The $\Delta(1232)^{++}$ baryon is OK

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Consider the $\Delta^{++}(1232)$ baryon. Standard Model textbooks state that the single particle wave functions of its three *uuu* quarks are symmetric ground state s-waves. This claim is based on the following argument: The $\Delta^{++}(1232)$ is the lightest state of the *uuu* quarks. Therefore, each of its three *uuu* quarks should be a single particle ground state s-wave, namely, a symmetric spatial state. Furthermore, the quantum numbers of the $\Delta(1232)^{++}$ are $J^\pi = 3/2^+$, which is a symmetric spin state. Hence, the data demonstrate a fiasco of the Fermi-Dirac statistics of ordinary quantum mechanics (see e.g. [1], p. 5).

This is an incomplete approach, because it resembles the case where one examines just a single tree and ignores the entire forest. And indeed, the following lines describe the entire relevant data. The four $\Delta(1232)$ baryons

$$(\Delta^-,\ \Delta^0,\ \Delta^+,\ \Delta^{++}), \tag{1}$$

are members of the lightest isospin quartet of the Δ baryons. Hence, the analysis should go as follows. Let us examine two isospin multiplets

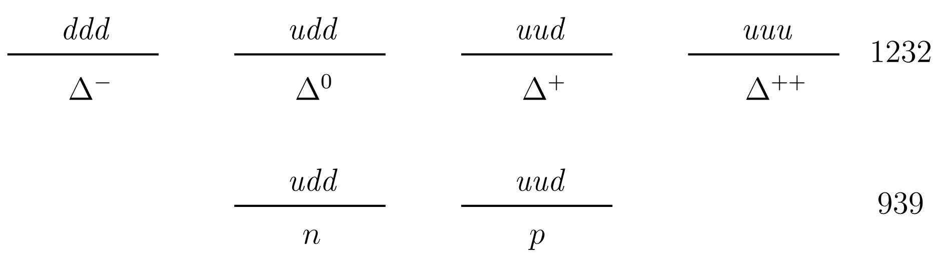

Fig. 1: Energy levels (in MeV) of members of two baryonic isospin multiplets. Valence quarks of each baryon are marked above its line.

Fig. 1 illustrates the energy levels of the two I=1/2 nucleons and those of the four I=3/2 $\Delta(1232)$ baryons. The goodness of the isospin notion indicates that all the $\Delta(1232)$ baryons have the same space, spin and isospin symmetry (for reading a proof of this claim, see [2], p. 73). Furthermore, fig. 1 shows clearly that the Δ^0 and the Δ^+ baryons are *excited states* of the neutron and the proton, respectively. As excited states, the laws of ordinary quantum mechanics prove that the Δ^0 and the Δ^+ baryons should have excited space and spin states. This conclusion holds for every member of the isospin quartet (1). Hence, the single particle spatial part of the Δ^{++} uuu quarks is *not* a ground state s-wave and its entire state is consistent with the laws of ordinary quantum mechanics.

Points A, B refer to the Δ^{++} baryon, which is the lightest baryon of this kind, and show where QCD went wrong.

A. QCD aims to provide an answer to the wrong question: What are the quark's additional degrees of freedom that enable 3 uuu valence quarks be in the $1s^3$ state without violating the Pauli exclusion principle?

B. This page proves that the right questions are: What is the proton structure, and what are the laws of strong interactions, that put the 3 uuu valence quarks in a state that is not $1s^3$?

For further reading, see [3]

References:

[1] F. Halzen and A. D. Martin, *Quarks and Leptons* (Wiley, New York, 1984).

[2] S. S. M. Wong, *Introductory Nuclear Physics* (Wiley, New York, 1998)

[3] E. Comay, EJTP, **9**, No. 26 (2012) 93118
`http://www.ejtp.com/articles/ejtpv9i26p93.pdf`