ENERGY SPECTRA AND KERMA DOSES OF NEUTRON BEAMS PRODUCED BY CYCLOTRON

Kiyomitsu Kawachi, Tatsuaki Kanai, Tetsuo Inada,
Toshiyuki Hiramoto, Hirotsugu Ogawa and Takanobu Yamada

National Institute of Radiological Sciences

I Introduction

NIRS cyclotron has been mainly used for fast neutron cancer therapy. This intense fast neutron beam is produced by bombarding a thick beryllium target with 30 MeV deuterons. It is very important to know the physical characteristics, such as energy spectral distribution and kerma dose, of this neutron beam for the intercomparison of the biological properties and the clinical results. And knowledge of the physical properties of neutrons produced by bombarding the other thick target of light elements with protons and deuterons will also be needed for discussing the neutron producing machine proporsal, which satisfy the radiotherapy criteria of dose rate and penetrability.

II Experimental Method

The measured neutron beams were produced by bombarding thick lithium and beryllium target with proton and deuteron beams which were accelerated by using the isochronous cyclotron at NIRS. The target assembly included beam current read out capability and electron suppresion to insure accurate beam current measurements.[1]

The time-of-flight technique was employed for the spectral measurements of these neutron beams. The detector used for these measurements was a stilben, 2.54 cm length by 5.08 cm diameter, mounted coaxially with respect to the incident neutrons on a photomultiplier. The efficiency of this detector employed a data of Jones and Toms[2] for neutron below 16 MeV and a data corrected from the calculated results using a Kurz code[3] for higher neutrons. The lower cut-off energy of this efficiency curve and its effect to the higher energy regions has been evaluated in another experiment for different discrimination level of the fast signal and the slow coincidence signal at several energies to check the validity of these efficiency data. Standard fast electronics were used to process each event and time-of-flight spectra were recoded and analyzed by NIRS cyclotron neutron data processing system using an on-line TOSBAC-40C computer.

The neutron energy spectra were calculated from these time-of-flight spectra crrected for the detector efficiency with respect to neutron energies and the interval of time per channel.

In these time-of-flight measurements, the single turn extraction was employed for accelerated deuteron energies of lower than 22.5 MeV, whereas, for the higher deuteron energies and 60 MeV protons, it could not unfortunately be employed due to serious r.f. induction on coaxial transmission line through which gating pulse is fed to deflector electrode.

III Results and Discussions

A typical result of the spectral measurement for bombarding the thick beryllium target with 30 MeV deuteron beams which commonly used for the fast neutron therapy at NIRS is shown in Fig.1. This figure displays the angular dependence of the neutron spectra and each curve is labeled with the angle of neutron flight direction relative to the incident deuteron beams. In this figure, the higher energy component shows rather strong angular dependence, whereas the lower energy component is less dependent on angle. The energy distributions of neutrons produced by deuterons of 16 and 22.5 MeV incident on the thick beryllium and lithium targets were also obtained.

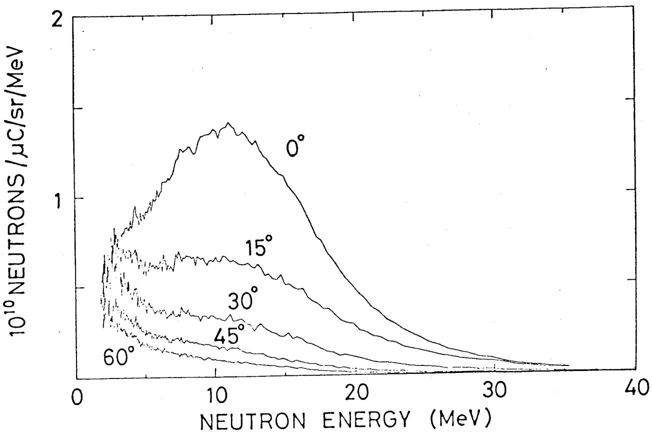

Fig.1 Typical energy spectra of neutrons produced by bombarding thick beryllium target with 30 MeV deuterons.

The angular dependence of the mean neutron energies and the integrated neutron yield for neutrons above the detection threshold energy at 2.4 MeV were obtained for these spectra. The angular distributions of the integrated neutron tissue kerma dose for thick beryllium and lithium (d,n) reactions are plotted in Fig.2. The tissue kerma doses in air were also calculated for these measured neutron energy spectra by the use of ICRU kerma factor.

Further, we intended to discuss the difference of kerma in ICRU muscle tissue and in Shonka A-150 plastic which is used as the wall material of tissue equivalent chamber.

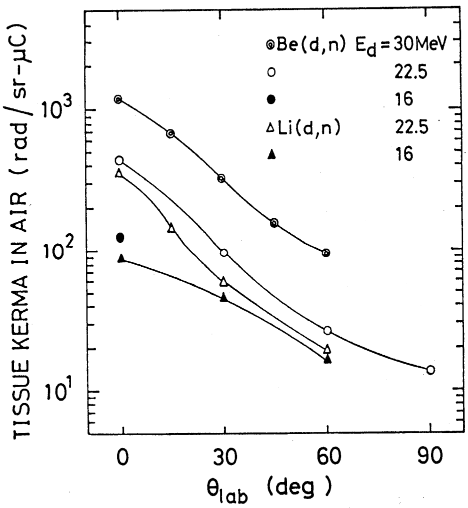

Fig.2 Angular distributions of integrated neutron tissue kerma dose in air for neutrons above 2.4 MeV.

References

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