Kaon-Nucleon Interactions in The Skyrme Model

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We study kaon-nucleon interactions in the Skyrme model by using a modified bound state approach, where the kaon is introduced around the physical nucleon. The method is more suited to the study of weakly interacting kaon-nucleon systems. We have found a bound state with binding energy of order ten MeV. We also discuss the $\bar{K}N$ interaction and find that it consists of an attraction in the middle range and a repulsion in the short range.

KEYWORDS: Skyrmions, Kaon nucleon interaction, Hyperon resonances

1. Introduction

Recently, kaon-nucleon systems have been receiving a lot of attention in hadron physics. For example, Akaishi and Yamazaki predicted that the anti-kaon ($\bar{K}$) and nucleon (N) interaction was strongly attractive and that, due to the strong attraction, they formed a bound state which was identified with $\Lambda(1405)$. This particle is well-known as a candidate of an exotic baryon whose properties can not be explained by a simple quark model. Based on the features of the $\bar{K}N$ interaction, there have been large number of discussions in a few body nuclear systems with the kaon. However, the properties of these few-body systems are yet undetermined. One of the reasons for this is that the kaon-nucleon interaction is not well understood.

Kaon-nucleon interactions have been derived from a phenomenological approach and chiral theories. In the chiral theory, kaon-nucleon interaction is based on the four-point local interaction called the Weinberg-Tomozawa interaction. Because of the point-like nature of this interaction, in chiral theory, divergences appear in theoretical calculations.

In this study, we consider that the chiral theory is important because it can describe properties of particles in the low energy region. Furthermore taking nucleon structures into account, we expect to avoid the divergent problems. As an approach which satisfies these requirements, we use the Skyrme model and investigate the kaon nucleon interactions.

2. Method

Let us start with the Skyrme Lagrangian [1–3]

$$L = \frac{1}{16}F_\pi^2 \mathrm{tr}\left(\partial_\mu U \partial^\mu U^\dagger\right) + \frac{1}{32e^2}\mathrm{tr}\left[\left(\partial_\mu U\right)U^\dagger, \left(\partial_\nu U\right)U^\dagger\right]^2 + L_{WZ} + L_{SB}, \qquad (1)$$

where U is the SU(3)-valued chiral field. The first and second terms are the normal Skyrme Lagrangians and the third term is the contribution of the chiral anomaly called the Wess-Zumino term [4–6]. The last term in Eq. (1) is the explicitly chiral symmetry breaking term due to the finite masses of up, down, and strange quarks. In this study, for simplicity, we consider the chiral limit for the u, d