Study of ^{16}O$(p, p'\gamma)^{16}$O reaction

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Introduction

Scattering of light particles such as protons, neutrons, α-particles, etc., provide valuable insight about the structure of low lying states of the target nuclei. Such measurements are generally analysed using phenomenological optical model potential calculations for most of the projectile energies [1]. For high energies of incident projectile(>30 MeV), microscopic impulse approximation holds good and gives sufficiently accurate results. However, at energies below 30 MeV, incident projectile has enough time to interact with many nucleons in the target nucleus as opposed to the assumption of microscopic impulse approximation. Consequently, assumption of microscopic impulse approximation becomes invalid and nuclear physicists struggle to fit the experimental data for energy less than 30 MeV [2].

Very recently we have carried out detailed measurements to study the low lying states of ^{12}C using inelastic scattering of proton on ^{12}C nucleus. The measured production cross section of the states have been analysed using both microscopic and phenomenological macroscopic optical model calculations [3]. We have continued this program to study alpha-cluster nuclei by carrying out one more measurement of inelastic scattering of proton on ^{16}O. Here we report about this very recent measurement. A large body of experiments have reported cross section measurements of in-elastically scattered protons from ^{16}O. However, only very few experiments have been carried out by detecting the γ-rays from the excited states of the ^{16}O target nucleus.

The measurement of γ-ray production cross section from inelastic scattering of protons from ^{16}O is also useful for astrophysical studies. Gamma rays from sun during solar flare events, sites of star formation and supernova explosions are being detected for long time through satellite based observatories. These astrophysical γ-rays can provide crucial information about the isotopic composition of the sites of their generation. γ-ray production cross-section data is essential for the extraction of isotopic abundance data from the γ-ray lines.

This paper reports the initial results of the γ-ray production cross section measurements from ^{16}O nuclei using proton beam of energy 8 to 20 MeV.

Experimental Details

The experiment was performed at BARC-TIFR Pelletron facility, Mumbai. A mylar ($C_{10}H_8O_4$) target was bombarded by proton beams of energy 8-20 MeV. Energy loss of the proton beam in the target was calculated using SRIM software and was found to be 0.35-1.25% of incident proton beam energy. The γ-rays from the decay of the excited states of ^{16}O were detected using a $3.5'' \times 6''$ $LaBr_3$:Ce scintillation detector placed at a distance of 25 cm from the target chamber. A pile-up rejection circuit was setup to reject the piled up

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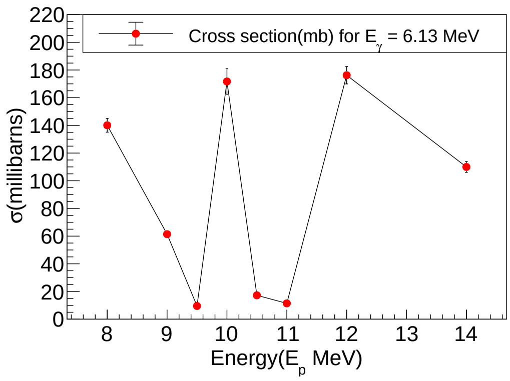

FIG. 1: Total cross-section of production of 6.13 MeV γ-ray for different energies of incident proton.

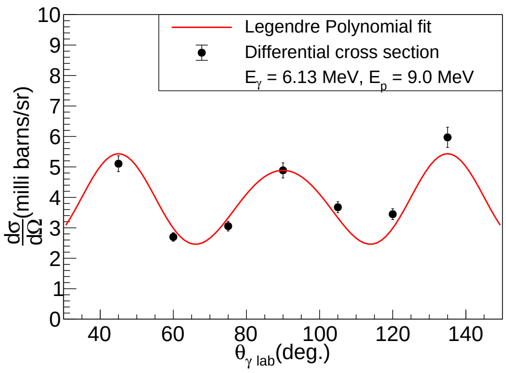

FIG. 2: Differential cross-section of 6.13 MeV γ-ray for various angles at 9 MeV energy of incident proton. Red line is the fit of Legendre polynomial series.

events. Data was acquired using LAMPS data acquisition software. The $LaBr_3$:Ce detector was placed around the target at angles of 45°, 60°, 75°, 90°, 105°, 120° and 135° for angular distribution measurements.

Monte Carlo simulations were carried out using GEANT4 simulation toolkit. The whole experimental setup was simulated to obtain full energy peak efficiency of $LaBr_3$:Ce detector for γ-rays of energy 6.13, 6.92 and 7.12 MeV. The simulations were done for 10^7 events.

Results and Discussion

The differential cross section was calculated using formula

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{Y}{N_p N_t \Omega \epsilon}$$

where, Y is the yield of γ-rays, N_p is the number of incident protons, N_t is the number of target nuclei per cm^2 and ϵ is the full energy peak efficiency of $LaBr_3$:Ce detector for the relevant γ-rays energy. Figure 1 shows the total γ-ray production cross section for 6.13 MeV γ-ray from ^{16}O for protons of energy 8 to 14 MeV. Figure 2 shows the differential cross section for the production of 6.13 MeV γ-ray for various angles. The angular distribution data was fitted with series of Legendre polynomials:

$$W(\theta) = \sum_{l=0}^{l=l_{max}} a_l P_l(\cos\theta)$$

with l_{max}=6 (l is even) for 6.13 MeV γ-ray (E3 transition).

Work is in progress to analyse the full experimental data. The results will be compared with the optical model potential calculations.

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