POHANG NEUTRON FACILITY BASED ON ELECTRON LINAC

G. N. Kim[#], R. Machrafi, H. Ahmed, and D. Son
Institute of High Energy Physics, Kyungpook National University, Daegu 702-701, Korea
Y. S. Lee, H. S. Kang, M. H. Cho, I. S. Ko, and W. Namkung
Pohang Accelerator Laboratory, POSTECH, Pohang 790-784, Korea

Abstract

The Pohang Neutron Facility 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. As a nuclear data production facility, it has been equipped with a CAMAC data acquisition system consists of a neutron-gamma separation system and a four-position sample changer. A ^{6}LiZnS(Ag) glass scintillator has been used as a neutron detector at the end of the evacuated flight tube of 11 m long. The data acquisition system has been tested measuring total cross sections by using the neutron time-of-flight method.

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.

Since December 1999, a turbo MCS system combined with a circuit based on direct pulse discrimination has been installed and worked in different transmission measurements [2]. As activities at PNF are diversely increasing, the improvement of the data acquisition system is required. Recently, this system has been improved by the addition of a new CAMAC data acquisition system, which consists of a neutron-gamma separation circuit, a four–position sample changer controlled remotely by the CAMAC module and software program for simultaneous accumulation of the neutron TOF spectra from 4 different detectors. To test this system, we have measured the neutron total cross-sections of natural tungsten (W) and titanium (Ti) samples by using the neutron TOF technique.

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 [3]. 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 [4].

A Ta target was designed and constructed for the neutron production by way of Bremsstrahlung under high power electron beams [5]. 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 [6].

During the experiment, the electron linac was operated with a repetition rate of 10 Hz, a pulse width of 1.5 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.

[#] Email: gnkim@knu.ac.kr

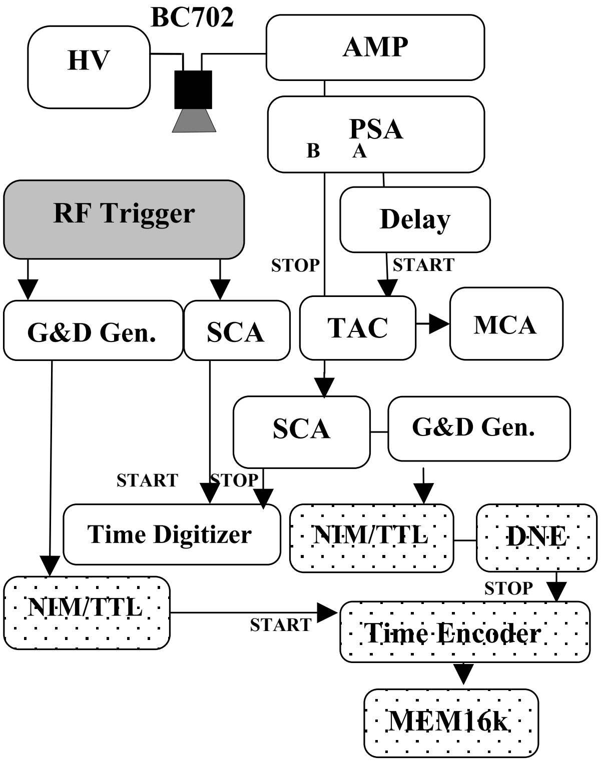

Fig. 1. Block diagram of data acquisition system. The white box indicates NIM module and the dotted box indicates the CAMAC module.

DATA ACQUISITION SYSTEM

Two different data acquisition systems were used for neutron TOF spectra measurements: one for NIM based system and the other for CAMAC based system. The main purpose of the NIM based system is neutron–gamma separation and the parallel accumulation of the neutron TOF spectra if necessary. 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. TAC output was connected to an ORTEC-550A single channel analyzer (SCA). One of SCA output signals was used as a stop signal of a 150 MHz Turbo MCS (Time Digitizer), the other was sent to a CAMAC based system. The start signal of Time Digitizer signal come from the RF trigger.

The CAMAC based system consists of a data acquisition part and a control part of the sample changer (SC). The SCA output signal of the NIM based system was connected to the detector number encoder (DNE) through the NIM/TTL converter. The DNE allows the data taking up to four detectors simultaneously. The output of the DNE give a stop signal for the time encoder which operate with 4096 channels and a minimal dwell time of 0.5 μs width per channel.

The 10-Hz RF trigger signal for the modulator of the electron linac was connected to a gate and delay generator (G&D Gen.); the output signal was used as a start signal of the time encoder. One of signals from the time encoder was sent to 16 K capacity memory module (MEM 16K), which collects the TOF spectra during the measurement

The control of the SC was done by an operating module for physical device, which operates the sample changer up to a distance of 1 km. The signal from this unit is delivered as a request to the position control module to change the sample and interrupts the measurement until the next sample reaches its position. The CAMAC part is controlled by PC software via an interface card and crate controller (not shown in Fig. 1). Parallel data acquisition with both the NIM system and the CAMAC system may be used if one desires to optimize the dwell time for different energy regions of the TOF spectra. A command file written in special script language synchronizes the CAMAC and the NIM system.

TOTAL CROSS-SECTION MEASUREMENT

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.

In the total cross-section measurement, we used natural W and Ti metal plates, 10 ×10 cm^2 in cross-sectional area by 0.2 mm and 0.5 mm in thickness, respectively. A set of notch filters of Co, In, and Cd plates with thickness of 0.5 mm, 0.2 mm, and 0.5 mm, respectively, was also used for the background measurement and the energy calibration. The total data taking times for W and Ti were 30.02 and 25.2 hours, respectively, with the same times for the open beams.

The neutron total cross-sections of natural W and Ti were obtained in the energy range from 0.1 eV to 100 eV by using Eq.'s (1) and (2). The statistical error can be determined from Eq. (1) and varied 0.1 to 40% depends on the neutron energy for this measurement. The systematic uncertainties came from the following sources: uncertainties from a) the flight path measurements (2 %), b) background estimation (0.04 %), and c) dead time, normalization, and others (2%).

The present measurement for the neutron total cross-sections of natural W is compared with other data measured by Schmunk [7], Chrien [8], Harvey [9], and Selove [10] and the evaluated data in ENDF/B-VI [11]. The present measurement is generally in good agreement with other data and the evaluated one as shown in Fig. 2 (a). The error bars in this figure indicate the statistical error only. Figure 2 (b) shows the result of neutron total cross-sections for natural Ti compared with the other data measured by Schmunk [7] and Joki [12] and the evaluated data in ENDF/B-VI [11]. The present results are generally in good agreement with the previous data and the evaluated data except for some discrepancy above 30 eV.

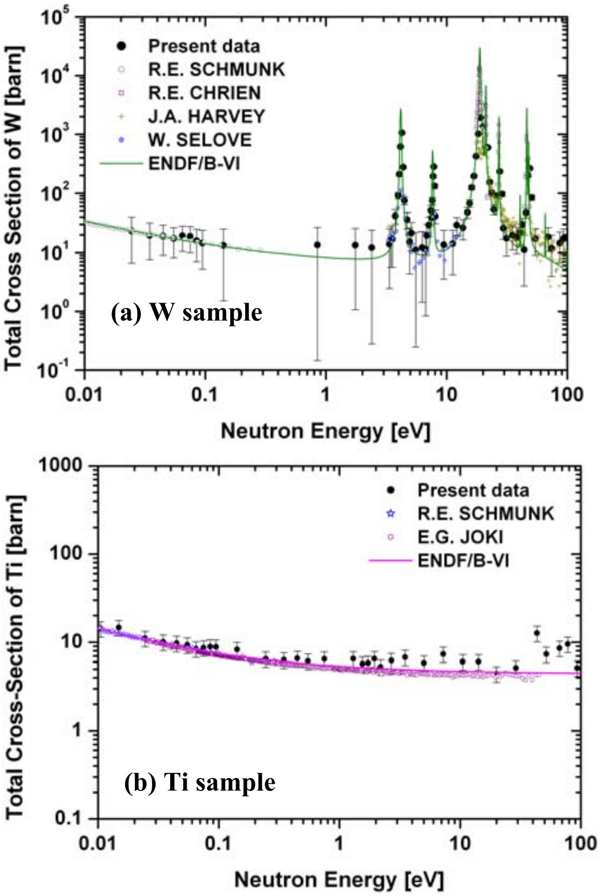

Fig. 2. The neutron total cross sections of (a) W and (b) Ti compared with the previous data and the evaluated data in the neutron energy region from 0.01 eV to 100 eV.

CONCLUSIONS

The Pohang Neutron Facility was equipped by a new data acquisition system. Two different data acquisition systems were introduced; one for NIM based system and the other for CAMAC based system. The main purpose of the NIM based system is neutron–gamma separation and the parallel accumulation of the neutron TOF spectra if necessary. The sample changer controlled remotely by the CAMAC based system can be possible to take data up to 4 different samples simultaneously and reduce systematic errors due to the intensity variation. The system has been tested by measuring the total cross-sections of natural W and Ti samples by using the neutron TOF method.

The neutron total cross-sections of natural W and Ti were obtained in the energy range from 0.01 eV to 100 eV with the statistical error of 1- 40 % depends on neutron energy. The present measurements are in good agreement with the evaluated data in ENDF/B-VI and other experimental data.

ACKNOWLEDGEMENTS

The authors would like to express their sincere thanks to the staff of the Pohang Accelerator Laboratory for strong support. This works is partly supported through the Long-Term Nuclear R&D program by the Korea Atomic Energy Research Institute and through the Science Research Center (SRC) program by the Institute of High Energy Physics, Kyungpook National University.

REFERENCES

[1] G. N. Kim et al., "Proposed neutron facility using 100-MeV electron linac at Pohang Accelerator Laboratory," Proc. Nuclear Data for Science and Technology, Trieste, May 19-24, 1997, p. 556, Italy (1997).
[2] G. N. Kim et al., J. Korean Phys. Soc. 38, 14 (2001).
[3] H. S. Kang et al., IEEE Trans. Nucl. Sci. NS44, 1639 (1997).
[4] H. S. Kang et al., "Beam Acceleration Result of Test Linac," Proc. 1st Asian Particle Accelerator Conf. (Tsukuba, Japan, Mar. 23-27, 1998), 743 (1998).
[5] W. Y. Baek et al., "Design of the photoneutron target for pulsed neutron sources at PAL", Proc. Workshop on Nuclear Data Production and Evaluation, Pohang, Aug. 7-8, 1998. Korea (1998).
[6] G. N. Kim et al., Nucl. Instr. and Meth. A 485, 459 (2002).
[7] R. E. Schmunk, P. D. Randolf, and R. M. Brugger, J. Nucl. Sci. Eng. 7, 193 (1960).
[8] R. E. Chrien, and R. L. Zimmerman, Bull. Am. Phy. Soc., 3, 19 (1958).
[9] J. A. Harvey, G. G. Slaughter, and R. C. Block, Bull. Am. Phy. Soc., 3, 177 (1958).
[10] W. Selove, Phys. Rev. 84, 864 (1951).
[11] R. F. Ross, ENDF-201, ENDF/B-VI Summary Documentation, BNL-NCS-17541, 4th ed. (ENDF/B-VI), Brookhaven National Laboratory (1991).
[12] E. G. Joki, J. E. Evans, and R. R. Smith, J. Nucl. Sci. Eng. 11, 298 (1961)