Regulariztion dependence of $S = 0$ and $S = -1$ meson-baryon system in the chiral unitary model

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We investigate the dependence of s-wave meson-baryon scattering amplitudes of $S = 0$ and $S = -1$ on different regularizations within the framework of the chiral unitary model. We employ two different regularization schemes, *i.e.* dimensional and form-factor regulariaztions to tame the divergences in the model. We also study the analytic structures of T-matrices, using those regularization schemes. We find that while the form-factor regularizaion produces almost the same results as the dimensional regularization did, the on-shell approximation is to some extent limited in the case of the form-factor regularization. Having chosen parameters properly, we show that the regularization dependences can be minimized. In this report we want to concentrate on the properties of the resonances. We utilize the Lagrangian called as Weinberg-Tomozawa term to obtain the kernal, V for Bethe-Salpeter (BS) eqution as follows,

$$\mathcal{L}^1_{MB} = \frac{i}{4f^2}\langle \bar{B}\gamma^\mu[(\Phi\partial_\mu\Phi - \partial_\mu\Phi\Phi)B - B(\Phi\partial_\mu\Phi - \partial_\mu\Phi\Phi)]\rangle, \tag{1}$$

$$V(\sqrt{s})_{ij} = -\frac{C_{ij}}{4f^2}(\sqrt{s} - M_i - M_j)\sqrt{\frac{M_i + E_i}{2M_i}}\sqrt{\frac{M_j + E_j}{2M_j}}, \tag{2}$$

where M_i and E_i stands for the ith baryon mass and energy respectively. We perform dimensional regularization shown in Refs. [1, 2] and form factor regularization schemes to tame the divergence of on-shell gactorized BS equation. (see also Refs. [1, 2]) Form factor we use is

$$F(q^2) = \left(\frac{\Lambda^2 - m^2}{\Lambda^2 - q^2}\right)^n, \tag{3}$$

where Λ denotes a four dimensional cut-off parameter. n represents monopole (MF) with $n = 1$ and dipole (DF) with $n = 2$. In on-shell factorized BS equation, By the choice of a regularization scheme, propagator becomes differnt in the schemes mainly [3]. As a effective counter term, we insert subtrction parameter "a" as follows,

$$T = \left[I - V\left(G + \frac{2M}{(2\pi)^2}a\right)\right]^{-1} V, \tag{4}$$

where a is a diagonal matrix of the meson-baryon channels. Subtraction parmeters for $S = 0$ and $S = -1$ are obtained in the table.1. In $S = 0$, the resonance, $N(1535)$ on the second Riemann sheet is plotted in left two of the figure.1. The pole positions for $N(1535)$ are $(1502-41i)$MeV for DF and $(1517-41i)$MeV for MF while DIM finds the pole at $(1516-37i)$ MeV. In $S = -1$ $\pi\Sigma$ mass distribution for $\Lambda(1405)$ resonance is obtained from the regularizations properly in the other. It shows the peak around 1400MeV clearly. By calculating residues around the poles in the second Riemann sheet **??**, We could confirm that the resonances, $N(1535)$ and $\Lambda(1405)$ are tightly coupled to $K\Sigma$ and $\pi\Sigma$ that confirms the situation

	$a_{\pi N}$	$a_{\eta N}$	$a_{K\Lambda}$	$a_{K\Sigma}$	$a_{\bar{K}N}$	$a_{\pi\Lambda}$	$a_{\pi\Sigma}$	$a_{\eta\Lambda}$	$a_{\eta\Sigma}$	$a_{K\Xi}$
DIM	2.0	0.2	1.6	-2.8	-1.84	-1.83	-2.00	-2.25	-2.38	-2.67
DF	3.00	0.93	2.38	-1.87	0.22	0.59	0.47	-0.12	-0.20	-0.36
MF	3.83	1.73	3.26	-1.12	1.03	1.36	1.22	0.64	0.54	0.36

Table 1: Subtraction parameters. The left side : $S = 0$. The Righ side : $S = -1$.

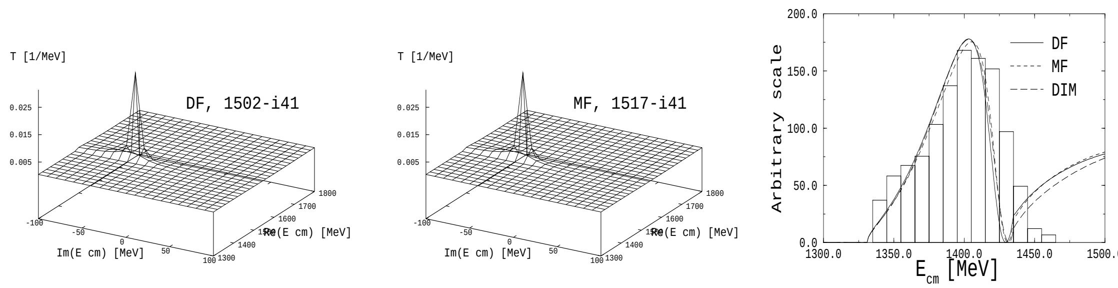

Figure 1: The left two : Poles of DF and MF. The right : mass ditribution of $\pi\Sigma$

of quasi bound state interpretation. We have investigated $S = 0$ and $S = -1$ meson-baryon processes, in particular, focusing on their dependence on regularizations. Starting from the effective chiral Lagrangian to the lowest order $\mathcal{L}^1_{MB}$, also known as the Weinberg-Tomozawa term, we have constructed the pseudo-potential which is used as a kernel of the Bethe-Salpeter equation. In order to solve the Bethe-Salpeter equation, we utilize the on-mass-shell approximation. While the dimensional regularization is widely adopted in almost all works, we introduced two different schemes of the regularization: The dimensional regularization, the monopole-type form factor, and the dipole-type form factor. The resonance $\Lambda(1405)$ in the $S = -1$, and $N(1530)$ in the $S = 0$ were well reproduced in the present work and turned out to be rather insensitive to the types of regularizations apart from small difference in higher-energy region. we also investigated the analytic structure of the partial-wave amplitudes and found that three poles exist in them.

We employed three different regularizations: The dimensional regularization, the form factor regularizations with monopole and dipole types. The differences due to regularizatons found in observables are mainly due to the different behavior of the propagator $G(\sqrt{s})$, because of which in higher-energy region the regularizations change the prediction of the observables. Thus, we conclude that one need to vindicate methods used so far to describe meson-baryon processes.

References

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