

SCPY322 Nuclear and Particle Physics

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Lecture 6. Friday 6, May 2021

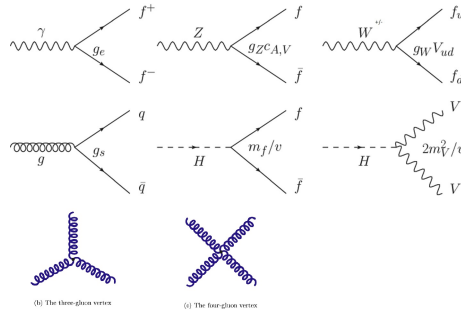
Reviews of the Last Lecture

7 Fundamental Interactions (Cont.)

We have a set of standard model particles, i.e., leptons and quarks, a set of gauge bosons of fundamental force fields, except gravity. The fundamental interactions are described in form of Yukawa-type interaction, i.e., interact by exchange gauge bosons.

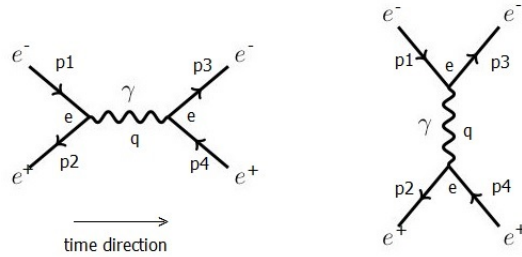
The interaction is convenient to describe by Feynman diagram:

- charged particle is represented by arrow, its anti-particle is represented in opposite direction. Neutral particle is represented by a line without arrow, i.e, its anti-particle is itself
- gauge bosons are represented by a wavy lines correspond to their nature of interaction, i.e., wave for photon, dashed line for massive vector bosons, and spring for strong gluon.
- interaction vertex is represented by incoming particle emit/absorb gauge boson and go out, with specified charge, i.e., electric charge, weak charge, or color charge.
- gluons interact with themselves, i.e., 3-gluon vertex and 4-gluon vertex, according to non-linear Yang-Mills vector field
- Higgs particle coupling with fermions and vector gauge bosons



7.1 Electromagnetic interaction

Charged particles interact exchange photon, a quantum of EM fields, i.e., $e^-e^+ \rightarrow e^-e^+$ Bhabha scattering.



The correct diagrams represent conservation of energy-momentum, charge, and all quantum numbers, i.e.,

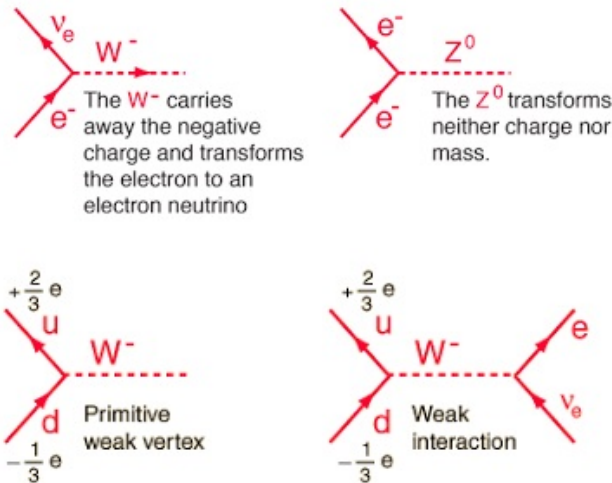
$$(a) \quad p_1 + p_2 = q = p_3 + p_4 \quad (7.1)$$

$$(b) \quad p_1 - p_3 = q = p_4 - p_2 \quad (7.2)$$

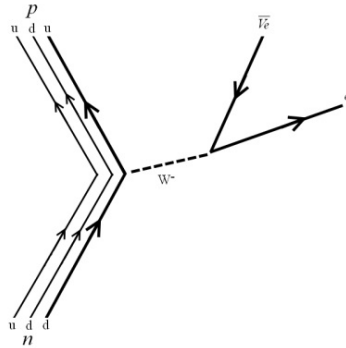
$$L_e \quad 1 + (-1) = 0 = 1 + (-1) \quad (7.3)$$

7.2 Weak interaction

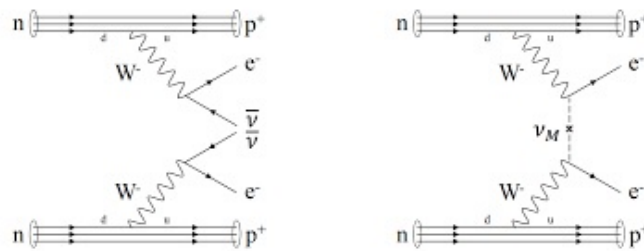
Primitive weak interactions



For example beta decay



Double beta decay (ν_M is Majorana neutrino)

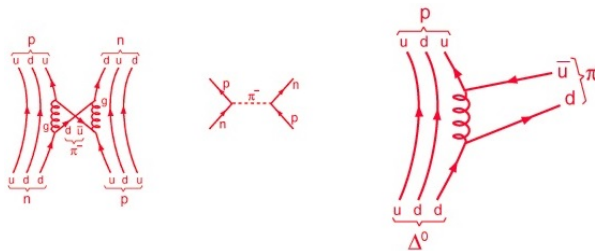


7.3 Strong interaction

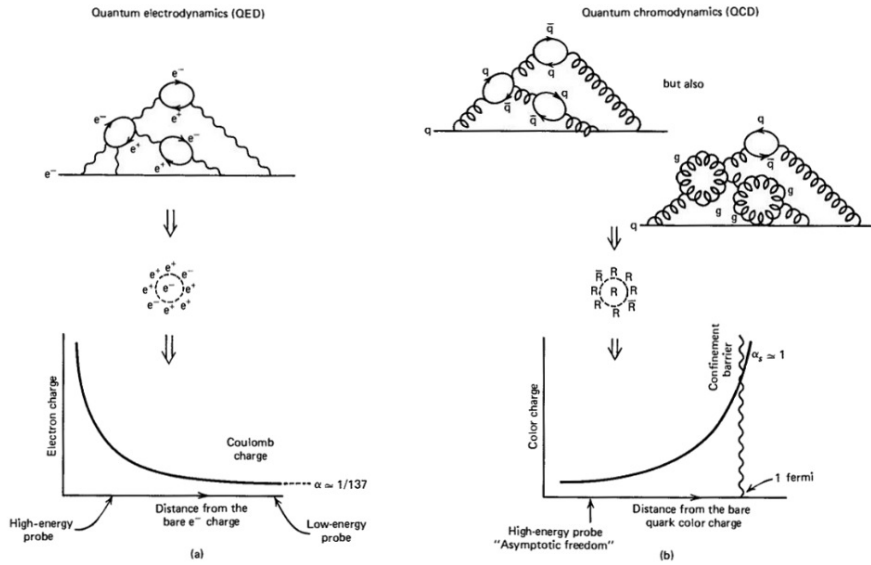
Primitive strong nuclear interactions

$$\text{Yukawa} \quad p + n \rightarrow p + n \quad (7.4)$$

$$\text{Decay} \quad \Lambda^0 \rightarrow p^+ + \pi^- \quad (7.5)$$

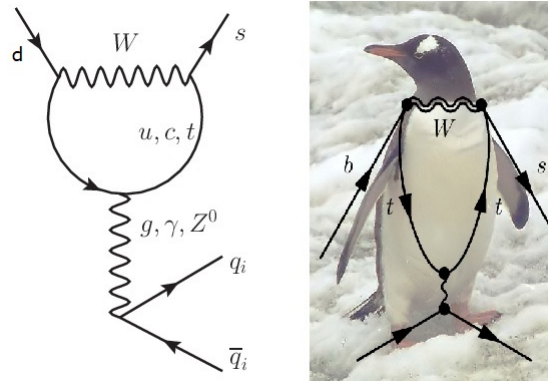


Asymptotic freedom of gluon fields



7.4 Electroweak unification and Higgs particle

Penguin diagram of d-quark EW decay



Higgs production

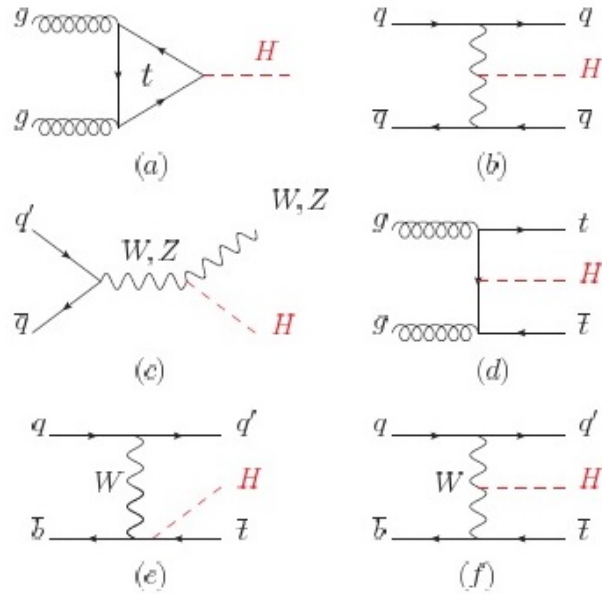
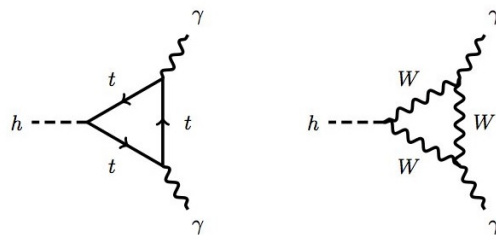


Figure 11.1: Main Leading Order Feynman diagrams contributing to the Higgs production in (a) gluon fusion, (b) Vector-boson fusion, (c) Higgs-strahlung (or associated production with a gauge boson), (d) associated production with a pair of top (or bottom) quarks, (e-f) production in association with a single top quark. with top quarks.

Higgs decay



LHC and the Higgs boson

