

## I. INTRODUCTION

Decoherence is the quantum phenomenon by which the coherence of a quantum system can be destroyed when it is put in contact with a large environment [1, 2]. The Schrödinger equation is a linear differential equation, consequently any linear combination of solutions is also a solution of the problem. Thus, a general possible quantum state is a superposition of quantum states. Nevertheless, such a state does not appear in the classical macroscopic world. The decoherence interpretation of quantum mechanics [1] claims that this is due to the interaction with the environment, which destroys the quantum correlations between the states of the system, making it to transite from a quantum superposition state to a classical-like mixture of states. Moreover, only a small set of states take part of the classical-like mixture; they are called *pointer states* [1].

The study of decoherence is important for several reasons: i) it might be responsible for the emergence of classical properties out of the underlying quantum nature of the physical systems, ii) it is a major problem for the construction of a quantum computer since it will produce the loss of the necessary quantum entanglement. Thus, both for fundamental reasons (i) and for practical purposes (ii) it is important to characterize the decoherence process and its effects on the physical properties of a quantum system.

Along this line of study, it is important to address the issue of the effect produced in the coherence of a quantum state when the environment evolves between different quantum phases. There have been several works on the relation between decoherence and an environmental quantum phase transition [3–8]. Recently, we have presented a novel phenomenon in which the decoherence of the system suffers dramatic changes when the environment crosses an excited state quantum phase transition (ESQPT)[9]. An ESQPT is a nonanalytic evolution of the system as the control parameters in the Hamiltonian vary. It is similar to a ground state quantum phase transition but affecting to excited states. Correspondingly, an ESQPT can be classified in the thermodynamic limit as first order, when a crossing between two excited levels is present, or continuous, when the number of interacting levels is locally very large at an excited energy but without crossings.

In Ref. [9] we presented briefly the case of a qubit in interaction with an environment modelled as a two-level boson system undergoing a continuous ESQPT. We used a particular simple Hamiltonian in terms of single control parameter to model the environment in order