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The Use of ^{3}He Tubes in a Neutron Monitor Latitude Survey

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Abstract

We have investigated, both with a latitude survey and extensive simulations, the use of a ^{3}He neutron detector in place of a standard NM-64 BF_3 neutron detector. For several years, we have conducted an annual sea level neutron monitor latitude survey aboard a U.S. Coast Guard icebreaker travelling from Seattle, Washington to McMurdo, Antarctica and return (Bieber et al., 1997). The equipment has consisted of a three-tube BF_3 NM-64 monitor mounted on the ship's deck.

This past year, we replaced one of the monitor's three BF_3 detectors with a ^{3}He detector. This counter was operated during the voyage from Hawaii to McMurdo and then to Seattle. To our knowledge, this is the first latitude survey using a ^{3}He detector; we report a preliminary comparison of the survey data from the ^{3}He detector and the BF_3 detectors.

1 Introduction

Neutron monitors (Simpson, 1951) continue to provide unique long term measurements of the galactic cosmic ray fluxes over the energy range 1-30 GV. The latitude survey technique (see Moraal et al., 1989 and references therein) has long been used to describe changes in the interplanetary spectrum, with application to, for example, determination of the effects of the alternating magnetic polarity of the Sun on cosmic ray modulation in the heliosphere. A neutron monitor latitude survey is performed by transporting a portable monitor over a wide range of Earth's magnetic latitude, calculating the geomagnetic cutoff rigidity along the path, and determining the relationship of the cutoff rigidity to the count rate.

Over the years there have been many surveys of this type (e.g. Simpson, Fonger and Treiman, 1953; Moraal et al., 1989; Bieber et al., 1995). These have primarily been conducted near solar minimum modulation periods, so that the corrections for temporal changes in the modulation level are minimized, and the interplanetary conditions approach a "steady-state".

We are presently conducting an annual series of such surveys aboard a U. S. Coast Guard icebreaker (Polar Star or Polar Sea), which each austral summer carries our portable monitor from Seattle, USA to McMurdo, Antarctica and return. The monitor used in this investigation has been a three-tube NM-64 design placed in a standard shipping container mounted on the ship's deck. Summary data are returned each hour, and detailed (1-second resolution) data are stored for later retrieval.

As we began to construct three new stations in northern Canada for the Spaceship Earth project (Bieber and Evenson, 1995), we found the cost of procuring the many large BF_3 tubes necessary for this project prohibitive. Using the general design envelope of commercially available ^{3}He-filled neutron detectors, we did extensive simulations (see Clem, 1999, this Conference) to produce a design that closely simulates the performance of a BF_3 detector. These units are now commercially available as model LND25373, from LND, Inc. We then decided to use the opportunity provided by this year's annual latitude survey to verify this ^{3}He neutron counter simulation. In the Table we summarize the physical characteristics of the BP-28, the new ^{3}He and also the older detector design used in the IGY monitors.

Table: Neutron Counters Used in NM-64 and IGY Monitors

	NM-64 Monitors		IGY Monitors
	BP-28	**LND25373**	**NW G-15-34A**
Diameter (cm)	14.8	4.8	3.8
Length (cm)	191	191	87
Gas Type	BF_3, 96% ^{10}B	97% ^{3}He + 3% CO_2	BF_3, 96% ^{10}B
Operating Voltage	2800V	1350V	1950V
Pressure (mm-Hg)	200	3040	450
Thermal Neutron Absorption Pathlength (cm)	41.0	1.9	18.2

In this paper we report a preliminary comparison of the measured response of the two types of tubes, over a 0–17.4 GV range of geomagnetic cutoff rigidity. Details of our simulation studies may be found in Clem, 1999 (this Conference).

2 Survey Instrumentation

In Figure 1 we show the track of the Polar Sea for the period November 1998–April 1999, along with contours of the vertical cutoff rigidity; the monitor covered one of the widest rigidity ranges yet achieved in a shipborne survey. As part of our program to study the ^{3}He tubes, in December 1998, at a stopover in Honolulu, we replaced one of the BF_3 tubes in the monitor with a ^{3}He tube. Thus, from Honolulu onwards the monitor consisted of the two BF_3 tubes (Left and Center) and one ^{3}He tube (Right). In this preliminary report we will use only the Center (BF_3) channel because of sporadic noise pickup in the Left (BF_3) channel. This report is based on the preliminary hourly data received from the Polar Sea, and focuses on describing the relative response of the two types of tubes. We leave a full survey analysis for the future, when we have the full dataset. Many corrections need to be applied during a full analysis of the survey data, including the variation of the count rate with the roll angle of the ship (see Bieber et al., 1995), the corrections for temporal changes in modulation level, calculation of the apparent cutoff along the ship's track (see Clem at al., 1997), and identification and removal of noise events (we used a preliminary version of the ^{3}He electronics, which was affected by electronic interference until this was corrected when the ship

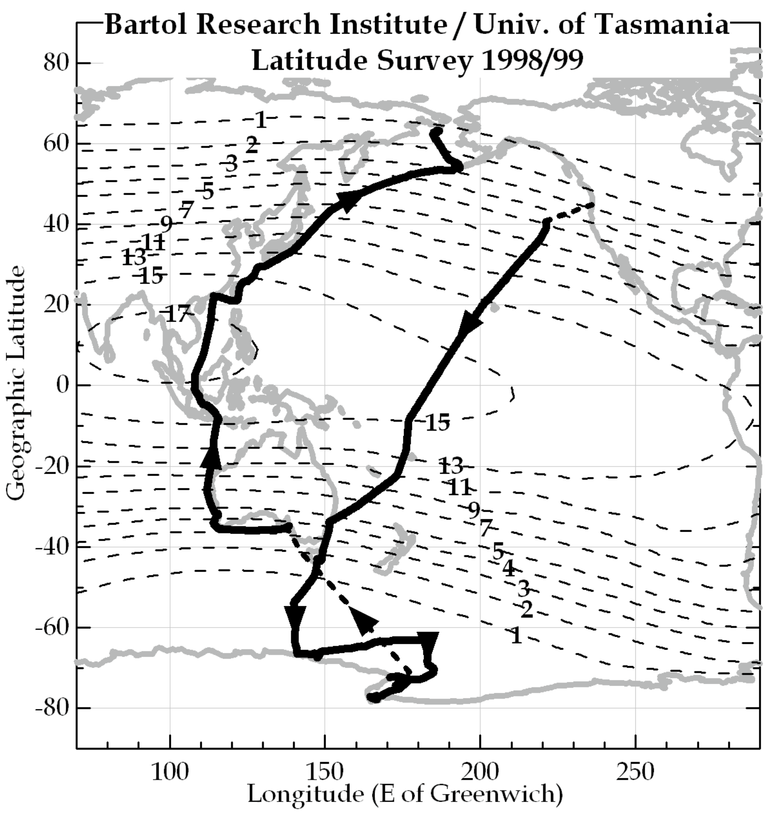

Figure 1

Dashed Lines are Contours of Constant Vertical Cutoff Rigidity reached Hobart, Australia). In this paper we report only data from after this time. In addition, a computer failure resulted in the loss of data between McMurdo and Adelaide, on the return trip (this is shown by the horizontal axis gap in the Figure).

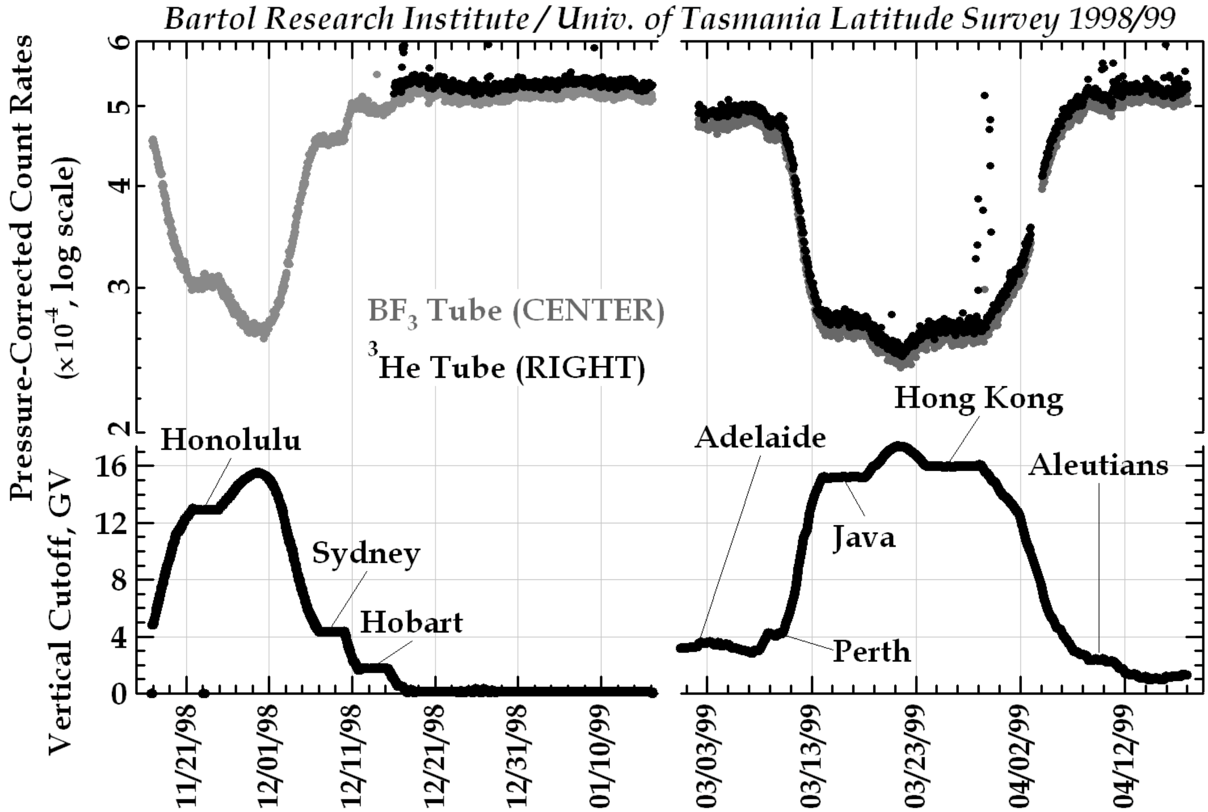

Figure 2

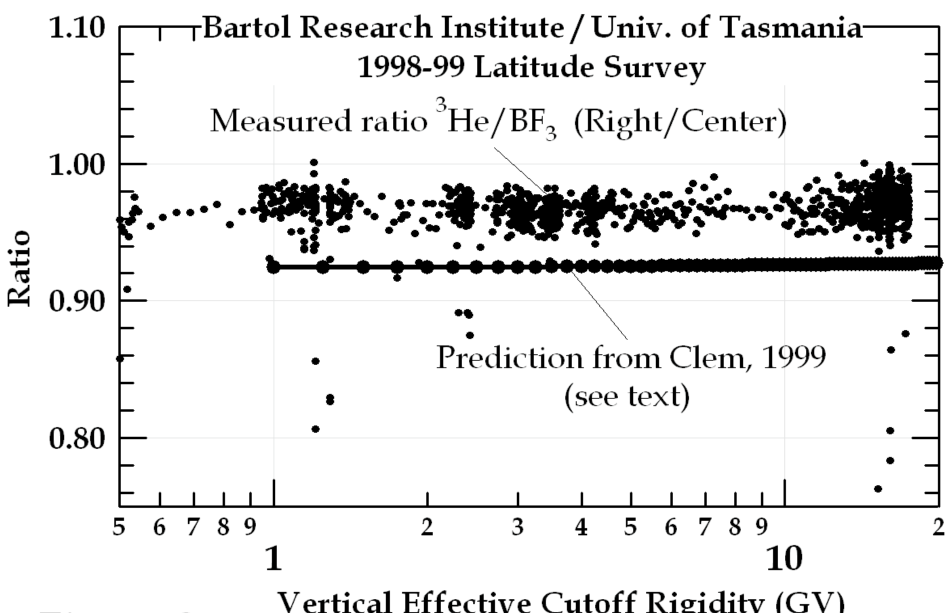

Figure 3

3 Data Analysis

In Figure 2 we show the overall pressure-corrected counting rate profile as a function of time (top panels) and the vertical cutoff rigidity (bottom panels), with the ^{3}He tube plotted in black and the BF_3 tube in grey. The calculated vertical effective geomagnetic cutoff was used (Shea, Cooke and McCracken, 1965; Cooke et al., 1991) using a trajectory code based upon the Tsyganenko magnetosphere model (Lin, Bieber, and Evenson, 1995). No corrections for changes in the modulation level have yet been made to these data; these would not be important for the counting rate ratios.

Figure 3 plots the variation of the ratio ^{3}He/BF_3 as a function of the vertical cutoff rigidity. Over this very wide range of rigidities the ratio is constant to better than one percent. The predicted ratio, based on our simulations, is also shown in Figure 3. The measured ^{3}He NM-64 detector response is approximately five percent higher than these predictions, however small differences in the experimental setup (e.g. the detector mounting systems within the moderator tube) could easily contribute to this difference. (see Clem, 1999, this Conference).

4 Summary

We have conducted a 3-NM-64 latitude survey over the period November 1998 to May 1999, using, for the first time, a ^{3}He neutron detector in place of one of the three BF_3 counters. The ^{3}He detector design was developed after extensive simulation studies. This survey, one of an annual series, covered a very wide range of cutoff rigidities, from 0 to 17.4 GV. We find that the efficiency and energy response of the ^{3}He detector is nearly identical to that of the BF_3 detector, and that these detectors can be used in a standard NM-64 monitor.

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