



Influence of kinematic cuts on the net charge distribution

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Abstract

The higher moments of the net charge distributions, e.g. the skewness and kurtosis, are studied within an infinite hadronic matter calculation in a transport approach. By dividing the box into several parts, the volume dependence of the fluctuations is investigated. After confirming that the initial distributions follow the expectations from a binomial distribution, the influence of quantum number conservation in this case the net charge in the system on the higher moments is evaluated. For this purpose, the composition of the hadron gas is adjusted and only pions and ρ mesons are simulated to investigate the charge conservation effect. In addition, the effect of imposing kinematic cuts in momentum space is analysed. The role of resonance excitations and decays on the higher moments can also be studied within this model. This work is highly relevant to understand the experimental measurements of higher moments obtained in the RHIC beam energy scan and their comparison to lattice results and other theoretical calculations assuming infinite matter.

Keywords: Heavy Ion Collisions, Transport Simulations, Higher Moments

1. Introduction

One of the main goals of heavy ion research is the exploration of the phase diagram of strongly interacting matter. At high temperatures and low baryo-chemical potentials lattice QCD calculations have established a cross-over transition between the hadron gas and the quark gluon plasma phase. It is expected that at lower temperatures and higher densities the transition turns into a first order phase transition separated by a critical endpoint from the cross-over region. Since there are no first principle calculations available up to date it is crucial to establish experimental observables that indicate the critical behaviour of the system formed in heavy ion collisions. Higher moments of the net charge and net baryon number distributions, e.g. the skewness and kurtosis, are very promising for this purpose, since they are sensitive to higher powers of the correlation length [1]. If strongly interacting matter passes through a critical endpoint the correlation length increases and this is imprinted in the higher moments of the particle distributions [2, 3]. Since the quark gluon plasma is formed in heavy ion collisions as a transient state of finite volume, it is important to investigate the dynamical evolution of the system when passing through the critical region [4]. The STAR

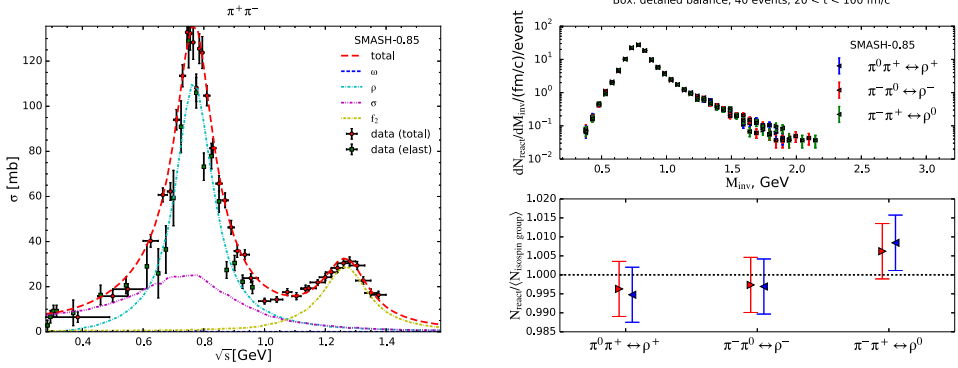


Fig. 1. Left: The different channels contributing to the $\pi^+ - \pi^-$ cross-sections are shown including a comparison to the PDG values [12] for the total and elastic cross section. Right: Detailed balance over the whole invariant mass distribution (upper panel) and summarized for individual reactions (lower panel).

collaboration has recently measured the beam energy dependence of higher moments [5]. The measurements of multiplicity or conserved charge fluctuations are affected by a multitude of other effects such as volume fluctuations due to centrality cuts, global conservation laws, detector efficiencies and finite statistics [6, 7, 8, 9, 10] that have to be taken into account before drawing conclusions about the phase diagram. In this work, the effect of cuts in momentum space on the higher moments of the net charge distribution is studied within a hadronic transport approach.

2. Higher moments in the transport approach

Infinite hadronic matter is calculated within a hadronic transport approach SMASH (Simulating Many Accelerated Strongly-interacting Hadrons) in a box ($V=10^3 \text{ fm}^3$) with periodic boundary conditions. There is either one particle species with purely elastic scattering or pions that are allowed to form ρ mesons. Fig. 1 (left) shows the (in) elastic cross-section of pions as a function of the center of mass energy of the binary collision in comparison to experimental data. Detailed balance is fulfilled in all reactions and in all phase space bins as shown in Fig. 1 (right). On the order of 5 million events are simulated to reduce the statistical error bars for the kurtosis calculation. The volume of the box is divided into 10 intervals ($\Delta x = 1 \text{ fm}$) and the higher moments are calculated from the final particles after resonance decays. We have checked that the initial distribution follows the expectations from a binomial distribution and free streaming does not change this result. The statistical errors for the skewness and kurtosis are estimated following the procedure explained in [11].

In Fig. 2 (left), it is shown, that the kurtosis saturates after 10 fm/c time evolution to the values expected for a binomial distribution and does not change systematically afterwards. Therefore, all calculations are done after $t = 10 \text{ fm/c}$. In addition, for a box with 400 pions and an elastic cross-section $\sigma = 10 \text{ mb}$, there is no temperature dependence of the results for the kurtosis in the range from $T = 120 - 200 \text{ MeV}$ (see Fig. 2, right). Therefore, we use a temperature of $T = 160 \text{ MeV}$ in the following.

3. Results for the $\pi - \rho$ system

Before coming to the more interesting $\pi - \rho$ system, let us have a look at the influence of momentum space cuts in a box with 200 pions and a constant elastic cross-section of $\sigma = 30 \text{ mb}$. In experiments kinematic cuts are required for acceptance and efficiency reasons, therefore we choose a realistic cut of $0.3 < p < 2 \text{ GeV}$ where p is the absolute value of the 3-momentum. In the case of a heavy ion reaction that would correspond to a cut in transverse momentum. In Fig. 3 the skewness and kurtosis without momentum

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