Generalized Parton Distributions Experimental Challenges and Opportunities

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Hall A Workshop

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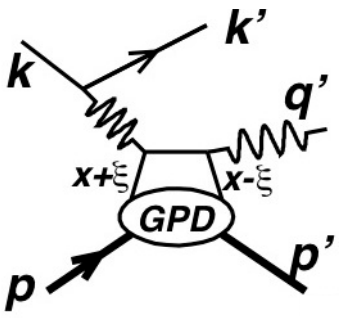
PDFs, GPDs, and Form Factors

- Forward parton distributions *q(x)*
  - Accessible from DIS cross sections
- Generalized parton distributions *H(x,ξ,t)*
  - Accessible from the deep excusive scattering amplitude (DVCS, mesons…)
  - ξ fixed by kinematics, $\xi \approx x_B/(2-x_B)$
    - *x* = average momentum fraction
    - 2ξ = skewness
- Form factors:
  - Accessible in amplitude of elastic (e,e')

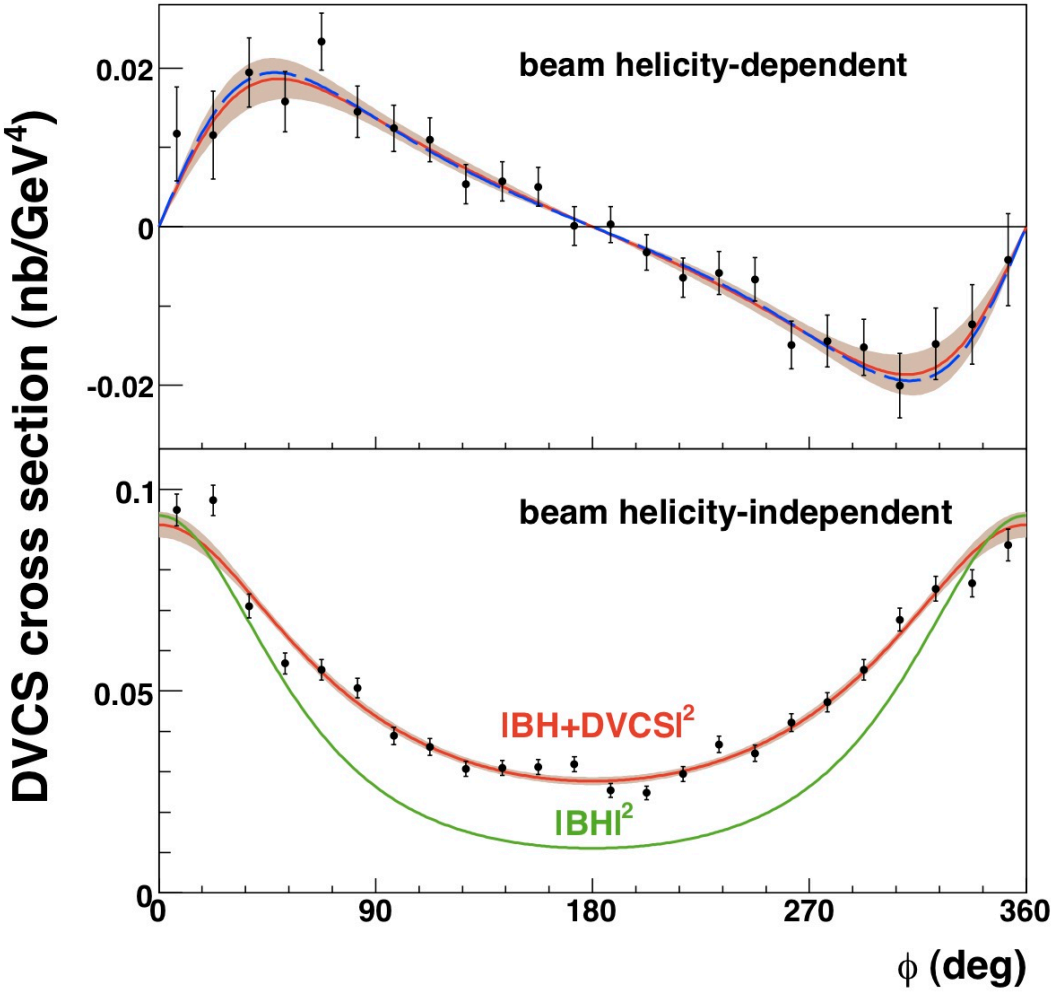


Leading Twist and Higher Twist

- GPDs and PDFs are the leading term in a $1/Q^2$ expansion of the cross section (or amplitude).
- Precision cross sections *vs* Q^2 are essential for isolating the leading twist terms.
  - Hall A data suggests $Q^2 \geq 2$ GeV^2 sufficient for DVCS
  - HERA data suggests strong corrections for finite meson size even for $Q^2 \sim 10$ GeV^2 in Deep Meson
    - Vector meson data probably easier to interpret than pseudoscalar production

Hall A E00-110 H(*e,e'γ*)*p*

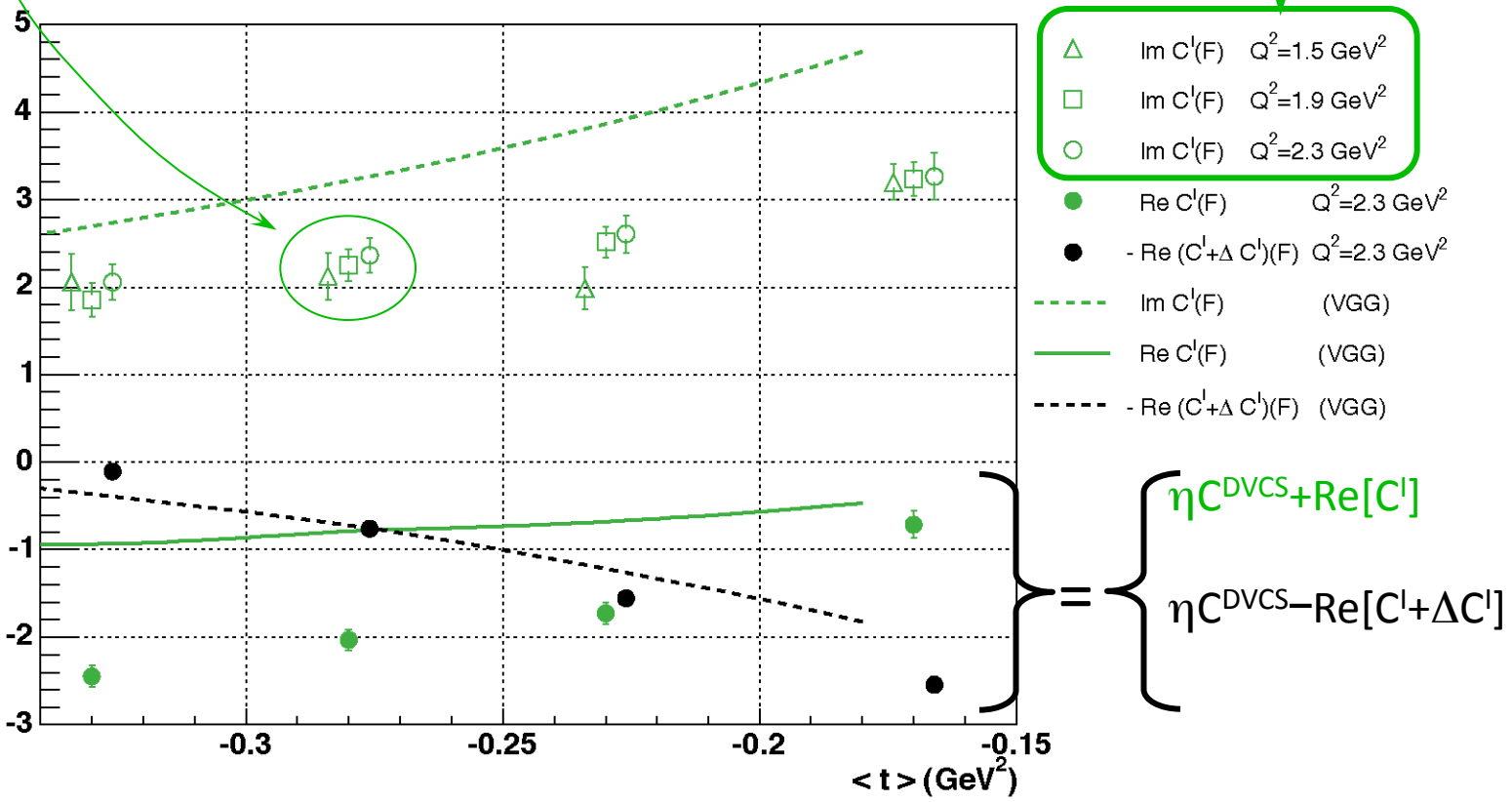
- C. Muñoz *et al.*
- Azimuthal dependence in one bin in Q^2, x_B, t
- $\Delta\sigma \sim Im[DVCS^*BH] \sim GPD(\xi,\xi,t)$
- $d\sigma \sim |BH|^2 + Re[DVCS^*BH] + |DVCS|^2$
  - Separation à *la* "Rosenbluth" in E07-007 (2010)



GPD Results, Helicity-Dependent Cross Sections

(C.Muñoz Camacho, *PRL* **97**:262002)

- Q^2-independence of the imaginary part of the interference
  - Dominance of Twist-2 (GPD)
  - « VGG » model correct to 30%



Flavor Separation

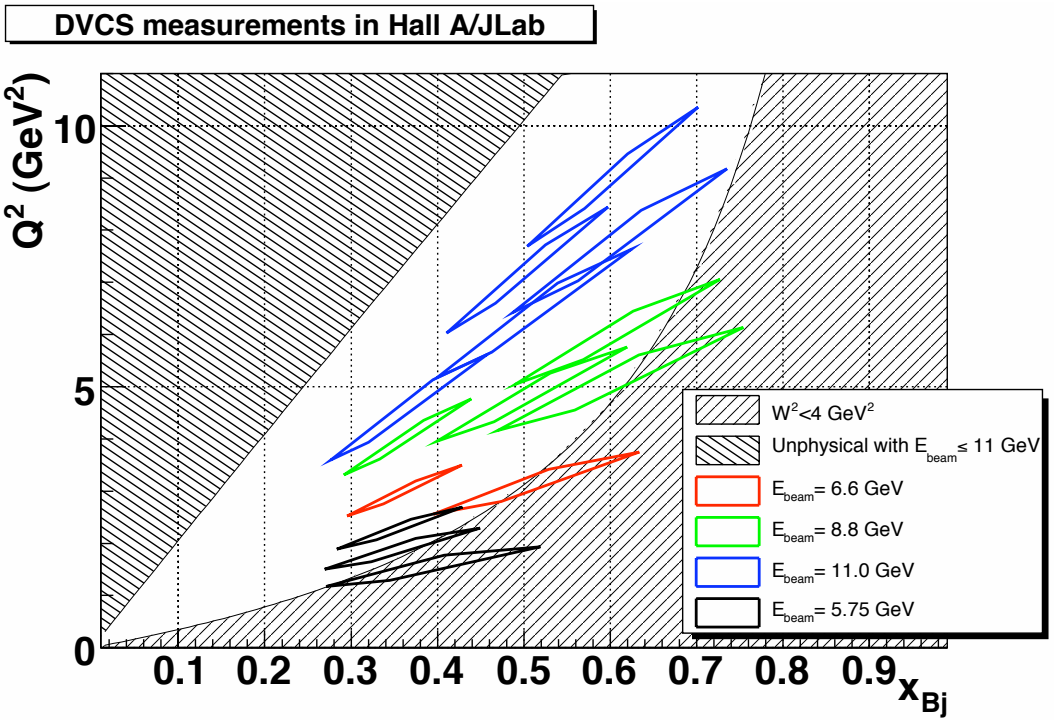
- u/d separation possible with p/n DVCS
  - nuclear corrections for quasi free n(e,e'γ)n on D, ^{3}He targets
  - Exclusivity challenges to separate coherent and QF DVCS at low *t*.
    - Recoil tagging of either coherent nucleus or spectator protons
    - Direct neutron detection.
    - Are either options feasible in Hall A/C at L>10^{36} ?
- u/d/s separation in principle accessible via deep meson production
- Gluons accessible in J/Ψ production, deep ϕ, and QCD evolution of (p+n) DVCS
  - LOI submitted (E. Fuchey, C. Hyde) for Deep-ϕ with SBS

QCD Evolution

- Theory is well understood.
  - Incorporated into GPD models
- Must be included in extraction of leading twist
  - $A \sim \mathrm{GPDs}(\ln Q^2) + \Sigma_n \mathrm{HT}_n(\ln Q^2) / Q^{2n}$
- Evolution is small in `sweet spot' of JLab $0.2 < x_B < 0.5$

DVCS at 12 GeV

- Cross sections on unpolarized targets *vs* Q^2 to isolate Leading-Twist
- Complete measurements with longitudinally and transversely polarized targets
  - Isolate all four proton GPDs on "diagonal" $H(\xi,\xi,t)$, $E(\xi,\xi,t)$, $\tilde{H}(\xi,\xi,t)$, $\tilde{E}(\xi,\xi,t)$
- All evidence suggests the importance of the precision of spectometers
- Continue with D, ^{3}He
  - Need cross sections on neutron



DVCS Interference Terms, Polarized Target

$$s_1^{\mathcal{I}} = 8K\lambda y(2-y)\Im\mathrm{m}\left[C^I(\mathcal{F})\right]$$

$$\mathcal{C}^{\mathcal{I}}_{\mathrm{unp}} = F_1\mathcal{H} + \frac{x_{\mathrm{B}}}{2-x_{\mathrm{B}}}(F_1+F_2)\widetilde{\mathcal{H}} + \frac{\Delta^2}{4M^2}F_2\mathcal{E}$$

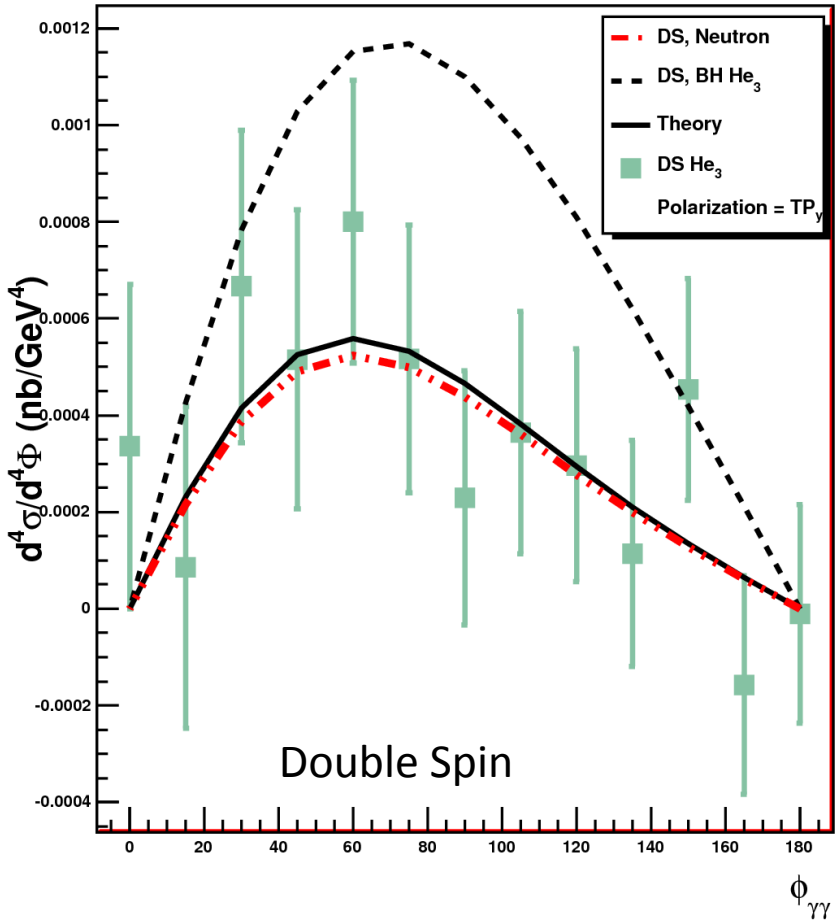
$$\mathcal{C}^{\mathcal{I}}_{\mathrm{LP}} = \frac{x_{\mathrm{B}}}{2-x_{\mathrm{B}}}(F_1+F_2)\left(\mathcal{H} + \frac{x_{\mathrm{B}}}{2}\mathcal{E}\right) + F_1\widetilde{\mathcal{H}} + \frac{x_{\mathrm{B}}}{2-x_{\mathrm{B}}}\left(\frac{x_{\mathrm{B}}}{2}F_1 + \frac{\Delta^2}{4M^2}F_2\right)\widetilde{\mathcal{E}}$$

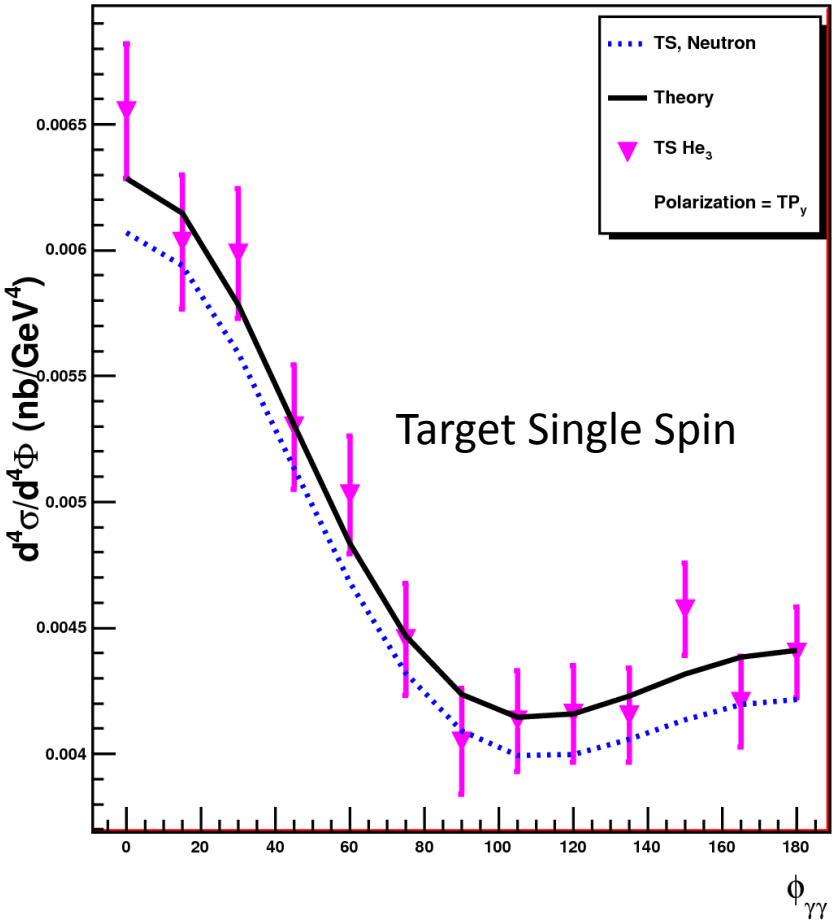
$$\mathcal{C}^{\mathcal{I}}_{\mathrm{TP}+} = (F_1+F_2)\left\{\frac{x_{\mathrm{B}}^2}{2-x_{\mathrm{B}}}\left(\mathcal{H} + \frac{x_{\mathrm{B}}}{2}\mathcal{E}\right) - \frac{x_{\mathrm{B}}\Delta^2}{4M^2}\mathcal{E}\right\} - \frac{x_{\mathrm{B}}^2}{2-x_{\mathrm{B}}}F_1\left(\widetilde{\mathcal{H}} + \frac{x_{\mathrm{B}}}{2}\widetilde{\mathcal{E}}\right)$$
$$+\frac{\Delta^2}{4M^2}\left\{4\frac{1-x_{\mathrm{B}}}{2-x_{\mathrm{B}}}F_2\widetilde{\mathcal{H}} - \left(x_{\mathrm{B}}F_1 + \frac{x_{\mathrm{B}}^2}{2-x_{\mathrm{B}}}F_2\right)\widetilde{\mathcal{E}}\right\}$$

$$\mathcal{C}^{\mathcal{I}}_{\mathrm{TP}-} = \frac{1}{2-x_{\mathrm{B}}}\left(x_{\mathrm{B}}^2F_1 - (1-x_{\mathrm{B}})\frac{\Delta^2}{M^2}F_2\right)\mathcal{H} + \left\{\frac{\Delta^2}{4M^2}\left((2-x_{\mathrm{B}})F_1 + \frac{x_{\mathrm{B}}^2}{2-x_{\mathrm{B}}}F_2\right)\right.$$
$$\left.+\frac{x_{\mathrm{B}}^2}{2-x_{\mathrm{B}}}F_1\right\}\mathcal{E} - \frac{x_{\mathrm{B}}^2}{2-x_{\mathrm{B}}}(F_1+F_2)\left(\widetilde{\mathcal{H}} + \frac{\Delta^2}{4M^2}\widetilde{\mathcal{E}}\right)$$

^{3}He(e,e'γ)npp 7 days@10^{37} ✕ HRS Polarized-X (sideways)

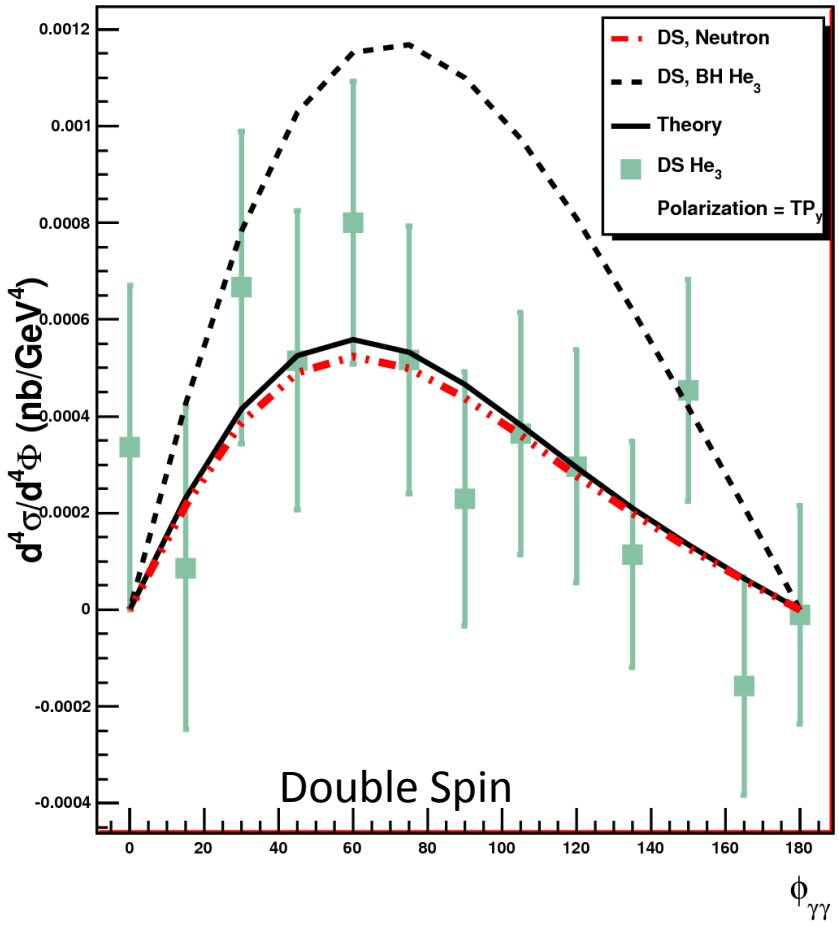
k=8.8 GeV, Q^2 = 3 GeV^2, x_B=0.36, $-t$=*0.21* GeV^2, Δt = *0.1* GeV^2

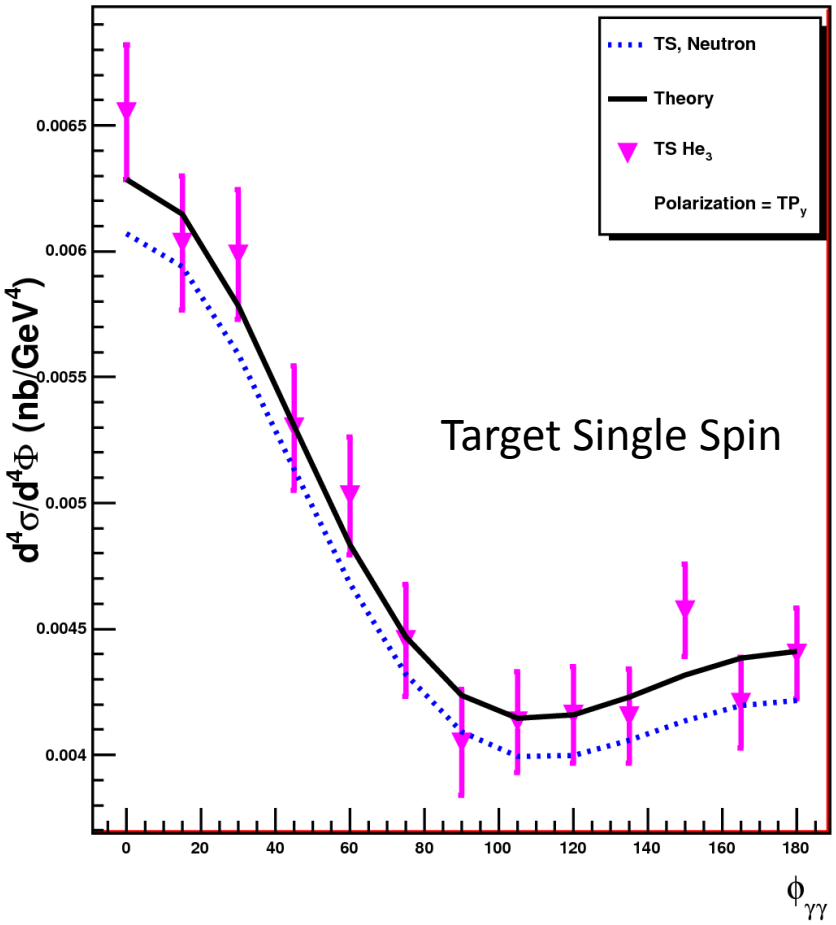




^{3}He(e,e'γ)npp 7 days@10^{37} × HRS Polarized-Y (normal)

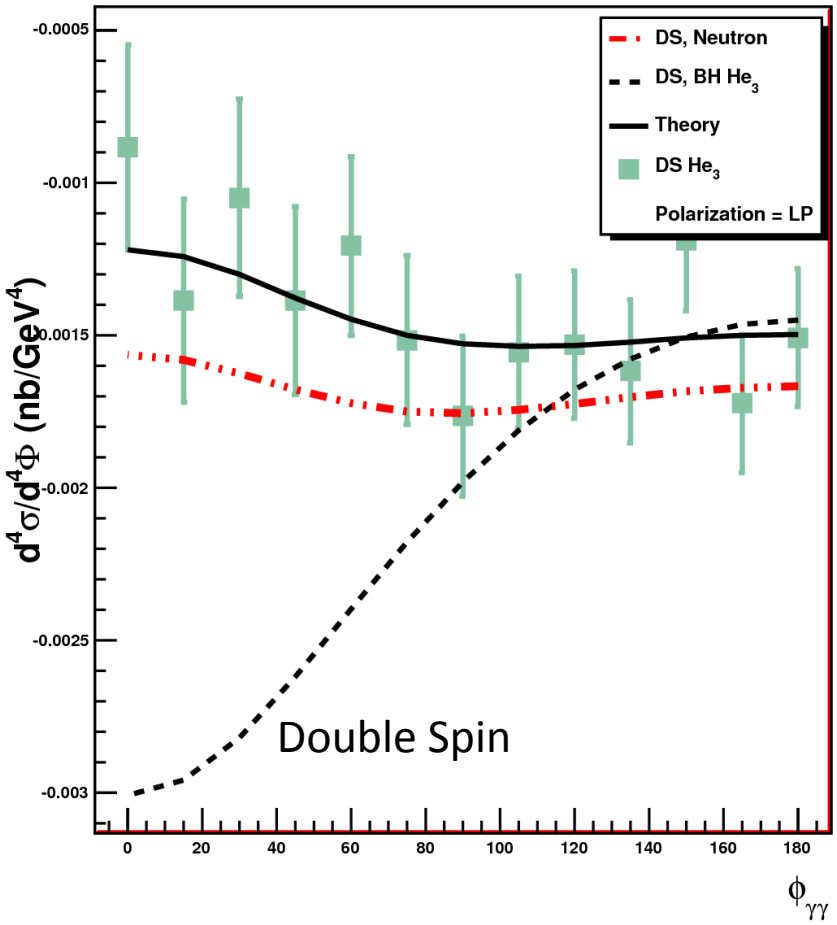
k=8.8 GeV, Q^2 = 3 GeV^2, x_B=0.36, $-t$=*0.21* GeV^2, Δt = *0.1* GeV^2

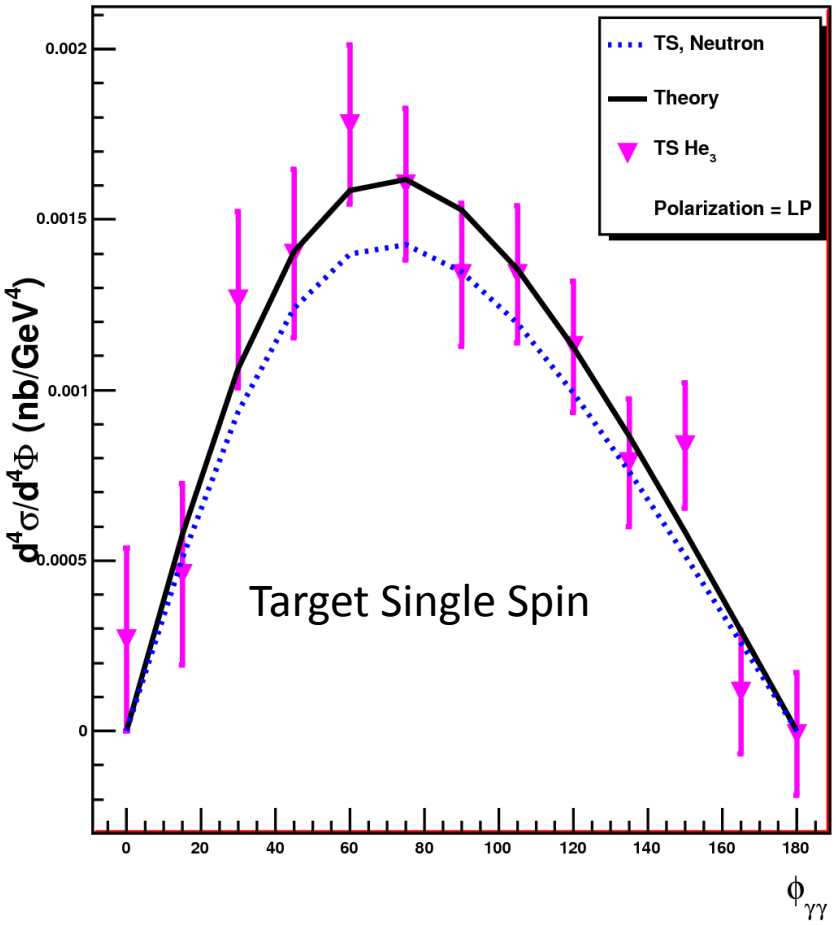




^{3}He(e,e'γ)npp 7 days@10^{37} × HRS
Polarized-Z (longitudinal)

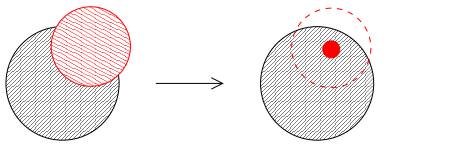
k=8.8 GeV, Q^2 = 3 GeV^2, x_B=0.36, $-t$=*0.21* GeV^2, Δt = *0.1* GeV^2



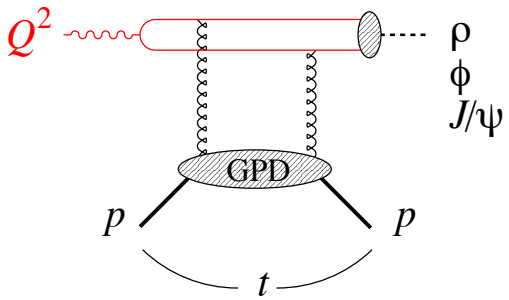


Deep Vector Meson

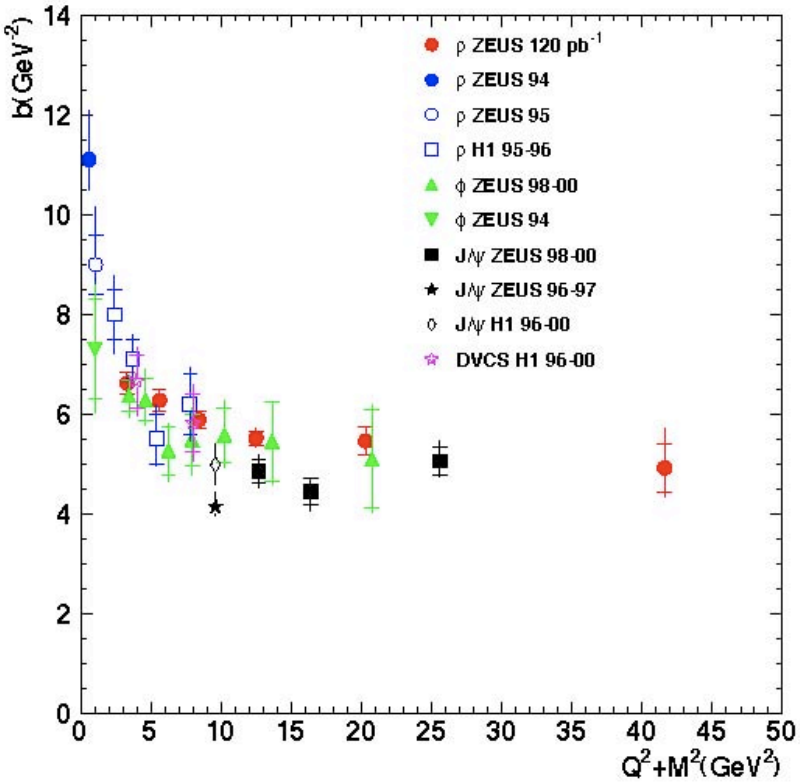
- Universal approach to scaling in *t*-slopes



(a) $Q^2 = 0$ $Q^2 \gg R^{-2}_{\text{hadron}}$



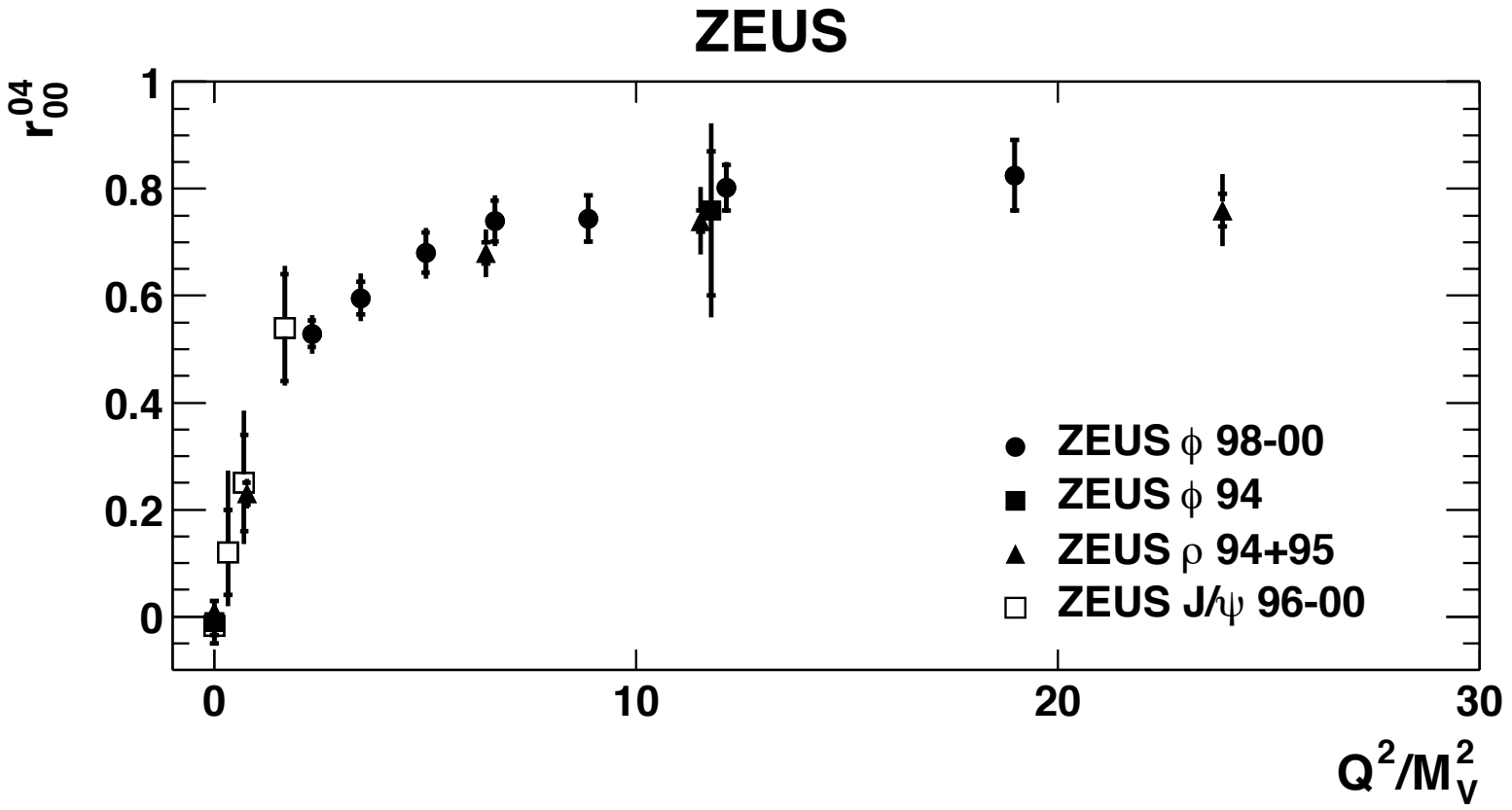
(c)



- Finite meson size corrections to perturbative *t*-channel amplitude

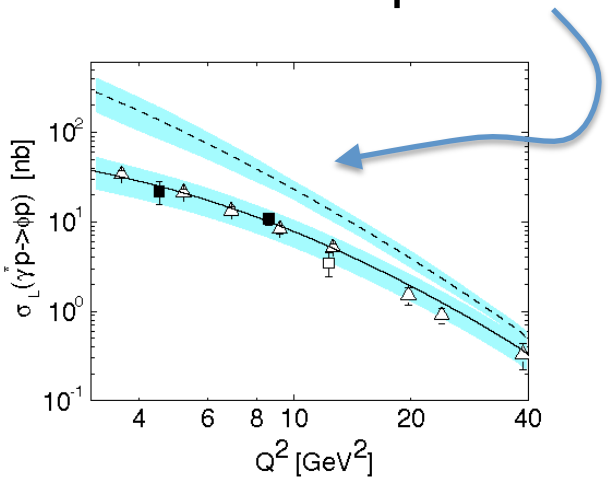
Extraction of σ_L from decay angular distribution

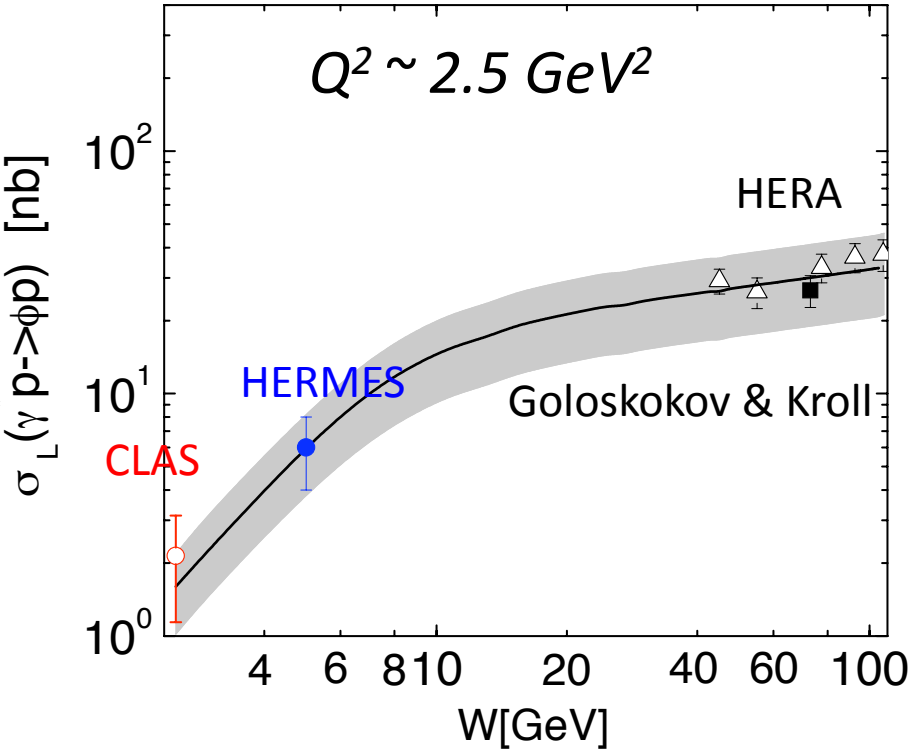
- Dominance of σ_L at large Q^2.
  - *ArXiv 0907-1217*



Deep ϕ Production

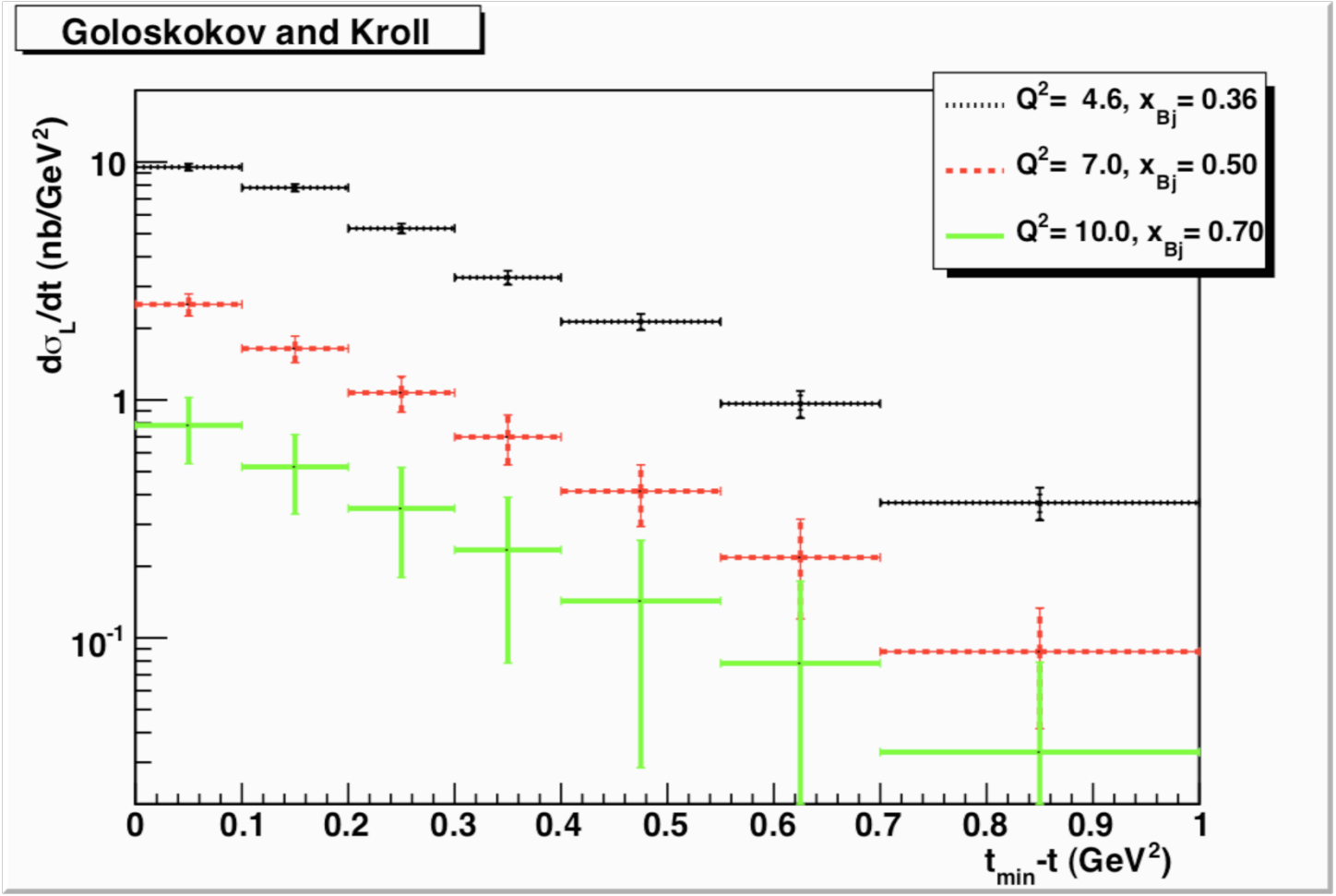
- Gluons dominate over *s*-quarks
- Evidence for two gluon exchange, but with large corrections for finite size of ϕ-meson





Deep Phi Hall A 2009 LOI HRSxSBS
E. Fuchey *et al*

- 30 days each setting
- 10^{37}
- p=n for gluons



Conclusions

- Cross sections are essential for realistic analysis of GPD data
- More work needed for targets/detectors for "neutron" targets D, ^{3}He
- Approved program is a good start.
  - Needs to run early
- A full program is required to fully deliver on the promise of spatial imaging.
- A full program can extract all GPDs on the diagonal $x=\xi$.