3 EXPERIMENTAL INVESTIGATIONS

Caroline Robson

3.1 Aims and Objectives

The aims of the initial experimental work were to become accustomed to the methods employed in scintillation detectors and to obtain a measurement of the incident muon flux to be compared with theory. Using an arrangement of scintillators on a test stand a series of investigations was carried out to determine the ideal power supply voltage for the photomultiplier tube and the differences in count rate from running two and three scintillators in coincidence. Another scintillator of the type that was expected to be used in the detector design was then added and the efficiencies of the different types compared.

The main objectives were:

- To find the optimum power supply voltage for the PMT so that an idea of the type needed for the detector could be obtained
- To find the flux rates obtained with two and three way coincidence and compare with theoretical predictions
- To test a piece of new scintillator and compare the results to those from the MINOS scintillators.
- To be aware of potential problems involved in the working of a scintillation detector and gain experience of how to solve them

3.2 Experimental Method

3.2.1 Set Up of the Test Stand

A test stand had been constructed by Drs Mark Lancaster and David Waters in order to form the basis of these tests. The stand consisted of an optical box containing an array of 15 organic polystyrene scintillators of a type used in the MINOS project routed through a Hamamatsu M16 PMT (see figs 28a and 28b, below).

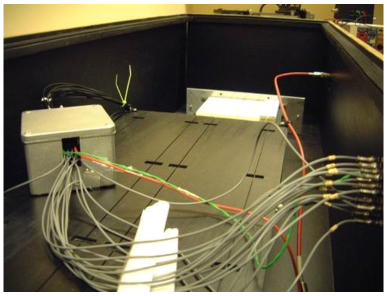
Fig.28a 

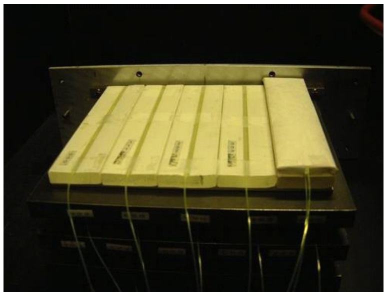
Fig.28b 

Fig.28 a: The inside of the test stand's optical box with the lid removed The MINOS scintillators lie at the back and the PMT is housed inside the metal box in the foreground. The grey LEMO cables are plugged into the back of the patch panel. **Fig. 28b: The arrangement of the 15 MINOS scintillators.** On the top lies the new piece of scintillator which was later used to determine the geometry of the new detector.

The dimensions of the MINOS scintillator strips were 168 x 40 x 10 mm and they were arranged in three layers of five each at a distance of 33±2mm. The arrangement had been used in a previous experiment and the scintillators had been placed with an offset of 5mm on the middle layer. Each strip was covered in a white reflective covering in order to help reflect photons back into the material and had a groove down the centre of its length on the top surface, into which was glued one end of a length of wavelength-shifting fibre. The other end of the fibre from each of the scintillators was connected to an ordinary optical cable which was fed into the PMT. The electrical output LEMO cables were routed to the back of a patch panel mounted on the wall of an optical box inside which the components sat. Via the connectors on the outside, any of the 16 PMT channels (15 for the scintillators and one empty) could be selected and routed through the electronics crate, which consisted of an amplifier to boost the signal, a discriminator to turn the analogue signal into a digital pulse, an OR gate, a coincidence (AND) unit and a counter to record the number of hits. A schematic can be seen in fig.29, below. The power supply for the PMT also sat in this crate. During the experiments the optical box was covered with a dark cloth in order to cover any cracks through which light may have entered. It was extremely important to ensure that while the PMT was connected to its power supply that no light entered the box as, entering through the wavelength-shifting fibre, it would have overloaded and severely damaged the sensitive PMT. The high voltage power supply to the PMT was always ramped up slowly to the working voltage in the region of 1kV

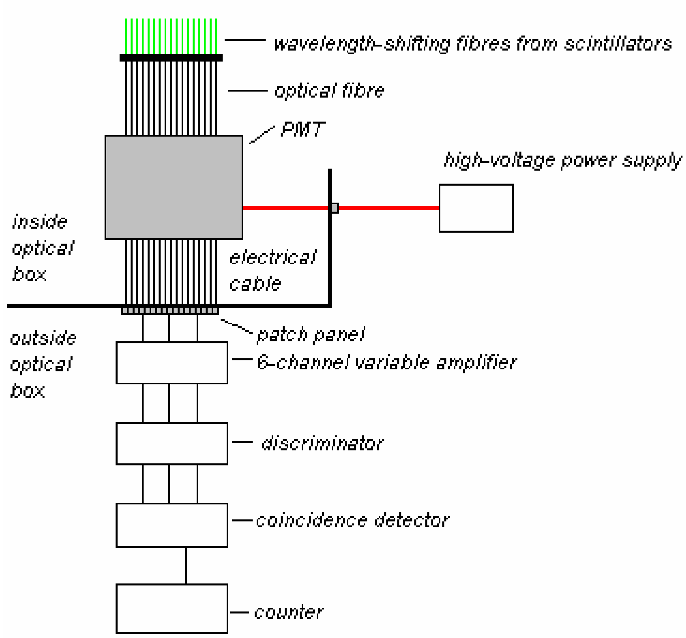


Fig.29: Schematic diagram of the optical and electrical components of the test stand

The scintillators and their corresponding patch connections were numbered from 0 to 14 as follows (see figs 30a and 30b, overleaf). Whenever particular patch connnections were not being used they were terminated with 50? resistors in order to prevent stray currents from producing unwanted signals.

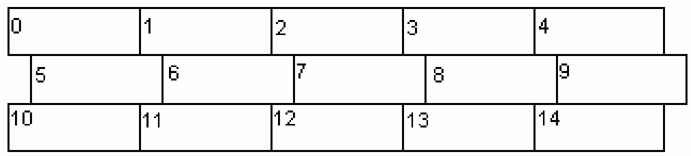


Fig.30a: Numbering of Scintillators

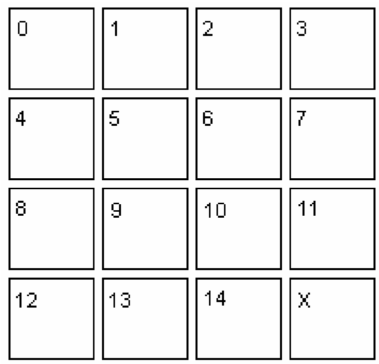


Fig.30b: Corresponding numbering of patch panel

3.2.2 Tests Using the MINOS Scintillators

An initial test was carried out using scintillators 1, 6 and 11 in coincidence with each other, meaning that a count was only recorded if all three recorded an event at the same time. With the PMT power supply set at 950V, the scintillators were run for 5 minutes and the timings of the counts recorded. It was found that although for most of the time the counts went steadily upwards, 'bursts' occurred from time to time where the counter would suddenly leap up in value. Four such bursts occurred within the five minutes.

Before the source of the bursts could be investigated, it was important to determine the optimum working voltage of the PMT upon which further tests were to be based. These results were needed in order to decide upon the sensitivity of the power supply needed to run the Hamamatsu M16 in the final model. The voltage was varied on the crate power supply in steps of 10V from 850V to 950V and the timings of the count occurrences recorded. The detector was run for 3 minutes each time. It was found that the PMT performed very poorly up to a value of 920V, with some of the single count and burst occurrences appearing to be correlated with movement in the room e.g. people walking in and out past the equipment. After 920V up to 950V the count rates were much steadier and more counts were recorded. It was determined that the PMT should be run at 950V for all of the subsequent experiments.

Voltage	850	860	870	880	890	900	910	920	930	940	950
Counts	Time/s	Time/s	Time/s	Time/s	Time/s	Time/s	Time/s	Time/s	Time/s	Time/s	Time/s
1				2.15		0.25	0.45	0.15	0.09	0.15	
2								0.29	0.16	0.16	0.11
3			0.35				1.01	1.02	0.26		0.28
4						0.41	1.42	1.47	0.3	0.25	0.35
5				3		0.53	1.51	1.57	0.34	0.3	0.4
6						1.01	1.55	1.58	0.41		0.45
7	2	1.3				1.38	2.38	2.09	0.45	0.46	0.57
8								2.14	1.11		
9						1.49		2.55	1.31	0.48	
10						2.06			1.56	1	
11			1.11						2.19	1.14	
12	2.17	2.54							2.24		
13			1.26						2.25	1.23	
14									2.35	2.09	
15									2.36		
16	2.21									2.18	1.32
17										2.26	1.37
18										2.49	1.4
19											2.07
20											2.43
21											
22											
23						2.47					
24	3.01										
25											2.46
26					1.2						2.59
27					1.26						
28					1.4						
29					1.46						
30					1.5						
31					2.28						
32											
33											
34											3.2
35											
36											3.27
37											
38											
39											3.34
40											
41											3.39
42											3.46
43											3.5
44											3.54
45											
46											
47											
48											
49											
50											4.09
51											4.12
52											4.55

Fig.31 : Results for 850 – 950 volts

Analysis of results

From fig.31 it is clear to see that as the voltage increases, more single increase counts (i.e. count increases by one rather than a large jump) are recorded. Because of this only the results above 920 volts will be considered.

Calculation of Count Rates

By plotting the number of counts against time (Appendix I, graphs 1-4) the count rate per minute could be calculated. To do this the gradient of each graph was found. Graphs 1-4 all show a positive linear trend with not much scatter from the line of best fit. This gives an initial indication that the results are precise. The count rates for 930 V to 950 V are: -

930 V -	**4.75 s^{-1}**
940 V-	**6.25 s^{-1}**
950 V-	**9.50 s^{-1}**
950 V 5 mins -	**11.00 s^{-1}**

Are the counts random, or are they systematic noise?

The results for 950v for 5 minutes were taken and the time interval calculated, see appendix 1 table 1. The time interval is the time difference between each recorded count. If the time interval is very similar, this suggests that the muons are recorded at a very steady rate, and are not random, or that a regular source of noise is being detected.

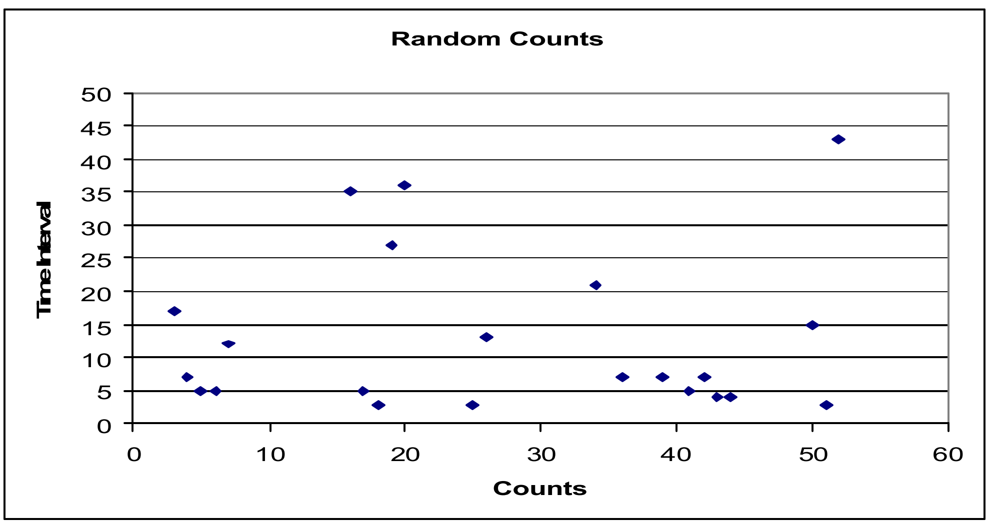


Fig.32 : Determination if counts rates are regular.

Fig. 32 shows no trend, indicating that the muons are being detected at random times.

No clear count rate can be determined from this. Even 950v for 3 minutes and 5 minutes give different count rates. The counts appear to be random and graphs 1 – 4 show that there is a linear trend for each voltage, but no voltage has the same count rate.

What was noticed was that there appear to be big jumps in counts for no noticeable reason. This is a factor that is affecting the results, as the longer the time for which the muons are recorded, the more jumps there are going to be and the higher the count rate. From the initial results this appears to be true.

Adjusting the initial results for noise

From the above discussion it is clear that noise is a major factor affecting the results. By taking the initial results and subtracting the bursts, new count rates can be calculated. To do this the results were taken and the number of counts was adjusted so that it increased by only one each time.

Results

Voltage	930v	940v	950v	950v - 5mins
Number of counts	Time (s)	Time (s)	Time (s)	Time (s)
1	0.09	0.15		
2	0.16	0.16	0.11	0.11
3	0.26	0.25	0.28	0.28
4	0.3	0.3	0.35	0.35
5	0.34	0.46	0.4	0.4
6	0.41	0.48	0.45	0.45
7	0.45	1	0.57	0.57
8	1.11	1.14	1.32	1.32
9	1.31	1.23	1.37	1.37
10	1.56	2.09	1.4	1.4
11	2.19	2.18	2.07	2.07
12	2.24	2.26	2.43	2.43
13	2.25	2.49	2.46	2.46
14	2.35		2.59	2.59
15	2.36			3.2
16				3.27
17				3.34
18				3.39
19				3.46
20				3.5
21				3.54
22				4.09
23				4.12
24				4.55

Fig.33 – Adjusted results

Analysis of Results

Count Rates

From the gradient of each graph (Appendix II, graphs 1-4) the count rates were determined:

930V - **4.5 min $^{-1}$**
940V- **4.5 min $^{-1}$**
950V - **4.5 min $^{-1}$**
950V- **4.0 min $^{-1}$**

These results are much more consistent than the previous results, and shows that the bursts are a serious issue that needs to be addressed. These results give an average of 4.5 counts per minute.

Although the results seem to be consistent, there appears to be a regular non-linear shape that appears in the graph. This seems to be due to the fact the counts only seem to be detected in short intervals, with long intervals between the detections.

This can be illustrated by plotting a line graph of all the points joined up, see Appendix II – graphs 5-8.

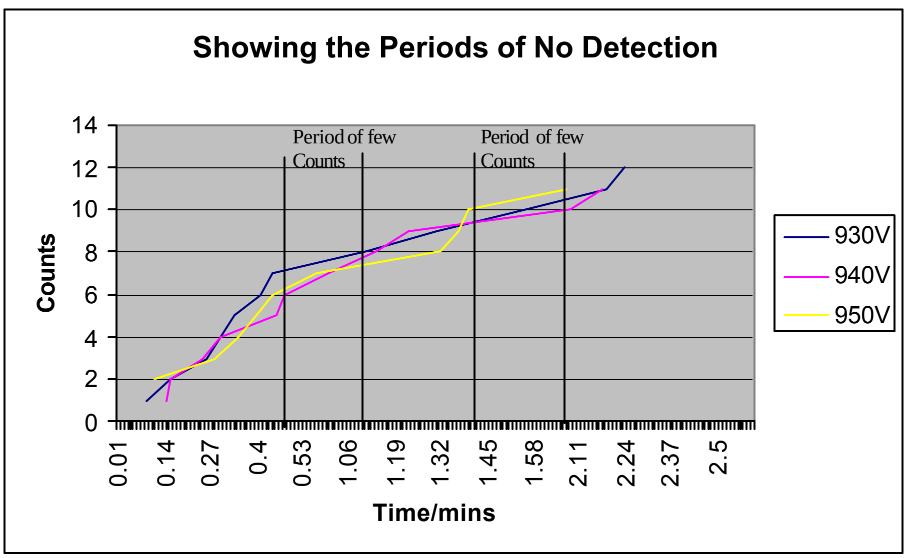


Fig.34 : the line graphs showing the count pattern

Fig.34 shows long periods with a very shallow gradient, which means that very few muons are being detected, followed by short periods with large gradients, indicating bursts

The large intervals with no muons being detected appear to be clustered around 1 and 2 minutes

Summary

Although there is an average of 4.5 counts per min, there appears to be a phenomenon of clusters of results.

Locating the noise source Caroline Robson

To test for electrical interference, the empty 16th PMT channel (channel 15) was run on its own, without any of the other channels connected to the electronics. The idea was that there should be no signal from a channel with no optical fibre attached to the other end. This was done twice for two minutes and count rates of 1405 and 1360 were observed, implying that electrical interference or faulty electronics could be to blame. Different amplifier channels were tested and gave similar results, as did trying different channels on the discriminator and two other coincidence units.

Despite there being no input to channel 15 on the PMT, its electrical output cable was still wired up to the back of the patch panel. This was removed and the equipment tested again with channel 15 wired from the patch panel to the crate. No counts were recorded and therefore it was shown that the interference was coming from the equipment inside the optical box and not from the crate as previously suspected. It was noticed that the LEMO cables connecting the PMT to the back of the patch panel were tangled up with each other and the power lead and earth cables of the PMT. With the channel 15 LEMO reattached to the back of the panel, the power lead and the earth were removed from the bundle and the empty channel tested again. The results for four counts of two minutes were 1020, 779,156,146, which although in general show a reduction, did not show the elimination of noise. The next step was to separate the LEMO cables from each other and tape them onto paper separators to keep them as far apart as possible. This appeared for the most part to solve the problem and when 1,6 and 11 were run for three lots of five minutes the count rate went steadily up without bursts.

Further tests

With the burst problem eliminated, further tests were carried out. Firstly, all of the other sets of three scintillators (0,5,10), (2,7,12), (3,8,13) and (4,9,14) were each tested for three sets of five minutes in order to compare the efficiencies of the different scintillators. Two-way coincidence tests of the top two layers (0,5), (1,6), (2,7), (3,8) and (4,9) were also carried out in the same manner. Due to the greater solid angle covered by this arrangement and therefore the greater likelihood of a muon arriving on a trajectory that will produce a coincidence, the count rates for two-way coincidence were higher than that for three-way. The method of recording the counts was altered to accommodate this, with the total number of counts recorded every 10s instead of recording the timing of each count. Individual count rates for all 15 scintillators were taken but varied wildly and were attributed mostly to noise as without coincidence logic, noise cannot be eliminated easily. The coincidence method contributes greatly to the reduction of noise as due to the speed of the electronics (approximately 10kHz) and the length of the pulse from the discriminator (10ns) the chance of receiving two coincident noise signals is reduced to one in 10 000. Finally each layer was used separately to test how the count rate changed with an increase of the scintillating area. First one, then two etc. up to all five on each layer were run through an OR gate for two minutes, recording a count if any of the scintillators were hit.

950v Results with no Noise Simon Bevan

The purpose of this experiment was to take more 950v results to see how the results taken previously compared with results taken when the source of noise has been eliminated.

Voltage	950v -1	950v - 2	950v - 3
Number of counts	Time (s)	Time (s)	Time (s)
1		0.06	0.08
2	0.15	0.33	0.14
3	0.19	0.44	0.15
4	1.05	0.48	0.16
5	1.11	1.03	0.25
6	1.16	1.04	0.26
7	1.39	1.21	0.37
8	2.21	1.3	0.48
9	2.35	2.12	1.16
10	2.38	2.24	2.05
11	2.49	2.53	2.32
12	3.35	3.37	2.45
13	4.12		2.5
14	4.33		
15	5		

Fig.35: No noise 950v results

Analysis of Results

Count Rates

From the gradient of each graph (see Appendix III – graphs 1-3) the count rates were determined: –

950V 1 - **3.0 min^{-1}**
950V 2 - **3.5 min^{-1}**
950V 3 - **3.5 min^{-1}**

These results are again more consistent than the previous results, but do however give a different count rate of 3.5 counts per minute, compared to the previous rate of 4.5 per min.

As with the initial results that were adjusted for noise, there appears to be a regular shape that appears in the graph. This seems to be due to the fact the counts seem only to be detected in short intervals, with long intervals between detections.

Again this can be illustrated by plotting a line graph of all the points joined up (see Appendix III, graphs 4-6). The large intervals appear to be clustered around 1 and 2 minutes

Summary

From the gradient of each graph the count rates were determined: –

950V 1 - 3.0 min^{-1}
950V 2 - 3.5 min^{-1}
950V 3 - 3.5 min^{-1}

The average count rate is 3.5 counts per min, compared to previous results for which the count rate is in the range of 3-5 per minute.

PMT 'Warm Up' Time and Area Testing

Results were taken to see if the PMT needs time to 'warm up.' The power to the PMT was connected and results taken straight away, with the scintillators in 3-way coincidence with (1,6,11). Results were taken every ten minutes.

Results

Time/min	Counts	Counts in ten minutes	Counts/mi
10	34	34	3.4
23	88	54	2.347826
33	190	136	4.121212

Fig.36: Testing to see of the PMT needs to warm up

Time/min	Counts	Counts in ten minutes	Counts/mi
10	36	36	3.6
20	79	43	2.15
30	133	90	3
40	172	82	2.05

Fig.37: – Testing to see of the PMT needs to warm up (second try)

Analysis of Results

The consistency of the count rates shows that the PMT does not need time to warm up and results can be taken straight away if desired.

Testing Various Three Way Coincidences

Results

Coincidence	(0, 5, 10)			(2, 7, 12)			(3, 8, 13)			(4, 9, 14)		
Number of counts		Time (s)			Time (s)			Time (s)			Time (s)	
1	0.38	0.02	0.04	0.35	0.09	0.09	0.11	0.04	0.3	0.34	0.26	0.02
2	0.39	0.38	0.15	0.45	0.22	0.15	0.26	0.09	0.44	0.37	1.23	0.33
3	0.44	1.02	0.41	1.04	0.34	0.33		0.1	0.55	0.38	2.05	0.59
4	0.46	1.14	2.06	1.1	0.53		0.56	0.16	1.25	1.58	2.3	1
5	1.18	1.14	2.28	1.41	1.02	0.42	1.04	0.19	1.29	2.28	2.45	1.3
6	1.25	1.19	2.35	2.02	1.46	0.49	1.45	0.23	1.3	3.5	3.1	2.1
7	1.51	1.24	2.36	2.07	2	0.51	1.51	0.26	2	4.04	3.53	3.05
8	2.19	1.30	3.29	2.14	2.01	0.56		0.31	2.08	4.29		3.31
9	2.23	1.56	3.37	2.37	2.35	1.39		0.34		4.4		
10	2.28	2.01	3.43	2.41	2.49	1.39	1.56		2.29			
11	2.29	2.09	3.48	2.54	3.07	1.47	2.01	0.43	2.37			
12		2.31	4.04	3.43	3.29	2.04	2.03	0.51	2.4			
13	2.35	2.46	4.15	3.5		2.16	2.11	1.06				
14	2.48	2.55		4.19	3.58	2.17	2.27	1.47	3.18			
15	2.52	2.59	4.25	4.32	4.12	2.2	2.39	2.02	4			
16	3.30	3.04	4.30		4.3	2.3	2.43	2.3	4.21			
17	3.35	3.09	4.32		4.4	3.18	3.08	2.37				
18	3.50	3.25	4.33		4.59	3.29	3.16	3.12	4.23			
19	4.23	3.27	4.54			3.34	3.28	3.21	4.35			
20	4.55	3.37				4.01	3.37	3.29	4.38			
21		3.38				4.18	3.43	3.47	4.57			
22		3.56				4.22	3.5	3.53				
23		4.16				4.22	4.02	4.04				
24		4.26				4.53	4.17					
25		4.32					4.3	4.22				
26		4.44						4.51				
27		4.45										
28		4.53										

Fig.38: Results for various 3 way coincidences

Analysis of results

For graphs see Appendix IV, graphs 1-16

Graph	Counts/min
1	4.6
2	5.9
3	3.5
4	**4.7**
5	3.7
6	3.5
7	4.75
8	**4**
9	5.8
10	4.5
11	4.3
12	**4.9**
13	1.7
14	1.9
15	1.3
16	**1.8**

Fig.39: Count rates for all tests, where bold results indicate averages

Summary of Results

Coincidence	Counts/mi
0,5,10	4.7
1,6,11	4
2,7,12	4
3,8,13	4.9
4,9,14	1.8

Fig.40 : Summary of average count rates

The results show an inconsistency in the scintillators. (4,9,14) appears to have a much lower count rate than the others, and (0,5,10) and (3,8,13) are to be consistent with each other but higher than (1,6,11) and (2,7,12) which appear to be consistent with each other.

Again there are gaps at 1:30 and 3 minutes.

The results show that when comparing the new scintillator to previous count rates, it must be done consistently with the same set of scintiallors.

Testing Various Two Way Coincidences

Results

Coincidence		0,5			1,6			2,7			3,8			4,9	
Time	No of Counts			No of Counts			No of Counts			No of Counts			No of Counts		
0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.10	7	8	7	1	3	5	1	3	1	2	1	4	1	1	1
0.20	11	11	12	5	8	7	2	7	5	6	6	7	3	5	6
0.30	15	17	19	6	10	8	6	11	10	7	6	8	5	7	7
0.40	22	19	22	9	12	12	12	11	11	9	11	12	8	11	9
0.50	24	24	25	10	13	15	12	13	12	10	14	14	9	14	9
1.00	30	30	29	16	15	19	20	14	14	12	16	19	10	16	12
1.10	34	34	35	20	17	21	22	15	16	13	18	23	11	16	13
1.20	37	38	37	21	18	25	24	17	19	18	20	25	13	19	14
1.30	46	46	44	28	21	30	27	19	23	20	24	27	15	22	17
1.40	49	50	48	30	22	30	31	21	27	25	26	27	18	22	19
1.50	51	51	49	36	29	36	35	25	29	27	28	29	21	23	22
2.00	55	54	49	37	29	42	36	29	32	28	32	33	23	24	22
2.10	60	59	54	40	34	43	40	32	37	28	35	34	25	29	24
2.20	63	74	61	41	37	47	49	33	40	29	35	35	28	29	24
2.30	70	75	64	43	40	50	51	36	41	31	38	37	30	29	26
2.40	72	79	70	45	41	51	56	38	46	32	38	41	32	29	29
2.50	78	84	78	53	45	55	57	39	47	35	40	44	33	31	34
3.00	81	90	80	54	48	58	58	41	48	37	41	48	34	32	44
3.10	87	93	82	56	50	62	60	46	53	44	45	50	34	34	48
3.20	90	97	89	57	55	65	65	52	57	48	46	51	35	34	50
3.30	116	103	89	62	59	71	69	53	59	49	49	53	41	35	51
3.40	124	106	99	68	64	72	73	54	63	50	52	57	41	35	52
3.50	132	112	105	68	67	74	75	58	65	53	54	61	41	36	52
4.00	136	114	107	70	73	75	76	60	70	56	56	65	42	38	55
4.10	140	130	110	74	74	77	79	63	106	59	60	66	44	39	57
4.20	146	147	114	76	77	80	80	66	113	59	64	66	46	42	57
4.30	150	149	119	79	80	81	82	68	115	60	64	67	47	43	58
4.40	153	155	129	81	83	84	88	76	130	61	69	71	50	47	62
4.50	159	157	133	85	86	84	90	79	132	66	70	71	51	47	63
5.00	162	161	136	86	89	88	93	83	135	68	72	74	52	47	67

Fig.41 : All results for various 2-way coincidences

Analysis of Results

Graph	Counts/min
1	32.5
2	32.8
3	27
4	**31**
5	18
6	18
7	19
8	**18**
9	19
10	15
11	18
12	**18**
13	13.6
14	14.4
15	15.4
16	**14**
17	**11**
18	**9.6**
19	**11**
20	**10.5**

Fig.42: Count rates for all tests, where bold results indicate averages

Summary of Results

Coincidence	Counts/min 2 way	Counts/min 3 way	Ratio
0,5,(10)	31	4.7	6.60
1,6,(11)	18	4	4.50
2,7,(12)	18	4	4.50
3,8,(13)	14	4.9	2.86
4,9,(14)	10.5	1.8	5.83

Fig.43: Summary of average count rates. Brackets indicate extra scintillator added in 3-way coincidence. The ratio corresponds to 2way:3way.

Table 9 shows that again scintillator (4,9,14) seems to have a much lower count rate than the others, and (1,6,11) and (2,7,12) appear to be consistent with each other. But (0,5,10) and (3,8,13) are not consistent this time. (0,5,10) is again higher than the others but (3,8,13) is much lower than would have been anticipated. This indicates that scintillator 13 must be more sensitive than the others.Using coincidences of (1,6,11) or (2,7,12) the ratio of 2:3 scintillators can be considered as 4.5.

Testing All Individual Scintillators

Results

Scintillator	Number of counts in 2 min	Number of counts per min
0	225554	112777
1	112343	56171.5
2	135800	67900
3	80346	40173
4	79770	39885
5	125905	62952.5
6	66535	33267.5
7	144624	72312
8	92043	46021.5
9	57226	28613
10	644346	322173
11	403005	201502.5
12	319918	159959
13	120460	60230
14	166503	83251.5

Fig.44: Results of single scintillators being tested.

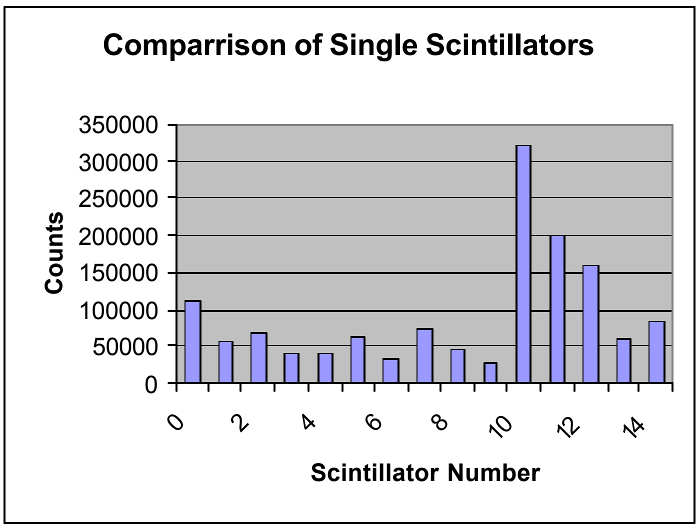


Fig.45: Comparison of all scintillators

Analysis of results

No sensible count rates can be taken from using single scintillators, due the high amount of noise that will be detected. Patterns can be seen in the results. From Appendix V, graphs 1-4, it can be seen that the bottom layer is much more sensitive than the other layers, especially scintillators 10, 11 and 12. This would explain the results : -

Coincidence	Counts/min 2 way	Counts/min 3 way	Ratio
0,5,(10)	31	4.7	6.60
1,6,(11)	18	4	4.50
2,7,(12)	18	4	4.50
3,8,(13)	14	4.9	2.86
4,9,(14)	10.5	1.8	5.83

Fig.46: Comparison of 2 and 3 way coincidences.

This also indicates why in (0,5,10) there is such a high count rate. This may also mean that the count rate that has been calculated for 3 way coincidences may be an overestimate.

The results show no new information, but do confirm previous results

Area Testing

Results

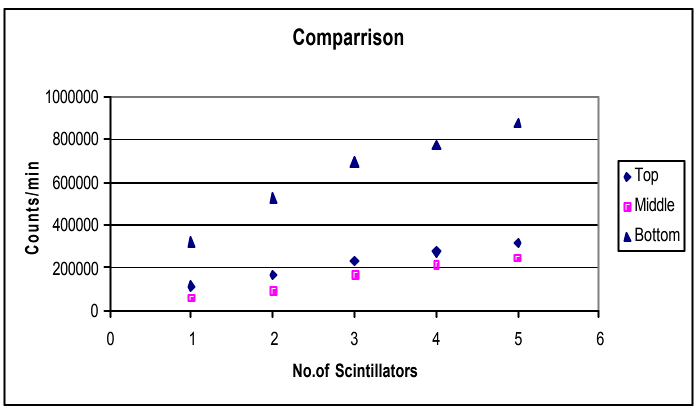


Fig.47: Count rate of various areas of each layer

Analysis of results

The graphs show that the count rate is linearly related to the area. The last point appears to not lay in the trend, but as calculated before, the scintillators (4,9,14) are less sensitive than the rest. The bottom layer again having much greater counts also confirms the previous results for single scintilltor counts.

3.2.3 Addition of the New Scintillator

Caroline Robson

A new scintillating tile was cut from a large sheet of material which would be used in the final detector. The tile had the same surface area as the MINOS scintillators but with a thickness of 5mm instead of 8mm (see fig.28b, p26) Again made of polystyrene but doped to a higher quality with the scintillating chemical, the new material had to be tested to find its efficiency compared with that of the older MINOS scintillators. The scintillator was wrapped in Tyvek, which is a mixture of paper and polythene often used in the building trade as an insulator. As a good reflector it was wrapped loosely over the tile to help reflect any photons which managed to escape the material. The wavelength-shifting fibre from the tile was connected to an optical fibre then into the PMT through the empty channel. As the new scintillator was not glued to the shelves in the test stand like the MINOS scintillators, it could be moved around.

Firstly its single count rate was taken over two minutes to compare with the other scintillators. Initially this gave an extremely noisy rate of 30000/min. It was noticed that the long leads from the patch panel to the amplifier were trailing on the floor,which could have lead to stray currents causing extra counts without the coincidence logic to eliminate this. With the leads lifted off the floor and placed on the bench instead, the count rate was taken three more times and the count rate consistently reduced to approxiately ¼ of its previous value.

The aim of using the new scintillator in coincidence with one of the MINOS ones was to test for proportionality of the count rate and the common surface area (as it could be moved) and to establish its relative efficiency. The new scintillator was placed on top of scintillator number 2 (chosen because its single count rate was closest to the average single count rate of the scintillators on the top later) with no gap in between. It was moved such that the common surface area between the two was varied through 0, ¼, ½, ¾, 1 and the total count rate in two minutes measured three times for each one.

Results

Simon Bevan

New Scintillator on its own	
2 mins	per min
16653	8326.5
16573	8286.5
16462	8231

Fig.48: New scintillator on its own

Scintillator 2 on it's own	
2 mins	per min
14016	7008
11570	5785
12106	6053

Fig.49: Scintillator 2 on its own

Overlap	Result 1	Result 2	Result 3	Average	per min
0	8	2	5	5.00	2.5
0.25	29	28	37	31.33	15.66667
0.5	56	54	51	53.67	26.83333
0.75	82	65	69	72.00	36
1	164	175	181	173.33	86.66667

Fig.50: 2-way coincidence of scintillator 2 and new scintillator

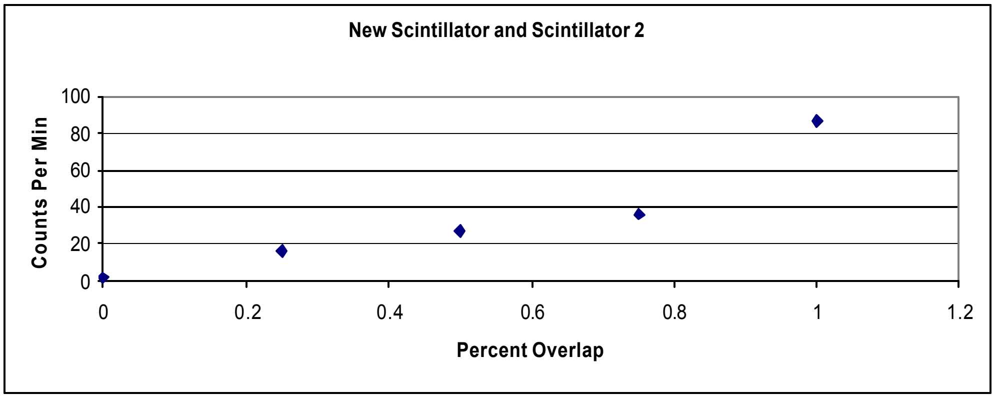


Fig.51: Graph showing the 2-way coincidence results for the new scintillator and scintillator 2

Figs. 48 and 49 show a comparison of the single count rates of the new scintillator and one of the old ones. They appear to be comparable, however the single count rates are determined mainly by noise and so cannot be relied upon to give useful data. Figs. 50 and 51 show that the count rate increases roughly linearly with an increase in common area. This is a promising result as it shows little evidence of noise contamination.

3.3 Summary

Simon Bevan

The initial testing of the apparatus showed that the results were very sensitive to noise. Investigating the noise source further, it was found that the source of noise was from wires interfering with each other. In separating the wires, the noise source was drastically reduced and sensible results could be taken. This was considered in the final design. Although the wires are not as long, they are still likely to suffer from cross talking. Therefore the detector was designed to be able to store the wires in a fashion as to minimize interference.

An important fact discovered was that each scintillator has a different efficiency. Again, this played an important role in the final design, where a redundancy was incorporated to allow for this. This was done in the programming of the FPGA board, where for two and three way coincidences, all possibilities were considered.

One of the main criteria of the testing was to be able to calculate the final dimensions of the detector. The experiments showed that for scintillators of size 168 x 40 x 10 mm, separated by a distance of 33±2mm, the count rate was 3-5 counts per minute for three way coincidence. In testing the new scintillator and comparing it to the scintillators in the test stand an idea of the relative efficiency was obtained, to be used in the calculation of the final geometry.

The ratio of 2:3 scintillators was found to be 4.5. This again was important in the development of the logic as it shows that in having logic that will enable 2, 3, or 4 way will allow an important element of redundancy to the final design.

The final important information that the initial tests showed was that the PMT had to run at 950V for any sensible results but that it does not need time to warm up.