Handout 14 (read by Feb. 5)

5.4.1 The Eightfold Way (M. Gell-Mann and Y. Ne'eman, Benjamin, New York, Amsterdam, 1964). First, we recall the evidence of an (approximate) SU(3) symmetry in the "particle zoo" by means of the meson octet and the baryon octet. To that end, we consider groupings of strongly interacting particles with similar masses and the same space-time properties, i.e., spin J and transformation behavior $P = \pm 1$ under parity. We organize these particles with respect to the so-called hypercharge Y and the isospin projection I_3. The hypercharge Y consists of the baryon number B ($B = 1$ for baryons and $B = 0$ for mesons) and the strangeness quantum number S,

$$Y = B + S.$$

The charge Q of a particle is given by the Gell-Mann-Nishijima relation

$$Q = I_3 + \frac{Y}{2}.$$

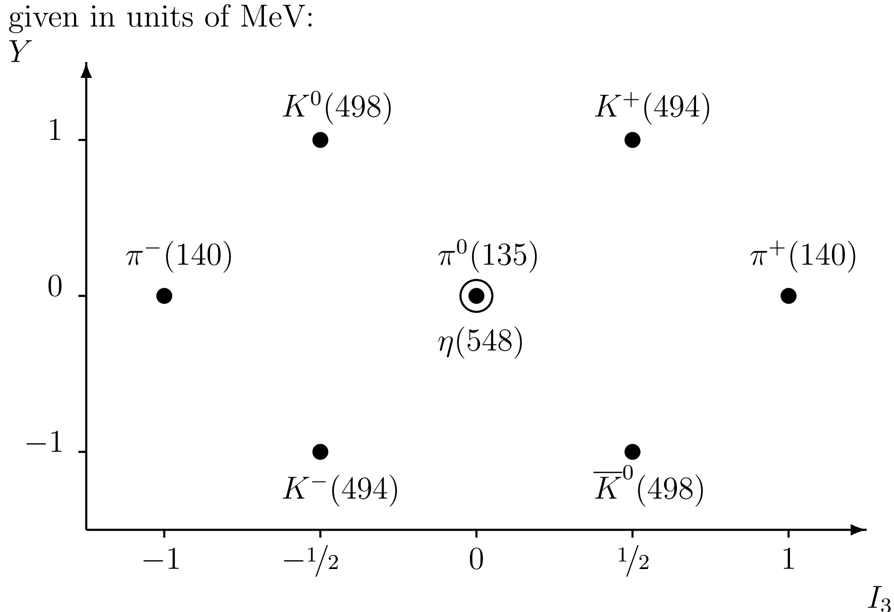
The quantities B, S, and I_3 are conserved in the strong interaction and the corresponding quantum numbers are additive.

A typical entry for mesons in the *2018 Review of Particle Physics* by the Particle Data Group (PDG) consists of specifying the combination $I^G(J^{PC})$. The so-called G conjugation is a rotation by $-\pi$ about the 2 axis followed by a charge-conjugation transformation:

$$G = C \exp(i\pi I_2).$$

Charge conjugation C is an internal symmetry transforming a particle state into the corresponding antiparticle state and viceversa. The eigenvalue of G is referred to as G parity. In the case of baryons, the entry consists of $I(J^P)$, because charge conjugation transforms a baryon with baryon number $+1$ into an antibaryon with baryon number -1.

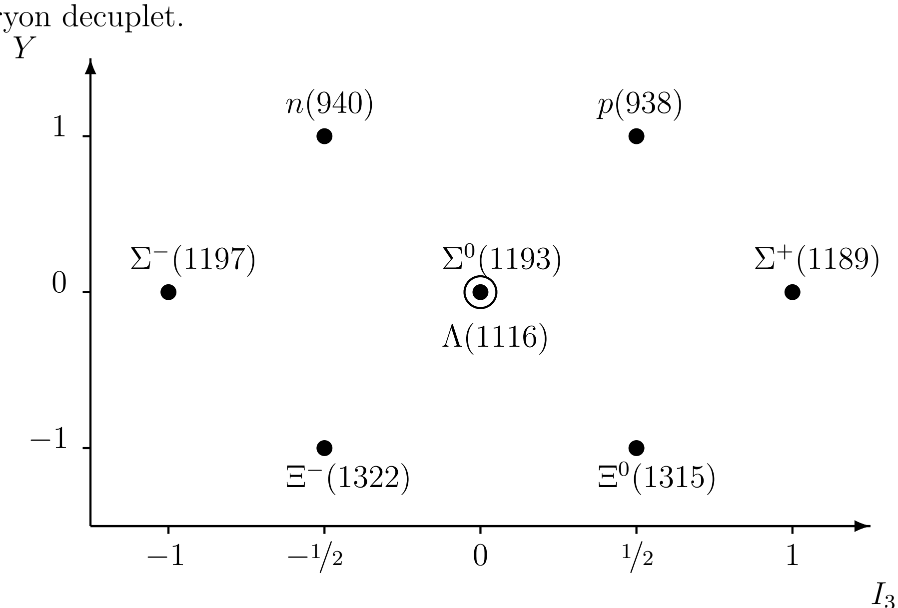
Let us consider the lightest pseudoscalar meson octet with $J^P = 0^-$ in an (I_3, Y) diagram. The circle and the ring indicate that two states with $(I_3, Y) = (0, 0)$ exist. The masses in brackets are given in units of MeV:

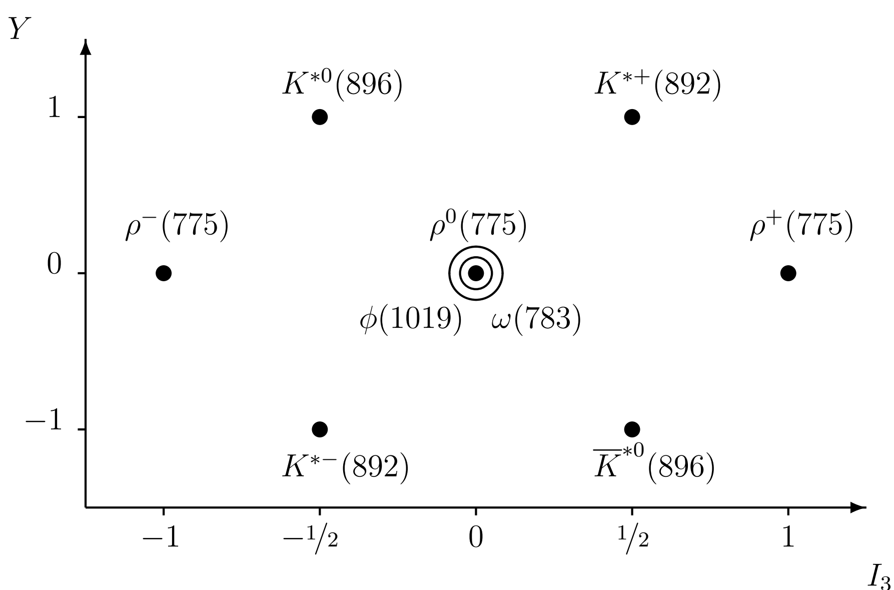


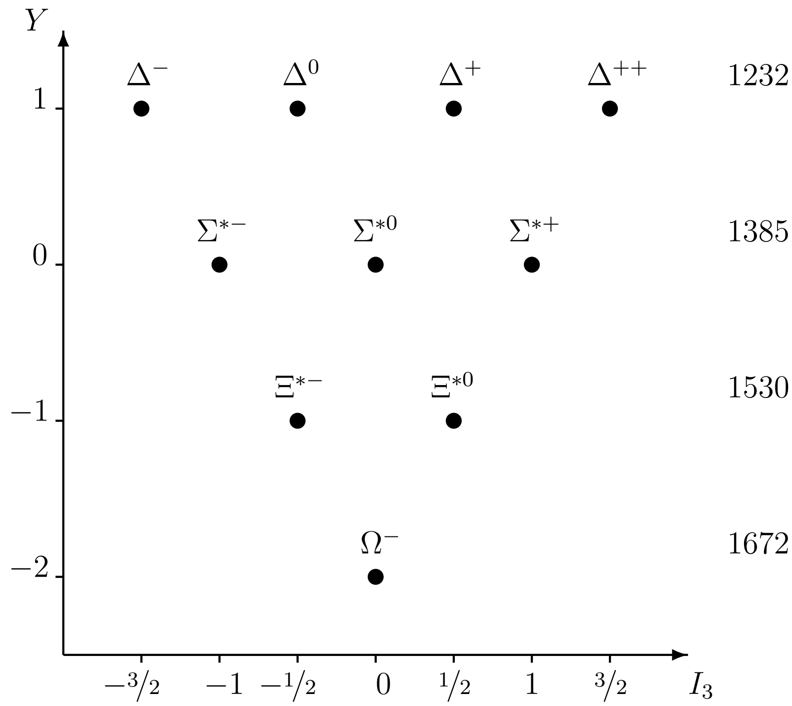
The corresponding PDG entries read

$$
\begin{aligned}
\pi^0 : &\quad 1^-(0^{-+}) \\
\pi^\pm : &\quad 1^-(0^-) \\
\eta : &\quad 0^+(0^{-+}) \\
K^\pm : &\quad \frac{1}{2}(0^-) \\
K^0\,(\overline{K}^0) : &\quad \frac{1}{2}(0^-)
\end{aligned}
$$

Note that the pairs (K^+, K^0) and $(\overline{K}^0, K^-)$ each form isospin doublets. Within the quark model, the states of the pseudoscalar octet are composite states originating from the coupling of a quark triplet $q = (u, d, s)$ with a conjugate triplet $\bar{q} = (\bar{u}, \bar{d}, \bar{s})$ consisting of antiquarks. At the beginning of the 1960s, the yet partially incomplete multiplets were taken as evidence of an approximate SU(3) symmetry. In particular, the existence of the then still missing Ω^- baryon was predicted. Further SU(3) multiplets are the baryon octet, the vector-meson nonet, and the baryon decuplet.







Y
Δ^-
Δ^0
Δ^+
Δ^{++}
1232
Σ^{*-}
Σ^{*0}
Σ^{*+}
1385
Ξ^{*-}
Ξ^{*0}
1530
Ω^-
1672
1
0
-1
-2
$-3/2$
-1
$-1/2$
0
$1/2$
1
$3/2$
I_3