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Four types of phase transitions in interacting boson system at high temperatures

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Within the framework of the mean-field model, the thermodynamics of the relativistic bosonic system of interacting particles and antiparticles in the presence of a Bose-Einstein condensate is investigated. It is assumed that the total isospin (charge) density is conserved. It is shown that the particle-antiparticle boson system reveals four types of phase transitions into the condensate phase. Three types belong to the phase transition of the second order and one to the first order. We show that the grand canonical ensemble is not suitable for describing a bosonic system of particles and antiparticles in the presence of condensate, but an adequate study can be carried out within the framework of the canonical ensemble, where the chemical potential is a thermodynamic quantity that depends on the canonical free variables.

Primary author: ANCHYSHKIN, Dmytro (Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, FIAS)

Presenter: ANCHYSHKIN, Dmytro (Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine, FIAS)

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