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Investigation of neutron-induced background in HPGe detectors – first phase

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Background induced by neutrons is a poorly understood background component for all low-level systems. In shielded laboratories, neutrons can still be produced by interactions of cosmic rays (hadronic cascades, negative muon capture) and by natural radioactivity, via spontaneous fission or (α, n) reactions. Predicting all background components correctly is crucial for designing efficient shielding and applying appropriate eventrejection strategies.
The interactions of fast neutrons in a coaxial p-type high-purity germanium detector (HPGe) have been studied experimentally and by the detector simulation tool GEANT4. Neutrons and gamma-rays emitted from a 241Am-Be source with an activity 370 MBq were used for a detailed investigation of their interactions in a coaxial p-type HPGe. In HPGe detector, the main energy deposition mechanisms of neutrons with energies between 0.5 and 10 MeV, are elastic and inelastic scattering. Elastic and inelastic scattering of neutrons for HPGe energy thresholds below about 50 keV give the largest contribution to the interaction probability, and may be an important effect to take into account in future gamma-ray spectrometers based on gamma-ray tracking. (Ljungvall and Nyberg, 2005)
The experimental setup consisted of a 241Am-Be source encapsulated in a case of stainless steel and in an aluminium shell placed coaxially 161.2 mm above a 50% coaxial p-type HPGe detector in a low-level shield. Two circular iron absorbers were placed above the detector to absorb the abundant gamma rays of 241Am and so reduce the dead time and a plastic beaker was used to keep the distance of the source to the detector.
The experimental results were compared with GEANT4 simulations of the neutron and gamma-ray interactions with the detector and shielding. Precise geometry of the setup was coded including individual material impurities. Detailed analysis of both, experimental and simulated spectra was carried out. Elastic and inelastic scattering of fast neutrons were observed, as well as their capture. Ge peaks at energies 68.6 keV, 564.0 keV, 597.0 keV, 688.1 keV, 836.1 keV, 1039.6 keV and 1215.7 keV have typical triangular shape, which is due to the inelastic scattering of fast neutrons on Ge. A Peak at the energy of 68.8 keV corresponds to the reaction 73Ge(n, n'gamma)73Ge*, peaks at energies 564.0 keV and 597.0 keV to the reaction 76Ge(n, n'gamma)76Ge*, peaks at energies 688.1 keV and 836.1 keV to the reaction 72Ge(n, n'gamma)72Ge*, and the peak at the energy of 1215.7 keV to the reaction 70Ge(n, n'gamma)70Ge*.
The results of this work have shown that the GEANT4 simulation tool and the neutron cross section data implemented into GEANT4 are suitable for neutron simulations and give good results at least up to neutron energy 11 MeV, which is the maximum energy of neutrons from 241Am-Be source. Concluding, GEANT4 was validated for further studies by comparing experimental results with simulations.

Ljungvall, J., Nyberg, J., 2005. Nucl. Instr. Meth. in Phys. Res. A 546, 553–573

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