INTRODUCTION

The identity of the source of the cosmic radiation is one of the oldest and most interesting unanswered questions of 20th-century physics. While it has become increasingly clear that these energetic particles owe their existence to some of the most violent processes that occur in our galaxy (e.g., supernovae), a detailed understanding of the cosmic ray source and the conditions of galactic propagation has not been achieved. Of particular interest in this regard is the isotopic composition of the cosmic radiation since nuclear abundance anomalies would provide the most exciting clues as to their nuclear origin. The iron isotopes provide the most fruitful candidates for such a study since they are both abundant and are least modified by galactic transport. To date the most accurate isotopic studies of the iron group cosmic rays have ruled out large deviations from solar system source composition. In order to achieve a convincing separation of the isotopes of iron it is necessary to design an instrument which can collect over $10^4$ iron nuclei and achieve a mass resolution of $\sigma \approx 0.15$ amu.

Three important developments have made the design of such an instrument possible: (1) With considerable impetus from the new generation of accelerators, magnet and cryogenic technology has reached the stage where very large volumes can be filled with uniform fields in excess of 2 T; (2) A track recording plastic detector made of CR-39 has been developed that is sensitive to minimum-ionizing particles of the so-called very heavy group ($20 \leq Z \leq 30$) has very good charge resolution, yields etched tracks of very high optical quality, and can be made in films thin enough that multiple Coulomb scattering can be neglected; and (3) the advent of the space shuttle will make it possible to lift payloads weighing many tons into orbit for periods of several weeks.
One of the authors (GT) has conceived of an instrument (SPIRIT) which capitalizes on these recent developments and can achieve the required collecting power and resolution in a 10-day shuttle flight using only passive components. A three-tiered passive hodoscope consisting of track-recording plastic with a thin (60-μm) central layer will record the trajectories of cosmic ray particles through a magnetic field with an average strength of 2 T. These particles will be traced to their end of range in a stack of CR-39 where their charge will be determined by measurements of etched cone length. The measurement of magnetic rigidity in combination with the measurement of range will be used to determine particle mass.

**THE SUPERCONDUCTING MAGNET**

In order to achieve the resolution and collecting power necessary to meet the experimental objectives of SPIRIT, a superconducting magnet with an average field of 2 T over a control volume of 1 m³ is needed. The control volume must be clearly accessible to cosmic radiation entering from a polar angle from 0 to about 45° (see Fig. 1). Spatial gradients need to be kept below 4 T/m, so that shifts in detector orientation expected during flight will not result in a degradation of resolution. The entire apparatus must be contained in the space shuttle orbiter cargo bay which has a dynamic envelope diameter of 4.57 m.

The proposed magnet consists of six coils. The four inner coils generate a uniform high field over the control volume. The two outer coils will generate a smaller field over a larger volume so that the entire assembly will have a zero net dipole moment, which results in a negligible distant field.

The design of the SPIRIT magnet system is similar in concept to the high-current-density type of magnet which has been under development for the last four years [3-5]. This development work has come to fruition with the construction of the 2-m-diameter, 3.3 m long, 1.5-T thin solenoid which is designed to operate at a current density of $7 \times 10^8$ A/m² and at a stored energy of greater than 10 MJ [5]. This design concept, which is used in the TPC solenoid [5], is particularly applicable for use in space.

The SPIRIT magnet has the following characteristics: (1) Intrinsically stable high-current-density superconductor is used, (2) quench protection is based on the use of LBL shorted secondary concept, (3) cooling of the superconducting magnet is

![Fig. 1. Cross-sectional view of SPIRIT experiment showing the six-coil superconducting magnet system.](image-url)