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O.V. Dumbrais, N.M. Queen

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O.V. Dumbrais, N.M. Queen*

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* On leave of absence from the University of Birmingham, UK

Recent measurements above 20 GeV at Serpukhov[1] indicate unexpectedly large differences between the values of the corresponding particle and antiparticle total cross sections for several reactions. These differences are particularly large in the case of kaon-nucleon scattering, for which the existing data suggest approximately constant cross sections with the values

$$\sigma(K^+ p) = (17.3 \pm 0.2)\ \text{mb}, \quad \sigma(K^- p) = (21.0 \pm 0.5)\ \text{mb}, \tag{1}$$

$$\sigma(K^+ n) = (17.6 \pm 0.4)\ \text{mb}, \quad \sigma(K^- n) = (19.9 \pm 0.7)\ \text{mb}$$

for laboratory energies ω between 20 and 55 GeV. It is hard to reconcile these results with the Pomeranchuk theorem[2], which requires the asymptotic equality $\sigma(K^+ N) = \sigma(K^- N)$.

If $\sigma(K^+ N)$ and $\sigma(K^- N)$ are assumed to tend to different asymptotic limits, then from a twice subtracted dispersion relation it follows[2] that the amplitudes $f^{\pm}_N \equiv D^{\pm}_N + i A^{\pm}_N$ for forward $K^{\pm} N$ scattering behave asymptotically such that

$$a^{\pm}_N(\omega) \equiv \frac{D^{\pm}_N(\omega)}{A^{\pm}_N(\omega)} \approx \frac{(\sigma^{\mp}_N - \sigma^{\pm}_N) \log \omega}{\pi \sigma^{\pm}_N}, \tag{2}$$

in contrast with the generally expected limit $a_N^{\pm} \to 0$ It is therefore of interest to estimate in what energy region the qualitative behaviour of the phases of the amplitudes in this case would differ from that which has hitherto been expected and, in particular, at what energies experimental information on $a_N^{\pm}$ would allow an independent test of the Pomeranchuk theorem. In order to study the consequences of a violation of the Pomeranchuk theorem, we shall assume for definiteness that for $\omega \geq 55$ GeV the $K^{\pm}N$ total cross sections are equal to their asymptotic limits, for which we take the values (1).

Consider the twice-subtracted dispersion relation in the form[3]

$$D_N^{\pm}(\omega) = I_N^{\pm}(\omega) + \frac{k^2}{4\pi^2} \int_{\omega_0}^{\infty} \frac{d\omega'}{k'} \left[\frac{\sigma_N^{+}(\omega')}{\omega' \mp \omega} + \frac{\sigma_N^{-}(\omega')}{\omega' \pm \omega} \right], \quad (3)$$

where the term $I_N^{\pm}$ contains two subtraction constants (the $K^{\pm}N$ scattering lengths), pole terms depending on the squares of the KNY coupling constants g_Y^2 $(Y = \Lambda, \Sigma)$, and a dispersion integral over $A_N^{-}(\omega)$ from the unphysical $\pi\Lambda$ threshold to some energy $\tilde{\tilde{\omega}}$ in the low-energy physical region, which we choose to be $\tilde{\tilde{\omega}} = 574$ MeV; the integrations over σ_N^{+} and σ_N^{-} begin at $\omega_0 = m_K$ and $\omega_0 = \tilde{\tilde{\omega}}$, respectively.

Using the existing experimental data up to 55 GeV (references to the data below 20 GeV are listed in [3]), together with our assumptions about the asymptotic behaviour of $\sigma_N^{\pm}$, the integral term in (3) may be accurately evaluated. However, the low-energy contribution $I_N^{\pm}(\omega)$ suffers from serious uncertainties, mainly because of our poor knowledge of the g_Y^2 and the structure of

$A_N^-(\omega)$ for unphysical energies $\omega < m_K$. Most previous estimates [3] of the g_Y^2 are now dubious, since they were obtained from dispersion relations with only one subtraction, which are invalid under our assumptions. The remaining evidence for the values of g_Y^2 is rather meagre. In principle the g_Y^2 could be obtained by evaluating a twice-subtracted dispersion relation, e.g. (3), at the low energies at which $D_N^{\pm}$ are already accurately known. However, it is found [3] that the use of such a dispersion relation at these energies cannot give a good determination of the g_Y^2 because of strong cancellations.

If the existing parameters [3] are used to calculate $I_N^{\pm}$, we find that the uncertainties in the values of $D_N^{\pm}$ predicted by (3) at the energies of interest are very large and arise almost entirely from those in $I_N^{\pm}$. The reason for this is that $I_N^{\pm}(\omega)$ is proportional to ω for large ω, as is evident from its explicit form [3]. Although with increasing energy the contribution $I_N^{\pm}(\omega)$ is eventually dominated by the integral term in (3), which behaves asymptotically with an additional logarithmic factor, even in the 1000 GeV range the term $I_N^{\pm}$ is still a very significant contribution to $D_N^{\pm}$ and is cancelled almost completely by contributions from higher energies. This is a serious defect of the familiar twice-subtracted dispersion relations, which was already evident from their analysis at lower energies [4].

Because of this situation, we adopt the procedure of simply estimating the total value of $I_N^{\pm}$ and its error by requiring that the dispersion relation predictions for $D_N^{\pm}$ are compatible with the existing experimental data (summarized in [3]) on the phases of the $K^{\pm}N$ forward elastic and charge-exchange processes for $\omega \gtrsim 2$ GeV. Numerical calculations of $I_N^{\pm}$ in terms of the existing low-energy parameters showed that at $\omega = 2$ GeV the asymptotic dependence $I_N^{\pm}(\omega) \approx \pm C_N \omega$ already holds to within a few per cent. The fit to the data with this dependence requires $C_p = (-3.9 \pm 0.3)$ GeV^{-2} and $C_n = (-2.4 \pm 0.3)$ GeV^{-2}.

Our final predictions for $a_N^{\pm}$ at various energies are presented in Table 1. Since the total errors on $a_N^{\pm}$ arise mainly from $I_N^{\pm}$, they are practically independent of energy. Moreover, these errors are primarily systematic, i.e., the values of $a_N^{\pm}$ are determined with high accuracy to within an additive constant. Below a few GeV, our predictions for $a_N^{\pm}$ are in good agreement with earlier dispersion relation predictions[3]. With conventional Regge pole extrapolations for the asymptotic behaviour of $\sigma_N^{\pm}$, the ratios a_N^- remain consistent with zero at all energies above a few GeV, while a_N^+ slowly tend to zero from negative values. The results of Table I, on the other hand, require $a_N^- < 0$ and $a_N^+ > 0$ for $\omega \gtrsim 300$ GeV. Within the errors, however, they are also compatible with changes of sign of a_N^+ at much lower energies.

It has been remarked[5,6] that a logarithmic increase of $|a_N^{\pm}|$ with energy would require an asymptotic shrinkage of the width of the diffraction peaks in order to avoid a violation of unitarity. However, our numerical results show clearly that this requirement would become effective only at energies very much higher than those considered here, because of the slow rate of growth of $|a_N^{\pm}|$.

Proposals have been made[5,7] to use measurements of the K^0 regeneration amplitude on nucleons or nuclei as a sensitive test of the Pomeranchuk theorem. In Table I we show our predictions for $a_{reg} \equiv \mathrm{Re}\, f_{reg} / \mathrm{Im}\, f_{reg}$, where f_{reg} is the regeneration amplitude on protons, given by $f_{reg} = f_n^+ - f_n^-$ by charge independence. As in the case of $a_N^{\pm}$, the values of a_{reg} are determined essentially to within an additive constant. We note that in our case a_{reg} exhibits a change of sign at some energy $\omega \lesssim 300$ GeV, a behaviour which is qualitatively different from the slow approach to a constant positive value predicted by conventional Regge pole extrapolations. Moreover, this change of sign is most likely to occur at an energy within the Serpukhov range, so that measurements of a_{reg} would provide a sensitive test of the Pomeranchuk theorem. For comparison, we also list in the table our corresponding predictions for the regeneration phase $\Phi_f \equiv \arg(i f_{reg})$, in terms of which the regeneration data are usually analysed but which is less convenient for our purposes.

Values of the regeneration amplitude on neutrons may easily be extracted from the results shown in Table I. This amplitude, although not directly accessible to experiment, is of interest in connection with regeneration on nuclei. We find that the real parts of the regeneration amplitudes on protons and neutrons change sign in a very similar manner, from positive to negative values with increasing energy. Therefore a similar behaviour is also expected for the regeneration amplitudes on nuclei. In particular, under our assumptions the regeneration phase analogous to Φ_f should asymptotically increase to $1/2\,\pi$ for an arbitrary nucleus, in contrast with the conventional predictions, according to which it tends to a constant negative value.

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Table 1

Predictions from the dispersion relation (3). The errors on the quantities a are practically independent of energy (see text) and are therefore shown only once.

k (GeV/c)	a_p^-	a_p^+	a_n^-	a_n^+	$a_{reg.}$	Φ_f (deg.)
6	0.00	−0.37	−0.00	−0.11	0.50	-26^{+84}_{-43}
25	0.01	−0.12	0.01	−0.03	0.31	-17^{+66}_{-42}
40	0.00	−0.07	−0.01	−0.00	−0.04	3^{+52}_{-55}
100	−0.03	0.01	−0.04	0.04	−0.67	33^{+30}_{-67}
200	−0.06	0.06	−0.07	0.07	−1.10	47^{+21}_{-62}
300	−0.08	0.09	−0.08	0.09	−1.35	53^{+17}_{-54}
400	−0.09	0.11	−0.09	0.10	−1.52	56^{+16}_{-50}
Errors	± 0.07	± 0.09	± 0.08	± 0.09	± 1.40	