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Publication Date
1970-01-05
Submitted to Physical Review

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January 5, 1970

AEC Contract No. W-7405-eng-48

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REGGE-POLE FIT TO SERPUKHOV $\pi^{-}p$ TOTAL CROSS SECTION DATA

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January 5, 1970

ABSTRACT

An additional Regge pole with a negative residue and a positive signature is suggested to fit the high energy $\pi^{-}p$ total cross sections recently measured at Serpukhov. We give some experimental implications for the total cross sections and the ratio of the real to the imaginary part of the forward scattering amplitude of $\pi^{-}p$ at high energies.
In Fig. 1, we present the recent Serpukhov\textsuperscript{1} data for $\pi^- p$ total cross sections from 20 to 65 GeV/c. Also plotted is an earlier version of the data from Brookhaven\textsuperscript{2} at lower energies for both $\pi^- p$ and $\pi^+ p$. In the spirit of former Regge pole analyses,\textsuperscript{3} a best \( \chi^2 \) fit to these data was obtained. For the 38 experimental $\pi^+ p$ points from Refs. 1 and 2, a \( \chi^2 \) of 131 was the result. Curve (a) in Fig. 1 shows this fit. We see that the fit is poor for $\pi^- p$ above 50 GeV/c. The theoretical curve (a) is characteristically going down smoothly but the experimental points flatten out and even have a suggestion of a rise. In Table I we summarize the fits we have tried. The Regge poles used were $P$, $P'$, and $\rho$. The intercepts of $P'$ and $\rho$ were both set at a value of 0.5. Variations of these parameters give little change to our results.

A natural suggestion to improve the situation described above is to introduce an additional Regge pole of positive signature (like $P'$) but of negative residue in the forward direction ($t = 0$). We find that a large range of allowable intercepts $\alpha_N$ for the negative pole can be made to fit the data. In Fig. 1, we show the solution (b) which was fitted to 29 $\pi^- p$ and 9 $\pi^+ p$ data points. We then calculated the $\pi^+ p$ above 20 GeV/c. A comparison with the measured $\pi^- n$ cross sections\textsuperscript{1} (which by charge symmetry should be equal to $\pi^+ p$) gives good agreement. This solution has the same asymptotic total cross section $\sigma^\infty_T(\pi^\pm p)$ equal to 33.0 mb given by Barger and Phillips\textsuperscript{4} for their cut model. As we shall see below, about the same asymptotic value is also preferred by the sum rules discussed later. The $\chi^2$ for curve (b) is given in Table II. Also in Table II are presented other solutions. We notice
that the $\chi^2$ is good until $\alpha_N$ goes below 0.63. The coefficient $c_0$ in this table is defined in Ref. 3. In Fig. 2, we show the relation between $\sigma_T^\infty(\pi^\pm p)$ and $\alpha_N$ for 38 data points when $\alpha_p = \alpha_p = 0.5$. In Fig. 3 the predicted values of the ratio of the real to the imaginary part of the forward amplitude, $A'(0)$, are shown for two of the solutions. We observe that this ratio goes through zero and becomes positive in the range of pion incoming momenta, $P_{lab}$, soon to become available. Former Regge pole fits could only approach zero for this ratio asymptotically. In Fig. 4, the same two solutions (a) and (b) are again presented to predict the total cross sections for $\pi^\pm p$ from 20 to 800 GeV/c.

This paper can be considered as an extension of Ref. 3 but restricted to the forward direction of the $\pi^\pm p$ system. The equations we need of that reference are Eqs. (1) and (5) and also Eqs. (29) and (31). The latter two equations are the sum rules for the positive-signature Regge trajectories, $P$, $P'$, and $N$, and for the negative-signature, $\rho$, Regge trajectory. When these sum rules are used the intercepts of $P'$, $N$, and $\rho$ become limited in range. An adequate fit gave a $\chi^2$ of 67.5 for 48 $\sigma_T$ data points. The ten $\pi^-n$ cross sections were included as $\pi^+p$ points. The positive sum rule had $\chi^2 = 2.8$, the negative sum rule $\chi^2 = 0$, the $\chi^2$ for $\sigma_T$ was 64.7, and $\sigma_T^\infty(\pi^\pm p) = 31.9$ mb, $\alpha_p = 0.71$, $\alpha_N = 0.79$, and $\alpha_\rho = 0.64$.

In conclusion, with a simple extension within the Regge-pole framework, we have shown that the $\pi^-p$ and $\pi^-n$ total cross sections measured at Serpukhov can be easily explained. We reserve to a later time whether the $N$ pole has a trajectory with a particle on it or not.
and whether factorization is obeyed or not. These questions become important when we expand our considerations to data away from the forward direction.

ACKNOWLEDGMENTS

The author thanks Dr. Donald M. Austin and Dr. William Greiman for valuable assistance in programming and is grateful to Professor Geoffrey F. Chew for the hospitality of the Theoretical Group at the Lawrence Radiation Laboratory.
Table I. Asymptotic limit $\sigma_T^\infty (\pi^\pm p)$ for $\alpha_p = \alpha_\rho = 0.5$.

<table>
<thead>
<tr>
<th>Number of data points</th>
<th>Type of data</th>
<th>$\sigma_T^\infty (\pi^\pm p)$</th>
<th>$\chi^2$</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>$\pi^- p$</td>
<td>22.2 mb</td>
<td>87</td>
<td>1 and 2</td>
</tr>
<tr>
<td>9</td>
<td>$\pi^+ p$</td>
<td>20.5 mb</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>$\pi^+ p$ and $\pi^- n$</td>
<td>21.4 mb</td>
<td>29</td>
<td>1 and 2</td>
</tr>
<tr>
<td>38</td>
<td>$\pi^- p$ and $\pi^+ p$</td>
<td>22.0 mb</td>
<td>131</td>
<td>1 and 2</td>
</tr>
</tbody>
</table>

Table II. Negative pole solutions assuming $\alpha_p = \alpha_\rho = 0.5$ for 38 points.

<table>
<thead>
<tr>
<th>$\alpha_N$</th>
<th>$\sigma_T^\infty (\pi N)$</th>
<th>$C_0$ (mb GeV)</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$N$</td>
<td>$P'$</td>
</tr>
<tr>
<td>0.9972</td>
<td>1000 mb</td>
<td>-497.8</td>
<td>46.5</td>
</tr>
<tr>
<td>0.99</td>
<td>290 mb</td>
<td>-143.0</td>
<td>46.7</td>
</tr>
<tr>
<td>0.95</td>
<td>75.8 mb</td>
<td>-37.4</td>
<td>49.5</td>
</tr>
<tr>
<td>0.90</td>
<td>48.7 mb</td>
<td>-26.2</td>
<td>53.4</td>
</tr>
<tr>
<td>0.80</td>
<td>35.6 mb</td>
<td>-28.3</td>
<td>67.1</td>
</tr>
<tr>
<td>0.767</td>
<td>33.0 mb</td>
<td>-30.1</td>
<td>70.1</td>
</tr>
<tr>
<td>0.69</td>
<td>28.0 mb</td>
<td>-33.0</td>
<td>70.6</td>
</tr>
<tr>
<td>0.65</td>
<td>24.6 mb</td>
<td>-29.6</td>
<td>59.2</td>
</tr>
</tbody>
</table>
FOOTNOTES AND REFERENCES

* This work was supported in part by the U. S. Atomic Energy Commission.

† Visiting Scientist.


FIGURE CAPTIONS

Fig. 1. Total cross sections for $\pi^+p$ from Refs. 1 and 2 compared with solutions (a) and (b).
- from Ref. 2.
- from Ref. 1.

Fig. 2. The asymptotic cross section $\sigma_T^\infty(\pi^+p)$ as a function of the intercept $\alpha_N$.

Fig. 3. The predicted $\text{Re} A'(0)/\text{Im} A'(0)$ for two solutions of Table II
(a) $\alpha_N = 0.767$, $\sigma_T^\infty(\pi^+p) = 33.0$ mb; (b) $\alpha_N = 0.9973$, $\sigma_T^\infty(\pi^-p) = 1000$ mb.
- $\pi^-p$, - $\pi^+p$.

Fig. 4. The predicted total cross sections for the same two solutions (a) and (b) of Fig. 3.
- $\pi^-p$, - $\pi^+p$. 
Fig. 1
Fig. 2

\[ \sigma_T^{\pi^+ p}(\text{mb}) \] vs. \( \alpha_N \)

- Values range from 10 to 1000.
- Points are marked at intervals of 0.1 in \( \alpha_N \).
- The graph shows an increasing trend as \( \alpha_N \) approaches 1.
Fig. 3

\[ \sigma_T^\omega(\pi^\pm p) = 1000 \text{ mb} \]
\[ \alpha_N = 0.9973 \]

\[ \sigma_T^\omega(\pi^\pm p) = 33.0 \text{ mb} \]
\[ \alpha_N = 0.767 \]
\[ \sigma_T^\infty (\pi^\pm p) = 1000 \text{ mb} \]
\[ \alpha_N = 0.9973 \]

\[ \sigma_T^\infty (\pi^\pm p) = 33.0 \text{ mb} \]
\[ \alpha_N = 0.767 \]

Fig. 4
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