THE HEAO-3 COSMIC RAY ISOTOPE SPECTROMETER†

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Abstract. This paper describes the Cosmic Ray Isotope instrument launched aboard the HEAO-3 satellite on September 20, 1979. The primary purpose of the experiment is to measure the isotopic composition of cosmic ray nuclei from Be-7 to Fe-58 over the energy range 0.5 to 7 GeV/nucleon. In addition charge spectra will be measured between beryllium and tin over the energy range 0.5 to 25 GeV/nucleon. The charge and isotope abundances measured by the experiment provide essential information needed to further our understanding of the origin and propagation of high energy cosmic rays. The instrument consists of 5 Cerenkov counters, a 4 element neon flash tube hodoscope and a time-of-flight system. The determination of charge and energy for each particle is based on the multiple Cerenkov technique and the mass determination will be based upon a statistical analysis of particle trajectories in the geomagnetic field.

1. Introduction

The determination of the charge and mass composition of the primary cosmic radiation is important for many astrophysical problems, in particular stellar nucleosynthesis and high energy particle acceleration mechanisms. It will allow the question about the existence of a galactic cosmic ray halo to be addressed, thereby giving information about the strength and topology of the galactic

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magnetic field. This information can best be obtained at relativistic energies, where composition changes due to solar modulation and ionization losses are negligible and where nuclear interaction cross-sections are constant or vary only slowly with energy.

However, at the high energies where the results are simpler to interpret, the measurements are more difficult to perform. Especially the determination of the mass becomes complicated, as the dE/dX-total E methods which are useful at lower energies, fail at multi-GeV energies, where the particle range is an order of magnitude greater than the mean nuclear interaction length. At present the only possibility to obtain a mass estimate is to measure the magnetic rigidity

\[ R = \frac{P M}{Z}, \]  

where \( M \) is the atomic mass, \( P \) the particle momentum/nucleon and \( Z \) is the charge. As no superconducting magnet of sufficient strength, size and cryostat lifetime which can separate isotopes in this energy range is as yet available, we have developed a method based upon the use of the geomagnetic field. Figure 1 compares the charge and energy range of the present experiment with the ranges of previous experiments.

By comparing fluxes of particles with accurately measured charge and momentum obtained at different geomagnetic cut-off conditions, one can in a conceptually straightforward manner determine the mean mass of the particles in each element [1–3]. By a more detailed analysis based upon distinct features of the cut-off we hope to determine the individual masses of a smaller sample of particles [4, 5].

The measurement accuracy required for isotope determinations has led us to design an instrument using Cerenkov counters only. This ensures good charge resolution at high charges, as Cerenkov counters in contrast to scintillation counters do not saturate, even for very high ionization densities. In order to obtain precise momentum determinations over an extended range it has been necessary to use a sequence of 5 counters and to develop new radiator materials with low refractive indices.

The precision needed also demanded the use of thick radiators, i.e., many g cm\(^{-2}\) in the particle path. The resulting high interaction rate means that the instrument is more suited to detailed comparisons between neighbouring elements than to the determination of absolute abundances.

2. Scientific Objectives

The HEAO-3 C2 instrument is designed to determine:
- The mass composition of the most abundant elements between beryllium and iron in the energy range 0.5 to 7 GeV/nucleon;