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Investigation of Double Differential Cross Sections of (γ, p) Reaction for ^{12}C Nuclei

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Photonuclear reaction data, is important for basic and applied research. In additional to this, double differential data is especially vital in the field of nuclear medicine. The increase in the number of patients, admitted for treatment of cancer with heavy ions, poses a serious problem in terms of the risk of secondary cancer, as a result of exposure to particles of different energy and angle values, released after the nuclear reaction. The main point here is the possibility of damaging organs other than the treated one by the radiation generated in the reactions during the heavy ion therapy. Based on this, in order to assess the risk of secondary cancer the investigations of the double differential cross sections of reaction are required. Double differential cross sections of (γ,p) photonuclear reaction for ^{12}C nuclei were calculated as functions of incoming photon energy and angle. Nuclear reaction simulation program TALYS 1.2 was used in the calculations. The calculated cross sections were compared with both the experimental cross sections and the evaluated cross sections available in literature.

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1. Introduction

Nuclear reactions usually involve light particles and/or photons (p, n, α, γ) colliding with a nucleus. Nuclear reactions are usually induced by bombarding a sample with energetic subatomic particles or high-energy photons. The photon is a massless and neutral particle. In comparison with other particles it has a weaker interaction with the target nucleus, and therefore it is less damaging to it. For this reason it is often preferred over the other particles [1].

Photonuclear reactions are very important for the understanding of the structure of the atomic nucleus and are widely used for variety of applications, such as calculations of the absorbed dose in the human body during radiotherapy, nuclear waste transmutation, astrophysical nucleosynthesis, physics of fusion and fission reactors [2].

^{12}C is the more abundant carbon isotope of the two stable carbon isotopes, amounting to 98.93% of the carbon element. It is a very important element for medical applications, because all positron-emitting radionuclides are produced by photoneutron and photoproton reactions in the nuclei of ^{12}C, ^{16}O and ^{14}N. Since measured positron emission tomography images change with time after irradiation, as a result of the different decay times of the radionuclides, the signals from activated ^{12}C, ^{16}O and ^{14}N within the irradiated volume can be separated from each other. Most information is obtained from the carbon and oxygen radionuclides which are the most abundant elements in the soft tissues.

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Therefore in this study, double differential cross section for ^{12}C was calculated with nuclear reaction simulation code TALYS 1.2 [3] and compared to existing experimental data in EXFOR [4] data file.

2. Methods and results

TALYS is a nuclear reaction simulation code, for the analysis and prediction of nuclear reactions. The basic objective behind its construction is the simulation of nuclear reactions that involve neutrons, photons, protons, deuterons, tritons, 3He and alpha particles. TALYS integrates the optical model, direct, preequilibrium, fission and statistical nuclear reaction models in one calculation scheme and gives a prediction for all open reaction channels.

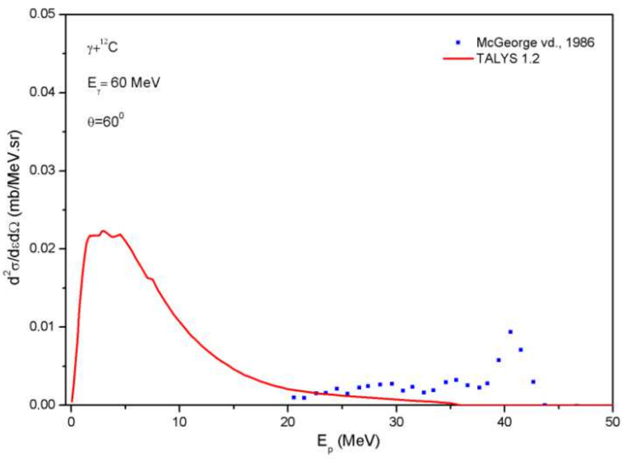

Fig. 1. Double differential cross section for ^{12}C(γ,p) reaction at 60 MeV and 60°.

In this study, double differential cross sections of (γ,p) photonuclear reaction for ^{12}C nuclei were calculated as functions of incoming photon energy (60 MeV, 80 MeV and 200 MeV), for different angles (60° and 120°).

2.1. Results

The calculated ^{12}C (γ,p) double differential reaction cross sections are shown in Figs. 1–6. The obtained results have been compared with the experimental data existing in the EXFOR databases.

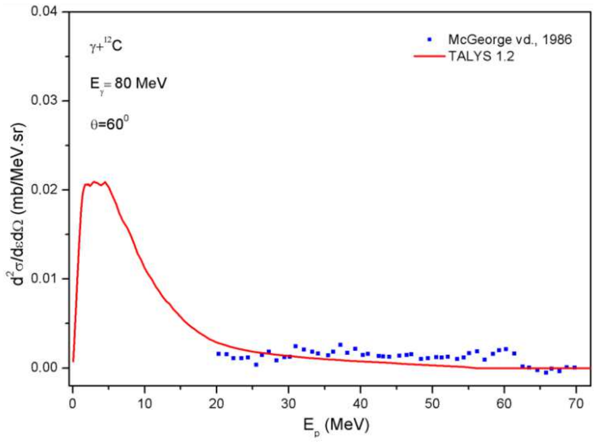

Fig. 2. Double differential cross section for ^{12}C(γ,p) reaction at 80 MeV and 60°.

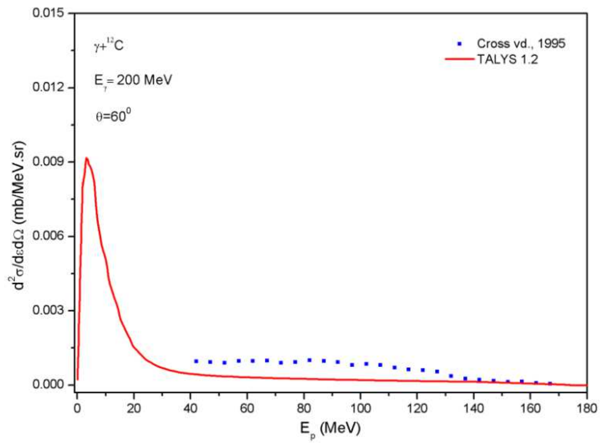

Fig. 3. Double differential cross section for ^{12}C(γ,p) reaction at 200 MeV and 60°.

3. Conclusions

It can be seen that double differential cross section increases with increasing excitation energy and, after reaching a maximum value, decreases. It is seen that at the same angle, as the excitation energy increases, and at the same excitation energy, as the angle increases, the theoretical calculated double differential cross section of (γ,p) reaction increases, which is in agreement with the experimental data.

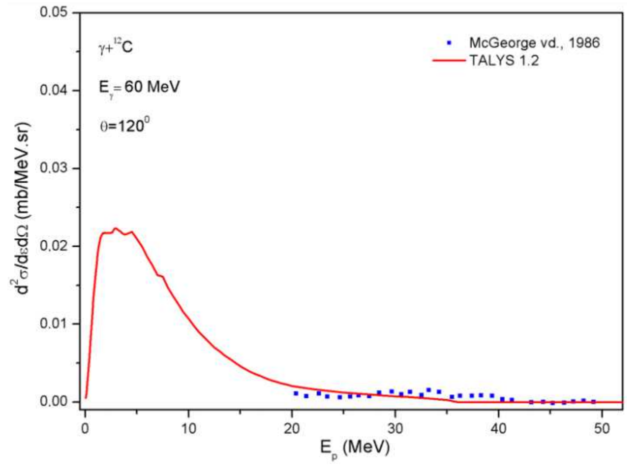

Fig. 4. Double differential cross section for ^{12}C(γ,p) reaction at 60 MeV and 120°.

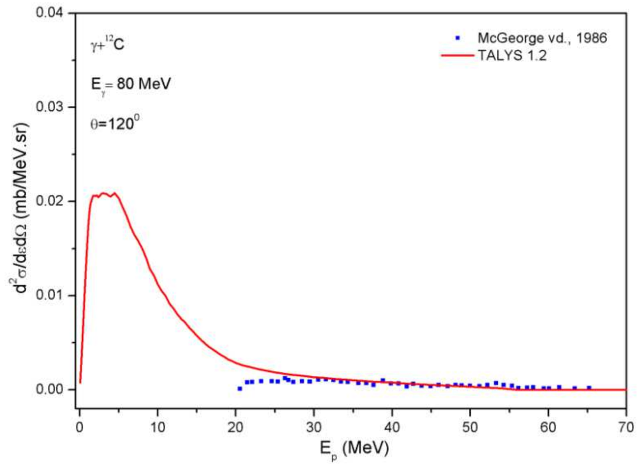

Fig. 5. Double differential cross section for ^{12}C(γ,p) reaction at 80 MeV and 120°.

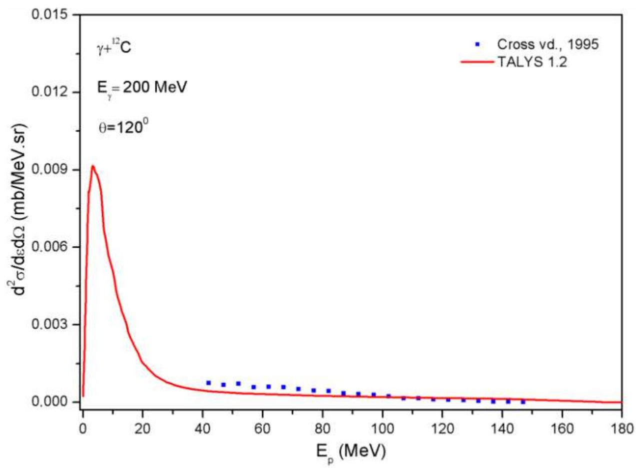

Fig. 6. Double differential cross section for ^{12}C(γ,p) reaction at 200 MeV and 120°.

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