Particle mixing, two level systems and gauge theory

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Abstract

In this thesis I will discuss the theory of two level systems and the theory of the oscillating particles in quantum field theory.
In the first chapter I will consider the time evolution of a two level system, a qubit, to show that it has inside a local in time gauge invariant evolution equation. I construct the covariant derivative operator and show that it is related to the free energy. The gauge invariance of the time evolution of the two level system is analogous to the phenomenon of birefringence.I also show that the two level systems present a Berry-like and an Anandan-Aharonov phase. Finally, I discuss entropy environment effects and the distance in projective Hilbert space between two level states to show that the last one is properly related to the Aharonov - Anandan phase.
In the second chapter I review the result obtained in QFT for particle mixing, analyzing the theoretical construction and the oscillation formula in the fermion case.I will emphasize the differences between the quantum mechanics formulas and the QFT formulas.The unitary inequivalence between the flavor and the mass eigenstates is also shown and the structure of the current for charged fields is finally discussed. I found a non - perturbative vacuum structure for the mixing particles that, among the other things, will lead to a non zero contribution to the value of the cosmological constant (chapter 3).
Several links between first and second chapter will arise from this thesis and will shed the light on the fact that it is possible to construct a generic two level quantum field theory, that is an extension of the quantum mechanics bit theory in a quantum field theory framework.