Event shape and Multiplicity dependence of ϕ meson production in pp collisions with ALICE at the LHC and Characterization of Heavy-ion Collisions using Relativistic Kinetic Theory

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Introduction

Historically the pp collisions were considered as a baseline for the formation of QGP in heavy-ion collisions due to their significantly smaller system size compared to heavy-ion collisions. In pp collisions, it was expected that the final state particles are mostly the result of the fragmentations of the two protons. Recent measurements of identified particle production from the experiments at the LHC have revealed surprising discovery of QGP-like behavior, such as strangeness enhancement [1] and double ridge structure [2] in high multiplicity proton+proton (pp) collisions, which raise concerns whether pp collisions can be used as a proper benchmark for comparison with heavy-ion results to understand the formation of a medium with high temperature/energy density. These behaviours have important consequences in understanding the data from heavy-ion collisions at the LHC energies as one should consider the contribution of QGP-like effects in small systems. They open new directions for theoretical and experimental studies of small collision systems. To understand the recent measurements, it is important to perform double differential studies of various observables in pp collisions with event shape and charged-particle multiplicity. Event shape observables like transverse spherocity, allows the possibility to separate the events with high and low number of multiparticle interactions, to isolate the behavior of particles inside jets (hard processes) and pertaining to the soft processes [3, 4]. A comprehensive differential study using event shapes would reveal interesting features, which could be exploited to improve theoretical models.

Study of resonances containing strange quarks as a function of charged-particle multiplicity, would provide important contribution to the origin of QGP-like effects in pp collisions. Hadronic resonances are produced in the bulk of the expanding medium in heavy-ion collisions and they can decay while still traversing in the medium. The decay daughters may interact with other particles in the medium, which would result in suppression of resonances while their reconstruction, as the invariant mass of the daughters may not match that of the parent particle. This process is known as re-scattering. In other hand, resonances can be regenerated as a consequence of pseudo-elastic collisions in the hadronic phase of the medium, which would result in their enhancement. Resonances, with relatively higher life-time, might not go through any of the above mentioned processes. Thus, the interplay of these processes makes the study of resonances in heavy-ion collisions more fascinating. Also resonances like $\phi(1020)$ contains strange (or anti-strange) quarks, they can be used to study strangeness production. It is also important to create a bridge between the small systems to heavy-ion collisions to understand the recently discovered phenomena, which is the primary motivation of the thesis.

Objectives and Results

Here, we are highlighting the major objectives and important results in the following points, which will give a glimpse of the works done in the thesis. In the conference presen-

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tation, the detailed results will be shown.

1. We have performed a double differential (Event shape and Multiplicity) study of ϕ meson production with ALICE at the LHC. We observe that ϕ behaves like a particle with net strangeness of one or two in small systems even though its net strangeness is zero [5, 6]. It has been observed that the bulk production in minimum-bias pp collisions remains independent of collision energy. It is also observed that the p_{T}-spectra gets harder with increasing collision energy. The ratio of p_{T} spectra in different multiplicity classes to the minimum bias spectrum shows that the yield increases with increasing charged particle multiplicity. It is found that the integrated yield and mean transverse momentum are independent of collision energies and they solely depend on the charged-particle multiplicity. The event shape analysis successfully separates a event based on its geometrical shape, isotropic vs jetty. These results can shed light to explore the QGP-like conditions in high-multiplicity pp collisions.

2. We have given predictions of the elliptic flow of charged and identified particles in Xe + Xe collisions at $\sqrt{s_{NN}} = 5.44$ TeV using A Multi-Phase Transport model (AMPT) [7, 8], which helps as a baseline for experimental data.

3. We phenomenologically attempt to formulate a model to characterize the heavy-ion collisions using relativistic kinetic theory in the form of Boltzmann Transport equation (BTE) using relaxation time approximation (RTA). Using this model, we have successfully explained the nuclear modification factor and elliptic flow [9–11].

4. We have studied the transport properties of the hadron gas using the BTE-RTA formalism in non-extensive statistics [12].

Summary

In the current scenario, with the discovery of QGP-like behavior in pp collisions at the LHC, the study of resonances like ϕ meson will play an important role in understanding the particle production mechanism in pp collisions. The unique and peculiar property of ϕ meson in strangeness sector makes it even more interesting. The usage of event shape observables like transverse spherocity along with charged particle multiplicity allows to disentangle the collisions based on its geometrical shape. The present attempt to formulate a model to characterize the heavy-ion collisions using relativistic kinetic theory in the form of Boltzmann Transport equation using relaxation time approximation may help to connect hadronic collisions to nucleus-nucleus collisions. The research work discussed in the PhD thesis has led to 15-international journal publications.

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