Possible Detection of Large Solar Particle Event at Balloon Altitudes during the 2001-2002 TIGER Flight

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ABSTRACT

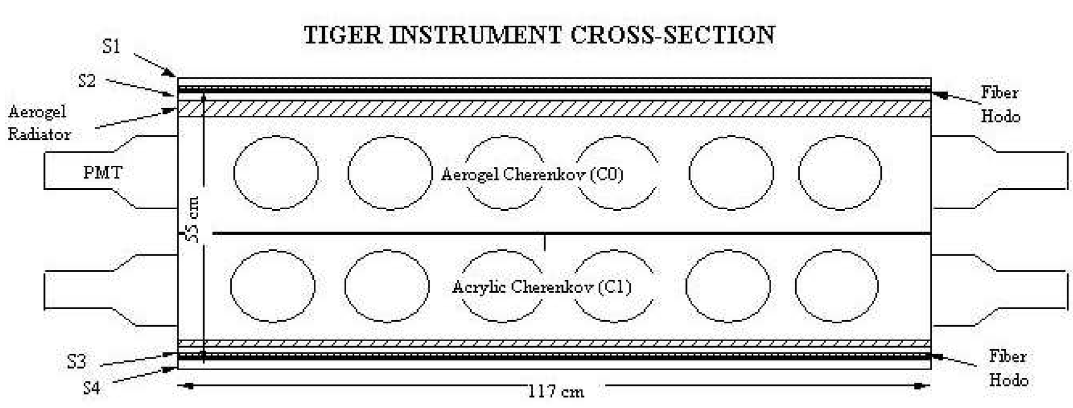
The Trans-Iron Galactic Element Recorder (TIGER) was launched on December 21, 2001 and flew for about 32 days on a long-duration balloon mission from McMurdo Base in Antarctica. On December 26, 2001 at about 5:30 UT, a ground-level solar particle event (M7.6 flare) was observed by a number of neutron monitors. The SIS instrument aboard the ACE spacecraft measured the elemental composition and particle energy spectra up to ∼150MeV/nuc during this event. While not designed to operate under such conditions, TIGER data for the same period show interesting variations in the count rate and composition of the measured particles that may be related to the detection of heavy Solar particles (Si to Fe) in the ∼GeV/nuc range. We discuss the TIGER observations in relation to other available data from this event.

1 Introduction

The objective of the Trans-Iron Galactic Element Recorder (TIGER) experiment is the measurement of the elemental abundances of galactic cosmic ray nuclei with charge $26 \leq Z \leq 40$. These elements can help distinguish between a warm stellar atmospheric (FIP enhancement; e.g. [6]) and cold interstellar dust and gas (refractory enhancement; [3]) GCR source. For this purpose, several long-duration balloon flights from McMurdo, Antarctica, are planned for the balloon-borne instrument over the course of a few years. The first such flight commenced in December 2001 towards the end of the solar maximum and the ∼32 day period of data collection spanned the ground-level solar energetic particle (SEP) event starting at 5:30UT on December 26, 2001.

TIGER data gathered during the first five hours of this event show interesting deviations from the data gathered during the other time periods, suggesting possible detection of solar particles above 600MeV/nuc. The TIGER instrument is described in more detail in [8] and [5]. Preliminary results for the heavy-element abundance measurements from the first flight will be presented elsewhere at this conference [5].

Figure 1



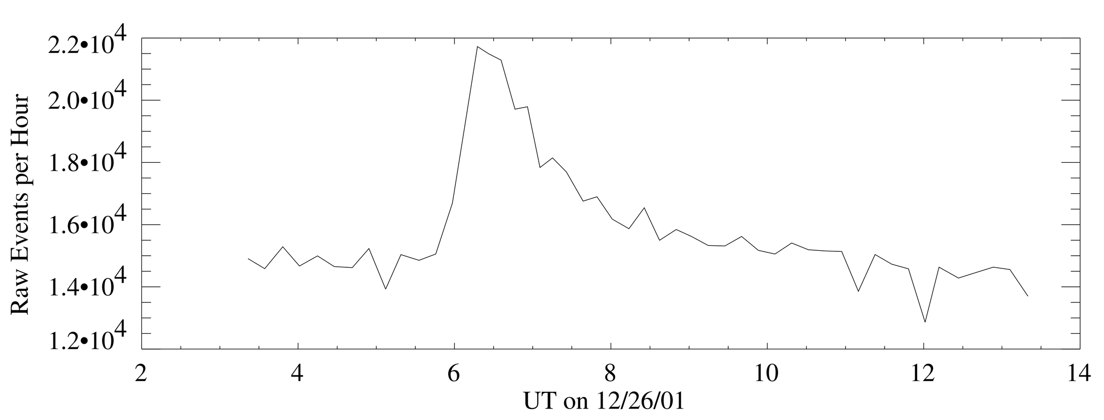
Cross section of TIGER.

2 Instrument & Data

The TIGER instrument consists of two sets of hodoscopes and two double layers of scintillators at top and bottom and two čherenkov detectors with different radiators (silica aerogel and acrylic). Figure 1 shows a schematic of the setup.

TIGER was designed to trigger on heavy elements $Z \gtrsim 13$ traversing the detector stack. The solar event created a net rise in raw triggers as shown in Figure 2. Because of confusion from low-Z hits during this time the number of properly reconstructed particle tracks and thus properly identified particles actually decreases during these hours, since the position determination efficiency drops from ∼80% to under ∼60% during that time and the instrument encounters additional deadtime.

Figure 2



Raw TIGER counts during SEP event (No dead time correction)

3 ACE & TIGER

The CRIS instrument [9] onboard the ACE spacecraft can be used to establish quiet-time GCR fluxes in the energy range of interest here. In addition, the SIS instrument [10], is used to fix the low-energy ($\lesssim$ 150MeV/nuc) compositional data during the event.

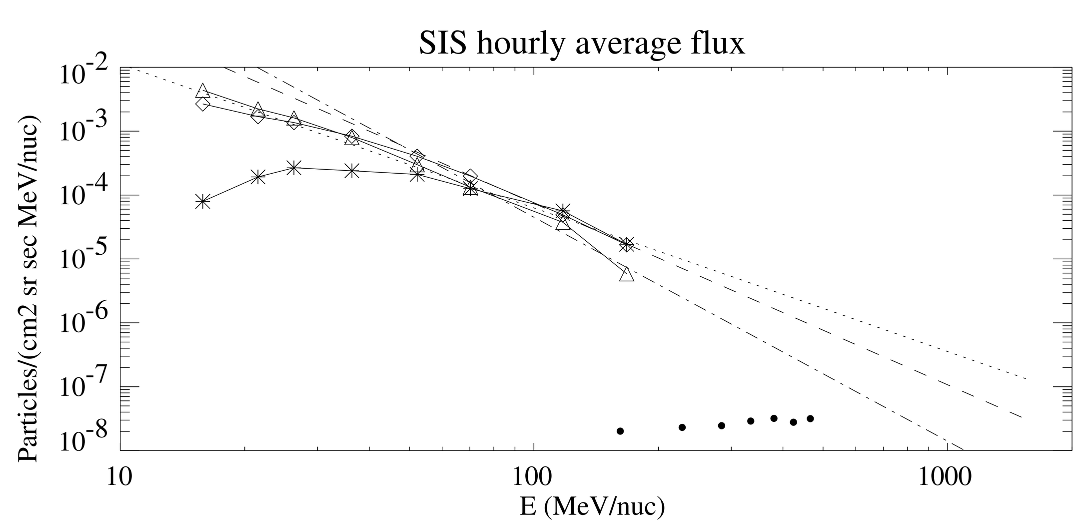
Since the TIGER instrument has a residual atmospheric overburden of about 5g/cm^2 and 5.2g/cm^2 instrumental grammage to the lower Cherenkov counter, iron nuclei impinging on the atmosphere need to have at least ∼650 MeV/nuc to trigger the instrument at vertical incidence. This sets the lower limit of the lower TIGER energy range. The upper range starts where the particles can trigger the C_0 Cherenkov detector around 2.5GeV/nuc.

Figure 3 shows the total hourly-average iron spectra at zero, one and two hours into the SEP event as measured by SIS. Note that the first spectrum for 5–6UT (marked with an asterisk) does not show the full flux at low energies yet, while the last one for 7–8UT (marked with triangles) is already dropping off at high energies.

Also shown is an indication of the *galactic* CR flux as measured by CRIS at higher energies, averaged over the 27 days prior to this SEP event (filled circles).

The straight lines indicate linear fits to the three highest-energy channels of SIS as they extrapolate into the GeV/nuc region at zero (dotted), one (dashed) and two hours (dash-dotted) into the event.

Figure 3



SIS Fe measurements: hourly averages 5-6UT (∗), 6-7UT (⋄), and 7-8UT (Δ); CRIS quiet-time averages (•) and projections from SIS spectrum to higher energies at zero (dotted), one (dashed) and two hours (dash-dotted).

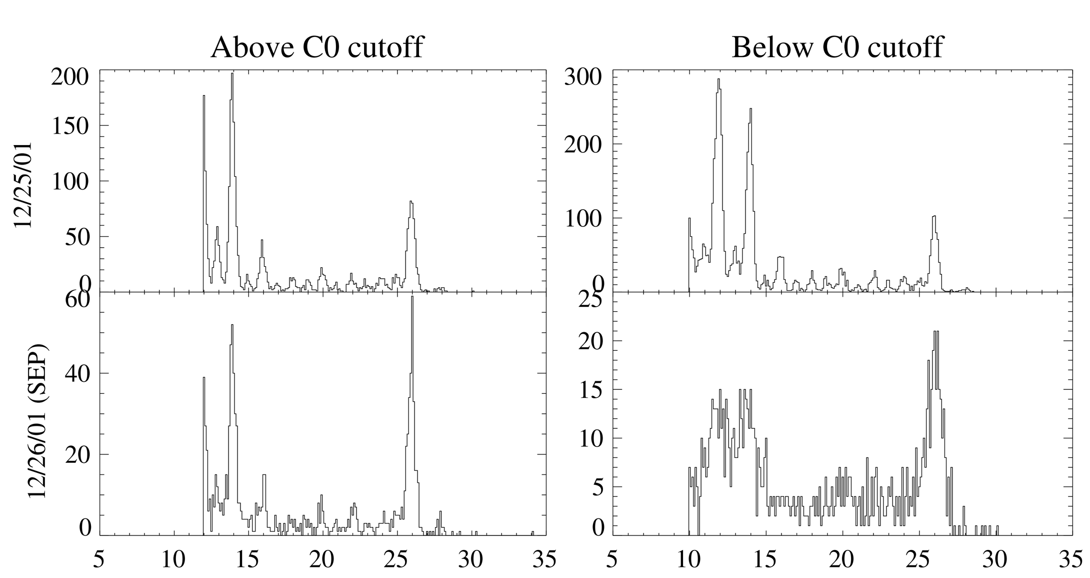
4 Discussion

It is clear that it is at least possible that solar particles contributed to the measured TIGER fluxes for the first one or two hours of the event. This suggests study of the TIGER data during this time in order to attempt to extend the SIS measurements in energy by about an order of magnitude.

For example, in the SIS energy range, the event showed an energy-dependent enhancement in Iron (expressed as Fe/O) with more iron at higher energies. The Fe/(S+Ar+Ca) ratio is measured to be ∼4 between ∼10MeV/nuc and ∼170MeV/nuc [2]. At 285Mev/nuc, the CRIS instrument indicates Fe/(S+Ar+Ca)≈1.75 [4] compared to the TIGER raw ratio of about 1 at ∼1GeV/nuc under 5g/cm^2 of atmosphere.

If the solar accelerator is indeed capable of accelerating iron into the GeV/nuc region this should visibly influence the data gathered by TIGER.

Figure 4



TIGER Z histograms during 6:10-8:15UT one day before and during the event.

Figure 4 shows the measured charge histograms in the two TIGER energy ranges during the two hours of greatest activity and during the same time on the previous day. It is clear that resolution was degraded in the lower TIGER energy range as a result of confusion of events by low-Z particle background. This manifests itself in an absolute drop in the raw counts for each of the elements, which is an indication of the track-reconstruction problems during this time.

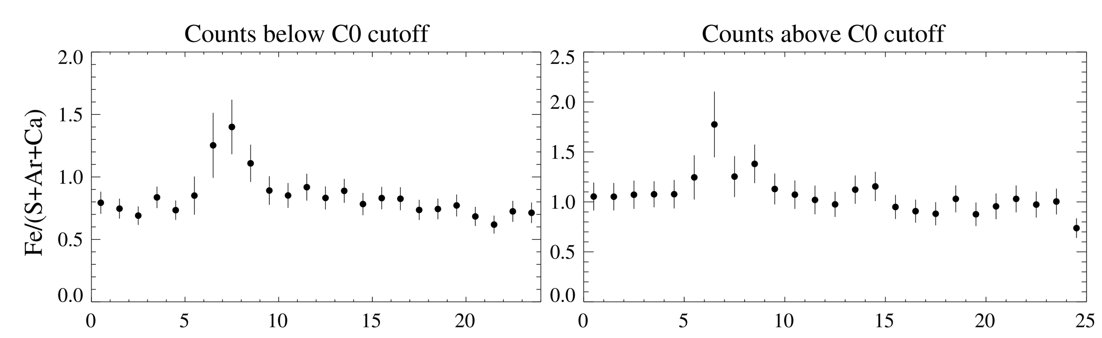
However, the underlying algorithm was never designed to deal with these conditions; preliminary research indicates that its efficiency can be improved if the known problems during this time are taken into account.

However, both energy ranges do show more iron during the SEP event than before, more clearly seen in the higher-energy range, as there is less deterioration of resolution there.

This is also shown in Figure 5, which additionally indicates the shorter duration of the change in Fe/(S+Ar+Ca) in TIGER in the higher energy range, as expected.

During 2001, at the maximum of solar activity when this event took place, eleven SEP events of comparable magnitude occured, compared to three each in 2000 and 2002 and one in 1999. At the time of this writing, no event of such magnitude has occured in 2003 yet and thus it seems unlikely that the next planned TIGER flight during the 2003/2004 Antarctic campaign will yield another such opportunity to study the high-energy tail of the SEP population.

Figure 5



Raw TIGER ratios vs. UT on 12/26 (statistical error bars only)

5 Outlook

Our preliminary analysis shows that the ratio of Fe/(S+Ar+Ca) for both of the TIGER energy ranges is consistent with that observed by SIS, indicating that heavy ions during an SEP event might be accelerated to energies in the GeV/nuc range. Additional analysis of the TIGER data will be required to attempt to reduce the number of events rejected by our software selection and to verify that the TIGER ratio is not an artifact of the high event rate.

Acknowledgements

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