DORT Analysis of Iron and Concrete Shielding Experiments at JAERI/TIARA

Chikara KONNO, Fujio MAEKAWA, Masayuki WADA
Intense Neutron Source Laboratory, Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken 319-1195 JAPAN
e-mail: konno@fnshp.tokai.jaeri.go.jp

Hiroshi NAKASHIMA
Planning Division for Neutron Science, Japan Atomic Energy Research Institute
Tokai-mura, Naka-gun, Ibaraki-ken 319-1195 JAPAN

Kazuaki KOSAKO
Sumitomo Atomic Energy Industries, Ltd.
2-10-4, Ryogoku, Sumida-ku, Tokyo 130-0026 JAPAN

The accuracy of DORT calculations with HILO86R and multigroup libraries processed from LA-150 (P_5 Legendre expansion) was investigated through the analysis of the shielding experiments on iron and concrete for 40 and 65 MeV neutrons at JAERI/TIARA.

1. Introduction

Legendre expansion order for scattering matrix in Legendre-expanded multigroup libraries is usually at most 5 because of calculation constraint. The accuracy of Sn calculations with multigroup libraries of P_5 Legendre expansion may become poor with increase of neutron energy since P_5 Legendre expansion can not present forward-peaked angular distribution of secondary neutrons precisely. Reference 1 showed that the two-dimensional Sn code DORT3.1 [2] calculations with multigroup libraries of P_5 Legendre expansion represent the shielding experiments for D-T neutrons as accurately as the continuous energy Monte Carlo code MCNP [3] calculations with libraries (no Legendre expansion) . P_5 Legendre expansion is considered to be adequate up to 14 MeV neutrons. Recently Sn calculations with HILO86 [4] or HILO86R [5], which is a multigroup library of P_5 Legendre expansion up to 400 MeV, are carried out for shielding calculation of ion accelerators of more than a few hundreds MeV. Therefore we analyzed the shielding experiments [6,7] on iron and concrete for p-^{7}Li quasi-monoenergetic source neutrons (40 MeV and 65 MeV) performed at JAERI/TIARA with DORT3.1 in order to examine accuracy of Sn calculations with multigroup libraries of P_5 Legendre expansion for neutrons above a few tens MeV.

2. Overview of Shielding Experiments on Iron and Concrete at JAERI/TIARA

The shielding experiments were performed with collimated p-^{7}Li neutron source of 40 and 65 MeV at Takasaki Ion Accelerator for Advanced Radiation Application (TIARA), at JAERI. Figure 1 shows the experimental arrangement. The test shield of iron and concrete from 10 cm up to 200 cm in thickness was located at the end of the collimator with or without an additional iron shield. Neutron spectra were measured with a BC501A scintillator and Bonner Ball detectors on the beam axis and at 20 and 40 cm off the beam axis behind the test shield.

3. Calculation Procedure

The Sn code DORT3.1 was used in the analysis. Only the collimated source neutrons and experimental assembly, which was modeled as a cylinder instead of a rectangular parallelepiped, were adopted in the analysis according to Ref. 5. The first collision source was calculated from collimated source neutrons with the GRTUNCL code. The following multigroup libraries (P_5 Legendre expansion) were used.

1) HILO86R, 2) LA-150 52g without ETA, 3) LA-150 100g without ETA,
4) LA-150 52g with ETA, 5) LA-150 100g with ETA

The multigroup libraries of 2) - 5) below 100 MeV were generated with NJOY94.105 [8] patched for LA-150 and TRANSX2.15 [9] codes from the nuclear data library LA-150 [10] up to 150 MeV which LANL released recently. The 52g and 100g mean the group structure; 52g is the same structure (52 groups) as that of HILO86R and 100g is the structure (100 groups) of 1 MeV interval from 0.5 MeV to 100.5 MeV. The ETA is an abbreviation of extended transport approximation [9], which was devised mainly for fast breeding reactors in order to mitigate the effects of truncating the Legendre expansion at finite order. The multigroup libraries of 4) and 5) were used to examine the effect of ETA on high energy neutrons. Moreover MCNP-4A calculations [11] were also carried out with the continuous energy library processed from LA-150 with NJOY94.105 for accuracy check of LA-150 itself.

4. Results and Discussion

The comparison between the calculations and measurements for neutron spectra above 10 MeV on the beam axis is carried out in this paper. Figure 2 shows the measured and calculated neutron spectra of the iron experiment for 43 MeV neutrons. The calculations overestimate neutron flux more with the thickness of the assembly. In order to compare the calculations with the measurements precisely, the ratios of the calculated values to the experimental ones (C/E) of integrated neutron flux at the peak and continuum regions are plotted in Figs. 3 - 10. The C/Es of all the calculations tend to increase with the thickness of assembly, though the increase rates of C/Es are different each other. The main reason of the overestimation of the calculations with LA-150 is attributed to LA-150 itself, since the increase tendency of C/Es also appears in the MCNP calculation. Although the DORT calculations with 100g are larger than those with 52g, the effect of the group structure is not so large since the largest difference is 20 %.

The DORT calculations without ETA are smaller than the MCNP calculation. This reason is that neutrons elastically scattered to forward direction are smaller since the multigroup libraries of P_5 Legendre expansion produce less forward-peaked angular distribution for elastic scattering than the original LA-150, which is strongly forward-peaked. It is noted that the DORT calculations without ETA underestimate the measurements even for thinner assemblies. This reason is not clear yet, but this is also one of influences due to P_5 Legendre expansion. The C/Es of the DORT calculations without ETA are 0.5 - 2.1 for the assembly of more than 1 m in thickness. The DORT calculation with HILO86R shows the similar tendency with those without ETA. Probably the ETA is not considered in HILO86R.

The correction of the influences due to P_5 Legendre expansion by ETA seems to be well in the iron experiment for 43 MeV neutrons; the DORT calculations with ETA are similar with the reference MCNP calculations. However, the ETA overcorrects much in the other experiments; DORT calculations with ETA are larger by 2.5 times at maximum than the reference MCNP calculations. It is found that the ETA is not always appropriate for neutrons above a few tens MeV. The C/Es of the DORT calculations with ETA are 1.5 - 3.5 for the assembly of more than 1 m in thickness.

5. Concluding Remarks

The accuracy of DORT calculations with HILO86R and multigroup libraries processed from LA-150 (P_5 Legendre expansion) was investigated through the analysis of the shielding experiments on iron and concrete for 40 and 65 MeV neutrons at JAERI/TIARA. The following remarks were found through the comparison of measurements and calculations of neutron flux above 10 MeV.

1) All the calculations tend to overestimate the measurements with the thickness of assembly.
2) DORT (LA-150 without ETA) and DORT (HILO86R) is smaller by 50 % at maximum than MCNP (LA-150). Their C/Es are 0.5 - 2.1 for the assembly of more than 1 m in thickness. They also underestimate the measurements for thinner assemblies.
3) The ETA overcorrects the influences due to P_5 Legendre expansion too much. DORT (LA-150 with ETA) is larger by 2.5 times at maximum than MCNP (LA-150). Their C/Es are 1.5 - 3.5 for the assembly of more than 1 m in thickness.

References

[1] Konno C., et al. : Proc. 20th Symposium on Fusion Technology, Sep. 7-11, 1998, Marseille, France, pp. 1263 - 1266 (1998).
[2] Rhodes W.A. and Mynatt F.R. : Nucl. Sci. Eng., 99, 88 (1988).
[3] Briesmeister J.F. (edited): LA-12625-M, Los Alamos National Laboratory, (1993).
[4] Alsmiller R.G., et al. : ORNL/TM-9801 (1986).
[5] Kotegawa H., et al. : JAERI-M 93-020 (1993).
[6] Nakao N., et al. : Nucl. Sci. Eng., 124,228 (1996).
[7] Nakashima H., et al. : Nucl. Sci. Eng., 124,243 (1996).
[8] MacFarlane R.E. and Muir D.W.: LA-12740-M (1994).
[9] MacFarlane R.E. : LA-12312-MS (1992).
[10] Young P.G., et al. : Proc. International Conference on Nuclear Data for Science and Technology, May 19-24, 1997, Trieste, Italy, pp.1440 - 1442 (1998).
[11] Wada M. et al. : "Benchmark Test of JENDL High Energy File with MCNP," in this proceeding.

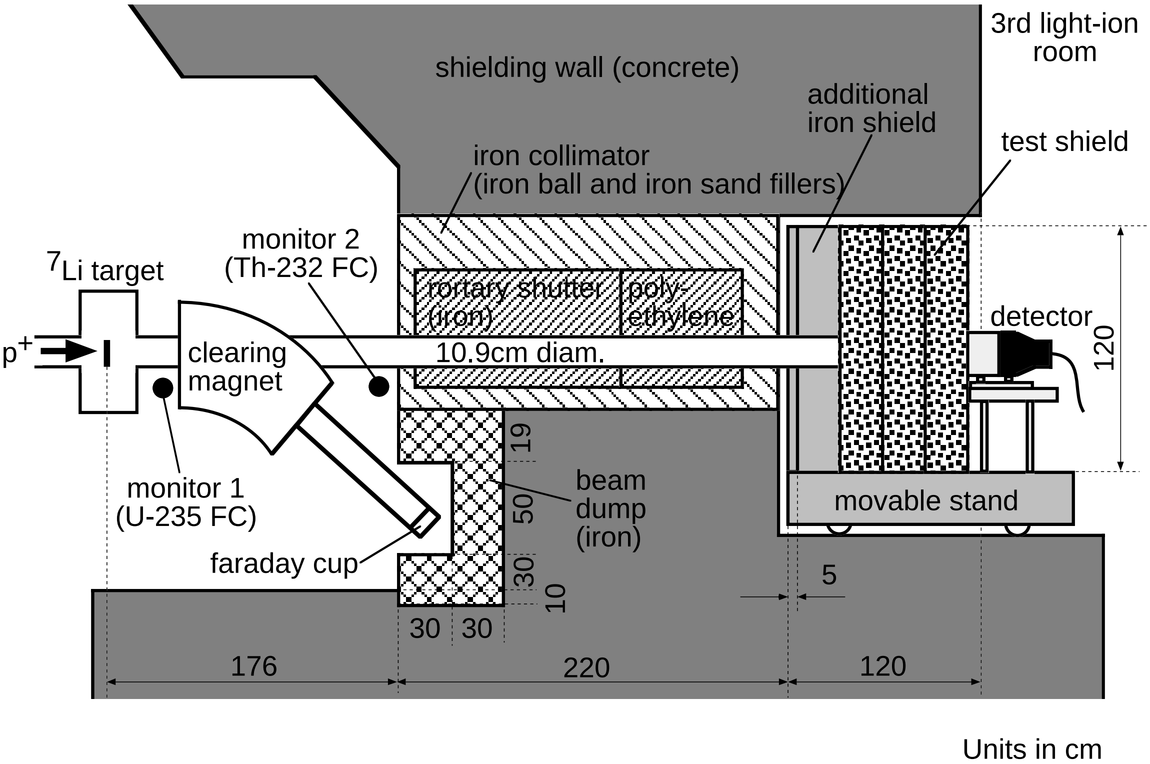

Fig. 1 Experimental arrangement of shielding experiments at JAERI/TIARA.

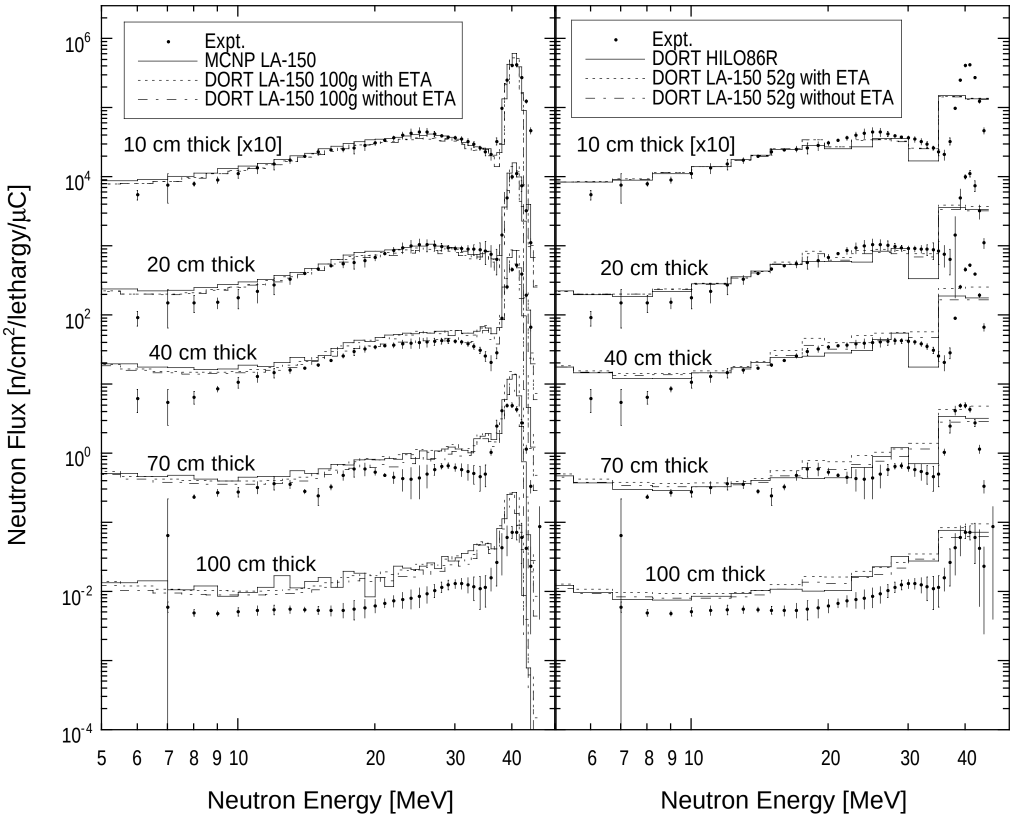

Fig. 2 Measured and calculated neutron spectra of the iron experiment for 40 MeV neutrons.

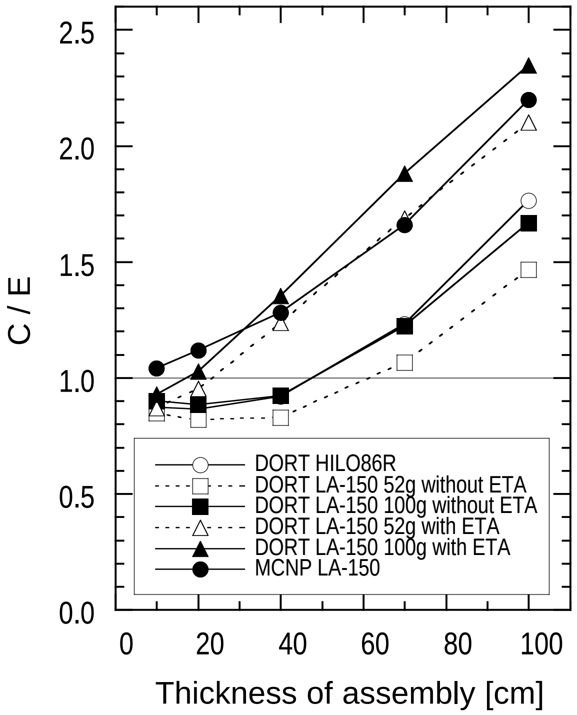

Fig. 3 C/E of peak neutron flux (35 - 45 MeV) of the iron experiment for 40 MeV neutrons.

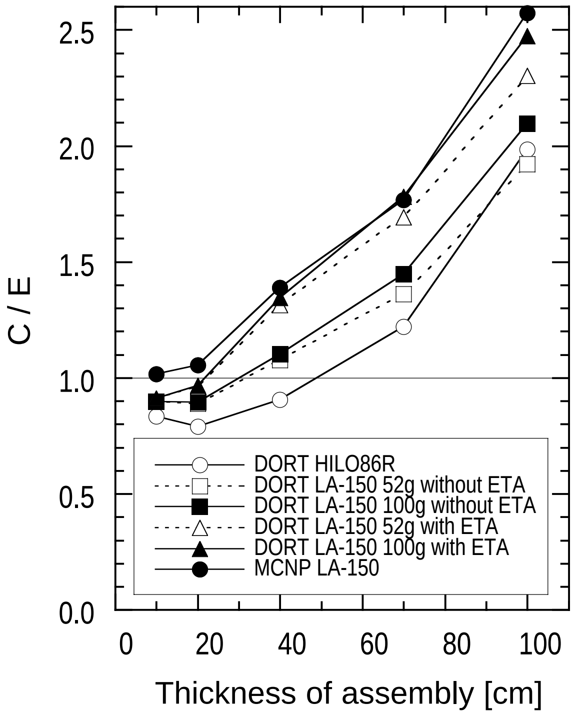

Fig. 4 C/E of continuum neutron flux (10 - 35 MeV) of the iron experiment for 40 MeV neutrons.

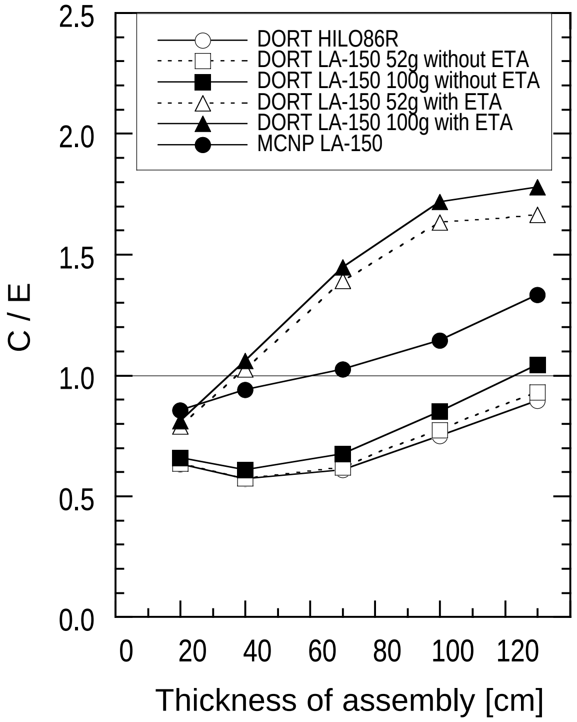

Fig. 5 C/E of peak neutron flux (60 - 70MeV) of the iron experiment for 65 MeV neutrons.

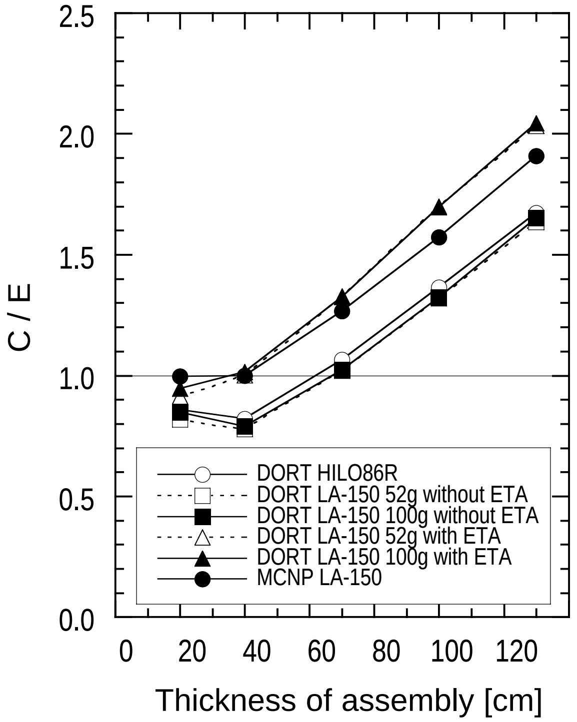

Fig. 6 C/E of continuum neutron flux (10 - 60 MeV) of the iron experiment for 65 MeV neutrons.

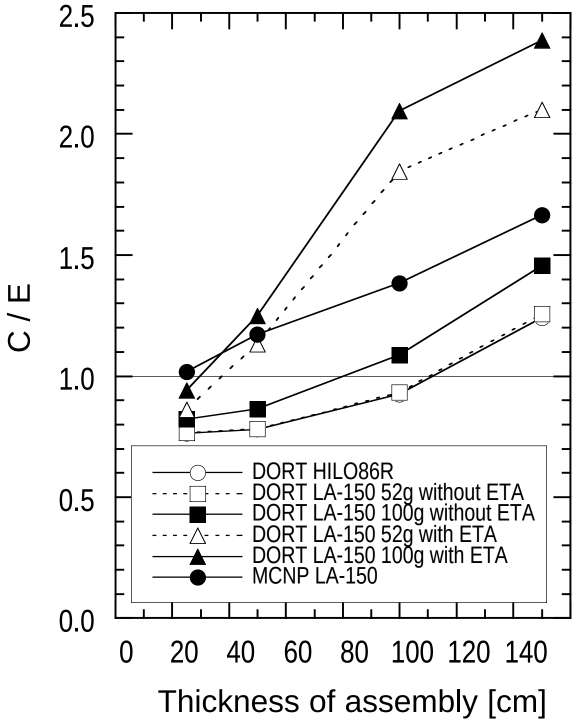

Fig. 7 C/E of peak neutron flux (35 - 45 MeV) of the concrete experiment for 40 MeV neutrons.

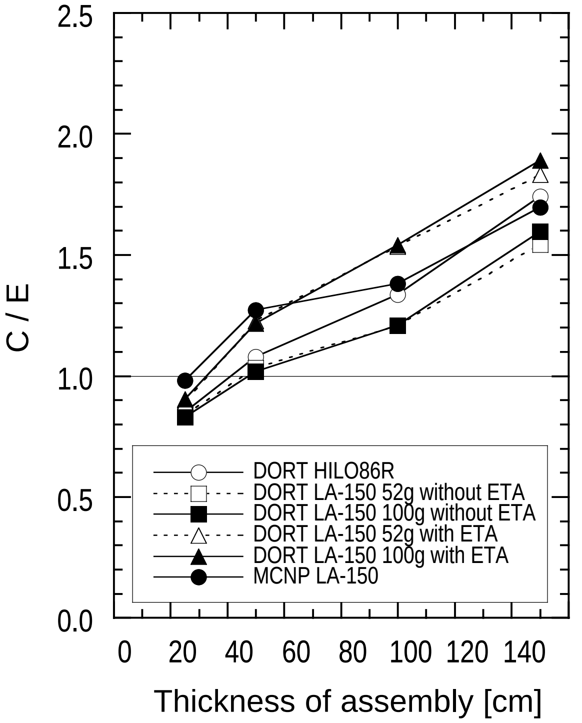

Fig. 8 C/E of continuum neutron flux (10 - 35 MeV) of the concrete experiment for 40 MeV neutrons.

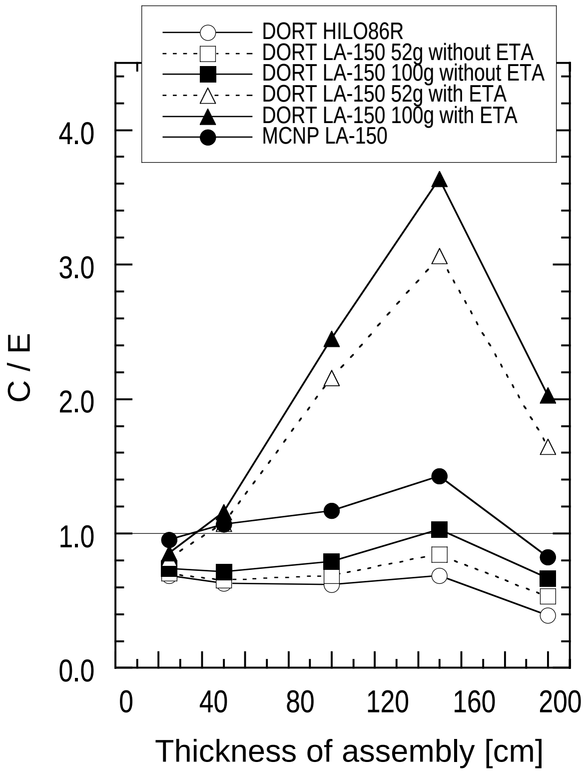

Fig. 9 C/E of peak neutron flux (60 - 70 MeV) of the concrete experiment for 65 MeV neutrons.

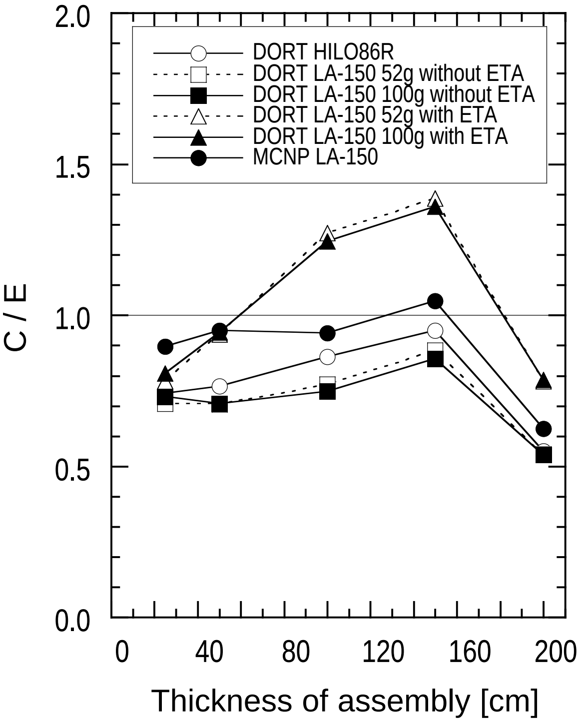

Fig. 10 C/E of continuum neutron flux (10 - 60 MeV) of the concrete experiment for 65 MeV neutrons.