CLEO III Silicon Vertex Detector and Assembly Database

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Abstract

The vertex detector currently in operation at the Cornell Electron-positron Storage Ring (CESR) will be upgraded with a new four-layer double-sided silicon vertex detector. I have designed a database to keep track of massive amounts of information on the status and quality of each of the 511 detector channels and the corresponding readout electronics.

Introduction

The vertex detector currently operating in the CLEO experiment at Cornell University is used to gather data on high-energy particles, specifically quarks and leptons. To date, the CLEO detector can handle luminosity of 5.5 x 10^{32} cm^{-2} s^{-1} and uses radiation-soft CMOS (Chemical Metal Oxide Substrate) technology. CLEO has begun a major upgrade to the detector, which will help gather data at a faster rate and prolong its life span.

The CLEO II detector will be upgraded with a new four-layer double-sided silicon vertex detector [1]. In order to cope with an expected factor of three increases in luminosity, the CLEO III detector will use radiation hard electronics. The new detector is a barrel shaped design (see Fig. 1) with solid angle coverage of 93% [1]. The detector will be wirebonded to the electronics via flexible circuits. The electronics, which consists of resistors, capacitors, preamplifiers, and digitizers, are placed together on hybrids and the attached to support cones [1]. The ultimate goal will be to prolong its life span and improve the yield and cost of the detector by having the electronics attached to hybrids [2].

The Si-3 team working at Cornell is also building a database discussed later in this paper in order to keep track and share information amongst itself and other universities involve in the project. This database will keep track of individual detector components (e.g., detectors, flexes, and readout electronics) as well as the ladder building assembly. The database will keep track of specific information such as number of open and shorted channels, leakage current, breakdown voltage, etc. of each detector component and the ladder building assembly components. It is especially important to keep track of current leakage before and after assembly since current leakage can lead to vast amounts of noise within the detector. This massive amount of information will help in testing and performance of all the 511 channels of the detector, scheduled for installation in 1999.

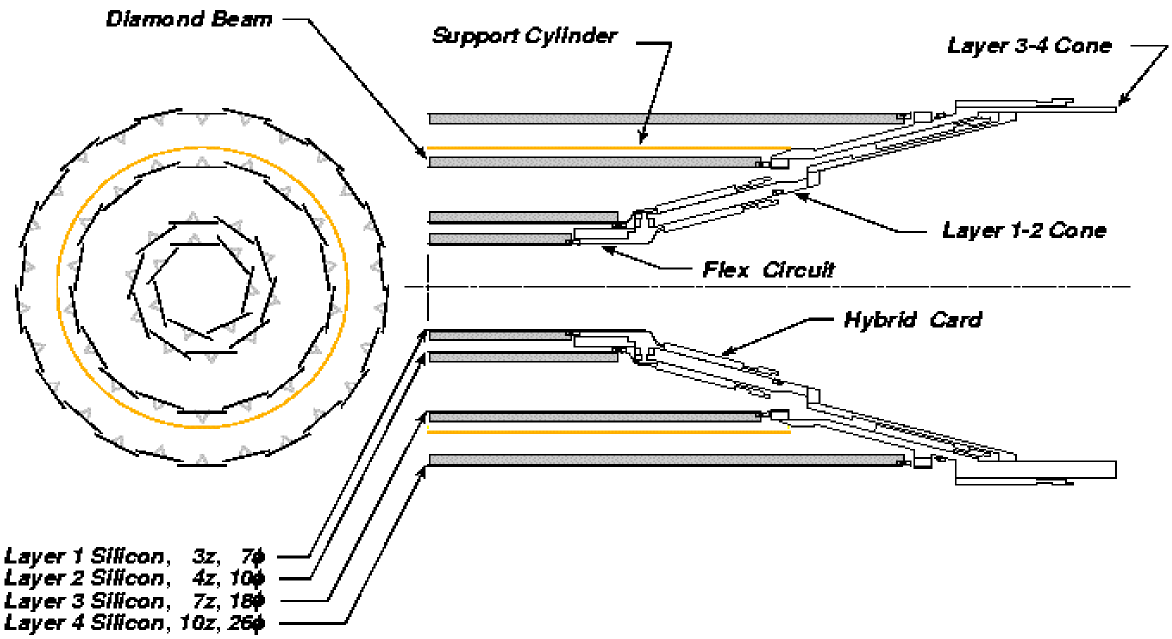

FIGURE 1. Front and side view of the CLEO III silicon design.

Detector Design

In order to improve the reliability and reduce the cost of designing detectors, the Si-3 staff has chosen a simple design where bias resistors and decoupling capacitors are not integrated into the design of the detectors but is mounted on a separate hybrid board. There will be 511 strips for both the r-ϕ and z side on each detector.

Flexible Circuits

In order for the electronics to receive signals from the detector, a flex cable shown in Fig 2 is wirebonded between the ends of the detectors and the electronics sitting on endcones. Since the detector has 511 strips per side, the flex cable must also have the same number of strips per side.

The copper strips on the flex circuit run parallel at 100 µm pitch along the circuit similar to that of the p-side of the detector.

Like the detector, flex circuits are tested in order to find open and shorted channels. One of the main issues with flex circuits is lost channels due to low wire bonding success rate. The Si-3 staff believes that these contaminants may occur during either the processing or cutting phase of flex fabrication. The Si-3 staff will try to use the nanofabrication lab at Cornell and clean the flexes using plasma. Preliminary test results show that plasma cleaning results in higher wire bonding success rate.

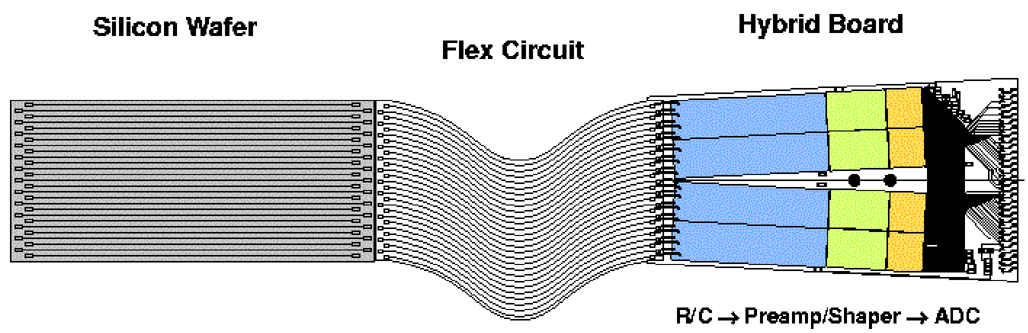

FIGURE 2. Detector, Flex, and Hybrid Board.

RC Circuits

The CLEO II detector originally integrated its bias resistors and decoupling capacitors on the detector itself. This concept led to yield problems (pinholes) within the detector due to integration of readout capacitors on the detector.

The upgraded silicon detector will remove the readout electronics from the detector and mount them on hybrid boards as previously discussed. Maximum charge is collected between the detector and readout electronics due to the fact that the RC on the hybrid must be greater than the detector capacitance. This is true if you think of the capacitors as being in parallel with each other. When particles pass through the detector, ionization takes place there by discharging the detector capacitor. If the R/C capacitor is larger, then the discharge is absorbed by the R/C capacitor. Hence, current flows from the detector to the RC via the flex circuit. The current is measured with readout electronics in order to determine which strips are traversed by particles.

Readout Electronics

The silicon detector readout electronics consists of a front-end preamplifier and a back-end ADC (analog-digital-converter). The readout electronics is used to measure the current and particle passage between the detector and RC previously discussed.

The front-end electronics consists of a preamplifier, shaper, and buffer gain stage [1]. The preamplifier has 128 channels and uses radiation-hard technology unlike the radiation-soft technology used by CLEO II. When the switches are closed, the shaper and gain stage return to a stable baseline allowing signals to be picked up by the back end electronics.

The back end electronics consists of a 128-channel analog-digital-converter. The back end electronics stores the results of the particles passage in a FIFO (first-in-first-out) bus line [1]. To initialize back end electronics, serial bit strings are used and are read out in bytes along parallel buses [2].

There is more design specifications that go along with the readout electronics. However, for the purposes of understanding readout electronics in general, only the basic concepts were discussed.

Database

In order to keep up with the information provided by all universities involved with the silicon project, the Si-3 staff is in the process of designing a database to keep tabs on testing of individual detector components and the ladder building production once all the information is available.

In order to build a database system, a combination of forms, reports, macros, and visual basic codes will be used. Since most of the information is already available, our task is to create a database where the user enters the main switchboard in order to lookup or update existing information stored in MSAccess. This process can again be accomplished through the use of visual basic code or by updating the information in the table design and transferring this information to a form sheet. Perhaps the easiest way of designing most of these reports is the use of wizards in MSAccess. Here, the user takes all the available information given and inputs it into an access wizard. The wizard configures a design with all the information displayed. When the process is done the information is saved to the switchboard.

Detectors:

N-side: View n-side results (all detectors)
Update information of n-side detectors
Inquire about n-side detectors

P-side: View p-side results (all detectors)
Update information of p-side detectors
Inquire about p-side detectors

Flex Circuits:	Hybrid:
View flex circuit results	RC:
Inquire about flex circuits	Front-Back end electronics
Updates on flex circuits	Starter Assembly

FIGURE 3. Structure of the Database

Specifically, our goal is to keep track of information on detectors, flex circuits, hybrids, and starter assembly parts. Information pertaining to open and shorted channels, leakage current, voltage depletion, etc. will be maintained and updated as each component is tested and used for production. Fig 3 shows the design for the database structure. For the purposes of database assembly, only the detector parameters will be discussed.

Database Structure

The database structure is a hierarchical design that incorporates detectors, flexes, hybrids, and starter assembly within the main switchboard. Access moves through the structure based on the information requested. Once the user is in that domain information is made available by typing the ID number of either detector, flex circuit, hybrid or starter assembly. At the present time however, only information pertaining to detectors and flexes are available.

Detector Parameters in the Database

In detector testing and production, detectors are designed and constructed by Hamamatsu Corporation in Japan. The detectors are then re-tested at Oaklahoma, Purdue, and Cornell Universities. The database at Cornell will take the results of all the universities and store it in the database situated here at Cornell. Table 1 shows a list of information that will be stored on the database from Hamamatsu and the universities involved. Once this information is inputted into the database, information on flex circuits, hybrids, and starter assembly will be added to the database. Once testing results are underway the information can be viewed through the World Wide Web.

Conclusions

The database serves to store information and update the progress of the silicon detector. Since there will be a massive amount of information on detector testing, flex circuits, hybrids, and starter assembly production, it is important that the information is readily available to the Si-3 staff and others who wish to update, modify, or use the information. Also in the case where there is discrepancies in testing results or loss of hard copies, the information is again readily available on the database.

Researching the vertex detector and building a database has helped me to become aware of how even the smallest of task helps one to see the big picture in the overall grand design. Although there was little physics involved in learning about the detector, I have become aware of just how physics and electronics are inter-related.

Acknowledgements

I would like to thank Prof. Giovanni Bonvicini for providing the opportunity for me to participate in the Research Education for Undergraduate. Programs such as this has helped my understanding of how physics and engineering are inter-related.

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Finally, I appreciate the financial support I received from Harvard University.

References

1. Patrick Skubic, *The CLEO III Silicon Vertex Detector*, representing the CLEO collaboration at the Vertex 97 conference, Mangaratiba, Brazil.

2. CLEO III proposal CLNS 94/1277 (unpublished).

Table 1. Detector parameters

Hamamatsu Measurements: • Guard ring current • Average Current • P-side opens or shorts (number and list) • N-side opens or shorts (number and list) • P-side high current channels (number and list)
Oaklahoma Measurements: • Number of high current p-strips • P-side high current cut • Number of high current n-strips • N-side high current cut • Depletion voltage • URL link: To Oaklahoma test files
Purdue Measurements: • P-side guarding current • N-side p-stop current • P-side opens or shorts (number and list) • N-side opens or shorts (number and list) • P-side high current channels (number only) • N-side high current channels (number only)
Cornell Measurements: • P-side guarding current before gluing • N-side p-stop current before gluing • P-side guarding current after bonding to flex • N-side p-stop current after bonding to flex