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CP conservation in the strong interactions

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There is no empirical evidence for CP conservation in the strong interactions. As there generally is a renormalizable, parity-odd coupling between the field strength and its dual, this requires an explanation from theory.

I will therefore first review what interactions are present when constructing an effective theory for hadrons from QCD. But I will also point out, that from such considerations alone, it cannot be decided whether the effective interactions (that, e.g., give mass to eta-prime) are misaligned (CP violation) or aligned (no CP violation) with the quark mass phase.

To see whether or not there is a material effect of the parity-odd operator in QCD requires therefore an understanding of how field configurations from different topological sectors contribute to the path integral or, in canonical quantization, whether topology implies different ground states that are in general not parity eigenstates. To that end, I will review the pertinent homeomorphisms between the SU(2) subgroups of the strong interactions and the boundaries of spacetime or spatial hypersurfaces.

As for the Euclidean path integral approach, I will note that pure gauge configurations on the boundary only follow when the latter is placed at infinity. Picard-Lefschetz theory then implies that steepest-descent integration contours cover all field configurations within a topological sector that one can find in the infinite spacetime volume. Consequently, the limit of infinite spacetime volume must be taken before summing over sectors, and it turns out that parity violation then vanishes. Commuting these limits, as tacitly done in standard approaches, corresponds to a singular deformation of the original Cauchy contour, falsely suggesting parity-violating results.

Regarding canonical quantization, I will note that the usually considered theta-vacua are not properly normalizable, which is at odds with the probability interpretation from the axioms of quantum mechanics. The root of this problem is the summation over gauge-redundant configurations in the orthonormality relations among theta-vacua. Imposing that (in temporal gauge) the wave functionals and Hilbert-space operators are well-defined when the inner product covers each physical field configuration one time and one time only, I recover that the consistent states satisfy Gauß' law and are moreover eigenstates of parity.

References:
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