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

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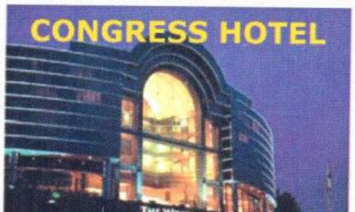

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Posters Session - Physics

1 - Monte-Carlo calculations for the development of a BNCT neutron source at the Kyiv Research Reactor.

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The results presented in this paper display our continuing steps toward development of a neutron source with parameters required by Boron Neutron Capture Therapy(BNCT) at the Kyiv Research Reactor (KRR). The purpose of this work was:

1) calculation of the neutron flux which can be achieved at the greatest possible approach of a patient to the reactor core (380 cm from the core center);
2) analysis of the influence of a nickel collimator and a nickel-60 filter on the characteristics of the neutron beam;
3) creation and validation of the MCNP calculational pattern for an actual core load in the KRR.

Results of calculations were carried out by means of the MCNP4C code included:

1) An epithermal neutron flux of 3e+9 to 5e+9 neutron/cm^2/s with an epithermal-to-fast flux ratio of 80 to 230 could be obtained at the KRR, using a natural nickel layer on the interior borated polyethylene collimator wall and a nickel-60 filter.
2) Use of the nickel-60 filter may be useful to increase the ratio epithermal-to-fast flux without a substantial decrease in the magnitude of the epithermal neutron flux.
3) The MCNP model proposed in this paper could also be useful for reactor safety calculations.

3 - Characteristics of BDE dependent on ^{10}B concentration for accelerator-based BNCT using near-threshold ^{7}Li(p,n)^{7}Be direct neutrons.

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Introduction: Intra-operative boron neutron capture therapy (BNCT) conducted in Japan has the advantages of (1) high dose delivery to deeper regions and (2) the possibility to be performed together with the procedure to debulk the tumor in one surgical operation if accelerator-based irradiation systems are installed at hospitals. In order to realize compact irradiation systems with flexible irradiation directions suitable for it, we have revealed the feasibility of intra-operative BNCT using direct neutrons from the 7Li(p,n)7Be reaction near its threshold (1.881 MeV) . The judging parameter was the size of the region satisfying the dose requirements in protocol (treatable region), for Japanese intra-operative BNCT of brain tumors. Then, the boron-dose enhancer (BDE) has been introduced to increase the contribution of the 10B(n,a)7Li dose. The treatable protocol depth (TPD), which is the greatest depth of the treatable region usually on its centerline of the irradiation field, was introduced as a possible index for BDE materials based on ease and simplicity in comparing physical characteristics of irradiation fields. However, the 10B concentration is different for each irradiation at present due to the differences of patient physiology and amount induced, etc. In this study, the characteristics of the BDE are identified as to the dependence of polyethylene BDE thickness on the 10B concentration using TPD as an evaluation index.

Materials & Method: The production of neutrons and gamma rays in the Li target was simulated with Lee's method and their transport was calculated using MCNP-4B. These methods were validated through phantom experiments considering angular dependences. Doses in a cylindrical water phantom of 18 cm in diameter and 20 cm in length were computed for the proton energy of 1.900 MeV. BDE was assumed to be polyethylene cylinders of 18 cm in diameter. The present dose protocol for intra-operative BNCT for brain tumors in Japan are specified in terms of the treatable dose for tumor due to HCP (15Gy), the tolerance dose for normal tissue due to HCP (15Gy) and the tolerance dose for normal tissue due to gamma rays (10Gy). The doses are evaluated as physical absorbed dose. TPD for above mentioned dose protocol was evaluated for 10BTumor values of 10 ppm to 100 ppm and the 10BTumor to 10BNormal ratio (T/N ratio) of 2 to 10.

Results & Conclusions: The TPD was increased by increasing T/N ratio, and by increasing 10BTumor and 10BNormal for constant T/N ratio. In the case where the achievable range of T/N ratio is the same, an increase in 10BTumor has the advantage over a decrease in 10BNormal that the TPD is increased more effectively. However, the BDE thickness (BDE(TPDmax)) for the maximum TPD (TPDmax) is influenced more rapidly, which means that the fluctuation of 10BTumor causes more deviation on BDE(TPDmax). As the achievable 10BTumor increases over a certain level, BDE(TPDmax) becomes zero. This demonstrates the effectiveness of the compact irradiation system without BDE and the feasibility of its use in BNCT.

5 - Dose-rate scaling factor estimation of THOR BNCT test beam.

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Introduction: A test beam was build at Tsing Hua Open-pool Reactor (THOR) for BNCT preliminary experiments since 1998 and a new beam was designed and was under construction for further clinical trials. Dose rate scaling factor (DRSF) is defined as the measured dose rates in a physical phantom divided by the treatment planning computed dose rates in a corresponding phantom. Because the differences between measured and computed dose rate results are always exist, DRSF relates to modify computed dose rates to approach measured dose rates. As the value of DRSFs are estimated and input in the BNCT treatment planning: NCTPlan, the computed dose distributions will represent the irradiated dose rate distributions that a phantom or a patient really received.

Materials and Methods: Neutron activation analysis and dual ion chamber techniques were choosed to measure and analyze the depth dose rate distributions of THOR BNCT test beam. Structured gamma and neutron spectra at the test beam exit were applied as the reactor source in the treatment planning code. Depth dose rate distributions of all dose components, thermal neutron, fast neutron, photon and boron-10, of THOR BNCT test beam were measured and analyzed by means of relevant instruments and techniques. A new PC version, Monte-Carlo based, treatment planning code: NCTPlan, developed by the BNCT medical physics group of Beth Israel Deaconess Medical Center (BIDMC) and a Snyder head phantom were applied to compute and assess the dose rate distributions of THOR BNCT test beam in this work. Dosimetric experiments were performed under 1.5MW reactor power condition, and the Snyder head phantom was located at the front of exit point of THOR BNCT test beam. Boron-10 concentrations considered in tumor and normal tissue preset as 30 ppm and 7.5 ppm respectively.

Results and Discussion: Depth dose rate distributions of thermal neutron, fast neutron, photon, boron-10 in tumor, boron ¡V10 in normal tissue, tumor total dose and normal tissue total dose were measured and represented respectively. Maximum tumor total dose rate occurs at about 2 cm depth. Values of DRSFs were estimated: 0.55 for thermal neutron, 2.88 for fast neutron, 0.86 for photon, 0.57 for boron-10 (normal) and 0.56 for boron-10 (tumor). Weighted NCTPlan (NCTPlan*DRSF) computed dose rates were matched with measured results very well (less than 1 % difference) for thermal neutron, fast neutron and boron both in tumor and normal tissue. For fast neutron, it has larger difference (about 13%). This may be caused by the uncertainty of the Monte Carlo reactor source file.

Conclusions: Monte Carlo based BNCT treatment planning is a convenient tool for computing the therapeutic dose distributions. Accuracy of treatment planning is very important for radiotherapy. Estimation of DRSF is a necessary and important work for any reactor beam running BNCT. The techniques and experiences performed in this work will continually improved and applied in the next tests and trials of THOR BNCT new beam in later 2004.

7 - Tape high power neutron producing target for NCT.

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Solid lithium targets with intense liquid cooling are used now for accelerator based boron neutron capture therapy. Typical power of available proton beam is within 5 kW, the one of the accelerators under construction – 25 kW. New approach in target conception is needed for more high power proton beam developed for decrease of treatment time. Innovative lithium target for more high power proton beams is proposed. Main idea is based on energy accumulation at movable tape. The target is made of flexible carbon fiber tape. Its moving device relative to charged particle beam directed to the target contains tape transport mechanism with magazines for tape introduction and receiving with winding drums. This tape can be made by coating the layer of neutron producing matter (hydride, nitride, oxide or fluoride of lithium) on the substrate. The active matter layer can be covered by protective film, of lithium oxide, for example to prevent from mechanical damage. To improve the heat removal from the operating part the substrate can be made of the substance with high thermal conductivity, of aluminum, for instance. In case if coefficient of thermal expansion of active material and substrate matter are different the active material can be put on substrate (tape) in

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fragments along the tape with their length comparable with the tape width. The patent was received for this target.

9 - Development of equipments for determination of BNCT source spectral parameters.

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The knowledge of neutron and gamma ray energy spectra can strongly influence the BNCT information about delivered dose to target volume as well as to the surface healthy tissue region. This region is very often decisive to keep assessed healthy tissue limit. Modification of neutron Bonner spectrometer to one block i.e. Bonner Spectrometer Monoblock (BSM) and gamma ray Si semiconductor spectrometer are being developed and verified in real conditions of LVR-15 reactor beam for these purposes. BSM consists of polyethylene (PE) block with Cd and PE with boron shielding. Seven detectors of thermal neutrons (DTN) are inserted in seven measuring channels with different thickness of PE for on-line measurement in geometry of scattered beam. A special insertion with set of foils is used for irradiation in the direct beam. Designed Bonner Spectrometer Monoblock (BSM) is presented in paper as Fig.1.

Gamma radiation spectrometer dosimeter SPEDOG was chosen as a base for development of methodology for scattered gamma ray beam measurement. Silicon detector is sensitive, less then 10+ 4 counts/s is permitted input level. The principles of Compton scattering can be applied when materials with low Z (atomic number) are used as scattering sample. Thin layer of aluminum can be used for these purposes.

The first test measurements for development of spectrometers were implemented in NRI in conditions of known, standard spectra (NRI Laboratory of Spectrometry), as well as in conditions of reactor beam (reactor LVR-15).

Laboratory of Spectrometry: Neutron and gamma spectra escaping the surface of iron spheres of 30, 50 and 100 cm in diameter and water spheres of 30 and 50 cm in diameter were used for that test measurement. A neutron source Cf-252 with the emission of 3x10+8 n/s was positioned in the center of a sphere. Typical configuration for measurement in standard fields is shown in Fig.2. The cones, used for neutron and gamma shielding enabled to determine the background in real conditions. Different materials and thickness of cones were used: PE+B (polyethylene with boron) for neutrons, Fe-iron for gamma rays.

Reactor beam: Epithermal neutron beam was constructed on LVR-15 reactor, the facility has been used for BNCT clinical trials. Today free beam parameters are: Fepi = 7.13 x10+8 /cm2s, Ffast = 5.16x10+7 /cm2s, Dg = 1.98 Gy/h. The first test measurement for developed equipments was performed in October 2003, development will continue during 2004. The Fig.3 is showing the sensitivity of BSM readings in different spectra. In Fig.4 gamma spectra with and without scattering sample are demonstrated in group structure.

11 - The irradiation system and dose estimation joint-system for NCT wider application in Kyoto University.

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The research for neutron capture therapy (NCT) at the Kyoto University Research Reactor (KUR) is remarkably developing for the last few years. However, the most important subject is the preparations for the KUR provisional shutdown coming in March 2006. In this paper, our present concept and plan are reported about the novel irradiation system and dose estimation system for wider applications of NCT. For the irradiation field, the target nuclear reaction was selected to 7Li(p,n)7Be and the neutron moderator was selected to heavy water. The minimum proton current was about 13 mA for epi-thermal neutron irradiation, and about 9mA for mix-neutron irradiation. In thermal neutron irradiation, the proton current needed more than 18 mA for 2.5-MeV protons, but only 4 mA for 5.0-MeV protons. For the dose estimation system, we are aiming at the completion of the "dose estimation joint-system". The data from the on-line measurement systems such as beam monitors and gamma-ray telescopes are fed back to the results for the in-body dose estimation, and then the dose estimations for irradiation field and a living body are jointed. For the beam-monitor system, multi-chamber method was adopted. The surveys were performed for the wall materials and chamber-gases.

13 - Design and construction of shoulder recesses into the beam aperture shields for improved patient positioning at the FiR 1 BNCT facility.

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Introduction: At the FiR 1 BNCT facility when a patient has been positioned for a lateral irradiation field the supine position has not been applicable because of collision of shoulders and the beam aperture collar. To facilitate this situation and to improve patient comfort shoulder recesses were designed horizontally on both sides of the beam aperture.
The increase in the radiation dose to the patient's body was a concern and this was studied both by modeling with the MCNP code and by performing dose measurements before and after the modifications at the irradiation facility.

Materials and Methods: The geometrical modeling for the shoulder recesses was done using computer modeling, the treatment planning system and plastic models tested in the treatment simulator. Dose simulations were performed with MCNP using an anthropomorphic human model based on the BOMAB phantom. Measurements of the effect of the recesses to the dose distribution around the beam aperture were performed using the twin ionization chamber technique.

Results: MCNP simulations showed that the main contribution to the increase in the effective dose was from the neutron dose of the arm. Dose measurements using the twin ionization chamber technique showed that neutron dose increased on the sides as predicted by the MCNP model but there was no noticeable change in the gamma doses.

Discussion: In the design of the facility the whole body dose of the patient was estimated with a DORT model to be 0.6 Sv/h. In this work for the worst case with the arm inside the shoulder recess the estimate was 0.7 Sv/h. The increase of the effective dose to the patient's body (mainly due to the dose increase in arm) was considered acceptable, and a decision was made to construct recesses for shoulders by modifying the beam aperture.
When making the recesses into the lithium containing neutron shield material tritium contamination had to be taken into account. An underpressurised glove box was constructed and machine tools with local exhaust were used to confine the sawdust.
According to the first experiences with head and neck tumor patients the new shoulder recesses allow for more comfortable treatment position.

Conclusions: The shoulder recesses give space to more flexible patient positioning and can be considered as a significant improvement of the Finnish BNCT facility. By limiting the depth and height of the recesses the effect on the neutron shielding was minimized.

15 - A dosimetric study on the use of bolus materials for treatment of superficial tumors with BNCT.

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For treatment of superficially located tumors, such as head and neck cancers that invade the skin, the tumor dose may remain low on the skin when such tumors are treated with epithermal neutrons in boron neutron capture therapy (BNCT). When the Finnish research reactor (FiR 1) epithermal neutron beam is used, the total tumor dose on skin is approximately only 35% of the dose maximum. In conventional radiation therapy a shaped bolus has been used as a scattering material placed on top of the target to increase the surface dose. The aim of the present study was to examine the effects of bolus material for treatment of superficially located tumors with BNCT, to verify the calculated (n,g) reactions rates of Mn-55 and Au-197 and the neutron and the gamma doses in a phantom with bolus, to measure the neutron activation of the bolus materials after irradiation, and to estimate, using data from the depth dose, when it might be advantageous to use a bolus in BNCT.