II. DISCUSSION

Let us comment this computation and show how it is different from the usual one presented in textbooks.

Let us recall the essential steps of the "standard procedure". One first writes the scalar fields ϕ in the unitary gauge as in (2). Then, for $\mu^2 < 0$, one finds the minima of the potential $V(\phi) = \mu^2\phi^\dagger\phi + \lambda(\phi^\dagger\phi)^2$, which are of the form $|\phi| = \frac{v}{\sqrt{2}}$ for $v = \sqrt{-\mu^2/\lambda}$. In the variables (η, U), this implies that $\eta = \frac{v}{\sqrt{2}}$ and that U can be *any function* with values in $SU(2)$. This U contains the symmetry of the fundamental configuration of the fields ϕ. In a quantum approach, this would be the vacuum of the theory.

Symmetry breaking enters then the scene to *fix by hand a particular value to the U fields*. Then, performing a *true* gauge transformation with $u = U$ (in our notations) yields essentially the same computation as the one presented here. We stress the fact that such a gauge transformation is only possible when the U fields are no longer dynamical variables. Indeed, if they were some of the new variables which parametrize the ϕ fields, then no gauge transformation with a *fixed* gauge group element $u = U$ would be possible.

The v parameter inserts mass terms in the Lagrangian written in terms of the gauge transformed fields.

In this "standard procedure", the obtained Lagrangian does not support a $\underline{SU(2)}$-gauge action because this symmetry is *forbidden* to act on the scalar fields ϕ, which are required to be written in the chosen form $\phi = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v+\eta' \end{pmatrix}$. This is indeed the meaning of the fact that U is fixed once and for all in order that it can be removed by a true gauge transformation.

In our computation, there is a *clear separation between what happens to fields variables and the genesis of mass terms.*

Indeed, the requirement $\mu^2 < 0$ is not necessary to obtain and to reveal the field content in terms of photon fields (A_μ), charged and neutral current fields ($W^\pm_\mu$, Z_μ), neutrino and electron fields (ν_L, e_L, e_R). The Lagrangian obtained in (8) is written for any values of μ^2.

As a consequence, the Lagrangian (8) does contain two phases: one where the fields $W^\pm_\mu$, Z_μ and $e_L + e_R$ get masses and one where these fields remain massless.

In the phase $\mu^2 < 0$, finding the minimum of the potential $V(\eta) = \mu^2\eta^2 + \lambda\eta^4$ of the field η in (8) yields the *unique solution* of the form $\eta = \frac{v}{\sqrt{2}}$. It is unique because η is constrained to be real and positive. It is then convenient to perform a development of η around this