Higgs bosons in particle physics and in condensed matter

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Higgs bosons – the amplitude modes – have been experimentally investigated in condensed matter for many years. An example is superfluid ^{3}He-B, where the broken symmetry leads to 4 Goldstone modes and at least 14 Higgs modes, which are characterized by angular momentum quantum number J and parity (Zeeman splitting of Higgs modes with $J = 2^+$ and $J = 2^-$ in magnetic field has been observed in 80's [1]). Based on the relation $E^2_{J+} + E^2_{J-} = 4\Delta^2$ for the energy spectrum of these modes, Yoichiro Nambu [2] proposed the general sum rule, which relates masses of Higgs bosons and masses of fermions. If this rule is applicable to Standard Model, one may expect [3] that the observed Higgs boson with mass $M_{\rm H1} = 125$ GeV has a Nambu partner – the second Higgs boson with mass $M_{\rm H2} = 325$ GeV. Together they satisfy the Nambu relation $M^2_{\rm H1} + M^2_{\rm H2} = 4M^2_{\rm top}$, where $M_{\rm top}$ is the top quark mass. Also the properties of the Higgs modes in superfluid ^{3}He-A, where the symmetry breaking is similar to that of the Standard Model, suggest the possible existence of two electrically charged Higgs particles with masses $M_{\rm H+} = M_{\rm H-} \sim 245$ GeV, which together obey the Nambu rule $M^2_{\rm H+} + M^2_{\rm H-} = 4M^2_{\rm top}$. A certain excess of events at 325 GeV and at 245 GeV has been reported in 2011, though not confirmed in 2012 experiments.

1. O. Avenel, et al. PRL **45**, 1952 (1980); R. Movshovich, et al. PRL **61**, 1732 (1988).
2. Yoichiro Nambu, Fermion - boson relations in BCS type theories, Physica D **15**, 147 (1985).
3. G.E. Volovik and M.A. Zubkov, Nambu sum rule in the NJL models: from superfluidity to the models of top quark condensation, Pis'ma ZhETF **97**, 344 (2013).

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