The Flexible Spectator Model of Generalized Parton Distributions and Its Application to Hard Exclusive Processes

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Exploring hadrons with electromagnetic probes: Structure, excitations, interactions
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- GRG, O. Gonzalez-Hernandez, S.Liuti, PRD(2015) arXiv:1311.0483
- GRG, O. Gonzalez-Hernandez, S.Liuti, arXiv:1401.0438
- Ahmad, GRG, Liuti, PRD79, 054014, (2009)
- Gonzalez, GRG, Liuti PRD84, 034007 (2011)
- GRG, Gonzalez, Liuti, PRD91, 114013 (2015)
- GRG, Gonzalez Hernandez, Liuti, J. Phys. G: Nucl. Part. Phys. **39** 115001 (2012)
- Gonzalez Hernandez, Liuti, GRG, Kathuria, PRC88, 065206 (2013)
- GRG, Liuti, PoS DIS2016 (2016) 238
- GRG, Liuti, EPJ Web Conf. 112 (2016) 01009
- J.Poage, Tufts U. dissertation (2016)
- GRG, Liuti, arXiv:1710.01683 (DPF 2016)

OUTLINE

A.

- GPDs, Model– Reggeized spectator “flexible parameterization”
- Valence quarks: Chiral Even → Odd
- π^0 ,η production
- Gluon & Sea GPDs
- Some Observable quantities

B.

- Meson photoproduction – Regge - QCD

GPD definitions – 8 quark + 8 gluon (twist 2)

Momentum space nucleon matrix elements of quark field correlators

see, e.g. M. Diehl, Eur. Phys. J. C 19, 485 (2001).

$$\frac{1}{2}\int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p',\lambda'|\,\bar{\psi}(-\tfrac{1}{2}z)\,\gamma^+\psi(\tfrac{1}{2}z)\,|p,\lambda\rangle\Big|_{z^+=0,\,\mathbf{z}_T=0}$$
$$= \frac{1}{2P^+}\bar{u}(p',\lambda')\left[H^q\gamma^+ + E^q\frac{i\sigma^{+\alpha}\Delta_\alpha}{2m}\right]u(p,\lambda),$$

$$\frac{1}{2}\int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p',\lambda'|\,\bar{\psi}(-\tfrac{1}{2}z)\,\gamma^+\gamma_5\,\psi(\tfrac{1}{2}z)\,|p,\lambda\rangle\Big|_{z^+=0,\,\mathbf{z}_T=0}$$
$$= \frac{1}{2P^+}\bar{u}(p',\lambda')\left[\tilde{H}^q\gamma^+\gamma_5 + \tilde{E}^q\frac{\gamma_5\Delta^+}{2m}\right]u(p,\lambda),$$

Chiral even GPDs
-> Ji sum rule

$$\left\langle J_q^x\right\rangle = \tfrac{1}{2}\int dx\left[H(x,0,0)+E(x,0,0)\right]x$$

$$\frac{1}{2}\int \frac{dz^-}{2\pi} e^{ixP^+z^-} \langle p',\lambda'|\,\bar{\psi}(-\tfrac{1}{2}z)\,i\sigma^{+i}\,\psi(\tfrac{1}{2}z)\,|p,\lambda\rangle\Big|_{z^+=0,\,\mathbf{z}_T=0}$$
$$= \frac{1}{2P^+}\bar{u}(p',\lambda')\left[H_T^q\,i\sigma^{+i} + \tilde{H}_T^q\frac{P^+\Delta^i-\Delta^+P^i}{m^2}\right.$$
$$\left. + E_T^q\frac{\gamma^+\Delta^i-\Delta^+\gamma^i}{2m} + \tilde{E}_T^q\frac{\gamma^+P^i-P^+\gamma^i}{m}\right]u(p,\lambda$$

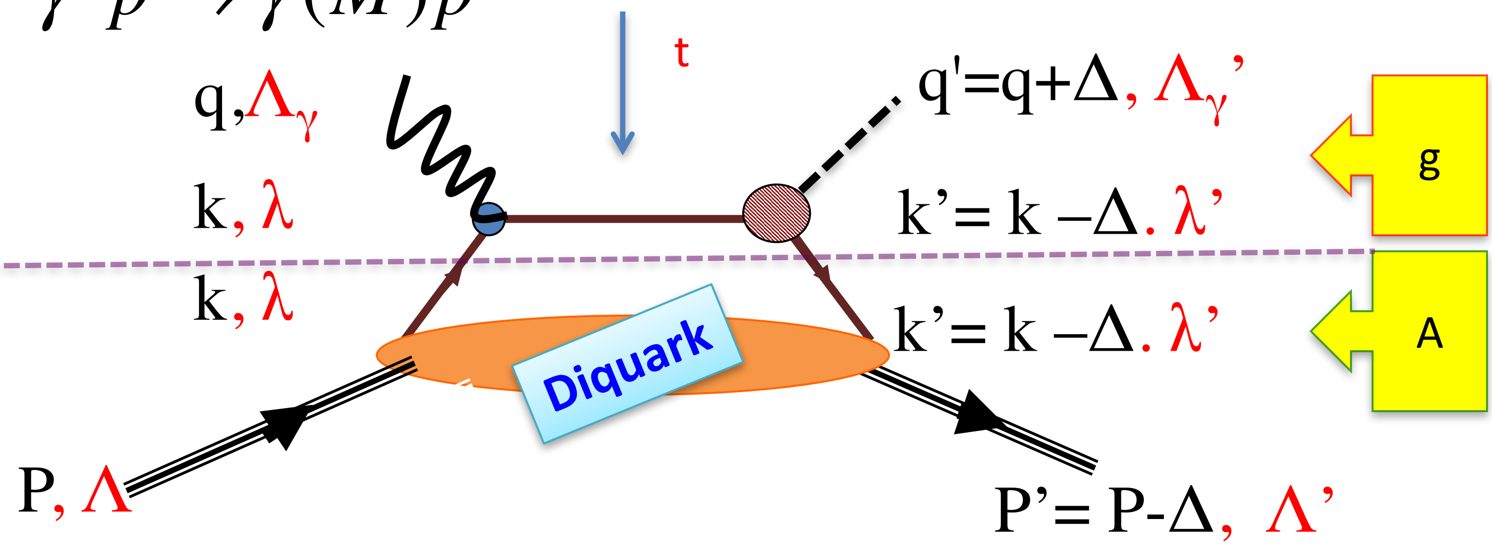
Chiral odd GPDs
-> transversity
How to measure and/or parameterize them?

The Model for valence quarks– Reggeized Diquarks

The Model – first for Chiral Even –
Reggeized Diquark Spectator
Diquark: Color anti-3, scalar & axial vector

Connecting to exclusive processes (DVCS, DVMP…)

$$\gamma^* p \rightarrow \gamma(M) p'$$



Convolution of "hard part" with quark-proton **Helicity** amplitudes

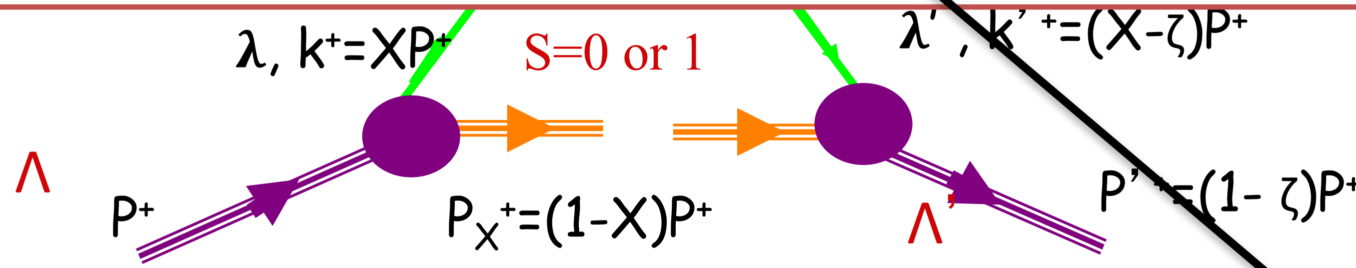
$$f_{\Lambda_\gamma,\Lambda;\Lambda'_\gamma,\Lambda'} = \sum_{\lambda,\lambda'} g_{\lambda,\lambda'}^{\Lambda_\gamma,\Lambda'_{\gamma(M)}}(x,k_T,\zeta,t;Q^2) \otimes A_{\Lambda',\lambda';\Lambda,\lambda}(x,k_T,\zeta,t),$$

λ= +(-) λ' chiral even (odd)

See Ahmad, et al. PRD75, 0904003 (2007); ibid, EPJC63, 407 (2009) .

see Ahmad, GG, Liuti, PRD79, 054014, (2009)
for first chiral odd GPD parameterization
Gonzalez, GG, Liuti PRD84, 034007 (2011) chiral even GPD

Procedure to construct **Chiral Even GPDs** & observables
Spectator color anti-3 diquark model & Reggeization



Product of diquark l.c.w.f.’s → $A_{\Lambda\,\lambda;\,\Lambda'\,\lambda'=-\lambda}$ — **Odd**

$A_{\Lambda\,\lambda;\,\Lambda'\,\lambda'=-\lambda}$ → chiral **Odd** GPDs + Evolution

g ⊗ A → exclusive process helicity amps

pdf’s, FF’s, dσ/dΩ & Asymmetries: parameters & predictions

$A_{\Lambda\,\lambda;\,\Lambda'\,\lambda'=-\lambda}$ → all chiral **Odd** GPDs→DVCS, DVMP

Chiral odd quark GPDs

One question is: how do we normalize chiral-odd GPDs?

Physical constraints on the various chiral-odd GPDs are

Forward limit

$$H_T(x,0,0) = q_{\Uparrow}^{\uparrow}(x) - q_{\Uparrow}^{\downarrow}(x) = h_1(x)$$

Transversity

Form Factors

Integrates to tensor charge δ_q

$$\int H_T^q(x,\xi,t)\,dx = \delta q(t)$$

$$\int \bar{E}_T^q(x,\xi,t)\,dx = \int \left(2\tilde{H}_T^q + E_T^q\right) dx = \kappa_T^q(t)$$

"transverse moment" κ_T^q

$$\int \tilde{E}_T(x,\xi,t)\,dx = 0$$

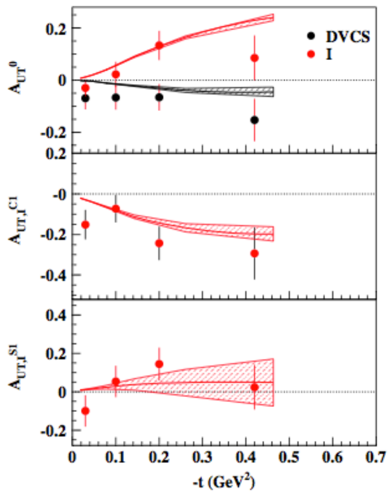
No direct interpretation of E_T .

Azimuthal correlations for electrons (or neutrinos to separate *P* violating parts)

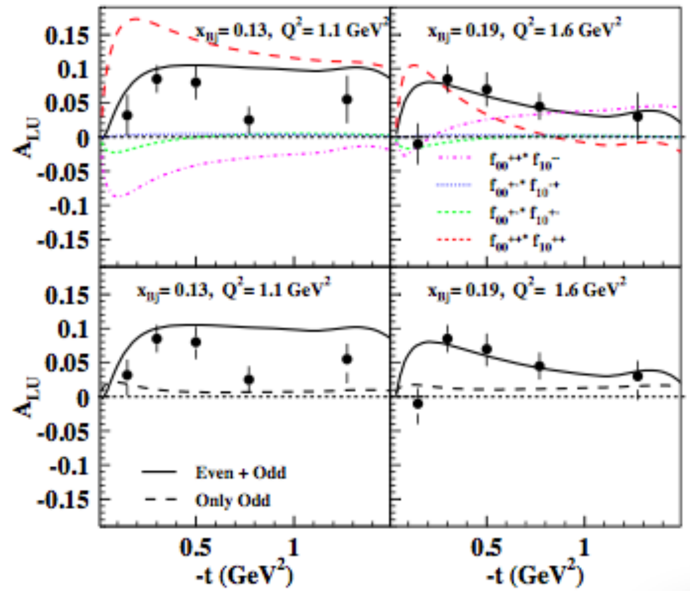
$$
\begin{aligned}
\frac{d^4\sigma}{d\Omega d\varepsilon_2 d\phi dt} \quad &= \quad \Gamma\left[\frac{d\sigma_T}{dt} + \varepsilon_L \frac{d\sigma_L}{dt} + \varepsilon \cos 2\phi \frac{d\sigma_{TT}}{dt}\right.\\
&+ \quad \sqrt{2\varepsilon_L(\varepsilon+1)} \cos\phi \frac{d\sigma_{LT}}{dt}\\
&+ \quad \varepsilon \sin 2\phi \frac{d\sigma_{T'T}}{dt}\\
&\pm \quad \left.\sqrt{2\varepsilon_L(\varepsilon+1)} \sin\phi \frac{d\sigma_{L'T}}{dt}\right] \qquad (
\end{aligned}
$$

Some results GG, Gonzalez Hernandez, Liuti, PRD84, 034007 (2011) . . .(2016);

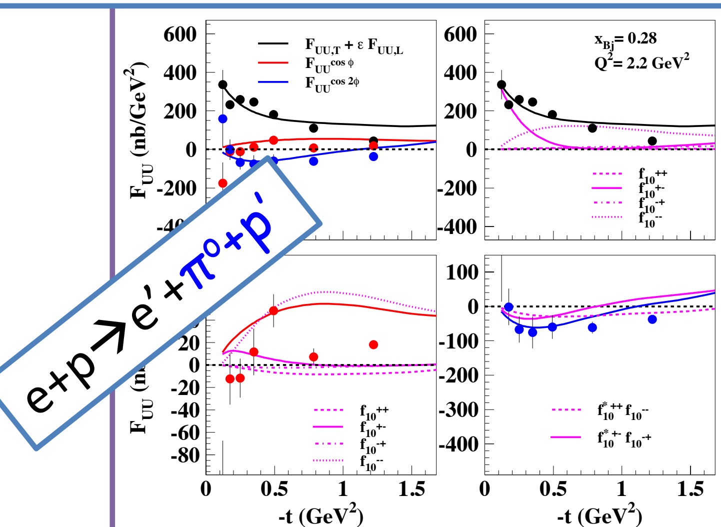
Beam charge asymmetry
HERMES A_{UT} coefficients

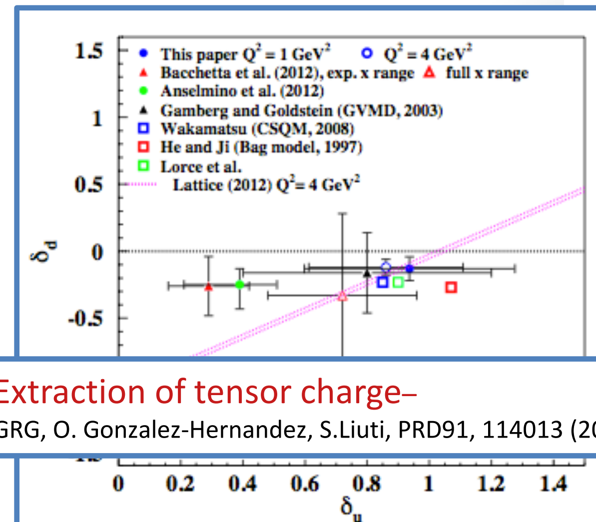


Beam spin asymmetry
(CLAS data –DeMasi, et al.)



Hall B data, Bedlinskii, et al. PRL 109, 112001 (2012)





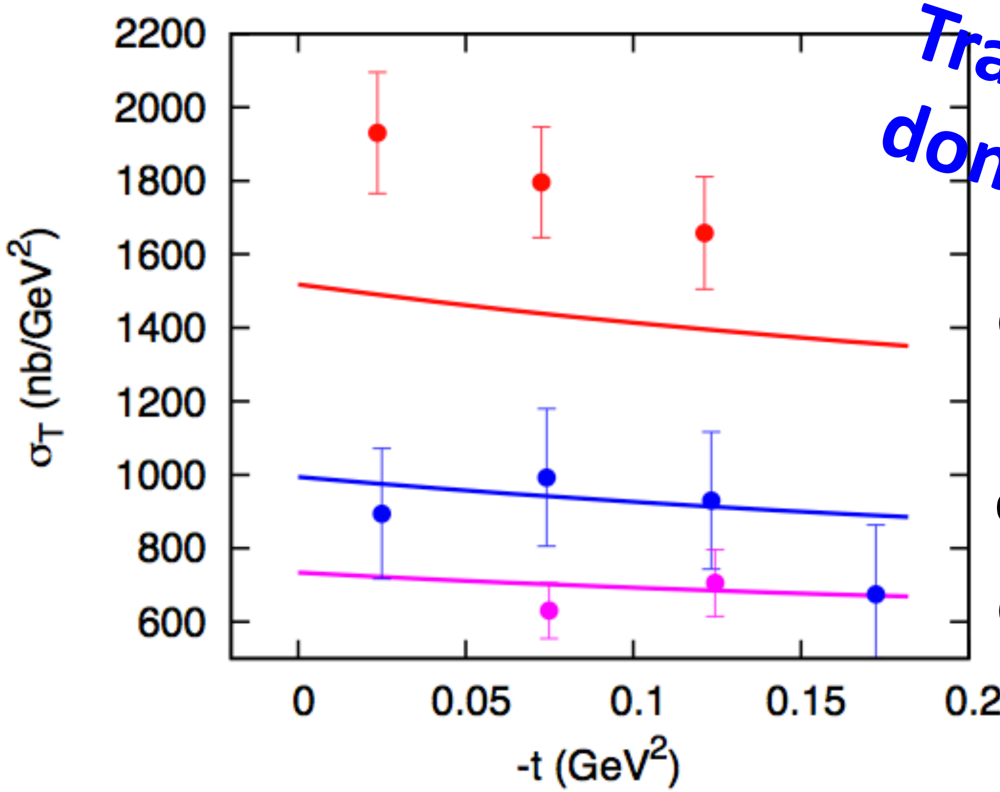
Extraction of tensor charge–
GRG, O. Gonzalez-Hernandez, S.Liuti, PRD91, 114013 (2015)

Hall A data x_B=0.36

courtesy F. Sabatie & M. Defurne

PRELIMINARY

Transverse γ^* dominates σ



Q^2=1.5 GeV^2

Q^2=1.75 GeV^2

Q^2=2.0 GeV^2

See **"Rosenbluth separation"** showing large $d\sigma_T$ /dt vs. $d\sigma_L$ /dt

Twist 3 dominates

M. Defurne at INT Aug.2017

Gluon GPDs

Gluon GPDs

$$\frac{1}{\bar{P}^+}\int\frac{dz^-}{2\pi}e^{ix\bar{P}^+z^-}\langle P',\Lambda'|G^{+i}(-\frac{1}{2}z)G^{+i}(\frac{1}{2}z)|P,\Lambda\rangle\Big|_{z^+=0,\vec{z}_T=0} =$$

$$\frac{1}{2\bar{P}^+}\bar{U}(P',\Lambda')[H^g(x,\xi,t)\gamma^+ + E^g(x,\xi,t\frac{i\sigma^{+\alpha}(-\Delta_\alpha)}{2M}]U(P,\Lambda)$$

Even t-channel parity & Gluon helicity conserving

$$\frac{-i}{\bar{P}^+}\int\frac{dz^-}{2\pi}e^{ix\bar{P}^+z^-}\langle P',\Lambda'|G^{+i}(-\frac{1}{2}z)\tilde{G}^{+i}(\frac{1}{2}z)|P,\Lambda\rangle\Big|_{z^+=0,\vec{z}_T=0} =$$

$$\frac{1}{2\bar{P}^+}\bar{U}(P',\Lambda')[\tilde{H}^g(x,\xi,t\gamma^+\gamma_5 + \tilde{E}^g(x,\xi,t\frac{\gamma_5(-\Delta^+)}{2M}]U(P,\Lambda)$$

Odd t-channel parity & Gluon helicity conserving

Gluon & Sea quark distributions Spectator Model

– generalize Regge-diquark spectator model

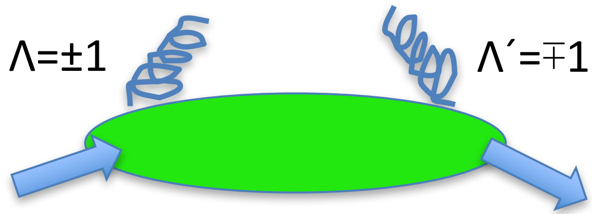
- N→ ***g*** + "color octet N" spectator ($8\otimes 8 \supset 1$)
  (could be spin ½ or 3/2)
- (N→ ***anti-u*** + color 3 "tetraquark"uuud)

- How to normalize?
  $$H_g(x,\xi,t)_{Q^2} \to H_g(x,0,0)_{Q^2} = xG(x)_{Q^2}$$
- Evolution →
- Sea quark distributions $H_{anti-u}(x,0,0)$ . . .

- Use pdf's to fix x dependence

- Small x ~ Pomeron

Extension to Gluon "Transversity"



$$
-\frac{1}{P^+}\int\frac{dz^-}{2\pi}\,e^{ixP^+z^-}\langle p',\lambda'|\,\mathbf{S}F^{+i}(-\tfrac{1}{2}z)\,F^{+j}(\tfrac{1}{2}z)\,|p,\lambda\rangle\Big|_{z^+=0,\,\mathbf{z}_T=0}
$$
$$
= \mathbf{S}\,\frac{1}{2P^+}\,\frac{P^+\Delta^j-\Delta^+P^j}{2mP^+}
$$
$$
\times\;\bar{u}(p',\lambda')\Big[H_T^g\,i\sigma^{+i}+\tilde{H}_T^g\,\frac{P^+\Delta^i-\Delta^+P^i}{m^2}
$$
$$
+E_T^g\,\frac{\gamma^+\Delta^i-\Delta^+\gamma^i}{2m}+\tilde{E}_T^g\,\frac{\gamma^+P^i-P^+\gamma^i}{m}\Big]\,u(p,\lambda).
$$

4 GPDs: M.Diehl, EPJC19, 485 (2001)

What about Gluon "transversity"? Double helicity flip *does not mix* with quark distributions

Transversity for on-shell gluons or photons : no |0> helicity

$$|+1)_{trans} = \{|+1> + |-1>\}/2 = |-1)_{trans}$$

$$|0\,)_{trans} = \{|+1> - |-1>\}/\sqrt{2}$$

$$\text{helicity } |\pm 1 >= \{-/+x - iy\}/\sqrt{2}$$

$$x = -|0)_{trans} = P_{parallel}$$

Linear polarization in the plane

$$y = i\sqrt{2}\,|+1)_{trans} = P_{normal}$$

Linear polarization normal to the plane

GG&M.J.Moravcsik, Ann.Phys.195,213(1989).

Construct helicity flip amps Spectator Model, then GPDs

$$A_{++,+-} = \sqrt{1-\xi^2}\,\frac{t_0-t}{4M^2}\left(\tilde{H}^g_T + (1-\xi)\frac{E^g_T+\tilde{E}^g_T}{2}\right)$$

$$A_{-+,--} = \sqrt{1-\xi^2}\,\frac{t_0-t}{4M^2}\left(\tilde{H}^g_T + (1+\xi)\frac{E^g_T-\tilde{E}^g_T}{2}\right)$$

$$A_{++,--} = +e^{-i\phi}(1-\xi^2)\frac{\sqrt{t_0-t}}{2M}\left(H^g_T + \frac{t_0-t}{M^2}\tilde{H}^g_T - \frac{\xi^2}{1-\xi^2}E^g_T + \frac{\xi}{1-\xi^2}\tilde{E}^g_T\right)$$

$$A_{-+,+-} = -e^{i\phi}(1-\xi^2)\frac{\sqrt{t_0-t}^3}{8M^3}\tilde{H}^g_T,$$

Compare to spectator model results

$$\tilde{H}^g_T = 0$$

$$(1-X)A^0_{-+.--} = (1-X')A^0_{++,+-}$$

$$\tilde{E}^g_T = 0.$$

As in Hoodbhoy & Ji, PRD58, 054006 (1998)

Using the Reggeized Spectators Model

How to Measure? What Processes? Long standing question.

M. Diehl, T. Gousset, B. Pire, and J. P. Ralston, Phys. Lett. B411, 193 (1997).
X. Ji and J. Osborne, UMD PP#98-074, hep-ph/9801260.
P. Kroll, M. Schurmann, and P. A. M. Guichon, Nucl. Phys. A598, 435 (1996).
P. Hoodbhoy & X. Ji, PRD58, 054006 (1998)

Measuring Gluons in Nucleons

DVCS

$$\frac{d^5\sigma}{dx_{Bj}dQ^2d|t|d\phi d\phi_S} = \frac{\alpha^3}{16\pi^2(s-M^2)^2\sqrt{1+\gamma^2}}|T|^2$$

$$T(k,p,k',q',p') = T_{DVCS}(k,p,k',q',p') + T_{BH}(k,p,k',q',p'),$$

$$|T|^2 = |T_{\rm BH} + T_{\rm DVCS}|^2 = |T_{\rm BH}|^2 + |T_{\rm DVCS}|^2 + \mathcal{I}\ .$$

$$\mathcal{I} = T^*_{BH}T_{DVCS} + T^*_{DVCS}T_{BH}.$$

For unpolarized e+p→e'+γ+p' cross section depends on azimuthal angle ϕ.
cos3ϕ term in interference dσ measures gluon transversity GPDs (CFF's)

$$\frac{\sqrt{t_0-t}^3}{8M^3}\left[H_T^g F_2 - E_T^g F_1 - 2\tilde{H}_T^g\left(F_1 + \frac{t}{4M^2}F_2\right)\right]\cos 3\phi$$

$\mathcal{H}_T^{\,g} \sim \int dx\, H^g_T /(x-\xi)(x+\xi)$ CFF's

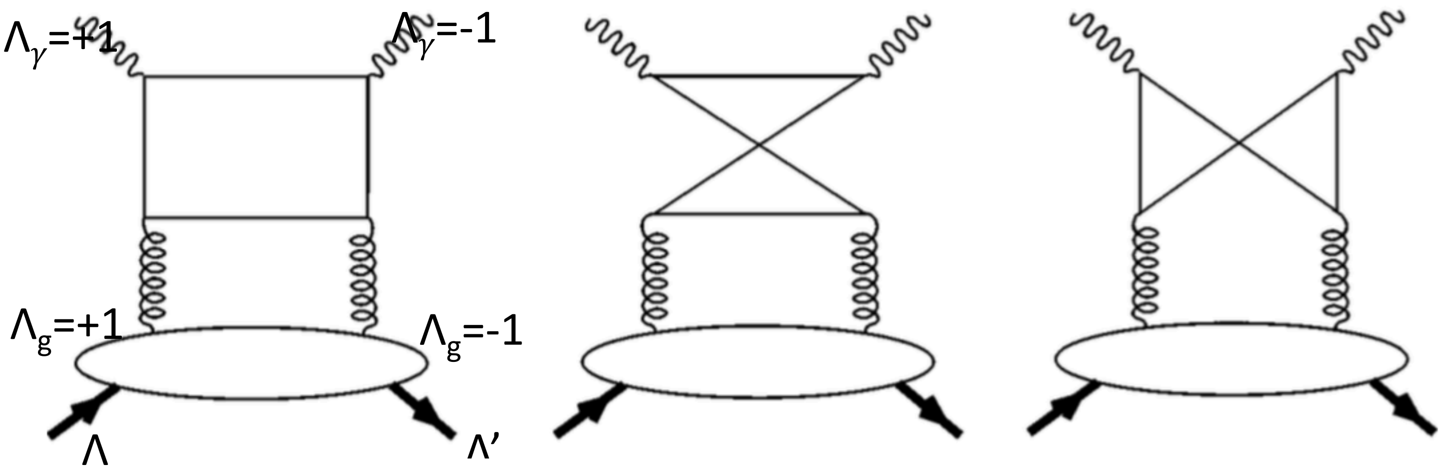
See Diehl, *et al*. PLB411, 193 (1997);
Diehl, EPJC25, 223 (2002);
Belitsky, Mueller, PLB486, 369 (2000).

$A_{\Lambda',-1;\,\Lambda,+1}$ **Gluon Transversity** contributes to DVCS ~ α_s

$$M_{\Lambda',\Lambda'\gamma=-1;\Lambda,\Lambda\gamma=+1} = -\frac{\alpha s}{2\pi}\sum_q e_q^2 \int_{-1}^{+1} dx \frac{A_{\Lambda',\Lambda' g=-1;\Lambda,\Lambda g=+1}(x,\xi,t)}{(\xi - x - i\varepsilon)(\xi + x - i\varepsilon)} \; C'(x,\xi,Q^2)$$

DVCS cross sections: $d\sigma/dt \propto \sum |M_{\Lambda' \ldots}|^2$

***Interference with Bethe-Heitler contains *cos*3φ modulation to distinguish from (leading twist) quark contribution ***



$$T^{\mu\nu} = \frac{\alpha_s}{2\pi}\left(\sum_q e_q^2\right)\int_{-1}^{1} dx \frac{x}{x^2-\xi^2}\left[1 + \frac{x_B^2-\xi^2}{x^2-\xi^2}\ln\left(\frac{x_B^2-x^2}{x_B^2-\xi^2}\right)\right] n_\alpha n_\beta T^{\mu\nu\alpha\beta} \,,$$

e,

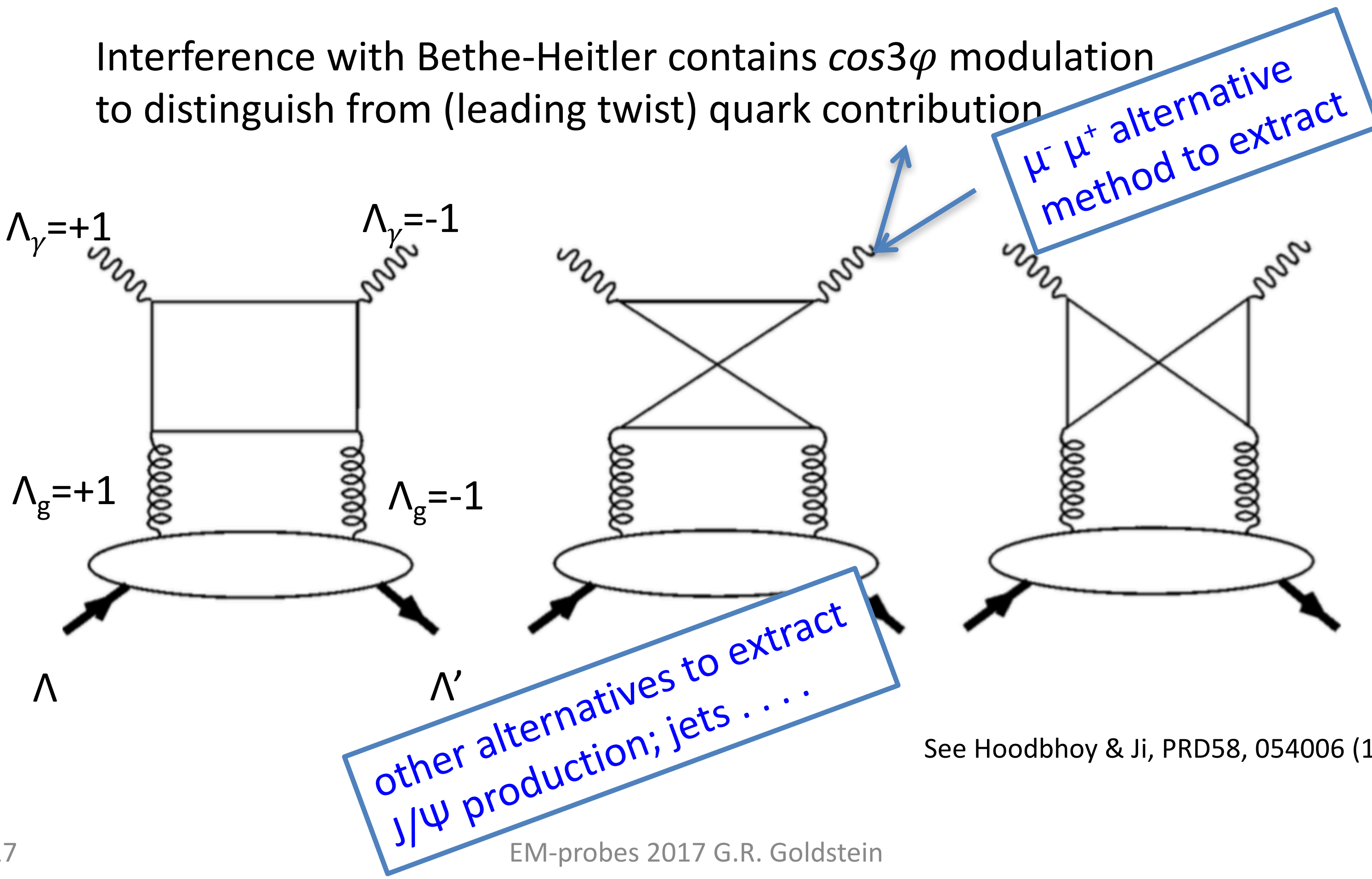
See Hoodbhoy & Ji, PRD58, 054006 (1998)

$$T^{\mu\nu\alpha\beta} = \frac{1}{x}\int \frac{d\lambda}{2\pi} e^{i\lambda x} \langle P'S'|F^{(\mu\alpha}(-\frac{\lambda}{2}n)F^{\nu\beta)}(\frac{\lambda}{2}n)|PS\rangle \,.$$

$A_{\Lambda',-1;\Lambda,+1}$ contributes to DVCS ~ α_S

$$M_{\Lambda',\Lambda'\gamma=-1;\Lambda,\Lambda\gamma=+1} = -\frac{\alpha s}{2\pi}\sum_q e_q^2 \int_{-1}^{+1} dx \frac{A_{\Lambda',\Lambda' g=-1;\Lambda,\Lambda g=+1}(x,\xi,t)}{(\xi - x - i\varepsilon)(\xi + x - i\varepsilon)} \quad C'(x,\xi,Q^2)$$

Interference with Bethe-Heitler contains $cos3\varphi$ modulation to distinguish from (leading twist) quark contribution



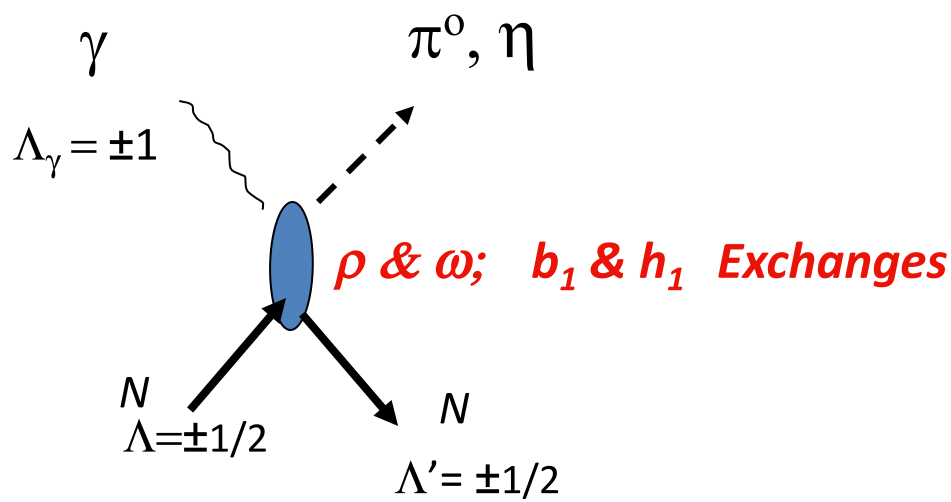
See Hoodbhoy & Ji, PRD58, 054006 (1998)

Summary

- Flexible parameterization for chiral even valence quarks from form factors, pdfs & DVCS **R✖**Dq
- Extended **R✖**Dq to **R✖**Spectator
- **New Extension to gluons & the sea**
- Consider Gluon sector
  - Helicity conserving & Helicity →gluon ***Transversity***
- Measurements?
- **More phenomenology to come**

Meson Photoproduction

Pseudoscalar photoproduction
$\gamma + p \rightarrow (\pi^0 \text{ or } \eta) + p$



$$\frac{d\sigma}{dt} = \frac{\pi}{2sk^2}\sum_{i=1}^{4} | f_i |^2,$$

- 4 helicity amps

$$f_{\Lambda_\gamma,\,\Lambda;\,0,\,\Lambda'} \text{ for } \gamma(q,\,\Lambda_\gamma)+N(p,\,\Lambda) \rightarrow \pi^0(q')+N(p',\,\Lambda'),$$

$$f_1 = f_{+1,+\frac{1}{2};0,+\frac{1}{2}},\ f_2 = f_{+1,+\frac{1}{2};0,-\frac{1}{2}},\ f_3 = f_{+1,-\frac{1}{2};0,+\frac{1}{2}},\ f_4 = f_{+1,-\frac{1}{2};0,-\frac{1}{2}}$$

f_1 **&** $f_4 \propto \Delta^1$; $f_2 \propto \Delta^0$; $f_3 \propto \Delta^2$

Also γ + N → K + Λ or Σ with strange exchanges

Regge pole amps

- Natural and unnatural parity Regge *poles* (GG& J.Owens, PRD7, 865 (1973).)

Natural
odd signature
vectors
ρ & ω

$$f_1 = f_4 = \frac{\beta_1^V}{\Gamma(\alpha_V(t))}\Delta\frac{1-e^{-i\pi\alpha_V(t)}}{sin(\pi\alpha_V(t))}\nu^{\alpha_V(t)}e^{-\Delta^2 c_V/2}$$

$$f_2 = -f_3 = \frac{-\beta_2^V\Delta^2}{2M\Gamma(\alpha_V(t))}\frac{1-e^{-i\pi\alpha_V(t)}}{sin(\pi\alpha_V(t))}\nu^{\alpha_V(t)}e^{-\Delta^2 c_V/2}$$

"conspiracy" Δ^2

unnatural
odd signature
axial vector
b_1 & h_1

unnatural parity, $f_1 = f_4 = 0$, and

$$f_2 = +f_3 = \frac{\beta_1^A\Delta^2}{2M\Gamma(\alpha_A(t)+1)}\frac{1-e^{-i\pi\alpha_A(t)}}{sin(\pi\alpha_A(t))}\nu^{\alpha_A(t)}e^{-\Delta^2 c_A/2}.$$

Regge pole amps: t-dependent power behavior + residues

For even integer α(t) *f* 's have "**nonsense wrong signature zeros**"
"exchange degeneracy"

For vector mesons α(t) ≈ ½ + t, => NWSZ at t ≈ - ½ GeV^2

For axial vectors α(t) ≈ $0.8(t – m_\pi^2)$ no NWSZ

Regge cuts

- Elastic rescattering via Pomeron → Regge-Pomeron cuts
- Also Subleading rescattering via lower α poles → RR cuts

Regge pole

$$g_n^R(s,t) = \beta_n(t)\frac{\Delta^n}{M^{n-1}}\frac{\eta - e^{-i\pi\alpha(t)}}{\sin\pi\alpha}\left(\frac{\nu}{M}\right)^{\alpha(t)}$$

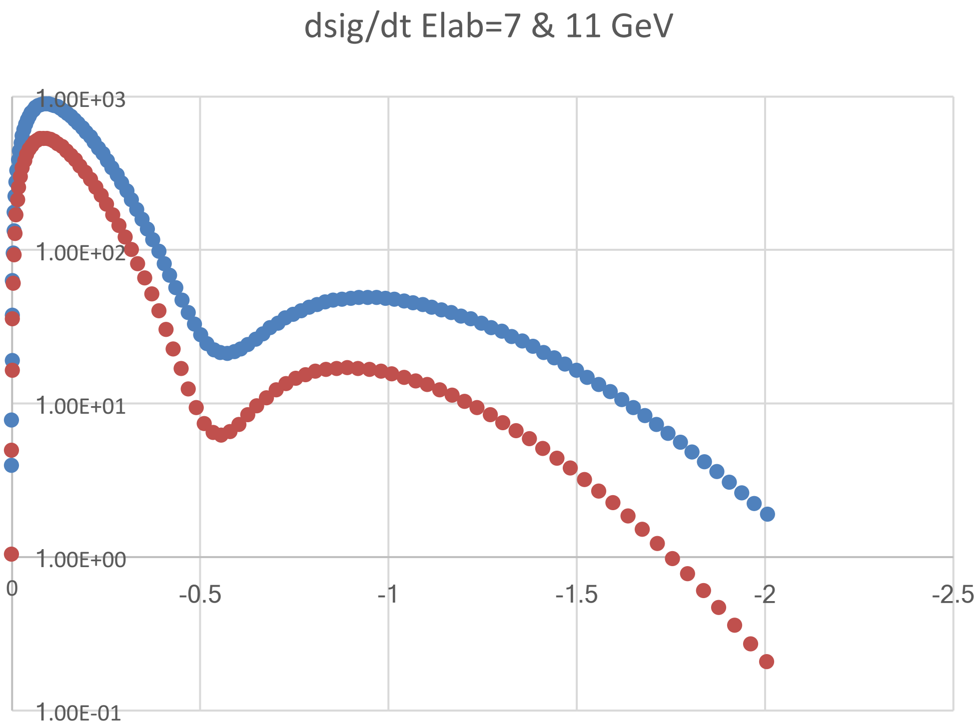
In impact parameter b space

$$\chi^R(s,b) = \frac{1}{k\sqrt{s}}\int \Delta d\Delta J_n(b\Delta) g_n^R(s,\Delta^2)$$

Convoluted with eikonal profile of Pomeron ($\nu^{1+\varepsilon}$)
Can also have lower lying Regge with I=0: f_2 & S=2
$\alpha \approx 1/2 + t \rightarrow \nu^{\alpha(t)}$

$$g_n^{\mathrm{cut}}(s,t) = ik\sqrt{s}\int bdbJ_n(b\Delta)\chi^R(s,b)\chi^P(s,b)$$

$d\sigma/dt(\pi^0)$ vs. E_{lab}



SLAC data

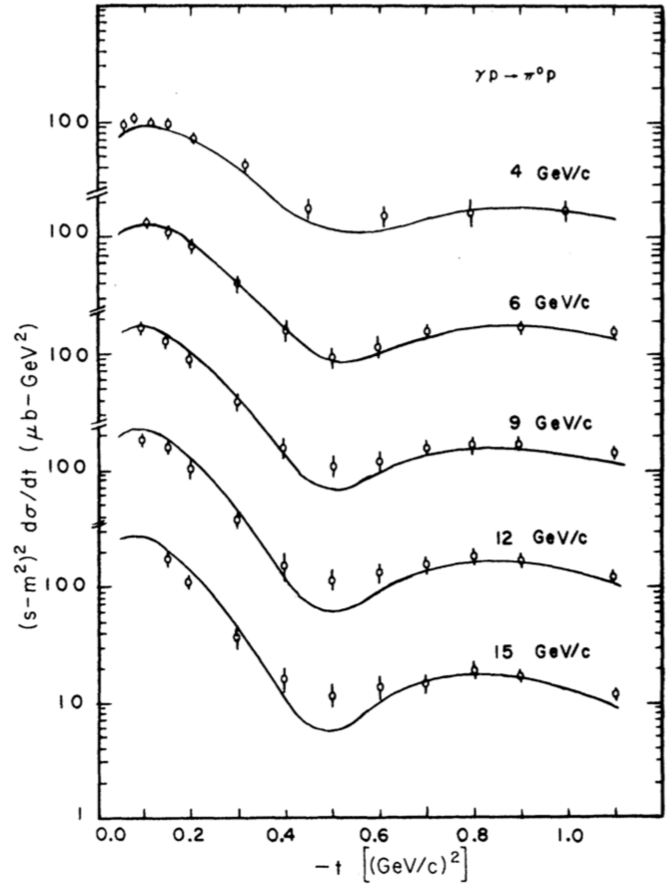
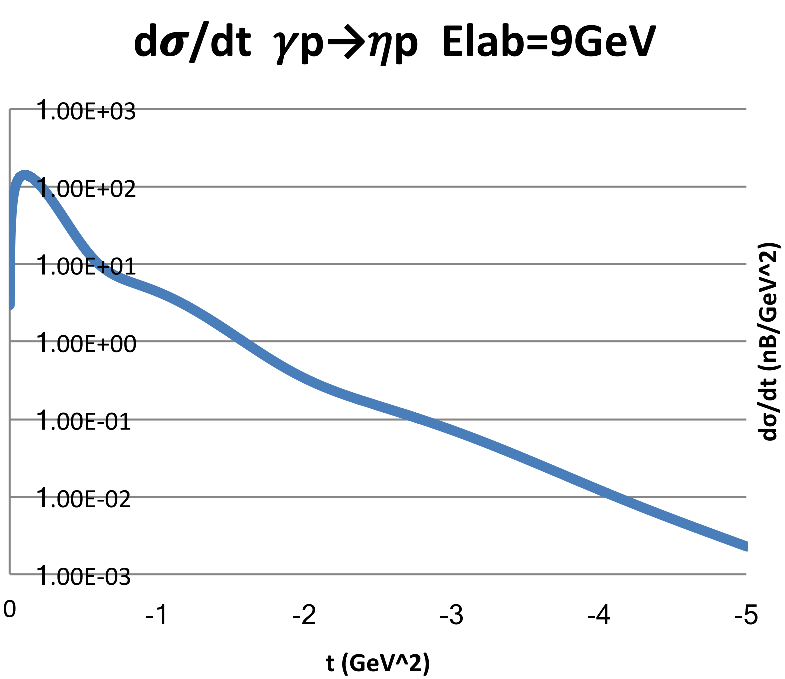


FIG. 1. Differential cross section for $\gamma p \to \pi^0 p$. The 4-GeV data are from Ref. 13 while the rest are from Ref. 7.

GG & Owens, PRD7, 865(1973)

New variations with modified Pomeron
& cuts

Dip sharpened – **evidence of NWSZ**



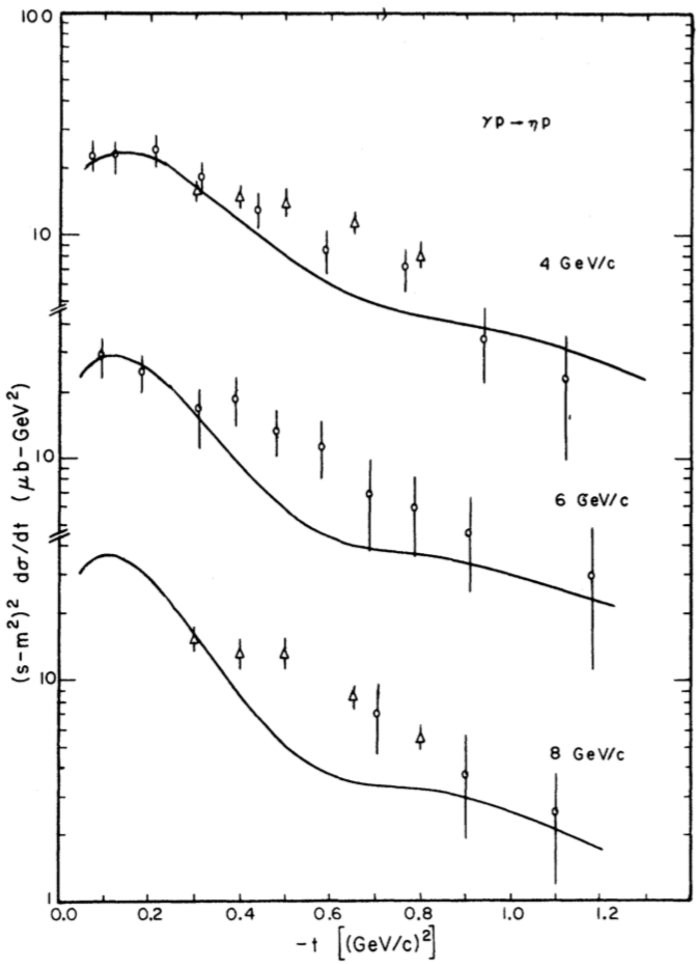
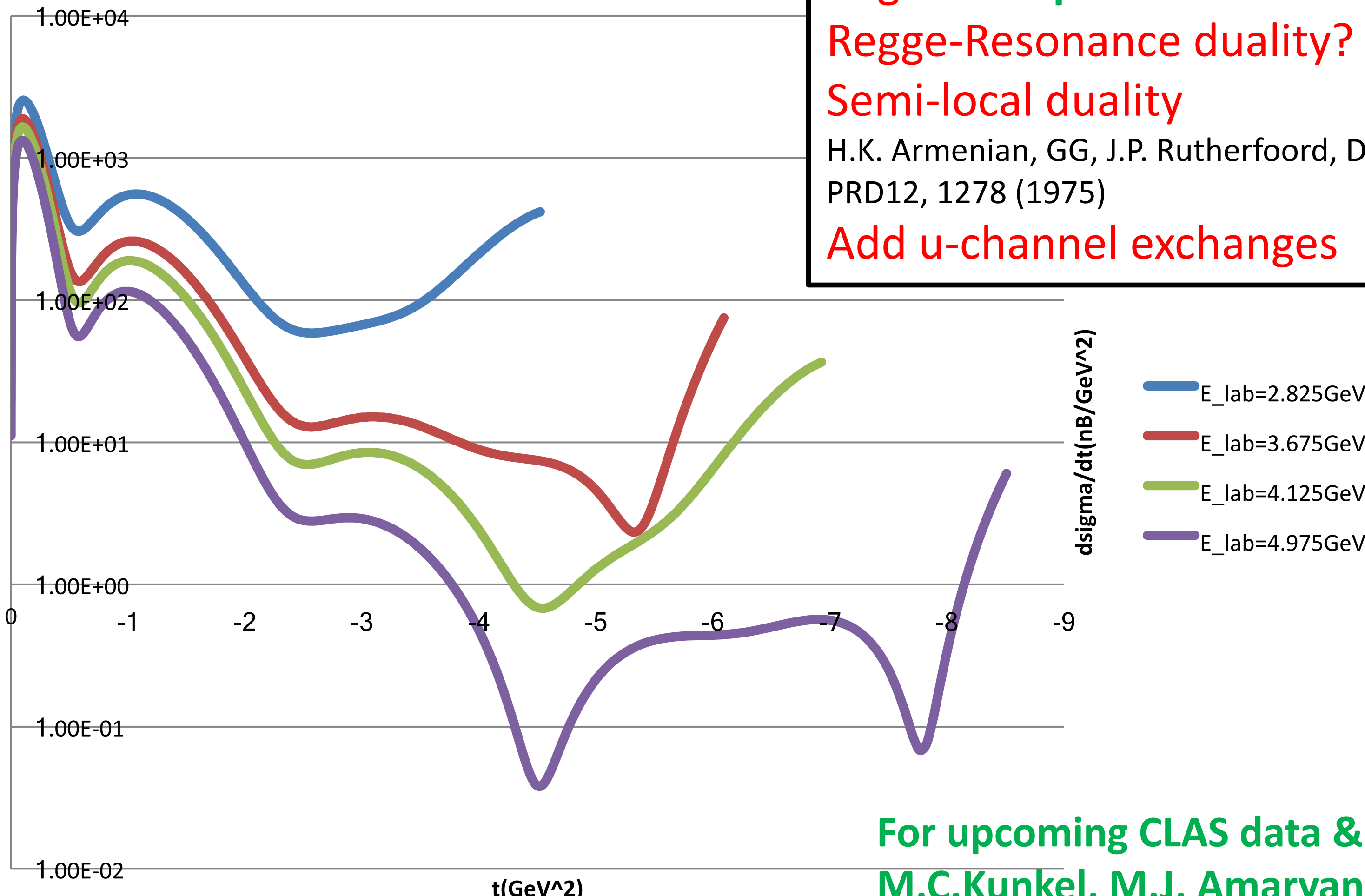


FIG. 5. Differential cross section for $\gamma p \to \eta p$. The data points denoted by Δ are from Ref. 12 and those denoted by ○ are from Ref. 13.

GG & Owens, PRD7, 865(1973)

π^0 dsigma/dt vs. t



Extend model to all t for
Comparison with resonance
Region. - **dips**
Regge-Resonance duality? FESR &
Semi-local duality

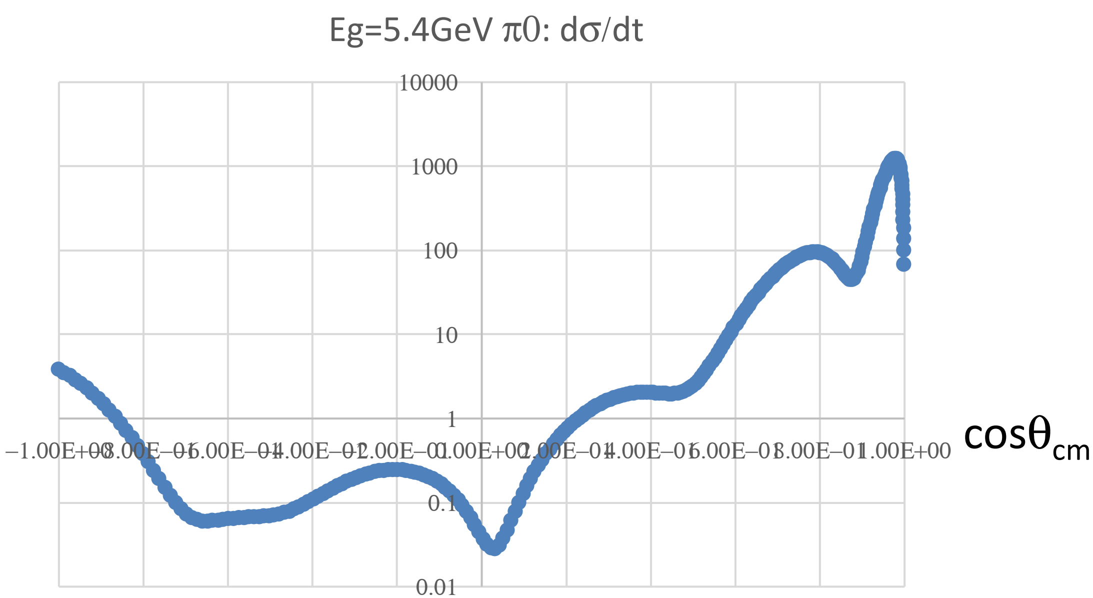
H.K. Armenian, GG, J.P. Rutherfoord, D.L. Weaver, PRD12, 1278 (1975)

Add u-channel exchanges

For upcoming CLAS data & analysis
M.C.Kunkel, M.J. Amaryan,
I.I. Strakovsky, J. Ritman, GG

π^0 dσ/dt @ E_γ=5.4 GeV @ fixed CM angles

- Wide angles => **large scale** => should validate PQCD for photoproduction
- Kroll, et al.: ~ 2 orders of magnitude below the model !
- Kroll, et al.: Why? Log corrections? Higher twist?
- c.f. chiral odd contributions to e+p→ π^0+p



Wide angle power laws

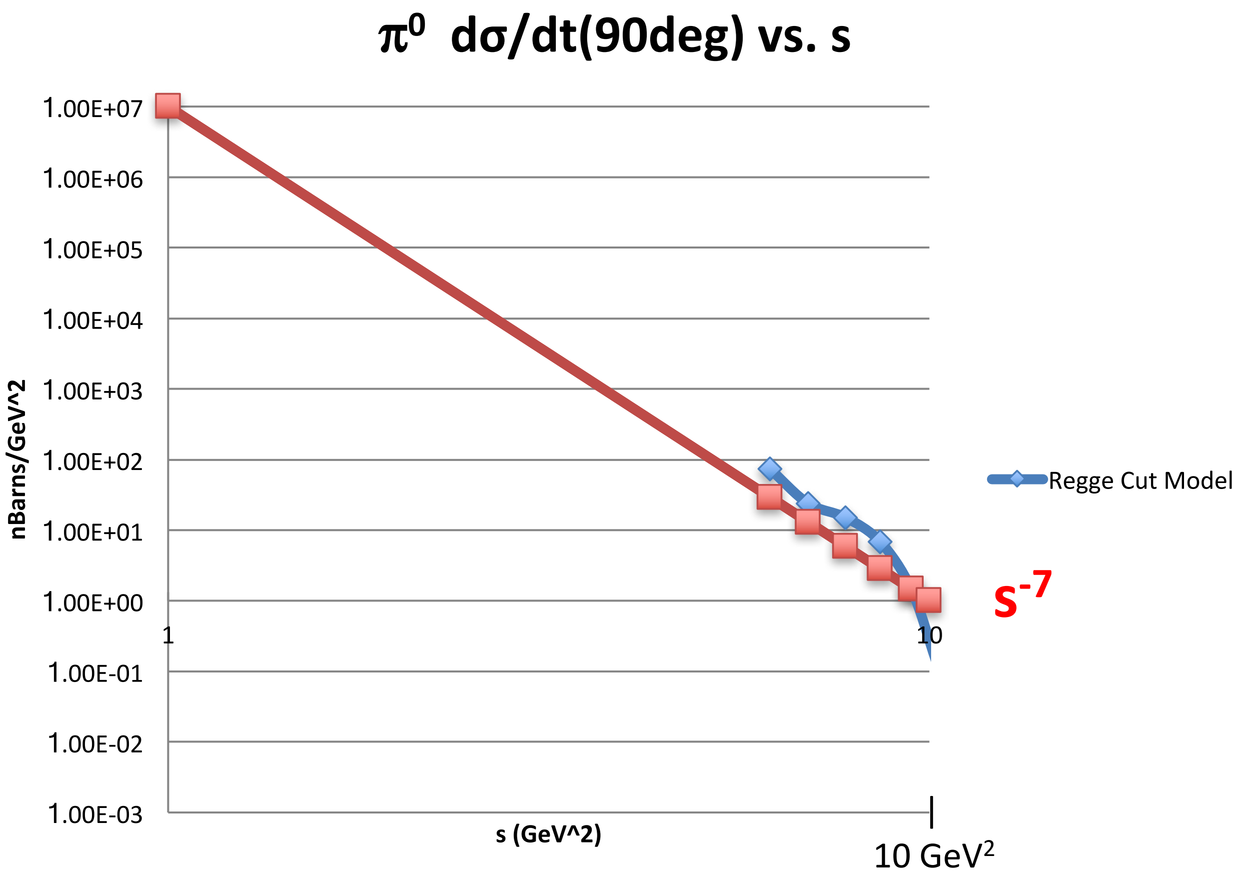
Brodsky-Farrar: Constituent Counting Rules

$d\sigma/dt \propto s^{-7}$ fixed t/s or fixed CM angles

at 90^{o} our R+RP cuts model falls faster

– Regge model: only t-channel Regge poles & cuts

quark-hadron duality?



GlueX Beam asymmetry for π^0 & η

Al Ghoul, et al. PRC95, 042201 (2017)

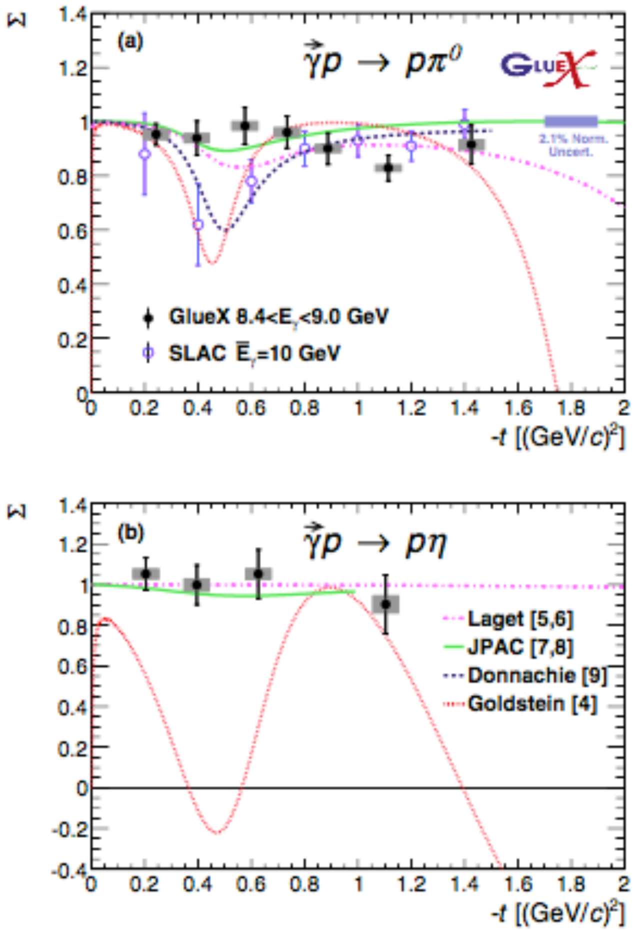


FIG. 6. Beam asymmetry Σ for (a) $\vec{\gamma}p \to p\pi^0$ and (b) $\vec{\gamma}p \to p\eta$ (black filled circles). Uncorrelated systematic errors are indicated by gray bars and combined statistical and systematic uncertainties are given by the black error bars. The previous SLAC results [19] at $\overline{E}_\gamma = 10$ GeV (blue open circles) are also shown along with various Regge theory calculations.

Dip prediction from **NWSZ at t ≈ -0.5 GeV^2 !!?**

Regge-Regge cuts fill in somewhat . . .

What can erase NWSZ?

$\Sigma = \text{Re}\,(f_1^* f_4 - f_2^* f_3)/\, d\sigma/dt$

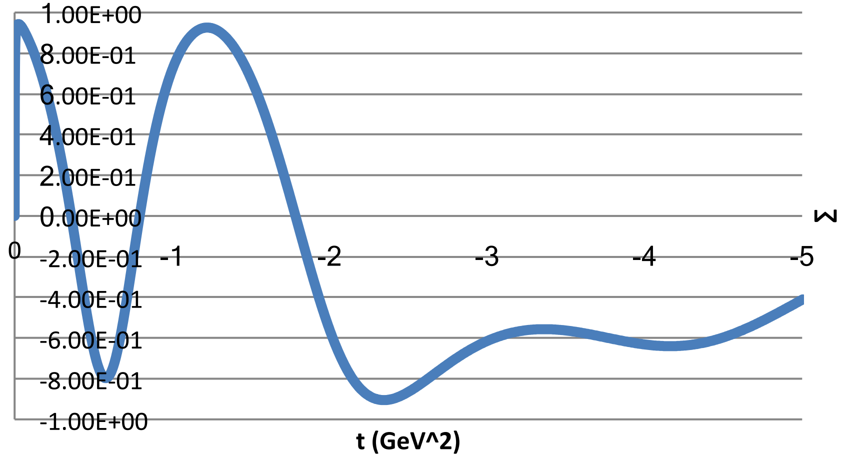
measures

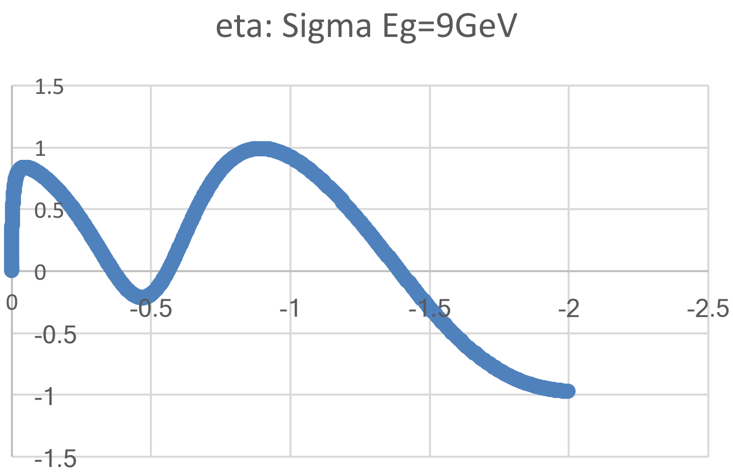
Natural parity – Unnatural parity asymmetry

for NWSZ leading ρ & ω → 0 at ~ -0.4 GeV^2

leaving b_1 & h_1 + RP + RR cuts

Asymmetry $\gamma\uparrow$ p→η p





R poles ONLY

R poles + RP cuts

***b_1 , h_1* fill somewhat**

$\gamma + N \rightarrow \pi^{\pm} N'$

- π pole for small t → peak GG & Owens, Nucl.Phys.B71, 461 (1974)

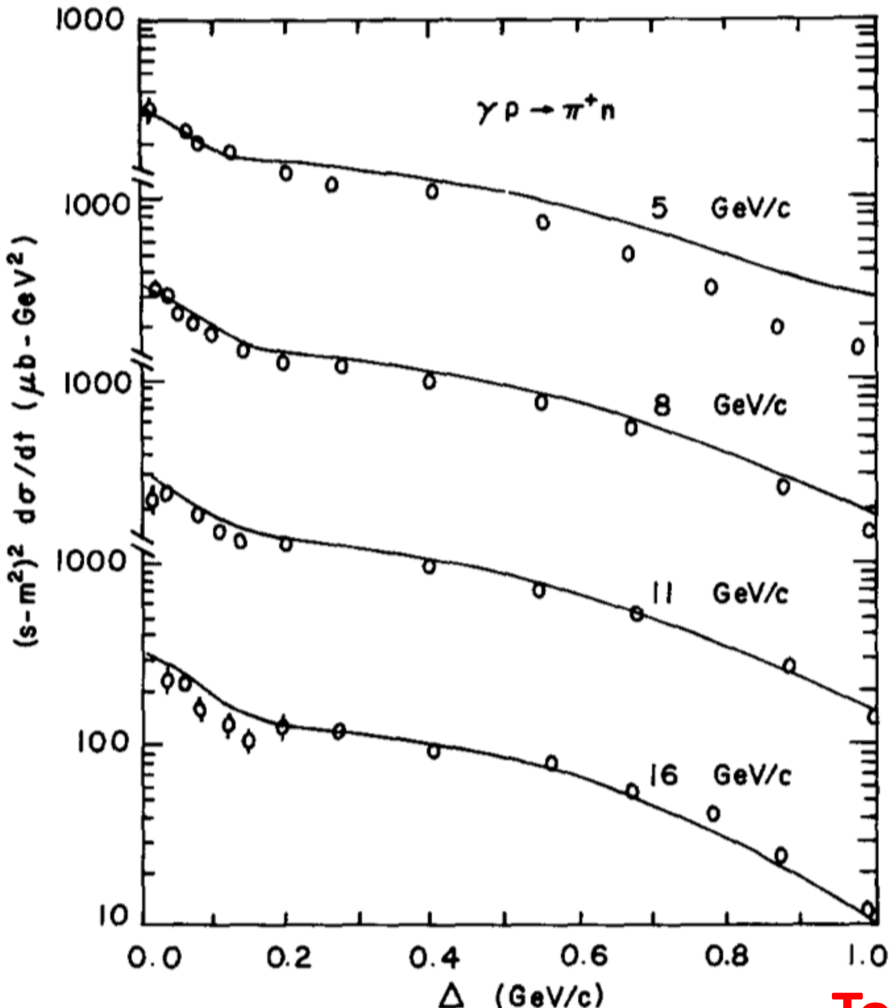


Fig. 2. The fit to $d\sigma/dt$ for $\gamma p \rightarrow \pi^+ n$.

"conspiracy" Δ^2: RP cuts!

$d\sigma/dt$ for π^- & π^+

Σ beam asymmetry

Ratio π^- / π^+

Target asymmetry

P recoil pol. asymm

Includes **R P**
AND **R R** cuts
+ "background term"
for higher |t|

To be updated

In process

- $\gamma + N \rightarrow \pi^{\pm} \Delta$
- $\gamma + N \rightarrow K\Lambda$ & $K\Sigma$

OTHER REGGE TYPE APPROACHES

- Mathieu, Fox, Szczepaniak PRD92 & 95 [JPAC]
- Kashevarov, Ostrick, Tiator PRC 96
- Donnachie & Kalashnikova, PRC 93
- Guidal, Laget, Vanderhaeghen, NPA627; LagetPRC72

PQCD inspired handbag approach

- Kroll, et al. EPJC 17, 33, 73; EPJA53

Summary B.

- Meson Photoproduction shows traditional Regge behavior
  - – s dependence, dips in cross sections
- Asymmetries show conflict with NWSZ, but behavior of $d\sigma/dt$ has dips
- Wide angle constituent counting rules ?
- PQCD & “handbag” orders of magnitude low