Relative Abundances and Energy Spectra of C, N, and O as Measured by the Advanced Thin Ionization Calorimeter Balloon Experiment

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Abstract

We present results on the spectra and relative abundances of C, N, and O nuclei in the cosmic radiation as measured from the Advanced Thin Ionization Calorimeter Balloon Experiment (ATIC). The ATIC detector has completed two successful balloon flights from McMurdo, Antarctica lasting a total of more than 35 days. ATIC is designed as a multiple, long duration balloon flight, investigation of the cosmic ray spectra from below 50 GeV to near 100 TeV total energy, using a fully active Bismuth Germanate calorimeter. It is equipped with a large mosaic of silicon detector pixels capable of charge identification and as a particle tracking system, three projective layers of x-y scintillator hodoscopes were employed, above, in the middle and below a 0.75 nuclear interaction length graphite target.

1. Introduction

Study of C, N, and O is important for various reasons. Next to H and He, C and O are the most abundant elements in cosmic rays. Studies show an odd-even effect where tightly bound even Z and N are more abundant. The main process that separates C and N is well understood. The carbon is produced through a resonance level at an excitation energy of 7.654 MeV in ^{12}C. The production is achieved through the so-called triple-α reaction in helium-burning stars, where the unstable ^{8}Be captures a third α through the above-mentioned resonance and de-excites with a low branching ratio (4×10^{-4}) by γ-emissions to the ground state of ^{12}C. Nitrogen, however, originates in CNO processing by the conversion

pp. 1869–1872

of C and O during hydrogen burning. It is interesting to note that a further stage of stellar evolution is an α capture by ^{12}C to produce ^{16}O, and it is the absence of a resonance in ^{16}O that prevents all the carbon to change to oxygen. There has been little knowledge of generation sites for these nuclei[2]. It is not known whether they come from short-lived massive stars or from long-lived progenitor of asymptotic red giant branch stars. This stems from the fact that the threshold temperature for production of both carbon and nitrogen is reached in both stellar types. In this paper, we discuss relative abundances and the energy distribution of CNO.

2. The ATIC Detector

The ATIC detector is comprised of a fully active 50 cm wide BGO calorimeter, preceded by a graphite target of 1.6 nuclear interaction length, x-y scintillator hodoscopes, and a fully depleted Si matrix mosaic at the top, having an acceptance opening half angle of 24^o. The BGO crystals of $2.5 \times 2.5 \times 25.0\ cm^3$ are arranged in 8 layers. Each layer consists of 40 BGO crystals with the long axis aligned alternatively along the X and Y directions. The detector is described in detail elsewhere [1].

3. Analysis, Discussion and Results

In December 2000, ATIC performed its first Long Duration Balloon (LDB) Flight from McMurdo, Antarctica. Duration of the flight was 16 days and ATIC recorded approximately 3×10^7 triggers. Recently, (December 2002) ATIC completed its second LDB flight from McMurdo which lasted 19 days.

Fig. 1. shows relative abundances of elements from Li to Ne. Carbon and oxygen dominate the spectrum as expected. This superb charge resolution with high acceptance yielding good statistics is obtained by a two-fold coincidence of Si matrix array. The total energy deposition in the calorimeter for a sample of CNO is shown in Fig. 2. At this stage we have analyzed 32046 events only from the 2000 ATIC flight. Our data analysis is still in progress and we hope to analyze more CNO data from the 2002 ATIC flight in the near future. As expected the plot obeys a power law dependence $\frac{dN}{dE} = CE^{-(1+\gamma)}$ at high energy. All error bars are statistical in nature. Note the statistical fluctuations in the high energy region of the spectrum will diminish as we analyze more data. The 2002 ATIC flight data will improve the statistics by more than a factor of two.

We also looked at the relative abundances of C, N, and O. Shown in Fig. 2, is the expanded region of $5.5 < Z < 8.5$ and the data for C, N and O show distinct peaks. These preliminary counts are 13043 ± 114, 5521 ± 74 and 13482 ± 116 for

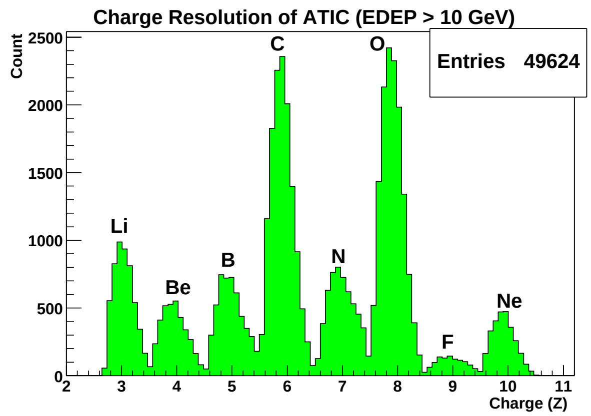

Fig. 1. Charge resolution of the ATIC detector for events > 10 GeV.

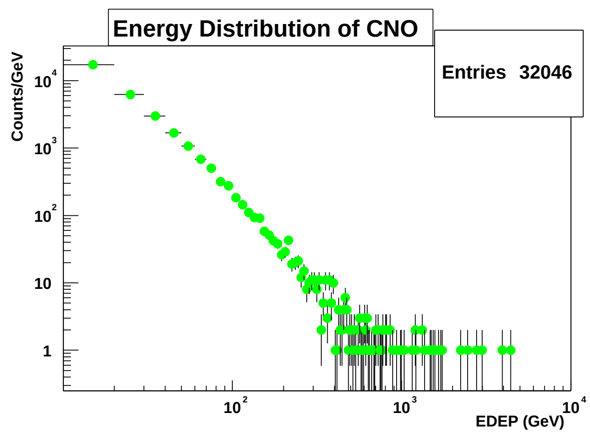

Fig. 2. Energy distribution of CNO for events > 10 GeV.

C, N, and O, respectively and constitute the first such measurements over a wide range with a single instrument. Note the uncertainties are statistical only. We still have to study the systematic uncertainties associated with different elements.

4. Conclusions

In this paper, we have discussed the analysis of CNO for the first flight of ATIC in 2000. The total energy spectrum is consistent with a power law. We also presented preliminary relative abundances of C, N, and O, for the first time over such a wide range of energy. The data analysis is still in progress. With the 2002 ATIC flight, we will improve statistics by more than a factor of two.

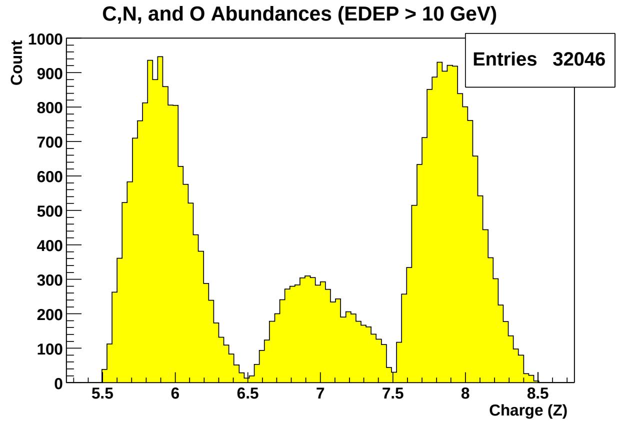

Fig. 3. Relative abundances of C, N, and O for events > 10 GeV.

5. Acknowledgments

This work has been supported in the United States by NASA Space Physics (NAG5-5307), and the Louisiana Board of Regents.

6. References

1. Guzik T. G. et al. 1999, Proc 26th ICRC, Salt Lake City, 5, 9
2. Henry R. B. et. al. 2000, ApJ, 541, 660