

THE HIGH RESOLUTION FLY'S EYE (HiRes):
PARAMETERS AND MOTIVATION

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Abstract

Columbia University, the University of Illinois Urbana Champaign, and the University of Utah are building a new detector called the High Resolution Fly's Eye detector (HiRes) which detects the presence of extensive air showers (EAS) in the atmosphere and measures the longitudinal development of these showers.

This paper discusses the physics objectives of HiRes.

Introduction

The results of the present Fly's Eye experiment indicate that there is interesting structure in the cosmic ray energy spectrum above 10 EeV^1 and the possibility of point sources that produce cosmic rays above 1 EeV^2 . We also demonstrated that the Fly's Eye detector can be used to measure the chemical composition of the primary cosmic rays³ and the proton air cross section⁴ above the center of mass energy of 30 TeV . In order to study these topics in a definitive way, we must:

1. Increase the data rate above 10 EeV by at least an, order of magnitude to $>200 \text{ events/year}$. ,

2. Improve the detector's ability to measure the longitudinal shower development. We characterize this ability by the detector's ability to locate shower maximum. HiRes is designed to have a shower max resolution $<30 \text{ g cm}^{-2}$ (rms).
3. Improve the angular resolution and acceptance in the EeV region to increase sensitivity to point sources.

The HiRes Detector

These goals can be simultaneously achieved by the construction of three identical detectors with improved angular resolution. These detectors will be placed on the vertices of an equilateral triangle. The parameters of the HiRes detector are as follows

Number of stations	3
Distance between stations	14 km
Mirrors(2M diameter)/station	54
Phototube angular aperture	$1^\circ \times 1^\circ$
Angular coverage/station	240° azimuthal 3° - 57° elevation

Monte Carlo studies indicate that the above detector would have an aperture of $5 \times 10^9 \text{ m}^2 \text{sr}$ above 10 EeV, an energy resolution of 10 – 20%, and shower max identification uncertainty of less than 30 g cm^{-2} . This aperture would increase as a function of energy and saturate above 100 EeV. Figure 1 shows the calculated aperture as a function of cosmic ray energy.

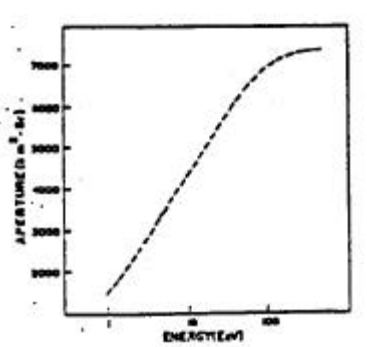


Figure 1.
HiRes Aperture for Showers with
 $X_{\text{max}} < 30 \text{ g cm}^{-2}$

Physics Objectives

The HiRes detector is designed to study the nature and sources of high energy cosmic rays, which is the central issue in ultra-high energy cosmic ray physics. HiRes is also optimized to measure some of the important properties of hadron interactions.

To illustrate the relationship between the quantities observable by HiRes and the nature and sources of high energy cosmic rays, we classified the sources according to their distance from the earth.

1. 10 kpc. These may be compact sources, like Cygnus X-3, in the Galactic disk. At EeV energies and above, cosmic rays should be poorly confined in the galactic magnetic field, so anisotropy would be expected. Above 10 EeV, heavy nuclei would be confined, and light nuclei should arrive from directions near the galactic plane.
2. 50 kpc. This is of the size of our Galaxy. Jokipii and Morfill⁵ have shown that cosmic rays above 10 EeV can be produced by the large scale termination shock wave of a (hypothetical) galactic wind. Calculations show that cosmic rays accelerated by this process would have the proper energy spectrum and would exhibit a cutoff in the energy spectrum above 10 EeV. This production mechanism favors heavy nuclei with small anisotropy.
3. < 100 Mpc. Active galactic nuclei, AGN⁶, (in particular radio lobes of AGN's) may be sources of > 100 EeV cosmic sources. Although the primary energies of cosmic rays at the point of production may be larger than 100 EeV, interaction between these cosmic rays with photons would ultimately shape the energy spectrum. In particular, if these particles are photonic, then photo-meson production through collision with microwave photons would drain energy from cosmic rays near 100 EeV and create the so called Greisen-Zatsepin-Kuz'min cut-off. High energy gamma rays would be the decay product of these reactions. The possible existence of stronger magnetic fields in the nearby Virgo super cluster would trap 100 EeV or greater cosmic rays and result in an increased flux of high energy gamma rays. These gamma rays would have energies > 50 EeV. Depending on their trajectories in the Earth's magnetic field, they exhibit unique longitudinal shower profiles. HiRes will be the only detector capable of detecting and identifying these gamma rays, should they exist.
4. > 100 Mpc. Interactions with microwave and radio photons would cause cosmic rays from extremely distant sources to be proton-dominated regardless of the source composition. These distant sources might include AGN's and cosmological sources such as cosmic strings.⁷ Because of the distant nature of these sources, the cosmic rays arriving from them must be isotropic and exhibit the Greisen-Zatsepin-Kuz'min cutoff. High energy gamma rays emanating from these reactions would also interact with the microwave and radio photons and be severely attenuated.⁸

In summary, by extending the measurement of the energy spectrum, anisotropy, and chemical composition above 100 EeV, and by searching for neutrinos and high energy gamma rays, we will be able to distinguish between the primary models of cosmic ray acceleration.

We are also interested in the hadronic interaction information that the high energy cosmic rays are capable of providing. We list the following:

1. Investigations carried out by Gaisser et al.⁹ indicate that the longitudinal shower shape is related to the cosmic ray composition and is sensitive to different hadronic interaction models. Detailed comparison between simulation profiles and Fly's Eye data will be presented at this Conference.¹⁰
2. We will be measuring the p-air inelastic cross section to greater precision over a center-of-mass energy region between 30 TeV and 200 TeV.
3. We will be able to search for unusual shower shape events, events whose showers started early in the atmosphere (i.e. strongly interacting particles) or deep in the atmosphere (i.e. weakly interacting and long-lived particles).

With stereo detectors, we will be able to separate bright but slowly moving light generating objects from traveling with the speed of light.

Acknowledgement

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Reference:

1. P. V. Sokolsky et al., OG 6.1.6., these proceedings.
2. G. L. Cassiday et al., Phys. Rev. Lett. 21,2329 (1989).
3. G. L. Cassiday et al., Ap. J. 356, 669 (1990).
4. R. M. Baltursaitis et al., Phys. Rev. Lett. 52, 1380 (1984).
5. J. R. Jokipii and G. Morfill, Ap. J. 312, 170 (1987).
6. P. L. Bierman and P. A. Strittmatter, Ap. J. 322,, 643 (1987).
7. J. P. Ostriker, C. Thompson, and E. Witten, Phys Lett. B180, 231 (1986).
C. T. Hill, D. N. Schram-, and P. T. Walker, Phys. Rev. 1007 (1987).
8. F. Halzen et al., Phys. Rev. D4 ,342,(1990).
9. T. K. Gaisser et al., Proc. 21st ICRC, 8, 55 (1990).
10. P. V. Sokolsky et al., OG 6.3, these proceedings.

