DIS 97

CHICAGO 4/16/97

MEASUREMENT OF THE POLARIZED NEUTRON STRUCTURE FUNCTION g_1^n AT HERA

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FOR THE
HERMES COLLABORATION

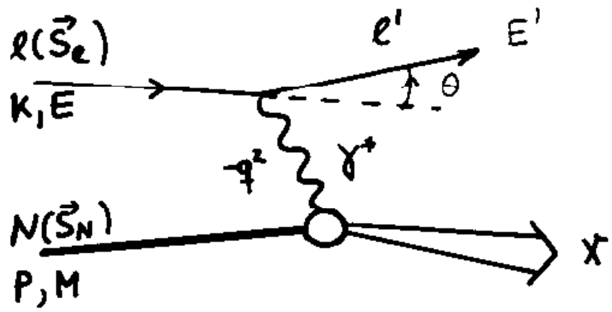
FORMALISM
EXPERIMENTAL METHOD
MEASUREMENT OF A_1^n / g_1^n
EVALUATION OF Γ_1^n
SUMMARY

RESULTS ARE BASED ON THE FIRST YEAR 1995 DATA TAKING PERIOD OF THE HERMES EXPERIMENT AT HERA.

POLARIZED NEUTRAL CURRENT DEEP INELASTIC SCATTERING

- KINEMATICS

$$\ell(\vec{S}_\ell) + N(\vec{S}_N) \longrightarrow \ell' + X$$



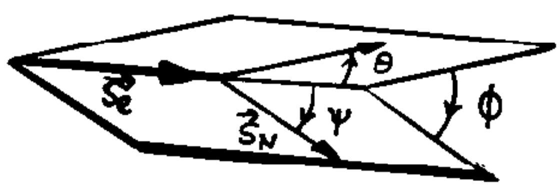
$$Q^2 = -q^2 \simeq 4EE'\sin^2\frac{\theta}{2}$$

$$\nu = \frac{qP}{M} = E - E' = y \cdot E$$

$$x = \frac{Q^2}{2qP}$$

$$\gamma^2 = \frac{Q^2}{\nu^2} = \frac{4x^2M^2}{Q^2}$$

- LONGITUDINALLY POLARIZED LEPTONS



ψ - ANGLE BETWEEN LEPTON MOMENTUM AND TARGET SPIN

φ - ANGLE BETWEEN LEPTON SCATTERING PLANE AND TARGET SPIN PLANE

- **BORN CROSS SECTION IN ONE-PHOTON APPROXIMATION**

$$\frac{d^3\sigma(\psi)}{dx\,dQ^2 d\phi} = \frac{d^3\bar{\sigma}}{dx\,dQ^2 d\phi} + \frac{d^3\Delta\sigma}{dx\,dQ^2 d\phi}$$

- **SPIN - INDEPENDENT CONTRIBUTION**

$$\frac{d}{d\phi}\left(\frac{d^2\bar{\sigma}}{dx\,dQ^2}\right) = \frac{1}{2\pi}\frac{4\pi\alpha^2}{x\,Q^4}\left(1 - y + \frac{y^2}{2(1+R)}\right) F_2(x,Q^2)$$

$$R = \frac{\sigma_L}{\sigma_T} = \frac{(1+\gamma^2)F_2}{2xF_1} - 1$$

- **SPIN - DEPENDENT PART** $\Delta\sigma(\psi) = \sigma(\psi) - \sigma(\psi+\pi)$

$$\frac{d^3\Delta\sigma(\psi)}{dx\,dQ^2\,d\phi} = \frac{4\alpha^2}{Q^4}\, y \Big[\cos\psi \Big\{\Big(1 - \frac{y}{2} - \frac{y^2\gamma^2}{4}\Big) g_1(x,Q^2) - \frac{y}{2}\gamma^2 g_2(x,Q^2)\Big\}$$

$$- \gamma \sin\psi \sqrt{1 - y - \frac{y^2\gamma^2}{4}}\Big(\frac{y}{2}\, g_1(x,Q^2) + g_2(x,Q^2)\Big)\cos\phi\Big]$$

$\gamma^2 = \frac{4x^2M^2}{Q^2}$

- $\psi = 0$ OR π, i.e. $\vec{S}_e \parallel \vec{S}_N \Rightarrow \Delta\sigma_{\parallel} \sim g_1$
- $\psi = \pm\frac{\pi}{2}$, i.e. $\vec{S}_e \perp \vec{S}_N \Rightarrow \Delta\sigma_{\perp} \sim \frac{y}{2} g_1 + g_2$

- **CROSS SECTION ASYMMETRIES RELATED TO VIRTUAL PHOTON ASYMMETRIES**

$$A_{\parallel} = \frac{\Delta\sigma_{\parallel}}{2\bar{\sigma}} = \frac{2x(1+R)}{(1+\gamma^2)}\frac{(g_1 - \gamma^2 g_2)}{F_2} = D\,(A_1 + \eta A_2)$$

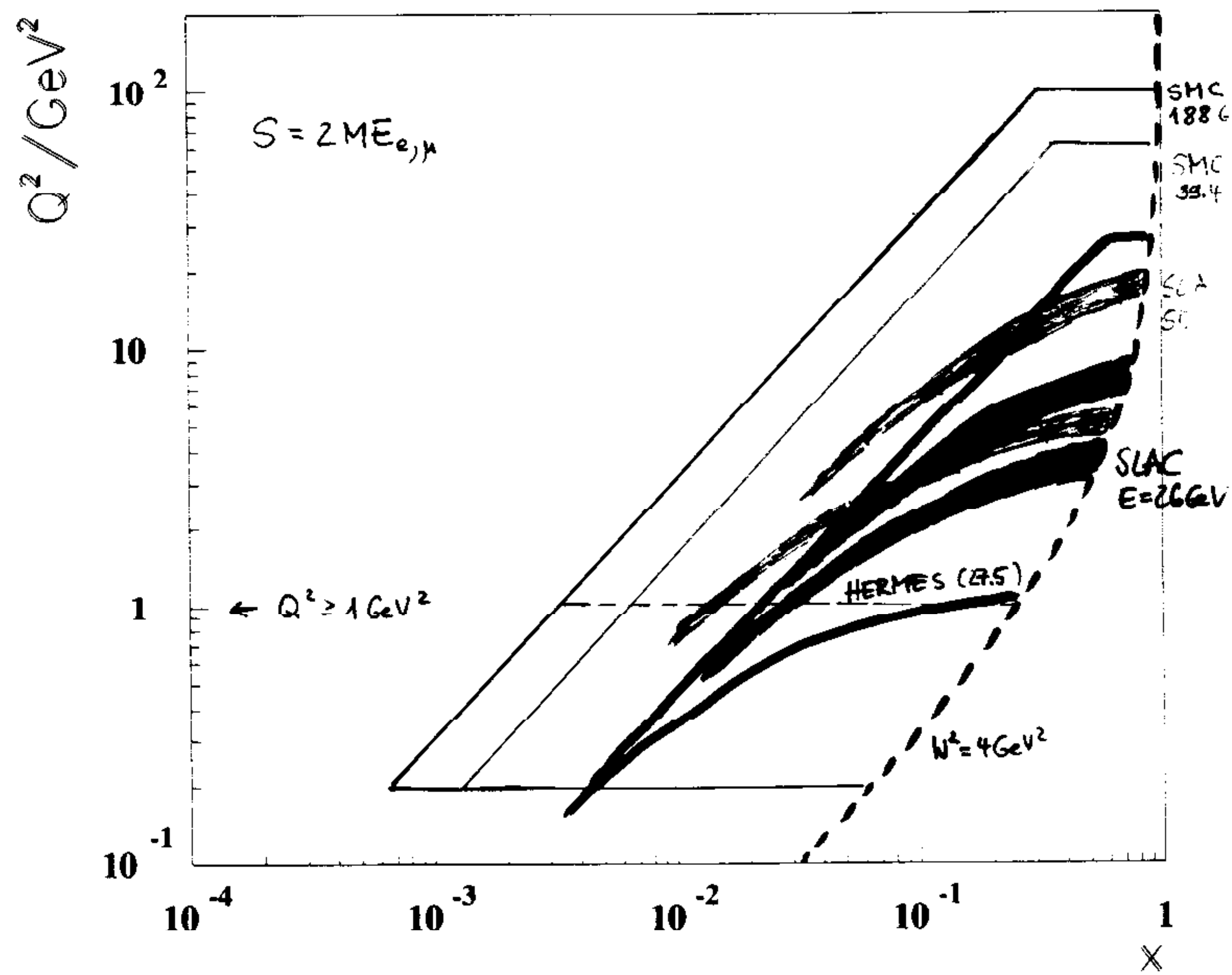
$$A_{\perp} = \frac{\Delta\sigma_{\perp}}{2\bar{\sigma}} = \frac{2x(1+R)}{(1+\gamma^2)}\frac{\gamma\,(g_1 + g_2)}{F_2} = d\,(A_2 - \xi A_1)$$

WITH BEHAVIOUR FOR $x \to 1$

$|A_1| \leq 1$

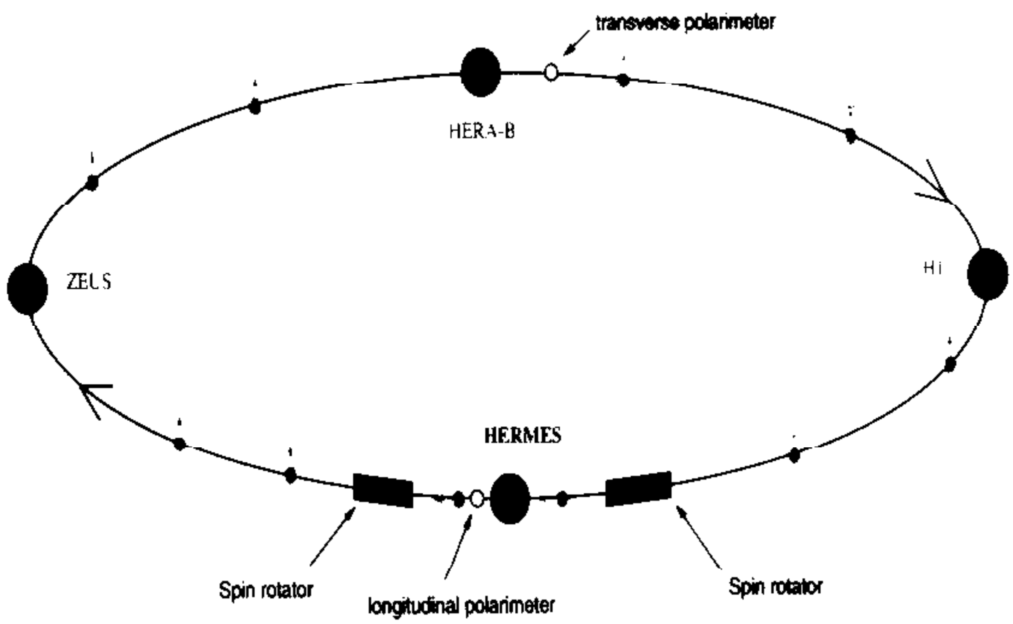
$|A_2| \leq \sqrt{R}$

EXPERIMENTAL STATUS

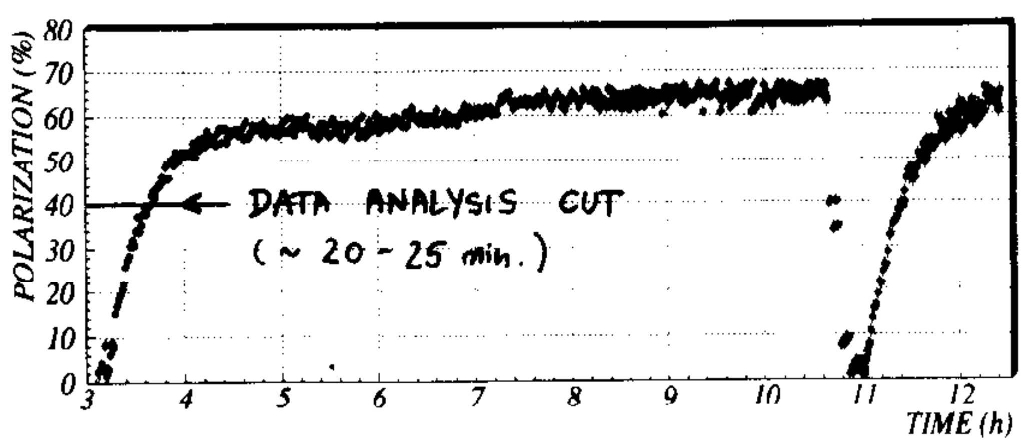


HERMES
SPIN PHYSICS FACILITY AT HERA

- BEAM
  - + $E = 27.5$ GeV e^+
  - + SELF POLARIZATION
    (SOKOLOV-TERNOV-EFFECT, $P_{max} = 92.4\%$)
  - + $\langle P \rangle_{BEAM} = 55\% \pm 5.4\%$ (sys.)



+ POLARIZATION BUILDUP vs FILLS

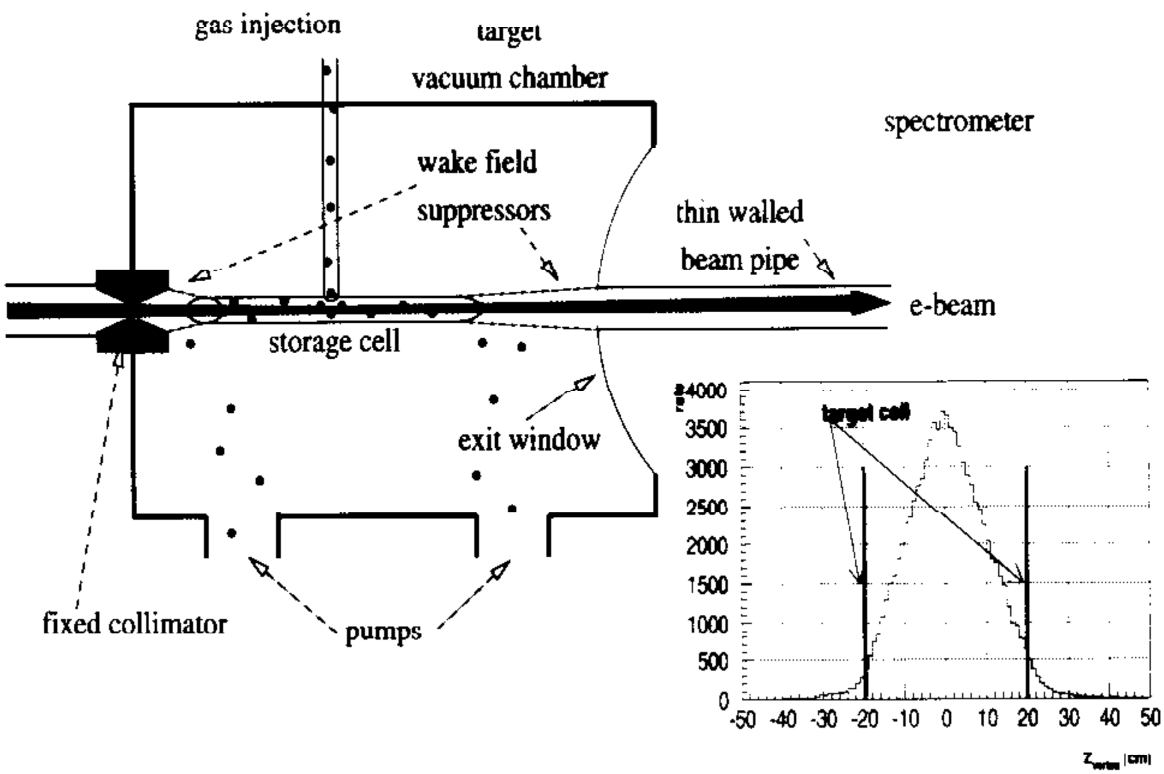


• INTERNAL ^{3}He GAS TARGET

+ POLARIZED ^{3}He SOURCE
  - PURE ^{3}He GAS
  - OPTICALLY PUMPED (SPIN EXCHANGE COLLISIONS)
  - LOW MAGNETIC HOLDING FIELD ~3.5 mT

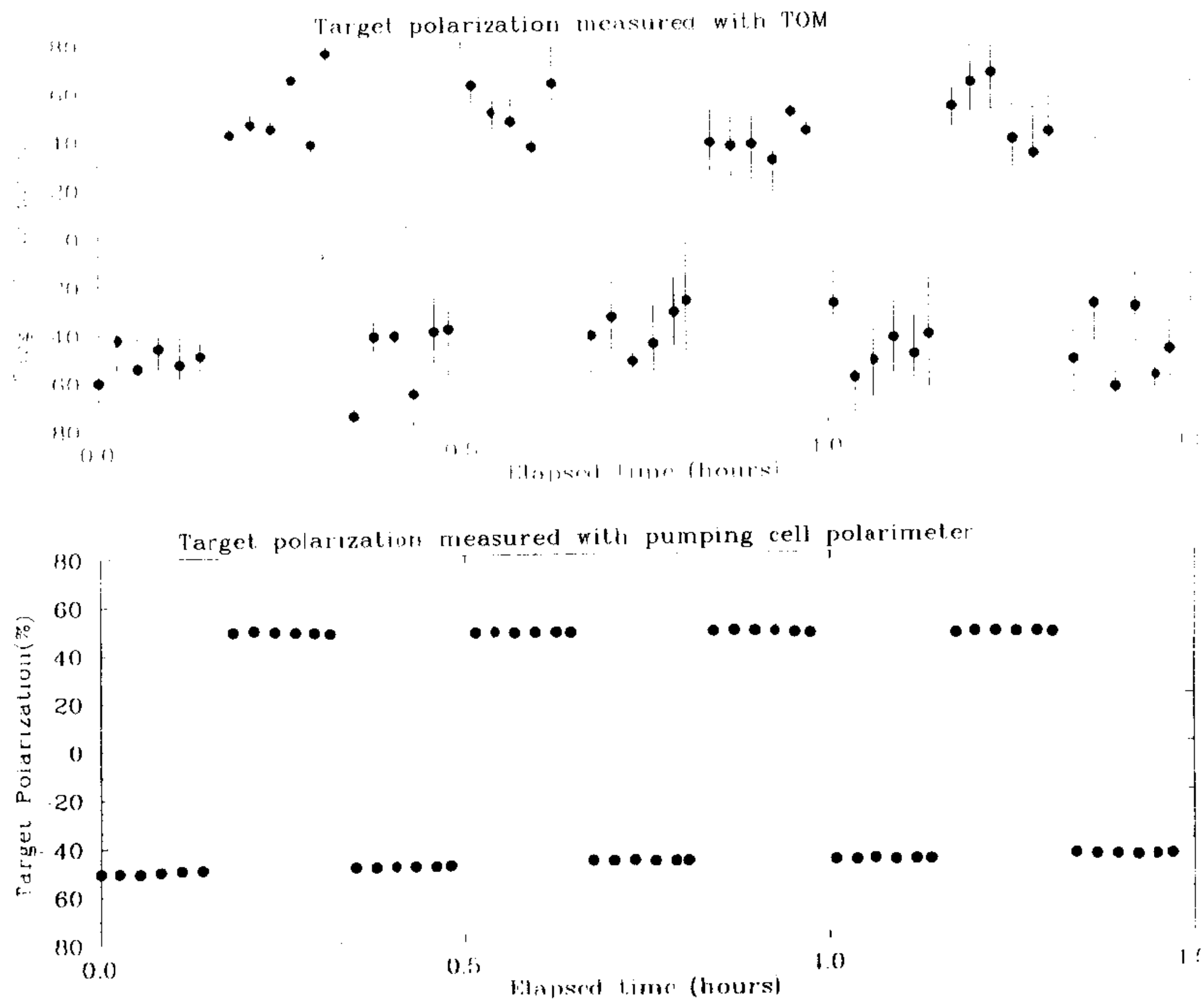
+ STORAGE CELL
  - ULTRA-THIN WALLS ($\lesssim 125\,\mu m$)
  - CRYOGENICALLY COOLED TO ~25 K

  $\Rightarrow$ $\sim 3.3 \cdot 10^{14} \cdot 3$ NUCLEONS /cm²

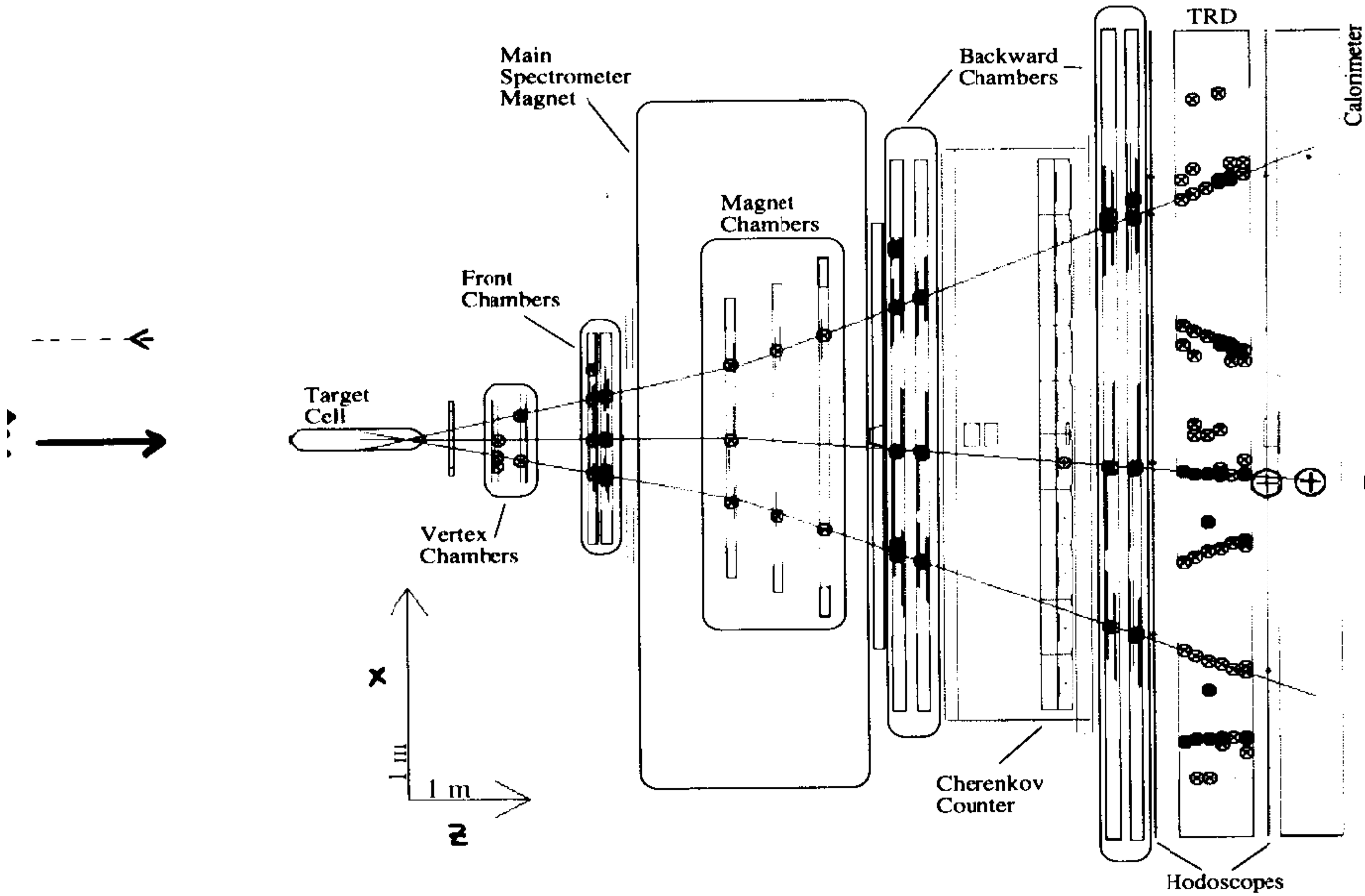


+ SWITCH OF TARGET POLARIZATION DIRECTION
  ~10 min. BY REVERSAL OF LASER HELICITY

+ $\langle P \rangle_{TARGET} \simeq 46\,\% \pm 5\,\%$ (sys.)


Target polarization measured with TOM
Elapsed time (hours)
Target polarization measured with pumping cell polarimeter
Target Polarization(%)
80
60
40
20
0
-20
-40
-60
-80
0.0
0.5
1.0
1.5
Elapsed time (hours)

THE HERMES DETECTOR



$\theta_y > 40$ mr

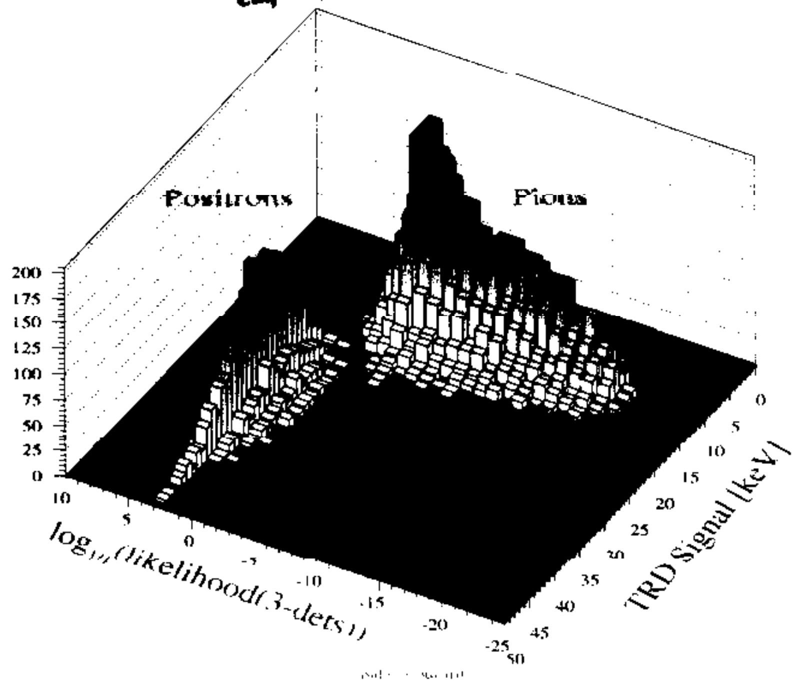
$E' > 3.5$ G

HUTA@HYDRA APR07/15:05

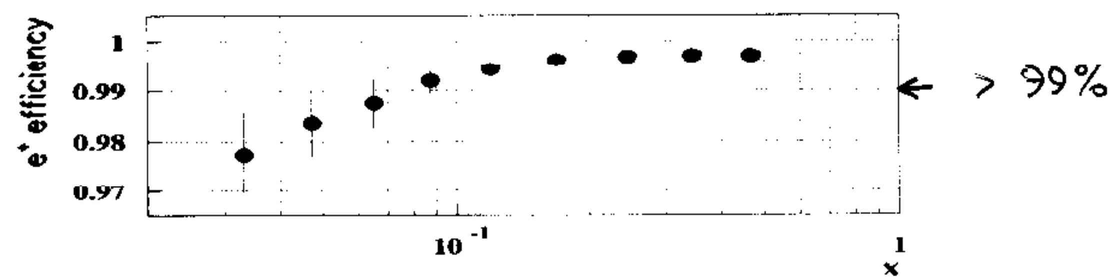
PARTICLE IDENTIFICATION

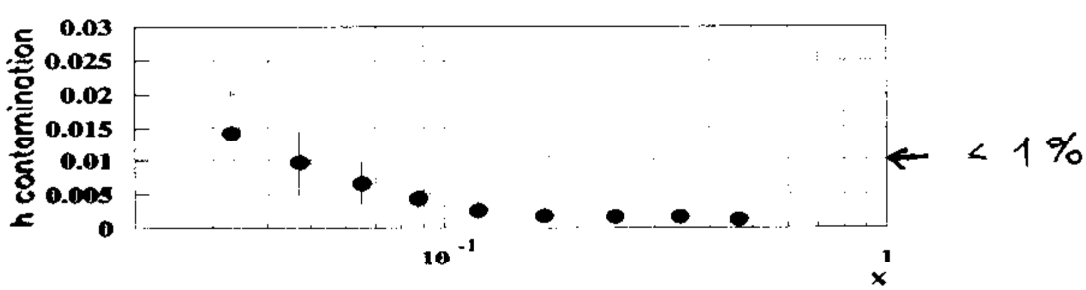
- POSITRON / PION SEPARATION

$$PID_3 = \log_{10} \frac{\prod_{i=1}^{3} P_i^e}{\prod_{i=1}^{3} P_i^h}$$



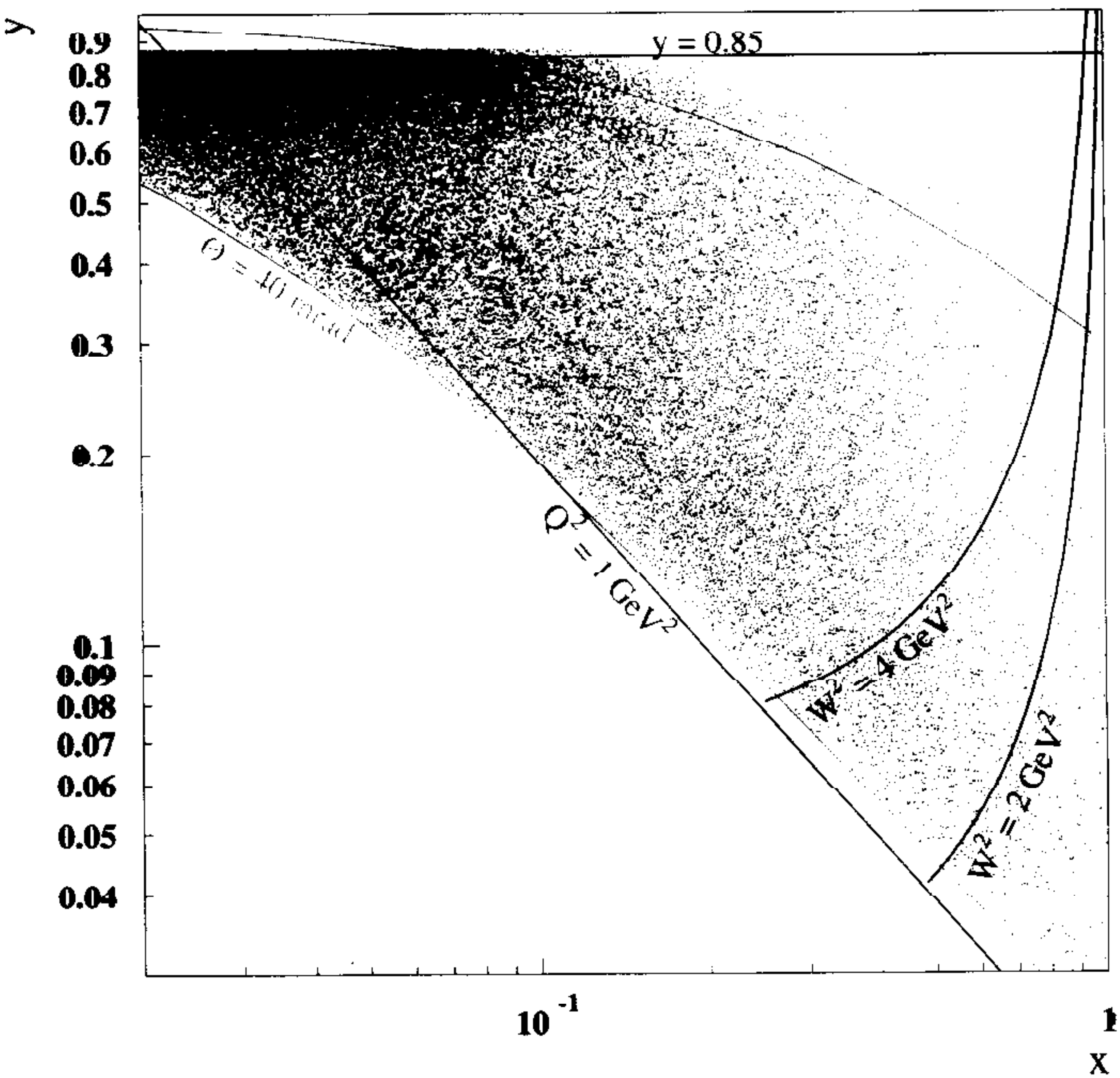
- POSITRON EFFICIENCY & HADRON CONTAMINATIC

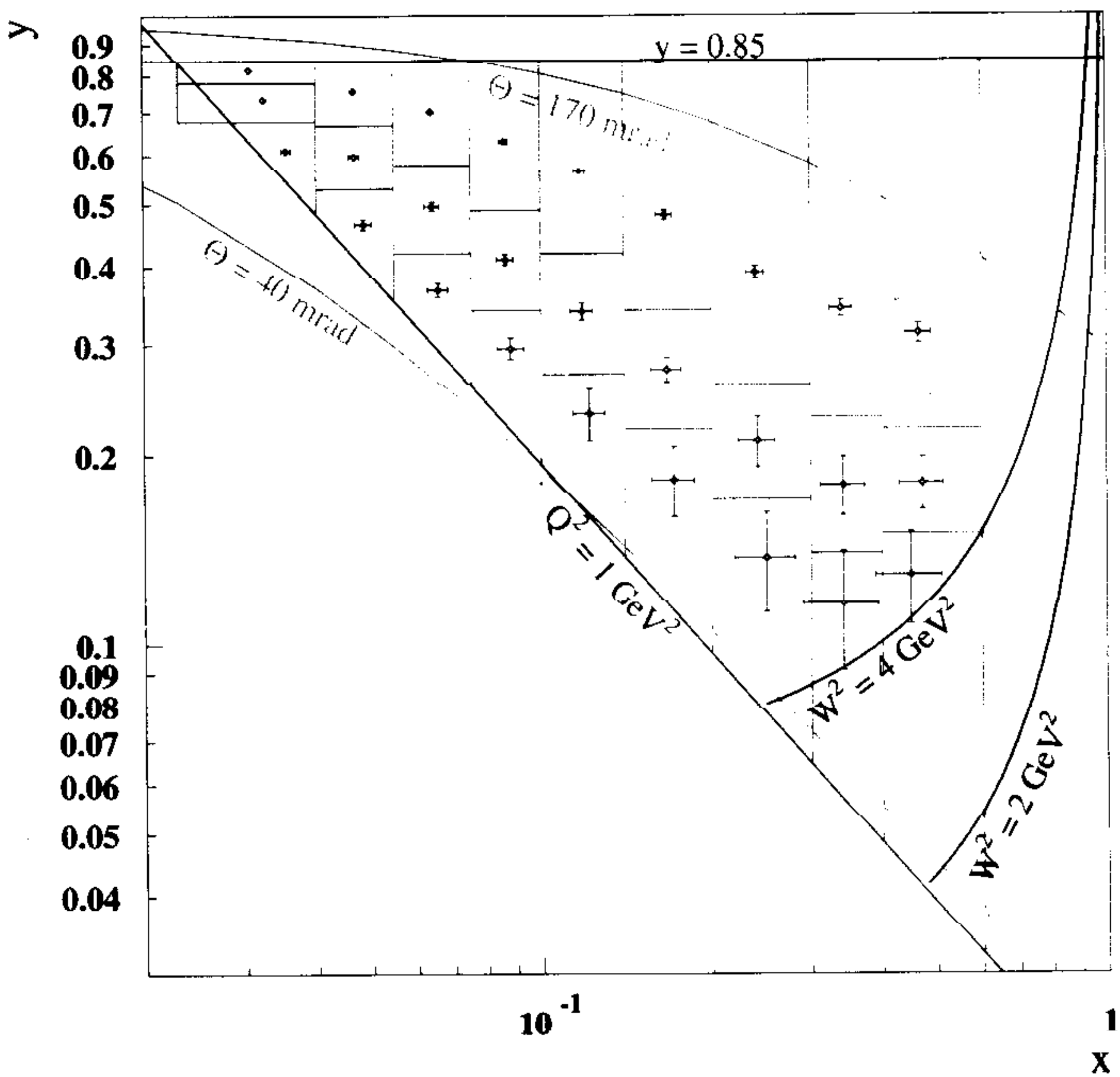




HERMES DATA 1995

- $\sim 5 \cdot 10^6$ DIS CANDIDATES
- $\langle P_{BEAM} \cdot P_T \rangle \simeq 25\%$





- BINNING IN X,Y PLANE
- ~ 13·10⁶ EVENTS PER SPINSTATE FOR ANALYSIS

MEASUREMENT OF A_1^{3He} / A_1^{n}

$$A_1^{3He} = \frac{1}{D} \cdot \frac{1}{\langle P_{BEAM} \cdot P_T \rangle} \cdot \frac{1}{\varepsilon} \frac{\left(\frac{N}{L}\right)^{\uparrow\downarrow} - \left(\frac{N}{L}\right)^{\uparrow\uparrow}}{\left(\frac{N}{L}\right)^{\uparrow\downarrow} + \left(\frac{N}{L}\right)^{\uparrow\uparrow}}$$

- ε : DEAD TIME CORRECTION ($\langle\varepsilon\rangle \simeq 90\%$)
- ASSUME : $\varepsilon^{\uparrow\downarrow} = \varepsilon^{\uparrow\uparrow}$

  $\mathcal{A}_{cc}^{\uparrow\downarrow} = \mathcal{A}_{cc}^{\uparrow\uparrow}$

  $A_2^{3He} = 0$

- BACKGROUND CORRECTIONS
  (PAIR PRODUCTION, HADRON CONTAMINATION)

- RADIATIVE CORRECTIONS

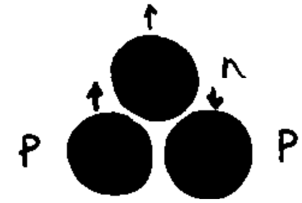
  $A_1^{3He,c} = A_1^{BORN} + \Delta A_1^{RC}$

  POLRAD [I.V. AKUSHEVICH, N.M. SHUMEIKO, J.P. G20 (1994) 513;
  PHYSICS OF ATOMIC NUCLEI 58 (1995) 1919]

  + COMPARISON OF INELASTIC TAIL CONTRIBUTION
    WITH HECTOR CODE
    [A. ARBUZOV et al., C.P.COMM. 94 (1996) 128;
    polARIZED ep : D. BARDIN et al., hep-ph / 9609399 (1996)]

- **NUCLEAR CORRECTIONS**

  INCLUDING PROTON CONTRIBUTIONS TO THE POLARIZATION OF ^3He



$$A_1^n = \frac{A_1^{3He,\,Born} - 2\,P_p^{3He}\,A_1^p\,f_p}{P_n^{3He}\,f_n}$$

- $f_{n/p} = \dfrac{F_2^{p/n}}{2F_2^p + F_2^n}$

  $P_n^{3He} = 0.86 \pm 0.02$

  $P_p^{3He} = -0.028 \pm 0.004$

  [J.L. FRIAR ET AL., PR C42 (1990) 2310;
  C. CIOFI DEGLI ATTI et al., PR C48 (1993) R968]

- A_1^p - PARAMETERIZED SLAC / SMC DATA

  [K. ABE et al., PRL 74 (1995) 346]

- $F_2^n = 2F_2^d - F_2^p$

  NMC FIT TO NMC, SLAC, BCDMS DATA

  [M. ARNEODO et al., PL B364 (1995) 107]

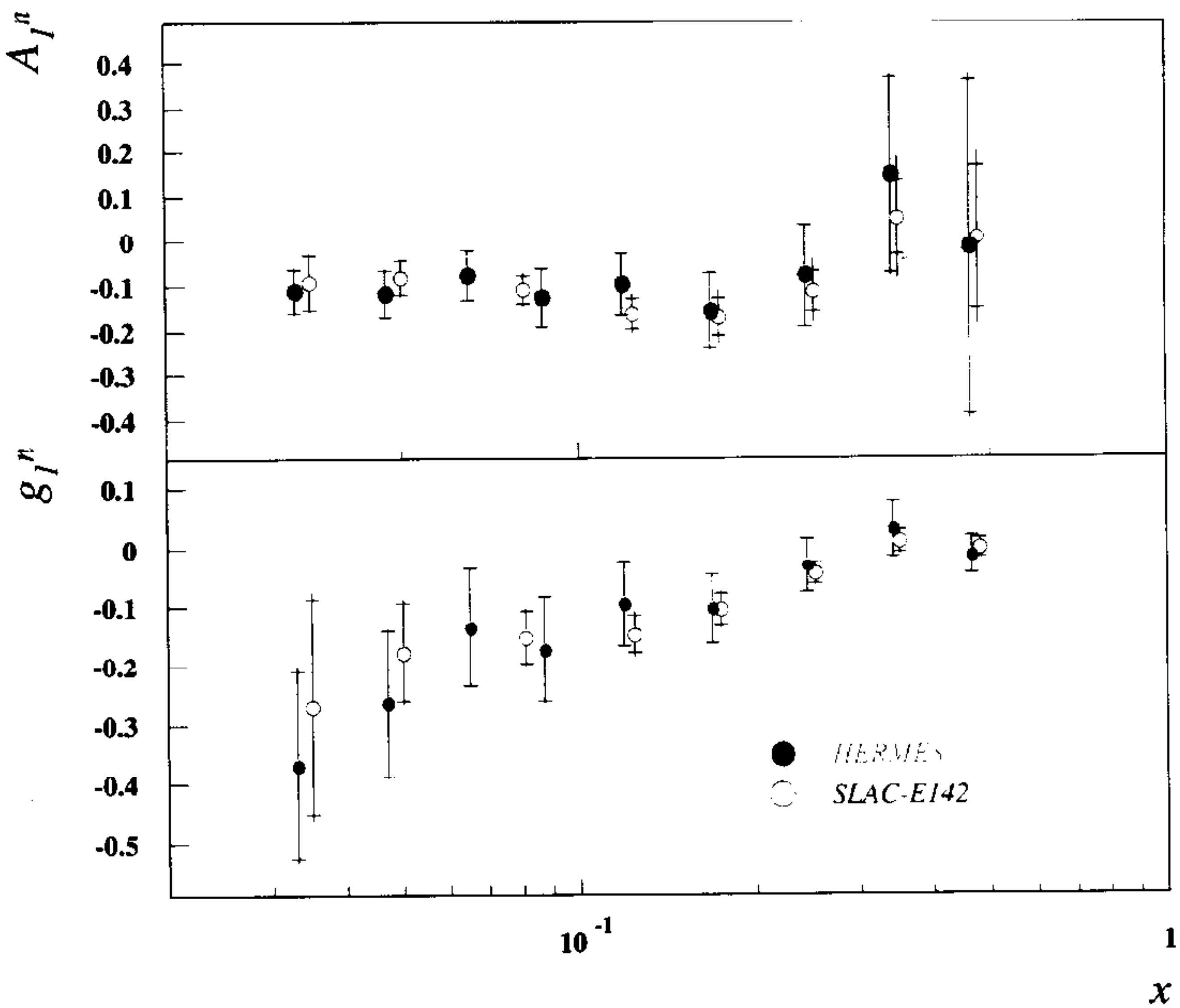
$$g_1^n = A_1^n \frac{F_2^n}{2x(1+R)}$$

R – SLAC PARAMETERIZATION

[L.W. WHITLOW et al., PL B250 (1990) 193]

- **SYSTEMATIC ERRORS FOR g_1^n**

+	POLARIZATION	: 6 - 8%
+	RADIATIVE CORRECTIONS	: 3 - 9%
+	NUCLEAR CORRECTIONS	: 3 - 9%
+	R, F_2^n, A_2	: 1 - 3%
		11 - 17 %



A_1^n
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
g_1^n
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
HERMES
SLAC-E142
10^{-1}
1
x

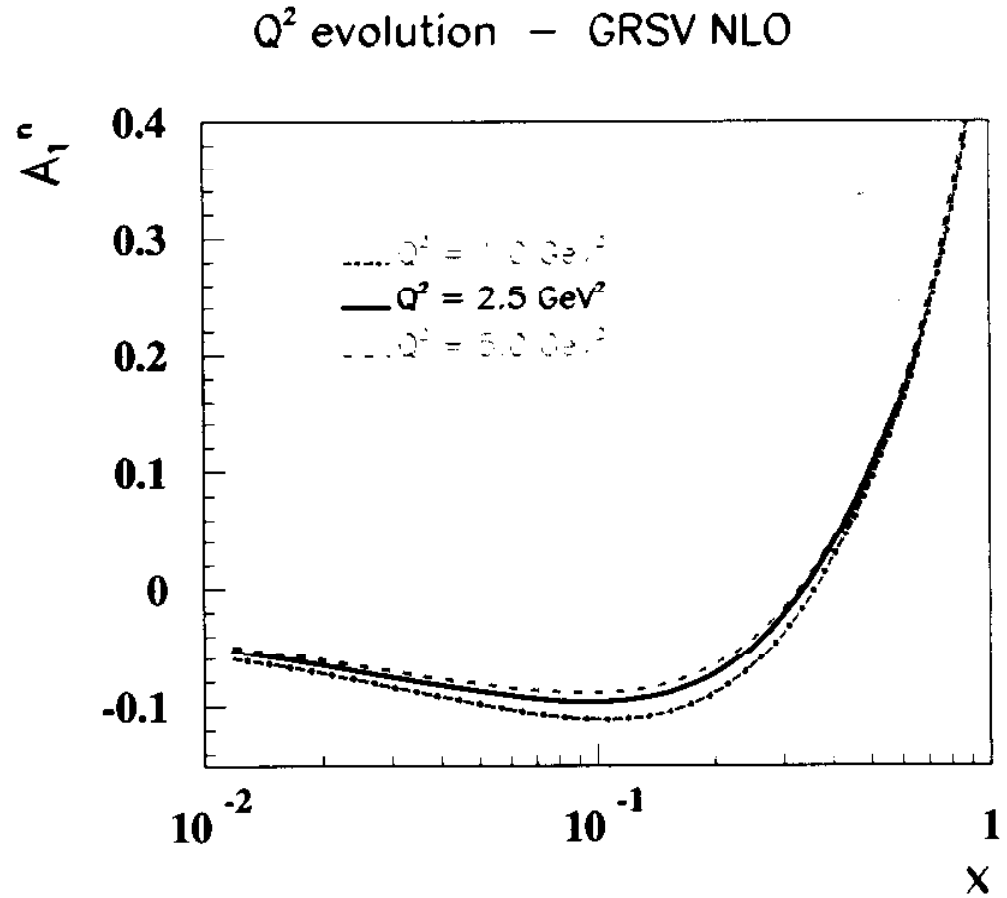
EVALUATION OF Γ_1^n AT $Q_0^2 = 2.5\ GeV^2$

- ASSUME A_1^n = CONST (x)

  NEGLECT Q^2 EVOLUTION ACC. TO pQCD

  [R.D. BALL et al., PL. B372 (1996) 255;

  M. GLÜCK et al., PR D53 (1996) 4775]



- MEASURED REGION $0.023 < x < 0.6$

$$\int_{0.023}^{0.6} g_1^n(x, Q_0^2)\, dx = -0.034 \pm 0.013\,(\text{stat.}) \pm 0.005\,(\text{sys.})$$

• EXTRAPOLATIONS

- $x \to 1$ + LINEAR INCREASE TO $A_1^n = 1$
  + USE PARAMETERIZATIONS

$$\int_{0.6}^{1} g_1^n(x, Q_0^2)\,dx = 0.002 \pm 0.003$$

- $x \to 0$ + REGGE BEHAVIOUR $g_1 \propto x^{-\alpha}$
  $\alpha = -0.5 \ldots 0$

FITTED TO THE DATA $x < 0.1$ FOR $\alpha = 0$

$$\int_{0}^{0.023} g_1^n(x, Q_0^2)\,dx = -0.005 \pm 0.005$$

HERMES ($^3He \to n$) $Q_0^2 = 2.5\,GeV^2$

$$\Gamma_1^n = \int_0^1 g_1^n(x, Q_0^2)\,dx = -0.037 \pm 0.013\,(stat) \pm 0.005\,(sys.) \pm 0.006\,(extrapol.)$$

E142 ($^3He \to n$) $Q_0^2 = 2\,GeV^2$

$$\Gamma_1^n = -0.031 \pm 0.006\,(stat) \pm 0.09\,(sys. + extrapol.)$$

SUMMARY

THE POLARIZED NEUTRON STRUCTURE FUNCTION g_1^n WAS MEASURED IN THE KINEMATIC REGION $0.023 < x < 0.6$ AND $1 < Q^2 < 15\ GeV^2$ BASED ON DATA COLLECTED IN 1995 WITH ENTIRELY NEW TECHNIQUES.

THE OBSERVED g_1^n DECREASES TOWARDS LOW x AND LEADS TO AN EVALUATION OF Γ_1^n AT $Q_0^2 = 2.5\ GeV^2$ WHICH IS CONSISTENT WITH RESULTS OF SLAC AND SMC.

DURING 1996 HERMES WAS RUNNING WITH A POLARIZED HYDROGEN TARGET WHICH WILL PROVIDE RESULTS ON g_1^p AND THE BJORKEN SUM RULE.