# HIGGS BOSON — MULTIPARTICLE FIELDS VS. STANDARD MODEL

**Tetiana Yushkevych, Oleksii Potiienko, Nataliia Chudak, Ihor Sharph**

**Odessa Polytechnic State University, Ukraine**

## *The main problems*

Let us first mention some problems of the Standard Model related to the introduction of the Higgs field.

✗ The mechanism of spontaneous symmetry breaking in the standard model is the result of two Lagrangian properties, both of which are postulated. Namely, the self-action of the Higgs field and the "non-typical" sign at the quadratic term of the Higgs field in the Lagrangian of the Standard Model.

✗ The postulation of the self-action of the Higgs field is in fact a postulation of the new kind of interaction that is not reduced to any of the four known interactions. In addition, it is introduced in a way significantly different from other interactions. The same applies to the Yukava`s interaction of fermions with the Higgs field. The presence of a theoretically predicted mass in a recently discovered boson, in our opinion, cannot be considered experimental evidence of the Higgs field self-action. The Higgs boson decay modes, known from the experiment, can be explained without the vertices generated by the Yukavian interaction. For example, the decay into fermion and antifermion (Fig. 1) can be described both with the help of the Yukava interaction vertex (Fig. 1a) and without it (Fig. 1b). Such processes are experimentally indistinguishable. Thus, ***the problem of the Standard Model is the introduction of additional (to the four known) non-gauge interactions, the existence of which has not been confirmed experimentally.***

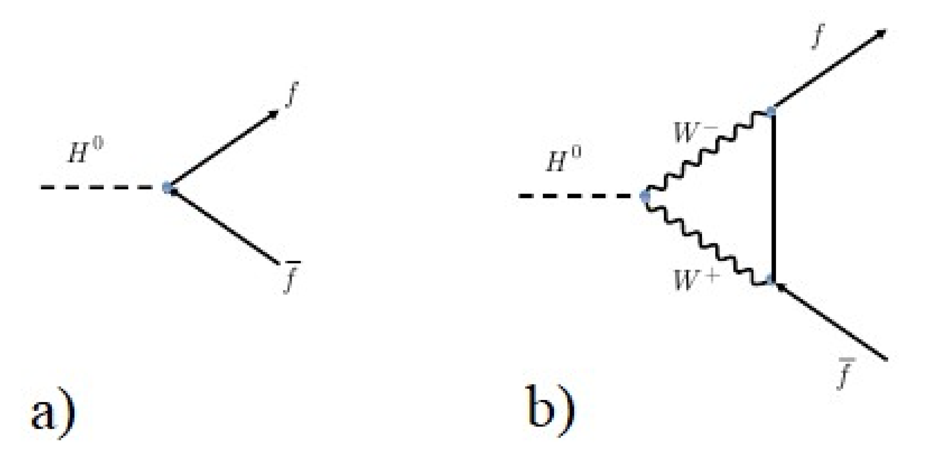


**Fig. 1**: Two experimentally indistinguishable processes of the Higgs boson decay into fermion and antifermion

✗ The Higgs boson of the Standard Model has a weak isospin of ½. At the same time, as reported by Particle Data Group [1], the experimentally known Higgs boson decay modes in the final state contain either particles with integer weak isospin, or an even number of particles with half-integer weak isospin. That is a contradiction. Since the Lagrangian of the Standard Model, before the Taylor expansion in the vicinity of the nonzero value of the Higgs field, has a global *SU*(2) symmetry, the weak isospin must be conserved. Since the expansion of the Lagrangian into the Taylor series with restriction to several terms cannot be "more correct" than the original Lagrangian, we conclude that the Standard Model contradicts the experimental data on the Higgs boson decay channels.

**$H^0$ DECAY MODES**

| | Mode | | Fraction ($\Gamma_i/\Gamma$) | Confidence level |
|---|---|---|---|---|
| $\Gamma_1$ | $WW^*$ | | | |
| $\Gamma_2$ | $ZZ^*$ | | | |
| $\Gamma_3$ | $\gamma\gamma$ | | | |
| $\Gamma_4$ | $b\bar{b}$ | | | |
| $\Gamma_5$ | $e^+e^-$ | | $<3.6 \times 10^{-4}$ | 95% |
| $\Gamma_6$ | $\mu^+\mu^-$ | | | |
| $\Gamma_7$ | $\tau^+\tau^-$ | | | |
| $\Gamma_8$ | $Z\gamma$ | | | |
| $\Gamma_9$ | $\gamma^*\gamma$ | | | |
| $\Gamma_{10}$ | $J/\psi\gamma$ | | $<3.5 \times 10^{-4}$ | 95% |
| $\Gamma_{11}$ | $J/\psi J/\psi$ | | $<1.8 \times 10^{-3}$ | 95% |
| $\Gamma_{12}$ | $\psi(2S)\gamma$ | | $<2.0 \times 10^{-3}$ | 95% |
| $\Gamma_{13}$ | $\Upsilon(1S)\gamma$ | | $<4.9 \times 10^{-4}$ | 95% |
| $\Gamma_{14}$ | $\Upsilon(2S)\gamma$ | | $<5.9 \times 10^{-4}$ | 95% |
| $\Gamma_{15}$ | $\Upsilon(3S)\gamma$ | | $<5.7 \times 10^{-4}$ | 95% |
| $\Gamma_{16}$ | $\Upsilon(nS)\,\Upsilon(mS)$ | | $<1.4 \times 10^{-3}$ | 95% |
| $\Gamma_{17}$ | $\rho(770)\gamma$ | | $<8.8 \times 10^{-4}$ | 95% |
| $\Gamma_{18}$ | $\phi(1020)\gamma$ | | $<4.8 \times 10^{-4}$ | 95% |
| $\Gamma_{19}$ | $e\mu$ | *LF* | $<6.1 \times 10^{-5}$ | 95% |
| $\Gamma_{20}$ | $e\tau$ | *LF* | $<4.7 \times 10^{-3}$ | 95% |
| $\Gamma_{21}$ | $\mu\tau$ | *LF* | $<2.5 \times 10^{-3}$ | 95% |
| $\Gamma_{22}$ | invisible | | | |
| $\Gamma_{23}$ | $\gamma$ invisible | | $<4.6$ % | 95% |

## *What we suggest*

We suggest to consider the Higgs field within the framework of the multiparticle fields model [2]. The quantized multiparticle fields describe the creation and annihilation of the particles which are the bound states of other particles, taking into account their inner structure. Within such model, the Higgs boson is considered as a bound state of two gauge bosons. **Within this model:**

➢ The positive sign of the quadratic term is not postulated, but is obtained from the dynamic equations of the two-particle Higgs field, which describes the bound states of two gauge bosons.
➢ The self-action of the Higgs field is also not postulated, but is a consequence of the weak interaction of gauge bosons.
➢ In our model, the Higgs field has an integer weak isospin, and it provides mass to all carriers of the weak interaction. So it corresponds to the experimentally observed Higgs boson decay modes.

## *How we solve these problems*

To solve the problem associated with the introduction of particle masses, a special Higgs field is introduced. In the transition from one inertial reference frame to another, it is assumed that it will appear as a scalar (i.e., the value of the function at the same space-time point is the same in all reference frames). However, in *SU* (2) transformations, it behaves as a spinor of weak isospin, i.e. has a weak isospin 1/2 and two components

$$\hat{H}(x)=\begin{pmatrix} H_{I_3=1/2}(x) \\ H_{I_3=-1/2}(x) \end{pmatrix}$$

In order to describe the decay channels of the Higgs boson, it is necessary to quantize the Higgs field. In order to do that, one needs to identify the physical degrees of freedom and separate them from the non-physical ones. Since quantization can be performed purely in the representation of the interaction, we must consider the "free" Higgs field, i.e. without interaction with the calibration field. At the same time, we cannot reject the self-action of the Higgs field, which is responsible for the spontaneous symmetry breaking, so we took the word "free" in quotation marks. The Lagrangian of such a "free" field has the form:

$$L=g^{a_1a_2}\frac{\partial H^*_{I_3}(x)}{\partial x^{a_1}}\frac{\partial H_{I_3}(x)}{\partial x^{a_2}}+m^2 H^*_{I_3}(x)H_{I_3}(x)-\lambda\left(H^*_{I_3}(x)H_{I_3}(x)\right)^2$$

Here $H_{I_3}(x)$ is the Higgs field of the Standard Model, the index $I_3$ means the eigenvalue of the third component of the weak isospin and runs two values $I_3$ = ½ and $I_3$ = -½. The notation $H^*_{I_3}(x)$ as usual means the value of the complex conjugate to $H_{I_3}(x)$. Here and further on the repeated index means summation. The notation $g^{a_1a_2}$ as usual means the components of the Minkowski tensor. We introduce a new field $h_{I_3}(x)$ using the relation $H_{I_3}(x)=\nu e_{I_3}+h_{I_3}(x)$ where ν is a complex number with an arbitrary argument, $e_{I_3}$ - components of the column, which determines the direction of spontaneous symmetry breaking in the area of two-component columns, on which the fundamental representation of the group *SU*(2) is realized.

After some transformations and eliminating the terms that do not affect the dynamic equations, the Lagrangian for the field $h_{I_3}(x)$ takes the form

$$L=g^{a_1a_2}\frac{\partial h^*_{I_3}(x)}{\partial x^{a_1}}\frac{\partial h_{I_3}(x)}{\partial x^{a_2}}-\lambda\left(\sqrt{\frac{m^2}{2\lambda}}\left((e^*_{I_3}h'_{I_3}(x))+(h'^*_{I_3}(x)e_{I_3})\right)+h'^*_{I_3}(x)h'_{I_3}(x)\right)^2.$$

Since the linear space of columns with complex components, on which the fundamental representation of the group *SU* (2) is realized, is two-dimensional, in addition to column which defines the "direction" of spontaneous symmetry breaking, there must be another orthogonal column $e^{\perp}_{I_3}$. Then we have a decomposition $h'_{I_3}(x)=H(x)e_{I_3}+G(x)e^{\perp}_{I_3}$, $h'^*_{I_3}(x)=H^*(x)e^*_{I_3}+G^*(x)(e^{\perp}_{I_3})^*$.

The field *H* (x) is naturally called the projection of the Higgs field on the "direction" of spontaneous symmetry breaking, and the field *G* (x) is the projection on the orthogonal "direction". Let us select the real and imaginary parts of the field *H* (x) and introduce the notation $\phi(x)=\Re(H(x)), G_1(x)=\Im(H(x)), G_2(x)=\Re(G(x)), G_3=\Im(G(x))$. For quantization, we must discard all terms, that are higher than quadratic, from the Lagrangian, and take these rejected terms into account within the representation of the interaction as influencing the time dependence of the Fock state, not of the field operators. Then we obtain such a Lagrangian of free fields:

$$L_0=g^{a_1a_2}\frac{\partial\phi(x)}{\partial x^{a_1}}\frac{\partial\phi(x)}{\partial x^{a_2}}-2m^2\phi^2(x)+g^{a_1a_2}\sum_{b=1}^{3}\frac{\partial G_b(x)}{\partial x^{a_1}}\frac{\partial G_b(x)}{\partial x^{a_2}}.$$

So, as usual in the Standard Model, we have one massive Higgs field $\phi(x)=\Re(e^*_{I_3}H_{I_3}(x))$ and three Goldstone massless fields $G_b(x)$, $b$ = 1,2,3.

Let us mention that for an arbitrary field configuration that contains these fields, there is a calibration equivalent configuration that does not contain such fields. Therefore, the Goldstone fields become nonphysical taking into account the interaction with *SU* (2). Thus, the Higgs physical field is determined by relation $\phi(x)=\Re(e^*_{I_3}H_{I_3}(x))$ and is a projection of the Higgs field on the direction of spontaneous symmetry breaking, or in the case of parameterization - with the field of fluctuations of the column norm around the nonzero vacuum value. In both cases, this physical part of the Higgs field is invariant with respect to the group of global *SU* (2) transformations. Therefore, the physical Higgs field $\phi$(x) has a weak isospin, which is equal to zero, which is consistent with the previously mentioned channels of decay of the Higgs boson. Most obviously, the zero equality of the weak isospin of the Higgs physical field is demonstrated by the presence of a decay channel into two photons that have a weak isospin equal to zero.

## Conclusions

In the proposed model, the self-action of the Higgs field is not a fundamental interaction. The Higgs boson is considered as a bound state of two gauge bosons. The self-action of the Higgs field is obtained as a consequence of the self-action of the non-Abelian calibration field corresponding to these bosons, and therefore, unlike the Standard Model, no additional fundamental interaction is required. Thus, the model under consideration is somewhat similar to the known Technicolor models. However, the proposed model has a number of significant differences from those models. First, our model does not require the introduction of new particles or new interactions. On the contrary, it aims to solve the above theoretical problems of the Standard Model using as a basis only those one-particle fields and their interactions that already exist in the Standard Model.

As already mentioned, the Higgs field of the Standard Model has the properties inherent to the calibration fields. Considering the Higgs boson as a bound state of gauge bosons may explain this fact. The Higgs field occurs as a component of the calibration field along one of the additional (above four) dimensions. In this case, the components along these measurements are considered scalars with respect to Lorentz transformations. In such models, the usual problem is how to physically interpret the additional dimensions. In the method of multiparticle fields, the role of such dimensions can be performed by the internal degrees of freedom of the particle, which is a bound state. In this case, since the internal state of the composite particle does not change during the transition from one inertial reference frame to another, the components of the calibration field along the internal degrees of freedom must be transformed as scalars with respect to Lorentz transformations.

1. P.A. Zyla et al. (Particle Data Group), Prog. Theor. Exp. Phys. 2020, 083C01 (2020) and 2021 update. (https://pdg.lbl.gov/2021/tables/contents_tables.html)
2. D.A. Ptashynskiy, T.M. Zelentsova, N.O. Chudak, K.K. Merkotan, O.S. Potiienko, V.V. Voitenko, O.D. Berezovskiy, V.V. Opyatyuk, O.V. Zharova, T.V. Yushkevich, I.V. Sharph, V.D. Rusov, Multiparticle fields on the subset of simultaneity, Ukrainian Journal of Physics 64(8), 732 (2019), https://ujp.bitp.kiev.ua/index.php/ujp/article/view/2019394/1441
3. K.K. Merkotan, T.M. Zelentsova, N.O. Chudak, D.A. Ptashynskyi, V.V. Urbanevich, O.S. Potiienko, V.V. Voitenko, O.D. Berezovskyi, I.V. Sharph, V.D. Rusov, An Alternative Method for Solving Two Problems of the Standard Model, https://arxiv.org/abs/1711.01914