IX^{th} '*BLOIS WORKSHOP*'

on Elastic and Diffractive Scattering

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Exclusive processes at intermediate energies:
hermes results and prospects

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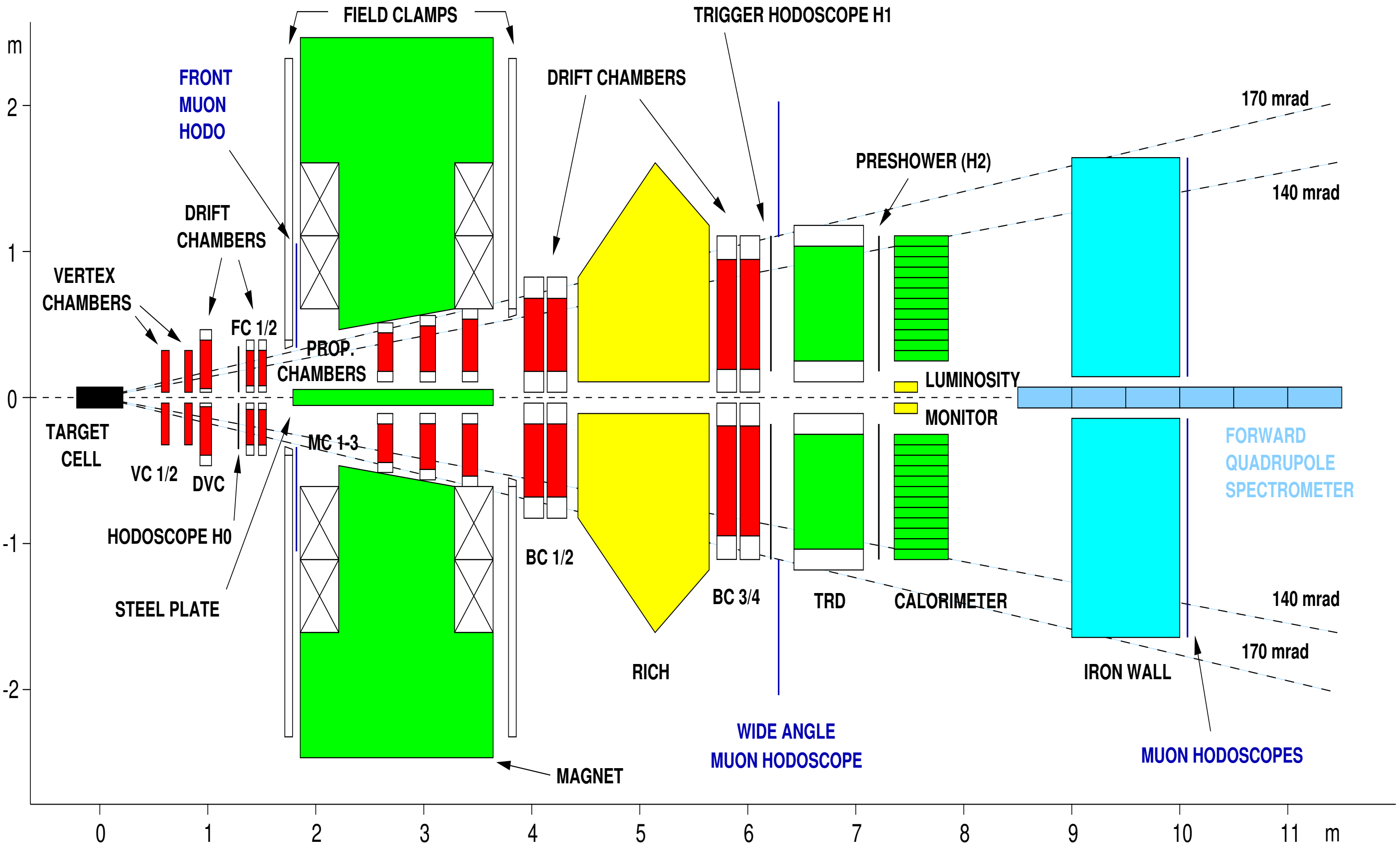
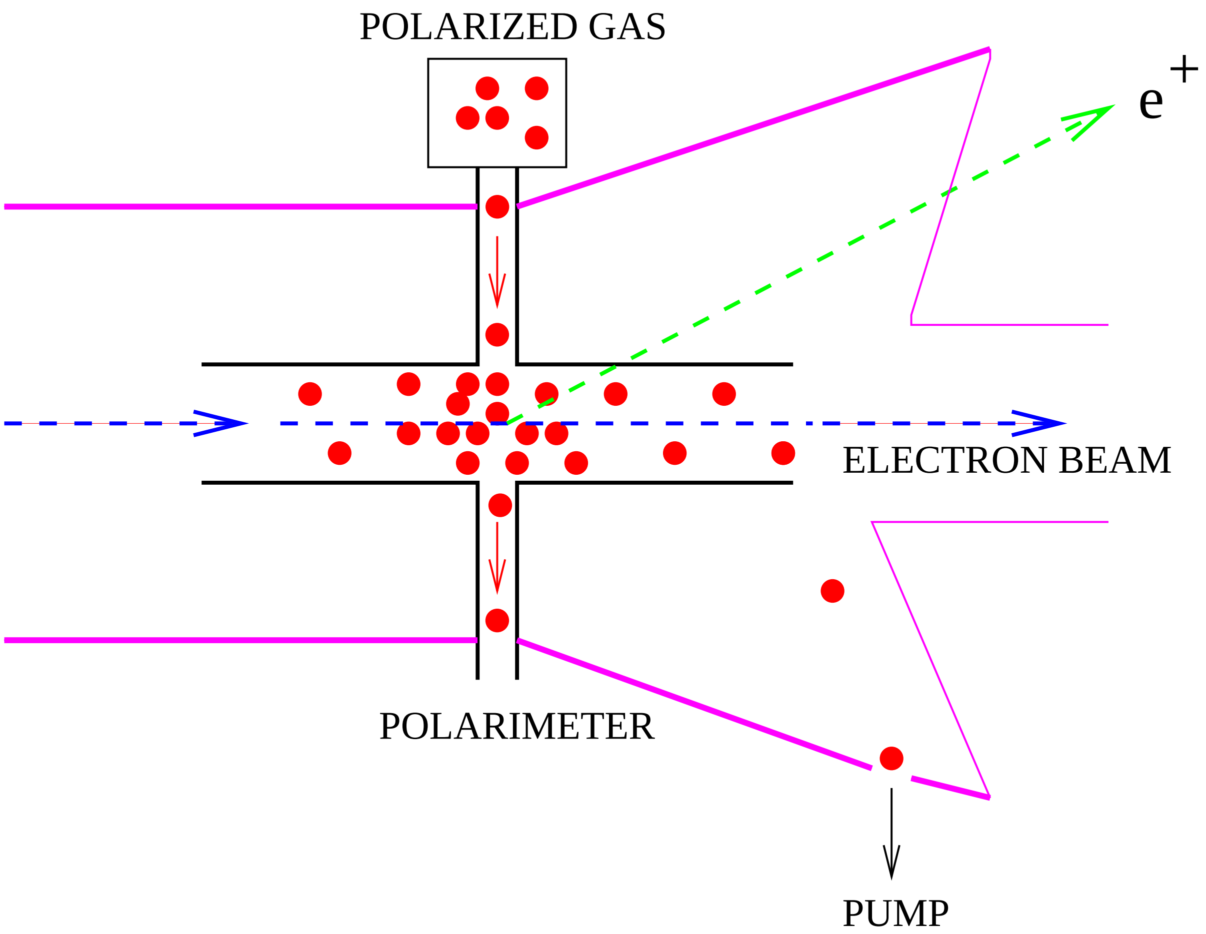
- The Experiment
- Objectives: GPDs
- Data:
  - Diffractive ρ^o and ϕ production
  - Deeply virtual Compton scattering
  - Exclusive π^+ production
- Prospects
- Summary

The Detector



- Two identical halves of forward spectrometer having acceptance $40 < \Theta < 220 mrad$ with momentum resolution $\leq 1\%$.
- Identification of electron with efficiency $> \; 97\%$ at hadron contamination $< 1\%$.
- Calorimeter resolution $\Delta E/E[\%] = (1.5 \pm 0.5) + (5.1 \pm 1.1)/\sqrt{E[GeV]}$
- Cherenkov detector momentum thresholds for pions 4 GeV/c and kaons 13 GeV/c in $'96,' 97$.
- RICH from 1998 with π^{+-} vs K^{+-} and p separation over all kinematical region.

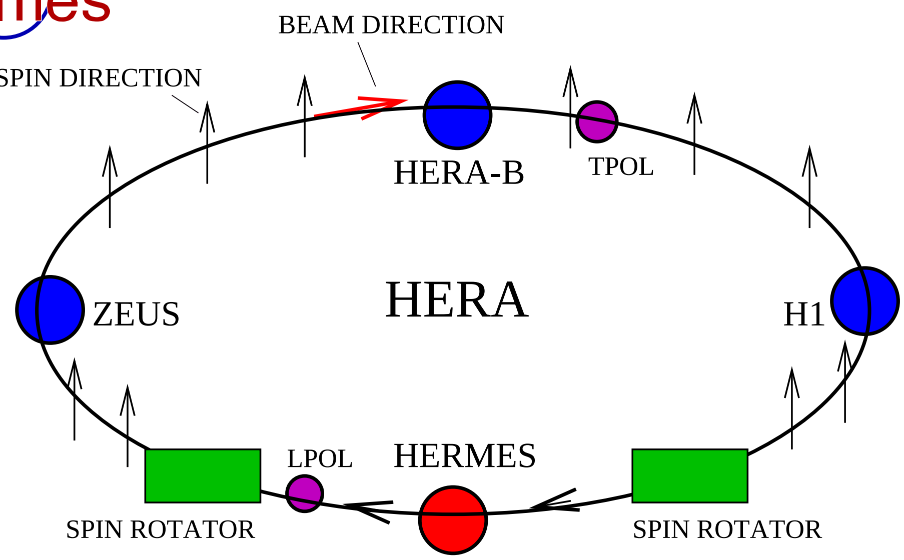
The Target

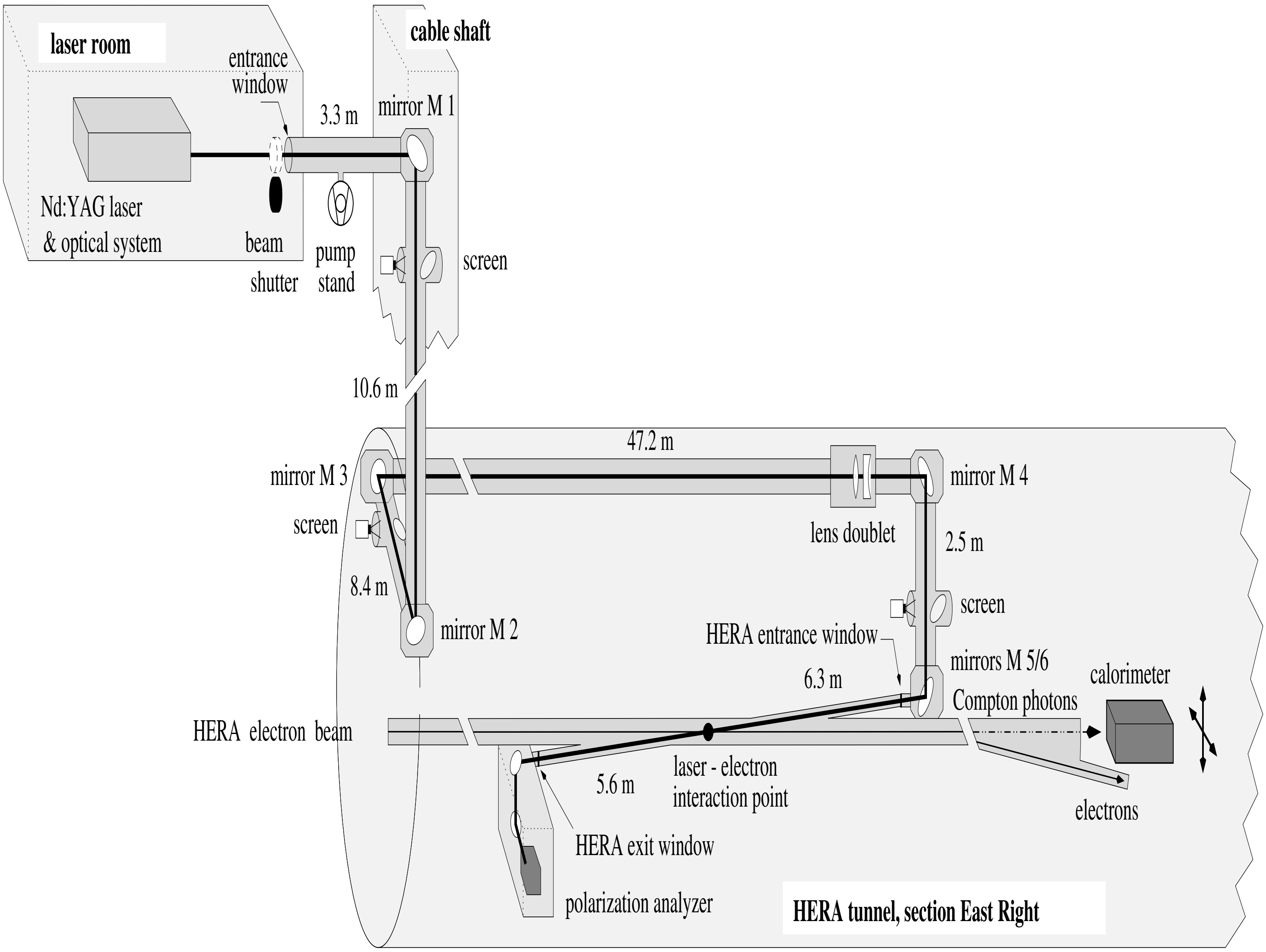


Internal storage cell gas target with high density:

- polarised: $\sim 10^{14}$ nucl./cm^2, polarization $\sim 88\%$ for H/D.
- unpolarised: $\sim 10^{15}$ nucl./cm^2
- high density runs at the end of the fill in 2000 with $^1H, ^2D, ^4He$ and ^{20}Ne gases at $\sim 5 \cdot 10^{15}$ nucl./cm^2.

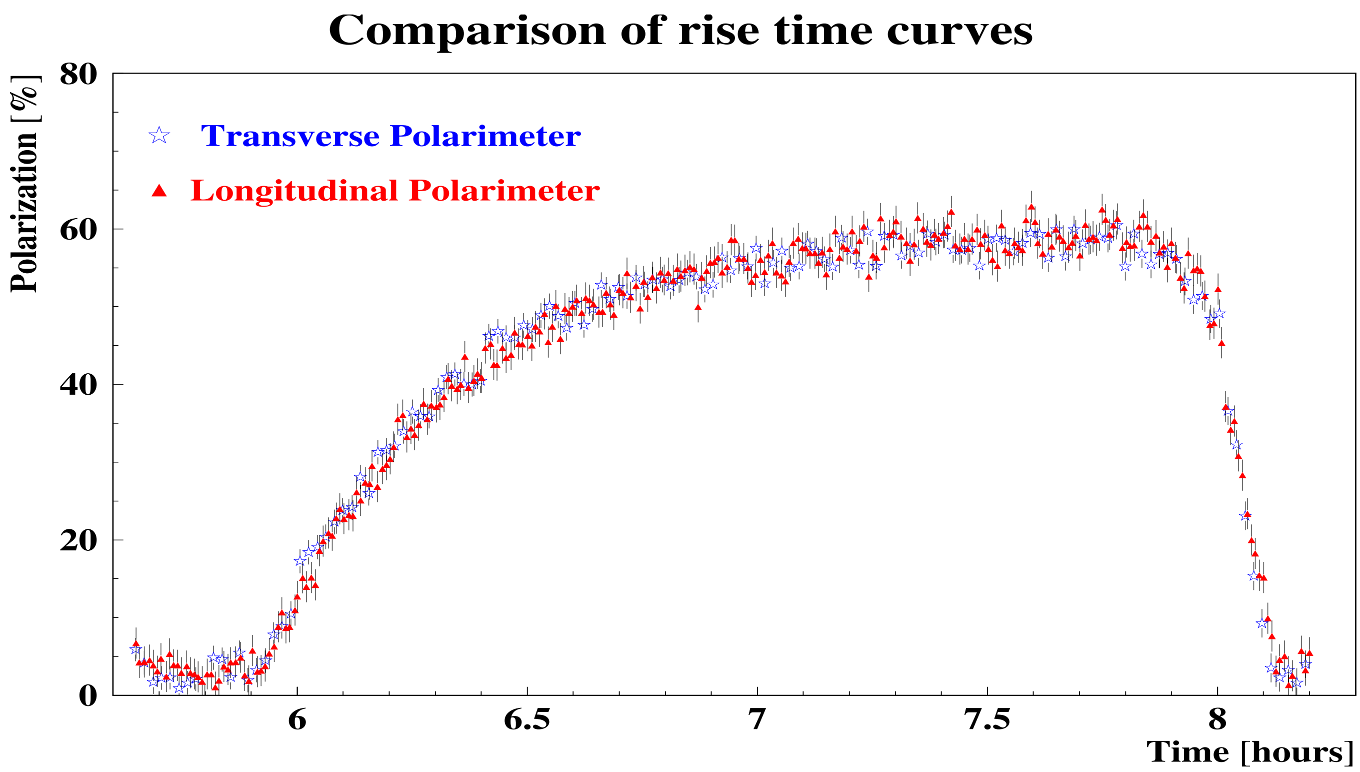
The Beam

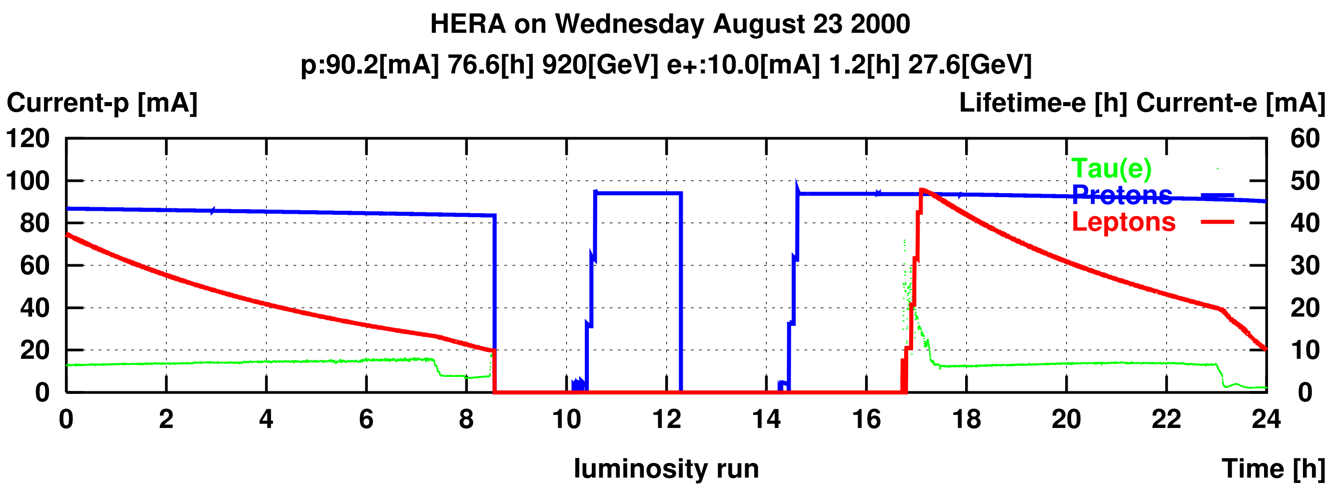




Relative systematic error of the beam polarization measurement at longitudinal polarimeter is 1.6% (NIM A of this summer, hep-ex/0009047 , DESY-00106).

The Beam Performance



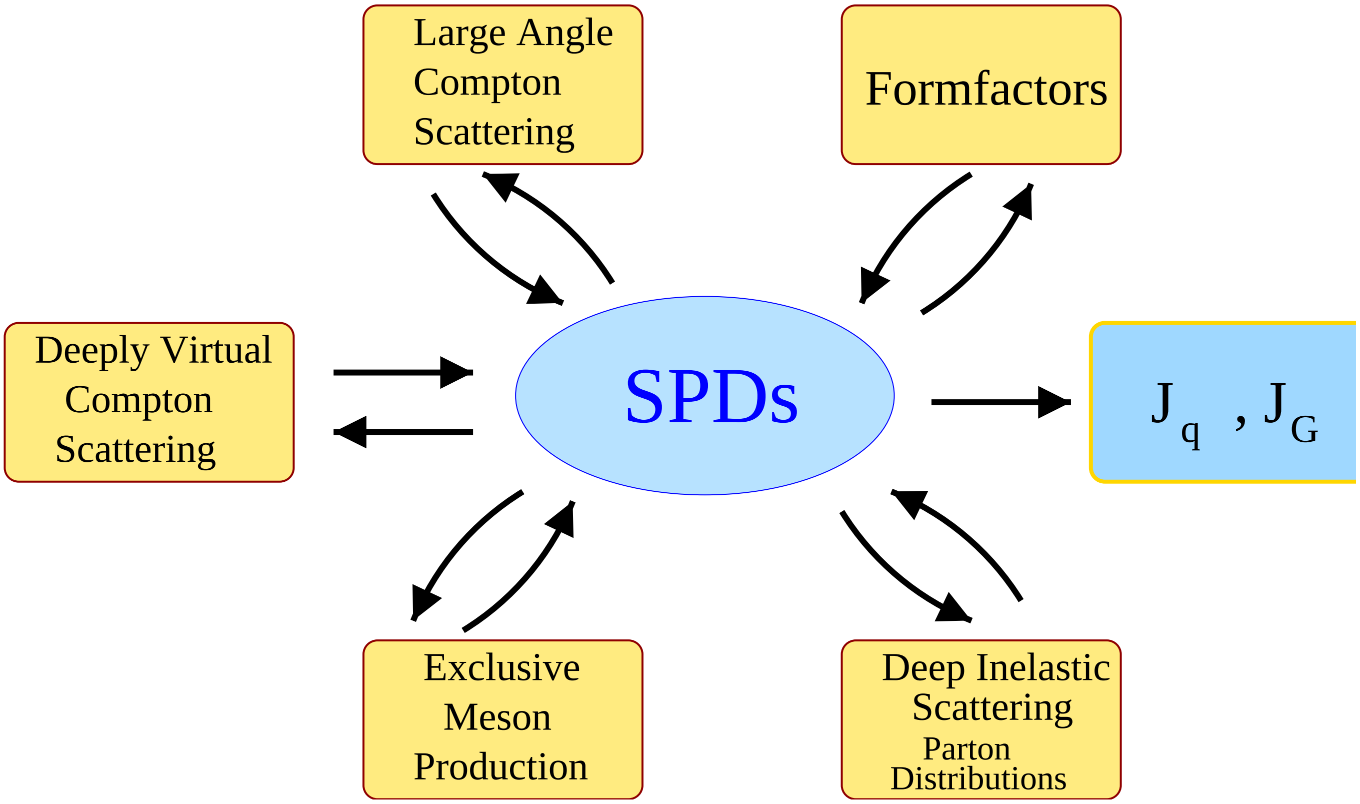


Longitudinally polarised $e^{\pm}$ beam at HERMES:
$P = 27.56$ GeV/c, current 50...10 mA, $P_{beam} = 40 \ldots 60\%$,
in 2000 high density unpolarized runs at the end of the fill at current $< 15 mA$.

The Objectives

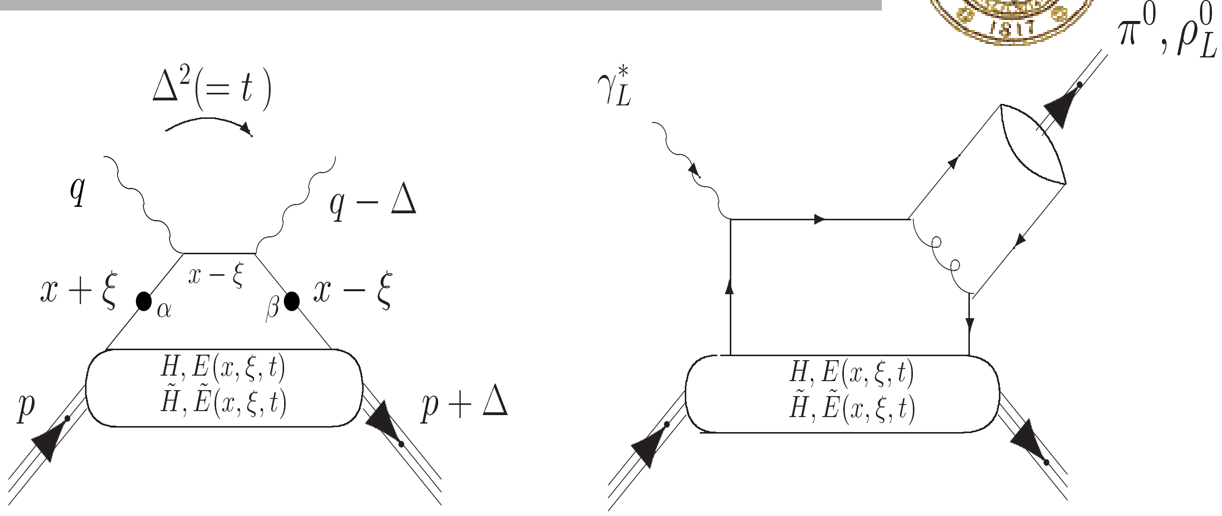
Generalized (or Skewed, or Off-forward)
Parton
Distributions:

Unified Theoretical Description of inclusive and (hard) exclusive processes [X.Ji PRL 78 (1997), 610;...]:



- GPDs : generalization of usual Parton Distributions and nucleon form factors
- Usual Parton Distributions (PDs): probability to find a parton in the nucleon with momentum fraction x
- GPDs: interference of 2 wave functions: parton with $x + \xi$ emitted from nucleon and parton with $x - \xi$ falls back. GPDs sensitive to momentum correlations.

GPD's - General Formalism



3 Variables:

- x mean value of the longitudinal momentum fraction (unaccessible)
- ξ exchanged long. momentum fraction. At Bjorken limit $\xi = \frac{x_B}{2-x_B}$
- momentum transfer $t = \Delta^2 = (p - p')^2$

4 different GPDs per flavor:

$H^q(x,\xi,t)$ $\tilde{H}^q(x,\xi,t)$ conserve nucleon helicity
$E^q(x,\xi,t)$ $\tilde{E}^q(x,\xi,t)$ flip nucleon helicity
$\Downarrow$ $\Downarrow$
$Unpolarized$ $Polarized$ γ^*

Quantum numbers of final states allow to select different GPDs:

- Vector mesons $\rightarrow$ unpolarised GPDs E, H
- Pseudoscalar mesons $\rightarrow$ polarised GPDs $\tilde{E}, \tilde{H}$
- DVCS $\rightarrow$ pol. and unpol. GPDs $E, H, \tilde{E}, \tilde{H}$

GPDs Sum Rules

1st Moments: Integration over x gives the following sum rules:

$$\int_{-1}^{1} dx H^q(x,\xi,t) = F_1(t)$$
$$\int_{-1}^{1} dx E^q(x,\xi,t) = F_2(t)$$
$$\int_{-1}^{1} dx \tilde{H}^q(x,\xi,t) = G_A(t)$$
$$\int_{-1}^{1} dx \tilde{E}^q(x,\xi,t) = G_P(t),$$

where F_1, F_2 are Dirac and Pauli form factors and
G_A, G_P are the axial-vector and pseudo-scalar form factors.

In the limit $\xi = 0$ and $t = 0$:
$H^q(x,0,0) = q(x_B)$
$\tilde{H}^q(x,0,0) = \Delta q(x_B)$

where $q(x_B)$ and $\Delta q(x_B)$ are quark and quark helicity distributions (no 'usual' equivalents for E^q and $\tilde{E}^q$).

2nd Moment of unpolarized GPDs in limit $t = 0$ total quark angular momentum (X.Ji):

$$J_q = 0.5 \int_{-1}^{1} dx\, x \left\{ H^q(x,\xi,t=0) + E^q(x,\xi,t=0) \right\}$$

which decomposes as $J_q = \Delta \sum /2 + L_q$
where $\Delta \sum /2$ is the quark spin and L_q is orbital angular momentum.

Estimation of Balitsky and Ji (Phys.Rev.Lett.79:1225-1228,1997)
$1/2 =\sim 0.15(\Delta \sum /2) + \sim 0.1(L_q) + 0.25_{\pm 0.16}(J_g)$
where J_g is total gluon angular momentum.

due to the polarization and charge of lepton beam.

Measure lepton charge asymmetry at unpolarized e^{+-} beams and unpolarized target get access to real part of H_1, $\tilde{H}_1$:

$$\delta_{ch} d\sigma^{unpol} = d\sigma(e^+ p) - d\sigma(e^- p)$$

$$\sim cos(\phi_\gamma) \cdot Re\left\{ F_1 \mathbf{H}_1 + \frac{x_B}{2-x_B}(F_1 + F_2)\mathbf{H}_1 - \frac{t}{4M^2} F_2 \mathbf{E}_1 \right\}$$

Measure lepton helicity asymmetry at long. polarized beam and unpolarized target get access to imagionary part of $\mathbf{H}_1, \tilde{\mathbf{H}}_1$:

$$\delta d\sigma = d\sigma(e^{+\rightarrow} p) - d\sigma(e^{+\leftarrow} p)$$

$$\sim sin(\phi_\gamma) \cdot Im\left\{ F_1 \mathbf{H}_1 + \frac{x_B}{2-x_B}(F_1 + F_2)\tilde{\mathbf{H}}_1 - \frac{t}{4M^2} F_2 \mathbf{E}_1 \right\}$$

Real and imaginary parts of DVCS amplitudes can be expressed through GPDs:

$$Im\mathbf{H}_1 = -\pi \sum_q e_q^2 \Big(H(\xi, \xi, t) - H(-\xi, \xi, t) \Big)$$

$$Im\tilde{\mathbf{H}}_1 = -\pi \sum_q e_q^2 \Big(H(\xi, \xi, t) + H(-\xi, \xi, t) \Big)$$

$$Re\mathbf{H}_1 = \sum_q e_q^2 \Big(P \int_{-1}^{1} H(x, \xi, t)\big(\tfrac{1}{x-\xi} + \tfrac{1}{x+\xi}\big) dx \Big)$$

$$Re\tilde{\mathbf{H}}_1 = \sum_q e_q^2 \Big(P \int_{-1}^{1} \tilde{H}(x, \xi, t)\big(\tfrac{1}{x-\xi} - \tfrac{1}{x+\xi}\big) dx \Big)$$

analogous expressions for $\mathbf{E}_1$ and $\tilde{\mathbf{E}}_1$

GPD's - First Guess

Quadratic combination of GPDs appear in the unpolarized cross section.

Evaluation of the electroproduction amplitudes in the leading order for γ, π^o and ρ^o_L on proton target (M.Vanderhaeghen, P.A.M. Guichon, M. Guidal, Phys.Rev.Lett. **80** (1998) 5064) :

$$H^P_{DVCS}(x,\xi,t) = 4/9H^{u/p} + 1/9H^{d/p} + 1/9H^{s/p}$$

$$H^P_{\rho^0}(x,\xi,t) = 1/\sqrt{2}\{2/3H^{u/p} + 1/3H^{d/p}\}$$

$$H^P_{\pi^0}(x,\xi,t) = 1/\sqrt{2}\{2/3\tilde{H}^{u/p} + 1/3\tilde{H}^{d/p}\}$$

Assumption that H^q proportional to the unpolarized quark distribution taken MRS(S_o) parametrization:

$$H^{u/p}(x,\xi,t) = 1/2u(x)F^{u/p}(t)$$
$$H^{d/p}(x,\xi,t) = d(x)F^{d/p}(t)$$
$$H^{s/p}(x,\xi,t) = 0$$

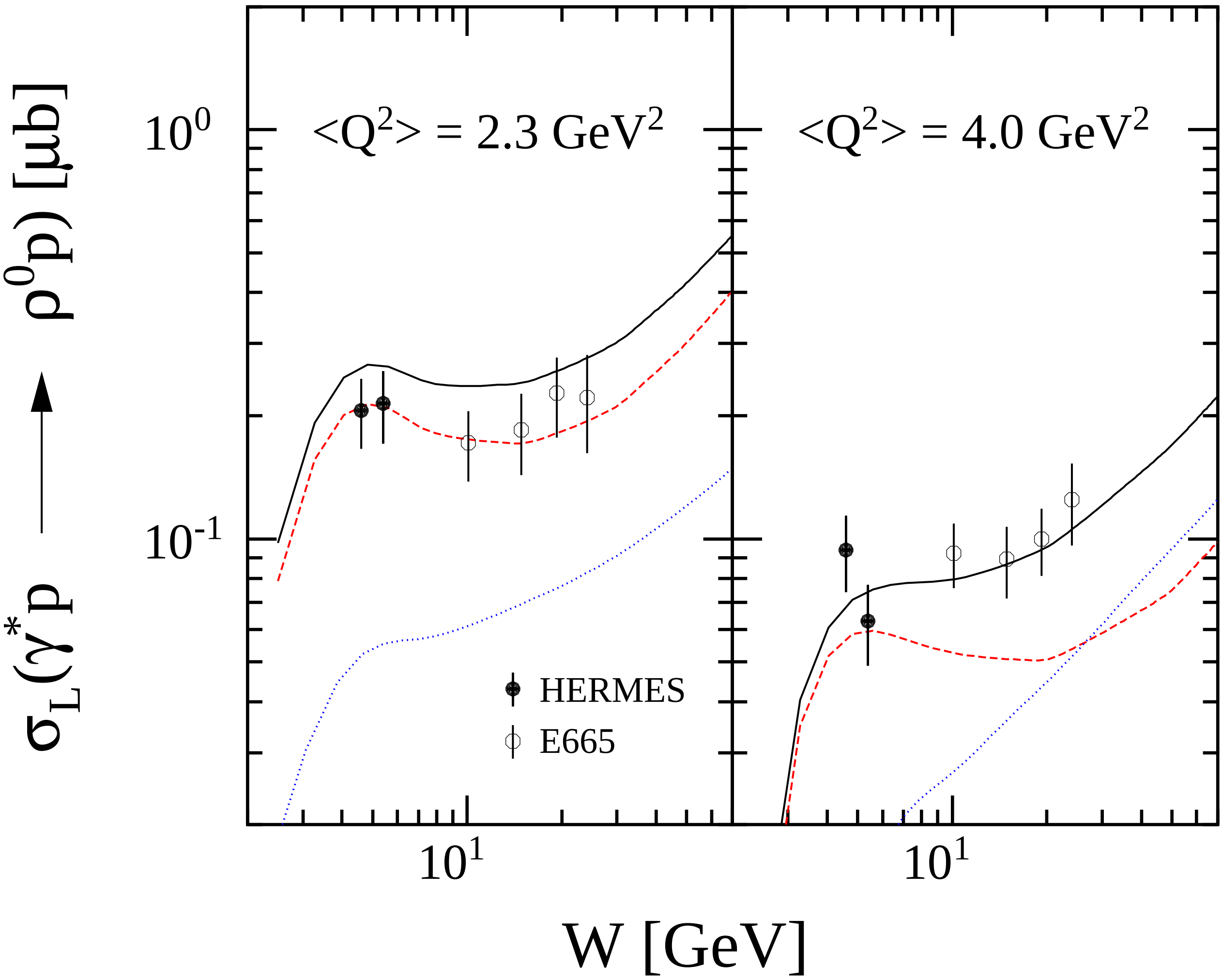
similar expressions for $\tilde{H}^{q/p}$. Bjorken sum rule is satisfied.

Improvements in (M.Vanderhaeghen, P.A.M. Guichon, M. Guidal, Phys.Rev.D **60** (1999) 094017) with higher twist effects in a phenomenological fashion and Q^2-dependence in strong coupling constant α_s.

ρ^o Longitudinal Cross Section

Compared with calculations of

M.Vanderhaeghen, P.A.M. Guichon, M. Guidal, Phys.Rev.Lett. **80** (1998) 5064.



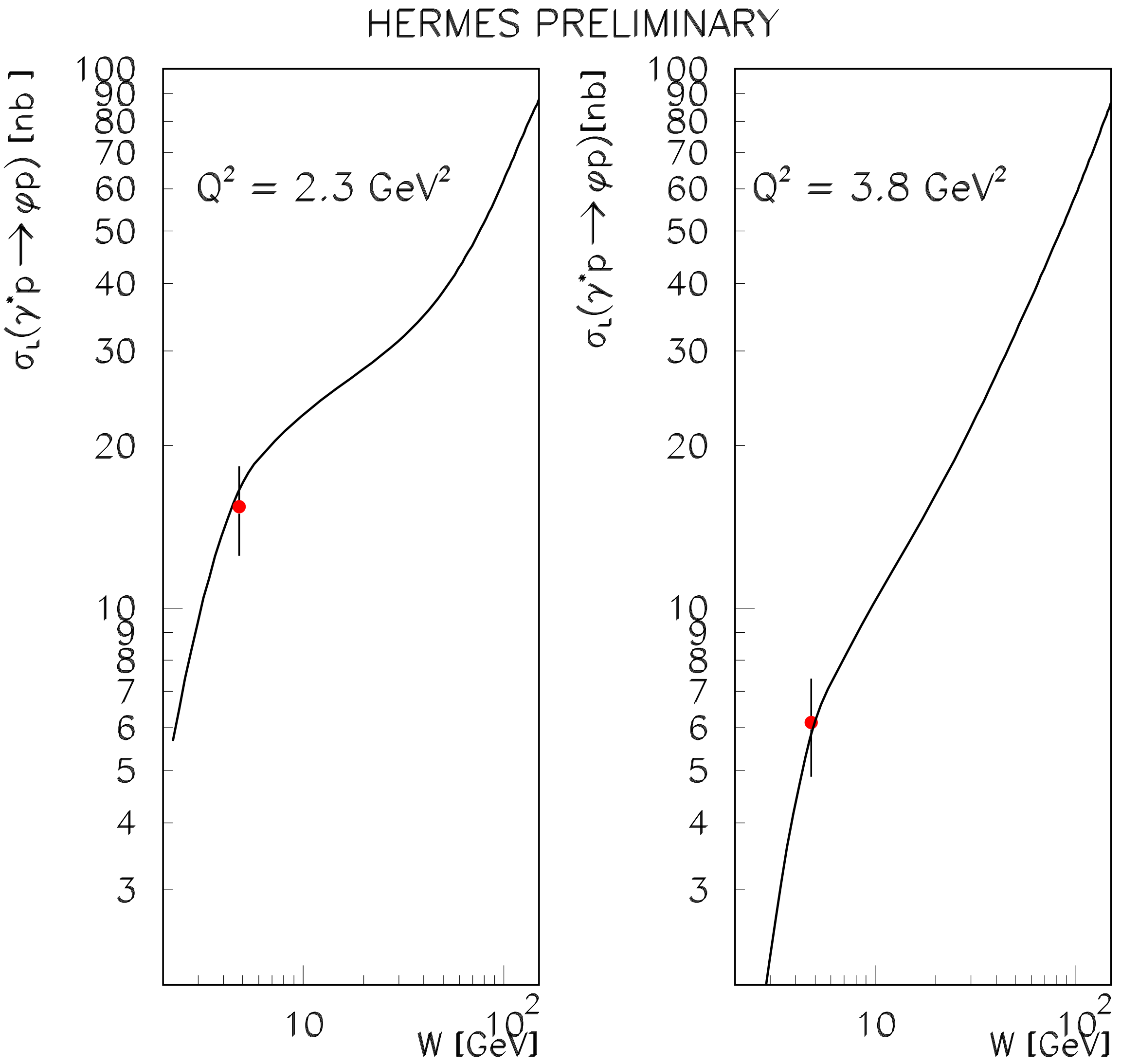
Blue curve - 2-gluon exchange, red - quark exchange, black - sum.

$\rightarrow$ Domination of quark exchange at $W \sim 5$ GeV.

ϕ Longitudinal Cross Section

Comparison with recent OFPD calculations

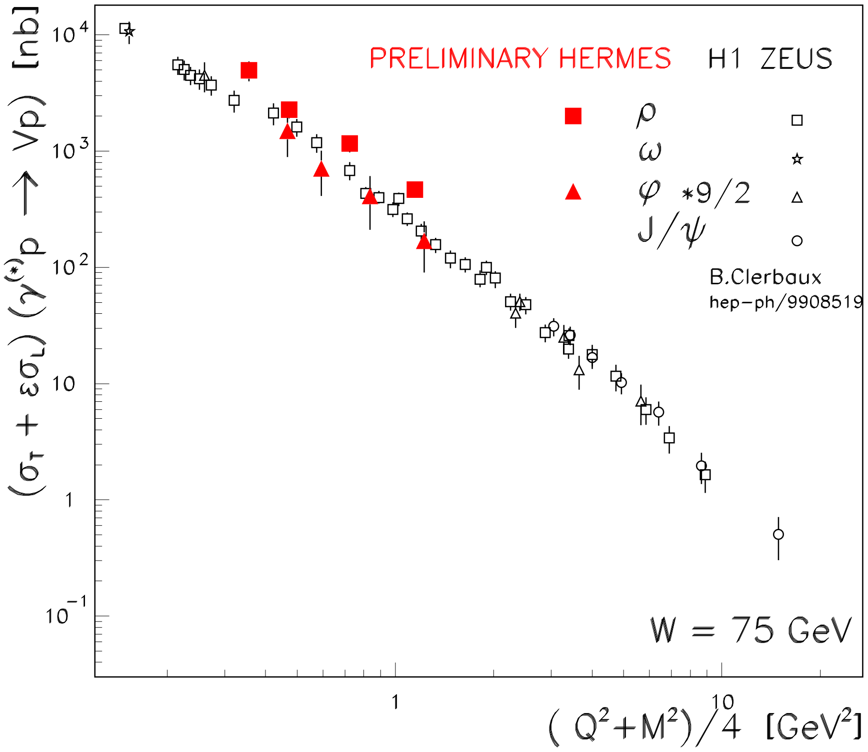
of M. Guidal, privat communications



Solid curve - 2-gluon exchange.

$\rightarrow$ Domination of soft IPomeron or 2-gluon exchange.

$\sigma_{\rho^o,\phi}$ scaled up to $W = 75$ GeV



Use $W^{\delta_{\rho^o}(Q^2)}$ dependence from H1 and ZEUS data for HERMES $(\sigma_L + \sigma_T)$ of ρ^o and ϕ cross sections by means of the linear fit of the points at $\delta(0) = 0.22$ and $\delta(3.5) = 0.4$

H.Abramowicz,A.Caldwell DESY 98-192, H.Abramowicz DESY 00-025,hep-ph/0001054

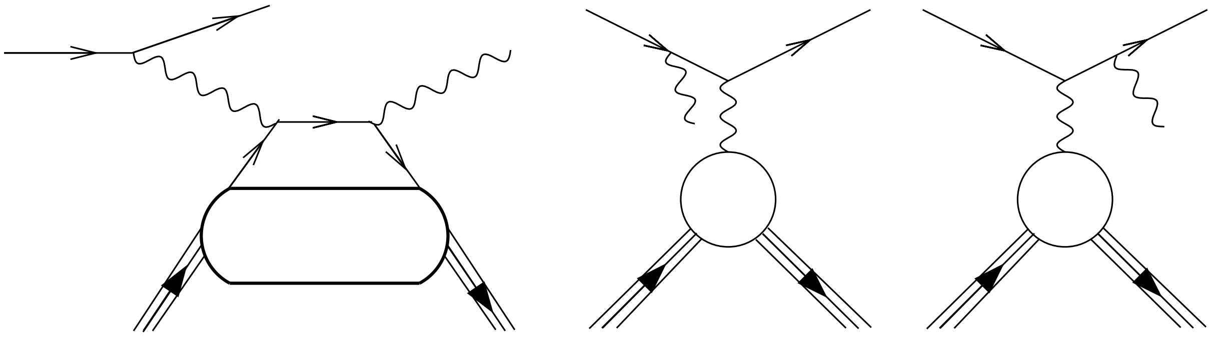
$\rightarrow$ ρ^o at HERMES - additional to 'IPomeron exchage' mechanism involved

$\rightarrow$ ϕ at HERMES - consistent with 'IPomeron exchage', but can not distinguish $\delta_{\rho^o}(Q^2)$ and $\delta_\phi(Q^2)$ dependences at present statistics.

Full presentation of Vector Meson analysis at HERMES is in M.Tytgat talk.

Deeply Virtual Compton Scattering

$$e + p \rightarrow e^{'} + \gamma + p$$



(a) (b)

- (a) Feynman diagram for DVCS
- (b) Photon radiation from the incident and scattered lepton in the Bethe-Heitler process
- Impossible to distinguish between photons originating from DVCS and those from the Bethe-Heitler (BH) process but exploit the interference between the DVCS and BH processes to obtain DVCS amplitudes:

$$\frac{d^4\sigma}{d\phi dt dQ^2 dx} = \frac{xy^2}{32\,(2\pi)^4\,Q^4} \frac{|\tau_{\mathrm{BH}} + \tau_{\mathrm{DVCS}}|^2}{\left(1 + 4x^2m^2/Q^2\right)^{1/2}}, \quad (1)$$

where τ_{BH} and τ_{DVCS} are the BH and DVCS amplitudes.

- Leading order helicity term depending on the helicity of the incident lepton is

$$(\tau^*_{\mathrm{BH}}\tau_{\mathrm{DVCS}} + \tau^*_{\mathrm{DVCS}}\tau_{\mathrm{BH}})_{pol} = \frac{4\sqrt{2}\,me^6}{tQx} \cdot \frac{1}{\sqrt{1-x}}$$
$$\times e_l P_l \left[-\sin\phi \cdot \sqrt{\frac{1+\epsilon}{\epsilon}} \mathrm{Im}\tilde{M}^{1,1} \right] \quad (2)$$

where $\tilde{M}^{1,1}$ is the linear combination of DVCS helicity amplitudes that contributes in the case of a polarized beam and an unpolarized target, ϵ is polarization parameter of virtual photon.

DVCS

DVCS and Bethe-Heitler

Bethe-Heitler (BH):

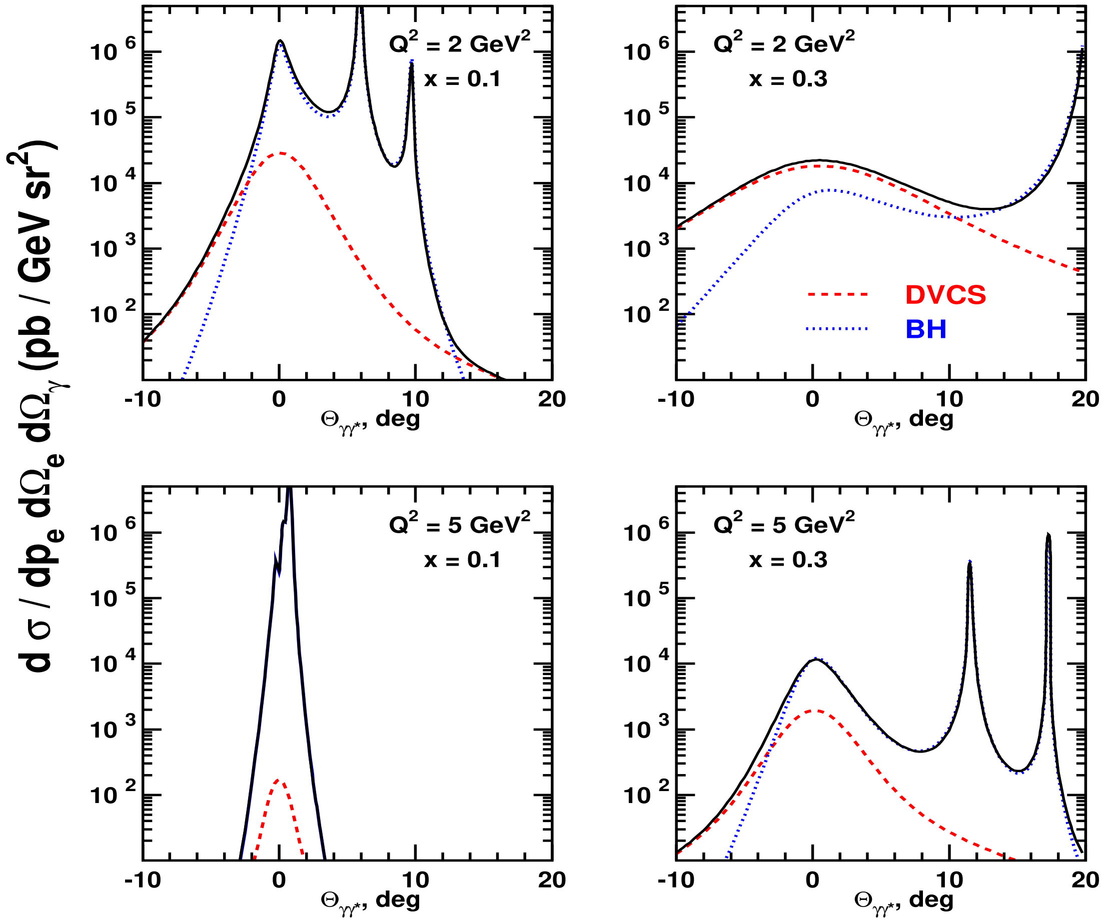
(Elastic lepton-proton scattering with γ radiation by lepton in initial or final state)

Interfering process leading to same final state

Can be exactly calculated when Dirac and Pauli form factors known

Cross sections at E=27.5 GeV (HERMES):

'In-plane' cross section: scattering plane = reaction plane (see below)



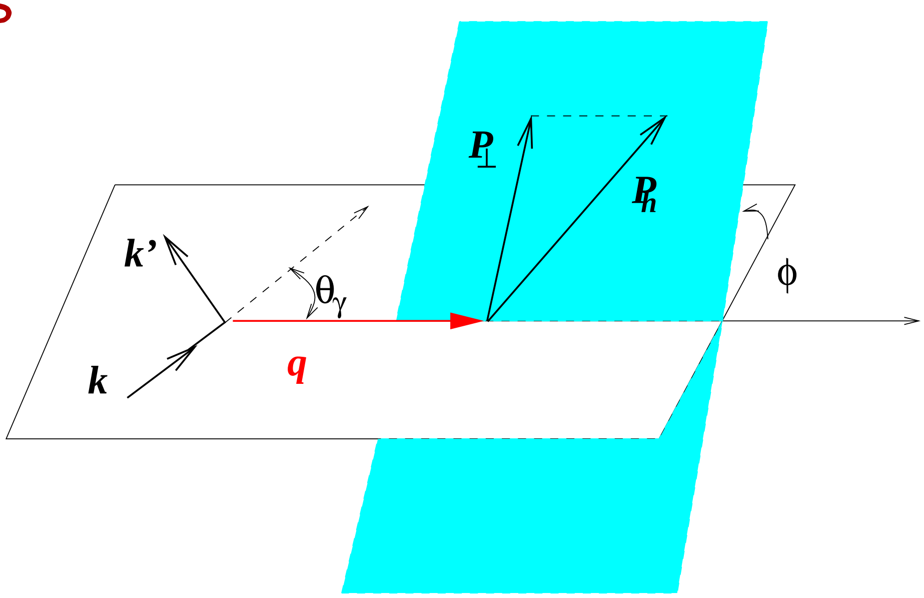
DVCS dominated by BH in most of kin. region !

DVCS-BH interference:

$\Longrightarrow$ Use BH as a vehicle to study DVCS !

[W.-D. Nowak, DIS 2001.]

DVCS

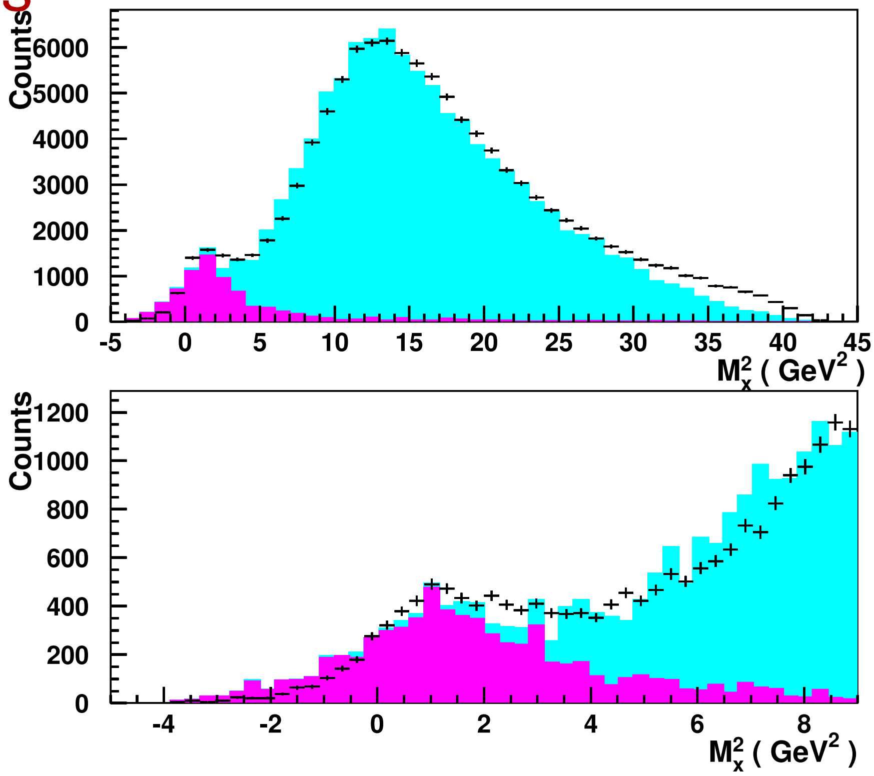


For DVCS the $sin(\phi)$ moment of the single spin azimuthal asymmetry with longitudinal beam polarization and unpolarized target:

$$A_{LU}^{sin\phi} = \frac{2\int_0^{2\pi} d\phi \, sin(\phi)\,(d\sigma_+ - d\sigma_-)}{<|P_B|>\int_0^{2\pi} d\phi\,(d\sigma_+ + d\sigma_-)}$$

ϕ is the angle between scattering plane and meson production plane.

DVCS



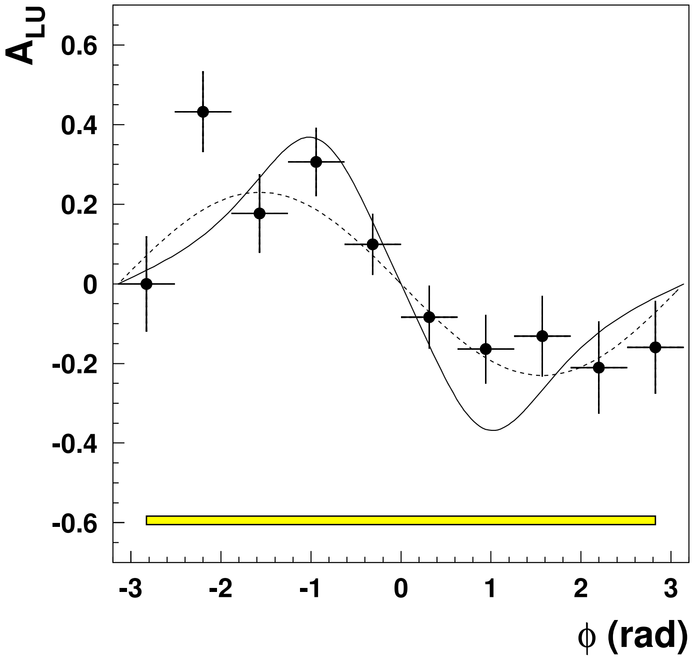
Negative $M_X^2 = (q + P_p - k)^2$ is due to the worse resolution determined by the calorimeter defuned as $M_X = -\sqrt{-M_X^2}$.

Data:

- 400.000 events from 1996+1997 years with one positron track and one untracked cluster in the calorimeter
- Kinematic requirements: $Q^2 > 1$ GeV^2, $W^2 > 4$ GeV^2, $15 < \Theta_{\gamma^*\gamma} < 70$ mrad to avoid bias on reconstraction of small angles
- Backgound contamination of $\pi^0 \rightarrow \gamma\gamma$ decay misidentification due to the calorimeter granularity is $< 5\%$. Use preshower to estimate $\gamma\gamma$ contamination: response for 1 photon $\sim 80\%$, for 2 photons $\sim 95\%$.

But need more data with $electron$ beam for the charge asymmetry.

DVCS

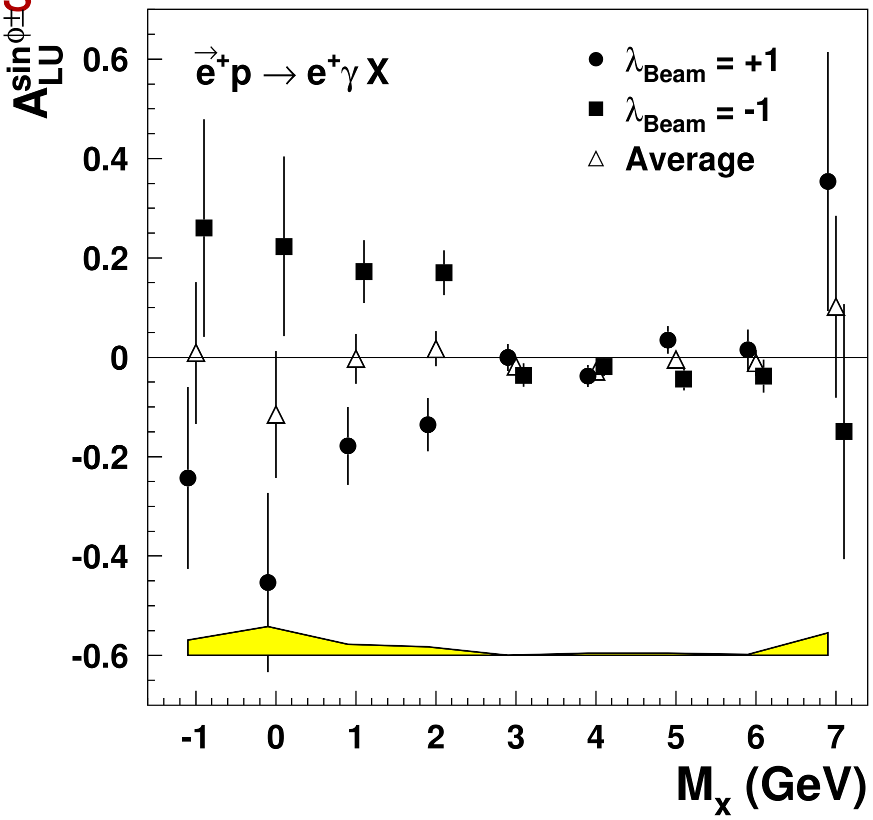


$$A_{LU}(\phi) = \frac{1}{\langle |P_l| \rangle} \cdot \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}, \tag{3}$$

where N^+ and N^- are luminosity normalized yields with corresponding beam helicity states, $\langle |P_l| \rangle$ is the average magnitude of the beam polarization.

Data at $0.4 < M_X < 1.4 GeV$, $< Q^2 >= 2.6$ GeV^2,
$< x >= 0.11$, $< -t >= 0.25$ GeV^2.
M_X cut includes ADVCS ($e^{'}\gamma\Delta^+$).
No $sin(\phi)$ dependence at higher missing mass.
Agreement with calculations of M.Vanderhaeghen, Talk at DESY, 15.02.2000.

DVCS

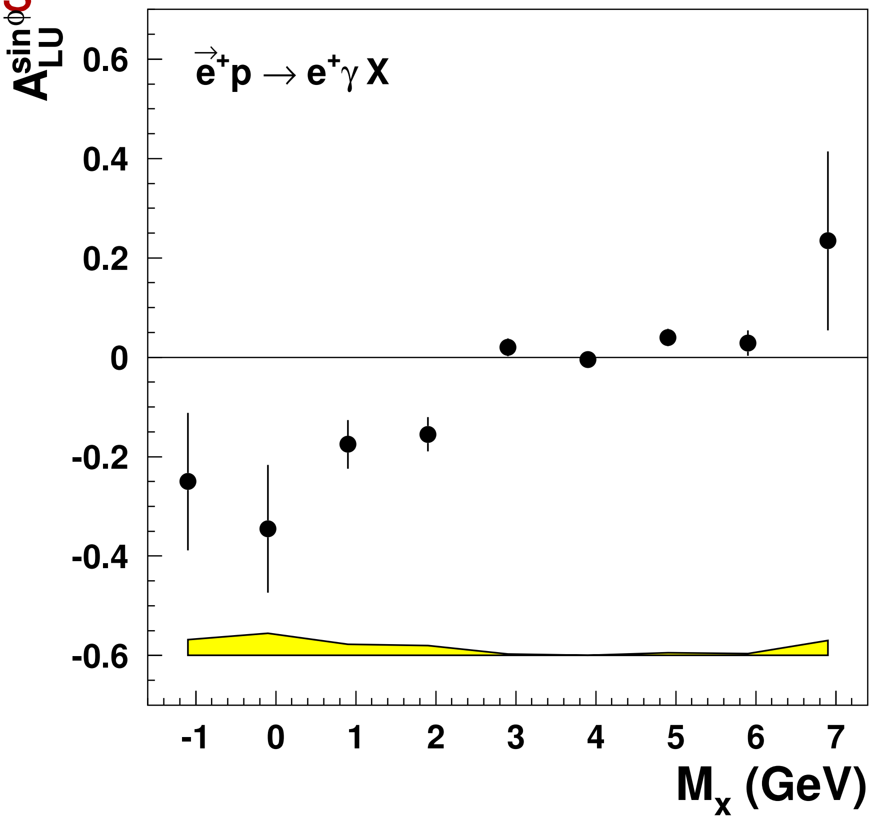


The $sin(\phi)$-weighted moment

$$A_{LU}^{\sin\phi^{\pm}} = \frac{2}{N^{\pm}} \sum_{i=1}^{N^{\pm}} \frac{\sin\phi_i}{|P_l|_i}, \tag{4}$$

The $sin(\phi)$ moment of the single spin azimuthal asymmetries for the positive helicity state, the negative state and the helicity average.
The sign in agreement with helicity dependence of the DVCS-BH interference term. The beam-spin averaged data corresponds to the expectations for the unpolarized beam and target.
$\rightarrow$ Effect comes from the beam polarization only.

DVCS



The beam-spin analysing power is $sin(\phi)$ moment of the single spin azimuthal asymmetry.

$$A_{LU}^{\sin\phi} = \frac{2}{N} \sum_{i=1}^{N} \frac{\sin\phi_i}{(P_l)_i}, \tag{5}$$

where $N = N^+ + N^-$

$\rightarrow$ Measured significant asymmetry at $M_X \sim 1GeV$ expected from the interference between DVCS and BH processes.

Exclusive π^+

LL.Frankfurt, M.V. Polyakov, M.Strikman, M.Vanderhaeghen (PRL 84 (2000) 2589, PRD 60 (1999) 014010), M.V. Polyakov, M.Vanderhaeghen DIS 2000 proceedings.
Large SSA expected for transverse target:

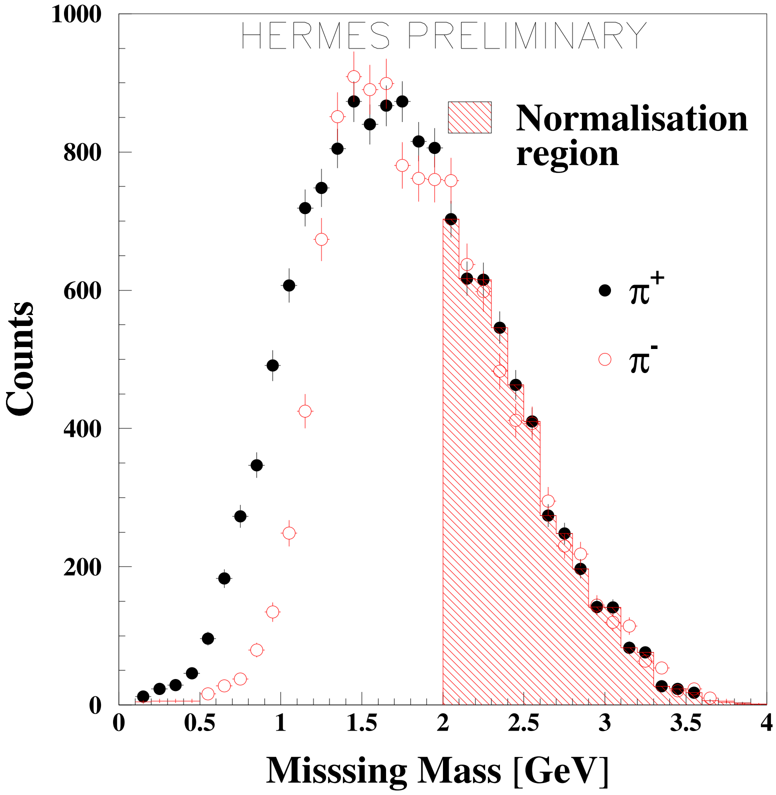
$$\sigma \sim |S_{\perp target}| \cdot sin\phi \cdot \frac{\sqrt{t_{min}-t}}{-t+M_P^2} \cdot \tilde{H}(\xi,\xi,t)$$

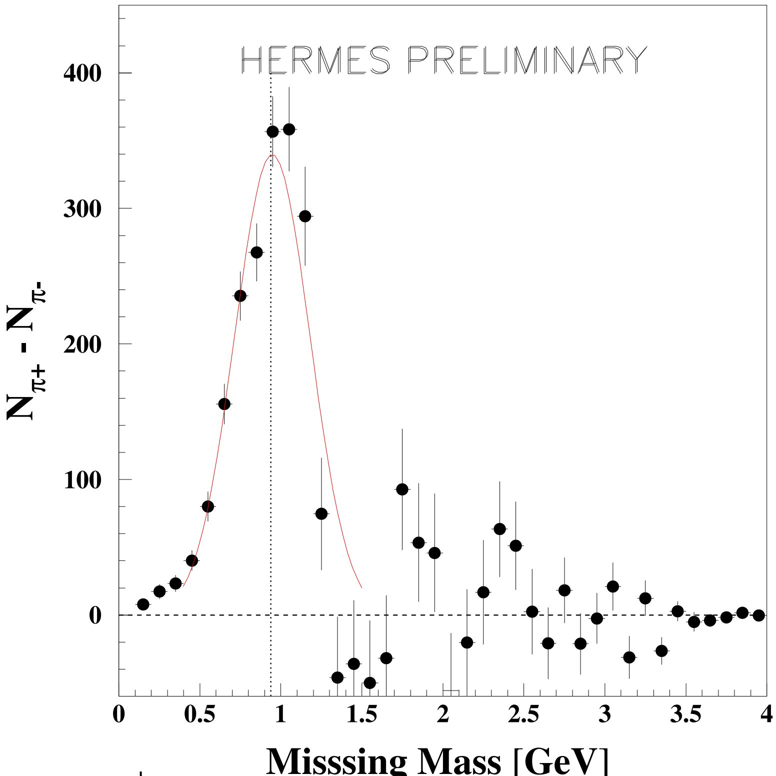
$\gamma^* p \to n\pi^+ \sim (2\Delta u + \Delta\tilde{u}) - (2\Delta d + \Delta\tilde{d})$,
π pole constitutes about 70% to the longitudinal cross section

$\gamma^* p \to \Delta^0\pi^+ \sim (2\Delta u + \Delta\tilde{u}) - (2\Delta d + \Delta\tilde{d})$,
no π pole contribution.

SSA is interference between the pseudoscalar and pseudovector contributions

Exclusive π^+

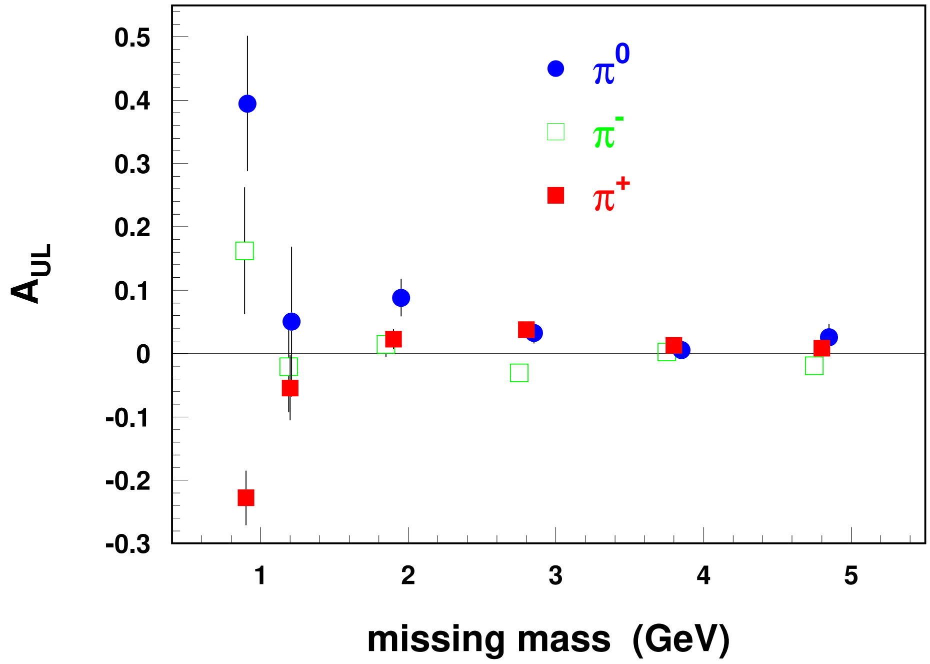




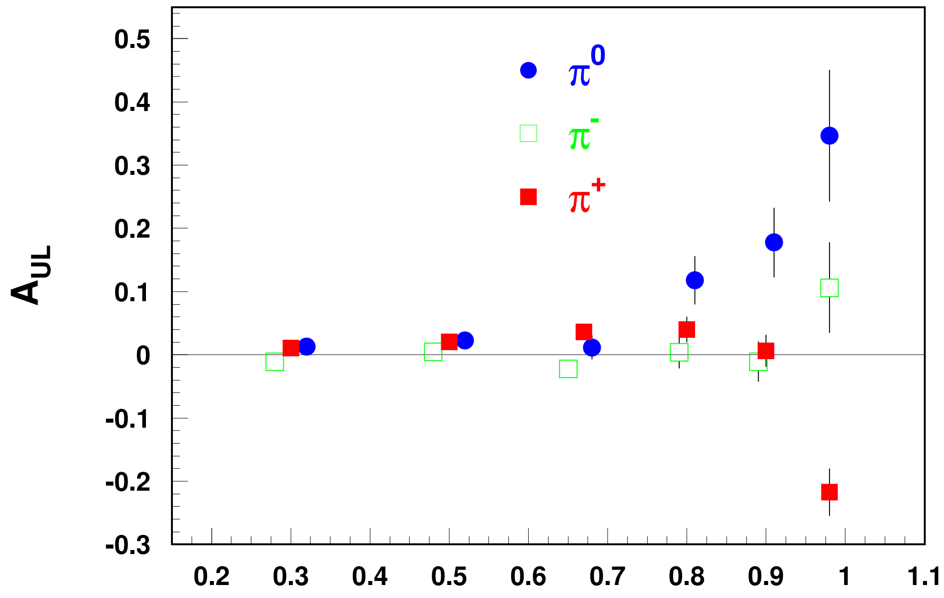
$\rightarrow \sim 1.7k$ exclusive π^+ for 96+97 data

$\rightarrow$ missing mass resolution ~ 0.25 GeV.

Single spin asymmetry of π's



Semi-inclusive π^+ and π^- at $|t| < 0.5$ GeV^2



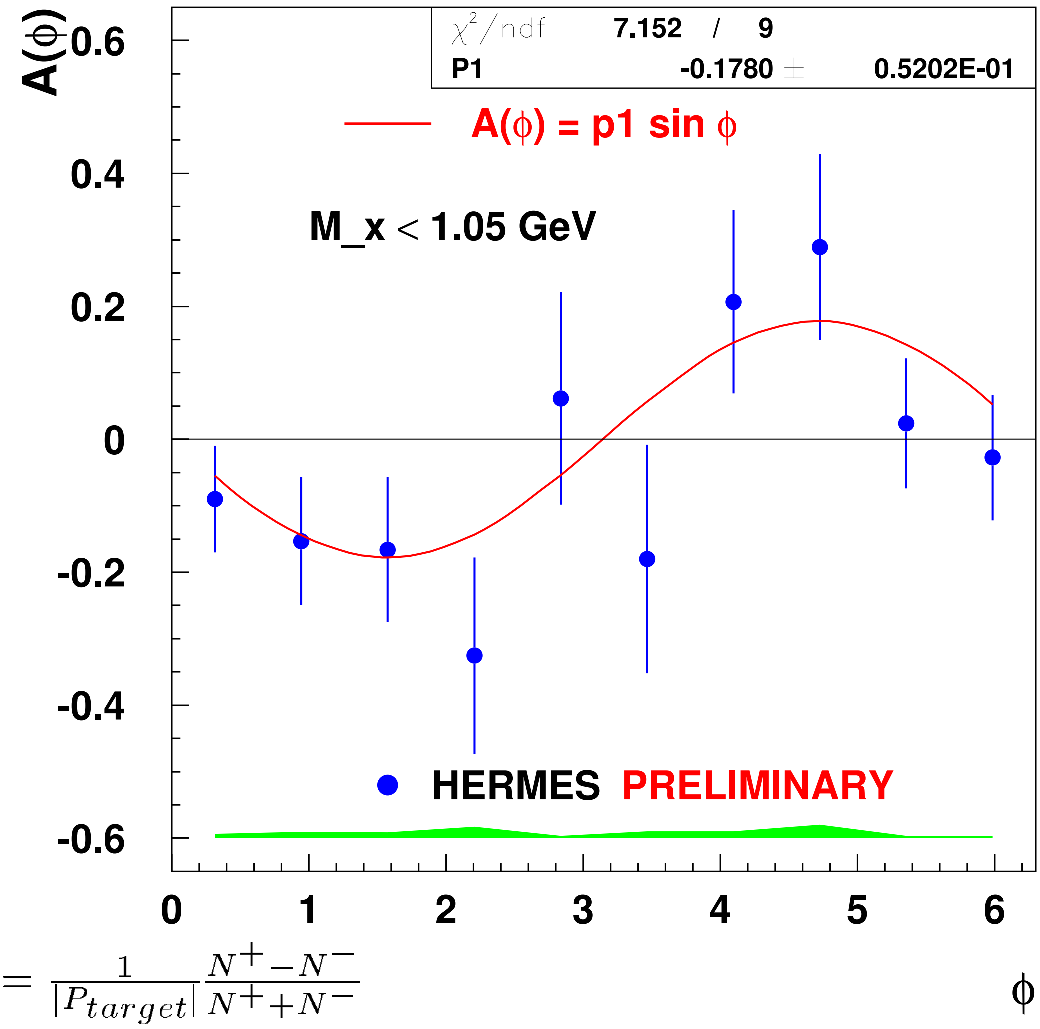
Preliminary, uncorrected for smearing and acceptance

$$A_{UL}^{sin\phi} = \frac{1}{P_T} \frac{\int_0^{2\pi} d\phi\, sin(\phi)\, dN_+ - \int_0^{2\pi} d\phi\, sin\phi\, dN_-}{0.5(\int_0^{2\pi} d\phi\, dN_+ + \int_0^{2\pi} d\phi\, dN_-)}$$

$\rightarrow$ Large SSA in the exclusive region. The sign is opposite to the predictions for transverse target (L.L. Frankfurt, M.V. Polyakov, M. Strikman, M. Vangerhaeghen Phys.Rev.Lett. 84, 2000, 2589.)

Cross section asymmetry

Exclusive π^+ leptoproduction on Hydrogen



$$A(\phi) = \frac{1}{|P_{target}|}\frac{N^+ - N^-}{N^+ + N^-}$$

Acceptance $\epsilon(\phi)$ cancels in the ratio.

Background corrected

$$A(\phi) = \frac{1}{|P_{target}|}\frac{N^+ - N^- - |P_{target}|A_{bg}(N^+_{bg} + N^-_{bg})}{N^+ + N^- - A_{bg}(N^+_{bg} + N^-_{bg})}$$

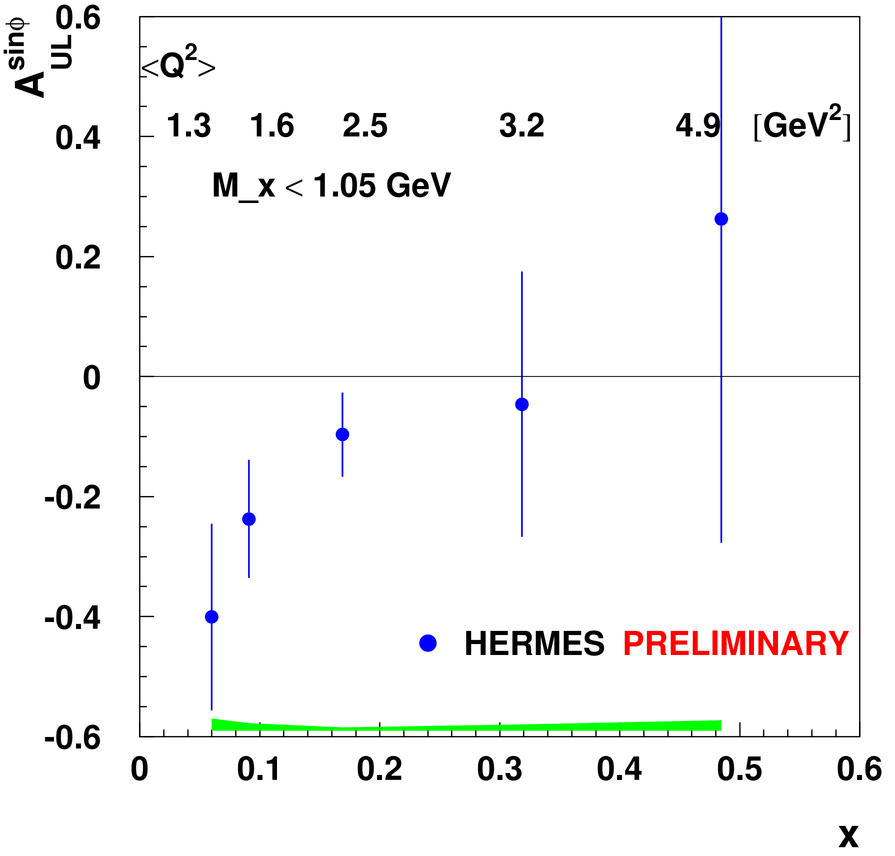
From π^- $\rightarrow$ Signal/Background ~ 5

Extrapolation from neighborhood region $A_{bg} = 2.5 \pm 2.5\%$

Domination of target polarization in systematic error.

$A_{UL}^{sin\phi}$ VS X

Exclusive π^+ leptoproduction on Hydrogen



$$A_{UL}^{sin\phi} = \frac{1}{P_T} \frac{\int_0^{2\pi} d\phi\, sin(\phi)\, dN_+ - \int_0^{2\pi} d\phi\, sin\phi\, dN_-}{0.5(\int_0^{2\pi} d\phi\, dN_+ + \int_0^{2\pi} d\phi\, dN_-)}$$

HERMES:

$$\sigma_{pol} \sim sin\phi \cdot \left\{ S_\perp \sigma_L + S_L \sigma_{LT} \right\}$$

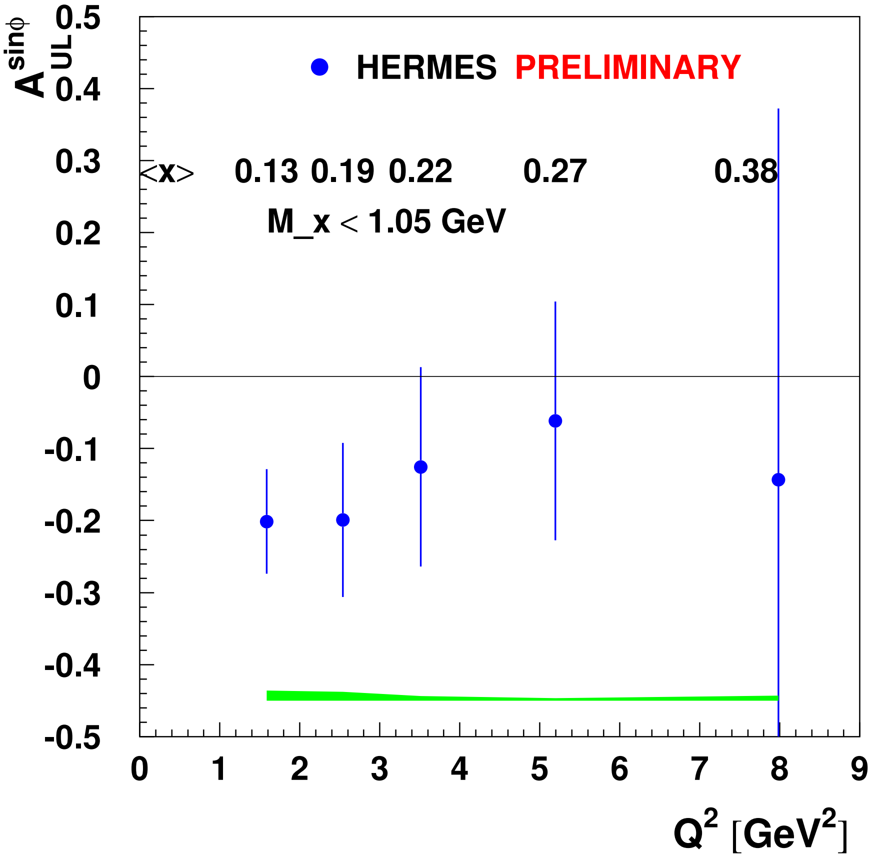
$$\frac{S_\perp}{|S_\perp + S_L|} \sim 0.17$$

σ_{LT} suppressed by $1/Q$ but $S_\perp < S_L$: both terms are on the same order.

$\rightarrow$ Transversely polarized target needed
$\rightarrow$ Transverse target running in 2002...

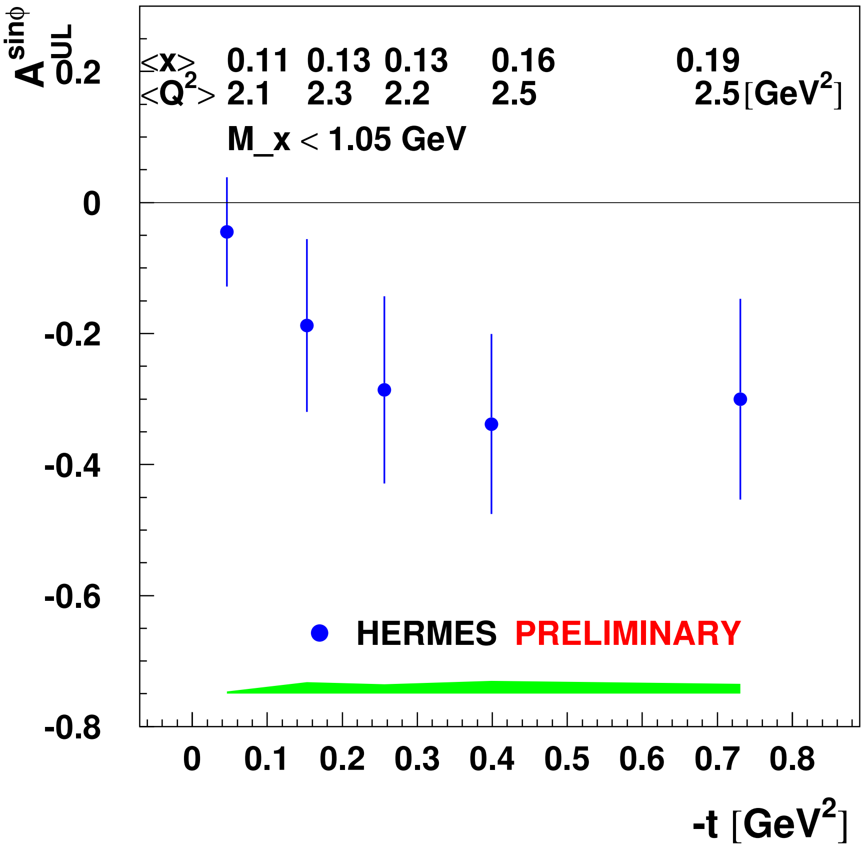
$A_{UL}^{sin\phi}$ vs Q^2

Exclusive π^+ leptoproduction on Hydrogen



$A_{UL}^{sin\phi}$ vs t

Exclusive π^+ leptoproduction on Hydrogen



$\rightarrow$ Asymmetry arise at $|t| > m_\pi^2$ (pion pole).

Prospects

- Measurement of transversity distributions δq and improved mesurement of helicity distributions Δq with transversely polarized target.
  In 2002... at $e^{\rightarrow} p^{\uparrow} \rightarrow e' \pi X$
  $E = 27.5$ GeV, $P_T = 0.75$ expected $7 \cdot 10^6$ reconstracted DIS events after the cuts: $Q^2 > 1$ GeV^2, $W > 2$ GeV, $0.02 < x < 0.7$, $y < 0.85$.
- Measurement and selection of exclusive reactions to access GPDs with a new Recoil Detector (accepted project) and unpolarized p target.
  Continuation of unpolarized 'high density' runs in 2002...

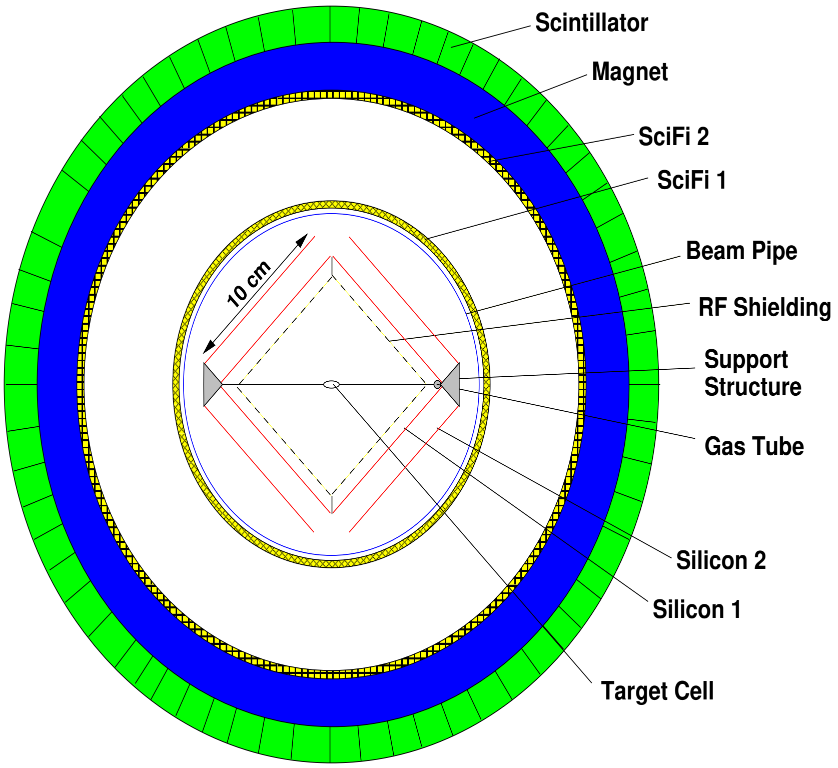
DVCS	$\gamma^* p \rightarrow \gamma p$	$H, \tilde{H}, E, \tilde{E}$
exclusive pseudoscalar meson production	$\gamma^* p \rightarrow \pi^+ n$ $\gamma^* p \rightarrow \pi^0 p$	$\tilde{H}, \tilde{E}$
exclusive vector meson production	$\gamma^* p \rightarrow \rho^o p$ $\gamma^* p \rightarrow \phi p$	H, E

Annual integrated luminosity $\sim 2 fb^{-1}$ with unpolarized target.

Kinematical cuts on DVCS:

$E_{e'} > 3.5$ GeV, $E_\gamma > 1$ GeV, $P_p > 0.2$ GeV, $W^2 > 4$GeV^2, $Q^2 > 1$ GeV^2, $15 < \Theta_{\gamma\gamma^*}$ mrad.

Conceptual Detector Design



Si-tracker
recoil proton tracking (lower momenta) p momentum from dE/dx π/p PID from dE/dx
SciFi
recoil proton tracking (higher momenta) charged pion tracking p momentum from deflection π/p PID from dE/dx
Magnet
proton momentum with SciFi Møller background reduction
γ-detector
neutral pion detection

30 cm along the beam

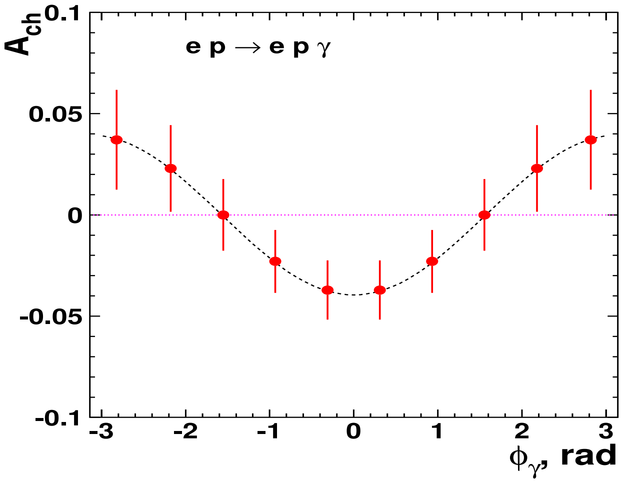
- DVCS: t resolution $\sim< 0.15$ GeV^2
- DVCS: strong background suppression of ADVCS($e^{'}\gamma\Delta^{+}$).
- exclusive π^{+}: background suppression of $e^{'}\pi^{+}\Delta^{o}$
- suppression of double-dissociative background for exclusive vector meson production

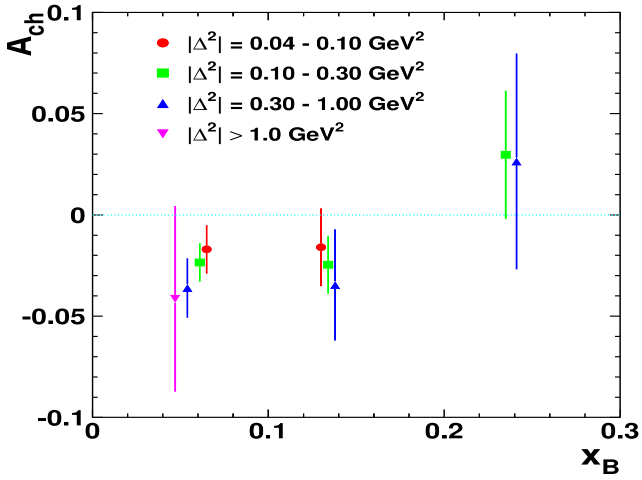
Prospects

HERMES Measurements with a Recoil Detector, Projections[1]

A) Measure lepton charge asymmetry in DVCS:

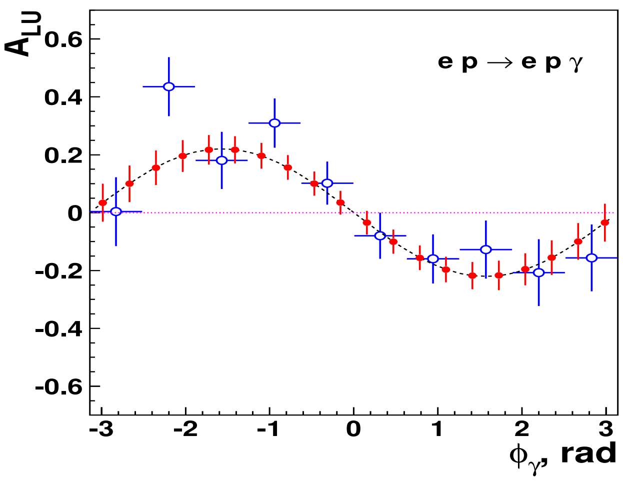
unpolarized beam, unpolarized target

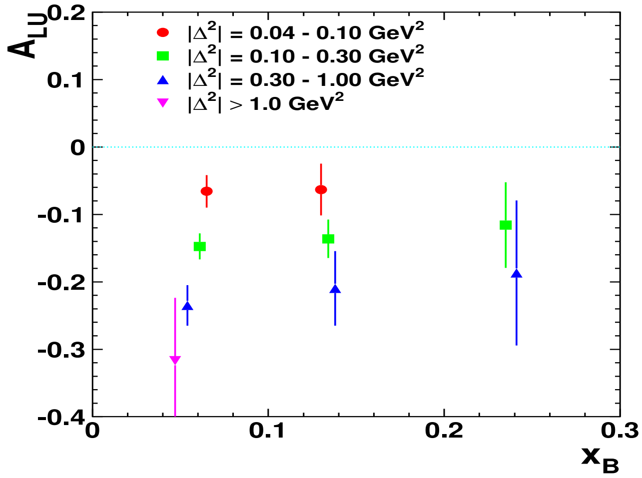




B) Measure lepton helicity asymmetry in DVCS:

polarized beam, unpolarized target





Open circles in left panel: HERMES PRELIMINARY (1996/97 data)

[1] [V.Korotkov, W.-D.Nowak, in prep.]

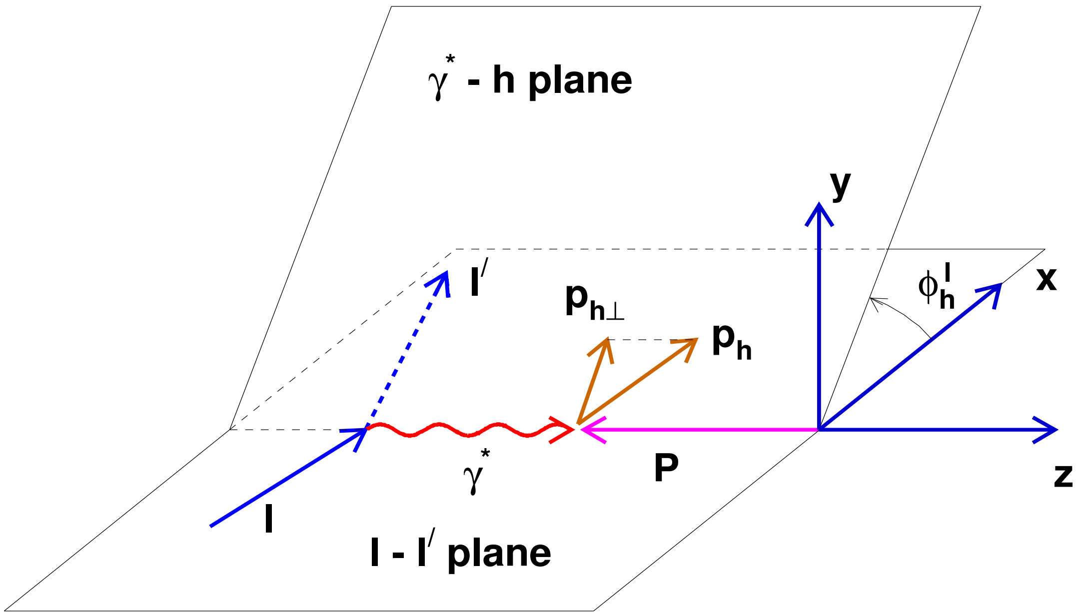
Transversity through the Collins Effect: Method

weighted asymmetry

[Mulders, Tangermann 96, Kotzinian, Mulders 97]

$$A_T(x,y,z) \equiv \frac{\int d\phi^\ell \int d^2 P_{h\perp} \frac{|P_{h\perp}|}{z M_h} \sin(\phi_s^\ell + \phi_h^\ell)\ (d\sigma^\uparrow - d\sigma^\downarrow)}{\int d\phi^\ell \int d^2 P_{h\perp} (d\sigma^\uparrow + d\sigma^\downarrow)}$$

ϕ_s^l is azimuthal angle of target spin vector w.r.t. γ^* axis



Factorization w.r.t. x and z:

$$A_T(x,y,z) = f \cdot P_T \cdot D_{nn} \cdot \frac{\sum_q e_q^2\ \delta q(x)\ H_1^{\perp(1)q}(z)}{\sum_q e_q^2\ q(x)\ D_1^q(z)}$$

$D_{nn} = (1-y)/(1-y+y^2/2)$: transverse spin transfer coefficient

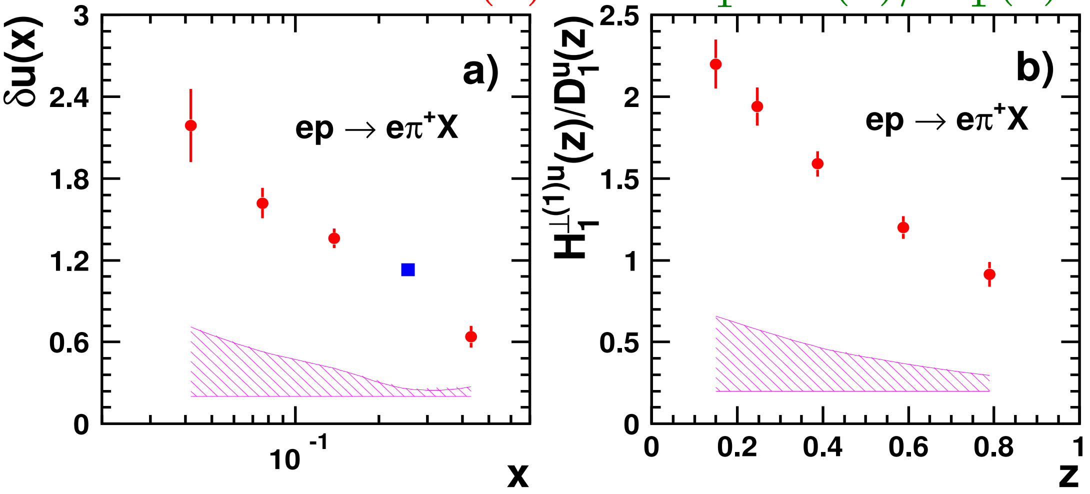
NOTE: $H_1^{\perp(1)q}$ accessible from e^+e^- data (LEP,Belle)

[W.-D. Nowak, DIS 2001.]

Transversity through the Collins Effect: Prospects [1]

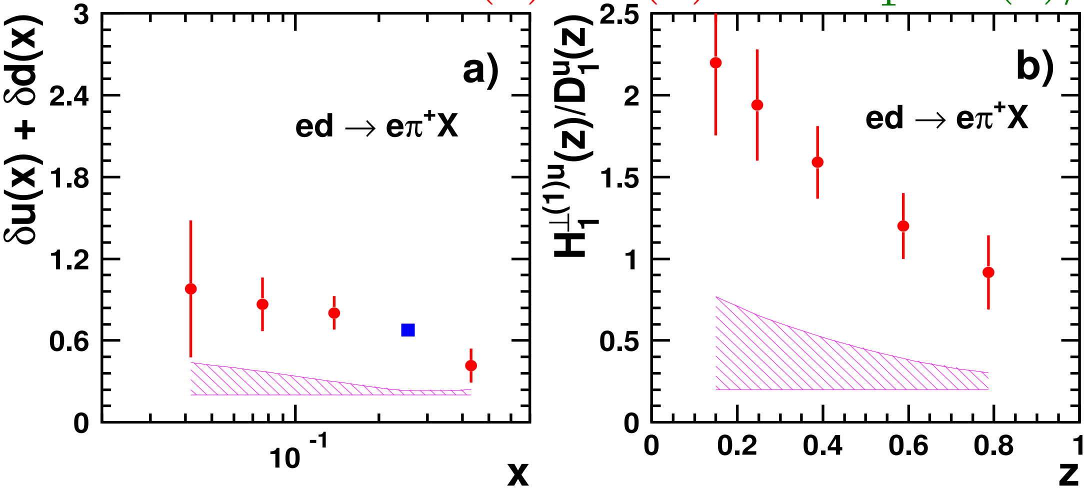
OPTION 1: proton target

Projections for $\delta u(x)$ and $H_1^{\perp(1)u}(z)/D_1^u(z)$



OPTION 2: deuteron target

Projections for $\delta u(x)+\delta d(x)$ and $H_1^{\perp(1)u}(z)/D_1^u(z)$



⇒ HERMES chose option 1 for 2001+

NOTE: δd extraction possible by adding option 2
(→ combined analysis)

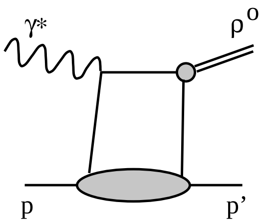
[1] [V.Korotkov, W.-D.N.,K.Oganessyan, EPJC 18, 639 (2001)]

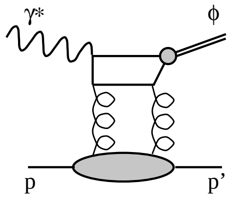
[W.-D. Nowak, DIS 2001.]

hermes

SUMMARY

- Longitudinal ρ^o cross section at domination of 'quark exchange' mechanism and ϕ cross section with '2-gluon exchange' are in agreement with GPDs predictions.





- First measurement of significant SSA $(-0.20 \pm 0.05_{stat} \pm 0.05_{syst})$ relative the longitudinal polarization of the beam performed in the DVCS sample.
  It has been accessed through DVCS-BH interference and is in the agreement with the theoretical prediction.

- Clear π^+ exclusive peak observed.
  Significant negative SSA of exclusive π^+ measured in the first time at longitudinal polarised target.

- A transversely polarized proton target in the next running period will complement the results of SSA of exclusive pion production.

- Significant improvement in resolution and systematics expected at the operation of the Recoil Detector in measuring hard exclusive reactions.

$\rightarrow$ *First steps towards the extraction of GPDs are done and next planned.*