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Measurements of neutronic characteristics of the KENS target-moderator-reflector assembly

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Abstract

Neutron beam characteristics were measured at KENS regarding the renewal of the target-moderator-reflector assembly. The recovery of the cold neutron flux was confirmed as well as improvements in the pulse shape of the thermal neutrons. The measurements were also compared with LCS (LAHET code system) neutronic calculations.

Introduction

The target-moderator-reflector assembly (TMRA) of the spallation neutron source at KEK (KENS) was renewed due to diminution of the cold neutron flux which was caused by deterioration of the cadmium decouplers [1]. The new TMRA was designed not only to recover the cold source but to have several improvements. The features are:

1. a full recovery of the cold neutron flux by the installation of a new decoupler,
2. a beryllium-graphite composite reflector replaced the full beryllium reflector to minimize the cost with little reduction in the beam intensity,
3. a change of the decoupling energy from 400 eV to 100 eV in the thermal source resulting in an increase of the thermal and epi-thermal neutron flux,
4. thermal neutrons with narrower pulse widths by poisoning the thermal moderator with gadolinium,
5. a 20% increase of neutron flux by a replacement of the tantalum target blocks by those of tantalum-clad tungsten.

Before and after the renewal, series of measurements were performed to characterize the thermal and cold sources; the absolute neutron intensities, energy spectra, and pulse shapes were measured.

Measurements

The measurements were carried out on the beamlines H9, C1, and C4 (Fig. 1). The thermal moderator, ambient temperature light water, is facing normal to the incident proton beam, and the cold moderator, solid methane at 25 K, is placed at 45°. Detailed descriptions of the KENS TMRA can be found in Ref. [1, 2].

The absolute neutron intensities were measured by means of activation detectors on the C4 and H9 beamlines. The cadmium subtraction method was employed to obtain the thermal or cold flux. The neutron capture cross section for the activation detectors, thin gold plates, were calculated with the measured energy spectra. Neutron energy spectra were measured on the same beam lines with a U-235 fission counter. TOF counts were properly converted to the energy spectrum with the U-235 fission cross section. Neutron pulse shapes were measured on the C1 and H9 beamlines with He-3 counters by monochromating the beams with mica or pyrolytic graphite (PG). PG was used at 20 K to reduce the thermal diffuse scattering, and mica was at room temperature. The first to 15th Bragg scattering peaks of PG (002), corresponding energies of 1.87 meV to 416 meV, were observed, and the second to 26th peaks of mica, 0.841 meV to 142 meV, were measured. Apparatus for the pulse shape measurement is schematically drawn in Fig. 2.

The measurements were compared with full TMRA modeled LCS (LAHET code system) neutronic calculations. See Ref. [1] for details on the calculation.

Results

Neutron energy spectra for the cold and thermal sources are shown in Fig. 3 together with LCS neutronic calculations. Figure 3(a) clearly shows the recovery of the cold neutron flux; the neutron intensity has been tripled below 0.4 eV, but no change above. The change in the energy spectrum confirmed that the deteriorated cadmium decoupler was blocking the neutron beam. One can notice that the Maxwellian peak energy of the new spectrum is slightly lower than the old. The new moderator has the same structural design but better thermal insulation that effects a 19% reduction of the methane temperature with the same refrigerator. The LCS calculation agrees with the measurement except the lower energy regions (< ~10 meV) where the methane cross section kernel is not adequately reliable.

Figure 3(b) shows the neutron energy spectra for the thermal moderator. Several changes in the TMRA design have resulted in different spectra. At higher energies (> 100 meV), the intensity is increased by a factor of 1.3 due to changes of the target material, the reflector elements, and in the decoupling energy. In the thermal energy region (1 meV - 100 meV), it is slightly decreased by the gadolinium poisoning, and again increasing toward the minimum energy. This trend corresponds to the pulse widths shown in Fig. 4(b) where the new pulse width is narrower only in the thermal energy region. The energy spectra of the measurement and the LCS calculation for the light water moderator are in good agreement.

The absolute intensities are summarized in Table I. Several corrections were applied to the measurement to represent the moderator surface flux. Neutron scattering in the air and in vacuum windows, the cos θ law, self-shielding of the activation detector, and other small corrections were properly applied. The systematic uncertainty on the measured intensity was 5% which was dominated by the activation measurement. The neutronic calculations in the table are listed as the neutron flux which is to be absorbed in 0.5 mm thick cadmium. Statistical errors on the measurements and calculations are both 2%. The LCS calculations are in good agreement with the measurements except that for the cold moderator in the old TMRA, where no cadmium decoupler deterioration was simulated.

The neutron pulse widths are shown as FWHM (full width half maximum) in Fig. 4. The FWHM was obtained by subtracting the time resolution after fitting the pulse shape with the Cole-Windsor function [3]. The time resolution of the pulse corresponded to the energy dispersion of the monochromatic beam. It was dominated by the beam divergence, and the correction for it became 1% at the lowest energy and 4% at the highest. For the cold moderator, the pulse widths in the measurements are essentially the same except for the fact that the pulse widths in the new TMRA measurement are shifted to lower energy by 19% due to the moderator temperature change.

For the thermal moderator, the effect of the gadolinium poison is obvious. The width is narrowed by 10% - 20% in the thermal energies. Wider pulses below the Maxwellian peak are due to slower rise time, and only a small difference in the pulse width seems to exist between with and without the gadolinium poison. It is not well understood yet, and further investigations are under way. The neutronic calculations have less qualitative agreement with the measurements, but the energy dependence of the pulse width is quantitatively simulated. Some of the measured pulse shapes for the thermal moderator are plotted in Fig. 5. Higher peaks and steeper tails in the new measurements are apparent.

Conclusions

We measured neutron beam characteristics, the absolute intensity, energy spectra, and pulse shapes regarding the renewal of the TMRA at KENS, and we confirmed the following improvements:

1. the cold neutron intensity has been recovered,
2. the thermal and epi-thermal neutron flux has increased by a factor of 1.3,
3. the pulse shape of the thermal neutrons has been narrowed with an increase of the peak intensity.

We hope that scientific activities at KENS with the renewed spallation neutron source will flourish more than ever.

Acknowledgements

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References

[1] M. Kawai, S. Yasui, M. Furusaka, T.Ino, N. Torikai, and Y. Kiyanagi, "Renewal of KENS TMRA," this conference.
[2] N. Watanabe, S. Ikedam, and Y. Ishikawa, "KENS Target Station," Proc. ICANS-IV (1982) 181.
[3] I. Cole and C. G. Windsor, "The Lineshapes in Pulsed Neutron Powder Diffraction," Nucl. Instr. and Meth. 171 (1980) 107.

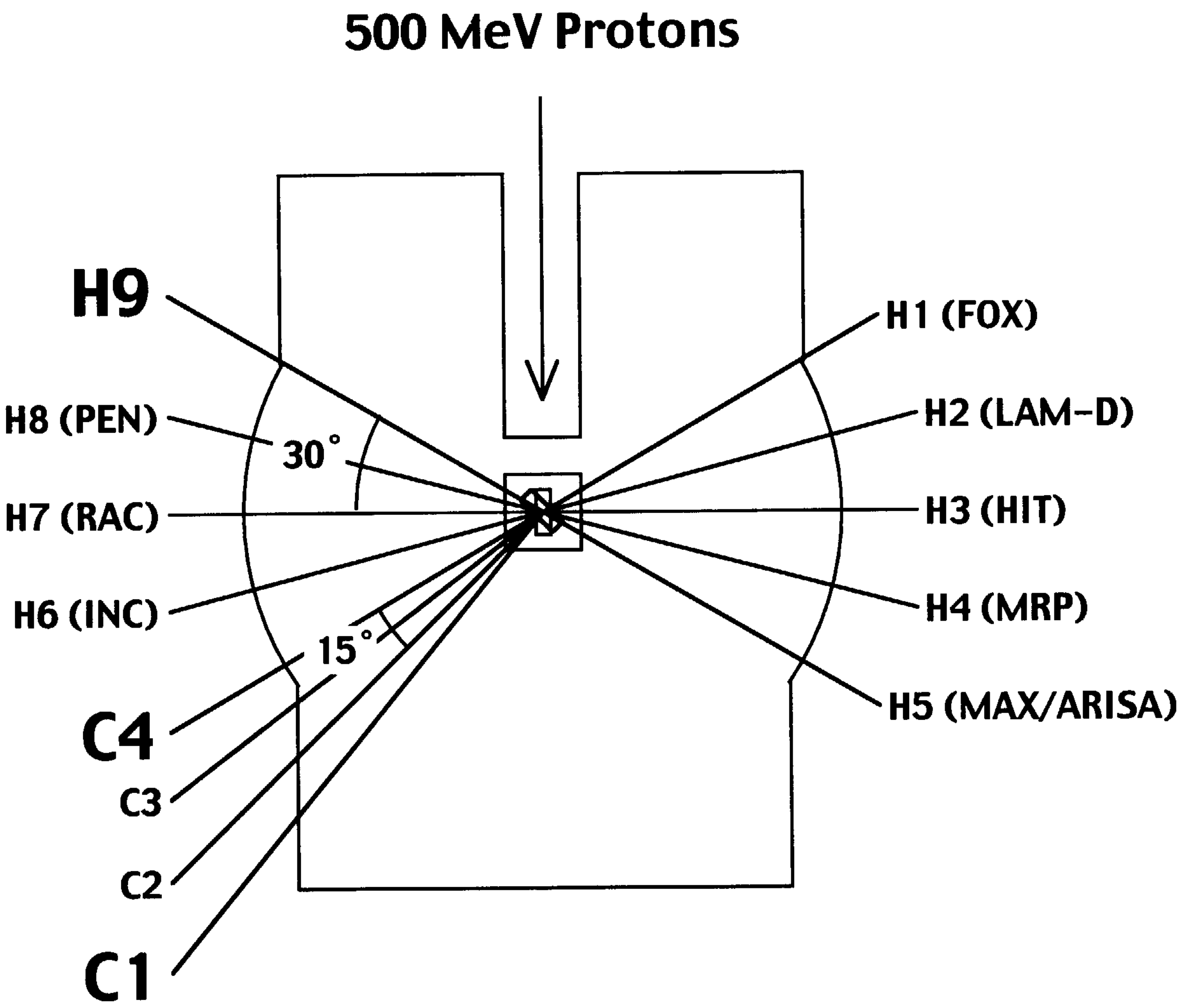

FIG. 1. KENS beamlines. Initials C and H indicate the cold and thermal beamlines. The H9 beamline looks the light water moderator surface at an angle of 30°; and the C4 at 15°.

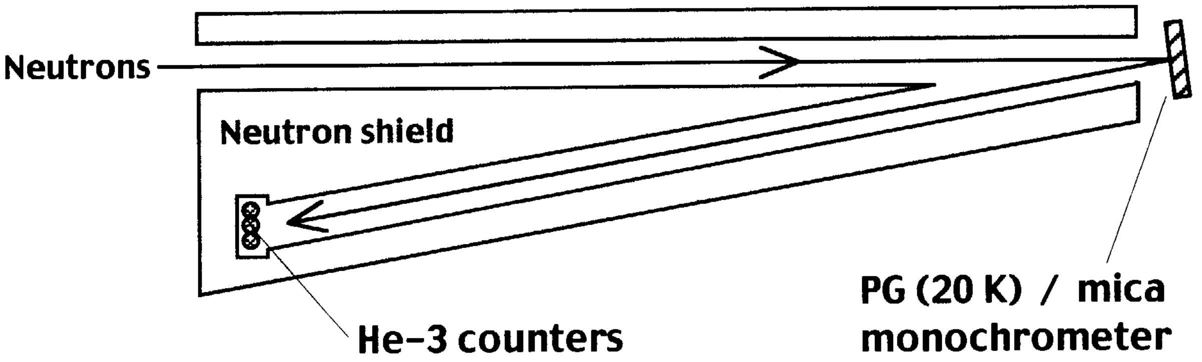

FIG. 2. Schematic view of the pulse shape measurement. The scattering angle is 85°. PG or mica was used as a monochrometer. Beam collimators are located upstream.

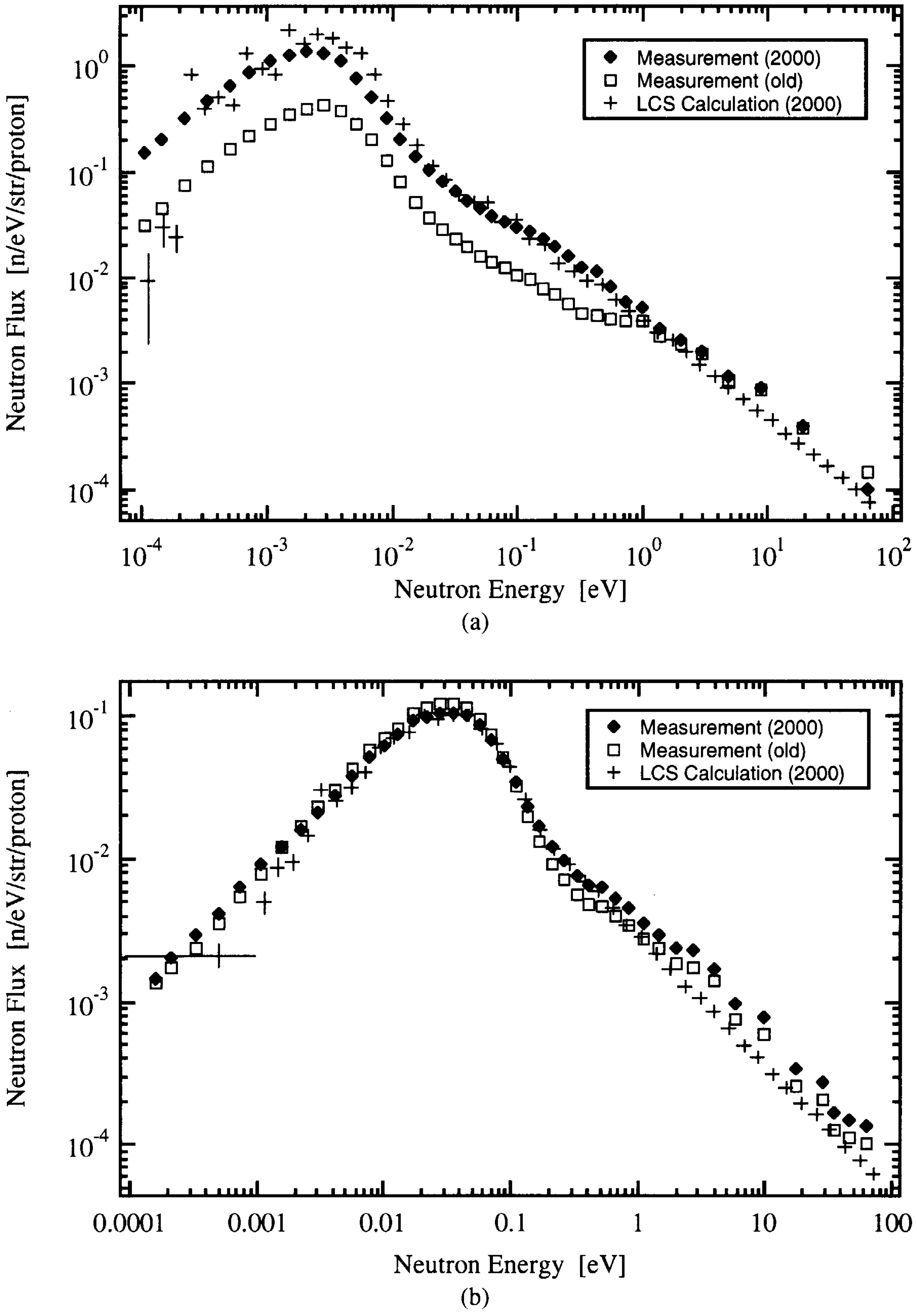

FIG. 3. Neutron energy specra for (a) the solid methane cold moderator and (b) the light water thermal moderator. The new and old TMRAs are represented as "2000" and "old," repectrively.

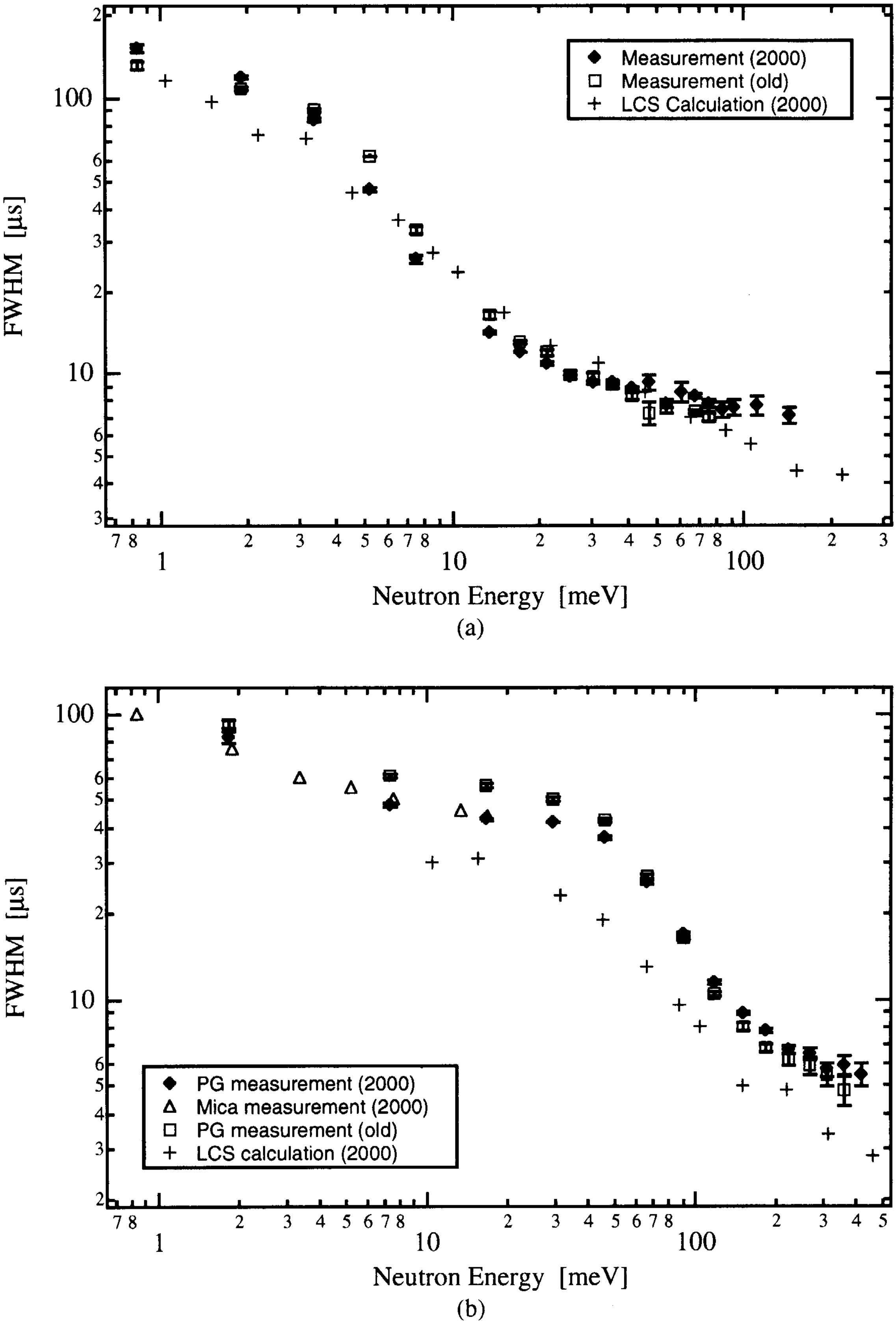

FIG. 4. Neutron pulse widths (full width half maximum) for (a) the cold moderator and (b) the thermal moderator. Mica was used in (a), PG and mica in (b).

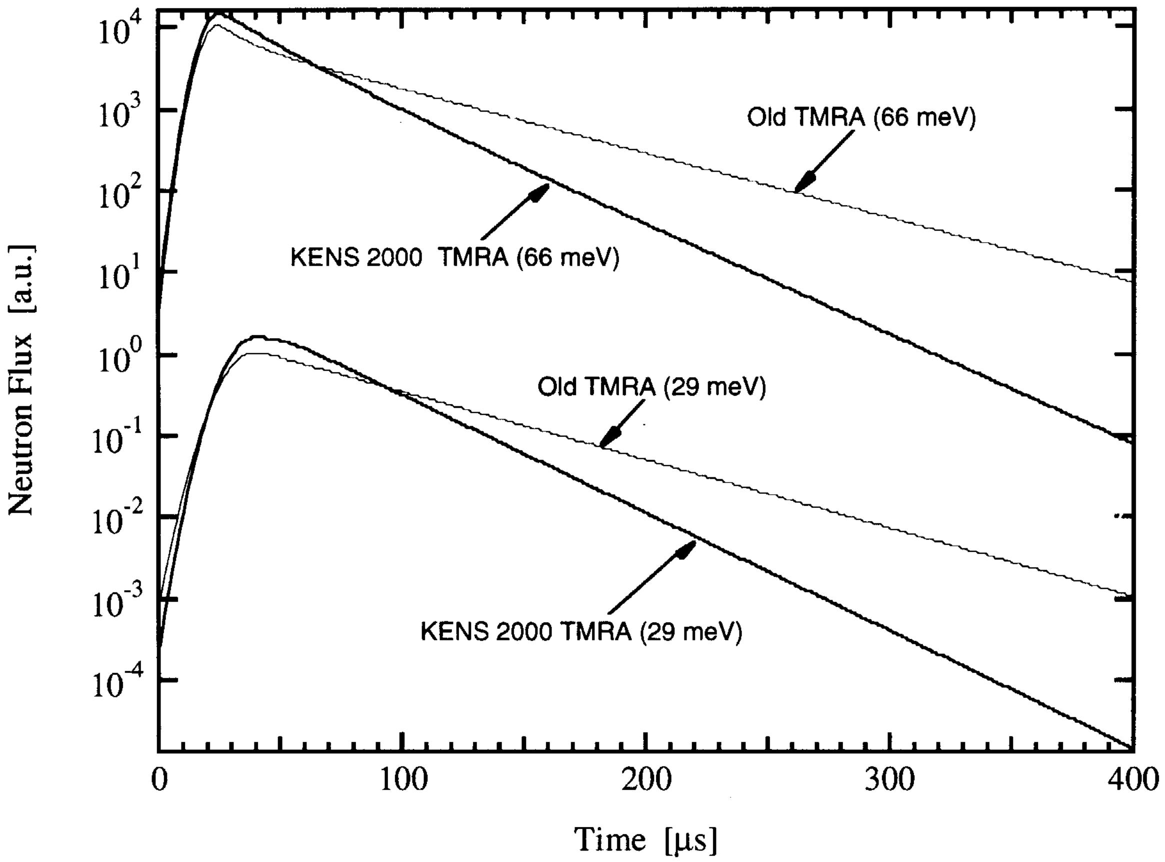

FIG. 5. Measured pulse shapes. The intensities are relatively normalized at each energy.

	Thermal Flux	Cold Flux
KENS 2000 TMRA		
Measurement	1.19×10^{-2}	1.90×10^{-2}
LCS Calculation	1.20×10^{-2}	2.17×10^{-2}
Old TMRA		
Measurement	1.17×10^{-2}	0.75×10^{-2}
LCS Calculation	1.11×10^{-2}	1.84×10^{-2}

TABLE I Absolute intensities of the thermal and cold neutrons. The units are neutrons/str/proton. Systematic uncertainties on the measurements are 5%. Statistical errors are 2% both on the measresments and on the LCS calculations.