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COSMIC RAY INDUCED NEUTRON BACKGROUND IN GAMMA SPECTROMETRY

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Abstract - W*e developed an ultralow-level background gamma-ray spectormeter, using active and passive shield devices at the same time. This article discusses the cosmic ray induced neutron background in Ge-spectrometry. It can be noted that surrounding plastic shield lead to increasing intensity of (n,γ) lines, because of neutron thermalization.*

1. INTRODUCTION

The background spectrum of Ge-detectors can be categorized by the following components: environmental gamma radioation, radioacitvity in the constrution material of the detector, radioimpurity in the shielding material, cosmic rays: nucleons, muons and activations, radon and its progenies, neutrons form natural activity (fission and (α, n) reacitions).

Neutrons from natural fission and (α, n) reacitions become significant only at extreme low level counting deep underground.

Cosmic-ray secondaries of interest for background considerations of ionizing detectors are only muons and neutrons. Of the nucleonic component the protons are negligible in intensity compared to the neutrons and are mostly converted into neutrons when reacting with the shield material.

The neutron flux is attenuated by a length of 120-150 g/cm^2 and is therefore influenced by building structures or other overburden above the spectrometer shield, whereas the muon flux is attenuated on much longer scales (about ten times more near sea level). Tertiary neutrons are produced in the lead from μ-capture and by photonuclear reaction of fast muons.

The study of nuclear gamma-ray lines that are produced by isomeric transitions in Ge detectors offers the possibility of estimating the neutron spectrum inside the shield [1].

2. EXPERIMENT

Gamma-ray spectrometer system developed in this work consists of passive and active shielding. The passive shielding is made of 120 mm thick low-active lead. In order to reduce the enhanced Compton scattering of the 511 keV gamma-rays on copper it is decided to redesign lining of the Pb chamber. Monte-Carlo calculations have been performed in order to select the most appropriate material and the optimal thickness. It is found that Sn is more appropriate than the most frequently used Cd. The optimal thickness of Sn is found to be 3.5 mm. The Sn X-rays are reduced by 0.5 mm of Cu. Scintillating plates were arranged to surround the top and four sides of lead shielding. The active shielding consist of 5 plastic scintillations (0.5 m x 0.5 m x 0.05 m) which are surrounding the passive Pb shield. The germanium detector was GMX type made by ORTEC corp. The relative efficiency is 36%, and due to the thin surface dead layer and Be window has good efficiency even on 10 keV. Integral count rate of passive shielding detector is 0.95 c/s in the energy range from 50-1800 keV, which is very good value for the ground passive shield. Integral count rate with active shield is 2.5 times reduced – from 0.95 c/s to 0.32 c/s at energy interval 40 keV-2700 keV.

The nuclear reactions taking place in two steps: (1) the formation of a compound nucleus in a highly excited virtual level, and (2) the dissociation of this compound nucleus leading to a state of high excitation of the product nucleus. The product nucleus, which decay promptly by electromagnetic transitions, ends up in the ground state or in some low-lying metastable level called isomer. Since the lifetimes of the Ge isomers are much longer than the microsecond anticoincidence times of standard instruments, the emitted lines are not vetoed by the shield. Thus the lines produced by the activation of Ge nuclei are the strongest in the background of a Ge spectrometer.

In Figure 1 an example for a neutron dominated spectrum is presented. All labeled lines are induced by neutrons in the Ge-crystal itself. Because to muon spectrum is reduced scientifically, the neutron induced lines is very intensive.

Muons are both very penetrating and prime source of fast neutrons. These fast neutrons generate photons by means of neutron-neutron reactions in the high Z materials surrounding the high Z materials surrounding the crystal assembly and after sufficiently slow down they create radioisotopes through the activation processes mainly in Ge crystal [2]. The photons from the decay of these isomers are observed on the spectrum if their half-lives are significantly longer than the coincidence resolving time of 1ms at present work. Intensity of some neutron induced lines are presented in Table I. The intensity of lines from (n,n') reactions, which originates from fast neutrons, are very small. In Figure 1 only the lines at 595.9 keV is visible. The neutron induced lines at 68.7 keV, 562.8 keV and 691 keV, from ^{73*}Ge, ^{76*}Ge and ^{74*}Ge [1] are not observble. It can be noted that surrounding plastic shield lead to increasing intensity of (n,γ) lines, because of neutron thermalisation.

When a muon collides with high Z materials, it produces many kinds of secondary particles such as electrons, positrons and protons. These secondary particles are absorbed by lead shielding and generate gamma rays by means of bremsstrahlung or annihilation process. With our developed active shielding the 511 keV annihilation line was reduced by the factor of 7 by the anticoincidence gate

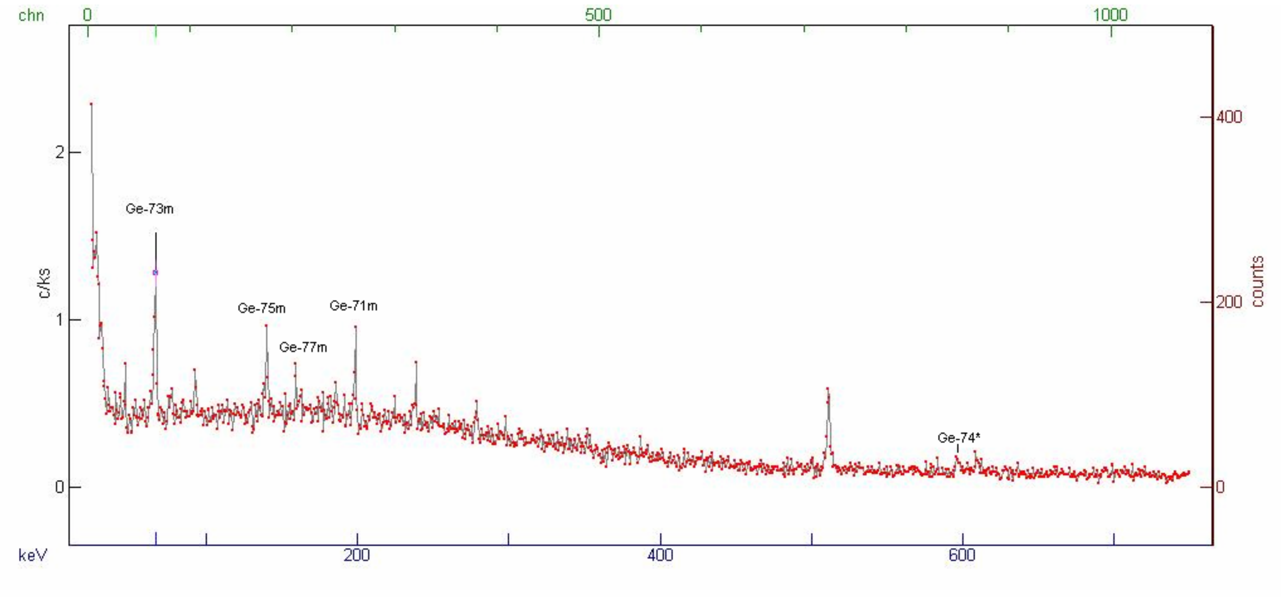

Figure 1. *Background spectrum of a 36% HPGe detector at sea level, in active plastic veto shield and passive shield of 120 mm thick low-active lead, 3.5 mm of Sn and 0.5 mm of Cu.*

Table I. *Intensity of gamma lines induced by neutrons*

E [keV]	Reaction	$T_{1/2}$[s]	I_0[c/ks] passive Pb+Sn shield	I_1[c/ks] passive shield + plastic detectors (without gating)	I_2[c/ks] passive shield + plastic detectors (with gating)
66.7	^{72}Ge(n,γ)^{73m}Ge	0.5	1.55±0.19	1.98±0.51	1.78±0.29
139.7	^{74}Ge(n,γ)^{75m}Ge	47.7	0.42±0.19	1.32±0.53	1.08±0.26
159.5	^{76}Ge(n,γ)^{77m}Ge	52.9	0.44±0.22	0.78±0.48	0.54±0.23
198.9	^{70}Ge(n,γ)^{71m}Ge	0.022	0.55±0.23	1.02±0.53	0.52±0.27
595.9	^{74}Ge(n,n´)^{74*}Ge		0.49±0.13	<0.44	0.24±0.12

3. DISSCUSION

We developed an ultra low-level background germanium spectrometer using active and passive shielding. The cosmic-ray-induced background is significantly suppressed by the developed active shield devices, which consists of an array of plastic scintillations and anticoincidence electronics.

Intensity of lines from (n,n') reactions are very small or not observable. It can be noted that surrounding plastic shield lead to increasing intensity of (n,γ) lines, because of neutron thermalisation. The reduction of neutron lines by active shield is very small, so the additional anti-neutron shield is requaried.

From the line intensities in Table I. using the neutron cross sections from Ref. [3] the neutron flux in the low level laboratory is calculated (Table II). Only the weak gamma-ray of 159 keV from the neutron capture on ^{76}Ge yields unrealistic high flux values.

Table II. *Calculated neutron flux*

Isotope	Φ(cm^{-2}s^{-1})
^{70}Ge	2.4(14)
^{72}Ge	0.99(27)
^{74}Ge	2.9(13)
^{76}Ge	68(42)

REFERENCE

[1] G. Heusser, “Background in ionizing radiation detection – illustrated by Ge-spectrometry”, *Proceedings,* World Scientific Singapore, 1994.

[2] Jong In Byun et al., “An anticoincidence-shielded gamma-ray spectrometer for analysis of low level environmental radionuclides”, *Applied Radiation and Isotpes,* 58 (2003), pp. 579-583.

[3] Handbook on nuclear activation data, *International Atomic Energy Agency*, Vienna, 1987.

Sadržaj – U radu je prikazana analiza uticaja neutrona na fon niskofonskog gama spektrometra. Niskofonski gama spektrometar je razvijen primenom aktivne i pasivne zaštite Ge detektora. Pokazano je da korišćena plastična zaštita usled efekata usporavanja neutrona dovodi do povećanja (n,γ) linija.

GAMA ZRAČENJE U GAMA SPEKTROMETRU IZAZVANO NEUTRONIMA

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