Time-Evolution of Collective Meson Fields and Amplification of Quantum Meson Modes in Chiral Phase Transition

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One of the recent interests associated with the physics of the relativistic heavy-ion collisions is to study the dynamics of matter at very high energy density. Especially, it is interesting to investigate the dynamics of the chiral phase transition in connection with the problem of the formation of a disoriented chiral condensate. In order to investigate the time-evolution of the order parameter and of the fluctuation modes around it in the chiral phase transition, we have formulated the time-dependent variational approach to dynamics of quantum fields in terms of a squeezed state or a Gaussian wave functional[1]. The main advantage of this approach to the dynamical problem lies in the fact that both the degrees of freedom of the mean field and the quantum fluctuations can be treated self-consistently. We have investigated the time-evolution of a collective meson field in the dynamical chiral phase transition in the $O(4)$-linear sigma model [2]. The time-evolution of the mean field, i.e., the chiral condensate with the direction of the sigma field, is depicted in the left in Fig.1. The relaxation to the vacuum value is seen due to the inclusion of the quantum fluctuation modes. If we do not take into account of the quantum fluctuation modes fully, the relaxation is not seen. Thus, we conclude that the quantum fluctuation modes play an important role in this relaxation process. Also, the amplification of the amplitudes of quantum fluctuation modes with low momenta in the direction of pion fields occurs accompanying with the relaxation of the chiral order parameter. (See, the middle and the right figures in Fig.1.) This phenomena may be understood in terms of a parametric amplification as was mentioned by many authors. However, there is another possibility to amplify the fluctuation modes [3]. It is shown approximately and analytically that both the parametric amplification and the resonance due to the forced oscillation occur. Thus, it is pointed out that there actually coexist two mechanisms to amplify the quantum fluctuation modes in the late time of the chiral phase transition, namely, that a forced oscillation works as well as a parametric resonance.

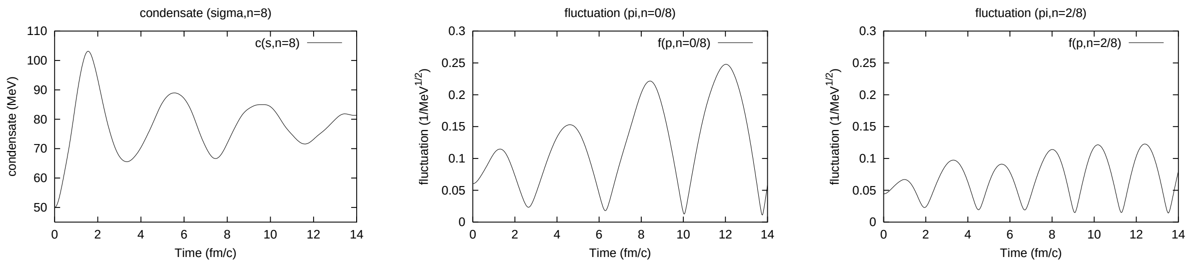

Figure 1: The time-evolutions of the mean field (left) and the lowest (middle) and the second excited pion modes (right).

References

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