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Holographic spin alignment of vector mesons in magnetized plasma

We establish a holographic framework for investigating spin alignment (ρ_{00}) of flavorless vector mesons using gauge/gravity duality. By analyzing dilepton production via meson decay, we derive a universal relation between production rates per spin channel and the in-medium spectral function—computable holographically for strongly coupled systems. Applying this to J/ψ and ϕ mesons in a moving thermal bath via the soft-wall model, we find starkly contrasting behaviors at T = 150 MeV: J/ψ spectral functions exhibit sharp resonance peaks, signaling quasi-stable $\bar{c}c$ bound states; ϕ mesons show no resonant structures, indicating melted $\bar{s}s$ pairs. Under an instantaneous freeze-out assumption, we map these spectral functions to free-streaming observables by projecting onto states near the vacuum meson mass. This reveals: J/ψ: $\rho_{00} > 1/3$ (positive deviation) in the helicity frame; ϕ: $\rho_{00} < 1/3$ (negative deviation), implying distinct global spin-alignment properties. Further analysis of J/ψ spin parameters (λ_θ, λ_φ, λ_{θφ}) demonstrates their sensitivity to magnetic fields, momentum, and temperature—providing quantitative insights into QCD medium effects.
Moreover, we apply our model to real heavy-ion collisions for three different spin quantization directions. Further comparisons with experimental data show qualitative agreement for spin parameters in the helicity and Collins-Soper frames.

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