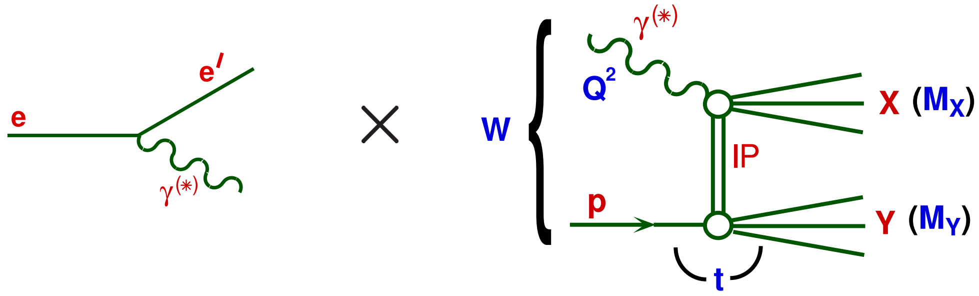
Inclusive Diffraction at HERA

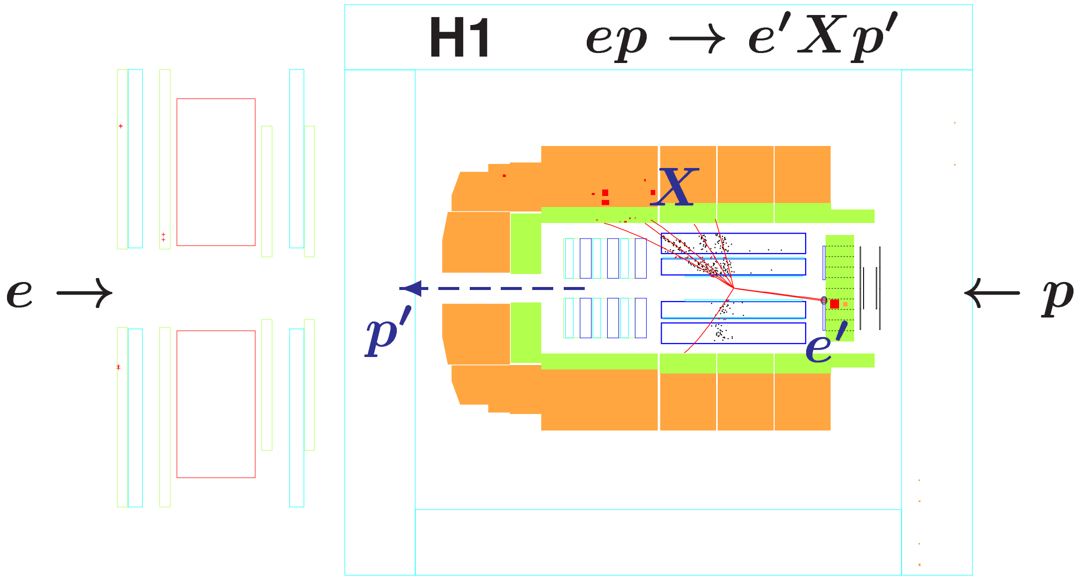
Paul Newman, Birmingham University
representing the H1 and ZEUS Collaborations.

- Diffraction at HERA.
- The Diffractive Structure Function $F_2^{D(3)}$ at Low Q^2.
- Rapidity Gaps Between High p_T Jets in Photoproduction.

Diffraction at HERA

At HERA, diffractive $\gamma^{(\star)}p$ interactions can be studied . . .



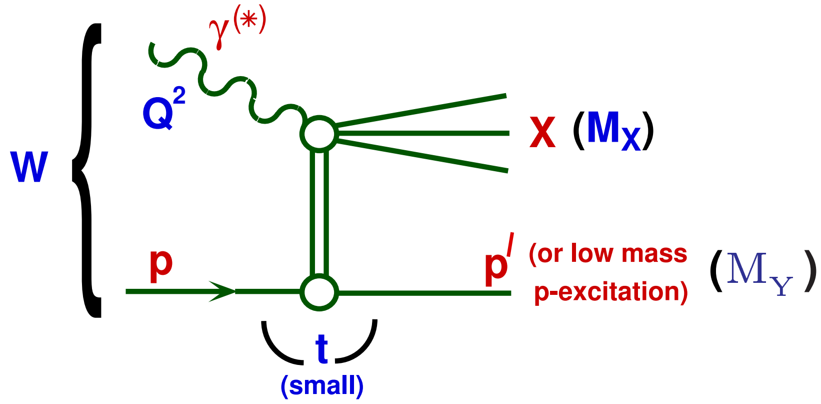


All five kinematic variables can be measured:

- $Q^2 \sim 0$, $|t| \sim 0$. $\rightarrow$ similar to soft hadronic diffraction.
- Large Q^2. $\rightarrow$ pQCD at $\gamma^* I\!P$ vertex. γ^* 'probes' $I\!P$?
- Large $|t|$. $\rightarrow$ $I\!P$ itself calculable in pQCD?

. . . All regions interesting - transitions particularly revealing?

Diffraction of Virtual Photons, $\gamma^{\star} p \rightarrow Xp$



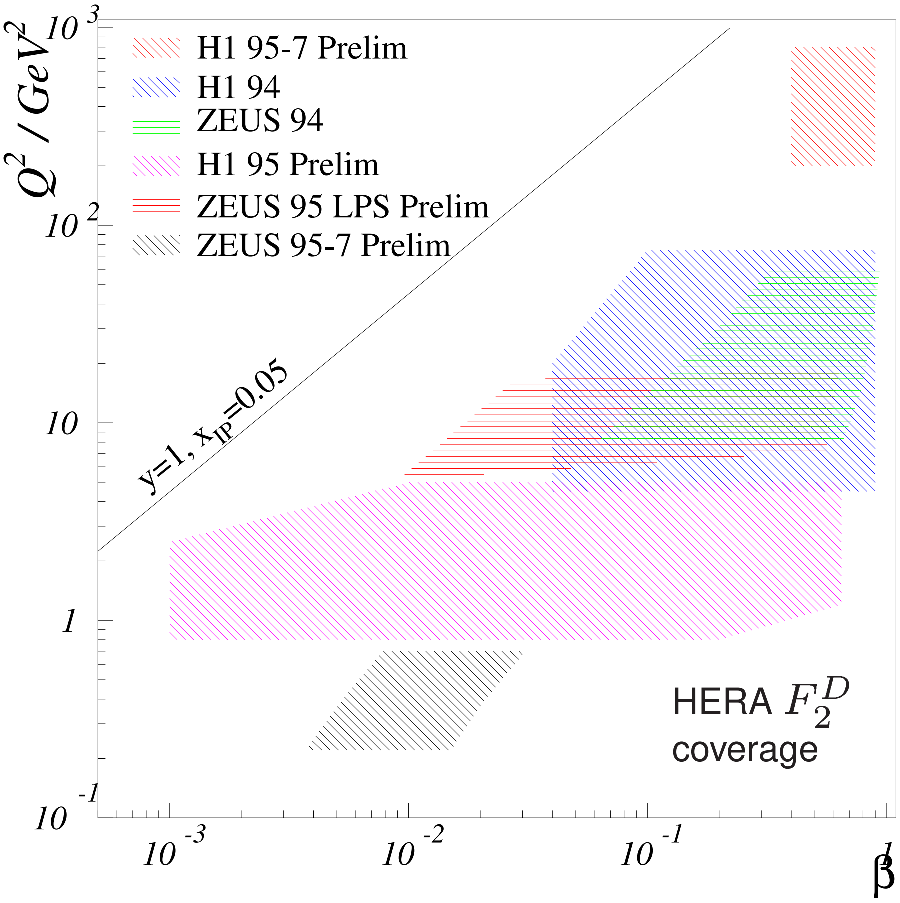
$$x_{I\!P} = \frac{q.(p-p')}{q.p} = x_{\mathrm{I\!P}/\mathrm{p}}$$

$$\beta = \frac{Q^2}{q.(p-p')} = x_{q/\mathrm{I\!P}}$$

$$(x = x_{I\!P}\beta)$$

Data presented as a Diffractive Structure Function . . .

$$F_2^{D(3)}(\beta, Q^2, x_{I\!P})$$



New ZEUS BPC data ($0.2 < Q^2 < 0.7\ \mathrm{GeV}^2$) start to fill transition to photoproduction.

Method 1: Decompose observed M_X distribution.

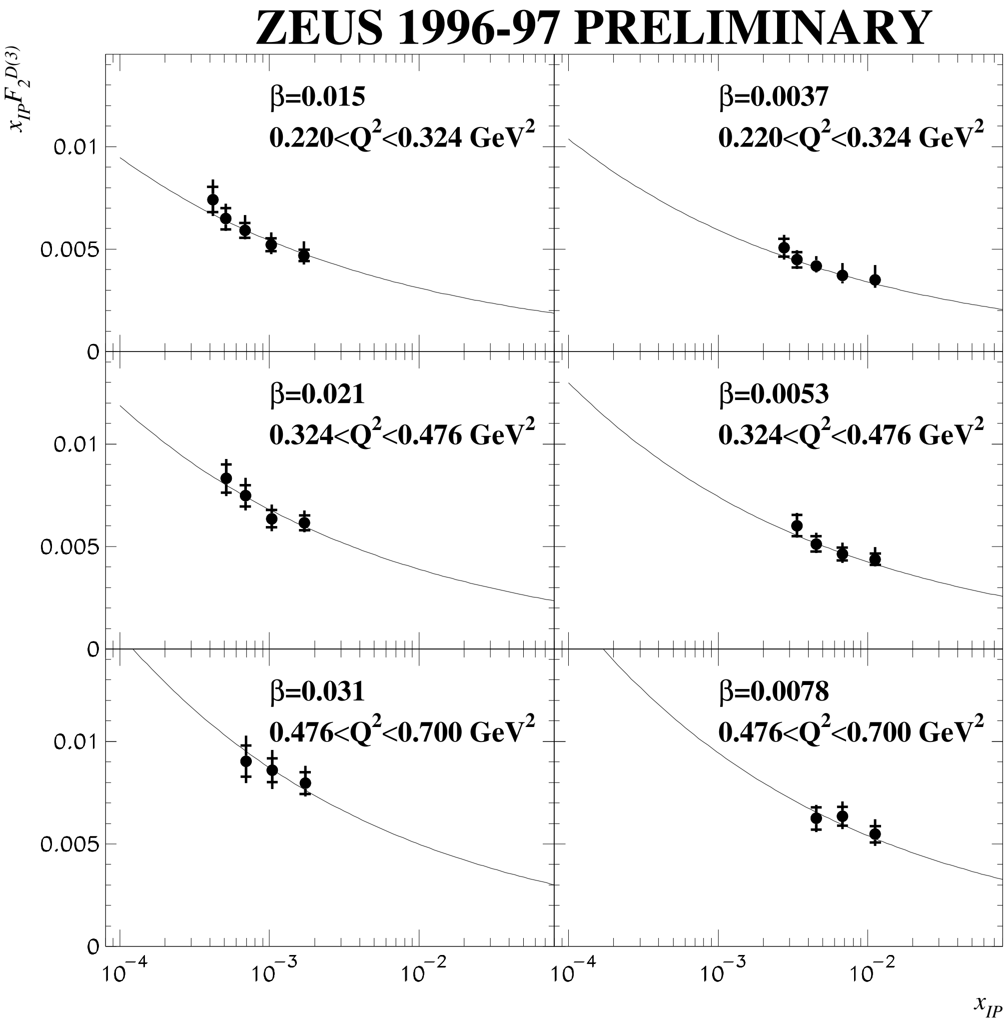
Method 2: Measure leading proton in LPS.

$x_{I\!P}$ Dependence of $F_2^{D(3)}$ at low Q^2

Diff. structure function $F_2^{D(3)}(\beta, Q^2, x_{I\!P})$ for $M_Y \lesssim 6\ \mathrm{GeV}$

By comparing M_X decomposition and LPS methods . . .

P-dissociation contribution $= 29 \pm 15\ (\mathrm{stat.})\ \%$



Fit to

$F_2^{D(3)}(\beta, Q^2, x_{I\!P}) =$

$A(\beta, Q^2) \cdot (1/x_{I\!P})^a$

Consistent with

Regge factorisation

of $x_{I\!P}$ dependence

In Regge pole models, $a = \langle 2\alpha_{I\!P}(t) - 1 \rangle \ldots$

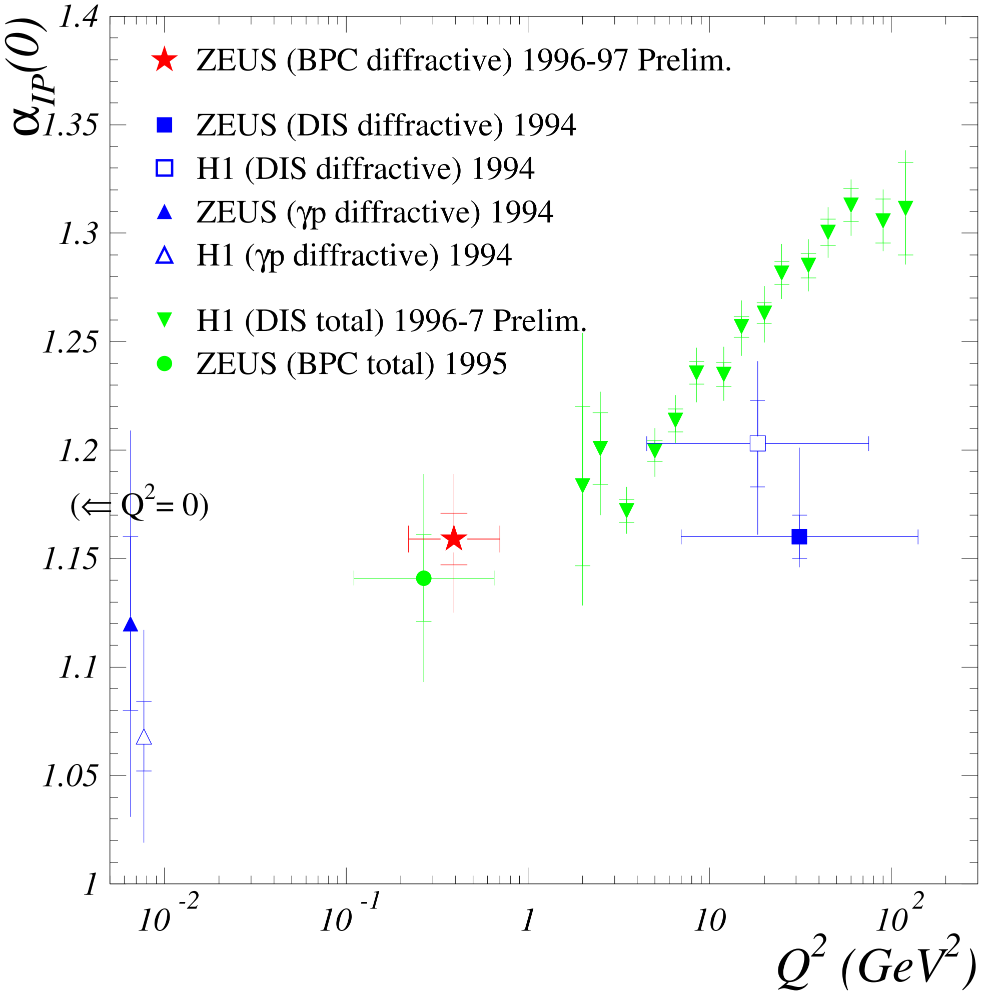
$$\langle \alpha_{I\!P}(t) \rangle = 1.126 \pm 0.012\ (\mathrm{stat.})\ ^{+0.027}_{-0.032}\ (\mathrm{syst.})$$

Variation of Energy Dependence with Q^2

Expressed through Regge parameterisations . . .

$x_{I\!P} F_2^D \sim A(\beta, Q^2) \; x^{2-2\langle\alpha_{I\!P}(t)\rangle}$ $\qquad F_2 \sim B(Q^2) \; x^{1-\alpha_{I\!P}(0)}$

Effective pomeron intercept $\alpha_{I\!P}(0)$, corrected for finite t . . .



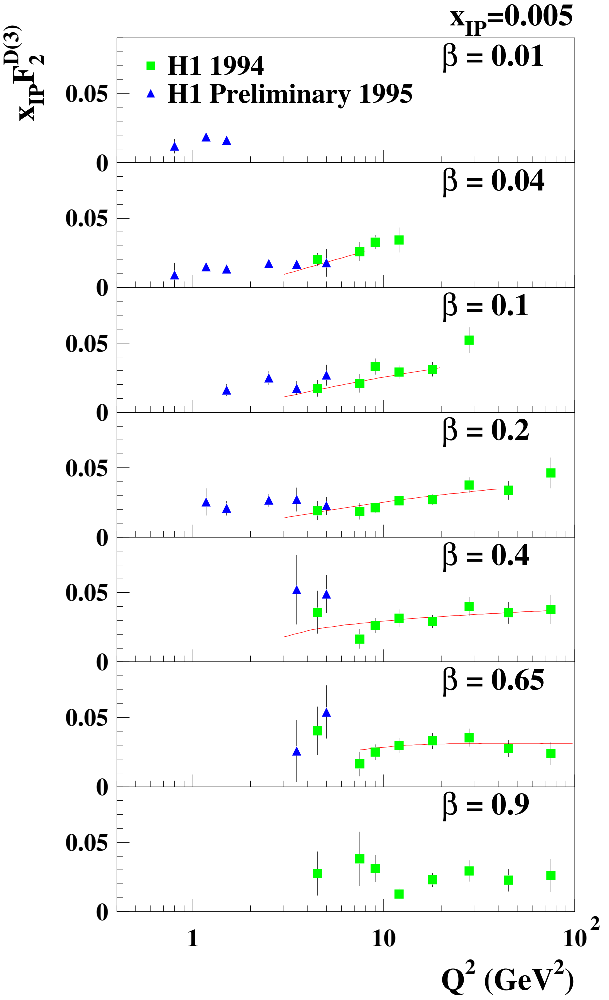
Also From LPS, $\alpha_{I\!P}(0) = 1.18 \pm 0.06\,(\mathrm{stat.})\,^{+0.06}_{-0.09}\,(\mathrm{syst.})$

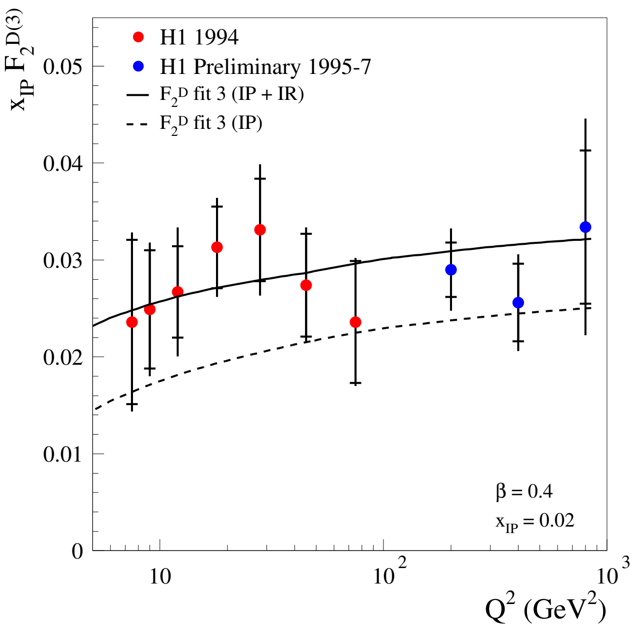
At low Q^2, diffractive and inclusive $\alpha_{I\!P}(0)$ compatible.

At higher Q^2, diffractive and inclusive $\alpha_{I\!P}(0)$ incompatible.

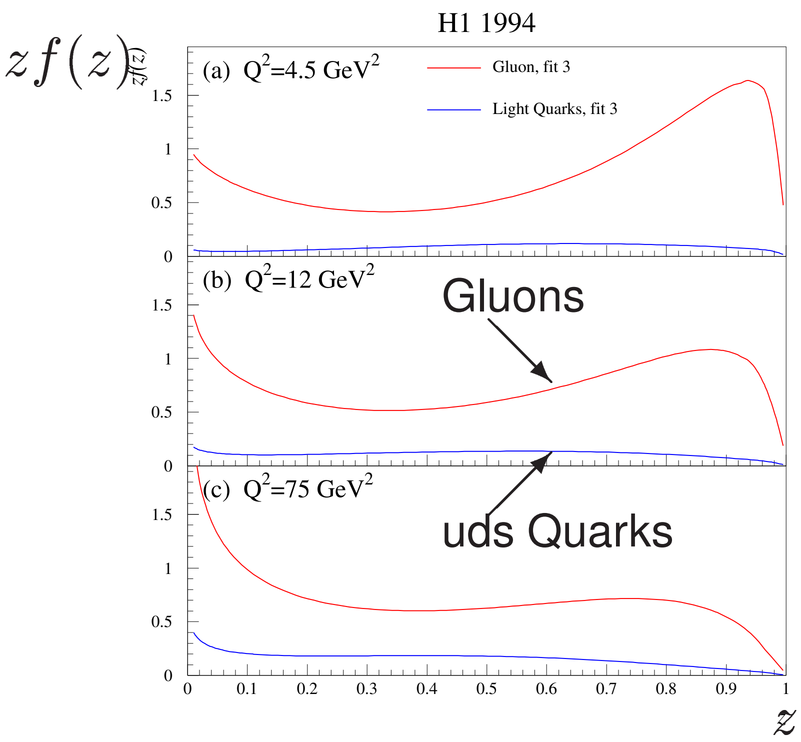
(Energy dependences of diff & incl become more similar at high Q^2.)

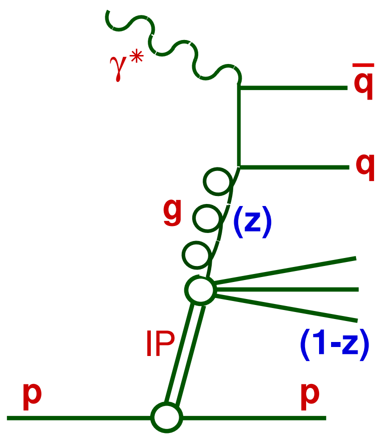
β/Q^2 dependence of $F_2^{D(3)}$





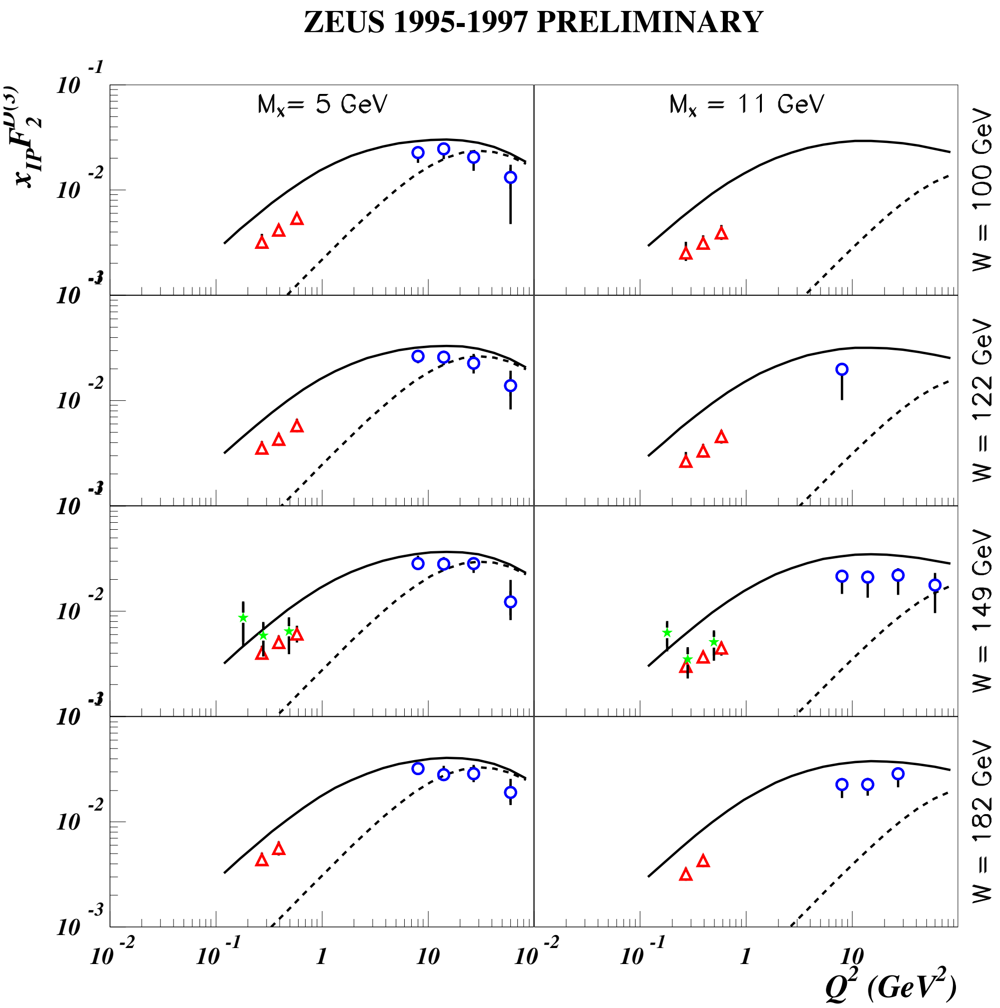
Rising scaling violations over large range of Q^2 up to large fractional momenta (β)





DGLAP analysis yields $\mathbb{P}$ parton distributions dominated by “hard” gluons.

Q^2 Dependence of F_2^D



△ M_X Prelim

★ LPS Prelim

○ 94

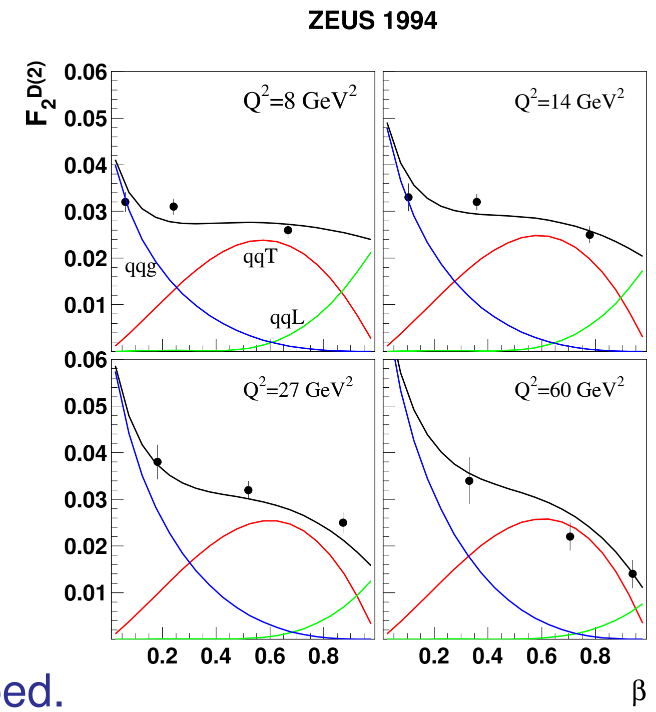
—— Sat'n ($q\bar{q} + q\bar{q}g$)

- - - Sat'n ($q\bar{q}$)

(94 and M_X data scaled to remove p-diss)

Clear transition at low Q^2. Similar to that in total F_2.

'Saturation' Model (Golec-Biernat & Wüsthoff)



Describes $Q^2 \to 0$ transition in F_2 and Q^2 dependence of diff, incl $\alpha_{\mathbb{P}}(0)$.

No new free parameters for diffraction!

Good agreement with high Q^2 diff data.

Diff'n of $\gamma^* \to q\bar{q}g$ dominates at low β.

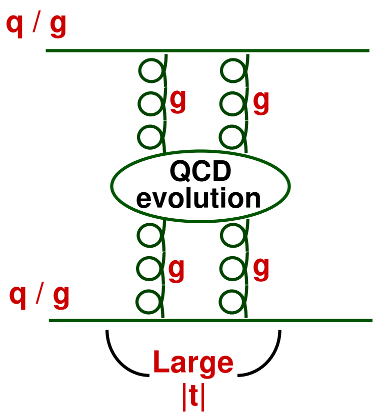
Applicability of present $q\bar{q}g$ model questionable at low Q^2.

Qualitative features of transition described.

Rapidity Gaps between Jets at $Q^2 = 0$

Parton level

Elastic parton-parton scattering
in Regge limit ($\hat{s} \gg \hat{t}$), yet
pQCD calculable ($\hat{t}$ large)? ... BFKL?



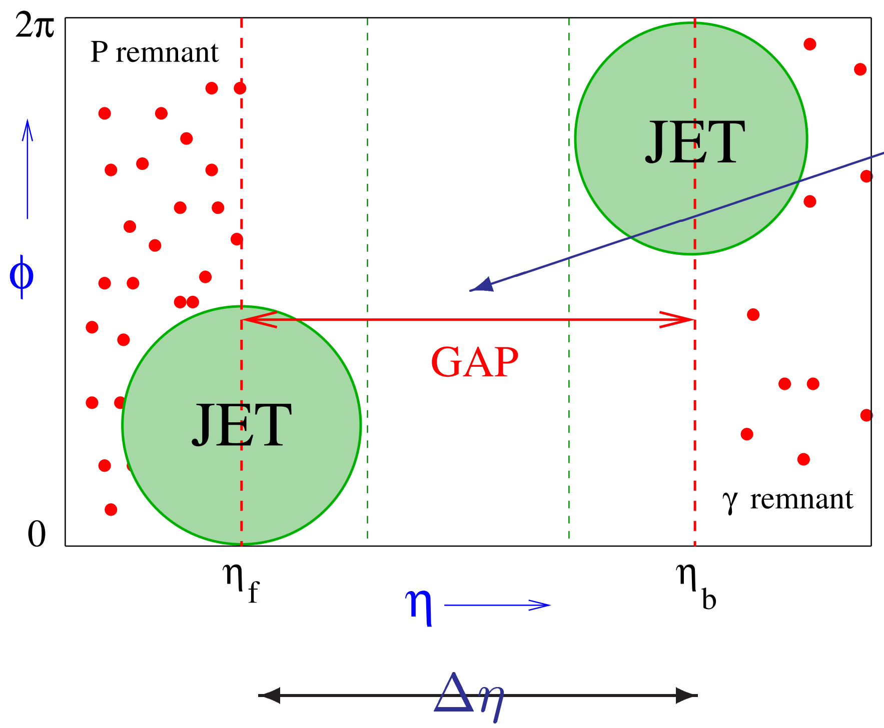
Hadron level Classic experimental signature is rapidity gap between high p_T jets. $|\hat{t}| \sim p^2_{t,jet}$

Complication: Remnant-remnant interactions produce hadronic activity between jets?

New Measurement Method:

Require two central jets (inclusive k_t clustering algorithm):

$$E_t^1 > 6\ \mathrm{GeV} \qquad E_t^2 > 5\ \mathrm{GeV} \qquad \Delta\eta > 2.5\ \mathrm{GeV}$$



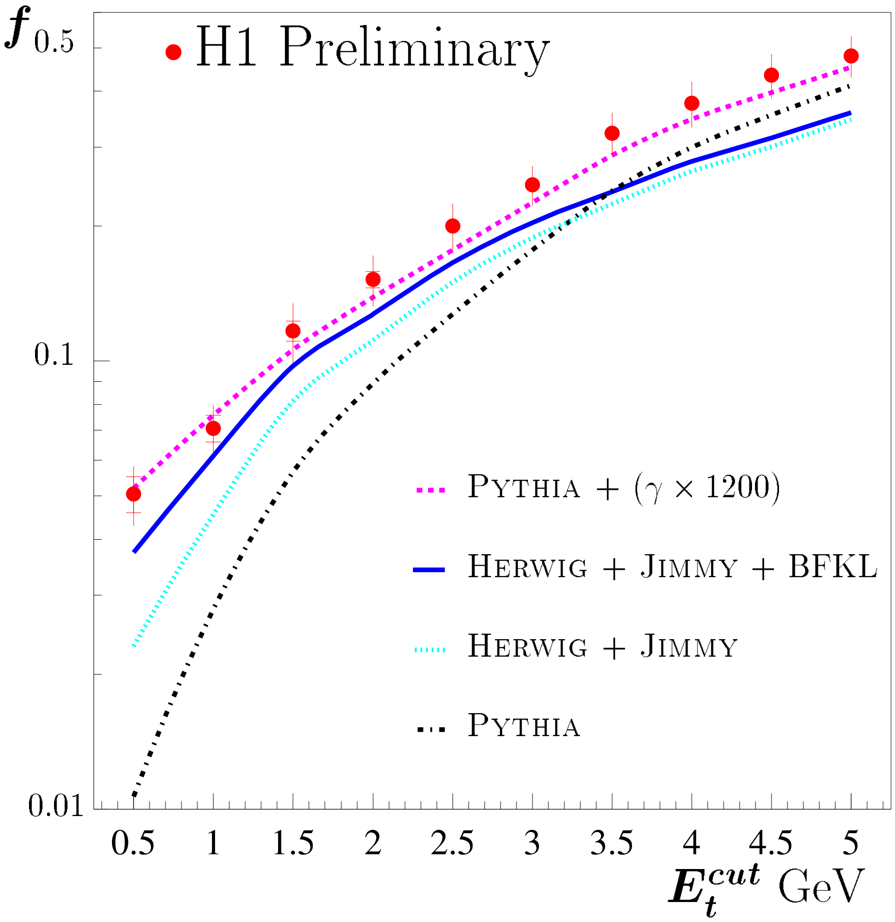
$\not{E}_t^{jets} = \sum E_t$
for $\eta_f > \eta > \eta_b$.
outside two leading jets

Rapidity gap event if
$\not{E}_t^{jets} < E_t^{cut}$

Vary E_t^{cut} to study effect of spectator interactions.

Dependence of Gap Fraction on E_t^{cut}

f = Fraction of events with $\not{E}_t^{jets} < E_t^{cut}$ $(\Delta\eta > 2.5)$



pQCD treatment of spectator interactions possible at large E_t^{cut}?

Models with standard γp matrix elements and multiple interactions (HERWIG + JIMMY, PYTHIA) underestimate f

Models with high $|t|$ colour singlet exchange more successful

HERWIG + JIMMY + BFKL: LO BFKL calculation of $qq \to qq$

(q, g couplings. - $\alpha_s = 0.17$).

PYTHIA + $(\gamma \times 1200)$: $qq \to qq$ through γ exchange.

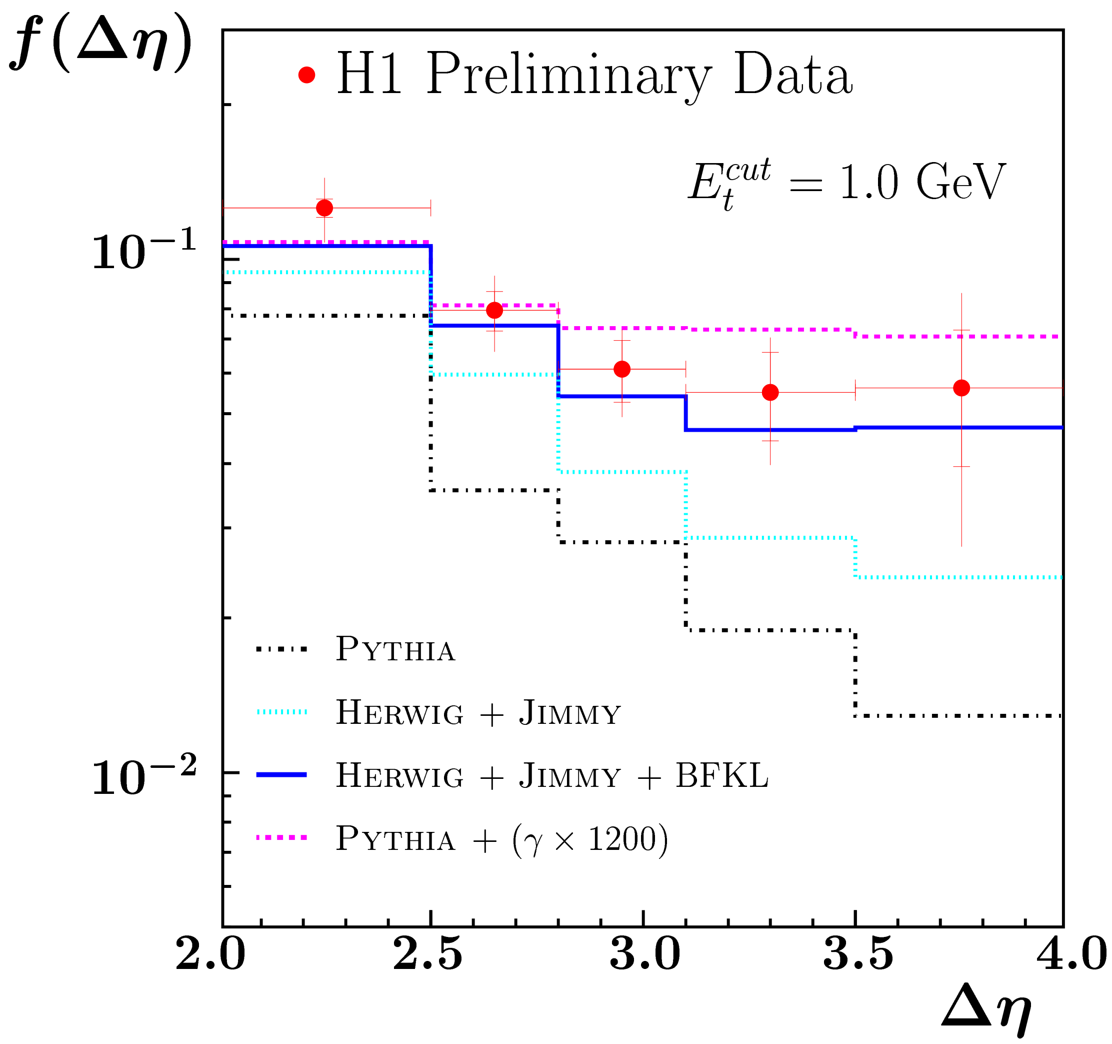
(q coupling only - tuned to data).

Tuning of multiple interactions still required!

Dependence of Gap Fraction on $\Delta\eta$

Dependence on jet separation $\Delta\eta$ particularly sensitive to dynamics.

Measured for various E_t^{cut}, $1\ \mathrm{GeV}$ chosen here.



Clear signal above standard γp models, increases with $\Delta\eta$

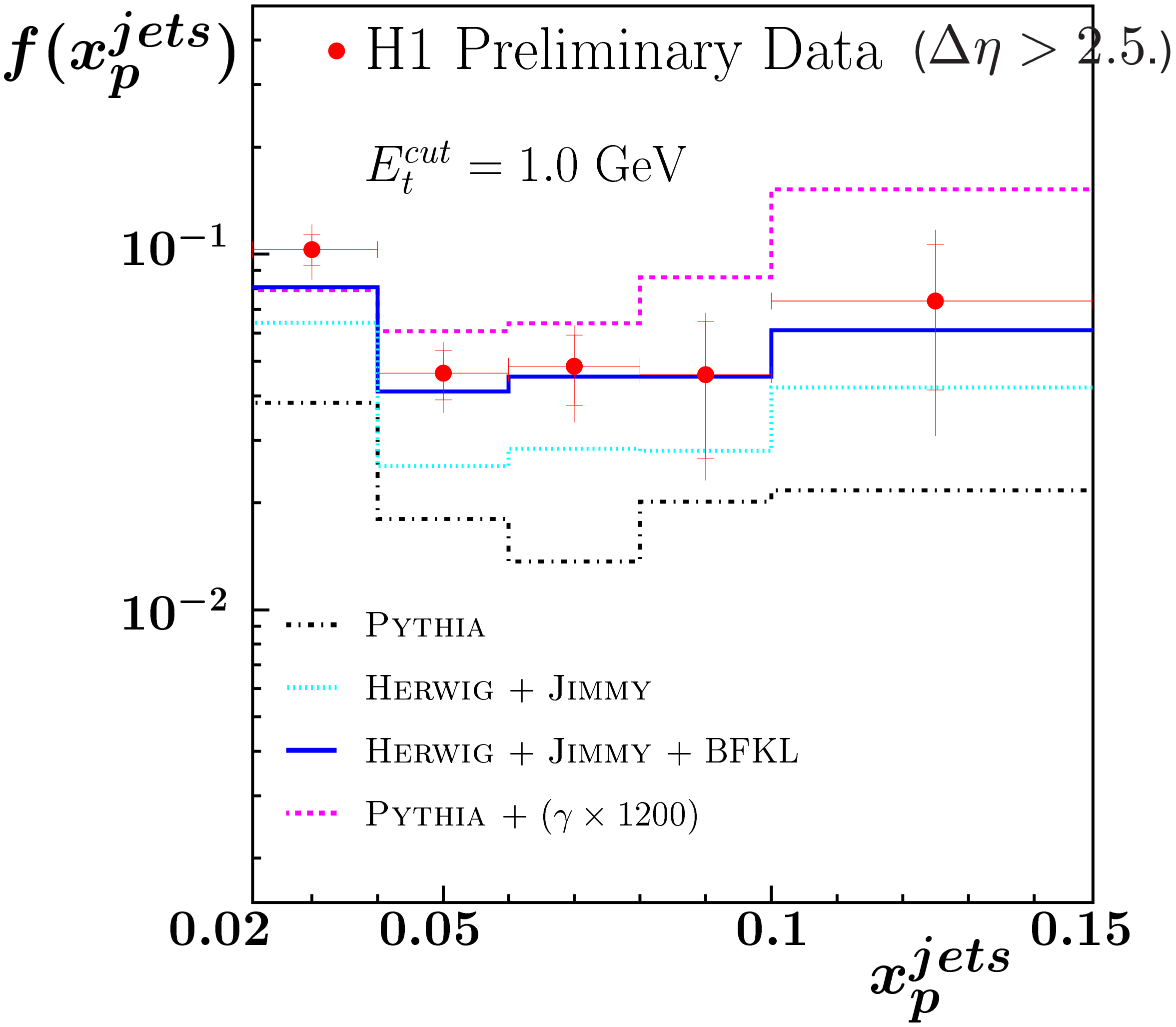
Gap fraction at large $\Delta\eta$ significantly larger than Tevatron $p\bar{p}$.

Both models simulating colour singlet exchange describe data.

Dependence of Gap Fraction on x_p^{jets}

q, g composition of proton changes with x

x_p^{jets} dependence of f sensitive to q, g couplings of exchange.



Clear signal above standard γp models at all x_p^{jets}.

PYHTIA + γ differs in shape from HERWIG + BFKL.

Data favour some g coupling to exchange? - Improved statistics needed!

Summary

- New data in two previously unexplored regions . . .

- F_2^D data for $0.2 < Q^2 < 0.7\,\mathrm{GeV}^2$:
  - Effective $\mathbb{P}$ intercept significantly larger than soft $\mathbb{P}$
  - Energy dependence of $\sigma^{\mathrm{diff}}/\sigma^{\mathrm{incl}}$ consistent with simple Regge prediction.
  - Transition $Q^2 \to 0$ qualitatively similar to inclusive F_2

- Rapidity Gaps between Jets in Photoproduction:
  - Clear signal for colour singlet exchange at high $|t|$.
  - Good treatment of spectator interactions is crucial.
  - Sensitivity to q, g couplings of colour singlet exchange.