

Analysis Note 2: Cosmic Muons

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Thresholds Tables

PMT	Threshold Voltage (mV)	Counts	Count Rate (counts/sec)
Bar 1 Left	97.5	30433 ± 174	1014 ± 5.8
Bar 1 Right	85.8	15347 ± 124	512 ± 4.1
Bar 2 Right	76.8	17362 ± 132	578 ± 4.4
Bar 2 Left	120.5	17776 ± 133	592 ± 4.4

Table 1: Threshold voltages and count rates for PMT detectors left and right sides.

2-Fold Count Rates

PMT	Bar 1	Bar 2
	Trial 1	Trial 2
Coincidence 1 (counts/sec)	93.5 ± 1.8	97.5 ± 1.8
Coincidence 2 (counts/sec)	107.7 ± 1.9	106.9 ± 1.9

Table 2: 2-fold coincidence rates for the top and bottom PMT tubes.

4-Fold Count Rates

All PMT's Sides	Trial 1	Trial 2	Trial 3	Trial 4
Count Rates (counts/sec)	5.333 ± 0.422	5.30 ± 0.42	4.733 ± 0.397	5.10 ± 0.41

Table 3: 4-fold coincidence rates for both PMT's including the sides.

Count Rate vs. Angular Distribution of θ and $\cos^2(\theta)$

θ (deg)	θ (rad)	Counts	Count Rate (counts/sec)
90	1.5708	106 ± 10	3.533 ± 0.343
80	1.3963	135 ± 12	4.5 ± 0.4
70	1.2217	115 ± 11	3.833 ± 0.357
60	1.0472	87 ± 9	2.9 ± 0.3
50	0.8727	59 ± 8	1.966 ± 0.256
40	0.6981	53 ± 7	1.766 ± 0.242
30	0.5235	33 ± 6	1.1 ± 0.2
20	0.3491	17 ± 4	0.566 ± 0.137
10	0.1745	12 ± 3	0.4 ± 0.1
0	0.0000	11 ± 3	0.366 ± 0.110

Table 4: Angular distribution parameters that demonstrate muon zenith angular dependence.

Time Delay Table

Peak	Total Count	Time Delay (μ s)	Mean Bin	RMS
1	235 ± 15	1.46	1480 ± 0.041	0.617 ± 0.032
2	295 ± 17	2.60	2647.55 ± 0.14	2.221 ± 0.126
3	266 ± 16	3.82	3810.930 ± 0.598	6.217 ± 0.502
4	255 ± 16	5.02	4967.68 ± 1.16	9.310 ± 0.913
5	202 ± 14	6.16	6063.310 ± 0.786	9.225 ± 0.670
6	124 ± 11	7.32	6238.06 ± 1.45	10.370 ± 1.519
7	257 ± 16	8.00	6776.16 ± 0.82	9.850 ± 0.840

Table 5: This is the raw data for time delay calibration. Each peak is gaussian and follows multiple minute trials. Information here is what eventually leads to muon half-life predictions

Time Calibration Parameters

$$t_{delay} = a \cdot x + b \quad (1)$$

- $a = 0.001202 \pm 0.000086$
- $b = -0.58 \pm 0.43$

Figure 1: The function is a linear fit with slope and intercept parameters.

Count Rate vs. Zenith Fit Parameters

$$f(x) = A \cos^2(\omega x + \phi) + B \quad (2)$$

- $A = 3.60 \pm 0.28$
- $B = 0.341 \pm 0.072$
- $\omega = -1.10 \pm 0.12$
- $\phi = 1.692 \pm 0.076$

Figure 2: This is the angular dependence θ fit parameters.

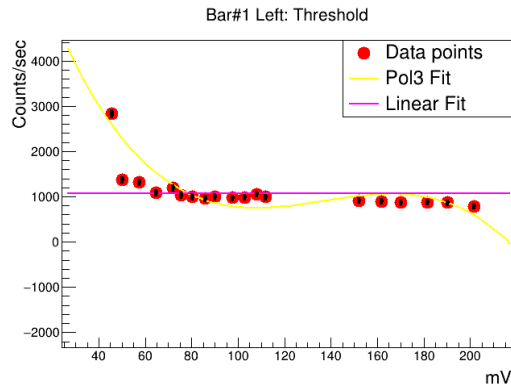
Count Rate vs. $\cos^2(\theta)$ Fit Parameters

$$f(x) = mx + b \quad (3)$$

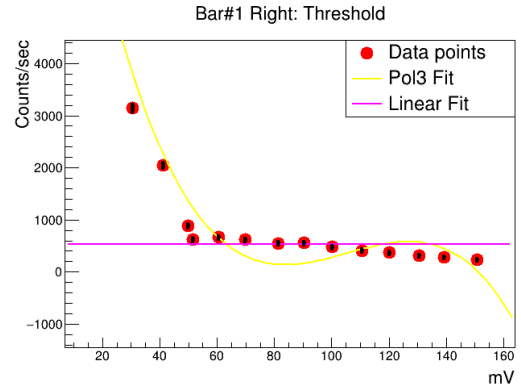
- $m = -3.57 \pm 0.20$
- $b = 3.85 \pm 0.17$

Figure 3: This is the angular dependence $\cos^2(\theta)$ fit parameters that linearizes the data.

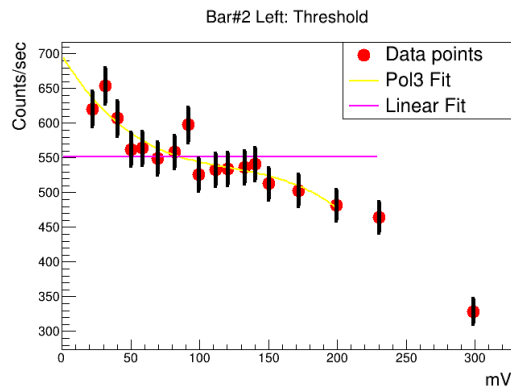
Threshold Plots



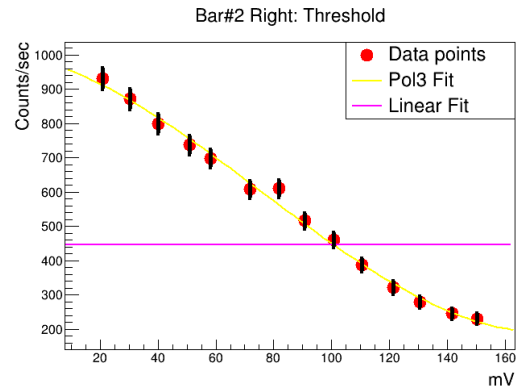
(a) PMT top Left sided plot.



(b) PMT top Right sided plot.



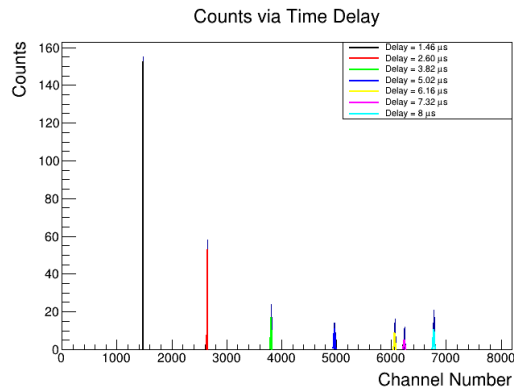
(c) PMT bottom left sided plot.



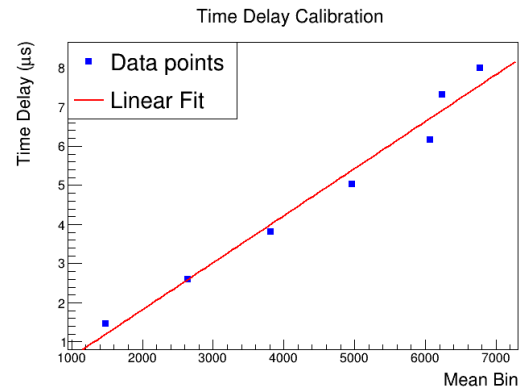
(d) PMT bottom Right sided plot.

Figure 4: Plots that are Representative of count rate and thresholds to get a threshold voltage for each sided PMT.

Delay Histogram and Calibration Plot



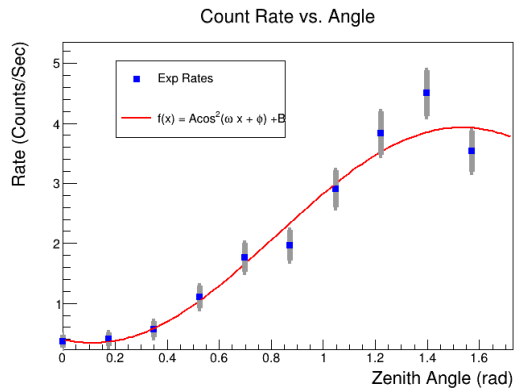
(a) The delay histogram generated by taking voltage pulses from oscilloscope to DAQ to then generate spectrum.



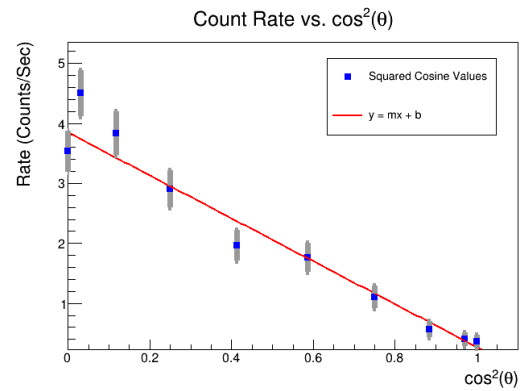
(b) Perform calibration on each delay peak defining linear relationship to be able to convert bin to delay time.

Figure 5: This step in the lab is where you take voltage pulses to generate spectrum, then analyze them to perform calibration then see if system is counting muon properly and to obtain half-life.

Angular dependence plots of Muons



(a) Muon count rate vs θ (rad) plot.



(b) Muon count rate vs $\cos^2(\theta)$ plot.

Figure 6: Both plots are representative that muon count rate can be modeled by angular fitting. For the cosine squared it makes since for muon rate to decrease.