σ exchange in the NN interaction within a chiral unitary approach

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The advent of unitary extensions of chiral perturbation theory, $(U\chi PT)$ [1,2], has allowed to have a fresh look at $\pi\pi$ scattering up to higher energies than allowed by standard chiral perturbation theory (χPT), and obtain dynamically all the scalar meson resonances below 1.2 GeV, including the σ meson which appears as a pole in the second Riemann sheet with a mass around 500 MeV and a width around 450 MeV. The new chiral perspective on the nature of the σ calls for a rederivation of the σ exchange contribution to the NN potential. In meson exchange models [3] the exchange of a σ, thought as an elementary particle, is responsible for the intermediate range attraction. In the present work we have performed a calculation by considering the contribution to the NN potential from the exchange of two pions which interact among themselves through the dynamical framework of $U\chi PT$. The loops in the meson-meson propagator and the vertex functions involving triangle diagrams with two pions and one intermediate nucleon or Δ, are regularized with a natural cut off of the order of 1 GeV. With this input one obtains a potential which differs appreciably from the the elementary particle exchange one. The latter is just a Yukawa function which has maximum strength at q=0 in momentum space, while the potential which we obtain has a peak around q=0.5 GeV and the strength at q=0 is about six times smaller than in the maximum. Translated to coordinate space, the potential we find has an asymptotic behaviour similar to the σ potential of [3] in the version where the box diagram with Δ in the intermediate states, which gives also a contribution to the intermediate range attraction, is also considered. Our potential also provides a moderate attraction at intermediate energies and then it becomes repulsive at short distances, starting already at 0.9 fm. This behaviour is quite novel and surprising. However, it has been recently shown [4] that this potential, in addition to the one from box diagrams with exchange of two uncorrelated pions and intermediate Δ states, and one very reasonable ω exchange, provides a scalar potential in remarkable agreement with the Argonne v_{14} potential of [5]. This novel theoretical derivation of the scalar NN potential opens new possibilities to see medium modifications to the scalar potential in nuclei, now that the large medium modifications of the scalar isoscalar $\pi\pi$ interaction in the nuclear medium predicted in the chiral models have been proved experimentally in the the recent Mainz measurements of the $\pi\pi$ invariant mass distribution in the $(\gamma, \pi^0\pi^0)$ reaction in nuclei [6].

References

1.J.A. Oller and E. Oset, Nucl. Phys. A620 (1997) 438; E A652 (1999) 407
2.J.A. Oller, E. Oset and J.R. Pelaez, Phys. Rev. Lett. 80 (1998) 3452
3.R. Machleidt, K. Holinde and Ch. Elster, Phys. Rep. 149 (1987) 1
4.D. Jido, E. Oset and J.E. Palomar, Nucl. Phys. A694 (2001) 525
5. R.B. Wiringa, V.G. Stoks and R. Schiavilla, Phys. Rev. C51 (1995) 38
6. V. Metag, Workshop on Chiral fluctuations in hadronic matter, Orsay, Sep. 2001.