Standard Model $\to O(10^{-3})$ fm:

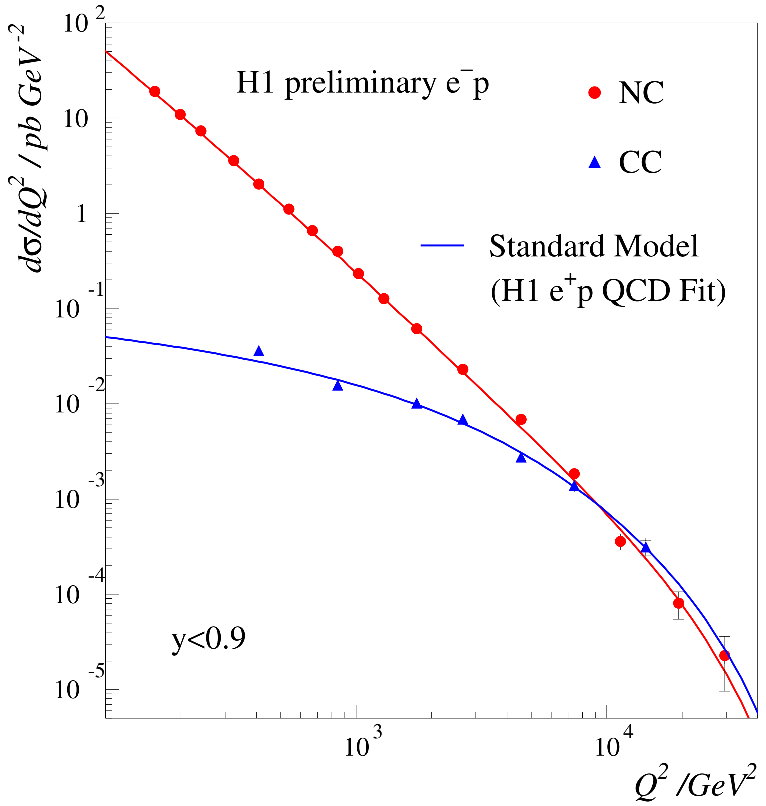
Boson Exchange

$$\frac{\mathrm{d}^2\sigma_{NC}}{\mathrm{d}Q^2\,\mathrm{d}x} \sim \alpha^2 \qquad \frac{1}{Q^4} \qquad \frac{1}{x}\,\Phi_{\gamma,Z}$$

$$\frac{\mathrm{d}^2\sigma_{CC}}{\mathrm{d}Q^2\,\mathrm{d}x} \sim G_F^2 \left(\frac{M_W^2}{M_W^2+Q^2}\right)^2 \frac{1}{x}\,\Phi_W$$

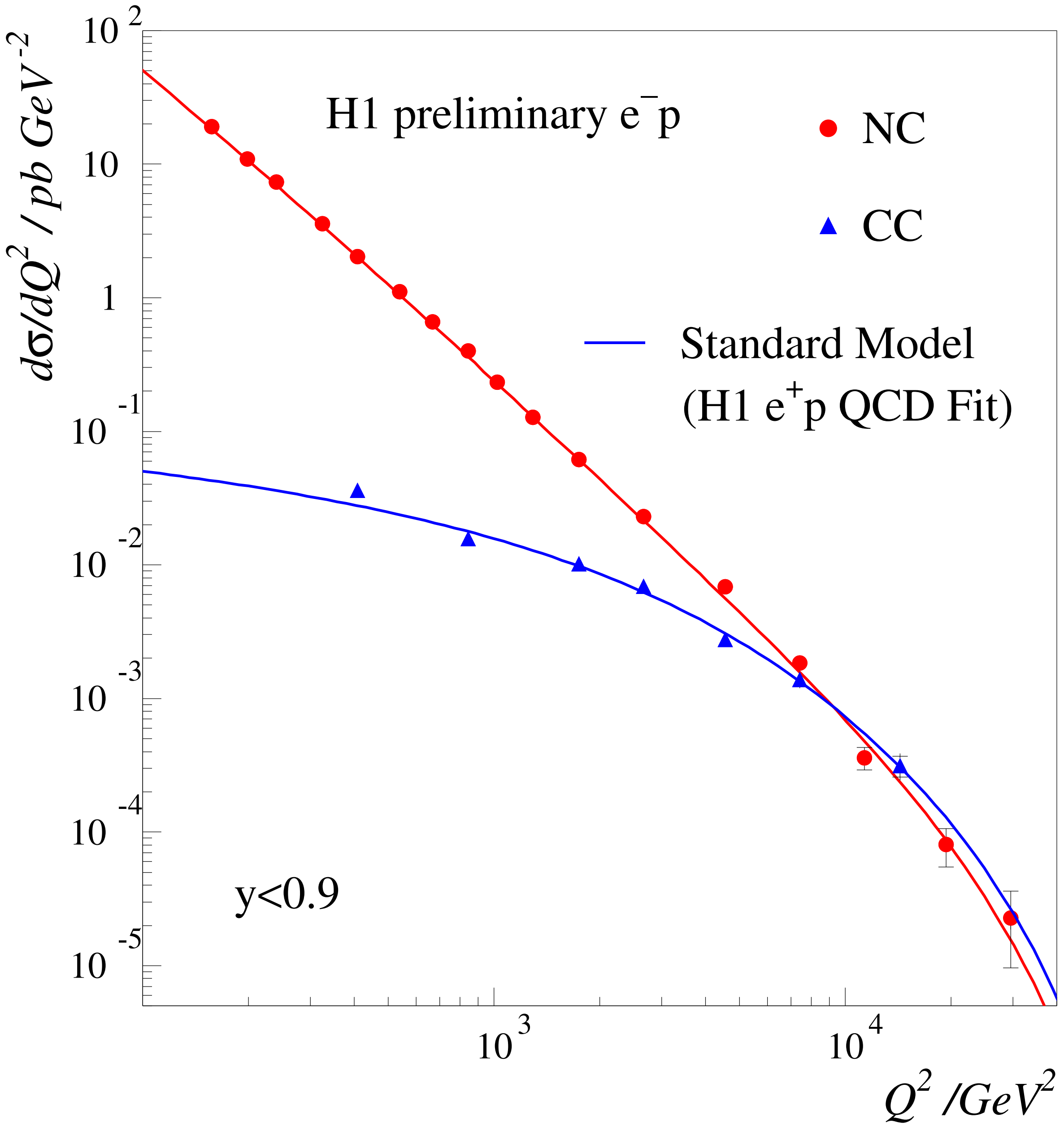
Electron–Proton Collisions

$\frac{d\sigma}{dQ^2}$

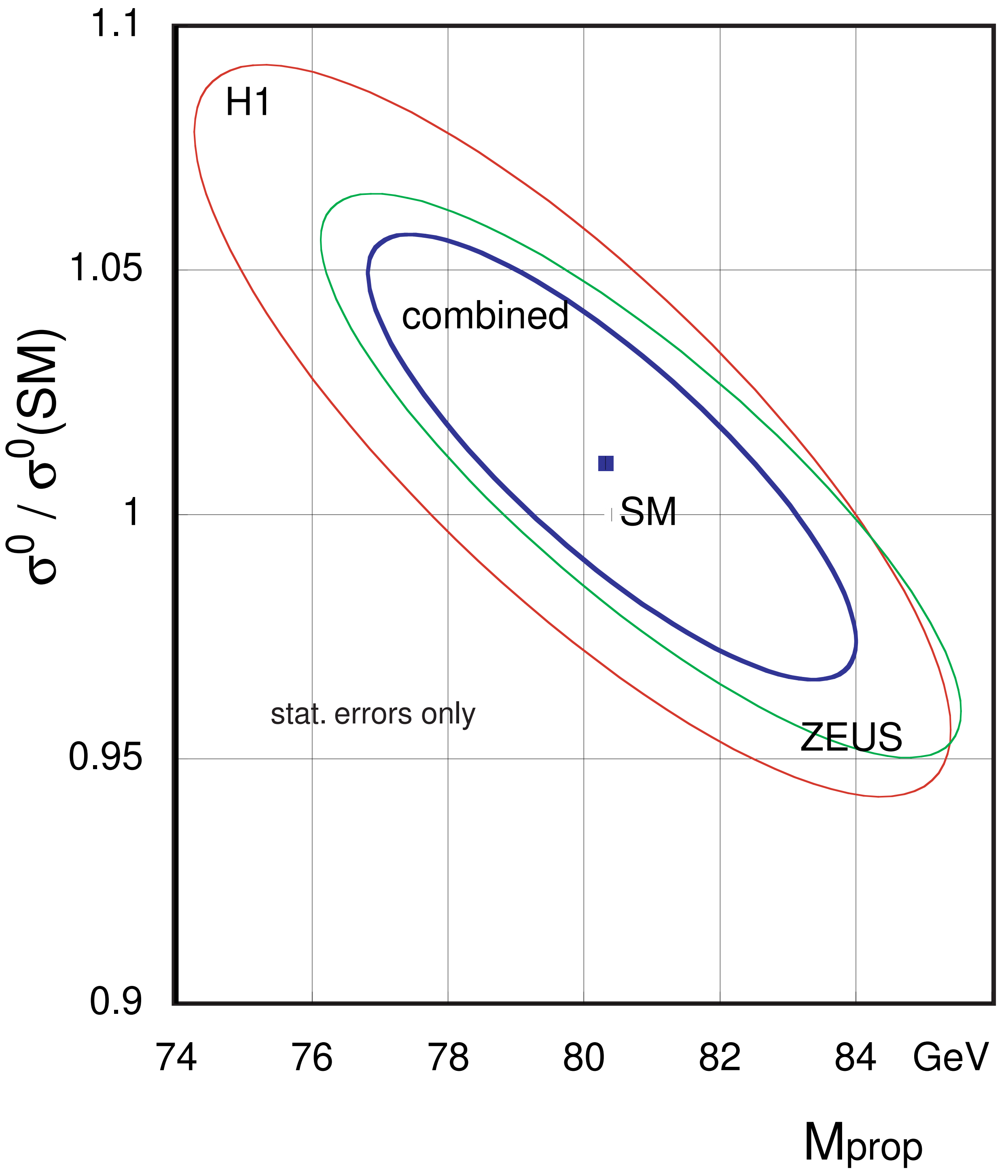


Q^2

Electro-weak unification at scale $\sim 10000\ \mathrm{GeV}^2$.



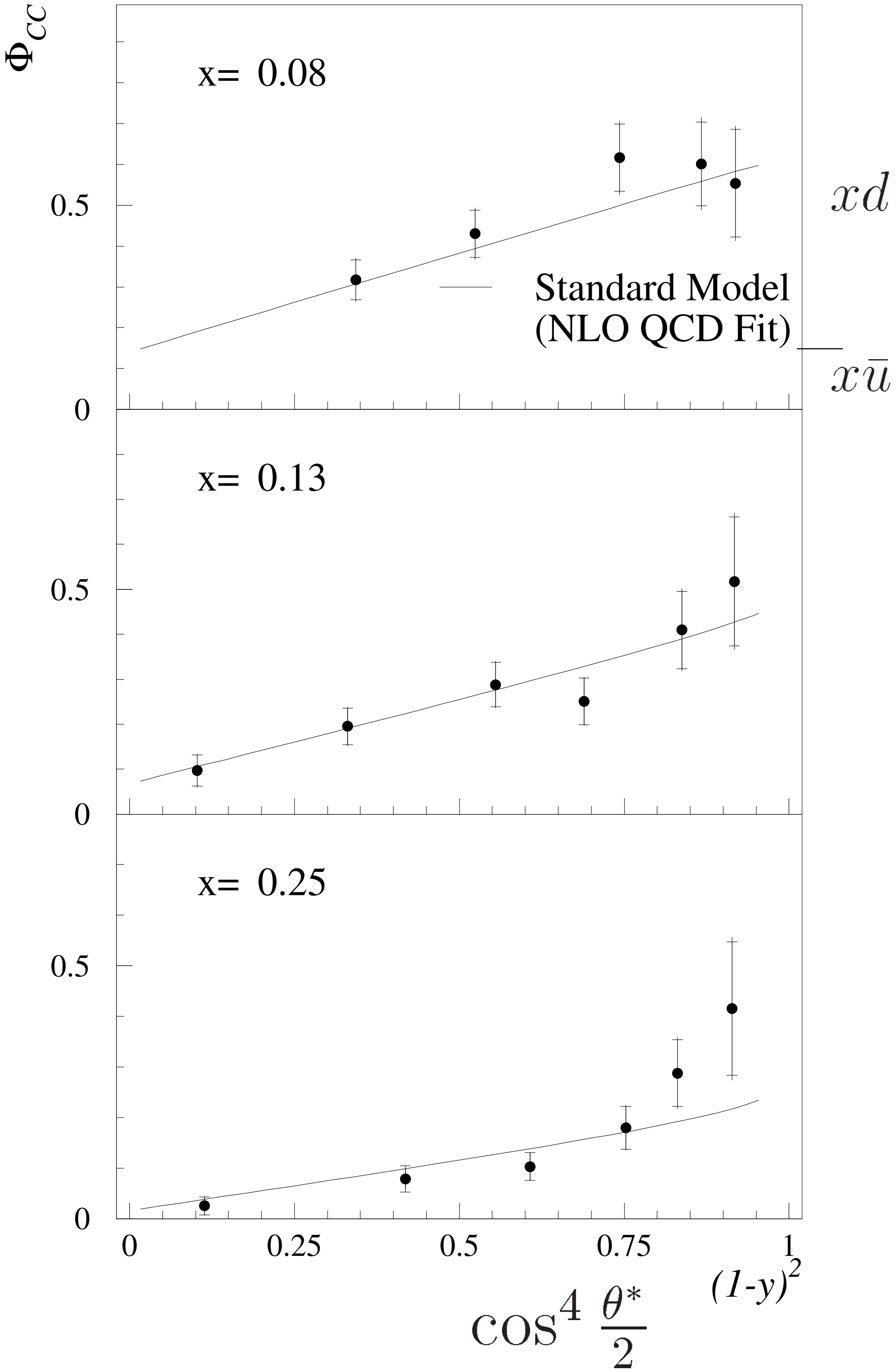
H1 preliminary e⁻p
NC
CC
Standard Model
(H1 e⁺p QCD Fit)
y<0.9
$d\sigma/dQ^2$ / pb GeV^{-2}
Q^2 /GeV^2
10^2
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^3
10^4

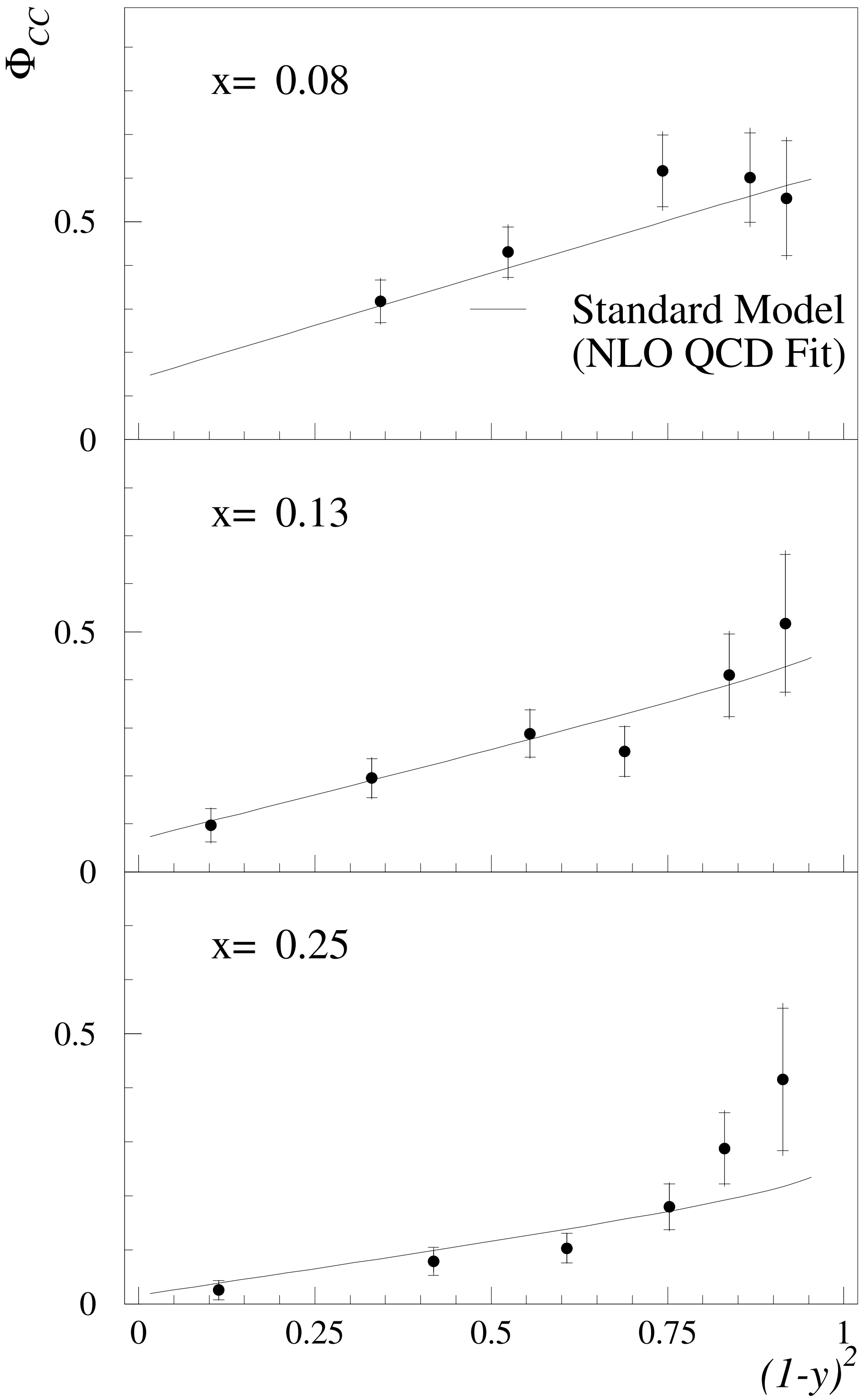


1.1
1.05
1
0.95
0.9
σ0 / σ0(SM)
H1
combined
SM
ZEUS
stat. errors only
74
76
78
80
82
84
GeV
Mprop

eq Scattering Angle at $O(10^{-3})$ fm:

$$\Phi_{CC}^{e^+p} \sim \overset{\Longrightarrow\Longleftarrow}{1} \quad x\bar{u} + \overset{\Longrightarrow\Longrightarrow}{\cos^4\left(\frac{\theta^*}{2}\right)} \quad xd$$





Φ_{CC}
x= 0.08
x= 0.13
x= 0.25
Standard Model
(NLO QCD Fit)
0
0.5
0
0.25
0.5
0.75
1
$(1-y)^2$

Lepton–Quark Scattering Angle

$$\Phi_{CC}^{e^+p} \sim x\bar{u} + \cos^4\left(\frac{\theta^*}{2}\right) xd$$

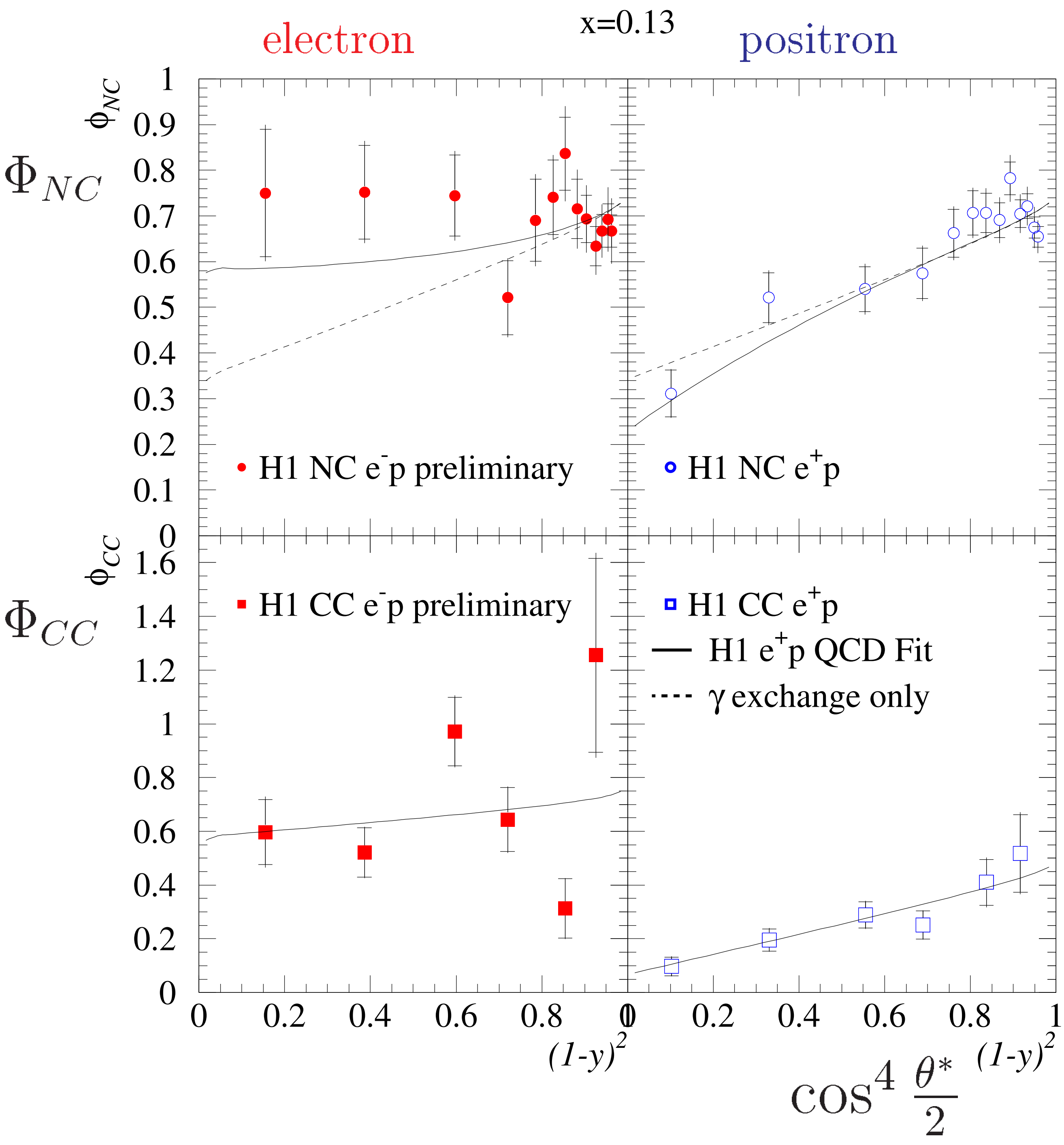
$$\Phi_{CC}^{e^-p} \sim xu + \cos^4\left(\frac{\theta^*}{2}\right) x\bar{d}$$

$$\begin{aligned}\Phi_{NC}^{e^\mp p} &\sim \left(1 + \cos^4\frac{\theta^*}{2}\right) \\ &\times \left(\frac{4}{9}(xu + x\bar{u}) + \frac{1}{9}(xd + x\bar{d})\right) \\ &\pm \text{additional terms with } \gamma, Z\end{aligned}$$

Standard Model $\rightarrow O(10^{-3})$ fm:

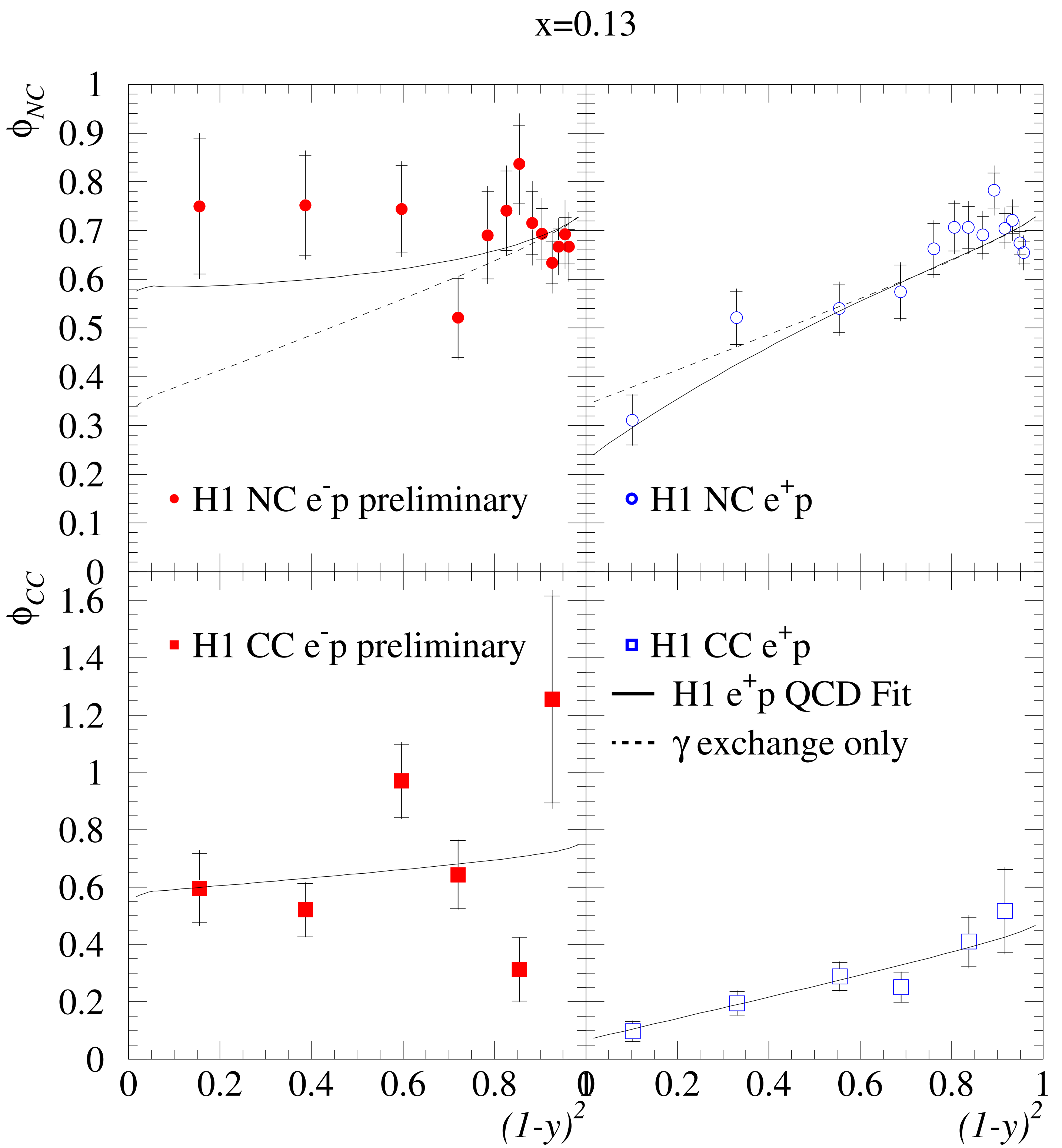
Lepton–Quark Scattering Angle

at $\sqrt{s_{eq}} = 110$ GeV



Spin 1/2 – spin 1/2 scattering confirmed $\sim 20\%$,

photon-Z interference observed.

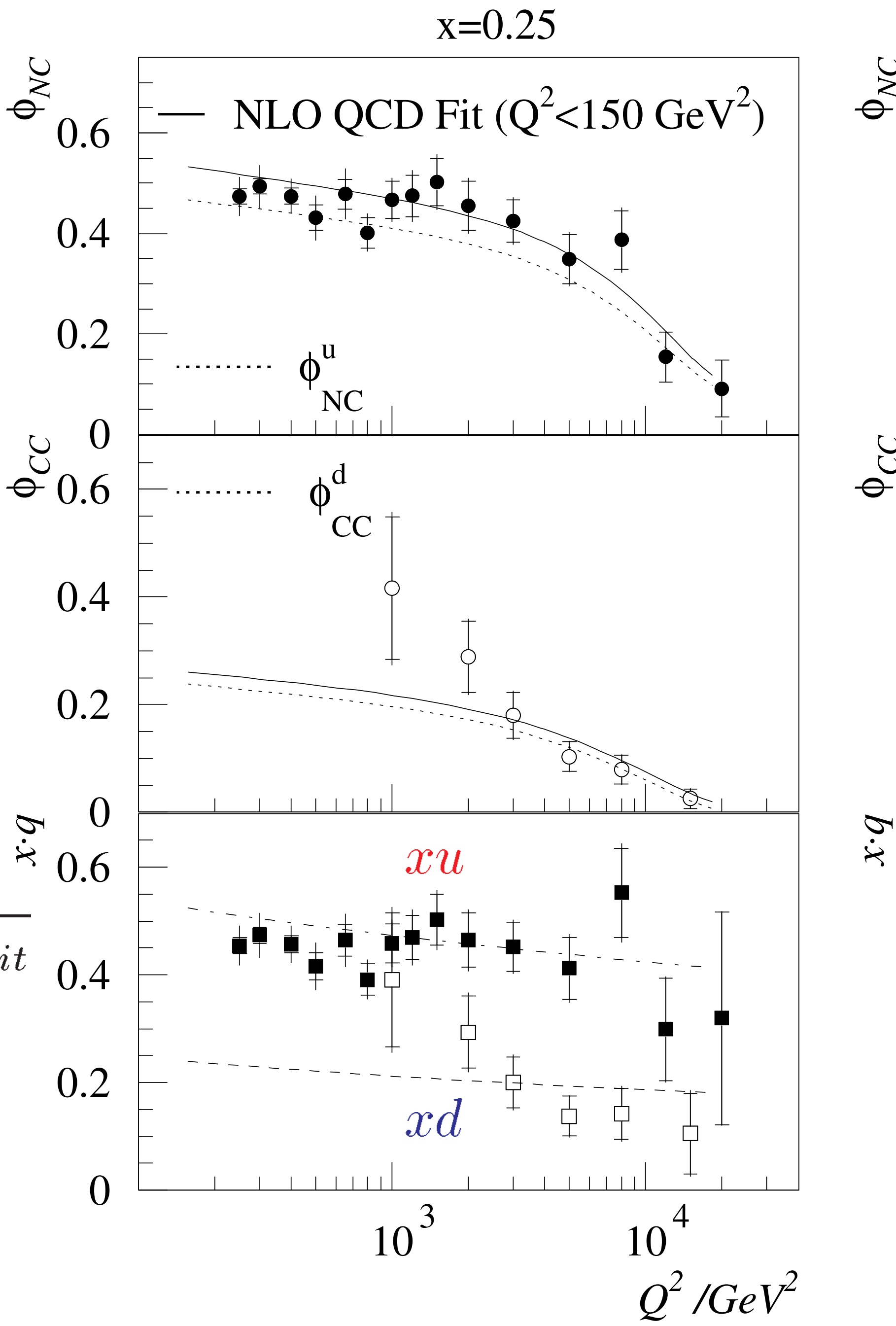

x=0.13
ϕ_{NC}
ϕ_{CC}
H1 NC e$^-$p preliminary
H1 NC e$^+$p
H1 CC e$^-$p preliminary
H1 CC e$^+$p
H1 e$^+$p QCD Fit
γ exchange only
$(1-y)^2$
$(1-y)^2$

Valence Quarks at $x = 0.25$

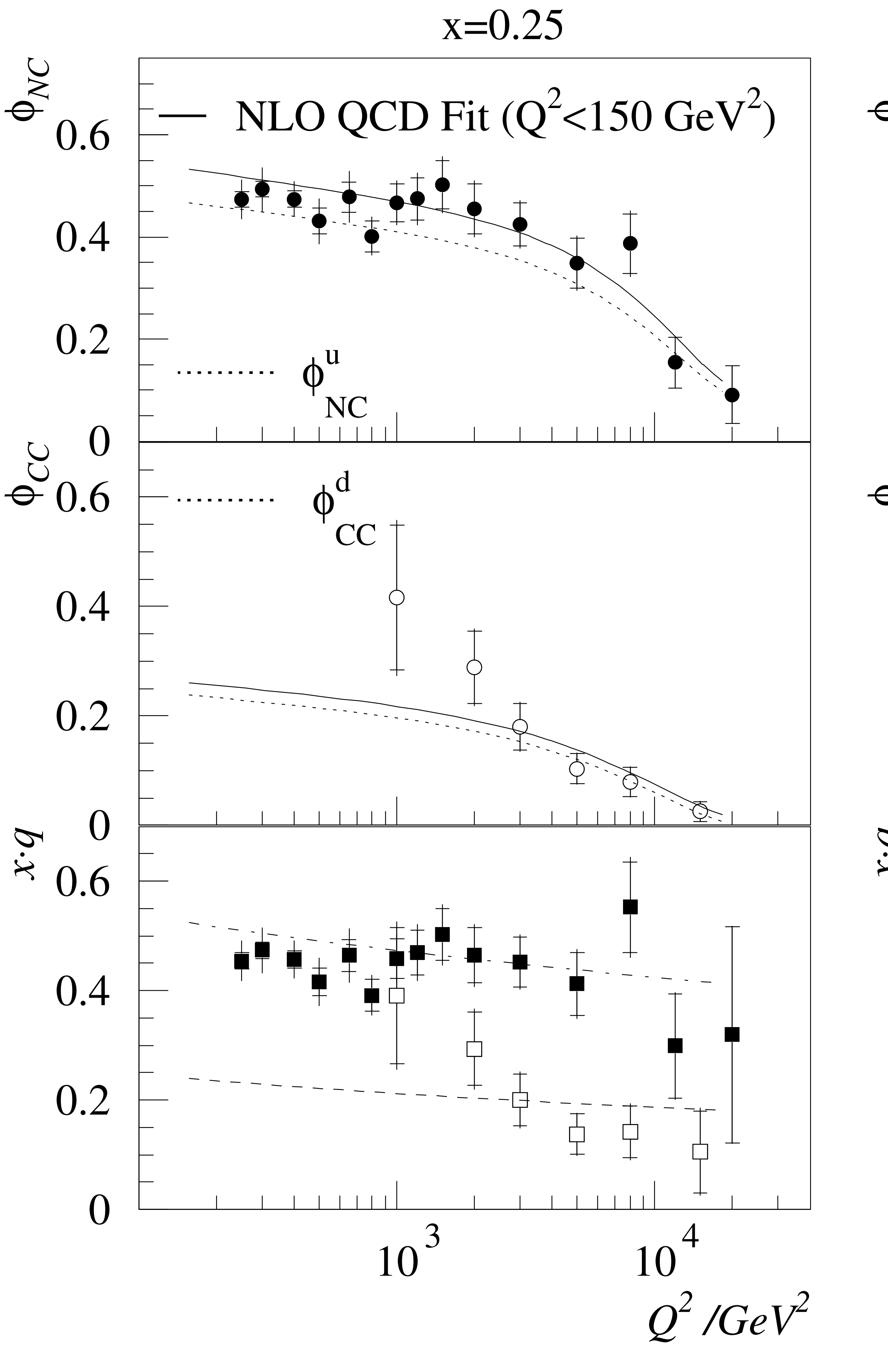
Φ_{NC}

Φ_{CC}

$$xq = (xq)_{qcd\,fit} \, \frac{\Phi}{\Phi_{qcd\,fit}}$$

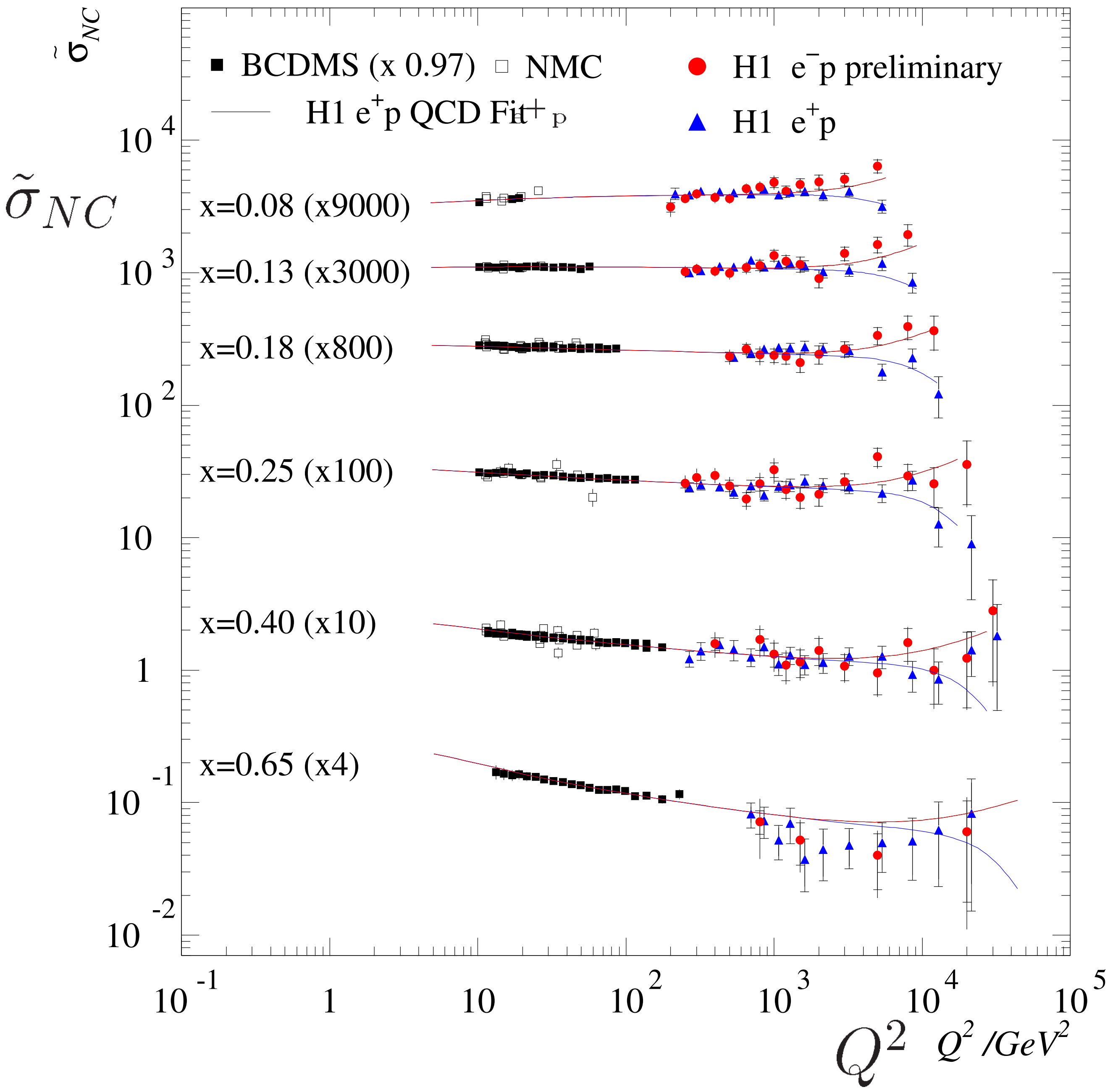


Complementary measurement:
no assumptions on nuclear binding effects.



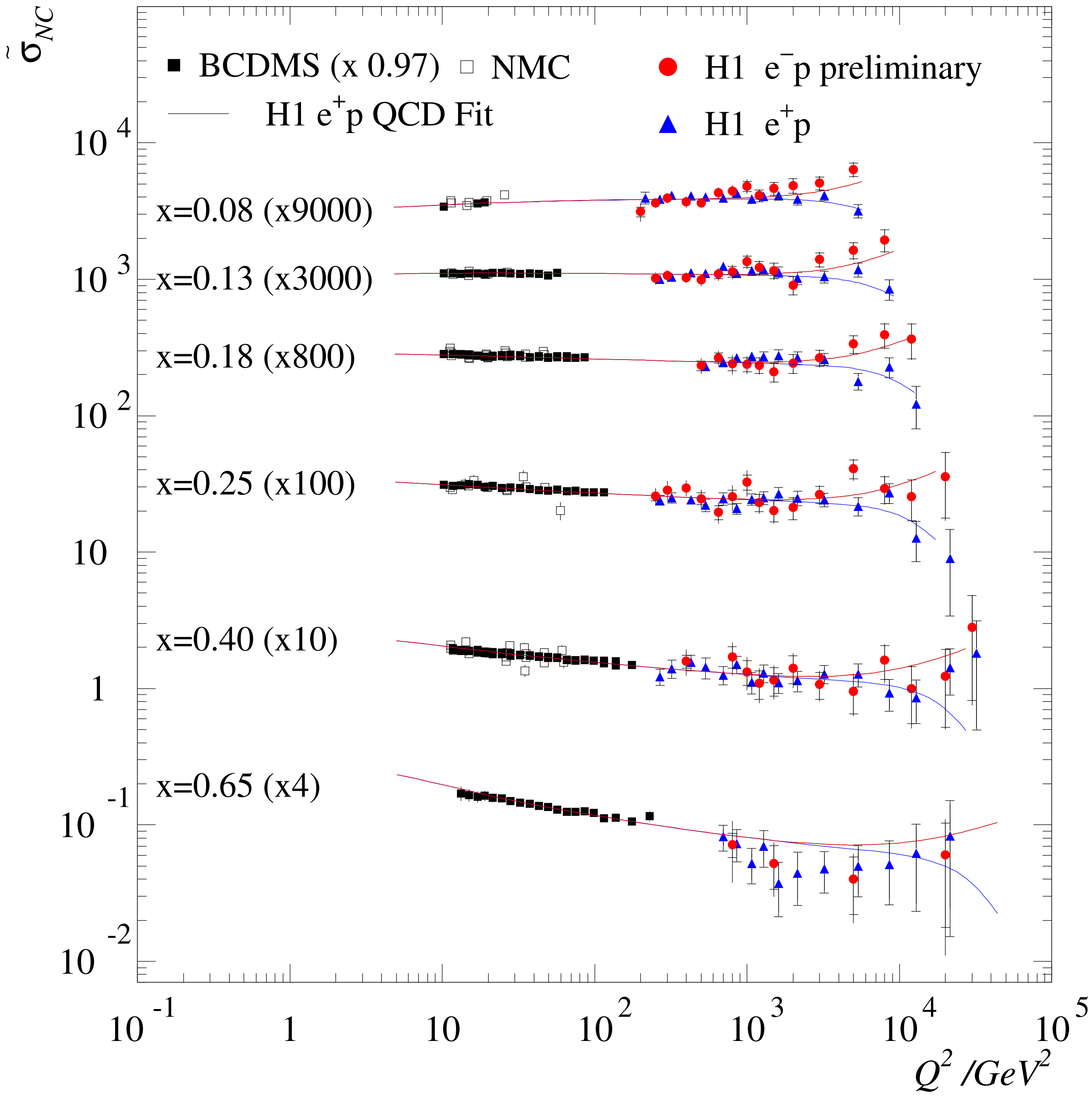
x=0.25
ϕ_{NC}
NLO QCD Fit (Q^2<150 GeV^2)
ϕ^u_{NC}
ϕ_{CC}
ϕ^d_{CC}
$x \cdot q$
0.6
0.4
0.2
0
10^3
10^4
Q^2 /GeV^2

NC Cross Sections e^-p and e^+p



Photon–Z interference!

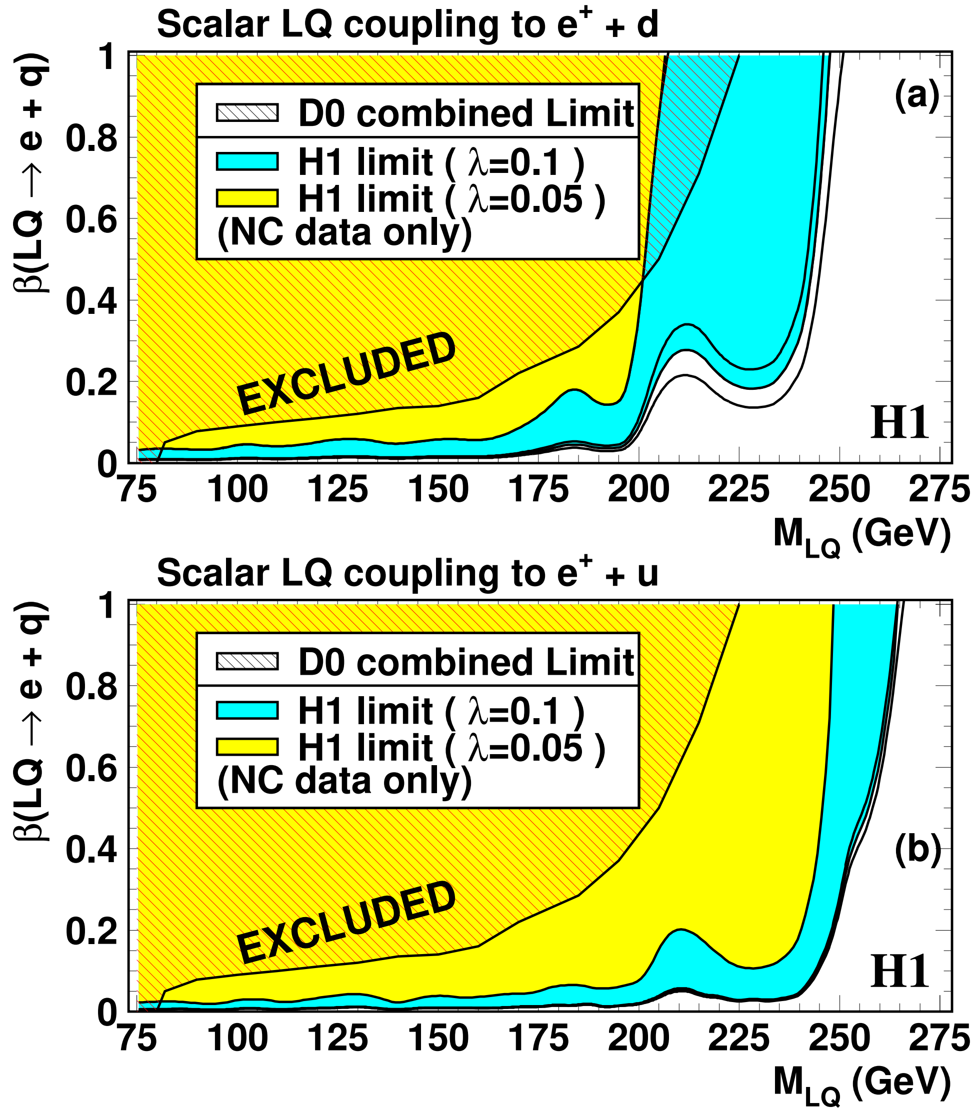
Too many e^+p events at high Q^2 and high $\sqrt{s_{eq}}$.



$\tilde{\sigma}_{NC}$
BCDMS (x 0.97)
NMC
H1 e^-p preliminary
H1 e^+p QCD Fit
H1 e^+p
x=0.08 (x9000)
x=0.13 (x3000)
x=0.18 (x800)
x=0.25 (x100)
x=0.40 (x10)
x=0.65 (x4)
$Q^2\ /GeV^2$

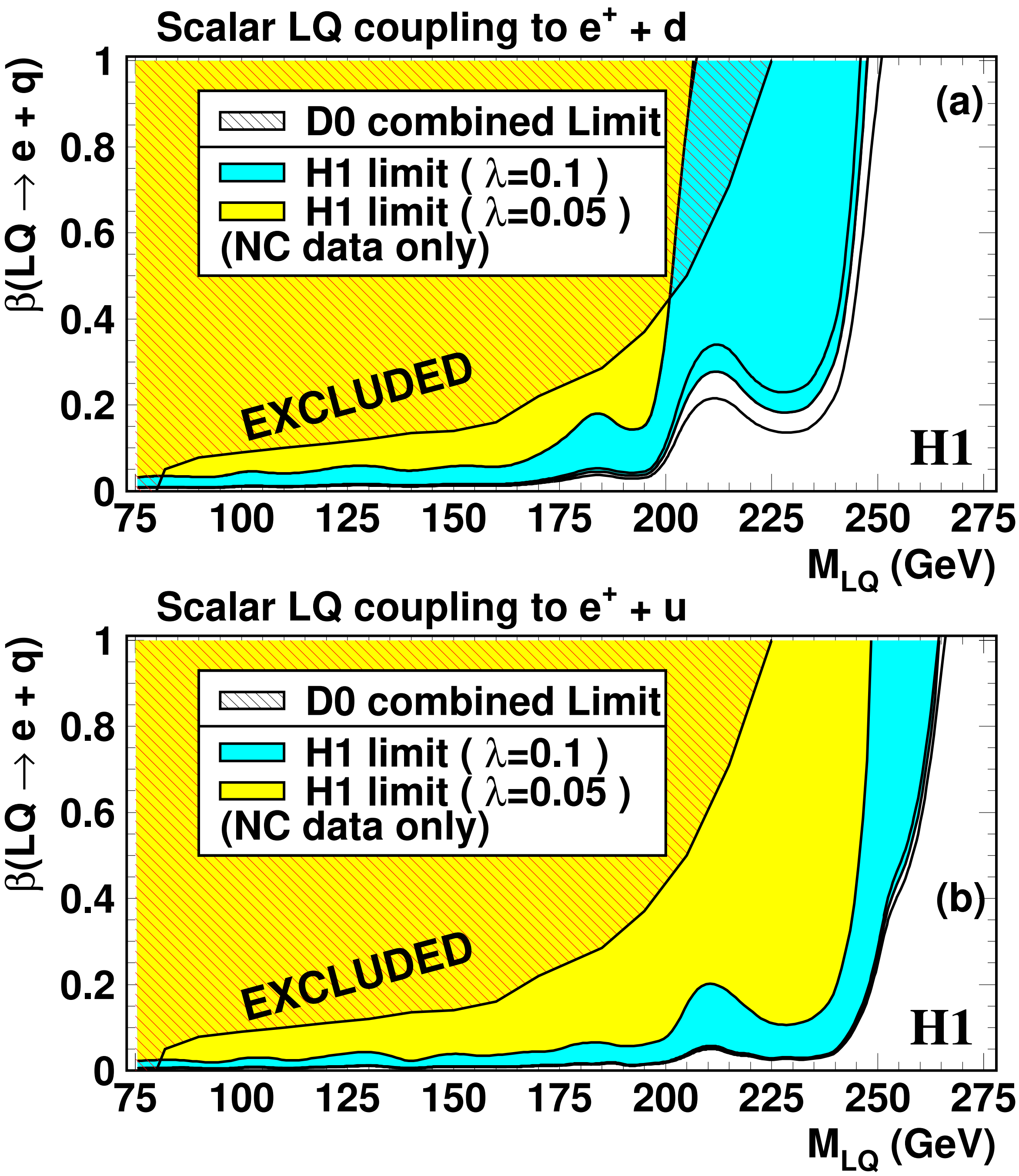
Search for Leptoquarks:
Unique Discovery Window in *ep* at Low Branching Ratio

β



M_{LQ}

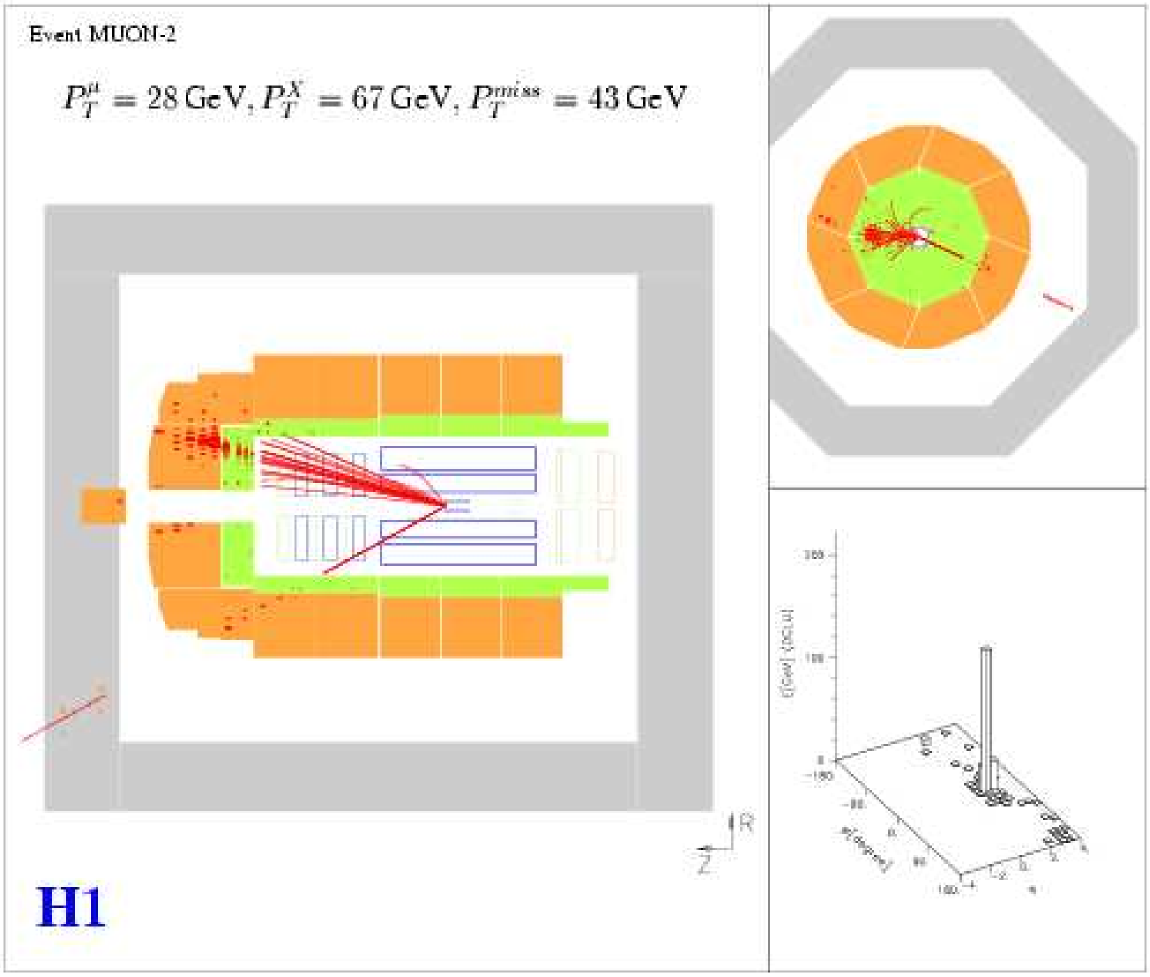
excess $O(2s.d.)$ at mass ~ 200 GeV $\rightarrow$
QCD effects shift to leptoquark mass ~ 210 GeV.



Scalar LQ coupling to e+ + d
β(LQ → e + q)
D0 combined Limit
H1 limit (λ=0.1)
H1 limit (λ=0.05)
(NC data only)
EXCLUDED
(a)
H1
M_LQ (GeV)
Scalar LQ coupling to e+ + u
β(LQ → e + q)
D0 combined Limit
H1 limit (λ=0.1)
H1 limit (λ=0.05)
(NC data only)
EXCLUDED
(b)
H1
M_LQ (GeV)

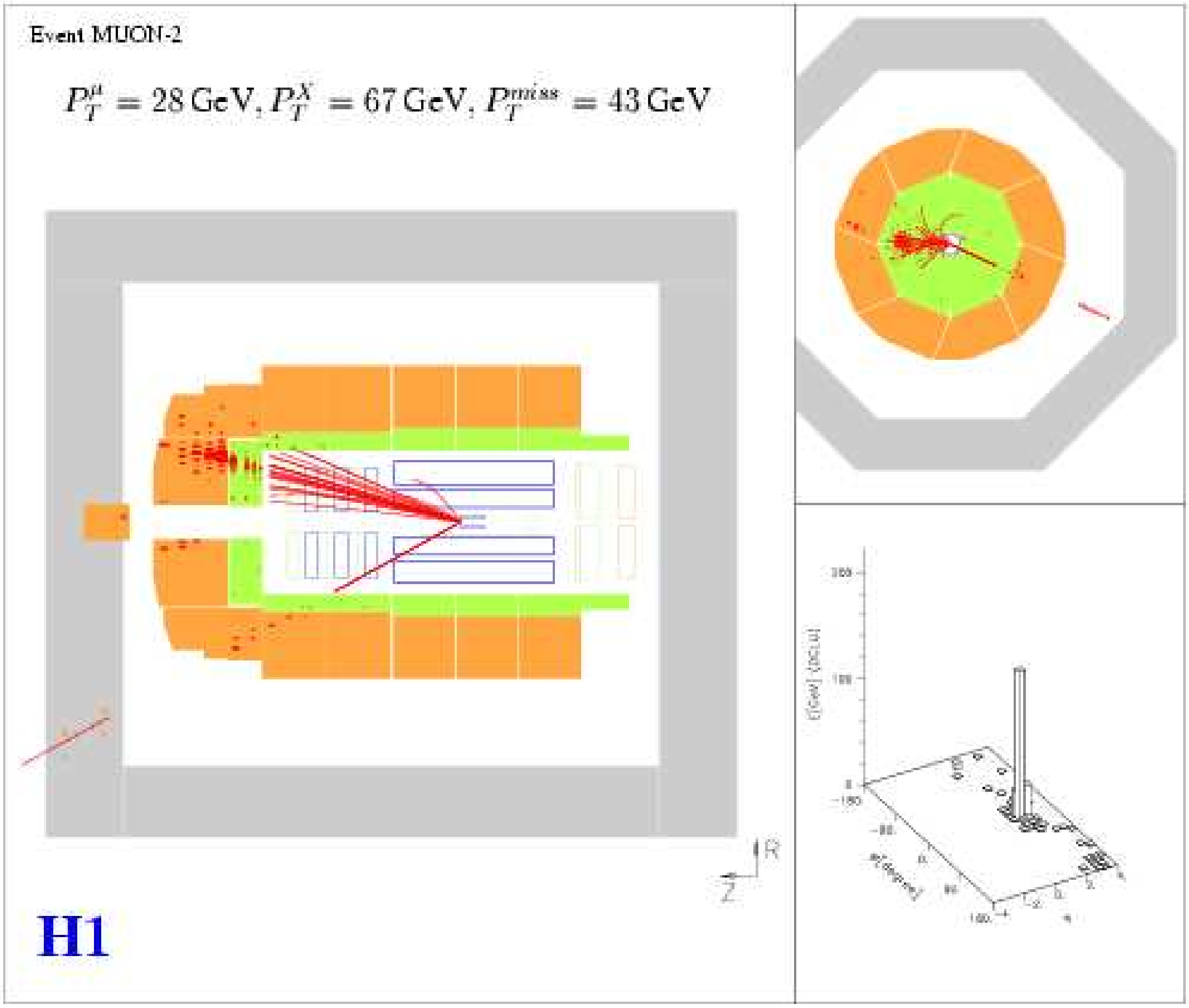
Unexplained Events:
High-p_T μ, High-p_T Jet, Large P_T^{miss}

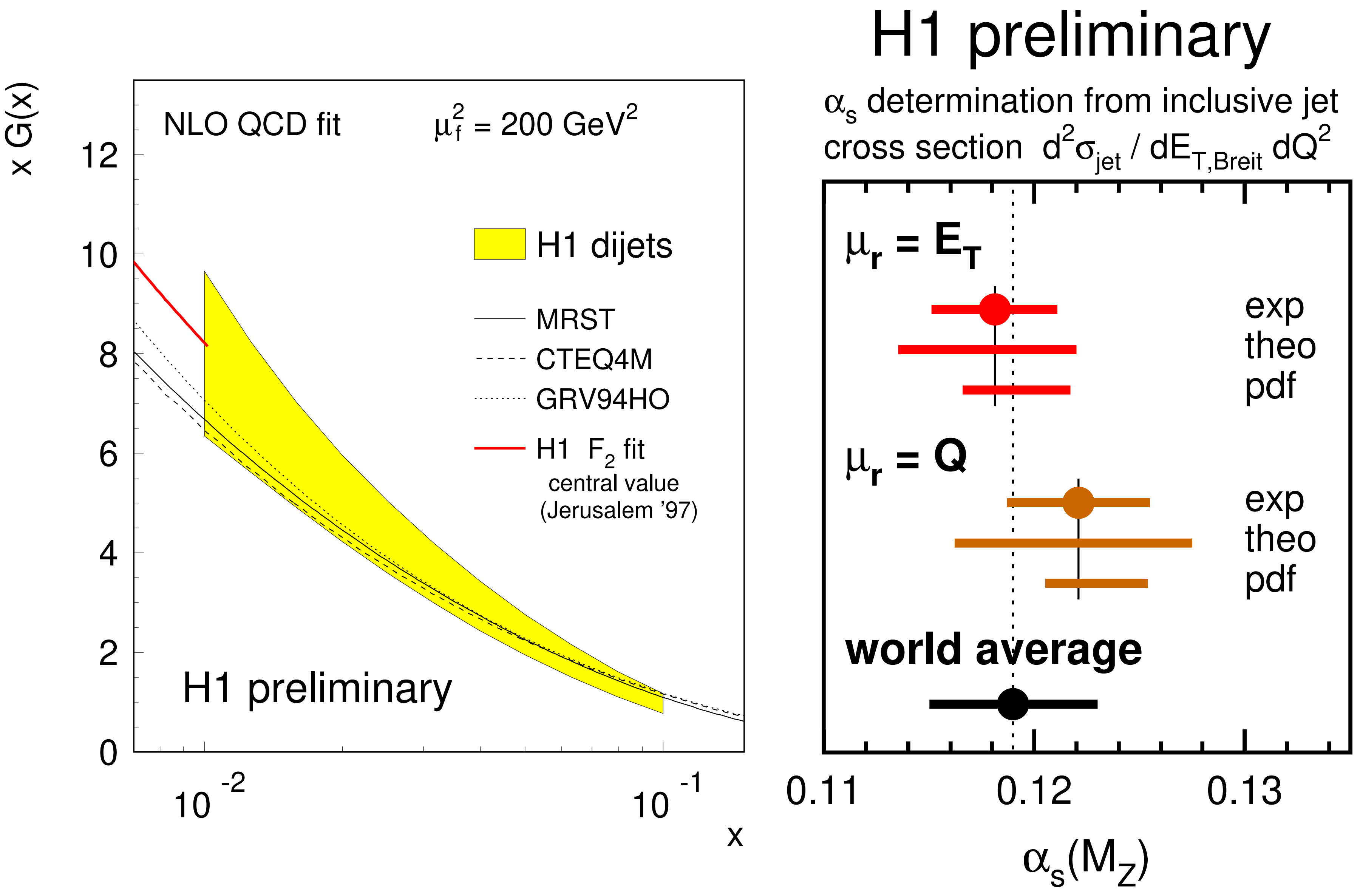
$$e^+p \to \mu^+X$$



Observed: 5 events. Standard Model: 0.8 events

$$e^+p \to \mu^+ X$$


Event MUON-2
$P_T^\mu = 28\,\mathrm{GeV}, P_T^X = 67\,\mathrm{GeV}, P_T^{miss} = 43\,\mathrm{GeV}$
R
Z
H1



H1 preliminary
α_s determination from inclusive jet cross section $d^2\sigma_{jet} / dE_{T,Breit}\, dQ^2$
NLO QCD fit
μ_f^2 = 200 GeV^2
H1 dijets
MRST
CTEQ4M
GRV94HO
H1 F_2 fit
central value
(Jerusalem '97)
H1 preliminary
x G(x)
x
$\mu_r = E_T$
exp
theo
pdf
$\mu_r = Q$
exp
theo
pdf
world average
$\alpha_s(M_Z)$