Assembly of a Spark Chamber, and

Development of a Straightness Monitor Using Laser Interferometry: Temperature Probe Analysis

AJ McGauley

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Physics Department, University of Notre Dame

In Collaboration With:

Matthew Lucia

Thomas Rehagen

Zachary Liptak

Advisor:

Dr. Michael Hildreth

Abstract

Two projects will be discussed in this paper. The first is the assembly of a Spark Chamber for the Notre Dame Department of Physics. Spark Chambers are cosmic ray detectors developed in the 1950-60s that provide a visible electric ‘spark’ outlining a cosmic particle’s path. Though no longer precise enough for modern research, the very visible form of the data output makes a Spark Chamber an ideal demonstrational device. We continued work on the spark chamber, replacing the scintillator plates, photomultiplier, and thyratron, with the ultimate goal of placing the working Spark Chamber on display in Jordan Science Hall.

The second project is a small project within an effort to create a system for measuring the precise position of the Beam Position Monitors at SLAC, with the ultimate goal of using the system in the future International Linear Collider. A setup using laser interferometry was explored. This setup was expected to be very responsive to temperature fluctuations, necessitating an accurate measurement of the ambient temperature. The DataStudio temperature probes utilized quickly demonstrated a strong disparity in temperature measurement, so an effort was made to discover the exact nature of the disparity and discern a relationship for future cross-calibration.

Spark Chamber Project

Introduction

Spark chambers were pioneered in the early 1950s, and they remained the primary detectors for cosmic ray research through the 1970s. By the 1980s, spark chambers had been replaced by superior devices, such as drift chambers or silicon detectors. Today, spark chambers are obsolete instruments with inferior spatial and time resolutions.

The premise behind a spark chamber is brilliantly straightforward. When a high energy particle, generally a cosmic ray such as a muon, travels through gas, such as Neon or Helium, it will leave a trail of ionized gas molecules behind it as it interacts with the gas. This ionized trial is very weak, and the molecules quickly recombine to their neutral state, so the vast majority of cosmic particles cascading from the sky travel through our environment unnoticed. However, if a strong enough voltage difference is immediately applied along the trail, the slightly ionize trial is the clear path of least resistance for the charged particles, and a 'spark' will flash along the ionized pathway. This spark, visible to the naked eye, will both indicate the cosmic particle event and trace the exact pathway of the particle. This data can then be collected by photographic equipment and analyzed to yield information about the high energy particles.

For our purposes the quantitative information yield by a spark chamber is irrelevant. Instead, we are interested in the highly visible qualitative output of a spark chamber. The 'spark' is visible to the naked eye. Therefore, a spark chamber is an excellent demonstrational device for cosmic rays or for particle physics in general. The Department of Physics at Notre Dame intends to construct a working spark chamber and place it in a display case in the Jordan Hall of Science for educational purposes. Our task this summer was then to complete the construction of a spark chamber that maximizes the frequency and intensity of sparks, and to install the spark chamber in the display case.

Progress

Significant work had been done prior to the summer of 2008. Undergraduates Matt Lucia, Nick Battafarano, and Justin Pilot worked extensively on assembling the spark chamber during the summer of 2006. They were able to get the chamber operational, but the thyratron was critically damaged at the end of the summer, effectively ending their work for that period. Therefore, at the being of this summer we had two primary tasks to get the chamber operational again. First, we needed to completely replace the thyratron. Second, we wanted to replace the old standard 2" photomultipliers with newer silicon photomultipliers [Figure 1].

At the beginning of the summer we thoroughly tested the spark chamber as it stood. Using the old photomultipliers, the coincidence and discriminator units appeared to be fully functional, and the power supply for the thyratron was working. Because the thyratron was broken, we could not test actual chambers.

A new 5C22 hydrogen thyratron was purchased to replace the old one. Also, a mount was constructed by Matt Lucia to protect the thyratron and protecting it from possible injury. We did not have time to install the thyratron and test it.

The new silicon photomultipliers (PMs) were obtained from the QuarkNet Center at Notre Dame. Two new scintillator paddles were prepared for the PMs. We carved grooves and set optical fiber in the paddles, sealing the fiber with epoxy [Figure 2]. To maximize the collected light, metallic tape was taped over the fiber to maximize internal reflection [Figure 3], and the closed end of the fiber was painted over with a reflective paint so that all light collected within the fiber would exit out the open end. A ferrule was attached to the open end of the fiber and glued into a plastic barrel to provide an externally light-tight link to the PM. The paddles were then wrapped in one layer of Tyvek, a diffusive reflexive covering, and then two layers of Tedlar to make the covering light-tight. Overlapping seams were taped down and then covered with electrical tape. Several different wrapping strategies were tried with the Tedlar. We decided to minimize overlap within a wrapped layer because the paddles would be visible to the public in the display case and should therefore be as smooth and neat as possible. Some overlap was still needed in order to ensure the seams were seal, but this was minimized to occur just on the ¼ inch sides of the paddles.

Once the paddles were wrapped, a small hole was cut around the plastic barrel for the output cable to link with the PM. The Tedlar around the barrel was sealed shut by painting Black Goop around edge of the barrel. As the time of writing, the paddles must be tested to ensure they are fully light-tight when exposed to visible light.

Conclusion

This summer was moderately successful. Significant and material progress was made on this project, most notably with the construction of the new scintillator paddles, and we are closer to our ultimate goal of a fully functional chamber. All individual components have been assembled or constructed. We still must assemble the final setup and troubleshoot whatever problems arise. Ultimately, we will be able to install the spark chamber in the Jordan Hall of Science, providing a valuable addition to the scientific and educational community at the University of Notre Dame.

Temperature Probe Project

Introduction

This project was a small part of a general effort to explore a laser interferometry system that will provide a very precise measurement of the spatial stability of a linear collider. For an overview of the main project, please see “Development of a Straightness Monitor Using Laser Interferometry” by Matt Lucia in this publication.

It is expected that the laser interferometry system will be affect by temperature fluctuations in the environment, so we measured the ambient air and the optical bench temperatures for every test we ran, intending to observe and understand what effects the temperature would have our data. However, we quickly discovered that our temperature probes were measuring significantly different values for the exact same conditions, in the order of 2 full degrees Celsius off of each other. Since the two probes were the only two we would have available, we then endeavored to test the probes in controlled environments to determine if there would be a regular offset that we could use to cross-calibrate the probes in our later calculations.

Results

We first tested the temp probes by placing them in an ice-water mix and observing their reported values as the water warmed overnight. This yielded a clear offset of 1.5° [Figure 4]. However, testing the probes by exposing them to ambient air overnight consistently yielded an offset of 2.1° over several trials [Figure 5]. These differing results suggested that the probes may not have a linear relationship, so we chose to focus the analysis on just the temperature range of interest, which is normal room temperature of our lab.

The temperature probes were set to measure the air temperature at a 1 second sampling rate, typically for 10 hours runs. Runs were generally done overnight so as to minimize the thermal disturbance caused by people working in the lab. All data was analyzed by finding the arithmetic difference between the probes’ measurements for each discreet sample and then binning the resulting array into a histogram.   The temperature probes measured to the nearest 0.1°C.

For the first several runs, the 2.1° offset continued to show, but then suddenly the data yielded 2 independent peaks on 1.6° and 1.8° [Figure 6]. Over the next 2 weeks, the temperature probe data continued to yield nonlinear data, including a bizare triple peak [Figure 7].

At the end of the summer, a few runs again yielded an offset of 2.1°, but not consistently.

Conclusion

The temp probes did not indicate enough stability relative to each other to yield a consistent mathematical relationship. The probes were only rated to the nearest 1 degree Celsius by the supplier, and it appears that we cannot achieve any appreciably greater precision. Due to the low precision of our instruments, we have therefore not been able to analyze the influence of ambient temperature on the laser interferometry system.

Acknowledgments

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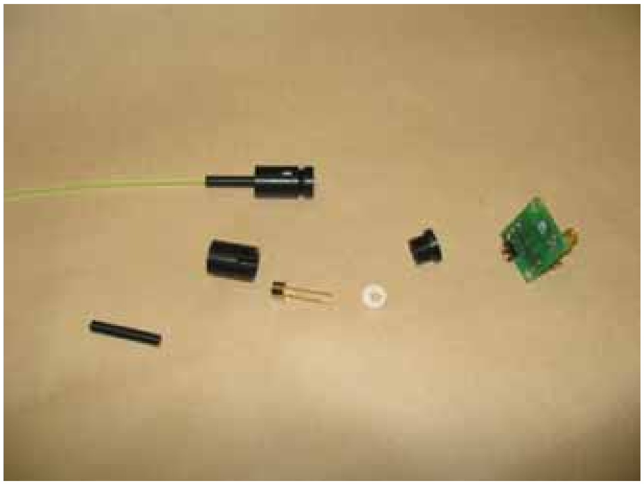

Figure 1 – At the top is a sample fiber with the ferrule and barrel attached. In the middle is the Silicon photomultiplier.

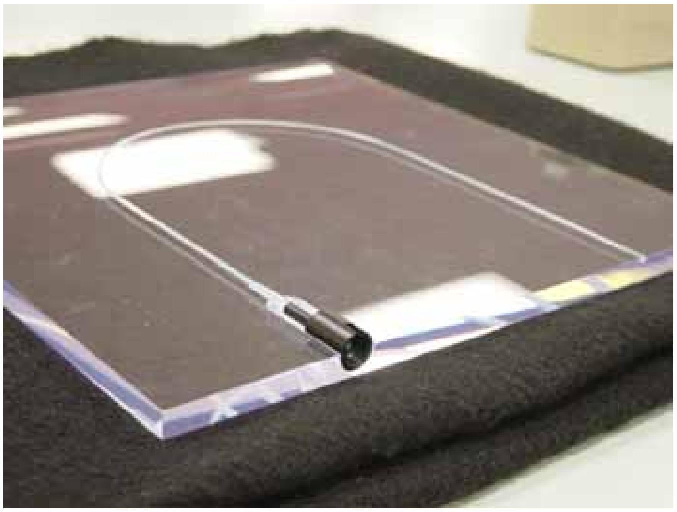

Figure 2. The white rectangles are glare from the overhead lights.

Figure 3

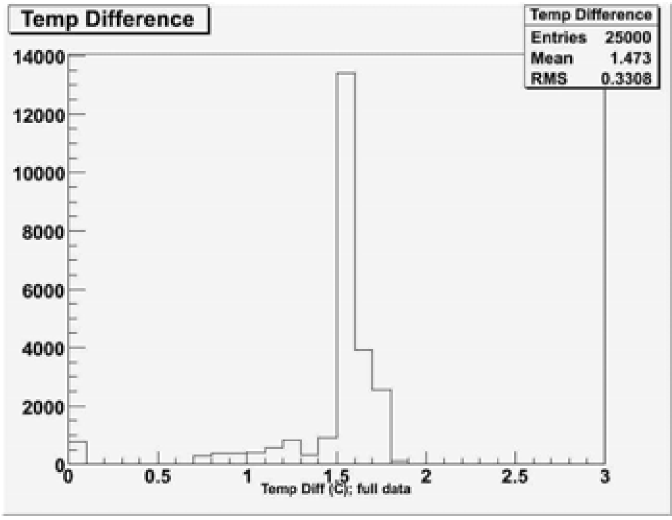

Figure 4: 10 hour run in ice-water mixture

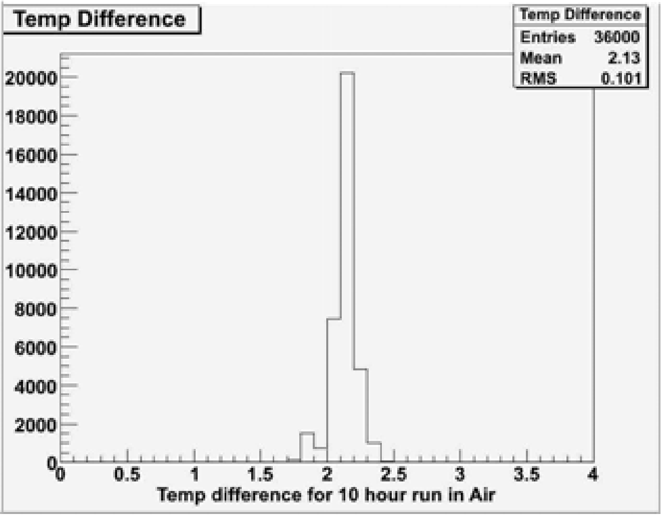

Figure 5: When the data yielded the expected results, 2.1 was the clear mean and mode.

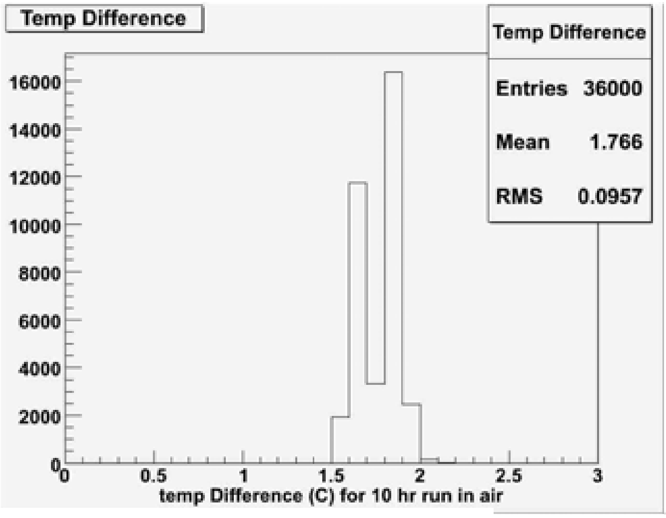

Figure 6: Run for July 14th

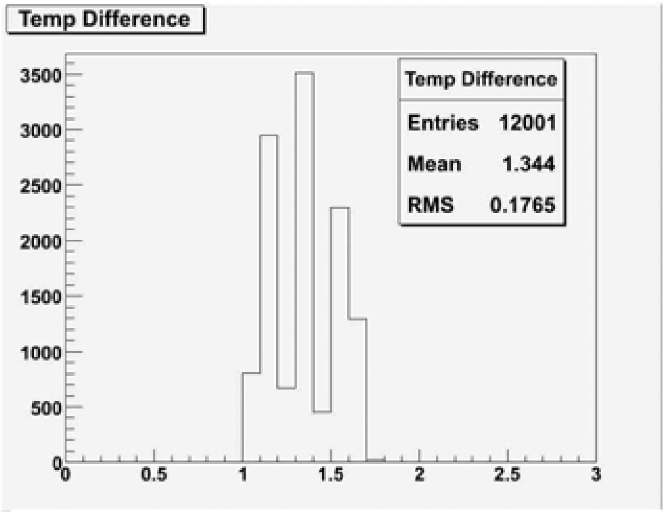

Figure 7: Run for July 18th. First 12,000 seconds of an overnight run.