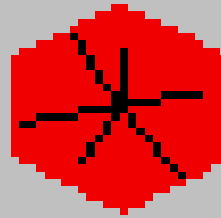


**HEP**



**OSU**

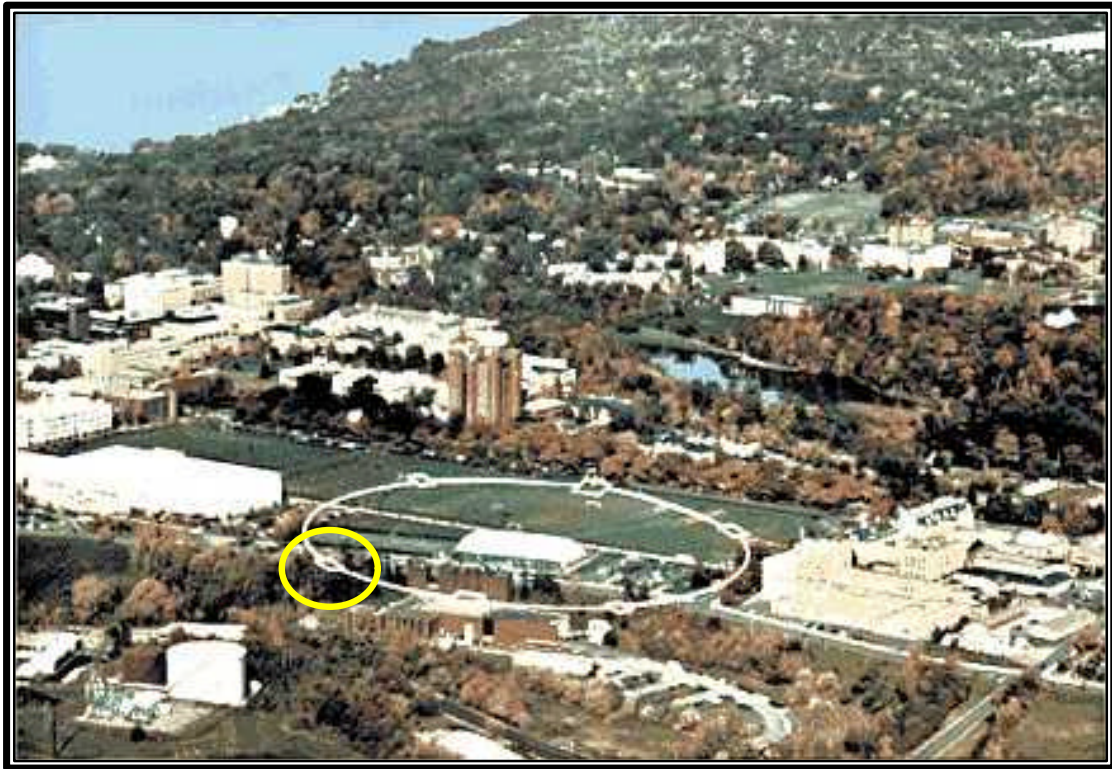
**High Energy Physics**

# **OSU involvement with CLEO III update**

**Jim Honea - Angelo State University**

**Richard Kass - OSU Professor**

Fig. 1. CLEO location at CESR



## 1. Overview

In order to produce increased sensitivity to the physics of  $B$ , Tau, and Charm decays, the Cornell Electronic Storage Ring (CESR)<sup>1</sup> is being upgraded to a luminosity of  $1.7 \times 10^{33} / \text{cm}^2/\text{s}$ . Also referred to as upgrading to B-factory luminosities. This will also give the opportunity to experience rare decays and the possibility of measuring time-independent CP violation. To efficiently use the increased luminosity, the CLEO detector, located inside CESR as seen in Fig.

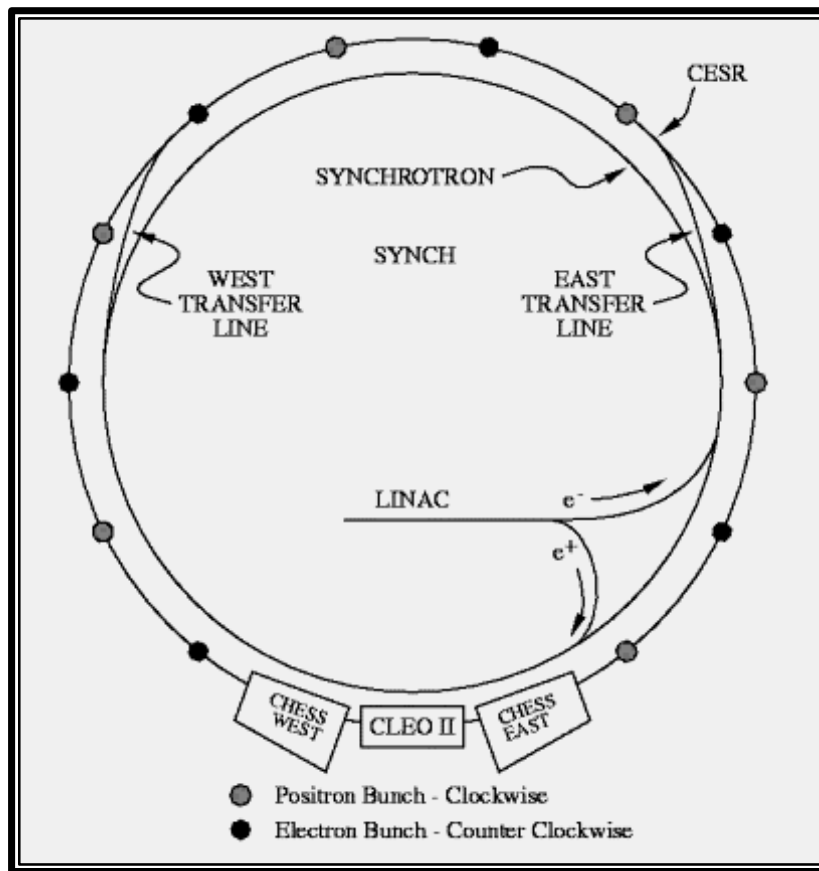
<sup>1</sup> CESR is located at Cornell University in Ithaca, New York

1, will be upgraded with a new silicon tracker (Si3), a new drift chamber, and a new particle identification system [1]. CESR normally operates at an energy that is “just right” for producing  $B$  mesons through the annihilation of an electron and positron into a  $b$  quark and an anti- $b$  quark. Since the  $b$  quarks are heavy and relatively slow moving, they are more amenable to study than the lighter quarks. Experiments at CESR have provided much of the known information about  $b$  quarks, and have provided stringent quantitative tests of the Standard Model [2]. Fig. 2 may give you a better understanding of how the CESR really works. Electron and positron beams are circling this huge ring, on the order of microseconds, while

passing through the CLEO detector. In order to keep these beams moving in a circular path, huge magnets are placed strategically around the inside to bend these beams. Every time these beams come around, RF cavities give them a

boost of energy to replenish what the beam lost going around, and keep it going. With this type of momentum, the particles would travel very far in straight paths without out much curvature. So the magnets play a big role in this process.

Fig. 2. Explanation of CESR



## 2. CLEO III

CLEO III is a multipurpose high-energy physics detector incorporating neutral and charged particle detection and measurements, used to analyze electron-positron collision events generated by the CESR 10 GeV storage ring. The CLEO III detector is operated

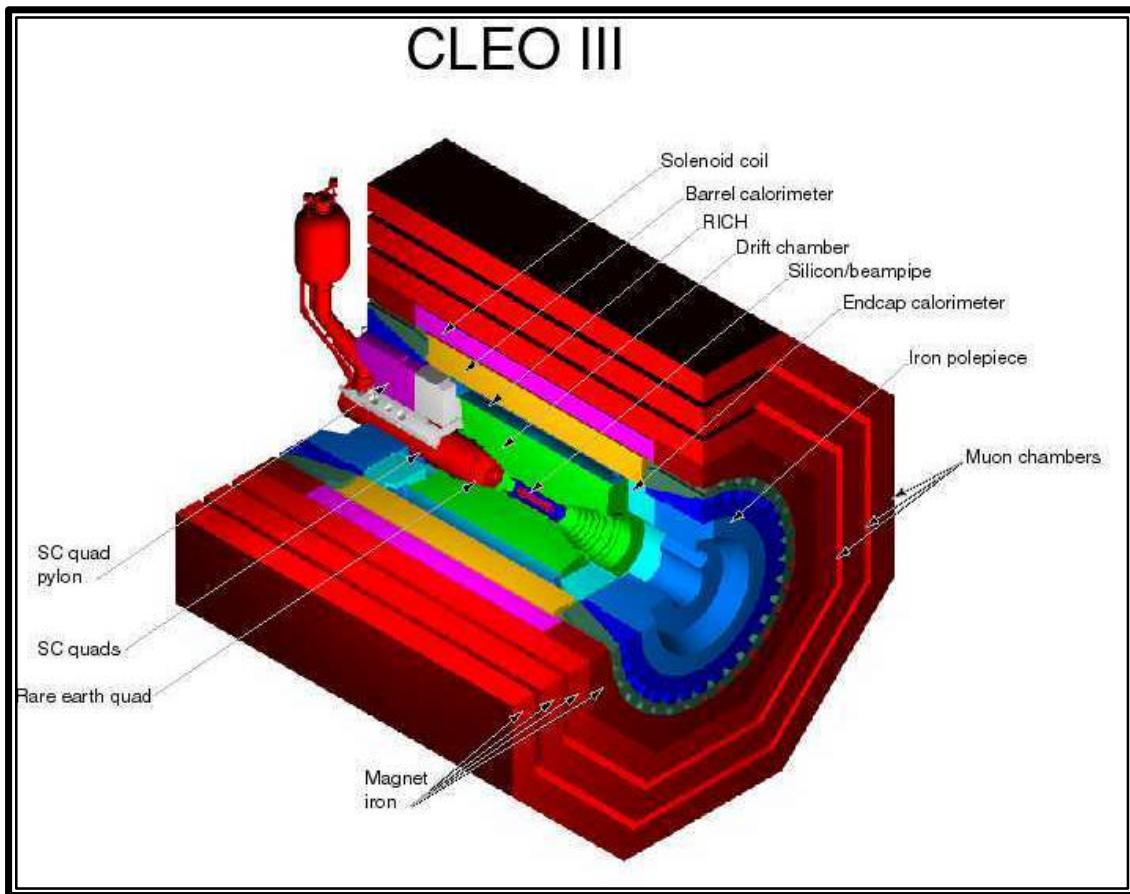
by a collaboration of over 100 physicists from many institutions, including Kansas, McGill, Minnesota, Syracuse, Vanderbilt, Virginia Tech, SUNY Albany, CalTech, UCSB, UCSD, Carleton University, CMU, Colorado, Cornell, Florida, Harvard, Illinois, Ohio

State, Oklahoma, Purdue, Rochester and SMU.

The detector itself is about 6 meters (~20 ft.) on a side, containing about 900,000 kilograms (~2 million lbs.) of iron and over 25,000 individual detection elements. Fig. 3 is a side view cross-section of the detector, with the electron-positron beam passing through the center of the detector. The

electron and positron beams collide and annihilate in the center of the detector, producing new, sometimes exotic and unfamiliar, matter (particularly  $b$  quarks). Most final state particles created in the collision pass through the beam pipe and enter the detector, though some particles travel along the beam pipe and thus escape detection [3].

Fig. 3. Cross Section View of CLEO III Detector



## 2. Silicon Tracker

A major part of the tracking system upgrade is the construction of a new four layer double-sided silicon tracker with 93% solid angle coverage and new

readout electronics [1]. This silicon tracker, Si3, is located in the direct center of CLEO. It is the small pink and

blue cylinder in the middle of Fig. 3. This is currently the project at OSU.

The silicon tracker consists of four silicon layers concentric with the interaction region beam pipe. This tracker along with the drift chamber make up the CLEO III detector, and together make all of the essential measurements desired in a high energy collision. The silicon measures  $x$ ,  $y$ , and  $z$ , and from these measurements, we can determine  $r$ ,  $f$ , and the cotangent of the polar angle, referred to as  $q$ . While the

drift chamber measures curvature. Both devices measure the azimuthal angle, referred to as  $\phi$ , and the impact parameter [1]. There are a total of 447 sensors, which make up 61 ladders on this mounting cone. It takes measurements by a voltage drop across the surface which creates an electric field that collects electrons as they are knocked out of the silicon lattice. Fig. 4 shows a three dimensional side view of the tracker along with an end view.

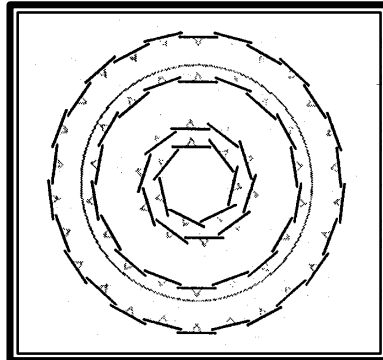
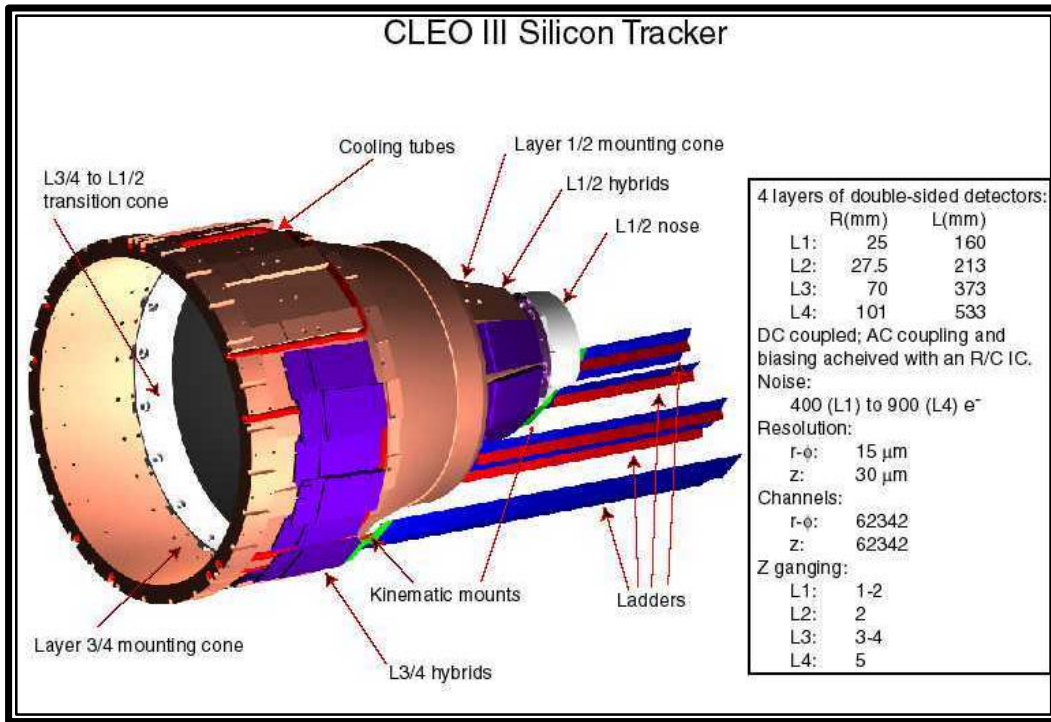


Fig. 4. Side and end views of Silicon Tracker

Each Silicon detector is double sided to enable the read out to be on the three-dimensional capability. Double-sided detectors give two independent coordinates for a hit, thus specifying a point in space. The sensitive strips on the detector sides that face away from the center run in and out of the screen, and are used to measure particle trajectories in the plane of the screen ( $r$ - $\phi$ ). The strips that face inward run in the plane of the screen, and measure trajectories in and out of the plane of the screen ( $r$ - $z$ ). For this side an extra metallization on the silicon is used to route the signals to the electronics at the ends of the detector. The old one-sided detectors only had the ability to read out one coordinate, thus producing some uncertainty in measurements. There are a total of 511 traces on either side of the sensor. These traces, or strips, are about

5 microns in size. This is about 1/20 the size of a human hair. Because of the limited space inside of the detector region, the electronics for all of these sensors have to be placed at an angle to the detecting surface. This requires a flex circuit to connect the silicon and the electronics. The electronics, which are mounted on a hybrid at each end of every ladder consists of four R/C chips which provide biasing resistors and AC coupling capacitors, four front-end chips, and four back-end ADC chips [1]. There are 122 double-sided hybrids and approximately 125,000 electronic channels. Fig. 5 shows a silicon sensor and an electronic hybrid connected by a flex circuit This was assembled here at OSU using a very high tech wire-bonding machine in a class 10,000 clean room.

Fig.5. Silicon detector and Hybrid



The electronics receiving all of this data have to be able to transfer it into readable information and send it somewhere. That is where I come into

this project, I am involved in the design and building of the electronics and power supplies behind the detection.

## 4. Schematic of Project

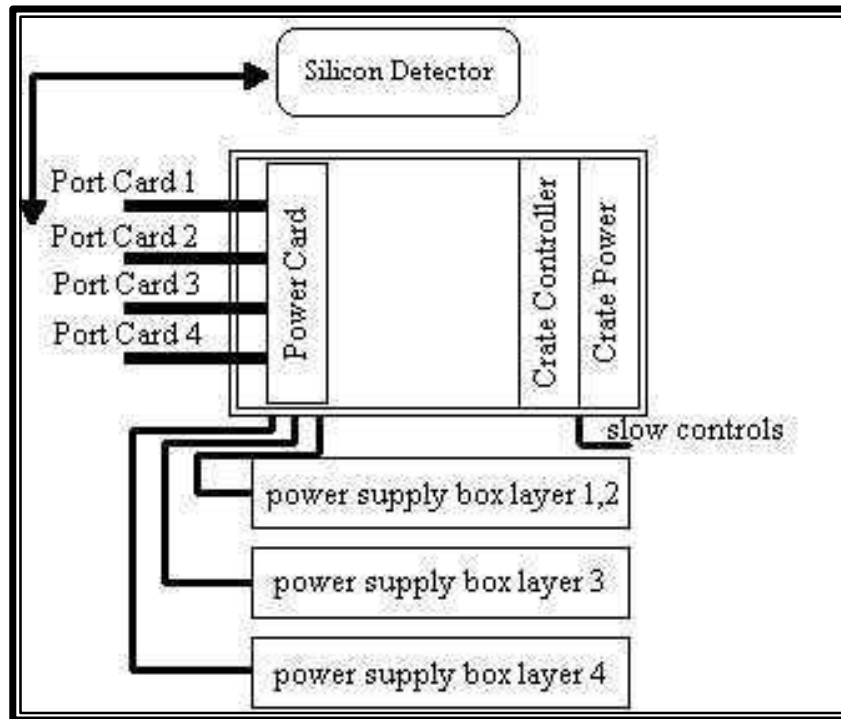


Fig. 6. Schematic Diagram of System

This diagram, Fig. 6, illustrates how the silicon detector will be run. When a collision occurs inside the detection chamber, a set of signals is produced on the surface of the silicon substrates. It is these signals that are past through the flex connectors and turned into readable data inside the hybrid. This data is then past to the port cards and then through the electronics inside the crate. This information is processed and sent to computers for analysis. Then the process starts all over again.<sup>1</sup>

Everything you see here has its own intricate part in the running of this

<sup>1</sup> These collisions occur on the order of micro-seconds. This is a lot of information being translated

silicon detector. We design and assemble almost everything in this schematic here at OSU. The crate in the center of this drawing, seen in greater detail later, is the center of this operation. It not only takes information from computers and relays it to the different port cards, but it also receives information from the detector itself through these same cards and sends it back to more computers. This is only half of the actual setup. There is an exact replica that works in unison with this one. In order to run this system, there are a set of six power supply boxes that produce a number of different voltages to power all the different pieces in this chain of electronics.

This project has been divided into two major sub groups. One being the crate design and assembly, and the other being the power supply design and assembly. Both of which I am involved

in. Even though I have had some involvement with the electrical design, I mostly carry out the mechanical design and assembly.

## 5. The Crate

The crate is the center of all the activity going on in this system. It is very hard to portray information about the development without showing

pictures, so the following is an illustration of our processes her with slight verbal explanation:

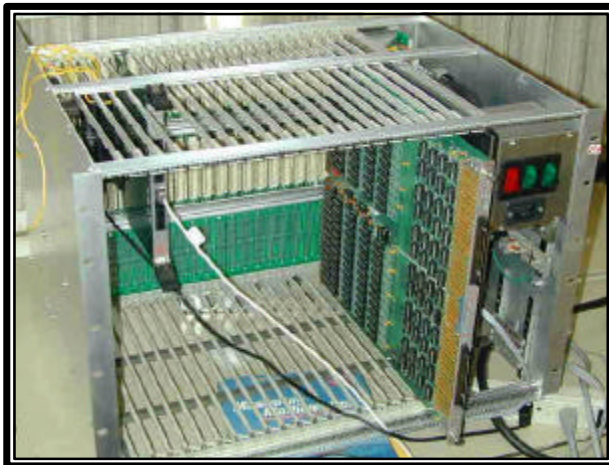
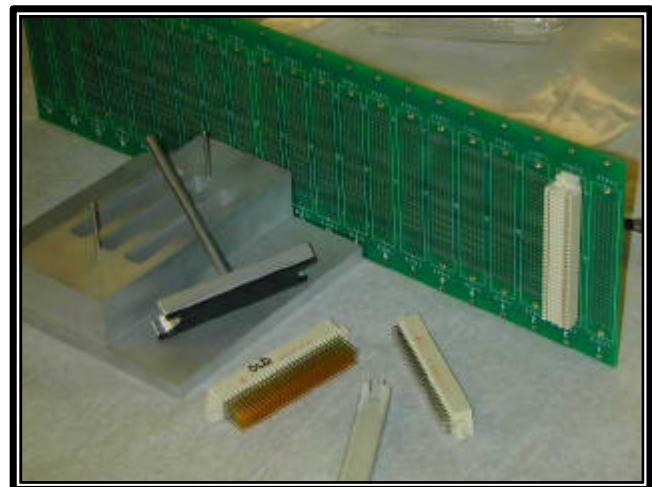


Fig. 7. Crate Condition Upon Arrival

Fig. 7 is what the crate looked like when I arrived ten weeks ago. It basically is an aluminum box that houses many electronic pieces. What you see here is the casing with some of the controls already installed in the right side of the box. The data card sticking part of the way out is just there for temporary adjustment. The real ones are still in production.

In order to connect the port cards to the crate, we needed to use a connection board. Research was done and it was determined that push-pin connectors would be best. They do not require any solder to assemble. The only tricky part to these connectors is how they push into the G-10 backing. They require a substantial amount of equal force, but not so much pressure that you bend or break pins. The jig you see in Fig. 8, I created in order to ease in this process. The pressure plate goes into an arbor press in the shop, and the G-10 fits

Fig. 8. Jig Created to Simplify Connector Assembly



onto the base by the way of those vertical aluminum rods sticking up from the ends of the base. When assembled right, all 160 holes line up, and the arbor

press enables equal pressure to be applied and the connector slides right in. This part of the project went surprisingly without glitches.

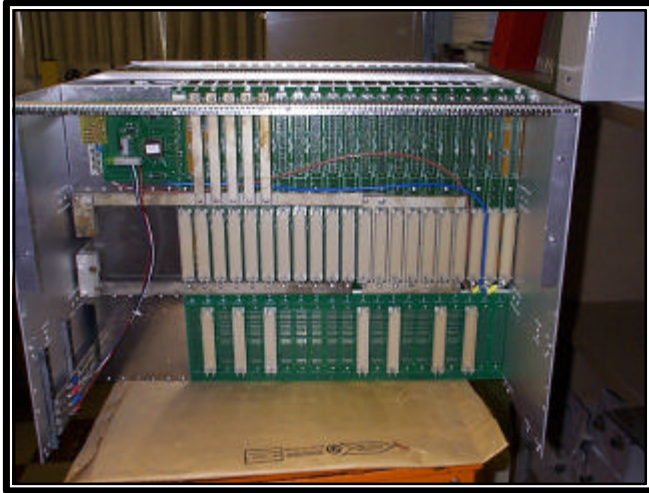


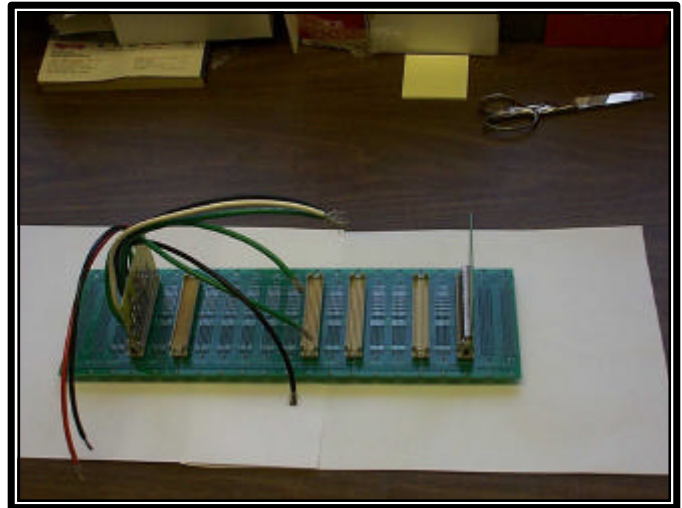
Fig. 9. Crate With Connector Boards

After all of the connector pins were inserted correctly into the board, the next step was to affix them to the crate. Fig. 9 shows the crate with these boards screwed into place. The end you see here is where the power connector cards will plug into. They go into the bottom section of pin connectors. On the flip side is where the data cards in Fig. 7 will go. With these connectors everything just pushes into place, no soldering or bonding is required. It makes things very nice for assembly and correction, if needed.

Fig.10 shows the finished connector board with a test power connection card pushed into one of the pin connectors. This gave us an idea if the preliminary design was going to work. Now that we were convinced that this was the correct design for this system, we needed to move onto the next step.

Fig. 10. Power Connection Card Creation and Testing

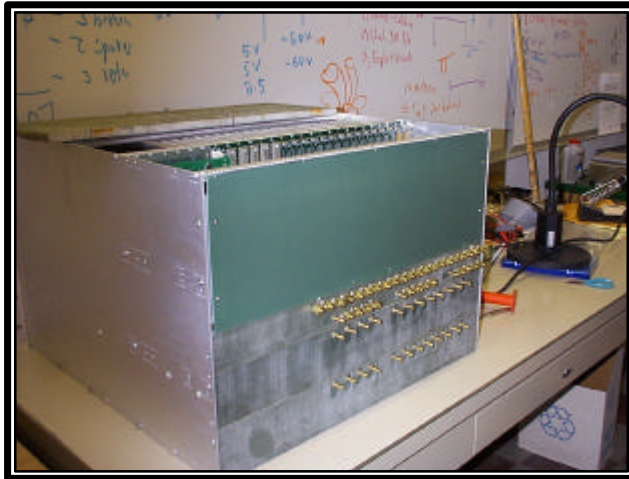
The power connection cards could not wire directly into the silicon detector because the crate has to be as a separate entity. The reason being, so when shipped to Cornell it can be connected up to the detector and the other computers. With great deliberation we decided to make the back of the crate out of half-inch G-10. This was for two main reasons. One, the G-10 is non-conductive so it is perfect for housing connectors. Second, it is very strong for its size. It gave us the stability we needed to keep the wires from putting too much pressure on the inside of the



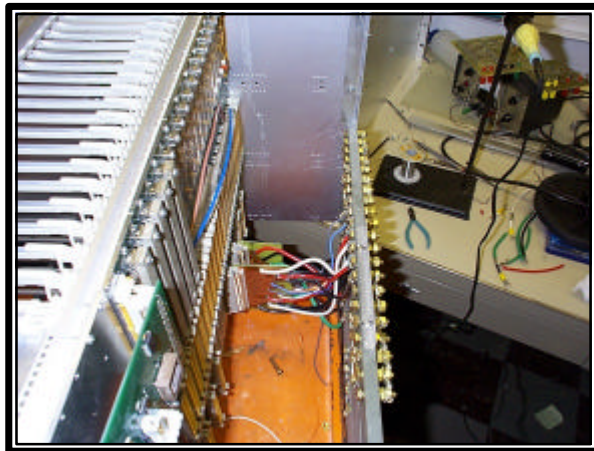
crate. It provides a good barrier to outside interference on the crate. In Fig. 11 you will see a finished version of the back plane. The top layer is 1/8" thick G-10 while the bottom three are 1/2" thick. The reason they are so much thicker is that they will take the brunt of the force. These G-10 pieces needed to

be cut to exact dimensions in order to replace the back panel of the crate and still be snug. Milling G-10 can be kind of dangerous. It is a fiberglass type substance, so when cut or milled it produces this fine dust that can be harmful if breathed in large quantities.

Fig. 11. Back Plane of Crate



Now that the back plane was completed, the next phase is the port cards and the data cards. We needed make test power cards and then install them into the crate to see if this is all going to work. Fig. 12 was taken after I installed these two power cards into



the

Fig. 12. Test Power Connector Installed

So precautions had to be taken in this part of the project. On the side of the crate you see in Fig. 11 will be where the wires come in from the silicon detector and meet up with the port cards, connected on the hidden.

These wires from the detector, some as big a 4-gauge, will be screwed into copper connectors and then bolted onto the G-10 by the  $\frac{1}{4}$ -20 bolts protruding from the panels. This may seem like overkill, and in a way it is, but it is necessary. If someone were to hit one of these wires it would just tear out of the G-10 not causing much damage, where as if it were connected directly to the power connector cards, it would rip the whole card away from the inside of the crate. Maybe causing internal damage in the system. These electronics are very sensitive and require a lot of protection.

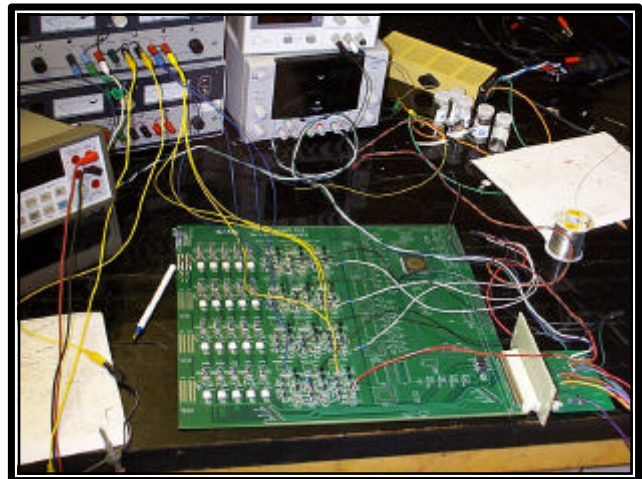


Fig. 13. Partly Completed Test Data Card

crate. The wiring and placement was not arbitrarily done. It was strategically layed out so that the wires were not cramped, and that the small space that we had to work with was efficiently used to it's potential. Fig. 13 is a picture of a data card in the process of being tested.

Because of the intricacies of the electronics on this card, a lot of preliminary tests need to be run in order to achieve what we want. Once these cards are installed and the crates are sent

to Cornell, they are final. Therefore the quality control and testing during this project has been very high and will continue to be, until finished

## 6. The Power Supply

The power supply, much like the crate, was done in many phases. Each of the six power supply boxes contains nine

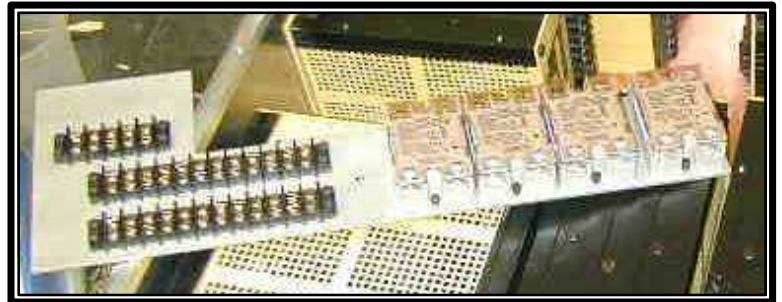


Fig. 14. Power Supply Box

different voltage sources that supply the voltage for everything that requires power in this system. Each voltage supply is a separate unit and needed to be installed into a box that makes them work as a unit. Fig. 14 is a power supply box in its preliminary stage. Inside this box there are the nine supplies, the little yellow units, that were manufactured in industry and installed here at OSU. In order to wire all of these individual units together and get them out to the crate, we needed a relay board and a cover plate with connections to the outside of the box. The plans were drawn for both

of these shortly thereafter, brought to me, and I built them. Fig. 15 shows a closer picture of the relay board that fits down inside of the power supply box and is where all of the wires are routed through. It regulates the voltages and monitors the supplies along with the computer board in the top left-hand corner of Fig. 14.

Fig. 15. Relay Board



Now that all of the major mechanical parts of the power supply boxes were finished, it was time to move onto the electrical aspect. Which brought up the thought: When you have this many wires and voltage supplies in such a tight space, the heat it going to be

tremendous. So a radiator, so to speak, was designed. Two copper plates were designed to sandwich a snake like copper tubing that would carry water and cool the system. These plates are to go on the top and the bottom of the box when completed. The electrical shop got

the box wired and now it was time for testing. Testing something like this is not very easy or even trivial. The choice of testing this massive source of voltage became a very complicated set of resistors, used to simulate a dummy load. But the question of heat arose again. Each of these resistors needed to be heat synched and dissipated somehow. The resistors were brought to me and I began to go to work. Fig. 16 shows the resistor board I came up with. We decided on 3/8" aluminum so the heat would dissipate throughout efficiently. To further the heat control, I put these boards on legs so that a fan could be blown across it and the air could get to the maximum surface area.

Fig. 16. Resistor Board

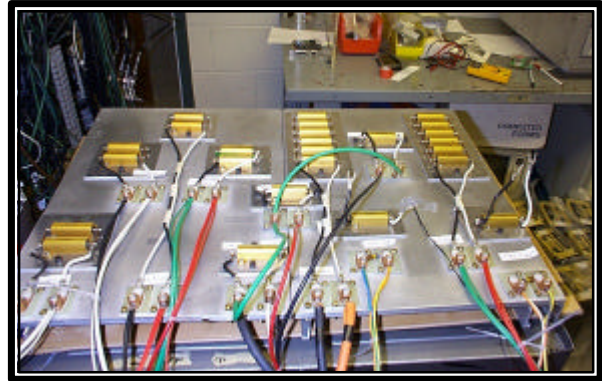
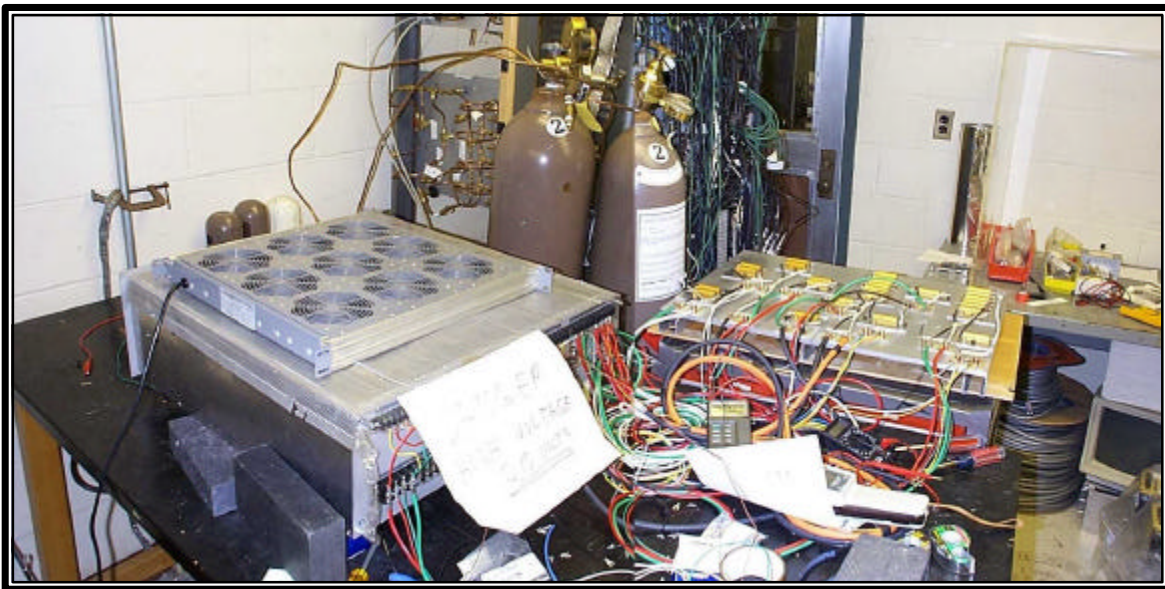


Fig. 17 is a picture of the entire setup of the testing procedure on the power supply box. The box is plugged into a 220 volt outlet in order to draw power to fun the voltage supplies.

Fig. 17. Test Setup for The Power Supply



This illustration looks kind of crude and unorganized, but a lot of thought went into this test procedure. This is nearly the final stage of the power supply box project. Eventually we will be able to

turn the system on overnight instead of a few hours at a time. The heat is a small concern, but with fans and time, is getting better. Fig. 18 is a picture of the thermometer monitoring the resistor

board just in case you didn't believe the abundance of heat created by these power supplies. Without the 15 lbs. of aluminum just think how hot they would get...



Fig. 18. Temp. Gauge

## 8. Applications

There are many applications to the CLEO III and the silicon detector inside of it. One of the preliminary ones is to study B-mesons. The study of B-mesons actually produced one of the first top quark discoveries. There were unexpected decays that produced a top quark. Another very important application is the assistance in the ongoing hunt for the Higgs Boson. Advancements are being made daily in this field.

Like stated earlier, CLEO will help discover and study CP violation using b-quarks. It will help to answer questions like:

Matter vs. anti-matter?

Despite charge, are they really the same?

There are also "real" world applications to this project also. There are ranges from x-ray and gamma-ray astronomy, to medical imaging. Many advancements are being made in mammography and the study of neurophysiological signals.

## 7. Conclusions

Production of most components is in progress and installation of the detector into CLEO III is expected to begin near the end of 1999. I won't

Personally see the completion of these projects, but I am glad I had the opportunity to add my effort to an ongoing project here at OSU. I learned

a lot of things and I hope I was of some assistance with my mechanical skills. Even though I was in experimental High Energy Physics, I personally experienced the more engineering side of this group, which I really enjoyed. A lot of things are involved in experiments.

The system or setup has to be created or built before one can even begin to take data. I was involved in the design and building of the pre-experimental equipment for a national detector. That is something I find very cool. I am very glad I did this.

## **8. Thanks**

I would like to thank Dr. Richard Kass for giving me the opportunity to work with him on this project. I really appreciate the fact that he trusted my judgment on many of these apparatuses. Many professors would have stood over my shoulder to make sure it was done the way “they” wanted. With Dr. Kass, he trusted that I would do a good job, and he actually asked my opinions on a few things. That really impresses me. I would also like to thank Don, in the electronics shop, he was also a great help

and friend in crime. Tom Kelch in the student shop provided a great deal of much needed assistance throughout the program. I would like to commend Linn VanWoerkom for putting up with 16 rambunctious big “kids”. This was a great program and I am very glad that I attended.

Thanks to Dr. Palmer for his consideration and guidance, and to the NSF for the opportunity to have programs like this one.

## **9. References**

- [1] Nuclear Instruments & Methods in Physics Research- Section A
- [2] Fundamental Particles and the Standard Model – Cornell Web Pages
- [3] The CLEO II Detector – Cornell Web Pages