The pseudoscalar meson and baryon octet interaction with strangeness zero in the unitary coupled-channel approximation

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The pion-nucleon interaction is an interesting topic and has attracted more attentions of the nuclear society in the past decades.
There are two very closed excited states of the
nucleon in the S_{11} channel, $N(1535)$ and $N(1650)$, which are
difficult to be described within the framework of the constituent
quark model. However, in the unitary coupled-channel
approximation of the Bethe-Salpeter equation, most of the excited
states of the nucleon are treated as resonance states of the
pseudoscalar meson and the baryon in the $SU(3)$ flavor space, so
are these two particles.

The $s-$ channel, $u-$ channel and Weinberg-Tomozawa contact
potentials of the pseudoscalar meson and baryon octet in the S-wave
approximation are calculated, and it is found that the πN $s-$ channel potential is repulsive and the other $s-$ channel
potential are weaker than the πN case,
while the $u-$ channel potentials in the S-wave approximation are
attractive.
Although the curves for ηN and $K\Sigma$ cases are not smooth
when $\sqrt{s} < 1300$MeV, it is far away from the energy region which
we are interested in, and we assume that it would not give an effect
on the pole position of the amplitude in the calculation.
However, the contact interaction originated from the
Weinberg-Tomozawa term is dominant in the pseudoscalar meson and the
baryon octet potential, and the correction from the $s-$ channel
potential and the S-wave $u-$ channel potential is not important.

A pole is generated dynamically at $1518 - i46$MeV on the complex
energy plane of $\sqrt{s}$ by solving the Bethe-Salpeter equation in
the unitary coupled-channel approximation with the 19th set of parameters, i.e., $a_{\pi N} = -2.0$, $a_{\eta N} = -1.7$,
$a_{K\Lambda} = -3.2$ and $a_{K\Sigma} = -3.2$.

In this work, the interaction of the pseudoscalar meson and the
baryon octet is studied within a nonlinear realized Lagrangian. The
$s-$, $u-$ channel potentials and the Weinberg-Tomozawa contact
interaction are obtained when the three-momenta of the particles in
the initial and final states are neglected in the S-wave
approximation.

In the sector of isospin $I = 1/2$ and strangeness $S = 0$, a resonance
state is generated dynamically by solving the Bethe-Salpeter
equation, which might be regarded as counterparts of the $N(1535)$

particle listed in the PDG data.
We find the hidden strange channels, such as ηN, $K\Lambda$
and $K\Sigma$, play an important role in the generation of the
resonance state when the Bethe-Salpeter equation is solved in the
unitary coupled-channel approximation.
The coupling constants of this resonance state to different channels
are calculated, and it is found that it couples strongly to the
hidden strange channels.

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