Electronics for GLD Calorimeter

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In the GLD detector concept, scintillator-based calorimeter is considered as the primary candidate, and new photon sensors will be used for the readout. In this paper a consideration on the required electronics for the calorimeter system is described.

1. INTRODUCTION

The GLD detector is one of the proposed detectors for the experiment at the international linear collider (ILC). It is relatively larger then other detectors, and thus the calorimeter systems (ECAL and HCAL) also have larger volumes. We are proposing a scintillator-based sampling calorimeter[1] for both ECAL and HCAL of the GLD detector, due to its inexpensive cost, well-established technology and the flexibility for the design. The same technology is chosen for the muon detector as well. Photon sensors are required for such systems, and the new devices called Silicon photomultiplier (SiPM) or similar one by Hamamatsu Photonics (Multi-pixel Photon Counter, MPPC) would be used in the strong magnetic field.

We describe the requirements for the electronics of the GLD calorimeter system, and discuss potential issues and challenges.

2. REQUIREMENTS FOR ELECTRONICS FOR GLD CALORIMETER

The SiPM was originally developed in Russia. It is in short a multi-pixel avalanche photodiode (APD) operated in the limited Geiger mode. The size is compact (several mm^3) and the active surface is $\sim 1 \times 1\mathrm{mm}^2$, which is suitable for direct coupling to the wavelength shifting (WLS) fiber going through a scintillator. The number of devices/channels, that should be the same as the number of scintillator pieces, are $\sim$ 6 million for ECAL, $\sim$ 30 million for HCAL and $\sim$ 10 thousand for the muon detector from the current estimate.

The active surface is divided into hundreds or thousands of pixels at the moment, and the number of pixels limits the dynamic range of the device because the pulse height from each pixel is almost the same to each other in the Geiger mode operation. Since we need to detect light signal from MIP to the shower maximum, the number of pixels should have up to about ten thousand; otherwise a saturation effect should be corrected for the energy measurement. Although noise rate of the new device is rather high ($\sim$ hundred kHz), MIP signal should be clearly detected. When we use ADC or something similar and set the MIP equivalent to 10 ADC counts, the ADC dynamic range needs to have 12 bit or more. In case of a Flash ADC, it could be more or less relaxed.

The electronics must be equipped with timing measurement capability. It will be easy to identify a bunch crossing for the current design of the bunch structure: more than 100 ns between bunch crossings in a bunch train. If we need to detect energy deposit from a slow neutron, $\sim$ 1 ns of timing resolution would be needed. Also, in order to distinguish cosmic rays by using timing information of the muon detector, similar time resolution will be necessary. If we want to measure a time-of-flight at the innermost layer of ECAL any way for the particle identification, less than 50 ps per TDC count would be needed.

Another issue for the electronics is the power consumption of the front-end readout system. In order to reduce power loss in cables as well as the total power, lesser power consumption is very preferred. It is still difficult to estimate at the moment, but $\sim$ 20 mW/ch may be feasible.

Data size and data transfer rate are also evaluated. In the current design of the bunch structure (200 ms between bunch trains), it is natural to read out the whole data in a bunch train after the bunch train. Assuming that we will be using a Gigabit Ethernet (1 Gbit/s) for the data transfer, up to 25 Mbytes (200 Mbit) can be transfered during the period (from a buffer storing the data). If a data size is 4 bytes/hit with zero suppression, $\sim$6 M hits/train or a few k hits/bx is possible. Detailed full simulation will be needed for accurate evaluation of the data amount, however there would be no problem for the issue with more advanced technology in the future and/or paralleling the system.

3. POWER SUPPLY AND READOUT FOR THE PHOTON SENSORS

The SiPM or MPPC are relatively new devices, and are still being developed actively, however so far there are some problems for the actual operation or production use.

The device has very narrow range of the bias voltage appropriate for the operations (less than 1 V), thus power supply should be quite stable, and modest temperature control may be necessary. Also, the operational range differs between pieces: a few V for the same wafer, and more than 10 V for the different wafer for SiPMs [2]. Therefore, the bias voltage must be set individually for the huge number of photo sensors.

According to an experience of [2], the operation voltage was determined at the test bench where 15 SiPMs were put under LED light such that 15 pixels in a device should be fired for MIP-equivalent signal. After the test, all SiPMs were grouped into modules so that the operation voltage was equalized within $\pm$ 2V in one module. They have already developed an ASIC for the calorimeter system, and the bias voltages of the SiPMs in a module can be adjusted within 5V range by a 8-bit DAC in the ASIC.

As mentioned above, R&Ds on the devices are still in progress, but the similar or better calibration and the power supply systems will be required for the GLD calorimeter and muon detector. In addition, a monitoring system for the whole system and/or each photon sensor should be prepared for the stable operation.

4. SUMMARY

In this paper, current or anticipated issues on the calorimeter electronics are discussed. Using the new photon sensors for the huge number of channels will require a system for the calibration and the operation, and the new dedicated ASIC may be needed.

We, the GLD calorimeter group, have a plan to perform beam tests around 2007, and thus a complete system including the electronics and DAQ system have to be prepared by addressing the above issues before then.

Acknowledgments

The authors would like to thank Felix Sefkow and Tohru Takeshita for useful discussions.

References

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