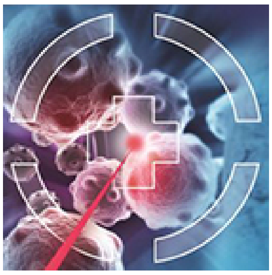

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PENH, an extension of PENELOPE code which includes proton induced nuclear reactions

PENH was initially developed as the extension of PENENELOPE (a code system for Monte Carlo simulation of electron and photon transport), which incorporated the electromagnetic transport of protons aiming to its application to protontherapy. Nevertheless, the absence of nuclear interactions prevented the accurate estimation of the dose deposition along the beam axis in protontherapy treatments, specially at the high energy entrance region of the beam, where the nuclear contribution is mostly concentrated. The inclusion of such effects has been recently accomplished by means of the use of evaluated nuclear data libraries in ENDF format, which are directly accessed by the code and used for the sampling of multiplicities and double differential cross sections of secondary particles. Among the later, light fragments (up to alphas) are transported as "equivalent protons" (with energies scaled to reproduce the range of the true particles and weight, which guarantees energy conservation) whereas the slower and more ionizing fragments (which include secondaries heavier than alphas and recoiling residual target nuclei) deposit their energy locally. Elastic scattering of protons is treated within an unified formalism which includes consistently the Coulomb and nuclear contributions. Cross-checks with Geant4 calculations using the same sets of evaluated data show excelent agreement

The Monte Carlo simulation of the production of beta+ emitters by a proton beam has recently atracted mayor interest, since the detection of the subsequent gamma rays allows the prediction of its range. It is a well known fact that the theoretical models implemented in the present day Monte Carlo codes are not capable of reproducing the experimental data on isotope production in this enery range and it's not foreseeable that they will be in the near future. Therefore, to get realistic estimations of the isototope production cross sections is a must for such calculations. Nevertheless different evaluated nuclear data libraries show noticeable discrepancies and the experimental data are usually scarce and/or do not cover te entire energy range of interest (experimental campaigns are under way to remedy it). Calculations with PENH have been performed with evaluated data extracted from the same libraries used for proton transportation and the available experimental data after interpolation. Also in this case, comparisons with Geant4 calculations on isotope production along the proton beam path in organic material at protontheray energies show excellent agreement. In particular, when experimental cross sections are provided, the agreement on the isotope production along the beam trajectory is also remarkable, which paves the way for the use of PENH in protontherapy treatment planning and verification.

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