High lying states in ^{10}Be

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Abstract

It is proposed to study the transfer reaction ^{10}B(^{10}B,^{10}Be)^{10}C to populate unbound states in ^{10}Be . In particular a search will be made for states that possess a large overlap with a ^{6}He+^{4}He cluster configuration by observing their decays to this final state. By measuring the complete kinematics of the reactions the excitation energies and spins of the ^{10}Be states with this cluster configuration can be determined, as well as any excitations in the daughter nuclei.

This measurement will form part of the CHARISSA collaboration's program to study neutron and proton rich light ions ($^{10-14}$Be, ^{8,9}B, ^{10}C), using stable beams at ANU and radioactive beams at GANIL.

1 Introduction

There has been much recent experimental and theoretical interest in the neutron rich beryllium isotopes [1-8]. In three previous measurements we have studied the neutron decay of the halo nucleus ^{11}Be [2] at the Australian National University (ANU), the symmetric fission of ^{12}Be [3] and the ground state breakup of ^{14}Be [9] at GANIL. These experiments successfully used the resonant particle spectroscopy (RPS) technique [10], developed in our studies of exotic clustering in light alpha–conjugate nuclei [11]. Using this technique the excited states of interest are observed by the coincident detection of the cluster fragments after breakup.

Clustering has long been known to play an important role in the structure and properties of light nuclei such as ^{8}Be. For example,the rotational band built on the ground state of ^{8}Be has a moment of inertia consistent with that of two touching alpha particles. This two-centre nature of ^{8}Be has a large impact on the structure of nuclei such as ^{9}Be, ^{9}B, ^{10}Be and ^{10}B which are formed by the addition of neutrons to the $\alpha + \alpha$ core. The ^{10}Be nucleus and other light nuclei with an $\alpha + \alpha$ core can be studied within the framework of the two-centre shell model [12], various molecular models [13, 14] and the antisymmeterized molecular dynamics model (AMD) [15, 16, 17]. A series of four states near 6MeV in ^{10}Be have been described in terms of configurations of two neutrons in two-centre orbits [7], in classical terms an α-2n-α cluster structure.

Evidence for a rotational band of states above 6MeV excitation with a large moment of inertia and therefore an extended nuclear system recently came from a study of the ^{7}Li(^{7}Li,α)^{10}Be $\rightarrow \alpha$ ^{6}He reaction at E_{lab} = 8MeV by Soić *et al.* [6]. Two states in ^{10}Be were observed to decay by alpha emission, at 9.6 and 10.2 MeV. Another state at 10.57 MeV was observed to decay by neutron emission. It was postulated that the 10.2 MeV state could be the 4^+ member of the rotational band built on the 6.18 MeV 0_2^+ state and so be a continuation of the two centre band. However, the spin of this state was not measured. This situation is further confused by the fact that another 4^+ state has been seen in this energy range at 11.76MeV in the ^{7}Li(α,p) reaction [18] which the author has suggested may be a member of the ground state rotational band with the 2^+ member at 3.368 MeV.

Another more recent measurement of the ^{7}Li(^{7}Li,α)^{10}Be $\rightarrow$ α ^{6}He reaction by a group at Florida State University (FSU) [19] seems to invalidate this hypothesis. Preliminary results from this measurement indicate that the 10.2 MeV state has a spin and parity of 3^-. This would go against the presently adopted systematics proposed by Soić.

Recently Freer *et al.* [20] have produced interesting new results on cluster structure in ^{10}Be at higher excitation using a radioactive ^{12}Be beam. The two neutron transfer reaction ^{12}C(^{12}Be,^{4}He,^{6}He) was studied and the excitation in ^{10}Be measured. Three new states at 13.2, 14.8 and 16.1 MeV were seen which may be associated with a α + ^{6}He cluster structure and a possible continuation on the 0_2^+ rotational band. Interestingly, the current compilation of ^{10}Be energy levels show no states between 11.76 and 17.79 MeV.

It is clear that further work is needed to confirm the spin of the 10.2 MeV state and the three states seen by Freer [20]. Also, the properties of the 10.57MeV state and the high excitation energy region (11-20MeV) of ^{10}Be are not fully understood. There remain many spectroscopic uncertainties relating to the energies and spins of states in this region and these clearly have to be resolved before any assertions over their molecular nature can be made. We intend to use the previously unstudied ^{10}B(^{10}B,^{10}Be)^{10}C reaction as an alternate method of populating states in ^{10}Be . This reaction has the advantage of a relatively small Q-value (-4.206 MeV) and therefore background from competing channels should be kept to a minimum. In addition this should allow higher excited states in ^{10}Be to be populated than is possible in the ^{7}Li + ^{7}Li reaction, enabling us to probe the suggestion of the recent GANIL work [20] that the cluster band extends up to 20MeV of excitation.

Using the MEGHA array will enable us to investigate this reaction with the wide angular coverage and good isotopic particle identification required to determine the enrgies and spins of these high lying states in ^{10}Be .

2 Experimental Method and Beam Time Request

It is proposed to use the ^{10}B(^{10}B,^{10}Be)^{10}C reaction (Q = -4.206 MeV) at E_{lab} = 80MeV to populate states in ^{10}Be above the ^{6}He + ^{4}He decay threshold (7.41MeV).

The measurements will use the MEGHA array with PSSDs and CsI stopping detectors to give full angle and energy information. Both ^{10}Be breakup fragments, ^{6}He and ^{4}He, will be detected using a combination of PSSDs and thin (70μm) Si quadrant detectors to allow isotopic particle identification. A schematic of two possible detector setups is given in figure 1. In previous measurements we have seen that a clean ^{6}He locus is observable even in the presence of the inevitable high flux of alpha particles, when we consider events that punch through the silicon into the CsI scintillator (Figure 2). In this way we are able to identify ^{6}He ions with E $\geq$ 32MeV with a relatively low background. Lower energy ^{6}He ions can be selected but this will also allow through a background from α + α events. Reaction simulations show that this would decrease our detection efficiency by a factor of 2 which is acceptable given the benefits of the cleaner spectra. Figure 3 details our simulated detection efficiency as a function of excitation energy both with and without this ^{6}He energy threshold constraint. The simulated detection efficiency for both setups detailed in figure 1 is given in figure 4. Assuming a detection efficiency of 5% with a 100μgcm^{-2} boron target, a 5nA beam (which previous measurements have shown give tolerable singles rates in the detectors) and a cross section of 10μbsr^{-1} (typical for such a charge exchange reaction), we can expect a count rate for ^{10}Be of about 500 per hour. Experience shows that this rate is usually sufficient for spin assignments to be made from angular correlations.

The experiment will utilise the MEGHA data acquistion system (320 channels) and the reaction target will be ^{12}C backed, boron oxide (B_2O_3). The Q-values for the ^{12}C(^{10}B,^{10}Be)^{11}C and ^{16}O(^{10}B,^{10}Be)^{16}F reactions are -17.895 and -15.974MeV respectively. These values are much larger than the reaction Q-value of interest and therefore are not expected to cause significant background contamination.

Calibration of the detection elements using ^{10}B ions elastically scattered from ^{12}C and ^{197}Au targets will need a 40MeV ^{10}B beam. This will enable us to calibrate the PSSDs in the energy regime of the reaction products.

3 Summary

We propose to use the ^{10}B(^{10}B,^{10}Be)^{10}C reaction (Q = -4.206 MeV) at E_{lab} = 80MeV to populate high lying states in ^{10}Be (10-20 MeV). The energies and spins of these states can then be determined. We estimate that this measurement will require 16 shifts of beamtime. A summary of the requested beam time is given in table 1.

Measurement	Beam	Energy (MeV)	Target	Shifts
Ion source, focusing and tuning	^{10}B	40	none	2
Debugging	"	40	^{197}Au	2
Calibrations	"	40	^{12}C , ^{197}Au	2
Reaction Data	"	80	B_2O_3	10
TOTAL				16

Table 1: Summary of requested beam–time.

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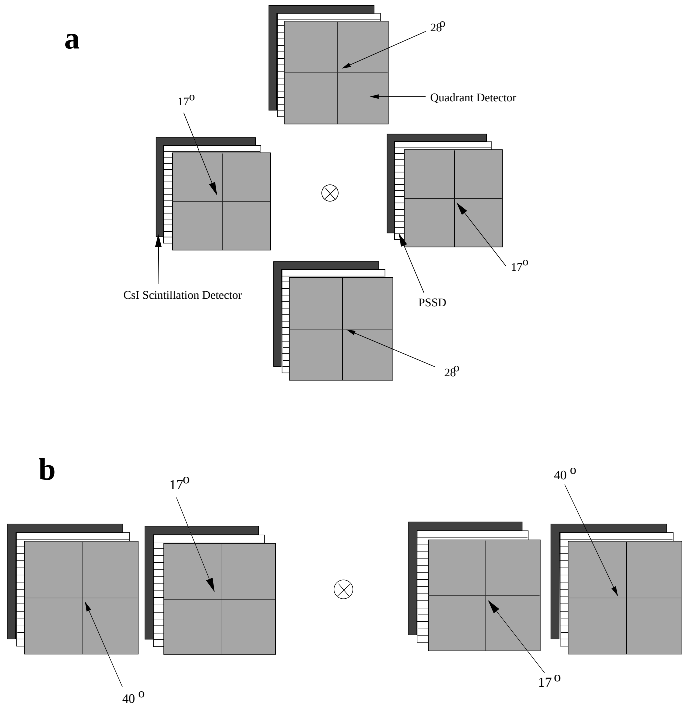

Figure 1: Schematic diagram of two different detection possibilities available.

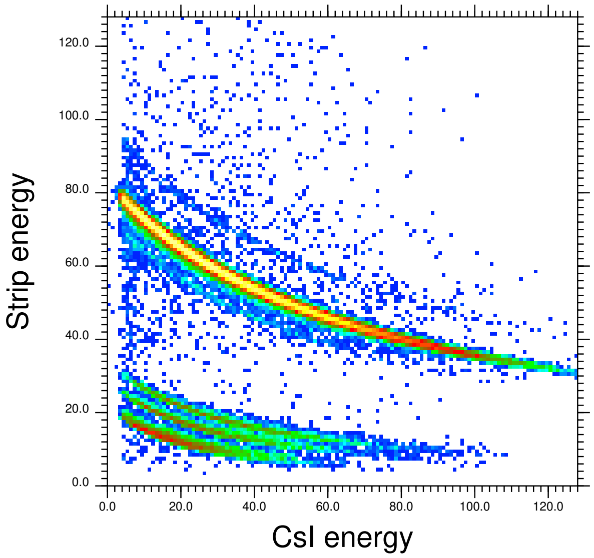

Figure 2: Particle identification spectra clearly showing the ^{6}He locus.

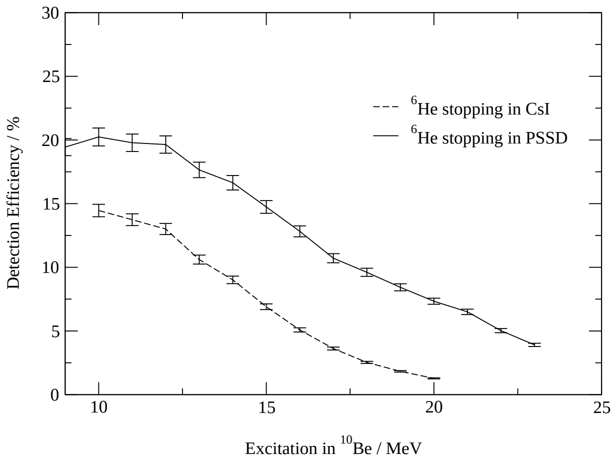

Figure 3: Simulated detection efficiency for detecting both ^{6}He ions which punch through to the CsI detectors and for those which stop in the silicon together with the alpha particle.

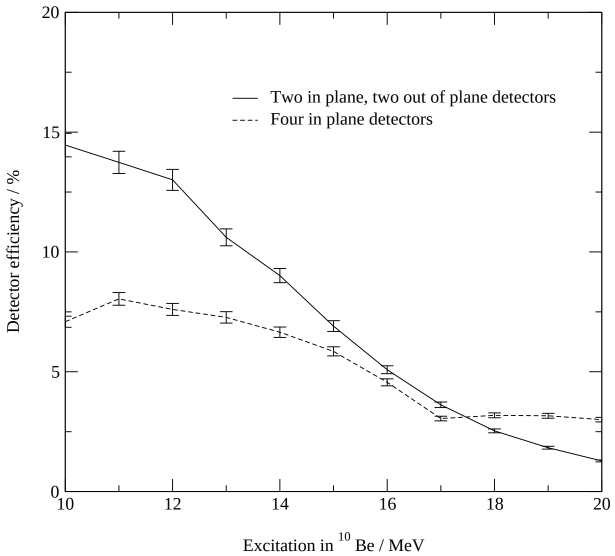

Figure 4: Simulated detection efficiency for detecting both He break up fragments in the out of plane setup (figure 1a) and the inplane setup (figure 1b).

List of Collaborators

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