THE USE OF THE PRIZMA CODE FOR MODELING THE LINEAR-ACCELERATOR-BASED PHOTONEUTRON SOURCES

K. S. Volosenko, O. V. Zatsepin, I. V. Penzin, S. I. Samarin, V. M. Shmakov

FSUE «RFNC – VNIITF named after Academ. E. I. Zababakhin», Snezhinsk, Russia

A code PRIZMA[1, 2] was developed at RFNC – VNIITF for solving radiation transport by the Monte Carlo method.

The code solves nonstationary nonhomogeneous linear equations describing individual and coupled transport of neutrons, photons, electrons, positrons, and ions in 3D geometry. The particles emitted by a specified source, generally nonstationary, are tracked through a medium, whose characteristics remain unchanged during the entire simulation.

Calculation efficiency is improved by the wide use of the variance reduction techniques developed in the code [3, 4] for solving the nonhomogeneous radiation transport equation, radiation shielding, characteristics of neutron and gamma emissions in detectors arranged inside and outside the reactor core, etc.

RFNC – VNIITF developed its own system to provide Monte Carlo calculations with nuclear data for different particles [5]. PRIZMA uses a PROM library [6] containing neutron cross-sections with data on gamma production, photo-atomic cross-sections with data on electron and positron production, photo-nuclear cross-sections with data on neutron and charged particle production, and data on the interaction of charged particles with matter. The sources of these data are international and domestic nuclear data libraries.

PRIZMA offers the user wide capabilities to describe system geometry [7], sources [8], and the characteristics to be estimated, such as the effective neutron multiplication factor, the average neutron lifetime from fission to fission, the average number of particles from a fission event, the number of reactions for individual nuclides, fluence, neutron and gamma spectra etc.

The estimates for the linear functionals of the transport equation solution can be obtained for arbitrary surfaces and regions in the system being modelled. All the functionals can be differential in space, time, particle direction, and energy.

One of the areas where the code is actively used is the computational and experimental study aimed to develop linear-accelerator-based photoneutron sources. Data from LINAC experiment [9] were used to develop and test calculation technology and photon cross-sections with photo-nuclear data. Our calculations satisfactorily agree with the experimental data and calculations by the code MCNPX [10].

To optimize parameters of conversion targets and tentatively determine the neutron yield and spectrum in order to choose appropriate measurement techniques, we used PRIZMA to estimate photon and neutron detection by the X-ray facilities BIM234.3000M and LIA-20 [11, 12]. Our calculations were done in different statements for a combined target of two materials. The flux of neutrons was modelled in one calculation: electrons propagated through the tantalum target and produced photons which then passed through the photoneutron target and produced neutrons.

The calculations we performed helped adjust parameters for non-analog modeling and study how the configuration of conversion targets and the external environment of the facility influence the neutron emission intensity and power. Calculated results were used to validate the concept of the high-power gamma-neutron generator that allows variation of the intensity of pulsed gammas and neutrons for the purpose of radiation resistance research.

References

1. **Kandiev, Y. Z.** PRIZMA Status [Text] / Y. Z. Kandiev, K. E. Khatuntsev, O. V. Zatsepin et al. // Annals of Nuclear Energy. – 2015. – Vol. 82. – P. 116–120.
2. **Kandiev, Ya. Z.** PRIZMA Status [Text] / Ya. Z. Kandiev, G. N. Malyshkin, O. V. Zatsepin et. al. // Joint International Conference on Supercomputing in Nuclear Applications and Monte Carlo, 27–31 October 2013, Paris, France. [CD-ROM]
3. **Zatsepin, O. V.** Biased modeling techniques implemented in the code PRIZMA for solving the deep penetration and detection problems of reactor physics [Text] / O. V. Zatsepin and Y. Z. Kandiev // J. Atomic Science and Technology Issues. Ser. "Mathematical Modeling of Physical Processes". – 2015. – Iss. 1. – P. 30–36.

4. **Kandiev, Ya. Z.** Modeling by Value Implemented in PRIZMA Code [Text] / Ya. Z. Kandiev, G. N. Malyshkin // V Joint Russian-American Computational Mathematics Conference, Sandia Report, SAN98-1591, 149 (1998).
5. **Shmakov, V. M.** Use ENDF-Format Libraries for Criticality Calculations at VNIITF [Text] / V. M. Shmakov, V. D. Lyutov, E. I. Cherepanova et al. // Proc. the Sixth International Conference on Nuclear Criticality Safety ICNC'99, Versailles, France (CD-ROM), P1_24, Sept 20–24, 1999.
6. **Kandiev, Y. Z.** Nuclear data libraries in the KOBRA system: the use of ENDL and ENDF [Text] / Y. Z. Kandiev, E. S. Kuropatenko, V. M. Shmakov, and E. I. Cherepanova // J. Atomic Science and Technology Issues. Ser. "Numerical Methods and Codes for Mathematical Physics". – 1986. – No. 1.
7. **Adeyev, A. V.** Geometrical capabilities for Monte Carlo calculations at RFNC – VNIITF [Text] : preprint No. 160 / A. V. Adeyev, I. V. Adeyeva, and N. A. Pavlova. – Snezhinsk : RFNC – VNIITF Press 1999.
8. **Kandiev, Y. Z.** Description of particle sources for solving radiation transport by the Monte Carlo method at RFNC – VNIITF [Text] : preprint No. 176 / Y. Z. Kandiev, E. A. Kashayeva, and G. N. Malyshkin. – Snezhinsk : RFNC – VNIITF Press, 2001.
9. **Sadineni, S. B.** Benchmarking photoneutron production of Mcnpx simulations with experimental results [Text] // UNLV Retrospective Theses & Dissertations. – 2002.
10. **Walters, L. S.** MCNPX user's manual. Version 2.1.5.
11. **Penzin, I. V.** Photoneutron Source Based on Linear Induction Accelerator [Text] / I. V. Penzin, D. V. Petrov, O. A. Nikitin et al. // SOCHI, IYNC2022.
12. Static and pulsed X-raying instuiments [Text] : collection of papers ; ed. by O. A. Nikitin and R. V. Protas. – Snezhinsk : RFNC – VNIITF Press, 2023.