CALIBRATION AND STABILITY MEASUREMENTS OF A FADC BASED DATA ACQUISITION SYSTEM FOR THE HIRES FLY'S EYE EXPERIMENT.

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ABSTRACT

A flash analog-to-digital (FADC) based data acquisition system has been designed and constructed for the HiRes Fly's Eye detector. The prototype system has been installed on a single mirror at Dugway, 'Utah. This system has been used to test calibration procedures and monitor the stability of the electronics. We present preliminary results for the calibration and stability tests.

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). Signals from each of the pmt's are continuously digitized at 10 MHz by a Flash Analog-to-Digital converter (FADC) based data acquisition system. A full. description of this system can be found in Boyer et. al. (1995x) and (1995b) A prototype system has been constructed and installed at the HiRes Fly's Eye site at Dugway Utah, and used to test the calibration procedure and monitor the stability of the electronics.

CALIBRATION

The total energy of an EAS is proportional to the fluorescence light detected by the HiRes detector. To measure the shower energy, it is necessary to know the constant of proportionality. Contributing factors are atmospheric transparency, mirror reflectivity, optical filter transmission, pmt quantum efficiency, and pmt/FADC gain per photo-electron (pe). While it is not necessary to know each factor individually, we try for as much redundancy as possible. A full description of the calibration procedure can be found in Bird, D. J. et al. (1994). We will discuss only the measurement of the gain per pe. The gain per pe can be monitored by looking at the statistics of the response to a stable Eli source. In addition, it can be measured directly if the single pe peak is observable. The single pe peak is well-separated from pedestal when the cluster is illuminated with a weak light source and operated at 1350-1450 volts.

Single Photo-Electron Calibration

The single pe calibration uses a pulsed LED. The LED emits blue light, but the spectrum continues into the UV. The light passes through a standard HiRes optical filter to obtain a UV source. The size and width of the pulse are controlled by a pulser. The maximum intensity pulse used yields about 50+ photo-electrons per pulse per pmt. Neutral density filters (NDF) reduce the light to less than one pe per pulse on average.

A single pe calibration was performed several times on the prototype cluster at Dugway. It was based on a run of about 10000 triggers at 5 Hz. The calibration was repeated many times at a test setup at Nevis Labs with higher statistics in order to study systematic effects. Results shown below are based on the latter runs, but are consistent with the Dugway calibration.

The data were taken over a period of about 1 week. Nearly 400000 triggers were taken in blocks of 10000 at a rate of about 5 Hz. The pulser which fired the LED also triggered the detector. Thus the pulse time was known. We found that the FADC pulse was > 90% contained within a fixed 600 nsec window. In order to reduce noise, we ignore the tail. As a check; we repeated the analysis with an 800 nsec window. We observed a 6.9% shift in the mean pulse area, but less than a 1% shift in the calculated number of pe.

Individual channels were adjusted to a nominal gain of about I integrated FADC count per pe at the operating voltage of 1050 volts. The pedestal was set to 10 counts. At 1050 volts, the single pe peak is not well-separated from the pedestal. However, at 1450 volts, the mean gain is about 5 counts per pe, and the single pe peak is visible. A pulse area distribution based on 50000 triggers at 1450 volts with a mean of about 1 pe is shown in Figure 1.

The gain is determined from the distribution in a straightforward manner. The distribution is a Poisson with a mean of about ì = 1 pe. The fraction of events in the pedestal is $e^{-ì}$. We choose a pedestal region such that the amount of signal in the pedestal region is small. The actual amount of pedestal is calculated by observing the fraction of the pedestal distribution in tile pedestal region. The gain is then the mean pulse area, divided by the mean pp.

Systematic errors were studied by varying the high voltage, the light intensity, and the pedestal region. The results are stable to within 1-2%. For example, the single pe calibration was done at both 1350 volts and 1450 volts with the same light source. The mean number of pe should agree. If we look at the difference for the 256 pmt's, the results agree on average to better than 1% with a spread of 3.5%.

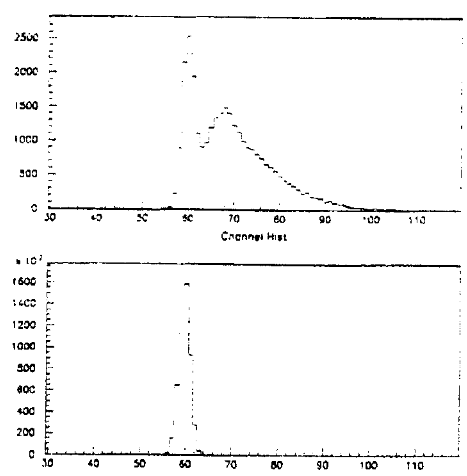

Fig. 1: An example of the single photoelectron peak compared to a pedestal distribution for the same channel

The Roving Flasher

One of the components of the calibration system is a light source referred to as the "roving flasher" because it is moved from mirror to mirror. The roving flasher emits a stable light pulse of uniform intensity. It is located at the center of the mirror and operates at 4 Hz. NDF's and a thin teflon diffuser control the intensity and uniformity of the illumination across the face of the cluster. The cluster gain is equalized by a variable gain amplifier on each channel of FADC electronics so as to achieve a uniform response to the roving flasher.

The gain per pe is monitored by looking at the width of the pulse area distribution for the roving flasher. The measured width depends on the pedestal width, the single pe width, and primarily the photon statistics. The pulse area is measured by summing the FADC counts for the duration of the signal. The limits of integration are determined by looking at the sum of all 256 pmt's in the cluster. The pedestal width is measured and is very small. We correct for it, but ignore it in the discussion below. The single pe width is largely due to the statistics of multiplication at the first stage. It can be inferred by comparing to the single pe calibration. If the gain is G, the measured width is ó, the mean number of integrated counts is ì, and the single pe width is áG, then the gain may be written as

$$G = \frac{\sigma^2}{\mu} \left(\frac{1}{1+\alpha^2} \right) \qquad (1)$$

We measured ó^{2}/ì for a variety of signal strengths using the roving flasher and NDF's. It was found to be constant within statistics over two orders of magnitude.

The single pe gain as measured at 1350 volts and 1450 volts is used to measure the LED intensity with no NDF. The LED, which is independent of pmt voltage, is then used to measure the gain at 1050 volts. The comparison to ó^{2}/ì for the roving flasher is a measure of the factor 1/1+á^{2}from Eq. 1. This comparison is shown in Figure 2. The quantity plotted is á^{2} for the 256 pmt's in the cluster. The mean value of á^{2} is 0.26 and does not, depend on the voltage of the single pe calibration. The spread observed is reasonable.

Having calculated á^{2}, both the single pe gain and the gain per incident photon can be monitored just using the roving flasher.

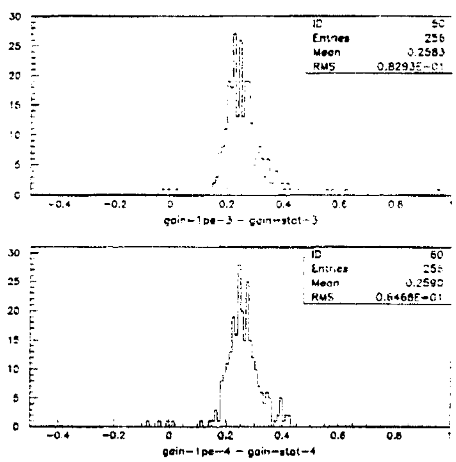

Fig. 2: The quantity á^{2} as defined in Eq. 1 is plotted for the 256 pmt's in the cluster. The two plots use the single pe calibration at 1350 volts and 1450 volts.

TEMPERATURE MEASUREMENTS

The ambient air temperature for a test cluster after startup was monitored using 4 digital thermometers. Temperature probes were mounted inside the cluster box, located at the top, left, right and bottom centers of the cluster. The probes were located in the regions near preamps, and mounted such that the probe was not in contact with the sides of the cluster box or the aluminum can surrounding the . preamps. The distribution of temperatures as a function of time is shown in Figure 3. The average room temperature through out the running time was 72 degrees F. The distribution shows the cluster temperature rising with a time constant of about 3 hours and stabilizing after about 8 hours. The temperature gradient, defined as the temperature difference between the temperature as measured at the top and bottom is well defined after one hour of running and remains constant after several hours of running. PEDESTAL STABILITY

Two studies were done to look at the stability of the pedestals as a function of time. The first study used the diagnostic data from one day of run' the test setup at Nevis, and the second study
the diagnostic data from one night of running T Dugway. Five channels were used to look at the all stability of the

pedestal; channel 7 located at M' a top center of the cluster, channel 112 centered `°`" the right side of the cluster, channel 119 located the center of the cluster, channel 127 centered on 'the left side of the cluster, and channel 246 located 'bottom center of the cluster. Both data sets show teat the pedestal is stable as a function of time.

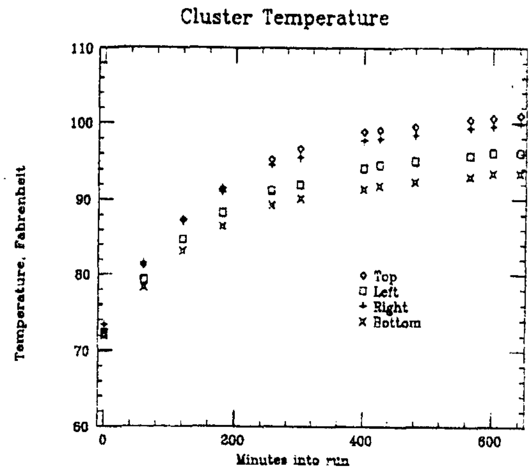

Fig. 3: Cluster temperature as a function of time.

GAIN STABILITY

Data was taken over a two day period to look at the gain stability of the test stand located in the lab. The system was turned on initially just before the first data run of the day and remained on throughout the day. The DAC values used for setting the electronic pedestal and gain were kept constant for both runs. Data runs consisting of approximately 500 internally triggered events were recorded every hour. The average pulse area over pedestal for each channel was determined by integrating over the region of the pulse and subtracting the pedestal as determined by integrating over a similar time window several microseconds prior to the pulse. The resulting average pedestal subtracted pulse area as a function of time for the same :5 channels used in the pedestal test are shown in Figure 4. The average pulse heights for each channel have not been corrected for variations in illumination of the cluster from the LED. The data shows a small decrease in gain as a function of time for all tubes. however, the gain recovers after each day.

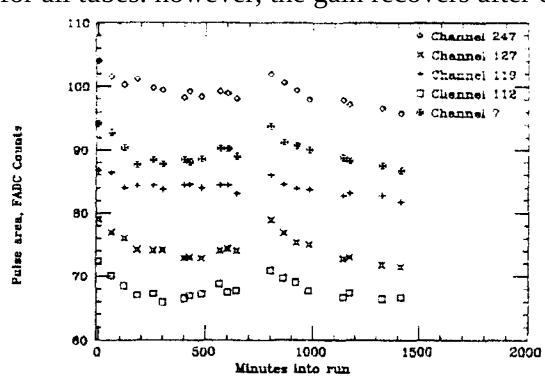

Fig. 4: The average pulse area in FADC counts as a function of time for five photomultiplier tubes. The Break at 800 minutes is data taken during day 2 of the test running.

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