Neutron Physics

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We study the velocity distribution and particle-wave duality of thermal neutrons emerging from a beam in the MIT research reactor using time-of-flight spectroscopy with a mechanical beam chopper. ¡more¿

DETERMINING REACTOR TEMPERATURE

In order to determine peak locations for the short and long distance neutron time of flight experiments, we first smoothed the data from the MCS by taking the average of each point and its four adjacent points on each side. Using these graphs, we found the maximum neutron count value and its corresponding time slot. We then used

$$C_0 = C_{1p} - \frac{L_1}{(L_2 - L_1)} (C_{2p} - C_{1p}) \tag{1}$$

to determine the time origin C_0 of the neutron beam, where L_1 and L_2 are the near and far distances, and C_{1p} and C_{2p} are the near and far peak values. Figure 1 shows the raw and smooth data and the shifted peaks for the value of $C_0 = .39\ ms$. Using

$$v = \frac{L}{(P - C_0)(0.001)} \tag{2}$$

we calculated the velocity v at each point P, where L is the distance from the chopper to the detector and $N_{corrected}$ is calculated by subtracting the average background neutron count from the original neutron count. We then plotted a semi-log graph of $\log\left(N_{corrected}/v^4\right)$ vs. v^2 (Fig. 2).

By fitting

$$-\frac{v^2}{v_0^2} - b = \ln\left(\frac{N_c}{v^4}\right) \tag{3}$$

to the linear segment of the graph (velocities $< 2500\ m/sec$), we determined the most probable velocity v_0 to be $2312.027 \pm 45.116\ m/sec$. To determine the reactor temperature, we used the following equation

$$E_0 = \frac{1}{2} m v_0^2 = k_b T\ ,$$

and found $T = 51.083° \pm .123°C$. Since this value is extremely close to the known reactor temperature of roughly $50°C$, we must conclude that neutron velocity must fit a Maxwell-Boltzmann distribution.

To further verify our result, we plotted graphs of velocity vs. neutron counts for both the long and short distance experiments using the smoothed data (Fig. 3). Though the short distance experiment does not yet show a full Maxwell-Boltzmann distribution—likely due to the fact that the neutrons have not had time to spread out—the long distance data clearly follows a theoretical Maxwell-Boltzmann curve corresponding to a temperature $T \approx 324K = 50.85°C$. We ignored the second peak in the distribution since it likely corresponds to velocities of fast neutrons.

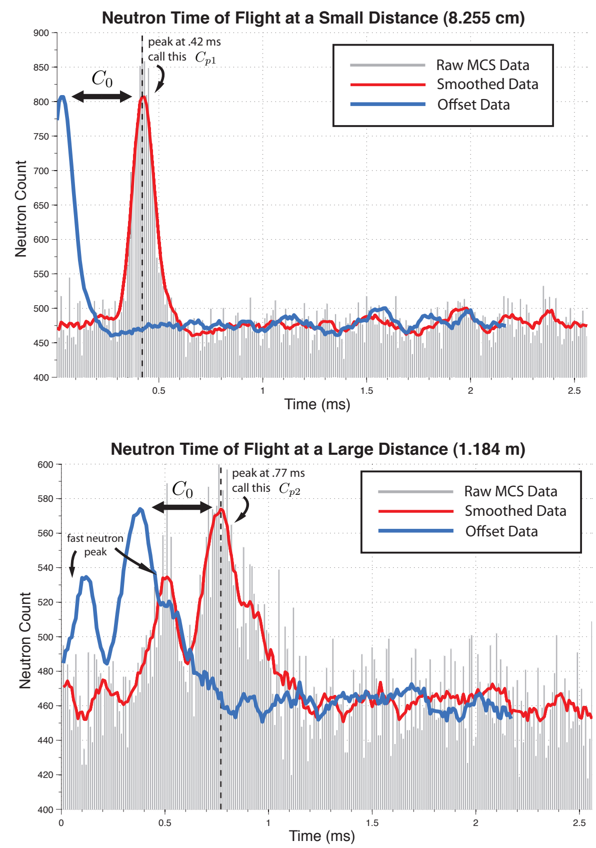

FIG. 1: The top graph shows raw, smoothed, and shifted data for short distance time of flight and the bottom graph displays the same data for long distance time of flight. We found $C_0 = .39\ ms$, $C_{p1} = 0.42\ ms$, and $C_{p2} = 0.77\ ms$. We assume the second, smaller, peak in the bottom graph corresponds to the distribution of fast neutrons. The peak does not appear in the short distance graph because the fast neutrons did not yet have ample distance and time to spread out from the slower-moving thermal neutrons.

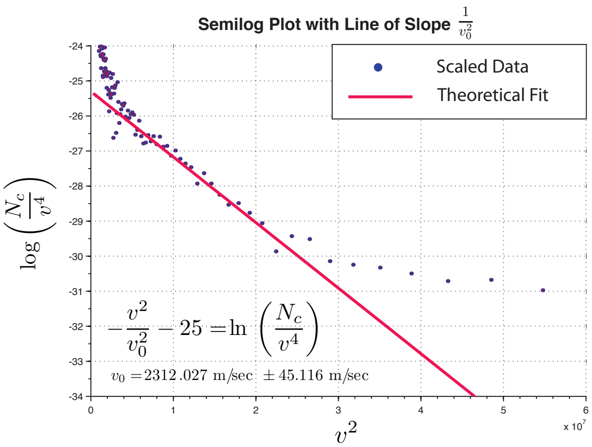

FIG. 2: Using this semi-log graph, we determined the most probable velocity v_0 to be 2312.027 ± 45.116 m/sec.

VERIFYING DEBROGLIE IN BRAGG SCATTERING OF NEUTRONS

Using the method described in the previous experiment, we smoothed and plotted the raw MCS data for each scattering angle of 15°, 20°, 25°, and 30° (Fig. 4 to aid with determining peak values[1]. We then calculated the offset C_0 to be 0.47 ms.

Figure 4 shows a plot of each shifted peak with background noise subtracted from the neutron counts. Using the peak times, we determine the peak velocities for each scattering angle.

[1] Data for the remaining experiments comes from an old data set given to us due to operating problems with the MIT Reactor

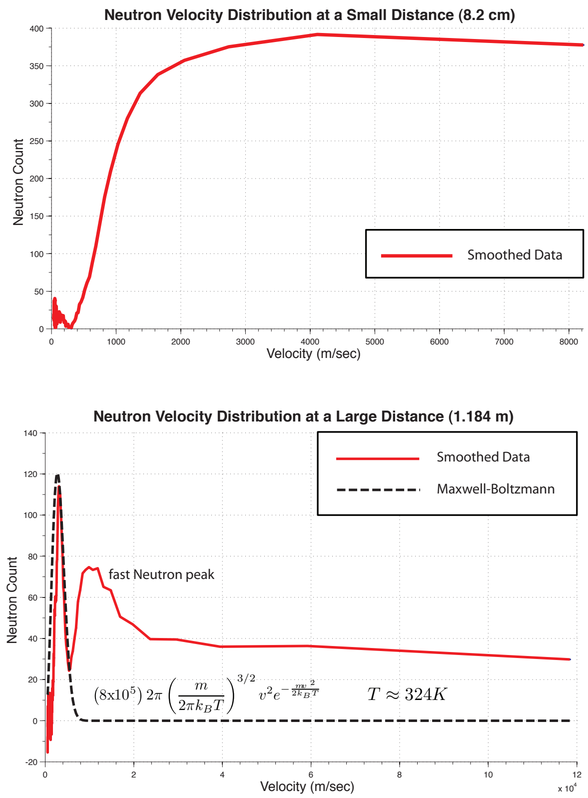

FIG. 3: Graphs of velocity vs. neutron count for both short (top) and long (bottom) distance experiments. The bottom graph clearly follows a theoretical Maxwell-Boltzmann distribution curve corresponding to a temperature $T \approx 324K = 50.85^{\circ}C$.

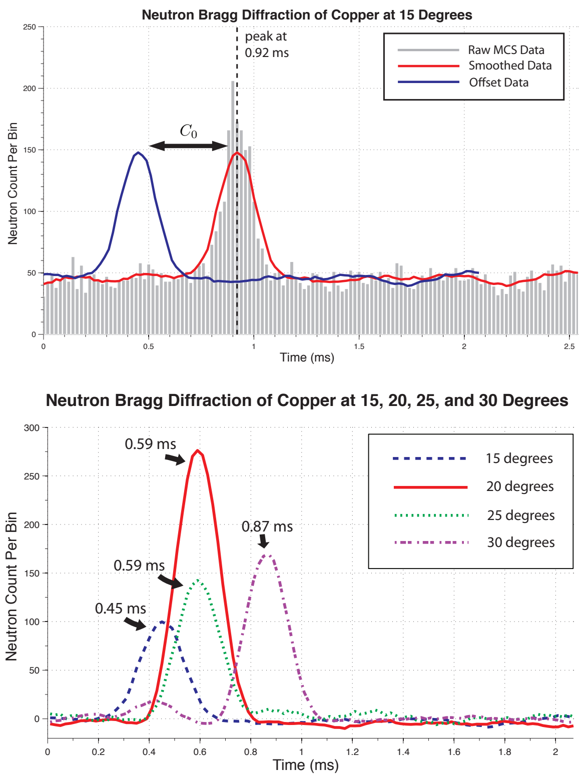

FIG. 4: (Top) Raw, smoothed, and shifted data for neutrons scattered at 15°. Using similar graphs for the other scattering angles, C_0 is determined do be 0.47 ms. (Bottom) Peaks for each scattering angle. Peak times are noted—these will be used to calculate the peak velocity for each angle.