

## Particle Physics, Autumn 2014 CMI

### Problem set 1

Due by beginning of lecture on Tuesday Oct 7, 2014

### Lightest baryons and mesons

Note: These problems are to be attempted without looking up the answers in books/internet. We have discussed the necessary background in class.

1. ⟨23⟩ The lowest lying (lowest mass) baryons made of the light quarks  $u, d, s$  are

$$n(udd), p(uud), \Sigma^-(dds), \Sigma^0(uds), \Sigma^+(uus), \Lambda^0(uds), \Xi^-(dss), \Xi^0(uss). \quad (1)$$

The valence quark constituents are indicated, suppressing symmetrization/anti-symmetrization of flavors.

- (a) ⟨3⟩ Tabulate the charge  $Q$ ,  $I_3$ ,  $B$  (baryon number) and  $S$  (strangeness) of these baryons. Note: Strangeness  $S$  counts the number of anti-strange quarks minus number of strange quarks.  $u, d$  form an isospin  $\frac{1}{2}$  doublet with  $I_3 = \pm\frac{1}{2}$  and strangeness zero. The strange quark is an isospin zero state.
- (b) ⟨3⟩ Arrange these 8 baryons in an  $I_3$  vs  $S$  plot, with  $I_3$  increasing to the right and  $S$  upwards. Identify the contours of constant charge in this diagram.
- (c) ⟨2⟩ Identify two isospin doublets, an isospin singlet and an isospin triplet from among these baryons (state the names of the particles involved).
- (d) ⟨3⟩ Guess a linear relation among these four quantum numbers ( $Q, I_3, B, S$ ) based on the data for these baryons.
- (e) ⟨12⟩ These are stable baryons, they do not decay exclusively through strong interactions. Draw lowest order quark level Feynman diagrams for the beta decay (i)  $n \rightarrow pe\bar{\nu}_e$  and strangeness changing weak decays (ii)  $\Lambda^0 \rightarrow p\pi^-$ , (iii)  $\Sigma^- \rightarrow n\pi^-$  and (iv)  $\Sigma^+ \rightarrow p\pi^0$ . Take time to run roughly from left to right. You may treat  $\pi^0$  as  $u\bar{u}$  and  $\pi^-$  as  $d\bar{u}$  here.
2. ⟨8⟩ The lowest lying (lowest mass) mesons made of the light quarks  $u, d, s$  are

$$\pi^-(d\bar{u}), \pi^0(d\bar{d} - u\bar{u}), \pi^+(u\bar{d}), K^0(d\bar{s}), K^+(u\bar{s}), K^-(s\bar{u}), \bar{K}^0(s\bar{d}), \eta^0(d\bar{d} + u\bar{u} - 2s\bar{s}). \quad (2)$$

- (a) ⟨3⟩ Tabulate the  $Q, I_3, B, S$  quantum numbers of these mesons.
- (b) ⟨3⟩ Arrange these mesons in an  $I_3$  vs  $S$  plot as before and mark the contours of constant charge.
- (c) ⟨2⟩ Check whether the proposed relation among  $Q, I_3, B, S$  is satisfied by these mesons.