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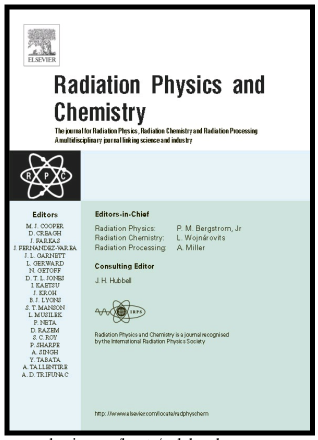

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Uncertainty propagation in activation cross section measurements

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Abstract

The IAEA Nuclear Data Section (IAEA NDS) has emphasized the importance of archiving experimental nuclear data with detailed description of the uncertainties to provide reasonable evaluated (recommended) data sets with their uncertainties to end-users. In order to achieve this goal, the IAEA NDS is transferring relevant knowledge to experimentalists by instructing uncertainty propagation for their specific experiments. This article discusses uncertainty propagation based on detailed description of uncertainties in neutron- and charged-particle-induced activation cross sections measured in our studies.

Key words: activation cross section, uncertainty, uncertainty propagation, covariance

1. Introduction

Activation of sample materials is a technique to determine nuclear reaction cross sections for radioisotope productions (activation cross sections) by measuring radiations from the radioactive products, and it has been widely applied to nuclear reactions with various projectiles (*e.g.,* neutron, charged-particle, photon) for many decades. Activation cross sections are basic nuclear data in a wide range of nuclear applications (*e.g.,* radioisotope production, reactor dosimetry, construction and decommission of nuclear facilities) as well as sciences (*e.g.,* nuclear astrophysics, cosmochemistry), and their experimental results have been utilized by end-users in various fields through compilation in the EXFOR library [1] and evaluation for development of general purpose nuclear reaction data libraries (*e.g.,* CENDL-3.1 [2], ENDF/B-VII.1 [3], JEFF-3.1.1 [4], JENDL-4.0 [5], TENDL-2015 [6]), activation data libraries (*e.g.,* EAF-2010 [7]) as well as dosimetry data libraries (*e.g.,* IRDFF-1.05 [8].) The uncertainty accompanied with the activation cross section is essential in determination of reasonable margin contributing to both safety and economy in nuclear applications.

If several data points of the activation cross sections are involved in determination of the quantity of interest (*e.g.,* reaction rate obtained by folding of energy dependent activation cross sections by the spectrum characterizing the incident particle field), the correlation (covariance) among the data points has to also be considered to avoid overestimation or underestimation of the uncertainty in the quantity of interest. Due to this situation, modern evaluation tries to provide not only the best estimate of the cross section but also their uncertainty and covariance describing correlation among data points of the same reaction or even different reactions ("cross correlation"). In order to provide the uncertainty and covariance in addition to the best estimate of the cross section based on the experimental knowledge, data evaluators need detailed documentation of the uncertainties in each experiment. However evaluators often face difficulty due to lack of sufficient documentation of the experiment. At the worst case the evaluators cannot find any uncertainty in the measured cross section, and it is also not rare to see a total uncertainty without its breakdown (*e.g.,* uncertainty due to counting statistics).

In order to improve the situation, the IAEA Nuclear Data Section (NDS) is encouraging experimentalists to perform appropriate uncertainty propagation and documentation in collaboration with external experts [9, 10, 11, 12, 13, 14]. However, we found that mere publications and presentations of guidelines are not sufficient to achieve our goal, and have thus recognized the importance to take more practical approaches relevant to designs for individual experiments.

In this article, we introduce two examples of our approach in real neutron- and charged-particle-induced activation cross section measurements performed in India and Japan, respectively, following a short summary on the basic concepts and uncertainty propagation formulae as well as a simple and hypothetical example demonstrating the importance of the uncertainty information for data evaluators.

2. Basic concepts and uncertainty propagation formulae

We consider various parameters required in cross section measurements (*e.g.,* number of counts, number of incident particles, number of atoms in the sample) as random variables

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