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Test of BeO prototype hybrids for SVXII

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Abstract

The noise performance of BeO prototype hybrids for the SVXII detector is examined. Most measurements were carried out using SVX2b readout chips. The noise observed in various stages of ladder assembly is consistent with expectations from circuit simulation results. No increase in noise is observed when a hybrid is glued directly to the surface of a sensor.

1 Introduction

The purpose of these tests was to make an assessment of the performance of BeO prototype hybrids for the SVXII detector. Two prototypes are available, one using SVX2 chips and one using SVX3 chips. Using an SVX2 hybrid, we read out a silicon sensor before and after the hybrid was glued directly on the surface, and looked for changes in the observed noise. SVX3 measurements were limited to the noise of a hybrid by itself due to the lack of detailed understanding of SVX3 chip operation at the present time.

A hybrid consists of a BeO substrate coated with a thick film printed circuit containing 6 conductor layers. Each holds two SVX2/3 chips as well as surface mount components.

Noise was measured in terms of the root mean square (rms) of 20 samples of a differential signal (referred to as dnoise). The differential signal of channel i is given by

$$D_i = ADC_i - \frac{1}{N-1}\sum_{i\neq j} ADC_j \qquad (1)$$

where ADC is the signal recorded by the channel in integer counts, and N is the total number of channels tested. Typically, 24 to 40 channels were tested at a time, and the dnoise values reported are an average from all the channels tested. Additionally, since an ADC count is not a meaningful unit, the dnoise values obtained have been scaled by the measured chip gain (in ADC/electrons) to convert them into electrons:

$$dnoise = gain^{-1} \times \frac{1}{N} \sum_j rms(D_j) \tag{2}$$

Unless otherwise noted, all tests were performed with a preamplifier bandwidth setting of 0 (fastest setting) and 120 ns integration time. Also, all measurements were carried out inside a dark metal box.

In order to have control measurements, some of the channels from a bare silicon sensor were first wire bonded to a readout chip mounted on a printed circuit board. Dnoise was measured as a function of bias voltage. Then the same measurements were made after glue was applied to the silicon, and after the hybrid was placed on the sensor, before and after the glue was cured, but always using the chip on the board. Finally, some of the channels from the chips on the hybrid were wire bonded to the silicon, and dnoise was measured using the hybrid.

To assemble the hybrids, first the surface mount components were soldered to the hybrid at 210°C. A flex test cable was also soldered, and the SVX2/3 chips were glued with a conductive epoxy cured at 150° C. SVX2 hybrids were instrumented with 2 chips each. On SVX3 hybrids we mounted only one chip set, and added additional bypassing to try to match recommendations for front end chip operation that were not known at the time the hybrids were manufactured.

2 Unloaded PreAmp Noise and Gain

Noise from SVX2 chips with floating inputs, both on a printed circuit board and on hybrids, was measured and compared to SPICE simulation predictions [1]. The necessary gain determination was done by measuring ADC counts as a function of calibration voltage and assuming a 50fF calibration capacitor. This was done independently for each chip: on average, the inverse gain was about 2400 electrons/count. Our assumption for the calibration capacitor value could easily be off by 10%, which results in the dominant uncertainty in all dnoise figures given in this paper. It is common (fully correlated) to all numbers and is not explicitly quoted, as it drops out of comparsions between measurements. For the chip on the board, the measured dnoise was 905 electrons. For two hybrids, the measured dnoise was 888 electrons and 900 electrons, respectively. The second of these hybrids was the one eventually glued to the silicon sensor. Simulation predicts the noise to be 820 electrons.

Noise was also measured on an SVX3 chip hybrid with floating inputs, with bandwidth setting of 0 and 100ns integration time. In this case the calibration capacitor is taken to be 37fF [2], and the inverse gain was 1650 electrons/count. The dnoise was measured to be 906 ± 55 electrons regardless of operating mode (dead-timeless or SVX2 mode).

3 Sensor Characterization

An SVX2 chip on a printed circuit board was used to characterize the bare sensor before placing anything on the surface. The silicon sensor tested was a Hamamatsu layer 0 double sided prototype with a p-side strip pitch of 50 microns, depletion voltage of 54V, and p-side capacitance per strip of 7.0 to 7.5pF. The leakage current is 65nA at 100V [3]. An RC filter for the bias voltage, and the bias ring connections, were kept within 2 cm of the readout chip. The bias ring on the (n-doped) underside of the silicon was wire bonded to a piece of aluminum foil which protruded beyond the edge of the sensor, allowing positive voltage to be applied with respect to the grounded p-side (the side read out). The silicon sensor was secured to the circuit board with kapton tape along the edges, keeping the tape away from active areas.

Figure 1a shows the dnoise from the readout chip wire bonded to every other one of some of the p-side strips on the sensor. Without bias voltage, one expects a high differential noise because the implants on the silicon are poorly isolated and thus the capacitance seen by one channel is very large. A small bias voltage isolates the p strips, reducing the single channel capacitance. At 30V, the fall off may be due to initial isolation of the n-side strips before full depletion at 54V. The dnoise as the bare sensor approaches depletion is 1446 ± 16 electrons [4], compared to the simulation prediction of approximately 1300.

4 Glue Application

We used Araldite glue, AW 106 resin and HV 953 hardener. In order to apply the glue to the sensor, we taped the long edges of the silicon to a surface with kapton tape. Epoxy was applied to the surface of the silicon and spread flat to the tape level using a razor blade. This leaves a uniform layer of glue. The method was first tested on a piece of scrap silicon, and the glue thickness was measured to be 0.003".

Figure 2a shows the dnoise as a function of bias voltage just after glue has been applied to the silicon. The shape and level of the noise have not changed significantly. Figure 2b and figure 1b show the dnoise after the hybrid has been placed over the glue, before and after the glue has cured, respectively. Notice that after the glue has cured the dnoise plot returns to its original shape, but while the glue is curing, the dnoise level is high. This high level of dnoise during curing is not understood, but due to the ephemeral nature of the circumstances,

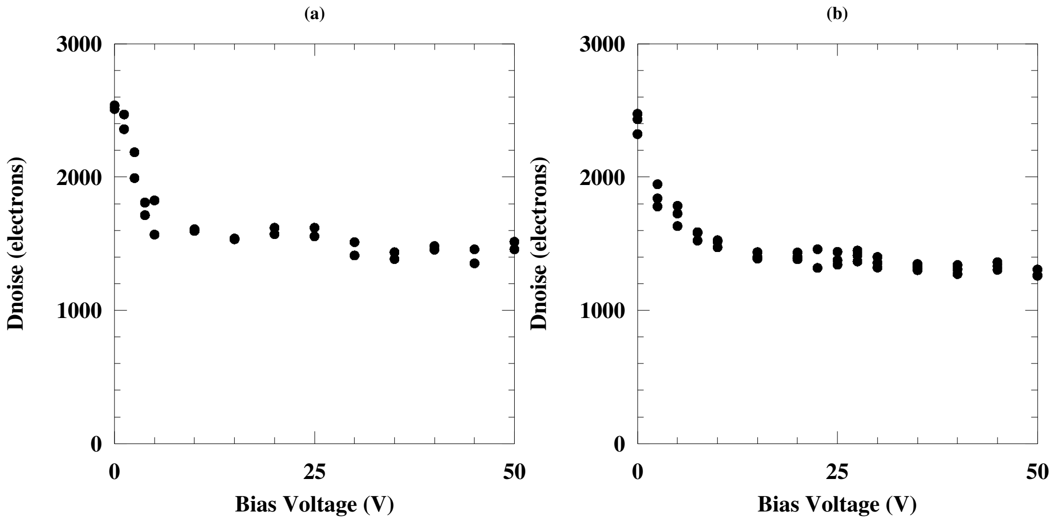

Figure 1: (a) The dnoise from the readout chip of the bare sensor vs. bias voltage. (b) The dnoise of the sensor with attached hybrid after the glue has cured, but still read out through the printed circuit board.

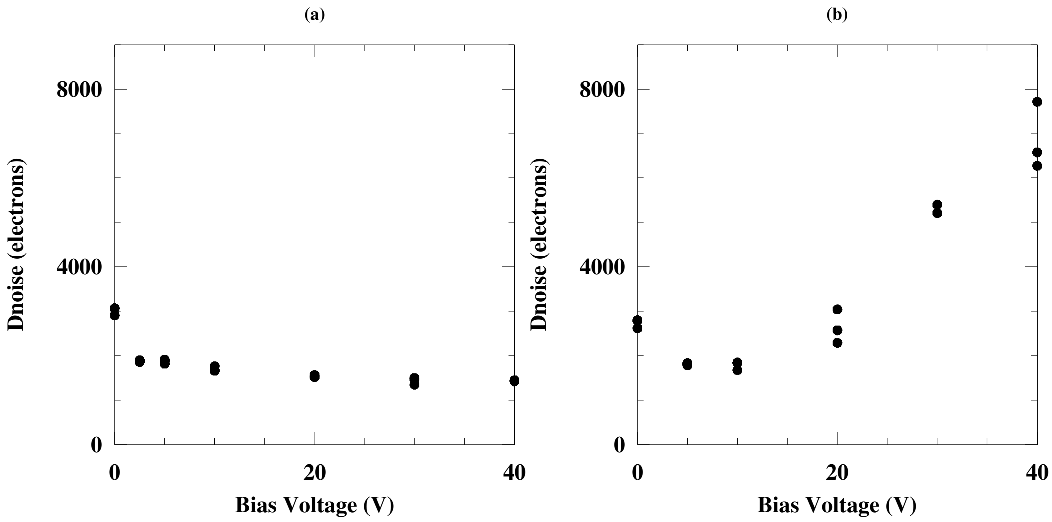

Figure 2: (a) The noise of the sensor read out through the printed circuit board just after a thin layer of glue was applied. (b) Dnoise of the sensor read out through the printed circuit board just after the hybrid was placed in position, before glue set.

Stage of assembly	Dnoise
Bare sensor	1446 ± 16
Sensor with uncured glue	1435 ± 21
Sensor with hybrid and cured glue	1464 ± 9
Bonded channels first chip of hybrid	1381 ± 14
Non-adjacent bonded channels second chip	1440 ± 19
Adjacent bonded channels second chip	1440 ± 14

Table 1: Dnoise of depleted sensor at various stages of assembly. The first three entries were read through the printed circuit board. The last three entries were read through the hybrid on the sensor.

not much work could be done on this problem, which could very well be due to a setup glitch. The glue was allowed to cure over a weekend, and during that time its exposure to moisture was minimized by sealing it in a box with a constant flow of dry air.

5 Hybrid on Sensor Results

After the hybrid was attached to the p-side, twenty-two channels from the first chip and 45 channels from the second chip were wire bonded to the silicon sensor. Channels bonded to adjacent strips were measured separately from non-adjacent channels for comparison. For these measurements the silicon was removed from the board used to characterize it, and the bias voltage was applied in a similar fashion as before. Bias connections were made on the end of the sensor with the hybrid, with the p-side grounded and positive voltage filtered on the hybrid and then wire bonded to the n-side.

Figure 3a and figure 3b show the dnoise from non-adjacent bonded channels and from adjacent bonded channels of the second chip, respectively. The dnoise from adjacent channels falls off faster at low bias voltage but levels off to the same dnoise as the non-adjacent channels beyond approximately 20V. Figure 4 shows the average dnoise from bonded channels on the first chip, which were all non-adjacent. Compared with figure 1a, the shape as well as the dnoise level at high voltage are nearly identical. Table 1 shows the depletion dnoise levels at various stages. The dnoise of the sensor is constant within error throughout all the measurements. This result gives evidence that gluing the hybrid directly on the sensor does not affect noise performance for SVX2 operation.

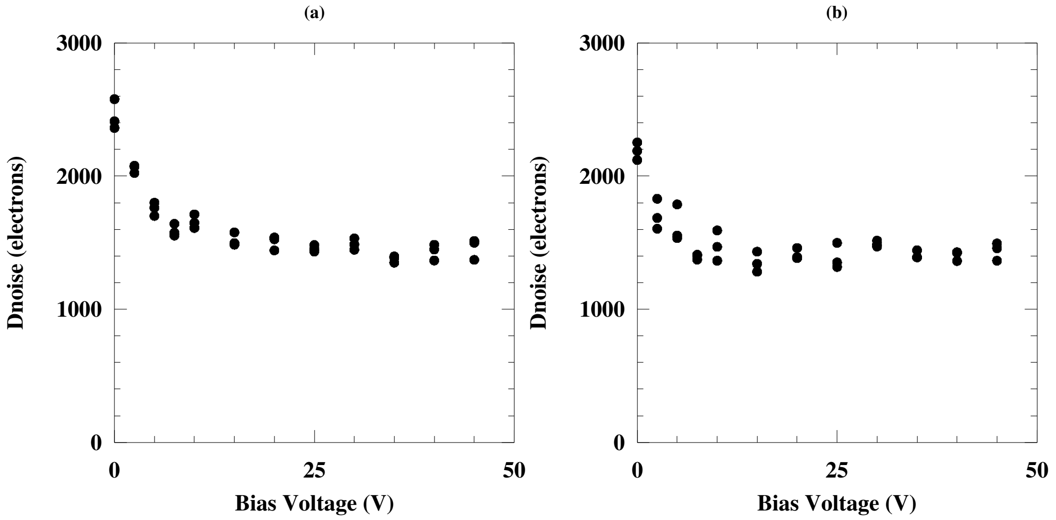

Figure 3: (a) The dnoise of the sensor with hybrid from the bonded non-adjacent channels of the second chip. (b) The dnoise of the sensor with hybrid from the bonded adjacent channels of the second chip.

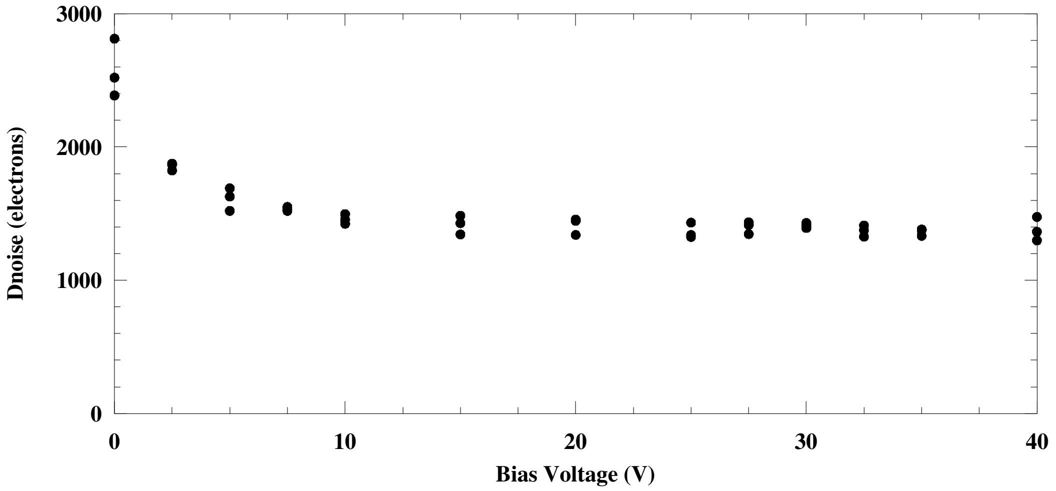

Figure 4: The dnoise of the sensor with hybrid from the bonded channels of the first chip.

Power Supply Configuration	Noise
All same supply first chip	5695 ± 572
All same supply second chip	5146 ± 515
AVDD separate first chip	4539 ± 149
AVDD separate second chip	4157 ± 152
DVDD separate first chip	4205 ± 172
DVDD separate second chip	3906 ± 141

Table 2: Common mode noise of the depleted sensor for the three power configurations read through the hybrid glued onto the sensor.

6 Effect of Power Distribution

The SVX2 hybrid on the sensor was operated with three different power supply configurations. First, AVDD, DVDD, and potential dividers for ramp pedestal and reference were fed from a single supply. Next, DVDD was powered from a separate source than AVDD and the ramp voltages. Finally, AVDD was separated while DVDD and the ramp voltages were fed from the same supply. The measured dnoise in all three power configurations was the same. However, when looking at the non-differential noise (i.e. the common mode noise) we found differences.

Table 2 shows the common mode noise for all three configurations and both chips on the hybrid. For the two supply configurations the noise is approximately at the same level, whereas the single supply configuration yielded a noise level approximately a thousand electrons higher. In all cases there is a significant common mode noise.

7 Conclusion

We have achieved some characterization of BeO prototype hybrids for the SVXII detector. Using SVX2 chips, we measured the dnoise in electrons of a biased sensor before and after attaching a hybrid. From the results, we determined that gluing a BeO hybrid directly onto a sensor does not increase the differential noise within the certainty of measurement.

The differential noise figures obtained in all tests are consistently higher than expectations from simulation, but the offset is within the systematic uncertainty in our gain determination (an incorrect gain would shift all noise measurements in the same direction).

References

[1] Hoeferkamp et al, SVX II Sensor/Preamplifier Noise Estimates, CDF Note 3618 (1996)

[2] The capacitor value was estimated by assuming the analog gain of the preamp plus pipeline to be the same as for SVX2 chips, and then comparing the SVX2 and SVX3 gains in counts per calibration volt for equal ADC ramp rate and digitization clock frequency. This comparison yielded a ratio of SVX3/SVX2 calibration capacitor values of 37/50.

[3] This current was not measured here because we did not have a sufficiently precise instrument. The current quoted is from sensor probing measurements. The sensor identification number is 33181-13-0b.

[4] The error quoted here and in the rest of this paper is statistical error only. The additional systematic error from the gain uncertainty is not explicitly quoted.