Measurements of ^{2}H(p,γ)^{3}He cross sections from 5 to 20 MeV

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Introduction

Radiative capture of a proton on a deuteron, ^{2}H(p,γ)^{3}He, is a reaction of great importance for multiple reasons. At very low energy below 1 MeV the capture cross section is important to understand the formation of ^{3}He during Big Bang Nucleosynthesis (BBN). At higher beam energies, this reaction involving a proton and a deuteron is essential to understand nucleon-nucleon interaction and the three-body force effect. We have previously reported measurements of cross sections and astrophysical S-factors for radiative proton capture on deuteron for energies relevant to the BBN process [1–3]. Here we report on our recent measurements at higher beam energies from 5 to 20 MeV relevant for studying the N-N interaction in nuclear three-body system. Over the decades, this particular reaction has been studied using both polarised and unpolarised beams of protons [4]. However, notwithstanding the significance of the reaction, there is not much data on the radiative capture cross-section of the proton on deuteron in the 2 to 20 MeV region. We have initiated a program to measure the angular distribution and absolute cross section of the capture γ-rays from 2 to 20 MeV.

Experimental Details

The measurements have been carried out at two different accelerator facilities. The cross-section for 5 MeV has been measured at the FOTIA facility at BARC, Mumbai. The measurements from 8 to 20 MeV beam energies have been conducted at the BARC-TIFR Pelletron accelerator facility. At the FOTIA facility, the capture γ-rays were measured in an array of four large volume LaBr$_3$:Ce detectors placed in a planar geometry around the target position. For the measurements at the Pelletron facility we have used three large volume LaBr$_3$:Ce detectors. In addition, we have also measured the γ-rays in a combined system of a large cylindrical LaBr$_3$:Ce detector snugly fitted inside an annular NaI(Tl) detector. The annular NaI(Tl) shield is used to reject the cosmic ray-induced events in the LaBr$_3$:Ce detector. This arrangement has been described in detail in [5]. For both measurements, a self-supporting CD$_2$ target foil of 1.38 mg cm^{-2} thickness was used. For every beam energy, the total charge incident on the target was measured using a beam current integrator connected to the beam dump. A schematic of the experimental setup for the Pelletron measurements is shown in Figure 1.

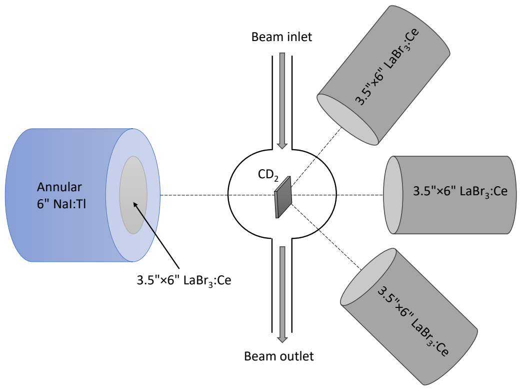

FIG. 1: Schematics of the experimental setup

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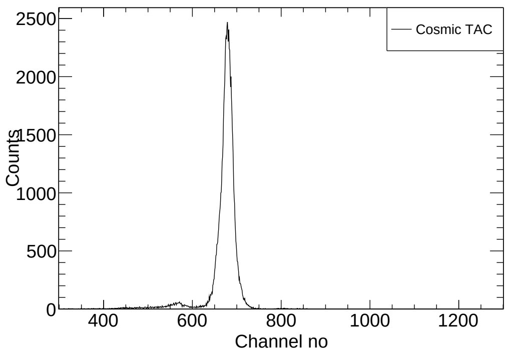

FIG. 2: The TAC spectrum for the combined detector assembly

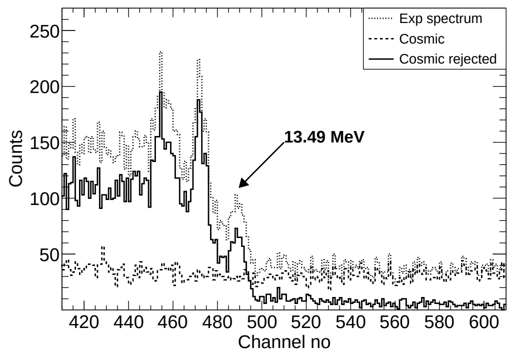

FIG. 3: Spectrum of 13.49 MeV γ-ray acquired in the experiment.

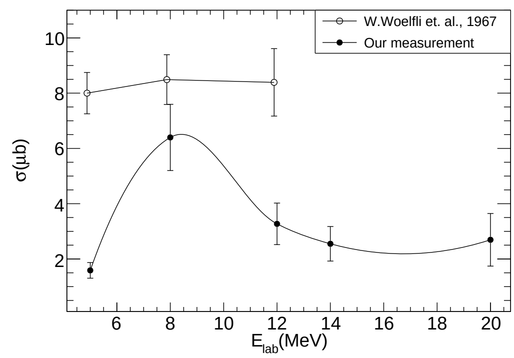

FIG. 4: The measured cross sections of γ-rays at five different beam energies.

Results & Discussion

Figure 2 shows the TAC spectrum recorded for cosmic ray muons passing through the combined assembly. A typical γ-ray spectrum measured at 12 MeV proton beam is shown in Figure 3. The capture of 12 MeV proton by deuteron generates γ-rays of energy 13.493 MeV. Data were collected for beam passing through a blank frame and also without beam for an extended period to estimate the overall background counts. Figure 4 shows the absolute capture cross sections for five beam energies. It is worth noting that there is no data in existing literature beyond proton energy of 12 MeV. We have generated new cross-section data for the ^{2}H(p,γ)^{3}He reaction up to 20 MeV. Deuteron being a very weakly bound, light two-body system, the capture mechanism is bound to be different from that of medium or heavy-mass targets. In addition, the capture cross section is expected to go down with increasing projectile energy. Our results show a definite pattern of the cross section peaking around 8 MeV and then decreases monotonically with increase in beam energy. This is the first such observation and is significantly different from the existing data (see Figure 4) showing no change in the cross sections up to 12 MeV. A fuller analysis and calculations involving advanced 2-body and 3-body forces are in progress.

Acknowledgments

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