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CaloClouds: Fast Geometry-Independent Highly-Granular Calorimeter Simulation

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Accurate and precise calorimeter modeling presents one of the most significant computational bottlenecks in modern high-energy physics simulation chains. For this reason, extensive work has been done to speed up calorimeter simulation and make it more computationally efficient. A highly promising method for achieving this speed-up is generative machine learning (ML) models. However, most approaches investigated so far are limited to fixed calorimeter geometries and resolutions. This work presents a major breakthrough in the field of ML calorimeter simulation by, for the first time, directly generating a point cloud of a few thousand space points with energy depositions in the detector in 3D space without relying on a fixed-grid structure. This is achieved through the use of a generative point cloud diffusion model. We showcase the performance of this approach using the specific example of simulating photon showers in the planned electromagnetic calorimeter of the International Large Detector (ILD) and achieve overall good modeling of physically relevant distributions.

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