Particle Ratio Fluctuations at LHC Energies

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At high-enough energies nuclear matter is supposed to transform into a state where nucleons are no longer the basic constituents but rather quarks and gluons. Phase transitions like this often show large fluctuations in various measurable quantities. In high energy interactions fluctuations can be studied in the number of produced particles of various species or even better in ratios of such numbers. We present a study of event by event fluctuations in $(K^+ + K^-)/\pi$ and $(p + \bar{p})/\pi$ ratios at LHC energies using HIJING and AMPT event generator to investigate detector and efficiency effects.

Introduction

At high-enough energies nuclear matter is supposed to transform into a state where nucleons are no longer the basic constituents but rather quarks and gluons. Phase transitions like this often show large fluctuations in various measurable quantities. In high energy interactions fluctuations can be studied in the number of produced particles of various species or even better in ratios of such numbers. These studies open new possibilities to investigate the phase transition between hadronic and partonic matter as well as the QCD critical point [1]. We have used AMPT and HIJING model to study the ratio fluctuations. The main goal of this work is to study various detector effects that is particle identification, acceptance and efficiency on the measurement of ratio fluctuation.

Particle number fluctuations and correlations in nucleus-nucleus collisions at SPS and RHIC energies have been studied in various models. Event-by-event fluctuations of pion-to-kaon, proton-to-pion and kaon-to-proton number ratios are calculated for the samples of most central collision events and compared with the available experimental data [2]. We will present our results at LHC energies using type AMPT and HIJING.

Particle Ratio Fluctuations

We define the deviation ΔN_A from the average number $\langle N_A \rangle$ of the particle type A by $N_A = \langle N_A \rangle + \Delta N_A$. Then the covariance for species A and B and scaled variance is defined as in reference [8] can be

$$\begin{aligned} \Delta(N_A, N_B) &\equiv \langle \Delta N_A \Delta N_B \rangle \\ &= \langle N_A N_B \rangle - \langle N_A \rangle \langle N_B \rangle \end{aligned} \quad (1)$$

scaled variance

$$\begin{aligned} \omega_A \equiv \frac{\Delta(N_A, N_A)}{\langle N_A \rangle} &= \frac{\langle (\Delta N_A)^2 \rangle}{\langle N_A \rangle} \\ &= \frac{\langle N_A^2 \rangle - \langle N_A \rangle^2}{\langle N_A \rangle} \end{aligned} \quad (2)$$

The fluctuations of the ratio N_A/N_B will be characterized by

$$\begin{aligned} \sigma^2 &= \frac{\omega_A}{\langle N_A \rangle} + \frac{\omega_B}{\langle N_B \rangle} \\ &- 2\rho_{AB} \left[\frac{\omega_A \omega_B}{\langle N_A \rangle \langle N_B \rangle} \right]^{1/2} . \end{aligned} \quad (3)$$

If species A and B fluctuate independently according to Poisson distributions then $\omega_A = \omega_B = 1$, which will be of statistical contribution only and the equation (3) becomes

$$\sigma^2_{stat} = \frac{1}{\langle N_A \rangle} + \frac{1}{\langle N_B \rangle} . \quad (4)$$

The experimental data for N_A/N_B fluctuations are usually presented in terms of the so

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called dynamical fluctuations [7] defined as,

$$\sigma_{dyn} \equiv \texttt{sign}\left(\sigma^2 - \sigma_m^2\right)\left|\sigma^2 - \sigma_m^2\right|^{1/2} ,(5)$$

where σ^2 is defined by (3), and σ_m^2 corresponds to the σ_{stat}^2, can be estimated by mixed events procedure. A mixed events can be constructed by taking a large number of nucleus-nucleus collision events, and measures the numbers of N_A and N_B in each event. Then all A and B particles from all events are combined into one *set*. One fixes a random number $N = N_A + N_B$ according to the experimental probability $P(N)$, takes randomly N particles (A and/or B) from the whole set, fixes the values of N_A and N_B, and returns these N particles into the *set*. This is the mixed event number one. Then one constructs event number 2, number 3, etc.

On an event–by–event basis the fluctuations are best studied in the experiments by calculating the quantity, "non-statistical" or "dynamical(ν_{dyn})" fluctuations which is more robust and free from efficiency corrections as suggested in the ref [9]. The ν_{dyn} for K/π is defined as:

$$\nu_{(K,\pi,dyn)} = \frac{\langle N_K(N_K-1)\rangle}{\langle N_K\rangle^2} - 2\frac{\langle N_K N_\pi\rangle}{\langle N_K\rangle\langle N_\pi\rangle} (6)$$
$$+\frac{\langle N_\pi(N_\pi-1)\rangle}{\langle N_\pi\rangle^2}$$

Finally $\nu_{(K,\pi,dyn)}$ and $\sigma_{(K,\pi,dyn)}$ are compared once the the efficiency and geometrical corrections are properly done.

Summary and Outlook

We have done the analysis using the AMPT and HIJING event generators at LHC energy for Pb-Pb collision by two different methods to measure particles ratio fluctuations which are $\sigma_{(K\pi,dyn)}$ and $\nu_{(K\pi,dyn)}$. These different methods have been used to extract the dynamical fluctuations, $\sigma_{(dyn,K\pi)}$ and $\nu_{(dyn,K\pi)}$ which doesn't required mixed event to calculate. The results from the study of centrality dependence of the dynamical fluctuation are presented. As it was reported at SPS and RHIC energies, the dynamical fluctuation is found to be positive and decreasing with increasing centrality. The collision centrality dependence of ratio fluctuations for A+A collisions as characterized by the variable $\nu_{dyn,K\pi}$ seems to be better fit with N_{part}. In order to gain insight into the origin of these fluctuations, we calculate $\nu_{(dyn,K\pi)}$ for K^+/π^+, K^-/π^-, K^+/π^-, and K^-/π^+. Furthermore we have performed a comparative study for scaling with $dN/d\eta$, N_{part} to observe the geometric effect. The correction due to measurement uncertainty are checked and addressed.

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