Note RD42-5

Results from the October 95 testbeam

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Abstract

We report on the performance of the diamond tracker prototype as studied during the test beam in October 1995 at CERN. Charge collection and spatial resolution of the detector were investigated. The spatial resolution of the 50 μm strip-pitch device varied from 9 μm to 14 μm depending on the irradiation ("pump state") of the detector.

1 Detector design

The diamond wafer, with a thickness of $610\,\mu$m was grown by the company Norton. The tracker denoted as F has 128 metal strips with a strip pitch of $50\,\mu$m and a strip width of $25\,\mu$m. The sensitive area is $6.4 \times 6.4\,\mathrm{mm}^2$. The detector was operated at 300 V. Its read out was performed by a VA2 chip. For the calibration of the system there was an external capacitor on one VA2 channel. A voltage step on the capacitor produced a known charge on the input of the amplifier. The measured calibration constant was $27\,\mathrm{e}^-$ per ADC count.

2 Experimental setup

The detector was put into a 100 GeV pion beam at CERN. The position of the hits was predicted by four planes of double-sided silicon strip detectors with a spatial resolution of about $1\,\mu$m in a single plane.

The properties of the diamond detector were studied in the so-called "unpumped" state (we refer to this state as F) as well as after irradiation ("pumped state") of the detector by ^{90}Sr for 17 hours (F*) and 28 hours (F**).

3 Off-line analysis

We used the TELANA program to process the data. It searches for signal clusters, calculates hit positions on the detectors and uses a straight line fit to find particle tracks. It also suggests shifts and rotations of the detectors for alignment. Reference detectors are aligned first and then the aligned telescope is used for a prediction of the hit position on the test detector. As a signal cluster on the diamond detector we accept a group of adjacent strips with each single strip having $(\frac{S}{N})_i > 1.5$ and the sum over the signal-to-noise ratio of all strips $\sum(\frac{S}{N})_i > 6$. Events with more than 1 cluster, events out of detector acceptance and hits with predicted impact point close to noisy or dead strips were rejected.

The hit position is calculated by the eta algorithm

$$x = \Delta \int_o^{\eta} \frac{dN}{d\eta} d\eta + x_0 \qquad (1)$$

where Δ is the strip pitch, x_0 corresponds to the position of the left strip centre and $\frac{dN}{d\eta}$ is obtained using

$$\eta = \frac{S_R}{S_L + S_R} \tag{2}$$

S_L (S_R) denotes the signal collected on the left (right) strip in the cluster. $\frac{dN}{d\eta}$ must be normalised. When there are more than two strips in the cluster the hit position is evaluated from the strip with the highest signal and the neighbour with the second highest signal. For single strip clusters the hit position is just given by the strip position.

4 Results

Fig. 1a) shows the distribution of the cluster width. In the unpumped state about 27% of all clusters are formed by two strips and about 50% of the clusters have more than two strips. After irradiation the contribution of clusters with more than two strips becomes smaller. As a consequence for the transparent analysis it is sufficient to collect the signal from three strips surrounding the predicted hit position.

The most probable signal collected on a given number of strips is plotted in Fig. 1b). After irradiation of the tracker for 17 hours the collected signal increased by a factor of 3. Further irradiation increases the collected signal moderately.

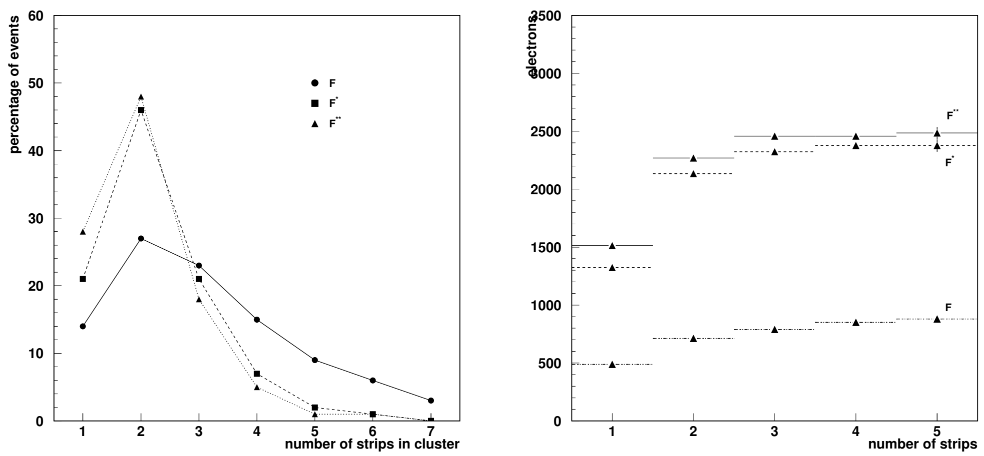

Figure 1: a) Cluster width b) Most probable signal collected on strips.

Fig. 2 shows the charge spread on the detector. The plots present the average signal deposited on a single strip which has its centre in the distance x from the predicted hit position. The horizontal line in the plot corresponds to our request to have $(\frac{S}{N})_i > 1.5$ in the cluster search.

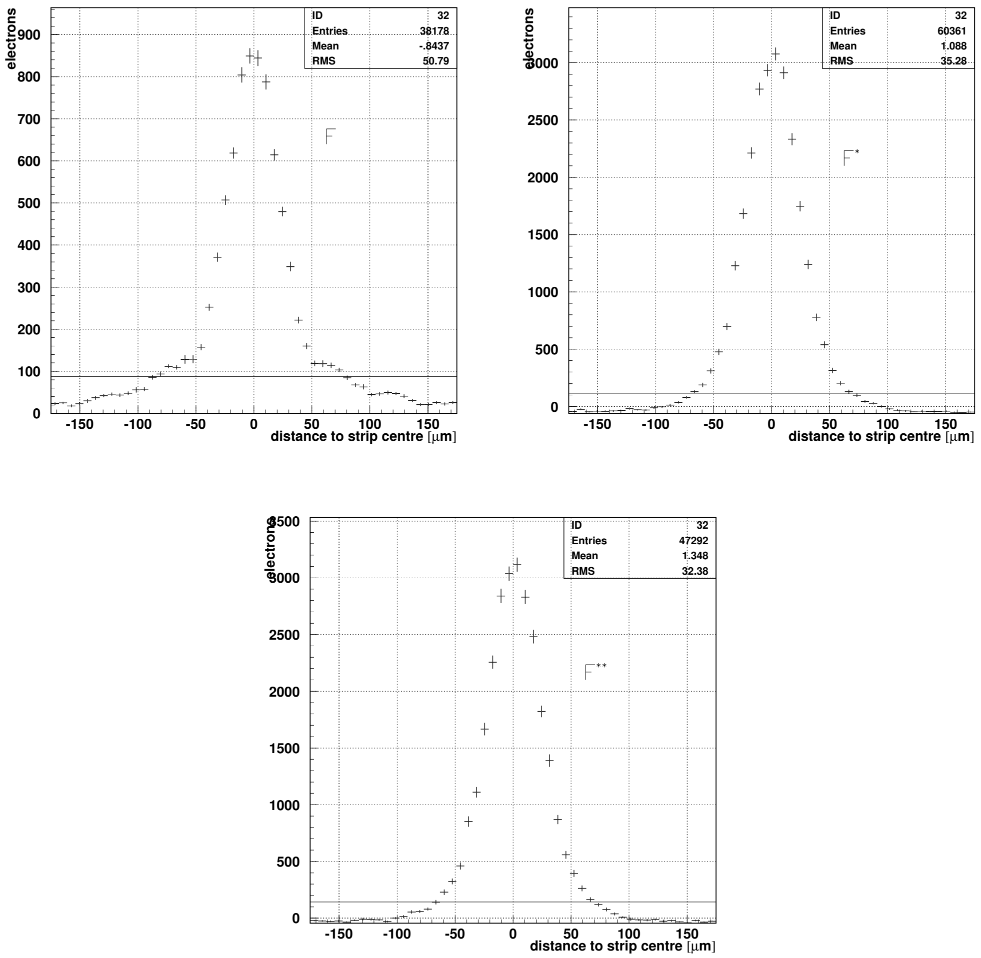

Figure 2: Average signal collected on a single strip in the distance x from the predicted hit position.

Fig. 3 presents the signal distributions. The signal is calculated as the sum of the signals on the three strips closest to the extrapolated hit position. The maximum of the signal distribution for detector F** is at (2440 ± 30)

electrons. The fit is an approximation [1] of the Landau function

$$S(x) = p_3 exp(-\frac{\lambda + e^{-\lambda}}{2}) \tag{3}$$

where $\lambda = \frac{x-p_2}{p_1}$. The results of the fit are given in Table 1. The signal increases by a factor of 3 with respect to the unpumped state. The increase in the signal-to-noise ratio is not so large because the noise of the detector is also increasing after irradiation. The average noise of a single strip for detector F** is 95 electrons.

	F	F*	F**
Signal [electrons]	780 ± 6	2390 ± 20	2440 ± 30
Noise [electrons]	58.5 ± 0.5	76.5 ± 0.1	94.5 ± 0.5
S/N	12.8 ± 0.1	27.1 ± 0.3	22.0 ± 0.3

Table 1: Comparision of signal and noise for different pumping states. Values of the signal S and the signal-to-noise ratio S/N are obtained from the fit of the Landau peak in the corresponding distributions. Noise N is a single-strip noise averaged over all strips of the detector.

The spatial resolution of the detector was measured to be $9\,\mu$m in the unpumped state. It changed to $14\,\mu$m after irradiation. In Fig. 4 residuals between measured and extrapolated position are plotted.

	F	F*	F**
σ [μm]	8.8 ± 0.1	13.8 ± 0.2	14.3 ± 0.2

Table 2: Spatial resolution of the diamond tracker

We compared the charge sharing between the strips for the unpumped detectors F and the pumped detector F**. The distributions of S_{neigh}/S_{tot} are shown in Fig. 5. S_{neigh} is the signal on the strip next to the strip closest to the predicted hit position and S_{tot} is the total signal in the cluster. One can see that there is a large amount of events with S_{neigh}/S_{tot} greater than 0.5 after irradiation of the detector. The plots in the bottom row of Fig. 5 are scatter plots of the residuals between predicted and measured hit position versus S_{neigh}/S_{tot}. The distribution of the track residuals for events with $S_{neigh}/S_{tot} > 0.5$ is shown in Fig. 6.

A small contribution to the degradation of the spatial resolution is also expected because of the higher percentage of one-strip clusters in case of detector F**.

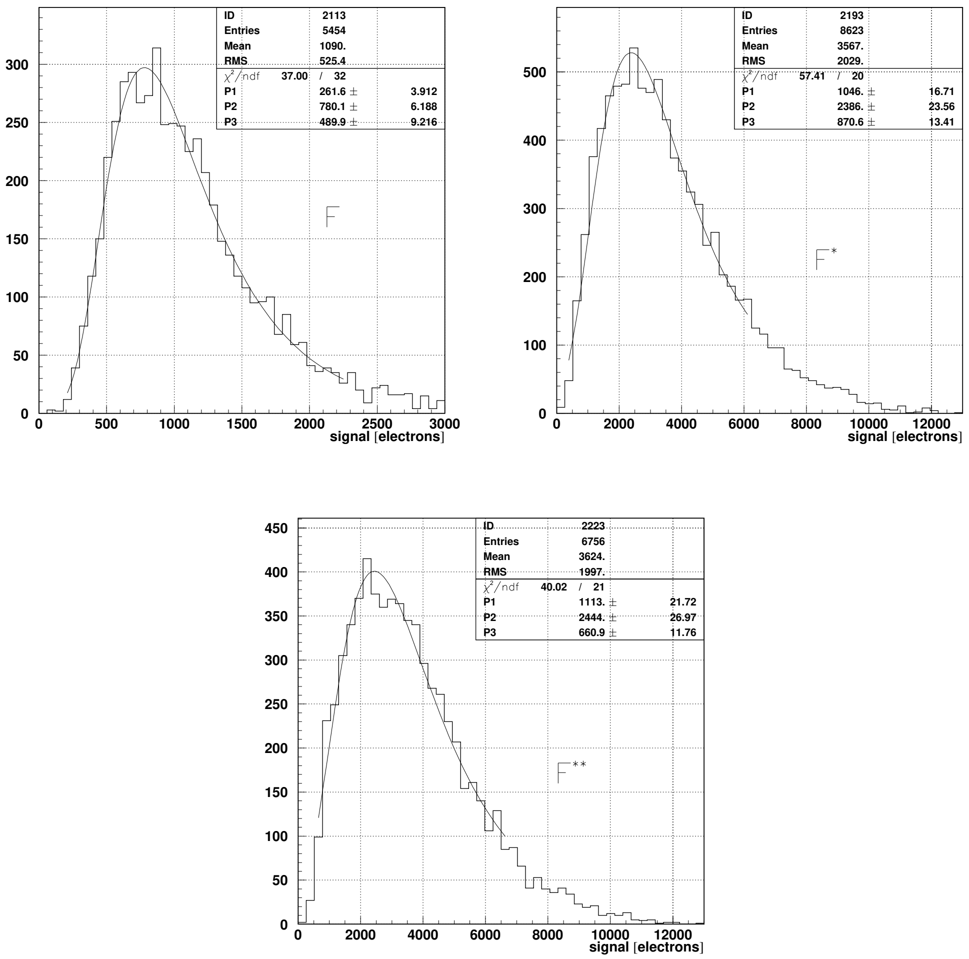

Figure 3: Signal distributions for detectors F, F^{*}, F^{**}. The signal is defined as a sum of signals of the three strips closest to the predicted hit position. The fit is the Moyal approximation of the Landau function.

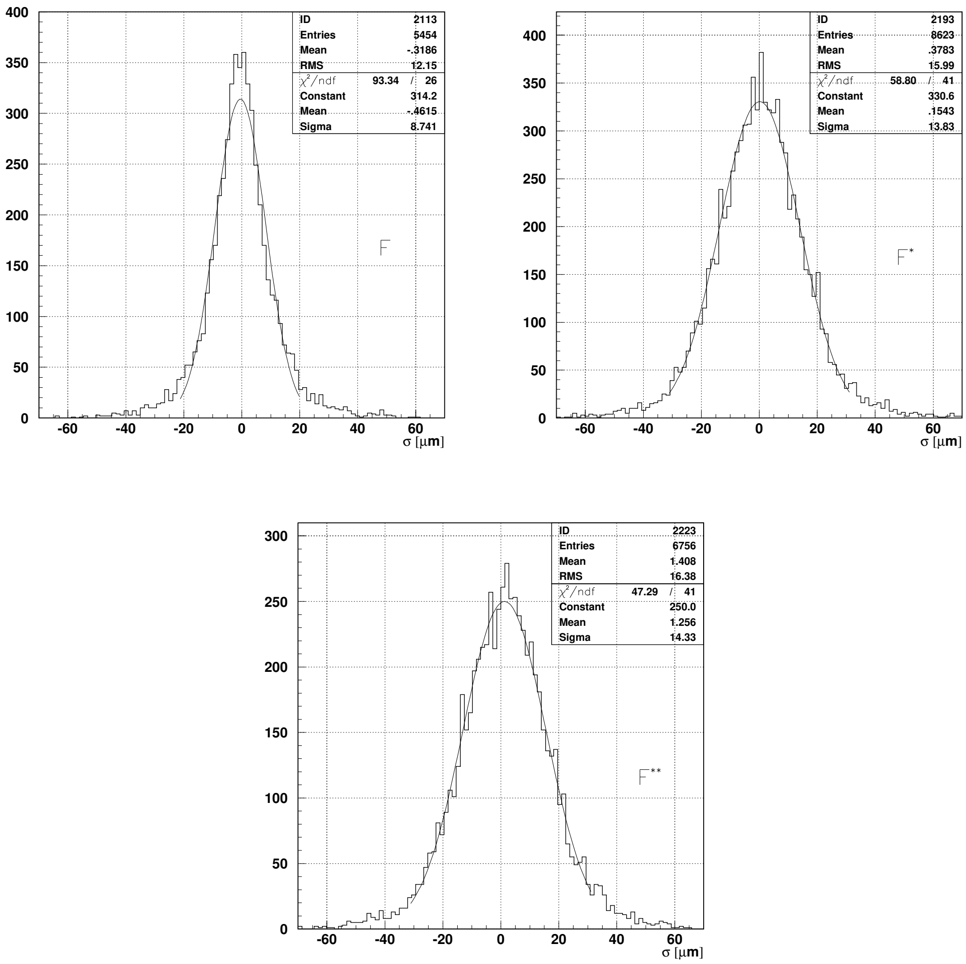

Figure 4: Spatial resolution. Results of the gaussian fit are summarised in Table 2.

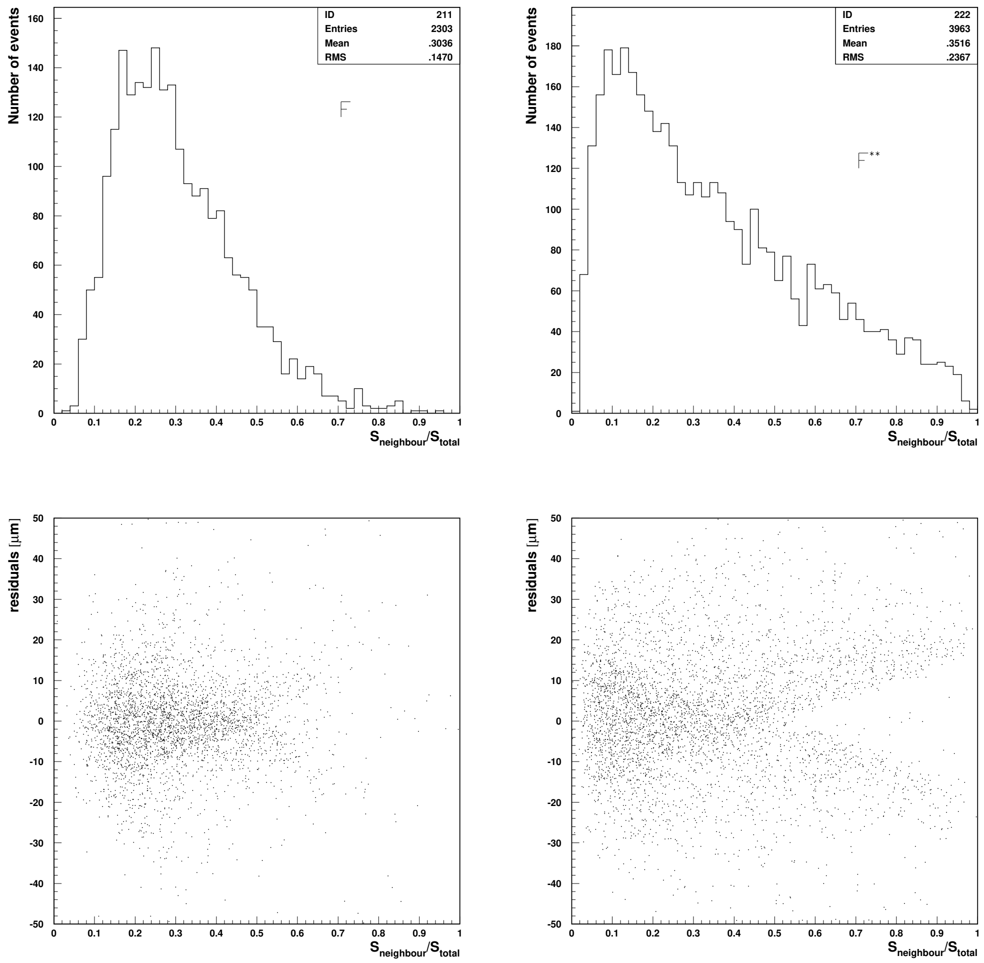

Figure 5: Distributions of S_{neigh}/S_{tot} and scatter plots of residuals vs S_{neigh}/S_{tot}. Only 2- and 3-strip clusters are in the plots.

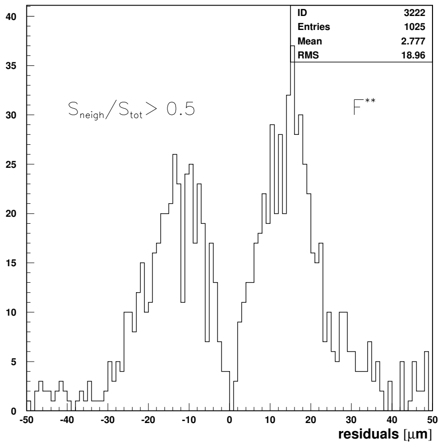

Figure 6: Residuals for the detector F** when a cut $S_{neigh}/S_{tot} > 0.5$ is applied. Approximately one quarter of 2- and 3-strip clusters has S_{neigh}/S_{tot} higher than 0.5.

5 Conclusions

The detector response to a minimum ionising particle depends on the irradiation of the detector. The increase of the signal saturates at approximately 2400 electrons. The irradiation also improves the S/N ratio which increases from 12.8 (unpumped) to 27 (F*) and 22 (F**) respectively.

The spatial resolution of the detector is $9\,\mu$m before irradiation. After irradiation we measure a spatial resolution of about $14\,\mu$m.

6 Acknowledgement

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References

[1] J. E. Moyal, Theory of Ionization Fluctuations, Phil. Mag. 46 (1955) 263.