#787,566,785,558

Final States, Jets and Charm Production in Diffraction at HERA

Luis Labarga
(Universidad Autónoma de Madrid)
Representing the

H1 and ZEUS Collaborations

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: :

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Diffractive Hard Processes

- Diffraction: successful (and simple!) phenomenological description of soft diffractive reactions in terms of $I\!P$omeron exchange.

- Need to understand diffraction in terms of QCD degrees of freedom, i.e., quarks and gluons.

- How? by probing short distances in diffractive processes. An indirect approach is the study of hadronic variables sensitive to gluon radiation. A more direct way is to measure the hard process itself, i.e. jet, charm, ... , production. Both methods are complementary.

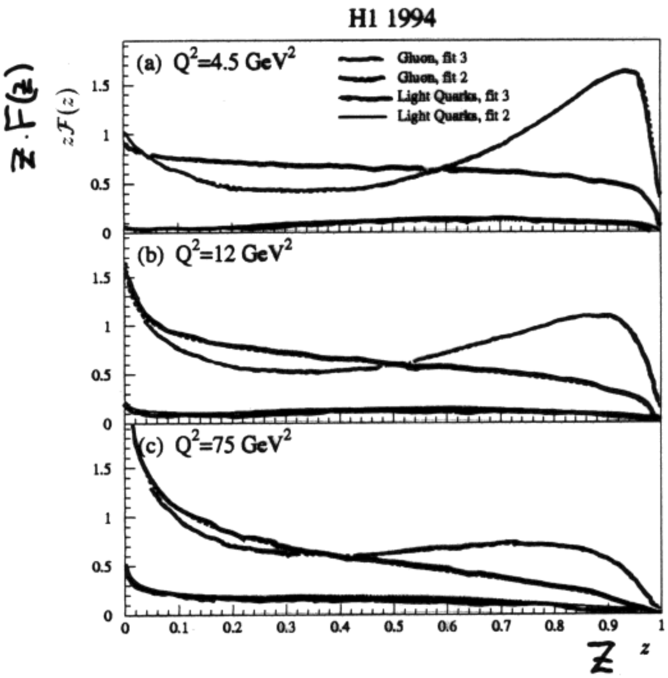
Towards a QCD-based model for diffractive hard scattering

Pioneered by Ingelman, Schlein (85);
Berger, Collins, Soper, Sterman (87);
Donnachie, Landshoff (87); ...

⟶ **Factorisable models:** (e.g. RAPGAP Jung)

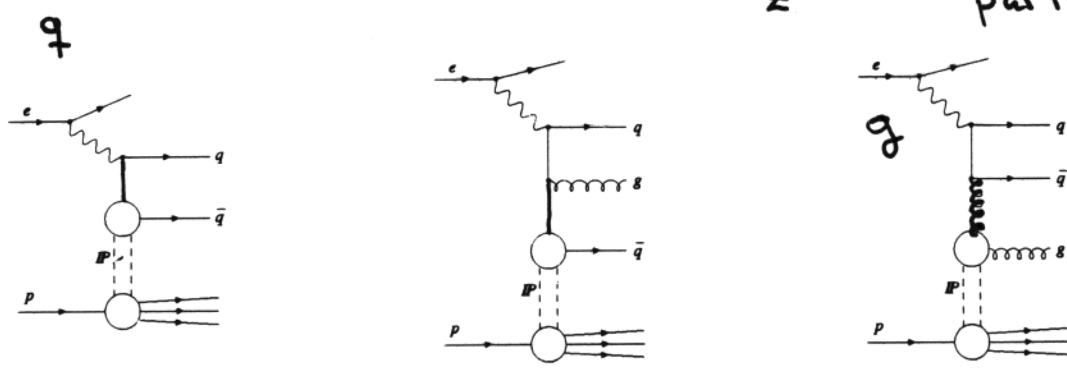
$\boldsymbol{\sigma}$ for hard process in DIS=

($\mathbb{P}$ flux in proton) **x**(Parton densities in $\mathbb{P}$) **x**(Matrix element)



Fit to $F_2^{D(3)}$

z: fract. momentum of $\mathbb{P}$ carried by parton

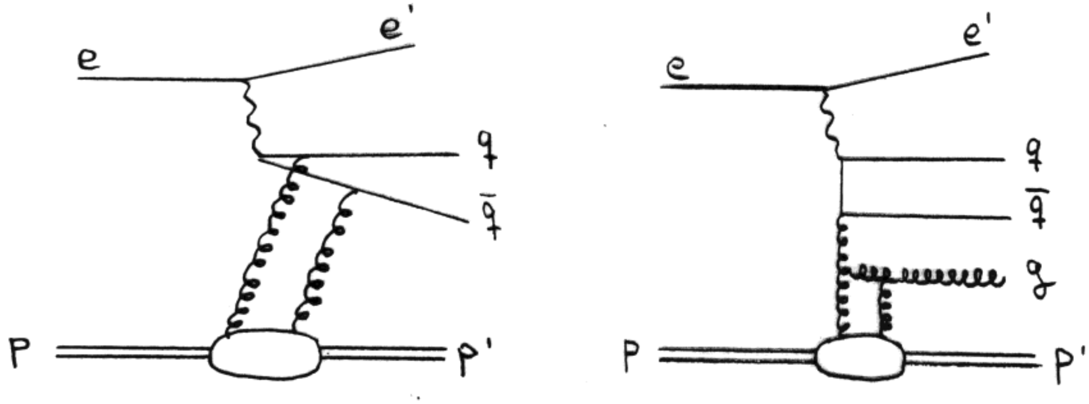


also **POMPYT** (Bruni,Ingelman);
Alvero,Collins,Terron,Whitmore;
Kunszt,Stirling; ...

→ **Non factorisable models:**

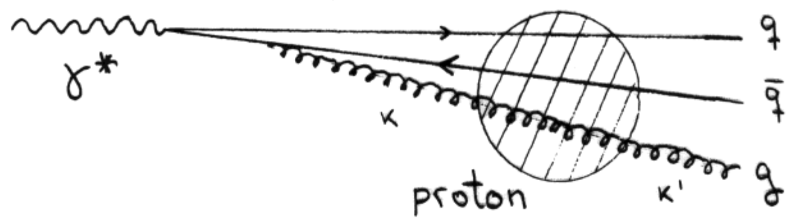
- **Double gluon exchange** (e.g. RIDI, Solano)

Ryskin, Besancon; Nikolaev, Zakharov, Genovese;
Bartels, Lotter, Wuesthoff ... ; Levin ... ; ...



- Semiclassical approach

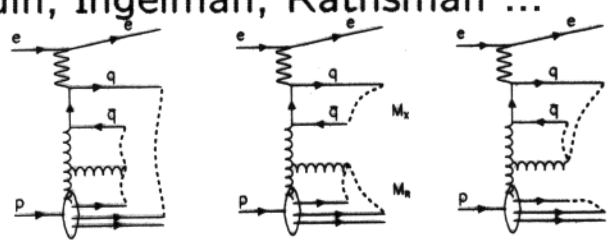
Buchmueller, McDermott, Hebecker ..



→ **Others:**

- **Soft Colour interactions**

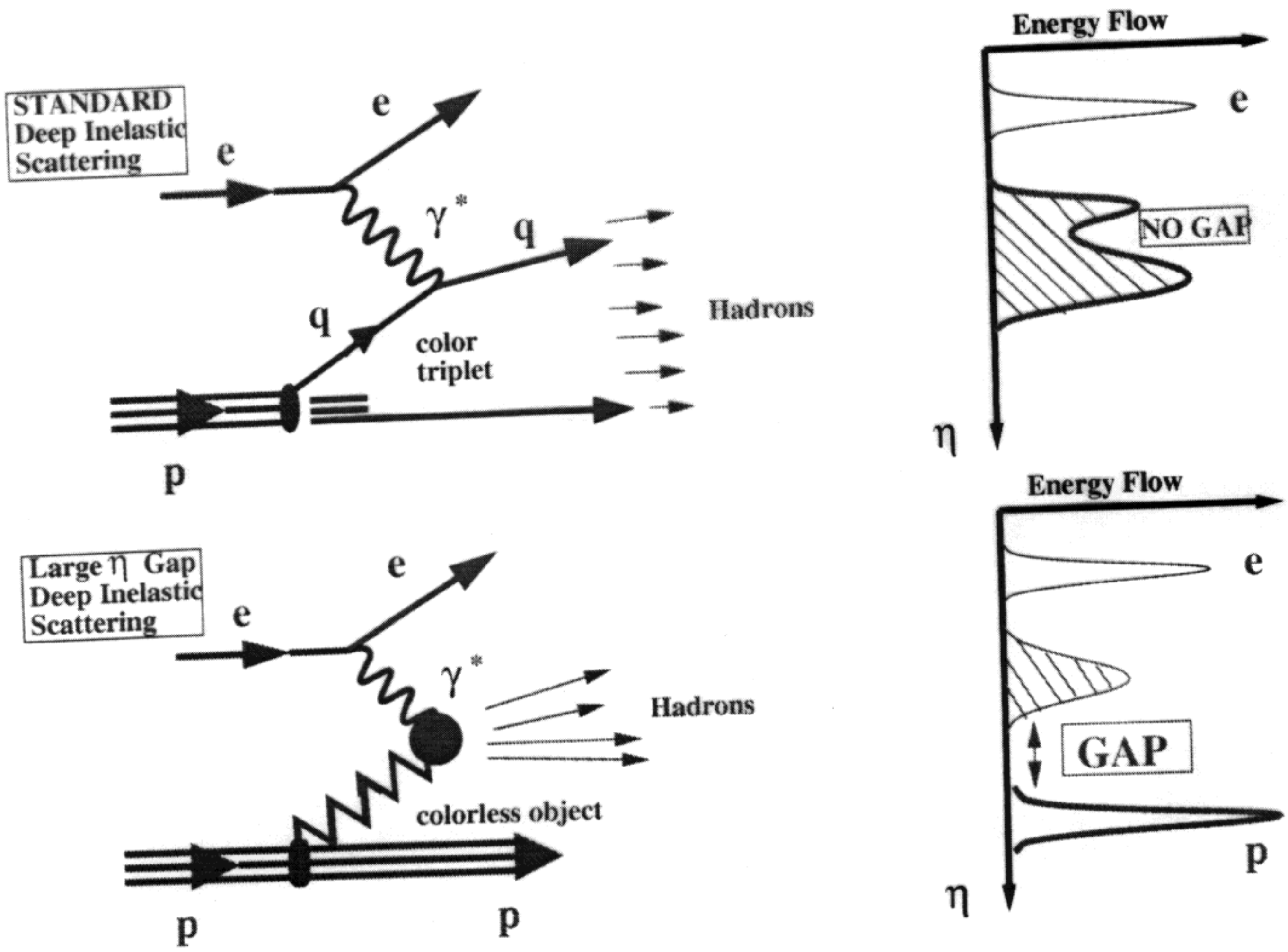
Edin, Ingelman, Rathsman ...



- **Point-like coupling (**Vermaseren, Barreiro, Labarga, Yndurain);

- ....

Experimental Techniques
(taking DIS as example)

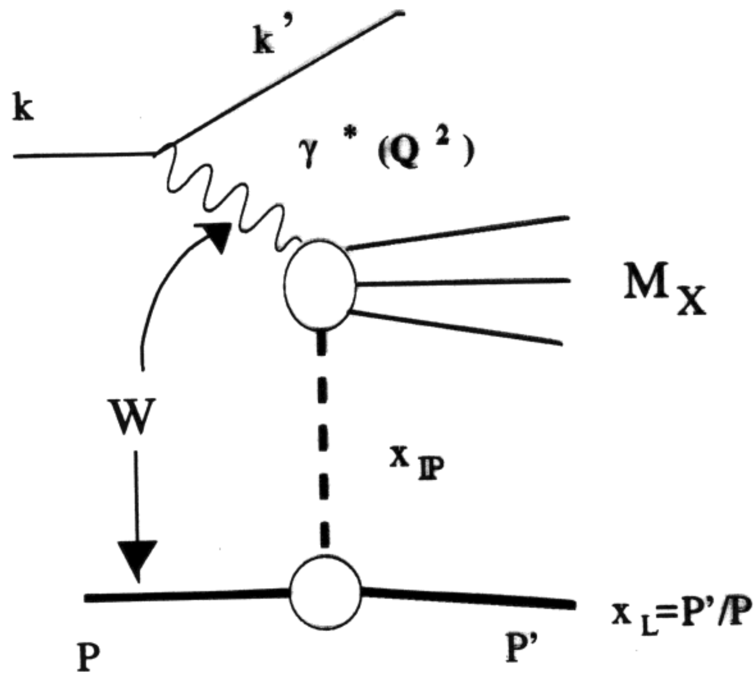


⟶ A large rapidity gap.

⟶ A fast forward proton.

⟶ Characteristic of the final state (non-diffractive contribution exponentially suppressed).

Hadronic Final States in diffractive DIS



Fast forward p detected with the LPS
$x_L^p \geq 0.95$ (no rapidity gap required)

ZEUS 1994

$4 < Q^2 < 90$ GeV^2, $52 < W < 250$ GeV
$4 < M_X < 35$ GeV, $0.0003 < x_{\mathbb{P}} < 0.03$

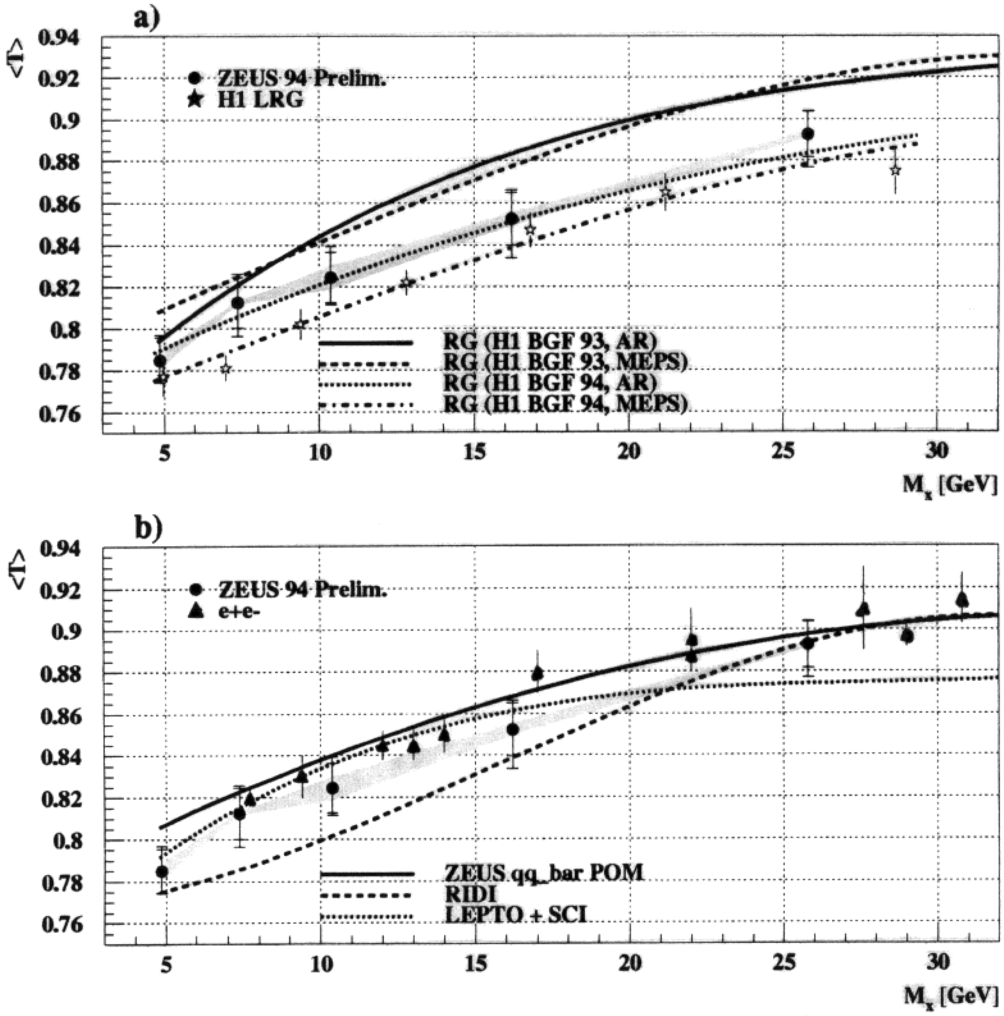
$x_{\mathbb{P}}$: fraction of incident proton momentum carried by colourless exchange.

Thrust: $$T = \max \frac{\Sigma |\vec{p}_i \cdot \vec{n}_T|}{\Sigma |\vec{p}_i|}$$

(in the $\gamma^* \mathbb{P}$ c.m.s.)

- T= 1 → Cigar-like final state M_X
- T= 0.5 → Spherical final state M_X

Thrust:

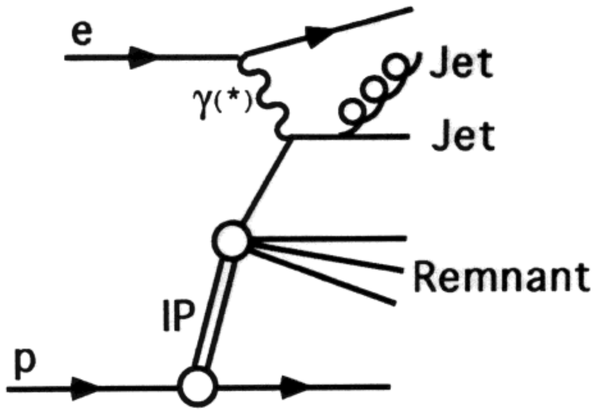


- ⟶ ZEUS LPS data less collimated than e^+e^- → a new mechanism in addition to hard gluon bremsstrahlung needed
- ⟶ Gluon-dominated $I\!P$ (H1 BGF 94, later fit 2) describes the data best
- ⟶ H1 LRG data less collimated than ZEUS LPS data (but similar ZEUS LPS results for $x_{I\!P} < 0.01$ and $x_{I\!P} > 0.01$ → no indication of presence of subleading $I\!R$)

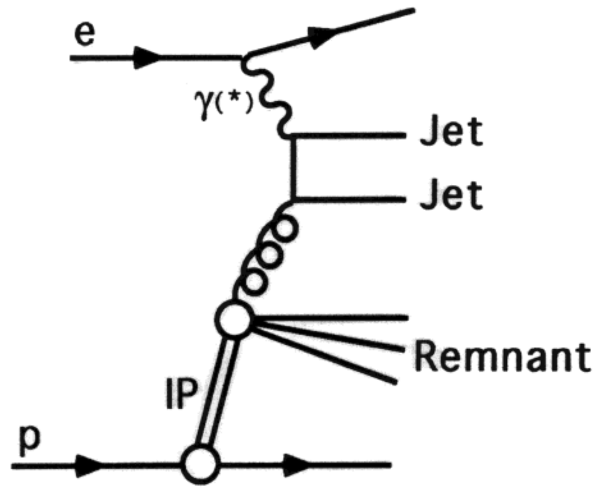
Diffractive Dijet Production at HERA

Mechanisms:

DIS and Direct Photoproduction

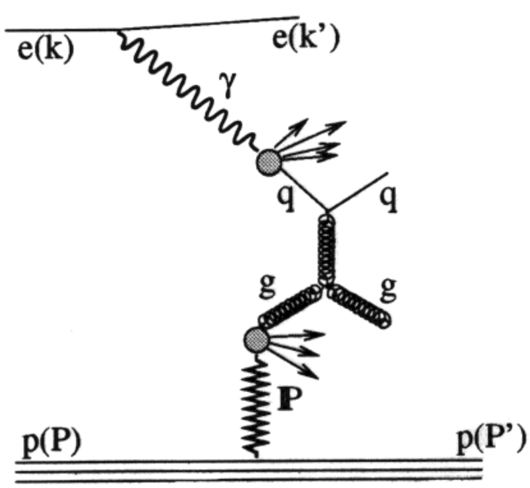


QCDC



BGF

Resolved Photoproduction



(b)

+ ...

Results from H1 1994 follow ...

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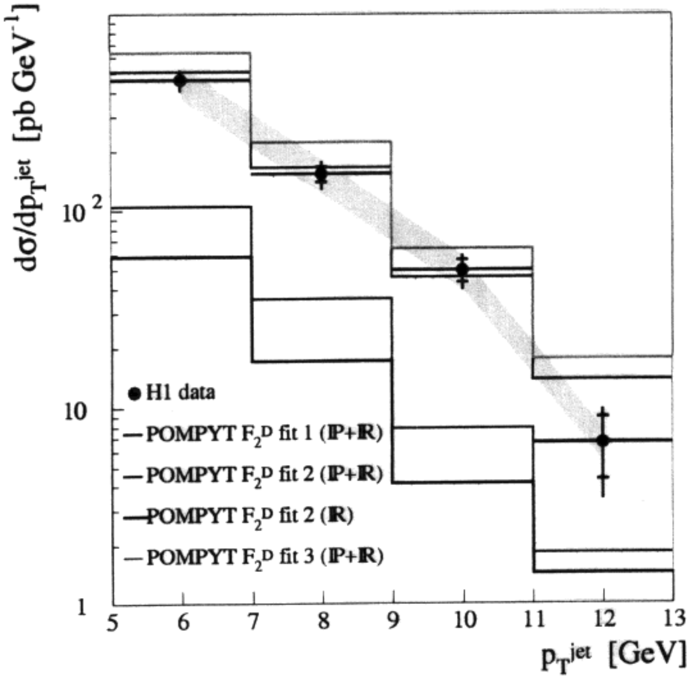
Diffractive Dijet Production, p_T spectra:
$\eta_{max} < 3.2$ (rapidity gap > 4.3)



Photoproduction

$Q^2 < 10^{-3}$ GeV^2

$0.25 < y < 0.7$

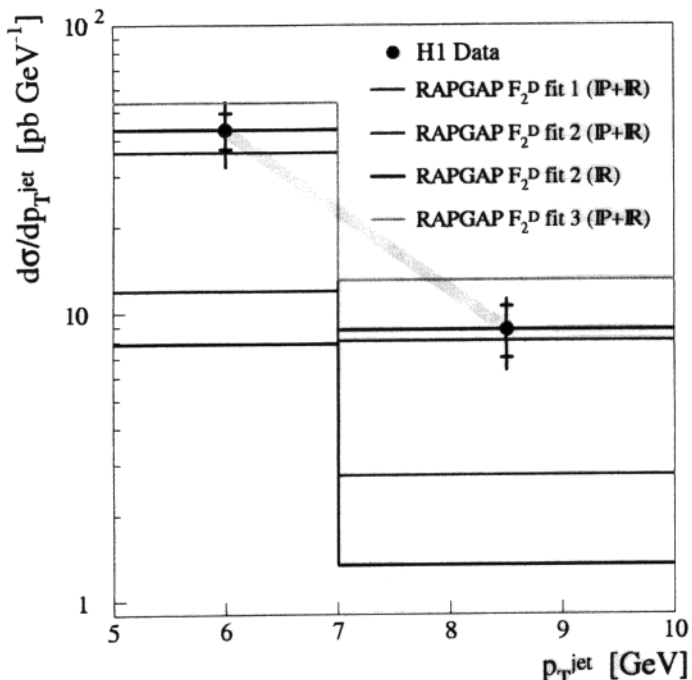
$x_{I\!P} < 0.05$

$M_Y < 1.6$ GeV

$|t| < 1.0$ GeV^2

2 jets $p_T^{jet} > 5$ GeV

$-1 < \eta_{lab}^{jet} < 2$



DIS

$7.5 < Q^2 < 80$ GeV^2

$0.1 < y < 0.7$

$0.005 < x_{I\!P} < 0.05$

$M_Y < 1.6$ GeV

$|t| < 1.0$ GeV^2

2 jets $p_T^{jet} > 5$ GeV

$-1 < \eta_{lab}^{jet} < 2$

fit 1: only quarks

fit 2: dominated by gluon flat on $z_{I\!P}$

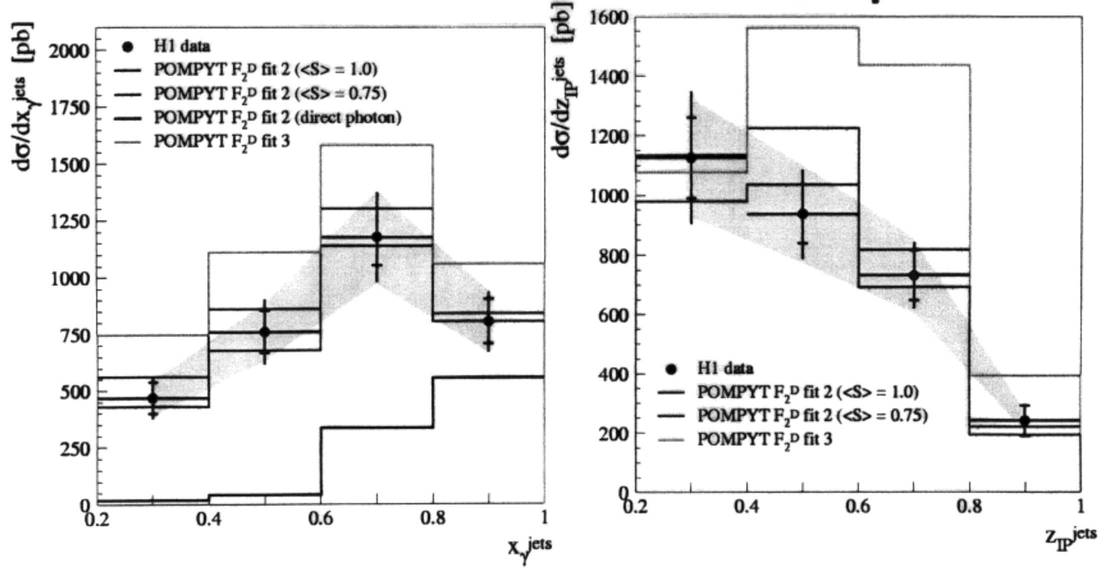
fit 3: dominated by gluon peaked at high $z_{I\!P}$

$\longrightarrow$ $I\!P$ exchange dominates

$\longrightarrow$ Gluon dominated $I\!P$

x_γ, $z_{I\!P}$: fraction of γ^*,$I\!P$ momentum transferred to the system X

Photoproduction



⟶ **Direct and Resolved components present**

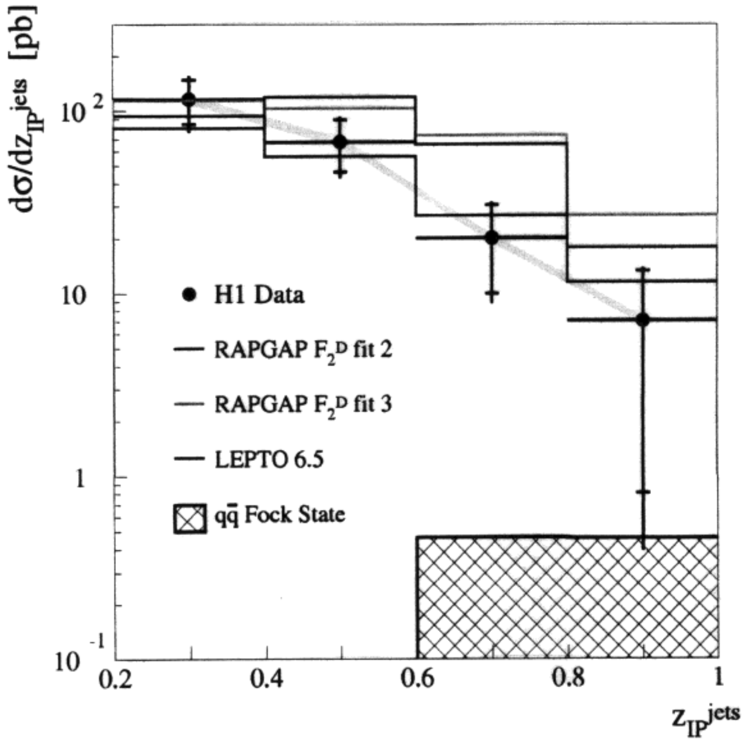
⟶ **Gluon dominated $I\!P$**

Survival Probability:

- In diff. Resolved PHP multiple interactions would be expected to destroy rapidity gaps → breaking of diffractive factorisation
- To estimate it apply a constant weight $< S >$ to the MC events (fit 2) with $x_\gamma < 0.8$
- $< S >$ may be as small as 0.1 at Tevatron

⟶ **Large survival probability, no significant evidence of diffractive factorisation breaking**

$z_{I\!P}$ distribution in DIS



⟶ Reasonable description if GAP due to soft color interactions between outgoing partons

⟶ No evidence for a large super-hard $I\!P$ contribution

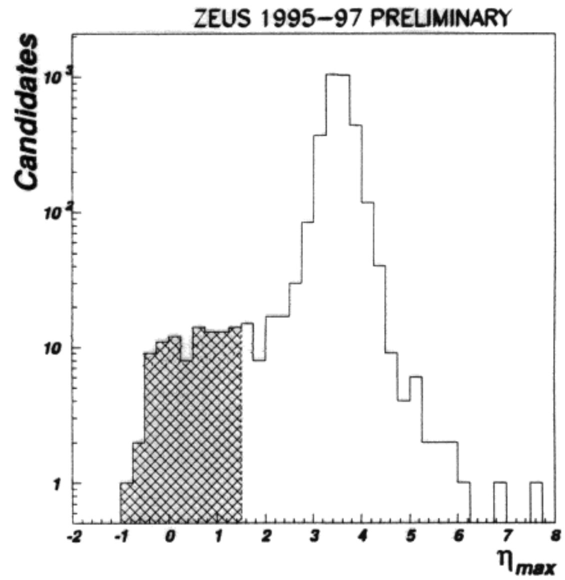
⟶ Gluon dominated $I\!P$

Charm Production in Diffr. DIS (ZEUS 95-97)

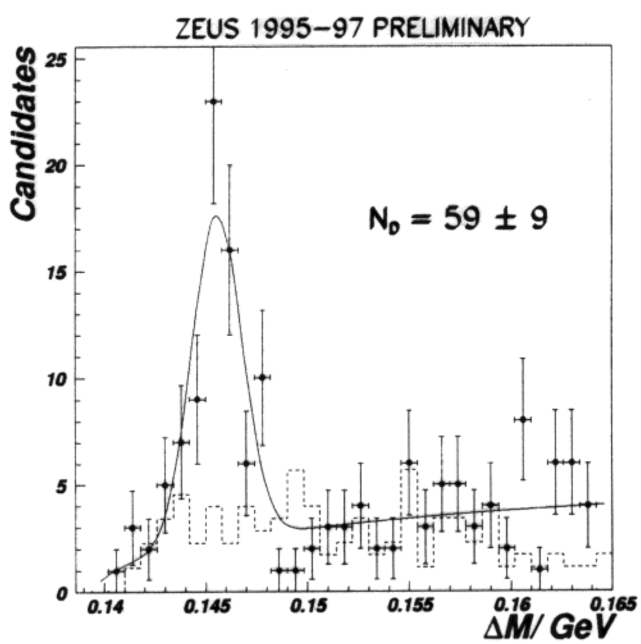
$$D^{*+} \rightarrow D^0\pi^+ \rightarrow K^-\pi^+,\pi^+ + \text{cc}$$

η_{max} distribution for events with a reconstructed $D^{*\pm}$:

$\longrightarrow$ Diffractive shoulder



$D^{*\pm}$ signal for events with $\eta_{max} < 1.5$ (rapidity gap > 2.8) :



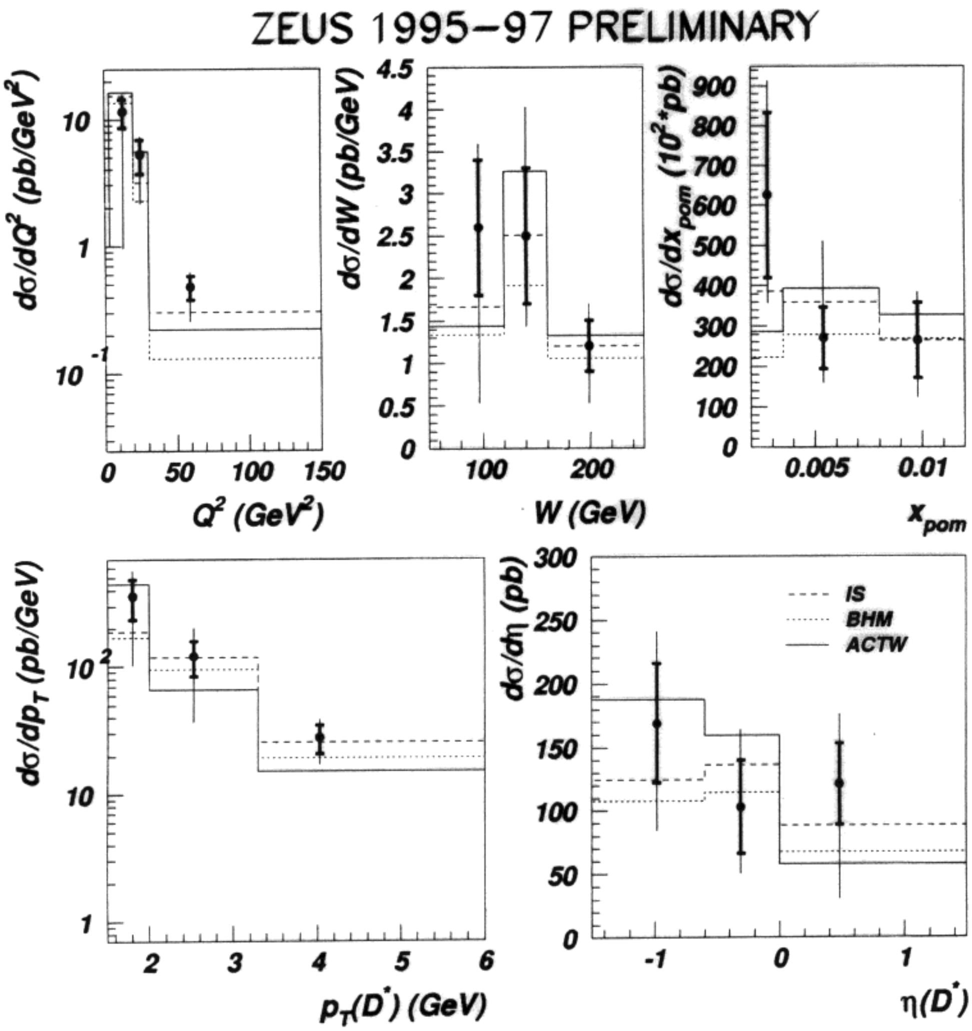
Diffractive $D^{*\pm}$ differential distributions

Corrected to:

$3 < Q^2 < 150$ GeV^2, $0.02 < y < 0.7$

$p_T(D^{*\pm}) > 1.5$ GeV, $|\eta(D^{*\pm})| < 1.5$

$0.002 < x_{I\!P} < 0.012$, $\beta < 0.8$



IS, ACTW: Factorisable $I\!P$ dominated by gluons

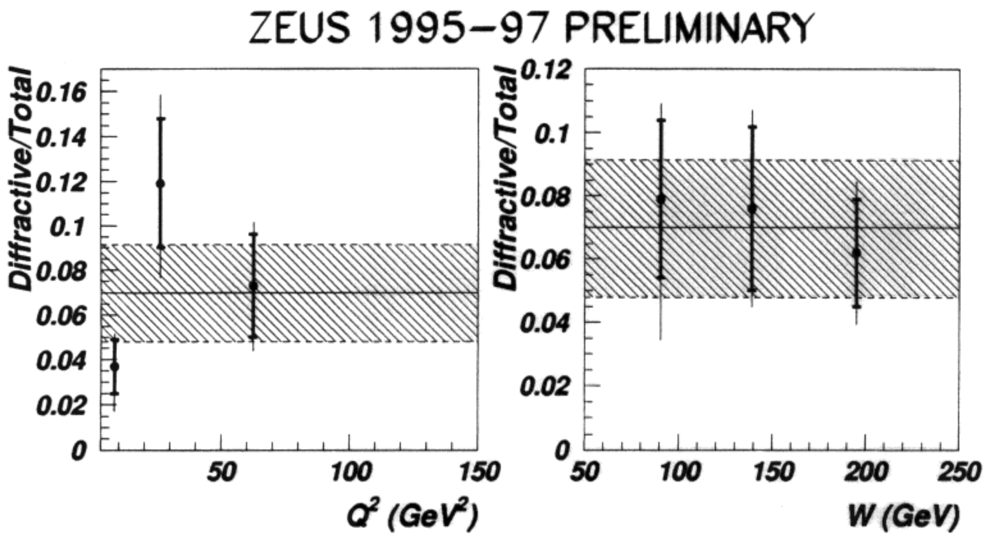
BHM: Partonic fluctuation of the γ^* interacting with the proton colour field

D$^{*\pm}$ production cross section:

$$\sigma(ep \to eD^{*\pm}Xp) =$$
$$379 \pm 66(sta)^{+99}_{-140}(sys) \quad pb$$

(IS: 326, ACTW: 352, BHW: 267 pb)

Ratio of diffractively produced D$^{*\pm}$'s to total D$^{*\pm}$'s:



$\longrightarrow$ a sizeable diffractive charm production

$\longrightarrow$ consistent with the fraction of total cross section attributed to diffractive scattering

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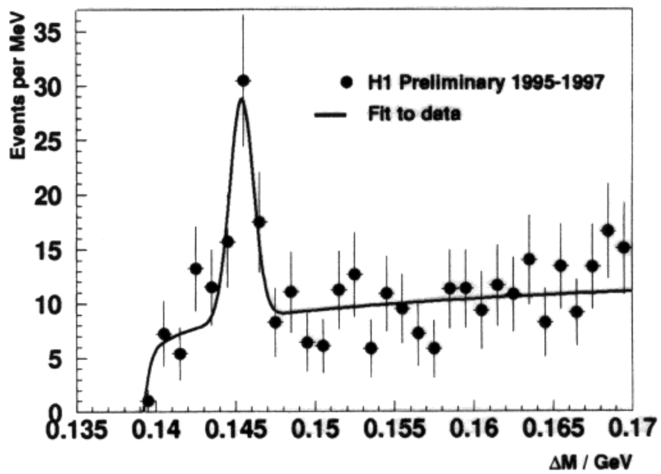
Charm Production in Diffr. DIS (H1 95-97)



N($D^{*\pm}$)$= 38 \pm 10(stat.) \pm 4(syst)$

$D^{*\pm}$ production cross section:

Corrected to:
$2 < Q^2 < 100$ GeV^2, $0.05 < y < 0.7$
$p_T(D^{*\pm}) > 2$ GeV, $|\eta(D^{*\pm})| < 1.5$
$x_{I\!P} < 0.04$, $M_Y < 1.6$ GeV, $|t| < 1$ GeV^2

$$\sigma(ep \rightarrow eD^{*\pm}Xp) =$$
$$150 \pm 40(sta) \pm 35(sys) \quad pb$$

CONCLUSIONS

Measurements of event shapes evolution with M_X, di-jet and charm production in diffractive ep scattering are consistently described by factorisable models incorporating a t channel exchange with gluon dominated parton distributions

other models, non factorisable, with different approaches for the diffractive reaction (some sort of two gluon exchange, partons from photon dissasociation interacting with the colour field of the proton ...) are also able to describe features of the data.

The study of charm production will be a very powerful tool (maybe the key) in the understanding of the basic processes in diffraction.