(Fragmentation in ep Collisions)

Hadronic Final State in Diffraction at HERA

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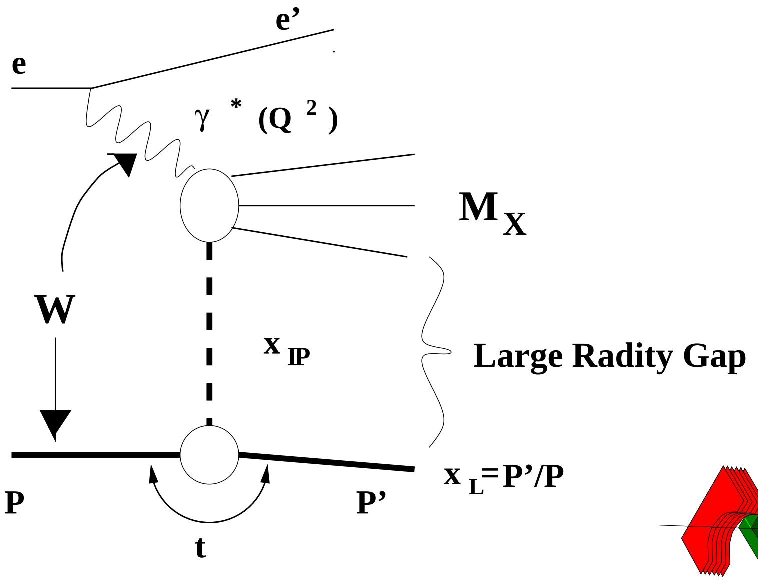
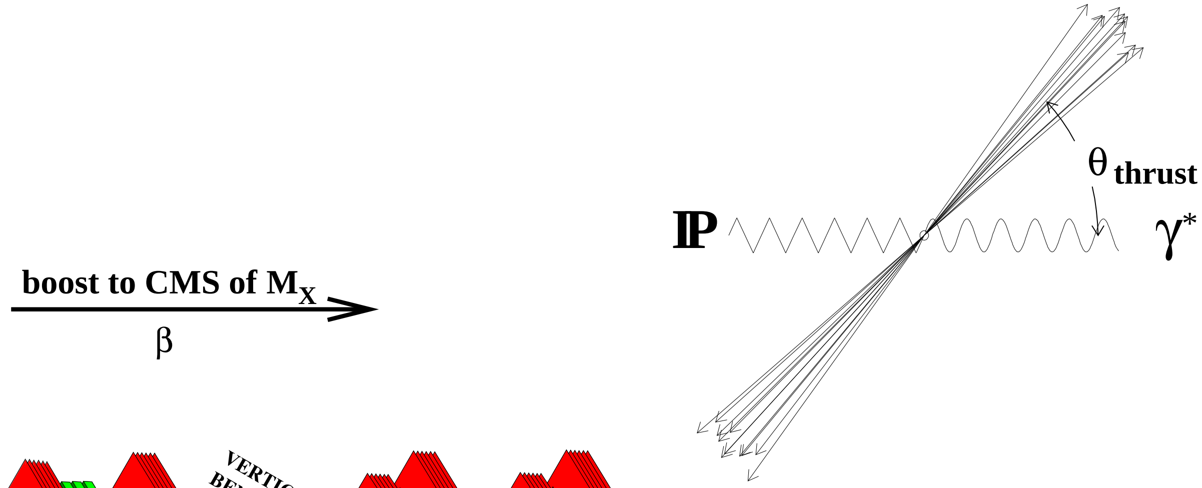
representing the

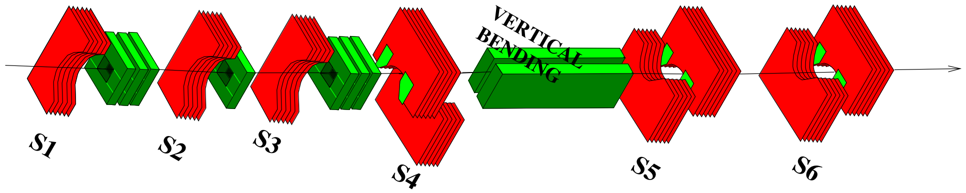
H1 and ZEUS Collaborations

- Introduction
  - Monte Carlo Models
- Global Event Shapes
- Di-Jets
- 3-Jets
- D^* Production in PHP
- Summary

Introduction: Diffractive Hadronic Final State







Leading Proton Spectrometer (LPS)

Methods of Selection

- measure the Leading Proton
  for example LPS proton with $x_L = 0.95$
- Large Rapidity Gaps (LRG)
- diffractive excess in $\ln M_X^2$ distribution

Aim

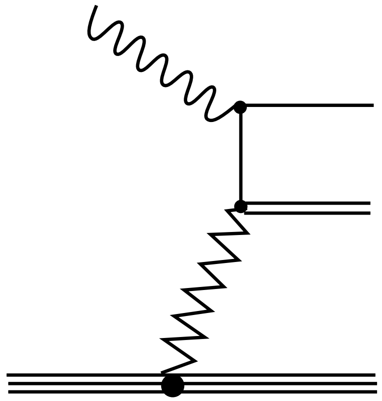
- Topology of hadronic final state
  $\rightarrow$ nature of $\mathbb{P}$ exchange

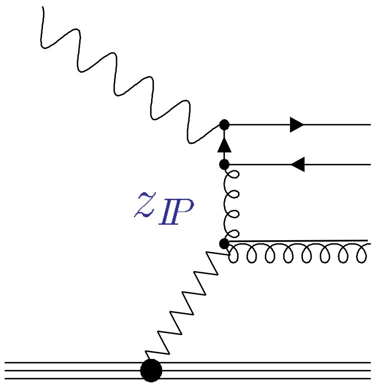
$\Rightarrow$ QCD factorization and diff. PDFs

$\Rightarrow$ test QCD calculations (high p_T)

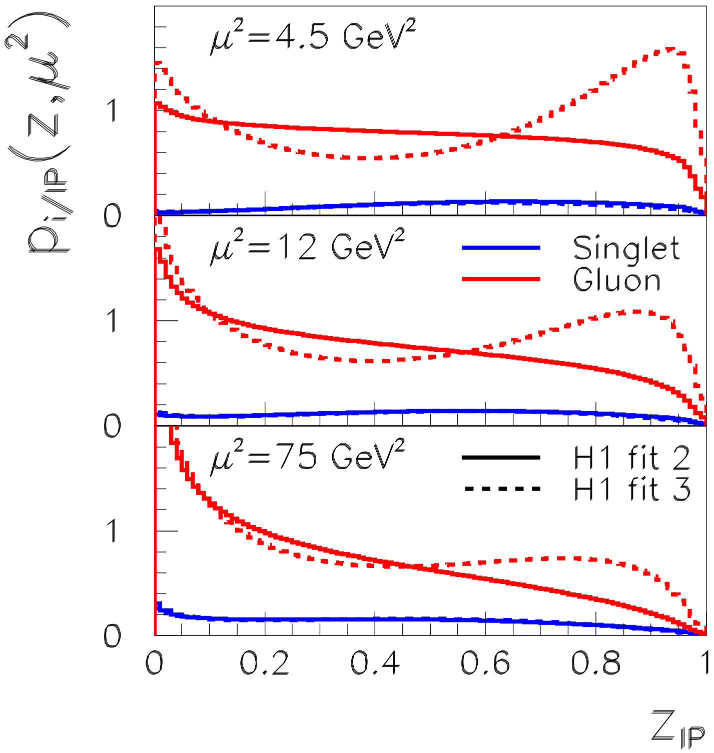
Global Event Shape $\rightarrow$ Particle Distribution $\rightarrow$ Jet Analysis $\rightarrow$ Charm Production

Monte Carlo Models: Resolved Pomeron – RAPGAP



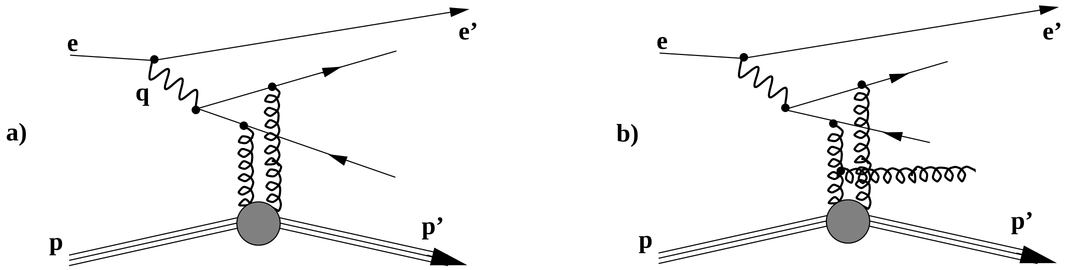


- Factorization: $F_2^{D(4)} = f_{I\!P/p}(x_{I\!P}, t) F_2^{I\!P}(\beta, Q^2)$



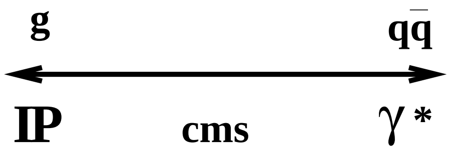
- $F_2^{I\!P}$: $\mathbb{P}$ PDFs from H1 fits to $F_2^{D(3)}$
- PDF's dominated by gluons
- soft $\mathbb{P}$ remnant
- subleading $\mathbb{R}$ exchange

Monte Carlo Models: 2-gluon Exchange – SATRAP, RIDI, BJLW



- high p_T diffractive final states

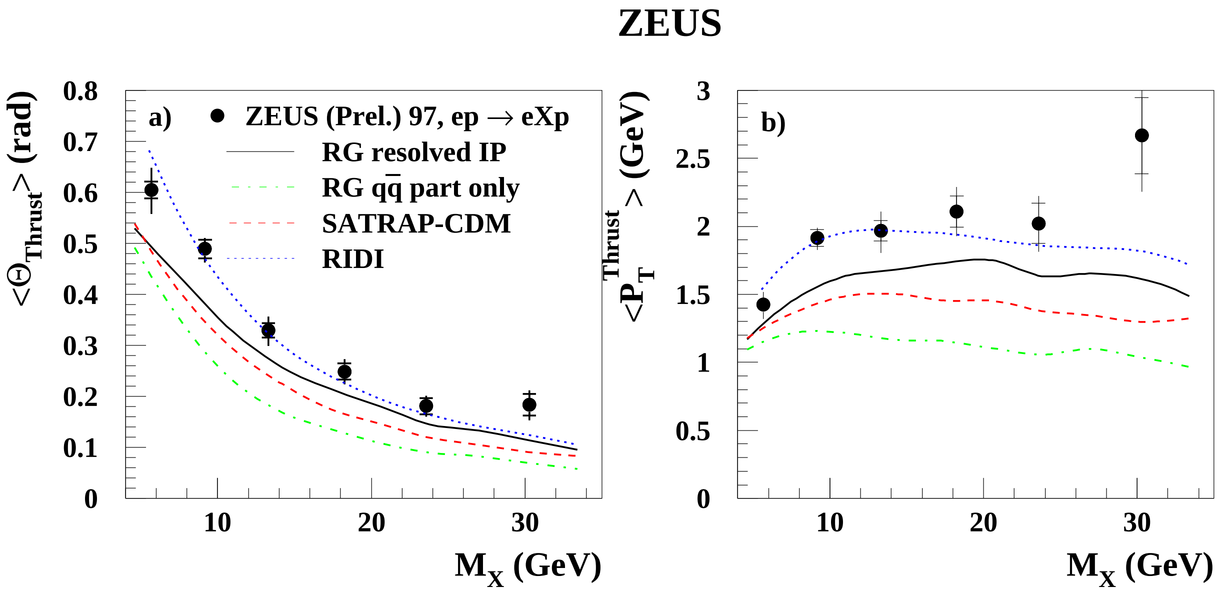
- $\mathbb{P}$ colorless 2-gluon exchange
- $q\bar{q}g$ events dominant at large M_X:

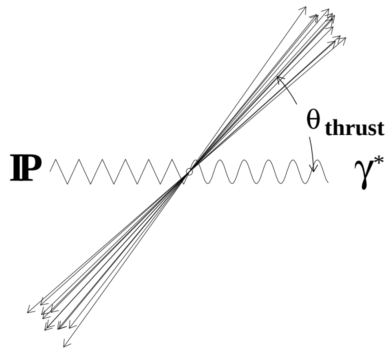


- SATRAP: Saturation Model
  - $g(x)$ from parameterization of $F_2(x, Q^2)$
  - strongly ordered k_T: $p_T^g \ll p_T^q$

  $\Rightarrow$ remnant-like gluon
- RIDI:
  - $g(x)$ from PDFs (CTEQ4M)
  - strongly ordered k_T: $p_T^g \ll p_T^q$
- BJLW:
  - $g(x)$ from PDFs (GRV NLO)
  - unordered k_T

Global Event Shape: ZEUS





$$p_T^{Thrust} = \frac{1}{2} M_X \sin \theta_{thrust}$$

Thrust $\quad T = \max_{\mathbf{n}} \frac{\Sigma_i |\mathbf{n} \cdot \mathbf{p}_i|}{\Sigma_i |\mathbf{p}_i|}$

- system more aligned with $\gamma^* I\!P$ axis as M_X increases
- high level of $p_T^{thrust} \simeq 2$ GeV
- mostly produced in $q\bar{q}g$ type events

?? additional source of k_T needed

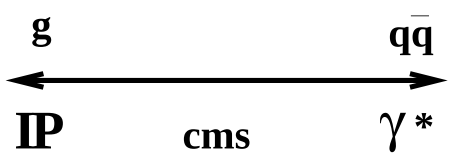
ZEUS: leading proton

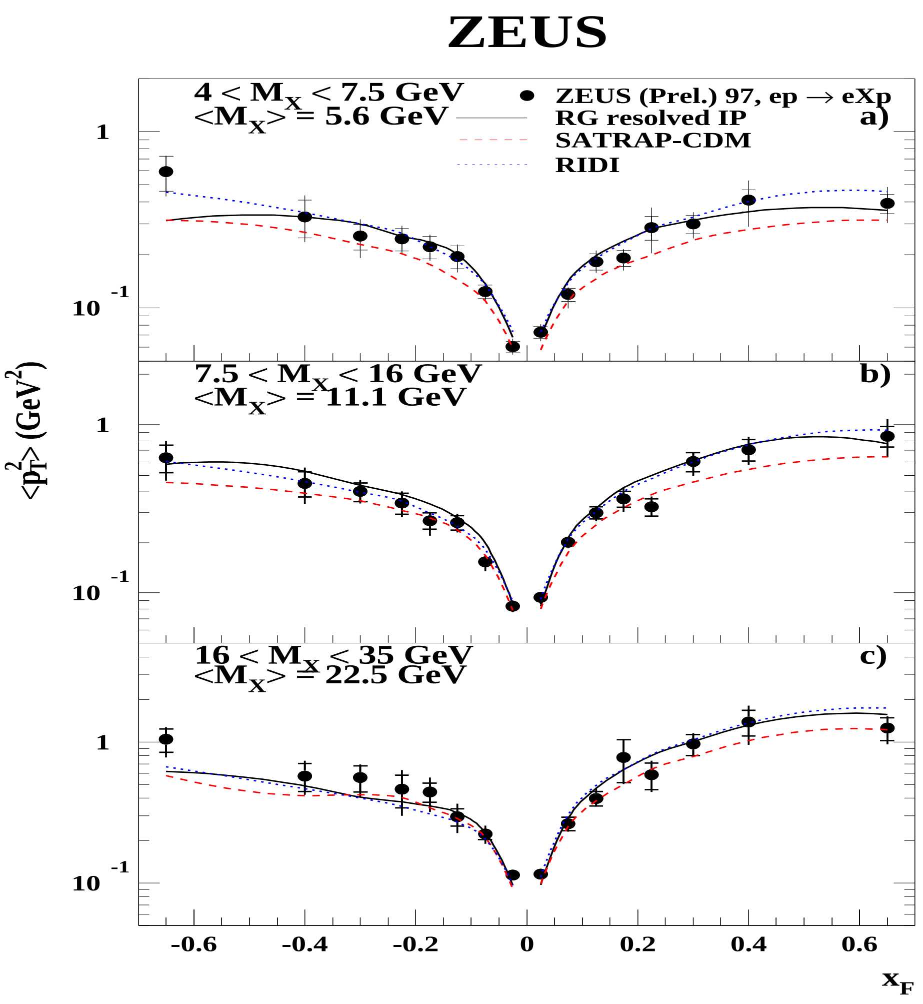
$4 < M_x < 35$ GeV, $4 < Q^2 < 90$ GeV^2,

$0.03 < y < 0.95$, $0.0003 < x_{I\!P} < 0.03$

Seagull Distribution: ZEUS

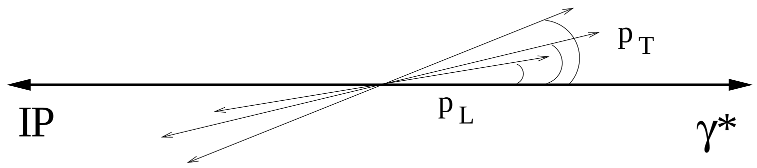
- Asymmetry between $\mathbb{P}$ and γ^* increasing with M_X
- described by resolved $\mathbb{P}$ (RAPGAP) $\rightarrow$ $\mathbb{P}$ analogous to inclusive DIS
- described by 2-gluon exchange (RIDI)





?? dominance of $q\bar{q}g$ final state $\Rightarrow$ jet study

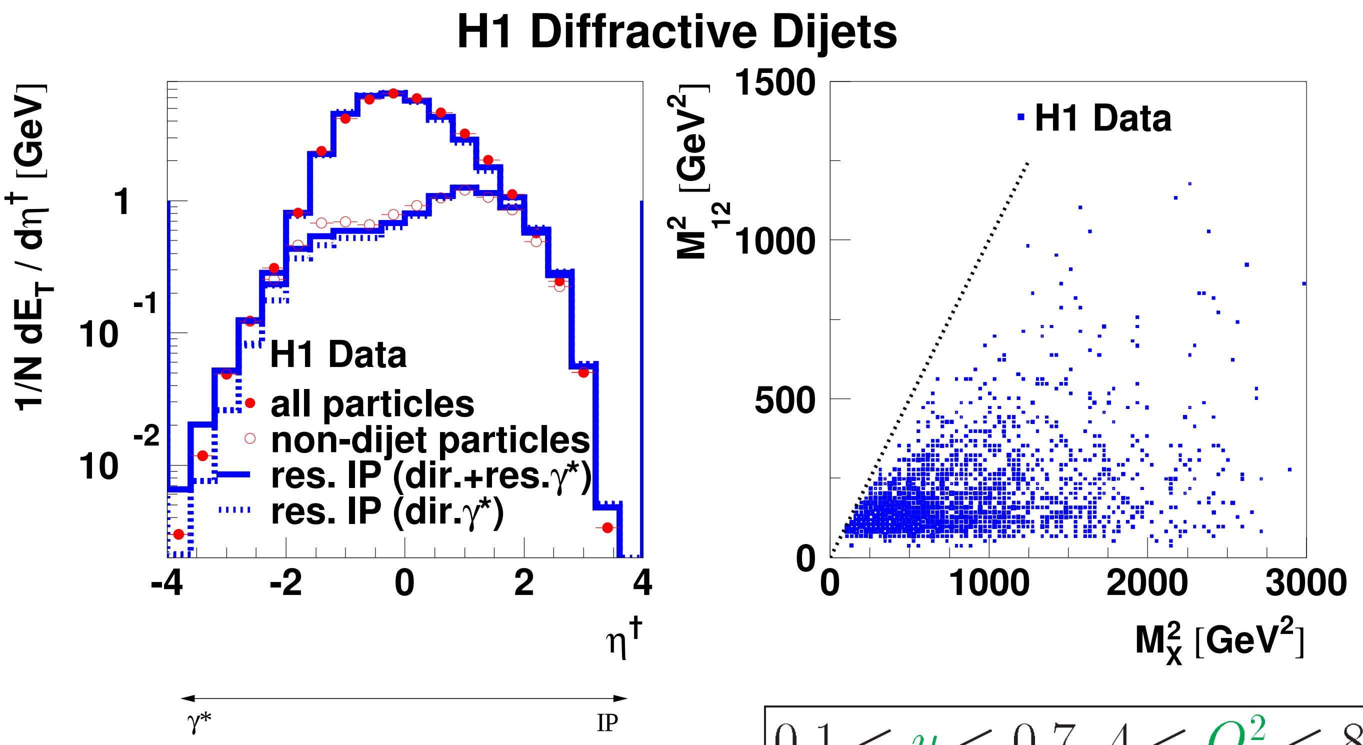
?? source of transverse momentum



$$x_F = p_L / p_L^{max} = 2\, p_L / M_X$$

Dijet Production: H1

- CDF cone algorithm ($R = 1.0$) $\gamma^* I\!P$ CMS
- LRG events: $3.2 < \eta < 7.5$
- Dijet Sample: $N_{jet} \geq 2$, $p_T^* > 4$ GeV



$0.1 < y < 0.7$, $4 < Q^2 < 80$ GeV^2,
$M_y < 1.6$ GeV, $x_{I\!P} < 0.05$, $|t| < 1$ GeV^2
$-3 < \eta^*_{jet} < 0$

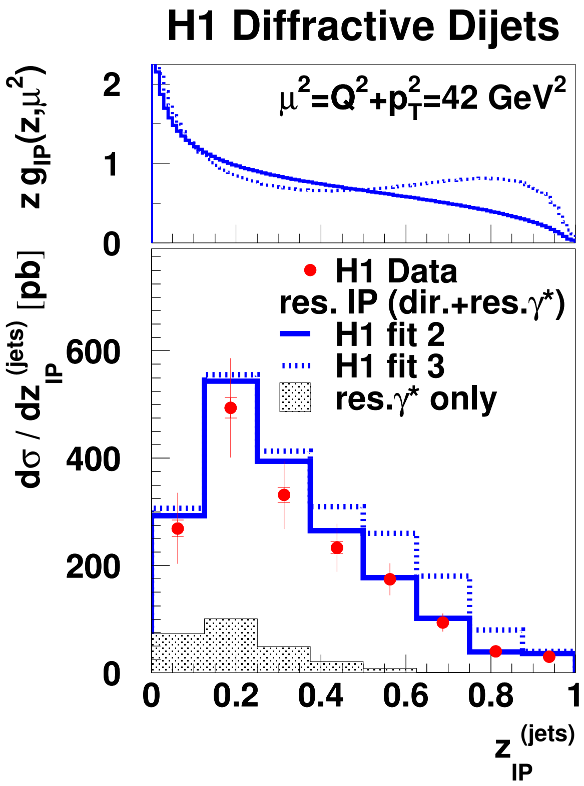
- $M_{12} < M_X$

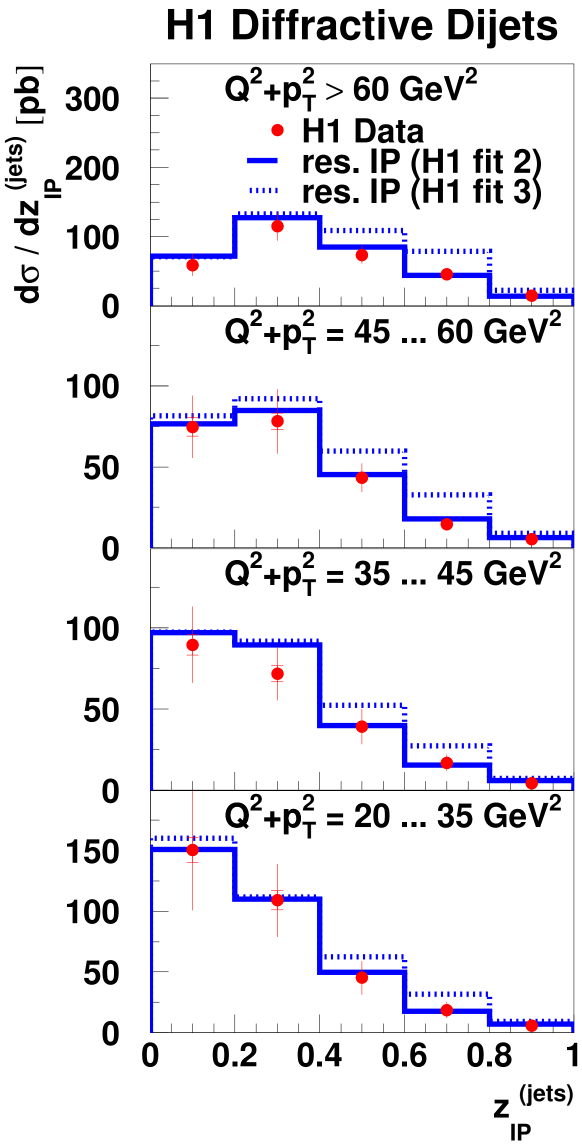
$\Rightarrow$ considerable hadronic activity outside dijets

Dijet Production: Gluon Distribution and Scale Dependence

- momentum fraction transferred to dijets:

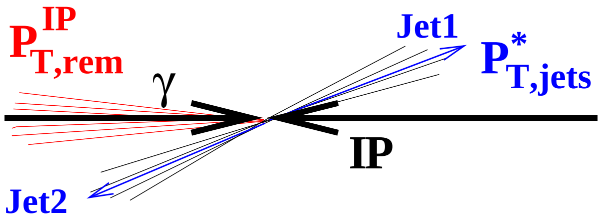
$$z_{I\!P}^{(jets)} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$



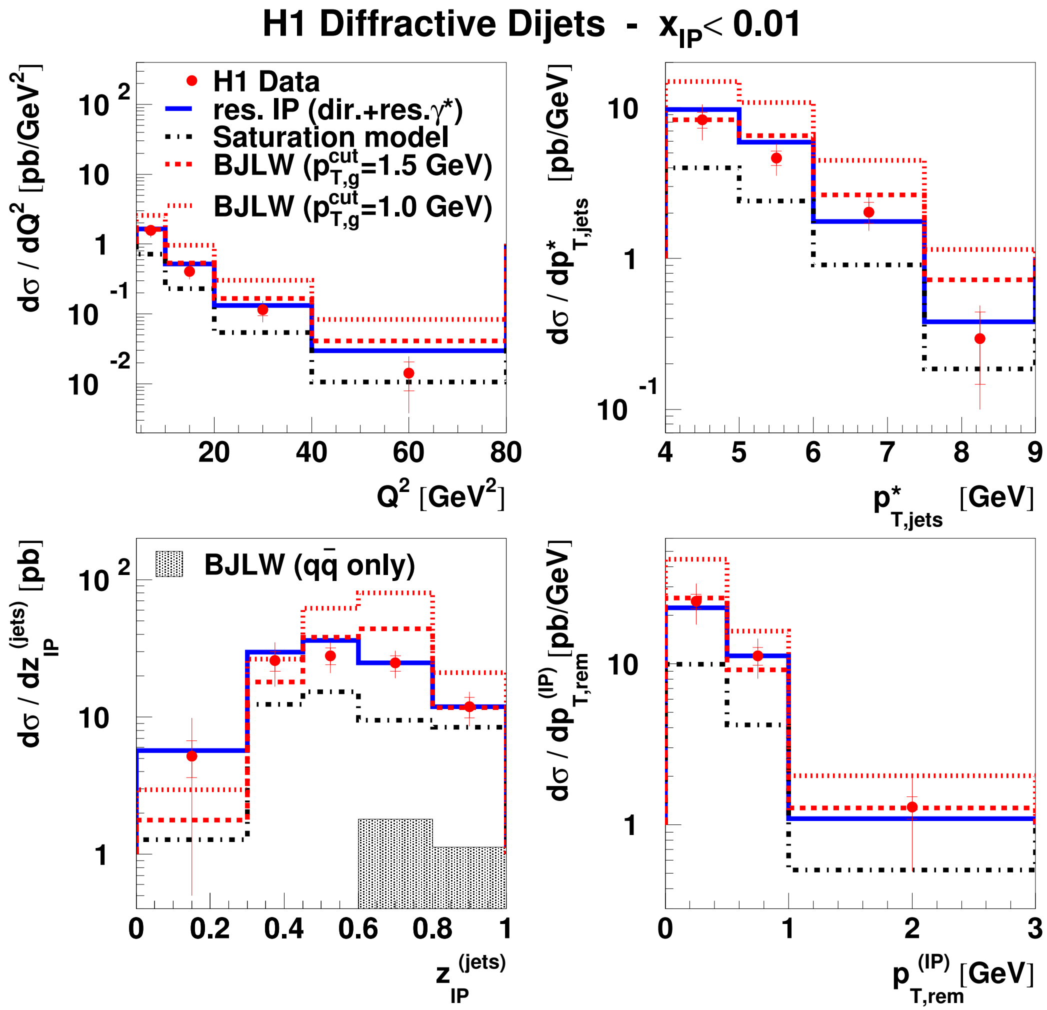


- sensitive to gluon distribution
- DGLAP evolution works for $I\!P$ PDFs

Dijet Production: k_T ordering



- $x_{I\!P} < 0.01$: avoid $I\!R$ exchange contribution, $q\bar{q}$ contribution small
- $p^{I\!P}_{T,rem}$: p_T of "$\mathbb{P}$ remnant"



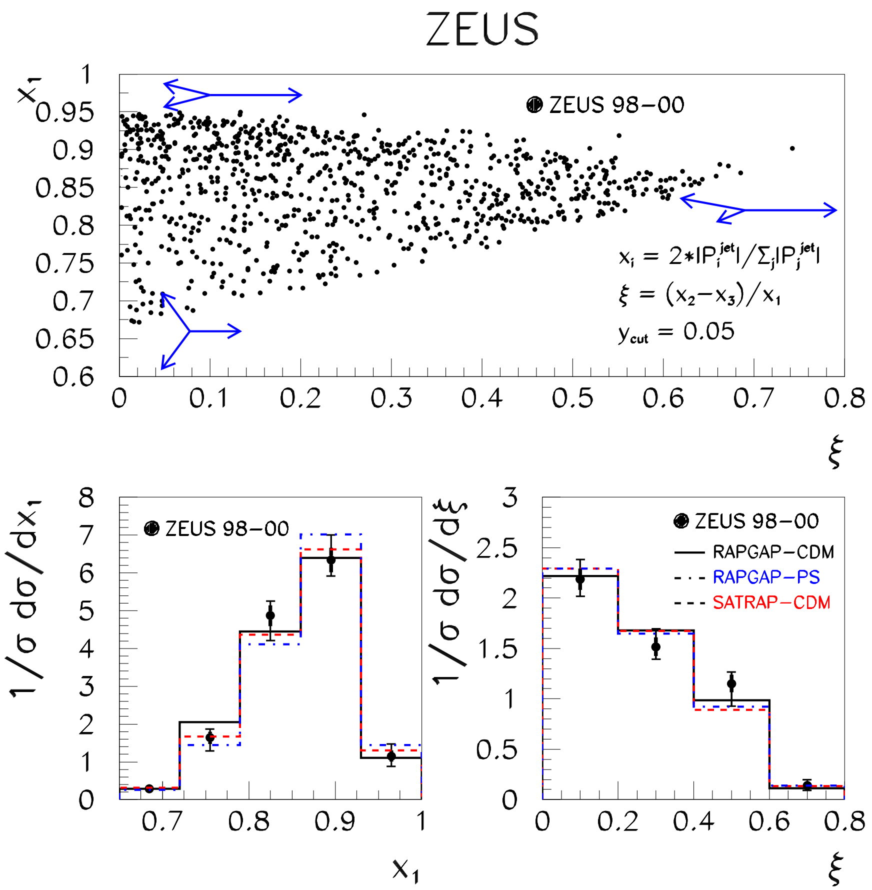
- BJLW (with non-ordered k_T) describes data well
- SATRAP (with $p^g_T \ll p^q_T$) too low
- resolved $\mathbb{P}$ (soft $\mathbb{P}$ remnant) best
- maybe ! non-ordered k_T contributions important
- or: higher order QCD contributions

3-jet Production: ZEUS

- exclusive k_T algorithm (E-scheme) in $\gamma^* I\!P$ CMS
- $y_{cut} = 0.05$: good parton-hadron correlation

$$y_{ij} = \frac{2 \cdot min(E_i^2, E_j^2)(1 - \cos\theta_{ij})}{M_X^2} < y_{cut}$$

- LRG events: $\eta^{max} < 3.0$
- $x_i = \frac{2 \cdot |P_i^{jet}|}{\sum_j |P_j^{jet}|}$, $x_1 \geq x_2 \geq x_3$
- $\xi = (x2 - x3)/x1$



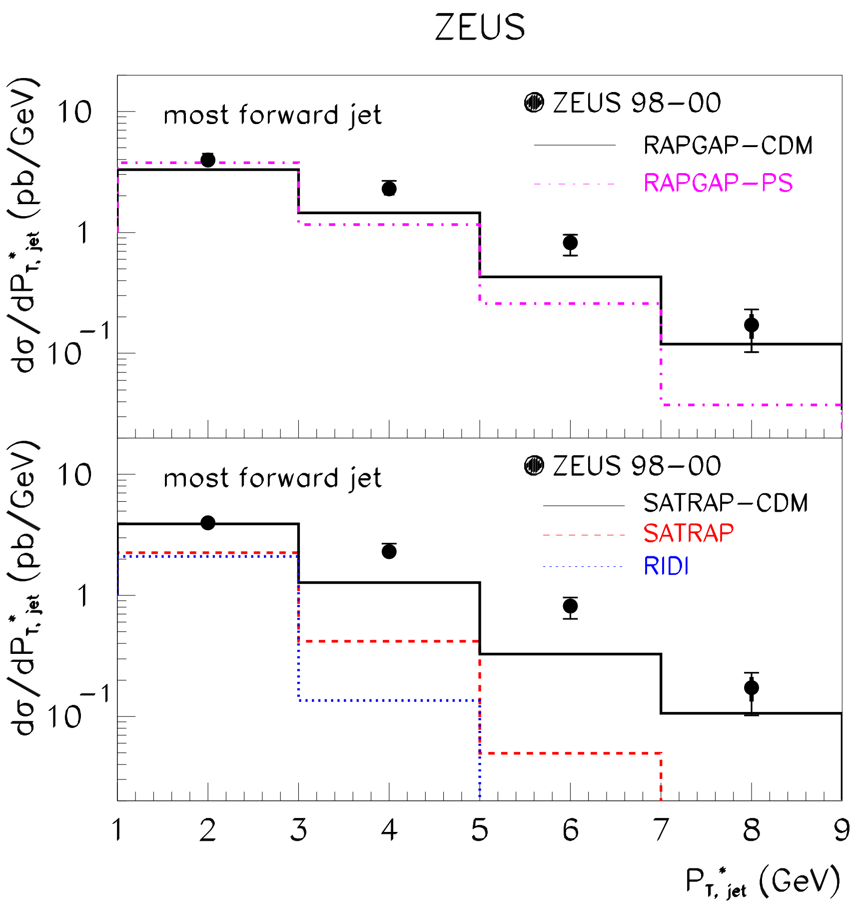
$$\boxed{5 < Q^2 < 100 \text{ GeV}^2,\ 23 < M_X < 40 \text{ GeV} \quad x_{I\!P} < 0.025,\ 200 < W < 250 \text{ GeV}}$$

- dominant configuration:
  one leading jet, 2 with similar energies

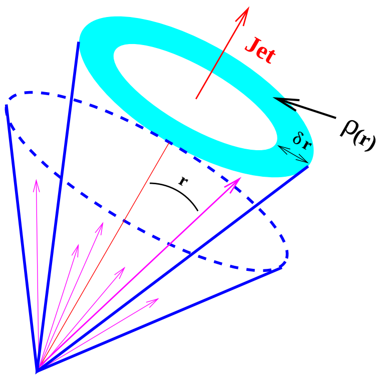
3-jet Production: p_T^* of Most Forward Jet

- dominant: $p_T < 3$ GeV
- sensitivity to higher order QCD processes

- RIDI: large $P^*_{T,jet}$ missing



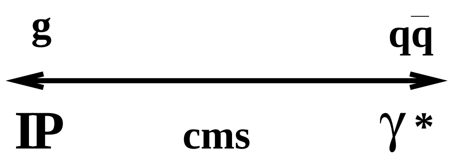
3-jet Production: Jet-Shape

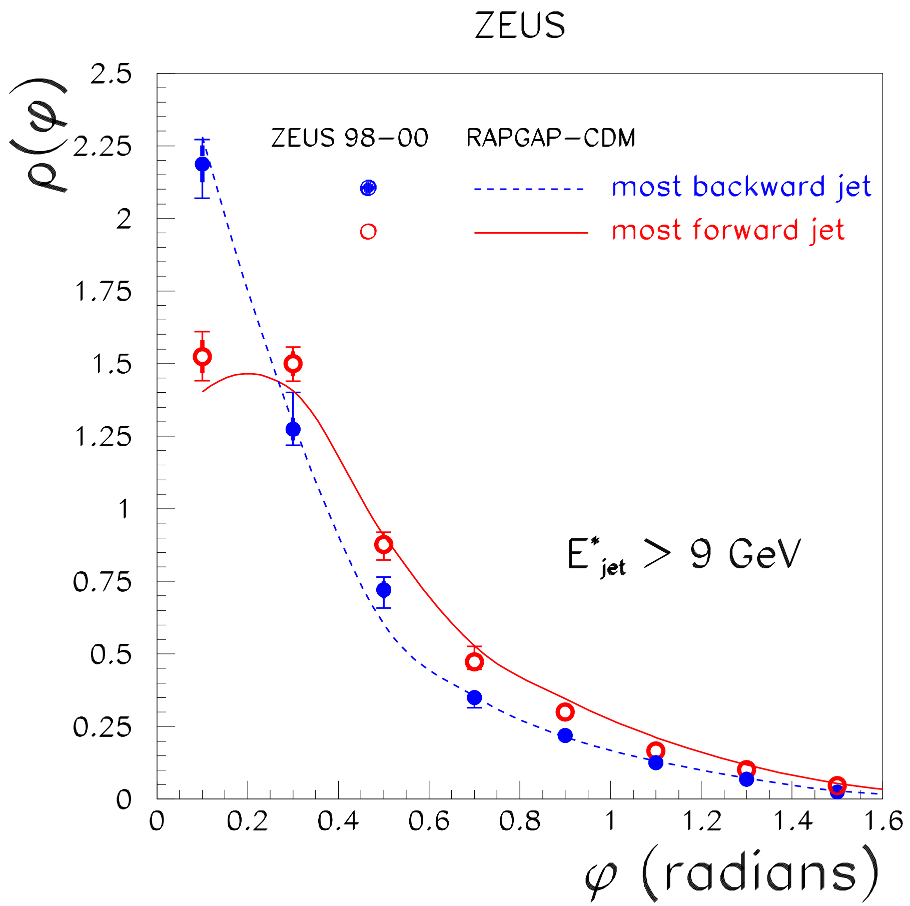


- jet shape of most-forward and -backward jet

$$\rho(\phi) = \langle \frac{1}{\delta\phi} \frac{E^{jet}(\phi \pm \delta\phi/2)}{E^{jet}} \rangle$$

- $E^*_{jet} > 9$ GeV
- "$\mathbb{P}$ jet" broader
- consistent with gluon in $\mathbb{P}$ direction

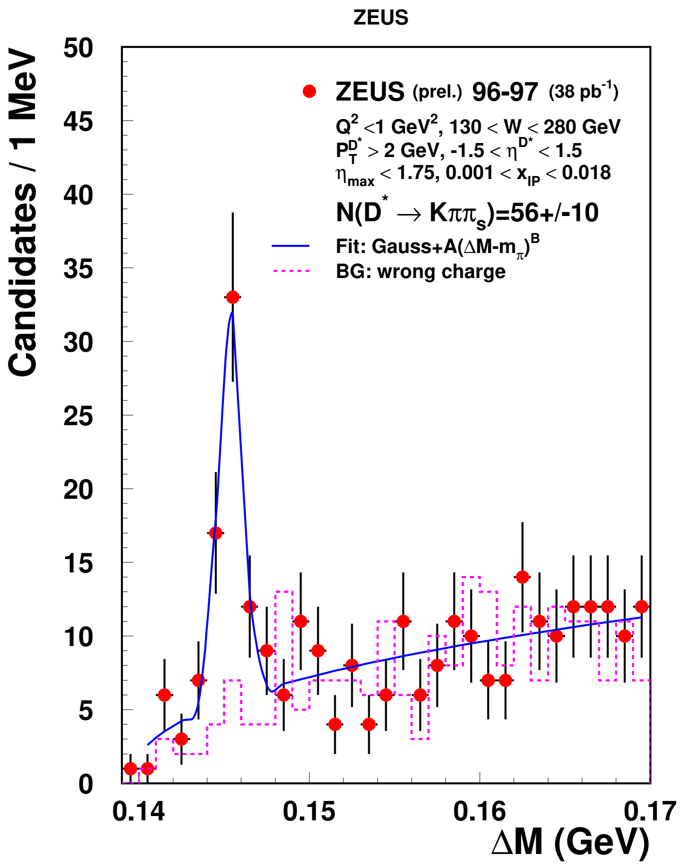




Diffractive D^* Production in PHP: ZEUS

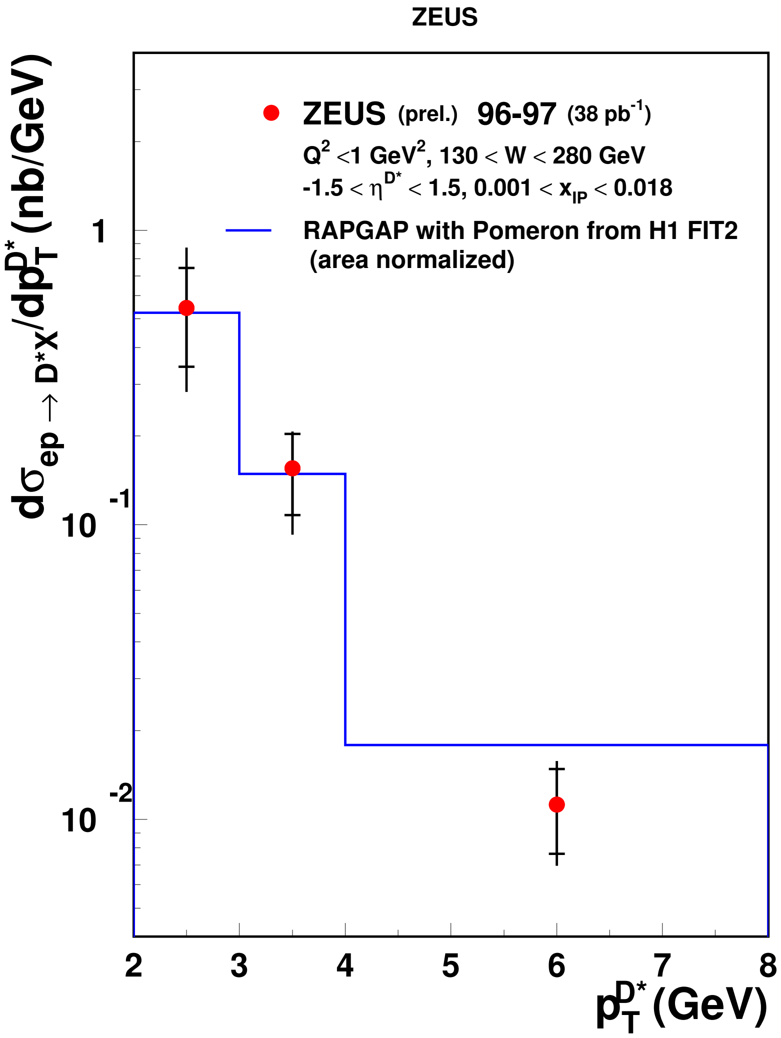
$$Q^2 < 1 \text{ GeV}^2$$

- LRG events: $\eta_{max} < 1.5$
- $D^{*\pm}(2010)$ Reconstruction:
  $$D^* \to \pi_S D^\circ \to \pi_S K \pi,$$
- B.R. $B = 0.0263 \pm 0.0010$
- Signature: $\Delta M = M(D^*) - M(D^\circ)$
  $$= 0.14542 \sim m_\pi$$
- $1.80 < M(D^\circ) < 1.92$ GeV



Diffractive D^* Production in PHP: Cross Section

$$Q^2 < 1\ \mathrm{GeV}^2,$$
$$130 < W < 280\ \mathrm{GeV},$$
$$p_T(D^*) > 2\ \mathrm{GeV},\ |eta(D^*)| < 1.5,$$
$$0.001 < x_{I\!P} < 0.018$$



$\Rightarrow$ ZEUS Prelim.: $\sigma^{diff}_{ep\to e'D^*Xp'} = \mathbf{0.74} \pm 0.21(stat.)^{+0.27}_{-0.18}(sys.) \pm 0.16(p.diss.)$ nb

Summary

- asymmetric particle production along $\gamma^* I\!P$ axis with more p_T in γ^* hemisphere
- more transverse momentum needed –
  Possibilities: non-k_T order contributions, higher order QCD diagrams
- parton final state dominated by $q\bar{q}g$ type events
- jet analysis constrains gluon distribution (H1 fit 2 for resolved $\mathbb{P}$)
- gluon emitted in $\mathbb{P}$ direction
- resolved $\mathbb{P}$ describes variety of measurements