Test of weak and strong factorization

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Abstract

Radiation risk assessment of personnel on long-term space missions requires the knowledge of organ (or tissue equivalent) doses in critical radiosensitive organs. It is therefore essential to perform careful measurements of the radiation exposure of the space crew, to investigate the shielding material efficiency and to certify that it is possible to simulate the radiation environment, both inside and outside a space vehicle. Because of the impracticality/impossibility of measuring radiation fields inside critical internal body organs or biological test specimens exposed to Galactic Cosmic Rays (GCRs) and Solar Particle Events (SPEs), there is a need for developing transport models, which can calculate the observables of interest for estimating the biological effects with certain accuracy. Essential for these transport models are adequate and reliable nuclear databases, especially for the reactions of high-energy heavy-charged (HZE) particles, which are the major contributors to the effective dose in space.

Over the years the theoretical description of nuclear fragmentation in heavy ion collisions has relied upon “abrasion-ablation” models and factorization of projectile fragment cross sections. For nuclear fragmentation cross sections, the concepts of “weak” and “strong” factorization have been developed. Weak factorization is predicted by the “abrasion-ablation” model and therefore considered valid, while strong factorization is believed to be violated to such extent so as not to be a useful concept. Weak factorization predicts that the projectile fragmentation cross-sections for the production of a given fragment from a given projectile in collisions with different targets differ only by a factor that is independent on the fragment species. Several semi-empirical models for calculating projectile fragmentation cross sections in the energy region 0.1 – 1.0 GeV/nucleon therefore rely on scaling procedures based on the weak factorization property.

However, this property is believed to hold consistently only for intermediate-mass fragments; the semi-empirical scaling procedures have therefore added several correction terms to get agreement with the measured cross sections. This “ad hoc” approach, albeit efficient in some cases, is unsatisfactory from a scientific point of view, and might break down if applied to more general conditions; the foundations of the abrasion-ablation theory should be systematically tested to decide whether this model can be successfully used for prediction or if it needs to be substituted for a more complex and articulate alternative.

In this paper, we present methods of testing both the weak and the strong factorization and discuss the importance of these tests for the validity of the abrasion-ablation model and the development of reliable and accurate nuclear databases used to simulate the radiation environment in space. Evaluation of these tests over experimental data is currently in progress and the final results will be published elsewhere.