TESTS OF THE ELECTROWEAK THEORY AT HERA

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1. INTRODUCTION
2. BASIC RELATIONS
3. STATISTICAL PRECISIONS
4. SYSTEMATIC EFFECTS
5. 'MODEL INDEPENDENT' ESTIMATES
6. W' & Z', LIMITS ON W & Z COMPOSITENESS
7. CONCLUSIONS

1.

INTRODUCTION

HERA : $e^{\pm}_{\lambda} p$ - COLLISIONS

H1, ZEUS

$\sqrt{s} = 134 \ldots 314$ GeV

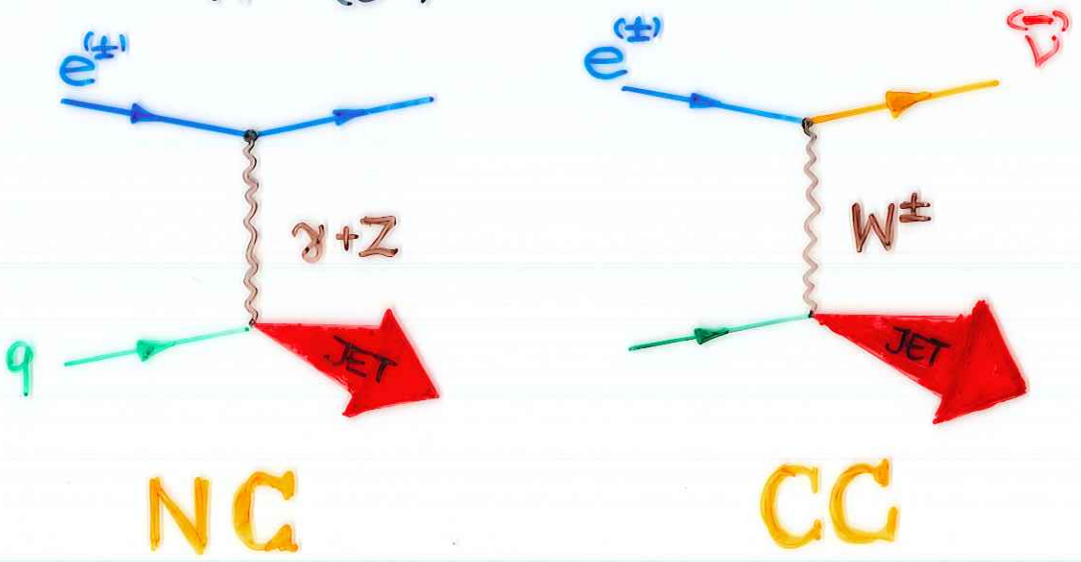
$\mathcal{L} = 1.5 \cdot 10^{31} \, cm^{-2} sec^{-1}$

$200 pb^{-1} \sim 150$ fully efficient days.

Q^2 : $10 \ldots 30\,000$ GeV^2

x : $10^{-4} \ldots 0.8$

y : .03 (jet) ... 1.
.1 ($e^{\pm}$)



NC CC

POLARIZATION (LATER) $\lambda = \pm .8$

BASIC RELATIONS

→ MEASURE : $\frac{d^2\sigma_{NC}}{dx\,dQ^2}(e^{\pm}p)$; $\frac{d^2\sigma_{CC}}{dx\,dQ^2}(e^{\pm}p)$

(+ USE $\lambda \neq 0$ too !)

$$d^2\sigma_i = d^2\sigma_i^{BORN} + d^2\sigma_i^{1LOOP}$$

↑ QED dominated

THE STRUCTURE OF THE BORN CROSS SECTIONS:

$$\frac{d^2\sigma_{NC}^{\pm}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left\{ Y_+ \left[\underbrace{F_2}_{\gamma^2} + C_1 \underbrace{kG_2}_{\gamma Z} + C_2 \underbrace{k^2 H_2}_{Z^2} \right] + Y_- \left[C_3 kxG_3 + C_4 k^2 x H_3 \right] \right\}$$

$$\frac{d^2\sigma_{CC}^{(\pm)}}{dx\,dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left\{ \frac{1}{\alpha^2}\frac{g^2}{16\pi^2}\frac{Q^2}{Q^2+M_W^2} \right\}^2 \frac{1\mp\lambda}{2} \cdot \left\{ Y_+ W_2^{(\pm)} \pm Y_- x W_3^{(\pm)} \right\}$$

$$Y_+ = 1 + (1-y)^2 - \frac{Ry^2}{R+1} \quad ; \quad Y_- = 1 - (1-y)^2 .$$

$$C_i = C_i(v_j, a_j, \lambda)$$

STRUCTUREFUNCTIONS:

NC:

$$[F_2, G_2, H_2] = x\Sigma(q+\bar{q})\,[Q_q^2, 2Q_q v_q, v_q^2+a_q^2]$$

$$[xG_3, xH_3] = 2x\Sigma(q-\bar{q})\,[Q_q a_q, v_q a_q]$$

CC:

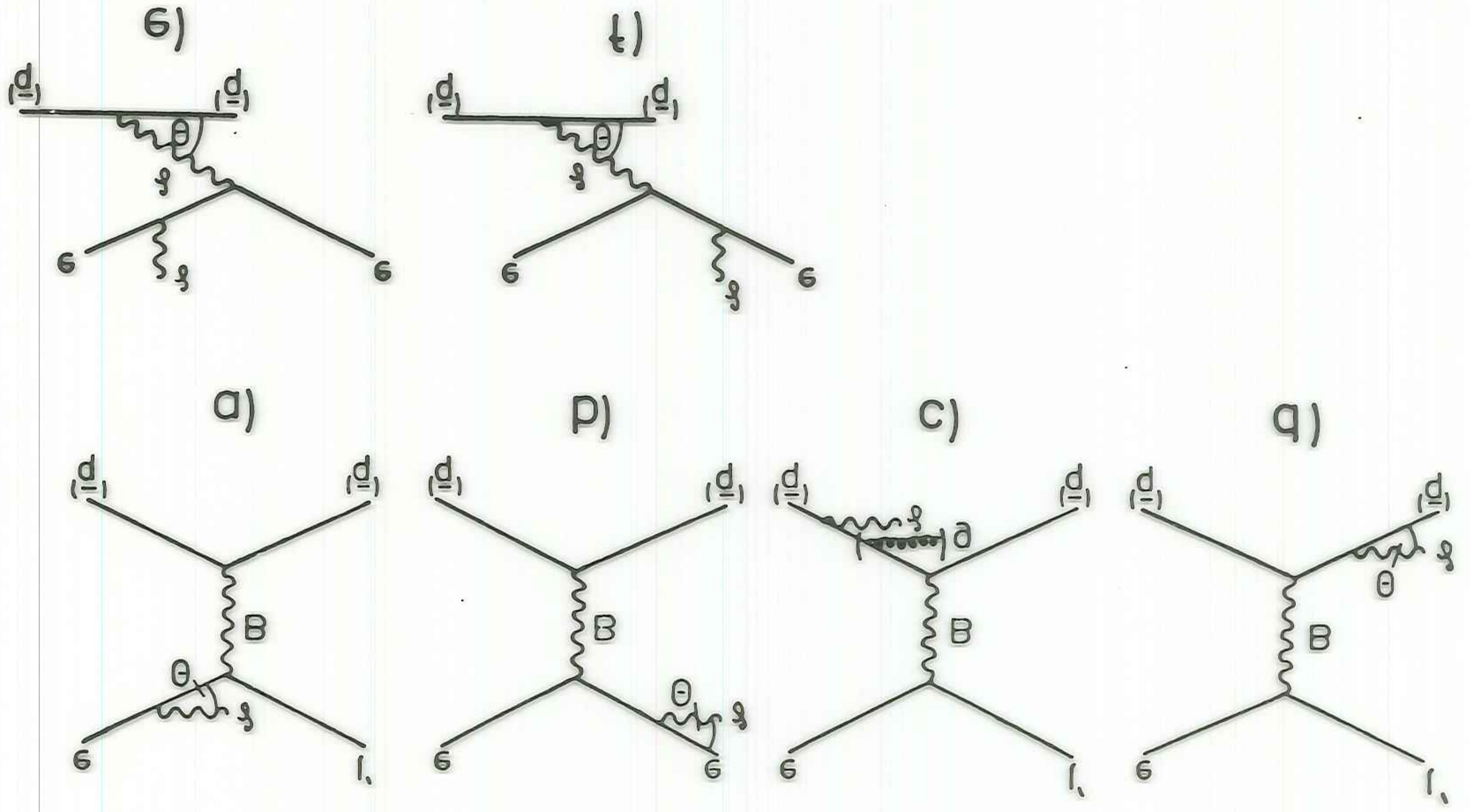
$$[W_2^-, xW_3^-] = [x\Sigma\, q_u + q_{\bar{d}}, x\Sigma\, q_u - q_{\bar{d}}]$$

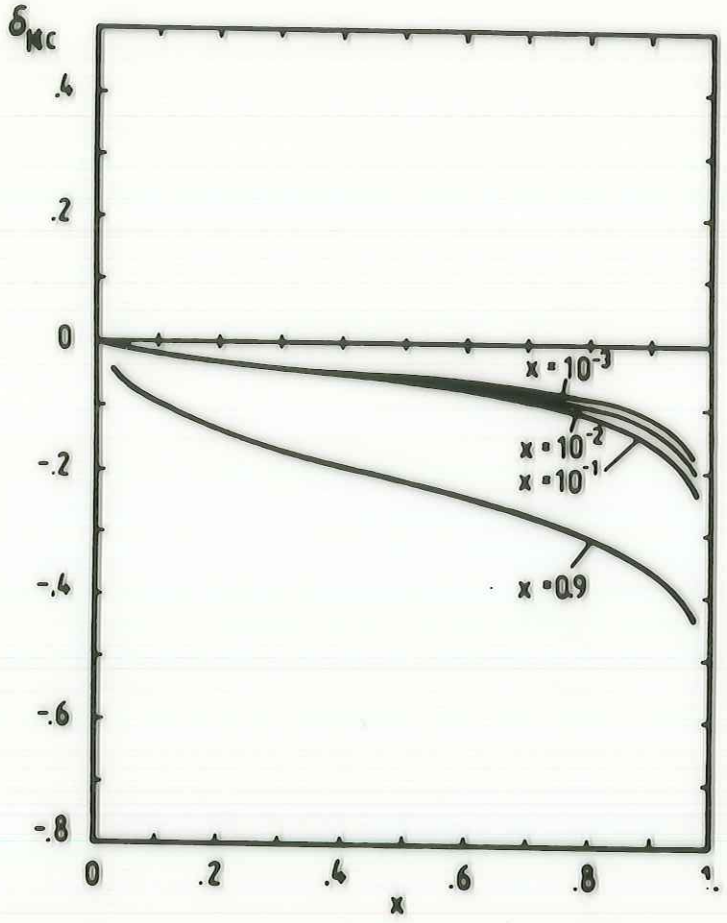
$$[W_2^+, xW_3^+] = [x\Sigma\, q_d + q_{\bar{u}}, x\Sigma\, q_d - q_{\bar{u}}]$$

COUPLINGS:

$$v_i = I_{3i}^L - 2Q_i \sin^2\theta_W$$

$$a_i = I_{3i}^L$$


e)
f)
a)
b)
c)
d)
B



JET-
MEASUREMENT

Fig. 2a

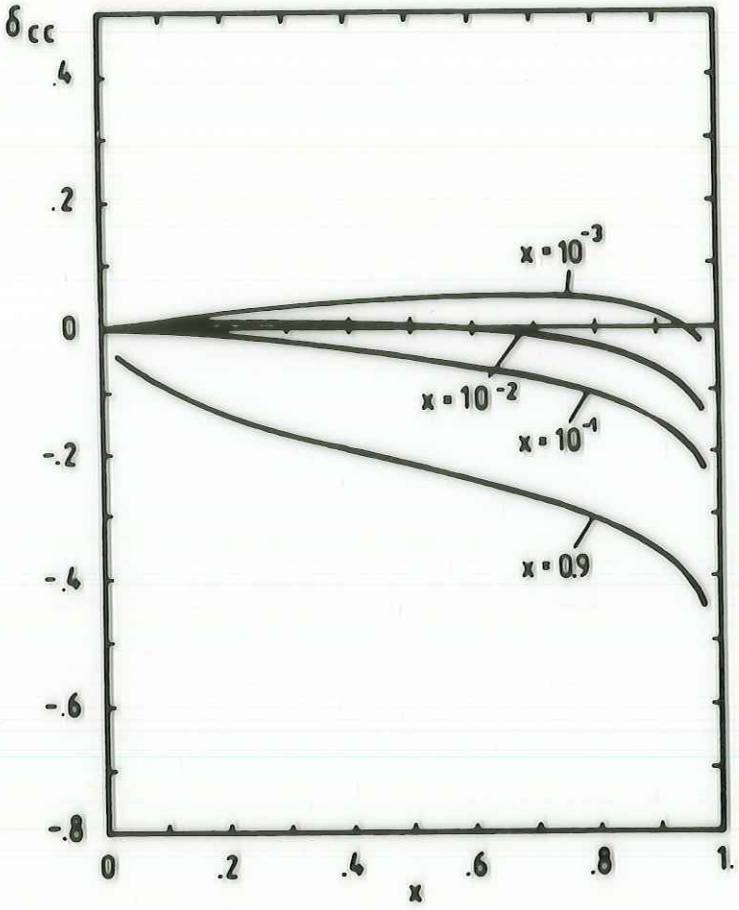


Fig. 2b

WHAT DO WE FIX, WHAT WILL BE FITTED ?

ELECTROWEAK PARAMETERS :

$$\alpha,\ g,\ G_F,\ M_W,\ M_Z,\ \sin^2\theta_W$$

ONLY 3 PARAMETERS ARE INDEPENDENT.

RELATIONS (+ RC) :

♣ TREE :

$$\sin^2\theta_W = 1 - M_W^2/M_Z^2$$

$$g^2 = 4\pi\alpha / \sin^2\theta_W$$

$$G_F = g^2\sqrt{2} / 8M_W^2 (1-\Delta r)^{1/2}$$

$\Delta r \to f(m_t, m_H)$

$$K_Z(Q^2) = \frac{Q^2}{Q^2+M_Z^2}\ \frac{1}{4s_\theta^2 c_\theta^2}$$

or :

$$K_W(Q^2) = \frac{G_F M_W^2}{2\sqrt{2}\alpha}\ \frac{Q^2}{Q^2+M_W^2}\ (1-\Delta r)^{1/2}$$

$$K_Z(Q^2) = \frac{G_F M_Z^2}{2\sqrt{2}\alpha}\ \frac{Q^2}{Q^2+M_Z^2}\ (1-\Delta r)^{1/2}$$

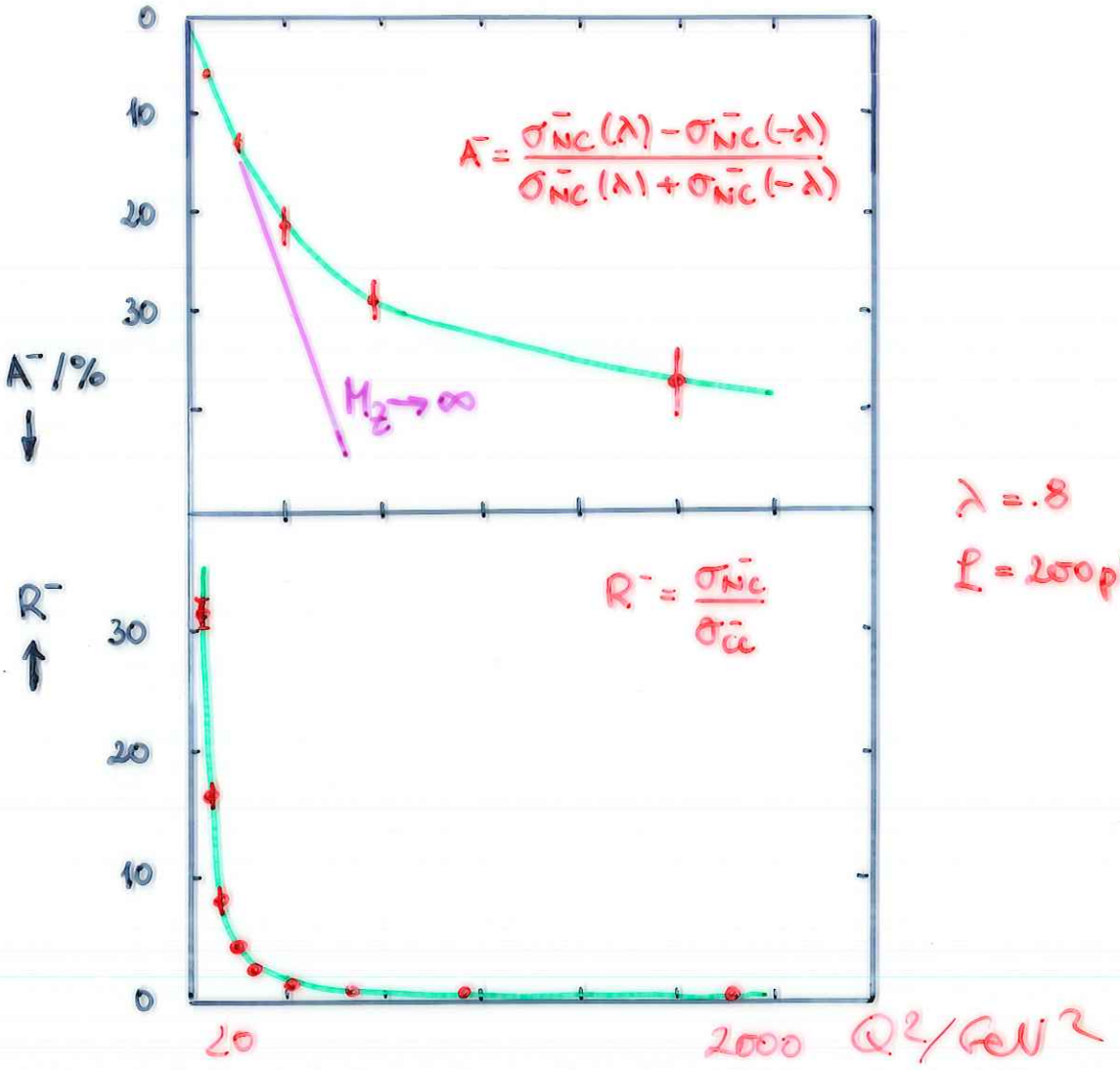
...

→ SYSTEMATIC SEARCH FOR SENSITIVITIES

REQUIRED : • OBSERVABLES

• PARAMETERS (fitting, fixing)

3. STATISTICAL PRECISIONS



SENSITIVITY OF EW-PARAMETERS
FIXING G_μ , M_Z

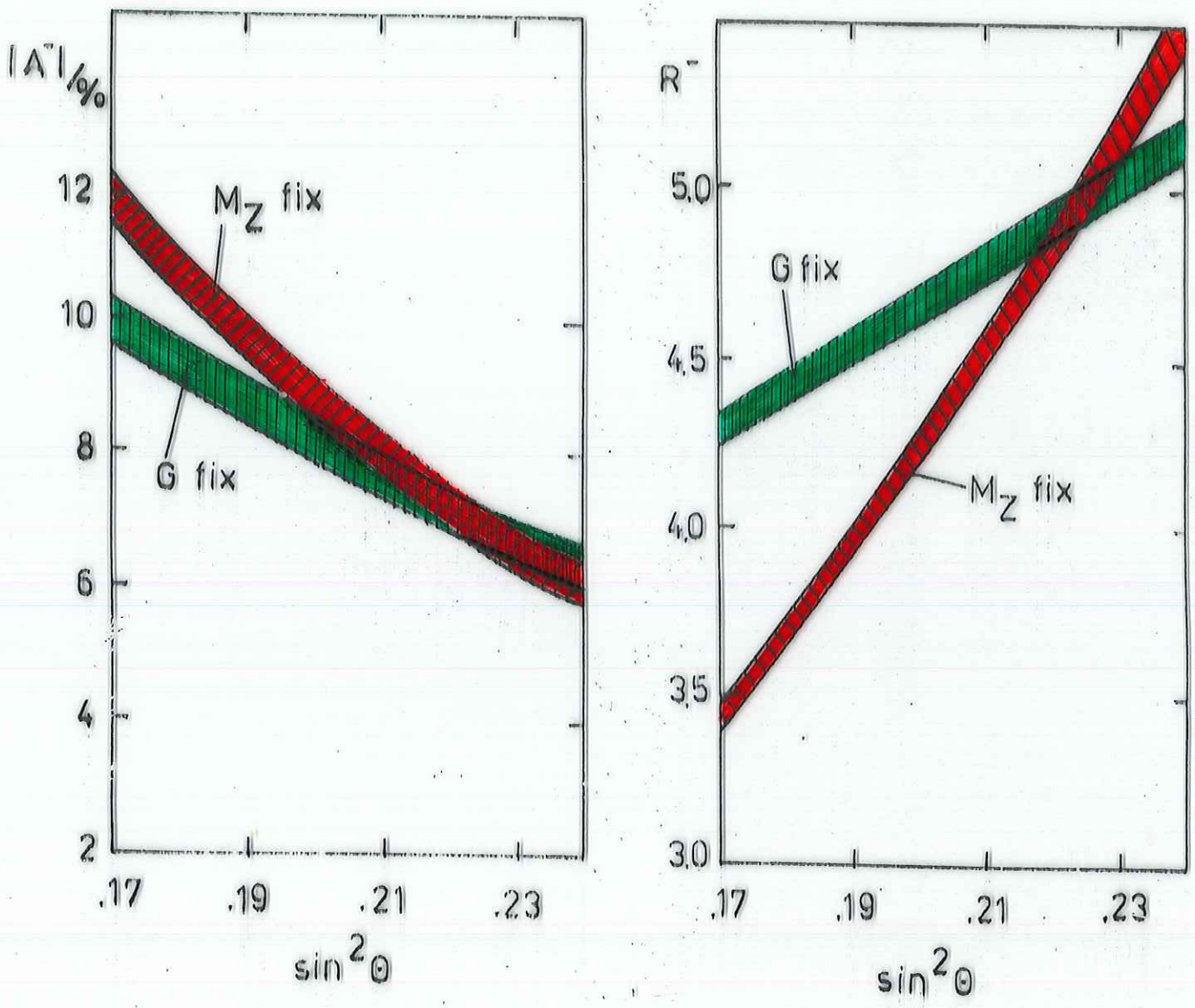


Fig. 2

$$\sin^2\theta = 1 - \frac{M_W^2}{M_Z^2}$$

CUT-DEPENDENCE OF THE STATISTICAL SENSITIVITY: A^- AND R^-

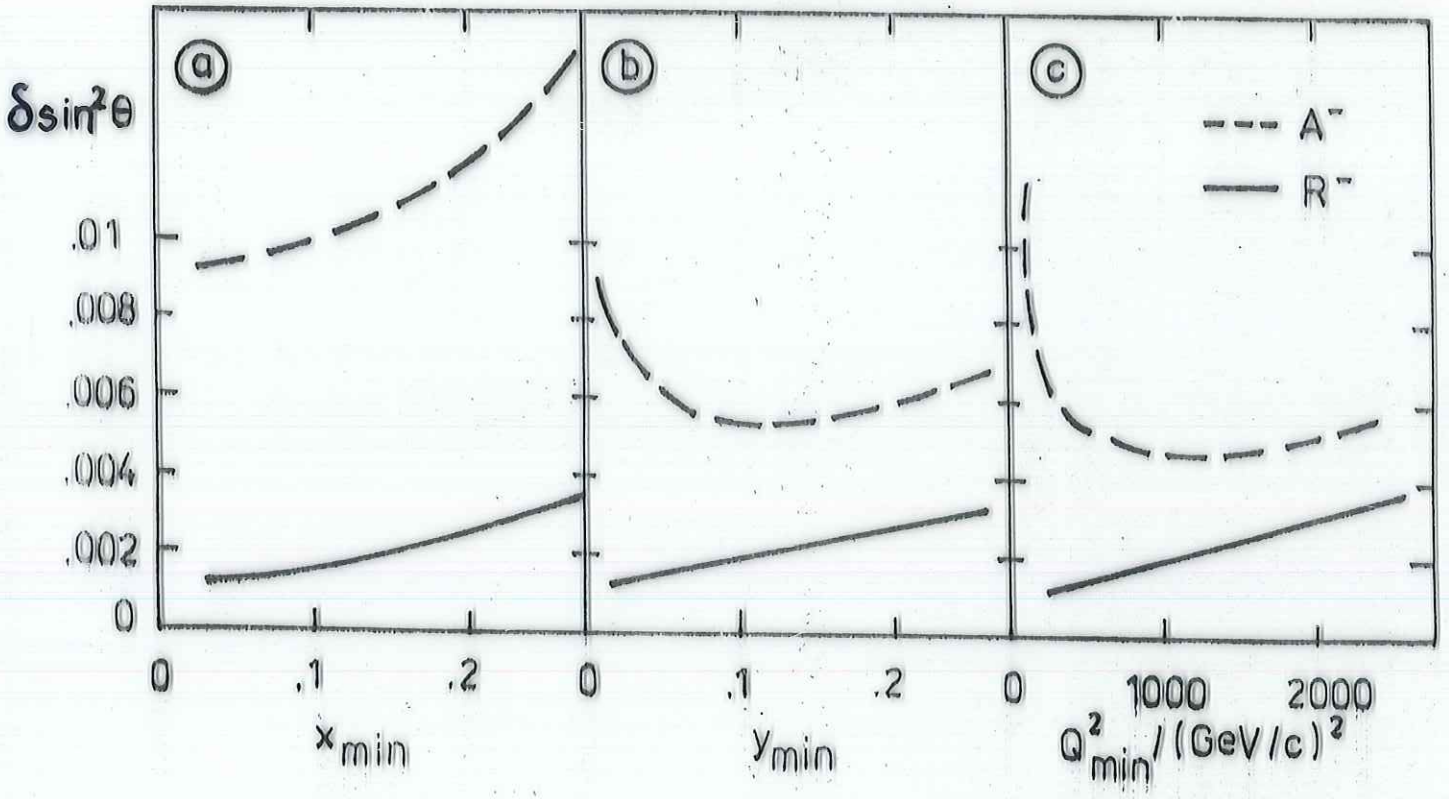


Fig. 3

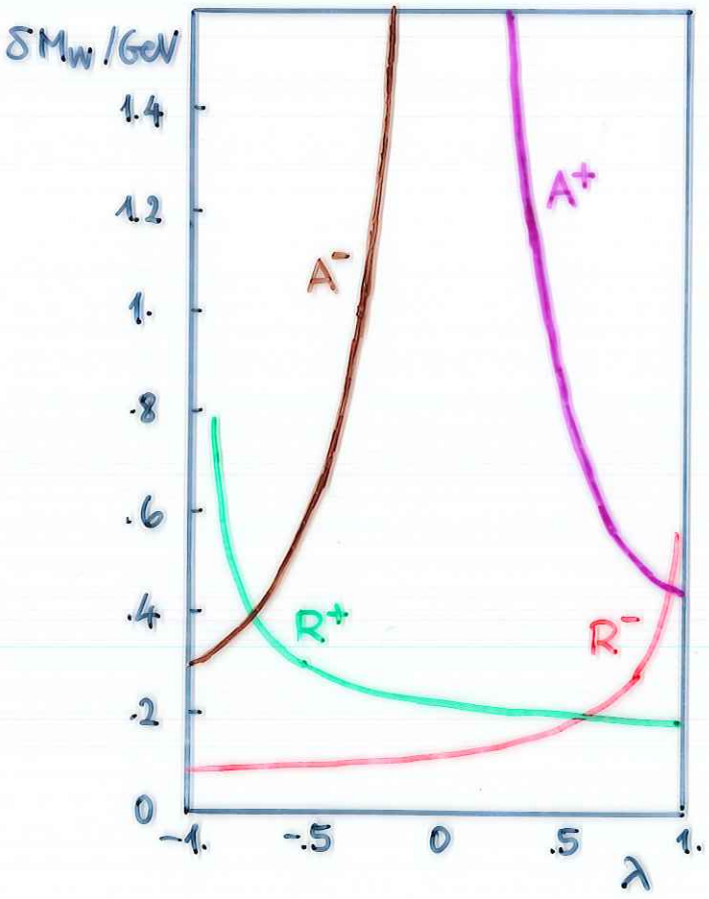
$\mathcal{L} = 200 pb^{-1}$

FINAL CUTS: $x > .1$

$y > .1$

$Q^2 > 500 GeV^2$

POLARIZATION: IS IT NEEDED ?!



STATISTICAL PRECISIONS

fixed / error		s^2_θ	M_Z	M_W	G_F
δs^2_θ	A^-		.005	.005	.007
	R^-		.002	.002	.005
δM_Z/GeV	A^-	3.02		.25	1.09
	R^-	.51		.10	.76
δM_W/GeV	A^-	2.53	.27		1.38
	R^-	.45	.10		.95

α

$\lambda = .8$

INFLUENCE OF THE ERROR OF THE FIXED (EW-INPUT UNCERTA
QUANTITY ON THE VALUE OF THE FITTED

fixed / Fixed	$\Delta \sin^2\theta$		ΔM_Z /GeV		ΔM_W /GeV	
	A^-	R^-	A^-	R^-	A^-	R^-
$\Delta s^2_\theta = \pm .001$			$-.58$ $+.57$	$\mp .26$	$-.54$ $+.53$	$\mp .28$
$\Delta M_Z = \pm 50$ MeV	$\pm .0001$	$\pm .0002$			$+.05$ $-.04$	$\pm .05$
$\Delta M_W = \pm 50$ MeV	$\mp .0001$	$\mp .0002$	$+.04$ $-.04$	$\pm .05$		

4. SYSTEMATIC EFFECTS

UNCERTAINTIES OF PARTONDISTRIBUTIONS : $x > .1$

δs_θ^2	SEA	$x u_v$	$x d_v$
A^-	$\mp .0003$	$\mp .0014$	$\pm .0011$
R^-	$\pm .0017$	$\pm .0031$	$\pm .0015$

- CALLEN-GROSS RELATION:

  SHIFT $R = 0 \rightarrow R = .1$

  $\delta s_\theta^2 = .0003$ $(.0008)$ A^- (R^-)

- SWITCHING m_Q ON AND OFF

  $m_c = 1.25$ GeV, $m_b = 4.5$ GeV, $m_t = 40$ GeV

  $\delta s_\theta^2 = .0001$ R^- even smaller for A^-

5. EXTENSIONS OF THE MODEL

GIVE UP:

- $\varrho = (M_W / M_Z \cos\theta)^2 = 1$ — Fig.
- $v = I_3^L - I_3^R - 2Q\sin^2\theta_0$ $\qquad I_3^R \neq 0$
  $a = I_3^L - I_3^R$
- Decouple the W-propagator from the other electroweak parame

δI_3^R :

e	u	d	
.056	.016	.034	A^-
.030			A^+ !

$\delta M_W^{loop} \simeq 400$ MeV , R^-.

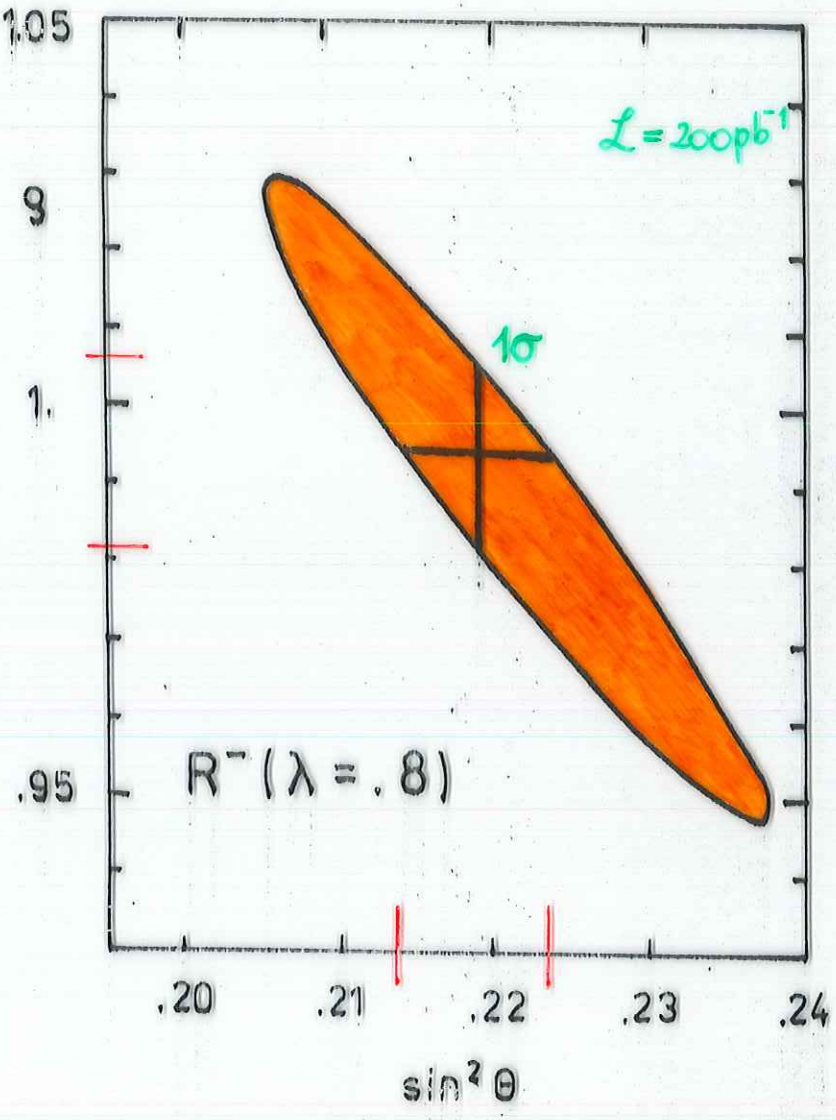
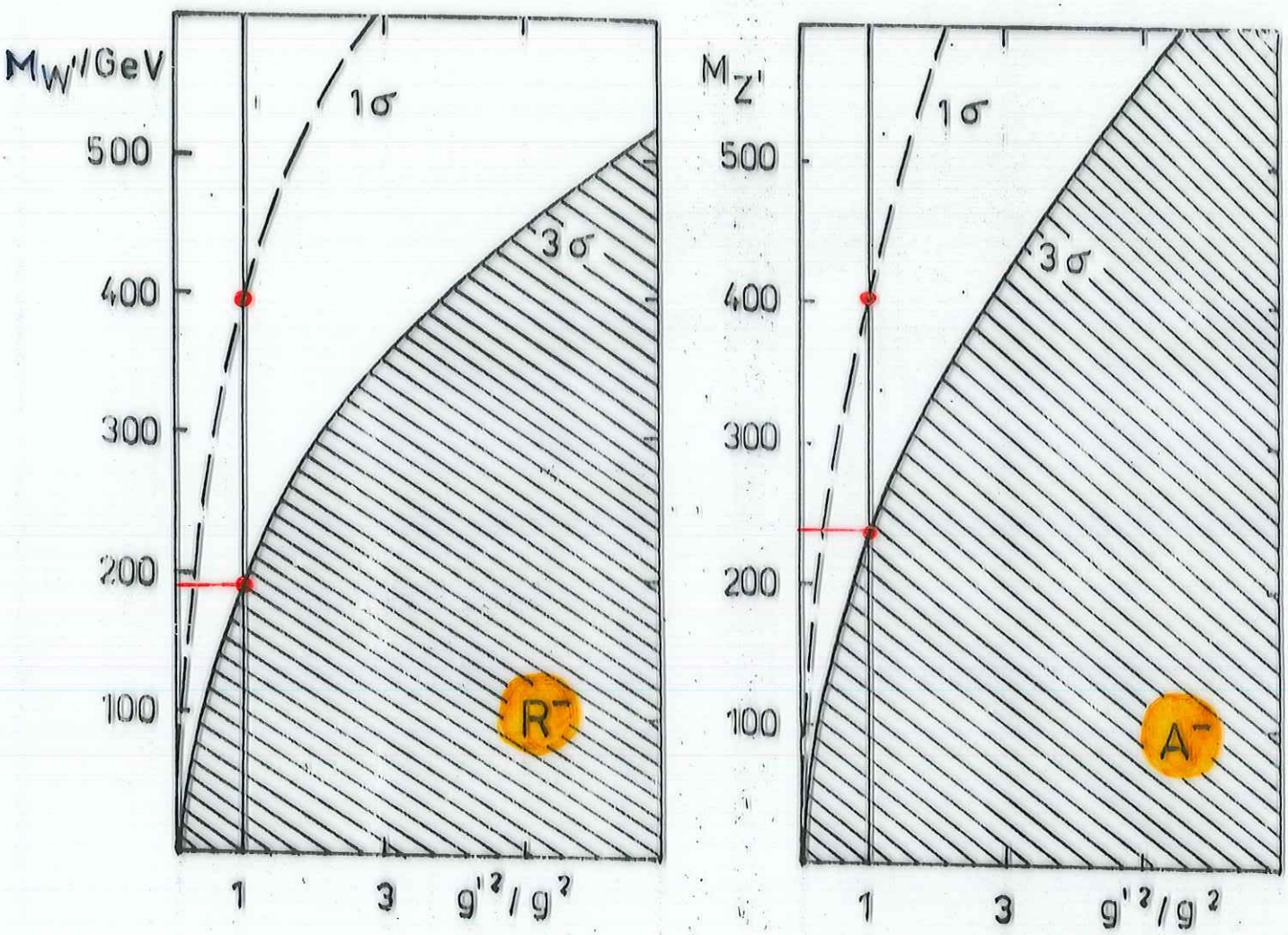

1.05
9
1.
.95
$\mathcal{L} = 200 pb^{-1}$
1σ
$R^-(\lambda = .8)$
.20
.21
.22
.23
.24
$\sin^2\theta$

Fig. 8

SENSITIVITY ON ADDITIONAL GAUGE BOSONS



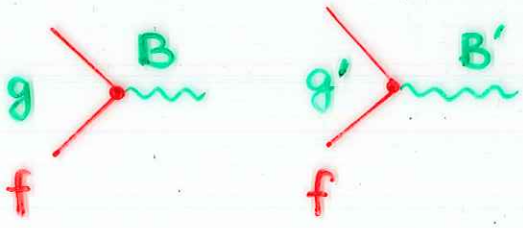
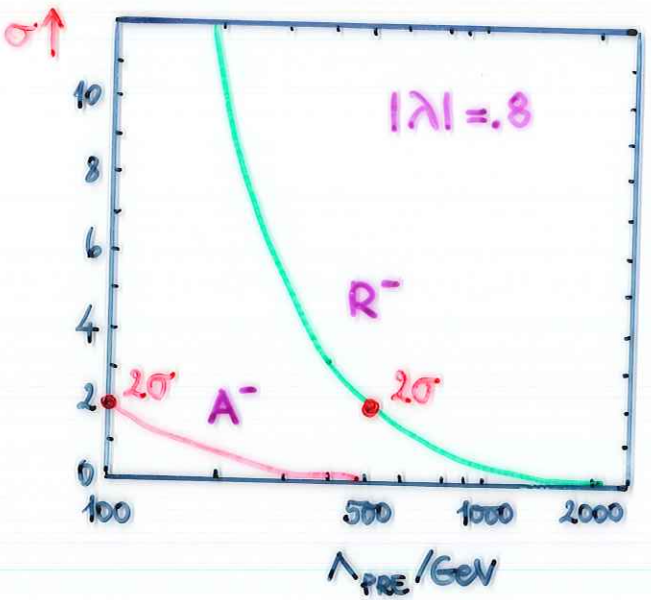


Fig. 9

$x > 0.1$, $y > .01$, $Q^2 > 500\ \text{GeV}^2$, $\mathcal{L} = 200\,\text{pb}^{-1}$

COMPOSITENESS SCALE: W's & Z's



$$K_{Z,W}(Q^2) = \frac{Q^2}{Q^2+M^2} \cdot A \cdot \frac{1}{1+\frac{Q^2}{\Lambda^2_{PRE}}}$$

7. CONCLUSIONS

- BEST PRECISIONS: Fix α, M_Z: FIT A THIRD PARAMETER

$\mathcal{L} = 200 pb^{-1}$: ± 100 MeV (stat) ± 100 (syst) δM_W

R^- $\pm .002$ (stat.) $\pm .002$ (syst.) δs^2_θ } $SU_{2L} \times U_{1Y}$

$x > .1$, $y > .1$, $Q^2 > 500\ GeV^2$

A^- : 2 ... 3 TIMES WORSE EVEN AT $|\lambda| = .8$ (statistics)

- R^- PRECISIONS DEPEND ONLY WEAKLY ON λ. $\lambda = 0$ INTRODUCES A FACTOR OF $*1.2$ ON δs^2_θ etc.

- MAIN SYSTEMATIC EFFECTS:

UNCERTAINTIES IN xs, xu_v, xd_v

$\sim \delta \to 0(\delta_{STAT})$.

OTHER UNCERTAINTIES : EW INPUT α_{LOT}, m_q LESS IMPORTANT

- $\delta g_{stat} = \pm .003$ R^- $\delta M_W = 400$ MeV R^- (propagator only)

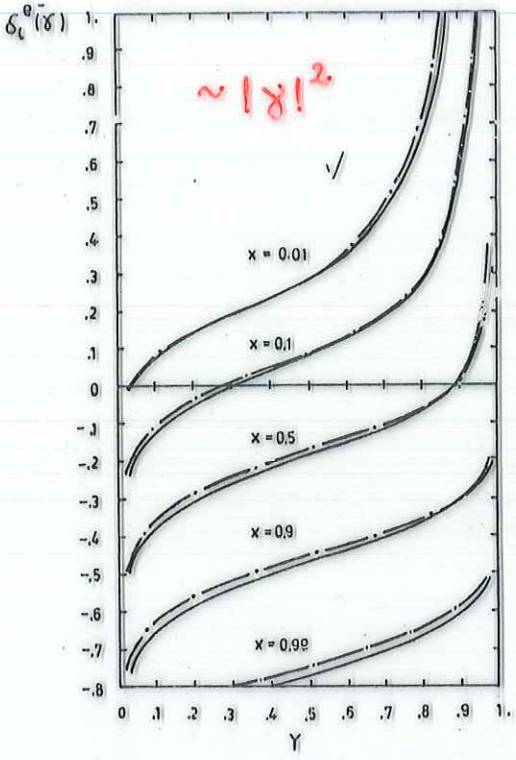
$\delta I^3_{Re} = \pm .03$ A^+

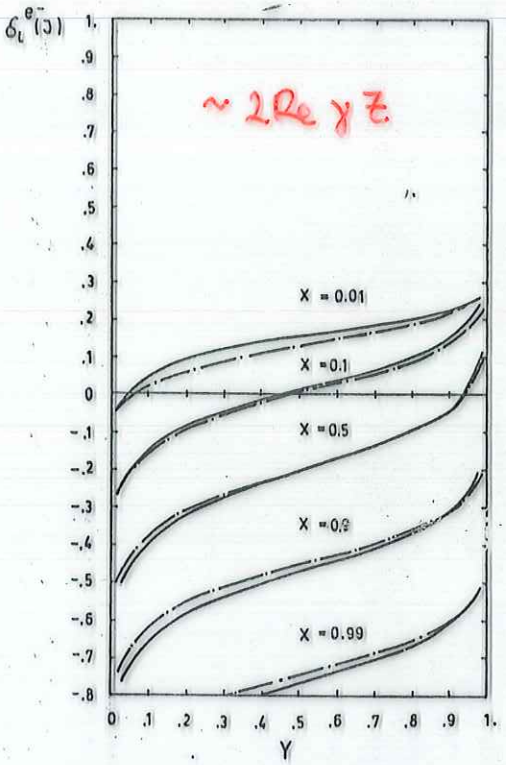
- $M_{Z'}$ 3σ (1σ) 230 (400 GeV)

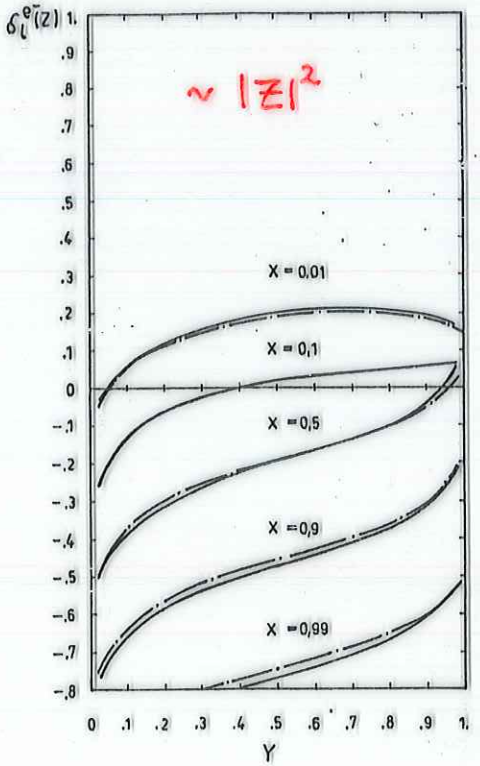
$M_{W'}$ 3σ (1σ) 190 (390 GeV)

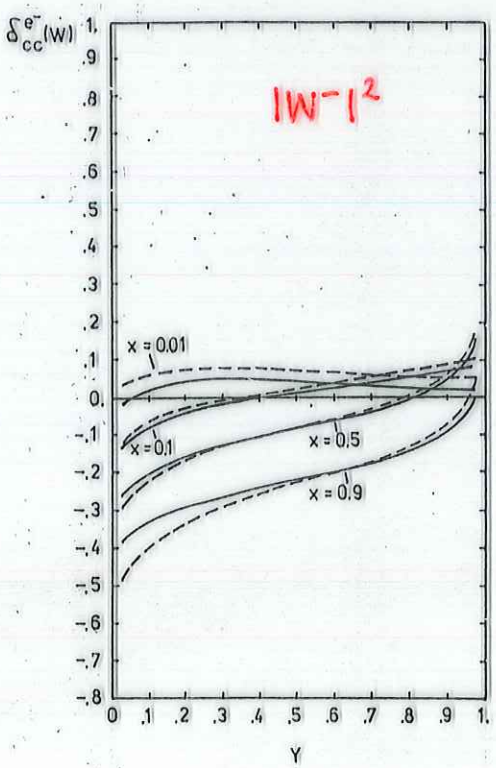
- $\Lambda_{PRE}(W,Z)$: 2σ A^- 100 GeV

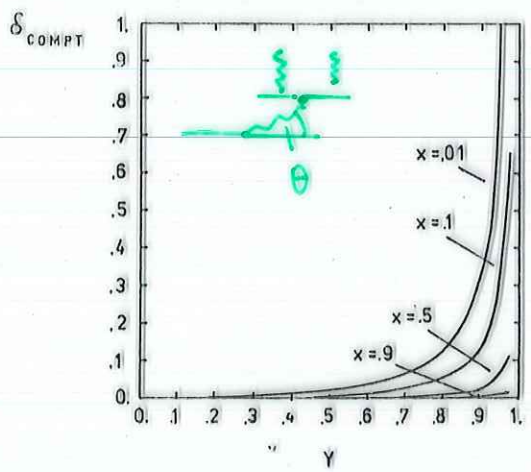
R^- 500 GeV

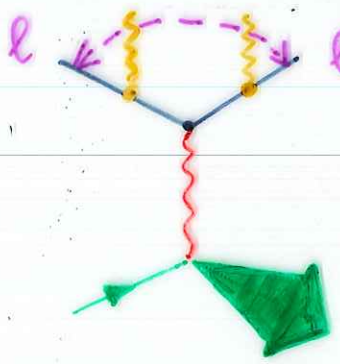




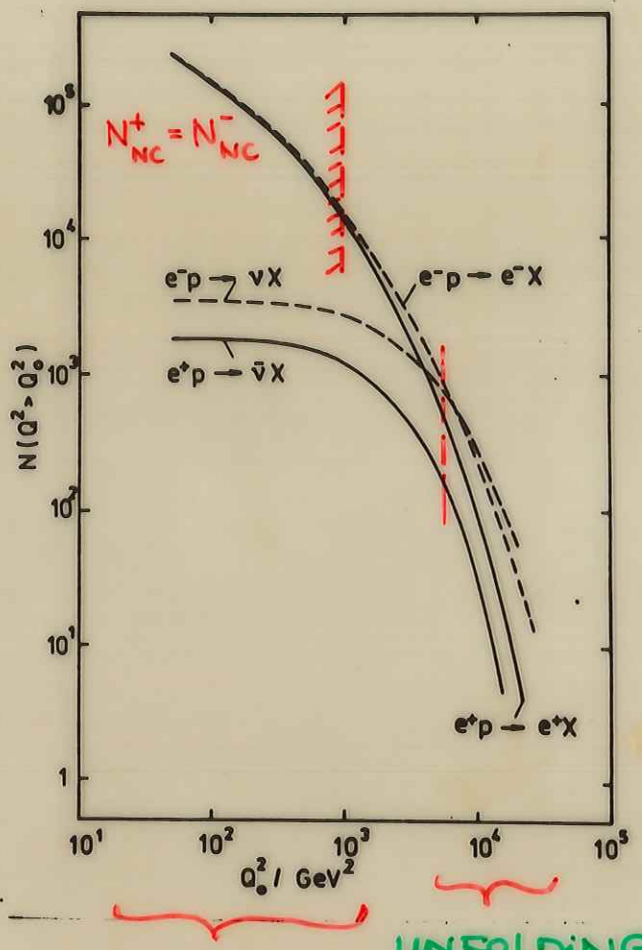








→ KINEMATICS (x, y)



EVENTRATES FOR $Q^2 > Q_0^2$:

$x > .01$, $y > .03$

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

UNFOLDING OF QUARK DISTRIBUTIONS

ELECTROWEAK TESTS ←

$N_{CC} \ll N_{NC}$

F_2^{em}

↓

QCD - TESTS