

Quality Control of Muon Detectors for BaBar at The Ohio State University

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Abstract:

Quality testing was conducted on the LST's that will replace the existing RPC's at BaBar. A laboratory was created to adequately test the LST's. Singles rates, efficiencies, and pulse heights were determined for several tubes. Work was put into learning how to utilize a digital gas flow system.

Introduction:

Before I explain the work that was conducted this summer, time will be spent on laying the background and motivation for the summer REU.

At the Stanford Linear Accelerator Center (SLAC) in California, a large detector named BaBar is used to probe decays of B and B -bar (the anti- B meson) mesons [1]. From the conjunction of these two hadrons, comes the name B/B-bar or with a little imagination,



The B meson is made from a d quark and an $anti-b$ quark pair. The B -bar meson is made from an $anti-d$ quark and a b -quark pair. These two particles are created at SLAC by what is aptly known as the B-Factory. As the name makes clear, this ‘factory’ produces millions of B/anti-B pairs so the interesting and rarer decays of these two particles can be recorded. How does the B-Factory mass produce these short lived particles? Through electron-positron annihilations, in what is known as the PEP-II (positron-electron project II) storage ring (see Figure 1). The PEP-II storage ring is the first asymmetric collider which means the positrons and electrons are at different energies (3.1 GeV and 9 GeV respectively) [2].

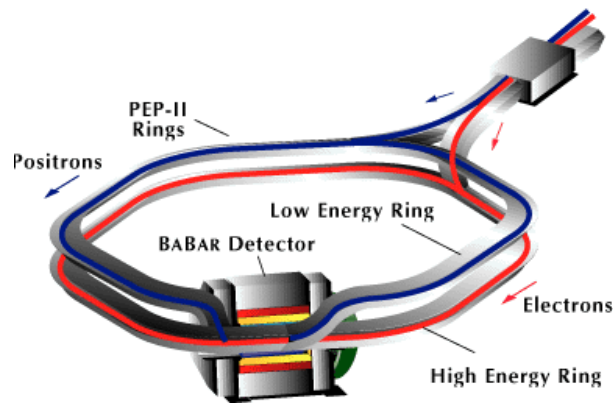


Figure 1: BaBar detector located at SLAC.

As mentioned earlier, the production of B/B-bar's are necessary to study slight differences in decay patterns of products from B's and the anti-particles of those products from the decay of B-bar's. The overarching goal of this vast project is to find out how and why the laws of physics vary minutely for particles and anti-particles. Theoretical models predict the existence of Charge-Parity (CP) Violation which would mean anti-matter decays differently (more or less) than matter. It is believed that for this reason, we have a universe of primarily one type of matter only – if CP violation did not exist (meaning equal amount of matter and antimatter) , the universe would have annihilated. The B and B-bar mesons are particles that decay into leptons, neutrinos, and lighter hadrons. There are many different decay pathways that occur but only about one in a thousand are useful in studying CP violation.

One particle that is produced in the decay process is the muon. This lepton has identical charge as that of an electron but a mass of about 200 times that of an electron. For this reason, the muon is not deflected easily by electric fields as electrons are [3]. While most other decay products are further decayed and detected in the silicon vertex detector subsystem or the calorimeter, muons are not – they are able to leave the whole system but not before passing through muon detectors where the trajectory of the muon can be found when the charged muon causes ionization in the gas filled chambers [4] (see Figure 2).

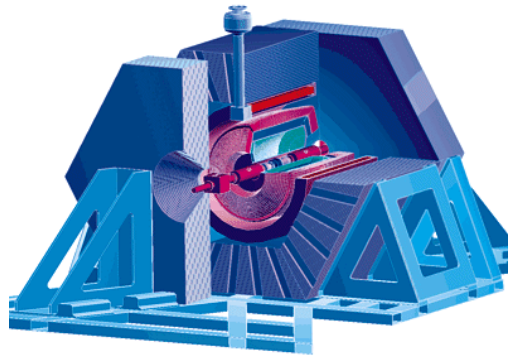


Figure 2: Cut away of BABAR detector. Muon chambers are located in outer octagonal sections.

The motivation behind this summer's work has been to replace the current muon detectors which are called resistive plate chambers (RPC's). The now defective RPC's are quickly becoming useless so an overhaul in the muon detection system is required if BABAR is to continue recording good and accurate data in the upcoming years. In late 2002, BABAR groups from Italy and the United State (including Ohio State) proposed to replace the RPC's with plastic limited streamer tubes (LST's). The tubes consist of four cells per tube. Each cell is a silver plated sense wire $100 \mu m$ in diameter [5]. The cells are located inside a graphite coated plastic PVC extruded structure which is contained in a plastic tube or sleeve which the gas mixture also occupies [5]. The sleeves are fitted with end pieces with gas inlets, and high voltage and ground connectors [5]. The updated muon detectors (all 1000 of them) will be installed in 2004 and 2005.

So one of the main tasks of this summer has been to test several prototypes of the LST's here at OSU. To do so, a gas mixture must be flown through the tubes while they are connected to high voltage. In the next section, the work done to test the quality of the LST's will be described chronologically.

Work:

In February of 2003, the BABAR group at OSU began work on a gas flow system to control the mixture of gases to be used with the LST [6]. Two gases are being tested: ZEUS and SLD whose components are

Gas	CO2	Isobutane	Argon
ZEUS	89%	8%	3%
SLD	88%	9.5%	2.5%

The percentages of the individual gases vary by a small number in each gas mixture so a precise and reliable to gas mixing system is required. A gas, multi-gas digital flow controller and meter from MKS instruments is being used. The controller is calibrated to the three gases being used. The first few weeks of the summer were spent learning how the MKS system operated and making sure the calibrations were correct. To cross-calibrate the flow of the MKS system, a bubble flow meter was used. Corrections had to be made for temperature and pressure. Figure 3 is an example of the error between the MKS flow meter and the bubble flow meter.

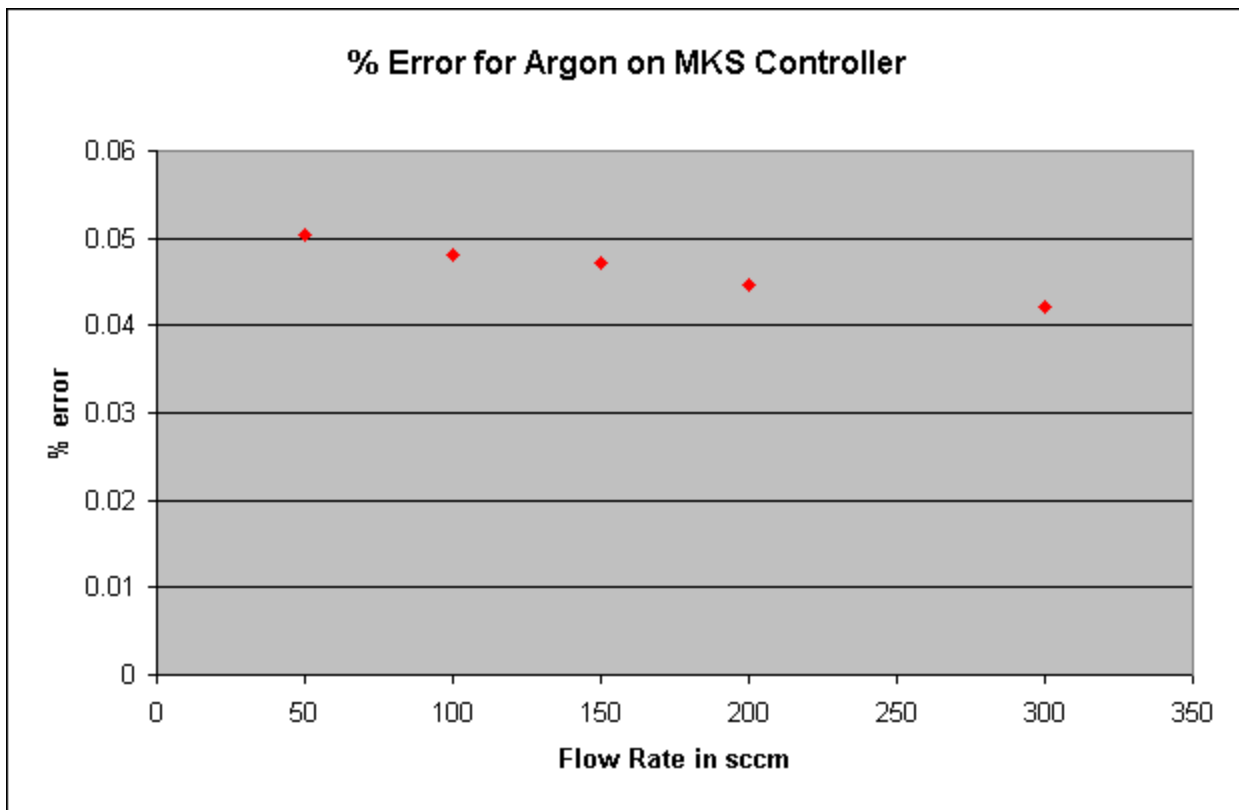


Figure 3: Error between MKS and bubble flow meter after adjusting for temperature and pressure. Horizontal axis is flow rate of MKS in sccm (standard cubic centimeters per minute).

Similar results were obtained for carbon dioxide and isobutane [6].

After the MKS system was fully operating, a prototype LST measuring 386 cm by 1.3 cm by 8.5 cm was ready to be examined. Future designs of the chambers will have larger dimensions

[6]. Gas was flown through the tube and high voltage connected to the tube. The first task was to measure pulse heights. Scintillators are placed above and below a cell. The scintillators can help measure the amount of cosmic rays that create a signal in the cell. The scintillators can pick up every cosmic ray that bombards them. Since the scintillators are above and below the cell, a particle that passes through both scintillators must also pass through the cell, possibly ionizing the gas in the cell which created an electrical signal on the anode wire (see Figure 4). The measurement of a signal from the cosmic rays depends on the voltage of the cell. With higher voltage, more particles will be detected by the cell.

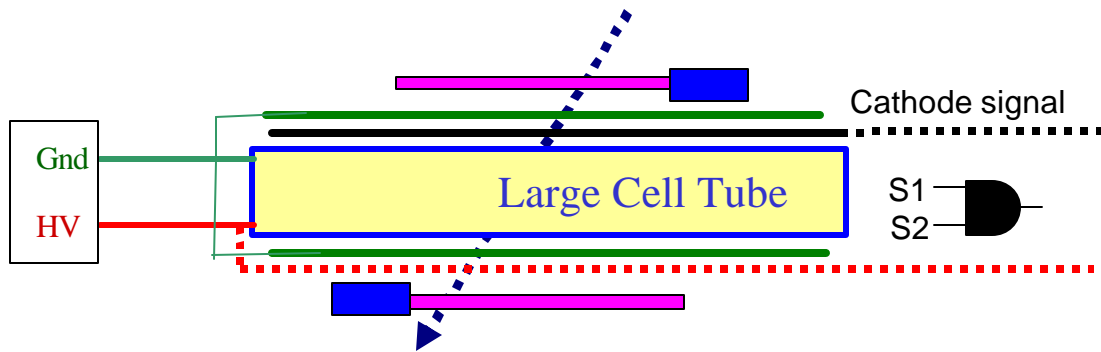


Figure 4: Apparatus for measuring pulse heights and efficiencies.

Efficiency is the percentage of signals (out of the total measured by the scintillators) that are measured by a cell. From the signals that are created within the cell, pulse heights can be measured.

Pulse heights tell how much charge is being deposited by the background, by cosmic rays or by some radioactive source. As can be seen in Figure 5, there is a peak in about the 350 bin range (each bin corresponds to 50 fC of charge) called the pedestal. This peak is associated with the overall background in the lab such as radio waves and computers. The second peak is associated with bombarding cosmic ray particles. Figure 6 shows the pulse height spectrum at a higher voltage.

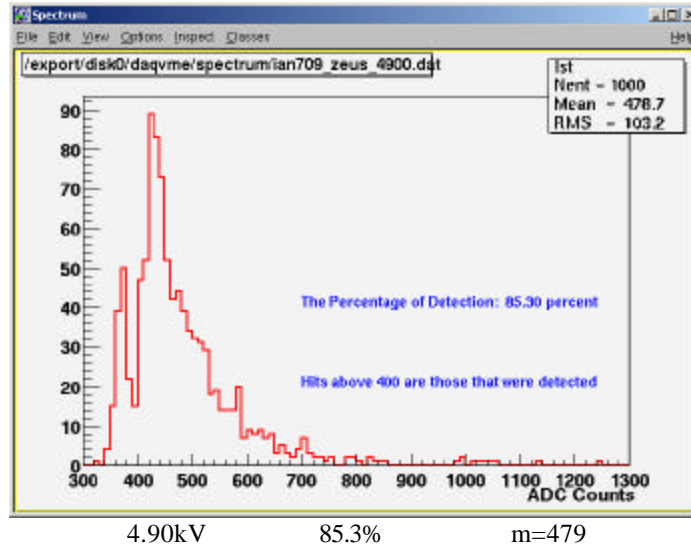


Figure 5: Pulse height for 4900 V. Two peaks are seen – from background and from cosmic rays.

In the higher voltage, the cosmic ray peak shifts to the higher bin (i.e. more charge is being collected) and the height of the peak lessens as the width increases. This occurs because the larger electric field causes more ionization in the gas. The cosmic rays ionize some of the gas and then those released electrons further ionize more gas and from a small number of electrons, millions can end up being ejected (each bin is about 16,000 electrons)!

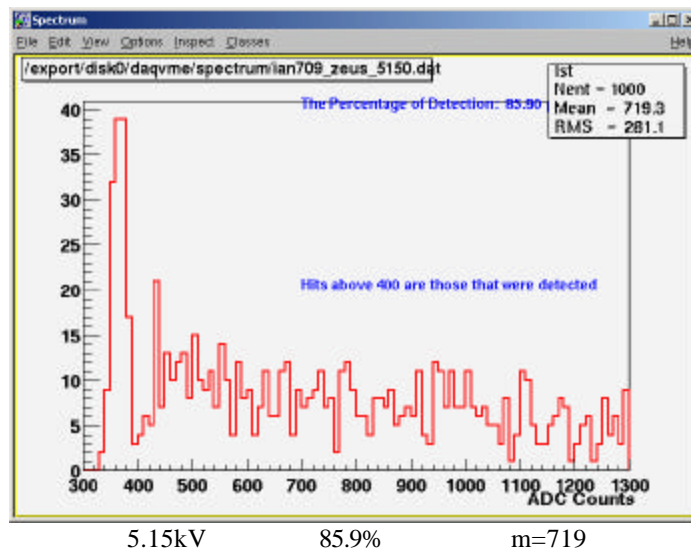


Figure 6: Pulse height for 5150 V. Left most peak is background while cosmic peak spreads out considerably due to the larger electric field.

Figure 7 displays a comparison of efficiencies and mean pulse heights (after pedestals have been subtracted) for the ZEUS and SLD mixtures. When changing flow rates or gas mixtures, the tube was flushed several times to insure that all of the old mixture was gone. Depending on the desired flow rate, flushing could take anywhere from a half minute to a few hours [7].

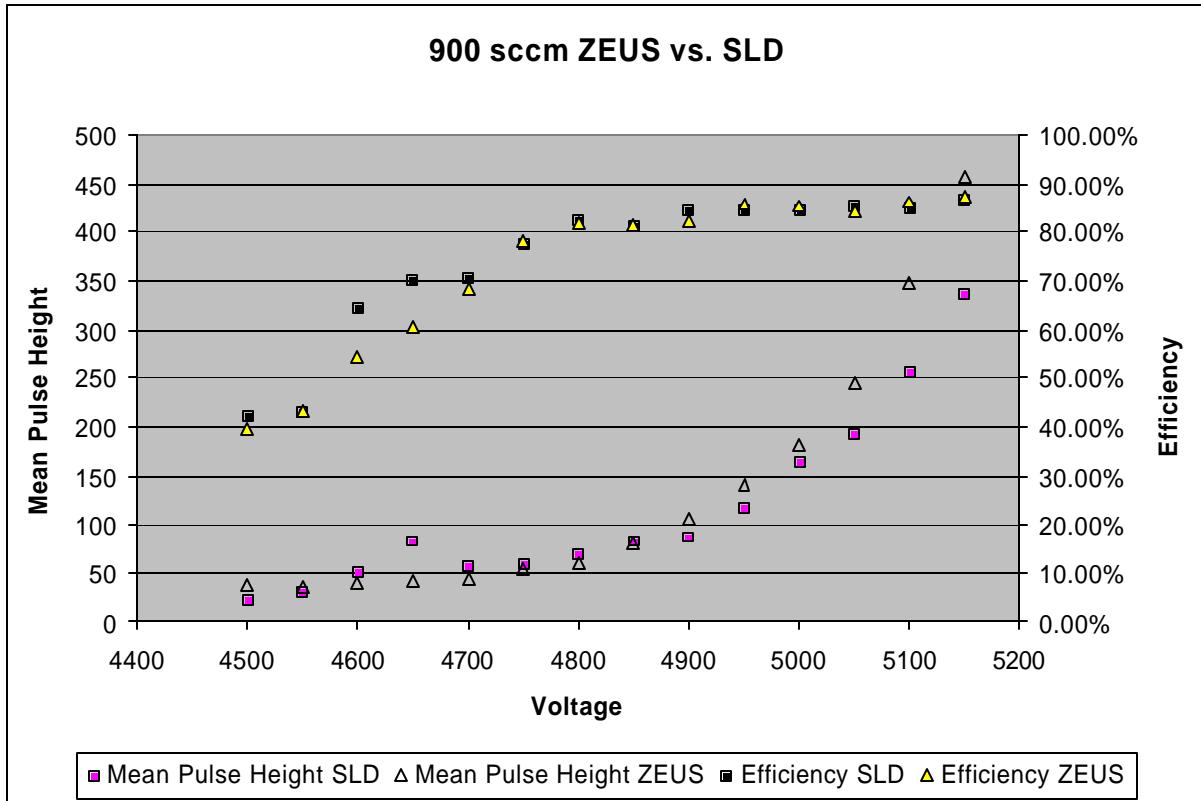


Figure 7: Comparison of ZEUS and SLD gases. More of these graphs can be seen at [6]

To insure repeatability, identical runs were conducted on different days with the same results.

Another test of the quality of the tubes is the measurement of each tube and cell's *singles rate*. Singles rates measure the triggers in the cells from cosmic rays and thermal processes. Figure 8 shows the singles rates for all four cells of a particular tube. Once again, as voltage increases, so does the electric field which ionizes more and more of the gas.

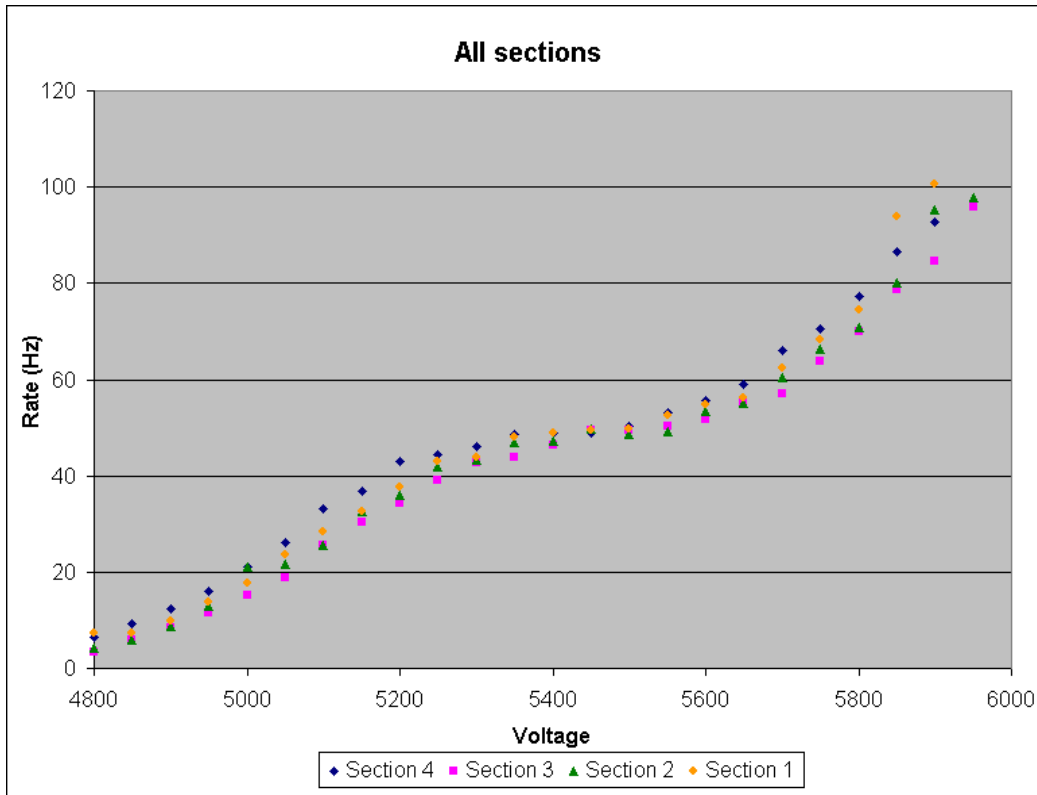
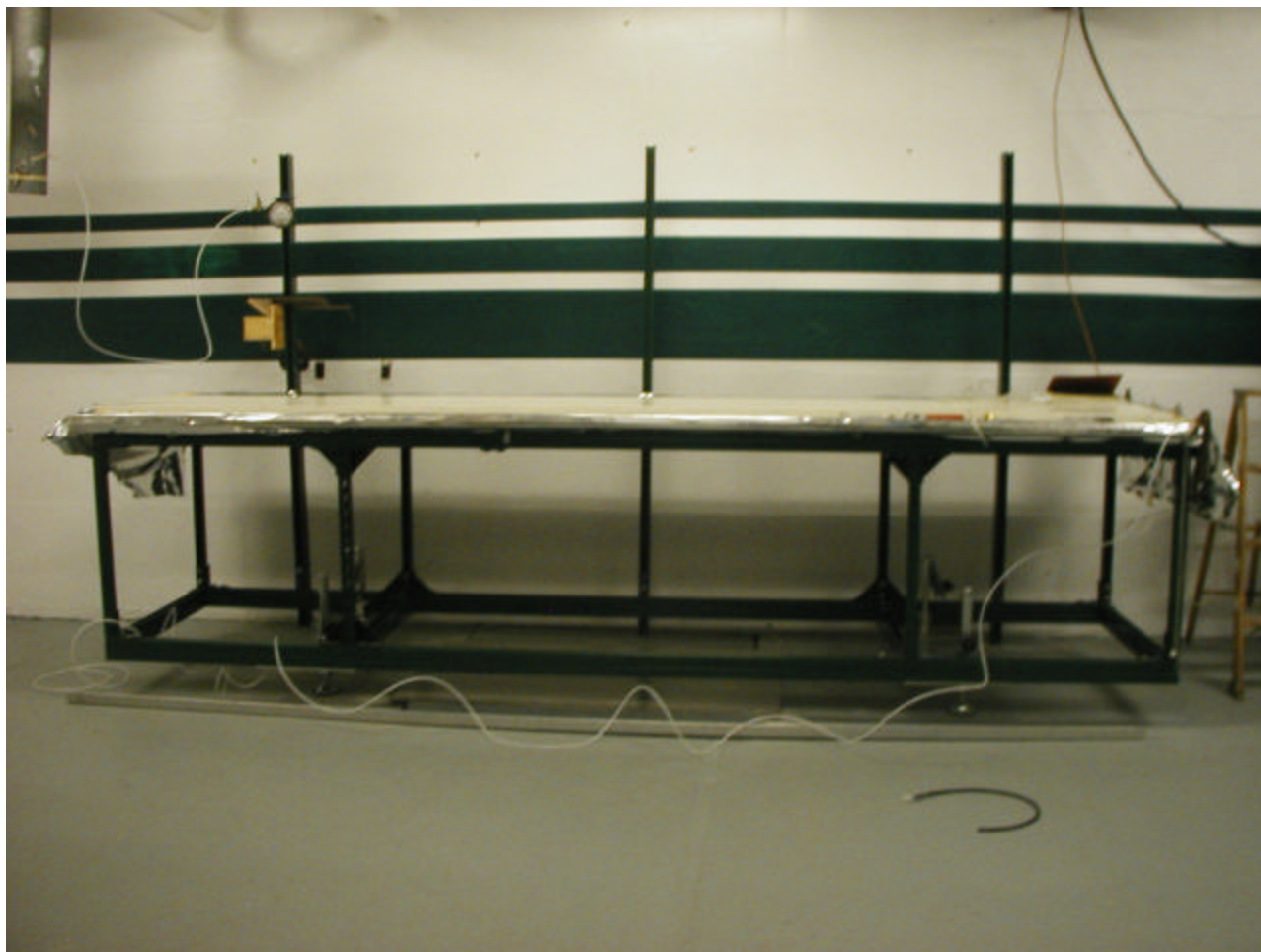


Figure 8: Singles rates [6].

It is important though, that at a certain range (5300-5500 V) a plateau occurs where the rate stabilizes. This important region allows the voltage to be varied slightly without a large boost in triggers. So the longer the plateau the better.

Another large project of the summer was the transformation of an unused room in the basement of Smith Laboratory to a testing station for the muon chambers. The room will service the many tubes that will eventually be installed in BABAR. All tubes (which are manufactured in Italy) must be tested for defects and reliability before installment. A scan table was built in the basement out of Unistrut (see Figure 9). A radioactive source will be attached to a scanner and scan the length of the tubes while the tubes are under high voltage. Output will be monitored [8]. Another table is in the process of being built which will be used as a gluing station for the tubes.



***Figure 9:** Scanning table. Actual scanning apparatus is not shown. It will be connected to the three upright Unistrut beams adjacent to the wall. Magnehelic is attached to left most upright. Fume hood is seen in upper left corner. High voltage system is just beyond sight, right of the table. More information on scanning device can be found at [8]. Tubes are an off white color and are laid on the table.*

The gas system was installed in the basement. Copper tubing was run from outside the room where the gas cylinders are located through the wall and connected to the MKS system. Much equipment was moved into the room from the upstairs lab such as computers, furniture, and the high voltage system. Smaller tasks in preparing the room were the installation of a magnehelic which measures the flow through the fume hood where the gas exits. Two alarms make sure that the fume hood is working at all times to warn if excess gas (which would be

potentially explosive) is building up in the room. A weather station keeps track of temperature, pressure, and humidity in the room.

Conclusion (what I learned):

This summer was a lot different than I had expected. It was the first time I delved into the life of the experimentalist. Not only did I learn about high energy physics but I also learned how things get done in the world of physics research. Experimental high energy physics is an especially large and integrated system where many people must work together – not only with colleagues in the same building, but colleagues across the country and across the world! In such a large cooperative field, organization and order are key habits and skills. I am thankful for participating in this REU because I learned so much more than I could have ever learned at my home small institution.

Acknowledgements:

First and foremost, I would like to thank my advisor, Dr. Richard Kass and Ian Schambach, whom I worked with closely. This of course would not be possible without funds from NSF-REU and The Ohio State University and the physics department. Others whom I worked with, directly or indirectly, were Dr. Klaus Honscheid, Bob Wells, Luke Corwin, James Morris, and Quincy Wong.

References:

- [1] All of the basic information on BABAR from the Introduction can be found at SLAC's public site, <http://www-public.slac.stanford.edu/babar/about.html> , unless otherwise noted
- [2] <http://www.slac.stanford.edu/slac/media-info/981026/richardson.html>
- [3] <http://www2.slac.stanford.edu/vvc/theory/leptons.html>
- [4] <http://www.llnl.gov/str/Wright.html>
- [5] <http://www.physics.ohio-state.edu/~klaus/LST/lst.htm>
- [6] <http://www-physics.mps.ohio-state.edu/~schambac/gas/gas.htm>
- [7] <http://www-physics.mps.ohio-state.edu/~schambac/gas/Flow%20Interactive.htm>
- [8] <http://www-physics.mps.ohio-state.edu/~corwin/lst/scan.htm>