NONLOCAL QUARK MODEL
FOR THE COMPOSITE HIGGS PARTICLE*

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We propose an interpretation of the Higgs boson as a scalar \(\bar{t}t\) bound state within a nonlocal Nambu model. The momentum-dependent top-quark mass is generated dynamically by the nonlocal four-quark interaction which results in a top-quark condensate that breaks chiral symmetry. We present a formula for the Higgs mass that elucidates how the nonlocality leads to true binding in the scalar channel with a Higgs mass below the sum of the constituent top-quark masses, in accordance with phenomenology.

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Conceptual problems with the elementarity of the Higgs particle [1–4] could be solved by introducing it as a composite particle within a nonlocal Nambu model [5]. The effective action for this model of the top-quark sector has the form [6] similar to the local case [7]

\[
S = \int \! d^4x \left( \bar{t}(x) \left( -i \partial_\mu \gamma^\mu + m \right) t(x) - \frac{G}{2} J(x) J(x) \right),
\]

with the nonlocal scalar current \(J(x) = \int \! d^4y g(y) \bar{t}(x + \frac{y}{2}) t(x - \frac{y}{2})\), where \(g(y)\) is the form-factor responsible for the nonlocality. We consider Lorenzian \(g_L(p) = (1 + (p/\Lambda)^2\alpha)^{-1}\) and Gaussian \(g_G(p) = \exp(-p/\Lambda_G)^2\) types, where \(\alpha\) and \(\Lambda\) are regularization parameters. In the chiral limit, the scalar \(tt\) bound state has a mass which is lower than the sum of the masses of its constituents [8]

\[
M^2 = 4m^2(0) - 4 \langle \langle m^2(0) - m^2(p) \rangle \rangle.
\]

In Fig. 1, we show the dependence of the masses for the top quark and the Higgs boson on the dimensionless coupling \(GA^2\) for three models of the nonlocal form-factor \(g(p)\).

In all three cases, the Higgs boson is described as a composite scalar mesonic bound state of $t\bar{t}$ quarks which get their mass from dynamical chiral symmetry breaking. The effective range $\Lambda$ is of the order of the electroweak gauge boson mass, while the coupling strength $G$ of the model is two orders larger than the Fermi coupling $G_F$. The two free parameters form a dimensionless number $GA^2$ which for our examples lies in the range of $3.35 \ldots 7.64$ suggesting the possibility to unify the heavy with the light quark sector, where $GA^2 \sim 5.6$ is found in these models.

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