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Study of the muon-induced neutron background with the LVD detector

H. Menghetti[a] and M. Selvi[a] on behalf of the LVD Collaboration

[a]Bologna University and INFN

1. Introduction

Neutrons can be produced in cosmic-ray muons interactions or muon-initiated cascades and can move far away from the muon tracks contributing to the background for large underground experiments searching for rare events such as neutrino interactions, proton decay etc. In this work we studied the neutron flux associated with the muon tracks in the LVD detector.

2. Large Volume Detector

LVD [1] is a neutrino telescope located in the Hall A of the Gran Sasso INFN laboratory; it consists of an array of 840 scintillator counters for a total mass of about 1000 tons. The detector is also equipped with a tracking system to reconstruct muons. Neutrons can be recognized through their interactions on protons which originate two subsequent pulses in a scintillator counter: a prompt signal due to the proton and a delayed signal due to the 2.2 MeV gamma ray from the neutron capture; the time delay distribution between the two pulses has an exponential shape with mean value 180 μs. The double signature can be seen in LVD by means of two different discrimination threshold; a high energy threshold, at about 7 MeV for the external counters (43%) and at about 4 MeV for the internal ones (57%), better shielded, for the proton recoil; a low energy threshold, at about 1 MeV and active for 1 ms after the high one, to allow the detection of the γ from the neutron capture. Taking into account the energy transfer in the interaction between neutron and proton, the proton quenching and the value of the high energy threshold of the detector, the neutrons with the double signature have energies greater than about 20 MeV.

3. Analysis and Results

We studied the neutron production in association with muons reconstructed with the LVD tracking system for both single muon events and multiple muon events. First we evaluated the production of neutrons per counter per event at various distances from the muon track. For single muons we use the distance between the reconstructed muon track and the center of the counter where the neutron is detected; we evaluated the neutron production up to 22 m from the tracks. For multiple muon events the distance is defined as the minimum one between each reconstructed track and the center of the counter where the neutron is detected and we evaluated the neutron production up to 13 m. We also studied the number of neutrons detected as a function of the energy released in the scintillator from the recoiling proton; the data follow a power law spectrum. Finally we evaluate the neutron production as a function of the muon track length in scintillator. The data are well fitted by the line $y = p1 + p2 \cdot x$ where the first parameter takes into account the neutron production in the rock as it is independent from the muon path length inside the liquid scintillator, while the second parameter takes into account the increase in the neutron production with the muon path length in scintillator. Comparing the two values we can conclude that 34% of neutron production is due to muon interaction in the rock, while 66% is due to muon interaction in the liquid scintillator, if muons are not accompanied by showers.

REFERENCES

1. Aglietta et al., Il Nuovo Cimento A **105** (1992) 1793.

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