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# *Determination of efficient neutron absorber layer inside the sample holder tube for measuring the cross-section in D beamline of TRR*

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## Abstract
Thermal neutron absorbers are mainly used around the research reactor experimental facilities to decrease the backgrounds that may affect the experiment results. This study aims to determine an efficient absorber layer within the sample holder tube manufactured for neutron cross-section measurements at the Neutron Powder Diffraction (NPD) facility of Tehran Research Reactor (TRR). A polyethylene sample holder was simulated in front of the NPD channel using MCNPX code. Since cross-section measurement necessitates a high level of precision, neutron shielding in the vicinity of the sample is probably required to absorb scattered neutrons from interaction with polyethylene. Here, $B_4C$ and cadmium layers and also a cadmium shutter have been investigated inside and at the beginning of the sample holder due to their high neutron capture cross-sections and scattering properties. According to the results, both of the proposed layers are effective in reducing relative cross-section discrepancies toward ENDF libraries while cadmium shutter is not required.
**Keywords: Neutron cross-section, Absorber layer, TRR, MCNPX**

## *1. Introduction*
To improve the precision of the measured and calculated cross-section data, a collimated monochromatic beam should be utilized. In the direct beam of neutrons, absorbent materials can be utilized to provide incident beam collimation. They may also be used in the vicinity of samples to shield the instrument from measuring the multiple scatterings. Scattered neutrons can also be shielded or collimated using neutron capture materials to decrease the background from sample environments and multiple scattering [1,2]. M.B. Stone et el. concentrate on characterizing the materials most likely to be used in neutron scattering instrumentation. Both monochromatic and polychromatic measurements by CG1B beam-line at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) were carried out. According to their results, boron carbide, gadolinium, cadmium, and boron nitride are all reasonable choices of materials for use in the vicinity of the neutron direct beam [1]. Adrian R. Rennie et el. provided specific data for a new boron carbide composite with nylon, Addbor N25 that allows mechanically tough components with complex shapes that are neutron absorbers to be produced. The results show that it can provide good shielding for thermal and cold neutrons [2].

## *2. Materials and method*
This work is structured to determine an optimum neutron shielding layer in the vicinity of the sample in order to minimize scattering and increase the accuracy of the cross-section value of the sample. The Monte Carlo radiation transport calculations have been carried out using MCNPX. The collimated monochromatic neutron beam of the Neutron Powder Diffraction (NPD) facility of the TRR is capable to provide a monochromatic neutron beam at 5 distinct energy ranges [3]. A system for measuring neutron cross-section is simulated by MCNPX (figure 1). In order to reduce the scattered neutrons caused by the interaction of the polyethylene with the collimated monochromatic beam or even the neutron backgrounds, a layer of absorber materials such as cadmium and $B_4C$ was simulated within the sample holder tube and the vicinity of the sample. To determine the optimal thickness of the absorber layers, four various thicknesses (100, 300, 500, and 1000 μm) were investigated monochromatic energy of 0.0832 eV. Moreover, a cadmium shutter was simulated at the beginning of the sample holder, to minimize the interactions of the polyethylene with the incident beam (figure 2). In order to determine the optimal cadmium shutter, various dimensions of the shutter and the slit, as well as different slit thicknesses, were studied. Monochromatic beams at the energies of 0.331, 0.0832, 0.0363, 0.02 and, 0.0132 eV were considered as the input source for determining cadmium shutter. A gold sample was placed at the end of the tube.

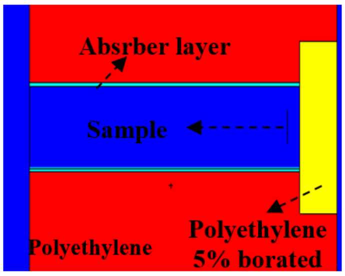


**Fig. 1.** Schematic of the simulated absorber layer inside of the sample holder tube

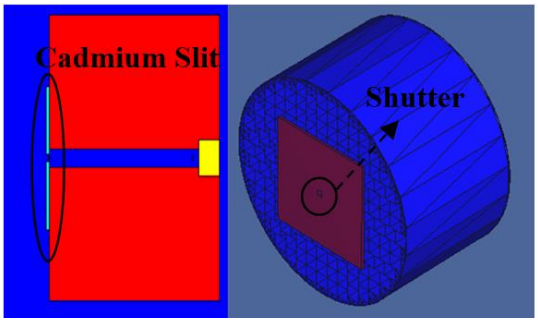


**Fig. 2.** Schematic of the Cadmium slit at the beginning of the sample holder

## *3. Results and discussion*

The (n,γ) cross-section of the sample has been compared with the ENDF library for determining the optimum absorber layer and cadmium shutter. Table 1 is related to the results of using $B_4C$ and Cd layers that were loaded separately inside of the sample tube. According to the results, both of the absorber materials are effective however, using $B_4C$ represents slighter relative discrepancies than Cd especially in small thicknesses. The calculations showed that both of the materials would conclude a relative discrepancy of 1.43% at 1 mm of thickness while without the absorber layers there is a relative difference of 2.8%. Different dimensions of slit and thicknesses did not affect the cross-section values but the dimension of the shutter has a very slight effect on cross-section data. Figure 3 shows relative discrepancies in different dimensions of the shutter. According to the figure, a shutter with dimensions of 1×1 $cm^2$ is marginally more successful in decreasing relative inaccuracy than another dimension of the shutter.

## *4. Conclusions*

According to the results, using both $B_4C$ and Cd is useful in order to decrease the relative discrepancies at the presence of the absorber layers with the thickness of 1 mm results in 1.43% of relative discrepancy while in their absence the discrepancy is equal to 2.8%. as Cd is toxic and produces secondary high energy gamma radiation, using the $B_4C$ layer is preferable which also concludes slighter discrepancies. By increasing thickness, discrepancies of both of the materials get close until they become equal in the thickness of 1 mm. The results show that using a cadmium slit has essentially little effect on cross-section values, with the biggest discrepancy of 0.2% at 1×1 $cm^2$ shutter dimensions at 0.331 eV compared to not applying one. Hence there is no necessity in applying a Cd slit.

**Table 1.** Cross-section measurement results of using $B_4C$ and Cd as the absorber layers

| Thickness (µm) | Fluence (1/cm$^2$) | Reaction density | Cross-section(b) | ENDF for 0.0832 eV | Relative discrepancy to ENDF(%) |
|---|---|---|---|---|---|
| | | | $B_4C$ | | |
| 100 | $8.48\times10^{-2}$ | 4.80 | $5.65\times10^{1}$ | $5.57\times10^{1}$ | 1.53 |
| 300 | $8.48\times10^{-2}$ | 4.79 | $5.65\times10^{1}$ | | 1.51 |
| 500 | $8.48\times10^{-2}$ | 4.79 | $5.65\times10^{1}$ | | 1.49 |
| 1000 | $8.47\times10^{-2}$ | 4.78 | $5.65\times10^{1}$ | | 1.43 |
| | | | Cd | | |
| 100 | $8.49\times10^{-2}$ | 4.80 | $5.66\times10^{1}$ | $5.57\times10^{1}$ | 1.57 |
| 300 | $8.48\times10^{-2}$ | 4.79 | $5.65\times10^{1}$ | | 1.52 |
| 500 | $8.48\times10^{-2}$ | 4.79 | $5.65\times10^{1}$ | | 1.49 |
| 1000 | $8.47\times10^{-2}$ | 4.78 | $5.65\times10^{1}$ | | 1.43 |
| | | Mono-energy source at 0.0832 eV without absorber layers | | | |
| - | $8.66\times10^{-2}$ | 4.96 | $5.73\times10^{1}$ | $5.57\times10^{1}$ | 2.81 |

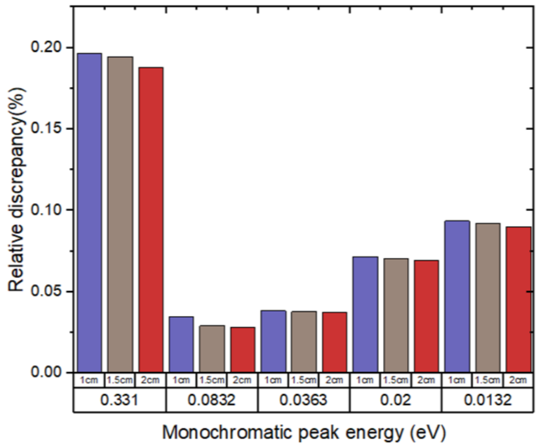


**Fig. 3.** The relative discrepancies between the (n,g) cross-section of the gold sample in the absence and presence of the Cd slit with different dimensions of the shutter

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