PHASE TRANSITION IN THE ELLIPTIC-FLOW EXCITATION FUNCTION

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A possible way of detecting the phase transition to the quark-gluon plasma is by revealing some rapid changes in the speed of sound ($c_s = \sqrt{\partial p/\partial e}$) for strongly-interacting matter. A sensitive measure of the speed of sound early on in the reactions is the elliptic flow. The elliptic flow is the anisotropy of transverse emission at midrapidity. At AGS energies, the elliptic flow results from a strong competition [1] between squeeze-out and in-plane flow, as illustrated in Fig. 1. In the early stages of the collision, the spectator nucleons block the path of participant

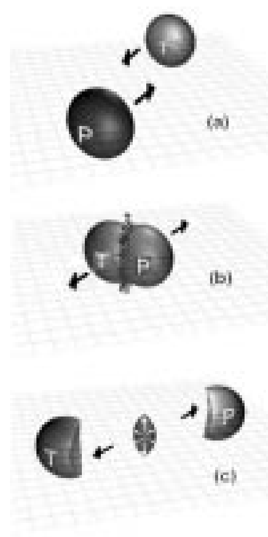

Figure 1: Schematic illustration of the collision of two Au nuclei at relativistic energies. Time shots are shown for an instant before the collision (a), early in the collision (b), and late in the collision (c).

hadrons emitted toward the reaction plane; therefore the nuclear matter is initially squeezed out preferentially orthogonal to the reaction plane. In the later stages of the reaction, the geometry of the participant region (i.e. a larger surface area exposed in the direction of the reaction plane) favors in-plane preferential emission.

The squeeze-out contribution to the elliptic flow and the resulting net direction of the flow depend on two factors: (i) the pressure built up in the compression stage compared to the energy density, and (ii) the passage time for removal of the spectator shadowing. In the hydrodynamic limit, the characteristic time for the development of expansion perpendicular to the reaction plane is $\sim R/c_s$, where R is the nuclear radius. The passage time is $\sim 2R/(\gamma_0\, v_0)$, where v_0 is the c.m. spectator velocity. The squeeze-out contribution should then reflect the ratio [2]

$$\frac{c_s}{\gamma_0\, v_0}\,. \tag{1}$$

According to (1) the squeeze-out contribution should drop with the increase in energy, because of the rise in v_0 and then in γ_0. A stiffer equation of state (EOS) should yield a higher squeeze-out contribution. A rapid change in the stiffness with baryon density and/or excitation energy should be reflected in a rapid change in the elliptic flow excitation function. A convenient measure of the elliptic flow is the Fourier coefficient $\langle \cos 2\phi \rangle \equiv v_2$, where ϕ is the azimuthal angle of a baryon at midrapidity, relative to the reaction plane. When squeeze-out dominates, the Fourier coefficient is negative.

To verify whether the expectations regarding the elliptic-flow excitation function are realistic, we have carried out Au + Au reaction simulations [3], in the energy range of (0.5–11) GeV/nucleon. The excitation functions calculated using a stiff EOS with a phase transition (open circles) and a stiff EOS with a smooth density dependence are compared in Fig. 2. For low beam energies ($\lesssim$ 1 AGeV), the elliptic flow excitation

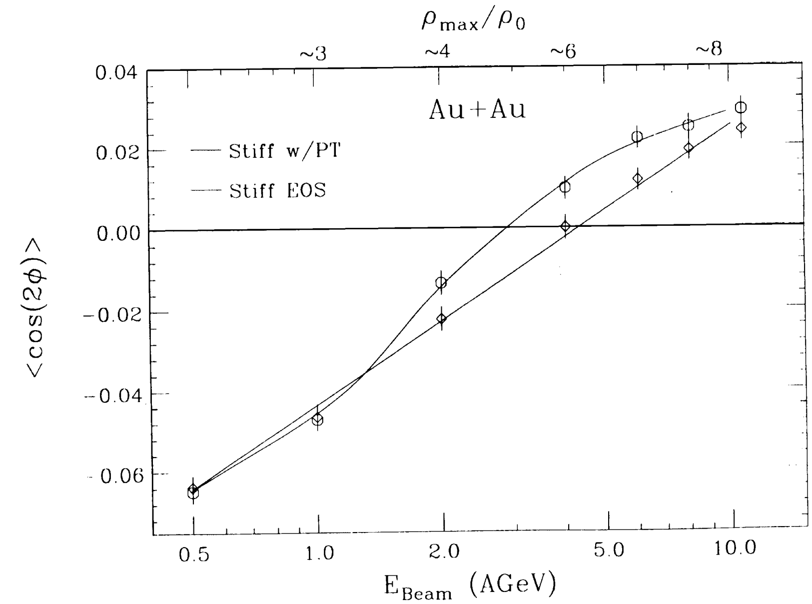

Figure 2: Calculated elliptic flow excitation functions for Au + Au. The open diamonds represent results obtained with a stiff EOS. The open circles represent results obtained with a stiff EOS and with a phase transition.

functions are essentially identical because the two EOS are either identical or not very different at the densities and temperatures that are reached. For $2 \lesssim E_{Beam} \lesssim 9$ AGeV the excitation function shows larger in-plane elliptic flow from the calculation which includes the phase transition, indicating that a softening of the EOS has occured for this beam energy range. This deviation is in direct contrast to the esentially logarithmic beam energy dependence obtained (for the same energy range) from the calculations which assume a stiff EOS without the phase transition. Present data on elliptic flow from EOS, E895, and E877 Collaborations [4] point to a variation in the stiffness of EOS in the region of ~(2–3) GeV/nucleon, corresponding to baryon densities of $\sim 4\,\rho_0$.

References

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