A New Neutron Detector Operating at the Antarctic Laboratory for Cosmic Rays

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Abstract. The Italo-Chilean collaboration for cosmic rays has been managing two observational sites: LARC (Antarctic Laboratory for Cosmic Rays, King George island) and OLC (Los Cerrillos Observatory, Santiago of Chile). Inside this collaboration a 3NM-64 detector with helium counters has been realized by the Italian counterpart. During the Antarctic summer campaign of 2006-2007 the new detector has been added to the laboratory. The period June-December 2007 has been used to evaluate its performance there. Main results are discussed.

Keywords: cosmic rays, nucleonic component, helium detector

I. INTRODUCTION

The Antarctic Laboratory for Cosmic Rays (LARC) is located on King George island (South Shetlands - Fildes Bay - Ardley Cove: 62.20°S - 301.04°E; 40 m a.s.l.). At present time the Laboratory is managed by the joint collaboration between the University of Chile (UChile/FCFM) and the Institute of Interplanetary Space Physics of the National Institute for Astrophysics (IFSI-Roma/INAF). The project is also supported by the National Antarctic Institute of Chile (INACh) and the National Program for Antarctic Research (PNRA) of Italy.

A 6NM-64 neutron monitor has been running at LARC since 1991 (see, for instance, [1]). It is equipped with standard BP-28 (10BF3) counters, as well as most of the IQSY detectors of the world-wide network for cosmic ray measurements. Up to now continuous measurements of the nucleonic component of cosmic rays have been carried out and several Solar Extreme Events as Ground-Level Enhancements (GLEs) have been recorded (GLE51 to GLE70).

In the mini network of neutron monitors supported by IFSI-Roma (see Figure 1 for its main characteristics) LARC is an important observational site because its cut-off rigidity (∼ 3 GV) allows that most of GLE events may be detected, being the maximum energy of the associated solar proton lower than 6 GV. The other way round, the probability that these events may be identified at the other three observatories is very lowered by their cut-off rigidity higher than 6 GV.

The most relevant scientific goal of the Italo-Chilean collaboration for LARC has been the upgrade of the detector to improve the statistical data quality together with the time resolution which are essential for studying relativistic solar proton events. To the purpose, a new 3NM-64 detector with helium counters (3NM-64 3He) has been added to the Laboratory during the Antarctic summer campaign of 2006-2007 [2]. With the financial support of the Italian PNRA, this monitor was fully realized and carefully tested out by IFSI staff. Finally, it was accurately calibrated with the standard NM-64 detector at the SVIRCO Observatory & TPL (INAF/IFSI-Roma research unit).

II. THE NEW DETECTOR WITH HELIUM COUNTERS

The geometry of the new neutron detector is just the same of the standard 3NM-64, with regard to dimensions, mass and shape of its loose components such as outer reflector, inner moderator and lead producer (see [3], and [4]). The choice of equipping the detector with helium counters was essentially determined by their price lower than the one of boron counters.

Comparative tests performed at SVIRCO Observatory & TPL in Rome proved the efficiency of helium counters to be equal or higher than the boron ones [2]. These results have been acquired with the LND 3He counters.

Fig. 1: The international mini-network of neutron monitors supported by IFSI-Roma.
type 25373 which have the same length (190.8 cm) of the boron standard APTEC BP-28.
During the Antarctic summer campaign of 2006-2007 the new Italian neutron monitor has been added to the former 6NM-64 \(^{10}\text{BF}_3\) of LARC. On January 28, 2007 it started to operate improving of more than 50% the counting rate capability of the observatory.

III. THE 3NM-64\(^{3}\text{He}\) OPERATING AT LARC

The period June-December 2007 has been used to evaluate the performance of the new detector versus the former, since during Antarctic winter severe environmental conditions have to be handled. As a result we have had the opportunity to test the response of the detector to the incoming cosmic rays together with the performances of the other instrumentations operating at LARC (see Figure 2).

Ambient temperature variations may affect the features of proportional counters (especially of helium ones; see [5] and references therein), meanwhile high level of relative humidity (RH > 65%) may cause noise in high voltage. Finally fast swings of atmospheric pressure might be not promptly followed by poor barometers.

The quality of pressure measurements is essential for a proper data correction (especially for one minute records). The Italian partnership has already added to the Bell & Howell (B&H) barometer operating at LARC since 1991 (quartz transducer, resolution 0.01 hPa, accuracy 0.5 hPa) other two instruments, achieving a total of three barometers running at the same time. The addiction of a Siap (aneroid, resolution 0.1 hPa, accuracy 3 hPa) and a DMA (vibrating cylinder, resolution 0.01 hPa, accuracy 0.3 hPa) has made possible the comparative check up of the barometers, improving the reliability of pressure corrected data (e.g. [6] and [7]).

The intensity data acquired by the 3NM-64\(^{3}\text{He}\) have been corrected for pressure variations with the same parameters (pressure level: 980 hPa and attenuation coefficient: 0.74 %/hPa) used for the boron 6NM-64, which has been assumed as calibrator. Furthermore, the corrected data have been normalized to their respective averages of June 2007 (\(^{3}\text{He}: 100\% = 152923\) cts/hour, \(^{10}\text{BF}_3: 100\% = 281251\) cts/hour). A good coherence between the responses of the two detectors to the incoming cosmic rays results from the top panel of Figure 2 as well as from the regression plot reported in the upper panel of Figure 3.

A particular care has been dedicated to the measurements of the atmospheric pressure variations because of their relevant influence in the correction of the high

Fig. 2: From top to bottom: Time history of nucleonic intensity recorded by \(^{3}\text{He}\) and \(^{10}\text{BF}_3\) neutron monitors and of environmental parameters (pressure, temperature and relative humidity [RH]).
The use of barometers (at least three units running at the same time) equipped with different transducers is very important to point out possible malfunctions induced by environmental causes. Temperature variations may be critical for quartz barometer with an inadequate thermal compensation. On the other hand, high relative humidity increases the damping factor of the air inside the vibrating cylinder therefore varies its resonance frequency and results in false barometric measurements. Finally, the intrinsic inertia of each type of pressure transducer delays in different way the barometers in following rapid changes of pressure. Apart from the accurate tests imposed by the severe environmental conditions of the Antarctic winter at LARC, a continuous check of the barometers prevents the happening of unnoticed drifts. In the occurrence, it is possible to take advantage from the use of three barometers to easily identify the one affected by hysteresis or other feature failures. The reference quartz barometer B&W has been checked against the DMA, an instrument of the same high class equipped with a different transducer: a vibrating cylinder.

The test has been carried out with a time resolution up to one minute in the periods characterized by rapid changes of the atmospheric pressure. In the lower panel of Figure 3 it has been reported an example of the quite identical and prompt responses of the two high accuracy barometers on August 10, 2007, when the pressure swung in a range of 30 hPa in only one day.

**IV. HELIUM DETECTOR RESPONSE TO AMBIENT CONDITIONS**

The efficiency and the long term stability of the new detector have been verified by means of multichannel analysis of the helium counters repeated in January 2008. The pulse height distributions (anti-coincidence and coincidence) were compared with the previous ones taken in June 2005 at SVIRCO and in January 2007 at LARC. The examined spectra resulted steady with the full widths at half maximum (FWHM) unchanged. Consequently, no variation in the counter efficiencies and in the discriminator thresholds has been detected. Despite the heating system, the room temperature in LARC building spanned over a range of 30°C, therefore the instrumental temperature effect on the new 3NM-64³He has been investigated. The 6NM-64¹⁰BF₃ was used as calibrator because of the much smaller temperature sensitivity of boron counters. The ratio of the ³He detector to the calibrator counting rate was calculated for each day to clean up the effect of primary cosmic ray variations. The data normalized to June 2007 have been plotted in the upper graph of Figure 4 together with their Simple Moving Average (three days). The daily temperature data and the SMA-3d have been reported as well (lower graph of Figure 4). The two time histories show a good correlation and point out the modulation of the instrumental temperature on the helium detector counting rate till November 23 (day 327). Since then the counting rate starts rising regardless room temperature. This results from the thaw in the LARC area. According with the progressive reduction of the snow and the ice close to the building, the absorption of lower energy neutrons tails off, therefore their contribution to the counting rate increases onwards. In spite of the same standard geometry components and dimensions, the snow effect is greater in the helium neutron monitor than in the boron one for the different responses of the counters to the low energy particles. The snow effect is much more evident in the bare counter configuration (only with the cylindrical moderator). A helium counter, identical to the ones used to build up the 3NM-64³He, was running in the analyzed period at LARC in a lead and reflector free configuration. Its normalized daily ratio to the rate of the calibrator (6NM-64¹⁰BF₃) has been used to highlight the snow absorption effect of lower energy neutrons during winter.

**Fig. 3:** Regression plot of the normalized daily data as obtained from ³He and ¹⁰BF₃ neutron monitors in the period 1 June - 31 December 2007 (upper panel) and an example of daily pressure records by two barometers of similar class (lower panel).
time and the similar slopes in the time histories of the two $^3$He detectors since the 23rd of November (see upper panel of Figure 4).

V. CONCLUSION

A comparative analysis has been performed on the responses of the new 3NM-64 $^3$He versus the 6NM-64 $^{10}$BF$_3$ operating at LARC in the period 1 June to 31 December 2007. The counting rates of the two monitors were accurately normalized against one another to verify the coherence of their performances also in the severe wintry environmental conditions of the Antarctic observational site. The proper response of the new neutron monitor to the incoming cosmic rays has made it adequate to be used together with the standard NM64 in the continuous registration of the nucleonic component. As result the counting rate capability of LARC has been increased of more than 50% and the consequent improvement of data statistics and short time resolution will be particularly valuable in recording solar particle events. The achievement of a good high resolution needs also reliable atmospheric pressure measurements, therefore the barometer responses have been investigated during the whole examined period and the outcome has been excellent.

The helium detector sensitivity to the instrumental temperature has been examined using again the standard 6NM-64 as calibrator. A variation of about 1% in the ratio of the daily normalized counting rates has been found against daily temperature changes over the time up to 25°C. In the same way the snow effect has been pointed out to be greater in the 3NM-64 $^3$He than in the 6NM-64 $^{10}$BF$_3$. The ratio to the calibrator raised up to 1% during the snow and ice melting in confirmation of the higher sensitivity of helium detector to lower energy particles. Finally, the snow effect on a helium bare counter has been described by the time history of its ratio to the calibrator counting rate.

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REFERENCES