9.2.2000
M.K.

High-Q^2:

Emmanuelle Perez (Saclay)
Ken Long (IC London)
Masahiro Kuze (KEK)

- Leptoquarks
- Contact Int. ($M \gg \sqrt{s}$) eeqq
- $e-\tau$, $e-\mu$ LFV
- excited fermions
- SUSY
- Higgs
- top (bottom) / EW

vs. TeV - Run II
HERA - upg.
LHC
(TESLA)

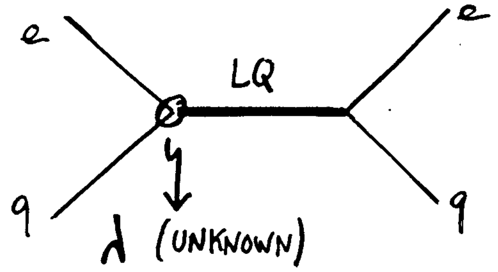
Caution: still rough/quick estimations & ideas ...

TERA = 寺 (temple) Buddism

SEARCHES FOR LEPTOQUARKS AT THERA

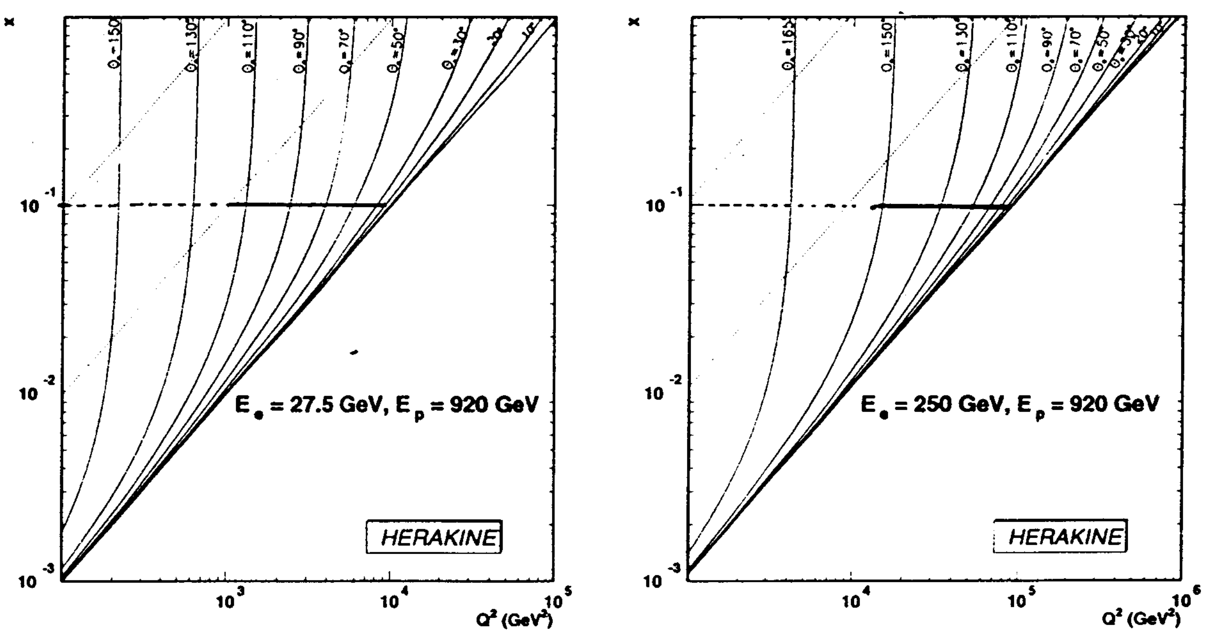
E. PEREZ

"LQ" = GENERIC e-q RESONANCE (e.g. $\tilde{q}$ in $\not{R}_p$ SUSY)



SIGNATURE : "NC DIS EVENTS LIKE" AT HIGH Q^2

$$\sigma \propto \frac{1}{s}\, q\left(x = \frac{M_{LQ}^2}{s}\right)$$



- DIFFERENCE COMPARED TO HERA :
  AT FIXED x/y, OUTCOMING LEPTON IS MORE CENTRAL AT THERA → fig.
- ROUGH ESTIMATE OF THERA SENSITIVITY :

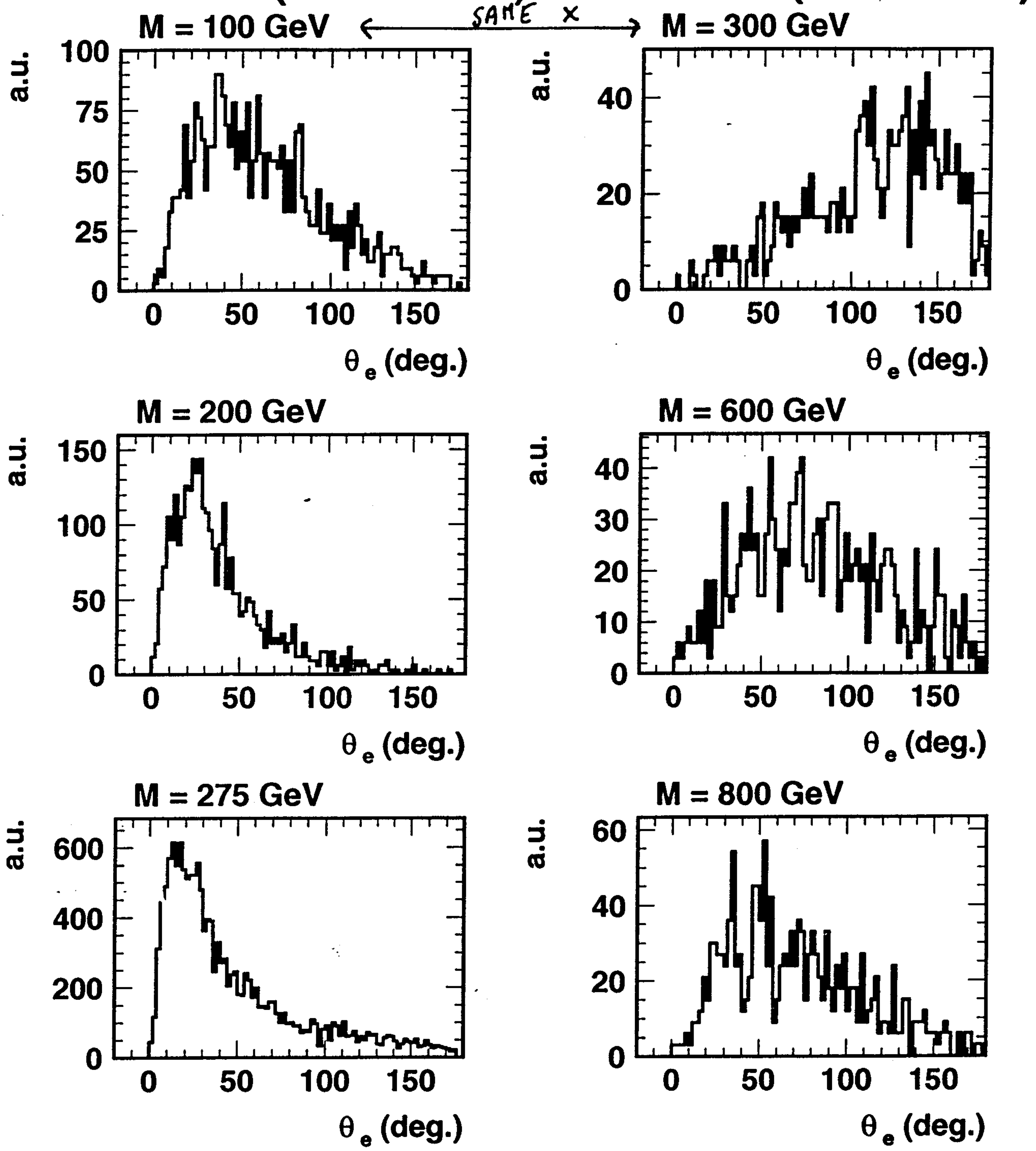
→ ANGULAR CUT (OR $y > y_{cut}$) TO ENHANCE LQ SIGNAL / NC DIS
($d\sigma/dy$: FLAT FOR SCALAR LQ, $\propto 1/y^2$ FOR NC DIS)

e.g. y_{cut} DECREASING FROM ~0.6 @ 200 GeV TO 0.2 @ 750 GeV
(SHOULD BE OPTIMISED FOR EXACT $\mathcal{L}$ AND SIGNAL EFFICIENCY)

→ ASSUME A GLOBAL RECONSTRUCTION $\varepsilon \sim 80\%$

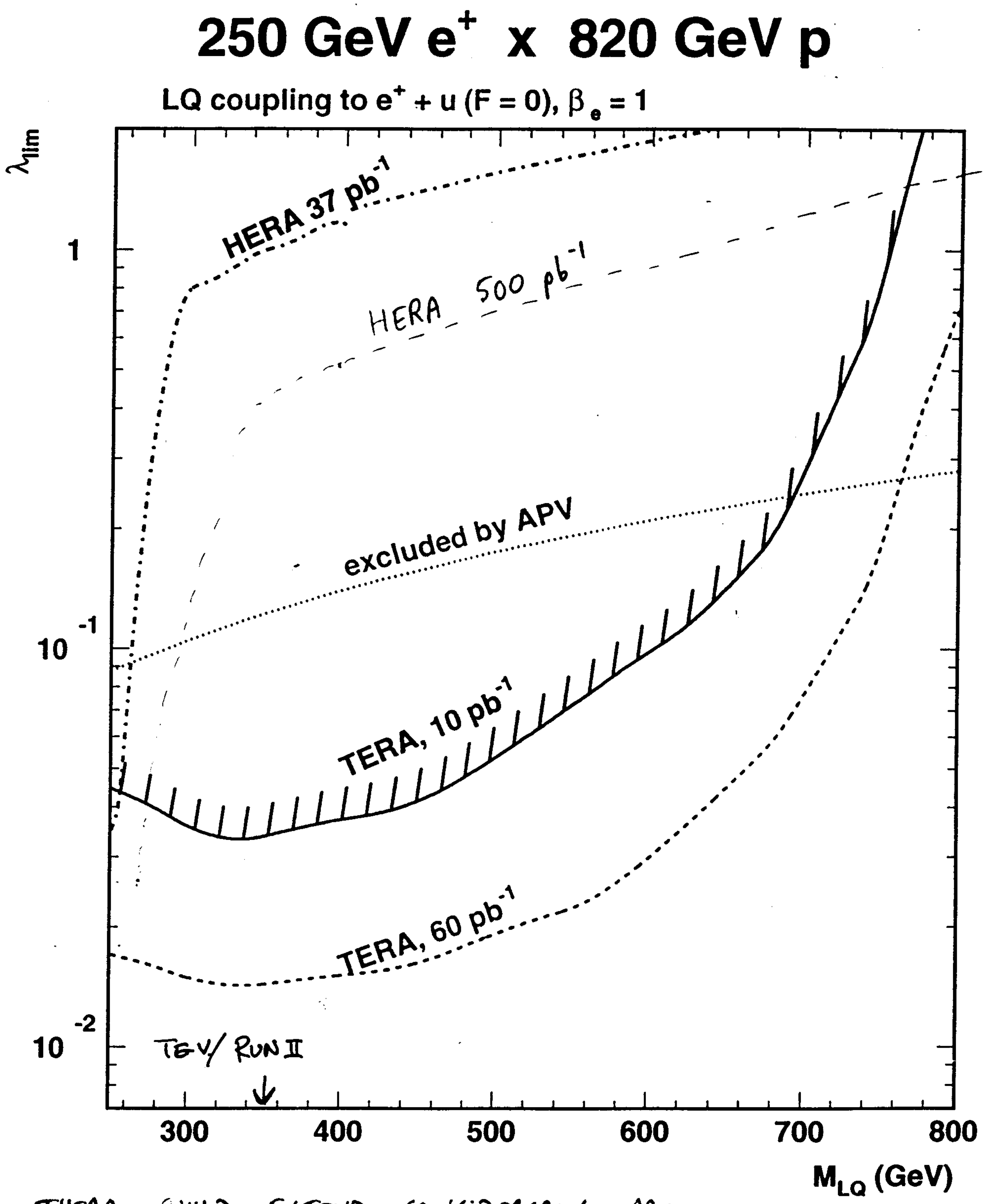
→ CONSTRAINTS ON LQs AT THERA

HERA (27.5 x 920) **TERA (250 x 920)**



⇒ AT THERA : OUTCOMING LEPTON MUCH MORE CENTRAL

↳ CAN EXPECT HIGHER EFFICIENCIES THAN THOSE OBTAINED AT HERA, FOR HIGHEST LQ MASSES

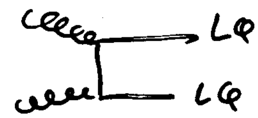


⇒ THERA COULD EXTEND CONSIDERABLY APV CONSTRAINTS

NB: Comparison with hep-ph/9912272 (χ^2 analysis of $d\sigma/dQ^2$):
Searching for a RESONANCE is much more powerfull

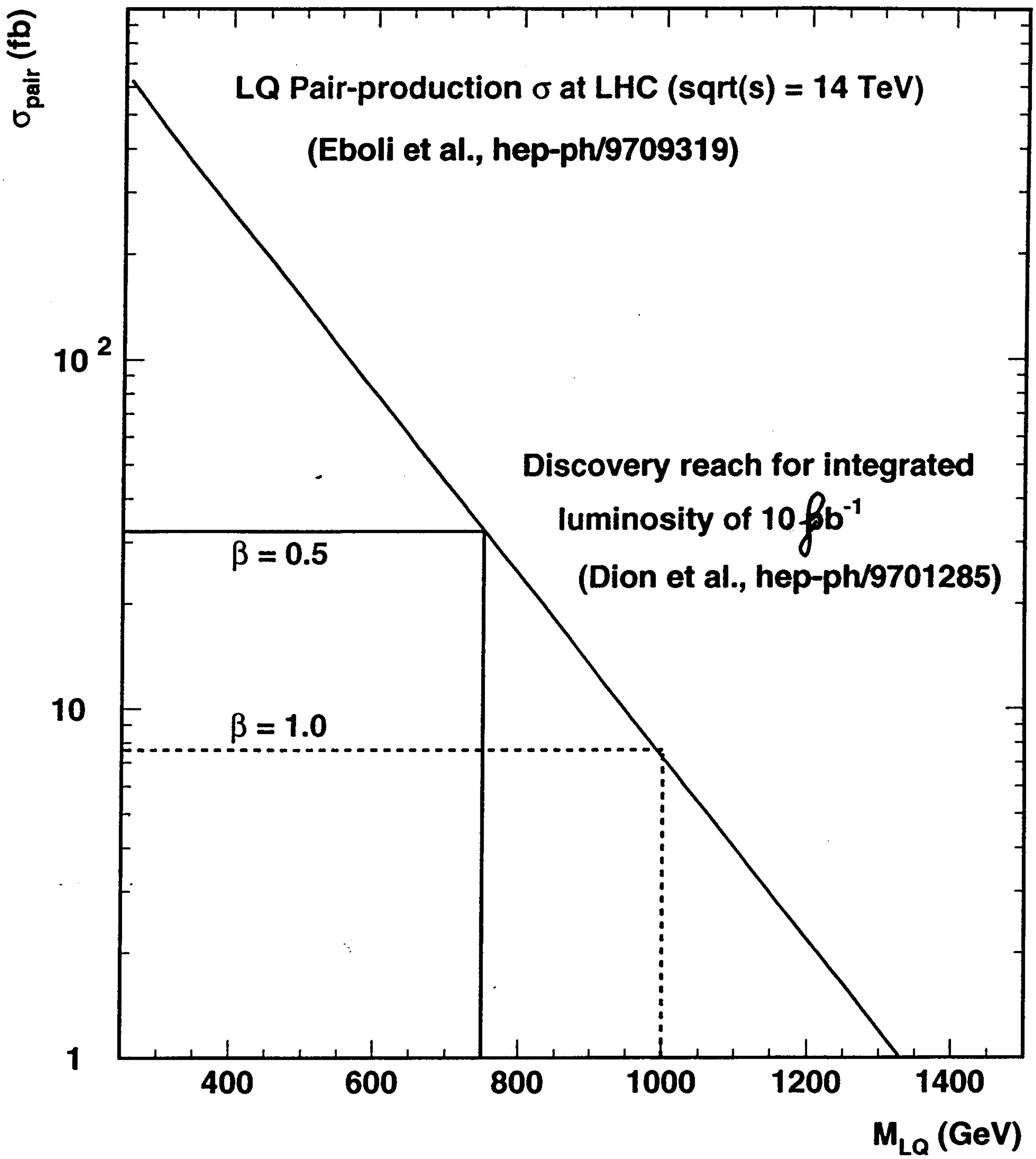
COMPARISON WITH LHC DISCOVERY POTENTIAL:

pp collider $\Rightarrow$ LQs produced by pair

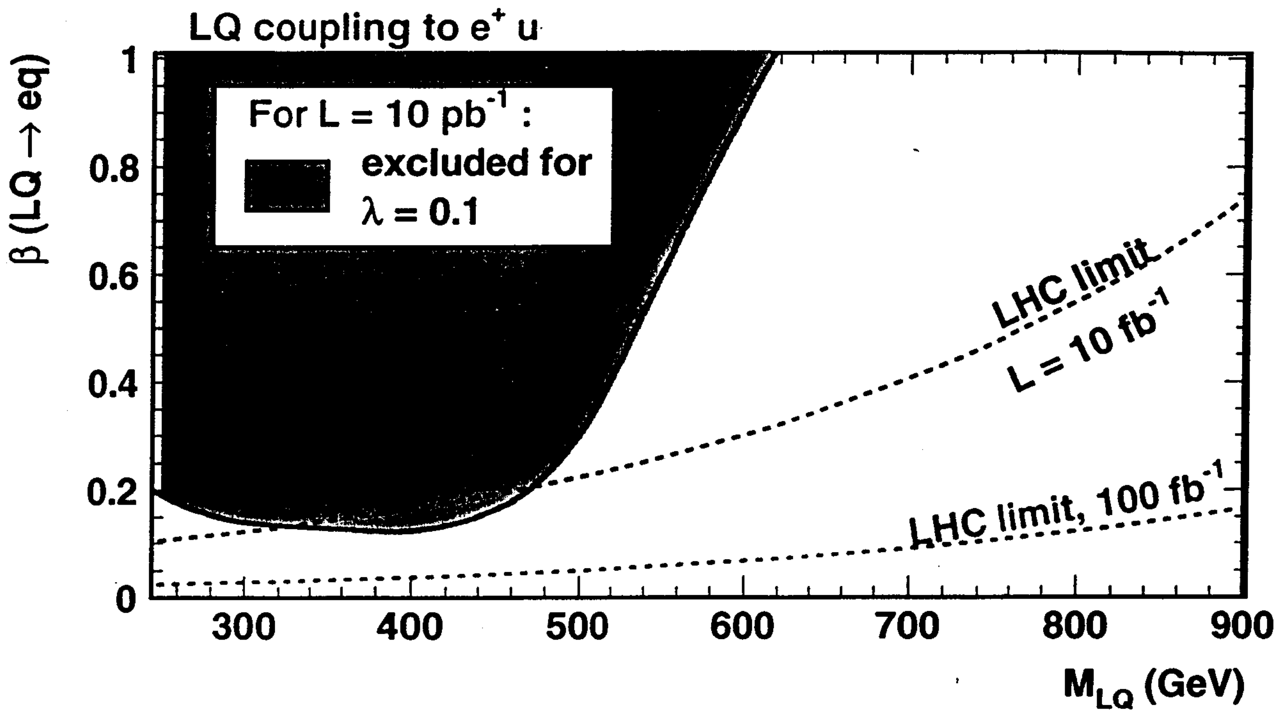


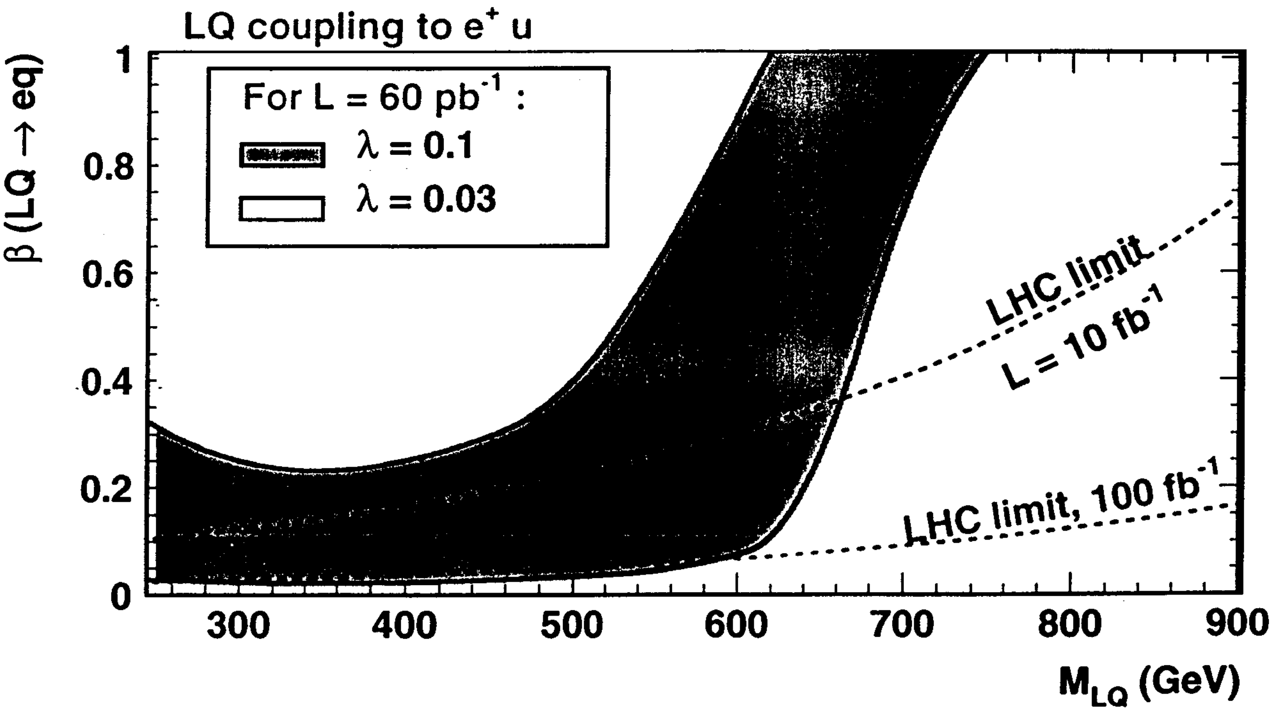
$\Rightarrow \sigma_{LQ}$ does not depend on λ

$\Rightarrow$ Express results as a function of β = BR(LQ $\to$ eq)



250 GeV e^+ x 820 GeV p





$\Rightarrow$ DIFFICULT FOR THERA TO DISCOVER A LQ NOT SEEN AT LHC

UNLESS :
- λ QUITE HIGH (eg $\lambda \sim \alpha_{EM}$)
- AND $\beta = BR(LQ \to eq)$ SMALL (eg $R\!\!\!/_p$ SUSY)

STILL: IF AN e-q RESONANCE IS DISCOVERED BEFORE (e.g. @ LHC)

THERA = IDEAL MACHINE TO DETERMINE THE QUANTUM NUMBERS OF THIS RESONANCE

- ANGULAR (y) DISTRIBUTIONS $\rightarrow$ SCALAR / VECTOR
- e^-p / e^+p COLLISIONS $\rightarrow$ FERMION NUMBER F OF LQ ($F=0$: $e^-\bar{q}$ $F=2$: e^-q)
- e POLARISATION $\rightarrow$ CHIRAL STRUCTURE OF INTERACTION ($e^-_L q$ OR $e^-_R q$. could rule out $\tilde{R}_p$ $\tilde{q}$ if e^-_R
- p POLARISATION $\rightarrow$ FLAVOR STRUCTURE (e^-u OR e^-d SINCE $\Delta u > 0$ $\Delta d < 0$)

$\hookrightarrow$ NOT FEASIBLE AT pp COLLIDER!

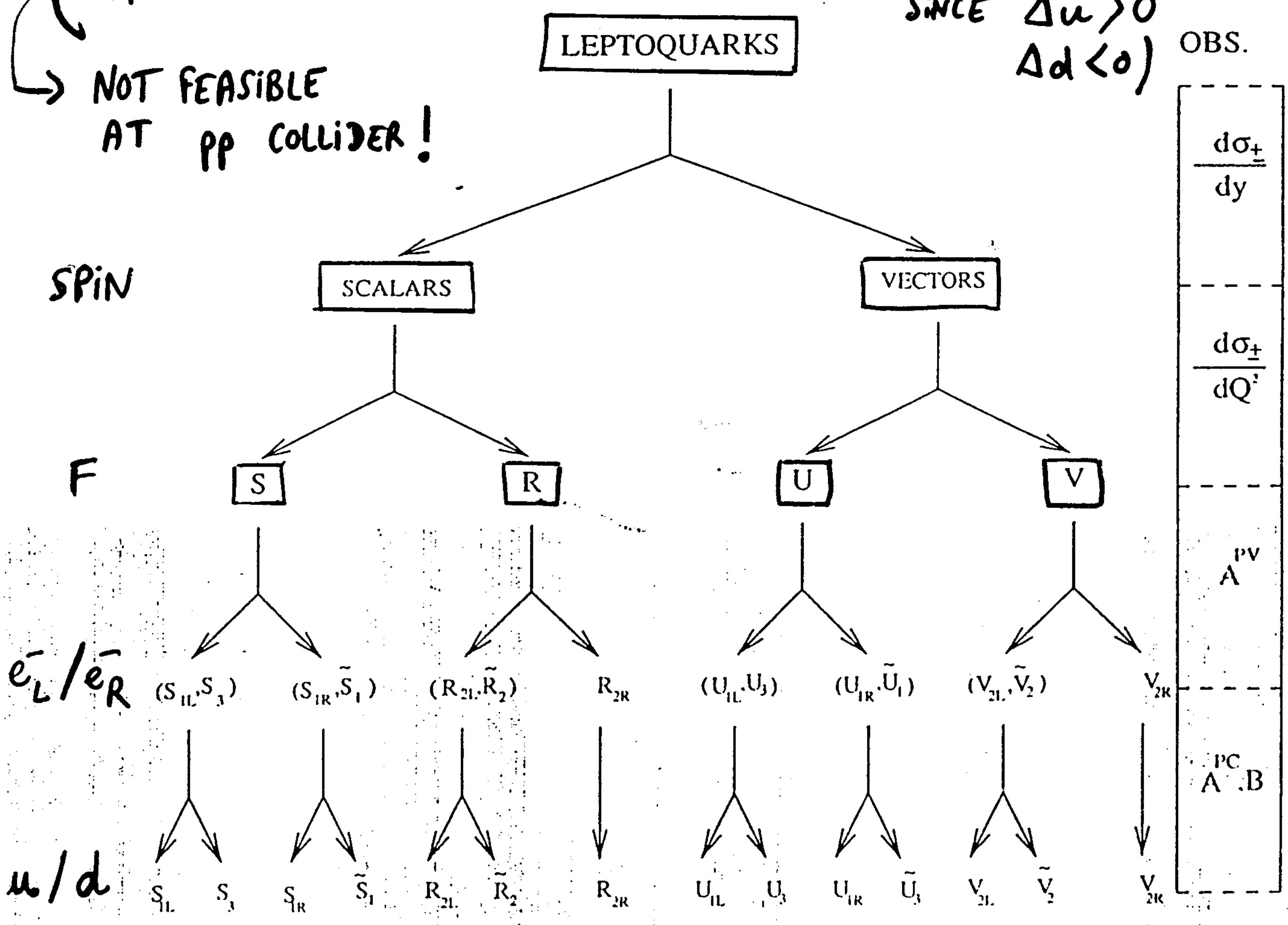
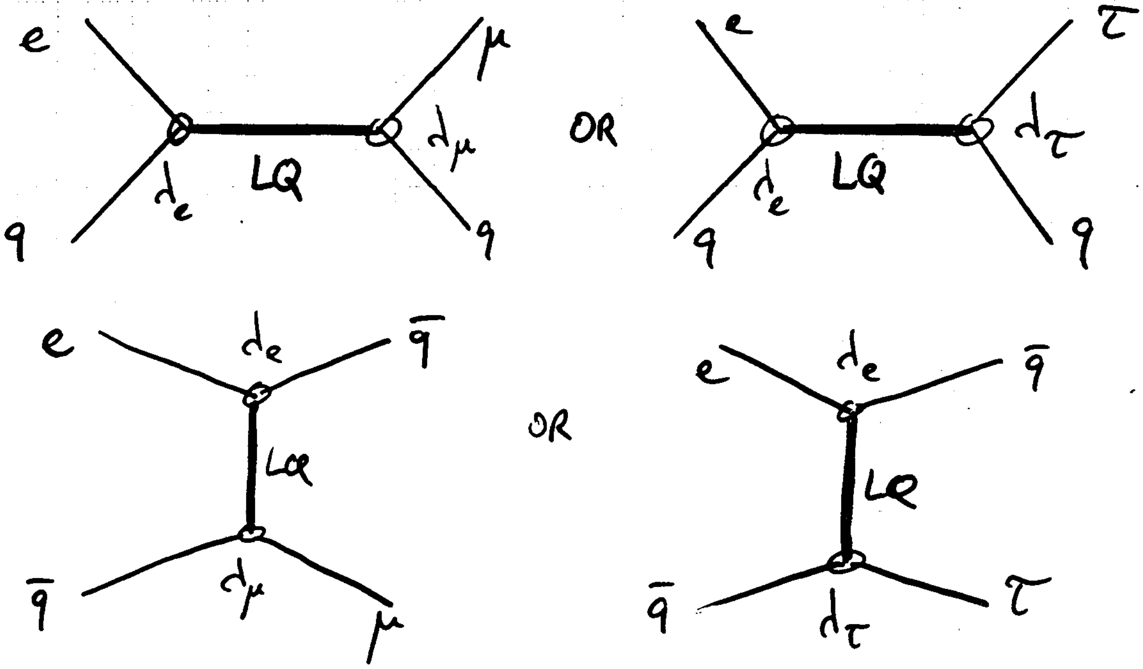


Figure 8: Schematic view for LQ identification.

$\hookrightarrow$ FROM J.M. VIREY et al hep-ph / 9912272

LEPTON FLAVOR VIOLATING LQ's AT THERA

= LQs POSSESSING COUPLINGS BOTH TO (e,q) AND TO (μ,q) (OR (τ,q)) PAIRS



FOR $M_{LQ} \gg \sqrt{s}$: CONTRACT PROPAGATORS
$\rightarrow$ $e\ell qq$ CONTACT INTERACTION

$$\sigma_{LFV} \propto s \left(\frac{\lambda_e \lambda_\ell}{M^2_{LQ}} \right)^2$$

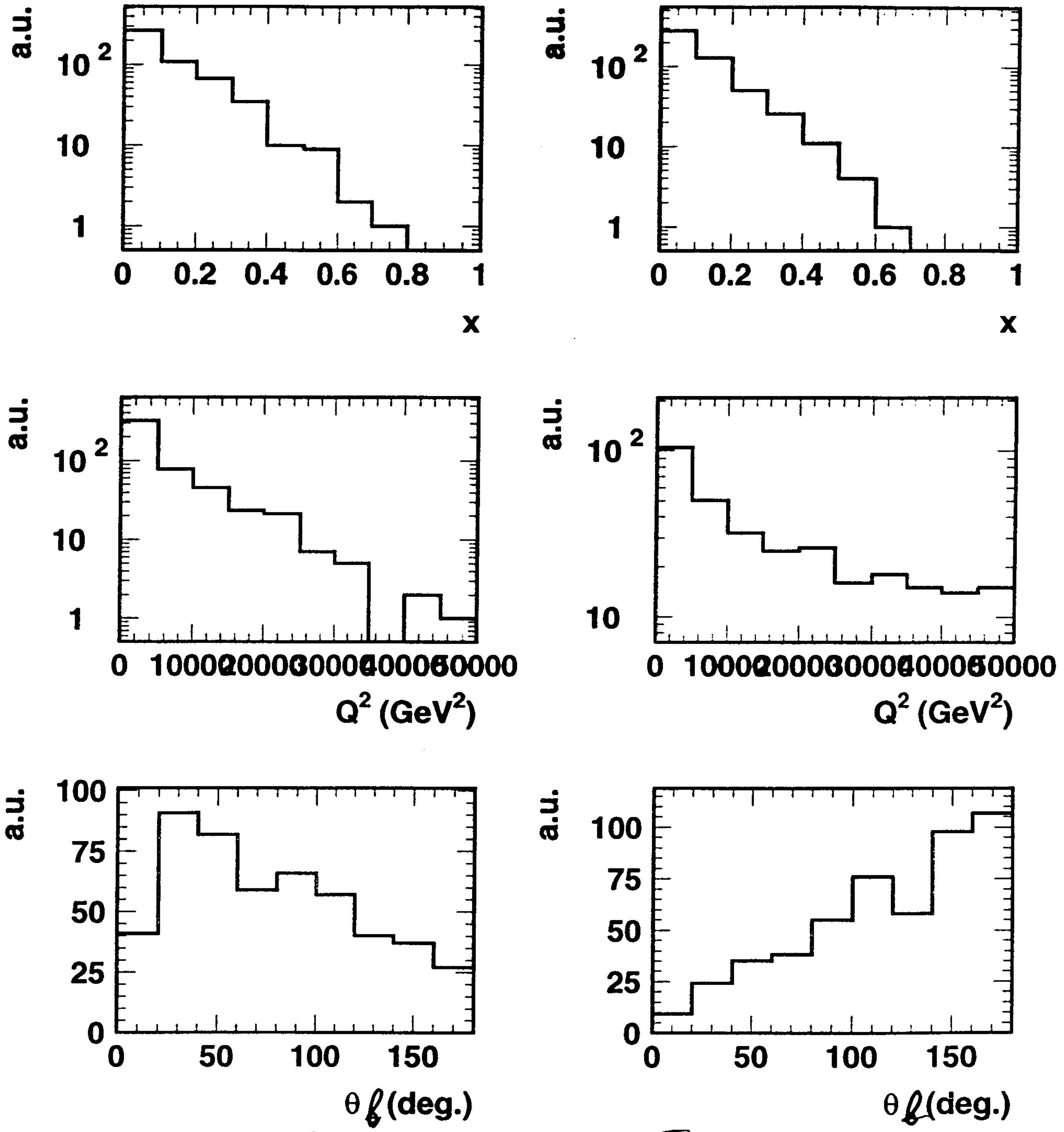
$\Rightarrow$ ASSUMING SAME SIGNAL ε AT THERA AND HERA :
(NOT TRUE A PRIORI SINCE $\neq$ DISTRIBUTIONS FOR θ_ℓ $\rightarrow$ fig.)

THERA @ $\sqrt{s} = 1$ TeV, $\mathcal{L} = 10\ pb^{-1}$
$\simeq$ HERA @ $\sqrt{s} = 300$ GeV, $\mathcal{L} = 100\ pb^{-1}$
SENSITIVITY ON $\frac{\lambda_e \lambda_\ell}{M^2}$ BETTER BY $\sim \sqrt{3}$ THAN THE ONE ACHIEVED YET AT HERA

LQs with M >> $\sqrt{S}$

(M = 5 TeV)

HERA (27.5 x 920) **TERA (250 x 920)**



→ FOR LQ → ℓq WITH $M_{LQ} \gg \sqrt{S}$:
OUTCOMING LEPTON MUCH MORE CENTRAL (BACKWARD)
AT THERA THAN AT HERA

example: Excited electron M. Kuze

Now: (ZEUS 96+97) $\sigma_{lim} \sim 0.1$ pb from 37 pb^{-1} @ $\sqrt{s} = 300$ GeV } for $f/\Lambda = 1/m_{e^*}$,

$(f/\Lambda)_{lim} = 2$ TeV^{-1} @ $m = 190$ GeV } $m_{e^*} \gtrsim 230$ GeV

TERA: crosssections (taken from Boudjema et al. 93, $\sqrt{s} = \underline{1.26}$ TeV)

"LEP × LHC"

$\sigma \sim$ 2 pb @ $m_{e^*} = 200$ GeV. $f/\Lambda = 1\ TeV^{-1}$

0.5 500 "

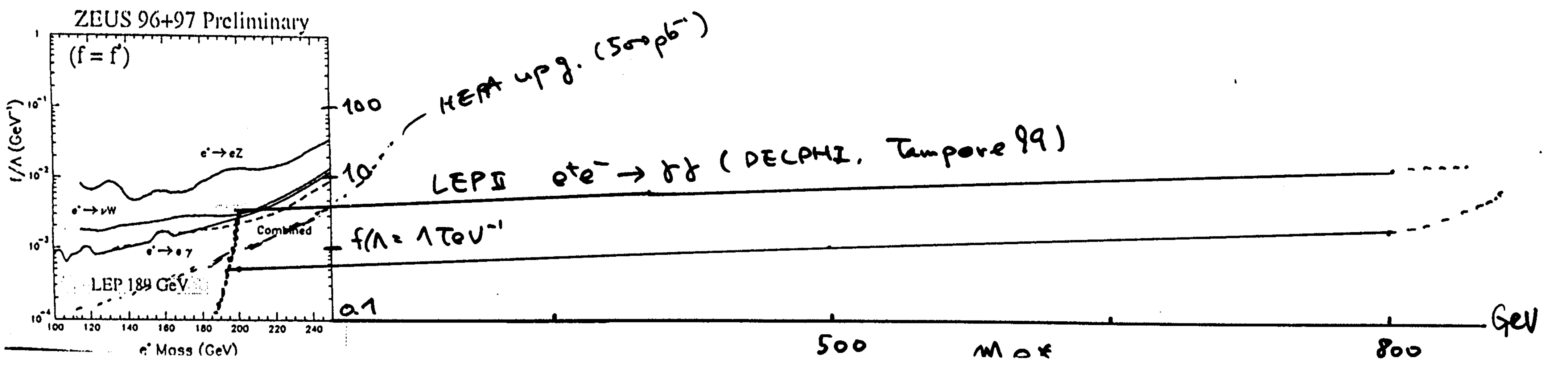
0.1 800 "

for $f/\Lambda = 1/m_{e^*}$,

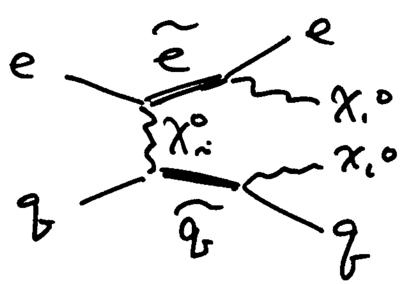
$m_{e^*} \gtrsim 650$ GeV

example: $\sigma_{lim} \sim 0.4\ pb^{-1}$ from $10\ pb^{-1}$ data

$\rightarrow (f/\Lambda)_{lim} \cong (0.5, 1, 2)\ TeV^{-1}$ @ $m = (200, 500, 800)$ GeV



example: MSSM $\tilde{e}\tilde{q}$ production M.Kuze



Now: (ZEUS 94-97) $\sigma_{lim} = 0.2\,pb$ from $47\,pb^{-1}$ @ $\sqrt{s} = 300\,GeV$
($\varepsilon = 40\%$)

$\frac{1}{2}(m_{\tilde{e}} + m_{\tilde{q}}) \gtrsim \underline{\underline{77\,GeV}}$ for $\tan\beta = 1.41$, $\mu = -100\,GeV$, $m_{\chi_1^0} = 60\,GeV$ $(M_2 = 2M_1)$

cf. HERA upgrade
~95 GeV from $500\,pb^{-1}$ (P. Schleper)

cross sections at TERA (Courtesy M. Corradi)

$m_{\tilde{e}}$	$m_{\tilde{q}}$	$m_{\chi_1^0}$	250x920	500x920	
100 GeV	100	50	2 pb	3 pb	e^-p
150	150	75	0.5	0.85	e^-p
200	200	100	0.14	0.3	e^-p
"	"	"	0.08		e^+p

$\tan\beta = 10$
$\mu = -500\,GeV$
$(M_2 = 2M_1)$

if $\varepsilon = 60\%$, $10\,pb^{-1} \to \sigma_{lim} = 0.5\,pb$
$100\,pb^{-1} \to 0.05\,pb$

exclusion reach $\frac{1}{2}(m_{\tilde{e}} + m_{\tilde{q}}) \gtrsim 150\,GeV$, $\gtrsim 250\,GeV$ } 250x920 e^-p

cf. $m_{\tilde{q}}$, m_{χ^0} limits from $\underline{\underline{LHC}}$?

SM HIGGS AT TESLA $\otimes$ HERA ?

E. PEREZ

- LEP 2 : CURRENTLY $M_H > 106$ GeV ($\sqrt{s} = 202$ GeV)
  WITH RUN AT $\sqrt{s} = 206$ GeV, CAN PROBE
  UP TO ~ 112 GeV

- LHC : FOR INTERMEDIATE MASS RANGE ($\sim 100 < M_H < 135$ GeV)
  MAIN PRODUCTION MODE : $gg \to H$
  BUT $M_H < 135$ GeV $\Rightarrow$ $H \to b\bar{b}, c\bar{c}$
  $\hookrightarrow$ HUGE BACKGROUND !!

  $\Rightarrow$ POSSIBILITIES :
  - $pp \to H$, $H \to \gamma\gamma$ (BR $\sim 0.2\%$)
    SEEMS $\sim$ HOPELESS
  - Associated production, e.g. $pp \to t\bar{t}H$
    FEASIBLE, BUT TAKES TIME ...

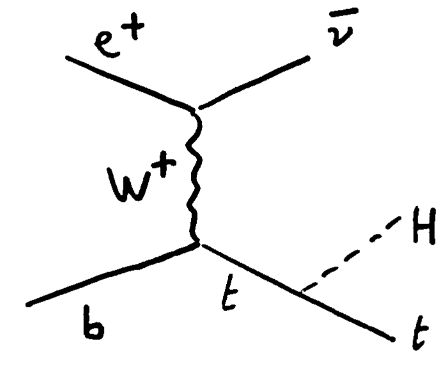
$\Rightarrow$ IF NO LIGHT HIGGS IS FOUND AT LEP 2 :
THE WINDOW $110 < M_H < \sim 135$ GeV
COULD STILL BE OPEN AFTER FEW (~ 3)
YEARS OF LHC RUNNING.
$\to$ IS THERE A HOPE TO SEE A LIGHT HIGGS
AT TERA ? [BEFORE TESLA !]

NB : TEVATRON RUN II : IMPROVED ANALYSES METHODS COULD LEAD
TO A SENSITIVITY .... WORK IS UNDER WAY....

PRODUCTION OF A LIGHT SM HIGGS @ TERA

cf studies done for LEP ⊗ LHC

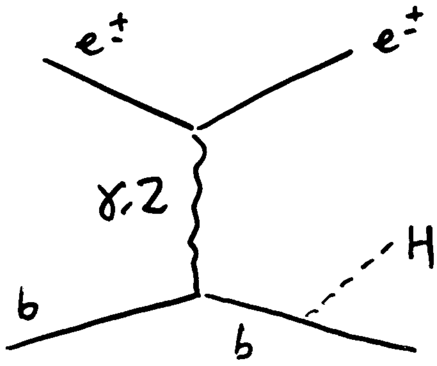
(1)



(only if e^+ in initial state)

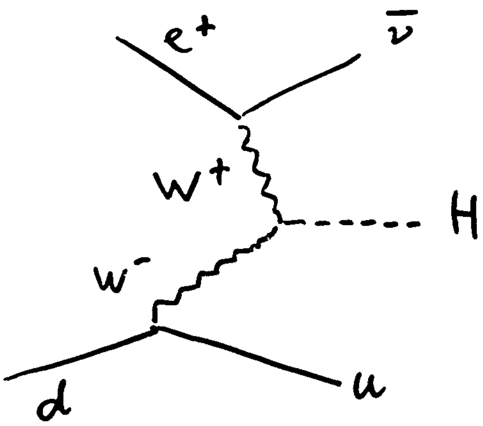
$\sigma \sim 2.6\ 10^{-4}$ pb
for $m_H = 100$ GeV
($\sqrt{s} = 1360$ GeV, ie 500×920)

(2)

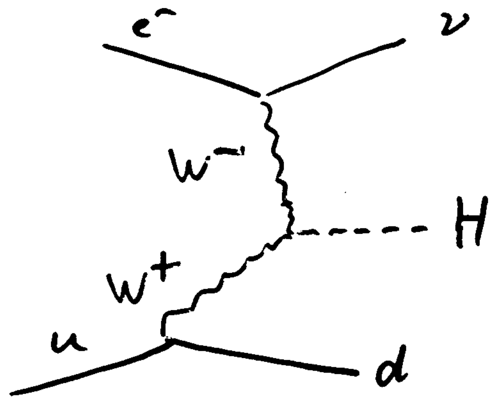


$\sigma \sim 6.\ 10^{-4}$ pb
@ $\sqrt{s} = 1360$ GeV

(3) WW FUSION :



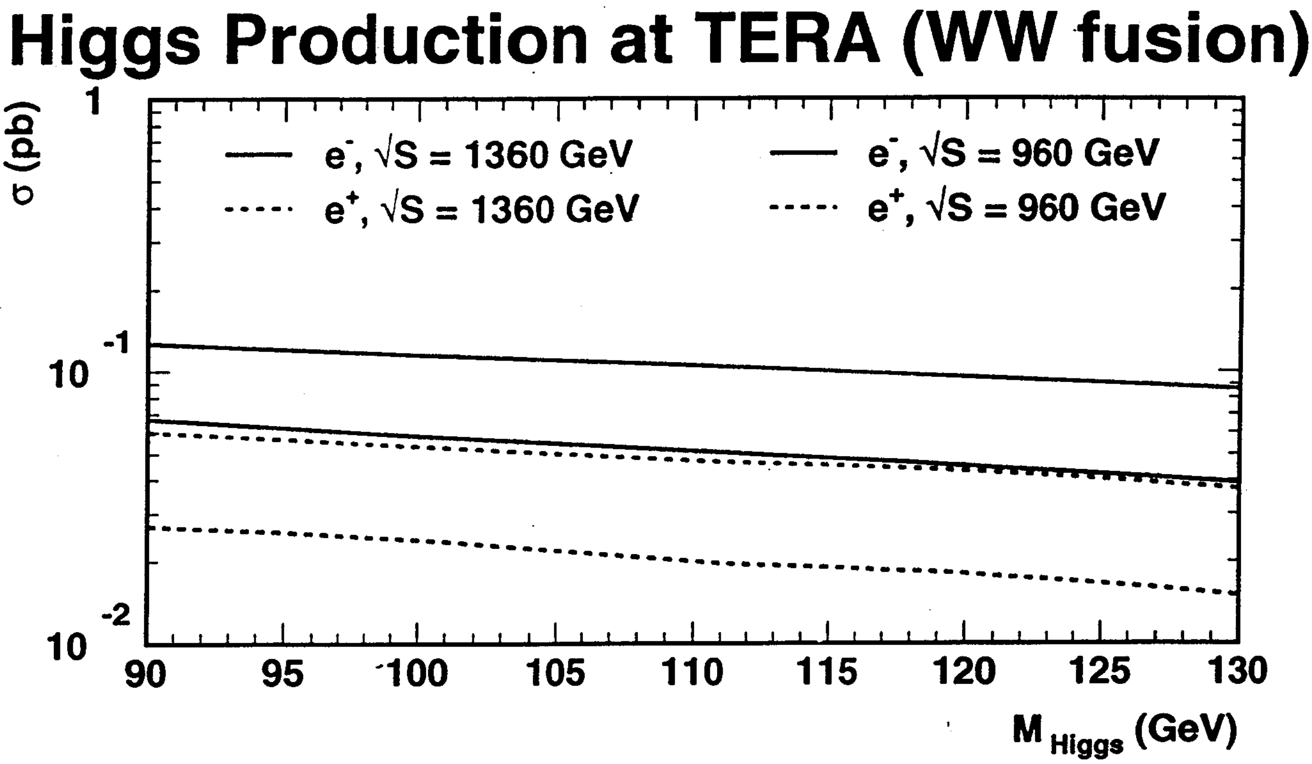
and



CROSS SECTIONS NOT TOO SMALL !!

(4) ZZ FUSION $\sigma_{ZZ} < \sigma_{WW}$

CROSS SECTIONS CALCULATED WITH COMPHEP.



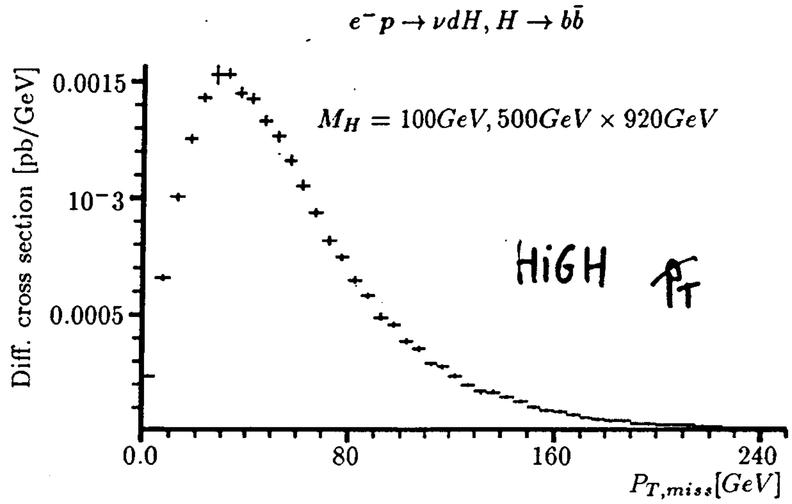
- σ HIGHER WITH e^- THAN WITH e^+ (incoming u) BY ~ FACTOR OF 2

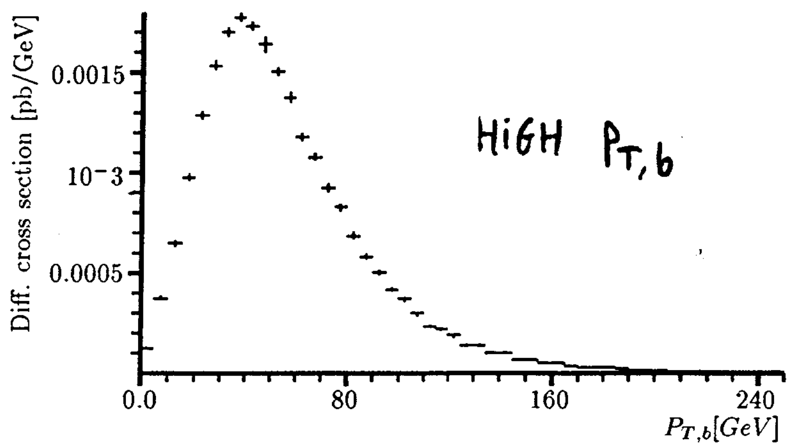
- FOR $E_e = 500$ GeV, $E_p = 920$ GeV ($\sqrt{s} = 1360$ GeV):

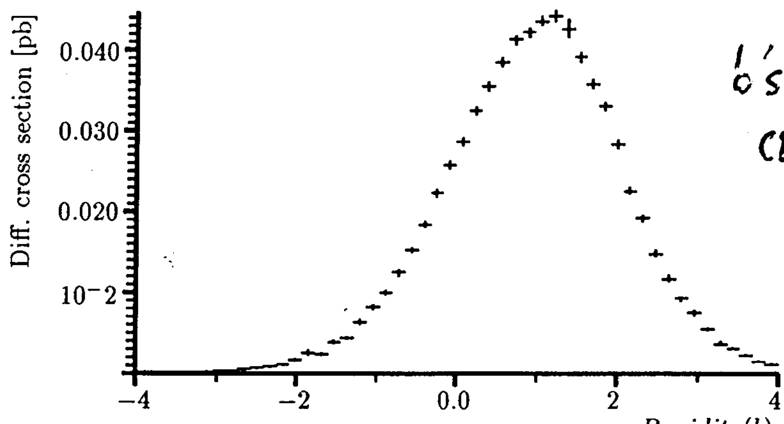
  $\sigma_{HIGGS} \simeq 0.1$ pb for $100 < m_H < 140$ GeV

- WITH POLARIZED e^- (L) THE CROSS SECTION IS ENHANCED BY A FACTOR OF TWO.

SM HIGGS AT THERA :



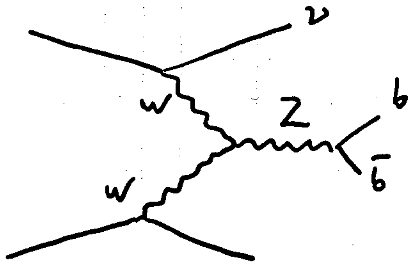


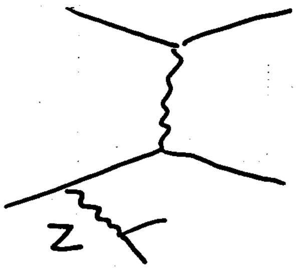


b's ARE QUITE CENTRAL

SM BACKGROUNDS TO HIGGS SIGNAL :

① Z production





+ .....

$M(b\bar{b})$ peaked at M_Z

LEP 2 excludes $M_H < 106$ GeV

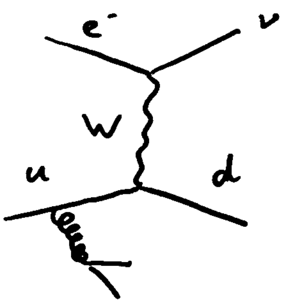
$\Rightarrow$ REQUIRE THAT $M(b\bar{b}) > 100$ GeV

WITH $M(b\bar{b}) > 100$ GeV : $\sigma_Z = 4.\,10^{-3}$ pb

② $\gamma \to b\bar{b}$ VIA $WW\gamma$ or γ radiation from fermion line

$M(b\bar{b}) > 100$ GeV $\rightarrow$ $\sigma_\gamma \simeq 10^{-4}$ pb

③ QCD radiation $gg \to b\bar{b}$



$\rightarrow$ $\sigma \sim 5.\,10^{-3}$ pb

④ "FAKE" BACKGROUNDS

eg $\gamma g \to b\bar{b}$, HIGH p_T DUE TO MISMEASUREMENT OF HADRONIC FINAL STATE

↳ TRY TO ESTIMATE FROM CURRENT γp DATA @ HERA

CONCLUDING REMARKS :

- AT LEAST 100 pb^{-1} NEEDED TO OBSERVE 10 EVENTS, B-TAG !

- STILL, WORHWHILE TO HAVE A CLOSER LOOK
  (ESPECIALLY IF NO H SEEN AT LEP2)
  → BETTER ESTIMATION OF BACKGROUND
  (YET "ROUGH, INCOMPLETE AND (PROBABLY) UNRELIABLE")

- A LAST WORD ABOUT MSSM HIGSSES:

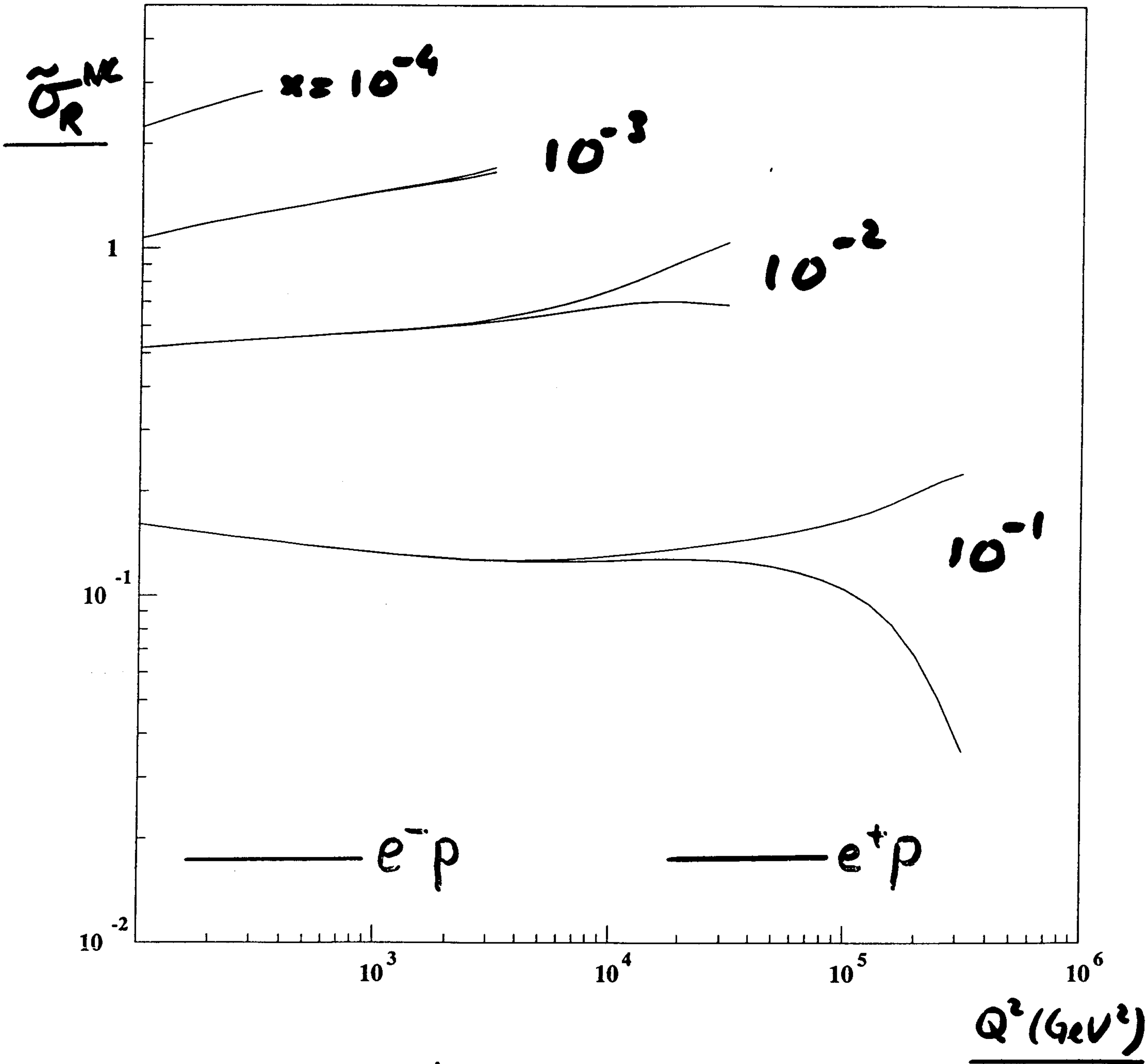
AND $\sigma(ep \to e b H)$ SMALL, SO HOPELESS EVEN AT HIGH $\tan\beta$

AND high $\tan\beta$ DOMAIN WILL BE COVERED BY TEVATRON

→ MSSM HIGSSES IS NOT FOR THERA
(@ high $\tan\beta$)

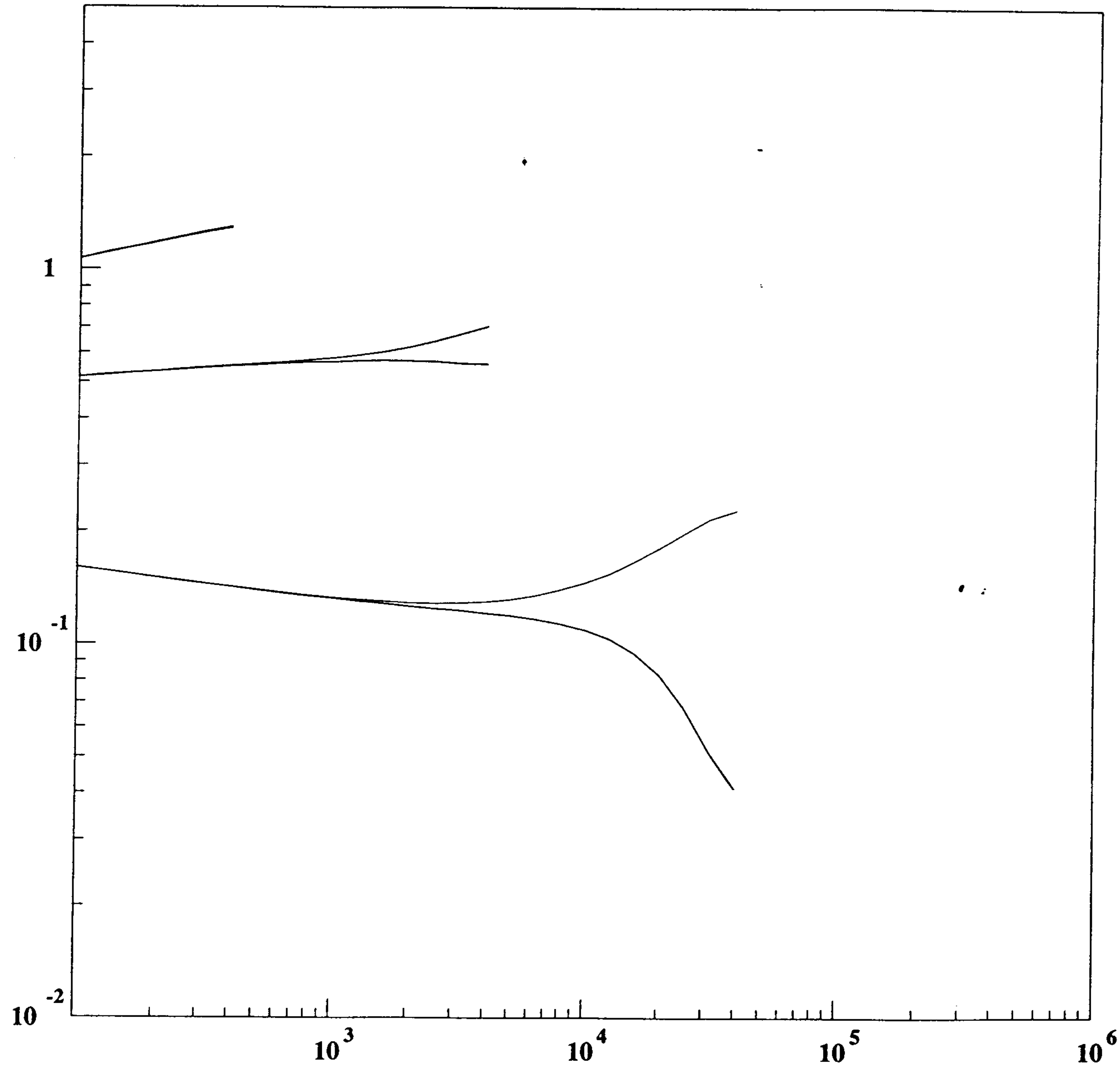
K. Long

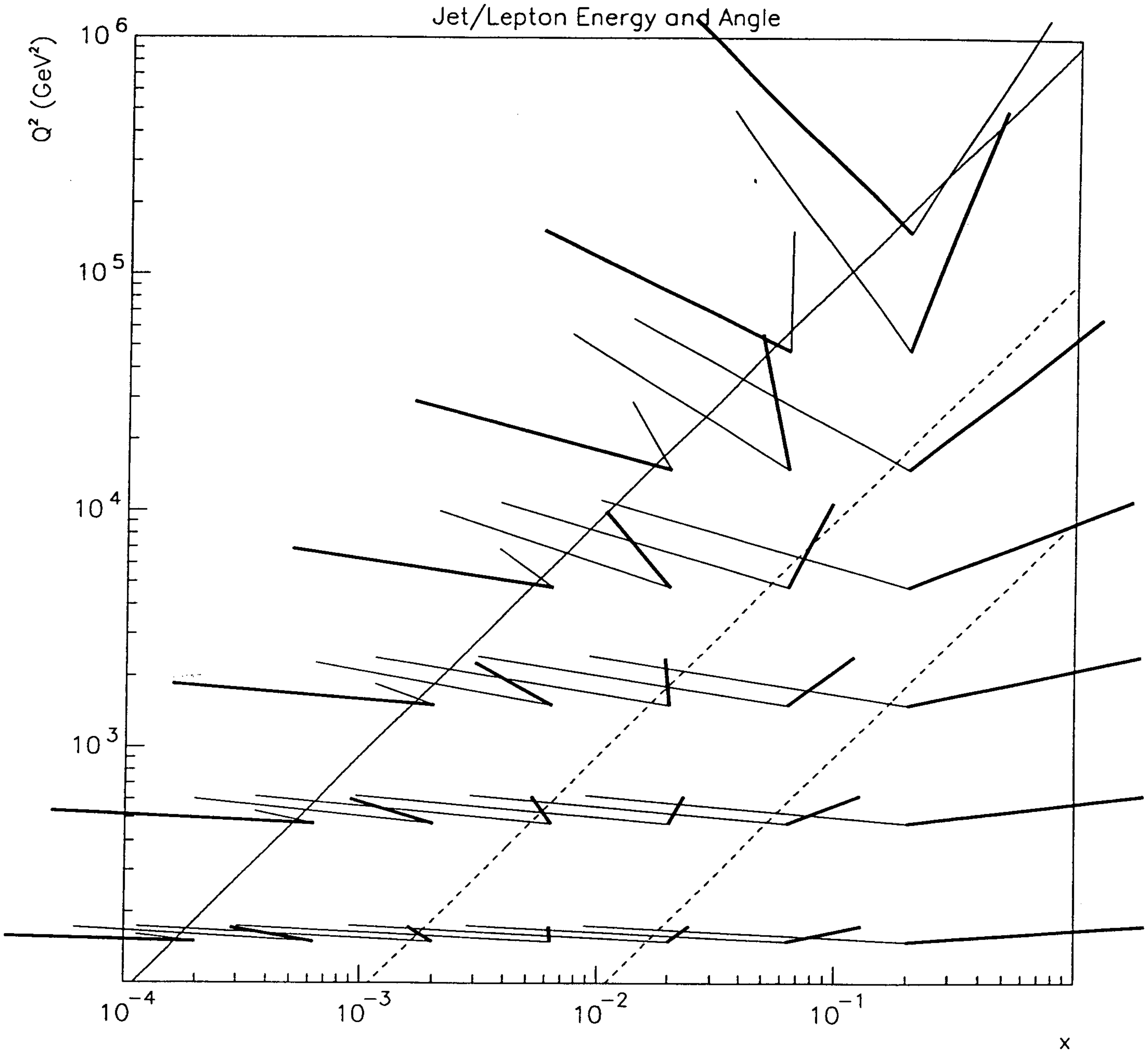
TERA: 250 × 920



$$\tilde{\sigma}_R^{NC} = \frac{Q^4 x}{2\pi Y_+ \alpha^2} \frac{d^2\sigma^{NC}}{dx\,dQ^2}$$

HERA: 27.5 x 920

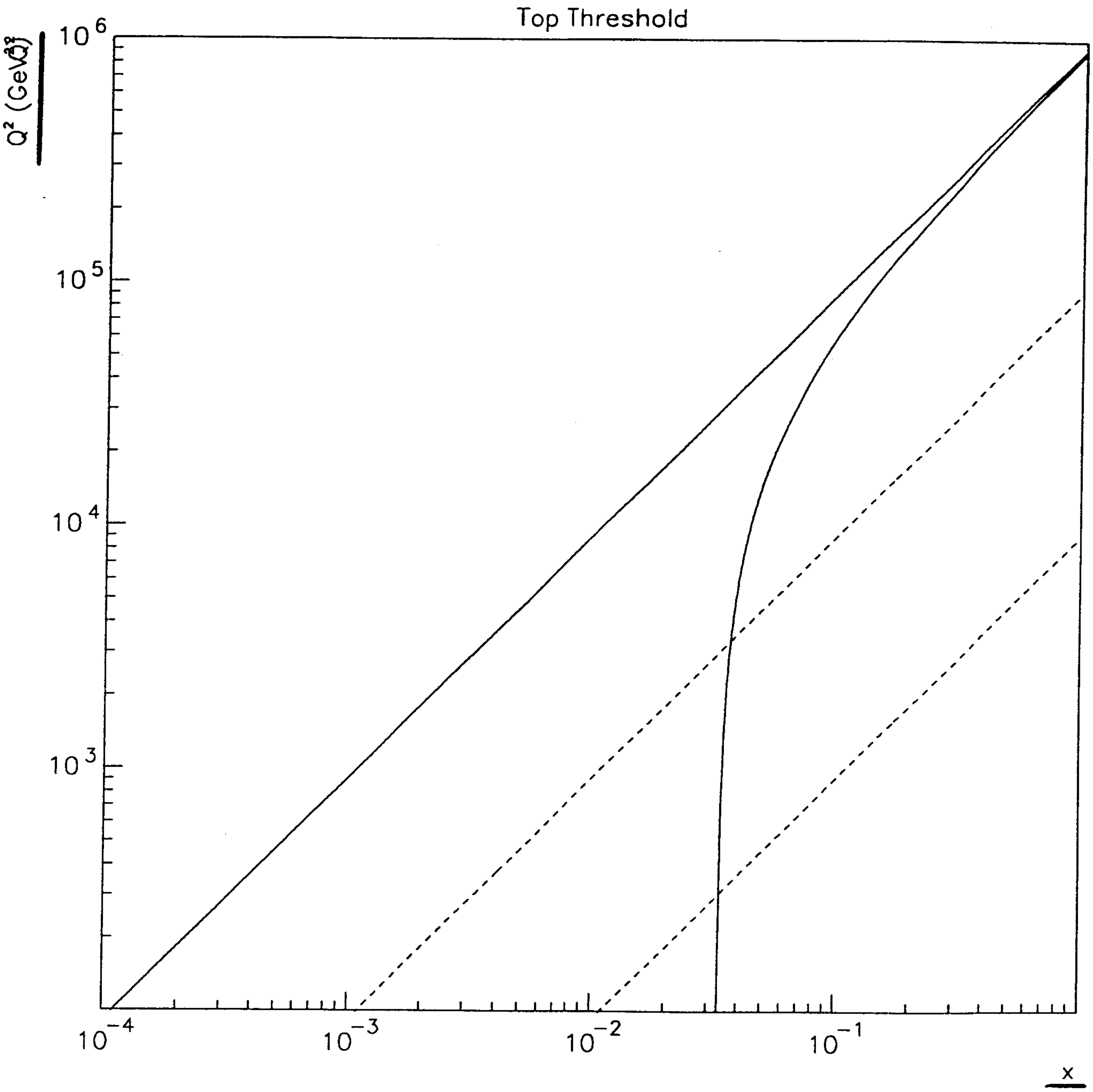




Jet/Lepton Energy and Angle
Q² (GeV²)
10⁶
10⁵
10⁴
10³
10⁻⁴
10⁻³
10⁻²
10⁻¹
x

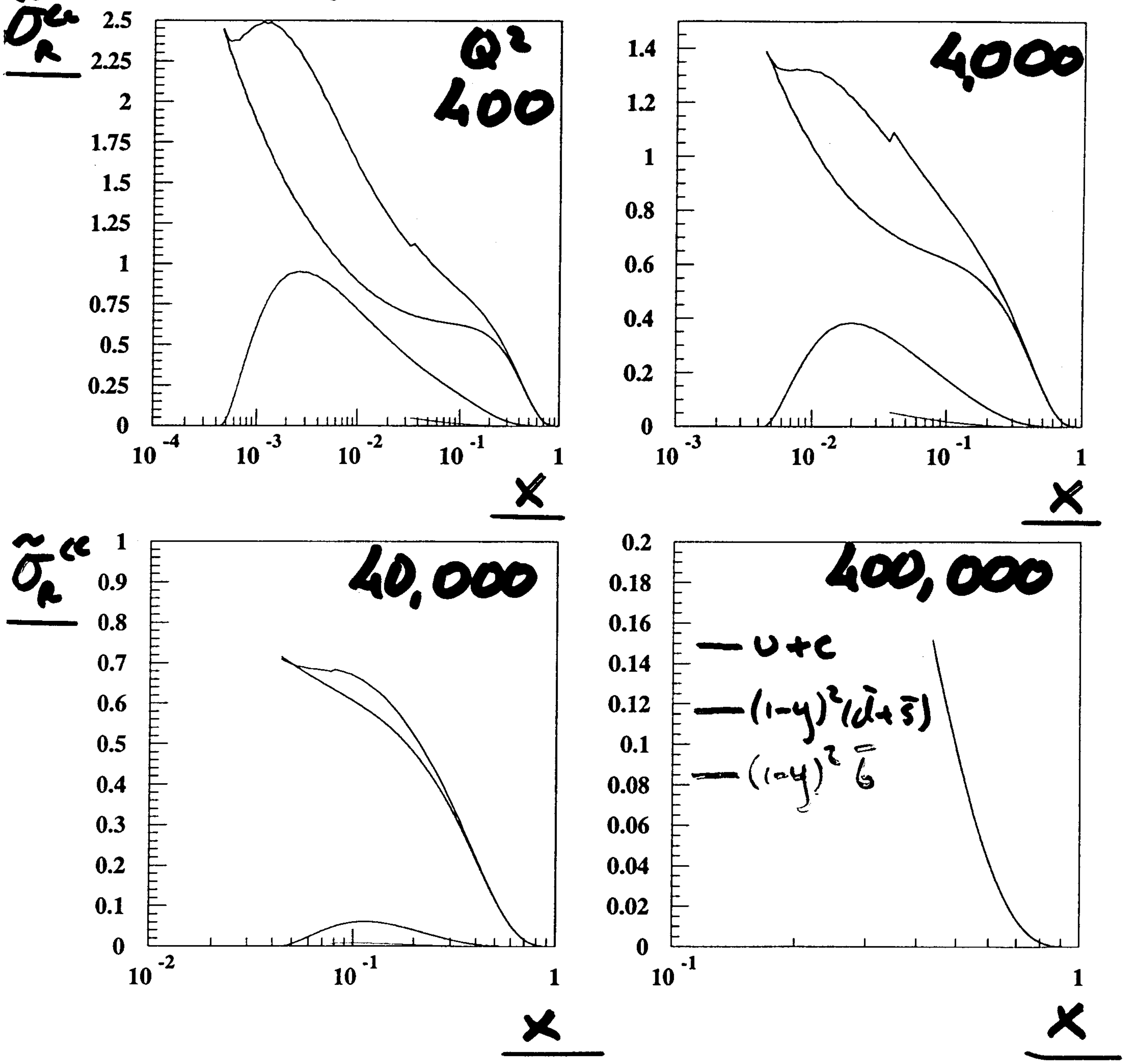
Top Threshold [CC]

TERA: 250 × 920



Electrons

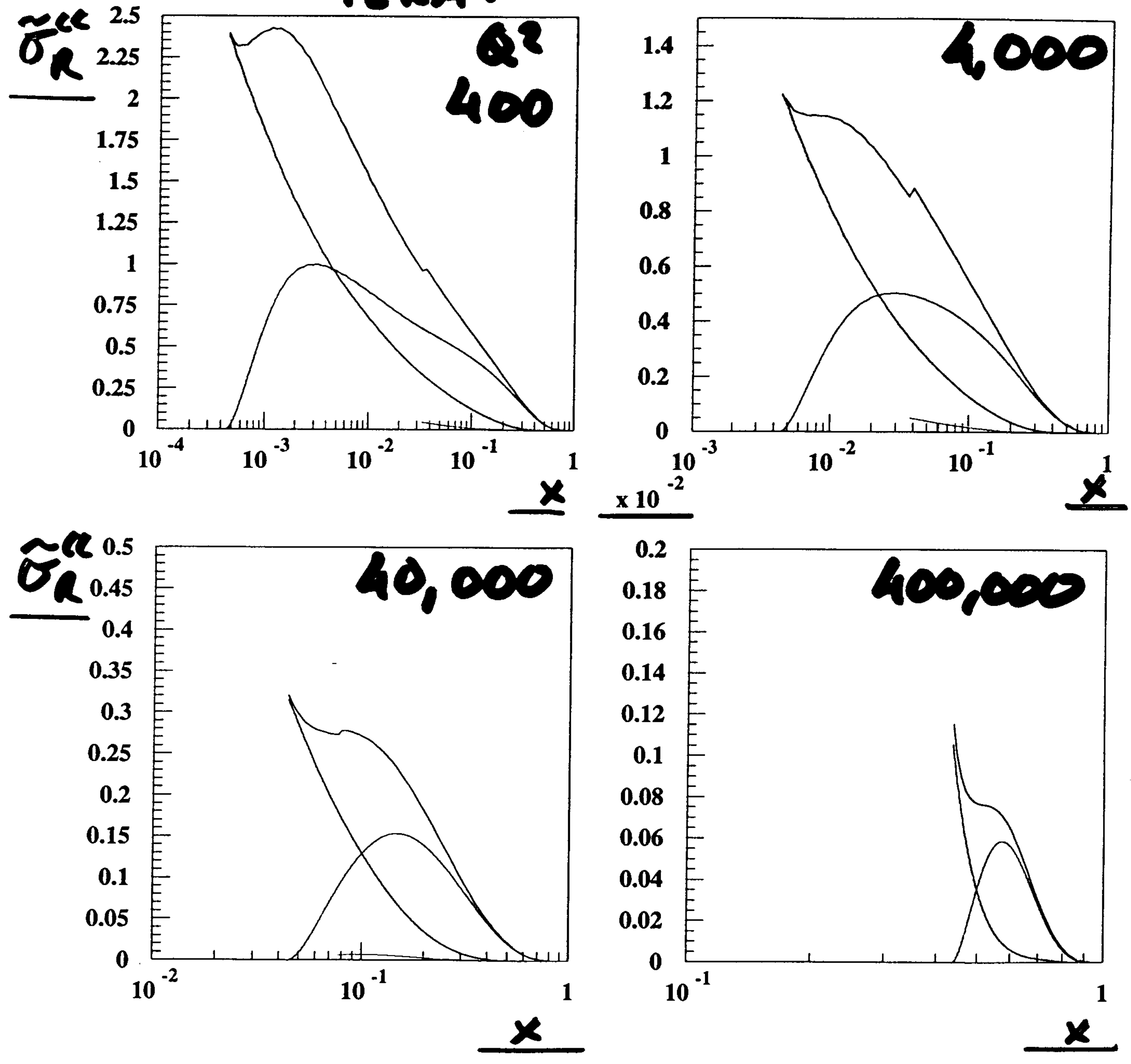
TERA: 250 x 920



$$\tilde{\sigma}_R^{cc} = \frac{2\pi x}{G_F^2}\left[\frac{Q^2+M_W^2}{M_W^2}\right]^2 \frac{d^2\sigma^{cc}}{dx\,dQ^2}$$

Positrons

TERA: 250 × 920



Summary

- LQ: probably not a discovery machine (LHC) but can <u>determine q-numbers</u> if it exists. ($\cos\theta^*$, e^+/e^-, e-pol. p-pol..)

- <u>LFV</u>: with $10pb^{-1}$, sensitivity $\lesssim$ HERA upg. need larger lumi.
  (same for non-LFV eeqq CI, and worse due to LHC potential $q\bar{q} \to \ell^+\ell^-$)

- e^*, ν^*: probably no competition from LHC? <u>can extend significantly</u> than LEP2 /HERA-up

- SUSY: luminosity-critical but can go beyond LEP2 <u>$\tilde{e}$ limits</u>
  (depends on $m_{\tilde{q}}$, m_{χ^0} from LHC!)
  $\cancel{R}_p$: perhaps same as LQ?

- Higgs: possibility of $100 < M_H < 135$ GeV
  <u>worth considering</u>!! need $> 100 pb^{-1}$

- <u>EW</u>: larger effect (but @ higher Q^2 → lumi needed.
  e-pol useful → to be studied.

- <u>$b(x, Q^2)$</u> from top $t\bar{t}$ events?