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]

$$S = \int \mathrm{d}^4x \left(\bar{t}(x) \left(-i\partial_\mu \gamma^\mu + m\right) t(x) - \frac{G}{2} J(x) J(x) \right) , \tag{1}$$

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

$$M^2 = 4m^2(0) - 4 \left\langle \left\langle m^2(0) - m^2(p) \right\rangle \right\rangle . \tag{2}$$

In Fig. 1, we show the dependence of the masses for the top quark and the Higgs boson on the dimensionless coupling $G\Lambda^2$ for three models of the nonlocal formf-actor $g(p)$.

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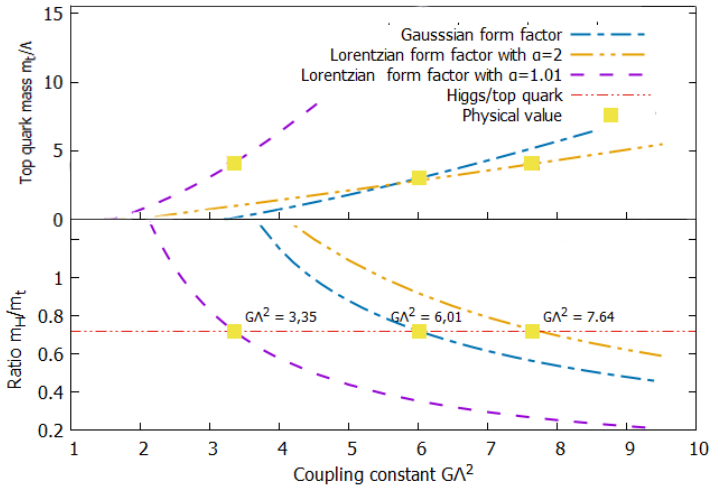

Fig. 1. Dimensionless top-quark mass and Higss-to-top-mass ratio as a function of the dimensionless coupling $G\Lambda^2$ for three nonlocality models. Details in the text.

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 Λ 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 $G\Lambda^2$ 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 $G\Lambda^2 \sim 5.6$ is found in these models.

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