Inclusive α Spectrum from ^{12}C(γ,α) Reaction

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Introduction

The ^{12}C(γ, 3α) reaction is a well-known phenomenon occurring above the α separation energy threshold of 7.36 MeV, resulting in the production of unbound ^{8}Be nuclei. When ^{12}C is excited beyond the α separation energy, this excess energy manifests as the kinetic energy of the α particle breakup. This phenomenon carries significant implications in radiotherapy applications that utilize high-energy photons for treatment, as it can lead to the photon-induced breakup of ^{12}C within tissue.

This issue assumes critical importance due to the sheer abundance of ^{12}C atoms in biological tissues and the relatively high photon fluxes employed in radiotherapy. Furthermore, the α particles produced in this process have a limited range of only a few micrometers within the tissue, creating micro-hotspots capable of delivering lethal doses of high LET radiation. These doses, unfortunately, remain undetectable at macroscopic levels but can potentially lead to severe neural damage.

To quantify the extent of this lethal damage caused by the ^{12}C(γ, 3α) reaction, it is essential to gather information about inclusive alpha production and the resulting alpha spectrum. Surprisingly, there are no existing measurements of this phenomenon in the current literature.

To address this knowledge gap, our study focuses on the ^{12}C(γ, 3α) reaction using a bremsstrahlung beam. We have conducted measurements of the inclusive alpha spectrum and subsequently reproduced these measurements through Talys-DWBA calculations. Detailed findings and analysis are provided in the following sections.

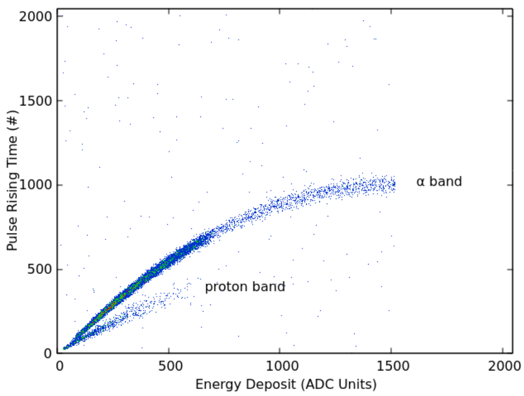

FIG. 1: Charge-Rising time particle discrimination showing proton and alpha bands

Materials and Methods

The investigation focused on the inclusive alpha spectrum resulting from the ^{12}C(γ, α)^{8}Be$\rightarrow$ 3α reaction, facilitated by the use of a dedicated setup designed for radiotherapy applications. Specifically, a carefully collimated bremsstrahlung beam with an endpoint energy of 14 MeV was directed at a 300μm thick natural carbon (^{nat}C) target.

To capture the breakup alphas, silicon de-

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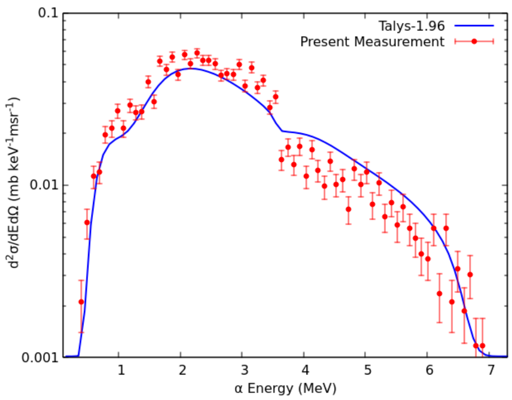

FIG. 2: Measured α Spectrum with Talys-DWBA calculations

tectors were strategically positioned at angles of 60°, -80°, and -120° relative to the photon beam. These detectors were preamplified using Ortec-IH142 preamplifiers and the data were acquired using CAEN-DT5743 digitizer.

To enhance the measurement accuracy, the detectors were biased at a lower voltage than the optimum resolution voltage, ensuring a measurable pulse rise time. Charge is used for the energy measurement. Particle identification was achieved by constructing 2D plots correlating charge and pulse rise time. The photon beam intensity was monitored using accelerator-built transmission-type beam monitor chambers, with a typical photon flux of $10^{13}/cm^2$ used in the experiments, and all data were systematically recorded.

The collected data underwent analysis, with the alpha colony of the measured 2D correlation being isolated and projected onto an energy scale, considering the charge-energy calibration. The resulting counts were binned into locally averaged histogram values. To convert these values into mb, the percentage of bremsstrahlung photons exceeding the breakup threshold of 7.36 MeV, as well as the target thickness, were factored in.

The measured inclusive alpha spectrum arising from the ^{12}C(γ, α)^{8}Be→ 3α reaction, driven by the 14 MeV endpoint energy bremsstrahlung beam, was subsequently replicated using Talys-DWBA breakup calculations. Specifically, the alpha spectrum at 60° was calculated for individual photon energies spanning the range of 7.4 to 14 MeV. Spectroscopic factors related to the 0^+ and 2^+ states of ^{8}Be were adapted from D. Chattopadhyay et al [2]. The spectrum corresponding to each energy was scaled according to the corresponding photon intensities within the bremsstrahlung beam and then summed [1]. Finally, the obtained spectrum was rigorously compared with the experimental data to assess the model's accuracy.

Results and Discussion

The Figure presents the measured inclusive alpha spectrum alongside theoretical calculations, showcasing a continuous range of alpha energies up to 7 MeV. The double differential cross sections, specific to solid angles, are observed at fractions of millibarns. Impressively, the theoretical calculations closely match the experimental cross sections.Within the spectrum, two distinct and well-defined clusters can be discerned. These clusters are attributed to the coupling of the 0^+ and 2^+ resonant states of 8Be, in conjunction with the direct breakup process.

The significance of these cross sections becomes apparent when considering the photon flux utilized in medical treatments and the abundance of carbon in biological tissue. However, it's worth noting that the direct breakup component is not readily apparent in the current measurement, as it is somewhat overshadowed by the sequential breakup phenomenon. Additionally, forward-angle measurements are absent due to challenges associated with Compton electron-induced pileups.

References

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