Detailed analysis of uncertainty quantification

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Introduction

The neutron capture cross-section is crucial for studying nuclear physics processes, including nuclear reaction kinetics, element creation, and the astrophysical process of nucleosynthesis. The quantitative values of the safety analysis and reactor design are essential [1–7]. Tantalum has qualities that are advantageous for use in nuclear systems. For accurate neutron transport calculations, it is therefore crucial to have a precise understanding of tantalum's neutron cross-section and uncertainty. In this work, we investigate the covariance analysis and concentrate on the ^{181}Ta(n,γ)^{182}Ta reaction cross section. This enables us to evaluate the uncertainties of nuclear data and their consequences for different applications. The precise calculation of reaction cross sections remains difficult, as the assessment of nuclear data is subject to inaccuracies caused by several sources. The uncertainties arise from results from experiments, theoretical models, and statistical data evaluations. A tool used in this study allows for the measurement of uncertainties by analyzing the relationship between various nuclear data parameters, known as covariance analysis. In this study, we also thoroughly analyzed of the uncertainty quantification correlated to the theoretically calculated cross section for the ^{181}Ta(n,γ)^{182}Ta reaction using Monte Carlo simulations. The Monte Carlo method is a useful technique for determining the uncertainty in theoretically calculated cross-sections of nuclear reactions. Through systematic variation of the critical nuclear inputs within their respective uncertainties, the theoretical parameters is analyzed.

Experimental Details

The experiment was carried out at the 6 MV Folded Tandem Ion Accelerator (FOTIA) facility, BARC, Mumbai. In this experiment, the proton having energies 2.5 MeV and 3.0 MeV were bombarded on a natural lithium target for neutron production purposes. EPEN code was used for the simulation of neutron flux. This code has been designed for the proton energy from the reaction threshold to 7.0 MeV.

Theroretical Calculations

The Monte Carlo method was utilized in the present study to assess the uncertainties in the theoretically calculated cross section for the ^{181}Ta(n,γ)^{182}Ta reaction. We specifically focus on the systematic variation of two key nuclear inputs: first the optical model potential and second the level density parameter. These inputs play a crucial role in the theoretical models to describe the nuclear reaction mechanism and energy-dependent cross-sections.

Result and Discussion

In the present work, efficiency calibration [8–10] of the HPGe detector for different gamma ray energies has been carried out using a standard ^{152}Eu point source. The geometry-dependent efficiency (ϵ_p) of the point source for source-detector was estimated using the following equation:

$$\epsilon_p = \frac{CK_c}{A_o I_\gamma \Delta t e^{-\lambda t}} \quad (1)$$

The measurement of the reaction cross-section of the $E_\gamma = 1121.290$ keV of ^{182}Ta ($t_{1/2} = 114.74d$) with intensity $I_\gamma = 35.29$ % was done

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TABLE I: Information about the level density and optical model parameters with associated percentage uncertainties.

Parameter	Value	Uncertainty (%)
Level density		
σ^2	1	20
α	0.0722	20
β	0.1953	30
γ	0.4103	30
Optical model		
r_d	1.3396	3
a_d	0.5146	4
d_1	12.9060	10
d_2	0.0182	10
d_3	11.5	10
r_v	1.2322	2
a_v	0.6509	2
v_1	50.8950	2
v_2	0.0069	3
v_3	0.00002	3
w_1	15.2180	10
w_2	87.9390	10
r_{so}	1.0710	10
a_{so}	0.59	10
w_{so1}	3.1	20
w_{so2}	160.0	20
v_{so1}	6.4650	5
v_{so2}	0.0040	10

after the cooling of 7200 seconds. The nuclear reaction cross-sections were calculated using the following activation formula:

$$\sigma_s = \sigma_m \eta \frac{A_s \lambda_s a_m N_m I_m f_m}{A_m \lambda_m a_s N_s I_s f_s} \frac{N_{corr(s)} C_{attn(s)}}{N_{corr(m)} C_{attn(s)}} \quad (2)$$

In the above equation, A_0 is the known activity of ^{152}Eu (A_0 = 6659 Bq as on 01 Oct 1999) point source.

The level density and optical model parameters and their associated percentage uncertainties used in the theoretical calculation of the cross-section for the ^{181}Ta(n,γ)^{182}Ta reaction are given in Table I. Fig. 1 shows the excitation function of ^{181}Ta(n,γ)^{182}Ta reaction at the neutron energies 0.53 and 1.05 MeV, obtained in this study and compared with the existing experimental data and presented the 95% confidence interval of the theoretical prediction in the energy range 0.5 - 4 MeV. We have done the covariance analysis for the nuclear reaction ^{181}Ta(n,γ)^{182}Ta. The measured

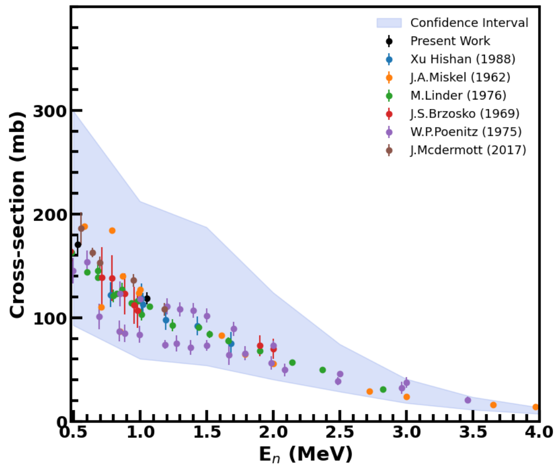

FIG. 1: Excitation function of ^{181}Ta(n,γ)^{182}Ta reaction with literature data and with confidence interval.

cross-sections have uncertainties ranging from 4 - 6 %. These precise results, along with their detailed uncertainties and covariance, are crucial for validating nuclear reaction codes and for the practical application of nuclear reactors. The details of the data analysis of the reaction cross sections and uncertainty quantification will be presented during the conference.

References

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