Graduate Course: Advance Particle Physics, University of Ioannina 26/10/22

Particle Physics Homework Assignment 1

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Problem 1: (a) Show that $1\,Kgr = 5.6\,10^{26}\,GeV$

(b) In a unit system where $\hbar = c = 1$ show that:

I. $1\,Gev^{-2} = 0.389\,mb$
II. $1\,m = 5.068\,10^{15}\,GeV^{-1}$
III. $1\,sec = 1.5\,10^{24}\,GeV^{-1}$

Use: $\hbar c = 197.3\,MeV\ fm$.

Problem 2: Show that:

I. The Compton wavelength for an electron is $\lambda_c = \frac{1}{m_e}$
II. The Bohr radius of a Hydrogen atom is $r_{Bohr} = \frac{1}{\alpha\, m_e}$
III. The velocity of an electron in the lowest Bohr orbit is α
IV. Calculate the numerical values for the three expressions above.

where $\alpha = \frac{1}{137}$ is the fine structure constant. The electron mass is $m_e = 0.511\text{MeV}$

Problem 3: Show that due to the fact that the electromagnetic interaction is relatively weak we can use the non-relativistic Schrödinger equation to describe the Hydrogen atoms.

Problem 4: The non-relativistic electromagnetic differential cross-section for scattering a beam of charged particles with charge $q=e$ off a heavy nucleus of charge $Q=Z|e|$ is calculated to be:

$$\frac{d\sigma}{d\Omega}=\left(\frac{Z\alpha}{4E}\right)^2 \sin^{-4}(\theta/2)$$

where $\alpha=\frac{1}{137}$ is the fine structure constant, θ is the scattering angle and E is the beam energy. This calculation assumes that $\hbar=c=1$. Compute differential cross section $\frac{d\sigma}{d\Omega}$ in μb for $E = 1\ GeV, \theta = 45^0, Z = 12$.

Problem 5: The LHC beam is not continuous but it has a bunch structure. Bunches of particles will collide every 25nsec at 14 TeV centre of mass energy with a luminosity (number of particles per sec per cm^2) of 10^{34} cm^{-2}sec^{-1}. The total inelastic proton-proton cross section at 14TeV is 70mb.

I. Compute the number of interactions occurring per second as well as every time two bunches collide.

These are called minimum bias interactions and are of no interest (background). The Higgs particle is expected to be produced at LHC mainly through the gluon-gluon production diagram ($gg \rightarrow H^0$) which has a cross section of about 40pb. One of the Higgs discovery channels involves searching for the Higgs decaying to two photons which has a probability (branching ratio) of $0.2\ 10^{-2}$.

II. How many minimum bias events are produced for every Higgs event observed via the two photon channel if one ignores detector effects?

(an extra correction to these must be applied due to the fact that not all the beam bunches have protons so the stated luminosity corresponds to fewer bunches, but this is beyond the purpose of this course)