Effects of e$^{\pm}$ Polarization on the Final States at HERA

Ringberg Workshop

New Trends in HERA Physics 2003

28 September - 3 October 2003

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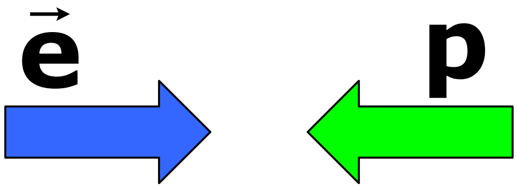
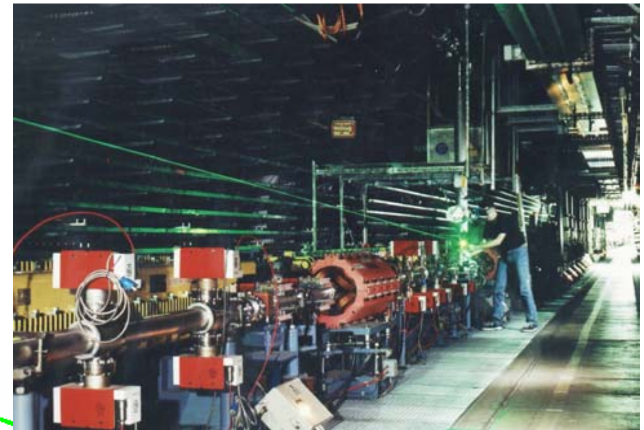
Outline

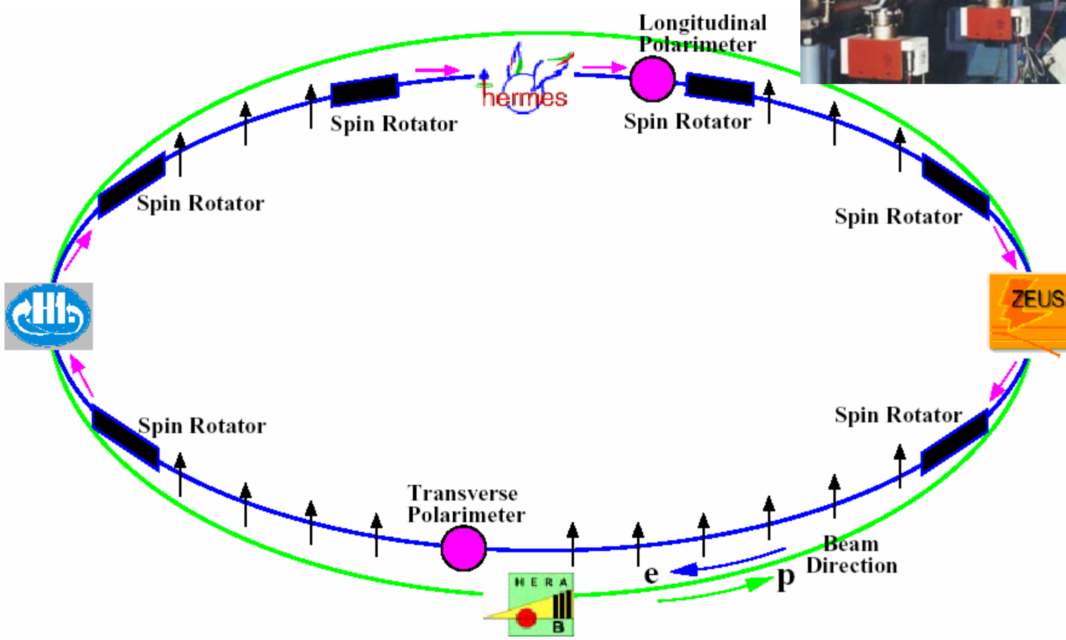
- **HERA II**
- **Polarization Dependent Inclusive Cross Section**
  CC, NC
- **Deeply Virtual Compton Scattering**
  cross section, asymmetries
- **Asymmetries in Particle Production**
- **Beam Spin Transfer to Λ-Baryons**
- **Conclusion**

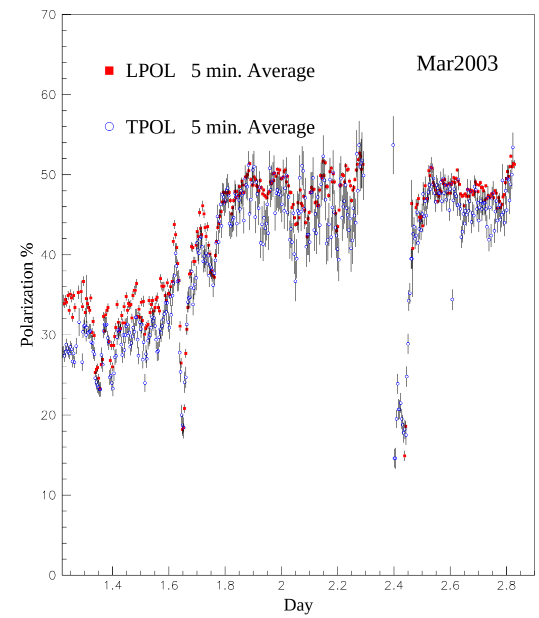
First Polarized e @H1+ZEUS in 2003



319 GeV







The HERA II Beam Options

e-beam

- **e^+ and e^-** ➔ ***beam charge dependencies***
- **longitudinally parallel/anti-parallel polarizations with expected values up to 50-60% with a precision of $\delta P/P \sim 1\%$** ➔ ***beam spin dependencies***

➔ **enhanced physics potential !**

high luminosity

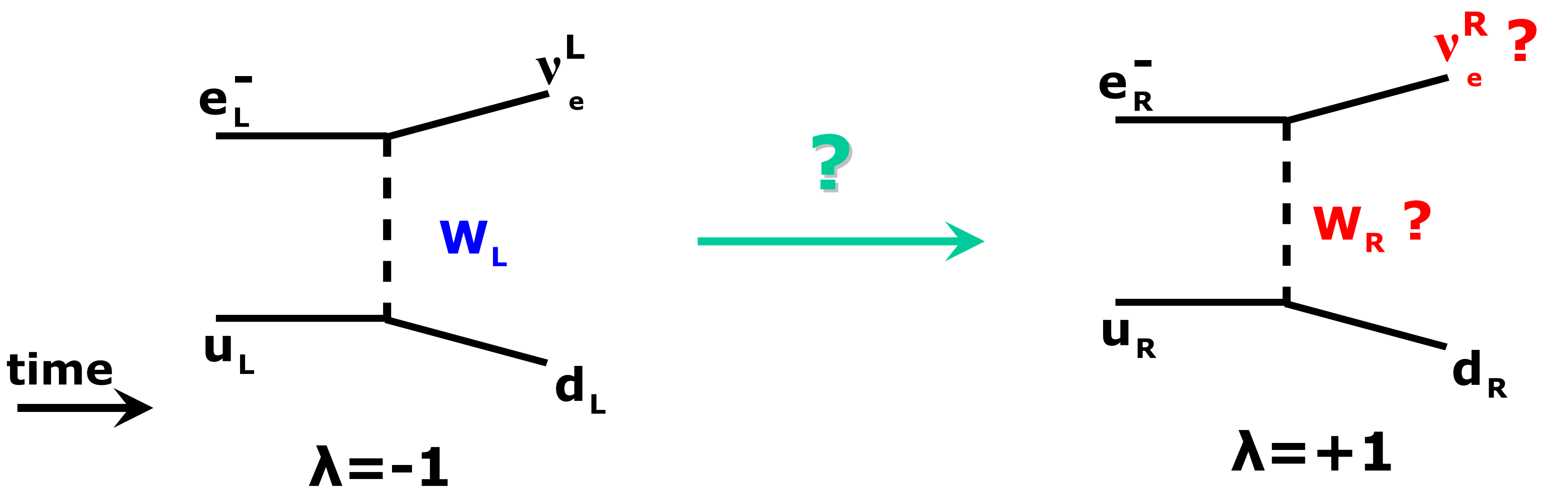
- **up to 1fb^{-1} until 2006,**
  i.e. about 200pb^{-1} per sample $e^+(\lambda=\pm 1)$, $e^-(\lambda=\pm 1)$ expected and wanted

but *p-beam unpolarized* still !

➔ **no access to polarized proton and photon PDFs (requires double spin asymmetries)**

The Classic's…

"Classic" Goal (I): Search for Right-Handed Currents in CC DIS



forbidden in Standard Model: $\sigma_{CC} \rightarrow 0$ for $e^{\pm}_R$

➔ *textbook* measurement !

Simulation of $\sigma^{\pm}_{CC}(\lambda)$

$$\sigma^{\pm}_{CC} = \frac{2\pi\alpha^2}{xQ^4}\kappa_W^2(Q^2)\frac{1\pm\lambda}{2}\left(Y_+W_2^{\pm} \mp Y_- xW_3^{\pm}\right)$$

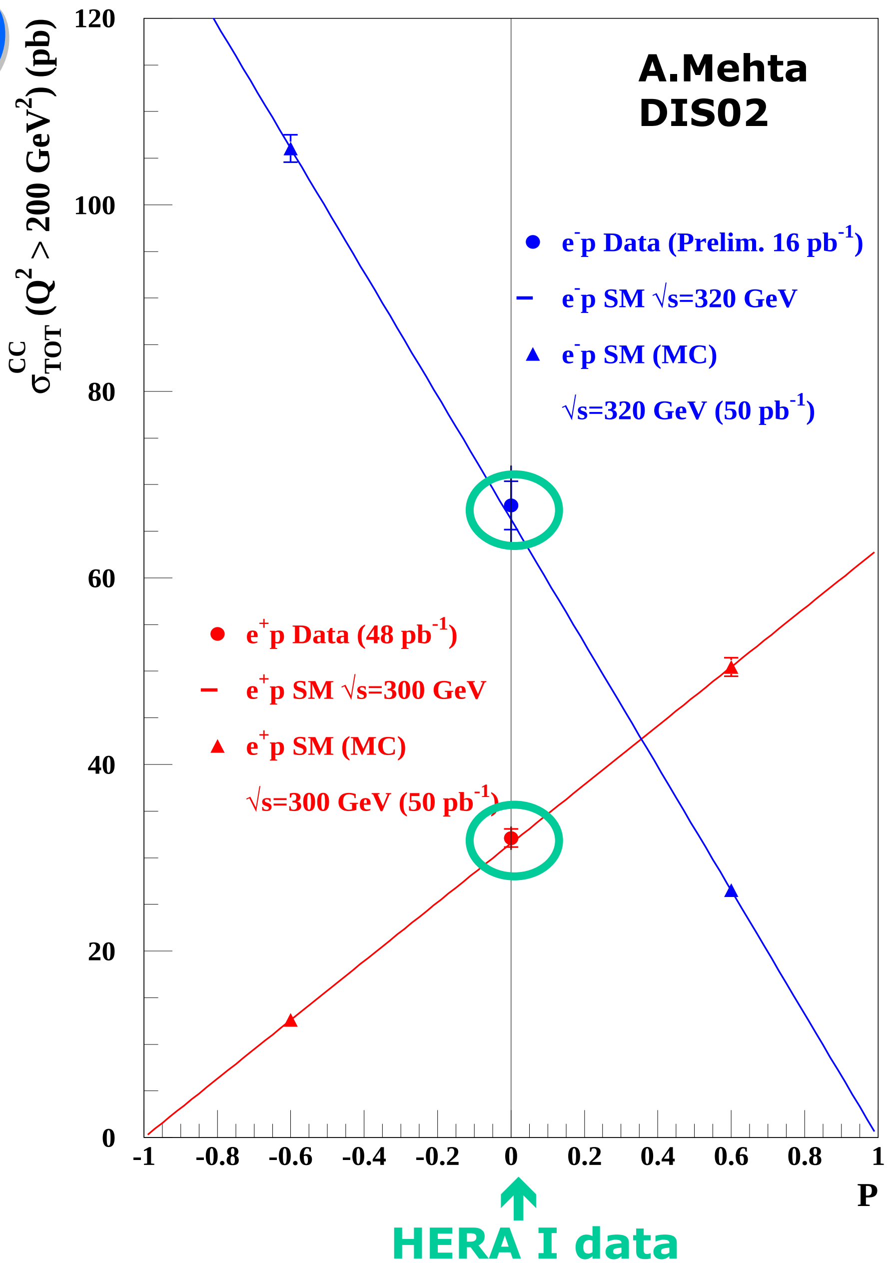
$$\text{with } Y_+ = 2 - 2y + y^2/(1+R)$$

$$Y_- = 1-(1-y)^2$$

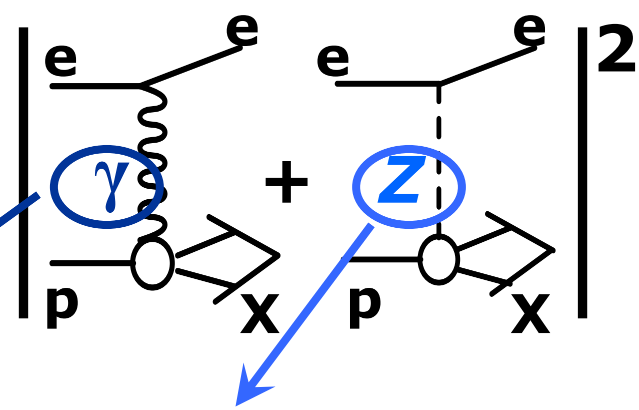
$$\kappa_W = \frac{Q^2}{Q^2+M_W^2}\frac{1}{4\sin^2\theta_W} \simeq 1 \quad \text{for } Q^2 \gg M_W^2$$

$50pb^{-1}$ per $\lambda=\pm0.6$
→ modest luminosity but high polarization needed

➔ new physics beyond SM if any deviation from straight line



"Classic" Goal (II): Parity Violation in NC



interference of electromagnetic and weak neutral currents
➔ vector (v) and axial-vector (a) contributions

$$\frac{d\sigma^{\mp}_{int}(\lambda)}{dQ^2 d\nu} = \frac{2\pi\alpha^2}{xQ^4}\kappa_Z\left(Q^2\right)\left\{Y_+\left(R=0\right)G_2\left(-v_e \pm \lambda a_e\right) + Y_- xG_3\left(\mp a_e + \lambda v_e\right)\right\}$$

- **depending both on beam polarization λ and beam charge (±)**
- **new structure functions G_2 and xG_3 containing quark couplings to the Z boson**

$$G_2(x) = 2x\Sigma_q v_q e_q\left(q(x)+\bar{q}(x)\right)$$

$$xG_3(x) = -2x\Sigma_q a_q e_q\left(q(x)-\bar{q}(x)\right)$$

$$v_f = T_{3f} - 2e_f \sin^2\theta_W$$

$$a_f = T_{3f}$$

Asymmetries in NC DIS

varying beam polarization [ed: SLAC 1978]

➔ **one *parity-violation asymmetry* per beam charge**

$$A^{\mp}(\lambda_1,\lambda_2)=\frac{d\sigma^{\mp}(\lambda_1)-d\sigma^{\mp}(\lambda_2)}{d\sigma^{\mp}(\lambda_1)+d\sigma^{\mp}(\lambda_2)} = -\kappa_Z\,\frac{\lambda_1-\lambda_2}{2}\left(\mp a_e\frac{G_2}{F_2}+v_e\frac{xG_3}{F_2}\,\frac{1-(1-y)^2}{1+(1-y)^2}\right)$$

v_e: ~0

$\frac{1-(1-y)^2}{1+(1-y)^2}$: ~0 for y→1, ~1 for y→0

varying of both λ and beam charge [μC: BCDMS 1981]

➔ ***'beam conjugation' asymmetry***

$$B(\lambda_1,\lambda_2)=\frac{d\sigma^{+}(\lambda_1)-d\sigma^{-}(\lambda_2)}{d\sigma^{+}(\lambda_1)+d\sigma^{-}(\lambda_2)} \simeq -\kappa_Z\left(a_e+\frac{\lambda_1-\lambda_2}{2}v_e\right)\frac{xG_3}{F_2}\,\frac{1-(1-y)^2}{1+(1-y)^2}$$

a_e: unpol. γZ-interference contribution

➔ **measurements require high polarization values and high Q2 values**

$$\kappa_Z=\frac{1}{4\cos^2\theta_W\sin^2\theta_W}\,\frac{Q^2}{M_Z^2+Q^2}\simeq 1.7\cdot 10^{-4}\,Q^2/\mathrm{GeV}^2$$

Simulation of $G_2(x,Q^2)$ at high Q^2

for $\lambda_2=-\lambda_1$ and $v_e=0$:

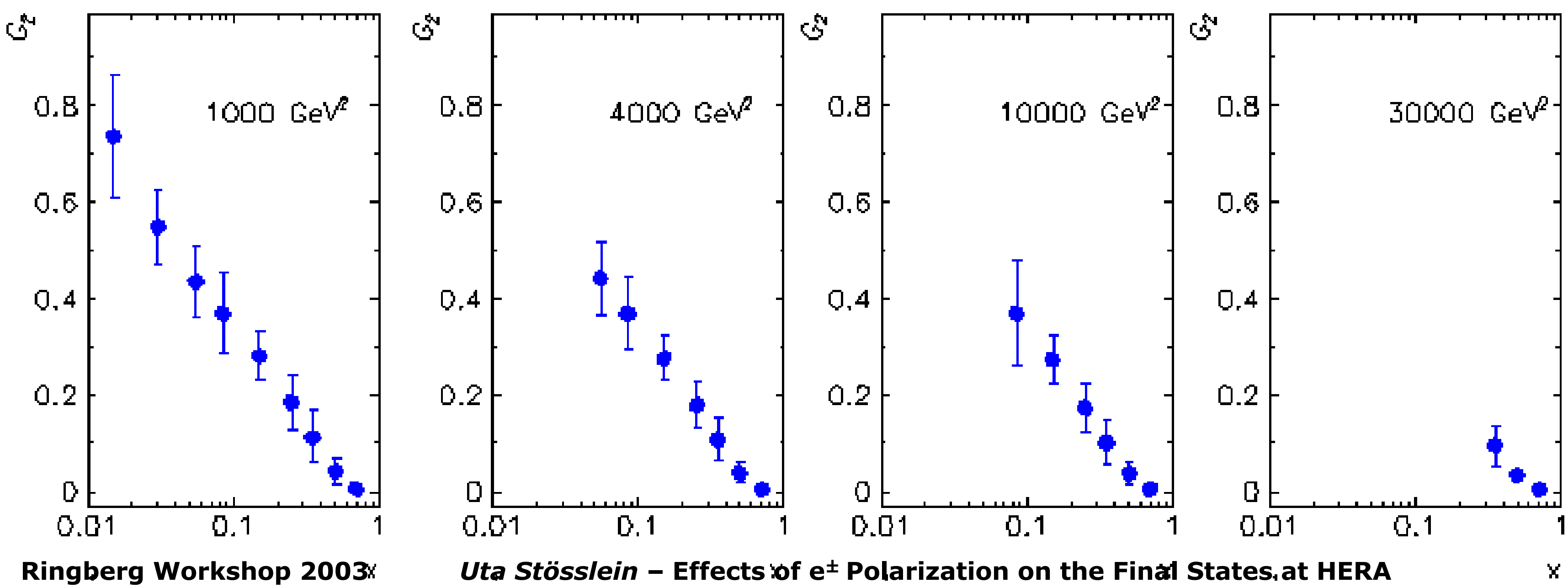
$$A^{\mp}(\lambda) = \mp\kappa_Z\lambda a_e \frac{G_2}{F_2} \overset{x\to1}{\sim} \pm\kappa_Z\lambda \frac{1+d_v/u_v}{4+d_v/u_v}$$

using approximation:

$$F_2 \simeq \frac{1}{9}x\left(4(u+\bar{u})+(d+\bar{d})\right)$$ → Singlett+ Non-Singlett

$$G_2 \simeq \frac{2}{9}x\left((u+\bar{u})+(d+\bar{d})\right)$$ → Singlett

➔ **extraction of $G_2(x,Q^2)$ using knowledge of $F_2(x,Q^2)$**



200pb⁻¹ per
$\lambda = \pm 0.5$

M.Klein DIS01

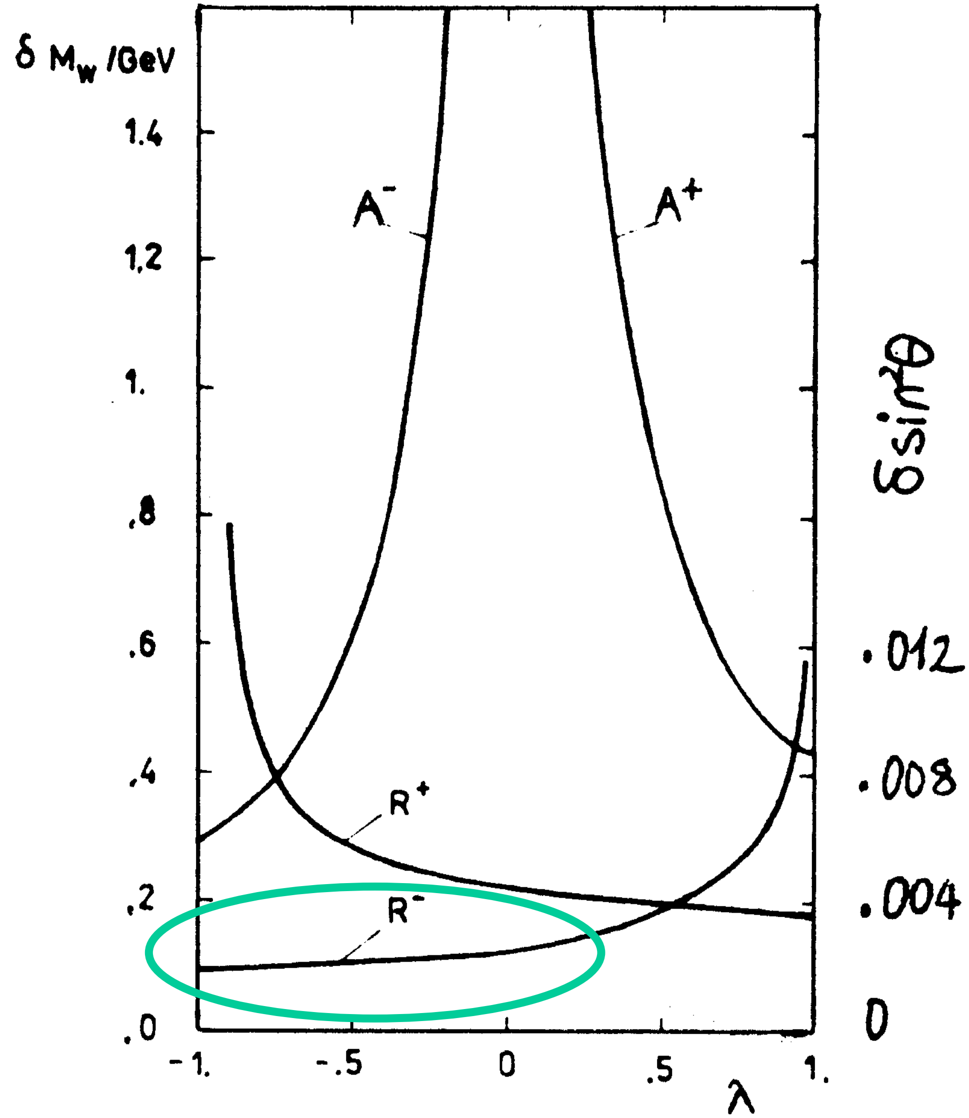
Test of Electroweak Parameter

J.Blümlein et al.
HERA WS87

employ beam polarization and charge to test M_W or $\sin^2\theta_W$ via

- **parity-violation asymmetry $A^{\pm}(\lambda)$**
- **cross section ratio $R^{\pm}(\lambda)$**

$$R^{\pm}(\lambda) = \frac{\sigma^{\pm}_{NC}(\lambda)}{\sigma^{\pm}_{CC}(\lambda)}$$

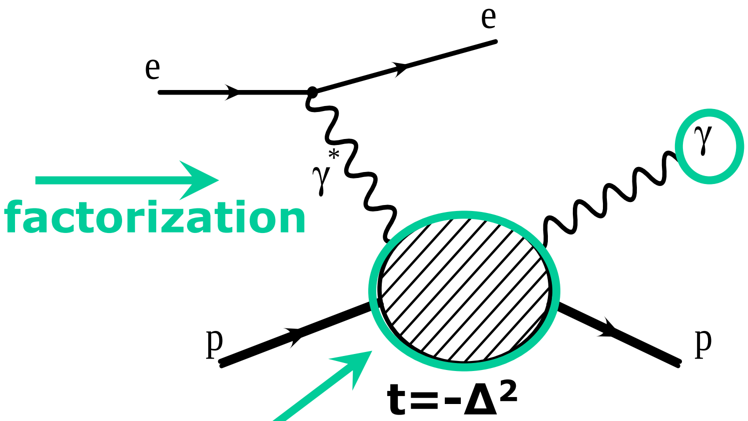


→ stat. error of M_W from R^- *best* and only 25% worse if $\lambda=0$ instead of -1 ($\delta\lambda=1\%$) although $\sigma_{CC}(\lambda=-1)/\ \sigma_{CC}(\lambda=0)\sim 2$

The "New" Classic's…

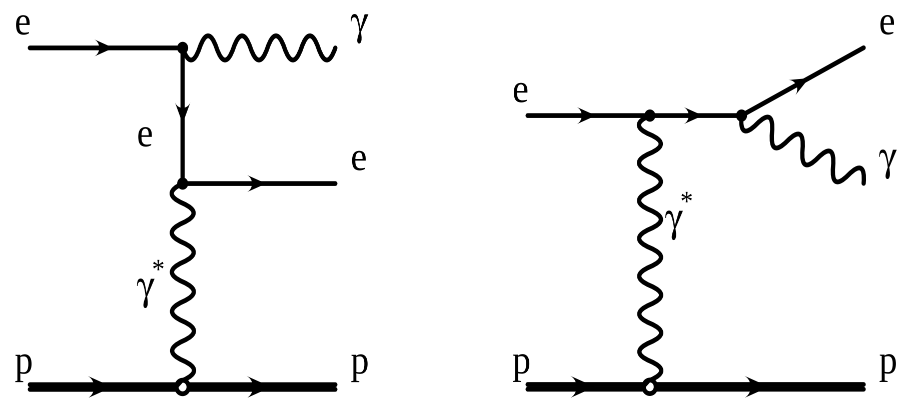
Deeply Virtual Compton Scattering

DVCS



new info on structure of nucleon!

Bethe-Heitler



diffractive production of a real photon

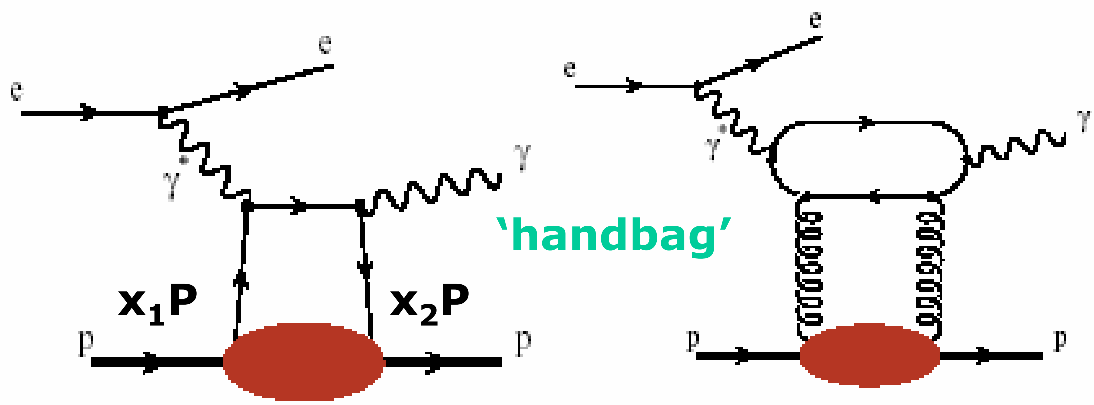
$$d^4\sigma/dx dQ^2 d|t| d\phi \propto |\tau_{DVCS}|^2 + |\tau_{BH}|^2 + |\tau^*_{DVCS}\, \tau_{BH}| + |\tau_{DVCS}\, \tau_{BH}^*|$$

DVCS **: QCD process → sensitive to *underlying dynamics***

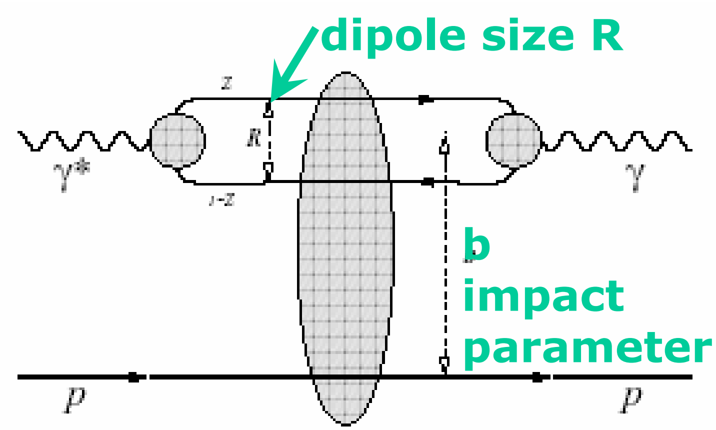
Bethe-Heitler **: QED process → background and *interference***

DVCS : Models

GPD **based models**



Color Dipole **based models**



- **GPD incorporate both a *partonic and distributional amplitude behavior***
  ➔ access to dynamical relation between different partons (particle correlations, orbital angular momentum)
  ➔ three-dimensional distribution of nucleon substructure
- ***QCD picture*** (hard scattering factorization: LO, beyond LO, beyond twist-2)

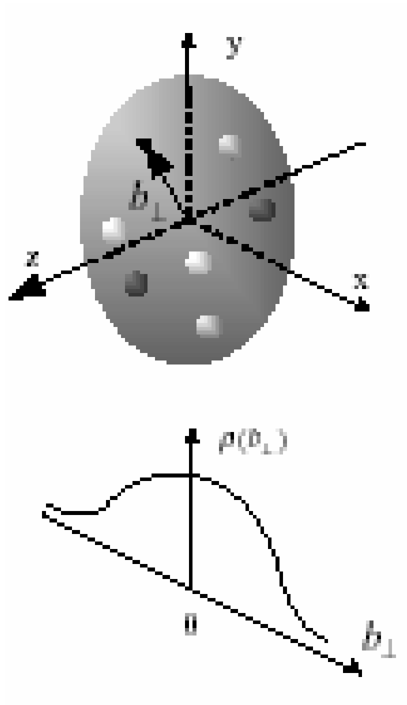
- **simple unified picture of diffractive processes**
  ➔ match soft and hard regimes
  ➔ implementation of e.g. saturation effects
- ***broad phenomenology***

[V.Belitsky, D.Müller,hep-ph/0206306]
[M.Burkhardt,PRD62(2000)071503]

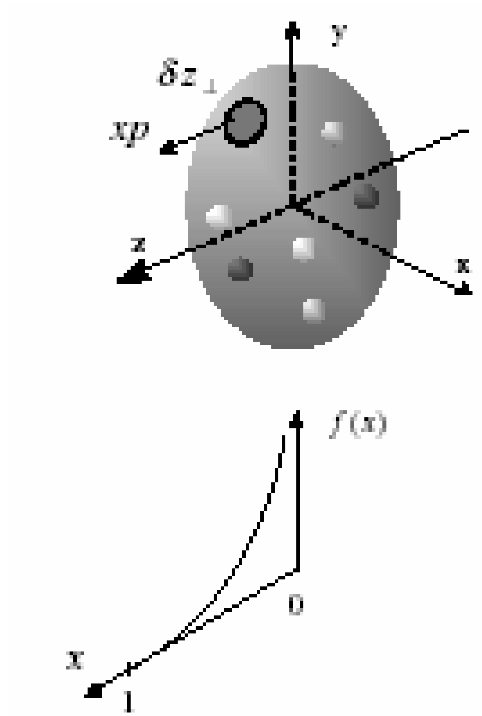
Nucleon Holography

GPD provide transverse location of partons in the nucleon

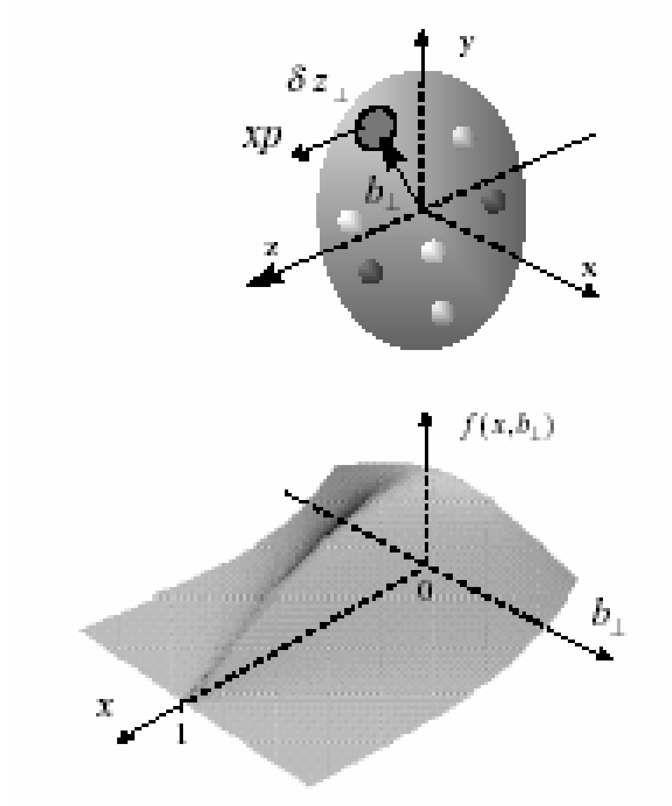
form factor



parton density



GPD at η=0

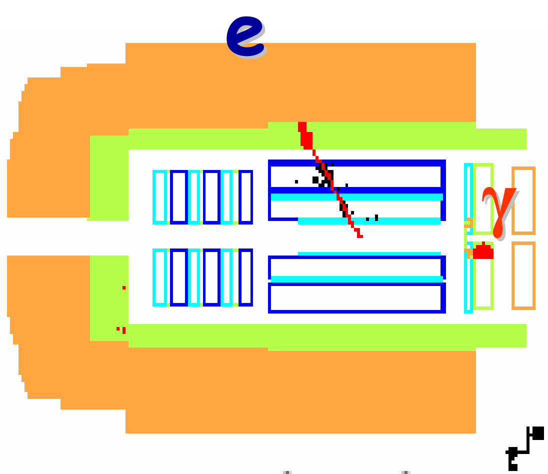


see also talks by A.Freund and
C.Weiss at HERA 3 WS02

$b \sim 1/(-t)^{1/2}$

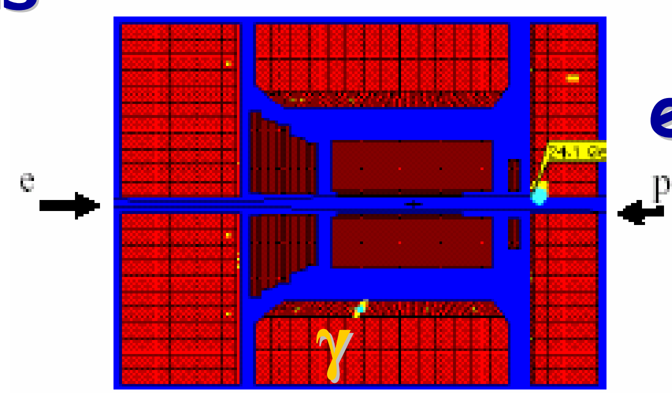
DVCS : Experimental Signatures

BH

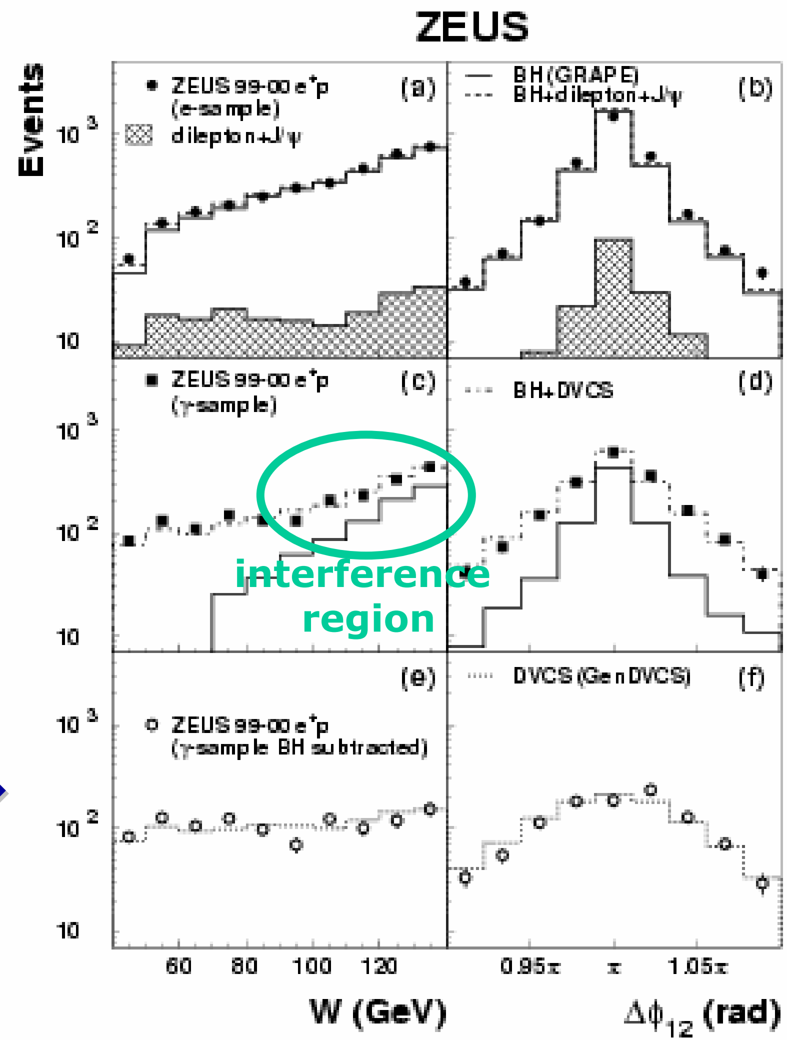


control sample

DVCS

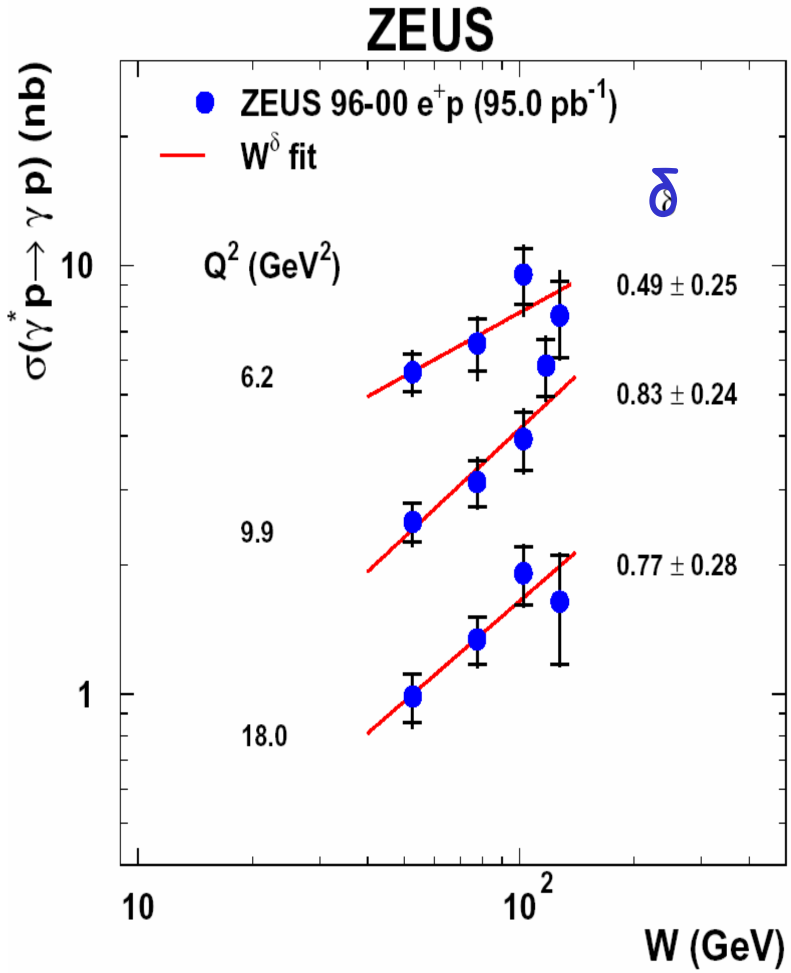


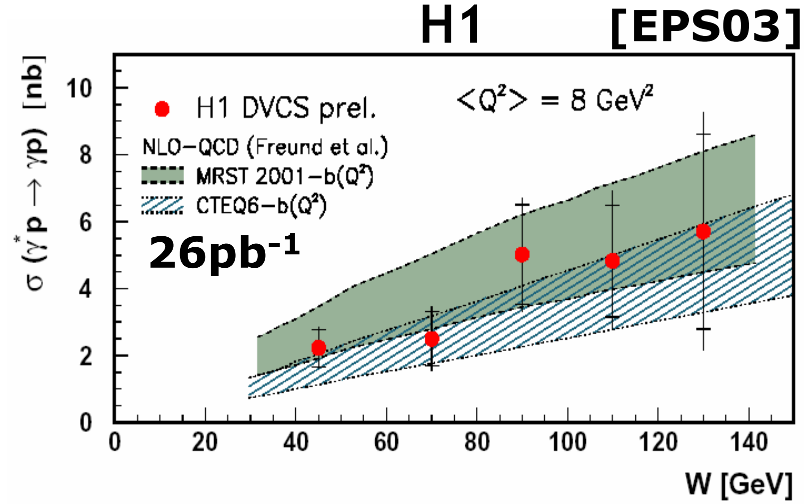
signal sample

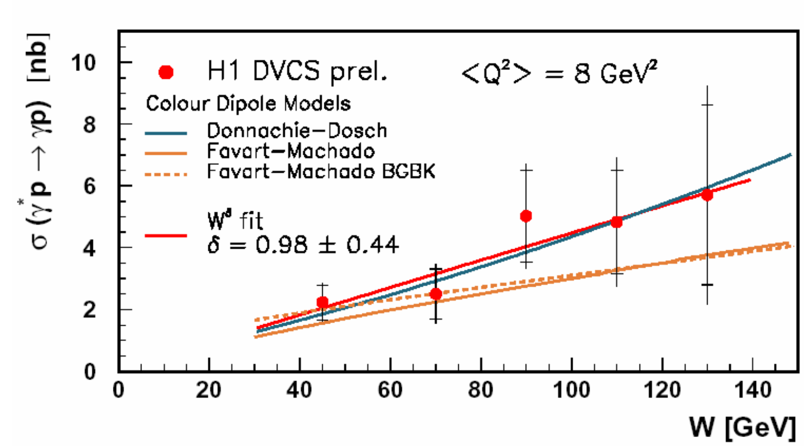


[hep-ex/0305028]

DVCS : Cross Section vs W

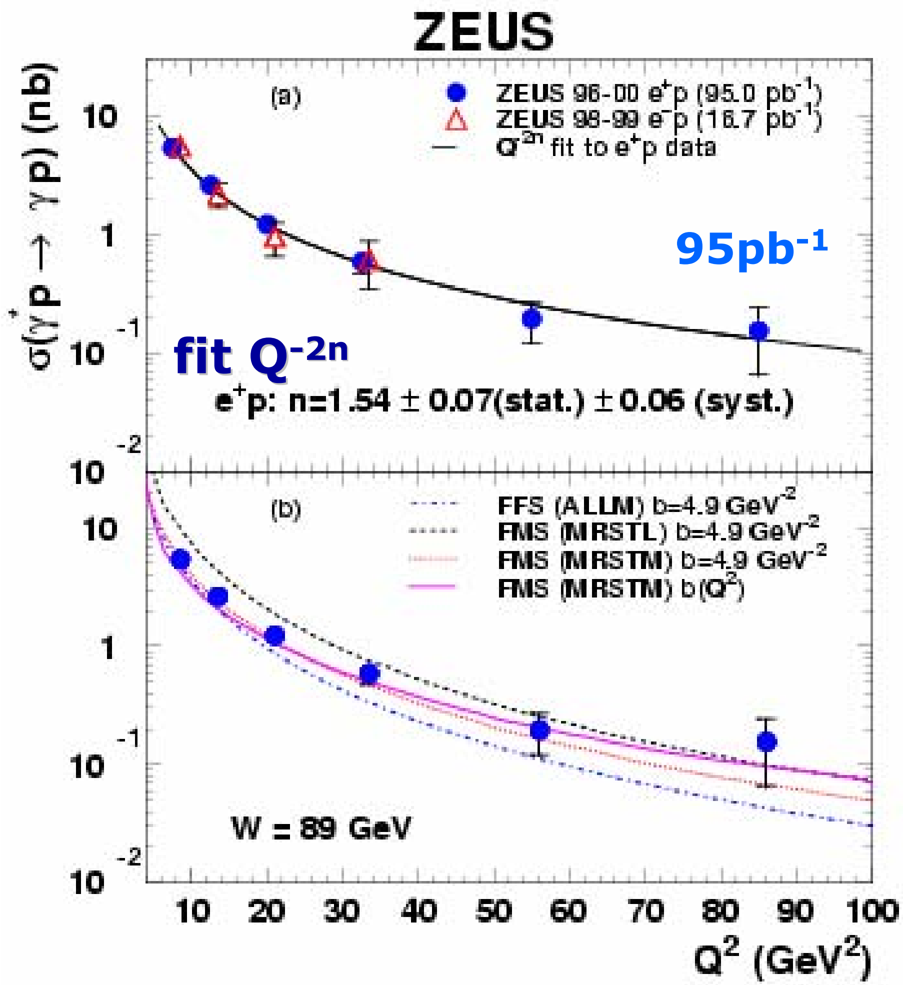


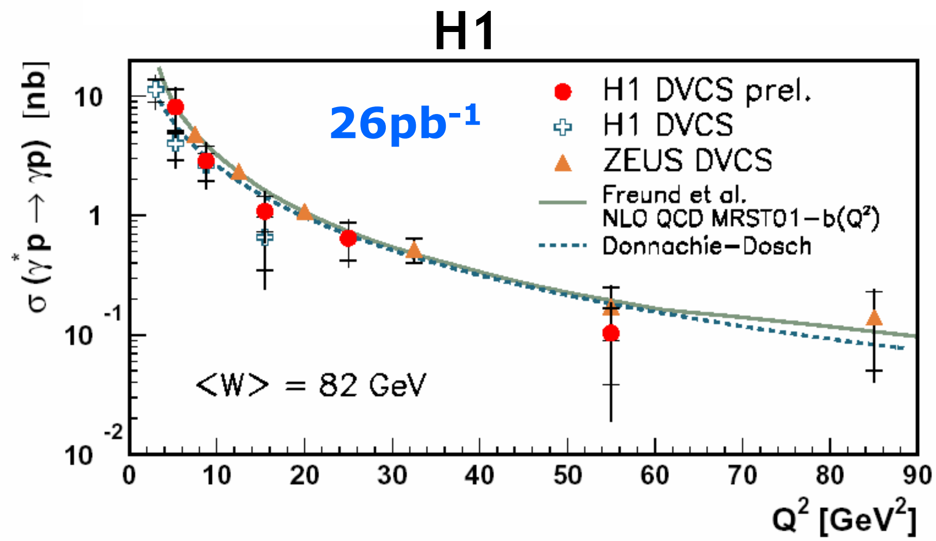




➔ **W dependence matches $W^{0.7}$ behavior of hard VM production**

DVCS : Cross Section vs Q^2





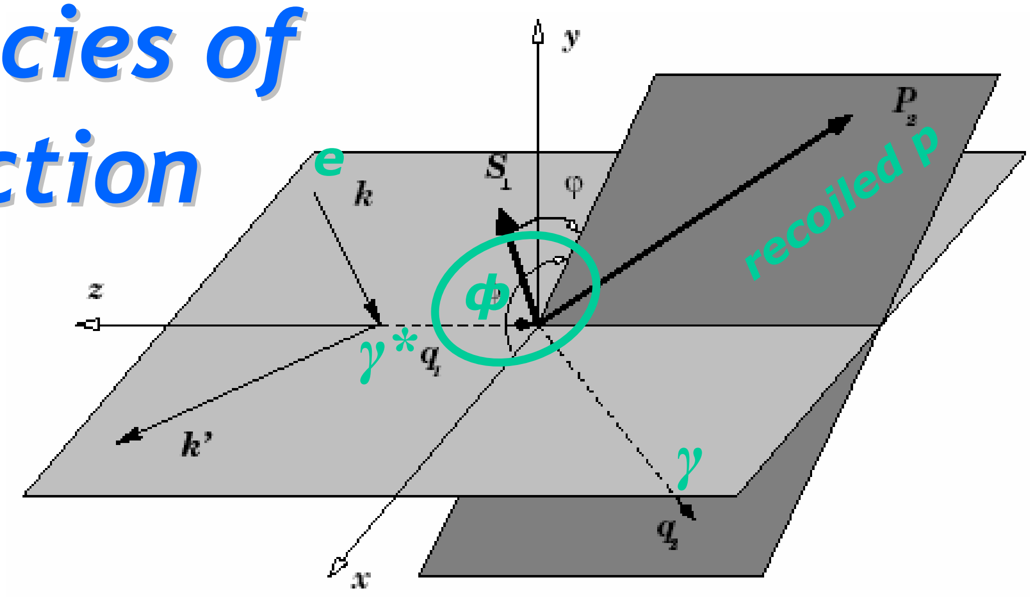
➔ **Q2 dependence well described by GPD or color dipole based models**

(integrated over exp. t range)

➔ HERAII : factor 10 more statistics expected

[V.Belitsky et al.,hep-ph/0112108]

Angular Dependencies of ep → epγ Cross Section



angle between the lepton and hadron scattering planes

$\phi = \phi_N - \phi_l$

BH

$$|\mathcal{T}_{\rm BH}|^2 = \frac{e^6}{x_{\rm B}^2 y^2 (1+\epsilon^2)^2 \Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left\{ c_0^{\rm BH} + \sum_{n=1}^{2} c_n^{\rm BH} \cos(n\phi) + s_1^{\rm BH} \sin(\phi) \right\},$$

DVCS

$$|\mathcal{T}_{\rm DVCS}|^2 = \frac{e^6}{y^2 Q^2} \left\{ c_0^{\rm DVCS} + \sum_{n=1}^{2} \left[c_n^{\rm DVCS} \cos(n\phi) + s_n^{\rm DVCS} \sin(n\phi) \right] \right\},$$

Interference

$$\mathcal{I} = \frac{\pm e^6}{x_{\rm B} y^3 \Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left\{ c_0^{\mathcal{I}} + \sum_{n=1}^{3} \left[c_n^{\mathcal{I}} \cos(n\phi) + s_n^{\mathcal{I}} \sin(n\phi) \right] \right\},$$

➔ ***Complex and rich angular structure*** **of the cross section!**

➔ **But, which angular dependencies are the relevant ones?**

Contributions for an Unpolarized p

employ angular structure to access more observables,
in particular in dependence on beam spin (λ) and charge (±)

cos*ϕ*, cos2*ϕ*

$$|\mathcal{T}_{\rm BH}|^2 = \frac{e^6}{x_{\rm B}^2 y^2 (1+\epsilon^2)^2 \Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left\{ c_0^{\rm BH} + \sum_{n=1}^{2} c_n^{\rm BH} \cos(n\phi) + s_1^{\rm BH} \sin(\phi) \right\},$$

T pol. p only

cos*ϕ* , λsin*ϕ* → *twist-3 !*

$$|\mathcal{T}_{\rm DVCS}|^2 = \frac{e^6}{y^2 Q^2} \left\{ c_0^{\rm DVCS} + \sum_{n=1}^{2} \left[c_n^{\rm DVCS} \cos(n\phi) + s_n^{\rm DVCS} \sin(n\phi) \right] \right\},$$

sin2*ϕ*→ L,T pol. p only

charge dep

cos*ϕ* , λsin*ϕ*

$$\mathcal{I} = \frac{\pm e^6}{x_{\rm B} y^3 \Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \left\{ c_0^{\mathcal{I}} + \sum_{n=1}^{3} \left[c_n^{\mathcal{I}} \cos(n\phi) + s_n^{\mathcal{I}} \sin(n\phi) \right] \right\},$$

known cos*Φ*-dependence due to lepton BH propagators

cos2*ϕ* , λsin2*ϕ* → *twist-3 !*

➢ DVCS amplitude with gluon transversity (twist-2, but α_S power supp.) :
- squared DVCS term : cos2*ϕ* and sin2*ϕ* dependencies
- interference term : cos3*ϕ* and sin3*ϕ* dependencies

➢ BH term: beam polarization dependence only in case of longitudinally or transversely (L,T) polarized target!

Beam Charge and Azimuthal Asymmetry

varying beam charge [HERMES 2002]
➔ ***beam charge asymmetry* (CA)**

$$CA = \frac{2\int_0^{2\pi} d\phi \ \cos(\phi)(d\sigma^+ - d\sigma^-)}{\int_0^{2\pi} d\phi \ (d\sigma^+ + d\sigma^-)} \qquad \propto c^{\mathcal{I}}_{1,\mathrm{unp}} - \frac{1}{3}c^{\mathcal{I}}_{3,\mathrm{unp}} - \frac{2(3-2y)}{2-y}\frac{K}{1-y}\left(c^{\mathcal{I}}_{0,\mathrm{unp}} - \frac{1}{3}c^{\mathcal{I}}_{2,\mathrm{unp}}\right)$$

or counting events scattered 'up' and 'below' lepton scattering plane
to get cosϕ weight ➔ 2 bins in ϕ

$$\Delta d\sigma^{\mathrm{unpol}} = d\sigma^{-,\mathrm{tot}} - d\sigma^{+,\mathrm{tot}}$$

$$\mathrm{CA} = \frac{\int_{-\pi/2}^{\pi/2} \Delta d\sigma^{\mathrm{tot}} - \int_{\pi/2}^{3\pi/2} d\phi \ \Delta d\sigma^{\mathrm{tot}}}{\int_0^{2\pi} d\phi \ d\sigma^{\mathrm{tot}}}$$

CA ~ **Re** ($\tau_{BH} \cdot \tau_{\mathbf{DVCS}}$)

varying azimuthal angle (beam spin and charge fixed)
➔ ***azimuthal angle 'asymmetry'* (AAA)**

$$\mathrm{AAA} = \frac{\int_{-\pi/2}^{\pi/2} d\phi(d\sigma - d\sigma^{BH}) - \int_{\pi/2}^{3\pi/2} d\phi(d\sigma - d\sigma^{BH})}{\int_0^{2\pi} d\phi d\sigma}$$

… requires very good ϕ resolution
and control of twist-3 contamination

AAA ~ **Re** ($\tau_{BH} \cdot \tau_{\mathbf{DVCS}}$)

Beam Spin Asymmetry

varying beam polarization [HERMES, CLAS 2001]
➔ **one *beam spin asymmetry* (SSA) per beam charge**

$$SSA = \frac{2\int_0^{2\pi} d\phi\ \sin(\phi)(d\sigma^{\uparrow} - d\sigma^{\downarrow})}{\int_0^{2\pi} d\phi\ (d\sigma^{\uparrow} + d\sigma^{\downarrow})} \qquad \propto s^{\mathcal{I}}_{1,\mathrm{unp}} - \frac{2(3-2y)}{3(2-y)}\frac{K}{1-y}s^{\mathcal{I}}_{2,\mathrm{unp}} - \frac{(1-y)(2-y)\Delta^2}{yQ^2}x_{\mathrm{B}}s^{\mathrm{DVCS}}_{1,\mathrm{unp}}$$

or counting events scattered 'up' and 'below' rotated-by-90^{o} lepton scattering plane (*left* and *right*) to get sinϕ weight ➔ 2 bins in ϕ

$$\Delta\sigma = d\sigma^{+} - d\sigma^{-}$$

$$\mathrm{SSA} = \frac{\int_0^{\pi} d\phi\ \Delta\sigma - \int_{\pi}^{2\pi} d\phi\ \Delta\sigma}{\int_0^{2\pi} d\phi\ d\sigma^{\mathrm{tot}}}$$

SSA ~ **Im** ($\tau_{BH} \cdot \tau_{\mathbf{DVCS}}$)

- **combination of SSA and CA or AAA gives access to full twist-2 $\tau_{BH} \cdot \tau_{\mathbf{DVCS}}$ amplitude**
- **BH contributions absent in CA and SSA measurements**

Unveiling GPD H

unveiling GPDs from determination of Fourier coefficients obtained from asymmetry measurements

CA
AAA
SSA

access both parts of CFF $\mathcal{H}$

$$\begin{Bmatrix} c^{\mathcal{I}}_{1,\mathrm{unp}} \\ s^{\mathcal{I}}_{1,\mathrm{unp}} \end{Bmatrix} = 8K \begin{Bmatrix} -(2-2y+y^2) \\ \lambda y(2-y) \end{Bmatrix} \begin{Bmatrix} \Re\mathrm{e} \\ \Im\mathrm{m} \end{Bmatrix} \boxed{F_1\mathcal{H} + \frac{x_B}{2-x_B}(F_1+F_2)\widetilde{\mathcal{H}} - \frac{\Delta^2}{4M^2}F_2\mathcal{E}} \rightarrow \mathbf{H}$$

$K^2 \sim -\Delta^2/Q^2 \sim 1/10$

high y needed
→ high γ^* pol.

Compton Form Factors
are convolutions of coefficient functions and GPDs : H, H̃, E, Ẽ
→ appear in *linear* combinations in interference term
→ but in *quadratic* combinations in unpol. cross section

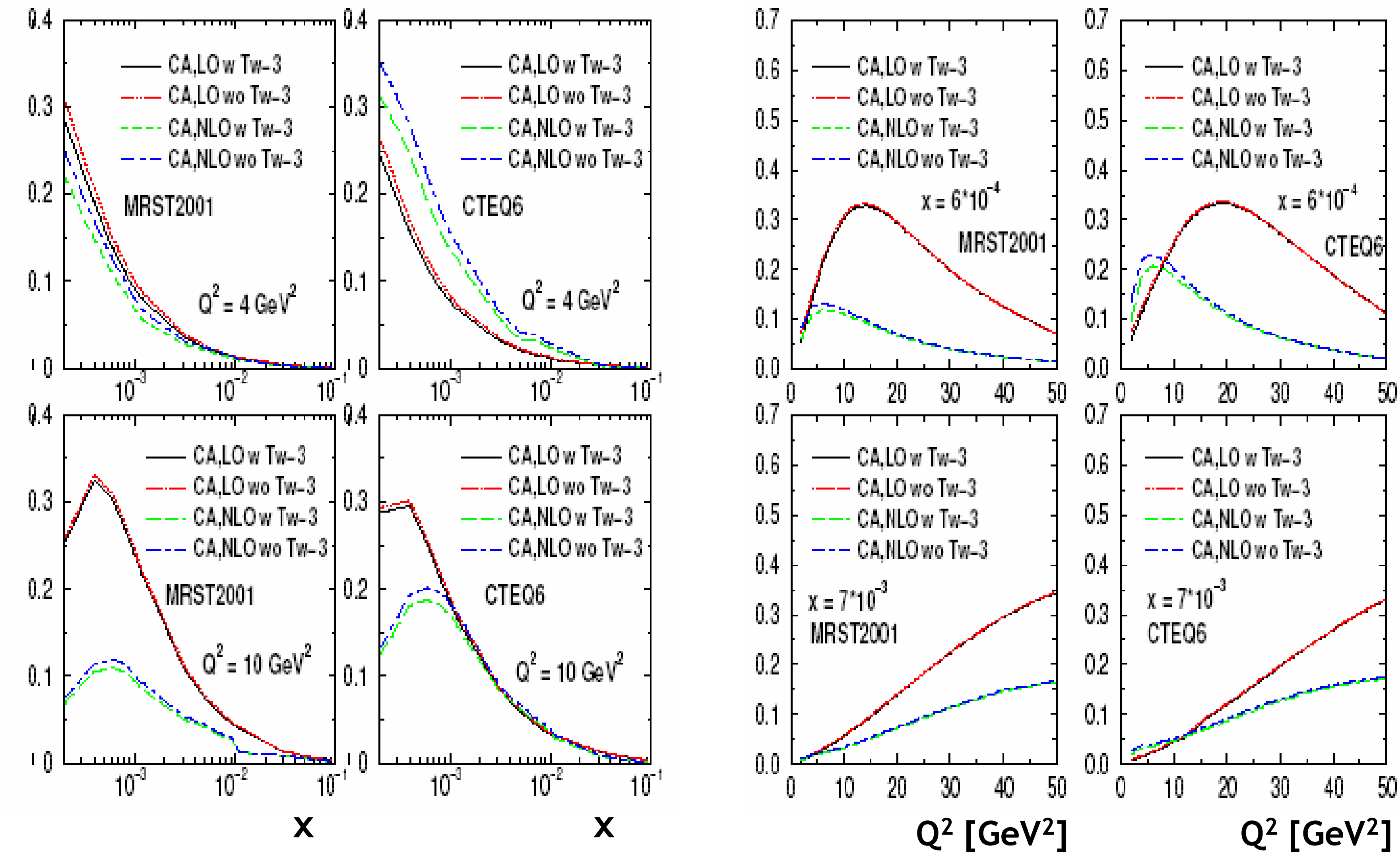
H (unpol. non-spin-flip)	like q, $\bar{q}$, g
H̃ (pol. non-spin-flip)	like Δq, $\Delta\bar{q}$, Δg
E (unpol. spin-flip)	no inlcusive equivalent!
Ẽ (pol. spin-flip)	no inlcusive equivalent!

complete seperation of GPD would require *in addition* data taken with polarized (T,L) target

[A.Freund, hep-ph/0306012]

CA Simulation for HERA

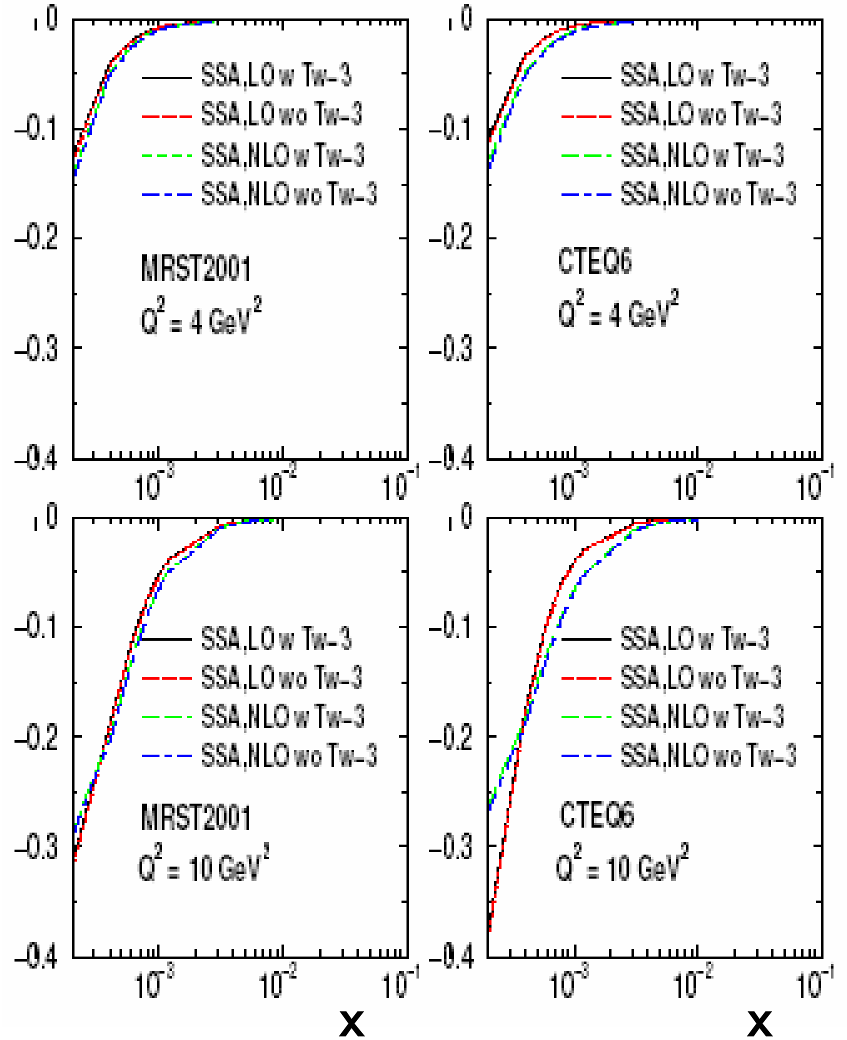
integrated over t, $-t<0.5\mathrm{GeV}^2$, and over ϕ

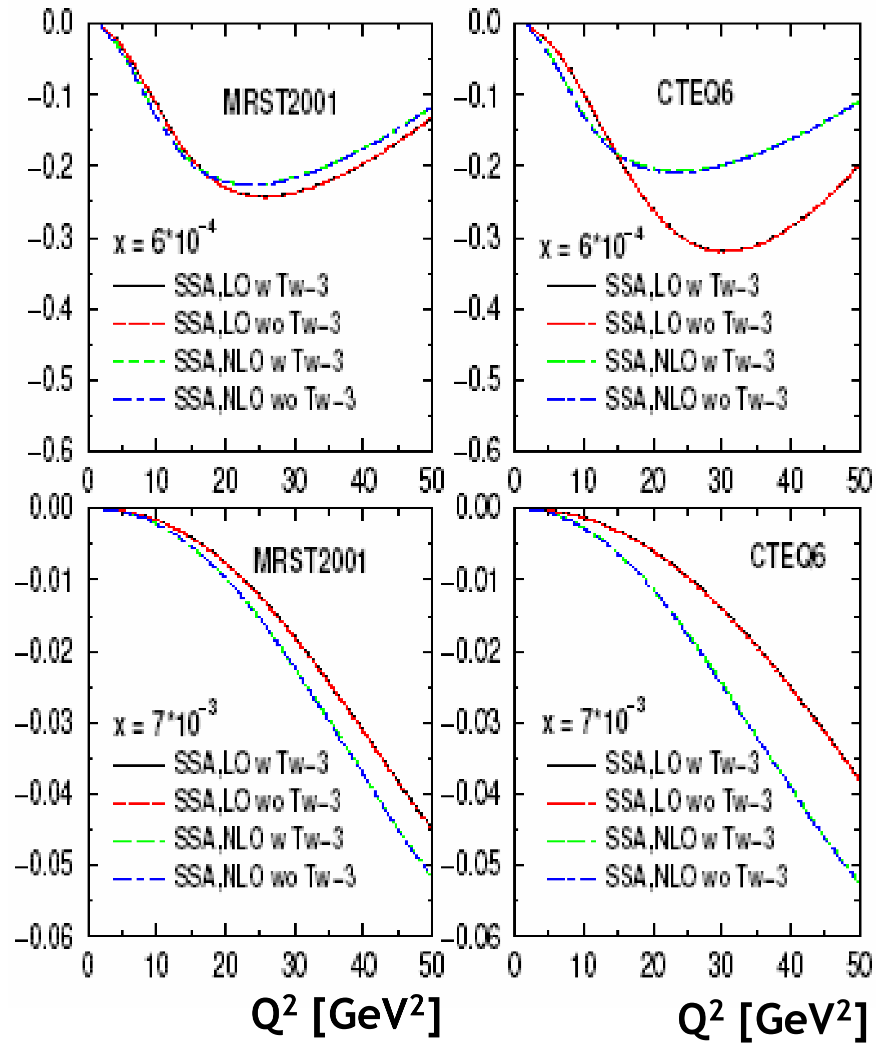


[A.Freund, hep-ph/0306012]

SSA Simulation for HERA ($e^{+}p$)

integrated over t, $-t<0.5\,GeV^2$, and over ϕ





Some Measurement Remarks

ϕ and t are difficult to measure
since scattered proton is *not* observed

$$\phi = \phi_{e'} - \phi_{p'} \approx \phi_{e'} - \phi_{\gamma}$$

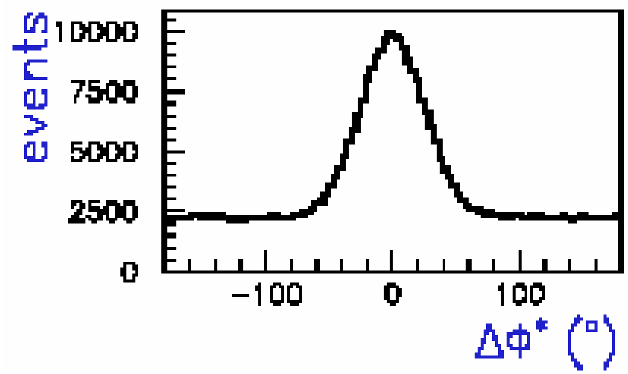
$$t = (p - p')^2 \approx -|\vec{p}_{T_e} + \vec{p}_{T_\gamma}|^2$$

➔ determination of ϕ and t via scattered e' and γ :

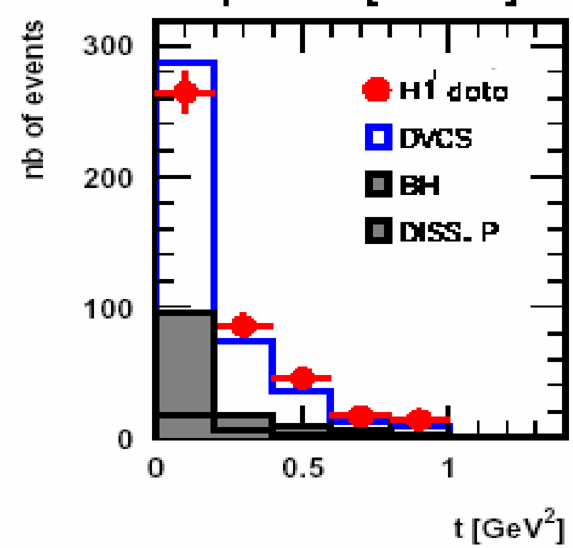
DVCS : backward e' and central γ and veto on p-diss background (→ forward instrumentation)

- **Δt dominated by E and θ resolution of γ**
- **$\Delta\phi$ dominated by E resolution of e'**

[R.Stamen, HERA3 WS02]



H1 prelim [EPS03]



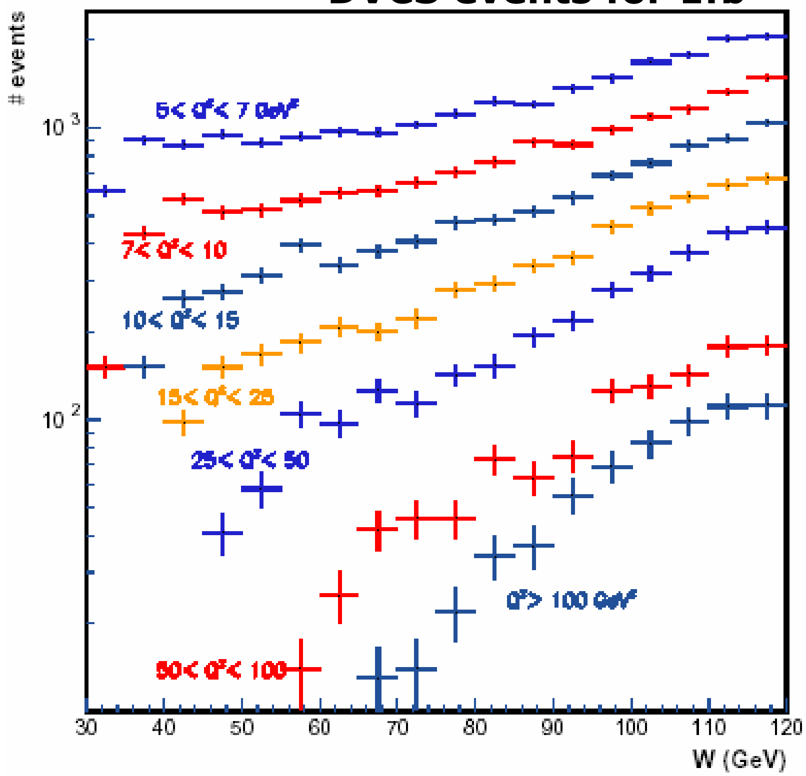
H1 VFPS and DVCS

- better suppression of p-diss background
- some bins in t

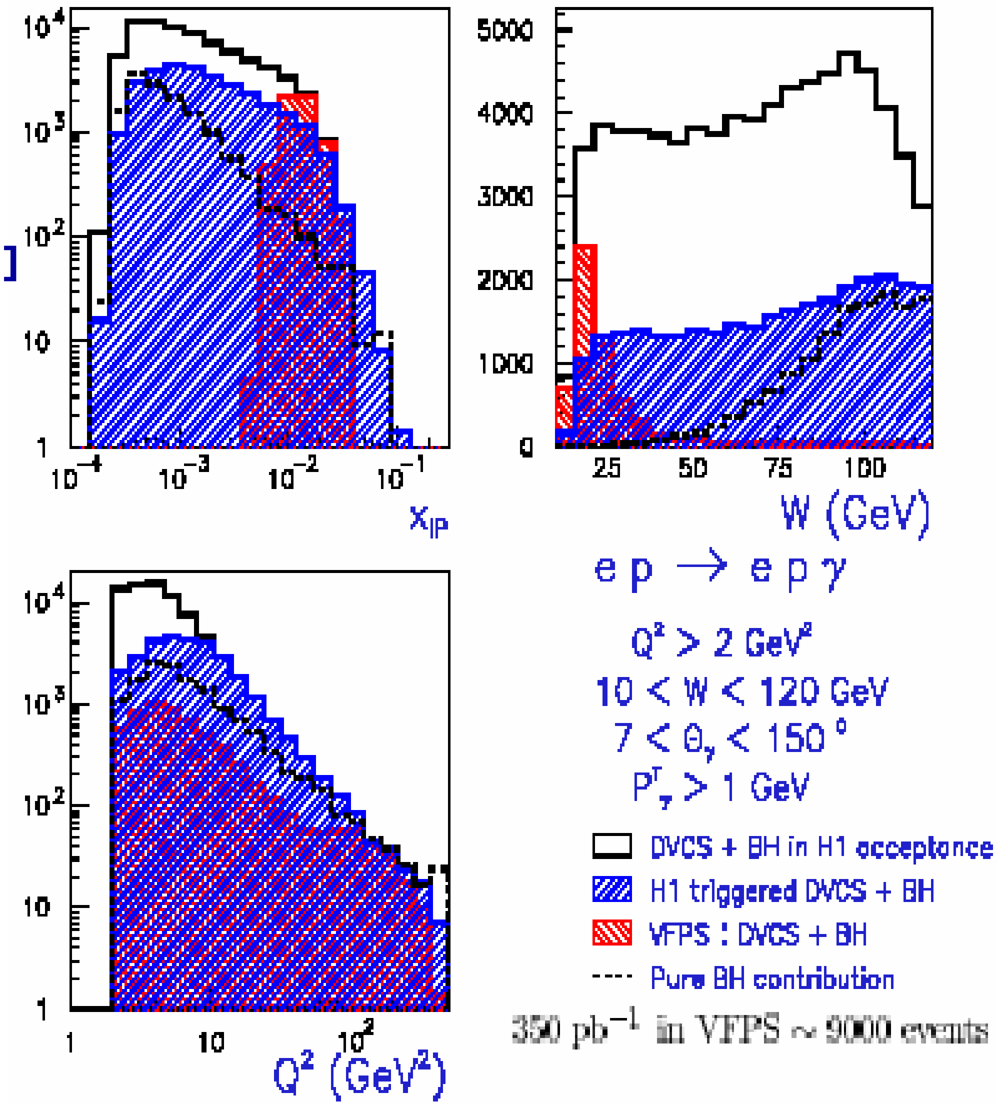
Δ_{sys}(b-slope) $\pm 2\,\mathrm{GeV}^{-2}$ **[H1-PRC01/00]**

- **more bins in ϕ…?**

DVCS events for $1\,\mathrm{fb}^{-1}$



[L.Favart, Trento03]



Simulations for HERA : Some Remarks

• **CA and SSA asymmetries predicted to be sizeable, calculations in LO, NLO, and twist-3 available, see also [V.Belitsky et al.,hep-ph/0112108]**

→ **changing of t cut-off to 1GeV^2 alters results on 10% level**

• **AAA predicted to have similar size as CA**

• **twist-3 effects estimated to be negligible for CA and for SSA**

• **NLO corrections are large, up to 100% for CA and up to 50% for SSA (large NLO gluon contribution in real part of DVCS amplitude)**

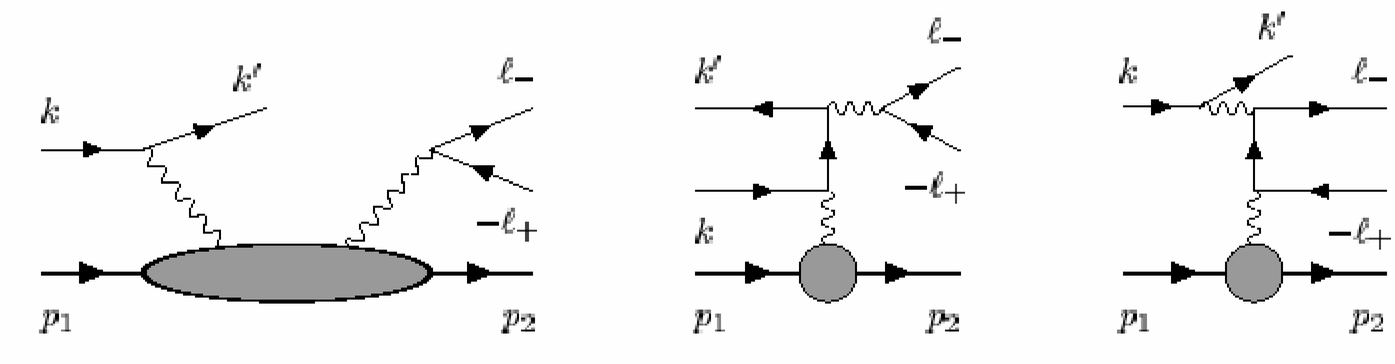
→ **NLO corrections important for precision extraction of GPDs**

• **in general: cross section and asymmetry data can be well modeled, but too many parameters not constrained yet!**

→ ***asymmetry measurements feasible*!**

[V.Belitsky, D.Müller,hep-ph/0307369]

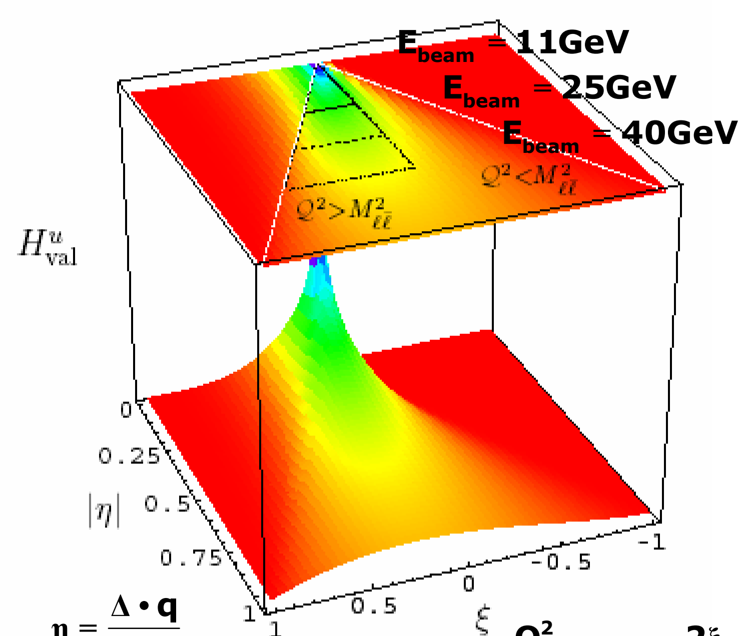
Time-like Virtual Compton Scattering



electroproduction of muon pairs allows clear study of GPDs via ***single beam spin***, single hadron spin, ***beam charge***, azimuthal and double spin asymmetries employing angular dependencies of recoiled p and of lepton pair

➔ **mapping in both scaling variables η and ξ ➔ constrain angular momentum sum rule:**

$$\int_{-1}^{1} d\xi\, \xi \left(H_{q,g}(\xi,\eta,\Delta^2) + E_{q,g}(\xi,\eta,\Delta^2)\right) = 2J_{q,g}$$



$\eta = \frac{\Delta \cdot q}{p \cdot q}$

$\xi = \frac{Q^2}{p \cdot q}; x_B = \frac{2\xi}{1+\xi}$

but cross section very small ➔ high luminosity!

[V.Belitsky et al.,hep-ph/0112108]

Another view on the angular momentum sum rule

$$J^q = \lim_{\Delta\to 0} \sum_{i=u,d,s} \frac{1}{2}\int_{-1}^{1} dx\, x \left\{ H^i(x,\xi,\Delta^2,Q^2) + E^i(x,\xi,\Delta^2,Q^2) \right\}$$
$$= \frac{1}{2}\left\{ (1+\kappa_p+\kappa_n/2)\, P^{u_{\rm val}} + (1+\kappa_p+2\kappa_n)\, P^{d_{\rm val}} + (1+\kappa_{\rm sea})\, P^{\rm sea} \right\}$$

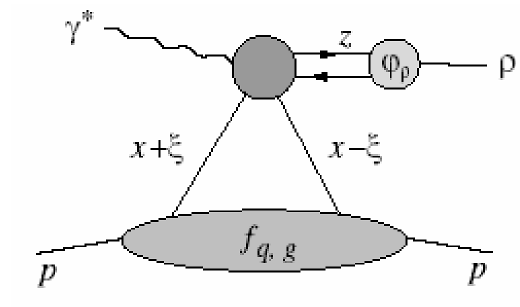
with proton and neutron magnetic moments

$\kappa_p = 1.793$ and $\kappa_n = -1.913$

and κ_{sea} is the orbital angular momentum carried by the quarks

momentum fraction P^i carried by the quarks can be deduced from DIS data alone

Elastic Particle Production



select different GPDs (and quark flavors) via detection of different final states

vector mesons : H, E , e.g. $\rho^0 \to 2J_u + J_d$ [X.Ji,hep-lat/0211016]

pseudoscalar mesons : $\tilde{H}, \tilde{E}$

transitions within the baryon octet : transition GPDs, e.g. $H^{su}_{p\to\Lambda}$

***but* additional complication due to presence of distribution amplitude of the particle, e.g. the pion wave function**

→ for unpol. e beam and *transv. pol. target* large asymmetries have been predicted, see e.g. [K.Goeke et al, hep-ph/0106012]

→ HERMES, CLAS, COMPASS

→special : exclusive strangeness production $\gamma^*_L p \to K^+ \Lambda$
where an azimuthal spin asymmetry can be measured on an *unpolarized* target by measuring the polarization of the recoiling hyperon through its angular distribution

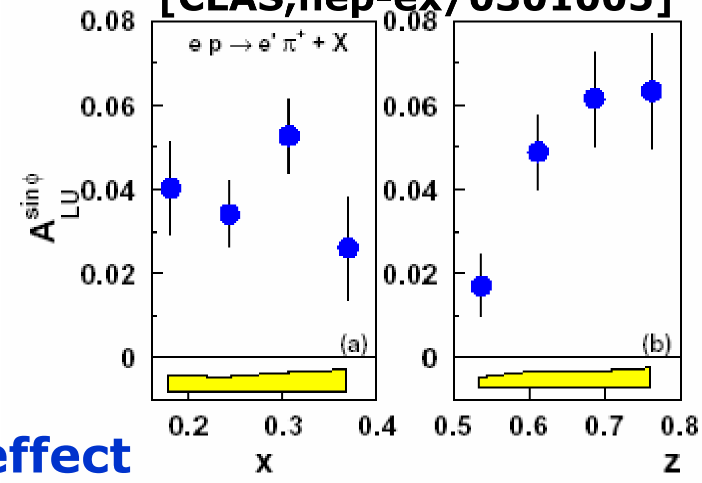
→ ***not studied yet for HERA***

Single Spin Asymmetry in π electroproduction

CLAS: first observation of a positive SSA in SiDIS π^+ production

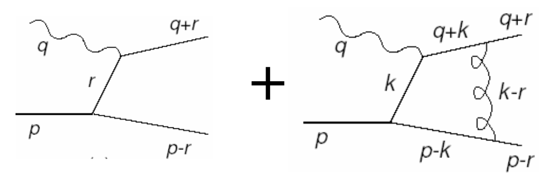
$$A_{LU}^{\sin\phi} = \frac{2}{P^{\pm}N^{\pm}}\sum_{i=1}^{N^{\pm}} \sin\phi_i$$

[CLAS,hep-ex/0301005]



but **expected to be zero in LO**
➔ related to either NLO or higher twist effect

NLO : [A.Afanasev,C.E.Carlson,hep-ph/0308163]
final state gluon exchange deliver contribution to anti-symmetric part of hadronic tensor



➔ lepton beam spin asymmetry is generated due to interference between absorption of longitudinal and transverse virtual photons

$A_{LU} \sim r_T / \sqrt{Q^2}$ **with transverse component of the final quark momentum r_T**

twist-3 : [A.V.Efremov et al.,hep-ph/0208124]
SSA arises from chirally odd twist-3 proton distribution function $e^a(x)$ in combination with chirally-odd and T-odd twist-2 Collins FF

➔ very interesting to test it also at HERA

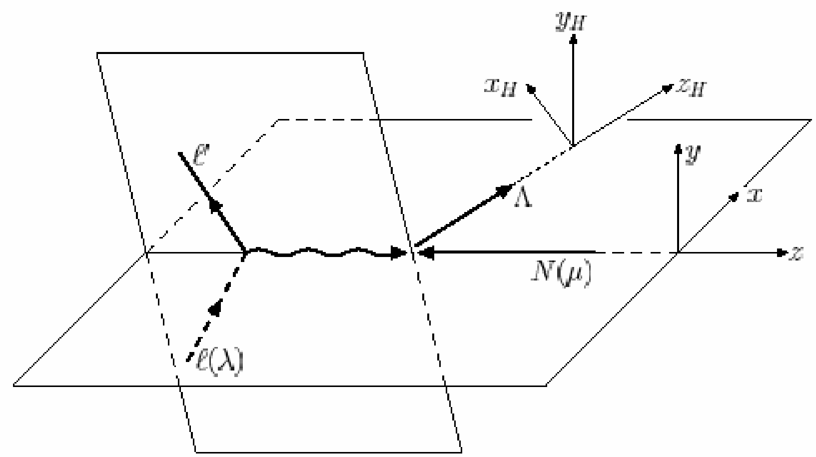
[M.Anselmino,hep-ph/0302008]

Beam Spin Transfer to Λ-Baryon

$$\ell(\lambda)\, p(\mu) \longrightarrow \ell\, \Lambda(h)\, X$$

four independent observables:

Λ production in the $\gamma^* - p$ c.m. frame:



the unpolarized cross-section

$$d\sigma^\Lambda = \frac{2\pi\alpha^2}{sx}\,\frac{1+(1-y)^2}{y^2}\sum_q e_q^2\, q(x)\, D_{\Lambda/q}$$

the double spin asymmetry

$$A_\parallel = \frac{d\sigma^\Lambda_{++} - d\sigma^\Lambda_{+-}}{2\, d\sigma^\Lambda} = \frac{y(2-y)}{1+(1-y)^2}\,\frac{\sum_q e_q^2\, \Delta q(x)\, D_{\Lambda/q}(z)}{\sum_q e_q^2\, q(x)\, D_{\Lambda/q}(z)},$$

the spin transfer from ℓ to Λ (with an unpolarized nucleon)

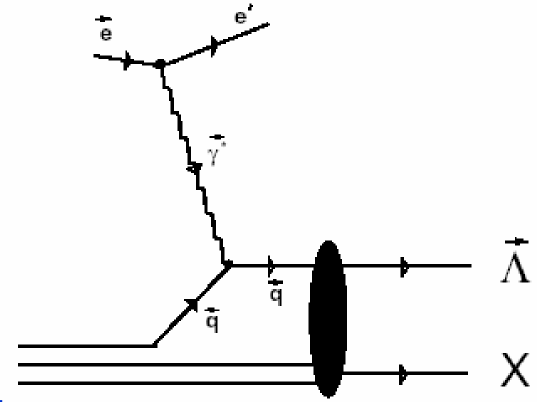
$$P_{+0} = \frac{d\sigma^{\Lambda+}_{+0} - d\sigma^{\Lambda-}_{+0}}{d\sigma^\Lambda} = \frac{y(2-y)}{1+(1-y)^2}\,\frac{\sum_q e_q^2\, q(x)\, \Delta D_{\Lambda/q}(z)}{\sum_q e_q^2\, q(x)\, D_{\Lambda/q}(z)},$$

and the spin transfer from N to Λ (with an unpolarized lepton)

$$P_{0+} = \frac{d\sigma^{\Lambda+}_{0+} - d\sigma^{\Lambda-}_{0+}}{d\sigma^\Lambda} = \frac{\sum_q e_q^2\, \Delta q(x)\, \Delta D_{\Lambda/q}(z)}{\sum_q e_q^2\, q(x)\, D_{\Lambda/q}(z)}.$$

in current fragmentation region
pol. FF $\Delta D_{\Lambda/q}(z)$
➔ sensitive to distribution of polarized quarks in unpolarized nucleon

Longitudinal Λ Polarization



parity violating weak deacy of Λ → pπ
→ distribution of decay angle θ* depends on
Λ pol. P : I(θ*) ~ 1 - α P cos θ* (α=0.64)
exp.: $P^{\Lambda} = P_{beam}\, D(y)\, S^{\Lambda}$ → requires high beam pol. and high y

→ Λ could contain polarized quark!
→ using relation pol FF pol PDF
Gribov-Lipatov 'reciprocity' relation [1971]

$$S_q^{\Lambda} = \frac{\Delta D_q^{\Lambda}}{D_q^{\Lambda}} = \frac{\Delta q^{\Lambda}}{q^{\Lambda}}$$

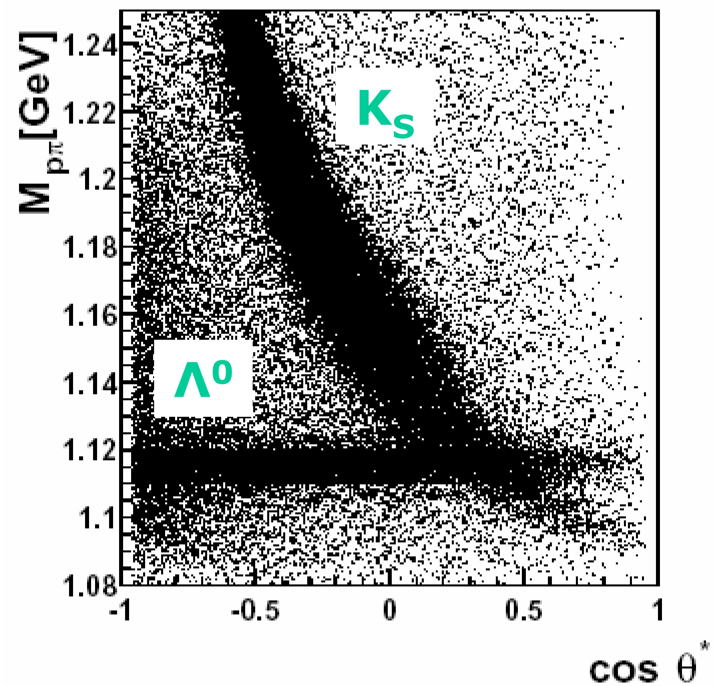
→ study Λ spin structure and test $SU(3)_f$:
[e.g. B.Ma et al., hep-ph/0208122]

Λ spin

$$\Delta u^{\Lambda} = \Delta d^{\Lambda} = \frac{1}{6}\Delta u_p + \frac{2}{3}\Delta d_p + \frac{1}{6}\Delta s_p$$
$$\Delta s^{\Lambda} = \frac{2}{s}\Delta u_p - \frac{1}{3}\Delta d_p + \frac{2}{3}\Delta s_p$$

proton spin

[C.Risler,H1,PhDthesis]



π momentum parallel **antiparallel**
to Λ flight direction

→ more data needed !
→ measurements seems to be feasible

Conclusion

HERA II with high luminosity and with longitudinally polarized electrons and positrons opens new horizons to study electroweak theory and parton dynamics

and

may deliver even surprises we could not imagine today…

For fruitful discussions I like to thank
Markus Diehl, Andreas Freund, Marco Stratmann, Christiane Risler.