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Abstract

Simulating complex spallation source setups related to background is time-consuming and it is connected with uncertainties. That's why neutron spectra measurements are very important for the optimisation of neutron scattering instruments. The goal of the task was to investigate effective shielding setups by measurements.

1. Neutron detector system

The developed BSS-System (within this project) was used to investigate effective shielding setups. Figure 1 shows the used detector and moderator spheres.

Figure 1: New BSS-system with PE moderators and Cu shells

2. Experimental Setup

The beamline BOA at PSI was chosen to investigate different material setups. Figure 2 shows the beamline layout.

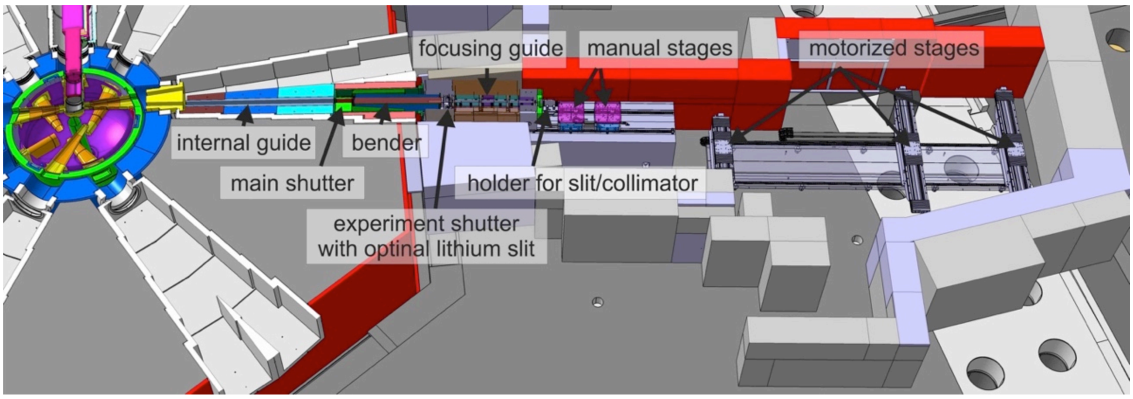

Figure 2: BOA beamline

The advantage of the BOA is that the beamline has a fast neutron beam as well as thermal/cold neutron beam. In addition the beams are separated in space. Figure 3 illustrates the separation. Figure 4 shows the spectrum measurement in the fast neutron beam. The thermal part of the beam was shielded by boron plates. Figure 5 contains the unfolded data.

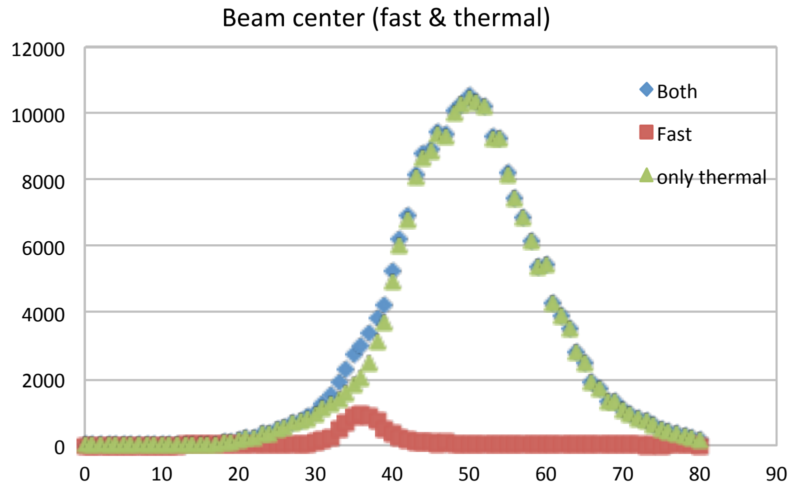

Figure 3: Fast and thermal neutron flux distribution at the BOA beamline

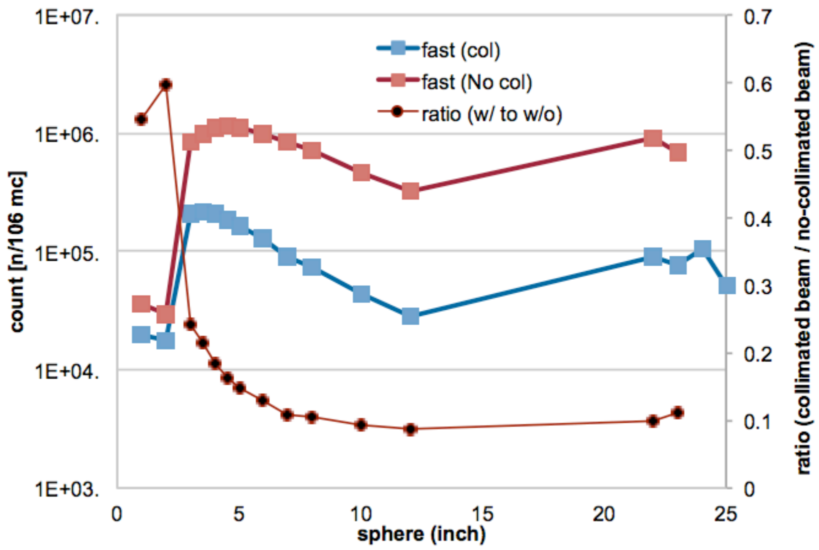

Figure 4: BOA – Fast neutron spectrum measured by the BSS system

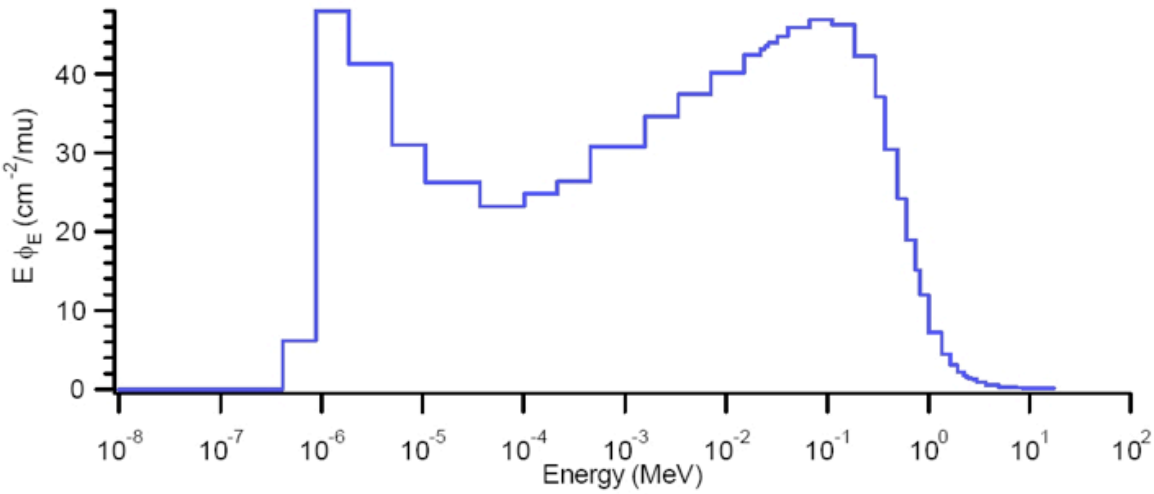

Figure 5: Unfolded neutron spectrum

3. Shielding box

A special shielding box was built which allows to measure/investigate the directional dependency of the neutron spectrum which includes the option to perform transmission measurements. Inside the box the BSS-system is positioned. The shielding box can be opened in any direction.

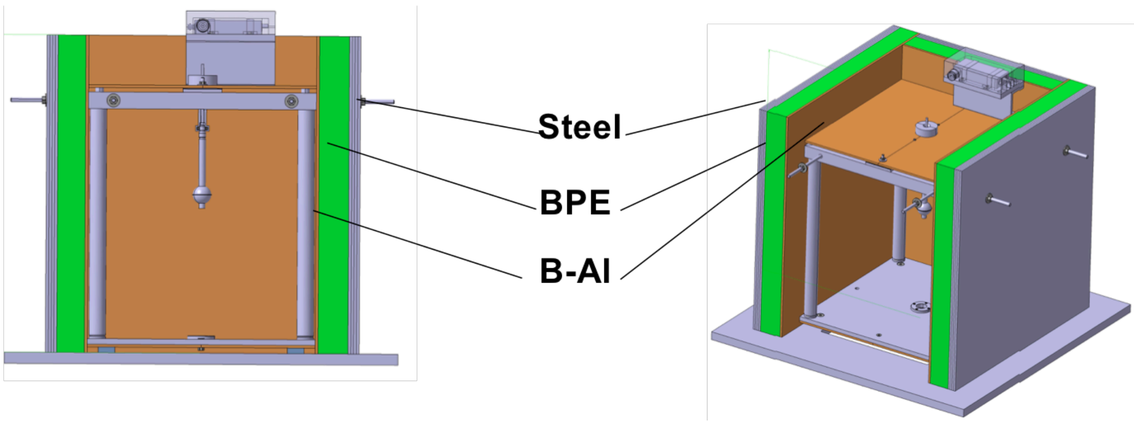

Figure 5: Shielding box for material investigations

The present setup (see figure 2) allows to vary a boron-layer (B-Al), borated polyethylene layer (BPE) and steel layers (several plates). The boron layer was 5 mm thick, the borated polyethylene 50 mm and the steel plates are 20 mm (4 times 5 mm). Figure 6 shows one setup at the beamline.

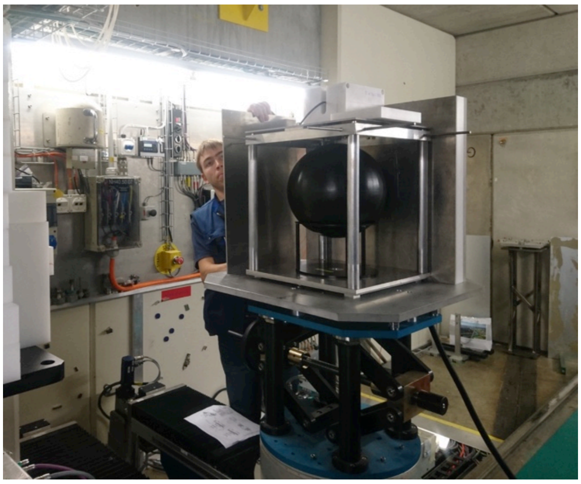

Figure 6: Measurement setup at BOA beamline

4. Results

4.1. Transmission measurements

In a first setup the shielding layer sequence (shown in Figure 7) was investigated. The green layer is the BAl-layer. The orange layer is the borated polyethylene and the yellow layer is steel.

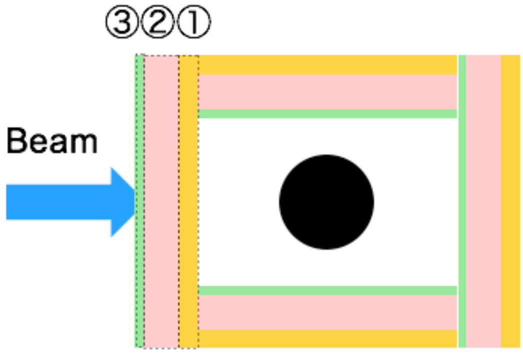

Figure 7: Transmission setup for the fast neutron beam at BOA

The measured results are shown in figures 8 a-c. All three material layers reduce already the fast neutron flux by a factor of three (figure 8a). The borated PE reduce strongly the epi-thermal neutron flux s by factor of 25 (figure 8b). The boron layer has only a 10-20 % effect. The conclusion is that 50 mm of borated polyethylene is a very effective shielding for the epi-thermal neutrons. The boron layer plus the borated PE layer reduce the thermal neutron flux (see figure 8c) by a factor of 40.

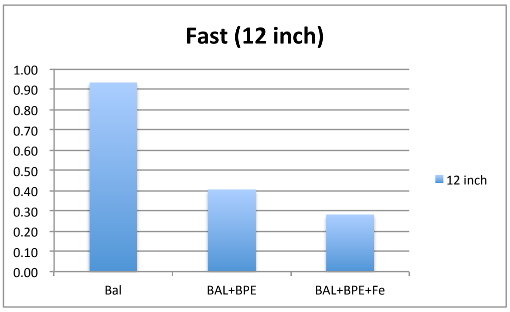

Figure 8a: Fast neutron transmission

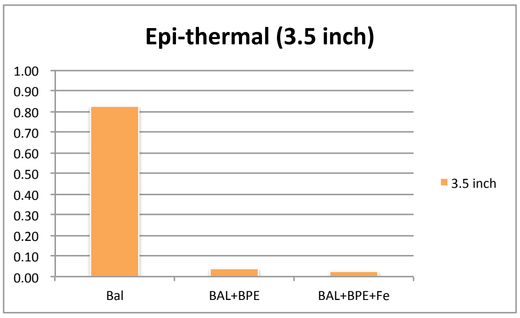

Figure 8b: Epi-thermal neutron transmission

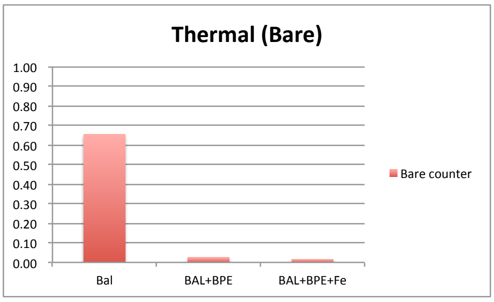

Figure 8c: Thermal neutron transmission

4.2 Background study

The measurement series at the BOA beamline was not only related to the effective shielding because the produced background by the shielding itself is also an important aspect for the right decision which shielding should be used for a sensitive neutron scattering experiment. Figure 9 shows the setup and the results are illustrated in the figures 10 a-c.

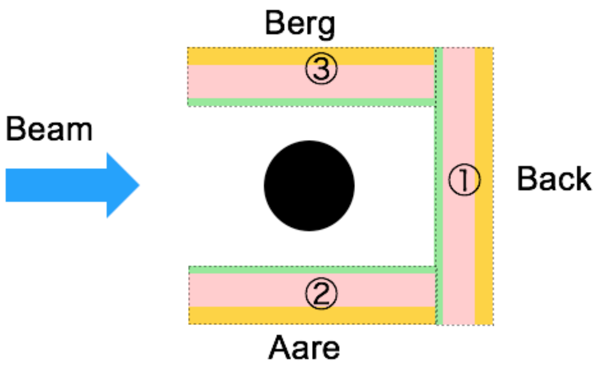

Figure 9: Scattering setup for the fast neutron beam at BOA

The figures 10a and 10b show that the back wall increases the fast and epi-thermal contribution by around 15 %. The side walls do not effect the epi-thermal and fast neutron flux. The thermal neutron flux is reduced by few percent depending which walls are mounted.

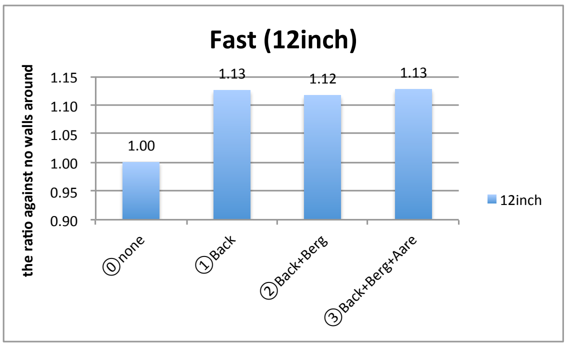

Figure 10a: Fast neutron contribution

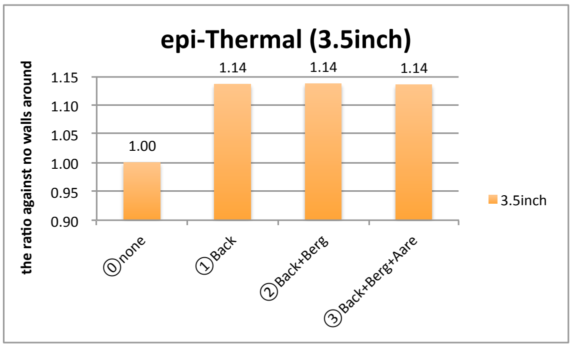

Figure 10b: Epi-thermal neutron contribution

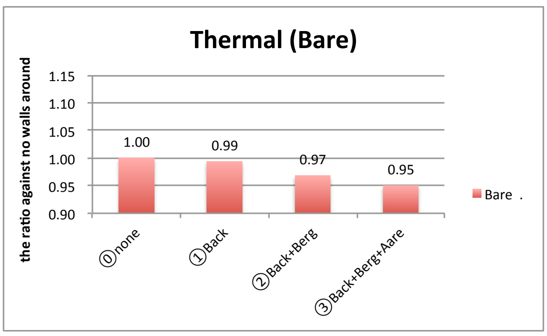

Figure 10c: Thermal neutron contribution

4.3 Scattering from concrete

The last experiment was done to investigate the effect of backscattering from concrete environments/walls. To prove the effect a concrete sample was positioned in the beam and the detector was shielded as shown in Figure 11.

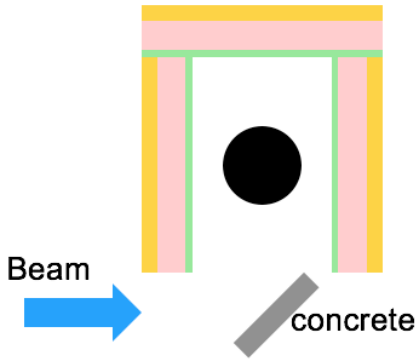

Figure 11: Concrete scattering setup

The concrete sample had a strong effect on the epi-thermal and thermal neutron flux. The epithermal neutron flux was increased by a factor 10 and the thermal neutron flux by a factor 8. A good shielding performance was measured by the use of the 5 mm BAl layer. The scattered epithermal and thermal neutrons were reduced strongly (see figure 12 a and b). If the borated PE layer was added the background could be reduced by an additional factor 2 for epithermal neutrons and a factor 7 for the thermal neutrons.

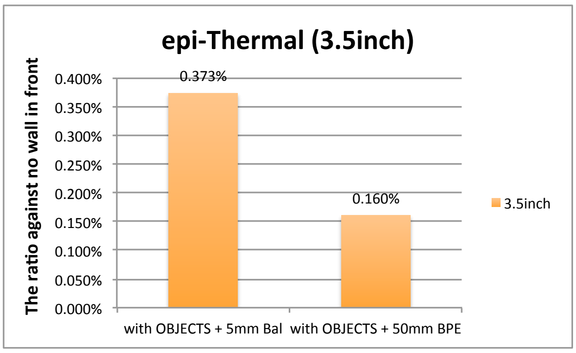

Figure 12a: epithermal scattering reduction

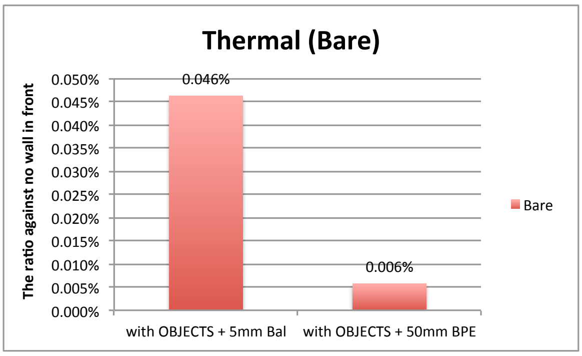

Figure 12b: thermal scattering reduction