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Cosmic ray nuclei at high energies: recent results from TRACER and future prospects

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Abstract.
The first balloon flight of the TRACER instrument in 1999 led to a new measurement of the energy spectra of cosmic ray nuclei from Z=8 to Z=26 at energies from a few GeV/nucleon to several TeV/nucleon. We will present and discuss the results, compare them with other recent measurements and examine the implications for current cosmic ray propagation and acceleration models. Finally, we will comment on the prospects of planned flights of the TRACER instrument on long duration balloons, and on the adaptation of the measurement technique to anticipated space missions.

1 Introduction

The TRACER instrument (”Transition Radiation Array for Cosmic Energetic Radiation”) was flown for the first time in September 1999 in a 28-hour balloon flight from Fort Sumner, New Mexico. The instrument was designed to measure the energy spectra of the heavy cosmic ray nuclei from oxygen (Z=8) to iron (Z=28). The measurement technique makes use of the relativistic rise with energy of the specific ionization generated by cosmic rays in gaseous detectors, and of the energy dependence of the yield of transition radiation. Some details about the technique and the data analysis approach are given by Hörandel at al (2001).

2 Energy Spectra of Cosmic Ray Nuclei

A unique feature of TRACER is the capability of deriving with a single instrument, the energy spectra of cosmic ray nuclei over three decades, from geomagnetic cutoff (∼4.5 GV) to several TeV/nucleon. At the time of this writing, the analysis is still in progress, but the energy spectra for individual elements resulting from this work, will be presented at the conference. Our work will concentrate on the major primary elements oxygen, neon, magnesium, silicon, and iron, and our results will be compared with those from other investigations, including those obtained by our group with the CRN detector on the Space Shuttle (Müller et al, 1991). It will be very instructive to compare the shape of the measured energy spectra with what might be expected in the context of galactic propagation model. It is now well known, at least up to energies around 100 GeV/n, that the propagation path length Λ_p of cosmic rays decreases with energy, as $E^{-\delta}$ with $\delta \approx 0.6$. In simple diffusion models without reacceleration in interstellar space, the effective path length Λ of cosmic rays is then determined by competition between diffusive propagation and loss by nuclear spallation:

$$\frac{1}{\Lambda} = \left(\frac{1}{\Lambda_s} + \frac{1}{\Lambda_p(E)} \right) \quad (1)$$

For relativistic nuclei, the spallation path length Λ_s is essentially independent of energy, but is commensurate with typical values of Λ_p, for instance, for iron $\Lambda_s = 2.3 g/cm^2$. If the cosmic ray energy spectrum at the source is a pure power law with index γ_0, one would expect the observed spectrum to exhibit a gradual steepening, reaching a spectral index $\gamma = \gamma_0 + \delta$ at high energies. For heavy elements like iron, this asymptotic slope would be obtained at higher energies than for the lighter elements, due to the dependence of Λ_s on the mass of the nucleus. Previous analysis of the energy spectra obtained with the CRN instrument, indicated qualitative agreement between the data and this model (Swordy et al, 1993), with the possible exception of the element Silicon (Z= 14). The present data from TRACER will permit a much more sensitive test of the model, because of the larger energy coverage and improved counting statistics. We will present and discuss the results of such an analysis.

3 Future Prospects

The 1999 balloon flight of TRACER provided significant data, and successfully tested a new detector concept. To fully

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exploit the technique, longer exposures are desirable. We therefore plan to use the instrument in a long duration balloon flight from Fairbanks, Alaska, in early summer 2002. This will be a circumglobal flight along the Arctic Circle, with an anticipated duration of about two weeks. If successful, this flight will improve the counting statistics by more than an order of magnitude.

Finally, instruments like TRACER should be used in space for durations of the order of years. This is especially important for measurements of interstellar secondary nuclei with good statistics, and without contamination by spallation produced nuclides in the atmosphere. Such elements, notably Li, Be, and B, are essential for determining the interstellar propagation path length.

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