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THE COSMIC RAY ISOTOPE SPECTROMETER (CRIS)

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ABSTRACT

The Cosmic Ray Isotope Spectrometer instrument on the Advanced Composition Explorer (ACE) spacecraft has been built and tested and will be launched into space in a few months. This paper briefly describes the overall instrument and expected performance.

INTRODUCTION

The history of low energy cosmic ray measurements is one of steady improvement both in collection power and in the ability to resolve different particle species. The Cosmic Ray Isotope Spectrometer (CRIS) instrument for NASA's ACE mission, with a geometry factor of ~250 cm^2-sr for angles of incidence less than 45° and the ability to resolve individual isotopes of iron, is a significant next step in this progression. There may well be charge-dependent biases in the observed cosmic ray elemental composition, for example, due to the acceleration process or due to escape from the source regions, but we expect there to be very little bias in the isotopic composition of a given element. In this regard, CRIS, with its large collection power and excellent isotopic resolution, has a significant advantage for studying cosmic-ray origin.

INSTRUMENT DESCRIPTION

A schematic of CRIS is shown in Figure 1. Large collection power is achieved by using a trajectory system employing scintillating optical fibers together with four identical stacks of large-area solid-state silicon detectors. The top optical fiber plane in the trajectory system is a trigger plane, below which are three pairs of optical fiber planes which measure particle X and Y positions with a resolution of about 80 microns rms. Each fiber plane is 26 cm x 26 cm and the fibers are 200 microns square. The trajectory system is described further in a companion paper, Binns, et al., OG 10.2.21. Figure 2 shows the vertical positions of the optical fiber planes and details of a single silicon detector stack. Each silicon detector is 3 mm thick by 10 cm in diameter; most have a double-groove structure which creates an active guard ring around a central active area of 57 cm^2, while others have only a single groove, giving a central area of 68 cm^2. These detectors, which are of the Li-drifted type, have a dead layer on the grooved surface ~ 60 microns thick. The dead layers and the detector active thicknesses were mapped using energetic ^{36}Ar nuclei at the National

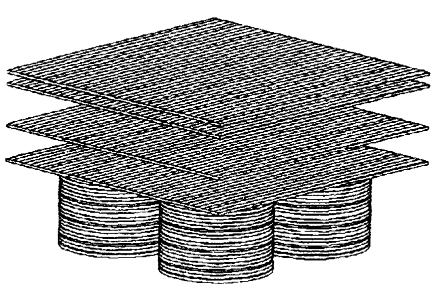

Figure 1. Schematic of CRIS showing the scintillating fiber hodoscope and four stacks of 15 solid-state detectors each.

Superconducting Cyclotron Laboratory at Michigan State University, as is described in Dougherty, et al., 1996.

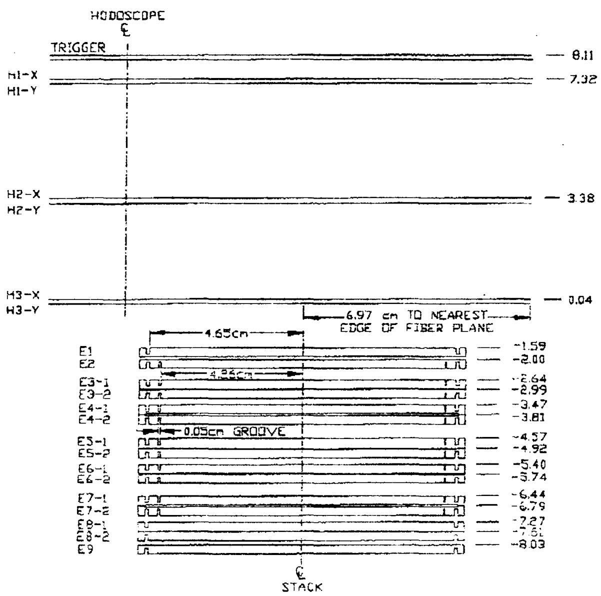

Figure 2. One of four CRIS detector stacks.

The guard-ring detectors detect particles entering or exiting through the side of a stack; the bottom-most detector of each stack detects particles which enter or exit the bottom. For each particle which passes through the trajectory-system trigger plane and stops in a stack, precise measurements are made of various energy losses. The four stacks of detectors are denoted by A, B, C and D. The names of the stack detectors (E1, E2, E3-1, etc.) are shown in Figure 2; E2A then refers to the E2 detector in the A stack. The energy losses in each of the four E1 detectors are measured separately. To reduce the total number of pulse height analyzers, however, the signals from detectors E2A and E2B are summed into a single pulse-height analyzer known as E2AB. Similarly, detectors E2C and E2D are summed into E2CD. Detectors E3-1A, E3-2A, E3-1B and E3-2B are summed into a single pulse height analyzer known as E3AB, and so on. The guard rings around detectors E3-1A, E3-2A, E3-1B and E3-2B are summed into a single pulse height analyzer called G3AB. In total, 32 separate pulse heights are measured for the stack detectors. The trajectory system provides the means of distinguishing which stack was entered. Coupled with the measured trajectory, detector thickness maps and the dead layer maps, the energy loss measurements provide multiple dE/dx and residual energy measurements, from which the charge, mass and total energy can be obtained. Multiple measurements provide the ability to reject background as well as improving the mass estimate by averaging several values. Figure 3 shows the energy range covered by CRIS as a function of particle charge, as well as an indication of the energy range where individual isotopes will be resolved. The resources used by CRIS are indicated in Table 1.

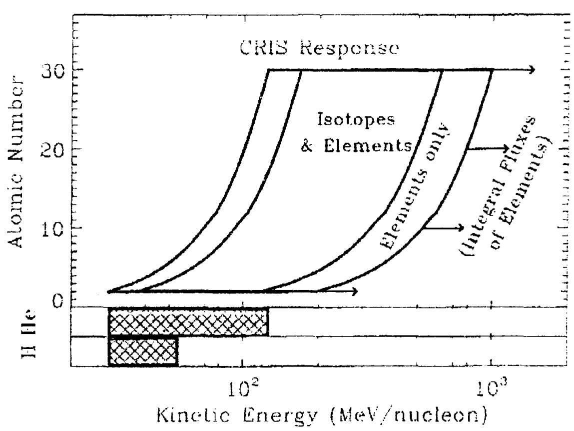

Figure 3. CRIS dynamic range in charge and kinetic energy. In the lowest energy band, widely spaced isotopes such as those of Ne will be separated.

Table 1: Resource Allocation for CRIS

Resource	Usage
Weight	29 kg
Power	12 W
Bit-Rate	464 bits/sec

Each pulse height analyzer has three electronic thresholds: a lower level discriminator, a threshold which in-geometry protons cannot quite reach, and a similar threshold for He. These signals make it possible to determine promptly whether an event corresponds to a proton, He or heavier nucleus. Events are categorized on-board according to this charge estimate, and how deeply they penetrate into the telescope, among other factors, and assigned a priority for telemetry readout. Heavy nuclei which stop deep in a stack have the highest priority since they have the most information for determining their mass. Rates and livetimes are recorded in order to be able to reconstruct the absolute particle fluxes independent of these on-board selection biases.

Figure 4 shows approximate numbers of isotopes for each element from Li to Zn which CRIS will be able to detect in a two year period. To date, the only precise measurements of cosmic-ray lifetime from a radioactive clock have been obtained from ^{10}Be. From Figure 4 it appears that we should be able to obtain additional measurements of cosmic-ray lifetime from ^{26}Al, ^{36}Cl and possibly even from ^{14}C. The latter isotope, by virtue of its short (~5000 year) half-life, might be able to probe very local conditions in the neighborhood of the solar system. Unfortunately there is no measured half-life available for ^{54}Mn, which complicates the interpretation of its abundance.

Event Rates in CRIS

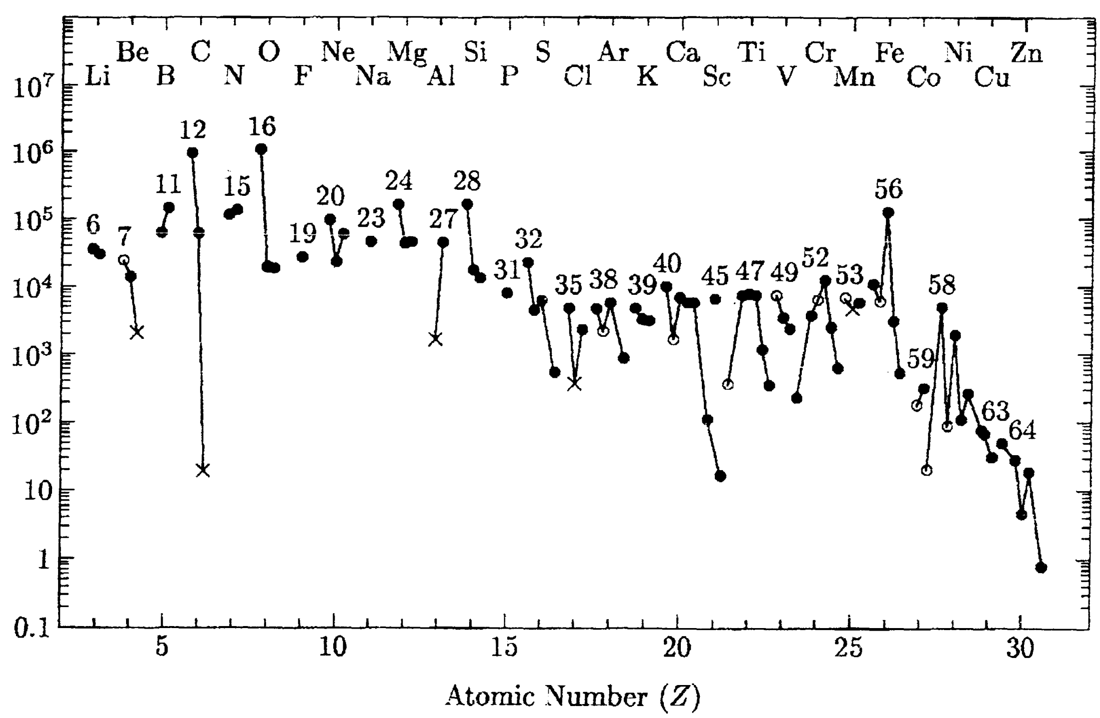

Figure 4. Estimated numbers of different isotopes which can be detected by CRIS in two years. The open circles indicate radioactive elements which decay only by electron capture. Radioactive clock isotopes are marked with x.

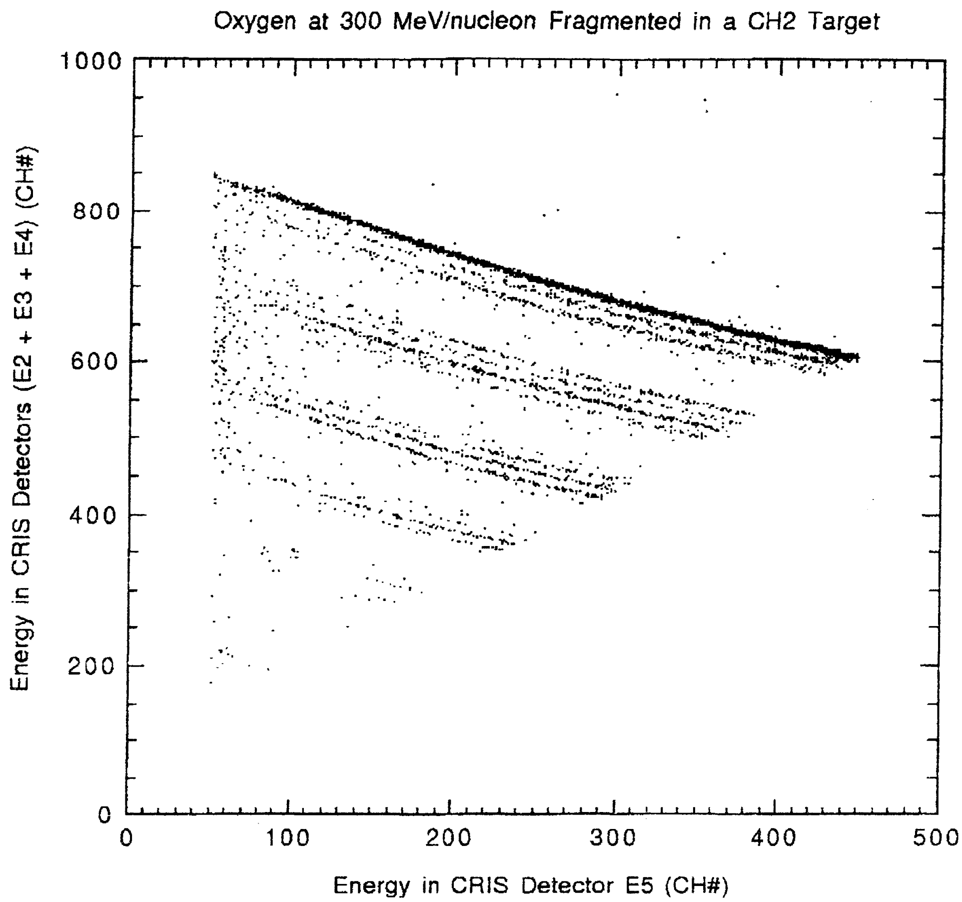

Figure 5. Scatter plot showing the sum of pulse-heights in detectors E2+E3+E4 versus the pulse height in E5 for particles that stop in detector E5.

PRELIMINARY ACCELERATOR RESULTS

CRIS was taken to the GSI accelerator in Darmstadt, Germany and exposed to 270 MeV/nuc ^{12}C, 300 MeV/nuc ^{18}O and 200 MeV/nuc, 500 MeV/nuc and 700 MeV/nuc ^{56}Fe beams incident on polyethylene targets to produce fragments. Figure 5 is a sample scatter plot showing fragments from 300 MeV/n ^{18}O. This figure corresponds to particles which stopped in the E5 detectors. No corrections have been made yet for the dead layers or for variations of the detector thickness and no cuts have been made to reject background events. It can be seen that the individual isotopes are quite well separated, even without these corrections.

ACKNOWLEDGMENTS

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