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Searching for Anisotropy with the HiRes-II Data

D. Ivanov[a], G. B. Thomson[a], and the HiRes Collaboration

(a) Department of Physics and Astronomy, Rutgers University, Piscataway, NJ 08854, USA

Presenter: G. B. Thomson (thomson@physics.rutgers.edu) usa-thomson-G-abs1-he14-poster

The HiRes collaboration has two detectors of ultrahigh energy cosmic rays located atop desert mountains in west-central Utah. The newer of these detectors, called HiRes-II, has been in operation since late 1999, and has a flash ADC data acquisition system. HiRes-II collects events of energies from about $10^{17.5}$ to 10^{20} eV. Typical angular resolutions are 5 degrees in the shower-detector plane and 0.5 degrees perpendicular to the plane. We will present searches for point sources of cosmic rays, and for extended sources. Comparison with previous experiments' results in these two areas will also be presented.

1. Introduction

The High Resolution Fly's Eye Experiment (HiRes) is a fluorescence experiment to study ultrahigh energy cosmic rays. The newer of its two detectors, called HiRes-II, is located atop Camel's Back Ridge in the U.S. Army Dugway Proving Ground in Utah. This detector consists of 42 mirrors and clusters of phototubes that observe the sky from 3 to 31 degrees in elevation angles and almost the whole azimuth. The mirrors collect cosmic ray showers' fluorescence light and focus it on 16x16 arrays of phototubes. Pulse height and timing information is saved for later analysis.

Using this information the geometry of the shower can be determined, the profile of the shower development in the atmosphere can be obtained, and the energy and direction of travel of the cosmic ray measured. Cosmic rays above about $10^{17.5}$ eV can be seen by the HiRes-II detector. The upper limit of event energies is determined by the GZK suppression [1] at about $10^{19.8}$ eV.

In this paper we use the monocular reconstruction of the HiRes-II data set collected from December, 1999, through August, 2004. This data set contains 10,326 events.

2. Resolution

The energy resolution is typically about 18%. The angular resolution is about ± 5 degrees in the direction of the shower-detector plane, and about ± 0.5 degrees in the normal direction.

The elongated shape of events' error ellipses complicates searches for point sources somewhat. But the area of the ellipse, about 10 square degrees, is less than that of an experiment whose uncertainty on the sky is a 2.5 degree radius circle (which gives about 20 square degrees).

Searches for extended structure (more than 5 degrees in size) in the arrival directions of cosmic rays are not impeded by the shape of our events' error ellipses.

3. Isotropic Distributions

Since the HiRes experiment collects data at night when the moon is down, the portion of the sky that is visible in the winter months has higher exposure than the summer sky has. There is a variation in exposure in declination as well as in right ascension. To search for anisotropy one must compare the data with what an isotropic distribution would give, hence we must calculate what an isotropic distribution would be.

We use what we call the “hour angle” method for this [2]. The distribution of events in hour angle and declination is independent of month of the year. This is also true in energy slices. So a simulation of an isotropic distribution can be made using the sidereal time distribution of each night and the distribution of hour angles and declinations. In fact what we do is go through the whole data in a “double do-loop”. For each event’s sidereal time we generate a simulated distribution of events in right ascension and declination using the whole hour angle - declination distribution. The sum of the simulated distributions of events yields a good estimate of what an isotropic sky would look like in the exact conditions of our experiment.

4. The Presentation

In the talk we will present information on the “hour angle” method, the distribution of events on the sky using error ellipses, and also using the centers of events binned in right ascension and declination. Sky maps of events with different energies will also be shown.

We will show distributions where we have summed over circles of various sizes to search for larger scale structure. Again, sky maps with energy cuts will be shown.

A classic method of searching for anisotropy uses an analysis of harmonics. We will present Raleigh vector information, and its energy dependence.

5. Acknowledgements

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