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Neutron Flux Calculation in a BNCT Research Facility Implemented in IEA-R1 Reactor

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A BNCT (Boron Neutron Capture Therapy) Research facility is under construction at the IEA-R1m reactor of IPEN-CNEN-SP. Calculations have been performed aiming the determination of an initial set of moderators and filters which will provide the best neutron/gamma beam characteristic for BNCT studies. Theses calculations relies on MCNP-4C radiation transport code and the results so far obtained can be regarded as satisfactory.

I. Introduction

A BNCT research facility was projected and is under construction in IEA-R1 reactor of IPEN-CNEN-SP. It is intended to allow the development of studies in Radiation Physics and Radiobiology such as: radiation field (neutrons and gammas) characterization; dose estimation and development of "in vitro" and "in vivo" biological studies.

The goal of this work is the determination of a set of moderators, filters and shielding which will lead to a radiation field (high thermal and epithermal neutron fluxes intensity, i.e. with minimum feasible contaminants – gamma rays and fast neutrons) suitable to BNCT studies.

The experimental set was computer modelled and calculations have been performed with the MCNP-4C[1] Monte Carlo radiation transport code.

II. Experimental Specifications

The facility, schematically shown in Fig. 1, is under construction. It is intended to be very versatile, enabling the obtainment of both thermal

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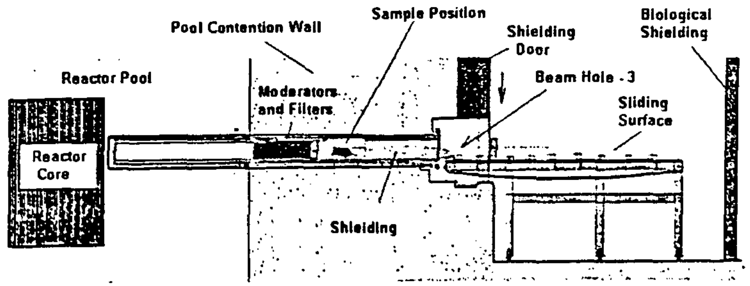

Fig. 1 Schematic view of the facility

and/or epithermal neutron beams from it. It consists of some cylindrical devices which serve as holders for moderators, filters, shielding and sample. These holders are designed to be inserted into beam hole #3 (a radial radiation tube) of the IEA-R1 reactor.

Outside the beam hole, in the experimental room of the reactor, a biological shielding will be built to isolate this facility from the rest of the room.

As the beam hole #3 has a 20.3 cm internal diameter and the sample irradiation position inside it is a cylindrical cavity with 12.8 cm diameter and 30 cm width, the samples will be limited to tissue culture, small animals and phantoms.

III. Computer Modelling

During the accomplishment of this work, the BNCT experimental facility was computer modelled in MCNP-4C; this MCNP gets along interactions utilizing material pointwise cross sections libraries. In this particular work ENDF/B-VI library has been used. Data for neutrons energies ranges from 10^{-11} MeV up to 20 MeV while photons and electrons energies range from 1 keV to 50 MeV.

Attempting to pursue the better as possible radiation field in the sample position, neutron and gamma ray spectra have been obtained through calculations for different sets of moderators, filters and shielding placed in the device holder inserted into BH#3. This set varied in composition (polyethylene, aluminum and lead), combination, shape and size.

A combined neutron/gamma transport calculation was carried along and their fluxes were tallied on different surfaces placed along the modelled facility. Neutron spectra was obtained for 4 distinct energy ranges setted to better guide the work on BNCT - thermal (E<0.5eV), epithermal (0.5eV<E<40keV), fast I (40keV<E<5MeV) and fast II (5MeV<E<20MeV).

Figure 2 shows the facility computational modelling. It can be easily seen a multitude of surfaces and regions transcending the basic "expected" structures. These extra modelled structures are created to improve problem solution efficiency through the designation of distinct importance values to different regions, therefore they are more frequent inside and along the beam-hole.

This efficiency improvement is achieved through an increased sampling of important events which reduces the uncertainty of the tallies. Results are therefore obtained with lowered time consuming simulations.

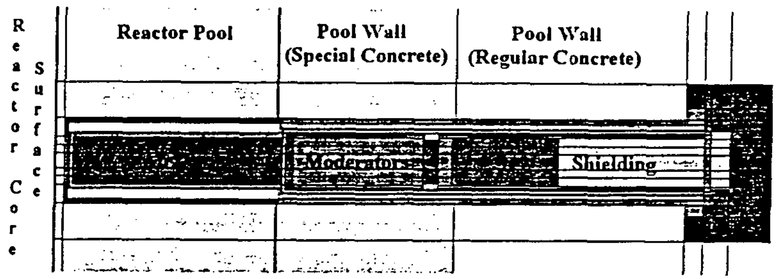

Fig. 2 Computer modelled facility

IV. Results

Simulations were performed for many different configurations of filters, moderators and shielding leading to distinct radiation fields at the sample position. An empty configuration (no moderators nor filters) was also taken into account (Fig. 3) leading to tallied fluxes consistent to

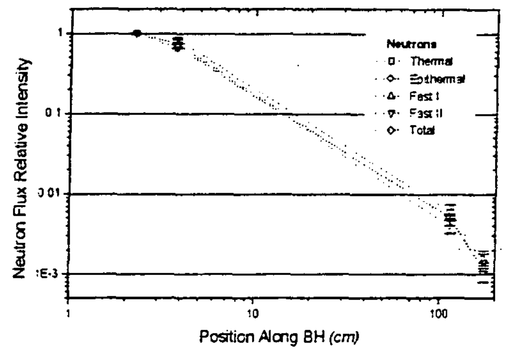

Fig. 3 Neutron fluxes along the beam hole in an empty configuration

experimental results obtained with activation foil detectors[21]. This agreement indicates the correct direction of the simulations so far performed.

Filters consisted of pure aluminum showed an improvement on the desired characteristics of the neutron flux with the enlargement of filter thickness. Such behavior is observed to thickness up to 60 cm. Above this value there seems to be no advantage which justifies the total neutron flux reduction (Fig. 4 and Fig. 5).

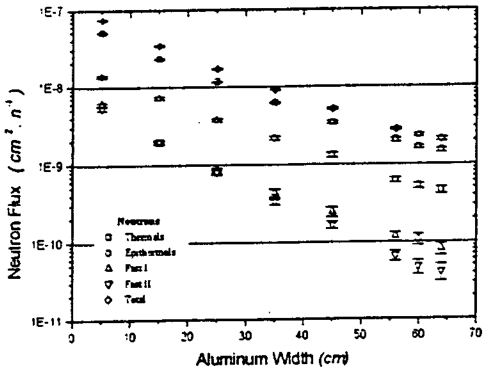

Fig. 4 Neutron fluxes dependence with aluminum filter width

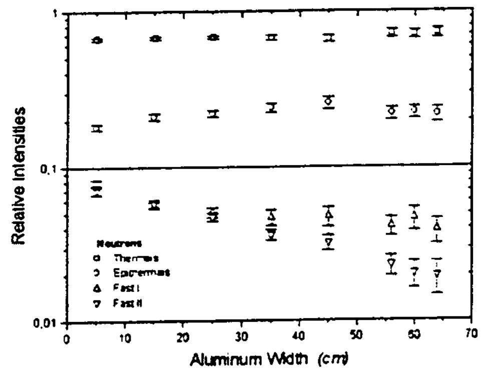

Fig. 5 Relative neutron flux intensities. These data refer to the ones shown in Fig. 4

Some attempts to further improve neutron spectra where conducted combining polyethylene to aluminum but it didn't show the expected results.

Neutron fluxes calculated outside BH#3, at its vicinity aperture, showed small values which. indicate that it will facilitate the biological shielding construction

V. Conclusions

The methodology so far applied to specify neutron flux and spectra at the sample position allows the response study of wide variety of moderators and filters configurations so to format radiation field to conditions so good as possible to BNCT research. This study is of a great value to determine the initial configuration to be used in the forthcoming experiments.

Results so far tallied showed a great reduction of fast neutrons with no similar decrease of thermal and epithermal neutrons. It was obtained a value of 12.2 (1.9) for the ratio between thermal neutrons to fast neutrons and a value of 3.7 (0.6) for the ratio between epithermal neutrons to fast neutron which are the desirable conditions in BNCT research area.

VI. References

1) "MCNP- A general Monte Carlo N-Particle Transport Code" - Version 4C. Los Alamos. Nat. Lab. (La-13709-M).

2) U. D. BITELLI, M. A. P. ALVES, M. A. DAMY, P. R. P. COELHO, "Mapeamento do fluxo de nêutrons térmicos no canal de irradiação 8 do Reator IEA-R1". 8° ENFIR, MG,Brasil (1991).

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