CLUSTER EMISSION OF ^{8}Be IN THE ^{28}Si+^{12}C FUSION REACTION AT LOW TEMPERATURE.

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Abstract

Inclusive as well as exclusive energy spectra of the light charged particles emitted in the ^{28}Si (E_{lab}=112.6 MeV) + ^{12}C reaction has been measured using the **ICARE** multidetector array. The data have been analysed by statistical-model calculations using a spin-dependent level density parametrization. The results suggest significant deformation effects at high spin and cluster emission of ^{8}Be.

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I. INTRODUCTION

In recent years, extensive efforts have been made to understand the decay of light di-nuclear systems (A<60) formed through low-energy heavy-ion reactions [1]. In most of the reactions studied, the properties of the observed fully energy damped yields have been successfully explained in terms of either a fusion-fission (FF) mechanism or a deep-inelastic (DI) orbiting mechanism behavior. The strong resonance-like structures observed in elastic and inelastic excitation functions of ^{24}Mg+^{24}Mg and ^{28}Si+^{28}Si have indicated the presence of shell stabilized, highly deformed configurations in the ^{48}Cr and ^{56}Ni compound systems respectively [1]. The present work aims to investigate the possible occurence of highly deformed configurations in the ^{40}Ca di-nucleus produced in the ^{28}Si+^{12}C reaction through the study of light charged particle (LCP) emission.

II. EXPERIMENTAL PROCEDURES

The experiment was performed at the IReS Strasbourg VIVITRON tandem facility using 112.6 MeV ^{28}Si beams on a ^{12}C(160 μg/cm^2) target. Both the heavy ions and their associated LCP's were detected using the **ICARE** charged particle multidetector array [2]. The heavy ions were detected in eight telescopes, each consisting of an ionisation chamber (IC) followed by a 500 μm Si detector. The in-plane coincident LCP's were detected using four triple telescopes (Si 40 μm, Si 300 μm, 2 cm CsI(Tl)), 16 double telescopes (Si 40 μm, 2 cm CsI(Tl)) and two double telescopes (IC, Si 500 μm) located at the most backward angles. Typical inclusive α energy spectra are shown in Fig.1.a.

III. EXPERIMENTAL RESULTS AND STATISTICAL-MODEL CALCULATIONS

The data analysis was performed using CACARIZO [3], the Monte Carlo version of the statistical-model code CASCADE. The angular momenta distribution, needed as the main input to constrain the calculation, was taken from ^{28}Si+^{12}C complete fusion data [4,5]. The other ingredients such as the nuclear level densities and the barrier transmission coefficients, are usually deduced from the study of the evaporated LCP spectra. Standard statistical-model calculations are not able to reproduce the shape of experimental α-particle energy spectra satisfactorily [3]. Several attempts have been made to explain this anomaly either by changing the emission barrier or by using a spin-dependent level density. In hot rotating nuclei forme density at higher angular momentum should be spin dependent. In CACARIZO, the level density, $\rho(E, J)$, for a given angular momentum J and energy E is given by the well known Fermi gas expression:

$$\rho(E,J) = \frac{(2J+1)}{12} a^{1/2} \left(\frac{\hbar^2}{2\Im_{eff}}\right)^{3/2} \frac{1}{(E-\Delta-E_J)^2} exp(2[a(E-\Delta-E_J)]^{1/2}),$$

Where a is the level density parameter, Δ is the pairing correction, $E_J = \frac{\hbar^2}{2\Im_{eff}} J(J+1)$ and $\Im_{eff} = \Im_0 \times (1 + \delta_1 J^2 + \delta_2 J^4)$ with $\Im_0$ the rigid body moment of inertia and δ_1, δ_2 the deformability parameters. By changing the deformability parameters one can simulate the deformation effects on the level densities. For the ^{28}Si + ^{28}Si reaction [6], the shape of the inclusive and exclusive α energy spectra are well reproduced by using large deformation effects [6]. Similarly the experimental inclusive α energy spectra for ^{28}Si + ^{12}C of Fig.1.a are better described by using deformation effects (dotted lines) than with the standard liquid-drop deformation (dashed lines).

The exclusive energy spectra of α-particle in coincidence with individual S and P ER's shown in Figs.1.b and 1.c are quite interesting. The dotted lines are the predictions of CACARIZO using non-zero values of the deformability parameters. The energy spectra associated with S are completely different from those associated with P. The latter are reasonably well reproduced by the CACARIZO curves whereas the model could not predict the shape of the spectra obtained in coincidence with S (Fig.1.b). This is due to the fact that an additional component might be significant in this case. One could suggest the hypothesis of a contribution arising from the decay of unbound ^{8}Be produced in a binary reaction ^{40}Ca $\rightarrow$ ^{32}S+^{8}Be. In order to determine the sources of both the α emission and ^{8}Be breakup the invariant cross sections in coincidence with P and S are plotted in Fig.2 in the ($V_{\perp}$,$V_{\parallel}$) plane. Fig.2.b shows the invariant cross sections in coincidence with P which maxima are centered on the compound nucleus velocity as expected for a fusion-evaporation mechanism. Fig.2.a presents two additional contributions (in circles) for angles close to 30° and 60° arising from the binary decay of unbound ^{8}Be. This conclusion is also consistent with the ER kinematical analysis of the S and P exclusive energy spectra (not shown here). The question of the real nature (FF or orbiting) of this decay process remains to be explored.

IV. SUMMARY

The α-particle energy spectra measured in coincidence with S have an additional component which may come from the decay of ^{8}Be, which is unbound and produced through the binary decay of ^{40}Ca $\rightarrow$ ^{32}S + ^{8}Be. Work is in progress to analyse the proton energy spectra as well as the in-plane angular correlations of both the α-particles and the protons.

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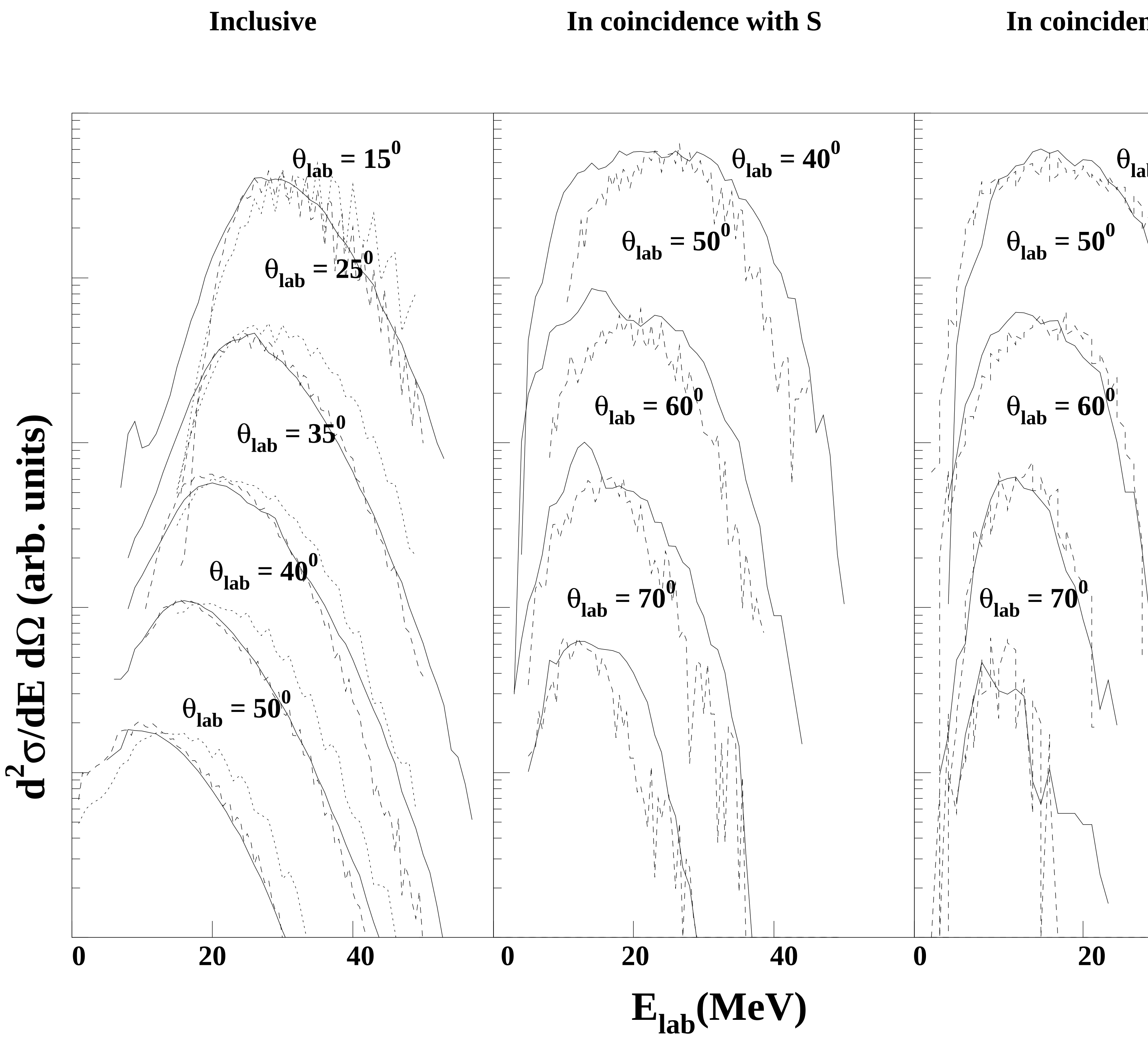
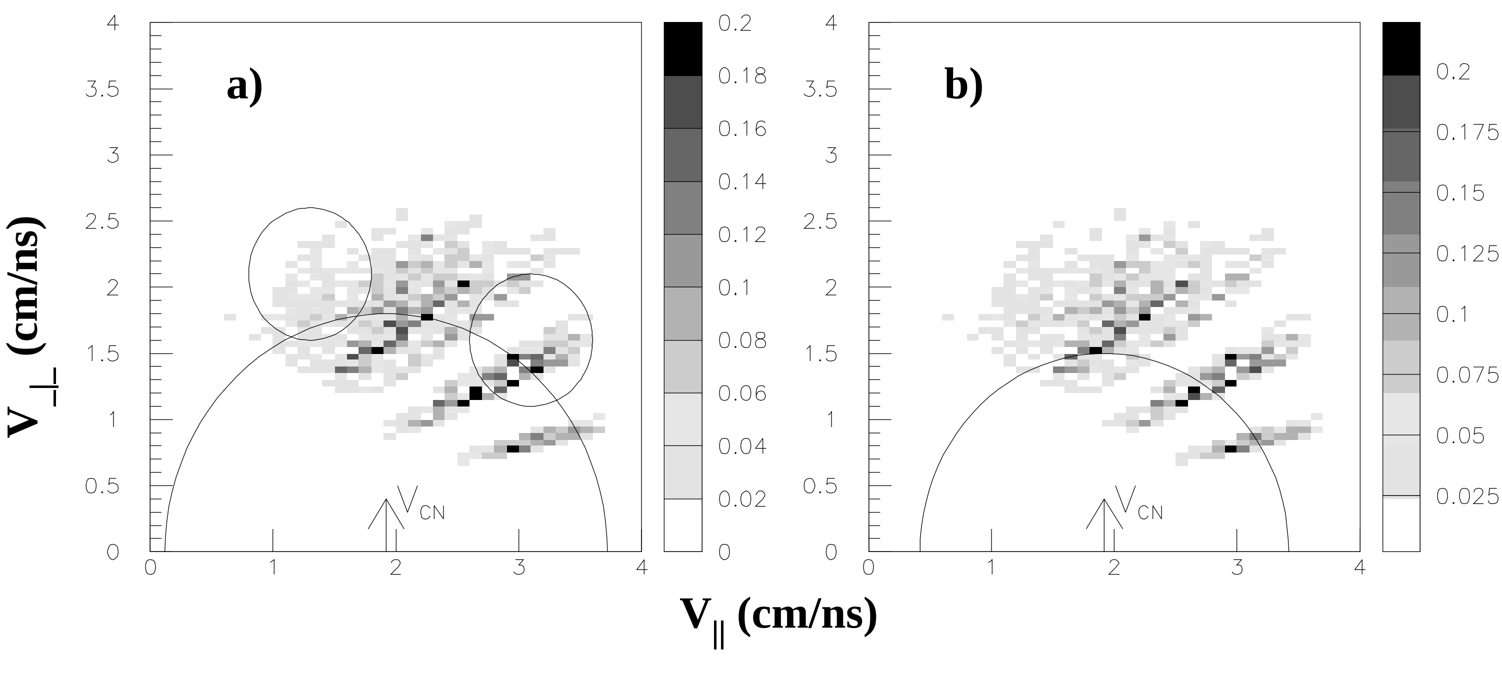
FIGURES

FIG. 1. Inclusive (1.a) and exclusive experimental (solid line) α energy spectra in coincidence with S (1.b) and P (1.c). The dotted and dashed lines are CACARIZO calculations with and without deformation.

FIG. 2. α invariant cross section in the ($V_\perp$,$V_\parallel$) plane in coincidence with S (2.a) and P (2.b), the two circles in (2.a) show the additionnal contribution arising from the decay of ^{8}Be.



Inclusive
In coincidence with S
In coinciden
$\theta_{lab} = 15^0$
$\theta_{lab} = 25^0$
$\theta_{lab} = 35^0$
$\theta_{lab} = 40^0$
$\theta_{lab} = 50^0$
$\theta_{lab} = 40^0$
$\theta_{lab} = 50^0$
$\theta_{lab} = 60^0$
$\theta_{lab} = 70^0$
$\theta_{lab} = 50^0$
$\theta_{lab} = 60^0$
$\theta_{lab} = 70^0$
$d^2\sigma/dE\, d\Omega$ (arb. units)
0
20
40
0
20
40
0
20
E_{lab}(MeV)



a)
b)
$V_{\perp}$ (cm/ns)
$V_{\parallel}$ (cm/ns)
V_{CN}
V_{CN}