Tutorial 2

(1) An experiment colliding electrons and protons is designed to look for the reaction $e^- + p \to X$ where X is an exotic heavy particle of mass 500 GeV/c^2.

(a) How high should the electron energy be if the experiment takes place in the centre-of-mass frame with electrons and protons colliding head-on ?

(b) How high should the electron energy be if the experiment is a "fixed target" experiment on protons at rest ?

(2) The differential cross section for the scattering of a particle of mass m off a heavy target is given by $\frac{d\sigma}{d\Omega} = \alpha \left| M\left(q^2\right) \right|^2$ where α is a constant, q is the 3-momentum, and M is the amplitude. The amplitude is given by $M = \frac{k}{q^2 + m_X^2 c^2}$ where m_X is the rest mass of the exchanged particle and k is a constant.

A new type of particle Y is discovered at a collider experiment. The experiment studies the scattering of particle Y off heavy nuclei. Measurements of $\frac{d\sigma}{d\Omega}$ at $q = 0.5$ GeV/c and $q = 5$ GeV/c have the same value. However, the measurment at $q = 0.5$ GeV/c has a negligible uncertainty and the measurement at $q = 5$ GeV/c has a fractional uncertainty of 1%. The uncertainty on q is negligible.

What can be deduced about the mass of the particle exchanged in the scattering ? Is this consistent with the weak force ?

3 The cross section for the production of a Higgs boson in proton-proton collisions at 14 TeV centre-of-mass energy is ~ 40000 fb. Estimate the integrated luminosity required to observe five Higgs bosons using a detector at a 14 TeV proton-protoncollider. List factors which could imply that your estimate is too low.

4 The Z^0 boson has a mass of 91 GeV/c^2 and a lifetime of 4×10^{-25} s. Assume that an electron and a positron (an anti-electron) can only interact with each other via an annihilation process to give a Z^0 i.e. electron+positron $\to Z^0$.

Consider an accelerator at which electrons and positrons collide. Sketch the dependence of the cross section for electron and positron interactions with the centre-of-mass energy of the collision. You do not have to evaluate the value of the cross section value - you have to show how it changes with centre-of-mass energy.