

VESSEL LIGHT COLLECTION STUDIES

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Picture by M. Volpi



THE UNIVERSITY OF
MELBOURNE



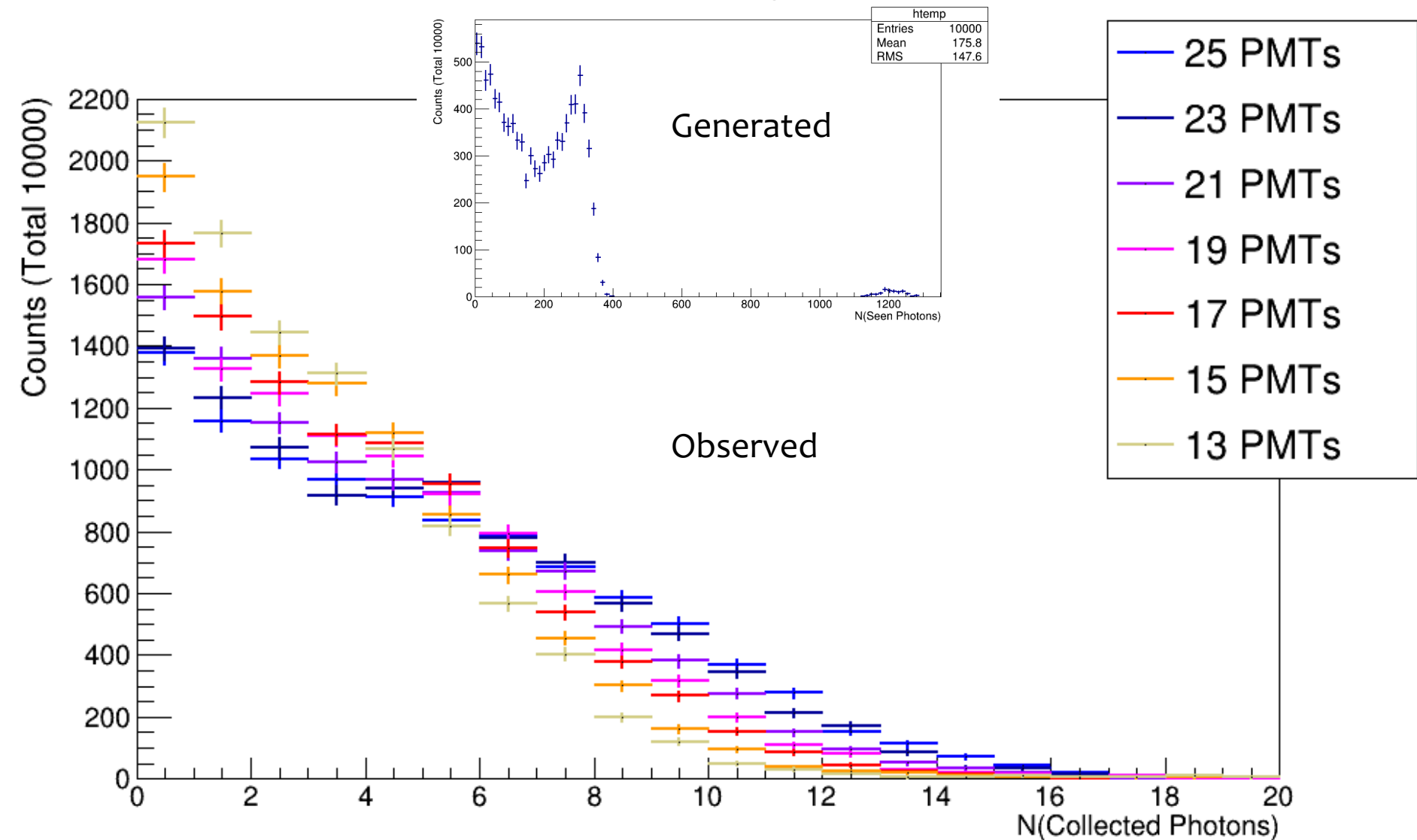
STAWELL
UNDERGROUND
PHYSICS LAB



LIGHT YIELDS PER # PMTs



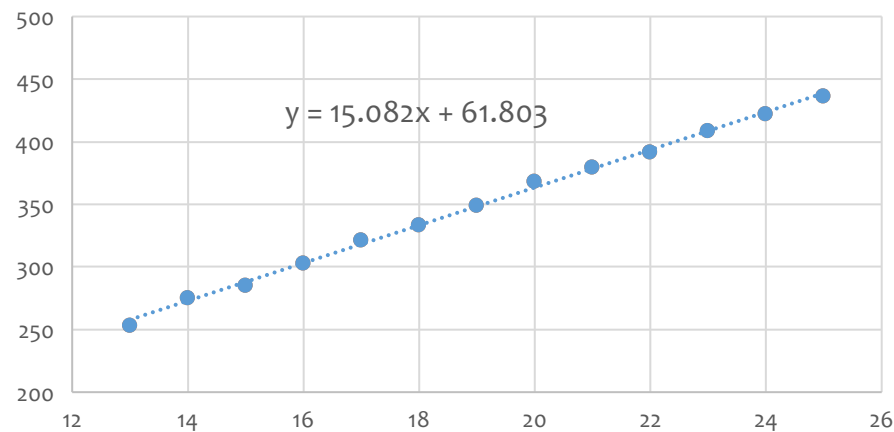
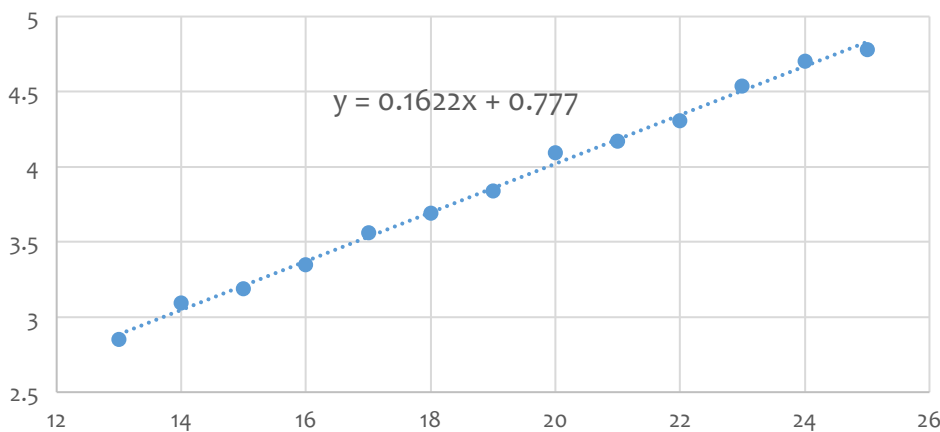
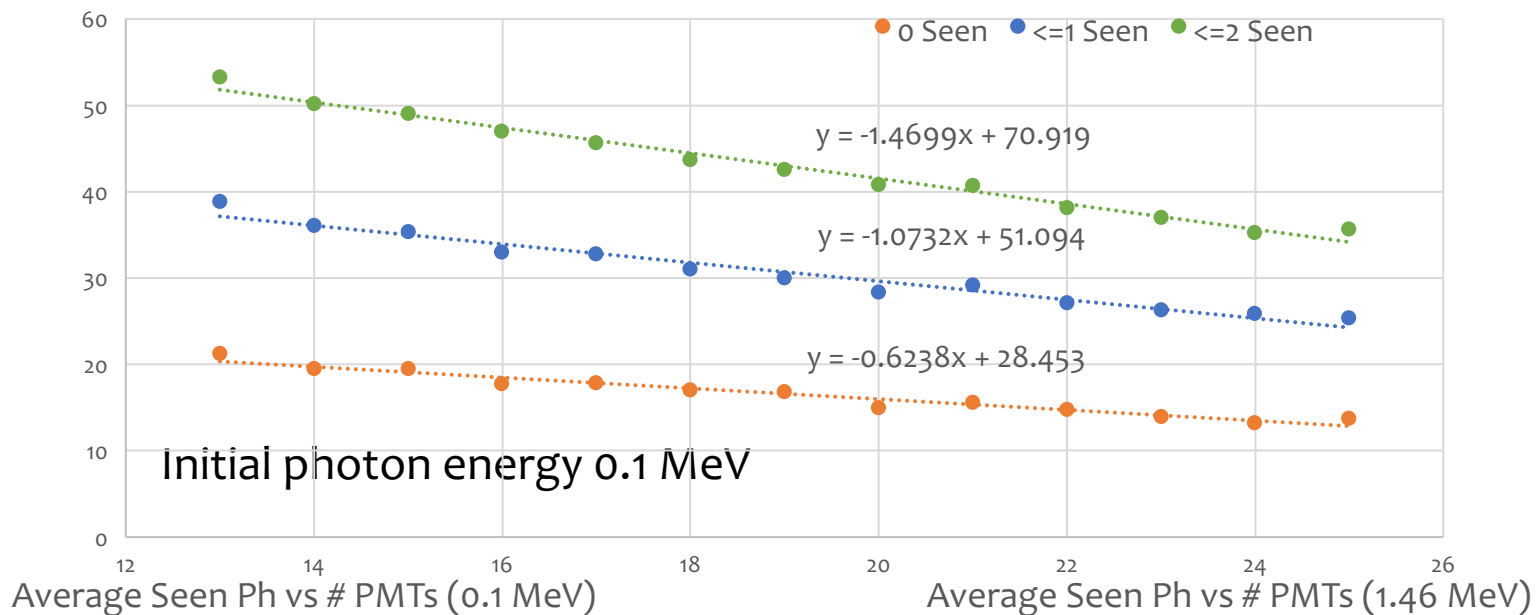
Initial photon energy 0.1 MeV



LIGHT YIELDS PER # PMTs



Percentage of events with $N(\text{Ph}) \leq X$



VETO ENERGY LIMIT



- Low energy measurements are limited by the PMTs dark noise rate
- Need to set threshold on # photon seen so that coincident dark count rate $\ll$ $1/\text{acquisition time}$ (background rate in crystals?)
- Hamamatsu R5912 specs:

		High voltage		
		1500V	1800V	
Dark Count (after dark condition for 15 hours) ¹⁾		—	4	8
Time Response ¹⁾	Anode Pulse Rise Time	—	3.8	—
	Electron Transit Time	—	55	—
	Transit Time Spread (FWHM) ³⁾	—	2.4	—
				kcps
				ns
				ns
				ns

COINCIDENCE RATES



$N = \# \text{PMTs}$, rate of dark counts $r = 4 \text{ kHz}$,
acquisition window $\tau = 1 \mu\text{s}$

RATE OF DARK
COUNTS $R_1 = N \cdot r$

RATE OF
2 COINCIDENT
DARK COUNTS $R_2 = N \cdot r \cdot (N-1) r \cdot \cancel{\tau} = \cancel{2} N(N-1) r^2 \tau$

RATE OF
3 COINCIDENT
DARK COUNTS $R_3 = N \cdot r \cdot (N-1) r \cdot (N-2) r \cdot \cancel{\tau^2} = \cancel{6} N(N-1)(N-2) r^3 \tau^2$

COINCIDENCE RATES



N pmts	Dark rate (Hz)	2 coincidences (Hz)	3 coincidences (Hz)
13	5.2E+04	2.5E+03	1.1E+02
14	5.6E+04	2.9E+03	1.4E+02
15	6.0E+04	3.4E+03	1.7E+02
16	6.4E+04	3.8E+03	2.2E+02
17	6.8E+04	4.4E+03	2.6E+02
18	7.2E+04	4.9E+03	3.1E+02
19	7.6E+04	5.5E+03	3.7E+02
20	8.0E+04	6.1E+03	4.4E+02
21	8.4E+04	6.7E+03	5.1E+02
22	8.8E+04	7.4E+03	5.9E+02
23	9.2E+04	8.1E+03	6.8E+02
24	9.6E+04	8.8E+03	7.8E+02
25	1.0E+05	9.6E+03	8.8E+02
26	1.0E+05	1.0E+04	1.0E+03
27	1.1E+05	1.1E+04	1.1E+03
28	1.1E+05	1.2E+04	1.3E+03
29	1.2E+05	1.3E+04	1.4E+03
30	1.2E+05	1.4E+04	1.6E+03
31	1.2E+05	1.5E+04	1.7E+03
32	1.3E+05	1.6E+04	1.9E+03

EVENTS LOST



- If dark counts are coincident with a signal in the crystal, the event may be rejected cause above threshold
- The fraction of event rejected is calculated

RATE OF COUNTS FOR NOISE IN THE PNTS WITH A COINCIDENT SIGNAL
IN THE CRYSTAL

$$R_{ci} = 2\tau K \cdot R_i$$

FRACTION OF CRYSTAL COUNTS WITH
A DARK COINCIDENCES

$$f_i = \frac{R_{ci}}{K} = 2\tau R_i$$

WITH $K = \text{PMT DARK INCRYSIAL}$
WITH NO SIGNAL
IN NOISE
($E < 100 \text{ keV}$)

$i = 1, 2, 3$

EVENTS LOST



$$\tau = 1\mu\text{s}$$

N pmts	1 dark count	2 dark coincidences	3 dark coincidences
13	1.0E-01	5.0E-03	2.2E-04
14	1.1E-01	5.8E-03	2.8E-04
15	1.2E-01	6.7E-03	3.5E-04
16	1.3E-01	7.7E-03	4.3E-04
17	1.4E-01	8.7E-03	5.2E-04
18	1.4E-01	9.8E-03	6.3E-04
19	1.5E-01	1.1E-02	7.4E-04
20	1.6E-01	1.2E-02	8.8E-04
21	1.7E-01	1.3E-02	1.0E-03
22	1.8E-01	1.5E-02	1.2E-03
23	1.8E-01	1.6E-02	1.4E-03
24	1.9E-01	1.8E-02	1.6E-03
25	2.0E-01	1.9E-02	1.8E-03
26	2.1E-01	2.1E-02	2.0E-03
27	2.2E-01	2.2E-02	2.2E-03
28	2.2E-01	2.4E-02	2.5E-03
29	2.3E-01	2.6E-02	2.8E-03
30	2.4E-01	2.8E-02	3.1E-03
31	2.5E-01	3.0E-02	3.5E-03
32	2.6E-01	3.2E-02	3.8E-03

CONCLUSION



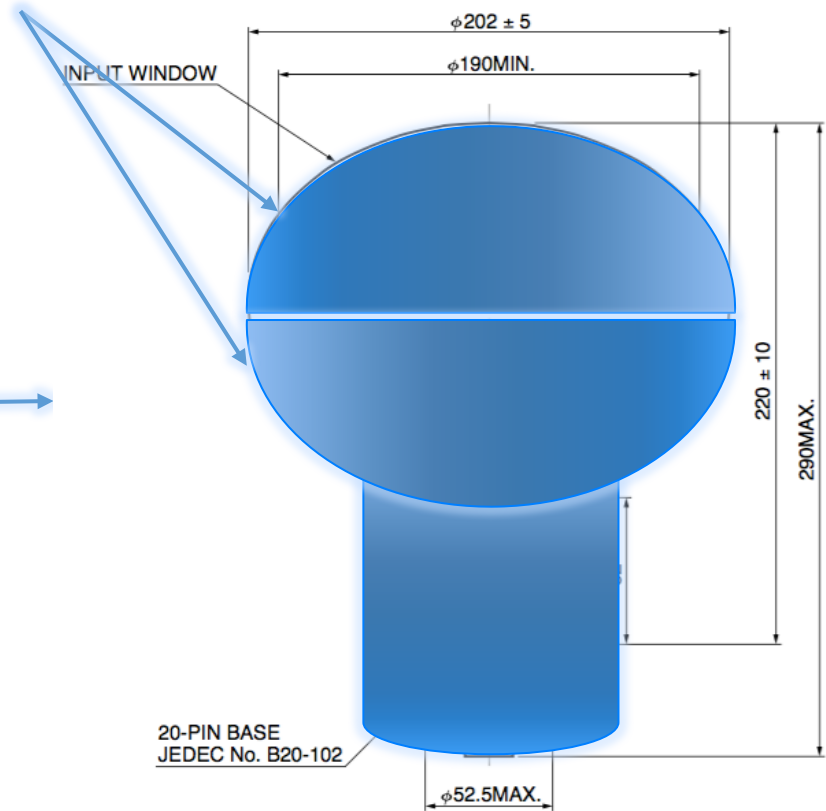
- 1.5%, 1.1%, 0.6% low energy events (0.1 MeV) are lost when a PMT dies and requiring $N(\text{Ph}) > 2$, $N(\text{Ph}) > 1$, $N(\text{Ph}) > 0$ respectively
- Average number of photon seen varies of 0.16 per PMT for low energy events (about 4% for 18 PMTs)
- Rate of event lost due to dark count estimated. Need to know acquisition time more precisely

Backup

PMT MODELING



Two paraboloids
(No ellipsoid classin TGeo)



Sensitive area has 95mm radius

LIGHT YIELDS PER # PMTs



Initial photon energy 0.1 MeV

N(PMTs)	Average	0 Seen	<=1 Seen	<=2 Seen
13	2.9	21.2	38.8	53.3
14	3.1	19.5	36.1	50.2
15	3.2	19.5	35.3	49.0
16	3.4	17.7	33.0	47.0
17	3.6	17.8	32.8	45.6
18	3.7	17.1	31.0	43.7
19	3.8	16.8	30.0	42.5
20	4.1	14.9	28.4	40.8
21	4.2	15.6	29.2	40.7
22	4.3	14.8	27.1	38.1
23	4.5	13.9	26.3	37.0
24	4.7	13.3	25.9	35.3
25	4.8	13.8	25.3	35.7

Initial photon energy 1.46 MeV

N(PMTs)	Average
13	253.6
14	275.2
15*	285.2
16*	302.9
17	321.7
18	333.8
19*	348.9
20*	368.4
21*	379.6
22*	391.5
23*	409.2
24*	422.4
25*	436.4

*files were incomplete.
About 80% of statistics was
available

EVENTS LOST



$$\tau = 0.1 \mu\text{s}$$

N pmts	1 dark count	2 dark coincidences	3 dark coincidences
13	1.0E-02	5.0E-05	2.2E-07
14	1.1E-02	5.8E-05	2.8E-07
15	1.2E-02	6.7E-05	3.5E-07
16	1.3E-02	7.7E-05	4.3E-07
17	1.4E-02	8.7E-05	5.2E-07
18	1.4E-02	9.8E-05	6.3E-07
19	1.5E-02	1.1E-04	7.4E-07
20	1.6E-02	1.2E-04	8.8E-07
21	1.7E-02	1.3E-04	1.0E-06
22	1.8E-02	1.5E-04	1.2E-06
23	1.8E-02	1.6E-04	1.4E-06
24	1.9E-02	1.8E-04	1.6E-06
25	2.0E-02	1.9E-04	1.8E-06
26	2.1E-02	2.1E-04	2.0E-06
27	2.2E-02	2.2E-04	2.2E-06
28	2.2E-02	2.4E-04	2.5E-06
29	2.3E-02	2.6E-04	2.8E-06
30	2.4E-02	2.8E-04	3.1E-06
31	2.5E-02	3.0E-04	3.5E-06
32	2.6E-02	3.2E-04	3.8E-06