Thermodynamical Variables from Spectator Decay in Heavy Ion Reactions ◇

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One of the major interests in the study of intermediate energy heavy-ion collisions is the understanding of the multifragmentation proccess in connection with liquid-gas phase transitions [1]. In recent experiments of the ALADIN collaboration kinetic energy spectra of fragments from the spectator decay have been interpreted as a signal for a liquid-gas phase transition [2], but this interpretation of the thermodynamical state is also under debate [3]. In this work we adress this question by studying the results of transport calculations [4] using the relativistic Landau-Vlasov (RLV) method [5]. On one hand, we determine a local temperature T_{loc} from an analysis of the calculated local momentum distributions. On the other hand, from a coalescence model we generate stable fragments and analyze their kinetic energy spectra. As in experimental analyses we apply a Siemens-Rasmussen blast model fit to the spectra to obtain a slope temperature T_{slope} and a radial flow velocity β. We have applied these methods in extracting the temperature in participant and spectator matter for Au on Au collisions at intermediate energies [6,7]. Here we limit our discussion to spectator matter.

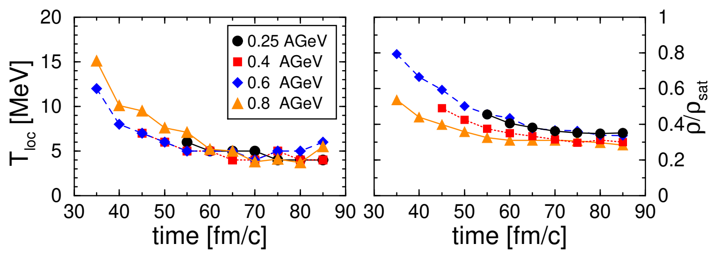

Fig. 1: Time evolution of the local temperature (left) and density (right) for spectator matter in semi–central Au+Au collisions at different incident energies [6,7].

Fig. 1 shows the time evolution of the local temperature T_{loc} and density in the center of the projectile spectator. We find that the local temperature and density show only a small dependence on the initial beam energy indicating that the spectator forms an intermediate equilibrium state and therefore looses information of the ingoing chanel. Similar results have been found in experimental studies [2]. It was already concluded in [4] that the spectator enters an thermodynamical instability region at $t \gtrsim 45$ fm/c. Thus, one expects multifragmentation from the equilibrated spectator source with $T_{loc} \approx 5-6$ MeV and $\rho \approx \left(\frac{1}{3}-\frac{1}{2}\right) \times \rho_{sat}$, values which are consistent with experiments [1,2].

It is therefore of interest to analyze this system with respect to fragment configurations in the coalescence model. Fig. 2 shows the fragment mass dependence of the slope temperature $T_{slope}(A_f)$. The independence of T_{slope} on A_f indicates the emission of fragments from an already thermalized source, consistently with the previous statements.

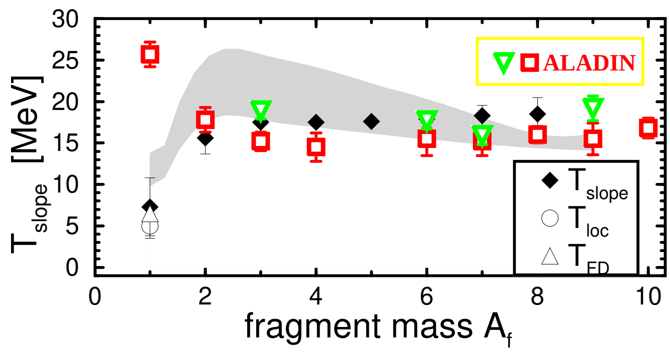

Fig. 2: Slope temperatures T_{slope} of nucleons ($A_f = 1$) and IMF's (full triangle), local nucleon temperature T_{loc} (open circle) in comparison to ALADIN–experiments [2]. The gray band is the result of a statistical model. Figur taken from [7].

The difference in T_{slope} for the nucleons and fragments is significant and can be explained by the Fermi motion inside the spectator fragment. Following Goldhaber [8] the Fermi motion of a disintegrating source leads to a width of the momentum spectra of the nucleons increasing their apparent temperature. The same is true for fragments formed. We demonstrate this in the present situation in a a statistical model. Initializing a Fermi gas at the range of temperatures and densities shown in Fig. 1 and applying a coalescence algorithm in the same way as in the transport calculation, we obtain slope temperatures of the produced fragments inside the gray band. These are consistent with the results of the transport calculation. The local and the apparent temperatures extracted from the calculations are in excellent agreement with the experimental analyses of the ALADIN data [2]. We conclude that the spectator forms a freeze-out configuration in thermodynamical equilibrium before decaying into fragments.

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