Theoretical approaches to hadrons in nuclear matter

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Recents developments on medium modifications of hadrons properties in nuclear matter are discussed. One of the main purposes will be to point out the importance of chiral dynamics in the nuclear many-body problem and specifically the influence of partial chiral restoration on in-medium hadron spectral functions. After a brief overview of the realization of chiral symmetry in a dense and/or hot medium, I will discuss the properties of the pion and collective scalar-isoscalar modes (sigma meson) representing the phase and the amplitude fluctuations of the chiral order parameter (the quark condensate) around the minimum of the effective potential. The dropping of the chiral order parameter may provide an explanation of the strong s-wave repulsion of negatively charged pions deduced from deeply bound pionic atom states recently observed in Pb isotopes. The effect of chiral restoration together with the softening of the pion dispersion relation yield a softening/sharpening (spectral enhancement) of the sigma mode and the in-medium pion-pion interaction. This provides a mechanism to explain the low invariant mass enhancement observed in two-pion production reactions induced either by incoming pions or photons. The question of matter stability in chiral theories and the role of pionic fluctuations will also be discussed with special emphasis on the role of the structure of the nucleon itself. In that respect I will point out the importance of existing and future lattice calculations to constrain effective chiral theories, with the example of fundamental quantities such as thermal and finite density susceptibilities. Finally I will present a brief overview of the mechanisms associated with chiral restoration, namely the dropping mass scenario and the hadronic one including axial-vector mixing, to explain the broadening of the rho meson peak observed in relativistic heavy ion collision at CERN/SPS. Recent developments such as the simultaneous softening of the rho and the sigma as well as the vector realization of chiral symmetry will also be discussed in relation with the SIS100/200 project to study hadronic matter at very high baryonic density.