

# The Charged Higgs-like Bosons Have Already Been Observed by the ATLAS and CMS Collaborations

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**Abstract** Taking into account a very solid quark compositeness model, based on the electrical charge densities of the nucleons found by R. Hofstadter, R. Herman, L. Durand and R. R. Wilson in the early 1960s, from which a new quantum number is deduced, and the experimental data on the Higgs boson obtained by the ATLAS and CMS Collaborations, this article shows that these collaborations have already seen the charged Higgs-like bosons by means of the  $WW$  channel. The data also imply that the charged and neutral Higgs-like bosons have similar masses, and that the Higgs-like bosons have odd parity like the other fundamental bosons of Nature. The ratio between the productions of charged to neutral Higgs-like bosons is calculated.

**Keywords** Charged Higgs-like Bosons, Higgs-like Boson, Higgs Boson

## 1. Introduction

In 2012 the ATLAS and CMS collaborations announced the remarkable discovery of a boson resembling the long sought Higgs boson of the Standard Model of Particle Physics [1,2,3] with a mass of about 125 GeV. That is why it has been called a Higgs-like boson.

Since then the Higgs-like boson has been observed in the channels  $\gamma\gamma$ ,  $ZZ$ ,  $WW$ ,  $\tau^+\tau^-$  and  $b^+b^-$  [4].

It is important to have in mind that the Standard Model does not provide any Higgs boson quantum number, so that the above Higgs decay modes are not explained in terms of selection rules dictated by Higgs quantum numbers.

On the other hand, taking into account the distributions of electrical charges inside the nucleons, as found by R. Hofstadter, R. Herman, L. Durand and R. R. Wilson [5,6,7,8], which are shown below in Figure 1, de Souza proposed in 2005 [9] that each quark is composed of two prequarks (called primons). Since then the compositeness model has been improved and proven to be more consistent with the experimental results.

According to the model there is a new quantum number  $\Sigma_3$  directly related to quark compositeness, and because of its existence, the Higgs-like boson is, actually, a multiplet. The model shows that this new quantum number is the reason behind the weak decays of hadrons [10] as shown below in Table 1. Please, see more details and other tables in reference [10].

As argued in the paper presented at Moriond 2014 [11], it is important to emphasize that the model agrees very well with Miller analysis [12] of the charge density in the center of the neutron, as he found a total charge of  $-(1/3)e$  inside its central positive core. The central hard core with a radius of about 0.2 fm has also been observed by many experiments at CERN and Fermilab along the years. In 2011 and 2013 it was observed by the TOTEM collaboration at 7 TeV [13,14] and 8 TeV [15].

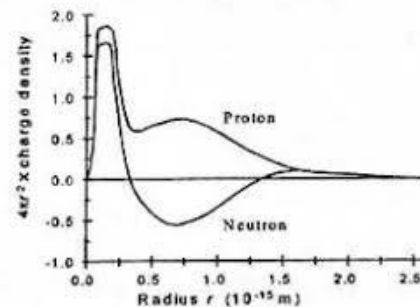


Figure 1. Electrical charge distributions in the nucleons.

It is important to pinpoint 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 Figure 1 above because according to R. Hofstadter, R. Herman, L. Durand and R. R. Wilson findings the hard core has a total charge of  $+(1/2)e$  and not  $+1e$ .

It is also worth recalling that charges do not appear in Bjorken scaling structure functions. Thus, at high  $q^2$  the de Broglie wavelength  $h/q$  is very small and, then, when the 3 inner prequarks are probed they are identified as being 3 valence quarks due to the lack of identification of their charges. Therefore, there is a complete entanglement between prequarks and valence quarks. And true quarks should be the so-called constituent quarks. Therefore, the quark compositeness scale is just 1-10 GeV and not the extremely high scales that have been considered in the searches for quark compositeness. The null results of such searches mean, actually, that primons are elementary.

As shown in reference [16] the quark compositeness model above presented solves a quite large number of problems in Particle Physics, such as the proton spin puzzle,

the number of quarks, the origin of the Cabibbo factors, the EMC effect, and the Krisch effect.

Table 1. Semileptonic decays of light baryons with their corresponding Cabibbo factors and  $\Delta\Sigma_3$ .

Decay	Cabibbo factor	$\Delta\Sigma_3$
$n \rightarrow p$	$\cos \theta_c$	0
$\Sigma^+ \rightarrow \Lambda$	$\cos \theta_c$	0
$\Sigma^- \rightarrow \Lambda$	$\cos \theta_c$	0
$\Sigma^- \rightarrow \Sigma^0$	$\cos \theta_c$	0
$\Lambda \rightarrow p$	$\sin \theta_c$	+1
$\Sigma^- \rightarrow n$	$\sin \theta_c$	+1
$\Xi^- \rightarrow \Lambda$	$\sin \theta_c$	+1
$\Xi^- \rightarrow \Sigma^0$	$\sin \theta_c$	+1
$\Xi^0 \rightarrow \Sigma^+$	$\sin \theta_c$	+1
$\Xi^- \rightarrow \Xi^0$	$\cos \theta_c$	0

## 2. A New Quantum Number

The main results for the quantum numbers of quarks and for the Higgs-like bosons are presented below in some tables and in a diagram. For details, please take a look at the corresponding references and at the web page [www.primons.com](http://www.primons.com).

### 2.1. The $\Sigma_3$ Quantum Numbers for Quarks

The  $\Sigma_3$  quantum numbers for quarks (Table 2) were calculated in references [9,10,11,16].  $I_3$  is the well known isospin.

Table 2: 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

### 2.2. The Higgs-like Boson Multiplet with its Quantum Numbers, Spins and Electrical Charges

The  $\Sigma_3$  quantum numbers for the Higgs-like bosons and their spins (Table 3) were calculated in references [11,16].

Table 3. The quantum numbers of the Higgs-like bosons

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

### 2.3. The Generators of Quark Masses

Table 4 below was taken from reference [16].

Table 4. Quarks and the Higgs-like bosons that generate their masses.

Quark	Mass (GeV)	Charge	Higgs-like boson
$u(p_1 p_2)$	0.3	+2/3	$H_{\pm 2}^+, H_{\pm 2}^-$
$c(p_1 p_3)$	1.5	+2/3	$H_{\pm 1}^+, H_{\pm 1}^-$
$t(p_1 p_4)$	170	+2/3	$H_{\pm 1}^+, H_{\pm 1}^-$
$d(p_2 p_3)$	0.3	-1/3	$H_0^0$
$s(p_2 p_4)$	0.5	-1/3	$H_{\pm 1}^0$
$b(p_3 p_4)$	4.5	-1/3	$H_{\pm 1}^0$

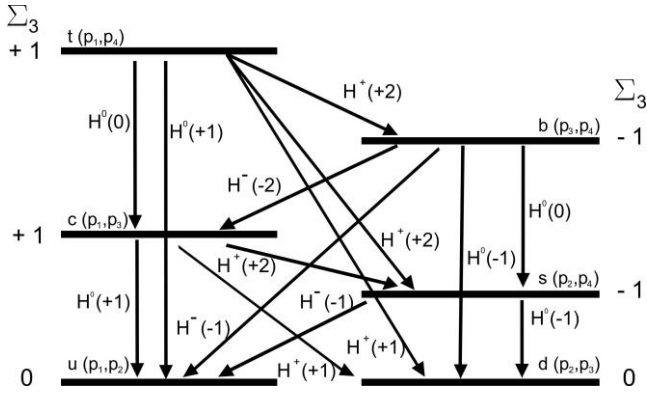
### 2.4. The Quark Transitions by means of Virtual Higgs-like Bosons

With the  $\Sigma_3$  assignments for quarks and for Higgs-like bosons we can construct the diagram below shown in Figure 2 for the virtual transitions between quarks mediated by Higgs-like bosons (to lowest order). The diagram was published in reference [11].

With respect to the diagram below, the BaBar Collaboration [17] has found an excess in the decay  $\bar{B} \rightarrow D^{(*)} \tau^- \bar{\nu}_\tau$  that points in the direction of the charged Higgs-like boson  $H_{-2}^-$ . In terms of quarks and primons this decay means  $b \rightarrow c + H_{-2}^-$  and  $p_4 \rightarrow p_1 + H_{-2}^-$  where  $H_{-2}^-$  is a virtual particle. In terms of  $\Sigma_3$  this decay means  $-1 = +1 + (-2)$ .

Therefore, in this decay due to a  $\Sigma_3$  current, there is the mediation of the Higgs-like boson  $H_{\pm 2}^-$ . Taking into account the results of this paper and the above argumentation, Ba-Bar can claim that it was the first to discover the charged Higgs-like bosons  $H_{\pm 2}^\pm$ .

Figure 2. The quark transitions via virtual Higgs-like bosons



### 3. Identifying the Neutral and Charged Higgs-like Bosons

It is important to have in mind that according to the quark compositeness model strong interactions conserve  $\Sigma_3$  while weak interactions do not. Taking into account Figure 1 above and the quark electrical charges de Souza proposed the structure for the proton shown in Figure 2 below which first appeared in reference [10] and later on in reference [16]. Let us, hence, now understand how the charged and neutral Higgs-like bosons are produced. Below only lowest order processes are considered. Of course, during the extremely short collision time the proton structure above shown in Figure 2 is completely disturbed and disrupted.

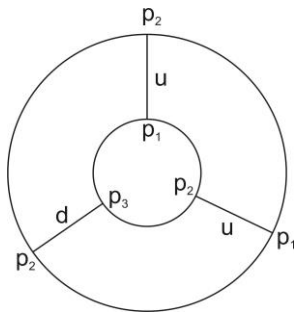


Figure 2. The structure of the proton in terms of quarks and primons (prequarks). Of course, this is just a pictorial representation in two dimensions of the two 3-dimensional layers of primons.

1) The neutral boson  $H_0^0$ :

Taking into account Table 4 above,  $H_0^0$  is formed by means of the interaction between  $p_2$  and  $p_3$  either from the same proton or from different protons in proton-proton collisions. We may symbolize this interaction by

$$p_1 \xleftarrow{H_0^0} p_2$$

Hence, the  $H_0^0$  boson can be more identified with the Standard Model Higgs boson. After its formation it decays in  $\gamma\gamma$ , in  $Z^0$  or in  $b^+b^-$ . Therefore, to lowest order the process is not  $H_0^0 \rightarrow Z^0 Z^0$  and thus, the intermediate state  $Z^0 Z^0$  comes about from 2  $H_0^0$  decays.

2) The charged bosons  $H_{\pm 1}^\pm$  and  $H_{\pm 2}^\pm$ :

Similarly to the formation of  $H_0^0$  above, considering Table 4, the bosons  $H_{\pm 1}^\pm$  are formed by means of the interaction between  $p_1$  and  $p_3$  either from the same proton or from different protons. We may symbolize the interaction by

$$p_1 \xleftarrow{H_{\pm 1}^\pm} p_3$$

The same holds for  $H_{\pm 2}^\pm$  which is formed via the interaction between  $p_1$  and  $p_2$  either from the same proton or from different protons. The bosons  $H_{\pm 1}^\pm$  and  $H_{\pm 2}^\pm$  may decay to  $W^\pm$  through the interactions  $H_{\pm 1}^\pm \rightarrow W^\pm$  with  $|\Delta\Sigma_3|=1$  and  $H_{\pm 1}^\pm \rightarrow W^\pm$  with  $|\Delta\Sigma_3|=2$  which taken together are confused with the off-shell decay  $H \rightarrow W^+W^-$ .

Let us now estimate the relative productions of all these bosons. Each proton has two  $p_1 p_2$  pairs, so that in each proton there is the production of 4  $H_{\pm 2}^\pm$ , and between the different protons there are 12  $p_1 p_2$  pairs. Therefore, we have the total production of 16  $H_{\pm 2}^\pm$ . As to  $p_1 p_3$  there are only 4 possible pairs (formed due to the proton structure disruption

during the collision), and thus there is the total production of only 4  $H_{\pm 1}^{\pm}$  bosons. By the same token, in the case of  $p_2p_3$  there are 14 possible pairs, so that there is the total production of 14  $H_0^0$ . Therefore, the relative production of WW pairs to ZZ pairs is about 1.43 which is a number that is within the experimental results up to now. And in the WW signal we have  $\frac{1}{4}$  of  $H_{\pm 1}^{\pm}$  and  $\frac{3}{4}$  of  $H_{\pm 2}^{\pm}$ .

Therefore, when only the  $\gamma\gamma$  and ZZ channels are considered we measure only the  $H_0^0$  boson and when the WW channel is considered we measure the charged Higgs-like bosons in the proportions shown above.

Although CMS claimed to have found in 2013 an excess of events WW [18], it was the ATLAS detector that performed a more precise observation of the Higgs boson decay to WW in 2015 [19]. Therefore, ATLAS actually observed the charged Higgs-like bosons  $H_{\pm 1}^{\pm}$  and  $H_{\pm 2}^{\pm}$ . The reported mass of 125.36 GeV by ATLAS means that the masses of the charged bosons are similar to that of the neutral boson  $H_0^0$ .

In the light of what was shown above we can also say that the  $H_{\pm 1}^0$  bosons have not yet been observed.

## 4. Consequences for Parity

It is well known that all fundamental bosons have negative parity, actually, almost all mesons. The only identified scalar meson is the resonance  $K_0^*(1430)$  and all the other possible candidates are all resonances:  $K_0^*(800)$ ,  $f_0(500)$ ,  $f_0(980)$  etc. Therefore, we should ask the very important question: **why a fundamental boson such as the Higgs boson would be the only exception?** As seen above it is not an exception: **the Higgs-like bosons has odd parity.** We see this easily if we admit that CP is a good symmetry in the Higgs-like decays above shown.

## 5. Conclusion

Considering the whole consistency of the quark compositeness model proposed by de Souza, we can say that the ATLAS and CMS collaborations have already observed the

charged Higgs-like bosons  $H_{\pm 1}^{\pm}$  and  $H_{\pm 2}^{\pm}$ . The data also allows us to say that the neutral and charged Higgs-like bosons have similar masses. It is also concluded that the Higgs-like bosons are pseudo-scalar bosons.

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## REFERENCES

- [1] G. Aad *et al.* (ATLAS Collaboration), 2012, Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC, Phys. Lett. B, 716, 1-29.
- [2] G. Aad *et al.* (ATLAS Collaboration), 2012, Combined search for the Standard Model Higgs boson in pp collisions at  $\sqrt{s} = 7$  TeV with the ATLAS detector, Phys. Rev. D, 86, 032003.
- [3] S. Chatrchyan *et al.* (CMS Collaboration), 2012, Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC, Phys. Lett. B, 716, 30-61.
- [4] M. Carena, C. Grojean, M. Kado and V. Sharma, 2018, Talk "Status of Higgs Boson" at PDG Workshop, Brookhaven National Laboratory, 25-27 October 2018.
- [5] R. Hofstadter and R. Herman, Phys. Rev. Lett. ., 6, 293, 1961; see, however, the reinterpretation of some of these results by L. Durand, Phys. Rev. Letters 6, 631, 1961
- [6] L. Durand, 1961, Inelastic Electron-Deuteron scattering and the Electromagnetic Structure of the Neutron, Phys. Rev. Lett., 6, 631.
- [7] D. N. Olson, H. F. Schopper, and R. R. Wilson, 1961, Electromagnetic Properties of the Proton and Neutron, Phys. Rev. Lett., 6, 286.
- [8] R. R. Wilson and J. S. Levinger, 1964, Structure of the Proton. Ann. Rev. Nucl. Sci., 14, 135.
- [9] M. E. de Souza, 2005, The Ultimate Division of Matter, Scientia Plena, 1(4), 83.
- [10] M. E. de Souza, 2008, Weak decays of hadrons reveal compositeness of quarks, Scientia Plena, 4(6), 064801-1.

- [11] M. E. de Souza, 2014, The Higgs Boson and Quark Compositeness, Proceedings of the 49th Rencontres de Moriond, 2014 QCD and High Energy Interactions, p. 61-64.
- [12] G. A. Miller, 2007, Charge Densities of the Neutron and Proton, Phys. Rev. Lett., 99, 112001.
- [13] G. Antchev et al. (TOTEM Collaboration), 2011, Proton-proton elastic scattering at the LHC energy of  $\sqrt{s} = 7$  TeV, Eur. Phys. Lett., 95, 41001.
- [14] G. Antchev et al. (TOTEM Collaboration), 2011, First measurement of the total proton-proton cross section at the LHC energy of  $\sqrt{s} = 7$  TeV, Eur. Phys. Lett., 96, 21002.
- [15] G. Antchev et al. (TOTEM Collaboration), 2013, Luminosity-Independent Measurement of the Proton-Proton Total Cross Section at  $\sqrt{s} = 7$  TeV, Phys. Rev. Lett., 111, 0120001.
- [16] M. E. de Souza, 2013, The Higgs-like Boson and Quark Compositeness, Frontiers in Science, 3(3), 81-88.
- [17] J. P. Lees et al., (BaBar Collaboration), 2012, Evidence for an Excess of  $\bar{B} \rightarrow D^{(*)} \tau^- \bar{\nu}_\tau$  Decays, Phys. Rev. Lett., 109, 101802.
- [18] L. Di Matteo and the CMS Collaboration, 2013, Search for Higgs decaying to WW at CMS, J. Phys.: Conf. Series 455, 012030.
- [19] G. Aad et al. (ATLAS Collaboration), 2015, Observation and measurement of Higgs boson decays to WW\* with the ATLAS detector, Phys. Rev. D, 92, 012006.