**A Measurement of the Timing Offset for The Pierre Auger Observatory**

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**INTRODUCTION**

The Pierre Auger Observatory aims to track cosmic ray showers backward in time through angular reconstruction in hopes of discovering a common origin. It has a hybrid design that features four fluorescence detectors and 1600 surface detectors that cover 3000 km² in southern Argentina [1]. Since the ultra-high energy particles of a cosmic-ray shower travel at very nearly the speed of light, timing measurements are critical in this reconstruction and are sensitive to nanosecond offsets.

This project focuses on the timing issues involved in the Auger Observatory. Specifically, we set out to accurately calibrate the timing offset between the surface detector array and each fluorescence detector. An accurate determination of the timing offset is critical for minimizing systematic errors in arrival direction reconstruction using events that are detected simultaneously by both surface and fluorescence detectors. The GPS timing instruments were constructed and calibrated in the lab and then transported to Malaquie, Argentina to make measurements at the site.

**MATERIALS AND METHODS**

The Central Laser Facility (CLF) plays an integral role in the determination of a timing offset between the SD array and the FD. It is a 5 ns laser pulse triggered every two seconds. A fiber-optic cable transports the laser pulse into a surface detector (Celeste) about 10 m away. A steered-beam director aims the pulse at a 3 degree angle to the fluorescence detector. The laser pulse will act as a "fake," dual-detected event.

**RESULTS**

![Figure 4: A graphical representation of the experimental signal path.](image)

- The black arrow points to the CLF where a program triggers the firing of the laser.
- The red arrow points to the CLF computer where the pulse is directed toward the fluorescence detector.
- The yellow arrow points to the timing box where the signal is detected at the surface detector, Celeste.

**Figure 3: Experimental set-up as performed in the field.**

- A PMT is positioned in the surface detector and at the fluorescence detector.
- A discriminator will be located at the output of each PMT and will lead to the input of the timing box.
- The timing box will stamp the output of the discriminator and save it to a file.

The timing data files of each of the two GPS clocks (timing box at each type of detector) will be compared to the trigger time from the CLF as well as the time from the GPSY II module to determine the offset.

The anode output signal from Celeste is then fed into a discriminator before being time-stamped by the timing box. We collect data from the CLF computer and GPSY II module, both of which will have timing information about the laser pulse.

We refer to the time that the computer program tells the laser to fire as the CLF time and the time that the laser is detected being fired at the CLF as the GPSY II time.

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**REFERENCES**


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**CONCLUSION**

The data from the CLF and Celeste is a key piece of the timing offset puzzle.

- The data consists of 500 points collected over the course of about 20 minutes.
- We can reliably use the GPSY II to determine arrival time at the surface detector, Celeste.
- The calculated uncertainty in the timing measurement is 9.64 ns.

In order for this experiment to produce results accurate on the order of nanoseconds, the timing offsets of each detector must be accurately calibrated. The systematics of the system can then be minimized and allow more accurate reconstruction of the cosmic shower event in space.