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Physics 20CL

After Lab Note: Radiation Absorption

Time: 7:30 pm to 11:50 pm, Apr. 13

See appendix for figures

Code: `https://github.com/YizhiJiao/Public`

This experiment was intended to measure the mass absorption wavelength of gamma ray (λ) from a Co-60 source by finding the relationship between the counts of Geiger counter (N) and density thicknesses of the materials (z). Equation (9) in the lab guide shows the relationship between the counts and the density thicknesses.

$$N = N_0 e^{-z/\lambda} \tag{1}$$

Since the equation is nonlinear, linear regression cannot be performed unless the data is transformed into $y = a * x + b$. The data is transformed by take logarithm of both sides of the equation:

$$\ln N = -\frac{z}{\lambda} + \ln N_0 \tag{2}$$

In this case, the slope is $-\frac{1}{\lambda}$, and the intercept is $\ln N_0$. Instead of using the original counts (N_{raw}), the counts per minute substrated by the background counts ($N - B$) was used as the N above . The data is shown in Figure 1. Run #1 is the background counts, Uncertainties are calculated in these ways.

$$\delta N_{raw} = \sqrt{N_{raw}} \tag{3}$$

$$\delta N = \frac{\sqrt{N_{raw}}}{\Delta t} \tag{4}$$

$$\delta(N - B) = \sqrt{\delta N^2 + \delta B^2} \tag{5}$$

Thus,

$$\begin{aligned}\delta(\ln(N - B)) &= \sqrt{\left(\frac{\partial \ln(N - B)}{\partial(N - B)}\delta_{N-B}\right)^2} \\ &= \sqrt{\left(\frac{1}{N - B}\delta_{N-B}\right)^2} \\ &= \frac{\delta_{N-B}}{N - B} \end{aligned} \tag{6}$$

Starting from Run #8, the data was collected with different absorbers. Three sets of data are plotted: all data with absorbers, data with absorbers of $z > 200$ mg/cm^2, and data with absorbers of $z > 400$ mg/cm^2. In Figure 2, the best-fit line does not pass all error bars, especially the error bars of the data of small z. The χ^2/df is about 2, which is close to 1, indicating the model fits the data with underestimated uncertainty. In Figure 3, although the best-fit line does not pass one data point's error bar, the χ^2/df is about 0.5, which is close to 1, indicating the model fits the data with overestimated uncertainty. In Figure 4, the best-fit line passes all error bars, and the χ^2/df is about 0.3, which is also close to 1, indicating the model fits the data with overestimated uncertainty. I choose the slope of the best-fit line in Figure 4 as the value of $-\frac{1}{\lambda}$ because the this model is within the 68% uncertainty region of all data points. Therefore, the mass absorption wavelength is 21.03934 ± 0.00011 g/cm^2. The uncertainty of the mass absorption wavelength is calculated by the following equation:

$$
\begin{aligned}
\delta_{\frac{1}{\lambda}} &= \sqrt{\left(\frac{\partial(\frac{1}{\lambda})}{\partial\lambda}\delta_\lambda\right)^2} \\
&= \sqrt{\left(\frac{-\lambda}{\lambda^2}\delta_\lambda\right)^2} \\
&= \frac{\delta_\lambda}{\lambda} \\
\delta_\lambda &= \delta_{\frac{1}{\lambda}} \cdot \lambda
\end{aligned}
\tag{7}
$$

In conclusion, the mass absorption wavelength was calculated successfully from measured data, and the uncertainty is relatively small. However, due to my lack of background knowledge, I am not sure if the result is correct and unable to further relate the mass absorption wavelength with the activity of the Co-60 source, etc. Even though the data does not show significant problem, there is an possible error that I put the absorbers facing down the slots. The absorbers has thickness, so the distance between the absorber and the source is not constant. This may cause an error in the data.

Appendix:

Run #	Time h:mm (pm)	Source Position	Absorber List	z [mg/cm^2]	Δt [s]	N_raw [cts]	δN_raw [cts]	N [cts/min]	δN [cts/min]	N-B [cts/min]	δ(N-B) [cts/min]	ln(N-B) [cts/min]	δ(ln(N-B)) [cts/min]
1	01:33	No Source	None	0	300	127	11.27	25.40	2.25	0.00	7.13		
2	01:46	Co-60, 6	None	0	60	177	13.30	177.00	13.30	151.60	14.23	5.02	0.09
3	01:48	Co-60, 5	None	0	60	209	14.46	209.00	14.46	183.60	15.31	5.21	0.08
4	01:49	Co-60, 4	None	0	60	306	17.49	306.00	17.49	280.60	18.20	5.64	0.06
5	01:51	Co-60, 3	None	0	60	408	20.20	408.00	20.20	382.60	20.82	5.95	0.05
6	01:52	Co-60, 2	None	0	60	833	28.86	833.00	28.86	807.60	29.30	6.69	0.04
7	01:53	Co-60, 1	None	0	60	1630	40.37	1630.00	40.37	1604.60	40.69	7.38	0.03
8	02:00	Co-60, 4	1, down	9.6	60	287	16.94	287.00	16.94	261.60	17.67	5.57	0.07
9	02:02	Co-60, 4	2, down	19.2	60	285	16.88	285.00	16.88	259.60	17.62	5.56	0.07
10	02:04	Co-60, 4	3, down	59.1	60	283	16.82	283.00	16.82	257.60	17.56	5.55	0.07
11	02:05	Co-60, 4	4, down	102	60	277	16.64	277.00	16.64	251.60	17.39	5.53	0.07
12	02:06	Co-60, 4	5, down	170	60	236	15.36	236.00	15.36	210.60	16.17	5.35	0.08
13	02:08	Co-60, 4	6, down	328	60	203	14.25	203.00	14.25	177.60	15.11	5.18	0.09
14	02:09	Co-60, 4	7, down	645	60	232	15.23	232.00	15.23	206.60	16.04	5.33	0.08
15	02:10	Co-60, 4	8, down	1120	60	219	14.80	219.00	14.80	193.60	15.63	5.27	0.08
16	02:12	Co-60, 4	9,down	2066	60	225	15.00	225.00	15.00	199.60	15.82	5.30	0.08
17	02:14	Co-60, 4	10, down	3448	60	198	14.07	198.00	14.07	172.60	14.95	5.15	0.09
18	02:15	Co-60, 4	11, down	7367	60	187	13.67	187.00	13.67	161.60	14.57	5.09	0.09
19	02:25	Co-60, 4	1, down	9.6	200	1012	31.81	303.60	9.54	278.20	18.14	5.63	0.07
20	02:30	Co-60, 4	2, down	19.2	200	976	31.24	292.80	9.37	267.40	17.84	5.59	0.07
21	02:34	Co-60, 4	3, down	59.1	200	871	29.51	261.30	8.85	235.90	16.93	5.46	0.07
22	02:41	Co-60, 4	4, down	102	200	827	28.76	248.10	8.63	222.70	16.54	5.41	0.07
23	02:45	Co-60, 4	5, down	170	200	795	28.20	238.50	8.46	213.10	16.24	5.36	0.08
24	02:49	Co-60, 4	6, down	328	200	780	27.93	234.00	8.38	208.60	16.11	5.34	0.08
25	02:52	Co-60, 4	7, down	645	200	731	27.04	219.30	8.11	193.90	15.64	5.27	0.08
26	02:57	Co-60, 4	8, down	1120	200	772	27.78	231.60	8.34	206.20	16.03	5.33	0.08
27	03:01	Co-60, 4	9,down	2066	200	731	27.04	219.30	8.11	193.90	15.64	5.27	0.08
28	03:06	Co-60, 4	8, down	1120	300	1113	33.36	222.60	6.67	197.20	15.75	5.28	0.08
29	03:11	Co-60, 4	9,down	2066	300	1093	33.06	218.60	6.61	193.20	15.62	5.26	0.08
30	03:16	Co-60, 4	10, down	3448	300	960	30.98	192.00	6.20	166.60	14.74	5.12	0.09
31	03:24	Co-60, 4	11, down	7367	300	815	28.55	163.00	5.71	137.60	13.73	4.92	0.10
32	03:30	Co-60, 4	11, down	7367	500	1434	37.87	172.08	4.54	146.68	14.05	4.99	0.10

Figure 1: Data table of the experiment, uncertainties included.

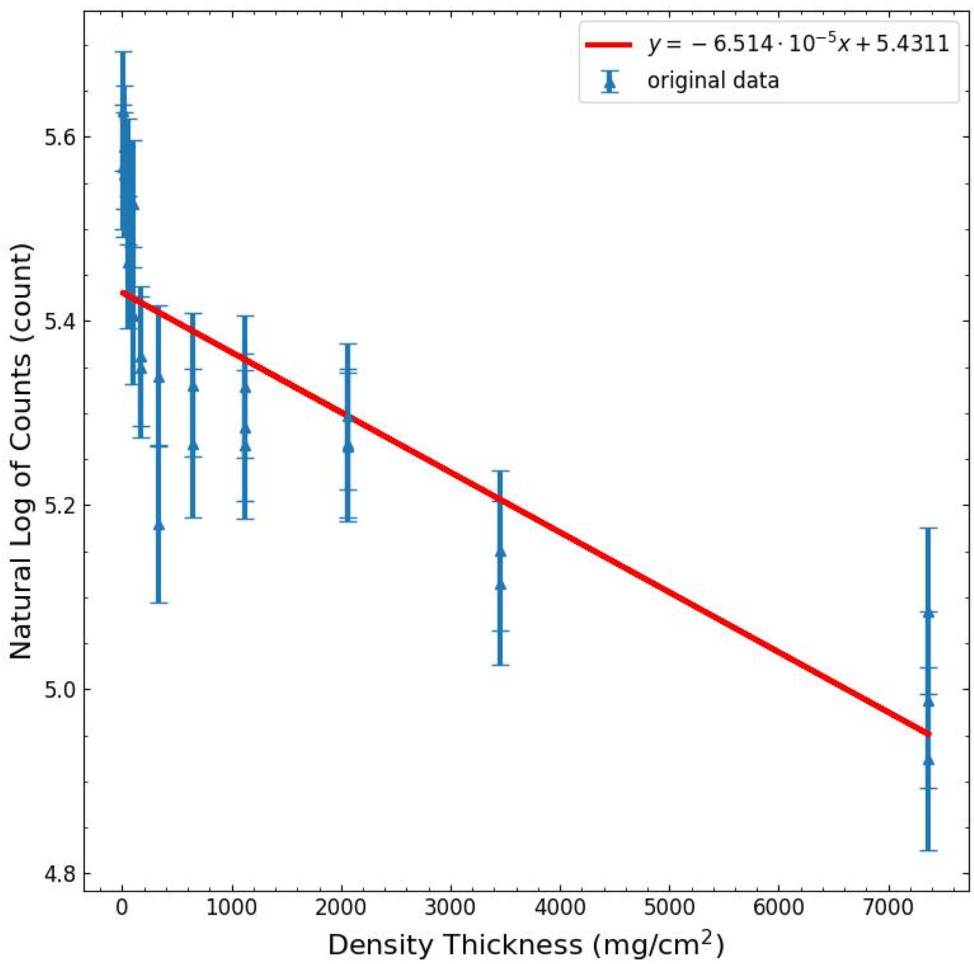

Figure 2: All data with a absorber. The best-fit line does not pass all error bars. $\chi^2/df \approx 2$. standard deviation of slope: $9.1 \cdot 10^{-6}$.

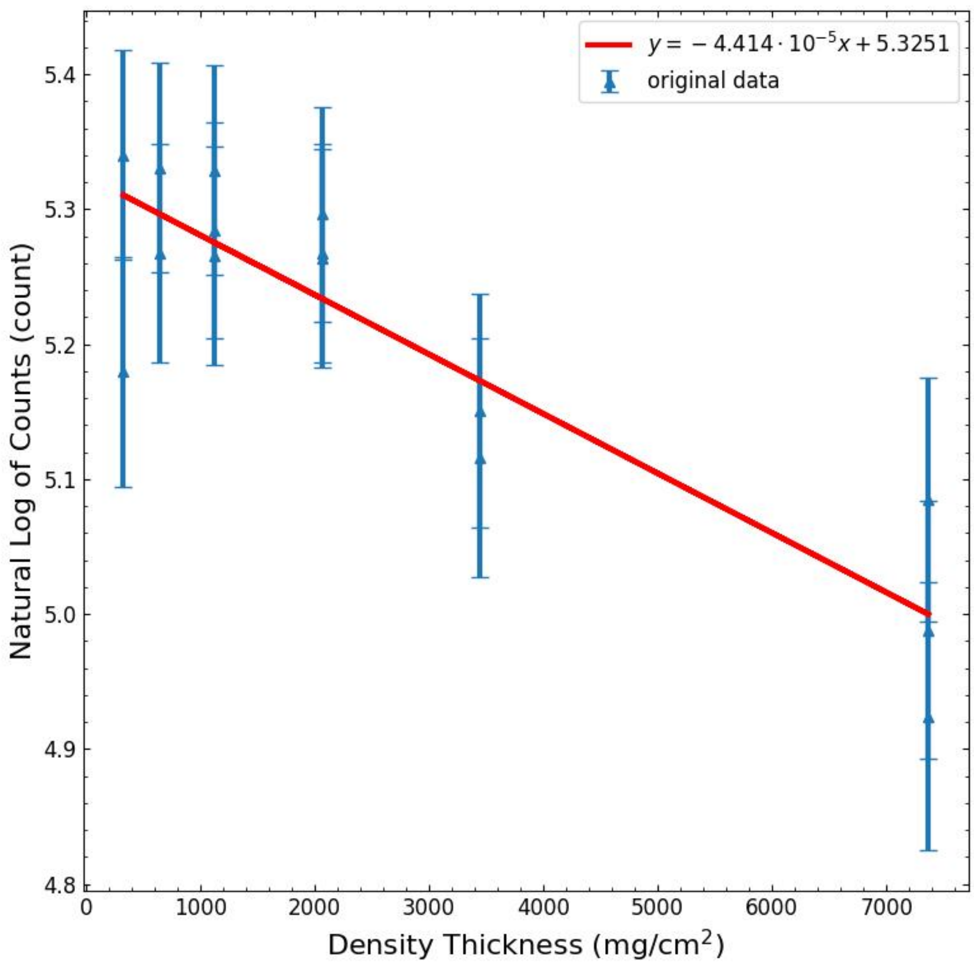

Figure 3: Only absorbers $z > 200$ mg/cm^2. The best-fit line does not pass all error bars. $\chi^2/df \approx 0.5$. standard deviation of slope: $6.1 \cdot 10^{-6}$.

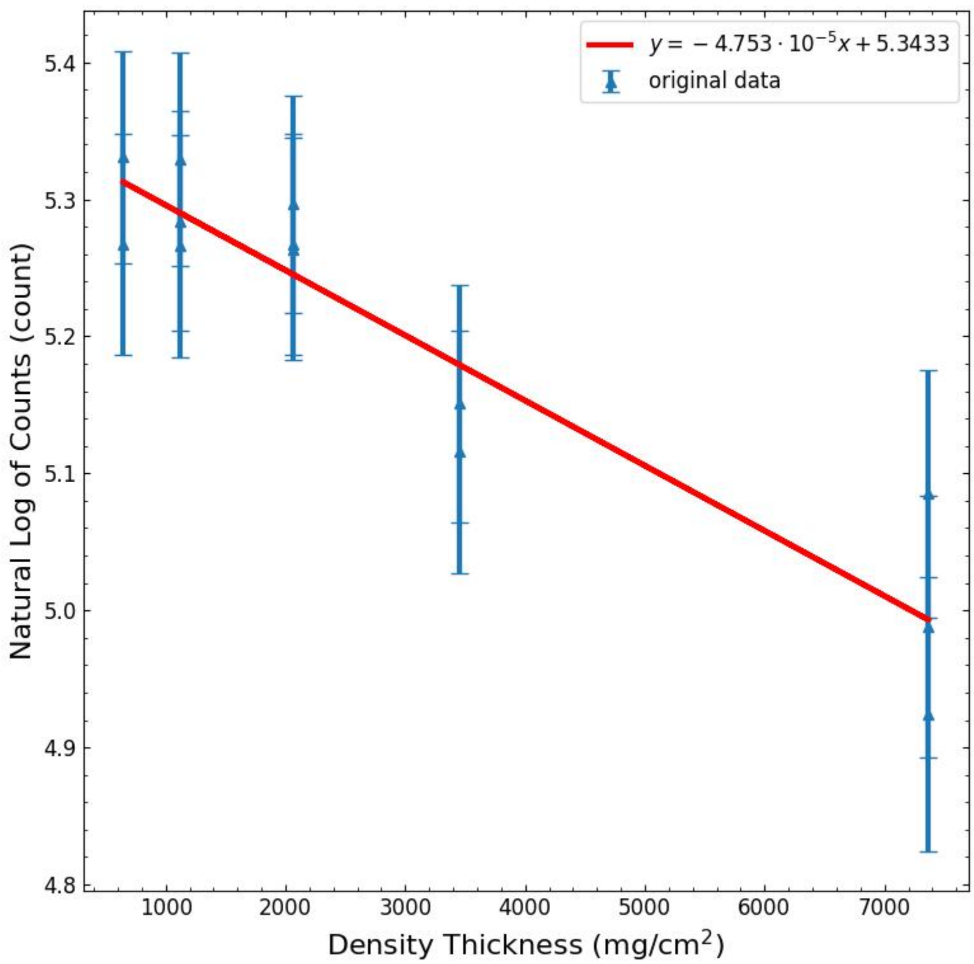

Figure 4: Only absorbers $z > 400$ mg/cm^2. The best-fit line passes all error bars. $\chi^2/df \approx 0.3$. standard deviation of slope: $5.38 \cdot 10^{-6}$.