On Exchange Degeneracy of Vector and Tensor Trajectories and the Total Cross Sections

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July 30, 1970

1. The main characteristics of the meson-nucleon total cross sections, $\sigma_T(\pi^+p)$, $\sigma_T(K^+p)$, and $\sigma_T(K^+n)$, are summarized as follows:

(I) The total cross sections except for $K^+p$ and $K^+n$ seem to become nearly energy independent above 25~30 GeV/$c$.

(II) The differences $\Delta \sigma_1 = \sigma_T(\pi^+p) - \sigma_T(\pi^-p)$ and $\Delta \sigma_2 = \sigma_T(K^+p) - \sigma_T(K^-p)$ have a tendency to become also energy independent.

(III) The difference $\Delta \sigma_3 = \sigma_T(K^+p) - \sigma_T(K^-n)$ is nearly zero, at least very small compared with $\Delta \sigma_1$ or $\Delta \sigma_2$ below 20 GeV/$c$.

(IV) The total cross section $\sigma_T(K^+p)$ is nearly energy independent below 20 GeV/$c$. Taking into account the above characteristics (I) to (IV), we discuss in this note a breaking of the exchange degeneracy of the vector and tensor trajectories and its implications.

2. Now, the imaginary parts of the forward spin non-flip amplitudes are generally expressed as follows:

$$
A(\pi^+p) = A_p^s + A_1^s \mp A_2^s,
$$

$$
A(K^+p) = A_p^K + A_1^K \pm A_2^K + A_3^K \pm A_4^K,
$$

$$
A(K^+n) = A_p^K + A_1^K \pm A_2^K - A_3^K \mp A_4^K,
$$

(1)

where the $A_p$ and $A_i$'s may have singularities besides simple poles and are specified by the $t$-channel isospin ($I_t$) and charge conjugation parity ($C$), $A_p$ (Pomeranchuk term), $A_1(I_t=0, C=+)$, $A_2(I_t=0, C=-)$, $A_3(I_t=1, C=+)$ and $A_4(I_t=1, C=-)$. From the equations the weak Johnson-Treiman relation follows on the assumption that the couplings of $K$ and $\pi$ to $A_i$ term are $SU_3$ invariant. Furthermore the $SU_3$ invariant coupling of $K$ and $\pi$ is assumed to $A_1$.

It follows from (III) that the exchange degeneracy (EXD) holds between $A_3$ and $A_4$ and the breaking of the EXD is proportional to the deviation of $\Delta \sigma_3^2$ from zero. One may also deduce the EXD between $A_1$ and $A_2$ from (IV), because $A_i (i \neq P)$ depends on energy by some power at not so high energy. This is referred to as solution (A). In the solution (A) the cross sections due to $A_p$ must be energy independent because the EXD holds for $A_1$ and $A_2$ and for $A_3$ and $A_4$, including other $J$-plane singularities besides the usual simple poles.

3. It is, however, a difficulty for the usual Regge pole theory that $\sigma_T$ becomes almost energy independent at such a low momentum as 30 GeV/$c$. Thus we are led to modify the amplitudes due to the Regge poles alone by introducing the Regge cuts, especially the vacuum cut. We, then, suggest another, more interesting, solution which satisfies (I) to (IV) but breaks the EXD between $A_1$ and $A_2$. This solution (B) implies that the breaking of the EXD between $A_1$ and $A_2$ must be compensated by a strong energy dependence of the Pomeranchuk term, $A_p$. This type of solution (B) is seen, for example, in the strong vacuum cut model by Barger and Phillips, where $F=1.23$ for the vector nonet but $F=3.1$ for the tensor nonet, if we take the nonet coupling scheme for both $CF = ff + dd)$. The compensation mechanism of the energy dependence of the breaking EXD by the Pomeranchuk term and the $SU_3$ invariant coupling of $K$ and $\pi$ make also the strengths of the vacuum cut $SU_3$ invariant approximately for $KN$ and $\pi N$ scatterings.

If, in the solution (B), we renormalize the breaking EXD term $\Delta A_1 = A_1 - A_2$ into
the strong energy dependent Pomeranchuk term, the resultant term appears to behave similar to the $A_F$ term in the solution (A). Since the solutions (A) and (B) are seemingly equivalent, if one restricts oneself only to the total cross sections below 30 GeV/$c$, we have the following relations:

$$
\sigma_T(\pi^-p) - \sigma_p = 4F_v \sigma_A,
$$
$$
\sigma_T(\pi^+p) - \sigma_p = 4F_v = 4F_v \sigma_A,
$$
$$
\sigma_T(K^-p) - \sigma_p = 4F_v \sigma_A,
$$
$$
\sigma_T(K^-p) - \sigma_p = 4F_v - 2 \sigma_A.
$$

where $\sigma_A = A_4/p_L$ and $\sigma_p = (A_p + A_4)/p_L$, and the nonet coupling scheme is assumed for $A_4$ and $A_p$. It should be noted that the $F$ value of the vector nonet alone appears in Eq. (2).

4. Besides the energy dependence of $\sigma_T$ above 30 GeV/$c$, the following phenomena appear to be favourable to the solution (B) than the solution (A): (1) Exotic baryonic resonances $Z^*$ may be expected in the $K^+p$ and $K^-n$ channels, but no exotic mesonic resonances in the $K^-\pi^+$ channel or in the $\pi^-\pi^+$ channel, since the EXD breaking results from the coupling of the $I_L=0$ singularities to the proton but not to the Pomeranchuk energy range. Owing to the EXD breaking in $I_L=0$ channel $Z^*$ appears also in the channel $I_L=0$ as well as $I_L=1$. Experiments indicate both resonances $Z_0 (1865)$ and $Z_1 (1900)$. (2) The ratio of the real part $D$ to the imaginary part $A$ of the forward amplitude, $\alpha = D/A$, is different from the one predicted by the solution (A). Since $F_T \neq F_v$, $\alpha$ of the strangeness exchange process such as $\pi N \rightarrow K \Lambda Y$ and $\bar{K}N \rightarrow \pi \Lambda Y$ is most different, but $\alpha$ is little different from the EXD value for the elastic, and $\bar{K}N$ or $KN$ charge exchange (CEX) processes. A rather large polarization of the $\Lambda$ in the process $K^-\pi^+ \rightarrow \pi^-\Lambda^0$ indicates the finite $\alpha$. (3) Although duality constraints with $SU_3$ invariance imply two sets of the EXD baryonic resonances $(8_8,8_7,1)$ and $(8_8,8_7,10_0)$, the breaking of the $t$-channel EXD may induce the breaking of the EXD in the direct channel resonances, where $F$ in a set is not necessarily the single value, for example, $F_0 \neq F_\pi$. This inequality and $F_T \neq F_v$ yield the breakdown of the factorizability. (4) Constant behavior of the differences $\Delta a$ as stated in (II) indicates that there appear similar constant behaviors in $da/dt|_{t=0}$ for $K^-p$ CEX, $\pi^-p$ CEX and $K^-n$ CEX processes in the Serpukhov energy range.