HOW DO GPDs LOOK LIKE?

1. DYNAMICAL MODELS

   E.G. CONSTITUENT QUARKS

   CHIRAL QUARK SOLITON MODEL

   ...

2. LATTICE QCD → LATER

3. "THE ART OF ANSATZ"

$$\mathrm{GPD}(x, \xi, t)$$

BOUNDARY CONDITIONS

$H^q(x, 0, 0) = q(x)$ etc.

SUPER-SIMPLE ANSATZ:

$\mathrm{GPD}(x, \xi, t) = f(x, \xi)\, F(t)$

- SUPER-SIMPLE ANSATZ:

  $H^q(x, \xi, t) = q(x)\, F(t)$

→ MORE LATER

- MORE REFINED:

  → START FROM USUAL PARTON DENSITIES

  → GENERATE ξ DEPENDENCE CONSISTENT WITH LORENTZ INVARIANCE

$$\int dx\, H(x, \xi, t) = F(t)$$

$$\int dx\, x\, H(x, \xi, t) = A(t) + \xi^2 B(t)$$

$$\vdots$$

HOW TO MEASURE GPDS ?

8. FACTORIZATION

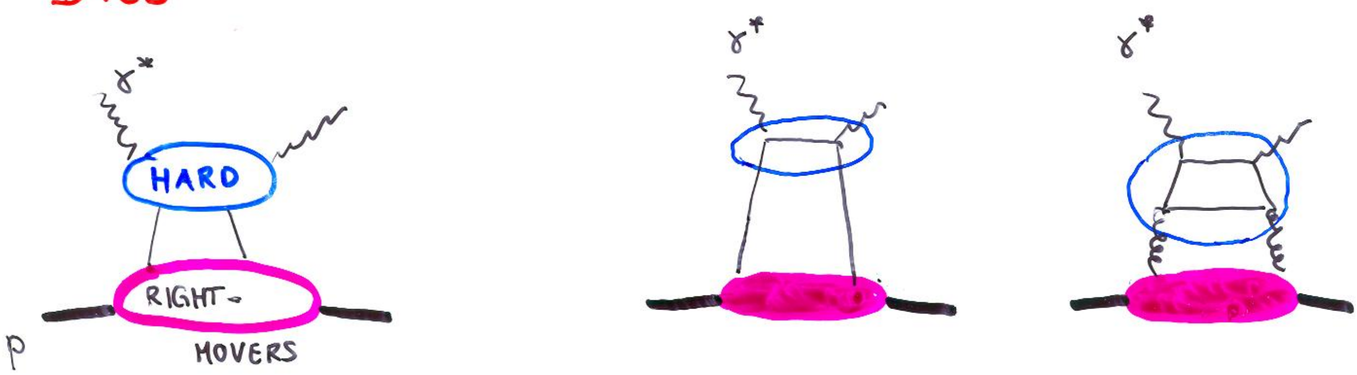
IN BJ LIMIT $Q^2 \to \infty$ $\quad W^2/Q^2$ FIXED

t FIXED

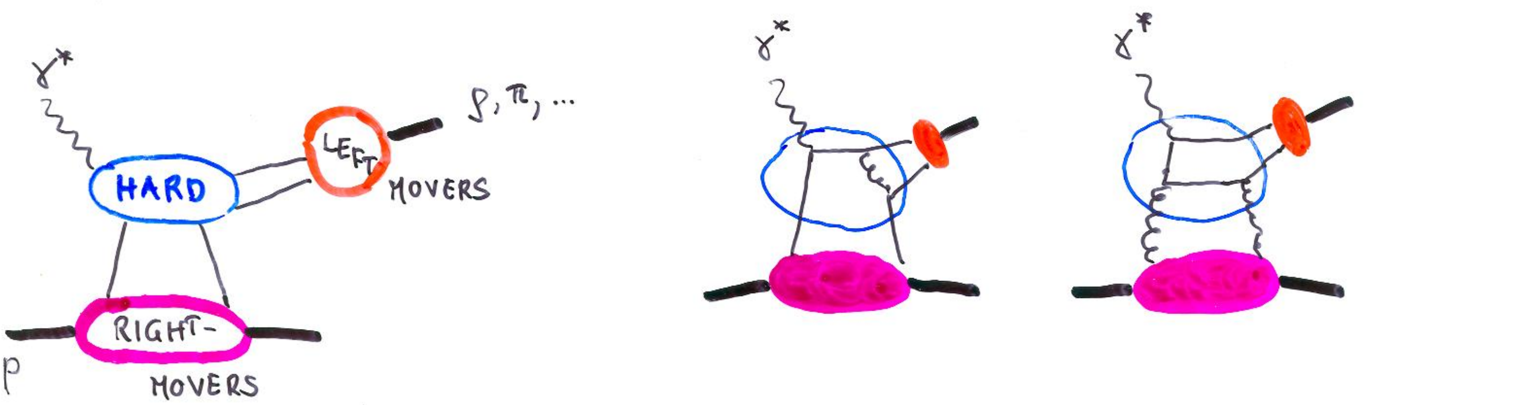
(i.e. $Q^2 \sim W^2 \gg |t|, \Lambda^2_{QCD}$)

UP TO POWER SUPPRESSED ($\sim 1/Q^n$) TERMS

DVCS



MESON PRODUCTION



● EXTRA INTERNAL PARTON AT LO (α_s)

→ EXTERNAL HARD MOMENTUM $\sim Q$ GETS "DILUTED"

FLAVOR SEPARATION (on p target)

DVCS : $\frac{4}{9} u + \frac{1}{9} d + \frac{1}{9} s \quad + \mathcal{O}(\alpha_s)\, g$

ρ : $\frac{1}{\sqrt{2}} \left(\frac{2}{3} u + \frac{1}{3} d + \frac{3}{8} g \right)$

ω : $\frac{1}{\sqrt{2}} \left(\frac{2}{3} u - \frac{1}{3} d + \frac{1}{8} g \right)$

ϕ : $\frac{1}{3} s + \frac{1}{8} g$

SPIN "FILTER"

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

Vector Mesons : H, E

Pseudoscalar Mesons : $\tilde{H}, \tilde{E}$

} FROM PARITY INVARIANCE

SCALING :

$$\mathcal{A}_{DVCS} \sim \int_{-1}^{1} dx \, \frac{1}{\xi - x - i\epsilon} \, GPD(x, \xi, t; \mu^2 = Q^2) \pm (x \to -x)$$

$$+ \mathcal{O}(\alpha_s)$$

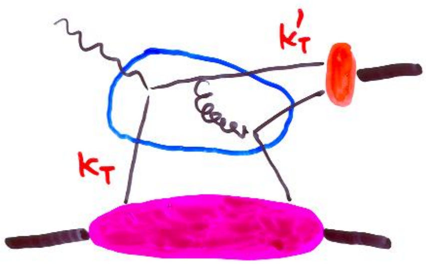
$$= \mathcal{A}_{DVCS} (\xi, t, \ln Q^2) \quad \text{BJ SCALING}$$

$$\mathcal{A}_{MESON} \sim \frac{\alpha_s}{Q} \int_{-1}^{1} \ldots \text{(the same)}$$

$$= \frac{1}{Q} \, \tilde{\mathcal{A}}(\xi, t, \ln Q^2)$$

ONE SOURCE OF POWER - SUPPRESSED EFFECTS :

"INTRINSIC k_T"



$$\int dx\, dz \quad GPD(x, \dots) \; T_H(x, z, \xi) \; \phi(z)$$

$$\rightsquigarrow$$

$$\int dx\, dz \; d^2k_T\, d^2k_T' \; GPD'(x, k_T, \dots) \; T_H'(x, z, \xi, k_T, k_T') \; \psi(z, k_T')$$

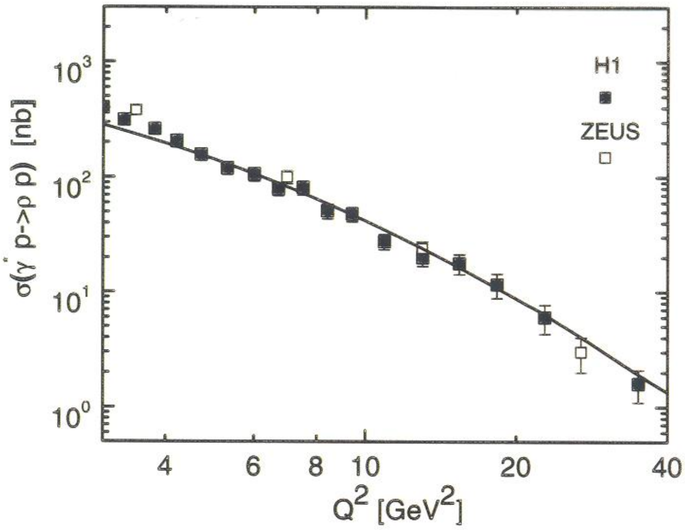
MODEL CALCULATIONS →

SUBSTANTIAL EFFECTS EVEN

FOR $Q^2 \sim$ few GeV^2

TYPICAL PROPAGATOR :

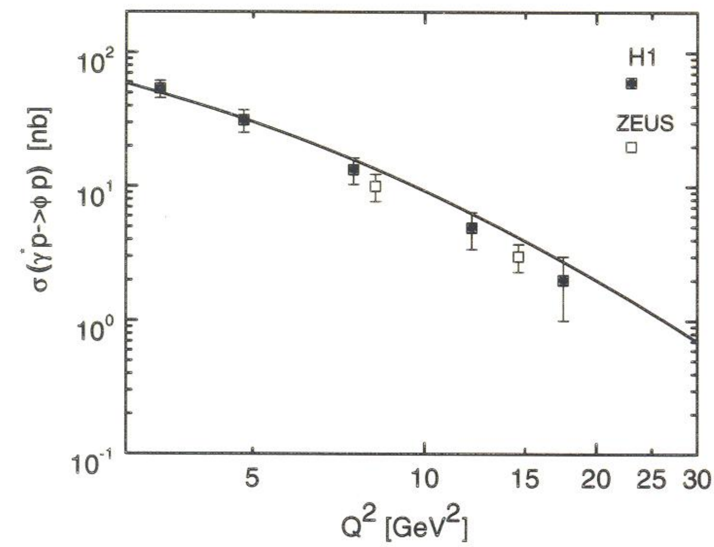
$$\frac{1}{z \frac{x-\xi}{2\xi} Q^2 + (\vec{k}_T - \vec{k}_T')^2}$$



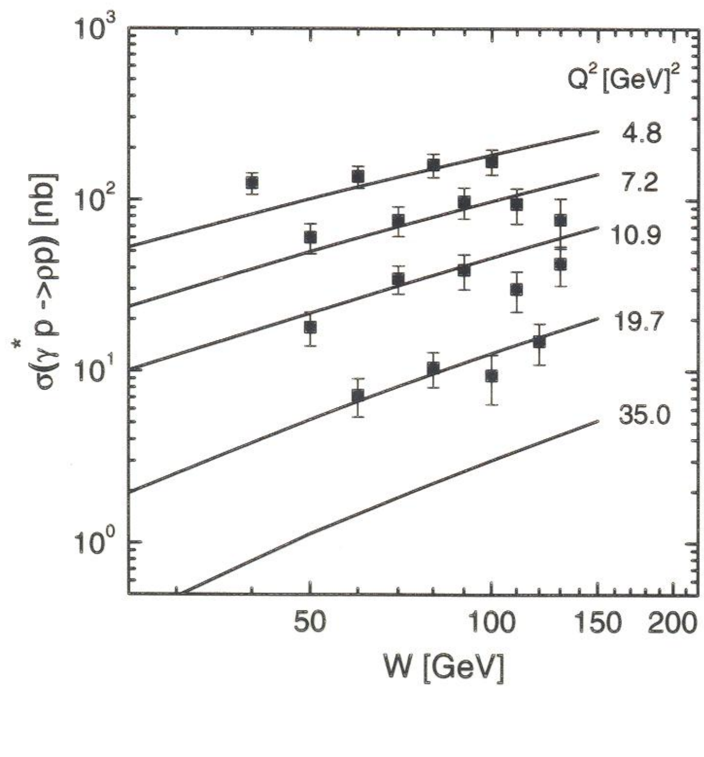
CALCULATION
AT LO(α_s)

INCLUDING k_T
FROM MESON
WAVE FUNCTION

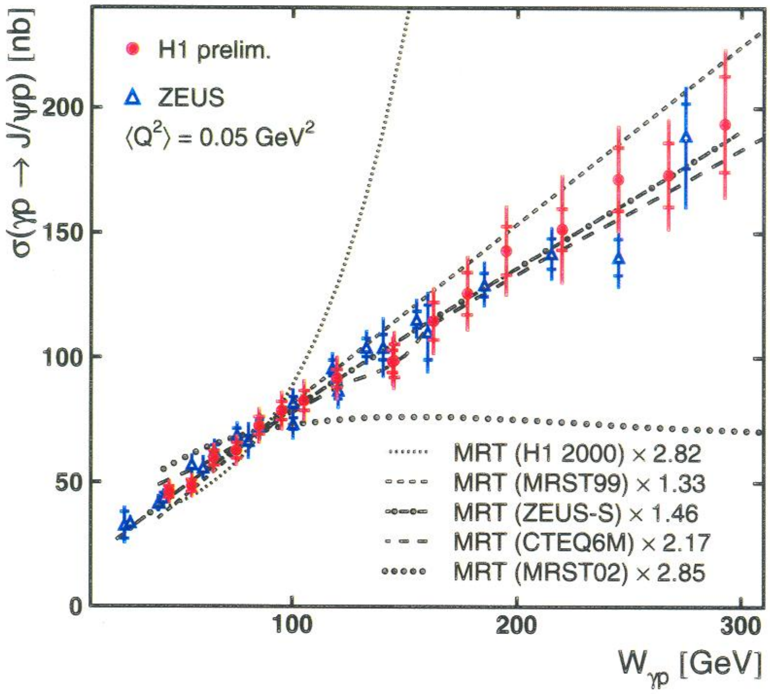
PLOTS FROM hep-ph/0501242



P. KROLL,
S. GOLOSKOKOV
'05

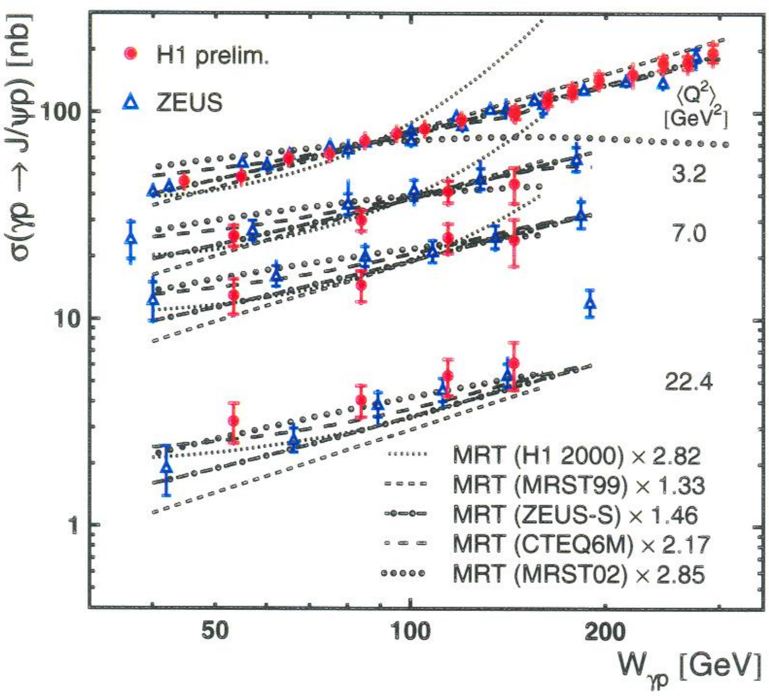


FIGURES BY PH. FLEISCHMANN (H1)



CALCULATION

T. TEUBNER et al. '05

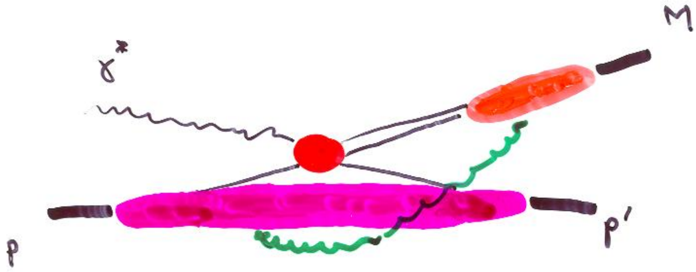


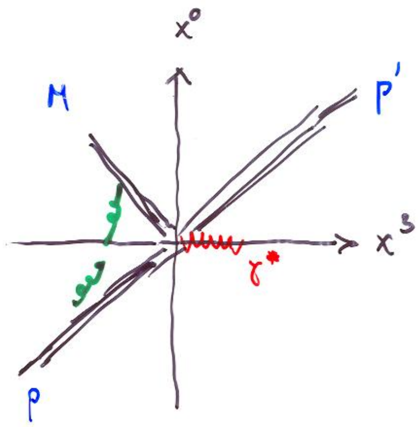
J/ψ PRODUCTION

m_c PROVIDES HARD SCALE

STRONG SENSITIVITY TO GLUON DISTRIBUTION

FACTORIZATION BREAKING SOFT EXCHANGES

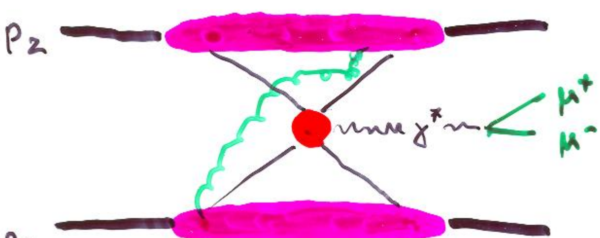


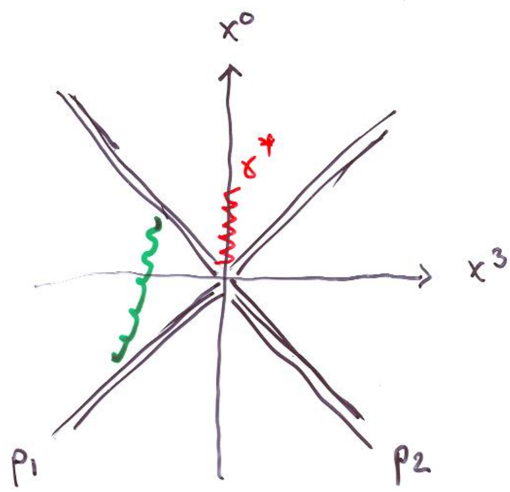


→ EFFECTS CANCEL TO LEADING POWER $1/Q$

ALSO HAPPENS IN EXCLUSIVE HADRON-HADRON PROCESSES

e.g. $pp \to pp + \mu^+\mu^-$





FOR FACTORIZATION IN pp NEED

SUM OVER FINAL STATES

10. DVCS $\quad ep \to ep\gamma$

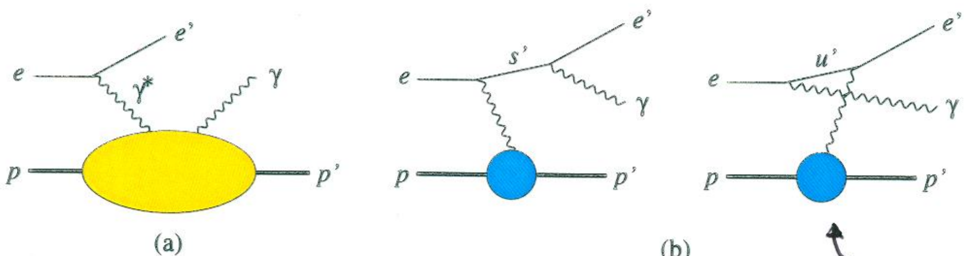
VARIABLES : $Q^2,\ t,\ x_B$ (OR ξ)

$$y = \frac{q \cdot p}{k \cdot p} = \frac{Q^2}{x_B\,(s_{ep} - m^2)}$$

k ← BEAM MOMENTUM

ϕ

COMPTON $\qquad$ BETHE - HEITLER



PARAMETRIZED BY

$F_1(t)$, $F_2(t)$

$d\sigma_{COMP} \sim \frac{1}{Q^2}\ \frac{1}{y^2}$ ← FROM $e \to \gamma^* e$ VERTEX

FROM γ^* PROPAGATORS

$d\sigma_{BH} \sim \frac{1}{t}$

$\Rightarrow \quad d\sigma_{COMP} \ll d\sigma_{BH}$ $\quad$ UNLESS y SMALL

(s_{ep} LARGE)

$d\sigma_{INT}$ $\quad$ INTERFERENCE → PHASE INFORMATION ON $\mathcal{A}(\gamma^* p \to \gamma p)$

FILTERED OUT IN $d\sigma(e^+) - d\sigma(e^-)$

10. DVCS $\qquad ep \to ep\gamma$

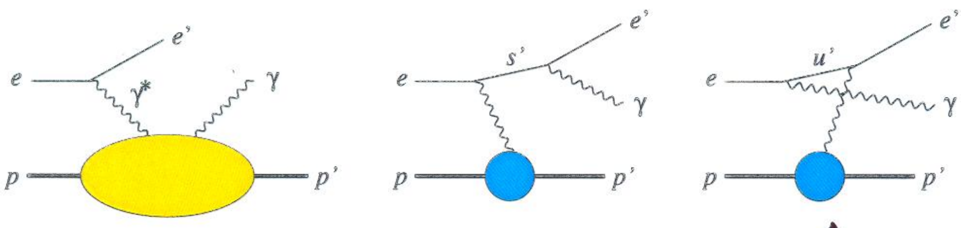
VARIABLES : $\quad Q^2,\ t,\ \ x_B$ (OR ξ)

$$y = \frac{q \cdot p}{k \cdot p} = \frac{Q^2}{x_B\,(s_{ep} - m^2)}$$

BEAM MOMENTUM

ϕ ROTATION ANGLE AROUND γ^* AXIS

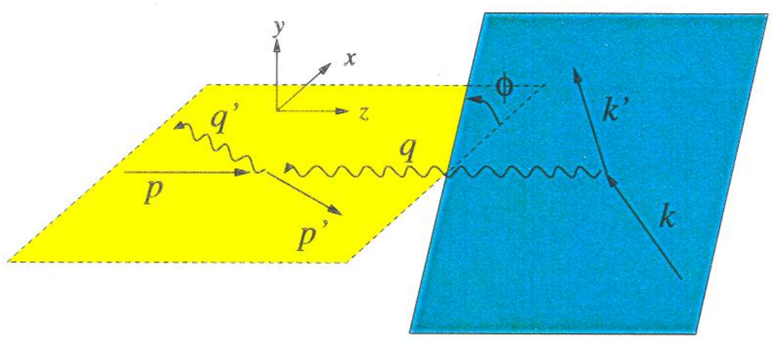
COMPTON $\qquad\qquad$ BETHE - HEITLER



(a) $\qquad\qquad\qquad$ (b)

PARAMETRIZED BY

$F_1(t)\ ,\ F_2(t)$



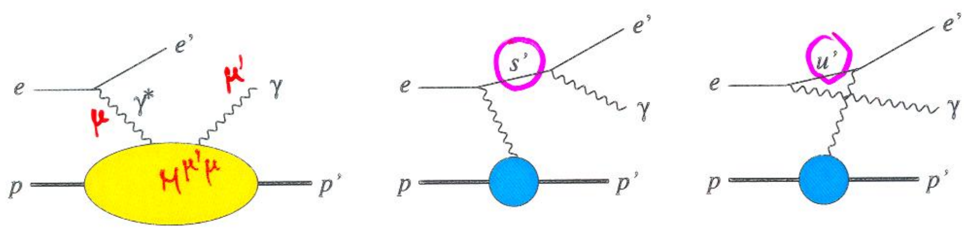
OPERATOR OF ROTATION AROUND z :

$$e^{i\phi J_z}$$

- $d\sigma_{BH}$ *) DROPS OUT IN SINGLE SPIN ASY'S (BEAM OR SPIN $\frac{1}{2}$ TARGET)

(*) BUT NOT $d\sigma_{COMP}$

→ ALSO ACCESS TO $d\sigma_{INT}$



(a) (b)

$$\frac{d\sigma_{INT}}{d\phi\, dx_B\, dQ^2\, dt} = e_\ell \Big[\ldots \cos\phi \;\mathrm{Re}\, \hat{M}^{++} + \ldots \cos 2\phi \;\mathrm{Re}\, \hat{M}^{+0} + \ldots \cos 3\phi \;\mathrm{Re}\, \hat{M}^{+-} + O(1/Q) \Big]$$

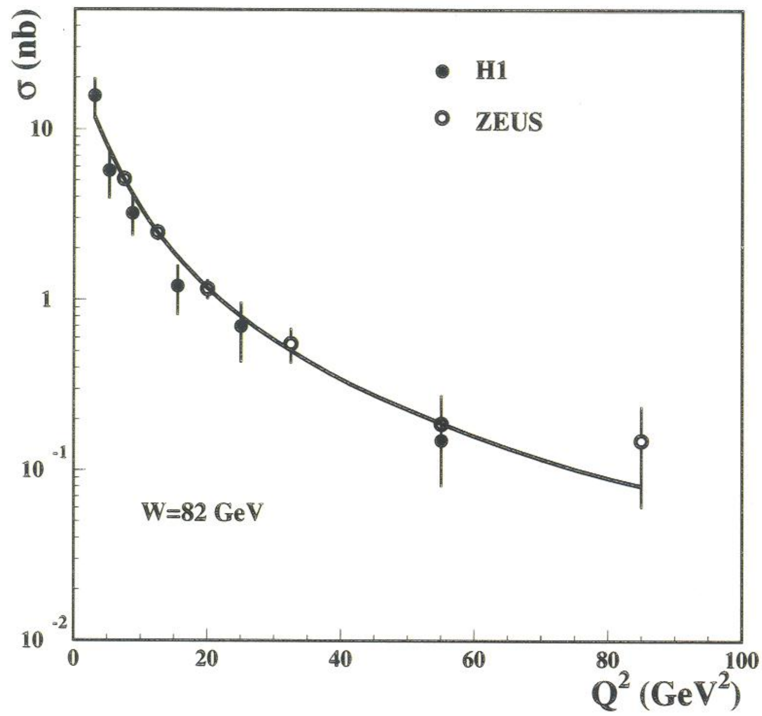
$$+ \; e_\ell P_\ell \Big[\ldots \sin\phi \;\mathrm{Im}\, \hat{M}^{++} + \ldots \sin 2\phi \;\mathrm{Im}\, \hat{M}^{+0} + O(1/Q) \Big]$$

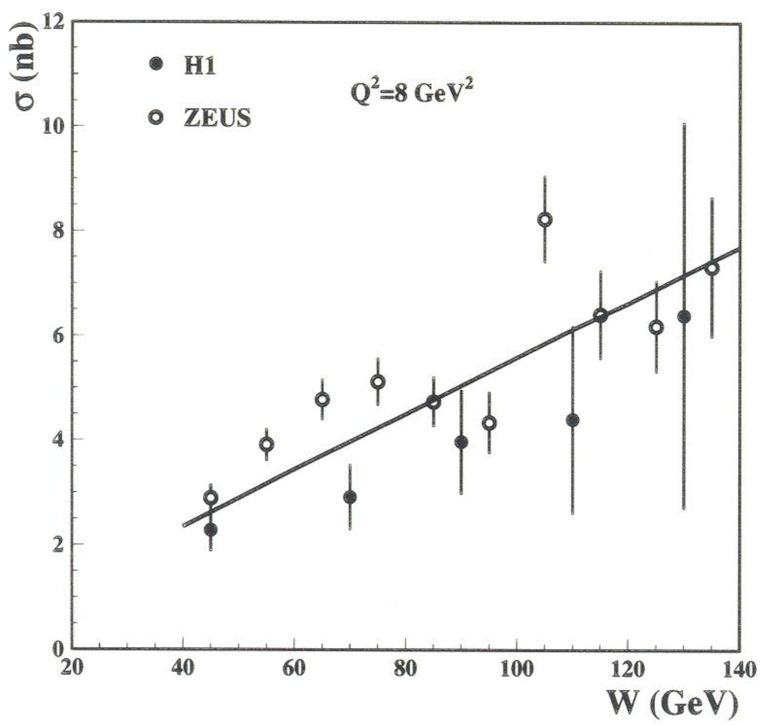
$\hat{M}^{\mu'\mu}$ = SUPERPOSITION OF DVCS HELICITY AMPLITUDES

ϕ - DEPENDENCE : ANALYZER OF γ^* HELICITY

HAVE EXTRA KNOWN ϕ -DEP'CE FROM PROPAGATORS $1/s'u'$

PLOTS FROM hep-ph/0507183





$\sigma(\gamma^* p \to \gamma p)$

VS. MODEL FOR GPDs BY V. GUZEY, M. POLYAKOV '05

CALCULATION AT LO(α_s)

WHICH GPDs SENSITIVE TO ?

UNPOLARIZED TARGET :

INTEGRAL $\int dx \ldots H$

$$\hat{M}^{++} = \sqrt{1-\xi^2}\,\frac{\sqrt{t_0-t}}{2m}\left[F_1\,\mathcal{H} + \xi(F_1+F_2)\,\tilde{\mathcal{H}} - \frac{t}{4m^2}F_2\,\mathcal{E}\right]$$

SENSITIVITY TO E WITH TRANSVERSE TARGET

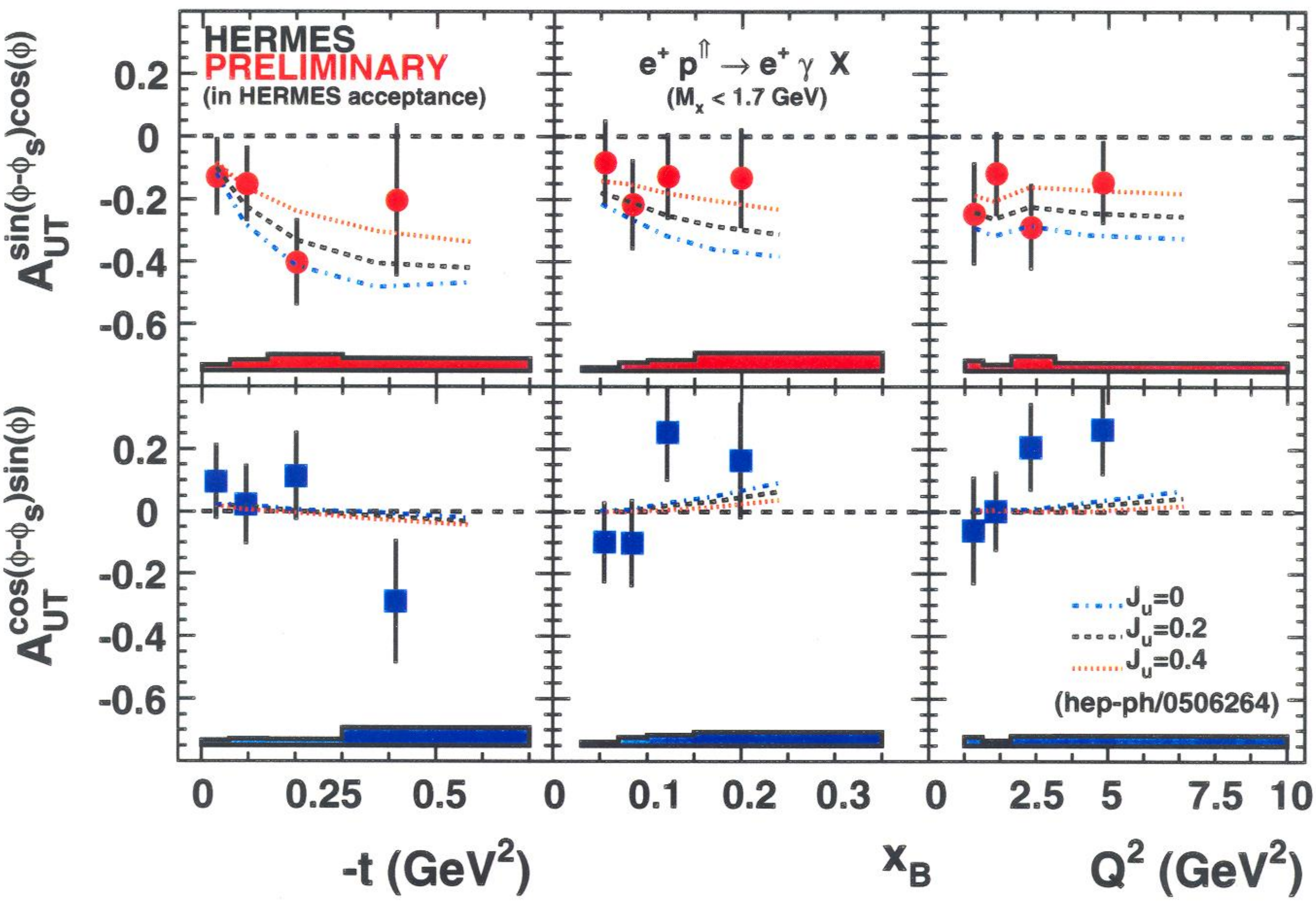
$\rightarrow$ $$-\frac{t}{4m^2}F_2\,\mathcal{H} + \frac{t}{4m^2}F_1\,\mathcal{E}$$ + SUPPRESSED TERMS

FOR TARGET SPIN $\perp$ HADRON PLANE

$\rightarrow$ $$-\frac{t}{4m^2}F_2\,\tilde{\mathcal{H}} + \frac{t}{4m^2}F_1\,\xi\tilde{\mathcal{E}}$$ + SUPPRESSED TERMS

FOR TARGET SPIN $\parallel$ HADRON PLANE

$$A_{UT}(\phi, \phi_S) = \frac{d\sigma(\phi, \phi_S) - d\sigma(\phi, \phi_S + \pi)}{d\sigma(\phi, \phi_S) + d\sigma(\phi, \phi_S + \pi)}$$
$$= \sum_i A_{UT}^{f^i} f^i(\phi, \phi_S)$$



PRELIM. HERMES DATA

VS. MODEL FOR GPDS WITH J_u AS PARAMETER IN $E^u(x, \xi, t)$

SUMMARY

- FACTORIZATION → SCALING BEHAVIOR
  → HELICITY SELECTION RULES

  SOME PROCESSES DO NOT FACTORIZE

- DVCS : MOST DETAILED ACCESS TO GPDS

- MESON PRODUCTION : EXTRA INFORMATION
  FLAVOR STRUCTURE

  BUT MORE INVOLVED DYNAMICS