Scalars 2023

Contribution ID : 37

pNGBs under finite temperature

Friday 15 Sep 2023 at 15:15 (00h15')

Content :

The true nature of the Higgs particle (is it fundamental or composite?) is still under investigation.
One plausible realization, which provides also a solution to the ElectroWeak hierarchy problem, is to identify the Higgs field with one of the pseudo-Nambu-Goldstone bosons (pNGBs) arising from the spontaneous and explicit breaking of a global symmetry at some UV scale. However, for the physically relevant scenarios this Effective Field Theory (EFT) description demands a non-negligible fine-tuning in order to explain the scale-separation and in most of the times the associated effective potential becomes a source of EFT's break down so the latter cannot be trusted.
In this work we give an example where both the previous concerns are resolved.
In particular, we consider an EFT containing the pNGBs arising from the breaking of an approximate global symmetry at the scale f where in all of our applications we will be interested in the scenarios in which the spontaneous and explicit symmetry breaking is of the SO(N+1) --> SO(N) pattern. The produced pNGBs span a space of non-trivial geometry which consists of the set of points a fixed distance from the origin in R^{N+1}.
Under this framework we evaluate the effective potential at 1-loop order including both the zero- and finite-temperature corrections and analyze the thermal history of the model. Key characteristic of our case is the demand of a radiatively and thermally stable effective potential. This naturally leads us to consider the Laplace-Beltram eigenvalue as our tree level, zero-temperature, potential which corresponds to the well-known Gegenbauer polynomials. The latter offer multiple non-degenerate vacua that can generate a natural hierarchy of scales between the pseudo-Golstone masses and the scale of spontaneous symmetry breaking, provided the order of the polynomial is large enough.
Moreover choosing the Gegenbauer polynomials we are in position to determine, obtaining an upper bound for only one single parameter, when quantum and thermal corrections are free of inconsistencies keeping the effective potential real and rendering the EFT description valid. Since the latter is ensured we find that the model exhibits a weak first order phase transition via thermal fluctuations which lead to the production of Gravitational Wave (GW) signals which however are very weak.
On the other hand, as a final step of our analysis we assume that the above pNGB

model corresponds to a hidden sector which is not themalized during reheating. As a consequence, the model exhibits a first order phase transition merely via tunnelling which means that the transition is strong and we show that there is a parameter space for which the associated GW signals are stronger and could be detected by the current and future experiments.

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Session classification : Parallel Session 2

Track classification : --not yet classified--

Type : --not specified--