Beam tests of a diamond strip detector with fast radiation hard readout electronics (SCT32)

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January 20, 1997

1 Introduction

A diamond strip detector (Norton diamond F) based on CVD diamond substrate has been tested in a beam test at the CERN SPS X5 area with high energetic pions. The detector is 6.8×6.8 mm^2 large with 25μm wide strips at a pitch of 50μm. Two adjacent strips were connected together to one readout channel of a radiation hard DMILL SCT32 readout chip [1]. Hence the actual readout pitch is 100μm. Prior to the beam test the detector has been pumped with a ^{90}Sr source for 17 hours.

The reference system consists of 4 reference planes, which measure both horizontal and vertical track coordinates with a precision of 1.5μm. The diamond detector was placed in the center of the telescope during the tests. The readout of the diamond detector was controlled by a sequencer which supplied the control signals to the SCT chip. After receiving the trigger signal provided by scintillators it sent the hold signal to the SCT to store the signal. The times of the hold signal and the scintillator trigger were recorded in a TDC (100ps/TDC count). This time information was later used in the analysis to determine the precise delay between hold and trigger signal.

In the analysis events are selected by requiring exactly one track measured in both co-ordinates in all reference planes. The particle track is reconstructed as a straight line and a track extrapolation is made to the diamond detector. Tracks were demanded to be in the central region of the diamond detector. Events with a predicted hit on the first eleven and last three strips of the diamond were rejected because of electronic problems on these SCT readout channels.

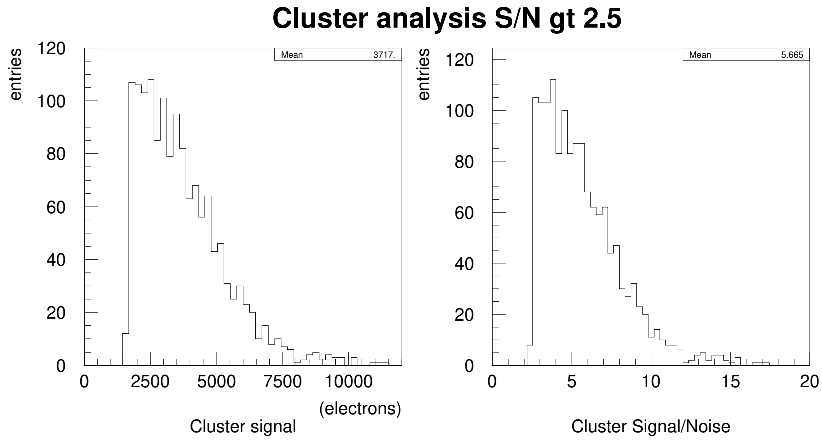

Figure 1: Cluster signal distribution and signal to noise distribution obtained in the cluster analysis with a S/N threshold of 2.5

2 Cluster analysis

Prior to the cluster search the raw data are corrected for the channel pedestal and common mode shifts of the signal. This yields a gaussian noise distribution with a standard deviation of 656 electrons for a single channel. A calibration constant of $138e^{-}/ADC$ was determined by laboratory measurements of the chip noise. A cluster on the diamond is defined as sequence of strips with a signal to noise ratio (S/N) higher than 1.0 . Clusters were accepted in the analysis if the total cluster S/N was higher than 2.5 and the cluster was located in a 0.3mm wide region around the predicted hit position. The cluster position was reconstructed with the η-algorithm.

Using the TDC data a time window was determined, where the hold signal was recorded in a 12ns wide region around the peaking time of the amplifier (see section 3). Events with a hold time in this window are accepted for the cluster analysis.

Figure 1 shows the cluster signal distribution and the cluster S/N distribution for the diamond. A mean signal of 3700 electrons and a mean S/N of 5.7 was measured. Both values are biased towards higher signal, or S/N, due to the threshold on the cluster S/N. Figure 2 shows the residual of measured minus predicted hit position for the diamond. The measured spatial resolution of 36μm is close to the digital resolution of readout pitch divided by $\sqrt{12}$.

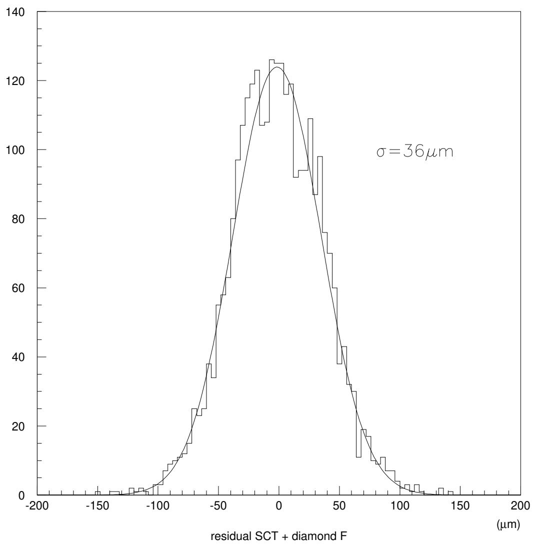

Figure 2: Diamond F residual distribution

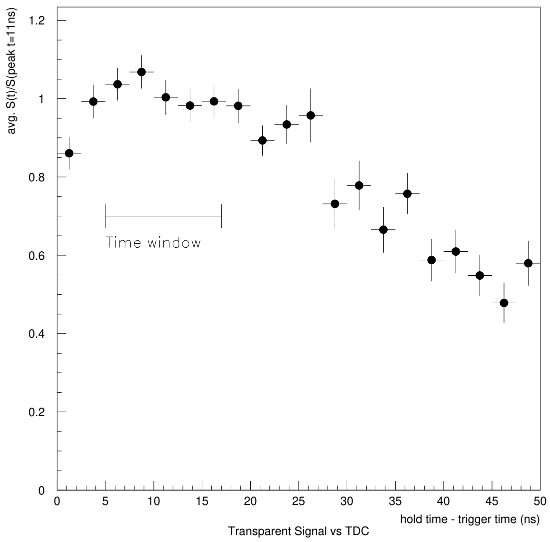

Figure 3: Transparent signal on three strips versus time difference of hold and trigger signal

In the cluster analysis with a threshold of 2.5 on the cluster signal to noise the efficiency is determined to be 67% only. Previous test beam measurements indicated an efficiency higher than 90% for this diamond [2]. The difference is thought to be due to two reasons: Firstly for some events the hold signal was not properly distributed to the SCT chip, thus the signal not measured. Secondly the cut on the cluster S/N removes events with small signals from the analysis. To cross-check the latter hypothesis a so-called transparent signal analysis was carried out on the diamond data.

3 Transparent signal analysis

In order to obtain an unbiased estimate of the diamond signal, only the hit prediction is used on the signal search. No cut is applied to the number of clusters found on the diamond or diamond signal. The so-called transparent signal is calculated as the signal sum of three strips closest to the predicted hit position. In this way also small signals are considered in the analysis.

Figure 3 shows the average transparent signal versus the time difference between hold and trigger signal. The average signal is normalized to the average

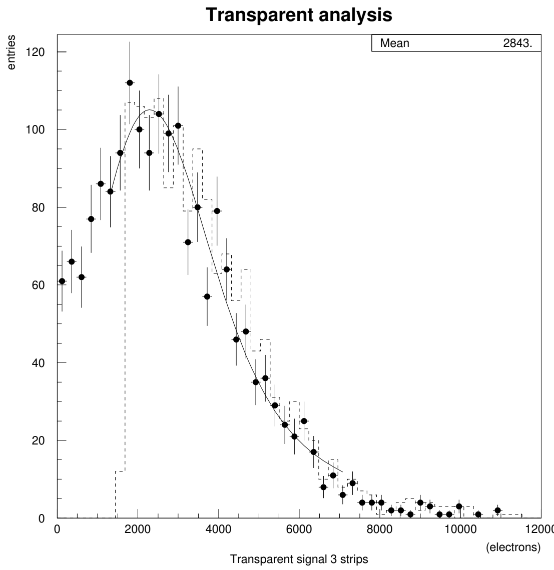

Figure 4: Transparent signal on three strips (markers) fitted by a Landau convoluted with a gaussian distribution (solid line). The cluster signal obtained with a S/N threshold of 2.5 is superimposed as a dashed line.

peak signal. The plot indicates the time window used in full analysis. A clear decrease of signal is observed for events where the hold signal arrives after the peaking time of the amplifier. Figure 4 shows the transparent signal on three strips for events in the time window (markers). A Landau distribution convoluted with a gaussian ($\sigma_{fit} = \sqrt{3}\sigma_{noise}$) is fitted to the transparent signal. This yields a peak transparent signal of 2300 e^-, equivalent to a S/N of 3.5, and a mean signal of 2843 e^-, corresponding to a mean S/N of 4.33. Previous measurements of this diamond with slow electronics (VA2) yielded a most probable signal of 2240 electrons [2]. The comparison indicates that no significant part of the signal is lost due to the fast shaping time. Using previous signal measurements of this diamond and the noise obtained for the SCT one expects a peak S/N comparable to the measured S/N. As a dashed line the cluster signal obtained with a S/N threshold of 2.5 is superimposed. The difference for small signals suggest that the S/N threshold removes some fraction of the signal distribution and hence contributes to the inefficiency.

4 Conclusion

A CVD based diamond strip detector with 100μm readout pitch has been tested with fast radiation hard readout electronics. As a readout chip the SCT32 with a peaking time of 25 ns was chosen. An equivalent noise charge of 656 electrons was measured for the SCT chip connected to the diamond after common mode correction. Track signals were reconstructed on the diamond yielding a spatial resolution of 36μm and a mean S/N of 4.3.

References

[1] SCT32 reference !!!!

[2] W.Adam, H.Pernegger, Behaviour of CVD diamond strip detectors in magnetic field, RD42-TN-6