Coleman-Weinberg mechanism for spontaneous chiral symmetry breaking in the massless chiral sigma model

S. Tamenaga[1], H. Toki[1], A. Haga[1,2], and Y. Ogawa[1]
[1] *Research Center for Nuclear Physics (RCNP), Ibaraki, Osaka 567-0047, Japan*
[2] *Department of Engineering Physics, Electronics, and Mechanics, Nagoya Institute of Technology, Gokiso, Nagoya 466-8555, Japan*

We study the effect of one-loop corrections from not only nucleon but also bosons in the massless chiral sigma model, where we perform the Coleman-Weinberg renormalization scheme [1]. This renormalization procedure has a mechanism of spontaneous symmetry breaking due to radiative corrections in ϕ^4 theory.

We also apply it to the system of nucleon and bosons with chiral symmetry where the negative-mass term of bosons does not exist. Here we use the massless chiral sigma model that the chiral sigma model, which has good properties in the nuclear matter and finite nuclei [2], is a modified model. Spontaneous chiral symmetry breaking is derived from the contribution of nucleon and boson loops which generates the masses of nucleon, scalar meson, and vector meson dynamically. It is for the first time that we can obtain the stable effective potential in the chiral model as shown in the left hand side of Fig. 1. This good feature comes from taking the renormalization procedure before the chiral symmetry breaking.

A renormalization scale m is introduced to the model in order to avoid a logarithmic singularity in the massless phase. The renormalized potential is given by

$$V_{all}^{R} = \frac{\gamma - 1}{8\pi^2} g_\sigma^4 (\phi^2 + \boldsymbol{\pi}^2)^2 \left[\ln\left(\frac{\phi^2 + \boldsymbol{\pi}^2}{m^2} \right) - \frac{25}{6} \right],$$

where γ is defined as the absolute ratio of boson loop potential to nucleon loop potential. Our model depends on the renormalization scale. When we take the limit $m \to \infty$, we find that there is the cancellation between nucleon and boson loop and that the chiral symmetry restores in the right hand side of Fig. 1. Once a renormalization scale has a finite value except for zero or infinity, the symmetry among fermion and bosons is broken. Spontaneous symmetry breaking occurs at the same time, and the masses of both nucleon and bosons are generated dynamically.

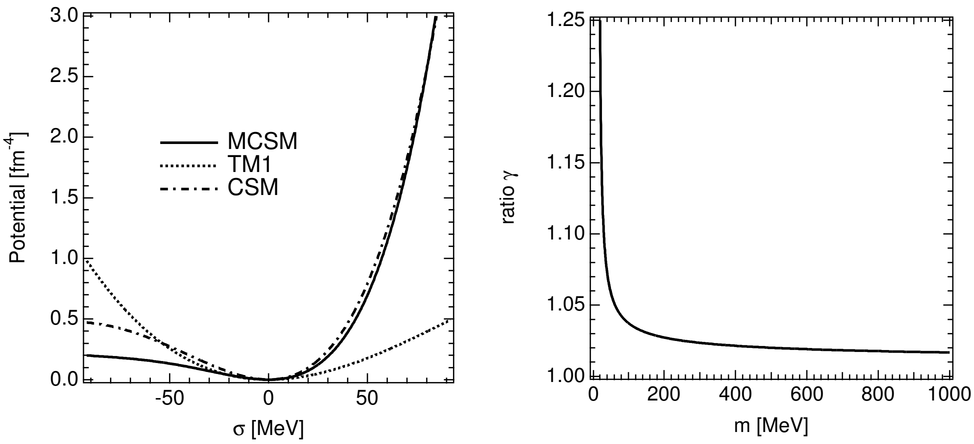

Figure 1: **Total potential as a function of σ at $m = f_\pi$, and the dependence of the ratio on renormalization scale m.**

By the way, not only the vacuum fluctuation with the ordinary chirally symmetric renormalization but also that in the Walecka model are unnatural by the naive dimensional analysis [3]. We find that naturalness restores by introducing vacuum flucutations from both nucleon and bosons in the Coleman-Weinberg renormalization procedure consistent with chiral symmetry.

References

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