ZEUS results on inclusive diffraction

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on behalf of

- Diffractive cross section
- $Q^2$ and $W$ dependences
- Diffractive structure function $Q^2$ and $\beta$ dependences

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Inclusive diffraction $\gamma^* p \rightarrow Xp$

- $\gamma^* p$ cross section
  \[
d\sigma_{\gamma^* p}^D \frac{d\sigma_{e^+ e^- \rightarrow Xp}}{dM_X} = \frac{\pi Q^2 W}{\alpha(1 + (1 - y)^2)} \frac{d^3\sigma_{e^+ e^- \rightarrow Xp}}{dQ^2 dM_X dW}
\]

- 3-fold differential diffr. structure function
  \[
  F_2^{D(3)}(\beta, Q^2, x_{IP}, t) = \frac{\beta Q^4}{4\pi\alpha^2(1 - y + y^2 / 2)} \frac{d\sigma_{e^+ e^- \rightarrow Xp}}{d\beta dQ^2 dx_{IP}}
  \]

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Selection of events $\gamma^* p \rightarrow Xp$ with $M_x$ method

Properties of $M_x$ distribution:

- flat vs $\ln M_x^2$ for diffractive events
- exponentially falling for decreasing $M_x$ for non-diffractive events

\[ \frac{dN}{d\ln M_x^2} = D + c \cdot \exp(b \cdot \ln M_x^2) \]

- $D$, $c$, $b$ from a fit to data
- contamination from reaction $e^p \rightarrow eXN$

Forward Plug Calorimeter (FPC):

CAL acceptance extended by 1 unit in pseudorapidity from $\eta=4$ to $\eta=5$

$\rightarrow$ higher $M_x$ and lower $W$

$\rightarrow$ if $M_x > 2.3$ deposits $E_{FPC} > 1$ GeV recognized and rejected!

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Selection of events $\gamma^* p \rightarrow Xp$ with LPS method

\[ x_L = \frac{p'_z}{p_z} \]

- Measurement of $t$ distribution
- Free of $p$-diss background
- Low acceptance $\rightarrow$ low statistics
Cross section $Q^2$ dependence (LPS method)

- Transition to a constant cross section as $Q^2 \rightarrow 0$
  (similar to total cross section $\sigma_{\gamma p}$)

- Main features of the data described by BEKW parameterization
  (Bartels, Ellis, Kowalski and Wüsthoff)

$F_T^{q\bar{q}} \sim \left( \frac{x_0}{x_{IP}} \right) n_T(Q^2) \beta(1 - \beta)$
$F_T^{q\bar{q}} \sim \left( \frac{x_0}{x_{IP}} \right) n_\sigma(Q^2) \ln \left( 1 + \frac{Q^2}{Q_0^2} \right)(1 - \beta)^\gamma$

- $q\bar{q}$ fluctuations dominant at low $Q^2$

Extension to lower $Q^2$, higher $W$, higher $M_x$
Cross section $W$ dependence ($M_x$ method)

$\gamma^p \rightarrow X N$ cross section

$$
\frac{d\sigma_{\gamma^p \rightarrow X N}^{\text{diff}}(M_x, W, Q^2)}{dM_x} = \frac{\pi Q^2 W}{\alpha(1 + (1 - y)^2)} \cdot \frac{d^3 \sigma_{ep}^{\text{diff}}}{dQ^2 dW dM_x}
$$

p-dissociation events with $M_N < 2.3$ GeV included

- $M_x < 2$ GeV: weak $W$ dependence
- $M_x > 2$ GeV: $d\sigma/dM_x$ rises with $W$
\( \alpha_{IP} \) from diffractive and total \( \gamma^* p \) scattering

**Diffractive cross section:**

\[
\frac{d\sigma_{t\text{ diff}}}{dM_X^2} \sim (W^2)^2(\alpha_{IP}^{\text{diff}}(t) - 1)
\]

- Form fit to data
- Value of \( \alpha_{IP}^{\text{diff}} \) higher than soft Pomeron
- Indication of a rise of \( \alpha_{IP}^{\text{diff}} \) with \( Q^2 \)

**Total cross section:**

\[
\sigma_{t\text{ tot}}^\gamma = \frac{4\pi\alpha}{Q^2} F_2(x,Q^2) \sim \frac{1}{W^2} \text{Im} T_{\gamma^* p \rightarrow \gamma^* p}(W^2,t=0) \sim (W^2)^{\alpha_{IP}^{\text{tot}}(0)-1}
\]

Data (4<M_X<8 GeV) consistent with the same \( W \)-dependence for the diffractive and the total cross section:

\[
\alpha_{IP}^{\text{diff}} \sim 1 + (\alpha_{IP}^{\text{tot}} - 1)/2
\]
**$F_2^{D(3)}$ $Q^2$ dependence (LPS method)**

- Positive scaling violation at all values of $x_{IP}$
- $F_2^{D(3)} \propto Q^2$ at low $Q^2$
- Data well described by BGK saturation model

**Extension to higher $x_{IP}$**

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$F_2^{D(3)} \beta$ dependence (LPS method)

- Different $\beta$ dependences in diffractive and nondiffractive regions
- Data well described by BGK saturation model

Extension to higher $x_{IP}$

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**$F_2^{D(3)}$ at fixed $x_{IP}$ (M$_X$ method)**

**ZEUS**

$F_2^{D(2)}(\beta, Q^2) = x_{IP}F_2^{D(3)}(x_{IP}, \beta, Q^2) |_{x_{IP}=x_0}$

- Maximum near $\beta = 0.5$ consistent with a $\beta (1 - \beta)$ behaviour suggesting main contribution from a quark antiquark state.

- For high $\beta$ $F_2^{D(2)}$ decrease with rising $Q^2$.

- As $\beta \to 0$ $F_2^{D(2)}$ rises. The rise becomes more strong as $Q^2$ increases.

**Evidence for pQCD evolution**
Summary and outlook

- Recent data from ZEUS with improved precision and extended kinematic range
  - $Q^2$ dependence of the diffractive cross section softens for $Q^2 \to 0$
  - $W$ dependence of diffractive and total cross section similar at high $Q^2$
  - data described by dipole models (BEKW, saturation)

- New data in the high $x_{IP}$ region:
  - scaling violations of $F_2^{D(3)}$ at all $x_{IP}$
  - different $\beta$ dependences of $F_2^{D(3)}$ at low $x_{IP}$ and high $x_{IP}$

- Indication for $\alpha_{IP}$ to rise with $Q^2$ in diffraction

- $F_2^{D(2)}$ pQCD like evolution with $\beta$ and $Q^2$