Mid-term exam of Particle Physics
Thursday November 15th 2018

Exercice I

Questions on the lecture

Reply shortly and succinctly to the questions below. The shortest answer that details all the relevant arguments is the best.

1. What is G-parity? Explain the logic behind this quantum number and in which cases is it useful.
   G-parity is multiplicative quantum number, which is a generalization of charge conjugation. It is applicable to isospin multiplets and to systems of particles. The G operator is obtained by a rotation of 180 degrees around the isospin quantization axis, followed by the charge conjugation $\hat{C}$. *The Strong interaction conserves both* C *and isospin. It follows that if a process is forbidden by charge conjugation, other processes obtained by isospin rotation are also forbidden. In isospin multiplets that contain an* $I_3 = 0$ *member (integer* I*), this member is the only* $\hat{C}$*-eigenstate. If its eigenvalue is* C*, the G-parity of the multiplet is* $C(-1)^I$ *(in practice this relation is used for* $I = 0, 1$*). If G-parity is not conserved the process cannot occur via strong interaction.*

2. Explain the behavior of the QCD running coupling constant. Which characteristics of the strong interaction does it allow to explain?
   The running coupling is the evolution of the coupling constant from its value at a given energy (renormalization scale). In a quantum field theory, virtual quark-antiquark pairs can be created around a quark, as long as they live less than about $\hbar/mc^2$ *(*m *is the mass of the quark). These pairs screen the initial quark's color charge, and as a result the coupling becomes smaller at large distances due to this phenomenon. The exact same thing exists in QED. Thus, in QCD, there is also an opposite effect: in addition to the effect of screening from virtual* $q\bar{q}$ *pairs, the gluons can interact with themselves. These gluons carry away color, so that they cause anti-screening that makes the strong coupling,* α_s*, larger at large distances. While screening is proportional to the number of quark flavors, anti-screening is proportional to the number of colors (related to the number of gluons). The balance between the two causes* α_s *to decrease at small distances (leading to the asymptotic freedom of quarks in a hadron) and to diverge in large distances (leading to the confinement of quarks in a hadron).*