International Journal of Modern Physics A

JETS AND FLOW EFFECTS ON TRANSVERSE MOMENTUM FLUCTUATIONS

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Received (November 29, 2004)
Revised (Day Month Year)

We briefly review the nonequilibrium description of parton thermalization then extend the formulation to account for contributions to fluctuations from flow and the energy loss of the high transverse momentum particles. Calculations are then compared to the measured ransverse momentum fluctuations.

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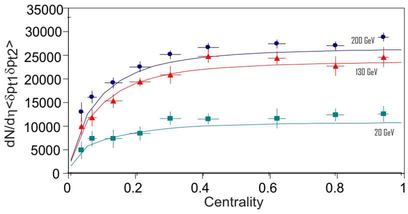
Keywords: Relativistic Heavy Ions, Event-by-event fluctuations.

1. Introduction

In series of publications [1] it was shown that one can describe the centrality dependance of average transverse momentum $\langle p_t \rangle$ to the onset of thermalization in heavy ion collisions, also in [1] it was shown that the fluctuations of transverse momentum $\langle \delta p_{t1} \delta p_{t2} \rangle$ also follow the same trends as $\langle p_t \rangle$. In this talk we will continue along the same lines of the above references and extend the discussion to include flow and jets. One can see that thermalization occurs as the scattering drives the phase space distribution within a small fluid cell toward a Boltzmann distribution that varies in space through the temperature $T(\mathbf{x}, t)$. Near local equilibrium, spatial correlations occur because the fluid is inhomogeneous these spatial correlations fully determine the momentum correlations. To quantify those ideas Boltzmann transport equation was used in [1] to show how thermalization alters the average transverse momentum such that $\langle p_t \rangle = \langle p_t \rangle_o S + \langle p_t \rangle_e (1 - S)$ where S is the survival probability [1]and $\langle p_t \rangle_o$ is the initial value that is determined by the particle production mechanism, while $\langle p_t \rangle_e$ is the equilibrium value and this is inversely proportional to time. To relate the centrality dependance to the onset of thermalization we see that the survival probability S decreases with increasing centrality so that the average p_t peaks for impact parameters near the point where equilibrium is established beyond this point hydrodynamic evolution will change $\langle p_t \rangle_e$ as the lifetime increases. Systems formed in the most central collisions can experience cooling that reduces$\langle p_t \rangle_e$ with proper time τ as $\langle p_t \rangle_e \propto \tau^{-\gamma}$ [1].



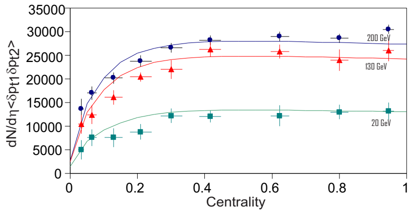


Fig. 1. dynamic p_t fluctuations computed with flow (right) and with jet(left). Continous lines are our calculations compared with data points [3]. Centrality is determined by the number of participants relative to zero impact parameter.

2. Flow and p_t Fluctuations

To study p_t fluctuations we introduce the two-body momentum correlation function $r(\mathbf{p}_1, \mathbf{p}_2) = N(\mathbf{p}_1, \mathbf{p}_2) - N(\mathbf{p}_1)N(\mathbf{p}_2)$. This is related to multiplicity variance R_{AA} as shown in [1]. For particles with momenta $\mathbf{p}_1$ and $\mathbf{p}_2$, dynamic p_t fluctuations [1] $\langle \delta p_{t1} \delta p_{t2} \rangle \propto \int \, d\mathbf{p}_1 d\mathbf{p}_2 \, r(\mathbf{p}_1, \mathbf{p}_2) \delta p_{t1} \delta p_{t2}$ where $\delta p_{ti} = p_{ti} - \langle p_t \rangle$; STAR measures this observable. Dynamic fluctuations depend on two-body correlations and, correspondingly, are quadratic in the survival probability. If the initial correlations are not far from the local equilibrium value, we can write $\langle \delta p_{t1} \delta p_{t2} \rangle = \langle \delta p_{t1} \delta p_{t2} \rangle_o S^2 + \langle \delta p_{t1} \delta p_{t2} \rangle_e (1 - S^2)$ [1]. The initial fluctuations $\langle \delta p_{t1} \delta p_{t2} \rangle_o$ is determined by the particle production mechanism, while $\langle \delta p_{t1} \delta p_{t2} \rangle_e$ describes the system near local equilibrium. We applied the wounded nucleon model to estimate $\langle \delta p_{t1} \delta p_{t2} \rangle_o$. ISR measurements imply $\langle \delta p_{t1} \delta p_{t2} \rangle_{pp} / \langle p_t \rangle_{pp}^2 \approx 0.015$. We used HIJING to estimate R_{pp} and R_{AA}, thus building in resonance and jet fluctuations.

Spatial inhomogeneity induces spatial correlation since it is more likely to find particles near a dense clump. So spatial correlations fully determine the momentum correlations , this is similar to ideas in [7], since the distribution at each point is thermal, the mean p_t at each point is proportional to the temperature $T(\mathbf{x})$, so that $\langle \delta p_{t1} \delta p_{t2} \rangle_e \sim \int r(\mathbf{x}_1, \mathbf{x}_2) \delta T(\mathbf{x}_1) \delta T(\mathbf{x}_2)$, where $r(\mathbf{x}_1, \mathbf{x}_2)$ is the spatial correlation function, $\delta T = T - \overline{T}$, and $\overline{T}$ is the density-weighted average. Using the result from [1] we define the near equilibrium fluctuations as $\langle \delta p_{t1} \delta p_{t2} \rangle_e = F \frac{\langle p_t \rangle^2 R_{AA}}{1 + R_{AA}}$. The dimensionless quantity F depends on ξ_t / R_t where ξ_t is the correlation length and R_t is the width of transverse density profile. We compute F assuming $R_t \propto N_{\rm part}^{1/2}$; $F = 0.046$ for $\xi_t / R_t = 1/6$. We used HIJING to estimate R_{AA}.

To include flow and study the energy dependence of fluctuations, we take the flow velocity β to be a function of centrality as measured in [2], this choice modifies $\langle p_t \rangle_e^2$ such that $\langle p_t \rangle_o^2 \rightarrow \langle p_t \rangle_e^2 \{ \frac{1+\beta}{1-\beta} \}$. We see that our model with flow can fit the most central collisions at the highest beam energies by taking flow into account. We want to mention that we did not take fluctuation of the flow it self into account [4]. Calculations in figs 2 illustrate the common effect of thermalization on two-body p_t observables. The solid curves in all figures are fit to STAR fluctuation data.

3. jet quenching effects

We want to include the effect of quenched jet partons to p_t fluctuations. To do so we start by looking at p_t of both soft and hard particles as a random walk such that the soft particles get kicked among themselves and also by hard parton with effective change in their p_t as $p_{ti}^2 \rightarrow p_{ti}^2 + k_s^2 \nu_i$ where ν_i is the number of scattering suffered by i^{th} soft parton. This approach will lead to $\langle \delta p_{t1} \delta p_{t2} \rangle \propto k_s^2 \int \int \delta n_{t1} \delta n_{t2} r(x_1, x_2) dx_1 dx_2$, where k_s is the transverse momentum change per collision among soft particles and δn is the deviation of density seen by the soft particle from the average density of the medium.

As the jet partons passes through the medium it deposits some of its energy to the medium, or may be absorbed completely in a random walk model. It was shown in [5] that the 10 GeV fast parton can loss $14GeV/fm$ when traversing the dense matter, so it is almost absorbed inside the medium, so that its initial p_{ti} is decreasing such that $p_{ti}^2 \rightarrow p_{ti}^2 - k_h^2 \nu_i$, where p_{ti} is the initial jet momentum and ν_i is the number of collisions the i^{th} hard particle has suffered. One can compute k_h but what is important here is the ratio k_h/k_s so we will use this ratio as a fitting parameters to STAR data. Now we add the contributions from soft and hard components of the fluctuation to each other weighted by fractions of soft and hard particles production f [6] respectively, so we get

$$\langle \delta p_{t1} \delta p_{t2} \rangle \approx (1 - f^2 + f^2 (k_h/k_s)^2) \langle \delta p_{t1} \delta p_{t2} \rangle_e, \tag{1}$$

where $\langle \delta p_{t1} \delta p_{t2} \rangle_e$ is given in section 2. We used equation (1), with $k_h/k_s = 2$ to fit experimental data as shown in figure 1.b. We see that in the most central collision which we expect one can see mini jets, the effect of quenching this mini jets will give better agreement with the data compared to the one without jets.

To conclude our results we see that space correlations induces momentum correlations, this idea is similar to [7]. We showed that flow or jets can give better agreement to p_t fluctuations in most central collisions for Au+Au at RHIC. We can not see whether flow alone or jets can be the major reasons for p_t fluctuations.

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