The Caloric Curve from 8 GeV/c NegativePion, Anti-proton + Gold

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The caloric curve for hot nuclei formed in 8 GeV/c negative pion, anti-proton + gold has been investigated. This system is excellent for studying the thermodynamic properties of hot nuclei since the target nucleus is rapidly heated with little compression via collisions induced by GeV hadron beam. This data was collected from experiment E900a which was performed at the Brookhaven National Laboratory in the summer of 1998. The light charged particles and intermediate mass fragments from the reaction were detected using the Indiana Silicon Sphere (ISiS) 4π detector array [1].

In order to determine the caloric curve for this system, the excitation energy (E*) has been constructed from the experimental data based on an event-by-event basis. The excitation energy for an event is assigned according to the prescription,

$$E^* = \sum_{i=1}^{Mc} K_i^{CP} + M_n \langle K_n \rangle + Q + E_g$$

Here K_i is the kinetic energy of each thermal-like charged particle in an event of multiplicity M_c. In order to differentiate between charged particles associated with the fast cascade and those which originate from a thermal-like source, the thermal-like charged particles are defined as:

$$K_i \leq 30 \text{ MeV for } Z = 1$$

$$K_i \leq 9.0Z + 40 \text{ MeV for } Z \geq 2$$

The second term in the excitation energy equation involves the neutron multiplicity M_n which are taken from the measured charged particle vs. neutron correlations from Goldenbaum *et al* [2]. The average kinetic energy of neutrons $\langle K_n \rangle$ is initially estimated from Coulomb-corrected proton spectra and then iterated to obtain a self-consistent value $\langle K_n \rangle = T_{th}$, where $T_{th} = (E^*/a)^{1/2}$ and $a = A/11$ MeV^{-1}. Q is the mass difference of the reconstructed events. E_γ is a small term to account for gamma de-excitation of the residual nucleus and excited fragments. E_γ is assumed to be $E_\gamma = 1\text{MeV}(M_c+M_n)$. The corrections for ISiS geometry are also included in the calculation to obtain the final value of the excitation energy.

The heating curve for the 8 GeV/c π^-, $\bar{p}$ + ^{197}Au is constructed from the thermal-like excitation energy from reconstructed data and the double isotope ratio temperature [3]. According to Albergo *et al*, if the chemical and thermal equilibrium are achieved, the temperature of the hot nuclei can be determined from double isotope ratio:

$$T_0 = \frac{B}{\ln(aR_0)}$$

where B is the binding energy difference for the fragment, a is a factor that depend on statistical weights of the ground state nuclear spins, and R_0 is the ground-state population ratio at freezeout (Y) for fragment (A,Z). In particular,

$$R_0 = \frac{Y(A_1, Z_1)/Y(A_2, Z_2)}{Y(A_3, Z_3)/Y(A_4, Z_4)}$$

where the isotope pairs (1,2) and (3,4) must differ by the same number of neutron and / or proton.

Since the measure yields include the cumulative effects of secondary decay and some other processes, Tsang *et al*. have defined a correction factor κ for each double isotope ratio. The measured yields R_{app} is defined as $R_{app} = \kappa R_0$, where R_0 is the equilibrium yields ratio. Therefore, one can determine the freezeout temperature T_0 from the relation

$$\frac{1}{T_{app}} = \frac{1}{T_0} + \frac{\ln k}{B}$$

The heating curves for the 8 GeV/c 8 GeV/c π^-, $\bar{p}$ + ^{197}Au are constructed from two different isotope ratios $\left(\frac{d/t}{^3He/^4He}\right)$ and $\left(\frac{p/d}{^3He/^4He}\right)$. The top panel of figure 1 shows the caloric curves for π^- + ^{197}Au using the apparent temperatures. The bottom panel is the caloric curves constructed from the corrected temperature using Tsang's correction factor κ.

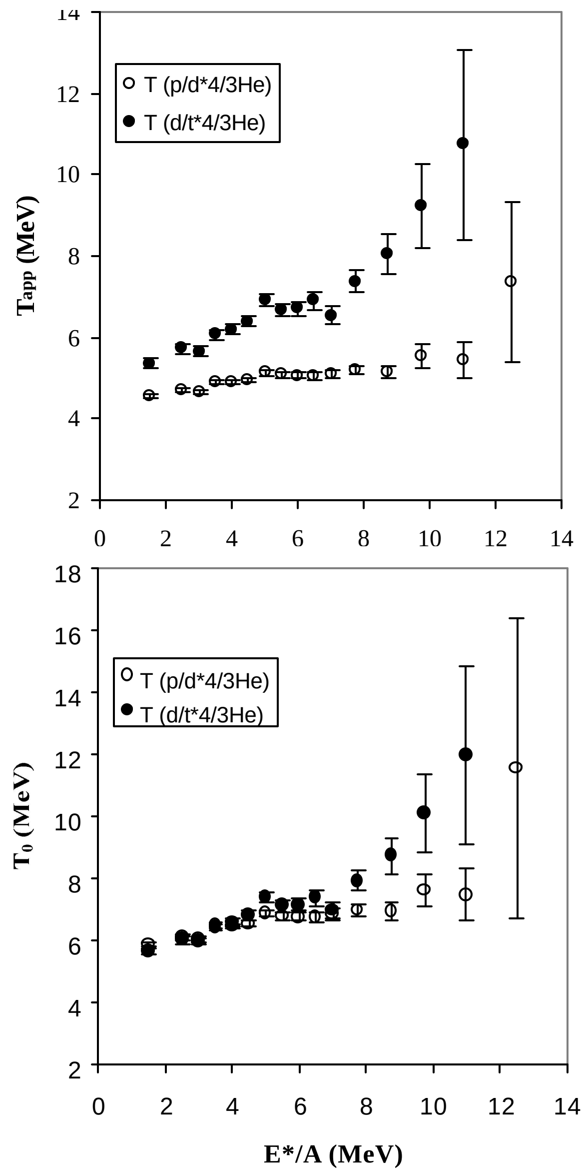
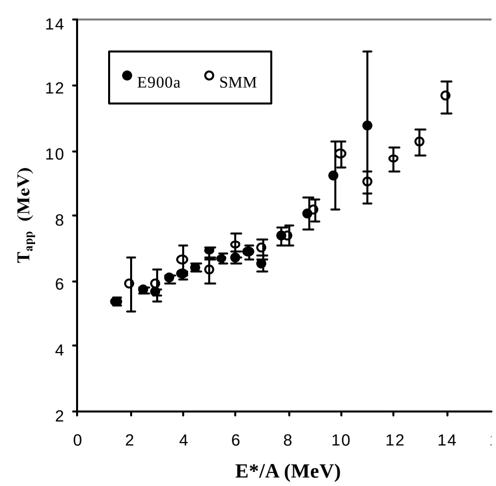


Figure 1: The caloric curves from two double isotope ratio thermometers using the apparent yield ratio (Top panel), and using the corrected temperatures (Bottom panel).

Due to poor statistics, there are considerable uncertainties in temperatures at high excitation energy per nucleon. With the apparent temperatures, the caloric curves from the two isotope temperatures are different. These temperatures are similar at low excitation energy per nucleon when using Tsang's correction factors. The differences between the two isotope temperatures at higher excitation energy per nucleon can be explained from the fact that the correction factors were calculated for sequential decay effects for T < 4.5 MeV. In order to improve the correction at higher excitation energy, one needs to investigate the dependence of the correction factor (κ) on the excitation energy.



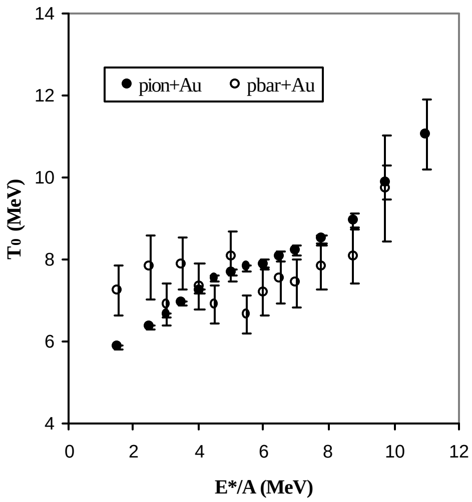


Figure 2 Caloric curve using (d/t)/(^{3}He/^{4}He) thermometer from π+Au data compares with $\bar{p}$+Au data.

The beam composition was about 98% π^-, 1% $\bar{p}$ and 1% K^- at the target. Figure 2 show the comparison between the caloric curves, using (d/t)/(^{3}He/^{4}He) thermometer, from π^- + Au and $\bar{p}$ + Au. Since there are small amount of $\bar{p}$ + Au data, the statistics are very poor. However, one may say that the caloric curves from the two data are in the same range. The caloric curve derived from the $\bar{p}$ data is flatter below 10 MeV.

Figure 3: Caloric curve using (d/t)/(^{3}He/^{4}He) thermometer from E900a experiment compares with the caloric curve simulated from SMM model.

The caloric curve from the experimental data is also compared to the caloric curve constructed from the simulation from the Copenhagen statistical multifragmentation (SMM) model. Figure 3 shows the comparison between the caloric curve from E900a data and SMM model. The heating curve from the SMM model is in agreement with the heating curve from the experimental data.

References

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