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Simulations of proton beam propagation in matter using entropic moment method

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Simulations of proton beam propagation in matter using entropic moment method

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Synopsis Atomic interactions of ions with the penetrated medium lead to a strong evolution of ion charge-state fractions as a function of the target thickness. In this paper, we present a fast and accurate method in order to simulate the slowing-down of ions in matter. Our model relies on the averaging of the transport equation leading to fast simulations of the deposited dose by particles beam. Simulations have been performed for the case of proton beams propagating through water. Results have been compared with Monte Carlo simulations.

Quantitative information on the penetration of charged ions through matter, in particular the energy loss, is of considerable interest in basic science, in medicine and in technology, and therefore has been studied through various methods [1]. Until the middle of the past century, studies of charged-particle penetration were stimulated almost exclusively by the needs of fundamental physics research, but applications in other areas gradually became important. Simulations of slowing-down of ion beams in thick targets aims at characterizing the spatial and energy distributions of incident particles and secondary fragments in matter. In particular, biological effects are due to energy deposition, which may be accurately calculated with Monte Carlo codes, but these are limited by the amount of needed statistics. Moreover, solving directly the system of linear transport equations for the motion of particles is computational time consuming, and thus nowadays incompatible with practical applications.

To overcome this limitation, a new code has been developed at CELIA [2]. This code resolves the linear Boltzmann equation using moment method. It consists in averaging the distribution function over the angles to obtain these moments. An entropy minimization theorem is used as closure relation for superior moments (M_2). Also, the M_1 model has been established. The equation system also obtained has been discretized by using a relaxation scheme [3]. This code is validated and exploited for electron and photon transport [2].

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Our objective is to extend it for heavy ion transport. For this paper, we focus on proton beams in matter. One of the difficulties of this study is to determine the stopping power of ions in any matter. By using theoretically-calculated cross sections for proton-matter interaction processes, we determine stopping power and dose, as well as properties such Bragg peak. This one is in good agreement with Monte Carlo simulations. Many test-case results will be presented in comparison with FLUKA [4], for 1D to 3D cases (see *e.g.* Fig. 1).

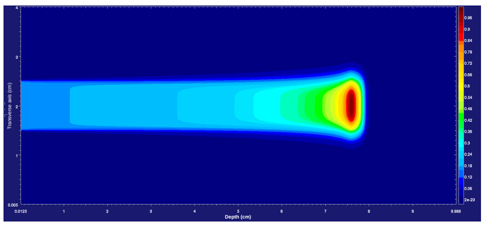

Figure 1. Deposited dose in water by 100 MeV protons, for a 2D simulation. Results are normalized to the maximum value.

The treatment of the physical processes required in the case of heavy ions (helium and carbon ions) is underway.

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