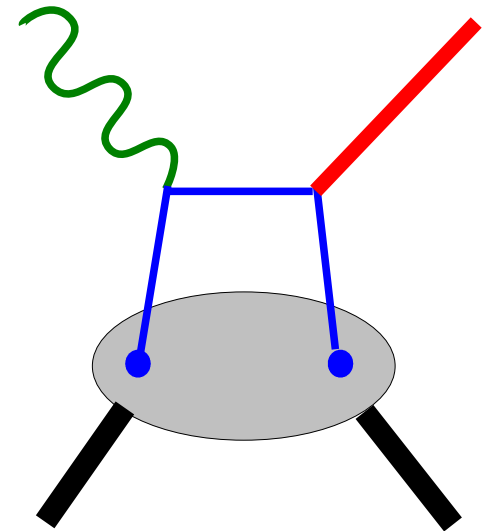


# HERMESでの DVCSターゲットスピン非対称度 $A_{UT}$ 測定

- Generalized Parton Distribution: GPD
  - GPD and  $J_q$
  - Deeply Virtual Compton Scattering
- Target Transverse Spin Asymmetry  $A_{UT}$
- Model dependent constraint on  $J_u$  and  $J_d$
- Summary



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他HERMES Collaboration

# Proton Spin Problem

Generalized Parton Distribution (GPD) provides access to J.

Proton spin:  $\frac{1}{2}$

$$= J_q + J_g$$

Semi-inclusive DIS:  
Sivers function:  $L_u > 0?$

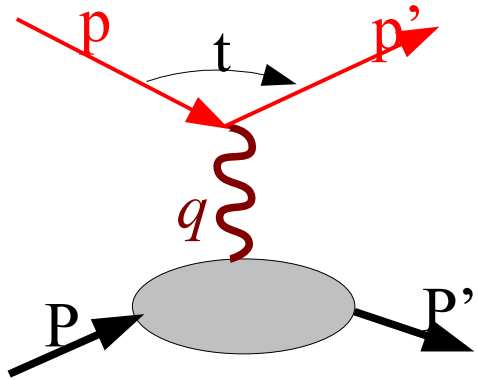
$$= \frac{1}{2} \Delta \Sigma + L_q + \Delta G + L_g$$

Inclusive DIS:  $\Delta \Sigma \sim 0.2$   
Semi-inclusive DIS:  $\Delta q_{\text{sea}} \sim 0$

DIS, p-p collision:  
 $\Delta G > 0$

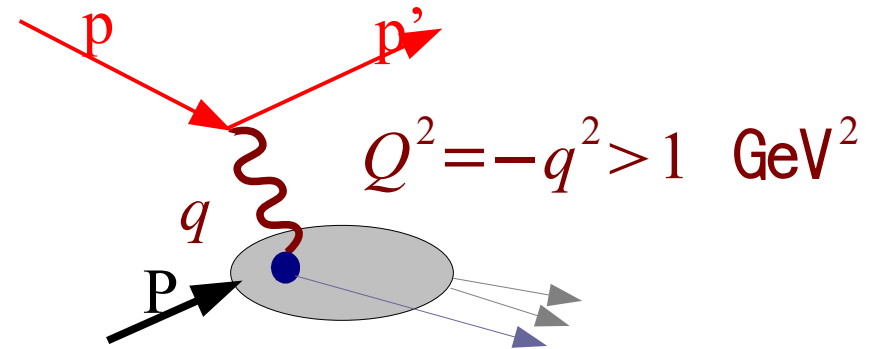
# Generalized Parton Distribution

Elastic scattering



Form Factor:  $F(t), G(t)$

Deep Inelastic Scattering

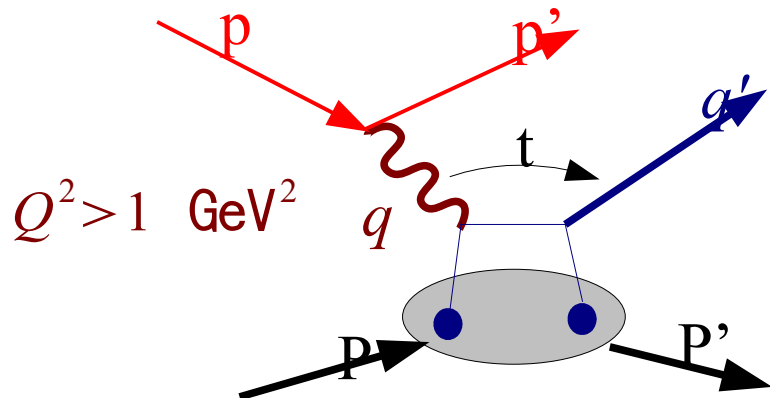


Parton distribution:  $q(x), \Delta q(x), \delta q(x)$

Hard Exclusive Production:  $e + N \rightarrow e' + N' + \{\gamma, \rho, \pi, \dots\}$

Generalized Parton Distribution:

$H, E, \tilde{H}, \tilde{E}$



GPD and total angular momentum

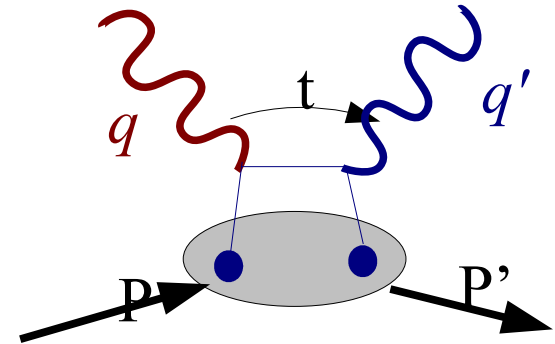
$$J_{q,g} = \frac{1}{2} \int_{-1}^1 dx x [H^{q,g}(x, \xi, t \rightarrow 0) + E^{q,g}(x, \xi, t \rightarrow 0)]$$

# Hard Exclusive Production and GPD

## Deeply Virtual Compton Scattering: (DVCS)

$$e + N \rightarrow e' + N' + \gamma$$

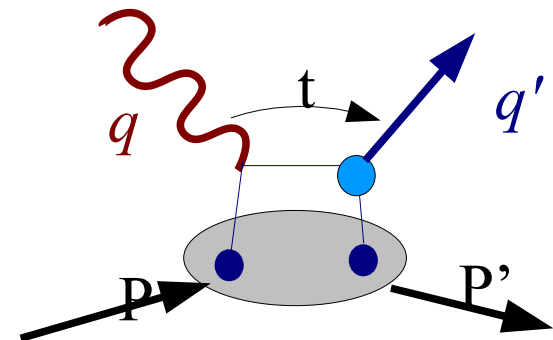
Involved GPDs:  $H, E, \tilde{H}, \tilde{E}$   
clean reaction



## Hard exclusive meson production:

$$e + N \rightarrow e' + N' + \{\rho, \pi, \dots\}$$

vector meson:  $H, E$   
pseudo-scalar meson:  $\tilde{H}, \tilde{E}$



Factorization for longitudinal photons only

**Meson Amplitude** should be taken care

Quark flavor sensitivity

# GPD and $J_q$

## GPD and total angular momentum

$$J_{q,g} = \frac{1}{2} \int_{-1}^1 dx x [H^{q,g}(x, \xi, t \rightarrow 0) + E^{q,g}(x, \xi, t \rightarrow 0)]$$

$$\int_{-1}^1 dx x \sum_q H^q(x, \xi) = M_Q^{(2)} + \frac{4}{5} d_1 \xi^2$$

$$\int_{-1}^1 dx x \sum_q E^q(x, \xi) = (2J_Q - M_Q^{(2)}) - \frac{4}{5} d_1 \xi^2$$

2<sup>nd</sup> moment of PDF:

$$M_q^{(2)} = \int_0^1 x q(x) dx$$

(Goetze et al., Prog.Part.Nucl.Phys.47 (2001) 401)

## $E^q(x, \xi)$ and $J_q$ :

$$E(x, \xi) = E^{DD}(x, \xi) - \theta(\xi - |x|) D\left(\frac{x}{\xi}\right)$$

D-term:

expected to be 0 from HERMES BCA results

$$E^{DD}(x, \xi) = \int_{-1}^1 d\beta \int_{-1+|\beta|}^{1-|\beta|} d\alpha \delta(x - \beta - \alpha\xi) h(\beta, \alpha) e(\beta) \rightarrow e(x) = A q_{val}(x) + B \delta(x)$$

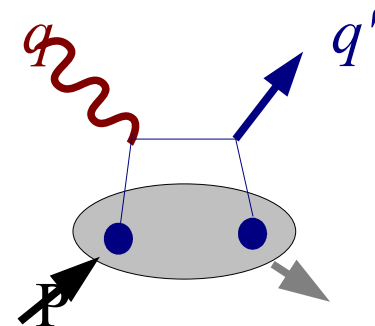
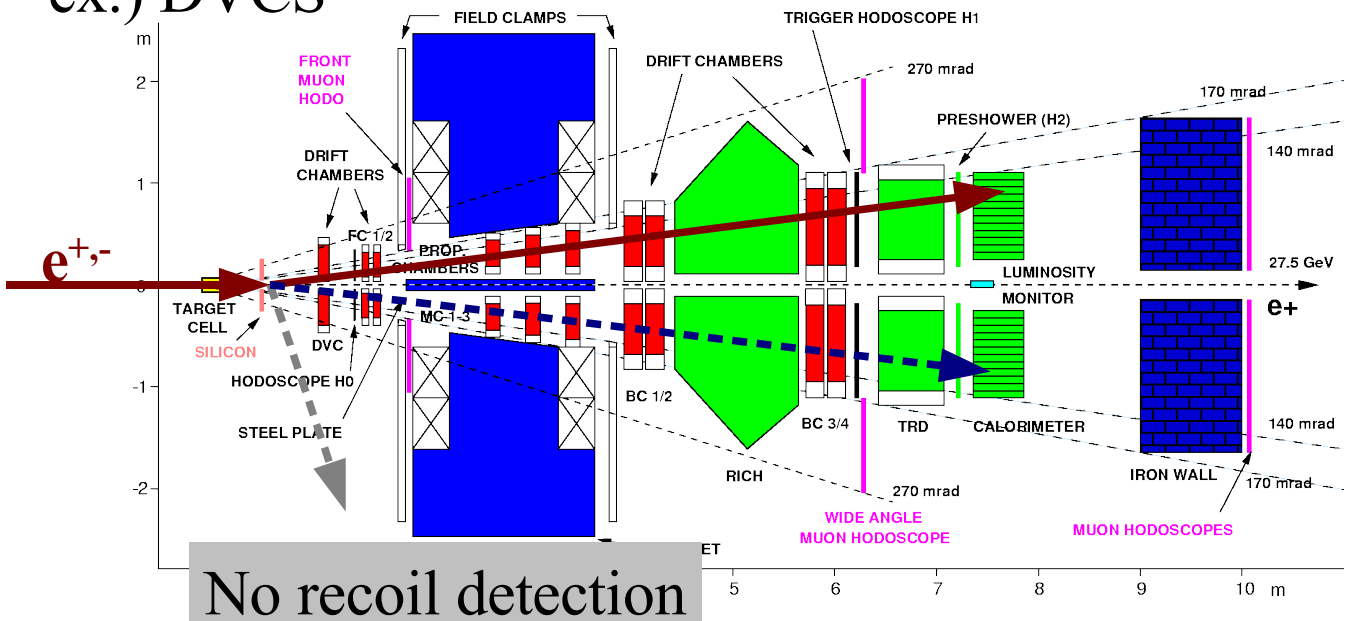
$$A_q(x) = \frac{2J_q - M_q^{(2)}}{M_{q_{val}}^{(2)}} q_{val}(x)$$

$$B_u = 2 \left[ \frac{1}{2} \kappa_u - \frac{2J_u - M_u^{(2)}}{M_{u_{val}}^{(2)}} \right]$$

$$B_d = \kappa_d - \frac{2J_d - M_d^{(2)}}{M_{d_{val}}^{(2)}}$$

# HERMES spectrometer

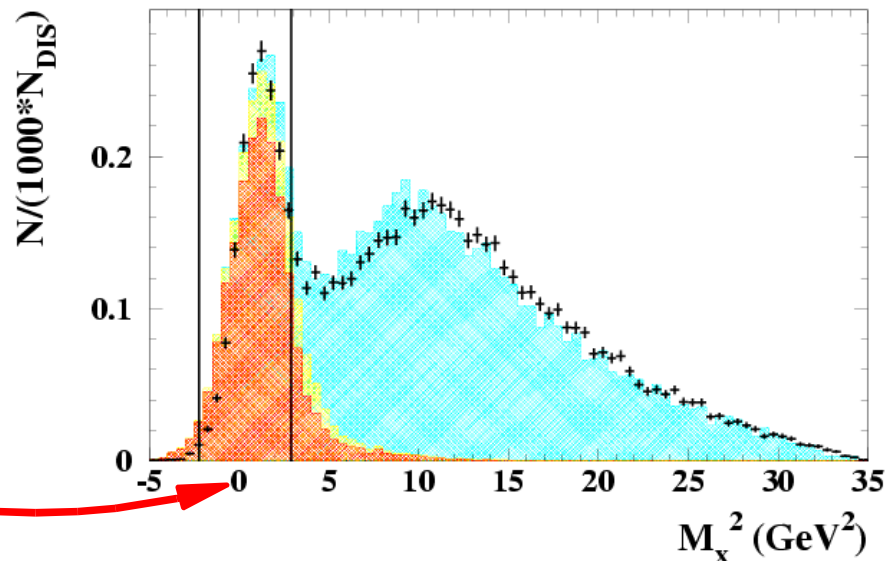
ex.) DVCS



Exclusive reaction:  
via **missing mass**

$$M_X^2 = (q + P - q')^2$$

Exclusive production events  
were selected with a  $M_X$  cut



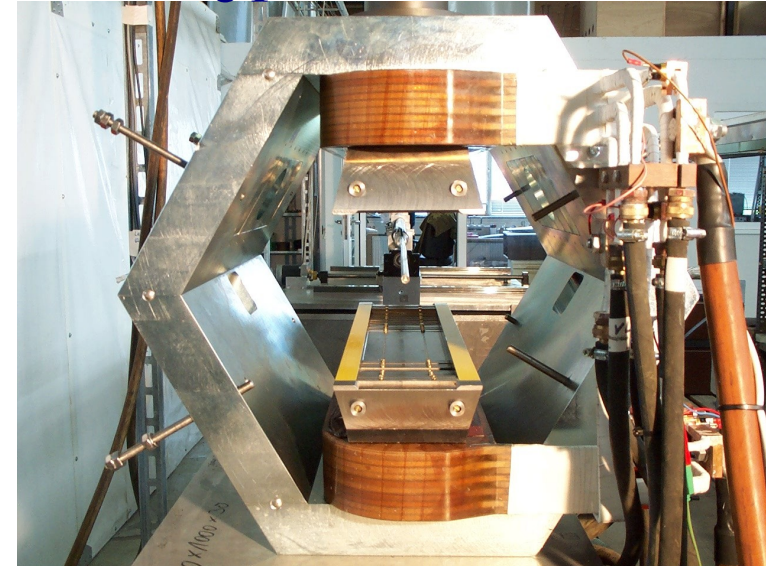
# Target Spin Asymmetry: $A_{UT}$

## Transversely hydrogen gas target

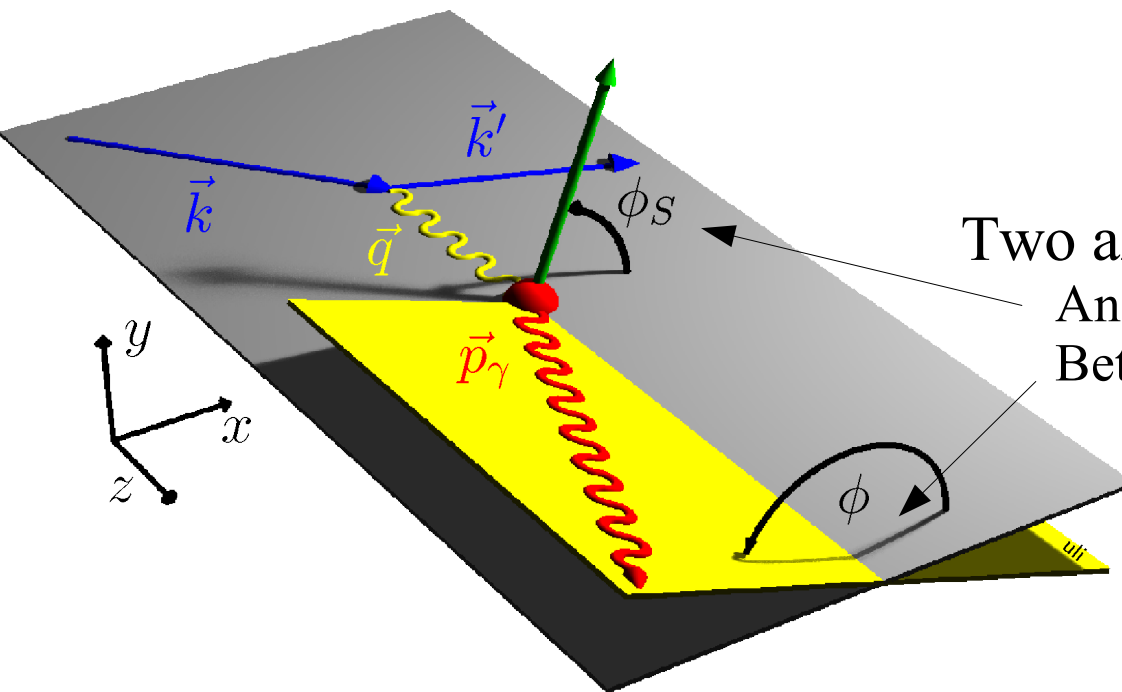
2002 – 2005

analysis are based on 2002-2004 data.

$\langle |P_T| \rangle \sim 80\%$



HERMES transverse polarized target magnet



Two azimuthal angles:

Angle of the target spin direction

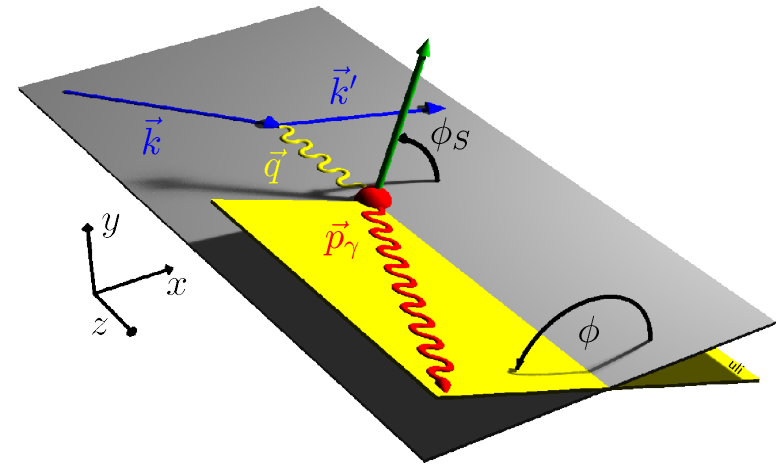
Between the lepton and photon (meson) planes

$$A_{UT}(\phi, \phi_S) = \frac{1}{S_{\perp}} \frac{d\sigma(\phi, \phi_S) - d\sigma(\phi, \phi_S + \pi)}{d\sigma(\phi, \phi_S) + d\sigma(\phi, \phi_S + \pi)}$$

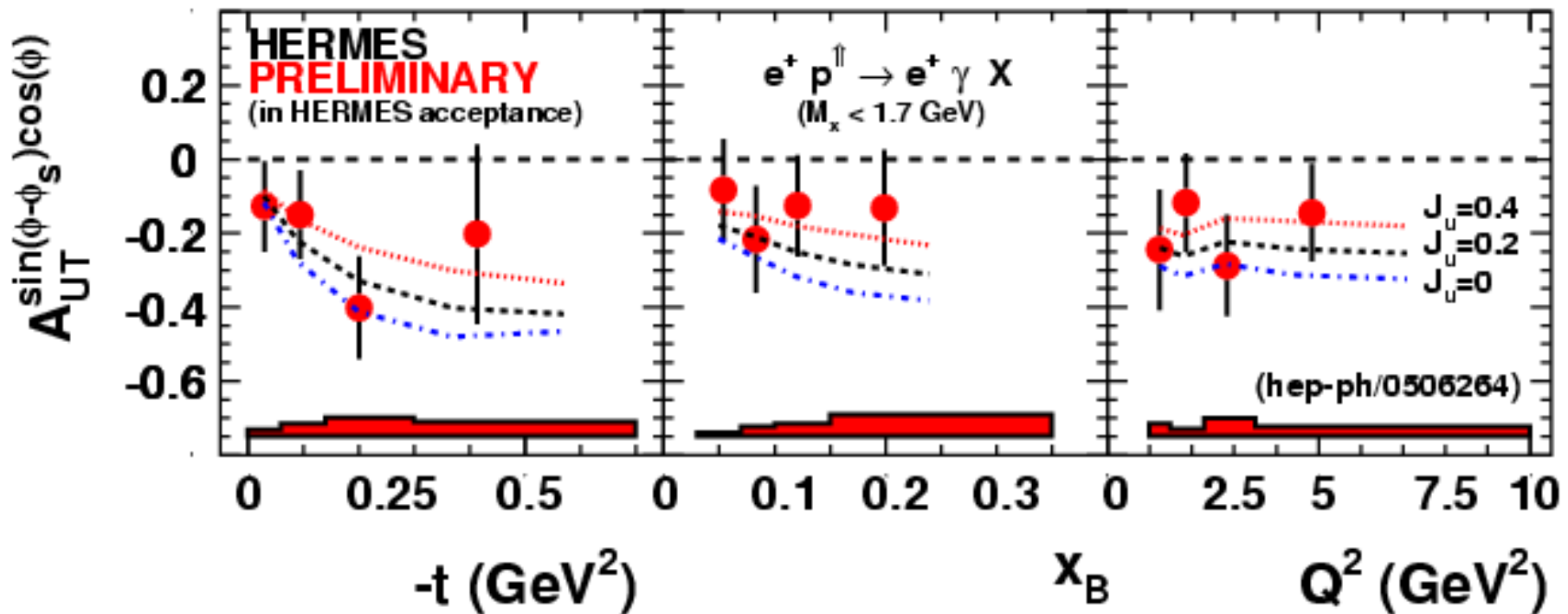
$$A_{UT}^{\sin(\phi - \phi_S) \cos(\phi)} \propto \mathfrak{I} [ F_2 \mathbf{H} - F_1 \mathbf{E} ]$$

# DVCS Target Spin Asymmetry $A_{UT}$

$$A_{UT}^{\sin(\phi-\phi_S)\cos(\phi)} \propto \Im [ F_2 H - F_1 E ]$$



HERMES 2002-2004 data:  $\sim 60\text{pb}^{-1}$

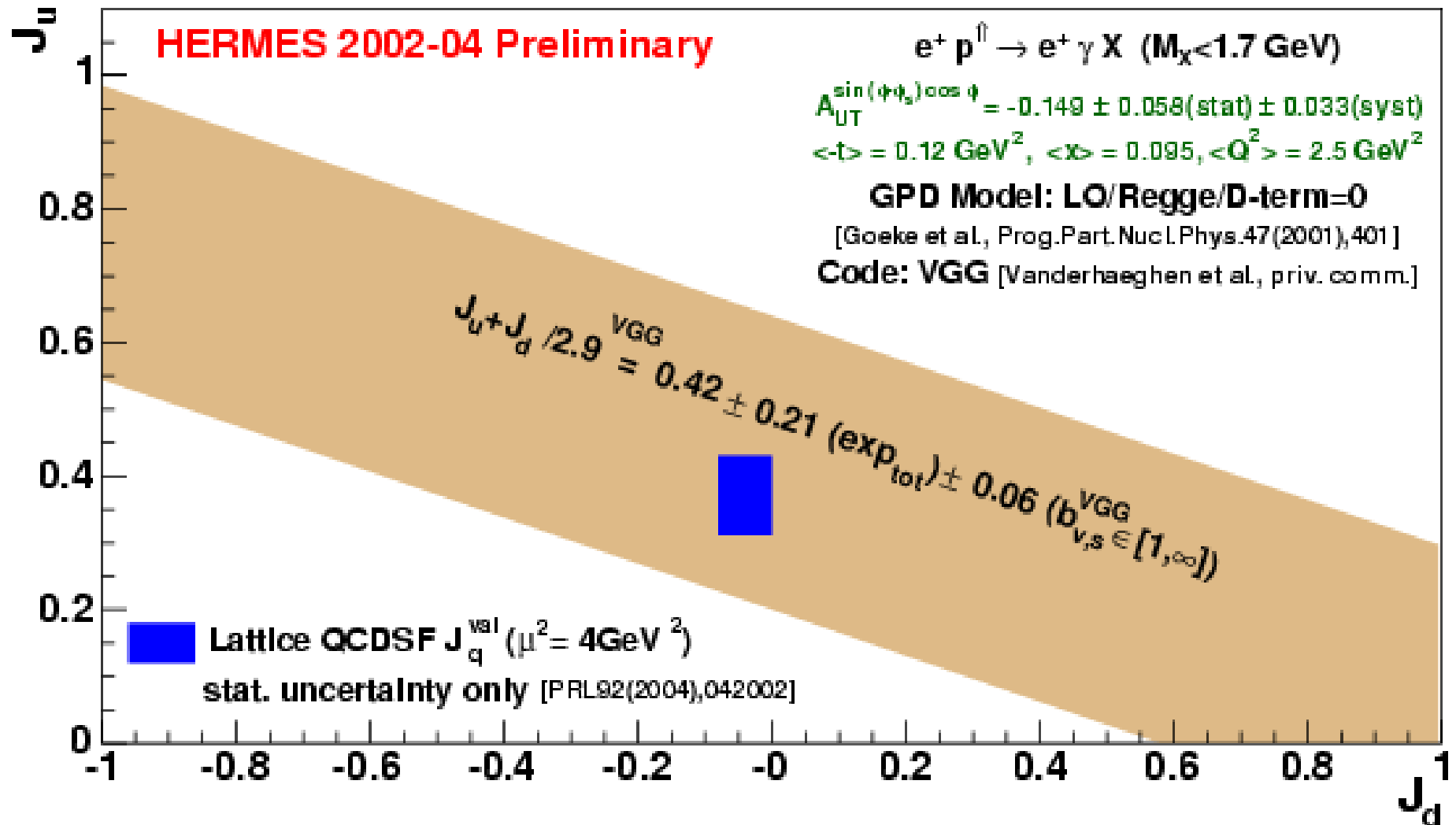




# Model dependent constraint on $J_u$ and $J_d$ from $A_{UT}$

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

Constraint on  $J_u$  and  $J_d$ :  $\chi^2(J_u, J_d) \leq \chi_{min}^2 + 1$



# Summary

- Generalized Parton Distribution
  - Connect PDFs and Form factors
  - Access to the total angular momentum
- Single Spin Asymmetry in Hard Exclusive Production
  - DVCS is clean process to access GPD
  - Transverse Target Spin Asymmetry is sensitive to  $J_q$
- HERMES measured
  - non-zero TSA in DVCS and the  $x$ ,  $-t$ , and  $Q^2$  dependence
  - Model dependent constraint on  $J_u$  and  $J_d$
  - $J_u + J_d/2.9 = 0.042 \pm 0.021 \pm 0.06$  for VGG model
- Outlook
  - Data taken in 2005 doubles the statistic.

*End*