Equipments for Neutron Induced Experiments by Using a Monoenergetic Neutron Beam

著者	Niizeki T., Ishii K., Kabasawa M., Kawamura T., Maeda K., Miura K., Orihara H., Takahashi Y.
journal or publication title	CYRIC annual report
volume	1986
page range	98-102
year	1986
URL	http://hdl.handle.net/10097/49340

I. 19 Equipments for Neutron Induced Experiments by Using a Monoenergetic Neutron Beam

Niizeki T., Ishii K.**, Kabasawa M., Kawamura T., Maeda K.*, Miura K.***, Orihara H.** and Takahashi Y.
Department of Physics, Faculty of Science, Tohoku University
College of General Education, Tohoku University*
Cyclotron and Radioisotope Center, Tohoku University**
Tohoku Institute of Technology***

Recently, monoenergetic neutron beams of a medium-low energy region ($20 \leq E_p \leq 100$ MeV) have began to use as a comparative probe with protons to study the nuclear structure and reaction mechanism. In particularly, the studies of the (n,γ)[1], (n,n')[2] and (n,p)[3] reaction have shown the usefulness of these kinds of research. Here we describe the facilities and technique for the monoenergetic neutron beams which have been applied for the neutron scattering experiments. These developments have been carried out at the neutron time-of-flight (TOF) facility of the Tohoku University AVF cyclotron. An application of the neutron beams has provided the neutron scattering experiments of the angular range from 10° to 145° at 35 MeV. Some comments about future developments for the study of neutron induced reactions such as (n,γ), (n, charged particle) and (n,n'X) measurements are also presented.

Neutron production targets

A monoenergetic neutron beam was obtained by use of the charge exchange reaction of $^7Li(p,n)^7Be$ (Q = -1,644 MeV). Natural Lithium (about 93% abundance of ^7Li) targets are bombarded by protons. The neutron production target was placed at the exit of the beam swinger magnet. This technique made it possible that the measurements of the angular distributions of the emitted particles were carried out at a fixed place by changing the direction of the incident neutron beams. Energy spread of the neutron beam was obtained about 700 keV which was consisted of the energy loss of the incident protons in the production target and the inseparable contamination of the first excited state of ^7Be. This transition located at an excitation energy of 0.429 MeV was populated as almost same strength as the ground state transition. The second excited state of ^7Be at an excitation energy of 4.57 MeV sometimes seriously interfered with inelastically scattered neutrons. The continuous background above 3.24 MeV in an excitation energy region of the final state did not contribute the difficulty of the background subtraction at the time to get the yields of inelastically scattered neutrons. The primary proton beam was stopped by the water (H_2O) which did not make the background at the lowlying region of the residual nuclei because of the large negative Q-value (Q = -16.21 MeV) of the $^{16}O(p,n)^{16}F$ reaction. An illustrative figure around the neutron production target and is shown in Fig. 1.

Shadow bar and collimation system

The main source of the background was considered to come from the air and the materials near around the scattering target. At the time of forward angle measurements, intense neutrons from the production target made serious backgrounds. In order to reduce these backgrounds at the direction of the detector position, concrete walls of one meter long, and collimaters constituted with lead and iron blocks were placed. A shadow bar was also used to prevent neutrons come from the production target. This system shown in Fig. 1 made it possible to measure the scattered neutron at the minimum angle of $\theta_{Lab.} = 10°$.

Scattering targets

In the case of neutron scattering experiments, it is very difficult to collimate the neutron flux. The scattering targets can not be supported by a massive frame which is a usual way for the charged particle induced reaction. Thus the targets have to be suspended with very little mass compared with target itself to minimize the background from the target frame. We used nylon strings to suspend the scattering target as shown in Fig. 1.

Neutron detectors

Two types of neutron detectors were used to provide the events for neutron signals. One type was the same as described in Ref. 4, having the dimensions of 50 cm length, 10 cm height and 5 cm width being filled with NE213 liquid scintillator. The other type is a cylindrical container of NE213 liquid scintillator with the dimensions of 20.3 cm ϕ in diameter and 5 cm in depth, to which a 12.7 cm ϕ photomultiplier was coupled. As shown in Ref. 4, both type have a good character of the n-γ discrimination and time resolution.

Neutron beams

A typical neutron energy distributions are shown in Fig. 2, where the neutrons have been produced by the $^{7}Li(p,n)^{7}Be$ reaction at E_p = 37 MeV. The neutron flux was obtained from the cross section for the $^{7}Li(p,n)^{7}Be$ reaction averaged over the angles near 0°.

Applications

The arrangement described here gives a monoenergetic neutron beam of the variable incident angles on a scattering targets. This system makes it possible to measure the ejected particles and γ-rays from the neutron induced reaction by use of the large detector system at a fixed position. Several important applications about the neutron induced reactions are considered to be able to be done at the present energy region.

Radiative neutron capture reactions are one of the promising probe to investigate the isovector giant quadrupole resonance (IVGQR)[5] which has been observed only in pion single charge exchange reactions. The interference effect between the IVGQR and IVGDR gives the A_1 term of the Legendre polynomial in the angular distribution of the emitted γ-rays. The incident energy dependence of the A_1 term strongly varies at the location of the IVGQR. In order to study the isovector excitation mode, (n,p) reaction (ΔT_z=+1) is also very useful. The advantages of the (n,p) reaction compared with the (p,p)(ΔT_z=0) and (p,n)(ΔT_z=-1) reaction considered to be followings; (1) isovector components are concentrate to the $T=T_0+1$ state, (2) there is no background come from $T=T_0$ and $T=T_0-1$ component and $T_<$ excitation, (3) statistical background is considered to be small because these states can be observed at lowlying region of the residual nucleus. Thus, the study of the isovector excitation mode (IVGDR, IVGQR etc.) by use of the neutron beam expected to be performed.

References

1) Snober V. A. et al., Phys. Rev. Lett. 32 (1974) 317.
2) Finlay R. W. et al., Nuclear Instruments and Methods 198 (1982) 197.
3) Brady F. P. et al., Proceedings of International Conference on Spin Excitations in Nuclei (Telluride). Edited by Petrovich, Brown, Garvey, Goodman, Lindgram and Love. pp. 382.
4) Orihara H. and Murakami K., Nucl. Instrum. and Methods 188 (1981) 15.
5) Bergquist I. et al., Proceedings of the 1983 RCNP International Symposium, pp. 861.

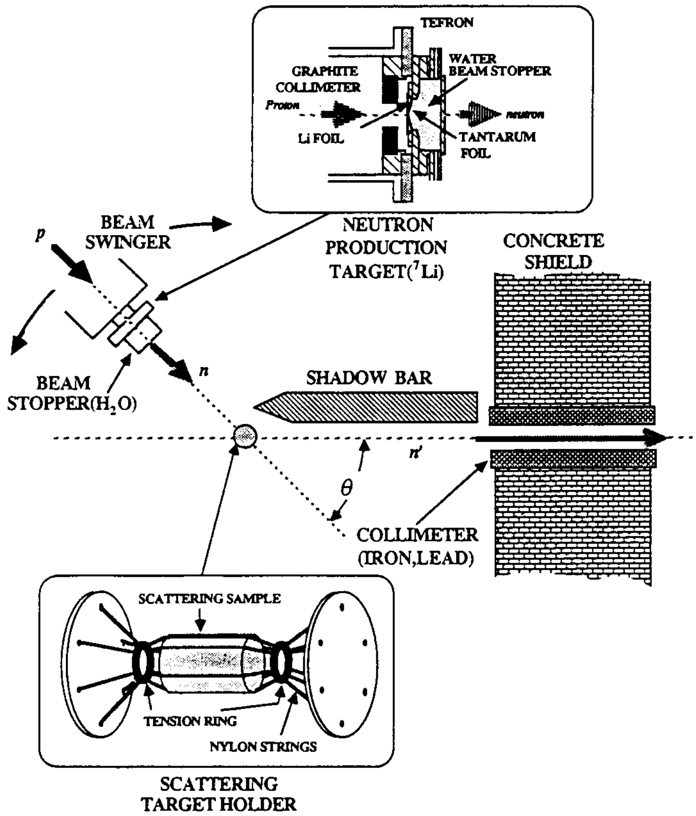

Fig. 1. Layout of the neutron scattering experiment.

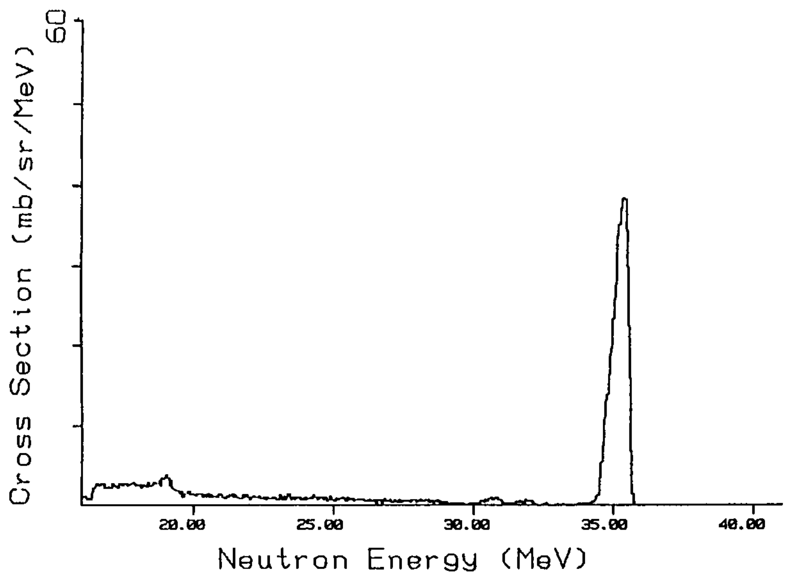

Fig. 2. Neutron energy distribution from the $^{7}Li(p,n)^{7}Be$ reaction.

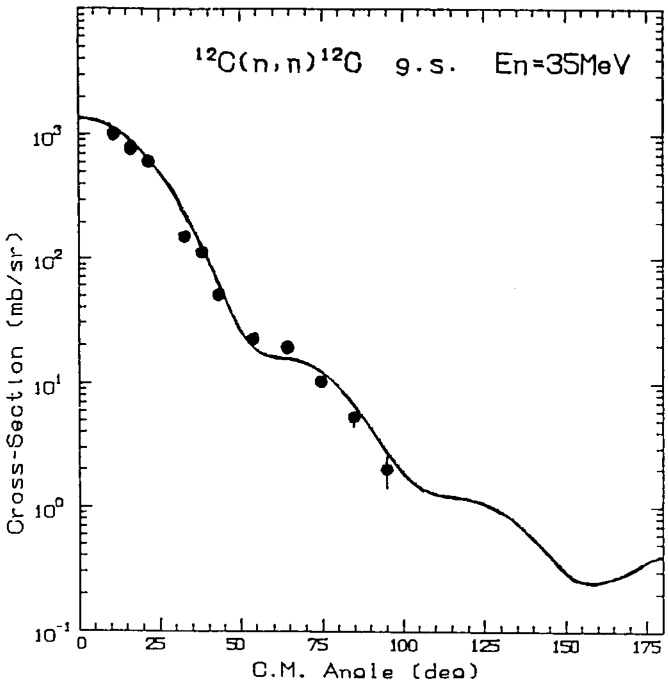

Fig. 3. Angular distributions of the $^{12}C(n,n')^{12}C$ reaction.