Test of factorization in DIS and $\gamma$-p at HERA

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on behalf of the H1 Collaboration

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Diffraction 2014, Primošten, Croatia
HERA
1992–2007
DESY, Hamburg, GE
H1 & ZEUS – 4π

$e^\pm$ 27.5 GeV
p 920 GeV
$\sqrt{s} = 318$ GeV

Ep = 820–920 GeV
$L_{int} = \sim 0.5$ fb$^{-1}$/experiment

Ep = 460 GeV
$L_{int} = 12.4$ pb$^{-1}$

Ep = 575 GeV
$L_{int} = 6.2$ pb$^{-1}$
Diffractive kinematics

\[ Q^2 = -q^2 = (k - k')^2 \]
\[ x = Q^2 / 2Pq \]
\[ x_{IP} = q(P - P')/qP = 1 - E'p/Ep \]
\[ \beta = x/x_{IP} \]
\[ z_{IP} = (Q^2 + M_{j j}^2)/x_{IP} y_s \]
\[ M_Y = m_p \ldots \text{intact proton} \]
\[ m_p \leq M_Y \leq 1.6 \text{ GeV} \ldots \text{intact proton or proton dissociation} \]

Collins factorisation, proven:
\[ d\sigma_{ep \rightarrow eX p} (\beta, Q^2, x_{IP}, t) = \sum_i f_i^D (\beta, Q^2, x_{IP}, t) \cdot d\sigma_{ei} (\beta, Q^2) \]

Proton Vertex Factorisation, consistent with data:
\[ f_i^D (\beta, Q^2, x_{IP}, t) = f_{IP/p} (x_{IP}, t) \cdot f_i (\beta, Q^2) \]
Diffractive dijet production

direct, dominant for DIS
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\[ x_\gamma = \frac{\sum_{i \in \text{jets}} (E_i - P_{z,i})}{\sum_{i \in \text{X}} (E_i - P_{z,i})} \]

\[ \gamma^* (q) \rightarrow (u) \]

\[ \text{jet} \]

\[ M_{12} \]

\[ z_{IP} \]

\[ x_{IP} \]

\[ p(P) \]

\[ p(P') \]

resolved, important for γ-p

\[ \gamma^* (q) \]

\[ e(k) \]

\[ e(k') \]

\[ x_\gamma \]

\[ (u) \]

\[ \text{jet} \]

\[ M_{12} \]

\[ X(P_X) \]

\[ x_{IP} \]

\[ z_{IP} \]

\[ (v) \]

\[ \text{jet} \]

\[ \text{remnant} \]

\[ p(P) \]

\[ p(P') \]

picture holds in LO
Diffractive dijet production

direct, dominant for DIS

\[ x_\gamma = \frac{\sum_{i \in \text{jets}} (E_i - P_{z,i})}{\sum_{i \in X} (E_i - P_{z,i})} \]

resolved, important for $\gamma$-p

picture holds in LO

Collins
Diffractive dijet production

direct, dominant for DIS

Will the photoproduction preserve factorization, or will additional remnants interaction destroy the rapidity gap signature?

Collins picture holds in LO
**Breaking(?)**


\[ E_T^{\text{jet1}(2)} > 5(4) \text{GeV} \]


\[ E_T^{\text{jet1}(2)} > 7.5(6.5) \text{GeV} \]

**H1** and **ZEUS** did not converge on same answer -> new and independent measurement by H1

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**H1** and **ZEUS** did not converge on same answer -> new and independent measurement by H1
Experimental Methods

- LRG method:
  - no activity in forward part of the calorimeter
  - + high statistics
  - - proton dissociative background

- Proton Tagging:
  - detection of the outgoing proton in forward proton spectrometers (PS)
    - FPS and VFPS
  - + direct extraction of diffractive variables, $t$ dependence
  - + free of p-diss background
  - - small acceptance $\rightarrow$ low stats
Diffractive PDFs

- extracted from inclusive DIS measurement
- H1 2006 fit A & B
- diffractive jets constrain the gluon part of DPDF at high $z$
- H1 2007 Jets, ZEUS SJ
Dijets in DIS (1)

- measurement of di-jets in diffraction using the FPS detector (arXiv)
- comparison with NLO predictions (nlojet++) with H1 2006 Fit B and H1 2007 Jets implementation

very good agreement between data and NLO QCD observed, consistency with old LRG measurement (HERA-I) shown
Dijets in DIS (2)

- analysis of full HERA-II statistics based on the LRG method is in preliminary stage
- comparison with NLO QCD with H1 2006 Fit B performed

very good agreement between data and NLO QCD observed
Dijets in DIS (3)

- analysis of events with proton tagged in VFPS
- comparison with NLO QCD (nlojet++) with H1 2006 Fit B performed, “validation region” of the γp analysis
- \( \mu_{r,f} = \sqrt{\left(E_T^{jet1} + Q^2/4\right)} \quad 4 < Q^2 < 80 \text{ GeV}^2 \)

\[
\begin{align*}
0.2 < y < 0.7
\end{align*}
\]

\[
\begin{align*}
E_T^{\ast \text{jet1}} > 5.5 \text{ GeV} \\
-1 < \eta^{\text{jet1}} < 2.5 \\
|t| < 0.6 \text{ GeV}^2 \\
0.010 < x_p < 0.024 \\
z_p < 0.8
\end{align*}
\]

very good agreement between data and NLO QCD observed
Dijets in γP (1)

- Analysis repeated with same conditions except for $Q^2$
- NLO QCD: Frixione et al. (x-check with Klasen & Kramer)
  - $\mu_{r,f} = \sqrt{(E_T^{jet1} + Q^2/4)}$
- DPDF: H1 2006 Fit B
- $\gamma$PDF: GRV HO

Data over-predicted by MC
Dijets in $\gamma P$ (2)

- data over-predicted by NLO
- hint visible for $E_{T}^{jet1}$ (could explain non-observation of ZEUS), suffers from large uncertainties
Dijets in $\gamma P$ (3)

- naively, $x_\gamma \rightarrow 1$ (direct) should not show any suppression
- resolved component expected to be suppressed
- surprisingly, suppression is observed almost independently on $x_\gamma$

problem with rather large uncertainties solved by...
Dijets in $\gamma P$ and DIS (1)

- double-ratio of data/NLO cancels most of systematics uncertainties
- integrated result:

$$\frac{(\text{DATA}/\text{NLO})_{\gamma P}}{(\text{DATA}/\text{NLO})_{\text{DIS}}} = 0.55 \pm 0.10 \text{ (data)} \pm 0.02 \text{ (theor.)}$$

Factorization breaking in diffractive photoproduction observed with sufficient statistical precision not due to proton dissociation
Dijets in γP and DIS (2)

- double-ratio of data/NLO cancels most of systematics uncertainties
- binning driven by DIS statistics
- data/NLO:
  - DIS: \(\sim 1.07\) × PHP: \(\sim 0.61\)

Statistically significant deviation from unity, constant in \(E_{T1}^{jet}\) as well as \(z_{IP}\)
new preliminary results on diffractive dijets from the H1 Collaboration (shutdown 2007!) presented

in DIS, all independent measurements are consistent with Proton Vertex Factorization

in Photo-Production, deviation from unity in the double ratio is consistent with factorization breaking:

\[
\frac{(\text{DATA/NLO})_{\gamma p}}{(\text{DATA/NLO})_{\text{DIS}}} = 0.55 \pm 0.10 \text{ (data)} \pm 0.02 \text{ (theor.)}
\]

stay tuned for final publications (coming SOON)
backup
# Cross Sections

<table>
<thead>
<tr>
<th>Data/NLO QCD</th>
<th>PHP</th>
<th>DIS</th>
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<tbody>
<tr>
<td>242 ± 15 (stat.) ± 33 (syst.) pb&lt;br&gt;400^{+140}_{-90} (scale) ± 80 (DPDF) pb&lt;br&gt;0.60 ± 0.08 (data) ± 0.21 (theor.)</td>
<td>29.7 ± 2.0 (stat.) ± 2.7 (syst.) pb&lt;br&gt;27.2^{+10.2}_{-5.9} (scale) ± 5.3 (DPDF) pb&lt;br&gt;1.09 ± 0.10 (data) ± 0.40 (theor.)</td>
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