BARC–TIFR Pelletron Linac Facility Beam Time Request @2024

Title of the Experiment: Investigating the Cluster Structure of ^{10}B

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Affiliation: BARC

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Motivation of the experiment: In the proposed experiment, the aim is to accomplish the following measurements:

(1) Sufficient ^{6}Li-α coincidence events for the identification ^{10}B states through which it breaks into ^{6}Li and α.
(2) Detection of 2α-d coincidence events to establish the α-α-d cluster configurations.
(3) A comprehensive study of all the possible breakup channels which may provide signatures of new cluster configurations in ^{10}B.

Beam details: Beam spices: ^{10}B,

Beam energy in (MeV): 33 MeV, 45 MeV

Beam current in (pnA) : 4pnA

Beam Port: Hall 1-30D.

Buncher requirement: Yes/ No Yes

Number of shifts (1 shifts=8 hr.) required: 15

Experiment details:

1. **Objective of Experiment:** Attached
2. **Description of Experiment:** Attached

- **Whether the experiment is part of PhD /Post Doc. Work** Yes
- **Details of Beam time availed of in recent past on this experiment and / or by the PI:** Beam used: ^{6}Li, Beam energy: 30 MeV, Target: ^{112}Sn (thickness ~ 540μg/cm^2)
  Title: Measurement of (n+α) Breakup Cross Section in $^{112}Sn(^{6}Li,^{5}He)^{113}Sb$ Reaction
  Beam Time: 16-09-2023 to 21-09-2023
- **Details of papers published / presented in journals / symposia, etc. based on recent experiments:** None

TITLE OF THE EXPERIMENT: Investigating the Cluster Structure of ^{10}B

PURPOSE AND MOTIVATION:

Clustering phenomena occurring in lighter nuclei such as $^{6,7}Li$, $^{8,9,10}Be$, $^{10,11}B$, ^{12}C, ^{16}O have a wider influence over nuclear structure, dynamics and astrophysics. It is well established that the low-lying states in ^{8}Be can be described as having a two-center α-α structure [1]. Several studies concerning the analysis of reaction mechanisms induced by lithium isotopes on medium-to-heavy mass targets (as elastic and inelastic scattering, transfer and breakup reactions) have been extensively reported [2–4], providing pronounced evidence of dominant α+d and α + t cluster configurations in ^{6}Li and ^{7}Li, respectively. Similarly, ^{12}C structure has also been the subject of several high-precision experiments that aims at understanding its cluster structure, particularly; the direct decay of the Hoyle state into three α particles [5] which explains abundance of ^{12}C in the universe.

Another fairly less explored lighter nucleus is ^{10}B, which is also considered to be weakly bound with respect to α +^{6}Li breakup with breakup threshold of 4.5 MeV. The structure of ^{10}B is involved in the $^{6}Li(\alpha,\gamma)^{10}B$ reaction, which, together with the $^{10}B(\alpha,d)^{12}C$ reaction, might offer an alternative path to the traditional triple-α process in first generation stars[6]. Recently, a comprehensive R-matrix fit has been performed on the reaction cross section data of $^{6}Li(\alpha,\gamma)^{10}B$ reaction to investigate its astrophysical significance [7].

Moreover, there has been theoretical predictions, that, just like the α-α-2n cluster structure of ^{10}Be explains the existence of its three states at 6.18 MeV (0+), 7.54 MeV (2+) and 10.15 MeV (4+) [8], there must also be isobaric analog states in ^{10}B as well. These are 0+ state at 7.56 MeV, 2+ state at 8.9 MeV [9] and third one at 11.6 MeV [10, 11]. The emergence of these levels implies that ^{10}B is a highly clustered state which may exist in the form of α-α-d or ^{6}Li-α cluster.

By thoroughly studying the breakup reactions concerning ^{10}B into ^{6}Li+α channel, it is possible to gain deeper insight into the inverse reaction of ^{6}Li (α, γ)^{10}B reaction which is one of the significant modes of production of ^{10}B and other elements in stellar environment. Therefore, the breakup studies of ^{10}B into different clustered fragments are much essential.

In the present proposal, the chief aim of experiment constitutes the following measurements:

1. Sufficient ^{6}Li-α coincidence events for the identification ^{10}B states [10, 11] through which it breaks into ^{6}Li and α. This will shed light on the structure of ^{10}B as a cluster of ^{6}Li+ α.

2. Detection of 2α-d coincidence events to establish the α-α-d cluster configurations.

3. A comprehensive study of all the possible breakup channels which may provide signatures of new cluster configurations in ^{10}B.

PAST ENDEAVOURS:

Earlier, we have conducted an experiment on^{11}B+^{165}Ho reaction system to study the breakup of ^{11}B, which is also considered to be a weakly bound nucleus with respect to α+^{7}Li breakup with breakup threshold of 8.7 MeV. Several outgoing charged particles such as ^{9,10}Be, ^{6,7,8,9}Li, ^{4,6}He were clearly identified from the ΔE vs. E plot of the correlated events detected using the strip detector telescopes. The production of ^{8}Be was observed in this reaction by the reconstruction of relative energy for 2α coincidence events which shows the emergence of 92 keV energy peak. The source of the two coincident alpha particles could be i) a reaction involving triton stripping transfer followed by the breakup of ^{8}Be or ii) a direct breakup of ^{11}B into α+α+t or ii) a sequential breakup of ^{11}B→^{7}Li*+alpha →t+α+α. However, assuming the first mode of breakup, the Q value distribution of the reaction events determined from the measured kinetic energies of the alpha particles and the recoil energies of the residual nuclei shows that the probability of 2-alpha breakup is dominant around optimum Q-value of the triton transfer reaction. The Q-value distributions with respect to other reaction processes are expected to shed further light on other reaction mechanisms. Moreover, ^{7}Li-α coincidence events were also detected and the corresponding E_{rel} vs. Q value plot for such events ^{7}Li-α cluster states in ^{11}B. Moving towards same path, it is expected that ^{6}Li-α or α-α-d cluster signatures must be obtained (whose breakup threshold is only half of the ^{11}B) when we study the breakup of ^{10}B in presence of medium or heavy mass target.

PROPOSED REACTION:

With the above motivations, it is proposed to study the reaction ^{10}B+^{120}Sn. The target is so chosen because, in the literature [12], the elastic, inelastic, and transfer angular distributions for the ^{10}B+^{120}Sn system have been extensively studied at different beam energies through the Coupled Reaction Channels Calculations. And, it has been concluded that additional channels like projectile breakup need to be included in the coupling scheme to explain the elastic data better. So, the aim of the present experiment is not only to investigate the cluster structure of ^{10}B that we propose to measure all possible breakup channels for ^{10}B, but also to improve the description of the elastic scattering angular distribution by incorporating them into Coupled Channels Calculations and to have a comprehensive study of all the reaction mechanisms.

Details of the experimental setup and beam time requirement is given below.

EXPERIMENTAL SETUP:

For the proposed experiment, following detectors are required for the detection of reaction products:

1. A wide angular coverage telescope array comprising of Si strip detectors for the detection of light charged particles as shown in the Fig. 1 and it will be placed near the grazing angle at a distance of 17 cm from the target.

2. A few smaller size telescopes consisting of Si Surface Barrier Detectors will also be used mainly to measure elastic, inelastic and transfer products at forward angles.

3. Two monitor detectors will be required for the normalization.

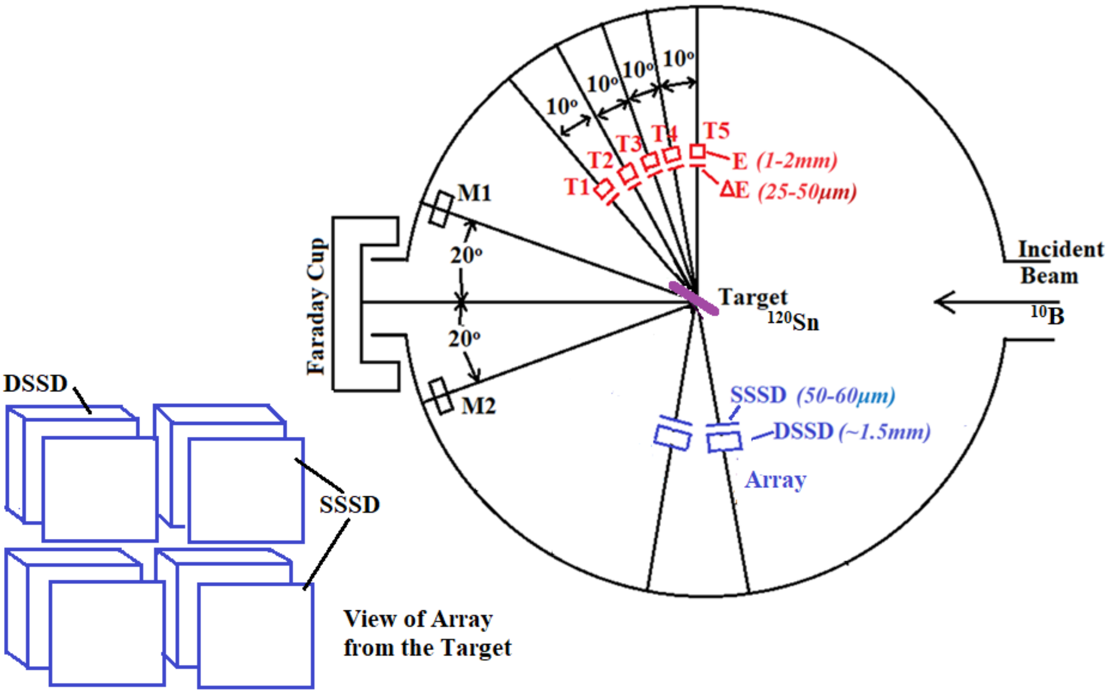

Fig.1: Schematic diagram of the experimental set up

BEAM TIME REQUIREMENT:

We plan to carry out the measurement on $^{10}B+^{120}Sn$ reaction system at two energies: one at near barrier (33 MeV) and other one at above barrier energy (45 MeV). We shall use a self-supporting ^{120}Sn target having thickness ~400µg/cm^2. We require pulsed beam of ^{10}B having 4 pnA current. Using this experimental setup, we expect to have 30 coincidence/hr for ^{6}Li-α coincidence events. Therefore, to have sufficient coincidence counts (>2000) at each energy, we request for 5 days of beam time.

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