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Bose–Einstein condensation and muon production in ultra-high energy cosmic ray particle collisions

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Collisions of cosmic ray particles with ultra-high initial energies larger than 0.1–1 EeV with nuclei in the atmosphere lead to creation a strongly interacting matter under extreme conditions and open a wide room for appearing of the novel dynamical features for production of secondary particles. In particular, the estimations obtained for the space density of charged particles at freeze-out and its critical value within the model of certain ring diagrams allow the possibility of lasing behavior for secondary pions at least for nuclear interactions with ultra-high energy cosmic ray (UHECR) particles. The pion-lasing behavior results in the shift to larger multiplicities and, as consequence, can provide, in general, the enhanced yield of cosmic muons. The Muon puzzle is a well-known problem in the physics of high-energy cosmic rays one of the aspects of which is the muon bundle excess compared to simulations within available phenomenological models. In the present work critical value of the space particle density for onset of Bose–Einstein condensation of the boson wave-packets into the same wave-packet state is estimated with help of the improved formula obtained within model of multiparticle symmetrization for UHECR energy domain. Energy dependence of mean multiplicity of pions is evaluated for the cases of absent of the Bose–Einstein effects and for presence of laser-like behavior for pions. The possible influence of the Bose–Einstein condensation is discussed for the muon production in UHECR particle collisions with the atmosphere.

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