PARTONDISTRIBUTIONS AND Λ_{QCD} AT HERA

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1. INTRODUCTION

HERA: $\overset{(\pm)}{e}p \rightarrow \begin{pmatrix} \overset{(-)}{\nu}_e \\ e^{(\pm)} \end{pmatrix} X$

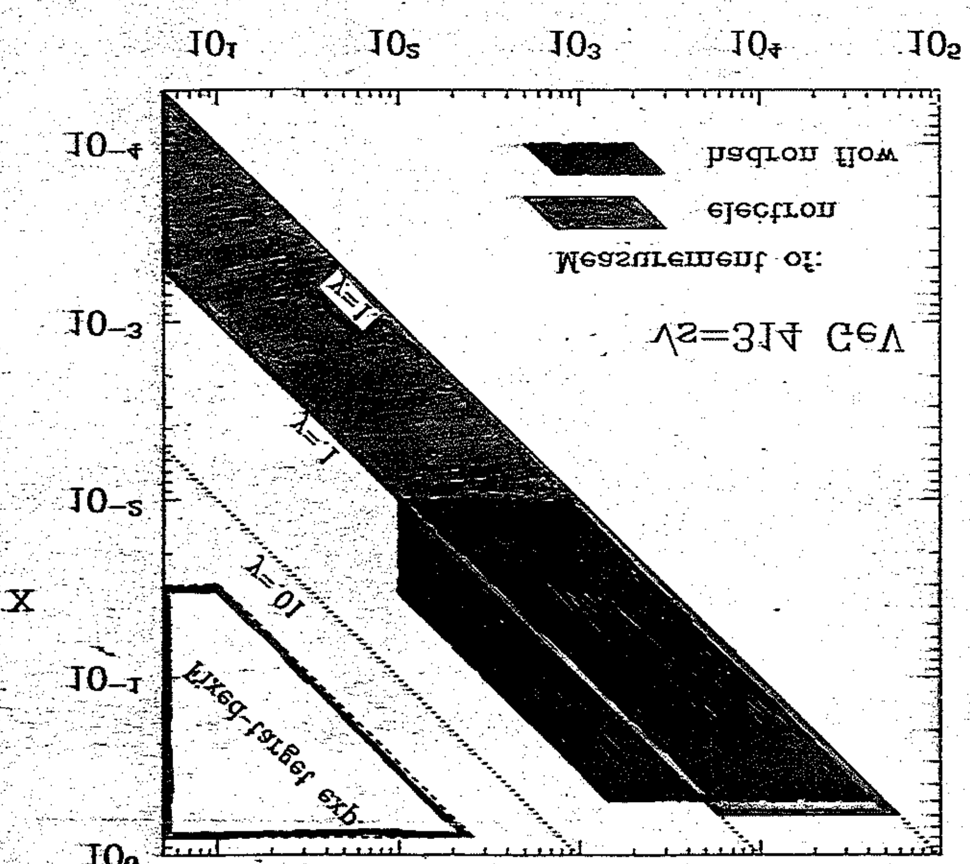
$S = 4 \cdot 30 \cdot 820 \ \mathrm{GeV}^2$

$\mathcal{L} = 1.5 \cdot 10^{31} \ \mathrm{cm}^{-2} \mathrm{sec}^{-1}$

$\hookrightarrow 200 \ \mathrm{pb}^{-1} \simeq 150$ fully efficient days.

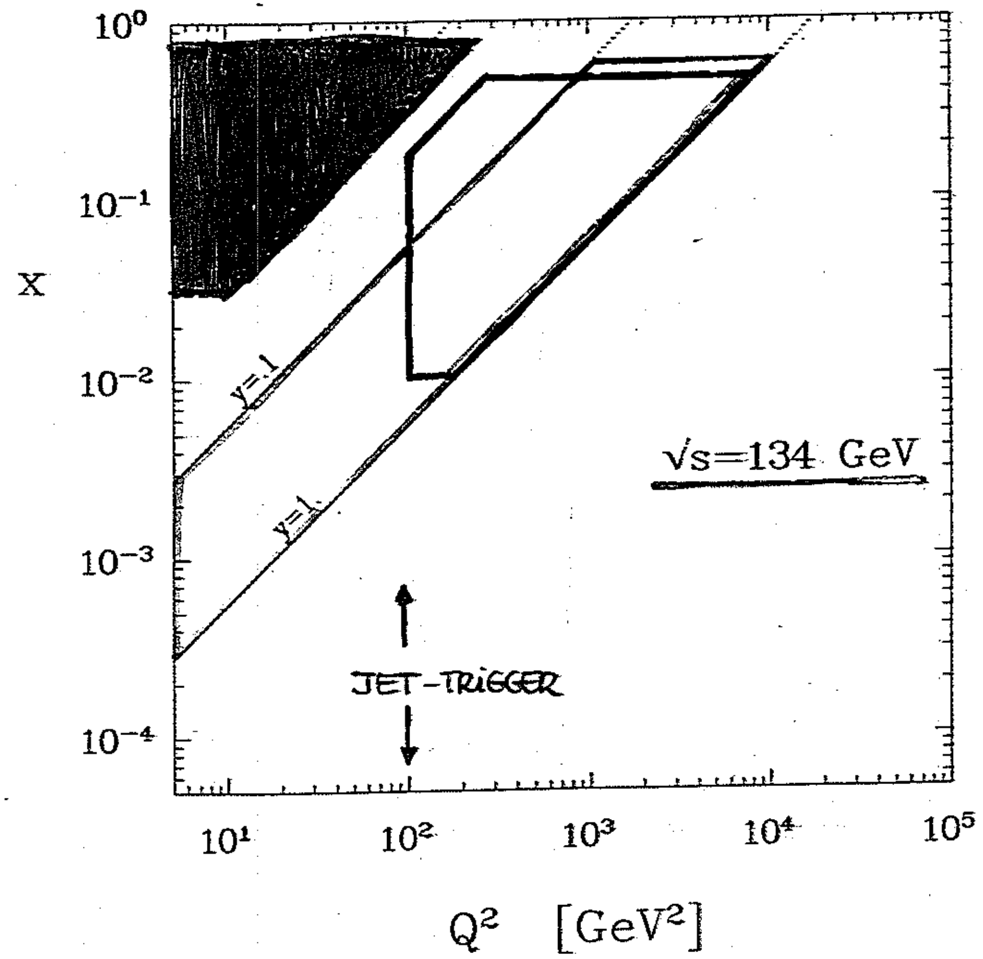
- BOTH x & Q^2 - RANGES ARE EXTENDED BY TWO ORDERS OF MAGNITUDE
  - $x \sim 10^{-4}$
  - $Q^2 \sim O(10^4 \ \mathrm{GeV}^2)$

- WIDE RANGE IN Q^2 FOR QCD TEST
- HUGHE STATISTICS AT LOW x (NC)
- $e^{\pm}p \rightarrow \overset{(-)}{\nu}_e X$ MEASURABLE AT HIGH Q^2.



hadron flow
electron
Measurement of:
√s=314 GeV
y=1
y=.1
y=.01
fixed-target exp
x
10^-4
10^-3
10^-2
10^-1
10^0
10^1
10^2
10^3
10^4
10^5
Q^2 [GeV^2]

Fig. 1



10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
x
y=.1
y=1
√s=134 GeV
JET-TRIGGER
10^1
10^2
10^3
10^4
10^5
Q^2 [GeV^2]

5 ORDERS OF MAGNITUDE IN Q^2

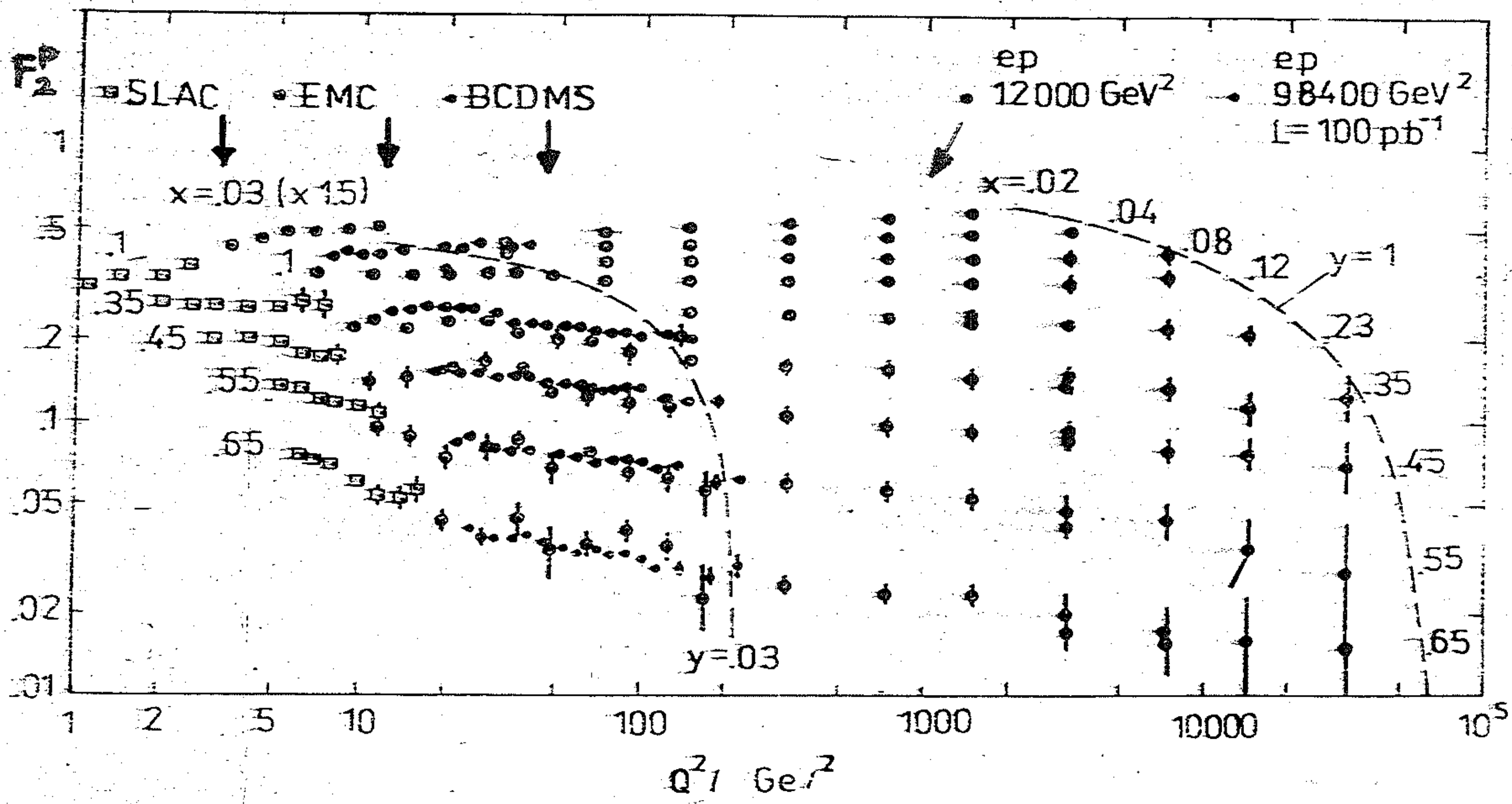


Fig. 6

2. QUARKDISTRIBUTIONS AT HIGH Q^2

FROM 4 CROSS SECTIONS (AT HERA)

$$\frac{d^2\sigma_{NC}^{e^+p}}{dx\,dy} \quad \frac{d^2\sigma_{NC}^{e^-p}}{dx\,dy} \qquad \frac{d^2\sigma_{CC}^{e^+p}}{dx\,dy} \quad \frac{d^2\sigma_{CC}^{e^-p}}{dx\,dy}$$

4 COMBINATIONS OF QUARK-DISTRIBUTIONS CAN BE UNFOLDED IN PRINCIPLE.

- NOTE, HOWEVER, THAT $\sigma_{NC}^{e^+p}$ & $\sigma_{NC}^{e^-p}$ ARE <u>ALMOST IDENTICAL AT LOW Q^2</u> ($Q^2 \lesssim 1000\ \mathrm{GeV}^2$)
- , THAT A REASONABLE CC-STATISTICS CAN ONLY BE MEASURED AT <u>HIGH Q^2</u> ($Q^2 \gtrsim 500\ \mathrm{GeV}^2$)

<u>TWO METHODS:</u> (J.B., M. Klein, T. Naumann, T. Riemann, HERA proc. I, p.69 ; G. Ingelman, R. Rückl, Z. Phys. C in press) DESY 89-25

- EXACT UNFOLDING: e.g.

$$\begin{pmatrix} \sigma_{NC}^{e^+p} \\ \sigma_{NC}^{e^-p} \\ \sigma_{CC}^{e^+p} \\ \sigma_{CC}^{e^-p} \end{pmatrix} = \left(A_{ij}(y, Q^2)\right) \begin{pmatrix} u_v \\ d_v \\ \sum_i u_i + \bar{u}_i \\ \sum_i d_i + \bar{d}_i \end{pmatrix}$$

- APPROXIMATE REPRESENTATIONS:

e.g.

$$\sigma_{CC}^{e^-p} \propto x u_v \quad , \quad \sigma_{CC}^{e^+p} \propto x d_v \quad , \quad x \gtrsim .25$$

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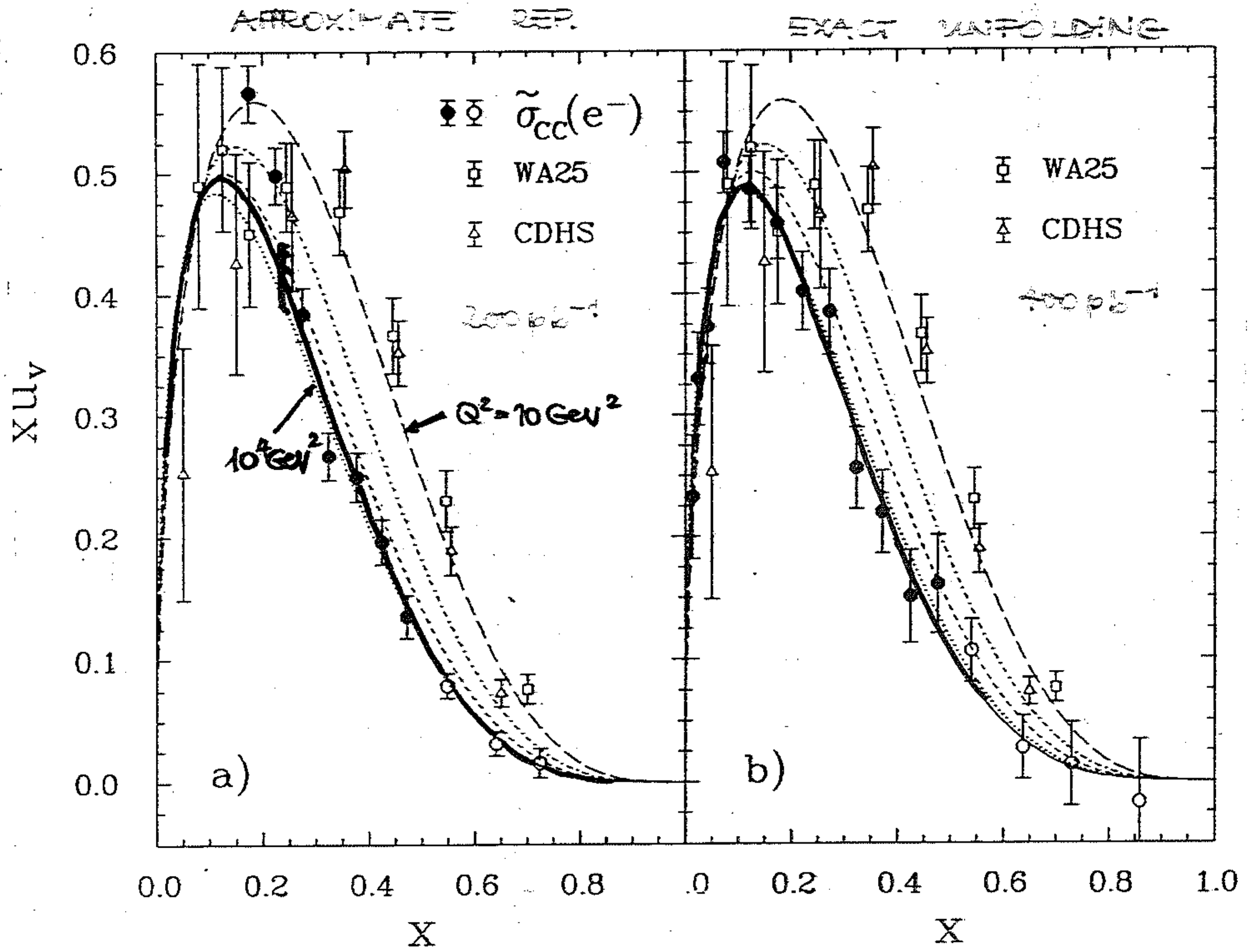
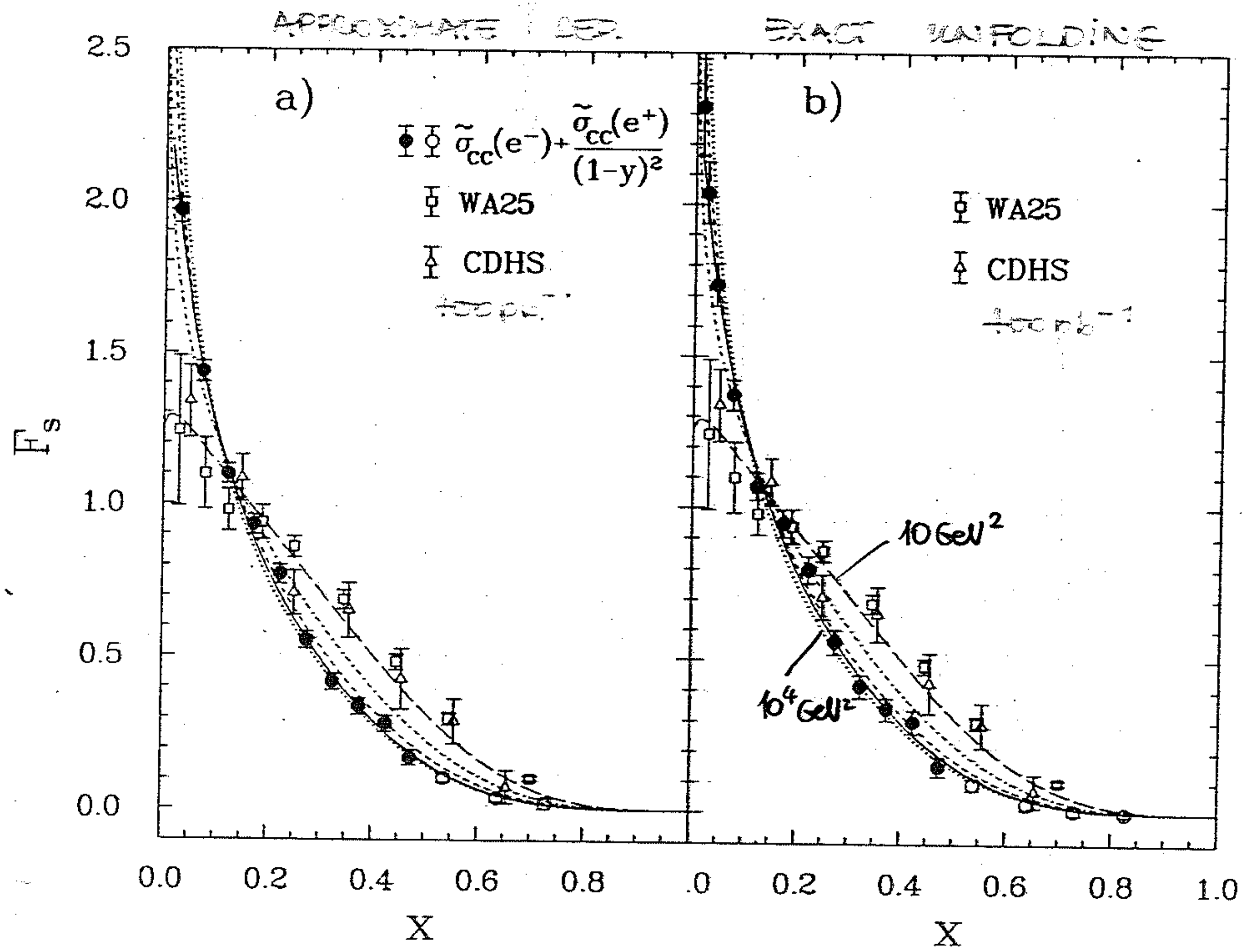




$F_s = x \sum_i (q_i + \bar{q}_i)$

3. Λ_{QCD} & $\alpha_s(Q^2)$ *)

$$F(x,Q^2) = a\, F_{NS}(x,Q^2) + b\, F_S(x,Q^2)$$

$$\frac{\partial}{\partial t} F_{NS}(x,t) = P_{qq}(x) \otimes F_{NS}(x,t) \qquad (N)$$

$$\frac{\partial}{\partial t} \begin{pmatrix} F_S(x,t) \\ G(x,t) \end{pmatrix} = \begin{pmatrix} P_{qq}(x) & 2N_f\, P_{qG}(x) \\ P_{Gq}(x) & P_{GG}(x) \end{pmatrix} \otimes \begin{pmatrix} F_S(x,t) \\ G(x,t) \end{pmatrix} \qquad (S)$$

$$t = \frac{2}{\beta_0} \ln\left[\ln(Q^2/\Lambda^2) / \ln(Q_0^2/\Lambda^2) \right] \quad ; \quad \beta_0 = 33 - 2N_f$$

AMONG THE COMBINATIONS OF PARTONDISTRIBUTIONS WHICH CAN BE EXTRACTED AT HERA

$u_v,\ d_v,\ u_v \pm d_v,\ e_u u_v - e_d d_v,\ \sum_i (q_i + \bar{q}_i),\ \sum_i (u_i + \bar{u}_i),\ \sum_i (d_i + \bar{d}_i),$
$F_2 = \sum_i e_i^2 (q_i + \bar{q}_i)$ etc.

ONLY F_2 ALLOWS A MEANINGFUL QCD TEST.

$$F_2(x,Q^2) = \frac{1}{6}\, x\, \Delta_p(x,Q^2) + \frac{5}{18}\, x\, F_S(x,Q^2)$$

$$\Delta_p = \sum_i (u_i + \bar{u}_i - d_i - \bar{d}_i)$$

$$F_S = \sum_i (q_i + \bar{q}_i)$$

*) J.B., G. INGELMAN, M. KLEIN, R. RÜCKL, PHE 89-01, DESY 89-101.

i) STATISTICAL PRECISION :

MC-DATA : $\Lambda = 200$ MeV

$\sqrt{s}$ [GeV]	$\int \mathcal{L}\,dt$ [pb^{-1}]	Q^2_{min} [GeV^2]	x_{min}	FIT	Λ / MeV	RESTRICTED RANGE Λ/MeV
314	200	100	.25	(N)	145 ± 48	175 ± 176
			.01	(N) + (S)	297 ± 76	177 ± 135
			.01	-"-, $xG(Q_0^2)$ fix	215 ± 16	201 ± 25
	100	10	10^{-4}	(N) + (S)	196 ± 5	225 ± 25
134	100	20	.25	(N)	200 ± 47	460 ± 263
			.01	(N) + (S)	211 ± 27	227 ± 58

ii) SYSTEMATIC EFFECTS :

- RESTRICTED RANGE : SMEARING EFFECTS $\leq 10\%$

  J. FELTESSE

- CALIBRATION UNCERTAINTIES OF THE ELECTROMAGNETIC & HADRONIC CALORIMETER

$$\hat{E}_{e'} = E_{e'}(1+\varepsilon_e) \quad ; \quad \hat{E}_H = E_H(1+\varepsilon_h)$$

WE CONSIDER : a) $x \geq 10^{-2}$, $Q^2 \geq 100\ \mathrm{GeV}^2$: JET-MEASUREMENT

b) $10^{-4} \leq x \leq 10^{-2}$, $Q^2 \leq 100\ \mathrm{GeV}^2$: ELECTRON-MEASUREMENT

$$\left.\begin{array}{l} \text{a) } \Delta\Lambda = \pm 70\ \mathrm{MeV},\ \varepsilon_h = \pm 0.04 \\ \text{b) } \Delta\Lambda = \pm 45\ \mathrm{MeV},\ \varepsilon_e = \pm 0.01 \end{array}\right\} \text{ SCALES LINEARLY WITH } \varepsilon \text{ FOR } \varepsilon \ll 1.$$

STATISTICAL ERRORS AT $\int \mathcal{L}\, dt = 200\ \mathrm{pb}^{-1}$:

a) $\delta\Lambda = 135\ \mathrm{MeV}$

b) $\delta\Lambda = 25\ \mathrm{MeV}$ (LO QCD)

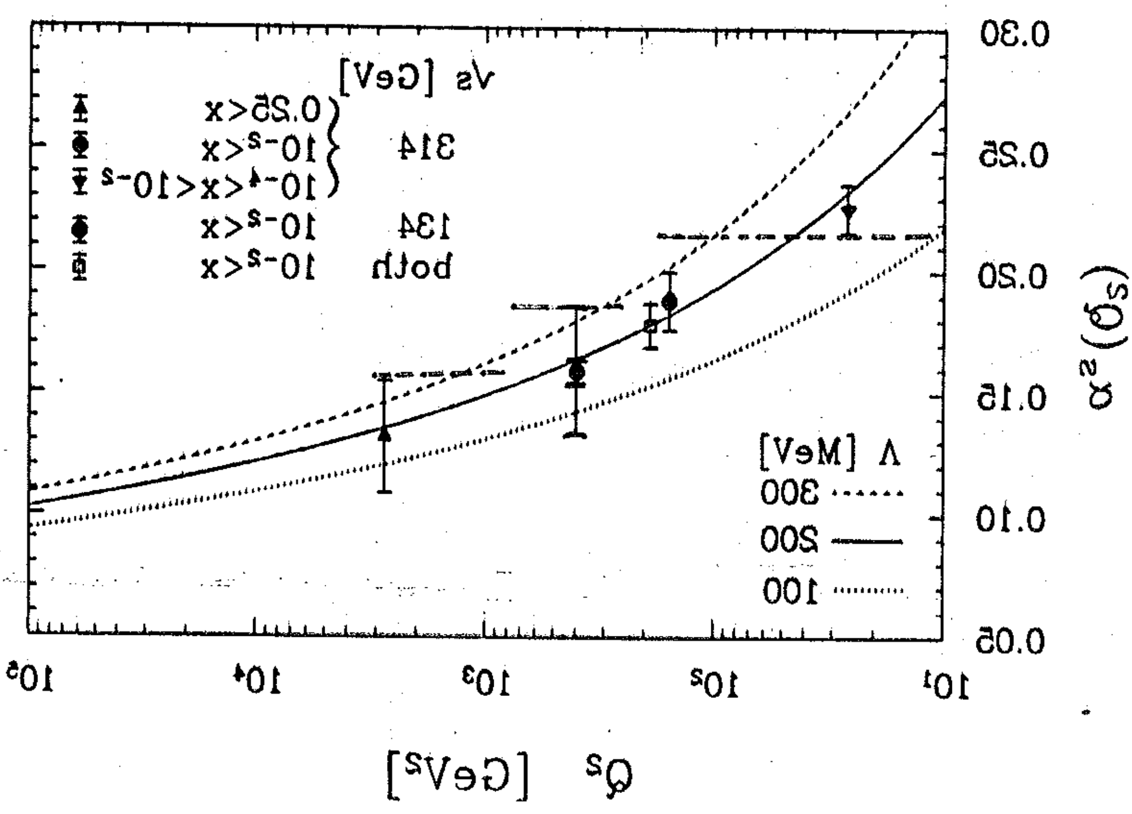

$\alpha_s(Q_s)$
Q^2 [GeV^2]
Λ [MeV]
300
200
100
$\sqrt{s}$ [GeV]
314
$0.25<x$
$10^{-2}<x$
$10^{-4}<x<10^{-2}$
134 $10^{-2}<x$
both $10^{-2}<x$

Fig. 8

4. THE GLUON DISTRIBUTION

a) QCD ANALYSIS : $xG(x, Q_0^2)$, $Q_0^2 = 4\,\mathrm{GeV}^2$

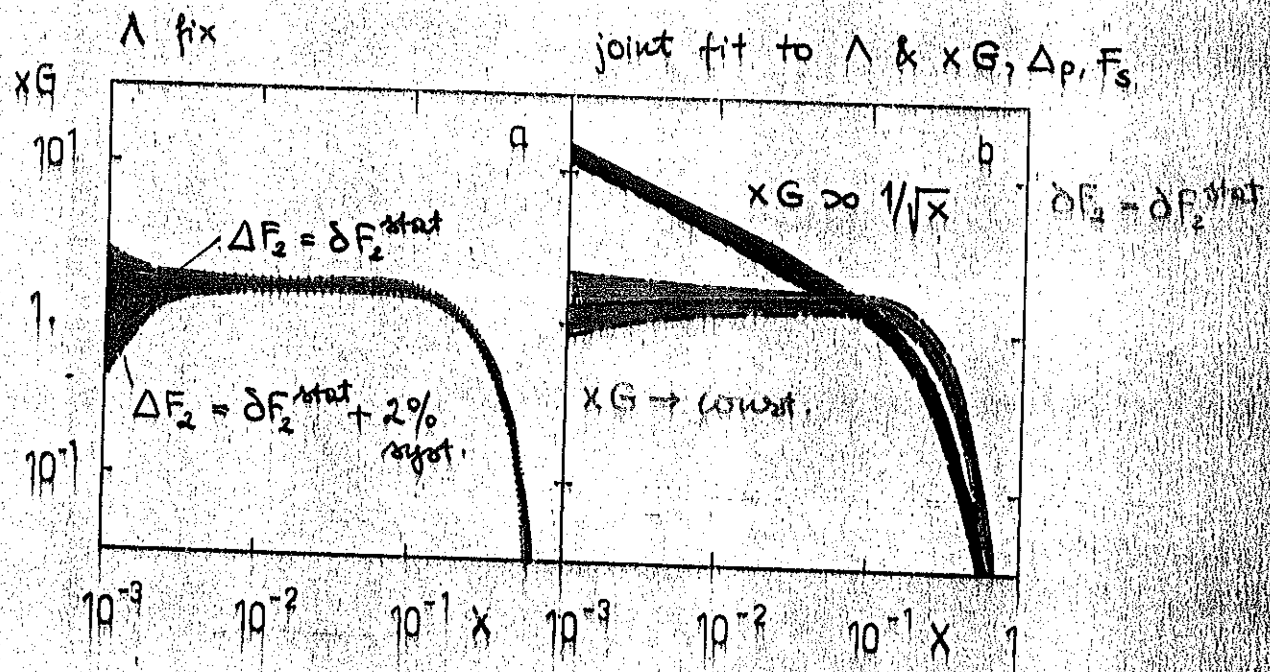
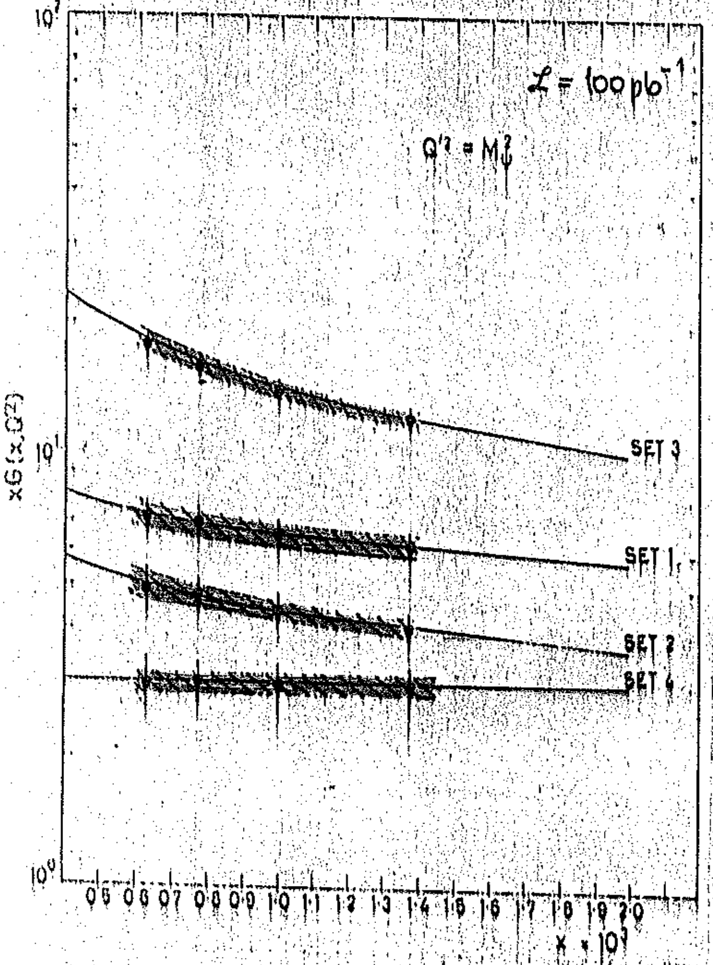
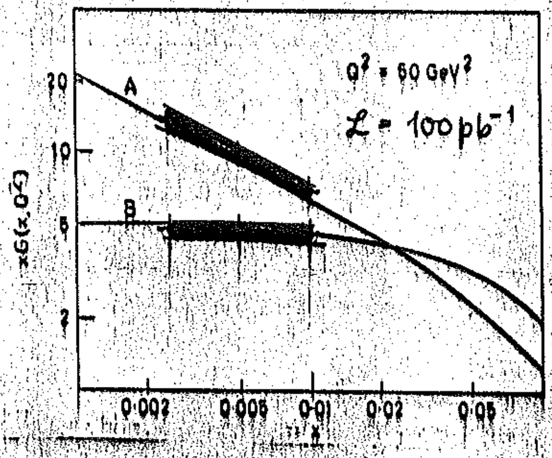


Fig. 4 a) xG(stat) and (stat. ⊕ syst.) for $\delta\Lambda = 0$
b) xG(stat) from joint fit of Λ and xG with xG(DO) and $xG \sim 1/\sqrt{x}$. ; $x \geq 10^{-3}$, $\mathcal{L} = 100\,\mathrm{pb}^{-1}$

J.B. et al. 'New theories in Physics', 1988, WS, p. 228



S.M. THACZYK et al. HERA '88, Vol. 1 p. 265



A.M. COOPER - SARKAR et al. HERA '88 Vol. 1, p. 231

b) J/ψ - PRODUCTION CROSSSECT.

$$\frac{d\sigma^{ep}_{J/\psi}}{dy} = \frac{1.5\,\alpha}{\pi}\,\frac{1}{y}\,Y_+\,\bar{x}\,G(\bar{x}, Q^2 = M_\psi^2) \times \log\frac{Q^2_{max}}{Q^2_{min}}\ nb$$

$$\bar{x} \sim 3.4\,M_\psi^2/S_1$$

//// NORMALIZATION UNCERTAINTY (ZEUS)

c) F_L - MEASUREMENT

$$F_L^{QCD}(x,Q^2) = \frac{\alpha_s}{4\pi}\cdot(I_1 + I_2)$$

$$I_1 = \frac{16}{3}\int_x^1 \frac{dy}{y}\left(\frac{x}{y}\right)^2 F_2(y,Q^2)$$

$$I_2 = 8\sum_i e_i^2 \int_x^1 \frac{dy}{y}\left(\frac{x}{y}\right)^2\left(1-\frac{x}{y}\right)\cdot G(y,Q^2)$$

d) γ-g - FUSION (d'Agostini et al, Seminar 'Physics at Future Colliders')

5. CONCLUSIONS

1. HERA WILL PROBE THE PROTON STRUCTURE VIA DEEP INELASTIC SCATTERING
   - UP TO $Q^2 \sim O(10^4\,\mathrm{GeV}^2)$
   - DOWN TO $x \sim 10^{-4}$
2. QUARK DISTRIBUTIONS CAN BE UNFOLDED FROM CROSS SECTIONS AS FUNCTIONS OF x FOR $Q^2 \sim 10^3 \ldots 10^4\,\mathrm{GeV}^2$.
3. THE LOW X RANGE $10^{-4} < x < 10^{-2}$ FOR $10 < Q^2 < 10^3\,\mathrm{GeV}^2$ COULD BECOME A NEW TESTING GROUND FOR QCD. $F_2(x, Q^2)$ CAN BE MEASURED THERE WITH HIGH STATISTICS. THERE ARE STILL MORE EFFORTS NEEDED TO WORK OUT THE THEORY OF QCD EVOLUTION IN THIS RANGE.
4. THE GLUON DISTRIBUTION CAN BE DETERMINED BY DIFFENT METHODS, PARTICULARLY AT LOW X.
5. THE PRECISE MEASUREMENTS OF THE ABOVE QUANTITIES ARE LONG TERM TASKS REQUIRING IN THE CASE OF THE QCD TEST TO CONTROL SYSTEMATICS AT THE PER CENT LEVEL.