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Effective Bending Point to Reduce Dose-Equivalent of a Bending Duct Streaming System

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Abstract

In this study, the Monte Carlo analysis is carried out to find out an effective bending point to reduce the neutron streaming on the outer surface of the two-bent rectangular duct streaming system. As a function of the bending point of the first leg, neutron dose-equivalent rate distributions are calculated not only along the centerline in the bending duct but also on the extension line of the first leg. On the outer surface on the extension line of the first leg, the neutron dose-equivalent rates are increase exponentially as the bending point comes up to the surface. On the other hand, those distributions along the centerline in the duct have a minimum point on the bending point of it. Finding the effective bending point is one of the most positive applications of the Monte Carlo method to a shielding design.

1 Introduction

In this study, the following two-bend (three-legged) rectangular duct neutron streaming system is prepared, and the neutron streaming the shielding system is analyzed by the continuous energy Monte Carlo code MCNP 4B[1]. Concept of the duct neutron streaming system is shown in Fig. 1.

1. Dimensions of the duct streaming system are $150 \text{x} 150^{\square} \text{x} 200$ cm.
2. The shield around the duct is a homogenized material of 80 volume percents of stainless steel and 20 volume percents of water. The homogenized shield is expected to have superior shielding ability not only for fast neutrons but also for secondary gamma rays produced by H (n,γ) reaction of thermal neutrons in water.
3. Diameter of the duct is fixed on 15.0^{ϕ}cm and the bending angle between the first duct and the second one, and also the second duct and the third one is a right angle, respectively. The distance between the inlet and the outlet of the second leg is fixed on 50 cm, so that the dose-equivalent rates are calculated as a function of the bending point of the first leg, unirarerally.
4. Point isotropic neutron source of 14 MeV is located at 50 cm-distance from the inlet of the first-leg.

2 Simulation of Effective Bending Point

1. The point detector estimators are set along the center line of the duct and the NESXE's (Next Event Surface Crossing Estimator)[2] are set along the extension line of the first leg. The NESXE estimator is not provided in the MCNP 4B code. Therefore, instead of the point detector estimator, the NESXE estimator was newly built into the subroutine TALLYD of the MCNP 4B code.

2. The weight window importance is assigned in every 5-cm-thik cell to get enough collisions in the cells. As the results, the fsd's (fractional standard deviation) of the calculated dose-equivalent rates are less than 0.075 (7.5 %).

The cells, $1 \sim 45$, for weight window importance, detector locations of the point detectors and the NESXE's are indicated in Fig. 2.

3 Results and Discussions

The neutron dose-equivalent rate distributions at Pout-1 and at Pout-2 in Fig.1 are shown in Fig.3. As shown in Fig. 3, the profile of the dose-equivalent rates at Point 2 that is the crossing point on the extended line of the first leg and the outer surface of the shielding system, increases exponentially. On the other hand, the profile of it at Point 1that is the outlet of the third leg has the minimum point at the bending point of 100 cm. As the bending points coming up to the outer surface, the more source neutrons coming up the Pout 1. Then the dose-equivalent rate at Pout-1 increases exponentially as the function of the first leg bending point. The dose-equivalent rate distributions along the centerline of each duct are shown in Fig. 4 and the following attenuation factors (F_a) of the dose-equivalent rates are obtained from Fig. 4 for each leg.

1. Bending point of the first leg is at 50 cm.
    - F_a of the first leg: 1/3
    - F_a of the second: 1/50
    - F_a of the third leg: 1/500
2. Bending point of the first leg is at 100 cm.
    - F_a of the first leg: 1/10
    - F_a of the second: 1/200
    - F_a of the third leg: 1/500
3. Bending point of the first leg is at 150 cm.
    - F_a of the first leg: 1/15
    - F_a of the second: 1/250
    - F_a of the third leg: 1/50

In the case of (1), F_a of the third leg, 1/500 is the maximum in the three, but F_a's of the first and the second leg is the minimum in the three. Because the length of the first leg is only 50 cm and the distance from the source point to the second leg is near than that of the other cases, the more source neutrons enter the second leg directory. In the case of (2), F_a of the second leg, 1/250 is the maximum in the three, but F_a of the third leg is the 1/10 of the (1) and (2). Because the length of the third leg is only 50 cm, so the large attenuation factor is not expected for it. In the case of (2), F_a of the second leg is a little bit small than that of the (3), but F_a of the third is the maximum in the three. Accordingly, the minimum dose-equivalent rate at the outlet of the third leg is made up in the case of (2).

4 Concluding Remarks

On the outer surface on the extension line of the first leg, the neutron dose-equivalent rates are increase exponentially as the bending point comes up to the surface. On the other hand, those distributions along the centerline in the duct have a minimum point on the bending point of it.

In this study, Monte Carlo method is useful to find out an effective bending point of a duct streaming system, and it is one of the most positive applications of the Monte Carlo method to a shielding design.

References

[1] "MCNP^{TM} - A General Monte Carlo N-Particle Transport Code Version 4B," J. F. Briesmeister, Ed., *LA-12625-M*, Los Alamos National Laboratory (1997).

[2] K. Ueki, A. Ohashi and M. Kawai, "Continuous Energy Monte Carlo Analysis of Neutron Shielding Benchmark Experiments with Cross Section JENDL-3," *J. Nucl. Sci. Technol.* **30**(1993)4.

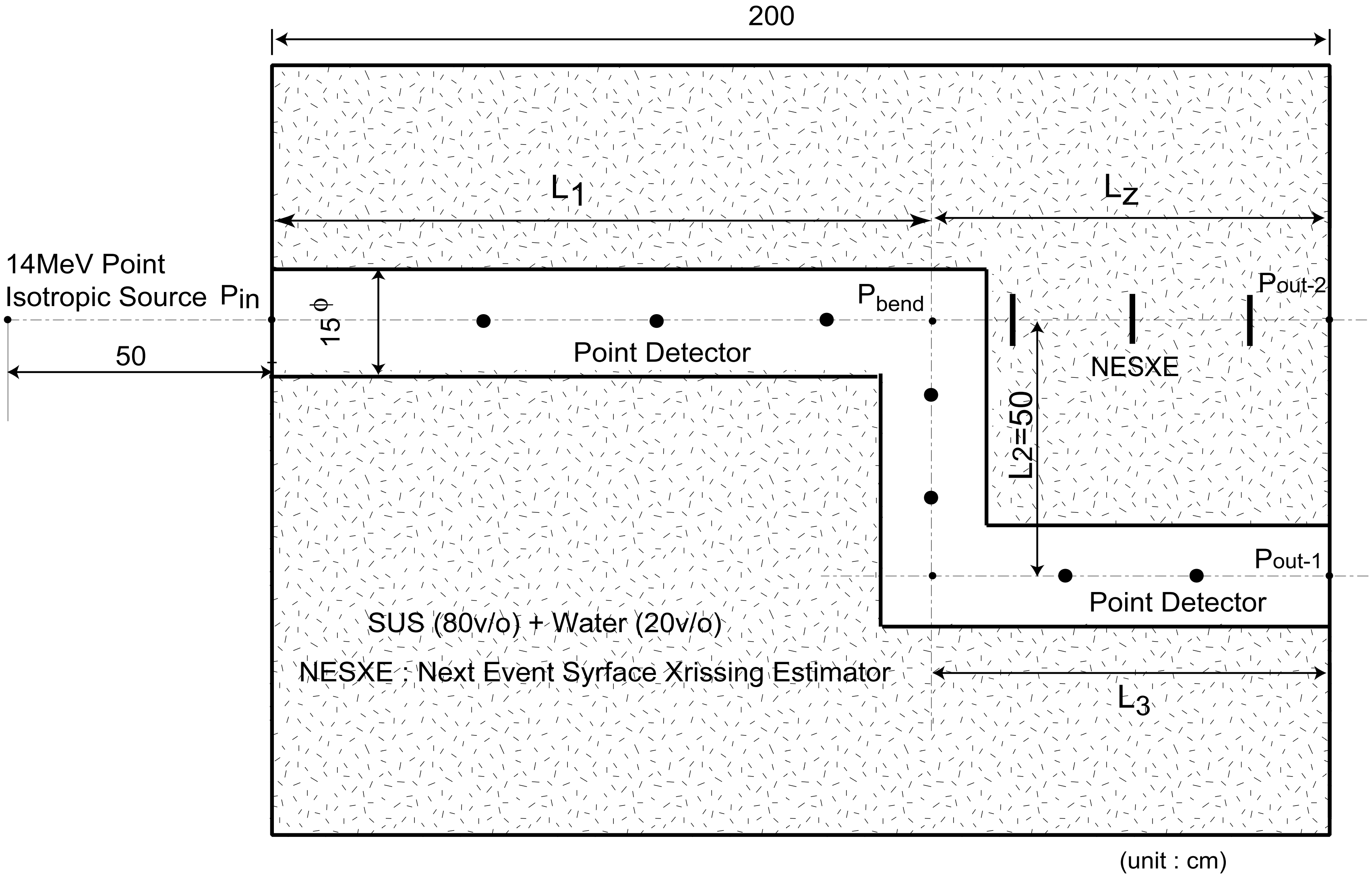

Fig. 1 Seeking the effective bending point. Pbend to reduce neutron streaming through the duct streaming system.

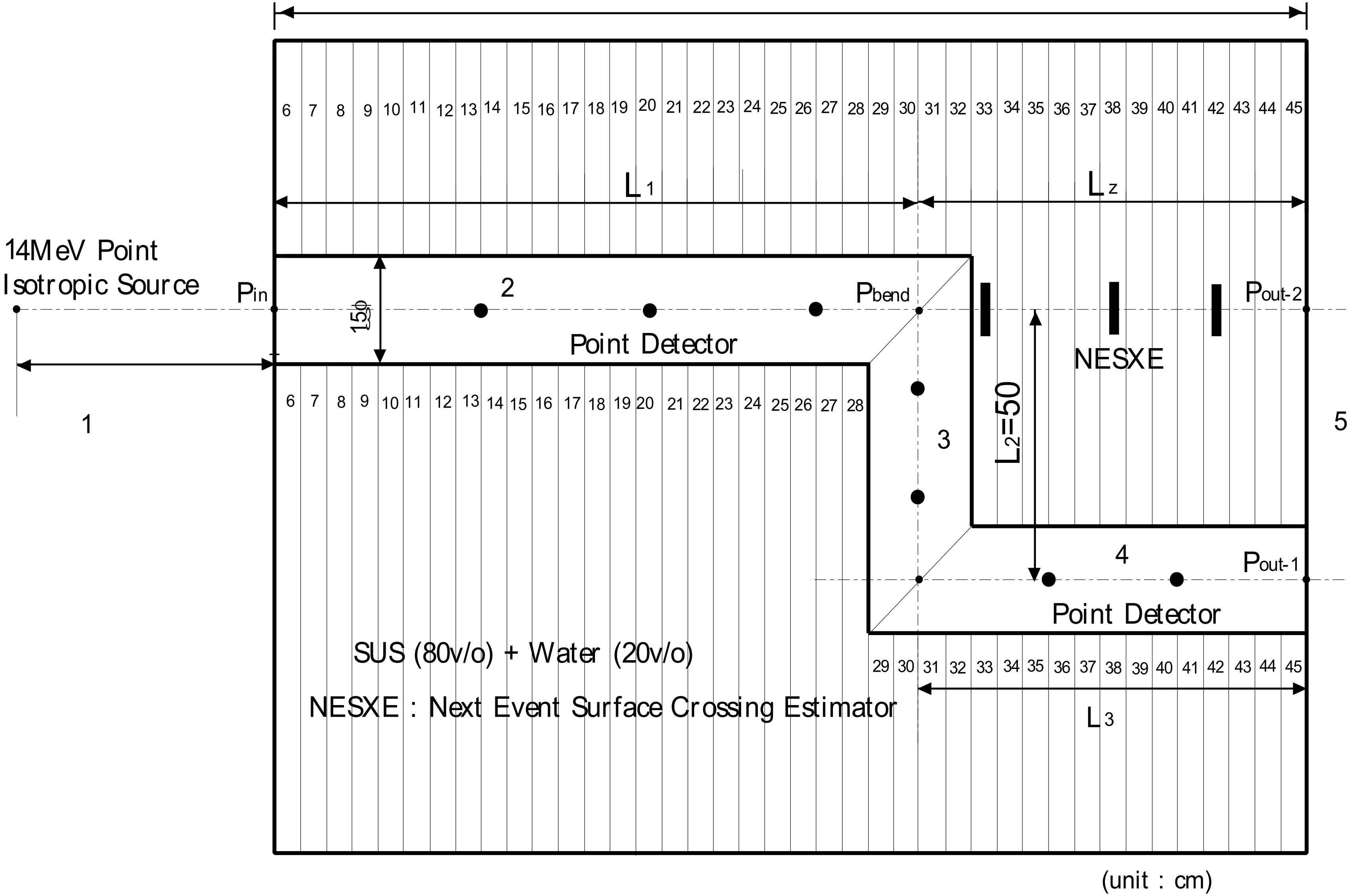

Fig.2 Cell structurs to calculate the contribution from each cell to a detector located in the duct.

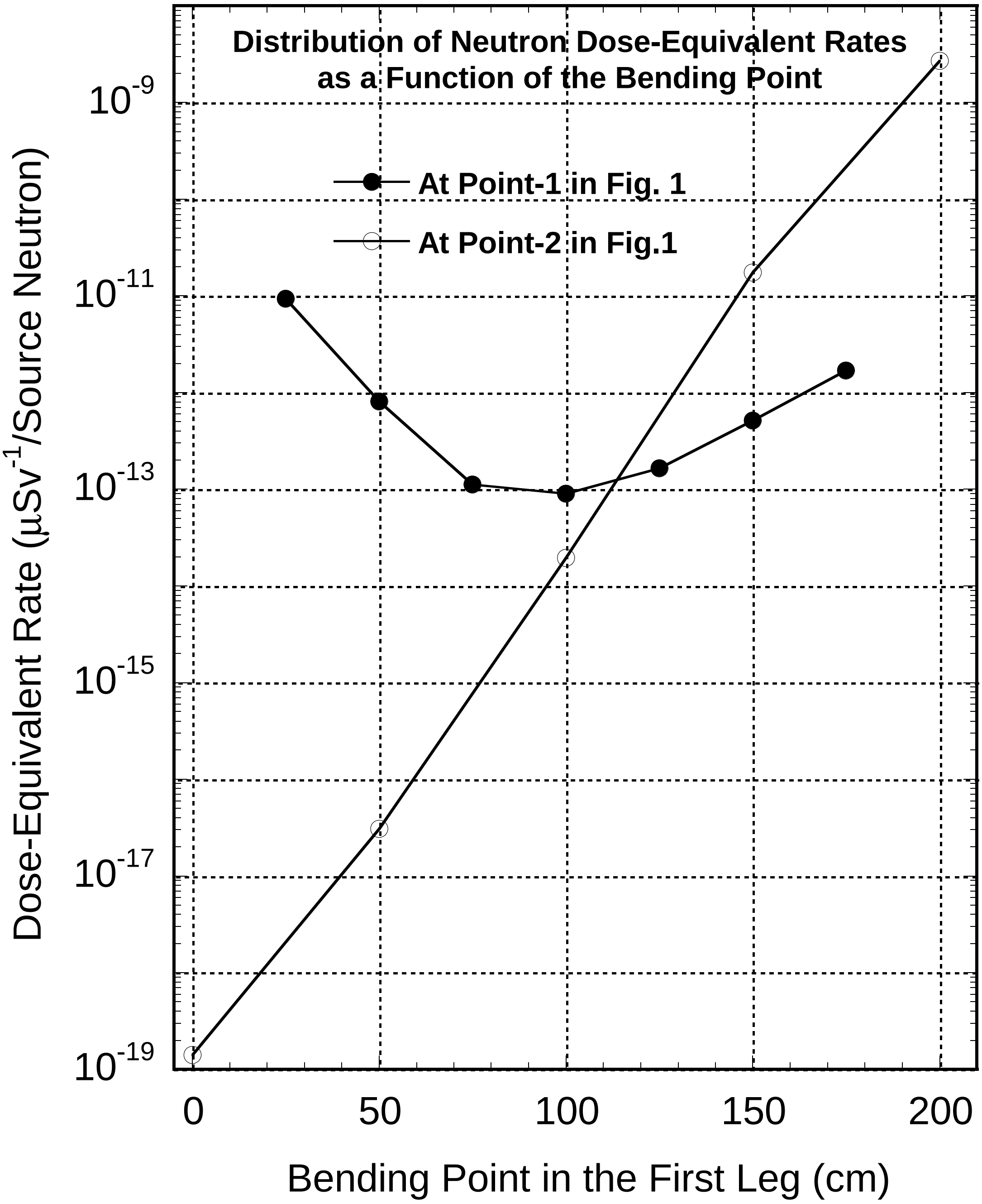

Fig. 3 NCNP 4B calculated neutron dose-equivalent rate distribution at Point-1 and Point-2 in Fig.1, as a function of the Bending Point.

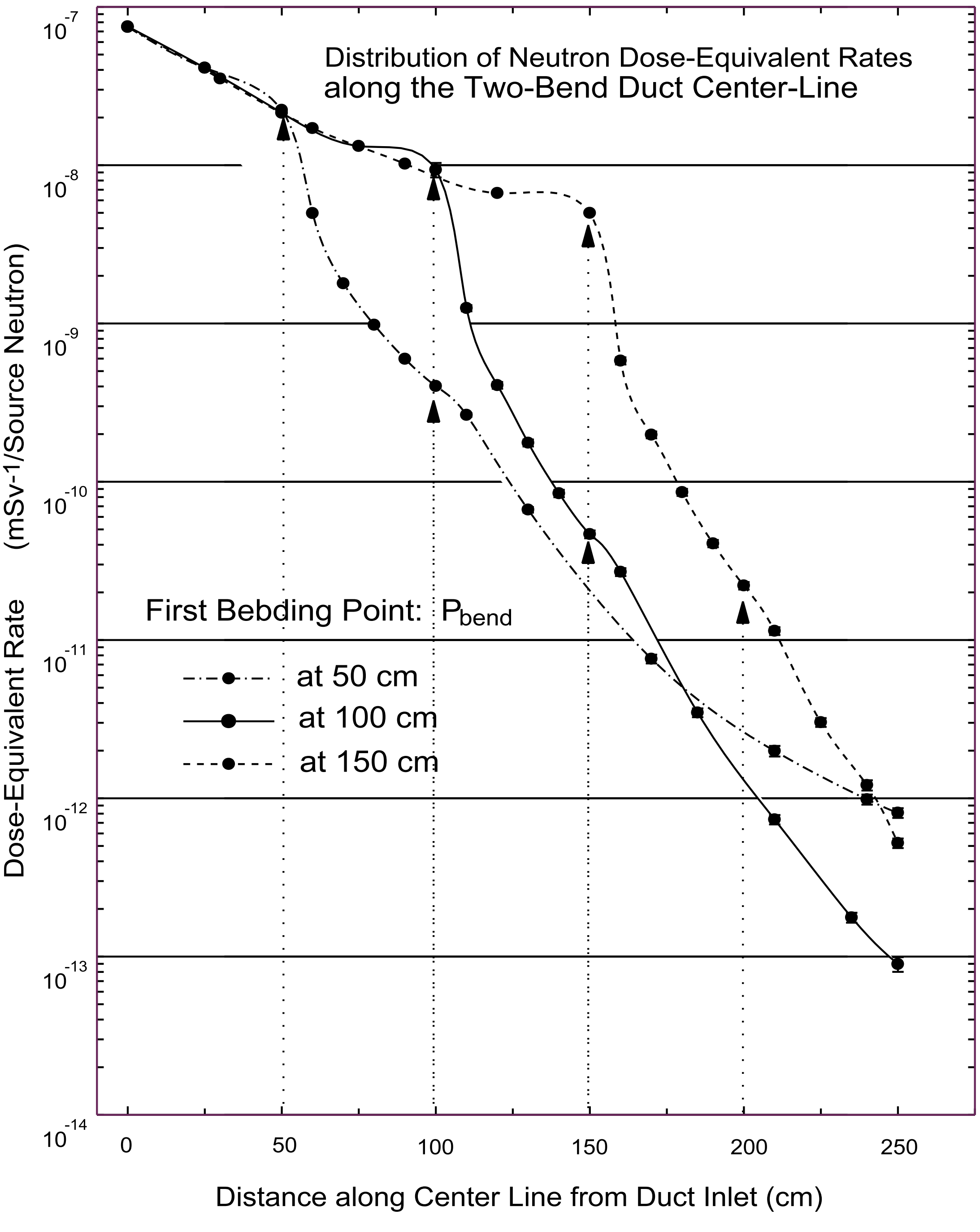

Fig.4 MCNP 4B calculated neutron dose-equivalent rate distribution along the two-bend rectangular-duct center-line. Point isotropic source of 14 MeV Neutron is located at 50 cm from the center of the duct inlet.