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Baseline Response of Silicon Strip Detectors and Comparison of Cost-Effective Amplifiers

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Abstract: Silicon strip detectors are a proven and more affordable technology. However, they are susceptible to high radiation damage. As part of the characterization of the effects of high radiation on silicon detectors, a baseline performance of these detectors under normal, low radiation conditions needs to be established. We did this by using an optimized setup and an infrared laser to simulate particle incidents. The detectors responded to applied bias voltage as expected. We then compared the performance of both economy amplifiers and an expensive amplifier as part of the optimized setup. For all intents and purposes, the economy amplifier worked just as well as the expensive amplifier.

Introduction:

Silicon strip detectors are currently being used as tracking systems for the Compact Muon Solenoid (CMS), because they are a proven and more affordable technology. In addition, these detectors use relatively lower bias voltages and are more straightforward to operate [1]. The limitations of these detectors are their susceptibility to high radiation exposure, which damages the detectors. Radiation can cause defects in silicon detectors, leading to fewer charges and electron-hole pairs. Radiation also changes the depletion voltage of the detectors, and can cause leakage.

Before the effects of high radiation on silicon detectors can be fully characterised, we need to establish a baseline performance of these detectors under normal, low radiation conditions. Testing the effects of real particles on silicon detectors would require special equipment to produce these particle beams. It is much simpler and cost effective to simulate

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particle incidents with an infrared laser to study the particle effects of the detectors. An infrared laser also creates less signal noise, and is more precise and controllable. The laser must be infrared (specifically, 1060nm) because silicon is opaque to visible light, but transparent to infrared light, which penetrates about 1mm into silicon [2]. The detector signal output needs to be amplified by a high frequency amplifier, which can be very costly. Therefore there is a need to test inexpensive (economy) high frequency amplifiers to determine if they can be used in place of expensive high frequency amplifiers.

The goal of the current study is to establish the baseline performance of the silicon detectors, and to compare the performance of economy amplifiers versus expensive amplifiers.

Methods

In order to investigate the behavior of the prototype silicon detectors, we used the following equipment: A DC power supply for the entire experimental setup, a pulse generator to create the controlled signal for the infrared laser; an oscilloscope to measure the detector output voltages and amplifier noise, an attenuator to shape the laser pulse; a high frequency amplifier to amplify the prototype silicon detector output signal, an infrared laser to simulate the particle incidents, and a light-proof box to shield the detectors from ambient light.

Current-Voltage (IV) Profiling was used to measure charge collection and depletion voltage of the detectors under normal conditions. We then measured the output voltage as a function of the applied bias voltage of the detectors. Also we compared peak voltage outputs of inexpensive amplifiers vs expensive amplifiers. Finally, we measured the background noise inherent to the equipment setup. This was done using the LabView software to collect and analyze data, as well as automating some aspects of this process.

Results

The detector output voltage data was collected in response to increasing bias voltage applied, with different equipment setups: with the economy amp versus the expensive (AM-01) amp (Figure 1.), with the AM-01 amp using a short pulse (Figure 2.), and with equipment separation (Figure 3.).

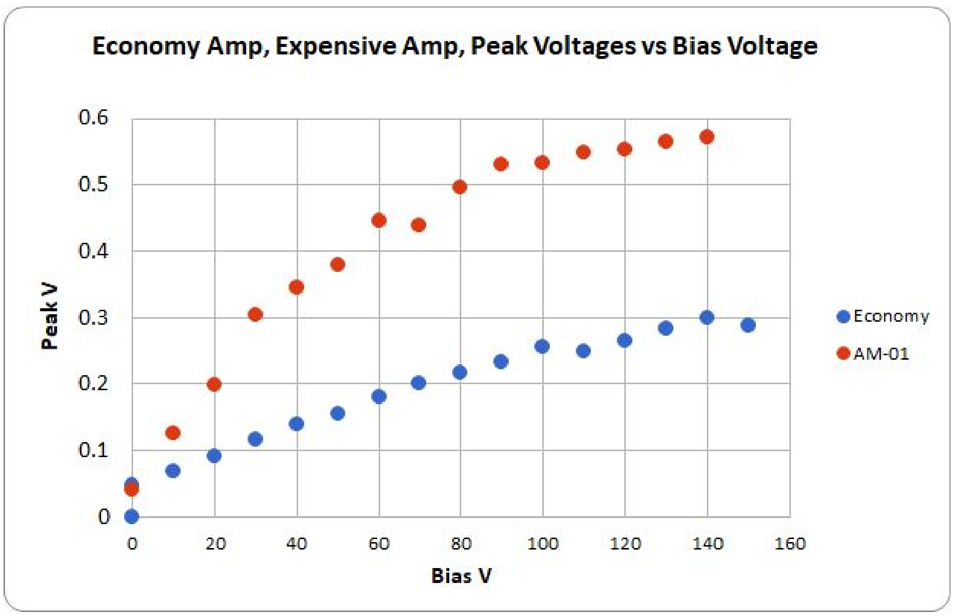

Figure 1. Comparison of voltage behavior of Economy Amplifier versus Expensive Amplifier (AM-01)

From Figure 1, we conclude that both the economy amplifier and the expensive amplifier have similar peak voltage behavior.

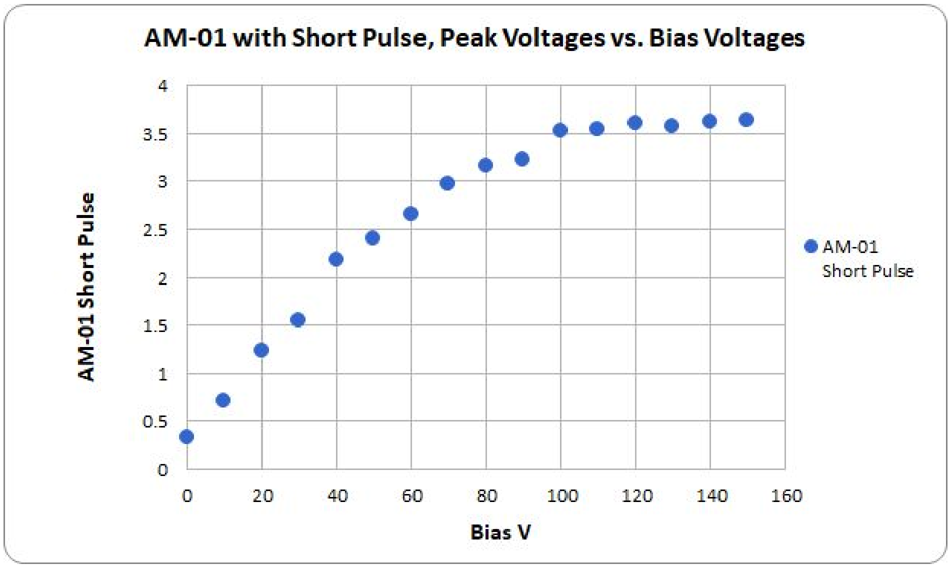

Figure 2. Voltage characteristics of AM-01 amplifier with short pulse.

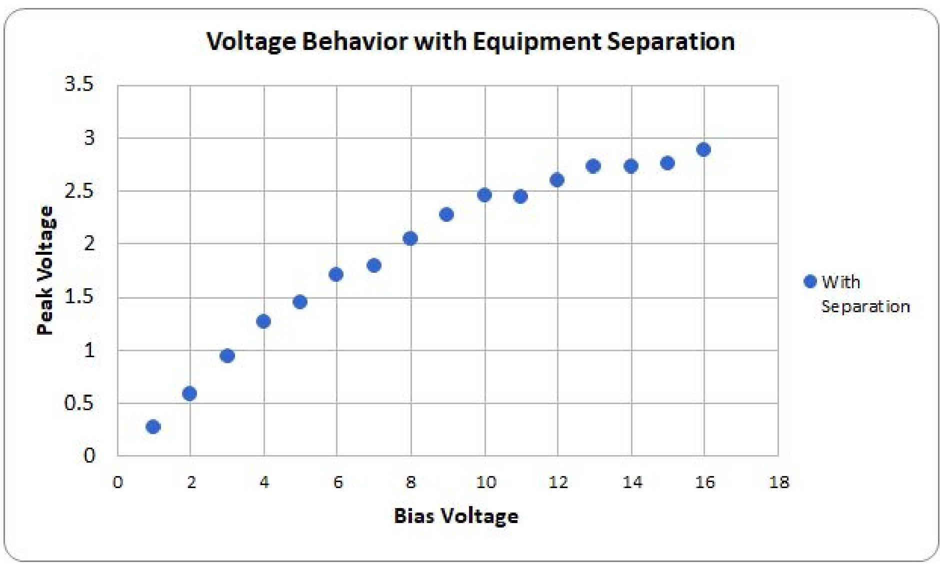

Figure 3. Voltage characteristics of detector when separated from pulse generator.

Detector output current data was collected in response to increasing bias voltage applied and was with the pulse generator on (Figure 4. Left). The experiment was repeated with the pulse generator off (Figure 4. Right).

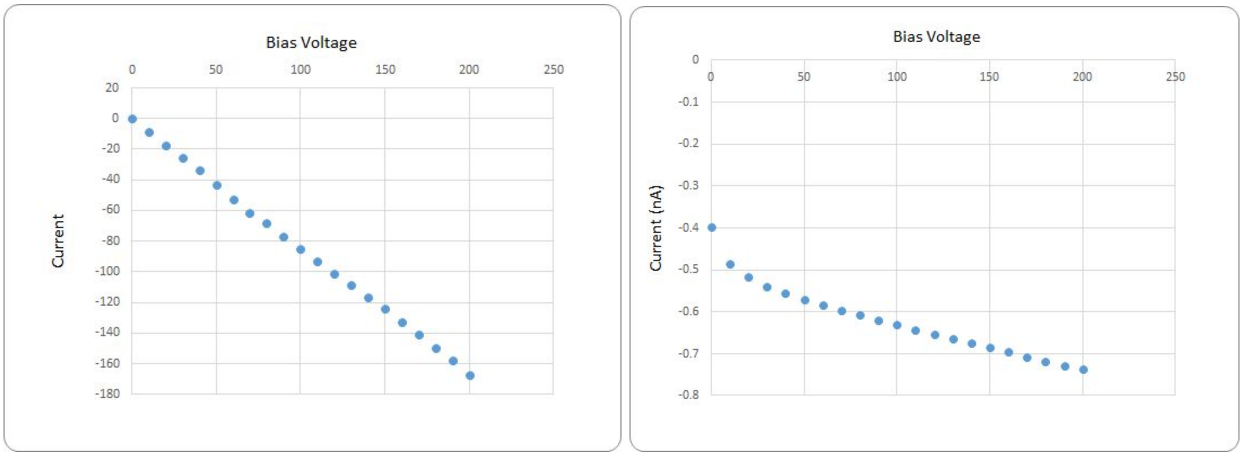

Figure 4. Current voltage profiles. Left: pulse generator off; Right: pulse generator on.

Discussion/Conclusion

We optimized the system setup. The current experiment established the baseline behavior for the detector prototypes under normal conditions with simulated particle incidents. The detectors performance was in line with expectations. We then set out to compare if the economy amplifiers could perform as well as the expensive amplifier. For all intents and purposes, the economy amplifier worked just as well as the expensive amplifier.

In the future, we would like to compare the our current-voltage profiling data with data from capacitance-voltage profiling.

References:

[1] Green JA et. al. Conceptual Design for a Silicon Strip Cosmic-Ray Muon Detector for SNM. Unpublished, Fermilab internal proposal.

[2] Spieler, Helmuth. Semiconductor Detector Systems. Oxford: Oxford UP, 2014.

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