Lithium production in heavy ion reactions at 47 MeV/u

C. Bottosso, R. Wada, K. Hagel, J. B. Natowitz, L. J. Qin, T. Keutgen, Z. Chen, and P. K. Sahu

In the past few years many efforts have been carried out to investigate the characteristics of the emitting source created at the early stage of various heavy ion collisions using light particles of Z = 1 and Z = 2. Quantities such as density, temperature and symmetry energy have been studied to better understand the reaction processes [1]. To extend this work, we now perform an analysis to examine the influence of heavier particles on our earlier analysis. For this purpose, we have analyzed the energy spectra of ^{6}Li and ^{7}Li emitted in various reactions using ^{10}B, ^{20}Ne, ^{40}Ar, ^{64}Zn as projectiles and ^{112}Sn and ^{124}Sn as targets, all at the same incident energy of 47 MeV/u. This work, as the previous one, was done using NIMROD [2].

The energy spectra have been studied as a function of the violence of the collision which is correlated to an increase in excitation energy and leads to an increase of the charged particle and neutron multiplicity. We have divided the total multiplicity spectrum (given by the sum of light charged particle and neutron multiplicity) into four regions and have assumed that the most violent events, given by the top 30% multiplicity window, correspond to the more central collisions. We label these four regions Bin1, the most peripheral collisions to Bin 4 the most central. For each multiplicity window we have obtained differential lithium multiplicity spectra and we have performed moving source fits with three sources. In this way we were able to approximately separate the contributions from the projectile like fragment source (PLF), the intermediate velocity source (NN) and the target like fragment source (TLF). The three source fitting allows us to have a schematic picture of the emission process.

An example of the ^{6}Li multiplicity spectra for ^{64}Zn + ^{112}Sn system is shown in Fig. 1. As we can see, the most forward angles (q = 4.31 and q = 6.41) are dominated by the PLF contribution for which the velocity is fixed, by definition, near the beam velocity. On the other hand at the most backward angles the fit indicates that most of the Lithium ions originate from the target like source.

In addition this technique allows to estimate velocities, emission barriers, temperatures and particle multiplicities for each source, providing an idea of the evolution of the system. The parameters extracted from the fit for ^{6}Li for the ^{64}Zn + ^{112}Sn spectra are shown in Table I.

Table I. Multiplicity, temperature, Coulomb energy and source velocity for NN, PLF and TLF functions given by the fit for ^{64}Zn + ^{112}Sn.

	Multiplicity	*Temperature*	*Coulomb barrier*	*Velocity*
NN	0.0470±0.0011	16.00±0.02	11.000±0.046	4.884±0.049
PLF	0.0040±0.0012	12.00±0.02	10.000±0.347	7.967±0.045
TLF	0.0028±0.0045	3.00±0.04	4.000±3.622	0.001±0.074

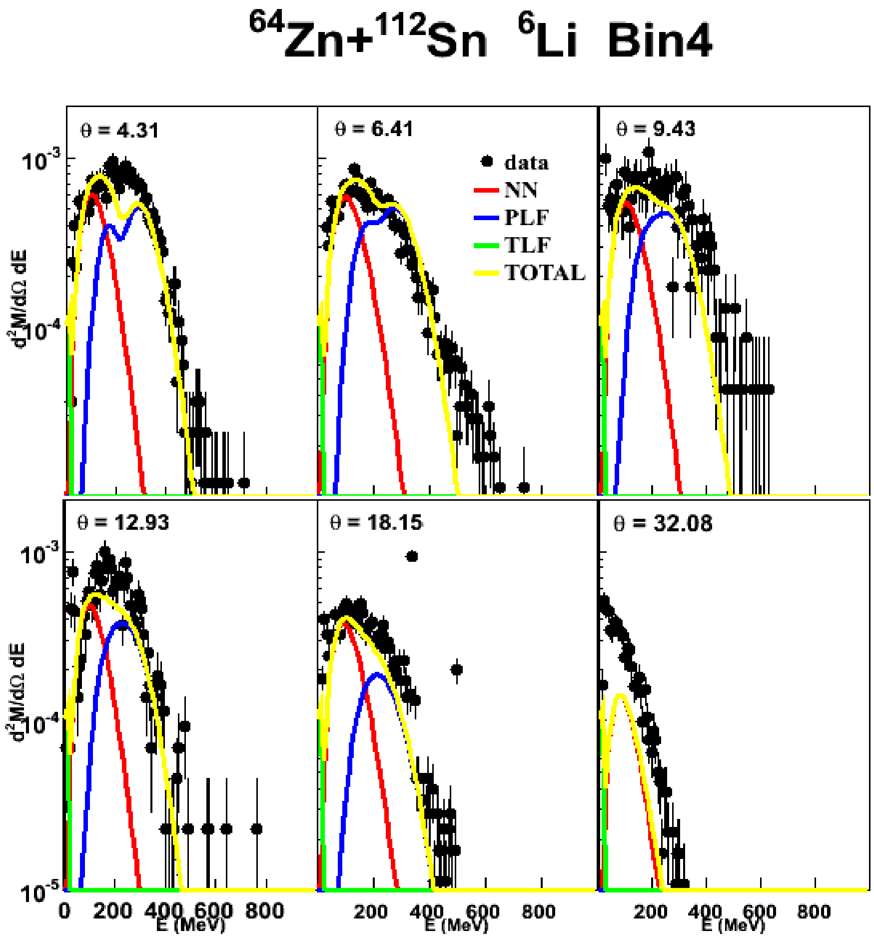

Figure 1. Multiplicity spectra for ^{6}Li in ^{64}Zn + ^{112}Sn system. Black dots are experimental data, fit with PLF function (blue line), NN function (red line) and TLF function (green line). The yellow line represents the total function, given by the sum of the previous three.

To the first approximation extracted source velocities come near expected values. In fact the calculated velocity in the NN source turns to be 4.77 cm/ns, which is close to the half of beam velocity, while it is 8.58 cm/ns for the PLF, which is about 90% of beam velocity. This gives us confidence in the quality of the fit.

To study the evolution of our data with collision violence, we show in Fig. 2 the ^{6}Li and ^{7}Li NN multiplicity for ^{64}Zn + ^{112}Sn system as a function of the centrality.

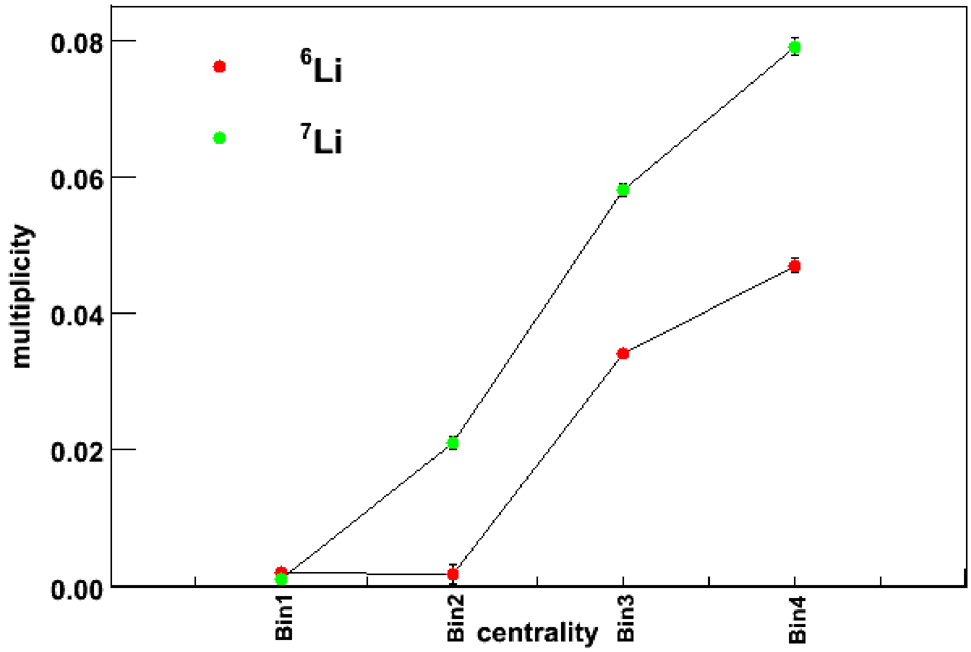

Figure 2. Lithium multiplicity in ^{64}Zn + ^{112}Sn system sorted by bin. Red dots represent ^{6}Li multiplicity values, green dots ^{7}Li.

We note that the number of lithium ions emitted after the collision increases with the collision violence but, in general, the absolute multiplicity is very small compared to values obtained for a particles. For example, in the case of most central collision, the multiplicity for NN component a particles is 2.009±0.230 as compared to the ^{7}Li multiplicity of 0.0470±0.0011.

This analysis has been done for every reaction system and leads similar results. That allows us to conclude that lithium makes only a very small contribution and does not significantly change the characteristics of the emitting source.

[1] L. J. Qin *et al.*, *Progress in Research*, Cyclotron Institute, Texas A&M University (2006-2007), p. II-5

[2] S. Wuenschel *et al., Progress in Research,* Cyclotron Institute, Texas A&M University (2006-2007), p. II-34