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Optimization of the beam shaping assembly and local protection of the accelerator source of epithermal neutrons

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Introduction

Boron Neutron-Capture Therapy (BNCT) holds much promise for cancer treatment through the selective destruction of tumor cells which first accumulate the stable nonradioactive isotope 10B and are then irradiated by neutrons. Intense fluxes of epithermal neutrons, or neutrons with energies between 1 and 30 keV, are needed for this purpose. The best way of generating such neutrons is the reaction 7Li(p, n)7Be that yields a quite large number of neutrons with the softest energy spectrum. The neutrons are moderated to required energies in a Beam Shaping Assembly (BSA) which includes a moderator, a reflector, an absorber, and, in some cases, a filter.

Materials and Methods

Proton, neutron, and gamma transport was simulated by the Monte Carlo method with the use of a PRIZMA code and the ENDF/B-VII library of data on neutron and gamma interaction with matter. Data on neutron production in the reaction 7Li(p, n)7Be and high-energy gamma production in the reaction 7Li(p, γ)8Be $\rightarrow 2\alpha$ were taken from a nuclear physics data handbook and data on the gamma-generating reaction 7Li(p, p)7(1*)Li were prepared on the basis of the EXFOR database. The BSA is described in detail in accordance with the drawings; the silo and the main elements of the accelerator are presented by simple figures with mass and composition conservation. The deep distribution of doses was calculated in the modified Snider phantom with the concentration of 10B set to be 15 ppm in healthy tissue and 52.5 ppm in tumor. The spatial dose rate distribution outside the silo was determined on a fictitious screen one meter from its wall.

Results

We considered several BSA versions which differed in size and composition. The best of them is the version with a composite moderator consisting of magnesium fluoride (closer to the target) and aluminum fluoride (closer to the outlet). The graphite reflector in the forward hemisphere helps attain much higher doses in tumors which seat at depths up to 6 cm. For deeper tumors, the dose can be increased with the use of a lead reflector. We propose employing a proton beam of energy 2.3 MeV which is close to the energy at which the reaction cross section reaches a maximum. The use of higher energy protons can only be justified for tumors which seat deeper than 7 cm. The optimized BSA is manufactured; it produces proton beams that to a great extent meet BNCT requirements. We considered several versions of local protection. It is found that the best solution is to place borated polyethylene on the inside of the silo's door. This allows us to meet the radiation safety standards and generate neutrons for a long time.

Conclusion

A BSA consisting of a moderator, a reflector, and an absorber is used to generate neutron beams for BNCT. For the first time we propose here employing a composite moderator formed by magnesium fluoride near the neutron-producing target and aluminum fluoride near the outlet along with a composite reflector with graphite in the forward hemisphere and lead in the backward hemisphere and generating neutrons via the reaction 7Li(p, n)7Be induced by 2.3-MeV protons. Through numerical simulation of neutron and gamma transport we have shown that the proposed solutions make it possible to shape a therapeutic neutron beam which to a great extent meets BNCT requirements.

Keyword: BNCT, BSA

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PGNAA facility at RA-3: numerical approach towards first measurements of biological samples for BNCT

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