Nuclear Physics - Problem Set 3 - Solution

Problem 1)

Starting from the end, since each deuteron has a charge $Q = e$, 2 $\mu$A of current correspond to $1.25 \cdot 10^{13}$ deuterons/s impinging on the target. Since the atomic mass number of tritium is 3.016 g/mol, the target has a density of $4.0 \cdot 10^{19}$ atoms/cm$^2$ and the luminosity is hence $5 \cdot 10^{32}$. Meanwhile, the cross section is $1.3 \cdot 10^{-26}$ cm$^2$/sr and the solid angle subtended by the detector is $0.002 \text{m}^2/(3 \text{m})^2 = 2.22 \cdot 10^{-4}$ sr for an integrated cross section $D_s = 2.9 \cdot 10^{-30}$ cm$^2$ and a count rate of 1440 neutrons per second.

Problem 2)

a) The density of carbon is 2.265 g/cm$^3$, and the atomic weight (by definition) is exactly 12, so the areal density is $\tau = 2.265 \text{ g/cm}^3 \cdot 1 \text{ cm} \cdot 1 \text{ mol}/12 \text{ g} \cdot 6.022 \cdot 10^{23}/\text{mol} = 1.137 \cdot 10^{23}/\text{cm}^2$. To stay below the stated luminosity, we need less than $10^{34}/1.137 \cdot 10^{23}$ electrons/s = 8.798 $10^{10}$ electrons/s. Each electron has a charge of 1.602 $10^{-19}$ C, so this corresponds to a current of 14.1 nA (pretty low compared to the 100 $\mu$A that the accelerator can deliver). CLAS12 makes up for the low luminosity by its large solid angle (approximately $2\pi$ sr as opposed to a few msr for most spectrometers).

b) 100 M events in 24 hours of running corresponds to 1157 events per second. Since $dN/dt = L\Delta\sigma$, I conclude that $\Delta\sigma$ equals $\Delta\sigma = 1.157 \cdot 10^{-31}$ cm$^2 = 0.1157 \mu$b.