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Altitude survey of the galactic cosmic ray flux with a Mini Neutron Monitor

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Abstract

We present the results of a survey of the galactic cosmic ray (GCR) flux measured at different altitudes, from the sea level, up to ~4600 m a.s.l. This altitude survey was carried out with a "Mini" Neutron Monitor (MNM), and performed inside a small area of the central part of Mexico (centered around the 19° N and 97° W position) where the geomagnetic cutoff rigidity is ~7.8 GV. In particular, the latitudinal variation of the survey was less than 1°. making negligible the associated changes in the geomagnetic cutoff rigidity (~0.4 GV). This is the first time that an altitude survey has been performed using a MNM. This survey allowed us to compute the barometric coefficient $\beta = 0.00732 \pm 0.00054\ \mathrm{mbar}^{-1}$ and $\beta = 0.00729 \pm 0.00055\ \mathrm{mbar}^{-1}$ when we correct our data by the differences in the cutoff rigidity. This coefficient may be used to calibrate and correct the data of other cosmic ray detectors. We show that from the sea level up to ~4600 m the barometric coefficient is constant and does not depend on the altitude as found in previous surveys. For comparison, we also present the counting rates measured by the NM64 located at Mexico City, as well as other observations carried out to determine the stability of the MNM.

Keywords: Cosmic rays; Neutron monitors; Barometric coefficient

1. Introduction

The observation and study of high energy particles from cosmic origin are of great interest given that their flux may help to answer fundamental questions about the high energy processes in the universe. Particularly, in the local environment the cosmic rays (CR) carry out information about the most energetic events on the solar systems: solar flares and coronal mass ejections (Bazilevskaya et al., 2014).

After its discovery, the study of the CR flux gained great interest (Neher et al., 1953, 1954, 1955, 1968, 1969, 1972, 2000) and the instruments intended to detect this flux, the Neutron Monitors (NM), proliferated up to a network of 51 NMs in 1957.

Since then, it became clear that two major factors affect the CR flux at the Earth surface: the atmospheric absorption (altitude dependence) and the geomagnetic field effect (latitudinal dependence). And a number of sea level and high altitude surveys have been performed to shed light on these dependences of the CR flux (Moraal et al., 1989; Stoker and Moraal, 1995; Villoresi et al., 2000). In particular (Raubenheimer and Stoker, 1974), investigated with detail the pressure effects on the counting rate of neutron monitors during two airborne surveys. They found that the barometric parameter slowly varies with the altitude, reaching a peak value around 750 mbar. Due to the nature of this kind of experiment (a fast airborne experiment) the number of data measurements at low altitudes

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(pressure higher than ~ 800 mbar) is very low. Therefore, a slow and controlled experiment at low altitudes, to verify the barometric coefficient dependence with altitude is needed.

The number of NM stations grew up to 100 by the end of the 1960s, and today about half of them are still operating (Shea and Smart, 2000). These NM are located in a large range of latitudes and altitudes, and conforming the World Wide NM Network (Mavromichalaki et al., 2011, WWNMN, www.nmdb.eu). The WWNMN makes it possible to perform spectral and solar neutron measurements, as well as anisotropy studies (Stoker and Moraal, 1995; Moraal et al., 2000; Villoresi et al., 2000; Artamonov et al., 2016). Although, to perform reliable spectral and modulation studies, the NMs must be distributed along different cutoff rigidities, and they have to be well inter-calibrated.

In order to inter-calibrate different monitors of the WWNMN, it has been developed the "Mini Neutron Monitor" via the neutron monitor program of the Unit for Space Physics at the Potchefstroom Campus of the North-West University in South Africa. An example of the utility MNM as calibrator was published recently by Aiemsa-ad et al. (2015).

The Institute of Geophysics of the National Autonomus University of Mexico (UNAM) acquired a MNM (Fig. 1) as part of the study and calibration of the response of the High Altitude Water Cherenkov (HAWC) Gamma Ray Observatory (Abeysekara et al., 2014, 2015) to the flux of low energy CRs.

Previously to its installation at the HAWC site and making use of its portability, we have measured the CR flux in different locations in Mexico City, and more important, we performed an altitude survey, from the sea level up to ~ 4600 m a.s.l.

In this work, we present the instrument (Section 2), the data acquired in different locations, the comparison between the MNM rates and the Mexico City Neutron Monitor (6NM64) (Section 3). We present the data of the altitude survey and the high accuracy barometric coefficient obtained from this survey (Section 4). The Cutoff Rigidity Correction and comparison between our results and other barometric coefficients reported in the literature are in Section 5. Finally, we present our summary and conclusion in Section 6.

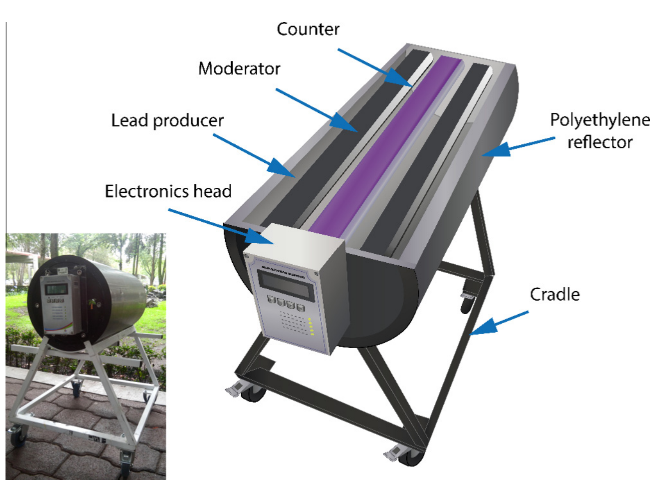

Fig. 1. Scheme of the mini neutron monitor internal structure and a the photography of the MNM at the National University of Mexico (UNAM).

2. The Mini Neutron Monitor

A portable NM called Mini Neutron Monitor has been developed by the Unit for Space Physics at the Potchefstroom Campus of the North-West University in South Africa.

The MNM central tube has a diameter of 88.9 mm and a longitude of 700 mm, and is filled with $^{10}BF_3$ at a pressure of 933 mbar (700 mmHg) (Heber et al., 2015).

This gas-filled proportional counter is surrounded by a moderator made of a low atomic number material, where the neutrons are thermalised.

The moderator is surrounded by a cylinder of lead producer, where the incident neutrons are multiplied due to the spallation process, and a larger number of neutrons and protons are ejected from the nucleus of the lead. In this process, a fraction of the kinetic energy of the incident particles is transferred to the target nucleus as excitation energy.

Finally the MNM is covered by a reflector material, in this way, thermal neutrons are confined in the interior, and the MNM is shield from the environmental neutrons. A schematic representation of the MNM is presented in Fig. 1. The reflector material, generally made of paraffin wax or polyethylene (hydrogenous material), also moderates the energy of the incident neutrons. In general, the MNM is similar to the NM64 but smaller (for the differences in the spectral response of both types of monitors, see, Krüger et al., 2008; Krüger and Moraal, 2010). Figs. 2–4 show typical measurements of the MNM.

3. Observations at Mexico city

The main purpose of the MNM at Mexico is to serve as reference for the scaler system of HAWC, which may be used for relatively low energy CR studies, e. g. for of solar energetic particles (Abeysekara et al., 2012, 2015). Prior to its definitive installation at the HAWC site, and in order to check its stability, we performed some tests, the most relevant are presented here.

On April 2014, the MNM was installed inside an office of the Institute of Geophysics. This office is in the second of a three floor building, therefore the MNM was covered by two layers of concrete. Fig. 2 shows the observations during the April 2014 period. The top panel shows the counting rate (black dots) as well as its moving average with a one hour window (red line). The ambient pressure is plotted in the central panel, and the temperature of the detector is shown in the bottom panel.