A γ-Spectroscopy System for Atmospheric Radon Detection

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INTRODUCTION

Radon isotopes and their decay products cause most of the natural radioactivity in atmosphere at ground level (Jacobi, 1964; Altshuler et al., 1964; UNSCEAR, 1988, 1993; Porstendorfer, 1994; Kathren, 1998). ^{222}Rn (Radon) and ^{220}Rn (Thoron) enter the atmosphere from the Earths surface, where they are produced via radioactive decay of the precursors ^{238}U and ^{232}Th respectively. The major contribution to the natural radioactivity dose is from the inhalation of the daughters of this gas. They are attached to very fine particles (Bergamini et al., 1973; Porstendorfer, 1994; Mohammed et al., 2000) and deposit on the surface of the different parts of the respiratory system with a probability dependent on aerosol particle sizes (ICRP, 1994).

The dynamics of the gas could be similar to that of the atmospheric particulate and the daily change in concentration can be correlated to it. The γ-rays produced by the Radon daughters come both from the earth surface and from the radon contained in the air. For a detector placed in a fixed position, the first contribution remains constant over the time while the second follows the change in gas concentration in air. In order to determine the two contributions a system composed by three sodium iodide detectors has been designed and installed on a tower at the LNL (Laboratori Nazionali di Legnaro).

The aim of this project is to understand the behavior of γ emissions from ground surface at different altitudes and also to study the correlation between the atmospheric conditions, like the altitude of the atmosphere inversion layer, and the radon concentration in air.

SETUP DESCRIPTION

The setup is composed by three 3” x 3” NaI(Tl) cylindric shape detectors placed at three different altitudes (8 m, 16 m, and 24 m) in outdoor conditions (see figure 1 for a view of the detector to be mounted). Each detector is shielded by a cylindric shape lead with 5 cm thickness on the lateral side, and it is put on two 10 cm x 10 cm lead brick with a 5 cm thickness. This shielding works in order to cover the detectors from the γs which come from the ground. A plastic tube and an aluminum cage cover each detector to protect it from the rain, wind, and also birds which can destroy the detectors itself and the cables. The NaI power supply is provided by a 12 V battery.

All acquisition system is adapted in order to work in outdoor conditions. The preamplifier signals is acquired by a TNT2 digital acquisition card produced by Caen. The card is powered by an homemade power supply which converts the 24 V given by a battery pack into +6 / -6 V needed by the card. The acquisition system is placed in a plastic box near the tower where the detectors are installed. Since the optimal card temperature range is between 288 K and 308 K an heater and ventilation system has been installed piloted by a thermostat. The spectra are acquired continuously in list mode and then analyzed in time slices suited to evaluate the behavior of the Radon concentration.

Fig. 1. A detector with shielding (see text) before being mounted on the tower.

A rate of about 30 Hz (the threshold is at is observed in each detector and a 20% reduction in the rate is shown between the first altitude and the third one due to the suppression of the γ-rays contribution from the ground. The installation of the three detector system finished in september 2010 and spectra has been acquired continuously in a period from october 2010 until december 2010.

In a preliminary analysis we have plotted the integral of the entire spectra in a region from 500 keV (just below the 511 keV e^+e^- peak) up to 3 MeV (where there is no contribution from the environmental radioactivity).

No subtraction for cosmic ray background has been done in this first analysis stage and the γ-ray emitted from the ground has been considered constant and at the level of the minimum observed counting.

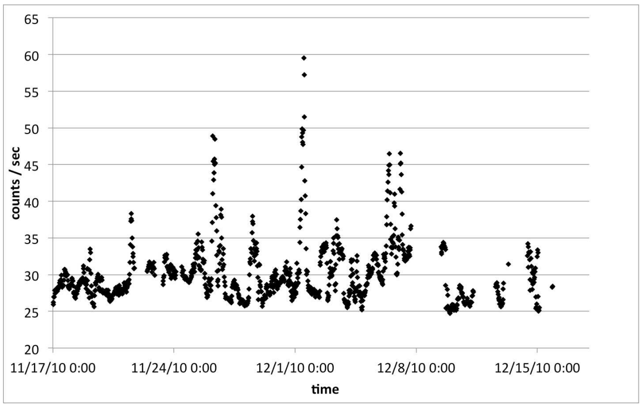

Fig. 2. Preliminary analysis of the radon concentration during time for the first detector. The day night cycle is evident.

The fluctuation in the detected γ-rays during the measured time is shown in figure 2 and a correlation with the day night cycle is clear and a preliminary Fourier analysis confirm that. In particular, a peak due to ^{7}Be has been observed after rain episodes which bring the particles produced by cosmic rays in the higher atmospheric layers down to the ground. Next step will be the comparison of the acquired spectra with several atmospheric parameters. The analysis is in progress.

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