Background Considerations for the $^2\text{H}(^7\text{Be},^3\text{H})^6\text{Be}$ Experimental Data Using the Phase Space Model

K. Y. Chae*
Department of Physics, Sungkyunkwan University, Suwon 440-746, Korea

V. Guimarães
Instituto de Física, Universidade de São Paulo, C.P. 66318, 05389-970 - São Paulo, SP, Brazil

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The $^2\text{H}(^7\text{Be},^3\text{H})^6\text{Be}$ reaction was measured at the Holifield Radioactive Ion Beam Facility of the Oak Ridge National Laboratory in 2004 to search for the resonances in the unbound $^6\text{Be}$ nucleus. The results showed, however, no resonance was evident in the experimental data, which implied that the direct transfer to $^6\text{Be}$ levels was not particularly strong compared to other reaction mechanisms that produced tritons in their exit channels. In the present work, theoretical calculations with background considerations are performed to better understand the cross-section data for the $^2\text{H}(^7\text{Be},^3\text{H})^6\text{Be}$ reaction using the phase space model.

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I. INTRODUCTION

Nuclear reactions often produce large numbers of light particles which come from nuclear reaction mechanisms other than the one originally desired. One example is the $^2\text{H}(^7\text{Be},^3\text{H})^6\text{Be}$ measurement performed at the Holifield Radioactive Ion Beam Facility (HRIBF) at the Oak Ridge National Laboratory (ORNL) in late 2004 [1], which is summarized in Section II. The purpose of that measurement was to search for resonances in the unbound $^6\text{Be}$ nucleus by detecting recoiling tritons. As summarized in the next section, however, the existence of a resonance was not evident in the experimental data, indicating that the direct transfer to $^6\text{Be}$ levels is not particularly strong compared to other reaction mechanisms. The upper limits on the $^7\text{Be}(d,t)^6\text{Be}$ reaction cross-section for hypothetical levels were set in Ref. [1], but further investigations are required to better understand the experimental data.

Background considerations might be useful in understanding the origin of tritons in the spectrum include the phase space model (PSM) [2] and the three-body continuum (sequential decay) [3,4]. In the current article, the PSM is adopted to explain the triton spectrum of the $^7\text{Be}(d,t)^6\text{Be}$ reaction measurements.

II. SUMMARY OF THE $^2\text{H}(^7\text{Be},^3\text{H})^6\text{Be}$ DATA

The experimental setup and the data shown in this section are taken and summarized from Ref. [1]. The $^7\text{Be}(d,t)^6\text{Be}$ reaction was measured in inverse kinematics at the HRIBF by utilizing a radioactive $^7\text{Be}$ ($t_{1/2} = 53.2$ days) beam at an energy of 100 MeV to search for resonances in the unbound $^6\text{Be}$ nucleus. The beam impinged on deuterated polyethylene ($\text{CD}_2$)$_n$ targets, and the recoiling tritons were detected by using a silicon detector array (SIDAR). The SIDAR was composed of six $\Delta E-E$ telescopes (100- and 500-$\mu\text{m}$ thick) to identify incident charged particles. Each telescope was backed by a 300-$\mu\text{m}$-thick “veto” detector in order to reject $^3\text{He}$ particles that punched through the $E$ layer. A total of 18 silicon strip detectors were used to form the array. Each detector was segmented into 16 annular strips, which enabled us to extract the angular distributions of the observed energy levels. The observed spectra of tritons obtained at 16 different angles, however, were rather featureless.

*E-mail: kchae@skku.edu; Fax: +82-31-290-7055
indicating that reaction mechanisms other than direct transfer to $^6$Be levels also produced tritons.

The differential cross-section of the $^2$H($^7$Be,$^3$H)$^6$Be reaction versus $^6$Be excitation energy obtained at several SIDAR strips (angles) is plotted in Fig. 1. If any energy levels in the $^6$Be nucleus were strongly populated through the $^7$Be($d$,$t$)$^6$Be reaction, the figure should exhibit a peak at around the corresponding triton energy range. As shown in the figure, however, no $^6$Be levels were evident. The peak-like structure at $E_x \sim 13$ MeV shown in the spectrum obtained at 13.6° is due to $^3$He particles that punched through the “veto” detector.

Because no $^6$Be levels were evident, a study of possible background mechanisms could be useful to better understand the experimental data. In the present work, the PSM is introduced to estimate the triton’s energy distributions.

III. PHASE SPACE MODEL (PSM)

The PSM was originally developed by Enrico Fermi as a statistical method for computing high-energy collisions of protons with multiple production of particles [2]. In the case of nuclear collisions at very high energy, some $\pi$-mesons (pions) and anti-nucleons might be produced, which cannot be interpreted by using the conventional