Measurement of Exclusive Diffractive Dijet Production in Deep Inelastic Scattering

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The only lepton-proton collider

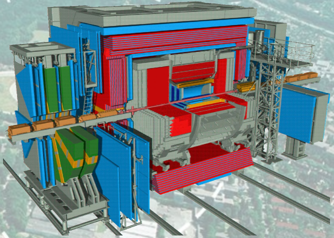
HERA II(2003-2007)
$L = 372\,\mathrm{pb}^{-1}$

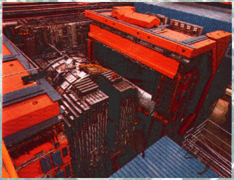
$$\underbrace{\begin{aligned} E_{\mathrm{lepton}} &= 27.5\,\mathrm{GeV} \\ E_{\mathrm{proton}} &= 920\,\mathrm{GeV} \end{aligned}}$$

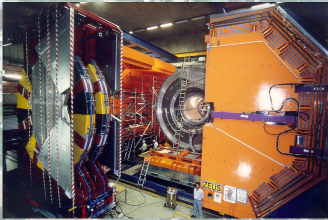
$$\Downarrow$$

$$\sqrt{s} = 318\,\mathrm{GeV}$$

HERA

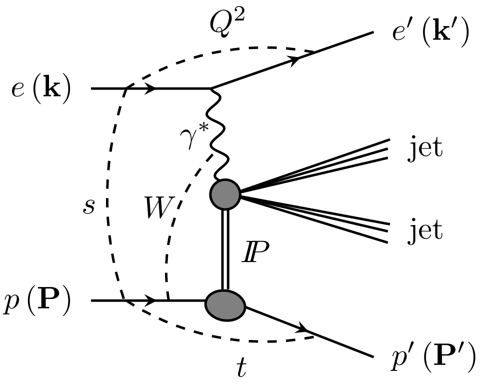






PETRA

Kinematic variables



DIS

- $\mathrm{q} = \mathrm{k} - \mathrm{k}'$
- $\mathrm{Q}^2 = -\mathrm{q}^2$
  $\mathrm{Q}^2 > 1\ \mathrm{GeV}^2 \Rightarrow \mathrm{DIS}$
- $\mathrm{W}^2 = (\mathrm{P} + \mathrm{q})^2$
- $\mathrm{s} = (\mathrm{P} + \mathrm{k})^2$
- $\mathrm{x} = \frac{\mathrm{Q}^2}{2\mathrm{P}\cdot\mathrm{q}}$

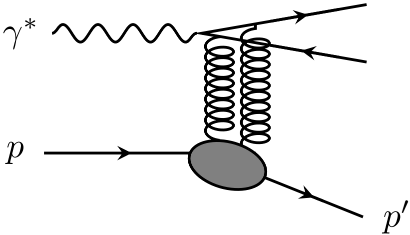
Diffraction

- $\mathrm{x}_{I\!P} = \frac{(\mathrm{P}-\mathrm{P}')\cdot\mathrm{q}}{\mathrm{P}\cdot\mathrm{q}}$
- $\beta = \mathrm{x}/\mathrm{x}_{I\!P}$

Diffractive Dijet Production Mechanisms

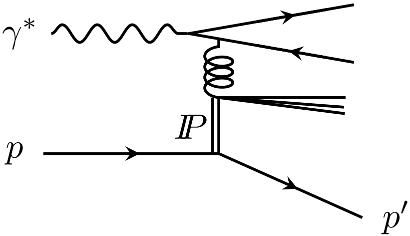
Phys. Lett. B386 (1996) 389-396

2-gluon exchange



fully perturbative calculations based on proton PDFs

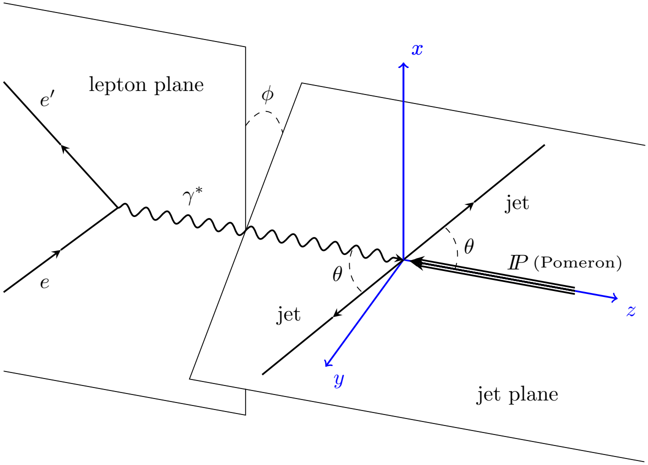
Boson-Gluon Fusion



calculations based on pomeron structure function

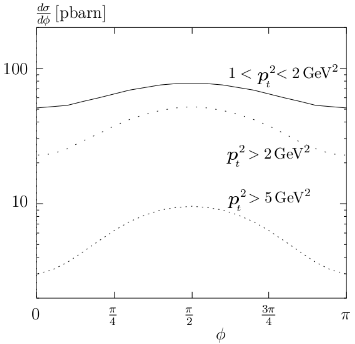
Diffractive Dijet Production in $\gamma^* - \mathbb{P}$ CMS

$$\mathrm{e} + \mathrm{p} \rightarrow \mathrm{e}' + \mathrm{p}' + \mathrm{jet} + \mathrm{jet}$$

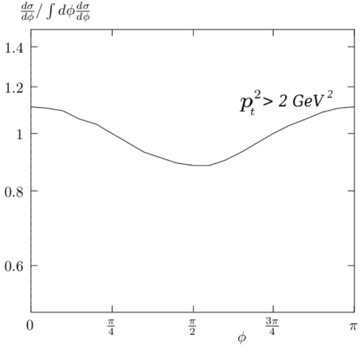


- ϕ - angle between lepton and jet planes
- θ - polar angle of a jet

2-gluon exchange



BGF



$$\mathrm{d}\sigma/\mathrm{d}\phi \propto 1 + \mathrm{A}\cos(2\phi)$$

- $\mathrm{d}\sigma/\mathrm{d}\phi$ described by the same function in both mechanisms
- two-gluon exchange mechanism predicts negative A
- boson-gluon fusion mechanism predicts positive A

Detector Level MC

SATRAP - RapGap 3.01/26 + HERACLES 4.6.3(radiation)
+ JETSET 7.4(hadronisation)

- colour dipole model with saturation
- $q\bar{q}$ and $q\bar{q}g$ in a final state
- description of p_T and ϕ distributions of the dijet sample required hadron level reweighting

Background MC

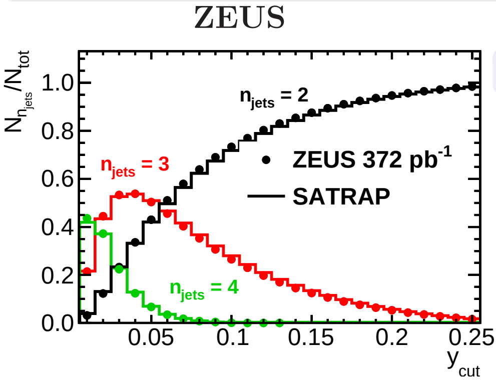
non-diffractive DIS - DJANGOH 1.6 + HERACLES + ARIADNE
diffractive PHP - PYTHIA 6.2

Hadron Level Predictions

- 2-gluon exchange model - RapGap 3.01/26
- BGF Resolved Pomeron - RapGap 3.01/26

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

θ_{ij} is the angle between objects (i, j) and M_X is the total mass of hadronic system.



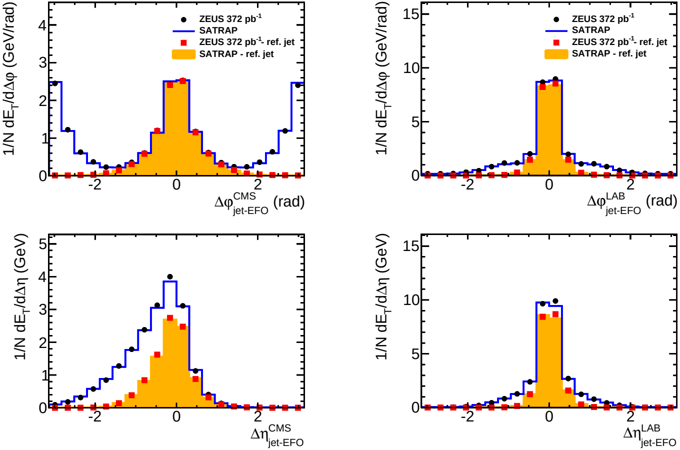
$y_{cut} = 0.15$

- if $y_{ij} < y_{cut}$ then i and j are merged
- every particle must be clustered into a jet

Transverse Energy Flows

$\gamma^* - \mathbb{P}$ CMS | Laboratory Frame

ZEUS | **ZEUS**



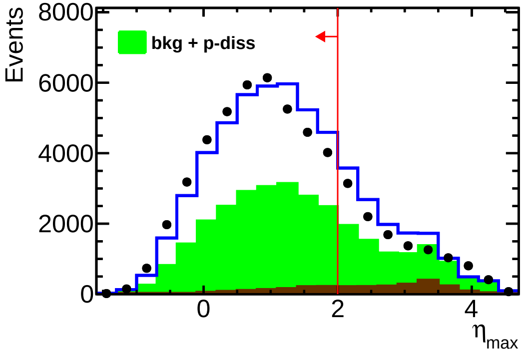
ref. jet
i.e. jet with
higher p_T in
lab. frame

Weighted SATRAP describes the jet shape of exclusive dijet sample in both CMS and laboratory frames

Proton dissociation

Reweighting of the M_Y distribution of p-diss MC to the data using p-diss enriched samples

$$\frac{d\sigma_{\gamma+p\to jet1+jet2+Y}}{dM_Y^2} \approx \frac{1}{M_Y^{1.4\pm0.6}}$$



fraction of p-diss determined by a fit to the η_{max} distribution

$$f_{pdiss} = 45 \pm 4(stat.) \pm 15(syst.)\%$$

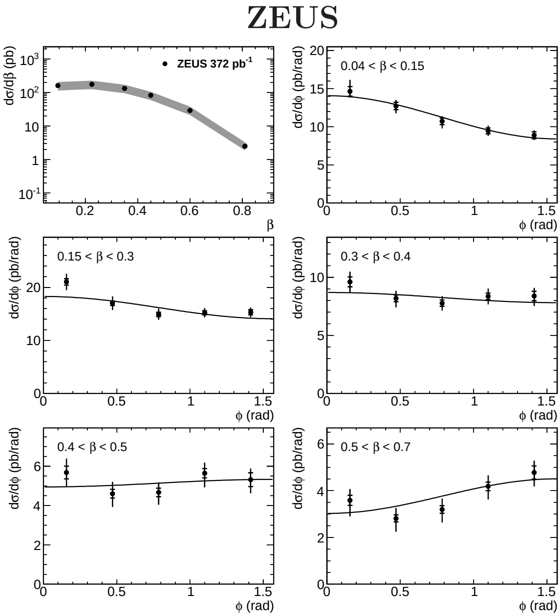
Hadron Level

Kinematic range to which data are unfolded

$$\begin{array}{rcl} 25\ \mathrm{GeV}^2 < & Q^2 & \\ 90\ \mathrm{GeV} < & W & < 250\ \mathrm{GeV} \\ 5\ \mathrm{GeV} < & M_X & \\ & x_{\mathbb{P}} & < 0.01 \\ & n_{jets} & = 2 \\ 2\ \mathrm{GeV} < & p_{T\ jet} & \end{array}$$

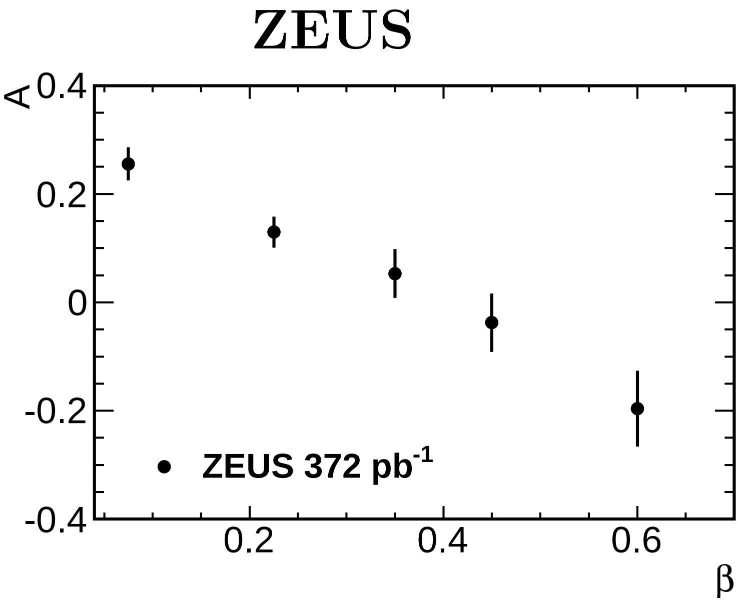
Unfolding and Regularisation

- TSVDunfold (Nucl. Instrum. Meth. A372 (1996) 469-481)
  Singular Value Decomposition with Regularisation



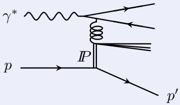
$$d\sigma \propto 1 + A\cos(2\phi)$$

full statistical covariance matrix and the systematic uncertainties included in fit using the profile method


ZEUS
A
0.4
0.2
0
-0.2
-0.4
0.2
0.4
0.6
β
ZEUS 372 pb-1

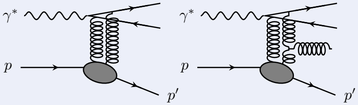
- hadronisation simulated with colour dipole model as implemented in ARIADNE
- proton dissociation not included

Resolved Pomeron Model (G.Ingelman and P.Schlein et al.)



- generated with gluon densities obtained from H1 2006 fits A and B

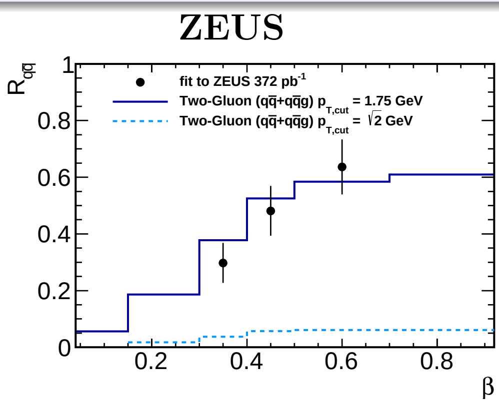
Two-Gluon-Exchange Model (J. Bartels and H. Jung et al.)



- generated with GRV parametrisation of the gluon density functions

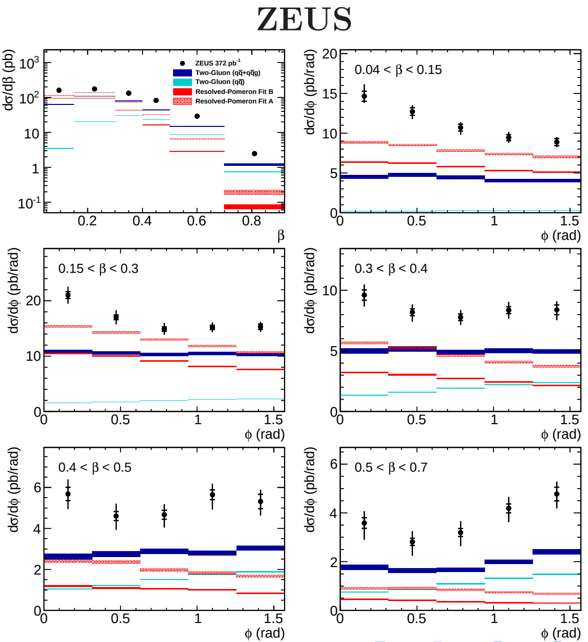
Contribution of $q\bar{q}$ events

- $q\bar{q}$ and $q\bar{q}g$ differ in shape
- the ratio $R_{q\bar{q}} = \sigma(q\bar{q})/(\sigma(q\bar{q}) + \sigma(q\bar{q}g))$ depends on the $p_{T\,\mathrm{cut}}$ applied during generation

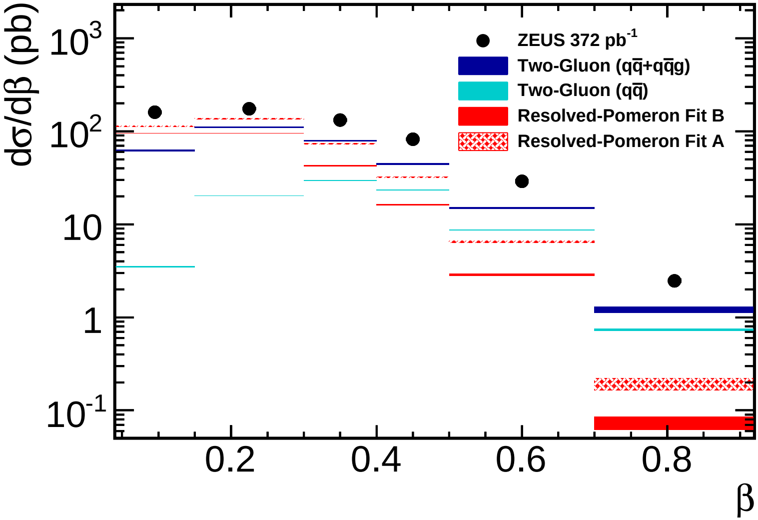


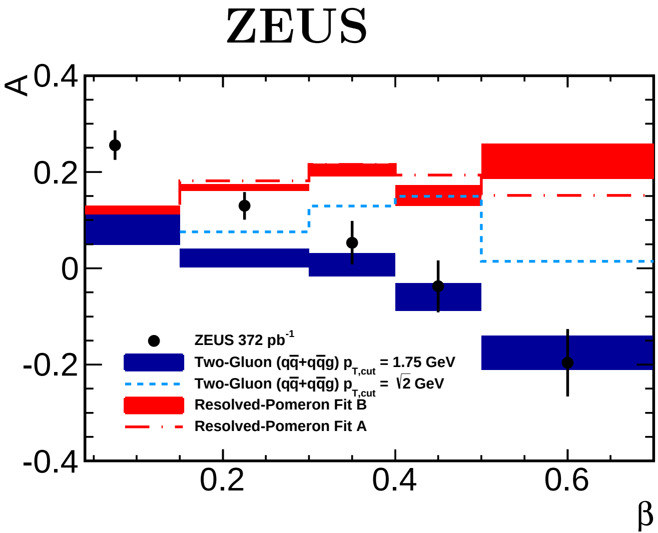
$p_{T\,\mathrm{cut}} = 1.75$ GeV gives good description of measured ratio

Cross sections and models



$d\sigma/d\beta$ - comparison with models





Only stat. uncertainties of model predictions are presented

Summary

- transverse energy flows as functions of pseudorapidity and azimuthal angle have been measured

- the single differential cross section as a function of β and the double differential cross section as a function of β and the azimuthal angle ϕ of exclusive dijets in diffractive DIS has been measured for the first time at HERA

- the data favour 2-gluon exchange model of quark anti-quark production over BGF but both models underestimate the total cross section

Thank You for Your Attention!