Attenuation of photons in Milagro using Single Hadrons

Gaurang B. Yodh and Anthony Shoup

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1 Introduction

This study shows that light propagation in data is quite different from that in current version v2.6 of the proton MC. This is done using selected single hadron like events.

We have shown before that single hadrons unaccompanied by air showers can be selected by requiring that greater than 80 percent of hits in the air shower layer lie along the speed of light in water line on a plot of tt=(t-tmax) versus rr, where rr is the distance of a hit pmt from the pmt with maximum pulseheight and tt is its time delay with respect to hit time of the max tube. Hits which lie within the range, abs(tt-4.5*rr)<20 are picked out, where tt is in nano-seconds and rr is in meters. The selection method is shown in Figures A. Upper plot is for data and lower plot is for Julie's proton v2.6 MC.

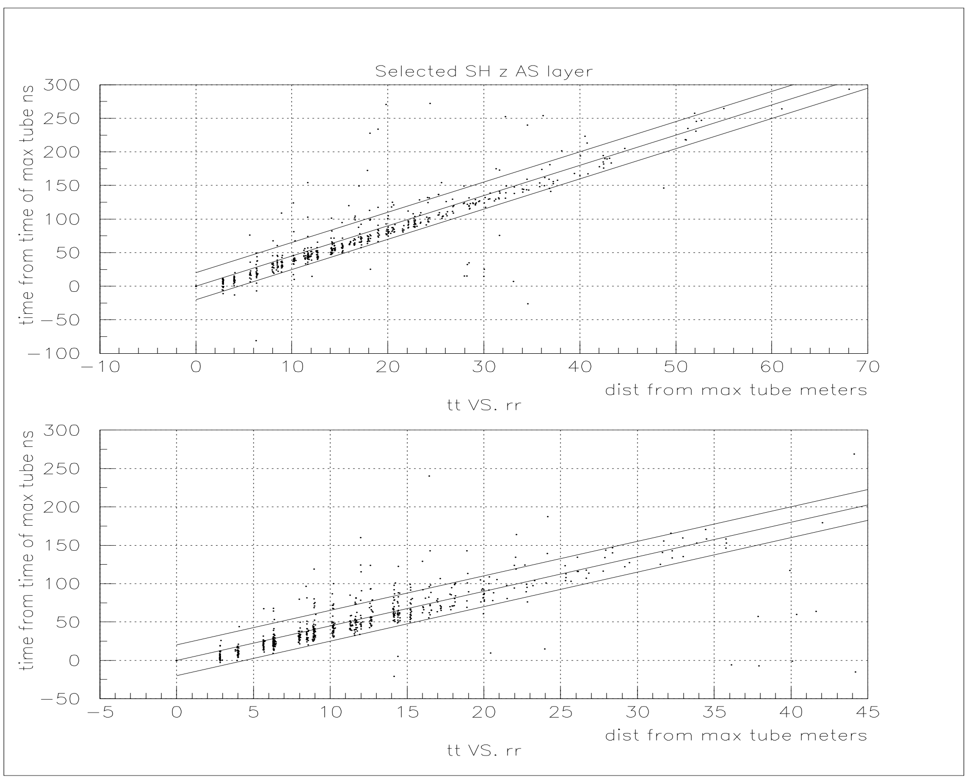

Figure A: Illustration of Single hadron selection.

For these selected SH events we compare the pe-sum distributions in the air shower layer for data and MC in Figure B.

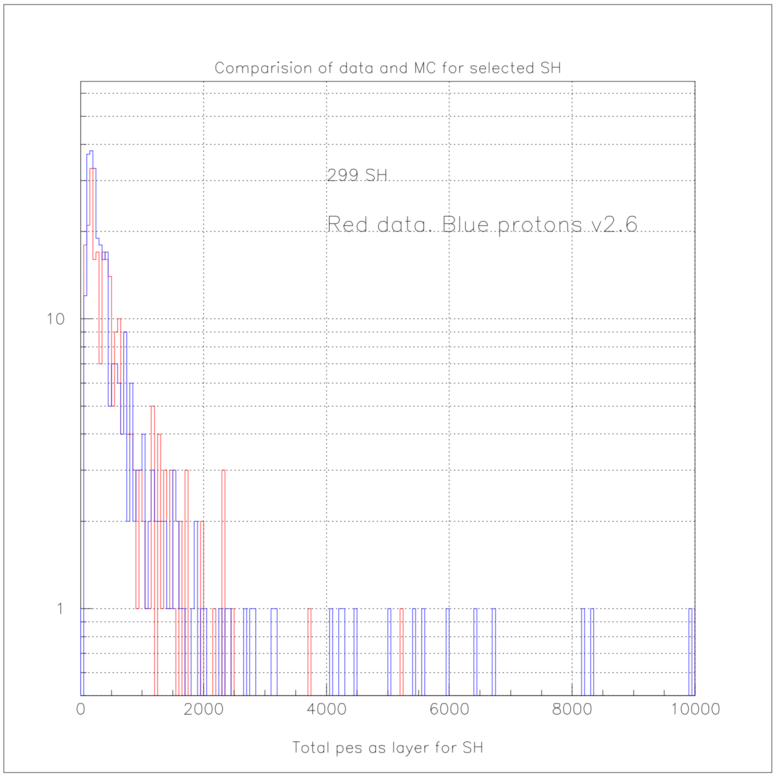

Figure B: Pe-sum distribution for selected SH for data and MC

There is good agreement between these distributions showing that the method for SH selection is not likely to introduce large biases in the analysis of this paper.

To determine how photons generated by the single hadron are propagated through the water, i.e how they are attenuated, the following procedure is used.

(1) First only hits which lie along the speed of light in water as defined above are used so that if there are other shower particle hits outside this region they are removed. This makes it highly unlikely that shower contamination in SH selected from data influence the study.

(2) Next, the pmts in the air shower layer are grouped into annular rings of width 1.94 meters with respect to the position of the max tube in the air shower layer.

(3) The occupation number in each ring is determined by taking the ratio of hit tubes to all the tubes in each ring. This is done for each single hadron event and all events are added together.

As is shown below, over a distnce range of about 15 meters to 45 meters the occupation number distribution is an exponential. This distribution is used to find an effective attenuation length for light generated near the max tube by the single hadron.

This study uses Monte Carlo generated samples of single hadrons with energies greater than 10 or 50 Gev incident upon Milagro, for which the first interaction is required to be in the water so showers are excluded. These are processed through GEANT with different conditions for absorption, scattering and baffles or no baffles. For each of the MC samples of single hadrons an effective attenuation length is determined and finally compared with similar attenuation length derived for real data. The GEANT conditions used for the MC samples are described below:

1. MC SH No absorption, No scattering and No baffles
2. MC SH 40m absorption, No scattering and No baffles
3. MC SH No absorption, 40m scattering and No baffles
4. MC SH 40m absorption, 40m scattering and No baffles
5. MC SH No Absorption, No scattering and baffles
6. MC SH 40m absorption, No scattering, and baffles
7. MC SH No absorption, 40m scattering and baffles
8. MC SH 40m absorption, 40m scattering and baffles
9. Rob's MC SH v-2.6 and baffles
10. SH from Julie's protons v-2.6 and baffles.
11. SH selected from GRB-2727-0213.dat data file

The no absorption, no scattering data sets, with and without baffles, are used to determine effects of overall geometry in the air shower layer. In the analysis presented here we assume the following function to fit the distributions: We call the occupancy numbers y and radial distance from max tube x. Geometrical attenuation is called Λ_g and light attenuation is called Λ_{at}.

$$y = A \times exp[-x(\frac{1}{\Lambda_g} + \frac{1}{\Lambda_{at}})] \tag{1}$$

For no scattering and no absorption $\Lambda_{at} = \infty$. For cases with absorption or scattering or both, appropriate Λg corresponding to no baffles or baffles, is put into the fits to find Λ_{at}.

2 Results

2.1 No Baffles, No Absorption, No Scattering:

First we show the occupation number versus distance distribution for the case which has **no absorption, no scattering and no baffles.** The effective attenuation length so obtained should reflect the geometric effects for light propagation in Milagro. This is shown in Figure 1:

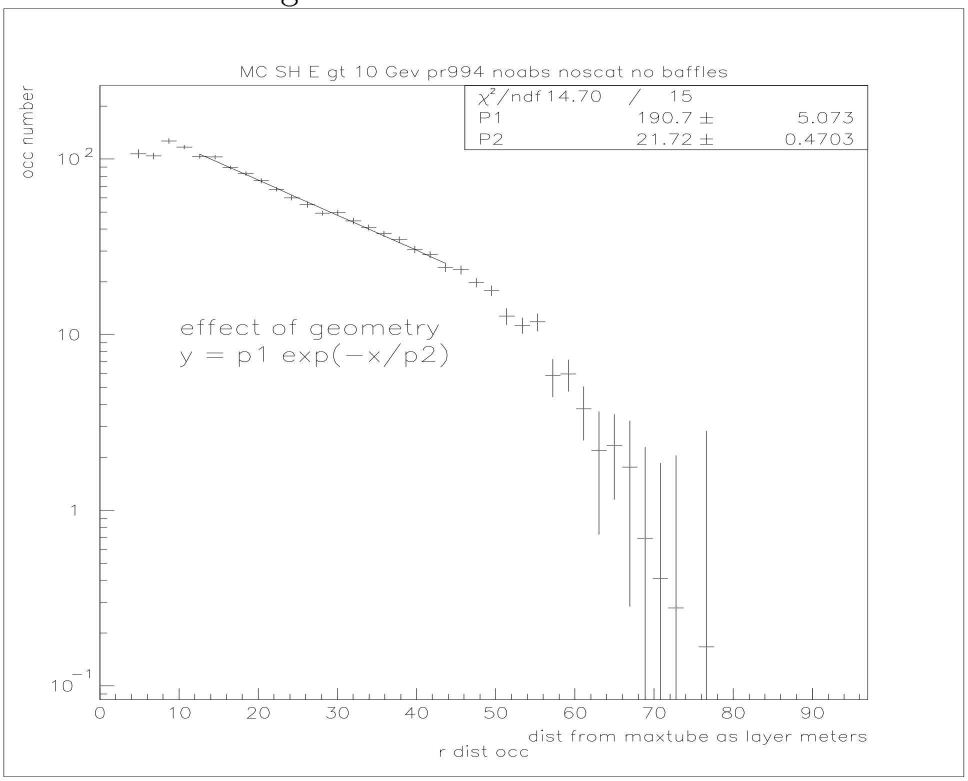

Figure 1: Light propagation: no abs no scat no baffles.

The effective attenuation length obtained for Case 1 is

$$\Lambda_g = 21.7 \pm 0.7 \text{ meters}$$

This result shows that even if we had no absorption and no scattering and no baffles the occupation number distribution gives a finite answer for effective attenuation length. Now we examine the effect of introducing absorption or scattering or both but still with no baffles.

2.1.1 No Baffles, 40m Absporption, NO Scattering

Figure 2 is for 40m absorption and no scattering and no baffles. The value for

$$\Lambda_{at} = 30.2 \pm 1.1 \text{ meters}$$

as compared to the 40m input value.

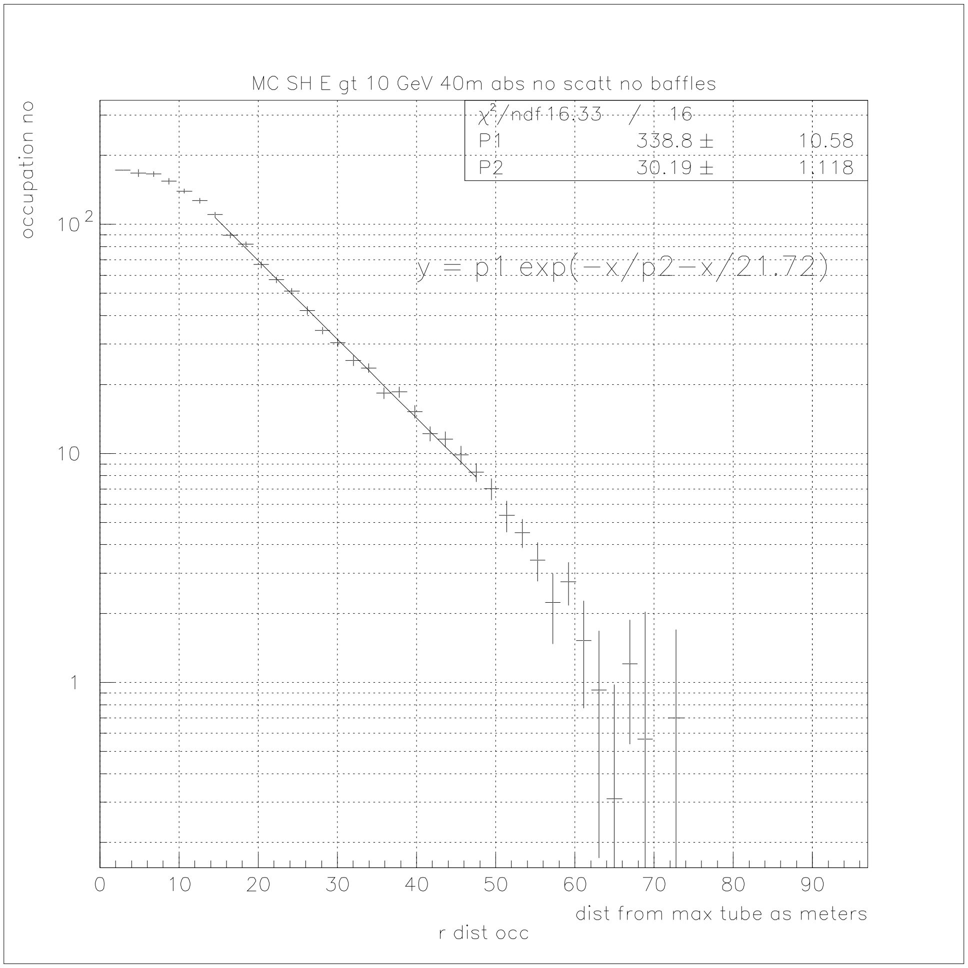

Figure 2: Light propagation: 40 m abs no scat no baffles

2.1.2 No Baffles, NO Absorption, 40m Scattering

Figure 3 is for no absorption and 40m scattering and no baffles. The value for

$$\Lambda_{at} = 47.6 \pm 2.3 \text{ meters}$$

as compared to the 40m input value.

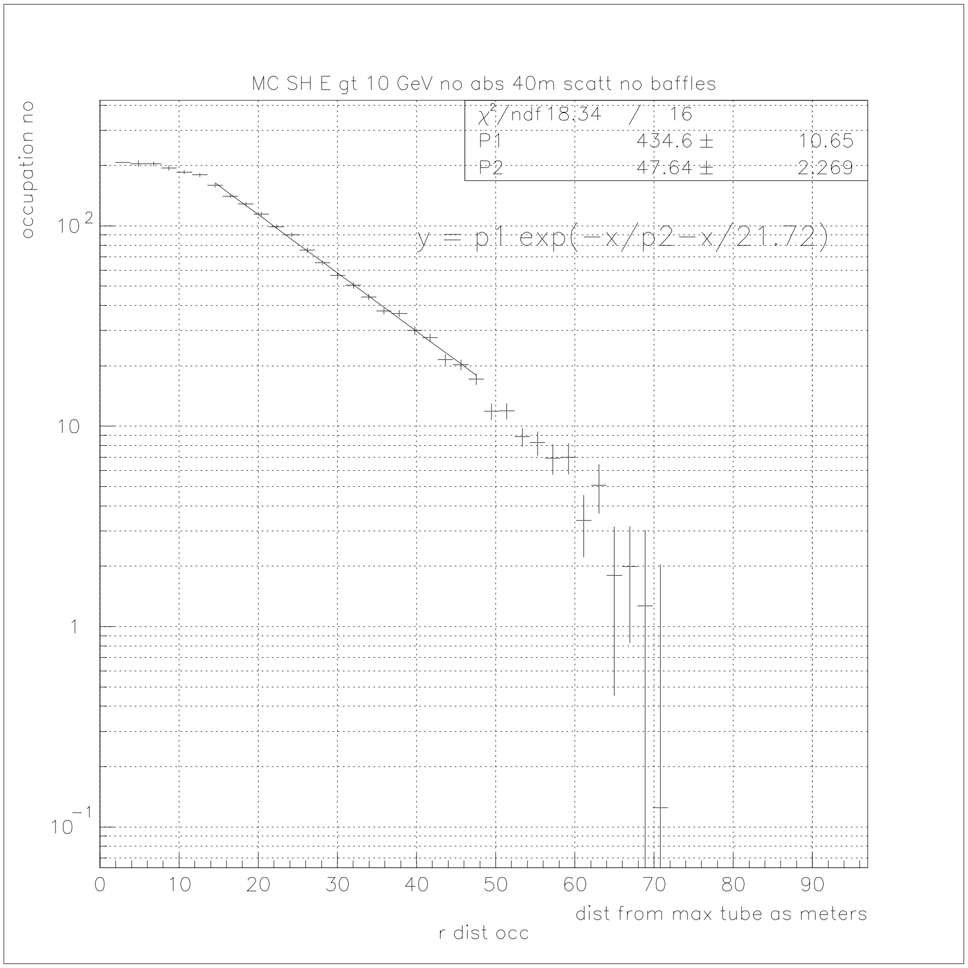

Figure 3: Light propagation: no abs 40m scat no baffles.

2.1.3 No Baffles, 40m Absoprtion, 40m Scattering

Figure 4 is for 40m absorption and 40m scattering and no baffles. The value for

$$\Lambda_{at} = 17.7 \pm .45 \text{ meters}$$

as compared to the input values. The two lines shown correspond to geometry and attenuation plotted separately and the best fit is also shown.

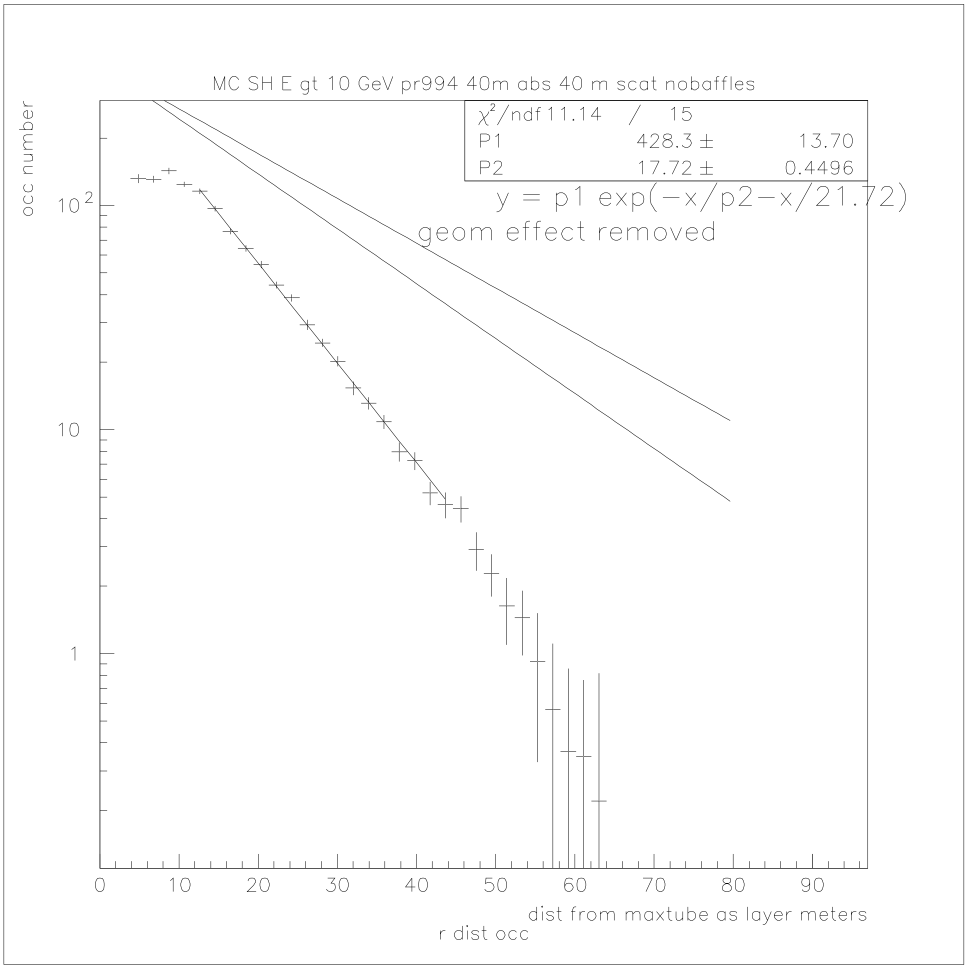

Figure 4: Light propagation: 40 m abs 40 m scat no baffles

2.2 With Baffles: NO absorption NO scattering

Now we show what happens when baffles are added in the simulation GEANT program. First we show the case for no absorption and no scattering and baffles to indicate the geometrical effects in Milagro air shower layer according the MC. This is shown in Figure 5. The value of the geometrical effect due to baffles gives for the attenuation length:

$$\Lambda_g = 14.33 \pm .88 \text{ meters.}$$

This is used in the figures which follow to find Λat.

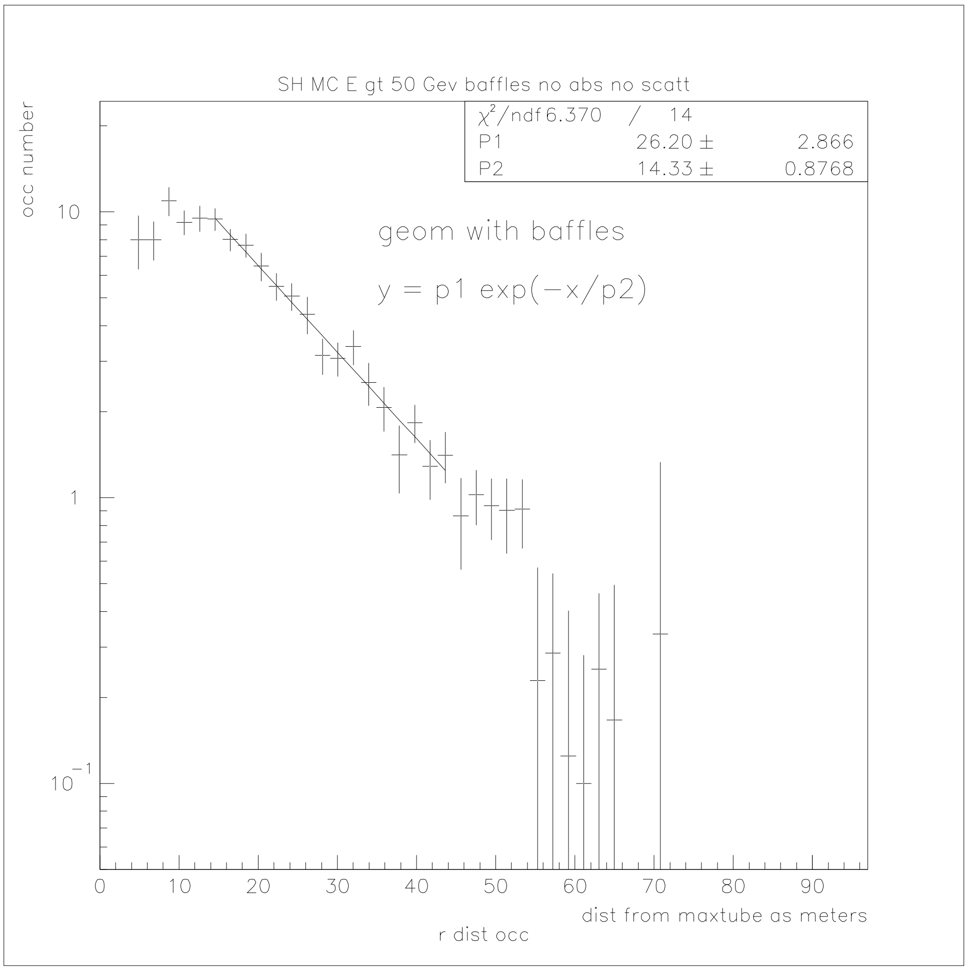

Figure 5: Light propagation: no abs no scat baffles

2.2.1 With Baffles: 40m absorption NO scattering

Now we show what happens when attenuation and scattering are separately added to baffles in figures 6 and 7 and Figure 8 shows both together. First we show the case for 40m absorption and no scattering and baffles in Figure 6. The value of the attenuation length is found to be:

$$\Lambda_{at} = 32.4 \pm 4.5 \text{ meters.}$$

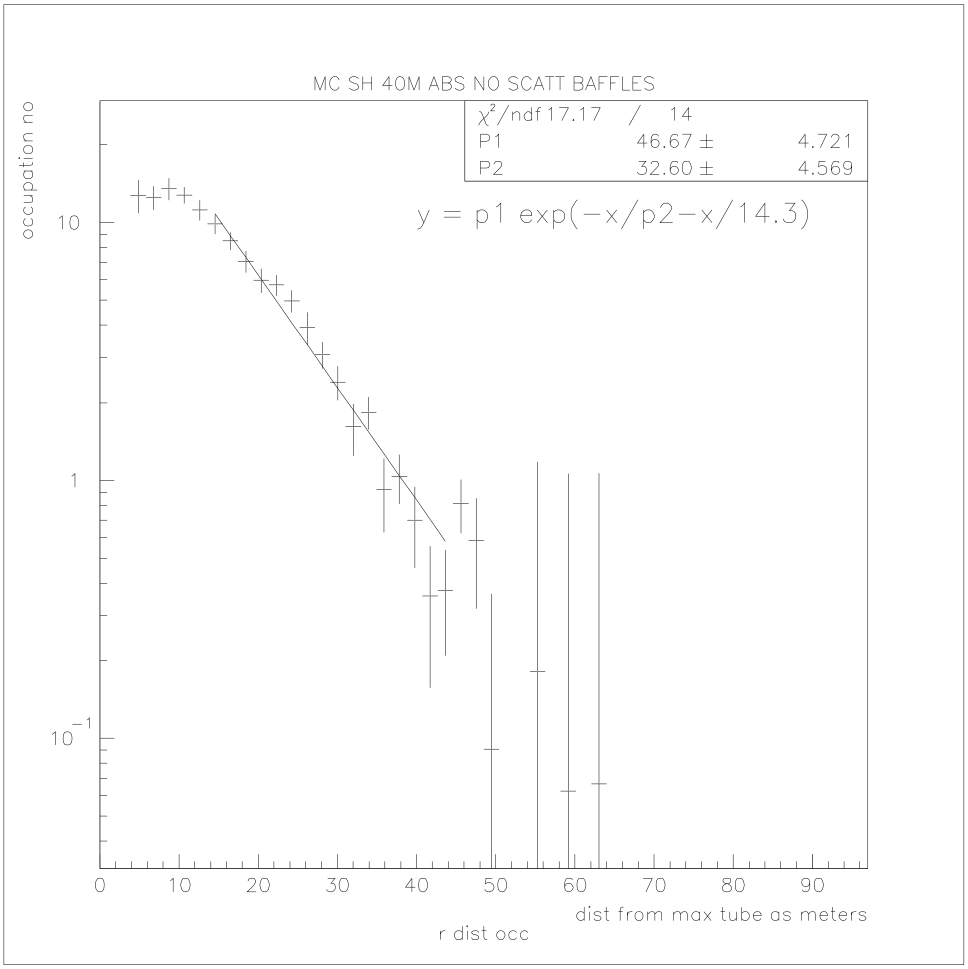

Figure 6: Light propagation for 40m abs and baffles

2.2.2 With Baffles: NO absorption 40m scattering

Now we show what happens when only 40m scattering is included in Figure 7.The value of the attenuation length is found to be:

$$\Lambda_{at} = 34.7 \pm 2.2 \text{ meters.}$$

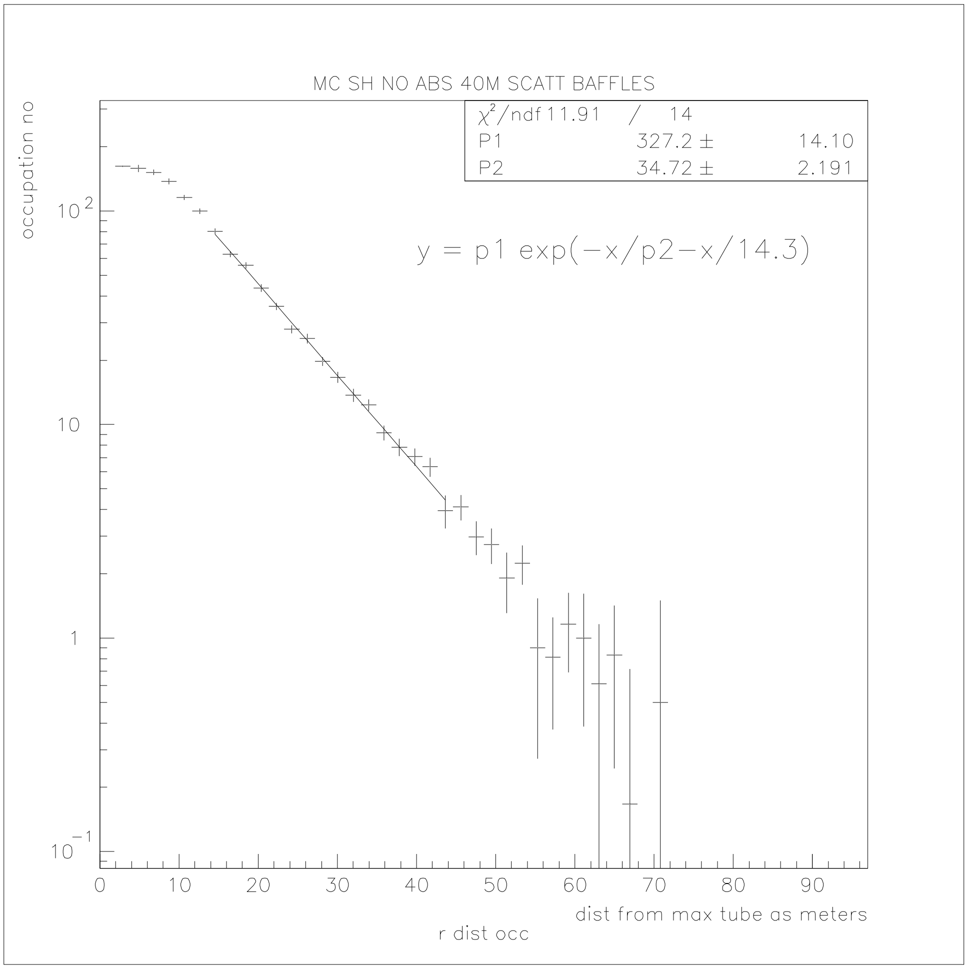

Figure 7: Light propagation for 40m scatt. only and baffles

2.2.3 With Baffles: 40m absorption 40m scattering

Now we show what happens when 40m absorption and 40m scattering is included in Figure 8.The value of the attenuation length is found to be:

$$\Lambda_{at} = 13.3 \pm 0.66 \text{ meters.}$$

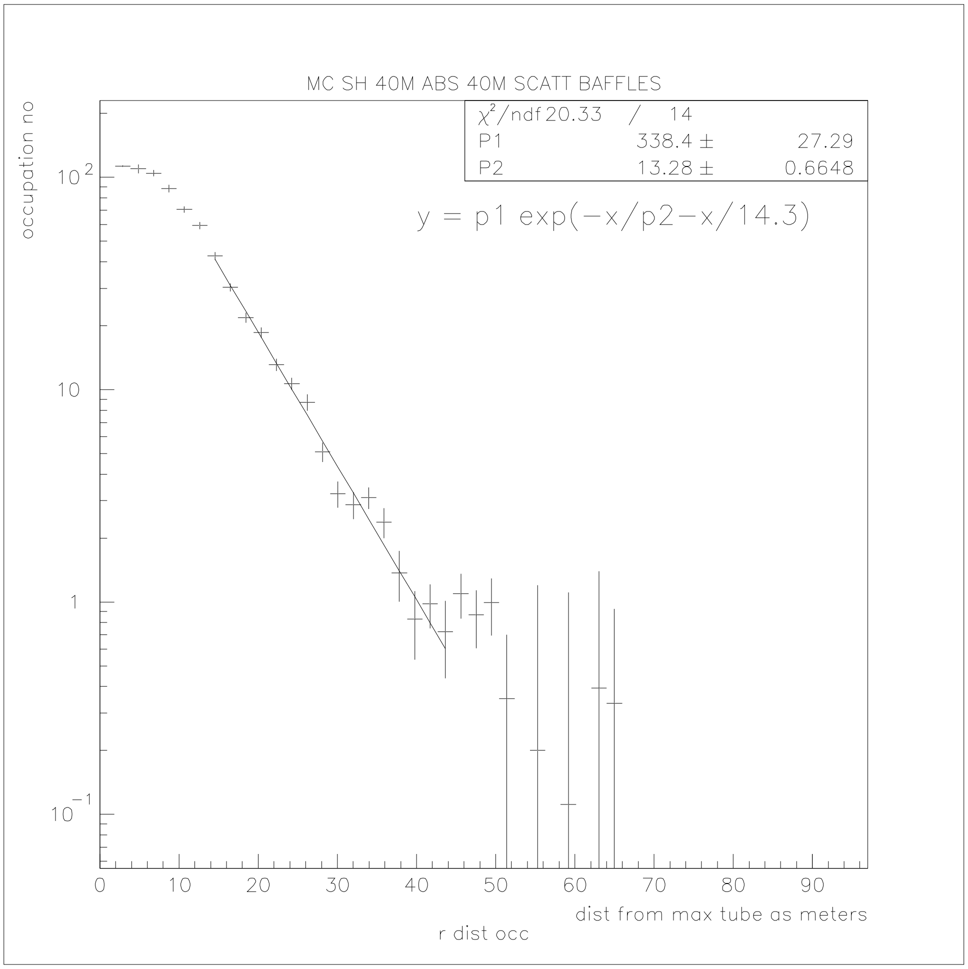

Figure 8: Light propagation for 40m abs 40m scat and baffles

2.3 Monte Carlo's with v-2.6: Rob's SH and SH from Julie's protons

2.3.1 Rob's SH MC v2.6

Next we show what is obtained using **v2.6 by using a large sample of MC SH generated by Rob** in Figure 9 ..

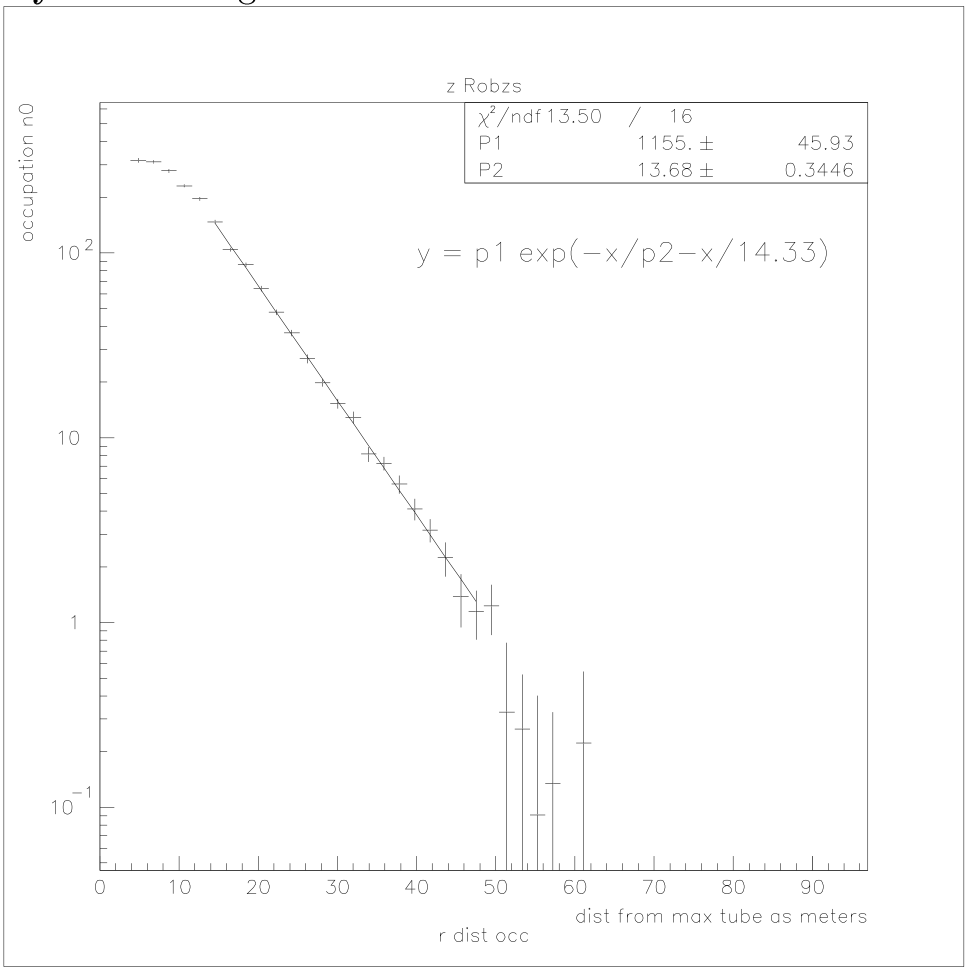

Figure 9: Light propagation for Rob's SH MC

The effective attenuation length obtained is :

$$\Lambda_{at} = 13.88 \pm 0.34 \text{ meters}$$

2.3.2 SH seclected from Julie's v2.6 proton showers

The distribution for **SH selected from Julie's v2.6 proton showers** is shown in Figure 10. For these SH one gets a similar small effective attenuation length.

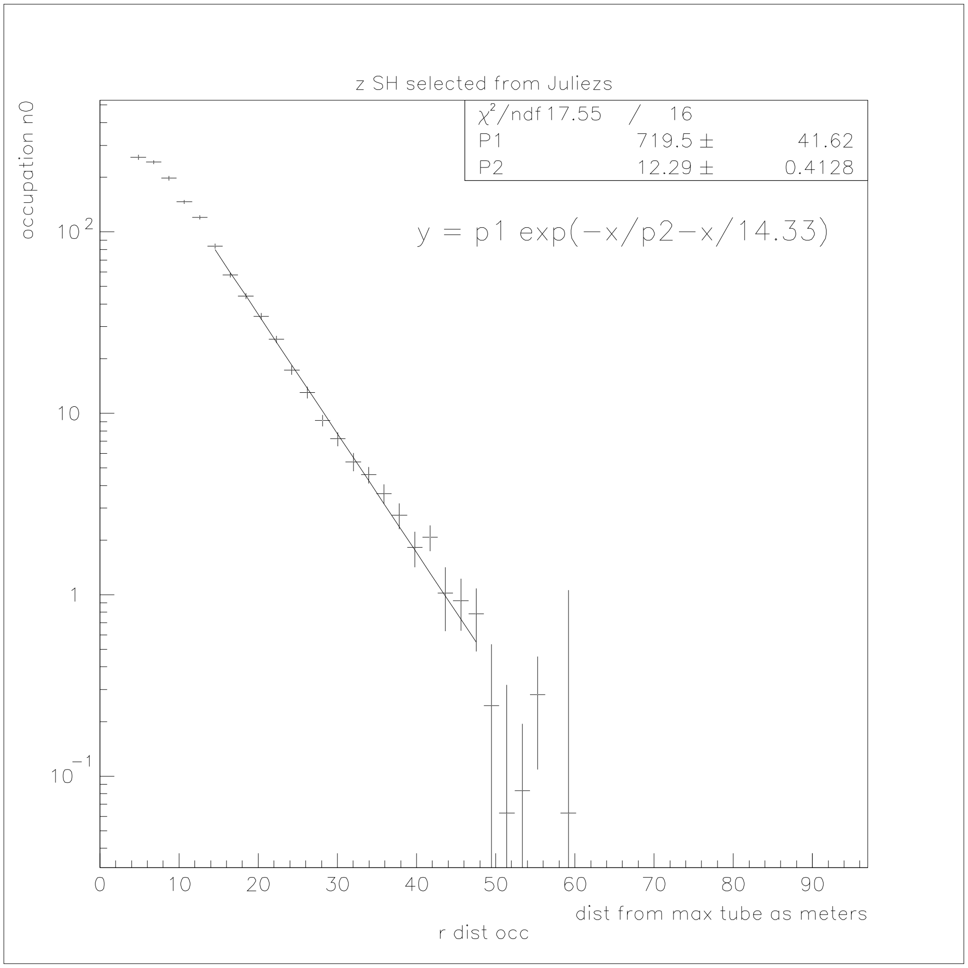

Figure 6: Light propagation for SH from Julie's v2.6 protons

The effective attenuation length obtained for this sample is comparable to that for Rob's SH and is equal to:

$$\Lambda_{at} = 12.3 \pm 0.42 \text{ meters}$$

2.4 SH from GRB data file:

Now finally we show what is obtained for **a GRB data file**, selecting SH the same way as for Julie's proton trigger file. This is shown in Figure 11 in which the fit is to single exponential. The value of attenuation length is

$$15.65 \pm .30 \text{ meters.}$$

This is larger than Λ_g= 14.33 meters obtained for the case with no scattering, no absorption and baffles and smaller than Λ_g =21.72 obtained for the case of no scattering, no absorption and no baffles.

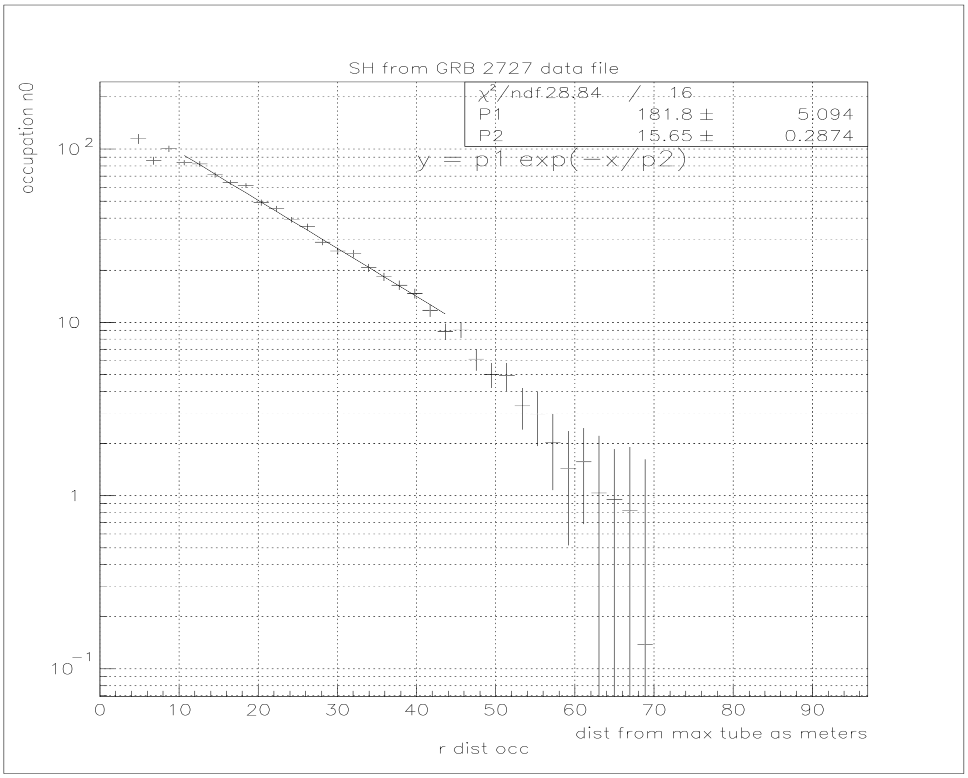

Figure 11: Light propagation for GRB data file

If one wants to determine what this value means for geometrical attenuation, then a way to do this is to take as given a value for Λ_{at} and fit the observed distribution from the data for Λ_g. The question is what should one take for attenuation from Don's measurements as he measures absorption plus scattering at a fixed wavelength. To bracket this question we take several assumed values of Λ_{at} and find the geometrical Λ_g needed to fit the data. This is shown in the following list :

1. Λ_{at} = 20 meters then Λ_g= 72 ± 6.1 m
2. Λ_{at} = 28 meters then Λ_g= 35.5 ± 1.4 m

3. Λ_{at} = 35 meters then Λ_g= 28.3 ± 0.9 m

4. Λ_{at} = 40 meters then Λ_g= 25.7 ± 0.7 m

We remind you that Don's measurements vary between from about 6m to about 14m for attenuation in the long tube and that he measures both absorption and scattering at 350 nm.

3 Conclusions

These results are summarized in Table I so as to be able to see the results at a glance.

Sample	Abs	Scatt	Baffles	Λ	Λ_g	Λ_{at}
MC SH	no	no	no	21.7±0.7	21.7±0.7	
MC SH	40	no	no	12.6±.2		30.2±1.1
MC SH	no	40	no	15.0±.2		47.6±2.3
MC SH	40	40	no	9.7±.16		17.7±.5
MC SH	no	no	yes	14.3±.9	14.3±.9	
MC SH	40	no	yes	10.±.5		32.4±4.5
MC SH	no	40	yes	10.2±.2		34.7±2.2
MC SH	40	40	yes	6.9±.2		13.3±.66
MC SH Rob v2.6	18	no	yes	7.0±.1		13.8±0.3
MC SH JM 2.6	18	no	yes	6.6±.14		12.3±0.3
VII. SH GRB2727	-	-	-	15.5±.3		

The Table shows three possible values for Λ: (1) Λ without a subscript, which is the best fit to a single exponential to the straightline part of occupation number versus distance plots, (2)Λ_g which corresponds to geometry with or without baffles when absorption and scattering are turned off and (3) Λ_{at} which is the value which satisfies the equation

$$\frac{1}{\Lambda} = \frac{1}{\Lambda_g} + \frac{1}{\Lambda_{at}} \tag{2}$$

when either absorption, scattering or both are turned on. The table shows that Λ for data is inconsistent with any of the Λs with baffles put in.

From the results shown, it is clear that there are still serious differences between data and simulations at least as far as light propagation. It may be that attenuation as used in the simulation - that is absorption and scattering - does not represent our water correctly or that there are reflections which are not properly incorporated in the Monte Carlo or that the baffles are not doing what we think they should be doing or some combination of all of these.