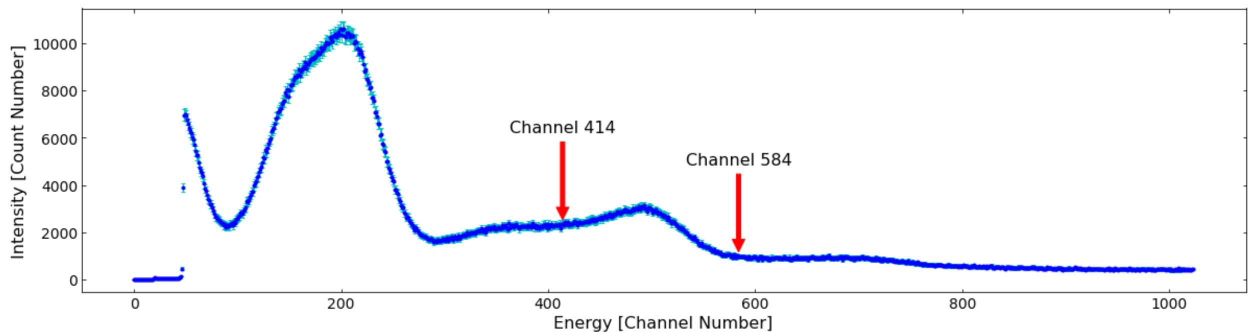
PHYS 128 AL
Lab 1 Mossbauer Effect
MW session
Student: Aether ZHOU
Group member: William HAN, Lucas WATKINS

Table of content

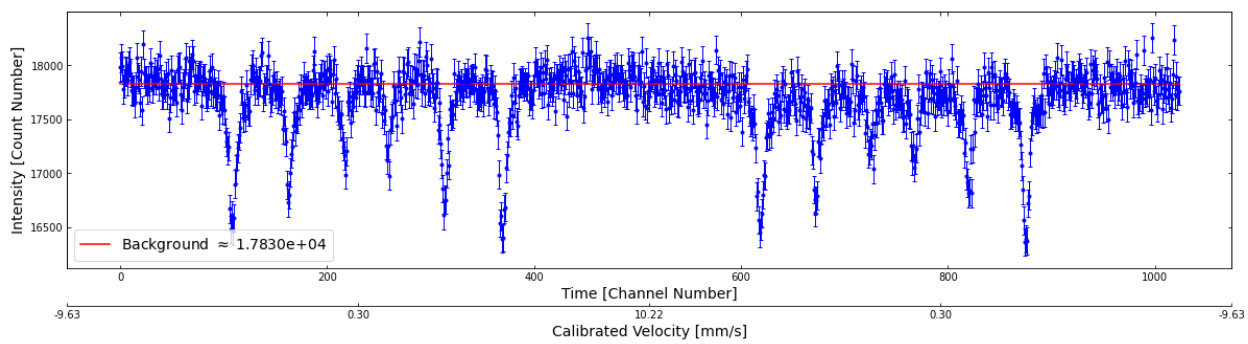
==================================

Row Data	2
Analysis questions	3
Exercise	6
Error analysis	8
Daily log	10
Conclusions	13

Row data:
Background spectrum, we start from this to identify regions of interest, and then block other channels to reduce noise of Mossbauer data.



Absorption spectrum of Fe-57, each peak corresponds to a transition of energy level.



Analysis questions (1,2,3 and 5)

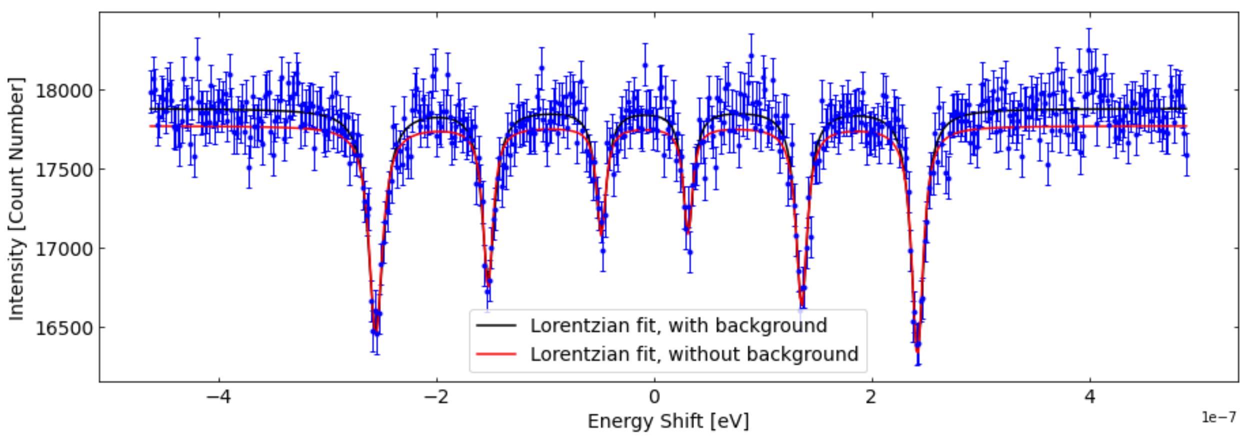
1. Magnetic moment given by https://www-nds.iaea.org/nuclearmoments/

mu_{1/2} = 0.0964 * mu_N
mu_{3/2} = 0.-0.1553 * mu_N
mu_N = -3.152451 * 10^(-12) [eV/G]

Mean [eV]	Half-Width/2 (uncertainty) [eV]	Magnetic Field [Gauss]
-2.39701e-07	1.05602e-08	302091
-1.35757e-07	9.7546e-09	290644
-3.2994e-08	8.44929e-09	234492
4.60977e-08	9.83128e-09	327621
1.49256e-07	9.33953e-09	319546
2.53488e-07	1.04869e-08	319467

The averaged magnetic field is measured to be 2.9897 * 10^5 G with uncertainty about 10%.
(3 * 10^5)/(4 * 10^4)

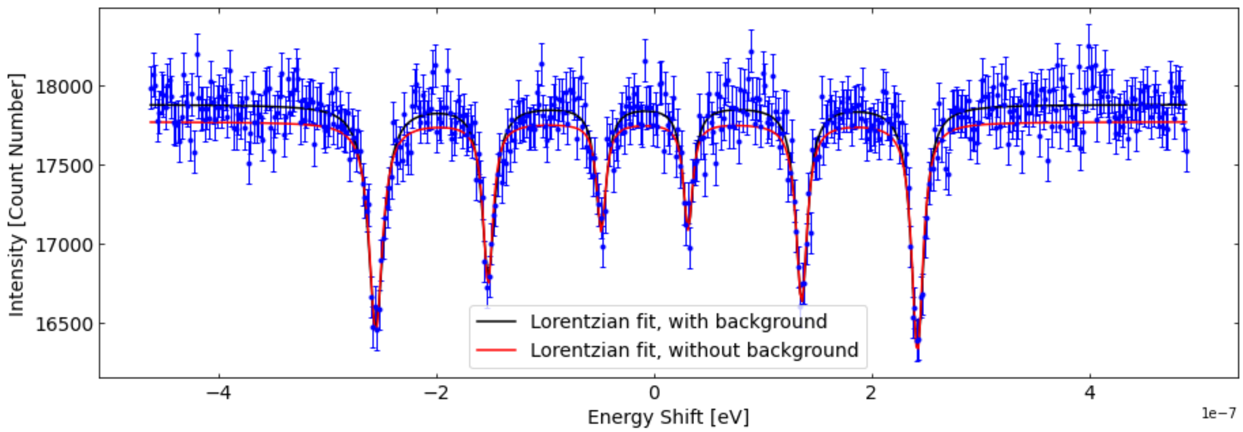
2. Gaussian fit



Mean [eV]	Standard Deviation [eV]	Amplitude[Counts]
-2.5546e-07	7.25672e-09	-2.14659e-05
-1.52159e-07	5.70546e-09	-1.25392e-05
-4.88677e-08	4.91007e-09	-7.21061e-06
3.12669e-08	4.30211e-09	-6.65309e-06
1.35871e-07	6.06749e-09	-1.52095e-05
2.42227e-07	6.08498e-09	-2.02773e-05

Standard deviation is similar in both with and without background fitting. Though not obvious from the plot, sigma with no background is smaller than the one with background. Error is larger for peaks with smaller amplitude, which is reasonable, since low peaks are harder to distinguish from the background noise.

3. Lorentzian fit



We propagate the linewidth for absorption peaks to get the true error for the magnetic field.

5.

Each channel represents a certain range of wavelengths of EM waves. Around wavelengths that can excite a transition, the gamma ray is absorbed by the target so the detector won't "see" that range of EM waves. Hence, the channels where the data points start declining corresponds to the required energy for transition to happen.

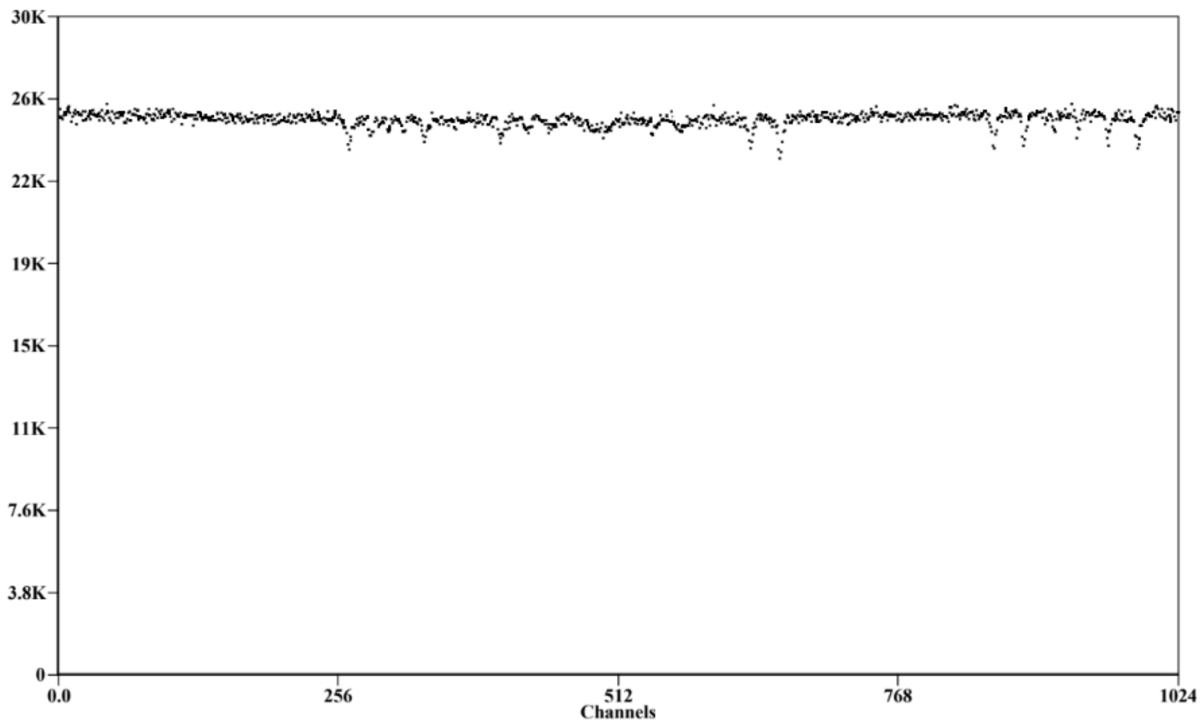
By setting the window on the PHA, we can block a certain range of spectrum that we are not interested in, and hence reduce the background noise.

During Mossbauer mode, one single count indicates the EM waves that get into the detector within a window of 200 micro sec exceeds some threshold value. And within an operational cycle (about 200 milli sec), each count (200 micro sec window) is registered to a distinct channel, so all 1024 channels will be "scanned" during a "pass."

As the radioactive source is driven back and forced, the doppler effect will create a continuous spectrum. Since motion of the source is time related, while channels measure time, they can also be calibrated into velocities that characterize the motion of the source, and can then be converted into energy or wavelength of gamma rays.

According to the manual, the CAD moves at -9.59 mm/s at start of each sweep, which is registered as channel 0, and reaches the positive maximum speed of 10.22 mm/s at middle of the pass (channel 500). And then decelerate to -9.59 mm/s again and reach the end of the channel (a single pass). So, as we double the window of each channel to 400 micro sec, the information density is increased, and the CAD is expected to complete the double cycle during a single operational cycle.

We expect to see four sets of symmetrical absorption peaks evenly spaced, but the actual data seems weird.



exercise

128 AL   Jan. 18   W   1:00 PM

Mossbauer

Exercises

1a $\Delta t \sim \tau \sim 0.1\ \mu s$ $\hbar \leq \Delta E_0 \Delta t \simeq \Gamma \tau$ $E = \hbar\omega$

$\Delta E_0 \sim \Gamma \geq \frac{\hbar}{\tau}$ $\Gamma \simeq 6.582 \times 10^{-9}$ eV $=$

$\tau \searrow \ \Gamma \nearrow$ $\hbar \simeq 6.582 \times 10^{-22}$ MeV s

1b Fe^{57} $m = 57u$ $R = \frac{(14.4\ keV)^2}{2(57)(931.494\ MeV/c^2)(c^2)} = 0.0019527$ eV

$\frac{R}{E_0} \simeq 1.356 \times 10^{-7}$

- Conservation of momentum
- Velocity of nucleus $\ll c$ non-relativistic

1c $\Gamma \sim 10^{-8}eV < 10^{7}eV \sim$ hyperfine

$R \sim 10^{-3}eV \gg 10^{7}eV$

Not observable experimentally, $R \gg$ hyperfine, no enough precision

2 $R \gg \Gamma \rightarrow$ resonant absorption ($2R \leq \Gamma$) may NOT be observed

3 $E_{phonon} = k_B \Theta_D = 0.0411$ eV

$\uparrow 477K$

4a $min(E_{recoil}) = E_{phonon} = \cancel{477}\ 0.0411$ eV

4b. $\Gamma \leq R < E_{phonon}$ No

4c. Conservation of momentum

$E_r - 8R$

Quantum nature of nucleus

$\mu_N \simeq 3.152 \times 10^{-14}$ MeV T^{-1}

Fe^{57} groundstate

5a $\mu = (+0.09064)\left(\frac{e\hbar}{2m_p}\right) \simeq 2.857 \times 10^{-13}$ eV/G

5b $H \sim 10^5$ G

$\Delta E = -\mu H m_j / I = -5.714 \times 10^{-8} (m_j)$ eV

5c $\Delta E = -\mu H (-3/2)/(3/2) = 2.857 \times 10^{-8}$ eV

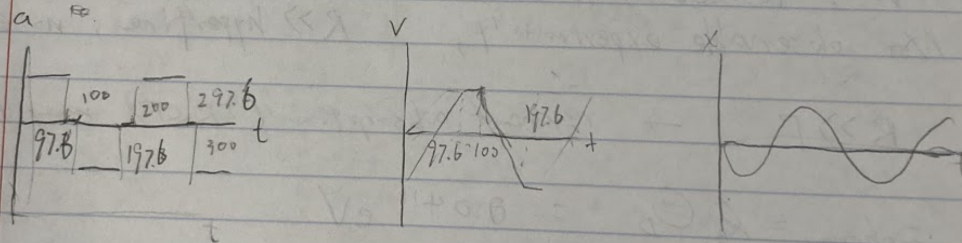
$E_{splitting} \sim 10^{-7}$ eV $< \Delta E$ narrow enough

5d $+ \cancel{\mu_1 H}$ $2\mu_1 H / \tfrac{3}{2}$ $-\mu_1 H/\tfrac{3}{2}$

$\left(\frac{2H}{3}\right)\mu_1$

6 $\Delta E = \frac{v E_0}{c} \sim 10^{-7}$ eV

7a



7b $\frac{10000}{250} = 40$ counts 1024 Channels

7c

7d

8

Error propagation and related calculations

By Taylor's book

Section 3.6 More About Independent Uncertainties 61

Uncertainties in Products and Quotients

Suppose that $x, \ldots, w$ are measured with uncertainties $\delta x, \ldots, \delta w$, and the measured values are used to compute

$$q = \frac{x \times \cdots \times z}{u \times \cdots \times w}.$$

If the uncertainties in $x, \ldots, w$ are *independent and random,* then the fractional uncertainty in q is the sum in quadrature of the original fractional uncertainties,

$$\frac{\delta q}{|q|} = \sqrt{\left(\frac{\delta x}{x}\right)^2 + \cdots + \left(\frac{\delta z}{z}\right)^2 + \left(\frac{\delta u}{u}\right)^2 + \cdots + \left(\frac{\delta w}{w}\right)^2}. \tag{3.18}$$

In any case, it is never larger than their ordinary sum,

$$\frac{\delta q}{|q|} \leqslant \frac{\delta x}{|x|} + \cdots + \frac{\delta z}{|z|} + \frac{\delta u}{|u|} + \cdots + \frac{\delta w}{|w|}. \tag{3.19}$$

With percent error of energy shift, one can calculate percent error for magnetic fields.

ΔE [10^{-9} eV]	$\Gamma/2$ [10^{-9} eV]	Percent Error [%]
−239.7	10.56	4.41
−135.8	9.75	7.19
−33.0	8.45	25.6
46.1	9.83	21.3
149.3	9.34	6.26
253.5	10.49	4.14

x_f

$x_i - x_f$

$\delta q = \sqrt{}$

$\delta q = \left|\frac{dq}{dx}\right| \delta x$

$\sigma_{counts} = \sigma_{channel}$

$P(x)$

$\delta p \rightarrow \frac{dP}{dx}\delta x$

$\frac{dP}{dx} = \frac{-\Gamma/2\pi \cdot 2(x-\mu)}{[(x-\mu)^2+(\Gamma/2)^2]^2}$

$= \frac{\Gamma(\mu-x)/\pi}{[(x-\mu)^2+(\Gamma/2)^2]^2} \; A +$

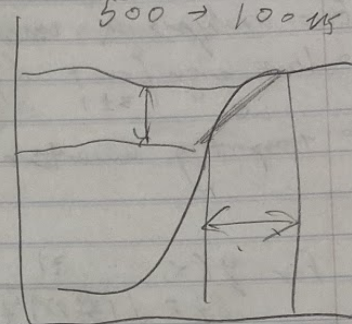
$\frac{dq_{Lor}}{dx} = \frac{1}{2\pi}\frac{1}{(x-\mu)^2+(\Gamma/2)^2}$

$+ \frac{1}{\pi}\frac{-(\Gamma/2)^2}{((x-\mu)^2+(\Gamma/2)^2)^2}$

$= \frac{1}{\pi}\frac{\frac{1}{2}(x-\mu)^2+\frac{1}{2}(\Gamma/2)^2 - 2(\Gamma/2)^2}{[(x-\mu)^2+(\Gamma/2)^2]^2}$

1000 → 200 ms

500 → 100 ms



-9.59 10.22 3 2 1 0 1 2 3

$\Gamma_{9.59}$ 10.22 -9.59

x_i x_f

Error

dwell time dead time doppler shift level splitting

- Channel → time → velocity → energy shift → magnetic fi[eld] H

magnetic moment μ

- Counting (492.416 − X)

$X = \frac{10.22+9.59}{495}$

mid − x

$\Delta E_{doppler}$

$\Delta E_{magn.}$

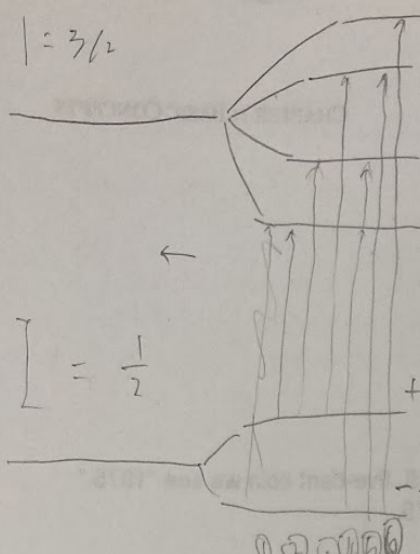
ΔE_{trans}

$\Delta E + E_0$

$(\Delta E_{m_i} - \Delta E_{m_j}) = \Delta E_{doppler} + E_0$

C_0 γ

$J = 3/2$



$-\frac{3}{2}$ $E = -1$ 0.15

$-\frac{1}{2}$ $E = -\frac{1}{3}$ 0-05

$+\frac{1}{2}$ $E = +\frac{1}{3}$ -0.05

$+\frac{3}{2}$ $E = +1$ -0.15

$J = \frac{1}{2}$

$+\frac{1}{2}$ $E = 1$ 0.1

$-\frac{1}{2}$ $E = -1$ -0.1

① ② ③ ④ ⑤ ⑥

m_j

-2 $-\frac{2}{3}$ $\frac{4}{3}$ $\frac{2}{2}$

$-\frac{4}{3}$

$\Delta E + E_0$

$$H = \frac{\Delta E}{\frac{\mu_{\frac{1}{2}} m_{\frac{1}{2}}}{1/2} - \frac{\mu_{\frac{3}{2}} m_{\frac{3}{2}}}{3/2}}$$

$-2 \quad -\frac{4}{3} \quad -\frac{2}{3} \quad \frac{2}{3} \quad \frac{4}{3} \quad 2$

① -0.25

$\mu_{\frac{1}{2}} = +0.09064$ nm

② -0.15

$\mu_{\frac{3}{2}} = -0.15531$ nm

③ -0.05

④ 0.05

-255.6

⑤ 0.15

-8

⑥ 0.25

3.152451

$\times 10^{-4}$

Log

==

Jan.18 W

15:00

We turned the devices on to check softwares (step 1-7 in lab manual)

We need to alter the scale for y-axis (default scale is too large to show the detailed property of the radioactive source)

We figured out that x-axis indicates energy/wavelength/frequency of photon, and y-axis indicates number of photon (cumulative energy)

And we can scroll to alter y-axis

16:00

We put the aluminum sheet in, but didn't get desired data (single peak)

We might misidentified iron foil & aluminum sheet

16:30

We took data for foil, but no desired outcome

Questions

1. Which is iron enriched foil and which is aluminum sheet?
2. Why is x-axis still channels instead of time in mossbauer mode?
3. Which is 14.4 eV peak?
4. What's up with oscilloscope / sync out?
5. Are we even oscillating?

===

Jan.18 W

15:00

We turned the devices on to check softwares (step 1-7 in lab manual)

We need to alter the scale for y-axis (default scale is too large to show the detailed property of the radioactive source)

We figured out that x-axis indicates energy/wavelength/frequency of photon, and y-axis indicates number of photon (cumulative energy)

And we can scroll to alter y-axis

16:00

We put the aluminum sheet in, but didn't get desired data (single peak)

We might misidentified iron foil & aluminum sheet

16:30

We took data for foil, but no desired outcome

Questions

1. Which is iron enriched foil and which is aluminum sheet?
2. Why is x-axis still channels instead of time in mossbauer mode?
3. Which is 14.4 eV peak?
4. What's up with oscilloscope / sync out?
5. Are we even oscillating?

Jan. 23 M
15:00
We finished exercises
We start taking data without sheet target
15:20
Taking data with aluminum sheet
15:30
Taking data with iron sheet

We figured out which is the iron sheet and collected mossbauer data

==

Jan. 25 W
13:00
Taking empty comparison data (no target)
Taking mossbauer effect data (iron target)
Analyzing mossbauer data acquired for jan. 23

===

Jan. 30 M
13:00
Testing 400 micro sec dwell time
Analysis

==

Feb.2 W
Writing report

Conclusions

We measured transition energy of Fe-57 with precision about 10 percent, and studied the hyperfine structure of atoms.

Though our data is subjected to several systematic error (i.e. CAD dead time), we still extract some quantitative properties of Fe-57 atoms with reasonable precision.