CORRELATIONS AND FLUCTUATIONS AT RHIC

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Particle correlations and fluctuations measured by RHIC experiments at √sNN=130 GeV were discussed. The source size parameters were similar to those measured at the CERN-SPS, and no long duration time of particle emission were observed. It was pointed out that the dependences of longitudinal and transverse radius parameters on the pair momentum are explained with a single mT scaling function observed at the SPS energy. Fluctuation studies of mean pT of charged particles and of mean ET in an electromagnetic calorimeter found no significant non-statistical fluctuations by PHENIX, but some indication in charge independent ⟨pT⟩ by STAR.

1 Introduction

The correlation and fluctuation studies of hadrons in ultra-relativistic heavy-ion collisions reveal particle dynamics in a hadronization process at a thermal freeze-out temperature, where strong interactions between constituent particles in hadronic gas end substantially as a result of expansion of the volume. The particle yields and their momentum distributions including correlation and fluctuation signals are fixed at this stage. The particle correlations tell us the space-time evolution of the hadronic gas, while the particle fluctuations provide information of diffusion dynamics of the fluid. It has been discussed that such hadronic gas might be formed via a Quark-Gluon-Plasma(QGP) phase after the quark fluid cools down, if QGP matter is created during a collision. In such a scenario, signals of particle correlations and fluctuations could contain remnants of another multi-particle dynamics of de-confined quarks and gluons in the QGP epoch.

2 Correlation measurements

Suppose matter made of hadrons has an alternative phase of matter composed of de-confined quarks and gluons. Such the partonic matter should indicate different relations among thermo-dynamical variables from that of the hadronic matter since of a larger degree of freedom and due to presence of the Bag pressure in the hadronic phase. If QGP matter is created during a nuclear collision, the matter has to transit to normal nuclear matter beyond an energy gap at a critical temperature or density, since we have not seen any
partonic matter at zero temperature in this world. The QGP matter explosively expands as cooling down until the body reaches the critical temperature or density. In case the phase transition is in the first order, the expansion may slow down at the phase boundary due to a softening of the equation of state. Consequently a prolonged lifetime of particle emission is anticipated. The duration time of particle emission is an experimentally observable quantity in particle correlation measurements as a difference between the widths of the peaks in the correlation functions in the direction of pair (“outward”) and perpendicular to it (“sideward”) in the longitudinal center of mass system (LCMS).\(^1\) Therefore a larger source size parameter in the outward direction than that in the sideward direction can be a signature of QGP formation. Certainly we have to note that this idea should work completely for a static particle source, but the particle source in question is explosively expanding.

The STAR collaboration\(^2\) has published the first RHIC result of two-pion correlations measured at the mid-rapidity in the 12\% most central event class in Au+Au collisions. The PHENIX collaboration\(^3\) has also presented their pion correlation data in the same collision. The data are quite consistent each other. The systematic study of source size parameters as a function of c.m. energy indicates no jumps or steep changes of the parameters from the SPS to RHIC energies, but shows a gradual decrease of chaoticity and an increase of the longitudinal source size as is expected in the boost invariant model.

The ratios of \(R_{\text{out}}\) to \(R_{\text{side}}\) at various energies from AGS to RHIC are compiled in Fig.1. There were predictions that the ratio could be double or
Figure 2. The source size parameters as a function of transverse mass $m_T$ of the pair particles observed. The lines show the $m_T$ scaling function observed at the SPS energy.

larger at the RHIC energy, but they are excluded in the Au on Au collisions at this energy. The ratios seem consistent with unity over the entire range, and we conclude that no large temporal components are observed in the $R_{out}$ measurement.

Figure 2 shows the source size parameters of the STAR data as a function of transverse mass of the pair particles. It indicates that positive and negative pions behave identical and that the $m_T$ dependence exists. The $m_T$ dependence in the longitudinal direction has been predicted by several models including hydro-dynamical expansion in a source. Recently the NA44 collaboration discussed that both the transverse and longitudinal radius parameters at the SPS energy are fitted well with a single scaling function $R = A/\sqrt{m_T}$, where $A = 3.0 \pm 0.2$ fmGeV$^{1/2}$. The lines inserted in Fig.2 show the function, which seems to reproduce the dependences of both transverse and longitudinal radius parameters at the RHIC energy. We will examine this hypothesis in the second RHIC-year runs at $\sqrt{s_{NN}} = 200$ GeV.

3 Fluctuation measurements

Fluctuation study is another tool to pin down the phase transition from QGP matter to hadronic matter. If a QCD mixed state where partonic bubbles coexist in hadronic matter, is produced in a period of transition, and if the transition is too fast to maintain local equilibrium, fluctuations not following the statistics of hadronic particles are anticipated in physical quantities relat-
ing to particle productions. Therefore, a particle fluctuation beyond statistics might be a signature of the QGP formation. Theorists suggest to measure locally conserved quantities such as net baryon number, electric charge or strangeness. Enormous efforts are under going to extract these quantities. Data available at this moment are the event-by-event mean momentum fluctuation of charged particles and the fluctuation of mean transverse energy measured in an electromagnetic calorimeter. The PHENIX collaboration has presented the mean $p_T$ fluctuation of the top 5% centrality events in Au+Au collisions. The distribution is quite well reproduced over four orders of magnitude by a Gamma function with given parameters extracted from the semi-inclusive $p_T$ measurements. The collaboration has made a very careful mathematical analysis and preliminarily concluded that no significant excess from the statistically independent emissions were observed. The same conclusion has been drawn for the mean $E_T$ distribution.

4 Summary

We have discussed the new results of particle correlation and fluctuation studies from the RHIC experiments. The source size parameters observed in Au on Au collisions at $\sqrt{s_{NN}}=130$ GeV are similar to those at the SPS energies. There are no indications of a huge source formation or a prolonged mixed phase as the similar observations at the SPS or AGS energies. The source size parameter dependences on the pair momentum is reproduced by a single $m_T$ scaling function observed at the SPS energy. No significant non-statistical fluctuations in $<p_T>$ and $<E_T>$ were observed by PHENIX, but some indication in charge independent $<p_T>$ is reported by STAR.

References

8. J.G. Reid for the STAR Collaboration, talk at “Quark Matter 2001”.

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