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Four types of phase transitions in interacting meson (boson) matter at high temperatures

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Basic examples of processes where interacting meson matter can occur are heavy-ion collisions and recent “TeV” collisions of protons. Processes where many particles are created after collision are not very likely. However, they can be observed and obtained with significant statistics. Most of these particles are pi-mesons. To understand what happens in such exotic matter, we need theory. Our goal was to investigate the possibility and peculiarities of the formation of Bose condensate in a pion-antipion system or any other two-component bosonic system with interaction.

We want to generalize our previous results, starting from the introduction of the thermodynamic mean-field model [1]. Later on, in the framework of this approach the Bose-Einstein condensate was included into consideration firstly for a zero isospin (charge) density in the system [2], and then a system of interacting particles and antiparticles with finite isospin density [3,4]. Based on recent results of our work, we introduce a general classification of phase transitions at high temperatures in a two-component meson system with strong interaction and fixed isospin density. All phase transitions can be partitioned into four groups or classified into four types of phase transitions (*it is important to note that our classification has no relation to the order of the phase transition, which in general is a subject of the statistical thermodynamics, for example, with the Ehrenfest classification*). Every type of phase transition we specify has its order of phase transition.

[1] D. Anchishkin, V. Vovchenko, Mean-field approach in the multi-component gas of interacting particles applied to relativistic heavy-ion collisions. *J. Phys. G* **42**, 105102 (2015). [<https://doi.org/10.1088/0954-3899/42/10/105102>].

[2] D. Anchishkin, I. Mishustin, H. Stoecker, Phase transition in an interacting boson system at finite temperatures. *J.Phys. G* **46**, 035002 (2019). [<https://doi.org/10.1088/1361-6471/aafa8>].

[3] D. Anchishkin, V. Gnatovskyy, D. Zhuravel, V. Karpenko, Self-interacting particle-antiparticle system of bosons. *Phys. Rev. C* **105**, 045205 (2022). [<https://doi.org/10.1103/PhysRevC.105.045205>].

[4] D. Anchishkin, V. Gnatovskyy, D. Zhuravel, V. Karpenko, I. Mishustin, H. Stoecker, Phase Transitions in the Interacting Relativistic Boson Systems. *Universe* **9**, 411 (2023). [<https://doi.org/10.3390/universe9090411>].