Overview of SIDIS Experiments in Halls C

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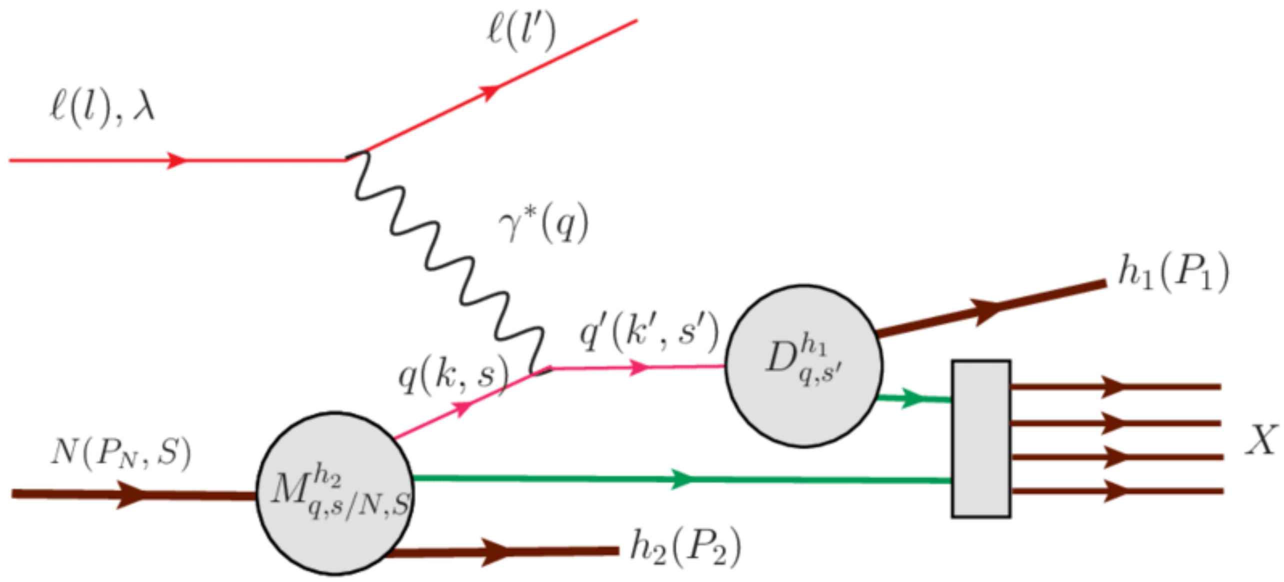


- Semi-Inclusive Deep Inelastic Scattering (SIDIS)
- Past, Present and Future of Hall C SIDIS
- Opinions

Preliminaries

- Thanks to the many people for sharing their slides from previous talks.

- My apologies in advance for any mis-statements or misrepresentations I may make; they are my mistakes, not yours!

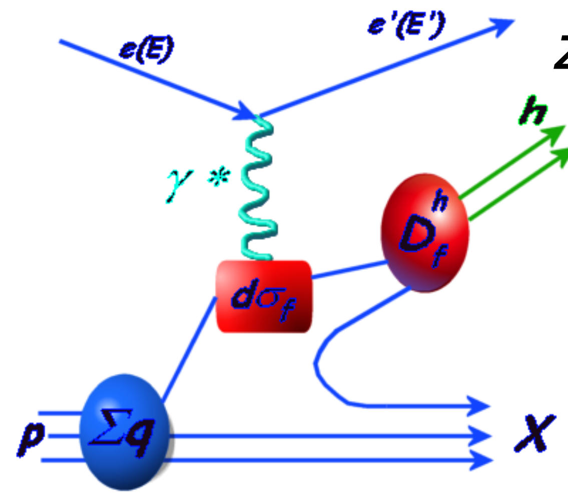
Do parton distributions and fragmentation functions factorize at Jefferson Lab energies?

Flavor Decomposition of SIDIS

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

$f_q(x)$: parton distribution function

$D_q^h(z)$: fragmentation function



$z = E_h/\nu$

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

- 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 $P_{h\perp}$

SIDIS in Hall C

Past

- E00-108: 6 GeV beam with HMS and SOS spectrometers $\pi^{+/-}$ (H,D)

Present

- E12-09-002 (CSV): 12 GeV with HMS and SHMS $\pi^{+/-}$ (D)
- E12-09-017 (pT-SIDIS) $\pi^{+/-}$, $K^{+/-}$ (H,D)

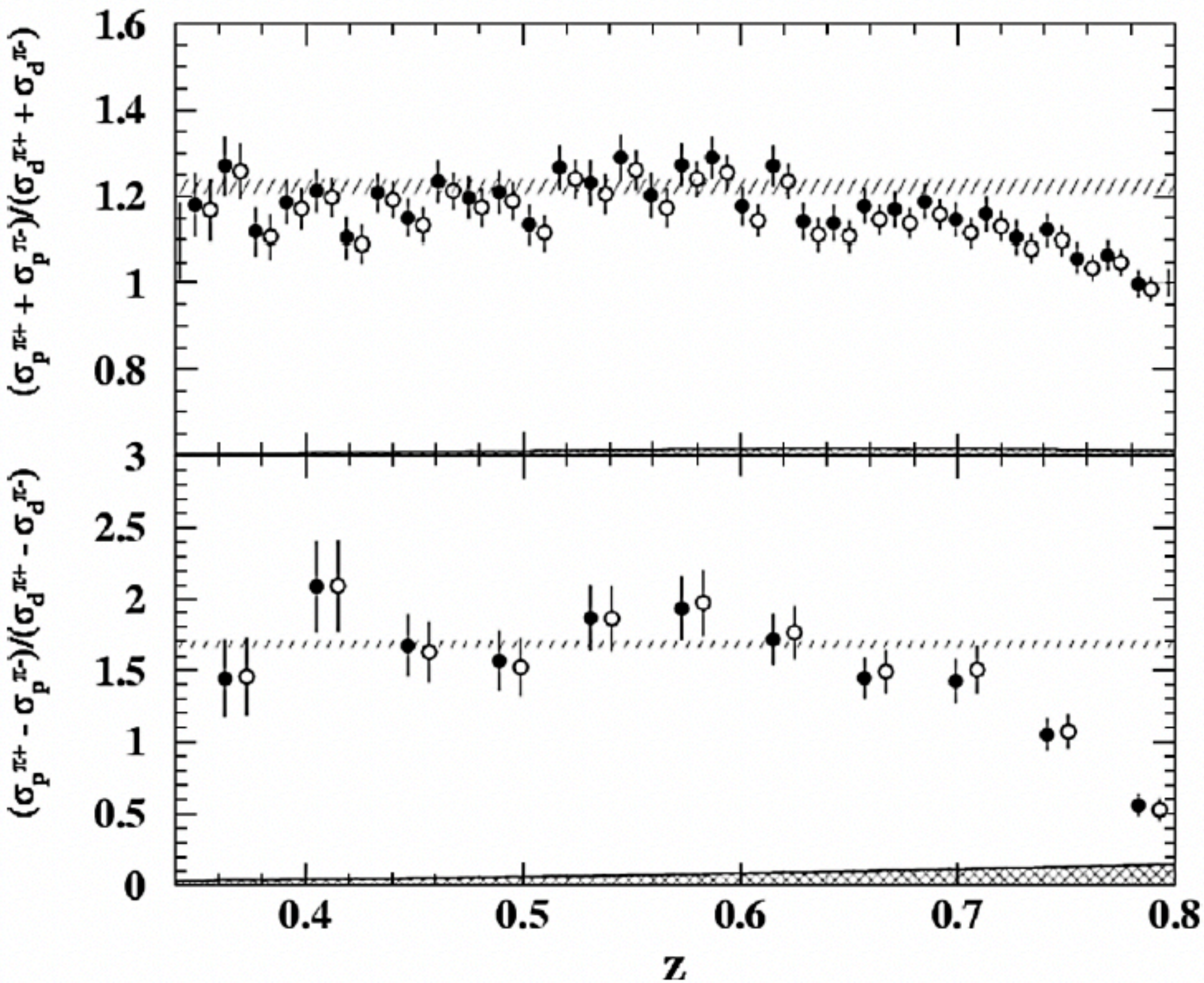
Future!

- E12-13-007 (π^0-SIDIS) HMS and NPS + PR12-23-014 (R) (H,D)
- E12-06-104 (R-SIDIS) $\pi^{+/-}$ (H,D)
- C12-15-006 Tagged DIS!

Past

Factorization Test: E00-108

$$\frac{\sigma_p(\pi^+) + \sigma_p(\pi^-)}{\sigma_d(\pi^+) + \sigma_d(\pi^-)} = \frac{4u(x) + 4\bar{u}(x) + d(x) + \bar{d}(x)}{5[u(x) + d(x) + \bar{u}(x) + \bar{d}(x)]}, \qquad \frac{\sigma_p(\pi^+) - \sigma_p(\pi^-)}{\sigma_d(\pi^+) - \sigma_d(\pi^-)} = \frac{4u_v(x) - d_v(x)}{3(u_v(x) + d_v(x))},$$



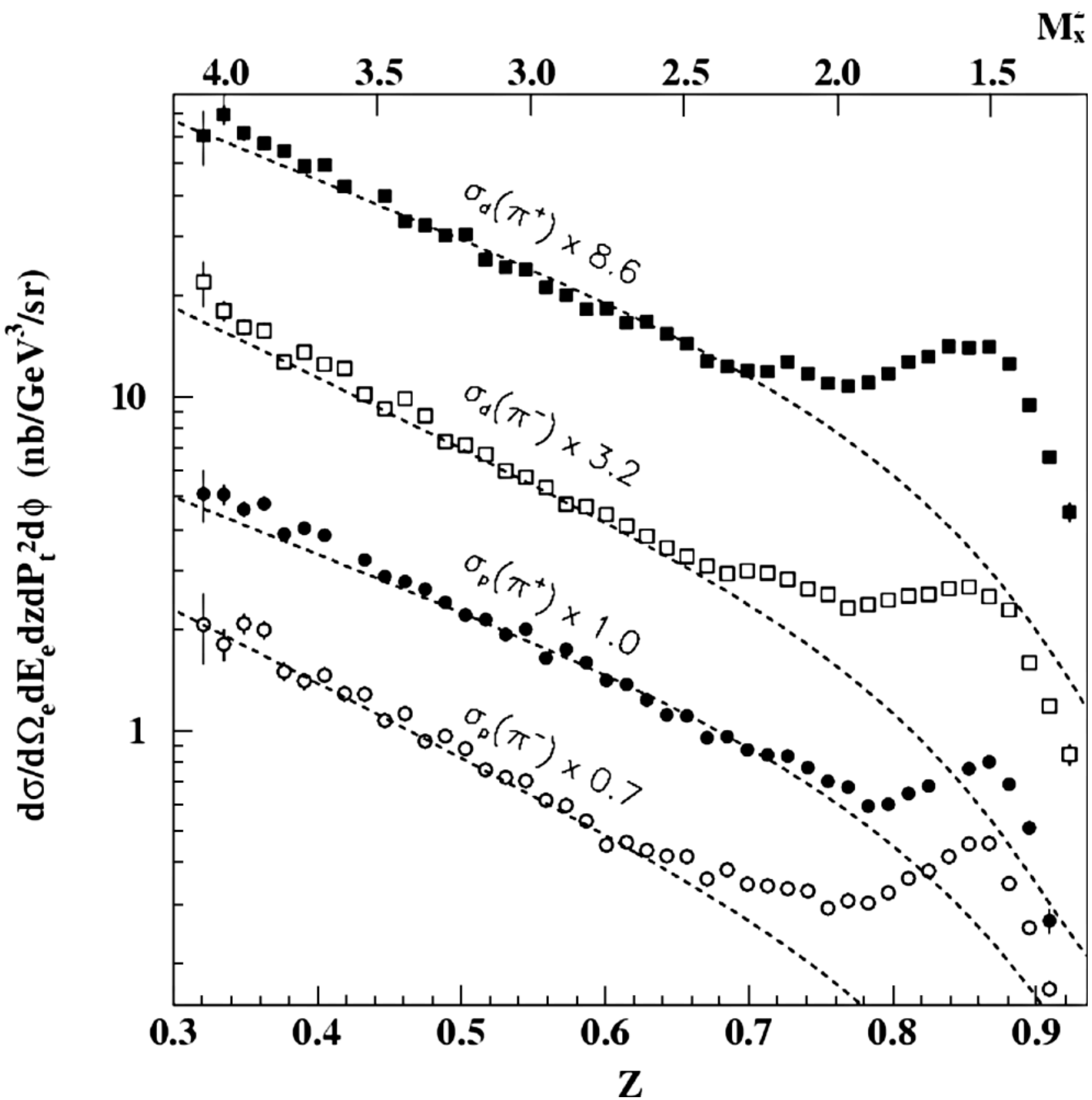
JLab E00-108 Results

T. Navasardyan et al., PRL 98 022001 (2007)

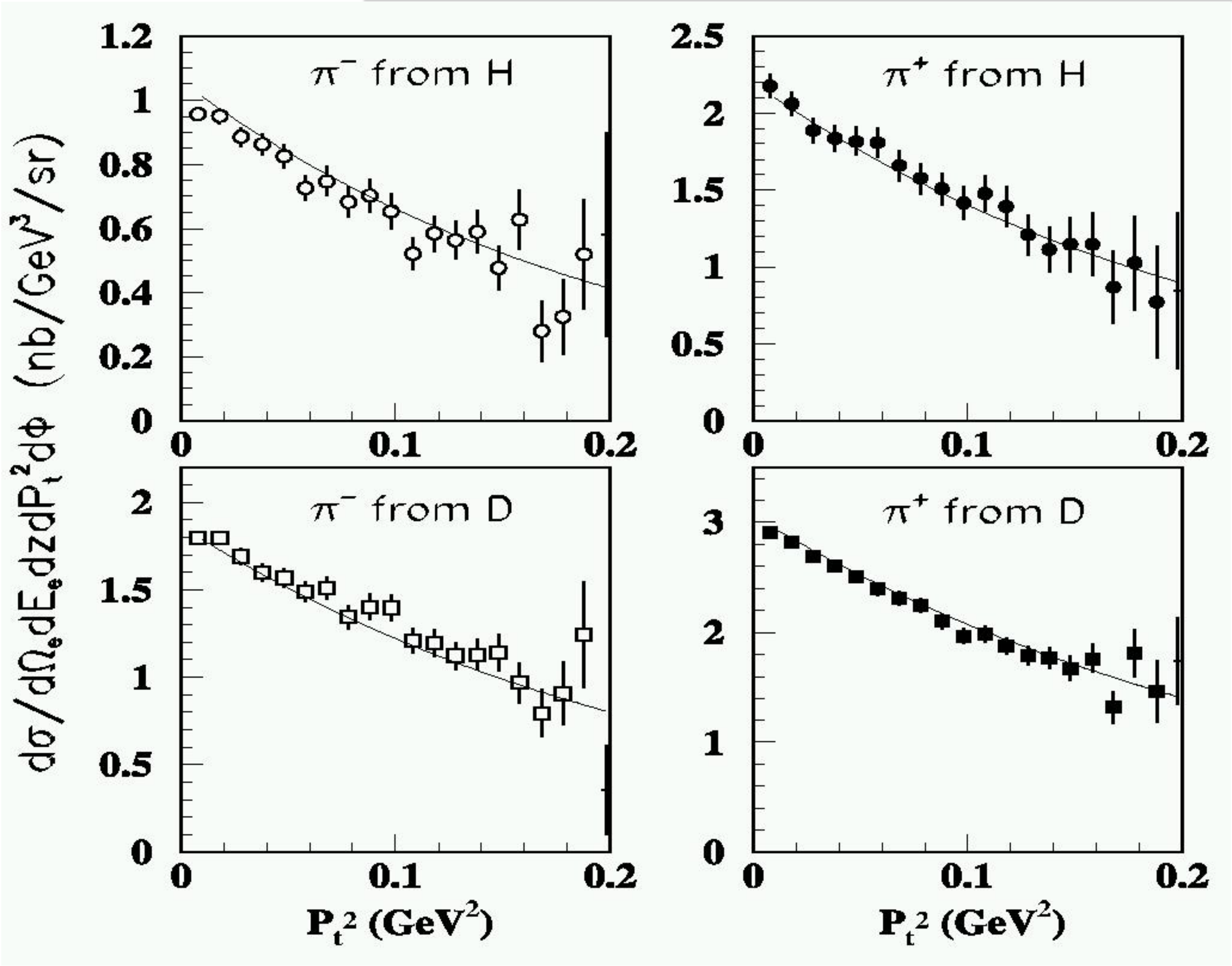
- Cross section/simulation based on factorization prediction

- Good Agreement at low z
- Delta Resonance at high z

T. Navasardyan et al., PRL 98 022001 (2007)



JLab Measurement: E00-108



- E= 5.5, x=0.3, Q^2=2.3
- Similar, but different slopes for H, D
- Using simple gaussian+Cahn model, combined data yields momentum widths of pdf and fragmentation functions

from Phys. Lett. B665 (2008) 20

Present

Charge Symmetry Violation (CSV) Experiment E12-09-002

Introduction

What is Charge symmetry?

Charge symmetry (CS) is a specific rotation in isospin space. It is the invariance with respect to rotation of π about the T2 axis.

$$[H, P_{CS}] = 0 \qquad P_{CS} = \exp(i\pi T2)$$

$$P_{CS}\,|d\rangle = |u\rangle \qquad P_{CS}\,|u\rangle = -\,|d\rangle$$

Low Energy: CS in nuclei

CS operator interchanges neutrons and protons

- pp and nn scattering lengths are nearly the same
- $M_n \simeq M_p$
- $B(n,{}^3He) \simeq B(p,{}^3H)$ and energy levels in other mirror nuclei are equal (to 1%)
- $m({}^3He) \simeq m({}^3H)$

After electromagnetic corrections CS respected down to $\sim$ 1%

QCD: Quark level

- $u^p(x,Q^2) = d^n(x,Q^2)$
  $d^p(x,Q^2) = u^n(x,Q^2)$
- Origin of CS violations:
  $\rightarrow$ Electromagnetic interaction
  $\rightarrow \delta m = m_d - m_u$

Naively, one would expect CSV would be on the order of $(m_d - m_u)/\langle M\rangle$, where $\langle M\rangle$ is roughly $0.5 - 1.0$ GeV
$\rightarrow$ CSV effect about 1%

CSV

Motivation

- **Charge symmetry violation** is an important ingredient for pushing the **precision frontier in the partonic structure of the nucleon**
- Charge symmetry is often assumed in extracting PDFs from data – where the data is limited in sensitivity to CS violation
- The validity of charge symmetry is a necessary condition for many relations between structure functions and sum rules
- Flavor symmetry violation extraction $\bar{u}(x) \neq \bar{d}(x)$ relies on the implicit assumption of charge symmetry (in the sea quarks)
- Charge symmetry violation viable part of explanation for the anomalous value of the Weinberg angle extracted by NuTeV experiment
- CSV is related to our understanding of the flavor dependence of the quark masses (one of the key unsolved problems in Physics –
  why is $m_d \sim m_u \neq m_s \neq m_c \neq m_b \neq m_t$)

SIDIS Formalism

Charge Symmetry Violation

In the PDFs:

$\delta d(x) = d^p(x) - u^n(x), \delta u(x) = u^p(x) - d^n(x).$

$$CSV(x) = \delta d - \delta u$$

In Fragmentation Functions

$$\delta D(z) = \frac{D_u^{\pi^+} - D_d^{\pi^-}}{D_u^{\pi^+}}$$

Leading order methodology for iso-scaler targets (Londergan, Pang, and Thomas PRD54(1996)3154)

$$R^D_{meas}(x,z) = \frac{4N^{D\pi^-}(x,z) - N^{D\pi^+}(x,z)}{N^{D\pi^+}(x,z) - N^{D\pi^-}(x,z)} = \frac{4R_Y(x,z) - 1}{1 - R_Y(x,z)} \tag{1}$$

where $N^{D\pi^\pm}(x,z)$ is the **measured yield** of $\pi^\pm$ electroproduction on a deuterium target, $R_Y = N^{D\pi^-}/N^{D\pi^+}$ is the yield ratio, and we rely the following:

Factorization

$$N^{\mathrm{N}h} \propto \sum_i e_i^2 q_i^{\mathrm{N}}(x) D_i^h(z)$$

Impulse Approximation

$$N^{D\pi^\pm}(x,z) = N^{p\pi^\pm}(x,z) + N^{n\pi^\pm}(x,z)$$

CSV in the Valence Region

Leading order experimental analysis → will need higher order global analysis

Londergan, Pang and Thomas PRD54(1996)3154

$$D(z)\ R(x,z) + A(x)CSV(x) + F(z)\delta D(z) = B(x,z)$$

$$D(z) = \frac{1-\Delta(z)}{1+\Delta(z)}, \Delta(z) = \frac{D_u^{\pi^-}(z)}{D_u^{\pi^+}(z)}$$

$$CSV(x) = \delta d - \delta u$$

$$R(x,z) = \frac{5}{2} + R^D_{meas}$$

$$A(x) = \frac{-4}{3(u_v + d_v)}$$

$$F(z) = \frac{4+\Delta(z)}{3(1-\Delta^2(z))}$$

$$B(x,z) = \tfrac{5}{2} + R^D_{sea\_S}(x,z) + R^D_{sea\_NS}(x)$$

$$R^D_{sea_{NS}}(x) = \frac{5(\overline{u}^p(x) + \overline{d}^p(x)}{[u_v^p(x) + d_v^p(x)]}$$

$$R^D_{sea_S}(x,z) = \frac{\Delta_s(z)[s(x)+\overline{s}(x)]/(1+\Delta(z))}{[u_v^p(x) + d_v^p(x)]}$$

$$\Delta_s(z) = \frac{D_s^-(z) + D_s^+(z)}{D_u^+(z)}$$

$A(x)$ and $B(x,z)$ are computed from PDF and FF fits

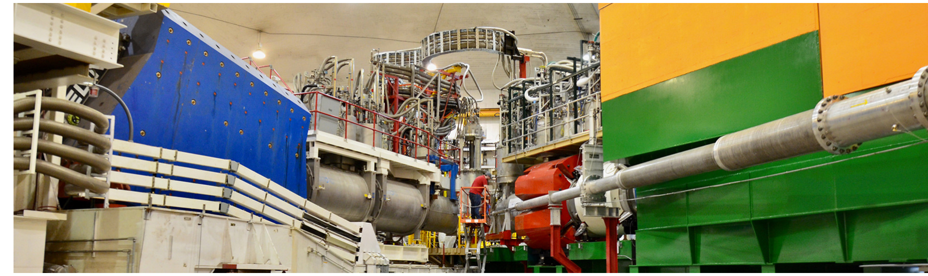
CSV

Extract simultaneously D(z) and CSV(x) from each (Q^2,x) setting

CSV

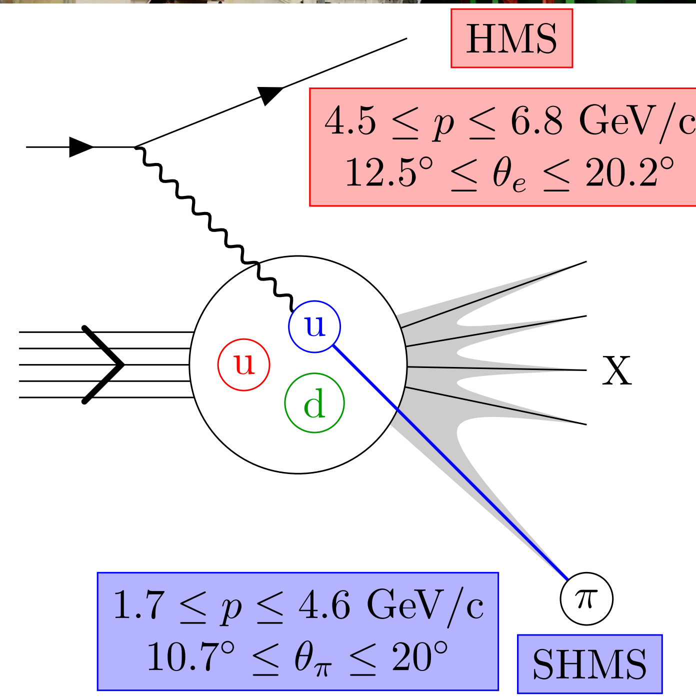
Experiment in Hall C – E12-09-002

Measurements: D$(e, e'\pi^+)$ and D$(e, e'\pi^-)$



Setup

- 11 GeV e^- beam
- 10 cm LD$_2$ target
- SHMS $\rightarrow \pi^\pm$, HMS $\rightarrow e'$



Each x setting has 4 z measurements

z_j = 0.4, 0.5, 0.6, 0.7

$$R_Y(x,z) = Y^{D\pi^-}(x,z)/Y^{D\pi}(x,z)$$

$$\boxed{R^D_{\text{Meas}}(x,z) = \frac{4R_Y(x,z) - 1}{1 - R_Y(x,y)}}$$

Q^2 = 3.5 GeV^2 $\rightarrow$ x = 0.30, 0.35, 0.40, 0.45
Q^2 = 5.1 GeV^2 $\rightarrow$ x = 0.45, 0.50, 0.55, 0.60

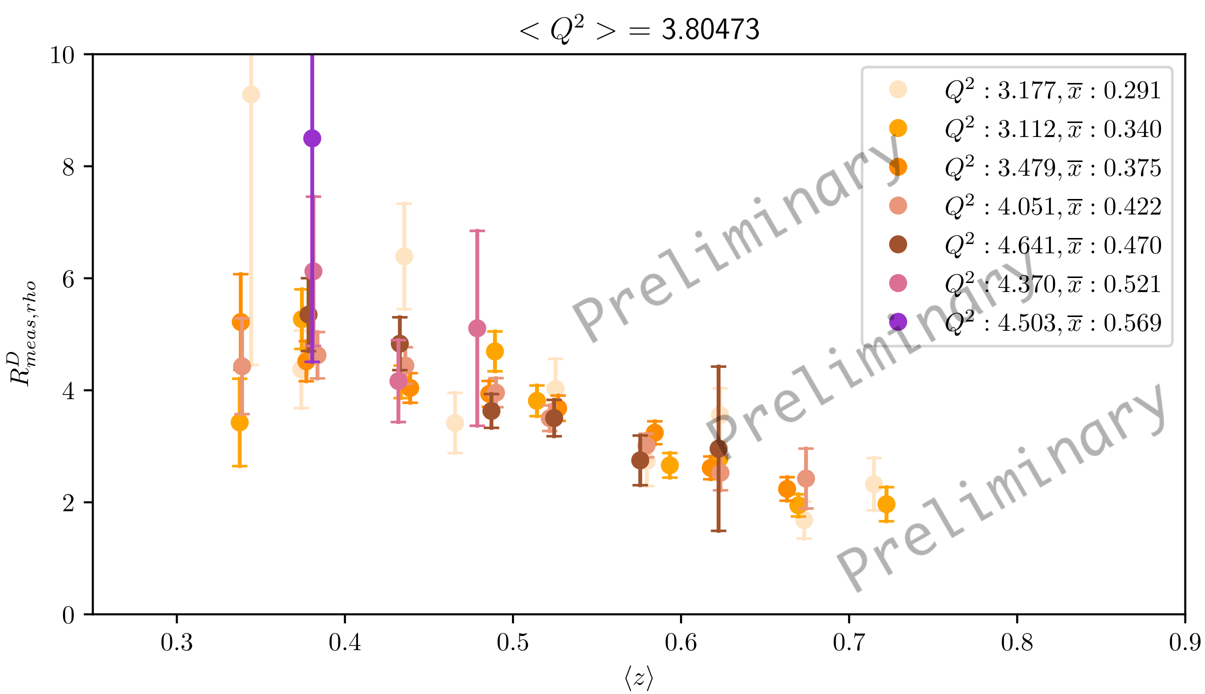
Assuming $\delta D(z) = 0$, for each Q^2 we have 16 equations and 8 unknowns: $D(z_j)$ and $CSV(x_i)$

$$D(z)\ R(x,z) + A(x)CSV(x) = B(x,z)$$

CSV

R^D_{meas} Results

$$D(z)\ R(x,z) + A(x) CSV(x) = B(x,z)$$
$$R(x,z) = \frac{5}{2} + R^D_{meas}(x,z)$$



$R^D_{meas}(x,z)$ for $Q^2 = 4$ GeV^2 bin projected on z axis.
$R^D_{meas}(x,z) = \frac{4R_Y(x,z)-1}{1-R_Y(x,z)}$

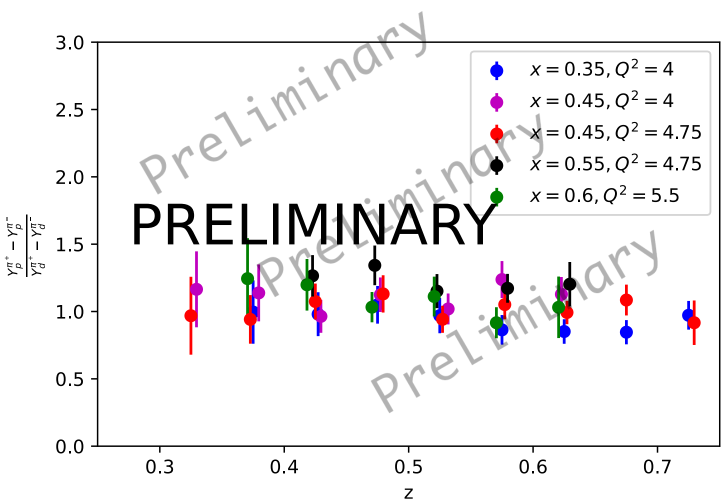
CSV

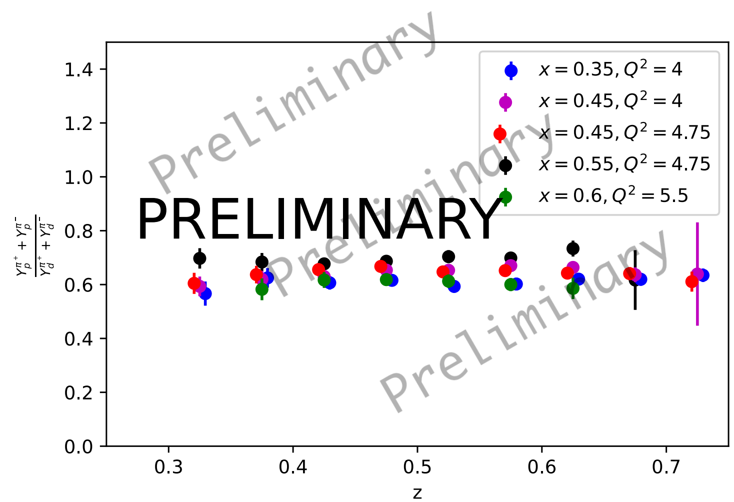
Factorization

Charge Ratio Sum and Differences

$$\frac{\sigma_p^{\pi^+} - \sigma_p^{\pi^-}}{\sigma_d^{\pi^+} - \sigma_d^{\pi^-}} = \frac{4u_v(x) - d_v(x)}{3\left(u_v() + d_v(x)\right)} = R^-$$

$$\frac{d_v}{u_v} = \frac{4 - 3R^-}{3R^- + 1}$$





Ratios should not depend on z.

$$\frac{\sigma_p^{\pi^+} + \sigma_p^{\pi^-}}{\sigma_d^{\pi^+} + \sigma_d^{\pi^-}} = \frac{4u + 4\overline{u} + d + \overline{d}}{5(u + \overline{u} + d + \overline{d})}$$

Simultaneous Extraction of $\Delta(z)$ and $CSV(x)$

Fragmentation ratio and valence CSV parton distribution

Four parameter fit

$$\Delta(z) \equiv \frac{D_u^{\pi^-}(z)}{D_u^{\pi^+}(z)} = z^\alpha(1-z)^\beta$$

$$CSVx \equiv \delta d - \delta u = x^a(1-x)^b(x-c)$$

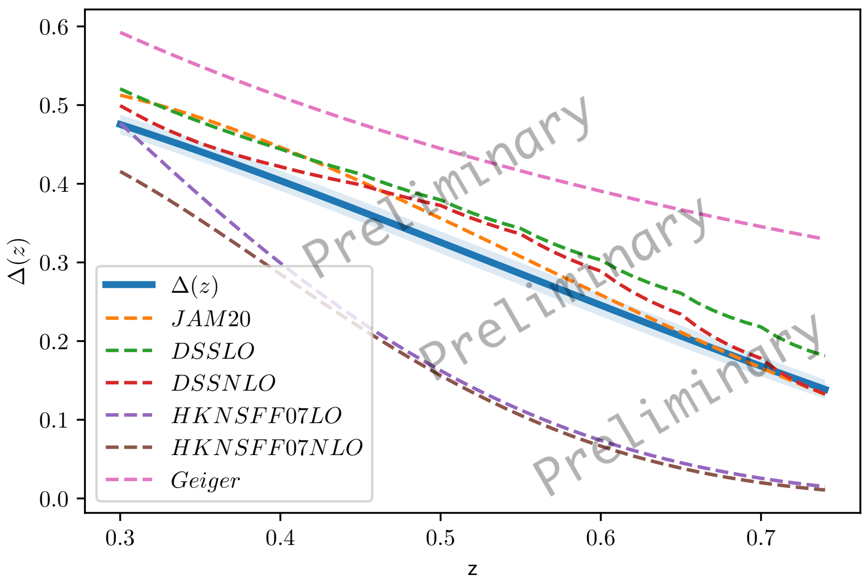
c is determined from the constraint: $\int_0^1 CSV(x)dx = 0$

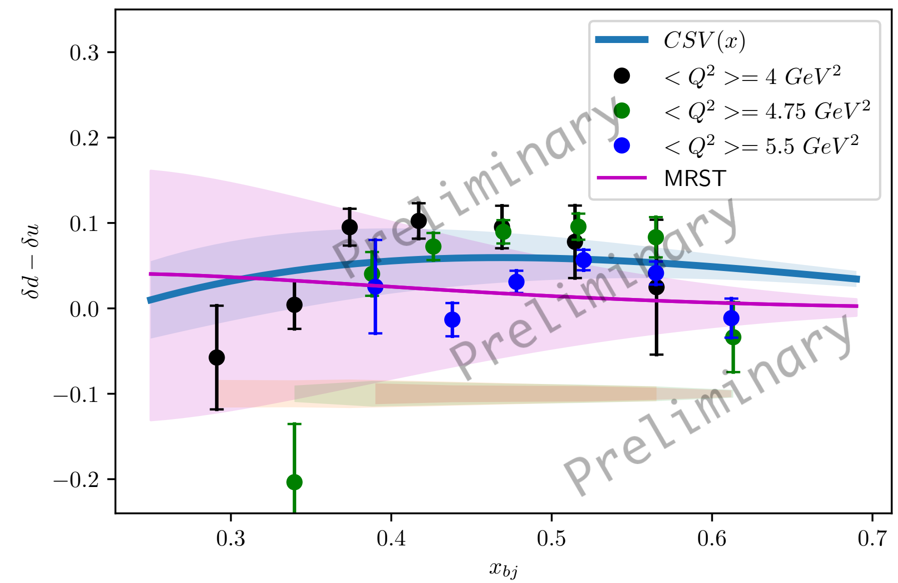
$$c = \frac{\int_0^1 x^{(a+1)}(1-x)^b}{\int_0^1 x^a(1-x)^b} = \frac{B(a+2,b+1)}{B(a+1,b+1)}, B(x,y) = \frac{\Gamma(x)\Gamma(y)}{\Gamma(x+y)}$$

$$R^D_{fit}(x,z) = \frac{B(x,z) - A(x)CSV(x)}{D(z)} - \frac{5}{2}$$

CSV

Results after standard ρ background subtraction





$$\Delta(z) \equiv D_u^{\pi^-}(z)/D_u^{\pi^+}(z) = z^\alpha(1-z)^\beta$$

$$CSVx \equiv \delta d - \delta u = x^a(1-x)^b(x-c)$$

The data points on the right are plotted using the extracted Δ, $R^D_{meas}(x,z)$, and the equation below

$$CSV(x) = \frac{B(x,z) - D(z)\ R(x,z)}{A(x)}$$

Jefferson Lab Exp. E12-09-017: Precise measurements of $(e,e'\pi^{\pm})$ and $(e,e'K^{\pm})$ cross sections at Semi-Inclusive Deep Inelastic Scattering (SIDIS) Kinematics

- Precise measurements to test the assumptions of factorization of SIDIS process at photon invariant momentum transfer $Q^2=q^2-\nu^2$, at moderate Bjorken $x = Q^2/2M\nu$ (M is proton mass)
- Allow exploration of assumptions of favored/disfavored fragmentation of different flavor quarks using ^1H and ^2H targets
- Investigate possible target mass effects
- Investigate possible higher twist effects
- Complement SIDIS measurements in large open acceptance detector CLAS at Jefferson Lab Hall B

SIDIS cross section with Transverse Momentum-dependent Parton and Fragmentation Distributions (TMDs)

$f_q(x, \mathbf{k}_\perp)$ *: parton distribution function as function of intrinsic parton k_T*

$D_q^h(z, \mathbf{p}_\perp)$ *: fragmentation function as a function of fragmentation p_T*

Cross section for SIDIS hadron of fractional energy z_h and transverse momentum P_T

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

from Anselmino et al. (hep-ph/0412316v1)

Experiment E12-09-017: pT SIDIS

Model for basic data interpretation

- Now perform $k_\perp$ integration and keep terms order $O(k_\perp/Q)$ on previous cross section expression to get

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

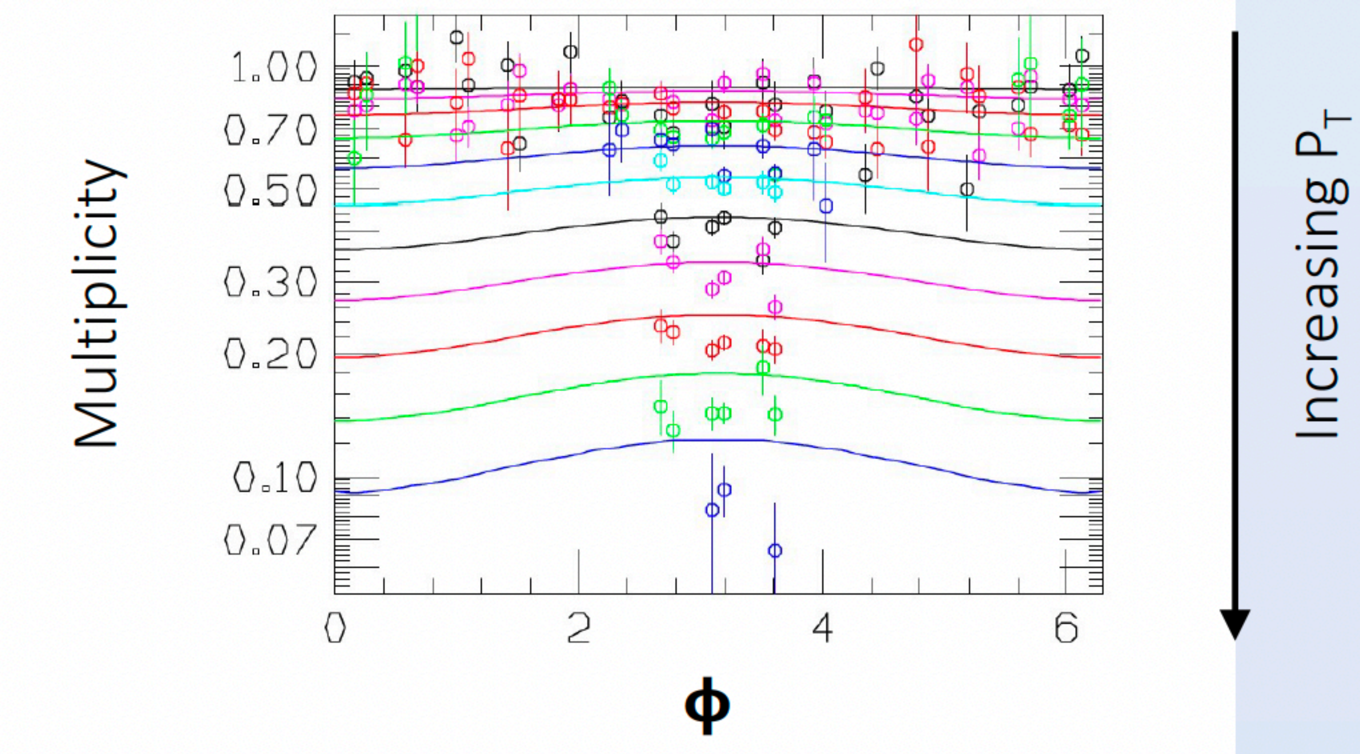
where $\langle P_T^2\rangle = \langle p_T^2\rangle + z_h^2\langle k_\perp^2\rangle$

- At each (x, Q^2 ,z) fit multiplicities with $y = M_0 b e^{-bP_T^2}\left(1 + AP_T cos(\phi)\right)$
- Fit parameters are M_0 , A, and $b = 1/\langle P_T^2\rangle$
- Results very preliminary

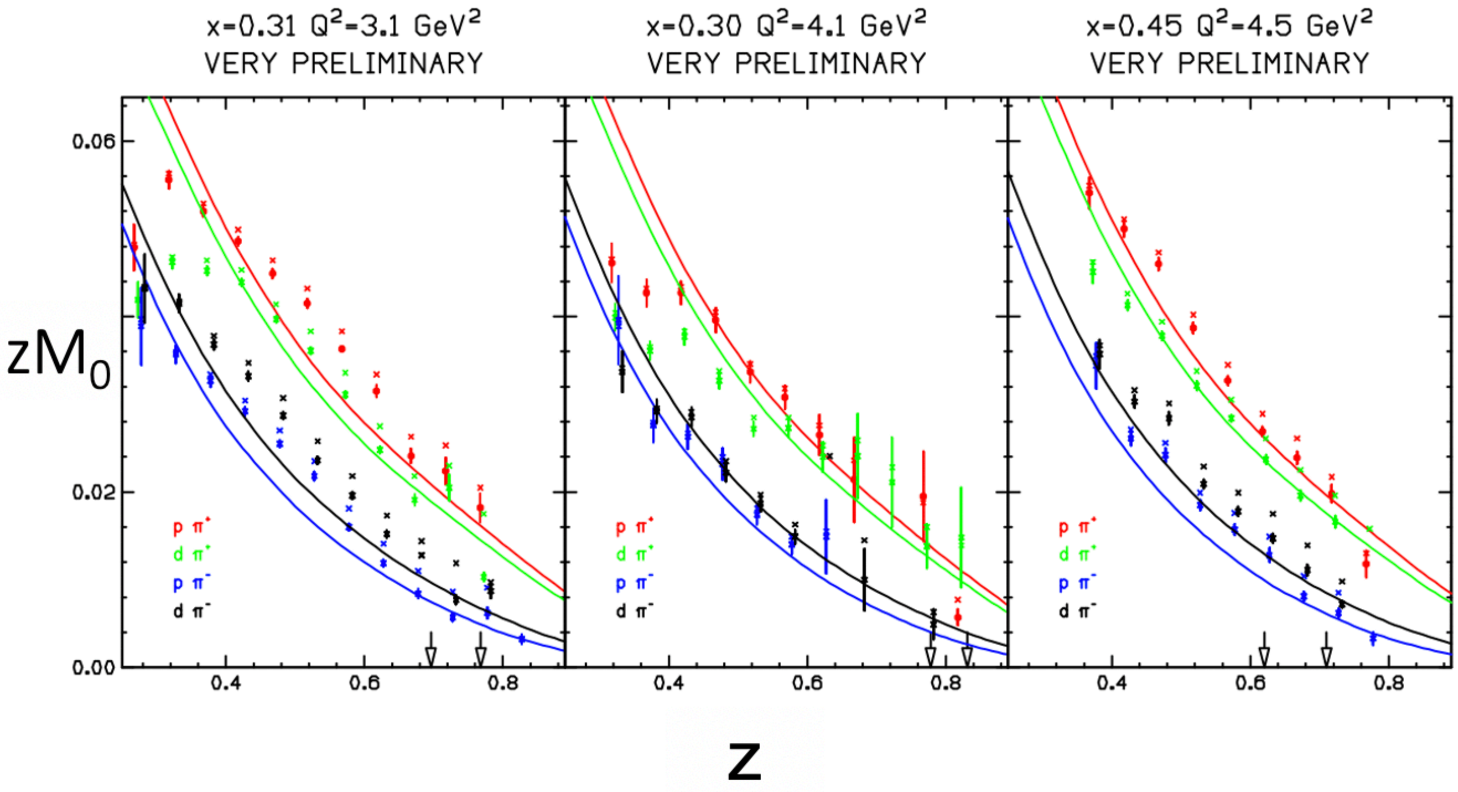
Experiment E12-09-017: pT SIDIS

Example of fits of parameterization to multiplicities

$\pi+$ x=0.31 Q2 = 3.1 z = 0.33 N=151 χ^2/dof = 1.9

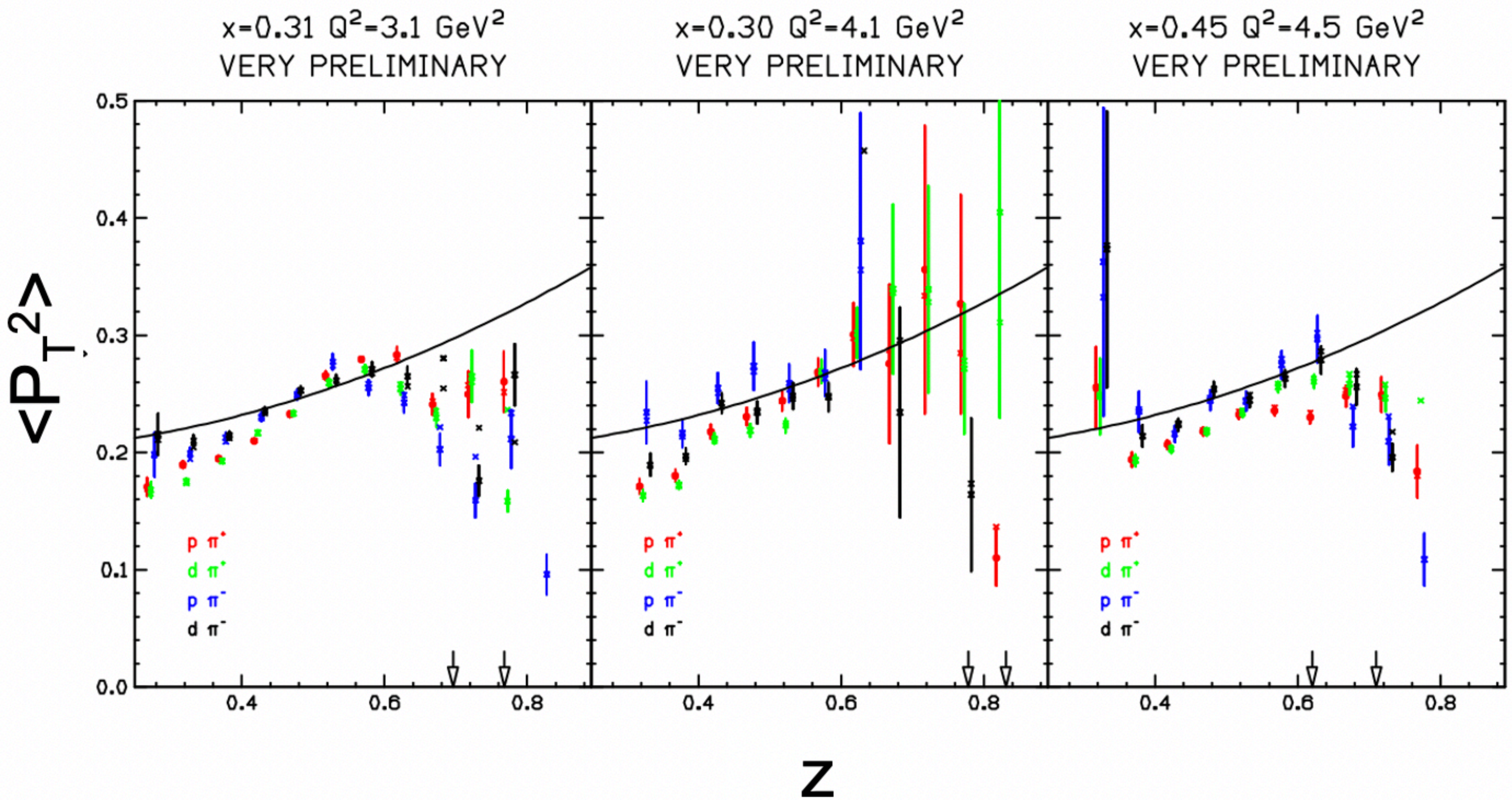


Fit Results for $y = M_0 b e^{-bP_T^2}(1 + AP_T cos(\phi))$ Parameters



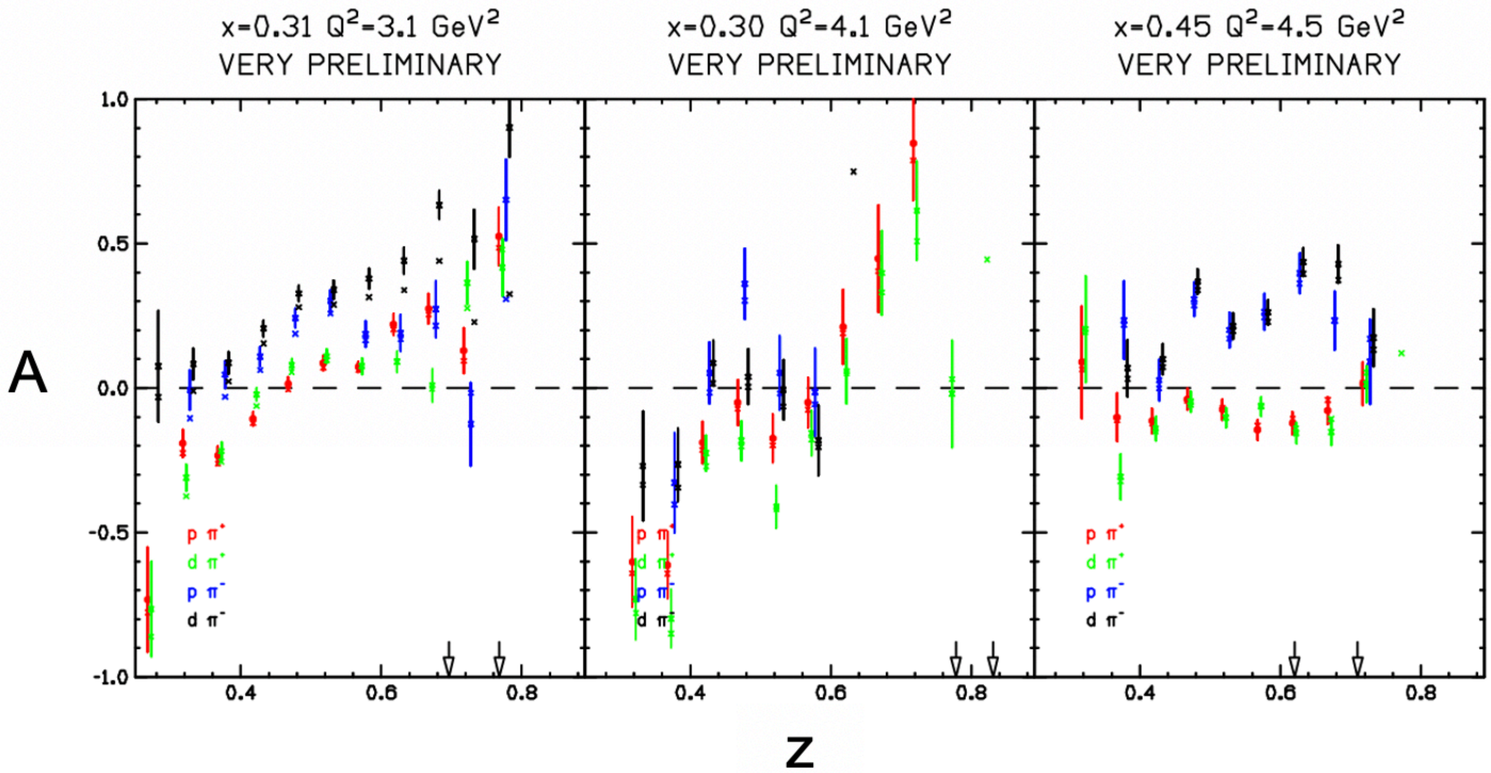
Curves are DSS frag. functions with CTEQ5 pdfs. The solid circles are with DVM **ρ** subtraction, while the crosses are with no **ρ** subtraction. The left-hand arrow shows the z value for (W')**2=3 GeV, while the right-hand arrow is for (W')**2 = 2.5 GeV**2.

Fit Results for $y = M_0 b e^{-bP_T^2}(1 + AP_T cos(\phi))$ Parameters



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 (0.2 GeV^2 here) for both favored and unfavored FF), and $\langle k_\perp^2 \rangle$ is the intrinsic q transverse momentum width (also 0.2 GeV^2) for both u and d quarks.

Fit Results for $y = M_0 b e^{-bP_T^2}(1 + AP_T cos(\phi))$ Parameters



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

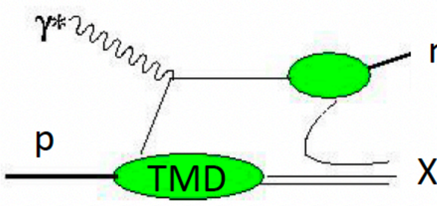
Future

Experiment E12-13-007: π^0 SIDIS

E12-13-007 – SIDIS basic (e,e'π^0) cross sections

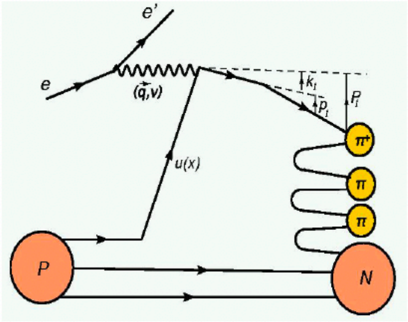
Linked to framework of *Transverse Momentum Dependent Parton Distributions*

- Validation of factorization theorem needed for most future SIDIS experiments and their interpretation
- Need to constrain TMD evolution w. precision data
- Questions on target-mass corrections and ln(1-z) re-summations require precision large-z data



$TMD^q(x,k_T)$

Transverse momentum widths of quarks with **different flavor (and polarization)** can be different



$P_T = p_t + z\, k_t + O(k_t^2/Q^2)$

E12-13-007 goal: Measure the basic SIDIS cross sections of π^o production off the proton, including a map of the P_T dependence ($P_T \sim \Lambda < 0.5$ GeV), to validate(*) flavor decomposition and the k_T dependence of (unpolarized) up and down quarks

(*) Can only be done using spectrometer setup capable of %-type measurements (an essential ingredient of the global SIDIS program!)

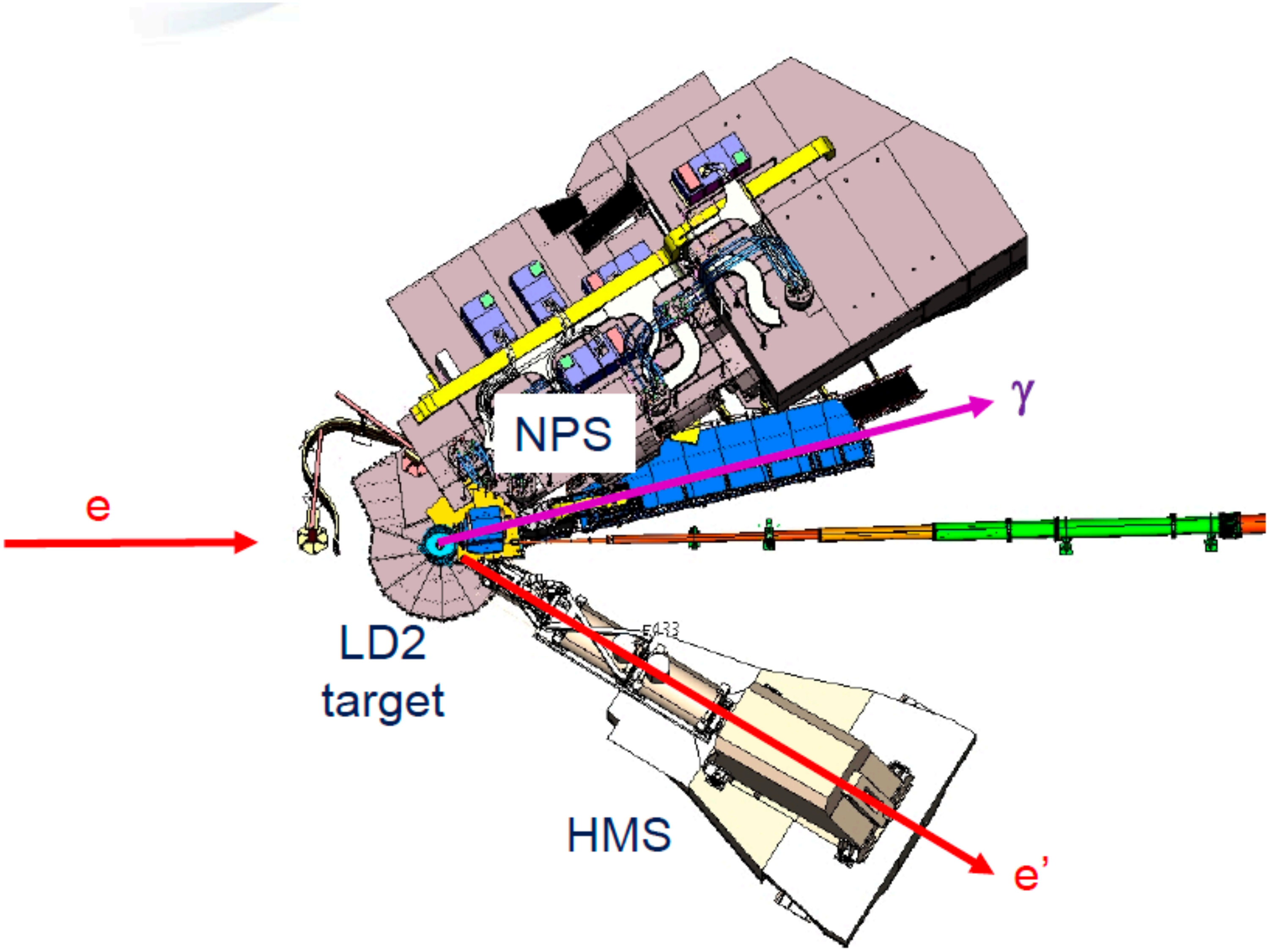
Requires new ~25 msr Neutral-Particle Spectrometer

Advantages of (e,e'π^o) beyond (e,e'$\pi^{+/-}$)

- ❑ Many experimental and theoretical advantages to validate understanding of SIDIS with neutral pions
- ❑ Can verify: $\sigma^{\pi^o}(x,z) = ½ (\sigma^{\pi^+}(x,z) + \sigma^{\pi^-}(x,z))$
- ❑ Confirms understanding of flavor decomposition/k_T dependence

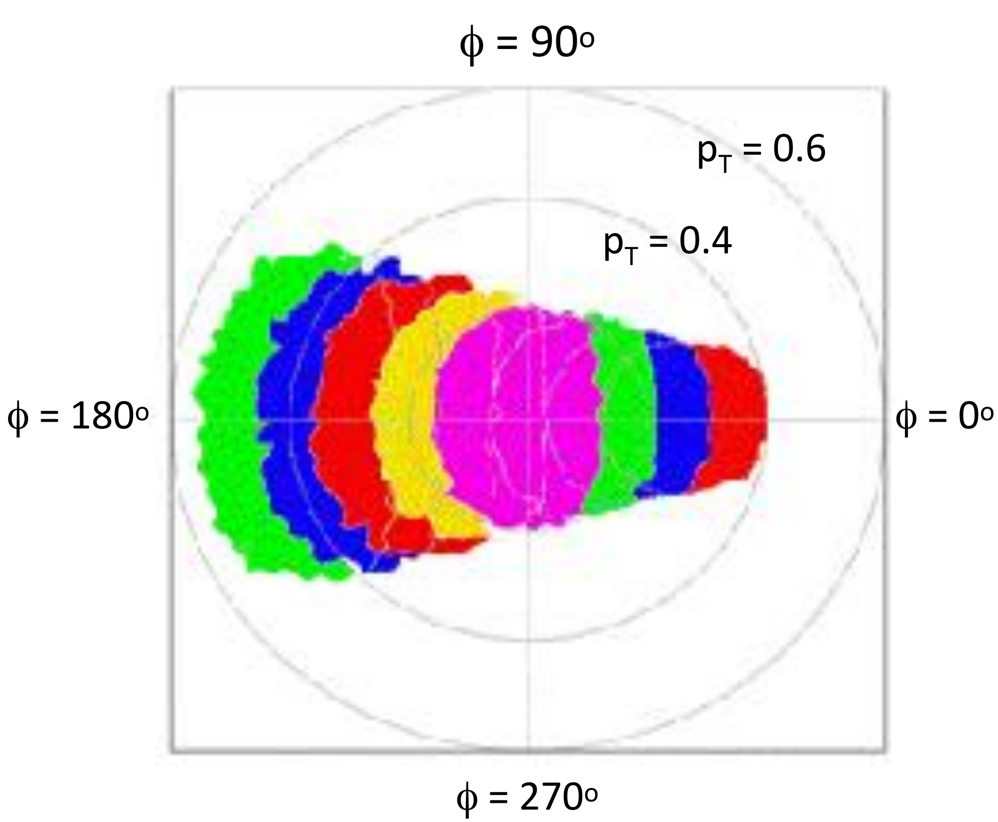
PAC: "the **cross sections** are **such basic tests of the understanding of SIDIS** at 11 GeV kinematics that they will play a **critical role** in establishing the entire SIDIS program of studying the partonic structure of the nucleon."

Experiment E12-13-007: π^0 SIDIS

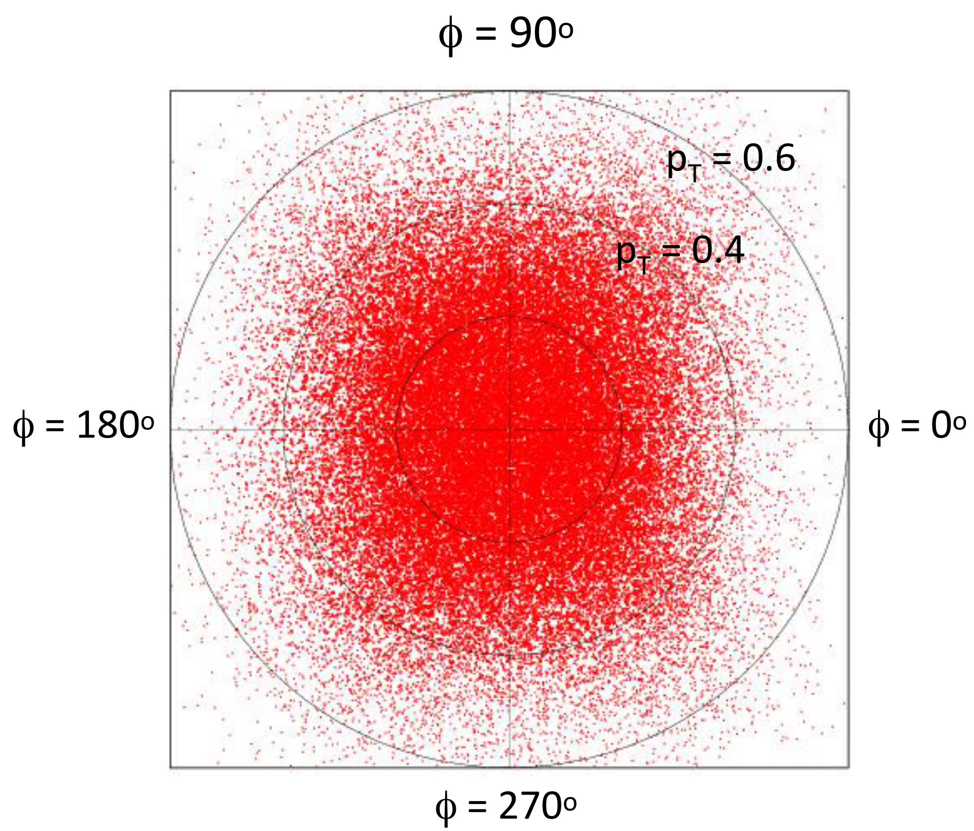


$P_{h\perp}$ Coverage of SIDIS experiments

$(e,e'\pi^{\pm})$ with SHMS
E12-09-017

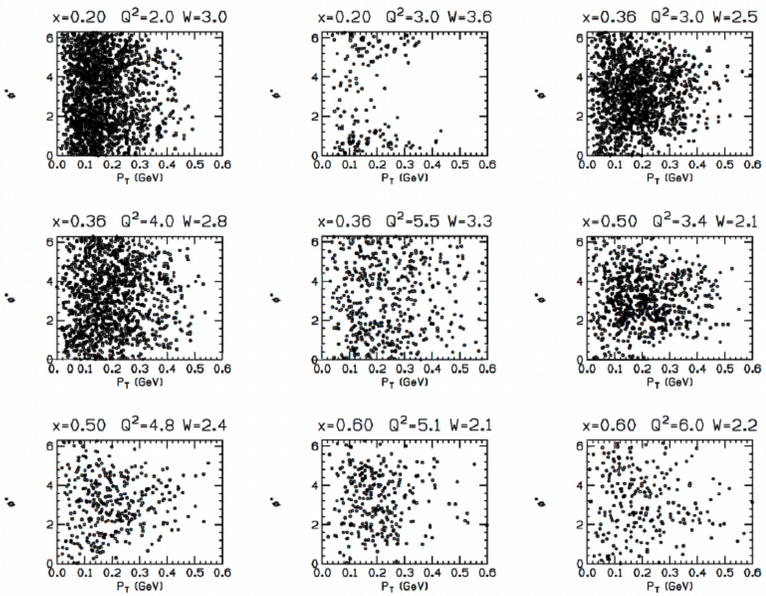


$(e,e'\pi^{0})$ with NPS
E12-13-007



PR12-23-014: SIDIS basic (e,e'π^0) cross sections

Angles for which NPS has good acceptance in (z,p_T)

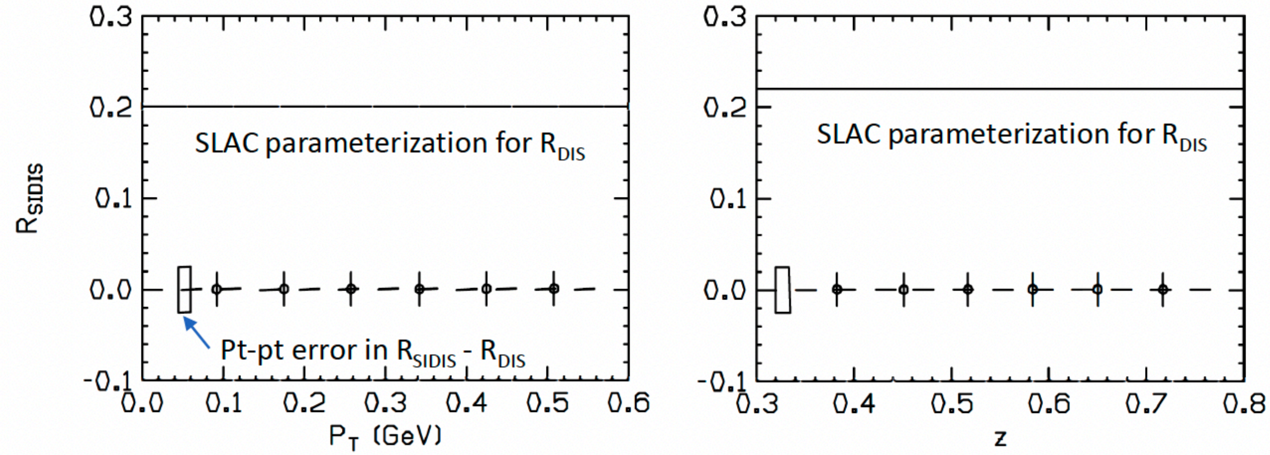


Set	x	Q^2	W	E	ϵ	E'	θ_e	θ_π	d	I	D_p	D_d
		GeV^2	GeV	GeV		GeV	deg	deg	m	μA	day	day
Ib	0.20	2.0	3.0	8.5	0.64	3.17	15.7	8.9	4	50	0.1	0.1
IIIa	0.36	3.0	2.5	6.4	0.51	1.96	28.3	11.2	3	28	0.1	0.1
IVb	0.36	4.0	2.8	8.5	0.52	2.58	24.7	9.9	4	40	0.1	0.1
V	0.36	5.5	3.3	10.6	0.41	2.46	26.6	7.5	4	40	0.3	0.3
VIIIa	0.60	5.1	2.1	6.4	0.46	1.87	38.1	13.2	3	28	0.3	0.3
VIa	0.50	3.4	2.1	6.4	0.67	2.78	25.3	16.9	6	28	0.1	0.1

New Run Group addition proposal to PAC51 (P. Bosted, E. Kinney, H. Mkrtchyan, V. Tadevosyan, R. Ent, T. Horn, et al.)

Measure $R_{LT} = \sigma_L/\sigma_T$, the ratios of d/u cross sections, the transverse momentum dependence of the cross section, and the spin-independent and beam-spin-dependant modulations of the cross section

Projections for R_{LT} SIDIS as function of p_T and z



Physics goals are driven by the need to more fully understand the production processes that enter SIDIS for better understanding of the 3D nucleon structure

- Dynamic and target higher twist, deep-exclusive processes, VM, CSV

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Experiment E12-06-104: R SIDIS

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 energies and electron scattering angles, while keeping the Q^2, x, z, and p_T constant. Will use the two magnetic spectrometers in Hall C.

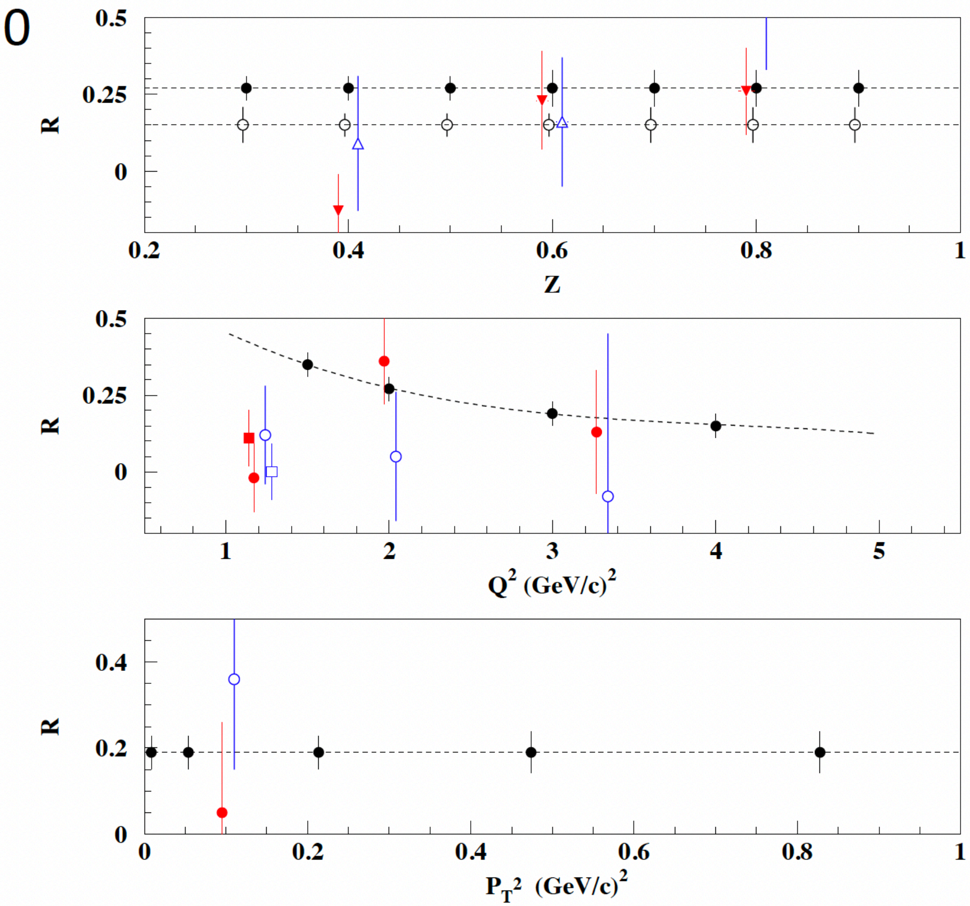
$$\varepsilon = \left[1 + 2\left(\frac{Q^2}{4M^2x^2}\right)\tan\frac{\theta^2}{2}\right]^{-1}$$

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

Experiment E12-06-104: R SIDIS

$R = \sigma_L/\sigma_T$ is a basic aspect of the photon-parton interaction

- First DIS evidence that quarks had spin ½ (R→0 as $Q^2 \to \infty$)
- Almost no experimental knowledge of R in SIDIS

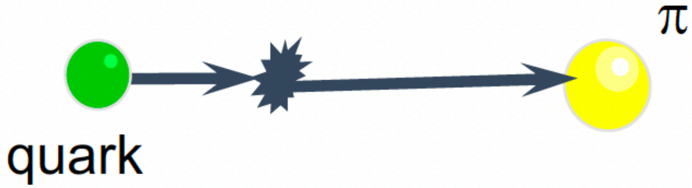


Projections for E12-06-104 vs existing Cornell Data
(projections assume R_{SIDIS} = R_{DIS})
Comparable 1.6% systematic uncertainties not indicated

Projections: Solid Black H, Open Black D π
Cornell:
Top panel: solid red (open blue) π^+ (π^-) on LH_2
Middle : solid red (open blue) dots are π^+ (π^-) on LH_2
solid red (open blue) squares are π^+ (π^-) on LD_2
Bottom : solid red (open blue) dots are for π^+ (π^-) on LH_2

Experiment E12-06-104: R SIDIS

- An essential measurement in understanding SIDIS in LO factorized form at these energies



$\sim\Sigma e_q^2 q(x)\, D_q^{\pi}(z)$

  - ➢ Previous JLab cross section experiments experiments suggest this factorized picture is valid at JLab energies at appropriate final hadronic state energies

- We will be able to test many common assumptions used in SIDIS analyses:

$$R_{SIDIS} = R_{DIS}?$$

$$R^{\pi^+}_{SIDIS} = R^{\pi^-}_{SIDIS}? \qquad R^{H}_{SIDIS} = R^{D}_{SIDIS}? \qquad R^{\pi^+}_{SIDIS} = R^{K^+}_{SIDIS}? \qquad R^{K^+}_{SIDIS} = R^{K^-}_{SIDIS}?$$

- Important for determining spin structure function g_1^h (need term $(1 + \varepsilon R)$ to get g_1^h/F_1^h from $A_{\parallel}{}^h$)
- At low z, expect DIS Q^2 behavior ($\sim 1/Q^2$), but as z→ 1, expect Deep-Exclusive Q^2 behavior ($\sim Q^2$)
- Completely unknown p_T behavior, which might impact on TMD analyses

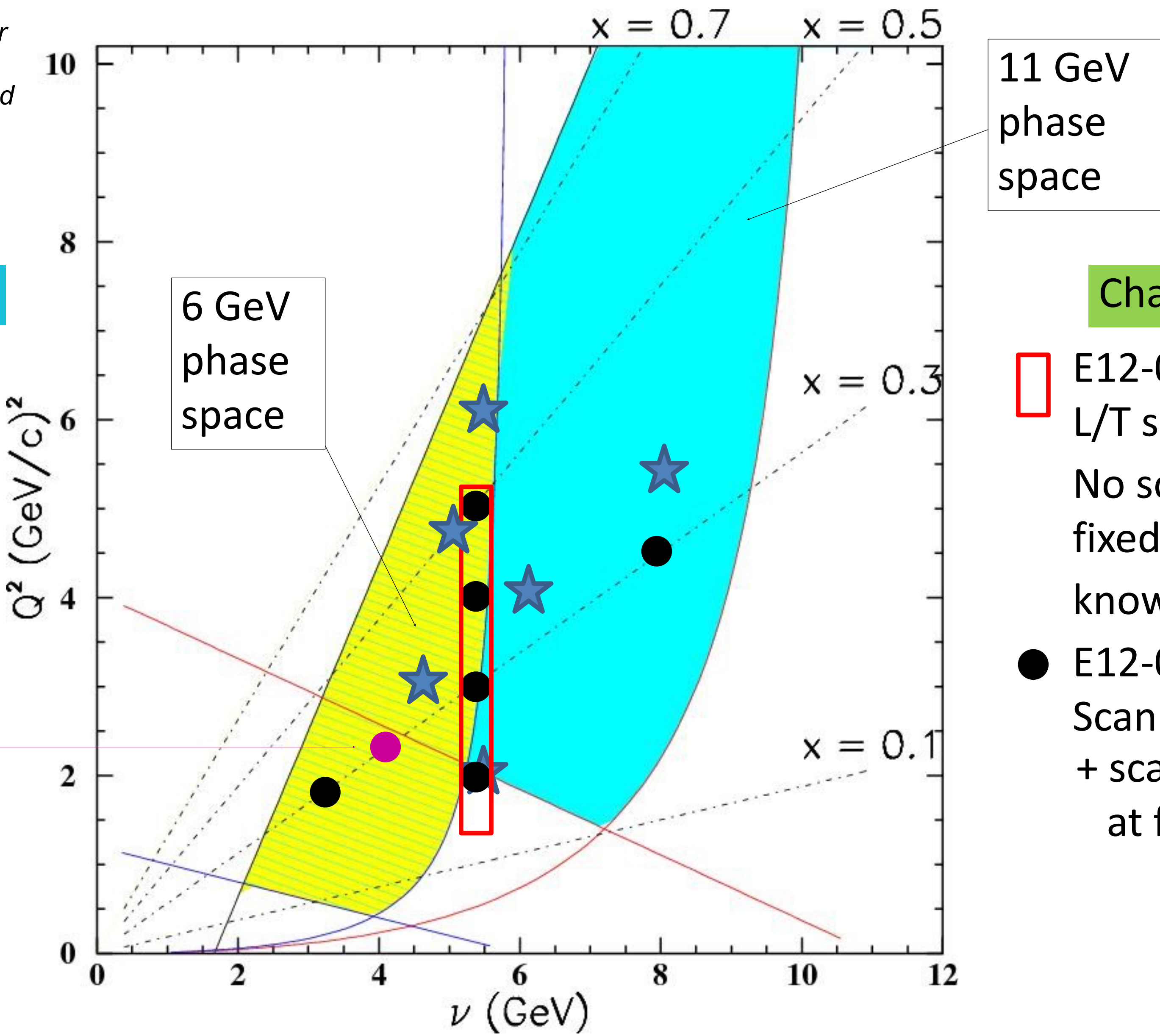
Hall C Kinematic Reach

HMS + SHMS (or NPS) Accessible Phase Space for SIDIS

Accurate cross sections for validation of SIDIS factorization framework and for L/T separations

E12-13-007
★ Neutral pions:
Scan in (x,z,P_T)
Overlap with
E12-09-017

E00-108
(6 GeV)



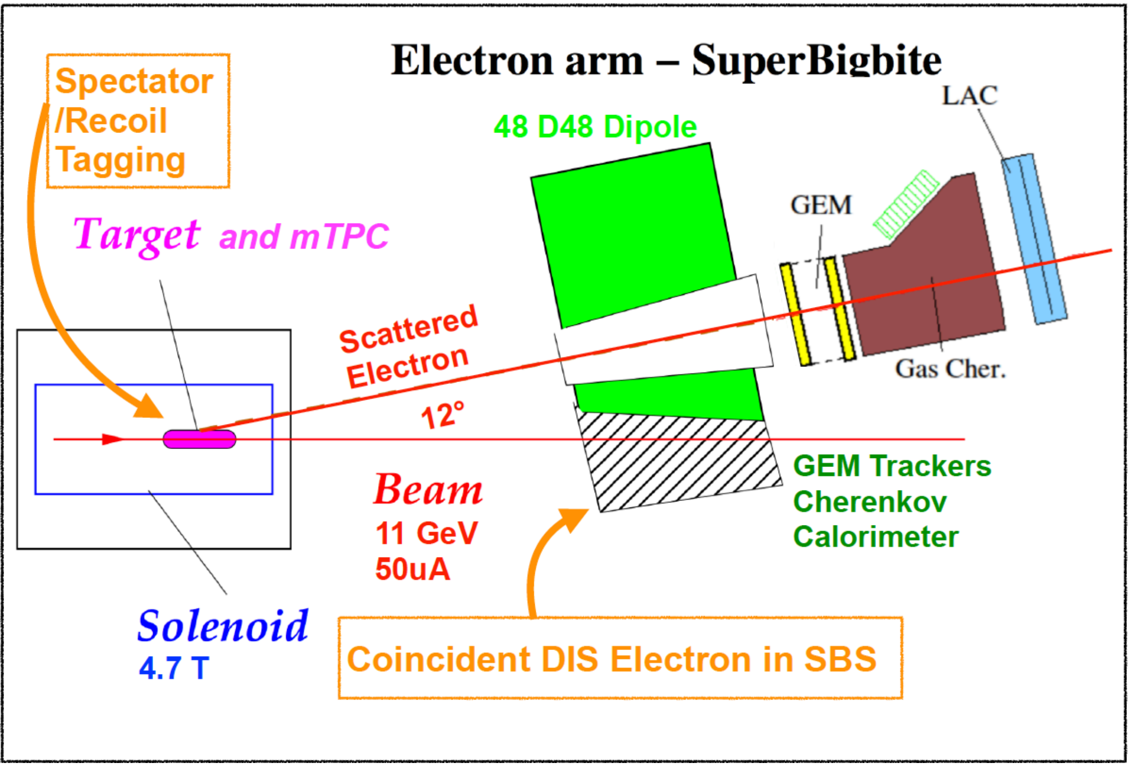
Charged pions:

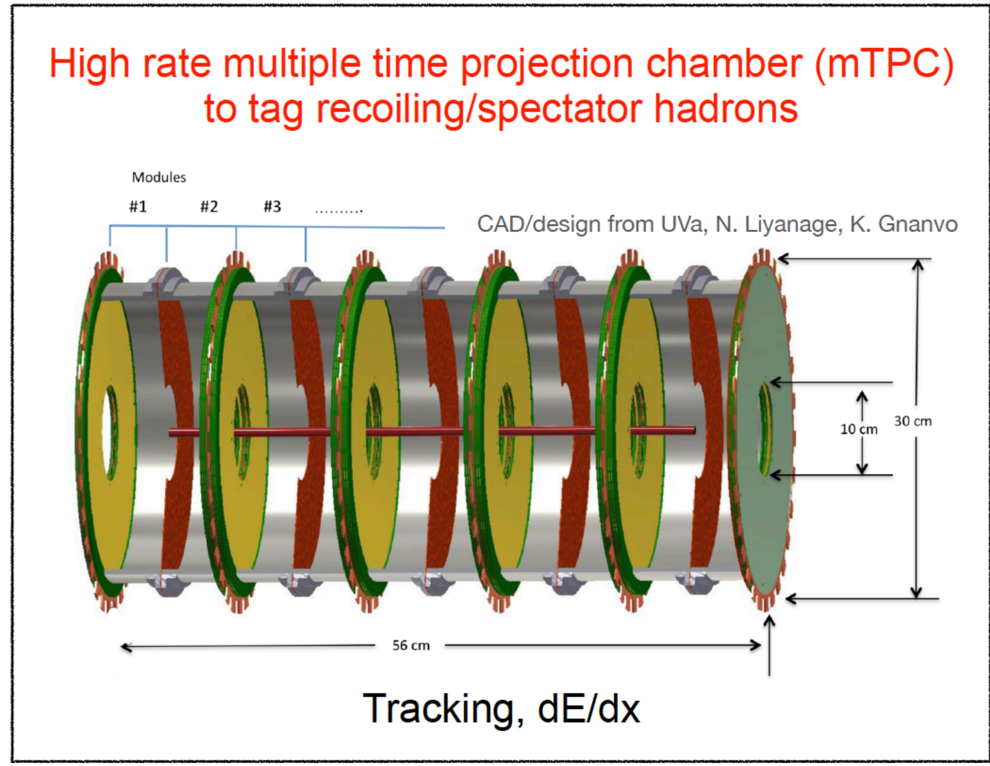
- E12-06-104
  L/T scan in (z,P_T)
  No scan in Q^2 at fixed x: $R_{DIS}(Q^2)$ known
- ● E12-09-017
  Scan in (x,z,P_T)
  + scan in Q^2
  at fixed x

The Tagged Deep Inelastic Scattering (TDIS) Experiment

Knowledge of meson structure is critical to a complete understanding of the emergence hadron mass.

Lack of meson targets ⇒ No direct measurement





TDIS is a direct measurement of the mesonic content of nucleons and extraction of the pion's F_2 structure functions, by deep inelastic scattering off the virtual-meson cloud.

The well established spectator tagging used to access the "meson cloud" target.

C1 conditionally approved with A- rating for 27 PAC days (up for jeopardy review @ PAC 51)

Two Additional Run-group Experiments Approved

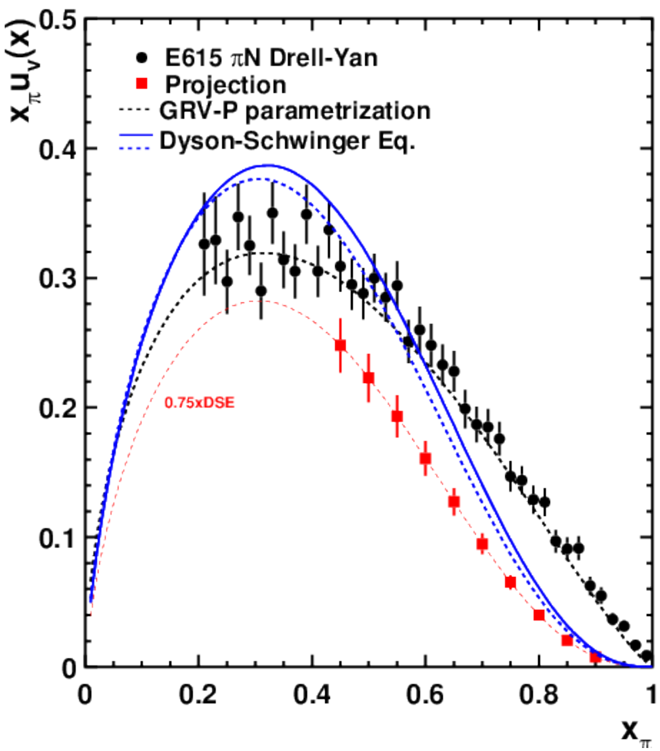
Run-group: TDIS, kaon-TDIS and neutron-TDIS

Many-fold increased interest in the technique and the science goal - over 50 publications with more than 1200 citations (e.g. LRP white paper & EIC yellow report).

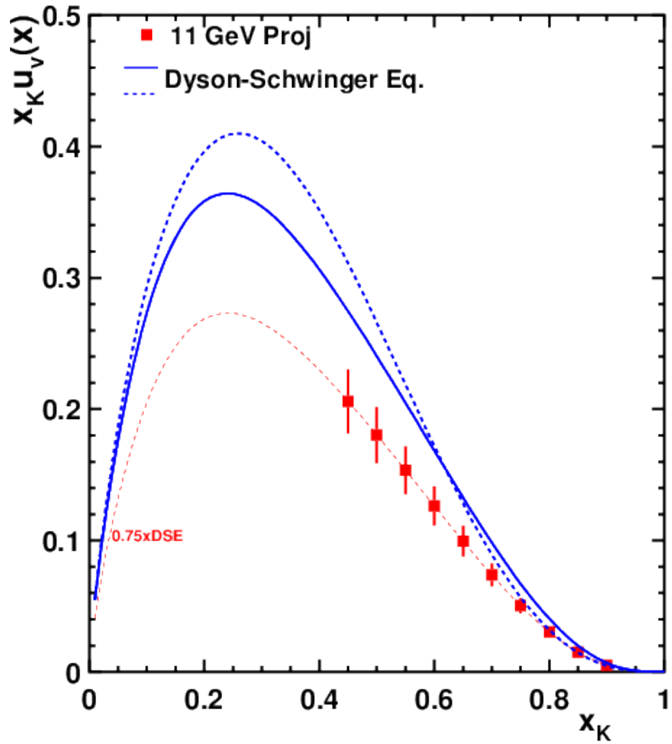
Significant theory progress - global QCD analysis including leading neutron HERA data

Substantial experimental progress - mTPC based recoil detector, streaming readout, simulations validated with BoNUS12 data, high rate & high occupancy tracking algorithm

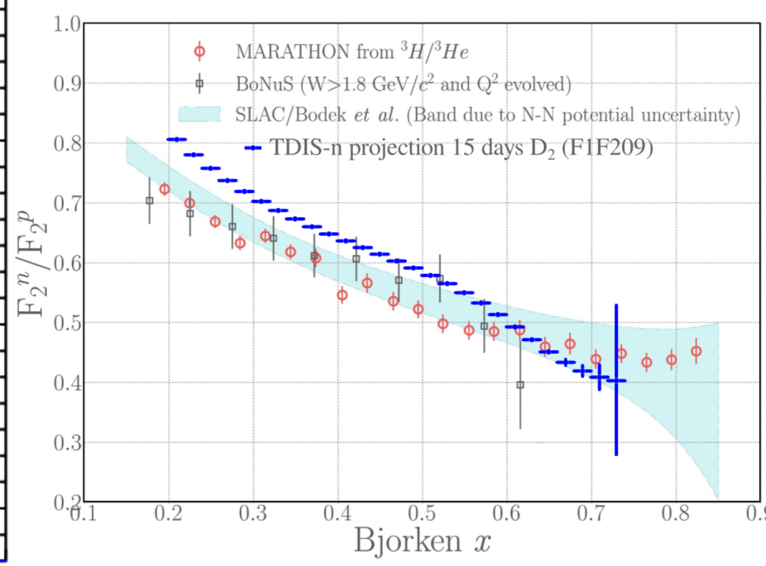
TDIS



kaon-TDIS



neutron-TDIS



TDIS will be a pioneering experiment and a necessary first step for future experiments at the EIC and 22 GeV JLab.

Strong Hall C Capabilities

- Hall C is at the high luminosity frontier, precisely measuring small cross sections and performing longitudinal/transverse separations are our bread and butter

- The ability to rapidly switch between different targets can greatly reduce systematic uncertainties, and a wide choice of nuclei is possible

- Do not fail to appreciate the ability to set a spectrometer at a precise angle; alignment of large collider detectors takes years can take years (e.g. Fermilab W mass result)

- High luminosity measurements with polarized beams and targets are well established capabilities at Jefferson Lab

- Flexibility to change experimental layout (spectrometers, calorimeters, compact photon source) allows for optimized measurements with precision

Concluding Opinions

- The general capabilities of the Hall allow a broad SIDIS program already at 12 GeV; the focus is on precise measurements of small cross sections and the ability to perform longitudinal/transverse separations.
- The first 12 GeV experiments have produced new results!
- The high precision Hall C experiments will complement those of Hall B.
- As we explore SIDIS at 12 GeV, we will move beyond the nucleon as a collection of free point objects! These are the signatures of the emergent physical structure we wish to understand!!!

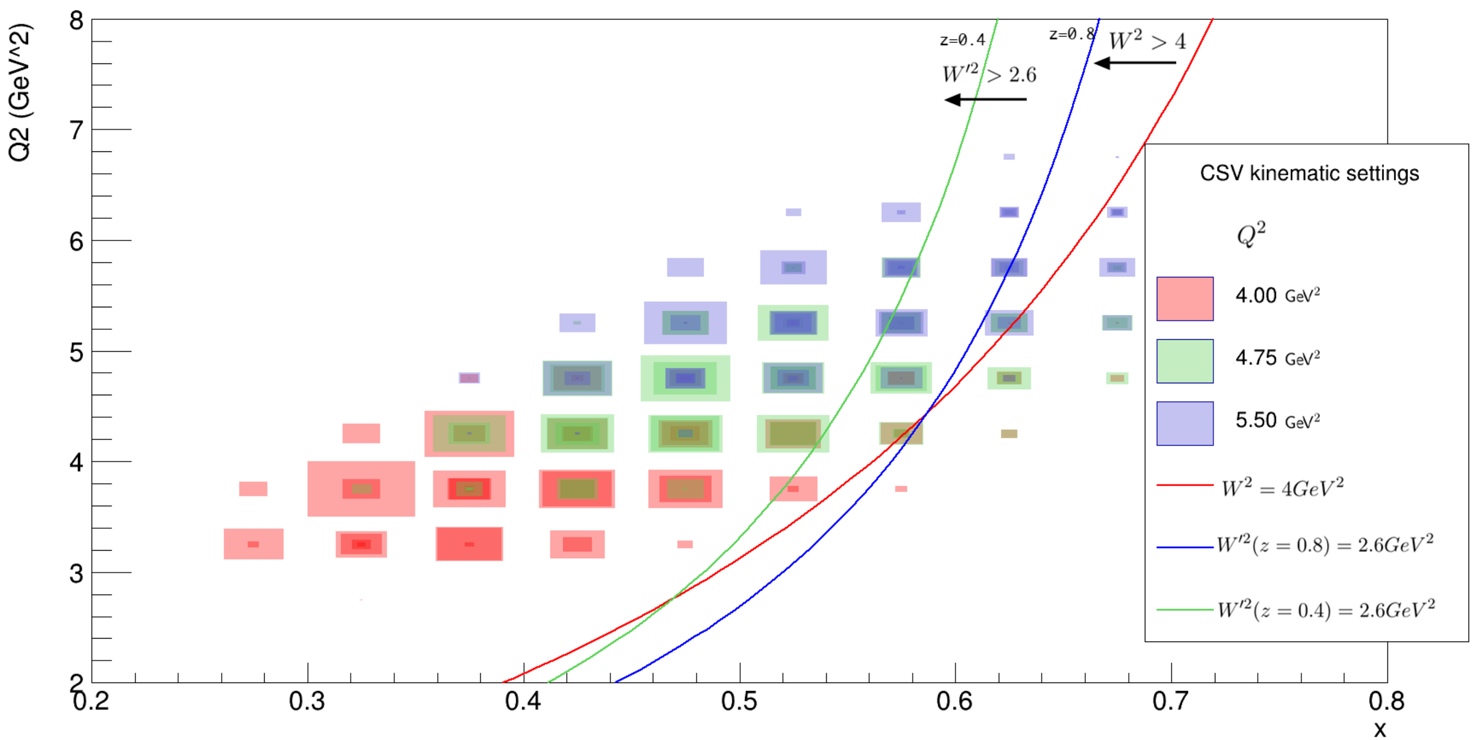
Backup Slides

CSV

Experiment E12-09-002

Kinematic Coverage

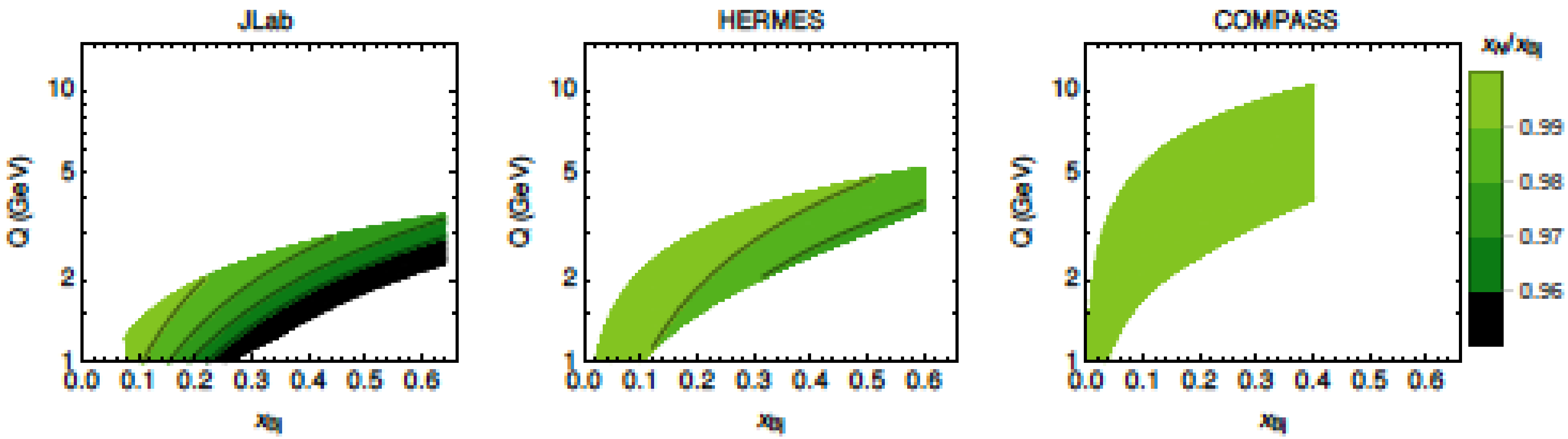
Charge Symmetry Violating Quark Distributions via Precise Measurement of π^+/π^- Ratios in Semi-inclusive Deep Inelastic Scattering.



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

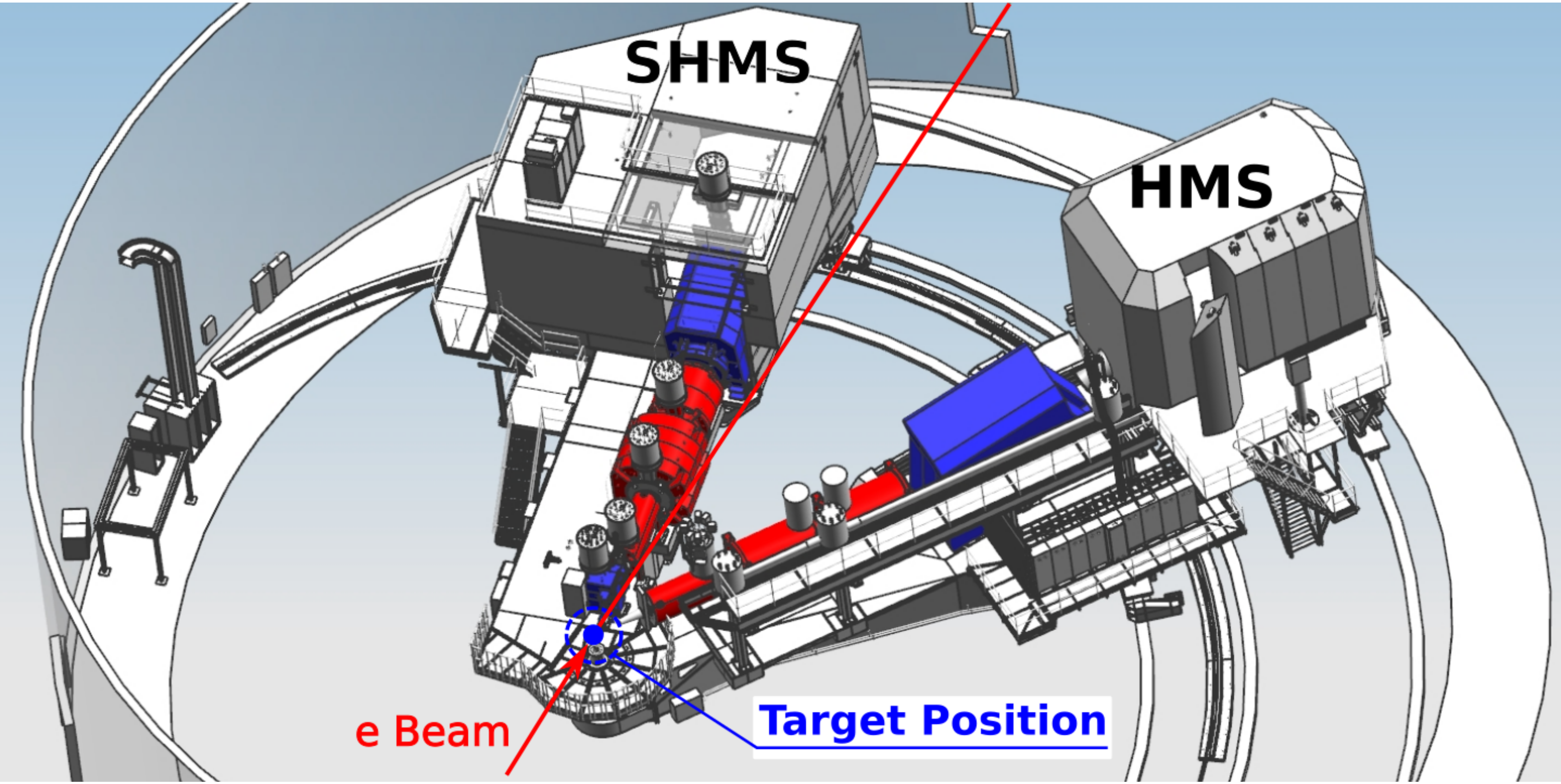
New Theoretical Guidance

Mapping the Kinematical Regimes of Semi-Inclusive Deep Inelastic Scattering,
M. Boglione, A. Dotson, L. Gamberg, S. Gordon, J.O. Gonzalez-Hernandez, A. Prokudin, T.C. Rogers, and N. Sato, (2019), ArXiv:1904.12882

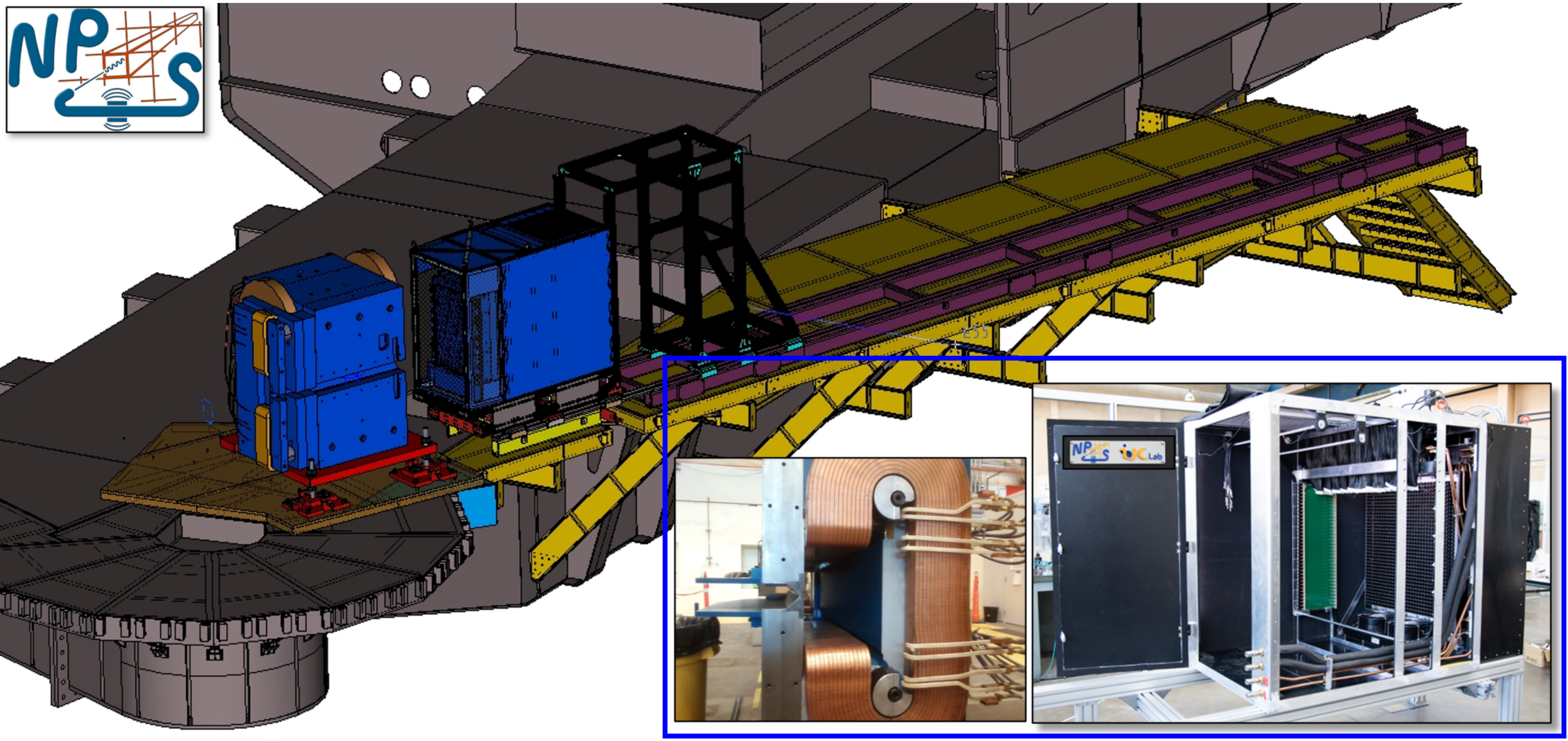


Example: Study of kinematic deviation between Nachtmann and Bjorken x

What are the tools available?

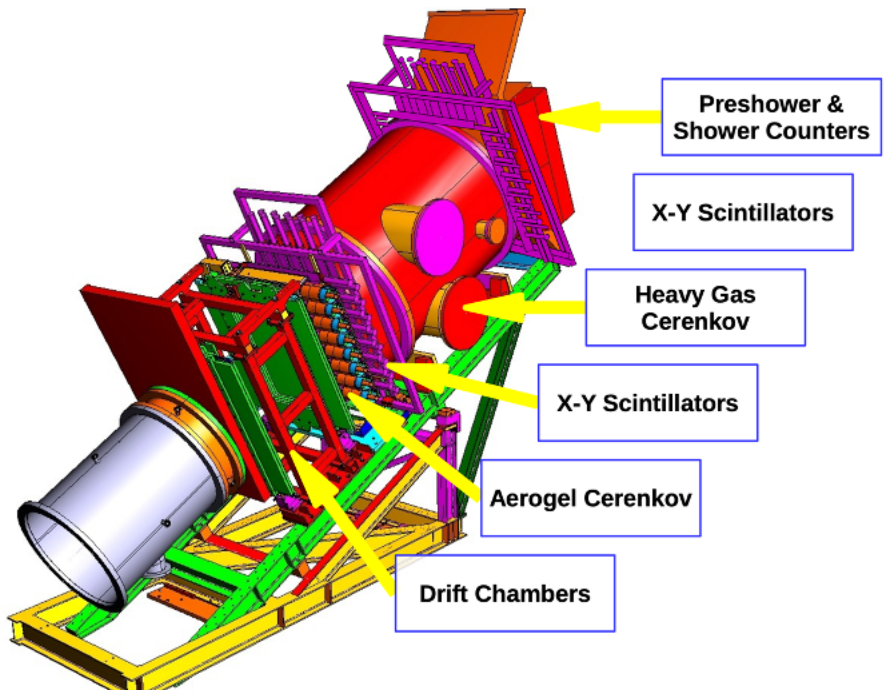


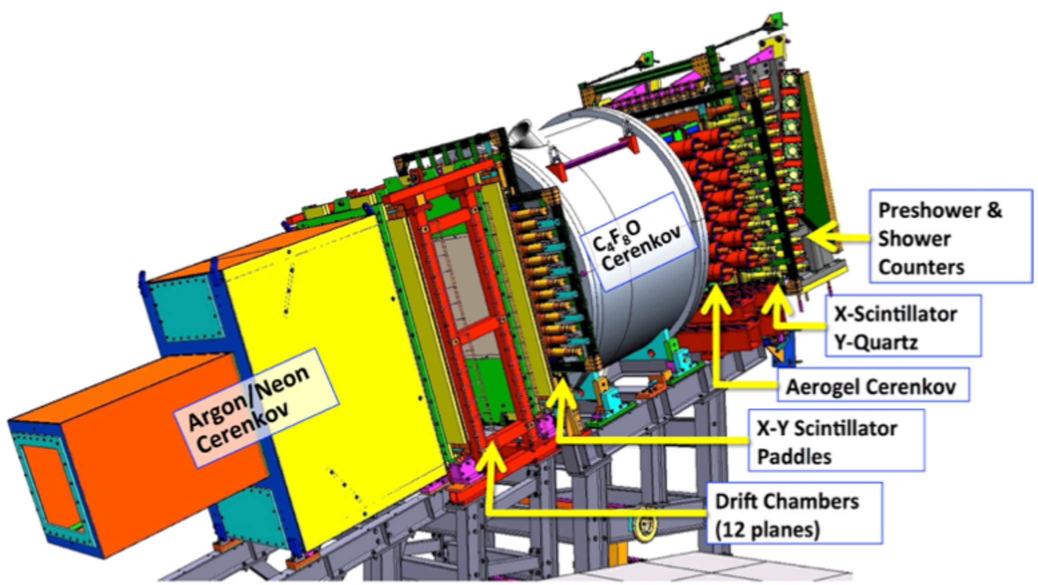
Neutral Pion Spectrometer



HMS and SHMS: Base Spectrometers

- HMS and SHMS that can reach 6+ and 11+ GeV/c with 10% momentum bites (single and coincidence mode)
- 0.1% reconstruction efficiency easily demonstrated
- Excellent PID
- Cerenkov and lead glass shower counters
- Can go up to 5.5 and 10.5 deg with sub-mrad pointing accuracy





Experimental Hall C