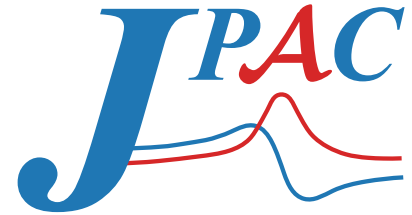


# $J/\psi$ Photoproduction Near Threshold: Where we are and where we can go



Daniel Winney  
Instituto de Ciencias Nucleares (ICN)  
Universidad Nacional Autónoma de México (UNAM)

Photoproduction Studies on the Deuteron and  
Helium-3 in Hall D  
20 April 2026



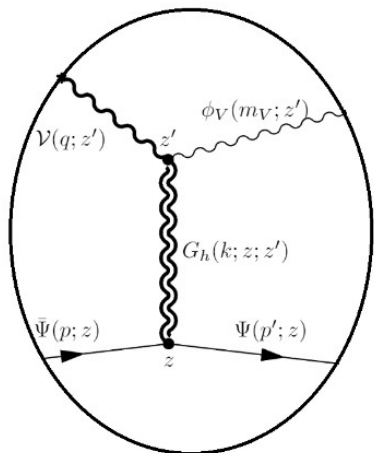
Instituto de Ciencias Nucleares UNAM



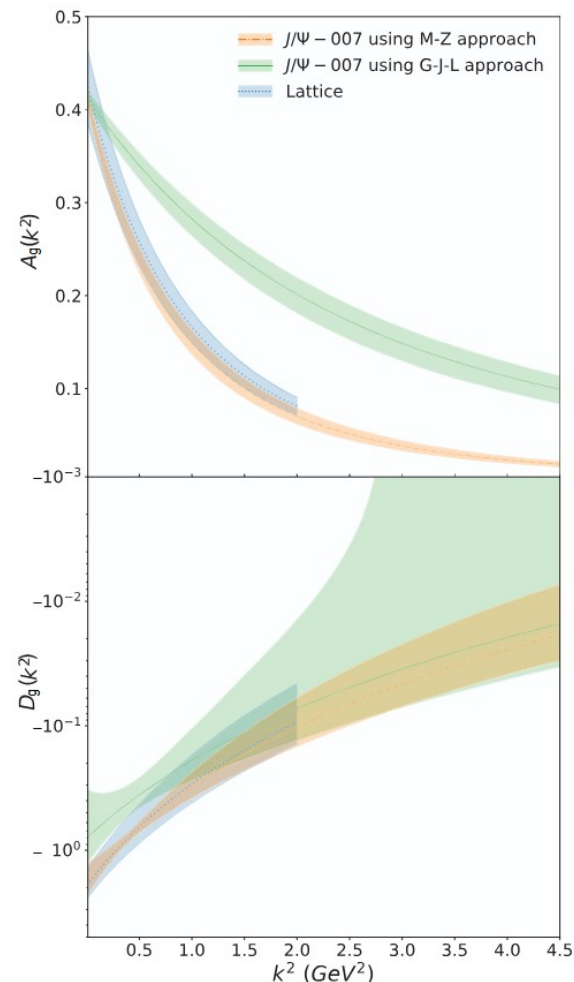
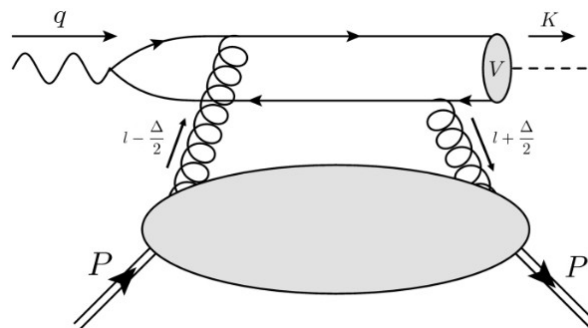
# Physics-rich reaction

## Key measurements of proton structure

May give experimental access to gluon gravitational form factors, mass radius, and trace anomaly contributions to proton mass



Guo, Ji, & Liu [Phys.Rev.D 103 (2021) 9, 096010]



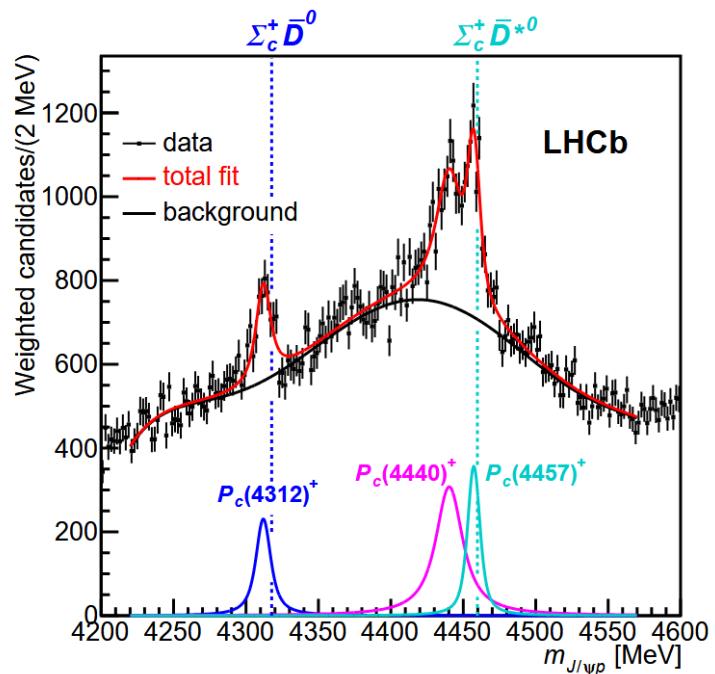
Mamo & Zahed [Phys.Rev.D 101 (2020) 8, 086003]

$J/\psi$ -007 [Nature 615 (2023) 7954, 813-816] 2

# Physics-rich reaction

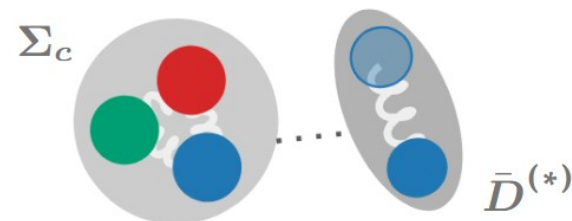
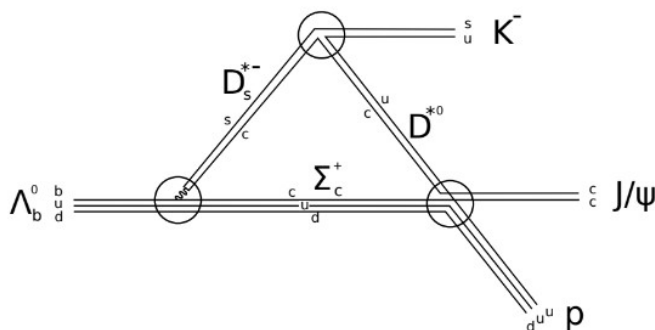
## Hidden charm pentaquarks

Direct access to the signal channel of five-quark states  
first seen at LHCb in 2015



LHCb [Phys.Rev.Lett. 122 (2019) 22, 222001]

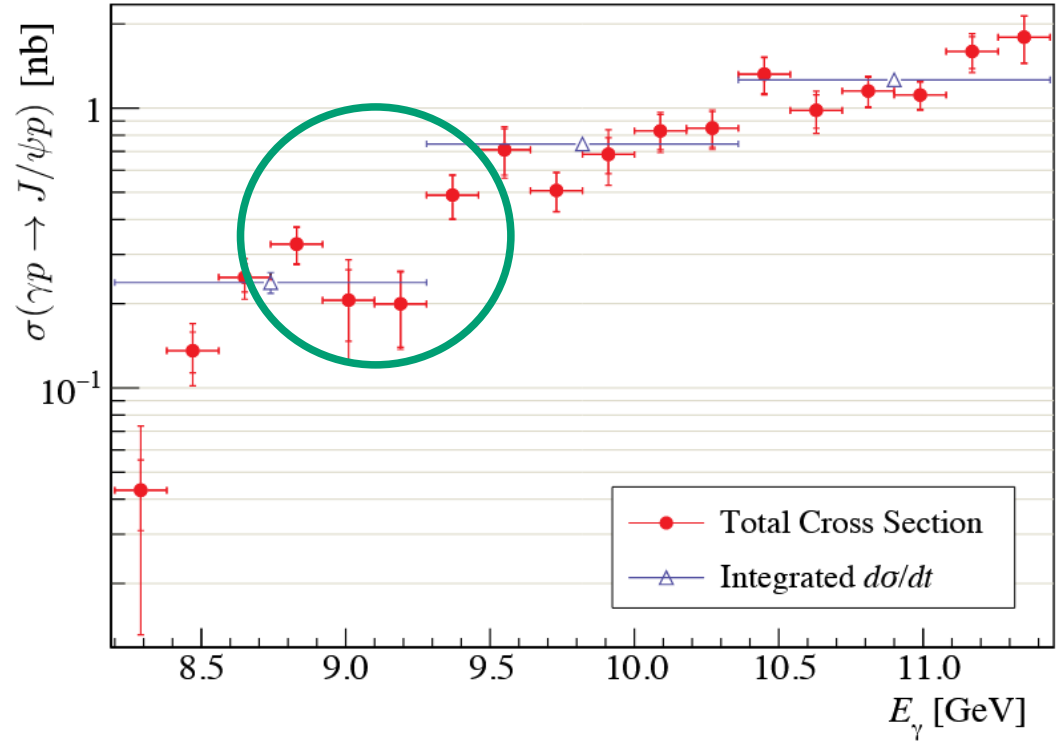
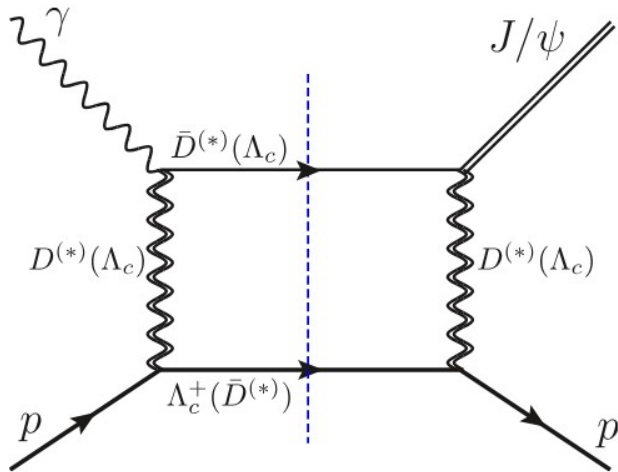
Mikhasenko [arXiv:1507.06552]



Direct photoproduction  
removes possible triangle  
singularities!

# Status as of 2023

Du et al. [Eur.Phys.J.C 80 (2020) 11, 1053]



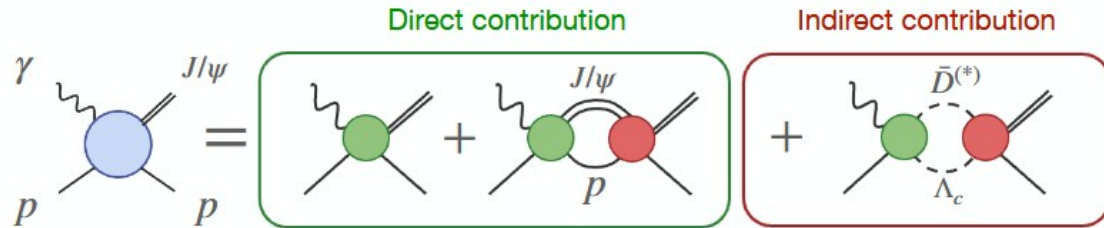
GlueX [Phys.Rev.C 108 (2023) 2, 025201]

# Status as of 2023

“Size” of cusps can be misleading...

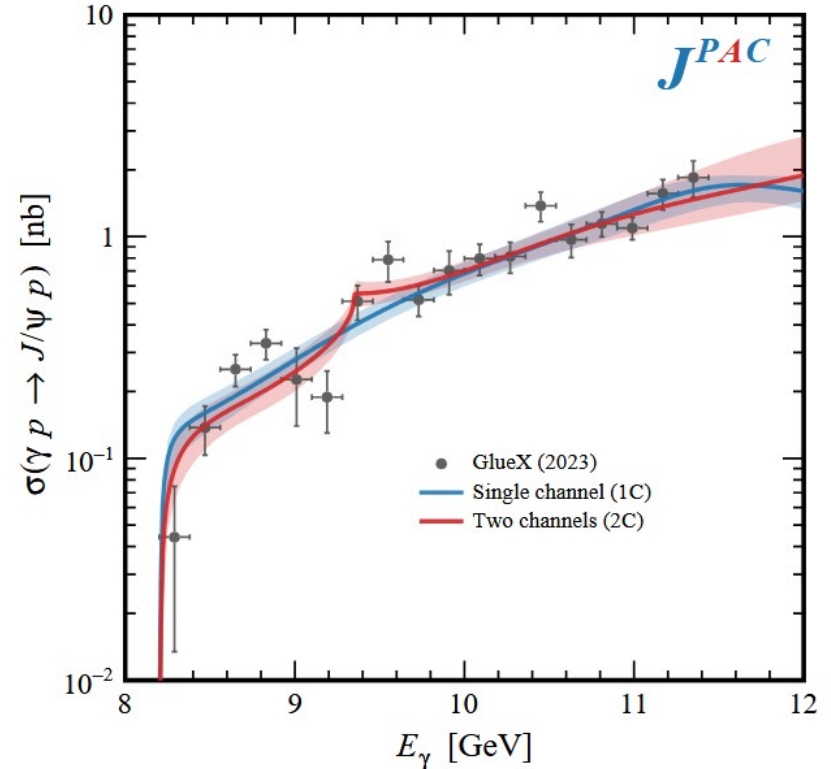
$$\zeta_{\text{th}} = \frac{|F_{\text{direct}}^{\psi p}(s_{\text{th}})|}{|F_{\text{direct}}^{\psi p}(s_{\text{th}})| + |F_{\text{indirect}}^{\psi p}(s_{\text{th}})|} < 0.75$$

Unitarity is also often ignored completely...



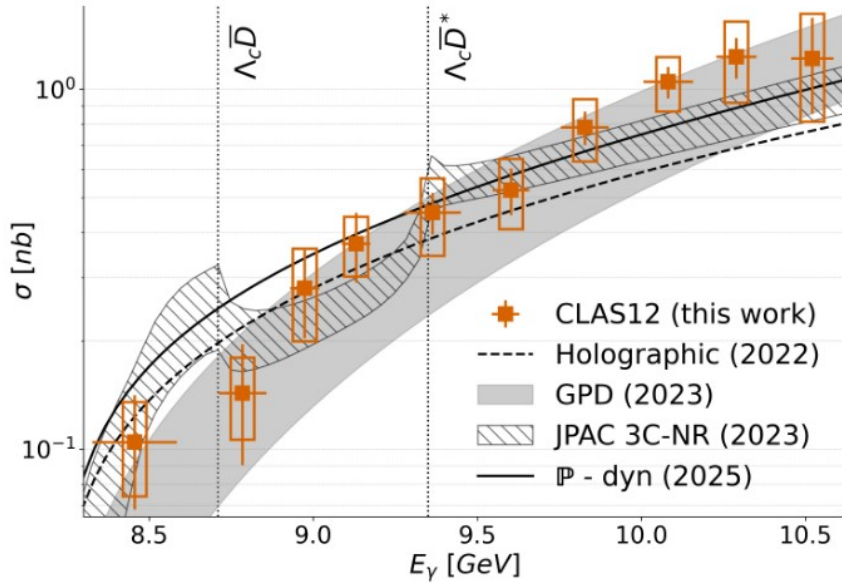
Not enough to simply plot a curve through the data points!

JPAC [Phys.Rev.D 108 (2023) 5, 054018]

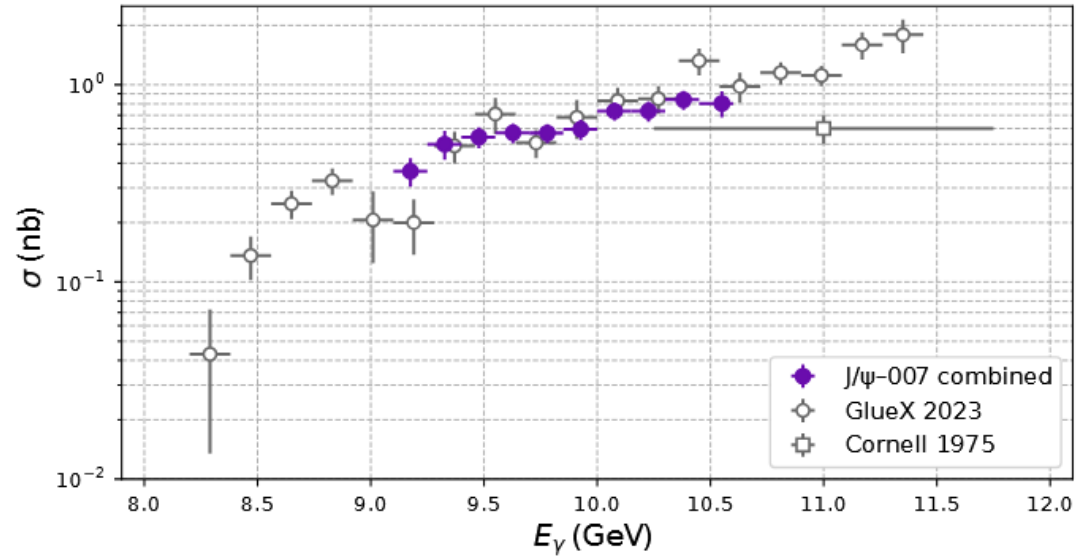


# Status as of 2026

CLAS [arXiv:2602.22128]

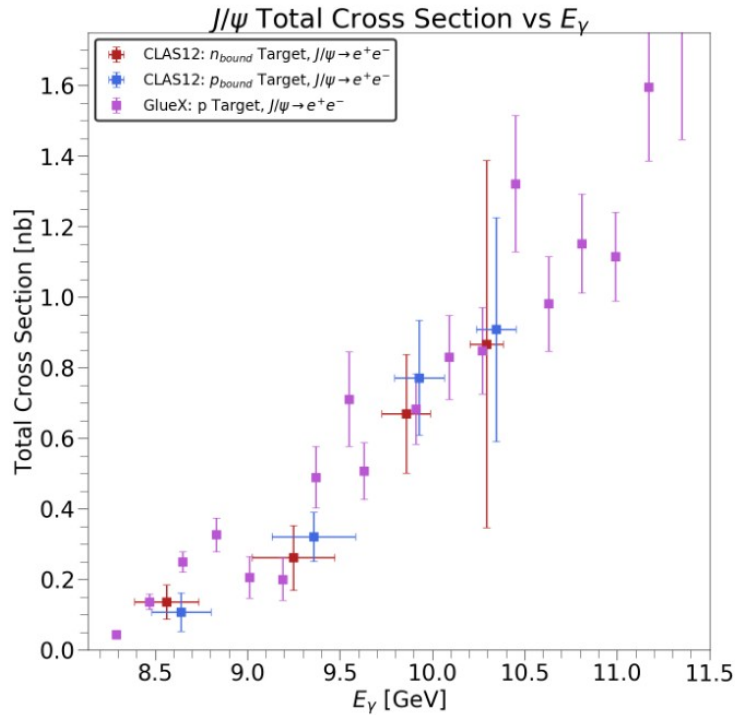


J/ $\psi$ -007 [arXiv:2602.14416]



# Studies on LD2 target

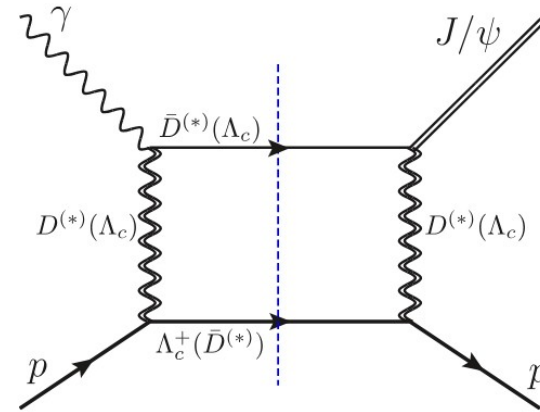
R. Tyson [PhD Thesis, U. Glasgow]



Photon vertex introduces charge-asymmetry in open-charm loop mechanism...

$$\gamma \rightarrow D^{*+} D^{*-} = F_{I=0} + F_{I=1}$$

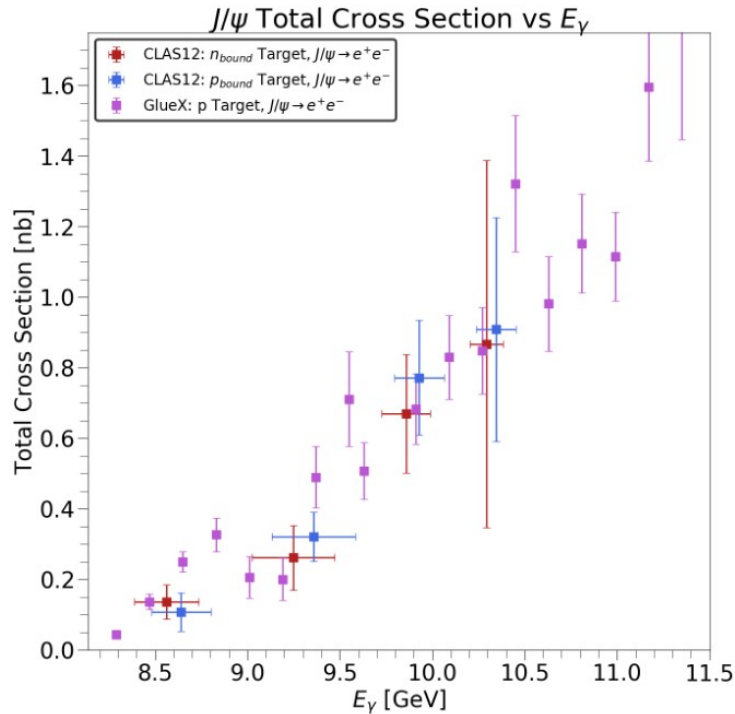
$$\gamma \rightarrow D^{*0} \bar{D}^{*0} = F_{I=0} - F_{I=1}$$



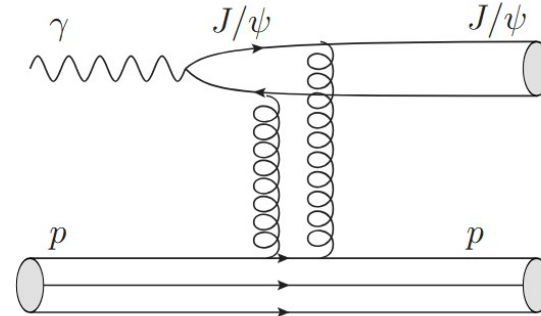
Charge conservation forbids electric interactions in proton target but not neutron!

# Studies on LD2 target

R. Tyson [PhD Thesis, U. Glasgow]



Gluon exchanges, however, are isospin invariant!



Upper bound on the proton-neutron production asymmetry can help distinguish production mechanisms!

# Other studies

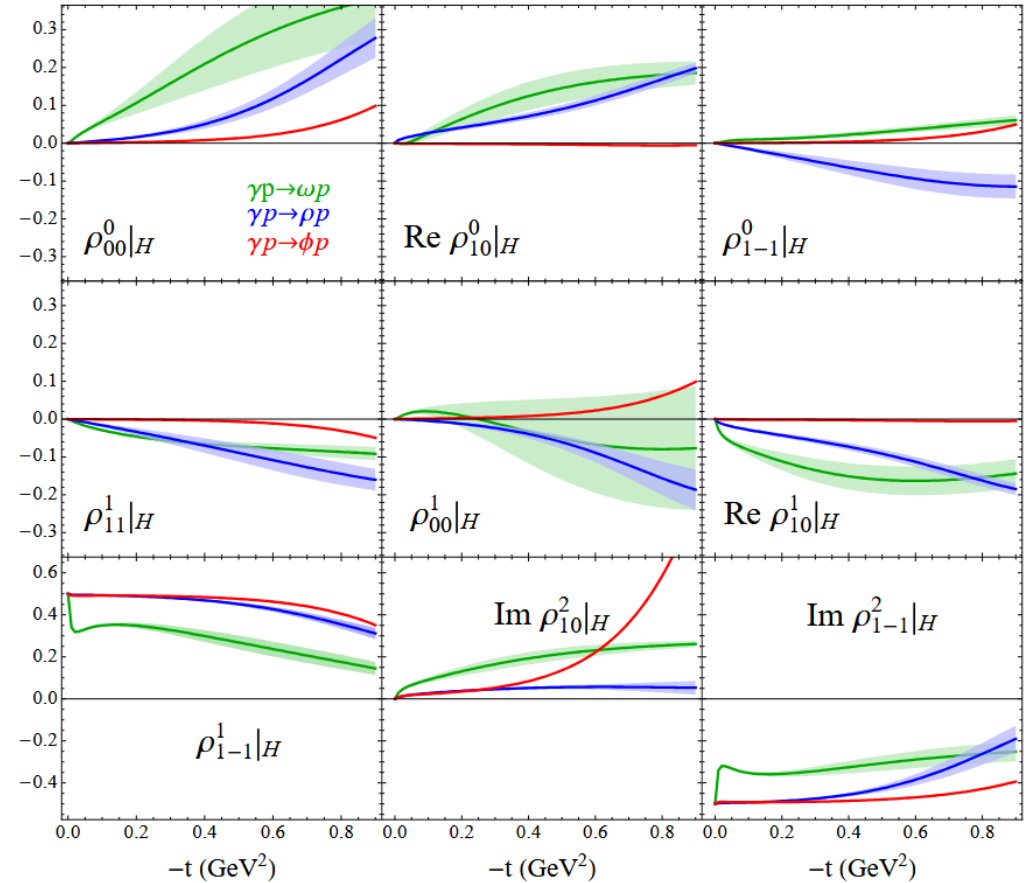
JPAC [Phys.Rev.D 97 (2018) 9, 094003]

Helicity dependence is another important tool to access production dynamics.

$$\rho_{\lambda\lambda'}^0 = \frac{1}{N} \sum_{\lambda_\gamma \lambda_p \lambda_{p'}} \langle \lambda_\gamma, \lambda_p | T | \lambda, \lambda_{p'} \rangle \langle \lambda', \lambda_{p'} | T^* | \lambda_\gamma, \lambda_p \rangle$$

$$\rho_{\lambda\lambda'}^1 = \frac{1}{N} \sum_{\lambda_\gamma \lambda_p \lambda_{p'}} \langle \lambda_\gamma, \lambda_p | T | \lambda, \lambda_{p'} \rangle \langle -\lambda', \lambda_{p'} | T^* | \lambda_\gamma, \lambda_p \rangle$$

$$\rho_{\lambda\lambda'}^2 = \frac{-i}{N} \sum_{\lambda_\gamma \lambda_p \lambda_{p'}} \lambda_\gamma \langle \lambda_\gamma, \lambda_p | T | \lambda, \lambda_{p'} \rangle \langle -\lambda', \lambda_{p'} | T^* | \lambda_\gamma, \lambda_p \rangle$$



# Helicity conservation

$J/\psi$  photoproduction is  $s$ -channel helicity conserving at high energies (Pomeron exchange)

$$\langle \lambda, \lambda_{p'} | T | \lambda_\gamma \lambda_p \rangle \propto (\epsilon_\gamma \cdot \epsilon_\psi^*) \propto \delta_{\lambda_\gamma \lambda_\psi}$$

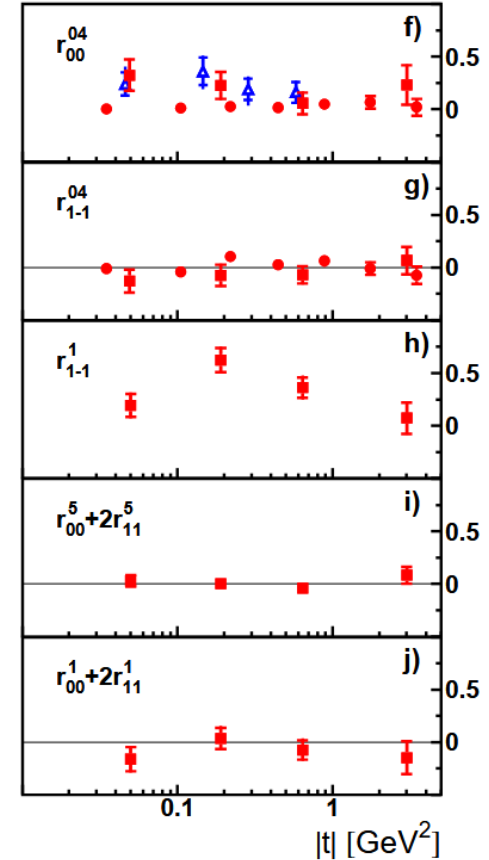
$$\rho_{\lambda\lambda'}^\alpha = 0 \quad \text{except} \quad \rho_{1,-1}^1 = -\text{Im} \rho_{1,-1}^2 = \frac{1}{2}$$

Sometimes assumed at low energies too...

$$\mathcal{M}(\varepsilon_V, \varepsilon) = \frac{8\sqrt{2}\pi\alpha_S(M_V)}{M_V^2} \phi^*(0) G(t, \xi) (\varepsilon_V^* \cdot \varepsilon)$$

Guo, Ji, & Liu [Phys.Rev.D 103 (2021) 9, 096010]

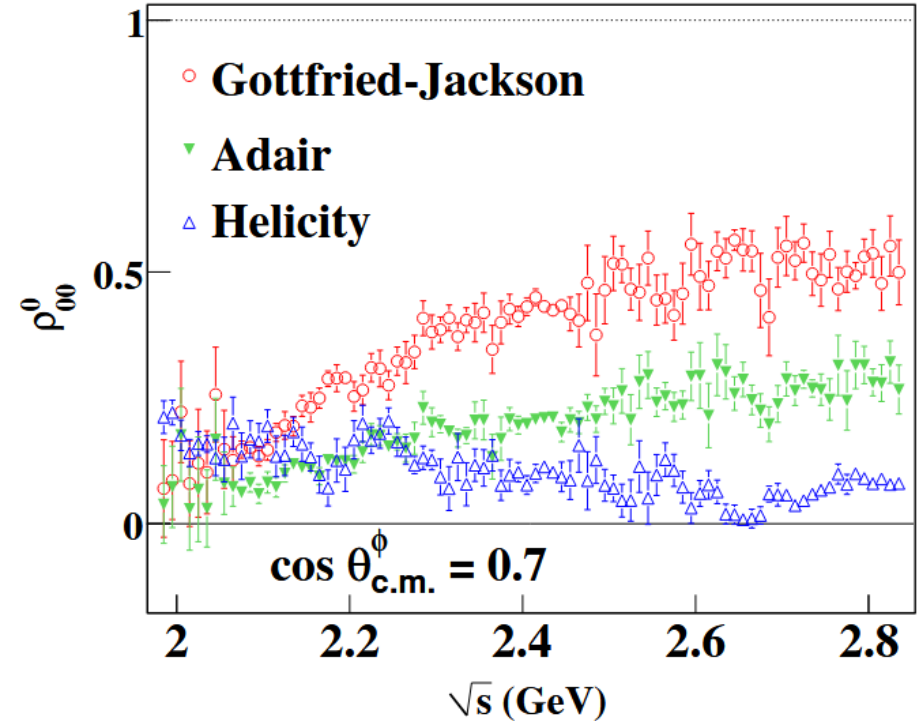
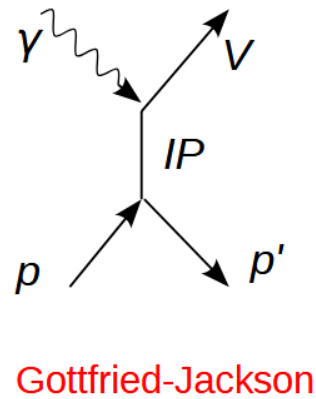
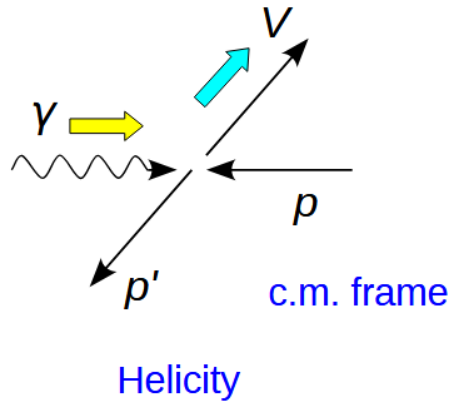
H1 [Eur.Phys.J.C 46 (2006) 585-603]



# Helicity conservation

CLAS [Phys.Rev.C 89 (2014) 5, 055208]

SCHC observed to not hold in near-threshold  $\phi$  photoproduction....



How do the holographic or GPD frameworks change if there non-trivial helicity structure?

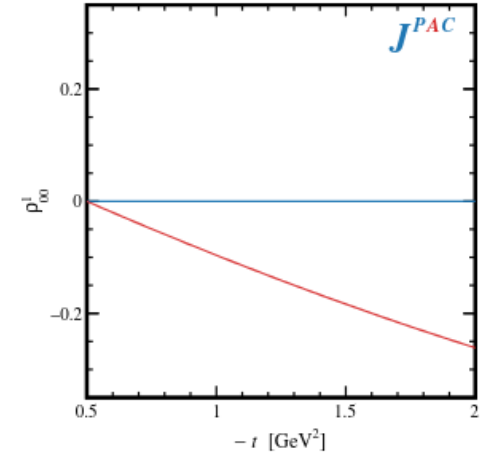
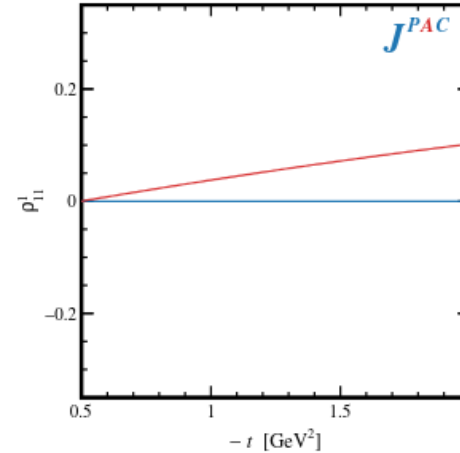
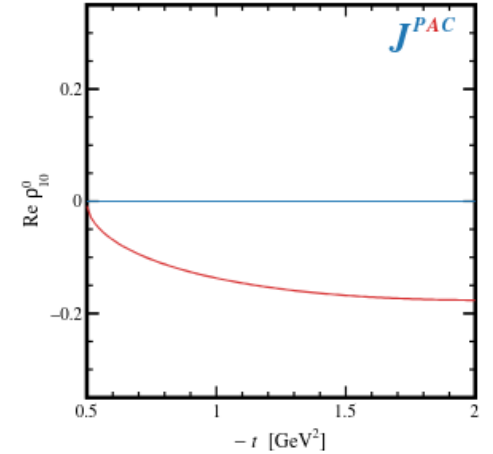
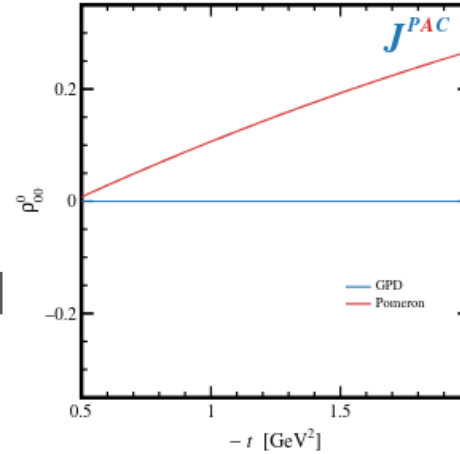
# Helicity conservation

JPAC [Phys. Rev. D 100, 034019 (2019)]

$$\langle \lambda, \lambda_{p'} | T | \lambda_\gamma \lambda_p \rangle \propto (\bar{u} \gamma_\mu u) [\epsilon_\gamma^\mu (q \cdot \epsilon_\psi^*) - (\epsilon_\gamma \cdot \epsilon_\psi^*) q^\mu]$$

12 possible helicity structures... need helicity dependence predictions to connect measurement to models!

$$\begin{aligned} l_1^{\mu\nu} &= P^\mu [(P \cdot q) k^\nu - (k \cdot q) P^\nu] , & l_7^{\mu\nu} &= q^\mu \gamma^\nu \not{q} , \\ l_2^{\mu\nu} &= (k \cdot q) g^{\mu\nu} - q^\mu k^\nu , & l_8^{\mu\nu} &= P^\mu \gamma^\nu \not{q} , \\ l_3^{\mu\nu} &= (P \cdot q) g^{\mu\nu} - q^\mu P^\nu , & l_9^{\mu\nu} &= \gamma^\mu [(P \cdot q) k^\nu - (k \cdot q) P^\nu] \\ l_4^{\mu\nu} &= g^{\mu\nu} \not{q} - q^\mu \gamma^\nu , & l_{10}^{\mu\nu} &= \gamma^\mu [(k \cdot q) \gamma^\nu - k^\nu \not{q}] , \\ l_5^{\mu\nu} &= [(q \cdot P) g^{\mu\nu} - q^\mu P^\nu] \not{q} , & l_{11}^{\mu\nu} &= \gamma^\mu [(P \cdot q) \gamma^\nu - P^\nu \not{q}] \\ l_6^{\mu\nu} &= P^\mu [P^\nu \not{q} - (q \cdot P) \gamma^\nu] & l_{12}^{\mu\nu} &= \gamma^\mu \gamma^\nu \not{q} , \end{aligned}$$



**Thank you!**