PHYSICS 415/515 - Fall Semester 2025 - ODU

Nuclear and Particle Physics - Problem Set 3 - Solution

Problem 1)

By setting $E' = \frac{E}{1+\frac{2E}{M}(\sin\theta/2)^2} = 0.683$ GeV , I find $Q^2 = 3.413$ $(\text{GeV/c})^2$ and hence $\tau = \frac{Q^2}{4M^2} = 0.968$.
Using Eq. 5.39 in the book (replacing $|\mathbf{q}c|^4$ with Q^4) and multiplying with the recoil factor E'/E as indicated in Eqs. 6.1-6.2 in the book, I get a Mott cross section of $4.53 \cdot 10^{-8}$ $\text{fm}^2 = 4.53 \cdot 10^{-34}$ cm^2 = 453 pb (picobarn).

From Eq. 6.12 in the book, we have
$G_E^p = G_{Dipole} = 0.0297$ and $G_M^p = 2.79\ G_{Dipole} = 0.0828$.

Plugging it all into Eq. 6.10 yields
$d\sigma/d\Omega = 7.74 \cdot 10^{-36}$ cm^2 = 7.74 pb (pico-barn). Very tiny!

Problem 2)

Using the "point-like target" approximation, we calculate $d\Omega = (0.01\text{m})^2/(0.2\text{m})^2 = 0.0025$ sr, hence $d\sigma = d\sigma/d\Omega \cdot d\Omega = 1.94 \cdot 10^{-38}$ cm^2.
For the described target, we have L = 5 cm, ρ = 0.07085 g/cm3 [Wikipedia], atomic weight = 1.008u [Wikipedia] and $N_A = 6.022 \cdot 10^{23}$ => areal density is $2.116 \cdot 10^{23}$ protons/cm^2. The beam flux is 100 μA/e = $6.242 \cdot 10^{14}$ electrons/s. Hence the luminosity is $1.321 \cdot 10^{38}/\text{cm}^2/\text{s}$. Multiplying this with the cross section above, I get a count rate of 2.56/s. To achieve a precision of 10%, I need to get $\frac{\sqrt{N}}{N} = \frac{1}{\sqrt{N}} = 0.1$, so N > 100. This requires only 39 seconds of data taking, which is truly amazing given how small the cross section is!