Advanced Neutron Moderators for the ESS

Chapter 10 is an experimental paper carried out in the framework of the LENS collaboration. The experiment investigates the concept of a single-crystal reflector filter - a reflector filter that also transmits neutrons in the thermal energy range. This is based on the idea that heavy metals, such as lead and bismuth, are inefficient moderator materials. The article investigates this idea through enriched \(^{208}\)Pb. The article shows that the inability of these materials to moderate can be exploited to design a moderator that reflects neutrons from surrounding moderators of different spectral temperatures, with little change in energy. This results in the emission of a broad neutron spectrum (or multiple spectra) from the lead element. Since lead can also serve as a reflector filter, the geometry can be configured such that the broadspectrum lead moderator acts as a reflector filter for a cold moderator positioned behind it, thus increasing the neutron yield below the lead Bragg edge while still producing a broad spectrum of neutrons.

Chapter 7 comprises two conference proceedings and describes the development from the moderator system at the ESS suggested in the Technical Design Report (TDR) to the new moderator baseline (accepted in March 2015), known as the butterfly moderator. The chapter outlines the development process from TDR through the pancake moderator and to the butterfly moderator, and presents various key results. Ultimately, it is shown how this redesign and optimization results in a significant increase in cold and thermal brightness relative to the TDR proposal.

Chapter 8 is a study in which MCNPX simulations are transferred to ROOT and analyzed. A method for reconstructing the full emission distribution of the moderator brightness is developed. The ESS pancake moderator (and butterfly moderator in the sub-appendix) is studied. The brightness distributions are fitted to analytical functions that have been implemented in McStas. This enables more precise predictions of the expectations from ESS, which is not only a key requirement for experiments at ESS but also enables neutron instruments to be significantly better optimized before their construction. This, in turn, is expected to contribute significantly to the overall quality of the ESS.

Chapter 9 suggests a novel type of broad-spectrum moderator. This moderator concept is based on the idea that heavy metals, such as lead and bismuth, are inefficient moderator materials. The article investigates this idea through enriched \(^{208}\)Pb. The article shows that the inability of these materials to moderate can be exploited to design a moderator that reflects neutrons from surrounding moderators of different spectral temperatures, with little change in energy. This results in the emission of a broad neutron spectrum (or multiple spectra) from the lead element. Since lead can also serve as a reflector filter, the geometry can be configured such that the broadspectrum lead moderator acts as a reflector filter for a cold moderator positioned behind it, thus increasing the neutron yield below the lead Bragg edge while still producing a broad spectrum of neutrons.

Chapter 7 to 10 (further detailed below) present novel work in the form of three papers (two published articles, one submitted) and two conference proceedings.

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Chapter 10 is an experimental paper carried out in the framework of the LENS collaboration. The experiment investigates the concept of a single-crystal reflector filter - a reflector filter that also transmits neutrons in the thermal energy range because of the delta-function-like Bragg edge in a single crystal. The experiment compares single-crystal sapphire, sapphire powder and void. Sapphire was used, since no other single-crystal candidates (diamond, pyrolytic graphite and lithium uoride) could be obtained within the cost and time constraints of the experiment. Unfortunately, sapphire does not notably increase neutron yield, but the experiment proves the viability of a single-crystal reector filter and indicates a potential regain of the thermal neutrons lost to a conventional reflector filter, with little or no loss of the cold neutrons below the Bragg edge.