Detector for High Energy Neutron Spectrometry

著者	Nakao M., Sasaki M., Nakamura T., Nakao N., Shibata T.
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V. 1. Detector for High Energy Neutron Spectrometry

Nakao M., Sasaki M., Nakamura T. Nakao N., and Shibata T.**

Cyclotron and Radioisotope Center, Tohoku University
*Institute for Nuclear Study, University of Tokyo**

Introduction

With increasing use of high energy accelerator, the detection of secondary produced high energy neutrons having strong penetrability becomes more and more important for radiation shielding and safety.

But, there has been no available neutron spectrometer to detect neutrons of energies higher than about 100MeV, except the TOF(Time of Flight) method which can only be used in the limited field.

We therefore developed a self-TOF detector to obtain neutron spectrum of energy above 100MeV.

Materials and Methods

A self-TOF detector consists of an assemby of radiator, start and stop detectors. We assembled 20 sets of 10cm × 10cm and 6mm thick NE102A plastic scintillator as radiator, 10cm × 10cm and 5mm thick NE102A as a start detector, and nine sets of 20cm × 20cm and 2cm thick NE102A as stop detctors, in this order to the incident neutron beam.

Fig. 1 shows a schematic view of the detector's assembly. Nine stop detectors are set on a plane perpendiculer to the neutron beam and at 1m behind a start detector. When neutrons are incident on the radiator array, recoiled protons are produced by the H(n,n) reaction from a certain radiator. Output pulses from each radiator are counted separately with the photomultiplier coupled to each radiator, which gives the position of proton production and its energy loss, ΔE, in the radiator array. The energy of the recoil protons incident on the start detector E_p is determined by the TOF method between the start and stop detectors. Neutron energy is then determined by relativestic kinematics using induced proton energy corresponding to $E_p + \Delta E$.

Experiment

Experiment of CYRIC, Tohoku University

As the first experiment for this detector performance, we measured the spectrum of neutrons produced from the 1mm thick ^{7}Li target bombarded by 65MeV ^{3}He ions by using the AVF cyclotron of Cyclotron and Radioisotope Center (CYRIC). Fig. 2 shows the experimental geometry. The proton beam was inclined at 10Åāto the horizontal line with a beam swinger in order to shield neutrons producecd from the Faraday cup. The neutrons emerging from the Li target at 10° were then formed into a beam by the double collimators and transported down to the TOF extention room. In this experiment we used the detector assembly consisting of three radiators, one start and three stop detectors. Fig. 3 shows light output of the radator, start, and stop detectors. We can find the plateau peak of recoil protons at high energy end corresponding to the monoenergetic peak neutrons, especially in the stop detector.

Experiment of RIKEN

We secondly measured the spectrum of neutrons produced from the 10mm thick ^{7}Li target bombarded by 210MeV protons which were extracted from the separate-sector cyclotron of Institute of Physical and chemical Research (RIKEN). Fig.4 shows the experimental geometry. The charged particles which penetrated the thin target or produced in the target were transported to the beam dump by the dipole bending magnet. The neutrons emitted in the forward direction were measured with the detector through the collimator of 22cm × 22cm aperture and 120cm length. In this experiment we used the detector assembly consisting of six radiators and one start and three stop detectors.

Raw data and analysis

The measured light output data were analyzed as follows,

(1) Select only the proton event from the two dimensional (2D) distribution of stop detector's light output and recoil proton TOF spectra.
(2) Separate proton TOF spectrum by each radiator.
(3) Convert TOF spectrum into proton energy spectrum.
(4) Correct proton energy loss through the radiator.
(5) Change proton spectrum to neutron spetctrum with dividing by the efficiency.

Fig. 5 (a)(b) shows the 2D distribution of TOF(X-axis) and stop detector's light output (Y-axis) and that selected only recoil proton events(Fig. 5(b)) which were obtained at the CYRIC experiment. The 1D distributions projected on the X-axis, that is, the proton TOF spectra are also shown in Fig. 5(c)(d). The 2D distribution gives two gamma-ray peaks, proton and deutron events. The right peak was caused by gamma rays which were produced in the start detector and reached the stop detector, and the left peak was vice versa. Proton events were produced by the relevant H(n, n) reaction and deutron events by the C(n,d) reaction.

Fig. 6 shows the 2D distribution of TOF and stop detector's light output which were obtained at the RIKEN experiment. In this higher neutron energy experiment, the proton and deuteron events overlapped each other as seen in Fig. 6(b)., because proton and deutron did not fully loss their energy, but escaped from the stop detector.

To avoid the pile up of proton and deuteron light outputs, we placed 10cm × 10cm and 2.5cm thick brass bar between radiator and start detector to absorbe deuteron pulses. This results are also shown in Fig. 6(a). The deuteron pulses are fully absorbed in brass bar, but proton pulses are also absorbed especially in lower energy region at the same time.

Results and discussions

The neutron energy spectrum obtained at the CYRIC experiment is shown in Fig. 7(a) after the analysis desecribed in Sec. 4. The results is relatively compared with the neutron spectrum simultaneously obtained by the neutron TOF method with the 12.7cm-diam by 12.7cm long NE213 detector, since the efficiency of the self-TOF detector has not yet been calculated. Both spectra show rather good agreement in shape, but the energy resolution of the self-TOF detector is poor.

Fig. 8 gives the preliminary results of neutron energy spectrum obtained at the RIKEN experiment. Since we used the brass absober as described before, only high energy neutron components around 200MeV can be seen due to the absorption of lower energy protons.

To improve the discrimination level of proton and deuteron light output we will do experiment by the two ways as follows

(1) adding lead glass and plastic scintillator BC400 to stop detectors

(2) using the organic liquid scintillator NE213 as the stop detector instead of NE102A

Acknowledgments

We are deeply grateful to cyclotron operators at CYRIC and RIKEN. This work has been done as a Reseach Project with Heavy Ions at NIRS-HIMAC (National Institute of Radiological Sciences).

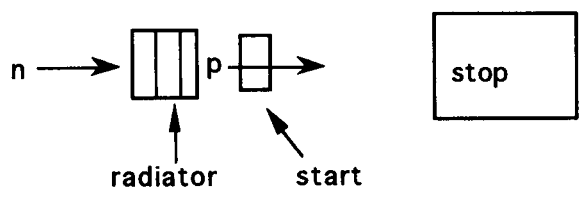

Fig. 1. Geometry of the Self-TOF detector.

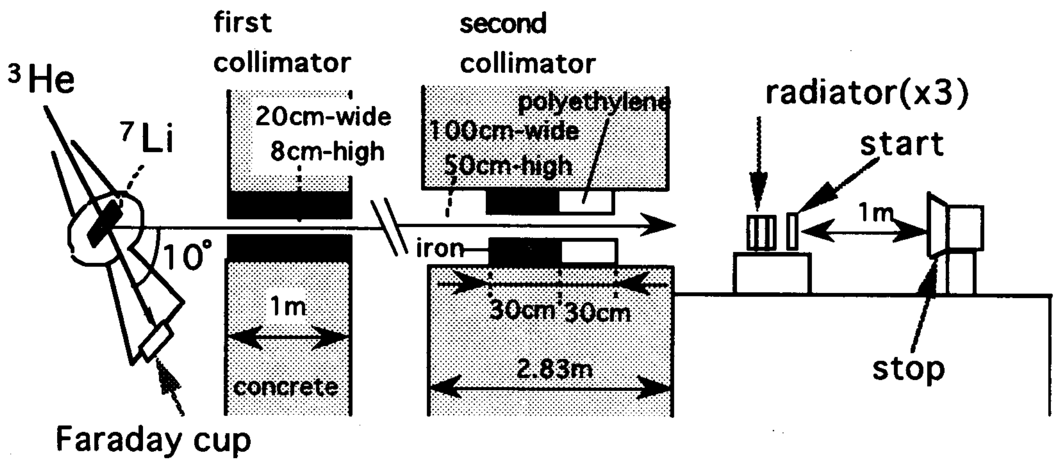

Fig. 2. Experimental setup at CYRIC.

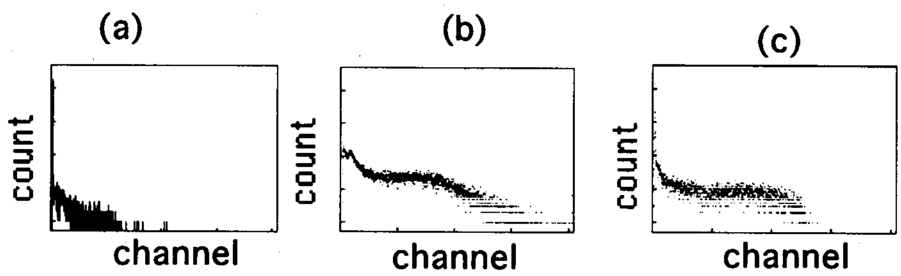

Fig. 3. Pulse height distribution of scintillation light output from (a)the first radiator, (b)the start detector, (c)the stop detector.

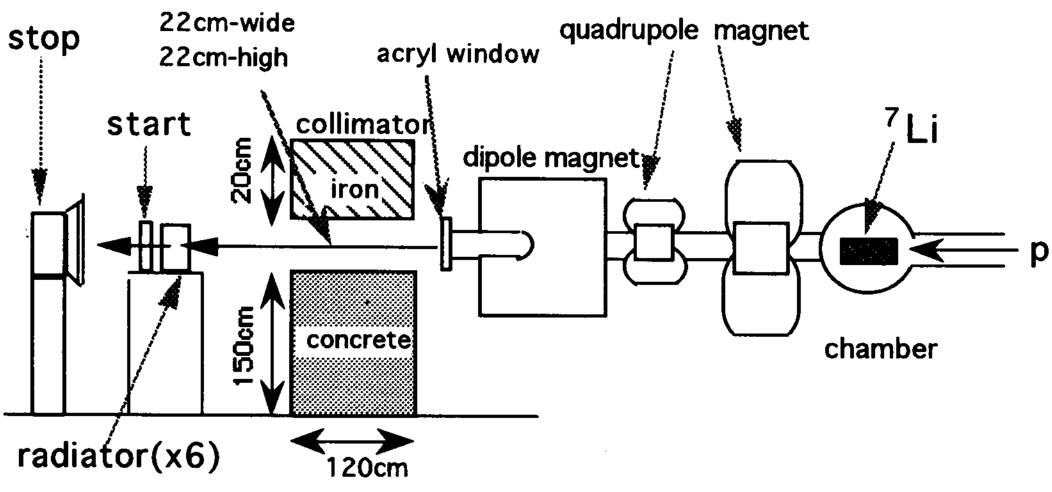

Fig. 4. Experimental setup at RIKEN.

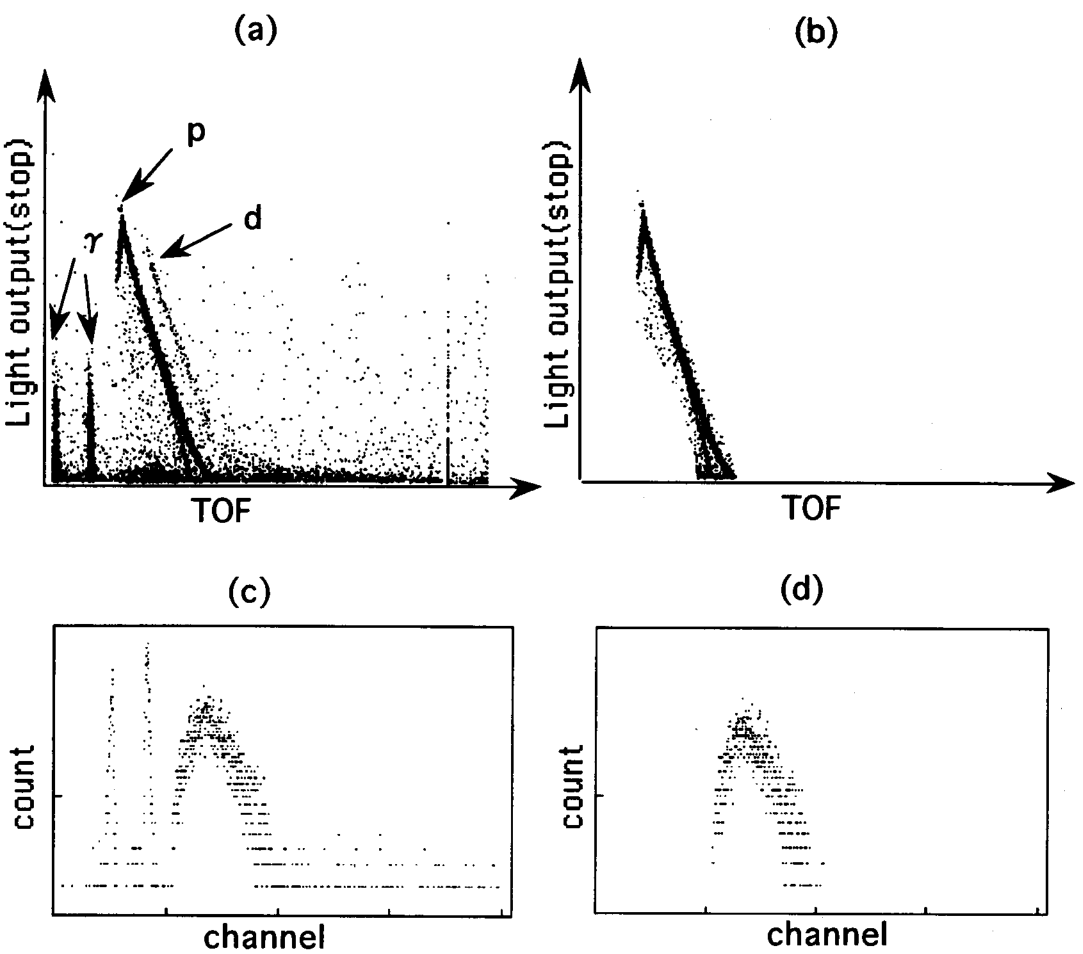

Fig. 5. Two dimensional plots of TOF and stop detector's light output (a) without selection, (b) after selection of proton events. The TOF spectrum (c) without selection, (d) after selection of proton events.

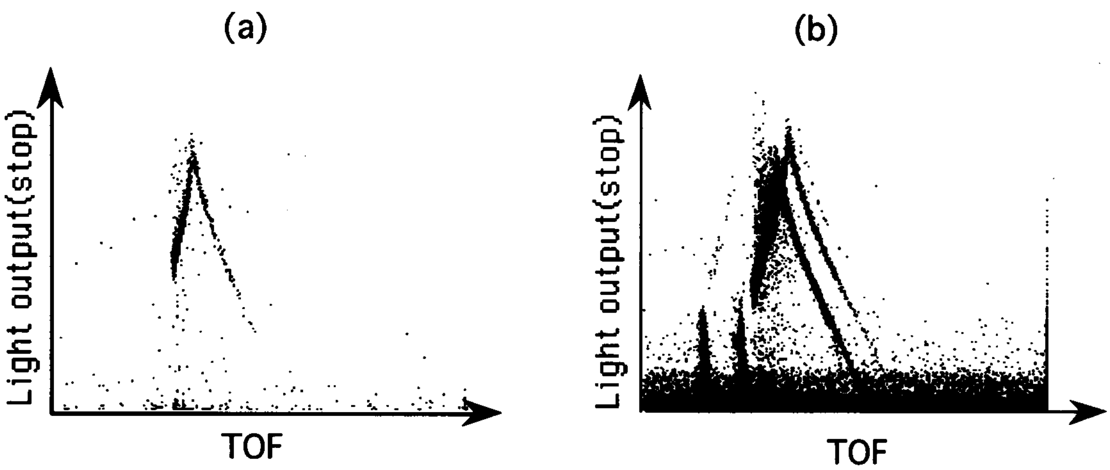

Fig. 6. Two dimensional plots of TOF and stop detector's light output (a)with brass absober, (b)without brass absober.

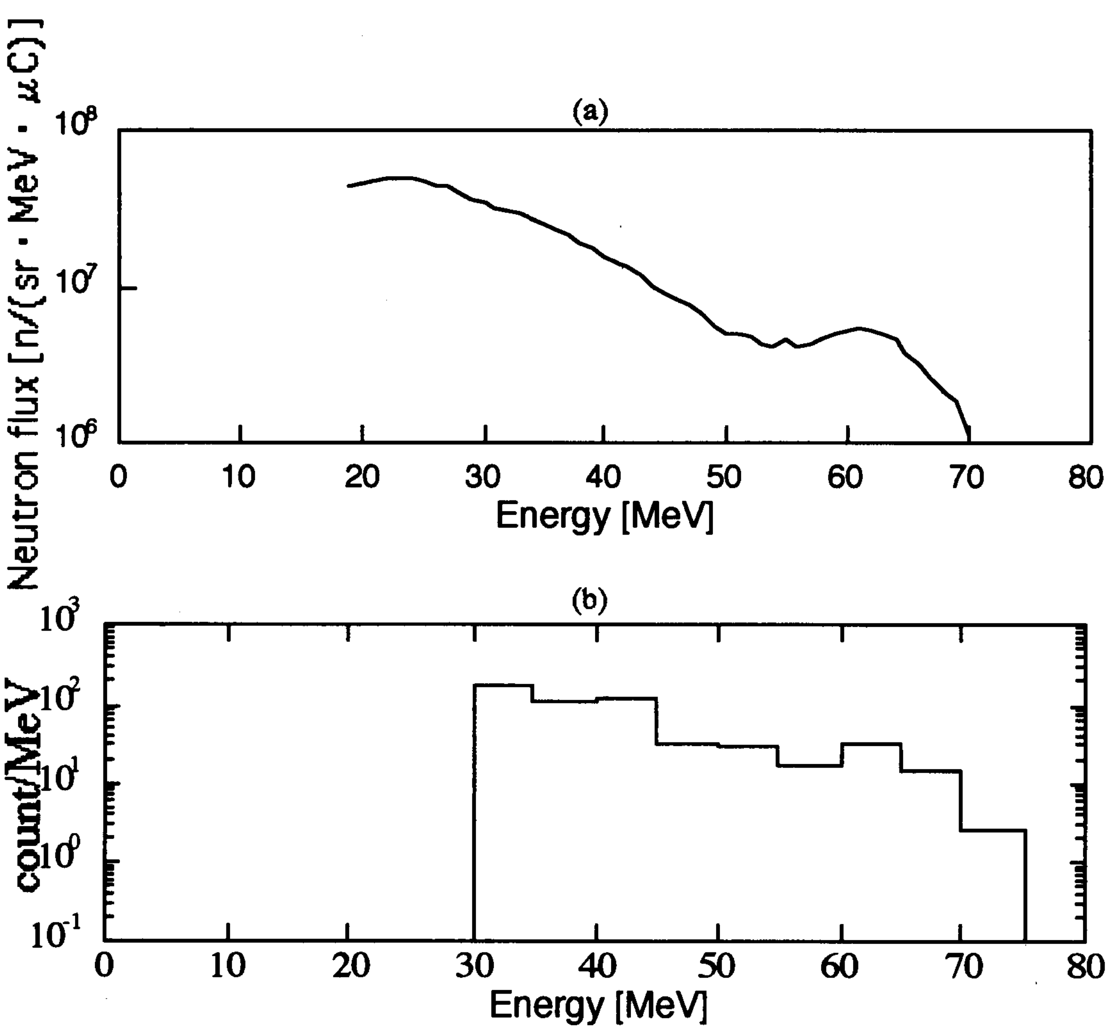

Fig. 7. Neutron energy spectra produced from ^{7}Li bombarded by 65MeV ^{3}He beams (a)obtained by self-TOF detector, (b)obtained by 12.7cm-diam by 12.7cm long NE213 detector with the neutron TOF method.

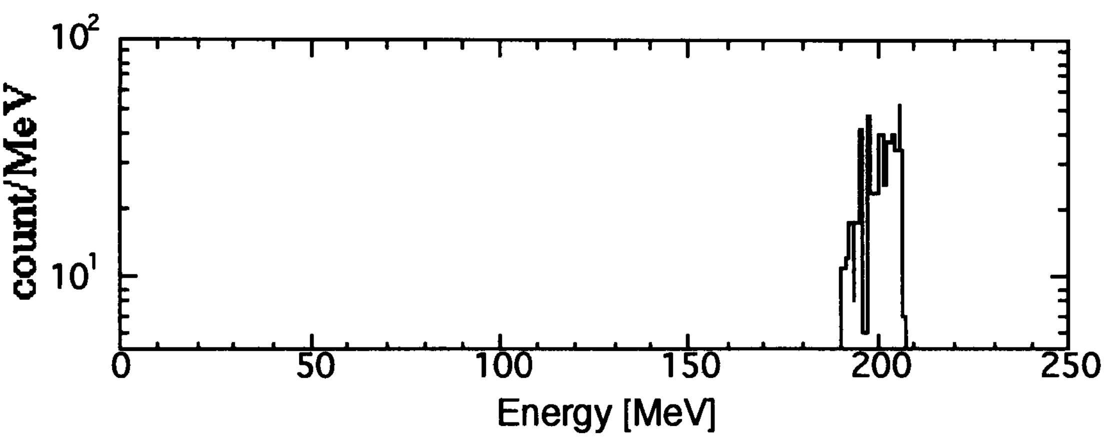

Fig. 8. Preliminary result of neutron energy spectrum produced from ^{7}Li bombarded by 210MeV protons which were obtained by self-TOF detector.