Studying Color Transparency through Backward π^0 Electroproduction off a Nuclear Target

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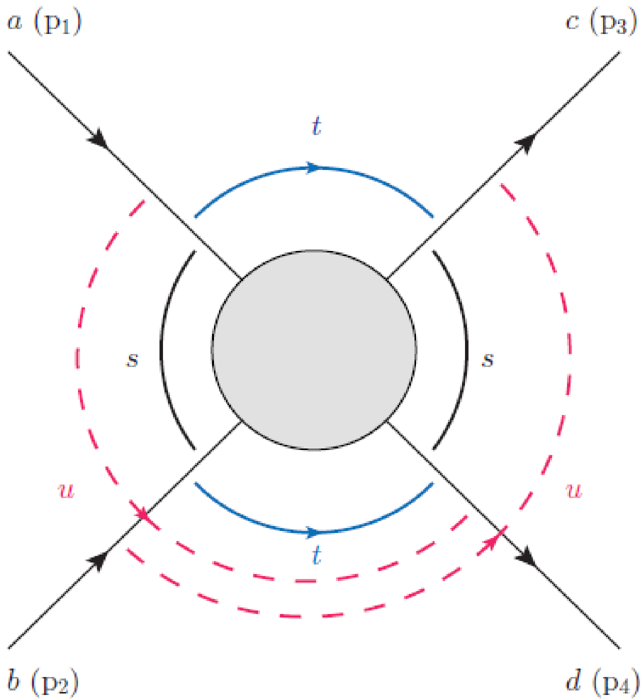
Mandelstam variables (*s*,*t*,*u*–channels)



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

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

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

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 ~ 0*, after interaction**

- **Target: stationary**
- **Meson: forward**
- **Measure of how forward could the meson go.**

***u*-channel: *–u~0*, after interaction**

- **Target: forward**
- **Meson: stationary**
- **Measure of how backward could the meson go**

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GPD–Like Model: TDA and Factorization

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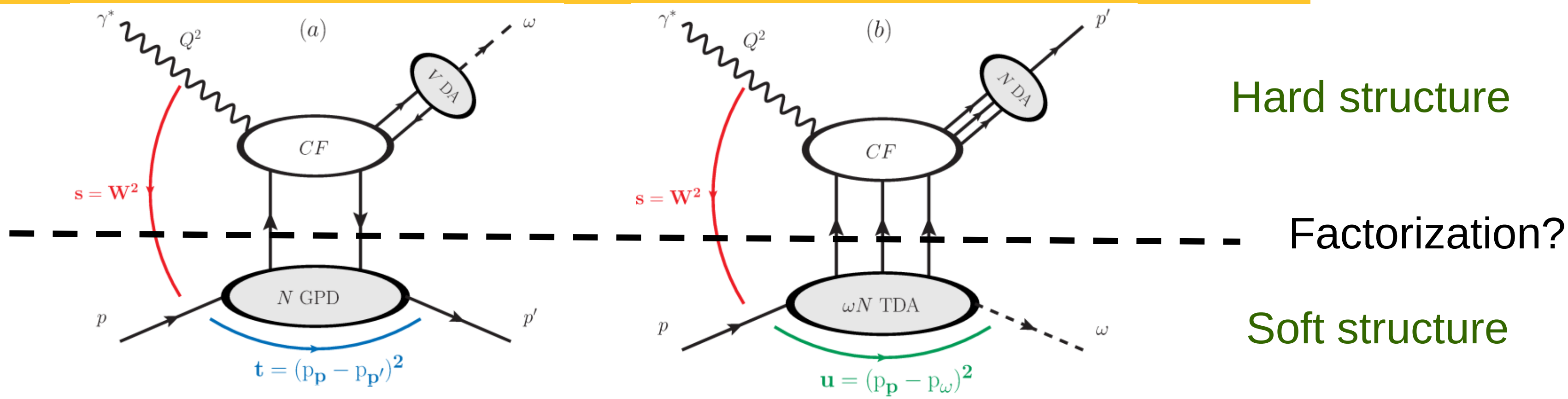

t–channel (Forward) *u*–channel (Backward)

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**

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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:

$$\xi_t = \frac{p_1^{\,+} - p_2^{\,+}}{p_1^{\,+} + p_2^{\,+}}$$ where $p_{1,2}$ refer to light cone + 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 $\Delta^u{}_T \approx (p_\pi - p_1)_T$

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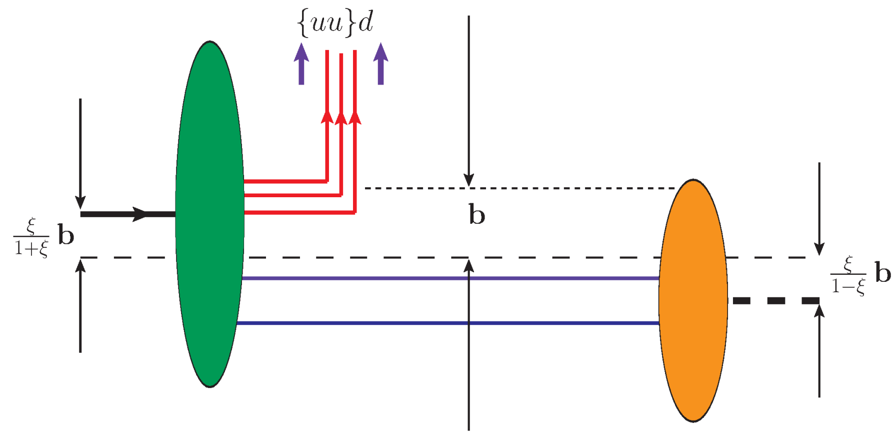
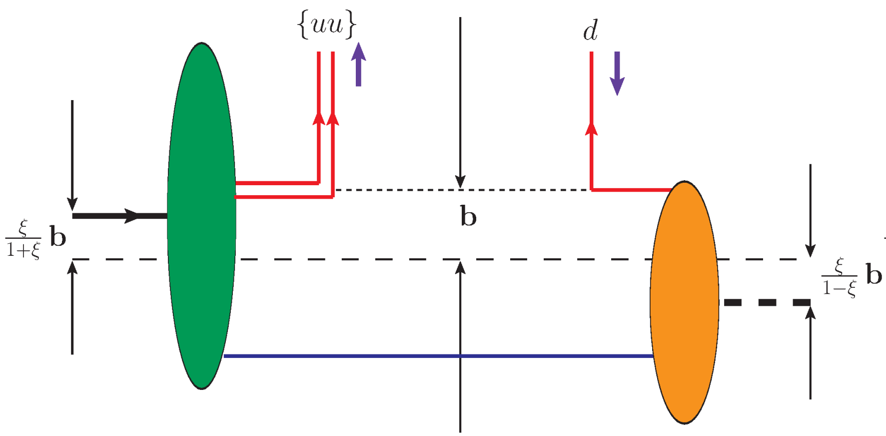
Impact parameter Interpretation of TDA

- 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



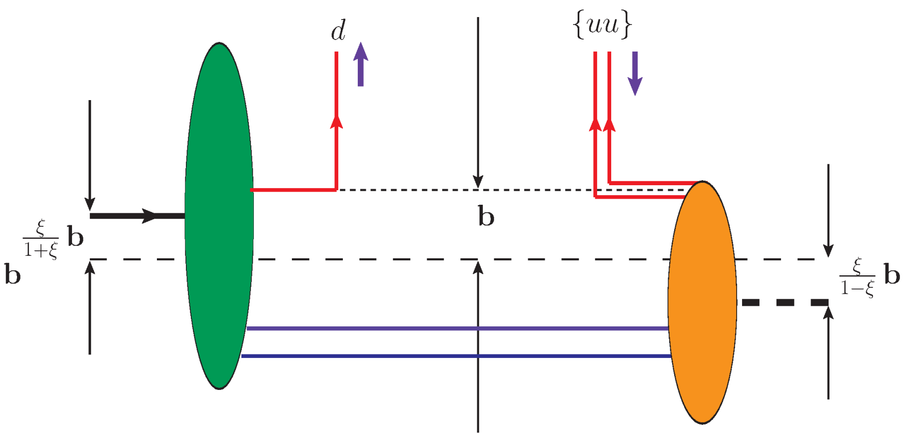
$\mathrm{ERBL}: \; x_3 = w_3 - \xi \geq 0; \quad x_1 + x_2 = \xi - w_3 \geq 0;$

$\longrightarrow$ All 3 quark momentum fractions x_i positive



$\mathrm{DGLAP\ I}: \; x_3 = w_3 - \xi \leq 0; \quad x_1 + x_2 = \xi - w_3 \geq 0;$

$\longrightarrow$ One x_i negative



$\mathrm{DGLAP\ II}: \; x_3 = w_3 - \xi \geq 0; \quad x_1 + x_2 = \xi - w_3 \leq 0;$

$\longrightarrow$ Two x_i negative

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Backward Angle Collinear Factorization

- **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 $2<Q^2<5$ 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

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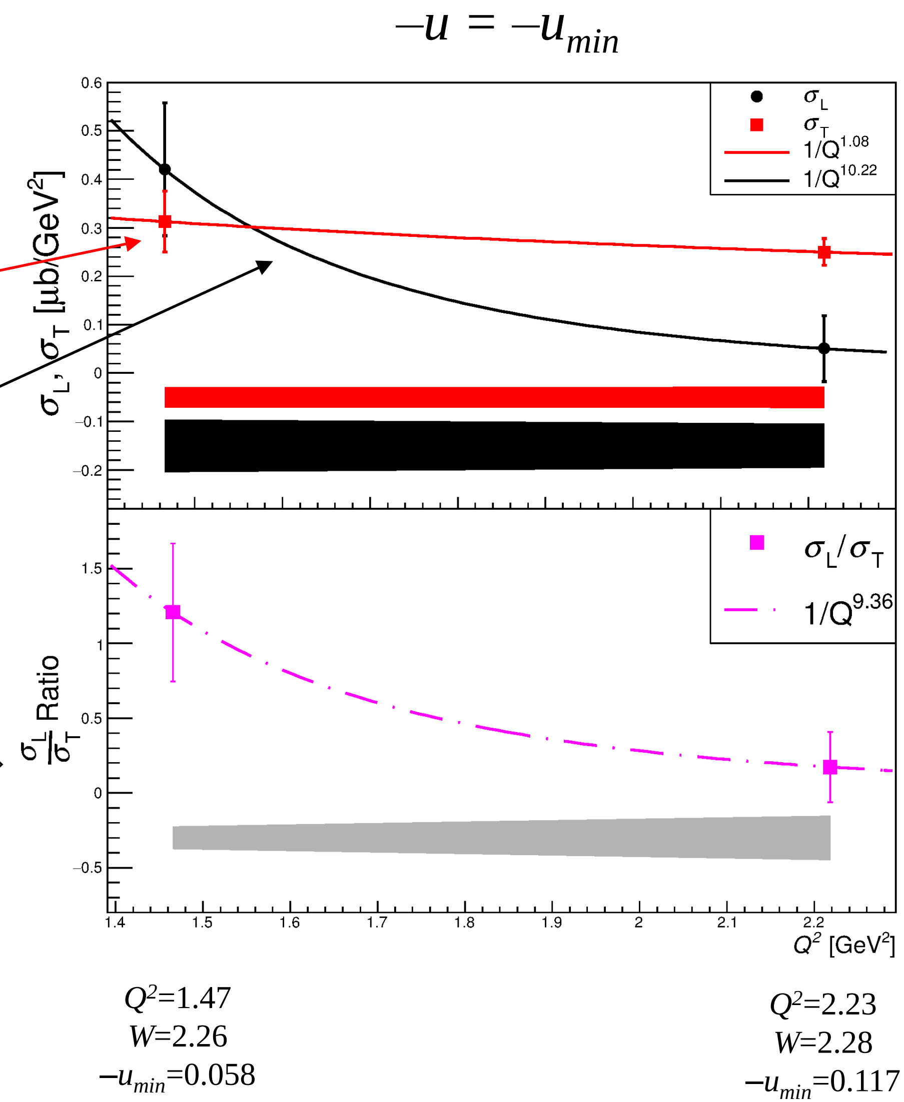
p(e,e'p)ω Q^2–Dependence from Hall C

- 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.



W. Li, et al. PRL **123** (2019) 182501

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TDA model Comparison to Data

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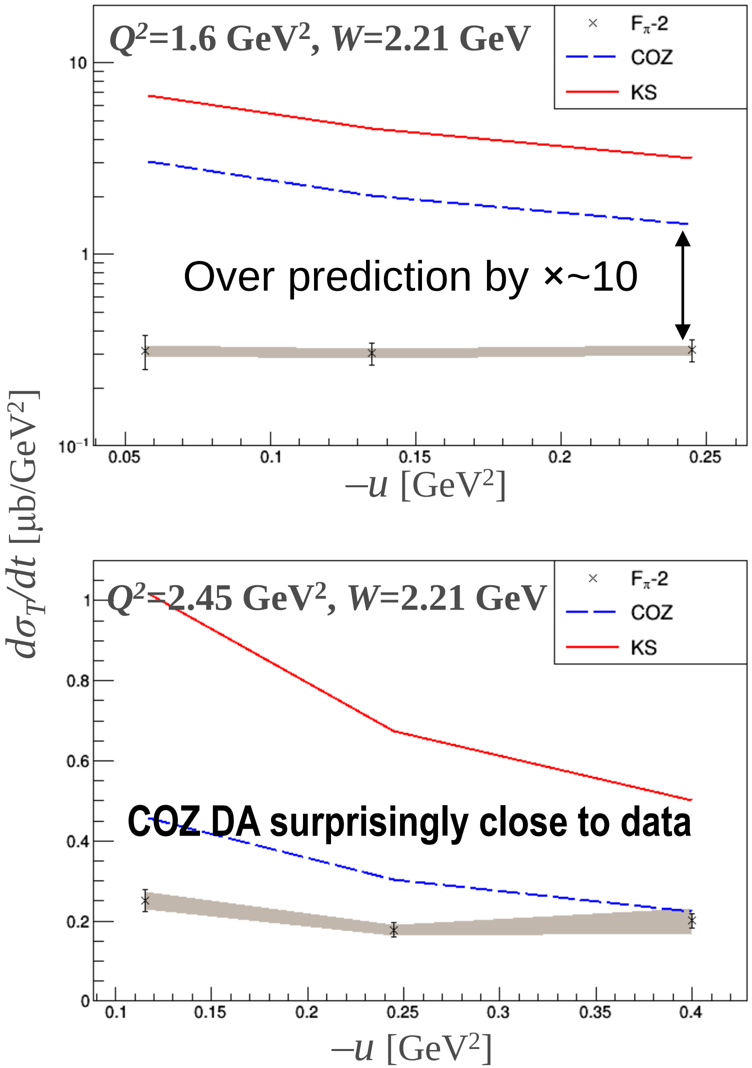
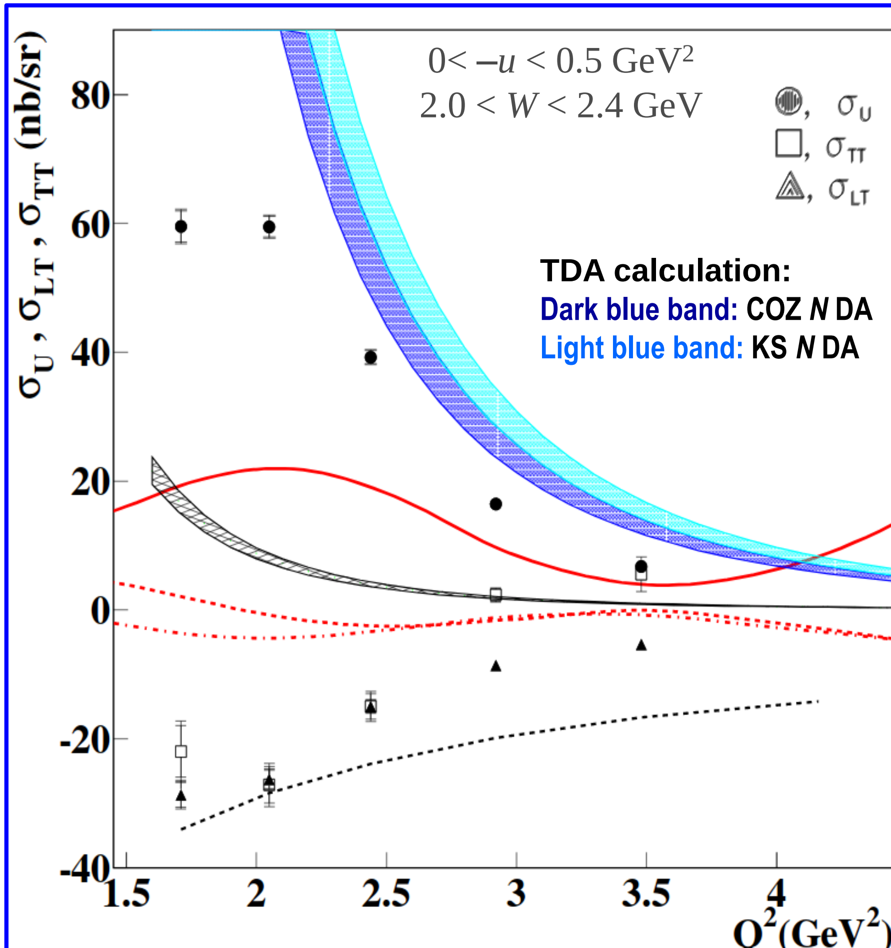


Hall C ω Electroproduction

W. Li, et al. PRL **123** (2019) 182501

Both data sets suggestive of early TDA scaling Q^2≈2.5 GeV^2 !?



Hall B π^+ Electroproduction

K. Park et al., PLB 7**80** (2017) 340

Extension to Higher Q^2

- **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)

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Hall C 12 GeV data already acquired

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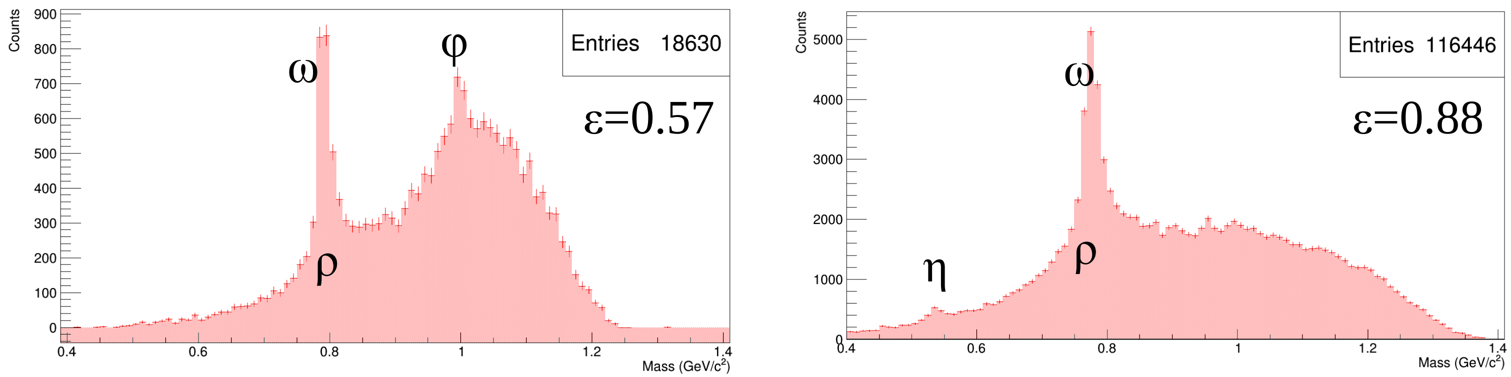
p(e,e'p)X Online Data Analysis

Q^2=3.00 W=2.32 θ_{pq}=+3.0° $-u$=0.15 ξ_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 *t*-channel L/T–separated *p(e,e'K⁺)Λ* 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	✓	✓

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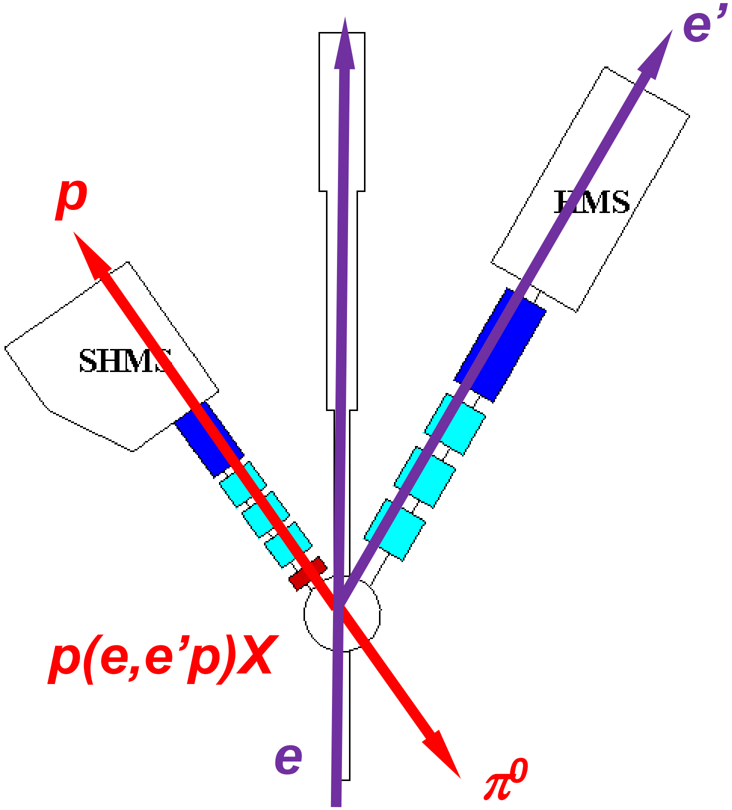
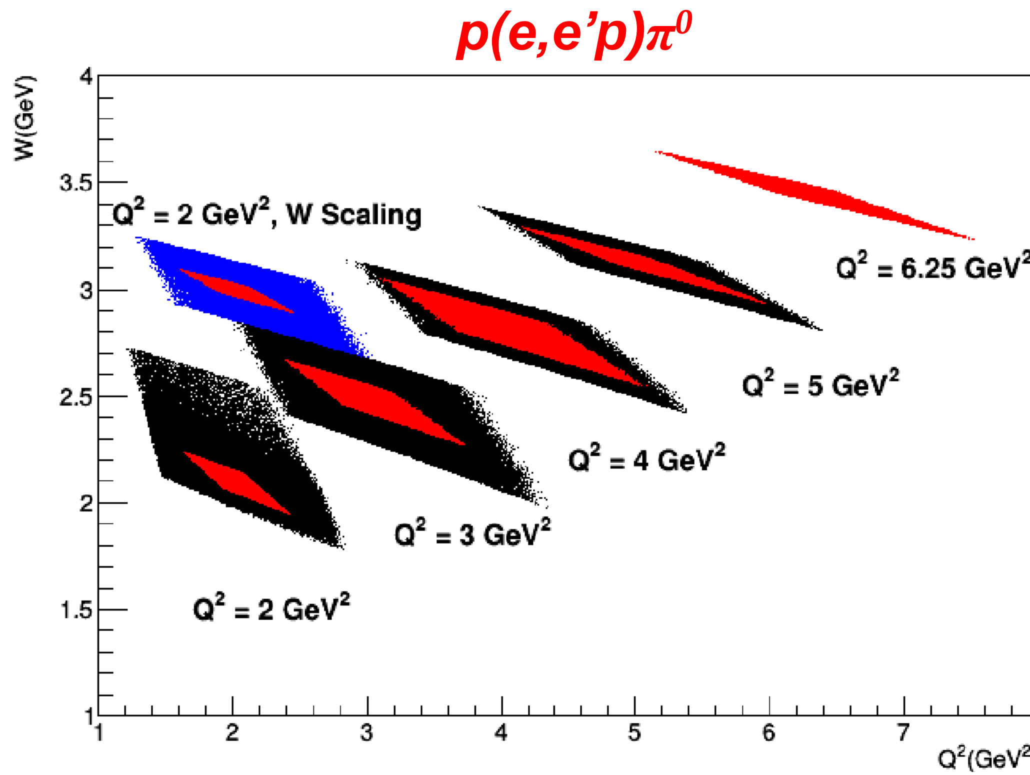
Backward Exclusive π^0 Production





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

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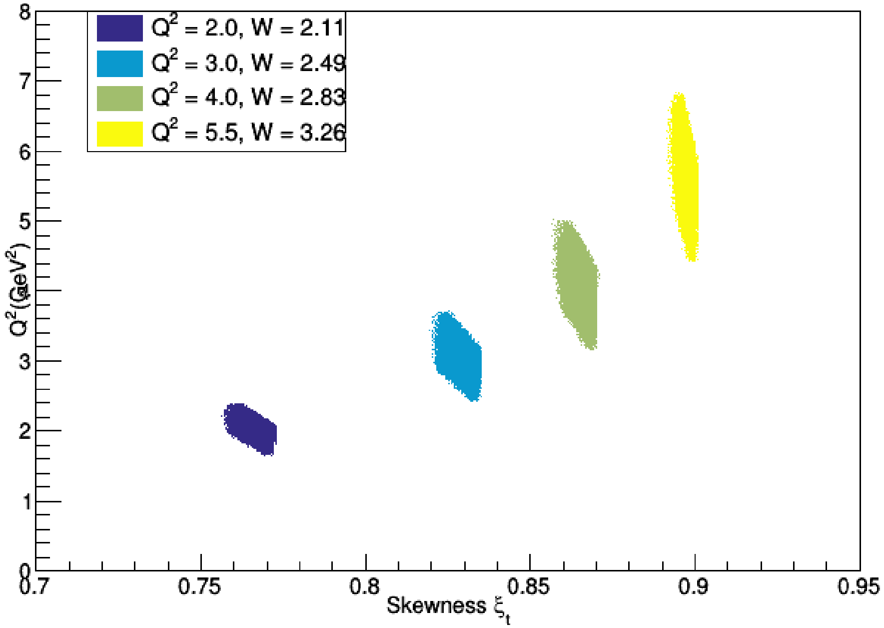
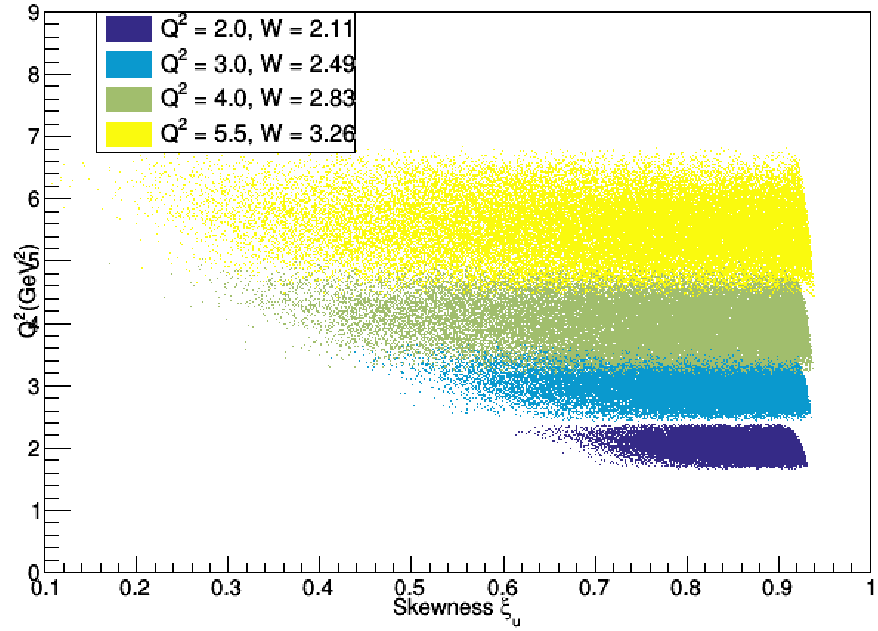
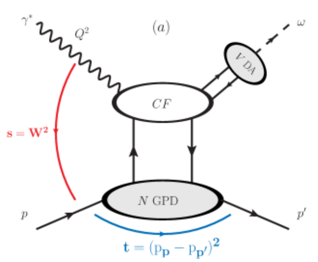
p(e,e'p)π^0 Skewness Range

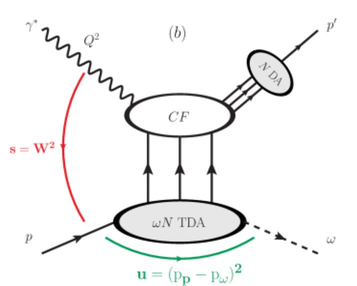






$$\xi_t = \frac{p_1^+ - p_2^+}{p_1^+ + p_2^+}$$ where $p_{1,2}$ refer to light cone + components

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



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

HMS and SHMS acceptance cuts, and diamond cuts applied

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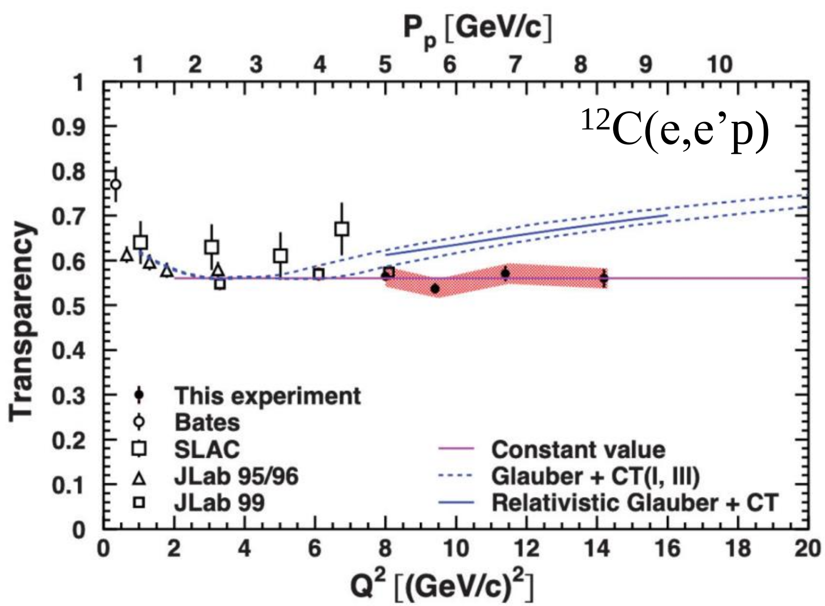
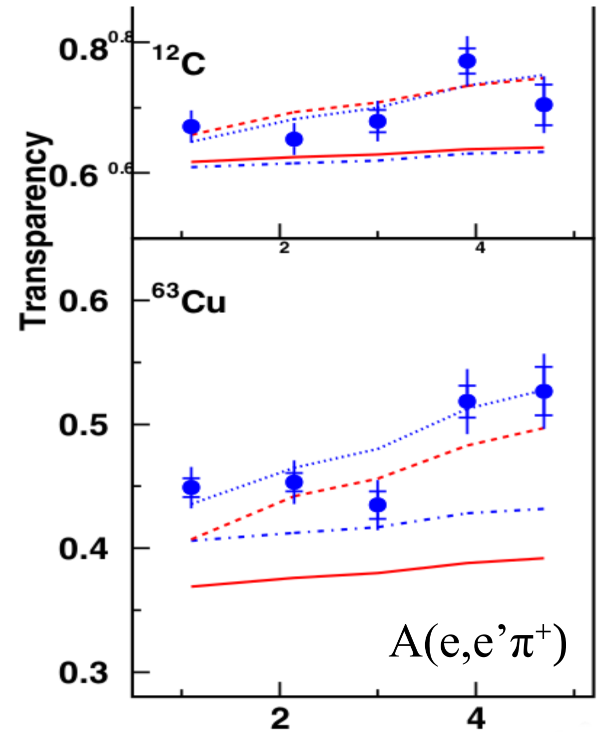
CT and Backward-angle Factorization

- CT has recently been shown to not apply in C(e,e'p) up to Q^2=14 GeV^2, in contrast to CT applying already in A(e,e'π^+) at Q^2≈5 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**

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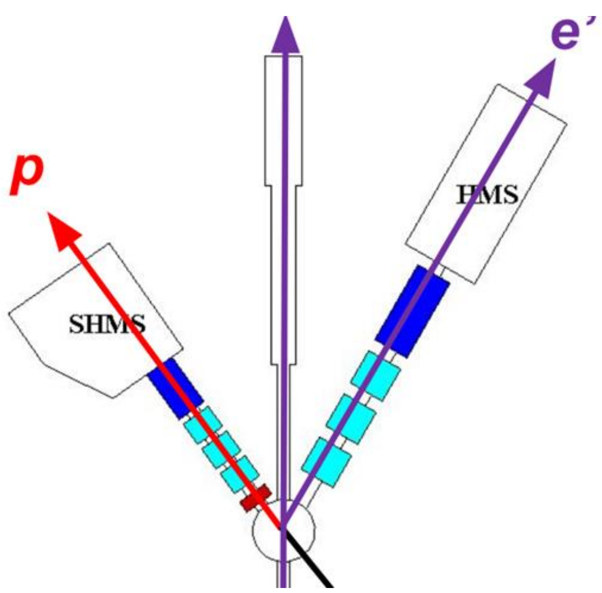
Backward-angle $A(e,e'p)\pi^0$

- 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_{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
14	1.5 @ 56.7°	9.9-9.5 @ 7°-9°	0.1-0.5 @ 187°-50°	-16.8 to -16.2	+0.6 to -0.1

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Theoretical considerations

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- Halls B,C 6 GeV data hint at applicability of backward-angle factorization mechanism as early as Q^2=2.5 GeV^2
- If this interpretation is correct, it can be confirmed by *u*-channel CT measurements such as A(e,e'p)π^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 $120<m_{missing}<500$ MeV. It is important to detect the high-momentum forward-going nucleon.
- More work would clearly be needed for model calculations of CT ratios for this new type of experiment. It gives rise to the intriguing idea of *"Half Color Transparency"* .[Bernard Pire]

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Summary

- **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

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TDA Formalism (e.g. u–channel π^0)

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- Fourier transform of the πN transition matrix element

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

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

Factorization scale

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

$$H^{\pi N}_{s.f.} = \{V^{\pi N}_{1,2}, A^{\pi N}_{1,2}, T^{\pi N}_{1,2,3,4}\}$$

- Factorizing out the u–dependence:

meson to nucleon transition form factor

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

J.P. Lansberg, B. Pire, K. Semenov–Tian–Shansky, L. Szymanowski, Phys. Rev. D **85** (2011) 054201

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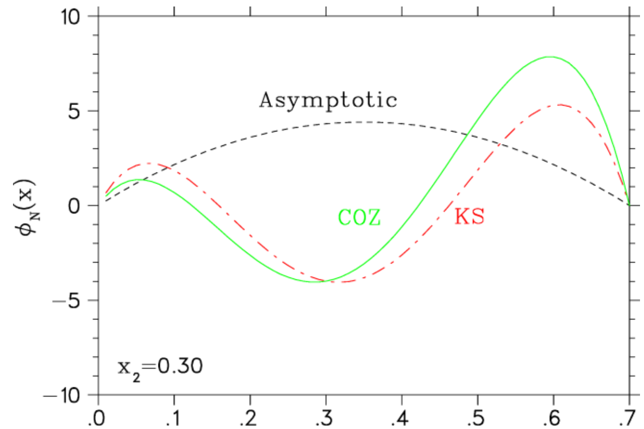
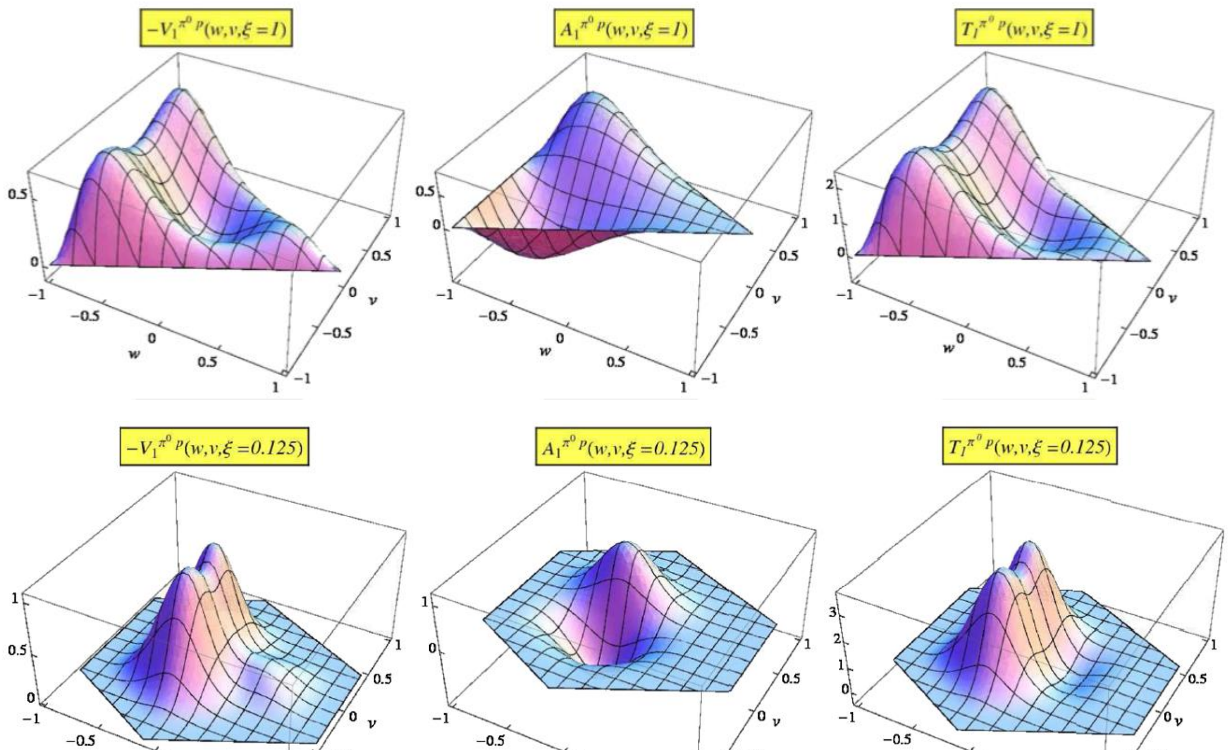
$\pi^0 p$ TDAs as functions of q–diquark coordinates

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





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

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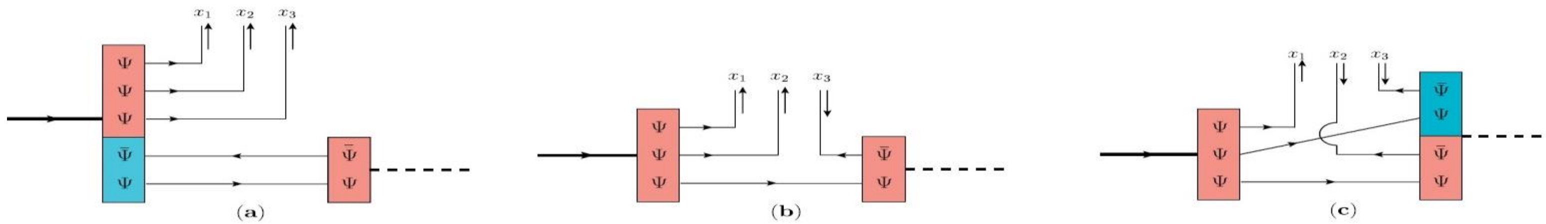
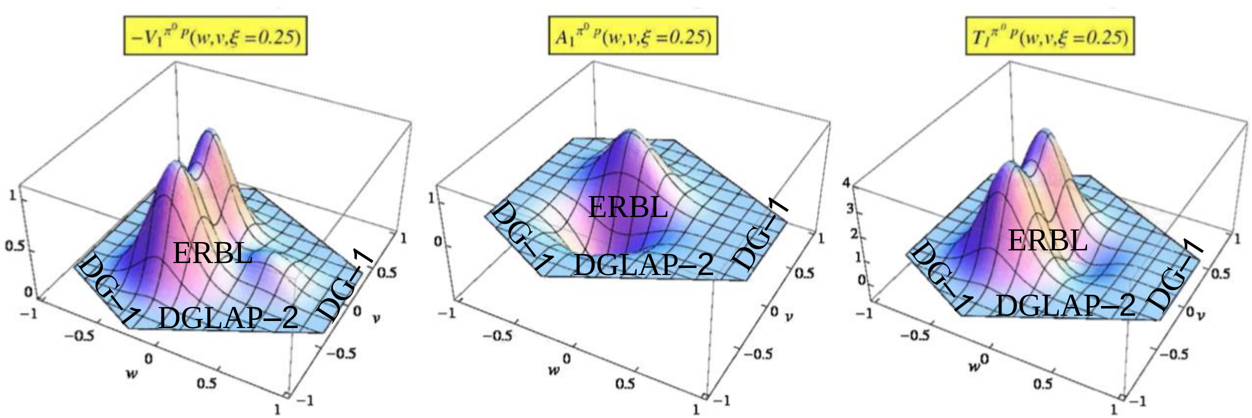
Main reactions of interest to date:

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



Interpretation of πN TDAs in light–cone quark model

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



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

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

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

J.P. Lansberg et al., PRD **85** (2012) 054201

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TDAs Formalism – 1

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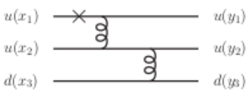
α		T_α	T'_α
1		$\frac{-Q_u(2\xi)^2[(V_1^{p\pi^0}-A_1^{p\pi^0})(V^p-A^p)+4T_1^{p\pi^0}T^p+2\frac{\Delta_T^2}{M^2}T_4^{p\pi^0}T^p]}{(2\xi-x_1-i\epsilon)^2(x_3-i\epsilon)(1-y_1)^2y_3}$	$\frac{-Q_u(2\xi)^2[(V_2^{p\pi^0}-A_2^{p\pi^0})(V^p-A^p)+2(T_2^{p\pi^0}+T_3^{p\pi^0})T^p]}{(2\xi-x_1-i\epsilon)^2(x_3-i\epsilon)(1-y_1)^2y_3}$

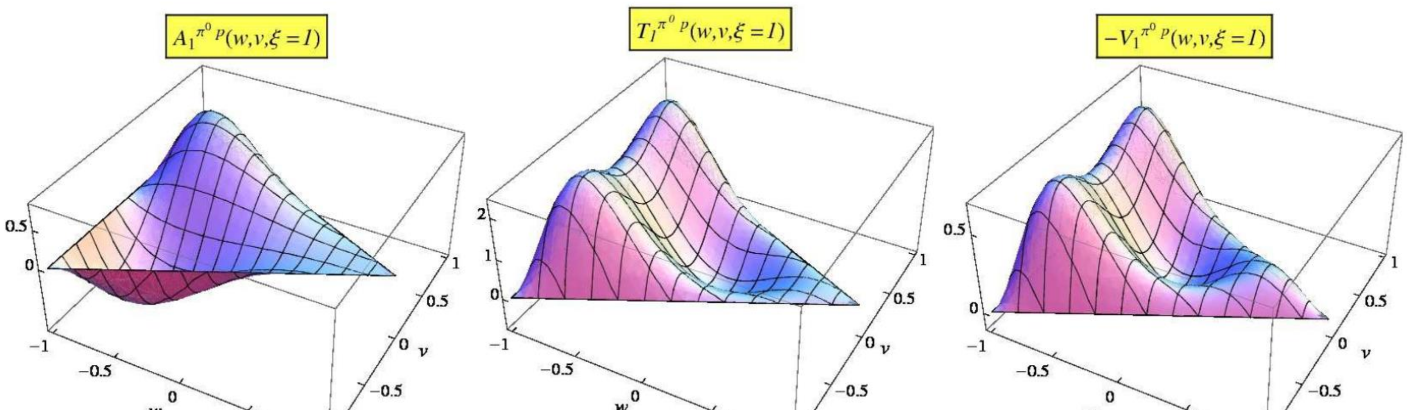
First three TDAs ←

$$V_1^{\pi^0 p}(x_1,x_2,x_3,\xi_u=1)=-\frac{1}{2}\times\frac{1}{4}V^P\left(\frac{x_1}{2},\frac{x_2}{2},\frac{x_3}{2}\right)$$

$$A_1^{\pi^0 p}(x_1,x_2,x_3,\xi_u=1)=-\frac{1}{2}\times\frac{1}{4}A^P\left(\frac{x_1}{2},\frac{x_2}{2},\frac{x_3}{2}\right)$$

$$T_1^{\pi^0 p}(x_1,x_2,x_3,\xi_u=1)=\frac{3}{2}\times\frac{1}{4}T^P\left(\frac{x_1}{2},\frac{x_2}{2},\frac{x_3}{2}\right)$$

Input PDF from Nucleon DA model:
- COZ (Chernak, Ogloblin, Zhitnitsky, 1989)
- KS (King and Schrajda, 1987)



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

computed as functions of quark-diquark coordinates

J.P. Lansberg et al., PRD **85** (2012) 054201

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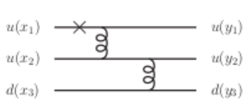
TDA Meson Production Cross Section

- Unpolarized exclusive π^0 production cross section:

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

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

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

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

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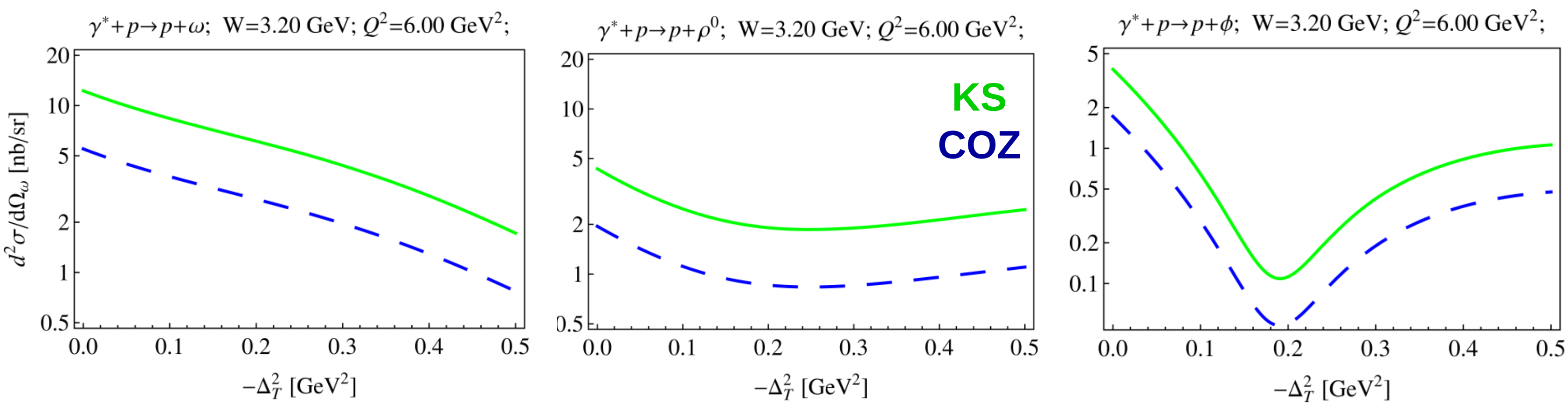
TDA Model Predictions for JLab E12–19–006

Fπ–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 σ_T » σ_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 $-u$.

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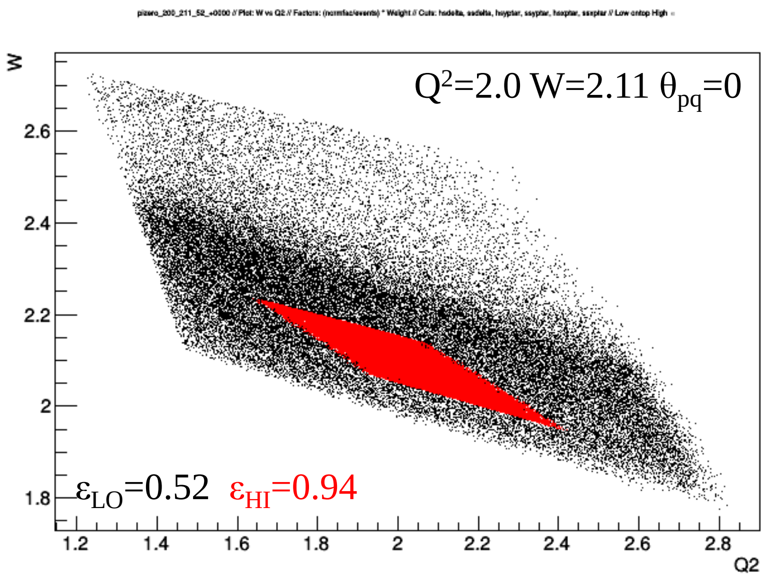
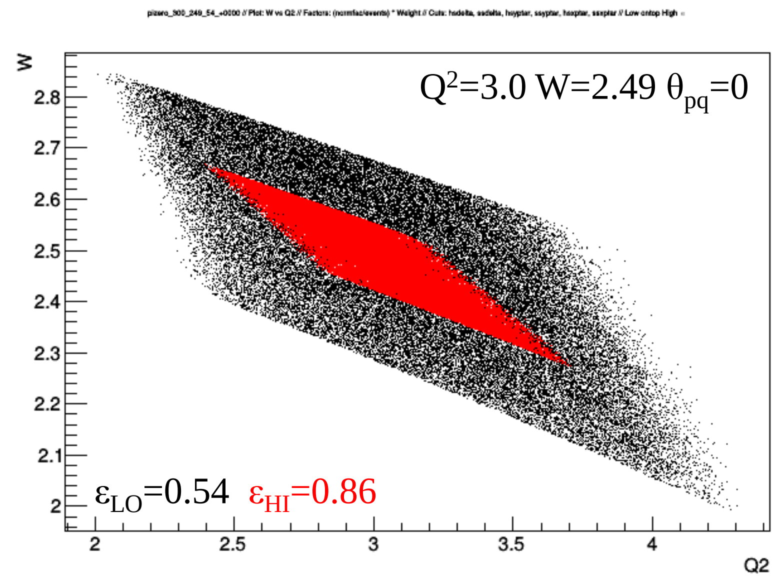
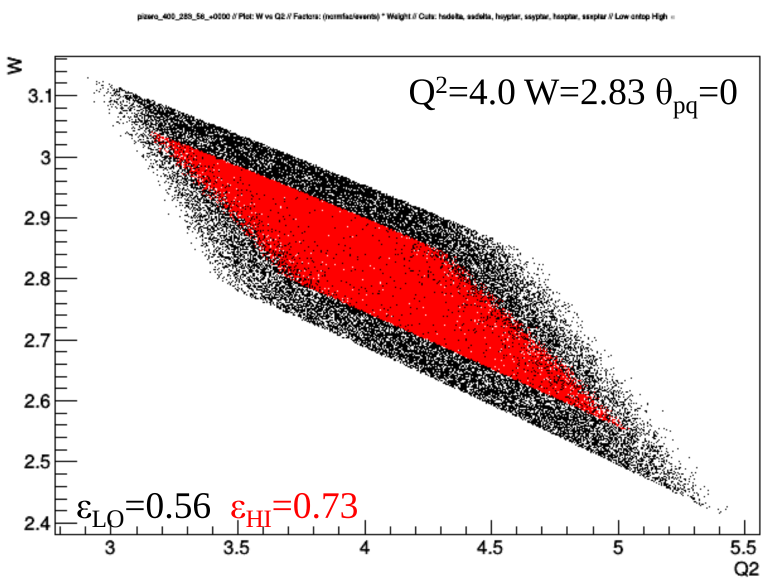
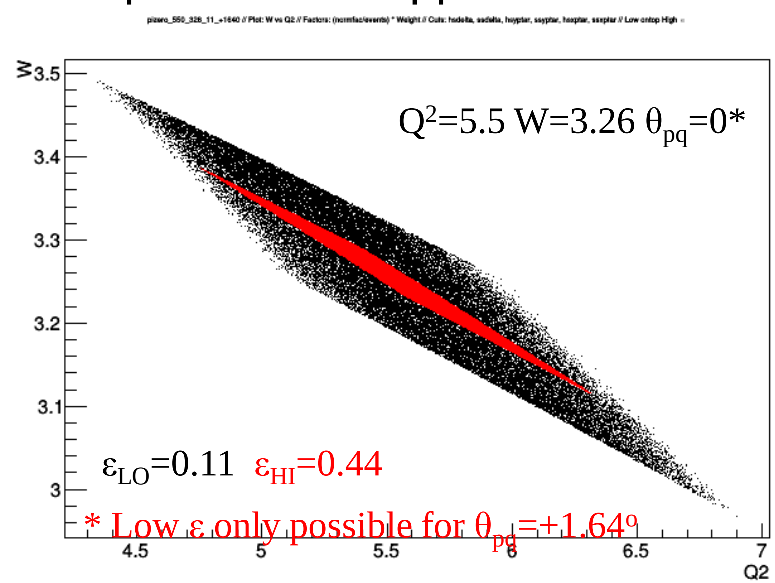
SIMC: Q^2–W overlap at high, low ε





p(e,e'p)π⁰: HMS and SHMS acceptance cuts applied





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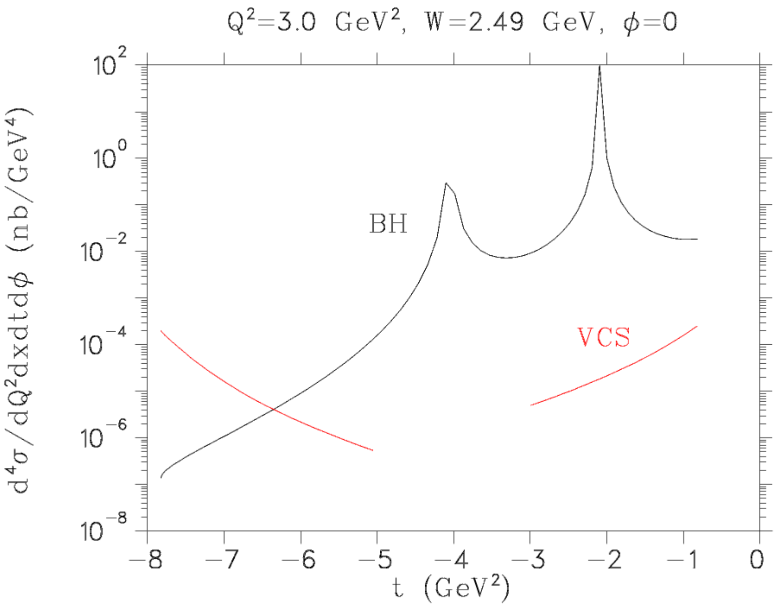
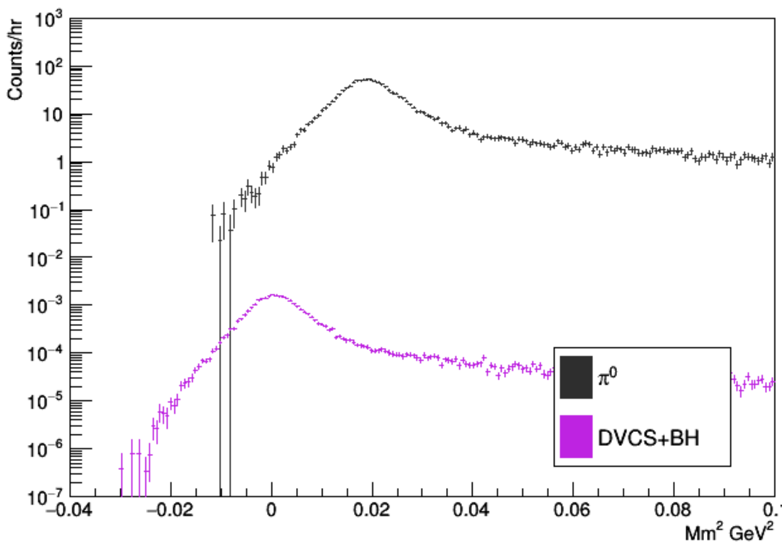
π^0 Channel Expected to be Clean

- 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.

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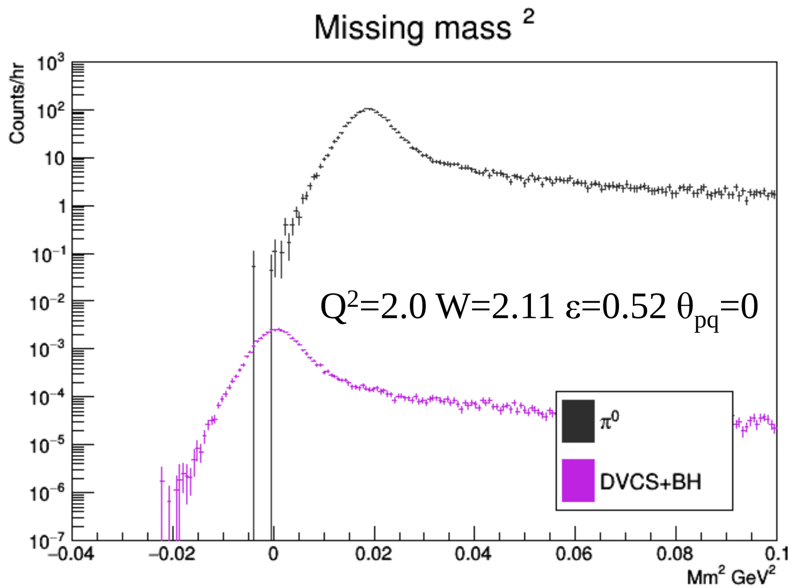
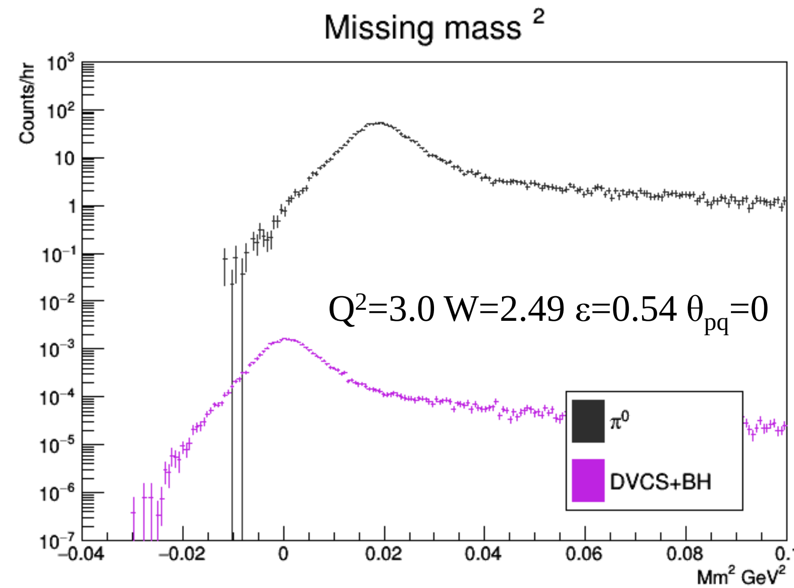
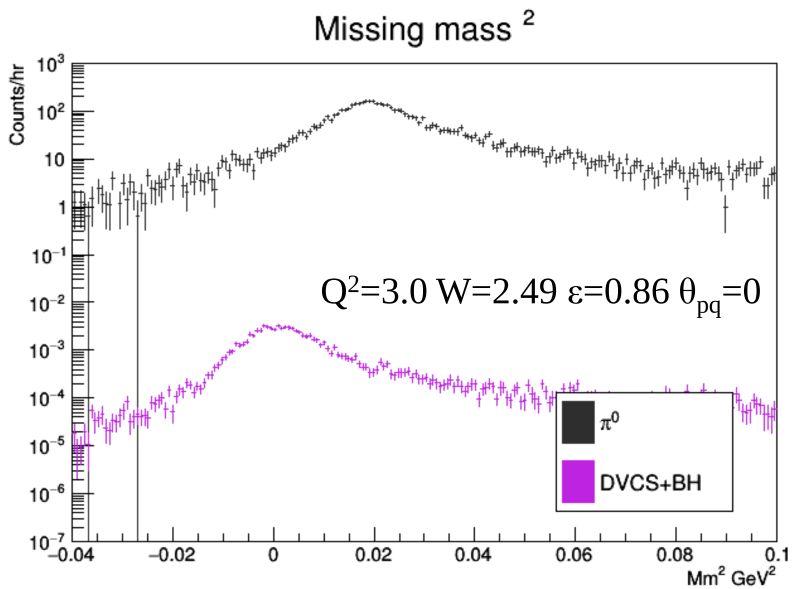
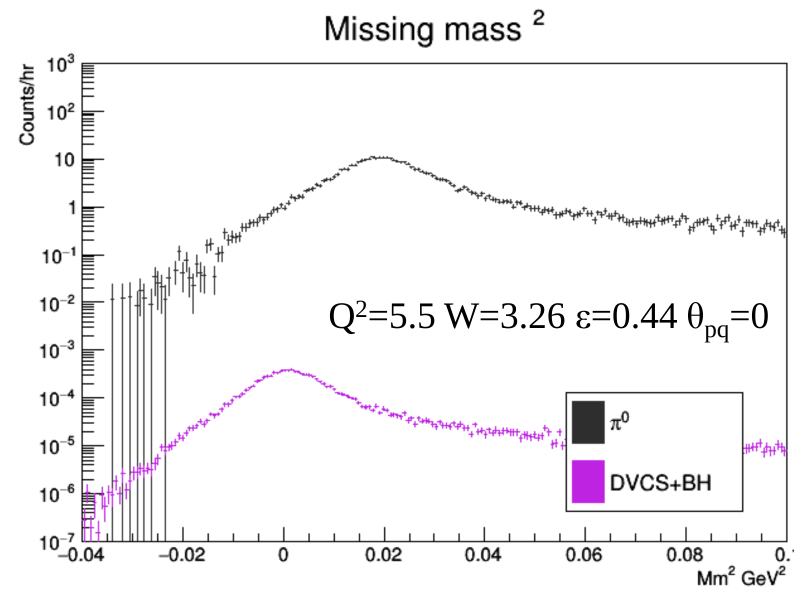
SIMC: Missing Mass squared





HMS and SHMS acceptance cuts, and diamond cuts applied





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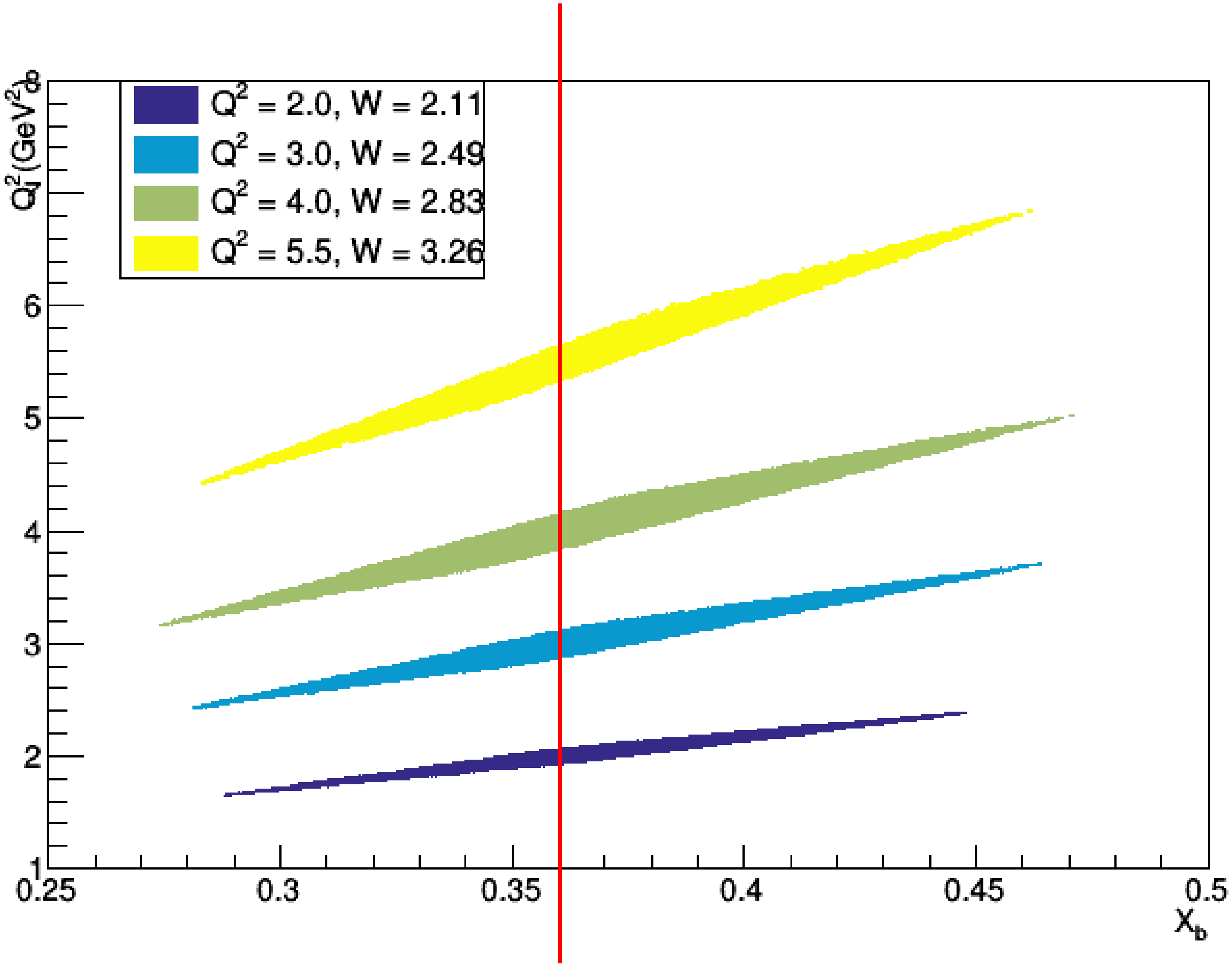
Central Kinematics are $x_{Bjorken}$=0.36



HMS and SHMS acceptance cuts, and diamond cuts applied

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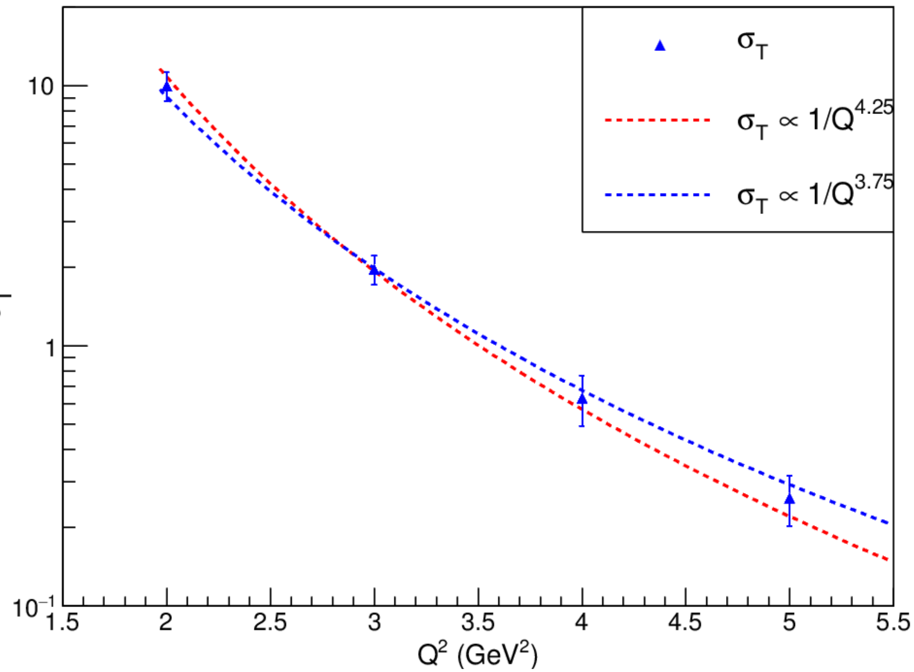
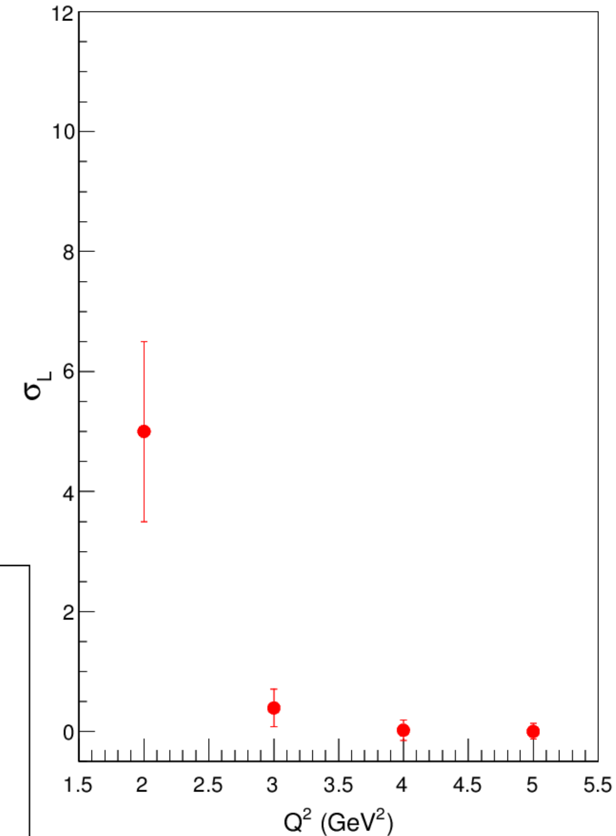
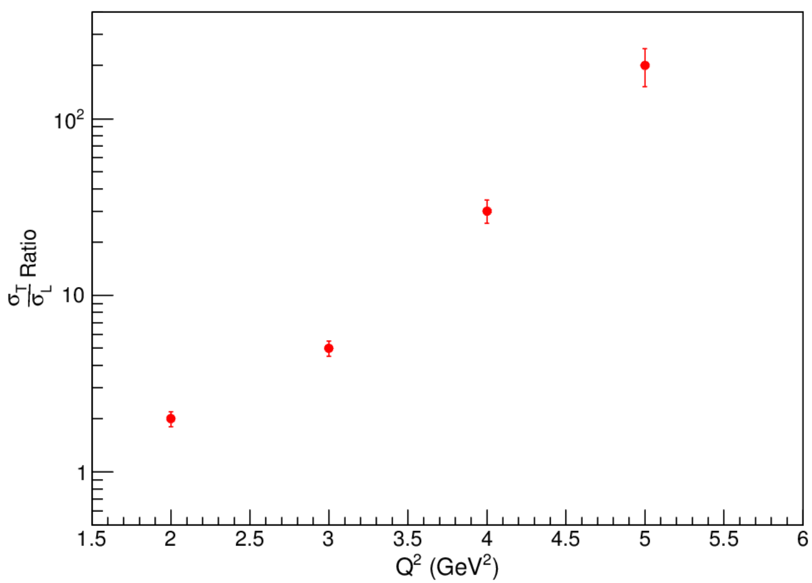
p(e,e'p)π^0 Q^2-dependence projections







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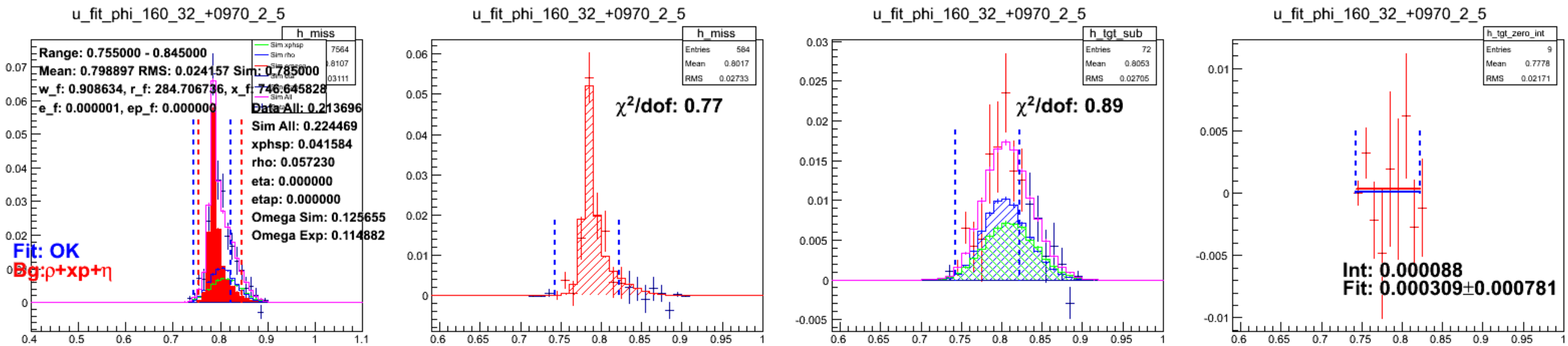
Missing Mass Background Removal



Omega

Background Sum

Zero=Data–ω–Bkd

Data (blue)

Xspace Sim (green)

ρ Sim (cyan)

ω Sim (red)

η or η' (black)

Sim Sum (pink)

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

- **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 that 100 raw counts**

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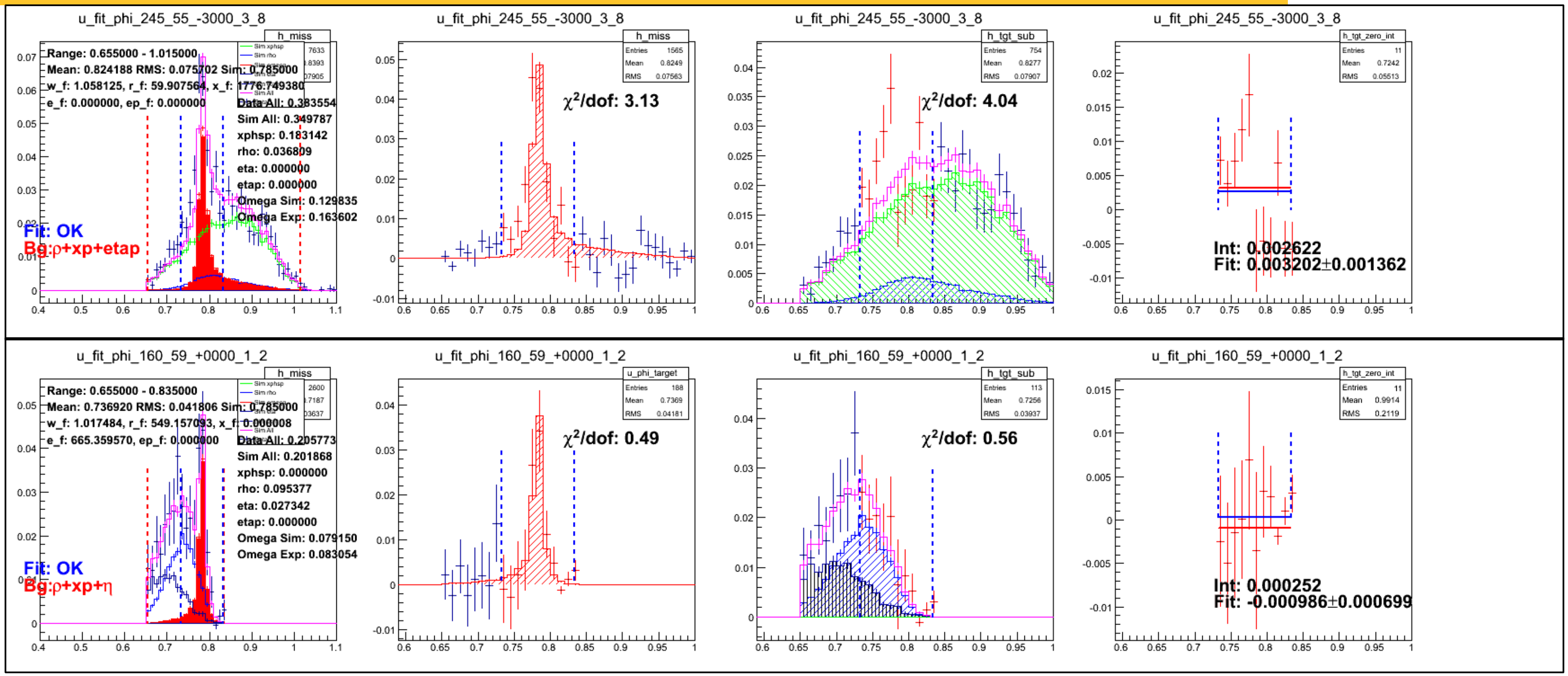
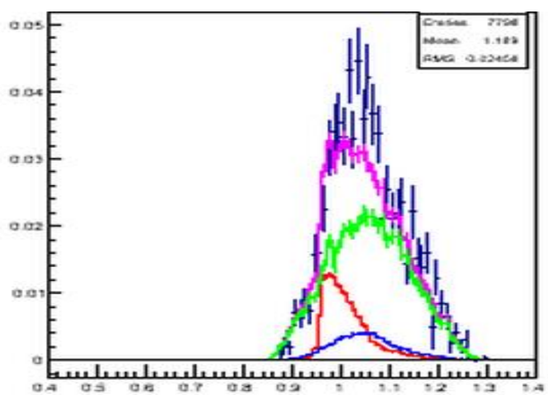
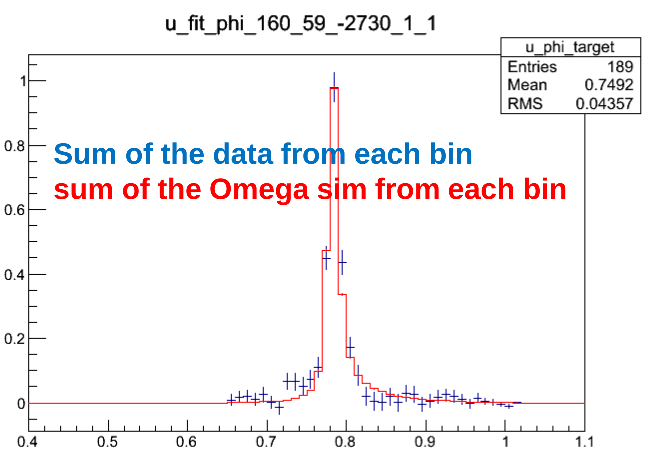
Background Extraction and Check







Reconstructed Missing Energy

Worse Example

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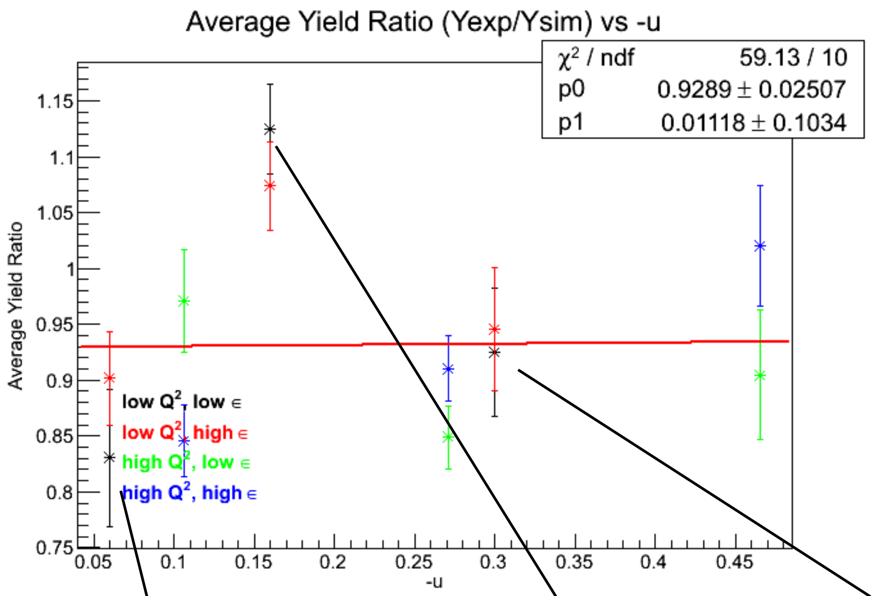
Yield Ratio and Model Cross–Section



$$\sigma_{\mathrm{T}} = \frac{t_0 + t_1 \cdot (-u)}{Q},$$

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

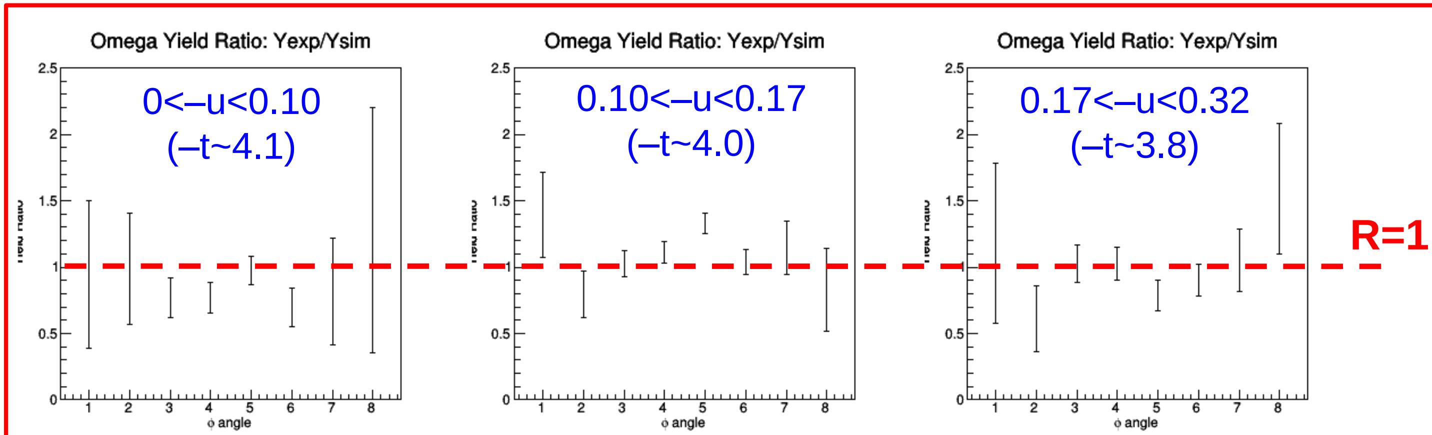
$$\sigma_{\mathrm{LT}} = \left[\frac{lt_0 + lt_1 \cdot (-u)}{Q^2}\right] \cdot \sin\theta^*,$$

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

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

Model Cross Section

$$\left.\frac{d^2\sigma}{dt\,d\varphi}\right|_{EXP} = R \left.\frac{d^2\sigma}{dt\,d\varphi}\right|_{SIMC}$$



Q^2=1.6 Low ε=0.33

Exp/Sim Yield Ratio

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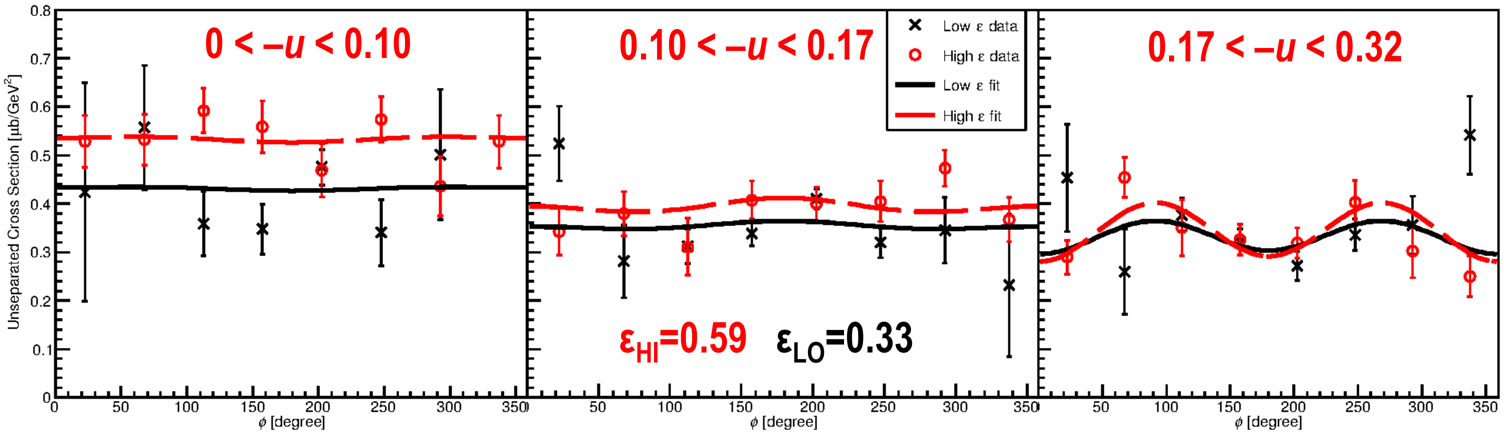
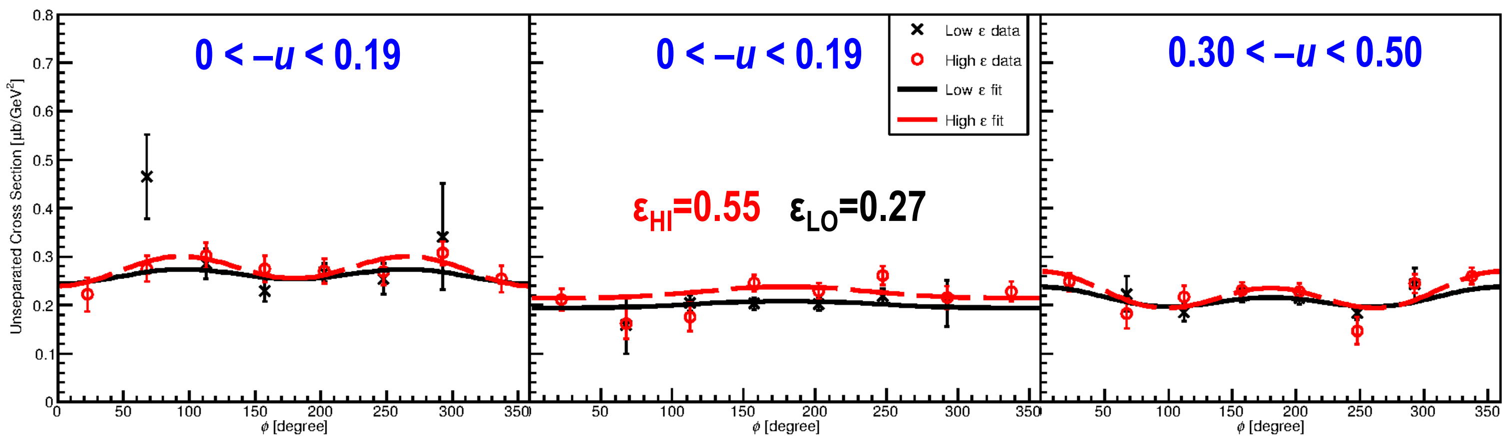
Unseparated Cross Sections

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

Q^2=1.60 GeV^2



Q^2=2.45 GeV^2



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Regge Trajectory Model by J–M Laget

University of Regina

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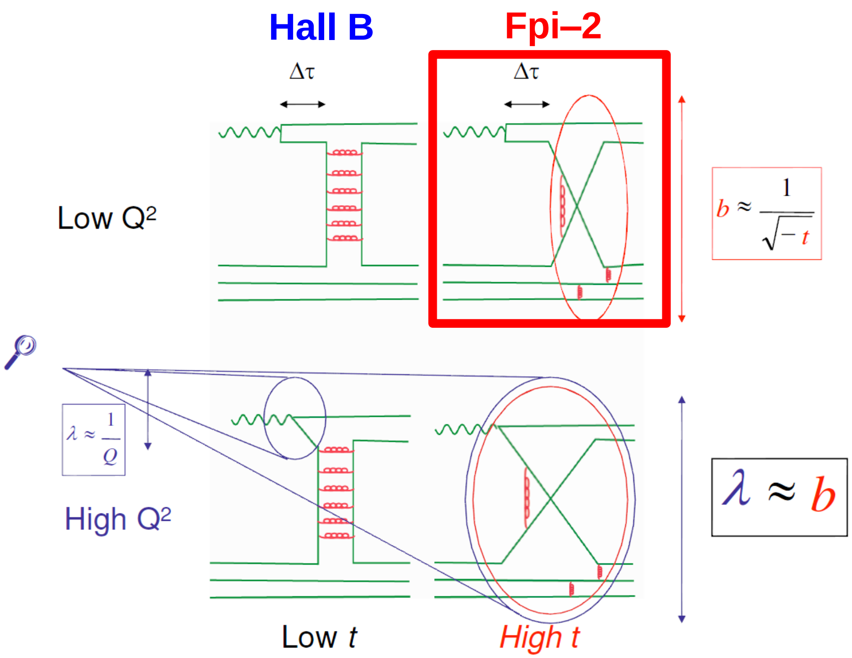
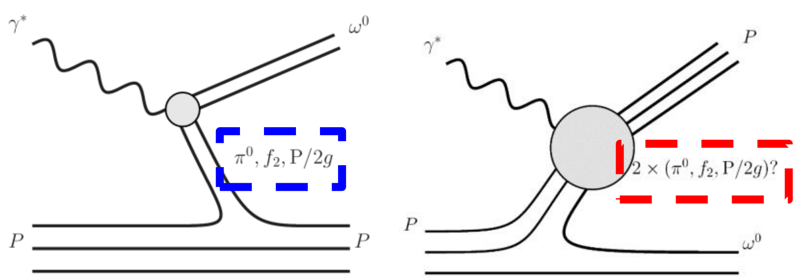
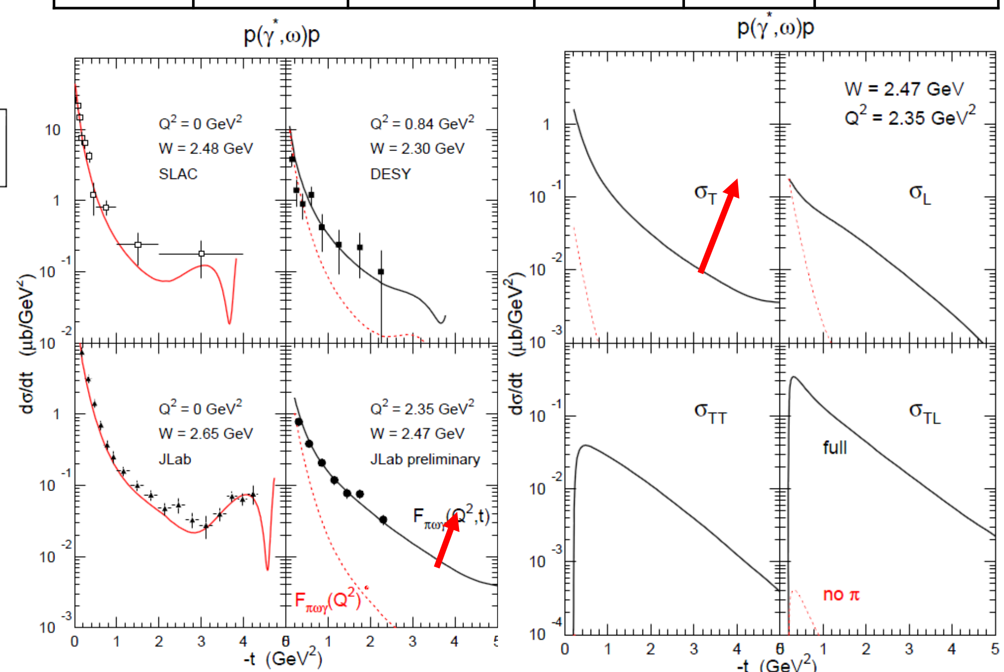
	W (GeV)	x	Q^2 (GeV²)	$-t$ (GeV²)	$-u$ (GeV²)
Hall B	1.8–2.8	0.16–0.64	1.6–5.1	< 2.7	> 1.68
Fpi–2	2.21	0.29	1.6	4.014	0.08–0.13
		0.38	2.45	4.724	0.17–0.24



Hard Scattering Mechanism schematics





t–Channel Forward

u–Channel Backward

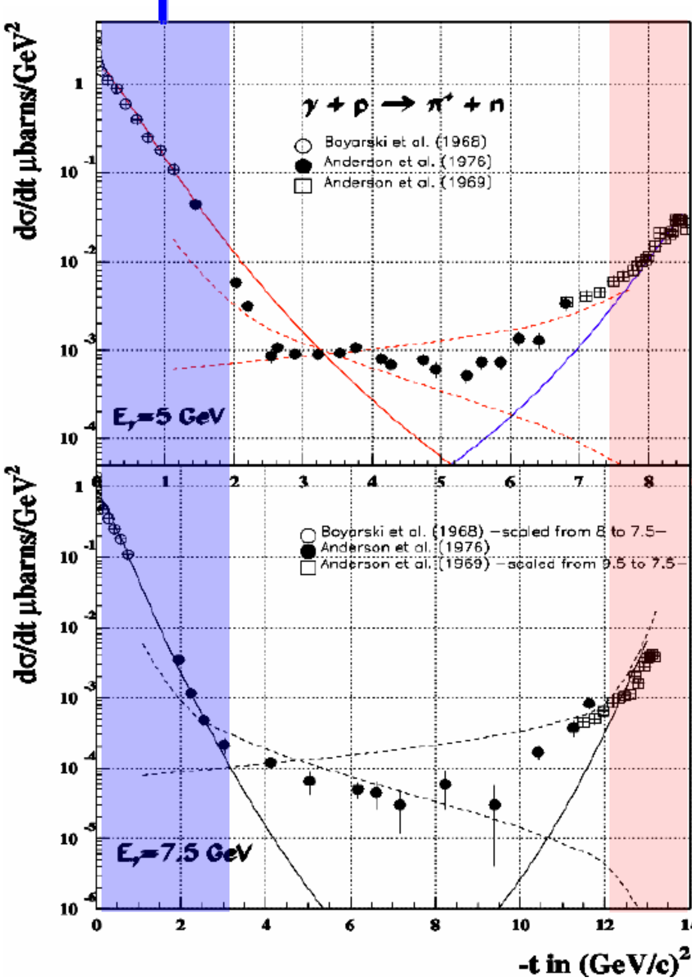
Fpi–2 kinematics: data suggest a u–channel contribution

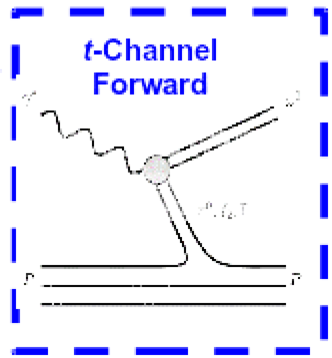
J. M. Laget, Phys. Rev. D 70, 2

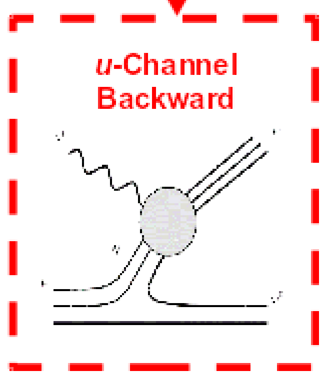
Hadronic Model: Regge Model by JM Laget

Garth Huber, huberg@uregina.ca

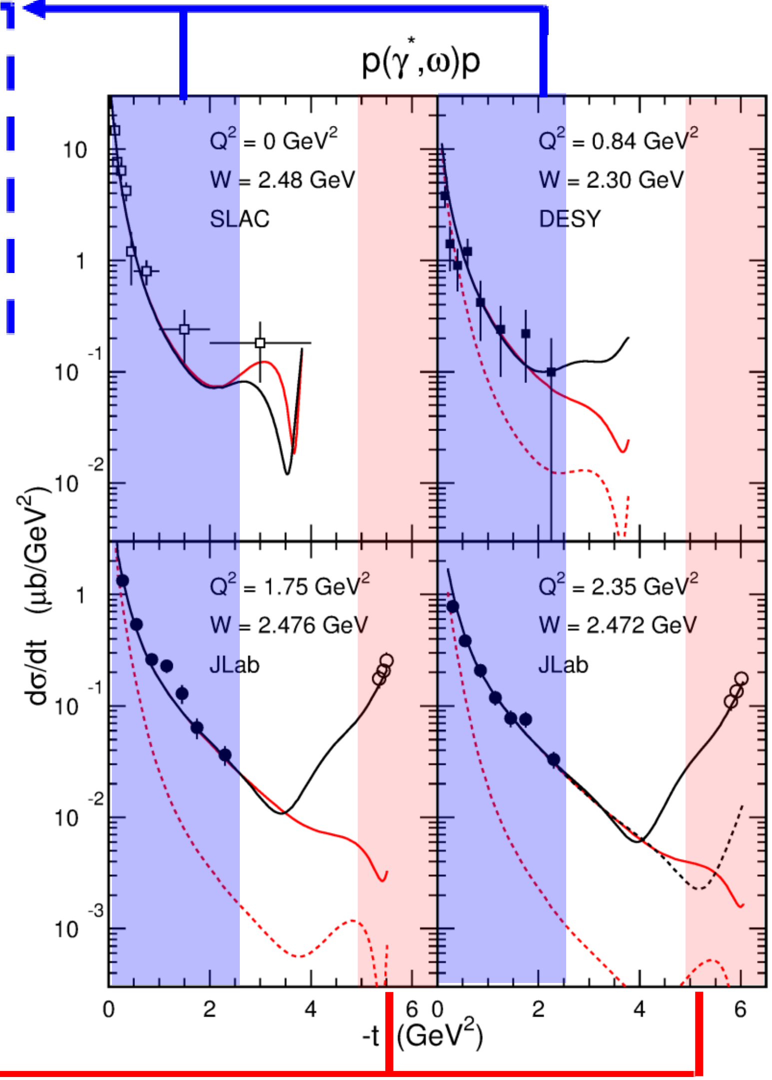
M. Guidal, J.-M. Laget, M. Vanderhaeghen, PLB **400**(1997)6







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



Soft structure → Hard → Soft transition!

Extension to Higher Q^2

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?

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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 GeV^2
- If this interpretation is correct, it can be confirmed by *u*-channel CT measurements such as A(e,e'p)π^0
- The observation of CT in A(e,e'p)π^0 by Q2=14 GeV2, 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?

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