Update on Hall C SIDIS experiments

P. Bosted, (with help from M. Jones, E. Kinney, H. Mkrtchyan, V. Tsaskis

Analysis from three Hall C experiments in 2018-2019

- Pt-SIDIS wide range of Pt for three (x,Q2) settings with detection of SIDIS p+ and pi- from proton, deuteron, and aluminum
- CSV-SIDIS (previous talk): 13 more settings in (x,Q2) for pi+ and pi- on deuteron but limited Pt coverage
- Kaon-LT (two talks ago): inelastic pi+ on proton target useful for measuring at high z the ratio $\mathrm{R} = \sigma_L/\sigma_T$

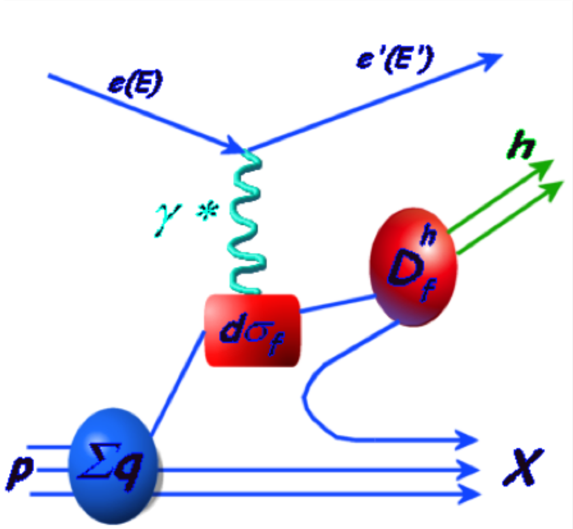
SIDIS

factorization?

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

$f_q(x)$: parton distribution functions

$D_q^h(z)$: fragmentation functions



- 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

The f and D functions depend on transverse momentum. Using proton and neutron (in deuteron targets)and both pi+ and pi- final states may allow determination of individual u and d quark Pt distributions

Improvements to data analysis

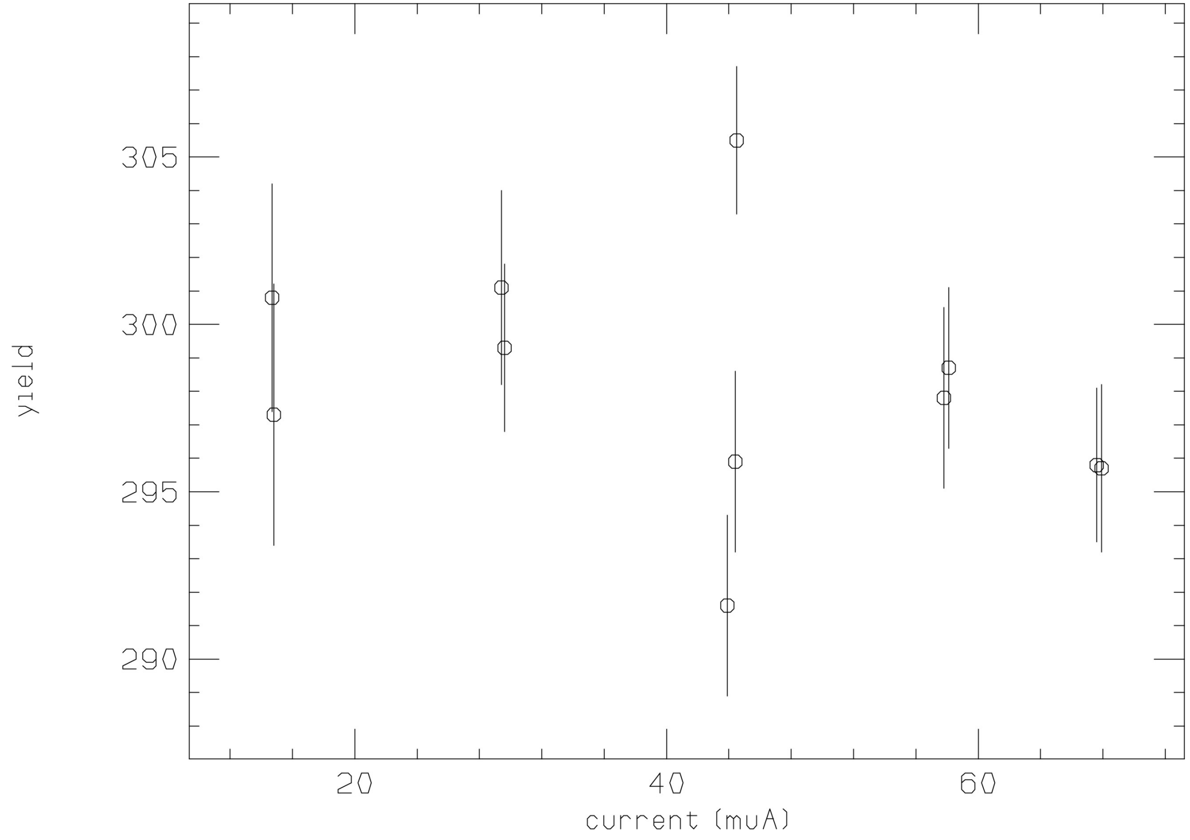
To correct for very large rate dependence to yields, with Mark Jones:

- Improvements in extracting TDC and ADC information
- Improved determination of hodoscope timing and “starttime”
- Patch for ADC due to large pedestals
- Improvements to tracking efficiency determination
- Correction (beyond what EDTM can do) for lost ADC values due to 100 nsec minimum time between pulses.
- Correction for incorrect reference times due to multiple trigger signals in the reference time (two extra in Spring18, one extra after that).
- Improved BCM calibration versus current

Improvements to data analysis

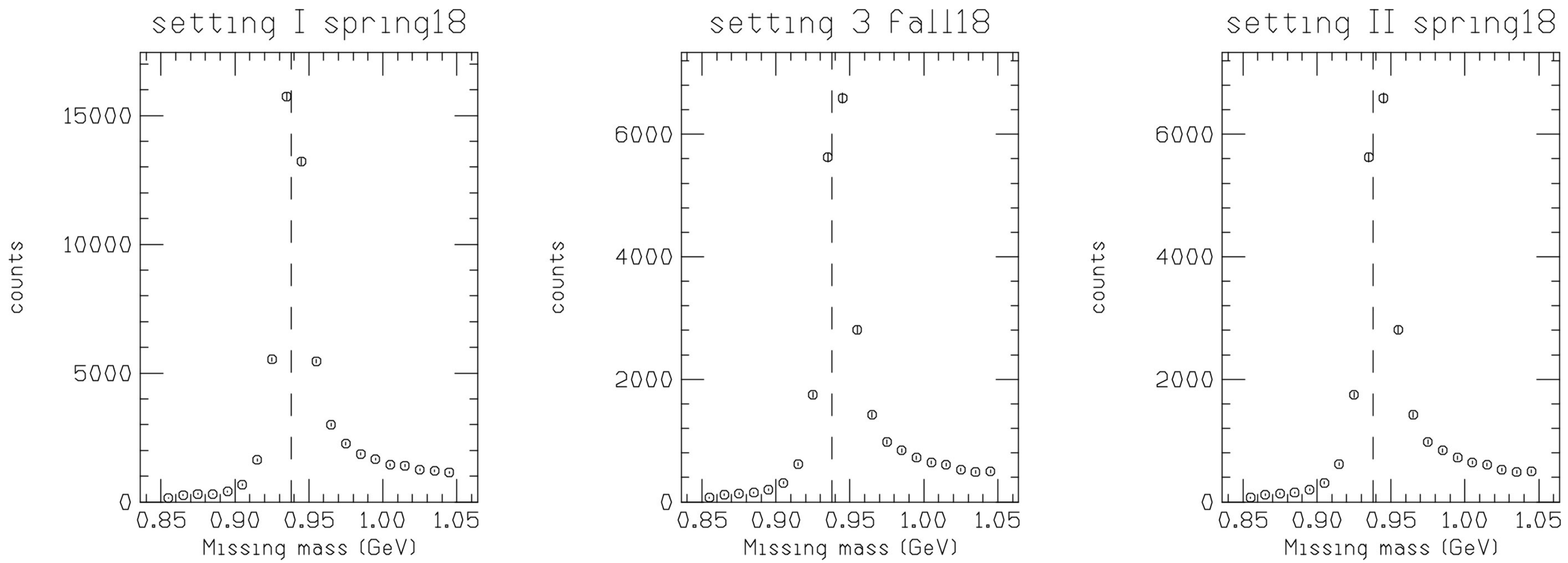
Using new code and parameters, find:

- Corrected yields no longer depend on beam current, while previously there were up to 20% changes.
- Yields from setting repeated in Fall18 now agree with yields from Spring18 (which has considerably larger effective dead time corrections)



Improvements to optics

- New SHMS matrix elements from Mark Jones
- Corrections of 0.9944 to 1 for HMS central momentum based on fit from Holly plus missing mass from exclusive pion production from our own data (all three experiments)
- Correction to HMS vertical offset of 2.7 mr based on fit from Carlos as well as making SIDIS cos(phi) distributions even in phi.



Improvements to SIMC

- Checked that parm06 works well for exclusive pion cross sections from all 3 experiments
- Found that param06 is too big in resonance region: changed to use a look-up table from MAID (resonance region is accessed in radiative corrections)
- Made rough fit to our data on e p -> e pi- Delta++ reaction since no fit available from anyone else.
- Added two more options for fragmentation functions. In SIDIS.
- Made code that generates SIMC outputs for every data run for SIDIS (with and without radiation), exclusive tails , SIDIS endcap contributions, and diffractive rho production “guess” (not being used in upcoming plots).

Overview of pt-scan ratios

- Scans in Pt at three (x,Q2) and two z bins
- Plots show ratios of data to data for pi+ on proton
- Curves are ratios from SIMC. Solid is with exclusive tail, dashed in without exclusive tail
- New results show less jitter, smoother trends than in January

Ratios to Hydrogen π+ -1- January 2020

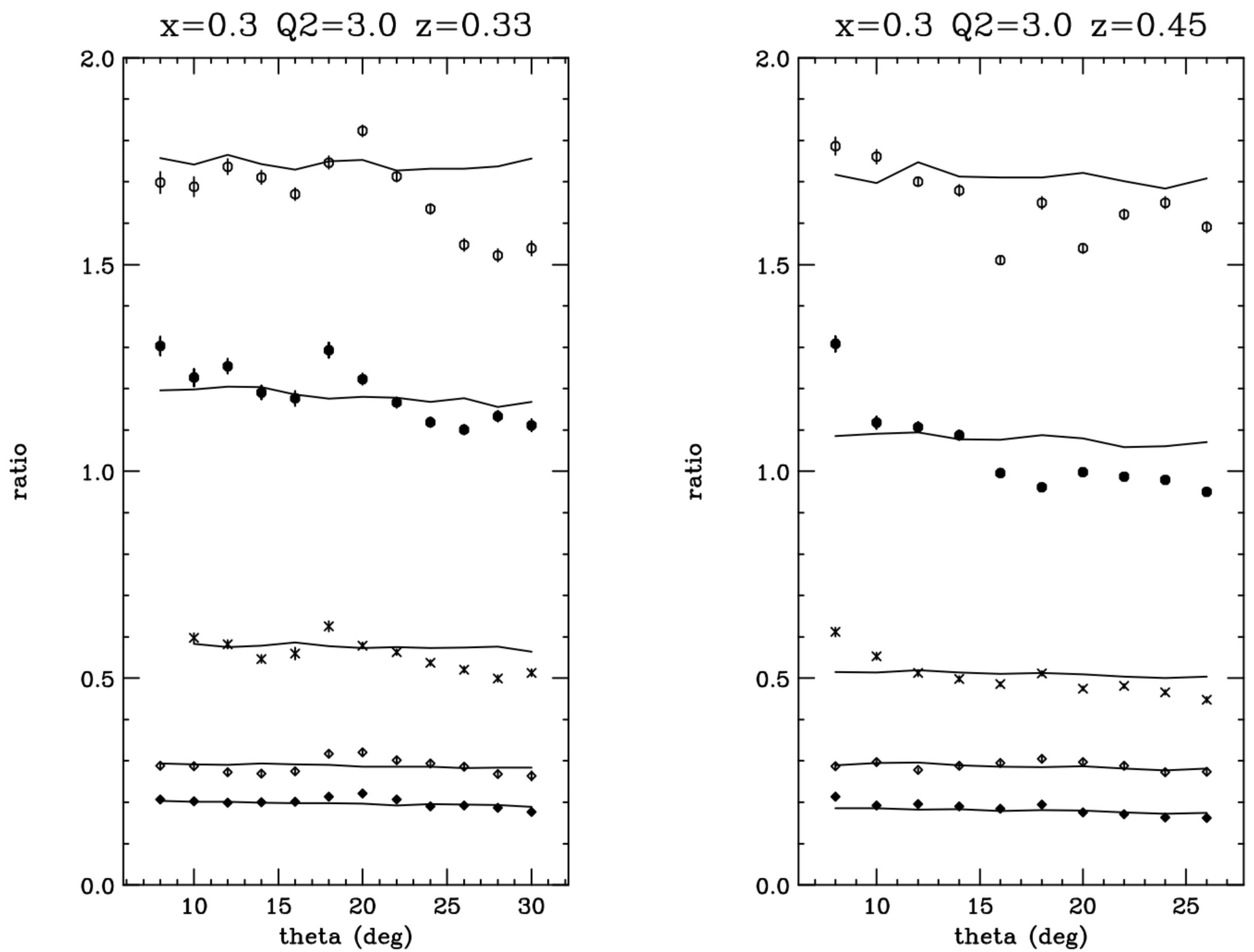
$^2H(\pi+)$

$^2H(\pi-)$

$^1H(\pi-)$

$Al(\pi+)$

$Al(\pi-)$



Curves: SIMC

E.R. Kinney

Hall C Collaboration Meeting

29 January 2020

Ratios to Hydrogen π+ -1- July 2020

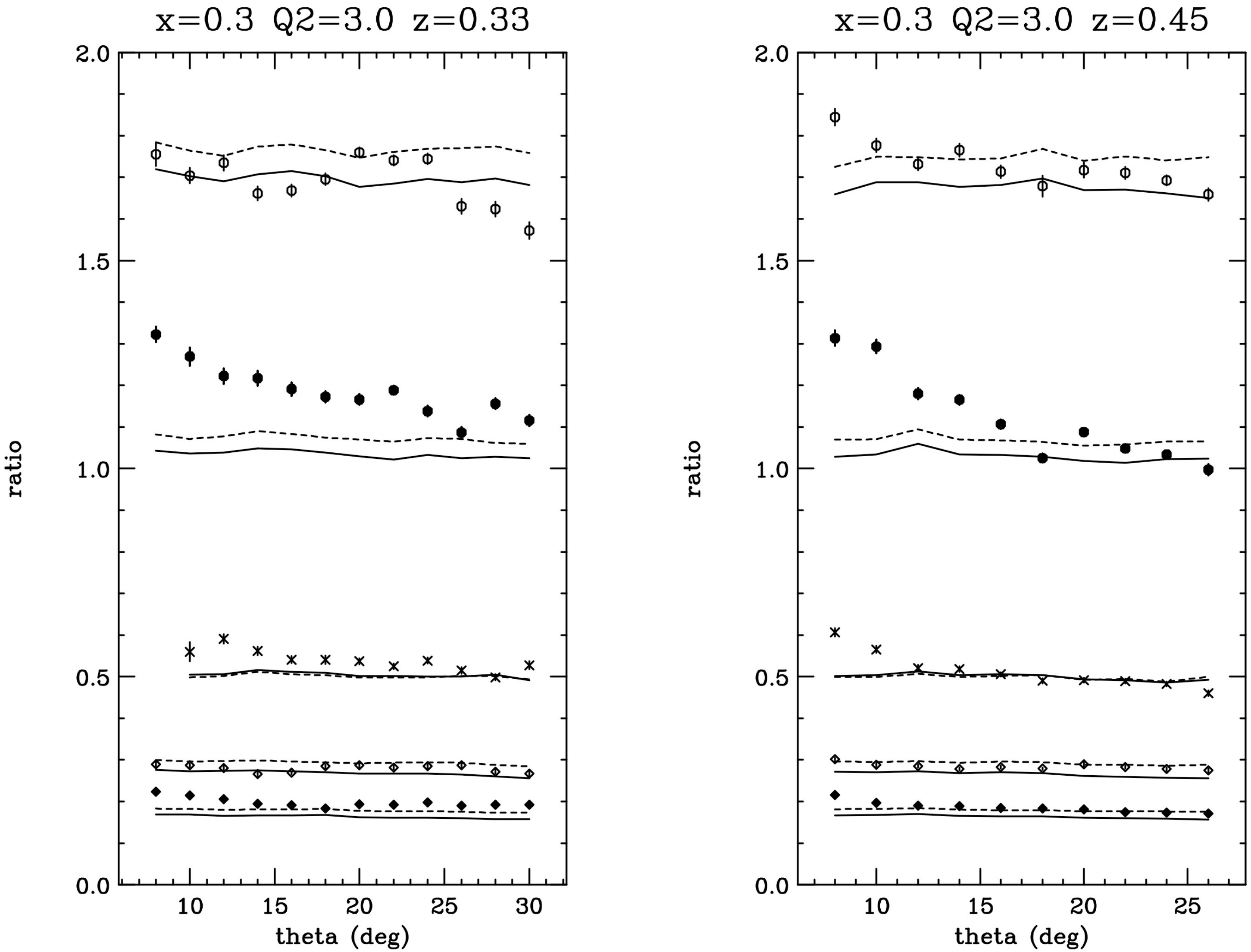
$^2H(\pi+)$

$^2H(\pi-)$

$^1H(\pi-)$

$Al(\pi+)$

$Al(\pi-)$



Curves: SIMC (dashed without exclusive tails)

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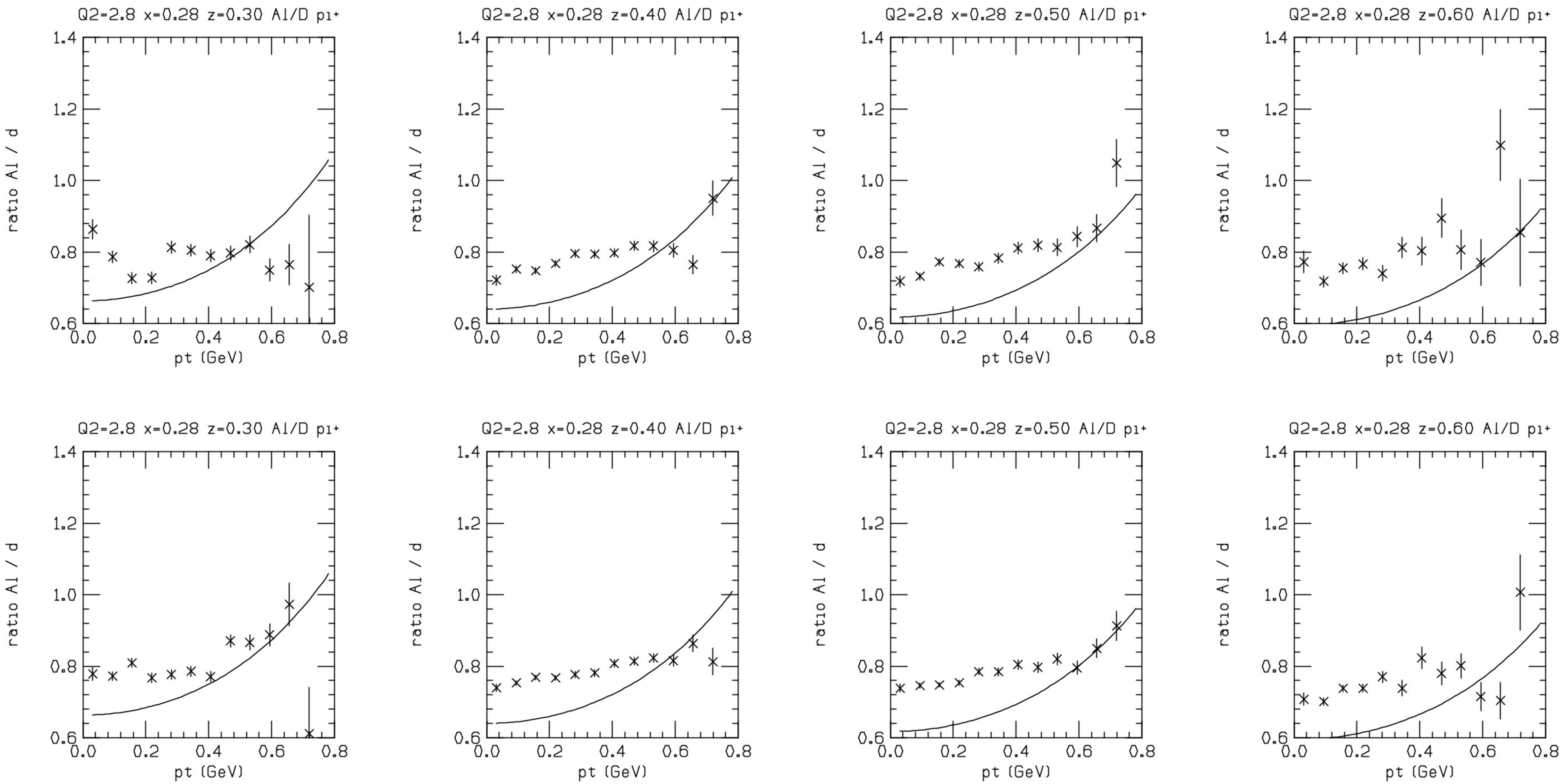
Analysis Procedure

- For each data run, select electron pion events with three sets of PID criteria (for systematic error studies) for pions and one for kaons. Accumulate events in time-coincidence peak and side-band accidental region. Apply cuts on spectrometer variables that avoids regions of poor acceptance or resolution.
- Store counts in bins of HMS scattering angle, z, pt, and phi*.
- Store counts and weights from SIMC for the simulations mentioned previously . Data are compared to radiated SIDIS plus radiated exclusive pions plus endcaps (except for dummy)
- Combine all runs together using ratios of data/SIMC in bins of x, Q2, z, pt, phi* for each target and for pi+, pi-, K+, K-
- In January, the chi2/d.f. for combing runs together was very poor: with all the work mentioned above, now much better.

Closer look at ratios Aluminum/deuteron

- Because I subtract modeled rates for endcaps, need good fit to the dummy target data
- Our small error bars can make significant improvement to world data set on nuclear dependence in SIDIS: shed light of Pt-broadening
- Small sample of the data on next slide compared to my fit to data from CLAS with 6 GeV electrons.
- Started on new fit to Hall C data. Seeking theory support for possible article.

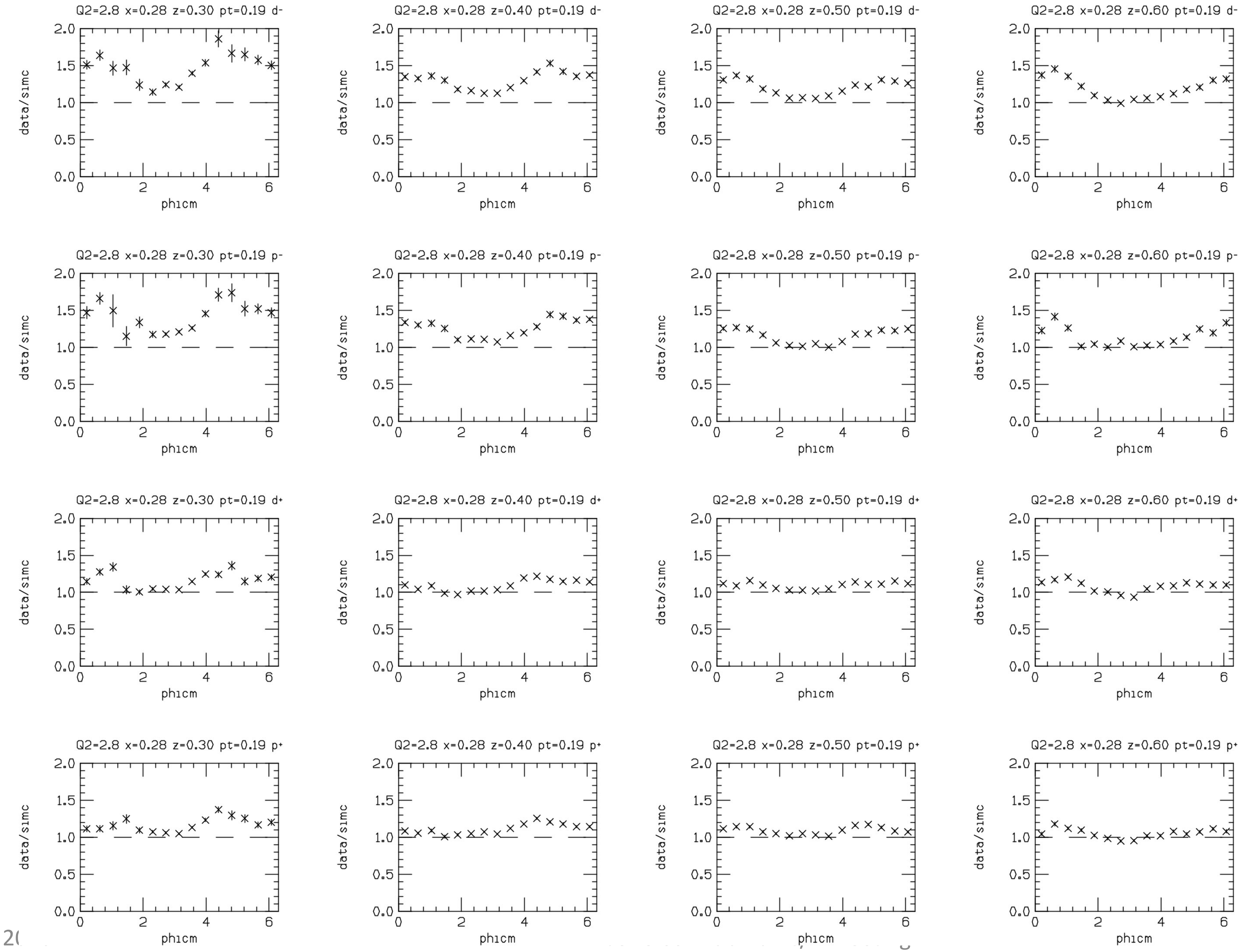
Closer look at ratios Aluminum/deuteron



Closer look at phi* dependance

- Cross sections have terms depending on cos(phi) and cos(2phi)
- These terms are “higher twist” as they drop with Q2
- They contain information on the transverse momentum dependence of the quark distributions
- Plots on next page show small sample of phi* distributions
- Generally are larger at larger pt
- Some differences between pi+ and pi- and proton and deuteron can be observed
- Seem larger at low z, especially cos(2phi) term
- Global fit in progress
- Fit is needed to study Pt-dependence at high Pt, where only limited phi* coverage is possible with spectrometers

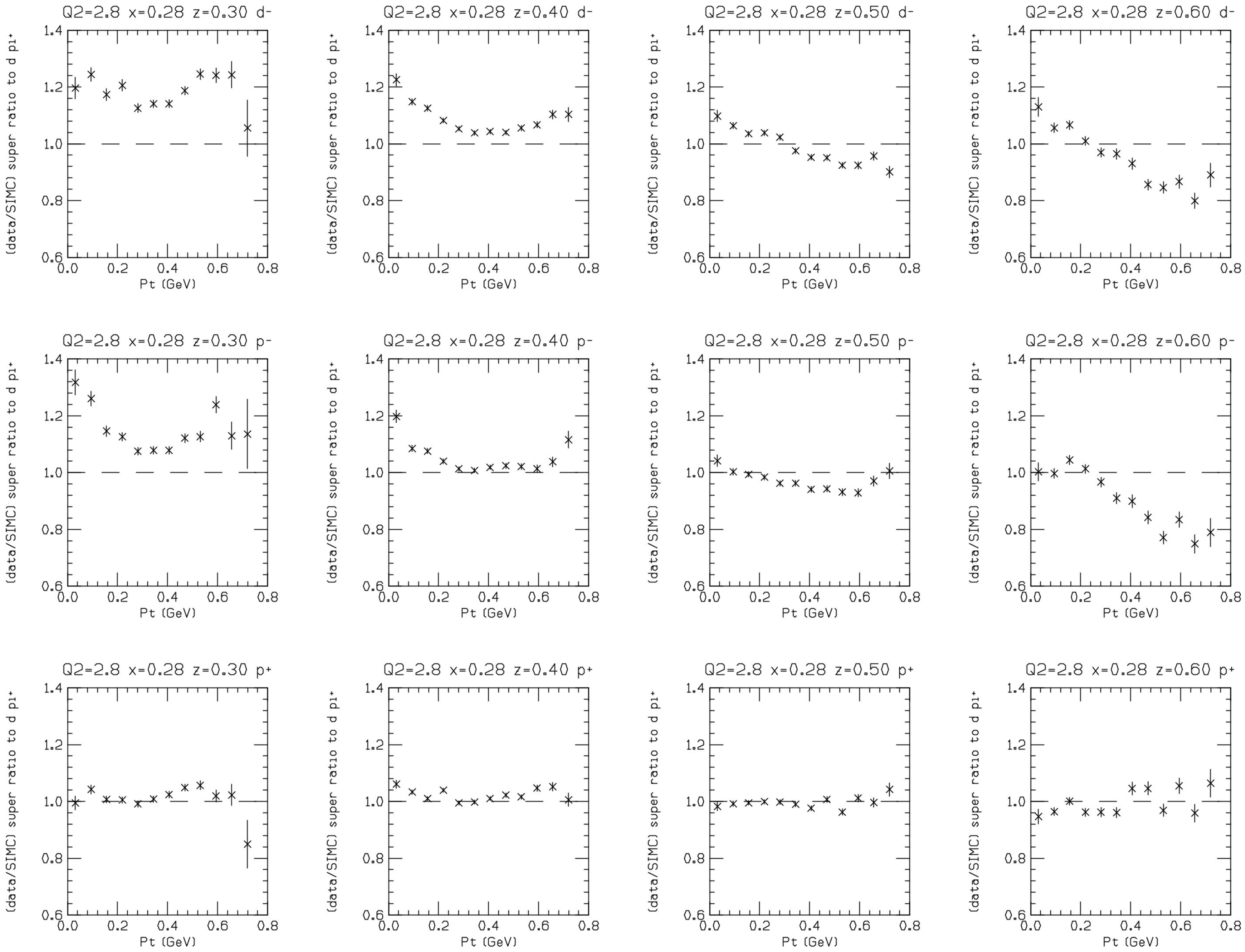
Closer look at phi* dependance



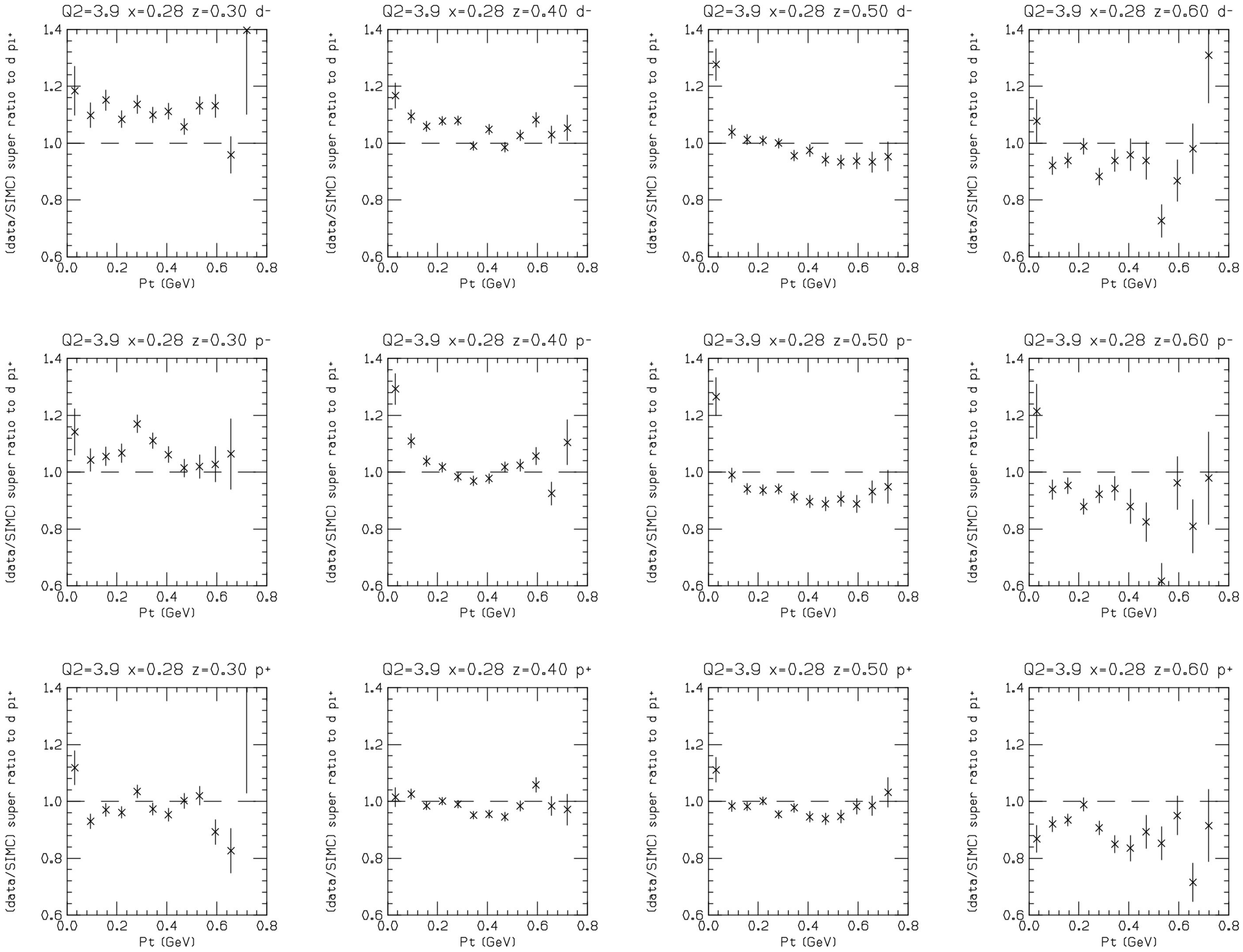
Closer look at Pt dependance

- Data from pt-SIDIS and CSV extend to typically pt=0.2-0.3 with full phi* coverage. Pt-SIDIS extend to pt=0.7 with limited phi coverage.
- Ratios of cross sections a good way to look for differences in pt-broadening due to differences in valance u, valance d, and sea quarks, complicated by differences in pt-broadening from favored and unfavored fragmentation functions.
- Plots on next page sshow a sample of super ratios (data/SIMC) for pi- on d (top), pi- on p (middle), pi+ on p(bottom) to pi+ on deuteron.
- Model in SIMC describes pi+ p/d ratios amazingly well. For pi- on both d and d, a downward slope is evident, especially at higher z (right hand panels).

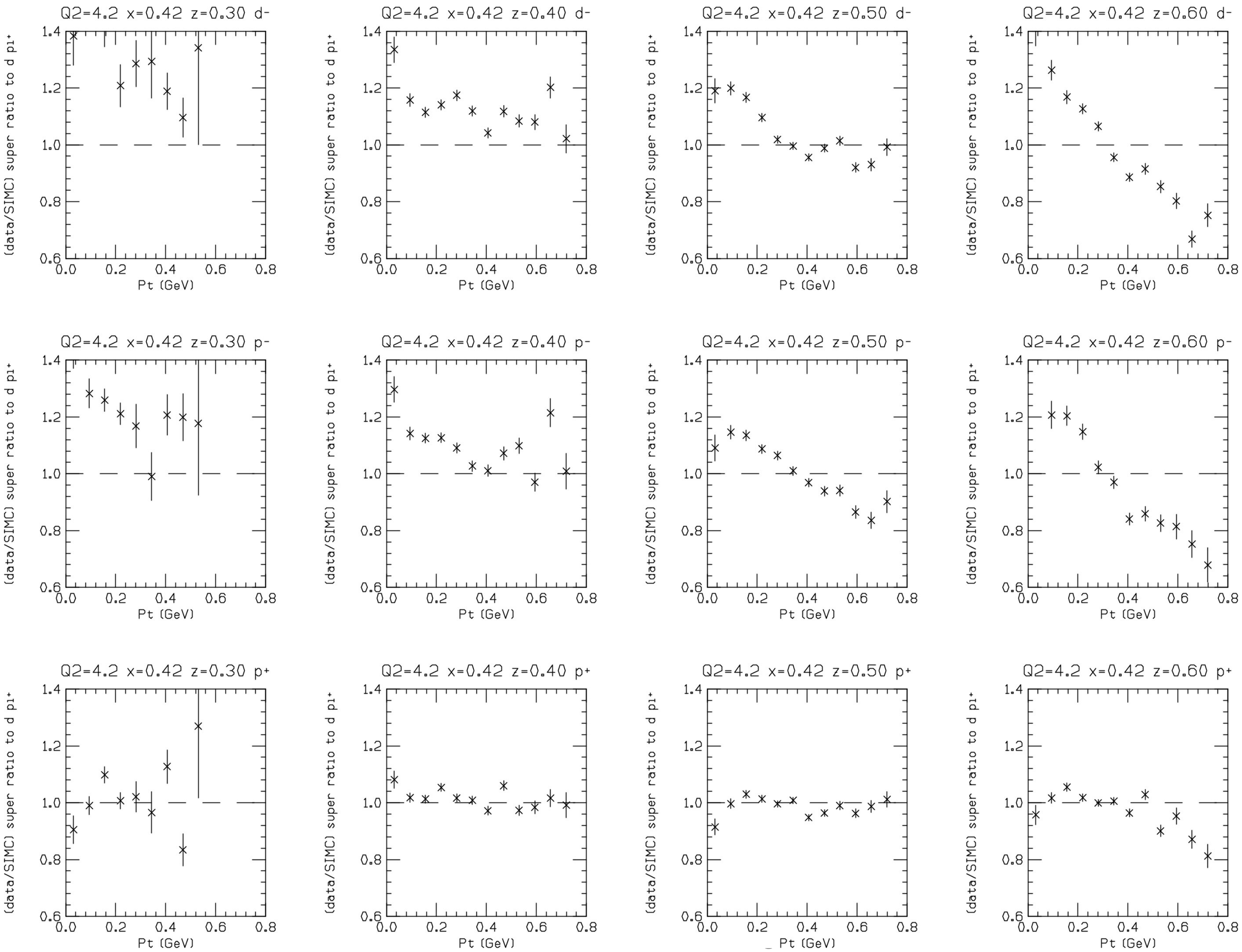
Super ratios (data/SIMC) to pi+ on deuteron Q2=3 x=0.3



Super ratios (data/SIMC) to pi+ on deuteron Q2=4.5 x=0.3



Super ratios (data/SIMC) to pi+ on d Q2=4.2 x=0.42



SIDIS fit

- Using MINUIT to fit about 50,000 cross section results from all three experiments. Parameters include :
- Pt-dependence of valance u and d quarks and sea quarks
- Pt and z dependence of both favored and unfavord fragmentation
- Cos(phi) and cos(2phi*) dependances on Pt, z, flavor
- Current results have much better chi2/d.f. than initial model, but some regions proving difficult to fit: may need additional higher twist terms. High z region is especially difficult.

Measurement of the ratio $R = \sigma_L/\sigma_T$ in Semi-Inclusive Deep Inelastic Scattering

E12-06-104, *Spokespersons:* P. Bosted, R. Ent, E. Kinney, and H. Mkrtchyan

- This experiment will make precise measurements of R in charged π and K SIDIS on H and D targets as a function of Q^2, fractional hadron momentum z, and hadron transverse momentum p_T

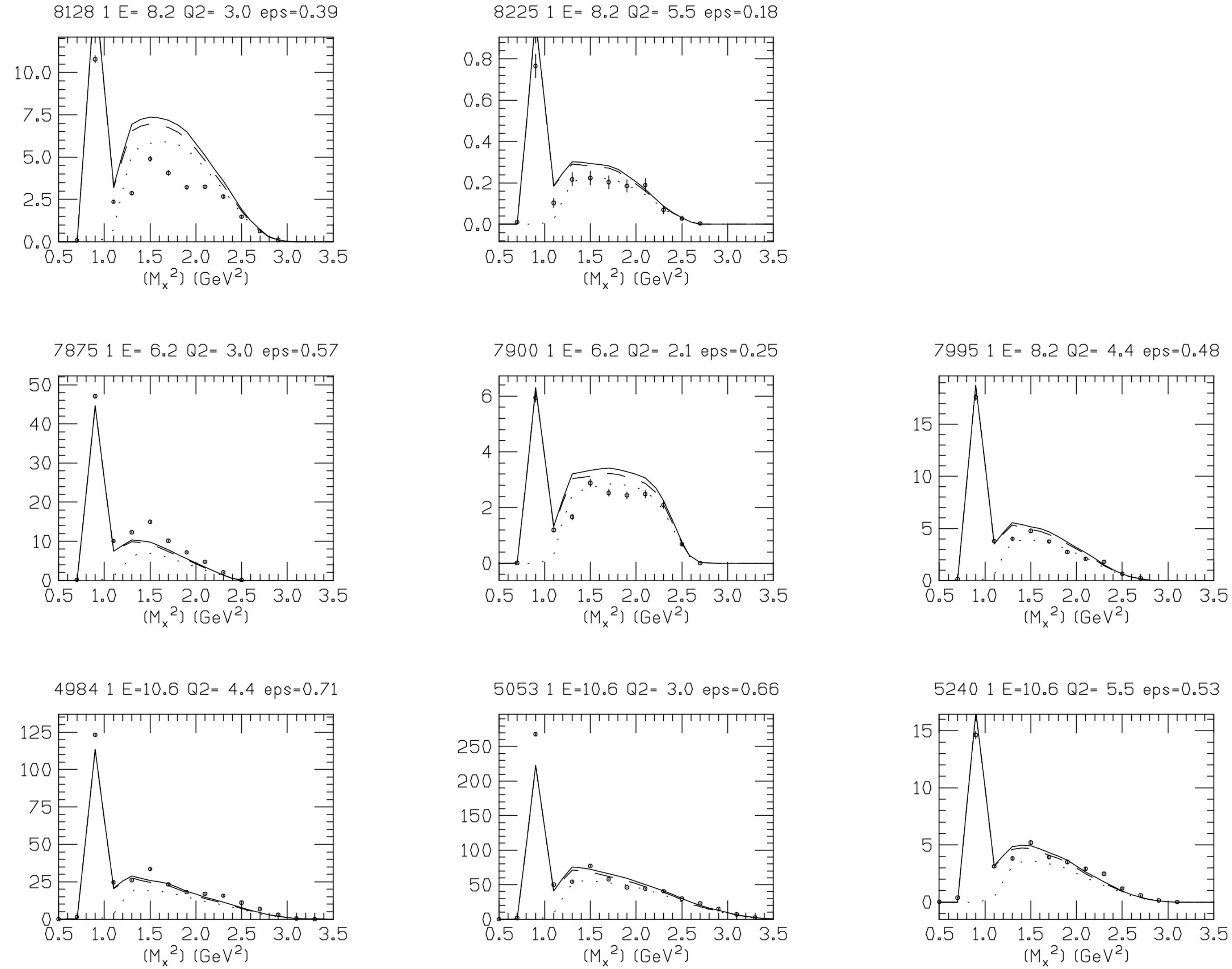
- Standard technique to measure R: Vary the virtual photon polarization ε by using different incident beam and electron scattering angles, while keeping the Q^2, x, z, and p_T constant. Will use the two magnetic spectrometers in Hall C.

$$\sigma = \Gamma(\sigma_T + \varepsilon\sigma_L + \varepsilon \cos(2\phi)\sigma_{TT} + [\varepsilon(\varepsilon+1)/2]^{1/2}\cos(\phi)\sigma_{LT})$$

First look at R-SIDIS at high z from KLT

- KLT runs have inelastic pions at z>0.75 for pi+ on proton
- Beam energies 6, 8, 10.6 GeV to provide range epsilon
- Plots on next slide show good agreement for exclusive pion peak in all cases (using param06 model)
- Inelastic data for E=10.6 generally agree well with SIMC model.
- At lower energies, model generally lower, but in one case it is the other way around. Very puzzling.
- Also, at lower Q2 and backward angles, clear peak from the Delta0 visible: s-channel
- More work needed, including looking at t-dependance

First look at R-SIDIS at high z from KLT



To-do list

- Study ep elastic runs for luminosity check and optics
- Fit Al/d ratios. Put fit in SIMC. Write paper on results
- Improve fit to SIDIS results on p,d, for pi+ and pi- . Put new fit in SIMC and iterate on results.
- Study systematic errors.
- Write paper on phi*, pt, z, Q2, x dependances of

cross sections (larger systematic errors) and ratios of cross sections (smaller systematic errors). Try to interpret in terms of different pt-widths for valance u, valance d, and sea quarks.

- Extract R at high z from KLT data. Write paper.
- Study ratio of K/pi. At first glance, not competitive with CLAS due to long length of SHMS. (most kaons decay away)

Ratios to Hydrogen π+ -2- January 2020

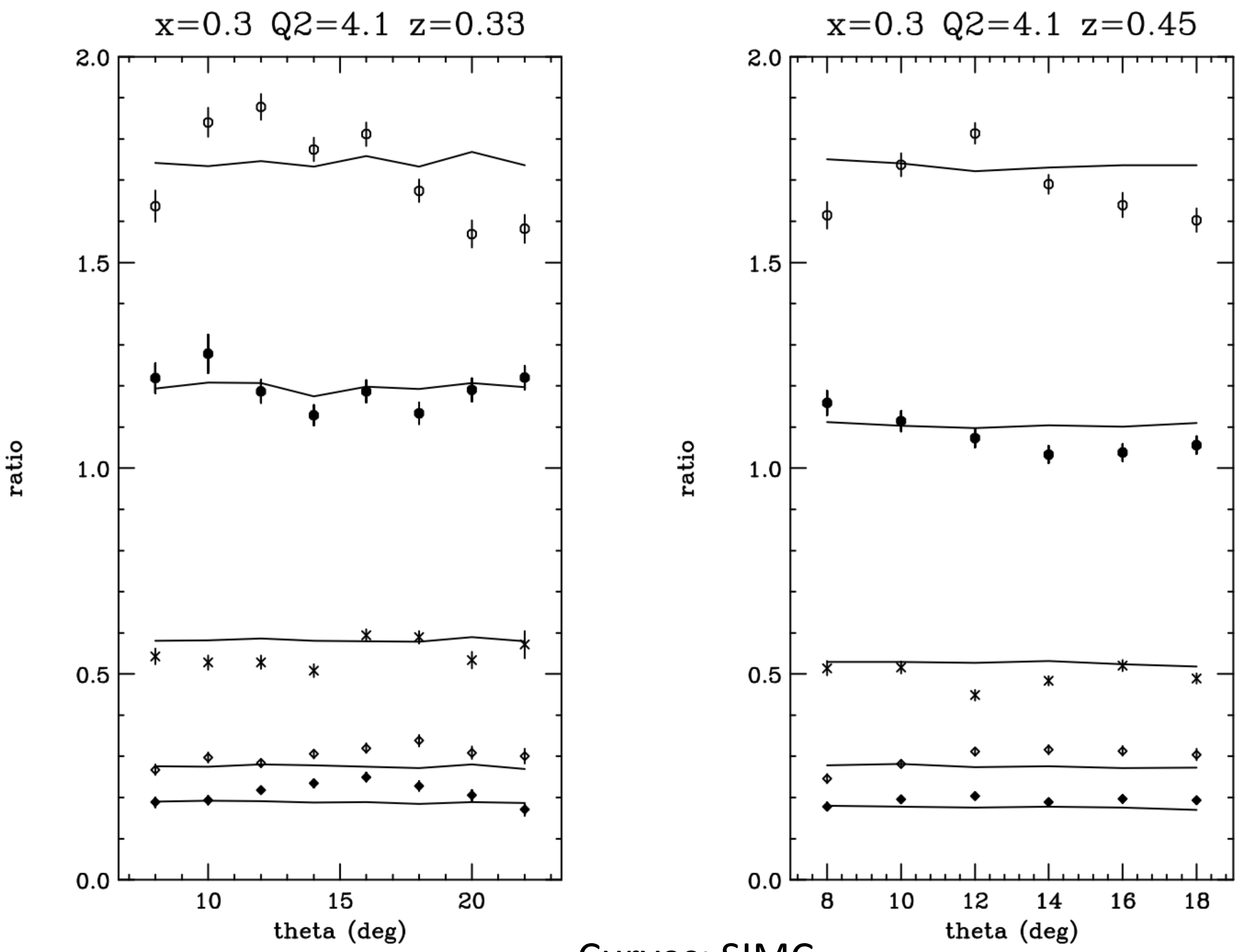
$^{2}H(\pi+)$

$^{2}H(\pi-)$

$^{1}H(\pi-)$

$Al(\pi+)$

$Al(\pi-)$



Curves: SIMC

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Ratios to Hydrogen π+ -2- July 2020

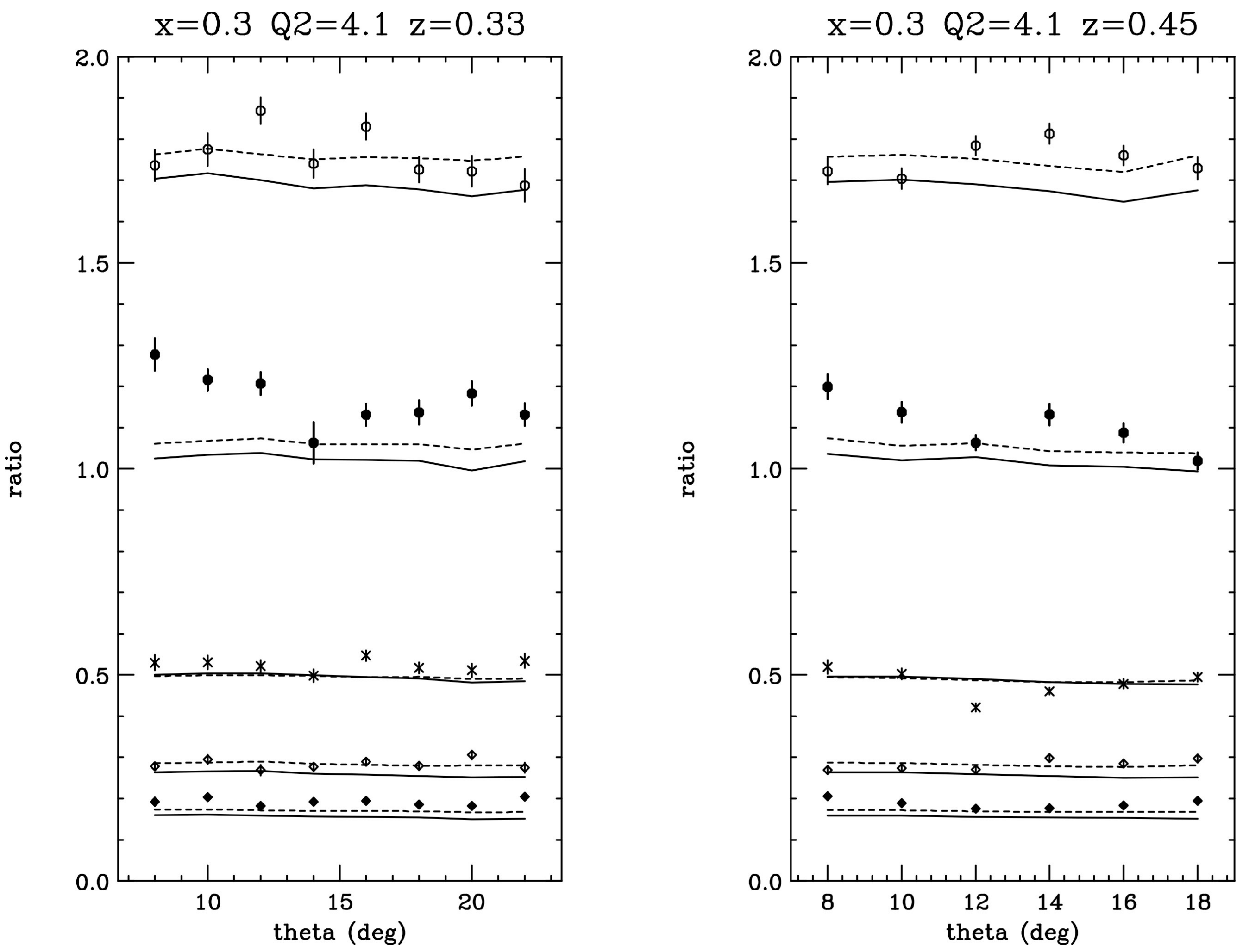
$^2H(\pi+)$

$^2H(\pi-)$

$^1H(\pi-)$

$Al(\pi+)$

$Al(\pi-)$



Curves: SIMC

Ratios to Hydrogen π+ -3- January 2020

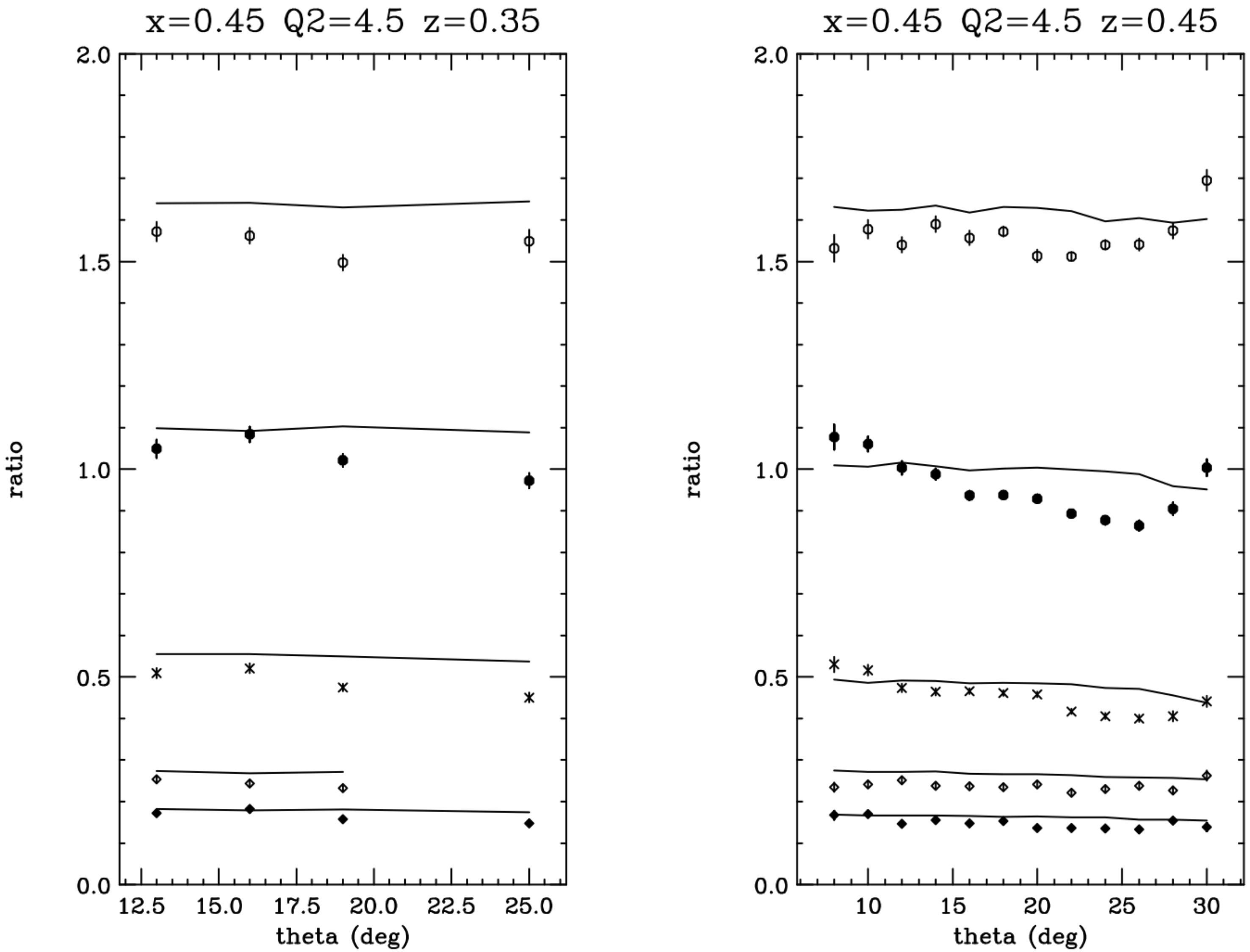
$^2H(\pi+)$

$^2H(\pi-)$

$^1H(\pi-)$

$Al(\pi+)$

$Al(\pi-)$



Curves: SIMC

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Ratios to Hydrogen π+ -3- July 2020

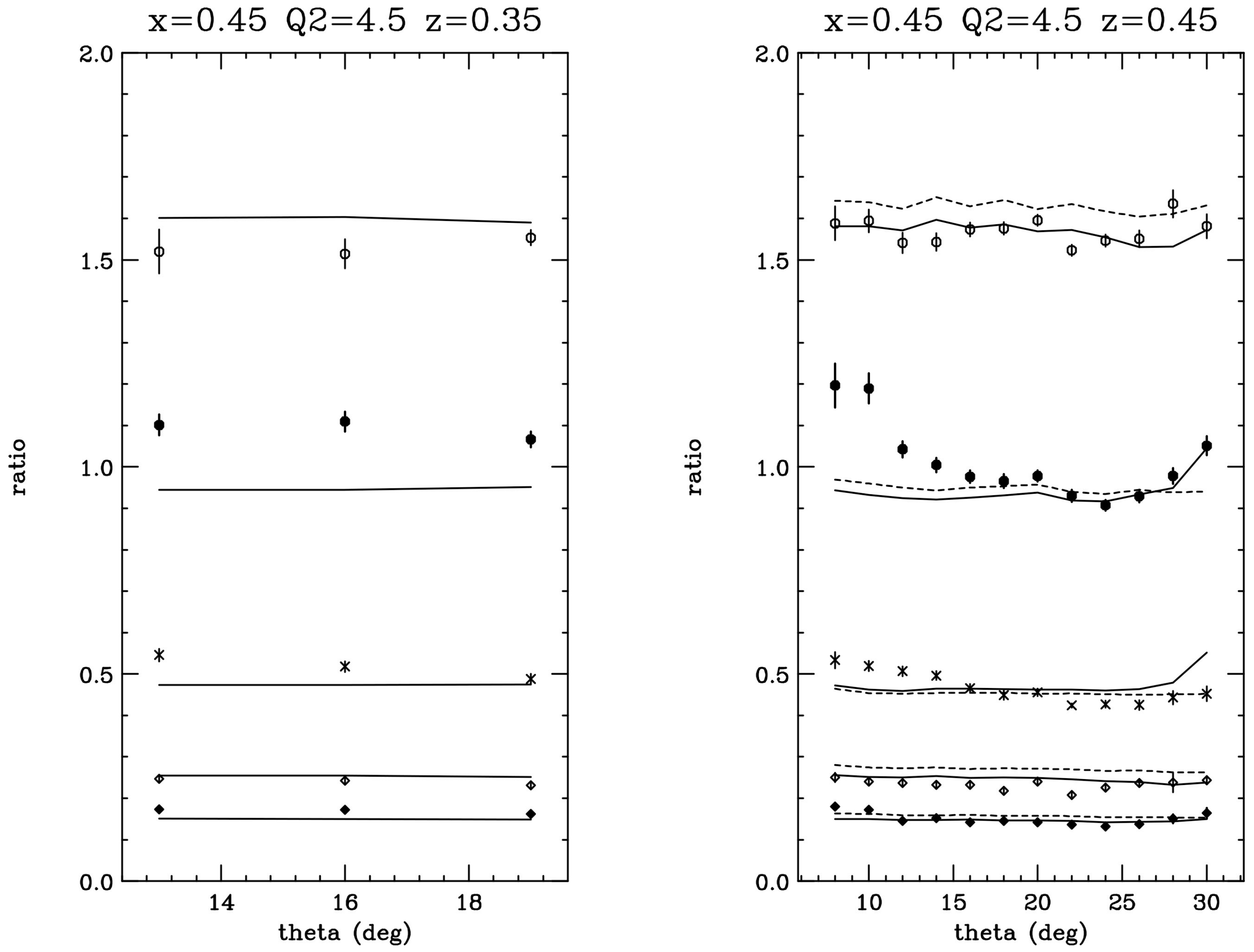
$^2H(\pi+)$

$^2H(\pi-)$

$^1H(\pi-)$

Al(π+)

Al(π-)



Big exclusive tails
Seen in data

Not seen in data

Curves: SIMC

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