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Neutrons and gamma-rays as environmental sources of HPGe detectors background operating underground

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Backgrounds induced by neutrons and gamma-rays are important background components for all experiments looking for rare events, such as dark matter interactions or neutrinoless ββ decay. Neutrons and gamma-rays can be produced by natural radioactivity, via spontaneous fission or (α, n) reactions and by interactions of cosmic rays. Predicting all background components correctly is crucial for designing efficient shielding and applying appropriate event-rejection strategies.
In deep underground laboratories only the hard component of cosmic rays contribute to background. Merely muons and neutrinos are able to penetrate so deeply. Next significant background component is radioactive contamination of detector construction materials and of the laboratory.
In order to investigate neutron induced-background, interactions of neutrons with a Ge detector were studied experimentally as the first step. Monte Carlo simulations using the GEANT4 simulation tool were carried out next for surface and deep underground laboratory.
The principal energy deposition mechanisms of neutrons with energies up to 11 MeV in the Ge detector are elastic and inelastic scattering. The dominant process for slow and thermal neutrons is the neutron capture, for fast neutrons the dominant processes are elastic and inelastic scattering. At neutron energies from 3.5 to 4.5 MeV, the inelastic scattering is the most probable interaction of neutrons with all naturally occurring germanium isotopes. This process is of interest for the background induction by fast neutrons, as indicated by cross sections of these reactions.
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. A typical feature of neutron interactions with a Ge crystal of the detector are triangular gamma-ray peaks. Such peaks were clearly observed in experimental spectrum obtained from a surface laboratory as well as in the simulation. Whereas, inelastic scattering will always contribute to the background of Ge detectors in the energy region of interest, Ge peaks are observed also in the background spectrum measured in deep underground laboratory and in the simulation, too. Copper and lead as well as aluminium and tin influence the spectrum strongly. Interactions of neutrons with these materials produce many gamma-lines visible in the spectrum and become a background source, which can hide or imitate the signal. In underground laboratories gamma-rays from radioactive contamination of material surrounding the detector as well as from contamination of construction parts of the detector itself contribute to background.
The experimental results were compared with GEANT4 simulation. Precise geometry of the setup was coded including individual material impurities. The simulated spectrum reproduces the main features of the measured spectrum fairly well considering the complexity of the interactions. Integral count rates were compared and the agreement of 98% was achieved.
The results of this work showed that the GEANT4 simulation toolkit is appropriate tool for estimation of the neutron and gamma-ray background components.

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