Saturation of the SVX Chip

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Overview: The purpose of this study was to investigate how the SVX chip behaves as its amount of stored charge (data) increases. The hypothesis was that the SVX signal from an event diminishes if the front end of the chip is already storing charge from a previous signal. This effect is called saturation.

Goals: 1) To verify that saturation effects occur in the SVX chip
2) To measure the magnitude of any effects that appear

Experimental setup: There were two main tasks for the experimental setup: to emit a measured signal to the chip and to read back the results. In order to emit controlled amounts of light, two pulse generators were connected to two light sources (LED's). The pulse generators were used to select how much light the LED's would send for each run. These light pulses were meant to simulate the photons that come from the scintillating fiber during a real collision. Figure 1 (below) is a visual representation of the timing of these pulses.

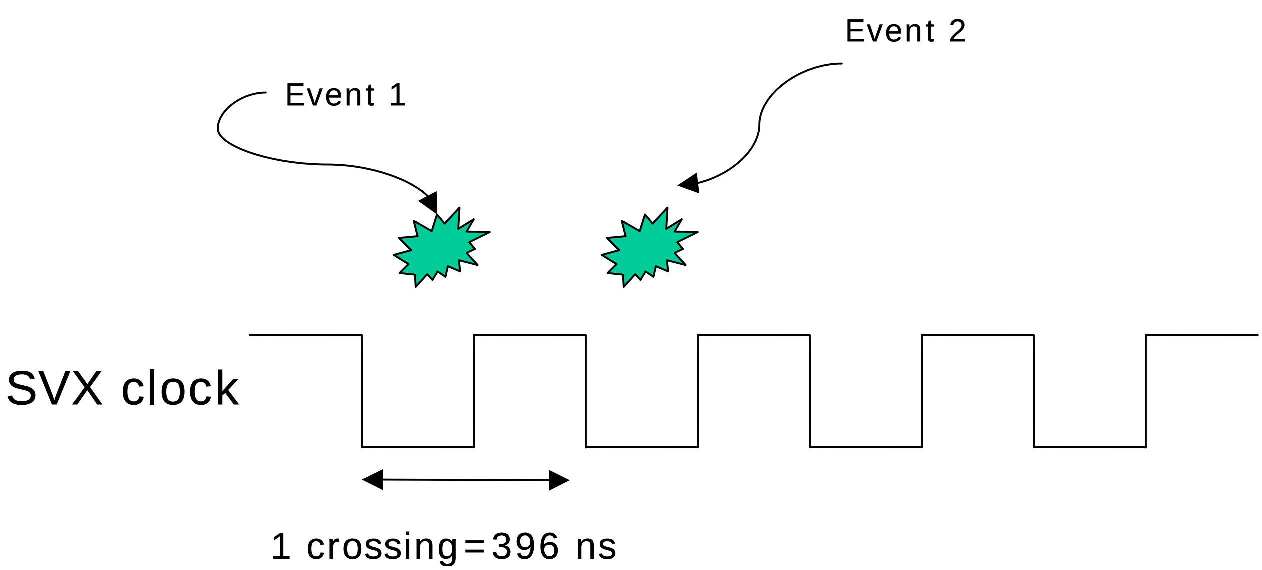


Figure 1: Basic schematic of SVX clock. In this experiment, Event 1 represents the early pulse signal, and Event 2 represents the main pulse signal. During a run with real collisions, these signals come from photons emitted from the scintillating fiber instead of the LED. In both scenarios, charge begins to build up on the SVX chip as more signals arrive.

It should be noted that the pulse emitted from the main generator was held at a fixed amount (1 pe), whereas the early pulses varied from 0 to 20 pe or more. Hence, we assumed that the early pulse was the dominant cause of any observable saturation.

In detecting and reading out the signal, several other devices were used. The VLPC chip received and measured the light emitted in a given pulse. Then, the VLPC sent this measurement to the SVX chip (mounted on AFE I), which in turn sent a digital number (ADC count) back to the PC. Hardware that helped in coordinating these data transfers included: VRB, 1553, Bit 3, and a sequencer. Figure 2 (below) is a schematic of the setup.

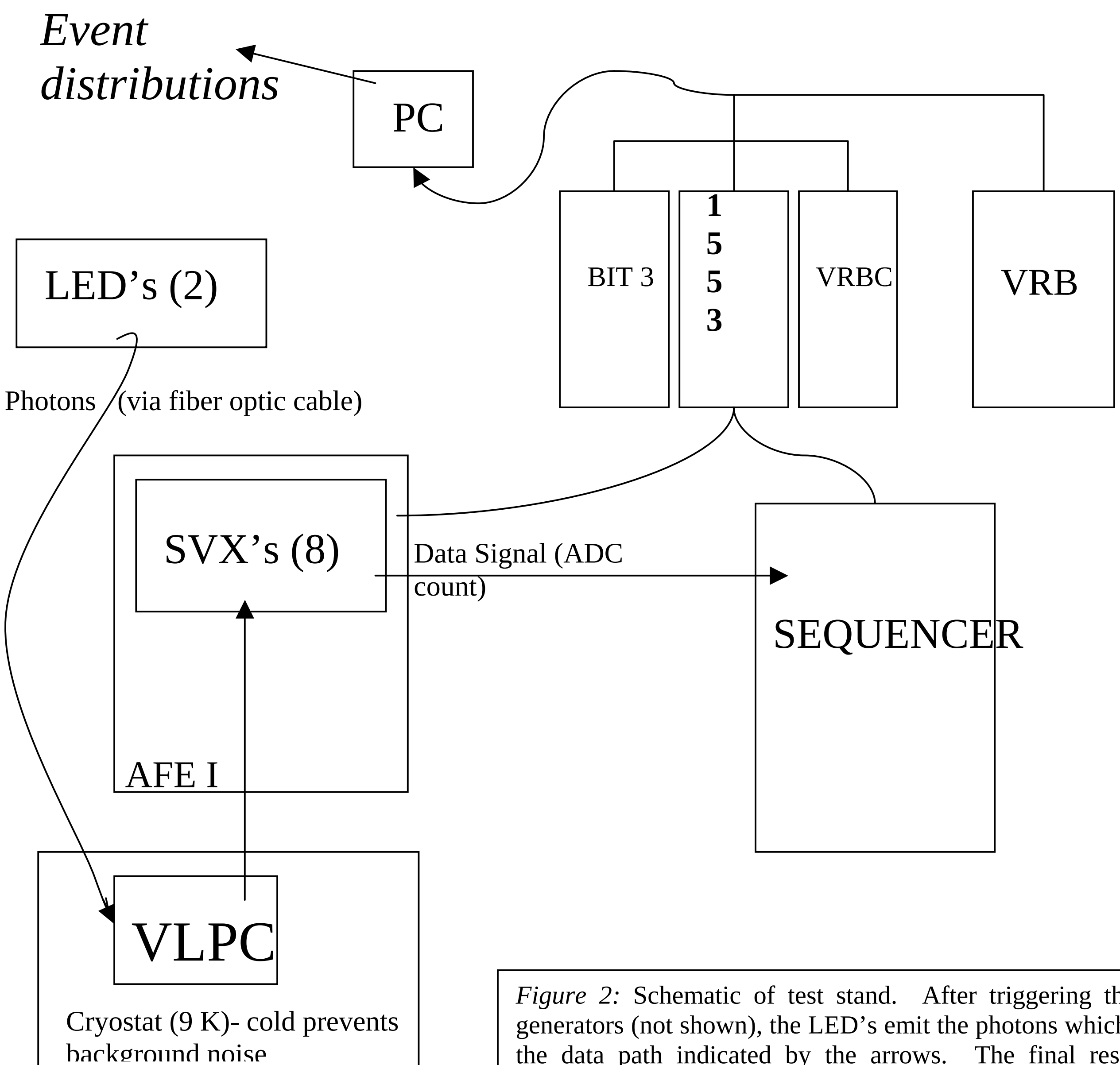


Figure 2: Schematic of test stand. After triggering the pulse generators (not shown), the LED's emit the photons which follow the data path indicated by the arrows. The final result is a collection of histograms generated by the PC, which describe the signal (charge) detected by the SVX due to the pulses (events).

The PC used at the test stand was equipped with a Visual Basic/Excel program which plotted event distributions (bin count vs. ADC signal) after each data run. This probability distribution indicated the average detected charge, μ, as well as the standard deviation, σ, for each pulse of light sent. The units of these quantities were ADC counts.

__Timing Note__: It was noted that if data is taken during the window immediately following SVX reset, the resulting data is invalid. Figure 3 below displays the timing of the SVX clock in detail.

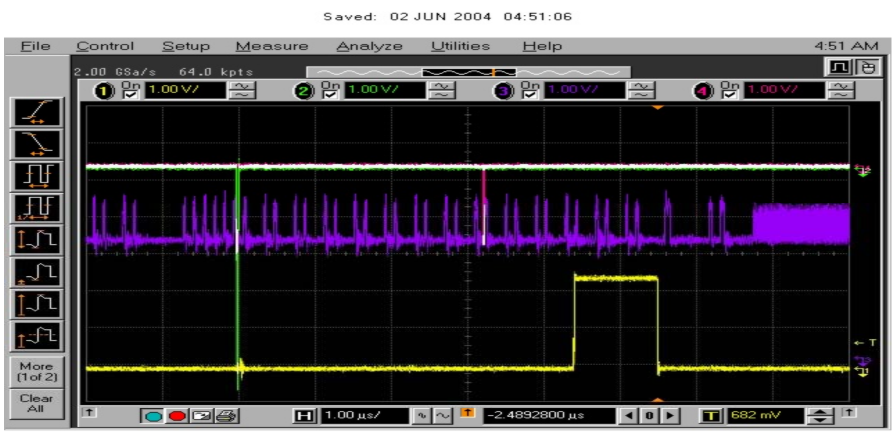


Figure 3: SVX clock. Earlier, Figure 2 showed a schematic of the SVX clock, with a crossing occurring every 396 nsec. These crossings appear below in figure 3, in between the pairs of peaks that arise to the right of the green marker. This crossing window is the time in which the SVX integrates the charge arriving from the events.

The unpaired group of peaks before the green marker corresponds to the SVX reset window, in which one cannot acquire valid data.

Task 1-Monitor Decay of a Signal as Amount of Light in Preceding Pulse Increases:

In order to observe the extent of signal loss as a function of chip saturation, the two generators were calibrated in order that their pulses be sent consecutively. The signal resulting from each of the two pulses is stored on its own capacitor in the SVX pipeline.

For each run, a different amount of light was selected in the early pulse. The main pulse was kept fixed. The PC recorded the resulting signal from the main pulse after each run. In the case of no saturation, the signal due to the main pulse should remain the same. However, the expectation in this experiment was to see a decrease in signal as the early pulse size increases. As shown in the plots below, saturation did cause the signal to decrease. As can be seen in the collection of histograms below, the mean ADC signal gradually decreases as the early pulse width increases.

To reiterate, Figures 4-7 reflect the amount of signal detected from the main pulse. As saturation effects increase, the average magnitude of this signal (μ) decays. See Fig. 4 caption for more background.

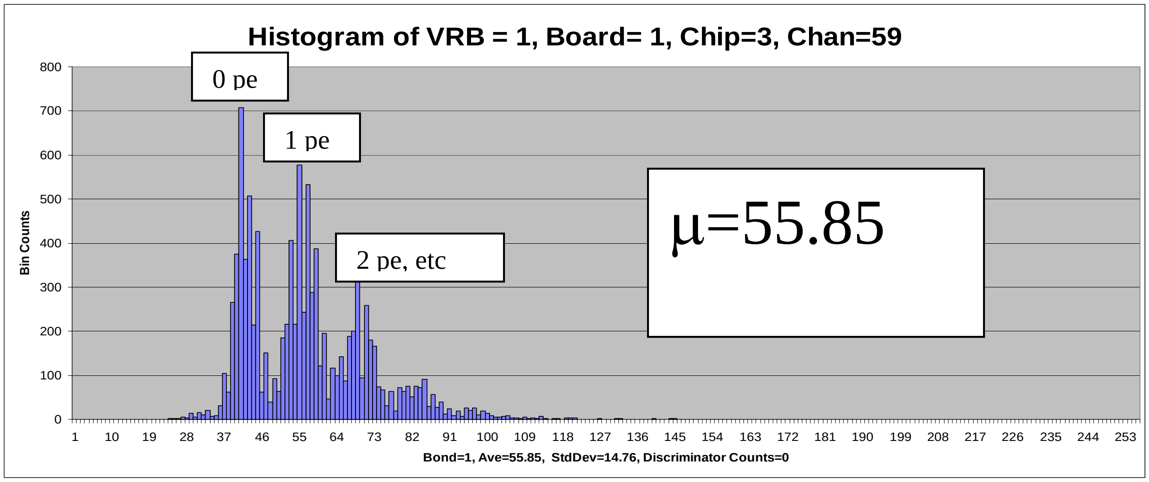


Figure 4: Bin count (number of events) versus signal (detected amount of charge in ADC counts). This figure corresponds to when the early pulse is disabled and the main pulse is turned on. The mean, 55, falls underneath the second peak of this Poisson distribution, which corresponds to 1 pe. This means that for all tests done in this experiment, the main pulse is contibuting ~1 pe worth of light.

Ramptrim for this collection of histograms (Fig. 4-7) was set at 350.

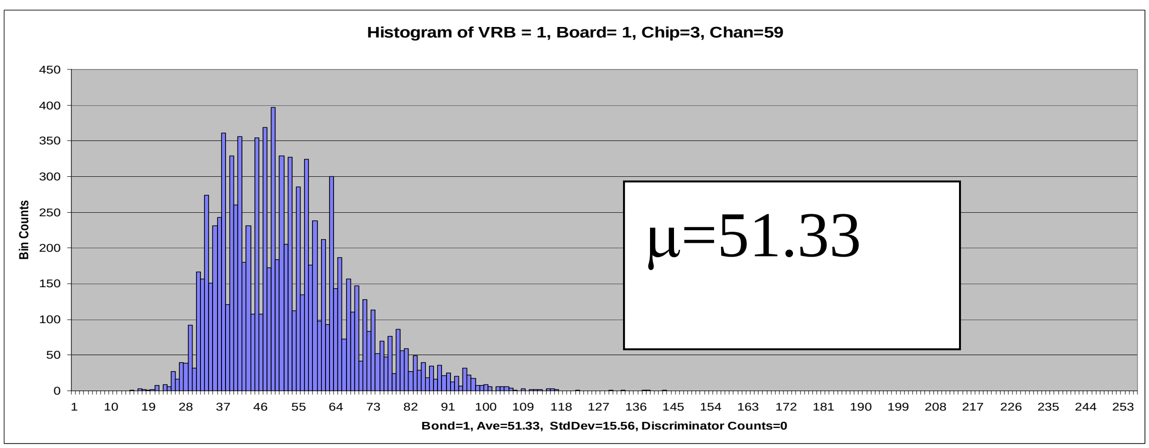


Figure 5: Bin count (number of events) versus signal (detected amount of charge in ADC counts). This figure corresponds to when the early pulse is at 8V and the width is 30 nsec. As in all of task 1 plots, the main pulse is kept at the same size (1 pe).

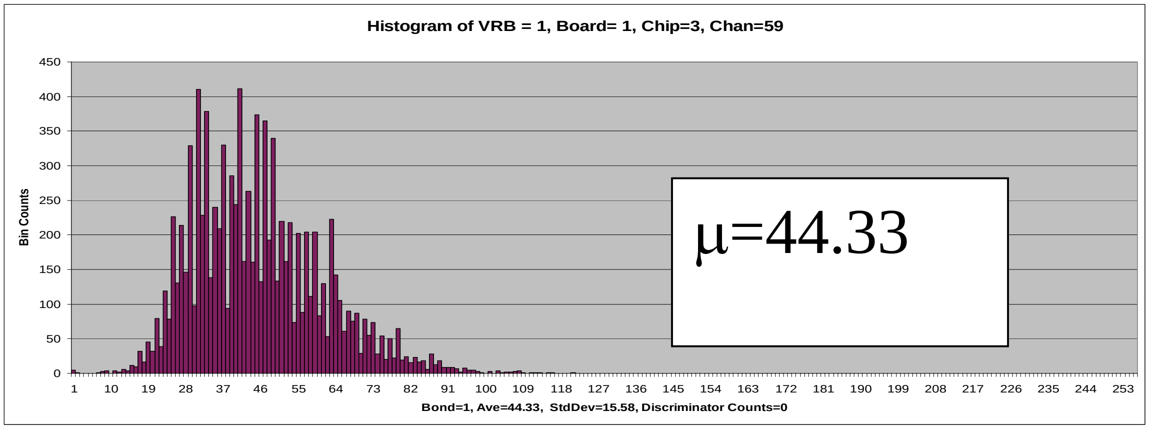


Figure 6: Bin count (number of events) versus signal (detected amount of charge in ADC counts). This figure corresponds to when the early pulse is at 8V and the width is 40 nsec. By increasing the width from 30 to 40 nsec, a large drop in μ was observed (almost 10 ADC counts)

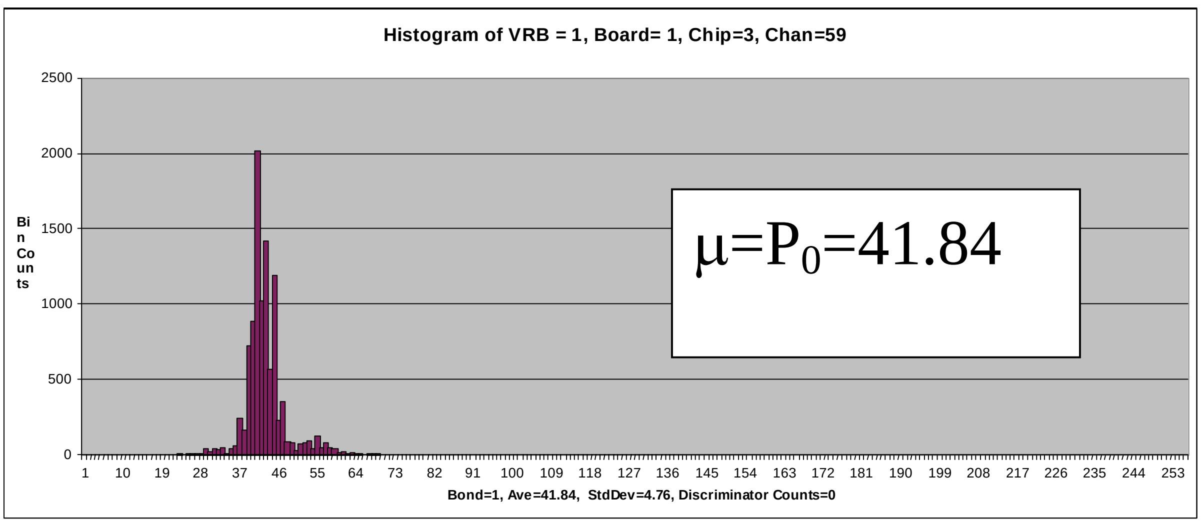


Figure 7: Bin count (number of events) versus signal (detected amount of charge in ADC counts). This figure displays the pedestal, when both the LED's are disconnected.

The correct signals corresponding to these distributions require the subtraction of the pedestal from each value. Nonetheless, the decreasing trend in signal is clear in these histograms.

Task 1 Primary Results:

In order to quantify the aforementioned loss in signal, a few terms need to be defined. First, it is most useful to think of the loss in terms of the fraction of signal lost. So, let S be the actual signal coming from the main pulse. To obtain this, we take the ADC signal from above and subtract the pedestal. In other words, for a given amount of light, we receive a signal

$$S = \mu - P_0 \qquad (1)$$

Also, let μ_0 represent the saturation-free signal of the main pulse; that is to say, the signal detected without the early pulse. The ratio μ/μ_0 is the loss fraction that indicates how much signal is lost due to saturation. For convenience, we will refer to it as L. So, for later reference

$$L = S/S_0 \leq 1 \qquad (2)$$

The plot below shows the relative signal loss as the early pulse size increases.

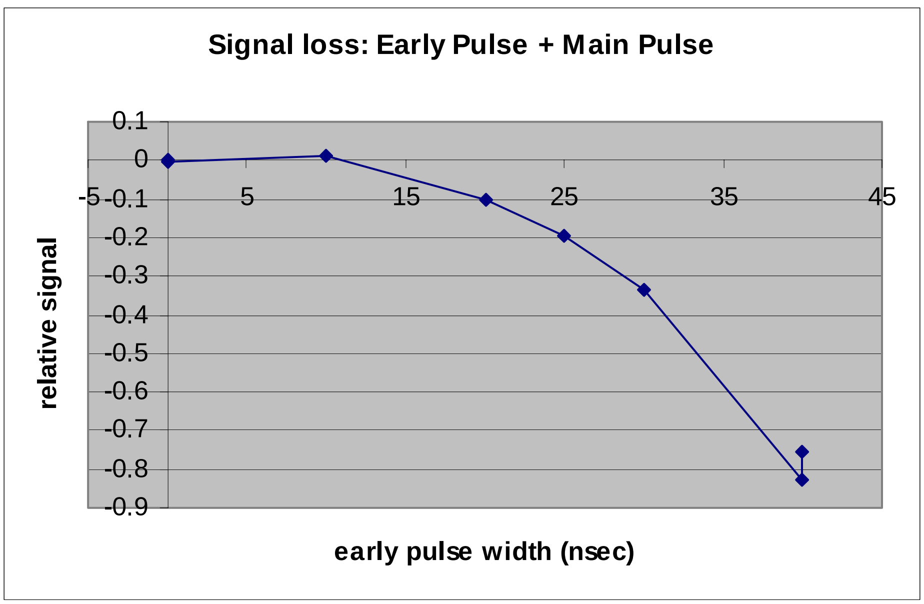


Figure 8: Fractional deviation from the desired signal, 1-L, as a function of width of the early pulse (nsec). After the second increase in early pulse width, saturation effects become quite visible.

This result satisfies the first part of the experiment (to verify that saturation occurs), but in order to properly quantify the results, the signal loss needs to be plotted as a function of photoelectrons in the previous signal. This is the objective of the next set of experimental procedures.

Task 2-Determining the amount of light in the early pulse:

In order to determine how many pe's were in each of the pulse sizes used in task 1, more Poisson distributions were made. This time, the main pulse generator was disabled so that the only light being sent was the early pulse. A few examples are shown below.

Early Pulse Only. Ramptrim=150

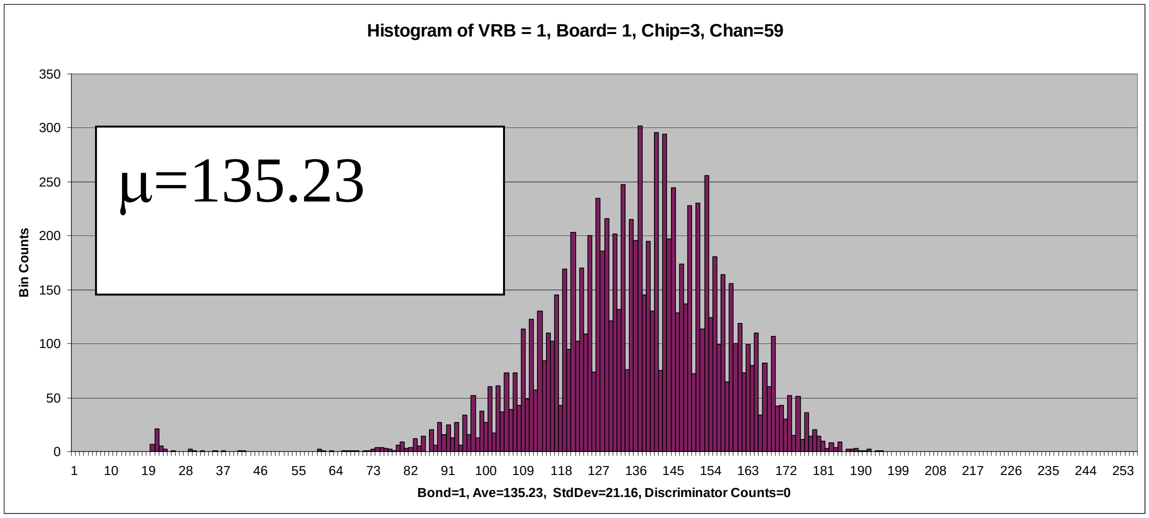


Figure 9: Bin count (number of events) versus signal (detected amount of charge in ADC counts). This histogram corresponds to the early pulse only, with a voltage of 8V and width of 40 nsec.

For all of these plots (Figures 9-12), the main pulse is disabled and the Ramptrim is at 150.

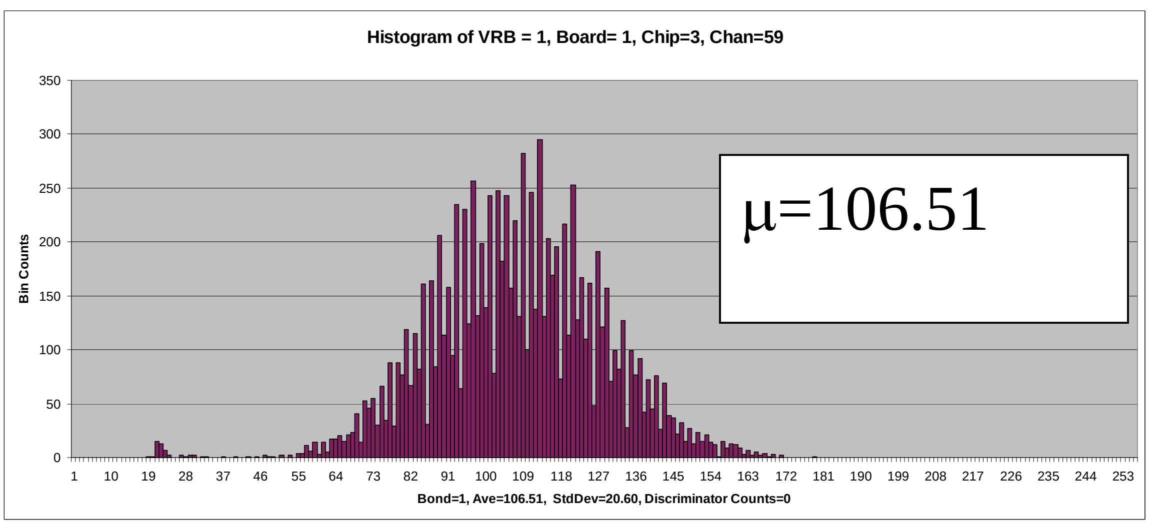


Figure 10: Bin count (number of events) versus signal (detected amount of charge in ADC counts). This histogram corresponds to the early pulse only, with a voltage of 8V and width of 30 nsec.

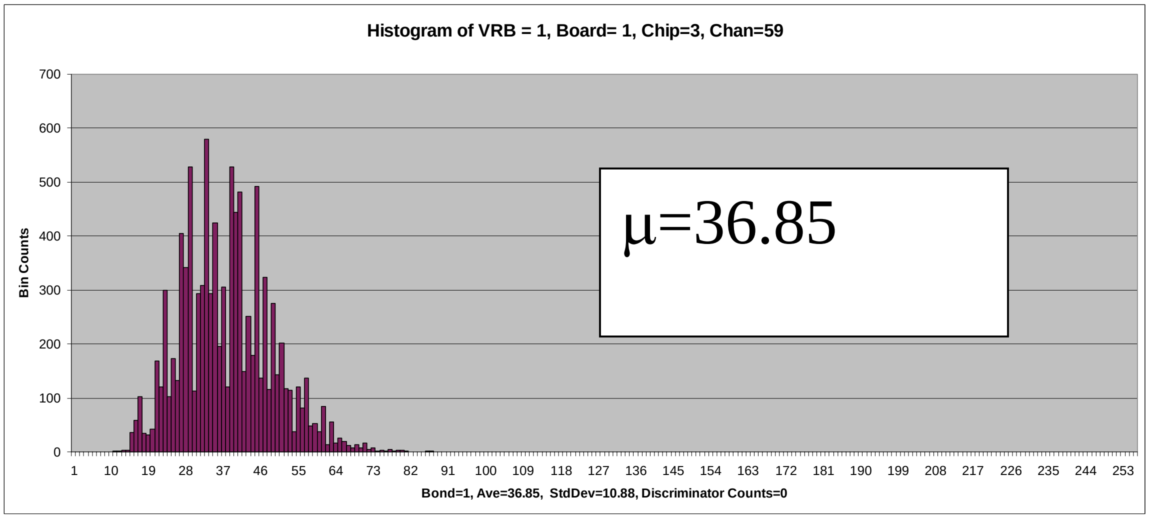
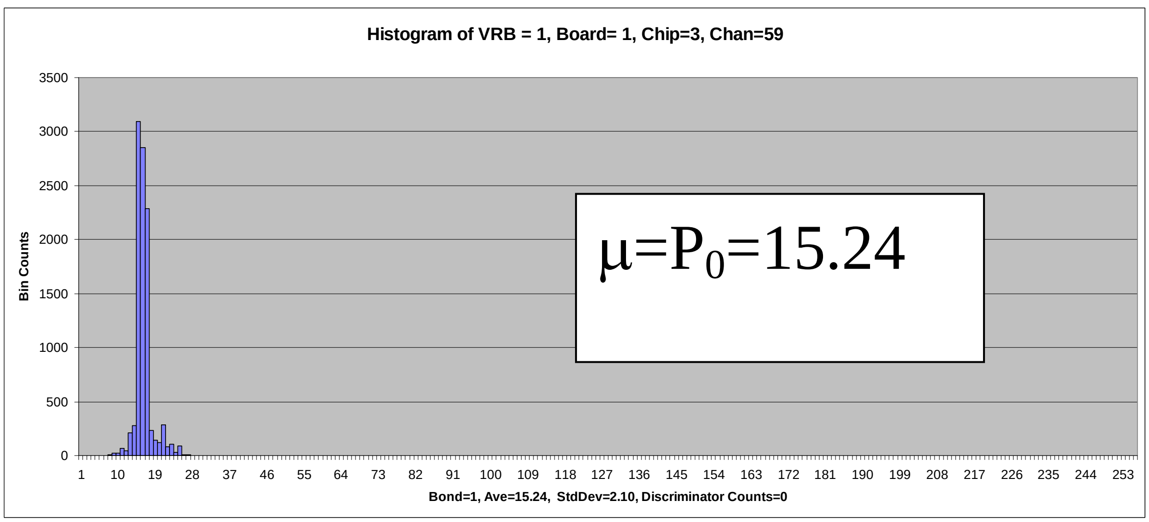


Figure 11: Bin count (number of events) versus signal (detected amount of charge in ADC counts). This histogram corresponds to the early pulse only, with a voltage of 8V and width of 10 nsec.



Pedestal

Figure 12: Bin count (number of events) versus signal (detected amount of charge in ADC counts). This histogram represents the pedestal, P_0 , (LED disconnected).

After recording the signals for each amount of light, the proposed step was to calculate the number of pe's in each pulse using the properties of the event distribution.

We use the relationships

$$N = S/g \qquad (3)$$

$$N = (S/\sigma)^2 \qquad (4)$$

* Calculated by PC from event distribution

where S=mean signal (with pedestal subtracted), N=number of pe's, g=gain, and σ=standard deviation

Task 2-primary results:

Using the above relationships, the number of photoelectrons was found for each of the pulses used in task 1. With the exception of the last data point, the relationship seems linear, as expected.

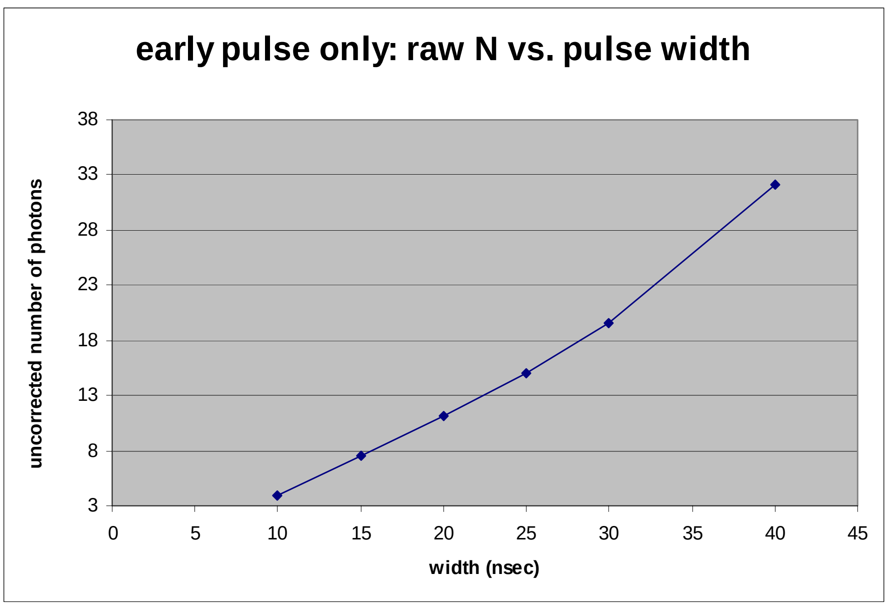


Figure 13: N (uncorrected number of photons in signal) vs. early pulse width (nsec). N was calculated from formula (4) for each amount of light used in task 1. The trend is linear, as expected, with the exception of the last data point. See below for explanation of the "uncorrected" N values.

Problem of Calculating N: It should be noted that the calculations of the N values in the above plot were based on the ADC signals due to the early pulse. This means that if those ADC signals were affected by saturation, then the N values are incorrect.

In order to check if saturation had occurred during the early pulse run, we plotted the gain as a function of pulse width. This was an easy test to analyze because the gain should remain at the same value, g_0 ,for all pulse sizes. The above equations allowed us to calculate the gain at each pulse of light using from the reported signal and standard deviation

$$g = \sigma^2/S \quad (5)$$

The plot on the following page shows the gain as the early pulse size increases.

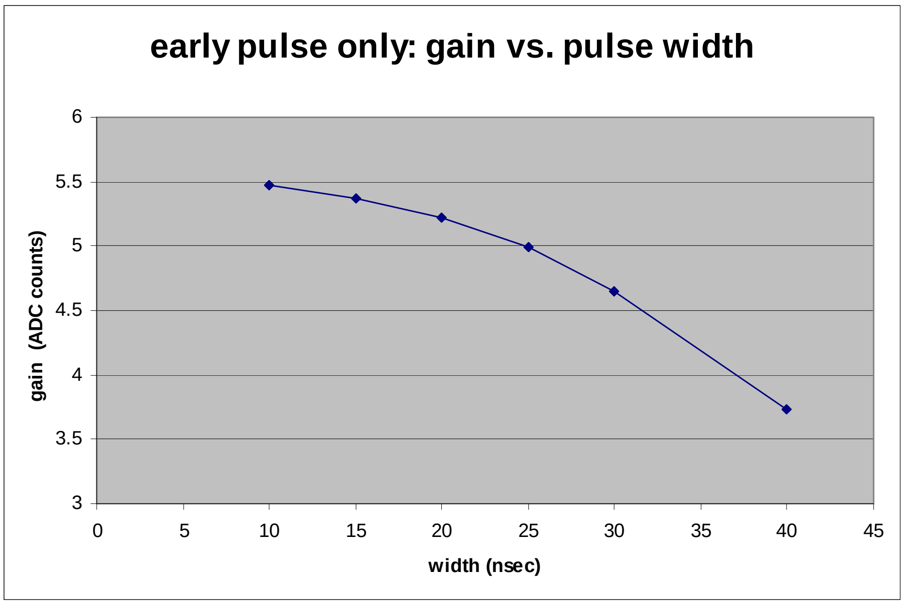


Figure 13: gain (ADC counts) vs. early pulse width (nsec). This plot confirms that saturation indeed occurs, even with only one pulse. We see that the gain drops ~10% at a width of 25 nsec (about 15 pe's).

From the graph above, it is clear that the gain decreases as the early pulse size increases. This drop means that the ADC signals used in calculating N were indeed diminished due to saturation effects. As a result, it is necessary to correct those signals in order to obtain a correct value of N for each run. It is interesting to note that saturation still occurred in the second half of the experiment; even with just one pulse of light, the effect can occur.

Correcting S and N:

In order to obtain a corrected number of photoelectrons in the previous signal, N', it was necessary to obtain a corrected ADC signal, S'.

It is important to remember that, for our experiment, the SVX saturation depended almost entirely on the early pulse because it supplied much more light than the main pulse. Therefore, the saturation that occurred with both generators running (task 1) should have almost the exact same magnitude as the saturation with only the early pulse running (task 2).

With our data from task 1, we defined the loss fraction, $L=S/S_0$. This quantity was used as a correction factor for the signal in task 2. Also, it was clear from Figure 8 that with when the early pulse size is small, saturation effects are absent. Therefore, the gain at these small pulse levels is the correct value, which we call g_0. The corrections were made as follows:

$$S' = S/L \quad (6)$$

and

$$N' = S'/g_0 \quad (7)$$

The final result is a corrected set of values for N (number of pe's) for each pulse size.

Final Result:

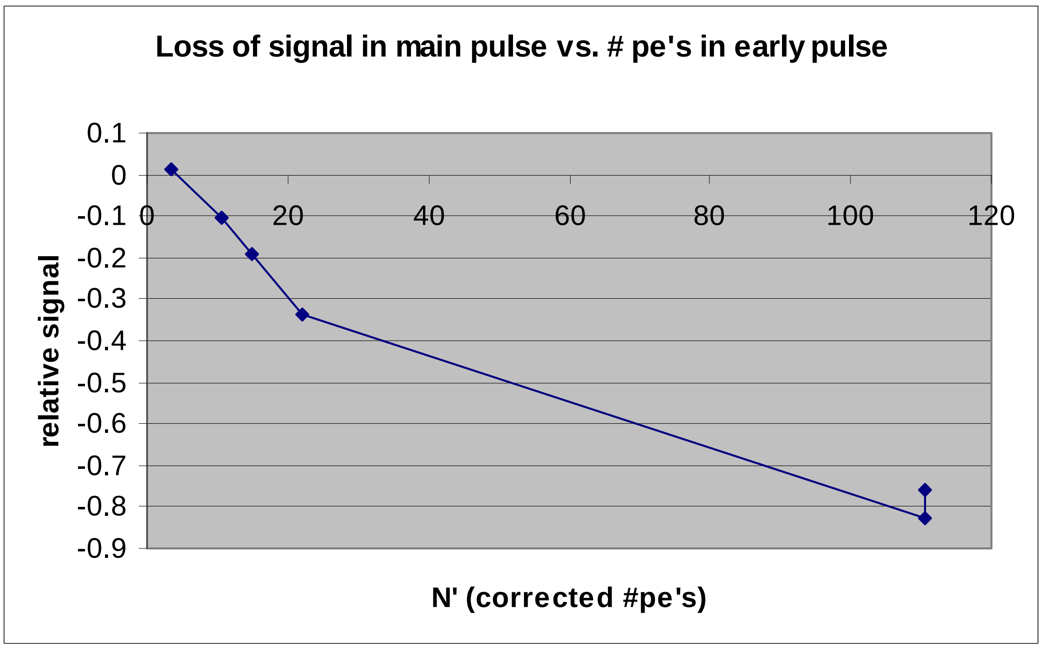


Figure 14: Fractional loss of ADC signal, 1-L, versus corrected number of pe's in early pulse signal, N'. This final result gives a more meaningful sense of the magnitude of saturation effects on the SVX chip. See below for key points.

In sum, task 1 was performed to find the *magnitude* of saturation effect, and task 2 was performed to *rescale* in terms of #pe. The above plot shows that:

-After an arrival of ~10 pe's, there is a 10% loss in signal
-After an arrival of ~20 pe's, there is a 30% loss in signal.

Conclusions:

This experiment affirmed that saturation does noticeably diminish SVX signals after a sufficiently sized previous signal (>10 pe). Further investigations might include: dependence of saturation on a given pipeline capacitor; accuracy of the assumption that task 1 correction factor is accurate for task 2; and implications of these results for preshower.