

## 5/10/17 Lecture 11 outline

- Write  $\mathcal{L}_{\text{mug}}$  and a bit of overview of the Standard Model and the topics for the rest of the class.

- Brief discussion of renormalization: loops give quantum corrections to masses and couplings. Examples.

- Cases where mass corrections are forbidden by symmetry. Recall gauge vs global symmetry.

- $P_{L,R} = \frac{1}{2}(1 \mp \gamma_5)$ ,  $\mathcal{L} = \bar{\psi}(P_L^2 + P_R^2)(i\not{d} - m)\psi = \bar{\psi}_R i\not{d}\psi_R + \bar{\psi}_L i\not{d}\psi_L - m\bar{\psi}_R\psi_L - m\bar{\psi}_L\psi_R$ .

Mass terms mix helicity, massless fermions can have well-defined helicity:  $\mathcal{L} = \bar{\psi}(P_L^2 + P_R^2)(i\not{d} - m)\psi = \bar{\psi}_R i\not{d}\psi_R + \bar{\psi}_L i\not{d}\psi_L - m\bar{\psi}_R\psi_L - m\bar{\psi}_L\psi_R$ .

- QED: seems the electron is a Dirac Fermion, with both helicities, since it is massive. Actually, the electron is chiral; this is seen when E+M are unified with the weak force. All of the known fermions of the SM are chiral. Not known if any fundamental (elementary) Dirac fermions exist in nature. Nothing forbids it, but since they can have large mass, unprotected by any symmetry, they are expected to be extremely massive if they exist, unless there is fine tuning. Actually, as far as we know, there is fine tuning.

- The large  $s$  limit.

- Helicity.

- Left and right-handed chiral fermions. Mention again SM Fermions, and that they're actually all chiral.

- Parity and its violation in  $\beta$  decays: into the looking glass.

- $CP$  and  $CPT$  and Feynman's story.

- Start isospin. History: nuclear physics has a symmetry that rotates proton into neutron. Sounds weird (they have different electric charges), but the point is that the strong force, i.e.  $SU(3)_C$  doesn't distinguish between  $ps$  and  $ns$ , though the electroweak force does.  $SU(2)_I$  representations, for  $p$  and  $n$ .