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The Phase Space Distance Between Collider Events

How can one fully harness the power of physics encoded in relativistic N-body phase space? Topologically, phase space is isomorphic to the product space of a simplex and a hypersphere and can be equipped with explicit coordinates and a Riemannian metric. This natural structure that scaffolds the space on which all collider physics events live opens up new directions for machine learning applications and implementation. Here we present a detailed construction of the phase space manifold and its differential line element, identifying particle ordering prescriptions that ensure that the metric satisfies necessary properties. We apply the phase space metric to several binary classification tasks, including discrimination of high-multiplicity resonance decays or boosted hadronic decays of electroweak bosons from QCD processes, and demonstrate powerful performance on simulated data. Our work demonstrates the many benefits of promoting phase space from merely a background on which calculations take place to being geometrically entwined with a theory's dynamics.

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