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Wien Filter Calibration

1 Purpose

To determine the velocity of the electrons in the 200keV beam using the Wien Filter (WF) at UITF. The voltage of the positive and negative terminals were adjusted to steer the beam in one direction. The magnetic field of the WF was then varied until the beam returned to its original position. The beam position was monitored at the viewer just after the WF (ITVK203).

2 Data

Table 1 below shows the raw data for the WF measurements. The voltage difference between the positive and negative terminals was varied between 0V and $\sim$ 8kV.

Positive Terminal (Volts)	Negative Terminal (Volts)	MWFK203 (Gauss-cm)	Delta V (Volt)
0	0	0	0
227	220	96	447
454	447	192	901
681	674	287	1355
908	901	382	1809
1143	1128	476	2271
1370	1355	569	2725
1597	1582	664	3179
1824	1810	758	3634
2051	2044	851	4095
2278	2271	946	4549
2505	2498	1042	5003
2740	2725	1137	5465
2967	2952	1229	5919
3194	3179	1322	6373
3421	3407	1415	6828
3648	3634	1508	7282
3875	3861	1596	7736

Table 1: Raw data for WF measurements.

3 Analysis

A plot of the voltage difference vs. the magnetic field gradient is shown below in Figure 1. The plot shows a linear relationship between the electric and magnetic fields of the WF. The plot was fitted with a linear regression and the equation for the trendline is shown.

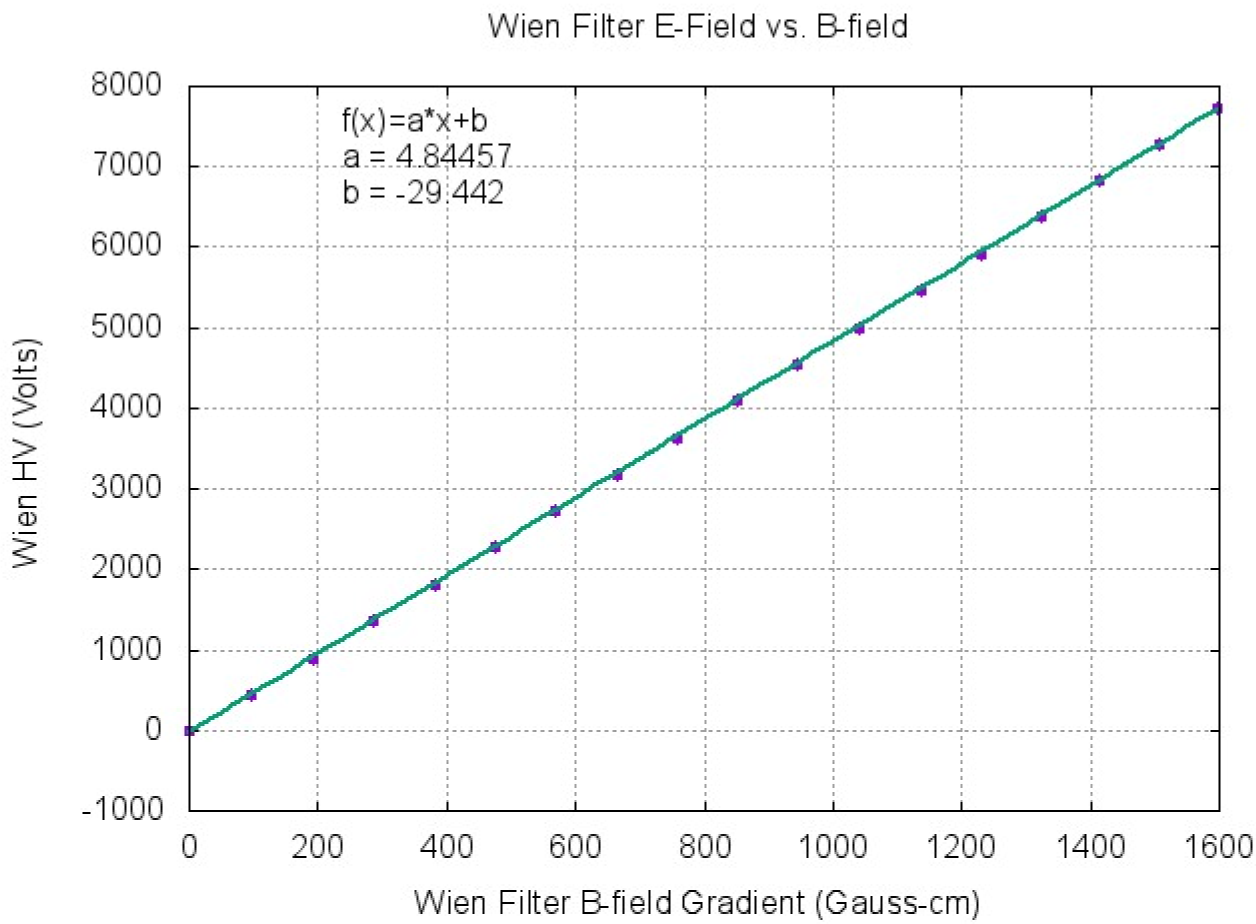

Figure 1: Plot of the WF voltage difference vs. the strength of the WF magnet.

To determine the velocity v of the electrons in the beam from the electric and magnetic fields, we start with the relationship

$$\frac{E}{B} = v \tag{1}$$

The electric field E between two parallel plates with voltage difference ΔV and separation distance d_E is

$$E = \frac{\Delta V}{d_E} \tag{2}$$

The magnetic field gradient G in cgs units is

$$G\,(\mathrm{G\,cm}) = B\,(\mathrm{G})\,d_B\,(\mathrm{cm}) \tag{3}$$

where d_B is the length of the maximum magnetic field within the WF. In order to get v in SI units, we need to convert G into T m:

$$G\,(\mathrm{T\,m}) = G\,(\mathrm{G\,cm}) \times \frac{1\mathrm{T}}{10^4\mathrm{G}} \times \frac{1\mathrm{m}}{100\mathrm{cm}} = B\,(\mathrm{T})\,d_B\,(\mathrm{m}) \tag{4}$$

We can solve for the magnetic field in equation 4 and plug it into equation 1 with equation 2 to get an equation for velocity v:

$$v\left(\frac{\mathrm{m}}{\mathrm{s}}\right) = \frac{\Delta V\,(\mathrm{V})}{d_E\,(\mathrm{m})} \times \frac{10^6 d_B\,(\mathrm{m})}{G\,(\mathrm{G\,cm})} \tag{5}$$

We can rewrite equation 5 to get an explicit relationship between ΔV and G:

$$\Delta V = \frac{d_E v}{d_B \cdot 10^6} G \,(\mathrm{G\,cm}) \tag{6}$$

Comparing this equation to the equation for the trendline in Figure 1, we see that the slope of the line is

$$\text{Slope} = \frac{d_E v}{d_B \cdot 10^6}$$

Solving for v yields

$$v\left(\frac{\mathrm{m}}{\mathrm{s}}\right) = \frac{(\text{Slope})\, d_B \cdot 10^6}{d_E} \tag{7}$$

Plugging in numbers with $d_E = 0.015\mathrm{m}$, $d_B = 0.30714\mathrm{m}$, and Slope $\approx 4.8446\frac{\mathrm{V}}{\mathrm{G\,cm}}$ (note that 10^6 has "units" of $\frac{\mathrm{G\,cm}}{\mathrm{T\,m}}$), the velocity is $v \approx 9.92 \times 10^7 \frac{\mathrm{m}}{\mathrm{s}}$ or $\beta = \frac{v}{c} \approx 0.331$. This corresponds to an electron energy of $E_e = \frac{m_e c^2}{\sqrt{1-\beta^2}} = \frac{0.511\mathrm{MeV}}{\sqrt{1-0.331^2}} \approx 541\mathrm{keV}$, which seems to be much higher than the 200keV energy gained from the gun high voltage.