GAP-97-015, Auger project technical note. Should the top surface of the water tank lining be black?

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Abstract

The current generation of Auger prototype water tanks have very long characteristic pulse widths in response to single penetrating particles (muons). This will hamper attempts to extract muon content information from EAS signals. It is possible to reduce the "integration-time" of the tank by making some fraction of the walls black, rather than Tyvec lined. This paper is an investigation via simulation of the effects of making the top surface black.

1 Introduction

A key goal of the water tank design is to maximize the direct muon content information which can be extracted from analysis of the photomultiplier output waveforms. The first AGASA water tank (AWT1) has its interior — bottom, side wall, and top — lined with the highly reflective material Tyvec ($\approx 90\%$ at 400 nm). Single muon pulses from this tank have a width of > 100 ns, and exhibit ragged back edge structure. It was shown in [1] that the exponential decay constant of these pulses (55 ns) can be reproduced in simulation if a peak water absorption length of 35 m is assumed. While formulating the design for the second water tank (AWT2) the question arises as to whether there is a way to "speed-up" the response of the tank. It would be possible to degrade the water quality, but this would be difficult to do in a controlled manner. It would also be possible to use a less reflective lining material, although this would decrease the amount of prompt "first-bounce" light. The possibility considered in this paper is leaving the top surface of the tank unlined, ie. black for the Japanese plastic bag design (PVC).

2 Simulation of muon telescope events

Exactly the same simulation procedure and parameters are used as in [1] except that the top surface of the tank now has a reflectivity of zero. Figure 1 shows the average simulated pulse shape for a fully lined tank, compared to one with a black top surface. This plot is for muon telescope events. Note that the peak height declines by $\approx 20\%$, while the total integrated pulse size falls by $\approx 60\%$. Also note that most of the remaining pulse width comes from the inclusion in the simulation of the intrinsic PMT pulse width, and the 85 m of RG58 cable which is used to carry the signal from the PMTs to the digital scope in the case of AWT1. With the newer R5912 PMTs, and a reduced length of cable on AWT2 (or higher bandwidth cable), the pulse would be still narrower.

3 Simulation of vertical muons over the full tank surface

The results in the previous section are for central, near-vertical, muon telescope events. By reducing the "integration-time" of Čerenkov photons in the tank a loss of uniformity is inevitable. To investigate this simulations were run for vertical particles incident over the full tank top area. Figure 2 shows the predicted uniformity for fully-lined and black-top configurations. There is certainly a loss of uniformity, although perhaps it is not as great as expected. Since "tube-hit" effects are not simulated at this time the result in the fully-lined case is in line with the experimental result given in [2]. Figure 3 shows the corresponding pe yield, and pulse height histograms. It is seen that fluctuation effects remain under control; the rms spread of the pulse height distribution increases from 19% to 24%.

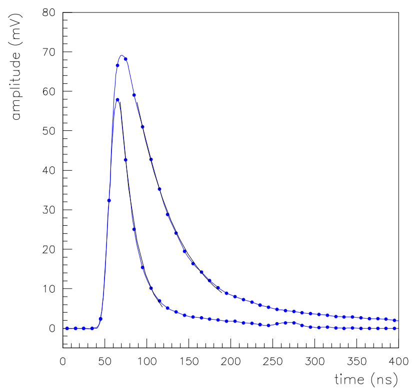

Figure 1: Simulated average muon telescope waveforms for black-top, and fully lined water tanks. These traces are for a single PMT's signal. The exponential decay constants of the pulse back edges are 21 ns and 55 ns respectively.

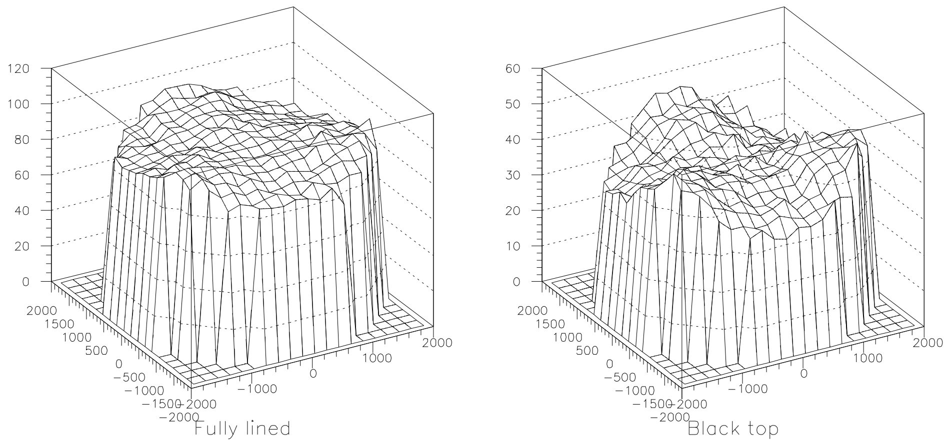

Figure 2: Mean photoelectron yield for simulated vertical, penetrating, muons incident over the tank top surface. Note the difference of the vertical scales. This plot is for the sum of all PMTs.

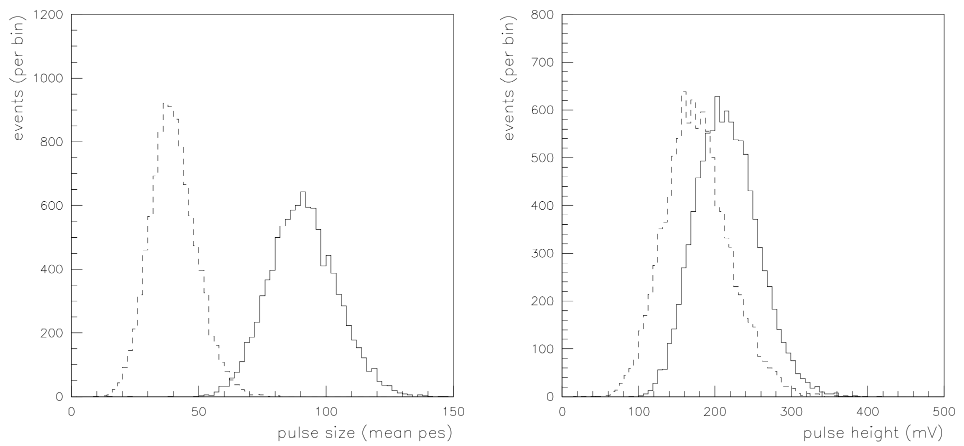

Figure 3: Distributions of pulse size, and pulse peak height, for simulated vertical, penetrating muons incident over the tank top surface. This plot is for the sum of all PMTs. The dashed histograms are for the black-top case, while the solid are for the fully-lined one.

4 Single event waveforms

To judge the possible improvement in tank performance when attempting to extract muon content information it is instructive to view single event waveforms. Figure 4 shows the waveforms for the first 8 simulated muon telescope events for the fully-lined and black-top runs. It can be compared directly with figure 5 from reference [1], where simulated and real fully-lined events are shown.

5 Conclusions

By making the top of the tank black the intrinsic pulse width becomes *much* narrower than for the present fully-lined tanks, with their long water absorption lengths. A reduction in photoelectron yield of approximately 60% can be expected. However, the new R5912 PMTs have a photocathode to first dynode collection efficiency of $\approx 90\%$, to be compared to $\approx 60\%$ for the existing R1408s; this will partially offset the loss. They also have a better single electron spectrum, so the pulse integral correlates more closely with

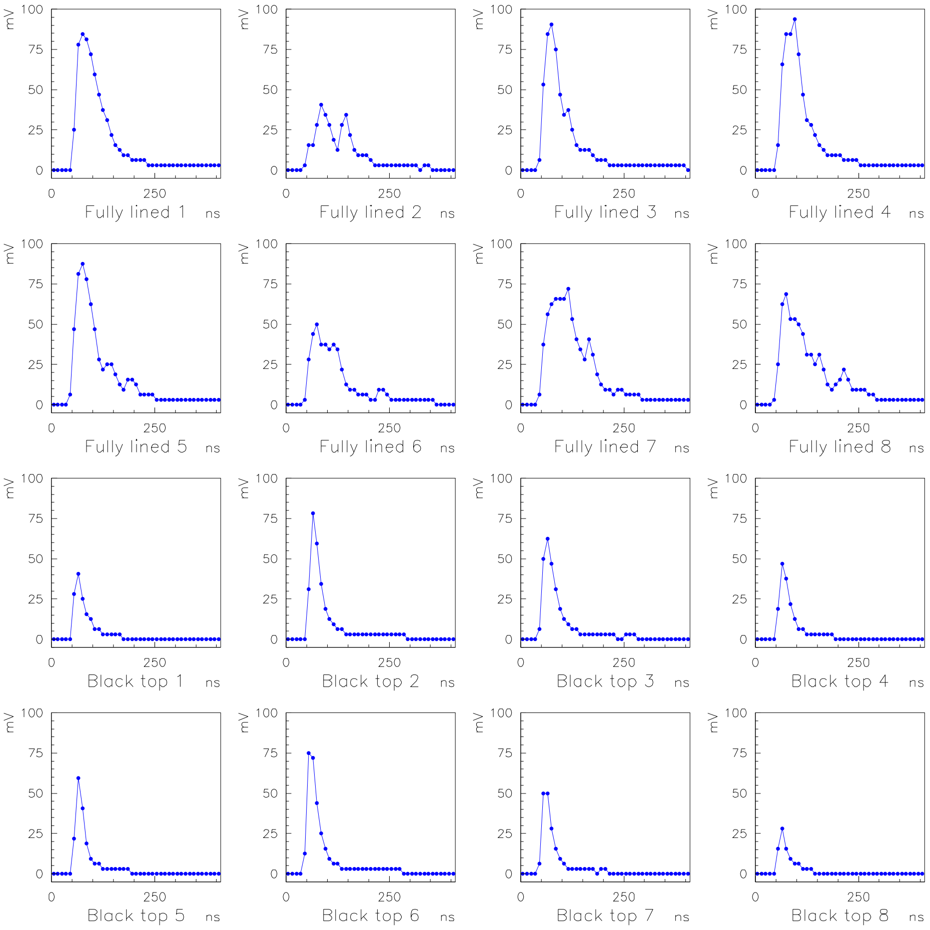

Figure 4: Individual waveforms for PMT1 in muon telescope events. Eight events are shown for a fully Tyvec lined tank; eight are shown for a tank lined on all surfaces except for the top.

the number of photoelectrons. (ie. The pulse size distribution gets tighter for a given mean number of photoelectrons.)

This paper only seeks to predict the performance of a black-top tank for single muons. A study should be done attempting to extract muon content information from simulated EAS traces. However, at the present time it seems that a black-top tank will have a considerable advantages, and is almost certainly worth a try.

As a follow up to this work I asked the Argentinian TANDAR group to make some experimental measurements using their very flexible test tank setup; an up-coming paper will detail that work [3]. Their results are both qualitatively, and to a large extent quantitatively similar to the simulations described here; however note that in this paper the simulation is set up for the AGASA tank in terms of water clarity, PMT cable type and length etc. and hence minor differences can be expected for the TANDAR tank.

References

[1] C. Pryke, Auger tech. note GAP-97-004, "Performance simulations of a 10 m^2 water Čerenkov detector and comparison with experiment", Available from `http://www-td-auger.fnal.gov:82/GAP_Index.html`

[2] N. Sakaki and M. Nagano, "Test of a Water Čerenkov Detector for the Auger Project at AGASA", *Proc. of ICRR Int. Symp. on Extremely High Energy Cosmic Rays*, (October 1996), In press.

[3] Auger tech note in preparation, "Experimental comparison in water tank detectors with tyvek and black top surface", F. Hasenbalg, P. Bauleo, A. Ferrero, A. Filevich, C. Guerard, D. Ravignani, and J. Rodriguez Martino. CNEA, Tandar, Buenos Aires, Argentina.