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CaloClouds: Fast Geometry-Independent Highly-Granular Calorimeter Simulation

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Simulating showers of particles in highly granular detectors is a key frontier in applying machine learning to particle physics. Achieving high accuracy and speed with generative machine learning models would enable them to augment traditional simulations and alleviate a significant computing constraint. This contribution marks a significant breakthrough in this task by directly generating a point cloud of O(1000) space points with energy depositions in the detector in 3D-space. Importantly, it achieves this without relying on the structure of the detector layers. This capability enables the generation of showers with arbitrary incident particle positions and accommodates varying sensor shapes and layouts. Two key innovations make this possible: i) leveraging recent improvements in generative modeling, we apply a diffusion model to ii) an initially even higher-resolution point cloud of up to 40,000 GEANT4 steps. These steps are subsequently down-sampled to the desired number of up to 6000 space points. We demonstrate the performance of this approach by simulating photon showers in the planned electromagnetic calorimeter of the International Large Detector (ILD), achieving overall good modeling of physically relevant distributions.

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