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Detector response functions for in situ high energy neutron spectrometry

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Fast and high energy neutron fields are produced through the interaction of energetic charged particles with matter, which is a concern for aviation, space exploration, radiotherapy and accelerator environments. To improve radiation risk models for exposed individuals it is necessary to fully characterise the different components of the mixed radiation fields at the point of exposure. In situ measurements of neutron fluence spectra can be achieved through spectrum unfolding, where the incident neutron energy distribution is deconvolved from the measured signature(s) using a library of energy-dependent response functions and mathematical or computational techniques. The detector response functions must span the full energy range for the application and account for non-linearities associated with the whole system, including the detector, electronics and acquisition. For neutrons with energies below 20 MeV, detector response functions can reliably be simulated subject to appropriate scaling to experimental data. However, for neutrons with energies above 20 MeV the availability and quality of reaction cross section data and models are insufficient for the simulation of detector response functions, requiring direct measurement at high energy neutron facilities providing ns-pulsed beams.

The experimental and analytical procedures to derive detector response functions for unfolding are presented for the example of organic scintillators. Detector response functions are simulated with Geant4 between 1-20 MeV and validated against measurements at fast neutron reference facilities AMANDE (Autorité de Sûreté Nucléaire et de Radioprotection, France), and PIAF (Physikalisch-Technische Bundesanstalt, Germany). For applications where neutrons exceeding 20 MeV are expected, nearly mono-energetic detector response functions are measured at the iThemba LABS (South Africa) neutron facility using time-of-flight techniques. The spectroscopic capabilities of modern (EJ-276) and traditional (BC-501A) detector systems are demonstrated through the unfolding of known neutron fields with MAXED, using simulated and measured detector response functions.

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