

OBSERVATION OF REAL AND SIMULATED SHOWERS USING THE
FIRST TWO HIGH RESOLUTION FLY'S EYE (HIRES) MIRRORS

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Abstract

Two prototype mirror units of HiRes have been operated at the Fly's Eye 1 site. Tracks from cosmic ray air showers have been observed by these mirror units. Also, pulsed laser beams have been produced from a known position and aimed in a known direction. The detected scattered light from the beams has been compared in geometry, timing, and amplitude with what is expected. There is reasonable agreement between the expected and the observed results, supporting the expectation that HiRes can achieve greatly improved resolution and sensitivity relative to Fly's Eye.

Introduction The prototype mirror units are aimed at a zenith angle of 53 degrees and view adjacent regions above Fly's Eye 2. Each mirror unit consists of a 4 segment 2 meter diameter mirror with a 16 x 16 array of hexagonal-faced photomultipliers in the focal plane. The angular aperture of each photomultiplier tube (PMT) is 1.01° between parallel sides of the hexagon, compared with 5.3° for the hexagonal light reflectors of the present Fly's Eyes.

Preliminary Results and Discussion The 2 mirror units have been used to observe air showers and pulsed laser beams. The purpose of this work has been to test the design of the system rather than to take calibrated data. For example, in this preliminary phase the surveying of mirrors has only been done to $1/2^\circ$ accuracy. However, the results can be used to check the approximate consistency of the observations with expectation.

We have observed well-defined tracks from air showers in the prototype system. As expected, most of the tracks are of short duration. A relatively long (8 is) track is shown in figures and 2. In Figure 1, the pattern of 256 PMT's in the image plane of the mirror is displayed by array of dots representing the center of each PMT face. (The pattern is oriented so that it matches the pattern that would be seen in viewing the sky. This pattern is inverted in the actual cluster of PMT'S.) The small squares represent triggering PMT'S which were identified as part of the track by the preliminary pattern recognition program. The small -f- signs represent tubes which triggered but were rejected as noise because of their position and/or timing. The figure

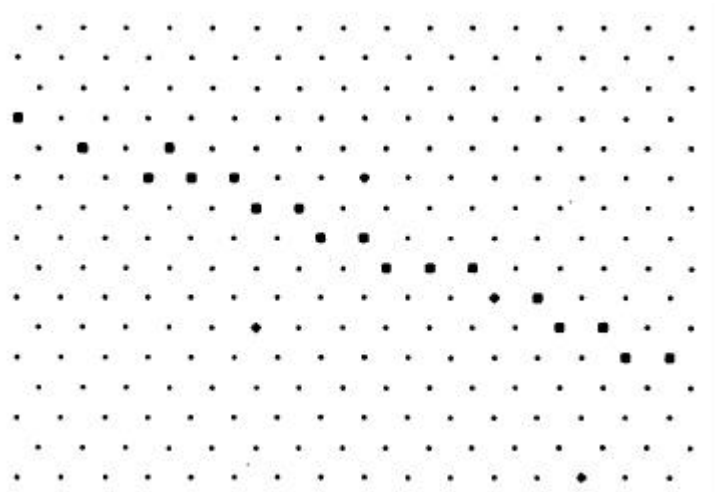


Figure 1 An air shower seen by a HiRes prototype mirror unit.
The tube positions in the image plane of the mirror are indicated by dots and the tubes which were triggered by an air shower are indicated by small squares.

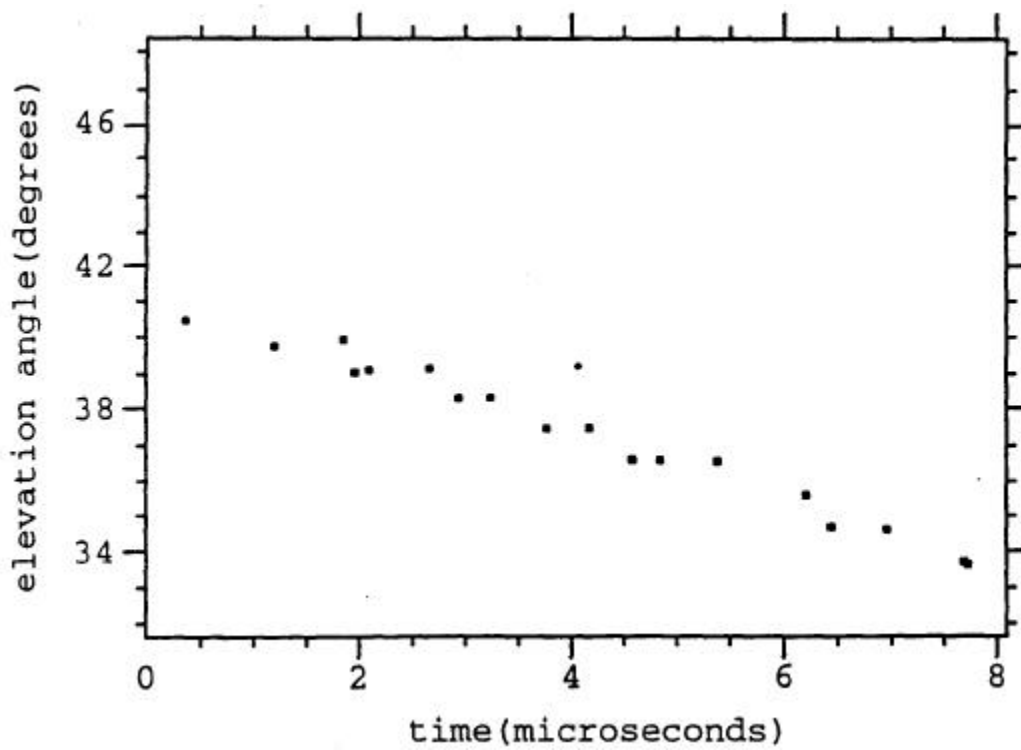


Figure 2 The elevation angles of the triggering tubes are plotted versus the triggering times for the shower shown in Figure 1.
Noise tubes are indicated by a small + symbols.

demonstrates that a well-defined shower image can be produced using an angular resolution of 1° . Figure 2 shows the relative time at which the tubes triggered as a function of the angle above the horizontal. Again, a well-defined pattern is observed.

As a way of comparing the geometry, timing, and pulse integrals of the HiRes prototype with expectation, a series of nitrogen laser shots (170 nJ, 337 nm) were done from a known location 7.6 km away. The directions and times of these pulses were recorded, as well as the relative pulse amplitudes. The laser beams were detected by HiRes at distances from 2.5 to 11.7 km by means of the light that was scattered from the beam. Figures 3 and 4 show the results from a laser shot which passed relatively close to Fly's Eye 1 and the HiRes prototype. In this case the beam was observed by HiRes at distances ranging from 2.5 to 2.6 km. The PMT's accepted as part of the signal but with pulse integrals corresponding to less than 400 photoelectrons are represented by x's in these plots. The PMT's with larger amplitudes are mostly confined to within $1/2^\circ$ of the beam. This suggests that a form of amplitude weighting should be used in the track-fitting process, as is done with the Fly's Eyes.

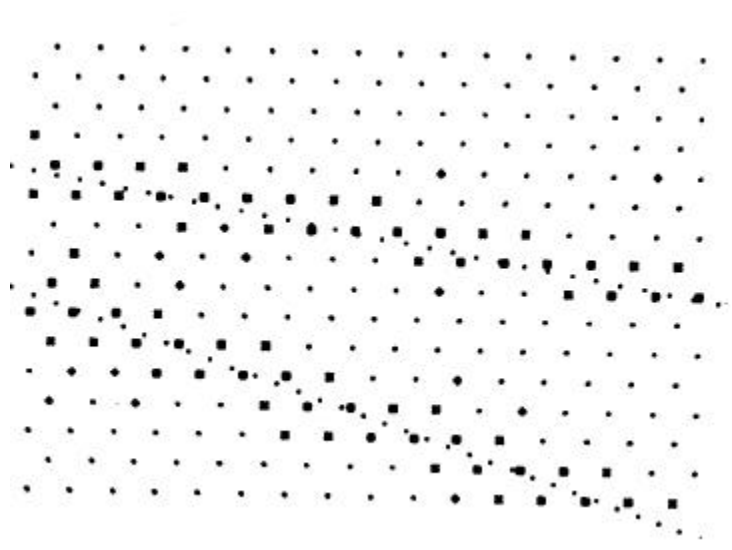


Figure 3 The tracks of a single laser shot seen in two HiRes prototype mirrors are superimposed. (The slope is different in the two mirrors because they observe the flash from different azimuthal angles. The PMT's with less than 400 photoelectrons are plotted by crosses. A dotted line represents the expected trajectory.

Figure 4 shows that the agreement between the expected and the measured times is better for PMT's with higher amplitudes. For the higher amplitude PMT's the r.m.s. deviations of the times from the expected curve is 68 ns. The lower amplitude PMT's tended to have triggered late, presumably due to time-slewage effects for low amplitude pulses. Some systematic deviations of the points from the expected curve are visible in Figure 4. There is some shifting of the data at the boundary between the mirrors which occurs at $t = 2.1$ ms in this plot. The correlation of the effect with the mirror boundaries suggests that the problem may be due to aberration effects or mirror misalignment. Because the HiRes mirrors have much more accurate shape than the Fly's-Eye mirrors it is expected that it will be possible to simulate aberration effects in detail and to correct for them.

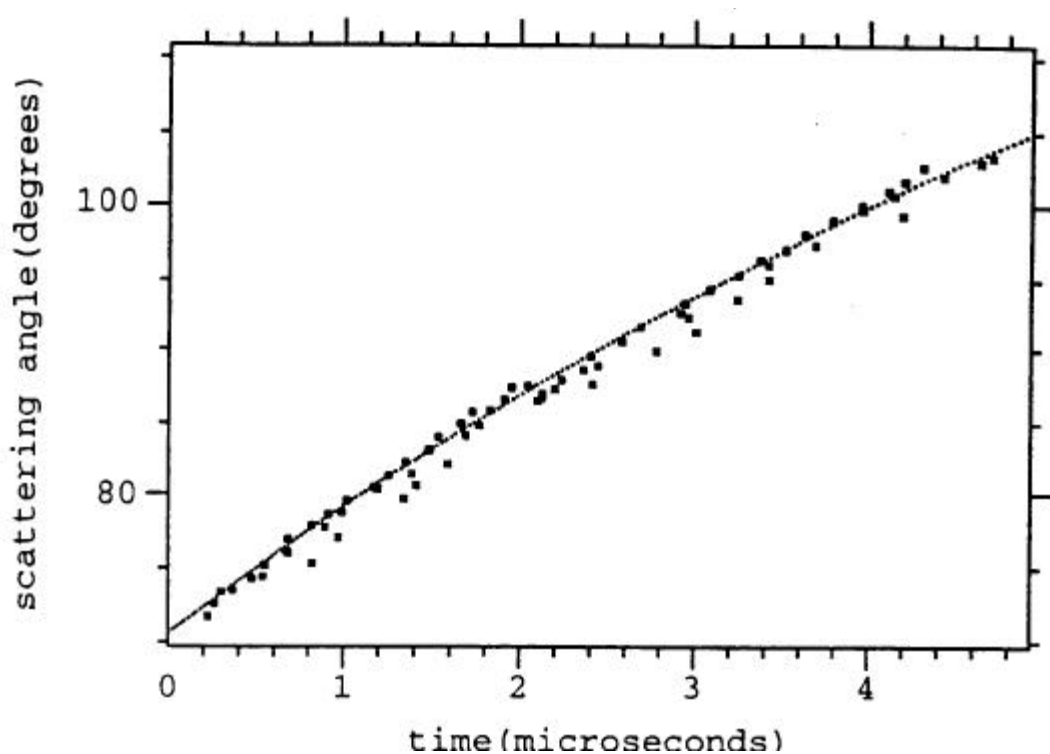


Figure 4 The scattering angle of the laser light is compared with the triggering times of the PMT's in the laser shot shown in Fig. 3. The symbols have the same meaning as those in Fig. 3.

For the laser track shown in Figures 3 and 4, the amplitude of the signal measured by HiRes was compared with that obtained by Fly's Eye 1 in 6° intervals centered on 87° and 93° . In both cases HiRes measures about 3 times as much light as Fly's Eye 1. This is consistent with what is expected due to the larger mirror area of the HiRes prototypes and their greater optical collection efficiency.

Conclusions The initial HiRes prototype tests have been successful. Data on laser flash geometry and PMT pulse amplitudes are consistent with the accuracy of the current calibration. More precise tests will be made after the mirror alignments and PMT gains have been more accurately determined. Some systematic effects are evident in the timing data which can be expected to be understood by combining tests with simulations. The high quality of the HiRes mirrors should allow optical detailed optical simulations to be combined with electronics simulations to give a more complete understanding of the response of HiRes to light from air showers.

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