A Measurement of the Pomeron Trajectory from Elastic $\rho^0$ Photoproduction Data

Benno List
University of Hamburg for the H1 Collaboration

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H1prelim-09-016
Introduction

- Photoproduction of $\rho^0$
  - No hard scales
  - Pure soft diffraction
- An ideal channel to investigate the soft pomeron
- Measurement in bins of $t$: Can extract Pomeron trajectory

\[
\frac{d\sigma}{dt} \propto W^{\frac{d}{2}}(\alpha(t) - 1)
\]
The ZEUS Result from 2000

- **ZEUS: EPJ C14(2000) 213-238.**

- Combination of low-energy data (Omega) with ZEUS and H1(‘93) measurements at high W

- Result:
  
  $\gamma p \to p^0 p : \quad \alpha_{p^0}^t(t) = (1.096 \pm 0.021) + (0.125 \pm 0.038)t$

  $\gamma p \to \phi p : \quad \alpha_{\phi}^t(t) = (1.081 \pm 0.010) + (0.158 \pm 0.028)t$
The 2005 H1 Analysis

- Measurement of elastic $\rho^0$ photoproduction from ~240000 events
- Kinematic range $20 < W < 90$ GeV
  $0 < |t| < 0.7$ GeV$^2$ (elastic data)
  → could measure W-dependence of $d\sigma/dt$ in a single experiment
- Result:
  $\alpha_{P,0} = 1.093 \pm 0.003{\text{(stat)}} + 0.008/-0.007 \text{ (syst)}$
  $\alpha_P' = 0.116 \pm 0.027{\text{(stat)}} + 0.036/-0.046 \text{ (syst) GeV}^{-2}$
  → almost identical with ZEUS result
Goal of the present analysis:

**Make a global fit of all data on elastic ρ⁰ photoproduction data in bins of t.**

We confine this analysis to $W > 8\text{GeV}$, to minimize the influence of subleading exchanges.

- **Input Data:**
  - H1 2005: H1prelim-06-011

- **Fit data in bins of t**
  - needs partially swimming of data to common t bins
  - For each t bin: 2 parameters: $d\sigma/dt (W_{0})$, $\alpha(t)$
  - Do a global fit, keeping correlations
Global Fit: Chi2

- Use similar method as used in $F_2$ averaging (H1, arXiv:0904.0929)

$$\chi^2 = \sum_i \frac{(m_i + \sum_k \sigma_{ik} b_k - f_i)^2}{\sigma_i^2} + \sum_k b_k^2$$

$m_i$ Measured values ($i = 1 \ldots M$)

$\sigma_i$ Errors (systematic and uncorrelated systematic)

$f_i(a_j)$ Function values

$a_j$ Parameters ($j = 1 \ldots N$)

$b_k$ Systematic error shifts ($k = 1 \ldots K$)

$\sigma_{ik}$ Coefficients for systematic errors

- Function parameters are defined separately for each $t$ bin

- Result of the fit:
  - Function parameters $a_j$, i.e. $d\sigma/dt (W_0)$ and $\alpha(t_i)$ in each $t$ bin
  - Shifts and errors for all sources of correlated errors
The Omega Data Set


- 3 Bins of \( E_\gamma \): 20-30, 30-45, 45-70GeV → \( <W> = 6.8, 8.3, 10.3 \) GeV
  
  Use data at 8.3 and 10.3 GeV (subleading trajectory largest at 6.8 GeV)

- \( 0.06 < |t| < 1 \text{GeV}^2 \)

- Original data recovered from plots in paper, moved to bin centres of fit and averaged

- Statistical errors scaled by \( \sqrt{\chi^2/df} \) of t-fit

- Correct for mass range of x-section definition
  
  \( 0.56 < m_{\pi\pi} < 0.92 \text{GeV} \rightarrow 0.27 < m_{\pi\pi} < 1.52 \text{GeV} \):

  factor \( 1.187 \pm 0.053 \)

- Overall normalization taken from t-integrated cross section, normalization error 10-13%
The H1 2005 Data Set

- Very precise data set, covering a large W range
- 10 sources of correlated systematic errors are considered
- Correlations are fully kept in the fit
- Dominant uncertainty: subtraction of p-dissociative bg. at large |t|
- Normalization uncertainty 5.3%
- Sufficient for $\alpha(t)$ determination at |t| < 0.6 GeV

![Graph showing Elastic $\rho^0$ Photoproduction](image)
The ZEUS 1994 Data Sets

- References:
  J. Breitweg et al. (ZEUS Collab.): EPJ C2 (1998) 247. (ZEUS low-t)

- ZEUS LPS: \(<W>=73\text{GeV}\), 4 t bins, 0.073 < |t| < 0.4\text{GeV}^2,
  mass range correction 1.09,
syst. errors: 11% uncorrelated, 6% normalization

- ZEUS low-t: \(<W>=71.7\text{GeV}\), 12 t bins for 0<|t|<0.5\text{GeV}^2
syst. Errors: 10% uncorrelated, 5% normalization
measurements are corrected for different t-binning and averaged


\(\gamma p \rightarrow p\eta\) Pomerion Trajectory from \(p^0\) Photoproduction

The ZEUS High-t Data Set

- Measurement of elastic rho production from 1995 data at $<W>$=94GeV for $0.3 < |t| < 1.6$GeV$^2$
- Correlated errors from proton dissociation subtraction are available and taken into account, plus 15% normalization uncertainty

![Graph showing data points and error bands](image)

The Global Fit

H1 PRELIMINARY

Elastic $\rho^0$ Photoproduction

- $\bigstar$: Omega
- $\blacktriangle$: H1 '05 Preliminary
- $\blacktriangleleft$: H1 '93
- $\blacksquare$: ZEUS '94 LPS
- $\blackbox$: ZEUS '94
- $\bullet$: ZEUS '95

Fit

Correlated Errors

H1prelim-09-016
The Fit Result

- Overall $\chi^2/\text{df} = 111.7 / 80$
  (106 data points - 2x13 parameters)
  $\rightarrow$ satisfactory fit quality

- Omega data at $W=8.3\text{GeV}$ lie systematically high
  $\rightarrow$ some tension in normalization, below $3 \, \sigma$

- Error correlations (especially from normalization) are fully propagated

- High $|t|$ bins profit from precise data at low $|t|$, which constrains the relative normalization of data sets
The new result from the global fit:

\[ \alpha_0 = 1.0871 \pm 0.0026 \text{(stat)} \pm 0.0030 \text{ (syst)} \]
\[ \alpha' = 0.126 \pm 0.013 \text{(stat)} \pm 0.012 \text{ (syst) GeV}^{-2} \]

\[ \chi^2/df = 14.7 / (13-2) \]
(correlations taken into account)

H1Prelim-06-011 (H1 data alone):
\[ \alpha_0 = 1.093 \pm 0.003 \text{(stat)} \pm 0.007 \text{ (syst)} \]
\[ \alpha' = 0.116 \pm 0.027 \text{(stat)} \pm 0.036 \text{ (syst) GeV}^{-2} \]

ZEUS EPJ C14(2000)213:
\[ \alpha_0 = 1.096 \pm 0.021 \]
\[ \alpha' = 0.125 \pm 0.038 \text{ GeV}^{-2} \]

All 3 results are in perfect agreement
(expected, as ZEUS and H1prelim-06-011 are consistent)

Compare to Donnachie & Landshoff:
\[ \alpha_0 = 1.0808 \text{ Donnachie, Landshoff PL B296(1992)227} \]
\[ \alpha' = 0.25 \text{ GeV}^{-2} \text{ Jaroszkiewicz, Landshoff, PR D10(1997)170; Landshoff, NP Proc.Suppl.12(1990)397} \]
The Three Results

- ZEUS (+Omega+H1 '94): suggests completely linear trajectory
- H1 '05: agrees with D&L slope at low t, is from a single experiment
- New result: gives same slope again, as expected
  BUT: is much more precise than ZEUS '00 result at low |t|,
  may hint at flattening of trajectory,
  compatible with D&L slope at low |t|!
Flattening of the Pomeron Trajectory?

- Do we see a flattening of the Pomeron trajectory? Has been predicted from Gauge/String duality and observed by UA8

- It seems that even at large $|t|$, the rho cross section does never fall with $W$, it seems to stay constant $\Rightarrow \alpha(t) \geq 1$


A. Brandt [UA8], NP B5141(1998)3.
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Summary and Conclusions

- A new global fit of elastic $\rho^0$ photoproduction data for $8 < W < 100$ GeV has been performed in 13 bins of $t$, at $0.01 < |t| < 0.95$ GeV$^2$, taking into account error correlations.

- From the $W$-dependence of $d\sigma/dt \sim W^{4(\alpha(t)-1)}$, the Pomeron trajectory has been extracted.

- The resulting values for $\alpha_P(t)$ are in agreement with
  - A fit to Omega+H1'93+ZEUS data
  - A fit to the H1 2005 data alone

- The new global fit shows significant deviation from D&L pomeron at $|t| > 0.5$ GeV$^2$.

- A linear Pomeron trajectory with slope $\alpha' = 0.125$ GeV$^{-2}$ is not excluded.

- But: data is also compatible with (and suggestive of)
  - the D&L pomeron at low $|t|$.
  - and a constant trajectory at larger $|t|$.