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Observation of pre-equilibrium alpha particles at extreme backward angles from ^{28}Si + ^{nat}Si and ^{28}Si + ^{27}Al reactions at E < 5 MeV/A*

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Abstract. α clusters are measured in ^{28}Si + ^{nat}Si and ^{28}Si + ^{27}Al reactions at $E(^{28}\text{Si}) < 5\,\text{MeV}/A$. Though forward angle data is explained well by the statistical model for compound nuclear emissions, the backward angle data indicate presence of pre-compound emissions.

PACS. 25.70.Gh Compound nucleus – 25.70.-z Low and intermediate energy heavy-ion reactions

1 Introduction

In heavy ion collisions at low incident energies ($E \sim$ 4–7 MeV/A) a dominant reaction mechanism is evaporation of light charged particles (LCP). The spectra of evaporation LCPs are generally explained well by the statistical model. However, there are many papers which report that the spectra of α-particles emitted from compound nuclei at high spin and excitation energy are not explained well by the statistical model calculations assuming a spherical compound nucleus [1]. It has been also observed that the entrance channel affects the equilibrium α-spectra to some extent [2]. These conclusions are however based on forward angle measurements only. On the other hand, the pre-equilibrium effects are considered to be negligible at these energies. In the light of these controversies we carried out an experiment where α-particles were measured at both forward and backward angles to have a more complete understanding of the reaction mechanism. The forward angle data was explained well in the framework of the statistical model for compound nuclear emissions. At extreme backward angles however, the data shows underpredictions in comparison to compound nuclear calculations.

2 Experiment

The experiment was carried out at the Nuclear Science Centre Pelletron facility, New Delhi. ^{28}Si^{9+} beam at incident energy of 130 MeV was bombarded on 1 mg/cm^2 of ^{nat}Si and ^{27}Al self-supporting targets. Standard two-detector Si telescopes were used for particle identification. Protons, deuterons, tritons, helions and alpha particles could be well separated. We, however, concentrate only on the alpha particles in this paper. The LCPs were detected in the telescopes at laboratory angles of 54°, 66°, 78°, 114°, 126° and 138°.

3 Results and discussion

Figure 1(a)-(d) shows the inclusive α-spectra measured from this experiment at forward and backward angles. We carried out statistical model calculations using the code ALICE91 [3] (the full Hauser-Feshbach calculations are not very different from ALICE91 results). The forward angle data is not reproduced well unless the excited compound nucleus is considered to be highly deformed. The deformations are calculated by using the rotating liquid-drop model. This observation reconfirms the earlier conclusions of [1,2]. However, at extreme backward angles the compound nucleus calculations fail to reproduce the data. This clearly indicates the contribution from non-compound effects, which has not been reported earlier as all the previous data were recorded at forward angles. As for mass symmetric systems the PEQ angular distributions are symmetric about 90° c.m. angle [4] there is a possibility that PEQ emissions become more prominent at extreme backward angles, even at such low energies. However one should determine which of the two laboratory angles is further away from 90° in the center of mass

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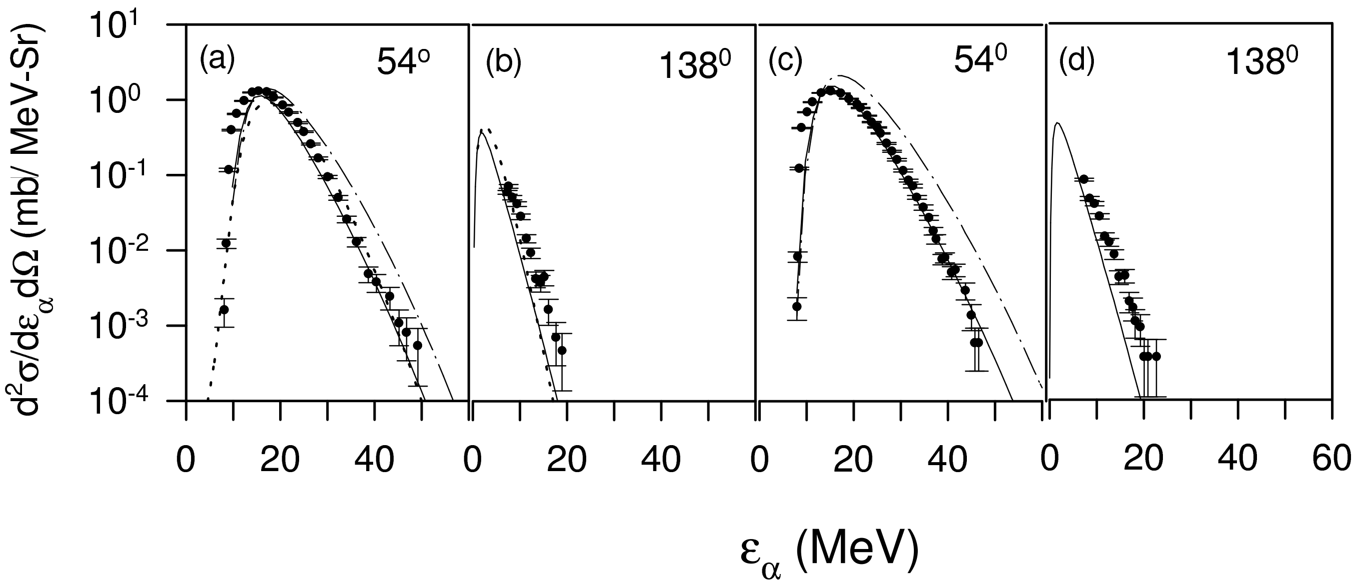

Fig. 1. Inclusive α-spectra for (a), (b) ^{28}Si + $^{\mathrm{nat}}$Si and (c), (d) ^{28}Si + ^{27}Al at the specified laboratory angles. The solid lines are ALICE91 calculations including RLDM deformation. In (a) and (c) also shown are ALICE91 calculations without deformation (dash-dotted lines). In (a), (b) the dotted lines are Hauser-Feshbach calculations.

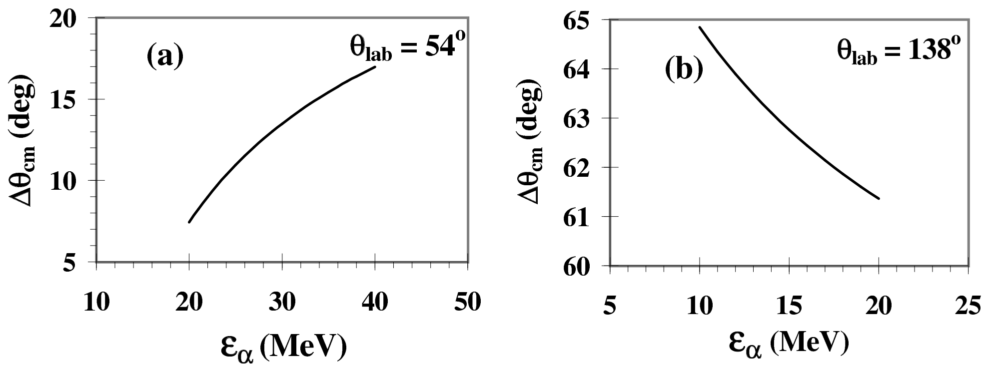

Fig. 2. The plot of $\Delta\theta_{\mathrm{cm}}$ $(=|\ \theta_{\mathrm{cm}} - 90°\ |)$ against the alpha-particle energy in the laboratory frame (ϵ_α). In (a) the range of θ_{cm} is between 82.56° and 73.03° and in (b) between 151.36° and 154.85°.

frame. In the present case, the c.m. angles corresponding to the tail part of the spectrum at 138° ($\epsilon_\alpha = 10$–$20\,\mathrm{MeV}$) (fig. 2(b)) is further away from 90° c.m. angle than the higher energy part ($\epsilon_\alpha = 20$–$40\,\mathrm{MeV}$) of the 54° spectrum (fig. 2(a)). However, the effect of pre-equilibrium is not very strong compared to that seen at the higher energies. Detailed study in this direction is in progress for a better understanding of this interesting effect.

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