Lee Wick models

1 Lee-Wick Standard model

- This paper describes the Lee-Wick Standard model and shows why quadratic divergencies are absent. The basic picture is shown in a toy example in the beginning:

  B. Grinstein, D. O'Connell and M. B. Wise, "The Lee-Wick standard model," arXiv:0704.1845 [hep-ph].

- Some phenomenological aspects of the Lee-Wick Standard model is worked out in the following papers:

  T. G. Rizzo, "Searching for Lee-Wick Gauge Bosons at the LHC," JHEP **0706** (2007) 070 [arXiv:0704.3458 [hep-ph]].

  J. R. Espinosa, B. Grinstein, D. O'Connell and M. B. Wise, "Neutrino masses in the Lee-Wick standard model," arXiv:0705.1188 [hep-ph].

  B. Grinstein, "Minimal Flavor Violation," arXiv:0706.4185 [hep-ph].

  T. R. Dulaney and M. B. Wise, "Flavor Changing Neutral Currents in the Lee-Wick Standard Model," arXiv:0708.0567 [hep-ph].

  F. Krauss, T. E. J. Underwood and R. Zwicky, "The process $gg \to h_0 \to \gamma\gamma$ in the Lee-Wick Standard Model," arXiv:0709.4054 [hep-ph].

2 original papers back in the 70s

- The 2 original works by Lee and Wick, where they introduce negative metric states and apply it to QED:

  T. D. Lee and G. C. Wick, "Negative Metric and the Unitarity of the S Matrix," Nucl. Phys. B **9** (1969) 209.

  T. D. Lee and G. C. Wick, "Finite Theory of Quantum Electrodynamics," Phys. Rev. D **2** (1970) 1033.

- Cutkosky et al. show in explicit examples, that it is possible to find sensible integration contours in the complex plane:

  R. E. Cutkosky, P. V. Landshoff, D. I. Olive and J. C. Polkinghorne, Nucl. Phys. B **12**, 281 (1969).

- These 3 paper discuss whether Lee-Wick theories violate Lorentz invariance.

  N. Nakanishi, Phys. Rev. D **3**, 811 (1971).

  T. D. Lee and G. C. Wick, Phys. Rev. D **3** (1971) 1046.

  N. Nakanishi, Phys. Rev. D **3**, 3235 (1971).

- There are two lectures notes explaining finite QED by Lee-Wick which are a good starting point to understand the basic picture and problems (unitarity and causality) of Lee-Wick theories:

  T.D. Lee, "A finite theory of quantum electrodynamics", in Elementary processes at high energy, part A, Ettore Majorana 1970 International School of Subnuclear Physics, Erice, July 1-19, Editor:A. Zichichi, Academic Press, New York and London, 1971.

  S. Coleman, "Field theories with indefinite metric," *In *Syracuse 1969, Proceedings, Eighth Annual Eastern Theoretical Physics Conference*, Syracuse 1970, 197-216*

3 non perturbative formulation

The nonperturbative formulation of Lee-Wick theories is under discussion.

- The result of the following paper is that they did not succeed to construct a path integral in the ususal way.

  D. G. Boulware and D. J. Gross, "Lee-Wick Indefinite Metric Quantization: A Functional Integral Approach," Nucl. Phys. B **233**, 1 (1984).

- Some other approaches to a nonperturbative picture...

  K. Jansen, J. Kuti and C. Liu, "Strongly interacting Higgs sector in the minimal Standard Model?," Phys. Lett. B **309**, 127 (1993) [arXiv:hep-lat/9305004].

  K. Jansen, J. Kuti and C. Liu, "The Higgs model with a complex ghost pair," Phys. Lett. B **309**, 119 (1993) [arXiv:hep-lat/9305003].

- The claim to be able to construct a meaningful path integral in the distributional sense. It is advantageous to be familiar with functional analysis and especially distributions to follow the reasoning.

  A. van Tonder, Int. J. Mod. Phys. A **22** (2007) 2563 [arXiv:hep-th/0610185].

- The series of papers shows that there are problems in the usual path integral formulation with respect to the Wick rotation in Lee-Wick theories, basically it is not possible to implement the Feynman "$+i\epsilon$" prescription in the Minkowski spacetime Lagrangian and perform a Wick rotation in order to arrive at the Lee-Wick model.

  S. W. Hawking and T. Hertog, "Living with ghosts," Phys. Rev. D **65**, 103515 (2002) [arXiv:hep-th/0107088].

  I. Antoniadis, E. Dudas and D. M. Ghilencea, "Living with ghosts and their radiative corrections," Nucl. Phys. B **767**, 29 (2007) [arXiv:hep-th/0608094].

  D. M. Ghilencea, "Higher dimensional operators and their effects in (non)supersymmetric models," arXiv:0708.2501 [hep-ph].