Low energy background measurement ($\sim$ 0.8 MeV) with the LVD

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Abstract. In the Large Volume Detector (INFN Gran Sasso National Laboratory, Italy) the low energy counting rate (E $\sim$ 0.8 MeV) of each counter is continuously monitored with a sampling rate of 6/hour. From the analysis of the time variation of these signals in correlation with the measurement obtained by a radon-meter we can conclude that the products of radon decay represent an important source of background for LVD counters in this energy range. In addition, we used these measurements to calibrate our counters in terms of radon detection sensitivity.

1. Detector and data taking

LVD, located in Hall A of the INFN Gran Sasso National Laboratory, is a large volume liquid scintillator detector whose main purpose is the search for neutrinos from Gravitational Stellar Collapses (GSC) in our Galaxy [1]. The LVD experiment has been in operation since 1992, under different increasing configurations. During 2001 the final upgrade took place: LVD became fully operational, with an active scintillator mass M = 1000 t. LVD now consists of an array of 840 scintillator stainless still counters, 1.5 m^3 each, and 4 mm thick, arranged in a compact and modular geometry. Each counter is shielded by iron layers whose thickness varies from 1.5 cm to 2 cm. The observation of neutrinos is made mainly trough the inverse beta decay reaction of electron anti-neutrinos on scintillator protons $\overline{\nu_e}+p \rightarrow n+e^+$ followed by the neutron capture $n + p \rightarrow d + \gamma$. There are two subsets of counters: the external ones (43%) operated at energy threshold $E_h \sim 7$ MeV, and inner ones (57%) better shielded from rock radioactivity and operated at $E_h \sim 4$ MeV. To detect γ pulses due to n-captures, all counters are equipped with an additional discrimination channel, set at a lower threshold $E_l \sim 0.8$ MeV. To monitor the background at the low energy threshold, every ten minutes the low threshold counting rate of each counter is measured during a time window of 10 seconds. The background is mainly due to: nuclear decays of ^{238}U, ^{232}Th and ^{40}K present in the rock, radon present in the experimental hall and to secondary neutral particles generated in muon interaction with rock or with the detector material [2]. An example of the low energy counting rate measured in one year of data acquisition is shown in figure 1 for the external and the internal counters; as expected the rate of the external counters, exposed to the rock, is higher than the internal ones.

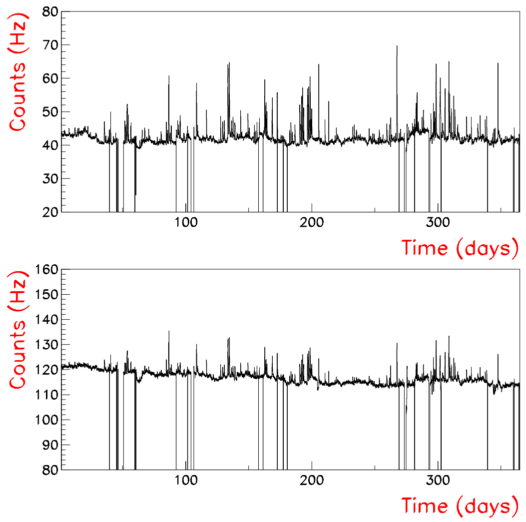

Figure 1. Low energy counting rate in one year of data for internal (top panel) and external (bottom panel) counters.

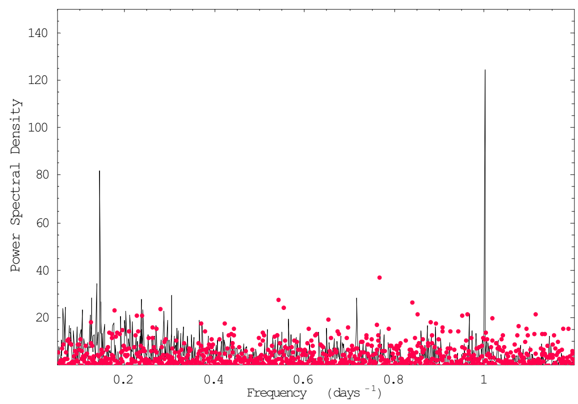

Figure 2. Spectral analysis result of the LVD data (black line) compared to normally distributed data (red point, white noise hypothesis). The LVD data show two main peaks (at 95% CL) corresponding to two signals with period 1 day and 7 days respectively.

2. Spectral analysis of the low energy events

To study the time variations of the low energy background we applied a spectral analysis to 6 years of the counting rate data. The analysis has been performed as follows: first we centered to zero the time distribution of the low energy counting rate, then we evaluate the Discrete Fourier Transform and the power spectral density that represents the energy included in a certain bin of frequency. The result of the analysis applied to the LVD data is shown in figure 2 and is compared to the result of a spectral analysis applied to normally distributed data with the same mean (zero) and the same variance of the LVD ones. While the simulated data show a power spectral density constant in frequency, as expected for the hypothesis of white noise, the LVD data show two main peaks that correspond to two periodical signals with frequency 1 day

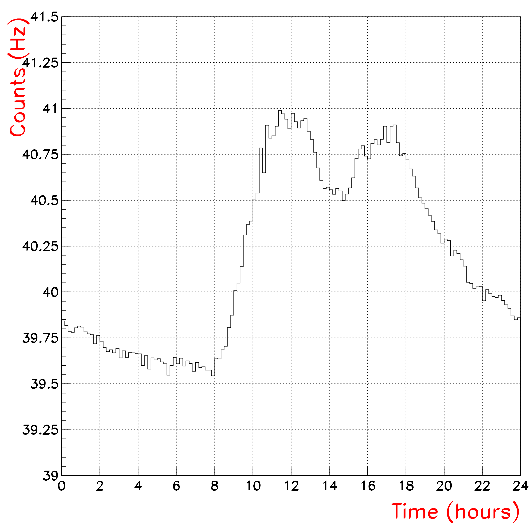

Figure 3. Daily modulation.

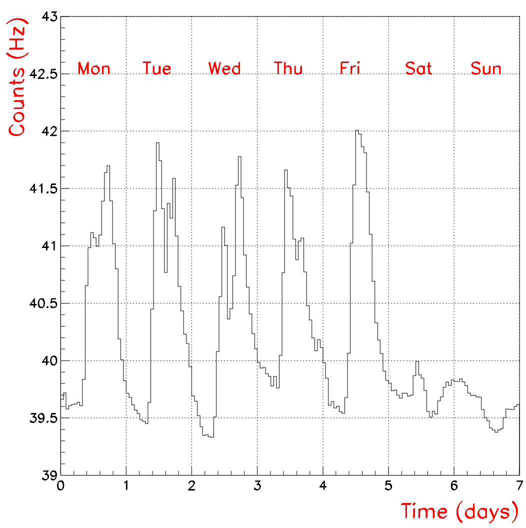

Figure 4. Weekly modulation.

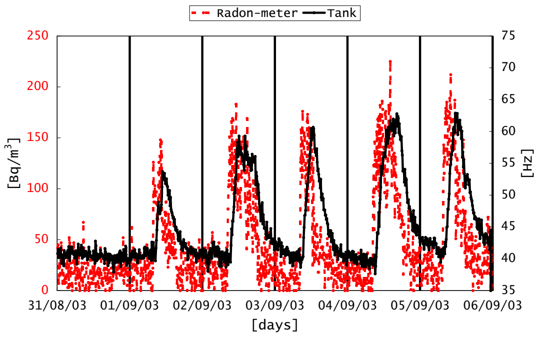

Figure 5. Comparison between LVD low threshold counting rate (red in s^{-1}) and the radon-meter data (black in Bq/m^3).

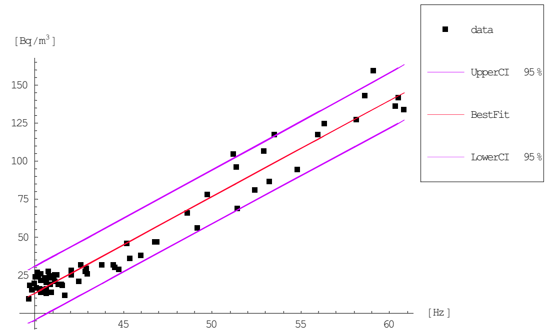

Figure 6. An example of correlation between radon-meter data and low threshold counting rate.

and 7 days respectively. To understand the shape of these periodical signals, we performed an over-binning of the low energy data in 24 hours and 7 days. The results are shown in figure 3 and in figure 4. A possible explanation of this behavior could be the variation of the local radioactivity concentration related to the human activity in the experimental hall. Indeed, for the daily modulation, there is a rising in the low energy counting rate during the working hours, and for the weekly modulation the daily behavior is present in the working days. To confirm this hypothesis we compare the LVD data with the data collected by a radon-meter located between two towers of LVD, a ionization chamber which measures alpha particles with an air flow of 1.0 l/min. As shown in figure 5 there is a strong correlation between the radon-meter data and the LVD ones; thus the modulation can be explained with a variation in the radon concentration due to the changing of the conditions of the hall ventilation and a radon injection to the hall atmosphere. From figure 5 we can observe a delay between the LVD data and the radon-meter data; the maximum of the correlation is obtained delaying the radon-meter data by about two hours with respect to the LVD ones. The delay can be explained looking at the radon decay chain: ${}^{222}_{86}Rn \underset{\alpha}{\longrightarrow} {}^{218}_{84}Po \underset{\alpha}{\longrightarrow} {}^{214}_{82}Pb \underset{\beta^-}{\longrightarrow} {}^{214}_{83}Bi \underset{\beta^-}{\longrightarrow} {}^{214}_{84}Po \underset{\alpha}{\longrightarrow} {}^{210}_{82}Pb$ (half-life 3.82 days, 3.11 min, 26.8 min, 19.9 min, 164 μs, 22.3 years respectively), since the radon-meter is sensitive to the α particle from the Rn and Po decays while the LVD is sensitive to gamma quanta mostly from Bi beta decay. With the radon-meter data we can try to evaluate the LVD low threshold counting rate sensitivity in terms of radon activity; an example is shown in figure 6: a variation of about 7 Bq/m^3 corresponds to an increase of 1 counts $\times$ s^{-1} in the LVD low threshold counting rate.

3. Summary

We performed the analysis of the low energy signals background of the LVD detector with several years of continuous measurement. The background shows a very clear daily and weekly modulation related to the variation of the radon concentration in the experimental hall. Comparing the LVD low threshold counting rate variations with the radon-meter data, we can evaluate the sensitivity of the LVD counters in terms of radon activity.

Acknowledgments

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References

[1] LVD Collaboration 1992 *Il Nuovo Cimento* A **105** 1793
[2] LVD Collaboration 2005 *Proc. of the Fifth Int. Workshop on The Identification of Dark Matter* p 471