Producing uncertainties and covariance matrix from intermediate data using a Monte-Carlo method

Greg HENNING [(1)], Francois CLAEYS [(1)], Nicolas DARI BAKO [(1)], Philippe DESSAGNE [(1)], Maelle KERVENO [(1)]

[(1)] Institut pluridisciplinaire Hubert Curien, F-67037 Strasbourg, France

Abstract: The necessary improvement of evaluated nuclear data for nuclear applications development is possible through new and high quality experimental measurements. In particular, improving (n, n') cross-section evaluations for faster neutrons is a goal of interest for new reactor fuels.

Our group at CNRS-IPHC developed an experimental program to measure (n, n' γ) cross-section using prompt gamma-ray spectroscopy and neutron energy determination by time-of-flight [1-3], with a focus on reaching the highest achievable level of accuracy. The collected partial cross-section can then be used to infer the total (n, n') one and contribute to evaluation improvement [1]. The extraction of the partial (n, n'γ) cross-sections from the recorded data involves using many external parameters (detector efficiencies, distance of flight...). Additionally, the steps of the data processing (event selection, calibration...) may introduce extra uncertainties and correlations between data points.

The usual method for combining and computing uncertainties is to use analytical developments based on the perturbation theory (e.g. $u_{f(x)}^2 = (\partial f/\partial x)^2 \times u_x^2$).
With multiple parameters and sources of uncertainty, deriving the final total combined uncertainty can be long and complex. This method makes the calculation of covariance hard and the inclusion of some unusual form of uncertainty (asymmetric, non-Gaussian) even more difficult. To overcome this issue, we developed a process relying on random sampling methods (a.k.a *Monte Carlo*) that processes intermediate analysis data to compute final values (cross-sections), uncertainties and covariance.

As a benchmark, we used the Monte Carlo method on ^{238}U [4] and reproduced the central values and uncertainties calculated using the analytical method. In addition, we were able to produce covariance matrices for (n, n'γ) cross-section. In some particular cases, the random sampling method is able to produce finer uncertainties that reflect the original data, while the analytical method smooths some features.

After explaining the method, presenting the results, we will discuss possible applications and extension of the method to other data set.

[1] M. Kerveno, et al., EPJ Web of Conferences 239, 01023 (2020)
[2] M. Kerveno, et al., EPJ Nuclear Sci. Technol. 4, 23 (2018)
[3] M. Kerveno, et al., Eur. Phys. Jour. A 51, 12 (2015)
[4] M. Kerveno, et al., Phys. Rev. C 104, 044605