Resent results on diffraction at HERA

Leszek Adamczyk

AGH - UST Cracow
On behalf of H1 and ZEUS Collaborations

August 1, 2014

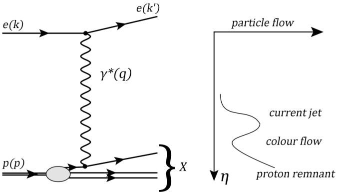
HERA ep collider 1992 – 2007, DESY, Hamburg

- The world's only electron/positron-proton collider
- $E_e = 27.6$ GeV and $E_p = 820(920)$ GeV (575, 460) HE(LE)

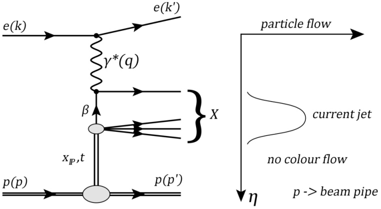
- Total integrated luminosity 0.5 fb^{-1}

Diffraction in ep collisions

Deep Inelastic Scattering (DIS)



Diffractive Scattering

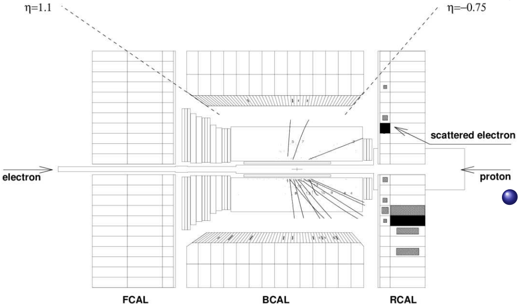


- $Q^2 = -q^2$ - virtuality of the photon
  $Q^2 \approx 0$ - photoproduction,
  $Q^2 \gg 0$ - DIS
- W - photon-proton center-of-mass energy
- x - Bjorken x - fraction of proton's momentum carried by struck quark
- $y = (p \cdot q)/(p \cdot k)$ - inelasticity

- x_{IP} - fraction of proton's momentum carried by exchanged color singlet
- $t = (p - p')^2$- four momentum transfer squared at proton vertex
- $\beta = x/x_{IP}$ - fraction of Pomeron momentum "seen" by the photon

This talk : $X = jet + jet + X'$; $X = jet + jet$; $X =$Vector Meson(VM)

Tagging diffractive events in experiment



- Large Rapidity Gap Method:
  - large acceptance
  - elastic and proton dissociative diffractive events are not distinguishable on event-by-event
- Forward Proton Spectrometer:
  - very small acceptance
  - clean proton tagging
  - direct measurement of t and x_{IP}

Factorization in diffractive scattering

- QCD factorization (strictly proven for diffractive DIS)

$$\sigma^D(\gamma^\star p \to Xp) = \sum_{parton\ i} f_i^D(x, Q^2, x_{IP}, t) \cdot \sigma^{\gamma^\star i}(x, Q^2)$$

f_i^D - Diffractive PDFs which obey DGLAP
- universal for all diffractive processes

$\sigma^{\gamma^\star i}$ - hard scattering cross section

- proton vertex factorization - experimental fact

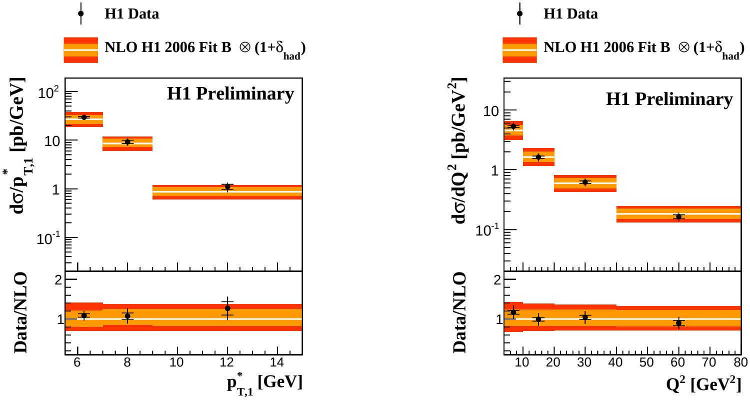
$$f_i^D(x, Q^2, x_{IP}, t) = \underbrace{f_{IP/p}(x_{IP}, t)}_{\text{Pomeron flux}} \cdot \underbrace{f_i^{IP}(\beta = x/x_{IP}, Q^2)}_{\text{Pomeron PDF}}$$

- Test of factorization: use NLO calculations and universal DPDFs to predict and confront with measurement the cross sections for particular diffractive final state. In this talk: diffractive dijet production

Diffractive dijet production with LRG in DIS

H1 Preliminary 2014

Kinematic range: $4 < Q^2 < 80$ GeV^2; $0.1 < y < 0.7$; $p_T^{jet} > 5.5, > 4.0$ GeV

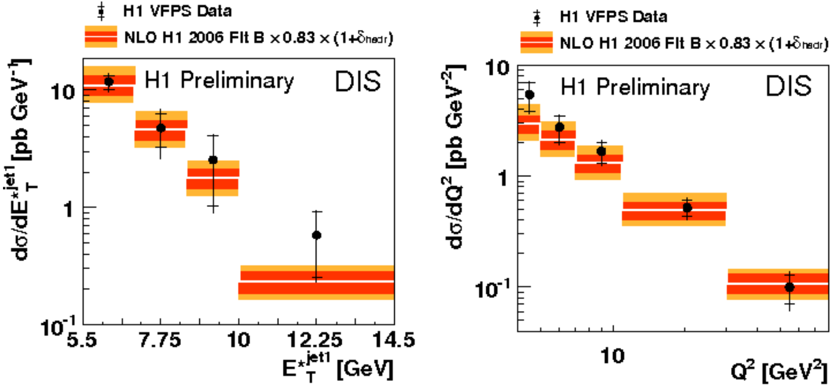


- Data compared to NLOJET++ with DPDF H1 2006 fit
- NLO QCD predictions describe data
- Factorization theorem holds!

Diffractive dijet in DIS with leading proton in VFPS

H1 Preliminary 2014

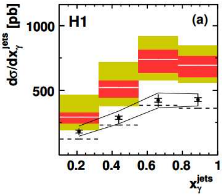
Kinematic range: $4 < Q^2 < 80$ GeV^2; $0.2 < y < 0.7$; $E_T^{jet} > 5.5, > 4.0$ GeV

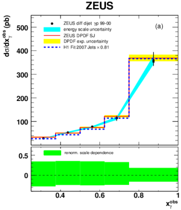


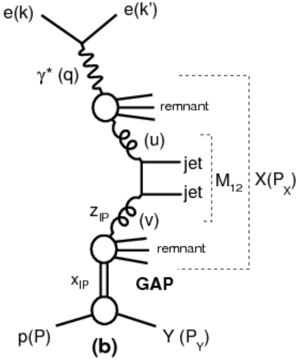
- Data compared to NLO with DPDF H1 2006 fit B
- NLO QCD predictions describe data
- Factorization theorem holds!

Diffractive dijet in photoproduction

- For dijets in DIS: factorization hold
- For dijet in PHP: HERA results not fully decisive
- Factorization breaking observed by H1 but not observed by ZEUS, in slightly different phase space





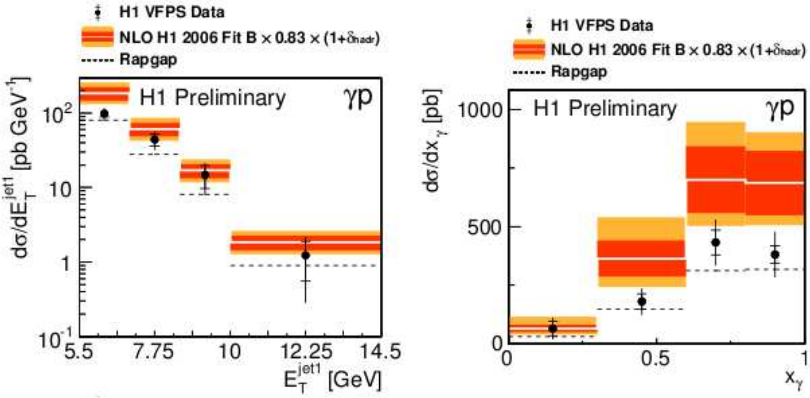


- in pp collisions (TeVatron) the factorization is broken
- quasi-real photon ($Q^2 \approx 0$) can develop a hadronic structure
- resolved photoproduction theory predicts suppression
- the suppression is supposed to be stronger at low scales and low x_γ
- however no dependence of suppression-factor visible

Diffractive dijet in PHP with leading proton in VFPS

H1 Preliminary 2014

Kinematic range: $Q^2 < 2$ GeV^2; $0.2 < y < 0.7$; $E_T^{jet} > 5.5, > 4$ GeV

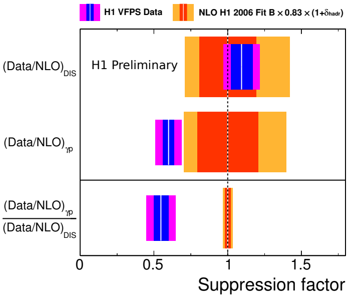


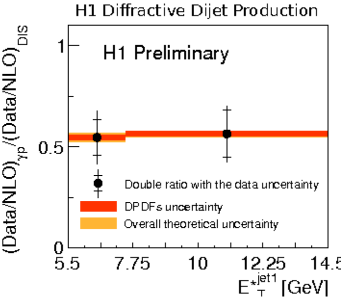
- Data compared to NLO with DPDF H1 2006 fit B
- Data lower than NLO prediction
- No hints for a higher suppression for low x_γ

Dijet in PHP and DIS with leading proton in VFPS

H1 Preliminary 2014

- Results with VFPS confirm LRG measurement
- Double ratio $(DATA/NLO)_{PHP}$ vs $(DATA/NLO)_{DIS}$





- Data/NLO: suppression factor in PHP 0.55
- No hint of a dependence of the E_T of leading jet
- Apparent difference between H1 and ZEUS not yet understood

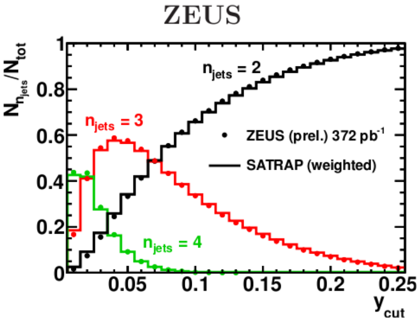
Exclusive dijet production in DIS

ZEUS Preliminary 2014

- Large Rapidity Gap method used to select diffractive events with
  - $Q^2 > 25$ GeV^2
  - $M_X > 5$ GeV
  - $90 < W < 250$ GeV
- exclusive k_t jet algorithm: objects i, j are merged as long as

$$k_t^2 = \min(E_i^2, E_j^2)\sin^2(\theta_{i,j}) < y_{cut} M_X^2$$

- exclusive dijet may originate from: two, three, many partons state
- resolution parameter $y_{cut} = 0.15$ optimizes efficiency vs. purity of dijet sample



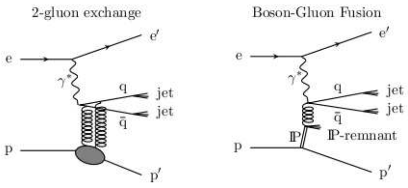
SATRAP:

- color dipole model with saturation
- $q\bar{q}$ and $q\bar{q}g$ in a final state
- good agreement with data
- used for detector level corrections

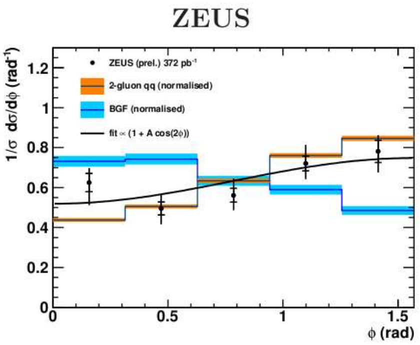
Exclusive dijet production in DIS

ZEUS Preliminary 2014

- select two hard jets $p_t > 2$ GeV to allow comparison to pQCD models



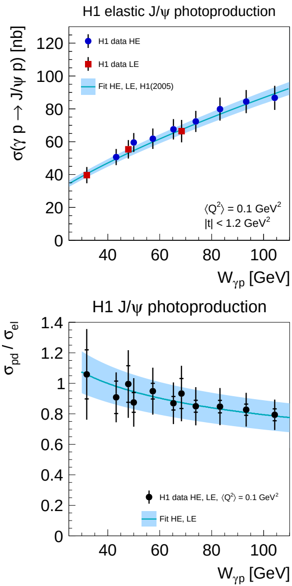
- Two-gluon exchange model (J. Bartels and H. Jung et al.)
- Resolved Pomeron model (G.Ingelman and P.Schlein et al.)
- models predict different shape for dijet azimuthal angular distribution



- data favor the two-gluon exchange model prediction
- The Resolved Pomeron model (BGF) does not describe this data

Elastic and p-diss. photoproduction of J/Ψ mesons

H1 Published 2013

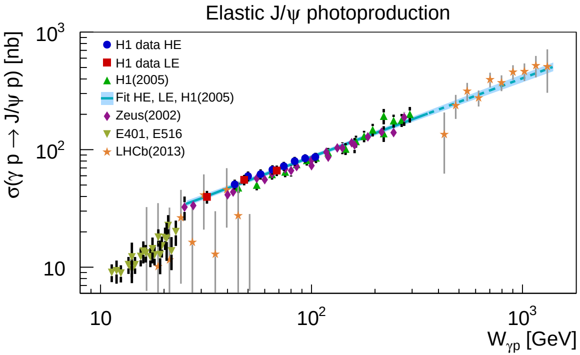


- Kinematic range: $25 < W < 100$ GeV
- Simultaneous fit of elastic and p-diss. cross sections to $\sigma(W) \propto (W/W_0)^{\delta}$
- Fit gives $\delta_{el} = 0.67 \pm 0.03$
- Value of δ_{el} is typical for hard processes.

- Ratio of p-diss. to elastic cross sections decreases with W. Is p-diss. process softer than elastic ?
- Not necessarily:
  - kinematic effect of W-independent $M_Y < 10$ GeV cut? Feynman scaling $x = 1 - M_Y^2/W^2$
  - predicted W-dependent survival probability for the proton dissociation process at high M_Y.

Elastic photoproduction of J/Ψ mesons

H1 Published 2013



- H1 measurement in the transition region from fixed target to previous HERA data
- Fixed target data: steeper slope, lower normalization
- Fit to H1 data extrapolated to higher W describes the LHCb data.

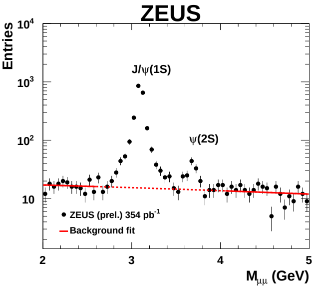
$\sigma_{\Psi(2S)}/\sigma_{J/\Psi}$ in DIS

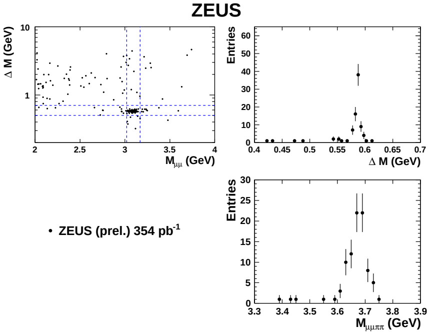
ZEUS Preliminary 2014

Kinematic range: $5 < Q^2 < 70$ GeV^2; $30 < W < 210$ GeV

- $J/\Psi(1S) \to \mu^+ + \mu^-$
- $\Psi(2S) \to \mu^+ + \mu^-$

- $\Psi(2S) \to J/\Psi + \pi^+ + \pi^-$
  $\to \mu^+ + \mu^- + \pi^+ + \pi^-$

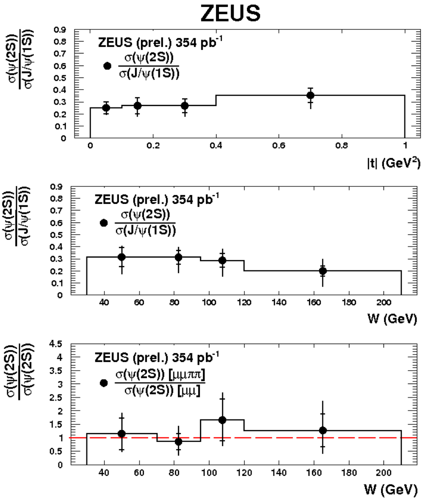


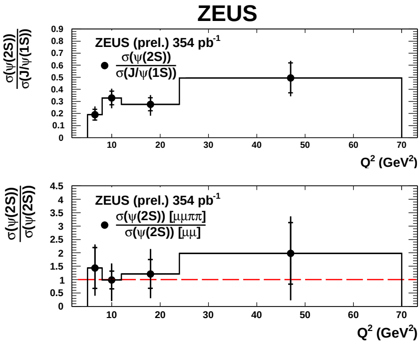


- Ratio insensitive to many systematic uncertainties
- Ratio gives information about the dynamics of the hard process
- pQCD predicts rise of the ratio with Q^2 reaching plateau at $Q^2 \gg M_\Psi^2$

$\sigma_{\psi(2S)}/\sigma_{J/\psi}$ in DIS

ZEUS Preliminary 2014





- Indication of an increase with Q^2
- Independent on W and $|t|$
- Results independent on $\Psi(2S)$ decay channel

Summary

- Diffractive dijets in DIS with LRG confirms factorization in DDIS
- Diffractive dijet production in PHP and DIS with leading proton:
  - in agreement with H1(LRG) (H1 data/theory 0.6, independent of x_γ)
  - not explaining H1/ZEUS results difference (ZEUS data described with NLO QCD)
  - new measurement of double ratios data/NLO in PHP and DIS shows suppression of 0.55 for PHP independent of kinematics
- Exclusive dijet production at DIS, measured by ZEUS, favor model prediction based on a two-gluon exchange
- Elastic and proton-dissociative cross sections of J/Ψ photoproduction were measured by H1. W dependence is typical for hard process
- The cross section ratio $\sigma(\Psi(2S))/\sigma(J/\Psi)$ was measured by ZEUS with improved precision.