Neutron Flux Measurement Produced by BNCT Target using Proton Beam

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1. Introduction

We are investigating neutron production target system performance for boron captured neutron therapy (BNCT).[1] The epithermal neutron is useful for this therapy and in present study we performed a simple method to measure neutron flux and energy, which are important for the accurate cancer therapy. The simple method and result of neutron flux and energy measurement experiment are presented.

2. Methods and Results

In this section the techniques used to measure the neutron flux and energy are described. The neutron production target system, electronics, signal processing, detector, and analysis result are presented.

2.1 Neutron Production Target system and Proton Beam Irradiation

Neutron production target system consists of three kinds of layers through the proton beam passage. In the target system main neutron production target is a thin lithium foil, which has large amount of neutron production cross section. To product neutron proton beam was extracted using MC-50 cyclotron installed at KIRAMS at energy of 18.3 MeV. The average proton beam current was 0.36 nA during a period of 600 sec beam irradiation.

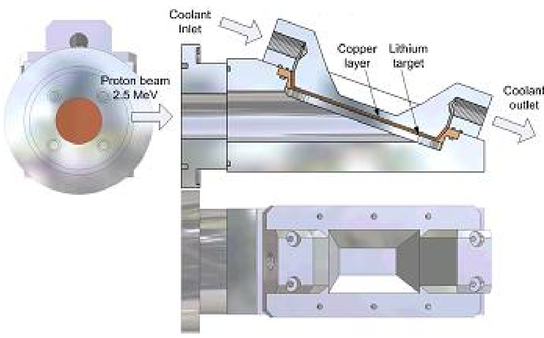

Figure 1. Layout of neutron beam production target system. Target system consists of a proton beam moderator, a neutron production target, a proton beam dump, and a cooling system.

To moderate proton beam less than several MeV from 18.3 MeV, a thick aluminum plate was used to moderate neutron energy. The incident proton beam without reaction can pass through nature lithium foil and dump at a thick copper plate. Target system has also the coolant flow passage for the thermal heating cooling which is generated by a dumped proton beam. Figure 1 is the schematic scheme of target system.

The target system was electrically isolated with the proton beam transportation system for the measuring of the incident beam current. The incident proton beam current was monitored by electrometer which was controlled by PC.

2.2 Detector and Measurement Method

While He-3 nucleus reacts with a neutron, then unstable He-4 produces. This unstable nucleus dissociates promptly to a proton and a triton with kinetic energy depending on the incident neutron kinetic energy.

Neutron flux measurement was performed by using the pressurized He-3 proportional counter, which is not sensitive relatively to gamma-rays than neutrons. We can identify simply by adjusting ADC discrimination energy level. He-3 counter is a diameter of 1 inch, a length of 10 inch, and a pressure of 4-atm. Counter was installed at a distance of 20 cm from nuclear reaction target and is perpendicular to beam direction. Counter was operated at 2000V. Figure 2 is the photo of the He-3 counter and charge sensitive preamplifier used in the present experiment.

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Figure 2. Layout of the He-3 proportional counter and preamplifier for signal processing.

After generating neutron by target system, neutron was moderated by 8-cm thick high density polyethylene (HDPE) plate to get a several hundred keV energy of epithermal neutrons. The HDPE moderator increases the neutron detection rate at He-3 counter because the reaction cross section increases as neutron energy decreases.

To simplify the detection efficiency determination, the absolute efficiency of the He-3 counter was determined before experiment as a function of distance between counter and source using by the moderated neutrons produced by Cf-252 fission source. At the present experiment setup the counter absolute efficiency was determined as 0.0054.

2.3 2 Electronics and Signal Processing

The analogue output of the charge sensitive preamplifier produced by He-3 counter was fed into the amplifier to adjust the signal shaping and gain matching. The output of the charge sensitive preamplifier has an exponentially decaying tail pulse. At relatively high count rates, the large decay time constant of a charge sensitive preamplifier causes severe pulse pile-up, as pulses are superimposed on the tails of the previous pulses [1]. A shaping amplifier is used to reduce pile-up. Multi channel analyzer was used for data collection and produce neutron energy spectrums. Total incident proton beam current was stored by electrometer. We controlled beam bombarding time and current to avoid fluctuation.

2.4 Analysis and Neutron Yield

Our target system produces three kinds of neutron s which have different origins. Main neutron production part is the proton beam moderator. To identify neutron originally produced from lithium target, three sets of experiment was performed; beam on without target system, beam on with target system, and beam on without lithium target. Figure 3 is the typical neutron energy spectrum obtained at the experiment.

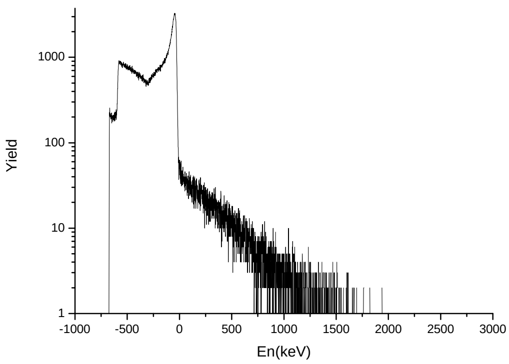

Figure 3. The spectrum of the neutron production target of a proton beam at 18.3 MeV.

During beam irradiation we also measured a beam current fluctuation. It determined as 12.3%. Considering this result the neutron production rate was determined as (9.3 ± 1.1) x10^5 neutrons/nA/sec, which was agreed well with the prediction of Monte Carlos simulation.

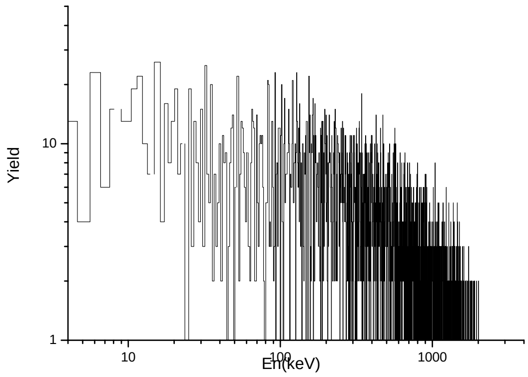

Figure 4. Unfolding neutron production spectrum which is corrected by neutron detection efficiency according with energy.

The high energy tail over neutron absorption energy , 0.764 MeV, is the portion of fast neutron region. The measured neutron energy spectrum was unfolded in consideration with the detection efficiency depended on neutron energy.[3] Figure 4 shows the unfolded neutron spectrum. It shows that our target system works as BNCT target system which requires several hundred keV neutrons.

3. Conclusion

A simple measurement method to determine the neutron beam energy was developed. The designed target system shows the expected performance as the BNCT target system.

Acknowledgement

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