STRUCTURE FUNCTION MEASUREMENT AND QCD-TESTS AT LEP×LHC

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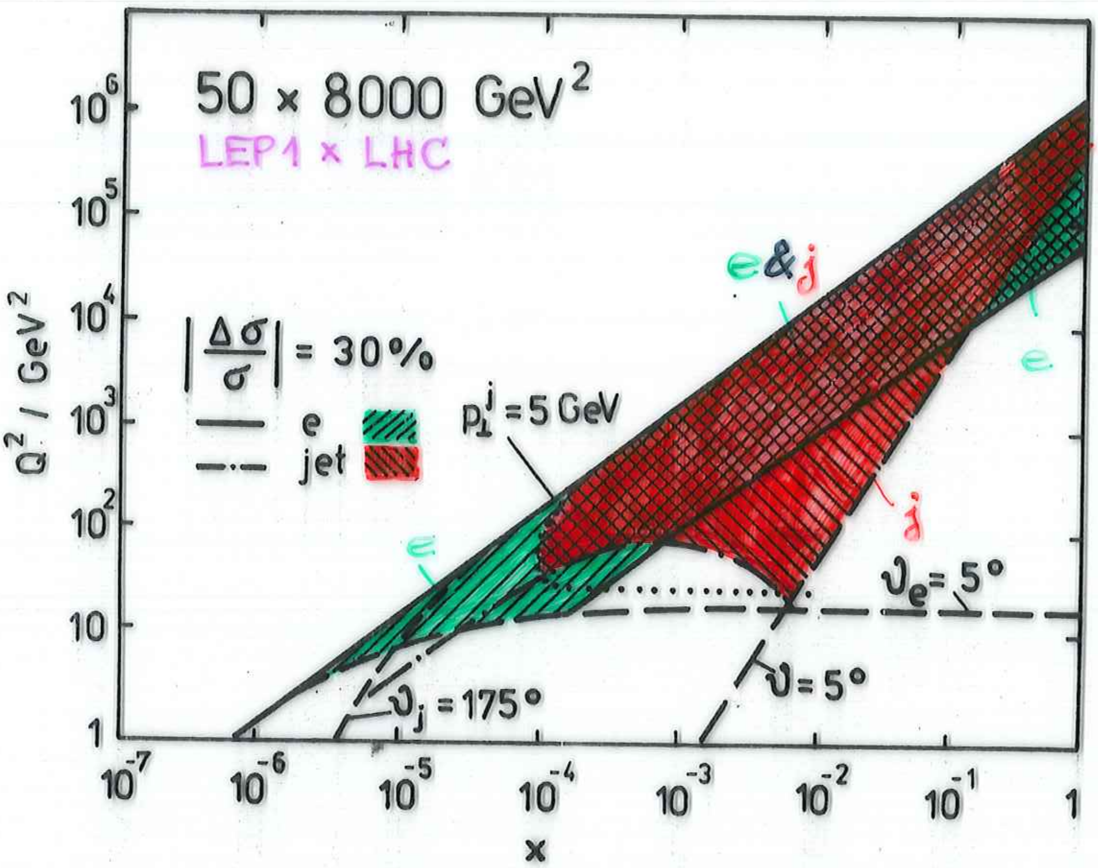
ZEUTHEN

- RADIATIVE CORRECTIONS AND JET MEASUREMENT

- MEASUREMENT OF STRUCTURE FUNCTIONS
- R-MEASUREMENT AND THE EXTRACTION OF xG
- QCD ANALYSIS
- CONCLUSIONS


50 × 8000 GeV²
LEP1 × LHC
Q² / GeV²
|Δσ/σ| = 30%
e
jet
e&j
e
j
e
p⊥ʲ = 5 GeV
ϑe = 5°
ϑ = 5°
ϑj = 175°
x

RADIATIVE CORRECTIONS AND JET MEASUREMENT

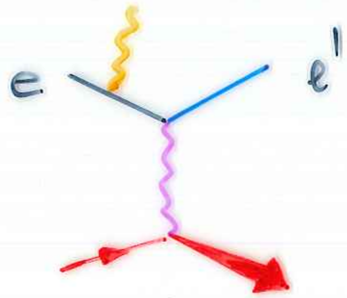
- WIDE KINEMATICAL RANGES, WHERE ONLY VIA JET MEASUREMENT x, Q^2, y ARE MEASURABLE

$\longrightarrow$ CHARGED CURRENT EVENTS

$\longrightarrow$ NEUTRAL CURRENT : $y < 0.1$

Fig

LEADING LOG DIAGRAMS :



ALL OTHERS ARE UNIMPORTANT!

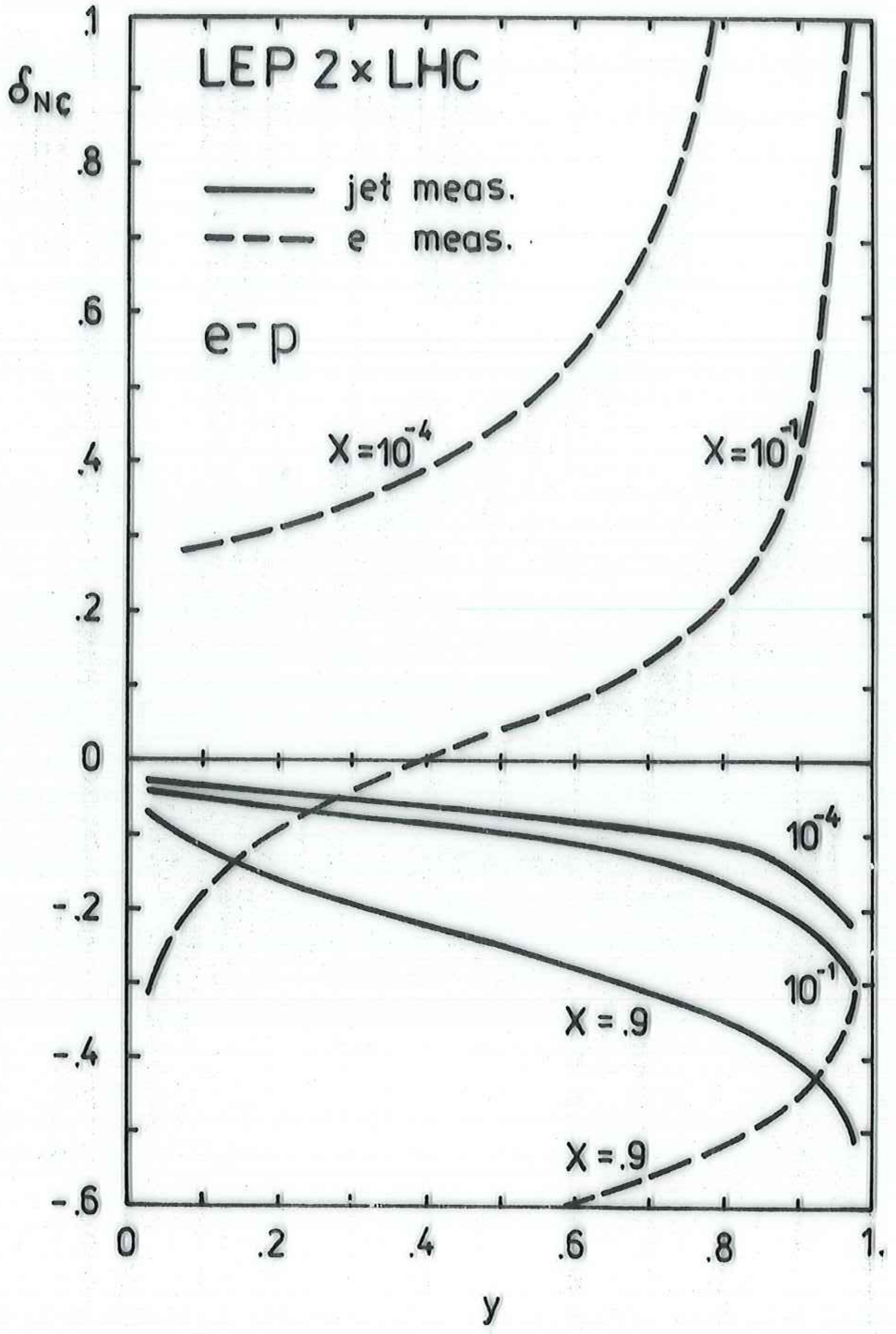
- COMPTON
- FINAL STATE BS (KLN)
- QUARK BS $\longrightarrow$ SCAL. VIOL.

JET-MEASUREMENT :

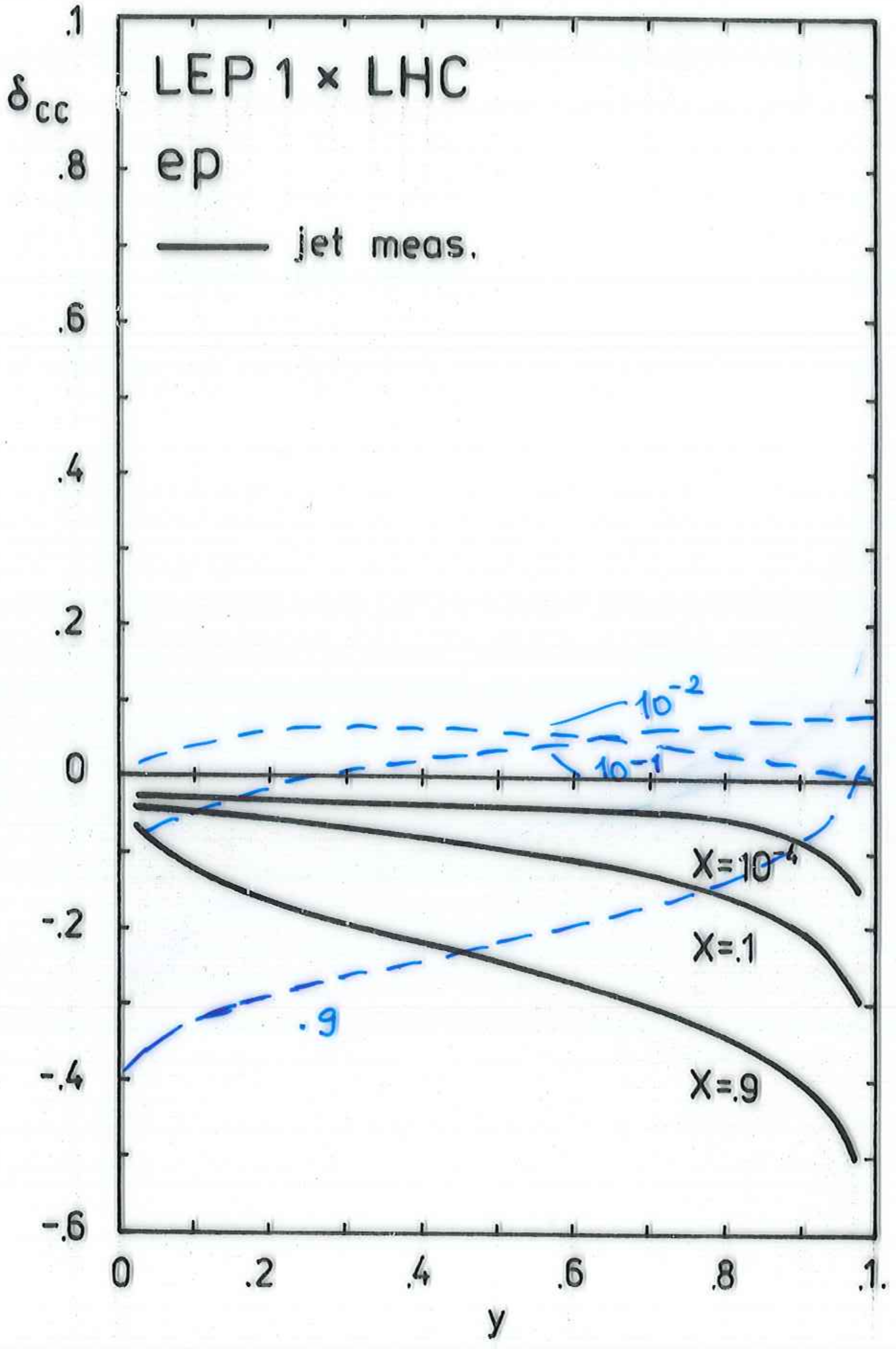
$$\frac{d^2\sigma^{QED}}{dx\,dy} = \frac{\alpha}{2\pi} \ln\left(\frac{Q^2}{\Lambda^2}\right) \cdot \int_0^1 dz \frac{1+z^2}{1-z}\left[\theta(z-z_0)\frac{y}{\hat{y}}\frac{d^2\sigma^B}{dx\,dy}\bigg|_{\substack{x=\hat{x}\\ y=\hat{y}\\ s=\hat{s}}} - \frac{d^2\sigma^B}{dx\,dy}\right]$$

$\hat{s} = s/z$, $\hat{y} = y \cdot z$, $\hat{Q}^2 = Q^2\,(1-y)/(1-y/z)$.

$z_0 =: \quad \hat{x}(z_0) = 1.$



LEP 2 × LHC
δ_{NC}
jet meas.
e meas.
e^-p
$X=10^{-4}$
$X=10^{-1}$
10^{-4}
10^{-1}
X = .9
X = .9
.1
.8
.6
.4
.2
0
-.2
-.4
-.6
0
.2
.4
.6
.8
1.
y

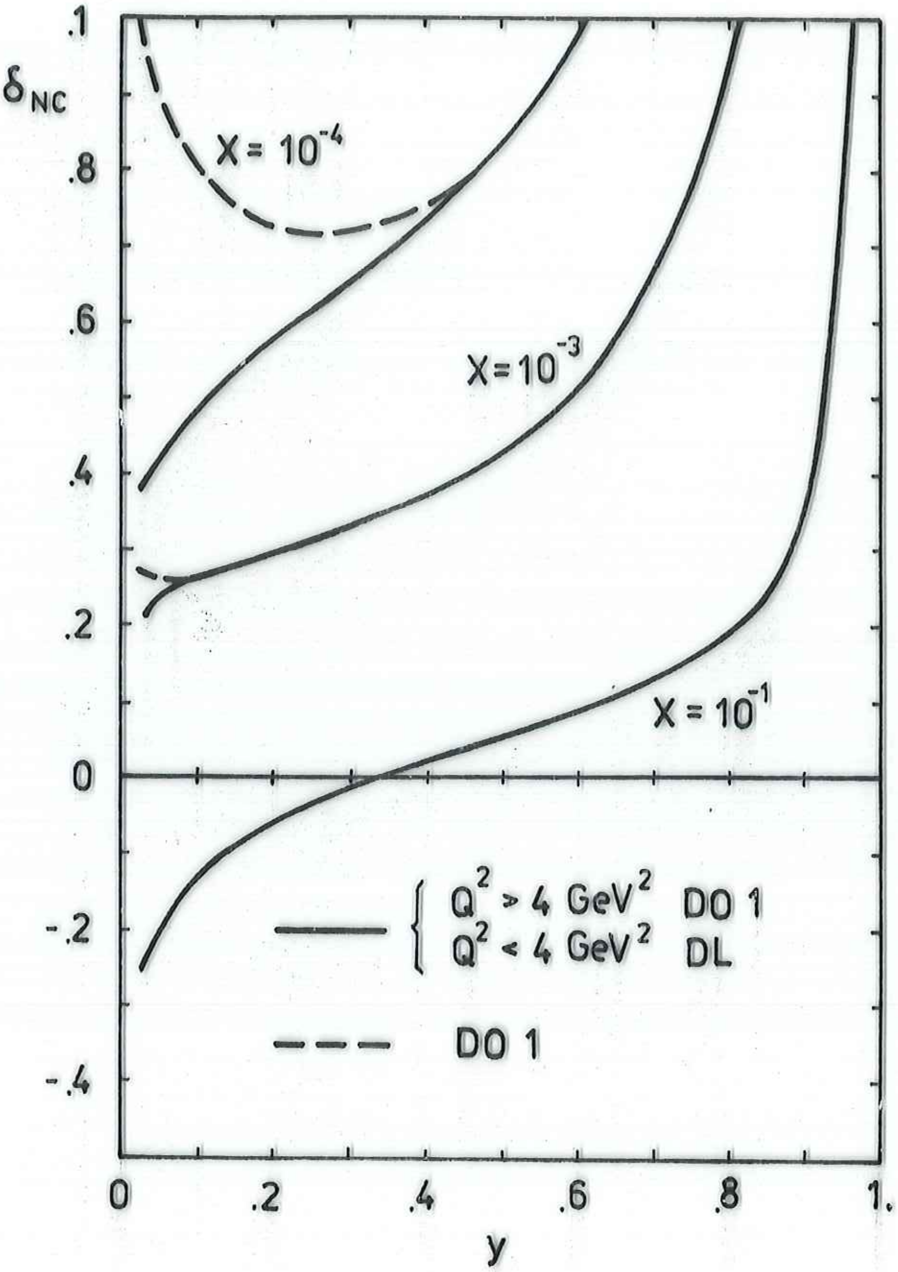


LEP 1 × LHC
ep
jet meas.
δ_{cc}
y
X=10^{-4}
X=.1
X=.9
10^{-2}
10^{-1}
.9
.1
.8
.6
.4
.2
0
-.2
-.4
-.6
0
.2
.4
.6
.8
.1.

INITIAL STATE RADIATION:

requires to know $\frac{d^2\hat{\sigma}^{BORN}}{d\hat{x}\,d\hat{Q}^2}$ AT VERY LOW $\hat{Q}^2$!

LEP 1 × LHC



QCD - PARTON DISTR. DO NOT APPLY ANYMORE.

→ DONNACHIE & LANDSHOFF TERMS : $\simeq x\overset{(-)}{q}_i \times \left(\frac{Q^2}{Q^2+M_\alpha^2}\right)^\beta$

NEUTRAL AND CHARGED CURRENT STRUCTURE FUNCTIONS

ep - OPTION: $\frac{d^2\sigma^{\pm}_{NC}}{dx\,dQ^2}$: 5 STRUCTURE FUNCTIONS

$F_2, G_2, H_2, xG_3, xH_3$

$\frac{d^2\sigma^{\pm}_{CC}}{dx\,dQ^2}$: 4 STRUCTURE FUNCTIONS

$W_2^+, W_2^-, xW_3^+, xW_3^-$

NC:

$\longmapsto$ MEASURE:

$$B_+(x,Q^2) = \frac{1}{2}\left[\frac{d^2\sigma^+}{dx\,dQ^2} + \frac{d^2\sigma^-}{dx\,dQ^2}\right]\frac{xQ^4}{2\pi\alpha^2}\frac{1}{Y_+}$$

$$= F_2(x,Q^2) + \varkappa_Z(-v+\lambda a)\,G_2(x,Q^2) + \varkappa_Z^2(v^2+a^2-2va\lambda)\,H_2(x,Q^2)$$

$\longrightarrow$ G.I.

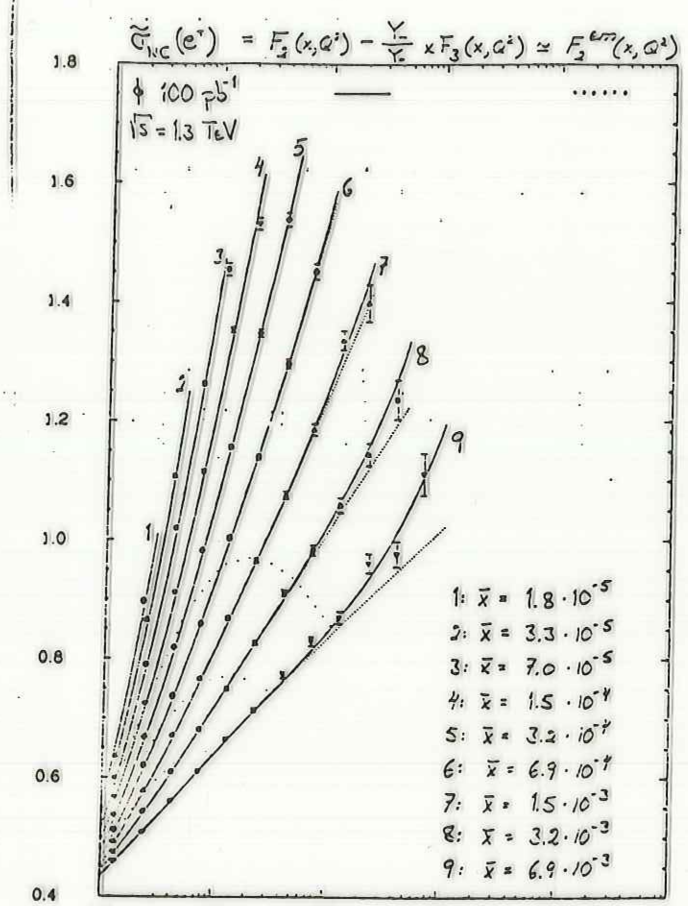
$$B_-(x,Q^2) = \frac{1}{2}\left[\frac{d^2\sigma^-}{dx\,dQ^2} - \frac{d^2\sigma^+}{dx\,dQ^2}\right]\frac{xQ^4}{2\pi\alpha^2}\;\frac{1}{\varkappa_Z(a-\lambda v)\,Y_-}$$

$$= xG_3(x,Q^2) + \varkappa_Z\,\frac{\lambda(v^2+a^2)-2va}{a-\lambda v}\,xH_3(x,Q^2)$$

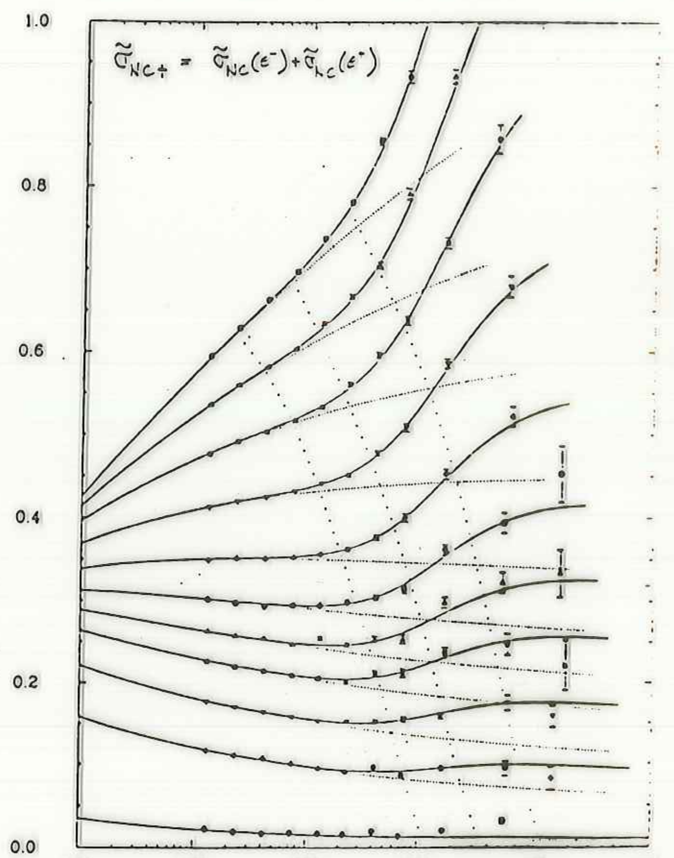
CC: NO SEPARATION REALLY POSSIBLE.

(2σ's , 4 SF's)

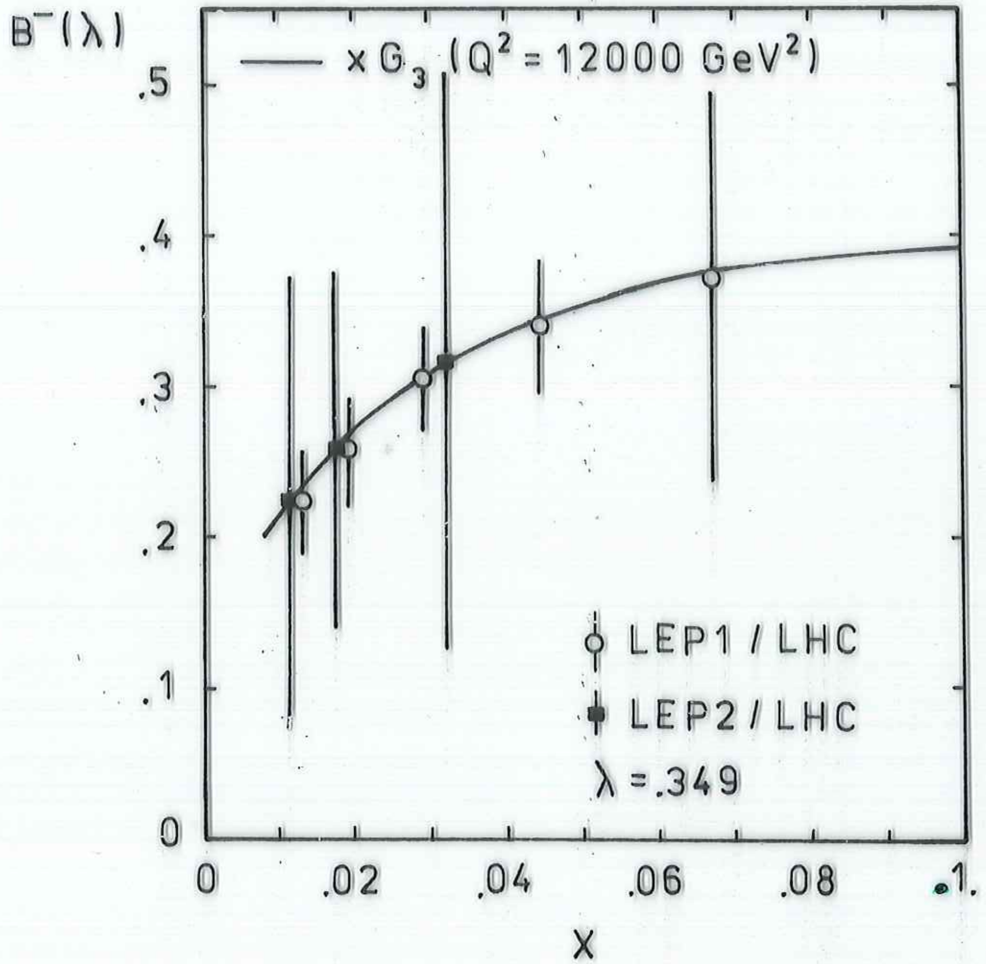
G. INGELMAN



$\tilde{\sigma}_{NC}(e^+) = F_2(x,Q^2) - \frac{Y_-}{Y_+} x F_3(x,Q^2) \simeq F_2^{em}(x,Q^2)$
100 pb^{-1}
$\sqrt{s}$ = 1.3 TeV
1: $\bar{x}$ = $1.8 \cdot 10^{-5}$
2: $\bar{x}$ = $3.3 \cdot 10^{-5}$
3: $\bar{x}$ = $7.0 \cdot 10^{-5}$
4: $\bar{x}$ = $1.5 \cdot 10^{-4}$
5: $\bar{x}$ = $3.2 \cdot 10^{-4}$
6: $\bar{x}$ = $6.9 \cdot 10^{-4}$
7: $\bar{x}$ = $1.5 \cdot 10^{-3}$
8: $\bar{x}$ = $3.2 \cdot 10^{-3}$
9: $\bar{x}$ = $6.9 \cdot 10^{-3}$
Q^2 [GeV^2]



$\tilde{\sigma}_{NC+} = \tilde{\sigma}_{NC}(e^-) + \tilde{\sigma}_{NC}(e^+)$
Q^2 [GeV^2]



B⁻(λ)
x G₃ (Q² = 12000 GeV²)
LEP1 / LHC
LEP2 / LHC
λ = .349
0
.1
.2
.3
.4
.5
0
.02
.04
.06
.08
.1
X

THE MEASUREMENT OF $R = \sigma_L / \sigma_T$ & xG

CONSIDER: LEP1 × LHC $\mathcal{L} = 1\,fb^{-1}$

LEP2 × LHC $\mathcal{L} = 100\,pb^{-1}$

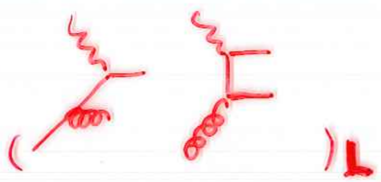
- 2 OVERLAPPING RANGES IN (x, Q^2) AT DIFFERENT y.

- $$\frac{\sigma_{NC}(x, Q^2; y_1)}{\sigma_{NC}(x, Q^2; y_2)} = \frac{Y_{+1} - y_1^2 R/(1+R)}{Y_{2+} - y_2^2 R/(1+R)} = r$$

$$R = \frac{F_L(x, Q^2)}{2x F_1(x, Q^2)}$$

$$\delta R = \frac{\sigma_1}{\sigma_2} \sqrt{\frac{1}{N_1} + \frac{1}{N_2}} \left| \frac{\partial R}{\partial r} \right| = r \frac{(1+R)^2 (Y_{2+} - y_2^2 R/(1+R))^2}{| Y_{1+} y_2^2 - Y_{2+} y_1^2 |} \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}.$$

Fig. 1, 2

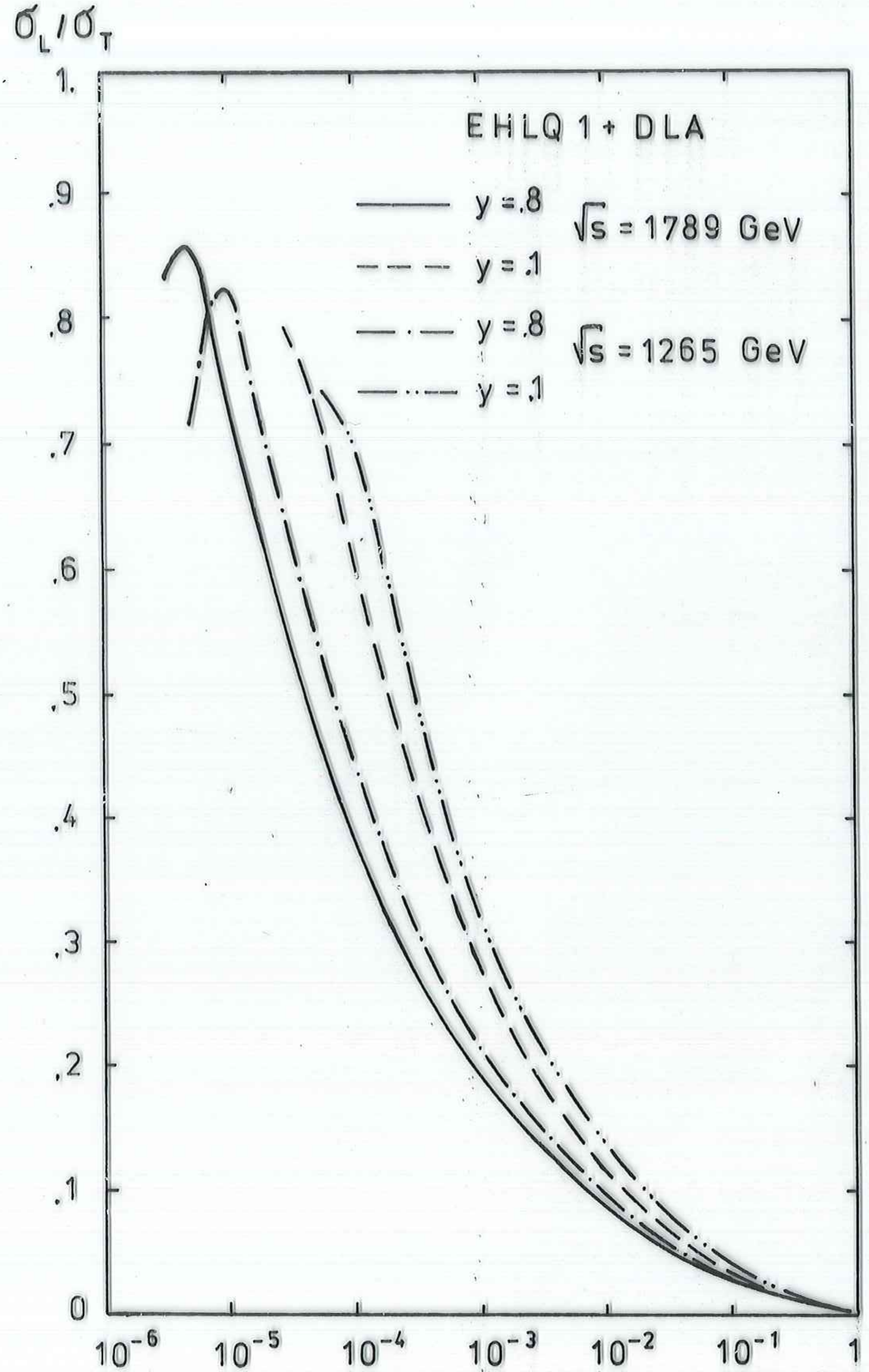
- 

↑
low x
Leading twist.

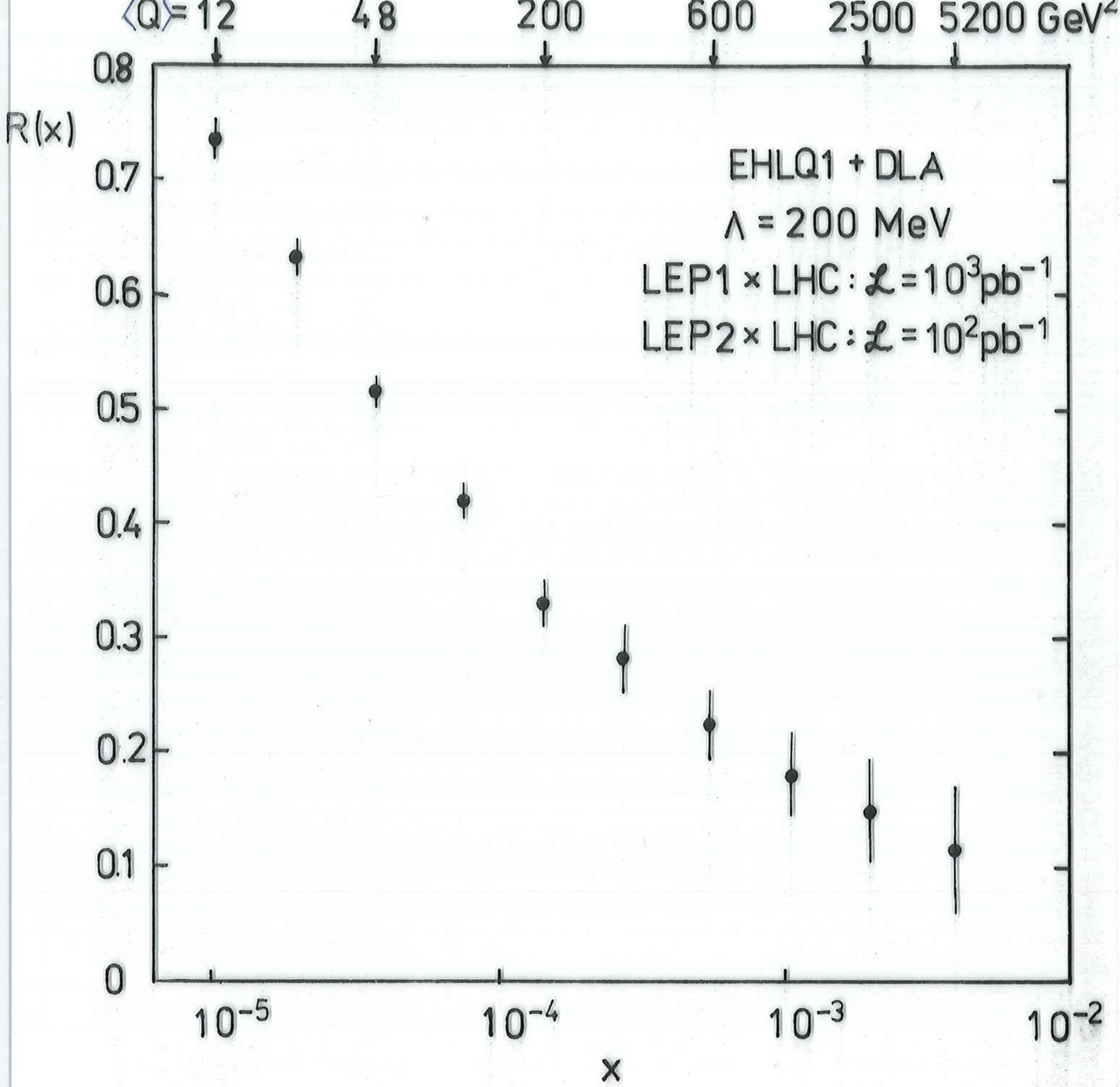
$$\boxed{xG(x, Q^2) \simeq 1.77 \frac{3\pi}{2\alpha_s(Q^2)} F_L(0.4x, Q^2)}$$

More complicated, if screening is included.

R



σ_L/σ_T
1.
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
EHLQ 1 + DLA
y = .8
y = .1
√s = 1789 GeV
y = .8
y = .1
√s = 1265 GeV
10^-6
10^-5
10^-4
10^-3
10^-2
10^-1
1
X



⟨Q²⟩ = 12
48
200
600
2500
5200 GeV²
R(x)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
EHLQ1 + DLA
Λ = 200 MeV
LEP1 × LHC : ℒ = 10³ pb⁻¹
LEP2 × LHC : ℒ = 10² pb⁻¹
10⁻⁵
10⁻⁴
10⁻³
10⁻²
x

QCD - ANALYSIS

- FIT DEPENDENCE ON $\alpha_s(Q^2, \Lambda)$ OF SCALING VIOLATIONS OF STRUCTURE FUNCTIONS

PROBLEM: NO DIRECT ACCESS TO F_2, $W_2^{\pm}$ etc.

- START WITH OTHER 'EXPERIMENTAL' INPUT:

NC ep:

$$B_+(\lambda; x, Q^2) = \frac{1}{2}\left[\frac{d^2\sigma^-}{dx\,dQ^2} + \frac{d^2\sigma^+}{dx\,dQ^2}\right]\frac{x\,Q^4}{2\pi\alpha^2}\frac{1}{Y_+}$$

NO y-dependence.

$\longmapsto$ Q^2-dep. Combination of 3 genuine SF's

$\lambda = 0$:

$$B_+(x, Q^2) = C_\Sigma(Q^2)\,\Sigma(x, Q^2) + C_\Delta(Q^2)\,\Delta(x, Q^2)$$

EVOLUTION:

$$B_+(x, Q^2) = C_\Sigma(Q^2)\left[E_{qq}(x, Q^2) \otimes \Sigma(x, Q_0^2) + E_{qG}(x, Q^2) \otimes x\,G(x, Q_0^2)\right]$$

$$+ C_\Delta(Q^2)\,E_{NS}(x, Q^2) \otimes \Delta(x, Q_0^2)$$

$$\lim_{Q^2/M_Z^2 \to 0} C_\Sigma(Q^2) = \frac{5}{18} \quad ; \quad \lim_{Q^2/M_Z^2 \to 0} C_\Delta(Q^2) = \frac{1}{6}$$

req.: 3 INPUT DISTRIBUTIONS

$x \gtrsim 0.25$: NON SINGLET RANGE ;

$$x\bar{q}_s = x\bar{q} \approx 0$$
$$xG \approx 0$$

$$B_+(x,Q^2) \simeq C_\Sigma(Q^2)\, E_{qq}(x,Q^2) \otimes V(x,Q_0^2)$$
$$+ C_\Delta(Q^2)\, E_{NS}(x,Q^2) \otimes \Delta(x,Q_0^2)$$

req.: 2 INPUT DISTRIBUTIONS AT Q_0^2 ; e.g. xu_v, xd_v or $x(u_v+d_v)$ and $x(u_v-d_v)$.

IF FURTHER $Q^2/M_Z^2 \ll 1$: 1 INPUT DISTR: $\left(\frac{4}{9}xu_v + \frac{1}{9}xd_v\right)$; SINCE C_Σ & $C_\Delta \to$ const.

- NO SIMILAR TREATMENT FOR CC (ep).
- POSSIBILITIES IN ed CC ($\longmapsto \equiv \nu$ - PHYSICS)

AIM OF QCD - FITS:

- CLEAR MEASUREMENT OF $\alpha_s(Q^2)$
- DETERMINATION OF Λ
- ——— " ——— OF $xG(x, Q_0^2)$.

WE WILL DISCUSS THESE ASPECTS STARTING WITH $B_4(x, Q^2)$, A GENERALIZATION OF $F_2(x, Q^2)$.

DEVIDE THE x - RANGE ($\simeq \langle Q^2 \rangle$ RANGE) TO DETERMINE $\alpha_s(\langle Q^2 \rangle)$:

i) $x \geq 0.25$ VALENCE RANGE

ii) $10^{-2} \leq x \leq 1$ Σ, Δ, G

iii) $10^{-4} \leq x \leq 10^{-2}$ — " — (PROBABLY $x\tilde{G}_2, x\tilde{G}_3$ .... TOO!

iv) $x \leq 10^{-4}$ — " — ——— " ——— SCREENING.)

$\longrightarrow$ STUDY RESPONSE : ALTARELLI, PARISI EQUATIONS.

$\longrightarrow$ FUTURE STUDIES REQUIRED TO INCLUDE LOW X EFFECTS

YET $\nexists$ CONSISTENTLY FORMULATED EVOLUTION EQUATIONS, WHICH EXTEND THE AP- EQU'S.

USE: LEP1 × LHC $\mathcal{L} = 1\,fb^{-1}$ LEP2 × LHC $\mathcal{L} = 100\,pb^{-1}$

NS-range : $x > .25$

NO FIT POSSIBLE FROM THE RARE DATA IN THIS RANGE.

range : $x \geq 10^{-2}$

$\alpha_s = .130 \pm .054$ $\langle Q^2 \rangle = 4.4 \cdot 10^3\ GeV^2$ LEP1 × LHC

⟶ STATISTICS SHIFTED TO LOWER X, COMPARED TO HERA, AT THE LUMONISITIES GIVEN.

TRY TO FORMALLY ANALYZE $F_2^{AP}(x, Q^2)$ FOR : $[10^{-2}, 10^{-4}] \ni x$.

range: $x \in [10^{-4}, 10^{-2}]$

'AP'-response :

$\delta\Lambda = 50\,MeV$, $\alpha_s = .170 \pm .010$ $\langle Q^2 \rangle = 290\ GeV^2$ LEP1 × LHC

$\delta\Lambda = 210\,MeV$, $\alpha_s = .165 \pm .038$ $\langle Q^2 \rangle = 375\ GeV^2$ LEP2 × LHC

STILL LOWER X, $10^{-6} \ldots 10^{-5} < x < 10^{-4}$

⟶ AP : $\delta\Lambda \lesssim 10\,MeV \,\big|_{STAT.}$

⟹ SCREENING MAY YIELD SMALLER SLOPES; LARGER $\delta\Lambda$, $\delta\alpha_s$.