Performance of a Prototype FADC Electronics System for the HIRES Fly's Eye

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ABSTRACT

We have instrumented one mirror unit of the HIRES prototype with both a Sample and Hold (S/H) and a FADC readout system. The relative performance of the two systems was compared by analyzing simulated cosmic ray showers generated with a high power UV laser. The performance of the FADC system was found to be consistent with expectations, and superior to the S/H system.

1. INTRODUCTION

The HIRES Collaboration has designed and built a prototype detector consisting of 14 mirror units - 3584 photomultiplier tubes (PMT's) - instrumented with a S/H readout system. The collaboration has for some time been considering the possibility of instrumenting the detector with a FADC readout system. A FADC system would give a time profile for each PMT signal, while the S/H system gives only the pulse integral for two different gate widths (~ 1ìsec and ~ 5ìsec) and the time at which the pulse exceeds a fixed voltage discriminator. The advantages of a FADC system are several:

- Signal to noise is optimized by choosing the window of integration off line.
- A concurrent measurement of the pedestal mean and width is automatically obtained.
- The S/H system only measures the correct pulse area if the tube triggers properly. Below threshold tubes are lost, as are tubes which had a noise trigger within the previous 25 ìsec.
- The time measurement with a FADC system is not subject to the slewing and fluctuation caused by fixed voltage discrimination.
- The time profile can in principle give more detailed information about the longitudinal development of the cosmic ray shower.

With these advantages in mind, we decided to instrument one mirror unit with an FADC readout in addition to the S/H system and run a head-to-head comparison of the two systems. The results were encouraging and have led us to begin the design effort for a full FADC system for HIRES.

2. THE FADC PROTOTYPE SYSTEM

Each PMT has a preamp attached to the base. The preamp output is passed through a high impedance tap to a shaper/amplifier board. The shaper/amplifier board has two outputs for each PMT which differ in gain by a factor of 8. Each output is continuously digitized with a 6-bit FADC with 256 bytes of memory with a sampling rate of 70 nanoseconds, providing a 17.9 ìsec history of the PMT signal. The trigger was taken from the S/H system. Whenever the mirror triggered, all 512 channels of FADC were read out.

2.1 FADC Analysis

The FADC data is first searched for hits. Software thresholds are set such that there are typically only several noise hits per event. The pulse area is found by searching forward and backwards for the zero-crossings. The pulse time is the time at which the pulse height reaches half maximum. The bins were interpolated between if necessary. Further analysis may show that this is not the optimal method, but it is already an improvement over fixed voltage discrimination. Hits isolated in time or space are then discarded, and the event geometry is fit using the remaining hits.

2.2 Laser Shots

We recorded and analyzed data for data for several sets of laser shots. Results presented here are for a set of shots fired from 3.4 km away on October 27. The geometry was fixed with the laser pointing somewhat away from HIRES, but the amplitude was varied by about a factor of 3.

The laser geometry was determined as closely as possible using both the surveyed position and direction of the laser and the hit information from the full set of recorded laser shots. The best fit geometry was then used to determine which tubes were illuminated and the expected hit times (t_{exp}). An independent fit to t_0 for each event was then performed. For illuminated tubes which did not trigger, the pulse area over a window around the expected time was integrated . In this manner, the pulse area was found even if the hit was below threshold. Times were only available for tubes with above threshold hits.

2.3 Sample and Hold Analysis

S/H hit information was used only if the hit time was within 1 ìsec of t_{exp}. Since the pulse widths exceeded 1 ìsec, the pulse area was measured using the 5 ìsec integration channel.

2.4 Calibration

Calibration was done identically for the two systems: each tube had its gain calibrated in the lab before installation. The rest of the electronics system was calibrated using a programmable pulse generator (PPG). The resulting pulse area measurements are expressed in photoelectrons.

3. RESULTS

The average pulse area over a set of laser shots agreed very well for the S/H and FADC systems. Fluctuations were compared to that expected due to photoelectron statistics. The results are shown in Figure 1. Each point shows the mean and fluctuation of the pulse area measured by a single PMT for a set of fixed amplitude and geometry laser shots. The different plot symbols correspond to different laser amplitudes. The solid curve is the expected resolution for the FADC measurement, and the dotted curve is the expected resolution for the S/H. The difference is due to the longer S/H integration. Note also that most of the low pulse area points are missing in the S/H plot since these tubes did not trigger.

3.1 Timing Results

In addition, the mean time and corresponding fluctuations for the two systems as a function of the mean number of photoelectrons ($< N_{pe} >$) were compared. The mean

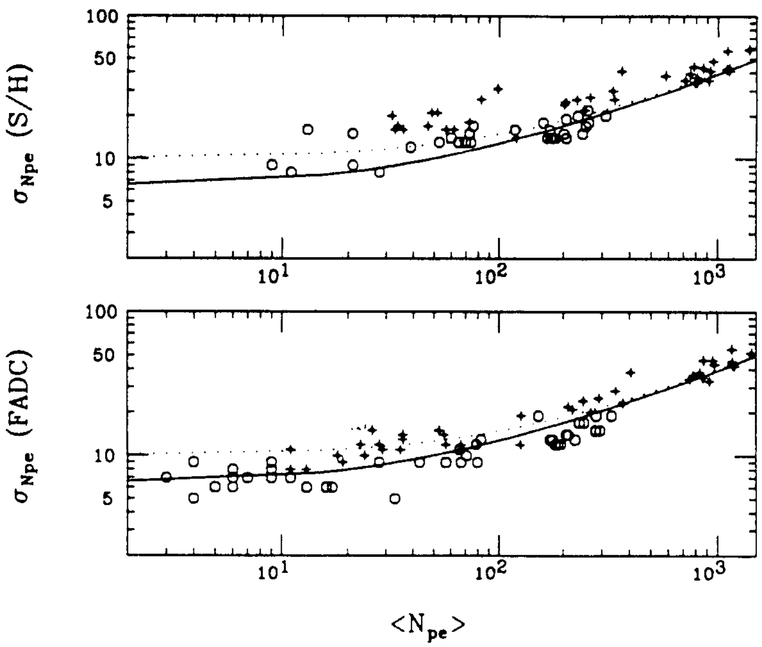

Figure 1: Pulse Area Resolution

times compared to the expected times are an indication of the systematic errors, and are shown in Figure 2. Some of the systematic error is due to the spherical aberration of the mirror and can be corrected for. However, for low pulse area, the S/H systematic error is dominated by slewing due to fixed voltage discrimination.

The time resolution is shown in Figure 3. It approaches 30 nanoseconds with the FADC system for large Npe, and is somewhat larger for the S/H system. However, the algorithm for finding hit times with the FADC system has not been optimized. For Npe < 100, we see that the resolution deteriorates for both systems. This is an inherent limitation of the timing method due to photoelectron fluctuations.

4. CONCLUSION

The FADC system has been shown to provide an improved measurement of both pulse area and pulse time. It has also proved to be straightforward to analyze and useful for understanding background fluctuations. We believe that a FADC system will expand the physics horizons of the HIRES experiment and improve the reliability of the detector.

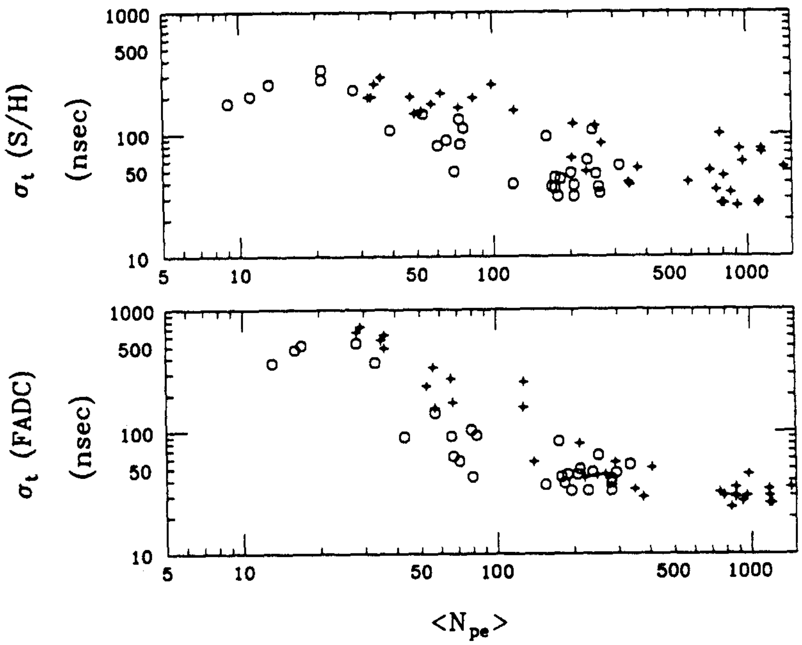

Figure 2: Time Offset

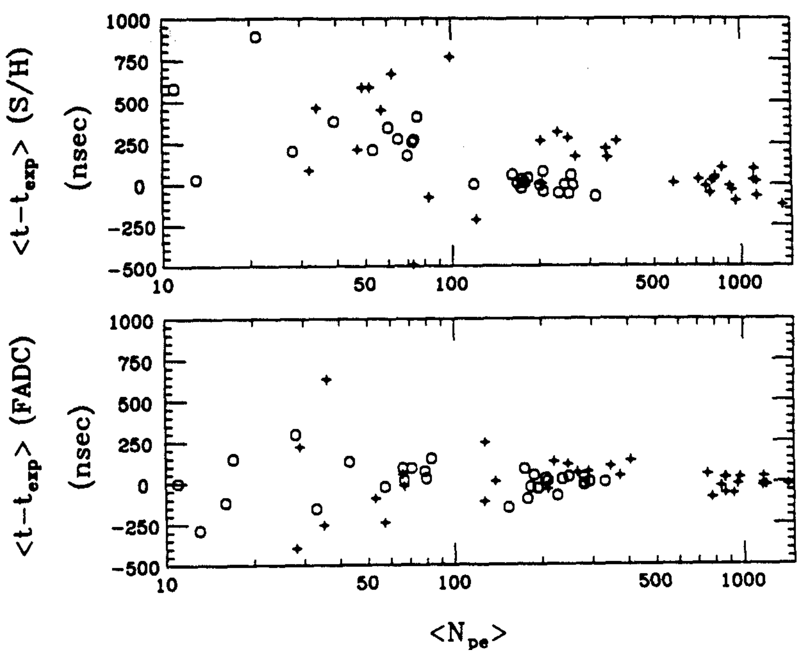

Figure 3: Time Resolution