Photon Adjoint Mode in PHITS

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An adjoint transport function has been added to PHITS. The function is an alternative method for solving photon transport problems with small detector volumes compared to the source region. The function follows the formalism of Hoogenboom (2000) [1]. The method and its performance are demonstrated here on test problems.

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1. Introduction

The adjoint method can be an efficient technique for solving radiation transport problems where the source is larger than the detector. Fukushima environmental radioactivity calculations fall within this class of problem, as gamma rays from radiocesium spread over a wide area contribute to the air dose rate. We therefore added a gamma ray adjoint function to the Particle and Heavy Ion Transport code System (PHITS) Monte Carlo code [2].

2. Method

The adjoint function simulates pseudo-photons. These are generated within in the detector region and are transported through space. They undergo adjoint interactions (corresponding to forward interactions in reverse) with matter. A new cross section library was developed based on JENDL-4.0 which contains adjoint incoherent and pair production interaction cross sections. The photoelectric effect is treated implicitly. Pseudo-photons are tallied when they cross the gamma ray source region. A new adjoint tally function ([T-Adjoint]) recovers the photon flux in the detector of the corresponding forward calculation.

3. Results

The adjoint function was confirmed as giving the correct results by comparing to a forward calculation for a gamma ray flux spectrum in an infinite medium. The adjoint function successfully reproduced the activity-to-dose conversion factor for the air dose rate at 1 m given homogeneously distributed cesium-137 in soil. The performance of the adjoint function was established by comparing the runtime for a generic large source and small detector transport problem against conventional forward mode and point tally calculations.

4. Conclusion

The adjoint function is a promising addition to PHITS for efficiently solving large source small detector gamma ray transport problems. Future developments are to add a ‘point energy’ routine, allowing the simulation of pair production interactions and line energy gamma ray radiation sources, e.g. discrete radioactive decay photons.

References

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