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.

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

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

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

- First DIS evidence that quarks had spin ½ (R→0 as $Q^2 \rightarrow \infty$)

- At moderate fixed x, falls as $1/Q^2$

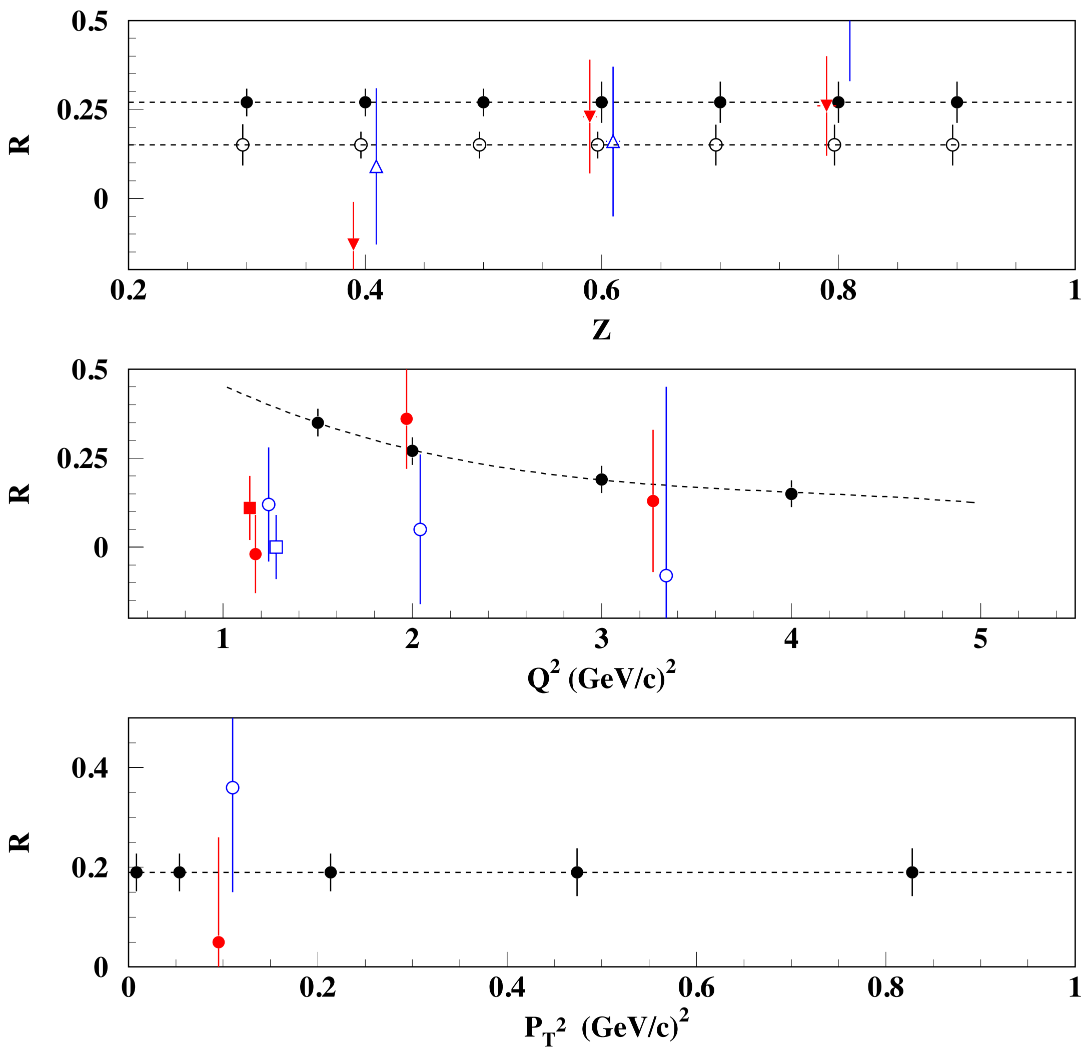
- At moderate Q^2 finite, non-zero, sensitive to indirect gluon effects and higher twist

- In naïve quark model, sensitive to intrinsic transverse momentum k_T:

$$R = 4(M^2x^2 - \langle k_t^2 \rangle)/(Q^2 + 2\langle k_t^2 \rangle)$$

Connected to TMDs!

Previous compared to proposed



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

- 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 $A_{\|}{}^h$)

- 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

E12-24-001: Measurement of the Nuclear Dependence of $R=\sigma_L/\sigma_T$ in Semi-Inclusive Deep Inelastic Scattering

Proposal to PAC 52

Spokespersons: P. Bosted (W&M),

W. Brooks (USM), R. Ent (JLab), D. Gaskell* (JLab), E. Kinney (U. Colorado), H. Mkrtchyan (Yerevan)

E12-24-001: Nuclear Dependence of R in SIDIS

Goal: Directly measure the nuclear dependence of $R=\sigma_L/\sigma_T$ in semi-inclusive DIS

→ No existing measurements of nuclear dependence of R in SIDIS

→ Potential impact on SIDIS results (dilution factor for polarized targets)

→ Potential impact on measurements of hadron-attenuation

→ **Exploratory** measurement to determine if more comprehensive program merited

Experiment: Measure cross sections and ratios for H, D, C, Cu targets at 3 beam energies

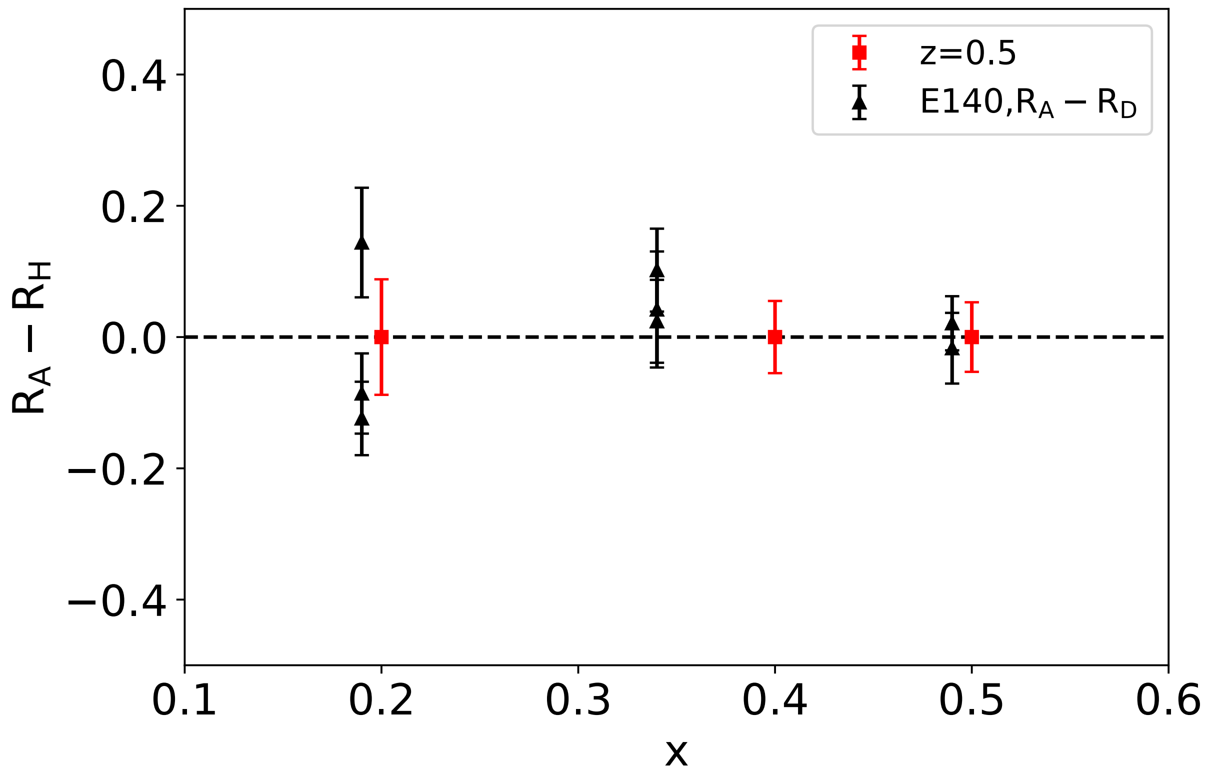
→ Allows LT separation

→ **E12-06-104** (R in SIDIS on H and D) in Hall C experiment scheduled for CY2025.

→ PR12-24-001 with E12-06-104 at select kinematics adding nuclear targets (^{12}C and ^{64}Cu).

▲ SLAC E140: Nuclear Dependence of R in DIS

■ PR12-24-001: Nuclear Dependence of R in SIDIS (projected precision)



Beam time request: 5 days

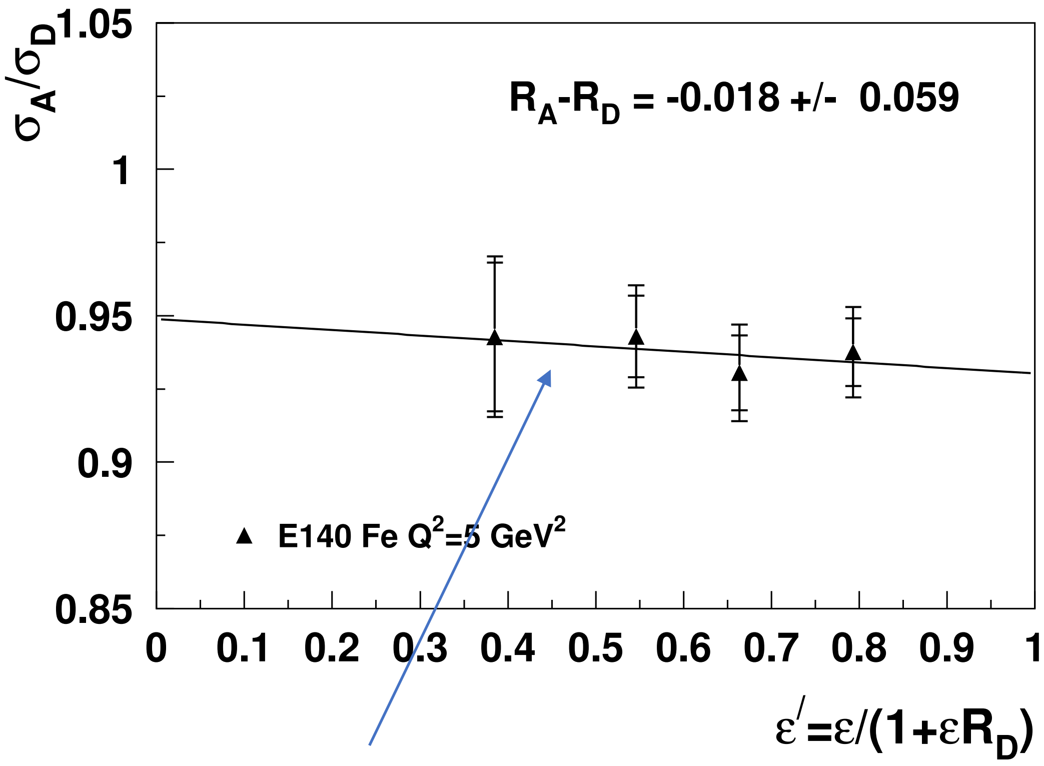
Extraction of R_A-R_H

Ultimate goal is to extract nuclear dependence of R in SIDIS

→ Rather than comparing R_A to R_H directly, precision can be improved by looking at ε dependence of target ratio

→ Point-to-point systematic uncertainty should be on the order of 1% for target ratio

Example: R_A-R_D from SLAC E140 (inclusive DIS)



Slope = R_A-R_D

$$\frac{\sigma_A}{\sigma_H} = \frac{\sigma_A^T}{\sigma_H^T}[1 + \epsilon'(R_A - R_H)]$$

$$\epsilon' = \epsilon/(1 + \epsilon R_H)$$

Requires measurement/knowledge of R_H, but since absolute value is small, not a large contribution to overall uncertainty

Beam Time Breakdown

Targets:
C = 3% RL (1.28 g/cm^2)
Cu = 6% RL (0.77 g/cm^2)

Beam currents:
I_{beam} = 25-50 μA

Statistics:
x=0.4, 0.5: 10k events
x=0.2: 5k events for low z
10k events z=0.85

x	Q^2 (GeV)^2	z	ε	Target	Time (π+) (hrs)	Time (π-) (hrs)
0.2	2.0	0.3-0.85 (0.4-0.65)	0.34, 0.66, 0.80	C	15.3	9.8
				Cu	19.1	13.5
				Subtotal (x=0.2)	**34.4**	**23.3**
0.4	4	0.5	0.31, 0.65, 0.79	C	7.3	-
				Cu	12.9	-
				Subtotal (x=0.4)	**20.2**	**-**
0.5	5	0.5	0.30, 0.64, 0.79	C	14.5	-
				Cu	16.4	-
				Subtotal (x=0.5)	**30.9**	**-**
				Total Production Time	**85.5**	**23.3**

E12-06-104: Original Choice of Kinematics & Beam Time

- Map R^H_{SIDIS} and R^D_{SIDIS} as a function of z at x = 0.2 and Q^2 = 2.0 GeV^2

168 Hours

  - Need to experimentally see if $R^H_{SIDIS} = R^D_{SIDIS}$, just as $R^H_{DIS} = R^D_{DIS}$!

- Map R^H_{SIDIS} as a function of z at x = 0.4 and Q^2 = 4.0 GeV^2

319 Hours

  - Test dominance of quark fragmentation
  - Study the inclusive-exclusive connection (soft vs. hard gluon exchange?)

- Map R^H_{SIDIS} as a function of p_T^2 at x = 0.3 and Q^2 = 3.0 GeV^2

311 Hours

  - Extend understanding of fragmentation process to high p_T
  - No guidance from factorization theorems here yet

- Add kinematics to map R^H_{SIDIS} for Q^2 = 1.5 - 5.0 GeV^2

88 Hours

  - Does R_{SIDIS} behave like R_{DIS} as function of Q^2?

+75 Hours
(overhead)

= 40 days

These data required for our understanding of SIDIS, and will further our understanding of fragmentation.
These data enter into completely unknown territory!

Goals

- scan in x at fixed $z = 0.5$ and small P_t
- scans in z at low P_t at two values of x
- scan in P_t at fixed x and z
- do both π^+ and π^- on proton target at every setting
- also take data with deuteron at a subset of the settings
- do carbon and copper at same settings as deuteron

Selection of (x, Q^2) settings

- Measuring R require multiple beam energies to achieve $\Delta\epsilon > 0.25$.
- Available beam energies: 6.3 GeV 8.4 GeV 10.5 GeV
- Also want $W >> 2$ GeV to be in ”deep region.
- Need $E'/E > 0.2$ to control radiative corrections and backgrounds in electron arm.
- For a lower beam energy of 6.3 GeV, $\nu_{max} = 5.3$ GeV (and $Q^2 = 10x$)
- For a lower beam energy of 8.4 GeV, $\nu_{max} = 6.8$ GeV (and $Q^2 = 13x$)
- Experimental constraint: $13.5 < \theta < 48$ deg.
- Experimental constraint: $7.5 < \theta_{\pi|} < 20$ deg.

Selection of (x, Q^2) settings

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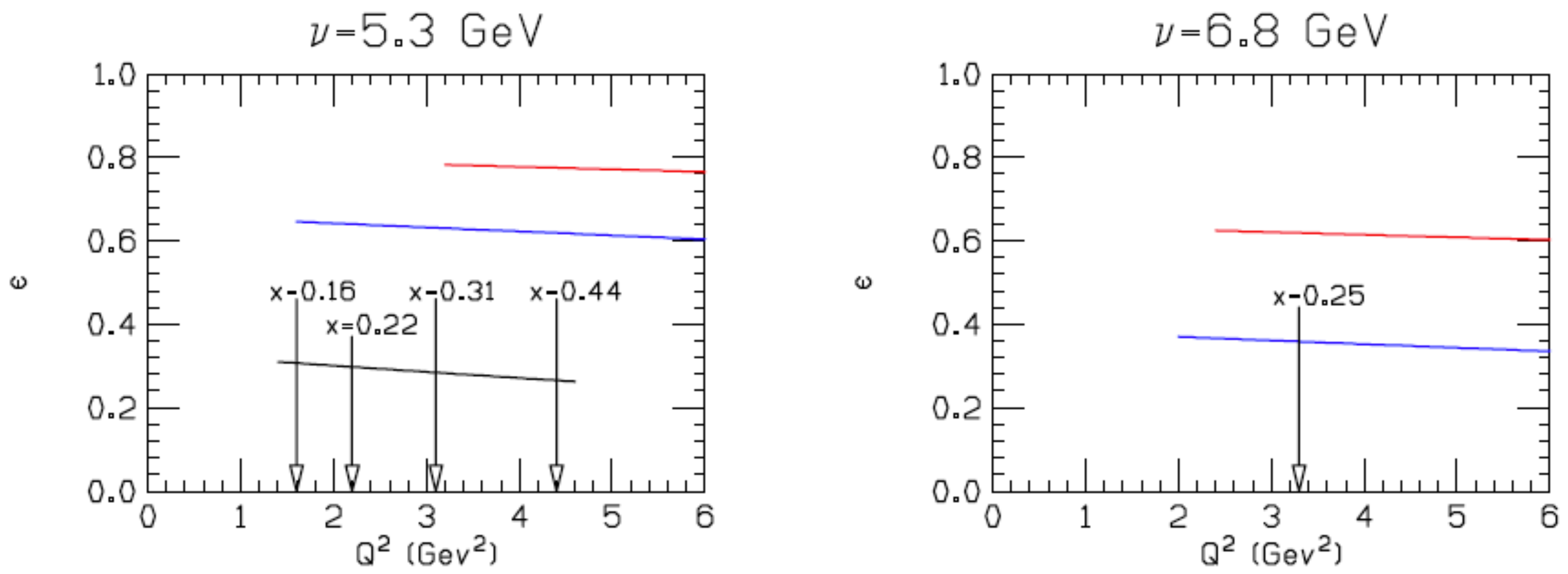
ur available beam energies: 6.3 GeV 8.4 GeV 10.5 GeV



- Four values of x at lower ν. Lowest x vlues use only 3 and 4 pass (HMS angle too small at 5-pass).
- One value of x at higher ν to explore higher Q^2 and W. Better setting for P_t and z scans too.

Selection of $z - scan$ settings

- Cannot do the two lowest x because the beam current that keeps SHMS 3/4 rate below 900 kHz is too low (less than 6 μA). So, pick $x = 0.25$ for the lower-x z-scan.
- Complement with a $z - scan$ at the highest x setting.
- Use full momentum range of SHMS ($-16\% < \delta < 35\%$) to cover $0.3 < z < 0.8$ with just three z central settings.
- Already have data at 3, 4, and 5 pass for $z > 0.75$ for π^+ from proton from KLT experiment at five (x, Q^2) points, over 30 PAC days of running. [Rates are very low at high z].
- Therefore, making highest z central value of 0.67.

Selection of P_t scans

- Due to very high rates at small angles, make default θ_{pq} (angle between pion and q-vector) 2 degrees: provides about 180 deg. coverage in ϕ^*.
- For 3 settings, can also use $\theta_{pq} = -1$ deg to get full ϕ^* coverage at $P_t < 0.3$ GeV.
- For one setting, can extend θ_{pq} out to 12 degrees to cover up to $P_t = 0.7$ GeV, but with limited ϕ^* coverage

Overview of Production running

x	Q^2	E(pass)	z	θ_{pq}	$A > 1$
0.16	1.6	3,4	.5	2	no
0.22	2.2	3,4	.5	2	no
0.25	3.3	4,5	.36,.5,.67	2	π^+ (all), π^-
0.25	3.3	4,5	.5	5.2, 8.5, 11.7	π^+ only
0.25	3.3	5	.5,.67	-0.8	yes
0.31	3.1	3,4,5	.5	2	π^+ only
0.31	3.1	5	.5	-1	π^+ only
0.44	4.4	3,4,5	. .52	2	yes yes
0.44	4.4	3,4,5	.40,67	2	no
0.44	4.4	5	.52	-2, 0	yes
0.44	4.4	5	.40, .67	-2, 0	no

Beam currents, running time

- maximum current at 3, 4, and 5 pass will be limited to about 56, 42, and 34 μA respectively due to expected load from Hall A.
- Also need to keep singles rates in SHMS below 900 kHz to avoid big corrections.
- Also keep ratio of accidental to real coincidences below 1 if possible.
- Optimize statistical error by running each setting according to square root of the rate, rather for a fixed number of events.
- This allows for measurements of the $\cos(\phi)$ and $\cos(2\phi)$ terms at 5 pass, where the rates are the highest.
- These results can be used to determine $\cos(\phi)$ and $\cos(2\phi)$ contributions at lower beam energies, where rates are lower.

Overview of Production running π^- on proton

E	x	Q^2	z	θ_{pq}	I (μA)	coin/hr	A/R	Hrs	K-counts
6.5	0.16	1.6	0.50	2.0	22.8	4.4	1.8	7.2	31.4
8.6	0.16	1.6	0.50	2.0	34.9	80.9	2.0	2.0	161.8
6.5	0.22	2.2	0.50	2.0	29.3	2.7	1.8	9.1	24.8
8.6	0.22	2.2	0.50	2.0	42.0	48.8	1.5	2.1	104.7
8.6	0.25	3.3	0.36	2.0	16.9	1.8	1.3	10.0	18.2
10.7	0.25	3.3	0.36	2.0	25.8	21.3	1.4	3.2	69.3
8.6	0.25	3.3	0.50	2.0	37.0	4.4	1.1	7.1	31.5
10.7	0.25	3.3	0.50	2.0	34.0	31.1	0.6	2.7	83.6
8.6	0.25	3.3	0.67	2.0	42.0	3.8	0.4	7.7	29.4
10.7	0.25	3.3	0.67	2.0	34.0	23.8	0.2	3.1	73.2
8.6	0.25	3.3	0.50	5.2	42.0	3.2	0.5	8.4	26.9
10.7	0.25	3.3	0.50	5.2	34.0	20.0	0.2	3.4	67.1
8.6	0.25	3.3	0.50	8.5	42.0	1.5	0.3	10.0	14.5
10.7	0.25	3.3	0.50	8.5	34.0	9.0	0.1	5.0	45.1
8.6	0.25	3.3	0.50	11.7	42.0	0.4	0.2	10.0	3.6
10.7	0.25	3.3	0.50	11.7	34.0	2.2	0.1	10.0	22.1
10.7	0.25	3.3	0.50	-0.8	23.4	23.4	1.1	3.1	72.6
10.7	0.25	3.3	0.67	-0.8	34.0	27.3	0.6	2.9	78.4

Overview of Production running (continued)

E	x	Q^2	z	θ_{pq}	I (μA)	coin/hr	A/R	Hrs	K-counts
8.6	0.25	3.3	0.50	11.7	42.0	0.4	0.2	10.0	3.6
10.7	0.25	3.3	0.50	11.7	34.0	2.2	0.1	10.0	22.1
10.7	0.25	3.3	0.50	-0.8	23.4	23.4	1.1	3.1	72.6
10.7	0.25	3.3	0.67	-0.8	34.0	27.3	0.6	2.9	78.4
6.5	0.31	3.1	0.50	2.0	40.4	1.6	1.7	10.0	16.4
8.6	0.31	3.1	0.50	2.0	42.0	21.2	0.9	3.3	69.1
10.7	0.31	3.1	0.50	2.0	34.0	64.4	0.5	2.0	128.8
10.7	0.31	3.1	0.50	-1.0	34.0	66.2	1.3	2.0	132.3
6.5	0.44	4.4	0.40	2.0	32.6	0.4	2.0	10.0	4.3
8.6	0.44	4.4	0.40	2.0	42.0	6.6	1.1	5.8	38.7
10.7	0.44	4.4	0.40	2.0	34.0	20.1	0.6	3.3	67.2
6.5	0.44	4.4	0.52	2.0	56.0	0.8	1.4	10.0	7.6
8.6	0.44	4.4	0.52	2.0	42.0	6.8	0.4	5.8	39.1
10.7	0.44	4.4	0.52	2.0	34.0	20.5	0.2	3.3	67.9

Overview of Production running (continued)

E	x	Q^2	z	θ_{pq}	I (μA)	coin/hr	A/R	Hrs	K-counts
6.5	0.44	4.4	0.52	2.0	56.0	0.8	1.4	10.0	7.6
8.6	0.44	4.4	0.52	2.0	42.0	6.8	0.4	5.8	39.1
10.7	0.44	4.4	0.52	2.0	34.0	20.5	0.2	3.3	67.9
6.5	0.44	4.4	0.67	2.0	56.0	0.6	0.4	10.0	6.3
8.6	0.44	4.4	0.67	2.0	42.0	5.7	0.1	6.3	35.7
10.7	0.44	4.4	0.67	2.0	34.0	17.1	0.0	3.6	62.0
10.7	0.44	4.4	0.40	-2.0	34.0	20.1	1.8	3.3	67.2
10.7	0.44	4.4	0.40	0.0	34.0	21.1	1.0	3.3	69.0
10.7	0.44	4.4	0.52	0.0	34.0	22.0	0.4	3.2	70.4
10.7	0.44	4.4	0.52	-2.0	34.0	20.5	0.8	3.3	67.9
10.7	0.44	4.4	0.67	0.0	34.0	18.7	0.1	3.5	64.9
10.7	0.44	4.4	0.67	-2.0	34.0	17.1	0.3	3.6	62.0

total (day): 8.4 (all), [2.3 (3-pass), 3.2 (4-pass), 2.8 (5-pass)]

Electron kinematics and rates

x	Q^2	W	E	ϵ	E'	θ_e	e^- kHz	π^- kHz	K^- kHz	π/e
0.16	1.6	3.05	6.5	0.32	1.2	26.5	2.	484.	16.	212.4
0.16	1.6	3.05	8.6	0.65	3.3	13.7	27.	231.	17.	8.4
0.22	2.2	2.95	6.5	0.31	1.1	31.6	1.	235.	7.	215.1
0.22	2.2	2.95	8.6	0.64	3.3	16.1	14.	88.	6.	6.4
0.25	3.3	3.28	8.6	0.32	1.6	28.7	1.	129.	6.	150.5
0.25	3.3	3.28	10.7	0.59	3.7	16.7	7.	45.	4.	6.9
0.25	3.3	3.28	8.6	0.32	1.6	28.7	1.	129.	6.	150.5
0.25	3.3	3.28	10.7	0.59	3.7	16.7	7.	45.	4.	6.9
0.25	3.3	3.28	8.6	0.32	1.6	28.7	1.	129.	6.	150.5
0.25	3.3	3.28	10.7	0.59	3.7	16.7	7.	45.	4.	6.9
0.25	3.3	3.28	8.6	0.32	1.6	28.7	1.	129.	6.	150.5
0.25	3.3	3.28	10.7	0.59	3.7	16.7	7.	45.	4.	6.9
0.25	3.3	3.28	8.6	0.32	1.6	28.7	1.	129.	6.	150.5
0.25	3.3	3.28	10.7	0.59	3.7	16.7	7.	45.	4.	6.9
0.25	3.3	3.28	8.6	0.32	1.6	28.7	1.	129.	6.	150.5
0.25	3.3	3.28	10.7	0.59	3.7	16.7	7.	45.	4.	6.9

Electron kinematics and rates (continued)

x	Q^2	W	E	ϵ	E'	θ_e	e^- kHz	π^- kHz	K^- kHz	π/e
0.31	3.1	2.79	8.6	0.63	3.3	19.2	6.	24.	2.	4.1
0.31	3.1	2.79	10.7	0.78	5.4	13.4	21.	11.	1.	0.5
0.44	4.4	2.55	6.5	0.28	1.2	44.7	0.	23.	0.	146.7
0.44	4.4	2.55	8.6	0.62	3.3	22.8	2.	4.	0.	2.2
0.44	4.4	2.55	10.7	0.77	5.4	15.9	7.	2.	0.	0.2
0.44	4.4	2.55	6.5	0.28	1.2	44.7	0.	23.	0.	146.7
0.44	4.4	2.55	8.6	0.62	3.3	22.8	2.	4.	0.	2.2
0.44	4.4	2.55	10.7	0.77	5.4	15.9	7.	2.	0.	0.2
0.44	4.4	2.55	6.5	0.28	1.2	44.7	0.	23.	0.	146.7
0.44	4.4	2.55	8.6	0.62	3.3	22.8	2.	4.	0.	2.2
0.44	4.4	2.55	10.7	0.77	5.4	15.9	7.	2.	0.	0.2

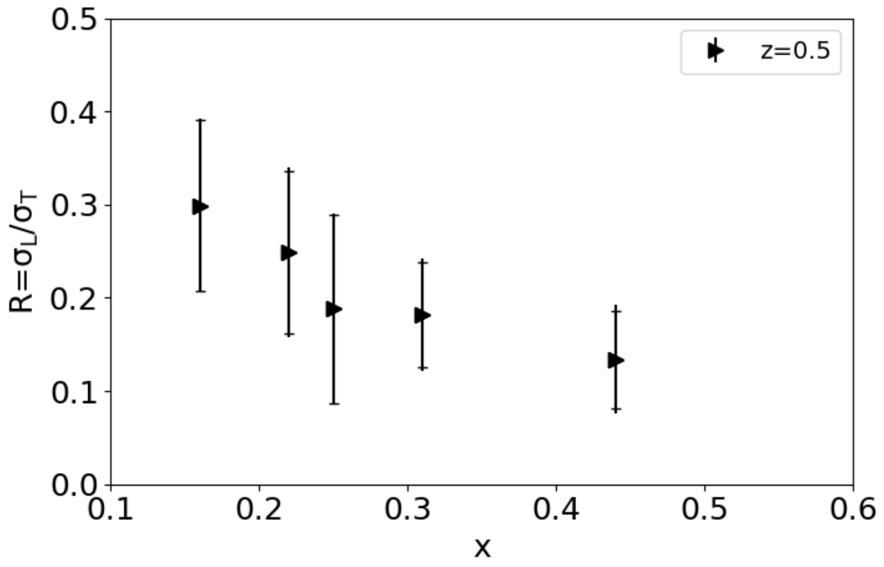
Pion kinematics and rates

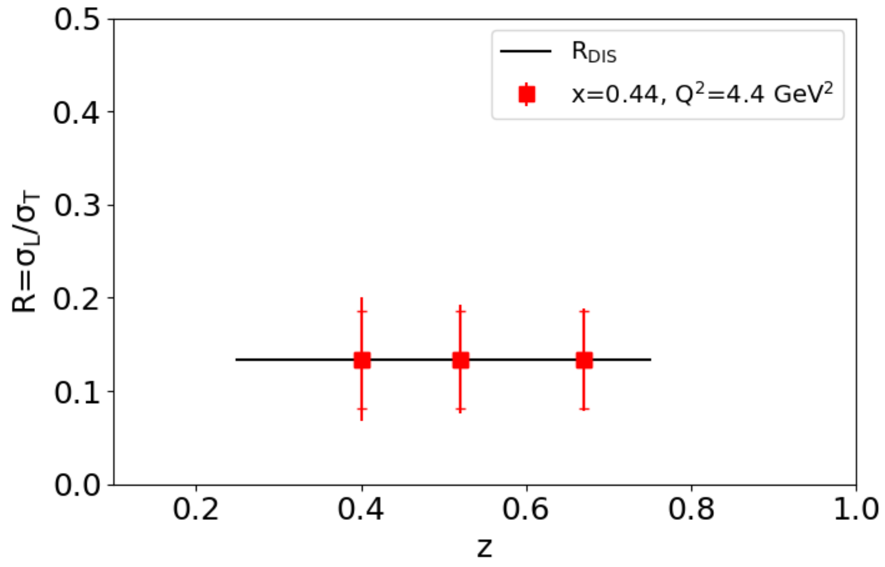
x	Q^2	z	P_t	P_π	θ_π	3/4 (kHz)	e/π
0.16	1.6	0.50	0.10	2.74	7.5	900	0.14
0.16	1.6	0.50	0.10	2.74	10.1	900	0.04
0.22	2.2	0.50	0.10	2.77	8.2	900	0.14
0.22	2.2	0.50	0.10	2.77	11.4	709	0.04
0.25	3.3	0.36	0.09	2.62	7.9	900	0.04
0.25	3.3	0.36	0.09	2.62	10.3	900	0.02
0.25	3.3	0.50	0.13	3.63	7.9	899	0.14
0.25	3.3	0.50	0.13	3.63	10.3	437	0.06
0.25	3.3	0.67	0.17	4.87	7.9	451	0.51
0.25	3.3	0.67	0.17	4.87	10.3	123	0.27
0.25	3.3	0.50	0.33	3.63	11.1	285	0.15
0.25	3.3	0.50	0.33	3.63	13.5	115	0.07
0.25	3.3	0.50	0.54	3.63	14.4	71	0.20
0.25	3.3	0.50	0.54	3.63	16.8	27	0.12
0.25	3.3	0.50	0.74	3.63	17.6	17	0.31
0.25	3.3	0.50	0.74	3.63	20.0	6	0.20
0.25	3.3	0.50	-.05	3.63	7.5	899	0.06
0.25	3.3	0.67	-.07	4.87	7.5	523	0.21

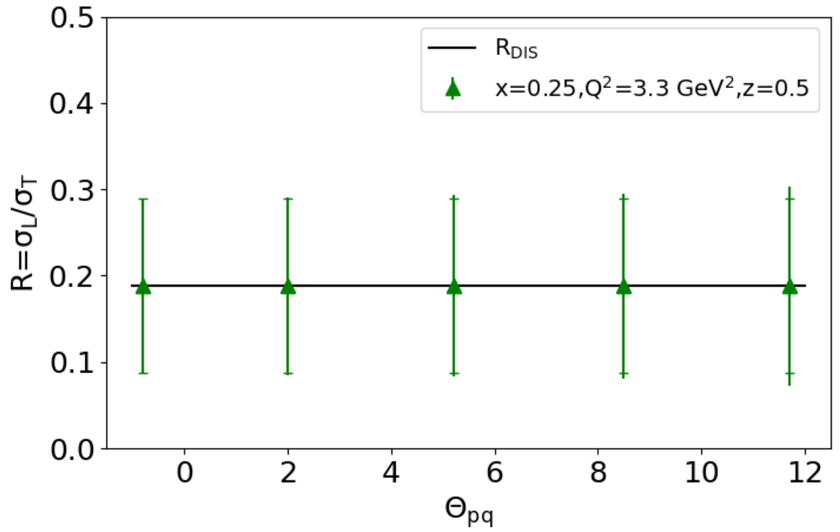
Pion kinematics and rates (continued)

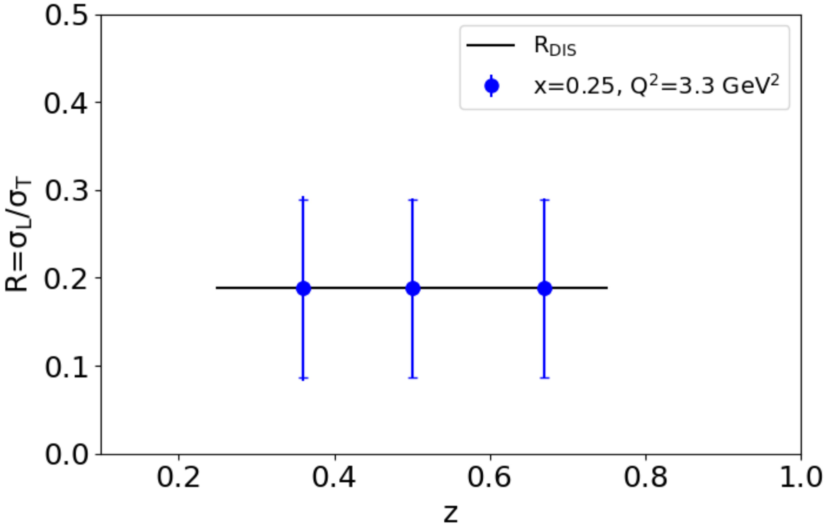
x	Q^2	z	P_t	P_π	θ_π	3/4 (kHz)	e/π
0.31	3.1	0.50	0.10	2.81	13.0	409	0.04
0.31	3.1	0.50	0.10	2.81	14.7	242	0.02
0.31	3.1	0.50	-.05	2.81	11.7	642	0.02
0.44	4.4	0.40	0.08	2.29	10.3	899	0.06
0.44	4.4	0.40	0.08	2.29	14.8	494	0.02
0.44	4.4	0.40	0.08	2.29	16.9	280	0.01
0.44	4.4	0.52	0.10	2.98	10.3	743	0.18
0.44	4.4	0.52	0.10	2.98	14.8	171	0.07
0.44	4.4	0.52	0.10	2.98	16.9	86	0.03
0.44	4.4	0.67	0.13	3.84	10.3	369	0.57
0.44	4.4	0.67	0.13	3.84	14.8	45	0.29
0.44	4.4	0.67	0.13	3.84	16.9	18	0.17
0.44	4.4	0.40	-.08	2.29	12.9	821	0.01
0.44	4.4	0.40	0.00	2.29	14.9	485	0.01
0.44	4.4	0.52	0.00	2.98	14.9	178	0.03
0.44	4.4	0.52	-.10	2.98	12.9	359	0.02
0.44	4.4	0.67	0.00	3.84	14.9	46	0.12
0.44	4.4	0.67	-.13	3.84	12.9	115	0.09

Projections from Dave Gaskell for this plan: R

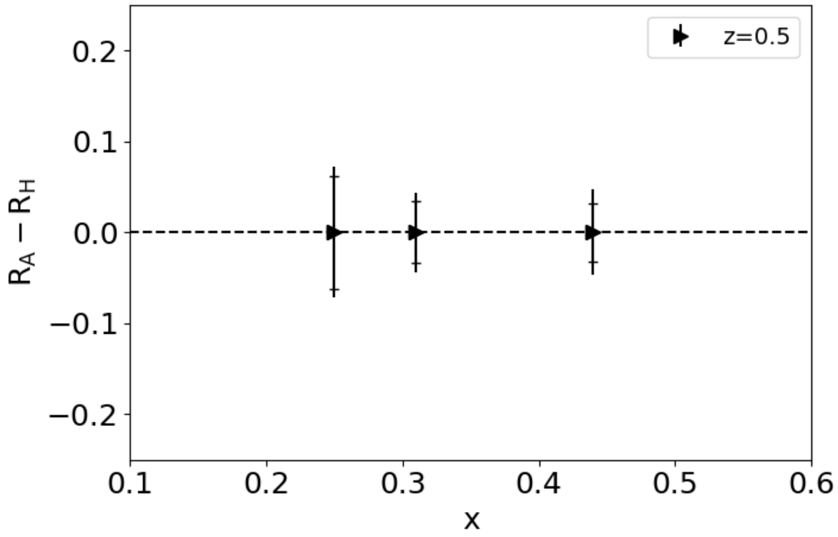


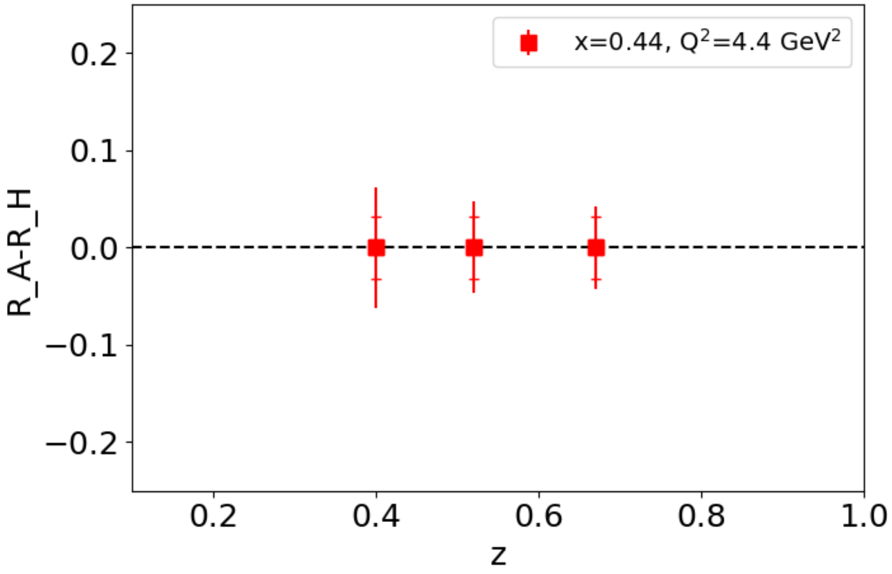


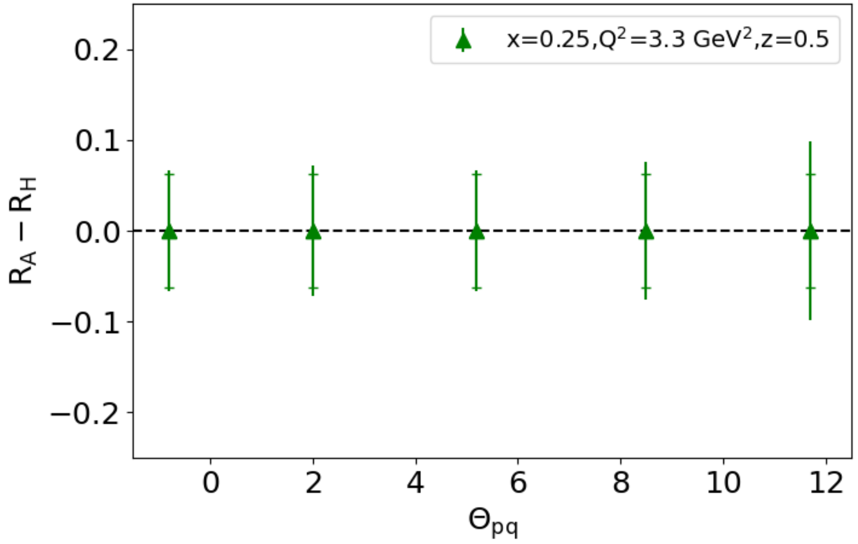


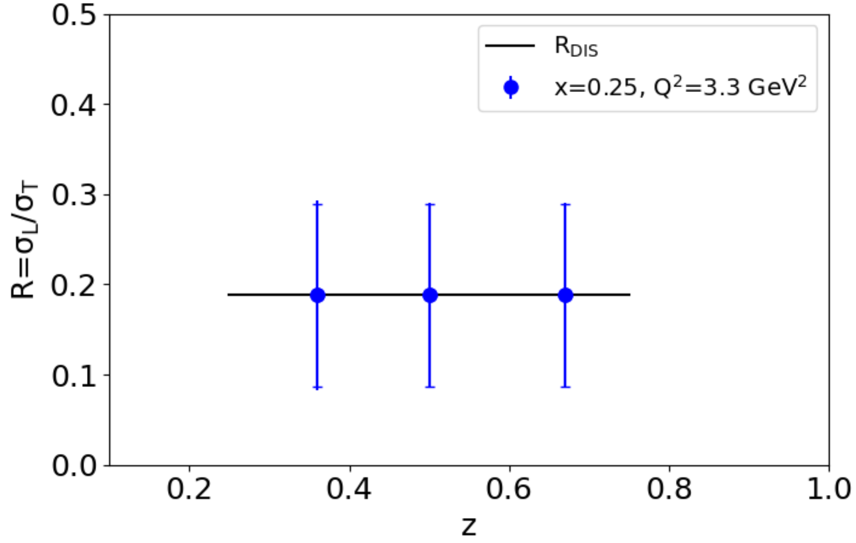


Projections from Dave Gaskell for this plan: R_A-R_H









Background and Calibration Runs

- Run Dummy target for 15% of time for π^- on proton target at every setting. ¡2¿
- Reverse HMS polarity for pair-symmetric background runs for the low-ϵ pass of each setting, for 10% of the time used for electron running. ¡3-¿
- Run for 25% of time with half of the nominal current.
- Run with HMS ELREAL trigger (pre-scaled if need be) at every setting for 15 minutes (unless rates low enough that ELREAL can be used for production running already) to check DIS xsection
- HEEP runs at every beam energy
- heEP scan of SHMS from $-16 < \delta < 40\%$ to extend useful acceptance range.

Summary

- Run plan nearly completed
- Run coordinators list available
- Preparation of online analysis ongoing
- Experiment start in late May 2025 at present
- Transformation to shift plan next
- Opening schedule for shift sign up next

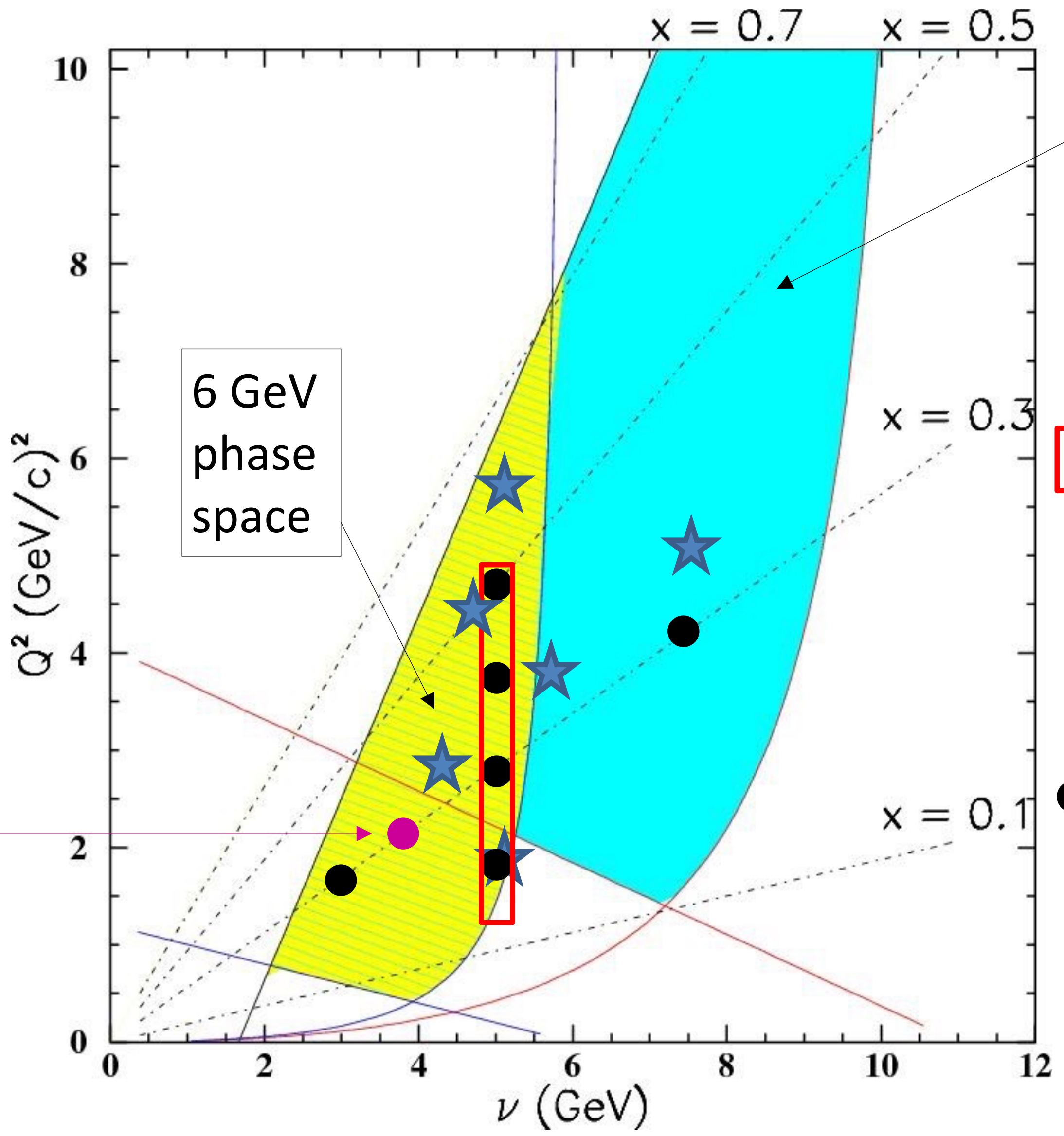
Backup

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

Original Kinematic Plan: z dependence at x=0.2, Q^2=2.0

TABLE I. L/T Separations as a function of z at (x, Q^2) = (0.20,2.00)

x	Q^2 (GeV^2)	W^2 (GeV^2)	z	W'^2 (GeV^2)	E' (GeV)	θ_e (deg)	q_γ (GeV)	θ_γ (deg)	ϵ	Eo (GeV)	R_{DIS}
0.20	2.00	8.88	0.30	6.48	1.271	28.26	5.513	6.27	0.34	6.6	0.27
			0.30	6.48	3.471	14.70	5.513	9.19	0.66	8.8	0.27
			0.30	6.48	5.671	10.27	5.513	10.57	0.80	11.0	0.27
0.20	2.00	8.88	0.40	5.68	1.271	28.26	5.513	6.27	0.34	6.6	0.27
			0.40	5.68	3.471	14.70	5.513	9.19	0.66	8.8	0.27
			0.40	5.68	5.671	10.27	5.513	10.57	0.80	11.0	0.27
0.20	2.00	8.88	0.50	4.88	1.271	28.26	5.513	6.27	0.34	6.6	0.27
			0.50	4.88	3.471	14.70	5.513	9.19	0.66	8.8	0.27
			0.50	4.88	5.671	10.27	5.513	10.57	0.80	11.0	0.27
0.20	2.00	8.88	0.65	3.68	1.271	28.26	5.513	6.27	0.34	6.6	0.27
			0.65	3.68	3.471	14.70	5.513	9.19	0.66	8.8	0.27
			0.65	3.68	5.671	10.27	5.513	10.57	0.80	11.0	0.27
0.20	2.00	8.88	0.85	2.08	1.271	28.26	5.513	6.27	0.34	6.6	0.27
			0.85	2.08	3.471	14.70	5.513	9.19	0.66	8.8	0.27
			0.85	2.08	5.671	10.27	5.513	10.57	0.80	11.0	0.27

Original Kinematic Plan: z dependence at x=0.4, Q^2=4.0

TABLE II. L/T Separations as a function of z at $(x, Q^2) = (0.40, 4.00)$

x	Q^2 (GeV^2)	W^2 (GeV^2)	z	W'^2 (GeV^2)	E' (GeV)	θ_e (deg)	q_γ (GeV)	θ_γ (deg)	ϵ	Eo (GeV)	R_{DIS}
0.40	4.00	6.88	0.30	5.08	1.271	40.40	5.692	8.32	0.31	6.6	0.19
			0.30	5.08	3.471	20.85	5.692	12.54	0.65	8.8	0.19
			0.30	5.08	5.671	14.55	5.692	14.49	0.79	11.0	0.19
0.40	4.00	6.88	0.40	4.48	1.271	40.40	5.692	8.32	0.31	6.6	0.19
			0.40	4.48	3.471	20.85	5.692	12.54	0.65	8.8	0.19
			0.40	4.48	5.671	14.55	5.692	14.49	0.79	11.0	0.19
0.40	4.00	6.88	0.50	3.88	1.271	40.40	5.692	8.32	0.31	6.6	0.19
			0.50	3.88	3.471	20.85	5.692	12.54	0.65	8.8	0.19
			0.50	3.88	5.671	14.55	5.692	14.49	0.79	11.0	0.19
0.40	4.00	6.88	0.65	2.98	1.271	40.40	5.692	8.32	0.31	6.6	0.19
			0.65	2.98	3.471	20.85	5.692	12.54	0.65	8.8	0.19
			0.65	2.98	5.671	14.55	5.692	14.49	0.79	11.0	0.19
0.40	4.00	6.88	0.85	1.78	1.271	40.40	5.692	8.32	0.31	6.6	0.19
			0.85	1.78	3.471	20.85	5.692	12.54	0.65	8.8	0.19
			0.85	1.78	5.671	14.55	5.692	14.49	0.79	11.0	0.19

Original Kinematic Plan: p_T^2 dependence at x=0.3, Q^2=3.0

TABLE III. L/T Separations as a function of p_T^2 at (x, Q^2) = (0.30,3.00)

x	Q^2 (GeV^2)	W^2 (GeV^2)	z	W'^2 (GeV^2)	E' (GeV)	θ_e (deg)	q_γ (GeV)	θ_γ (deg)	ϵ	Eo (GeV)	R_{DIS}	θ_{pq} (deg)
0.30	3.00	7.88	0.50	4.380	1.271	34.80	5.603	7.44	0.33	6.6	0.19	-2.0
			0.50	4.380	3.471	18.03	5.603	11.05	0.66	8.8		
			0.50	4.380	5.671	12.59	5.603	12.75	0.80	11.0		
0.30	3.00	7.88	0.50	4.380	1.271	34.80	5.603	7.44	0.33	6.6	0.19	0.0
			0.50	4.380	3.471	18.03	5.603	11.05	0.66	8.8		
			0.50	4.380	5.671	12.59	5.603	12.75	0.80	11.0		
0.30	3.00	7.88	0.50	4.380	1.271	34.80	5.603	7.44	0.33	6.6	0.19	5.0
			0.50	4.380	3.471	18.03	5.603	11.05	0.66	8.8		
			0.50	4.380	5.671	12.59	5.603	12.75	0.80	11.0		
0.30	3.00	7.88	0.50	4.380	1.271	34.80	5.603	7.44	0.33	6.6	0.19	10.0
			0.50	4.380	3.471	18.03	5.603	11.05	0.66	8.8		
			0.50	4.380	5.671	12.59	5.603	12.75	0.80	11.0		
0.30	3.00	7.88	0.50	4.380	1.271	34.80	5.603	7.44	0.33	6.6	0.19	15.0
			0.50	4.380	3.471	18.03	5.603	11.05	0.66	8.8		
			0.50	4.380	5.671	12.59	5.603	12.75	0.80	11.0		
0.30	3.00	7.88	0.50	4.380	1.271	34.80	5.603	7.44	0.33	6.6	0.19	20.0
			0.50	4.380	3.471	18.03	5.603	11.05	0.66	8.8		
			0.50	4.380	5.671	12.59	5.603	12.75	0.80	11.0		

Original Kinematic Plan: Q^2 dependence at z=0.5

TABLE IV. Additional L/T Separations as a function of Q^2 at variable (x, Q^2).

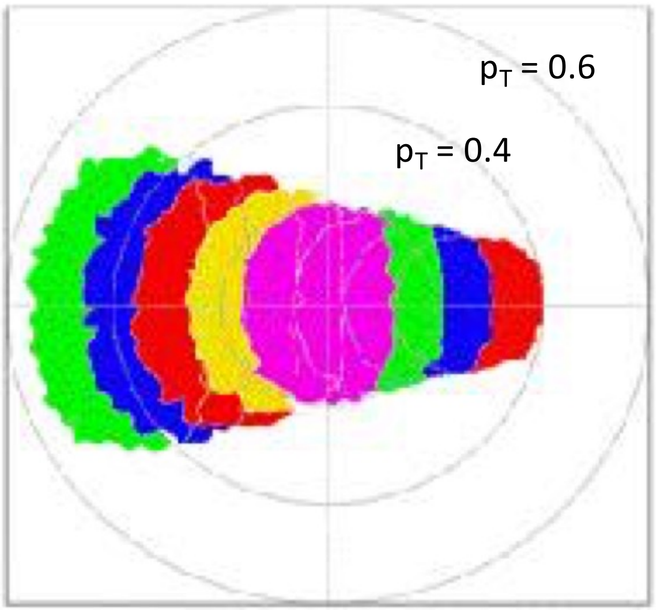
x	Q^2 (GeV^2)	W^2 (GeV^2)	z	W'^2 (GeV^2)	E' (GeV)	θ_e (deg)	q_γ (GeV)	θ_γ (deg)	ϵ	Eo (GeV)	R_{DIS}
0.15	1.50	9.38	0.50	5.130	1.271	24.41	5.468	5.51	0.35	6.6	0.35
			0.50	5.130	3.471	12.72	5.468	8.04	0.67	8.8	0.35
0.50	5.00	5.88	0.50	3.380	1.271	45.41	5.779	9.01	0.30	6.6	0.12
			0.50	3.380	3.471	23.34	5.779	13.77	0.64	8.8	0.12
			0.50	3.380	5.671	16.28	5.779	15.96	0.79	11.0	0.12

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

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

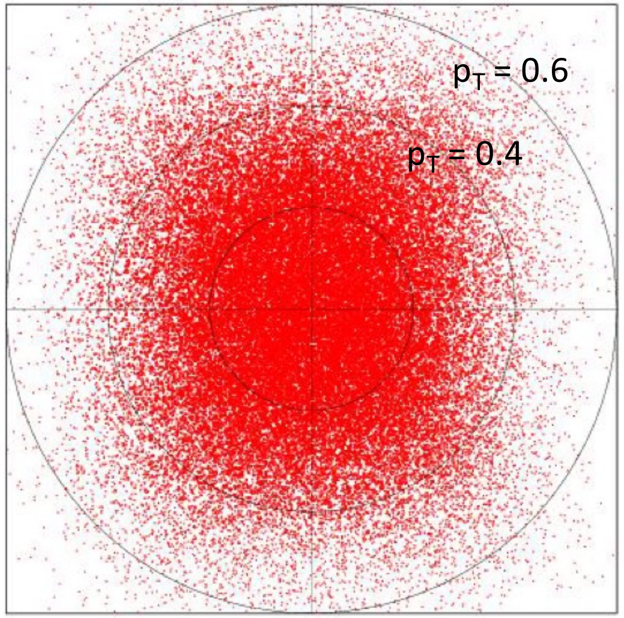
(e,e’π^{0}) with NPS
E12-13-007

ϕ = 90°

ϕ = 180°  ϕ = 0°

ϕ = 270°

ϕ = 90°

ϕ = 180°  ϕ = 0°

ϕ = 270°

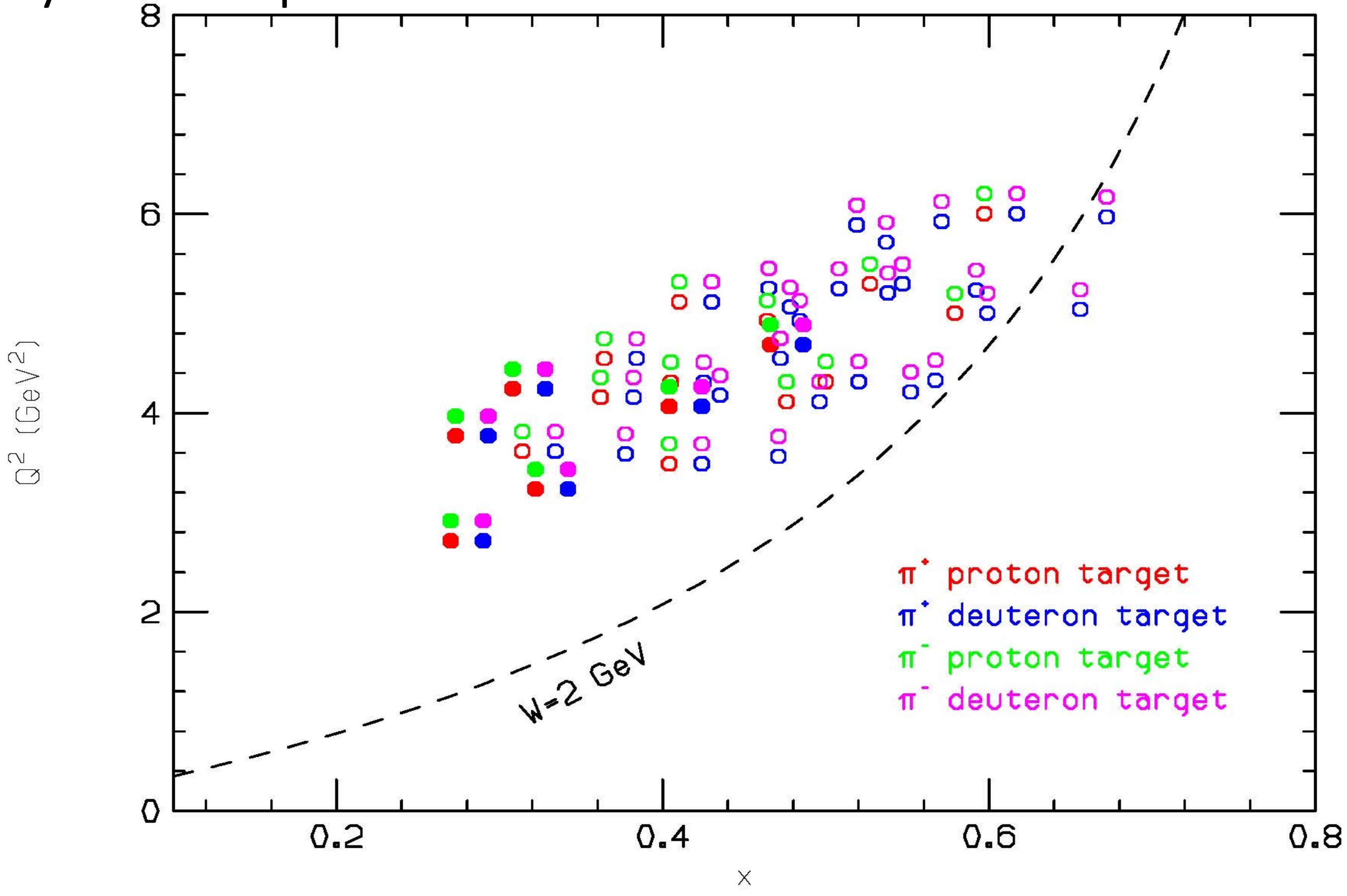
Kinematic coverage in (x,Q^2)

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



Detailed Kinematics

<u>E12-06-104:</u>

Data for π+ and π- from proton at all settings

Data from proton and deuteron at x=0.2

x	Q^2 (GeV^2)	z	θ_{pq} (degrees)	Targets	E_{beam} (GeV)	ϵ
0.2	**2.0**	**0.3,0.4,0.5,0.65,0.85**	**0.0**	LH2,LD2,**C,Cu**	**6.6**	**0.34**
		0.3,0.4,0.5,0.65,0.85	**0.0**	LH2,LD2,**C,Cu**	**8.8**	**0.66**
		0.3,0.4,0.5,0.65,0.85	**0.0**	LH2,LD2,**C,Cu**	**11.0**	**0.80**
0.4	**4.0**	0.3,0.4,**0.5**,0.65,0.85	**0.0**	LH2,**C,Cu**	**6.6**	**0.31**
		0.3,0.4,**0.5**,0.65,0.85	**0.0**	LH2,**C,Cu**	**8.8**	**0.65**
		0.3,0.4,**0.5**,0.65,0.85	**0.0**	LH2,**C,Cu**	**11.0**	**0.79**
0.3	3.0	0.5	-2.0,0.0,5.0,10.0,15.0,20.0	LH2	6.6	0.33
		0.5	-2.0,0.0,5.0,10.0,15.0,20.0	LH2	8.8	0.66
		0.5	-2.0,0.0,5.0,10.0,15.0,20.0	LH2	11.0	0.88
0.15	1.5	0.5	0.0	LH2	6.6	0.35
		0.5	0.0	LH2	8.8	0.67
0.5	**5.0**	**0.5**	**0.0**	LH2, **C,Cu**	**6.6**	**0.30**
		0.5	**0.0**	LH2, **C,Cu**	**8.8**	**0.64**
		0.5	**0.0**	LH2, **C,Cu**	**11.0**	**0.79**

<u>This experiment:</u>

Bold = kinematic settings for measurements with C and Cu targets (π+ only)

Bold, red = kinematic settings for measurements with C and Cu targets (π+ **and** π-)

Detailed Kinematics

E12-06-104:

Data for π+ and π- from proton at all settings

Data from proton and deuteron at x=0.2

x	Q^2 (GeV^2)	z	θ_{pq} (degrees)	Targets	E_{beam} (GeV)	ϵ
0.2	**2.0**	**0.3,0.4,0.5,0.65,0.85**	**0.0**	LH2,LD2,**C,Cu**	**6.6**	**0.34**
		0.3,0.4,0.5,0.65,0.85	**0.0**	LH2,LD2,**C,Cu**	**8.8**	**0.66**
		0.3,0.4,0.5,0.65,0.85	**0.0**	LH2,LD2,**C,Cu**	**11.0**	**0.80**
0.4	**4.0**	0.3,0.4,**0.5**,0.65,0.85	**0.0**	LH2,**C,Cu**	**6.6**	**0.31**
		0.3,0.4,**0.5**,0.65,0.85	**0.0**	LH2,**C,Cu**	**8.8**	**0.65**
		0.3,0.4,**0.5**,0.65,0.85	**0.0**	LH2,**C,Cu**	**11.0**	**0.79**
0.3	3.0	0.5	-2.0,0.0,5.0,10.0,15.0,20.0	LH2	6.6	0.33
		0.5	-2.0,0.0,5.0,10.0,15.0,20.0	LH2	8.8	0.66
		0.5	-2.0,0.0,5.0,10.0,15.0,20.0	LH2	11.0	0.88
0.15	1.5	0.5	0.0	LH2	6.6	0.35
		0.5	0.0	LH2	8.8	0.67
0.5	**5.0**	**0.5**	**0.0**	LH2, **C,Cu**	**6.6**	**0.30**
		0.5	**0.0**	LH2, **C,Cu**	**8.8**	**0.64**
		0.5	**0.0**	LH2, **C,Cu**	**11.0**	**0.79**

Goals:

1. Measure nuclear dependence of R_{SIDIS} for range of x at fixed z
   → Low x: no or small nuclear effects (inclusive), Large x: EMC region
2. Measurement for range of z for at least one x
3. Both π+ and π- for (part of) z-scan
4. Multiple values of A to explore nuclear dependence