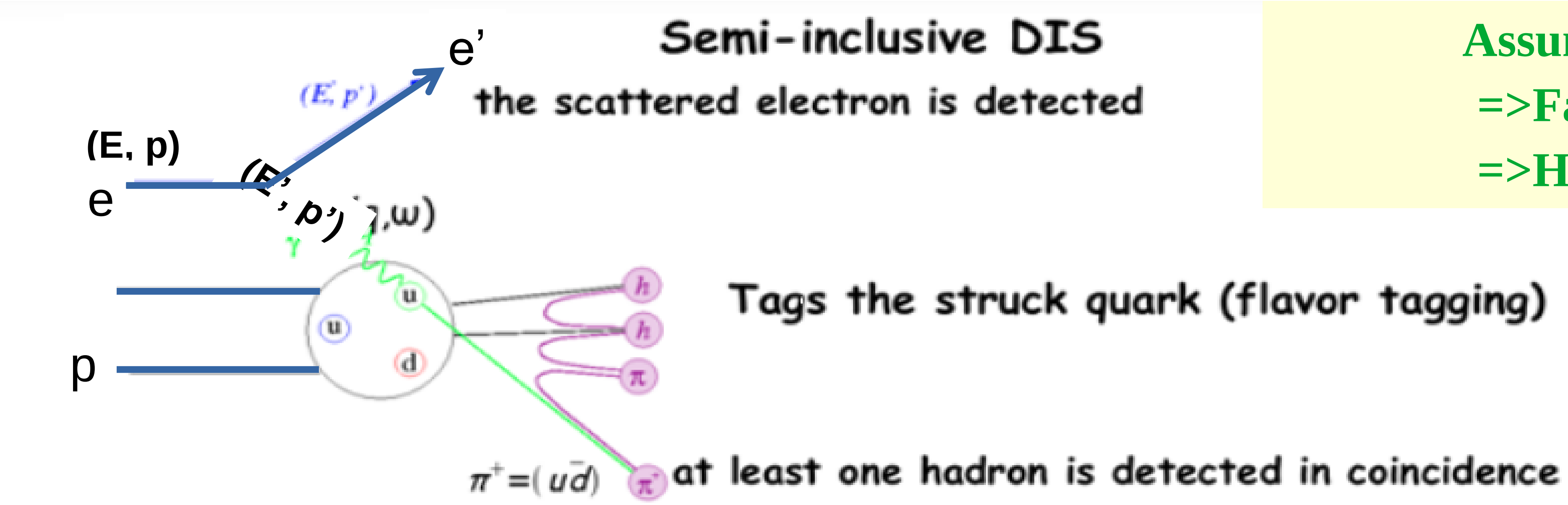
pt and phi* studies from 12-GeV era Hall C SIDIS experiments

Presenter: P. Bosted

Analysis from three Hall C experiments in 2018-2019

- Pt-SIDIS wide range of Pt for six (x,Q^2) settings with detection of SIDIS π^+ and π^- from proton, deuteron, and aluminum, for 0.3<z<0.9. No graduate student at present. Mostly being analyzed by myself.
- CSV-SIDIS: 26 more settings in (x,Q^2) for π^+ and p and π^- from deuteron (and some proton) but limited Pt coverage, again 0.3<z<0.9. Graduate students Hem Bhatt and Shuo Jia. (see previous talk).
- Kaon-LT: inelastic π^+ and K^+ on proton target useful for measuring SIDIS at high z , including the ratio $R = \sigma_L/\sigma_T$

Semi-Inclusive Deep Inelastic Scattering (SIDIS)



Assumptions:

=>Factorization

=>Hadronization

u => π^+
d => π^-

Few kinematic quantities :

x	=	$Q^2 / 2M_p\nu$: Fraction of proton's momentum carried by the quark (Bjorken x)
M_p	=	mass of proton
ν	=	energy Transfer in lab frame (E - E')
Q^2	=	4 momentum transfer squared = $4EE'\sin^2(\theta/2)$
z	=	fraction of energy transfer carried by outgoing hadron (pion) = E_h/ν $= \sqrt{(m^2_\pi + p^2_\pi)} / \nu$

Experiments overview

- HMS spectrometer detects electrons at scattering angles from 13 to 49 degrees, momenta from 1 to 6 GeV . Twenty-eight distinct settings: each divided into two (x,Q^2) bins. Solid angle 4 msr.
- SHMS detects particles on opposite side of the beam line. At angles from 6 to 30 degrees, momenta from 2 to 7 GeV.
- Beam energy mostly 10.6 GeV, beam currents 2 to 70 μA
- Targets are 10 cm liquid hydrogen and deuterium, and “dummy’ to measure aluminum endcap contributions.
- Trigger was time coincidence between two spectrometers. Typical rate about 3000 Hz.
- Only one hadron per event (unlike open detectors such as CLAS)

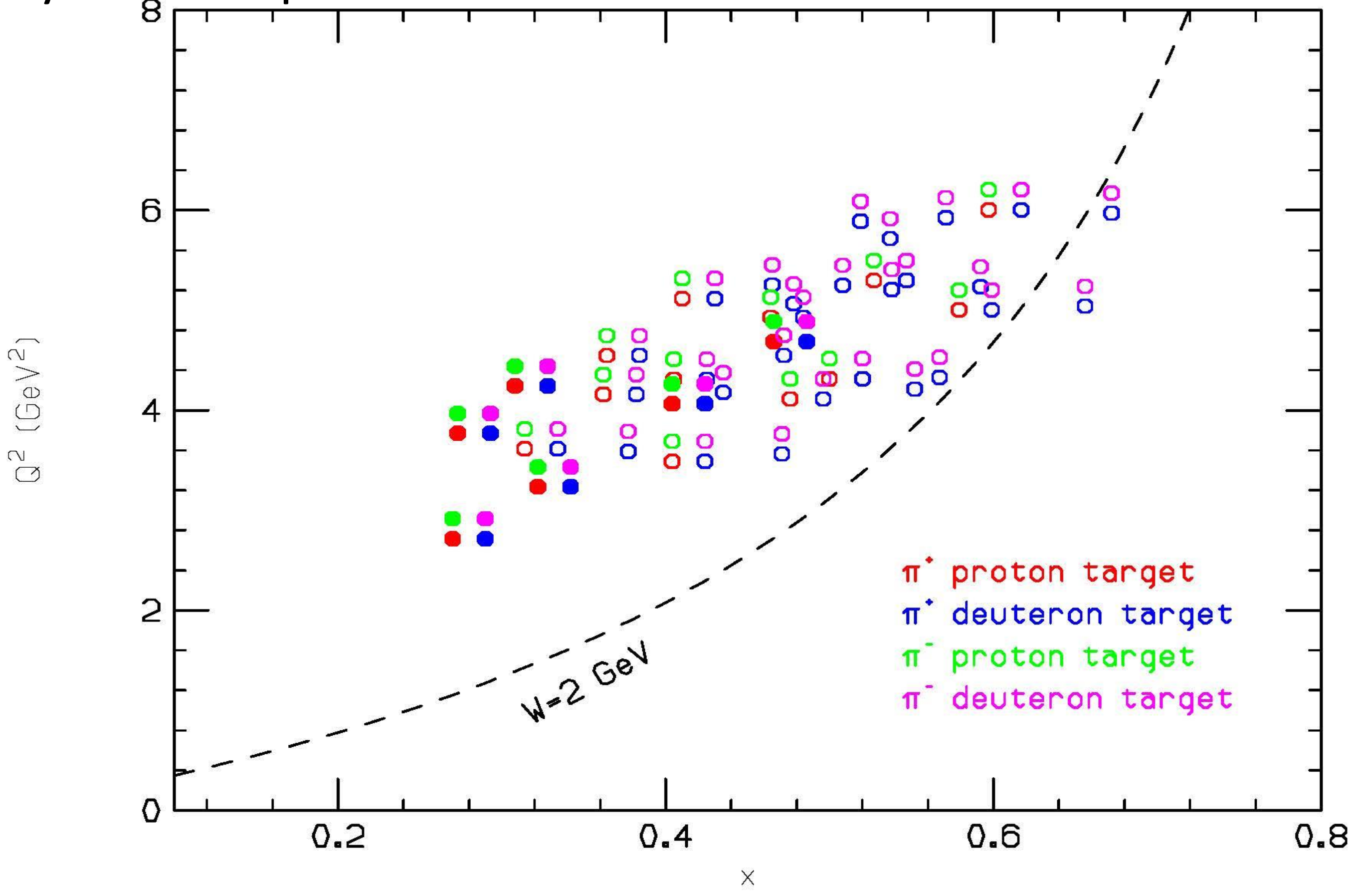
Kinematic coverage in (x,Q^2)

Solid circles are from pt-SIDIS, open circles CSV SIDIS

CLAS coverage extends to lower x and lower Q^2

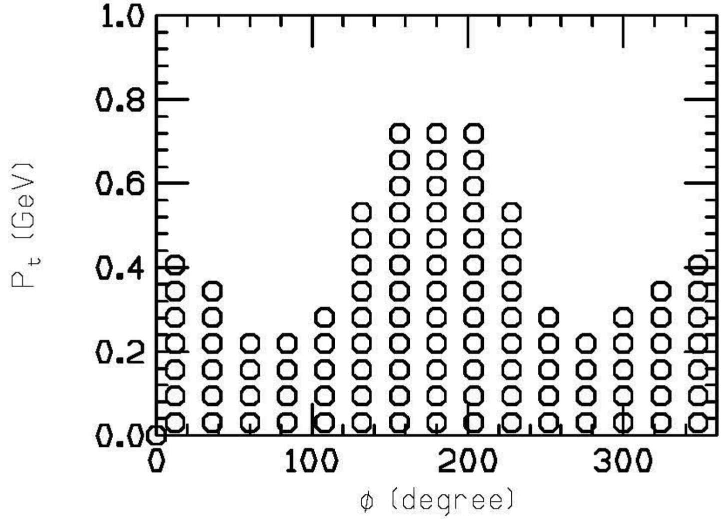
each circle has 10,000 to 1000,000 events

Dominated by valance quark distributions

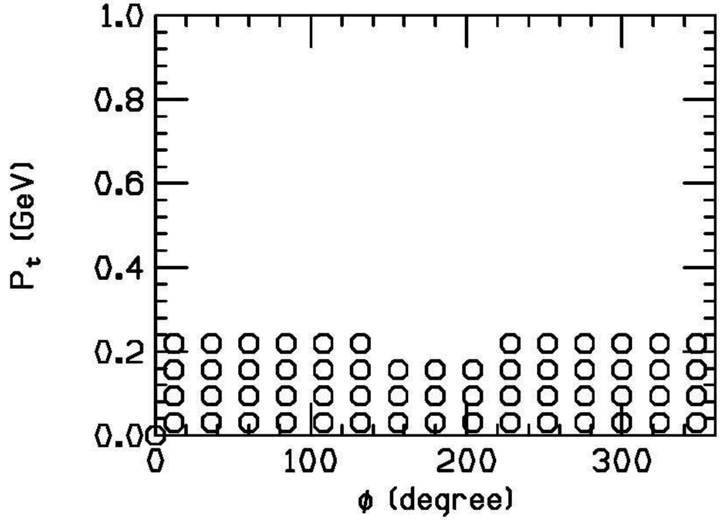


Kinematic coverage in P_t and ϕ

Typica pt-SIDIS setting at z=0.5



Typica CSV-SIDIS setting at z=0.5



Data Analysis Tasks Completed (more or less)

- Determination of beam energy and position
- Calibration of beam current monitors and target boiling corr.
- Computer and electronic dead time correction
- Debugging and improvements to tracking code
- Corrections for multiple trigger signals
- Calibration of spectrometer optics for -18<d<38% in SHMS
- Modifications to SIMC for better matching of data and simulation (shms_hut.f and hms_hut.f in particular))
- Calibration of all spectrometer detectors, including “hole” in heavy gas detector.
- Determination of pair-symmetric background (<1%)
- Optimization of PID for pions, kaons, and protons
- Improved models of exclusive pion and $\pi\Delta$ for rad. Corr.
- New model of diffractive rho contributions to cross sections.

Binning
For each of 56 (x,Q^2) settings
With separate files for π, K

- 6 target/polity bins (p+, d+, Al+, p-, d-, Al-)
- 20 bins in z from 0.1 1 to 1 (bin 1 for excl. bin 2 for Delta)
- 15 bins in phi from 0 to 360 degrees
- 16 bins in Pt from 0 to 1 GeV

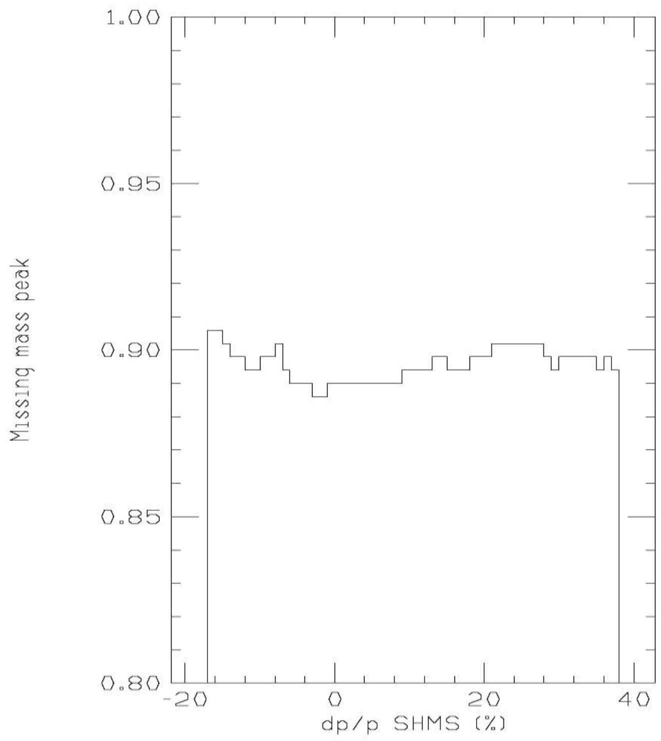
For each bin:

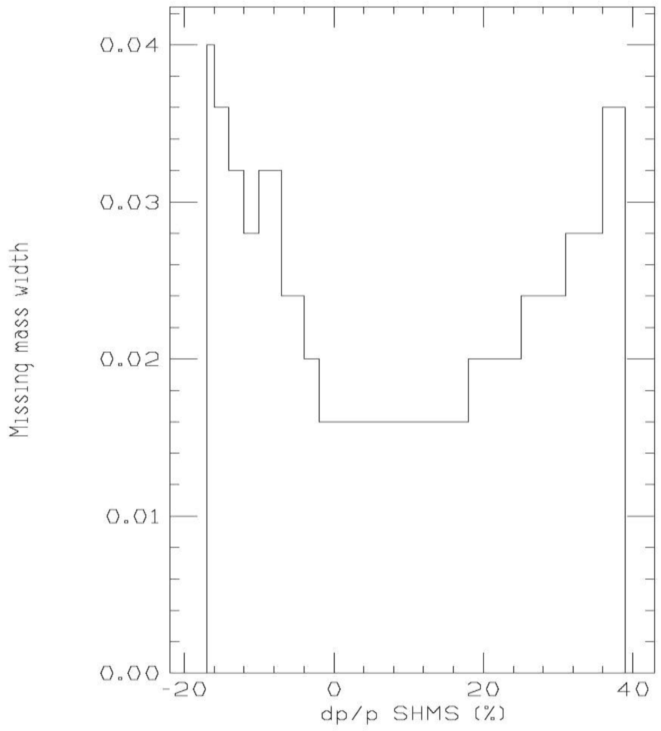
- Pions, kaons, and protons
- Monte Carlo predicted rate for 4 processes

Typically 500 bins with >50 counts for pt-SIDIS, 100 for CSV-SIDIS, kLT

Bins used individually in global fitting

Study of exclusive pion missing mass distributions versus dp/p in SHMS. Conclusion, can use -16<dp/p<36% because peak position is stable and a factor of two larger width is noacceptable.





Status of pion SIDIS results

- 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, COMASS, R_SIDIS as they become available.
- Meanwhile, have begun interpretation using our data only.

Formalism from Anselmino et al.

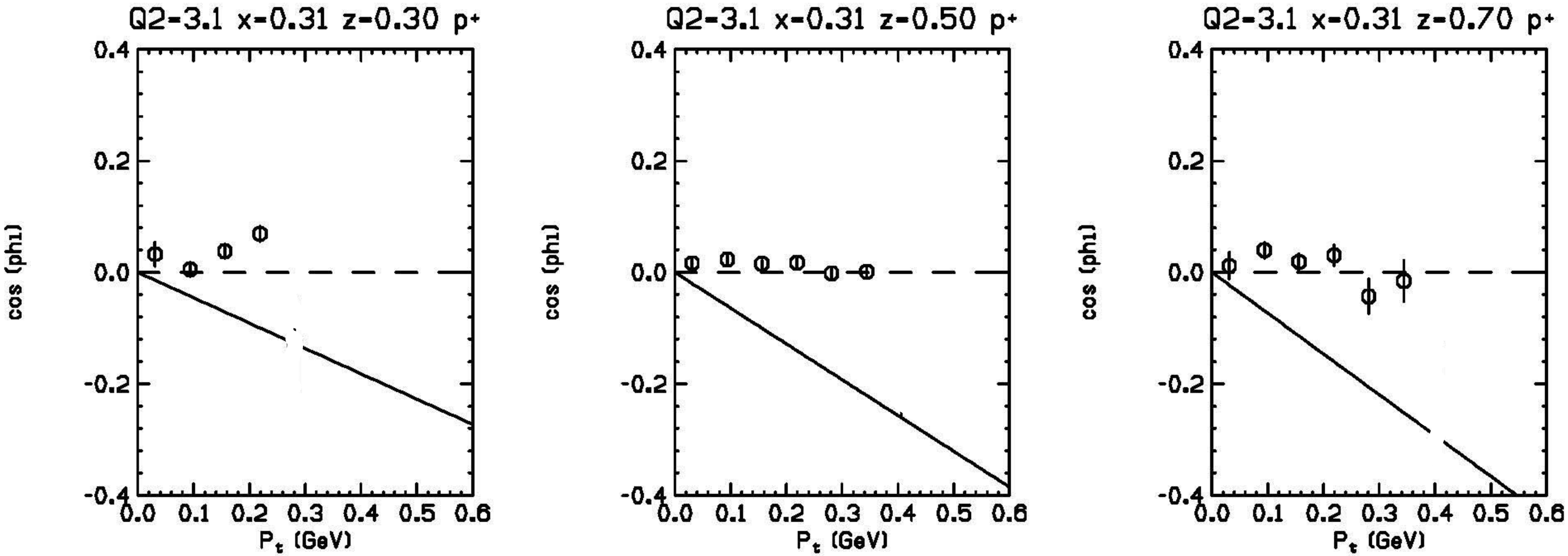
$$\frac{d^5\sigma^{\ell p\to \ell h X}}{dx_B\, dQ^2\, dz_h\, d^2\mathbf{P}_T} \simeq \sum_q \frac{2\pi\alpha^2 e_q^2}{Q^4} f_q(x_B)\, D_q^h(z_h)\left[1+(1-y)^2 -4\frac{(2-y)\sqrt{1-y}\,\langle k_\perp^2\rangle z_h P_T}{\langle P_T^2\rangle Q}\cos\phi_h\right]\frac{1}{\pi\langle P_T^2\rangle}\, e^{-P_T^2/\langle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

where $\langle P_T^2\rangle = \langle p_\perp^2\rangle + z_h^2\langle k_\perp^2\rangle$. The term proportional to $\cos\phi_h$ describes the Cahn effect [1].

By fitting the data [10] on unpolarized SIDIS we obtain the following values of the parameters: $\langle k_\perp^2\rangle = 0.25$ $(\mathrm{GeV}/c)^2$, $\langle p_\perp^2\rangle = 0.20$ $(\mathrm{GeV}/c)^2$. The results are shown in Fig. 1.

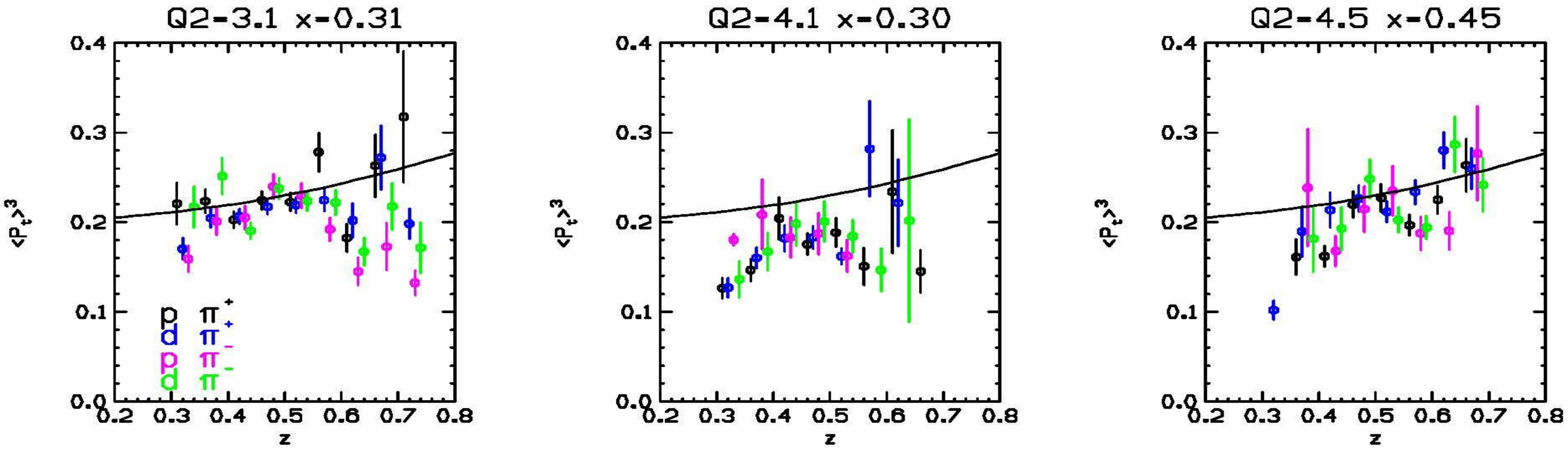
- Cahn effect predicts cos(phi) term proportional to <kt> of quarks
- Gaussian width has constant term from fragmentation plus quadric term in <kt>

Typical examples of cos(phi) term



- Solid line is from Anselmino paper. With about 500 MeV quark width. Our results instead consistent with very small quark kt width (<100 MeV).
- Confirms small cos(phi) seen at HERMES and CLAS, but with order of magnitude smaller error bars.
- COMPASS found that diffractive rho contribution has huge impact: effect on results under study use HEPGEN code.

Gaussian widths versus transverse momentum



- From simultaneous fit of cos(phi) term linear in Pt and cos(2phi) term quadratic in Pt, and Pt-slope to cross section.
- Solid lines are from Anselmino fit to EMC/Fermilab data
- Our results are somewhat similar, but don't clearly show predicted constant plus quardratic z-depenance.
- Not much difference between p, d targets, pi+ or pi-.
- Diffractive rho contributions (not considered in above figures) improve agreement with Anselmino fit, and furthermore <Pt> for favored and unfavored fragmentation consistent

To-do list

- Figure out why inclusive DIS fits F1F2IN09 and F1F2IN21 differ by about 5% in most of our kinematic range for deuteron.
- Compare DVM correction from Dave Gaskell with newer model from COMPASS as implemented in HEPGEN generater
- Figure out why cross sections for HMS yptar<0 and yptar>0 differ by about 4%
- Improve the radiative corrections for the kaon and proton SIDIS results by iterating on global fits to results.
- because pt-SIDIS and CSV have low statistical accuracy.
- Finalize extraction of R at high z from KLT data for pi+ and K+ .