On Possibility of Higgs Mechanism Break Down Due to the Instantons

R. Shulyakovsky *

Institute of Physics of National Academy of Sciences
F.Scorina av.,68, Minsk 220072, BELARUS

Abstract

It is shown that Higgs mechanism can be violated in 2-d Abelian Higgs model due to the instantons. It is supposed that discussion can be generalized into Weinberg-Salam theory.

Let us consider Abelian Higgs model:

$$L = -\frac{1}{4}F_{\mu\nu}F_{\mu\nu} + \frac{1}{2}(D_\mu\phi)^* D_\mu\phi - \lambda(\phi^*\phi - \rho^2)^2, \tag{1}$$

$$D_\mu = \partial_\mu - ieA_\mu, \quad F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu, \quad \mu,\nu = 0,1; \quad \lambda > 0,\ \rho > 0.$$

In perturbative approach we expect that gauge field gets the mass by means of Higgs mechanism. This approach deals with vacuum $A_\mu(t,x) = 0,\ \phi(t,x) = \rho$ only. Actually classical vacuum station of the model is degenerated. All classical vacua fall into distinct classes, which are characterized by an integer parameter N (Chern-Simons number) [1]. Different vacuum states $\mid N >$ can be connected to each other by means of tunneling transitions, which are described by instantons (Nielsen-Olesen vortices [2] play role of the instanton solutions in this theory). Thus the correct vacuum is [1]

$$\mid \Theta > \approx \sum_{N=-\infty}^{+\infty} e^{iN\Theta} \mid N > . \tag{2}$$

* *Electronic mail address:* `shul@dragon.bas-net.by`

Correct vacuum expectation value of the scalar field is zero contrary to naive perturbative vacuum:

$$< \Theta |\ \phi\ | \Theta > \approx \sum_{N,M=-\infty}^{+\infty} e^{i(N-M)\Theta} < M|\ \phi\ | N > =$$

$$= \sum_{N=-\infty}^{+\infty} < N|\ \phi\ | N > + O(e^{-\rho}) \approx \rho \sum_{N=-\infty}^{+\infty} e^{i\alpha_N(x)} = 0, \tag{3}$$

$\alpha_N(x)$ is a set of the static configurations which characterizes unequivalent vacua if $A_0(t,x) = 0$.

The result (3) means that initially broken gauge symmetry is restored. This situation corresponds to massless gauge field and 2-component scalar field in contrary to perturbative Higgs mechanism.

Additional arguments come from consideration of the confinement in the model [1]. The energy of attraction between external charges $+q$ and $-q$ (which can be introduced by means of Wilson procedure) is

$$E_\Theta(R) \sim e^{-S_{inst}} R\Big[cos\Theta - cos\Big(\Theta + \frac{2\pi q}{e}\Big)\Big], \tag{4}$$

where R is a distance between external particles. If $q = Ne$ the attraction disappears: $E_\Theta(R) = 0$. It can be interpreted as a screening of the external charges by means of the unlike-charged scalar particle pairs production. However description of such charged particles requires two-component field. Because of the total number of the independent field components is conserved the theory describes massless gauge field only.

We suppose that our results can be generalized into Weinberg-Salam theory. If instantons are not gauge and (or) lattice artifacts that Weinberg-Salam theory describes massless gauge bosons and charged scalar particles instead of the experimentally observed massive gauge bosons. This argument leads to the necessity of the using of an alternative mechanism of $W^\pm$ and Z^0 bosons masses generating.

References

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