"Shoot The Shower": Probing Atmospheric Clarity of the Shower/Detector Plane at HiRes

John Boyer, [1] Eric Mannel, [1] Lawrence Wiencke, [2]
for the HiRes Collaboration
(1) Columbia University, Nevis Labs, Irvington NY, USA (2) University of Utah, Salt Lake City, Utah, USA

A real-time system of a remotely controlled laser and pattern recognition is deployed at HiRes to probe the atmosphere between the observatory and high energy air showers shortly after their detection. Shower candidates are identified in real-time by a pattern recognition and pseudo distance algorithm deployed on the digital signal processors of the HiRes-2 DAQ system. Event parameters are then passed from the fluorescence detector to the local steerable laser. These requests interrupt the hourly full sky laser sweep and generate a sequence of shots along the shower plane. The detector at HiRes1 records the profiles of these laser shots that can be examined for the presence of clouds and other aerosols.

1. Introduction

Laser beams are used to probe the aperture of the HiRes observatory. Light scattered out of these beams is recorded by the same detectors that record light from air showers. Until recently the pattern of shot directions and energies was driven by a static list of geometries and energies selected because they sweep out much of the detector aperture and are useful for measuring aerosol parameters.

We have recently enhanced the technique so that real-time identification of air shower candidates can trigger sequences of laser shots. The idea is to probe the detector shower plane within a few minutes of shower detection. The technique tests the atmosphere in the region of the shower, and the detector hardware that recorded the shower. Figure 1 illustrates the arrangement. At present we are using the laser at the HiRes2 site to shoot showers identified by the HiRes2 detector. The laser shots are recorded by the HiRes1 detector. Implementation of the symmetric arrangement that will shoot showers from HiRes1 is in progress.

2. Selection of Candidates to Shoot

Candidates are selected on a mirror based algorithm implemented in the digital signal processing (DSP) hardware of the flash ADC system of the HiRes2 detector[1]. The selection is made as follows:

1: Identify a cluster of hits. The nearest neighbor separation between the centers of hit pixels in a cluster must be less than 1.8 degrees. Subsequent cuts

pp. 481–484

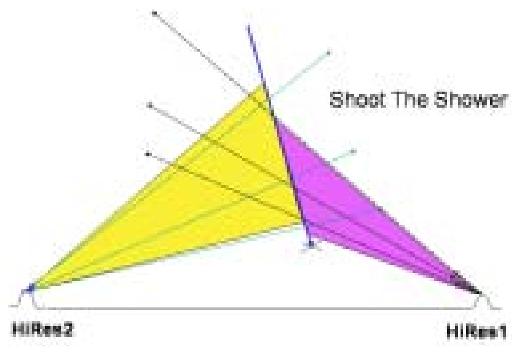

Fig. 1. Conceptual arrangement of Shoot the Shower.

are based on the biggest such cluster found.

2: Require more than 5 hits, where a hit is counted if a pulse is found in a scan of the FADC time bins in a pixel. This scan uses a threshold approximately 50% higher than the normal readout threshold.

3: Eliminate equal time events by requiring $\sigma_t > 200$ nsec.

4: Require the cluster have an elongated shape. A shape parameter, defined as $(L-S)^2/(L+S)^2$ where L and S are the long and short axes of the ellipse, must be greater than 0.8 It is calculated as $[(\sigma_{y^2} - \sigma_{x^2})^2 + 4\sigma_{xy^2}]/[\sigma_{x^2} + \sigma_{y^2}]^2$ where x and y are approximated by the pixel column number and row number.

5: Require a goodness of fit in pixel position vs time. A straight line fit of position vs time along the long axis of the ellipse is performed. The average deviation of actual position vs expected position is required to be less than one pixel (1 degree).

6: Require the net angular velocity be downward going and relatively slow. The straight line fit computes the vertical(b) and horizontal(a) components of the angular velocity in 1 degree pixels per 100 nSecs. We require $b > 0$ (downward) and both $|a|$ and $|b| < 0.125$.

7: Require the pseudo-distance to be greater than 10km. The pseudo-distance is defined as $1.72/(a*a+b*b)^{1/2}$.

3. Shooting the Laser at Showers

The requests are then passed to the PC that controls the laser system [2] located at the HiRes2 site. The parameters passed include the trigger time, pseudo distance, mirror ID and ID of the two pixels closest to the point the time vs position fit (an approximation of the shower detector plane) enters and leaves the mirror. The first laser shots are fired about 1-3 minutes after the shower trigger time. An additional 2-4 minutes are required to fire the shots along the shower detector plane. These times are limited by the speed of the steering mechanism.

The laser system has time to "shoot" about 4 requests per hour and still complete it's regular hourly sweep pattern. The detection rate of reconstructible showers that are further away than 10km is much less than one per hour. However, occasionally noise sources raise the request rate above 3 per hour. To avoid swamping the laser system we impose additional requirements:

- A request must be isolated in time by at least 5 seconds. Requests arriving at the same time, for example showers that span mirror boundaries, are allowed provided they include no more than 5 mirrors.
- Pseudo-distance is less than 100 km.
- No more than 3 requests serviced per hour with no more than 2 of these requests in the same mirror.

The number of shots fired at a shower depends on how well the request would favor stereo reconstruction. For showers falling from 45 to 135 degrees from the line between the two sites, 16 sets of 8 shots are fired at two energy settings and eight directions along the detector shower plane in roughly two degree steps, for a total of 128 shots. Roughly half that number are fired for requests between 10-45 and 135-170 degrees. Vertical shots are fired for request that fall in the opposite direction of the HiRes2 detector. Figure 1 shows an example of an air shower recorded in stereo and some of the laser shots that were fired at it.

Between January 27^{th} 2003 and May 3^{rd} 2003 the system fired at 244 shower requests. Of these requests roughly 20% were air showers seen in stereo. Most of these showers appear to be in regions that were free of obvious clouds and aerosol boundaries.

4. Acknowledgments

This work is supported by US NSF grants PHY 9322298, PHY 9974537, PHY-0098826, PHY 0071069, DOE grant FG03-92ER40732, and the Australian Research Council. The cooperation of Colonel Fisher, US Army and Dugway Proving Ground staff is appreciated.

5. References

1. Boyer J, et al. 2002, NIM A 372,457
2. Wiencke L, et al. 2001, Proc. of 27th ICRC HE140

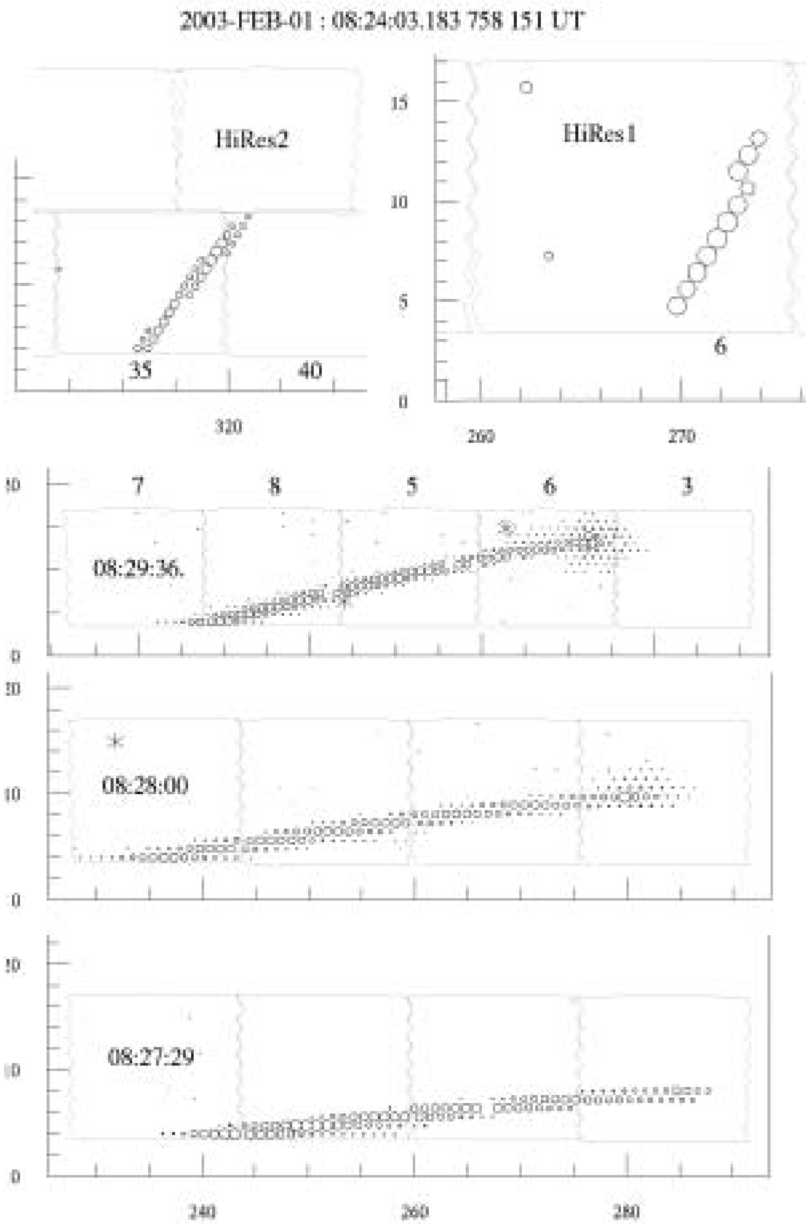

Fig. 2. Example of a air shower recorded in stereo (top two panels) and some of the laser tracks that were fired at it (lower three panels). In this example the laser has located a cloud layer that appears in the same HiRes1 mirror 6 in which the shower was observeda few minutes earlier.