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How Space Radiation Risk from Galactic Cosmic Rays at the International Space Station Relates to Nuclear Cross Sections

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Space radiation risk to astronauts is a major obstacle for long term human space explorations. Space radiation transport codes have thus been developed to evaluate radiation effects at the International Space Station (ISS) and in missions to the Moon or Mars. We study how nuclear fragmentation processes in such radiation transport affect predictions on the radiation risk from galactic cosmic rays. Taking into account effects of the geomagnetic field on the cosmic ray spectra, we investigate the effects of fragmentation cross sections at different energies on the radiation risk (represented by dose-equivalent) from galactic cosmic rays behind typical spacecraft materials. These results tell us how the radiation risk at the ISS is related to nuclear cross sections at different energies, and consequently how to most efficiently reduce the physical uncertainty in our predictions on the radiation risk at the ISS.

1. Introduction

Space radiation to astronauts is a major hazard for long-duration human space explorations. Two major sources of space radiation are the galactic cosmic rays (GCR) and solar energetic particles (SEP). GCR are ever-present and more energetic, thus they are able to penetrate much thicker materials than SEP. In order to evaluate the space radiation risk and design the spacecraft and habitat for better radiation protection, space radiation transport codes, which depends on the input physics of nuclear interactions, have been developed. Both ground-based and airborne experiments have been and will be used to improve the theoretical modeling of nuclear fragmentations as a function of energy and thus improve the accuracy of these transport codes. This study focus on the propagation of space radiation particles in materials, and the deterministic code HZETRN [1] is used in this study. A detailed sensitivity analysis to energy in deep-space GCR environments can be found in Ref. [2]. At the International Space Station, however, the geomagnetic field from the Earth affects the flux of charged particles at different energies differently. Fig. 1 shows the geomagnetic transmission function at the ISS (including the shadowing effect from the Earth) as a function of magnetic rigidity, while in deep space the function is unity by definition as there are no geomagnetic or shadowing effects. Therefore we expect different sensitivities to the energy in fragmentation cross sections, and these results tell us at what energies nuclear fragmentation most affects the GCR radiation risk at the ISS.

2. Results

A cross section as a function of energy is represented by its values at the following 18 discrete energy points E_i ($i = 1 - 18$) (equally separated logarithmically by a factor of $\sqrt{2}$): 0.053, 0.075, 0.106, 0.15, 0.212, 0.3, 0.424, 0.6, 0.849, 1.2, 1.697, 2.4, 3.394, 4.8, 6.788, 9.6, 13.58, and 19.2 GeV/u. For collisions at energies below E_1 (or above E_{18}), the cross section is taken to be the same as that at the energy E_1 (or at E_{18}), while an interpolated cross section is used for collisions at energies between two adjacent energies. In order to study the sensitivity to cross sections at energy E , we change the values of cross sections at E_i ($i = 2 - 17$), including all partial cross sections for all projectiles, by the same percentage Δ , while cross sections at all other energy points are unchanged. The total inelastic cross sections for all projectiles at this energy E_i also need to be increased