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Cluster structure effects of projectile in ^{7}Li+^{208}Pb reaction

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Abstract. Inclusive and exclusive cross sections have been measured for different projectile breakup channels. It is observed that the inclusive cross sections are larger than the exclusive ones. It is found that other processes, besides the direct breakup channel, significantly contribute to the inclusive channels. A clear α+x cluster structure has been found from coincidence data.

1. Introduction

The study of the reaction mechanisms induced by weakly bound stable nuclei of well known cluster structure like ^{6,7}Li and ^{9}Be is of current great interest. The Coulomb break-up of accelerated projectiles (^{7}Li in the present case) into (α+x) particles in the field of a heavy target nucleus is considered as an important phenomenon observed experimentally. Clustering is one of the most important ingredient of the nuclear many body problem [1]. Owing to the recent theoretical and experimental developments, the domain of the cluster studies is rapidly expanding toward highly excited and neutron rich nuclei [2]. Clustering is a general phenomenon [3] not only observed in light neutron-rich nuclei [4], but also in halo nuclei such as ^{11}Li [5] or ^{14}Be, for instance [6].

In the case of weakly bound nuclear systems (nuclei that have a larger breakup probability due to the low breakup thresholds), correlation among nucleons and pairing are manifested among others as an emergence of strong clustering and exotic shapes. In light α-like nuclei, clustering is observed as a general phenomenon at high excitation energy close to the α decay thresholds [7]. This has renewed interest in understanding the role of cluster states in nuclear synthesis [8]. The search for resonant structures in the excitation functions for various combinations of light α cluster (N = Z) nuclei in the energy regime from the Coulomb barrier up to regions with excitation energies of Ex =20-50 MeV remains a subject of contemporary debate [9]. Studying reactions induced by weakly bound nuclei has important outcomes for the cases of radioactive ion beams [10, 11, 12].

In this contribution, we report the data on the production of α particles in ^{7}Li induced reaction on the heavy target ^{208}Pb at near barrier energies. The main objective was to identify the reaction mechanisms responsible for the α particles production in the case of the use of a weakly bound projectile.

2. Experimental Details

The experiment was performed using a ^{7}Li beam delivered by the Laboratori Nazionali di Legnaro Tandem Van de Graaff accelerator having the following beam eneries 31,33,35 and 39 MeV. Beam currents ranged between 5 to 10 nA. A self-supporting ^{208}Pb target of thickness 200 μg/cm^2 was used. Light charged particles were detected with the 4π array (8πLP) set up described detail in [13, 14, 15, 16, 17, 18, 19, 20, 21]. The array is essentially made of two parts: a WALL in forward direction, covering the polar angles 2.5^0 to 34^0 and a BALL part covering the angles up to 163^0. The BALL consists of 126 telescopes. Each telescope consists of a Silicon surface barrier detector as ΔE, (300 μm thick), and CsI(TI) scintillator as E (5 mm thick). The angles from 34^0 to 163^0 are divided into 7 rings A, B, C, D, E, F & G. The WALL is a matrix of 11×11 telescope (the four at the corners and the central one for the exit hole of the beam are missing). This system allows for a very good identification of light charged particles: α, t, d and proton. ^{7}Li was completely stopped in the ΔE in our energy range. The data acquisition [22] has arranged to record for each telescope the Time Vs ΔE and ΔE Vs E_{res} matrices for particle identification. A typical 2D spectrum measured by a telescope at E_{lab} = 33 MeV is shown in Fig.1. One can observe different types of particles (p, d, t and αparticle) detected in ΔE vs. E_{tot} spectra (Fig.1b) are very clearly separated. Fig.1a Shows ΔE-T spectrum for the same energy. One can see from Fig.1a that the elastically scattered ^{7}Li is not observed in the ΔE-E_{tot} spectra as it is stopped in the ΔE (silicon detector).

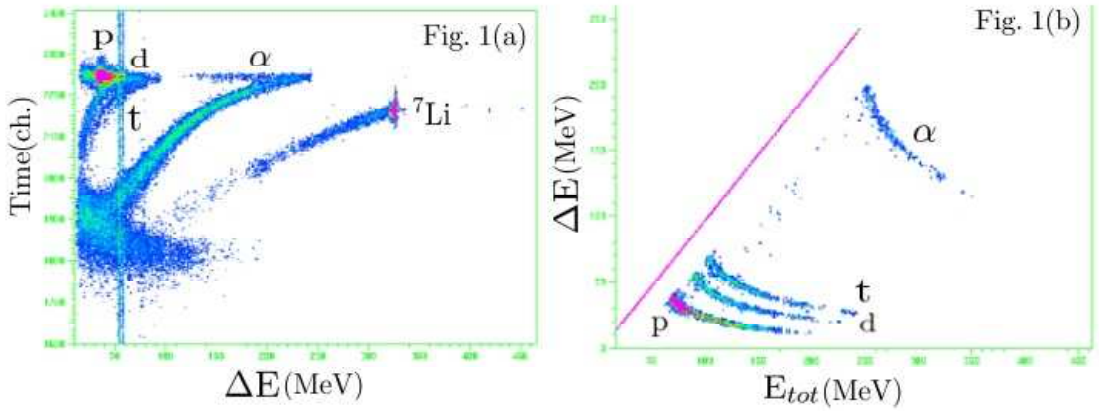

Figure 1. Experimental 2D particle spectra for ^{7}Li+^{208}Pb reaction.(a)ΔE Vs Time spectra at 33 MeV. The telescope was at forward angle (θ =20.6^0 and ϕ =346.53^0). All the particles are clearly observed including the elastic ^{7}Li. (b) same as (a) spectra of ΔE Vs E_{tot} . One can observe that the yields are less and also there is no elastic peak in Fig.1(b) as many particles (α,d,t...) were stopped in the ΔE detector.

3. Results and Discussion

We detected different types of particles emitted during the reaction process (both in singles and coincidence mode) around the Coulomb barrier energies same as in [23, 24]. Experimental 2D spectra are shown in Fig.1. Particles were identified by two methods: 1)using energy loss

information from ΔE and Eres for each telescope, 2) ΔE and Time. The time is a mixture of time of flight (TOF) and pulse shape discrimination rise time. From the above figure one can observe that different types of particles (p, d, t and α) have been detected including elastically scattered ^{7}Li. The different particles give indication of the presence of different types of processes involved in the reaction. The case of ^{7}Li is however more interesting as ^{7}Li has one bound excited state below the breakup threshold where as ^{6}Li has none. Coincidences were measured to gain insight on this point. The different channels were identified by making a coincidence between two observed fragments. The particles have different origins: 1) as the direct breakup of ^{7}Li from its resonance state at 4.63MeV into α and triton (t), 2) pickup of a neutron (very unlikely) to become ^{8}Be which breaks into (α+α) or 3) stripping of a neutron which produces ^{6}Li which afterward will break into α + deuteron(d). There was no neutron detector in the whole setup so no measurement was done using neutron in coincidence.

Deuterons and tritons of different energies are clearly separable and are expected to belong to the different types of sources as described above. The inclusive and exclusive angular distributions for the different coincidence measurements are shown in Fig.2. The exclusive differential cross sections were obtained for the following cluster channels (α+α),(α+d) and (α+t).

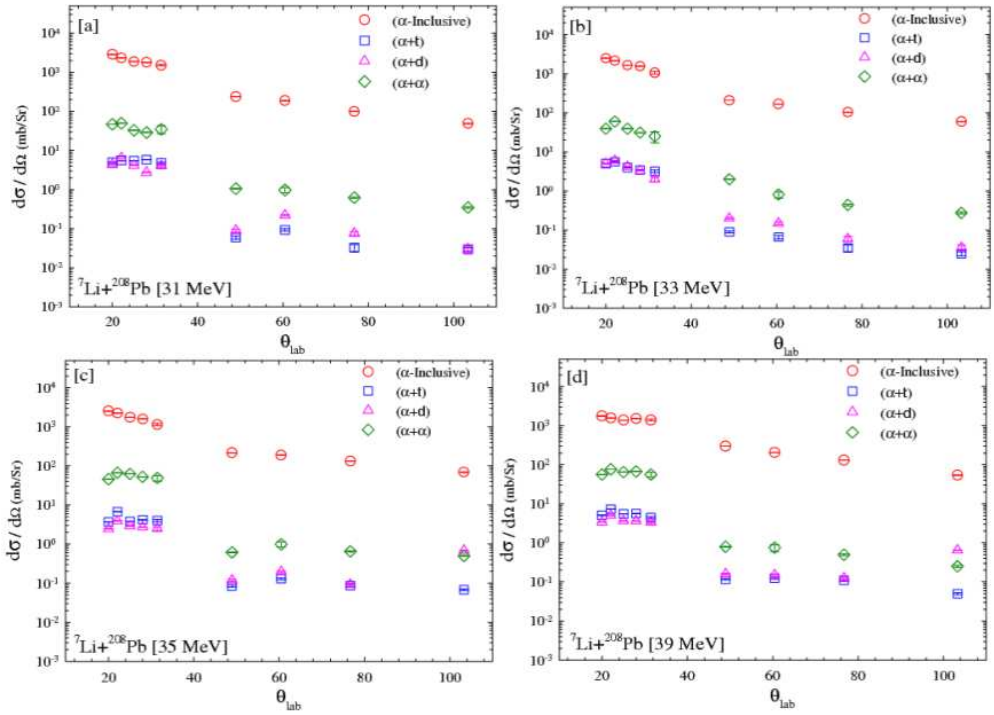

Figure 2. Inclusive and exclusive differential cross sections extracted from the coincidence data for different energies. (a) The differential angular distribution for 31 MeV. (b),(c) and (d) same as (a) only at different energy 33, 35, 39 MeV (see the text for details).

From the above figure one can clearly observe that the inclusive cross section is much larger than the exclusive cross section. This implies not only that the direct breakup channel is important but that processes besides breakup contribute significantly. The same type of conclusion was also reported in [24]. Quantitatively, about two orders of magnitude are missing. We can conclude that other reaction mechanisms which provides significant amount of α to the inclusive cross section need further study.

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