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Free Energy of a Large-N Pion Gas and Chiral Symmetry Restoration

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We study thermal properties of a large-N massless pion gas via a low-energy QCD approach given by an $O(N+1)/O(N)$ nonlinear sigma model. In order to attain this, we build diagrammatically the associated free energy to $O(TM^3)$ in the pion mass expansion through an effective vertex; we consider this since all its contributions coming from closed diagrams are to be taken into account. At this perturbative order, we do not have to deal with tadpole-like divergences or higher order loop contributions, thus yielding finite thermodynamical potentials. This allows us to calculate finite order parameters such as the quark condensate and its respective derivative, i.e., the scalar susceptibility, in the chiral limit, along with their associated critical exponents. These results are compared with our previous unitarized scattering analyses, where the chiral transition was studied via thermal properties of the scalar resonance $f_0(500)$. After all
this, we finally show that these more recent results reasonably agree both with lattice simulations and with our $f_0(500)$ studies for the chiral transition universality class.

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