Test Results of GaAs Strip Detectors in High Energy Particle Beams

W. Braunschweig, W. Karpinski, Th. Kubicki, K. Lübelmeyer, J. Ortmanns, D. Pandoulas, G. Pierschel, C. Rente, R. Siedling, O. Syben, F. Tenbusch, M. Toporowsky, Th. Wilms, B. Wittmer, W. J. Xiao

I. Physikalisches Institut RWTH Aachen, 52056 Aachen, Germany^a

Abstract

The first GaAs strip detector constructed in Aachen has been tested at CERN in a high energy particle beam in August and September 1994. The detector had a pitch of $200\mu\text{m}$ and was made of a $508\mu\text{m}$ thick Freiberger Si-GaAs wafer. Using the low noise Viking preamplifier chip [1] a signal to noise ratio of 13 was obtained at normal beam incidence for a bias voltage of 450V . Signal to noise ratios up to 26 were achieved depending on bias voltage and beam angle. Furthermore the spatial resolution of the GaAs detector was measured to be $72\mu\text{m}$ without any correction for multiple scattering.

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1 Detector Performance and Fabrication

The $508\mu\text{m}$ thick Freiberger wafer has been etched and processed in Aachen. 60 strips with 23mm length and $100\mu\text{m}$ width have been placed with a pitch of $200\mu\text{m}$ on the wafer. In addition to the strips the design included test pad detectors of different areas. Figure 1 shows the arrangement of detectors on the 2 inch wafer. Both contacts of the detector are Schottky contacts formed by NiCr/Au . The backside contact gets forward biased so that it has an ohmic behaviour

Due to the high bias voltage (up to 450V) the strip detector is AC coupled to the input of the Viking preamplifier chip and the high voltage is brought to the detector via a separate power supply line. A special hybrid to support the GaAs detector, the coupling capacitor chip, and the load resistors, has been used in the setup (figure 2). Figure 3 shows the way the detector was coupled to high voltage and preamplifier input.

2 Beam Test Setup

The experiment was carried out with several institutes in collaboration [2] using the X3 beam in the West Area of the SPS at CERN. Most of

Figure 1: The design of the GaAs detector

the data were taken with 50GeV electrons. To define the beam, an X-Y Si beam telescope was installed in the beam line. The telescope consisted of two boxes equipped with beam defining counters. One of the boxes was placed in front of the detectors under test while the other one was placed behind them. The distance between the two boxes was about 1.5m .

Each box included two scintillation counters and four Si strip detectors. The scintillation counters defined a beam of $2 \times 2\text{cm}^2$ while the Si strip detectors with $50\mu\text{m}$ pitch measured the position of the incident particles. Between the two reference boxes there was a specially designed table of $1 \times 1\text{m}^2$ area, which could be moved by

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Figure 2: Al_2O_3 hybrid for the GaAs detector

Figure 3: Circuit with detector, resistor and capacitor

Figure 4: Sideview of the test beam stand

stepping motors in two directions perpendicular to the beam line. The table included alignment holes for all test detectors and allowed their rotation by different angles. An overview over the beam test setup is given in figure 4.

Up to seven detectors could be tested at the same time in this setup. Each detector was mounted in an aluminum frame with alignment holes for positioning them on the table. To avoid multiple scattering the frames were only covered with mylar foil. The Viking preamplifier chips were mounted inside the frame on a special hy-

brid, while additional "repeater cards" for each detector were fixed to the outside of the frame. The low voltage for these readout modules was provided via twisted pair cables, while the high voltage for the GaAs detector was brought via a shielded two conductor cable from a floating battery supply. To avoid noise pick up in the beam area, a low pass filter was placed right beside the aluminum frame in the power supply line of the GaAs detector.

3 Readout

As mentioned before, the collaboration used the low noise Viking preamplifier chip for the readout of the whole system, including the X-Y Si telescope and all devices under test. Each detector was equipped with a repeater card for the definition of the timing and the low power control. The trigger for the readout was formed by the four scintillation counters and passed to the "SRS" module. The timing signals of this module were brought to the repeater cards and to a receiver and ADC in the CAMAC readout system. Figure 5 gives an overview of the readout system.

Figure 5: Schematic overview of the readout system

A single ADC channel was used to readout up to 64 Viking chips of 128 channels each. For this reason the dead time of the system was rather high, so that from the available 4000events/min only about 80events/min were read out. Additionally, every 15 seconds, four random trigger create pedestal events in the data sample. The CAMAC system was read out by a PC (486DX2) and the data were stored on disk (regu-

larly shifted to cartridge tapes). More detailed information about the readout system can be found in [2].

Within three weeks of beam time the collaboration collected $\sim 450k$ events. These resulted in $\sim 150k$ hits on the GaAs detector, since the latter did not cover the entire beam profile. The data sample includes runs with different bias voltages of the GaAs detector and different detector orientation with respect to the beam (see Figure 6).

Figure 6: Definition of the different beam angles in the test experiment

4 Results and Data Handling

Looking at the raw data of the GaAs detector, hits are clearly visible (shown for two different events in figure 7a) even without common noise and pedestal subtraction. After subtraction of common noise and pedestal, the identification gets even easier (figure 7b). Only every fourth channel of the Viking is bonded to the GaAs detector so that 32 GaAs channels are read-out.

A characteristic aspect of the Viking chip is the existence of common noise: For a given event, the pedestal position for each channel is constant relative to that for the other channels; however, the pedestal level varies from event to event. Therefore one can get rid of the common noise by subtracting the mean ADC count of the 128 channels from the data. Treating pedestal events in this way, one can determine the pedestal position and width for each readout channel.

Figure 7: raw data of the GaAs detector before (a) and after (b) common noise and pedestal subtraction

In case of the GaAs detector we found out that the correlated noise was different for the bonded and not bonded channels. Therefore we calculate the common noise using the mean ADC count of the bonded channels only. To avoid systematical errors, channels including a signal are excluded from the common noise calculation by an iterative algorithm.

Given the easily visible hits in the raw data (figure 7), the definition of a cluster algorithm is very easy: We consider a channel to be the seed of a cluster, if after pedestal subtraction it has a signal exceeding the width of the channel pedestal by a factor of four. With this definition, the amount of false hits is only 0.1%. Channels within ± 2 of the seed are then added to the cluster if their signal exceeds their pedestal width by a factor of at least two.

In figure 8 the cluster pulse height spectra for two different runs are shown. The pedestal in the two spectra is artificially inserted to give an idea of the signal to noise ratio. On the right side of figure 8 the multiplicity for the two runs is given. The bias voltage is 450V in both runs, while the beam angles are $\phi = 0^\circ$ and $\Theta = 0^\circ$ in the upper and $\phi = 0^\circ$ and $\Theta = 45^\circ$ in the lower case.

The dependence of the signal to noise ratio on the beam angle of incidence is given in figure 9.

Figure 8: Pulse height spectra and multiplicity for two runs after cluster finding. The pedestal is artificially inserted.

Figure 9: Dependence of the signal to noise ratio on the beam angle

The data vary between values of 13 and 26 and agree well with the theoretical expectation given by the curve. In figure 10 the variation of the signal to noise ratio with the applied bias volt-

Figure 10: Dependence of the signal to noise ratio on the bias voltage

age is shown. As expected the signal increases nearly linearly with the bias voltage. Consistent with the measurements on the test pads carried out before the beam test, the charge collection efficiency at 450V is calculated to be $29 \pm 3\%$ for this $508\mu\text{m}$ thick wafer.

With a simple center of gravity method one can calculate the position of the incident particle on the GaAs detector. For the calculation of the r.m.s. residual a linear fit through the reference sensors is calculated and the deviation of the measured GaAs position from this fit is plotted in figure 11. The residual of $72\mu\text{m}$ is close to the value of $200\mu\text{m}/\sqrt{12}$, which would be obtained for digital readout. However, no correction has been made for multiple scattering due to the other sensors present in the beam line.

5 Conclusion

The first GaAs microstrip detector fabricated in Aachen functioned very well. Particle hits are easy to identify even in raw data and the calculation of the signal to noise ratio leads to a value of 13 at 450V bias voltage and perpendicular beam incidence. The ratio varies from 8 to 26 with different bias voltages and beam angles. The spa-

Figure 11: R.m.s. residual for the 200 μ m pitch GaAs detector without corrections for multiple scattering

tial resolution of 72 μ m, uncorrected for multiple scattering, is close to the digital readout value of $200\mu\text{m}/\sqrt{12}$. Further results will be published in [3].

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