TRIGGER SENSITIVITY OF THE FADC .INSTRUMENTED HIRES FLY'S EYE

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ABSTRACT

A flash analog-to-digital (FADC) based data acquisition system has been designed for the HiRes Fly's Eye detector. A prototype system has been constructed and installed on a single mirror at Dugway, Utah. The trigger sensitivity of the system has been measured using laser shots fired from up to 20 km away. We present the preliminary results of this measurement.

INTRODUCTION

The HiRes Fly's Eye detector is designed to measure the energy and direction. of extensive air showers (EAS.) resulting from ultra high energy cosmic rays. The experiment uses the air fluorescence technique pioneered by the FIN-'s Eye collaboration. The detector consists of independent mirror units with each unit comprised of 256 photo-multiplier tubes (pmt's). Pmt Signals are continuously digitized at 10 MHz by a Flash-Analog-to-Digital Converter (FADC) data. acquisition system. A full description of this system can be found in Boyer et al. (1995a) and (1995b). A prototype has been constructed and installed at the HiRes Fly's Eve site at Dugway Utah. The trigger sensitivity has been studied using a set of laser shots seen by the FADC prototype mirror in coincidence with the fourteen mirror HiRes prototype in November 1996. In addition, the reconstructible aperture and corresponding trigger efficiency have been calculated with a Monte Carlo program for the thresholds measured with the FADC prototype. The results indicate that the primary trigger sensitivity is sufficient.

FADC PRIMARY TRIGGER DESCRIPTION

The primary trigger is based on the analog current sums of each row and column of 16 photomultiplier tubes (pmt's) in the cluster. A trigger occurs when several neighboring rows and/or columns fluctuate above the background simultaneously or successively. An example of the raw data from a triggered laser shot is shown in Figure 1.

The primary trigger requires four rows, or four columns, or three rows and three columns to exceed threshold. Channels must be adjacent, or at most one away from another above threshold channel. After doubling in time, signals must be coincident with a neighbor. Events with only three rows or three columns are prescaled to monitor the trigger efficiency. Larger

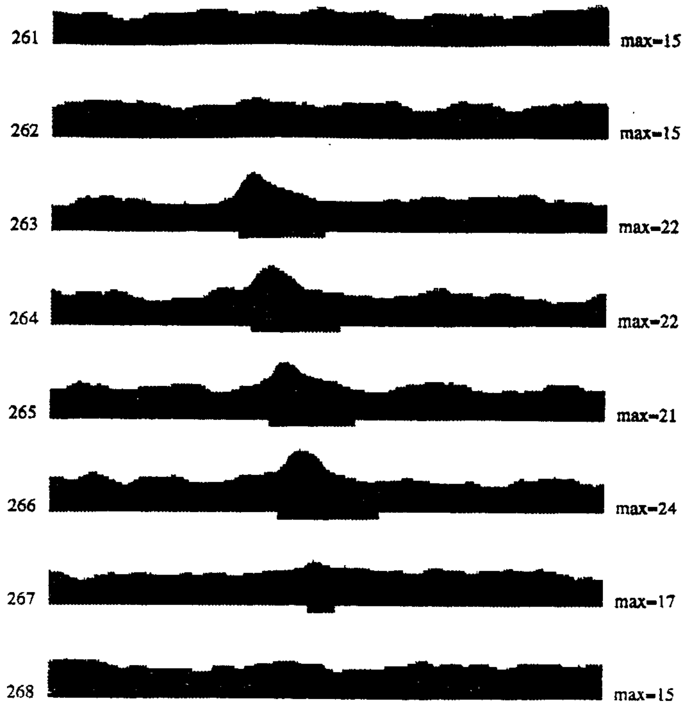

Fig. 1: Vertical trigger sum time profiles for a typical laser shot, from 11/ 12,/96. The darker bars underneath the raw data show the time that the channel is above threshold. The lighter bars shows the time stretched by a factor of two for determining coincidence between neighbors.

coincidences are so identified by the trigger code which is reported by the trigger hardware. These larger triggers are also used to trigger adjacent mirrors, and potentially another site.

The trigger sensitivity depends on the single channel threshold. The single channel threshold is adjusted until the primary trigger rate is as large as the system can comfortably handle with negligible dead time. The system is designed to handle a rate of threefold coincidences of about 1 kHz per mirror per view. For FADC prototype studies, this rate was limited to less than 100 Hz by the readout limitations of the test setup.

The FADC trigger is qualitatively quite different from the trigger currently in rise by the Sample and Hold (S/H) instrumented prototype. It requires only that four rows or columns in the mirror which views the largest portion of the track trigger. The threshold for a trigger channel is higher than it would be for a single pmt because a trigger channel sums the night sky noise for 16 pmt's. However, there are a number of offsetting factors:

• The simple pattern recognition due to looking at rows and columns allows for a lower threshold.
• For many geometries, signal from more than one pmt is included in the same row or column.
• Fast parallel digital processing and pipelining of tasks allows us to handle a high rate, and correspondingly, a low threshold.
• A reconstructible event typically has a portion of the track which is well above the single channel threshold. We need only trigger on that portion to get the whole event.

Table 1: Laser Shot Trigger Efficiency. Angle is the elevation angle of the laser. RP is the perpendicular distance to the track. $\ddot{A}_t$ is the difference in time for adjacent pmt's along the track. < N_{pe} > is the mean number of pe for the four pmt's with the most signal. S/H and FADC are the respective trigger efficiencies for the two, prototype detectors.

Angle	RP(km)	$\ddot{A}_t$ (nsec)	< N_{pe} >	S/H	FADC
30	10.0	350	88	100%	100%
35	11.5	420	72	100%	100%
40	12.9	500	59	100%	99%
45	14.1	580	52	99%	91%
50	15.3	670	49	97%	32%
55	16.4	760	45	51% 1	9%
60	17.4	860	N/A	14%	-

The conclusion to be drawn is that the trigger must be tested and modeled extensively to make sure that it works.

LASER SHOTS

The trigger efficiency was measured on a set of laser shots fired on 11 /12/96 with an energy of about 200 ìJ. Because the trigger for the S/H and FADC electronic systems are so different; their relative performance changes dramatically for different geometries. Furthermore., because laser shots have flatter profiles than cosmic ray showers, they are relatively more difficult for the FADC system to trigger on. Measurement of the trigger efficiency for laser shots for a number of geometries should, however, lead to an improved understanding of the trigger sensitivity for real cosmic ray showers.

The laser was located at a site about 20 km away from 5-.Mile-Hill. The shots were fired at a sequence of angles such that the same tubes were always illuminated. One hundred shots were fired at each position. The laser direction was changed in 5 degree steps between positions. The laser shots were simultaneously in view by the FADC prototype and the S/H instrumented HiRes prototype. A log was kept so that the exact firing times of each laser shot was known. The two systems triggered independently. Event times were measured using GPS clocks. Due to limitations particular to the test setup, the FADC system experienced some dead time. This was due to disabling and reenabling the trigger at known times which were recorded in the data stream. Laser shots that occurred during these known dead times were not included in the measurement of the FADC trigger efficiency. Table 1 summarizes the geometry, signal characteristics, and trigger efficiency for the FADC and S/H systems.

For this geometry - laser shots with RP near 15 km -- the FADC trigger threshold occurs when the largest four pmt signals have about 50 pe with a $\ddot{A}_t$ of about 650 nsec. The S/H threshold was 45 pe with $\ddot{A}_t$ of 760 nsec. The FADC trigger has an analog filter with a time constant of about 1 microsecond. The response depends weakly on the pulse width as long as it is less than 1 microsecond. The expected response to equal area pulses of width 650 nsec and 760 nsec respectively is about 5% higher for the narrower pulse. Therefore, the FADC threshold at 760 nsec would be 53 pe, or about 15% higher than the S/H threshold. However, when the FADC system is configured to handle its maximum trigger rate, the threshold should drop by at least 10%. Furthermore, the FADC trigger is expected to improve relatively for the more distant slower high energy tracks for which the detector is optimized. An additional set of laser shots from greater distance with higher energy is planned for early June. The results

Table 2: Reconstructible stereo aperture and trigger efficiency as calculated by Monte Carlo. The reconstructible aperture assumes 100% trigger efficiency. FADC and S/H are the respective trigger efficiencies.

Energy (EeV)	Aperture	FADC	S/H
1	124	100%	100%
3	1020	99.2%	100%
10	3910	97.8%	100%
30	8020	95.8%	97%
100	12520	95.4%	85%

will be presented at this conference.

The important test for the trigger is that it be efficient for reconstructible cosmic ray showers. We will try to answer this question with a Monte Carlo analysis. However; we will use the conservative running parameters measured with the FADC prototype.

APERTURE CALCULATION

We have studied the trigger efficiency for reconstructible events and calculated the apt rture using a Monte Carlo program. The FADC threshold was chosen so as to agree with'-he threshold used for the laser shot trigger test. The trigger efficiency was also calculated for the S/H system for comparison.

We generated 1000 reconstructible events at each of 5 energies: 1, 3, 10. 30. and 100 EeV. The detector configuration consisted of 42 mirrors at Camelsback and 22 mirrors at 5-Mile Hill, as planned by the end of 1998. A reconstructible event was required to be seen in stereo. At least one site had to observe the shower maximum bracketed by a minimum path length of +/- 100 gm/cc of atmosphere. In addition, the light intensity had to be at least. 100 pe per degree of track length for a minimum track length of 10 degrees. The other site was required only to observe 6 pmt's above an estimated single channel threshold in at least one mirror.

The FADC system was deemed to have triggered if both sites triggered independently, or if one site triggered a mirror with at least a -5-fold coincidence. For the FADC system, approximately 85%-90% of reconstructible events trigger both sites independently. Less than 5% fail to trigger altogether. The results are shown in Table 2.

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