ICANS-XI International Collaboration on Advanced Neutron Sources
KEK, Tsukuba, October 22-26, 1990

Some Neutronic Studies on Flux-Trap Type Moderator

Y. KIYANAGI and N. WATANABE*
Department of Nuclear Engineering, Faculty of Engineering,
Hokkaido University, Sapporo, 060 Japan
*National Laboratory for High Energy Physics,
1-1 Oho, Tsukuba-shi, Ibaraki 305 Japan

ABSTRACT

The neutronic performance of a flux-trap type moderator was studied by computer simulation in connetion with the KENS-II target-moderator system. It was confirmed that this system can provide 1.3-1.4 times higher neutron intensity than a traditional wing-geometry moderator system.

I. INTRODUCTION

A wing-geometry in target-moderator coupling is adopted in pulsed spallation source because it can diminish the leakage of fast and high-energy neutrons into the beam holes in comparison with a slab geometry. However, the intensity of slow neutrons emitted from a wing-geometry moderator is smaller than that from a slab-geometry one. A new type of target-reflector-moderator arrangement, a so called flux-trap type moderator, was proposed by the Los Alamos group1). A vertical proton-beam injection sheme is one of a solution to provide more neutron beams than a horizontal one, because the proton-beam line in the experimental hall can be removed in the front2). In the vertical injection sheme a flux-trap type moderator arrangement is indispensable, because the tremendous stream of fast and high-energy neutrons is unavoidable in a traditional wing-geometry. We performed some optimization studies on this moderator system by computer simulation and compared the neutron intensity between flux-trap type moderator and wing geometry one in order to examine whether this can be a promising candidate for the target-moderator system in KENS-II.

II. CALCULATIONAL MODEL

The calculational model of the target-moderator system is shown in Fig. 1. The proton energy proposed for KENS-II is 1 GeV. The target is split into two parts in flux-trap type moderator system. The target, in which protons are injected, is called here a front target and the other a rear target. The targets are made of tungsten. Total target length is 34.5 cm which is sufficient for 1 GeV protons to produce the saturated intensity of the spallation neutrons3). Four moderators are placed around the void space between the two targets. Light water moderators with a size of $10 \times 10 \times 5$ cm^3 are assumed. The system is surrounded by a beryllium reflector of 30 cm thick. The beam holes in the reflector are lined with 1 cm thick B_4C decouplers. They are not shown in the figure for simplicity.

For the calculation a Monte Carlo code for low energy neutron transport, MORSE-DD4), was used combined with a high energy transport code, NMTC/JAERI5). "slow neutrons" in this paper are defined here as those neutrons below 0.9 eV.

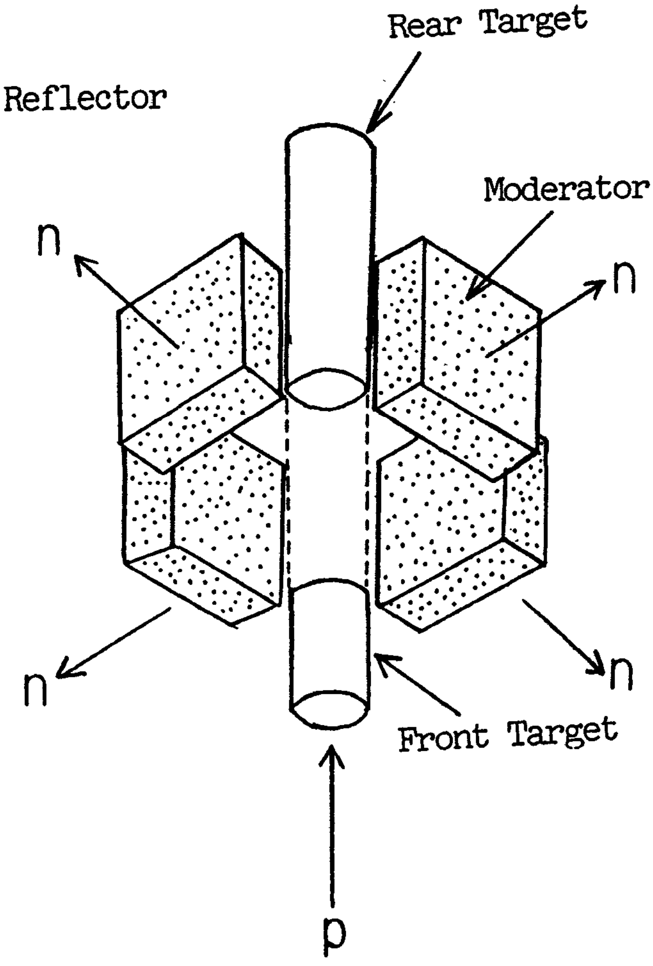


Fig. 1 Calculational model of the flux-trap type target-moderator system.

III. OPTIMIZATION STUDIES

Firstly, we examined the optimal length of the front target keeping the length of the void space between front and rear targets at 14 cm, which would just meet the moderator height of 10 cm with 1 cm thick decoupler and 1 cm allowances on top and bottom, and the target radius at 5 cm. The gap between moderator and target void was kept at 2 cm which is necessary to arrange the four moderators around the void space. Figure 2 shows the slow-neutron intensities from the moderators as a function of front-target lengths. The length dependence of the slow neutron intensity is rather modest : the optimal length is about 7-8 cm. We chose 7.5 cm for the front target length in the following calculations.

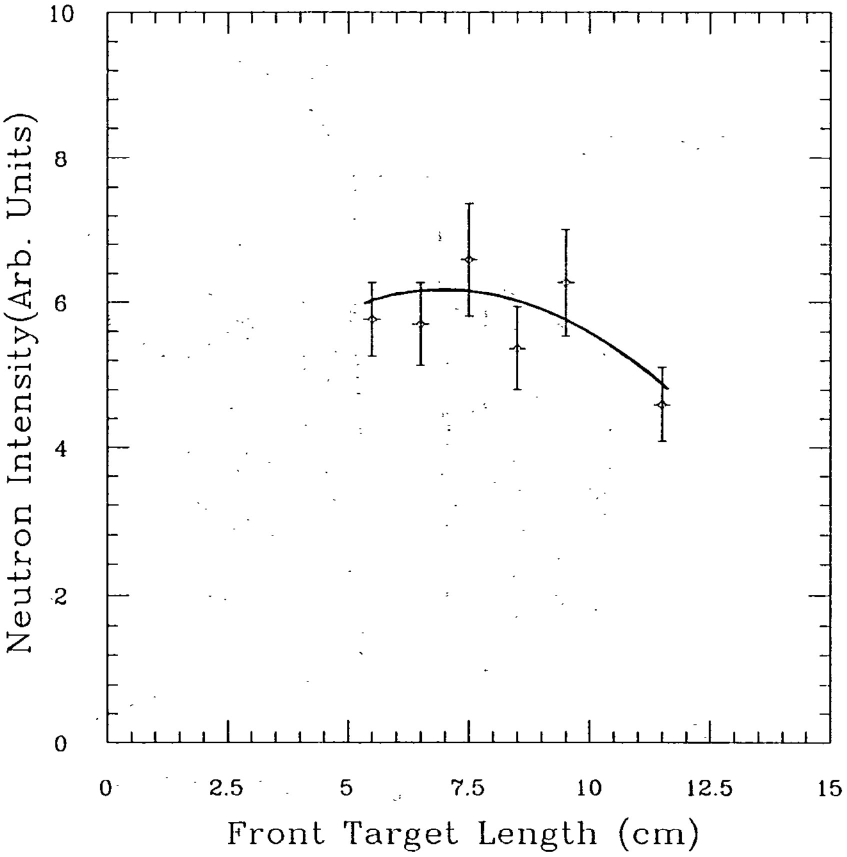


Fig. 2 Slow neutron intensity vs. front-target length.

Secondly, we examined the optimal target radius keeping the length of the target void at 14 cm, and the distance between the target center-line and the moderator at 7 cm. Figure 3 shows the slow-neutron intensities from the moderators as a function of target radius. The intensity is again unchanged up to a radius of about 8 cm. There is no gain with increasing target radius. This may be due to the tungsten target because the enlarged target simply bring about reflector missing without additional neutron production. We intend to look into a uranium target system later.

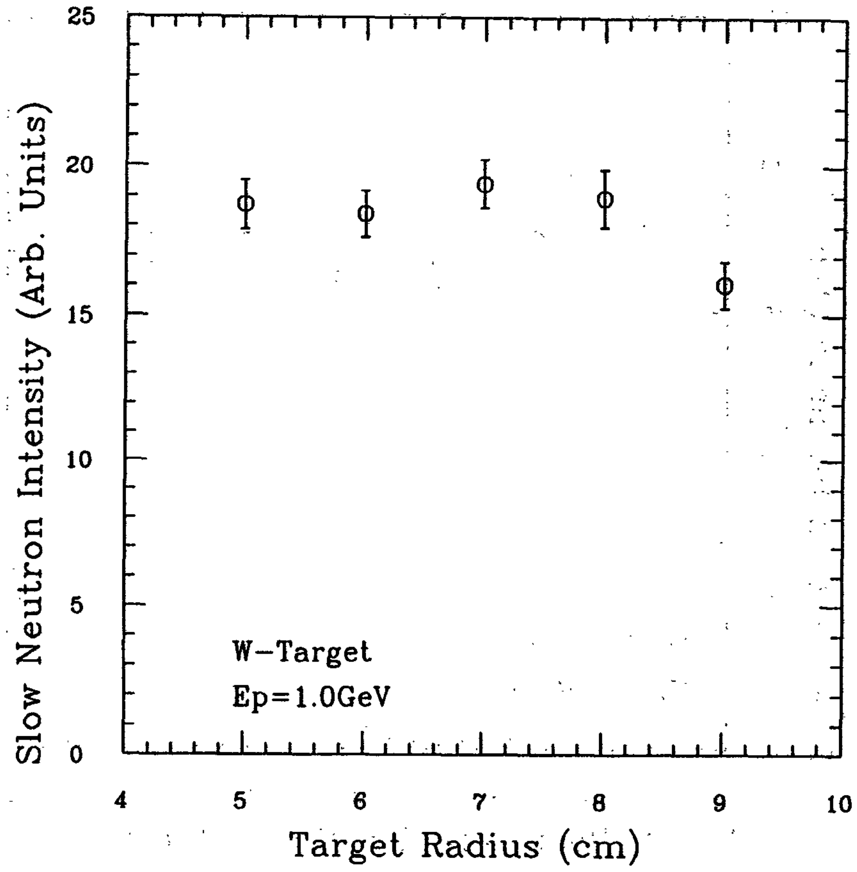


Fig. 3 Slow-neutron intensity vs. target radius.

Thirdly, we examined the optimal length of the void space between the two targets because the void length is one of the most important parameters on which the leakage of fast and high-energy neutrons to the beam holes strongly depends. The moderator was located at the center height of the target void keeping the gap between target void and moderator at 2 cm. Figure 4 shows the result. The slow-neutron intensity is almost unchanged within the statistical accuracy. This suggests the possibility to adopt a longer void space which makes it easy to suppress the hard component of neutrons leaking to the beam holes.

Next, we examined the slow-neutron intensity as a function of moderator thickness in order to obtain a better understanding of the target-moderator coupling nature of this moderator system. Other parameters were kept constant as before. Figure 5 shows slow-neutron intensity vs. moderator thickness. The maximum appears at about 7 cm. The feature is similar to the result of the slab-geometry moderator, suggesting that a flux-trap type moderator is closer to a slab-geometry moderator rather than a wing-geometry moderator in neutronic performance.

It is excepted that the rear surface of the moderator (near the target) will emit more slow neutrons than the front surface (opposite side), because the collision density of fast neutrons in the moderator will be larger in the rear

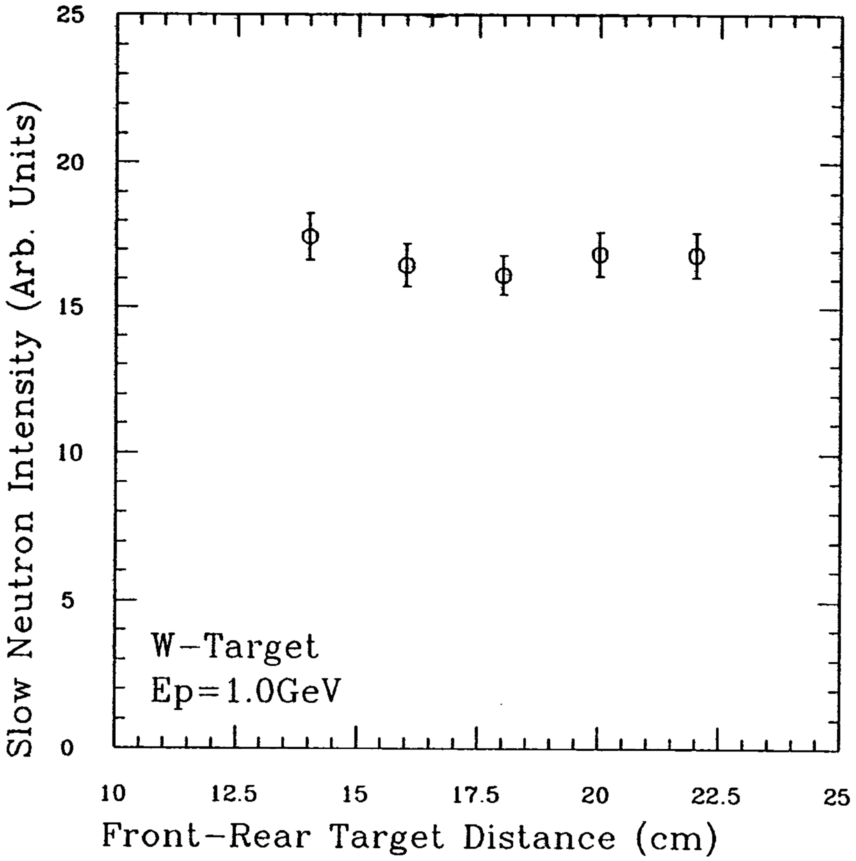


Fig 4 Slow-neutron intensity vs. void length between front and rear targets.

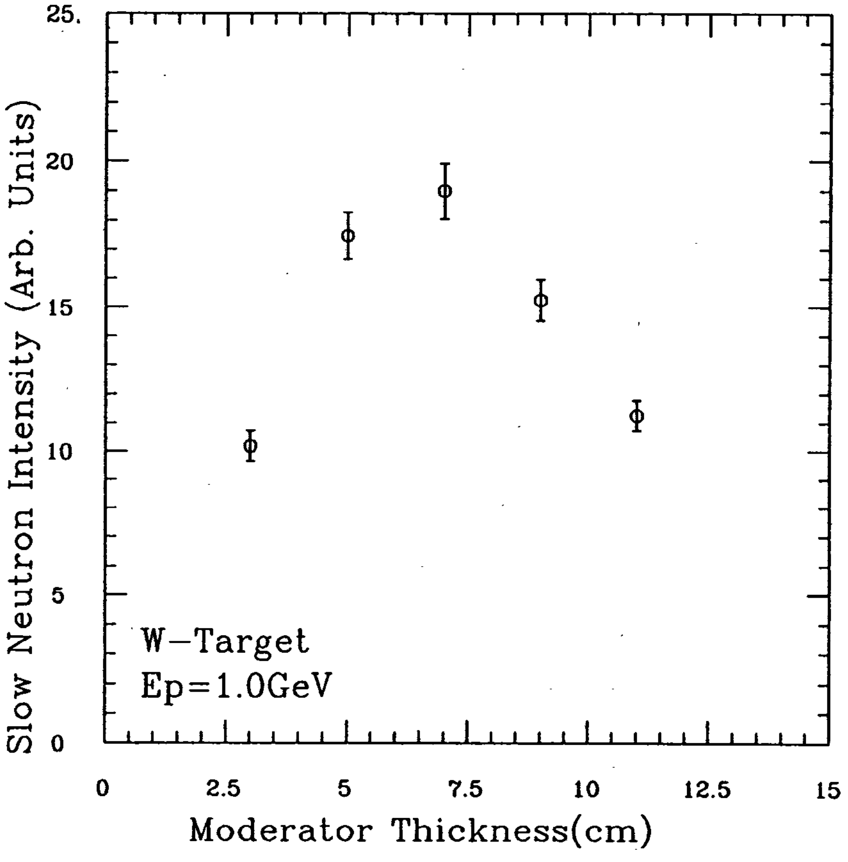


Fig 5 Slow-neutron intensity vs. moderator thickness.

side than in the front side. We can extract the neutron beam from the rear side as well because there is no target behind the moderator. In this case of course we assume that the moderator at the opposite side across the target void dose not exist. Then we calculated the neutron intensities from the rear and the front surfaces of the moderator as a function of target-moderator distance. In this case one moderator was placed around the target void for simplicity. All other parameters were fixed constant as before. Figure 6 shows the slow-neutron intensities from both surfaces of the moderator. The intensity gain from the rear compared to the front is unexpectedly small; only 10 %, suggesting that the neutron beam extraction from a rear surface of moderator is less interesting.

The slope is rather modest; approximately 10 % per 2 cm. This will make the engineering design of the target-moderator system easier: we can put the moderator around the void space with an enough spacial allowance, not sacrificing the intensity appreciably.

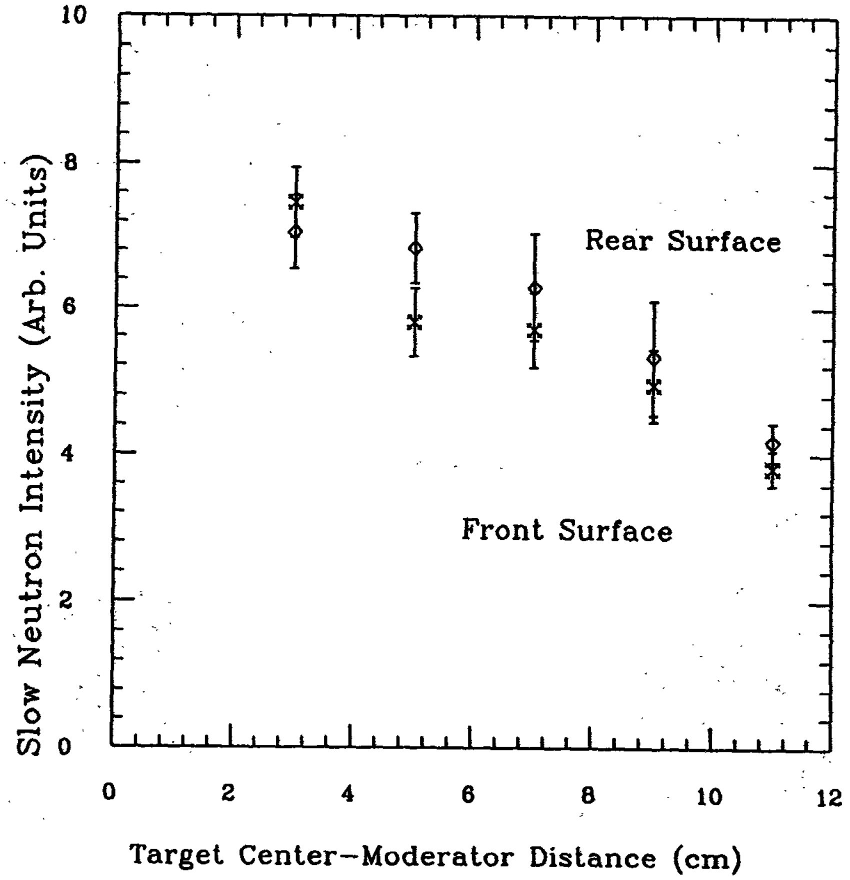
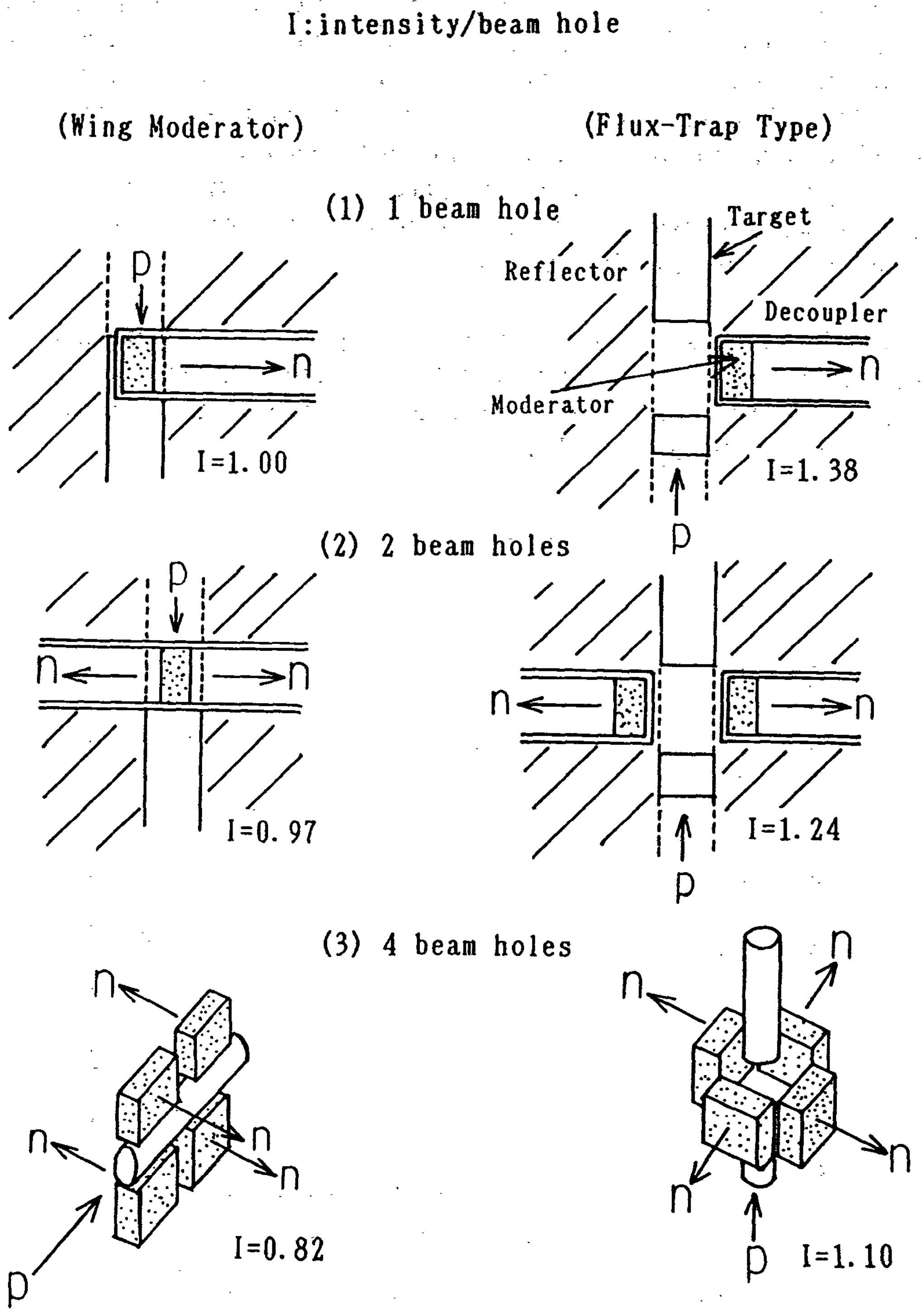


Fig. 6 Slow-neutron intensity vs. target-moderator distance.

IV. COMPARISON WITH WING-GEOMETRY MODERATOR

Finally, we compared the slow-neutron intensity from a flux-trap type

Fig. 7 Comparison of slow-neutron intensity between flux trap type moderator and wing-geometry moderator.



moderator system with that from a reference moderator system in a wing geometry. In all cases the gap between the cylindrical target surface and the moderator is kept at 2 cm. Figure 7 show the configurations of both systems. In the configurations of 4 beam holes, the reflector is not depicted for simplicity. The relative values of the slow-neutron intensity per moderator surface, I, are indicated in the figure. The results show that the flux-trap type moderator can provide 1.3-1.4 times higher intensity than the wing-geometry moderator.

V. CONCLUSIONS

The present results suggest that a flux-trap type moderator is a promising candidate for the target-moderator system in KENS-II. We are now investigating similar optimization studies on a coupled liquid-hydrogen-moderator system.

REFERENCE

1 G. J. Russell, H. Robinson, G. L. Legate, R. Woods, E. R. Whitaker, A. Bridge and K. J. Hughes : Proc. ICANS-IX (Villigen, Sept. 22-26, 1986) p-177
2 N. Watanabe : Proc. ICANS-XI (Tsukuba, Oct. 22-26, 1990) p-471.
3 Y. Kiyanagi, M. Arai and N. Watanabe : Advanced Neutron Sources 1988 (Proc. ICANS-X (1988)), Institute of Physics Conference Series Number 97, Institute of Physics, Bristol and New York, p-753
4 M. Nakagawa and T. Mori: JAERI-M 84-126 (1984).
5 Y. Nakahara and T. Tsutsui:JAERI-M 82-198 (1982).