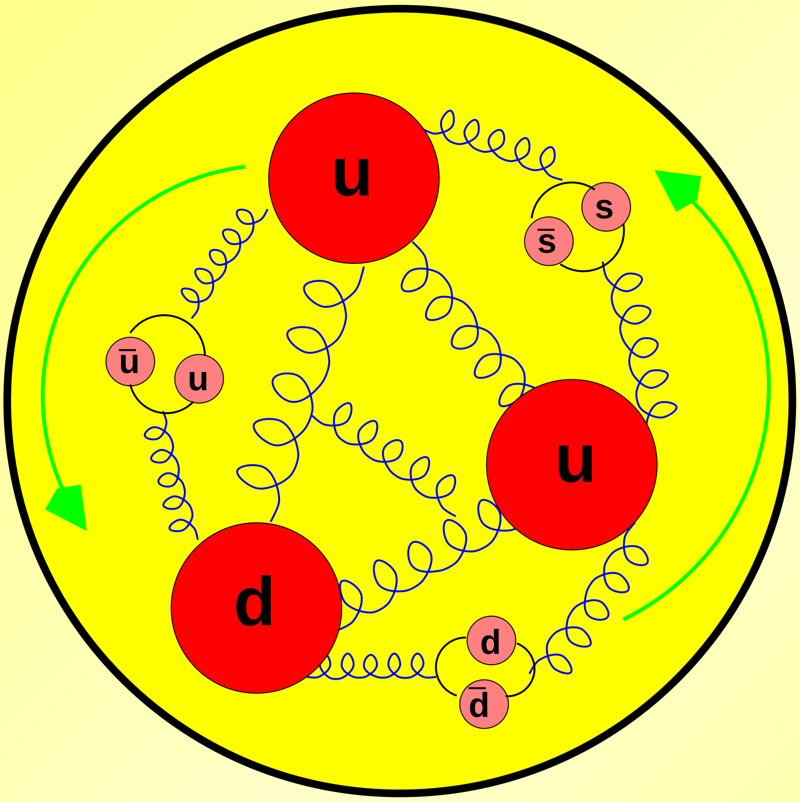
1 Contributions to the Nucleon Spin



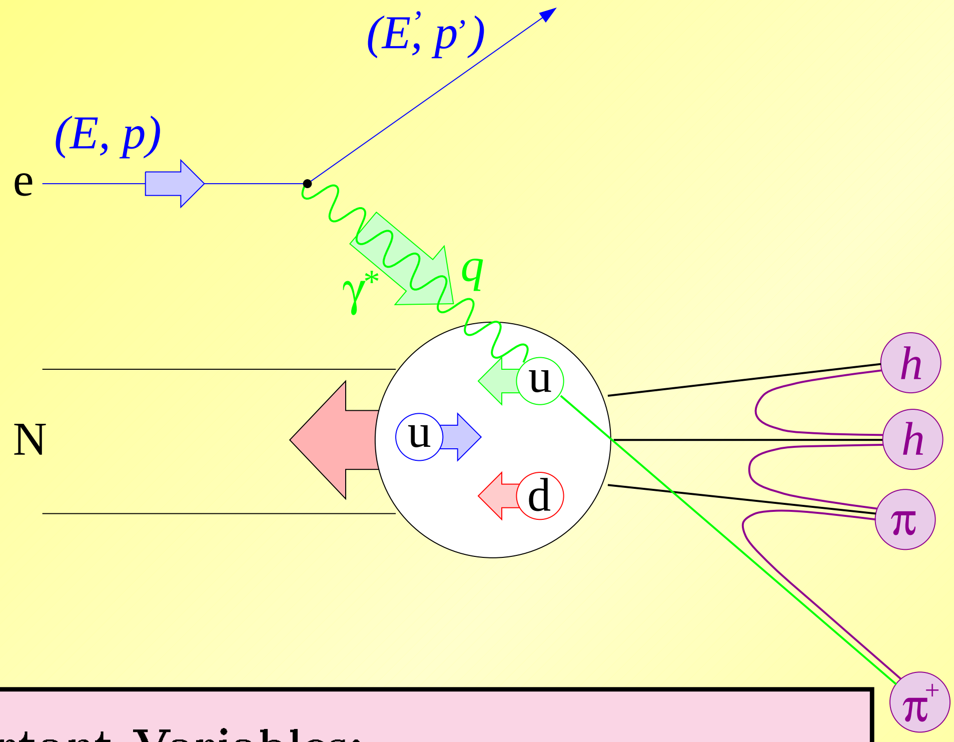
$$\frac{1}{2} = \frac{1}{2}\Sigma + \Delta G + \Delta L_{q/g}$$

$\Delta u + \Delta d + \Delta s$ PGF ?

ΔV ΔS

inclusive semi-inclusive

2 Polarized Deep Inelastic Scattering



Important Variables:

$$Q^2 \overset{lab}{=} 4EE' \sin^2(\tfrac{\theta}{2})$$

$$\nu \overset{lab}{=} E - E'$$

$$x \overset{lab}{=} \frac{Q^2}{2m\nu}$$

$$y \overset{lab}{=} \frac{\nu}{E} = \frac{p\cdot q}{p\cdot k}$$

$$z \overset{lab}{=} \frac{E_h}{\nu}$$

	inclusive	semi-inclusive
detect :	e′	e′ + h

Cross Section:

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

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

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

$$\begin{aligned} W_{\mu\nu} = & -g_{\mu\nu} F_1\left(x, Q^2\right) \\ & + \frac{p_\mu p_\nu}{\nu} F_2\left(x, Q^2\right) \\ & + \frac{i}{\nu}\epsilon_{\mu\nu\alpha\beta} q^\lambda S^\sigma g_1\left(x, Q^2\right) \\ & + \frac{i}{\nu^2}\epsilon_{\mu\nu\alpha\beta} q^\lambda (p \cdot q S^\sigma - s \cdot q p^\sigma)\, g_2\left(x, Q^2\right) \end{aligned}$$

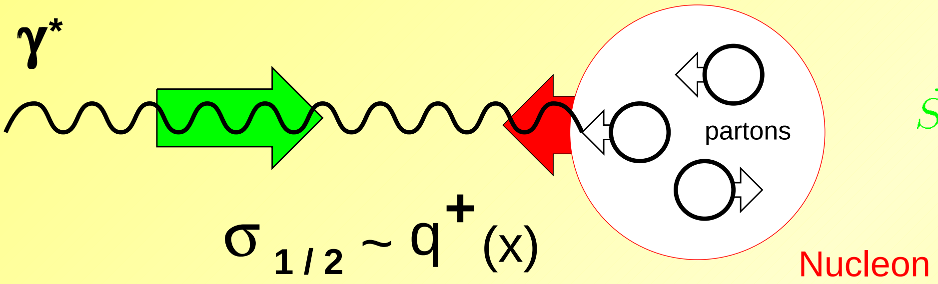
F_1,F_2 $\Longrightarrow$ **Unpolarized Structure Functions**

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

What is measured

3 Virtual Photon Asymmetry

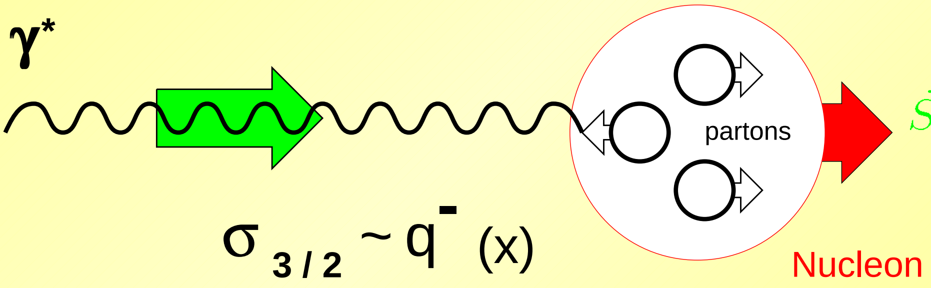
polarized Photon (Spin 1) can only probe quarks with spin opposite to its own:



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

$\sigma_{1/2} \sim q^+(x)$

$+$ means: quark spin parallel to Nucleon spin



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

$\sigma_{3/2} \sim q^-(x)$

$-$ means: quark spin opposite to Nucleon spin

$\Rightarrow$ flipping spin of target $\Rightarrow$ **Quark Spin Distributions:**

$$\boxed{\Delta q_f(x) := q_f^+(x) - q_f^-(x)}$$

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

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

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

Measurable Asymmetries:

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

The relation between the asymmetries is:

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

Where:

$$D = \frac{y(2-y)}{y^2 + 2(1-y)(1+R)} \qquad d = D\sqrt{\frac{2\epsilon}{1+\epsilon}}$$

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

D,d: virtual photon depolarization factor

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

ϵ: transverse pol. of the virtual photon

Quark Parton Model

In the infinite momentum frame:

$$
\begin{aligned}
F_1(x) &= \tfrac{1}{2}\sum_i e_i^2(q_i^{\uparrow}(x) + q_i^{\downarrow}(x)) \\
&= \tfrac{1}{2}\sum_i e^2 q_i(x)
\end{aligned}
$$

$2xF_1$ measures the momentum distribution of the quarks

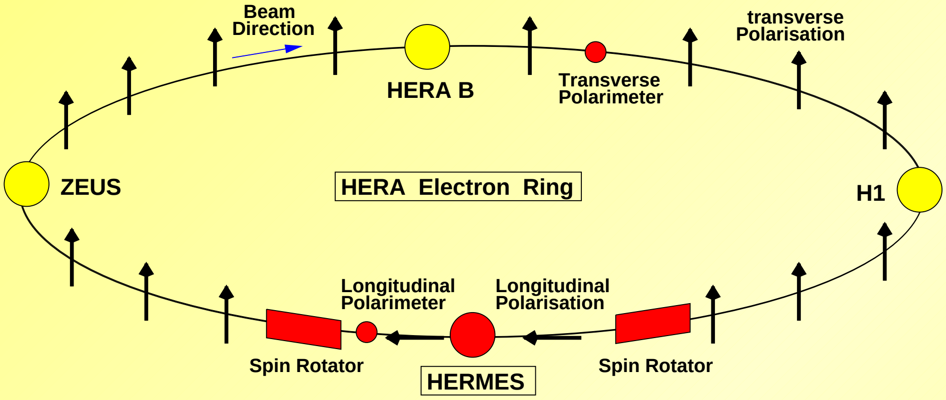
$$
\begin{aligned}
g_1(x) &= \tfrac{1}{2}\sum_i e_i^2(q_i^{\uparrow}(x) - q_i^{\downarrow}(x)) \\
&= \tfrac{1}{2}\sum_i e^2 \Delta q_i(x)
\end{aligned}
$$

g_1 measures the longitudinal spin distribution of the quarks

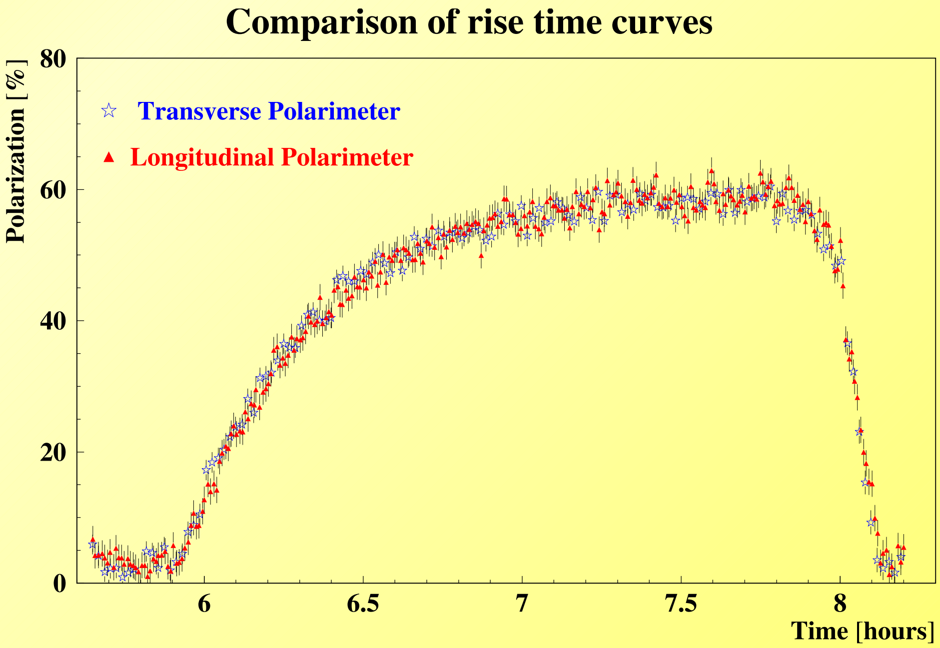
$$Neglecting : g_2 \Longrightarrow g_1(x) \approx \frac{F_1(x)}{D} A_{\parallel}$$

$$A_1 = \frac{\sigma_{1/2}-\sigma_{3/2}}{\sigma_{1/2}+\sigma_{3/2}} \simeq \frac{g_1}{F_1} = \frac{\sum_f e_f^2\, \Delta q_f(x,Q^2)}{\sum_f e_f^2\, q_f(x,Q^2)}$$

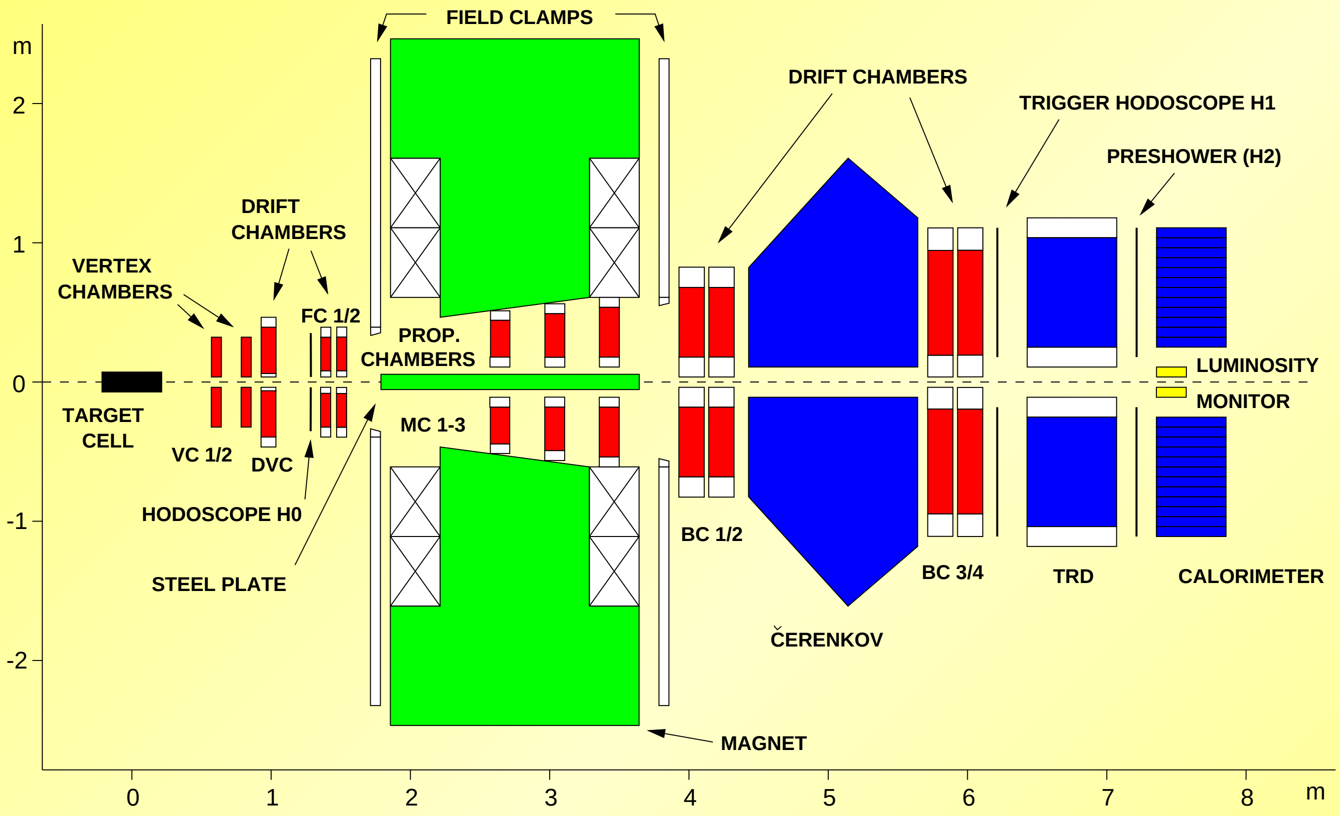
4 The Polarized Positron Beam at HERA



- **Self-polarization by emission of synchrotron radiation,** $P_b(t) = p_b^{max}[1 - exp(t/\tau)]$
- **Spin rotators $\rightarrow$ longitudinal polarization at HERMES IP**
- **2 Polarimeters**
- **average beam polarization** $\langle P_b \rangle \approx$ **55%**



5 The HERMES Experiment



- **Kinematic Range:**

  $0.02 \le x \le 0.8$ at $Q^2 \ge 1\text{GeV}^2$ and $W \ge 2\text{GeV}$

- **Reconstruction:**

  $\delta p/p$ 0.7 - 1.3%, $\delta\Theta \le 0.6$mrad

- **Particle ID:**

  Threshold Čerenkov (since 1998 RICH), TRD, Preshower, Calorimeter

  lepton identification efficiency ∼98%

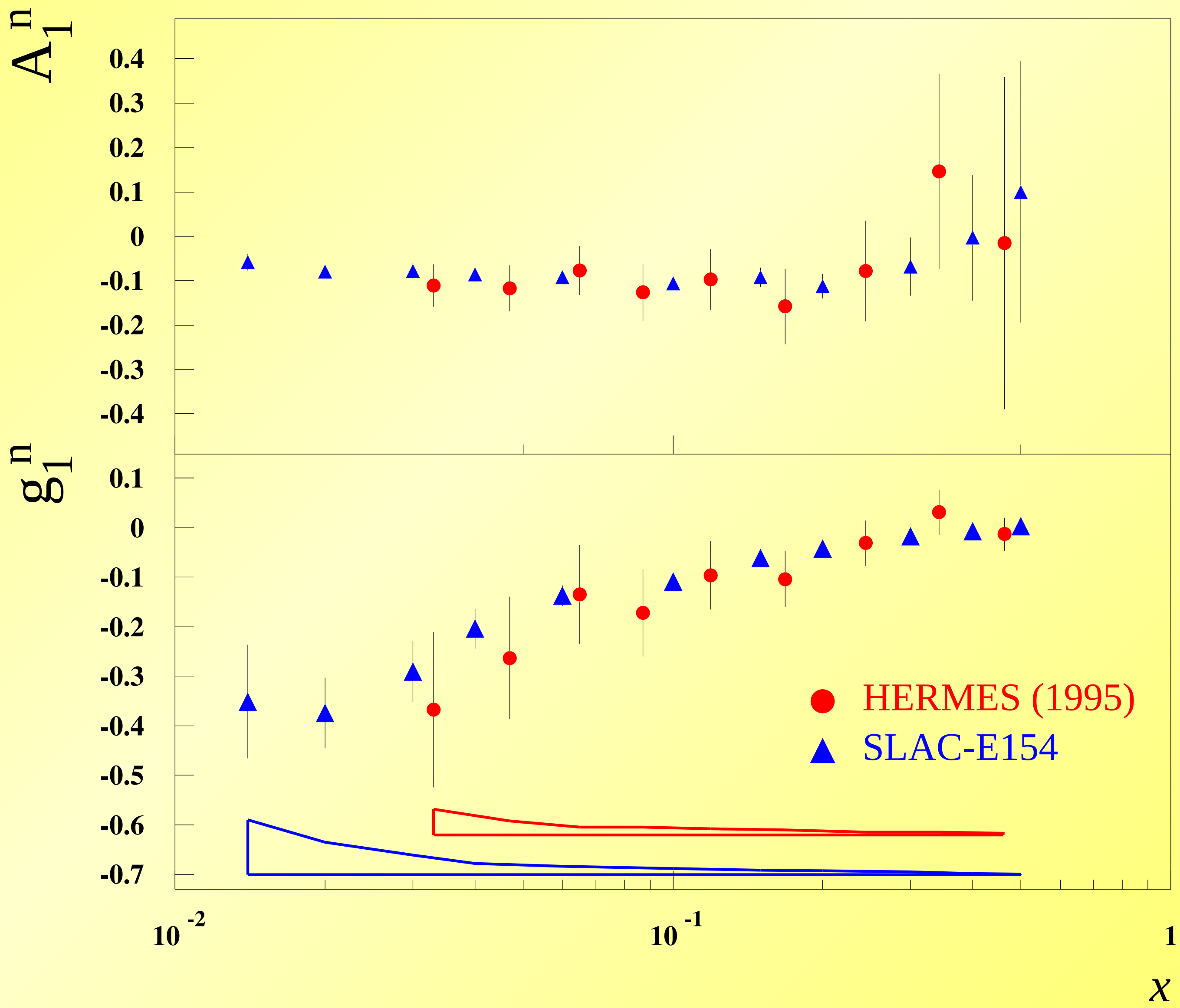
  hadron contamination of $\le 1\%$

6 Inclusive Results

Neutron Spin Structure Function $g_1^n(x)$

- from $^3\overrightarrow{\mathrm{He}}$ (SLAC E142/E154, DESY HERMES)

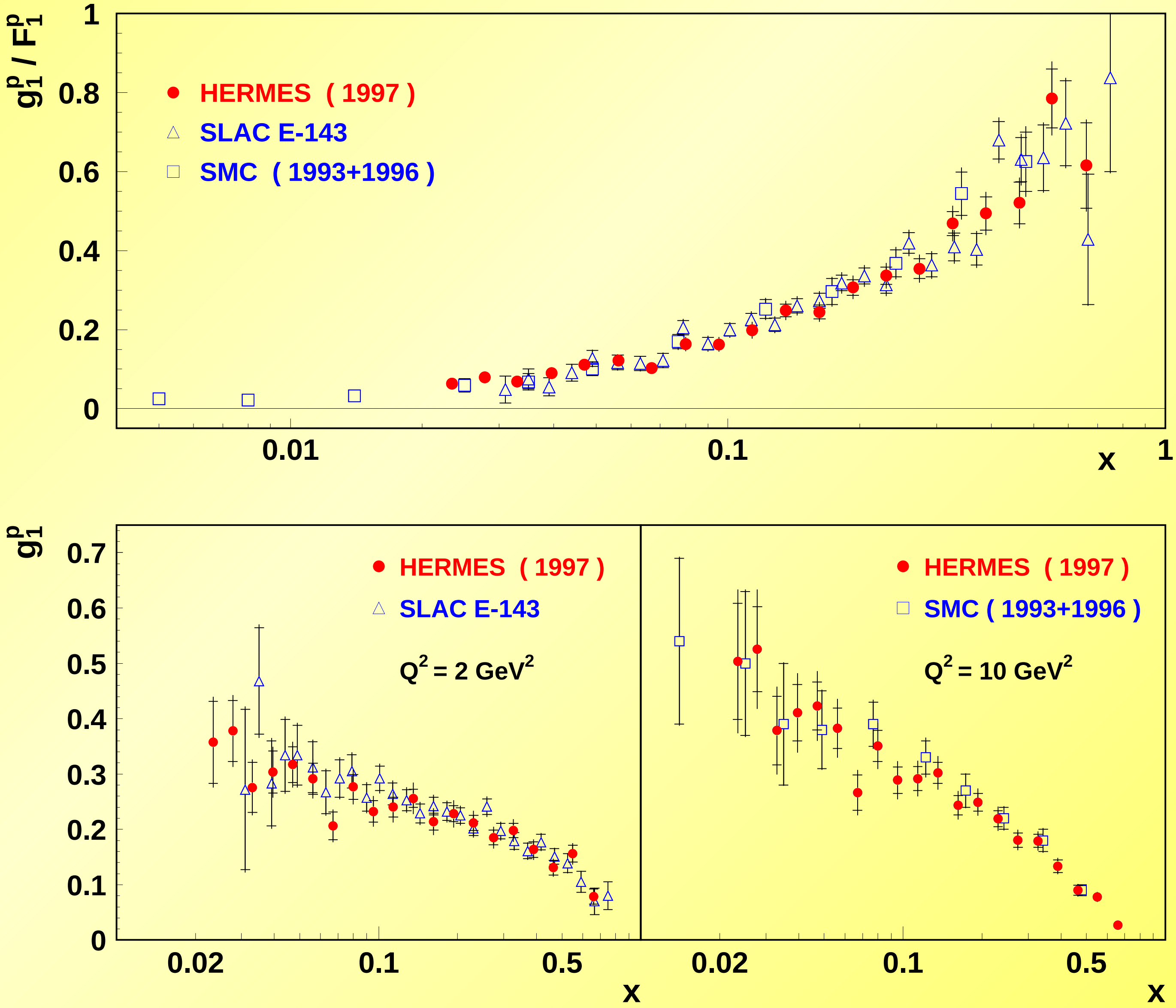
$$A_1^{^3\mathrm{He}} \longrightarrow A_1^{\mathrm{n}} \longrightarrow g_1^{\mathrm{n}} \simeq A_1^{\mathrm{n}} \cdot F_1^{\mathrm{n}} = A_1^{\mathrm{n}} \cdot \frac{F_2^{\mathrm{n}}}{2x(1+R)}$$



- from "$\overrightarrow{\mathrm{D}}$-$\overrightarrow{\mathrm{H}}$" data (SLAC E143, CERN SMC)

Proton Spin Structure Function $g_1^p(x)$

$$A_1 \simeq g_1/F_1$$



7 Bjorken Sum Rule

$$
\begin{aligned}
g_1(x) &= \tfrac{1}{2}\sum_i e^2 \Delta q_i(x) \\
\int g_1^p(x) &= \tfrac{1}{2}\left(\tfrac{4}{9}\Delta u + \tfrac{1}{9}\Delta d + \tfrac{1}{9}\Delta s\right) \\
\int g_1^n(x) &= \tfrac{1}{2}\left(\tfrac{1}{9}\Delta u + \tfrac{4}{9}\Delta d + \tfrac{1}{9}\Delta s\right)
\end{aligned}
$$

Δu, Δd and Δs polarized quark distribution functions

$$
\begin{aligned}
\int (g_1^p(x) - g_1^n(x)) &= \tfrac{1}{2}\left(\tfrac{1}{3}\Delta u - \tfrac{1}{3}\Delta d\right) = \tfrac{1}{6}(\Delta u - \Delta d) \\
\Delta u - \Delta d &= \tfrac{g_A}{g_V} \qquad (neutron - beta - decay)
\end{aligned}
$$

Bjorken Sum Rule

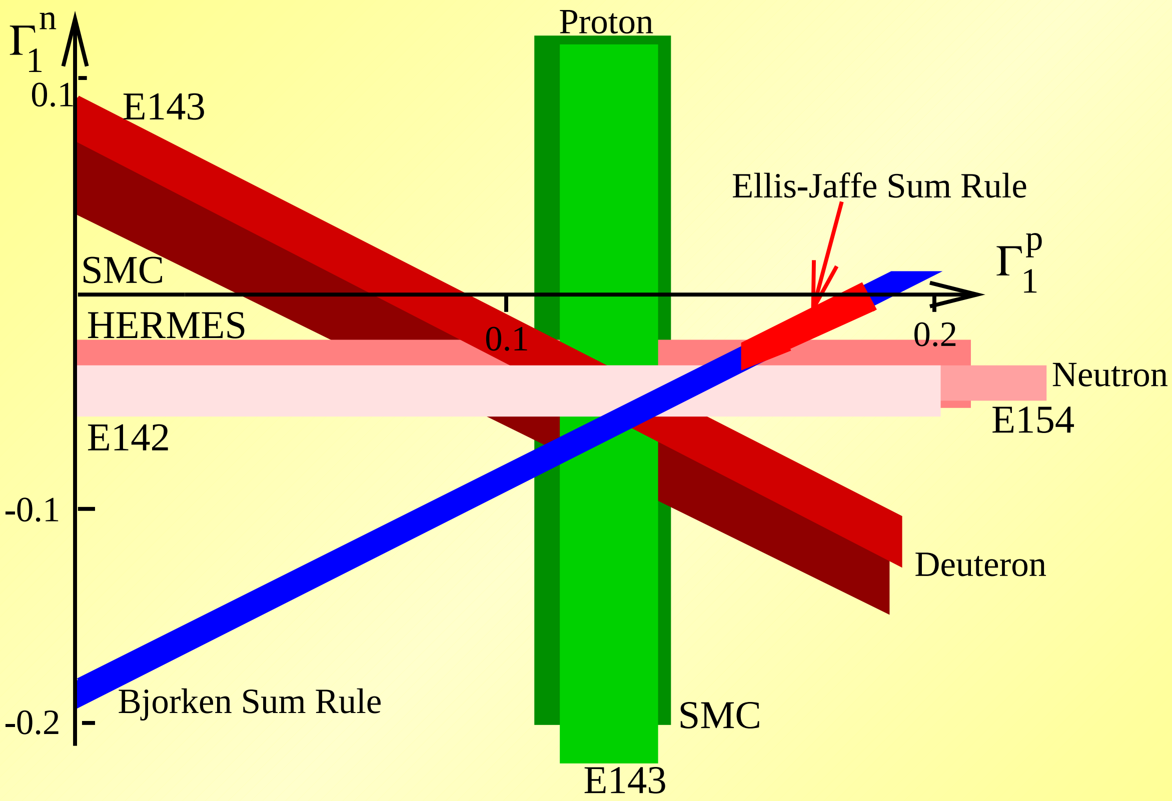
$$
\int (g_1^p(x) - g_1^n(x))dx = \tfrac{1}{6}\tfrac{g_A}{g_V} \cdot Corr(QCD)
$$

Corrections known to 4th order!

8 Bjorken Sum Rule

$$\int (g_1^p(x) - g_1^n(x))dx = \frac{1}{6}\frac{g_A}{g_V} \cdot Corr(QCD)$$

Corrections known to 4th order!



$$\Gamma_1^p = \int_{x=0}^{x=1} g_1^p(x)dx \qquad \Gamma_1^n = \int_{x=0}^{x=1} g_1^n(x)dx$$

- **Data fits use Next to Leading Order QCD analysis**
- **Bjorken Sum Rule OK @ 10% level**
- $\Delta\Sigma \approx 0.2 - 0.4$

9 Semi-inclusive Results

Use correlation between detected hadron and scattered q_f

$\longrightarrow$ 'Flavor - Tagging'

In LO-QCD:

$$A_1^{\mathrm{h}}(x,Q^2) \simeq \frac{g_1^{\mathrm{h}}(x,Q^2)}{F_1^{\mathrm{h}}(x,Q^2)} = \frac{\int dz \sum_f e_f^2 \Delta q_f(x,Q^2) D_f^{\mathrm{h}}(z,Q^2)}{\int dz \sum_f e_f^2 q_f(x,Q^2) D_f^{\mathrm{h}}(z,Q^2)}$$

- $(\Delta q_f), q_f$ **(Polarized) quark distributions**
- $D_f^{\mathrm{h}}(z)$ **are the fragmentation functions giving the probability that the (struck) quark of flavor f fragments into a hadron of type h.**

Assumptions:

- **Factorization (deep-inelastic scattering, hadronisation)**
- **Fragmentation functions spin-independent**

10 Verify Factorization

Use unpolarized semi-inclusive π Data

$$r(x,z) = \frac{N_p^{\pi^-}(x,z) - N_n^{\pi^-}(x,z)}{N_p^{\pi^+}(x,z) - N_n^{\pi^+}(x,z)}$$

where $N^\pi(x,z)$ Pion yield from DIS.

If factorization is valid.

$$N^{\pi^\pm}(x,z) \propto \sum_i e_i^2 \left[q_i(x) D_{q_i}^{\pi^\pm}(z) + \overline{q}_i(x) D_{\overline{q}_i}^{\pi^\pm}(z) \right]$$

e_i **quark charge**

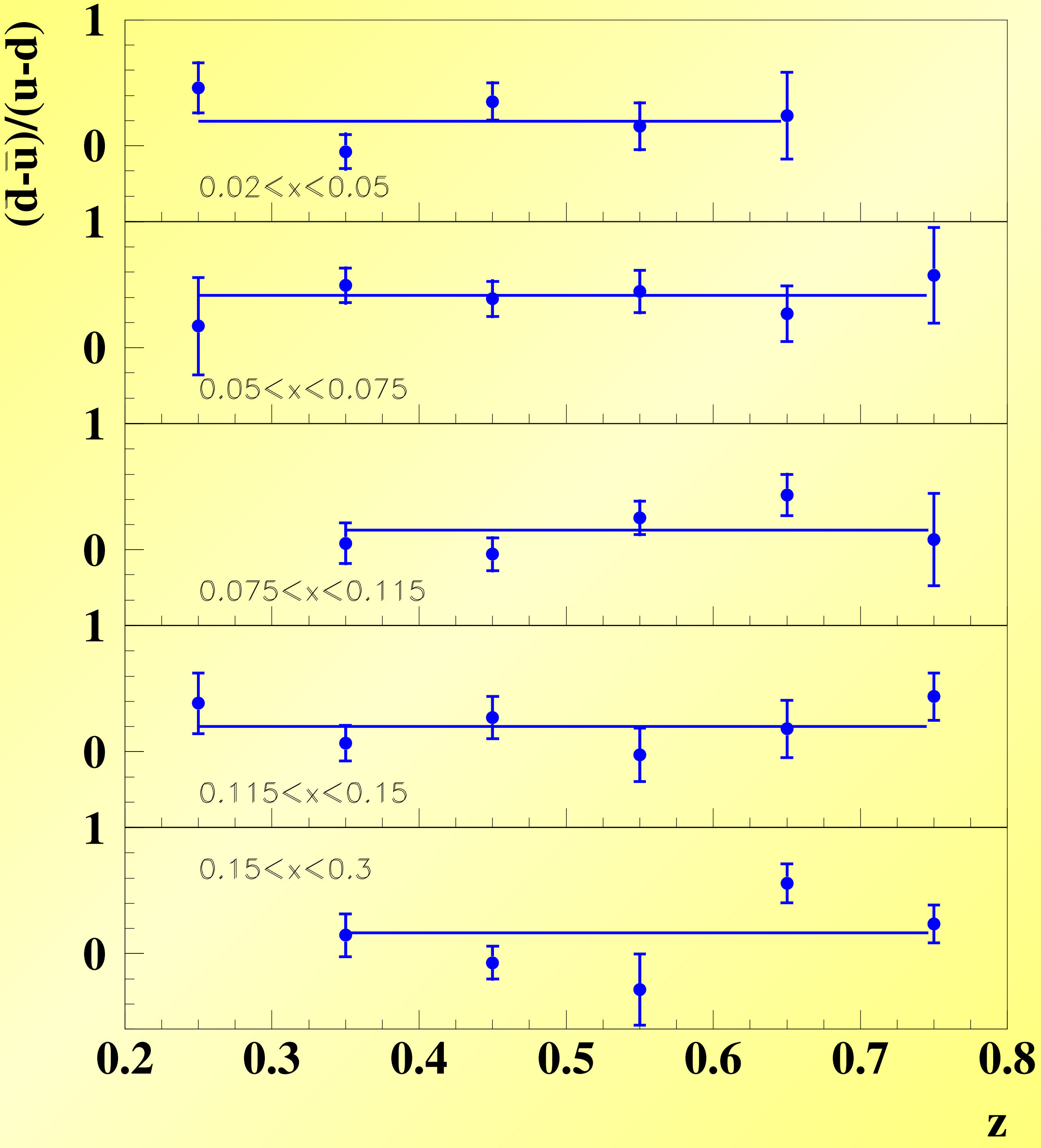
q_i **quark density distributions**

$D_q^{\pi^+}$ **Pion Fragmentation Function**

$$\frac{\overline{d}(x) - \overline{u}(x)}{u(x) - d(x)} = \frac{[1 - r(x,z)] - [1 + r(x,z)]}{[1 - r(x,z)] + [1 + r(x,z)]}$$

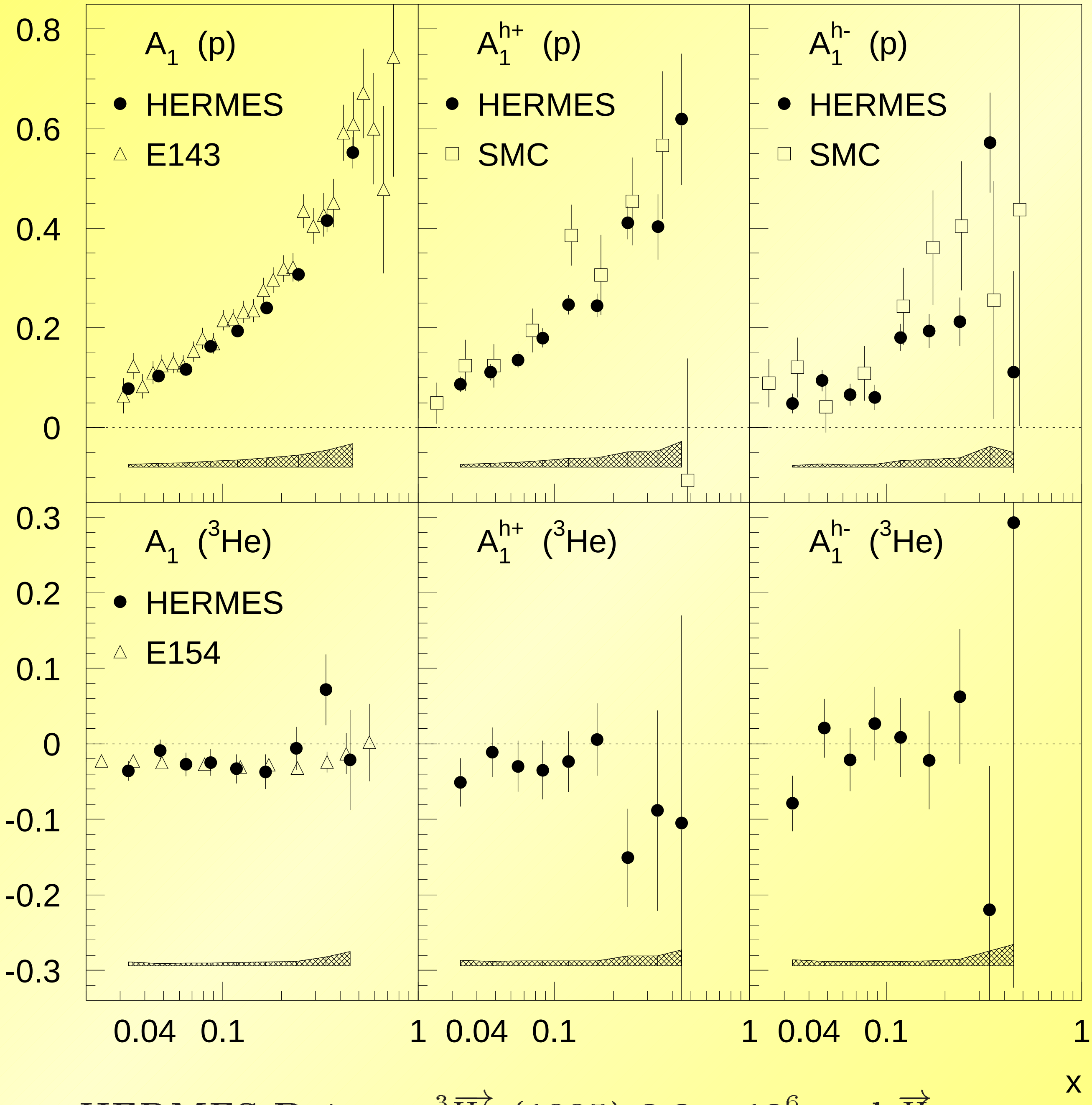
Factorization $\longleftrightarrow$ Independent of z

$$\frac{\bar{d}-\bar{u}}{u-d}$$



hep-ex/9807013

11 Hadron Asymmetries



- **HERMES Data on $^3\overrightarrow{\mathrm{He}}$ (1995) 2.2 x 10^6 and $\overrightarrow{\mathrm{H}}$ (1996+1997) 2.3 x 10^6 DIS events**
- **hadrons are selected in the current fragmentation region by** $z = E_h/\nu \geq 0.2$ **and** $x_F \geq 0.1$ **and** $W^2 \geq 10GeV^2$
- **hep-ex/9906035**

12 Δq-Extraction

- **Rewrite Photon-Nucleon Asymmetry**

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

- **Purity** $P_q^h(x,z)$ **gives probability that a quark q(x) was struck when a hadron h(z) is detected**
- **Purities are** spin-independent **quantities**
- **define**

$$\vec{A} = \begin{pmatrix} A^{h_1}(x) \\ \ldots \\ A^{h_m}(x) \end{pmatrix}, \vec{Q} = \begin{pmatrix} \Delta q_1(x)/q_1(x) \\ \ldots \\ \Delta q_n(x)/q_n(x) \end{pmatrix}, \mathcal{P} = \left[P_q^h(x)\right]$$

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

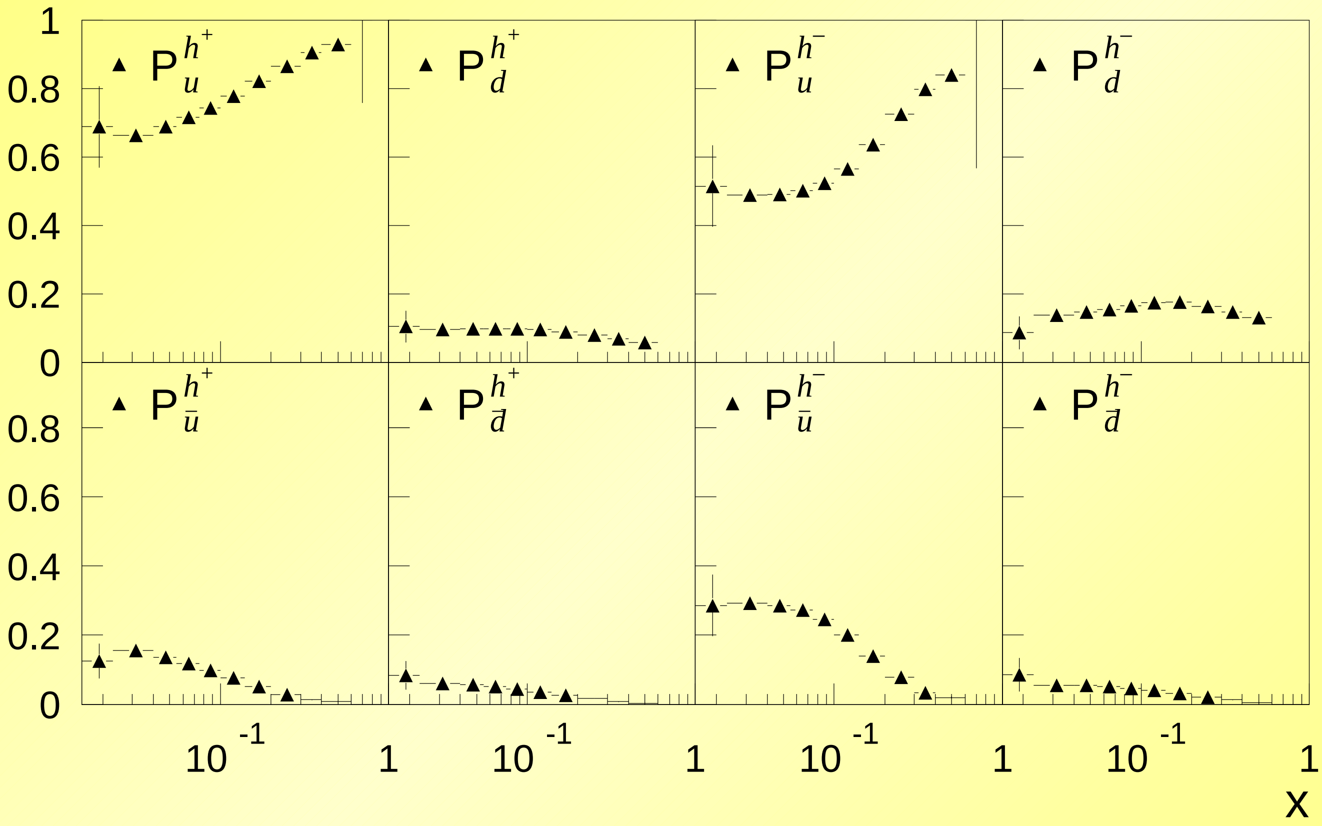
- **to extract quark polarizations solve**

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

Proton Purity Functions

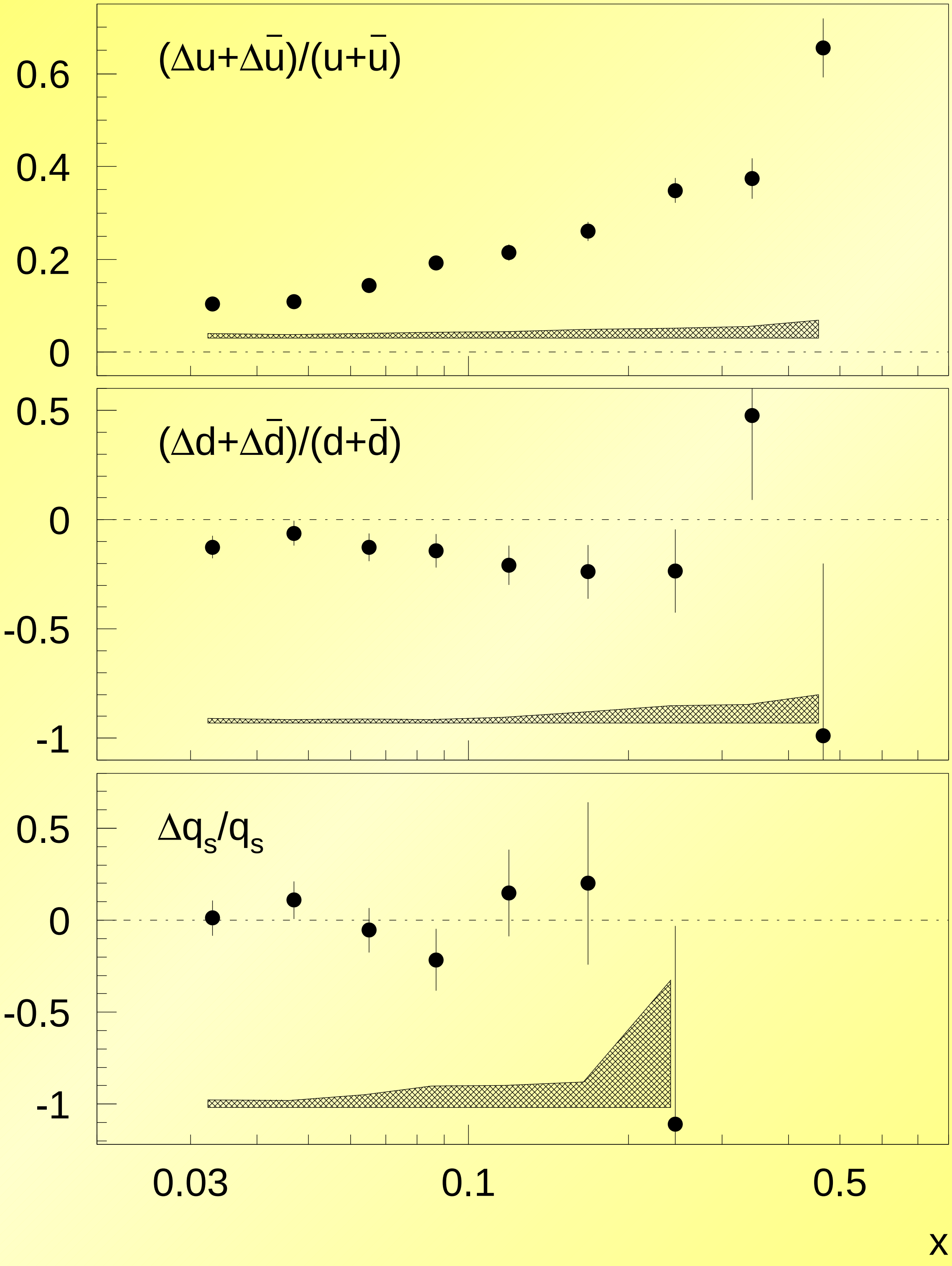
Purities $P^{h^\pm}_{u,\bar{u},d,\bar{d}}(x)$ for a proton target ($\int_{z_{min}}^{1} dz$):

positive hadrons **negative hadrons**



- **h^+, h^- asymmetries on the proton dominated by $\Delta u(x)$**
- **Sensitivity to $\Delta d(x) = \Delta u_n(x)$ via neutron (^{3}He-data)**
- **Sensitivity to $\Delta\bar{u}(x)$ & $\Delta\bar{d}(x)$ $\sim$ 10% for $x \leq 0.2$**

13 Flavor Decomposition

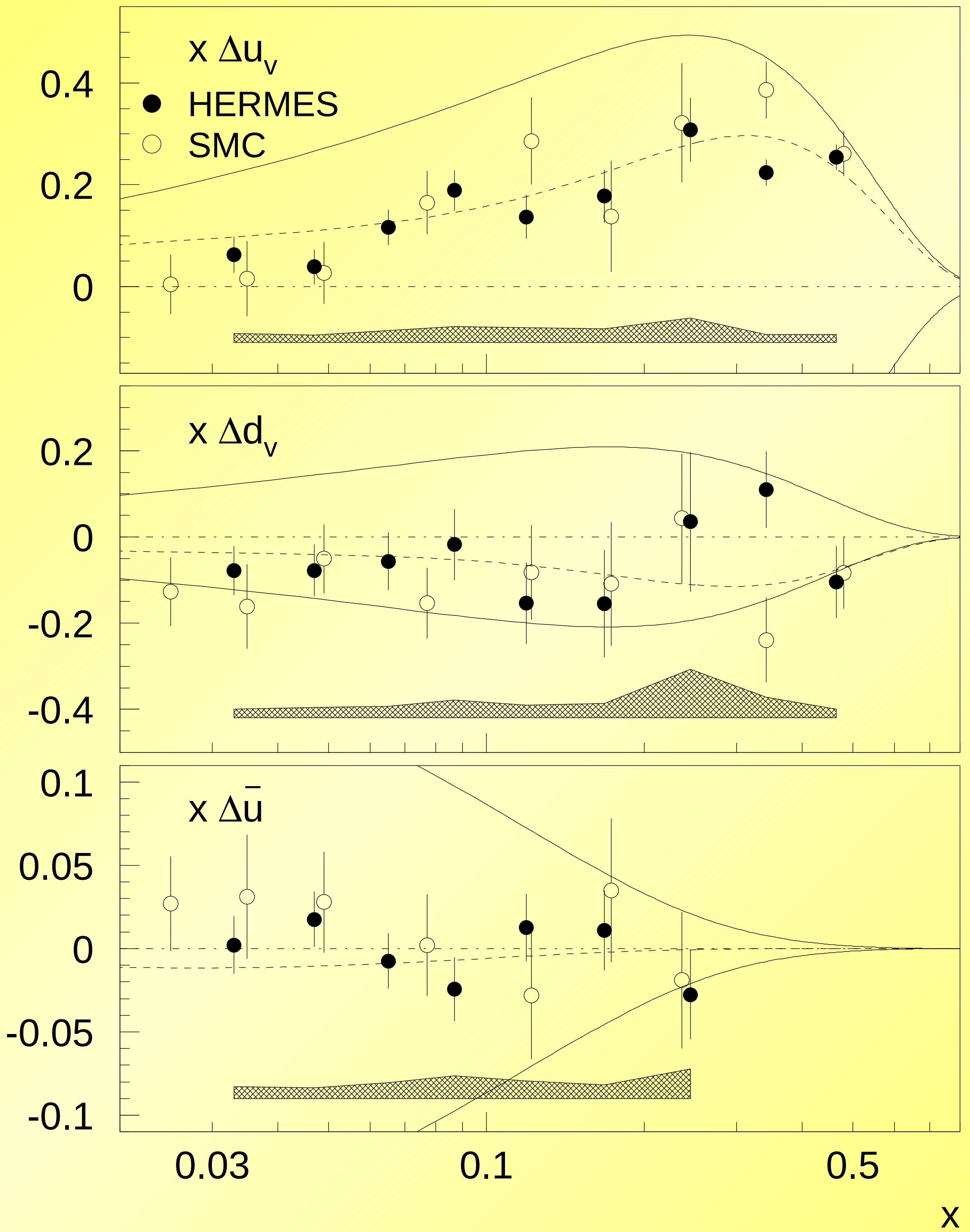


HERMES SEA Assumption:

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

data are presented at measured Q^2

Valence and Sea Quark Distributions

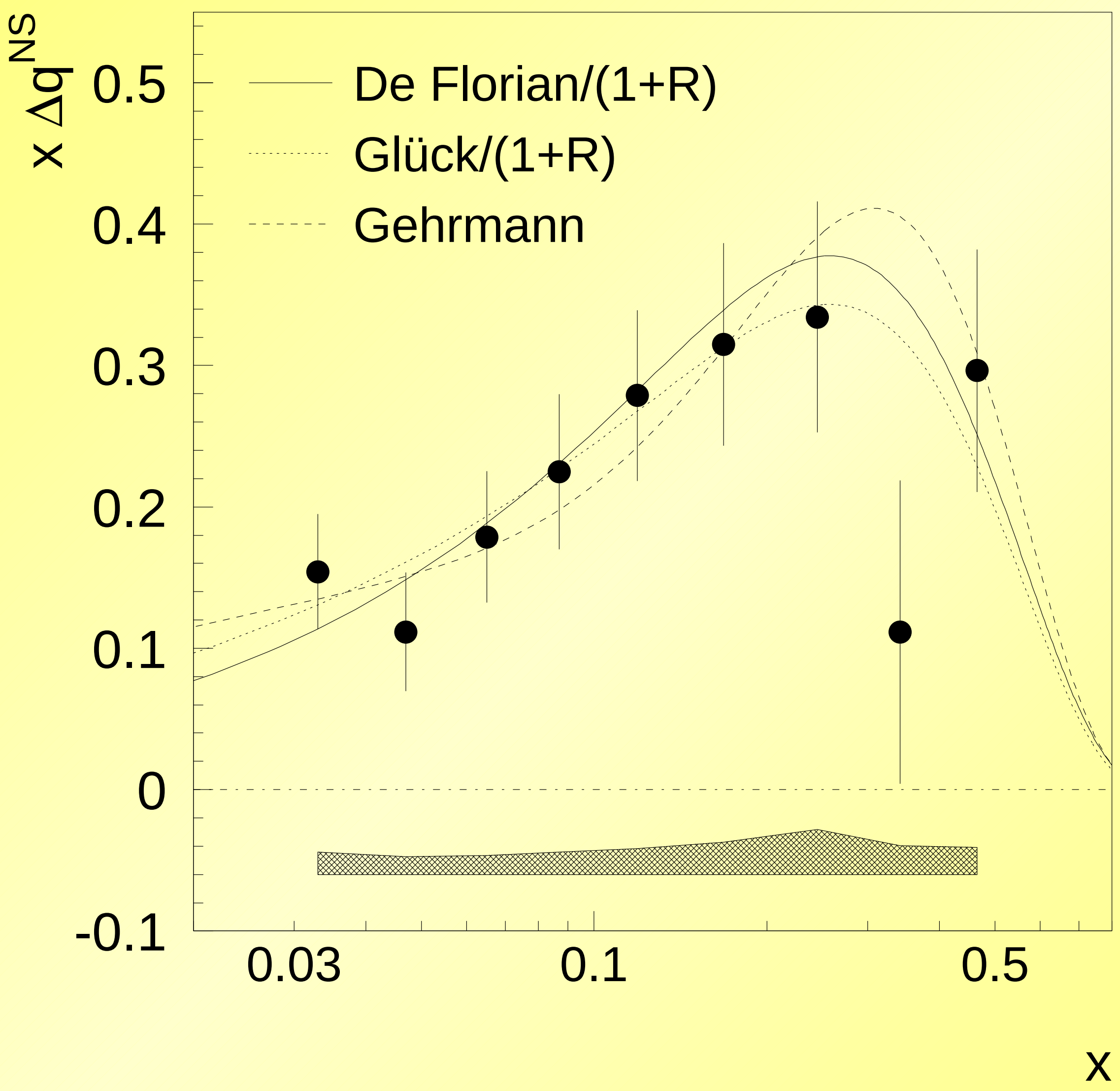


Dotted line Gehrmann and Sterling (Gluon A,LO)

SMC SEA Assumption:

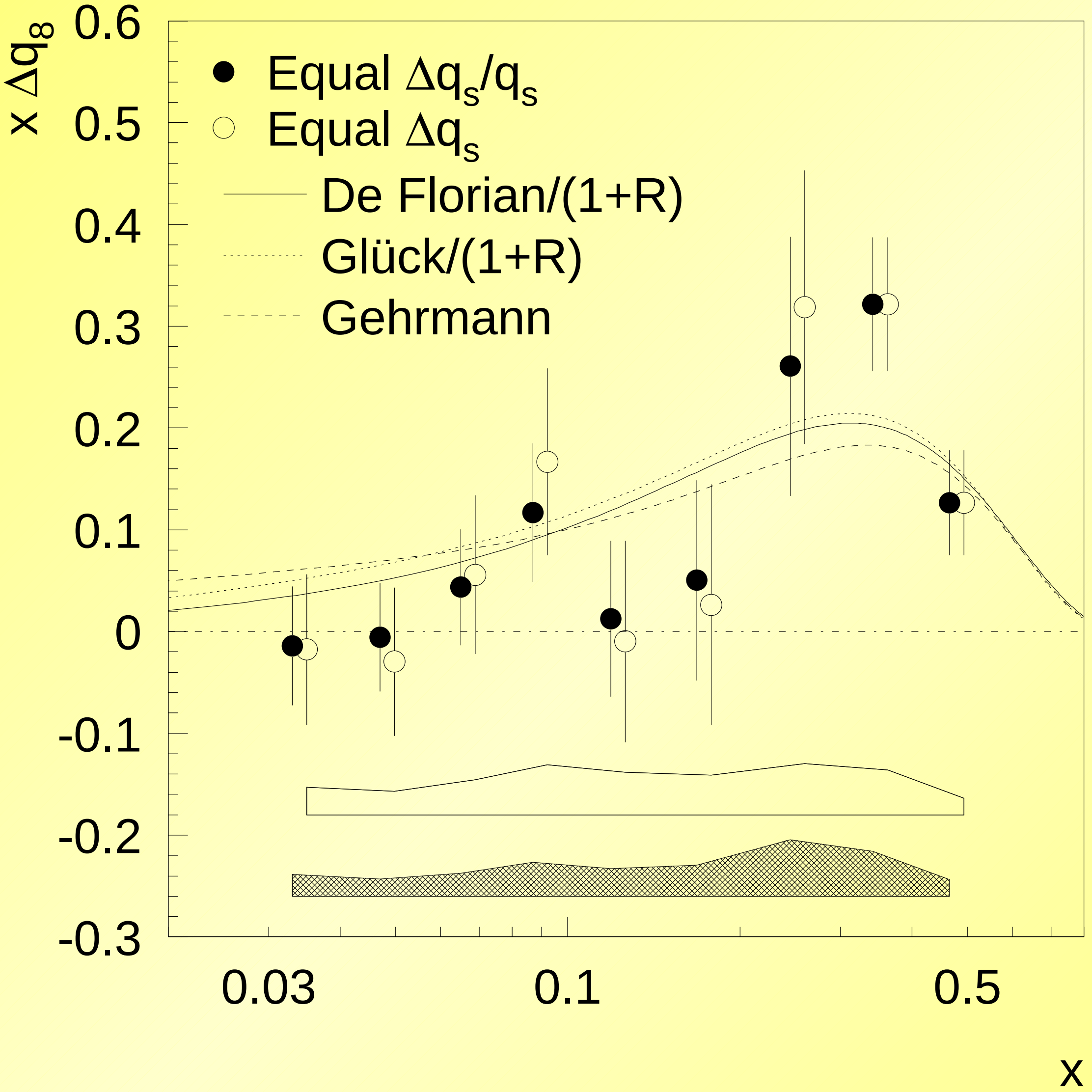
$\Delta u_s = \Delta d_s = \Delta s = \Delta \bar{u} = \Delta \bar{d}$

$x\Delta q^{NS}$



- **Non-singlet Contribution:**
  $x\Delta q^{NS} = x(\Delta u + \Delta\bar{u} - \Delta d - \Delta\bar{d})$
  at Q^2 **=** $\mathbf{2.5GeV^2}$

$x\Delta q_8$



- **Color Octet Combination:**
  $x\Delta q_8 = x(\Delta u + \Delta\bar{u} + \Delta d + \Delta\bar{d} - 2(\Delta s + \Delta\bar{s}))$
  at $Q^2 = 2.5GeV^2$
- **Open Circles** $\longleftrightarrow$ **Flavor Symmetric Sea**
- **Closed Circles** $\longleftrightarrow$ **Flavor Independent Polarization**

First and Second Moments

HERMES flavor decomposition ($Q^2 = 2.5$)

	total integral	prediction		Q^2
$\Delta u + \Delta \bar{u}$	0.56 ± 0.04	0.66 ± 0.03	SU(3)[1]	2.5
$\Delta d + \Delta \bar{d}$	-0.25 ± 0.08	-0.35 ± 0.03	SU(3)[1]	2.5
$\Delta s + \Delta \bar{s}$	-0.02 ± 0.05	-0.08 ± 0.02	SU(3)[1]	2.5

Low-x extrapolation via Regge parameterization.

HERMES Singlet (Δq_0), Triplet (Δq_3), and Octet (Δq_8)

	total integral	prediction		Q^2
Δq_0	0.28 ± 0.10	0.23 ± 0.04	SU(3)[1]	2.5
Δq_3	0.83 ± 0.09	1.01 ± 0.05	$\lvert g_A/g_V \rvert$	2.5
Δq_8	0.32 ± 0.13	0.46 ± 0.03	$(3F - D)$	2.5

HERMES valence distributions ($Q^2 = 2.5$) vs lattice QCD

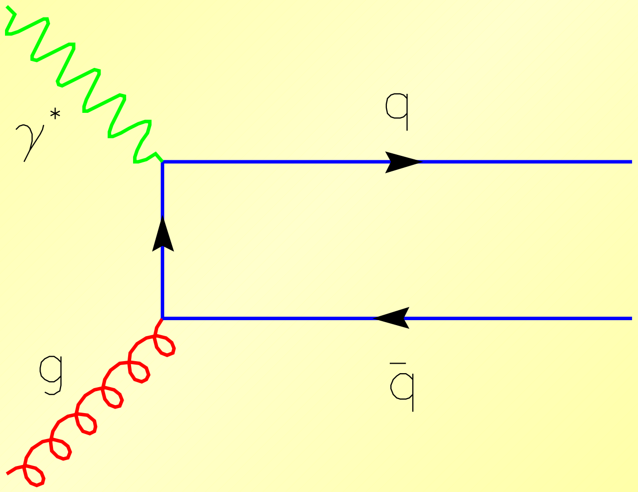
	total integral	prediction	Q^2
Δu_v	0.57 ± 0.09	0.84 ± 0.05[2]	5
Δd_v	-0.21 ± 0.16	-0.25 ± 0.02[2]	5
$x\Delta u_v$	0.124 ± 0.016	0.198 ± 0.008[2]	4
$x\Delta d_v$	-0.022 ± 0.034	-0.048 ± 0.003[2]	4

[1] **J. Ellis and M. Karliner, Phys. Lett. B 341 (1995) 397;**
[2] **M. Göckeler *et al.*, Phys. Lett. B 414 (1997) 81**

14 Gluon - Spin

Quark-Gluon dynamics is described in the framework of pQCD by the DGLAP evolution equations:

- **only indirect access to ΔG via the scaling violations of the spin structure function g_1**
- **direct access $\Delta G/G$ via photon-Gluon fusion (PGF) $(\gamma g \rightarrow q\bar{q})$**



How to study the Gluon Spin at Hermes:

- **replace high-p_T jets at collider experiments with high-p_T hadrons at Hermes**
  Bravar et al, Phys. Lett. B421(1998)349
  Afanasev et al, Phys. Rev. D58(1998)054007
- **Open Charm production**
- **Hidden Charm production**

Experimental Technique of

high-p_T hadrons

Measure the cross section asymmetry:

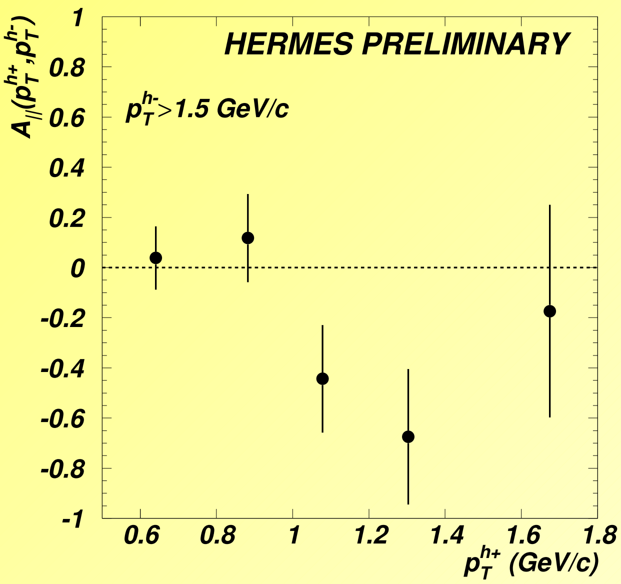
$$A_{||} = \frac{N^{\uparrow\downarrow} L^{\uparrow\uparrow} - N^{\uparrow\uparrow} L^{\uparrow\downarrow}}{N^{\uparrow\downarrow} L_P^{\uparrow\uparrow} + N^{\uparrow\uparrow} L_P^{\uparrow\downarrow}}$$

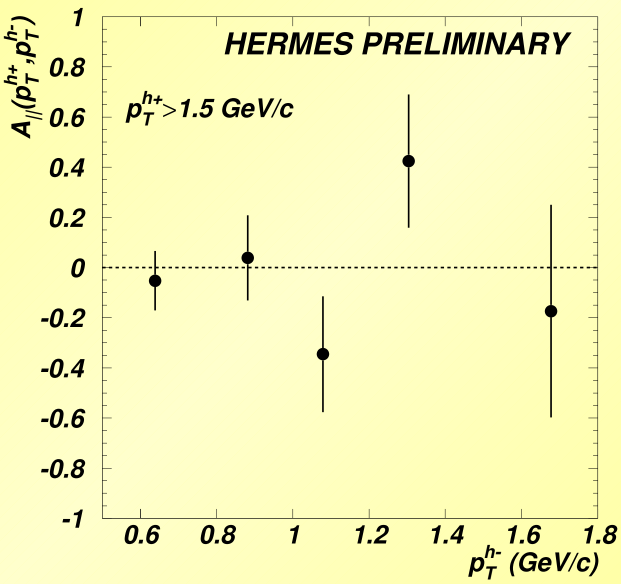
$N^{\uparrow\uparrow}(N^{\uparrow\downarrow})$: **number of hadron pairs with parallel (anti-parallel) target-beam spin orientation.**
$L^{\pm}$ **and** $L_P^{\pm}$ **are luminosity and polarization weighted luminosity**

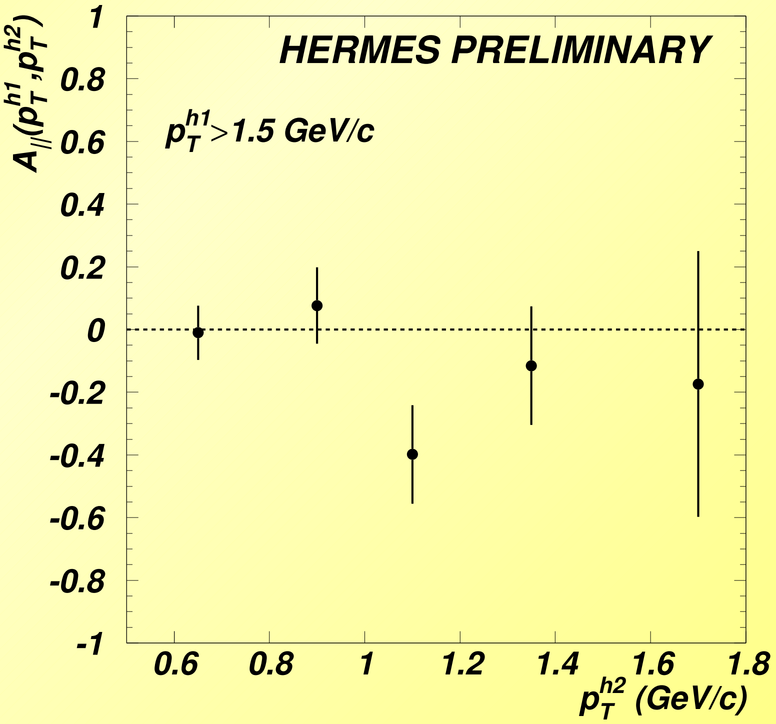
Require:

- **at least two hadrons in spectrometer: one** h^+ **and one** h^-**.**
- **both must be high momentum (>4.5 GeV/c) and high** p_T **(>0.5 GeV/c).**
- $M(2\pi) > 1.0$ **GeV/c**^{2}**, to remove** ρ **and** ϕ **resonances.**
- **The cross-section is maximal at** $Q^2 = 0$**. Thus, include statistics from quasi-real photo-production.**
  $\longrightarrow$ **do not force scattered** e^+ **in spectrometer**

Measured Asymmetry $A_{||}(p_T^{h^+}, p_T^{h^-})$



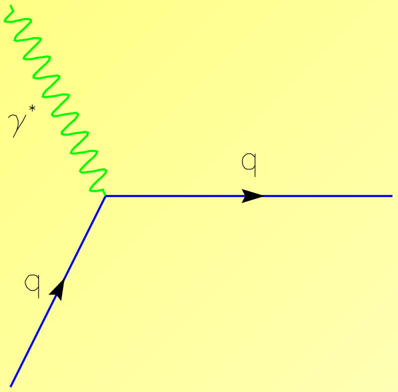




systematic error $\approx$ 6 % of measurement

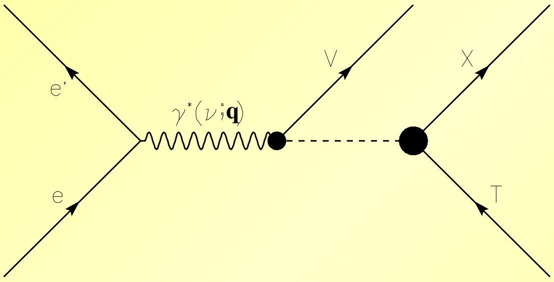
Interpretation

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



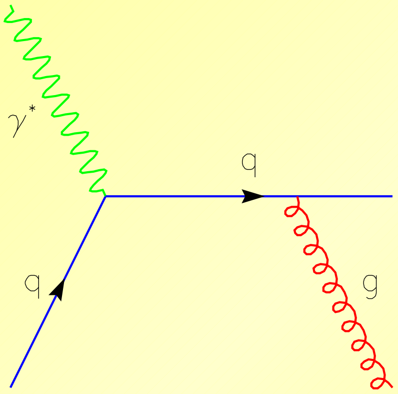
DIS

negligible contribution



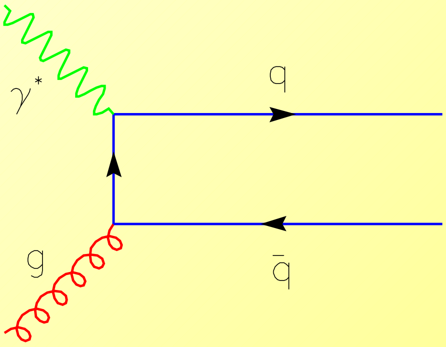
VMD

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



QCDC

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



PGF

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

Their spin asymmetries can contribute to the measured asymmetry:

$A_{||} = A_{\mathrm{QCDC}} f_{\mathrm{QCDC}} + A_{\mathrm{PGF}} f_{\mathrm{PGF}} + A_{\mathrm{DIS}} f_{\mathrm{DIS}} + A_{\mathrm{VMD}} f_{\mathrm{VMD}}$

.. estimate their relative contributions.

Model For $A_{\parallel}$ Interpretation

use Pythia (LO QCD) to determine the unpolarized fractions f_i of the assumed four cross section contributions ($i =$ dis, vmd, qcdc, and pgf):

$$A_{\parallel} = D \sum_{i=1}^{4} f_i \cdot A_i$$

Note: contributions of hadronic component of the photon not known for HERMES energies and assumed to be zero

- **calculated** $f_{\mathrm{DIS}} \approx 0$ **at** $\langle Q^2 \rangle = 0.06\ \mathrm{GeV}^2$
- **assume** $A_{\mathrm{VMD}} \approx 0$
- **calculated** $\langle D(y) \rangle = 0.9$

$$A_{\parallel} \approx D(f_{\mathrm{QCDC}} A_{\mathrm{QCDC}} + f_{\mathrm{PGF}} A_{\mathrm{PGF}})$$

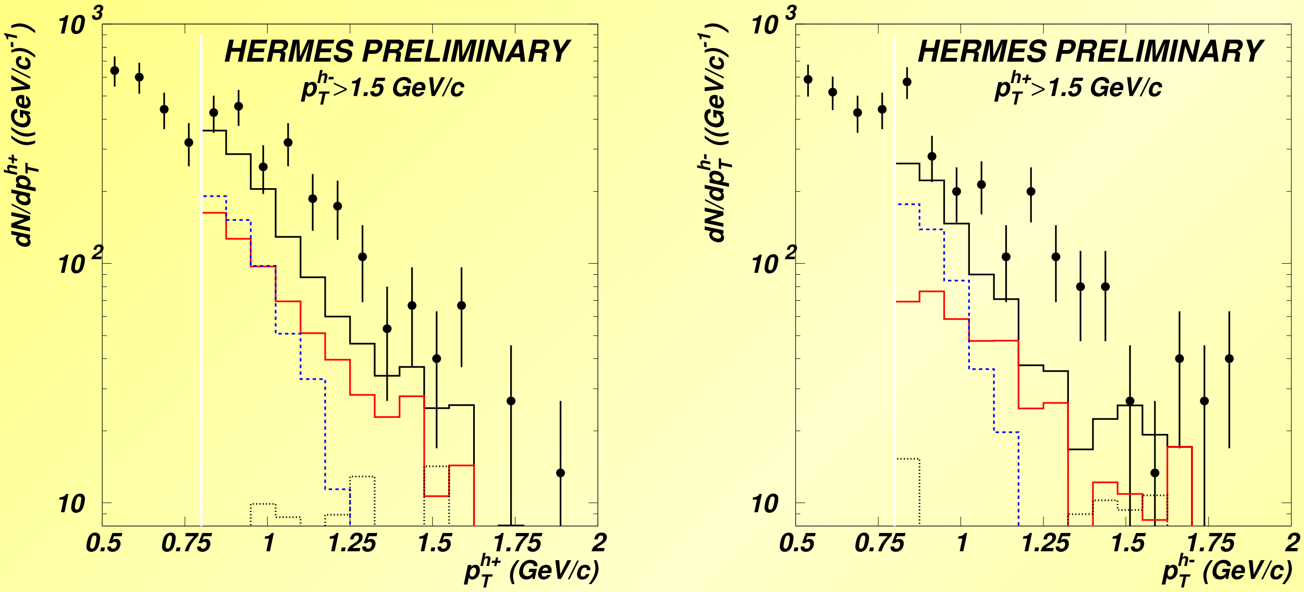
in small region of phase space one can write:

$$A_{\mathrm{PGF}} \approx \langle \hat{a}(\gamma g \to q\bar{q}) \rangle \left\langle \frac{\Delta G}{G} \right\rangle = \langle \hat{a}_{\mathrm{PGF}} \rangle \left\langle \frac{\Delta G}{G} \right\rangle$$
$$A_{\mathrm{QCDC}} \approx \langle \hat{a}(\gamma q \to q g) \rangle \left\langle \frac{\Delta q}{q} \right\rangle = \langle \hat{a}_{\mathrm{QCDC}} \rangle \left\langle \frac{\Delta q}{q} \right\rangle$$

- **calculated in LO QCD:** $\langle \hat{a}_{\mathrm{PGF}} \rangle = -1$
  $\langle \hat{a}_{\mathrm{QCDC}} \rangle = +1/2$

MC-Data Comparisons

Comparison of measured unpolarized cross section with predictions of model implemented in PYTHIA.



solid black = total, **solid red = PGF**,

dashed blue = QCDC, dotted black = soft VMD

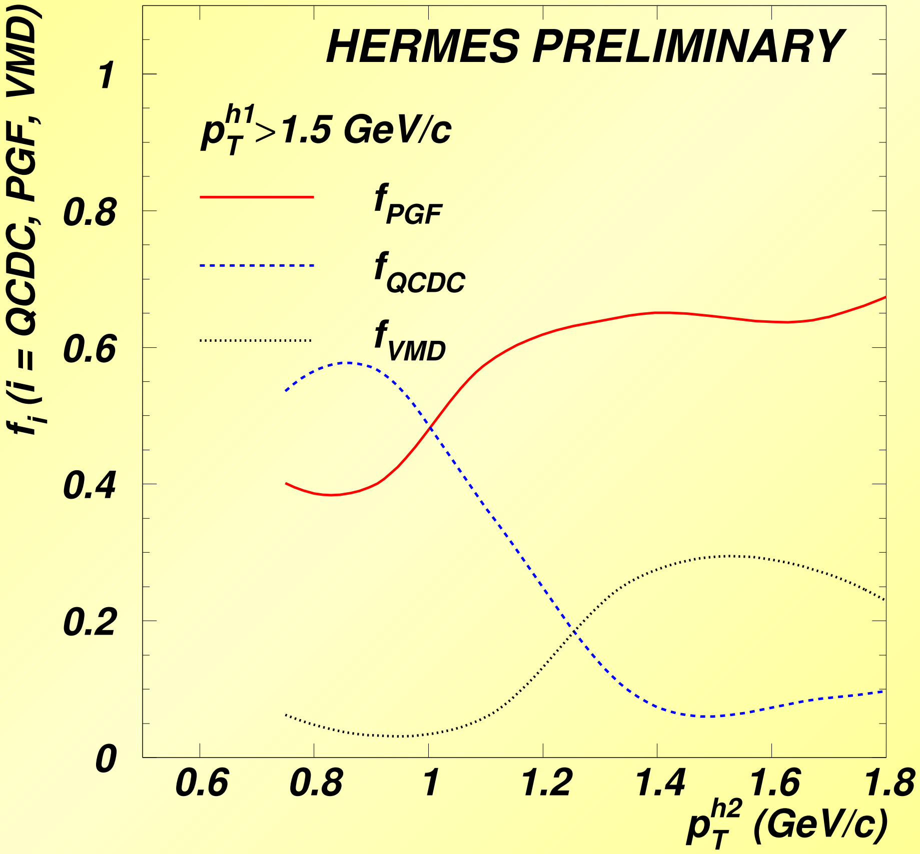
data are compared in a region where PYTHIA model is independent of $\hat{p}_T^{\min}$ cut-off parameter.

Other comparisons:

- other distributions: e.g. $\Delta\phi$
- other regions of phase space: e.g. in regions dominated by soft VMD.

Extracted subprocess fractions

The unpolarized model of the data is used to extract the unpolarized f_i's:



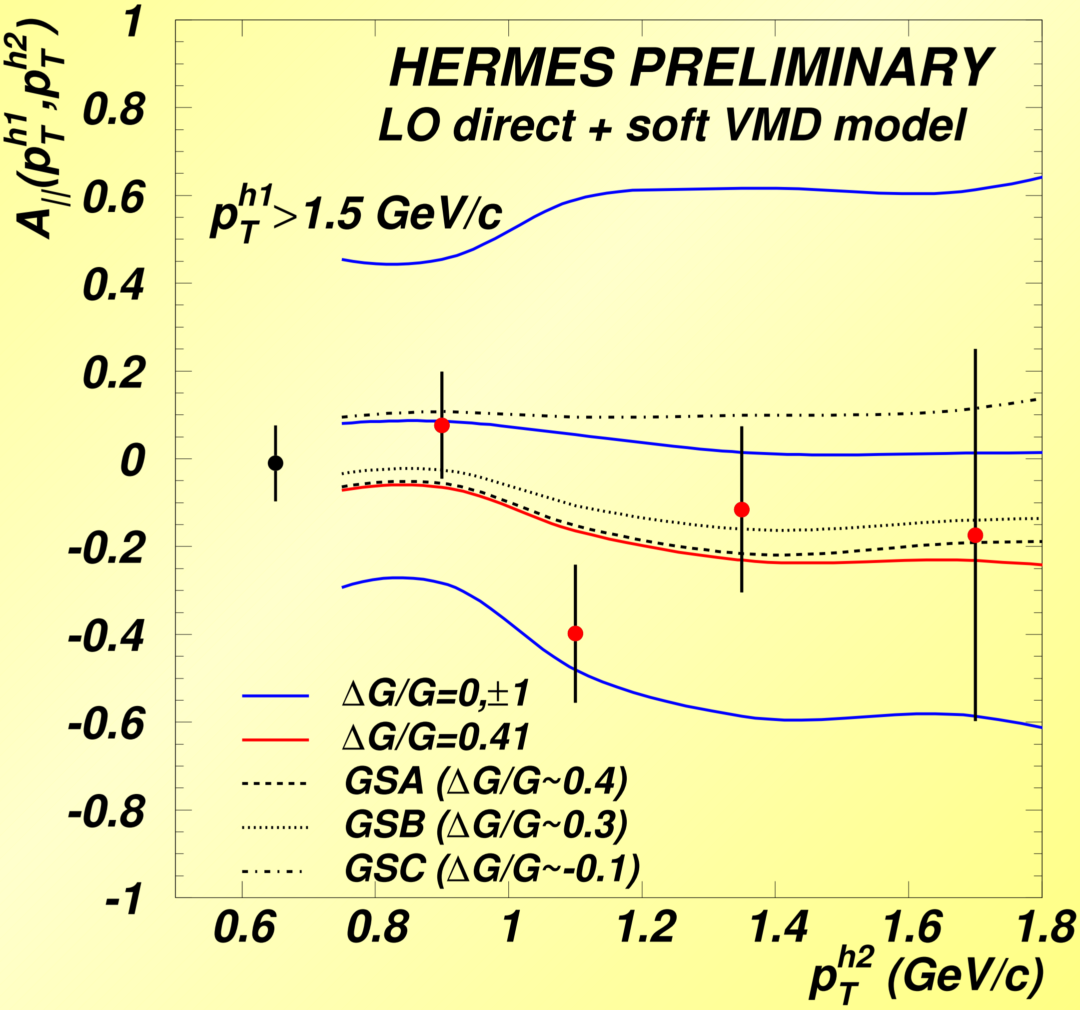
The negative asymmetry is observed where PGF is expected to dominate.

Uncertainty from possible contribution due to point-like hadronic structure of the photon.

Result Using PYTHIA Model

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

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



$\Delta G/G$ **is positive**

15 Open Charm

Theoretically 'cleanest' channel

$$A^D = \frac{N^D_{\uparrow\downarrow} - N^D_{\uparrow\uparrow}}{N^D_{\uparrow\downarrow} + N^D_{\uparrow\uparrow}} = 0.8 \frac{\Delta G}{G}$$

Detection–difficult

- $D^0 \to K^- \pi^+$, $\bar{D}^0 \to K^+ \pi^-$
  but large π background
- $D^0 \to K^- \mu^+ X$, $\bar{D}^0 \to K^+ \mu^- X$
  need clean K, μ PID
- **No confirmed signal for D^0 yet**

BUT

- **see a clear D^* signal from 1997 data**
- **implemented a RICH in 1998**

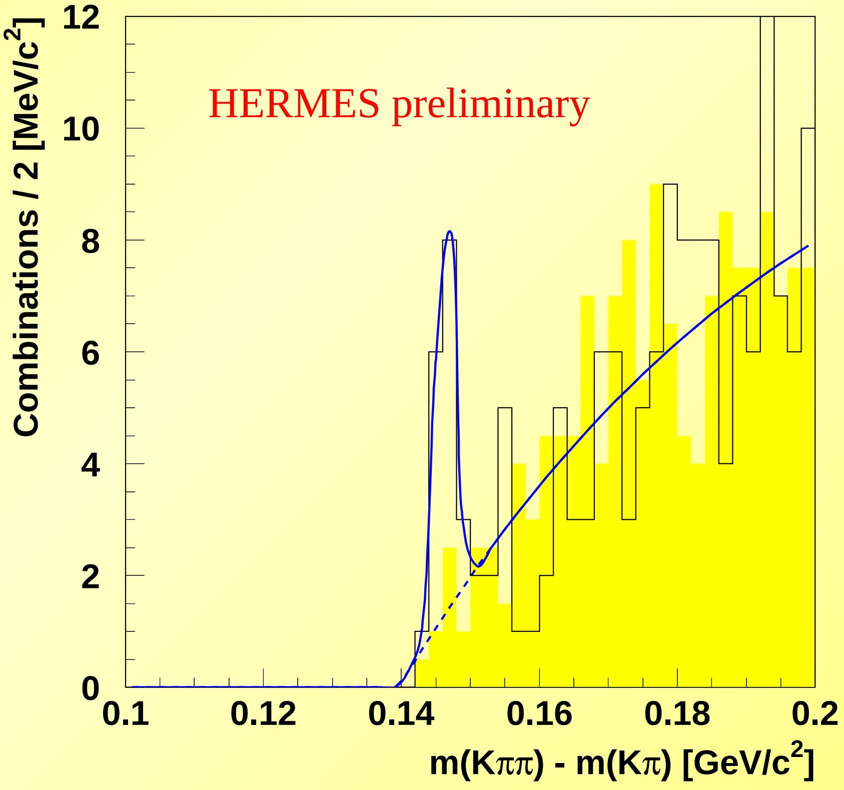
Decay

$$D^{*+} \rightarrow D^0 \pi^+_{slow}$$
$$\hookrightarrow K^- \pi^+ \quad (+cc.)$$

Detection – tagging by missing mass

$$\Delta M = M(D^*) - M(D^0)$$
$$= 145.42 \pm 0.05 MeV$$

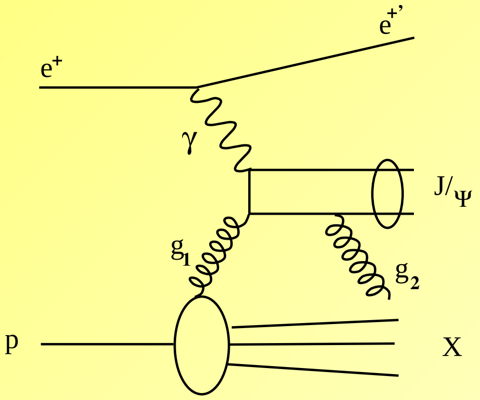
Signal



13 signal/ 7 background
on polarized and unpolarized targets

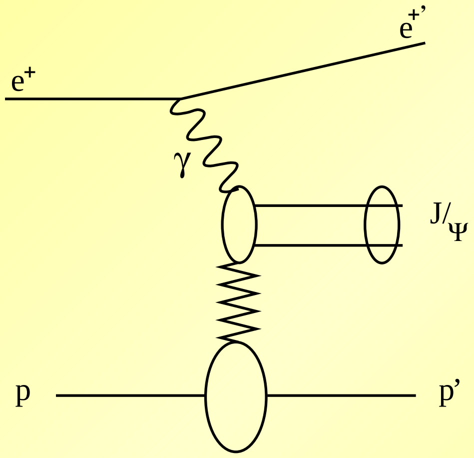
Hidden Charm J/ψ $(c\bar{c})$

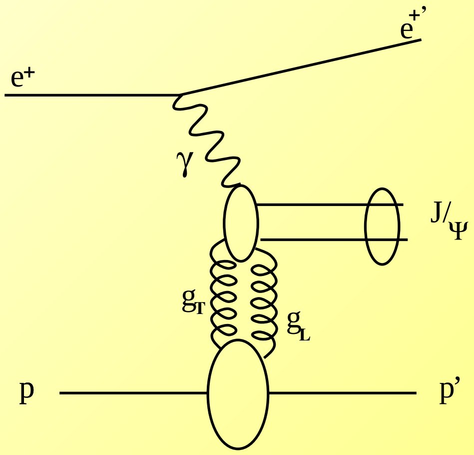
Color Singlet Model (Berger, Jones) (inelastic)



$A^{J/\psi} \sim 0.55 \, \frac{\Delta G}{G}$
estimated $\sim 30\%$,
at HERMES energy

Diffractive production



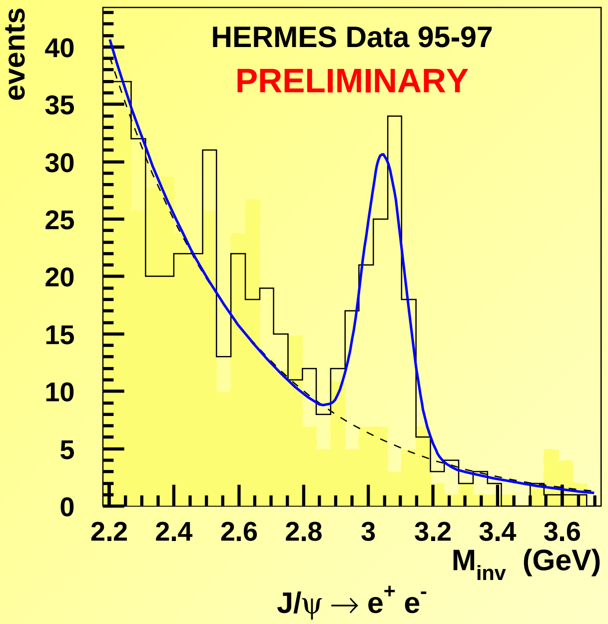


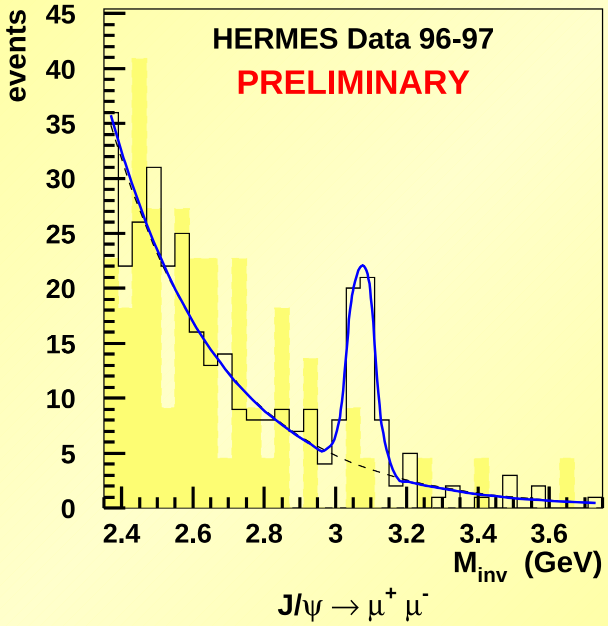
soft Pomeron exchange
SCHC

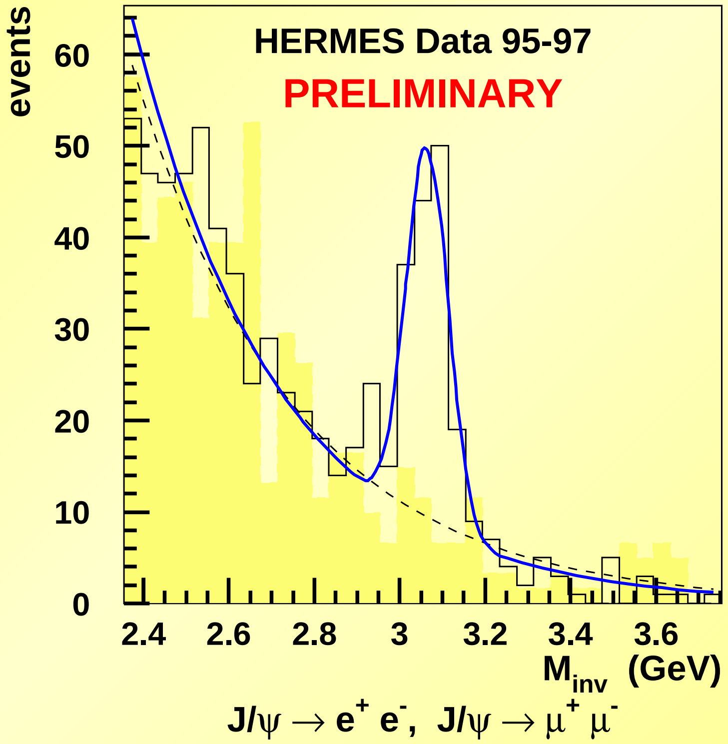
Two Gluon exchange
$A^{J/\psi} \sim \frac{\Delta G}{G}$?

No sensitivity to ΔG expected for diffractive J/ψ
However, $A^{J/\psi}$ still unmeasured quantity !

J/ψ signals 1995-1997





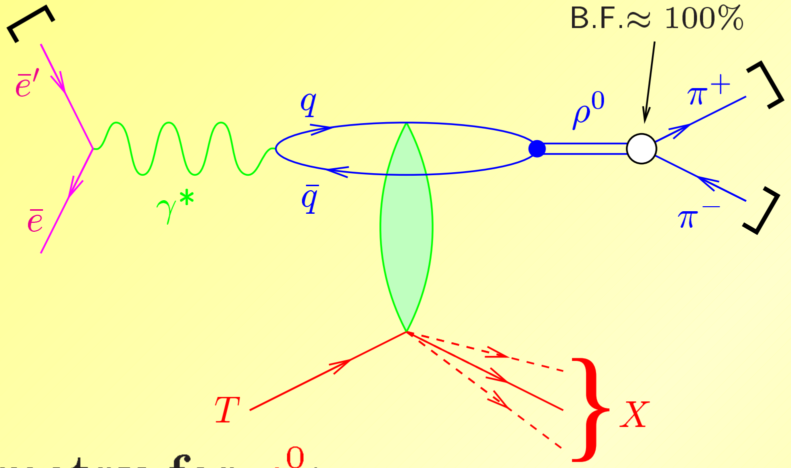


140 signal / 40 background

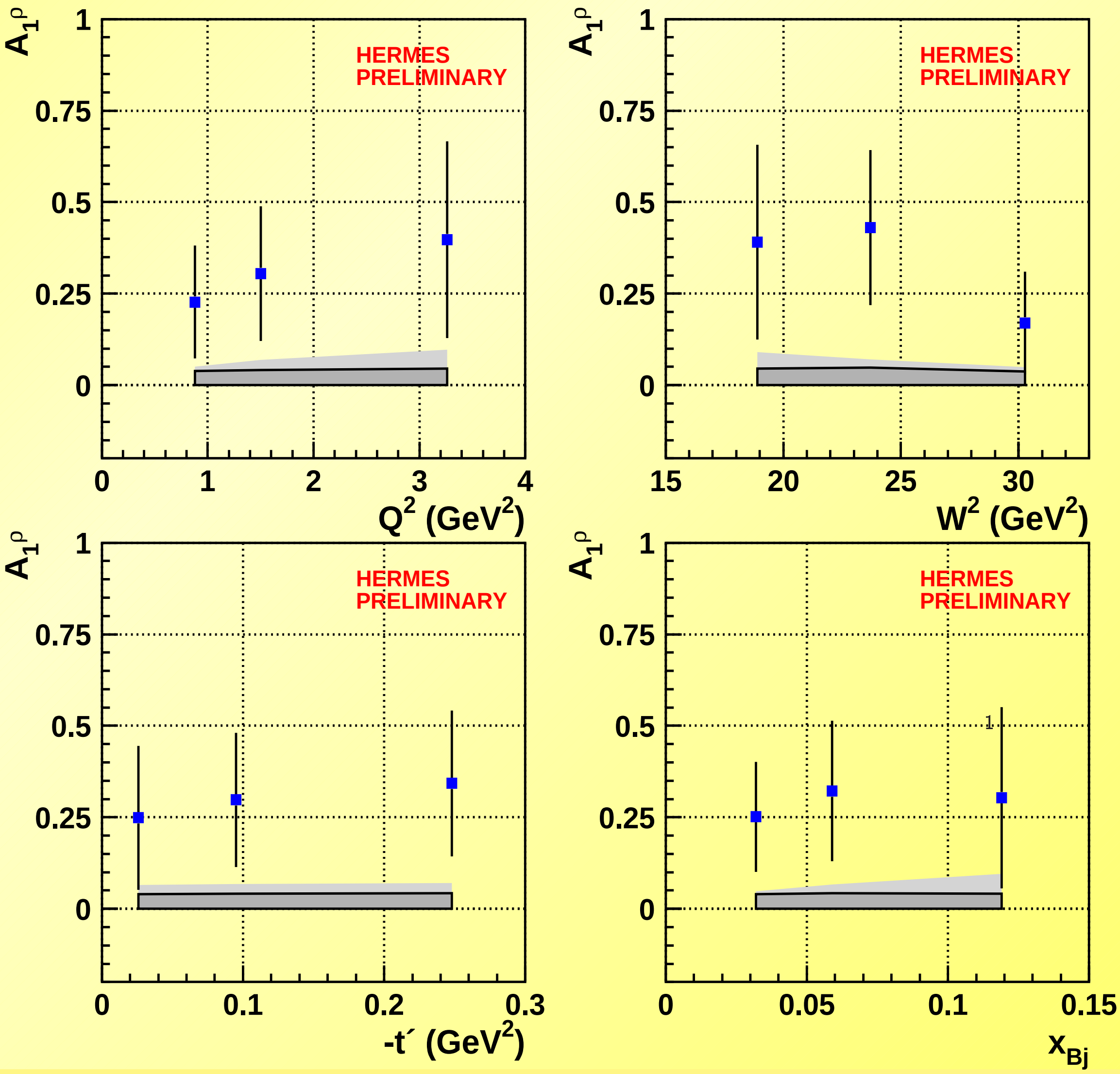
on polarized and unpolarized targets

16 Spin asymmetries in diffractive VMP

Naive expectation: no spin dependence



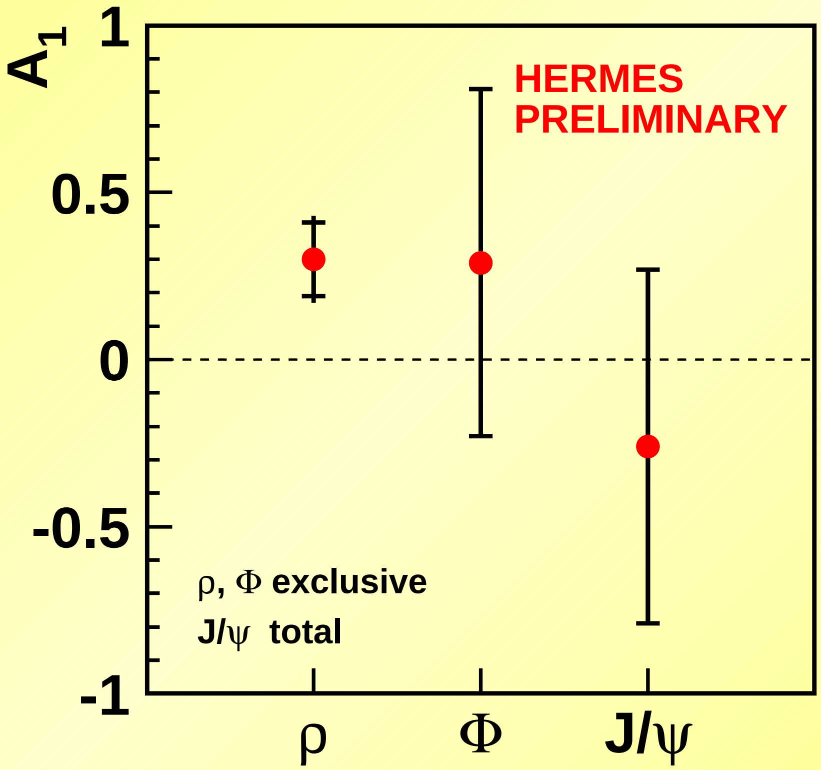
Spin asymmetry for ρ^0:



Spin asymmetries in diffractive VMP

Spin asymmetries for

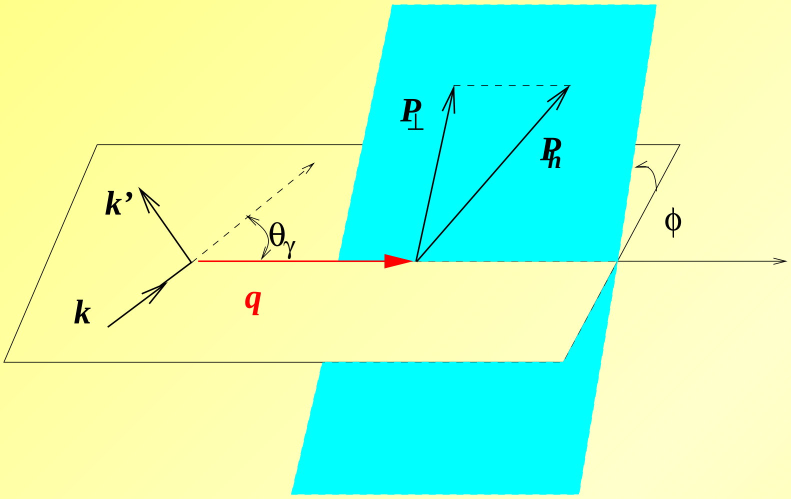
$$\rho^0 \to \pi^+\pi^- \qquad \phi \to K^+K^-$$
$$J/\psi \to e^+e^- \qquad J/\psi \to \mu^+\mu^-$$



ρ^0: 2.4 σ non-zero spin asymmetry
($< W >\sim 5$ GeV, Q^2 typ. 0.5 .. 5 GeV^2)
.. not observed by SMC
($< W >\sim 15$ GeV, Q^2 typ. 0.01 - few 10 GeV^2)

$\phi, J/\Psi$: no significant spin asymmetry

17 Single Spin Asymmetries



New HERMES Measurement:

measure **azimuthal moments** ($\sin\phi$) **of**

- **semi-inclusive π production**
- **single spin asymmetry with respect to longitudinally polarized target**
- **unpolarized beam**

$\Longrightarrow$ **Access to new SF's and FF's extending the description of the structure of the nucleon beyond the naive model ($g1, F1, ...$) of collinear, non-interacting quarks (k_t correlations, ..) (recent theoretical work on classification)**

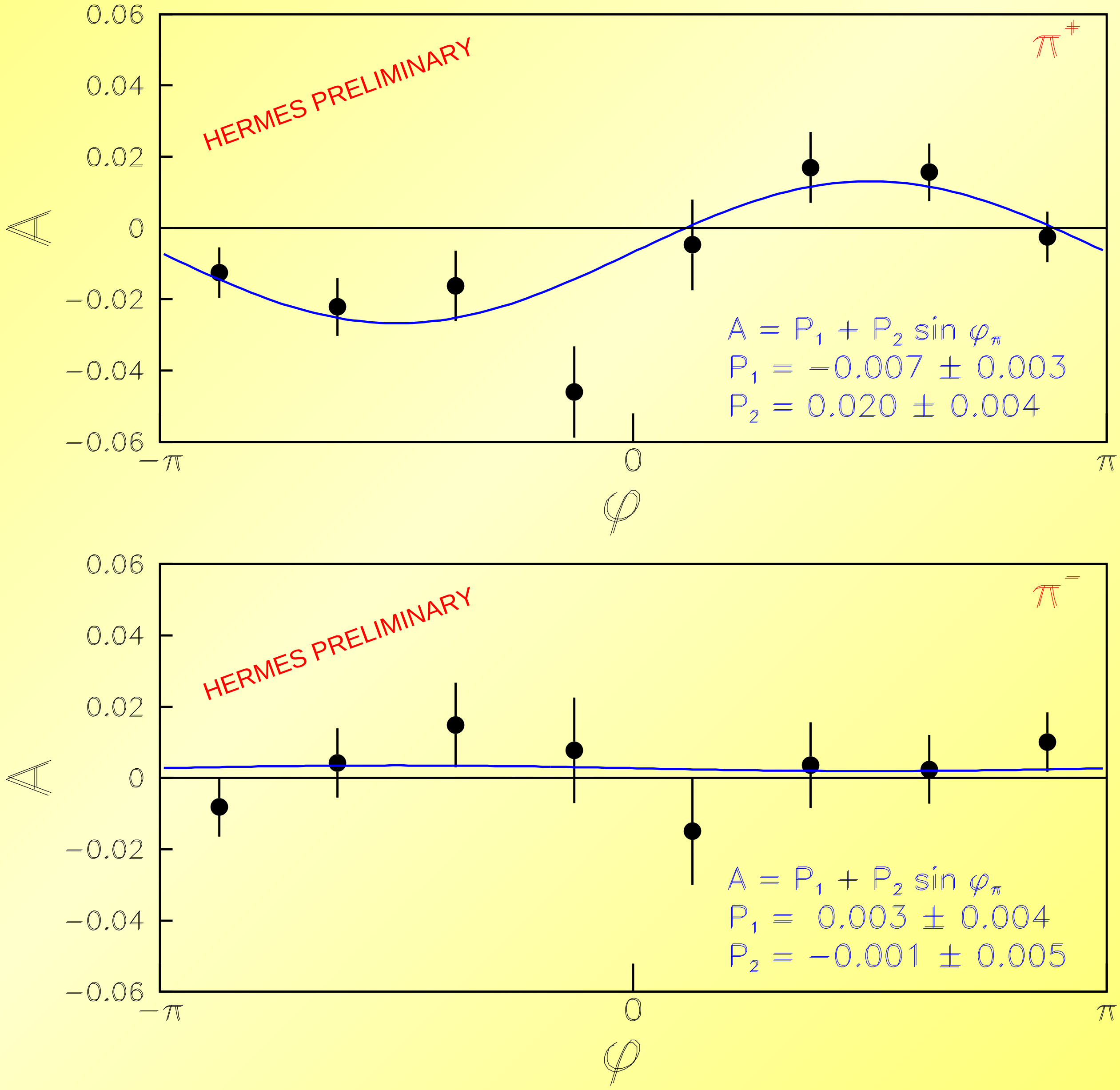
$$< sin\phi >_{OLO} \sim h_L(x) \cdot H_1^{\perp}(x)$$

Spin-Azimuthal Asymmetries

Longitudinal **target spin asymmetry:**

$$A(\phi) = \frac{1}{P_T} \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

$\overrightarrow{\mathrm{H}}$ data (1996+1997)

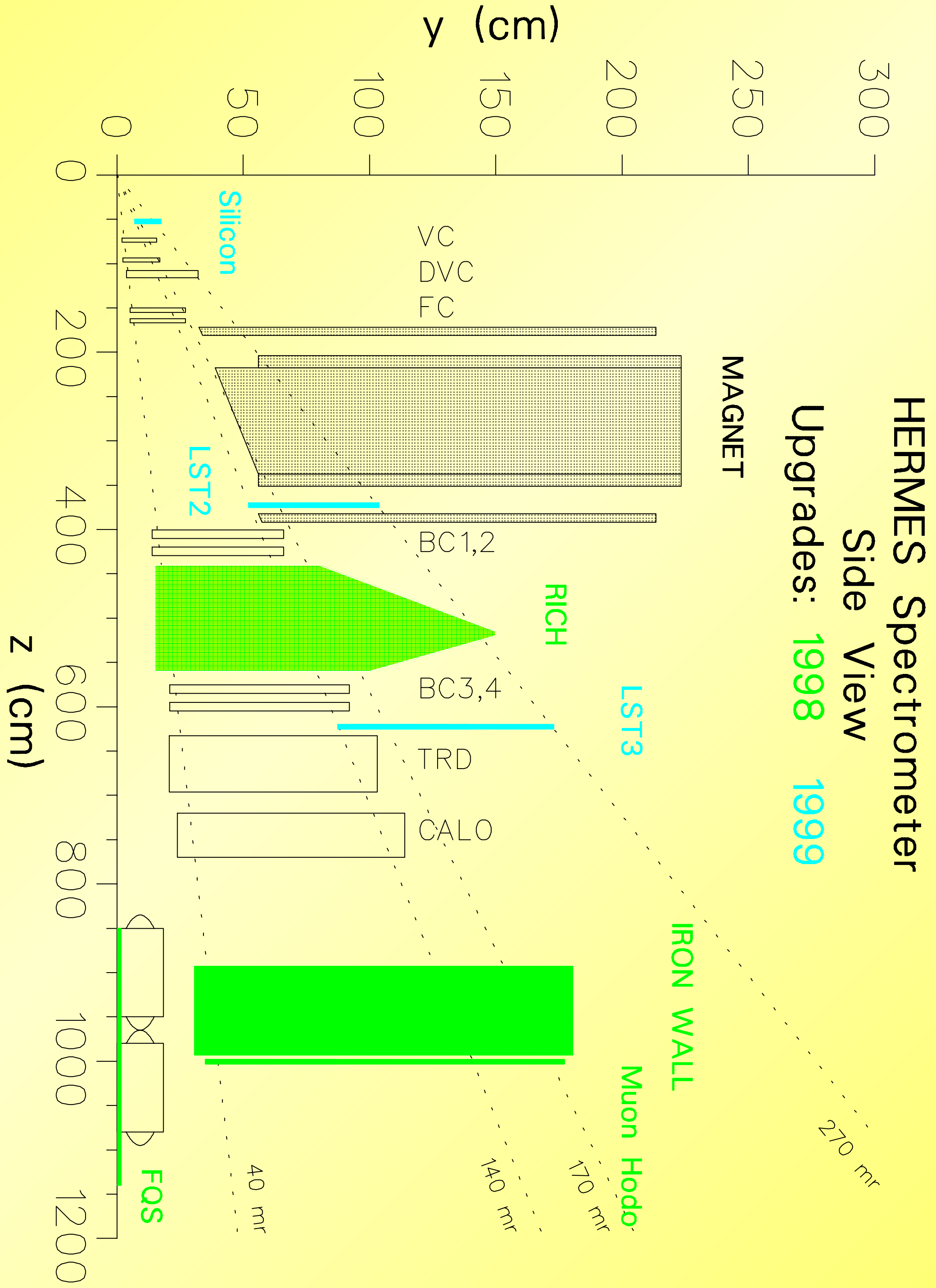


Non-zero asymmetries

⟶ T-odd effects in the fragmentation

18 Outlook

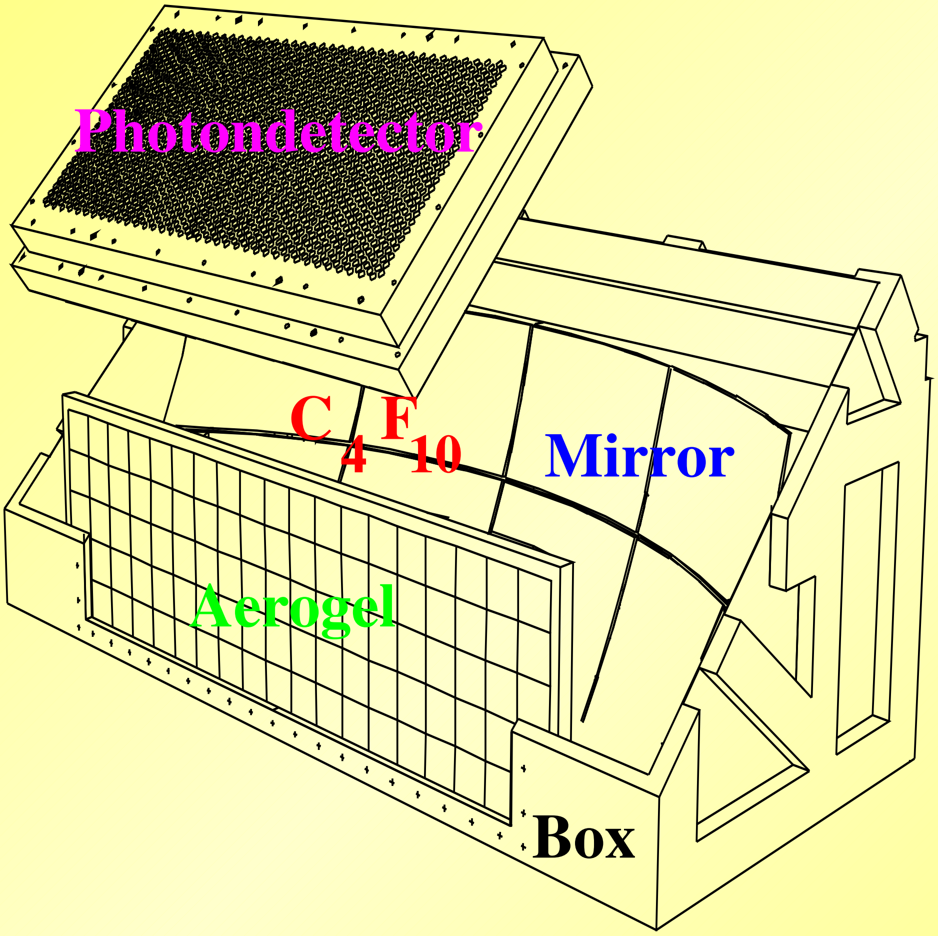
HERMES Detector Upgrades



Impact on HERMES Physics

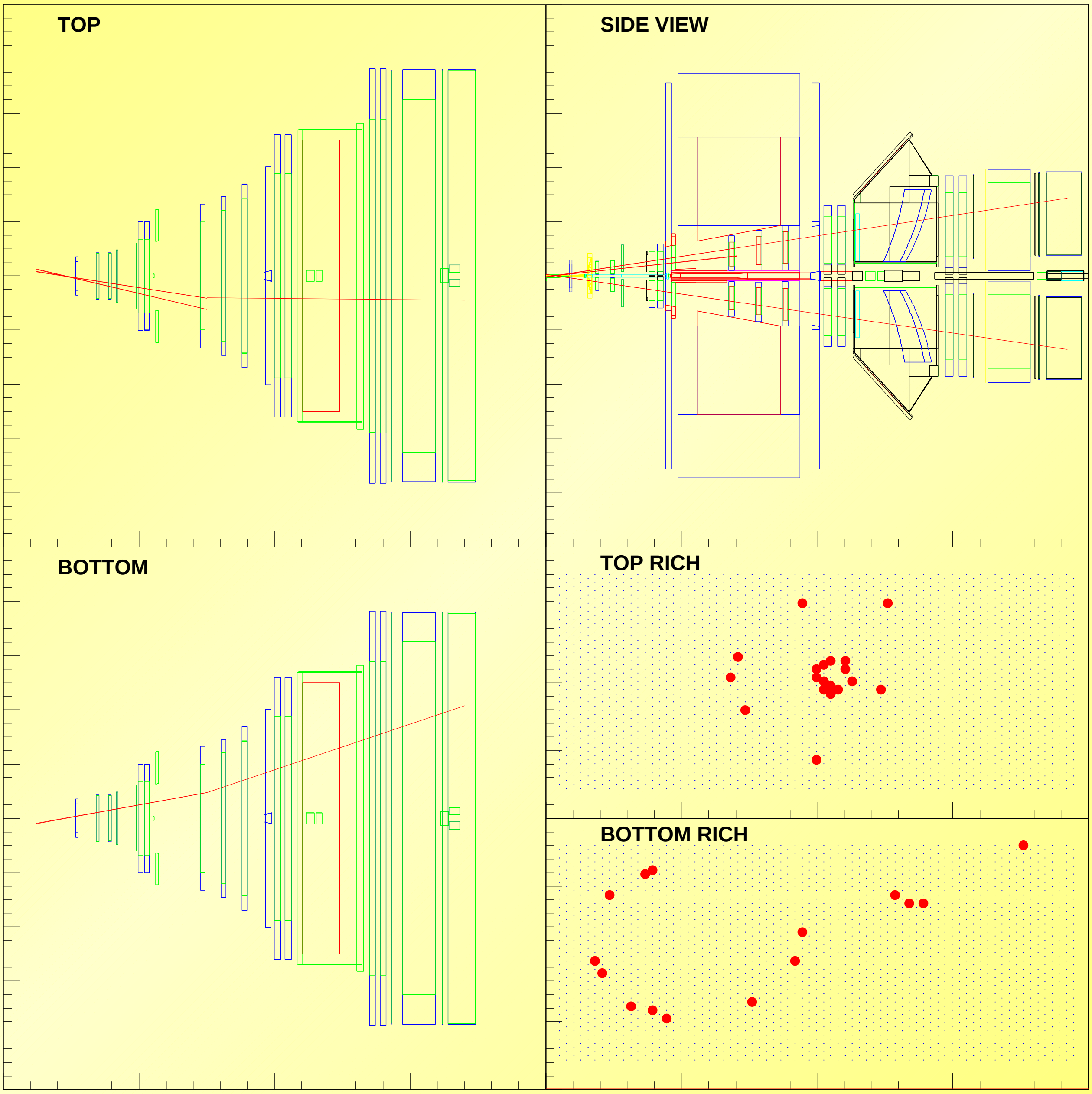
- **RICH**
  separate π, K, p over full momentum range
  $\longrightarrow$ Open Charm ($D^0/\bar{D}^0 \to K^-\pi^+/K^+\pi^-$)
  Background $\downarrow \geq$ 15 Significance $\uparrow \sim 4-5\sigma$
  $\longrightarrow$ Δs by $A_{\parallel}^{K^-}$
- **Forward Quadrupol Spectrometer (FQS)**
  detect scattered e± at small angles
  $\longrightarrow$ low Q^2 physics (J/ψ, D^0, high p_T hadrons, ...)
- **Muon-Detection System**
  μ identification for p $\geq$ 2 GeV/c
  $\longrightarrow$ factor 4 more inelastic J/ψ
- **Silicon detector**
  "Λ-Wheels":
  $\longrightarrow$ enhancement of Λ/Λ_C acceptance by 2
  "Proposed Recoil Detector":
  $\longrightarrow$ detection of recoil nucleons
  $\longrightarrow$ elastic / inelastic separation
  $\longrightarrow$ Vector-Meson Production, exclusive physics

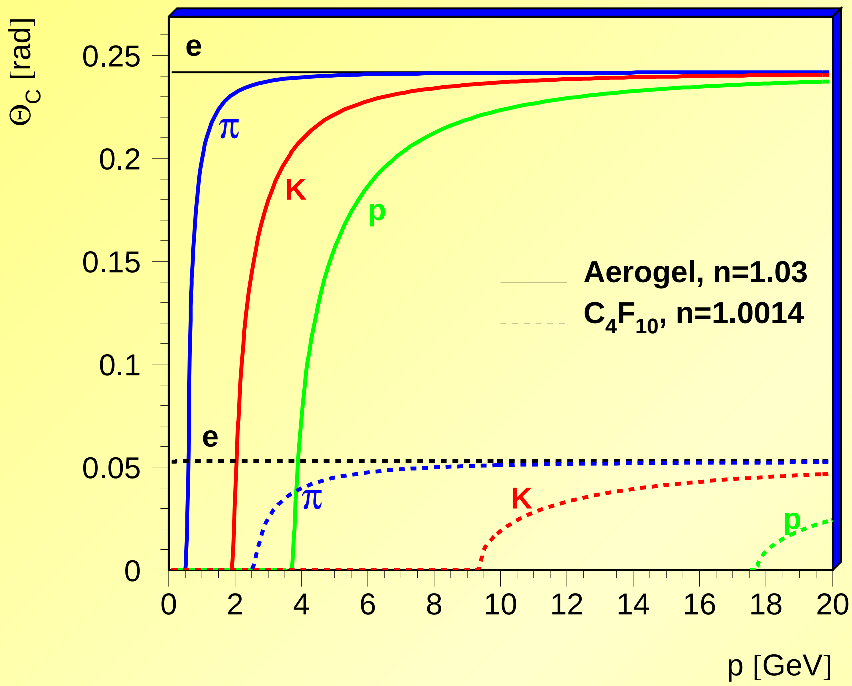
The HERMES RICH

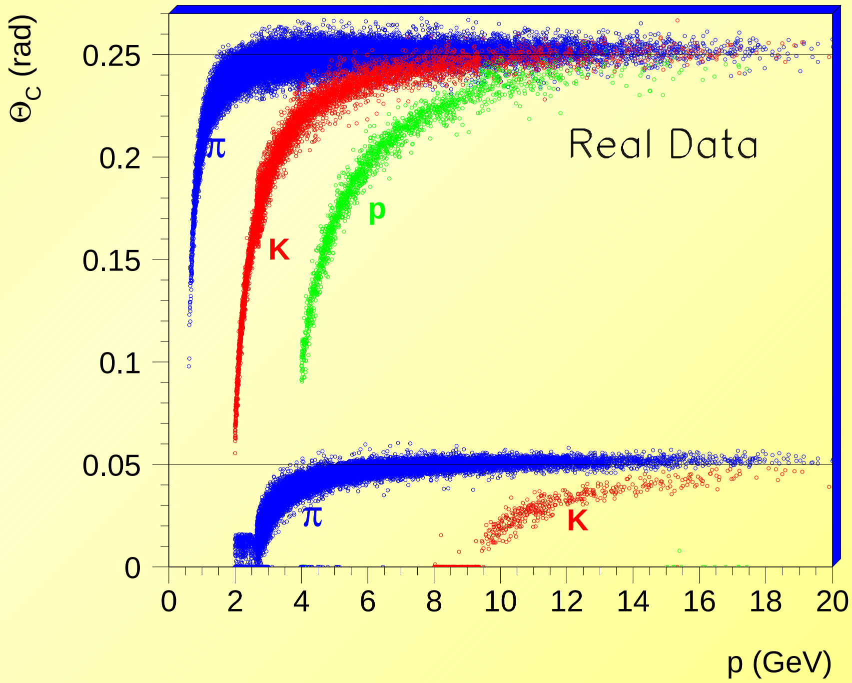


Photondetector:	2000 Philips XP1911/UV
	Read-out: PCOS4
Radiators:	Aerogel $\qquad$ C_4F_{10}
Mirror:	spherical mirror (r=2.2m)
	aluminised carbon fibers

A real π - Kaon event







$$\Theta_C = arccos(\frac{1}{n\beta}) \qquad p = \frac{mv}{\sqrt{1-\beta^2}}$$

Reached design angular resolution

19 Summary

- **Nice Set of Neutron Data** &
  Excellent Set of Proton Data
  - Δu **Positive**
  - Δd **Negative**
  - Δq_{Sea} **Compatible with Zero**
- **Indication for positive** $\frac{\Delta G}{G}$ **at** $\langle x_G \rangle = 0.17$
- **Double Spin Asymmetrie in VMP**
- **Saw Single-Spin Azimuthal Asymmetrie**
- **Collecting Deuteron Data Now**
- **Detector Potential Continues to Grow**
  - **RICH** $\longrightarrow$ **Open Charm**
  - **Separate Strange and Light Quark Sea by determining** $A_{\parallel}^{\pi^+} A_{\parallel}^{\pi^-} A_{\parallel}^{K^+} A_{\parallel}^{K^-}$
- **Not presented Unpolarized Physics Program**
  - **longitudinal and transverse polarization of** Λ
  - $\bar{u}/\bar{d}$
  - **Fragmentation Functions for**
    light quarks $\longrightarrow \pi$, **Kaon, Proton,** Λ
    Strange quarks $\longrightarrow$ **......**
  - **Diffractive Vector Meson Production**
    SCHC, nuclear effects (coherence length), ...
  - $\mathbf{F_2}^{N/He/Kr}/\mathbf{F_2}^{D} \longrightarrow$ **nuclear effects on** σ_L/σ_T

HERMES Projected Accuracy May 99