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ScienceDirect
Nuclear Physics B 891 (2015) 466–481
NUCLEAR PHYSICS B
www.elsevier.com/locate/nuclphysb

Correlation function intercepts for $\tilde{\mu}, q$-deformed Bose gas model implying effective accounting for interaction and compositeness of particles

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Received 21 November 2014; accepted 16 December 2014

Available online 19 December 2014

Editor: Hubert Saleur

Abstract

In the recently proposed two-parameter $\tilde{\mu}, q$-deformed Bose gas model (Gavrilik and Mishchenko, 2013) [3], aimed to take effectively into account both compositeness of particles and their interaction, the $\tilde{\mu}, q$-deformed virial expansion of the equation of state (EOS) was obtained. In this paper we further explore the $\tilde{\mu}, q$-deformation, namely the version of $\tilde{\mu}, q$-Bose gas model involving deformed distributions and correlation functions. In the model, we explicitly derive the one- and two-particle deformed distribution functions and the intercept of two-particle momentum correlation function. The results are illustrated by plots, and the comparison with known experimental data on two-pion correlation function intercepts extracted in RHIC/STAR experiments is given.

1. Introduction

Deformed Bose gas models based on a set of identical deformed (nonlinear) oscillators, or on deformed thermodynamic relations, provide nonlinear extension of standard Bose gas model which finds applications to physical systems with one or more factors of non-ideality [1–5]. In general, the effective description or modeling of essentially nonideal (nonlinear) systems usu-

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http://dx.doi.org/10.1016/j.nuclphysb.2014.12.017
0550-3213/

ally is performed by means of reexpressing of the physical quantities of the initial complicated system in terms of the analogous quantities of deformed model. Such two factors as composite structure of particles of a gas and the interaction between them are of main interest for us here. Concerning the compositeness of particles, let us mention the works [1,6–8] where q-deformed oscillators were applied for effective description of composite particles (like nuclei, nucleons, mesons, excitons, cooperons, atoms, molecules). Their Bose–Einstein condensation was also studied [9]. It was shown in [10,11] that two-fermionic (and two-bosonic) composite bosons can be algebraically realized on their Fock states by deformed oscillator algebra with the quadratically nonlinear deformation structure function (DSF) $\varphi_{\tilde{\mu}}(\hat{N}) = (1+\tilde{\mu})\hat{N} - \tilde{\mu}\hat{N}^2$, with $\hat{N}$ the number operator, and discrete deformation parameter $\tilde{\mu} = 1/m$ involved. On the other hand, q-deformation of Arik–Coon type [12] based on the DSF equal to the "q-bracket" $[N]_q = \frac{q^N-1}{q-1}$ was used for the effective description [13] of thermodynamics aspects (e.g., virial expansion) of Bose gas with interaction. So far, two aspects were treated *separately*, adhering to different methods and contexts. However, the task naturally arises of treating *jointly*: (i) compositeness of particles linked, through the realization, with quadratic or $\tilde{\mu}$-deformation; (ii) the interaction between particles modeled by q-deformation. We may expect that combining these two types of deformation into single one will reproduce effectively, in a unified manner, some specific features inherent to the thermodynamic or statistical quantities of more realistic systems of particles possessing *both interaction and compositeness*. The simplest variant of such unification is their functional composition or $\tilde{\mu}, q$-deformation. Of course, at the moment the ascription of the meaning of deformation parameters $\tilde{\mu}$ and q as responsible respectively for the compositeness and the interaction is rather formal, and the detailed consistent analysis providing a reformulation in the deformed model terms, including the relation with the parameters of interaction or compositeness, is not completed to sufficient extent.

First steps to the (microscopics of) effective taking of interaction and compositeness jointly into account are made by introducing the $\tilde{\mu}, q$-deformed Bose gas model [3,4] based on deforming the thermodynamics. Namely, in [3] the $\tilde{\mu}, q$-deformed Bose gas model was realized through deforming the total mean number of particles or the partition function by means of the deformed analog of the derivative $z\frac{d}{dz}$ (z is fugacity) and use of the "hybrid" (combined) DSF

$$\varphi_{\tilde{\mu},q}\left(z\frac{d}{dz}\right) \equiv \varphi_{\tilde{\mu}}(D_q) = (1+\tilde{\mu})D_q - \tilde{\mu}D_q^2, \quad D_q \equiv \left[z\frac{d}{dz}\right]_q. \tag{1}$$

This version of $\tilde{\mu}, q$-Bose gas model was constructed bearing in mind the goal of effective description of thermodynamics of *interacting* gas of *composite* bosons (made of two bosons or two fermions). In fact, the latter due to compositeness are no longer true bosons. For that model, the deformed virial expansion was studied. In the sequel to [3], the relation of the obtained virial coefficients of the $(\tilde{\mu}, q)$-deformed model (dependent explicitly on the deformation parameters $\tilde{\mu}$ and q) with scattering data of some interaction was explored [4], and the arising unusual temperature dependence of $\tilde{\mu}$ and q discussed and justified.

The version of $\tilde{\mu}, q$-deformed Bose gas model considered herein uses for its definition the same DSF $\varphi_{\tilde{\mu},q}$ as in [3] (composed of quadratically nonlinear SF and the q-deformed one). However, this time the DSF is exploited as the operator function of $\hat{N}$ for obtaining one- and two-particle distribution functions. The resulting model is also called $(\tilde{\mu}, q)$-deformed model.

Below we focus on one- and two-particle distributions and the related momentum correlation function intercept, and calculate them. Let us quote some preceding activity [14–21] on the (intercepts of) correlation functions for various deformed Bose gas models. The knowledge of the