Contribution ID: **30** Type: **not specified**

Accurate Monte Carlo modeling of biomedical cyclotrons: optimization of FLUKA physics and transport parameters for dosimetry, shielding and activation calculations

Thursday, 4 December 2014 15:00 (30 minutes)

Knowledge of the radiation field around biomedical cyclotrons is necessary for the design of shieldings, the classification of areas and the protection of the workers, the public and the environment. In recent years, Monte Carlo simulations have been used to create models able to predict, with good approximation, the radiation field around these accelerators. Since the complexity of the physical phenomena involved in the transport of radiation, the validation of these models with experimental measurements is necessary to be able to predict accurate results. The availability of Monte Carlo (MC) codes with up to date and accurate libraries for transport and interactions of neutrons and charged particles at energies below 250 MeV, as well as continuously increasing power of recent computers, allow the systematic use of simulations with realistic geometries in order to obtain equipment and site specific evaluation of the source terms, shielding requirements and othe!
r quantities relevant to radiation protection. In this work FLUKA has been used in order to model two types of cyclotron for Positron Emission Tomography (PET) radionuclides production, the General Electric PETrace (16.5 MeV) and ACSI TR19 (19 MeV), including their targetry, and one type of proton therapy cyclotron, the Varian/Accel 250isc, including the energy selection system. Simulations allow for estimation of several relevant quantities, like the effective dose distribution around the equipment; the effective number of neutron produced per incident proton and neutron spectral distribution; the activation of the structure of the cyclotron, the energy degrader and the vault walls; the activation of the ambient air, in particular for the production of 41Ar; alternative mixtures of shielding materials have been simulated and tested. Moreover, Monte Carlo simulations have been extensively used to study the feasibility of the direct cyclotron production of non-standard radio!
nuclides such as 89Zr and 99mTc through, respectively, the 89Y!
(p,n)89Z
r and the 100Mo(p,2n)99mTc reactions. Monte Carlo simulations have been validated against experimental measurements. Particular emphasis has been given to the choice of physics and transport parameters that allow to obtain results in agreement with the experimental measurements. Furthermore, critical aspects and problems encountered during the modelling will be discussed as well as the solutions that have been found.

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