11.38 GeV^2)
- Used SHMS angle down to 6.6 degrees (for π detection)
  HMS angle down to 13.5 degrees (e^- detection)
  separation HMS-SHMS > 17.5 degrees
- $M_X^2 = M_p^2 + Q^2(1/x - 1)(1 - z) > 2.9$ GeV^2 (up to 7.8 GeV^2)
- Improved coverage in all kinematic variables, especially ϕ and p_T
- Choice to keep Q^2/x fixed q_γ ~ constant (exception are data scanning Q^2 at fixed x)
- All kinematics both for π^+ (and K^+) and π^- (and K^-), both for LH2 and LD2 (and Aluminum dummy)

Status of Pion SIDIS

- Table with 21,000 cross section and multiplicity results for pion SIDIS pretty much finalized.
- The table includes both the subtractive and multiplicative radiative corrections used.
- The table includes one estimate of diffractive rho(DVM) contributions, which can be applied to the results by the user if desired.
- The results ideally will be incorporated into large global analyses by groups such as JAM, updated with new results from CLAS12, COMPASS, R_SIDIS as they become available.
- Meanwhile, have begun interpretation using our data only.

Interpretation Model -1-

- Based on formalism of Anselmino *et al.* (hep-ph/0412316v1)

$$\frac{d^5\sigma^{\ell p\to\ell h X}}{dx_B\, dQ^2\, dz_h\, d^2\boldsymbol{P}_T} = \sum_q e_q^2 \int d^2\boldsymbol{k}_\perp\; f_q(x,\boldsymbol{k}_\perp)\, \frac{2\pi\alpha^2}{x_B^2 s^2}\, \frac{\hat{s}^2+\hat{u}^2}{Q^4} \times D_q^h(z,\boldsymbol{p}_\perp)\, \frac{z}{z_h}\, \frac{x_B}{x} \left(1+\frac{x_B^2}{x^2}\frac{k_\perp^2}{Q^2}\right)^{-1}$$

- Perform k⊥ integration and keep terms order O(k⊥/Q) to get

$$\frac{d^5\sigma^{\ell p\to\ell h X}}{dx_B\, dQ^2\, dz_h\, d^2\boldsymbol{P}_T} \simeq \sum_q \frac{2\pi\alpha^2 e_q^2}{Q^4}\, f_q(x_B)\, D_q^h(z_h) \Bigg[(1+(1-y)^2) - 4\,\frac{(2-y)\sqrt{1-y}\,\langle k_\perp^2\rangle\, z_h\, P_T}{\langle P_T^2\rangle\, Q}\cos\phi_h\Bigg] \frac{1}{\pi\langle P_T^2\rangle}\, e^{-P_T^2/\langle P_T^2\rangle}\,,$$

where $\langle P_T^2\rangle = \langle p_T^2\rangle + z_h^2\langle k_\perp^2\rangle$

Interpretation Model -2-

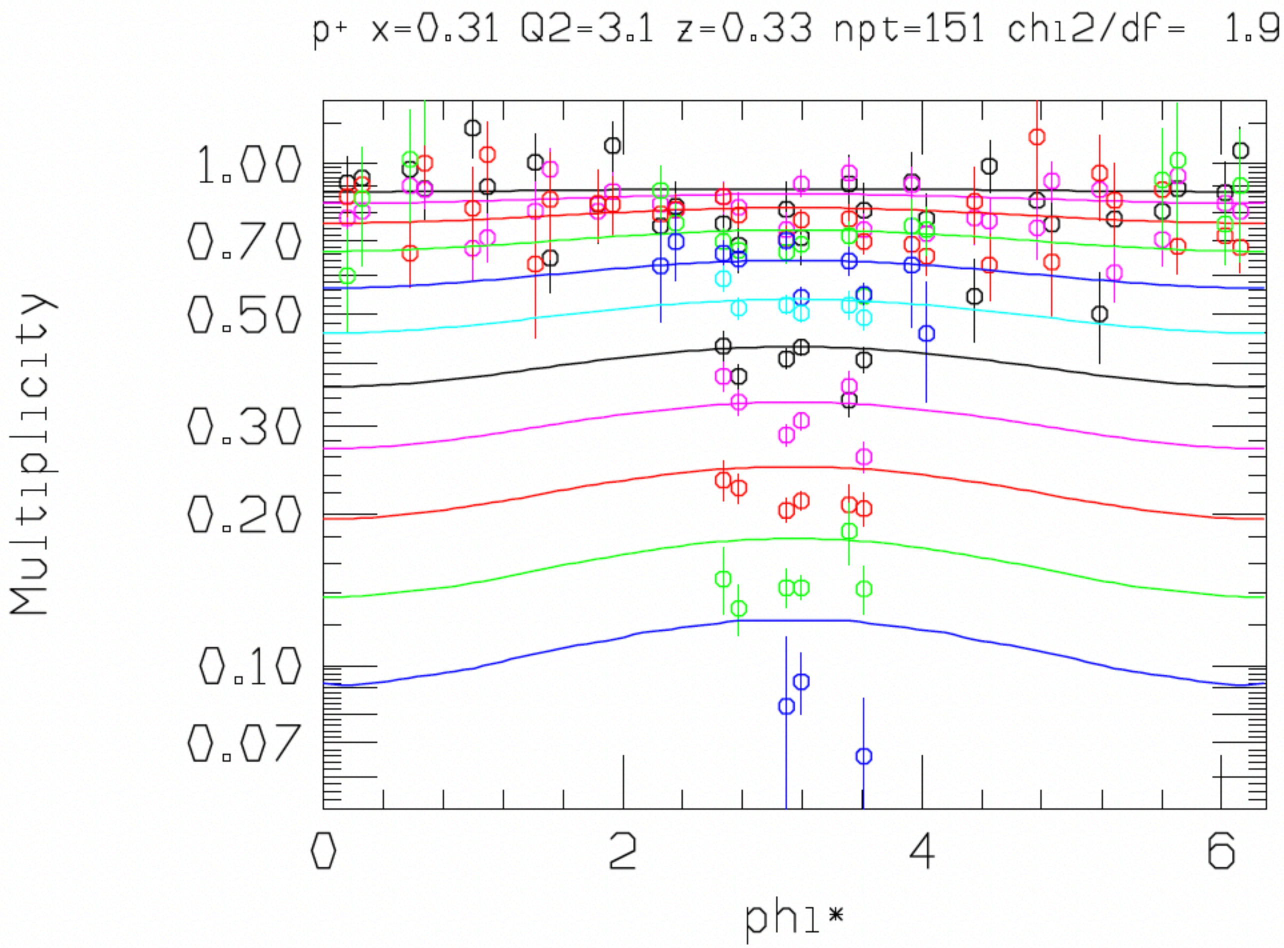
- At each (x, Q² ,z) fit multiplicities with $y = M_0 b e^{-bP_T^2}(1 + AP_T cos(\phi))$

$$\frac{d^5\sigma^{\ell p \to \ell h X}}{dx_B\, dQ^2\, dz_h\, d^2\boldsymbol{P}_T} \simeq \sum_q \frac{2\pi\alpha^2 e_q^2}{Q^4} f_q(x_B)\, D_q^h(z_h) \Big[(1 + (1-y)^2) - 4\frac{(2-y)\sqrt{1-y}\,\langle k_\perp^2\rangle\, z_h\, P_T}{\langle P_T^2\rangle\, Q} \cos\phi_h \Big] \frac{1}{\pi\langle P_T^2\rangle} e^{-P_T^2/\langle P_T^2\rangle},$$

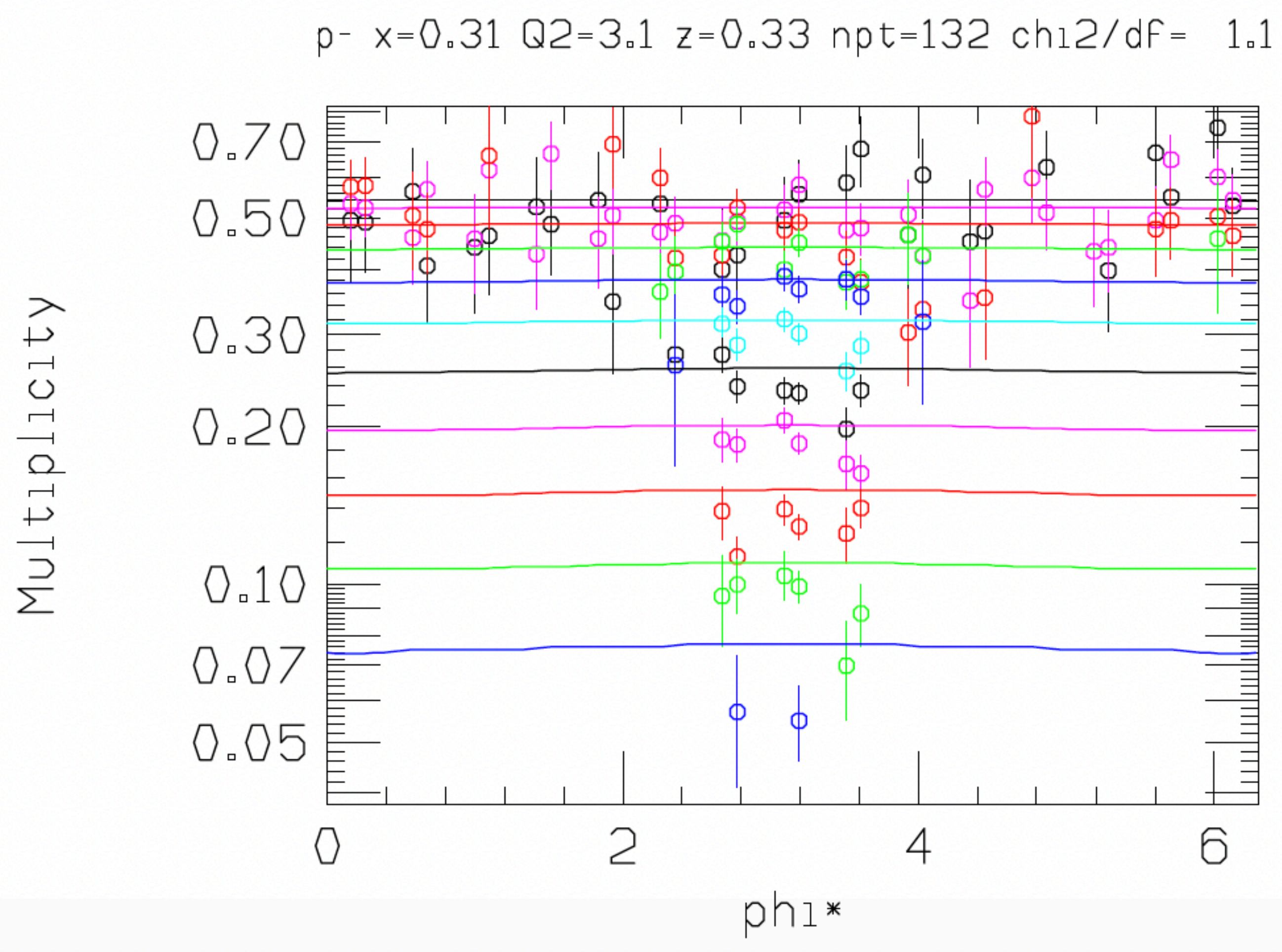
Fit parameters are M_0 , A, and $b = 1/\langle P_T^2\rangle$

Results are *very* preliminary…

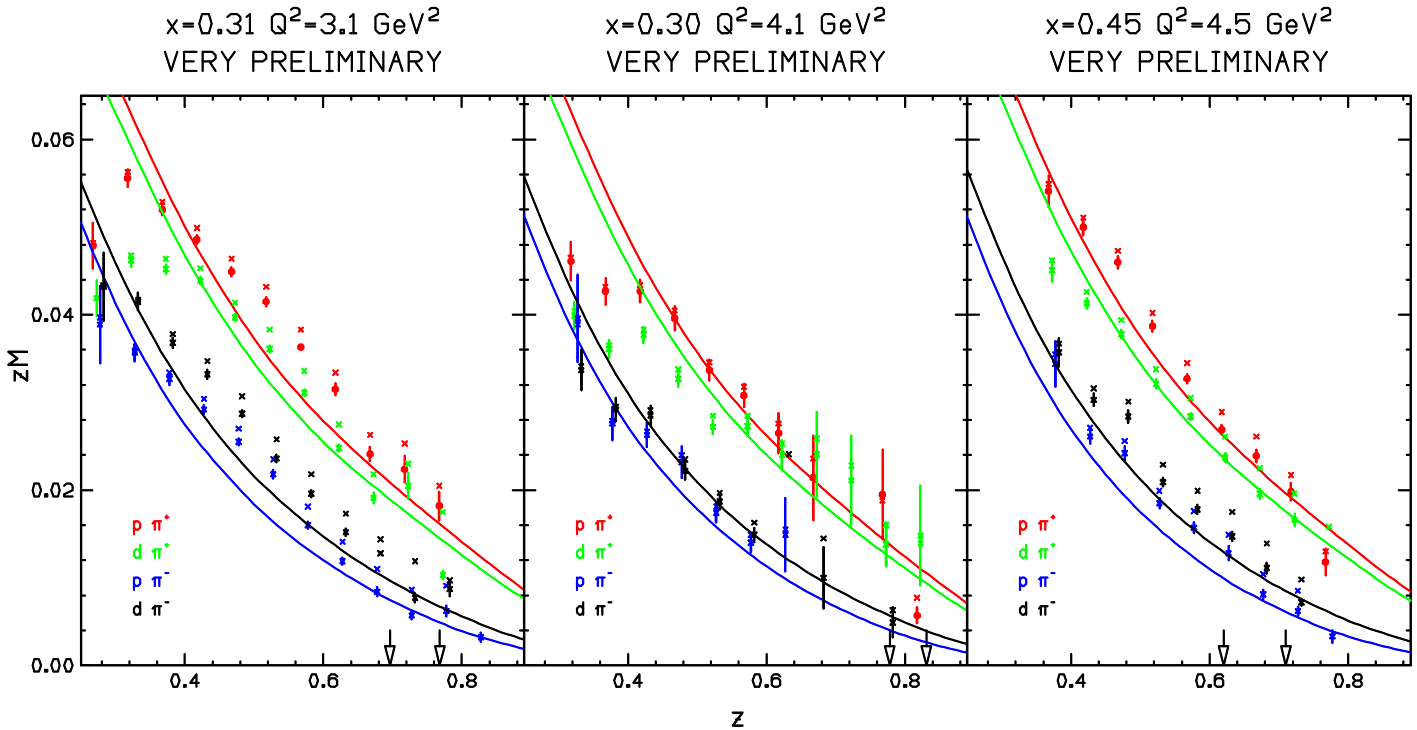
Fit Examples -1-



Fit Examples -2-

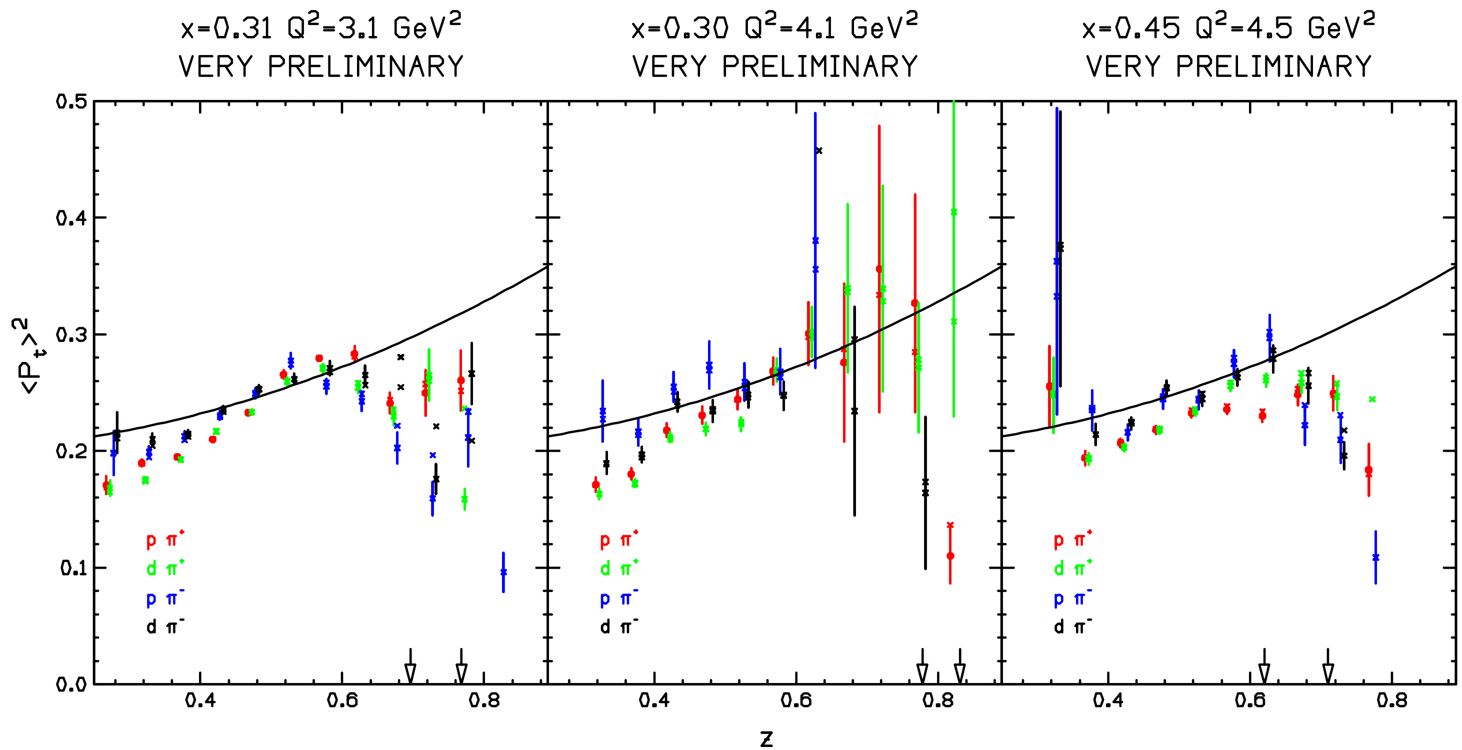


Fit to zM_0



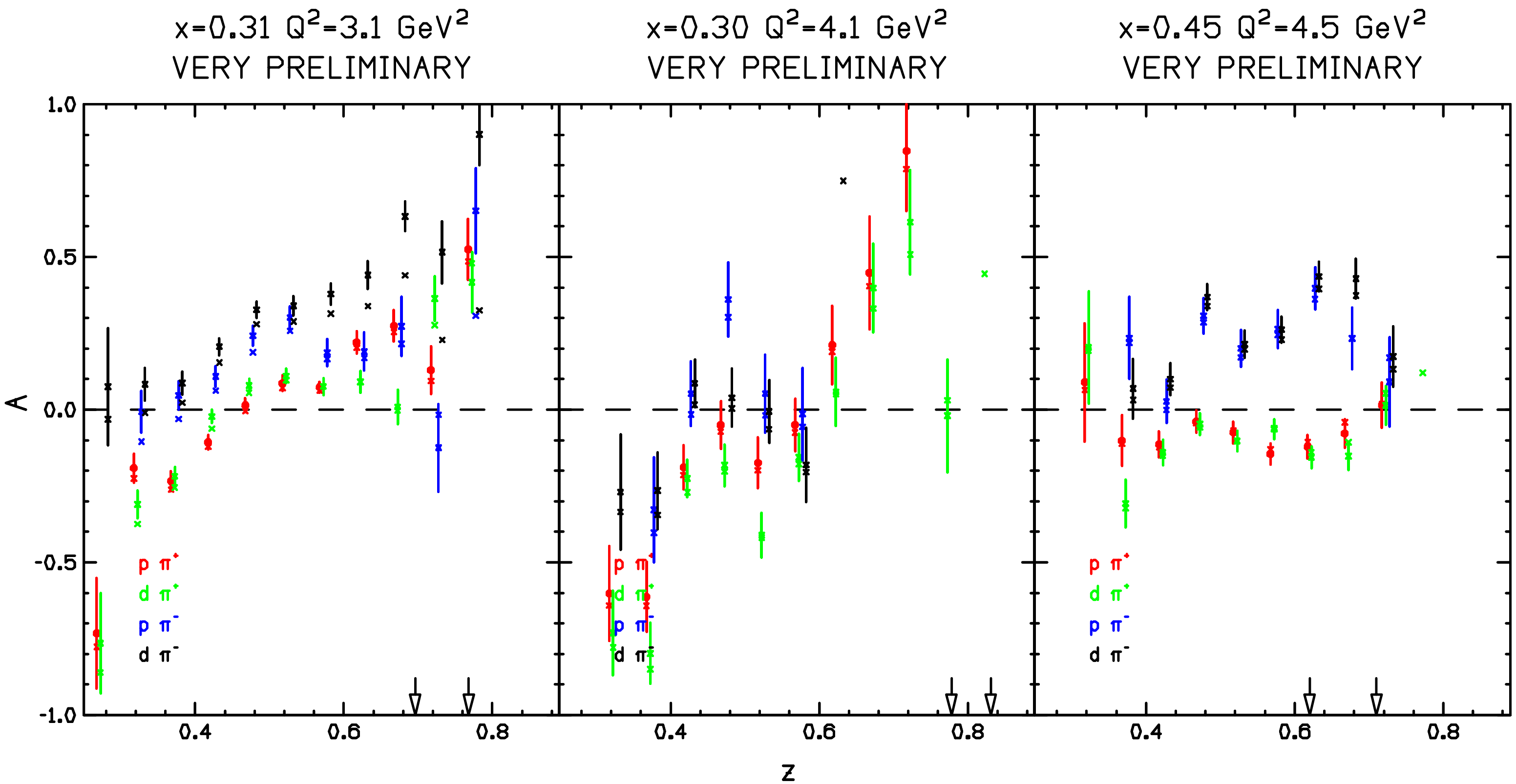
The results compared to the predictions using DSS fragmentation functions with CTEQ5 pdfs. The solid circles are with DVM rho subtraction using the standard SIMC parametrization, while the crosses (with no error bars) show how the results would look with no rho subtraction. The left-hand arrow at the bottom shows the z value for which (W')**2=3 GeV, while the right-hand arrow is for (W')**2 = 2.5 GeV**2. The DVM correction improves the agreement. If the correction were scaled up by a factor of two, the agreement would be better.

Fit to b (1/b shown)



The curve is of the form $\langle P_T^2 \rangle = \langle p_t^2 \rangle + z^2 \langle k_\perp^2 \rangle$ where $\langle p_t^2 \rangle$ is the width from fragmentation (PB used 0.2 GeV^2 for both favored and unfavored FF), and $\langle k_\perp^2 \rangle$ is the intrinsic quark transverse momentum width, which PB took to be 0.2 GeV^2 for both up and down quarks. Note fall off approaching (W')**2 > 3 GeV^2. The values for pi+ are all a bit smaller (for both p and d targets) than for pi-, possibly indicated a narrow width for favored fragmentation than for unfavored fragmentation.

Fit to A



Generally they increase with increasing z, are are significantly greater than 0 for pi-, but closer to zero for pi+. The Cahn effect would predict negative values of A, in contradiction with the data.

Kinematic Constraint of Cahn Effect?

- The paper by M. Boglione, S. Melis, A. Prokudin, arxiv:1106.6177, discusses the effects of a limited maximum quark transverse momentum allowed kinematically of the Cahn cos(phi) asymmetry and on the average value of $\langle P_T^2 \rangle$.
- For our kinematics, k⊥_max_squared = $(2-x)(1-x)Q^2$ (the limit for x>0.3) is always greater than 1.2 GeV^2. It turns out that there is no significant reduction in the magnitude of the Cahn asymmetry for reasonable choices for $\langle k_\perp^2 \rangle$ or 0.1 to 0.3 gev**2. This in contrast to HERMES and COMPASS, which have lower values for Q^2 , and lower values of x where a different limit on k⊥_max applies.

Plans for future

- Develop pion fits further, understand systematics
- Understand 5% normalization difference between inclusive d cross section and world data parameterizations
- Determine kaon cross sections
- Finalize high z pion L/T separation (using some of kaon LT data)
- Manuscript for pion cross sections/ratios in fall 2022; if observation about cos(phi) dependence holds, probably a separate report, but publication plan still under discussion