Elliptic Flow from a Parton Cascade

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In nucleus-nucleus collisions at the Relativistic Heavy Ion collider (RHIC), a system of deconfined quarks and gluons is expected to be formed for about 3 – 10 fm/c. Various signatures have been proposed to verify its existence [1]. Since the volume and lifetime of this matter may be much larger and longer than those given by the confinement scale $\approx 1/\Lambda_{QCD}$, it is expected that collective motion of these deconfined partons should arise and have observable consequences that provide information on the dynamics in quark-gluon plasma.

The collective motion of particles in heavy ion collisions can be studied via the elliptic flow [2, 3], which measures the azimuthal asymmetry of the transverse flow pattern, i.e., the average of squared transverse momentum asymmetry $< (p_x^2 - p_y^2)/(p_x^2 + p_y^2) >$. At RHIC energies, copious mini-jet production leads to a high density of partons on a very short time scale, and elliptic flow can be generated from interactions at the partonic level prior to hadronization. We have recently studied this effect [4] using the parton cascade code ZPC [5, 6].

Initial partonic conditions can be estimated for Au+Au collisions at RHIC energies via the HIJING generator [7]. We have considered simple idealized geometries for a first analysis. Initially, partons are uniformly distributed in the overlapping region of two disks each having a transverse radius of 5 fm with their centers separated by a distance equal to the impact parameter. For collisions of large nuclei at not very large impact parameters, the multiplicity is roughly proportional to the overlapping area. HIJING estimates for $b = 0$ a gluon rapidity density $\mathrm{d}N_g/\mathrm{d}y \approx 300$. Again as a first idealization we have assumed a uniform rapidity distribution from -5 to $+5$ and taken a momentum distribution given by a local thermal one at a temperature of 500 MeV. Furthermore, produced particles are taken to be formed on a hyperbola in the t-z plane, with z the beam direction and x-z plane the reaction plane, using a formation proper time $\tau_0 = 0.2$ fm.

At RHIC energies, the initial minijet system is dominated by gluons. Their subsequent time evolution can be described by the parton cascade model ZPC. In this model, only gluon-gluon elastic scattering has been included, with a cross section (σ_g) depending on an effective screening mass, which we vary in order to study the dependence of the elliptic flow on σ_g.

In Fig. 1, we show results for fixed impact parameter $b = 7.5$ fm. The time evolution of v_2 for different values of the gluon-gluon scattering cross section is shown. All asymptotic values are reached very early, $t < 2$ fm/c, well before the hadronization transition. For interaction length $\sqrt{\sigma/\pi}$ larger than the mean free path, the numerical method of particle partition [8] has been used in order to obtain stable solutions of the Boltzmann equation. For the typical cross section be-

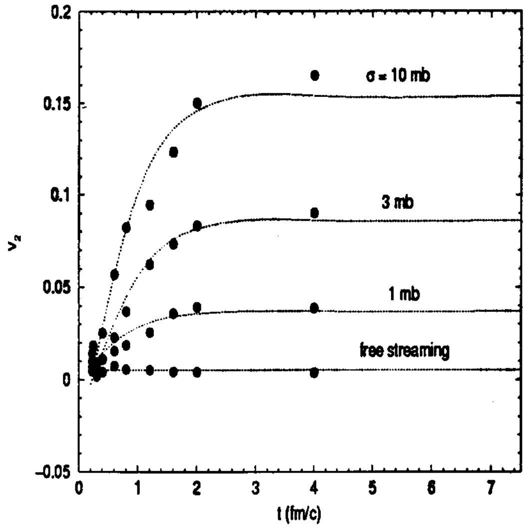

Figure 1: Time evolution of v_2 coefficient for different effective parton scattering cross sections in Au+Au collisions at $\sqrt{s} = 200$ GeV/nucleon and an impact parameter 7.5 fm. Filled circles are cascade data, and dotted lines are hyperbolic tangent fits to the data.

tween gluons, 3 mb, the final v_2 after the partonic stage is around 0.1 which is quite large and easily detectable. Since the screening mass, or equivalently, the effective parton scattering cross section is uncertain we have studied its effect on the elliptical flow by using different values for the cross section, i.e., 1 mb and 10 mb. We see that v_2 is rather sensitive to the cross section and increases with increasing parton scattering cross section. However, with finite parton scattering cross sections, values for v_2 are smaller than that in the ideal hydrodynamic limit, which is around 0.2 [3]. This demonstrates that very large dissipative corrections are at work since in the ideal fluid limit the flow depends only on the speed of sound that is in our case $1/\sqrt{3}$. The important role played by dissipative phenomena in collective properties of plasma evolution was also demonstrated in [6] in connection with the transverse energy evolution. For these initial conditions even Navier-Stokes is inadequate and the full microscopic parton cascade is necessary.

The strong dependence of the elliptic flow on the parton cross section could provide an important probe of the plasma dynamics if hadronization and final hadronic rescatterings do not modify the results too much. We cannot yet address this problem within the scope of ZPC and will study this important topic using a more comprehensive transport model that is being developed by us.

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