

CHEMNITZ-1: Spectral properties of neutron beams available at FRM II for use in BNCT

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With an undisturbed thermal flux of $8 \cdot 10^{14}$ n/cm²·s, the neutron source FRM II provides neutrons for science, industry and medical applications. Thereby, it facilitates different secondary sources to cover a wide energy range from cold over hot to fission neutrons. The hot neutrons are generated by interaction of thermalized neutrons with a graphite block heated to 2000 K. They are guided by a beam tube to a monochromator that can be chosen from either copper or silicon and subsequently to the irradiation position. The fast fission neutrons are generated via fission of ²³⁵U in a subcritical assembly consisting of two so-called converter plates. A beam tube guides these neutrons to a filter bank, adjusting the spectrum used for irradiation by a reduction of gamma radiation and a suppression of the thermal beam component and subsequently to the irradiation position of the patient. Currently, this beam is used for the treatment of patients via direct irradiation with fast fission neutrons.

As the mean neutron energy provided by the hot source amounts to 170 meV, FRM II's converter facility is better suited to facilitate the energy range utilized for BNCT in the treatment of deep-seated tumors. The conversion of the fast fission spectrum into an epithermal spectrum is thereby subject of the current investigations. All related simulations use Serpent 2, a Monte Carlo particle transport code developed at VTT Technical Research Center in Finland.

In this early stage model, the targeted object is a spherical structure with a diameter of 30 mm representing the tumor. It is placed in different depths of a cubic volume with an edge length of 400 mm consisting of A-150 tissue equivalent plastics representing the surrounding body. This simplified phantom is placed at the irradiation position at a distance of 5500 mm from the converter plates. In order to shift the energy distribution of the neutrons into the epithermal range, a moderator is placed between the irradiation position and the beam tube. The boron (n,α) reaction rate is evaluated in a two-step process. Starting with a ²³⁵U fission spectrum, the neutrons pass through the moderator before reaching the simulated body and resulting in a specific energy distribution. This distribution serves as a starting neutron distribution for the second step, in which the tumor volume is consisting of ¹⁰B only with a concentration of 0.0025 wt%. The distance of the tumor from the tissue surface is varied between 5 mm to 105 mm.

As a moderator material, PTFE, PE and LiF are used. The moderator thickness is varied depending on the material from 100 to 300 mm for PTFE and LiF as well as from 20 to 50 mm for PE. Three virtual detectors acquire the neutron energy spectrum at the source, immediately behind the moderator and in the mid-plane of the tumor. The (n,α) reaction rates at the latter position are compared for the unmoderated case and the different moderating materials. In addition, boron (n,α) reaction rates are also calculated for different depths of the tumor based on the spectrum of the hot neutron source and the geometrical outline of its irradiation position.

Future calculations will introduce several modifications to both, the model and the evaluated parameters. For the model, the fast neutron spectrum generated in the converter plates will be specified by using a full-core reactor model also taking all installations and secondary sources into account. The influence of the beam shaping collimator situated between the converter plates and the patient will also be part of this advanced model. The evaluated parameters will then also include the superficial neutron dose of the skin as well as the photon dose.