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Revised Energy Spectra for Primary Elements (H – Si) above 50 GeV from the ATIC-2 Science Flight

J. P. WEFEL[1], J. H. ADAMS, JR.[2], H. S. AHN[3], G. BASHINDZHAGYAN[4], J. CHANG[5], M. CHRISTL[2], A. R. FAZELY[6], O. GANEL[3], R. M. GUNASHINGHA[6], T. G. GUZIK[1], J. B. ISBERT[1], K. C. KIM[3], E. N. KOUZNETSOV[4], M. PANASYUK[4], A. PANOV[4], W. K. H. SCHMIDT[7], E. S. SEO[3], N. SOKOLSKAYA[4], J. WATTS[2], J. WU[3], V. I. ZATSEPIN[4]

[1]*Louisiana State University, Baton Rouge, LA, U.S.A*
[2]*NASA Marshall Space Flight Center, Huntsville, AL, U.S.A.*
[3]*University of Maryland, College Park, MD, USA*
[4]*Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, Russia*
[5]*Purple Mountain Observatory, Nanjing, P.R. China*
[6]*Southern University, Baton Rouge, LA, U.S.A*
[7]*Max Planck Institute fur Solar System Research, Katlenburg-Lindau, Germany*
Wefel@phunds.phys.lsu.edu

Abstract: The Advanced Thin Ionization Calorimeter (ATIC) long duration balloon experiment had a successful science flight (12/02 -1/03) accumulating 18 days of data during a single circumnavigation of Antarctica. ATIC measures the energy spectra of elements from H to Fe in primary cosmic rays using a fully active Bismuth Germanate calorimeter preceded by a carbon target, with embedded scintillator hodoscopes, and a silicon matrix charge detector at the top. Preliminary results from ATIC have been reported in previous conferences. The revised results reported here are derived from a new analysis of the data with improved charge resolution, lower background and revised energy calibration. The raw energy deposit spectra are de-convolved into primary energy spectra and extrapolated to the top of the atmosphere. We compare these revised results to previous data and comment upon the astrophysical interpretation of the data.

OVERVIEW

The Advanced Thin Ionization Calorimeter (ATIC) Experiment was developed to measure the energy spectra of the major primary elements (H–Fe), plus electrons, to as high energy as possible from balloon platforms, to search for signatures of particle acceleration sites. It is believed that particle acceleration associated with supernova remnant (SNR) shocks appears to be the best (but not the only) explanation for how galactic cosmic rays (GCR) below the "knee" achieve their high energies. Evidence that particle acceleration is taking place at SNRs is provided by electron synchrotron and gamma-ray emission measurements, but no direct detection of accelerated particles from specific sources has yet been achieved.

Cosmic ray transport in the galaxy is a diffusion process, in which the GCR hadronic component may traverse an equivalent distance of hundreds of galactic diameters during their lifetime. The diffusion coefficient is energy dependent and depends upon a number of physical parameters characterizing the confinement region (magnetic field turbulence, density, etc.). Moreover, the SNR acceleration mechanism is expected to have an upper energy limit imposed by the conditions in the expanding shell following the supernova explosion. Thus, one might well expect to find changes in the cosmic ray spectra of different elements as observations move to higher and higher energy. Current air shower results do show such effects, and ATIC is intended to provide direct particle-by-particle measurements to compare with both the air shower data and previous measurements.

A schematic diagram of the ATIC instrument is shown in Figure 1. The topmost element is a pixilated Silicon matrix detector (4480 pixels) to measure the charge of the incident particle. This is followed by three layers of scintillator hodoscopes (S1, S2, S3) embedded within a graphite target (0.75 proton interaction length). S1-S3 provides the instrument trigger and the x-y measurements from the scintillators are used for trajectory determination, along with shower centroid position provided by the eight layer BGO calorimeter. Each layer contains 40 BGO crystals of 25 mm x 25mm x 250 mm with alternate layers oriented orthogonally. The total energy deposited in the calorimeter is a measure of the incident particle energy [1].

Preliminary results from the on-going ATIC analysis have been presented previously [2-6]. These results have been based upon the charge resolution provided by the silicon matrix detector [7]. The top layers of scintillator, S1x and S1y, can also be used to measure the particle charge, thereby providing a second, independent measurement which improves the overall charge determination [8].

ATIC has been calibrated at the SPS at CERN with proton and electron beams [9]; has had a test flight from McMurdo in 2000-2001 [10]; returned good data from its science flight in 2002-2003 [11]; and had its second science flight terminated just after launch in 2005 due to a balloon failure. ATIC is anticipating completing its second science flight in 2007-2008, for which preparations are currently on-going.

The revised data presented here are from the first science flight and incorporate better charge determinations, an improved method of reconstructing the fluxes, corrections for interactions within the instrument, and an improved normalization. These revised spectra will be compared to other recent data and to expected astrophysical scenarios for the origin of these very high energy particles.

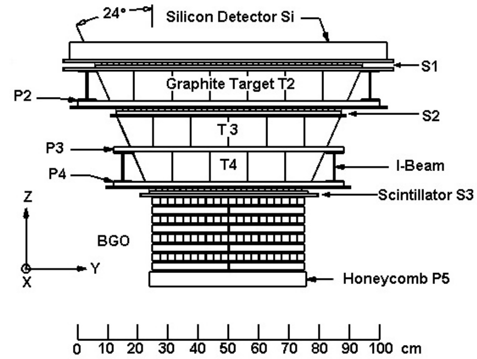

Fig. 1: Schematic diagram of the ATIC instrument in flight configuration.

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