Characterization of LST Z Plane Signals

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Abstract

The Resistive Plate Chambers (RPCs) used to detect muons in the BaBar detector are losing efficiency and are being replaced by Limited Streamer Tubes. Z planes are a component of the detector that gathers detects muons. It is desired to know how Z signals vary from across the plane. Using an Oscilloscope and Scintillator triggers, the output signals of the Z plane can be characterized at various points on the plane and analyzed. The results of this study indicate an approximate signal speed of $.58c$ with signals decreasing in pulse height and staying constant in pulse width for strips further down the output cable.

Introduction

The BaBar Experiment at Stanford Linear Accelerator Center (SLAC) has been looking for subtle difference in the properties of matter and anti-matter since it came online in 1999. This is being done by colliding electrons and positrons at high energy to create B mesons. Physicists then study the decays of these particles in hopes of finding CP violation, evidence of matter, antimatter asymmetry. To study these events, a highly efficient detector is needed. Among the particles created in these decays are muons, found in about 18% of all B decays [1]. The Babar detector is currently tracking muons with Resistive Plate Chambers (RPCs).

The RPCs, located in the Instrumented Flux Return portion of the BaBar detector, the outer most shell of the detector, have been continuously decreasing in efficiency since they were installed. In August 2004, installation of a replacement detector will begin. The candidate selected to replace the RPCs are Limited Streamer Tubes (LSTs). LSTs

receive signals through LST wires and Z-planes. The goal of this project is to investigate how Z-plane signals vary at different locations on the plane.

An LST module consists of an 8 cells, coated with a thin layer of graphite on three of the interior walls, 17mm x 15mm in cross section [2]. Through the center of each cell is a wire which is put on high voltage (HV). The wire is held tight in the center of the cells with two end caps and several spacers. The end caps have gas inlets and high voltage and ground connections. The cells flow a gas mixture of Isobutane, Argon and Carbon Dioxide which is ionized when a particle passes through it. The HV causes the ionized electrons to drift to the wire which ionizes more gas molecules. The ionized electrons are collected on the wire and carried onto the phi cathode wire that delivers the signal.

The ionization of the gas causes creates a magnetic field in the tube where the particle went through which induces a signal in the neighboring Z plane. A Z plane consists of a copper ground plane and 96 3.5cm wide copper strips placed horizontal to each other across the plane and perpendicular to the HV wire. Another ground plane is located on the other side of the LST module which nearly electromagnetically isolates the LST module and Z strip so the net positive charge, left after the electrons are carried off on the wire, induces a negative charge on the Z strip. Each strip is connected to an output wire to deliver the signal. With the wire signal and the Z signal, the coordinates through which the particle passed can be determined. To understand how these signals work, data was taken about pulse height and width, as well as differences in signal arrival times at various locations on the plane.

Materials and Methods

Measurements of the Z plane signals were made using a Tektronix THS730a Oscilloscope. The measurements utilized the average of waveforms function typically using 64 events. Measurements of pulse height and width were made using two methods, strip triggers and scintillator triggers. It should also be noted that the data was taken with the LST module on 5.0kV rather than its normal operating voltage of about 5.5kv in an effort to reduce saturation of the signal amplification system which distorts the averages. The average peak heights are therefore smaller than those that would be seen at normal operating voltages.

The scintillator trigger method uses two scintillator particle detectors to obtain a trigger area over a specific strip. These signals are then digitized by a discriminator and sent through a logic board to send a coincidence trigger to the oscilloscope indicating a particle went through the trigger area. This method was also used to gather data on the signal speed. This method of measurement aligns all the events with the arrival of the trigger signal which stays constant with respect to the detection of the particle in the scintillators for all measurements. Therefore the peak height measurement indicates the average voltage of the signal at the time where, on average, most of the signal comes through. The peak widths were measured at half height and were generally slightly wider than widths measured with a strip trigger. This is because strip triggers align the peaks of the pulses better than scintillator triggers. Z signals with higher pulse heights have shorter rise times than lower ones. This brings the average pulse height down, lowering the half height and widening the average signal out.

The strip trigger method triggers off of the signal from the strip itself using a 50mV threshold. The 50mV trigger level was chosen because it was the lowest threshold

that did not trigger at a significant rate from background noise. Because the Z plane acts like a large antenna, it gathers signals from sources of electromagnetic waves present in the experimental area. This method gives an average height more indicative of the average maximum pulses height of individual pulses because it aligns the pulses on their rising edge but excludes smaller pulses. This method can not be used to isolate the origin of the signal on the plane and does not trigger on small and baseline waveforms that are averaged into the scintillator averages. About 31% of scintillator triggered events are baselines or are below the strip trigger threshold.

Results

The scintillator trigger measurements of the pulse height showed a decrease in pulse height for strips further down the output wire. The least squares linear fit of the data showed a decrease of about 1.0933mV/strip with a χ^2/ν of 2.8620 (see Figure 1). The error bars for this data is the standard deviation of 45 measurements of peak height on the same strip. This is the same method used to acquire the error bars for Figures 2, 3, 4, and 5 as well. The average peak height for all strips was 501.0mV. The strip trigger measured higher pulse heights, an average of 1176mV, with a larger average voltage change between strips. The slope of the best fit linear regression showed an average decrease of 2.1432mV/strip (see Figure 2). The χ^2/ν for this linear model was 1.7458.

Pulse width measurements using the scintillator trigger gave an average width of 3.8234 μ s. The linear fit of the data has a slope of .0035 μ s/strip with a χ^2/ν 2.6764 (see Figure 3). Strip trigger pulse width gave an average width of 3.8127 μ s with a linear regression slope of -.0001 μ s/strip and χ^2/ν 1.3292 (see Figure 4).

The signal speed measurement, made from the half height point on the rising edge of the pulse, showed a signal speed of about .58 times the speed of light. The linear model of the data gave a slope of .2023ns/strip with a χ^2/ν 1.4645 (see Figure 5). The signal speed data was taken from every other strip, the pulse width and height measurements were made on every strip.

Discussion and Conclusion

The pulse height measurements both indicated a decrease in pulse height for strips further from the signal output end of the plane but the linear models do not agree on how much. There is a significant discrepancy between the scintillator triggers 1.0933mV/strip decrease and the strip triggers 2.1432mV/strip decrease. However, when testing the χ^2/ν of the scintillator trigger fit to the strip trigger data and vice versa, there is not a large change from the least squares fit lines χ^2/ν . Both models do similarly good jobs in describing the behavior of the data and so there is some uncertainty in what the exact relationship between strip location and pulse height is. The χ^2/ν changes from 1.7458 to 1.8280 for the scintillator fit on the strip data and from 2.8620 to 3.0399 for the strip trigger model on the scintillator data. It can be concluded however that pulses tend to decrease in height as they get further down the plane. The difference in average pulse height for all strips is due to the fact that the strip trigger method selects only events with greater than a certain minimum pulse height while the scintillator trigger receives a fair amount of low and baseline triggers that bring down the average.

Pulse width measurements for both techniques gave similar results. The average pulse width across all strips came out to be in agreement of each other within experimental error. The slope of the linear fit for each model came out with different

signs but the slopes were so slight that one would conclude that the pulse width stay approximately constant. This is supported by the χ^2/ν of a constant linear model for the width with a value equal to the average overall pulse width. In both cases, scintillator and strip trigger, the difference in χ^2/ν between the least squares linear model and constant width model showed little change, 2.6764 to 2.8574 and 1.3292 to 1.3354, respectively. There is little difference in the average pulse width across the plane.

The measurement of the change in signal arrival indicated an approximate signal speed of .58 times the speed of light, a reasonable figure. The χ^2/ν value for the linear fit from which that speed was calculated, 1.4645, shows a reasonably good fit with the model.

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References

- [1] The BaBar Collaboration. (1995, Mar.) Technical Design Report. [Online]. Available: <http://www.slac.stanford.edu/BFROOT/www/doc/TDR/>
- [2] The LST Team. (2003, May) A Barrel IFR Instrumented with Limited Streamer Tubes. [Online]. Available: <http://www.slac.stanford.edu/BFROOT/www/Detector/LST/documentation/LSTprop-A4-May30-ajss.pdf>

Figures

Figure 1. Pulse Height from Z strips along the plane using scintillator trigger method (numbered 1 to 96 going from the signal output to the end of the plane).

Figure 2. Pulse Height from Z strips along the plane using Strip Trigger method
(numbered 1 to 96 going from the signal output to the end of the plane).

Figure 3. Pulse width from Z strips along the plane using Scintillator Trigger method
(numbered 1 to 96 going from the signal output to the end of the plane).

Figure 4. Pulse width from Z strips along the plane using Strip Trigger method (numbered 1 to 96 going from the signal output to the end of the plane).

Figure 5. Signal arrival time after scintillator trigger (numbered 1 to 96 going from the signal output to the end of the plane).