Fragment kinetic energies in spectator decays

T. Odeh and W. Trautmann for the ALADIN collaboration

The kinetic energies of fragments from spectator decays at relativistic bombarding energies are puzzling in the sense that they exhibit the properties of an equilibrated decay, however with corresponding temperatures that are far above the breakup temperatures needed for statistical descriptions. This contradicts the assumption of equilibration which is the basis for the thermodynamical interpretation of the multifragmentation process and for the search for signals of a phase transition [1].

Here we report on new measurements for target spectators in the reaction ^{197}Au + ^{197}Au at E/A = 1000 MeV. Energy spectra of light charged particles and intermediate-mass fragments were measured with high-resolution telescopes placed at backward angles. The products of the projectile decay were measured with the time-of-flight wall of the ALADIN spectrometer [2] and the quantity Z_{bound} as a measure for the impact parameter was determined event-by-event.

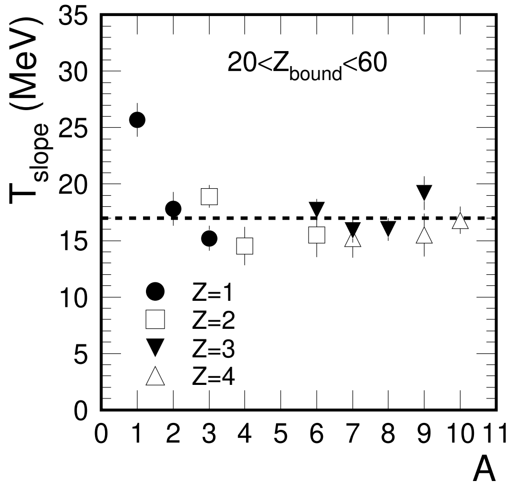

Figure 1: Slope parameters for isotopically resolved charged particles and fragments from the reaction ^{197}Au + ^{197}Au at E/A = 1000 MeV at Θ_{lab} = 150° as a function of the mass number A. For protons and α particles the value of the high-temperature component is shown.

The observed spectra exhibit Maxwellian shapes except for protons and α particles where two components with rather different slope temperatures may be discerned [3]. The low-temperature component characterized with temperatures $T \approx 5$ MeV has the features expected for evaporation from excited residual nuclei. In particular, its relative intensity is strongly correlated with the intensity of heavier fragmentation products. The high-temperature components have $T \approx 26$ MeV for protons and $T \approx 15$ MeV for α particles, the latter value being close to those observed for other species with $A \geq 2$.

The mean values of the slope temperatures for $20 \leq Z_{bound} \leq 60$ are shown in Fig. 1. Apart from the protons all spectra exhibit temperatures that are scattering closely around a mean value of 17 MeV (dashed line). The much higher value for protons may indicate a memory of the entrance channel as observed for neutrons from the same reaction [3]. This seems absent for the products with mass $A \geq 2$ which, in the spectator frame, have mean kinetic energies independent of bombarding energy and of equal magnitude in longitudinal and transverse directions [2].

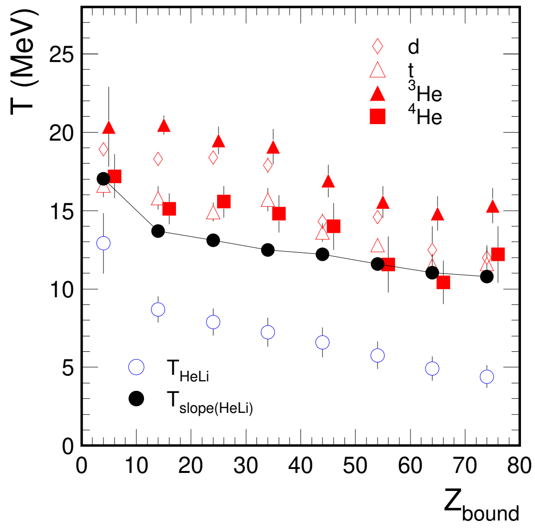

Figure 2: Slope temperatures for light charged particles of mass $2 \leq A \leq 4$ (squares, triangles and diamonds) and the isotope temperature T_{HeLi} (open circles) as a function of Z_{bound}. The full circles are the slope temperatures obtained for the fast breakup of a Fermi gas with finite temperature T_{HeLi} according to ref. [5].

It was suggested many years ago by Goldhaber that the kinetic energies in fast fragmentation processes may be connected to the Fermi momenta of the spectator nucleons prior to breakup [4]. He also pointed out that the resulting behavior is indistinguishable from that of the decay of a thermalized system with rather high temperature. This picture has been extended to the case of expanded fermionic systems at finite temperatures by Bauer [5]. Using the prescription given there and assuming a temperature equal to the measured values of T_{HeLi} [6] we obtain slope temperatures between 11 and 17 MeV close to those observed (Fig. 2).

References

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