First Results of a Mobile Neutron Monitor to Intercalibrate the Worldwide Network

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1. Abstract

Two calibration neutron monitors were completed in September 2002. We describe the performance of one of them on its voyage with the US/Australian 3NM64 neutron monitor from Seattle to McMurdo, Antarctica, and back, from 4 November 2002 to 19 April 2003. An accompanying paper discusses the calibration of the Sanae and Hermanus neutron monitors with the second calibrator.

2. Introduction

At the 27th ICRC in 2001, plans were described by Moraal *et al.* (2001) to construct a mobile neutron monitor to intercalibrate the world's network of neutron monitors. The main objective of this intercalibration is to derive intensity spectra from differential response functions. This will provide continuous spectral information about cosmic ray modulation to at least one decade higher in energy than is presently available. The design specification was that one should be able to calibrate neutron monitor count rates to within ±0.2% to produce spectra with an acceptable level of uncertainty. The requirements for, and the expected performance of, such a calibrator were described in detail in that paper.

Two of these neutron monitors were completed in September 2002, with the following final design: The counter is a ^{3}He filled tube of the type LND25382, 51 mm in diameter and 652 mm long. It is surrounded by a polyethylene moderator with inner and outer diameters of 60.5 and 99.5 mm, a lead producer with diameters 101 and 193 mm, and finally an outer reflector with diameters 194 and 350 mm. All these cylinders are 653 mm long. The front and back of the counter are covered with 50 mm polyethylene ends with a diameter of 350 mm. The total active length of the monitor therefore is 653 + 100 = 753 mm. Its mass is 201 kg, of which 145 kg is lead. It rests on a cradle with steerable wheels, and the total mass with cradle is 223 kg. The system records the number of counts, baromet-

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ric pressure, high voltage, temperature, GPS co-ordinates and GPS altitude once per second. Information is processed by a standard 233 MHz Pentium PCM4896 motherboard with 64 MB RAM, and is stored on two 20 GB hard disks, one fixed and one removable. A standard RJ45 UTP Ethernet plug connects the monitor to the network so that it can be accessed remotely at its IP address. Pressure is measured by a Digiquartz Paroscientific transducer. A full description and operation manual for the calibrator can be found at the internet address http://www.puk.ac.za/physics/Physics%20Web/Research/Cal%20NM.htm

The first calibrator was sent together with the US/Australian 3NM64 neutron monitor on a voyage by the US Coast Guard vessel Polar Sea between Seattle and McMurdo, Antarctica, from 4 November, 2002 until 19 April, 2003. These annual voyages are described in Bieber *et al.* (2001). The primary reason for this survey was to measure the latitude response of the calibrator against that of a standard 3-counter NM64. Numerical simulations with the Fluka code, described in Clem and Dorman (2000), indicate that the counting ratio between the monitors may change as much as 3% from equator to pole, due to their different energy responses. This calculated effect must be carefully measured and confirmed if one hopes to achieve calibration accuracies of ±0.2%.

3. Initial Results

The average hourly count rates of the two neutron monitors are shown as function of time in Figure 1A, starting on day 308 (4 November 2002), until day 473 (18 April 2003) for the calibrator, and day 482 (27 April 2003) for the 3NM64. The upper curve is for the 3NM64, and the bottom one for the calibrator. The ship departed from Seattle (cutoff rigidity $P_c \approx 2$ GV) on day 308, crossed the cosmic ray equator (maximum $P_c \approx 15.5$ GV) on day 332, and arrived at McMurdo, Antarctica at $P_c < 1$ GV on day 350. The return voyage started on day 427, crossed the cosmic ray equator again on day 461, and arrived back in Seattle on day 474. The route map can be found at http://www.bartol.udel.edu/ pyle/LatSurv0203.gif

There are many gaps in the calibrator data due to intermittent failures of the electronics. The origin of these stoppages is presently unknown. No temperature corrections were made, although these may be important (see accompanying paper). The count rate of the calibrator is ≈ 2200 per hour near the equator, and ≈ 4600 at McMurdo. Therefore, the Poisson statistical fluctuation on the hourly count rate is ≈ 2%. The equivalent count rates of the 3NM64 monitor are 60 000 and 125 000, respectively. Figure 1B shows the ratio of these count rates. The overall average value is 0.0375 ± 0.0007, or an inverse 3NM64/Calibrator ratio of 26.7 ± 0.5, and the dashed lines indicate the ±2% Poisson standard deviation. The observed standard deviation is about 2.5% because this ratio varies with latitude, other systematic effects as described in the accompanying paper, as well

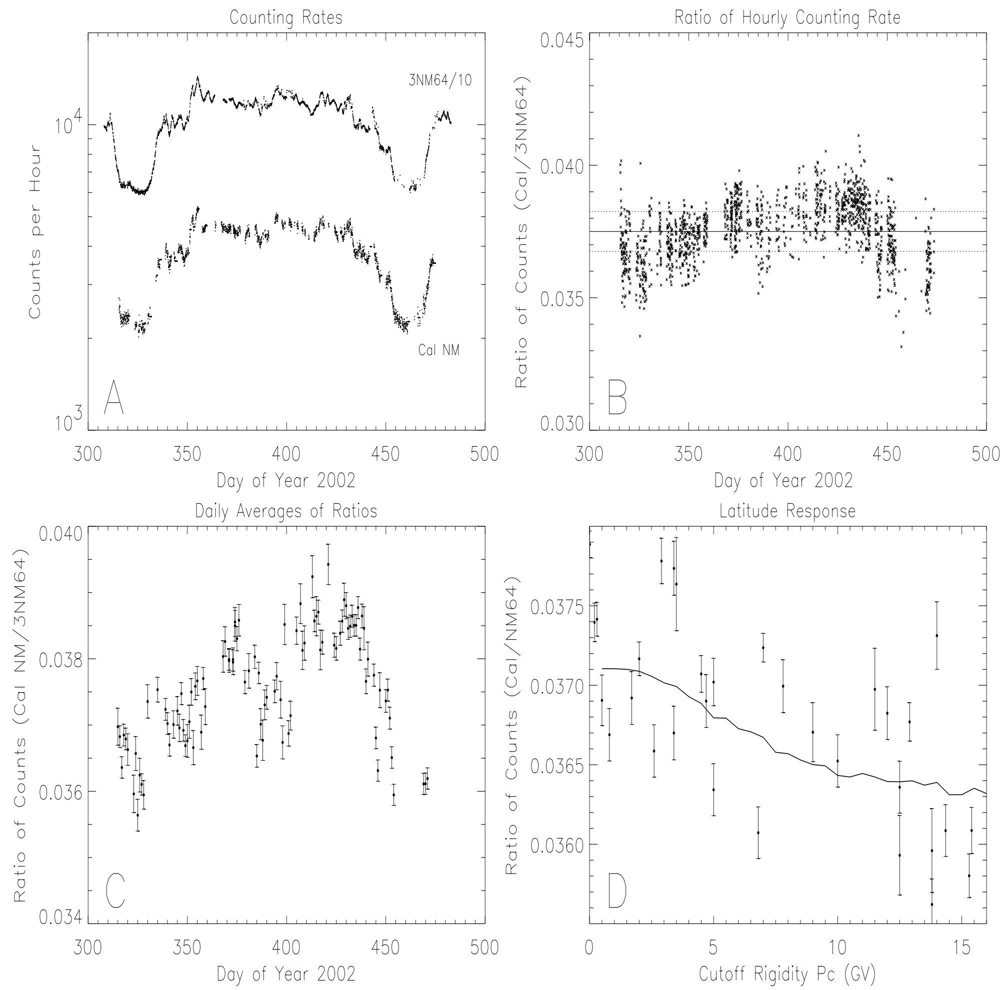

Fig. 1. Performance of the calibration monitor on its voyage to Antarctica from 4 November 2002 (day 308), until 18 April 2003 (day 473). Panel A: Counting rates of 3NM64 (divided by 10), and calibrator. Panel B: Counting ratios on an hourly basis. Panel C: Daily averages of counting ratios. Panel D: Ratios as function of estimated (see text) cutoff rigidity. The line is the ratio calculated from the Fluka simulation of the calibrator.

as multiplicity effects described by Hatton (1971). No temperature corrections were done in this preliminary analysis, but these may be important in view of the results of the accompanying paper. Figure 1C shows the daily averages of these ratios, with the error bars calculated from the number of completed hours for that particular day. Finally, the ratios are binned into rigidity intervals in Figure 1D. For this purpose, rigidities were estimated very roughly, with an accuracy of $\approx \pm 0.5$ GV, from Figure 1 of Bieber *et al.* (2001), because the actual calculations along the route for this voyage are not yet available. We expect that this uncertainty will have a negligible effect on the counting ratio, because its latitudinal dependence is so small. The curve in Figure 1D shows the calculated ratio for these two monitors, with the Fluka code and Monte Carlo processing, described in Clem (1999). This calculated ratio was divided by 0.4049, because the ratio was calculated for a 6NM64, instead of a 3NM64. The scatter in the observed ratios is quite large, although it seems that the observed ratio may indeed be smaller at the higher cutoff rigidities, as predicted. This can only be confirmed with more observations.

4. Summary and Conclusion

The first voyage of the neutron monitor calibrator successful. The average, overall ratio of calibrator counts/3NM64 counts is 0.0375 ± 0.0007, with an inverse ratio of 26.7 ± 0.5. There is evidence that this ratio is latitude dependent as predicted. This indicates that the physical processes of the calibrator are adequately understood. The uncertainties on the observed ratios are too large for a firm conclusion, however. This requires that the calibrator will have to make at least one more trip to Antarctica during 2003/2004.

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6. References

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