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Photonuclear Physics In MCNP(X)

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Introduction

Photonuclear physics has been overlooked within mainstream Monte Carlo radiation transport codes for some time. This has been primary due to a lack of complete, evaluated data. Such data now exist and are currently being integrated into the MCNP and MCNPX transport codes. A developmental code version, based upon MCNP4B, includes photonuclear physics. Verification of the new capability is nearly complete and validation is commencing.

Photonuclear Data

Past History

Until very recently, photonuclear data has existed as a patch-work of experimental measurements. These measurements typically focused on integral neutron production or total photoneutron cross section to the exclusion of other reactions. They also rarely included energy or angular emission spectra. It was therefore necessary to make numerous assumptions when trying to use these data for transport simulations.

Current Evaluations

The International Atomic Energy Agency (IAEA) convened a Research Coordination Project (CRP) on “Compilation and Evaluation of Photonuclear Data for Applications” in December of 1996. Photonuclear data by its definition being nuclear and thus isotopic in nature is being compiled separately from traditional elemental photoatomic data. The group intends to update the EXFOR library of experimental data, and to release a library of evaluated data files covering the major isotopes of structural, shielding, activation analysis, fission, transmutation, astrophysics and biological importance. That library is due to be finished at the end of this year and will be released as ENDF-6 formatted files containing complete information, i.e. double differential cross sections, suitable for use in transport calculations. In coordination with the CRP the Nuclear Theory and Applications group (T-2) of the Los Alamos National Laboratory (LANL) is producing a series of photonuclear evaluations as a subset of the Accelerator Production of Tritium (APT) project’s LA150 nuclear data library for neutron, proton and photonuclear data up to 150 MeV incident particle energy. Preliminary data from LANL and from other participants in the CRP have been made available for the purpose of developing the necessary routines for inclusion into the MCNP code family.

MCNP Modifications

Input Parameters

The first step in using the new photonuclear data is to be able to specify it within a material definition. There already exists an input material card and it was simply extended to recognize the new class of data, i.e. photonuclear. The card consists of isotope/atom fraction pairs to define the material. An interesting new option was added due to the lack of data for all isotopes. Isotopic substitution can be made via entries on a secondary material card, e.g. each component of elemental tungsten can be specified on the material card but then each isotope can be made to refer to ^{184}W for photonuclear calculations or to refer to no table at all. In this manner, the best available data can be used for neutron transport without having to provide complete corresponding photonuclear data.
Once the data is input, photonuclear physics has to be turned on. The current default is off due to the small influence of photonuclear for most problems and the unavailability of data. This could change such that the default would be to model photonuclear physics using whatever data were available. For problems where photonuclear interactions are important, collisional biasing is available.

Physics Routines

Photonuclear physics was implemented as a statistical based process. The total photon cross-section, photoatomic plus photonuclear, is used to determine the distance to the next photon collision. In analog mode, the collision is then sampled as being either photonuclear or photoatomic. If the collision is photoatomic, the traditional photon collision routine is used. Biased collisions split the particle, adjusting the weight of the two new particles by the ratio of the event probability and handing them to the appropriate routine. For photonuclear events, the routine then chooses the collision isotope from the separately maintained photonuclear list. An integer number of secondary particles (neutrons and photons for MCNP; neutrons, photons, and isotopes of H and He for MCNPX) is then sampled based on the ratio of the particle production cross-sections to the total. The number of particles to be sampled can be biased similar to electron physics. The emission parameters for each particle are then sampled independently from the reaction laws provided in the photonuclear data. Tallies and summaries are appropriately updated, variance reduction games are performed and the emitted particle is banked for further transport.

Output Information

Appropriate summary information has been added to the output file to reflect photonuclear contributions. Tally information remains as always with the addition of neutron and photon contributions from photonuclear events. Photonuclear absorption of photons and photon/neutron production has been added to the particle summary tables. Print Table 130 “Weight Balance By Cell” and Print Table 140 “Nuclide Activity By Cell” have similarly been updated to reflect the photonuclear interactions.

Verification/Validation Efforts

At this time, verification of all implemented options has been performed. This includes testing of input options; verification of total photon cross section and distance to collision algorithms; verification of collisional biasing; and verification of emission sampling algorithms. Validation of the new physics routines will be performed via comparison against integral measurements reported within the literature. ##Author’s note: these comparisons are in progress and will be ready to report by the paper submission deadline. ##

Conclusion

With the addition of photonuclear physics, MCNP(X) is now a fully coupled neutron-photon(-electron) Monte Carlo radiation transport code. This capability will improve the ability to simulate a variety of problems including accelerator shielding, dosimetry calculations and photon induced transmutation. This capability has been added to a developmental version of MCNP4B and will eventually be integrated into the release versions of MCNP and MCNPX.