# Evaluating importance maps for TRIPOLI-4$^R$ using deterministic or on-line methods

D. Mancusi, M. Nowak, E. Dumonteil

*ANS RPSD 2018–20th Topical Meeting of the Radiation Protection & Shielding Division of ANS*
Santa Fe, NM, August 26–31, 2018, on CD-ROM, American Nuclear Society, LaGrange Park, IL (2018)

# Evaluating importance maps for TRIPOLI-4® using deterministic or on-line methods

Davide Mancusi[1], Michel Nowak[1], and Éric Dumonteil[2]

[1]*Den-Service d'études des réacteurs et de mathématiques appliquées (SERMA), CEA, Université Paris-Saclay, F-91191, Gif-sur-Yvette, France*
[2]*IRSN, 31 Avenue de la Division Leclerc, 92260 Fontenay-aux-Roses, France*

## Introduction

Monte-Carlo particle-transport codes are often the tool of choice for performing quantitative radiation-protection studies. However, the estimation of the response of a particle detector in a strongly attenuated radiation field is very computationally intensive. Radiation-protection problems, by definition, fall into this class, and are therefore intractable with Monte-Carlo methods unless suitable variance-reduction techniques are applied.

A common need for variance-reduction methods is to evaluate particle tracks with respect to their expected contribution to the sought detector response. Any function providing such an estimate for each point of the phase space is generally known as an *importance map*. For a certain class of variance-reduction algorithms, the provably optimal choice for the importance function [1,2] is represented by the adjoint flux, i.e. the solution of the adjoint fixed-source Boltzmann equation [3].

## Description of Work

The goal of this work is to present the development of two new functionalities of the TRIPOLI-4® Monte-Carlo particle-transport code [4], that simplify the construction of a suitable importance map. First, a development version of TRIPOLI-4 has been coupled with the deterministic transport solver IDT [5]. The coupling allows users to seamlessly invoke IDT for the construction of the importance map, without having to convert the TRIPOLI-4 simulation geometry to another format. Multigroup cross sections are automatically condensed and homogenized. The TRIPOLI-4-IDT coupling thus allows users to perform Monte-Carlo calculations based on the CADIS methodology [6].

Second, we have implemented a new TRIPOLI-4 response function that makes use of the particle tracks generated by a direct (forward) simulation to produce an online estimate of the adjoint flux for a given detector response. The principle has already been described in the literature [7–9], but we propose a slightly different, collision-based estimator. The final goal of this work is to use the scored adjoint flux as an importance map for the same simulation.

## Results

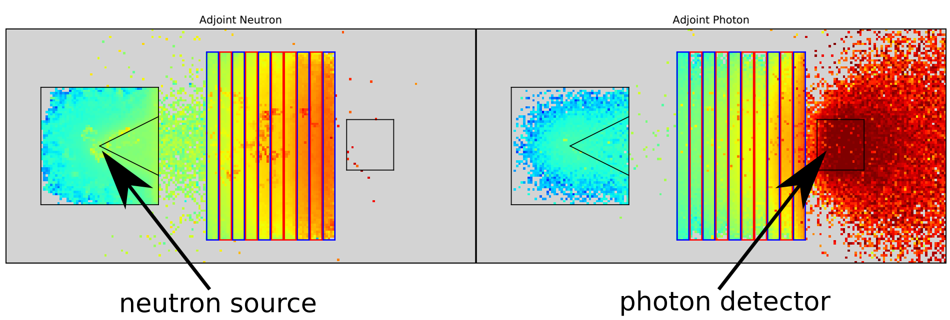


**Figure 1.** Neutron and photon adjoint flux scored by TRIPOLI-4 for a coupled neutron-photon shielding problem. The plots highlight the lack of information in low-density regions (air, grey).

We have verified that the importance maps calculated by IDT can yield sizeable accelerations compared to TRIPOLI-4's native importance-map-generation module, INIPOND [10]. A crucial role is played by the condensation and homogenization algorithms that construct the multi-group cross sections used as an input for IDT.

We also present in Figure 1 the result of an on-line estimation of the importance map for a coupled neutron-photon problem. This particular example is interesting because, in general, neutron-photon problems are difficult to efficiently solve using TRIPOLI-4's native importance-map-generation module. Using our new adjoint-flux response, we can pre-compute the importance map during a first calculation with a simpler, less efficient variance-reduction technique. The resulting adjoint flux can then be injected as an importance map into a new calculation and results in very large speed-up factors.

**References**


1. S. R. DWIVEDI, "Zero variance biasing schemes for Monte-Carlo calculations of neutron and radiation transport problems," *Nucl. Sci. Eng.*, **80**, *1*, 172–178 (1982).

2. J. E. HOOGENBOOM, "Zero-variance Monte Carlo schemes revisited," *Nucl. Sci. Eng.*, **160**, *1*, 1–22 (2008).

3. G. I. BELL and S. GLASSTONE, *Nuclear reactor theory*, Van Nostrand Reinhold Company, New York (1970).

4. E. BRUN, F. DAMIAN, C. M. DIOP, E. DUMONTEIL, F.-X. HUGOT, C. JOUANNE, Y. K. LEE, F. MALVAGI, A. MAZZOLO, O. PETIT, J. TRAMA, T. VISONNEAU, and A. ZOIA, "TRIPOLI-4®, CEA, EDF and AREVA reference Monte Carlo code," *Ann. Nucl. Energy*, **82**, 151–160 (August 2015).

5. I. ZMIJAREVIC and R. SANCHEZ, "Deterministic solutions for 3D Kobayashi benchmarks," *Prog. Nucl. Energy*, **39**, *2*, 207–221 (2001).

6. J. SWEEZY, F. BROWN, T. BOOTH, J. CHIARAMONTE, and B. PREEG, "Automated variance reduction for MCNP using deterministic methods," *Radiat. Prot. Dosim.*, **116**, *1–4*, 508–512 (2005).

7. T. E. BOOTH, "Automatic importance estimation in forward Monte-Carlo calculations," *Trans. Am. Nucl. Soc.*, **41**, 308–309 (1982).

8. T. E. BOOTH and J. S. HENDRICKS, "Importance estimation in forward Monte-Carlo calculations," *Fusion Sci. Technol.*, **5**, *1*, 90–100 (1984).

9. I. MURATA, D. FILGES, and F. GOLDENBAUM, "A new approach to estimate importance for weight window in forward Monte Carlo calculations," *Nucl. Sci. Eng.*, **159**, *3*, 273–283 (2008).

10. J. P. BOTH, J. C. NIMAL, and T. VERGNAUD, "Automated importance generation and biasing techniques for Monte-Carlo shielding techniques by the TRIPOLI-3 code," *Prog. Nucl. Energy*, **24**, *1–3*, 273–281 (1990).