Monte Carlo simulation to describe airborne survey effects

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INTRODUCTION

The airborne survey applied to radioactivity measurements and γ-ray spectroscopy is affected by sized corrections due to the surface topology and γ absorption in air. In addiction to that, the efficiency calibration of the system can't be made during the flight, but only at the ground surface. Therefore a cross check of the evaluated parameters used in the spectra analysis with simulations is required. The simulations should be carefully tested by comparing them with the experimental measurements and, only after a careful check of consistency, they can be used in order to improve the analysis of the experiments. To this purpose we have developed a tool to deduce the effect of the air on γ rays emitted by the soil ground and to reconstruct the spectra acquired by the detecting system at different altitudes. The software tool uses a Monte Carlo (MC) code based on GEANT4 [1].

THE MONTE CARLO CODE

The simulation procedure is divided into two steps. The first step is devoted to produce the γ rays which intercept the detector at different altitudes, while in the second step the spectra acquired by the detector are reconstructed. In this way the time needed is strongly reduced if compared with that of an almost infinite source. It is also possible to change the detector shape avoiding to repeat the first step, which is the most time consuming one. The radionuclide emitter (for each radionuclides we made a different simulation) is distributed homogeneously in the soil. The soil sample composition used in the code is given in table 1.

The soil source has a depth of one cubic meter, surrounded by the same soil. Soil 1 meter of deep is sufficient to absorb all γ rays we are interested in (the maximum energy is 2614 keV, emitted by the ^{208}Tl). The air volume investigated is limited to an area of 2 km x 2 km and it has been observed, due to the air absorption, that no gamma could exit laterally. In the simulation we assume that the air density is constant with altitude and we have implemented twelve different layers corresponding to the altitudes where we are interested to determine the gamma , that is: 0m, 1m, 10m, 30m, 50m, 75m, 100m, 150m, 200m, 300m, 400m, 500m (it has to be noted that the ARGS [2] flights usually at an altitude of 100 m). The simulated detector (described in a previous Annual Report [2]) is implemented removing the upward looking radon monitor detector on top and the effect due to the absorption in the vehicle fuselage is not considered. The detector, composed by 4 NaI(Tl) of 4 liters each, is placed at each selected altitude and the simulated spectra are reconstructed for each radionuclides of interest (^{137}Cs, ^{40}K, ^{238}U, ^{232}Th). For uranium and thorium, all γ rays in the radioactive chains are included in the simulation with their respective branching ratios. In Fig. 1 the potassium spectra at different altitudes are shown together. The energy resolution of the detector is applied a posteriori by using the values provided by the experimental data.

Table 1. Soil composition included in the code expressed in fractional mass of the elements.

element	fractional mass	element	fractional mass
Oxygen	0.467	Silicon	0.270
Aluminum	0.081	Iron	0.050
Magnesium	0.03	Calcium	0.044
Potassium	0.013	Sodium	0.016
Carbon	0.010	Hydrogen	0.010
Mercury	0.002	Copper	0.007

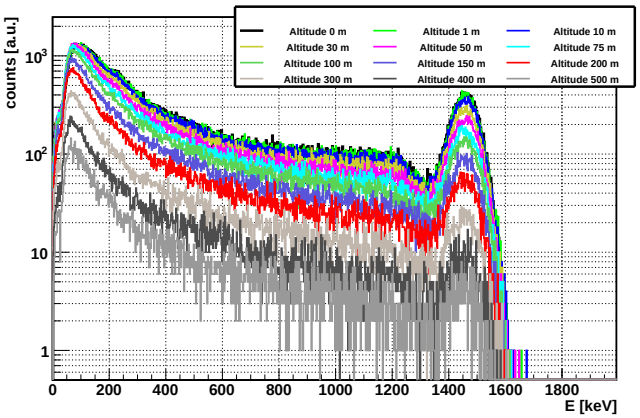

Fig. 1. The simulated spectra for a ^{40}K source homogeneously distributed in the soil is shown for different detector altitudes.

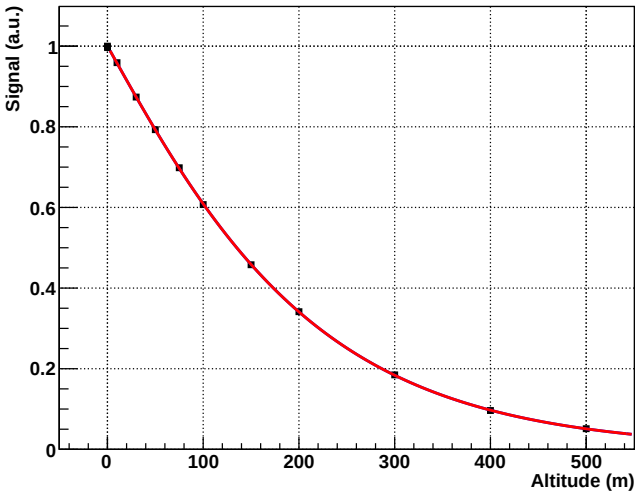

Fig. 2. The signal at different altitudes, normalized to that at the ground surface, observed by the detector for the ^{40}K source in the soil (black square). The fitting curve is also reported (red line). The fit well reproduce the points.

As shown in Fig. 1 for the possum 1461 keV line, the peak to total ratio varies from 11% to 3% (from 0 m to 500 m, respectively) due to the effect of Compton scattering in air. Reconstructing this behavior allows to fit more accurately the experimental data if compared with the sensitive spectra deduced with the ground calibration reducing the systematics in the spectra analysis.

The effect of the air absorption is also evaluated by determining the reduction of the signal observed by the detector at the different altitudes. In Fig. 2 we report the fraction of the ground signal observed by the detector placed at the different altitudes and summed over the energy range from 450 to 2900 keV. This is the same energy range used during the analysis of the airborne measurements (see [3] for a detailed description). The data points have been fitted by using two exponential curves:

$$f(x) = A \cdot (B\exp(-x/C) + (1-B)\exp(-x/D)) \quad (1)$$

where x is the altitude and A, B, C, and D are free parameters. In particular C and D represent the two half lengths selected. We used this parametrization since a simple exponential is not adequate to reproduce the air absorption, see as an example the IAEA Report in [4]. Further investigations are needed for this aspect of the analysis.

The informations, obtained by using the simulated spectra, could be implemented in the experimental analysis in order to extract the radioisotope concentration at the ground surface starting from the spectra at the given altitude. A comparison with experimental data is in progress.

Aknowledgment

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