FEE Rate Analysis

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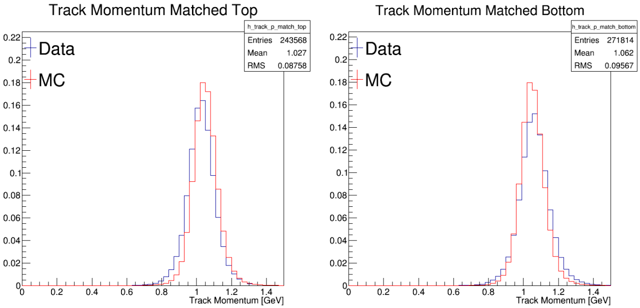
Introduction

- Full energy electron (FEE) rates in different spherical (ϕ and θ) regions of detector. Comparison of data (tungsten and carbon targets) to MC and calculations.
  - Beginning to resolve FEE rate problems seen in the past
- Measurement of Mott scattering differential cross sections
- Pass3, V3 Detector, Singles1 Trigger
- Data - 5772, and 5779 (Carbon); MC - 3.4.1 (beam-tri)

FEE Selection

- 10 ns timing window
- 0.85-1.2 GeV energy cut
- Greater than 2 cluster size
- Tracks are matched to clusters



Coordinate Definitions

- The beam is rotated by $\theta_r = -30.5$ *mrad* about the y-axis $\mathbf{R_y}$
- Use θ' and ϕ' for analysis (spherical coordinates with $\hat{z}$ along beam direction)

$$\vec{p}' = \mathbf{R_y}\ \vec{p}$$

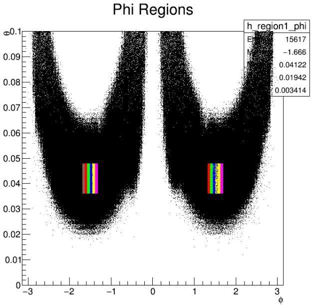
$$\begin{pmatrix} p'_x \\ p'_y \\ p'_z \end{pmatrix} = \begin{pmatrix} \cos\theta_r & 0 & \sin\theta_r \\ 0 & 1 & 0 \\ -\sin\theta_r & 0 & \cos\theta_r \end{pmatrix} \begin{pmatrix} p_x \\ p_y \\ p_z \end{pmatrix}$$

$$\theta' = \tan^{-1}\frac{p'_T}{p'_z} = \tan^{-1}\frac{\sqrt{p'^2_x + p'^2_y}}{p'_z}$$

$$\phi' = \begin{cases} \tan^{-1}\frac{p'_y}{p'_x} + \pi & \text{if } p'_y > 0 \ \&\ p'_x < 0 \\ \tan^{-1}\frac{p'_y}{p'_x} - \pi & \text{if } p'_y < 0 \ \&\ p'_x < 0 \\ \tan^{-1}\frac{p'_y}{p'_x} & \text{else} \end{cases}$$

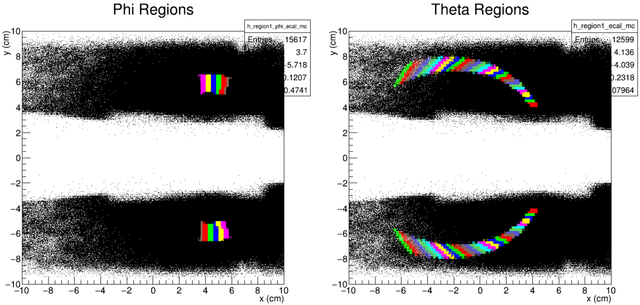
Region Definitions

- Definition of regions shown in the different colors. Black is not a part of any region
- ϕ regions (left): $\Delta\phi = 0.0666$, $\Delta\theta = 0.012$
  - $\phi \epsilon \pm [1.3, 1.7]$, $\theta \epsilon [0.036, 0.048]$
- θ regions (right): $\Delta\phi = 0.2$, $\Delta\theta = 0.02$
  - $\phi \epsilon \pm [1.7 \mp \Delta\phi, 2.7 \mp \Delta\phi]$, $\theta \epsilon [0.028, 0.088]$



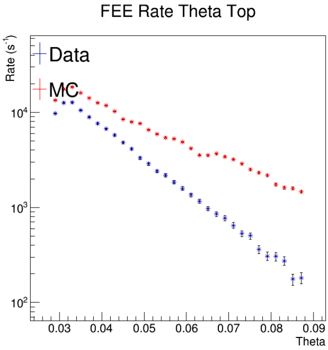
Region Definitions (Cont.)

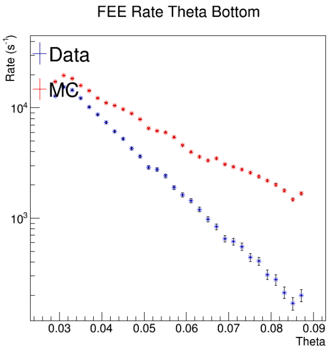
- Definition of regions shown from previous slide in x-y coordinates (projected onto Ecal face)
- ϕ regions (left) and θ regions (right)



Data and MC Major Differences

- Rates for Data and MC as function of theta on log scale
- Completely different trend in Data and MC, as much as a factor of 10 for large θ
- Need to compare to calculations





Calculations

- Mott cross section with form factor

$$\frac{d\sigma}{d\Omega}(E,\theta) = \frac{Z^2 e^4}{(4\pi\epsilon_0)^2 4E^2 \sin^4\frac{\theta}{2}}\left(1-\beta^2\sin^2\frac{\theta}{2}\right)|F(Q)|^2$$

- where $F(Q)$ is the electric form factor (shown on later slides), θ is the recoil angle, $\beta = \frac{v}{c}$, $E = 1.05 GeV$, and Q is the positive transferred 4-momentum which is given in the high energy limit

$$Q^2 = 4EE'\sin^2\frac{\theta}{2}$$

- where E' is the scattered electron energy

$$E' = \frac{E}{1+\frac{2E}{M}\sin^2\frac{\theta}{2}}$$

Calculations (cont)

$$L = \frac{I \rho N_{av} l}{eA} \text{ and } \Delta\sigma = \int_{\phi_j}^{\phi_j+\Delta\phi} \int_{\theta_j}^{\theta_j+\Delta\theta} \frac{d\sigma}{d\Omega} \sin\theta d\phi d\theta$$

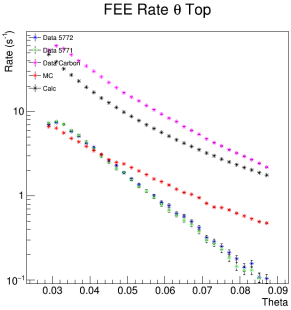
- The rate $\frac{dN}{dt}$ is the product of the luminosity L and the integrated cross section $\Delta\sigma$: $\frac{dN}{dt} = L\Delta\sigma$
  - Tungsten: $Z = 74$,$A = 183.35$, $\rho = 19.3 \frac{g}{cm^3}$, $I = 37.9nA$, and $l = 4.06\mu m$
  - Carbon: $Z = 6$, $A = 12$, $\rho = 2.26 \frac{g}{cm^3}$, $I = 25.7nA$, and $l = 196\mu m$
- Calculated rate was computed by iterating the integral over the differential cross section

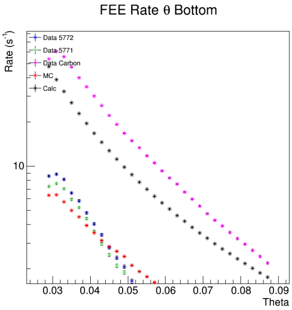
$$\frac{dN}{dt} = L\Delta\phi \sum_{i=1}^{N} \frac{d\sigma}{d\Omega}(\theta_i) \sin\theta_i \Delta\theta$$

- where $N = 10000$ and $\Delta\theta = \frac{\theta_{max} - \theta_{min}}{N}$

FEE Rate of θ Regions Tungsten

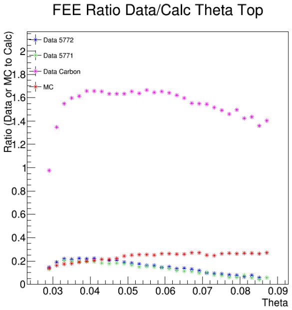
- Calculation does **NOT include form factor**
- General trend of calculations matches MC, but not Data
- Carbon seems to match the trend of the calculations much better than tungsten
- Note: Calculation are off by an arbitrary factor

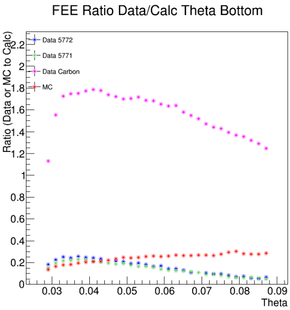




FEE Ratio of Calculation to Data or MC in θ

- Calculation does **NOT include form factor**
- Comparison of the ratios of Data and MC to Calculation (Mott Scattering): $\frac{\text{MC or Data Rate}}{\text{Calc Rate}}$
- MC matches the trend of calculations, Tungsten Data does not. Carbon matches better than tungsten
- Note: Calculation are off by an arbitrary factor



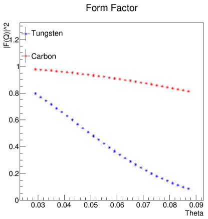


Form Factor

- Form Factor makes a large contribution

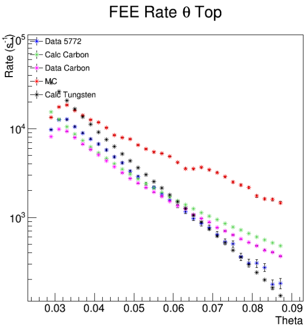
$$F_W(Q) = 3\frac{\hbar}{QR}^3 (\sin\frac{QR}{\hbar} - \frac{QR}{\hbar}\cos\frac{QR}{\hbar})$$
$$F_C(Q) = (1 - \frac{Z-2}{6Z}a^2Q^2)e^{-\frac{1}{4}b^2Q^2}$$

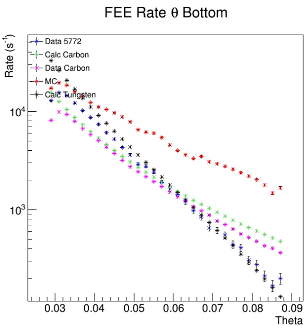
- where R is the nuclear radius, and a and b are nuclear parameters
  - For carbon, $a = 1.64$ and $b = \sqrt{a^2(1-1/A)+a_p^2}$; with a_p being the proton radius



FEE Rates of Calculation Compared to Data or MC in θ

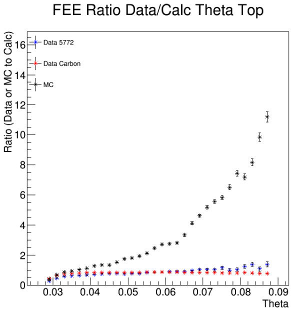
- Comparison of Calculation (Mott Scattering) Rates to Data and MC log scale
- Calcs and data (both tungsten and carbon) have the similar slope, and MC is now a poor match.
- Note: Calculation are off by an arbitrary factor

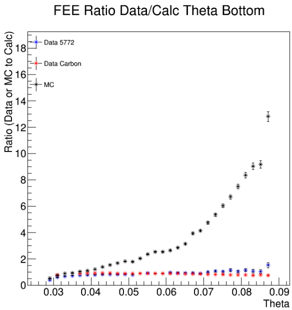




FEE Ratio of Calculation to Data or MC in θ

- Comparison of the ratios of Data and MC to Calculation (Mott Scattering): $\frac{\text{MC or Data Rate}}{\text{Calc Rate}}$
- Data matches the trend of calculations, MC does not.
- Note: Calculation are off by an arbitrary factor



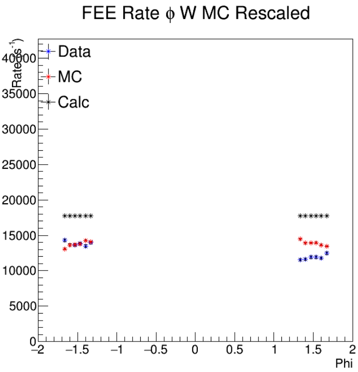


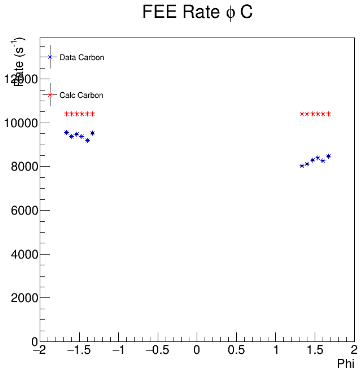
Corrected MC and Normalization

- EGS5 uses Thomas-Fermi form factor. This may only be valid for small angles
- Attempt to correct MC: $Rate_{MC} \rightarrow Rate_{MC}|F(Q)|^2$
- Data normalized based on time (7258 s), integrated charge (274.779 μC), blind (0.1), prescale (2^{11}), and deadtime
- Carbon run normalized based on (1851 s), integrated charge (47.626 μC), prescale (2^{7}), and deadtime
- MC normalized based on time (calculated from file size) and current (50 nA)

FEE Rate of ϕ Regions Tungsten

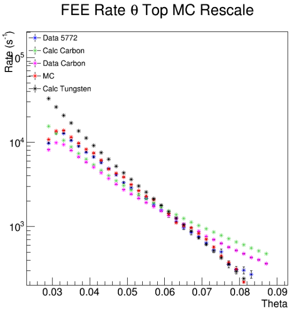
- Comparison of ϕ regions, should not have any ϕ dependence

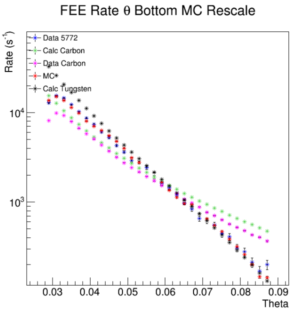




FEE Rates of Calculation Compared to Data and MC in θ. MC Corrected

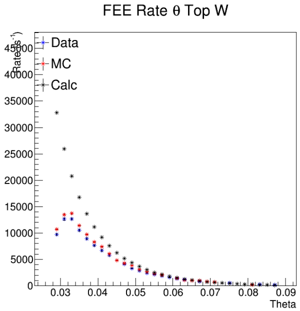
- Comparison of Calculation (Mott Scattering) Rates to Data and MC log scale
- **MC is now corrected with form factor**, MC seems to match





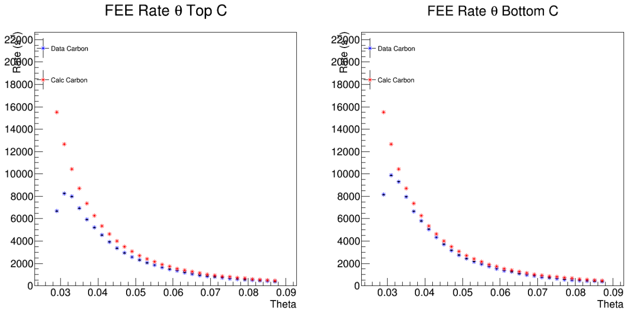
FEE Rates of Calculation Compared to Data and MC in θ for Tungsten. MC Corrected

- Comparison of Calculation (Mott Scattering) Rates to Data and MC for Tungsten
- First 3-4 data points at smaller θ may be experiencing Ecal edge effects



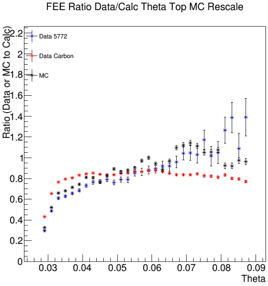
FEE Rates of Calculation Compared to Data and MC in θ for Carbon

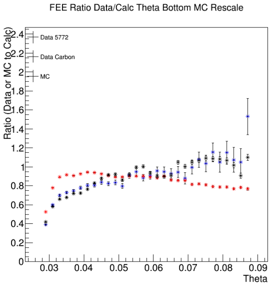
- Comparison of Calculation (Mott Scattering) Rates to Data and MC for Carbon
- First 3-4 data points at smaller θ may be experiencing Ecal edge effects



FEE Ratio of Calculation to Data or MC in θ. MC Corrected

- Comparison of the ratios of Data and MC to Calculation (Mott Scattering): $\frac{\text{MC or Data Rate}}{\text{Calc Rate}}$
- Data matches the trend of calculations, **MC is corrected with form factor**, and has a fairly constant ratio

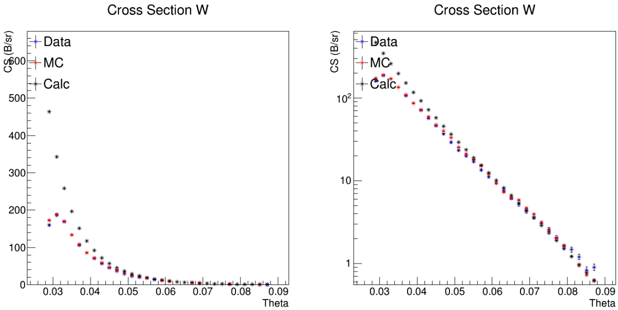




FEE Differential Cross Sections Tungsten

$$\frac{d\sigma}{d\Omega} = \frac{1}{L\ \Delta\Omega}\frac{dN}{dt}$$

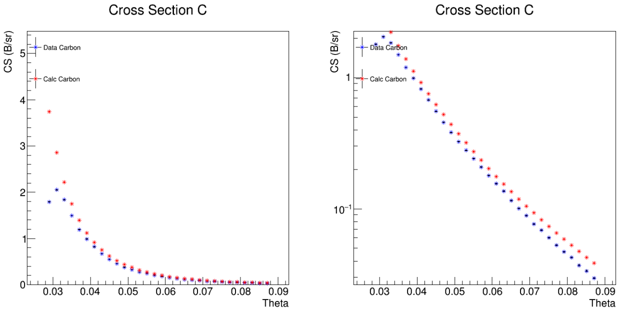
- Differential cross section $\frac{d\sigma}{d\Omega}(\theta)$ for tungsten (averaged in top and bottom) compared to calculations and MC



FEE Differential Cross Sections Carbon

$$\frac{d\sigma}{d\Omega} = \frac{1}{L\ \Delta\Omega}\frac{dN}{dt}$$

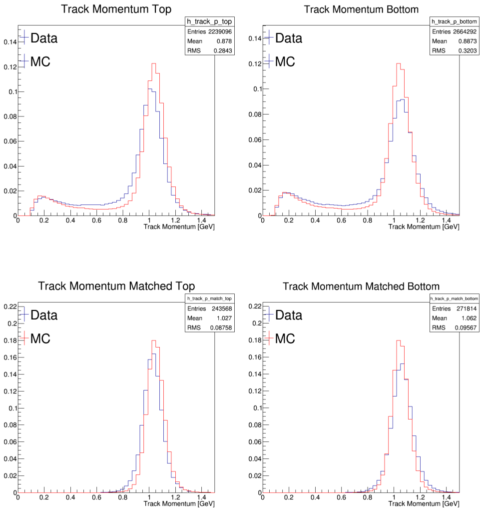
- Differential cross section $\frac{d\sigma}{d\Omega}(\theta)$ for carbon (averaged in top and bottom) compared to calculations



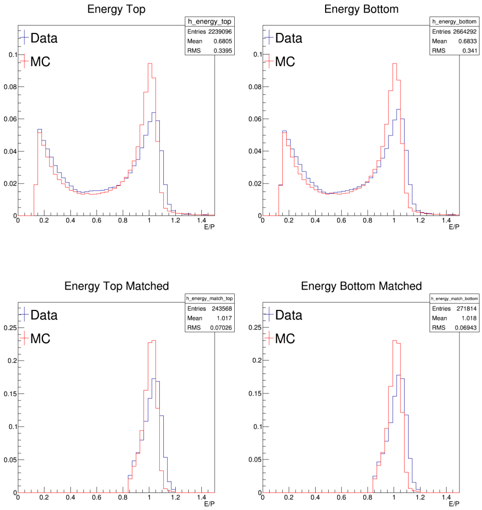
Conclusions

- Significant improvement over the past few weeks by introducing a form factor into calculations
- Corrected MC and Data for both tungsten and carbon runs reasonably match calculations
  - MC form factor possibly incorrect at the generator level
- Mott scattering differential cross section successfully measured for both tungsten and carbon
- In the near future: update as new MC comes along and write up a note

Track Momentum Before and After FEE Cuts & Matching



Cluster Energy Before and After FEE Cuts & Matching



E/P After FEE Cuts & Matching