An Alternative Anti-Coincidence for Angle Detecting Inclined Sensors (ADIS) System for Measuring Space Radiation

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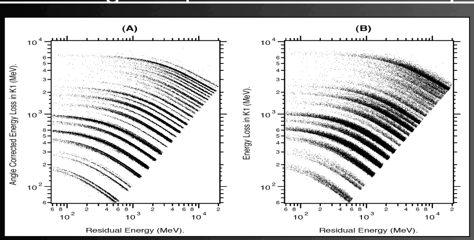
Abstract

Solar Energetic Particles(SEP's) and Cosmic Rays are a hazard to space instruments and astronauts. Measurement of these SEP's requires knowledge of their direction. One method for determining particle trajectory is ADIS. All SEP instruments need to indentify particles that are out-of-geometry. The present ADIS design uses a scintillating plastic to surround the active elements and act as anti-coincidence to determine particles that are out-of-geometry on the instrument. However, the plastic adds significant mass and presents machining difficulties– both drawbacks to a space instrumentation design. Segmented solid-state detectors with rings have been used as an alternative anti-coincidence technique to reduce mass and design complexity. A comparison of the efficiency of an instrument designed with the baseline plastic scintillator anti-coincidence and an instrument designed with silicon ring anti-coincidence is presented.

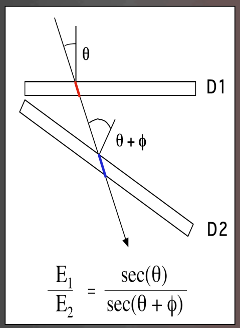
Determining Ion Species with the ADIS System



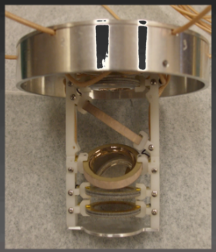
Telescopes of stacked solid-state detectors (SSDs) are the most common method to measure ions in the energy range of 10 -100s MeV/u. In order to have good resolution on the ion composition, the angle of incidence is required. The graph on the right shown above demonstrates the resolution of ion tracks without a correction for the incident angle of the particle. When the angle correction is implemented, the resolution of the track becomes significantly better as shown by the left graph. [1]

How is Ion Resolution Increased with ADIS?

The Angle Detecting Inclined Sensor (ADIS) system uses detectors inclined to the instrument axis to determine the angle of incidence. Consider an ion traversing a solid state detector (D1 right). The signal from that detector depends upon the amount of detector material traversed (red), which increases with the angle of incidence. (Exactly the effect that degrades charge resolution.) If a second detector, inclined to the first is added (D2 right), the particle path length (blue) will vary with the angle of incidence plus the (known) angle of inclination. By inverting the equation, the angle of incidence in a plane can be determined. If a third detector is added below D2, inclined at the same angle to the axis, but rotated 90 degrees about the axis, the angle of incidence (and also the azimuthal angle) can be determined.



$$\frac{E_1}{E_2} = \frac{\sec(\theta)}{\sec(\theta + \phi)}$$



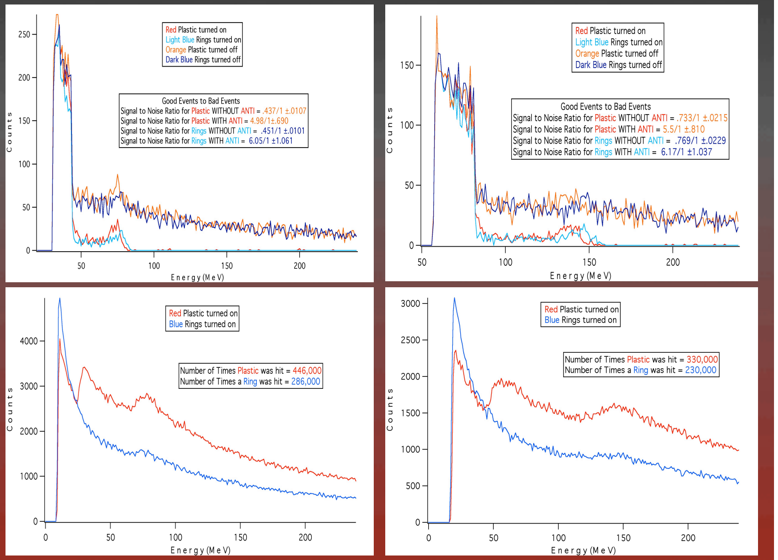
ADIS Design

What are design alternatives for the ADIS system? The ADIS design with the plastic scintillator has proven successful in accelerator testing and will be used on the GOES-R mission, but can be improved upon. The main change is the plastic scintillator anti-coincidence. The weight of an instrument is crucial because it determines the difficultly of sending the instrument into space and the plastic scintillator adds an appreciable amount of mass. The plastic scintillator also triggers the electronics every time an out-of-geometry particle enters the instrument. These triggers send signals to onboard electronics and can saturate the electronic response if too many events are coming in, increasing dead-time, and thus potentially missing in-geometry events.

The photograph on the left shows the plastic scintillator cup that surrounds the SSDs. The cup fits over the mount shown (right). The alternative ADIS design replaces the cup with small active rings that are placed around the active area of the SSDs in the mount.

Testing of the ADIS with Rings Design

Hydrogen *Carbon*



The axes labeled Energy(MeV) is the incident energy of the particle with the instrument**

Results for Using Rings as Anti-coincidence

- The graphs above were generated using a Monte-Carlo program that sends energetic particles into a defined target at random angles of incidence to simulate flux situations of particles in space.
- The top left and right graphs of Hydrogen and Carbon respectively, show histograms for a stopping detector in the ADIS system using both plastic scintillator and ringed detectors. The various plots include signal (20-45 MeV for Hydrogen and 55-80 MeV for Carbon) and noise (50-75 MeV for Hydrogen and 85-160 MeV for Carbon) in the detector.
- Seeing that the ADIS with rings can perform as well as the original design indicates that the full benefits of the ADIS system for ion detection can be achieved with rings, thus reducing the instrument's mass.
- The anti-coincidence graphs, bottom left and right for Hydrogen and Carbon respectively, show how frequently the rings are triggered as opposed to the scintillator. The lower rate keeps the electronics free from being saturated with signals, thus reducing dead-time.
- The ring ADIS is also much easier to construct and mount to avoid machining difficulties that come with the plastic scintillator cup.

Conclusion and Future Work

From simulation testing, the ADIS system with rings has shown to be as statistically comparable to the ADIS system with scintillator. This allows the design to becomes much shorter, less massive and easier to assemble, increasing it's appeal for being accepted on a flight mission.

The next step in development in the ADIS with rings design will be to test particles incident from the side of the instrument. Side testing will be necessary to ensure that the ring anti-coincidence will still determine what particles are out-of-geometry to keep them free from good events.

References

[1] J.J. Connell, C. Lopate, R.B. McKibben, Nucl. Instr. and Meth. 457 (2001) 220.