# Comment on "Controlling the dynamical evolution of quantum coherence and quantum correlations in $e^+e^- \to \Lambda\bar{\Lambda}$ processes at BESIII"

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(Received 29 January 2026; accepted 4 August 2026; published 31 August 2026)

We comment on the recent analysis reported in [Phys. Rev. D **113**, 016024 (2026)], where quantum coherence, entanglement, steering, and non-Markovian dynamics were investigated in the process $e^+e^- \to \Lambda\bar{\Lambda}$. While the mathematical framework employed in that work may be formally well defined, we argue that several physical assumptions underlying its interpretation require further clarification. In particular, the treatment of the produced hyperon-antihyperon pair as an open bipartite system evolving under correlated quantum channels does not appear to follow naturally from the physical properties of the process. Moreover, the operational meaning of quantum steering and non-Markovianity in this relativistic unstable-particle system remains unclear due to the absence of controllable local measurements, engineered environments, and experimentally accessible dynamical maps. We emphasize that quantum-information-inspired observables can provide useful characterizations of spin correlations in high-energy reactions when their operational interpretation and physical assumptions are carefully specified. Our purpose is therefore not to question the mathematical consistency of the analyzed formalism, but rather to clarify the physical limitations associated with its interpretation in the $\Lambda\bar{\Lambda}$ system.

DOI: 10.1103/hsvc-9cn1

The authors of Ref. [1] investigated quantum coherence and several forms of quantum correlations in the hyperon-antihyperon system produced in the reaction $e^+e^- \to \Lambda\bar{\Lambda}$, with particular emphasis on their angular dependence and their behavior under Markovian and non-Markovian quantum channels. Using tools from quantum information theory, the observed spin correlations were interpreted in terms of coherence, entanglement, quantum steering, and information backflow.

The application of quantum-information-inspired methods to high-energy particle systems is an interesting and rapidly developing direction of research. In this context, density matrices and tomographic techniques can provide valuable descriptions of spin correlations and polarization effects. Nevertheless, we believe that some of the physical assumptions adopted in Ref. [1] require a more careful discussion, especially concerning the interpretation of open-system dynamics and operational quantum-information concepts in the $\Lambda\bar{\Lambda}$ system.

*Remark 1.* The $\Lambda\bar{\Lambda}$ pair produced in the reaction $e^+e^- \to \Lambda\bar{\Lambda}$ originates from a single scattering event and subsequently propagates as two unstable relativistic particles [2]. After production, the system is not embedded in a controllable environment in the conventional sense used in open quantum systems. In standard quantum-information settings, correlated quantum channels generally arise from engineered system-environment couplings, shared reservoirs, or explicit dynamical interactions between subsystems [3,4]. By contrast, in the hyperon production process the reconstructed spin density matrix is determined primarily by the production amplitudes and decay kinematics. For this reason, the interpretation of the post-production evolution of the $\Lambda\bar{\Lambda}$ pair in terms of correlated dynamical noise channels requires additional physical justification. While phenomenological channels may be useful as mathematical probes of the robustness of spin correlations, interpreting their parameters as physically realized decoherence mechanisms in the BESIII process is less straightforward.

*Remark 2.* A related issue concerns the interpretation of Markovian and non-Markovian dynamics. In open quantum systems, non-Markovianity is usually associated with memory effects generated by information exchange between a system and an external environment [3]. Such behavior is typically characterized through structured reservoirs, bath correlation functions, or reduced dynamical maps. In the present case, however, the decay of the

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hyperons is governed by intrinsic weak-interaction lifetimes rather than by interactions with an experimentally identifiable environment. Consequently, the physical origin of the effective memory effects introduced in Ref. [1] remains unclear. Although one may formally define Markovian or non-Markovian channels acting on the reconstructed density matrix, the connection between these channels and the actual dynamics of the produced hyperon system has not been explicitly established. Therefore, the resulting quantities should be interpreted with caution as phenomenological characterizations rather than direct evidence of environmental information backflow.

*Remark 3.* The operational interpretation of quantum steering in the $\Lambda\bar{\Lambda}$ system also deserves clarification. Quantum steering is conventionally defined in a scenario where one observer can perform independently chosen local measurements and remotely prepare conditional states for another observer. In the hyperon system, however, spin information is inferred indirectly through decay distributions rather than through actively controlled spin measurements. Moreover, the available measurement settings are fixed by decay kinematics and detector geometry, and no tunable real-time measurement protocol analogous to standard steering experiments is available. Under these conditions, the computed steering quantifiers are more naturally interpreted as formal properties of the reconstructed spin density matrix rather than as demonstrations of experimentally realizable steering protocols. This distinction is important because the operational meaning of steering as a quantum resource relies on assumptions that are difficult to implement in unstable relativistic particle systems.

*Remark 4.* The discussion in Ref. [1] also tends to blur the distinction between mathematical quantifiers of quantumness and operational quantum resources. Quantities such as coherence measures, geometric discord, or steering monotones can certainly be evaluated once a density matrix is reconstructed. However, the physical interpretation of these quantities depends on the existence of experimentally meaningful protocols involving controllability, measurement accessibility, and dynamical manipulation. In high-energy particle physics, reconstructed density matrices primarily encode spin correlations fixed at the production stage. These correlations differ from the controllable quantum resources typically considered in quantum communication or quantum computation, particularly in terms of measurement accessibility, controllability, and operational implementation. Accordingly, statements regarding the hierarchy or protection of different quantum correlations in the $\Lambda\bar{\Lambda}$ system should be interpreted within this limited operational context.

*Main point.* The central issue is not whether the $\Lambda\bar{\Lambda}$ system may experience interactions during hadronization, propagation, or detection, but whether such effects can legitimately be described as correlated open-system quantum channels acting on a bipartite spin system. Hadronization is a highly nonperturbative QCD process responsible for producing the baryons themselves; it is not naturally interpreted as an external dynamical map acting on a preexisting two-qubit state. Similarly, detector interactions occur after the production process and do not correspond to controlled time-dependent channels acting on a shared bipartite quantum system. Consequently, the reconstructed spin density matrix extracted from decay distributions is more appropriately viewed as a static statistical characterization of production correlations rather than as a dynamically evolving quantum resource undergoing engineered decoherence. From this perspective, phenomenological channel models may still provide useful mathematical parametrizations, but their physical interpretation as actual environmental dynamics in the BESIII process should be stated more carefully.

In summary, we believe that the formalism employed in Ref. [1] can be mathematically well defined while still requiring a more cautious physical interpretation. The notions of correlated quantum channels, non-Markovianity, and steering in the $\Lambda\bar{\Lambda}$ system involve assumptions whose operational realization in relativistic unstable-particle experiments remains unclear. Clarifying these assumptions would help distinguish between formal quantum information diagnostics and physically realizable quantum information protocols in high-energy particle systems.

## DATA AVAILABILITY

There are no publicly available research data or software supporting this manuscript. Requests for further information or data should be sent to the authors.

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