19th International Conference on QCD in Extreme Conditions (XQCD 2023)

Contribution ID: **59** Type: **Talk**

Delta baryons in (hot) neutron stars

Wednesday, 26 July 2023 14:50 (25 minutes)

By applying a relativistic mean-field description of neutron star matter with density dependent couplings, we analyse the properties of nucleonic matter with delta baryons and nucleonic matter with hyperons and delta baryons. We calculate the baryon-meson coupling constants for the spin-1/2 baryonic octet and spin-3/2 decuplet in a unified approach relying on symmetry arguments such as the fact that the Yukawa couplings, present in the Lagrangian density of the Walecka-type models, must be an invariant under SU(3) and SU(6) group transformations. The coupling constants of the baryon with the scalar σ meson are fixed to reproduce the known potential depths for the hyperons and Δ resonances, in an approach that can be extended to all particles. We then apply the calculated coupling constants to study neutron star matter with hyperons and deltas admixed to its composition. We conclude that the Δ- is by far the most important exotic particle that can be present in the neutron star interior. It is always present, independent of the chosen parameterization, and might appear in almost every known neutron star, once its onset happens at very low density. Yet, its presence affects the astrophysical properties of the canonical 1.4 Mo star, and, in some cases, it can even contribute to an increase in the maximum mass reached. We also study the nuclear isentropic equation of state for a stellar matter composed of nucleons, hyperons, and Δ-resonances. We investigate different snapshots of the evolution of a neutron star, from its birth as a lepton-rich protoneutron star in the aftermath of a supernova explosion to a lepton-poor regime when the star starts cooling to a catalyzed configuration. We observe that Λ is the dominant exotic particle in the star at different entropies for both neutrino-free and neutrino-trapped stellar matter. For a fixed entropy, the inclusion of new particles (hyperons and/or delta resonances) in the stellar matter decreases the temperature. Also, an increase in entropy per baryon (1to2) with decreasing lepton number density (0.4to0.2) leads to an increase in stellar radii and a decrease in its mass due to neutrino diffusion. In the neutrino transparent matter, the radii decrease from entropy per baryon 2 to T=0 without a significant change in stellar mass.

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Session Classification: Parallel session A