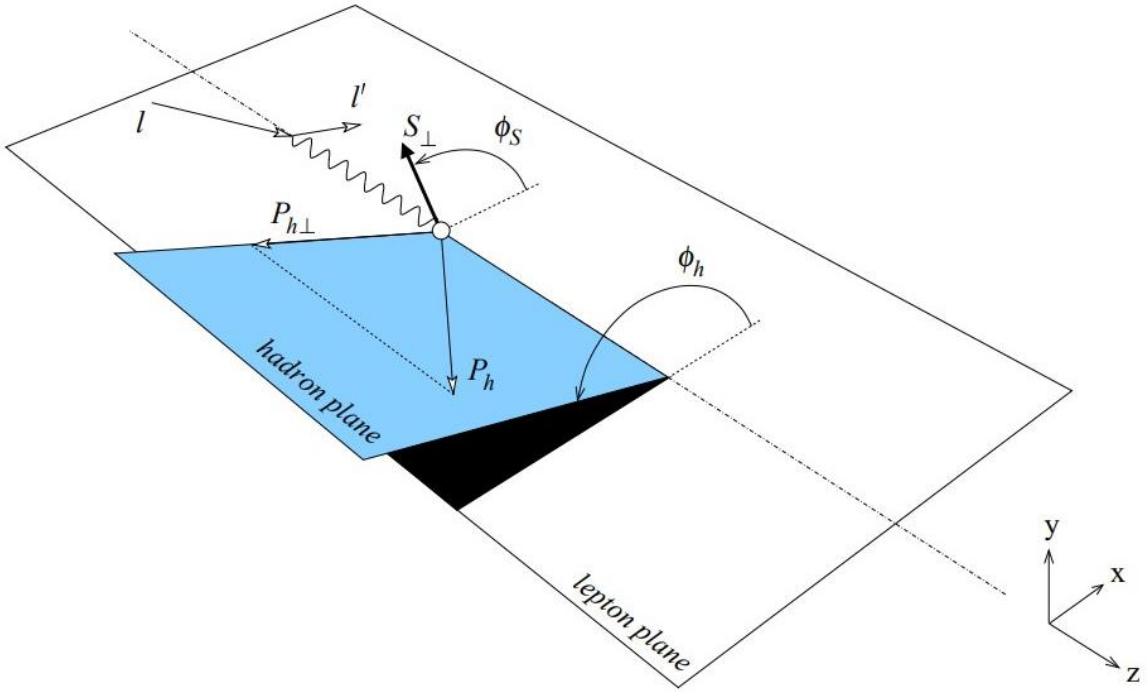
Winter Hall C Collaboration Meeting

π^0 SIDIS

Precision $(e, e'\pi^0)$ cross sections at low $P_{h\perp}$

L/T Separation of SIDIS $(e, e'\pi^0)$



Bacchetta et al. JHEP 0702 (2007) 093

Casey Morean, on behalf of

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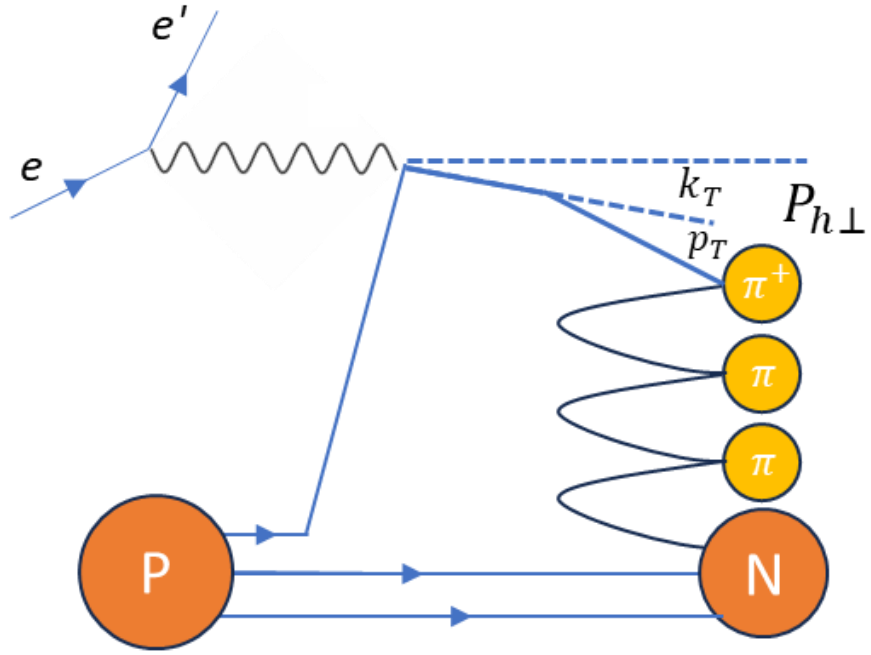
THE CATHOLIC UNIVERSITY OF AMERICA

Jefferson Lab

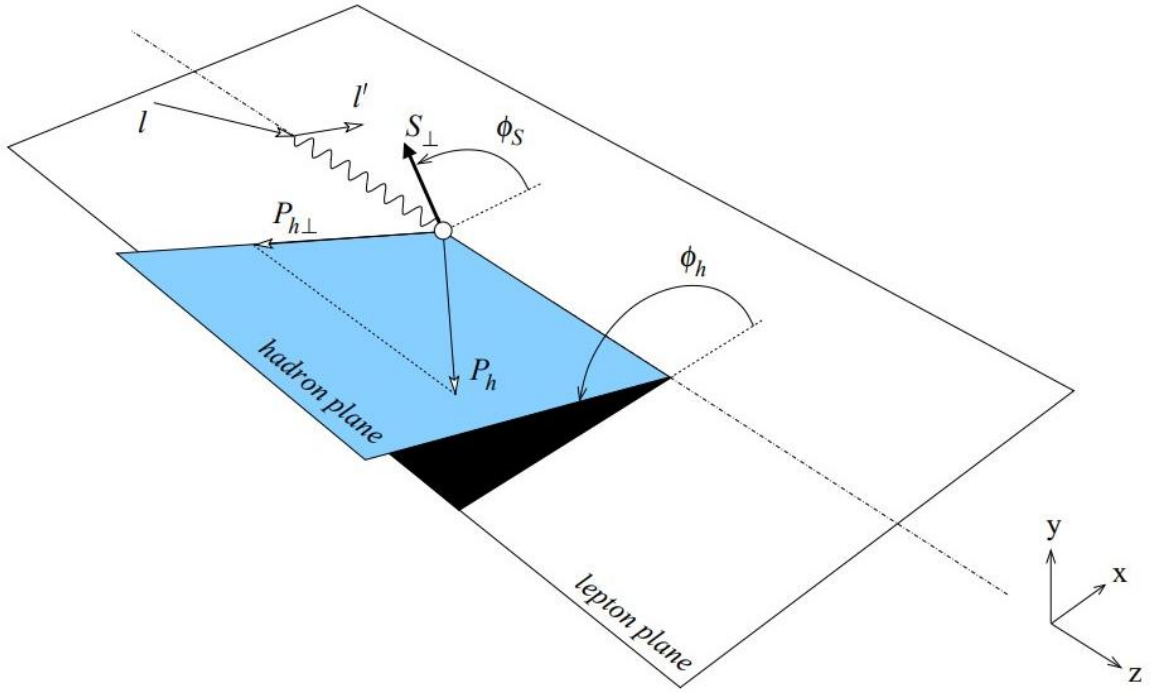
Exploring 3D Momentum Structure of the Nucleon

- From our experimental and theoretical understanding of partonic structure, we can move beyond the 1D momentum fraction (x_{bj}) picture of the nucleon.
- Semi-inclusive hadron electroproduction $\mathrm{N}(e, e'\pi^0)X$
  - Sensitive to quark transverse momentum, quark flavor, and quark spin
- SIDIS is a useful process for mapping the spin-correlated 3D structure of quarks within nucleons
- SIDIS is a major part of JLab 12GeV program for accessing TMDs



SIDIS Formalism

- General expression for SIDIS, 8 leading twist structure functions, 18 structure functions to twist-3
  - Bacchetta et al. JHEP 0702 (2007) 93
- Keeping only unpolarized target and beam polarized SIDIS structure functions up to twist-3
  - Subscripts indicate unpolarized and longitudinally polarized beam and target, respectively.



Bacchetta et al. JHEP 0702 (2007) 093

$$\frac{d\sigma}{dx\,dy\,d\psi dz\,d\phi_h dP_\perp^2} = \frac{\alpha^2}{xyQ^2}\frac{y^2}{2(1-\epsilon)}\left(1+\frac{\gamma^2}{2x}\right)\left\{F_{UU,T}+\epsilon F_{UU,L}+\sqrt{2\epsilon(1+\epsilon)}\cos\phi_h F_{UU}^{\cos\phi_h}+\epsilon\cos(2\phi_h)F_{UU}^{\cos 2\phi_h}+\lambda_e\sqrt{2\epsilon(1-\epsilon)}\sin\phi_h F_{LU}^{\sin\phi_h}\right\}$$

λ_e: lepton helicity

$$\gamma = \frac{2Mx}{Q}$$

$$\epsilon = \frac{1}{1+2\frac{|q^2|^2}{Q^2}\tan^2\left(\frac{\theta_e}{2}\right)}$$

SIDIS Formalism - Notation

- Kinematic Quantities

$$Q^2 = (l - l')^2 = 4E_e E'_e \sin^2(\theta_e/2)$$
$$\nu = E_e - E'_e$$
$$x = Q^2/2M\nu$$
$$W^2 = (P + q)^2$$

(Typical inclusive variables)

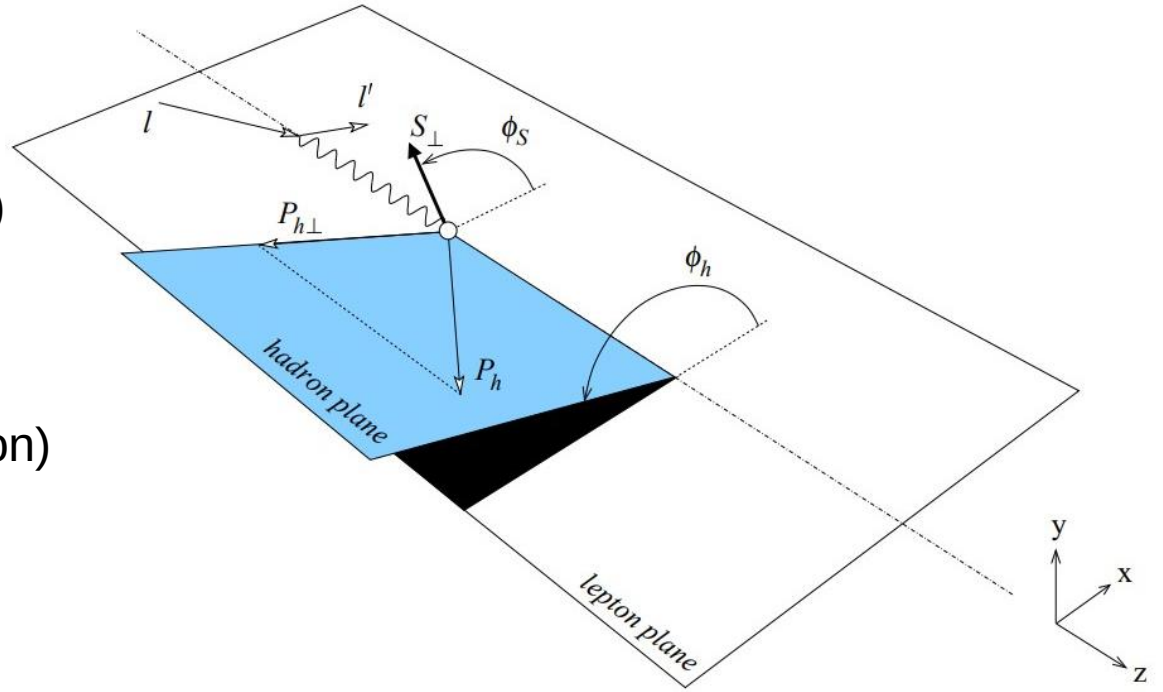
$$z = \frac{P \cdot P_h}{P \cdot q} = \frac{E_h}{\nu}$$

(Fraction of virtual photon energy carried by the hadron)

$$p_T^h = \left| p_h - \left(\frac{p_h \cdot q}{|q|^2} \right) q \right|$$

$W'^2 = M_X^2 = (P + q - P_h)^2$, larger z, smaller W'

ϕ_h: Angle between hadron and lepton planes



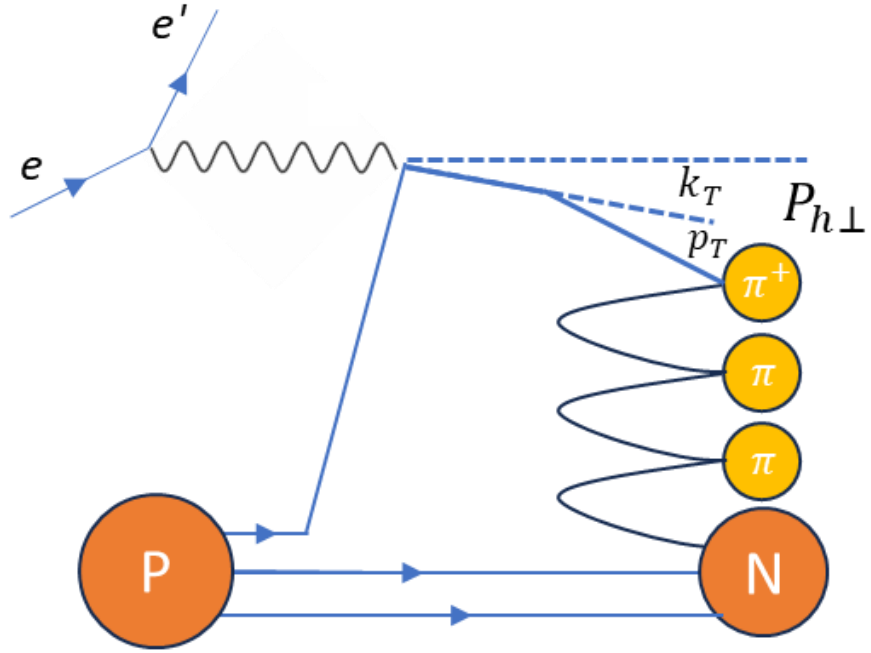
Bacchetta et al. JHEP 0702 (2007) 093

Transverse Momentum Dependence in SIDIS π^0 cross-section

- SIDIS cross sections depend on the transverse momentum of the hadron $P_{h\perp}$.
  - Arises from intrinsic transverse momentum (k_T) of the parton and the transverse momentum (p_T) of the fragmentation process
- Neutral pions are a good test and consistency check of flavor assumptions in extraction of TMDs with TM fragmentation
  - With a p_T and k_T dependence, a convolution is necessary to obtain $P_{h\perp}$

$$\frac{d^5\sigma^{\ell p\to\ell hX}}{dx_B dQ^2 dz_h d^2\boldsymbol{P}_T} \simeq \sum_q e_q^2 \int d^2\boldsymbol{k}_\perp f_q(x_B, k_\perp) \frac{2\pi\alpha^2}{x_B^2 s^2} \times \frac{\hat{s}^2+\hat{u}^2}{Q^4} D_q^h(z_h, p_\perp),$$

Anselmino et al. Phys. Rev. D 71, 074006 (2005)



$$< P_{h\perp}^2 > (z) = z^2 < k_t^2 > + < p_T^2 > (z)$$

- Quadratic dependence on z^2 intrinsic transverse motion

SIDIS π^0 Advantages

- Measuring SIDIS for both the proton and neutron
- Diffractive ρ production can be a significant background for charged π-SIDIS.

  $$\rho^0 \rightarrow \pi^+ + \pi^-$$

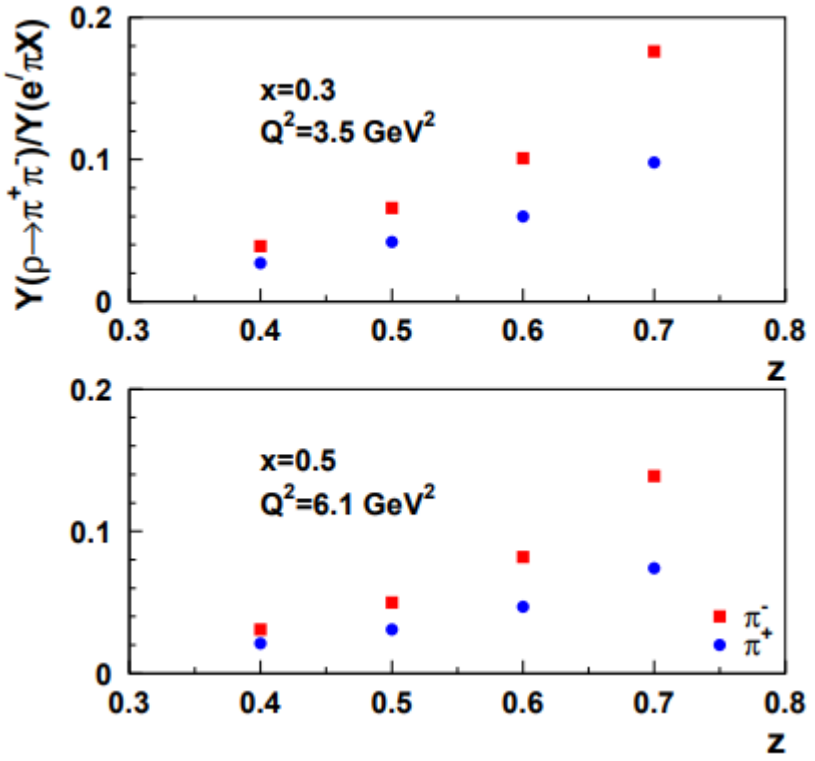
  - Not a problem for π^0 production.
- Background from SIDIS-$\rho^{+/-}$ is still a contribution but is not expected to be large.

  $$\rho^+ \rightarrow \pi^+ + \pi^0$$

- Can verify the SIDIS-π^o cross-section expectation.

  $$\sigma^{\pi^0} = \frac{1}{2}\left(\sigma^{\pi^+}(x,z,p_T) + \sigma^{\pi^-}(x,z,p_T)\right)$$

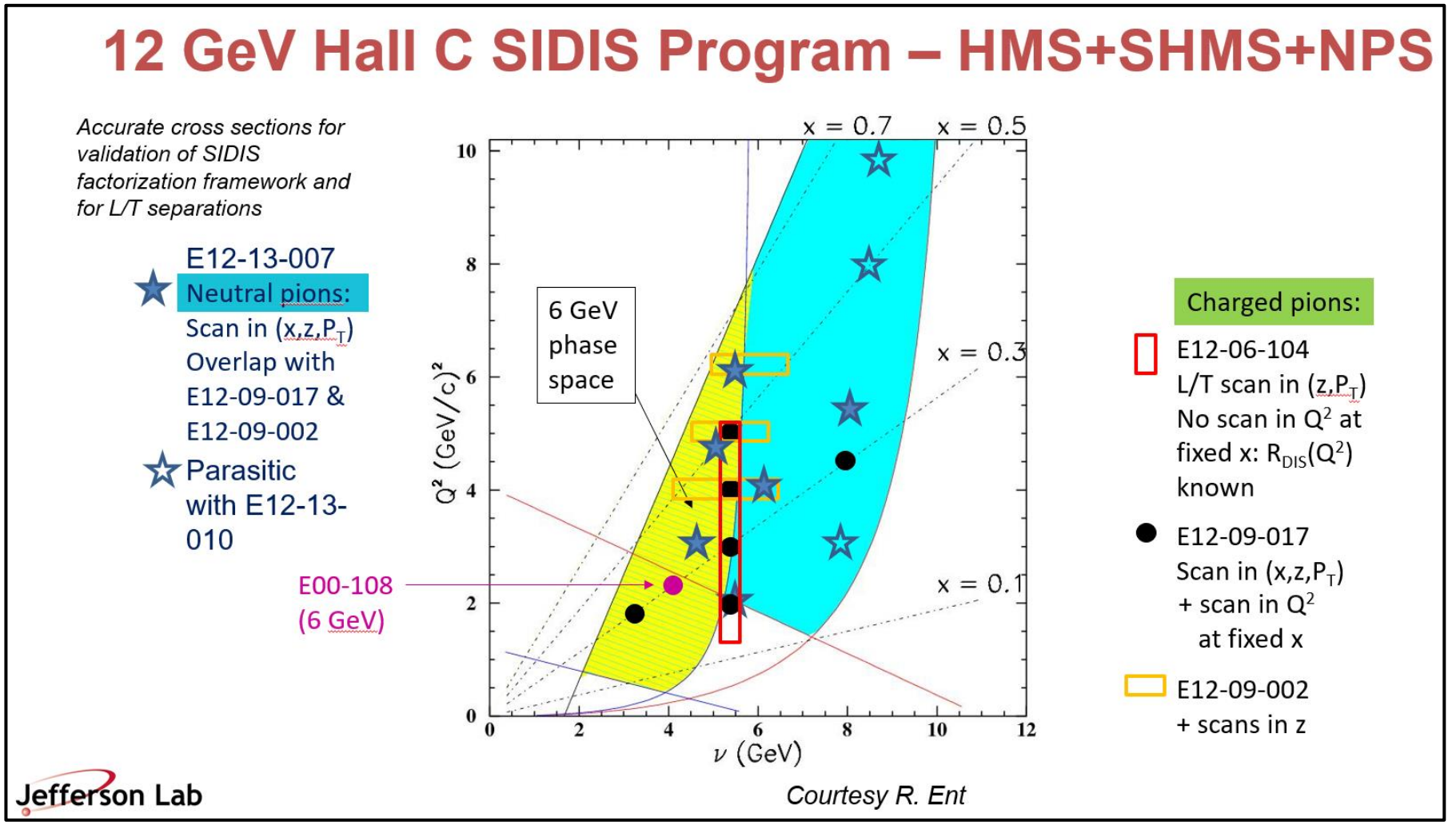
- Can get run coincident with DVCS experiments with NPS



Hafidi et al. CSV proposal: PR12-09-002

12 GeV Hall C π^0 SIDIS with HMS and NPS Phase Space

- Accessible phase space highlights, 6 GeV, 12 GeV comparison
- At a glance, not all kinematics included

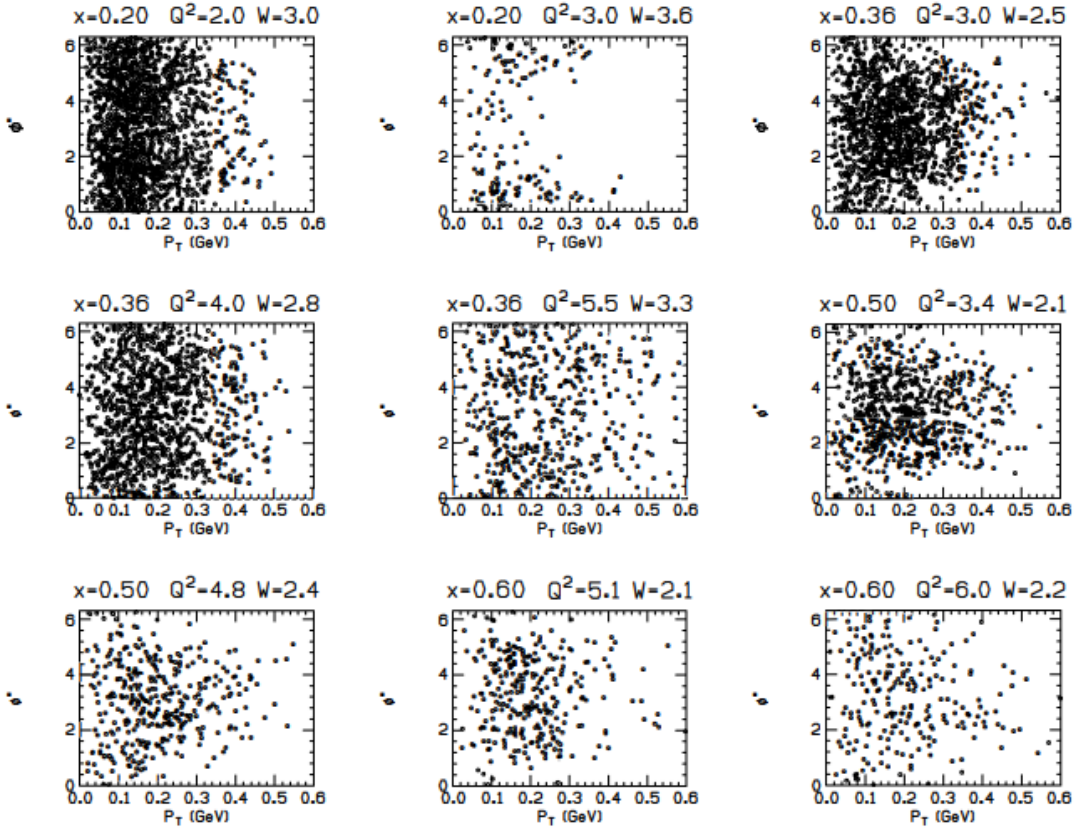


Courtesy D. Gaskell

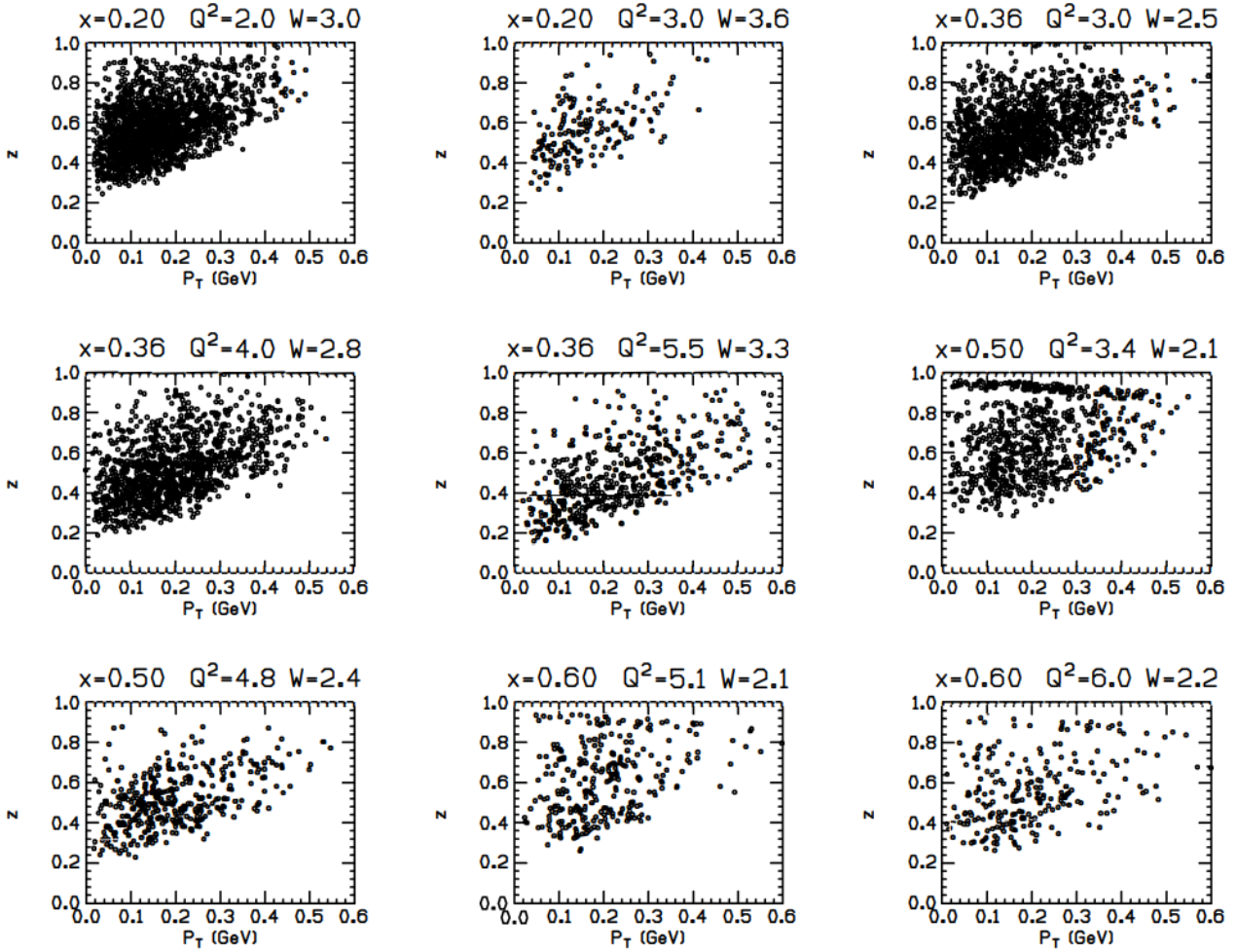
Hall C π^0 SIDIS with HMS and NPS Phase Space

- Phase Space highlights (SIMC)

ϕ *vs* P_T

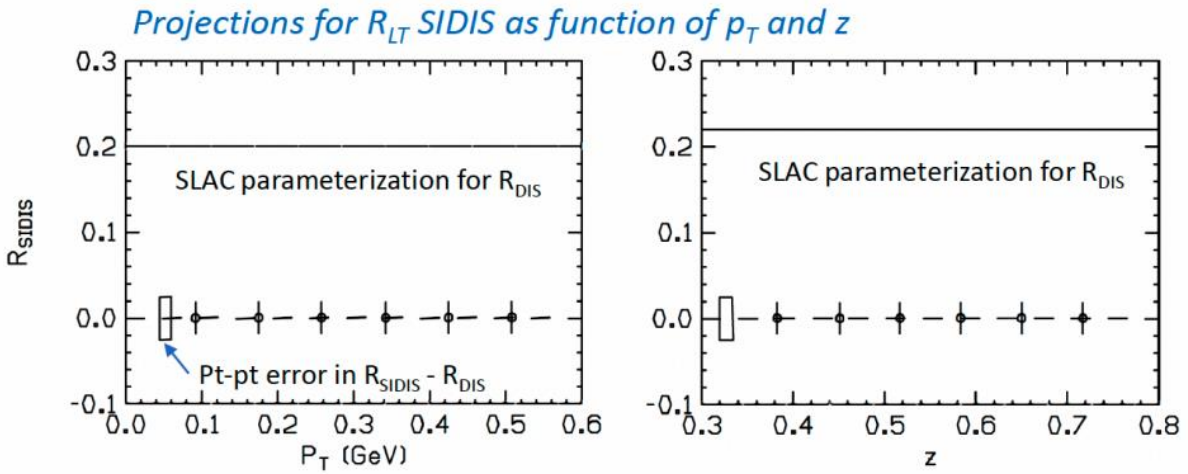


z *vs* P_T

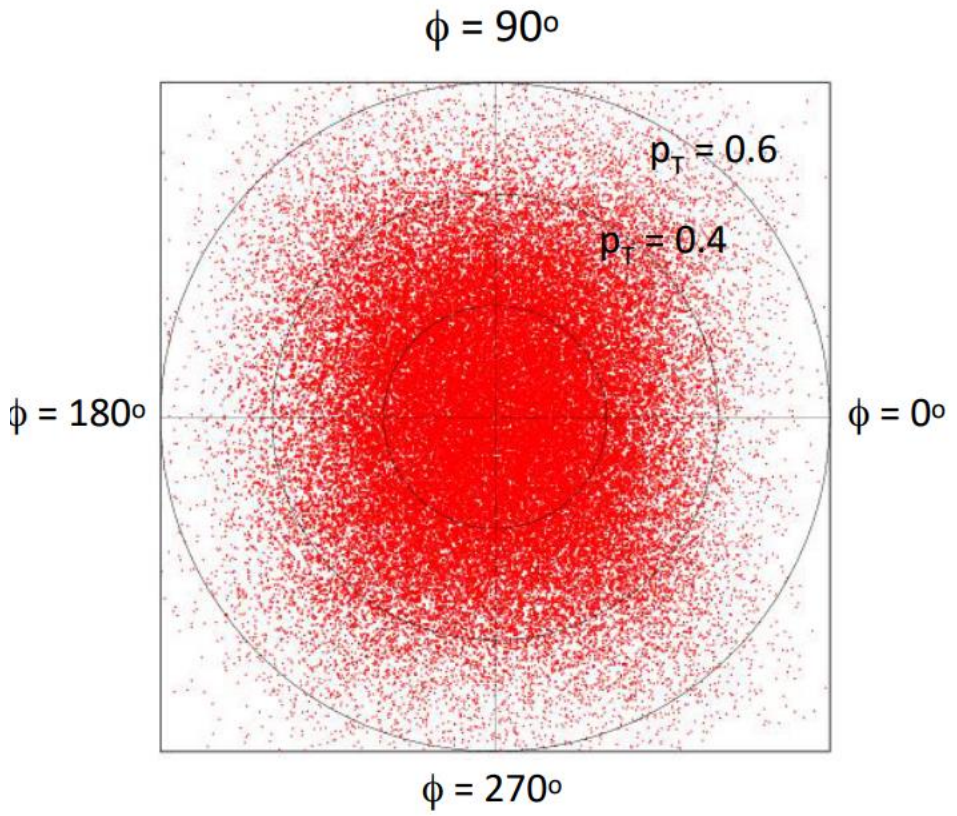


SIDIS π^0 L-T Separation

- No one has measured π^0 R_{LT}^{SIDIS} Expand on kinematics
  - Assumed $R_{SIDIS} = \sigma_L/\sigma_T$
- Needed to interpret any JLab SIDIS data
  - R_{SIDIS} dependence on z, hadron, $P_{h\perp}$?
- Do we understand Q^2 dependence as we approach $z = 1$?



(e,e'π⁰) with NPS E12-13-007

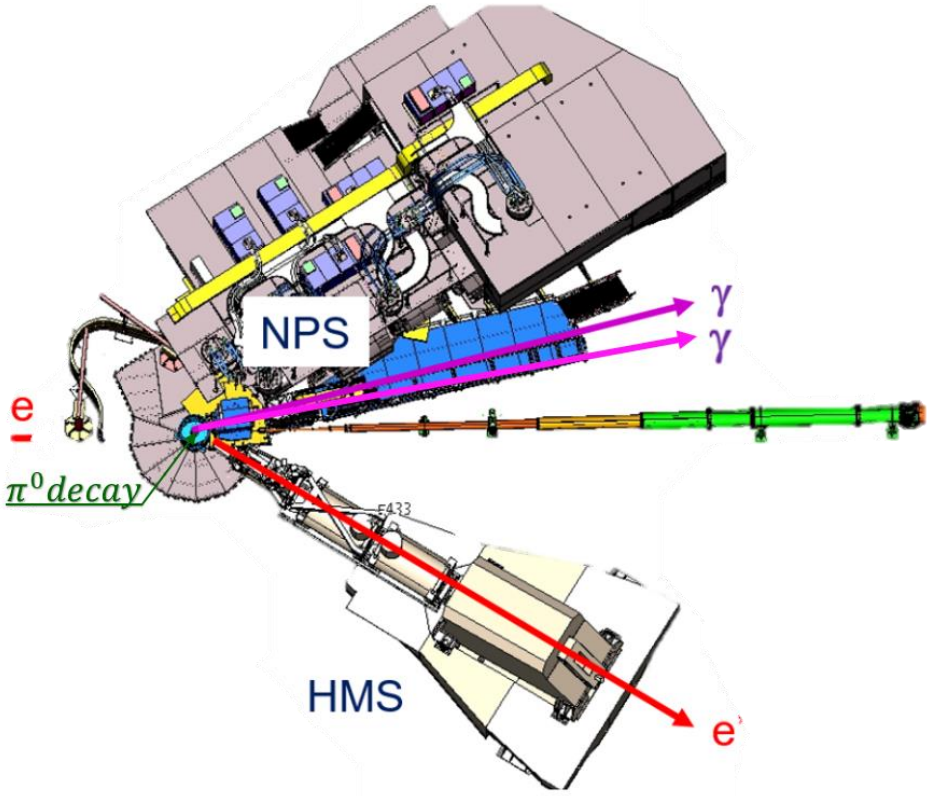


SIDIS π^0 Covered and Planned Kinematics

- More comprehensive overview tomorrow morning

Name KinC-	x_B	Q^2 GeV^2	E GeV	ϵ	E' GeV	θ_{HMS} deg	θ_{Calo} deg	q'_{Max} GeV	D_{Calo} m	H_2 Days	D_2
x25-1	0.24	2.10	6.397	0.470	1.734	25.13	8.68	4.63	6.0	1	1
x25-2	0.24	2.40	8.483	0.629	3.154	17.22	9.69	5.30	4.0	1	1
x25-3'	0.26	2.40	10.558	0.816	5.639	11.52	12.62	4.88	4.0	1	1
x25-4	0.25	3.00	10.558	0.663	4.163	15.01	9.37	6.36	6.0	1	1
x36-1	0.36	3.00	6.397	0.509	1.956	28.34	11.24	4.35	3.0	0.9	1.0
x36-2	0.36	3.00	8.483	0.747	4.042	17.01	14.36	4.35	3.0	0.4	0.5
x36-3	0.36	3.00	10.558	0.849	6.117	12.37	15.96	4.35	3.0	0.25	0.33
x36-4	0.36	4.00	8.483	0.515	2.562	24.77	9.89	5.83	4.0	1.0	1.0
x36-5	0.36	4.00	10.558	0.711	4.637	16.44	12.12	5.83	3.0	0.66	1.0
x36-6	0.36	5.50	10.558	0.402	2.416	26.85	7.40	8.05	4.0	1.66	2.0
x50-0	0.48	3.40	6.397	0.647	2.640	25.93	16.01	3.58	3.0	3.0	3.0
x50-1	0.48	3.40	8.483	0.818	4.726	16.75	18.98	3.58	3.0	1.5	1.5
x50-2	0.48	3.40	10.558	0.890	6.800	12.49	20.58	3.58	3.0	1.25	1.25
x50-3	0.48	4.80	10.558	0.767	5.253	16.92	15.45	5.12	3.0	2.5	2.5
x60-1	0.58	5.10	6.397	0.418	1.717	39.84	12.22	4.364	3.0	10	10
x60-2	0.58	5.10	8.483	0.697	3.803	22.93	16.57	4.364	3.0	7.5	7.5
x60-3	0.58	5.10	10.558	0.818	5.878	16.48	18.72	4.364	3.0	4.5	4.5
x60-4	0.58	6.00	10.558	0.741	5.052	19.31	16.09	5.182	3.0	7.5	7.5

Excerpt from static NPS runplan (arbitrary color scale)



π^o reconstruction in the NPS

More plots hidden!

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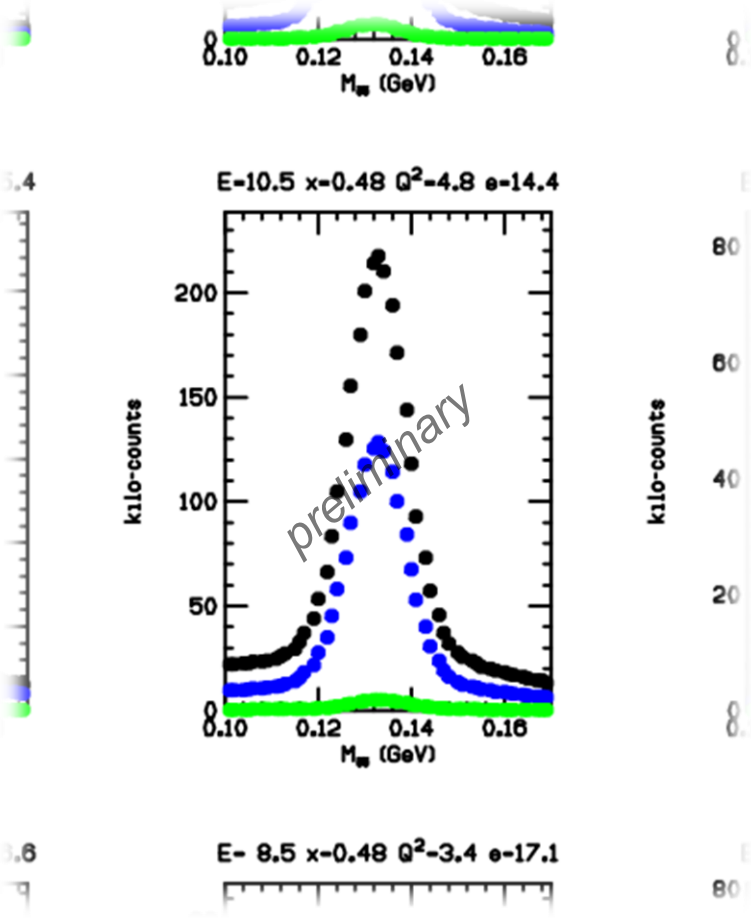
- Two-photon trigger configuration
- Gain calibration coefficients in the trigger
- Blocks undergo radiation damage over a long period of time
- Temperature dependence on light output (temperature monitoring)
- Clustering algorithm

- THEN reconstruct kinematic variables
  - Not a spectrometer, reconstructing pion location interesting

- See tomorrow's talks!



Plots courtesy of Peter Bosted

More plots hidden!

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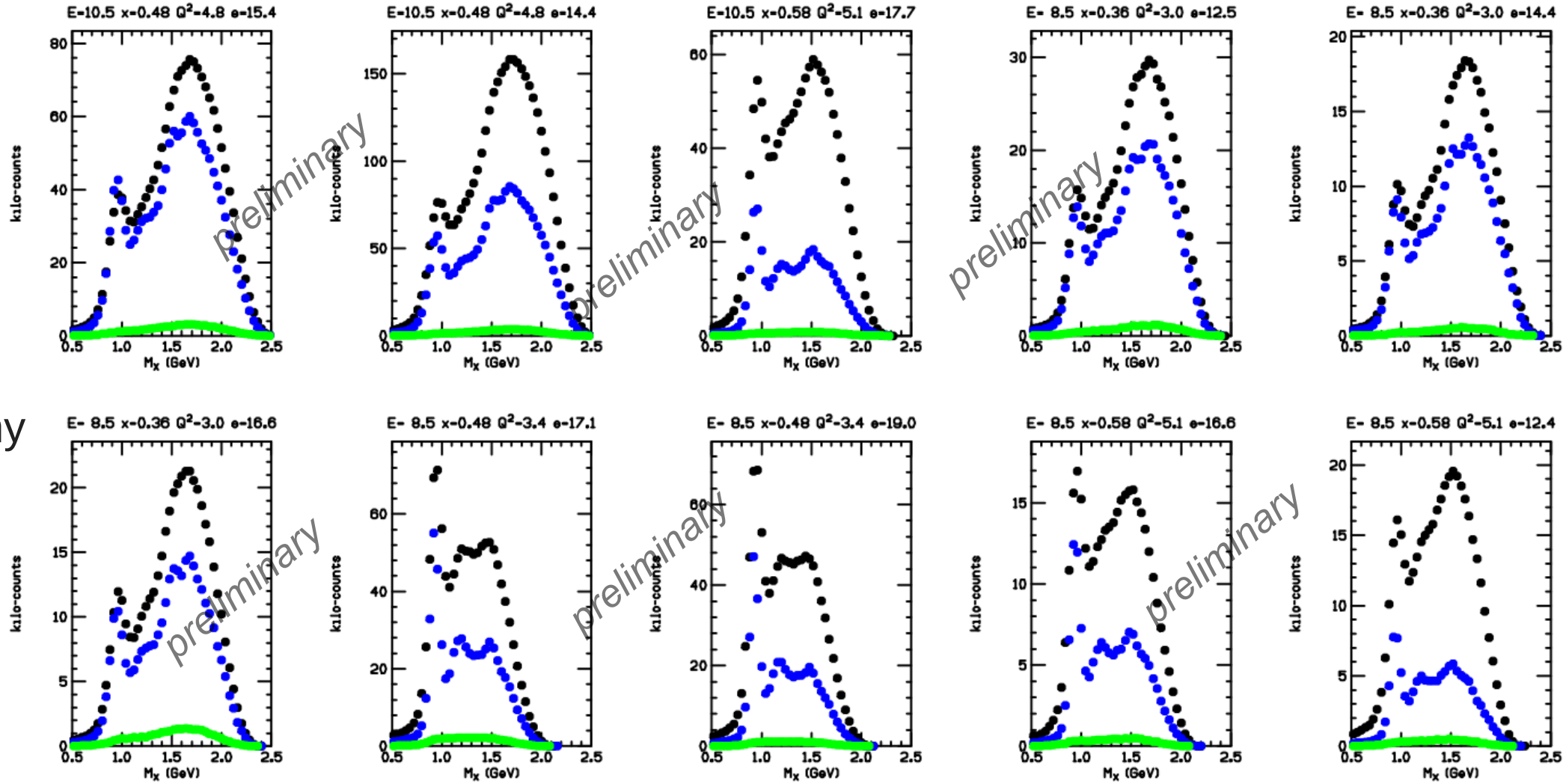
Black:LD2

Blue:LH2

Green:Dummy



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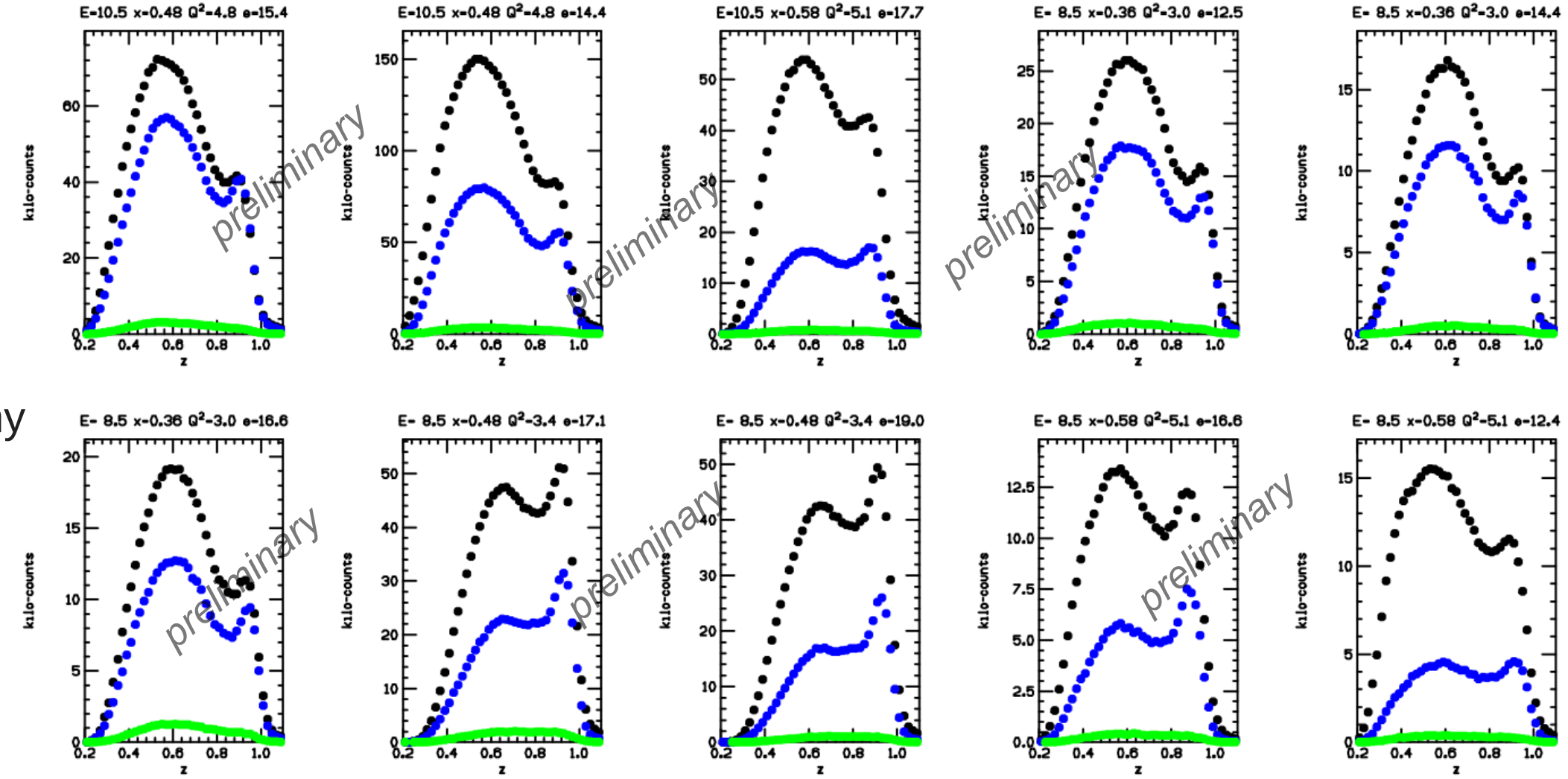

Plots courtesy of Peter Bosted

More plots hidden!

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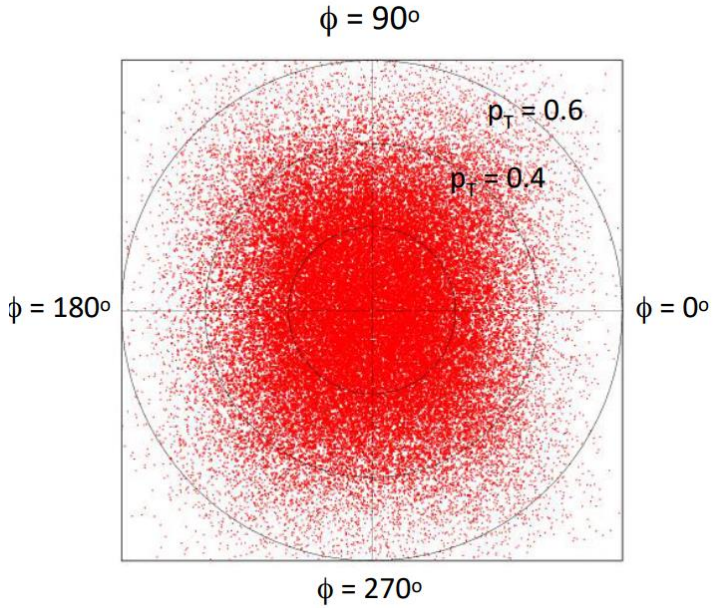
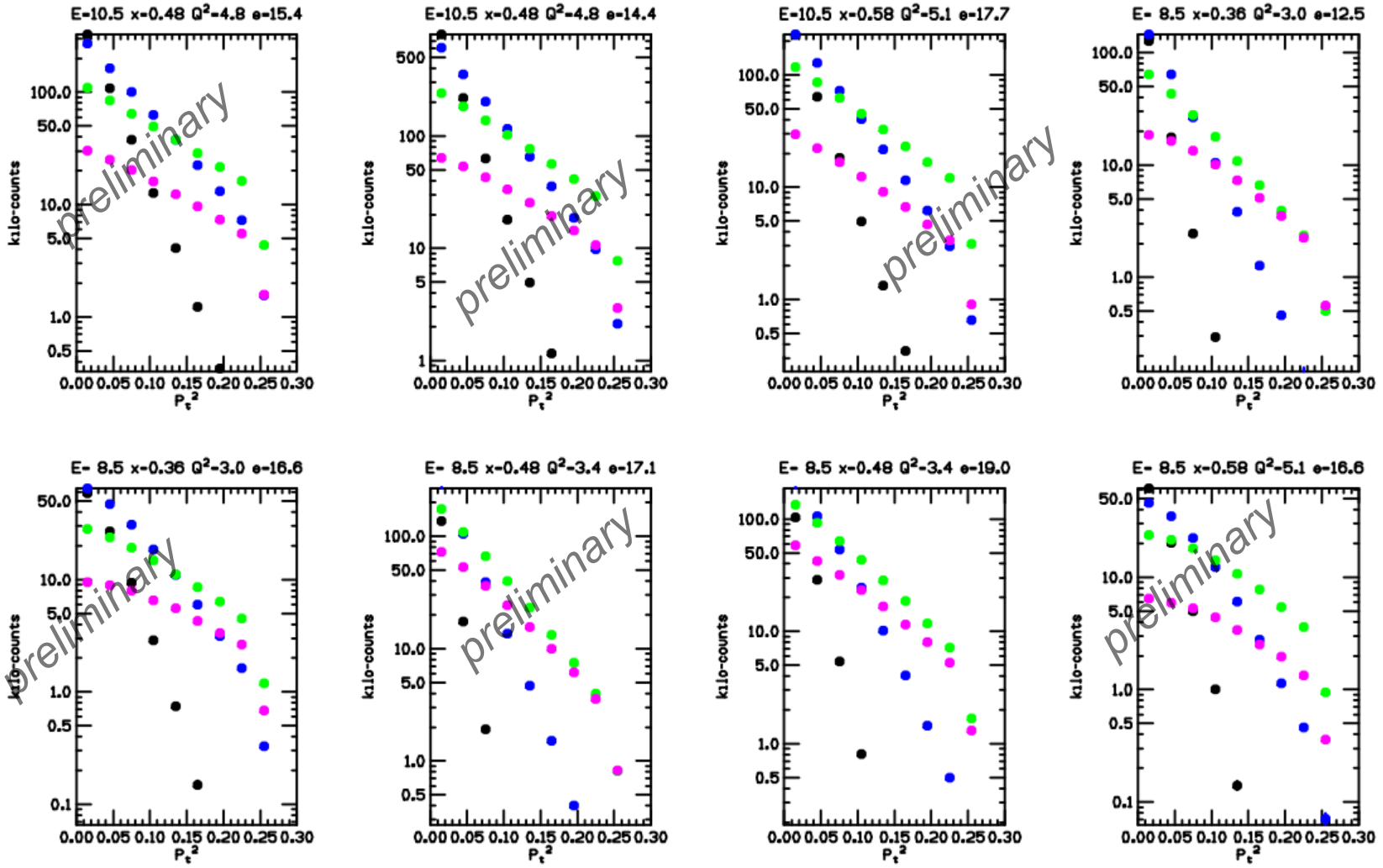
Black: 0.3< z <0.5

Blue: 0.5< z <0.7

Green:0.7< z <0.9





Plots courtesy of Peter Bosted

SIDIS π^0 Data Taking and Analysis

- Continue to take high precision data on the proton and neutron
  - Upcoming beam energies and kinematic settings will allow for L-T separation
- Detector calibrations, efficiency studies with the larger NPS collaboration (see tomorrow's talks!)
- Precision measurement of SIDIS cross-sections for the pion near the virtual photon direction
- Constrain intrinsic transverse momentum of the quark
  - favored and unfavored fragmentation functions
- π^0 SIDIS insensitive to ρ^o meson production, help constrain background in π^+ and π^- SIDIS
- In combination with charge pion and kaon data, able to analyze future SIDIS experiments
- Check out the NPS talks tomorrow morning for many more details