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TART Calculations of Neutron Attenuation and Neutron-induced Photons on 5% and 20% Borated Polyethylene Slabs

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August 28, 1992

Abstract:

The coupled neutron/photon transport code TART has been used to calculate the attenuation of neutrons and the production of induced photons for neutrons incidents on 5% and 20% borated polyethylene slabs. The neutron attenuation lengths are found to be 2.4 cm and 2.9 cm for 5% and 20% borated polyethylene, respectively.

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1. Introduction

The coupled neutron/photon transport Monte Carlo transport code TART[1] has been used to examine the effects of neutron shielding thicknesses for neutron attenuation and neutron-induced photons. Slabs of borated polyethylene were modeled with cylindrical geometry. Slabs 100 cm in radius and variable thickness from 1 to 20 cm were studied. In addition, two different mixtures of borated polyethylene were modeled. These mixtures were provided by Reactor Experiments, Inc.[2] and are listed in Table I.

200,000 neutrons histories were generated for each calculation. Neutrons were incident along the axis of the cylindrical slabs in a beam of zero radius. The neutrons were sampled from an energy spectra provided by L. Waters for neutrons emitted from a model calorimeter. Figure 1 shows the neutron spectrum.

2. Results

A. 5% Borated Polyethylene

Figure 2 shows the results of calculations for 5% borated polyethylene of thicknesses from 1 - 20 cm. The figure shows the percent of neutrons and neutron-induced photons transmitted and reflected from the slabs as a function of thickness. The percentage is calculated with respect to the number of incident source neutrons and is integrated over all energies. A fit to the curve for neutrons transmitted gives an attenuation length of 2.94 cm. Figures 3 and 4 show the photon and neutron energy spectra for both reflected and transmitted photons and neutrons.

B. 20% Borated Polyethylene

Similar calculations were performed for the case of 20% borated polyethylene. Figure 5 shows the percent of neutrons and photons reflected and transmitted from slabs of various thicknesses. From Figure 5 the neutron attenuation length is calculated to be 2.4 cm. Figures 6 and 7 show the photon and neutron energy spectra, respectively.

3. Discussion

In general, borated polyethylene is seen to reduce the amount of transmitted neutrons in an exponential fashion as a function of thickness. On the other hand, transmitted and reflected photons and reflected neutrons tend to approach constant values for slab thicknesses greater than about 5 cm.

Surprisingly there is little difference between the 5% and 20% mixtures of borated polyethylene. This is presumably because of the decreased moderating of neutrons in the 20% mixture. There is a difference in the energy spectra of neutrons transmitted and reflected for the two mixtures, with the 20% mixture attenuating more of the low energy neutrons below about 100 eV. The reduction is about a factor of 10 between 10 and 100 eV and about a factor of 100 below 10 eV. There is little difference in the neutron-induced photon energy spectra.

4. Conclusions

These calculations show that the effectiveness of neutron attenuation is a complicated function of the amount of boron loading in the shielding material. There appear to be competing effects of neutron moderation provided by carbon and hydrogen, and neutron capture provided by boron. These calculations will be continued for other mixtures (10% and 15%) of borated polyethylene as well as boron mixtures in non-flammable binders.

References:

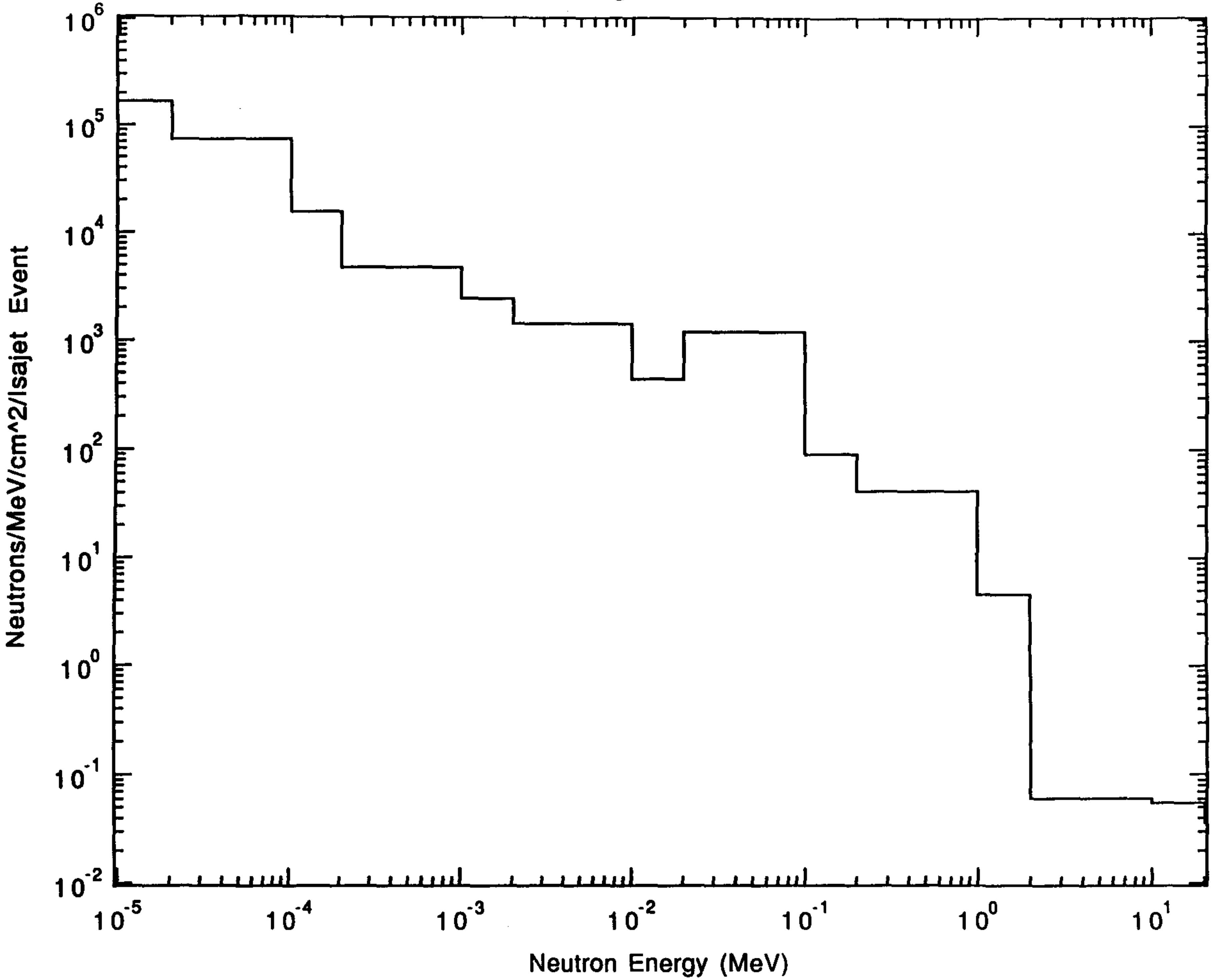
1. J. Kimlinger, N. Monson, and E. Plechaty, "TartNP, A Coupled Neutron-Photon Monte Carlo Transport Code," UCRL-50400 vol.14, 1976.

2. P. Lizak, faxed communication, Reactor Experiments, Inc., 1275 Hammerwood Ave., Sunnyvale, CA 94089, (408) 745-6770.

Table I: Borated Polyethylene Mixtures as provided by Reference (2) numbers are given as weight fractions

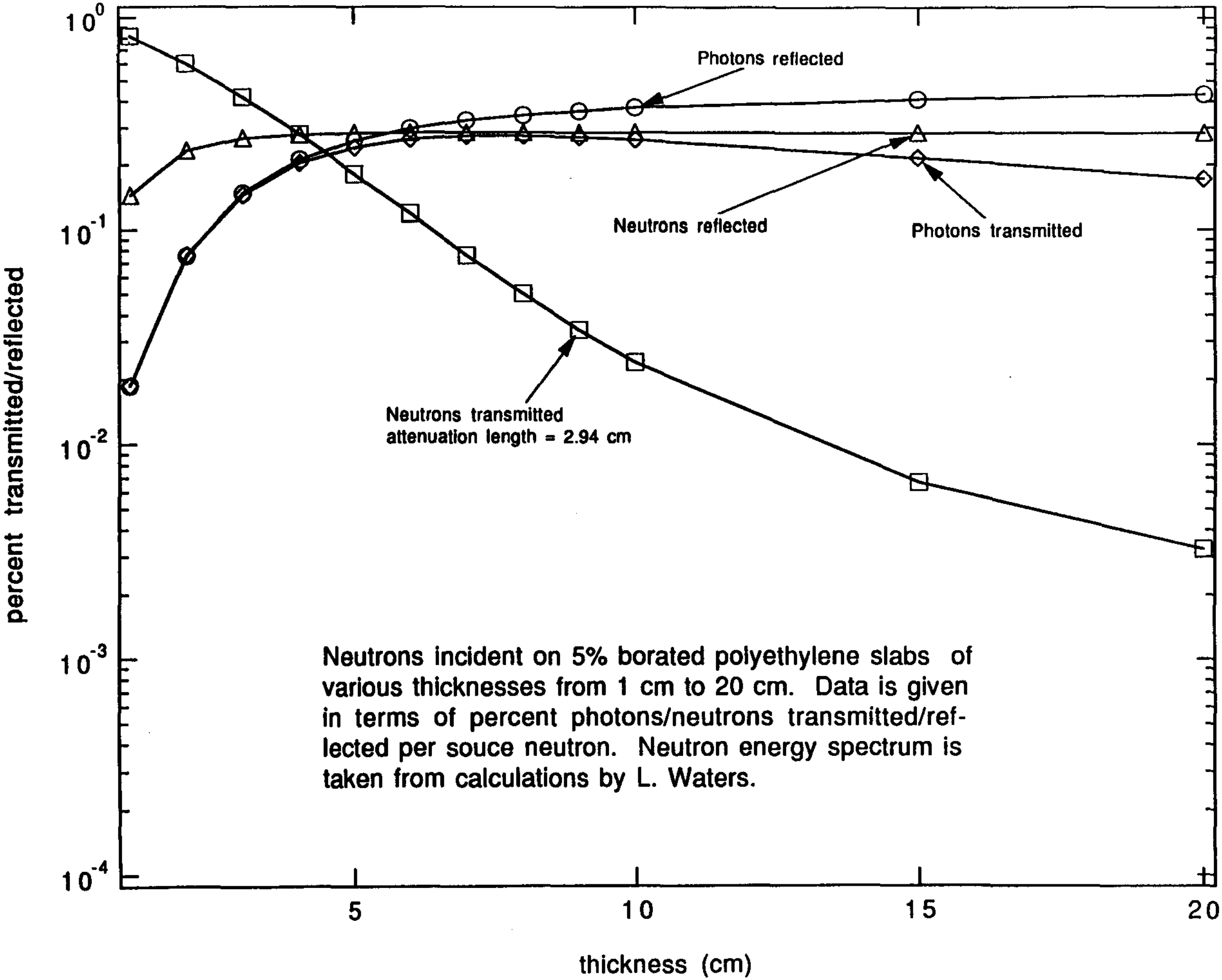
Element	5% Borated Polyethylene	20% Borated Polyethylene
H	0.116	0.105
C	0.612	0.680
^{11}B	0.040	0.150
^{10}B	0.010	0.050
Si	N/A	0.0068
O	0.222	0.005
Al	N/A	0.0003
Mn	N/A	0.0001
Fe	N/A	0.0025

Figure 1



Neutrons/MeV/cm^2/Isajet Event
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^-1
10^-2
10^-5
10^-4
10^-3
10^-2
10^-1
10^0
10^1
Neutron Energy (MeV)

Figure 2



Photons reflected
Neutrons reflected
Photons transmitted
Neutrons transmitted
attenuation length = 2.94 cm
Neutrons incident on 5% borated polyethylene slabs of various thicknesses from 1 cm to 20 cm. Data is given in terms of percent photons/neutrons transmitted/reflected per souce neutron. Neutron energy spectrum is taken from calculations by L. Waters.
percent transmitted/reflected
thickness (cm)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
5
10
15
20

Figure 3

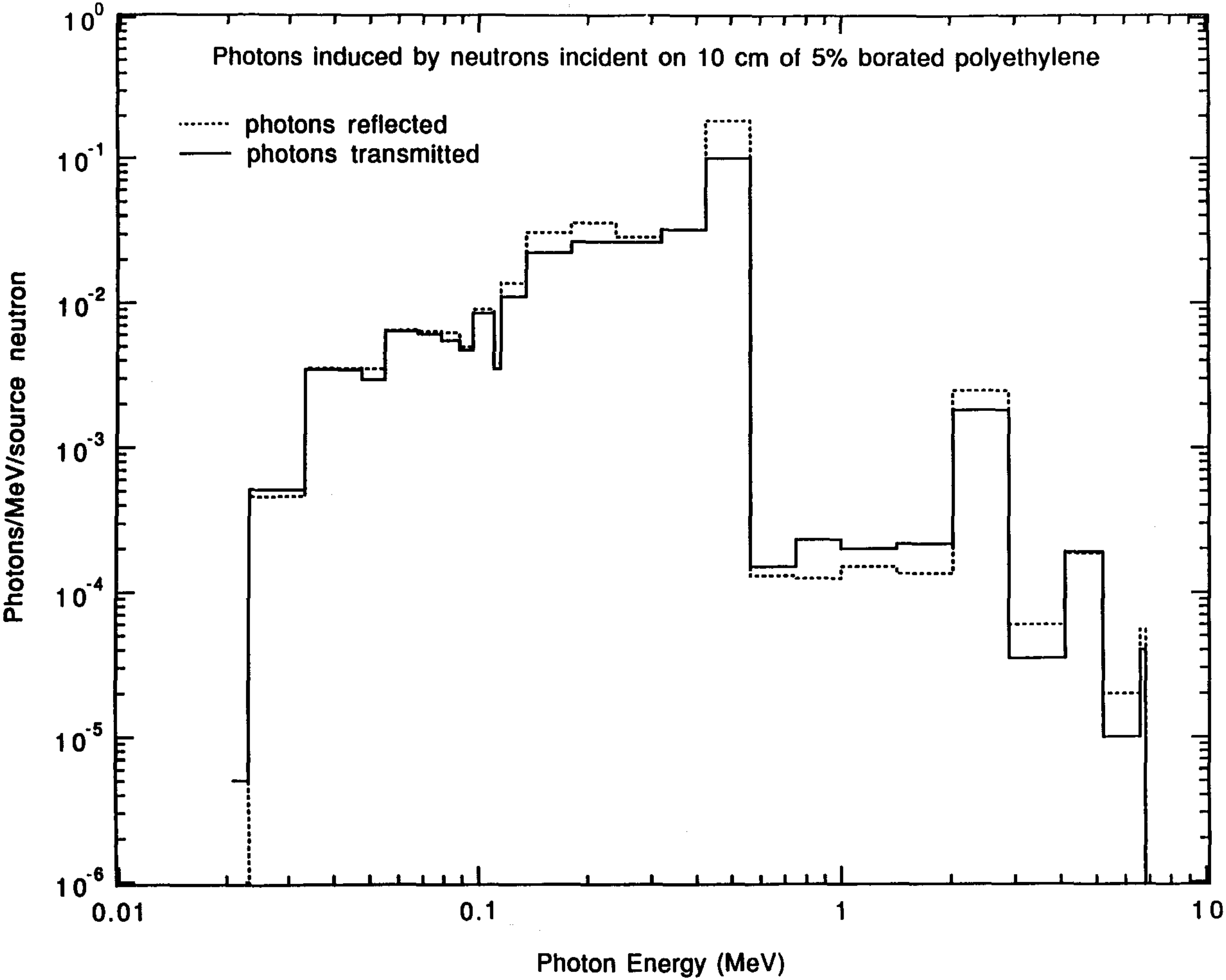

Photons induced by neutrons incident on 10 cm of 5% borated polyethylene
photons reflected
photons transmitted
Photons/MeV/source neutron
Photon Energy (MeV)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.01
0.1
1
10

Figure 4

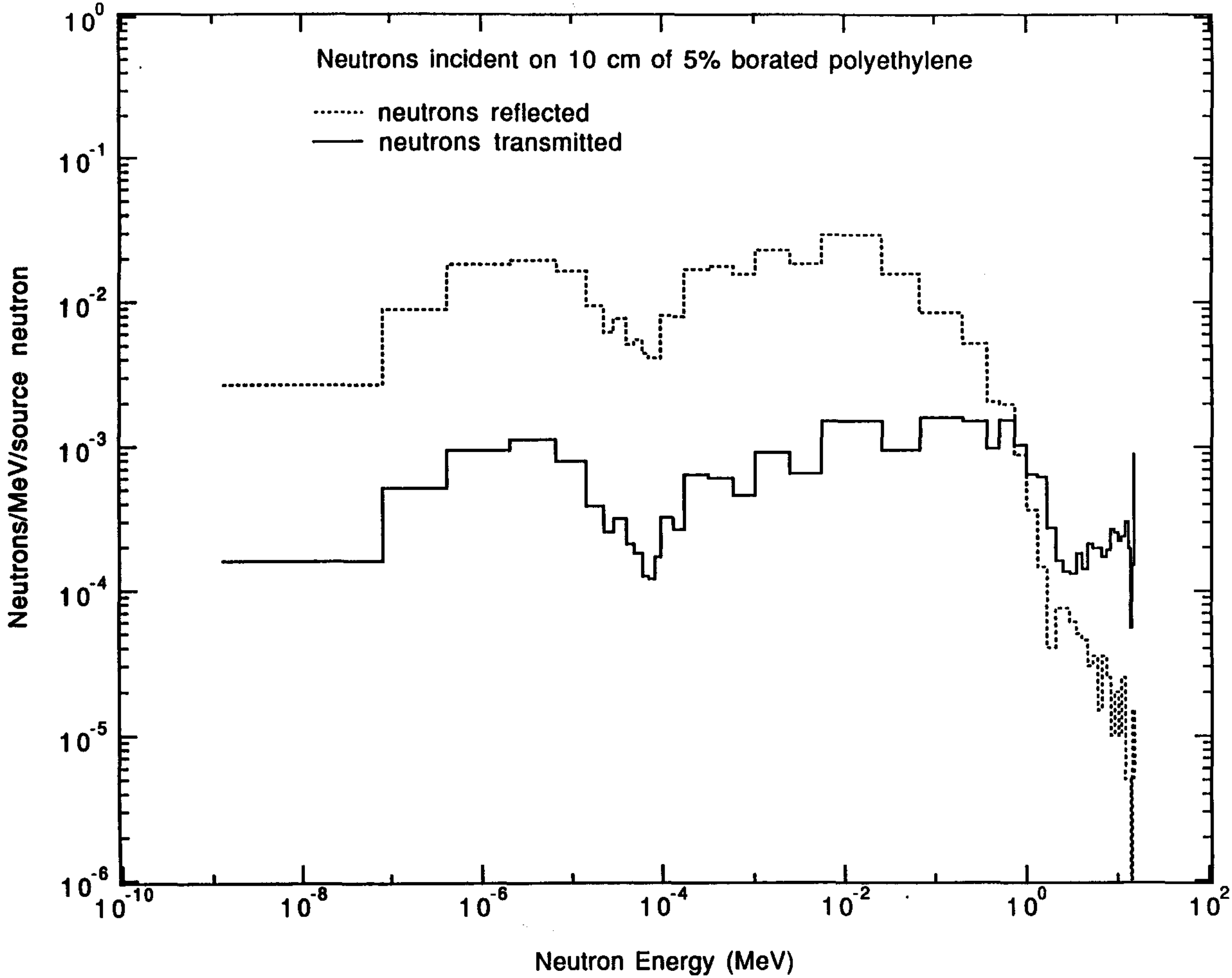
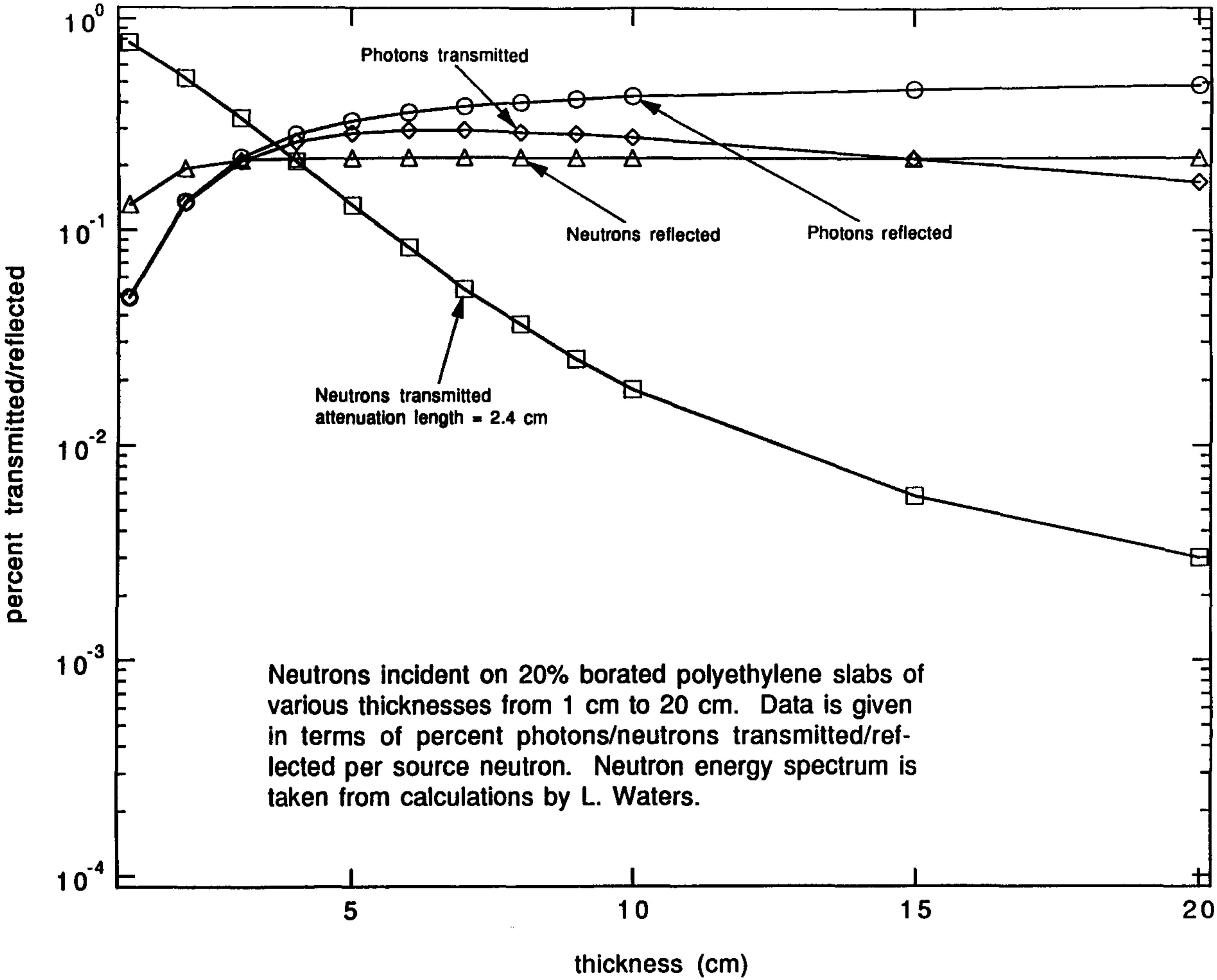
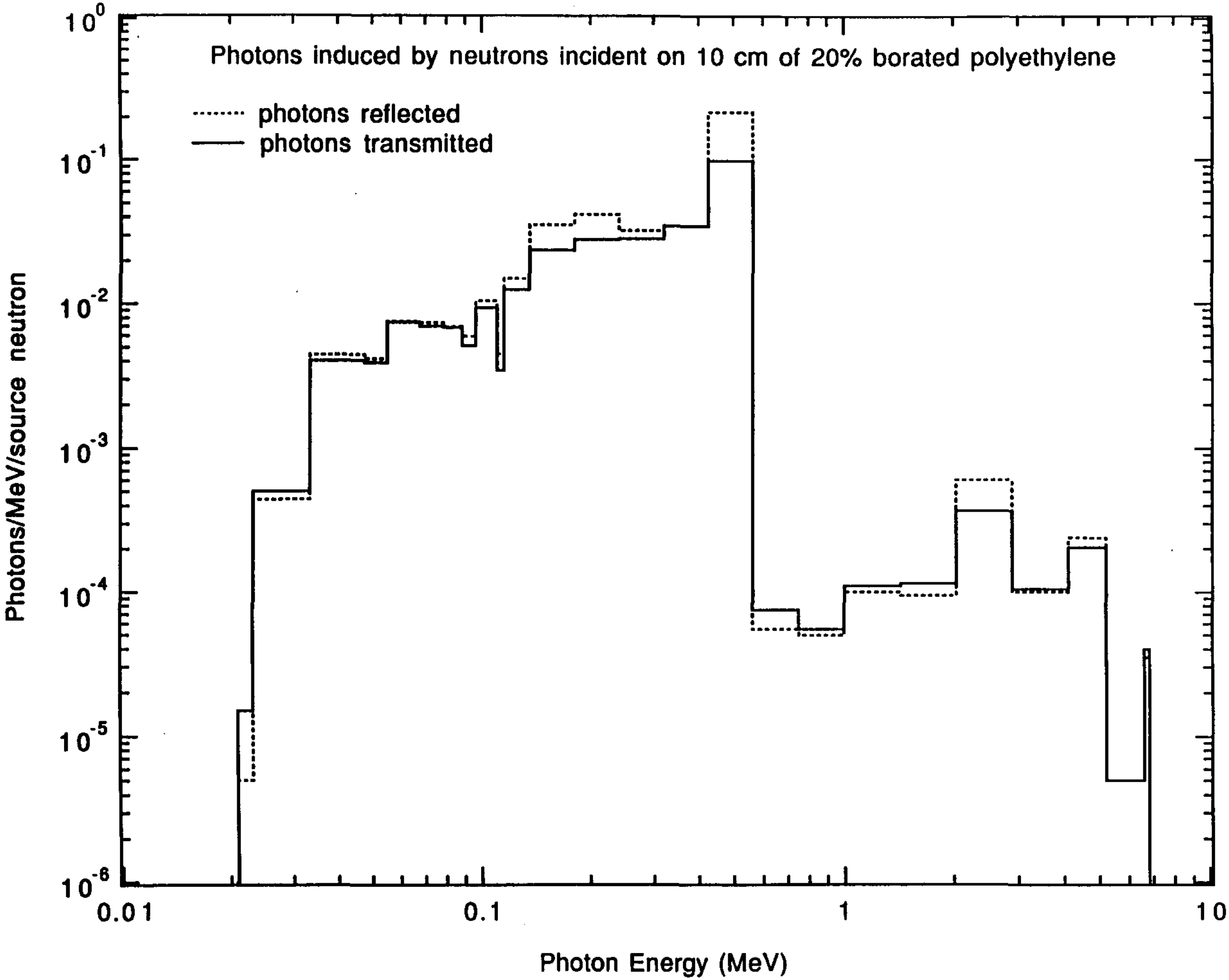

Neutrons incident on 10 cm of 5% borated polyethylene
neutrons reflected
neutrons transmitted
Neutrons/MeV/source neutron
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-10
10^-8
10^-6
10^-4
10^-2
10^0
10^2
Neutron Energy (MeV)

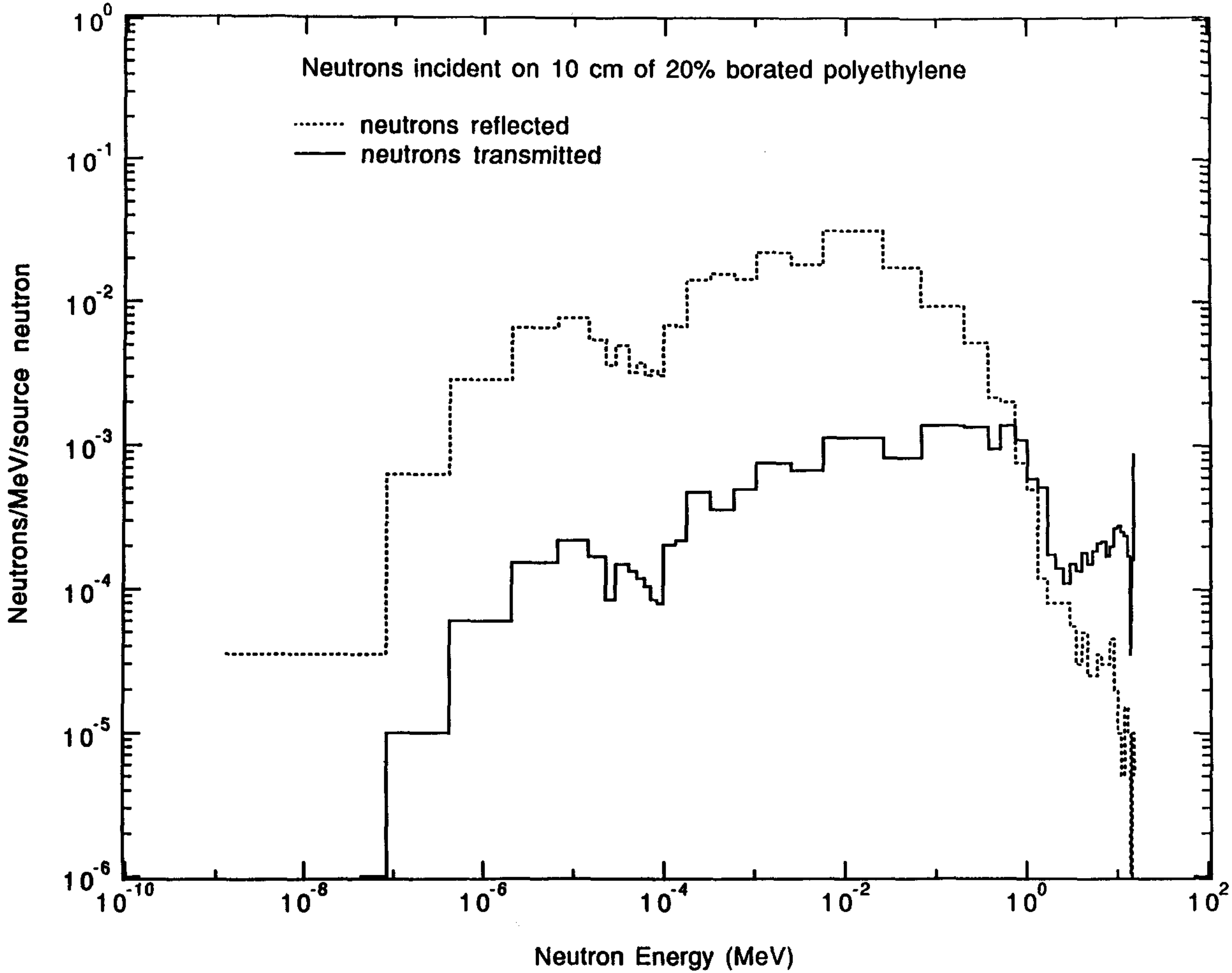
Figure 5



Photons transmitted
Neutrons reflected
Photons reflected
Neutrons transmitted
attenuation length = 2.4 cm
Neutrons incident on 20% borated polyethylene slabs of various thicknesses from 1 cm to 20 cm. Data is given in terms of percent photons/neutrons transmitted/reflected per source neutron. Neutron energy spectrum is taken from calculations by L. Waters.
percent transmitted/reflected
thickness (cm)
10^0
10^-1
10^-2
10^-3
10^-4
5
10
15
20

Figure 6


Photons induced by neutrons incident on 10 cm of 20% borated polyethylene
photons reflected
photons transmitted
Photons/MeV/source neutron
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
0.01
0.1
1
10
Photon Energy (MeV)



Neutrons incident on 10 cm of 20% borated polyethylene
neutrons reflected
neutrons transmitted
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Neutrons/MeV/source neutron
10^{-10}
10^{-8}
10^{-6}
10^{-4}
10^{-2}
10^{0}
10^{2}
Neutron Energy (MeV)