Double Differential Neutron Production Cross Sections for HZE Collisions Using Wallace's Method

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The analytical abrasion (knockout)-ablation model capable of making quantitative predictions of the neutron and light ion spectra from high-energy heavy-ion (HZE) collisions is widely used in the characterization of neutron transport and further assessment of radiation damage to the space craft and the crew members during long duration space missions. The abrasion formulation of the current model is based on the Glauber’s multiple scattering theory, which is derived using the Eikonal approximations. The Eikonal approximations in the Glauber’s model are developed using the small angle approximation, where the scattering is considered strictly in forward direction, in the plane of the incident momentum. However, neutron and light ion transport is inherently a three-dimensional problem and therefore requires nuclear models capable of generating double differential cross sections, both energy and angle, for use in the transport codes. Further, validity of Glauber’s small angle approximations for three or more particles in the final state after interactions is not clear. This study relaxes the small angle approximation in the development of abrasion-ablation model by adding higher order correction terms to the phase functions based on the formulations by Wallace. Wallace develops corrections terms to the phase function by using expansion of the Legendre Polynomials in the formulation of scattering amplitude, thus creating an infinite series where the leading order term is same as the Glauber’s model and the higher order terms are correction terms. In the present work, we have derived four higher order correction terms to the phase function using similar approach. The optical potential used in the calculation of the phase functions was reformulated using Gaussian approximations to the nuclear single particle densities. The neutron momentum distributions in the derivation of double differential cross sections were calculated using three term Gaussian model by Haines and Fujita. A comparison of double differential cross sections to evaluate the contributions of correction terms and also their stability at different energy range has been done. The double differential cross sections calculated using present model, with higher order correction terms, are compared to the published data from accelerator studies.