PHYSICAL REVIEW C VOLUME 30, NUMBER 2 AUGUST 1984

Apparent temperature of medium mass fragments

J. Aichelin*
National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, Michigan 48824
(Received 2 April 1984)

Employing a recently advanced model for fragmentation of heavy targets in medium and high energy nucleus nucleus collisions, we analyze the apparent slopes of the energy distribution of medium mass fragments. In this model a fragment is emitted after it has absorbed a nucleon from a hot spot, which is formed during the initial state of the reaction. The calculated slopes, being a combination of the hot spot temperature and the Fermi momentum, reproduce the available data very well.

Recently a paper was published[1] which suggests a liquid gas phase transition may have been observed in high energy nuclear reactions by showing that the apparent slope of the mass yield curve as a function of the temperature of the system has a minimum around 12 MeV. The main input in this calculation is the assumption that the system reaches thermodynamical equilibrium and therefore the slopes of the energy distribution of the fragments reflect the true temperature of the system. However the slopes have values between 9 and 20 MeV, whereas an analysis of the isotopic distribution results in temperatures around 3 MeV. Moreover an analysis of the measured double differential cross section $d^2\sigma/dEd\Omega$ shows that for nucleus nucleus collision a frame in which the fragments are emitted isotropically cannot be found.

We advanced a model[2,3] which describes the triple differential cross section $d^3\sigma/d\Omega\, dZdE$ of fragments created in heavy ion collisions. In this model, the charge yield distribution is obtained by the maximum entropy principle requiring only that the total charge is conserved and is therefore independent of the temperature of the system. Here the fragments originate from a cold part of the target describing the reaction as a two step process. In the first step the geometrically overlapping regions between projectile and target form an equilibrated zone resulting in a global destablization of the target. By emitting nucleons this zone decays. Parts of the surrounding cold nuclear matter may absorb a nucleon and, supported by the Coulomb force, escape as fragments. The fragmentation is considered as fast process, therefore the fragments keep the momentum they had at the moment of breaking off. The distribution of these momenta is isotropic and has a width given by[4]

$$\Delta = \tfrac{2}{5}k_F^2 A_F \frac{A_T - A_F}{A_T - 1} \quad , \tag{1}$$

where A_T,A_F are fragment and target mass and k_F denotes the Fermi momentum. The momentum distribution of the absorbed nucleons is thermal and given by $2mT$, where T is the temperature of the hot zone and m is the mass of the nucleon. The apparent temperature of the fragment momentum distribution is the sum of both divided by twice the fragment mass

$$T' = \left[2mT + \tfrac{2}{5}k_F^2 A_F \frac{A_F - A_T}{A_T - 1} \right] \Big/ 2A_F \quad .$$

For large fragment masses the second term dominates and we expect an almost linear dependence between T' the fragment mass. For lower fragment masses the first term cannot be neglected leading to a stronger increase of T' with decreasing fragment masses.

In thermodynamical models, where the fragments are assumed to come from an equilibrated nucleus one finds a linear relationship between the apparent temperature and the fragment mass. If a fragment of mass A_F is emitted from a system with mass $A_T = A_F + A_R$ momentum conservation leads to an apparent temperature of

$$T' = T\frac{A_R}{A_T} \quad ,$$

where T is the true temperature of the system. The slope of this straight line usually is used to determine the mass of the emitting system whereas the value of T is obtained by extrapolating the data to $A_R = A_T$.

Recently quite accurate data of fragment distributions at a certain angle ($\theta = 34°$) in p+Xe and p+Kr reactions were published.[5,6] We have shown that our model predicts even finer details of the charge yield distribution.[3] Here we analyze the measured apparent temperature of the fragments applying Eq. (1). Earlier studies have shown that in p-heavy ion collisions, center of mass system and the laboratory system coincide,[7] therefore the slope of the energy distribution is angle independent. The Fermi momentum is

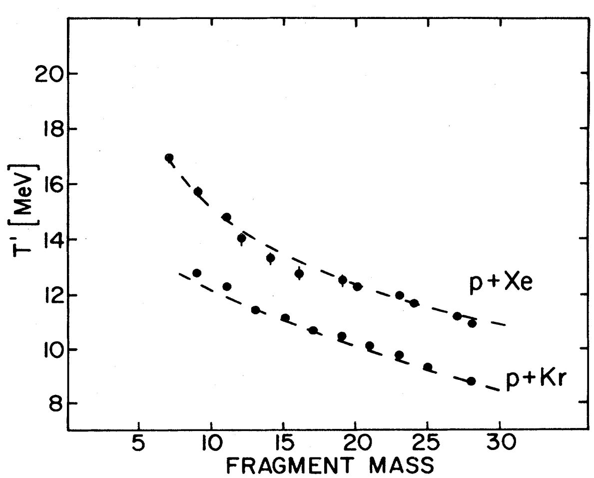

FIG. 1. Experimental (Refs. 5 and 6) and calculated apparent temperature for p+Xe and p+Kr as a function of fragment charge.

taken as 240 MeV/c. Without knowing the double differential cross section $d^2\sigma/dEd\Omega$ we cannot determine the temperature of the hot spot from experiment. Hence we considered it as a parameter chosen to 34.5 MeV and 10.25 MeV for Xe and Kr, respectively. These values are in between the error bars of the extracted one (11 MeV) for p + Au at 5 GeV.[2]

Figure 1 shows the calculated and the measured[5,6] apparent temperature as a function of fragment masses. The data show, as predicted, an almost linear dependence for heavier masses and a stronger increase of the apparent temperature for the lighter masses. The latter fact cannot be explained in a simple thermal model. Recently it was suggested to view A_R as a function of the fragment mass A_F.[8] However this requires an additional parameter whose physical interpretation is not obvious.

The data of triple differential cross sections $d^3\sigma/dEd\Omega\, dA$ so far available can be well described in a nonthermal model which predicts no physical relation between apparent temperature and slope of the mass yield curve. We think therefore it is premature to identify the apparent temperature with the true temperature of the system as well as assuming a physical relation between temperature and the slope of the mass yield curve as long as a description of the triple differential cross section $d^3\sigma/dEd\Omega\, dZ$ is not obtained in a thermal model.

---

*On leave from University of Heidelberg, West Germany.

[1]A. D. Panagiotou, M. W. Curtin, H. Toki, D. K. Scott, and P. J. Siemens, Phys. Rev. Lett. **52**, 496 (1984).
[2]J. Aichelin, J. Hüfner, and R. Ibarra, Phys. Rev. C **30**, 107 (1984).
[3]J. Aichelin and J. Hüfner, Phys. Lett. **136B**, 15 (1984).
[4]A. S. Goldhaber, Phys. Lett. **53B**, 306 (1974).
[5]A. S. Hirsch, A. Bujak, J. E. Finn, L. J. Gutay, R. W. Minich, N. T. Porile, R. P. Scharenberg, B. C. Stringfellow, and F. Turkot, Phys. Rev. C **29**, 508 (1984).
[6]J. A. Gaidos, L. J. Gutay, A. S. Hirsch, R. W. Minich, R. Mitchell, T. V. Ragland, R. P. Scharenberg, F. Turkot, R. B. Willmann, and C. L. Wilson, Phys. Rev. Lett. **42**, 82 (1979).
[7]A. I. Warwick, H. H. Wiemann, H. H. Gutbrod, M. R. Maier, J. Peter, M. Freedman, D. J. Henderson, S. B. Kaufman, E. P. Steinberg, and B. D. Wilkins, Phys. Rev. C **27**, 1083 (1983).
[8]D. Boal, submitted to Phys. Rev. C.