Flavor SU(3) breaking effects in the chiral unitary model for meson-baryon scatterings

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Properties of baryonic excited states are investigated with great interest both theoretically and experimentally. Recently, the chiral unitary model has been successfully applied to this problem, especially to the first excited states of negative parity ($J^P = 1/2^-$) such as $\Lambda(1405)$ and $N(1535)$ [1, 2]. Imposing the unitarity condition on the scattering amplitudes T_{ij} in the N/D method, we obtain the scattering equation in the matrix form [2]:

$$T_{ij} = V_{ij} + V_{ik} G_k T_{kj} \ , \tag{1}$$

where V_{ij} denotes the tree level interaction derived from the Weinberg-Tomozawa term in the chiral Lagrangian, and G_i is the loop integral regularized by the dimensional regularization. It is an advantage of this model that this equation can be solved algebraically. In actual calculations, the subtraction constants (a_i's), which are free parameters, are determined so as to reproduce experimental data. As a consequence, they have depended very strongly on scattering channels, as shown in Refs. [3, 4].

In this work, we investigate whether such channel dependence of the subtraction constants could be explained by the SU(3) breaking terms of the chiral perturbation theory. By doing this, we expect that the free parameters of a_i's could be controlled with suitable physics ground, namely the SU(3) breaking terms, in order to extend this model to various channels with predictive power. Here we keep using only one subtraction constant a commonly in all channels. The use of one subtraction constant is justified in the SU(3) limit [5]. The terms with the flavor SU(3) breaking appears as the quark mass matrix in the chiral expansion:

$$\mathcal{L}_{SB} = -\frac{Z_0}{2} Tr\Big(d_m \bar{B}\{\xi \mathbf{m} \xi + \xi^\dagger \mathbf{m} \xi^\dagger, B\} + f_m \bar{B}[\xi \mathbf{m} \xi + \xi^\dagger \mathbf{m} \xi^\dagger, B]\Big) - \frac{Z_1}{2} Tr(\bar{B}B) Tr(\mathbf{m}U + U^\dagger \mathbf{m}) \ . \tag{2}$$

where $f_m + d_m = 1$. Here we employ the standard notation. The terms in Eq. (2) are of order $\mathcal{O}(p^2)$. Here we do not take into account other chirally symmetric terms of order $\mathcal{O}(p^2)$, since we concentrate on the effects of the flavor SU(3) breaking.

Let us show the numerical results of the $\bar{K}N$ induced scatterings. The subtraction constant is determined by fitting threshold branching ratios. Without the symmetry breaking terms, we find the optimal value $a = -1.96$ (A). Now including the symmetry breaking term, the optimal value takes $a = -1.59$ (B). We also perform calculation with the physical meson decay constants: $f_\pi = 93$ MeV, $f_K = 1.22 f_\pi$, $f_\eta = 1.3 f_\pi$, and the optimal value is $a = -1.68$ (C). The calculated threshold values are presented in Refs. [3, 4], where we see that the agreement with data is improved by including the symmetry breaking effect. Note that this improvement is achieved without new free parameters. Using these optimal values, we calculate the cross sections of $K^- p \to$ (various channels) and $\pi\Sigma$ mass distribution (Fig. 1). For the results (A) (dotted line), the agreement with data is still good, and we obtain the

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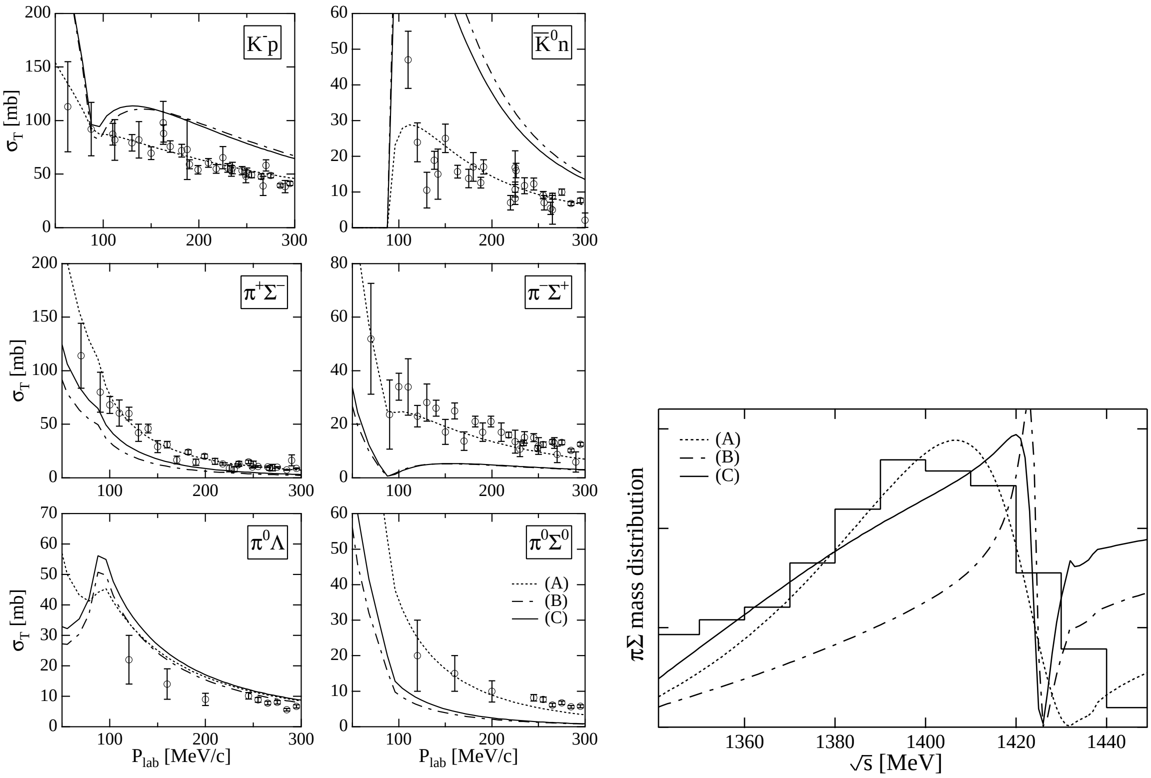

Figure 1: Left : Total cross sections of K^-p scatterings ($S = -1$) as functions of P_{lab}, the three momentum of the initial K^- in Laboratory frame. Right : Mass distributions of the $\pi\Sigma$ channel with $I = 0$. Dotted lines : (A), dash-dotted lines : (B), and solid lines : (C).

distribution which agrees well with experimental data. Now including the symmetry breaking terms (B), we find that agreement with data becomes worse (dash-dotted lines), contrary to our expectation. The results (C) are shown by the solid lines. While the use of the physical meson decay constants does not improve in the total cross sections drastically as shown in Fig.1, the shape of the peak in the $\pi\Sigma$ mass distribution becomes milder.

A reasonable prescription from symmetry consideration by including the symmetry breaking mass terms, which appear in the next-to-leading order of the chiral expansion, make theoretical predictions worse. So far, except for the use of channel dependent subtraction constants, we do not know what would resolve this problem. In the present framework, the role of the subtraction constants is very important. For more details, see Refs. [3, 4].

References

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