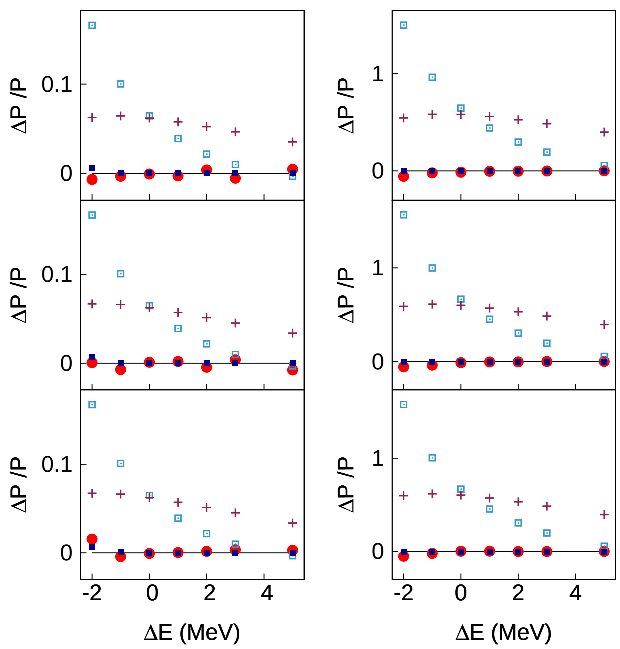

FIG. 6: (Color online) Evolution of $\Delta P/P$ as a function of ΔE calculated using quantum Monte-Carlo (filled circles), TCL2 (open squares), TCL4 (filled squares) and Markovian approximation (open crosses) for different coupling constant: $\eta = 0.003 MeV$ (left) and $\eta = 0.03 MeV$ (right). In both cases, $T = 5\hbar\omega$, $\hbar\omega$ and $0,1\hbar\omega$ are shown from top to bottom.

For both non-inverted and inverted potentials, the new technique is rather effective to reproduce the exact evolution with a rather limited numbers of trajectories. Other methods have also been benchmarked. The TCL2 method, which is now widely used in nuclear physics to estimate passing probabilities, turns out to deviate significantly from the expected result especially below the barrier and even in the weak coupling regime. To properly treat the dynamics of barrier transmission, higher orders in the coupling strength should be incorporated. TCL4 gives very good agreement with the exact evolution in all cases considered here. The conclusion of our present work is that both quantum Monte-Carlo approach and TCL4 could be considered as good candidates to include memory effects for situations of interest in nuclear physics. Henceforth, the TCL2 method which is widely used nowadays should be replaced by TCL4. The possibility to use stochastic formulation that are exact in average open new perspectives to describe a system coupled to a complex environment. The application to harmonic potential gives interesting insight into such a theory. Application to more general potential turns out to be less straightforward with the appearance of spikes which have been already observed in several formalism where non linear stochastic equations appear [28]. To make these theories more versatile, new methods like the one proposed recently in ref. [58] could be used.

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