HERMES
Past and Future
1995 - 2000 and 2001 - 2005

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on behalf of the
hermes Collaboration

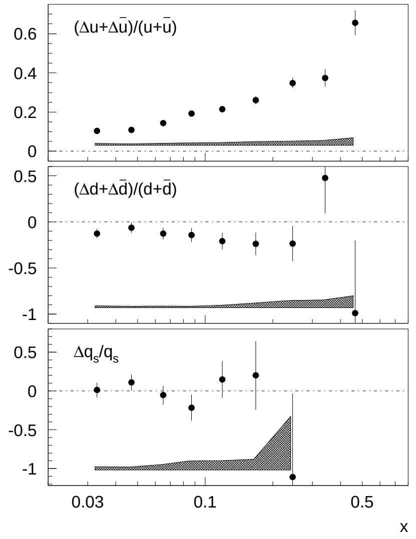
1 Spin Physics Results from HERMES

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

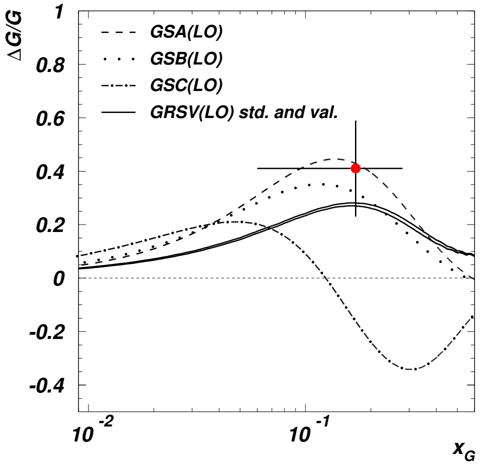
inclusive: g_p^1, g_n^1 $\to \Delta\Sigma$ | **PGF** | **exclusive:** π, γ

semi-incl.: flavor separation | **high-p$_t$ hadron pairs** | **Production**

Open Charm



hep-ex/9906035



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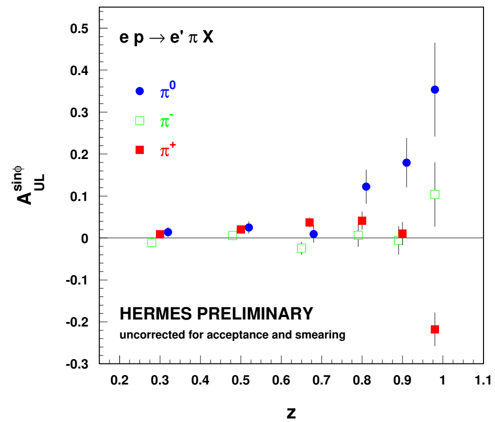
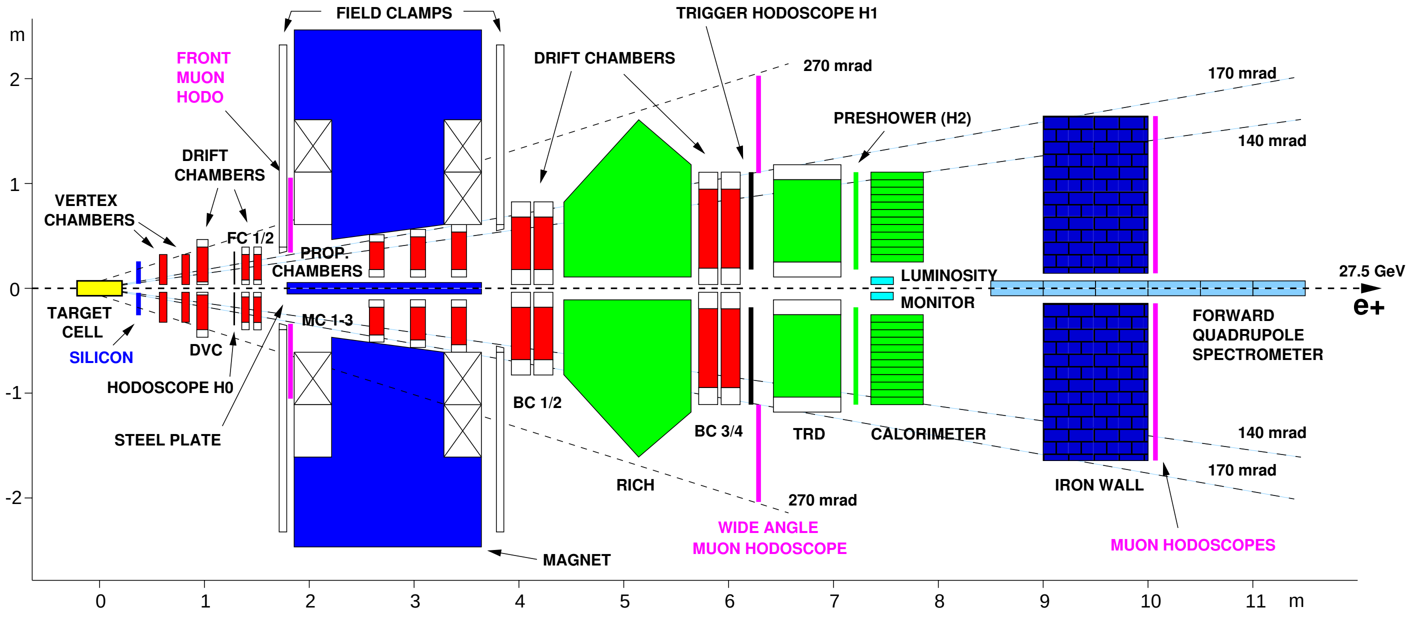
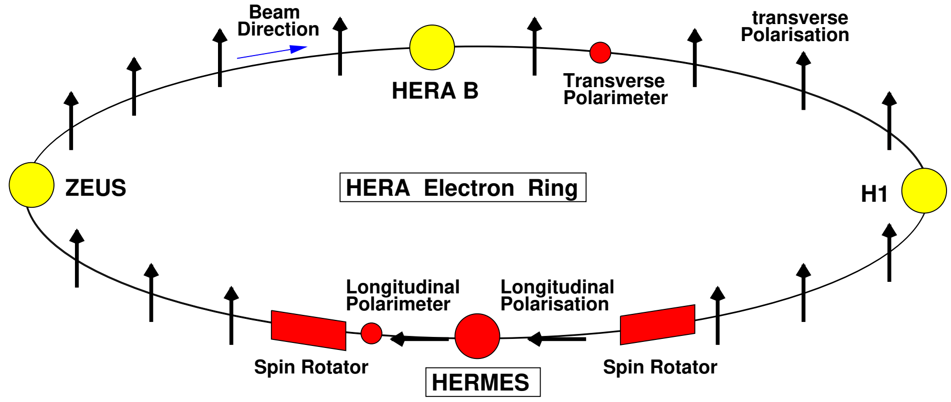


2 The HERMES Experiment at HERA

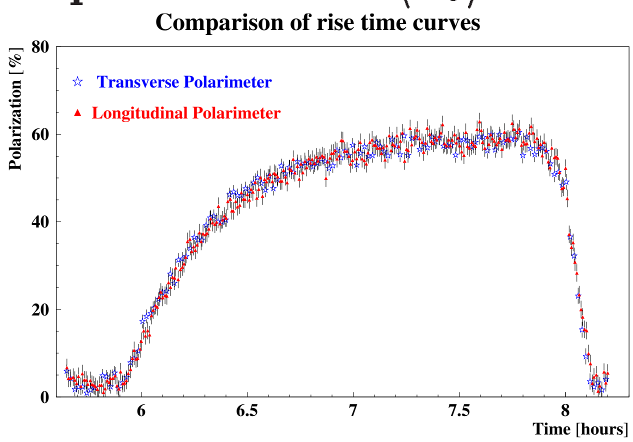


- **Kinematic Range:** $0.02 \leq x \leq 0.8$ at $Q^2 \geq 1\mathrm{GeV}^2$ and $W \geq 2\mathrm{GeV}$
- **Reconstruction:** $\delta p/p$ 0.7 - 1.3%, $\delta\Theta \leq 0.6$mrad
- **Internal Gas Target:** $\overrightarrow{He}$,$\overrightarrow{D}$, $\overrightarrow{H}$ unpol: H_2, D_2, He, N_2, Ne, Ar, Kr
- **Particle ID:** TRD, Preshower, Calorimeter
  $\rightarrow$ 1997: $\check{C}$erenkov   1998 $\rightarrow$: RICH + Muon-ID
  lepton identification efficiency: ~98%   hadron contamination: $\leq$ 1%

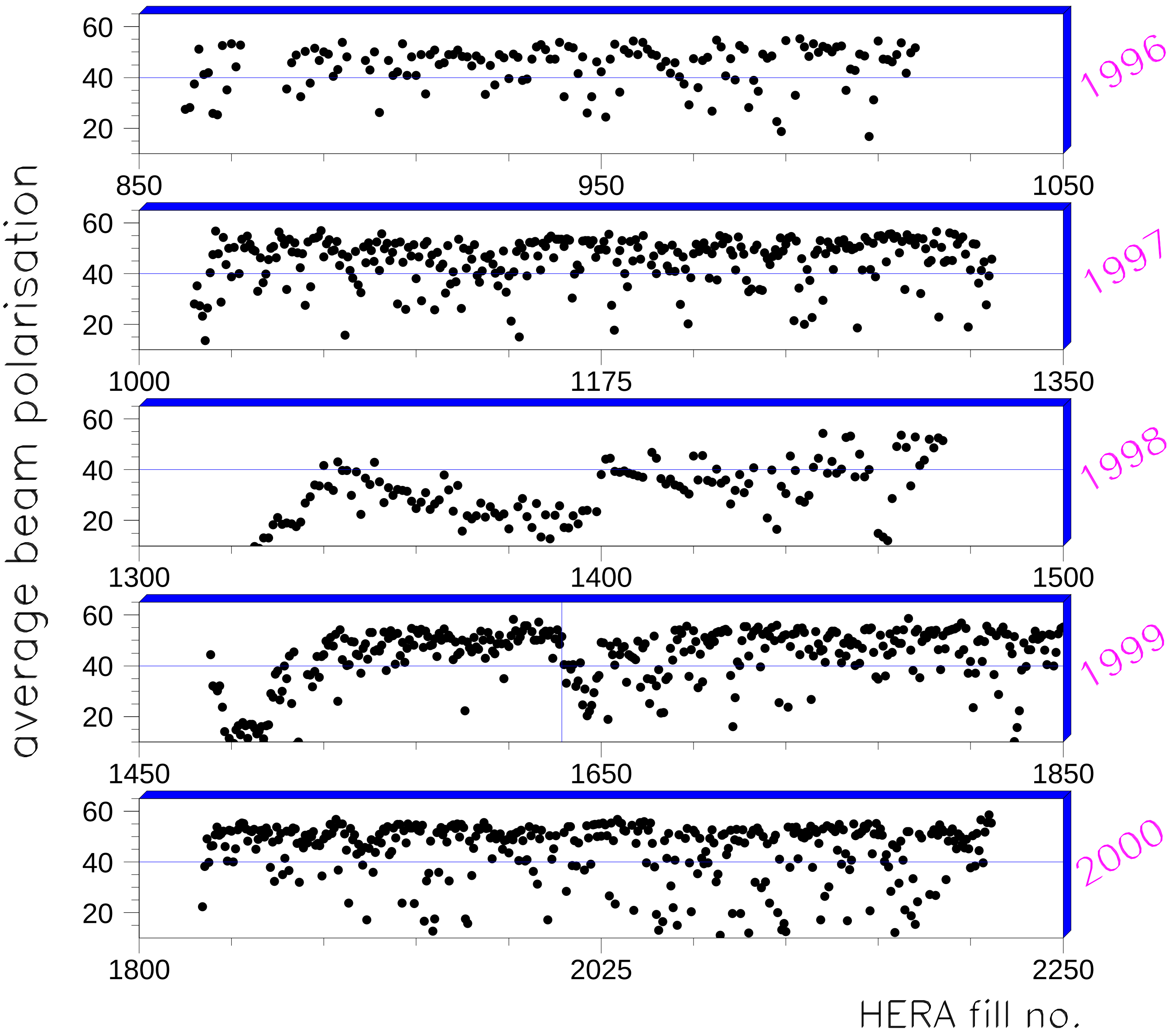
3 Polarized Positrons at HERA



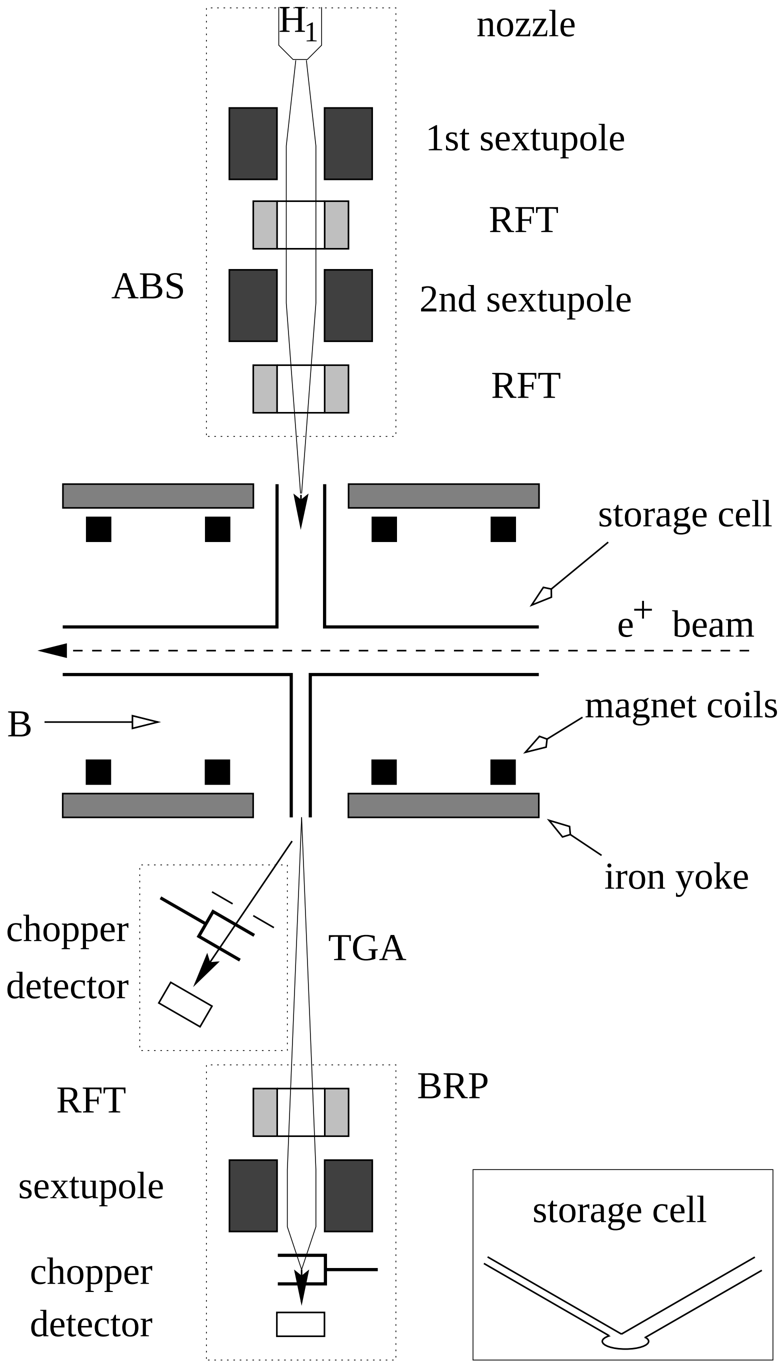
- Self-polarization by emission of synchrotron radiation, $P_b(t) = p_b^{max}[1 - exp(t/\tau)]$
- Longitudinal polarization at HERMES
$\rightarrow$ Spin rotators
- Polarimeters based on Compton Back-Scattering
  - Transverse Polarimeter
    Position asymmetry in the Compton cross section
  - Longitudinal Polarimeter
    asymmetry in the integral of the energy weighted Compton cross section
- average beam polarization $\langle P_b \rangle \approx 55\%$



Polarization 1996 - 2000



4 The Hermes Target



- **Cell walls 75μ aluminum, Drifilm coated**
- **Cell Temperature 35...260 K, helium cooled**
- **Holding field range 0...350 mT, $\Delta B/B \approx 0.015$**

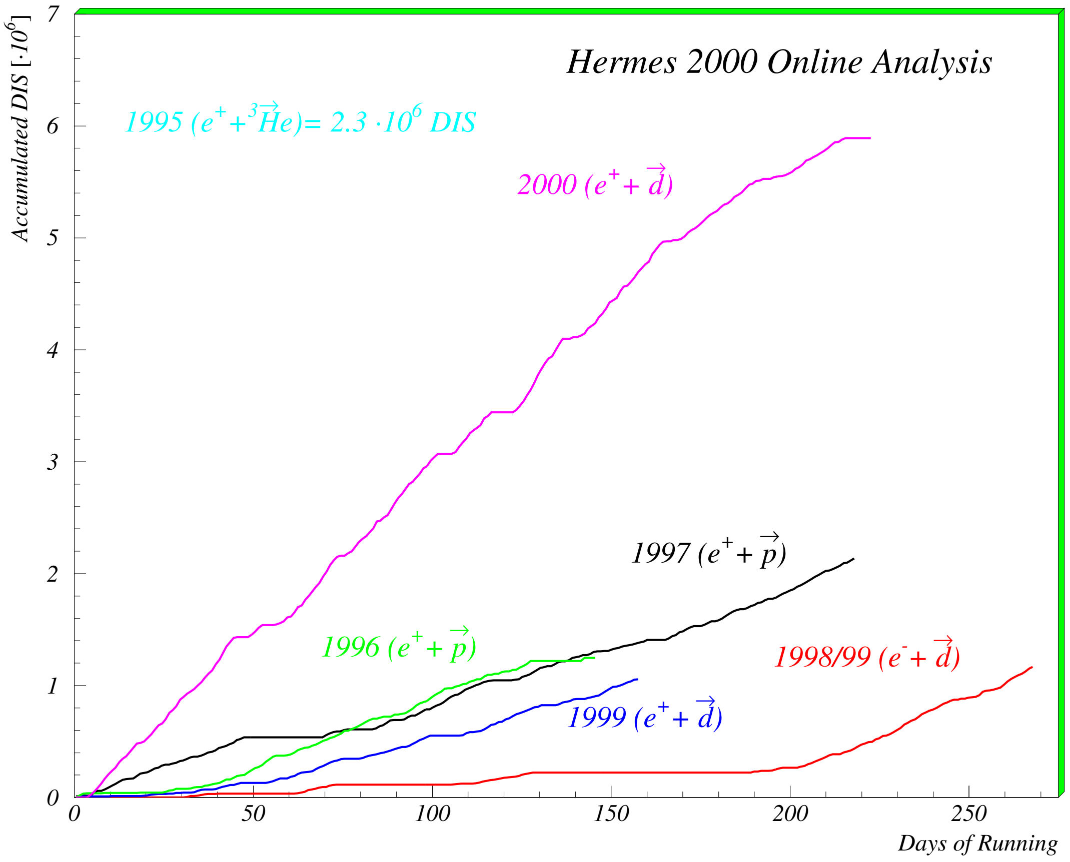
Running Conditions 1996 - 2000

$$P^T = \alpha_0^T(\alpha_r^T + (1 - \alpha_r^T)\beta)P_a^T$$

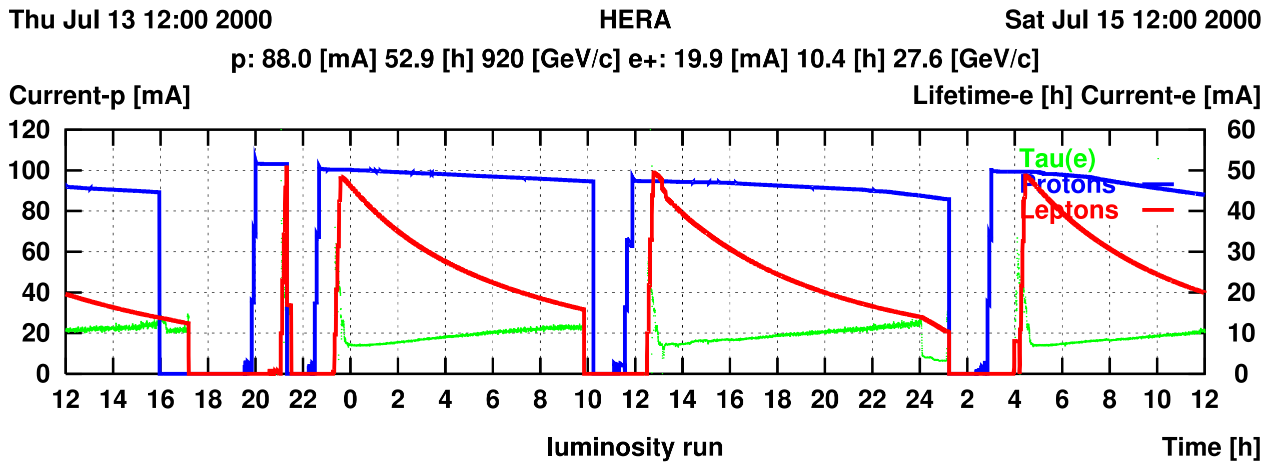
- P^T **Target Polarization (averaged)**
- α_0^T **Initial degree of dissociation**
- α_r^T **Recombination inside cell**
- β **Polarization of molecules,** $\beta = P_a/P_m$
- P_a^T **Polarization of atoms**

	1996/1997 Hydrogen	1998/1999 Deuterium	2000 Deuterium
$< d^T >$	7.5*10^{13}	7.5*10^{13}	14*10^{13}
T_c (K)	100	90	65
B^T (mT)	335	335	335
α_0^T	0.99±0.02	0.94±0.03	0.953±0.014
α_r^T	0.93±0.04	1.00±0.03	0.997±0.013
P_a^T	0.92±0.03	0.99±0.01	0.99±0.01
β	0.60±0.40	0.60±0.40	0.60±0.40
$< P^T >$	0.88±0.04	0.84±0.03	0.85±0.02

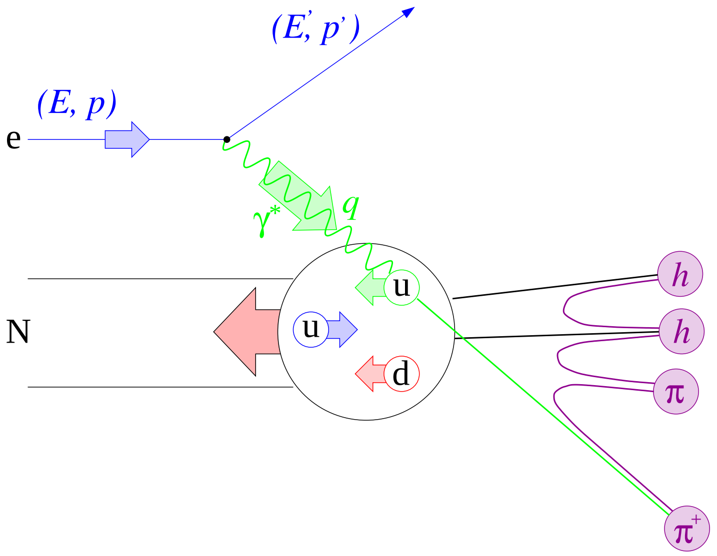
5 Accumulated Statistics 1996 - 2000



- **2000:** 50% more target density
- **2000:** Perfect HERA performance



6 Polarized Deep Inelastic Scattering



Important Variables:

$$Q^2 \overset{lab}{=} 4EE' \sin^2(\tfrac{\theta}{2})$$
$$\nu \overset{lab}{=} E - E'$$
$$x \overset{lab}{=} \frac{Q^2}{2m\nu}$$
$$y \overset{lab}{=} \frac{\nu}{E} = \frac{p\cdot q}{p\cdot k}$$
$$z \overset{lab}{=} \frac{E_h}{\nu}$$

Cross Section:

$$\frac{d^2\sigma}{d\Omega dE^2} = \frac{\alpha^2 E'}{Q^2 E} L_{\mu\nu} W^{\mu\nu}$$

$$L_{\mu\nu} = 2[k_\mu k'_\nu + k_\nu k'_\mu - \left(k \cdot k' - m_e^2\right) g_{\mu\nu} + i m_e \epsilon_{\mu\nu\alpha\beta} S^\alpha \left(k - k'\right)^\beta]$$

Where: $S^\alpha = \frac{1}{2}\overline{u}\left(k,s\right)\gamma^\alpha\gamma_5 u\left(k,s\right)$

$$W^{\mu\nu} = -g^{\mu\nu} F_1\left(x,Q^2\right) + \frac{p^\mu p^\nu}{\nu} F_2\left(x,Q^2\right) + \frac{i}{\nu}\epsilon^{\mu\nu\lambda\sigma} q_\lambda S_\sigma g_1\left(x,Q^2\right) + \frac{i}{\nu^2}\epsilon^{\mu\nu\lambda\sigma} q_\lambda \left(p\cdot q S_\sigma - S\cdot q p_\sigma\right) g_2\left(x,Q^2\right)$$

(for spin 1) + **quadropole terms** (b_1, b_2, b_3, b_4)

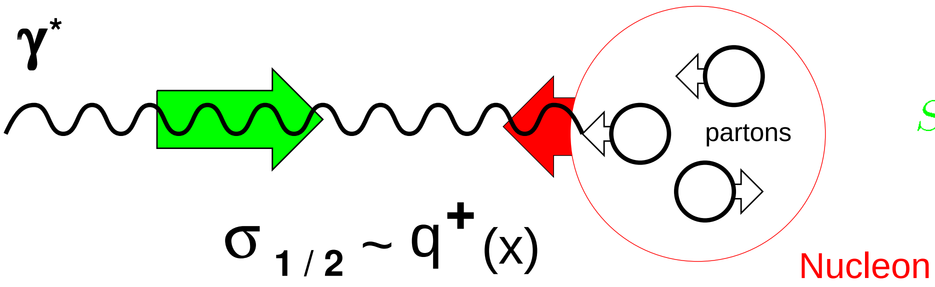
F_1,F_2 $\Longrightarrow$ **Unpolarized Structure Functions**

g_1,g_2 $\Longrightarrow$ **Polarized Structure Functions**

What is measured

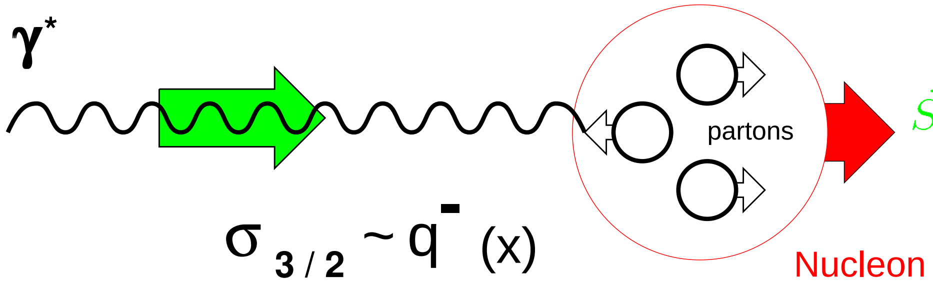
7 Virtual Photon Asymmetry

polarized Photon (Spin 1) can only probe quarks with spin opposite to its own:



$\vec{S_\gamma} + \vec{S_N} = 1/2$

$+$ means: quark spin parallel to **Nucleon spin**



$\vec{S_\gamma} + \vec{S_N} = 3/2$

- means: quark spin opposite to **Nucleon spin**

unpolarized target + beam	flipping spin of target
Quark Distributions:	**Quark Spin Distributions:**
$\boxed{q_f(x) := q_f^+(x) + q_f^-(x)}$	$\boxed{\Delta q_f(x) := q_f^+(x) - q_f^-(x)}$

$(\ f = u, d, s, \overline{u}, \overline{d}, \overline{s} \ )$

Virtual Photon Asymmetries:

$$A_1 = \frac{\sigma_{\frac{1}{2}} - \sigma_{\frac{3}{2}}}{\sigma_{\frac{1}{2}} + \sigma_{\frac{3}{2}}} = \frac{g_1 - \gamma^2 g_2}{F_1}$$

$$A_2 = \frac{\sigma_{TL}}{\sigma_T} = \frac{\gamma(g_1 + g_2)}{F_1} \qquad \gamma = \frac{2Mx}{\sqrt{Q^2}}$$

$$F_1(x) = \quad \frac{1}{2}\sum_i e_i^2 (q_i^+(x) + q_i^-(x)) \quad = \frac{1}{2}\sum_i e^2 q_i(x)$$

2xF$_1$ measures the momentum distribution of quarks

$$g_1(x) = \quad \frac{1}{2}\sum_i e_i^2 (q_i^+(x) - q_i^-(x)) \quad = \frac{1}{2}\sum_i e^2 \Delta q_i(x)$$

g$_1$ measures the spin distribution of quarks

Measurable Asymmetries:

$$A_{\parallel} = \frac{\sigma^{\overset{\rightarrow}{\Leftarrow}} - \sigma^{\overset{\rightarrow}{\Rightarrow}}}{\sigma^{\overset{\rightarrow}{\Leftarrow}} + \sigma^{\overset{\rightarrow}{\Rightarrow}}} \qquad A_{\perp} = \frac{\sigma^{\uparrow\rightarrow} - \sigma^{\uparrow\leftarrow}}{\sigma^{\uparrow\rightarrow} + \sigma^{\uparrow\leftarrow}}$$

The relation between the asymmetries

$$A_{\parallel} = D(A_1 + \eta A_2) \qquad A_{\perp} = d(A_2 + \xi A_1)$$

Where:

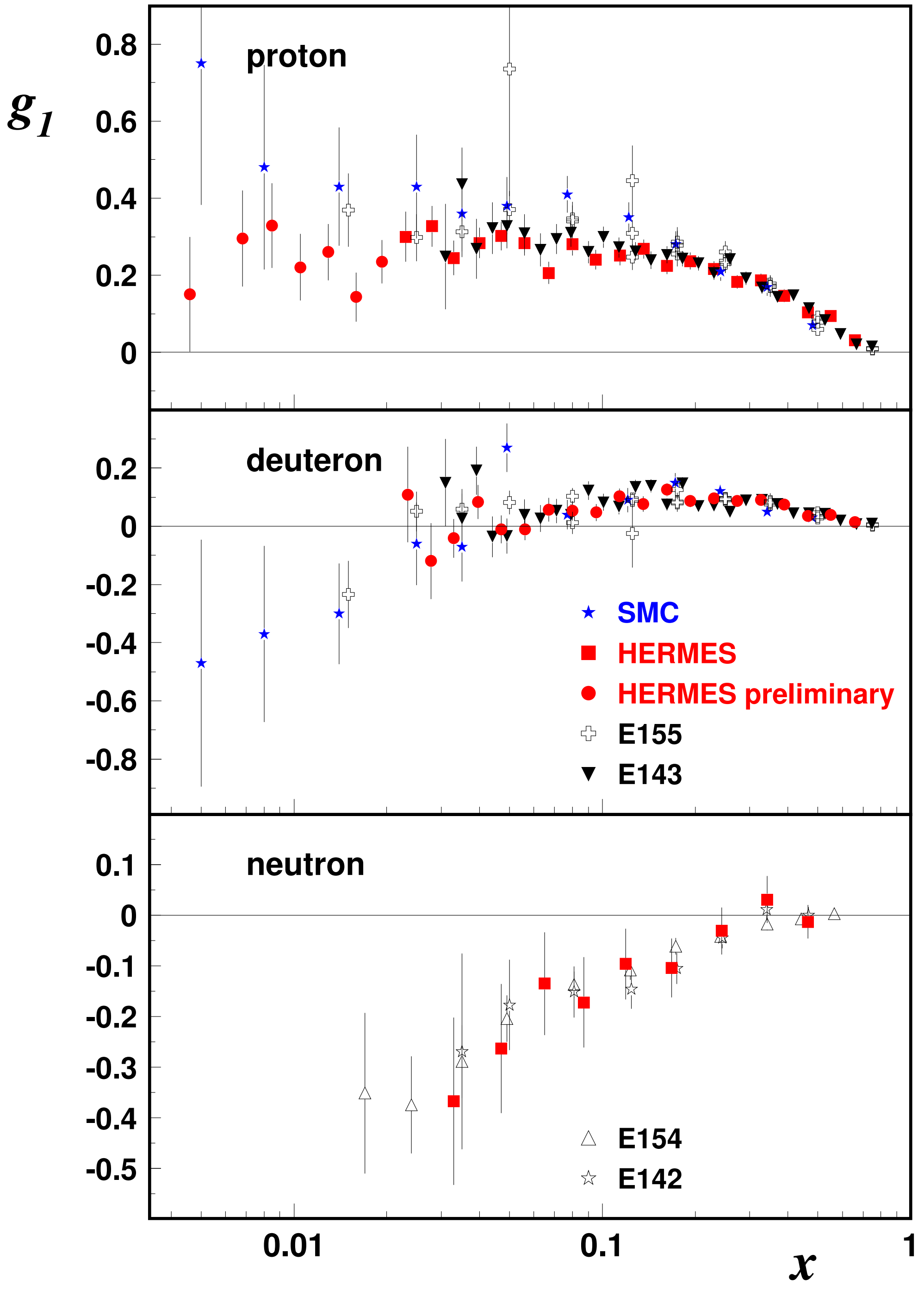
$$D = \frac{y(2-y)}{y^2 + 2(1-y)(1+R)} \quad \eta = \frac{2(1-y)\sqrt{Q^2}}{y(2-y)E} \quad d = D\sqrt{\frac{2\epsilon}{1+\epsilon}} \quad \xi = \eta\frac{1+\epsilon}{2\epsilon}$$

D,d: virtual photon depolarization factor

R: ratio of long. to trans. photo-absorption

ϵ: transverse pol. of the virtual photon

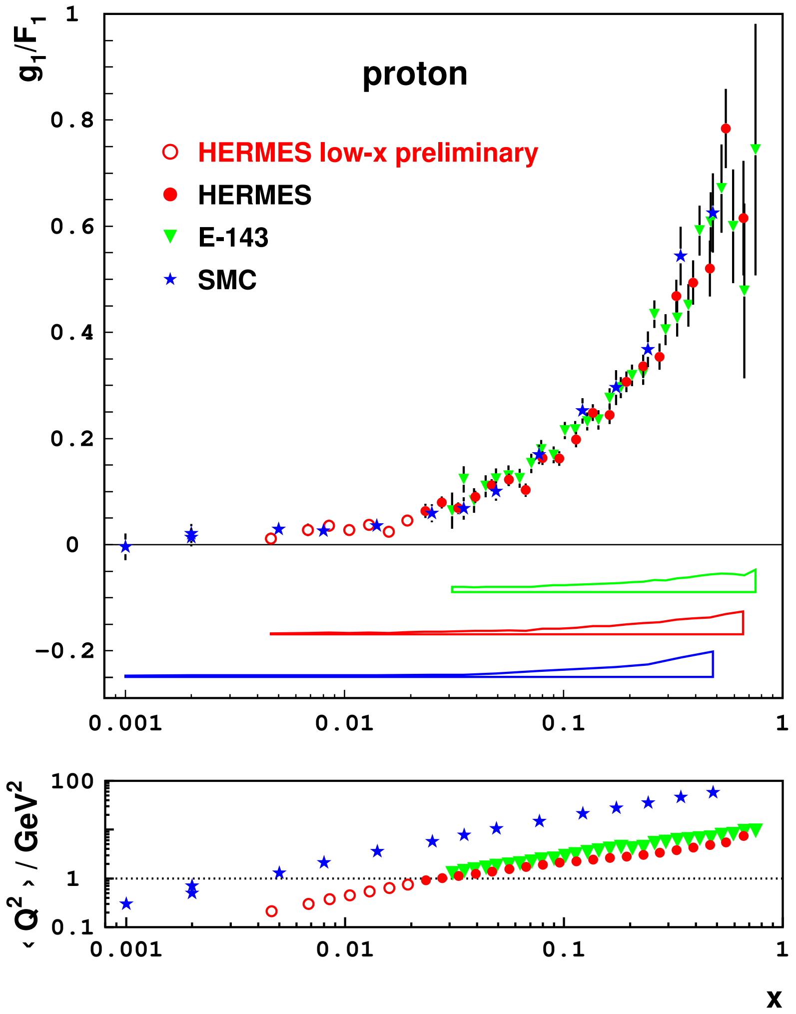
8 World data on g1(x)



Given at experimental $< Q^2 >$ per bin

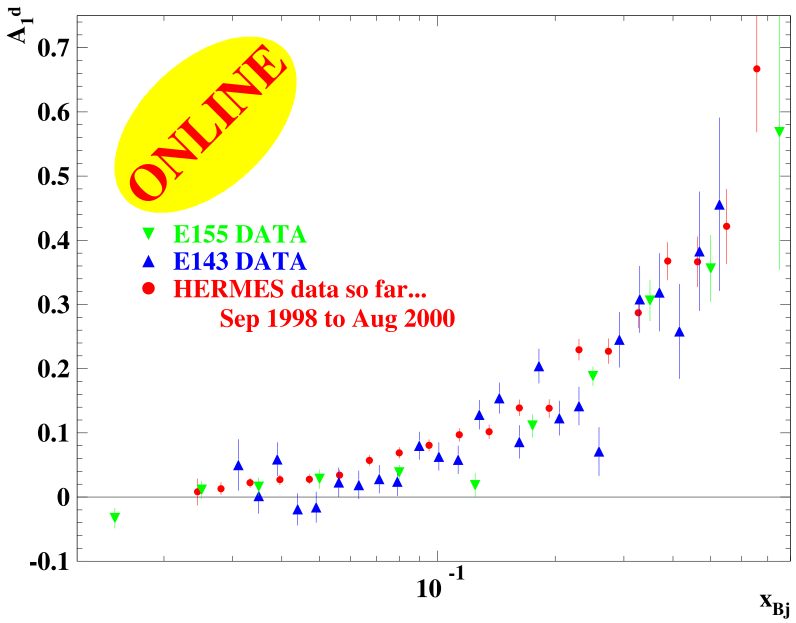
SMC data only shown for $Q^2 > 1GeV^2$

What is HERMES contributing



No statistically significant Q^2 dependence

What will HERMES contribute



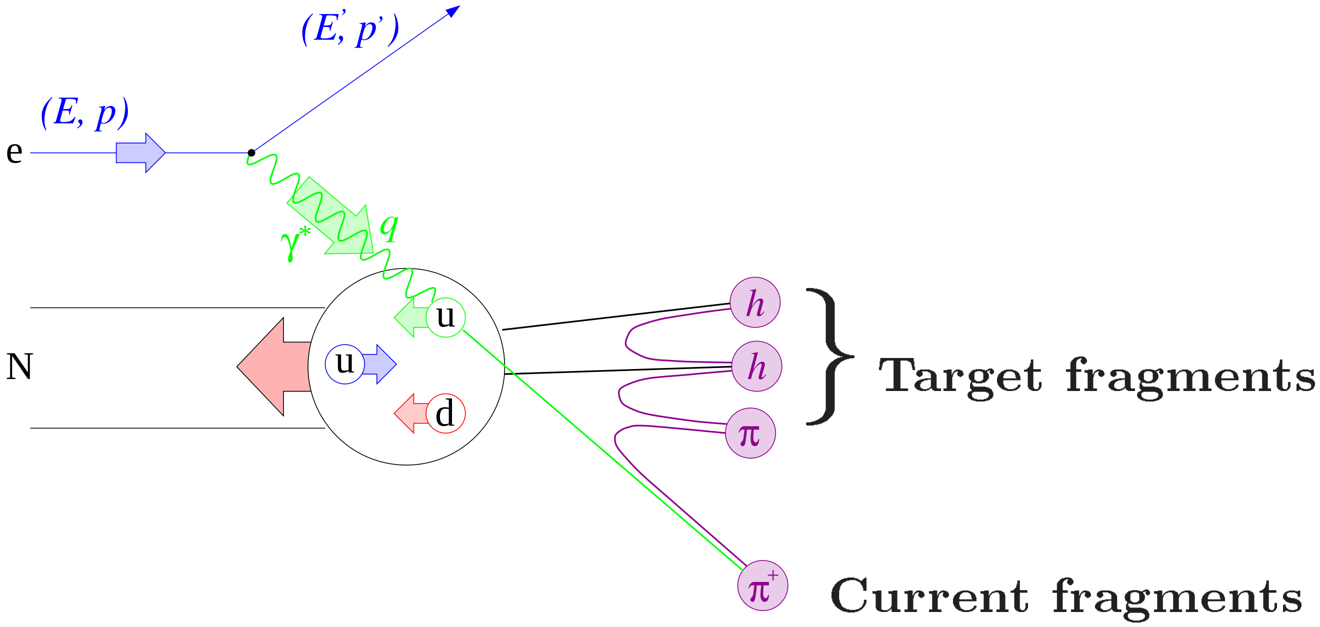
Excellent $\overrightarrow{\mathrm{D}}$ statistics:

8 Million DIS

1 Million tensor polarized $\overrightarrow{\mathrm{D}}$ - DIS

$\longrightarrow$ determination of b_1^D possible

9 Semi-inclusive DIS



Inclusive DIS: $\Delta\Sigma = (\Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} + \Delta s + \Delta\bar{s})$

Correlation between detected hadron and struck q_f

$\longrightarrow$ **'Flavor - Separation':**

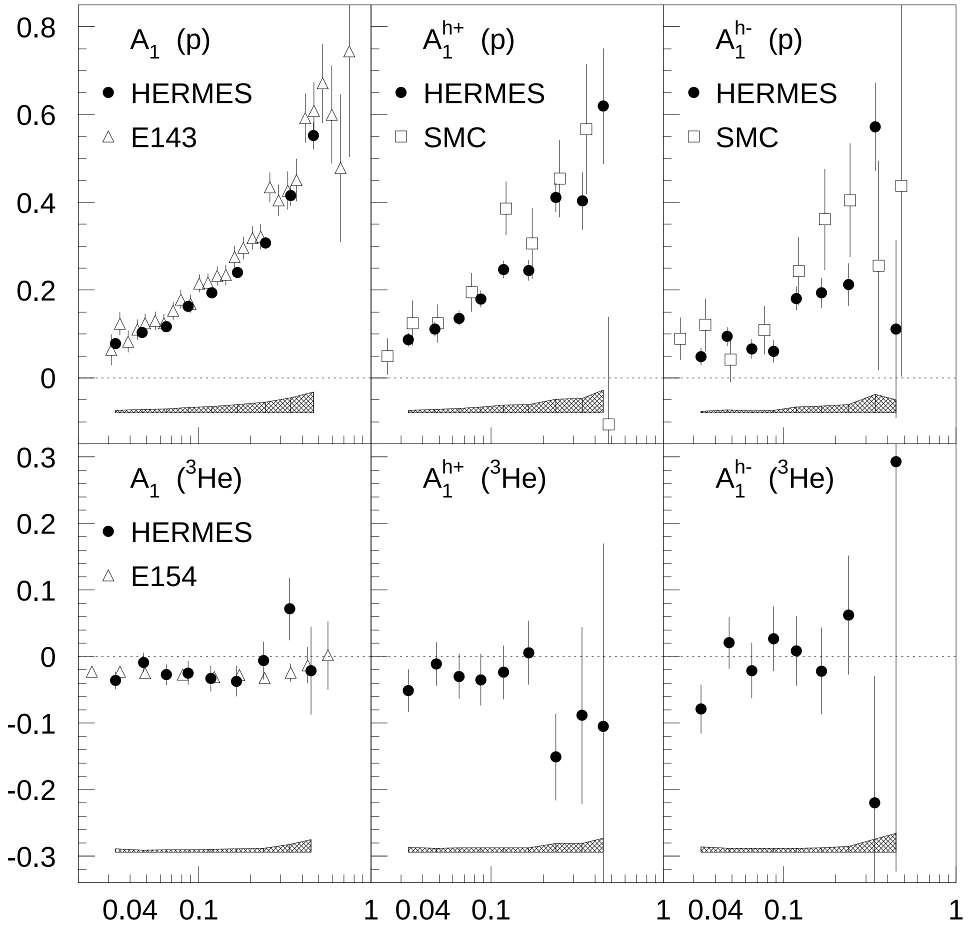
Semi-inclusive DIS: $\Delta u,\ \Delta\bar{u},\ \Delta d,\ \Delta\bar{d},\ \Delta s,\ \Delta\bar{s}$

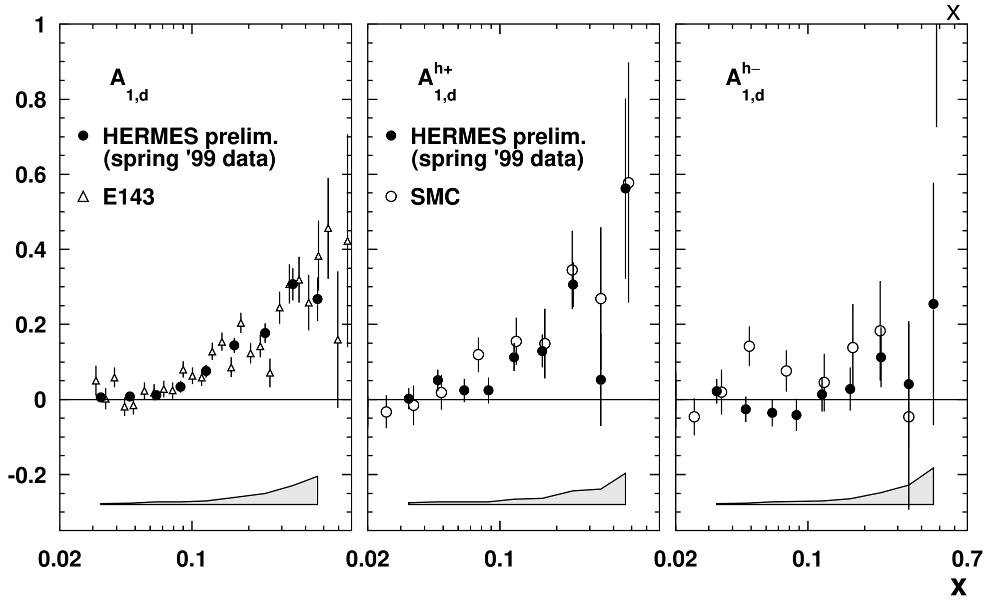
In LO-QCD:

$$A_1^{\mathrm{h}}(x,Q^2) = \frac{\sigma^h_{1/2}-\sigma^h_{3/2}}{\sigma^h_{1/2}+\sigma^h_{3/2}} = C \cdot \frac{\sum_f e_f^2 \Delta q_f(x,Q^2) \int dz\, D_f^{\mathrm{h}}(z,Q^2)}{\sum_f e_f^2 q_f(x,Q^2) \int dz\, D_f^{\mathrm{h}}(z,Q^2)}$$

- $(\Delta q_f), q_f$ **(Polarized) quark distributions**
- $D_f^{\mathrm{h}}(z)$ **fragmentation functions giving the probability that a (struck) quark of flavor f fragments into a hadron of type h.**
- $\mathbf{C} = \frac{1+R(x,Q^2)}{1+\gamma^2}$

10 Hadron Asymmetries





- **2.2 x 10^6 $^3\overrightarrow{\mathrm{He}}$, 2.3 x 10^6 $\overrightarrow{\mathrm{H}}$ and 0.9 x 10^6 $\overrightarrow{\mathrm{D}}$ DIS events**
- **hadrons selected in current fragmentation region by** $z = E_h/\nu \geq 0.2$ **and** $x_F \geq 0.1$ **and** $W^2 \geq 10 GeV^2$

11 Δq-Extraction

- **Rewrite Photon-Nucleon Asymmetry**

$$A_1^{\mathrm{h}}(x) = C \cdot \sum_q \underbrace{\frac{e_q^2 q(x) \int dz D_q^{\mathrm{h}}(z)}{\sum_{q'} e_{q'}^2 q'(x) \int dz D_{q'}^{\mathrm{h}}(z)}}_{P_q^h(x,z)} \frac{\Delta q(x)}{q(x)}$$

- $P_q^h(x,z)$ **Purity, the prob. that a hadron h originates from an event with struck quark f**

- **define**

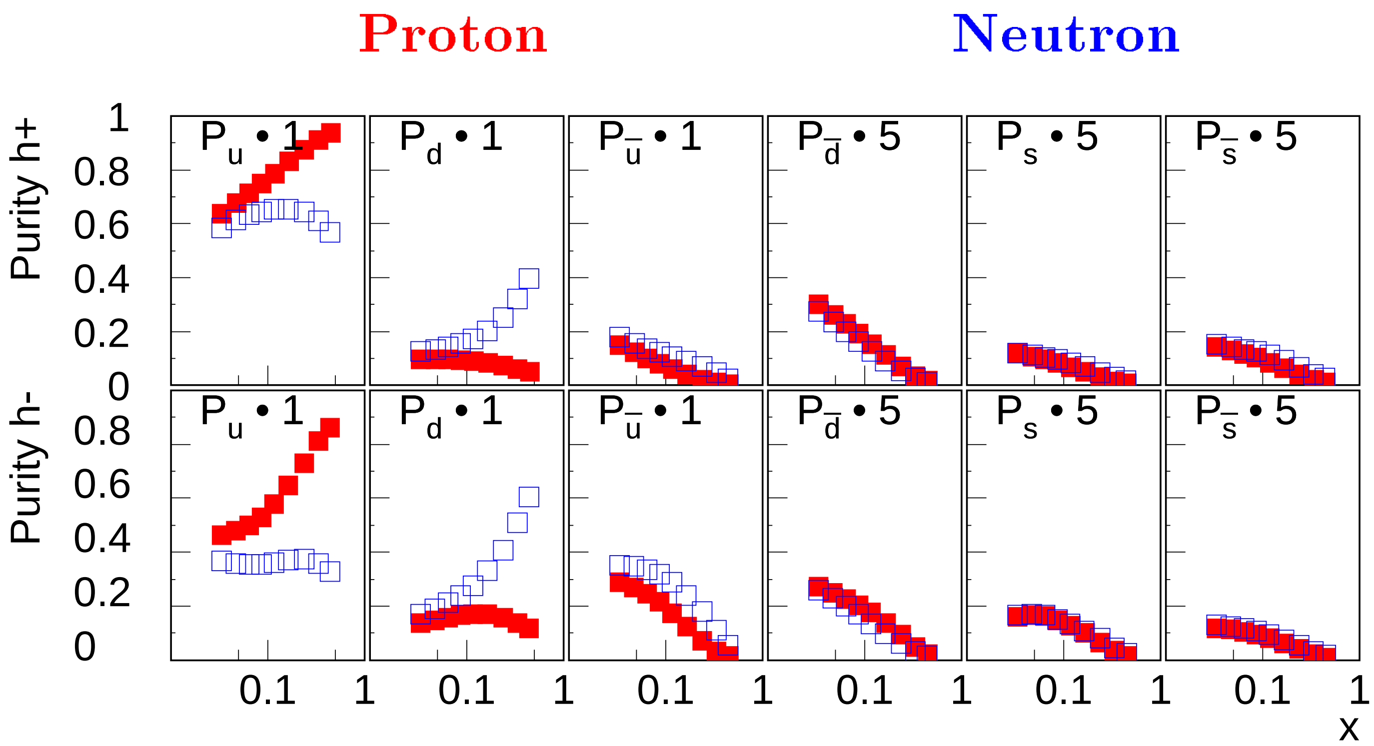
$$\vec{A} = \begin{pmatrix} A_{1,p}(x) \\ A_{1,p}^{h^+}(x) \\ A_{1,p}^{h^-}(x) \\ \ldots \\ A_{1,d}^{h^-}(x) \end{pmatrix} \vec{Q} = \begin{pmatrix} \Delta q_1(x)/q_1(x) \\ \ldots \\ \Delta q_n(x)/q_n(x) \end{pmatrix} \mathcal{P} = C \cdot \left[P_q^h(x)\right]$$

where $P_q^h(x,z) = \int_{z_{min}}^1 P_q^h(x,z)dz$

- **to extract quark polarizations solve**

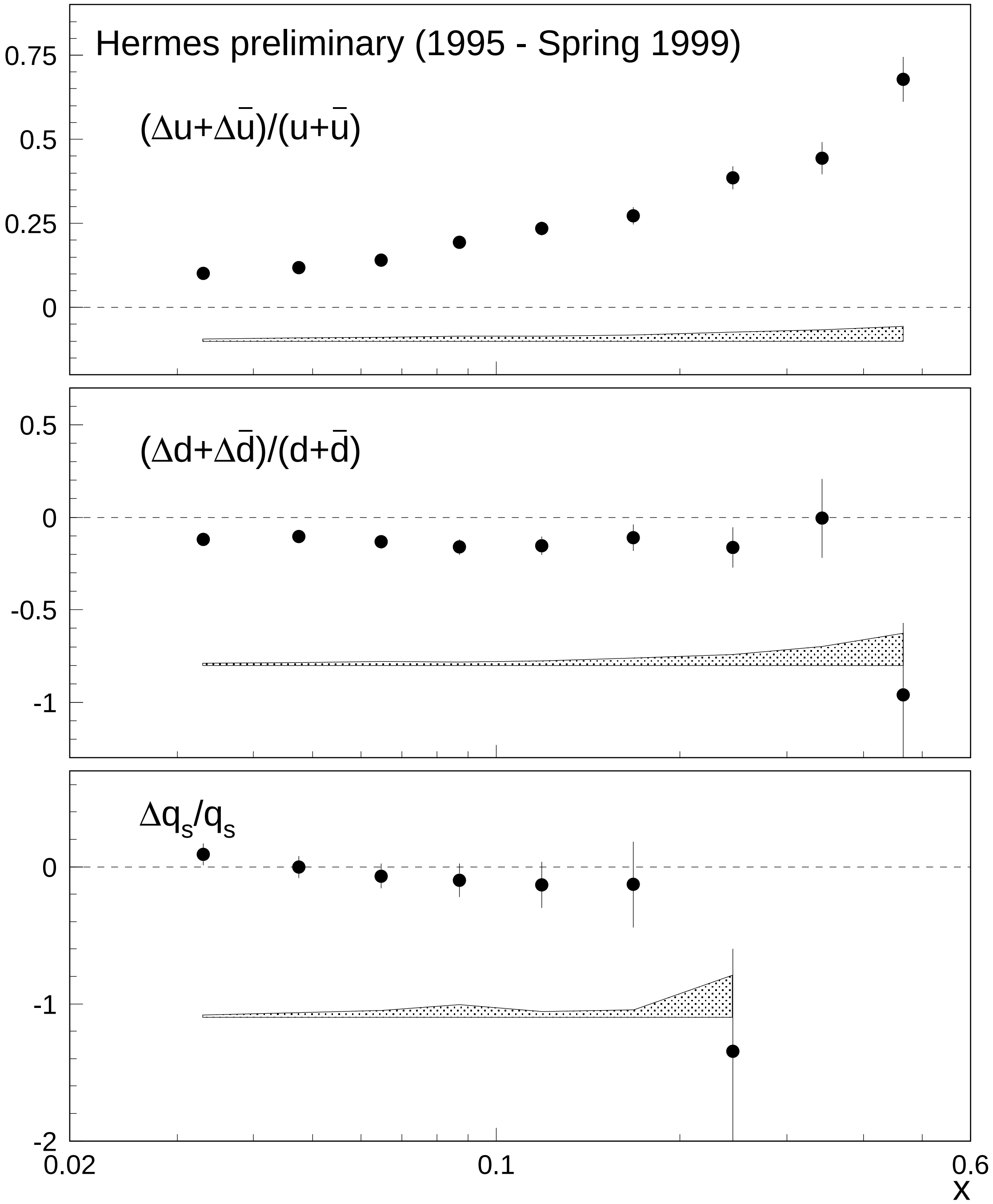
$$\boxed{\vec{A} = \mathcal{P}\vec{Q}}$$

Purity Functions for Proton/Neutron



- need Proton and Neutron (^{3}He, Deuterium) target to do complete flavor decomposition
- neutron parton distribution functions are iso-spin rotated compared to the proton

12 Flavor Decomposition

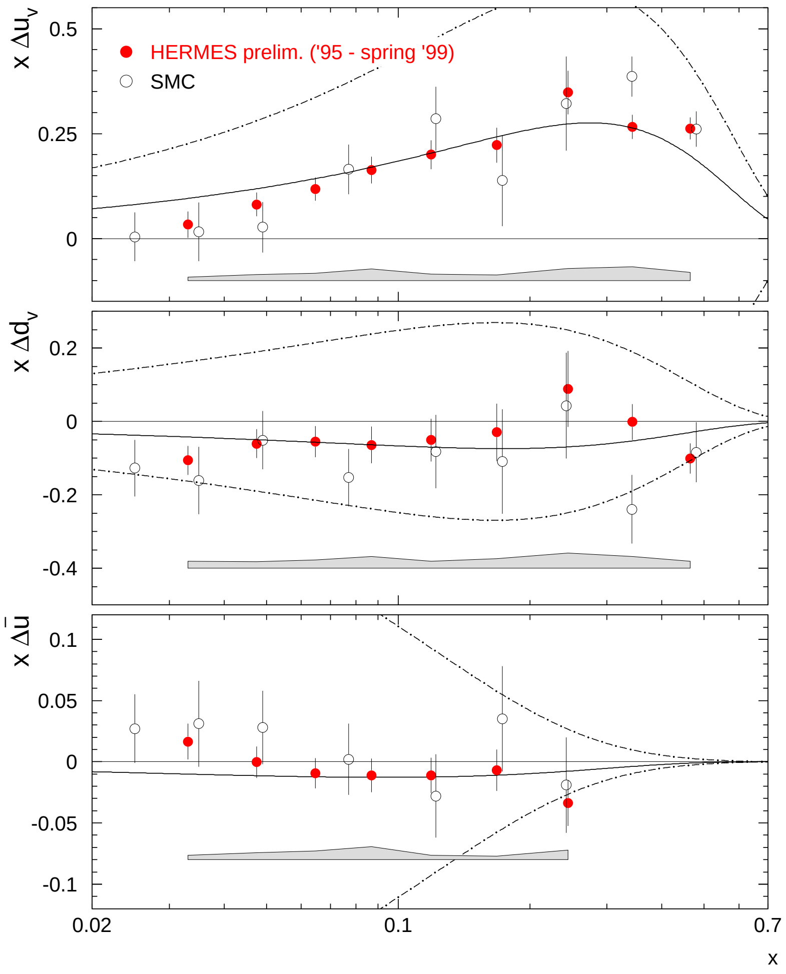


HERMES SEA Assumption:

$$\frac{\Delta u_s(x)}{u_s(x)} = \frac{\Delta d_s(x)}{d_s(x)} = \frac{\Delta s(x)}{s(x)} = \frac{\Delta\overline{u}(x)}{\overline{u}(x)} = \frac{\Delta\overline{d}(x)}{\overline{d}(x)} = \frac{\Delta\overline{s}(x)}{\overline{s}(x)}$$

data are presented at measured Q^2

13 Quark Polarizations at LO



Dashed: Positivity limit   Solid: GRSV

First moments at $Q^2 = 2.5$

$\Delta\Sigma = 0.30 \pm 0.04 \pm 0.09$

$\Delta q_s = -0.01 \pm 0.03 \pm 0.03$

PL B464 ('99) 123 ('95-'97)

- **Result insensitive to choice of sea assumption:**

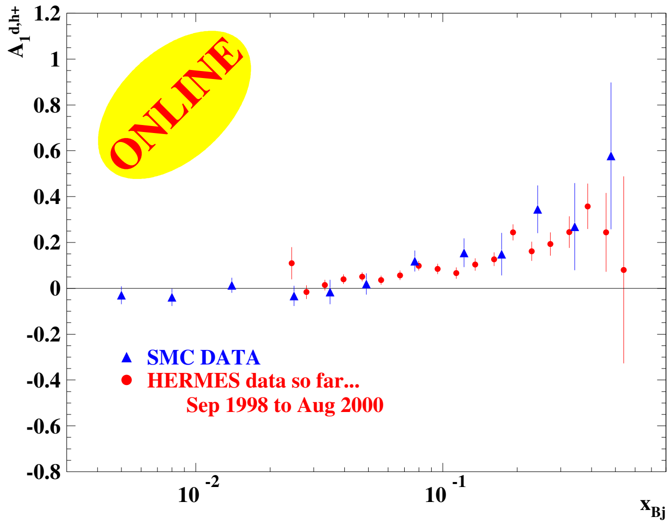
$$\frac{\Delta q_s}{q_s} \equiv \frac{\Delta u_s}{u_s} = \frac{\Delta d_s}{d_s} = \frac{\Delta s}{s} = \frac{\Delta \overline{u}}{\overline{u}} = \frac{\Delta \overline{d}}{\overline{d}} = \frac{\Delta \overline{s}}{\overline{s}}$$

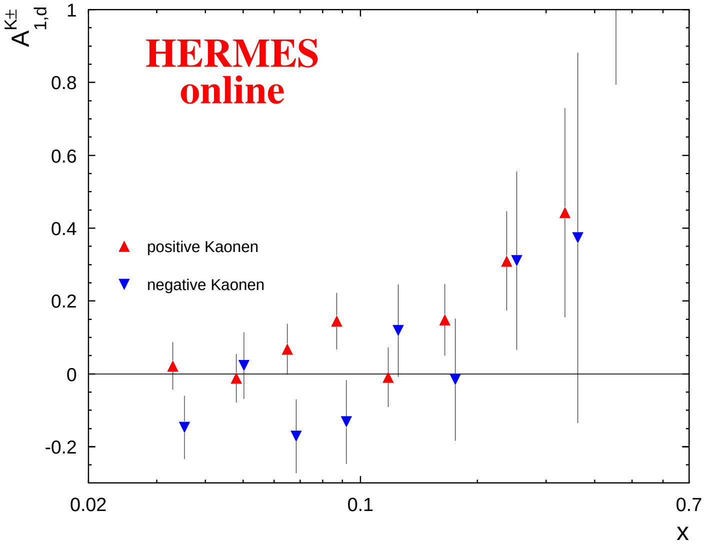
$$\Delta q_s \equiv \Delta u_s = \Delta d_s = \Delta s = \Delta \overline{u} = \Delta \overline{d} = \Delta \overline{s}$$

- **Agreement with Gehrmann, Stirling fit to inclusive data (Gluon A, LO)**

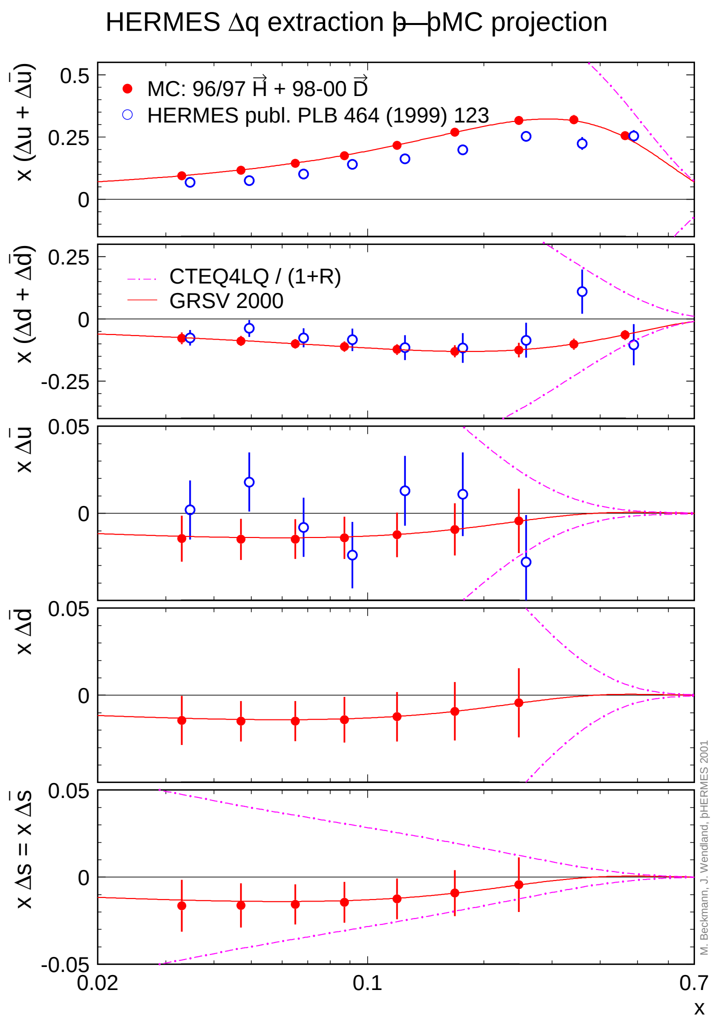
- **Conclusion on sea must await HERMES complete ^{2}D data set**

The Future of Hadron Asymmetries and Δq





$A_D^{K^\pm}$ corresponds to 1 x 10^6 DIS

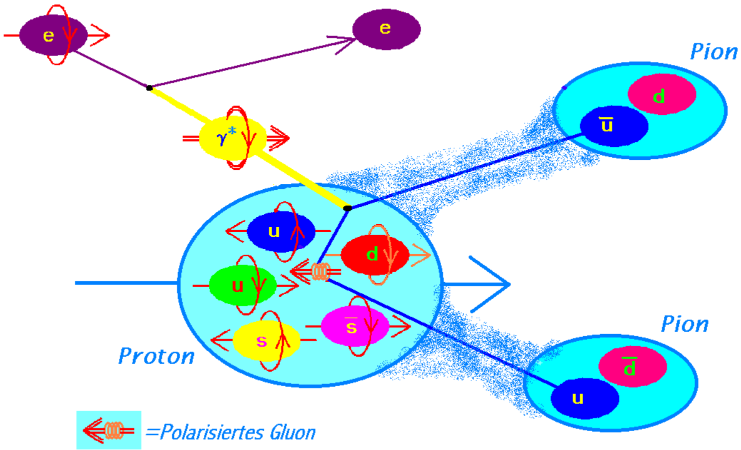


Based on HERMES data on tape

14 Gluon Polarization ΔG

Indirect Determination: Scaling violation of g1

Direct: Isolate the photon-gluon fusion process

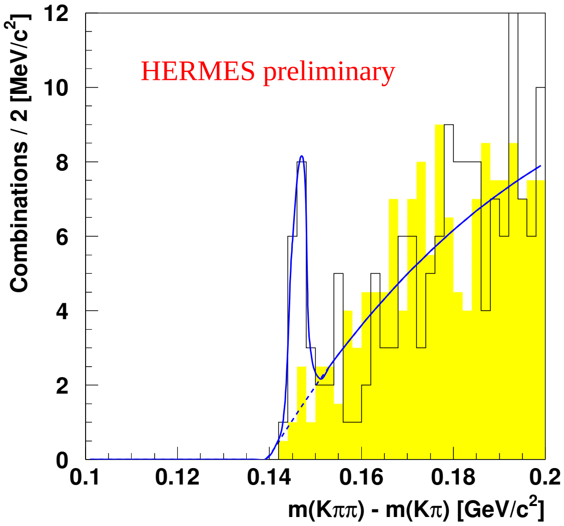


OPEN CHARM

reconstruct D^*, D^0

$$A_{||} = \frac{N_{c\bar{c}}^{\overrightarrow{\Leftarrow}} - N_{c\bar{c}}^{\overrightarrow{\Rightarrow}}}{N_{c\bar{c}}^{\overrightarrow{\Leftarrow}} + N_{c\bar{c}}^{\overrightarrow{\Rightarrow}}}$$

$$A^{\gamma p \to c\bar{c}} \sim \Delta G / G$$



$$D^* \to K + \pi + \pi_{slow}$$

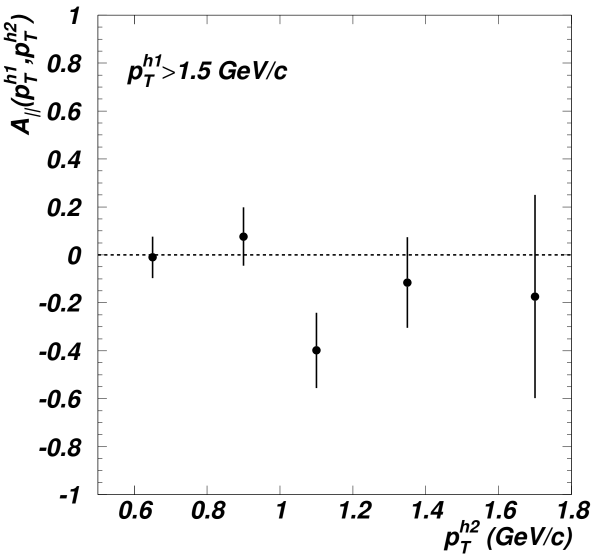
currently anal. RICH data

HIGH-P_T

pairs of high-P_T hadrons

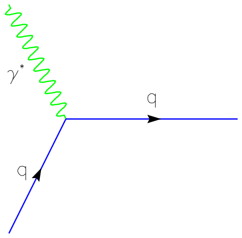
$$A_{||} = \frac{N_{h\pm}^{\overrightarrow{\Leftarrow}} - N_{h\pm}^{\overrightarrow{\Rightarrow}}}{N_{h\pm}^{\overrightarrow{\Leftarrow}} + N_{h\pm}^{\overrightarrow{\Rightarrow}}}$$

$$A^{\gamma p \to h^+ h^-} \sim \Delta G / G$$



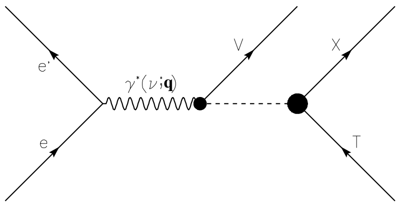
Interpretation

Assume four different processes may contribute (in LO QCD) to the high p_T h$^{\pm}$ pair production:



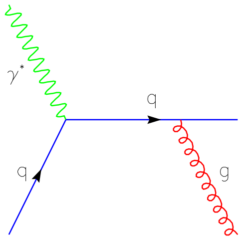
DIS

$$A_{DIS} \sim \frac{\Delta q}{q}$$



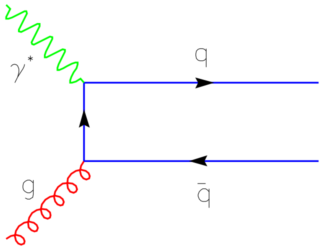
VMD

$$\mathbf{A}_{VMD} = \mathbf{0}$$



QCDC

$$A_{QCDC} \sim \frac{\Delta q}{q}$$

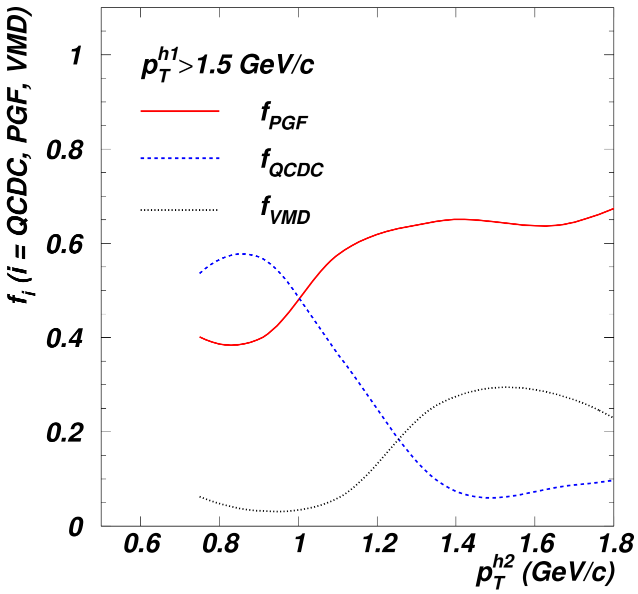


PGF

$$A_{PGF} \sim -1\frac{\Delta G}{G}$$

.. estimate their relative contributions using PYTHIA

$\rightarrow \Delta G/G$

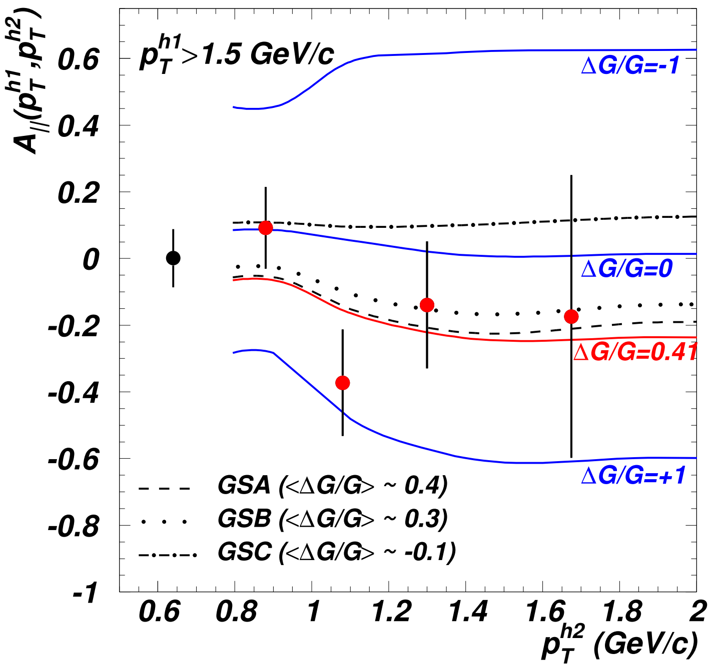


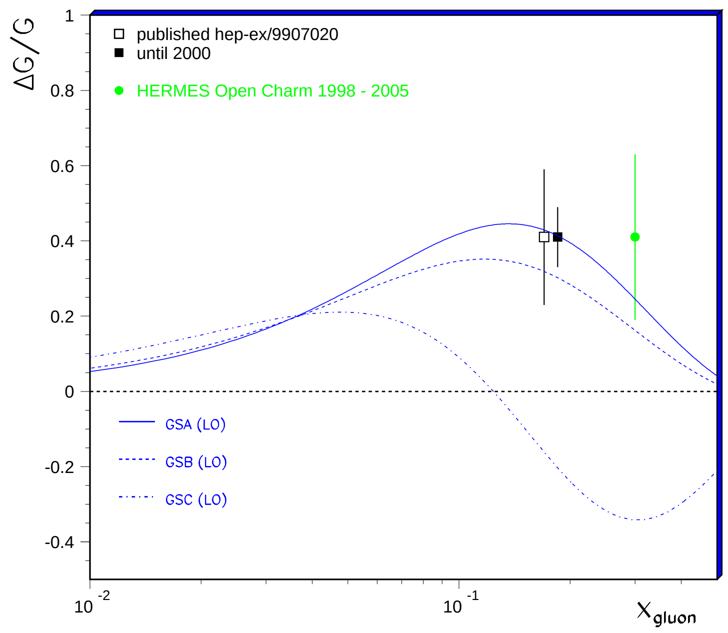
Result Using PYTHIA Model

$\Delta G/G$ is positive

$$\Delta G/G = 0.41 \pm 0.18\ \text{(stat.)} \pm 0.03\ \text{(exp.syst.)}$$

$$\textbf{at } \langle x_G \rangle = 0.17 \textbf{ and } \langle \hat{p}_T^2 \rangle = 2.1\ \textbf{GeV}^2$$



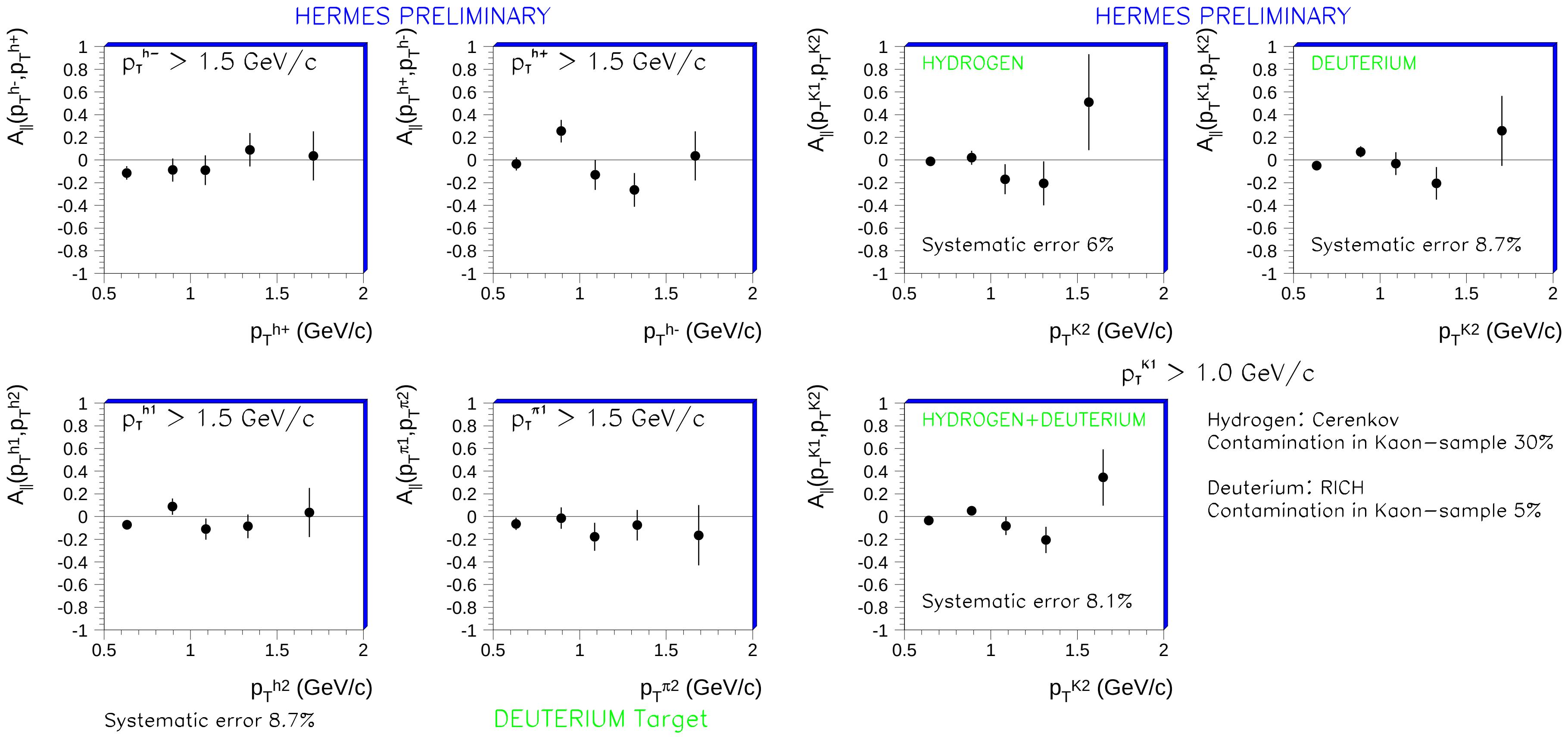


2 x smaller errors with 1998-2000 data

Extraction strongly Model dependent

15 Results with a Deuterium target

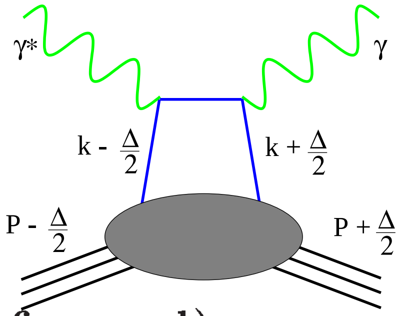
Included statistics corresponds to 8.9 $*10^6$ DIS (1998 - 2000)



$\Delta G/G$ Extraction still under way

16 Skewed Parton Distributions

Analysis of hard exclusive processes leads to a new class of parton distributions: $H, \tilde{H}, E, \tilde{E}$



On the light cone:

$t = \Delta^2$ $\quad\quad \Delta \neq 0 \rightarrow$ **correlations**

$x = k^+/P^+$ $\quad\quad \xi = -\Delta^+/2P^+$

ξ **skewness parameter (how far off-forward)**

ξ **the longitudinal fraction of momentum transfer**

$\mathrm{H}(x, \xi, t)$ – **helicity avg, no spin flip** $\quad\quad \mathrm{E}(x, \xi, t)$ – **helicity avg, spin flip**

$\tilde{\mathrm{H}}(x, \xi, t)$ – **helicity diff, no spin flip** $\quad\quad \tilde{\mathrm{E}}(x, \xi, t)$ – **helicity diff, spin flip**

Connection with DIS q - distribution functions:

$q(x) = H^q(x, \xi = 0, t = 0), \qquad \Delta q(x) = \tilde{H}^q(x, \xi = 0, t = 0)$

In the Bjorken limit: 2$\xi \rightarrow x_{Bj}/(1 - x_{Bj}/2)$

Connection with elastic form factors: first moments

$F_1^q(t) = \int_{-1}^{1} dx H_q(x, \xi, t) \qquad F_2^q(t) = \int_{-1}^{1} dx E_q(x, \xi, t)$

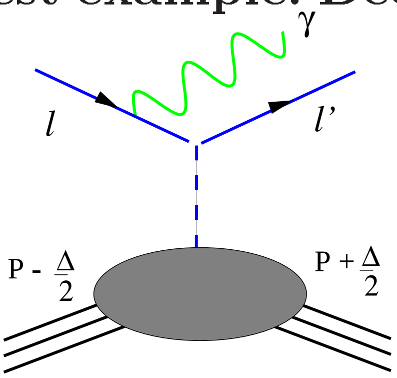
$G_A^q(t) = \int_{-1}^{1} dx \tilde{H}_q(x, \xi, t) \qquad G_P^q(t) = \int_{-1}^{1} dx \tilde{E}_q(x, \xi, t)$

Connection with quark angular momentum: second moments

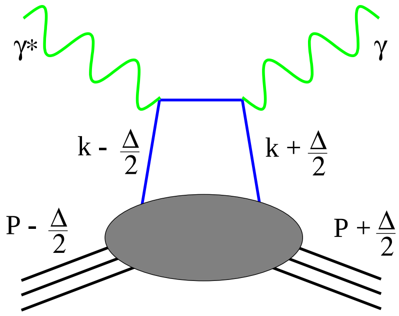
$$J^q = \frac{1}{2}\Delta\Sigma + L^q = \frac{1}{2}\int_{-1}^{1} x\ dx\ [H^q(x, \xi, t = 0) + E^q(x, \xi, t = 0)]$$

17 DVCS

Simplest example: Deeply Virtual Compton scattering



Bethe-Heitler



DVCS

Cross Section:

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

Isolate BH-DVCS interference term

$$\tau^*_{BH}\tau_{DVCS} + \tau^*_{DVCS}\tau_{BH} =$$

$$\frac{e^6}{t}\frac{m}{Q} \cdot \frac{4\sqrt{2}}{x} \cdot \frac{1}{\sqrt{1-x}} \quad e_l P_l[-sin(\phi)\sqrt{\frac{1+\epsilon}{\epsilon}} Im\tilde{M}^{1,1}]$$

e_l **lepton charge and** P_l **Polarization**

$$Im\tilde{M}^{1,1} = Im\{F_1\mathcal{H}_1 + \frac{x}{2-x}(F_1+F_2)\tilde{\mathcal{H}}_1 - \frac{\Delta^2}{4M^2}F_2\mathcal{E}_1\}$$

Link to SPDs:

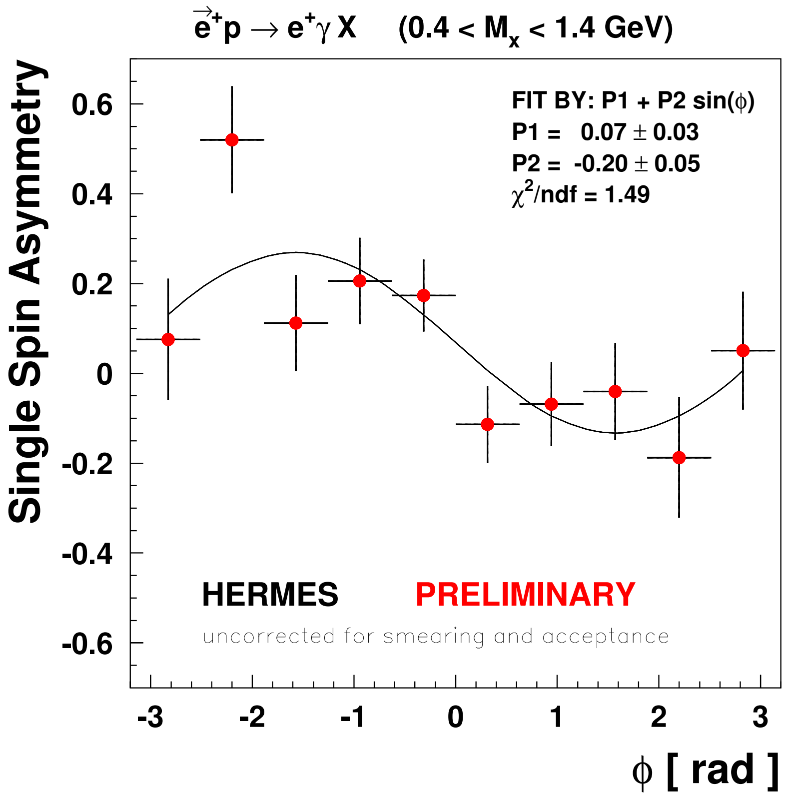
$$Im\mathcal{H}_1 = -\pi\sum_q e_q^2(H(\xi,\xi,\Delta^2) - H(-\xi,\xi,\Delta^2))$$

$$Re\mathcal{H}_1 = \sum_q e_q^2[P\int_{-1}^{+1}(H(x,\xi,\Delta^2)(\frac{1}{x-\xi}+\frac{1}{x+\xi})dx]$$

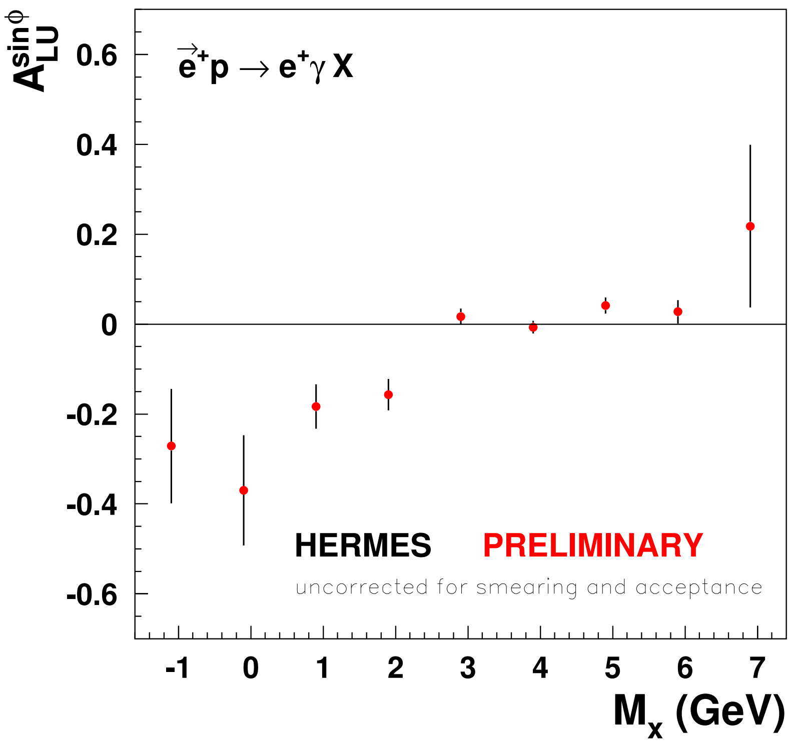
P: denotes Cauchy's principal value

Analogous expressions for $\tilde{\mathcal{H}_1}, \mathcal{E}, \tilde{\mathcal{E}_1}$ amplitudes

ϕ Dependence of SSA



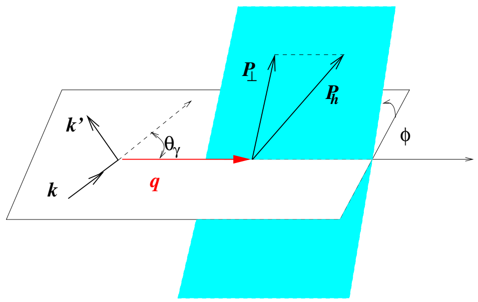
Single Spin Asymmetry



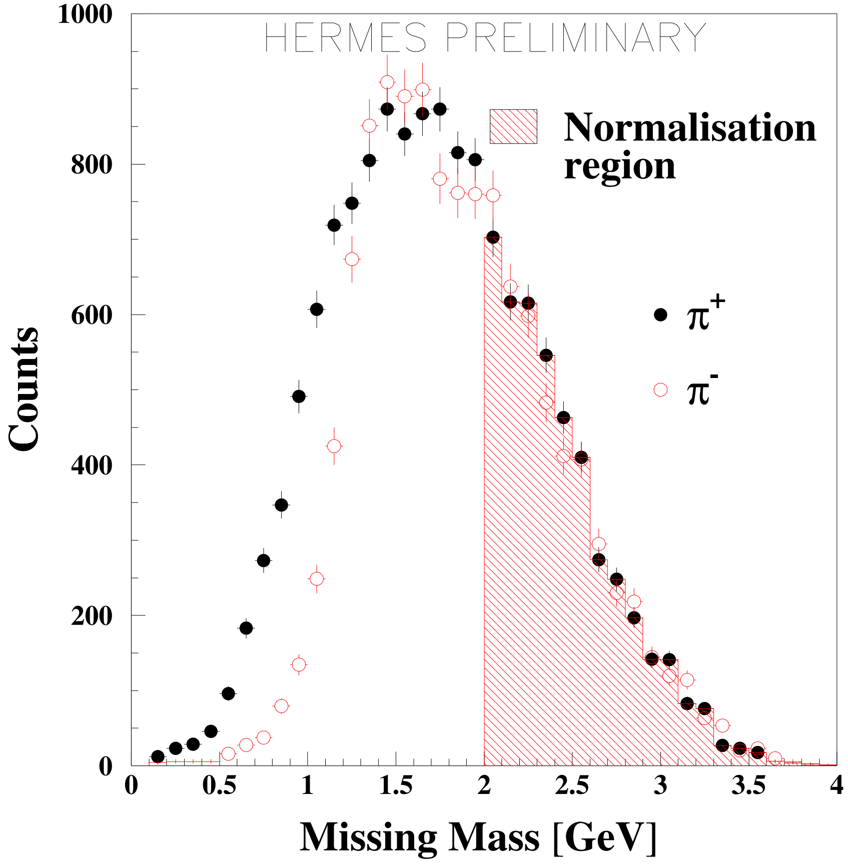
$$A_{LU} = \frac{1}{<|P_l|>} \cdot \frac{(N^+(\phi) - N^-(\phi))}{(N^+(\phi) + N^-(\phi))}$$

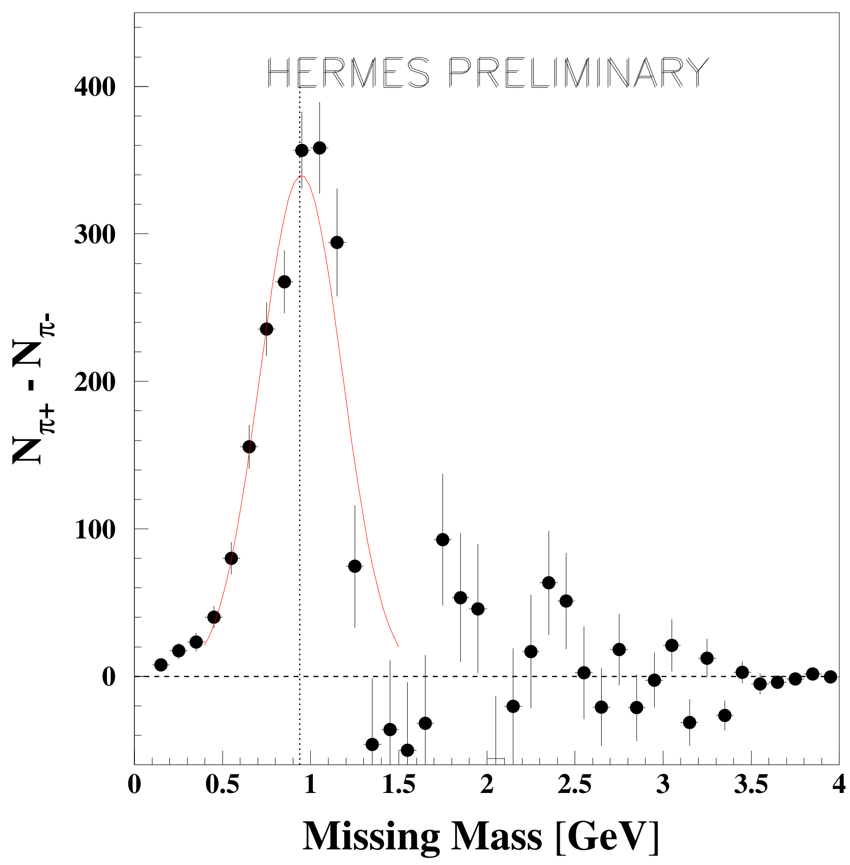
$$A_{LU}^{sin\phi} = \frac{2}{N} \sum_{i=1}^{N} \frac{sin(\phi_i)}{(P_l)_i}$$

1996 - 1997 Hydrogen data
with different beam helicities



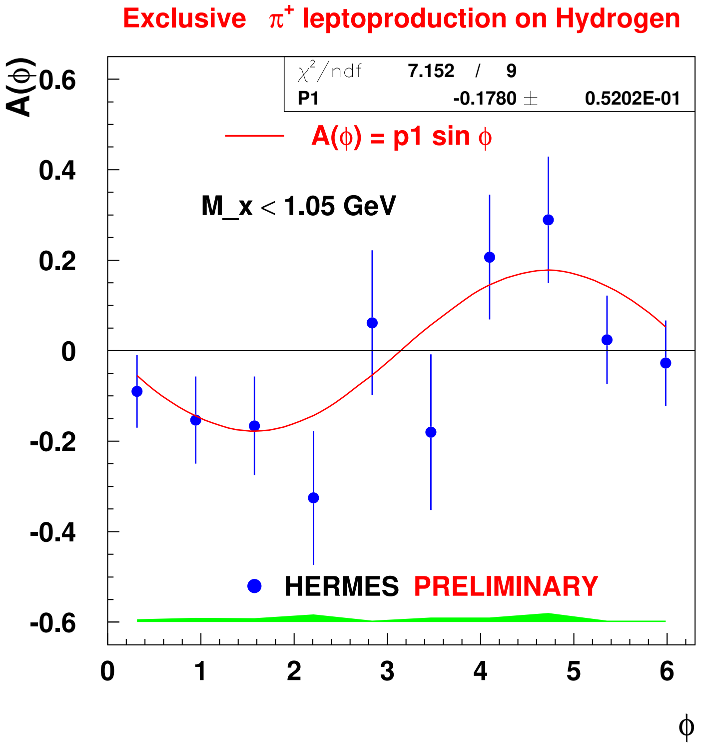
18 Exclusive Pion Production ep $\longrightarrow$ e'π^+n

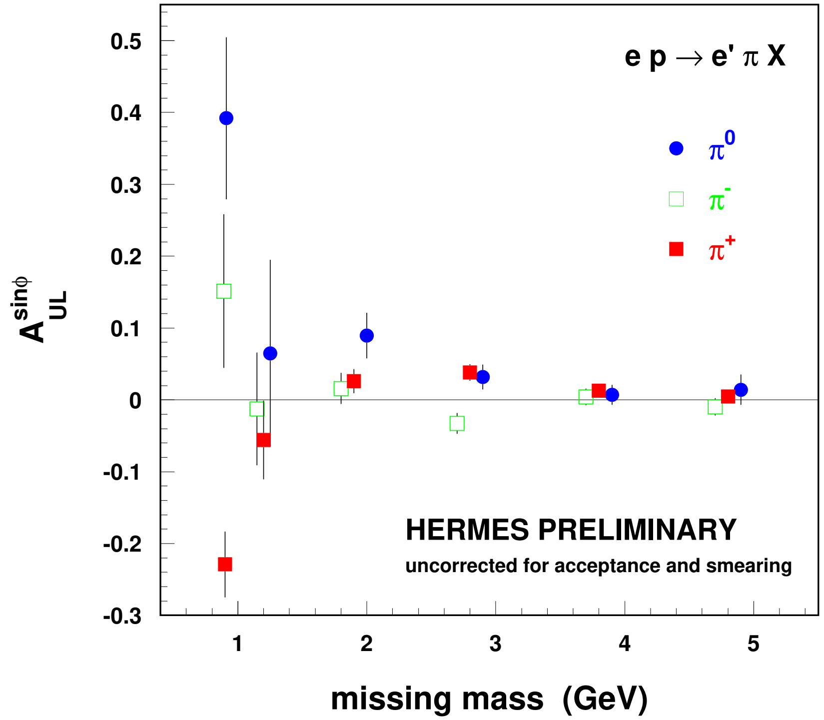


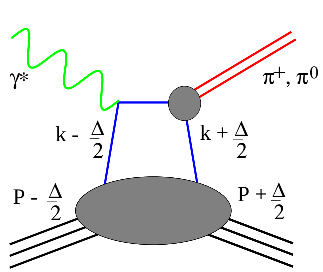


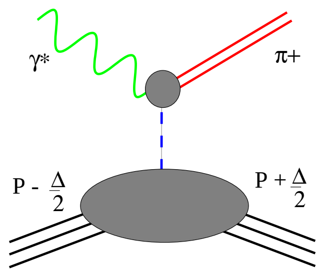
used data-set: 1996 - 1997 polarized Hydrogen data

SSA in 'exclusive' π Production









Theor. Predictions only for transversely polarized target

$A_{UL}^{\sin\Phi} \sim [P_\perp \sigma_L + P_\| \sigma_{LT}]$

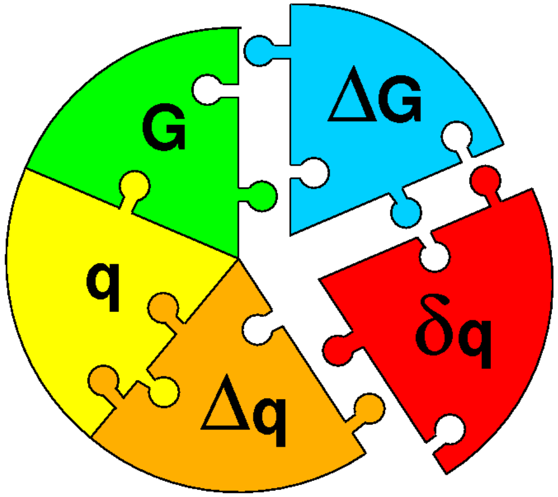
$P_\perp \sim 0.17$ **for HERMES**

OUTLOOK

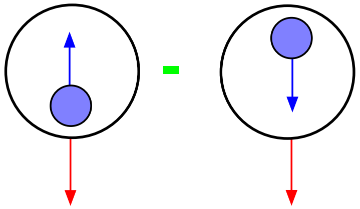
HERMES

in the new Millennium

2001 - 2006



Transversity 2001 - 2003

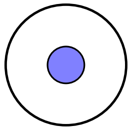
$\mathbf{h_1}$=


Unknown

tensor charges

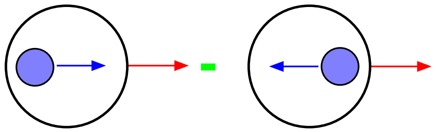
$\int_0^1 dx(\delta q_f(x,Q^2) - \delta\bar{q}_f(x,Q^2))$

$\delta\Sigma = \sum_f \int_0^1 dx(\delta q_f(x,Q^2) - \delta\bar{q}_f(x,Q^2))$

$\mathbf{f_1}$=


flavor charges

$\int_0^1 dx(q_f(x,Q^2) - \bar{q}_f(x,Q^2))$

$\mathbf{g_{1L}}$=


axial charges

$\int_0^1 dx(\Delta q_f(x,Q^2) + \Delta\bar{q}_f(x,Q^2))$

$\Delta\Sigma = \sum_f \int_0^1 dx(\Delta q_f(x,Q^2) + \Delta\bar{q}_f(x,Q^2))$

Features of $h_1(x)$:

- **in the absence of relativistic effects**

$$\delta q(x) = \Delta q(x)$$

- **unlike for g_1, the gluon polarization does not mix with quark polarization in h_1**
  $\rightarrow$ different Q^2 evolution
  $\rightarrow$ h_1 predominantly sensitive to valence quark polarization
  $\rightarrow$ possible comparison with lattice QCD
  $\delta\Sigma = 0.562 \pm 0.088$ **at** $Q^2 = 2GeV^2$

- **$h_1(x)$ is a chiral-odd distribution function, related to the spin flip of transversely polarized quarks**
  $\rightarrow$ $h_1(x)$ is inaccessible in inclusive DIS
  but can be probed via processes involving two chiral-odd objects

Measurement via the Collins effect:

unpolarized beam and a transversely polarized hydrogen target

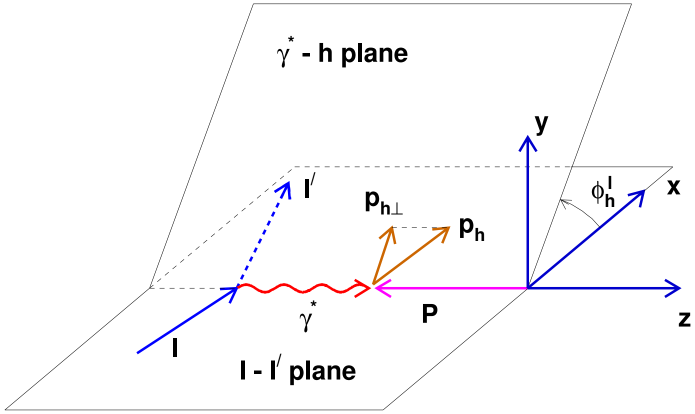
Weighted asymmetry [Mulders, Tangermann 96, Kotzinian, Mulders 97]

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

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.**



Assume:

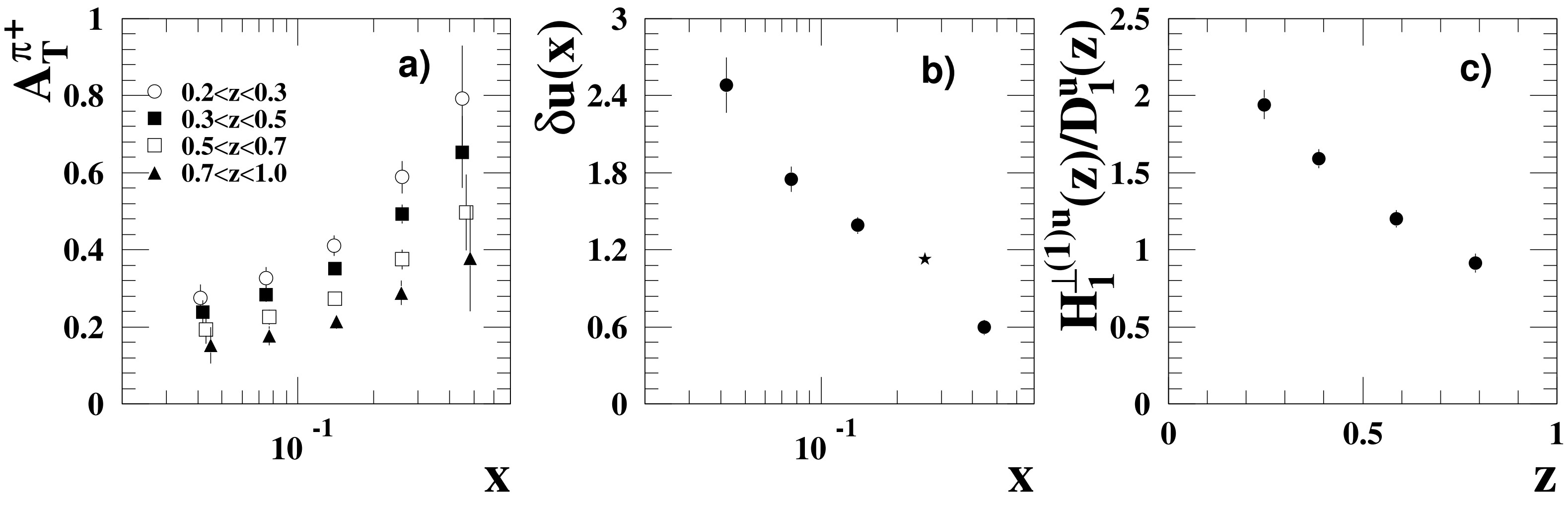
- u**-quark dominance**
- **Normalization:**

$\delta q(x_0) = \Delta q(x_0)$ **with** $x_0 = 0.25$

Predictions for HERMES:

$$A_p^{\pi^+}(x,y,z) = P_T \cdot D_{nn} \cdot \frac{\delta u(x)}{u(x)} \cdot \frac{H_1^{\perp(1)}(z)}{D_1(z)}$$

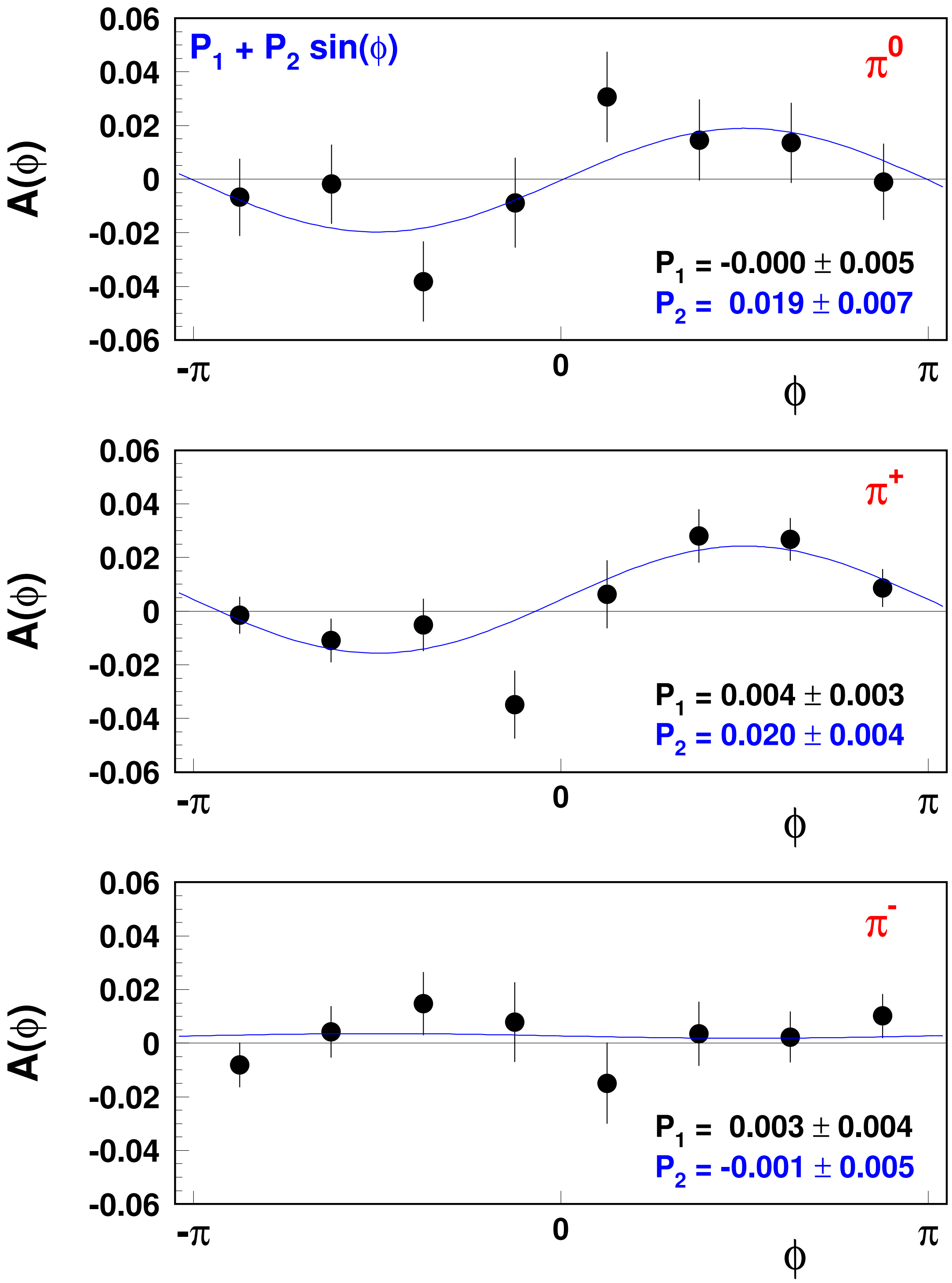
7 Million DIS collected with a transverse polarized proton target:



What do we already know (I)

$$A(\phi)_{UL} = \frac{1}{<|P_t|>} \cdot \frac{(N^{+}(\phi) - N^{-}(\phi))}{(N^{+}(\phi) + N^{-}(\phi))}$$

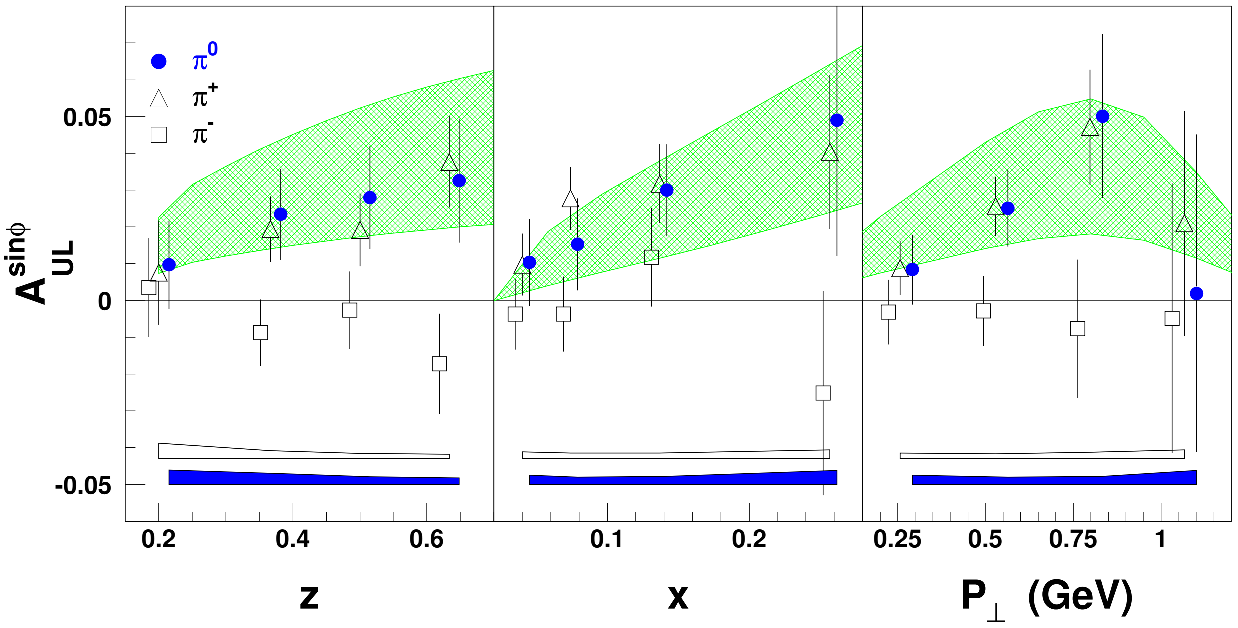
+ and - note target polarization direction



What do we already know (II)

$$A_{UL}^{sin\phi} = \frac{\frac{L^+}{L_p^+}\sum_{i=1}^{N^+} sin\phi^+ - \frac{L^-}{L_p^-}\sum_{i=1}^{N^-} sin\phi^-}{\frac{1}{2}(N^+ + N^-)}$$

+ and - note target polarization direction



$$< \frac{P_T}{zM_h} sin\phi >_{UL} \quad \sim \quad S_L \sum_{f,\bar{f}} e_f^2 x h_L^f(x) H_1^{\perp f}(z) + S_T \sum_{f,\bar{f}} e_f^2 x h_1^f(x) H_1^{\perp f}(z)$$

until now longitudinal polarized target: $S_T << S_L$

$S_T \sim sin\theta_\gamma \sim 20\%$

$$h_L(x) = h_1(x) - \frac{d}{dx} h_{1L}^{\perp(1)}(x)$$

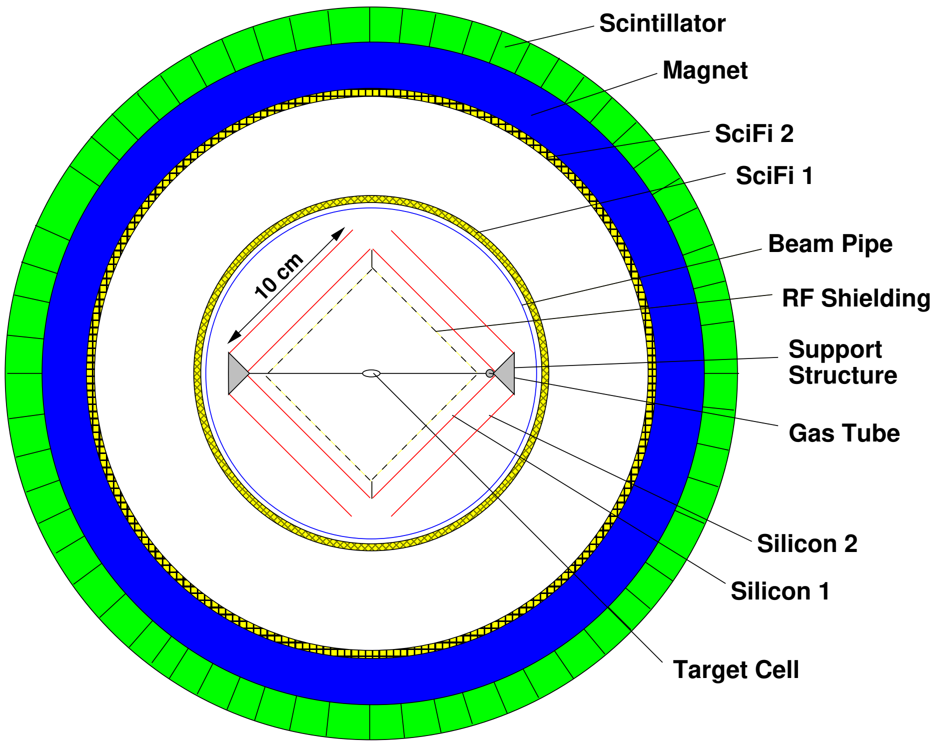
time-odd Collins spin dependent fragmentation function $H_1^{\perp u}(z) > 0$

h_1 can be measured

Exclusive Reactions 2004 - 2006

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

$\Longrightarrow$ Recoil Detector

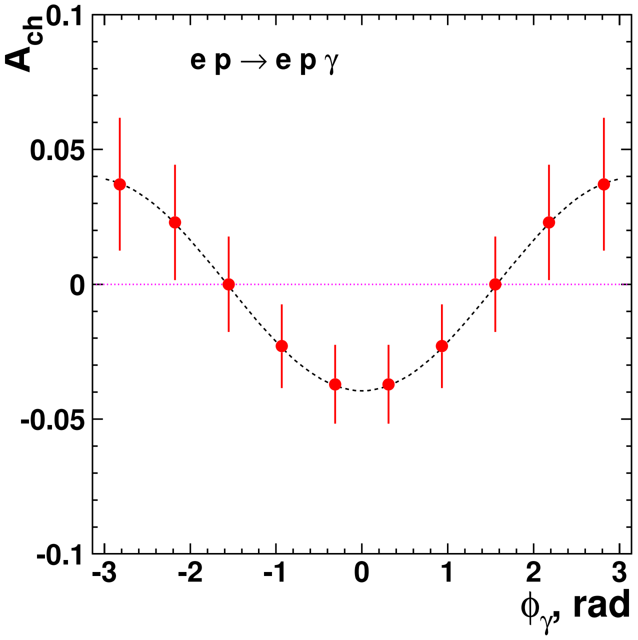


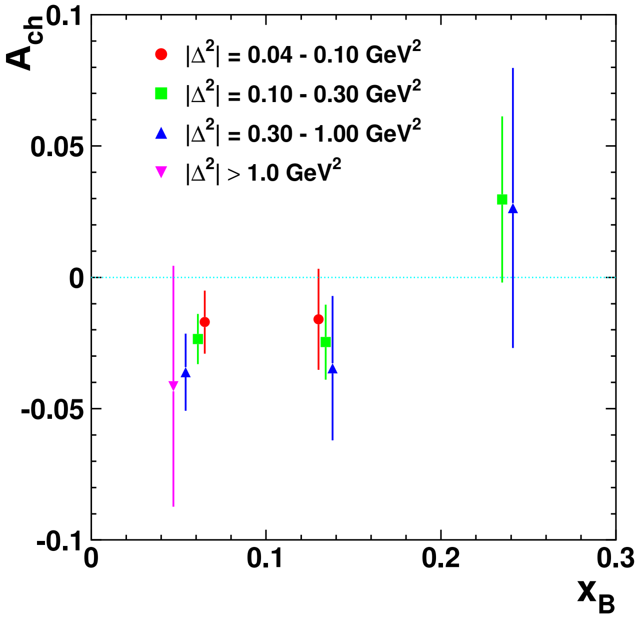
Schematic Cross Section

Predictions for Exclusive Reactions

Measure Lepton Charge Asymmetry in DVCS

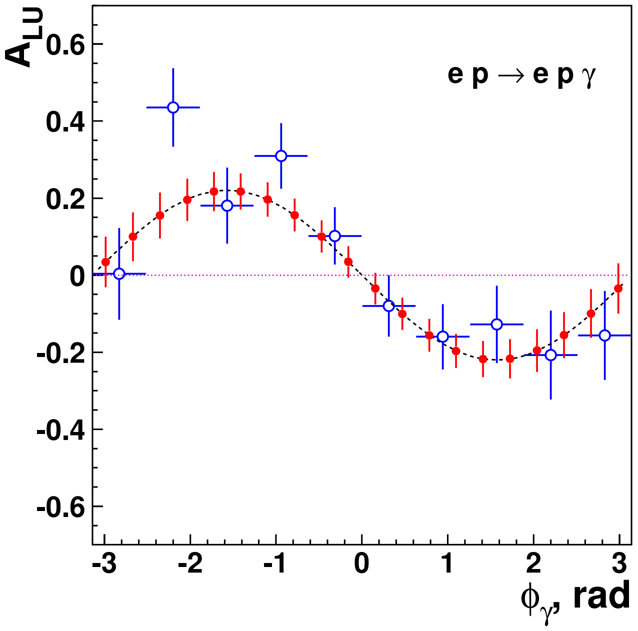
unpolarized beam, unpolarized target

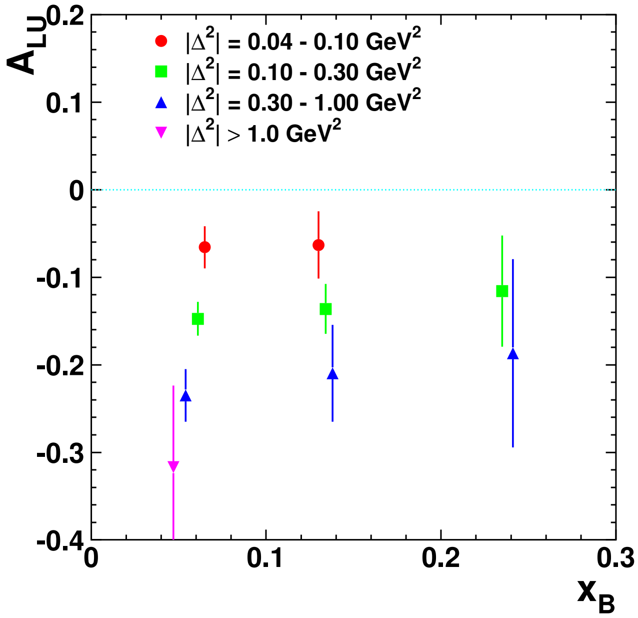




Measure Lepton Helicity Asymmetry in DVCS

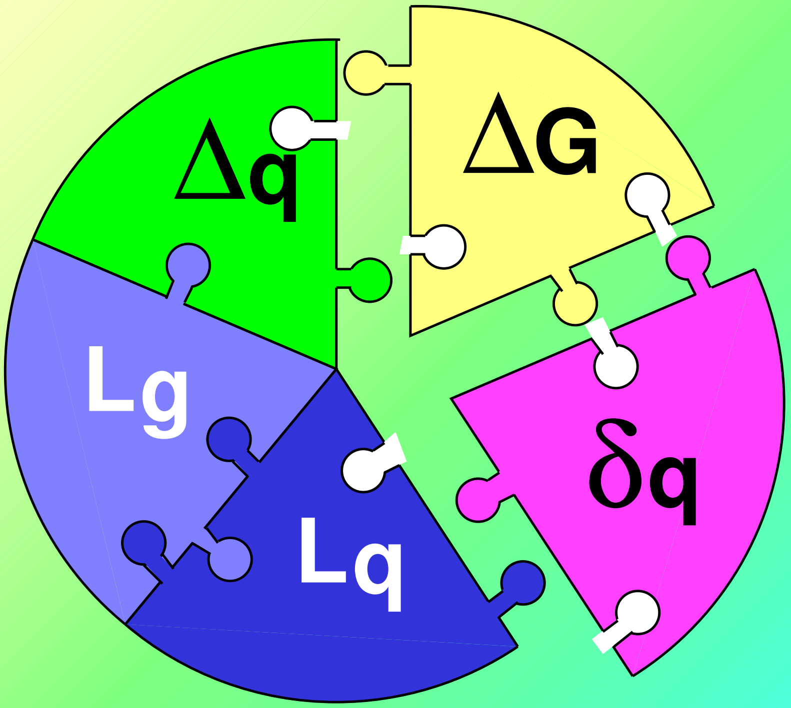
polarized beam, unpolarized target





open Circles: DVCS-data Hermes Preliminary

2006:
The Spin Puzzle



becomes hopefully solvable