Subatomic Physics II

Problem Set 8

Due on December 2, 2021, 11:59 PM

Problem 8.1: Higgs boson properties

During Run 1, the LHC discovered the Higgs boson and investigated many of its properties. Using the information from the CMS Higgs discovery paper and from the PDG website, answer the following questions:

- What are the dominant Higgs boson production channels at LEP and at the LHC? Draw the Feynman diagrams.
- What is the dominant decay channel of the Higgs boson at $M_h = 125$ GeV?
- Calculate the branching ratio of the Standard Model Higgs boson decay in the "golden channel" $h \to ZZ^* \to l_1^+ l_2^- l_3^+ l_4^-$, where l is either e or μ.
- The LHC discovered $h \to \tau^+\tau^-$ in 2016 but had to wait until 2020 to find $h \to \mu^+\mu^-$, despite the fact that muons are much easier to detect and reconstruct than τ's (why?). Explain why this is.

(4pt)

Problem 8.2: Fighting misconceptions

In 2012, many newspapers published news stories covering the Higgs boson discovery. These news stories often misinterpreted the real situation and sometimes spread misconceptions. Below are some typical examples of the false statements about the Higgs physics. For each statement, explain why exactly it is wrong and what should be the correct statement.

- Higgs bosons are responsible for masses of all other particles.
- Higgs mechanism gives mass to all massive objects in the Universe (ignoring Dark Matter).
- The Higgs mechanism produces mass, and masses gravitate, therefore the Higgs mechanism is the origin of gravity.

(3pt)

Problem 8.3: Non-standard Higgses

Many models beyond the Standard Model predict *extra* scalar bosons, in addition to the Higgs boson h already discovered. These new Higgs bosons can be neutral H or charged, H^+ and H^-, and can have properties very different from the properties of h.

Suppose that all new bosons are *fermiophobic*, that is, they do not couple to fermions but couple to the bosons and couple among themselves. Also assume that these new bosons are sufficiently heavy: $M_H, M_{H^\pm} > 300$ GeV.

- Draw all tree-level Feynman diagrams you can think of for production and, separately, for the decay of H and of $H^\pm$ at the LHC.
- New charged Higgs bosons $H^\pm$ can also modify the two-photon decay of the Standard-Model-like boson $h \to \gamma\gamma$. Explain how it can happen and draw the diagram supporting your explanation.

(3pt)