STATUS OF POHANG NEUTRON FACILITY BASED ON 100-MEV ELECTRON LINAC *

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Abstract

The Pohang Neutron Facility (PNF) based on the 100-MeV electron linear accelerator has been constructed as a nuclear data production facility in Korea. It consists of an electron linear accelerator, a water-cooled Ta target with a water moderator, and a time-of-flight path with an 11 m length. The 100-MeV electron linac uses a thermionic RF-gun, an alpha magnet, four quadrupole magnets, two SLAC-type accelerating sections, a quadrupole triplet, and a beam-analyzing magnet. The neutron total cross section of natural Dy has been measured in the neutron energy region from 0.025 to 100 eV by the neutron time-of-flight method. In order to reduce the gamma flash originated from the neutron target, we have employed a neutron-gamma separation system based on their different pulse shape. The present measurements are in general agreement with the ENDF/B-VI and the previous ones.

1 INTRODUCTION

Pulsed neutrons based on an electron linear accelerator (linac) are effective for measuring energy-dependent cross sections with high resolution by using the neutron time-of-flight (TOF) method covering the energy range from thermal to a few tens of MeV neutrons. The Pohang Neutron Facility (PNF) based on a 100-MeV electron linac was proposed in 1997 and constructed at the Pohang Accelerator Laboratory (PAL) on December 1998 [1]. Its main goal is to construct the infrastructure for the nuclear data production in Korea.

We have installed new collimator system consists of iron (Fe), H_3BO_3, and lead (Pb) rings with their diameter varying from 10 to 5 cm. In order to reduce the gamma rays from a Bremsstrahlung and that from a neutron capture, we have employed a neutron-gamma separation system based on their different pulse shape.

In order to show the ability of PNF as the nuclear data production facility, the total cross section of natural dysprosium (Dy) has been measured in the neutron energy range between 0.025 and 100 eV by using the neutron TOF method. The measured result has been compared with other measurements and the evaluated data.

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2 POHANG NEUTRON FACILITY

The PNF consists of an electron linac, a water-cooled Ta target, and an 11 m long TOF path. The electron linac consists of standard subsystems: a thermionic RF-gun, an alpha magnet, four quadrupole magnets, two SLAC-type accelerating sections, a quadrupole triplet, and a beam-analyzing magnet. The overall length of the linac is about 15 m. The RF-gun is one cell cavity with a dispenser cathode of 6 mm diameter [2]. The alpha magnet is used to match the longitudinal acceptance from the RF-gun to the first accelerating section. Four quadrupole magnets are used to focus the electron beam in the beam transport line from the thermionic RF-gun to the first accelerating section. The quadrupole triplet installed between the first and the second accelerating sections is used to focus the electron beam during the transport to the experimental beam line at the end of the linac. The characteristics of the electron accelerator are described in elsewhere [3].

A Ta target was designed and constructed for the neutron production by way of Bremsstrahlung under high power electron beams [4]. The Ta target was composed of ten Ta sheets, 49 mm in diameter and 74 mm in total length. There was 1.5 mm water gap between Ta sheets in order to cool the target effectively. The target housing was made of 0.5 mm thick titanium.

Since we have to utilize space and infrastructure at PAL, an 11 m long TOF path and a detector room were constructed vertically to the electron linac. The neutron guide tubes were constructed by stainless steel with two different diameters of 15 and 20 cm. The neutron collimation system was mainly composed of H_3BO_3, Pb, and Fe which were symmetrically tapered from 10 cm diameter at the beginning, 5 cm in the middle position where the sample was located, and 8 cm diameter at the end of guide tube where the neutron detector was placed. There is 1.8 m thick concrete between the target and the detector room. The details of PNF are described in elsewhere [4, 5].

During the experiment, the electron linac was operated with a repetition rate of 10 Hz, a pulse width of 1.0 μs, and the electron energy of 60 MeV. The peak current in the beam current monitor located at the end of the second accelerator section is above 50 mA, which almost is the same as that in the target.

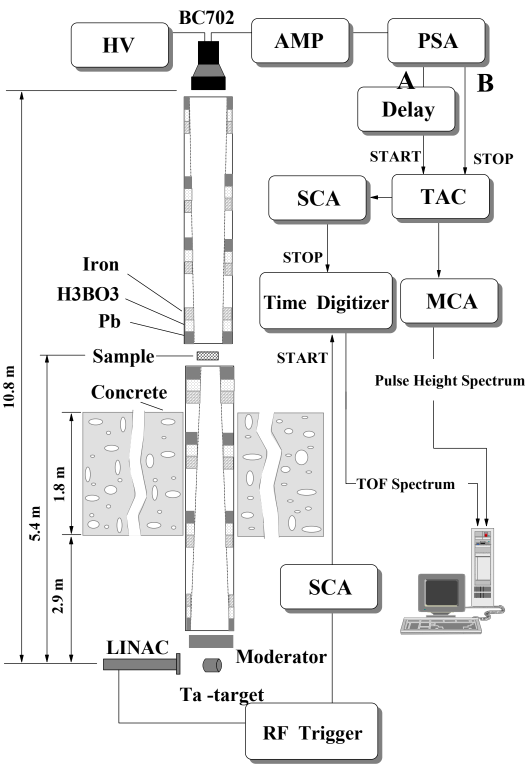

Figure 1: Experimental arrangement and a block diagram for data acquisition.

3 TOTAL CROSS SECTION MEASUREMENT

3.1 Experimental Arrangement

The experimental arrangement for the neutron total cross section measurements is shown in Fig. 1. The target is located at a position where the electron beam hits its center. To reduce the gamma flash generated by the electron burst in the target, the target is placed in 5.5 cm away from the center of the neutron guide to the backward direction. This target was set in the cylindrical water moderator contained in an aluminum cylinder with a thickness of 0.5 cm, a diameter of 30 cm and a height of 30 cm. The water level in the moderator was 3 cm above the target surface which was decided by the measurement of thermal neutron flux and also compared with the Monte Carlo simulation [4].

The sample was placed at the midpoint of the flight path. A natural Dy metal plate, 10×10 cm^2 in area by 0.5 mm in thickness, was used as a transmission sample. The purity of the Dy sample was better than 99.9%. A set of notch filters of Co, Ta, and Cd plates with 0.5, 0.2, and 0.5 mm in thickness respectively, was used for the background measurement and the energy calibration.

The neutron detector was located at a distance of 10.81±0.02 m from the photo-neutron target. A ^{6}Li-ZnS(Ag) scintillator BC702 from Bicron (Newbury, Ohio) with a diameter of 127 mm and a thickness of 6.35 mm mounted on an EMI-93090 photomultiplier was used as a detector for the neutron TOF spectrum measurement. This scintillator consists of a matrix of a lithium compound enriched to 95% ^{6}Li dispersed in a fine ZnS(Ag) phosphor powder.

3.2 Data Acquisition System

The block diagram of the data acquisition system is also shown in Fig. 1. The TOF signal from the BC702 scintillator was fed into a time digitizer, which was initiated by the electron burst, and the counts versus TOF channel for each sample were recorded in a personal computer. The present data acquisition system was different from the previous one [5] as shown in Fig. 1; we added a pulse-shape discrimination circuit in order to eliminate gamma-flash generated by the electron burst from the photoneutron target and gammas from the neutron captures as well. The dynode signal from a BC702 scintillator was connected through an ORTEC-571 amplifier (AMP) to an ORTEC-552 pulse-shape analyzer (PSA) in order to use a neutron-gamma separation. A fast NIM signal from "A" output of the PSA was delayed by 60 ns and used as a start signal of an ORTEC-567 time-to-amplitude converter (TAC). The "B" output signal from the PSA was used as a stop signal of the TAC. One of TAC outputs was connected to an ORTEC-550A single channel analyzer (SCA); the output signal was used as a stop signal of a 150 MHz Turbo MCS (time digitizer). This one was operated by a 16384-channel mode with a 0.5 μs width per channel. The other output signal of TAC was fed to a multi channel pulse-height analyzer (MCA). The 10-Hz RF trigger signal for the modulator of the electron linac was connected to a SCA; the output signal was used as a start signal of the time digitizer. The time digitizer was connected to a personal computer. The data were collected, stored and analyzed on this computer.

3.3 Data Taking and Analysis

In the transmission measurements, we have taken data with sample in (Dy sample) and out (open beam) periodically. Total data taking times for sample in and out are 18 and 16 hours, respectively. The net neutron TOF spectra for the Dy sample and the open beam are shown in Fig. 2 together with the estimated background level indicated by dash line. We could estimate the background level by using resonance energies of the neutron TOF spectra of notch-filters of Co, Ta and Cd.

The neutron energy E in eV corresponding to each channel I in the TOF spectrum is derived from the relation; $E = \{72.3 \times L/(I - I_0) \times W\}^2$, where L=10.81 ±0.02 m is the neutron flight path, W=0.5 μs is the channel width of the time digitizer, and I_0 is the channel of TOF=0 when the neutron burst was produced. In this experiment we found I_0 equals to 5 channels.

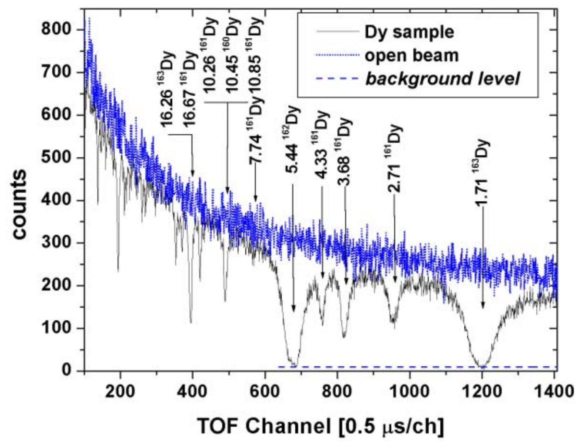

Figure 2. The neutron TOF spectra for sample in and out

The neutron total cross section is determined by measuring the transmission of neutrons through the sample. The transmission rate of neutrons at *i*-th group energy E_i is defined as a fraction of incident neutrons passing through the sample compared to that one in the open beam. Thus, the neutron total cross section is related to the neutron transmission rate $T(E_i)$ as follows:

$$\sigma(E_i) = -\frac{1}{\sum_j N_j} \ln T(E_i), \qquad (1)$$

$$T(E_i) = \frac{[I(E_i) - IB(E_i)]/M_I}{[O(E_i) - OB(E_i)]/M_O} \qquad (2)$$

where N_j is the atomic density per cm^2 of *j*-th isotope in the sample. $I(E_i)$ and $O(E_i)$ are the foreground counts, $IB(E_i)$ and $OB(E_i)$ are the background counts, and M_I and M_O are monitor counts for sample in and out, respectively. The monitor counts are obtained by integrating the TOF counts corresponding to the relevant energy region. The total cross sections of the Dy sample as a function of neutron energy were obtained by using the Eq. (1).

3.4 Results and Discussion

The total cross section of natural Dy has been obtained in the neutron energy region from 0.02 to 100 eV by measuring the neutron transmission rate with the TOF method. The present measurement for the neutron total cross section of Dy is compared with the previous results [6,7, 8, 9, 10, 11] and the evaluated data in ENDF/B-VI [12]. The present measurement is generally in good agreement with the existing measured and evaluated data as shown in Fig. 3.

4 CONCLUSIONS

The Pohang Neutron Facility based on an electron linac was constructed for nuclear data production in Korea. We have installed a new collimator system consists of iron, H_3BO_3, and lead rings with their diameter varying from 10 to 5 cm. In order to reduce the gamma rays from a Bremsstrahlung and that from a neutron capture, we have employed a neutron-gamma separation system based on their different pulse shape. In order to show the ability of PNF as the nuclear data production facility, the total cross section of natural Dy has been measured in the neutron energy region between 0.02 and 100 eV by using the neutron TOF method and a ^{6}Li-ZnS(Ag) scintillator as a neutron detector. The present measurement is in good agreement with other measurements and the evaluated data in ENDF/B-VI.

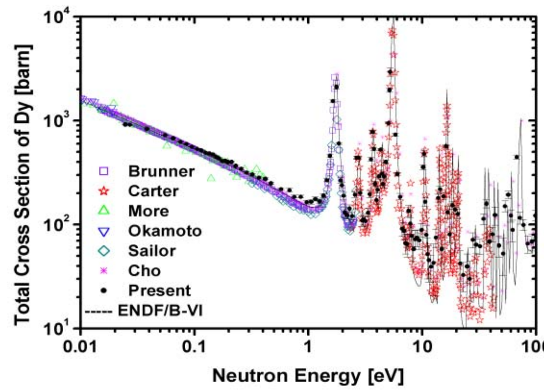

Figure 3. The neutron total cross sections of Dy compared with the previous data and the evaluated data in the neutron energy region from 0.01 eV to 100 eV.

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