Investigating the experimental capabilities of the quadrupole thermometer

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Fragmentation Reliably quantifying temperature is a significant challenge in experimental efforts to study the nuclear equation of state. Over the years, a variety of thermometers have been developed, the most recent being the momentum quadrupole thermometer [1]. This was first implemented using the Maxwell-Boltzmann distribution of a classical ideal gas and employed to quantify temperature differences resulting from neutron/proton asymmetry present in the fragmenting nuclear system [2,3]. Recently a Fermi-Dirac distribution has been employed. This approach may provide information on quantum effects in particle and cluster emission [4,5].

In an effort to better understand the information accessible in quadrupole thermometer based studies, data acquired at 47MeV/u using an early version of the NIMROD detector array have been reexamined. This data set spans systems from ^{4}He+^{112,124}Sn to ^{64}Zn+^{112,124}Sn [6]. We will constrain ourselves here to the most central events (bin 4) of the ^{40}Ar+^{112}Sn system.

Various thermometers have previously been shown to be sensitive to the identity of the fragment chosen as the probe [2,3,6]. This behavior has also been observed in this data set as shown in Fig. 1. The general trend in the quadrupole fluctuation thermometer has been shown to be T(^{1}H)<T(^{2}H)<T(^{3}H)~T(^{3}He) with T(^{4}He) varying in its relative magnitude [2,3]. This ranking of temperatures implies different sources or times of fragment emission. The issue of fragment emission time has been addressed in earlier studies employing slope and double isotope thermometers by cutting on the fragment surface velocity [6,7].

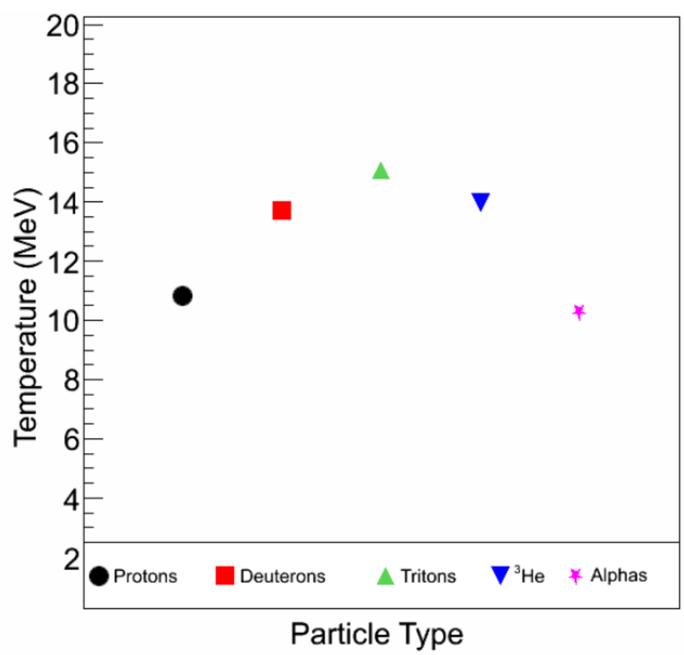

FIG. 1. Temperature as a function of particle type for ^{40}Ar+^{112}Sn.

To further probe features of the momentum quadrupole thermometer, a simple toy model of an isotropically emitting source was constructed. This model provides information on what effects, if any, could be expected from velocity cuts on the quadrupole thermometer. The initial calculations assume a Maxwell-Boltzmann distribution. The results of binning single source data along the transverse direction are shown in Fig. 2. Here the data are presented for two input temperatures as an integral of increasing transverse velocity. A third mixed source is also shown. It can be seen from this simulation that transverse cuts are unable to provide quality differentiation between sources well separated in

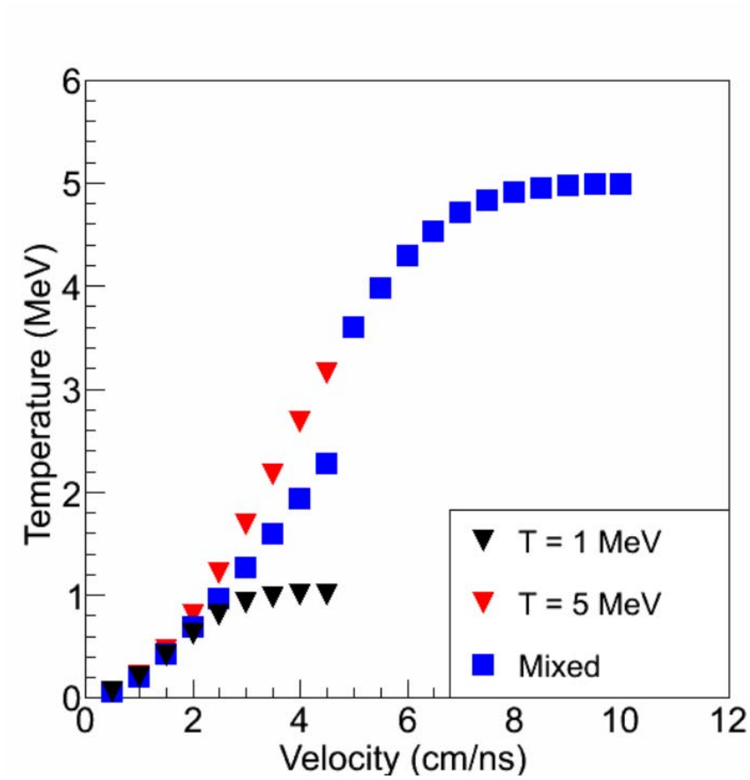

FIG. 2. Temperature derived from model as an integral of increasing transverse velocity. Sources are: black triangles T=1MeV, red triangles T=5 MeV, blue squares are an equal mixture of the previous sources

temperature. Thus, the continuum of sources that we observe in experimental data will not be differentiated by this method.

The top panel of Figure 3 shows the results of binning the quadrupole fluctuation data in equal increments of the velocity along the z –axis. For a single source, we observe a predominantly flat behavior of the derived temperature. Two additional sources, of equal intensity, were then added with offsets of +/- 4.5 cm/ns along the z-axis. The relative yield distribution of each source is seen in the center panel of Figure 3 and the derived temperatures in the bottom panel. From these figures, we see that the quadrupole based temperatures are sensitive to the source mixing. In each velocity window, this will depend upon the relative intensities and temperatures of the contributing sources.

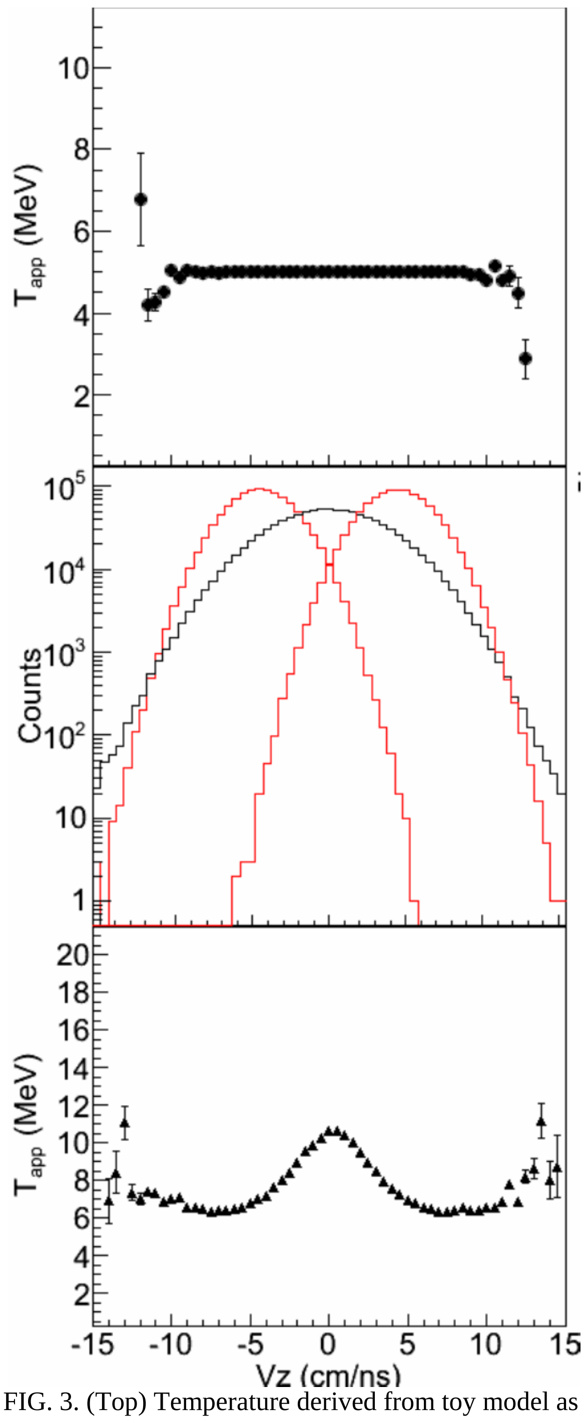

FIG. 3. (Top) Temperature derived from toy model as a function of z-axis velocity for a single source T= 5 MeV. (Middle) Yield of three sources as a function of z-axis velocity. Center source has T=12 MeV and outer sources have T=5 MeV. (Bottom) Temperature as a function of z-axis velocity for mixed sources

In Fig. 4, we have plotted experimental momentum quadrupole temperatures as a function of z-axis velocity obtained from bin 4 events from the reaction $^{40}Ar+^{112}Sn$ for Z=1,2 isotopes. In the previous studies [6] these data were fit assuming three contributing sources, a projectile like, target -like and intermediate velocity source. That assumption indicated different temperatures and multiplicities for the different sources. This is also evident in Figure 4, where we see that the experimental behavior of the momentum quadrupole thermometer for each particle type varies significantly as a function of the z-axis velocity.

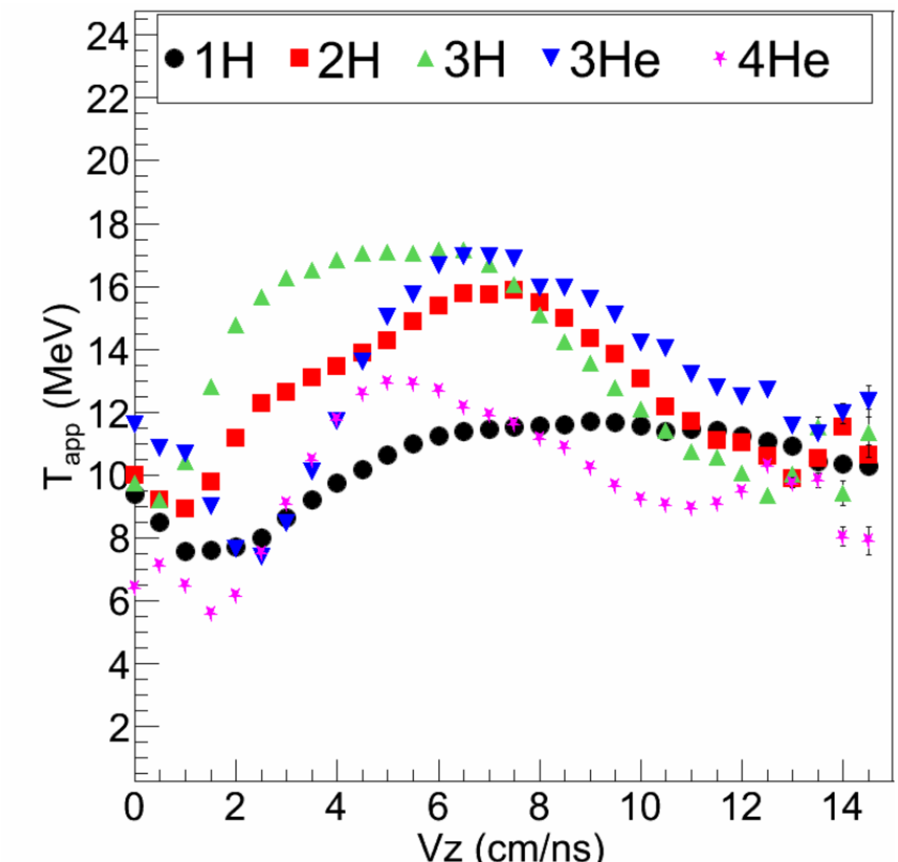

FIG. 4. Apparent temperature as a function of z-axis velocity for $^{40}Ar+^{112}Sn$ for particle types.

Unlike the fitting assumptions no a-priori definition of three well-defined sources has been made in constructing Figure 4. Given that the data reflect a continuous evolution of emission processes results of this type may lead to a better understanding of the reaction dynamics and provide a better method of source definition.

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