Measurement of the ^{7}Be(d,^{3}He)^{6}Li reaction and the Cosmological Lithium Problem

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Introduction

The anomaly in the ^{7}Li abundance, from observations and big-bang nucleosynthesis (BBN) theory is a well known unresolved problem in nuclear astrophysics, popularly known as the *cosmological lithium problem* [1, 2]. The BBN theory overestimates the ^{7}Li abundance by $3-4$ times compared to observations. Interestingly, there is a more severe anomaly for ^{6}Li where the BBN predictions underestimate the observed abundance by a factor of ~ 1000 [3]. However, many of the claimed ^{6}Li detections have been debated [4]. Over the years, considerable efforts have been given to search for solutions to the problems, from astrophysics to new physics beyond standard cosmology and particle physics [1]. The nuclear physics solution to this problem deals with reactions involving the production and destruction of ^{7}Be since the primary source of primoridal ^{7}Li is the decay of ^{7}Be. The production channel, ^{3}He(α,γ)^{7}Be has been extensively studied both theoretically and experimentally and the uncertainty in its reaction rate is less than 5% [2]. In recent years, several measurements studied the destruction of ^{7}Be by the ^{7}Be(d,p)^{8}Be(2α) reaction [5], considering even contributions of ^{8}Be higher excited states [6]. However the extent of the anomaly could not be explained.

In this context, the ^{7}Be(d,^{3}He)^{6}Li reaction not only produces ^{6}Li but also destroys ^{7}Be. Hence it may impact both the lithium anomalies. Till date there is only a single experiment measuring this reaction at $E_{cm} = 4.0$ and 6.7 MeV [7]. However the authors relied only on Monte Carlo simulation gates to select the reaction products ^{3}He and ^{6}Li. No kinematical signatures were shown to verify that the selected ^{3}He and ^{6}Li are indeed from the above reaction. Thus, detailed experimental investigation of the ^{7}Be(d,^{3}He)^{6}Li reaction is required.

Experiment

The experiment was carried out at the HIE-ISOLDE radioactive ion beam facility of CERN. The Scattering Experiment Chamber (SEC) [8] at the third beamline was utilised for the measurement. A 5 MeV/u ^{7}Be beam was incident on a 15 μm thick CD_2 target. A large array of Silicon detectors covering

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$\sim$ 32% of 4π was placed inside the SEC for detecting the charged particles emitted from the reaction. The details of the experiment can be found in Ref. [6, 9].

Analysis and Discussion

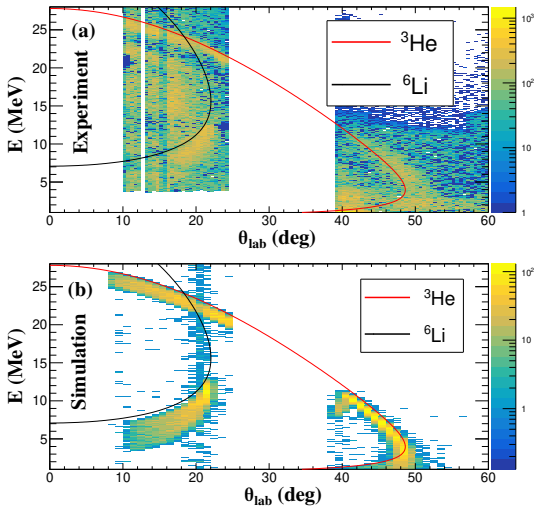

FIG. 1: E vs θ_{lab} plot of ^{3}He and ^{6}Li from ^{7}Be(d,^{3}He)^{6}Li reaction at 5 MeV/u. The data and simulations are shown in (a) and (b) respectively. The lines represent the kinematics corresponding to the ^{3}He (red) and ^{6}Li (black).

The ^{3}He and ^{6}Li from the ^{7}Be(d,^{3}He)^{6}Li reaction are detected in coincidence at the forward angles $8^\circ - 25^\circ$. Energy correlation gates from Monte Carlo simulations of the reaction were applied to filter the events of interest. The package NPTool [10] was used to carry out Monte Carlo simulations. In the angular range $40^\circ - 80^\circ$, the ^{3}He from ^{7}Be(d,^{3}He)^{6}Li is detected up to $\sim 50^\circ$. The energy (E) vs scattering angle (θ_{lab}) plot from data and simulations are shown in Fig. 1(a), (b) respectively. Clear kinematic signatures of ^{3}He and ^{6}Li from ^{7}Be(d,^{3}He)^{6}Li can be observed in the data (Fig. 1a). Another ^{3}He band is seen in Fig. 1a which corresponds to the 2.186 MeV excitation of ^{6}Li. Analysis is in progress to generate the angular distributions and excitation function of the ^{7}Be(d,^{3}He)^{6}Li reaction.

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