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# Jet-induced medium excitation and vortex ring within a $\phi^4$ field simulation

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We investigate medium response to jet energy loss using a self-interacting $\phi^4$ field coupled to an external source, with a focus on the formation of Mach cones and associated vortex rings. By employing an ensemble averaging technique, we demonstrate that the $\phi^4$ field can approach thermal equilibrium, where resonance modes play a critical role in facilitating this thermalization. From the energy-momentum tensor of the field at equilibrium, we extract key bulk properties of the medium, including its collective behavior, equation of state, and speed of sound, all of which align with the hydrodynamic description of a thermal medium. We further explore the structures of shock wave, diffusion wake, and the local vorticity field of the medium induced by jet energy loss, and find that these features are sensitive to the mass and coupling strength of the field. This work presents a novel approach for studying jet-medium interactions in high-energy nuclear collisions, providing a pathway to constrain quark-gluon plasma (QGP) properties through medium response signatures and to gain insights into the local polarization of the QGP induced by jets.

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