Further Studies of DBDS-39 in the November 1996 Beamtest

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Abstract

The excess activity of certain strips on DeBeers Diamond Sample 39 is shown to be due to charge deposited on adjacent dead strips. A toy Monte Carlo simulation using the average strip response function shows that the poor position resolution seen in DBDS-39 cannot be attributed to pedestal drift, rms noise, or strip-to-strip response variations. The calibration of DBDS-39 is re-examined.

1 Introduction

The November 1996 beamtest of the DBDS-39 tracker with VA electronics showed a large signal and poor resolution [1]. However, doubts were raised about the reliability of the data. In particular, three concerns were raised:

1. What is the nature of the so-called "hyperactive" strips, and do they contribute extra charge to the signal distribution?
2. Can further understanding be gained about the irregularity of DBDS-39 hit clusters and the poor position resolution of the detector?
3. Do high values of both signal and noise indicate problems with the e^-/ADC-count calibration of DBDS-39?

These issues will be discussed in the following sections.

2 DBDS-39 Hyperactive strips

The "hyperactive" strips are stimulated by charged particles passing as much as several hundred microns away, and appear as diagonal streaks on the plot of the track residual versus u position (see figure 1). Note that these streaks are invariably adjacent to dead regions. In contrast to the typically broad DBDS-39 hit clusters, these hits are almost exclusively single-strip hits. The lower plot of figure 1 shows single-strip hits with residuals worse than 100 μm. More than a thousand such hits appear on strip 12 in run 938. The most prominent hyperactive strips are 4, 12, 45, 71, 77, 84, 101, and 117.

In the absence of a nearby track, these strips are quiet (see figure 2). They have rms noise values comparable with those of strips in fiducial regions. Hence they are not noisy strips; they are strips with an abnormal and asymmetric response to nearby tracks.

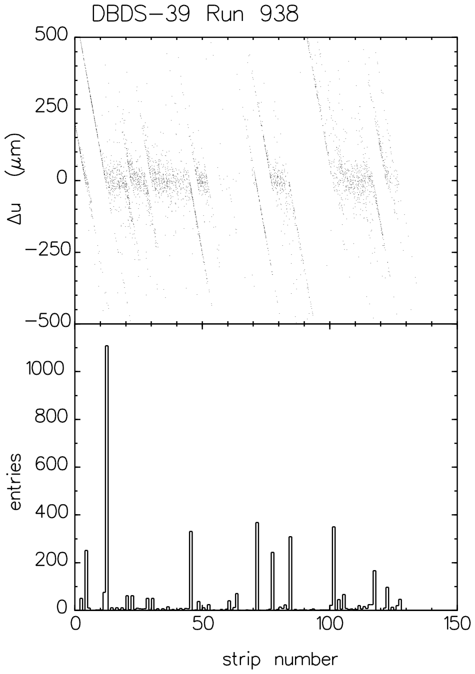

Figure 1: Hyperactive strips. The upper plot shows the difference between the hit position and the extrapolated track position as a function of the strip number. Hits on hyperactive strips appear as diagonal streaks. The lower plot shows single-strip hits with residuals worse than 100 μm.

The key to their abnormal response can be found in figure 2. The strip response functions are asymmetric in u. Strip 12 responds most strongly to tracks passing through the range of dead strips extending for several hundred microns to its left. This response does not vary as a function of v. Strip 84 responds most strongly to tracks passing through the range of dead strips to its left.

Here a "dead strip" is one which shows little or no response to nearby tracks (for example, see strip 29 in figure 3). These strips do carry rms noise, although it is typically one ADC count lower than the rms noise seen on nearby fiducial strips. There is an approximate correspondance between DBDS-39 strips marked with a dash in the online logbook [2], and those seen as dead strips in the offline analysis. The logbook denotes strips 4–9, 27, 44–45, 53, 59, 70–74, and 84-99 with dashes. An offset of one strip is necessary to match logbook strips 84–99 with the dead offline strips 85–100, which are bracketed by hyperactive strips 84 and 101. An offset of two strips is required to match logbook strips 70–74 with dead offline strips 72–76, which are bracketed by hyperactive strips 71 and 77. An offset of about two strips also matches most of the other dashed logbook strips with dead and hyperactive offline strips.

So the charge which should appear on the dead strips instead appears on their seemingly hyperactive neighbors. Regions in which this happens are excluded from the fiducial regions. Nevertheless, it is an interesting question whether the total charge, or signal, is being conserved in these cases. Is charge being lost or is spurious charge being generated?

The average response of the 16 fiducial strips to tracks passing within 50 μm is 106.2 ADC counts. The measured strip-to-strip response variation is 15% of that value. Excluded from the fiducial regions, but completely surrounded by them, are two non-fiducial regions of five strips each. These non-fiducial regions are centered around the two dead strips 21 and 29, and show

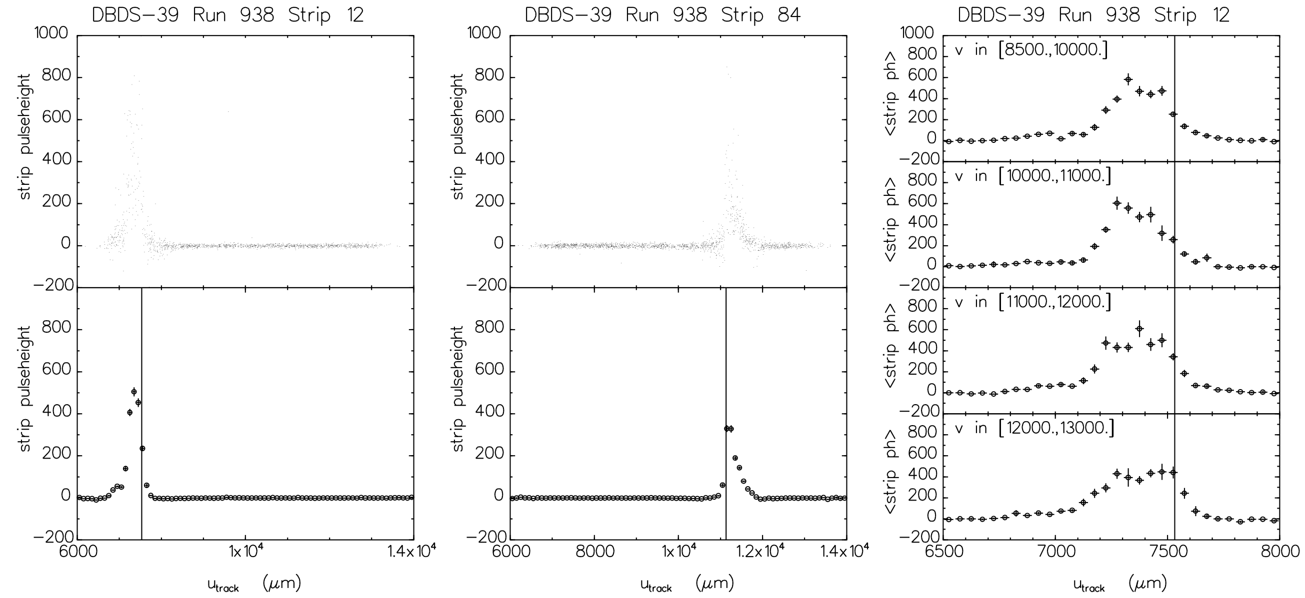

Figure 2: Strip response functions for two hyperactive strips. In the two plots on the left the pulseheight on strips 12 and 84 is shown for the full range of incident tracks. The strip response functions are asymmetric in u. The rightmost plot shows a closeup of the response of strip 12 to tracks in four distinct v ranges. The vertical lines in each plot mark the location of the strip in question.

characteristic diagonal streaking in figure 1. The average responses of the strips numbered 19 through 23 are 110.3, 131.5, 17.7, 143.0, and 117.5. The average response of these five strips taken together is 104.0, well within the range of the response of the fiducial strips. Similarly, the responses of the strips numbered 27 through 31 are 120.1, 140.1, 0.8, 126.1, and 125.0, for an average response of 102.4 ADC counts.

There is no evidence for either lost or excess charge. The charge that should have appeared on the dead strips appears to be redistributed onto nearby strips, which are consequently hyperactive.

The dead strips may be attributable to metallization, bonding, contacts, or individual dead electronics channels. They appear individually or in groups of five to fifteen consecutive channels. The resistance between adjacent strips was measured; however, there might be electrical problems between alternate strips since the ends of the strips are staggered to provide bond pads.

3 DBDS-39 Cluster Irregularity

The strip response functions for individual strips show some individual character (see figure 3). However, they do not show dramatic features, and the response functions of strips in fiducial regions appear to be generally consistent.

The response of a typical strip to tracks passing through and depositing similar amounts of charge, however, seems to be highly variable from track to track. Strip 34 has a typical individual strip response function, which would not lead one to expect the variable response

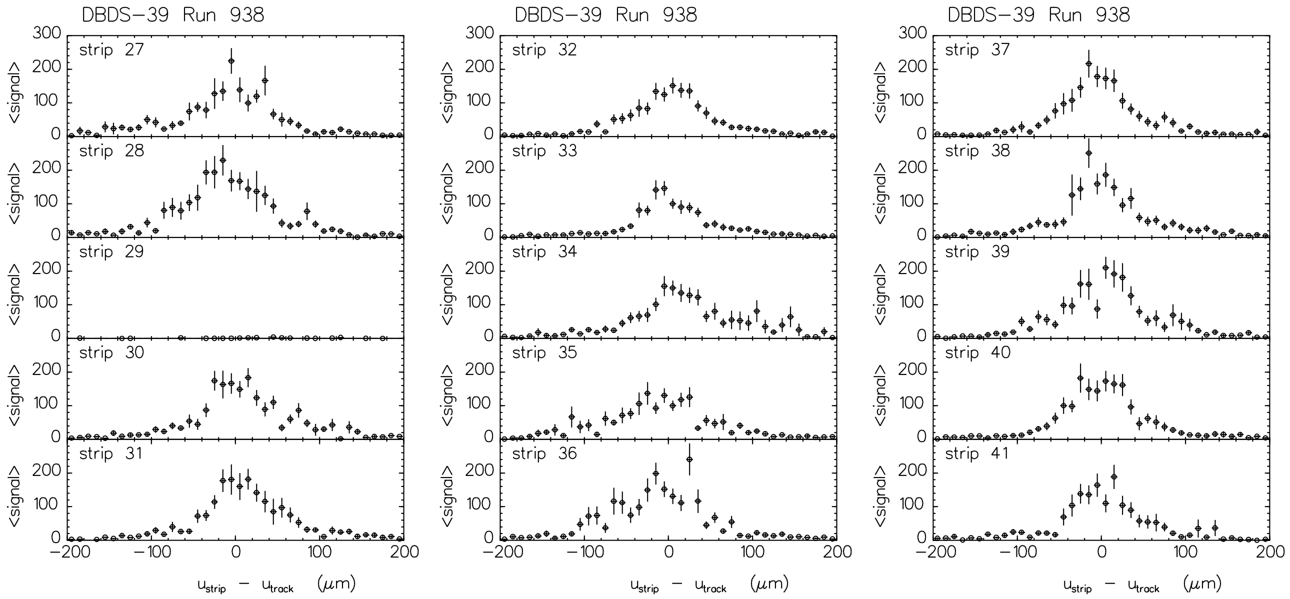

Figure 3: Strip response functions for fifteen contiguous strips. Strip 29 is dead. Strips 32 through 41 constitute a fiducial region. Note the sign convention such that u_{track} runs from right to left.

it shows in the three events displayed in figure 4. Time-dependent effects due to floating unbonded strips might provide an explanation for this effect. The time scale of the effect would have to be short, though, since all three of these events occurred in the first 500 events of run 938. A transient "turn-on" explanation is ruled out since it has been verified that events later in the run show the same behavior.

3.1 Pedestal Drift

The pedestals of DBDS-39 varied slightly as a function of time. The pedestals of the F detector varied by a significant fraction of the full ADC range. Some part of this variation was removed from the analysis by the standard pedestal follower, which operated on a thousand-event time scale, and by the common-mode correction, which operated on an event-by-event basis.

The pedestal and rms evolution for selected strips on both detectors was studied in the raw data of run 938 using a specialized fast pedestal follower operating on a ten-event time scale (see figure 5).

Strips 48 and 50 on the F detector were bonded to readout channels; strip 49 was unbonded and floating. The pedestals varied by 400 ADC counts over the course of the run, and the rms varied from 20 to 100 ADC counts.

Strips 33 through 34 on DBDS-39 are fiducial strips. They show some pedestal variation within a range of 20 ADC counts, and a stable rms of about 8 ADC counts. Dead and hyperactive strips on DBDS-39 have pedestal and rms behavior very similar to that of the fiducial strips. The common-mode correction and the standard pedestal follower should make the analysis of DBDS-39 fairly insensitive to these pedestal variations. However, the variations may still represent a contribution to the effective rms noise, offering a possible explanation for the fact that DBDS-39 appears to have 220 e^- rms noise per channel rather than the expected 100 e^-.

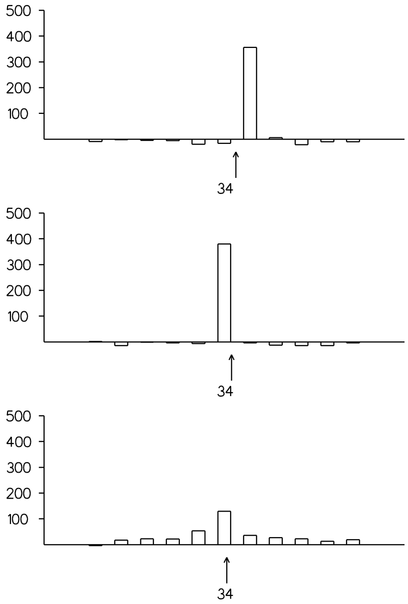

Figure 4: Three hit clusters of similar total signal size associated with tracks passing through strip 34. The arrow shows the position of the extrapolated track. The variability in the response of strip 34 cannot be accounted for by rms noise or by gain variations between strips. In the first event, the signal appears exclusively on strip 35; in the second event, on strip 34; and in the final event it is distributed over ten strips.

The F-detector shows large pedestal variations, which complicate the analysis of its data. The position resolution of F was 55 μm, twice the digital resolution expected for a 100 μm-pitch detector. The unbonded and floating intermediate strips on the F detector provide a possible explanation for the observed pedestal variations.

There are common features in the F and DBDS-39 pedestal variations. For instance there are spikes in the pedestal values from event 45000 through event 60000. These common features may indicate a problem with interference or with the bias voltage supply.

If the difference between the magnitude of the pedestal drift in DBDS-39 and in F is related to the number of unbonded floating strips, it may be desirable to ground such strips in future beamtests.

3.2 Hit Resolution Simulation

A toy Monte Carlo simulation of DBDS-39 has been carried out using its strip response function integrated over all fiducial strips (figure 5 in [1]). The gaussian core of the response function has a standard deviation of 0.83 strip pitch units. The response was simulated with a sigma of 0.8 as well as 1.6 strips. The value of 1.6 strips was used in order to approximate the tails of the strip response function, while retaining the normalization of 350 ADC counts. The effective noise due to the ADC digitization is insignificant compared with the rms noise and has not been included.

The simulation shows a resolution of 0.06 strips before adding in rms noise and strip-to-strip response variations. The resolution becomes 0.18 strips when 8 ADC counts of noise are added to each strip, and 0.20 strips when the measured 15% strip-to-strip response variation

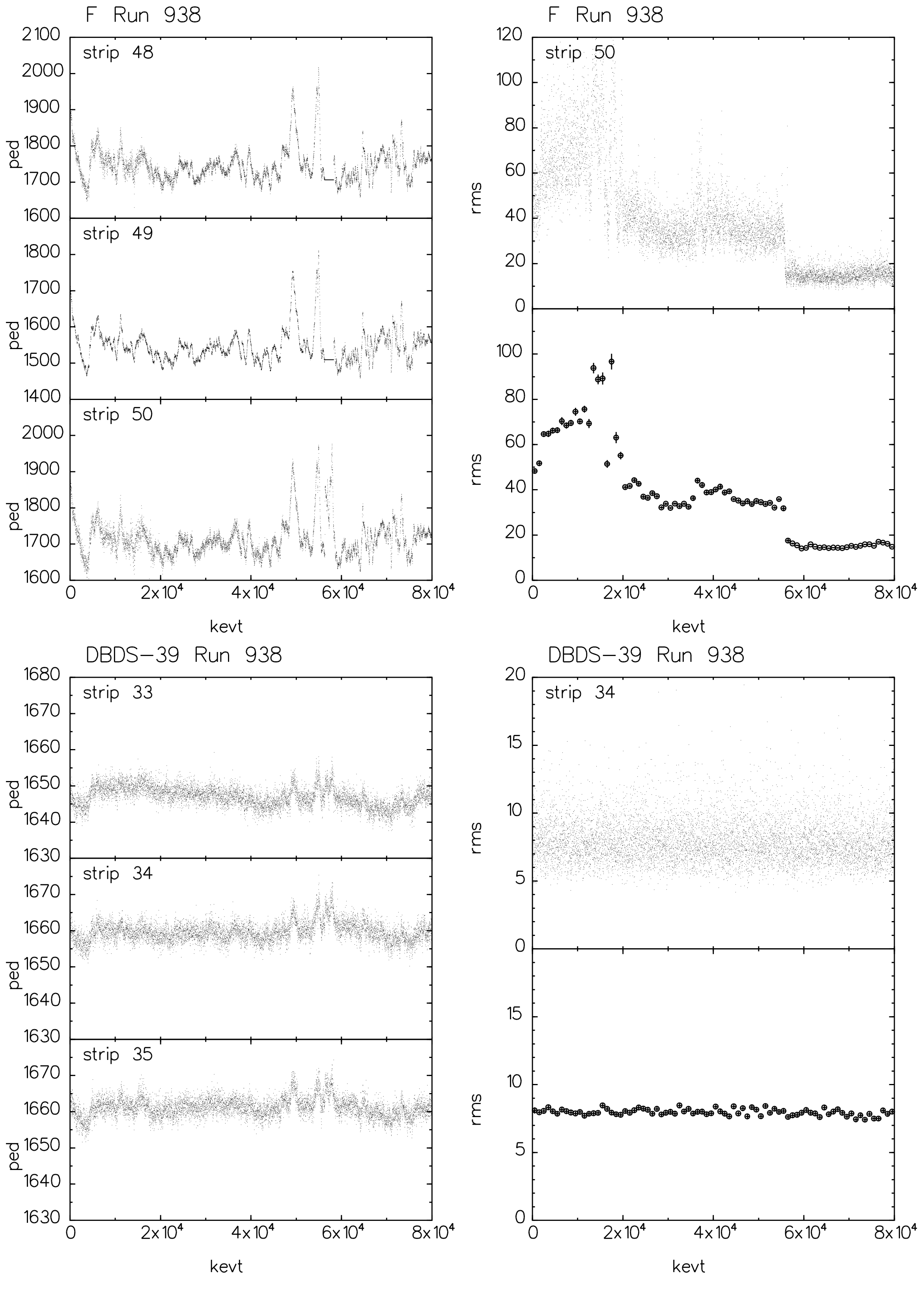

Figure 5: Pedestal and rms evolution for selected strips in the F and DBDS-39 detectors.

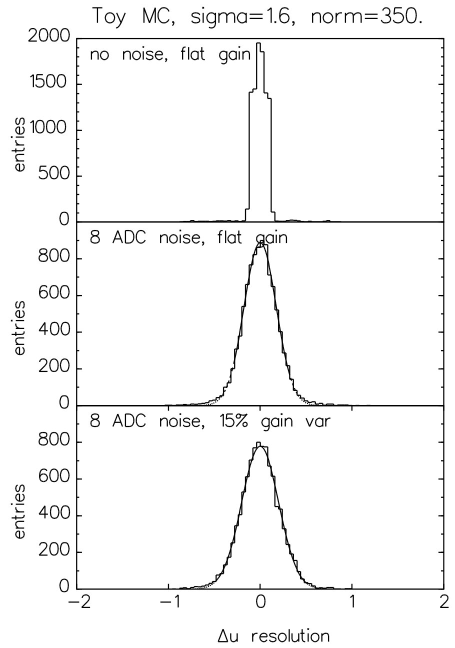

Figure 6: Toy Monte Carlo resolution. The simulated DBDS-39 resolution has a standard deviation of 0.06 strip units before adding in noise and gain variations. The resolution becomes 0.18 strips when 8 ADC counts of rms noise are added, and 0.20 strips when the measured 15% strip-to-strip response variation is also included. Digital resolution is 0.29 strip units.

is added (see figure 6). Digital resolution is 0.29 strip pitch units.

Increasing the strip-to-strip response variation to 30% yields a resolution of 0.27 strips. Using a 5-strip algorithm instead of an n-strip algorithm yields a resolution of 0.31 strips. Increasing the rms noise to 23 ADC counts (for a signal-to-noise ratio of 15/1) degrades the resolution to 0.45 strips.

Clearly, neither rms noise nor gain variations can be responsible for the poor DBDS-39 resolution of 0.70 strip pitch units. The pedestal drift is treated as a component of the effective rms noise, and is also excluded as an explanation for the poor resolution.

4 DBDS-39 Calibration Comparisons

Mean 5-strip signal sizes up to 439 ADC counts, with single-strip rms noise of 7.7 ADC counts, were seen in the offline analysis of the DBDS-39 beamtest data taken with VA readout electronics [1]. The online system used only the high 10 bits of the full 12 bits of ADC resolution which were passed to the offline analysis. Consequently the online DBDS-39 calibration of 114 ± 10 e^-/ADC count is divided by four to obtain the offline calibration of 28.5 ± 2.5 e^-/ADC count. This calibration implies a mean 5-strip signal size of up to 12500 e^- with single-strip rms noise of 220 e^-.

This calibration, while consistent with earlier calibrations, has been called into question. The first objection is that tests of DBDS-39 with fast SCT-32 electronics show a signal closer to 6000 e^-. However, an understanding of the timing and signal loss with that system has not yet been finalized. The second objection is that the VA amplifier noise is expected to be approximately 100 e^-, as seen in earlier beamtests. Additional contributions to the noise, such as pedestal variations, would have to be identified.

The readout hardware and analysis software were both modified for the November 1996 beamtest. A missing or extra bit in the readout chain could lead to a calibration error of a factor of two.

However, the noise and most probable signal were recorded from online histograms during the November beamtest [3]. The noise was 1.5–2 ADC counts and the signal distribution peaked at a most probable value of 60 ADC counts. Correcting for the two low bits missing from the online plots, this corresponds to 6–8 ADC counts noise and 240 ADC counts most probable signal, which agrees with the offline results. Since the calibration was determined using the online system, a bit error appears unlikely.

There is an unattributed notation in the logbook [4] which reads "Gain of Sirocco 5 and 6 increased by factor 2." However this seems to have occurred before the gain calibration was performed the following day [5].

The calibration can also be cross-checked using the other detectors tested in the same beamtest.

A cluster-based analysis of the run 939 data for the (alternate–)strip, pumped F detector showed a mean signal of 3600 ± 400 e^- at the measured calibration of 37 ± 4 e^-/ADC. This signal is consistent with our previous experience with F. More recently F has been aligned and transparent 3– and 5–strip signals consistent with the cluster-based signal have been measured. However, the data from the F detector should be treated with caution, as discussed in the previous section.

The X pixel detector showed an rms noise of 7.4 ADC counts per channel in run 938, corresponding to about 225 e^-. This agrees with the noise measured in DBDS-39. The mean signal is 1900 e^-, which is consistent with the signal of X when tested earlier as a strip detector.

The calibration of DBDS-39 appears to be correct.

5 Conclusion

Some further understanding has been gained about the DBDS-39 hyperactive strips, cluster irregularity, and signal size.

The hyperactive strips have been shown to be in fact manifestations of track hits on neighboring dead strips. There is evidence of signal being redistributed among strips, but no evidence of "extra" signal. The redistribution of signal occurs between strips, but not along strips; there is no dependence on the v position of the extrapolated track. Consequently, it appears unlikely that the dead strips are due to features in the diamond bulk. They may be artifacts of the metallization, bonding, contacts, or individual dead electronics channels.

Poor cluster position resolution in DBDS-39 does not seem to be attributable to observed pedestal variations, rms noise, or a measured 15% strip-to-strip response variation. Another explanation, such as time-dependent interference from unbonded floating strips, is necessary. It may be desirable in future beamtests to ground those strips which do not show a good signal when read out on the bench.

The DBDS-39 calibration, which is used to translate the sum of strip pulse heights in ADC counts into a signal in electrons, shows good agreement between online and offline distributions of signal and noise. It has been crosschecked with the X pixel and F (alternate–)strip detectors which were present in the same beamtest. The calibration appears to be correct. In future beamtests the silicon diode calibration crosscheck could be repeated.

Further beamtest data using the excellent signal-to-noise ratio provided by VA readout electronics with high collection distance diamond could help identify the source of the cluster irregularity in DBDS-39 as well as confirm the observed large signal.

References

[1] "DBDS-39 Performance in the November 1996 Beamtest," John Conway, Michael Walsh.

[2] November 1996 Beamtest Logbook, pages 24–25, probably 21 November 1996.

[3] Logbook, entry on 24 November 1996, 19:00h, run 938.

[4] Logbook, entry on 22 November 1996, 9:00h, before run 907.

[5] Logbook, multiple entries on 23 November 1996, after run 920 and before run 937.