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Collider Probes of Dark Energy Microphysics

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The physical description of dark energy comprises one of the most profound open questions in fundamental physics. While astrophysical observations tightly constrain the dark energy equation of state parameter w, this parameter is insensitive to differences in theoretical models which produce the same expansion histories. On the other hand, the sound speed of dark energy perturbations can serve as a key discriminator among models, but is largely unconstrained by current observations. In this work, we propose a fundamentally new approach: using collider measurements of beyond-the-Standard-Model (BSM) mediator resonances as a probe of DE microphysics. We construct an effective-field-theory framework in which a dynamical DE scalar is coupled to a pseudoscalar mediator in the 2HDM+a model. These couplings modify the propagation of the BSM mediator within a dark energy kinetic background, and induce invisible decay channels at colliders such as the LHC. By writing the decay widths and branching ratios of the mediator in terms of the sound speed, we show that these observables are sensitive to the properties of dark energy fluctuations and establish that colliders have the potential to distinguish between dark energy models which are otherwise degenerate. Our results establish a new paradigm in which high-energy collider experiments can probe the physics of cosmic acceleration and help to uncover the fundamental origin of dark energy.

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