Monte Carlo Simulation of the Response of MARIE

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Abstract

The instrument MARIE aboard Mars Odyssey is a charged particle telescope that is currently collecting data on galactic cosmic rays and solar energetic particles in Mars orbit. Calibration of the MARIE data to yield astrophysically important quantities such as particle fluxes or spectra exterior to the spacecraft requires detailed modeling of the transport of particles through the spacecraft and instrument.

In order to facilitate the calibration of the MARIE data, we have begun a program to simulate the response of MARIE using the FLUKA Monte Carlo radiation transport code.

1. Introduction

MARIE is a particle telescope sensitive to nuclei with $E \sim 30 - 450 MeV/nuc$ aboard Mars Odyssey that has been collecting data both in the cruise phase of the spacecraft from the earth to Mars, as well as in Martian orbit. The primary motivation for MARIE is to measure the radiation dose in transit to and at Mars, in order to assist in planning for eventual manned missions to Mars [9]. A side benefit of the MARIE data is that it provides a platform elsewhere in the inner heliosphere besides Earth for observing galactic cosmic rays and solar particle events [2,10]. An impediment to realizing the full potential of the MARIE data for this purpose is that the amount of pre-launch calibration and instrument characterization devoted to MARIE was significantly less than that for spacecraft with purely astrophysical motives such as ACE or ULYSSES.

In this paper we present an overview and preliminary results of a program to use detailed Monte Carlo modeling of the physical interaction of nuclei with the MARIE instrument, with the specific purpose of improving the calibration

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of the MARIE data for astrophysical uses. Other results of this effort are also presented elsewhere [7], as well as in these proceedings [8].

2. Instrument Overview

A schematic diagram of the MARIE silicon detectors is shown in Figure 1. The A1 and A2 detectors are square with active areas 3 cm on a side, and a

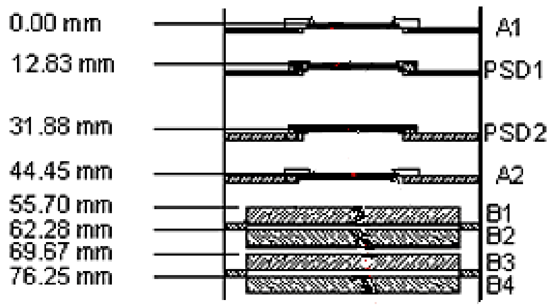

Fig. 1. Layout of the silicon detectors in MARIE. A1 is the "front" of the instrument.

thickness of 1 mm. The position sensitive detectors (PSD1 and PSD2) are squares with total thickness 0.3 mm, divided into two orthogonal planes each with 24 strips of width 1 mm. The detectors B1-B4 are circular in cross section, with thickness 5 mm, and diameter 5.84 cm.

The trigger condition for MARIE is A1-A2 coincidence. Because of this, the majority of the triggers are due to particles that enter the lightly shielded "front" of the instrument. Particles can also trigger by passing through the detector stack in the opposite direction. However the shielding by the bulk of the spacecraft as well as the entire MARIE detector stack means that these triggers are much less likely, and thus comprise a minority of the triggers for the instrument. Clearly, detailed information about the amount and composition of material behind MARIE will be necessary to simulate these triggers, and we are currently in the process of gathering this information and incorporating it in our model. For the purposes of this paper however, we will discuss only the simulation of the forward moving particles.

3. Model Overview

In order to model the response of MARIE, it was necessary to have a simulation environment that incorporated both an accurate description of the interaction physics of the energetic particles with the spacecraft structure and detector elements, as well as the distribution in energy and species of the energetic particles in the inner heliosphere. The Monte Carlo code FLUKA fulfills the first of these requirements, providing well tested models of particle interaction and transport [5,6]. In particular for our purposes with MARIE, FLUKA includes accurate models of the continuous energy loss by charged particles in matter, including a reliable parameterization of the fluctuations in energy loss [4]. For MARIE this is of importance due to the relatively low thickness of the A detectors and PSD's. In addition, FLUKA also treats possible nuclear interactions by incident protons with the material comprising the spacecraft and detectors, and work is underway to extend the nuclear interaction models to heavier incident nuclei as well [1]. To address the second requirement, we availed ourselves of the results of the FLEUR project [3], the purpose of which is to provide the infra-structure necessary to make FLUKA an efficient tool for space science and astrophysical applications.

4. Preliminary Results

In order to extract accurate particle spectra from the MARIE data, it is necessary to characterize (among other things) the instrument's geometric acceptance as a function of incident particle energy. Figure 2 shows the results of model determination of the geometric acceptance of MARIE as a function of energy for forward moving protons. At the highest energies plotted the acceptance is essentially that predicted by simply ray tracing through the MARIE geometry. As the energy drops below 50 MeV, the acceptance slowly drops, due to an increase in the number of large angle scatterings within the detector elements (A1 and the PSD's) that preferentially scatter particles away from A2. By the time the energy is down to 30 MeV, the acceptance is down to $\sim 95\%$ of the nominal value. Below $\sim$ 30 MeV the acceptance starts dropping rapidly as more and more particles lose all their energy in the spacecraft elements such as the walls of MARIE, A1 and the PSD's before reaching A2 and thus triggering.

5. Summary

Modeling of the geometric acceptance of MARIE shows that over the majority of the instruments energy range the acceptance is close to constant, with a roll off of a few percent below $\sim$ 50 MeV, and a rapid drop below $\sim$ 30 MeV. Further modeling and simulation work to completely characterize the response of MARIE continues.

6. Acknowledgments

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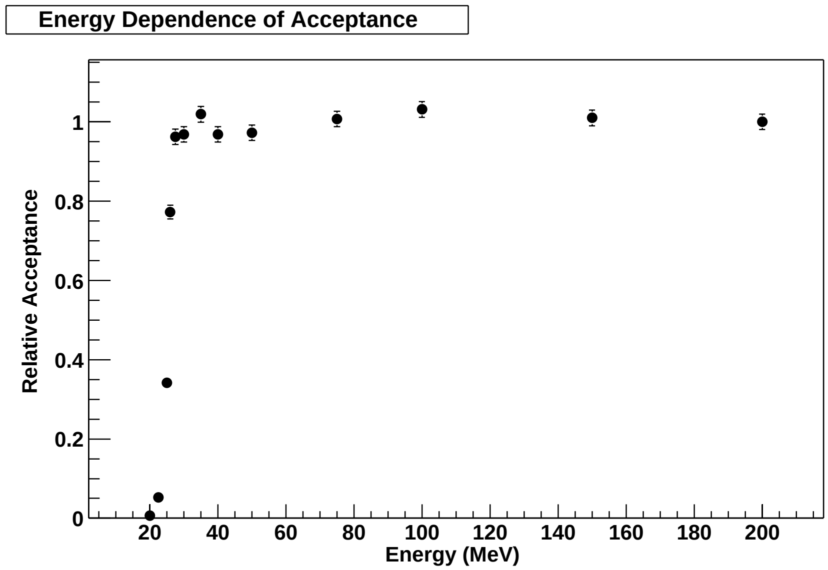

Fig. 2. The dependence of the geometric acceptance of Marie as a function of incident kinetic energy for protons. Acceptance's are plotted relative to that at 200 MeV.

7. References

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