GROOVED COLD MODERATOR TESTS

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ABSTRACT

We performed some grooved cold moderator experiments for methane at 20 K by using the Hokkaido University linac to obtain information to be used in the planning of the KENS-I' project. Cold neutron gains, spatial distribution of emitted beams and time distribution of the neutrons in the grooved cold moderator were measured. Furthermore, we assessed the effects of the grooved cold moderator on the performances of the spectrometers presently installed at the KENS-I cold source. We concluded that the grooved cold moderator benefited appreciably the performances of the spectrometers.

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1. INTRODUCTION

From the results of our experiments and laboratory experiences using the Hokkaido University cold source and the KENS source over a period of several years, we have concluded that the accelerator-based cold neutron source using a 20 K methane moderator is a safe, reliable and highly efficient device which can be applied as both a photo neutron source and a spallation neutron source$^{1\sim4)}$. Current operations of the KENS cold source have proved to be satisfactory, and it has been useful in many studies embracing various fields since fiscal year 1980.

The KENS-I' project is designed to increase the intensity of the present KENS-I source. This endeavor will require several sophisticated techniques$^{4)}$ among which is the optimum design and use of a grooved cold moderator chamber which will be feasible and economical. Several authors investigated the grooved moderator for thermal neutrons, but no work on the grooved cold moderator has been done as yet$^{5,6)}$. Current plans call for the installation of the new chamber in the presently in use fast neutron reflector under its limited space and restricted design conditions. In order to decide the appropriate dimensions and to get quantitative data of the pulse shape which will be needed to assess its influence on the performance of the spectrometers, we performed some preliminary experiments on the 20 K methane grooved moderator by using the cold source facility at Hokkaido University. Some of the results of the experiments and an assessment of the grooved cold moderators are reported in this presentation.

2. EXPERIMENTAL METHOD

The techniques used in the present experiments took advantage of the ordinary neutron time-of-flight technique and cryogenic facilities for the cold moderator. The experimental arrangement, shown in Fig. 1, has already been described in some detail in connection with the Hokkaido University cold source[2].

The grooved moderator chamber and a new flat one of the same dimensions as the KENS cold source replaced the commonly used cold moderator chamber. We purchased both a grooved chamber and a flat one made of aluminum, the dimensions of which are shown in Fig. 2, and attached them to the bottom of the heat exchanger of the cold source facility instead of to the actual moderator chamber. Because of the occurence of clogging of the methane at the entrance of the gas inlet tube, we had to replace the inlet tube with a wider one.

For the measurements of spatial dependence of the neutrons emitted from the grooved surface of the chamber, we utilized a movable, remotely controlled slit plate which was made of cadmium. The size of the slit was 4 mm in height and 100 mm in width, and the slit was placed parallel to the grooves and at the outside of the Dewar chamber as shown in Fig. 1. The measurements of the time dependence of the neutron pulse emitted from the chamber were performed by using the time-of-flight technique and a mica monochrometer.

3. EXPERIMENTAL RESULTS

A. Time-of-flight spectra

Emitting neutrons from a methane moderator at 20 K, the grooved and flat moderators had unique time-of-flight spectra as shown in Fig. 3. Both spectra were normalized for the fast neutron intensities emitted from the target. Relative fast neutron intensities were determined by measuring the β-activity induced by the (n,p) reaction of aluminum. A large enhancement of the time-of-flight spectra took place in the cold neutrons, resulting in an approximately doubled neutron gain.

B. Spatial dependence of emitted beams

Considerably irregular spatial distribution of the emitted neutron beam from the grooved surface was expected. We measured the dependence of the beam along the vertical direction of the grooved chamber by using the movable cadmium slit described above. Figs. 4 and 5 show the measured data for neutrons of energies 2, 5 and 50 meV respectively.

Although the overall spatial dependence in the grooved moderator was similar to the one in the flat moderator, the ratio of the intensities of the beams emitted from the bottom and the top of the grooves was cosiderably high. As seen from the figures, the ratio became larger as the neutron energy decreased.

C. Time dependence of pulses

We next measured the time dependence of the pulses by using a mica monochrometer with Bragg angle of 85°. Figs. 6 and 7(a) show the pulse spectra of 5.26 meV neutrons emitted from the tops and the bottoms of the grooves and from the whole grooved surface, which were all normalized to the peak height.

Fig. 7(b) shows a comparison of the three pulse spectra from the grooved moderator and a spectrum from the flat moderator. As is clearly recognized, the shapes of the pulses from the top and the bottom of the grooves are very similar but the starting time of the sharp rise in the latter one has a time delay of about 40 μs compared to the former one. This time delay approximately corresponds to the time-of-flight of the groove height for 5 meV neutrons. Thus the shape of the pulse spectra from the whole surface of the grooved moderator is apparently distorted as compared to the one from the flat moderator; moreover, the effective width is appreciably longer than that of the flat moderator.

4. EFFECTS OF PULSE SHAPE DISTORTION ON PERFORMANCE OF SPECTROMETERS

We report in this section our assessment of the effects of pulse shape distortion on the performance of the spectrometers. There are three spectrometers installed at the KENS' cold neutron source: SAN: a small angle scattering spectrometer, TOP: a polarized neutron spectrometer and LAM: a quasielastic spectrometer.

The former two spectrometers are equipped with 20 m long neutron guide tubes which provide sufficient time-of-flight length of incident neutrons. Thus pulse shape distortion is not a problem in the case of the former two. Furthermore, the increase of total intensity benefits primarily their performances.

In the case of the LAM, which is a conventional energy resolution quasielastic spectrometer, the pulse shape distortion affects the resolution to some extent. To assess this effect we calculated the elastically scattered neutron spectra from both the grooved and the flat moderators. The measured intensity distribution, y(t), on the time analyser is related to the neutron cross section $\sigma(E_1 \rightarrow E_2)$ and various instrumental conditions[7),

$$y(t) = \text{const.}\iint \eta(E_1)Z(t - \frac{l_1}{\sqrt{2E_1/m}} - \frac{l_2}{\sqrt{2E_2/m}})\sigma(E_1 \rightarrow E_2)R(E_2)dE_1dE_2$$

where $\eta(E_1)$ is the energy spectrum of neutrons emitted from the moderator, $Z(\tau)$ is the time distribution of the pulse, τ is the emission time, $R(E_2)$ is the resolution function of the analyser for the scattered neutrons and l_1 and l_2 are the first and second flight path lengths respectively.

Fig. 8 shows the calculated results of y(t) in the cases of the grooved and the flat moderators in which the cross section was assumed to be elastic and synthesized time distributions were used as shown in Fig. 9. As seen from Fig. 8, the effective pulse width in the case of the grooved moderator is about 15 percent longer than that obtained from the flat moderator. However, there is no appreciable difference in the pulse shape on the rising side. In the case of the LAM, intrinsic resolution is determined by the pulse shape on the rising side. Therefore, it was proved that the grooved cold moderator operates efficiently without diminishing resolution performance.

References

1) K. Inoue, et al.: J. Nucl. Sci. Tech., 13(1976)389.
2) K. Inoue, et al.: Nucl. Instr. Meth., 192(1982)129.
3) Y. Ishikawa, et al.: Proc. 4th Int. Collaboration on Advanced Neutron Source(ICANS), Tsukuba, Japan(Oct.1980).
4) N. Watanabe, et al.: Proc. 6th Int. Collaboration on Advanced Neutron Source(ICANS), Argonne, USA(June 1982).
5) J. M. Carpenter: Proc. 4th Int. Collaboration on Advanced Neutron Source(ICANS), Tsukuba, Japan(Oct.1980).
6) G. S. Bauer: ibid.
7) K. Inoue, et al.: Nucl. Instr. Meth., 178(1980)459.

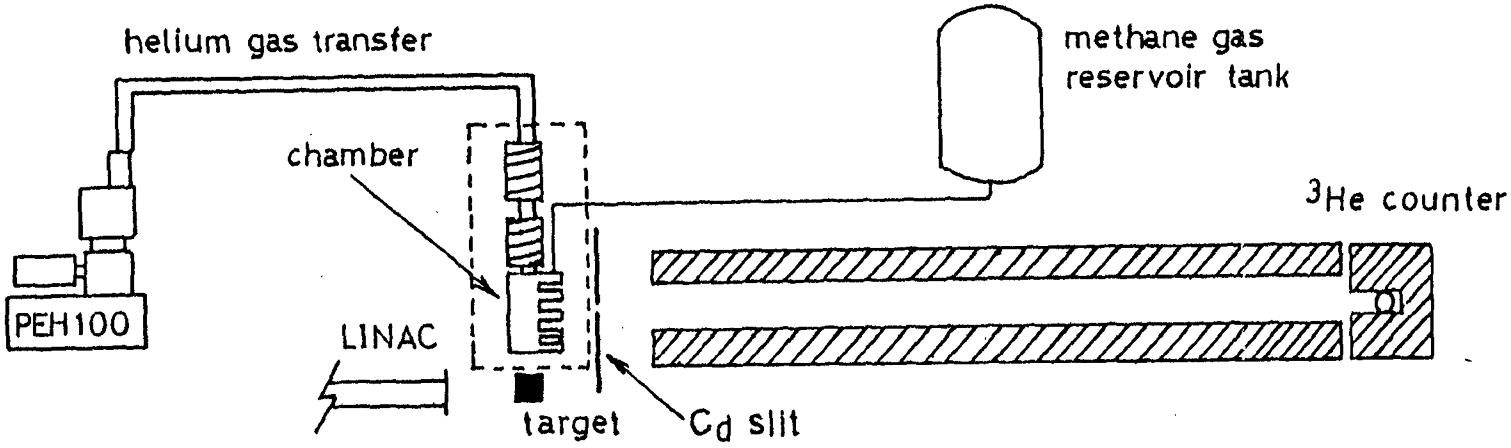

Fig. 1 Layout of the experimental facilities.

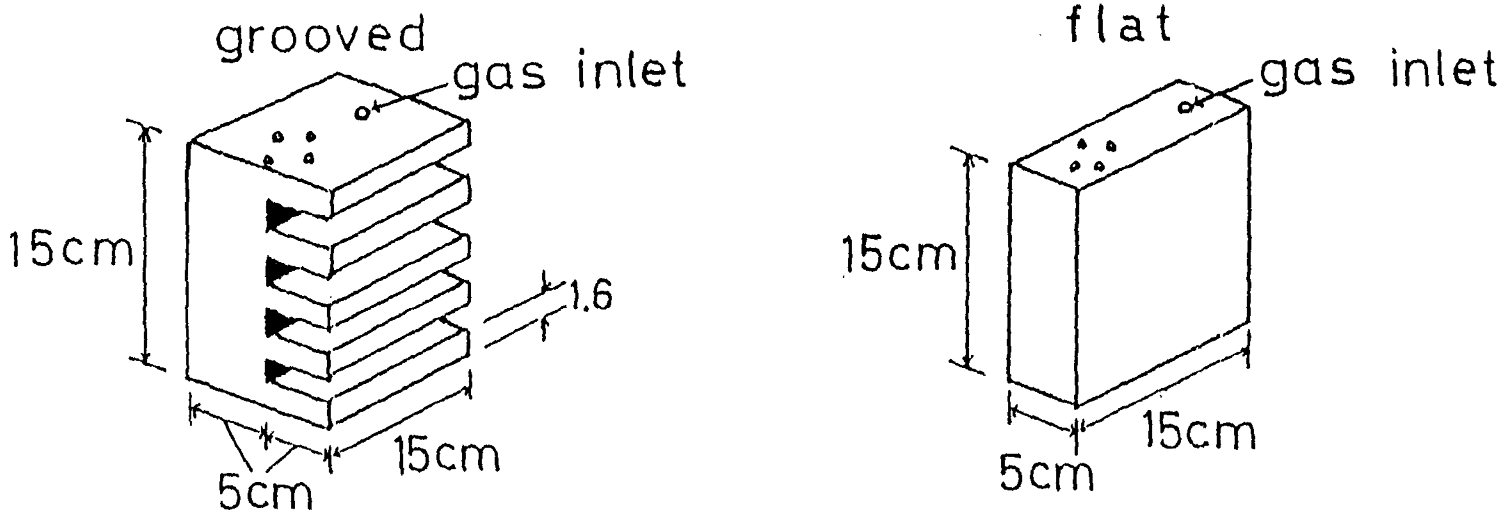

Fig. 2 Grooved and flat methane chambers.

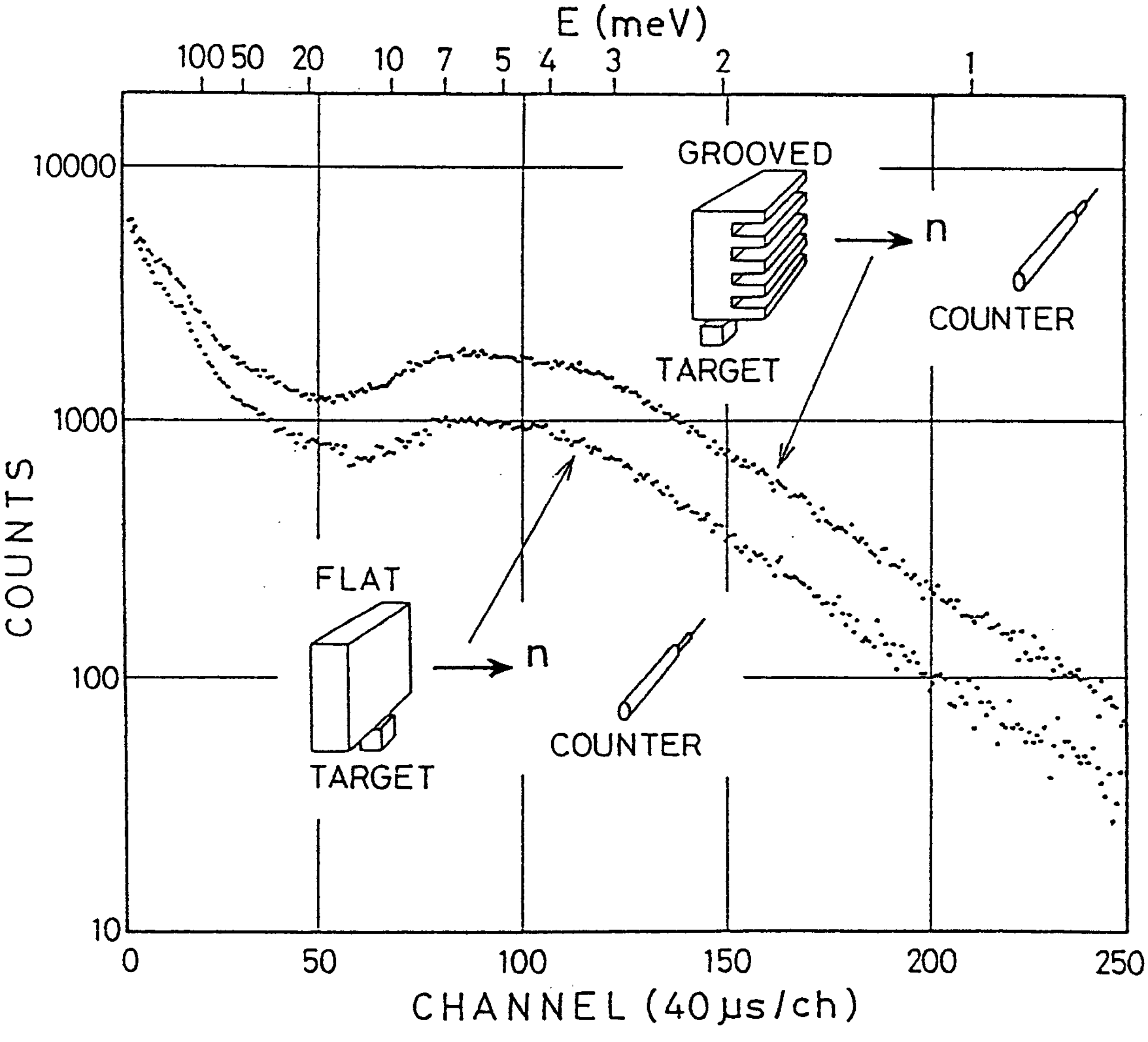

Fig. 3 Time-of-flight neutron spectra from grooved and flat moderators.

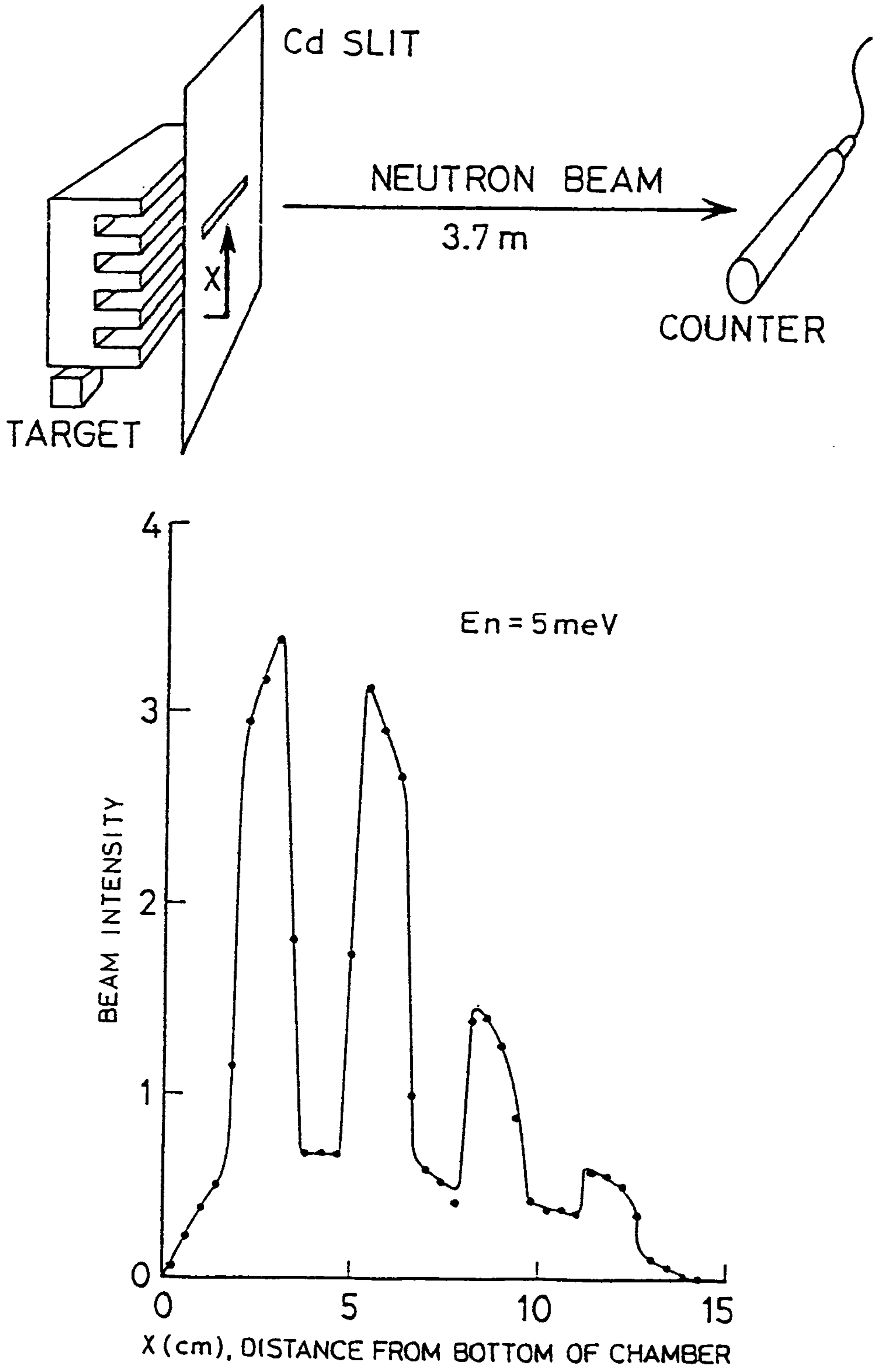

Fig. 4 Spatial dependence of emitted neutron beam with energy 5 meV.

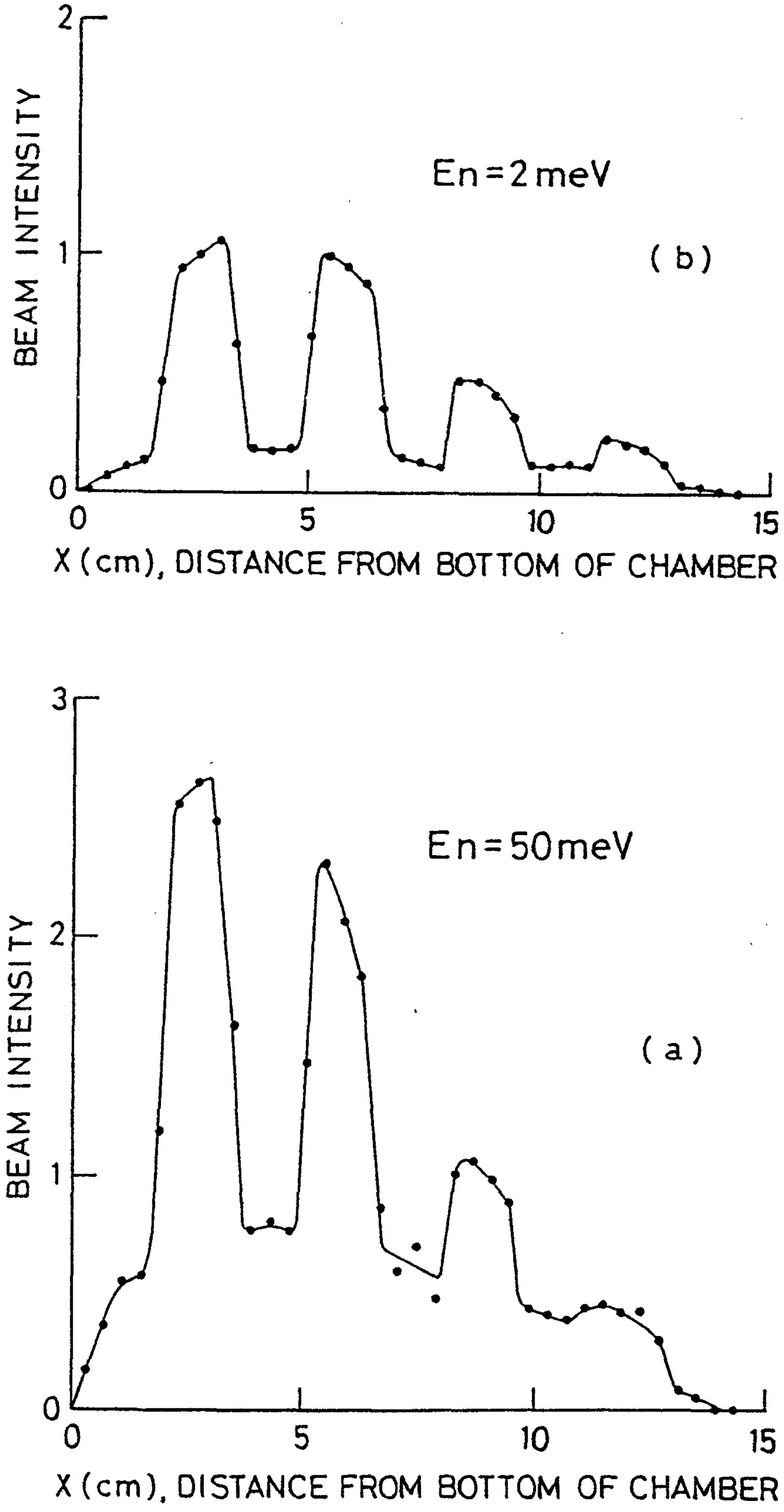

Fig. 5 Spatial dependences of emitted neutron beams with energies 50 meV:(a) and 2 meV:(b).

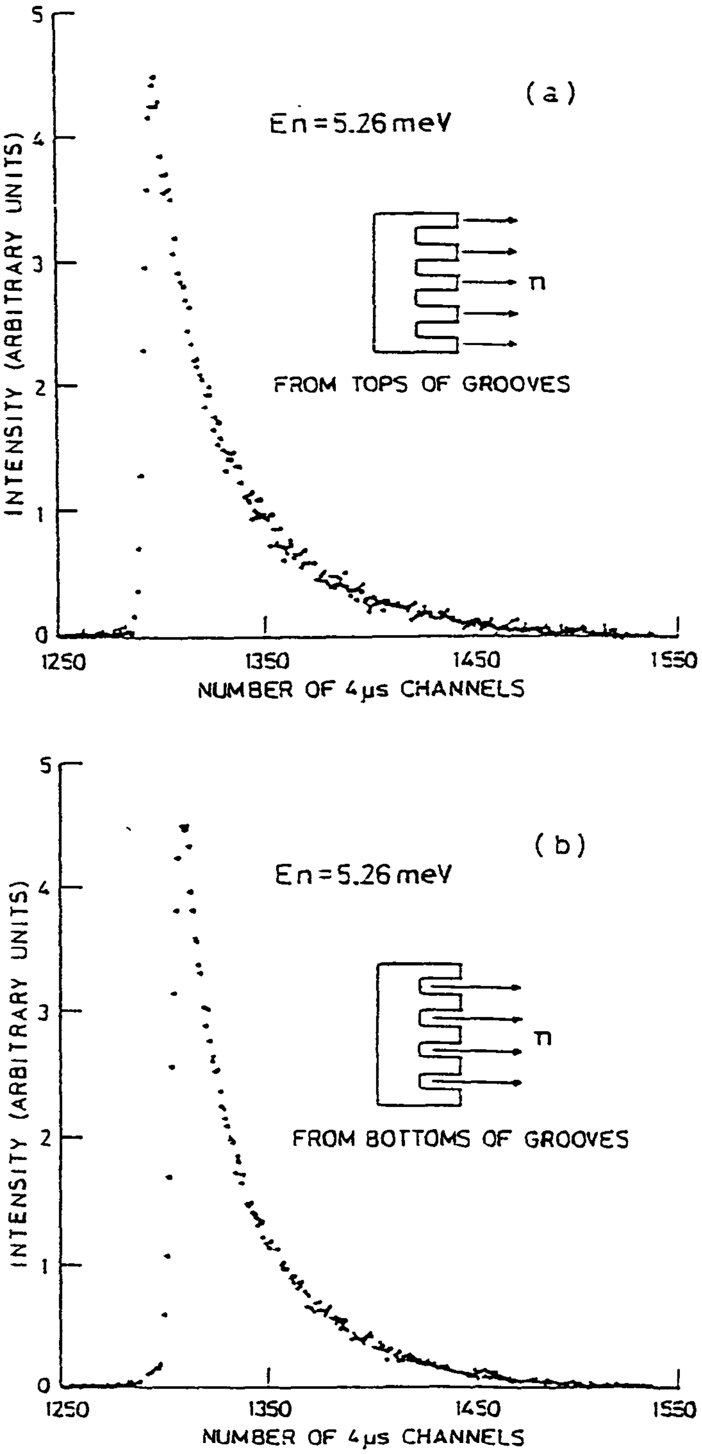

Fig. 6 (a) Time distribution of the pulse of neutrons emitted from the tops of the grooves. (b) Time distribution of the pulse of neutrons emitted from the bottoms of the grooves.

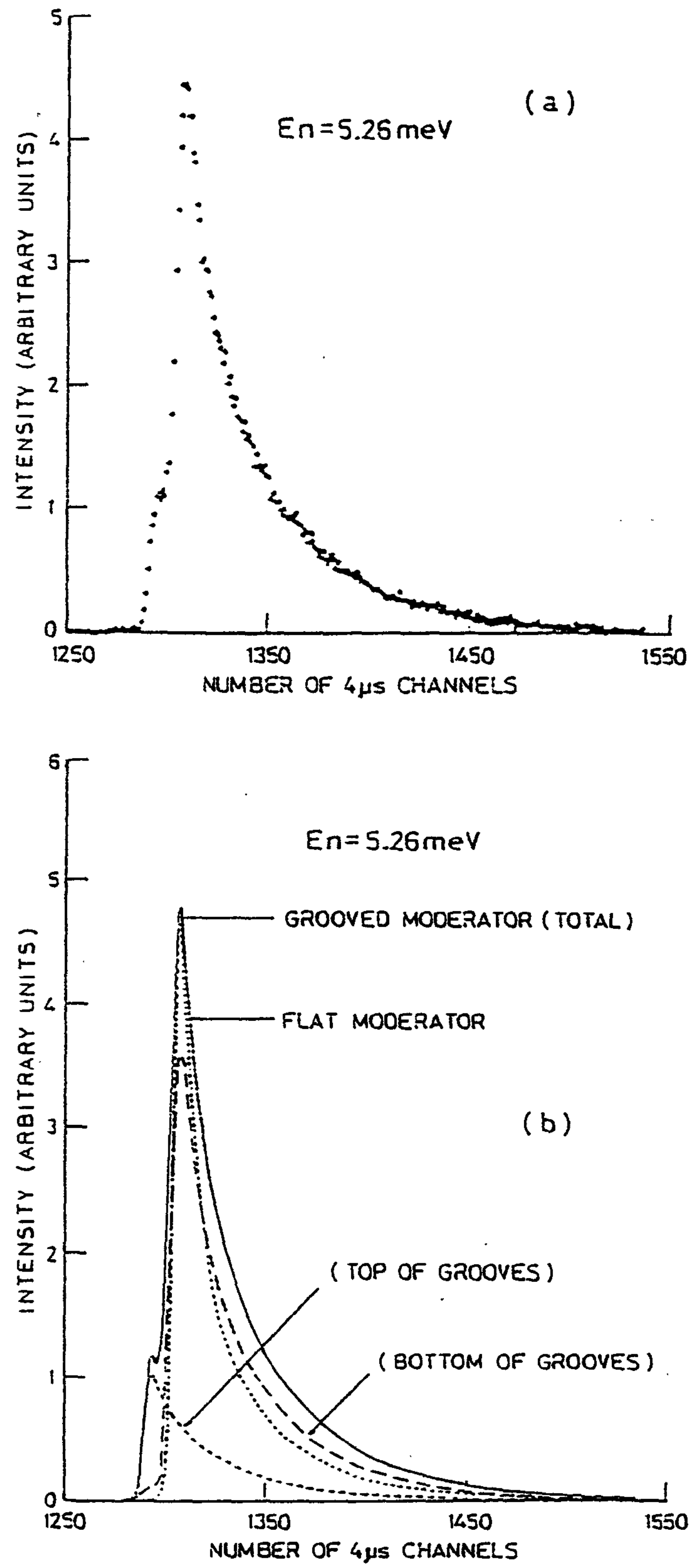

Fig. 7 (a) Time distribution of the pusle of neutrons emitted from the whole surface of the grooved chamber. (b) Comparison of the three pulses emitted from the tops and the bottoms of the grooves and the whole surface, and the pulse emitted from the flat chamber.

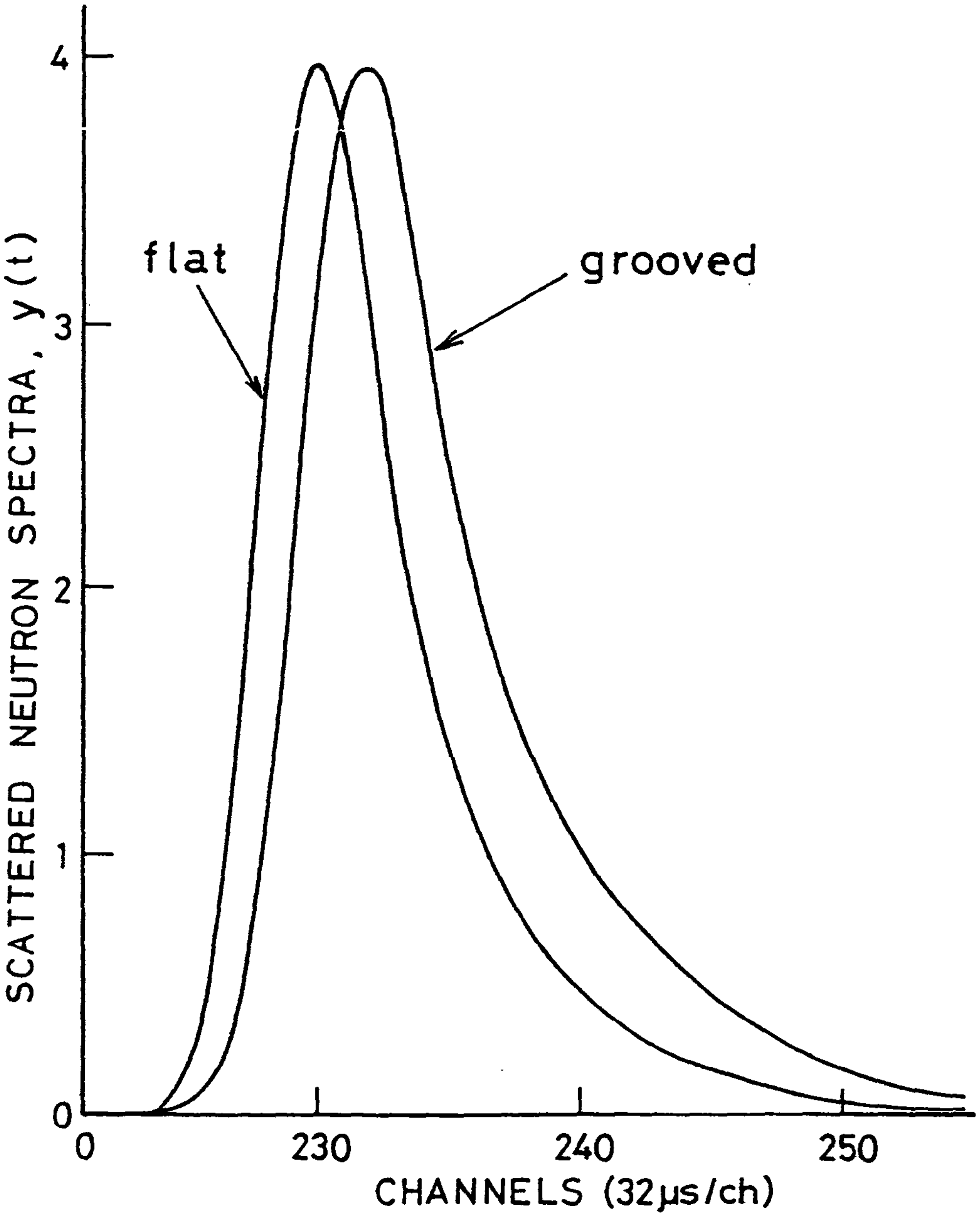

Fig. 8 Calculated scattered spectra for the grooved and the flat moderators using an elastic scatterer. These data exhibited effective resolutions.

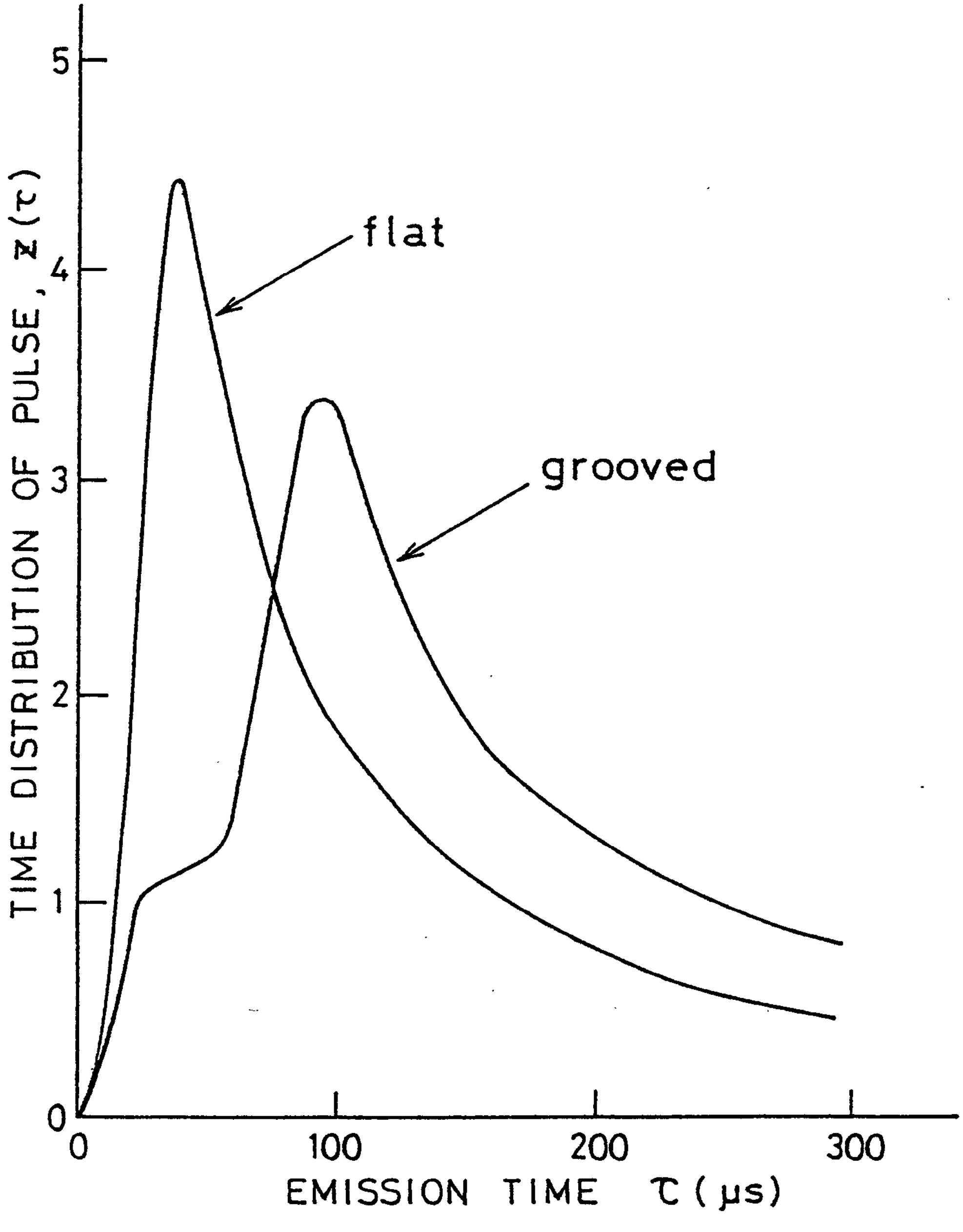

Fig. 9 Synthesized time distributions of the pulses used in the spectral calculation.