

Balloon Flight Tests of a Gas-Ionization-Chamber-Based Isotope Spectrometer

Mark E. Wiedenbeck and Barrett Milliken

*Jet Propulsion Laboratory, California Institute of Technology
Pasadena, California 91109 USA*

Abstract

The performance of the "Tracking Heavy Isotope Spectrometer Telescope for Low Energies" (THISTLE) is being investigated using data from a balloon flight carried out in 1993. We discuss the instrument design and show examples of its operation. Results of additional analysis will be presented at the conference.

1. Introduction

High resolution studies of the isotopic composition of heavy elements in the galactic cosmic radiation have been carried out aboard satellites over the past two decades. These investigations have relied on measurements of energy loss, ΔE , total energy, and trajectory for nuclei stopping in stacks of silicon solid state detectors. At the present state-of-the-art, such instruments can achieve mass resolution of $\lesssim 0.25$ amu (for iron-group nuclei) and have a geometrical acceptance of a few hundred cm^2 -ster. With this resolution and size it should be possible to study essentially all of the stable and long lived nuclides up through the iron group in the periodic table.

The elements above the iron group have very low abundances in nature, since these elements have binding energies per nucleon which exceed those of the lighter elements from which they must be formed. Thus the production of these species occurs only in special nucleosynthetic environments in which the necessary endothermic reactions are possible. However, the fact that these "ultraheavy" (UH) nuclides carry information about special sites of nucleosynthesis makes them of great interest scientifically.

Thus far, experiments designed to study the composition of ultraheavy cosmic rays have had difficulties resolving adjacent elements, and no serious attempts have yet been made to resolve UH isotopes. To undertake UH isotope studies will require exposures of at least several m^2 -ster-years with sensor systems which are able to achieve mass resolution $\lesssim 0.3$ amu for UH elements.

In this paper we discuss our investigations of a new type of sensor system with potential for combining excellent mass resolution with large collecting area.

2. Instrument Description

The "Tracking Heavy Isotope Spectrometer Telescope for Low Energies" (THISTLE) is a high-pressure gas ionization detector which provides measurements of ΔE , total energy, and trajectory for heavy nuclei which stop in its active volume. In earlier studies [1] we tested a small-area prototype sensor

system of this kind with accelerator beams of heavy ions and were able to achieve mass resolution ~ 0.25 to 0.35 amu for iron-group nuclei. In order to understand the response of larger area sensors in an actual cosmic ray environment, we constructed the THISTLE balloon instrument shown schematically in Figure 1.

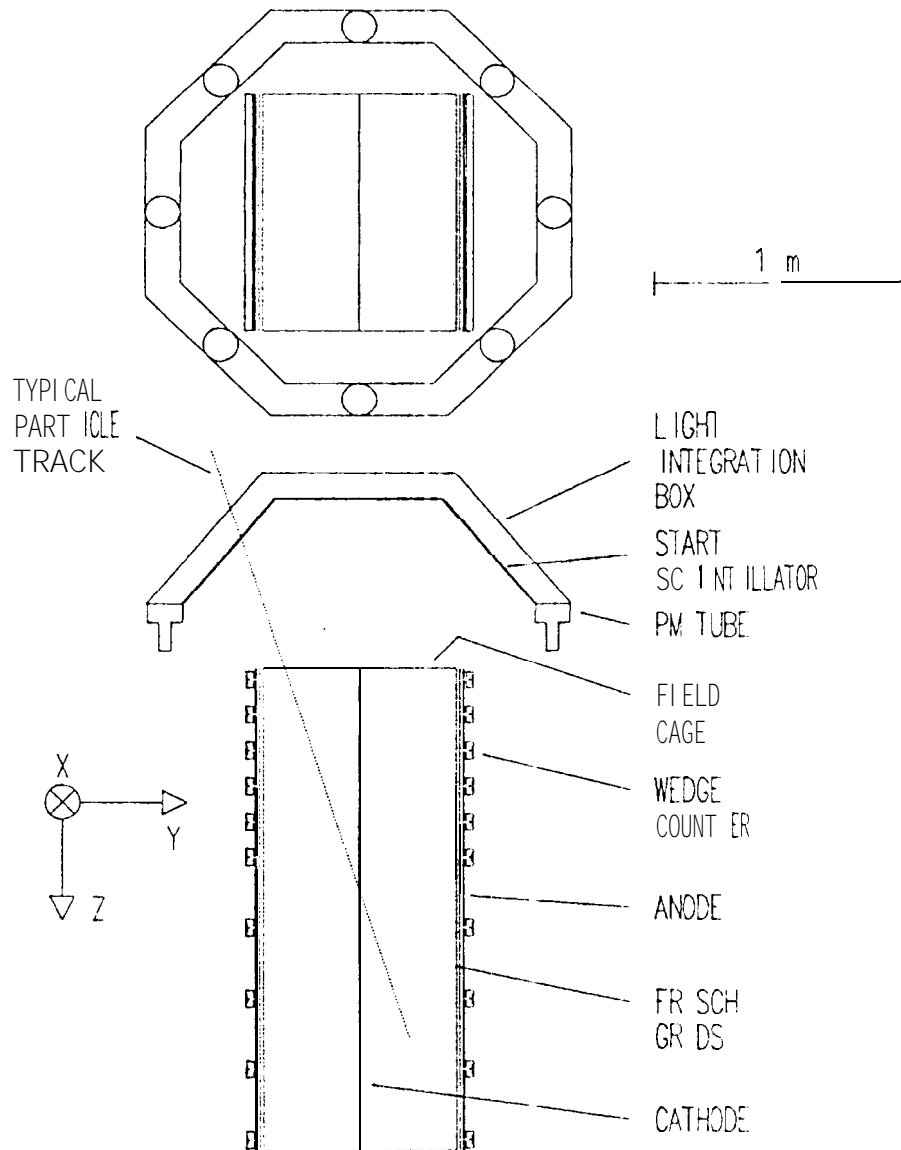


Figure 1. Schematic cross section of the THISTLE sensor system.

The main portion of the instrument consists of a gas volume which has an entrance aperture of 1 m x 0.8 m and a sensitive depth of 1.95 m. A thin foil cathode located along the mid-plane of the gas volume is held at a negative high voltage (~ 35 kV), while the outside of the volume is surrounded by field-shaping electrodes designed to produce a uniform electric field parallel to the y-direction. This field causes the ionization electrons produced by the passage of an energetic heavy nucleus to drift to one of two outside surfaces which are divided into a number of anodes which provide measurements of the ionization along well defined segments of the particle's track. The individual anode signals provide multiple measurements of the particle energy loss rate, while their sum gives the total energy.

The particle's trajectory through the gas volume is measured using a set of position-sensitive single-wire proportional counters ("wedge counters") which sample a small segment of the ionization signal between adjacent chamber anodes. The coordinate parallel to the particle track (y) is obtained from a drift time measurement based on a start signal from a scintillator located above the ionization chamber and a stop signal from the proportional counter wire. The orthogonal coordinate (x) is obtained using the division of the charge induced on a set of interleaved wedge-shaped electrodes by the proportional counter avalanche[2].

The ionization chamber is operated in a pressure vessel (which also serves as the balloon gondola) filled with a mixture of 95% Ar plus 5% CH₄ at an absolute pressure of 4 atm. Signals from all of the sensors are processed by electronics housed in a separate vessel mounted below the ionization chamber.

2. Balloon Flight

With a 1-2 day balloon flight, the THISTLE instrument can collect a sample of the most-abundant nuclides in the range $10 \leq Z \leq 28$, which is sufficient for evaluating the in-flight performance of the sensor system. A test flight was carried out from Lynn Lake, Manitoba, Canada on 13 August 1993. Data were collected at a float altitude of ~ 4 mbar for a period of 11 hours.

Figure 2 shows two examples of the response of the instrument to heavy nuclei which stop in the sensitive volume. The left two panels of these on-line displays show the two projections of the particle's track, one based on the charge division measurements and the other on the drift time measurements. Signals from the two halves of the chamber (separated by the cathode foil) are indicated with different symbols, open circles for the left and filled circles for the right. The right hand panel is a histogram of the ionization charge per unit length collected from the anode plates. The signals from the left half of the chamber are shown with grey bars and those from the right half are shown with black. The bars are scaled so that the maximum anode pulse height (indicated above the plots) is at full scale. This graph is essentially a plot of the particle's Bragg curve, with ionization density increasing as the particle slows down while traversing gas volume.

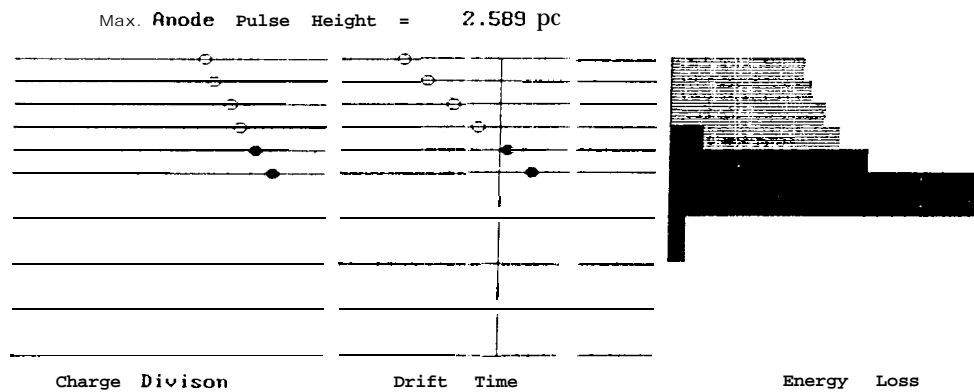
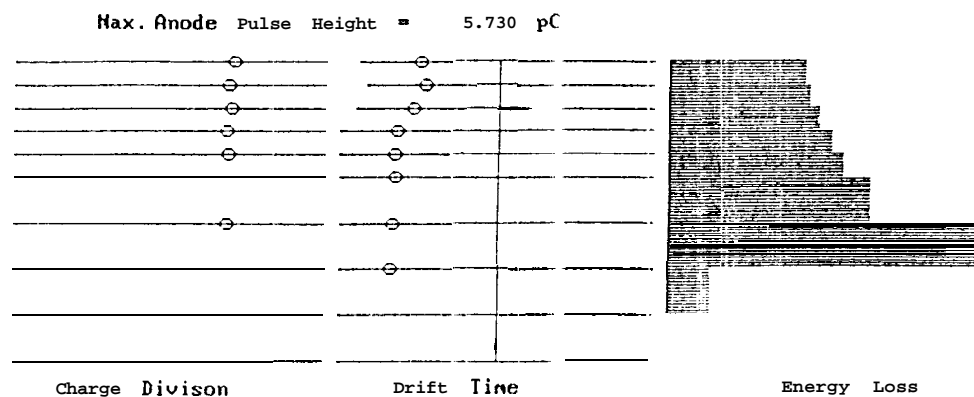


Figure 2. Plots of tracking and energy loss data for two heavy nuclei events.

The research described in this paper was supported by the National Aeronautics and Space Administration at the Jet Propulsion Laboratory of the California Institute of Technology. The THISTLE instrument was designed and constructed at the University of Chicago and we are pleased to acknowledge the contributions of the Chicago group, especially, Peter Meyer, Gary Kelderhouse, Skip Johnson, Bill Hollis, and Brian Lynch.

References

- [1] Leske, R. A. *et al.*, *Nucl. Instr. and Meth. in Phys. Res.*, **A277**, 627 (1989).
- [2] Leske, R. A. *et al.*, *Proc. 21st ICRC (Adelaide)*, 4.426 (1990).