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Standard Model of Particle Physics
Exercises Three

1. a. What was the total luminosity in the events collected by the ATLAS and CMS experiments at the LHC during 2011 and 2012? Hint: you will need to look this up.

1. b. How many $b\bar{b}$ pairs were produced at the LHC during those two years? Estimate how many Higgs bosons were produced.

2. a. Write down the Lagrangian for a $U(1)$ gauge theory with a Higgs field of charge q. Include the potential for the Higgs field.

2. b. Under what conditions on the parameters of the potential does the vacuum spontaneously break the gauge symmetry? Calculate the vacuum expectation value of the Higgs field.

2. c. Explain how and why the gauge field becomes massive and calculate its mass.

3. a. Show, for a Dirac spinor field Ψ, that $\bar{\Psi}\Psi = \bar{\Psi_L}\Psi_R + \bar{\Psi_R}\Psi_L$

4. a. Explain in detail why there are no bare mass terms allowed for any particles in the Standard Model.

4. b. How then, do the fermions acquire mass?

4. c. Write a gauge invariant interaction between the Standard Model Higgs field and the fields representing muons and anti-muons. Explain how this interaction allows the Higgs boson to decay into a muon/anti-muon pair.

4. d. Explain why the decay width of the Higgs boson into $\mu^+\mu^-$ is proportional to m_μ^2 and estimate how much more likely it is for the Higgs to decay to $\mu^+\mu^-$ than to e^+e^-.

5. Describe the basic structure of an LHC detector; describe the different sub-detectors and what they are each for. Describe how we can detect a photon? An electron? A proton? A muon? A neutrino?

6. Explain why, even though a 125 GeV Higgs prefers to decay into $b\bar{b}$ pairs over photons, the Higgs was first discovered via its decays to photons.