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# Duality and $\pi N$ charge-exchange data

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A previous analysis of $\pi^- p$ charge-exchange data, using the two-component duality hypothesis and fixed-$t$ dispersion relations, is updated to include recent polarization measurements and high-statistics differential cross sections.

In a previous paper[1] (hereinafter called DM), we have shown that the two-component duality hypothesis,[2] i.e., resonance dominance of the imaginary parts of those amplitudes corresponding to non-Pomeron exchange in the $t$ channel, when combined with the use of fixed-$t$ dispersion relations, leads to an economical but theoretically reasonable parametrization which may be used to obtain quantitatively satisfactory fits to $\pi N$ charge-exchange (CEX) data in the phase-shift region ($k_{\text{lab}} \lesssim 2$ GeV/$c$). The same technique has subsequently been successfully used to analyze data for $\gamma p \to K^+\Lambda$ (Ref. 3), and the pair of reactions $\pi^- p \to K^0\Lambda$ and $K^- p \to \pi^0\Lambda$.[4]

At the time of the previous analysis, no CEX polarization data were available, but recently measurements of this quantity have been made at the five momenta 1.03, 1.245, 1.44, 1.59, and 1.79 GeV/$c$,[5] and it is of interest to see whether the technique used in DM can also produce a satisfactory fit to this new type of data. The resulting resonance spectrum would be useful for other applications involving $N^*$'s in resonance-saturated fixed-$t$ dispersion relations. We have therefore updated the analysis of DM using all the $\pi N$ CEX differential cross sections (DCS) and measurements of the difference $\Delta = \sigma_T(\pi^+ p) - \sigma_T(\pi^- p)$ as before, and have now, in addition, included the new polarization measurements.[5] We have also taken the opportunity of improving the quality of the data set by including the recent DCS measurements of Blasberg *et al.*[6] at 0.502, 0.566, 0.618, 0.676, and 0.718 GeV/$c$, and the high-statistics DCS results of Nelson *et al.*[7] at 1.03, 1.59, 1.79, and 1.99 GeV/$c$. The data set now consists of 868 angular points and 29 values of $\Delta$. As before, the angular region is restricted to $|t| \leq 1$ GeV$^2$.

The technique used is precisely that used previously, and for details we refer to DM. Briefly, the imaginary parts of each resonant partial-wave amplitude of definite isospin is written

$$\mathrm{Im} f_{l\pm}(W) = \frac{1}{q}\,\frac{x(\frac{1}{2}\Gamma)^2}{(W_R - W)^2 + (\frac{1}{2}\Gamma)^2}$$

where $W_R$ is the mass, $\Gamma$ the total width, and $x$ the elasticity of the resonance. The width is given an energy dependence of the form

$$\Gamma(q) = \Gamma_R \left(\frac{q}{q_R}\right)^{2l+1} \frac{D_l(q_R r)}{D_l(qr)},$$

where $D_l$ is the barrier factor of Blatt and Weisskopf,[8] and $r = 0.45 M_\pi^{-1}$. The parameters $W_R$, $\Gamma_R$, and $x$ are constrained to lie within bands suggested by comparing different phase-shift analyses (for the details see DM). The only change in the spectrum we have made is to replace the $D_{13}(2029)$, for which there now seems less evidence, by a strongly suggested $F_{15}(1975)$ (Ref. 9).

An exception to the above resonance form is the $P_{33}(1232)$, which we treated as a fixed contribution with a form (given explicitly in DM) which gives a good fit to the phase shifts of Carter *et al.*[10] The imaginary parts at high energies are also treated as fixed contributions and, as in DM, we have evaluated them using the effective Regge-pole model of Barger and Phillips.[11] Real parts are then calculated from the fixed-$t$ dispersion relations in terms of the parameters $W_R$, $\Gamma_R$, and $x$ of each resonance.

Starting from our previous best solution having the barrier factors given above (model $c$ of DM, which had a normalized $\chi^2$ of 3.84 for 649 data points) we have varied the resonance parameters to fit the data set as described above. The final solution has a normalized $\chi^2$ of 3.70, and the resulting fit to some of the new data is shown in Fig. 1. The parameters of the solution are given in Table I. Comparing these with the most recent $\pi N$ phase-shift analysis,[9] we find that there is good agreement for the masses and elasticities,

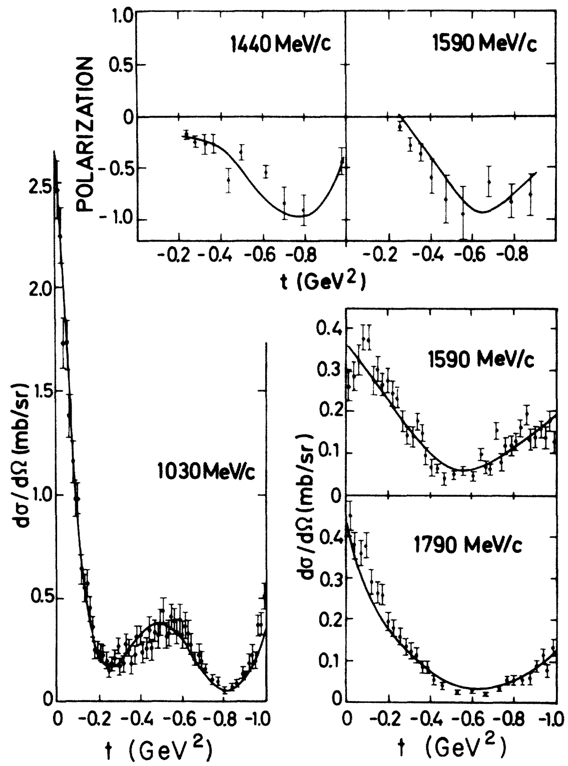


FIG. 1. Fit to some of the recent polarization (Ref. 5) and high-statistics DCS data (Ref. 7) for the solution shown in Table I.

but for those states with $\Gamma_R \gtrsim 150$ MeV we usually find substantially larger widths. An interesting feature of the Saclay solution[9] is that it predicts two $P_{11}$ states in addition to the well-established

TABLE I. Values of the resonance parameters. Those of the $P_{33}(1232)$ were kept fixed in the analysis.

| | $I=\frac{1}{2}$ | | | | $I=\frac{3}{2}$ | | |
|---|---|---|---|---|---|---|---|
| State | Mass (MeV) | Width (MeV) | $x$ | State | Mass (MeV) | Width (MeV) | $x$ |
| $S_{11'}$ | 1530 | 73 | 0.33 | $S_{31}$ | 1659 | 193 | 0.35 |
| $S_{11''}$ | 1700 | 145 | 0.46 | $P_{31}$ | 1925 | 170 | 0.15 |
| $P_{11'}$ | 1496 | 318 | 0.53 | $P_{33'}$ | 1232 | 113 | 1.0 |
| $P_{11''}$ | 1668 | 81 | 0.15 | $P_{33''}$ | 1743 | 185 | 0.12 |
| $P_{13}$ | 1700 | 334 | 0.20 | $P_{33'''}$ | 2130 | 170 | 0.20 |
| $D_{13}$ | 1513 | 109 | 0.46 | $D_{33}$ | 1649 | 399 | 0.15 |
| $D_{15}$ | 1655 | 175 | 0.44 | $D_{35}$ | 1964 | 168 | 0.16 |
| $F_{15'}$ | 1675 | 108 | 0.54 | $F_{35}$ | 1844 | 353 | 0.12 |
| $F_{15''}$ | 1975 | 110 | 0.05 | $F_{37}$ | 1925 | 224 | 0.44 |
| $F_{17}$ | 2051 | 344 | 0.09 | | | | |
| $G_{17}$ | 2161 | 338 | 0.23 | | | | |

Roper resonance, and it may be significant that our single additional $P_{11}$ has a mass, width, and elasticity all midway between the parameters of the two suggested new states.

We have not, at this time, explored further possible solutions, either by using different barrier factors (as was done in DM) or by varying the input spectrum, because the additional data we have used from Refs. 5–7 may not yet be final. However, it is already clear that the two-component duality hypothesis, when used in conjunction with fixed-$t$ dispersion relations, is capable of providing acceptable fits to all $\pi N$ CEX data (for $|t| \leq 1$ GeV$^2$) in the phase-shift region, including polarizations.

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