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Modernization of neutron monitor IGY-57

Abstract

The main goal of this article is the calculation of physical parameters of the neutron moderator for the thermalization of evaporated neutrons generated in the local lead generator of the neutron monitor IGY-57. Calculation was performed by using GEANT4 (for GEometry ANd Tracking) which is a platform for "the simulation of the passage of particles through matter," using Monte Carlo methods. On the basis of data gained during simulation we designed the "geometry" of the experimental setup which includes the thicknesses of moderator and reflector of the experimental setup. The reason to moderate the neutrons which are generated in the local lead generator of the neutron monitor IGY-57 is the fact that the counters that are used in our experimental setup can register only thermal neutrons. This is why process of thermalization of generated neutrons is of such great importance.

Key words: Reflector and moderator, energetic hadrons, cosmic radiation, nuclear disintegrations, GEANT4 simulation package, secondary neutron, neutron monitor IGY-57.

Introduction

There are two types of standardized neutron monitors. IGY neutron monitor was developed by Simpson in the early fifties of last century. It was a standard detector, studying temporal variations of the intensity of primary cosmic rays in the GeV energy range order in the near-Earth space during the International Geophysical Year (IGY) 1957/1958 [1]. Ten years later, Carmichael (1964) developed a neutron monitor larger NM64 with high counting rate. NM64 was the standard ground-based cosmic ray detector for the International Year of the Quiet Sun 1964 [2].

Main part

During the interaction of energetic hadrons of Cosmic Radiation coming from outside the monitor, with the nuclei of lead atoms the nuclear reaction of splitting takes place, resulting in a large number of secondary particles, including the evaporated neutrons, which can be detected by sections detectors [3]. However, the neutrons generated in the process of nuclear disintegrations are of relatively large (several MeV) energies and cannot be registered directly by proportional counters. Due to this fact the construction of the neutron monitor IGY-57 includes the local lead generator, paraffin moderators, and reflectors [4-5]. We designed the screening block of the neutron monitor IGY-57 and defined the layer of lead neutron generator, which surrounds the neutron counters, was defined.

Reflector and moderator for the neutron monitor IGY-57 were designed. The schematic view of the neutron monitor IGY-57 is presented in Figure 1 and the geometry of experimental setup in Figure 2. Two layers of hydrogen-containing substances (paraffin), one of which, in the form of tubes, surrounds proportional counters, and the second layer covers the section from the outside. Both layers are moderators of secondary neutrons with an initial energy of several MeV: during the process of diffusion of these neutrons in hydrogen-containing material multiple elastic collisions with protons occur, resulting in an average energy of the neutrons is reduced to the thermal value (about 10^{-2}eV). Thermal neutrons with sufficiently high probability can be detected by proportional counters [6-7]. The outer layer of hydrogen-containing substance, in addition, provides partial reflection of the secondary neutrons, going outside, back inside the neutron monitor, which increases its effectiveness, and screening monitor from background neutrons from the environment.

Using GEANT4 simulation package [8] a program to calculate the physical parameters of the neutron moderator for the thermalization of evaporated neutrons generated in the local lead generator of the neutron monitor IGY-57 was developed and a part of the simulation data can be seen in table 1.

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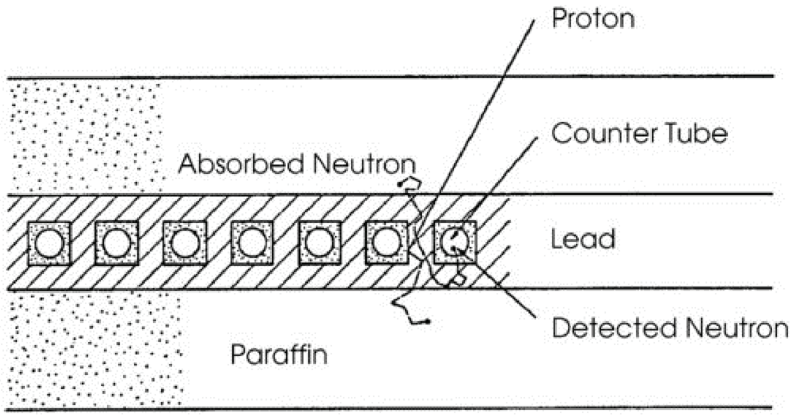

Figure 1 – Schematic view of the neutron monitor IGY-57

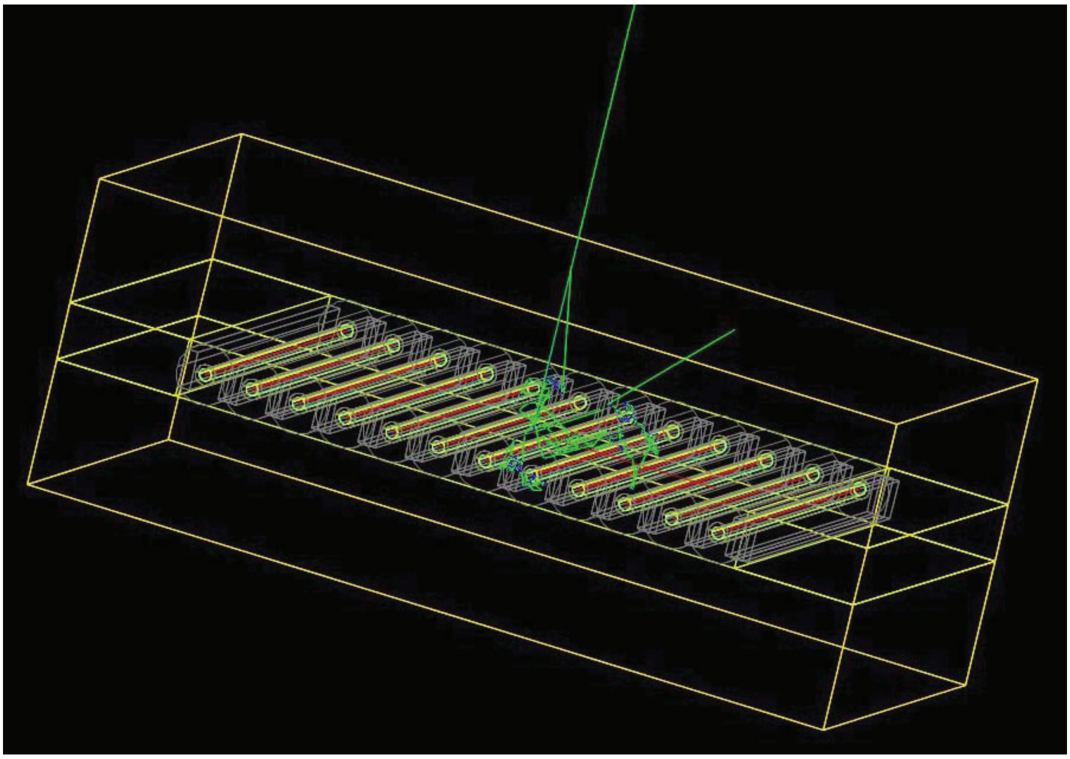

Figure 2 – Geometry of experimental setup

Table 1 – A part of the simulation data which shows the slowing down of a neutron during elastic scattering

Track number	Parent track	Particle	Energy, MeV	Time, s	material
1	2	3	4	5	6
|4	1	neutron	1.5189493	0.022325057	G4_PARAFFIN
|22	4	proton	0.78372971	0.026330826	G4_PARAFFIN
|4	1	neutron	0.73564793	0.026330826	G4_PARAFFIN
|23	4	proton	0.45720953	0.026954916	G4_PARAFFIN
|4	1	neutron	0.27868838	0.026954916	G4_PARAFFIN
|24	4	proton	0.049067209	0.029074836	G4_PARAFFIN
|4	1	neutron	0.22964809	0.029074836	G4_PARAFFIN

1	2	3	4	5	6
|25	4	C12[0.0]	0.02364005	0.030638043	G4_PARAFFIN
|4	1	neutron	0.20601453	0.030638043	G4_PARAFFIN
|26	4	C12[0.0]	0.013579322	0.03209486	G4_PARAFFIN
|4	1	neutron	0.19243893	0.03209486	G4_PARAFFIN
|27	4	proton	0.081363639	0.034951138	G4_PARAFFIN
|4	1	neutron	0.11111984	0.034951138	G4_PARAFFIN
|28	4	proton	0.05817511	0.035338087	G4_PARAFFIN
|4	1	neutron	0.052976595	0.035338087	G4_PARAFFIN
|29	4	proton	0.038246626	0.036458862	G4_PARAFFIN
|4	1	neutron	0.014750899	0.036458862	G4_PARAFFIN
|30	4	proton	0.0074692737	0.037450266	G4_PARAFFIN
|4	1	neutron	0.007285718	0.037450266	G4_PARAFFIN
|31	4	proton	0.0071676377	0.041052467	G4_PARAFFIN
|4	1	neutron	0.00012200661	0.041052467	G4_Pb
|32	4	Pb207[0.0]	1.5716819e-06	0.36145817	G4_Pb
|4	1	neutron	0.00012046115	0.36145817	G4_Pb
|33	4	Pb208[0.0]	2.7980022e-08	0.58471955	G4_Pb

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