New Results from H1

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

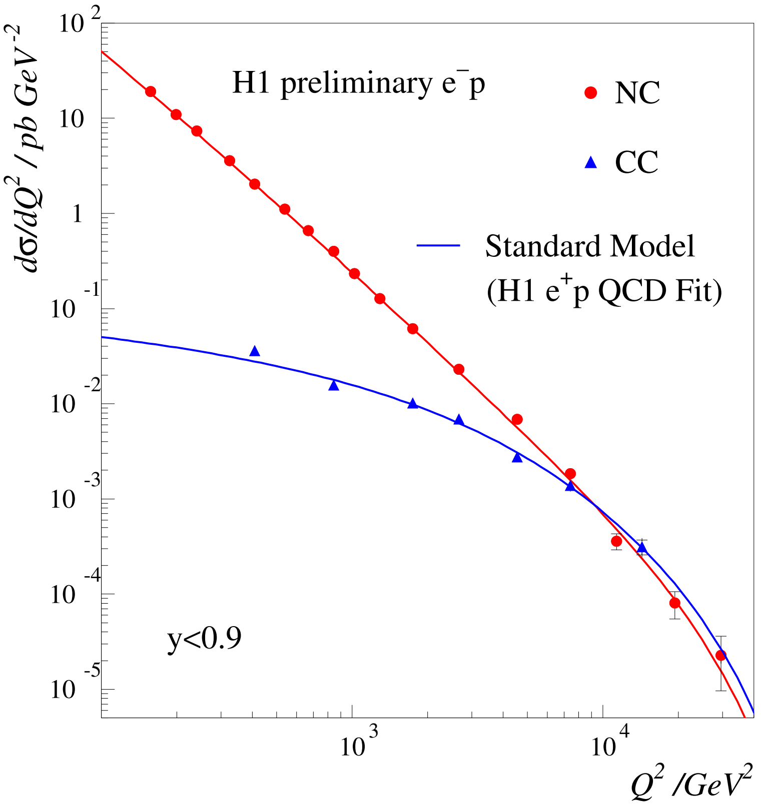
Boson Exchange

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

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

Electron–Proton Collisions

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

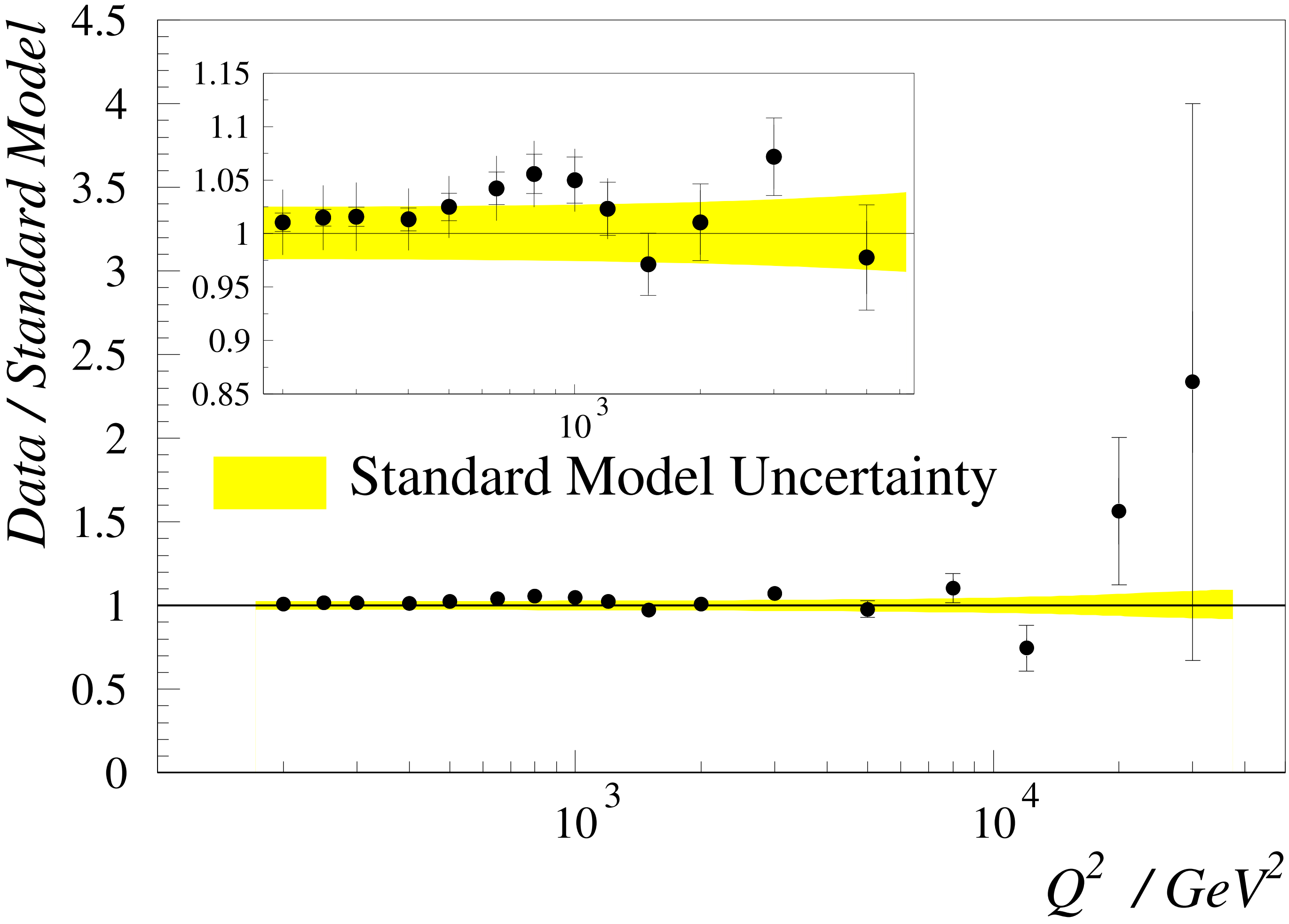


Q^2

Electro-weak unification at scale ~ 10000 GeV^2.

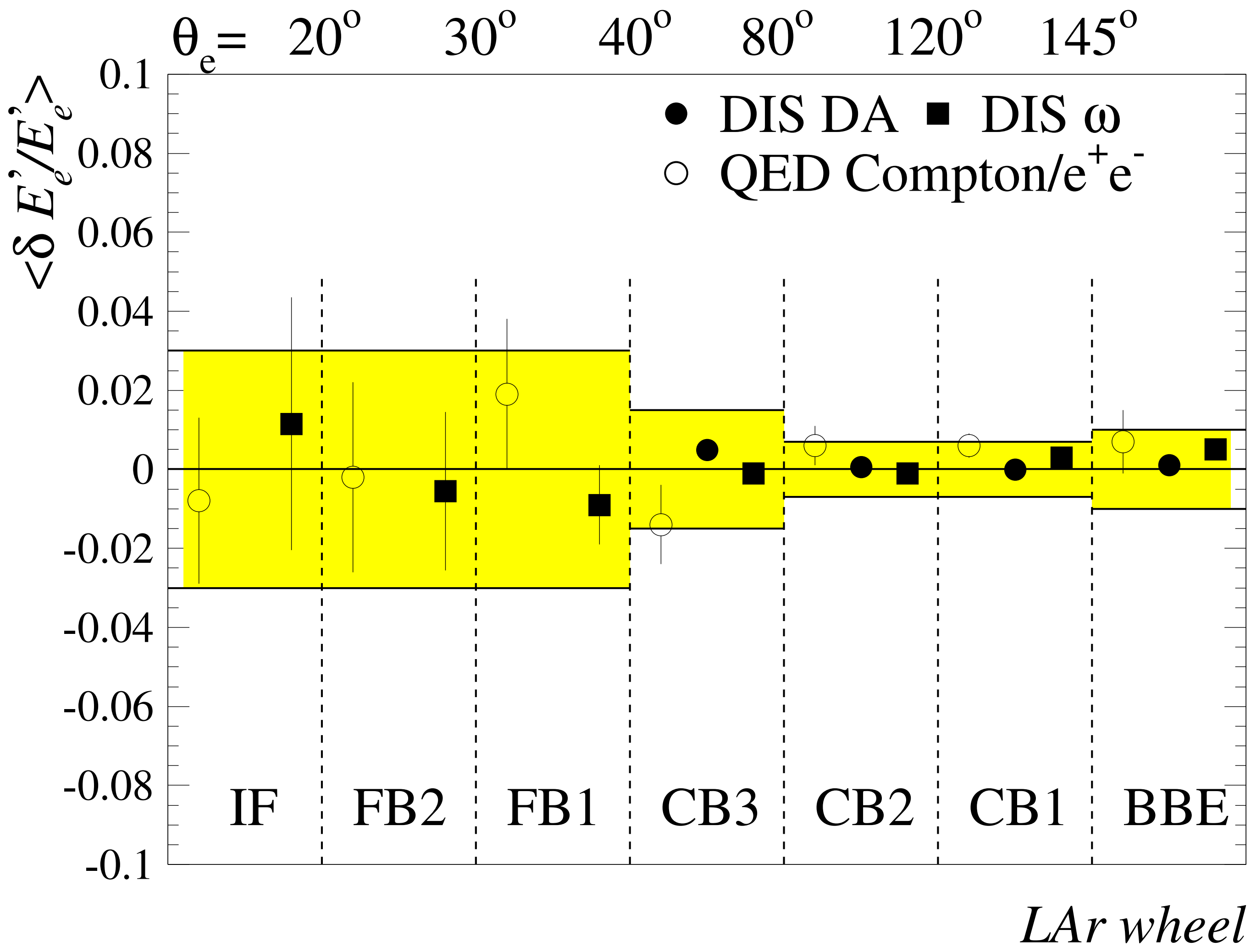
Charged Current $(e^+p \rightarrow \nu X)$: propagator mass $M = 80.9 \pm 3.3(stat) \pm 1.7(sys) \pm 3.7(\text{theo})$ GeV.

$\gamma\ Z$ in Positron-Proton Collisions



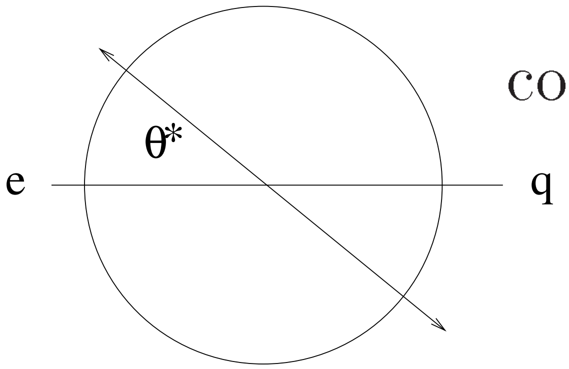
Precision: few percent level

Improved LAr Calibration: in situ confirmed test beam measurements



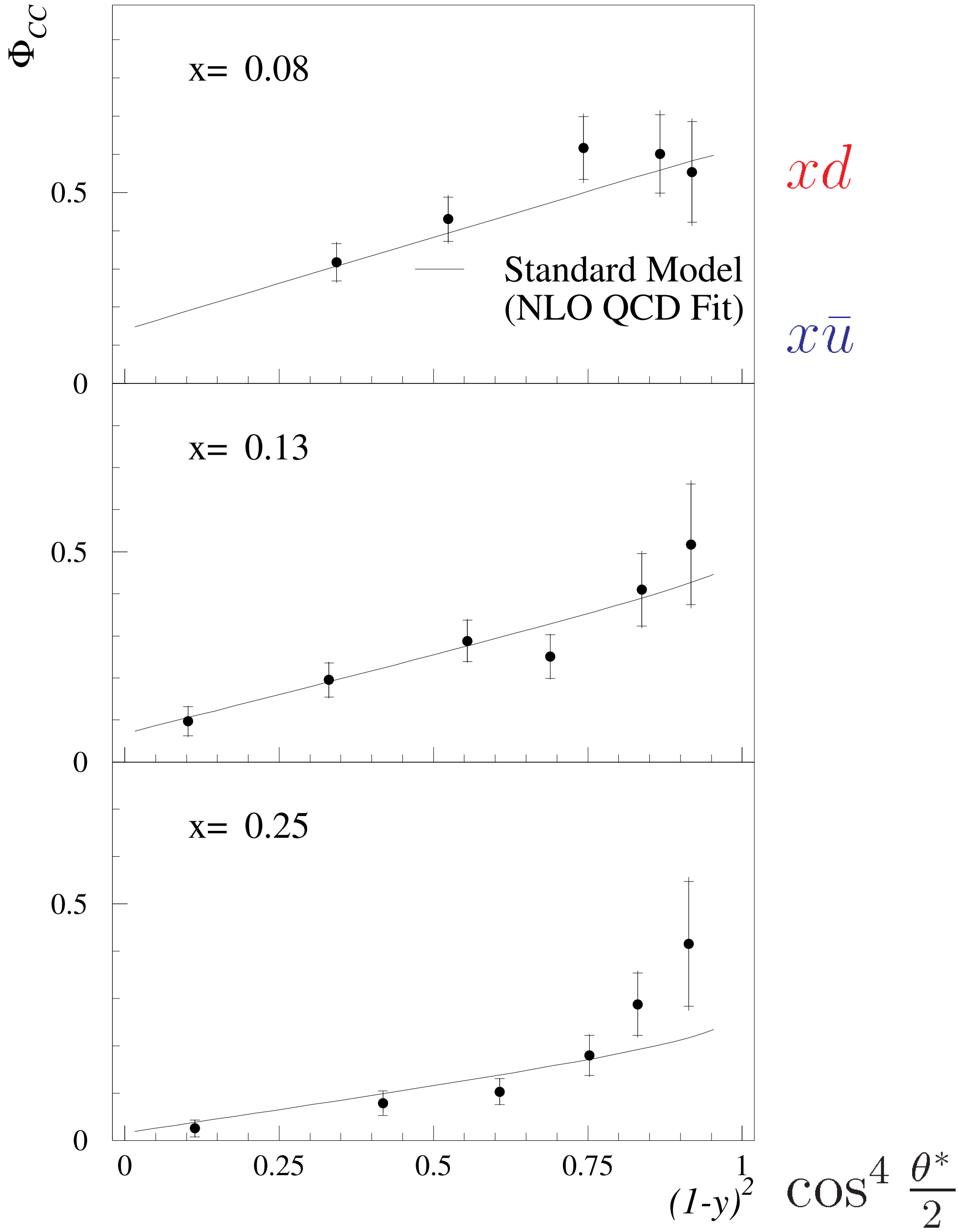
Long term investment.

Positron–Quark Scattering Angle



$$\cos^4 \frac{\theta^*}{2} = (1-y)^2 = (1 - \frac{Q^2}{s_{ep}\, x})^2$$

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



Lepton–Quark Scattering Angle

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

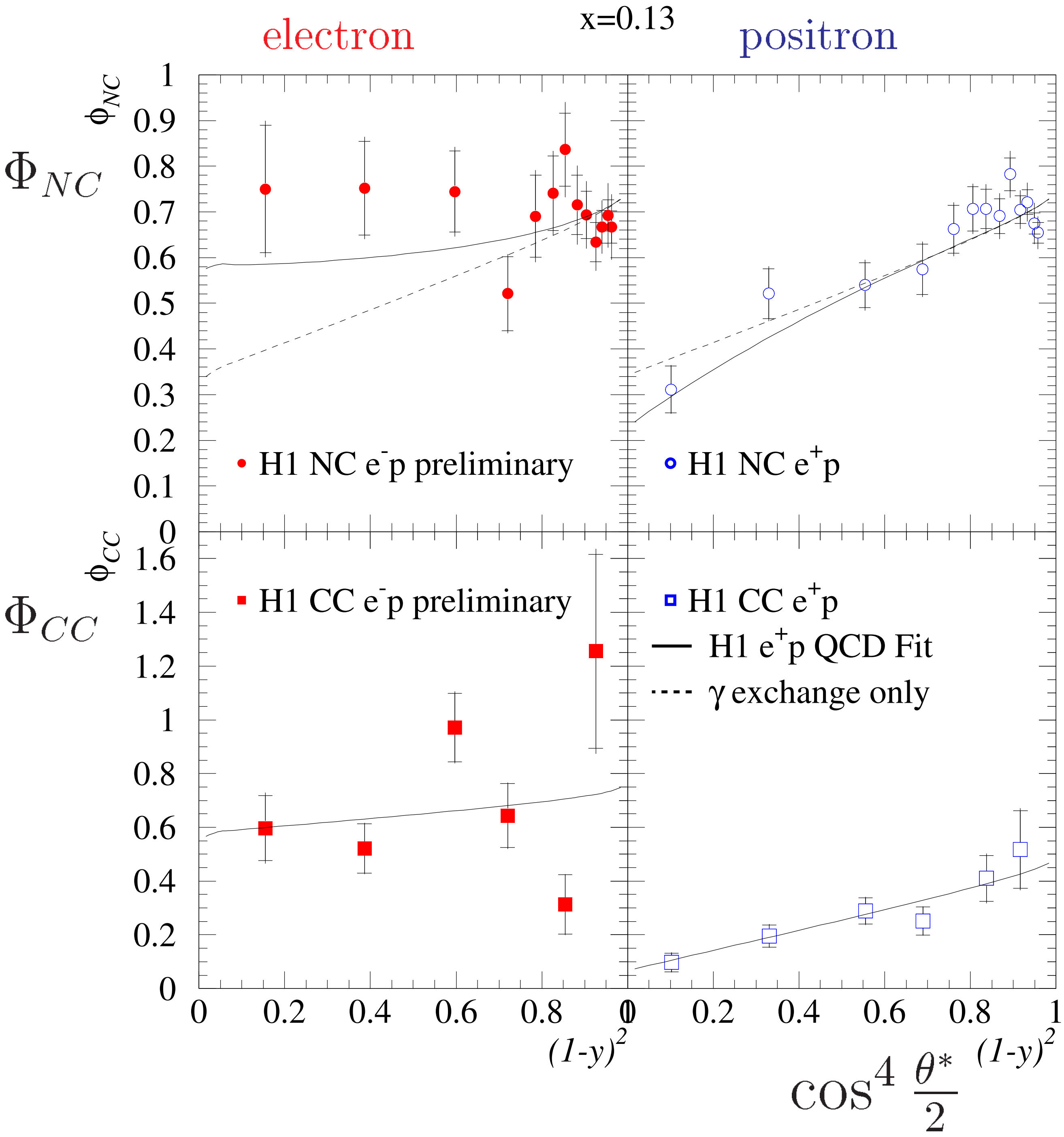
$$\Phi_{CC}^{e^-p} \sim xu + \cos^4\left(\frac{\theta^*}{2}\right) x\bar{d}$$

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

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 $\sim 20\%$,

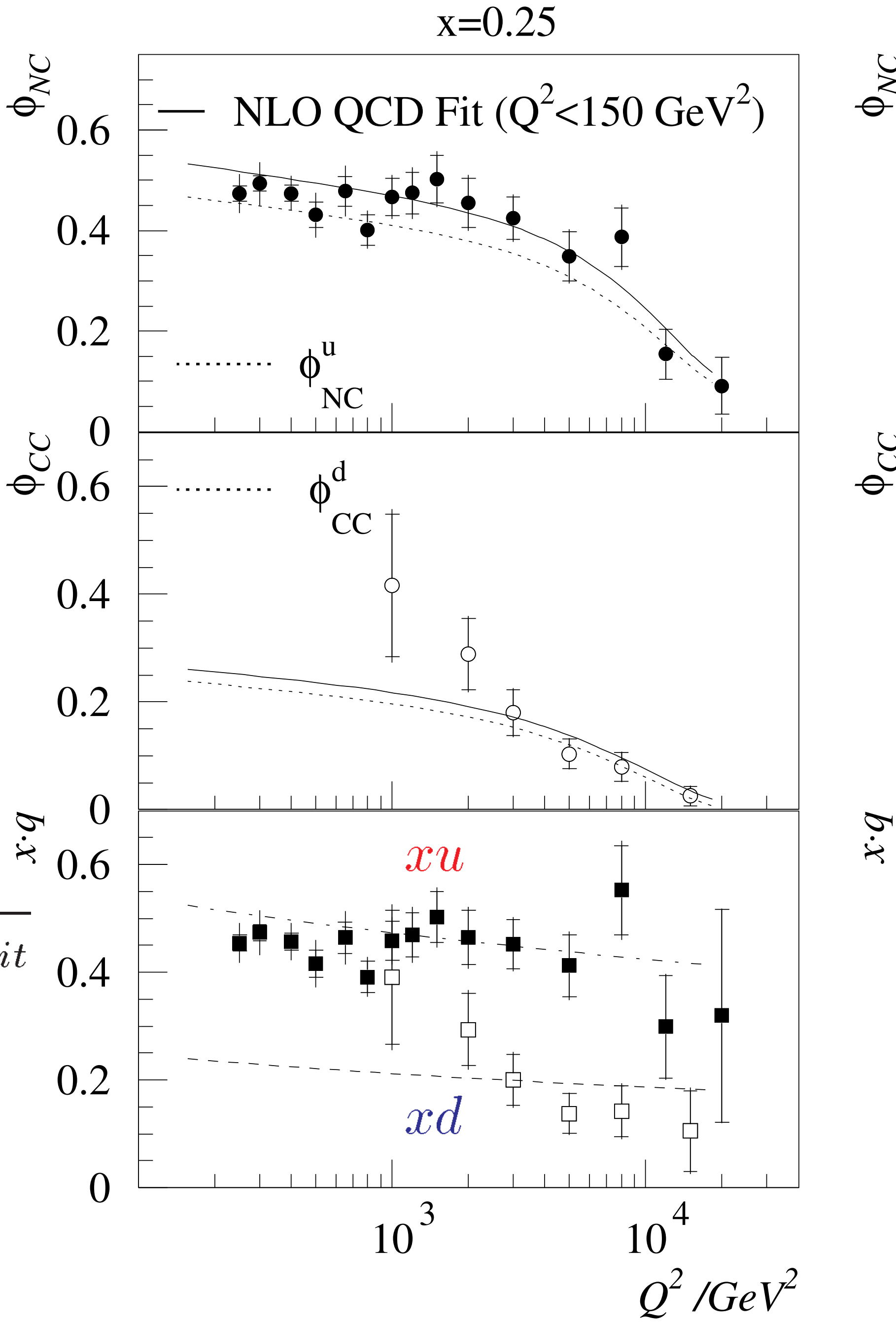
photon-Z interference observed.

Valence Quarks at $\sqrt{s_{eq}} = 150$ GeV

Φ_{NC}

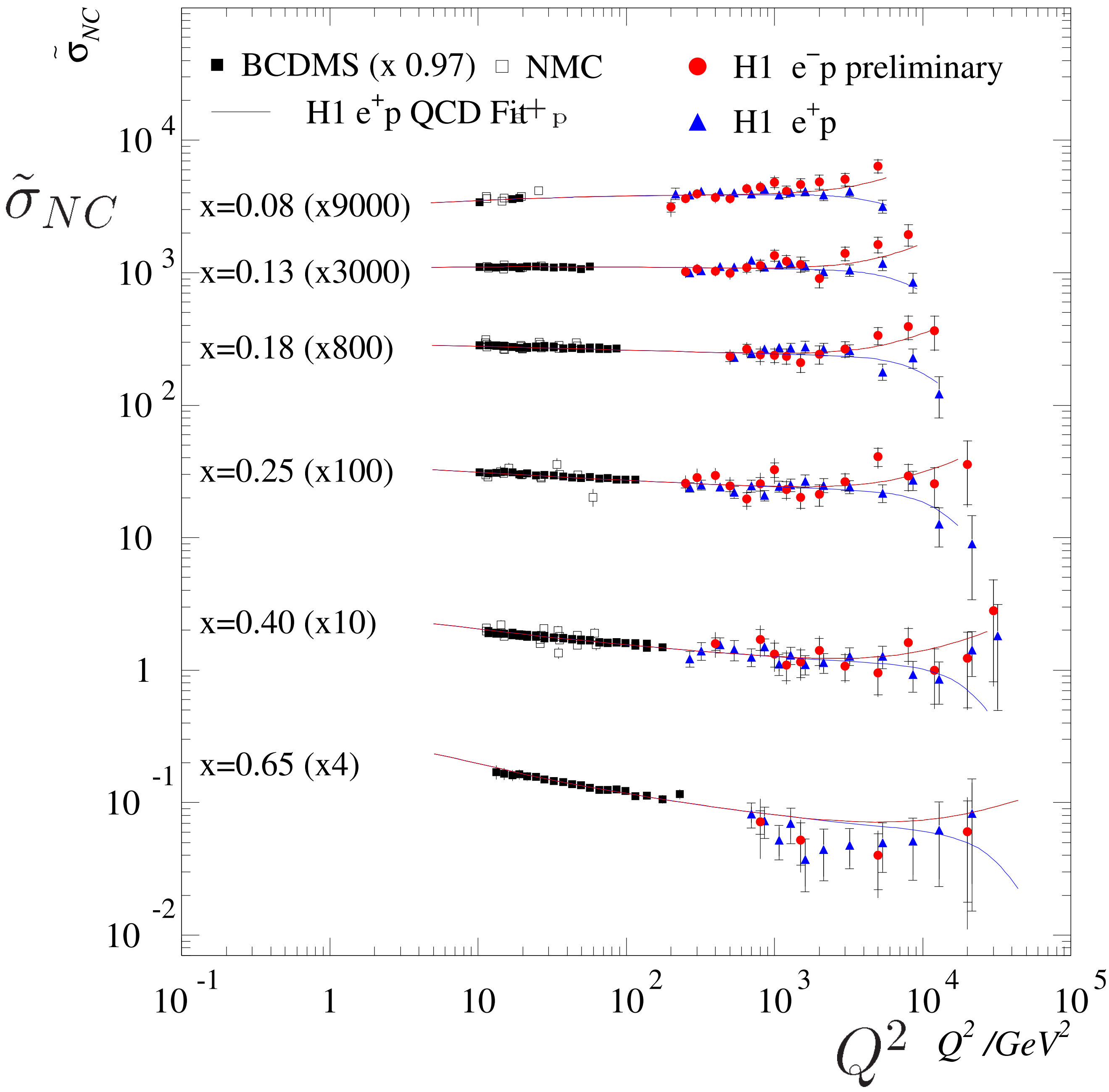
Φ_{CC}

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



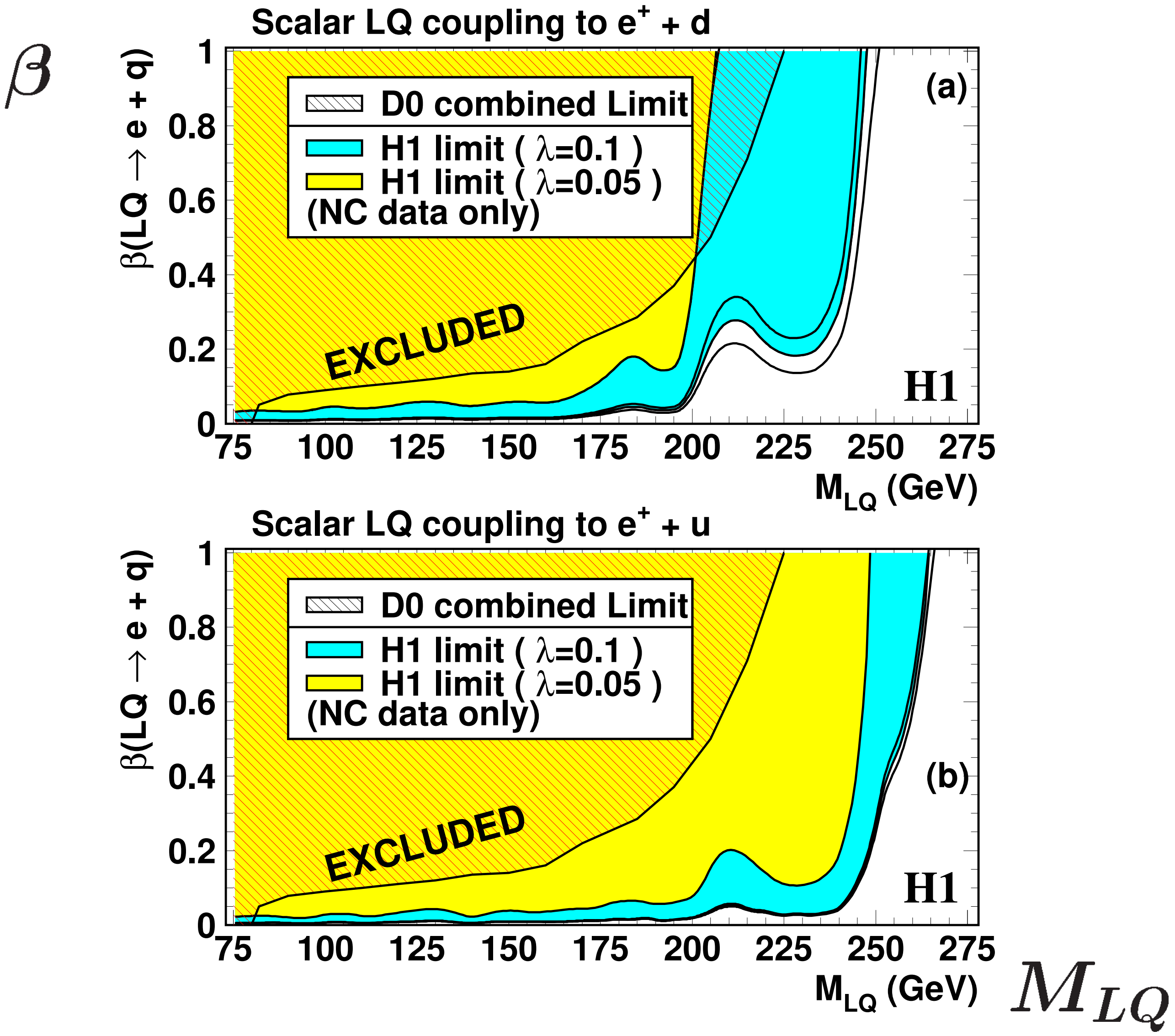
Complementary measurement:
no assumptions on nuclear binding effects.

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



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

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



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

Search for Lepton-Flavour Violating Leptoquarks: $e \leftrightarrow \tau$

LQ →

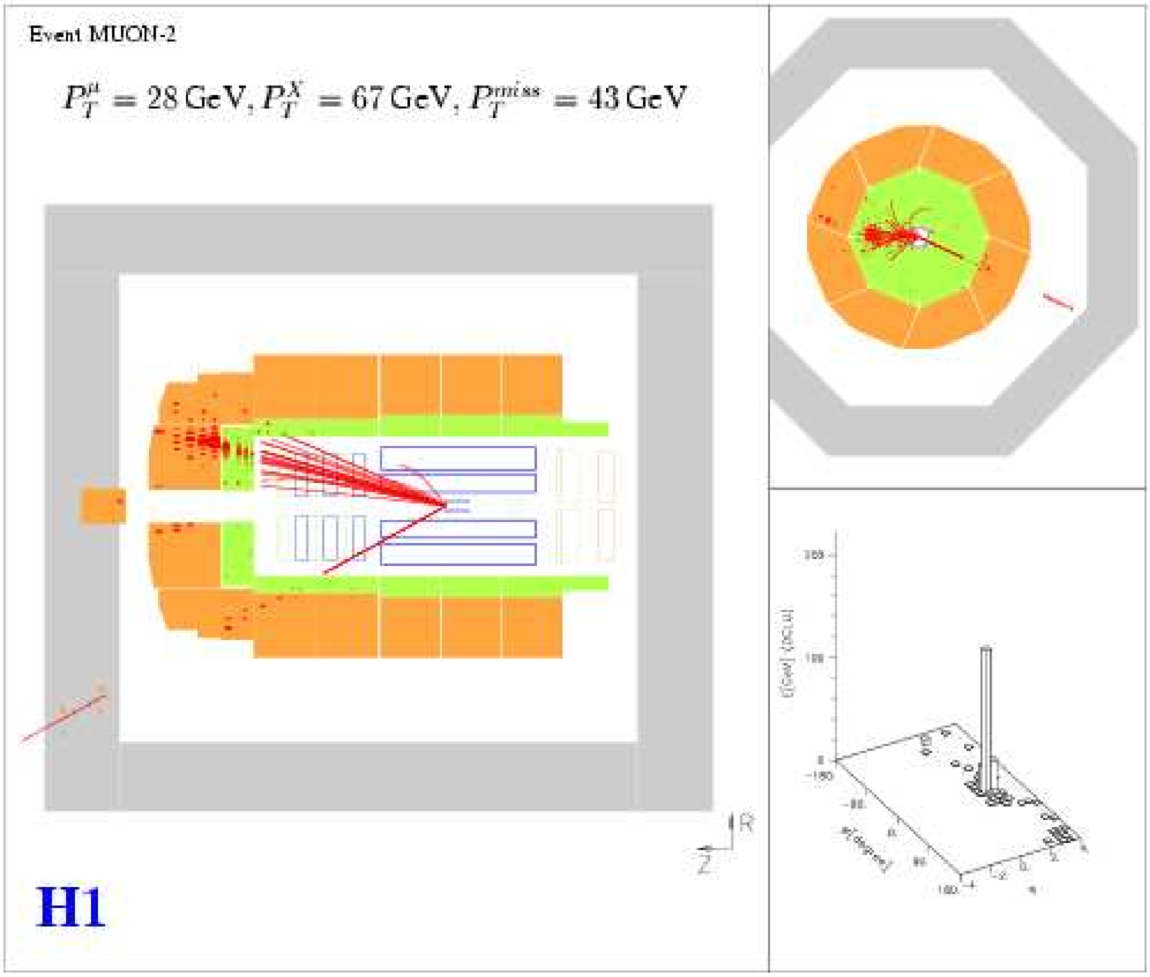
Quark Generations ↓

$e \longleftrightarrow \tau$							F = 0
BEST EXCLUSION UPPER LIMITS ON $\frac{\lambda_{1i}\ \lambda_{3j}}{M^2_{LQ}}$ (in 10^{-4} GeV^{-2}) FOR LEPTON FLAVOUR VIOLATING LEPTOQUARKS							
$q_i\ q_j$	$S_{1/2,L}$	$S_{1/2,R}$	$\tilde{S}_{1/2,L}$	$V_{0,L}$	$V_{0,R}$	$\tilde{V}_{0,R}$	$V_{1,L}$
1 1	$\tau \to \pi e$ 0.0032 H1: 0.046	$\tau \to \pi e$ 0.0016 H1: 0.037	$\tau \to \pi e$ 0.0032 H1: 0.062	G_F 0.002 H1: 0.015	$\tau \to \pi e$ 0.0016 H1: 0.015	$\tau \to \pi e$ 0.0016 H1: 0.013	G_F 0.002 H1: 0.0060
1 2	ZEUS: 0.12 H1: 0.047	$\tau \to K e$ 0.05 H1: 0.038	$\tau \to K e$ 0.05 H1: 0.063	$\tau \to K e$ 0.03 H1: 0.017	$\tau \to K e$ 0.03 H1: 0.017	ZEUS: 0.10 H1: 0.014	$K \to \pi \nu \bar{\nu}$ 2.5×10^{-6} H1: 0.0065
1 3	*	$B \to \tau \bar{e} X$ 0.08 H1: 0.065	$B \to \tau \bar{e} X$ 0.08 H1: 0.065	$B \to l \nu X$ 0.02 H1: 0.020	$B \to \tau \bar{e} X$ 0.04 H1: 0.020	*	$B \to l \nu X$ 0.02 H1: 0.020
2 1	ZEUS: 0.34 H1: 0.15	$\tau \to K e$ 0.05 H1: 0.095	$\tau \to K e$ 0.05 H1: 0.12	$\tau \to K e$ 0.03 H1: 0.020	$\tau \to K e$ 0.03 H1: 0.020	ZEUS: 0.10 H1: 0.023	$K \to \pi \nu \bar{\nu}$ 2.5×10^{-6} H1: 0.010
2 2	$\tau \to e \gamma$ 0.03 H1: 0.18	$\tau \to e \gamma$ 0.02 H1: 0.10	ZEUS: 0.48 H1: 0.13	ZEUS: 0.25 H1: 0.024	ZEUS: 0.25 H1: 0.024	ZEUS: 0.31 H1: 0.034	ZEUS: 0.13 H1: 0.014
2 3	*	$B \to \tau \bar{e} X$ 0.08 H1: 0.14	$B \to \tau \bar{e} X$ 0.08 H1: 0.14	$B \to l \nu X$ 0.02 H1: 0.035	$B \to \tau \bar{e} X$ 0.04 H1: 0.035	*	$B \to l \nu X$ 0.02 H1: 0.035
3 1	*	$B \to \tau \bar{e} X$ 0.08 H1: 0.16	$B \to \tau \bar{e} X$ 0.08 H1: 0.16	V_{ub} 0.002 H1: 0.022	$B \to \tau \bar{e} X$ 0.04 H1: 0.022	*	V_{ub} 0.002 H1: 0.022
3 2	*	$B \to \tau \bar{e} X$ 0.08 H1: 0.19	$B \to \tau \bar{e} X$ 0.08 H1: 0.19	$B \to l \nu X$ 0.02 H1: 0.026	$B \to \tau \bar{e} X$ 0.04 H1: 0.026	*	$B \to l \nu X$ 0.02 H1: 0.026
3 3	*	ZEUS: 0.72 H1: 0.23	ZEUS: 0.72 H1: 0.23	$\tau \to e \gamma$ 0.51 Z H1: 0.045	$\tau \to e \gamma$ 0.51 Z H1: 0.045	*	ZEUS: 0.38 H1: 0.045

For many species no competition for *ep* collisions.

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

Search for Isolated Leptons:
identical analysis of e^+p applied to 13.6pb^{-1} e^-p

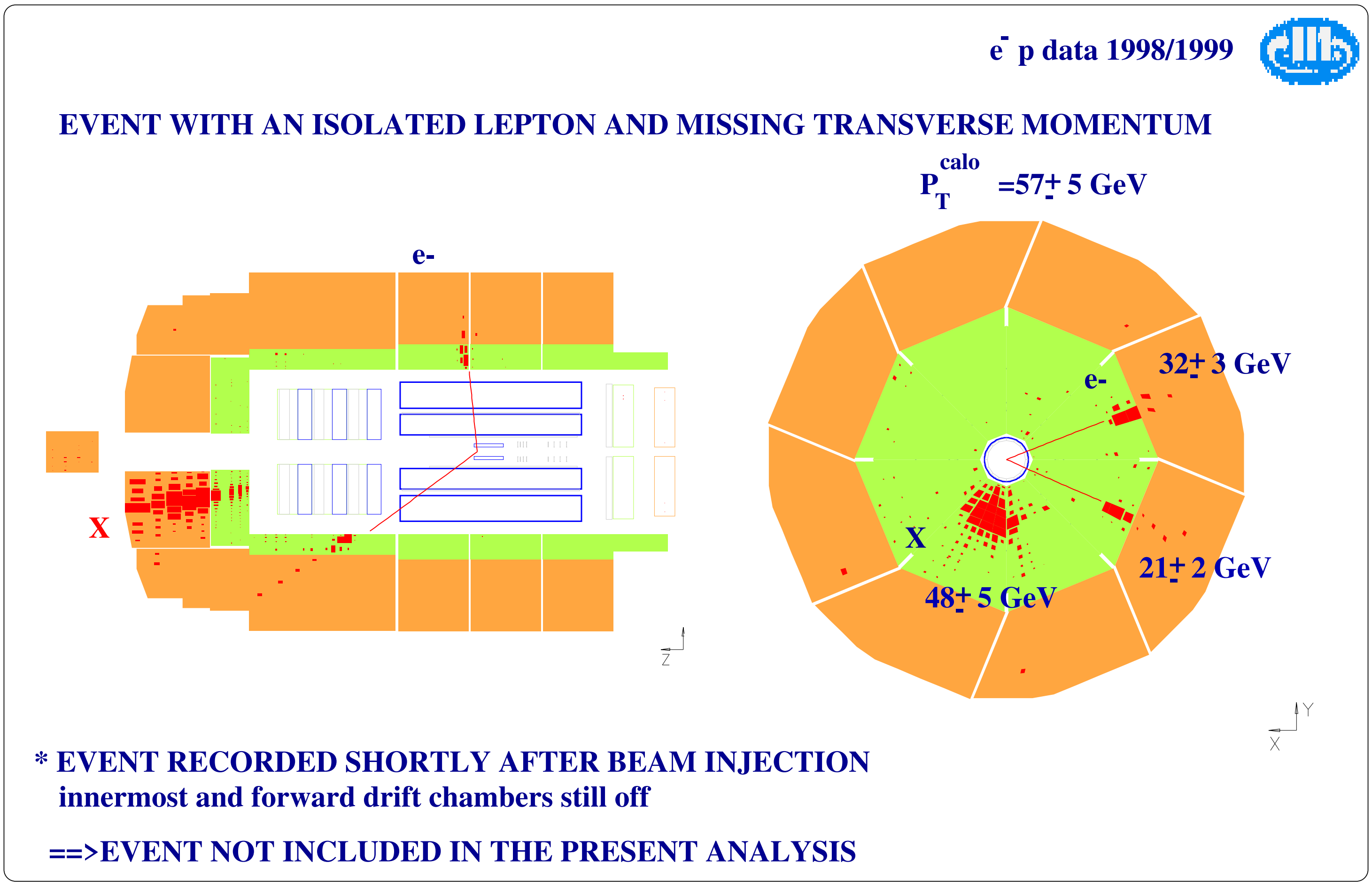
	Electron Channel	Muon Channel
Data	0	0
W production	0.63 ± 0.19	0.23 ± 0.05
Charged Current	0.08 ± 0.02	0.01 ± 0.01
Neutral Current	0.22 ± 0.05	0.03 ± 0.02
Photoproduction	< 0.02	< 0.02
Photon-Photon	0.05 ± 0.02	$0.09^{+0.09}_{-0.05}$
Total SM	1.0 ± 0.2	0.4 ± 0.1

No event.

Additional 2.7pb^{-1} e^-p luminosity taken immediately after HERA announcement "luminosity run": innermost and forward drift chambers still off $\Rightarrow$

Electron–Proton Collisions:

Isolated Electron, Isolated Particle, High-p_T Jet, Large P_T^{miss}



Again exceptional event at
large transverse momentum: $P_T^{calo} = 57 \pm 5\text{GeV}.$

Mechanism present also in $e^- p$ Collisions.

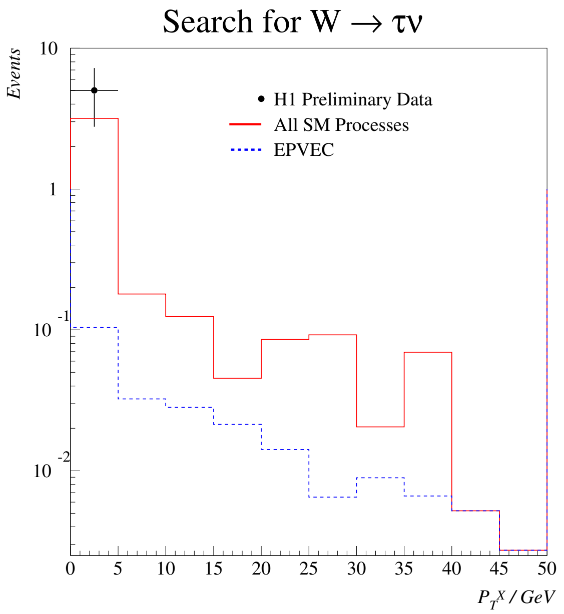
W Production in e^+p Collisions

H1 Preliminary

Electron	Data	St. Model	W
$P_T^X > 0\text{GeV}$	3	3.12 ± 0.70	2.24 ± 0.67
$P_T^X > 12\text{GeV}$	1	1.15 ± 0.25	0.78 ± 0.23
$P_T^X > 25\text{GeV}$	0	0.50 ± 0.12	0.38 ± 0.11
$P_T^X > 40\text{GeV}$	0	0.16 ± 0.04	0.14 ± 0.04

Muon	Data	St. Model	W
$P_T^X > 12\text{GeV}$	5	1.01 ± 0.28	0.87 ± 0.26
$P_T^X > 25\text{GeV}$	5	0.56 ± 0.15	0.49 ± 0.15
$P_T^X > 40\text{GeV}$	3	0.21 ± 0.06	0.19 ± 0.06

– Tau



P_T^X

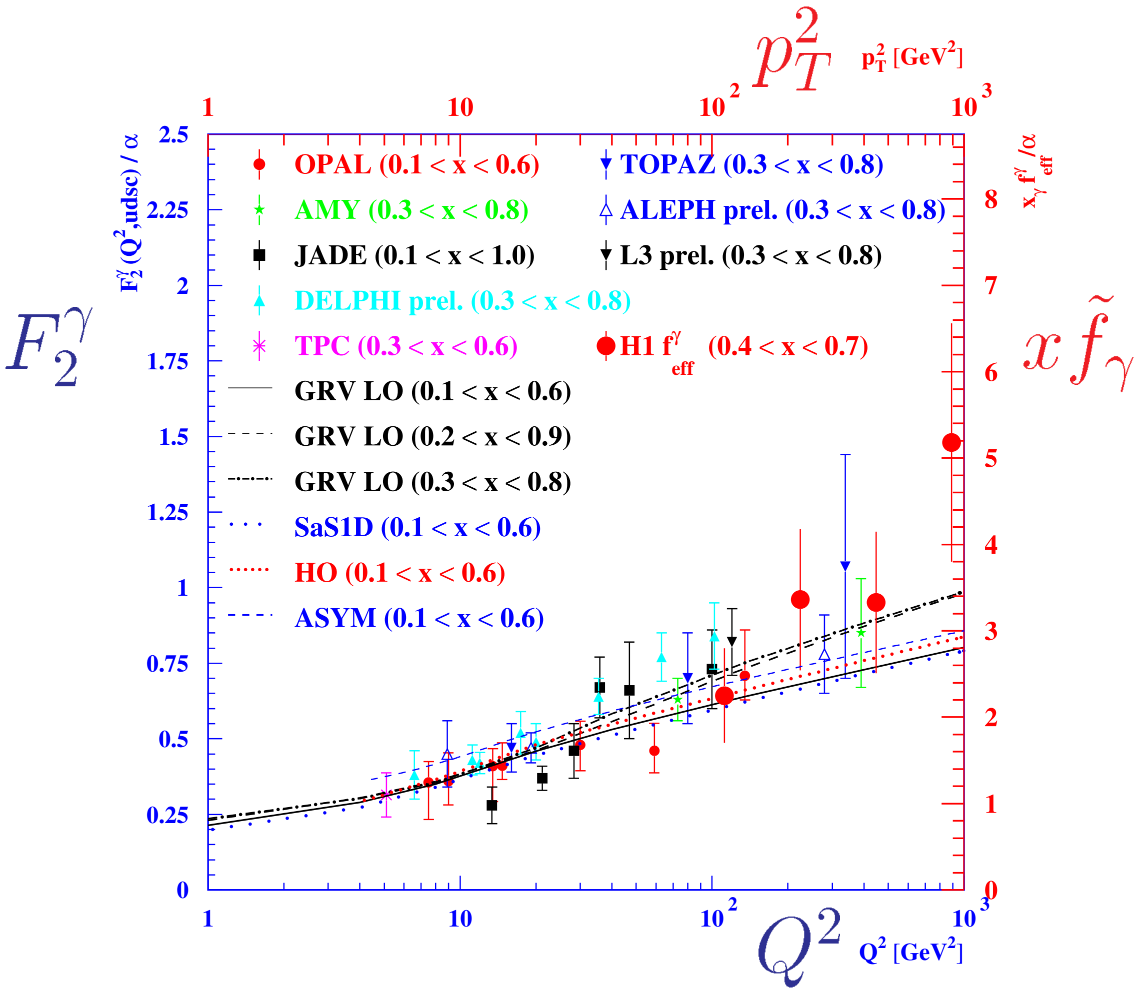
– Jets: too large QCD background

$\Rightarrow$ Outstanding events in muon channel.

Formation of Hadronic Matter from Highly Energetic Photons

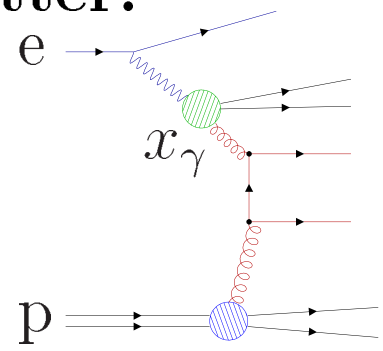
Structure Function | **Effective Parton Distribution**

$$F_2^\gamma = x_\gamma \, e_q^2 \, f_{q/\gamma} \qquad x_\gamma \tilde{f}_\gamma = x_\gamma \left(f_{q/\gamma} + \frac{9}{4} f_{g/\gamma} \right)$$



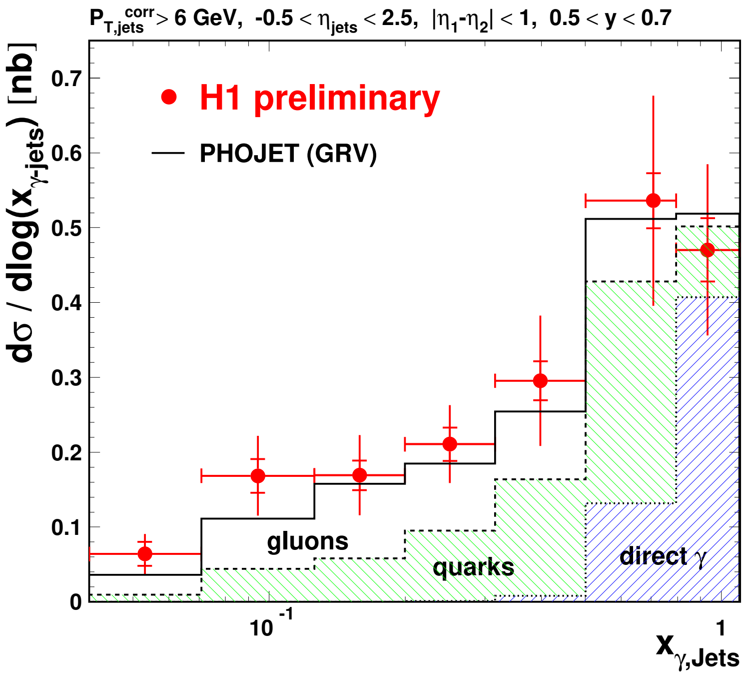
QCD: $$f_{q/\gamma} \propto \ln \frac{\mu^2}{\Lambda^2_{QCD}}, \quad \mu^2 = Q^2, p_t^2$$

Formation of Hadronic Matter:
Gluons



Di-Jet Cross Section:

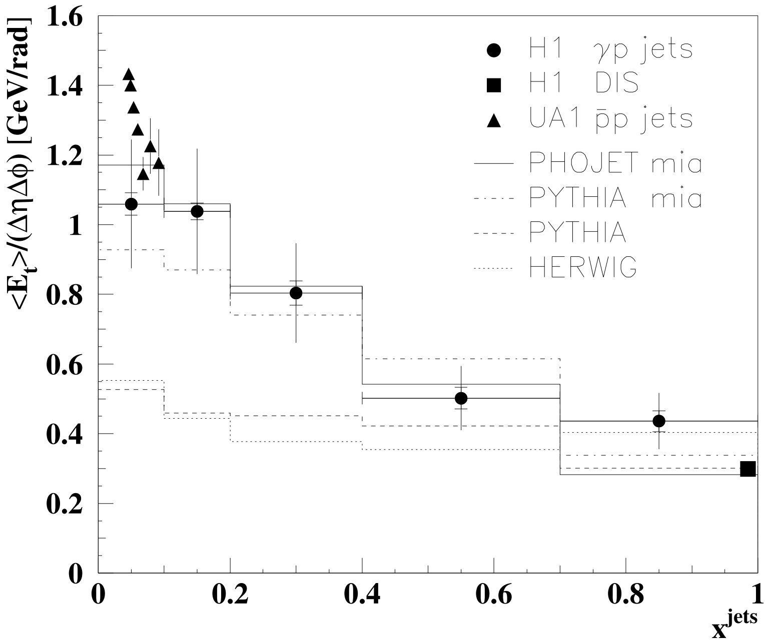
$$\frac{d\sigma}{d\log x_\gamma}$$



x_γ

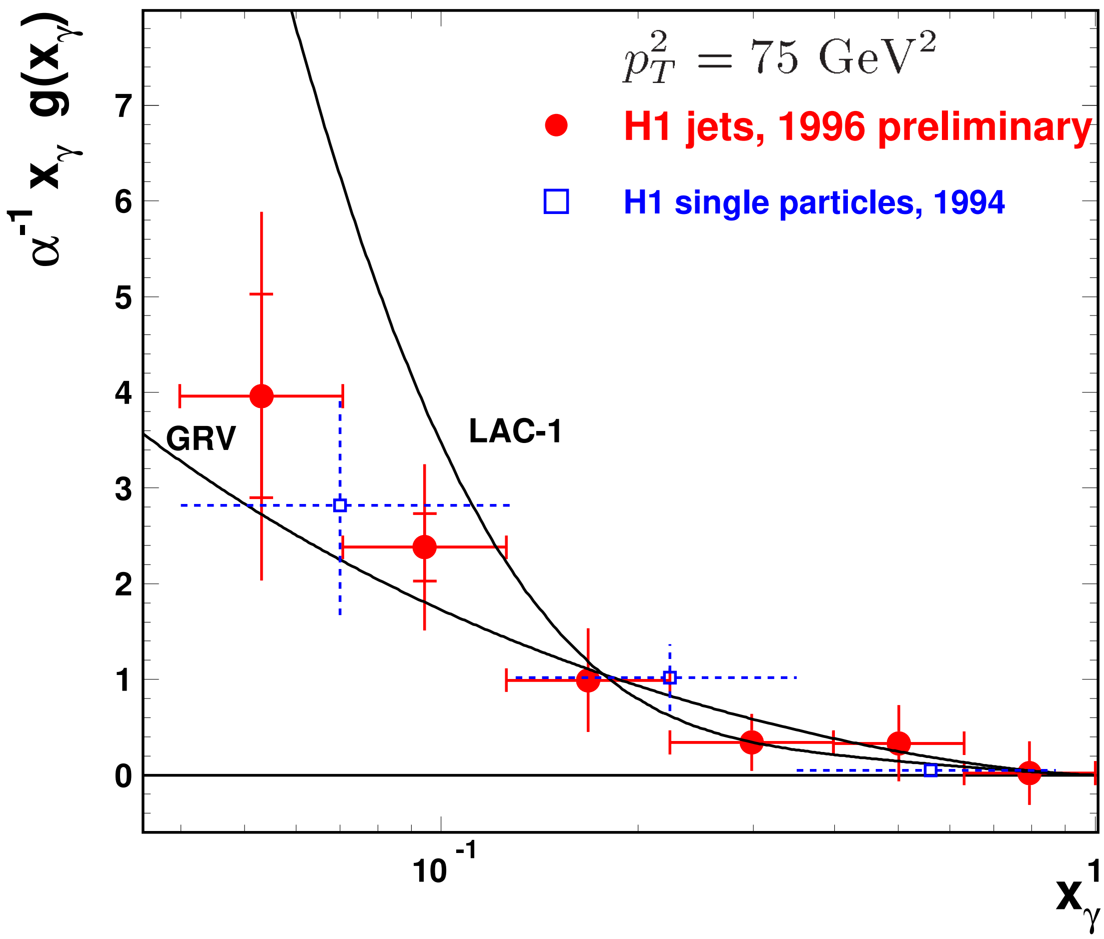
Transverse Energy Density outside jets:

$$\frac{\langle E_T \rangle}{\Delta\eta\Delta\phi}$$



x_γ

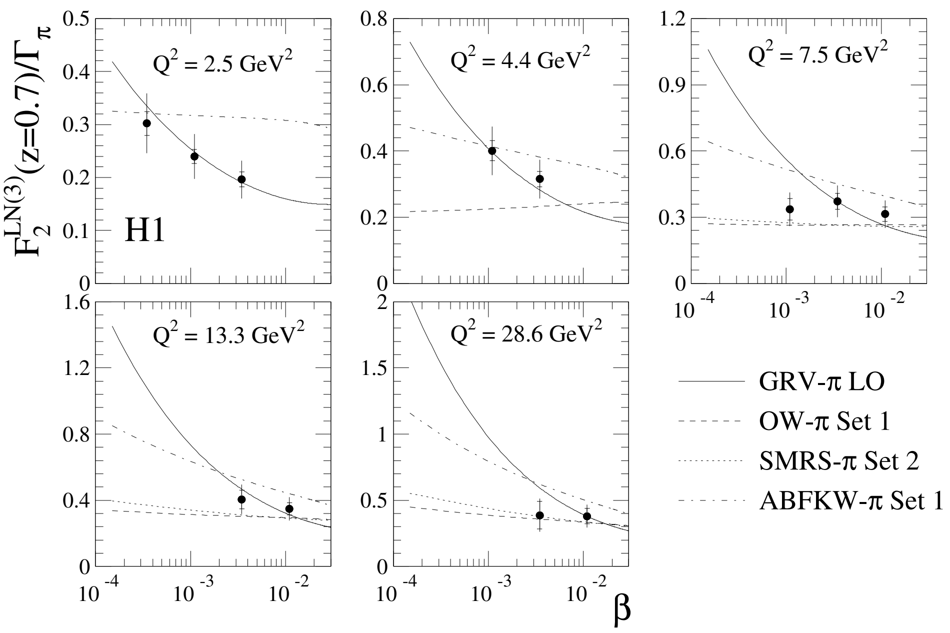
Gluon Distribution of Photon

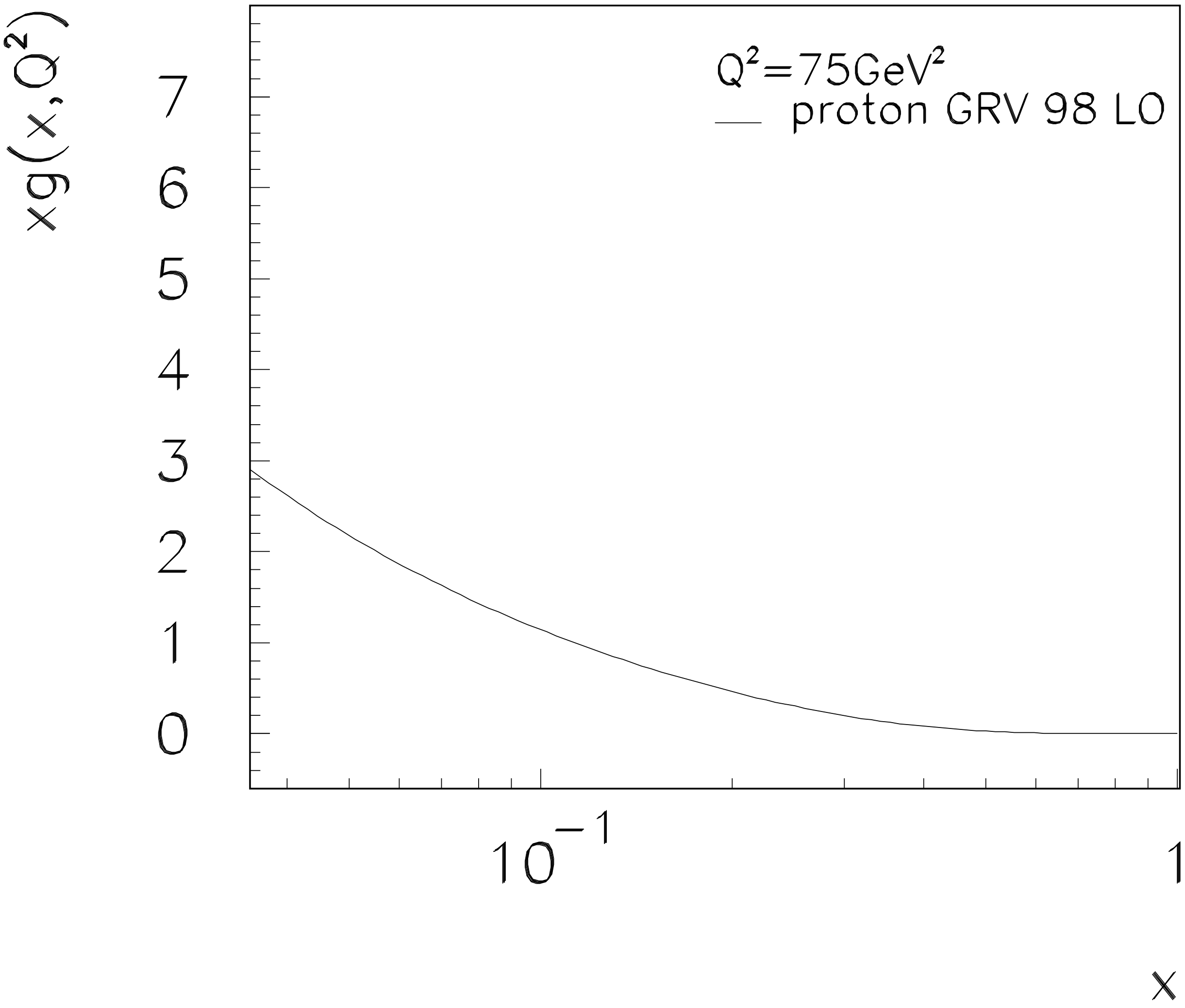


Universal gluon development in hadronic bound states.

E.g. GRV "valence like gluon", $xg(\gamma) = \alpha\ xg(\pi)$.

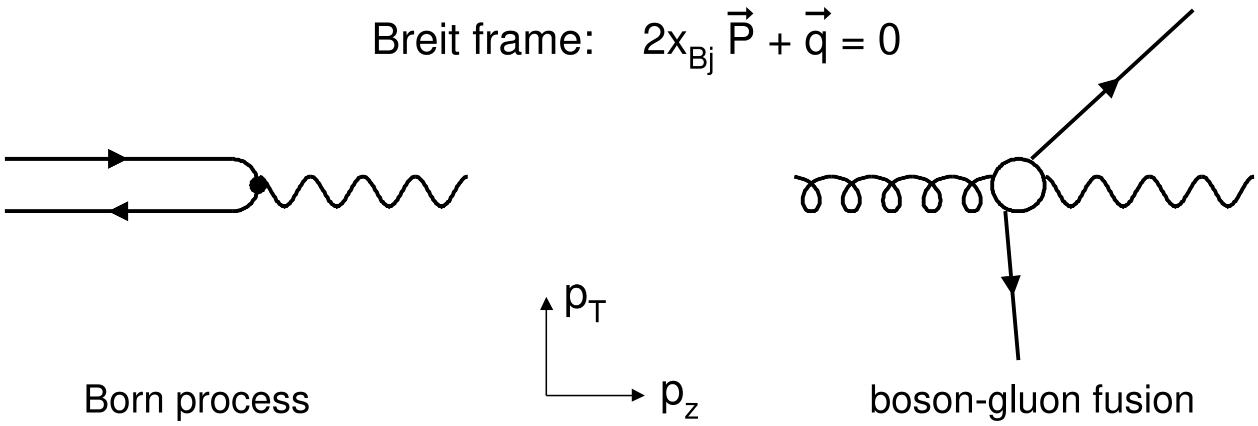
Pion:

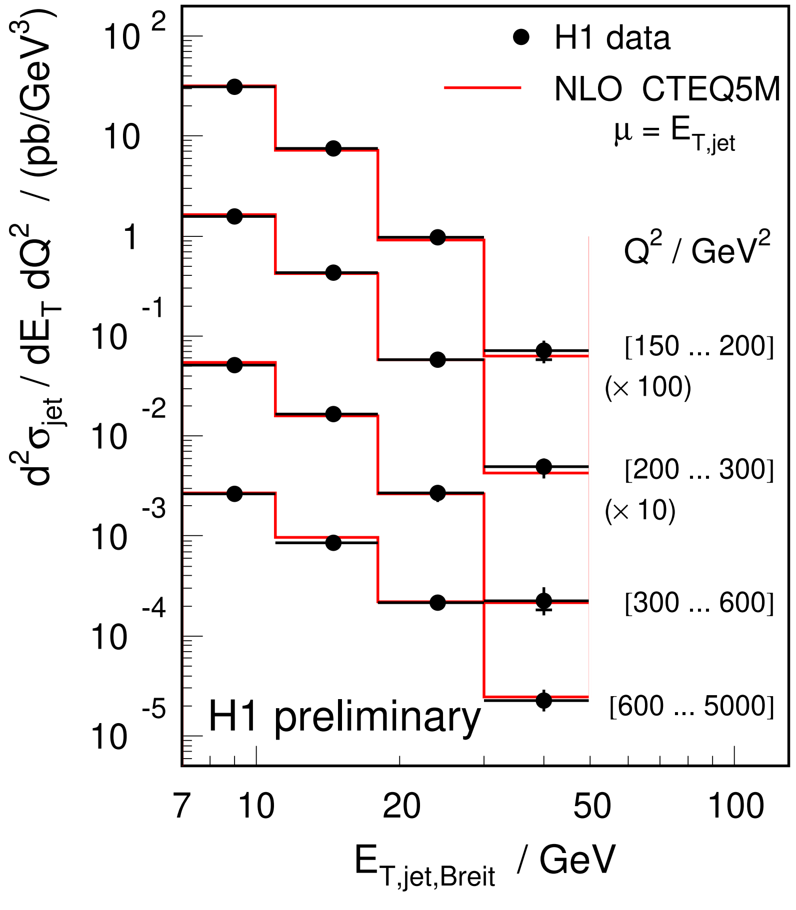




Q^2=75GeV^2
proton GRV 98 LO
$xg(x,Q^2)$
7
6
5
4
3
2
1
0
10^{-1}
1
x

Inclusive Jet Cross Section in DIS

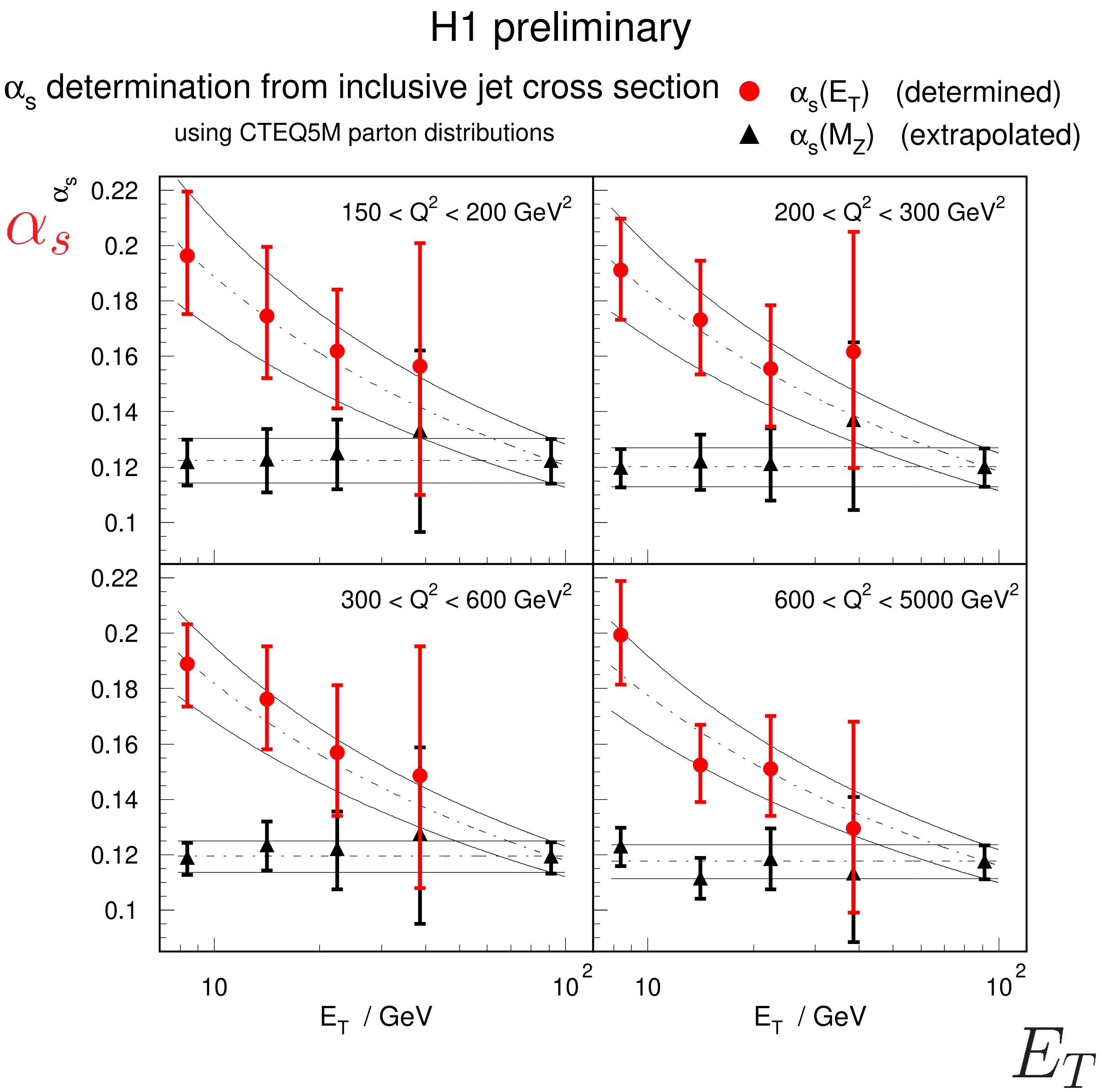




Well described by $O(\alpha_s^2)$ calculation

Strong Coupling Constant α_s

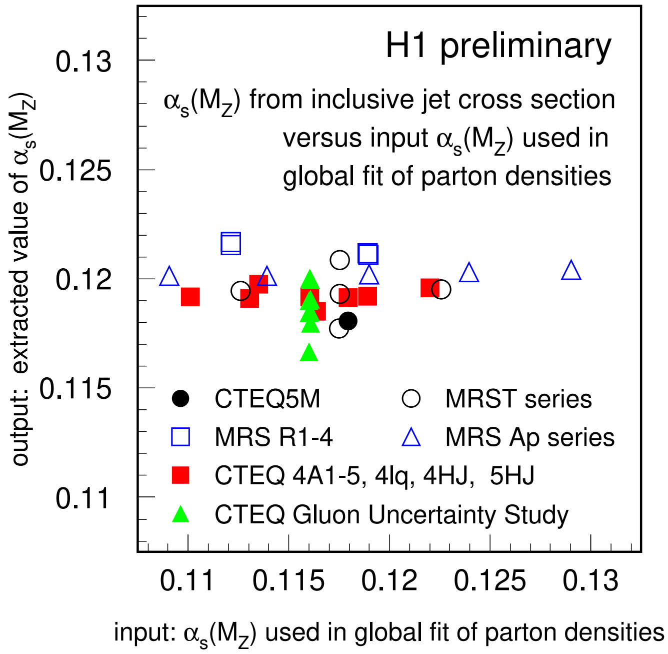
$$\sigma_{jet}^{\mathrm{QCD}} = \Sigma_{i=u,d,\ldots;\ n=1,\ldots} \quad \alpha_s{}^n \ C_{i,n}^{\mathrm{QCD}} \oplus f_{i/\mathrm{p}}$$



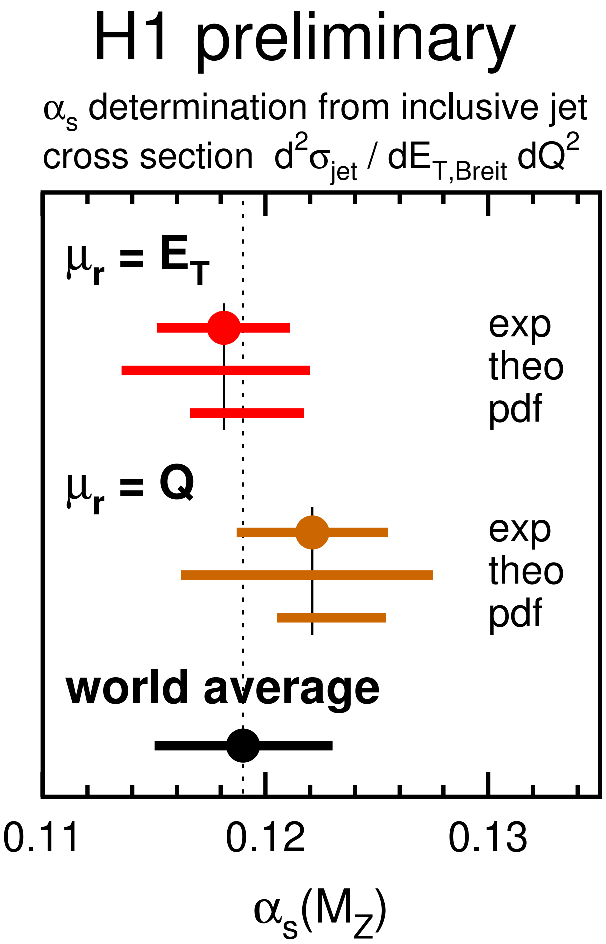
Consistent α_s extraction in each bin.

Strong Coupling Constant α_s

extracted α_s



pdf: input α_s

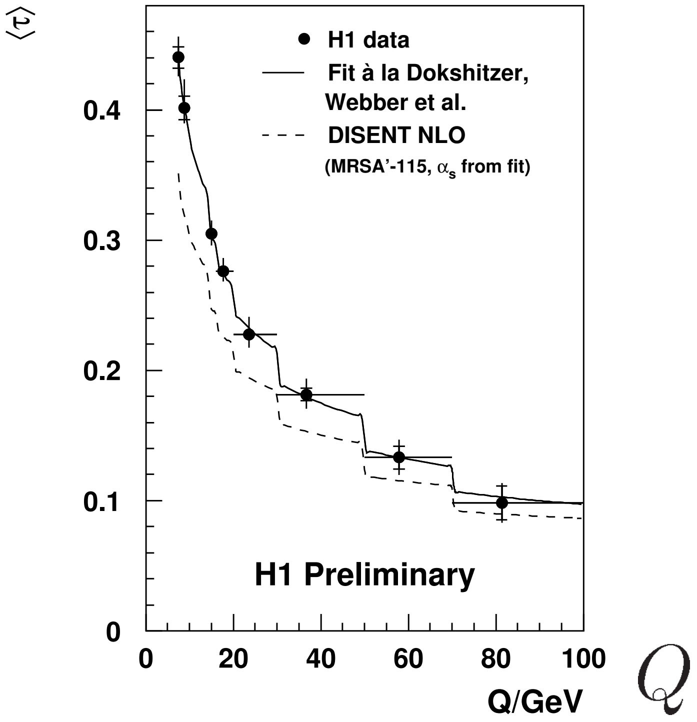


S.Bethke

Precision: now *ep* gives a significant contribution.

Analysis of Event Shape Observables

e.g. Thrust

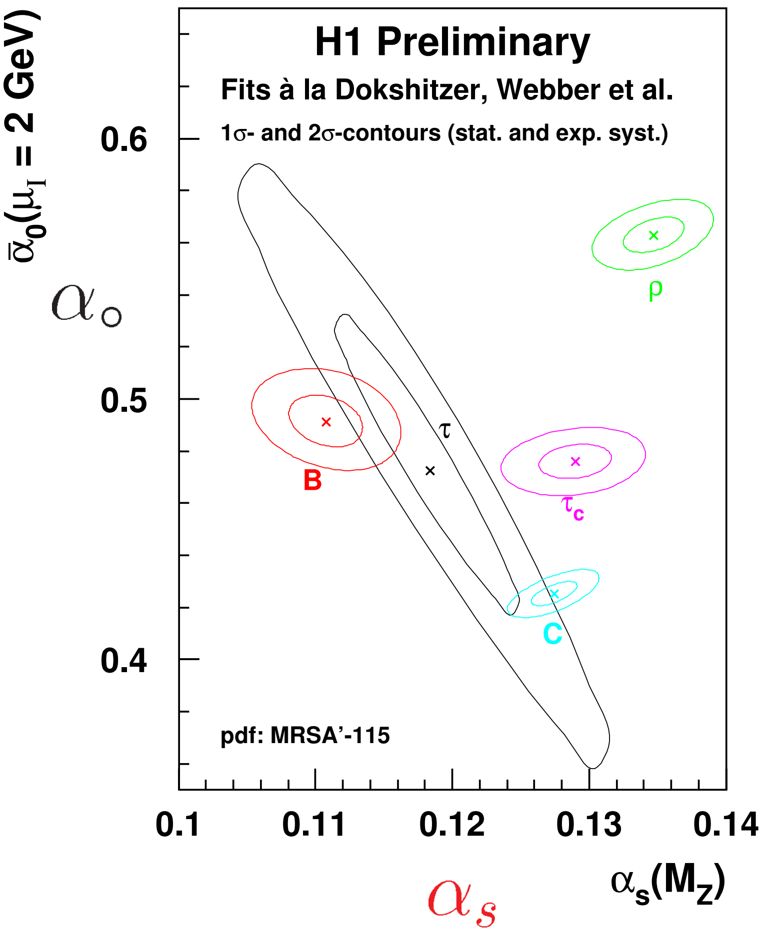


Consistency check:

Dokshitzer-Webber

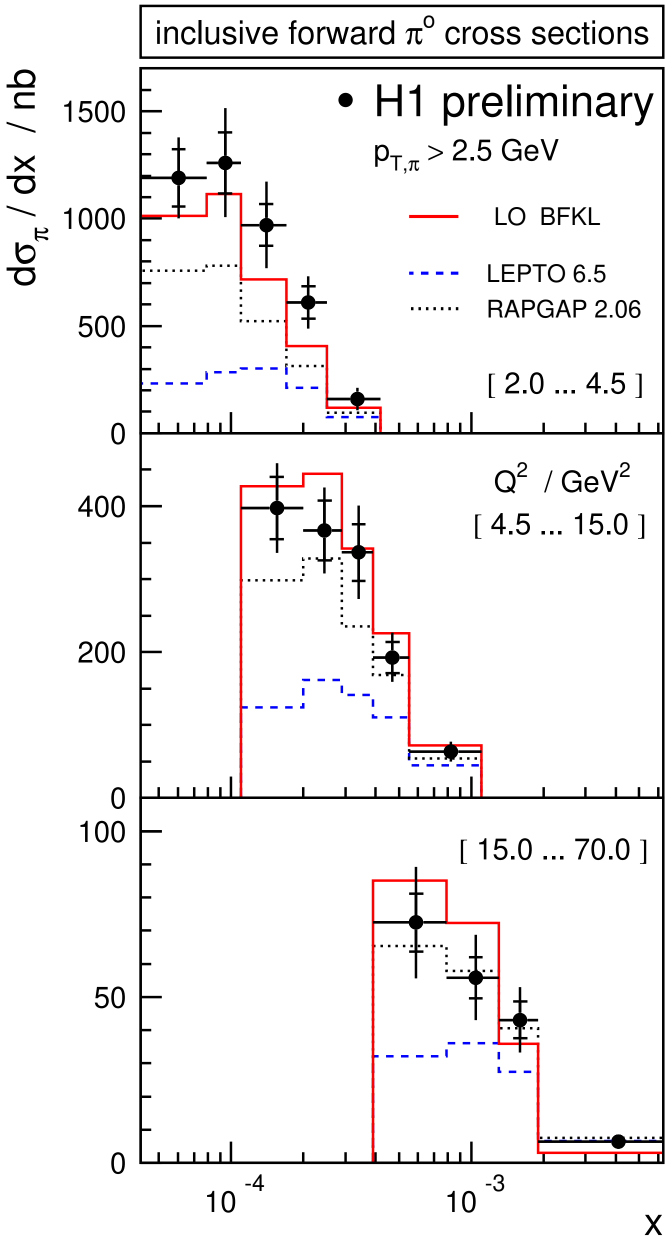
common $\alpha_\circ$ $\pm 20\%$,

relation to α_s.



Parton Evolution:
π° Mesons at High-$p_T^{\gamma^* p}$ and $\eta^{\gamma^* p} \approx 0$

$$\frac{d\sigma^{\pi^\circ}}{dx}$$

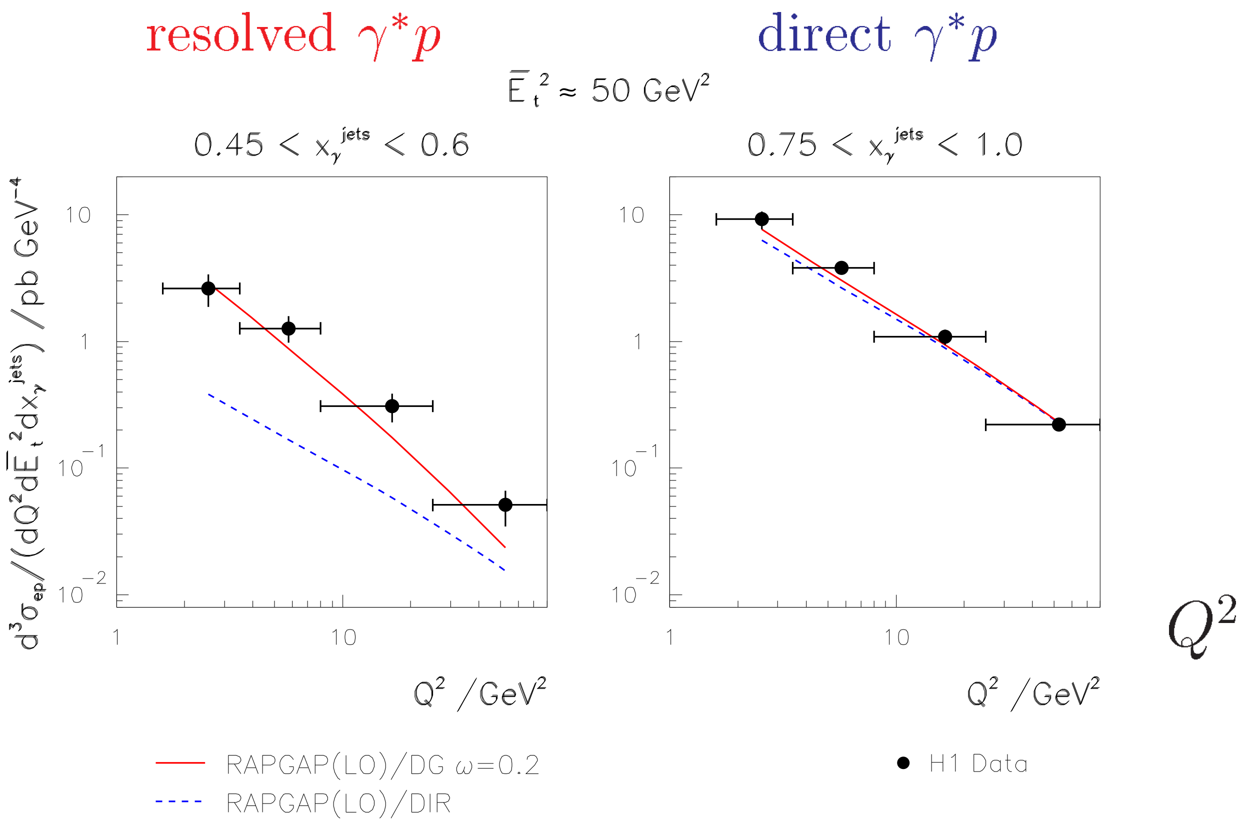


x

fails: LO QCD calculation with DGLAP type parton evolution using partons as of F_2,

succeeds: LO QCD, BFKL type parton evolution.

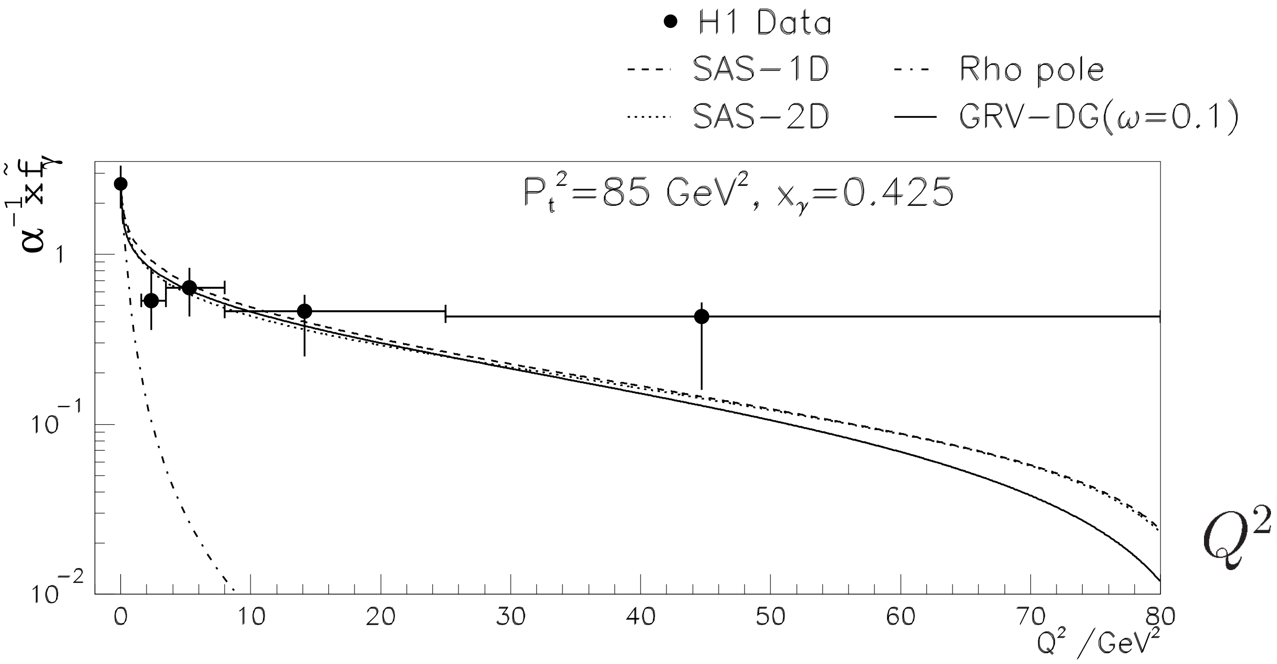
3-Diff. Di-Jets Cross Sections in DIS



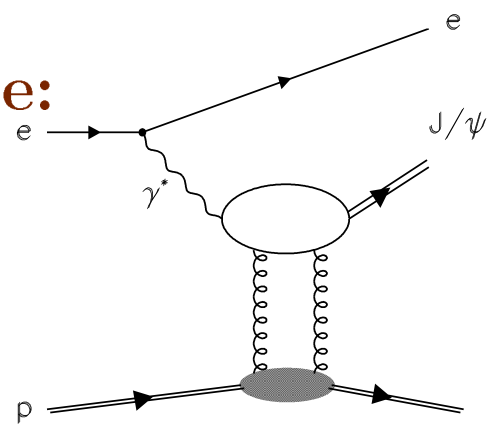
Quarks & gluons in virtual photons:

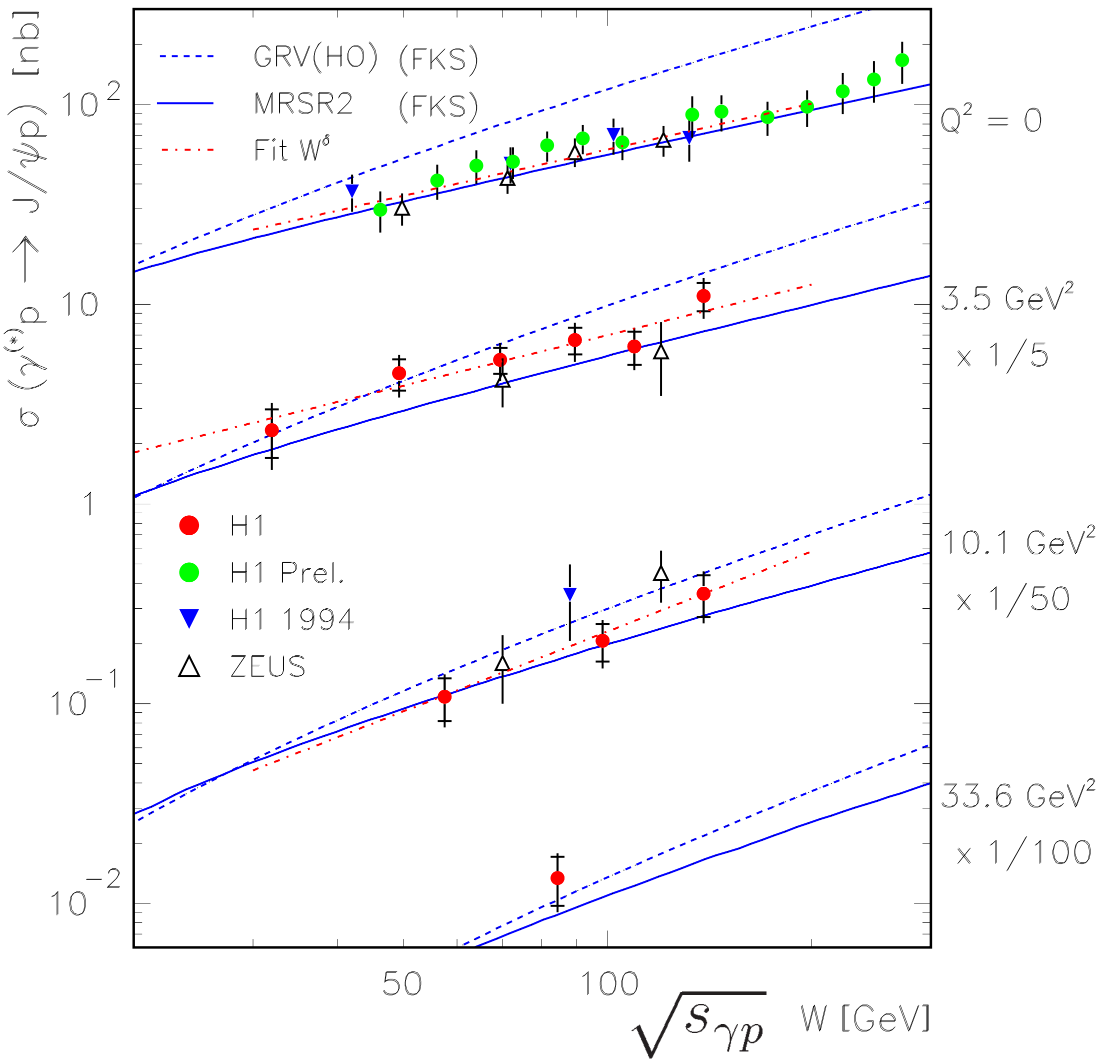
coverage of higher order QCD effects ?

what about $\Lambda^2_{QCD} \ll Q^2 \ll p_t^2$?



Colour Singlet Exchange: J/Ψ Cross Section



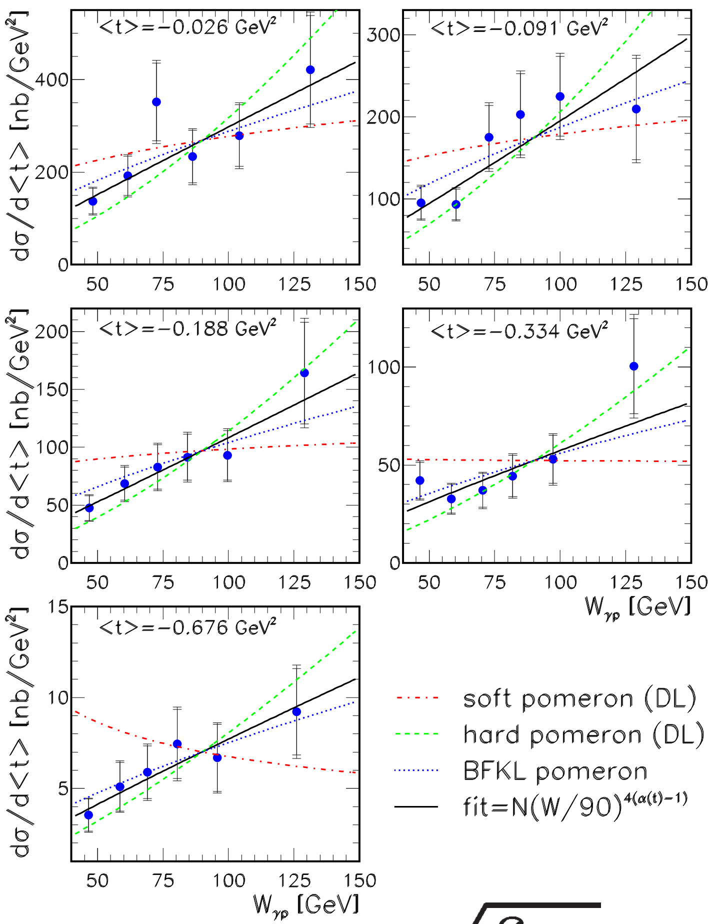


Highly sensitive to gluon in proton $|xg(x)|^2$ and charm mass within QCD dynamics.

Colour Singlet Exchange:
J/Ψ Trajectory

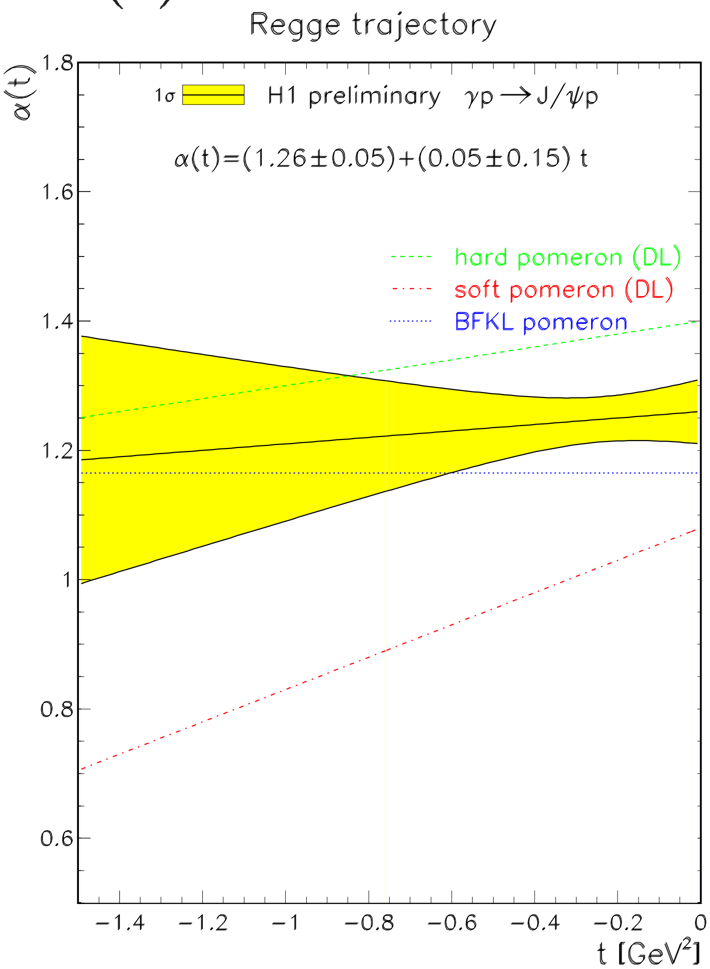
$$\frac{d\sigma}{d\langle t\rangle}$$

W dependence in bins of |t|



$$\sqrt{s_{\gamma p}}$$

$$\alpha(t)$$

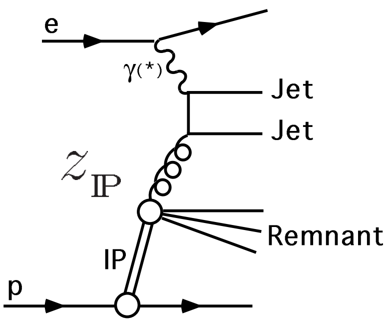


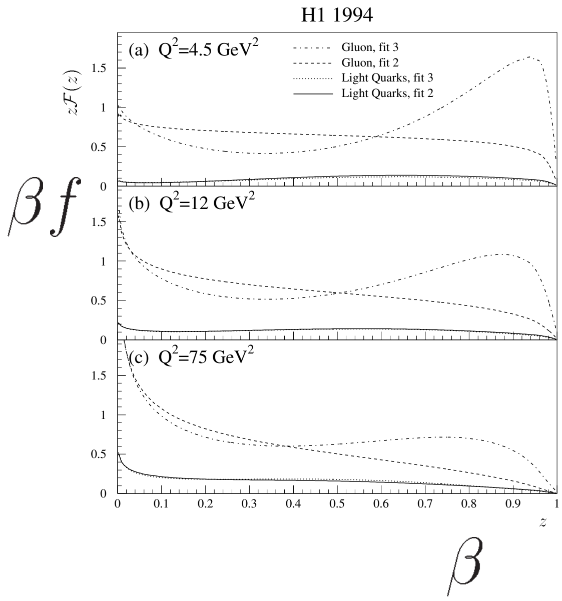
$$t$$

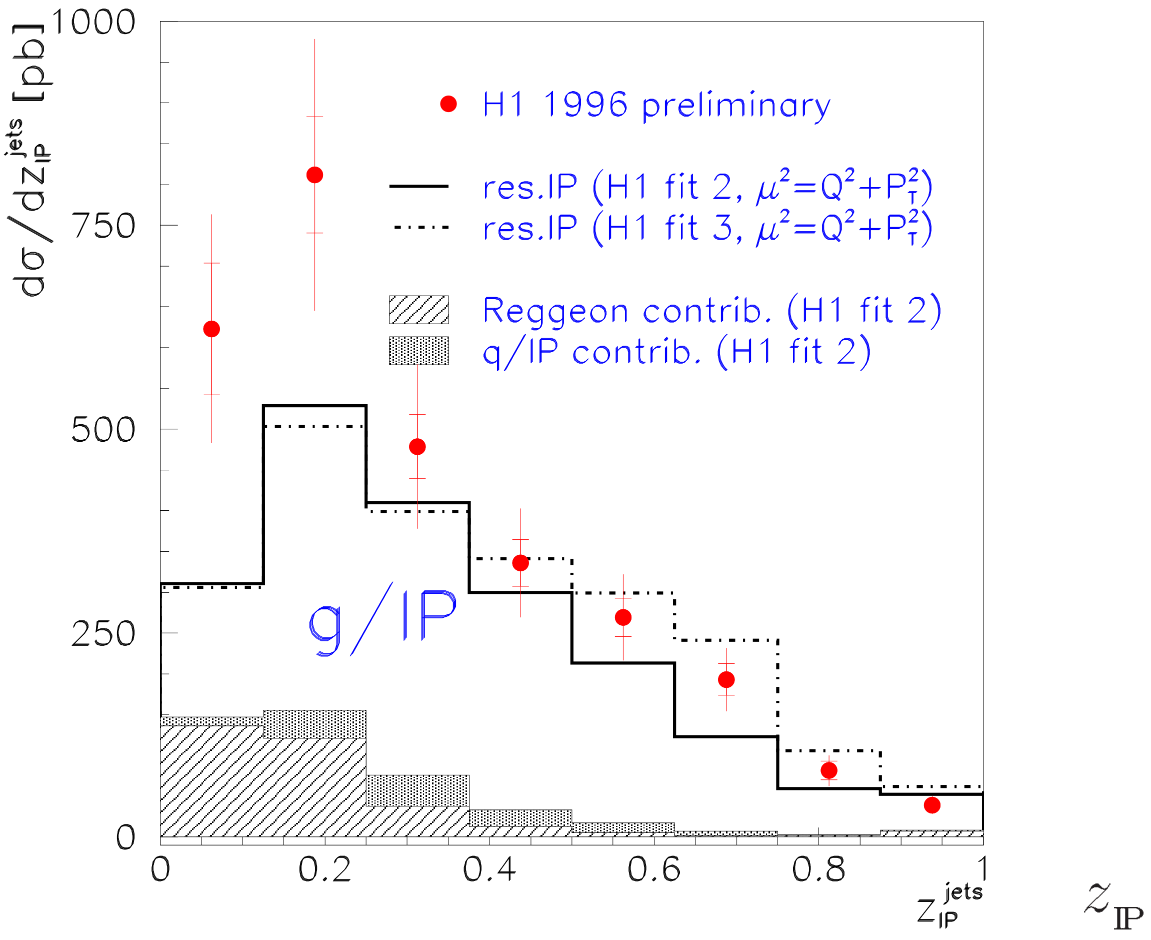
Single experiment: no shrinkage!?

Di-Jets in DIS Colour Singlet Exchange

inclusive $F_2^{D(3)} \to$ gluon

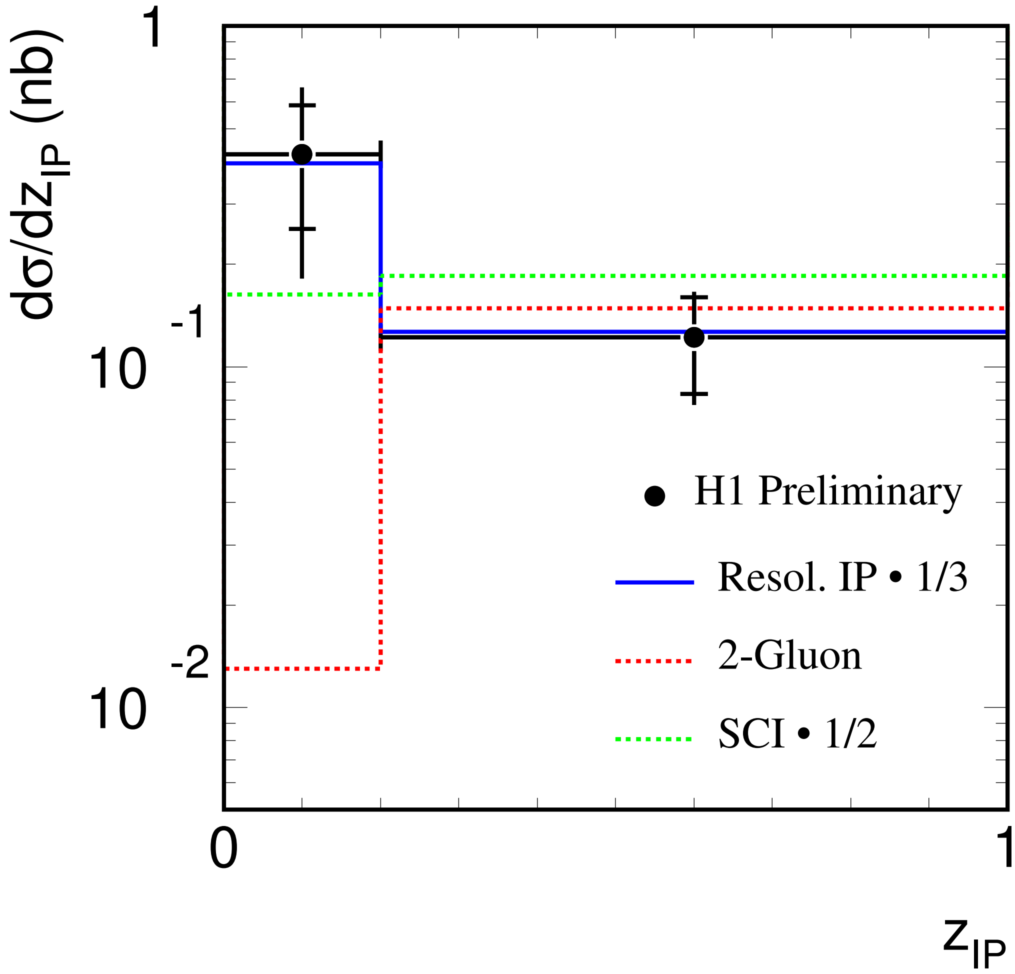






Very sensitive measure of gluon.

Diffractive Production of D^* Mesons



First deviation from consistent picture of inclusive measurements and hadronic final state ?

Summary

Beyond our structure function measurements:

proton, photon, pion, pomeron,

we are concentrating on the fundamental questions to our understanding of physics:

1. At resolution scale $O(10^{-3})$ fm: boson exchange in ep collisions ok to few %; lepton-quark scattering in $\sqrt{s_{eq}}$ bins ok to $O(20\%)$; exception: excess at high Q^2 and large $\sqrt{s_{eq}}$ to be carefully watched !

2. Observation of events with high-p_T isolated lepton(s), high-p_T jet(s), large missing transverse momentum: most striking signature at HERA, unexplained.

3. Strong interaction: α_s, parton evolution dynamics, multiple parton exchange.

The H1 Collaboration is enthusiastically looking forward to the coming e^+p period and the luminosity upgrade program !