CEBAF New Wien Control

How to Wien Voltage and Magnetic Field

Riad Suleiman

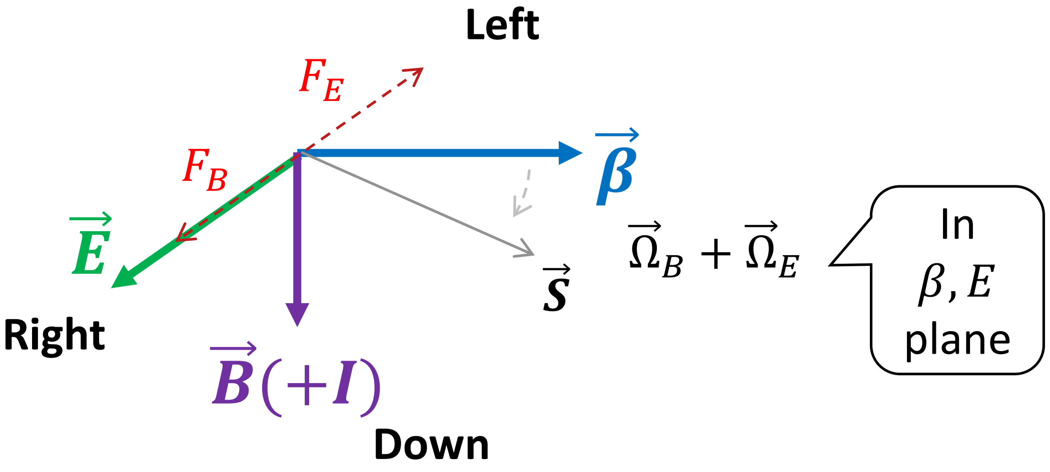
Wednesday, November 18, 2020

BMT Spin Equation

- In a Wien Filter with electric and magnetic fields transverse to electron beam velocity, spin precession relative to momentum in lab frame is given by following form of generalized Thomas-BMT equation:

$$\vec{\Omega} = \frac{e}{m}\left[G_M \vec{B}_y + \left(\frac{1}{\gamma^2 - 1} - G_M\right)\frac{\vec{\beta} \times \vec{E}}{c}\right]$$

$$\vec{\Omega} = \vec{\Omega}_B + \vec{\Omega}_E$$



- Spin Precession Angle: $\theta = \vec{\Omega}\, T$
- Time-of-Flight of electron beam in Wien determined by E-Field: $T = L_E/(\beta c)$

Electromagnetic Forces

Electron Charge, q	$-e$
Magnetic Force, F_B	$q\,\vec{\beta}c \times \vec{B}$
Electrostatic Force, F_E	$q\,\vec{E}$

$$B = E/(\beta c)$$

$$V = Eg/2$$

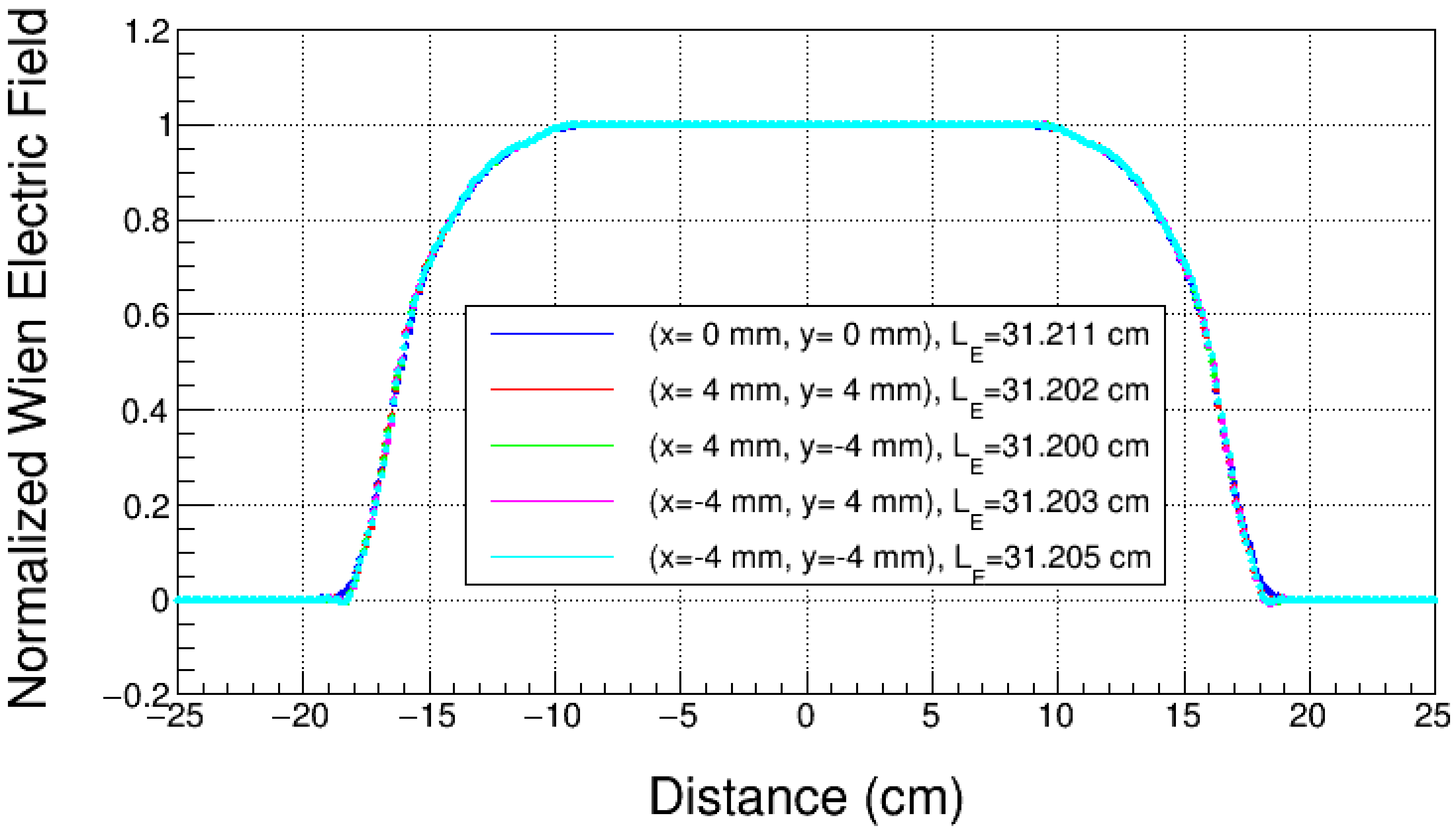
- c = 299792458.0 — Speed of Light (m/s)
- e = 1.602176e-19 — Electron Charge (C)
- mc^2 = 510998.950 — Electron Mass (eV)
- G_M = 0.00115965218091 — Electron Anomalous Magnetic Moment
- e/m = 1.758820088e+11 — Electron Cyclotron Frequency/Field (rad/(s T))
- L_E = 3.120e-01 — Electric Field Effective Length (m)
- L_B = 3.105e-01 — Magnetic Field Effective Length (m)
- g = 1.5e-02 — Wien Gap (m)
- E — Electric Field Strength (V/m or N/C)
- B — Magnetic Field (T or N·s/(C m))
- V — Plate Voltage on Beam Left

$$\theta = \frac{180}{\pi}\frac{e}{m}\frac{L_E}{\beta c}\left[G_M\frac{E}{\beta c} + \left(\frac{1}{\gamma^2 - 1} - G_M\right)\frac{\beta E}{c}\right]$$

Electric Field Effective Length

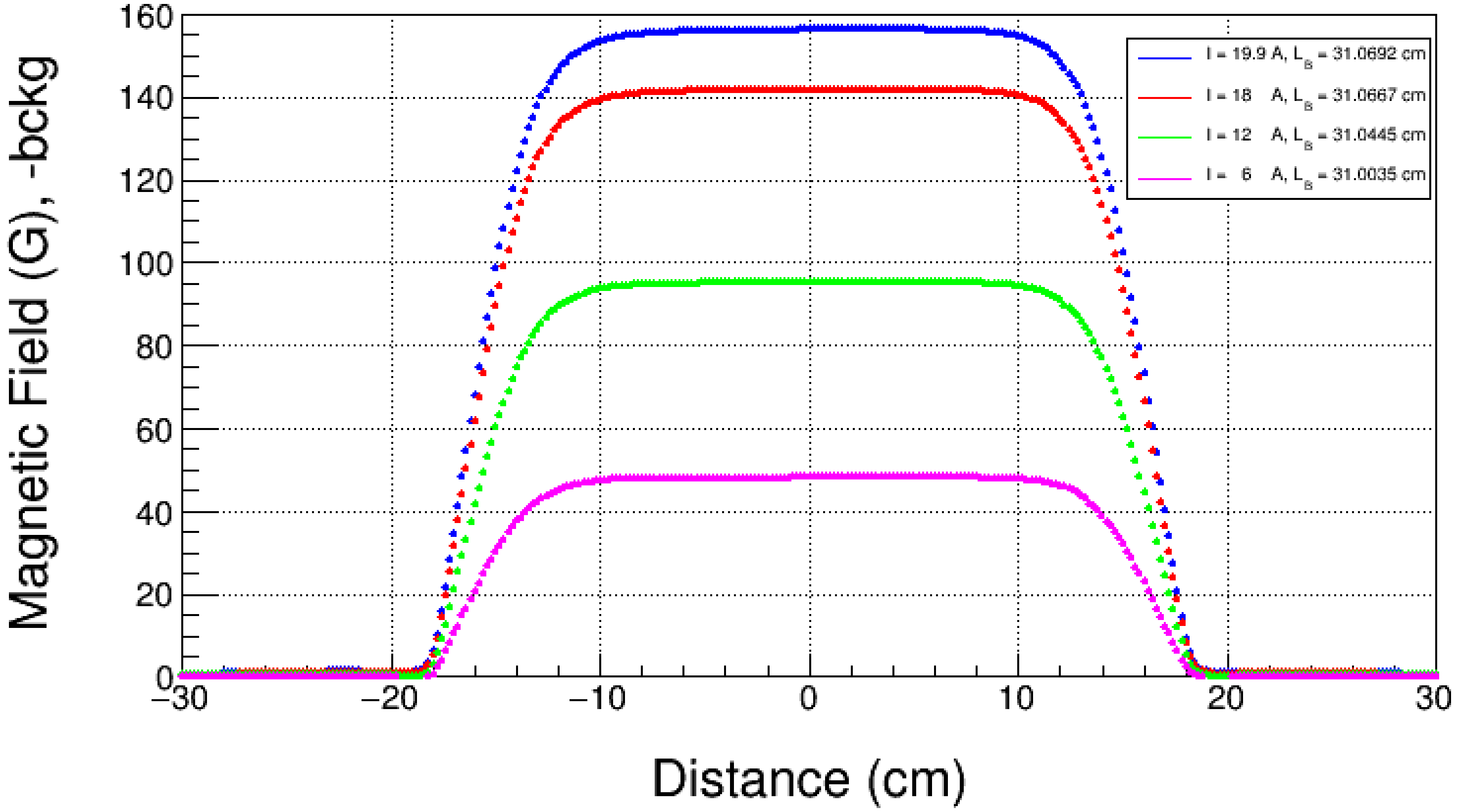
$$L_E = \frac{\int_{-25\ cm}^{25\ cm} E dz}{E_{max}}$$

CST model based on actual CEBAF drawings (faceted)



Magnetic Field Effective Length

$$L_B = \frac{\int_{-30\ cm}^{30\ cm} B dz}{B_{max}}$$



Wien Equations (Gun HV = 130 kV)

$B = E/(\beta c)$

$\mathrm{V} = Eg/2$

$$\theta = \frac{180}{\pi}\frac{e}{m}\frac{L_E}{\beta c}\left[G_M \frac{2}{g\beta c} + (\frac{1}{\gamma^2 - 1} - G_M)\frac{2\beta}{gc}\right] V$$

- Wien Angle: θ [deg] $= 0.00814225\, V$ [V]
- Plate Voltage: V [V] $= 122.816\, \theta$ [deg]
- Magnetic Field: Bdl [G cm] $= 0.00228739\, V$ [V]

Wien Equations (Gun HV = 200 kV)

$B = E/(\beta c)$

$V = Eg/2$

$$\theta = \frac{180}{\pi}\frac{e}{m}\frac{L_E}{\beta c}\left[G_M \frac{2}{g\beta c} + (\frac{1}{\gamma^2 - 1} - G_M)\frac{2\beta}{gc}\right] V$$

- Wien Angle: θ [deg] $= 0.00498929\, V$ [V]
- Plate Voltage: V [V] $= 200.429\, \theta$ [deg]
- Magnetic Field: Bdl [G cm] $= 0.00198609\, V$ [V]

Wien Angle: Set and Readback (given here at 200 kV, as an example)

- **Set Wien Angle to $\boldsymbol{\theta}$** (angle rotation to beam right is positive):
  - Beam Left Plate Voltage: V [V] $= 200.429\ \theta$ [deg]
  - Sign of voltage is same as sign of angle
  - Magnetic Field: Bdl [G cm] $= 0.00198609\ V$ [V]
  - Sign of voltage at beam right plate is opposite, $(-V)$

- **Read Wien Angle:**
  - Wien Angle: θ [deg] $= c_0 + c_1 \times 0.00498929\ V$ [V] $+ c_2\ V^2$
  - c_0, c_1, c_2: are determined by fitting Mott Asymmetry vs Plate Voltage
  - Ideally, $c_0 = \theta_0 = 0$, $c_1 = 1$, $c_2 = 0$, otherwise we will have to change "Set Wien Angle" procedure