Transverse Target-Spin Asymmetry Associated with DVCS on the Proton and a Resulting Model-Dependent Constraint on J_u vs J_d

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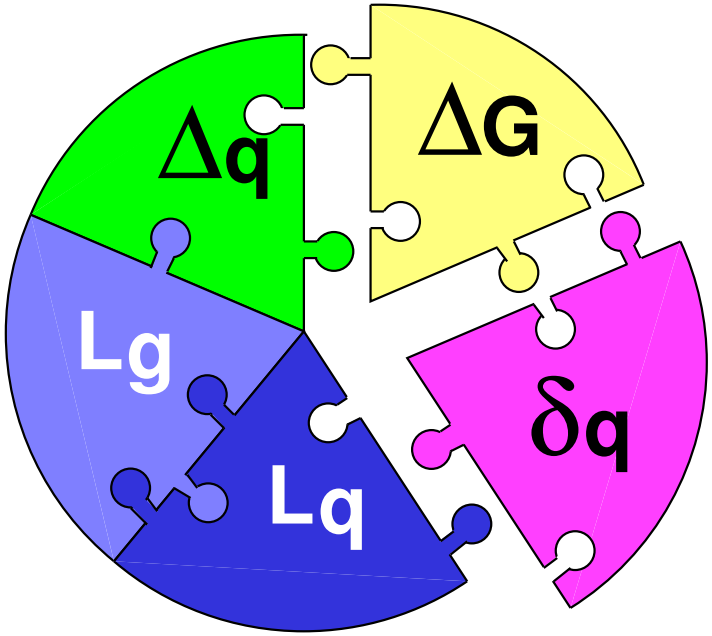
- Motivation: Spin Structure of the Nucleon from Generalized Parton Distributions
- Deeply Virtual Compton Scattering and Transverse Target-Spin Asymmetry
- The HERMES Experiment and the Preliminary Result on the TTSA
- A Model-Dependent Constraint on the Quark Total Angular Momenta in the Nucleon
- Summary and Outlook

Motivation: Spin Structure of the Nucleon



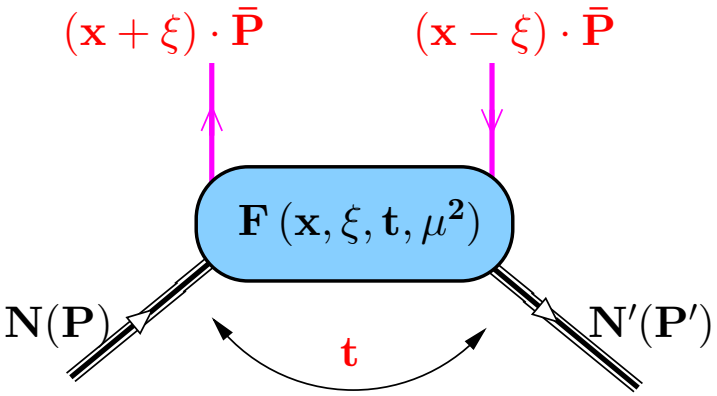
Nucleon Spin

$$\frac{1}{2} = \underbrace{\frac{1}{2}(\Delta u + \Delta d + \Delta s) + L_q}_{J_q} + \underbrace{\Delta G + L_g}_{J_g}$$

$\Delta\Sigma \sim 20 - 35\%$:	Measured in DIS
ΔG:	First measurements
L_q, L_g:	Unknown!

Generalized Parton Distributions $\Rightarrow$ J_q, J_g (L_q, L_g)

Generalized Parton Distributions



F: GPDs, defined through ME $\langle P'|\mathcal{O}_{q/g}|P\rangle$

$x \pm \xi$: Parton longitudinal momentum fractions

t: Invariant momentum transfer to the target

μ^2: Renormalization scale

- For a $S = \frac{1}{2}$ hadron, there are 4 twist-2 parton-helicity non-flip GPDs, H, E, $\widetilde{H}$, and $\widetilde{E}$:

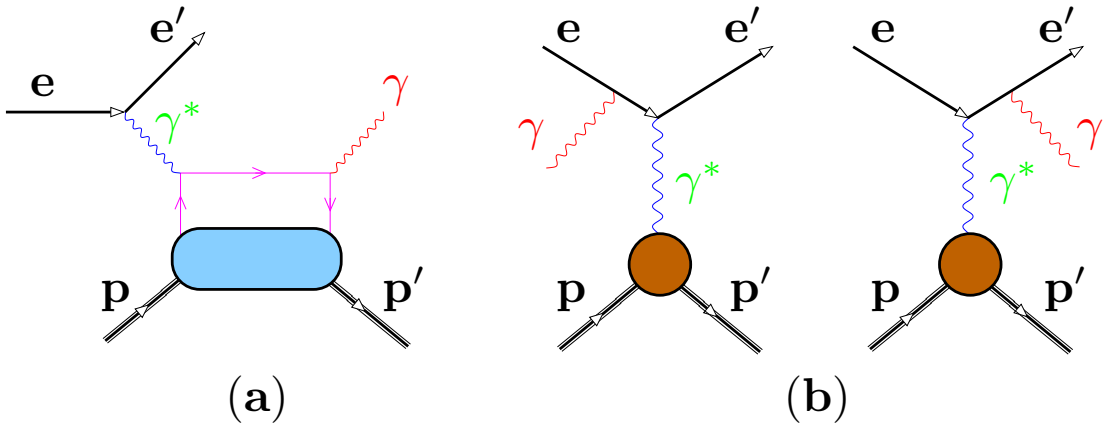
	unpolarized	polarized
nucleon-helicity non-flip	H	$\widetilde{H}$
nucleon-helicity flip	E	$\widetilde{E}$

- GPDs provide an access to J_q (Ji 1997):

$$J_q(\mu^2) = \frac{1}{2}\lim_{t\to 0}\int_{-1}^{1} dx\, x[H_q(x,\xi,t,\mu^2) + E_q(x,\xi,t,\mu^2)].$$

Deeply Virtual Compton Scattering

- The same final state in DVCS (a) and Bethe-Heithler (b) $\Rightarrow$ interference:



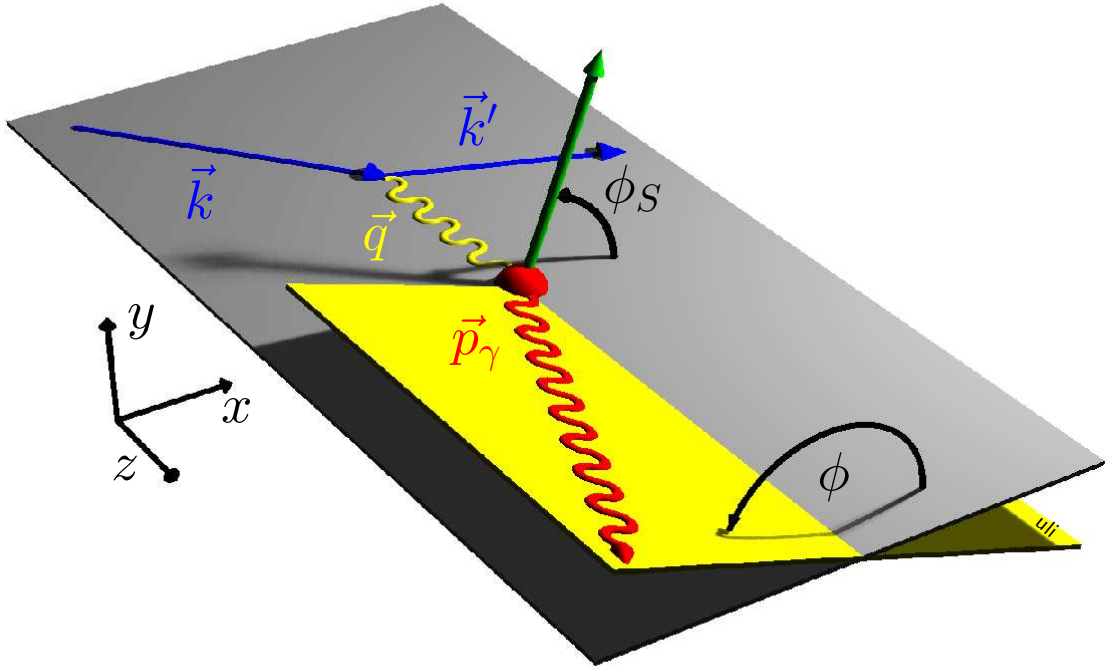
$$\sigma \propto |\mathcal{T}_{\rm BH}|^2 + |\mathcal{T}_{\rm DVCS}|^2 + \underbrace{(\mathcal{T}_{\rm BH}\mathcal{T}^*_{\rm DVCS} + \mathcal{T}^*_{\rm BH}\mathcal{T}_{\rm DVCS})}_{\mathcal{I}}$$

- $\mathcal{T}_{\rm BH}$ is parameterized in terms of nucleon FFs F_1 and F_2, calculable in QED.

- $\mathcal{T}_{\rm DVCS}$ is parameterized in terms of Compton FFs $\mathcal{H}$, $\mathcal{E}$, $\widetilde{\mathcal{H}}$, and $\widetilde{\mathcal{E}}$, which are convolutions of the respective GPDs with the hard-scattering kernels.

- At HERMES, $\mathcal{T}_{\rm BH} \gg \mathcal{T}_{\rm DVCS}$, $\mathcal{T}_{\rm DVCS}$ can be accessed through $\mathcal{I}$: both its amplitude and phase!

Transverse Target-Spin Asymmetry on the Proton



Transverse target-spin asymmetry (Ellinghaus, Nowak, Vinnikov, Ye, hep-ph/0506012)

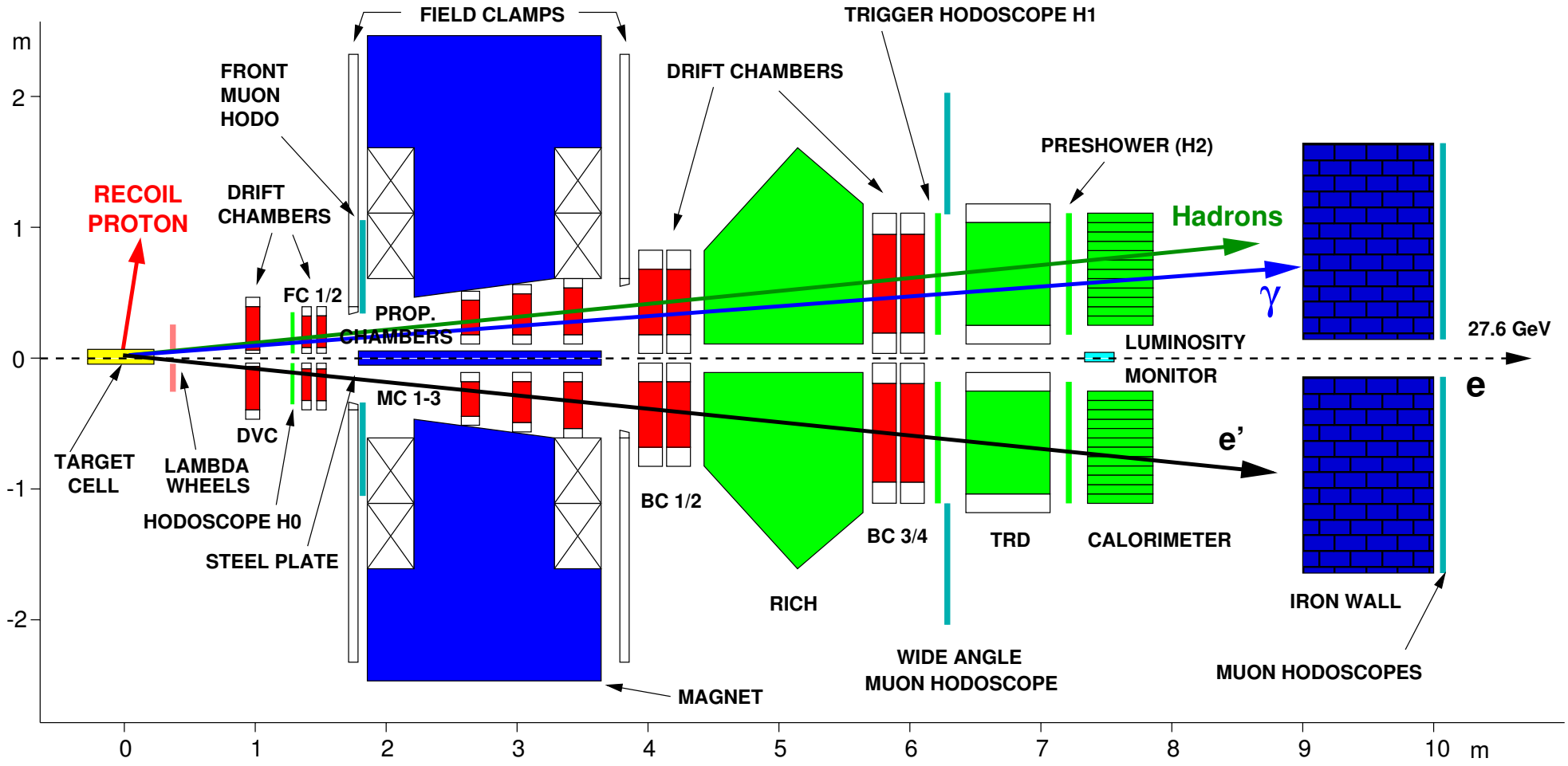
$$A_{UT}(\phi,\phi_s) = \frac{d\sigma(\phi,\phi_S)-d\sigma(\phi,\phi_S+\pi)}{d\sigma(\phi,\phi_S)+d\sigma(\phi,\phi_S+\pi)} \simeq \frac{\mathcal{I}^{\mathrm{TP}}}{\left|\mathcal{T}^{\mathrm{unp}}_{\mathrm{BH}}\right|^2}$$

$$\propto \mathrm{Im}[F_2\mathcal{H}-F_1\mathcal{E}]\cdot\sin(\phi-\phi_S)\cos\phi + \mathrm{Im}[F_2\widetilde{\mathcal{H}}-F_1\xi\widetilde{\mathcal{E}}]\cdot\cos(\phi-\phi_S)\sin\phi$$

$\Longrightarrow A_{\mathrm{UT}}^{\sin(\phi-\phi_S)\cos\phi}$ sensitive to $J_q = \frac{1}{2}\lim_{t\to 0}\int_{-1}^{1} dx\, x\,(H_q+E_q)$

The HERMES Experiment

- Transversely polarized hydrogen target data taking in 2002-2005.
- Recoiling protons were not detected.

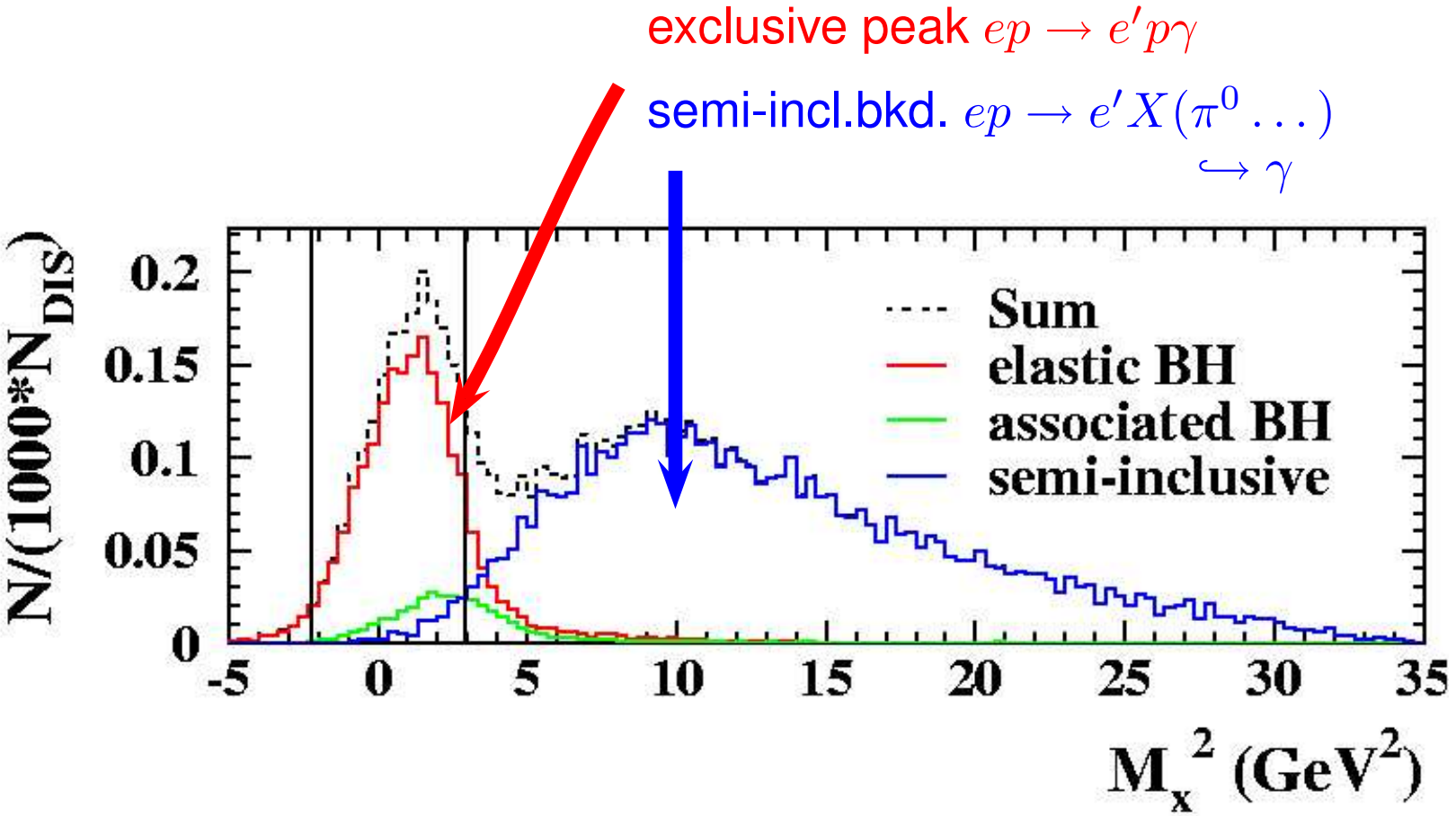


The HERMES Experiment

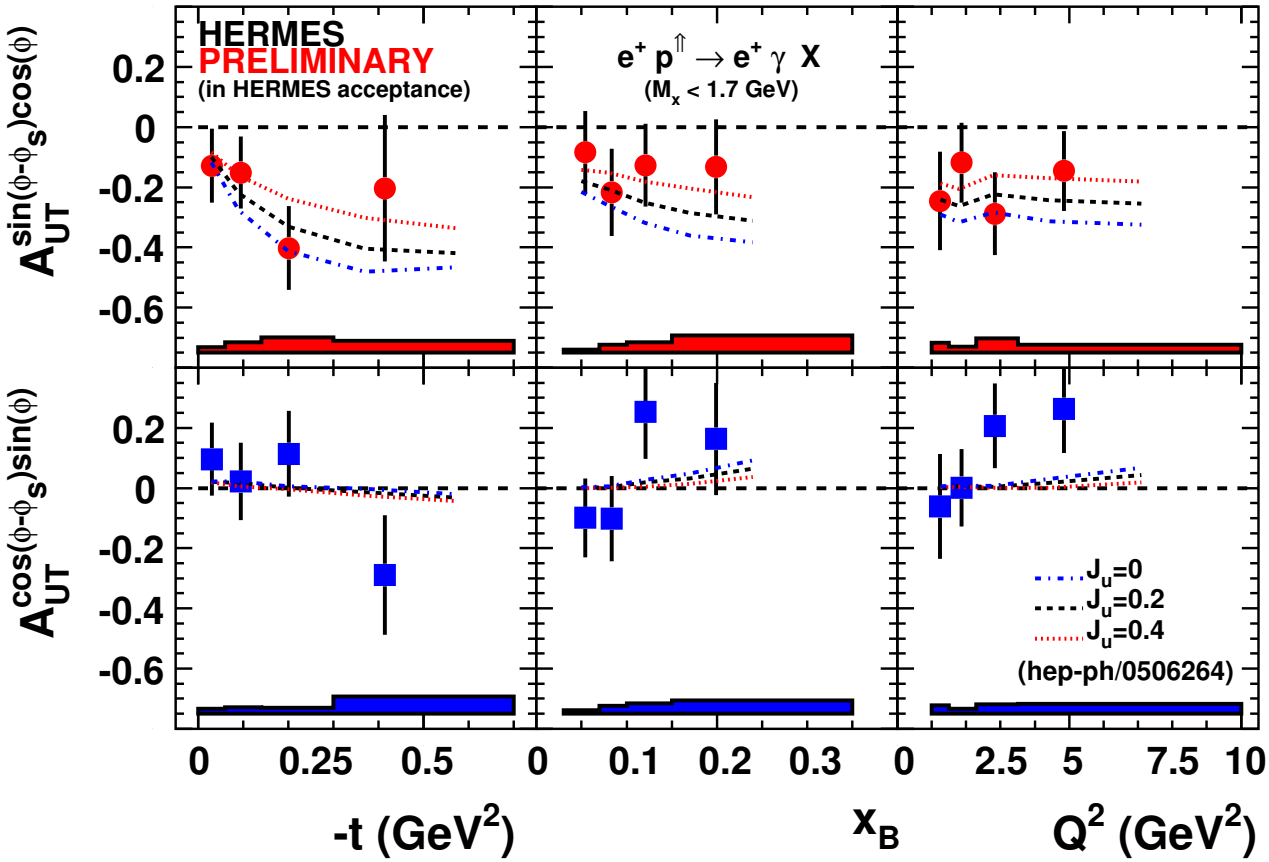
- Exclusivity of the measurement is maintained from the missing mass:

$$M_x^2 = (P_e + P_p - P_{e'} - P_\gamma)^2$$

- Semi-inclusive background contribution $\sim 5\%$ is determined from MC and corrected. Associated production contributes $\sim 11\%$.



Transverse Target-Spin Asymmetry from HERMES



$\propto \mathrm{Im}[F_2\mathcal{H} - F_1\mathcal{E}]$

$\propto \mathrm{Im}[F_2\widetilde{\mathcal{H}} - F_1\xi\widetilde{\mathcal{E}}]$

- The presented result is based on the HERMES 2002-2004 data, $\int Ldt \simeq 60$ pb^{-1}:
  $\sim$4 k events in $|t| < 0.7$ GeV^2, $0.03 < x_B < 0.35$, $1 < Q^2 < 10$ GeV^2.
- Goeke et al., Prog.Part.Nucl.Phys.47 (2001) 401: The nucleon-helicity flip GPD E in the forward limit is modeled by $e(x) = A \cdot q_{val}(x) + B \cdot \delta(x)$, according to χQSM model. The values A and B are related to J_q by: $\int dx\, x[q(x) + e(x)] = J_q$, $\int dx\, e(x) = F_2^q(0) = k^q$.
- hep-ph/0506264: $A_{UT}^{\sin(\phi-\phi_S)\cos\phi}$ sensitive to J_u and insensitve to the other parameters.

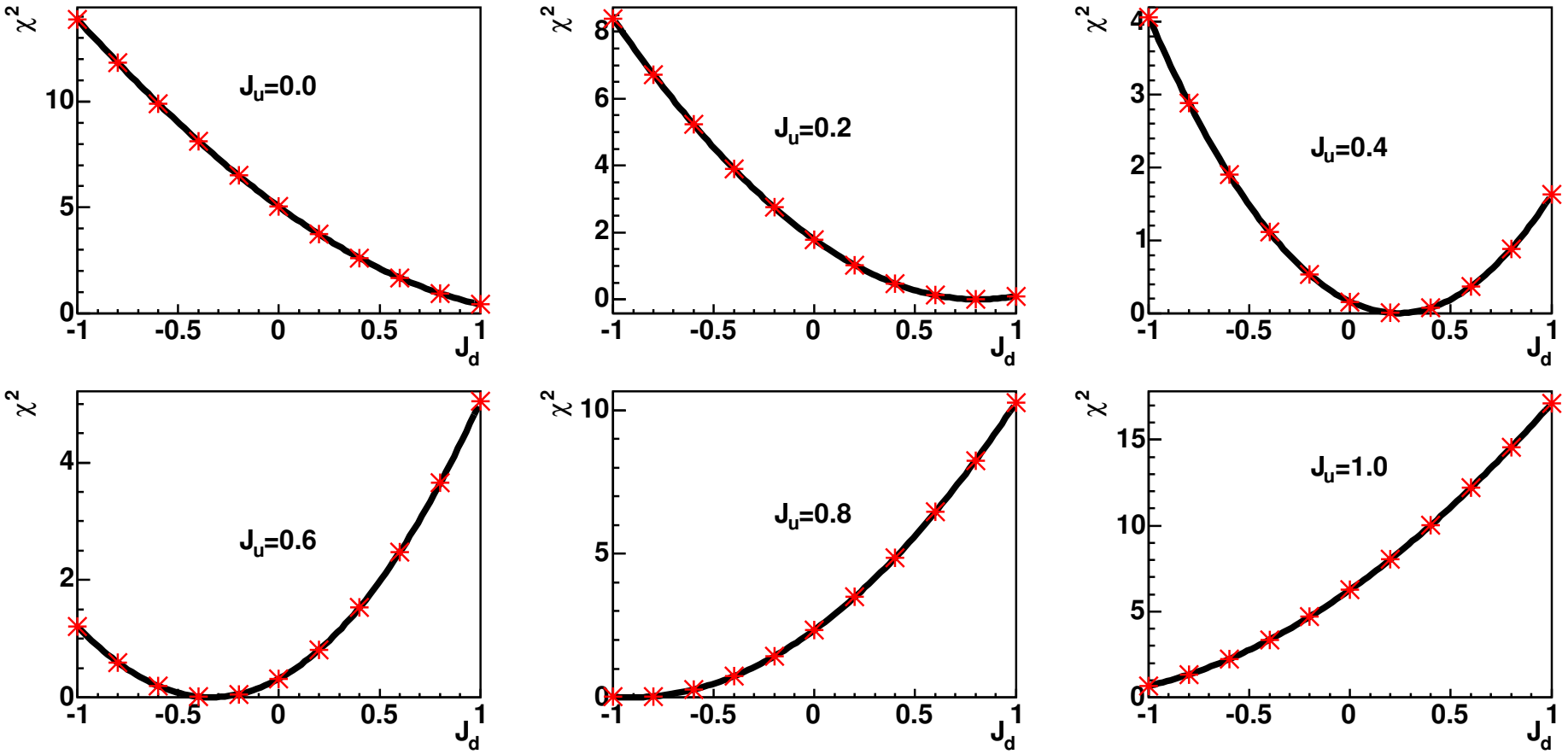
A Model-Dependent Constraint on J_u vs J_d

- In order to compare the theoretical predictions with the experimental results, calculate

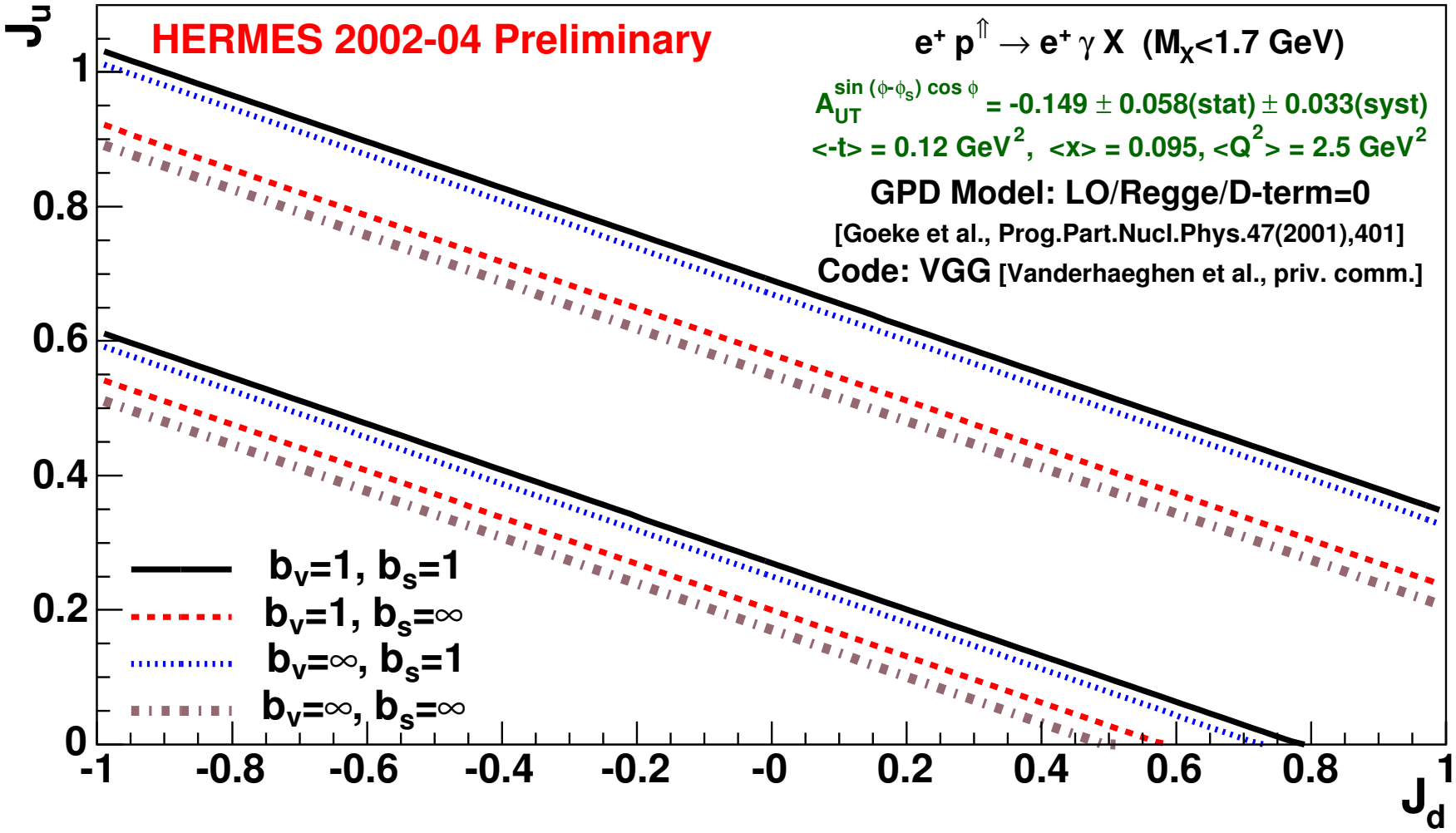
$$\chi^2_{exp}(J_u, J_d) = \frac{\left[A_{UT}^{\sin(\phi-\phi_S)\cos\phi}|_{exp} - A_{UT}^{\sin(\phi-\phi_S)\cos\phi}|_{VGG}(J_u, J_d)\right]^2}{\delta A^2_{stat} + \delta A^2_{syst}}$$

  in a step of 0.2 in J_u and J_d, and interpolate inbetween by a 5th order polynomial.

- The 1-σ constraint on J_u vs J_d is determined by $\chi^2(J_u, J_d) \leq \chi^2_{min} + 1$.

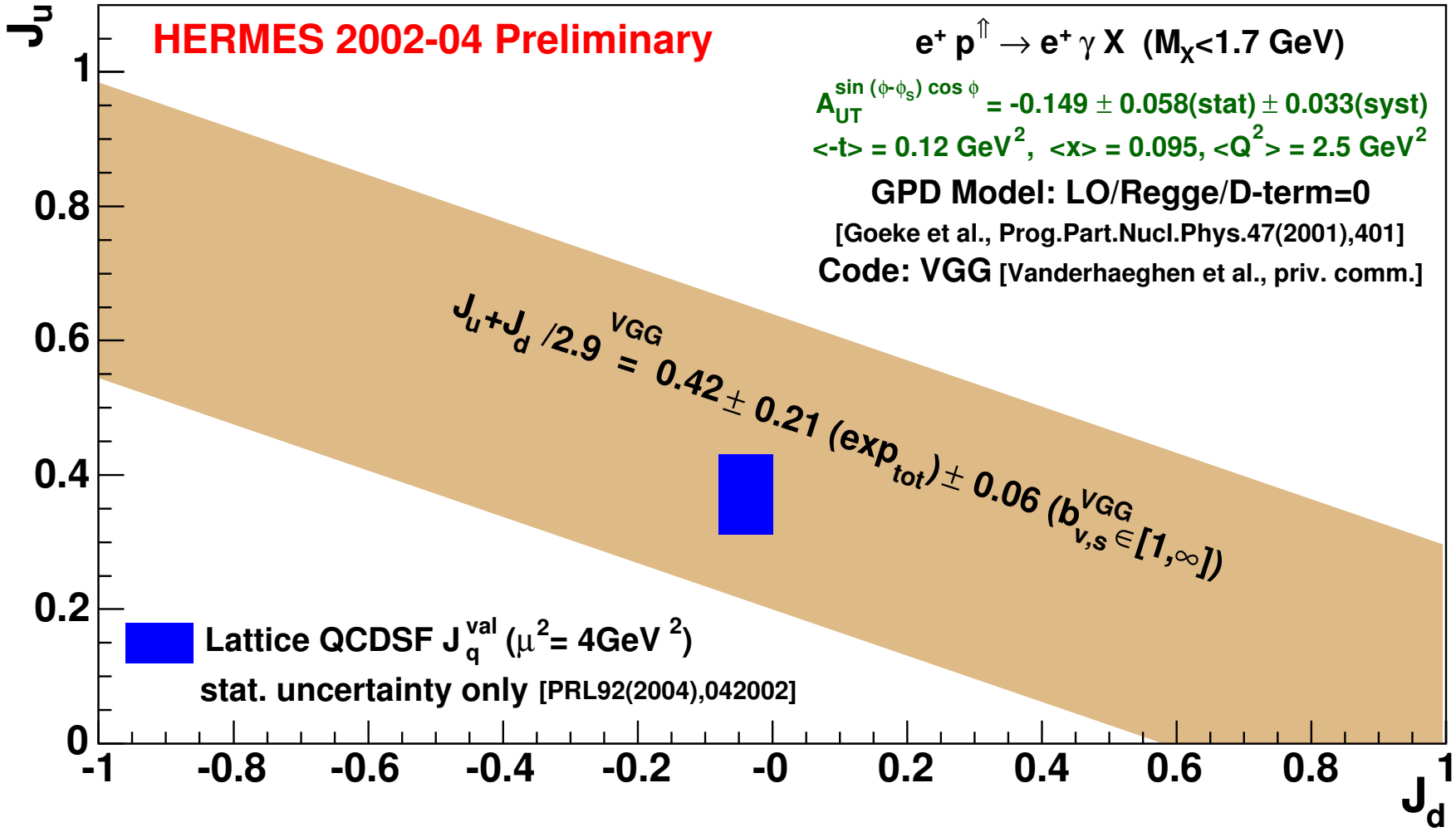


A Model-Dependent Constraint on J_u vs J_d



- The Regge ansatz is used to parameterize the t-dependence of the GPDs. The impact of using it or the factorized ansatz is found to be negligible (hep-ph/0506264).
- The D-term is set to zero, suggested by the HERMES results on the beam-charge asymmetry (hep-ex/0605108). If the D-term were modeled according to the χQSM, the constraint on $J_u + J_d/2.9$ is shifted upwards by 0.11.

A Model-Dependent Constraint on J_u vs J_d



- The quenched Lattice calculation was done with the the pion masses 1070, 870, and 640 MeV, and extrapolated linearly in m_π^2 to the physical value.

Summary and Outlook

Summary

- The TTSA associated with DVCS on the proton has been firstly measured at HERMES. This asymmetry is sensitive to the GPD E and to the quark total angular momentum J_q.
- A model-dependent constraint on J_u vs J_d is obtained by comparing the HERMES result on the TTSA and the theorectical predications based on a GPD model.

Outlook

- At present, the uncertainty is dominated by the statistical one. The situation will be improved after including the 2005 data: the statistics will be doubled.

HERMES is aiming at providing a more complete picture of nucleon spin.