Academic Writing
Spontenous CP violation & symmetry breaking within the physical representation of 2HDM

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Introduction

Firstly, the reader shall be aware what a so called "Higgs Boson" is within the standard model (SM) of particle physics. A Higgs Boson is a 0-charge particle that is an excited state of the Higgs Field; therefore giving way for the observed properties of the Higgs Field which gives masses to some gauge bosons due to spontaneous symmetry breaking of the electroweak symmetry. The spontaneous symmetry breaking is conducted by picking a vacuum expectation value; which is denoted as ν in most texts. [2]

As written previously, we have a Higgs Field. From the Higgs field I shall now introduce where Charge Parity (CP) violation comes into the picture when considering the structure of the field. The Higgs field is constructed in such a way that we can consider a 2 doublets under SU(2) symmetry, this creates the theoretical beyond standard model (BSM) idea of a 2 Higgs Doublet Model (2HDM), from which CP violation could be performed for new physics. With this theoretical 2 doublets of Higgs boson in SU(2) symmetry, there's theoretical back-up that would allow the construction of charged Higgs bosons; which is denoted as $H^{\pm}$ in most texts. Due to the properties of particle-antiparticle relations, we would get that the positively charged Higgs boson H^{+} would have the anti particle H^{-}. [1] Therein, the main idea is that when we have a particle and anti particle, which do not obey in the same manner in terms of interactions, we would have a broken CP symmetry (specifically getting a ν value which is a complex number with a non-zero imaginary part, leading way for different interactions akin to the CKM mechanism with weak CP violation). Thus, the goal of my thesis is to study the behaviour of spontaneous CP violation when we have a 2HDM model, specifically from the diagonal 4x4 eigenmass matrix for tree level and then for 1 loop corrections, to see the effect of the spontaneous symmetry breaking and CP violation.

Arguments

Now the curious or adventurous reader might ask themselves 'what for is this theoretical step?' Fortunately, I might say, that the primary reason why this topic need be researched further is based on the simple premise that we are entering the realm of new and recent physics. In some months from writing, the Higgs boson was announced 10 years ago at CERN; thus we are studying very new physics which still need further motivation for funding going into the future. Furthermore, since Higgs mechanism as an observable manifestation of a Higgs field has only recently been discovered, [5] further interpretations of the Higgs boson need be in effect. Specifically, when we consider what is seen in the current standard model we can indeed agree that it seems a bit systematic. In theory, the underlying structure has plenty of SU(2) symmetry relations which had need be created, specifically, there's isospin doublets for each quark generation, and the weak eigenstate for the quarks interact with vertex elements from the CKM matrix, which has known complex entries. Thus, there's a clear indication that interactions can be CP violated when things are not in phase (and thus cannot cancel out from some gauge). Specifically, there's a mathematical construct which allows this to occur within 2HDM. [1]

From my previous paragraph, it shall be clear that there's theoretical motivation to study physics which might arise from 2HDMI with spontaneous CP violation. However, the reader might not be convinced on purely theoretical steps needed, and would perhaps wish for elaboration regarding practicalities. It shall however be noted that during the 10 years since the Higgs boson was discovered, not too much excitement has arisen from particle physics – and some emphasis that the end has been met could naively be discussed. [2] However, the main issue is that progress usually comes in quick succession, especially with research; if the need be of further new physics, then the theoretical set up need be there. In general, the cost for constructing accelerators to construct new physics needs long term funding, a clear plan of discourse, a motivation, and specifically an aim for research. Thus if the mechanism that can be studied and perhaps observed as a product of 2HDM through CP violation could be plausible. In particular, there would be nothing in the current 2HDM that wouldn't disallow CP violation, [1] which shall specifically be considered, given that the studied fields are complex. As the fields are complex, and that the physics are not entirely set in stone for the probing of current accelerators, there need be adaptations with theoretical background to make sure that the experiments can fulfil whatever need be conducted, and make sure that the measurements and structure is well suited for detecting signals of new physics from 2HDM with spontaneous CP violation. Take for example here the currently only Higgs Boson (the one which is in the standard model), there needed be plenty of papers which set out the character of the signal that would show that there had occured an excitation of the Higgs field. Furthermore, the signal had to be fine tuned to make sure no error was there, the signal had to be analysed such that there wouldn't have been any background event that could have led to some strange statistics in the detection, and further arguments could be presented. Perhaps the signal ought to be weak for new physics that could arrise from 2HDM with spontaneous CP violation; then it would need

be carefully studied to make sure no background could give way for it. However, it shall therein be noted that a sound theoretical model that would predict the signal at that centre of mass (COM) energy $\sqrt{s}$ and how it would behave; else the scientists and analyst could just interpret it for noise.
One could obviously go on about the perks and motivation for discovering new physics through 2HDM with spontaneous CP violation. However, the reader might ask the question which answers this give way for; the answer to which is not clearly as obvious as one might suspect from my Introduction section. One of the things that we could discover is that we could be able to discover Flavor Changing Neutral Currents, which switch the quark flavour of some quarks (however these are usually removed through symmetries). [4] Such a discovery would be groundbreaking, as it is already known that the weak eigenstates for the quarks are not the same as the mass eigenstates (as in the observed eigenstates), and that the weak eigenstates is derived from a somewhat unitary (almost unit) transformation in absolute form of the matrix elements of the CKM matrix. However, the reader might have noticed that it was written "absolute form", and in reality, the matrix has complex entries due to the the Jarlskog invariance, [3] giving way for a non-integer multiplication of π in the complex exponent, and thus leading to the CKM matrix having complex entries. Thus if there's an equivalence for the Higgs Bosons, then it could be the case that it could be the case that there's some new physics that underlies the symmetry breaking for the spontaneous CP violation, which could only be realised when the COM energy $\sqrt{s}$ is high enough to realise it with experiments.

It shall however be highlighted for the reader that there could be many different new physics and Higgs mechanisms that could be realised; [1] thus it could be many different interpretation and theoretical BSM physics that could be realised. However, the biggest aspect of scientist is to make sure that there's flavours and interpretations to how the new physics could be; thus making sure to have proper knowledge of the different BSM physics needed could therein be necessary, as is the goal of my thesis by investigating one very interesting aspect oftentimes neglected.

Conclusion

In this paper I have gone over the primary arguments for why scientists should care about 2HDM with CP violation and cannot simply be fine and happy what we currently have, as we could realise deeper levels of physics that could give way for further adaptations. The primary purpose of this thesis can therein be understood as giving way for the calculations and energy levels needed for the 2HDM spontaneous CP violation to take place. Thus the reader can clearly see the that the need of a thesis akin to the one I am writing can give way for a deeper understanding of what could be achieved if we manage to develop higher level particle accelerators that could give way for high level physics that could unlock a deeper understanding.

References

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