The High Resolution Fly's Eye (HiRes) Project

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ABSTRACT

The High Resolution Fly's Eye (HiRes) project is half-way through its construction phase. W discuss the motivation for this project, the detector design, and current status. Preliminary results fro several years of data taking using the HiRes prototype detector have shown no significant problems wit the technical design. Data from the HiRes I and HiRes II prototypes are presented and discussed.

1. Introduction

Results from the Fly's Eye detector experiment (F.E. I and F.E. II) indicate that there is a spectr break in the cosmic ray spectrum followed by a flattening near 3 EeV. There is also evidence that th cosmic ray composition is changing from predominantly heavy to predominantly light in this energ region. Near 60 EeV, the spectrum shape is consistent with the expected Greisen-Zatsepin-Kuzmi cut-off but there is one outstanding event at 320 EeV that complicates the simple cut-off interpretatio Recently another event near 200 EeV has been reported by the AGASA ground array experiment[1,2,3,4

Given these results it was clear to us that we needed to build a detector with ten times greate sensitivity than the old Fly's Eye to explore the > 10 EeV region of the spectrum. At the same tim we felt that it was important to observe all data in stereo and improve the shower maximum (X_{max} resolution from the 45 gm/cm^2 achievable with the old Fly's Eye to between 20 and 30 gm/cm^2. Thi would make the detector resolution comparable to the expected natural fluctuations of pure Fe and proto cosmic ray nuclei. It would also let us measure the detector energy and X_{max} resolution by comparin two independent measurements - a technique whose power was demonstrated in the previous work.

2. The High Resolution Fly's Eye Detector

The Stage I High Resolution Fly's Eye Detector (HiRes) incorporates these goals. It was approve as a construction project in 1994 and will be completed in the summer of 1999. It consists of two site Five Mile Hill (the original F.E. I site) and a new site located on Camel's Back mountain. The tw sites are separated by 12.5 km. The HiRes detector gets its increased aperture and improved resolutio by decreasing the photoube aperture from 5 degrees by 5 degrees (the tube aperture of the Fly's Ey detector) to one degree by one degree, and by increasing the effective mirror diameter from 1.5 to 2.0m Because of the resultant increased signal to noise, showers at 20 km to 30 km impact parameter distanc can be clearly detected. The improved sampling along the track and full stereo coverage allows even shor tracks to be well reconstructed.

Each mirror is composed of four spherical glass segments, forming a single spherical mirror (see Fig 1). The phototube cluster consists of 256 close packed 40mm hexagonal phototubes manufactured b Phillips. The tubes are held in a cluster box which provides the high voltages and routes out the tub signals. The front of the cluster box consists of a piece of UV filter glass which cuts out light belo 300 and above 420 nm. At Camelsback, 42 mirrors are distributed in two rings, covering all azimutha angles and elevation angles from 3 to 33 degrees. The 22 Five Mile Hill site mirrors are distributed i

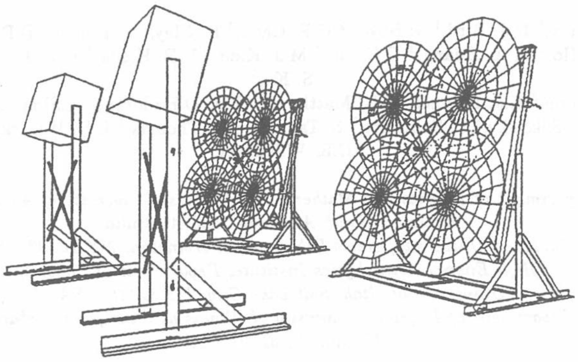

Figure 1: Mirror and cluster arrangement.

one ring, covering all azimuthal angles and elevation angles from 3 to 18 degrees. The mirrors and tub are housed in steel buildings with garage doors. The buildings come in two sizes, corresponding to tl two rings of mirrors. Each building contains two mirrors and the associated electronics.

The electronics consists of an FADC system which digitizes the signals coming from the individu phototubes in 100 ns samples as well as digitizing the sums of the vertical and horizontal columns tubes. The sum signals are used for trigger purposes. Once a minimal trigger condition is met, a high level trigger algorithm decides on an area of tubes around the triggered tubes for which informatic should be saved. Digitization of the signal pulse allows us to measure the width as well as the area of tl pulses and to sample the sky noise fluctuations both before and after the signal arrives.

The HiRes trigger aperture at 100 EeV is 13,000 $km^2 str$. The aperture after reconstruction cu which insure that the X_{max} resolution is better than 30 gm/cm^2 ranges from 4700 $km^2 str$ at 10 EeV t 10,000 $km^2 str$ at 100 EeV. The mean X_{max} resolution is $20 gm/cm^2$ and the statistical energy resolutic is ten percent. With this aperture we expect to detect about 500 events a year above 10 EeV and if w exptrapolate the current fluxes, about 5 events per year above 100 EeV. This last number is obvious very uncertain, however.

3. The High Resolution Prototype Detector.

Although the HiRes design is a straitforward extrapolation of the old Fly's Eye detector, we felt tha building and operating a prototype detector would be useful. The prototype detector would allow us t gain experience with the much larger number of phototubes, new mirrors, and new building design. W also wanted to try to do some physics with this prototype. We decided to aim the 14 prototype mirrors a Five Mile Hill over the CASA/MIA detectors[5] and do coincident measurements of lower energy (.1 EeV showers. Fluorescence photons, surface electron density and muon density is measured simultaneousl for showers that trigger both detectors. Such an intercalibration of different techniques has never bee done before.

An additional 4 mirror HiRes II prototype was also built at Camelsback. These mirrors point i the general direction of CASA/MIA, so that they have an overlapping field of view with the Five Mil Hill (HiRes I) prototype. The HiRes I and HiRes II prototype, operating together, give us a chance t understand stereo reconstruction of events as well as testing our knowledge of the atmospheric propagatio of light over long distances. A number of devices, including steerable YAG lasers and vertical Xeno flashers have been installed in the field of view of these detectors to help us understand resolution an atmospheric attenuation.

Both prototypes use an earlier version of HiRes electronics. This sytem integrates the tube signal

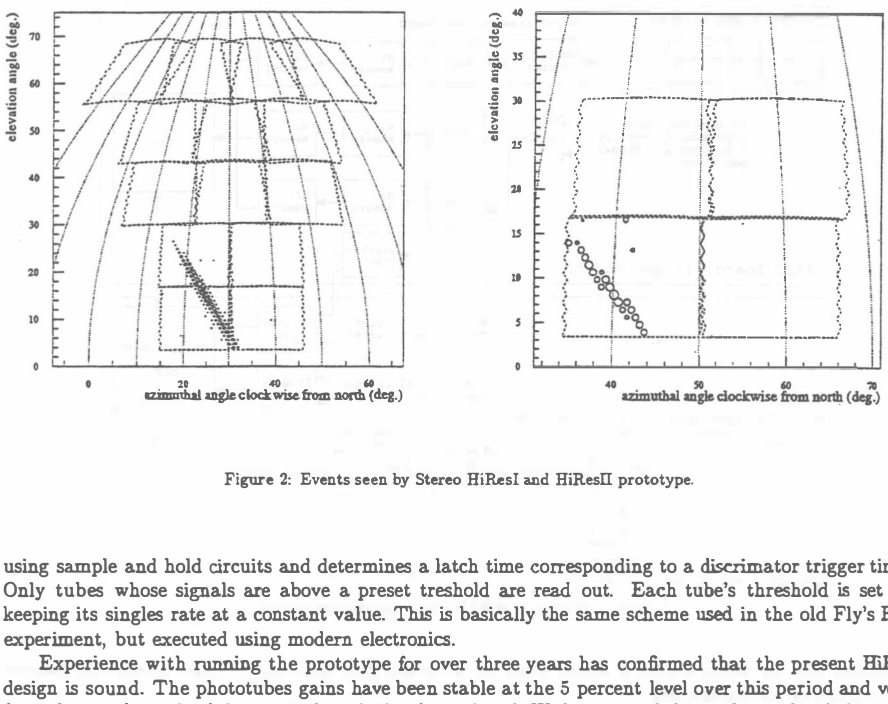

Figure 2: Events seen by Stereo HiResI and HiResII prototype.

using sample and hold circuits and determines a latch time corresponding to a discrimator trigger time. Only tubes whose signals are above a preset treshold are read out. Each tube's threshold is set by keeping its singles rate at a constant value. This is basically the same scheme used in the old Fly's Eye experiment, but executed using modern electronics.

Experience with running the prototype for over three years has confirmed that the present HiRes design is sound. The phototubes gains have been stable at the 5 percent level over this period and very few tubes or channels of electronics have had to be replaced. We have tested the mechanical and electrical elements of the design over several winters and summers with no significant problems.

Fig.2 shows a cosmic ray event seen by both HiRes I and HiRes II prototypes. This is typical of what a full HiRes track will look like - it is contained in two rings of one eye and is seen as a track in the lowest horizontal ring of the other eye. The trigger rate and precision of reconstruction of these events is again as expected. The very limited stereo aperture of this prototype precludes us from doing any significant physics with this data, however.

It is also clear from the prototype data that the increased sampling allows us a much more accurate reconstruction of the shower profile than has been heretofore possible.

4. Present Status and Future Plans.

Construction of buildings and installation of mirrors and power is essentially complete at Camel's Back. All 42 mirrors are in place and all 21 buildings have power and are operational. This summer, seven new buildings were constructed at Five Mile Hill. Together with the eight existing HiRes prototype buildings, these structures will house the 22 mirrors for this site. Fourteen new ring I mirrors have been installed in these seven houses. When the Hires I prototype running is complete later this year, the prototype clusters will be moved to their new locations to complete the 22 mirror ring.

In the remaining two and a half years, we will be installing phototube clusters and electronics. All tubes sent to us by Phillips are extensively tested at Utah. A laser scan of the photocathode establishes the individual tube sensitivity in amps/watt as a function of position on the tube face. The effective tube area as well as the gain characteristics are thus determined. Once pmt's are tested, they are assembled

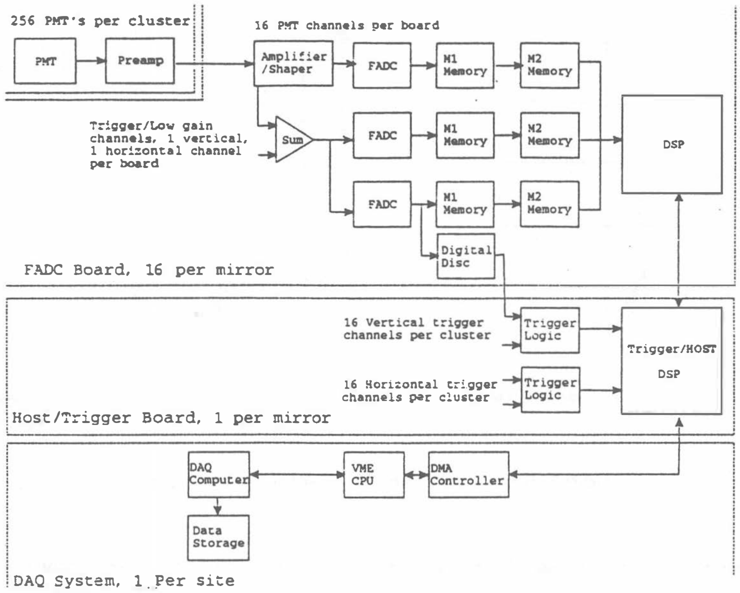

Figure 3: Schematic of FADC data acquisition system.

in clusters and the whole cluster is tested again for noise and gain uniformity. Clusters are then shipped out to Dugway for installation.

The FADC (whose block diagram is shown in Fig. 3) electronics has been undergoing extensive tests over the last year. A separate mirror whose tubes are read out by the FADC system and which looks in the same direction as one of the mirrors in the HiRes I prototype is used to compare stability, uniformity, linearity, noise suppression and trigger efficiency between the FADC and S/H systems. FADC hardware has been ordered and mass production of electronics will begin early in 1997.

As tube clusters and electronics modules are installed and debugged, data taking can commence. The detector is completely modular and we intend to begin limited data taking for the highest energy events sometime in 1997.

5. Bibliography

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