Elliptical Flow in Heavy Ion Collisions Near the Balance Energy

Y. M. Zheng*, C. M. Ko, B. A. Li+, J. Natowitz, and B. Zhang

Because of the opposite effects from the attractive nuclear mean-field potential and repulsive nucleon-nucleon scattering, nucleon in-plane collective flow in heavy ion collisions is negative at low incident energies but becomes positive at high incident energies [1]. Using the transport model, it has been found that the balance energy at which nucleon collective flow changes sign is the same for a stiff nuclear equation of state and a soft equation of state but with a reduced nucleon-nucleon cross section [2]. To determine which of the two equation of states describes correctly the nuclear matter properties and the heavy ion collision dynamics thus requires the study of other observables. One possibility is the nucleon differential flow [3], which gives the transverse momentum dependence of nucleon in-plane flow. It has been shown that the stiff equation of state leads to a larger differential flow at high transverse momenta than the soft equation of state. Other observable such as the elliptical flow, which measures the anisotropy in the transverse momentum distribution, is also possible in differentiating the effects due to the two equation of states [4].

We have considered collisions of two ^{48}Ca nuclei at an impact parameter $b = 2$ fm. Using a stiff equation of state with compressibility of 380 MeV, the balance energy found from the isospin-dependent transport model [5] is about 65.5 MeV. The same balance energy is obtained if one uses a soft equation of state with compressibility of 200 MeV and a reduced cross section of 0.88 σ_{NN}, where σ_{NN} is the free nucleon-nucleon cross section as used in the case of stiff equation of state. The two equation of states give, however, different elliptical flows as shown in Fig. 1, where the elliptical flow at the balance energy is about -0.7% for the stiff equation of state (solid circle) and about 0.5% for the soft equation of state with reduced cross sections (solid triangle).

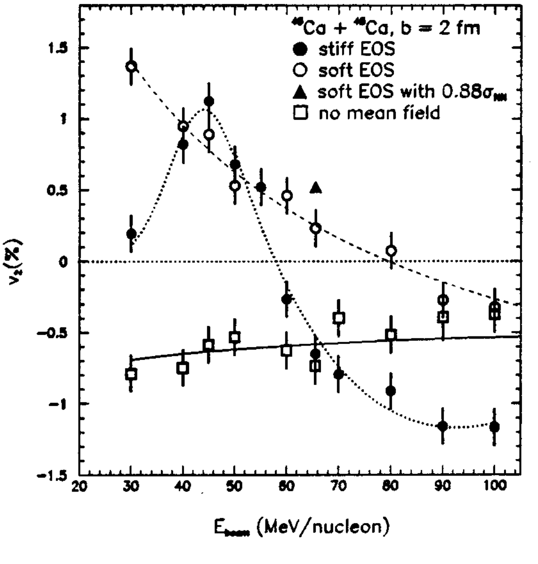

Figure 1: Elliptical flow as a function of incident energy. Open circles, solid circles, and open squares are, respectively, for a soft equation of state, a stiff equation of state, and without mean-field potential. The solid triangle is from a soft equation of state with a reduced nucleon-nucleon cross section.

To help understand the change in the sign of elliptical flow, we also show in the same figure the elliptical flow for the cases of no mean-field potential (open square) and soft equation of state with free nucleon-nucleon cross section (open circle). Without mean-field potential, the elliptical flow is negative as a result of the dominance of out-of-plane squeeze out over the in-plane flow. Including in the transport model a stiff equation of state, which gives an attractive potential in heavy ion collisions in this energy range, the elliptical flow becomes less negative due to increasing in-plane flow. Since a soft equation of state gives a more attractive potential than a stiff one, it enhances the in-plane flow and thus leads to a positive elliptical flow. Using a smaller nucleon-nucleon cross section reduces the out-of-plane squeeze out and further increases the elliptical flow.

In Fig. 1, we also show the incident energy dependence of the elliptical flow in the three cases of stiff equation of state, soft equation of state, and without mean-field potential. Significant differences are seen in these elliptical flows. Experimental measurements of the nucleon elliptical in heavy ion collisions near the balance energy is thus expected to allow us to obtain s simultaneously information about the nuclear equation of state and the nucleon-nucleon in-medium cross section.

*China Institute of Atomic Energy, P. O. Box 275 (18), Beijing 102413, China
+Department of Chemistry and Physics, P.O. Box 419, Arkansas State University, State University, AR 72467-0419

References

[1] G. D. Westfall and J. Péter, *Ann. Rev. Nucl. Part. Sci.* (1999), to be published.

[2] B. A. Li, Z. Z. Ren, C. M. Ko, and S. J. Yennello, *Phys. Rev. Lett. 76* 4492 (1996).

[3] B. A. Li and A. T. Sustich, *Phys. Rev. Lett.* in press.

[4] Y. M. Zheng, C. M. Ko, B. A. Li, J. Natowitz, and B. Zhang, to be published.

[5] B. A. Li, C. M. Ko and W. Bauer, *Int. J. Mod. Phys. E7* 147 (1998).