# THE HIGGS BOSON AND QUARK COMPOSITENESS

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Considering that each quark is composed of two prequarks it is shown that the recently found Higgs boson belongs to a triplet of neutral bosons, and that there are two quadruplets of charged Higgs-like bosons. The quantum numbers of these bosons are calculated and shown to be associated to a new kind of hypercharge directly linked to quark compositeness. Particularly, the quantum number of the recently found Higgs boson is identified. A chart for quark decays via virtual Higgs-like bosons is proposed. Justifications for quark compositeness are presented.

## 1 Introduction

The ATLAS [1,2] and CMS [3] collaborations have reported the remarkable discovery of a narrow resonance with a mass of about 126 GeV, resembling the long-sought Higgs boson predicted by the Standard Model (SM). This discovery was supported by data from the Tevatron [4]. At the Rencontres de Moriond 2014 ATLAS and CMS reported recent analyses on the Higgs boson that agree, in general, with SM predictions. In particular, the Higgs boson spin has been found to be zero. But, its parity continues to be an open issue because it became clear at this conference that the determined even parity for the Higgs boson is model dependent with respect to parity conservation. On the other hand, the BaBar collaboration has reported discrepancies with the SM at the $3.4\sigma$ level that points towards the direction of charged Higgs-like bosons [5].

## 2 The quark compositeness model

Taking as starting point the distributions of electrical charges in the nucleons, as found by Hofstadter [6], de Souza [7,8] has proposed a compositeness model for quarks in which each quark is composed of two prequarks, called primons. Hofstadter found that the nucleons have similar central cores with a radius of about 0.2 fm as well outer shells with radii of about 0.7 fm. According to the quark compositeness model the 6 quarks are formed by pairs of different primons from the set of 4 primons $p_1, p_2, p_3, p_4$, as $u = p_1p_2$, $d = p_2p_3$, $s = p_2p_4$, $c = p_1p_3$, $b = p_3p_4$ and $t = p_1p_4$. The eletrical charges are given as: $+5/6e$ for $p_1$ and $-1/6e$ for the other primons. Each primon is a fermion but with $S_z = \pm 1/4\ \hbar$ in order to obtain $S_z = \pm 1/2\ \hbar$ for quarks. As to isospin $p_1$ has $I_3 = +1/4$ , and $p_2, p_3, p_4$ have each $I_3$ equal to $+1/4$ or $-1/4$ [8]. From modified Gell-Mann and Nishijima relations it is found that a new quantum number $\Sigma_3$ is associated to primons [8], and as a consequence, also to quarks, according to Table 1 below. The values of $\Sigma_3$ for antiquarks are obtained from those displayed in Table 1 by just multiplying them by $-1$. Since $\Sigma_3$ is associated to primons and quarks, it is expected that leptons (and antileptons) and the bosons $\gamma$, $Z^0$, $\bar{Z}^0$, $W^+$ and $W^-$ should have $\Sigma_3 = 0$.

Table 1: The quantum numbers $\Sigma_3$ and $I_3$ for quarks.

| | $I_3$ | $\Sigma_3$ |
|---|---|---|
| c,t | 0 | +1 |
| u | +1/2 | 0 |
| d | -1/2 | 0 |
| s,b | 0 | -1 |

Table 2: The quantum numbers for the Higgs-like bosons $H^0$, $H^+$, and $H^-$.

| | $\Sigma_3$ | Spin |
|---|---|---|
| $H^0$ | $0, \pm 1$ | 0 |
| $H^+, H^-$ | $\pm 1, \pm 2$ | 0 |

It is important to notice that the Cabbibo factors of the specific weak decays of all hadrons are directly related to the values of $\Delta\Sigma_3$ for each respective decay [9]. This compositeness model solves a large number of problems in Particle Physics [8] such as the so-called proton spin puzzle. The model agrees also with G. Miller analysis [10] of the charge density in the center of the neutron since he found a total charge of $-1/3e$ inside its central positive core. The central hard core with a radius of about 0.2 fm has also been seen by many experiments at CERN and Fermilab along the years, and recently by the TOTEM collaboration at 7 TeV [11,12] and 8 TeV [13]. Therefore, the core is extremely tightly bound, and thus, if it were composed of valence quarks it would be incompatible with asymptotic freedom.

It is also important to observe that the current views for the proton as being composed of a hard core of valence quarks surrounded by either a pion cloud or a sea of $q\bar{q}$ pairs are incompatible with Hofstadter [6] results since according to his findings the hard core has a total charge of $+1/2e$ and not $+1e$. It is worth recalling that charges do not appear in Bjorken scaling structure functions [14]. We should have in mind that at high $q^2$ the de Broglie wavelength $h/q$ is very small and, thus, we probe the 3 inner prequarks and identify them as being 3 valence quarks due to the lack of identification of their charges.

## 3 The Higgs-like bosons quantum numbers

Taking into account the charges of primons, the composition of quark flavors above and the $\Sigma_3$ assignements for primons [8], the Higgs-like bosons quantum numbers are determined as displayed in Table 2. As it is discussed in reference 8 the mass of each quark is generated by the interaction between each pair of primons (forming a quark) via a Higgs-like boson. Thus, $H^{\pm}(\pm 2)$ generate the $u$ quark mass, and $H^{\pm}(\pm 1)$ generate the masses of quarks $c$ and $t$. The masses of quarks $s$ and $b$ are generated by $H^0(\pm 1)$ and $H^0(0)$ generates the mass of quark $d$. Since the $S_z$ values for the two primons composing each quark have to be equal to $+1/4\,\hbar$ and $+1/4\,\hbar$ or to $-1/4\,\hbar$ and $-1/4\,\hbar$, the Higgs-like boson spin has to be equal to zero.

## 4 The quantum number of the recently found Higgs boson

The recently found boson decays into many particles. The decays $H^0 \to b\bar{b}$ [15], $H^0 \to \tau\bar{\tau}$ [16], $H^0 \to W^+W^-$ [17], $H^0 \to Z^0\bar{Z}^0$ [18], and $H^0 \to \gamma\gamma$ [1,2,3] have been reported. In terms of $\Sigma_3$ values the right side for these decays are $+1 + (-1)$ for the decay $H^0 \to b\bar{b}$, and $0 + 0$ for the other

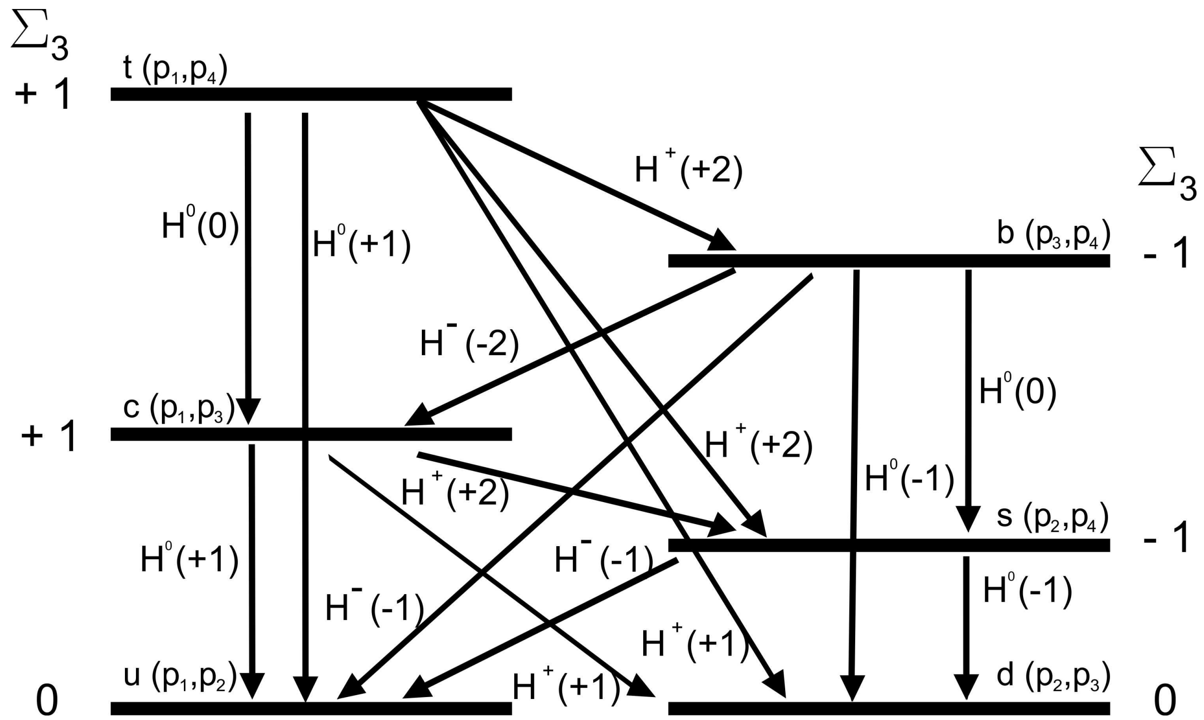


Figure 1 – Quark decays via virtual Higgs-like bosons

decays. This means that the recently found Higgs boson is, actually, the Higgs-like boson $H^0$ with $\Sigma_3 = 0$, that is, it is the boson $H^0(0)$. Because $H^0(0)$ is a neutral boson with spin zero it resembles the SM Higgs boson, but it is not.

## 5 The search for the charged Higgs-like bosons

The bosons $H^+$ and $H^-$ as well as the bosons $H^0(+1)$ and $H^0(-1)$ can be found from weak decays of heavy mesons such as the decay $\bar{B} \to D^{(*)}\tau^-\bar{\nu}_\tau$ analysed by the BaBar collaboration. BaBar has reported an excess that points in the direction of charged Higgs-like bosons [5]. All the weak decays $B^- \to D^0\tau^-\bar{\nu}_\tau$, $B^- \to D^{*0}\tau^-\bar{\nu}_\tau$, $\bar{B}^0 \to D^+\tau^-\bar{\nu}_\tau$ and $\bar{B}^0 \to D^{*+}\tau^-\bar{\nu}_\tau$ reported by BaBar satisfy the selection rule $\Delta\Sigma_3 = 2$ [9]. In terms of quarks and primons these decays mean, respectively $b \to c + H^-(-2)$ and $p_4 \to p_1 + H^-(-2)$, where $H^-(-2)$ is a virtual particle. Thus, in terms of $\Sigma_3$ these decays mean $-1 = +1 + (-2)$. Therefore, in these decays due to a $\Sigma_3$ current, there is the mediation of the Higgs-like boson $H^-(-2)$, and thus, these decays are

$$B \to D + H^-(-2). \tag{1}$$

In Fig. 1 all possible decays between quarks via virtual Higgs-like bosons are shown.

## 6 Estimating the values of Higgs-like bosons couplings in quarks

In the calculations below we assume about the same mass for all Higgs-like bosons, that is, we use the same value for $\mu$. This is reasonable because according to what was shown above, $H^0(0)$ and $H^\pm(\pm2)$ generate, respectively, the masses of $d$ and $u$ quarks, which are about 0.3 GeV. We use $m_q c^2 \sim G\frac{e^{-\mu r}}{r}$ where $m_q$ is the quark mass. For quarks $u$ and $d$ we take for $r$ the value between the two layers of primons from Hofstadter data, that is, $r \sim 0.5$ fm, and we take $\mu$ from the mass of the found Higgs boson, that is, $\mu \sim 10^2$ fm$^{-1}$. We obtain $g = G/\hbar c \sim 10^{21}$ which is an extremely high value and may be the reason behind quark confinement in the nucleons. For quarks $s, c, b$ and $t$ we take for $r$ their Compton wavelengths which are, respectively, $\lambda_s \sim 0.3$ fm, $\lambda_c \sim 0.1$ fm, $\lambda_b \sim 0.03$ fm and $\lambda_t \sim 10^{-3}$ fm. Taking for their masses the respective values

$m_u c^2 \sim m_d c^2 \sim 0.3$ GeV, $m_s c^2 \sim 0.5$ GeV, $m_c c^2 \sim 1.5$ GeV, $m_b c^2 \sim 4.5$ GeV and $m_t c^2 \sim 170$ GeV, and inserting these values into the above equation for $m_q$ we obtain the Yukawa couplings $g_u \sim g_d \sim 10^{21}$, $g_s \sim 10^{13}$, $g_c \sim 10^4$, $g_b \sim 10$, and $g_t \sim 1$.

## 7 Entanglement of prequarks, valence quarks and true quarks (constituent quarks)

The great success of the Standard Model is due to the large distance between the inner and outer layers of 3 prequarks, so that QCD deals with the 3 outermost massless prequarks and attributes to them the charges and masses of the 3 constituent quarks. This outer layer of 3 prequarks is not tightly bound according to Hofstadter results which is compatible with the idea of asymptotic freedom. This means that the 3 quarks and the outer layer of 3 prequarks are entangled. This way we can also understand why there is a mean coupling constant which is the coupling constant found by QCD. And also due to constituent quarks, which are the true quarks, the harmonic approximation is very good for describing baryon masses [19] and the radii of baryons [20]. In these two references one finds the calculation of the masses and radii of almost all baryons. This entanglement between prequarks and quarks mean that the null D0 collaboration results on quark compositeness [21] as well as the most recent results from CMS [22] should refer, actually, to prequarks (primons). That is, D0 and CMS have found that primons are pointlike.

## 8 Conclusion

We have presented a completely new view according to which the compositeness of quarks is directly connected with the recently found Higgs boson and this boson is, actually, just one of the neutral bosons of a triplet. It has been shown that there should also exist two quadruplets of charged Higgs-like bosons. The quantum numbers of all these Higgs-like bosons are calculated. A chart for the decays of quarks via virtual Higgs bosons is presented.

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