DBDS-39 Performance in the November 1996 Beamtest

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Abstract

DeBeers Diamond Sample 39 was studied in the RD-42 November 1996 beamtest. DBDS-39 had 50 μm pitch Cr-Au readout strips placed on the polished growth face of the diamond. Several hundred μm of material were removed from the substrate side, leaving 1180 μm of high collection distance material in which large signals above 10000 e^- were seen. However, clusters were broad and hit resolution was only 35 μm, compared with an expected digital resolution of 14.4 μm.

1 Introduction

DBDS-39 shows the largest signal yet measured for a diamond tracker in a beam. The signal appears in broad clusters with poor position resolution.

These data were taken between November 22 and 24, 1996, at the PS accelerator at CERN. The Strasbourg silicon telescope with modified Sirocco digitization was employed. Norton diamonds F and X were also tested, but will not be discussed in detail here.

2 Alignment and Fiducialization

The silicon planes of the Strasbourg telescope were aligned using the procedure discussed in an earlier RD-42 note [1]. The diamond detector was then aligned in both the uv coordinate plane and in the z dimension (along the direction of the beam) using the fit tracks from the silicon planes.

The previous 10-bit ADC resolution of the Sirocco digitizers was modified to 8-bit resolution for the silicon planes, and to 12-bit resolution for the diamond planes. This resulted in a new raw data format. Since the online readout retained 10-bit resolution, it also means that the online calibration constants for the diamond planes need to be corrected by a factor of four when used in offline analyses. Thus the DBDS-39 online calibration of 114 $\pm$ 10 e^-/ADC corresponds to a calibration of 28.5 $\pm$ 2.5 e^-/ADC for offline analyses [2].

The diamond is first aligned in the uv plane. The telescope coordinate u is initially assumed to be in the diamond plane and perpendicular to the diamond strips, while v is parallel to the strips. A clustered analysis selects diamond hit clusters near the position of tracks extrapolated from the silicon telescope. The diamond hit measures a position in u, and the difference between this position and the position in u of the extrapolated track, Δu, is plotted as a

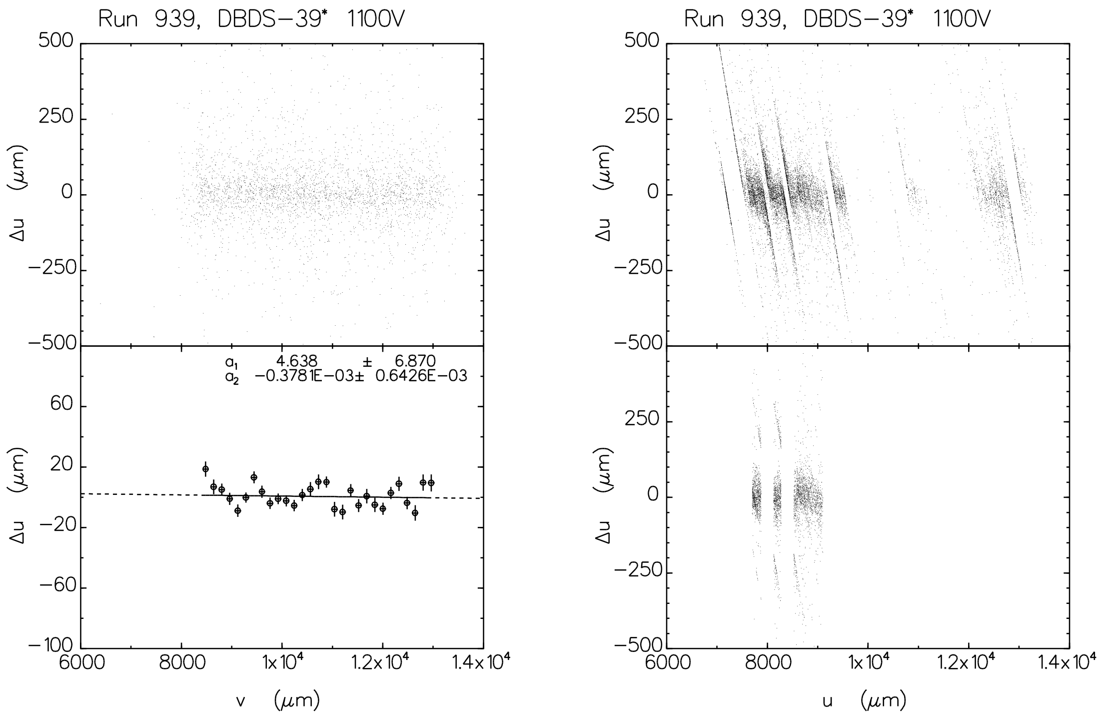

Figure 1: The plots on the left show the diamond alignment. The difference Δu between the diamond hit and the extrapolated track is plotted as a function of telescope v position. The top plot shows the scatter of the hits. The bottom plot shows the alignment fit using only hits with $|\Delta u| < 100$ μm within final fiducial cuts. The plots on the right show the fiducial region selection. Δu plotted as a function of telescope u position. The top plot includes noisy and inefficient strips. The bottom plot shows hits within selected fiducial regions; some remnants of the diagonal noise streaks are still visible.

function of v in figure 1 (on the left). Slope and offset corrections yield the diamond alignment parameters.

The plots on the right in figure 1 show Δu as a function of u, where u is the telescope coordinate perpendicular to the diamond strips. Dead and noisy strips are immediately apparent. The diagonal streaking is due to noisy strips which fire when a track intersects the diamond plane as much as 500 μm away. However, these strips are quiet in the absence of a nearby track; otherwise they would fail the rms cut on good hits.

Only a very small region of the diamond was suitable for analysis, 4500 μm in v, and an aggregate of about 900 μm in u, corresponding to less than twenty strips. Hits in the fiducial regions in u are shown in the bottom plot on the right of figure 1. Intruding diagonal noise streaks could not be avoided, and these contribute to the tails of the resolution distribution beyond 150 μm. This should not affect the fit for the resolution, however, since the fit is restricted to hits with a Δu between −100 μm and +100 μm.

The z position of DBDS-39 relative to plane 1 of the silicon telescope was initially uncertain. Track extrapolations using the initial z position of 7.0 cm yielded diamond resolutions above a hundred μm. It is possible that the ordering of the silicon telescope planes may have changed

Run Number	DBDS-39 status	rms noise ADC counts	3-strip signal ADC counts	5-strip signal ADC counts	resolution μm
920	part irrad 900 V	7.24	311.3	385.0	43.2
938	irrad 900 V	7.66	373.3	438.8	34.8
939	irrad 1100 V	7.72	347.2	430.6	42.5

Table 1: DBDS-39 properties as measured for each run: mean rms noise, mean three-strip and five-strip transparent signal, and resolution.

in the new raw data format, or else that the slot positions may have been recorded from the opposite side of the apparatus as compared with previous test beam runs.

The best z position was obtained from the data by varying z and fitting for the minimum rms of Δu (see figure 2). All three data runs agree to within a few cm on a DBDS-39 z position of 15.5 cm. It has been verified that other z positions within a few cm (*e.g.*, 18.0 cm obtained from a measurement of slot position) do not alter the results of the analysis.

3 Performance Results

The signal size in the diamond is measured by adding up the pulse heights on the strips nearest the extrapolated track position, provided that the track has passed through a fiducial region on the diamond. This transparent analysis does not depend on thresholds or clusterfinding in the diamond and therefore yields an unbiased estimate of the total signal which is contained in the specified number of strips.

Figure 3 shows distributions of the summed pulse heights of the central 3 and 5 strips, respectively. The shaded bin shows the rms noise distribution of a single strip, which has a mean of 7 or 8 ADC counts. The plots running from top to bottom show distributions for data runs 920, 938, and 939. DBDS-39 was initially biased at 900 V in run 920. It was not formally depumped and it may have still been partially pumped from earlier tests. It may also have been partially depumped by ambient light. Between runs 920 and 938, DBDS-39 was exposed to two ^{90}Sr sources. Run 938 shows a very mild pump up of 15 or 20%, still at 900 V. Finally, run 939 at 1100 V shows a slight decrease in signal size. The measured parameters are listed in table 1.

A 5-strip mean signal of 438.8 ADC counts in run 938 corresponds to 12500 $\pm$1100 e^- at a calibration of 28.5 $\pm$ 2.5 e^-/ADC, or 347 μm collection distance. Dividing the 5-strip mean signal by the single strip rms noise of 7.66 ADC counts yields a signal-to-noise ratio of 57/1.

In the past we have usually quoted 3-strip mean signals. For run 938 that would be 373.3 ADC counts, corresponding to 10600 $\pm$ 900 e^-, or 296 μm collection distance.

A cross check on the calibration has been performed using the (pumped) F detector in run 939. This detector suffered from poorly metallized strips and only every second strip was bonded to a readout channel. The other strips were left floating. No alignment of F was attempted; however, the cluster signal distribution is shown in figure 4. The mean signal is 97.9 ADC counts, and the mean seed strip rms is 9.5 ADC counts, for a signal-to-noise ratio of 10/1. Using the measured calibration constant of 37 $\pm$ 4 e^-/ADC, this corresponds to a mean signal of 3600 $\pm$ 400 e^-, or a collection distance of 100 μm. This is approximately consistent with earlier measurements of the F diamond signal, and provides limited support

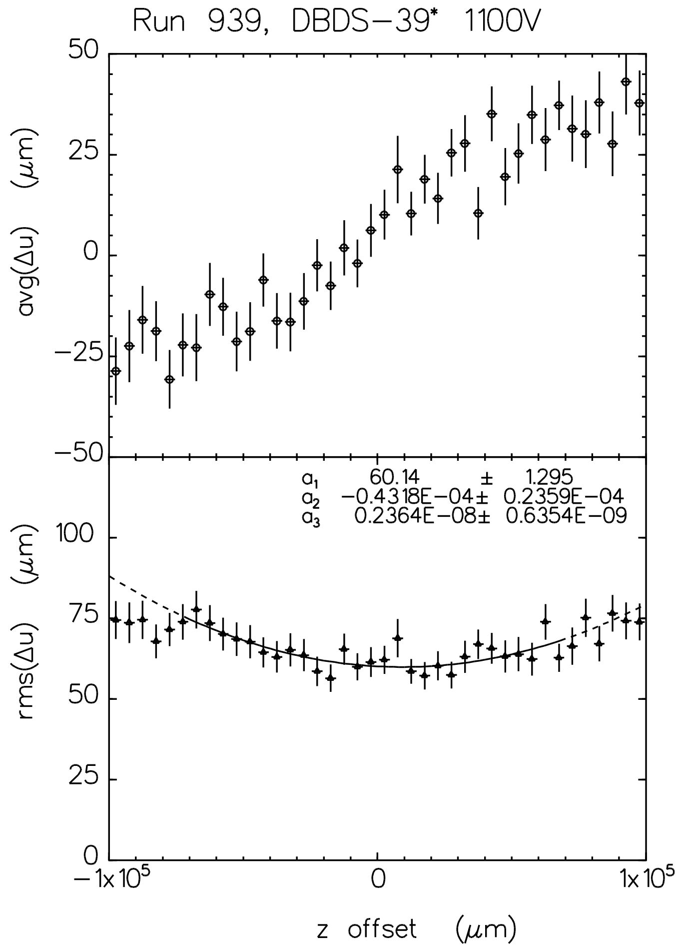

Figure 2: Obtaining the z position from data. The horizontal axis represents a z offset, ranging from -10.0 cm to +10.0 cm, to the nominal z position of 15.5 cm. The top plot shows the average Δu as a function of this offset. The linear slope in the top plot suggests that the beam is passing through the telescope at an angle of approximately 0.5 mrad to the telescope coordinate system. Deviations from linearity near ± 10 cm are due to a cut against outliers in Δu. The bottom shows a parabolic fit to the rms errors of the points in the top plot. The fit range is from -7.0 cm to +7.0 cm, and the minimum is located at +0.9 cm. This agrees to within a cm with the minima obtained from runs 920 and 938.

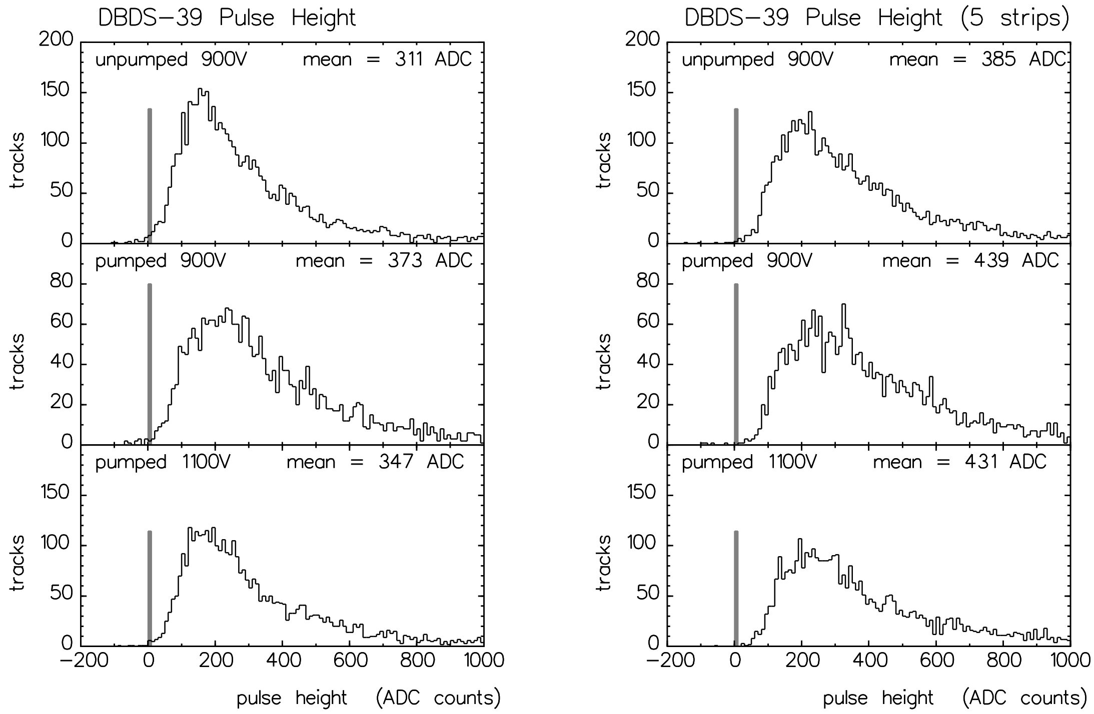

Figure 3: Three and five strip signal distribution for DBDS-39. The summed pulseheight of the central three strips around the extrapolated track is shown on the left, the sum of five strips on the right. The open histogram is the summed pulseheight. The shaded bin is the rms noise distribution of a single strip. The plots from top to bottom correspond to data runs 920, 938, and 939. Here and in the other plots "unpumped" refers to the state of the diamond before the pumping which occurred between runs 920 and 938. DBDS-39 was not depumped before run 920, and may have still been partially pumped from earlier tests.

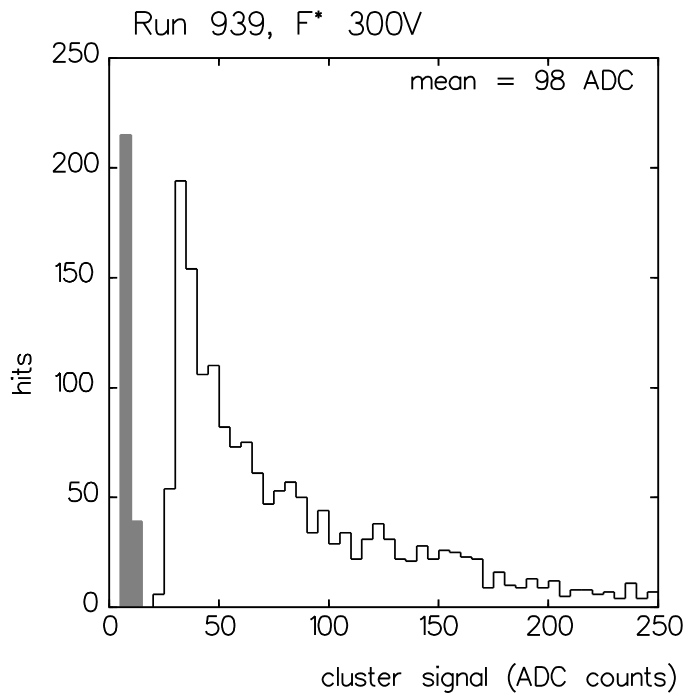

Figure 4: Calibration crosscheck. Cluster hit signal distribution for the pumped F detector in run 939. No alignment was attempted, and this is not a transparent signal distribution. The open histogram shows the hit pulseheight distribution, with a clear cutoff around 25 ADC counts. The shaded histogram shows the rms noise distribution of the cluster seed strip.

for the corresponding calibration of DBDS-39. The effect of the alternate-strip readout on the expected signal for F is, however, unknown.

The fact that the signal of DBDS-39 is not contained in 3 strips (nor completely in 5) indicates that this diamond has rather broad hit clusters. The average shape of the cluster may be inferred from the strip response function, shown in figure 5. This plot shows the average response of a strip to tracks falling in the range from five strips on the left to five strips on the right of the strip in question. A gaussian fit to the central region from –1.0 to +1.0 strips has a standard deviation of 0.83 strips, but there are large positive tails. These tails contrast with the behavior of other detectors (Norton F and X) tested with strips placed on the high collection distance side of the diamond; in those cases the tails were negative, dipping below zero beyond ± 1 strip units. The positive tails of DBDS-39 extend out to ± 5 strip units, or ± 250 μm.

The strip response function suggests that extending the pulseheight sum of the transparent analysis from 5 central strips, e.g. to 7 strips, would add ten or twenty ADC counts to the summed signal. The additional signal in such broad clusters would not be useful for tracking, however.

Multistrip clusters, if uniform, should allow improved position resolution due to charge sharing. Here the benchmark is digital resolution, 14.4 μm for a 50 μm pitch detector. However, the clusters in DBDS-39 are not uniform. Some sample clusters are shown in figure 6. There is great variability among the cluster shapes. Some are symmetric, others are irregular. The cluster width ranges from one to eleven strips. Neither the center of mass of the cluster nor

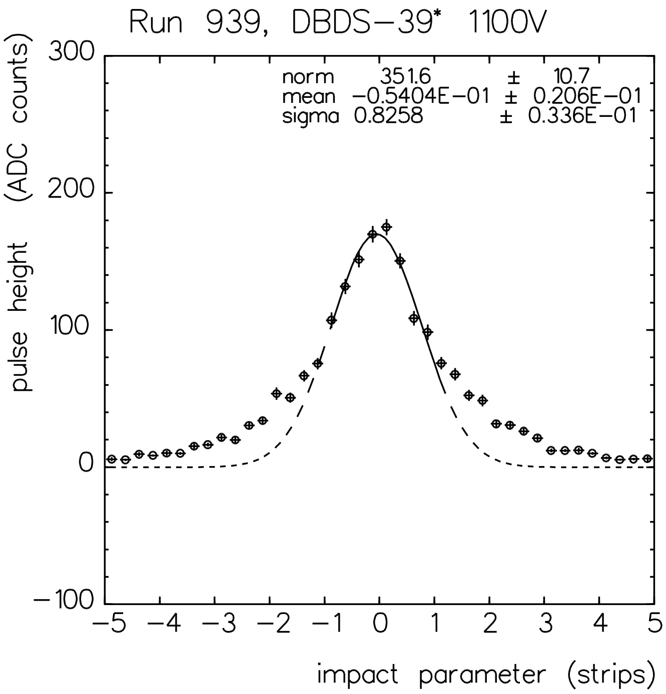

Figure 5: Strip response function for DBDS-39. The average pulseheight on a given strip is plotted as a function of the distance between the strip and the extrapolated track. The gaussian fit is performed in the range from -1.0 to +1.0 strip pitch units.

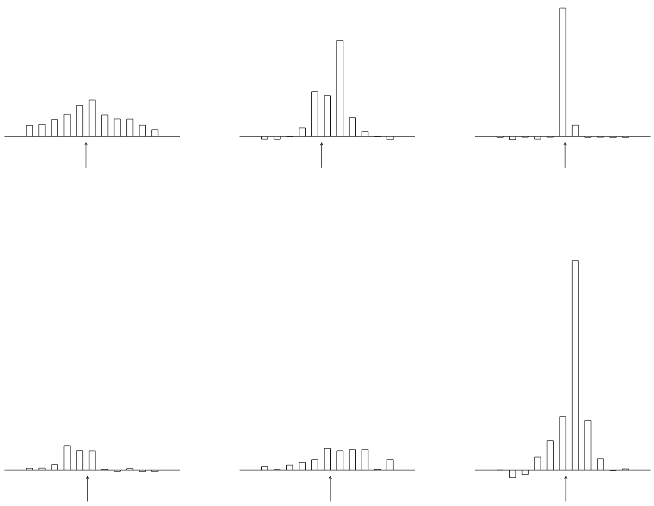

Figure 6: Sample hit clusters from DBDS-39 in run 939. The arrow shows the position of the extrapolated track. Both wide and narrow clusters are represented, with the largest pulseheight not necessarily found on the strip closest to the extrapolated track.

the strip with the maximum pulseheight necessarily falls close to the extrapolated track.

The alignment is believed to be accurate to a small fraction of a strip pitch. The resolution fits are shown in figure 7.

The correlation between the pulseheight on the strip nearest the extrapolated track and its neighbors is shown in figure 8. Previous diamonds with strips placed on the higher collection distance side showed negative correlation: large central strip pulseheight was associated with negative side strip pulseheight. DBDS-39 shows no sign of negative correlation.

Figure 9 shows, on the left, the number of strips included in the cluster as a function of the total cluster charge. The seed strip of the cluster must have a pulseheight three sigma over the rms noise of the strip. Additional strips must be two sigma over noise. The average number of strips per cluster levels off at five or six strips once the total cluster charge exceeds four hundred ADC counts. On the right in figure 9 is a plot of the summed pulseheight of the three strips nearest the extrapolated track, as a function of the interstrip position of the track. The middle of one strip is s = 0, the middle of the next strip is s = 1. The plot is consistent with either flatness or slight interstrip charge loss.

4 Conclusion

DBDS-39 is the thickest diamond tested so far in a beam. The analysis confirms the large signal size and good signal-to-noise ratio seen in bench tests of DBDS-39. However, the hit clusters are broad, and resolution is as much as three times worse than digital resolution. The diamond shows wide and irregular clusters. This contrasts with narrow clusters seen on the high collection distance side of Norton diamonds. Alternative explanations of the DBDS-39

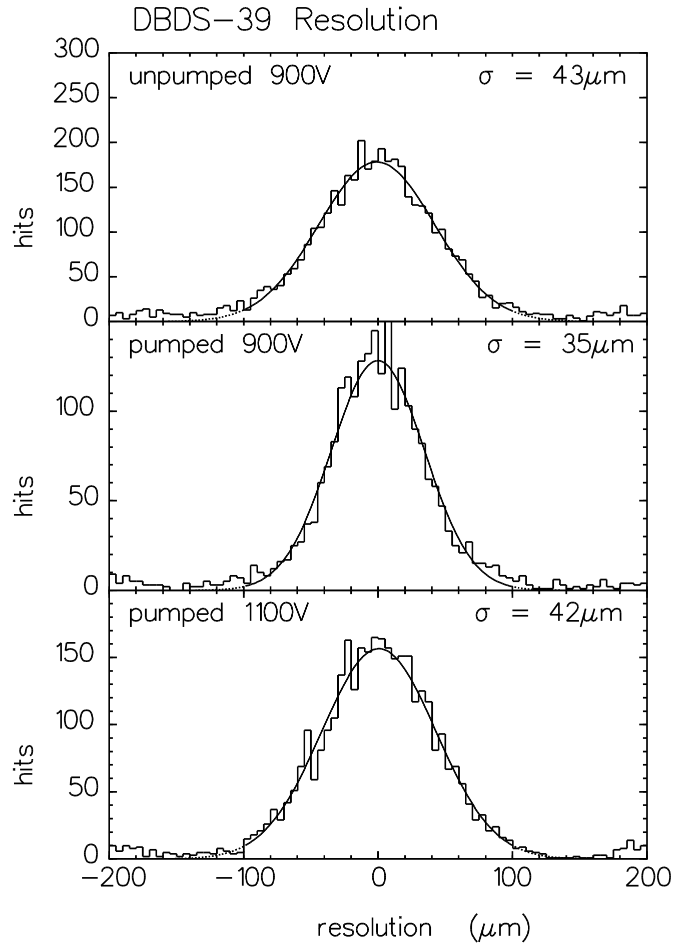

Figure 7: Resolution of DBDS-39 for runs 920, 938, and 939, shown with a gaussian fit in the range –100 μm to +100 μm. Entries beyond this range are noise hits entering due to the imperfect fiducial regions. Expected digital resolution for the 50 μm strip pitch is 14.4 μm.

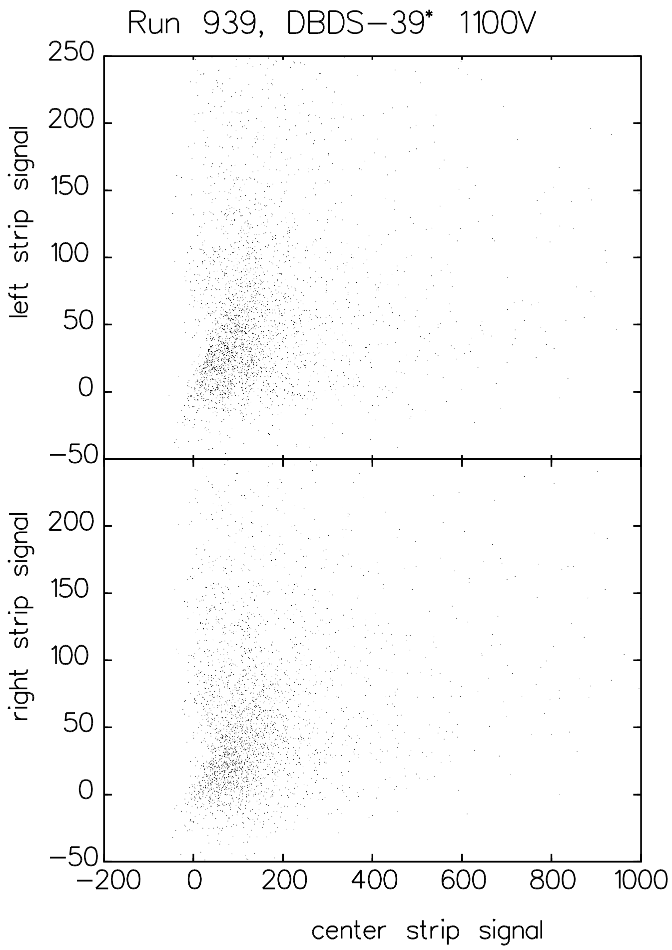

Figure 8: Correlation between the pulseheight on the central strip nearest the extrapolated track and the pulseheight on the left and right neighboring strips, respectively. No sign of negative correlation is observed.

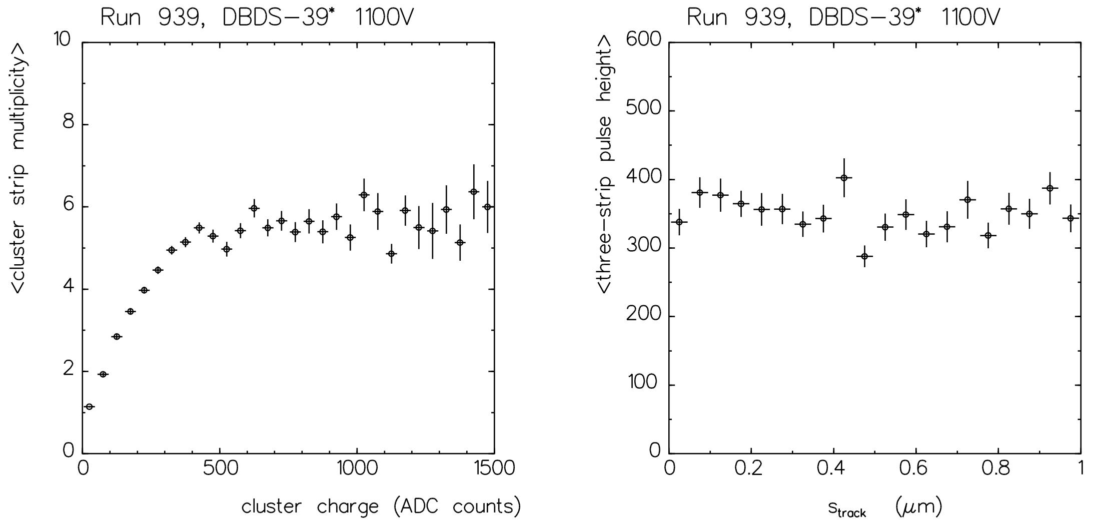

Figure 9: Number of strips per cluster as a function of total cluster charge, and three-strip summed pulseheight as a function of interstrip distance. The plot on the left shows the average number of strips included in the cluster in the n-strip algorithm. The average number of strips levels off at five or six strips above four hundred ADC counts total charge. The right plot shows the transparent three-strip signal sum for tracks passing through the diamond, as a function of the position of the track between the strips. The effect of any interstrip charge loss is small.

pulseshape are presently being modelled, taking into account the geometry and non-uniform collection distance of the diamond.

Interference from selectively noisy strips restricted the area of the diamond that could be used in the analysis. These noisy strips pass rms cuts and appear to fire only when stimulated by real hits located as much as 500 μm away. This problem has also been observed, though less frequently, with Norton diamonds.

Mean signals sizes above 10000 e^- have been seen in diamond for the first time in a beam test. However, the "wide and irregular cluster" problem and the "noisy strip" problem still pose challenges to the construction of practical tracking detectors.

References

[1] Note RD42-2, "Results from the 50 micron Diamond Tracker in the RD42 May 95 Beam Test at Cern," John Conway.

[2] private communication, Dirk Meier.