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MEASUREMENT OF COSMIC-RAY-INDUCED NEUTRONS USING MULTI-SHELL BONNER SPHERES

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Abstract: Cosmic-ray-induced neutrons are important to estimate the environmental dose for the aircraft crews. New Bonner spheres were designed for high-energy neutrons up to 10 GeV and their response functions were evaluated using the MCNPX transport code. The spheres consisted of an inner polyethylene shell covering the ^{3}He-filled spherical proportional counter, an outer polyethylene shell, and an inlet metal shell. Cosmic-ray-induced neutrons were measured at Korea Research Institute of Standards and Science together with the 10 existing Bonner spheres. Results of the neutron spectra showed that the response functions of the multi-shell Bonner spheres were calculated accurately.

Keywords: multi-shell Bonner sphere, MCNPX transport calculation, cosmic-ray-induced neutron

1. INTRODUCTION

The measurement of the spectral fluence of neutrons with Bonner spheres[1] is widely used to determine a neutron dose. The Bonner sphere spectrometer consists of a thermal neutron counter and several polyethylene spheres that are used as moderators. Korea Research Institute of Standards and Science (KRISS) has a Bonner sphere spectrometer composed of 10 polyethylene spheres from 7.62 cm to 30.48 cm in diameter with a ^{3}He-filled spherical proportional counter (type SP9, Centronic Ltd., UK). The responses of the spheres decrease rapidly as the neutron energy increases above 20 MeV and it is not easy to determine the spectral fluence of high-energy neutrons such as high-energy accelerator produced neutrons or cosmic-ray-induced neutrons by using unfolding procedures.

For high-energy neutron measurements, Bonner spheres with an inlet metal shell of medium to heavy elements[3] like copper, iron, and lead, namely a multi-shell Bonner sphere are used[4]. In order to develop a new multi-shell Bonner spheres, parameters such as the elements of the metal, thickness of the inlet metal shell and the outer polyethylene shell, and diameter of the inner polyethylene sphere have to be carefully studied. In this paper, the development of multi-shell Bonner spheres and the results of the cosmic-ray-induced neutrons are presented.

2. MONTE CARLO SIMULATIONS

New Bonner spheres with high sensitivity in high-energy regions were designed using the transport calculations by the MCNPX code version 2.6. The neutron cross-sections were taken from the ENDF/B-VI.6 library for low-energy neutrons and LA150 library for high-energy neutrons. Many different combinations of an inner polyethylene sphere, an inlet metal shell, and an outer polyethylene shell were studied. For the inner polyethylene spheres, diameters of 7.62 cm, 10.16 cm, and 12.7 cm were chosen. Iron, copper, and lead were considered as the metal elements for the inlet shells. The thicknesses of the inlet metal shells were 1.27 cm, 2.54 cm, and 3.81 cm. The diameter of the outer polyethylene shell was varied from 12.7 cm to 25.4 cm. The detailed realistic geometry model of the SP9 detector was taken from the PTB Report [2].

3. RESULTS

The final combinations of the inner polyethylene sphere, the inlet metal shell, and the outer polyethylene shell were summarized in Table 1. The response functions of the final combinations of the multi-shell Bonner spheres were calculated considering detailed geometry in the MCNPX transport code. The directional dependences of the responses were also studied and the responses were consistent within 3% from 0.001 eV to 10 GeV. The response functions are shown in Figure 1.

The cosmic-ray-induced neutron spectrum was obtained through an unfolding process. With the parameterized initial guess spectrum, the spectral fluence of the cosmic-ray-induced neutron was extracted with the MAXED[3] code of the UMG package developed for the unfolding process at PTB.

Figure 2 shows the cosmic-ray-induced neutron spectrum at KRISS. The measurements were done on the ground at an altitude of 142 m, latitude 36.392, and longitude of 127.369. In the figure, there is a large thermal peak because of background neutrons coming from the neutron irradiation room under the room where the measurement was undertaken. Even though the result is preliminary and contains background neutrons from the source, two cosmic-ray neutron peaks are shown clearly in Fig. 2, which suggests that the multi-shell detectors have high sensitivity to high-energy neutrons and the response functions of the multi-shell Bonner spheres were calculated validly.

Table 1 Density, diameter, and material of the multi-shell Bonner spheres. The density of the inner and the outer polyethylene is 0.951 g/cm^3. MSBS means multi-shell Bonner sphere.

Name	Diameter of the inner polyethylene sphere (cm)	Inlet metal shell			Inner/outer diameter of the outer polyethylene shell (cm)	Mass (kg)
		Metal	Density (g/cm^3)	Inner/outer diameters (cm)		
MSBS1	7.62	Pb,	10.76	7.62 / 12.7	12.7 / 5.24	9.88
MSBS2	10.16	Pb,	10.76	10.16 / 12.7	12.7 / 17.78	7.77
MSBS3	10.16	Cu,	8.72	10.16 / 12.7	12.7 / 17.78	6.73
MSBS4	10.16	Pb,	10.76	10.16 / 15.24	15.24 / 20.32	16.86

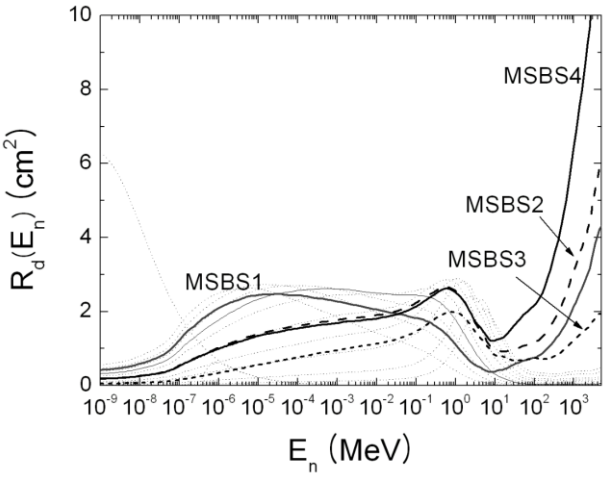

Fig. 1 Response functions of the multi-shell Bonner spheres. Response for polyethylene Bonner spheres are also plotted as dotted line.

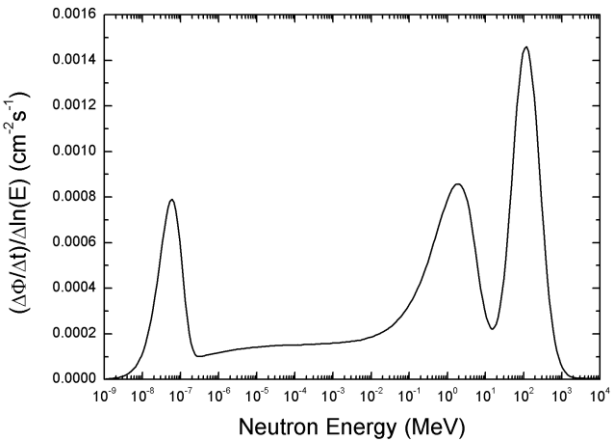

Fig. 2 Spectral fluence of cosmic-ray-induced neutrons at KRISS. See text in detail.

4. CONCLUSION

Multi-shell Bonner spheres with an inlet metal shell between an inner polyethylene sphere and an outer polyethylene shell were developed for high-energy neutron detection using the MCNPX transport calculation. Among many combinations, four multi-shell Bonner spheres that showed high sensitivity in high-energy regions were selected. The response functions were calculated by the MCNPX transport code taking account of detailed geometry. The response functions for four spheres are distinguishable each other obviously. The spectral fluence of cosmic-ray-induced neutrons was obtained using the multi-shell Bonner spheres together with other polyethylene spheres. The preliminary results show that the response functions are calculated reasonably.

5. REFERENCES

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