Muon Detection Testing at Nevis

Claire Thomas

Over the past few weeks we have done a simulation of the basic Outer Veto Setup at Nevis. We stacked four long Scintillator strips into our light tight box. Each of the strips has a wavelength-shifting fiber running through it and into a channel of the PMT. We also have four pairs of 'trigger strips,' which are 5 by 4.5 cm pieces of Scintillator. Each pair of triggers consists of an 'up' and a 'down' trigger. The two are opposite one another and rest either directly above or below the strips. They have fibers that lead into separate channels of the PMT. In this setup a Muon event is recorded whenever both top and bottom triggers detect a Muon. We look for Muon events by cutting on 1 photoelectron, which, with our ADC corresponds to 35 ADC counts.

According to Cosmic Muon data from the PDG, we should expect a Muon rate of $70m^{-2}s^{-1}str^{-1}$ at sea level. Since the solid angle for each of our triggers is 2.36 sterradians and they have a surface area of $.0025m^2$, we should expect a Muon rate of .413 Muons per second for each of the 4 trigger pairs. This corresponds to 25 Muons per minute per trigger counter, or 99.12 Muons each minute total. Each Muon should deposit about 10 photoelectrons, so after analyzing the data taken over the course of two hours, we expected to detect about 3,000 events per trigger that would peak at 350 ADC counts, or 10 pe's.

The first time we attempted to attach a PMT to a fiber holder, we shattered the face of the PMT. We then constructed spacers for the PMTs which would separate the PMT from the fiberholder. Early on we also found that crosstalk among the Trigger counters, which sit directly next to one another on the PMT face was triggering Muon events when there were none. We retook the data using five-fold coincidences, that is, for each Strip we demanded that the trigger counters *and* as each of the other Strips have a count greater than 1 photoelectron. This five-fold coincidence would ensure that the events on which we triggered were actually Muon events, and not a result of crosstalk. We repeated our experiment many times under different conditions, but I will present 6 different tests that we ran. Each of these experiments took data for two hours.

The first experiment that we did using five-fold coincidence as well as the new spacer produced disappointing results with very few photoelectrons and not nearly enough events. As Figure 1 shows, we saw very few photoelectrons on this first run, an average of 2.7, and we also saw incredibly few events. The event numbers decrease as the trigger counters get further from the PMT, and the statistics from the farthest trigger counter (trigger 1) are hardly enough to make any interpretation. Table 1 shows that though 2.7 is the average number of photoelectrons, each of the strips yields large variations in pe count, as do each of the triggers. We account for gain corrections in the software as we analyze our data, so this variation is probably due to inconsistency in polishing of the fibers.

To test whether we could get better data, we removed the spacer and did not fully secure the PMT to the holder. This reduced crosstalk from about 20% in the first test, to about 9% in the second, as exhibited by the table in Table 1. Figure 2 shows, we were still only seeing an average of 3 photoelectrons.

The total crosstalk is calculated by finding the crosstalk in each event. We demand that a PMT neighbor triggers at the same time as a muon event in the main strip. The number of ADC counts that bleeds into the neighboring channel is measured for each of the Strips neighbors. The counts are summed together for each neighbor and then a percentage crosstalk is found for a given event. Each of these percentages is histogrammed, and the final crosstalk is the mean value of the crosstalk histogram.

Figure 1:

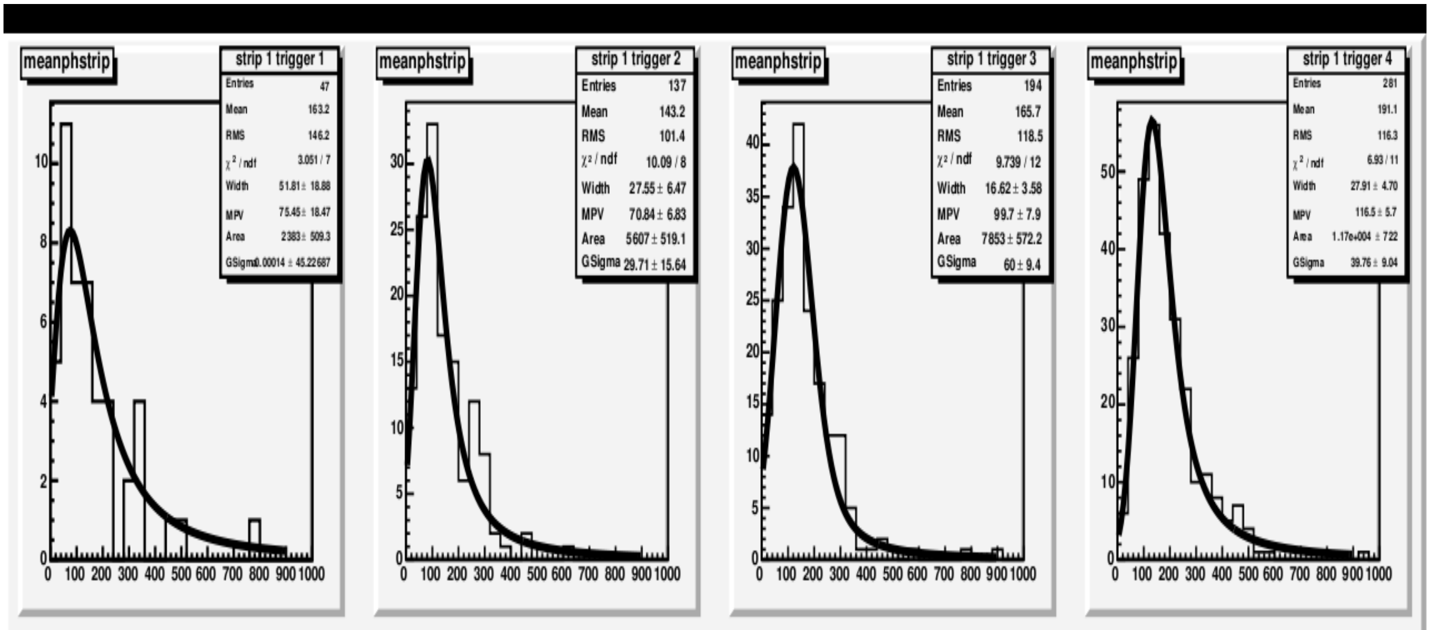

Fig 1. shows the data from Strip 1, taken when a spacer was used between the PMT face and the fiber holder. Trigger 1 (leftmost) is the farthest trigger from the PMT, moving right the triggers come closer. It shows that there are very few events, with very few photoelectrons. Though the events do increase as we approach the PMT (trigger 4, far right, is the nearest to the PMT), there are still too few events to draw any conclusions from this data.

Figure 2:

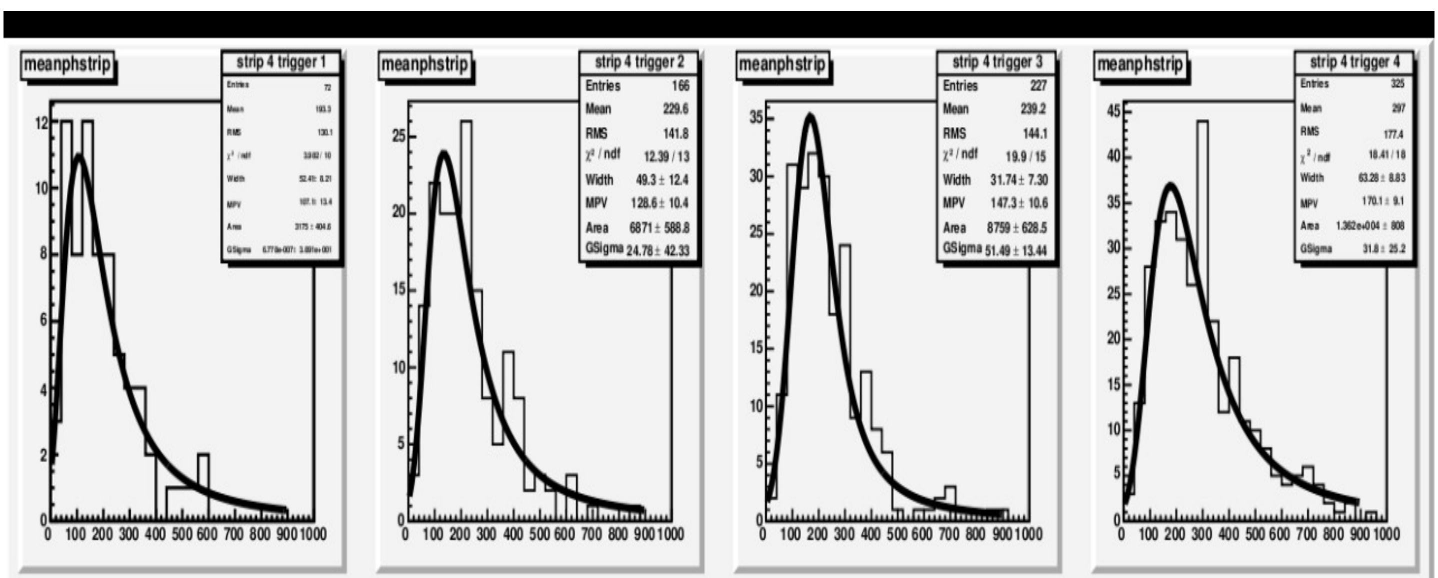

Fig 2. shows Strip 4 data, taken without the spacer to separate the PMT from the fiber holder. Trigger 1 (leftmost) is the farthest trigger from the PMT, moving right the triggers come closer. These plots show that there are more events, but there are still very few photoelectrons detected.

Table 1:

Crosstalk (percentages):

	Trigger no	T0 small spacer	T0 no spacer	T0 grease	T2 grease	T2 grease (gain online)
S1:	1	16.85	7.18	5.75	9.57	17.3
	2	16.31	6.92	9.27	9.9	15.05
	3	15.89	8.03	9.73	8.77	15.83
	4	19.93	10.38	12.6	11.31	17.55
S2:	1	20.99	11.99	14.39	12.32	16.77
	2	29.95	10.6	13.82	12.61	16
	3	27.71	11.64	14.8	15.43	16.98
	4	31.51	14.64	15.31	16.53	17.94
S3:	1	14.42	2.79	5.41	4.45	14.74
	2	12.2	5.04	4.51	5.13	13.88
	3	11.44	4.2	5.21	5.46	13.21
	4	13.5	5.35	7.41	6.8	13.19
S4:	1	19.54	9.9	13.34	13.78	13.7
	2	24.83	9.54	12.22	11.26	11.56
	3	26.2	10.4	13.39	13.21	14.25
	4	26.98	12.56	16.79	16.3	14.38
	average:	*20.51*	*8.82*	*10.87*	*10.8*	*15.15*

Table 1 *displays crosstalk values in percentages for each of the triggers on each of the strips. Removing the spacer from the PMT reduced the crosstalk greatly, and using optical grease increased the crosstalk (as expected). After seeing this increase in crosstalk with optical grease, we decided to add the crosstalk from each strip's neighboring channels back into the strips histograms. This can be seen in Figures 3 and 4.*

We then used optical grease between the PMT and the fiber holder to try to get more photoelectrons. This attempt brought us up to an average of 4.3 photoelectrons, and as Table 1 shows, it also brought us up to about 11% crosstalk. For this data we decided to go through our data, event by event, and add the crosstalk counts back into the central pixel. Figure 3, and Tables 3 and 4 show that this improved our ADC count, and thus our detected photoelectrons. After this addition we see 4.73 photoelectrons.

Our final two tests employed the newest addition to our DAQ, a trigger variable. Until now all data presented has been taken by triggering any time that one channel is above threshold (1 photoelectron). Our new trigger variable only reads data from the PMT if at least *two* channels are above the threshold. This reduced the total amount of data we took, but increased the number of muon events that we found. In these runs we continued to use optical grease with no spacer between the PMT and the fiber holder. The only difference between these last two experiments was the method by which gain corrections were applied. In the first, we continued to apply these corrections offline, in the program with which we analyzed our data. In the second, however, we used gain correction online as we took data. We correct for gain online using the preamp in the Maroc 2 chip. The data from each of these runs is shown in their respective columns of Tables 3 and 4. Figure 4 displays the data in which gain corrections were applied offline. The figure shows that in the nearest trigger (trigger 4) we see 1008 Muon events, which is very near our original expected value.

Figure 3:

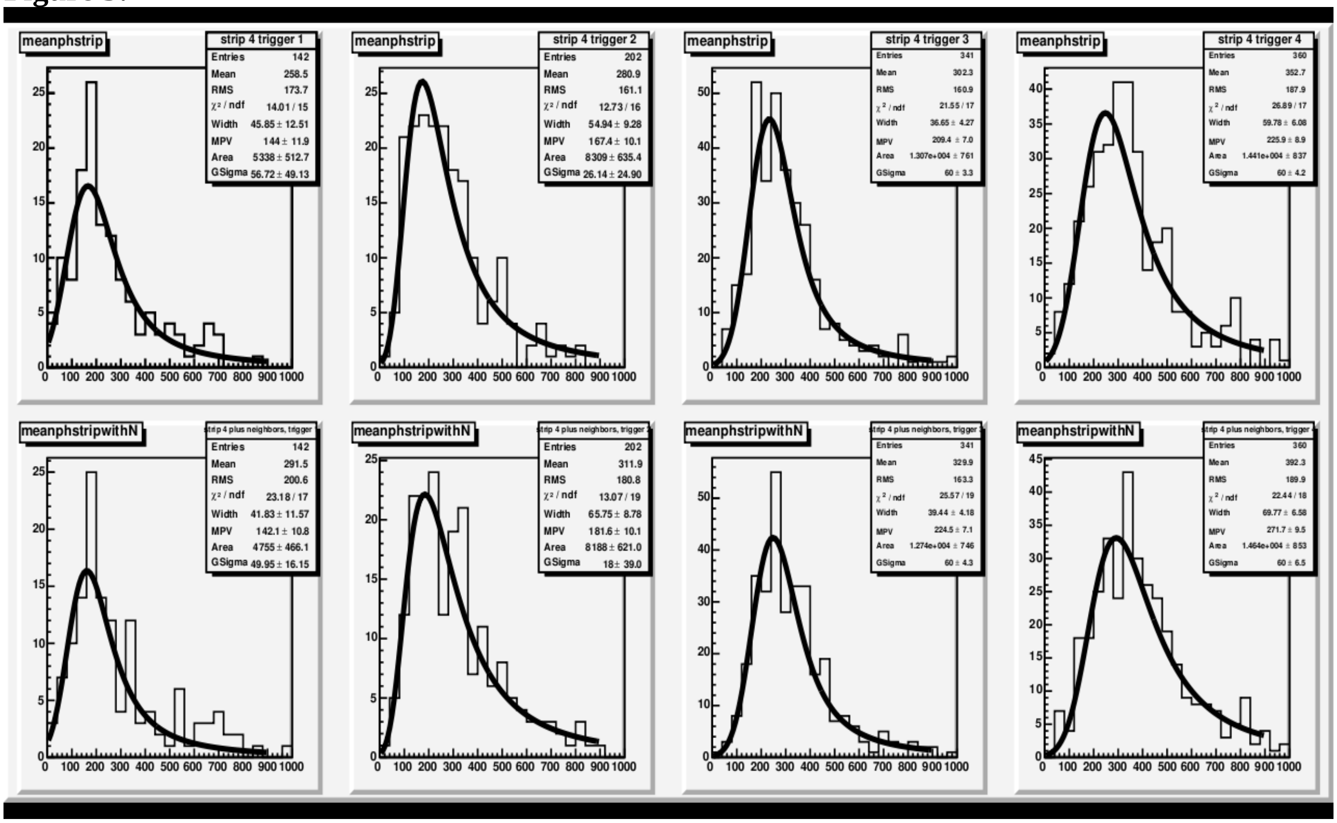

Fig 3. displays Strip 4 data from the experiment using optical grease. The top row displays the data before adding in the neighboring channel crosstalk, and the second row shows the data after the addition. This addition improved our count of photoelectrons, as displayed by the rightward shifting peaks of the second row of histograms.

Table 2:

Photoelectrons:

	Trigger no	T0 small spacer	T0 no spacer	T0 grease	T2 grease	T2 grease (gain online)
S1:	1	2.16	1.07	2.12	2.35	1.34
	2	2.02	2.37	2.8	2.83	2.16
	3	2.85	2.57	3.6	3.6	2.55
	4	3.33	3.93	4.87	4.88	3.43
S2:	1	1.9	2.25	3.76	3.52	5.03
	2	2.79	2.7	4.39	4.36	4.39
	3	3.03	3.42	5.44	5.1	5.53
	4	3.97	4.71	6.83	6.42	6.97
S3:	1	1.99	2.29	2.59	2.58	2.69
	2	1.84	2.03	2.89	3.04	3.05
	3	2.3	2.37	3.43	3.72	3.02
	4	2.99	3.66	4.71	4.83	4.4
S4:	1	2.69	3.06	4.11	4.1	4.88
	2	3.24	3.67	4.78	4.85	5.3
	3	3.32	4.21	5.98	5.72	6.58
	4	4.04	4.86	6.46	6.81	8.03
	average:	*2.78*	*3.07*	*4.3*	*4.29*	*4.33*

Table 3:

Photoelectrons with crosstalk added back in:

	Trigger no	T0 small spacer	T0 no spacer	T0 grease	T2 grease	T2 grease (gain online)	*average per strip*
S1:	1	2.32	1.47	2.21	2.54	1.82	
	2	2.42	2.51	3.15	3.07	2.22	
	3	3.08	2.83	3.81	3.82	2.88	
	4	3.84	4.31	5.5	5.3	4.13	*2.76*
S2:	1	---	2.57	4.02	3.81	3.81	
	2	3.65	2.92	4.95	4.93	5.02	
	3	3.49	3.77	5.99	5.81	6.47	
	4	5.02	5.39	8.03	7.56	8.09	*5.85*
S3:	1	---	2.37	2.75	2.71	3.6	
	2	2.04	2.14	2.99	3.18	3.46	
	3	2.45	2.42	3.62	3.88	3.86	
	4	3.17	3.66	5.19	5.08	4.84	*3.94*
S4:	1	4.46	2.99	4.06	4.63	4.09	
	2	3.77	4	5.19	5.36	5.95	
	3	4.21	4.5	6.42	6.48	7.5	
	4	5.09	5.78	7.76	8	5.15	*5.67*
	average:		*3.35*	*4.73*	*4.76*	*4.55*	

Figure 4:

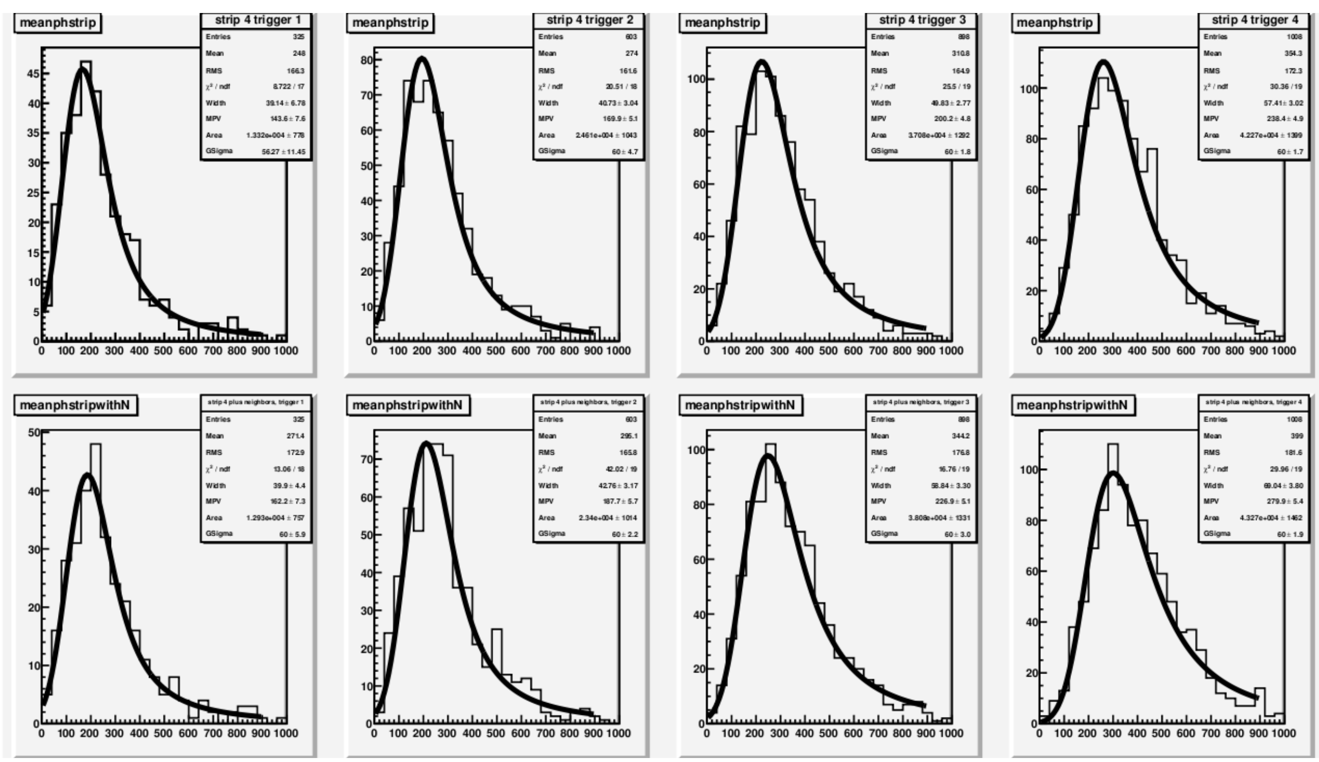

Fig 4. displays the results of Strip 4 for each trigger both with and without crosstalk added in. At the nearest trigger (rightmost plots) we have 1008 events, which is much closer but still a factor of 3 less than the expected 3000/trigger.

We still detect fewer photoelectrons than we expect and this problem could be attributed to poor fiber polishing in our experimental setup. This is primarily evidenced by the unexpected variation in pe count among the strips, each of which should detect the same Muon events. The attenuation length that we calculate of our fibers are shown in Table 2. The error is on the order of 10% for these values.

Table 5:

Attenuation length (cm):

Strip no	T0 small spacer	T0 no spacer	T0 grease	T2 grease	T2 grease (gain online)	*average per strip*
1	260.11	127.66	162.52	177.54	160.55	*177.67*
2	204.9	174.82	220.29	229.37	336.92	*233.26*
3	281.66	236.95	212.73	209.66	280.37	*244.27*
4	364.54	302.58	296.6	268.95	255.62	*297.66*