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The cosmic ray muon flux at WIPP

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Abstract

In this work, a measurement of the muon intensity at the Waste Isolation Pilot Plant (WIPP) near Carlsbad, NM, USA is presented. WIPP is a salt mine with a depth of 655 m. The vertical muon flux was measured with a two panel scintillator coincidence setup to $\Phi_{\text{vert}} = (3.10^{+0.05}_{-0.07})10^{-7}\ \text{s}^{-1}\,\text{cm}^{-2}\,\text{sr}^{-1}$.

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Keywords: Muon flux; Muon; Scintillator; Underground; Atmospheric; Cosmic

1. Introduction

The cosmic ray background consists of several different particles such as pions, electrons, protons, etc. They are coming either from space or are generated in the high atmosphere. The most numerous particles detectable in the underground are muons that are created when protons and secondary particles interact with atoms in the atmosphere. Experiments can be shielded from this cosmic activity by going deep underground. In this paper, we describe a measurement of the cosmic ray muon flux at the Waste Isolation Pilot Plant (WIPP) with an overburden of 655 m of rock and salt and located 30 miles east of Carlsbad, New Mexico [1]. Such measurements are useful in assessing the appropriateness of WIPP as a site for underground experiments that require shielding from cosmic radiation. The depth requirements and adequacy of a particular site vary depending on the nature and goals of a particular experiment. This paper does not attempt to address the appropriateness of the WIPP site as a general purpose underground laboratory, an exercise of intense activity within the scientific community at present. Such a task is beyond the scope of this

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paper. The paper focuses on the measurements of the muon flux at WIPP, which serves as an important input in evaluating the impact on specific experiments.

2. Experimental setup

The experiment to measure the muon flux in the underground of WIPP was conducted 655 m below the surface in the experimental Q-Area. Fig. 1 shows a cross-section of the geological layers around the WIPP. The detector consisted of two plastic scintillator panels each 305 cm long, 76.2 cm wide and 2.54 cm thick. Each panel had two light-guides mounted on the two narrow ends. A 12.7 cm diameter photo-tube with an operating voltage of 800 V was mounted on each light-guide enabling a double ended readout. The muon detection efficiency as a function of position for each panel was measured by placing two small scintillators above and below (see right part of Fig. 2). If the small detectors triggered coincident, a muon must have passed through the large panel. The number of events in the panel over the total number of triggers gives therefore the muon detection efficiency. Each position was tested with 10,000 coincidence events. High-energy, minimum ionizing muons would deposit about 5 MeV when traversing a scintillator paddle at normal incidence. The actual energy spectrum deposited in the panel exhibits a broad tail around this pronounced peak due to muons traversing at angles other than normal, straggling effects, and the finite energy resolution of the scintillator. Nonetheless, by summing the signal heights from the PMTs of each panel with a threshold of 3 MeV, a clean muon signal can be obtained well above the electronic noise and low-energy gamma background associated with a single PMT channel. The left part of Fig. 2 shows the positions of the test-tubes on the panel.The detector efficiency for muons was found to be 100±1% for all positions.

For the actual experiment panel 1 was mounted on top of panel 2 in a distance of 30.5 cm (see Fig. 3). A fourfold coincidence from the photo-tubes was required to record an event. The high voltage on each photo-multiplier tube (PMT) was adjusted by demanding an equal pulse height for a ^{90}Sr calibration source place in the center of each panel. The decay product of ^{90}Sr is ^{90}Y which decays emitting high-energy electrons, which were

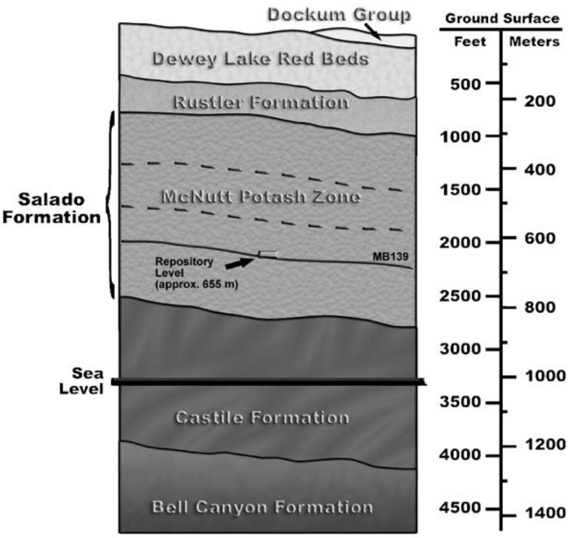

Fig. 1. The geological layers above an below the WIPP.

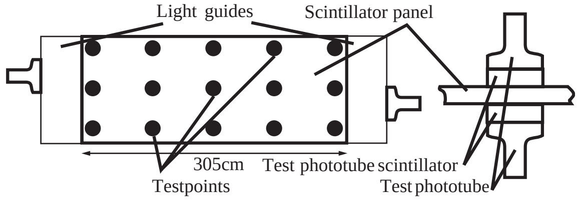

Fig. 2. Setup of the efficiency test. The left-hand side shows the panel setup, each dot marks the test positions on the large panel. On the right-hand side the schematic setup of the test photo-tubes is displayed.

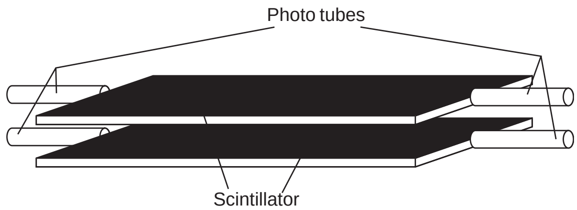

Fig. 3. Setup of the scintillator panels. They were placed on top of each other with a distance of 30.5 cm.