Probing the HiRes Aperture near 10^{20} eV with a Distant Laser

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Abstract

We have installed a vertical laser to test the reaches of the HiRes aperture where super GZK events are most likely to occur. This laser is located 34 km from the HiRes2 detector. It has been in operation since Nov 2002. 400 shots per hour are fired over 5 energy settings that range from below to well above detector threshold. The scattered light is observed by both detectors. We will report on the observations of these laser tracks and their relevance to the measurement of events near 10^{20} eV.

1. Introduction

At HiRes the distance to reconstructible showers increases with energy from approximately 10km at $10^{18.5}$eV, to 25 km at 10^{20}eV. Figure 1 shows the distance from the HiRes2 detector to reconstructed showers with energies above 10^{19}eV. The combination of atmospheric attenuation and shrinking angular size with shower distance limit the range of the HiRes stereo aperture for reconstructible showers extends to roughly 40 km. This outer range is important because it includes a significant fraction of the aperture for reconstructing events above the predicted GZK [1,2] cutoff near 6×10^{19} eV.

2. The Vertical Laser System at Terra Utah

To probe the reach of the HiRes aperture, we have installed an autonomous laser system that fires a vertical beam at regular intervals while the HiRes observatory is recording night sky data. The same detector hardware that records tracks from air showers also records tracks from this laser (figure 2). But unlike "super GZK" air showers, this laser can be fired and calibrated as often as desired.

The laser, located 21 km from the HiRes1 site and 34 km from the HiRes2 site, is on private ranch property in Terra Utah. This happens to be one of the few places in the HiRes field of view with grid power, a telephone line, and convenient access (figure 3). The system runs automatically during moonless periods of at least three hours. The time and relative energy of each pulse is recorded for off-

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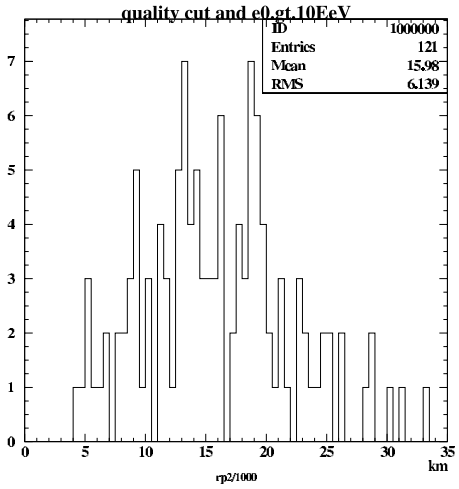

Fig. 1. Distance from the HiRes2 detector to showers above 10^{19} eV

line matching with the HiRes detector data. The absolute energy, polarization, and beam direction are calibrated each month. Table 1 lists a subset of the system parameters.

The maximum energy of the laser is about 6 mJ per pulse. It's 355nm wavelength falls in the middle of the UV light spectrum of air showers. As the pulse travels vertically, light is scattered out by the atmosphere. Under aerosol free conditions, the flux of light emitted at 90 degrees to the laser pulse direction (the viewing angle of the HiRes detectors) is roughly equivalent to the flux of light emitted at Xmax by a shower of $5x10^{19}$eV. Even under the haziest acceptable viewing conditions the equivalent shower energy of the laser changes by less than 25% due to aerosol scattering. After leaving the beam the amount of light that reaches the HiRes detectors can change by a much larger fraction. From this perspective, the laser provides a relatively stable reference marker to study how well the HiRes detector can see the further reaches of it's aperture. Moreover, both the laser and a high energy shower tend to generate a longitudinal profile with similar features. Xmax for reconstructible showers above $5x10^{19}$ eV usually falls in the lower elevation angles of the HiRes field of view because these showers develop deeper in the atmosphere. The atmosphere scatters the most light from the laser pulse near the ground where the pulse size and air density are largest.

3. Viewing distant laser tracks with the HiRes Detectors

Even under viewing conditions that are relatively hazy, both HiRes detectors record tracks from this system without difficulty. Figure 2 shows one of these

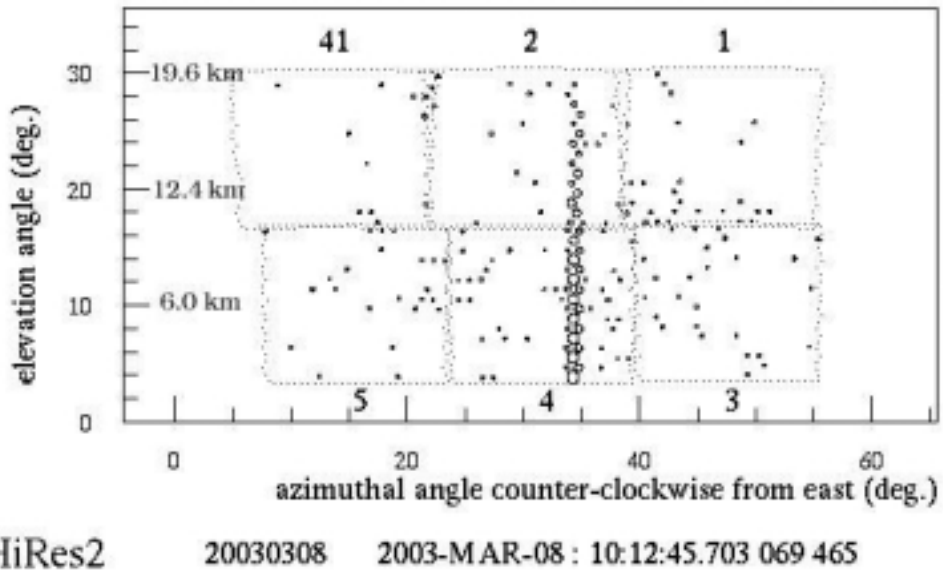

Fig. 2. A vertical track from a 4mJ pulse generated by the Terra laser as recorded by the HiRes2 detector 34 km distant. The amount of light scattered perpendicular to the beam is roughly equivalent to the scintillation light produced at Xmax by a $5x10^{19}$ eV air shower. This track was recorded under fairly hazy viewing conditions. (see text)

tracks recorded by HiRes2[3]. At the time this track was recorded the measured vertical aerosol optical depth was 0.1 which is about twice the average value.

The system has been in operation for 5 months. We are using this laser to test the reach of the HiRes aperture, to test energy resolution, and to measure aerosol optical depth over a long baseline. Results from a systematic analysis of this data will be reported.

4. Acknowledgments

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5. References

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3. Boyer J, et al. 2002, NIM A 372,457

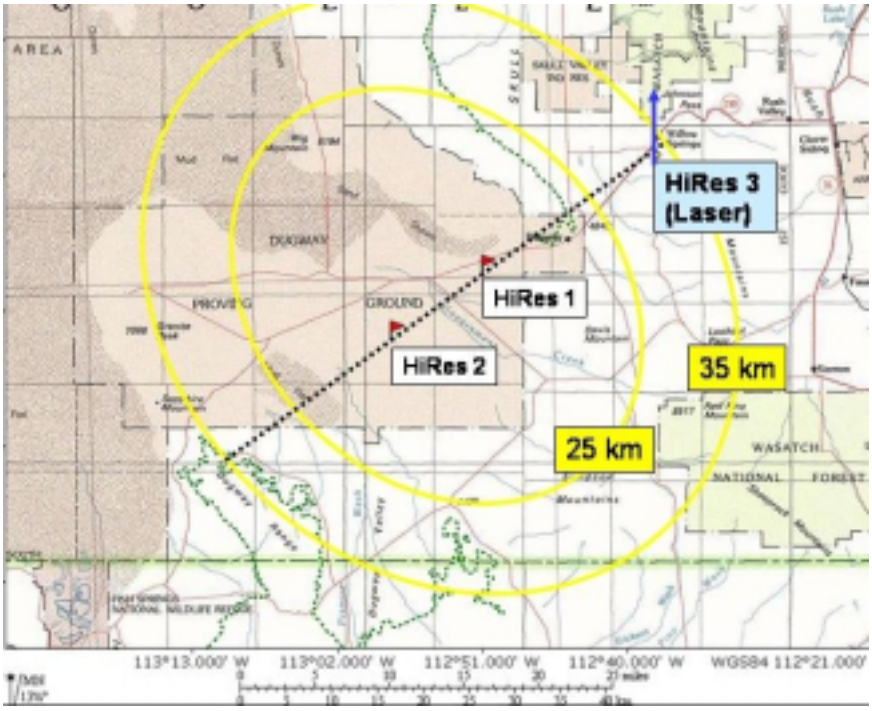

Fig. 3. This map shows the location of the vertical laser relative to the two HiRes detector sites. The two light colored ovals superimposed on the map are 25km and 35km from the most distant HiRes detector. The area between the ovals represents a likely region in the HiRes aperture for measuring reconstructible showers with$E{>}10^{20}eV$. The laser site is near the outer edge of this region.

Table 1. Properties of the Vertical Laser System.

Model(Type)	Big Sky Laser Ultra CFR (Frequency Tripled Nd:YAG)
Wavelength,Pulse Length	355 nm, 7 ns
Polarization	$< 5\%$ deviation from random
Direction	< 0.1 degrees from vertical
Energy/Pulse	2-6 milliJoules ($1.8x10^{15} photons/mJ$)
Shots/Hr	400 (20 shots x 5 energies x 4 sets/hour)
Distance to hr1/hr2	21.6/33.9 km