Diffractive Dijet and 3-Jet Electroproduction at HERA

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H1 Collaboration

DIS 2000, Liverpool, 27/04/2000

Structure:

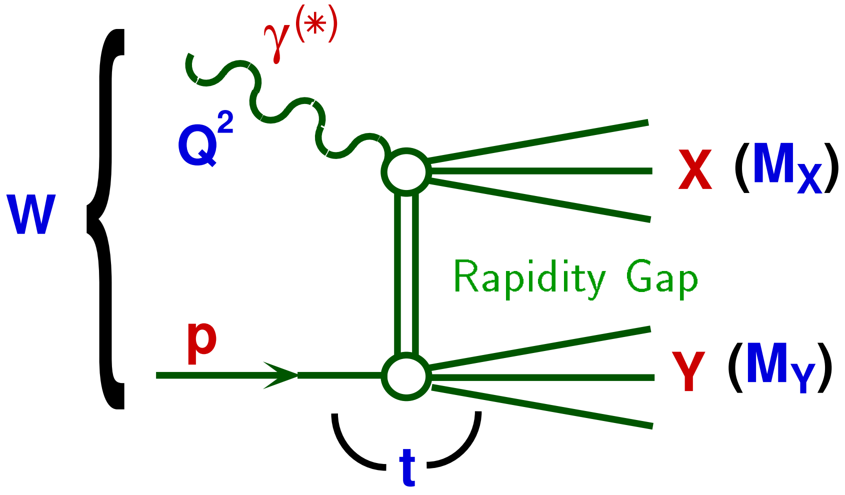
- H1 QCD fits to inclusive $F_2^{D(3)}$
  - Hard scattering and Regge Factorisation
  - Resolved γ^*

- Soft Colour Neutralisation
  - SCI / Semiclassical Models

- 2-Gluon Exchange
  - with and without strong k_t ordering

Motivation

- Unique possibility at HERA to probe structure of diffractive exchange with a γ^* (DIS off "$I\!P$", i.e. colourless exch.)
- Chance of illuminating underlying QCD dynamics

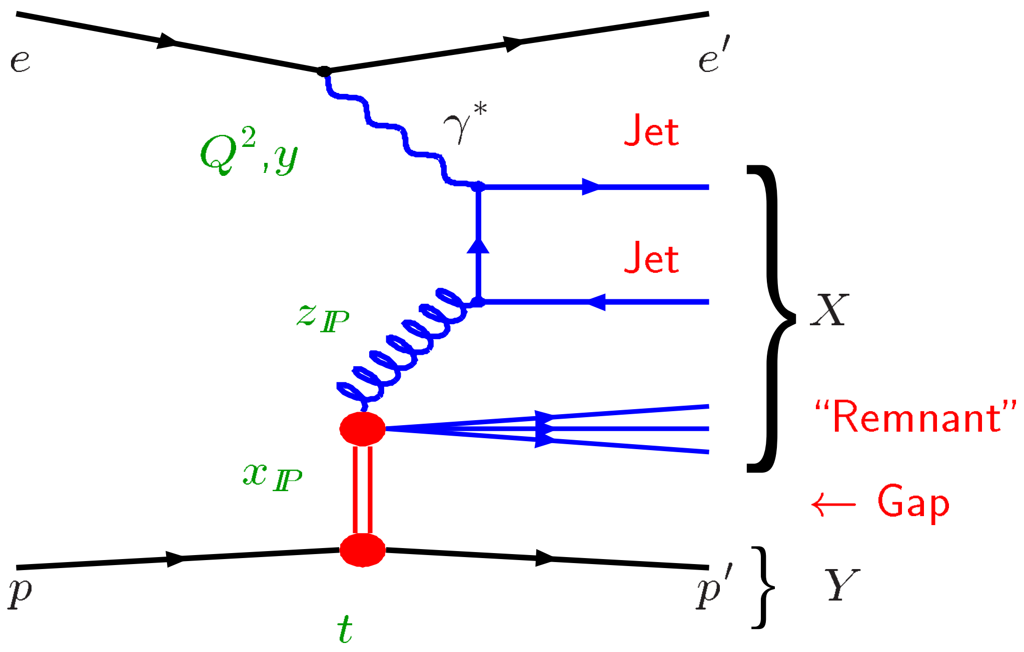


Questions:

- Just ordinary DIS plus add. colour neutralisation?
- Which part of σ^{Diff} attributable to pQCD and need not be absorbed into diffractive or "Pomeron" PDF's?
- Need something like a "Pomeron" particle?

Kinematics

Viewed in terms of a resolved (i.e. partonic) "Pomeron" model:



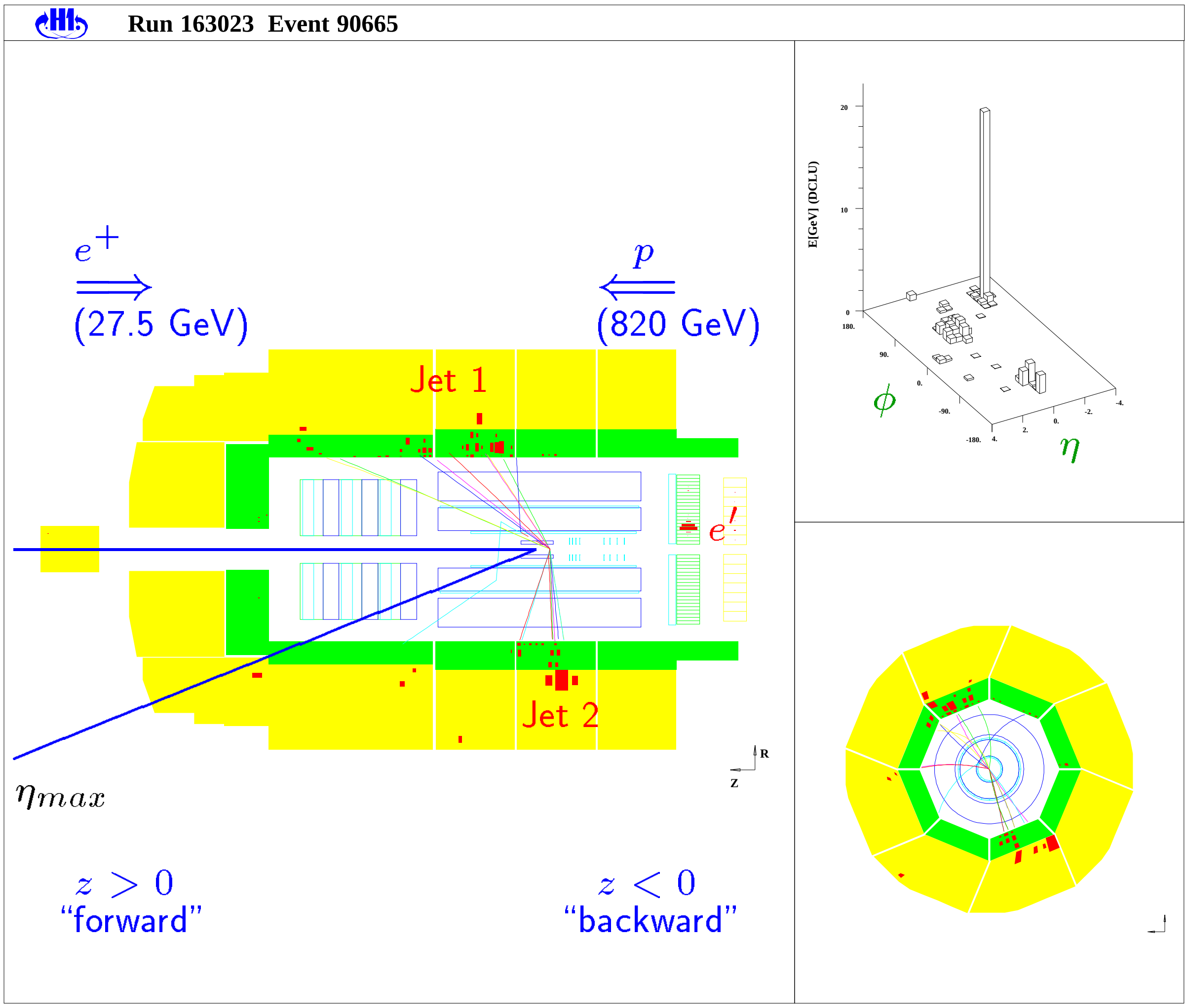
Q^2, y → DIS variables

$x_{I\!P} \approx \frac{Q^2+M_X^2-t}{Q^2+W^2-M_p^2}$ → longit. momentum fraction of colourless exchange w.r.t. p

$z_{I\!P} \approx \frac{Q^2+M_{12}^2}{Q^2+M_X^2}$ → momentum fraction of exchange coupling to γ^*

$|t|$ → $(\text{momentum transfer})^2$ at p vertex

Data Selection



DIS: $4 < Q^2 < 80\ \mathrm{GeV}^2;\quad 0.1 < y < 0.7$

Identified scattered positron in "backward" Calorimeter

Diffractive: $x_{I\!P} < 0.05;\ M_Y, |t|\ \ \mathrm{small}$

"Rapidity gap" selection: no hadr. activity in "forward" (outgoing p) region $(3.2 < \eta < 7.5)$

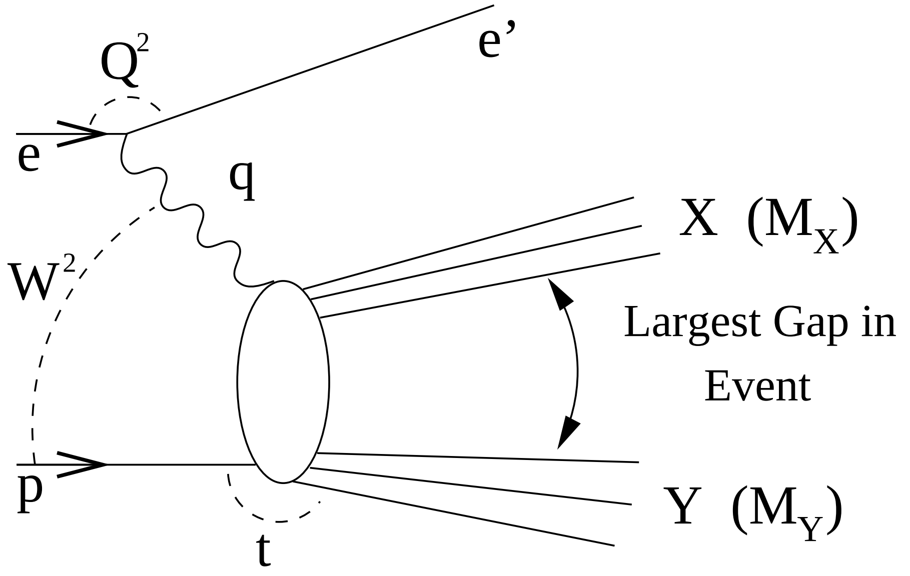
Jets: $p_T > 4\ \mathrm{GeV}$

CDF Cone algorithm $(R = 1.0)$ in $\gamma^* p$-CMS

$\mathcal{L}_{\mathrm{int}} = 17.9\ \mathrm{pb}^{-1}$ $\quad \mathrm{N}_{2-\mathrm{Jet}} \approx 2.500$ $\quad \mathbf{N_{3-Jet} \approx 130}$

Cross Section Measurement

Model indep. definition of diffraction on hadron level:



Definition of hadron level cross section:

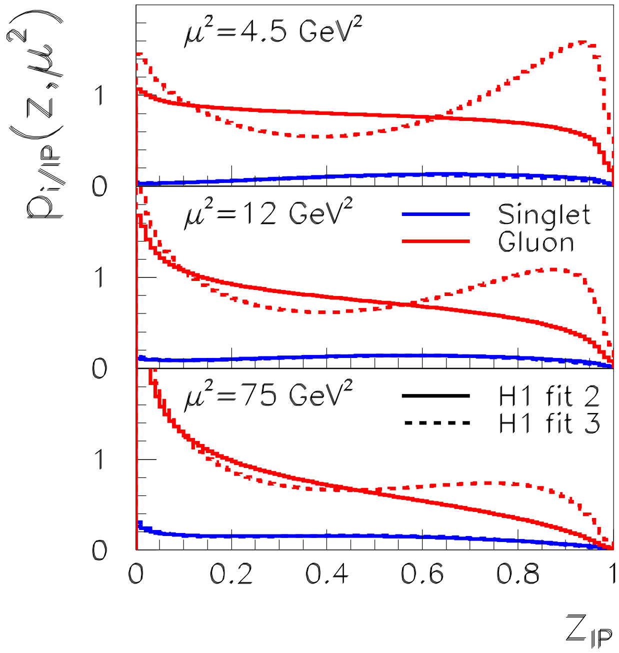
$4 < Q^2 < 80\ GeV^2$ $0.1 < y < 0.7$
$x_{I\!P} < 0.05$ $M_Y < 1.6\ GeV$ $\lvert t\rvert < 1.0\ GeV^2$
$N_{jets} \geq 2$ or $N_{jets} = 3$ $p^*_{T,jet} > 4\ GeV$ $-3 < \eta^*_{jet} < 0$

- Main sources of systematic error: Hadronic energy scales and model dependencies of corrections

H1 QCD fits to inclusive $F_2^{D(3)}$

- Regge Factorisation:

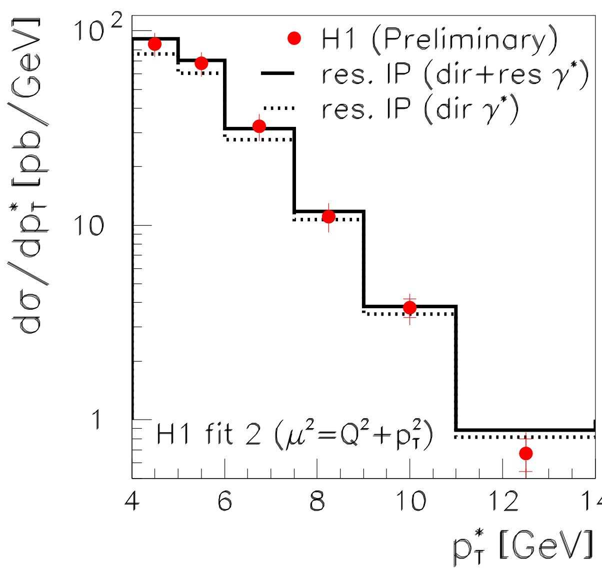
$$\sigma \sim f_{I\!P/p}(x_{I\!P}, t)\; F_2^{I\!P}(z, \mu^2)\; |M|^2\; (+subl.\ exch.)$$

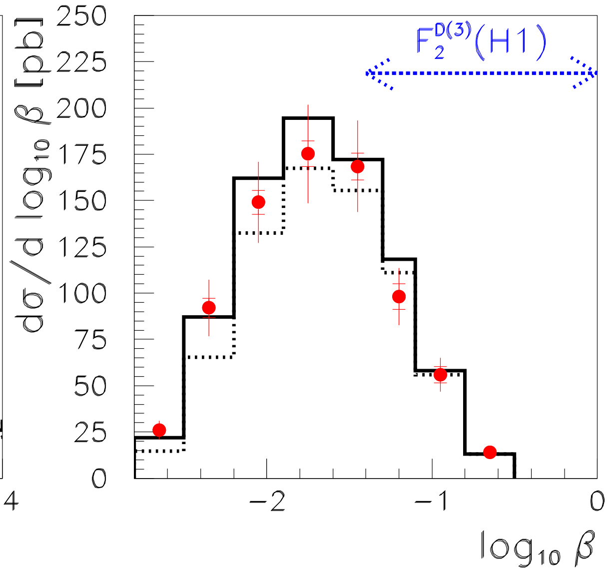


Partonic "Pomeron":
$F_2^{I\!P} = \sum_i e_i^2\, q_{i/I\!P}(z, \mu^2)$

$\rightarrow f_{q/I\!P}(z, \mu^2)$
direct!

$\rightarrow f_{g/I\!P}(z, \mu^2)$
indirect (scaling viol.)!



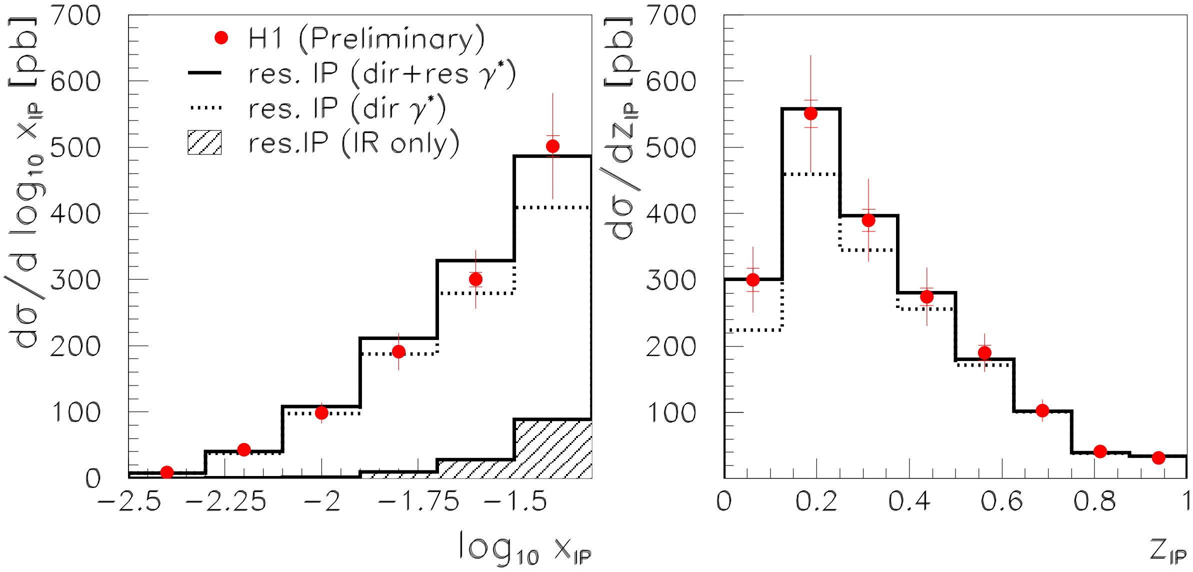


- Applying results of $F_2^{D(3)}$ QCD fits to jets works very well!
- β range very different!

$x_{I\!P}$

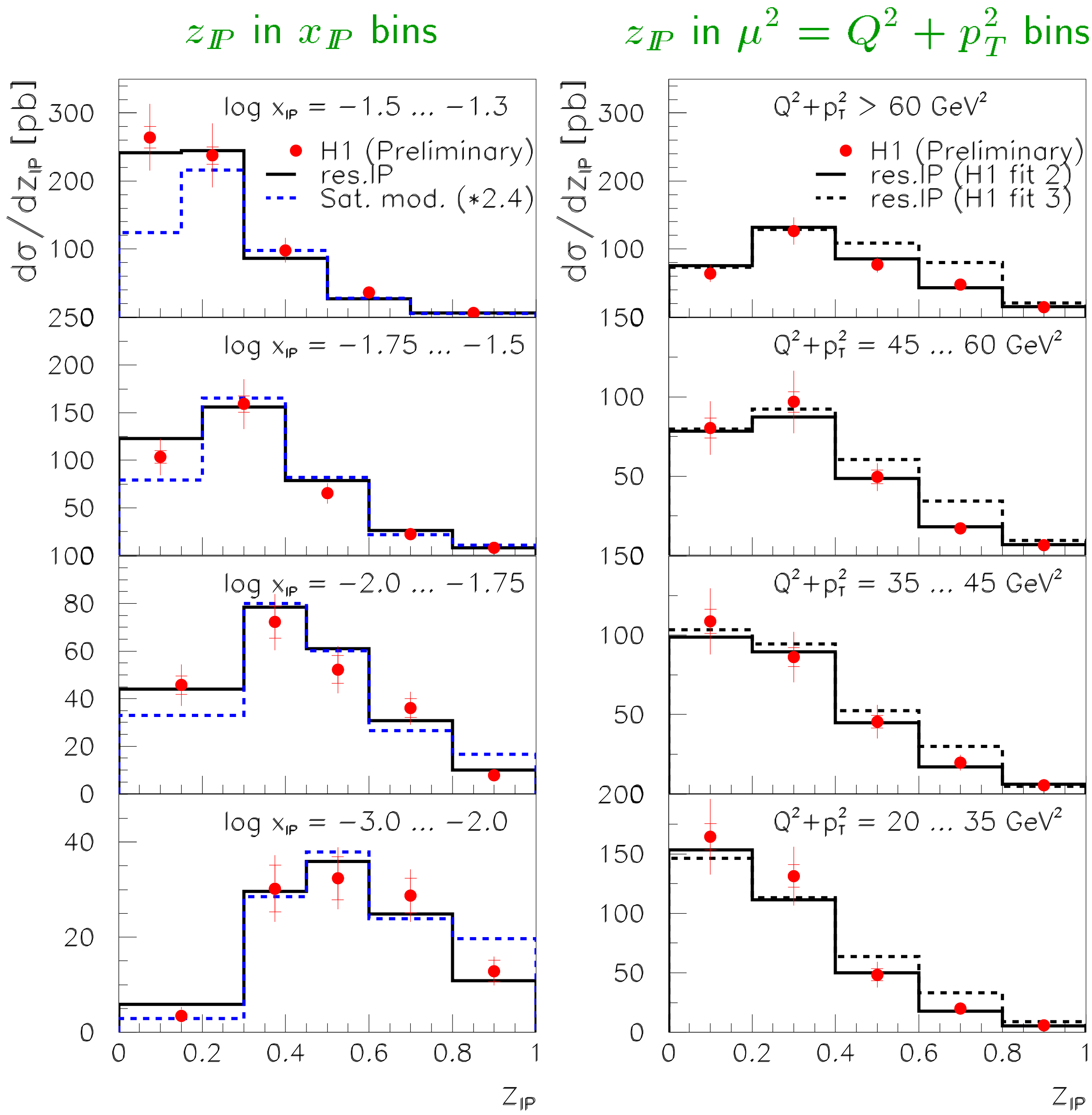
$z_{I\!P} \approx \frac{\text{Energy of Dijets}}{\text{total Energy}}$

(partonic $I\!P$: $p_i/p_{I\!P}$)



- $x_{I\!P}$ and $z_{I\!P}$ distributions well described (especially if resolved γ^* contrib. is added)
- Subl. exchange contribution small

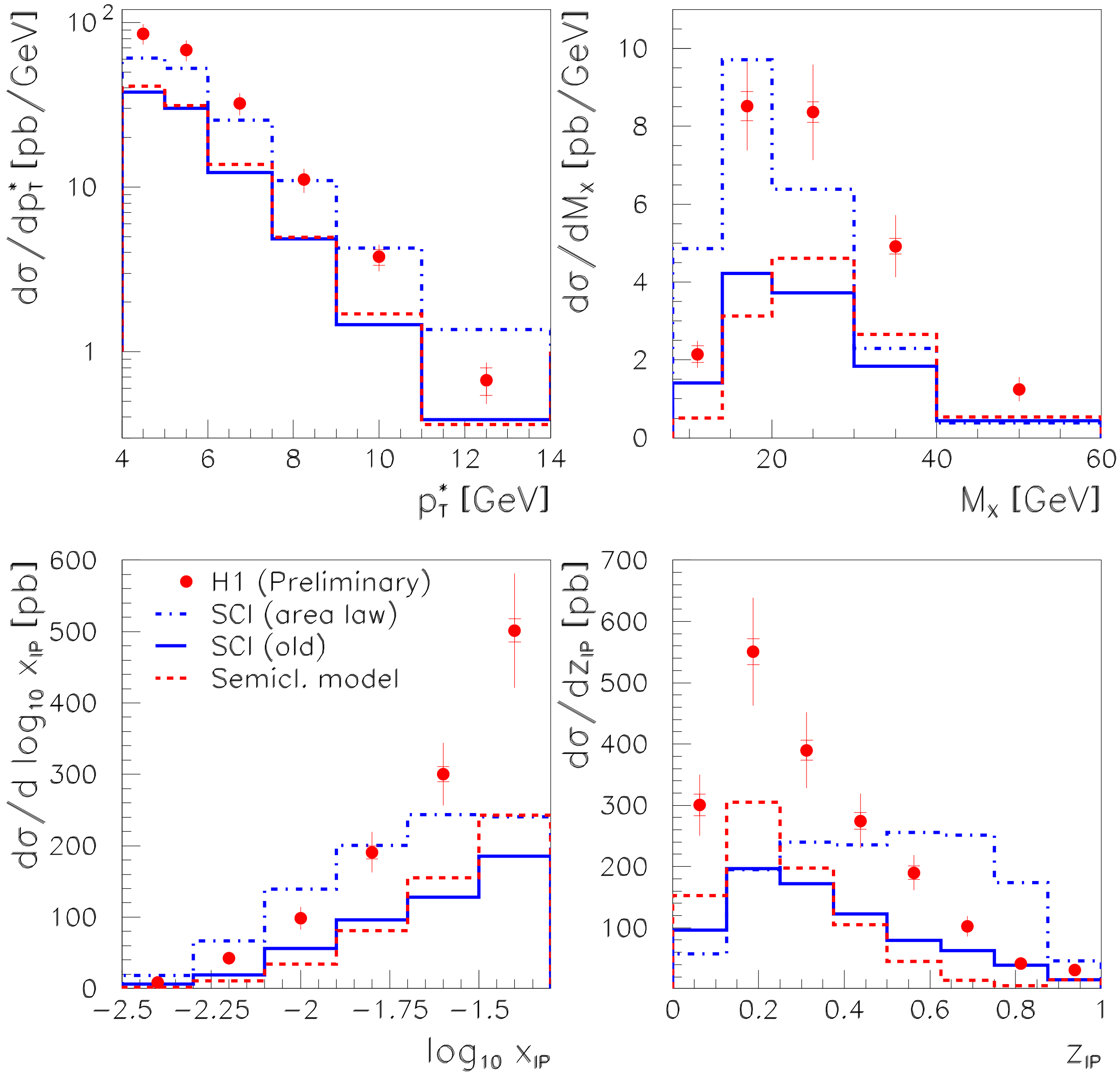
Regge Factorisation and Scale Dependence



- Data compatible with Regge fact.:
  $\sigma(x_{I\!P}, z_{I\!P}) = f_{I\!P}(x_{I\!P}) \cdot p_{i/I\!P}(z_{I\!P})$
- "*fit 2*" (flat gluon) agrees well with data;
  "*fit 3*" (peaked gluon) too high at high $z_{I\!P}$

Soft Colour Neutralisation

- Soft Col. Interactions (SCI) (Edin, Ingelman, Rathsman)
  - original and improved version ("generalized area law")
- Semiclassical Model (Buchmüller, Gehrmann, Hebecker)
  - p at rest: $q\overline{q}(g)$ scatter off superpos. of soft colour fields
  - diffractive PDF's from combined fit to F_2 and F_2^D

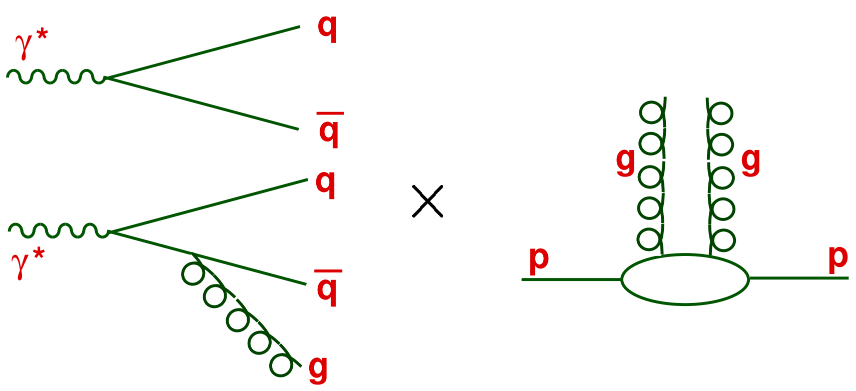


→ SCI(old) and Sc.M. roughly agree; too low by factor 2

→ SCI(new) normalisation OK, shapes not

2-Gluon Exchange Models

$$d\sigma \sim \left(x_{I\!P}\ g_p(x_{I\!P}, \mu^2) \right)^2$$

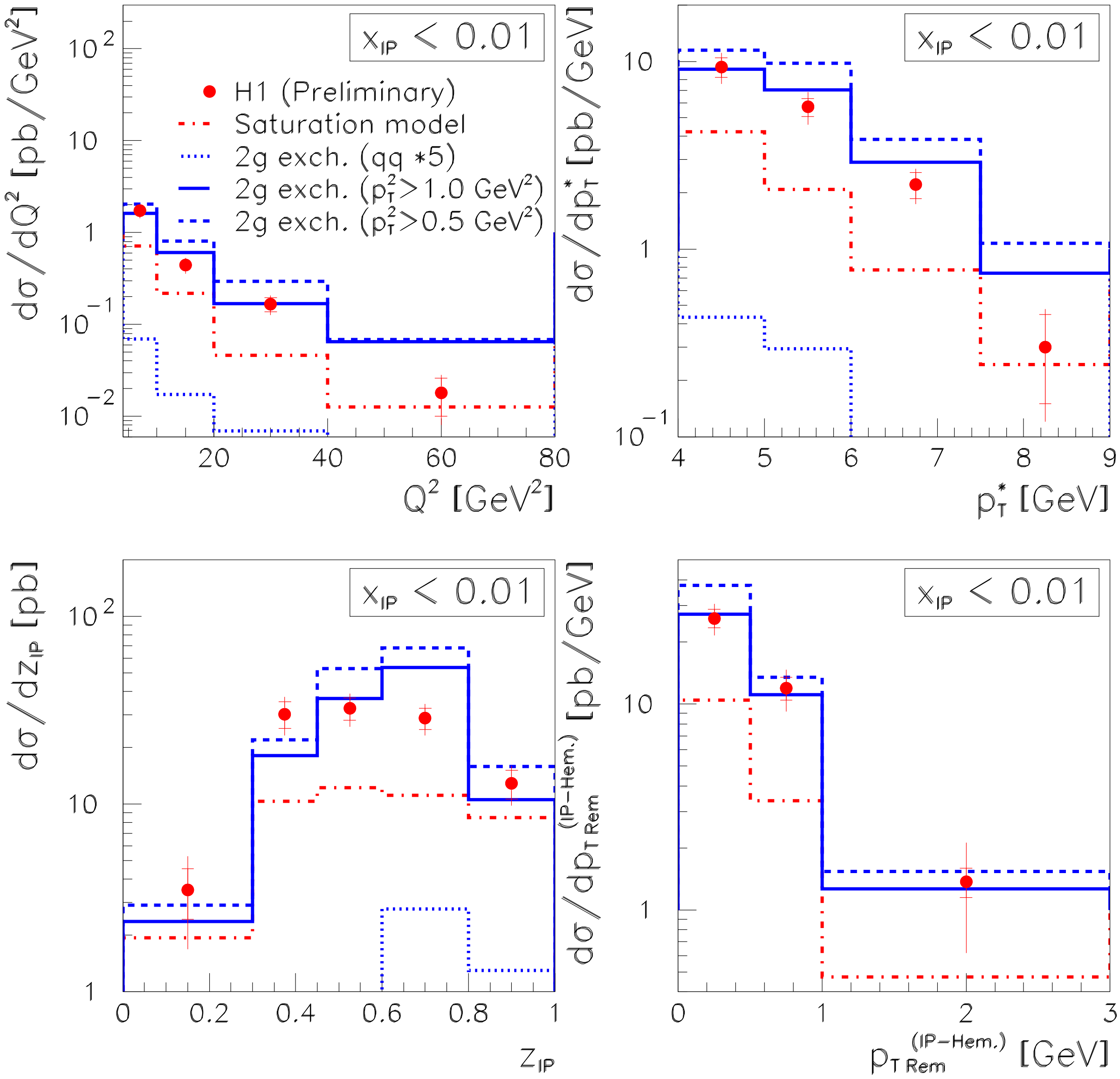


Models confronted with data here:

1. Saturation Model (Golec-Biernat, Wüsthoff)
   - Predict σ^{diff} after fit to $F_2(x, Q^2)$
   - strong k_t ordering condition: $k_t(g) < k_t(q)$

2. Model of Bartels, Jung, Wüsthoff
   - one free parameter ($g_p(x) \approx$ fixed): p_T-cut for all partons
   - NO k_t ordering condition!

- avoid large $x_{I\!P}$ region
  (valence region; sub-leading (quark) exchange)
  $\boxed{\Longrightarrow x_{I\!P} < 0.01}$



P_T in $I\!P$ hemisphere
NOT belonging to jets

- Saturation model too low
- Bartels et al. model
  - $q\overline{q}$ contribution very small
  - roughly describes data with $p^2_{t,(cut)} = 1.0\ \mathrm{GeV}^2$!
  - $p^2_{t,(cut)} = 0.5\ \mathrm{GeV}^2$ already overshoots!

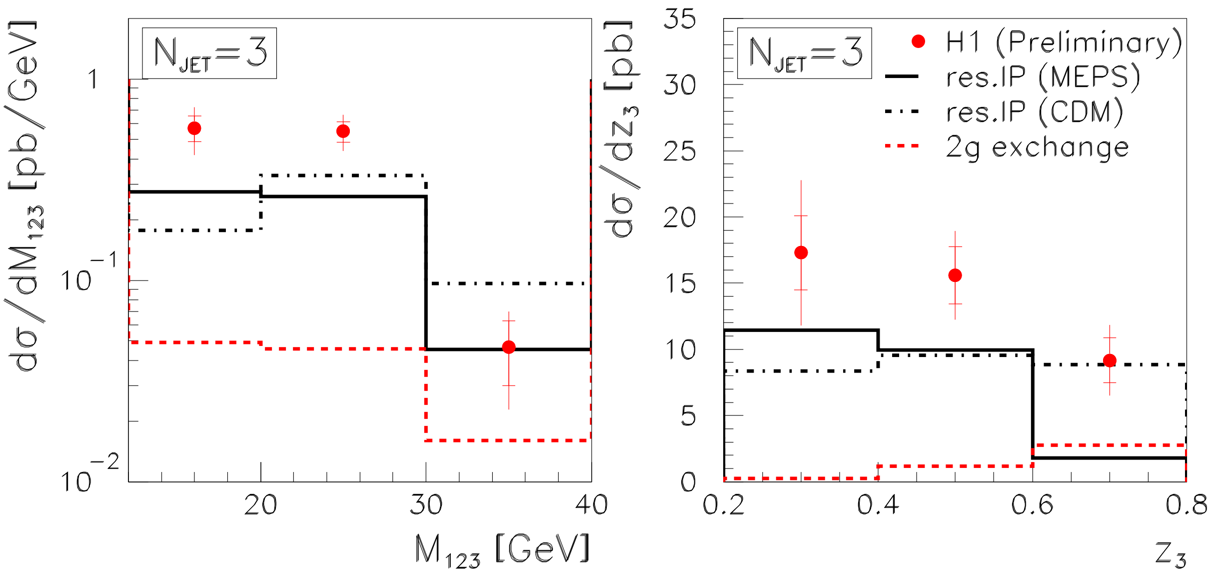
3-Jet production

$\longrightarrow$ ideal testing ground for $q\bar{q}g$ models!

Drawbacks:

- Measurement statistically limited ($N_{evt} = 130$ with $17.9\ \mathrm{pb}^{-1}$)
- 3-Jets kinematically imply large $x_{I\!P}$ values (all selected events have $x_{I\!P} > 0.01$)

Mass of 3-Jet system $\qquad z_3 = \frac{Q^2+M_{123}^2}{Q^2+M_X^2}$



- Data above LO QCD (H1 fits to $F_2^{D(3)}$) with different approaches for higher order approximations (MEPS, CDM)
- Bartels et al. $q\bar{q}g$ small (high $x_{I\!P}$?)

Conclusions

- High statistics measurement of diffractive DIS Dijets
- first look at 3-Jet events

"Resolved Pomeron" PDF's from fit to $F_2^{D(3)}$ (H1):

- Very good description of dijet data (esp. with resolved γ^*)
  - Lends support for factorisation of diffractive PDF's
  - Data compatible with Regge factorisation
  - H1 "fit 2" (flat gluon) favoured w.r.t. "fit 3"

Soft Colour Neutralisation:

- Orig. SCI and Semiclassical Model quite similar
- All Models fail either in shape or normalisation!

2 Gluon Exchange:

- Condition of strong k_t ordering (Saturation Model) underestimates cross section
- Bartels et al. calculation (no k_T ordering) describes roughly low $x_{I\!P}$ data
- Suppression of soft gluon radiation?

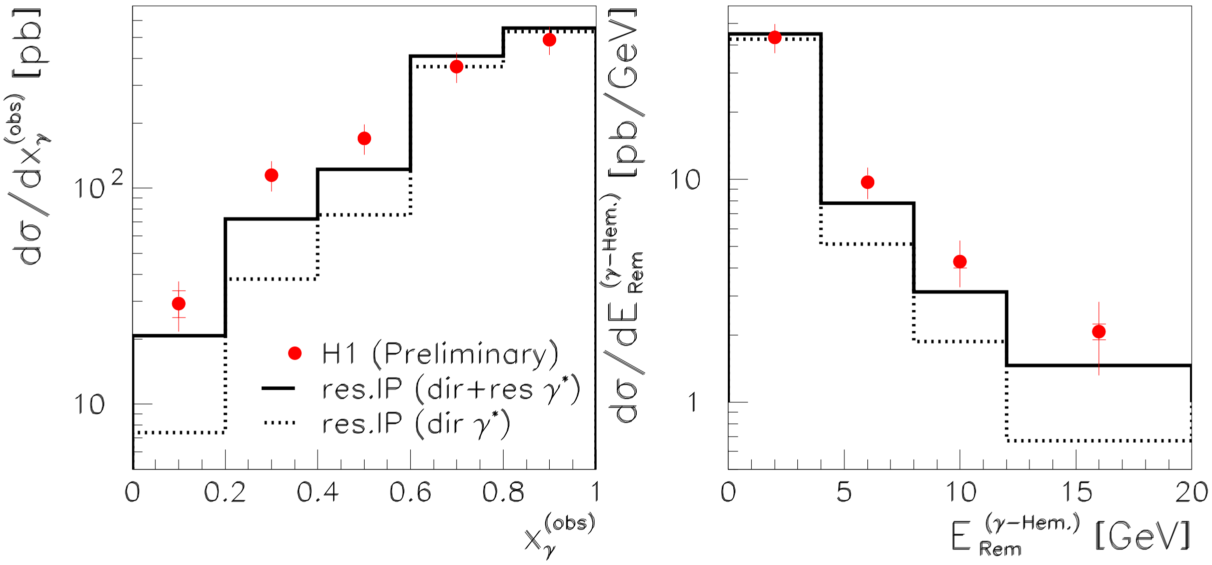
$\rightarrow$ First time that pQCD prediction can describe low-$|t|$ diffractice dissociation data!

Resolved virtual Photons

- Do resolved γ^* play a role? ($p_T^2 > Q^2$ mostly here)

$$x_\gamma^{(obs)} = \frac{\sum (E-P_z)_{\rm Jets}}{\sum (E-P_z)_{\rm all}}$$

Energy in γ^* hemisphere NOT belonging to jets



$\rightarrow$ data favour contribution of resolved γ^* (MC: SaS-2D), as was observed in inclusive DIS dijets