

Studying Color Transparency through u-Channel π^0 Electroproduction off a Nuclear Target

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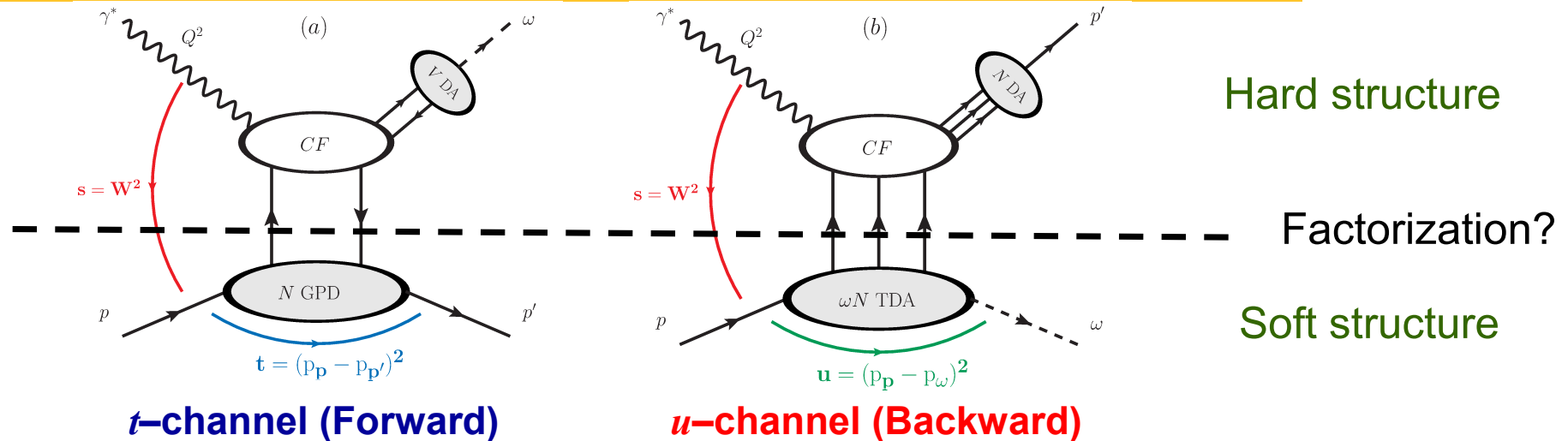
APS—DNP Meeting, New Orleans LA
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SAPIN-2021-00026

GPD–Like Model: TDA and Factorization



Baryon to Meson Transition Distribution Amplitude (TDA)

- Extension of collinear factorization to backward angle regime. Further generalization of the concept of GPDs.
- Backward angle factorization first suggested by Frankfurt, Polykaov, Strikman, Zhalov, Zhalov [*arXiv:hep-ph/0211263*]
- TDAs describe the transition of nucleon to 3–quark state and final state meson [*gray oval of plot b*]
- A fundamental difference between GPDs and TDAs is that TDAs are defined as hadronic matrix elements of 3–quark operator, while GPDs involve quark–antiquark operator
- **Can be accessed experimentally in backward angle meson electroproduction reactions**

Skewness in Backward Angle Regime

- **Forward angle kinematics**, $-t \sim -t_{min}$ and $-u \sim -u_{max}$, in the regime where handbag mechanism and GPD description may apply, Skewness is defined in usual manner:

$$\xi_t = \frac{p_1^+ - p_2^+}{p_1^+ + p_2^+} \text{ where } p_{1,2} \text{ refer to light cone } + \text{ components}$$

in $\gamma^*(q) + p(p_1) \rightarrow \omega(p_\pi) + p'(p_2)$

- **Backward angle kinematics**, $-u \sim -u_{min}$ and $-t \sim -t_{max}$, Skewness is defined with respect to u -channel momentum transfer in TDA formalism

$$\xi_u = \frac{p_1^+ - p_\pi^+}{p_1^+ + p_\pi^+}$$

- GPDs depend on x , ξ_t and $t = (\Delta^t)^2 = (p_2 - p_1)^2$
TDAs depend on x , ξ_u and $u = (\Delta^u)^2 = (p_\pi - p_1)^2$
- **Impact parameter space interpretation of TDAs is similar to GPDs, except one has to Fourier transform with respect to $\Delta^u_T \approx (p_\pi - p_1)_T$**

- **Kinematical regime for collinear factorization involving TDAs is similar to that involving GPDs:**
 - x_B fixed
 - $|u|$ –momentum transfer small compared to Q^2 and s
 - Q^2 and s sufficiently large
- Early scaling for GPD physics occurs $2 < Q^2 < 5 \text{ GeV}^2$
 - Maybe something similar occurs for TDA physics...

Two Key Predictions in Factorization Regime:

- **Dominance of transverse polarization** of virtual photon, resulting in suppression of longitudinal cross section by at least $1/Q^2$: $\sigma_T \gg \sigma_L$
- Characteristic $1/Q^8$ –scaling behavior of σ_T for fixed x_B

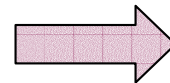
$p(e,e'p)\omega$ Q^2 -Dependence from Hall C

- To investigate Q^2 -dependence, fit lowest $-u$ bin values of σ_T and σ_L to Q^{-n} function

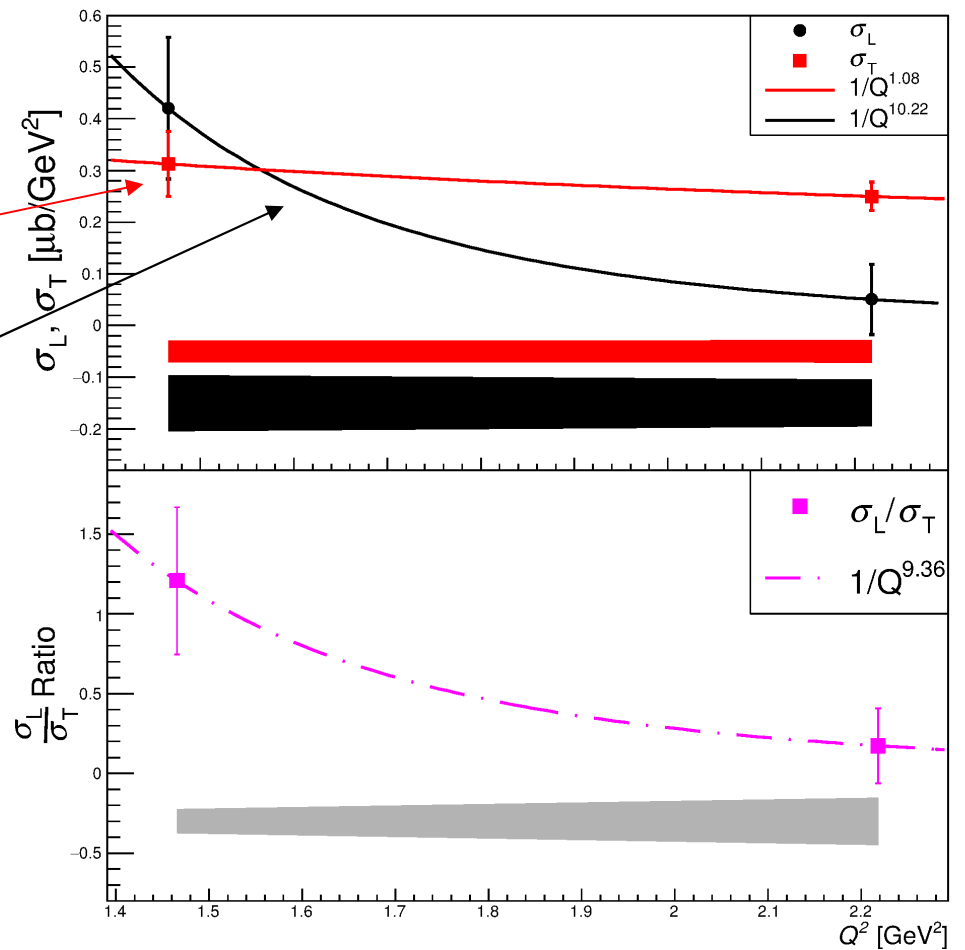
- σ_T appears to have a flat Q^2 -dependence within measured range
- σ_L shows much stronger decrease

- Decreasing L/T ratio indicates the gradual dominance of σ_T as Q^2 increases.

- Trend qualitatively consistent with prediction of TDA Collinear Factorization.



$$-u = -u_{min}$$



$$Q^2=1.47$$

$$W=2.26$$

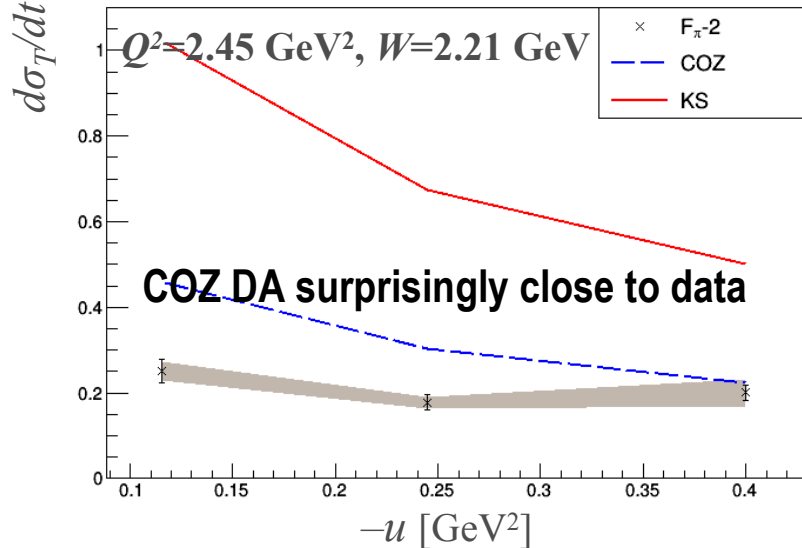
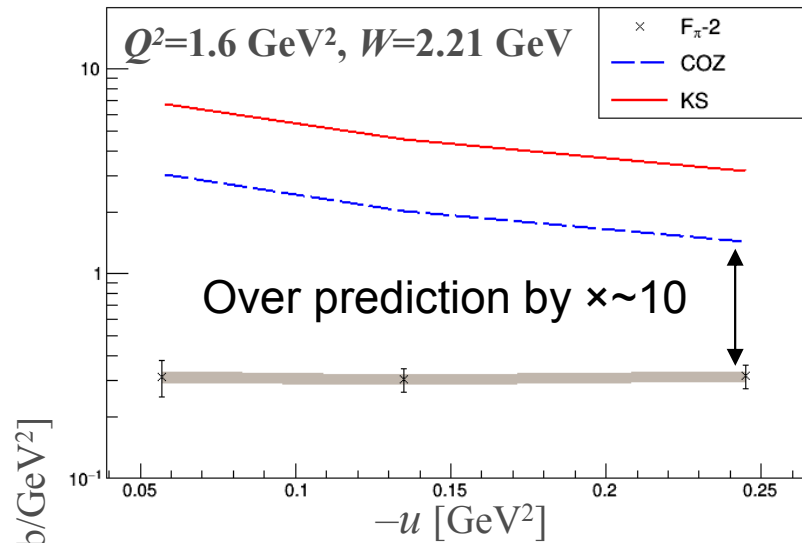
$$-u_{min}=0.058$$

$$Q^2=2.23$$

$$W=2.28$$

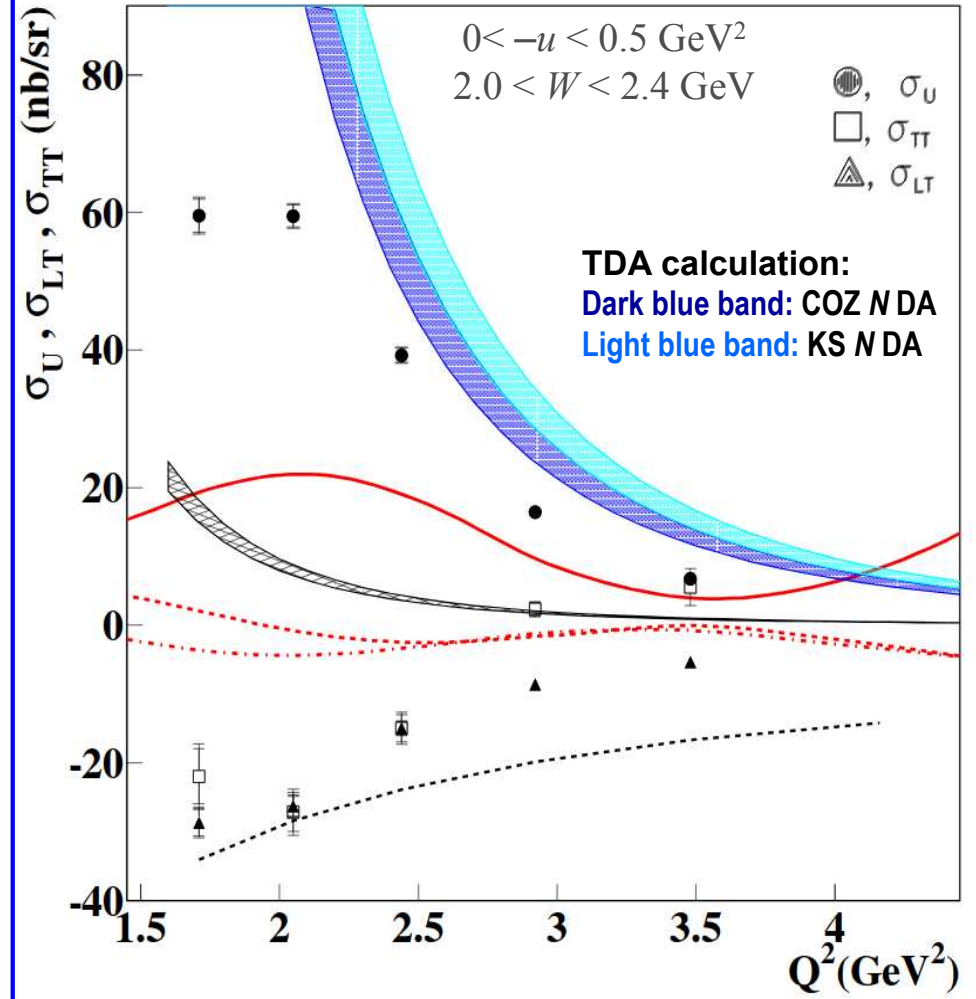
$$-u_{min}=0.117$$

TDA model Comparison to Data



Hall C ω Electroproduction
W. Li, et al. PRL **123** (2019) 182501

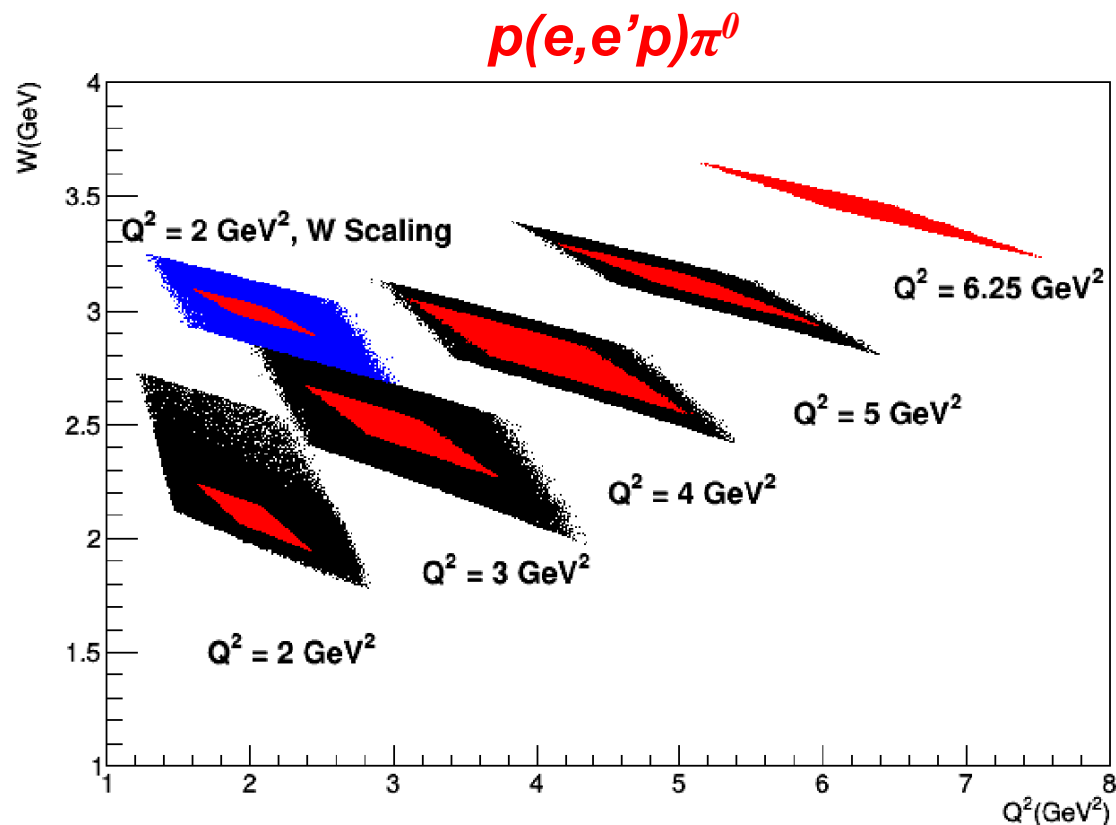
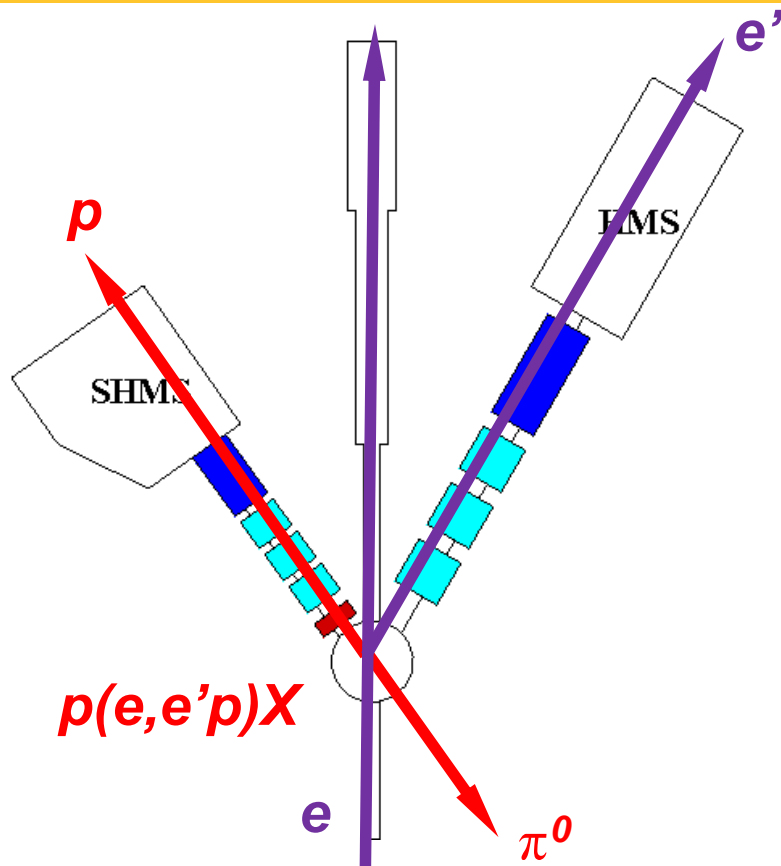
Both data sets suggestive of early
TDA scaling $Q^2 \approx 2.5 \text{ GeV}^2$!?



Hall B π^+ Electroproduction
K. Park et al., PLB **780** (2017) 340

- The 6 GeV JLab Halls B,C data are qualitatively consistent with the predictions of the backward–angle factorization / TDA formalism, but they are at a too low Q^2 to be in quantitative agreement.
 - CLAS–6 π^+ data, Hall C ω data
- Studies of the applicability of TDA formalism are being extended in the 12 GeV era, by measuring general scaling trend of separated L/T cross sections for a variety of u –channel reactions
 - 12 GeV data from Hall B
 - Hall C ρ , ω , φ data (E12–09–011)
 - Dedicated Hall C π^0 measurement (E12–20–007)

Backward Exclusive π^0 Production



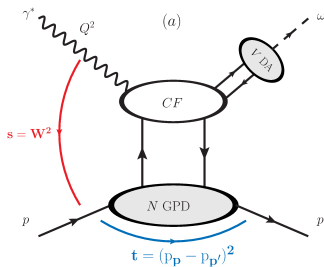
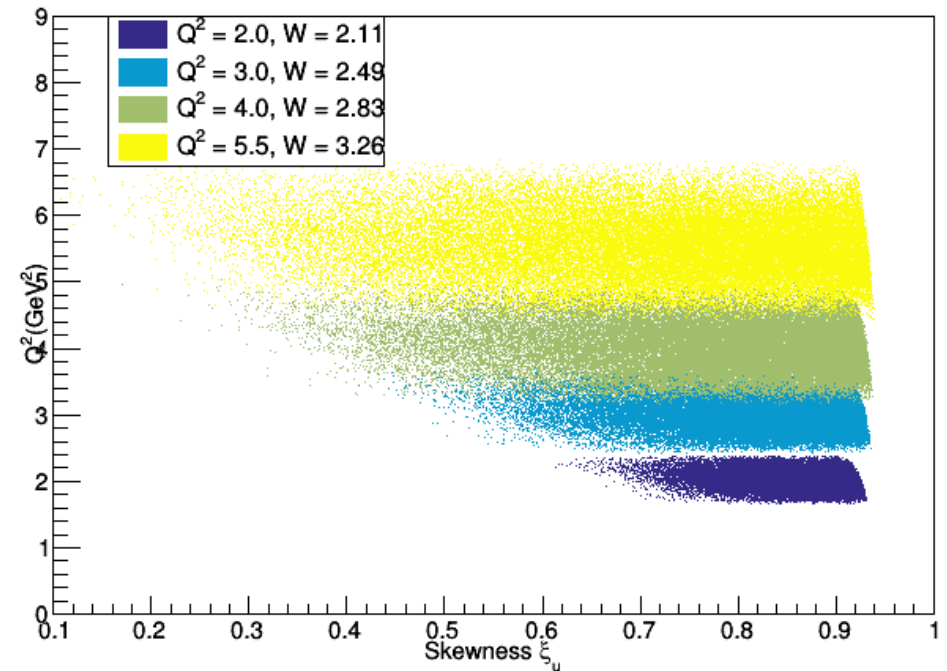
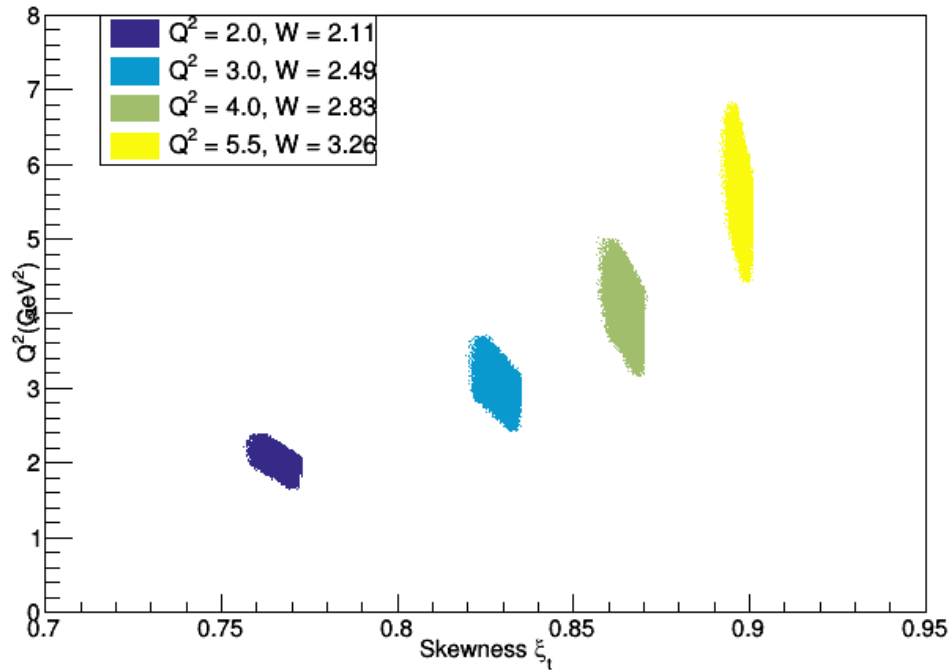
E12-20-007: $u \approx 0$ π^0 production in Hall C

Spokespersons: W.B. Li, G.M. Huber, J. Stevens

Purpose: test applicability of TDA formalism for π^0 production

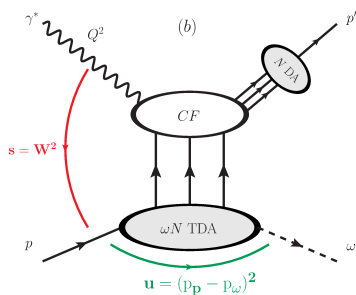
- Is σ_T dominant over σ_L ?
- Does the σ_T cross section at constant x_B scale as $1/Q^8$?
- Kinematics overlap forward angle $p(e, e'\pi^0)p$ experiment with NPS+HMS

$p(e, e' p) \pi^0$ Skewness Range



$$\xi_t = \frac{p_1^+ - p_2^+}{p_1^+ + p_2^+}$$

where $p_{1,2}$ refer to light cone + components
in $\gamma^*(q) + p(p_1) \rightarrow \omega(p_\omega) + p'(p_2)$



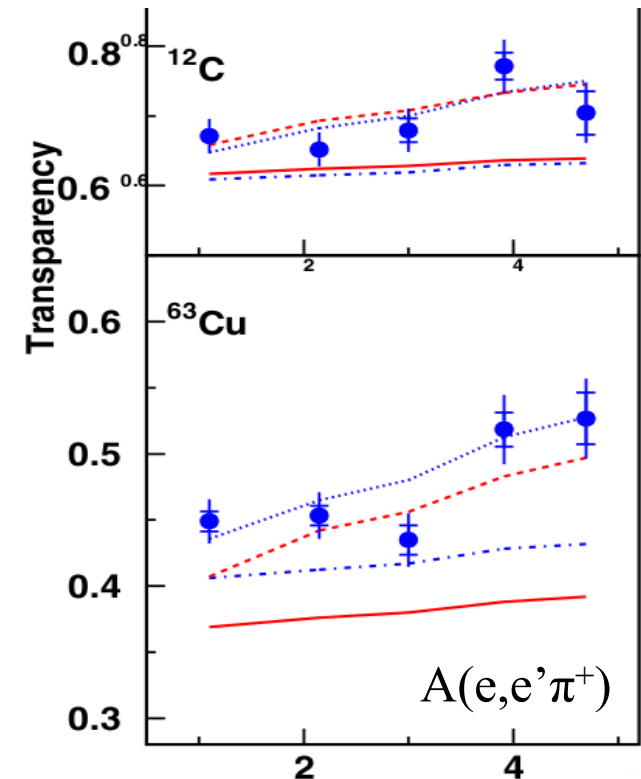
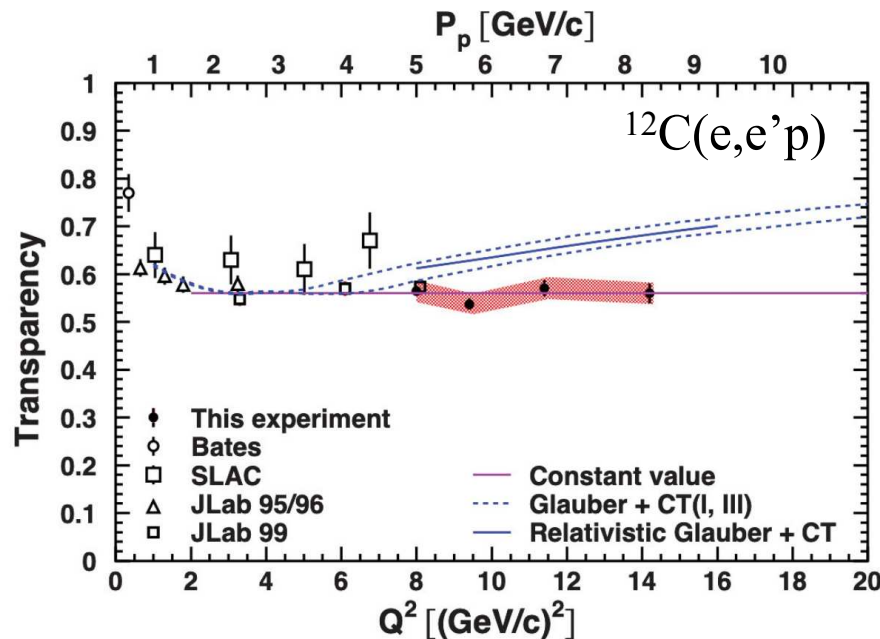
$$\xi_u = \frac{p_1^+ - p_\pi^+}{p_1^+ + p_\pi^+}$$

HMS and SHMS acceptance cuts,
and diamond cuts applied

CT and Backward-angle Factorization

- CT has recently been shown to not apply in $C(e,e'p)$ up to $Q^2=14 \text{ GeV}^2$, in contrast to CT applying already in $A(e,e'\pi^+)$ at $Q^2 \approx 5 \text{ GeV}^2$

Bhetuwal et al,
PRL 126 (2021) 082301

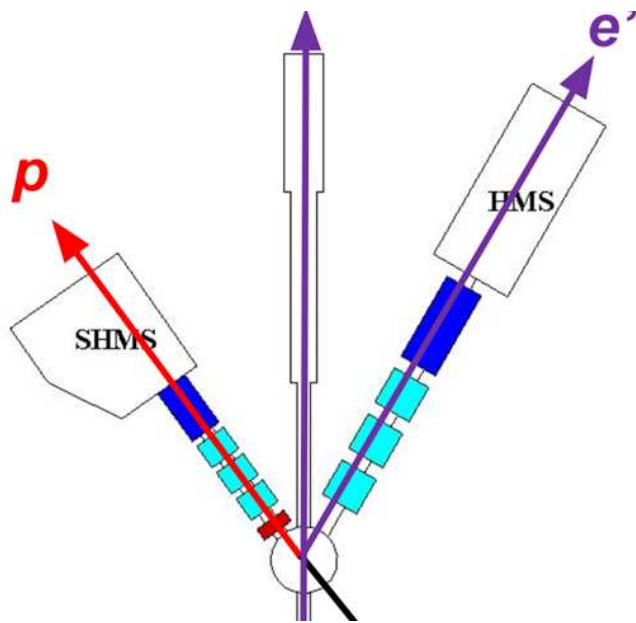


Clasie et al, PRL 99 (2008) 242502

- Color Transparency is a co-requisite of reaching the factorization regime, and is expected to be an equally valid requirement for both forward-angle and backward-angle factorizations**

Backward-angle $A(e,e'p)\pi^0$

- Since JLab 6 GeV data are qualitatively consistent with early factorization in backward kinematics, backward-angle meson production events with a high momentum forward proton may provide an alternate means of probing Color Transparency
- Example is π^0 production, but technique extendable also to vector meson production. A short test could be attempted in E12-20-007

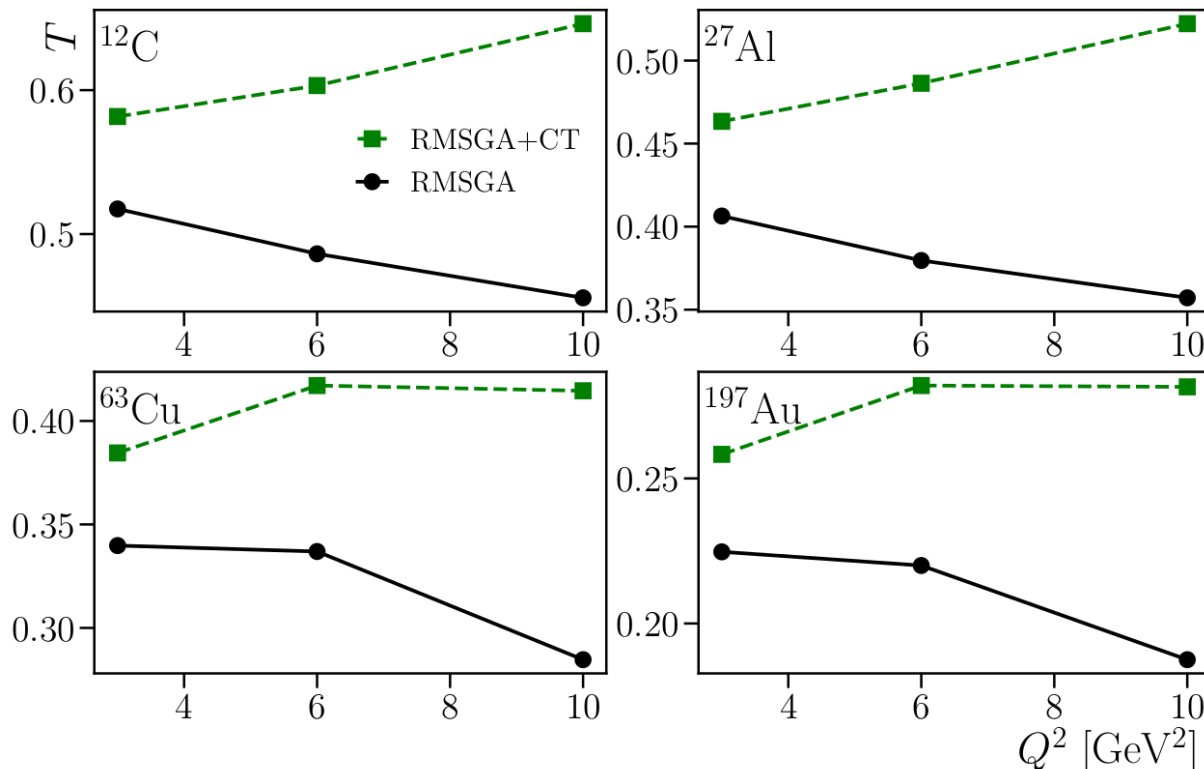


$A(e,e'p)\pi^0$ Kinematics $E_{\text{beam}}=10.6$ $W=2$ GeV					
Q^2 (GeV ²)	e' (GeV/c, deg)	p (GeV/c, deg)	π^0 (GeV/c, deg)	t (GeV ²)	u (GeV ²)
3	7.3 @ 11.3°	3.9–3.6 @ 23°–30°	0.2–0.5 @ 202°–95°	–5.7 to –5.2	+0.5 to –0.1
6	5.7 @ 18.1°	5.6–5.2 @ 19°–24°	0.1–0.5 @ 196°–79°	–8.8 to –8.2	+0.6 to 0.0
10	3.6 @ 29.7°	7.7–7.3 @ 13°–16°	0.0–0.5 @ 193°–61°	–12.8 to –12.1	+0.6 to –0.1

- Halls B,C 6 GeV data hint at applicability of backward–angle factorization mechanism as early as $Q^2=2.5 \text{ GeV}^2$
- If this interpretation is correct, it can be confirmed by u –channel CT measurements such as $A(e,e'p)\pi^0$
- **Considerations:**
 - CT will not appear in the same way for backward π^0 as for the other experiments. This is because the π^0 does not originate from a point–like quark configuration, it is attached to the TDA which has no small transverse distance inside
 - Even if factorization applies, the π^0 will be subject to strong interactions in the nucleus, such as absorption, or formation of a 2π state
 - One should not insist on detecting the final meson. Rather, it would be sufficient to require $120 < m_{\text{missing}} < 500 \text{ MeV}$. It is important to detect the high–momentum forward–going nucleon
- This new type of experiment gives rise to the intriguing idea of “*Half Color Transparency*”

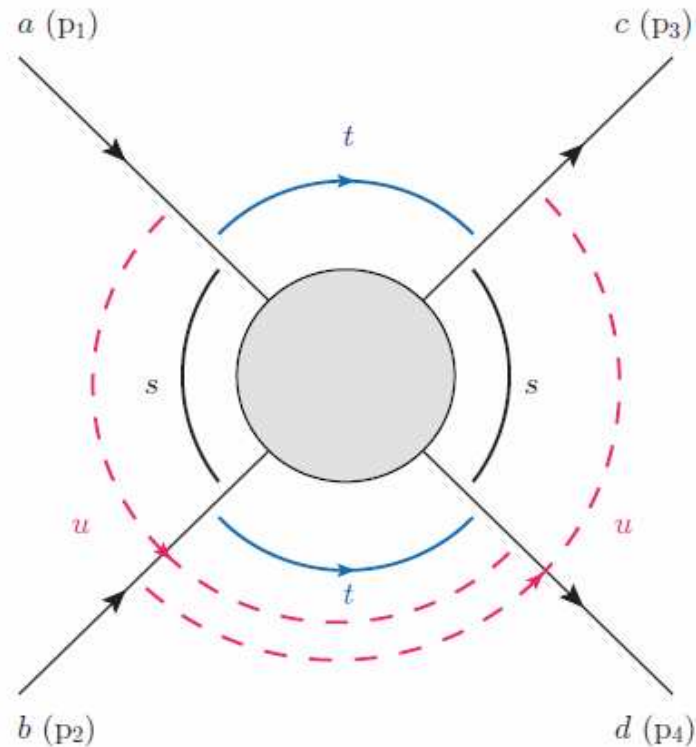
Model Estimate of Color Transparency

- Relativistic Multiple Scattering Glauber Approximation (RMSGGA)
- Flexible framework that treats kinematics and dynamics (nuclear wavefcn, FSI) relativistically, and applied to wide variety of hadron-, electron-, and neutrino-induced nuclear reactions
- Transparency Ratio: $T = \sigma^{\text{RMSGGA}} / \sigma^{\text{PWIA}}$
- Calculation is for Hall C kinematics on slide 11
- Clear CT effects are predicted, which set the stage for future proposal



- **New experimental technique pioneered at JLab Hall C has opened up a unique kinematic regime for study:**
 - Extreme backward angle ($u \approx 0$) scattering
 - Detect forward-going proton in parallel kinematics
 - Leaves “recoil” meson nearly-at-rest in target
- Possible access to **Transition Distribution Amplitudes**
 - Universal perturbative objects in u -channel, analogous to GPDs
 - Access to 3-quark plus sea component $\Psi_{(3q+q\bar{q})}$ of nucleon
- The approach of backward angle factorization regime can be studied via u -channel CT measurements, such as $A(e, e' p) \pi^0$, across a variety of nuclei
- For more details, see our paper:
MDPI *Physics* Special Issue on JLab Color Transparency Workshop,
[arXiv:2202.04470](https://arxiv.org/abs/2202.04470) <https://doi.org/10.3390/physics4020030>

Mandelstam variables (s, t, u -channels)



s : invariant mass of the system

t : Four-momentum-transfer squared between **target before and after interaction**

u : Four-momentum-transfer squared between **virtual photon before interaction and target after interaction**

t -channel: $-t \sim 0$, after interaction

Target: stationary

Meson: forward

Measure of how forward could the meson go.

u -channel: $-u \sim 0$, after interaction

Target: forward

Meson: stationary

Measure of how backward could the meson go

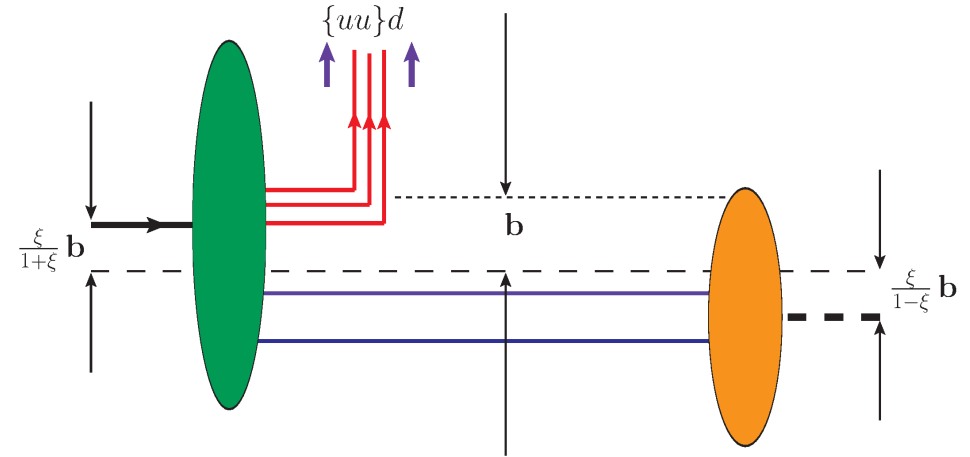
$$s = (p_1 + p_2)^2 = (p_3 + p_4)^2$$

$$t = (p_1 - p_3)^2 = (p_2 - p_4)^2$$

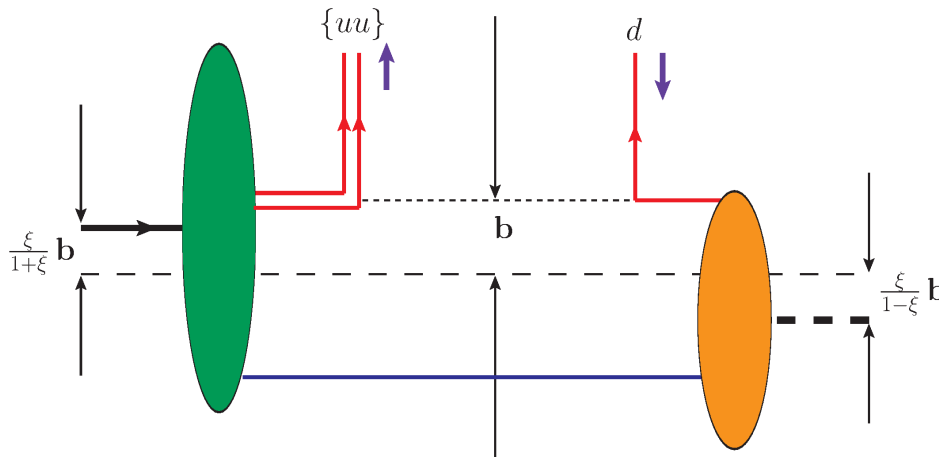
$$u = (p_1 - p_4)^2 = (p_2 - p_3)^2$$

Impact parameter Interpretation of TDA

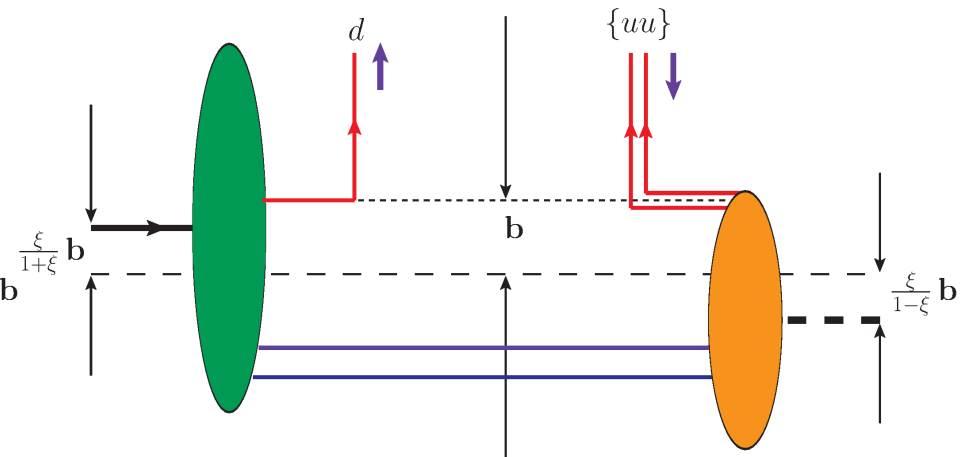
- After integrating over one momentum fraction x_i , the three exchanged quarks can be treated as an effective diquark+quark pair
- Impact picture then looks very much like that for GPDs



ERBL : $x_3 = w_3 - \xi \geq 0$; $x_1 + x_2 = \xi - w_3 \geq 0$;
 \rightarrow All 3 quark momentum fractions x_i positive



DGLAP I : $x_3 = w_3 - \xi \leq 0$; $x_1 + x_2 = \xi - w_3 \geq 0$;
 \rightarrow One x_i negative



DGLAP II : $x_3 = w_3 - \xi \geq 0$; $x_1 + x_2 = \xi - w_3 \leq 0$;
 \rightarrow Two x_i negative

TDA Formalism (e.g. u -channel π^0)

- Fourier transform of the πN transition matrix element

$$4\mathcal{F} \langle \pi_\alpha(p_\pi) | \hat{O}_{\rho\tau\chi}(\lambda_1 n, \lambda_2 n, \lambda_3 n) | N_\iota(p_1) \rangle$$

Factorization scale

$$= \delta(x_1 + x_2 + x_3 - 2\xi_u) \sum_{s.f.} (f_a)_\iota^{\alpha\beta\gamma} s_{\rho\tau,\chi} H_{s.f.}^{\pi N}(x_1, x_2, x_3, \xi_u, \Delta^2; \mu_F^2)$$

- πN TDA invariant amplitudes (eight TDAs at leading twist)

$$H_{s.f.}^{\pi N} = \{V_{1,2}^{\pi N}, A_{1,2}^{\pi N}, T_{1,2,3,4}^{\pi N}\}$$

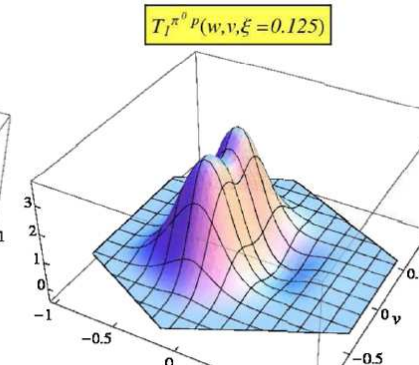
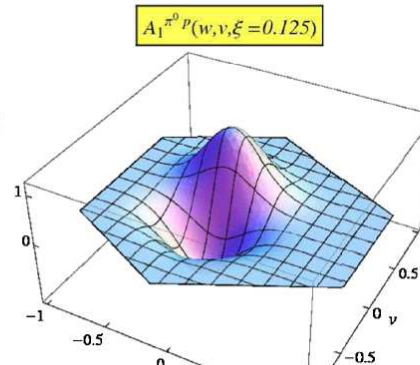
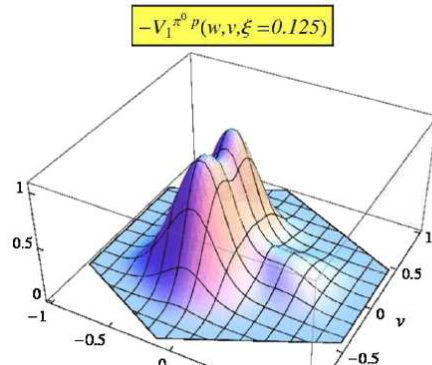
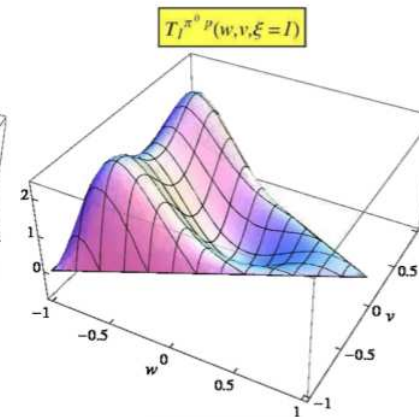
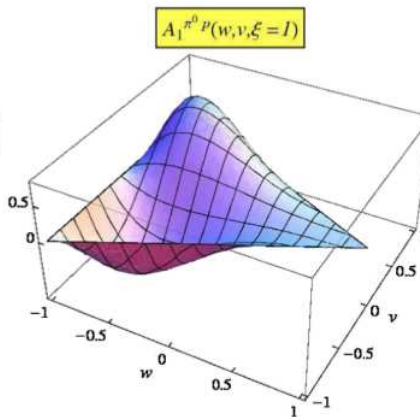
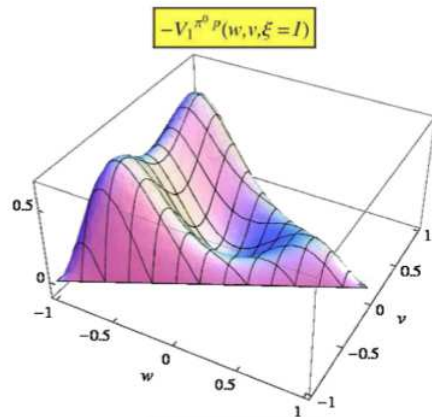
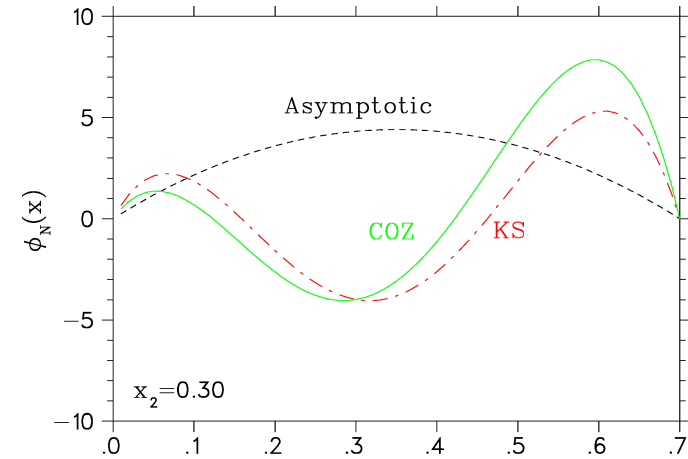
- Factorizing out the u -dependence:

$$H^{\pi N}(x, \xi_u, \Delta^2) = H^{\pi N}(x_i, \xi_u) \times G(\Delta^2) \quad \Delta^2 = u$$

meson to nucleon
transition form factor

$\pi^0 p$ TDAs as functions of q -diquark coordinates

$$w = \xi_u - x_3; \quad v = \frac{x_1 - x_2}{2}$$



$\pi^0 p$ TDAs (CZ): **Vector**

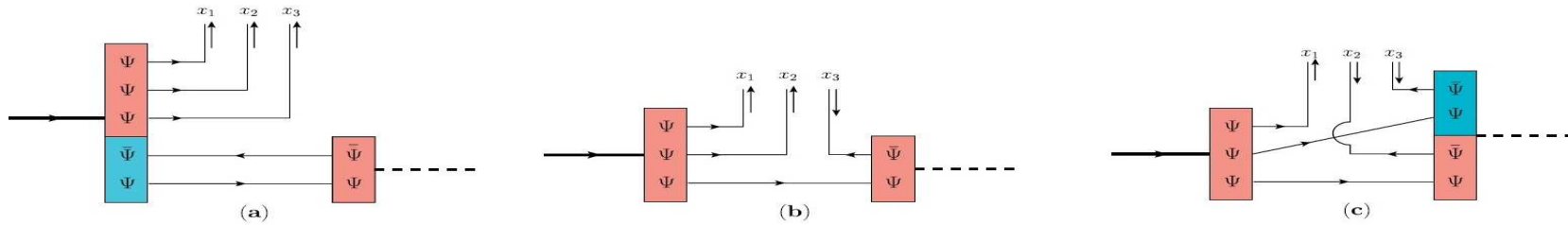
Axial-Vector

Tensor

Partonic Interpretation of TDA

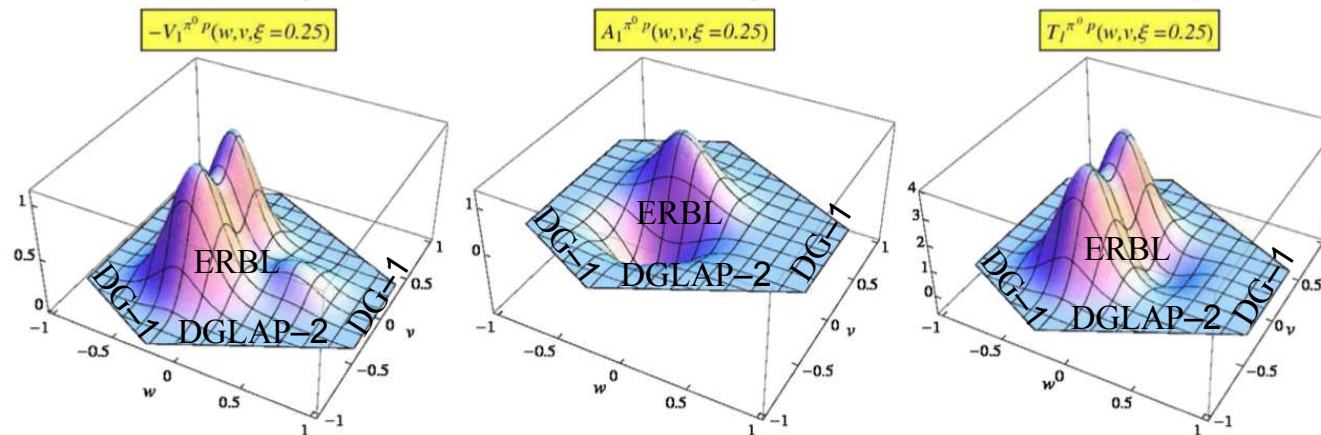
Main reactions of interest to date:

- Backward angle exclusive $\pi^0, \pi^+, \rho, \omega, \varphi$ production
- Backward angle DVCS



Interpretation of πN TDAs in light-cone quark model

- Quark sea contrib to baryon wf (ERBL region)
- Minimal Fock states of baryon & meson (DGLAP-1) region
- Quark sea contribution to meson wf (DGLAP-2)



$\pi^0 p$ TDAs (CZ): **Vector**

Axial-Vector

Tensor

$$v = (x_1 - x_2)/2$$

$$w = (x_3 - x_1 - x_2)/2$$

Model based on spectral representation w/ CZ sol for DA as input (function of quark-diquark coord)

TDA Formalism – 1

α	T_α	T'_α
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1	$\begin{array}{l} u(x_1) \text{---} \times \text{---} u(y_1) \\ u(x_2) \text{---} \infty \text{---} u(y_2) \\ d(x_3) \text{---} \infty \text{---} d(y_3) \end{array}$	$\frac{-Q_u(2\xi)^2[(V_1^{p\pi^0} - A_1^{p\pi^0})(V^P - A^P) + 4T_1^{p\pi^0} T^P + 2\frac{\Delta_1^2}{M^2} T_4^{p\pi^0} T^P]}{(2\xi - x_1 - i\epsilon)^2(x_3 - i\epsilon)(1 - y_1)^2 y_3}$	$\frac{-Q_u(2\xi)^2[(V_2^{p\pi^0} - A_2^{p\pi^0})(V^P - A^P) + 2(T_2^{p\pi^0} + T_3^{p\pi^0})T^P]}{(2\xi - x_1 - i\epsilon)^2(x_3 - i\epsilon)(1 - y_1)^2 y_3}$
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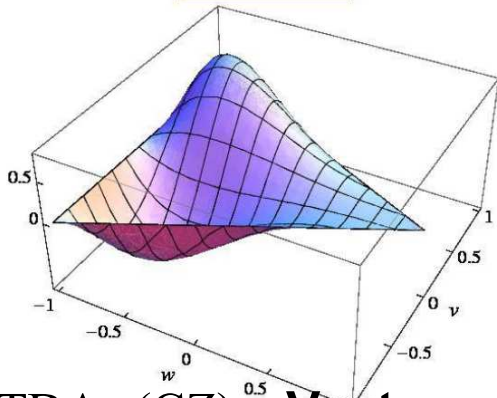
First three TDAs

$$\begin{aligned} V_1^{\pi^0 p}(x_1, x_2, x_3, \xi_u = 1) &= -\frac{1}{2} \times \frac{1}{4} V^P\left(\frac{x_1}{2}, \frac{x_2}{2}, \frac{x_3}{2}\right) \\ A_1^{\pi^0 p}(x_1, x_2, x_3, \xi_u = 1) &= -\frac{1}{2} \times \frac{1}{4} A^P\left(\frac{x_1}{2}, \frac{x_2}{2}, \frac{x_3}{2}\right) \\ T_1^{\pi^0 p}(x_1, x_2, x_3, \xi_u = 1) &= \frac{3}{2} \times \frac{1}{4} T^P\left(\frac{x_1}{2}, \frac{x_2}{2}, \frac{x_3}{2}\right) \end{aligned}$$

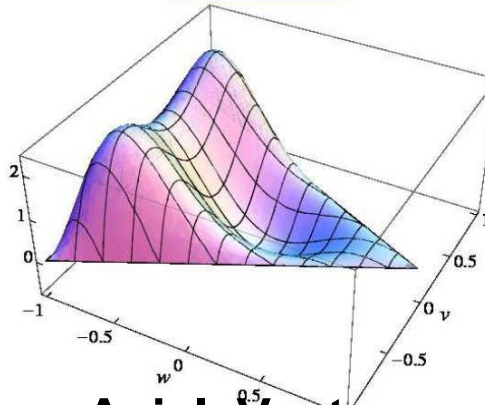
Input PDF from Nucleon DA model:

- COZ (Chernak, Ogloblin, Zhitnitsky, 1989)
- KS (King and Schrajda, 1987)

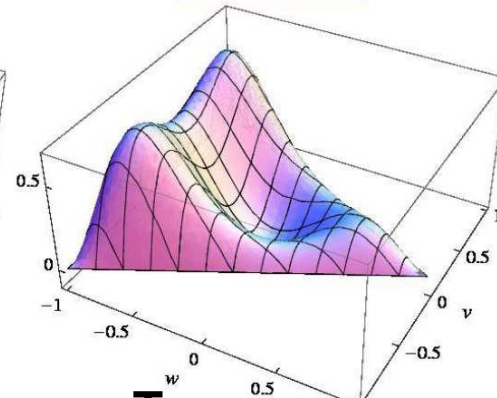
$A_1^{\pi^0 p}(w, v, \xi = 1)$



$T_1^{\pi^0 p}(w, v, \xi = 1)$



$-V_1^{\pi^0 p}(w, v, \xi = 1)$



$\pi^0 p$ TDAs (CZ): **Vector**

Axial-Vector

Tensor

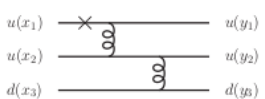
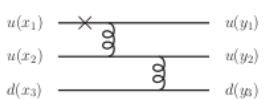
computed as functions of quark-diquark coordinates

TDA Meson Production Cross Section

- Unpolarized exclusive π^0 production cross section:

$$\frac{d^2\sigma_T}{d\Omega_\pi} = |\mathcal{C}^2| \frac{1}{Q^6} \frac{\Lambda(s, m^2, M^2)}{128 \pi^2 s (s - M^2)} \frac{1 + \xi}{\xi} (|\mathcal{I}|^2 - \frac{\Delta_T^2}{M^2} |\mathcal{I}'|^2)$$

$$\mathcal{I} = \int \left(2 \sum_{\alpha=1}^7 T_\alpha + \sum_{\alpha=8}^{14} T_\alpha \right) \quad \mathcal{I}' = \int \left(2 \sum_{\alpha=1}^7 T'_\alpha + \sum_{\alpha=8}^{14} T'_\alpha \right)$$

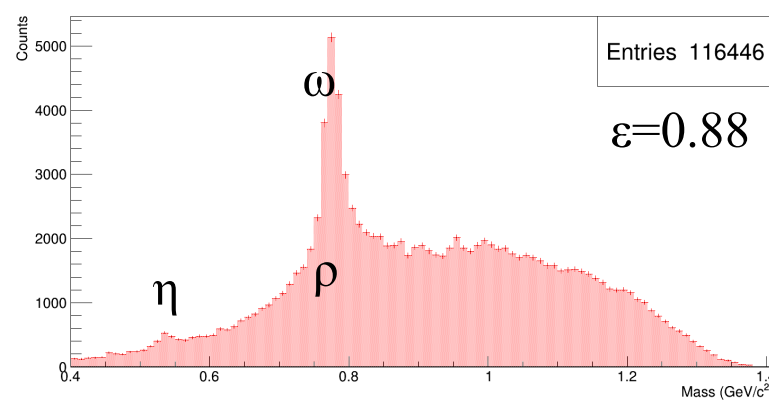
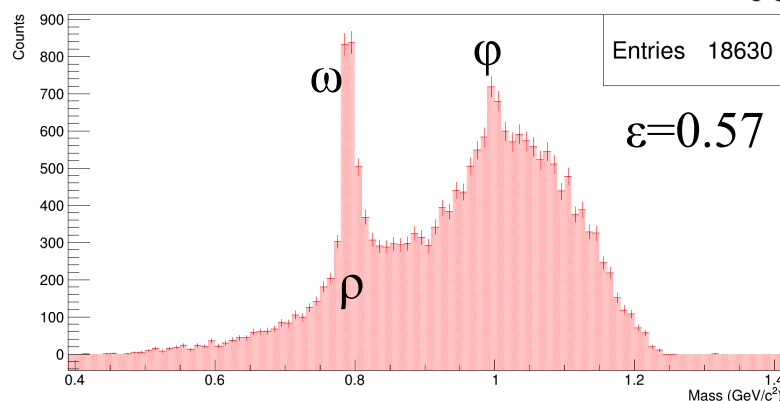
α	T_α	T'_α
1	 $\frac{-Q_u (2\xi)^2 [(V_1^{P\pi^0} - A_1^{P\pi^0})(V^P - A^P) + 4T_1^{P\pi^0} T^P + 2\frac{\Delta_T^2}{M^2} T_4^{P\pi^0} T^P]}{(2\xi - x_1 - i\epsilon)^2 (x_3 - i\epsilon)(1 - y_1)^2 y_3}$	 $\frac{-Q_u (2\xi)^2 [(V_2^{P\pi^0} - A_2^{P\pi^0})(V^P - A^P) + 2(T_2^{P\pi^0} + T_3^{P\pi^0}) T^P]}{(2\xi - x_1 - i\epsilon)^2 (x_3 - i\epsilon)(1 - y_1)^2 y_3}$

J. P. Lansberg, B. Pire, K. Semenov-Tian-Shansky, L. Szymananovski, Phys. Rev. D **85** (2011) 054021

Hall C 12 GeV data already acquired

$p(e, e'p)X$ Online Data Analysis

$$Q^2=3.00 \quad W=2.32 \quad \theta_{pq}=+3.0^\circ \quad -u=0.15 \quad \xi_u=0.15$$



Plots by Stephen Kay

K^+ L/T-experiment (E12-09-011)

Spokespersons: T. Horn, G.M. Huber, P. Markowitz

- Data acquired fall 2018–spring 2019
- Main purpose of experiment is to acquire ϵ channel L/T-separated $p(e, e'K^+)\Lambda$ data for reaction mechanism and K^+ form factor studies
- Abundant u -channel $p(e, e'p)X$ data acquired parasitically
 - Will allow backward angle studies for several meson states over a wide kinematic range

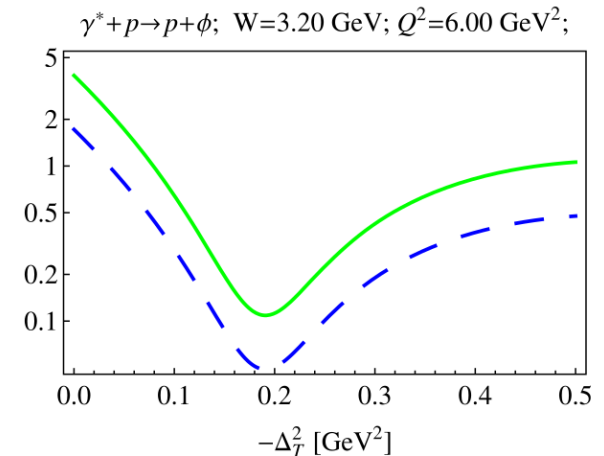
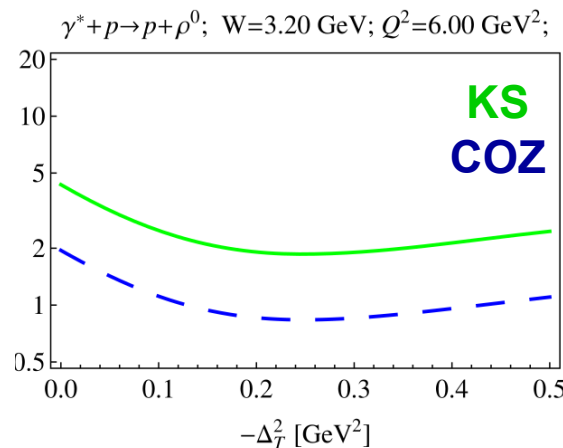
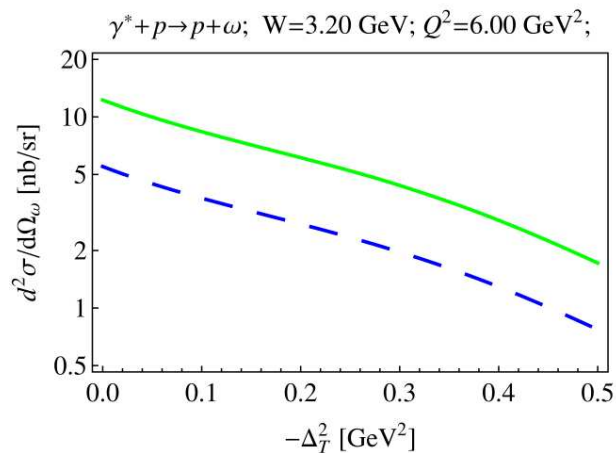
Setting	Low ϵ data	High ϵ data
$Q^2=0.50$ $W=2.40$	✓	✓
$Q^2=2.1$ $W=2.95$	✓	✓
$Q^2=3.0$ $W=2.32$	✓	✓
$Q^2=3.0$ $W=3.14$	✓	✓
$Q^2=4.4$ $W=2.74$	✓	✓
$Q^2=5.5$ $W=3.02$	✓	✓

TDA Model Predictions for JLab E12-19-006

F π -12 experiment (E12-19-006) L/T separations up to $Q^2=8.5$ GeV 2

Spokespersons: D. Gaskell, G.M. Huber, T. Horn

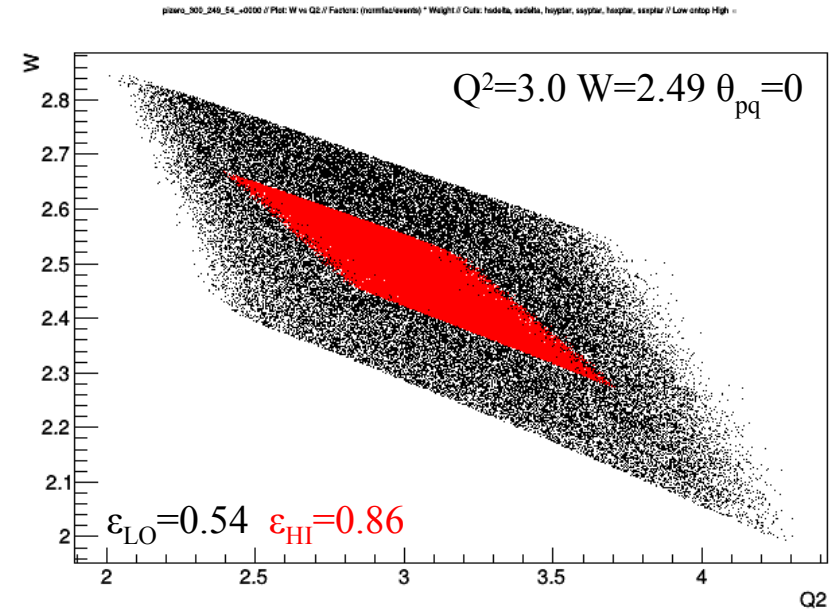
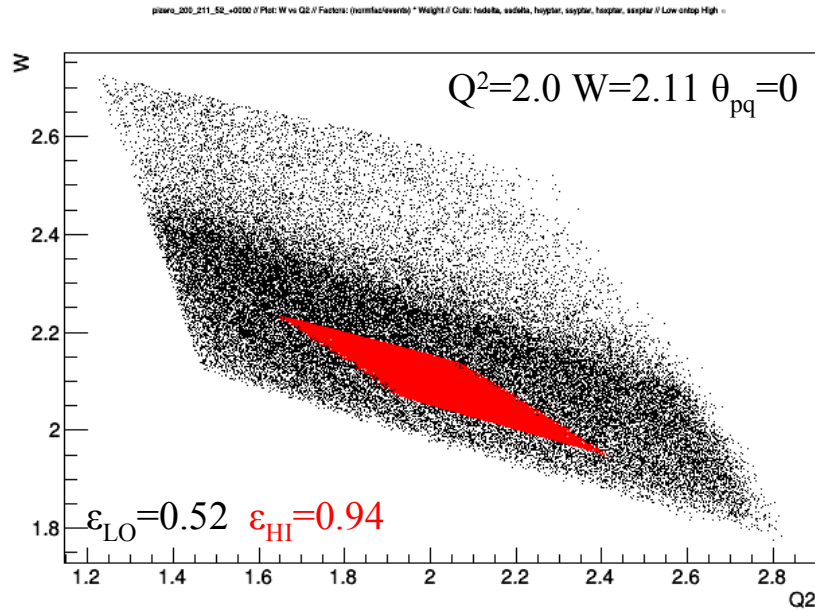
- **L/T-Separations over wide kinematic range will allow $\sigma_T \gg \sigma_L$ and $1/Q^8$ scaling predictions to be checked with greater authority**
- **u-channel ϕ -electroproduction particularly interesting**
 - **Sensitive to Strangeness content of nucleon**
- **Combined analysis of ρ , ω production allows one to disentangle isotopic structure of VN TDAs in non-strange sector**



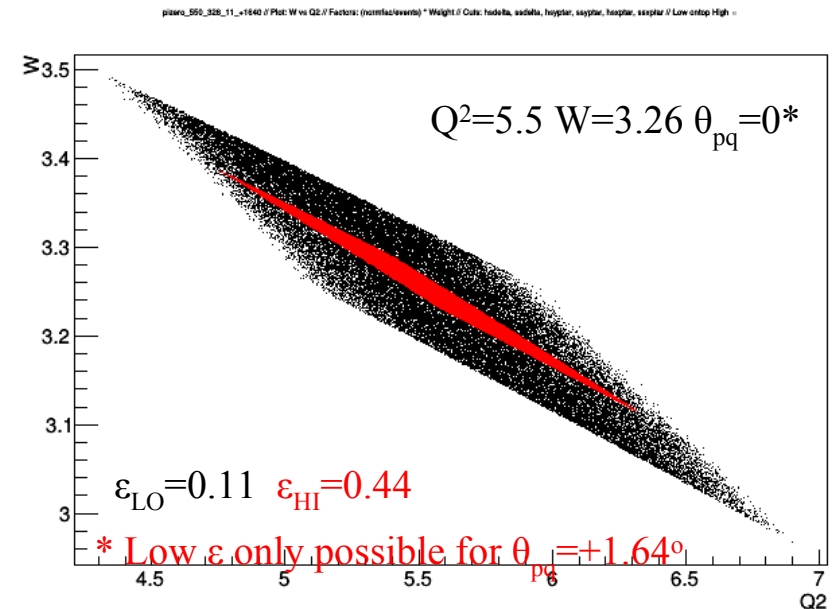
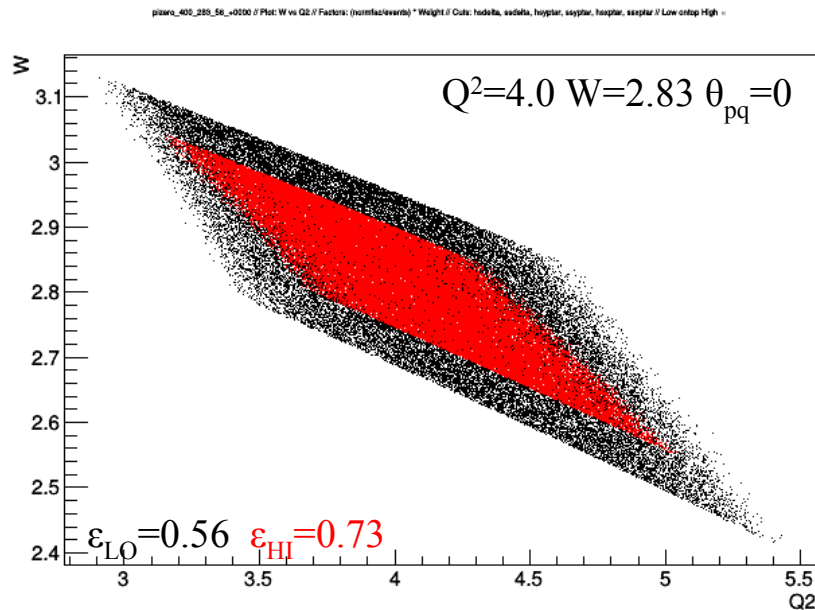
B. Pire et al., PRD 91 (2015) 094006

At $Q^2=6.0$ GeV 2 , ω predicted to remain dominant (unlike t -channel), ϕ to drop rapidly with $-u$.

SIMC: Q^2 - W overlap at high, low ϵ

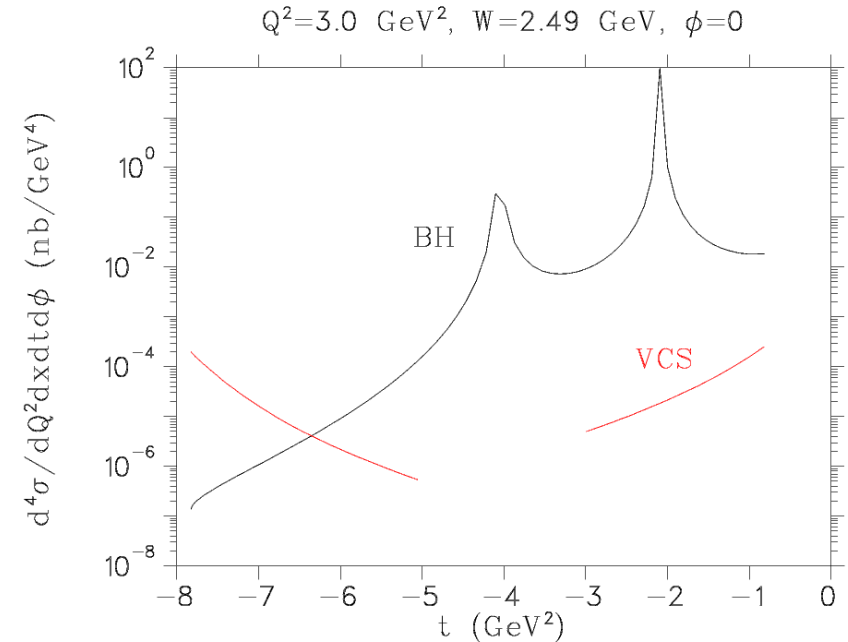


$p(e, e' p) \pi^0$: HMS and SHMS acceptance cuts applied

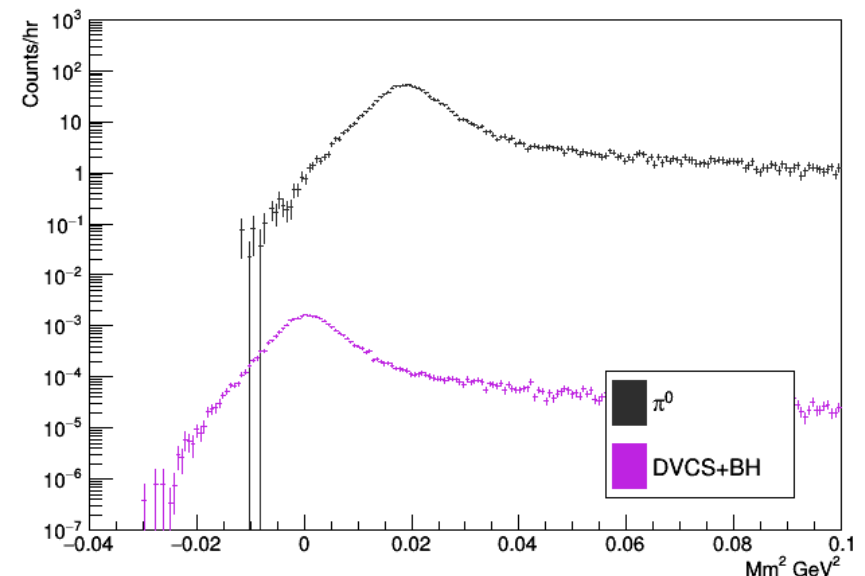


π^0 Channel Expected to be Clean

- In comparison to backward-angle ω electroproduction, there is little physics background in π^0 production.
- Bethe-Heitler process has no backward-angle peak, and will be negligible.
- VCS should dominate backward-angle γ production, but is expected to be much smaller than π^0 production.



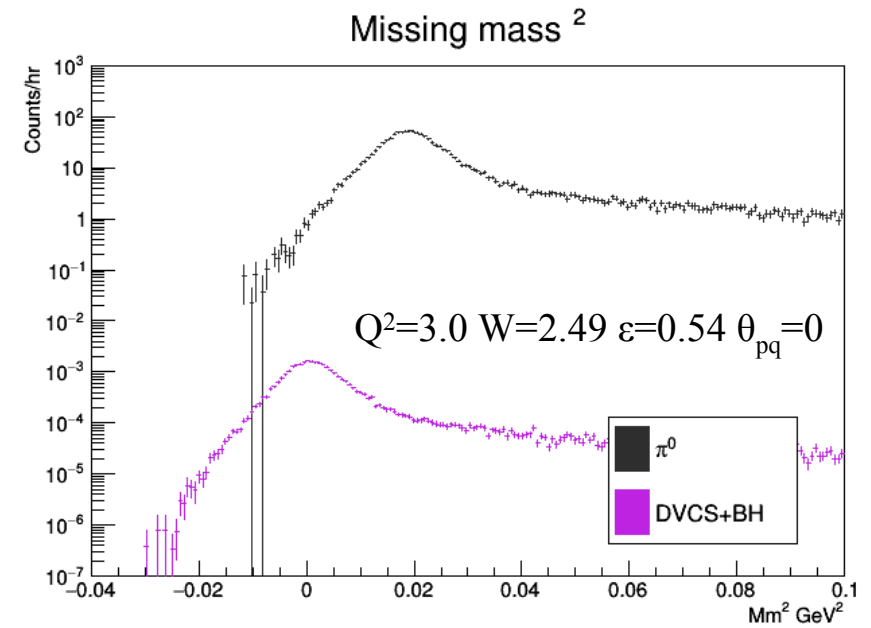
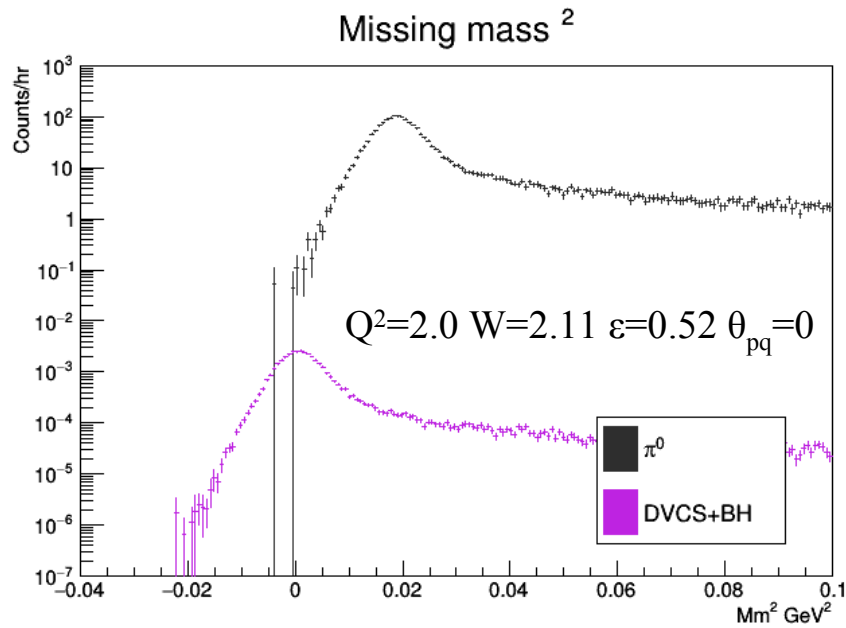
SHMS+HMS $Q^2=3.0$ Simulation



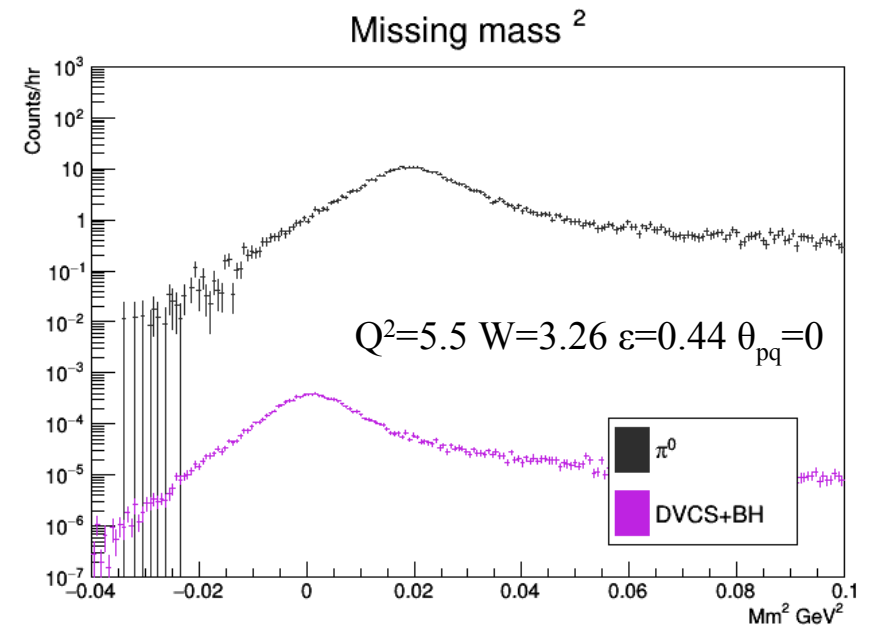
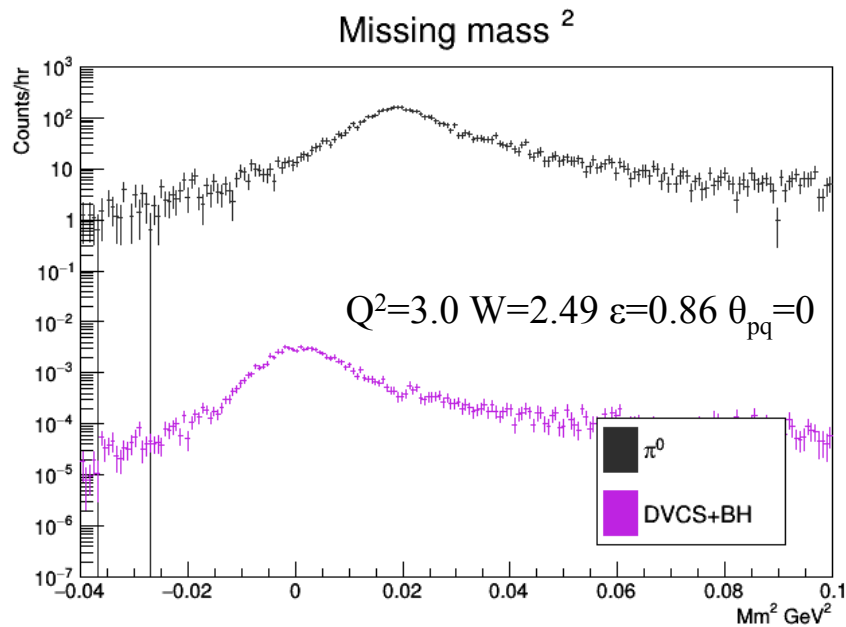
BH+VCS simulations based on code by P. Guichon and M. Vanderhaeghen.

- BH calculation is exact.
- VCS calculation makes use of ad-hoc ansatz based on u -channel ω data.

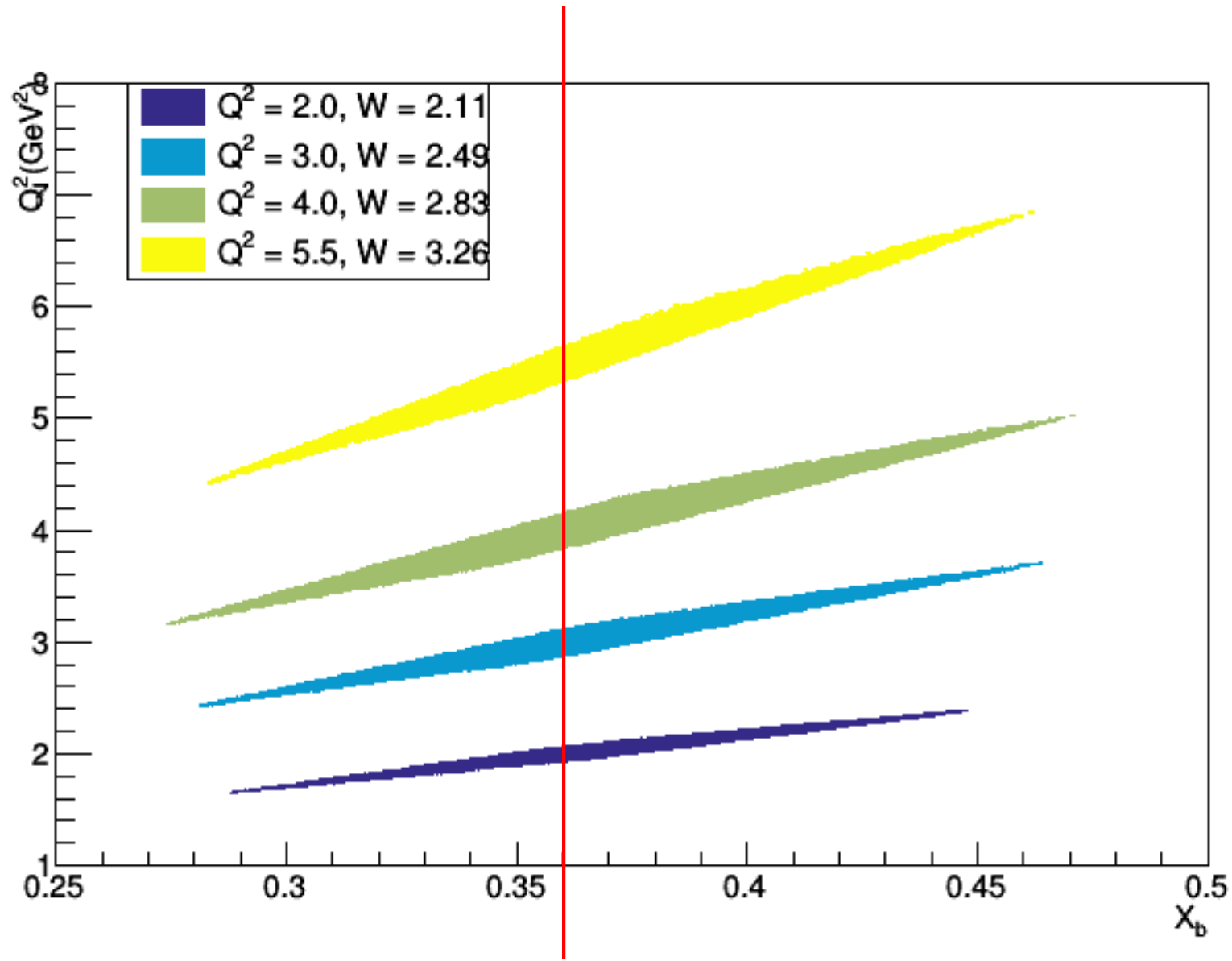
SIMC: Missing Mass squared



HMS and SHMS acceptance cuts, and diamond cuts applied

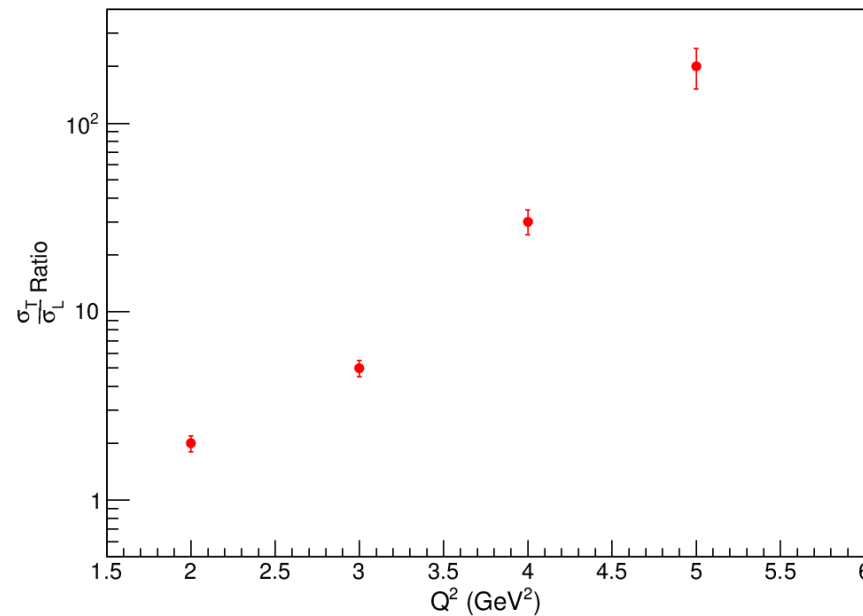
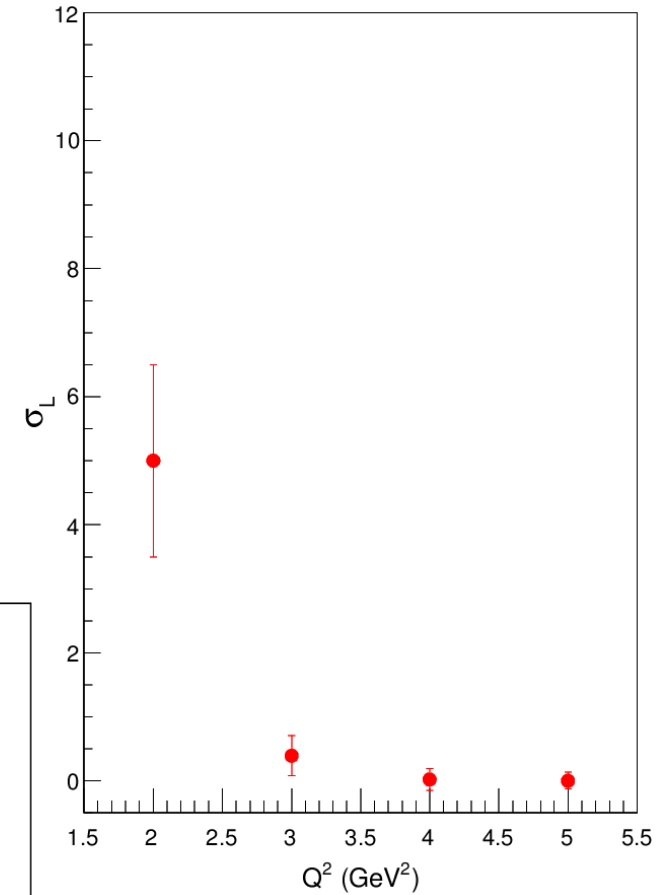
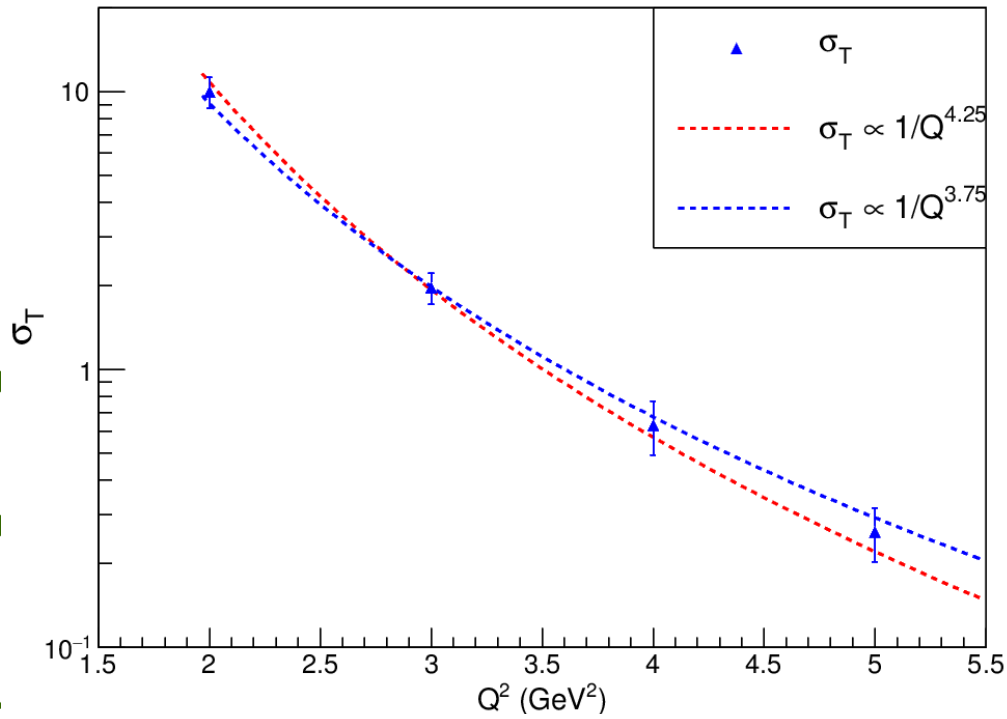


Central Kinematics are $x_{\text{Bjorken}} = 0.36$

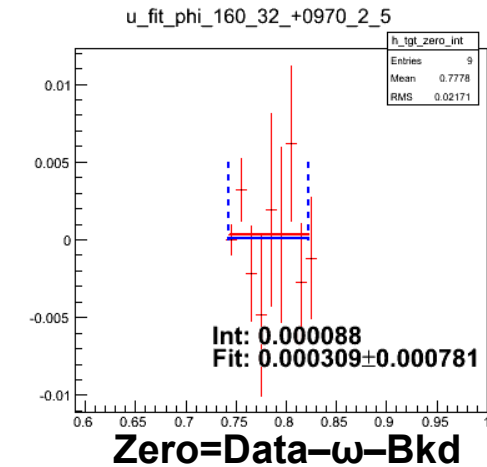
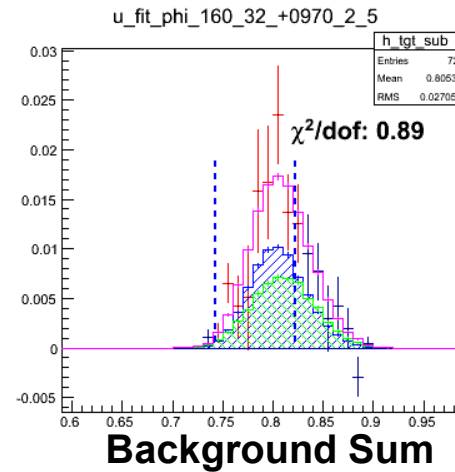
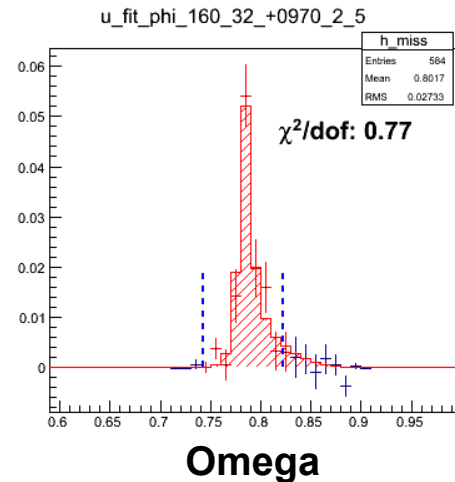
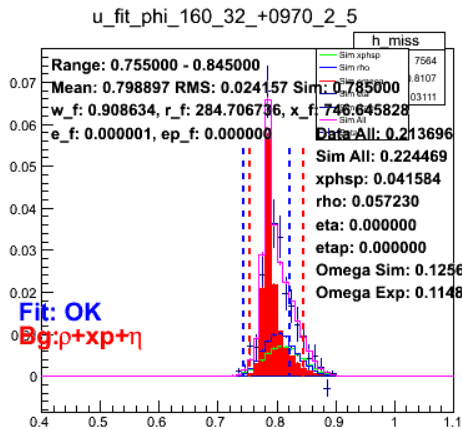


HMS and SHMS acceptance cuts, and diamond cuts applied

$p(e,e'p)\pi^0$ Q^2 -dependence projections



Missing Mass Background Removal



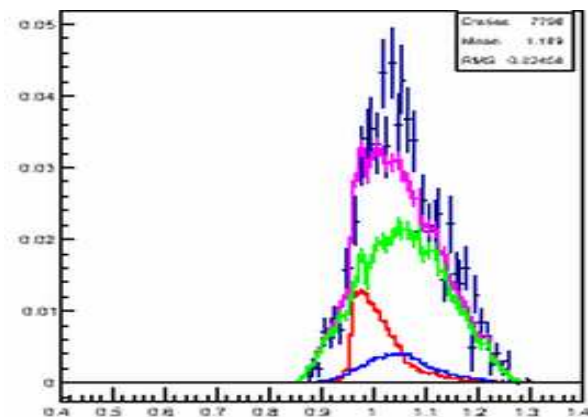
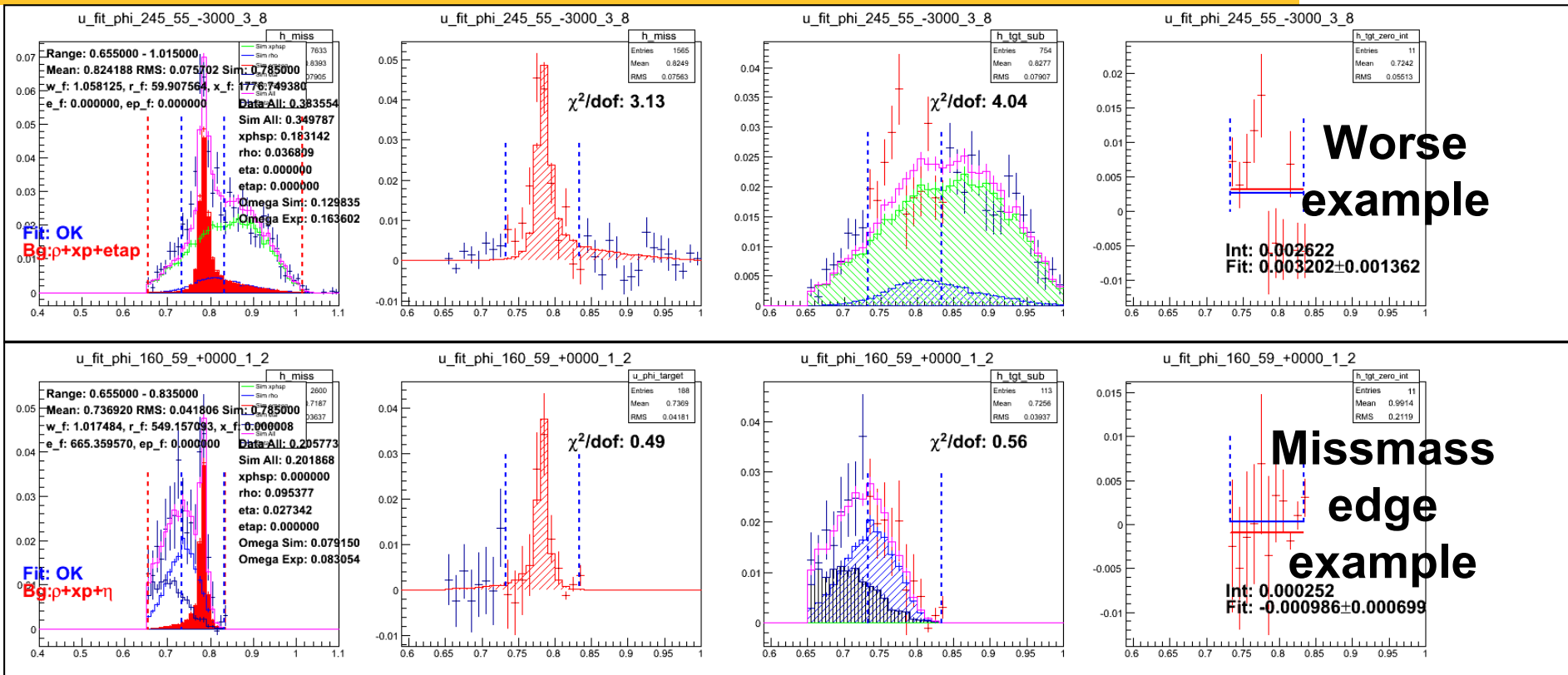
Data (blue)
 Xspace Sim (green)
 ρ Sim (cyan)
 ω Sim (red)
 η or η' (black)
 Sim Sum (pink)

$$R = \frac{Y_{Exp} - Y_{\rho \text{ sim}} - Y_{Xspace \text{ sim}} - Y_{\eta \text{ sim}}}{Y_{\omega \text{ sim}}}$$

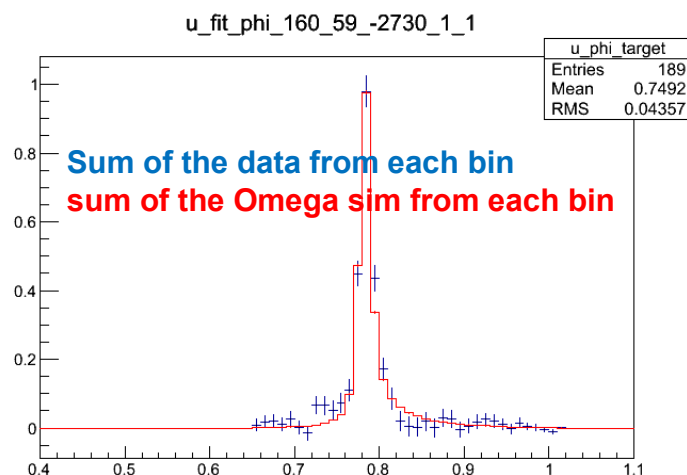
- **Fitting Limits (red dashed line):**
 - Not fixed, fit 95% data distribution
- **Integration Limits (blue dashed line):**
 - Fixed for all u-phi bins!
- **Bin Exclusion criteria:**
 - Radiative tail exceeds 50% total ω sim
 - Less than 100 raw counts

Background Extraction and Check

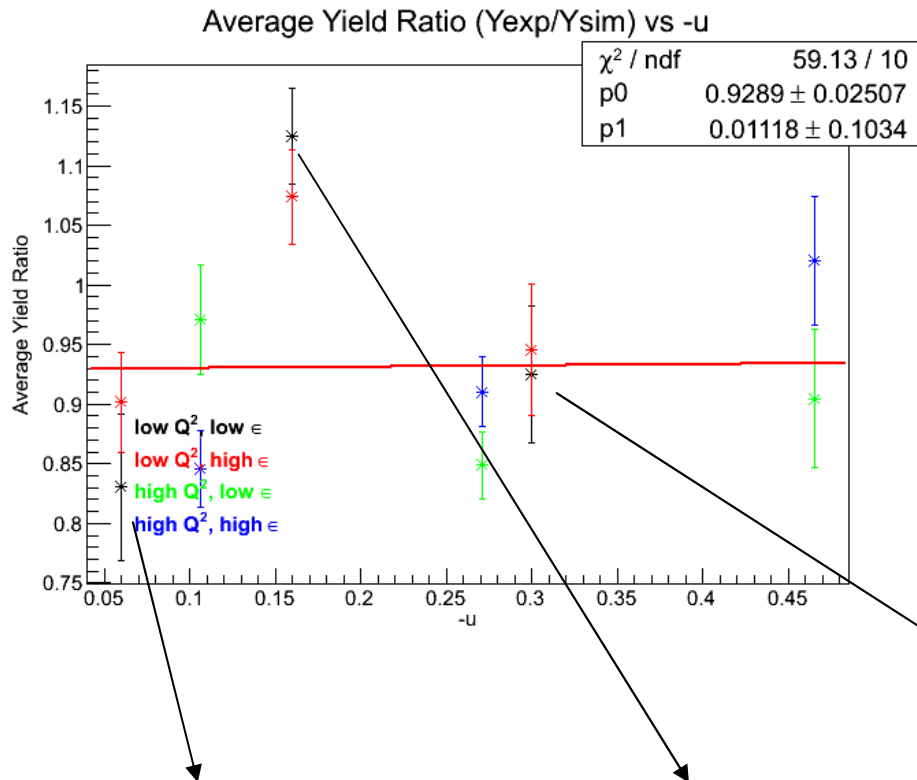
Garth Huber, huberg@uregina.ca



Reconstructed Missing Energy
Worse Example



Yield Ratio and Model Cross-Section



$$\sigma_T = \frac{t_0 + t_1 \cdot (-u)}{Q^2},$$

$$\sigma_L = \frac{l_0 + l_1 \cdot (-u)}{Q^4},$$

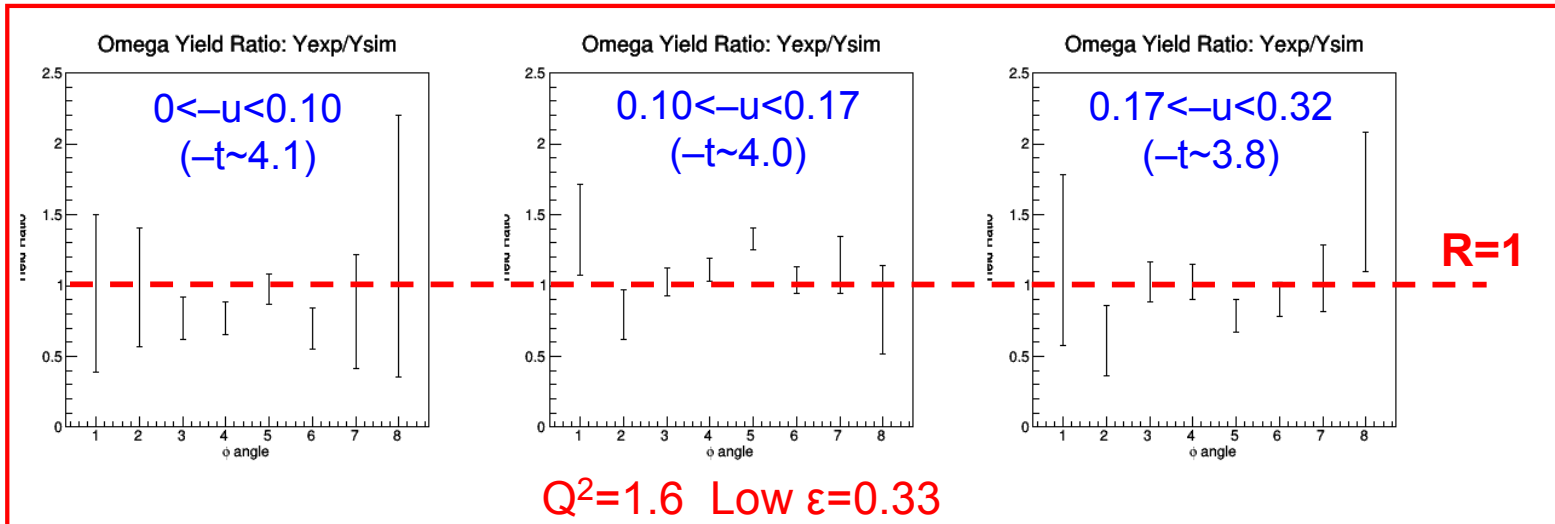
$$\sigma_{LT} = \left[\frac{lt_0 + lt_1 \cdot (-u)}{Q^2} \right] \cdot \sin \theta^*,$$

$$\sigma_{TT} = \left[\frac{tt_0 + tt_1 \cdot (-u)}{Q^2} \right] \cdot \sin^2 \theta^*,$$

$$2\pi \frac{d\sigma}{dt d\phi} = \frac{d\sigma_T}{dt} + \epsilon \frac{d\sigma_L}{dt} + \sqrt{2\epsilon(\epsilon+1)} \frac{d\sigma_{LT}}{dt} \cos \phi + \epsilon \frac{d\sigma_{TT}}{dt} \cos 2\phi$$

Model Cross Section

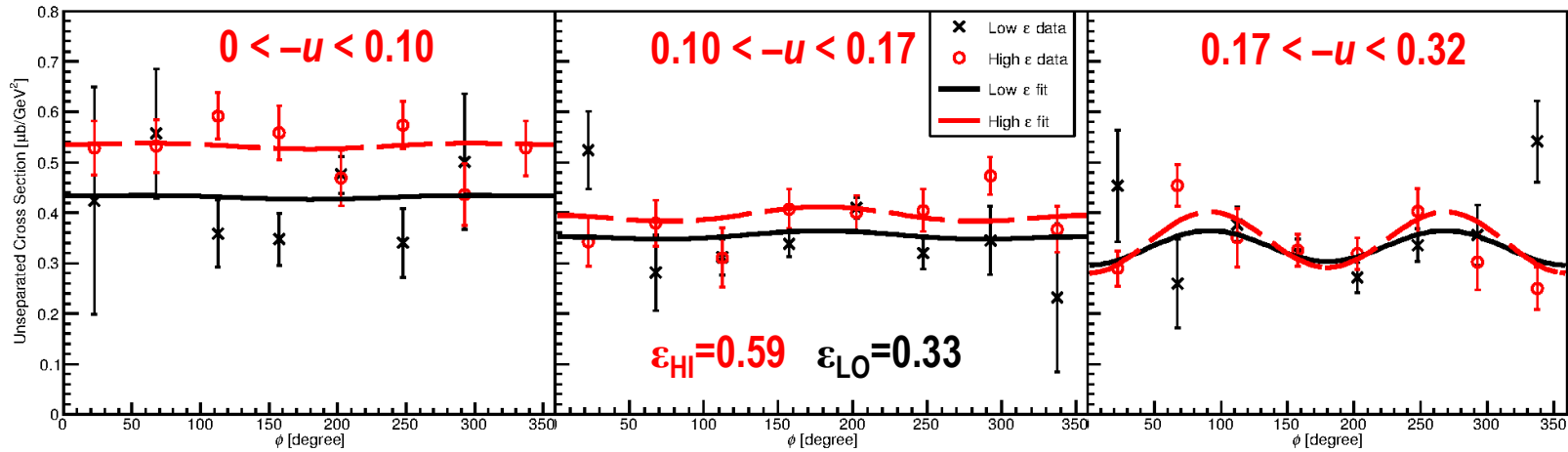
$$\frac{d^2\sigma}{dt d\phi}_{EXP} = R \frac{d^2\sigma}{dt d\phi}_{SIMC}$$



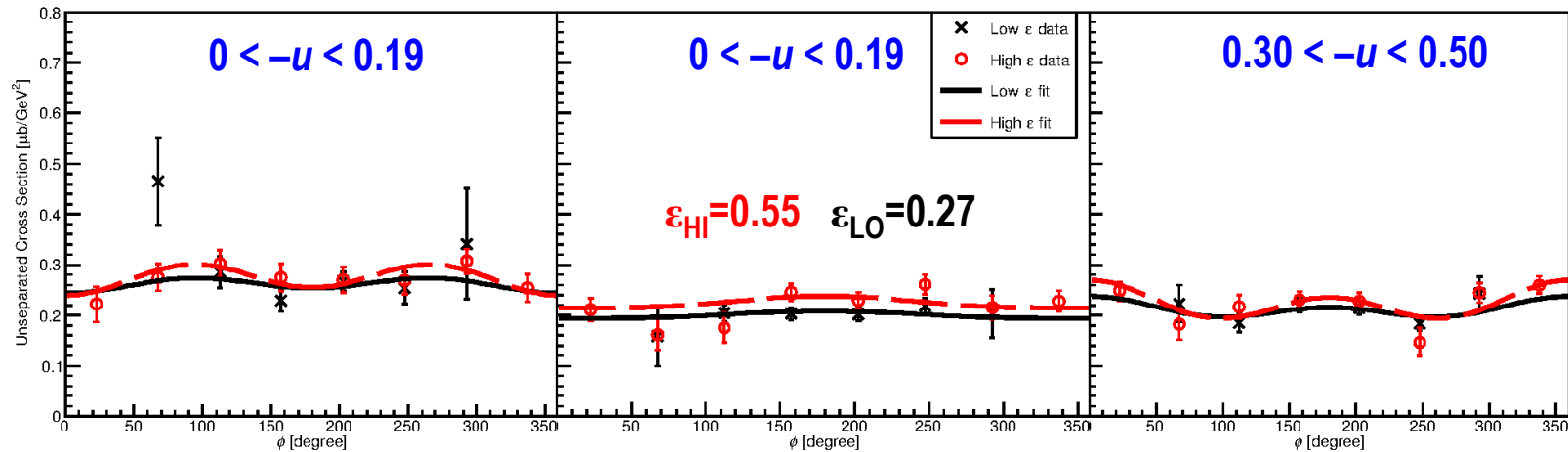
Unseparated Cross Sections

$$2\pi \frac{d^2\sigma}{dt d\phi} = \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_T}{dt} + \sqrt{2\varepsilon(\varepsilon+1)} \frac{d\sigma_{LT}}{dt} \cos\phi + \varepsilon \frac{d\sigma_{TT}}{dt} \cos 2\phi$$

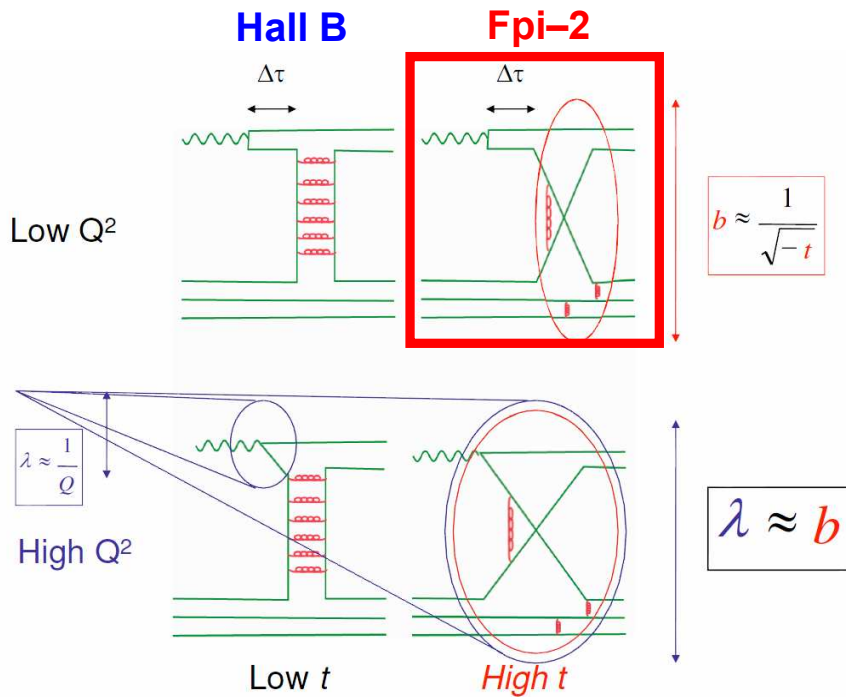
$Q^2 = 1.60 \text{ GeV}^2$



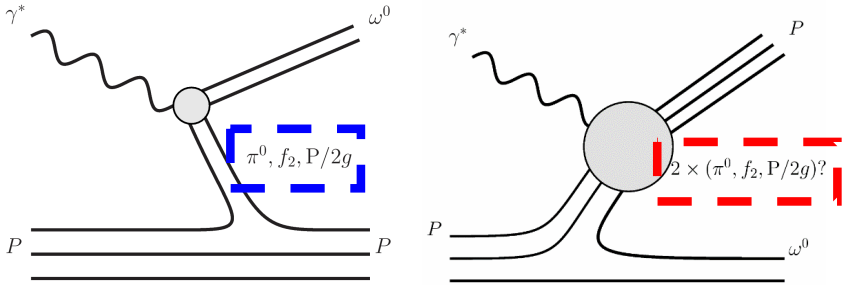
$Q^2 = 2.45 \text{ GeV}^2$



Regge Trajectory Model by J-M Laget



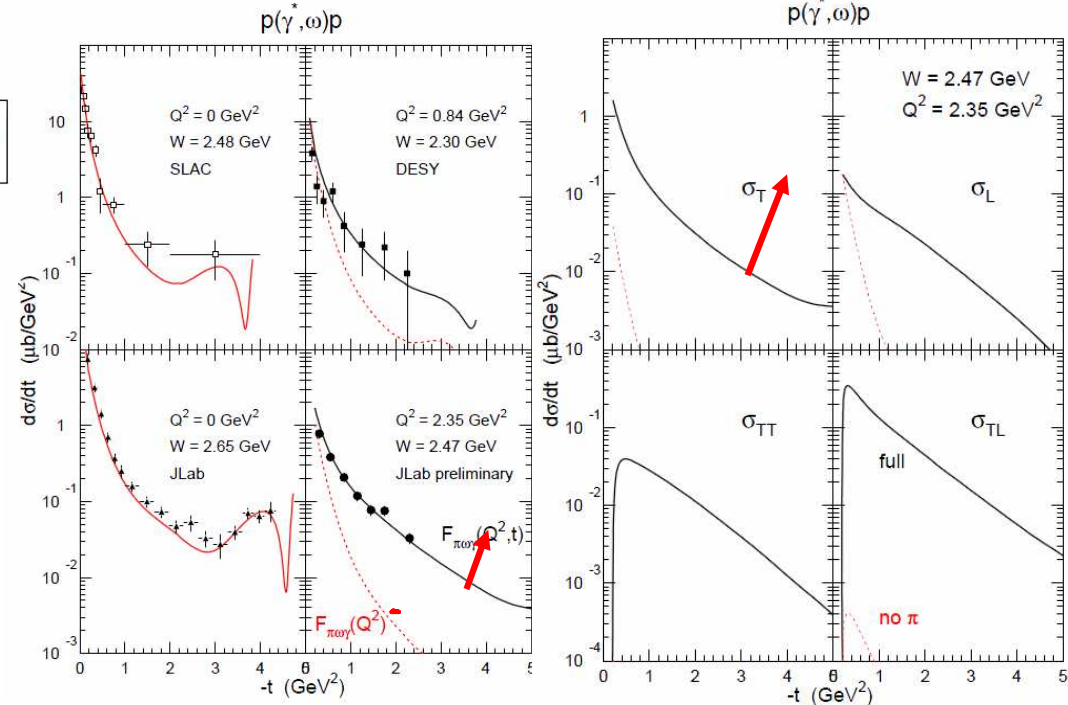
Hard Scattering Mechanism schematics



t-Channel Forward

u-Channel Backward

	W (GeV)	X	Q^2 (GeV ²)	$-t$ (GeV ²)	$-u$ (GeV ²)
Hall B	1.8–2.8	0.16–0.64	1.6–5.1	< 2.7	> 1.68
Fpi-2	2.21	0.29	1.6	4.014	0.08–0.13
		0.38	2.45	4.724	0.17–0.24



Fpi-2 kinematics: data suggest a u-channel contribution

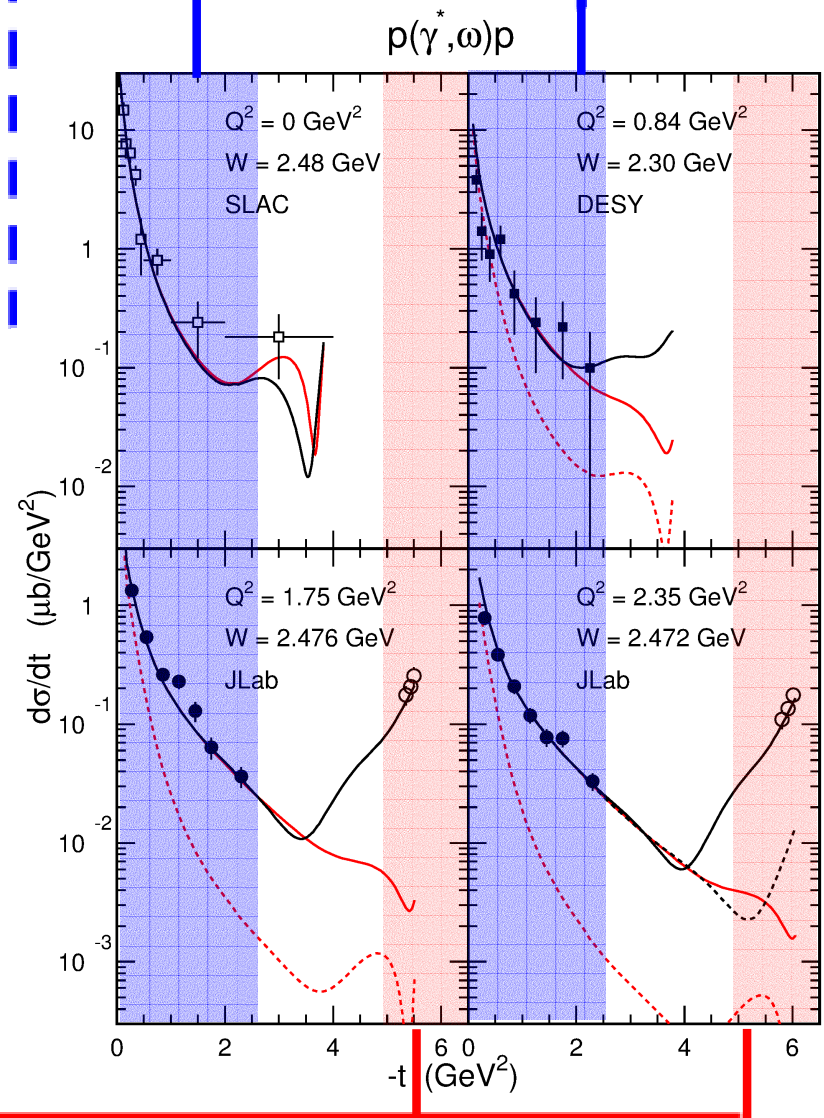
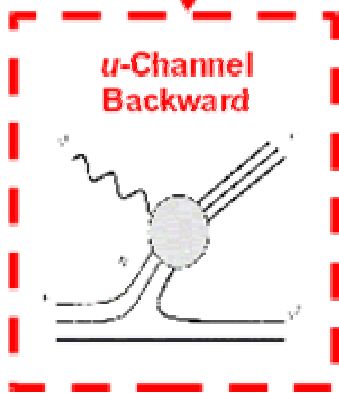
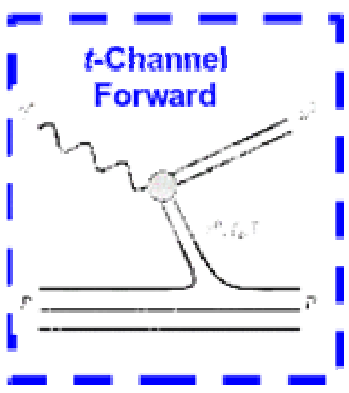
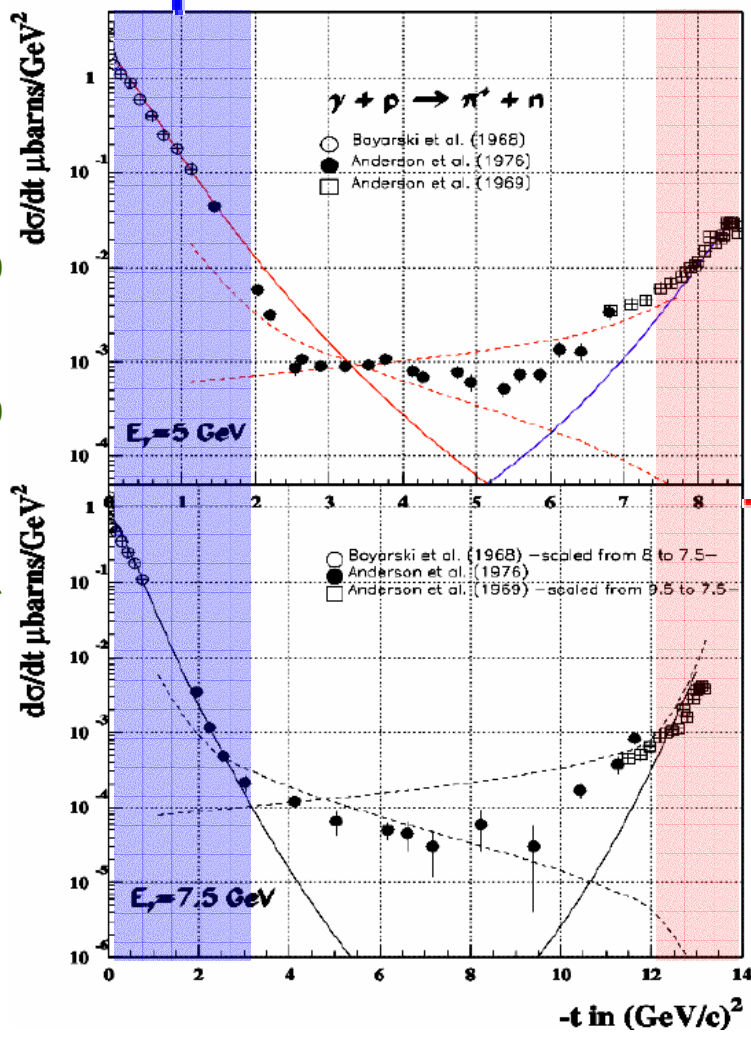
J. M. Laget,
Phys. Rev.
D 70, 2004

Hadronic Model: Regge Model by JM Laget

M. Guidal, J.-M. Laget, M. Vanderhaeghen, PLB 400(1997)6

J.-M. Laget, Private Communication (2018)

Garth Huber, huberg@uregina.ca



Soft structure → Hard → Soft transition!

1. Determine if the backward angle peak observed in exclusive ω electroproduction occurs also in other channels, over a broad kinematic range.
2. Measure the u -dependence of L/T-separated cross sections, to determine the relevance of Regge-rescattering and TDA mechanisms in JLab kinematics.
3. Assuming the backward angle peak is present, as expected, measure the σ_T/σ_L ratio over a wide Q^2 range for $W > 2$ GeV.
 - Where does $\sigma_T \gg \sigma_L$, as predicted by TDA formalism?
4. Determine the Q^2 -dependence of σ_T at fixed x_B .
 - Where does $\sigma_T \sim 1/Q^8$ as predicted by TDA formalism?

Questions to be addressed

- Halls B,C 6 GeV data hint at applicability of backward-angle factorization mechanism as early as $Q^2=2.5 \text{ GeV}^2$
- If this interpretation is correct, it can be confirmed by u -channel CT measurements such as $A(e,e'p)\pi^0$
- The observation of CT in $A(e,e'p)\pi^0$ by $Q^2=14 \text{ GeV}^2$, when it is absent in $A(e,e'p)$, would be a considerable achievement
- **Other Considerations:**
 - In the quasi-elastic process, the observed fast nucleon is part of the nuclear target. In the TDA picture, the fast proton comes from the partons of the original proton target.
 - It is not obvious that the fast proton from the u -channel interaction is the same as the original construct of the “original” valence quarks, thus would it really inherit all of the properties from the original proton?
 - Is the proton from the fast proton quasi-elastic process the same as the fast u -channel fast proton, and could this proton experience color transparency?