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QCD - TEST AT HERA

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OUTLINE:

1) INTRODUCTION
2) EVOLUTION EQUATIONS
3) STRUCTURE FUNCTIONS TO BE USED IN THE FIT
4) DETERMINATION OF Λ
5) SYSTEMATIC EFFECTS
6) THE GLUON DISTRIBUTION
7) FURTHER ANALYSIS

1) INTRODUCTION

- QCD TEST : USE MEASURED STRUCTURE FUNCTIONS OR/& CROSS SECTIONS

  ⟶ SCALING VIOLATIONS :

  Λ, $\alpha_s(Q^2)$, $xG(x, Q_0^2)$, ...

POSSIBILITIES AT HERA.

- WHICH STRUCTURE FUNCTIONS CAN BE USED ?
- KINEMATICAL RANGE (CHOICE OF $\sqrt{s}$) (RESOLUTION)
- THEOR. UNCERTAINTIES
- STATISTICAL ERRORS Λ, α_s ...
- SYSTEMATICAL PROBLEMS

⟶ WHERE (x, Q^2) DO WE KNOW EVOLUTION-EQUATIONS ?

2) EVOLUTION EQUATIONS

- AP - EQUATIONS , $x \gtrsim 10^{-2} \dots 10^{-3}$

  NO SCREENING EFFECTS (→ LOW X WG)

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

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

$$F_S = \sum_i \left(q_i(x,Q^2) + \bar{q}_i(x,Q^2) \right)$$

$$F_{NS} = \sum_i \alpha_{ij} \left(q_i(x,Q^2) - \bar{q}_j(x,Q^2) \right)$$

$$t = (2/\beta_0) \log \left[\log(Q^2/\Lambda^2) / \log(Q_0^2/\Lambda^2) \right]$$

DIFFERENT NUMERICAL METHODS FOR THE SOLUTION OF EVOL. EQ. :

- ABBOTT / BARNETT
- FURMANSKI / PETRONZIO
- ROBERTS et al.
- WU-KI TONG
- GONZALES - ARROYO et al.
- REYA
- KRIVOKHIZHIN
- VIRCHAUX

⋮

⟶ ≃ EQUIVALENT PROGRAMS (TESTED : AB, FP | JB, MK

NA4 MORE COMPARISONS)

$\longrightarrow \Lambda \quad (F_S \rightarrow xG)$

3) STRUCTURE FUNCTIONS TO BE USED FOR THE FIT

$\longrightarrow$ VARIOUS POSSIBILITIES IN PRINCIPLE

F_2: u_v, d_v, $u_v \pm d_v$, $e_u u_v - e_d d_v$, F_S, various flavour combin.

BEST CHOICE $x \sum_i u_i \equiv xU$

$\longrightarrow \delta\Lambda \sim 400$ MeV !

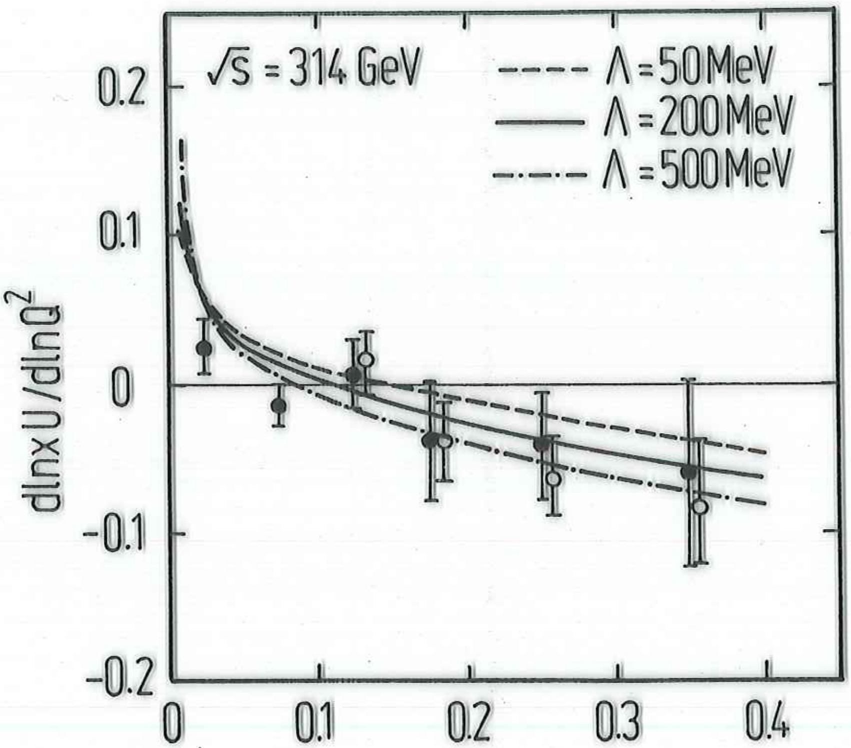
Fig.

- REQUIRES MEASUREMENT OF $\sigma_{NC}^{(+)}$ OR $\sigma_{NC}^{+} + \sigma_{NC}^{-}$
- UNFOLDING OF F_2; SEPARATION OF F_2 & F_L !

Figs.

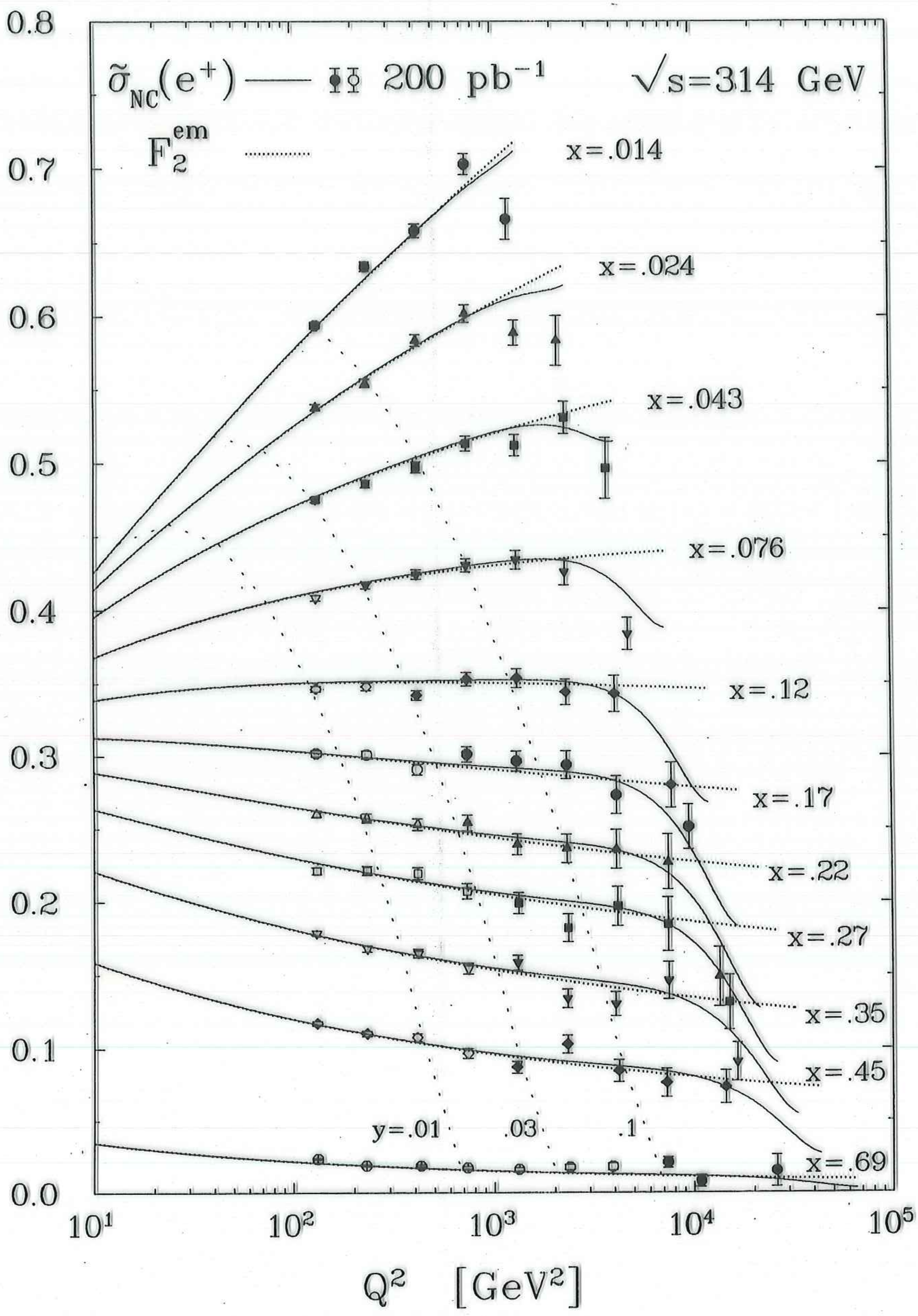
- USE WIDEST ACCESSIBLE RANGE IN x & Q^2. (INDEPENDENT OF ITS PARTICULAR SHAPE)

$\longrightarrow$ FIT Λ, $F_2(x, Q_0^2)$, $G(x, Q_0^2)$



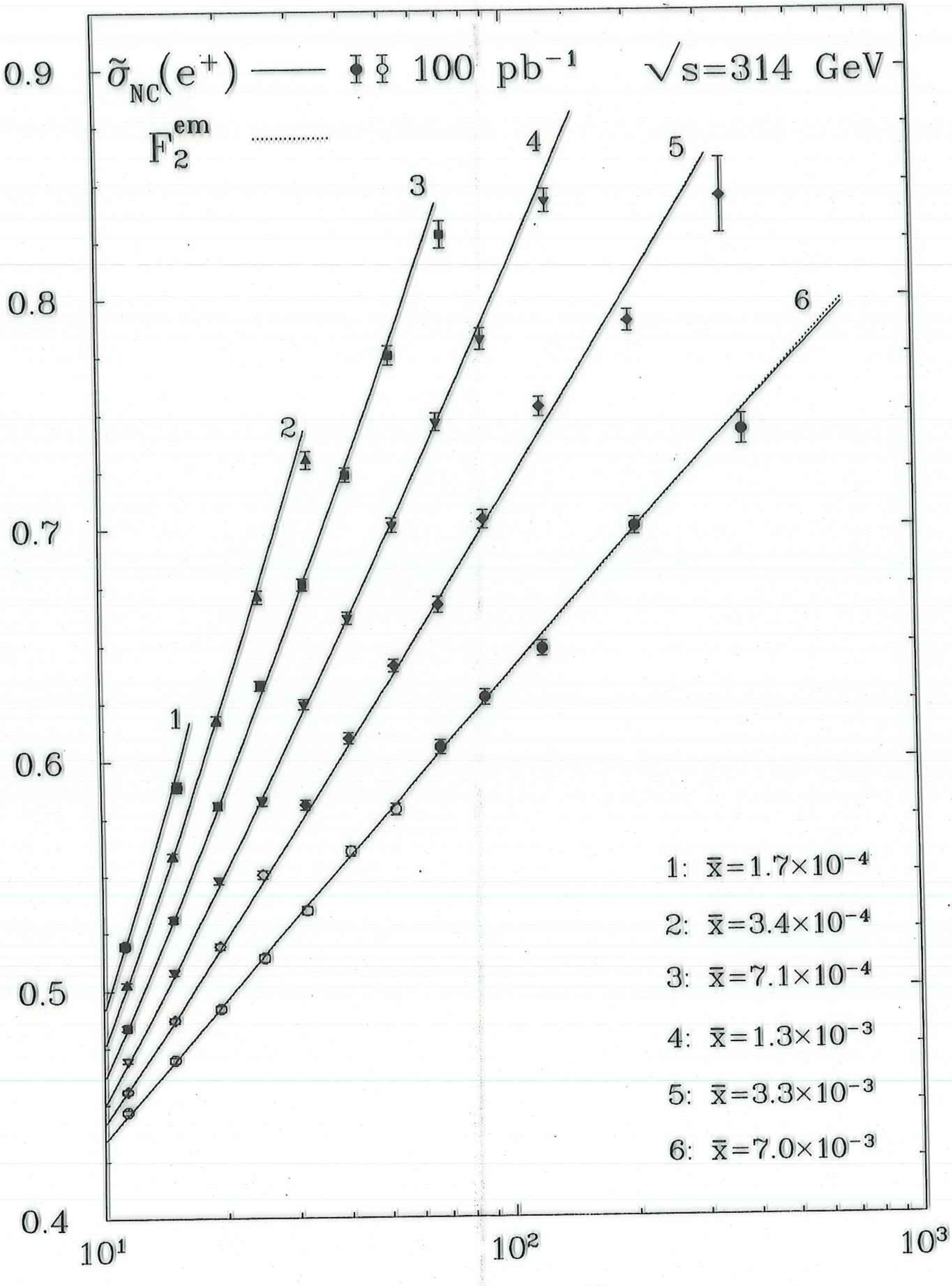
√s = 314 GeV
Λ = 50 MeV
Λ = 200 MeV
Λ = 500 MeV
0.2
0.1
0
-0.1
-0.2
dlnxU/dlnQ²
0
0.1
0.2
0.3
0.4
x

Fig. 2



$\tilde{\sigma}_{NC}(e^+)$ —— 200 pb^{-1}
$\sqrt{s}$=314 GeV
F_2^{em} ....
x=.014
x=.024
x=.043
x=.076
x=.12
x=.17
x=.22
x=.27
x=.35
x=.45
x=.69
y=.01
.03
.1
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
10^1
10^2
10^3
10^4
10^5
Q^2 [GeV^2]

Fig. 3



$\tilde{\sigma}_{NC}(e^+)$
100 pb^{-1}
$\sqrt{s}$=314 GeV
F_2^{em}
0.9
0.8
0.7
0.6
0.5
0.4
1
2
3
4
5
6
1: $\bar{x}=1.7\times10^{-4}$
2: $\bar{x}=3.4\times10^{-4}$
3: $\bar{x}=7.1\times10^{-4}$
4: $\bar{x}=1.3\times10^{-3}$
5: $\bar{x}=3.3\times10^{-3}$
6: $\bar{x}=7.0\times10^{-3}$
10^1
10^2
10^3
Q^2 [GeV^2]

Fig. 6

4) DETERMINATION OF Λ

- USE THE MAXIMAL AVAILABLE RANGE FOR F_2
- INDEPENDENTLY OF ITS SHAPE ! (χ^2-METHOD)

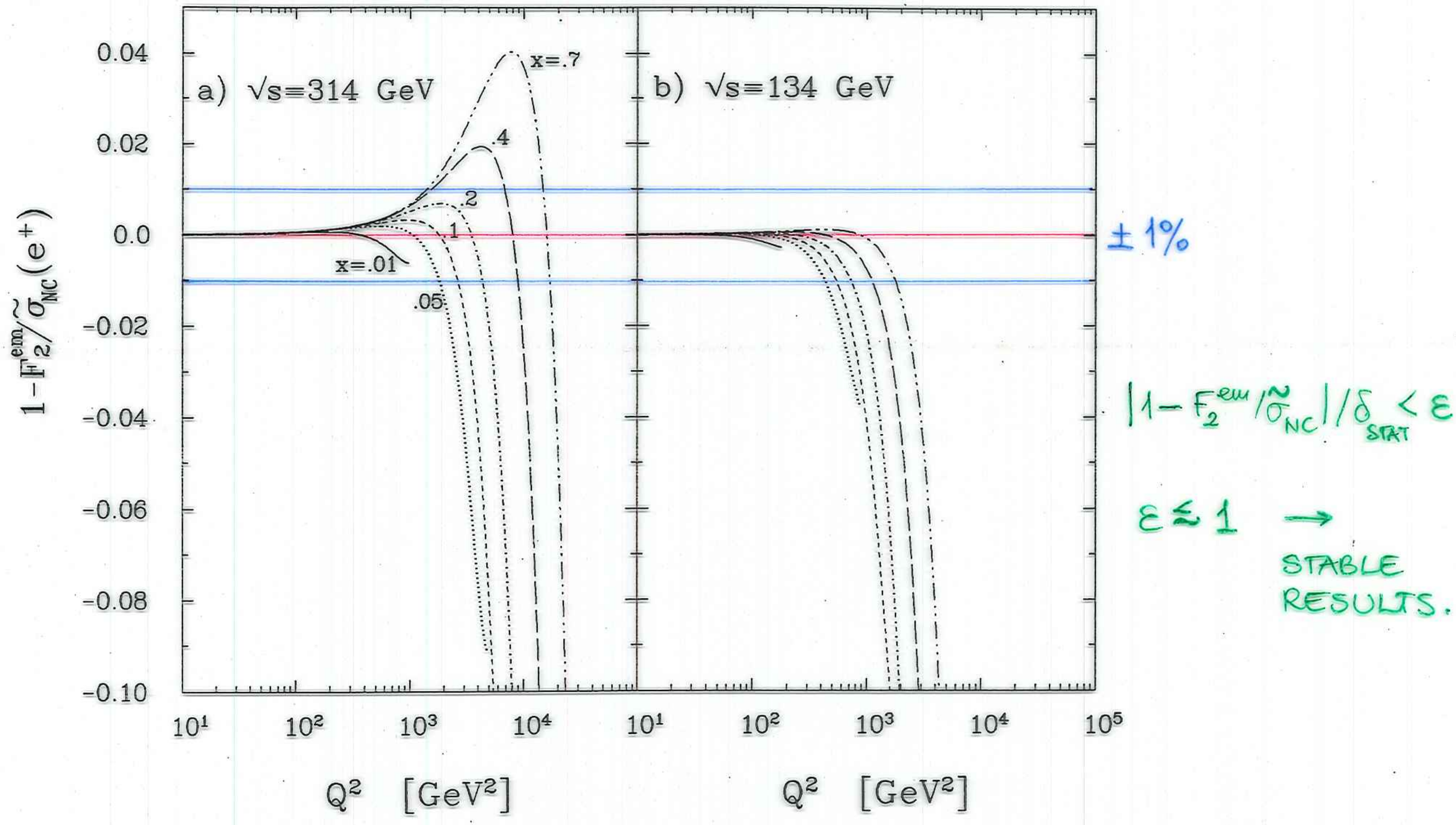
⟶ EXCLUDE THE RANGE, WHERE PROPAGATOR EFFECTS $\sim Q^2/(Q^2+M_Z^2)$ BECOME IMPORTANT

Fig.

- THE ERROR OF Λ DEPENDS STRONGLY ON THE NUMBER OF PARAMETERS TO BE FITTED, [$xG(Q_0^2)$ $F_2(Q_0^2)$].

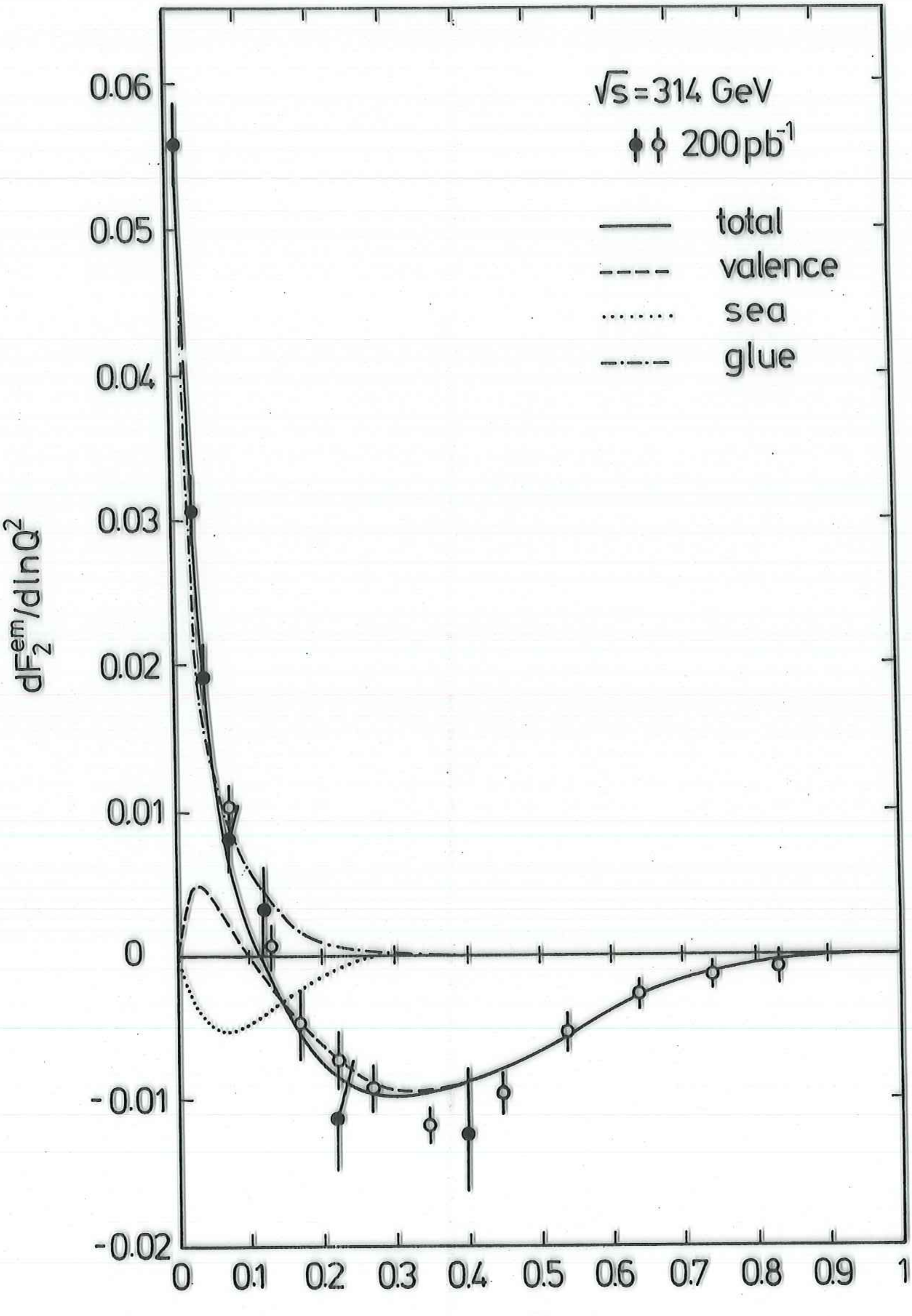
- EXCEPT OF THE RANGE $x \gtrsim 0.25$ ONE HAS TO DETERMINE $xG(x,Q_0^2)$ IN THE FIT SIMULTANEOUSLY

Fig.



a) √s=314 GeV
b) √s=134 GeV
x=.7
.4
.2
.1
.05
x=.01
$1-F_2^{em}/\tilde{\sigma}_{NC}(e^+)$
0.04
0.02
0.0
-0.02
-0.04
-0.06
-0.08
-0.10
10^1
10^2
10^3
10^4
10^5
Q^2 [GeV^2]
Q^2 [GeV^2]
± 1%
$|1-F_2^{em}/\tilde{\sigma}_{NC}|/\delta_{STAT} < \varepsilon$
$\varepsilon \lesssim 1$ →
STABLE
RESULTS.

Fig. 4



√s = 314 GeV
200 pb⁻¹
total
valence
sea
glue
dF₂^em/d ln Q²
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
x

Fig.5

KINEMATICAL DEPENDENCE OF $\delta\Lambda$

- x_{min}
- y_{min}
- Q^2_{min} , Q^2_{max}

Figs.

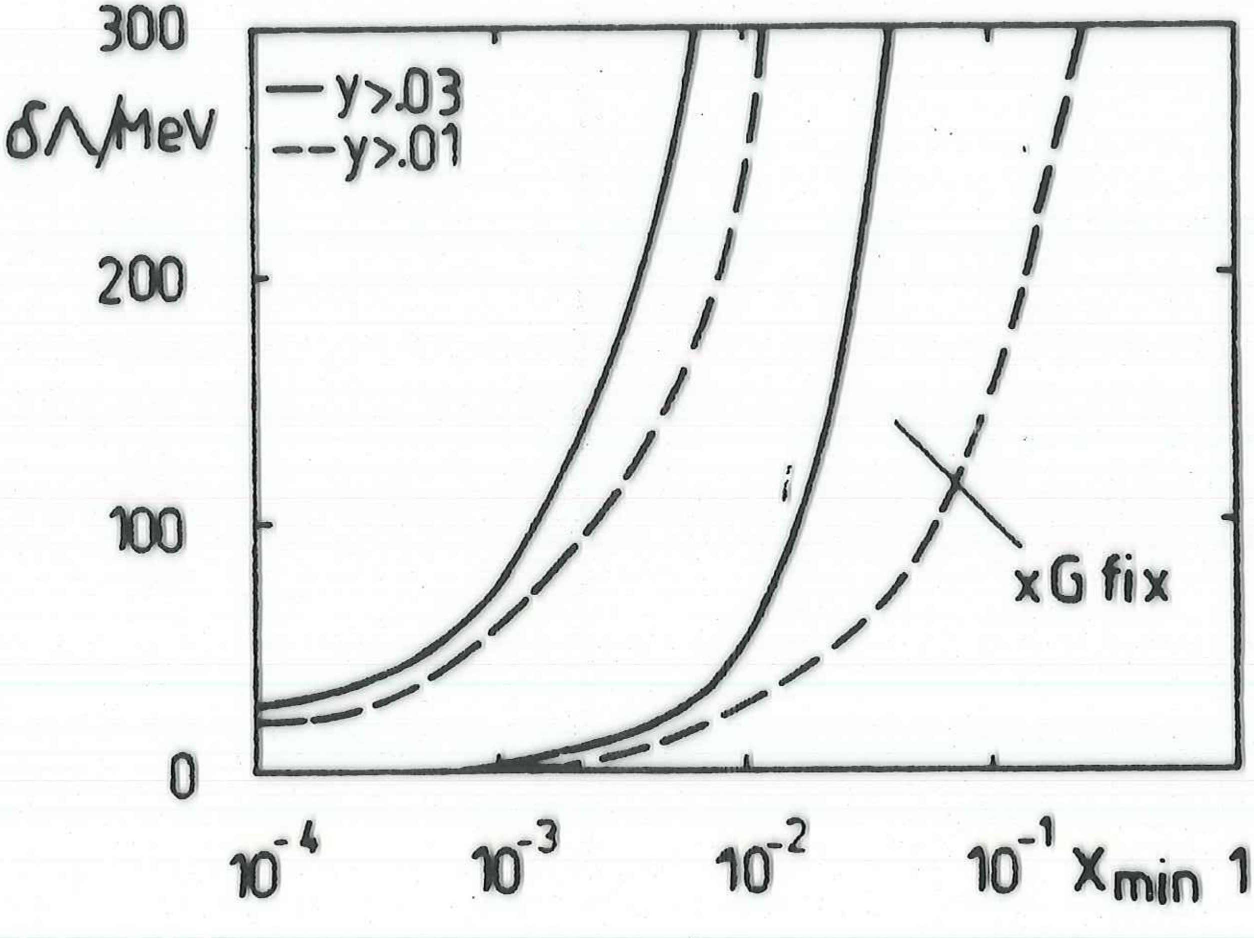
$x \geq 10^{-2}$: FELTESSE RANGE: $\delta\Lambda = 135\,MeV$
4π $\delta\Lambda = 76\,MeV$ ← TRUTH ?!

$\mathcal{L} = 200\,pb^{-1}$, $\sqrt{s} = 314\,GeV$

$x \geq 10^{-2}$ FELTESSE RANGE: $\delta\Lambda = 58\,MeV$
4π $\delta\Lambda = 27\,MeV$

$\mathcal{L} = 100\,pb^{-1}$, $\sqrt{s} = 134\,GeV$

⟶ COMBINATION OF LOWER $\sqrt{s}$ AND STANDARD $\sqrt{s}$ NEEDED.


300
200
100
0
δΛ/MeV
— y>.03
-- y>.01
xG fix
10^-4
10^-3
10^-2
10^-1
X_min
1

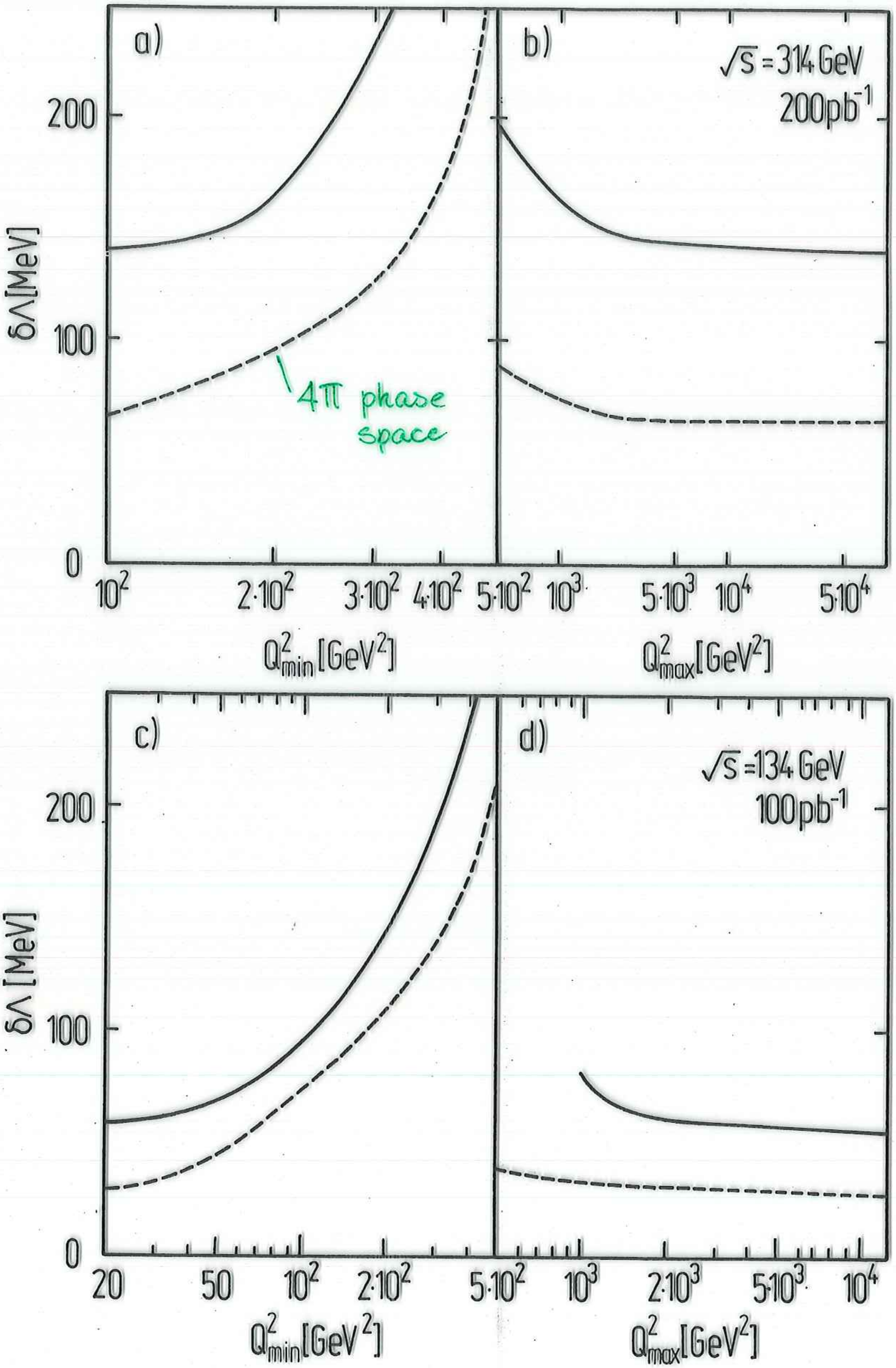
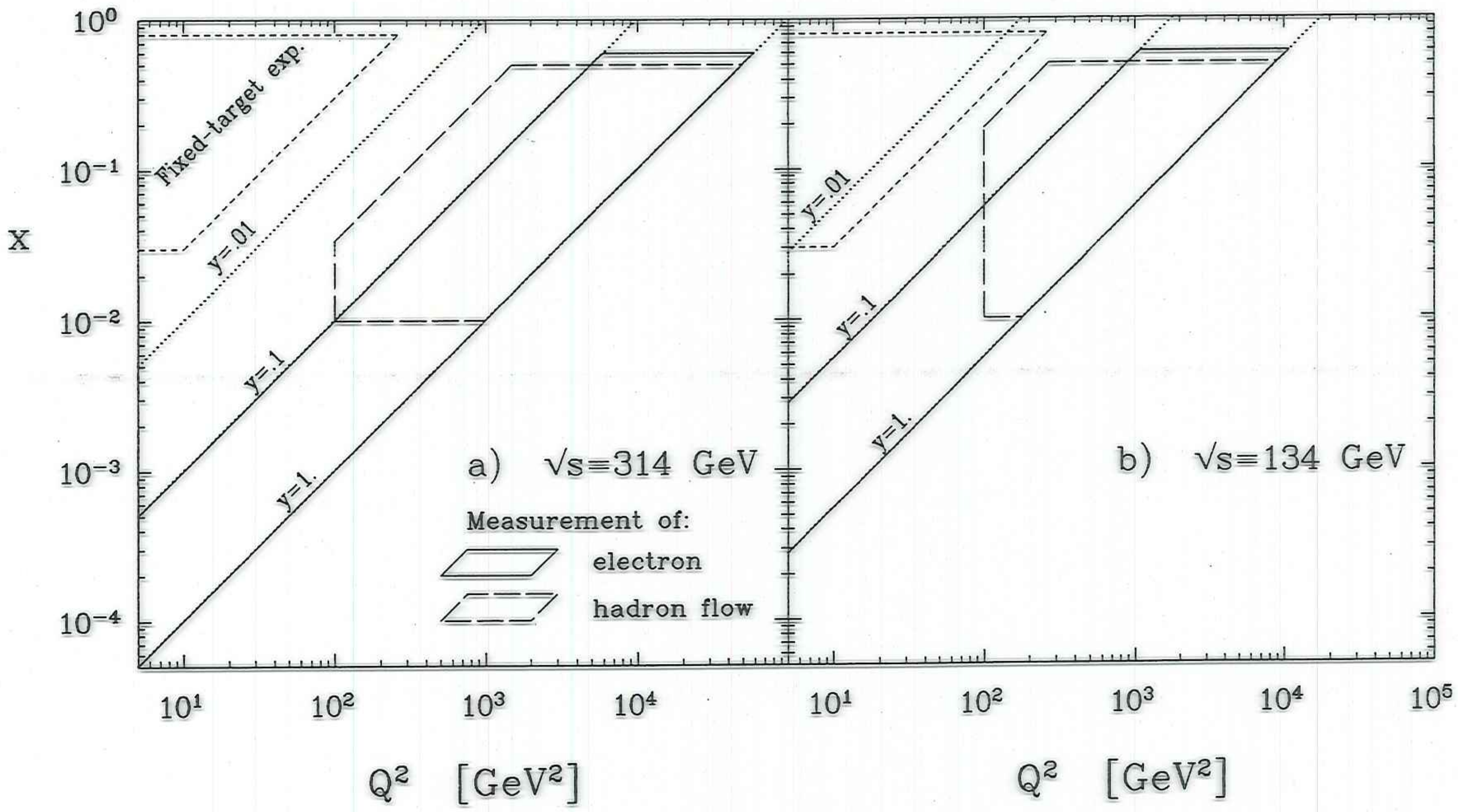

a)
b)
$\sqrt{s}$ = 314 GeV
200pb^{-1}
4π phase space
δΛ[MeV]
0
100
200
10^2
$2\cdot10^2$
$3\cdot10^2$
$4\cdot10^2$
$5\cdot10^2$
10^3
$5\cdot10^3$
10^4
$5\cdot10^4$
Q^2_{min}[GeV^2]
Q^2_{max}[GeV^2]
c)
d)
$\sqrt{s}$ = 134 GeV
100pb^{-1}
δΛ [MeV]
0
100
200
20
50
10^2
$2\cdot10^2$
$5\cdot10^2$
10^3
$2\cdot10^3$
$5\cdot10^3$
10^4
Q^2_{min}[GeV^2]
Q^2_{max}[GeV^2]

Fig.7



x
10^0
10^-1
10^-2
10^-3
10^-4
Fixed-target exp.
y=.01
y=.1
y=1.
a) √s=314 GeV
Measurement of:
electron
hadron flow
b) √s=134 GeV
10^1
10^2
10^3
10^4
10^5
Q^2 [GeV^2]

Fig. 1

5. SYSTEMATIC EFFECTS

$x \geq 10^{-2}$: $R_{QCD} \longrightarrow R = 0$ $\Delta\Lambda = \pm 20\,\mathrm{MeV}$.

$\Delta S_{CMS} = \pm 1\%$ (COMB. LOW/HIGH $\sqrt{s}$)

$\Delta\Lambda = 20\,\mathrm{MeV}$.

⇒ STRONG EFFECTS : CALORIMETER MISCALIBRATIONS.

$\Delta\Lambda_{SYST} \simeq \Delta\Lambda_{STAT}$ ($\mathcal{L} = 200\,pb^{-1}$) !

CAN BE CIRCUMVENTED : ELIMINATION OF THE BIG BULK EFFECTS IN

$\Delta E_{e,J} = E_{e,J}(1 \pm \varepsilon_{e,J})$

↑ MAY BE MEASURED !

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6. THE GLUON DISTRIBUTION

$$xG(x,Q_0^2) = A(\nu_G,\alpha)\,\frac{1}{x^\alpha}\,(1-x)^{\nu_G}(1+9x)$$

(POSSIBLE CHOICE COMP. WITH PRESENT DATA.)

$$\int_0^1 dx\; xG(x,Q_0^2) = \eta(Q_0^2) \simeq 0.45 \ldots 0.5 \quad (\text{fixed})$$

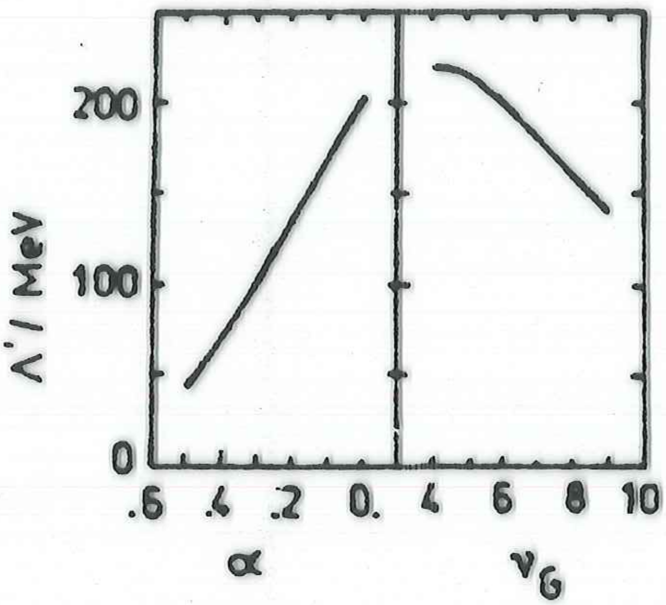
Fig.

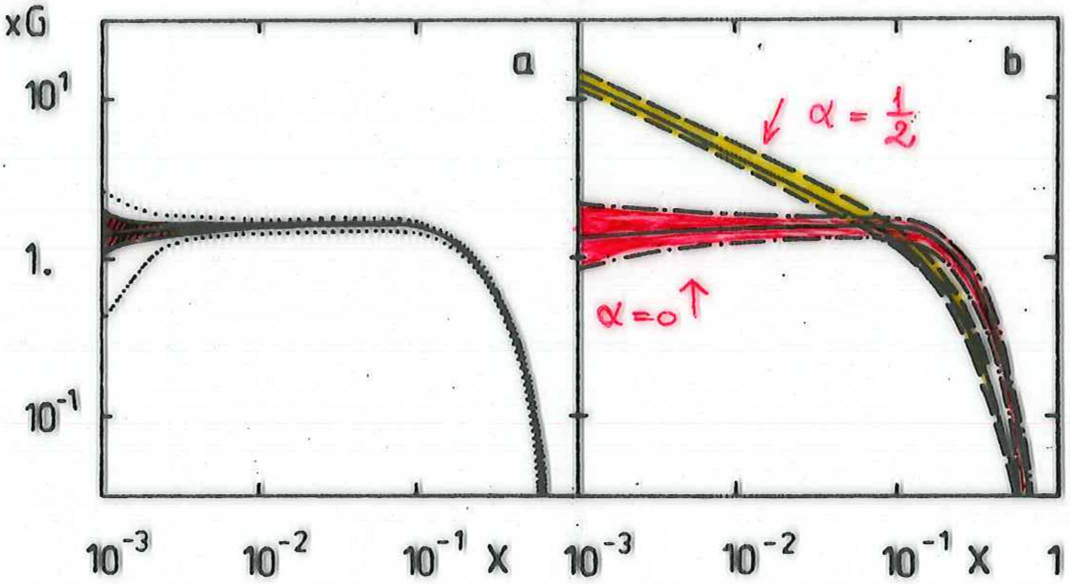
ALTERNATIVE ANALYSIS: Λ FROM OUTSIDE (BCDMS OR WORLDAVERAGE)

⟶ INPUT $\Lambda \pm \delta\Lambda$ FIT $\underline{xG \pm \Delta xG}$. (& $F_2 \pm \delta F_2$ AT Q_0^2).

Fig.

- COMBINE LOW/HIGH $\sqrt{s}$ DATA!
- USE SMALLEST POSSIBLE x's (WHERE FAN DIAGRAM EFFECTS ARE STILL SMALL).


200
100
0
Λ' / MeV
.6
.4
.2
0.
4
6
8
10
α
ν_G



$\delta\Lambda = \pm 63$ MeV

xG fit

100 pb^{-1}

low +

100 pb^{-1}

high $\sqrt{s}$.

7. FURTHER ANALYSIS

- Λ, xG - FITS FOR WIDEST ACC. KIN. RANGE

  ⟶ TO BE DISCUSSED (Θ_1, Θ_2 MEAS. etc.)

- SAME FOR LOWER $\sqrt{s}$ (E_p)

- COMBINED FIT

- SENSITIVITIES FOR $x \geq 10^{-2} \ldots 10^{-3}$

WORK IN PROGRESS: F_L & F_2 WITH SCREENING (xG DRIVEN)

⟶ FULL TERMS, NOT ONLY LEADING SINGUL.

↦ PLOTS: F_2, F_L (x, Q^2).

- QCD FIT & FIT TO R_{eH} WILL LAST LONGER THAN 1 MONTH.