Exclusive Pseudoscalar Meson Electroproduction

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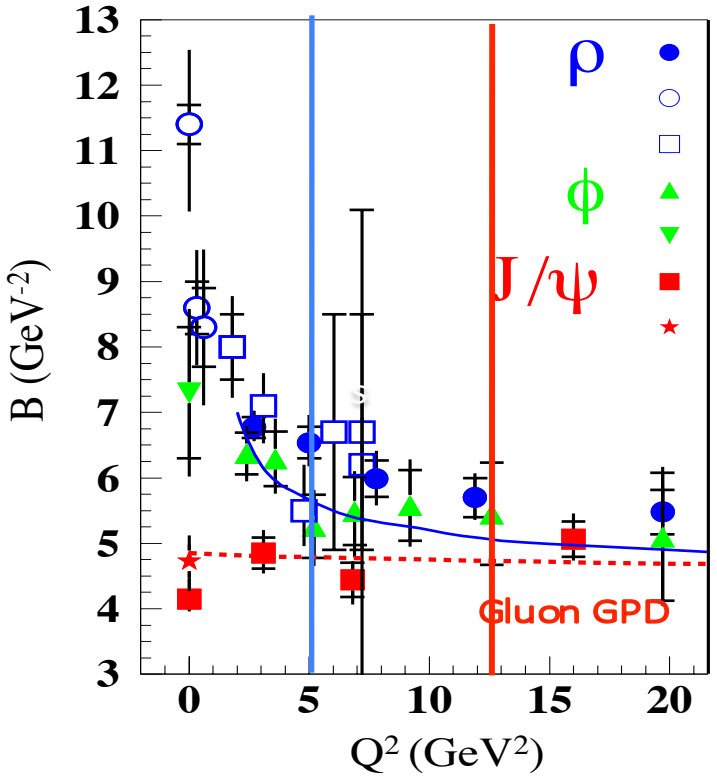
The CLAS Collaboration

The landscape

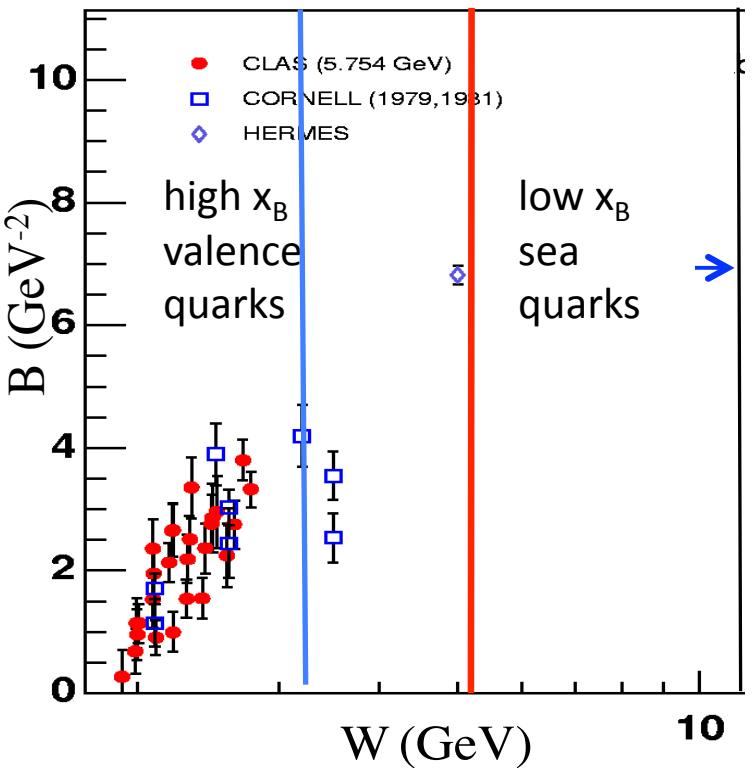
vector mesons

t-slopes vs Q^2 and W

CLAS 6 CLAS12



CLAS 6 CLAS12



Physics Motivation:

General Goals:

Assess and constrain QCD based models of the nucleon by means of quark flavor selectivities and spin and parity properties of mesons.

Assess the applicability of factorization: GPD/hard kernal handbag mechanism.

A specific goal:

Determine the role of non-leading terms in factorization
Exploit the unique sensitivity to transversity GPDs

Modus Operandi

- Measure structure functions and asymmetries over as wide a kinematic range in Q^2, x_B, t as possible.

- Make continuous connection between low Q^2 region where hadron based models are applicable to higher Q^2 region where QCD based models appear to be applicable

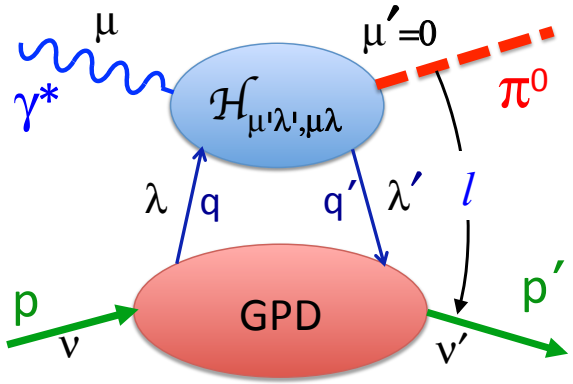
- Guide the progress in theory with new data.

Recap P. Krolls, S. Luiti

$$\sigma \sim \left|\mathcal{M}\right|^2$$

$$\mathcal{M} \in \left\langle F \right\rangle = \int dx \mathcal{H}_{\mu'\lambda'\mu'\lambda'} F \qquad \left(F = \text{GPD}\right)$$

$$\mathcal{H}_{\mu'\lambda'\mu'\lambda'} = \int d\mathbf{b}\, d\tau\, \hat{\Psi}(\tau, \mathbf{b})\ \mathcal{F}_{\mu'\lambda'\mu'\lambda'}\ \alpha_S e^{-S(\tau,\mathbf{b},Q^2)}$$



Dominant GPDs

Longitudinal $\sigma_L \sim \left|\mathcal{M}_L\right|^2 \sim \left\langle \tilde{H} \right\rangle, \left\langle \tilde{E} \right\rangle$

Transverse $\sigma_T \sim \left|\mathcal{M}_T\right|^2 \sim \left\langle H_T \right\rangle, \left\langle \bar{E}_T \right\rangle$

Interference $\sigma_{TT} \sim \left|\mathcal{M}_{TT}\right|^2 \sim \left\langle \bar{E}_T \right\rangle$

$\sigma_{LT} \sim \left|\mathcal{M}_{LT}\right|^2 \sim \left\langle H_T \right\rangle, \left\langle \tilde{E} \right\rangle$

$$\bar{E}_T = 2\tilde{H}_T + E_T$$

The Exclusive π and η Program (so-far)

CLAS6 Results:

π^0

$\sigma_u = \sigma_T + \varepsilon\sigma_L,\ \sigma_{TT},\ \sigma_{LT}$

BSA $A_{BP} \sim \sigma'_{LT}$

π^+

$\sigma_u = \sigma_T + \varepsilon\sigma_L,\ \sigma_{TT},\ \sigma_{LT}$

BSA $A_{BP} \sim \sigma'_{LT}$

η

$\sigma_u = \sigma_T + \varepsilon\sigma_L,\ \sigma_{TT},\ \sigma_{LT}$

BSA $A_{BP} \sim \sigma'_{LT}$

CLAS12 Proposed:

π^0

$\sigma_u = \sigma_T + \varepsilon\sigma_L,\ \sigma_{TT},\ \sigma_{LT}$

L/T σ_T, σ_L

BSA $A_{BP} \sim \sigma'_{LT}$

η

$\sigma_u = \sigma_T + \varepsilon\sigma_L,\ \sigma_{TT},\ \sigma_{LT}$

L/T σ_T, σ_L

BSA $A_{BP} \sim \sigma'_{LT}$

CLAS12 Pending:

π^+

$\sigma_u = \sigma_T + \varepsilon\sigma_L,\ \sigma_{TT},\ \sigma_{LT}$

BSA $A_{BP} \sim \sigma'_{LT}$

η, π^0, π^+

Trans TSA, Long TSA

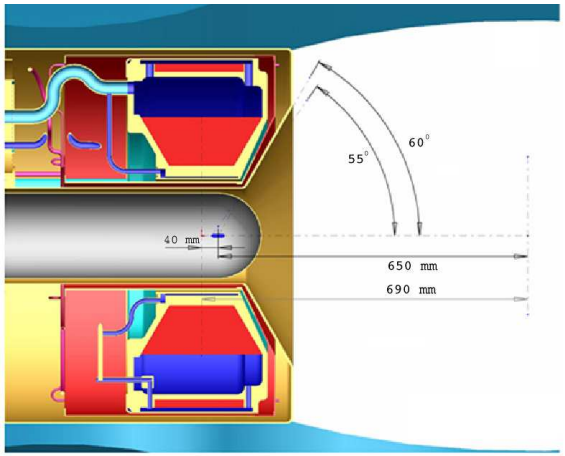
Hall A Data: π^0 $\sigma_u = \sigma_T + \varepsilon\sigma_L,\ \sigma_{TT},\ \sigma_{LT}$

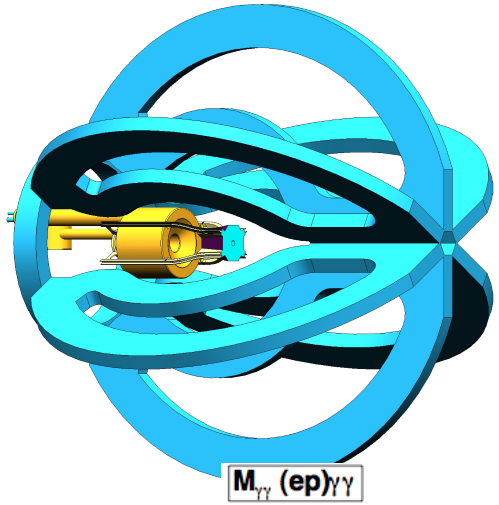
Hermes Data: π^+ Trans. Tgt. Asymm.

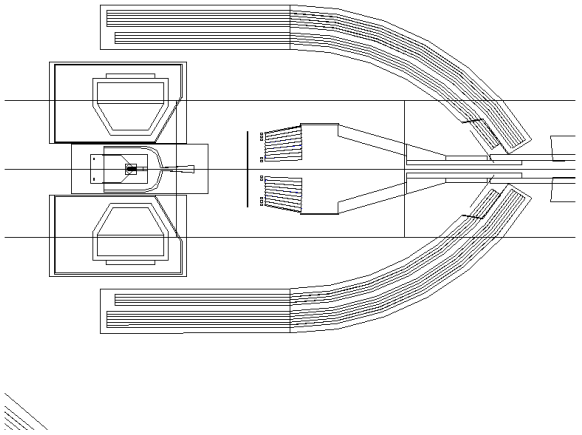
Hall C data: π^+

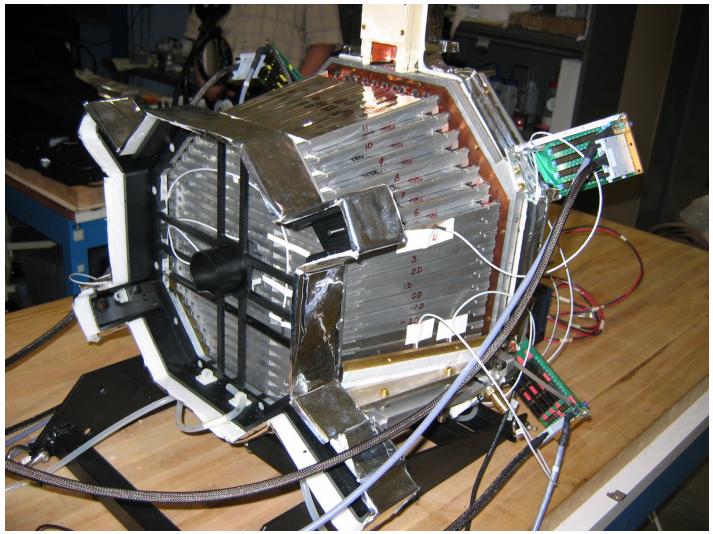
Hall C Proposed: π^0, π^+ σ_T / σ_L

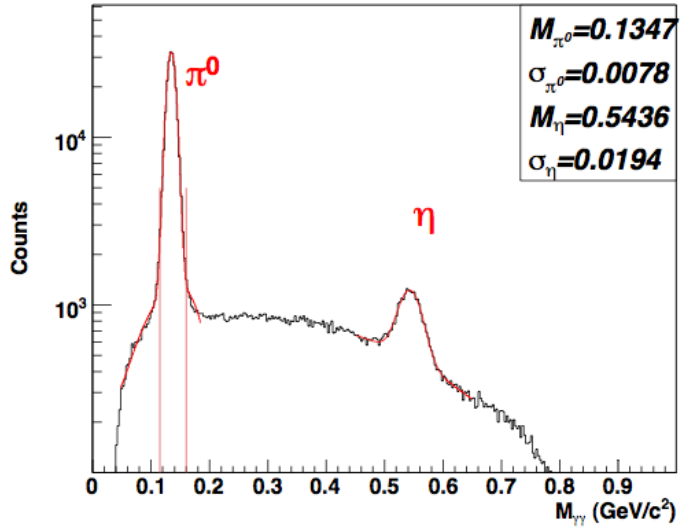
CLAS 6 Experiments π^0, η, π^+ - structure functions and BSA

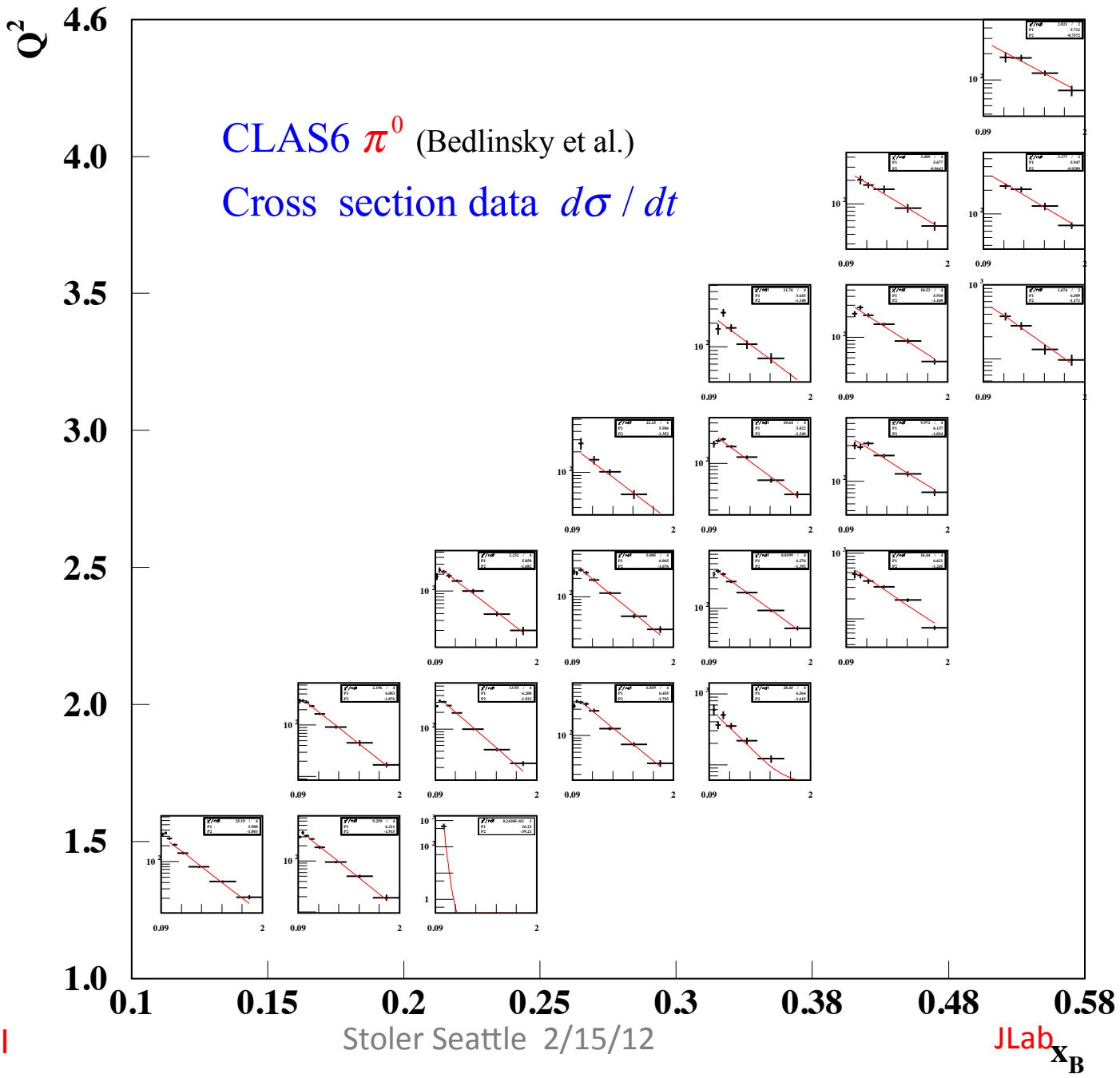




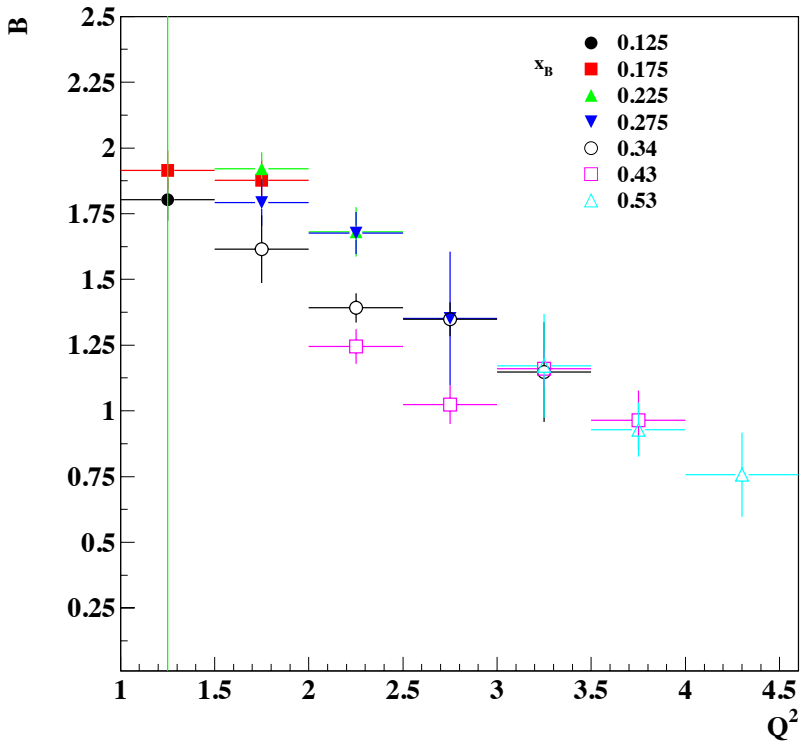


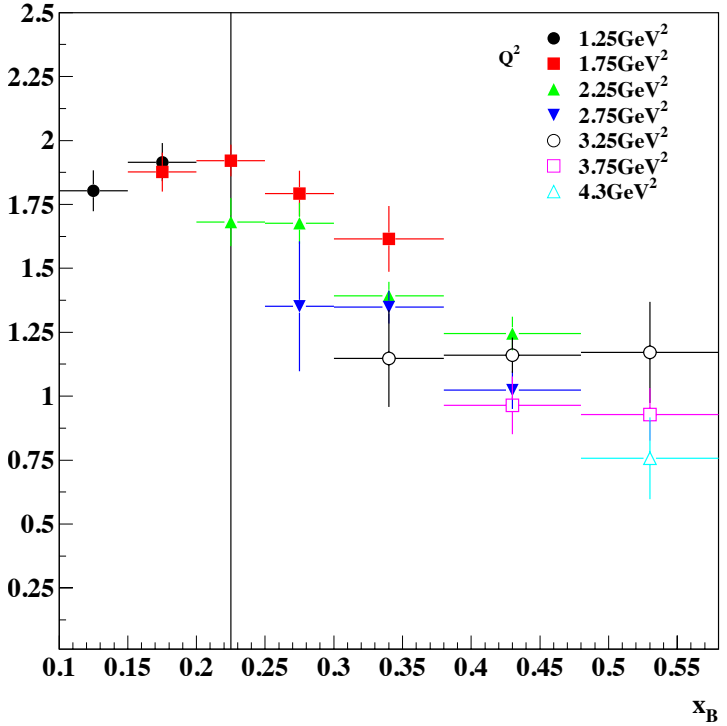




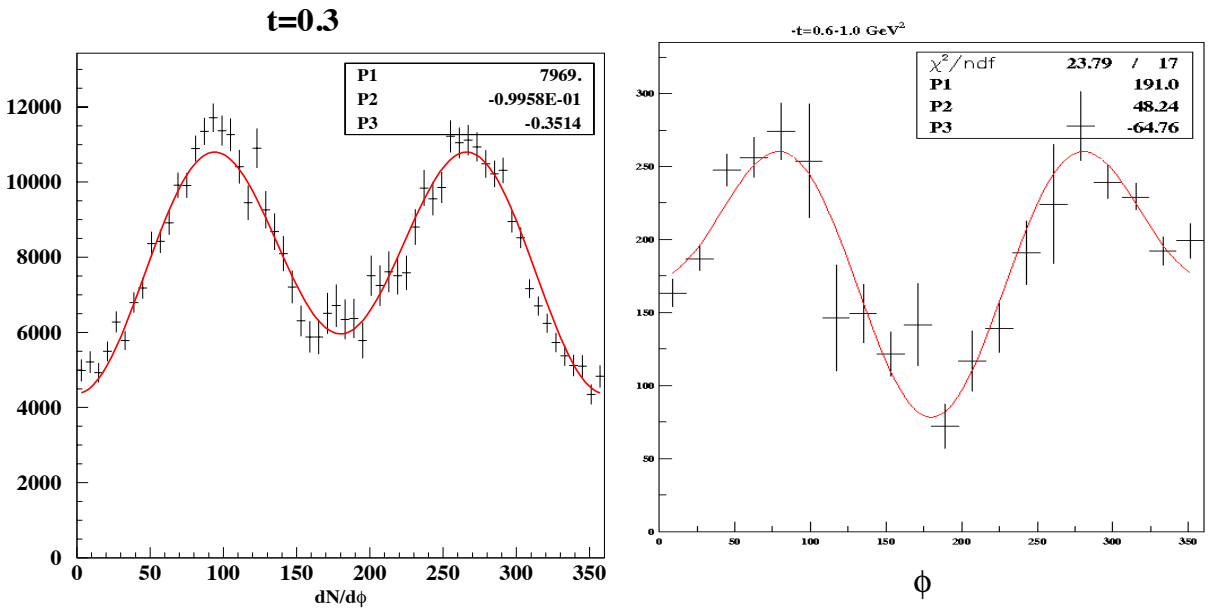

CLAS6 π^0 (Bedlinsky et al.)
Cross section data $d\sigma$ / dt
Q^2
4.6
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.1
0.15
0.2
0.25
0.3
0.38
0.48
0.58
x_B

t - slope parameter B vs. Q^2 and x_B

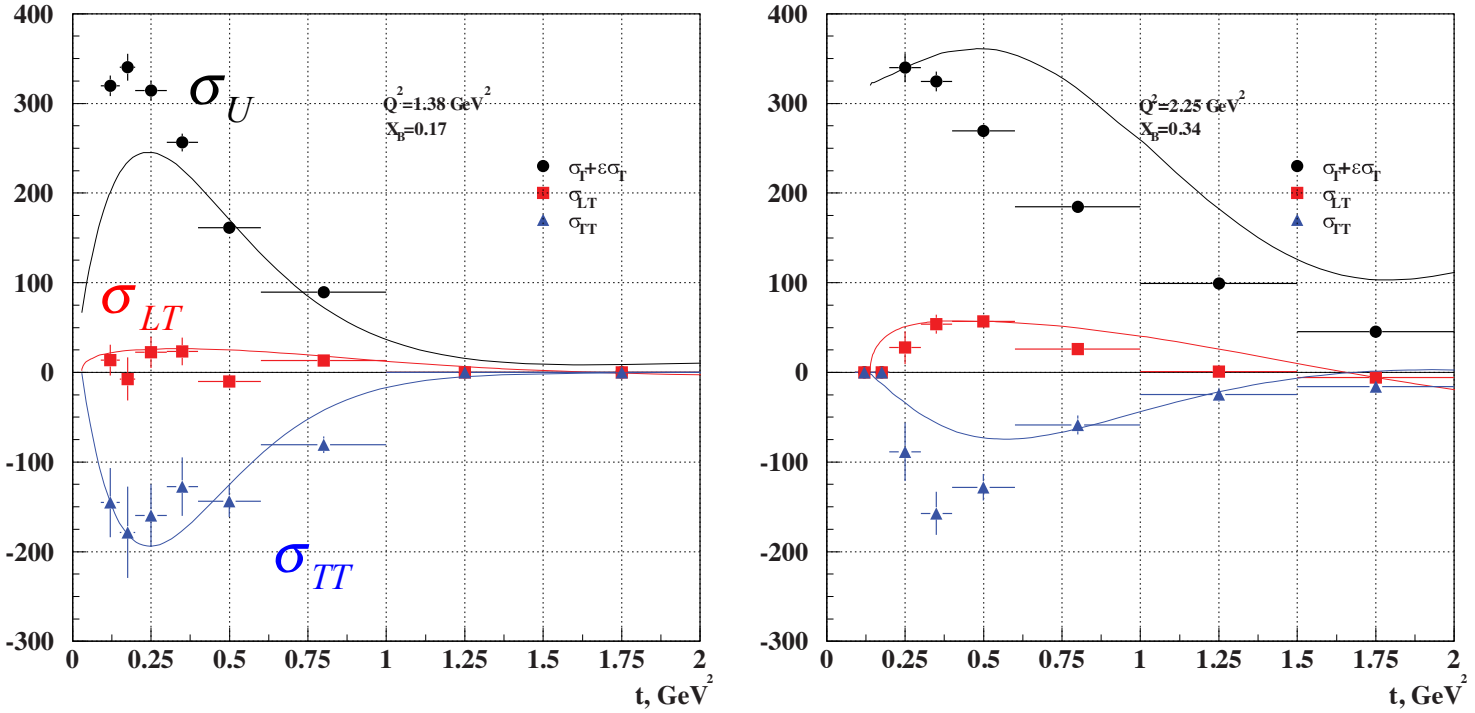




$Cos\phi$ dependence $\rightarrow$ $\sigma_T + \varepsilon\sigma_L$, σ_{TT}, σ_{LT}



Structure Functions



Curves: JM Laget, Regge

Structure Functions

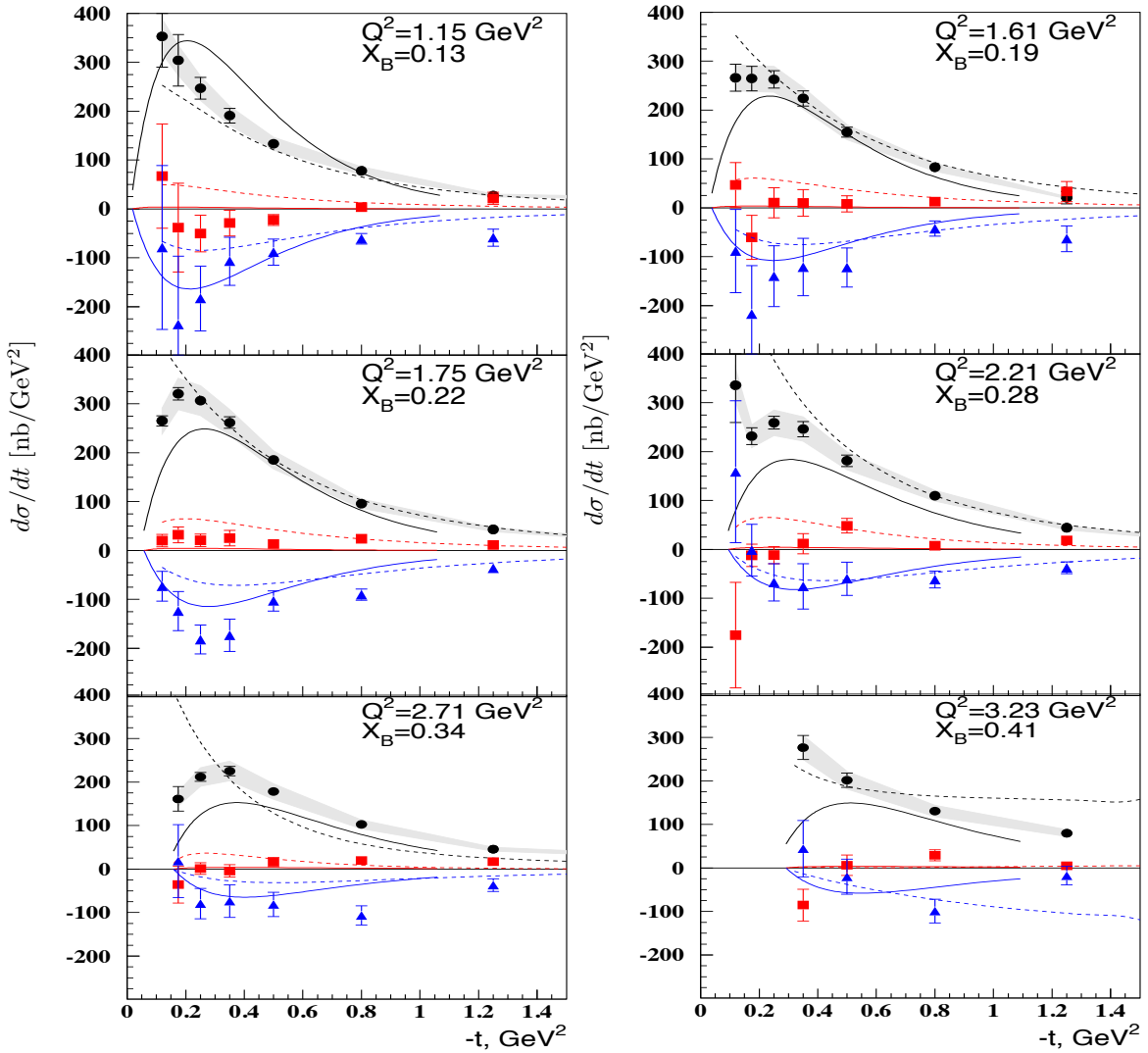
σ_U •

σ_{LT} •

σ_{TT} •

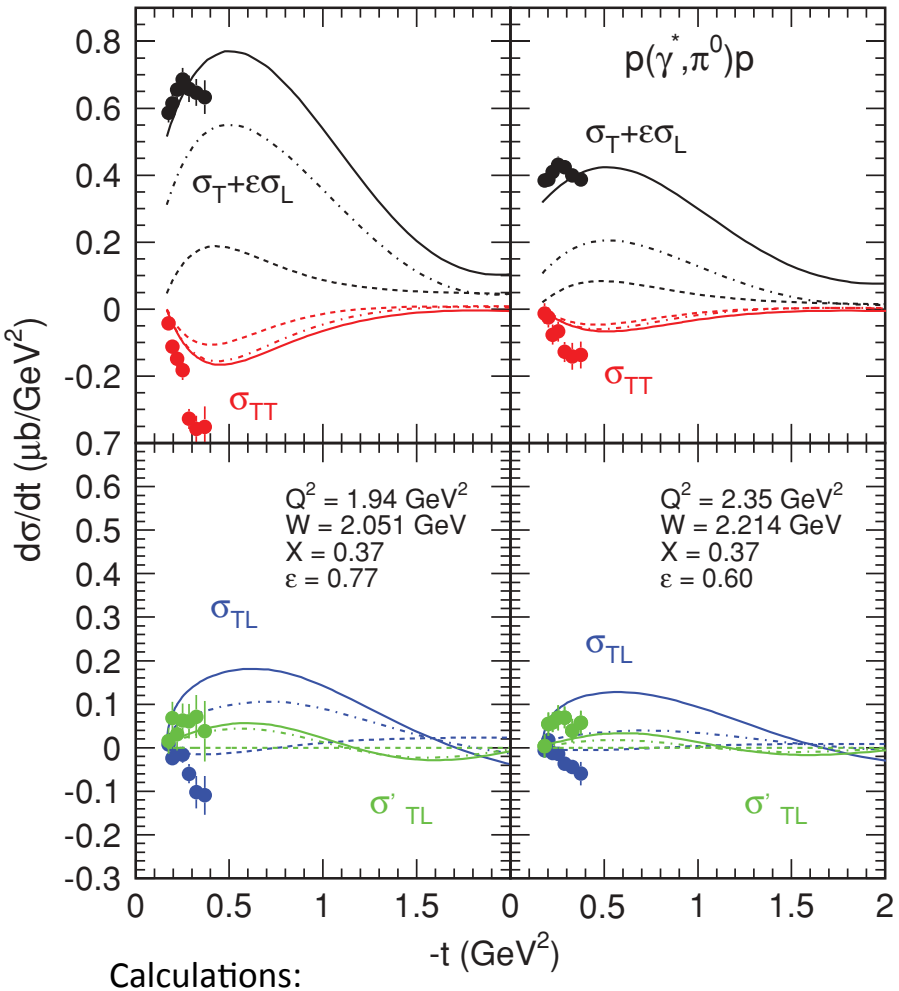
GK

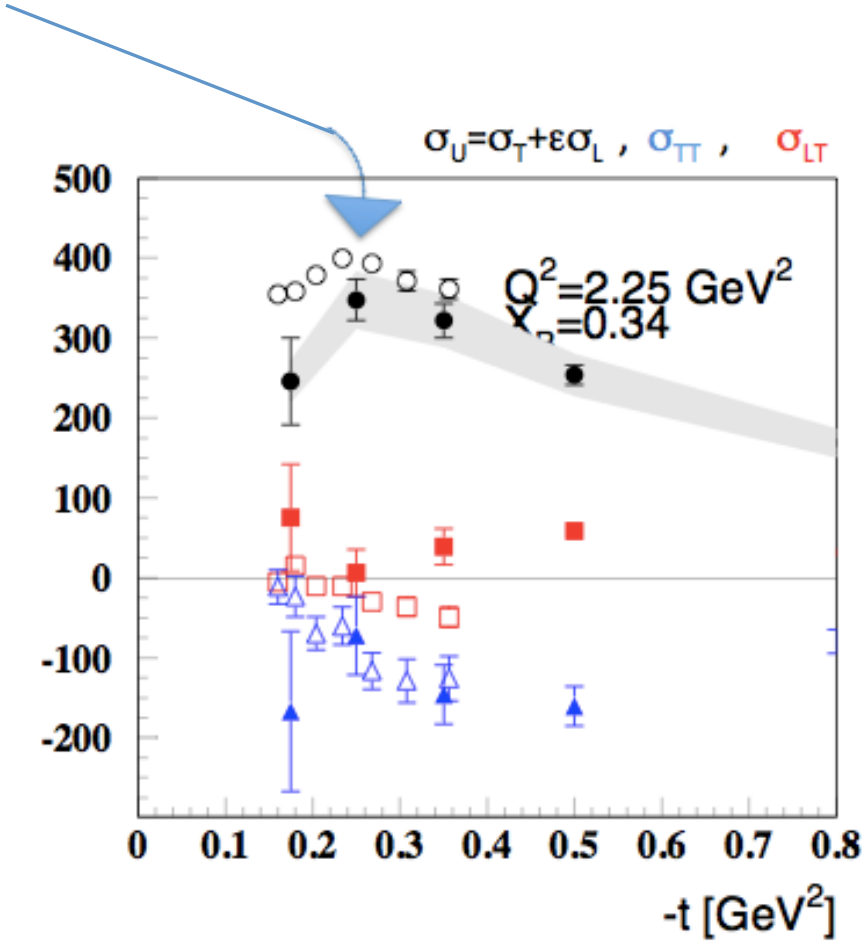
GL



Hall A experiment.

E. Fuchey et al. P. R. (2011)





Calculations:

J. M. Laget, Phys. Lett. B **695, 199 (2011)**

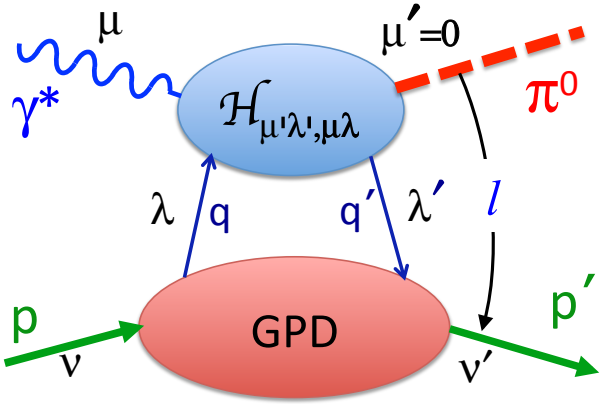
Transverse Amplitudes

Nucleon helicity non-flip.

$$M^{U}_{0+++} = \sqrt{\pi\alpha_e \frac{\mu_\pi^2}{Q^4}\frac{t'}{8m^2}}\left\langle \bar{E}_T \right\rangle_3 \qquad l=1$$

Nucleon helicity flip.

$$M^{U}_{0-++} = \sqrt{(1-\xi^2)\frac{\pi\alpha}{2}_e \frac{\mu_\pi^2}{Q^4}}\left\langle H_T \right\rangle_3 \qquad l=0$$



$$\frac{d\sigma_{TT}}{dt} = \frac{1}{2\kappa}\left|M^{U}_{0+++}\right|^2 = \frac{4\pi\alpha_e}{8\kappa}\frac{\mu_\pi^2}{Q^4}\frac{t'}{8m^2}\left|\left\langle \bar{E}_T \right\rangle_3\right|^2$$

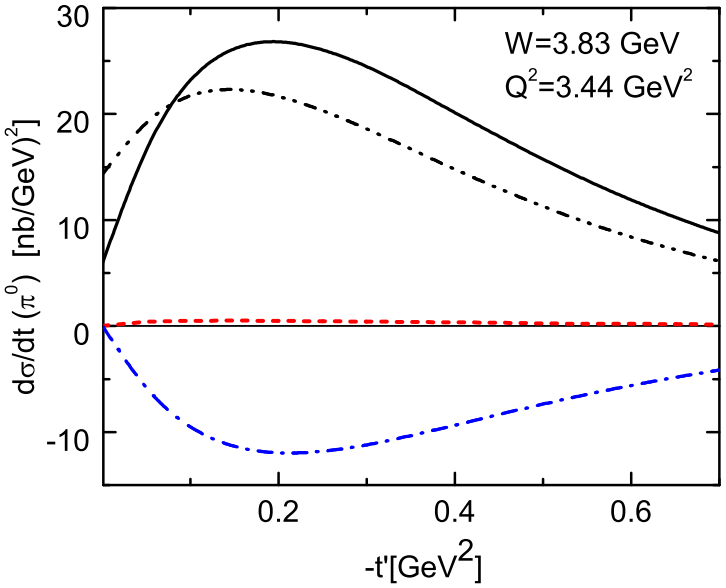
$$\frac{d\sigma_{T}}{dt} = \frac{1}{2\kappa}\left|M^{U}_{0-++}\right|^2 - \frac{1}{\kappa}\left|M^{U}_{0+++}\right|^2 = \frac{4\pi\alpha_e}{2\kappa}\frac{\mu_\pi}{Q^4}\left[(1-\xi^2)\left|\left\langle H_T \right\rangle_3\right|^2 - \frac{t'}{8m^2}\left|\left\langle \bar{E}_T \right\rangle_3\right|^2\right]$$

$l=0$ $\qquad$ $l=1$

G-K Increase

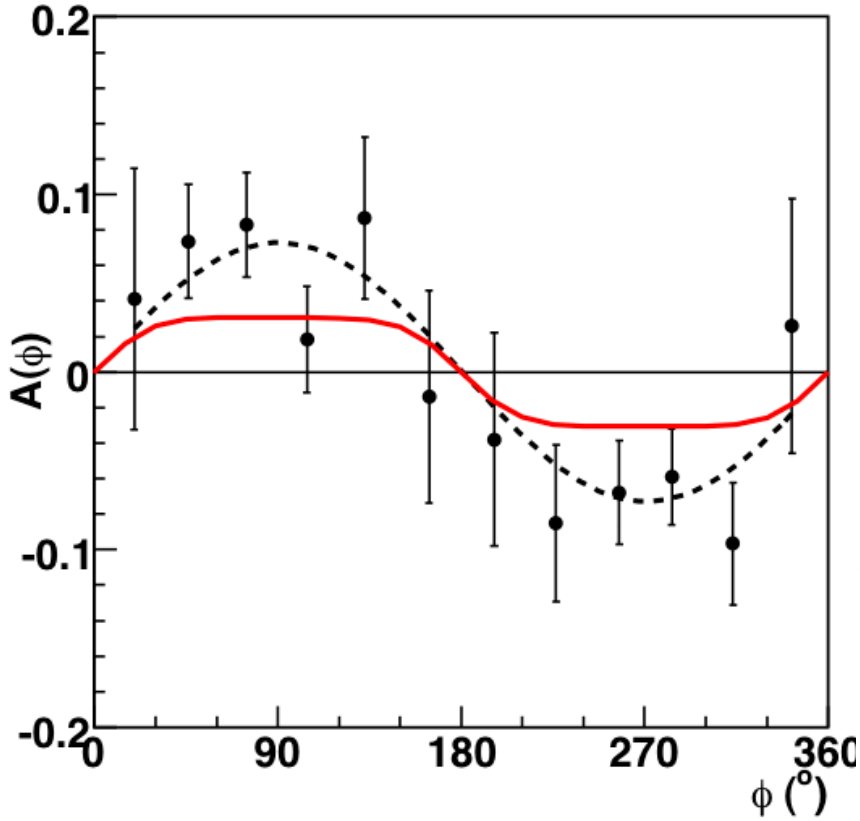
G-K: Increase H_T by ~10%

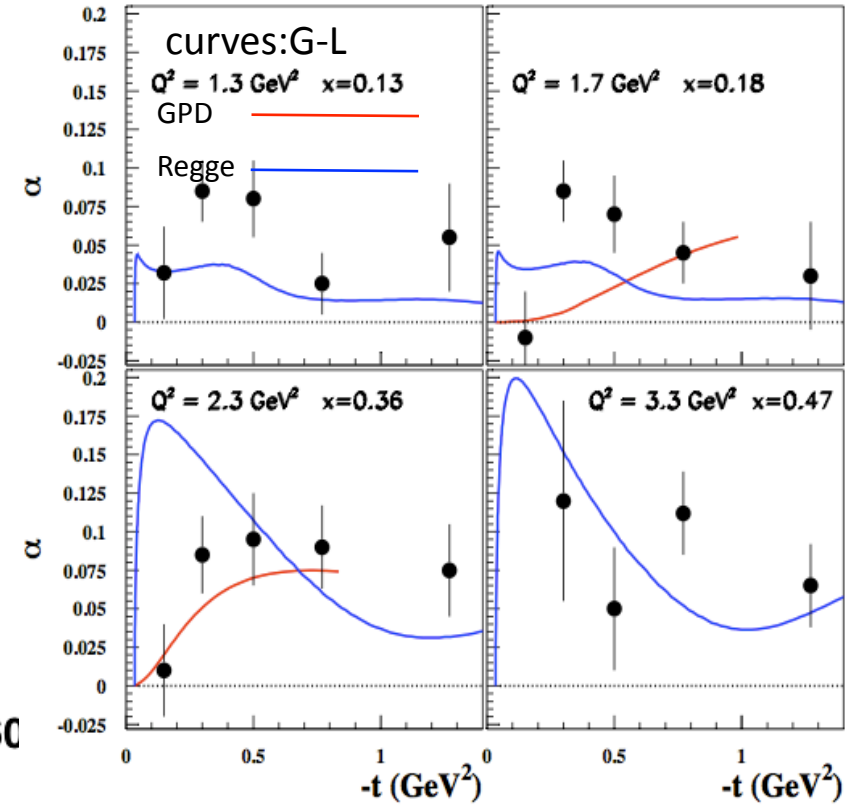
Dereade $\bar{E}_T$ by ~10%



π^0 Beam Spin Asymmetry

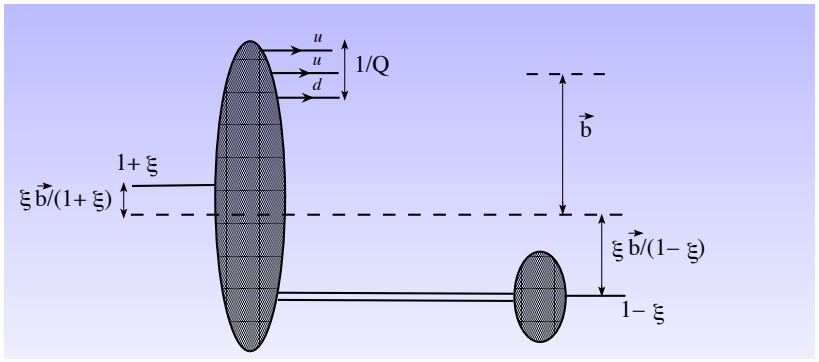
CLAS6 data (di Masi et al)

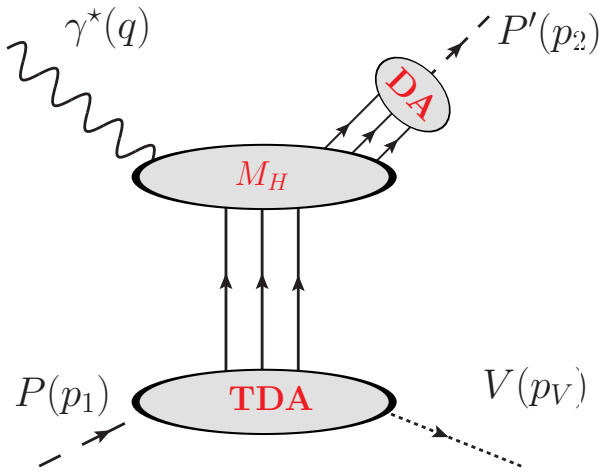


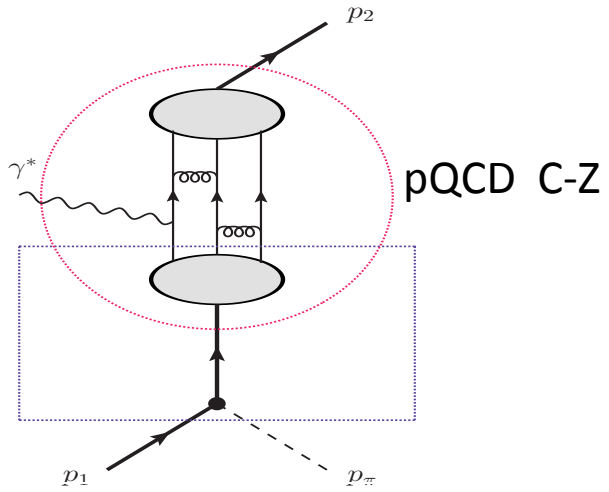


Backward π electroproduction - TDAs

J.P. Lansberg, B. Pire and L. Szymanowski

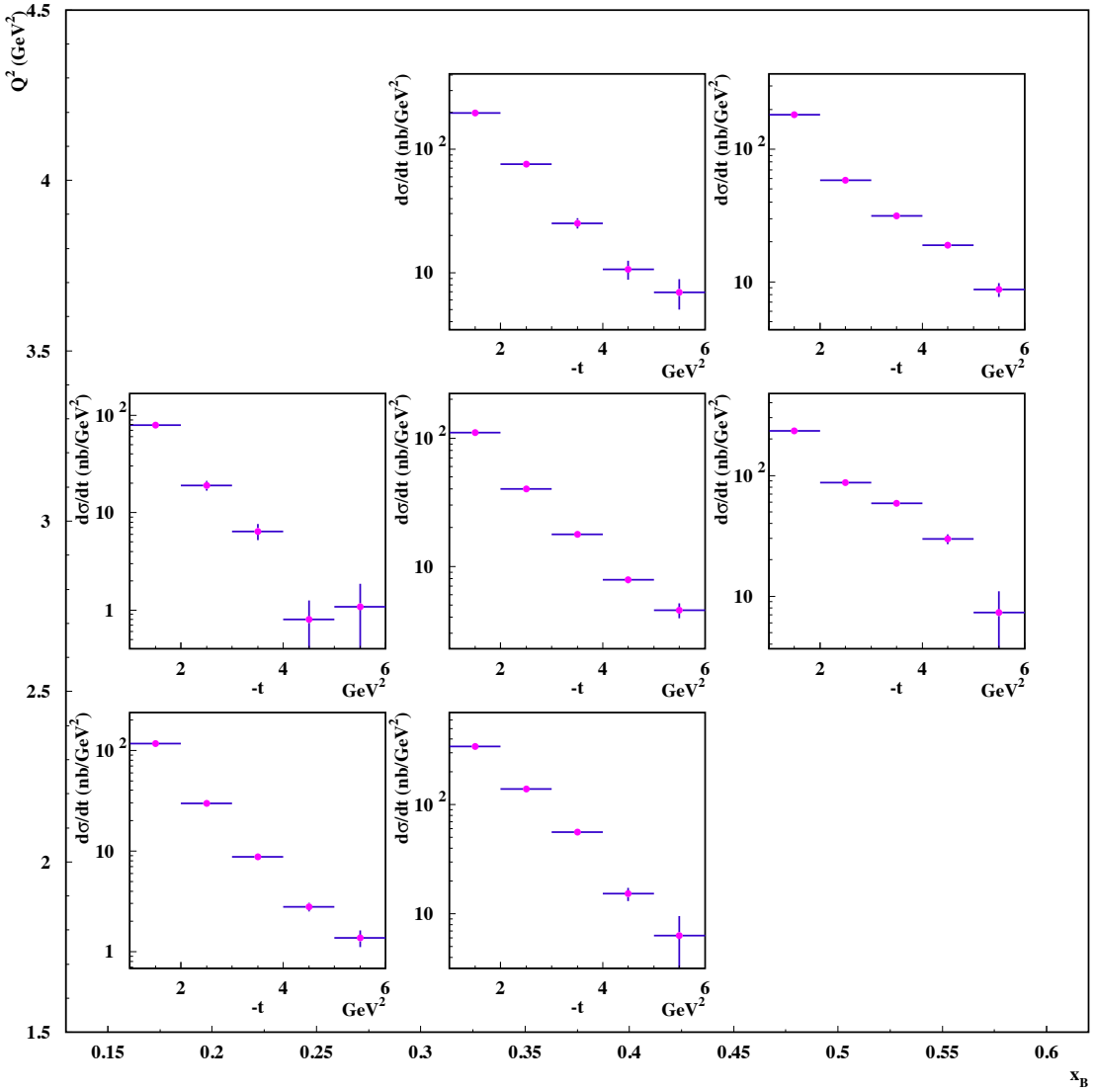






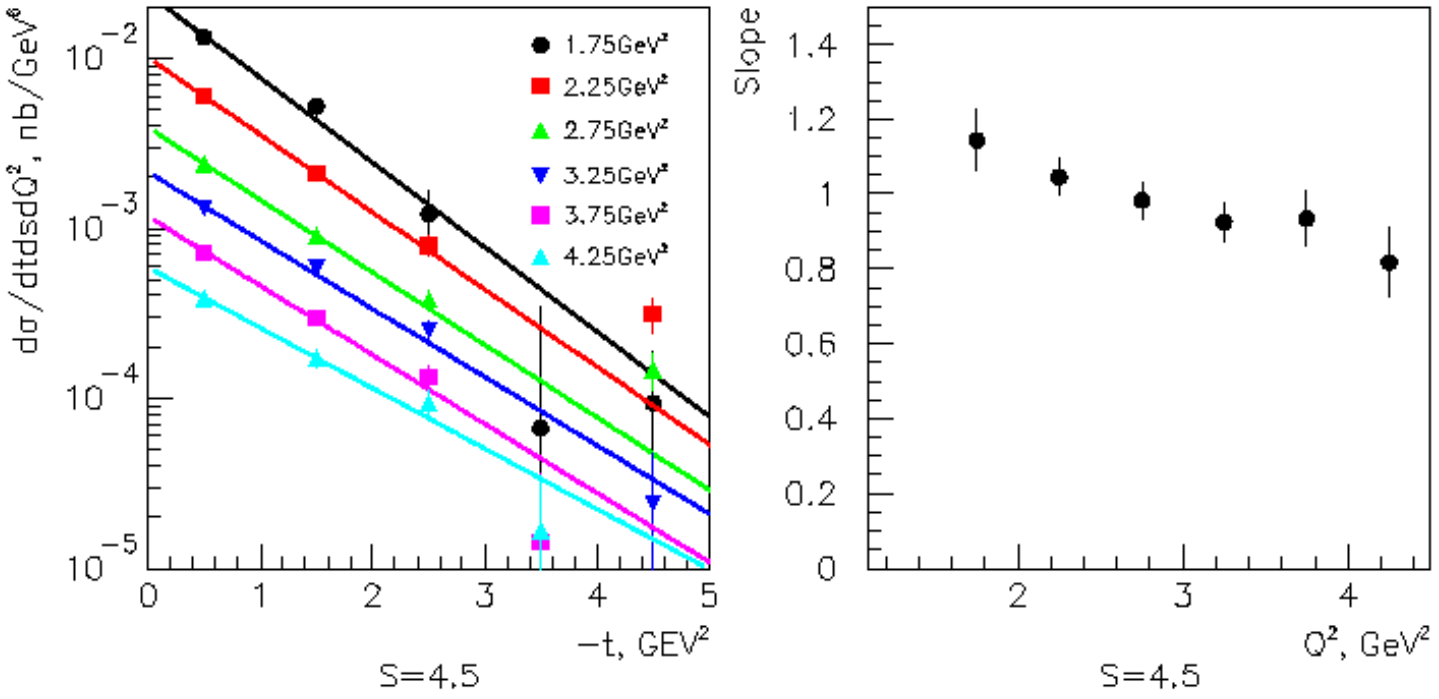
pQCD C-Z

CLAS π^0 data under analysis
$-t_{max} \sim 6$ GeV^2/c^2



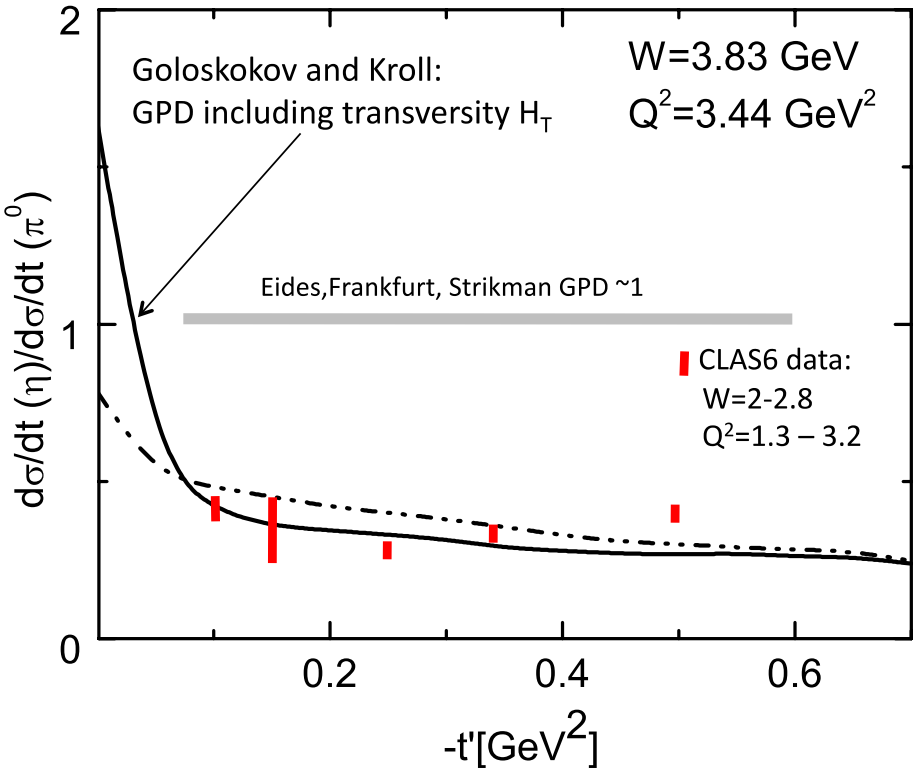
η electroproduction – CLAS6

t slopes



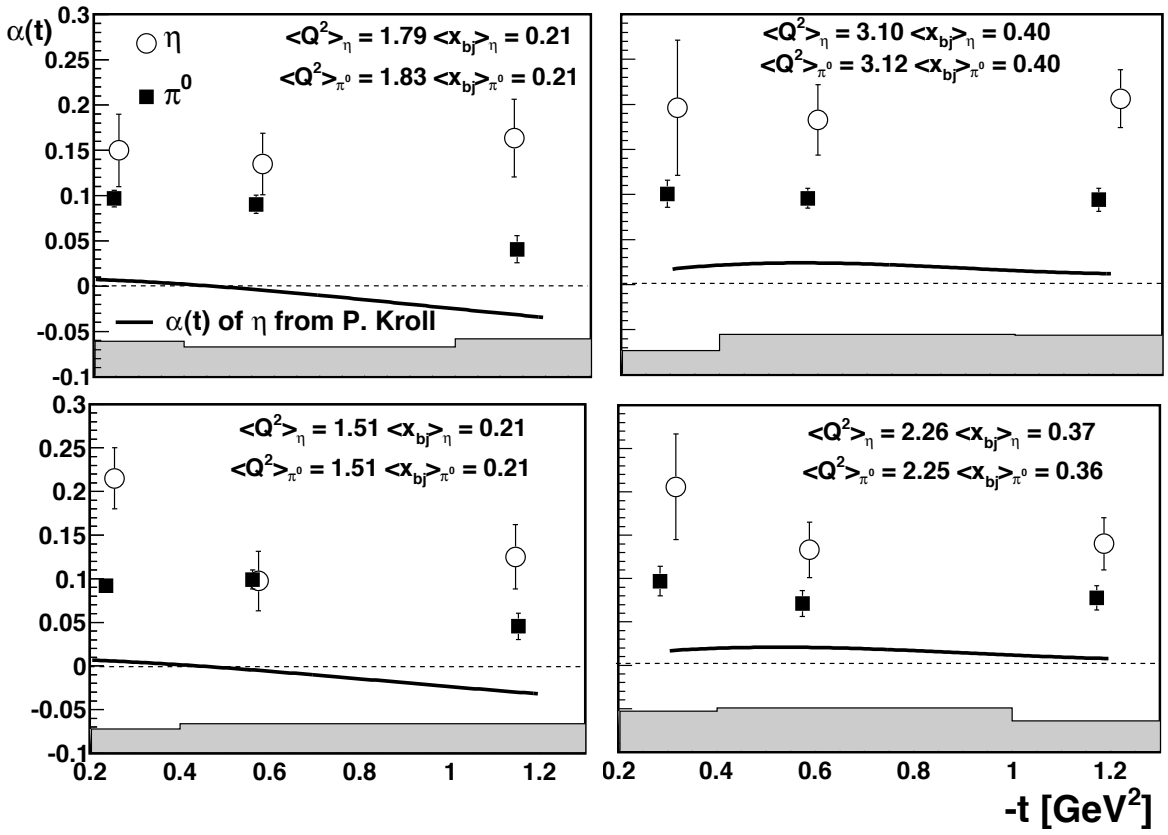
η electroproduction – CLAS6

Ratio η/π^0



η and π^0 Beam Spin Asymmetry

η(B. Zhao et al.)
π^0 (R. Di Masi et al.)



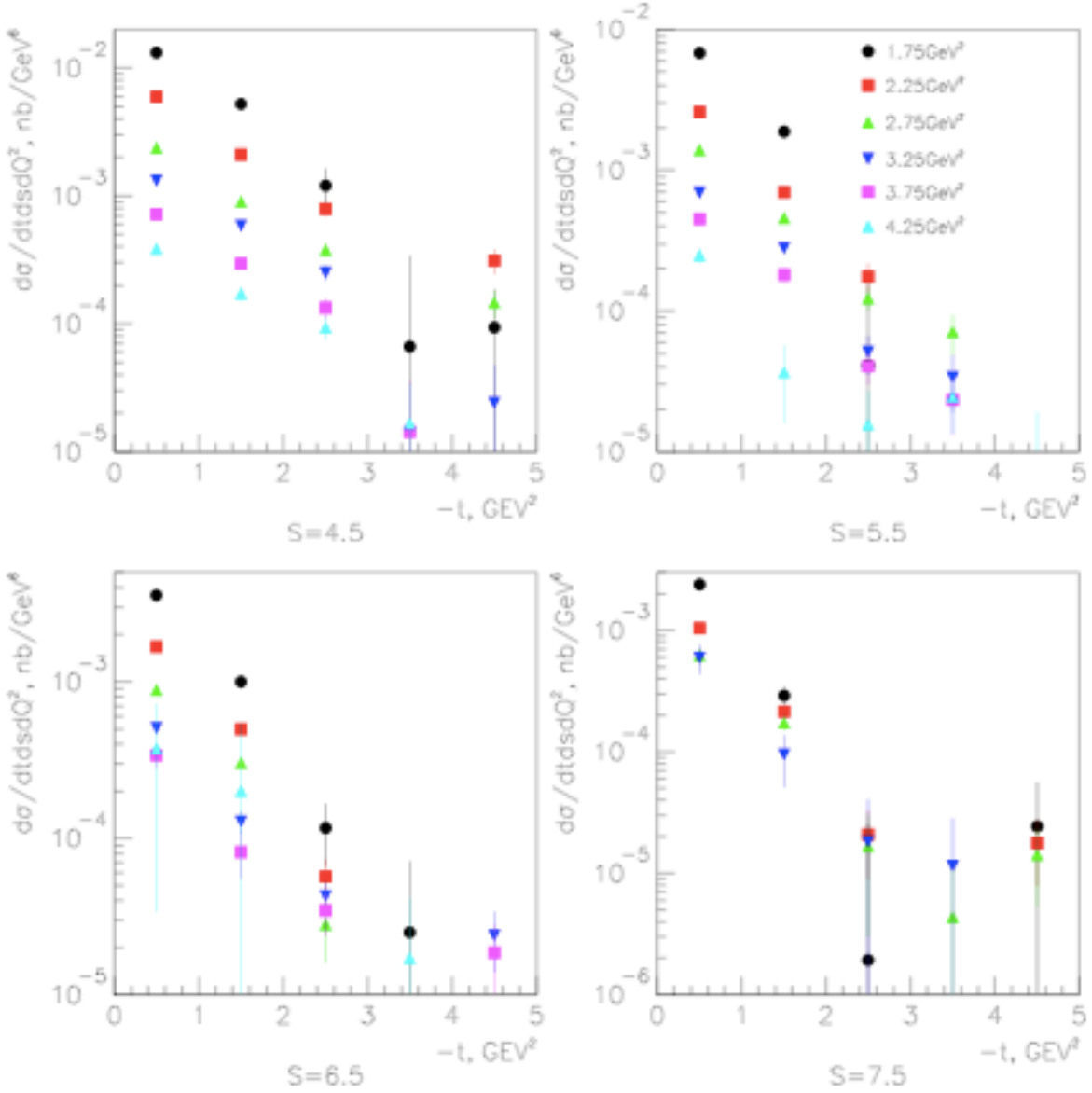
η electroproduction

CLAS 6 preliminary (analysis in progress)

$$ep \rightarrow ep\eta$$

$$\frac{d\sigma}{dtdsdQ^2}$$

a. $s = W^2 = 4.5\ GeV^2$
b. $s = W^2 = 5.5\ GeV^2$
c. $s = W^2 = 6.5\ GeV^2$
d. $s = W^2 = 7.5\ GeV^2$



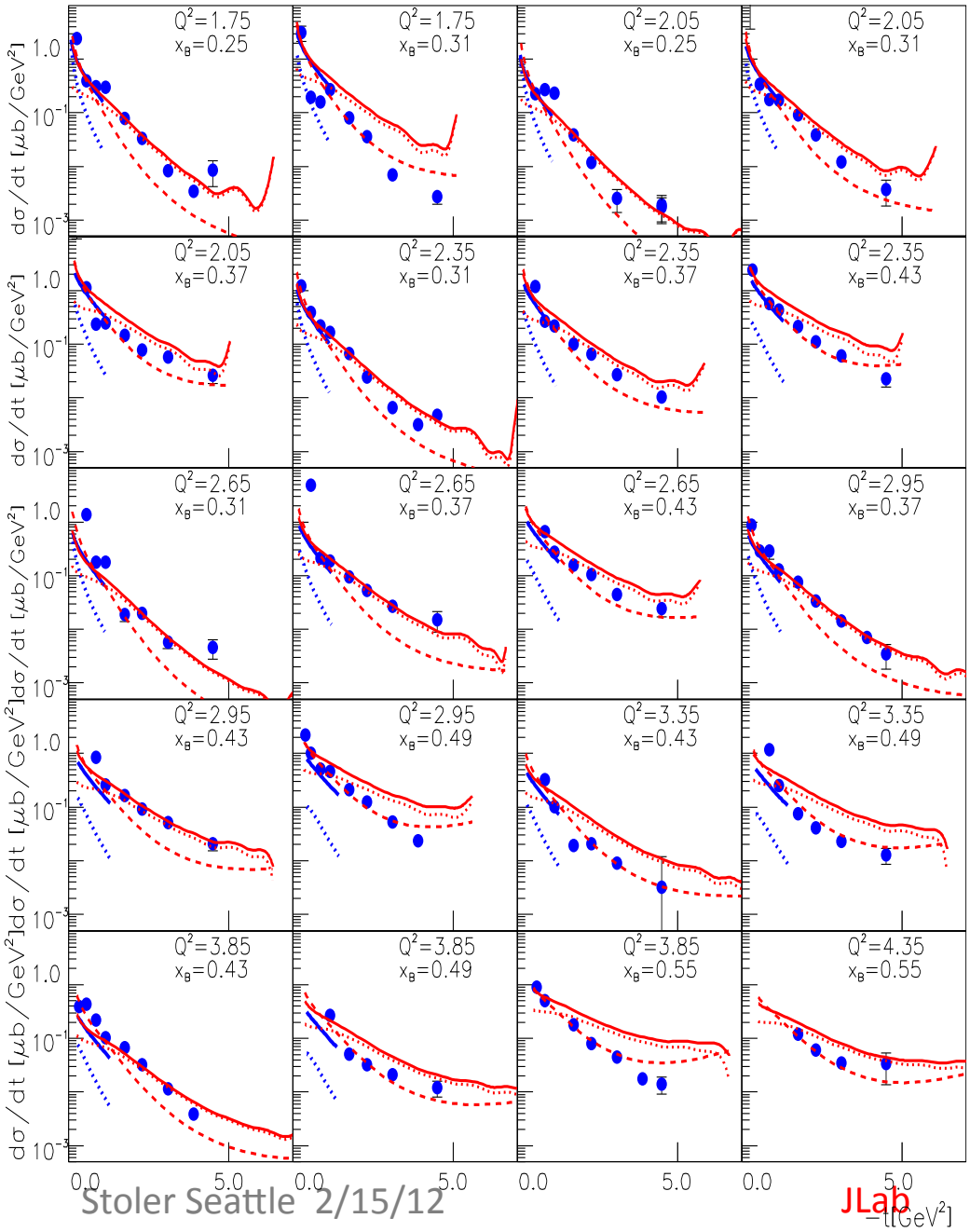
$\frac{d\sigma}{dQ^2}$ decreases with increasing W (decreasing x_B)

$ep \longrightarrow ep\pi^+$

K. Park et al. (CLAS)

J. M. Laget, Regge

S.V. Goloskokov, P. Kroll

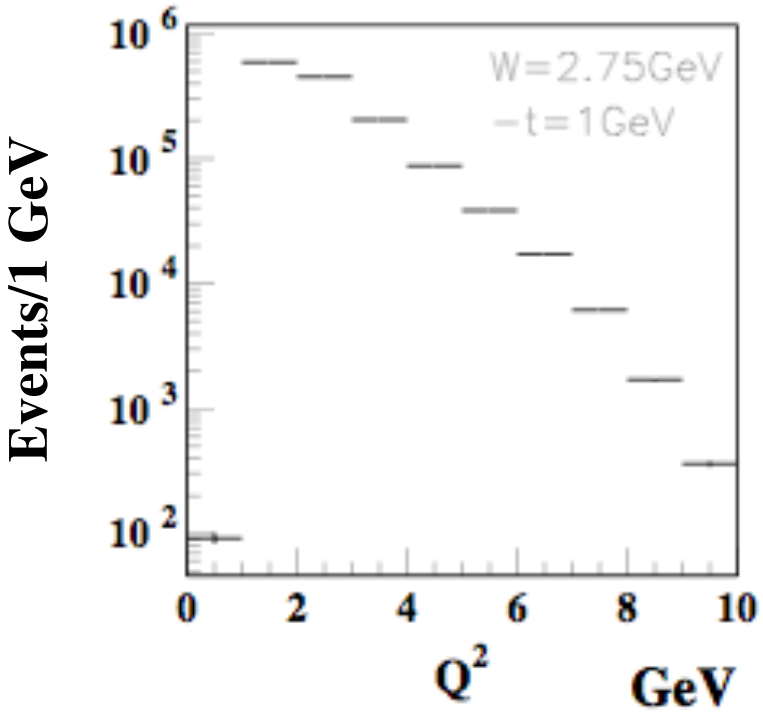


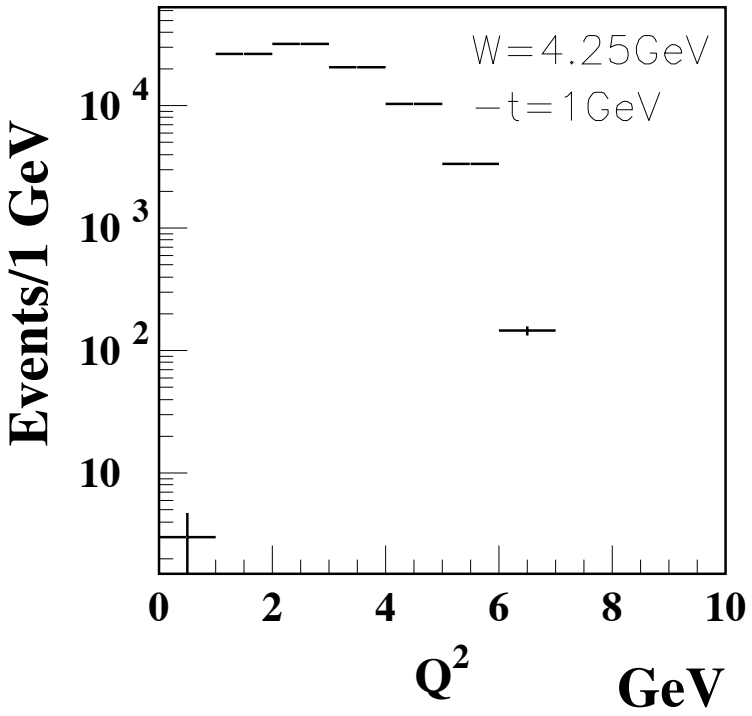
RPI

JLab

Simulations for CLAS12

Simulation for π^0 production with CLAS12





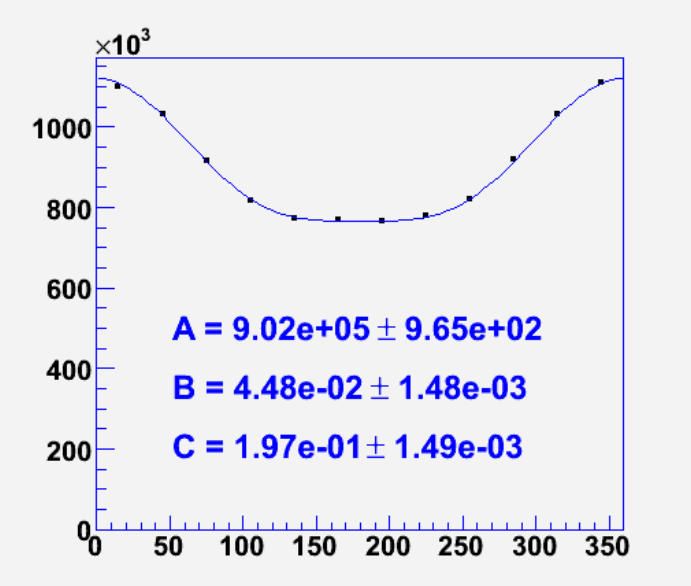
MC simulate π^0

$\sigma = A(1 + B\cos 2\phi + C\cos\phi)$

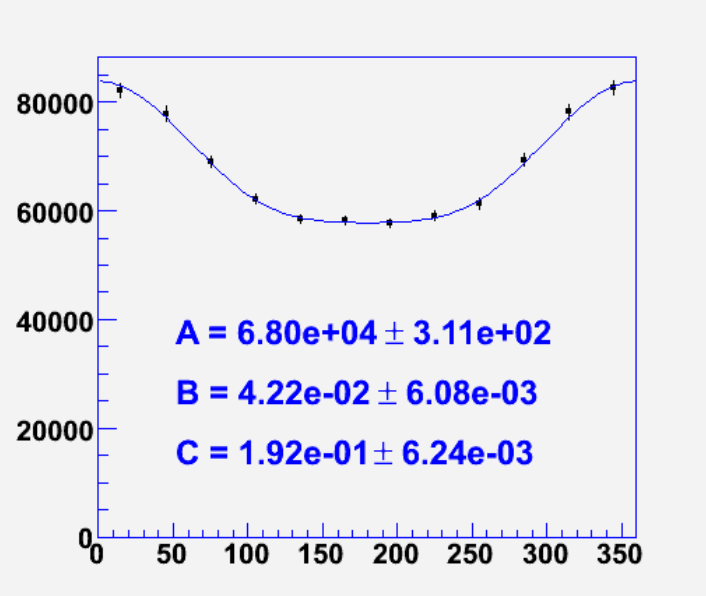
B=0.05, C=0.2

$-t = 0.5$ GeV^2/c^2

$Q^2 = 2$ GeV^2/c^2



$Q^2 = 8$ GeV^2/c^2



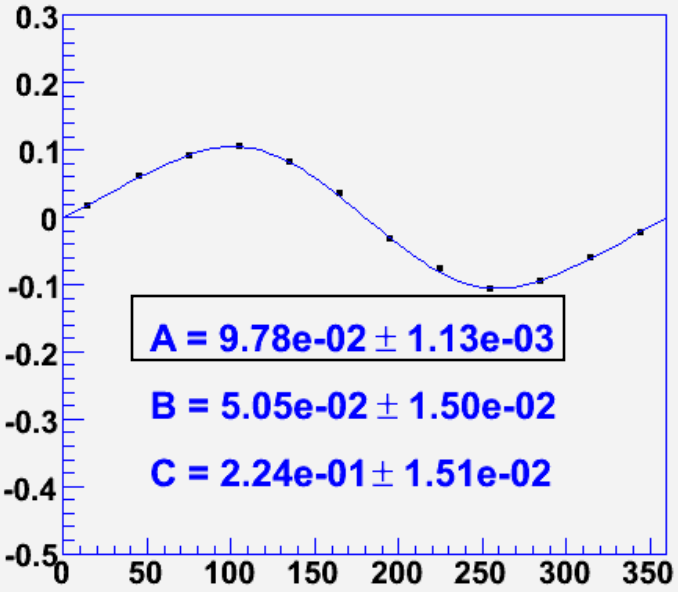
B,C~10%

Single Spin Beam Asymmetry

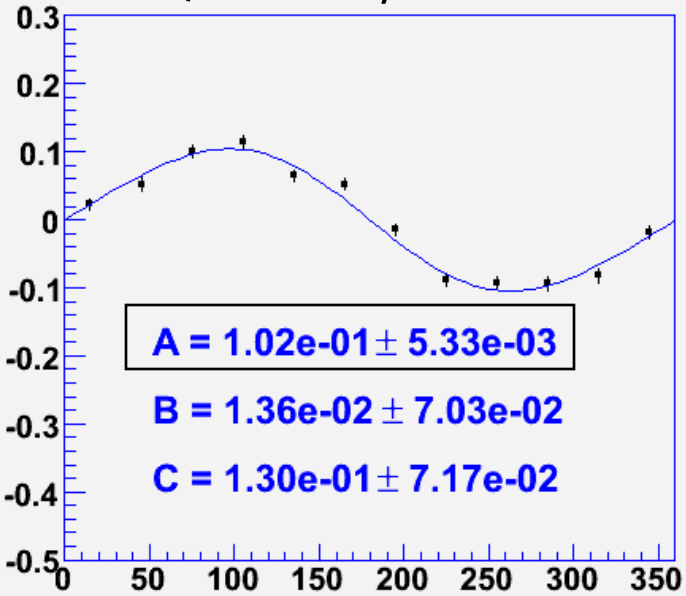
$\mathcal{A}$=Asinϕ/(1+Bcos2ϕ+Ccosϕ)

-t=0.5 GeV^2/c^2 x_B=0.5

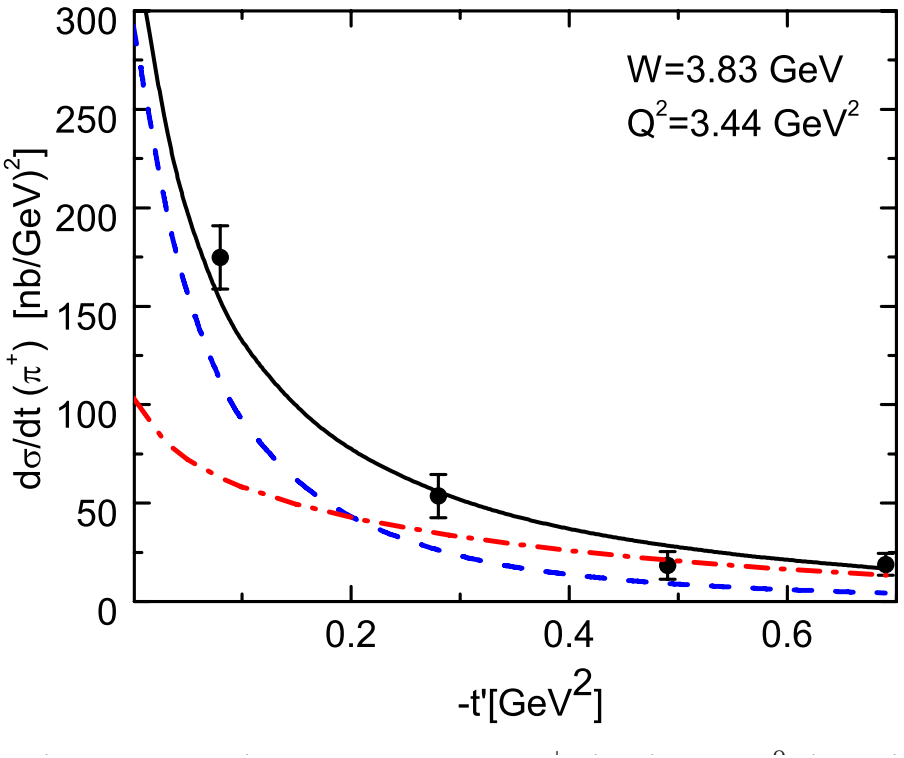
Q^2=2 GeV^2/c^2



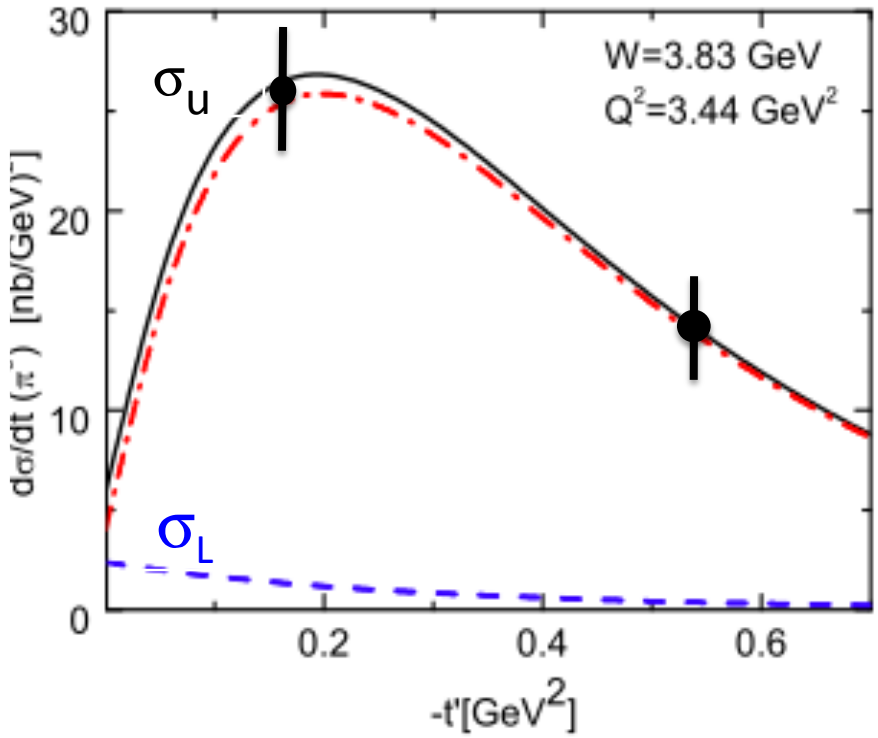
Q^2=8 GeV^2/c^2



π^+



π^0

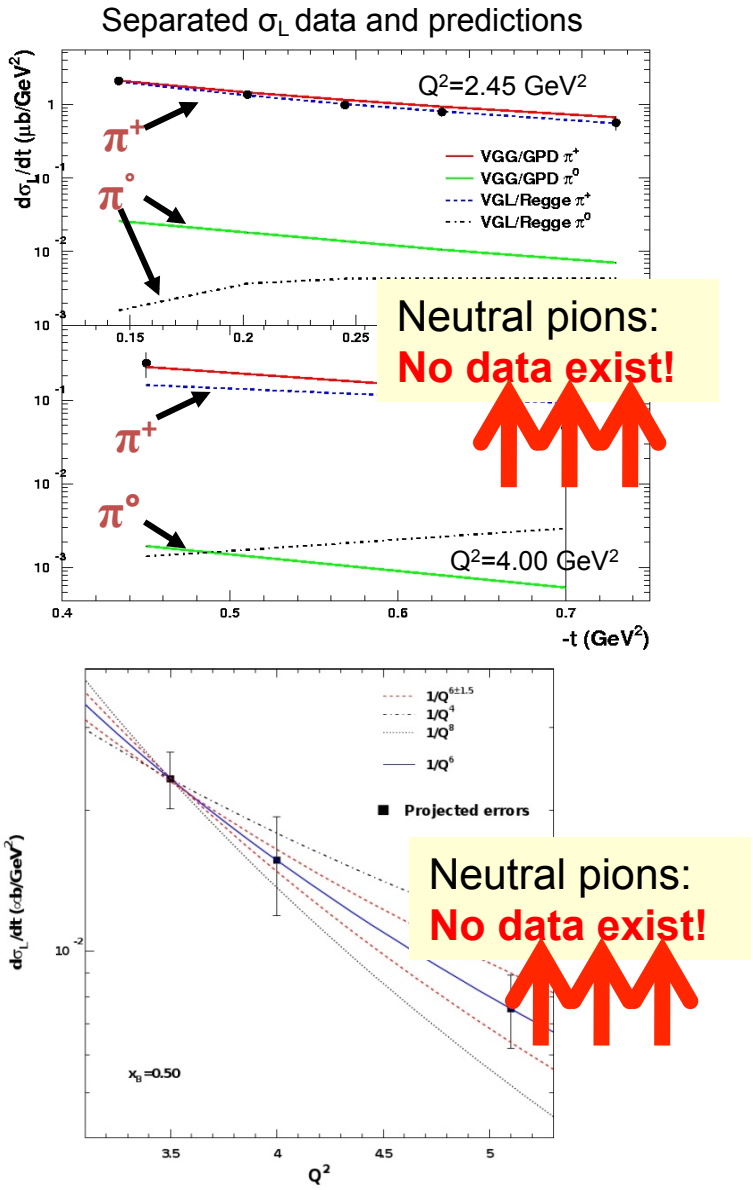


Note difference in Q^2 and vertical scale

PR12-11-102: Map σ_L and σ_T in π^o production

- GPD studies with pions require understanding relative contributions of σ_L and σ_T
  - In the limit where GPDs can be studied, $\sigma_L \sim Q^{-6}$, $\sigma_T \sim Q^{-8}$

- Is the relative contribution of σ_L in π° production significant?
  - 12 GeV: Opportunity to compare to separated σ_L and σ_T in π^+ production (E12-07-105)
  - Constrain the size of non-pole contributions
    - If smaller than anticipated may extract F_π to higher Q^2

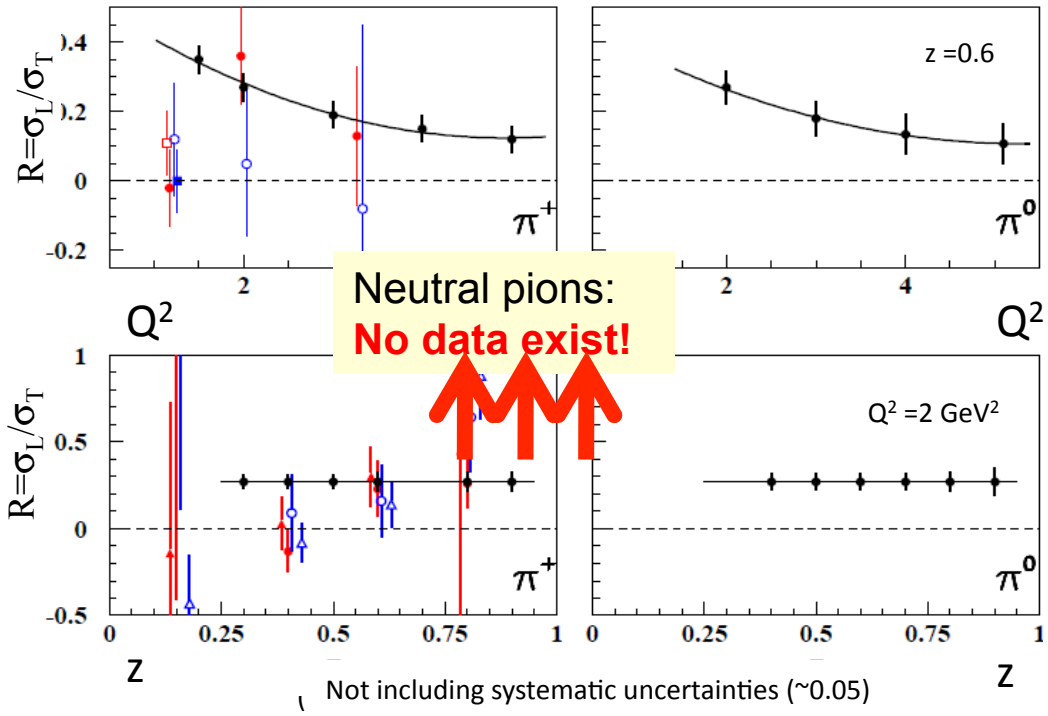


PR12-11-102: Separated σ_L, σ_T for studies of scaling in neutral systems and relative importance of pole and non-pole contributions

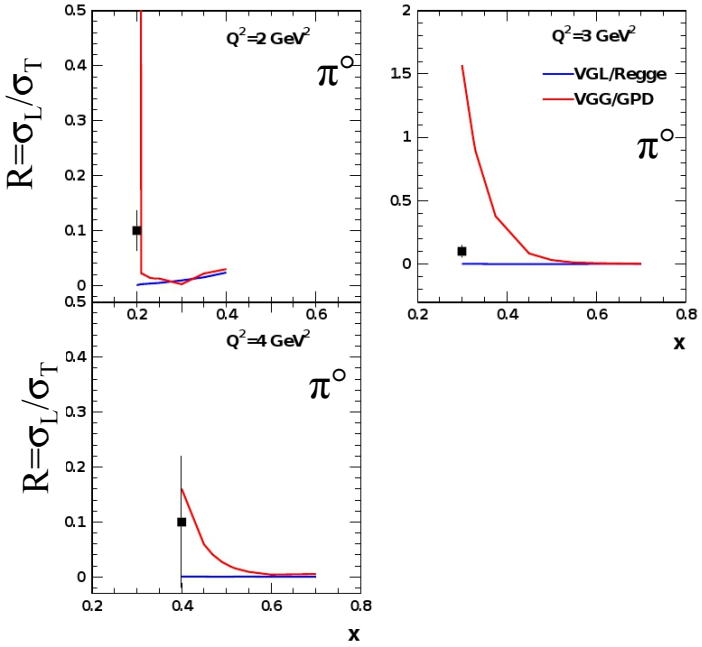
PR12-11-102: z-dependence of $R=\sigma_L/\sigma_T$

- Need to know z- and Q^2- dependencies of $R=\sigma_L/\sigma_T$ for π^o in addition to π^+,π^- for proper analysis of TMD measurements and corresponding angular asymmetries

SIDIS, z<1, projected data



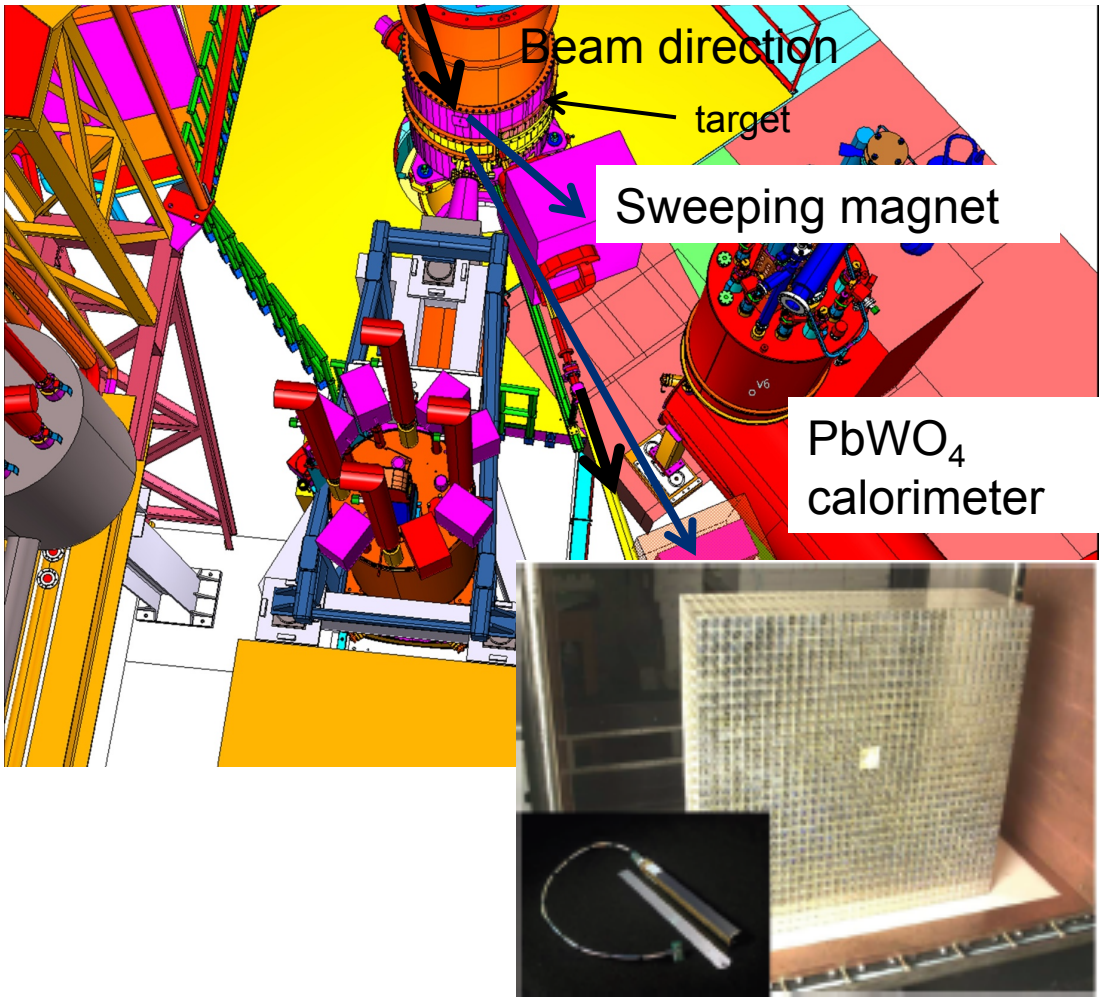
DES, z~1, projected data



PR12-11-102: precision $R=\sigma_L/\sigma_T$ data in transition from semi-inclusive deep inelastic scattering to exclusive scattering

PR12-11-102: π^o L/T facility in Hall C

- New $PbWO_4$ calorimeter facility provides π^o detection in Hall C
  - Initially for PR12-11-102
- Also provides opportunities to extend separations program for DVCS
  - PR12-11-102 provides initial separation for DVCS
  - Extensions to a broader kinematic range anticipated



MRI proposal submitted Jan 2012: CUA (Tanja Horn), ODU (Charles Hyde), FIU (Joerg Reinhold, Pete Markowitz)