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Effects of Mean Free Path Parameters for Reaction Cross-Section Calculations

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Abstract. In this study, effects of the mean free path parameters for ^{209}Bi(n,xn) reaction at 14.2 MeV, ^{58}Ni(n,xp) reaction at 9 MeV and 14.8 MeV induced neutron energies have been investigated by using k_{mfp} parameter in PCROSS calculations. In ALICE/ASH calculations, COST parameters have been investigated for ^{60}Ni(p,n)^{60}Cu, ^{209}Bi(d,n)^{210}Po and ^{241}Pu(p,2n)^{240}Am reactions. Obtained results have been compared with the experimental data taken from the literature.

Keywords: Mean Free Path, COST, ALICE/ASH, PCROSS, EXFOR

Reaksiyon Tesir Kesiti Hesaplamaları için Ortalama Serbest Yol Parametrelerinin Etkisi

Özet. Bu çalışmada, ortalama serbest yol parametrelerinin etkileri ^{209}Bi(n,xn) reaksiyonunda 14.2 MeV, ^{58}Ni(n,xp) reaksiyonunda 9 MeV ve 14.8 MeV giriş enerjili nötronlar ile k_{mfp} parametresi ile PCROSS hesaplamalarında araştırılmıştır. ALICE/ASH hesaplamalarında ise, COST parametreleri ^{60}Ni(p,n)^{60}Cu, ^{209}Bi(d,n)^{210}Po ve ^{241}Pu(p,2n)^{240}Am reaksiyonlarında incelenmiştir. Elde edilen sonuçlar, literatürde mevcut deneysel veriler ile karşılaştırılmıştır.

Anahtar Kelimeler: Ortalama Serbest Yol, COST, ALICE/ASH, PCROSS, EXFOR

1. INTRODUCTION

The probability of nuclear reaction occurrence is basically named as reaction cross–section. The investigation of the reaction cross–section may have critical importance for material development, avoiding unexpected nuclear reaction results also radioisotope production [1]. In some cases with the experimental difficulties or lack of data, theoretical calculations may came forward to cover the absence. For similar situations, scientists have developed different nuclear reaction codes to compute reaction cross–section, spectrum of out-going particles and dose calculations including many theoretical nuclear models. These models include lots of parameters that effect the results. In this study, effects of the mean free path parameters for previously given reactions have been investigated with PCROSS [2] and ALICE/ASH [3] codes. Calculated results have been compared with the experimental values taken form the EXFOR database [4].

2. CALCULATION METHODS

In this study, with the help of two theoretical calculation codes named as ALICE/ASH and PCROSS, we aimed to investigate the effects of mean free path parameters on reaction cross–section calculations. Among all other codes which scientists have developed to compute reaction cross–section, spectrum of out-going particles and dose calculations including many theoretical nuclear models, ALICE/ASH and

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PCROSS are two of the well-known and used. The maximum path which a particle could travel before it scatters or absorbed is called as the mean free path. The mean free path, which is symbolized with $\bar{\lambda}$, is calculated with a similar way like the average lifetime [5].

$$\bar{\lambda} = \frac{\int_0^{N_0} x dN}{\int_0^{N_0} dN} = \frac{\int_0^{N_0} x dN}{N_0} \tag{1}$$

Mean free path is calculated with the equation given in Equation 1. The number of particles which could travel the λ distance among N numbered incoming particles to a substance is calculated with Equation 2.

$$dN = -\rho\sigma N_0 e^{-\rho\sigma\lambda} d\lambda \tag{2}$$

By substituting Equation 2 into Equation 1 and take it's integral we obtain Equation 3 which is the mean free path equation. In here, ρ is the matter density and σ is the cross–section of matter–nucleus interaction [6].

$$\bar{\lambda} = \frac{1}{\rho\sigma} \tag{3}$$

3. RESULTS and DISCUSSION

Due to the travelled distance change in the case of incident particles more interaction with the target surface depending on the incoming particles effect parameter or angular momentum, there occurs an increase of the likelihood of particle release from the unified system. The neutron production cross–sections could be controlled for same target and same incoming energies by using different mean free path parameters with the COST+1 which is the mean free path replication parameters in ALICE/ASH code in where the Geometry Dependent Hybrid model was used which takes the previously mentioned effect into account. In the performed calculations, COST value was taken as 1 at first. Then, by increasing and/or decreasing the COST value, the similarities to the experimental values was observed. The comparisons between the calculated results and experimental values for ^{60}Ni(p,n) ^{60}Cu, ^{209}Bi(d,n) ^{210}Po and ^{241}Pu(p,2n) ^{240}Am reactions have been given below in Figure 1., Figure 2. and Figure 3, respectively.

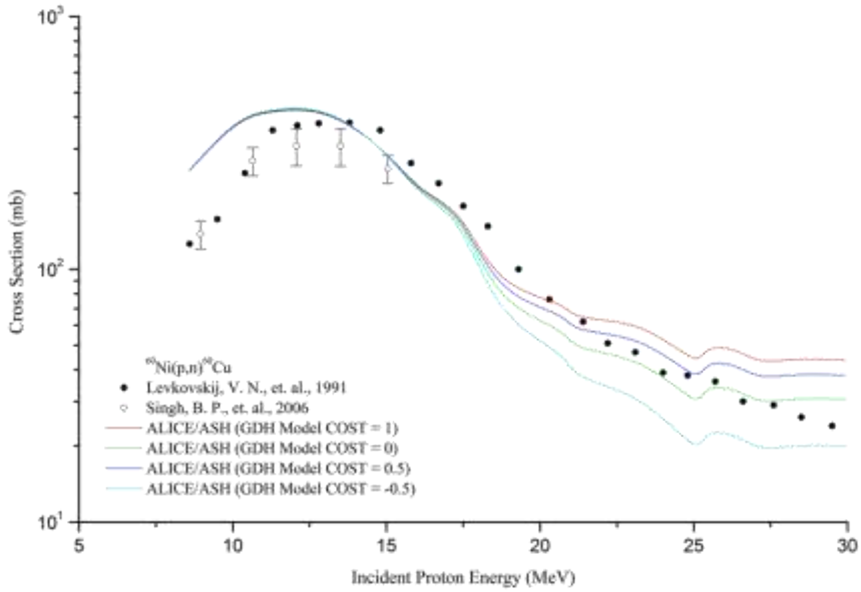

Figure 1. The comparison of the experimental values with the cross–section results in which the calculations were based on the ALICE/ASH COST parameter value for $^{60}Ni(p,n)^{60}Cu$ reaction.

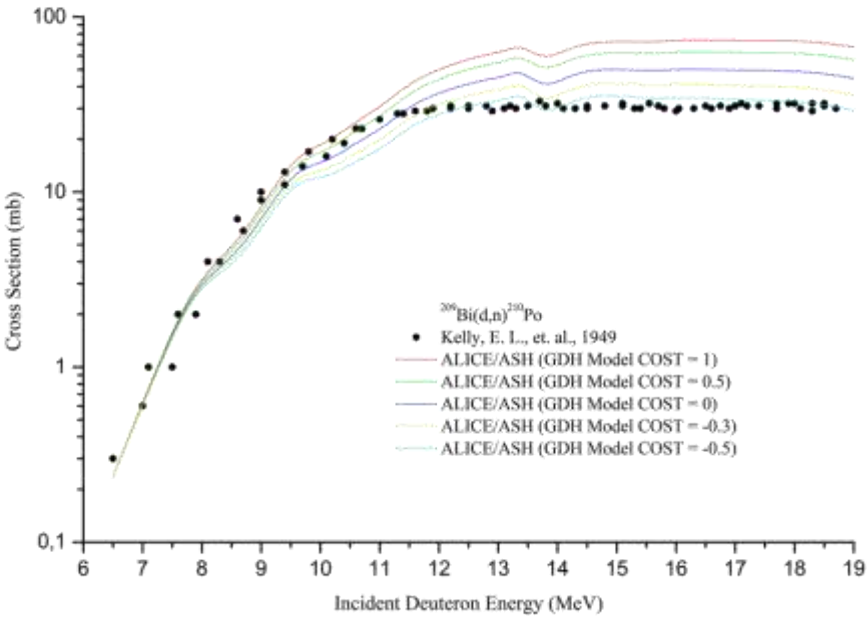

Figure 2. The comparison of the experimental values with the cross–section results in which the calculations were based on the ALICE/ASH COST parameter value for $^{209}Bi(d,n)^{210}Po$ reaction.

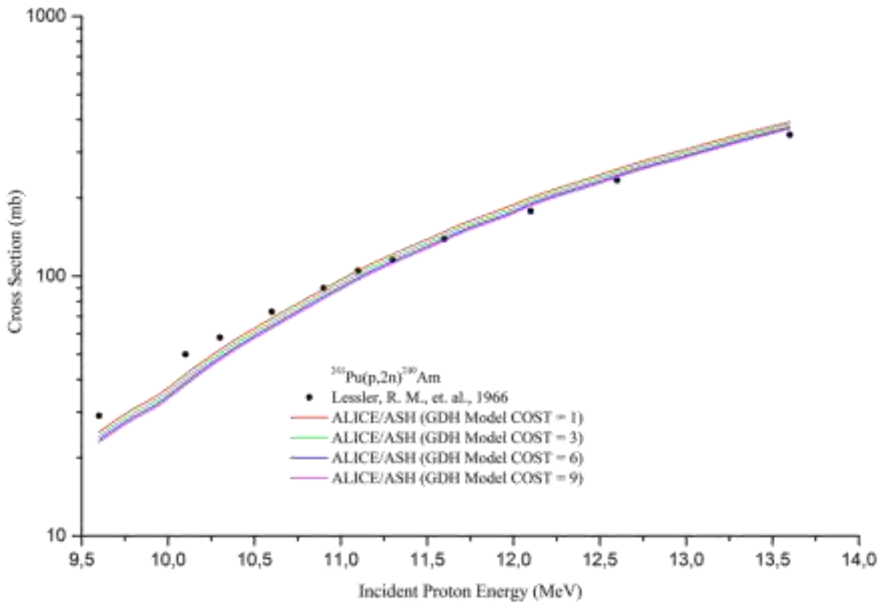

Figure 3. The comparison of the experimental values with the cross–section results in which the calculations were based on the ALICE/ASH COST parameter value for $^{241}Pu(p,2n)^{240}Am$ reaction.

The mean free path parameter used in the PCROSS code calculations is a parameter which come out at the statement to express the internal passing speeds. This parameter is given as k_{mfp} and its value used on the PCROSS code is 1,3. The calculations have been performed for different values of k_{mfp} for the (n,xn) neutron emission and (n,xp) proton emission reactions. The obtained results are given in Figures

4-6. In Figure 4, for ^{209}Bi(n,xn) reaction with 14.2 MeV incident neutron energy, the comparison of experimental result and decreasing k_{mfp} was given. In Figure 5 and Figure 6 the comparisons of experimental results and increasing k_{mfp} parameter calculations have been given for ^{58}Ni(n,xp) reactions with incident neutron energy of 9 and 14.8 MeV respectively.

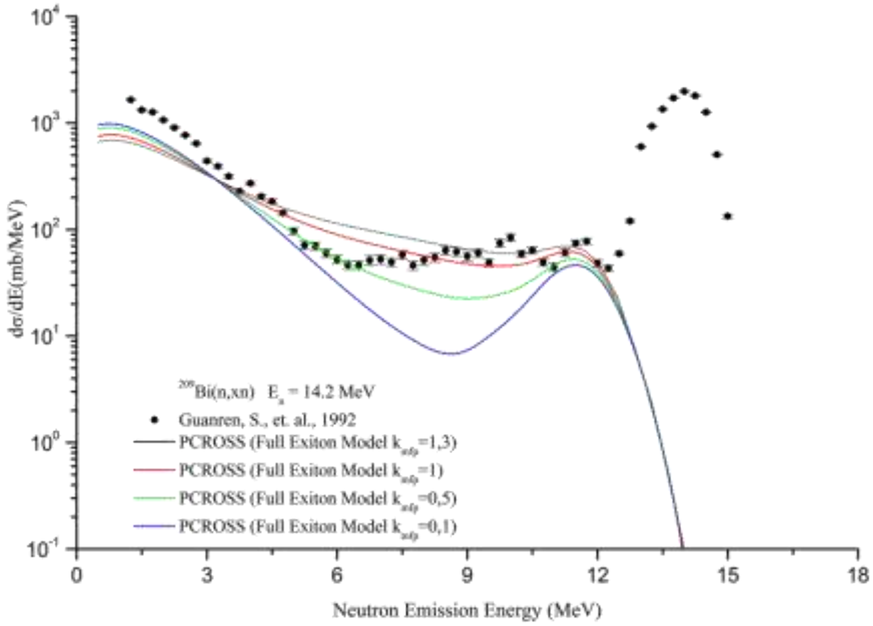

Figure 4. The comparison of the experimental values with the neutron emission spectra results in which the calculations were based on the PCROSS k_{mfp} parameter value for ^{209}Bi(n,xn) reaction with 14.2 MeV incident neutron energy.

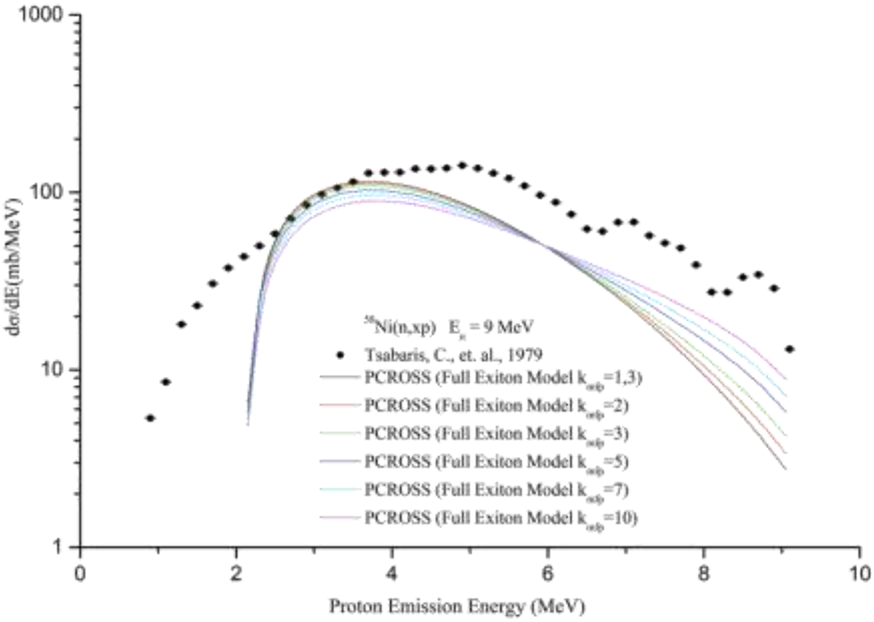

Figure 5. The comparison of the experimental values with the proton emission spectra results in which the calculations were based on the PCROSS k_{mfp} parameter value for ^{58}Ni(n,xp) reaction with 9 MeV incident neutron energy.

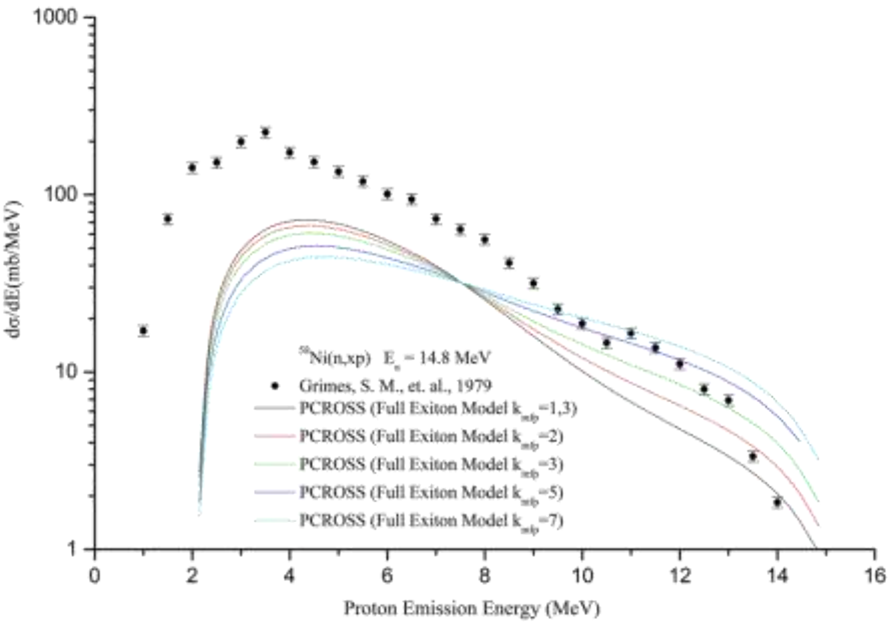

Figure 6. The comparison of the experimental values with the proton emission spectra results in which the calculations were based on the PCROSS k_{mfp} parameter value for ^{58}Ni(n,xp) reaction with 14.8 MeV incident neutron energy.

4. SUMMARY AND CONCLUSIONS

This study has been completed to investigate the effects of mean free path parameters to the reaction cross–section calculations. Obtained results can be summarized as following for both parameters investigated in this study:

1- The most agreed results with the experimental values by changing the COST parameters have been obtained with COST=0 for ^{60}Ni(p,n)^{60}Cu reaction, COST=-0.5 for ^{209}Bi(d,n)^{210}Po and COST=1 up to 11 MeV and COST=9 from 11 MeV incident proton energy for ^{241}Pu(p,2n)^{240}Am reaction.

2- The most agreed results with the experimental values by changing the k_{mfp} parameters have been obtained with k_{mfp} =1 for ^{209}Bi(n,xn) reaction with 14.2 MeV incident neutron energy in the neutron emission energy region of 5-12 MeV, k_{mfp} =10 for ^{58}Ni(n,xp) reaction with 9 MeV incident neutron energy in the proton emission energy region of 2-6 MeV and k_{mfp} =5 for ^{58}Ni(n,xp) reaction with 14.8 MeV incident neutron energy in the proton emission energy region of 8-14 MeV.

3- With the change of COST and k_{mfp} parameters which are the mean free path parameters in the nuclear reaction calculation codes ALICE/ASH and PCROSS, respectively; it is possible to obtain more close results to the experimental values.

4- It is possible to use the mean free path parameter optimization to calculate the reaction cross–section with accuracy in some cases like the experimental difficulties, lack of experimental data or the inability to performing the reaction.

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