Study of Long Term Stability of the Pierre-Auger Surface Detector Using Muon Events

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Abstract

In this report, we describe the techniques we have developed for the long term monitoring of the surface detectors of the Pierre Auger Observatory using raw muon traces collected from each detector at regular intervals. From these muon traces, we can perform offline monitoring of pedestals, relative gains of each channel (electronics+PMT), and the quality of the water and the liner. We are able to track the relative gains of each detector at the 2% level using these techniques. Additionally, the raw muon data allows us to perform an independent cross check of the online calibration algorithms used in the surface detectors, and to improve them.

1. Introduction

The Pierre Auger Surface Detector consists of 1600 water tanks each with three photomultipliers observing 12 tons of purified water within a Tyvek reflective liner. Each tank is viewed by three 9-inch PMTs. More details on Auger surface detectors can be found elsewhere [2]. Since the surface detectors are spread over an area of $\sim$3000 km^2 in terrain that is not always easily accessible, it is important to be able to monitor detector performance remotely. Monitoring of the Auger surface detectors is done in two different ways: (1) On-line monitoring done using the information that comes after some processing on the on-board computer contained in each surface detector as described in [3]. (2) Offline monitoring done by analyzing minimum-bias raw muon data collected at regular intervals from each detector. Since the Auger Observatory is still in its early stages, it is important to carefully cross check the on-line algorithms with offline analysis of minimum-bias data. This report describes the techniques developed to analyze the raw muon data in order to monitor various detector parameters.

An engineering array [1] of 32 surface detectors has been in operation for over a year and the results shown in this document are from this engineering array. A complete analysis of the engineering array monitoring can be found in [5,6].

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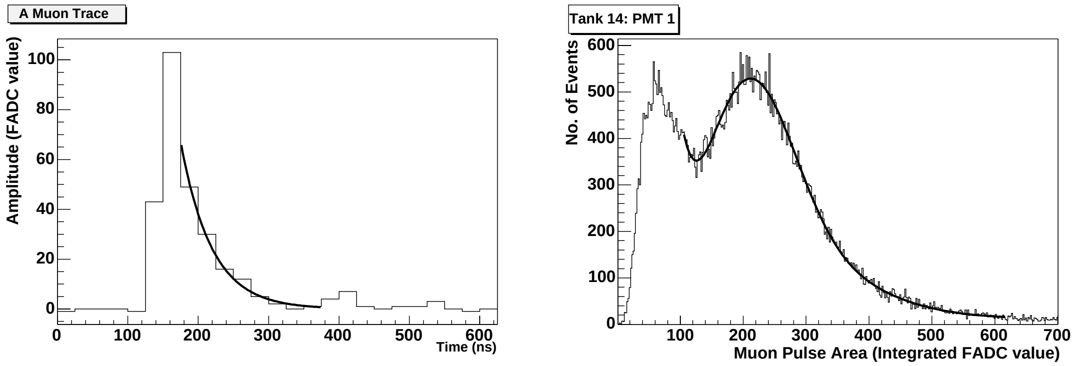

Fig. 1. Left, Typical muon FADC trace with fit for decay time. Right, histogram of muon spectrum with fit to determine position of 'hump'.

2. The Muon Data and Analysis

Starting in May 2002, muon traces were collected from each detector by requiring a coincidence among the three PMTs at a low threshold of 0.15 of the signal expected from vertical penetrating muons (VEM). For such a low threshold, most of the data collected were from muons. Every four hours, 1000 muon traces were recorded. This data was then analyzed offline. Figure 1. left is a typical flash ADC (FADC) trace of a muon event. Figure 1. right is a typical histogram of the pulse areas (after pedestal subtraction), and the characteristic peak (muon hump) from omni-directional muons can be seen.

From the muon data, we can study several detector parameters. From the pre-trigger part of the FADC trace, we perform an independent calculation of pedestals for monitoring and cross-checks. Pedestal determination is important as the quantity of interest is the integrated trace area and any pedestal error would significantly alter this value. Figure 2. shows typical behavior of the pedestals over a year. Most of the pedestals are quite stable, and show variations of less than 2% over a year.

The monitoring of muon hump (Figure 1. right) position allows us to monitor the relative gain (PMT+Electronics) of all the detectors. Figure 3. shows examples of the evolution of the muon hump position over a year. The steps seen in the plots are the result of known high-voltage changes. Using this technique, we can monitor the relative gain of the detectors at the 2% level.

The fall time of the muon pulses is determined by the water quality and the reflectivity of the TyVek liner, since Čerenkov emission is a very fast process. This quantity is a measure of the average path length of the photons in the tank before they reach a PMT and this path length is affected by the attenuation in water as well as losses at each reflection from the liner. Therefore, the pulse decay constant can be used to monitor the quality of the water and the liner (Figure 1.

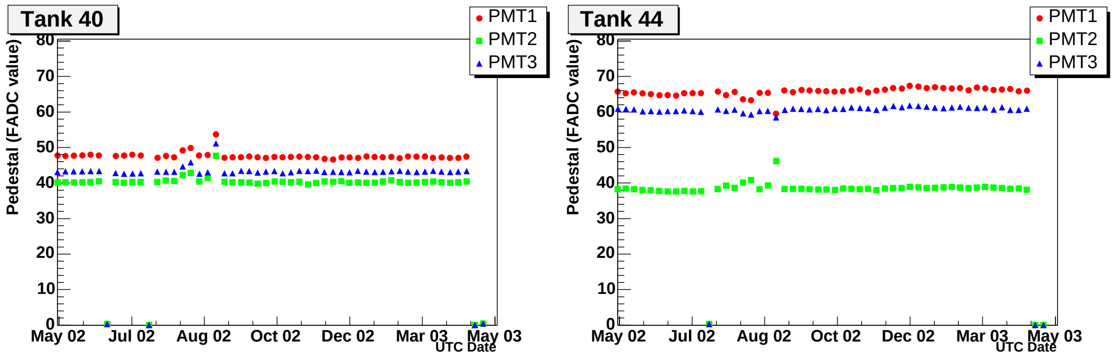

Fig. 2. Pedestals vs Time (12 Months) for two example tanks.

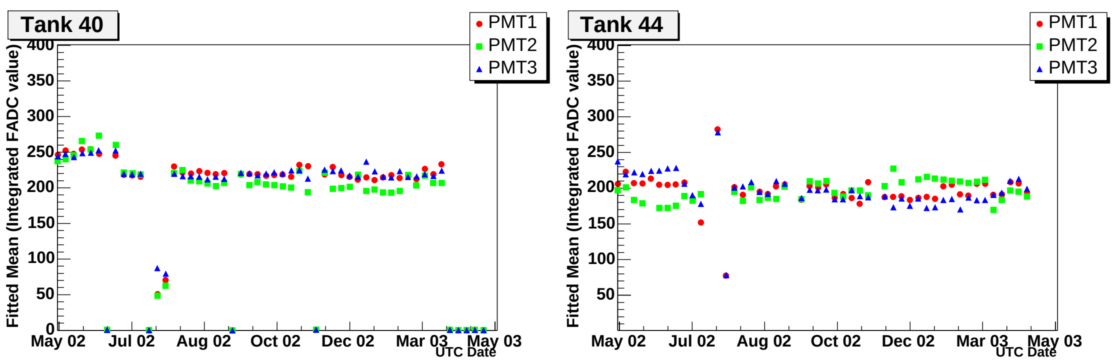

Fig. 3. Left, Muon hump vs time (12 months) for two example tanks.

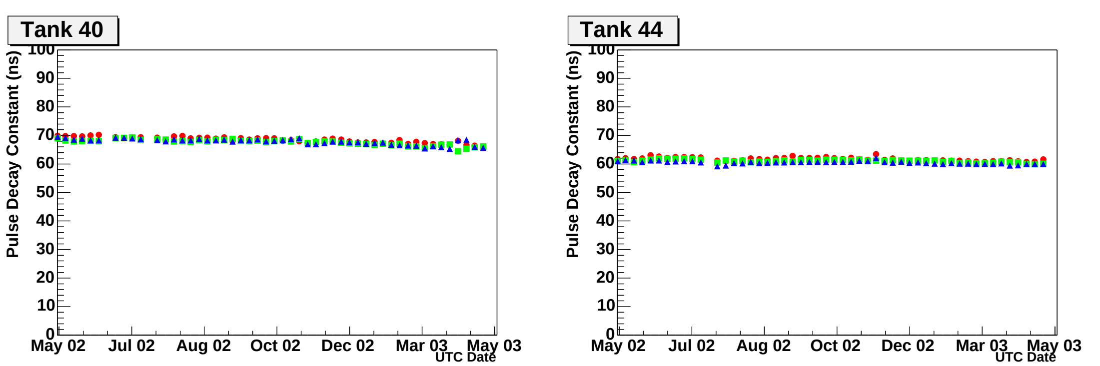

Fig. 4. Pulse decay constant vs time (12months) for two example tanks.

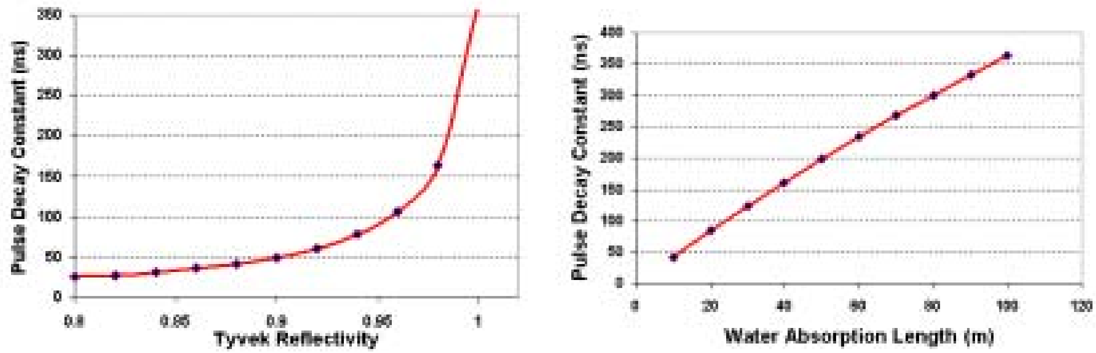

Fig. 5. Left, Pulse decay constant vs TyVek reflectivity (assumes 100 m water attenuation length). Right, Pulse decay constant vs absorption length (assumes perfect TyVek reflectivity). (both are from simulation)

left). Only traces that come from nearly vertical muons are used for this analysis. Figure 4. shows examples of how the pulse decay constants evolve over the course of a year. We are able to determine the decay constant to the 3% level. The value of the decay constant is effectively consistent with a mean path length of ∼20 m (given 100% TyVek reflectivity) or a TyVek reflectivity of about 94% (given 100 m mean path) as estimated by simulation, see figure 5. [4].

3. Summary and Conclusion

We have developed procedures to perform long-term monitoring of various parameters of the Auger surface detectors offline from the analysis of minimum-bias raw muon data collected every four hours from each detector. In particular, we can monitor pedestals, relative gains, and the quality of the water. The relative gains of each detector can be monitored with an accuracy of 2% using these methods. In addition, we have used this minimum bias data to independently cross-check the on-line calibration algorithms.

4. References

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