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October 11-15, 2004

Eleventh World Congress on Neutron Capture Therapy
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Eleventh World Congress on Neutron Capture Therapy

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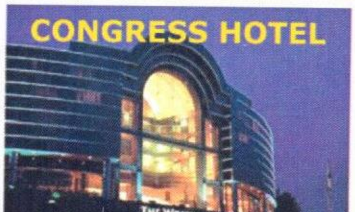

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Parallel Session 2 - Nuclear Engineering and Physics

Conclusion: The results obtained in this benchmark experiment indicate that we can validate the accuracy of the calculation of the neutron energy spectrum passing through the moderator and the thermalization in a phantom. As the next step to realize the BNCT at CYRIC, we have a plan to measure the absorbed dose distribution in a phantom with the same experimental arrangement, and perform the mock-up experiment by fabricating an irradiation assembly for BNCT which includes the cooling system for the neutron-producing target.

4:15 PM -

Optimization of an accelerator-based epithermal neutron source for neutron capture therapy.

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Abstract: A beam shaping assembly optimization for epithermal neutron beam production on accelerator based facility for neutron capture therapy are presented. Optimization objective is to cerate neutron beam with required for BNCT energy and intensity. Results of calculation were experimentally tested and are in good agreement with measurements.

Materials and methods: For last ten years active discussed and investigated problem of neutron source creation for neutron capture therapy based on non-expansive proton accelerator with beam energy 2-3 MeV and power 10-20 kW, which is possible to install in oncology clinics. In this paper presented investigation on chousing optimal moderator material, its size optimization, calculation and measurement epithermal neutron beam characteristics on an output port of moderator assembly. Main investigations were carried out for initial proton energy 2.3, 2.4, 2.8 MeV. Maximum neutron energy in this case is 0.6-1 MeV and total calculated neutron yield 6,3_1012, 8,1_1012 _ 1,37_1013 neutron per second for beam current 10 mA. Neutrons and gamma rays transport were calculated by using Monte Carlo computer codes S-95NCT and MCNP. As criteria for chousing material and optimum moderator size was taken 2 parameters - fepi – epithermal neutron leakage flux density (neutron energy more then 1 eV) from sphere surface for proton current 10 mA and - neutron and gamma rays dose rate in tissue per one epithermal neutron.

Results: Presented results obtained in investigations for mostly prospective moderators – heavy water, magnesium fluorine, polytetrafluoroethylene and Fluental®. Shown, that the best characteristics for epithermal neutron beam creation has magnesium fluorine. Optimized magnesium fluorine moderator thickness is 20 cm. More detail epithermal neutron beam characteristic was derived in calculation in-phantom absorbed dose distribution. In terms of absorbed dose distribution rate value in tumor/healthy tissue beam shaping assembly from magnesium fluorine in 1.25 times more effective then polytetrafluoroethylene and 1.8 times then Fluental®. For direct verification computer modeling was performed thermal neutron flux measurements inside water phantom. Thermal neutron beam flux measurement was performed by gold foil activation method. Calculation results and experimental measurements are in good agreement.

Conclusion: By calculation in-phantom dose distribution shown, that with such moderator, 2.3 MeV and 10 mA proton beam advanced depth is 9 cm, therapeutic ratio on depth 3 cm is 6, advanced depth dose rate on depth 9 cm is ~1 RBE Gy per minute, which means that maximum treatment time will be about 10 minutes.

4:35 PM -

A shielding design for an accelerator-based neutron source for boron neutron capture therapy.

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Research in boron neutron capture therapy(BNCT) at The Ohio State UniversityNuclear Engineering Department has been primarilyfocused on delivering a high qualityneutron field for use in BNCT using an accelerator-based neutron source (ABNS). An ABNS for BNCT is composed of a proton accelerator, a high-energybeam transport system, a 7Li target, a target heat removal system (HRS), a moderator assembly, and a treatment room. The intent of this paper is to demonstrate the advantages of a shielded moderator assemblydesign, in terms of material requirements necessaryto adequatelyprotect radiation personnel located outside a treatment room for BNCT, over an unshielded moderator assemblydesign.

4:55 PM -

An optimized neutron-beam shaping assembly for accelerator-based BNCT.

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Introduction: An easy to build and relatively cheap beam shaping assembly is studied here through an extensive MCNP investigation. The solution proposed consists of successive stacks of Al, polytetrafluoroethylene (PTFE) and LiF as moderator and neutron absorber, and Pb as reflector. The 7Li(p,n)7Be reaction and proton bombarding energies of 1.92, 2.0, 2.3 and 2.5 MeV have been considered for three moderator thicknesses (18, 26 and 34 cm).

Materials and Methods: In the geometry of the simulations, a whole-body phantom (with Snyder's head model) was considered. The doses were evaluated within the head phantom along its centerline. A 71.6 cm diameter lead reflector and a 15 cm diameter Al/PTFE/LiF moderator were considered. Also, a thermal neutron shield was placed at the exit of the moderator and reflector. A 10B concentration of 40 ppm in tumor and 11.4 ppm in healthy tissue were adopted. The treatment times were calculated assuming a 20 mA proton beam. In a second instance, the effect of the specific skin radiosensitivity and its 10B uptake were considered for the scalp. The dose assessment was performed through the calculation of Tumor Control Probabilities (TCP).

Results: The TCP curve is a function of the total tumor RBE-dose. Here, we translated the total tumor RBE-dose axis into a maximum total healthy tissue RBE-dose axis from our simulated results. From these TCP curves it is possible to evaluate the treatment capability for a particular beam shaping assembly knowing the maximum dose delivered to the healthy tissue and the treatment time. Figures of merit showing the maximum healthy tissue dose and treatment times (for a 98% TCP) were plotted for various beam shaping assemblies (in both cases, with and without the specific characteristics of the scalp).

Discussion: For 1.92 MeV protons, the maximum healthy tissue doses are the lowest for most of the positions in the brain, but the treatment times are excessively long. For the 2.0 MeV case, the maximum healthy tissue doses for relatively deep tumors stay below 12.5 RBE-Gy but with treatment times from one to about seven hours. For the resonance case (2.3 MeV) several points stay under the 12.5 RBEGy line and the shortest treatment times are near an hour. At 2.5 MeV, the best performance corresponds to the 34 cm moderator and treatment times less than 45 minutes (for tumors almost as deep as 5 cm). When the specific radiosensitivity and 10B uptake of the skin are assigned to the scalp the figures of merit show drastic changes. Nevertheless, some useful points remain under the 12.5 RBE-Gy limit (particularly for 2.3 MeV protons) and the treatment times are still reasonable (between 40 and 60 minutes).

Conclusions: The MCNP simulations show an acceptable behavior of Al/PTFE/LiF and Pb as beam-shaping assembly. They also show the advantage of irradiating the target with near-resonance-energy protons (2.3 MeV) because of the high neutron yield at this energy and yet sufficiently small fast neutron production, leading to lowest treatment times.

5:15 PM -

Lithium neutron producing target for BINP accelerator-based neutron source.

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The Budker Institute of Nuclear Physics and the Institute of Physics and Power Engineering, Obninsk, have proposed an accelerator based neutron source for neutron capture and fast neutron therapy at hospital. Innovative approach is based upon tandem electrostatic accelerator with vacuum insulation and near threshold neutron generation. Pilot facility is under construction now at the BINP. One of the main elements of the facility is lithium target, that produces neutrons via threshold 7Li(p,n)7Be reaction at 25 kW proton beam with energies 1.915 MeV or 2.5 MeV.
In the present report, results of experiments and simulations on neutron producing target prototype are presented, choice of target for the source under construction is substantiated, the necessary experiments are shown, and the conception of the target is presented.
The first model of neutron producing stationary target was tested under 20 kW electron beam. This target consisted of 0.2 mm thick molybdenum foil, that diffusely welded on an ARMCO steel disk. Ten rectangular grooves were on the disk for cooling by water

Parallel Session 2 - Nuclear Engineering and Physics

or liquid gallium. In the process of examination, heat removal up to 650 W cm–2 was provided using water, and liquid metal cooling resulted in the target destruction due to high chemical interaction of gallium with ARMCO steel.

A new target prototype was made consisting of tungsten disk 80 mm in diameter, 3 mm thick with thirteen cooling rectangular channels, pressed to titanium body without diffuse welding. Laborious diffuse welding was refused, which allowed to obtain more homogeneous temperature field on the surface of the target. Hydraulic resistance for heat carrier flow in the target and lithium layer temperature are calculated. Experiments are planned for the near future to study hydraulic and thermal regimes of target prototype. It is clear now that using water is possible for cooling of this target. This allows to refuse using gallium for cooling the target, therefore not to solve the problems of corrosion of target material and pump, arising from gallium influence.

Neutron producing target for the neutron source under construction is proposed to correspond to the existing prototype with the following fundamental modifications: i) target diameter is to be increased up to 10 cm for 25 kW proton beam, ii) it will be cooled with water only, iii) to provide efficient cooling at minimal water consumption, the target channels are to be spiral, iv) lithium layer is to be evaporated immediately in the target unit. Calculation showed that the lithium target could run up to 10 mA proton beam before melting. The material for proton beam absorber is to be determined after planned experiments on radiation blistering at the existing target prototype under available pulse proton beam. Diagnostic equipment provides detecting a-particles inside the vacuum chamber close to the target and detecting neutrons and g-rays outside. Other promising types of neutron producing target are also under development.

Manufacturing the neutron producing target up to the end of 2004 and obtaining a neutron beam on BINP accelerator based neutron source are planned during 2005.