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GROUND RADON AS A SOURCE OF ATMOSPHERIC NEUTRONS

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ABSTRACT

Using the Geant4 simulator total neutron spectra produced in reactions of α-particles from radon isotopes decay with soil constituents it was made for the energy range of 10^3 to 10^7 eV. The dependence of backscatter neutrons produced in soil from different ground depths have been made. The spectra of the neutrons originated from a different soil depths compared with the initial ones produced by radon interaction marks the depths of the neutron production in cm. The neutron Geant4 simulation curves compared with measurements made from 10^{-8} to 5 eV was made and shows distinct form and intensities. The cosmic-ray fluxes of neutrons arrived from atmosphere or produced in earth soil is sometimes greater than that produced by radon gas.

Keywords: *neutrons, ionizing radiation, atmosphere, radon gas.*

I. INTRODUCTION

The main part of the atmospheric neutrons of the natural origin is produced by showers initiated by cosmic rays. At smaller than 1 km high from the ground, the neutron flux is added with one more component call albedo neutrons. These are neutrons of the same atmospheric origin but scattered and moderated in the soil or produced by cascade energetic particles in nuclear reaction with the soil substance. The albedo flux constitutes a distinct peak of thermal ($\approx 2.5\cdot 10^{-8}$ MeV) and epithermal energies ($\approx 2.5\cdot 10^{-8}$ to $4\cdot 10^{-7}$MeV) in the lethargy ((i.e., neutron flux×energy vs. energy) spectrum [1] increasing as a distance from the ground decreases. The energy of fast neutron corresponds that of mean energy is greater than 400 keV. Thermal neutrons correspond those with energy less than 1 eV and epithermal neutrons those between 1eV to 400 keV.

II. METHOD & MATERIAL

Several papers [2-4] were published in the last years assuming natural underground radon as one more source of detectable fluxes of atmospheric neutrons. Such neutrons are born in (α , n) reactions of α-particles produced in the decay chain of radon isotopes with soil components. However, no quantitative estimation of the hypothesis has been performed yet. This paper presents results of simulation of the process of neutron following decay of radon isotopes and subsequent propagation of the neutrons to the ground surface. The simulation was performed on the base of Geant4, a widely used Monte Carlo toolkit for the simulation of the passage of particles through matter [5].

The decay chains of ^{220}Rn and ^{222}Rn isotopes resulting in emission of monoenergetic α-particles are shown in the Table 1a and 1b.

Table 1. Decay chains of the natural Radon isotopes

a	Isotope	$^{220}Rn \rightarrow$ $^{216}Po \rightarrow$ $^{212}Bi \rightarrow$ $^{212}Po \rightarrow$ ^{208}Pb				
	α-particle energy, MeV	6.29	6.8	6.050 (69.9%) 6.089 (27.12%)	4.73	Stable
b	Isotope	$^{222}Rn \rightarrow$ $^{218}Po \rightarrow$ $^{214}Po \rightarrow$ $^{210}Po \rightarrow$ ^{206}Pb				
	α-particle energy, MeV	5.5	6.0	7.69	5.3	Stable

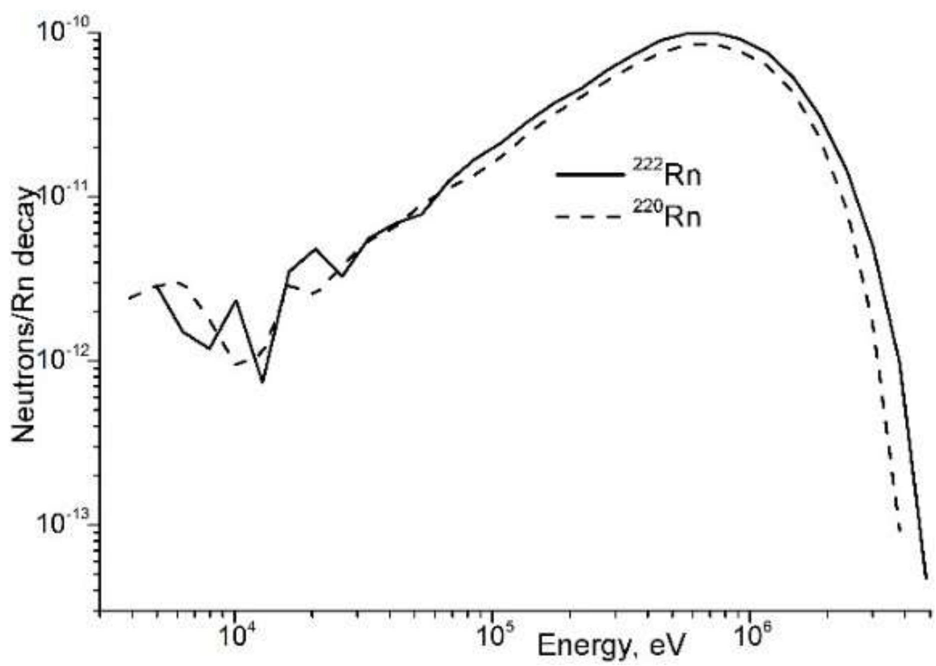

Fig. 1 –Total neutron spectra produced in reactions of α-particles from radon isotopes decay with soil constituents.

III. RESULT & DISCUSSION

Radon decay rate is controlled by the radon isotopes concentration and is the same in the each chain due to secular equilibrium. The total spectra of the neutrons produced by α-particles specified in the Table 1 are shown in Fig.1.

Because of very short ranges of the α-particles born, they produce neutrons or/and stop practically in a point of a decay. During successive scattering in soil some a part of the neutrons reaches a ground surface and egress to the atmosphere. A probability of that depends on a depth where (α, n) reaction occurred (see Fig. 2).

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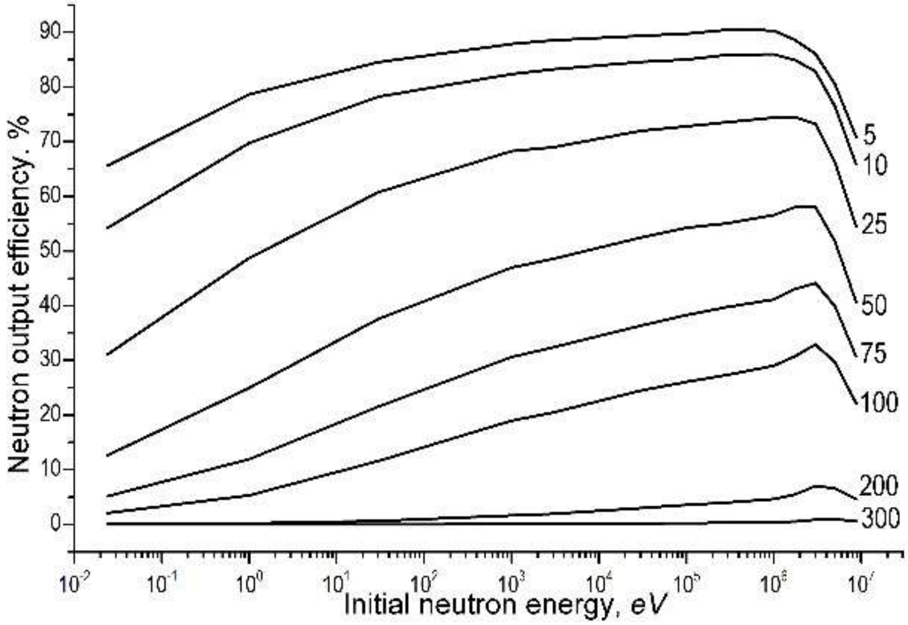

Fig.2 - A probability of a neutron escape from the ground from different ground depths. The numbers next the curves marks a neutron production depths in cm.

One can see that the depth of 3 meters is a maximal depth from which the neutrons are able to reach the ground surface. The spectra of the neutrons escaped from the soil from different depths are shown in Fig.3.

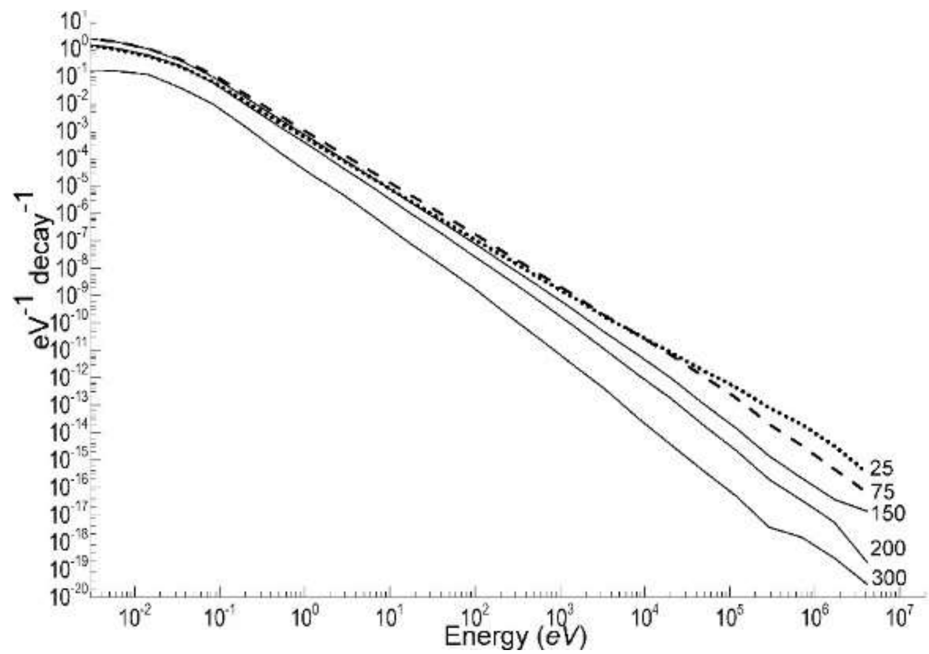

Fig.3 - The spectra of the radon decay origin neutrons egressed from a different soil depths. The numbers next the curves marks the depths of the neutron production in cm

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To obtain a resulting spectrum at the ground surface one need to integrate over the depth a product of neutron production rate by corresponding spectra at the surface shown above. The result for radon decay rate of 50 kBq m-3 [6] is shown in Fig.4 in a standard form of a lethargy spectrum compared with experimental data [1].

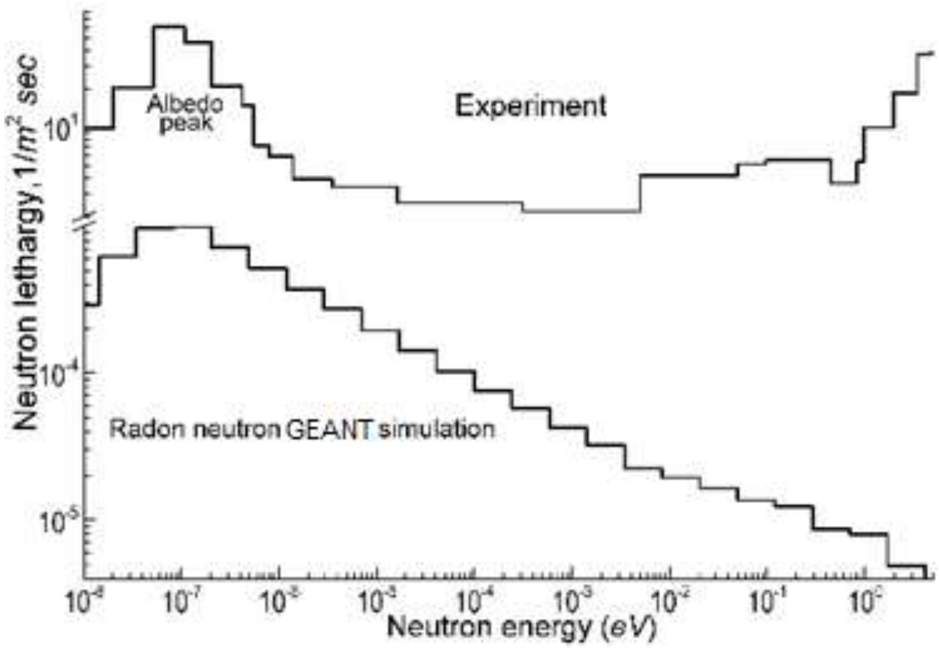

Fig.4 - The simulated spectrum of the neutrons of the ground radon origin

The result obtained should be compared with another "underground" source i.e. albedo. It is seen that the neutron flux of the underground radon origin in thermal energy far and away lower being compared with that of cosmic ray albedo and cannot noticeably increase the neutron flux near the ground.

IV. CONCLUSION

A simulation of propagation of the neutrons produced in the ground in result of decay of natural radon shows that such a source cannot provide any noticeable flux being compared with the albedo neutron flux. The two main sources of thermal and epithermal neutrons near the Earth's surface are cosmic rays and their interactions with the Earth's atmosphere and soil as well as the presence of radon gas that emits alpha particles that reaches the ground and in interactions produces these neutrons. In the range of energy ($10^3 – 10^7$ eV) the simulation of neutron produced versus radon gas presence agree very well. Another important information obtained by simulating neutrons ejected as a function of soil depth (cm) shows good efficiency up to 200 cm. The simulated spectrum of the neutrons of the ground radon origin and those measured do not agree very well. The albedo fluxes of neutron produced during rainfall periods have increased value due to water more rich than air in hydrogen atom.

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Figure captures

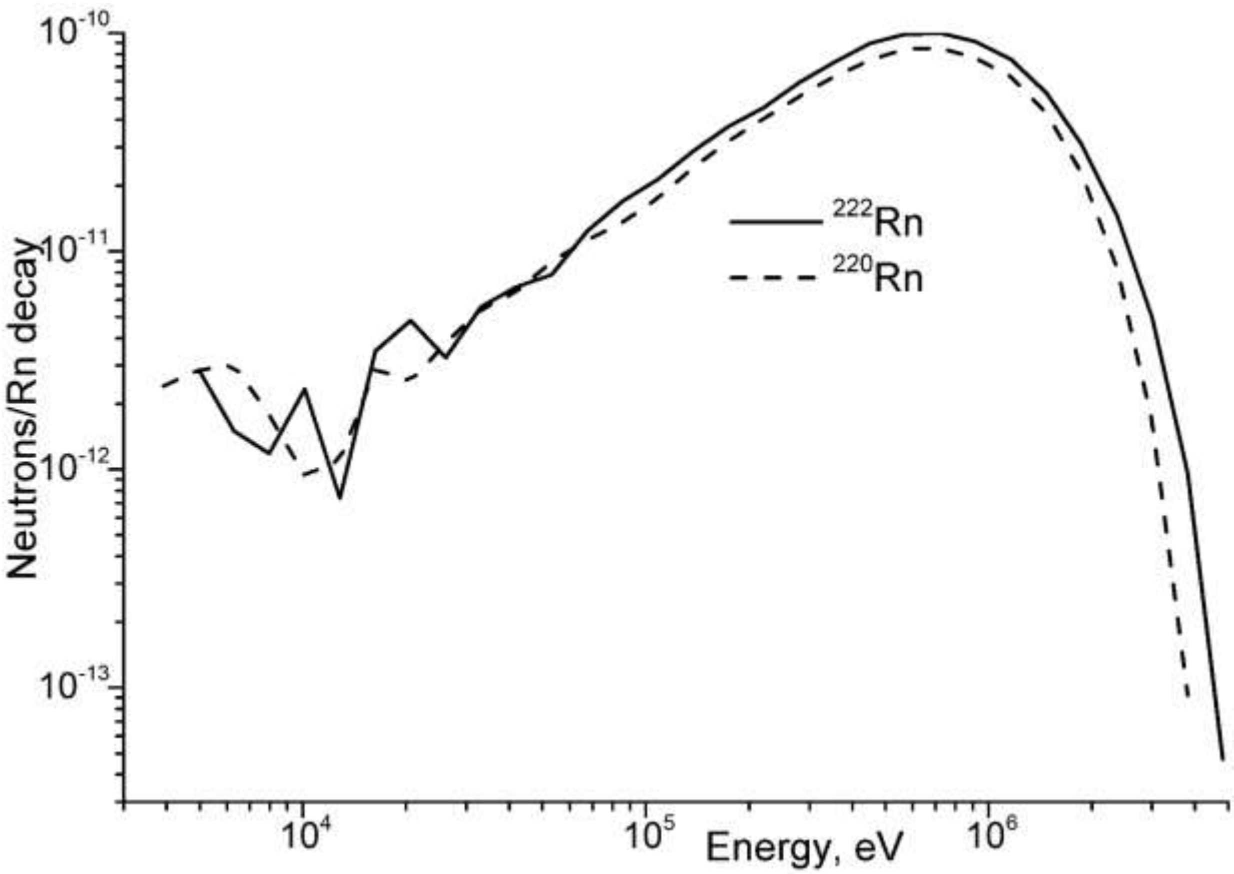

Fig.1 - Total neutron spectra produced in reactions of α-particles from radon isotopes decay with soil constituents

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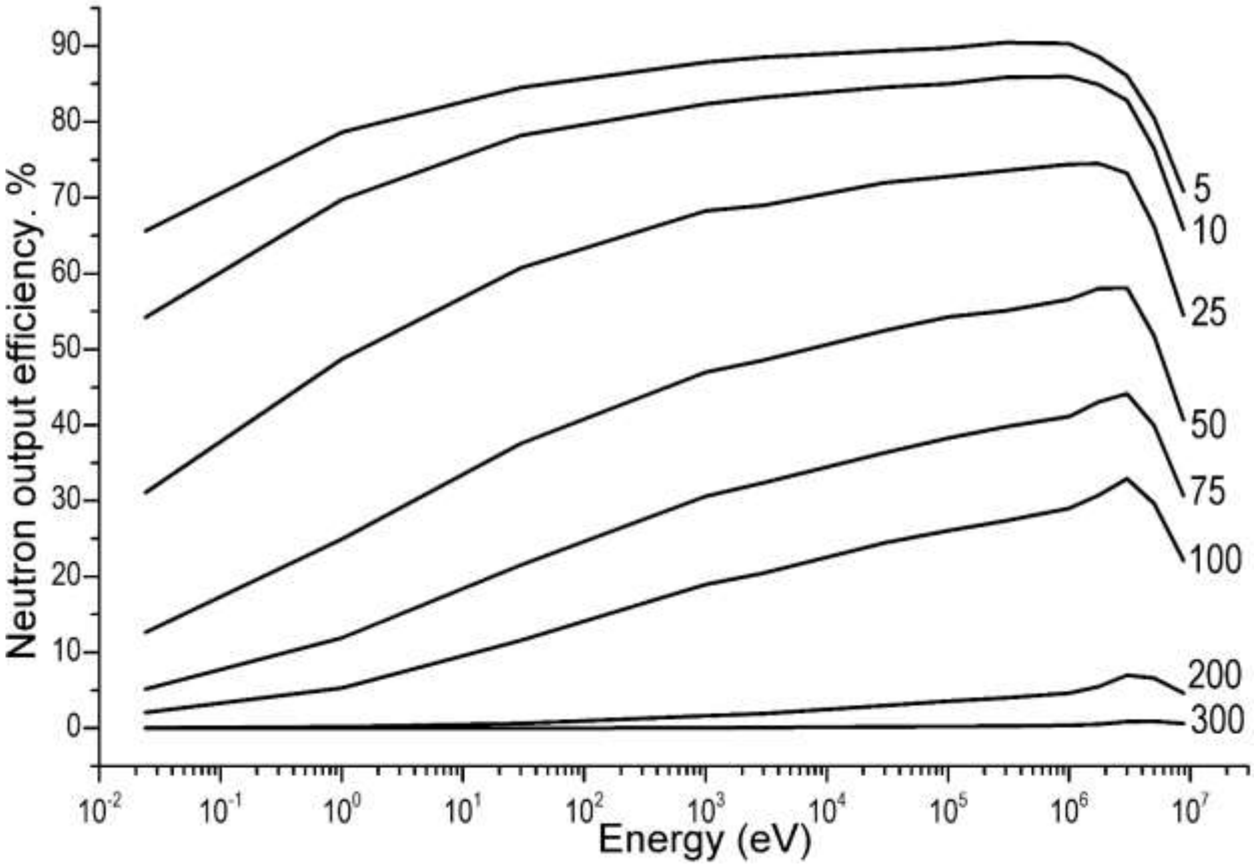

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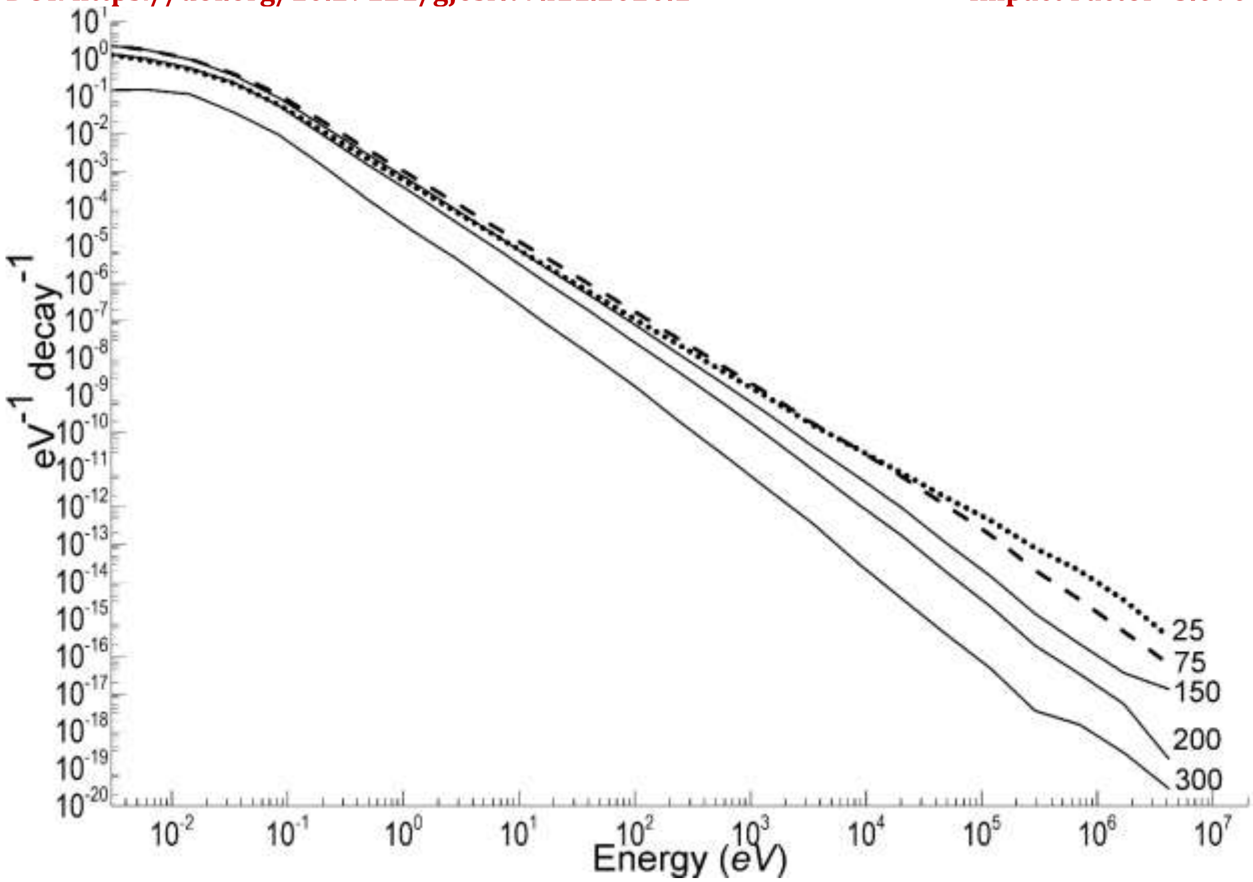

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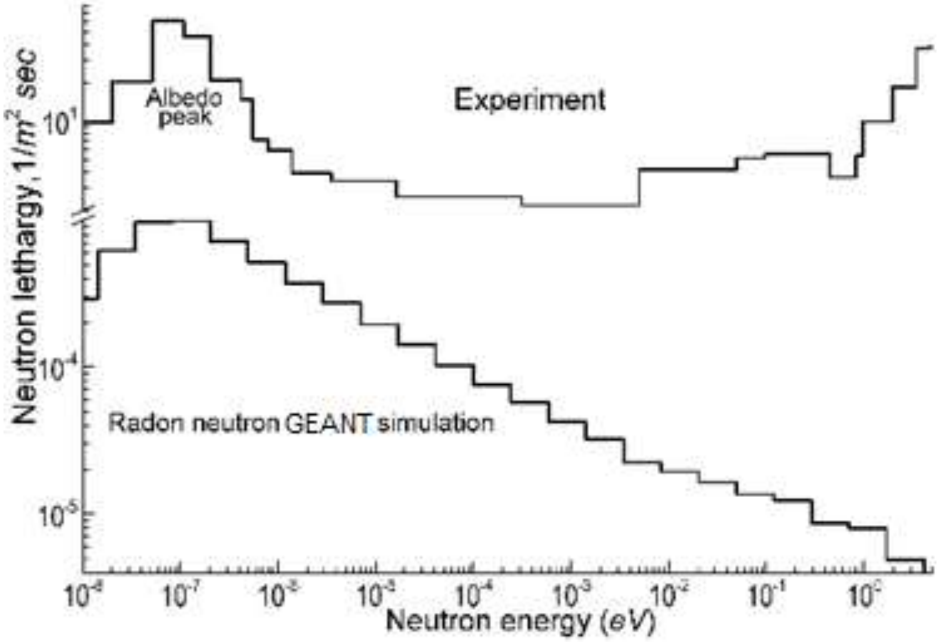

Fig.4 - The simulated spectrum of the neutrons of the ground radon origin

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