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Novel Monte Carlo simulations methods for neutron instrumentation

Abstract

The unique neutron yield and high performance requirements of the European Spallation Source (ESS) ERIC inspire new approaches in the design of neutron scattering instruments, both in terms of detection techniques and of radiation safety planning. Monte Carlo simulations are powerful tools for both challenges.

In addition to the challenges of the ESS, the recent scarcity of ^{3}He opened a new frontier in neutron detector development. A potent new ^{3}He-replacement solution for the large area detectors of the chopper spectrometers at the ESS is the Multi-Grid thermal neutron detector, an Ar/CO_2 gas filled proportional chamber with solid $^{10}B_4C$ neutron converter. As the high Signal-to-Background Ratio (SBR) is a key requirement, for these instruments Monte Carlo simulations were performed to determine the neutron induced intrinsic gamma and scattered neutron background of the detector and their impact on the SBR. Neutron activation and gamma production were simulated with MCNP for a general Ar/CO_2 gas filled detector. Also, a detailed Geant4 detector model was developed, validated and applied for neutron scattering simulations for the Multi-Grid detector, utilising the recently developed neutron simulation tools like NCryrtal and MCPL. The model was applied for shielding design development to reduce the scattered neutron background. The obtained results contribute to the optimisation of the shielding, coating and vessel design of the Multi-Grid detector module, leading to instruments with better SBR by design.

For shielding design, neutron activation and decay-gamma production was studied in the newly developed PE-B4C-concrete, highlighting the role of trace elements in safety planning. Realistic, measurement-supported material cards were developed for activity and decay-gamma dose rate simulations with MCNP.