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Fast, accurate, and precise detector simulation with vision transformers

The speed and fidelity of detector simulations in particle physics pose compelling questions about LHC analysis and future colliders. The sparse high-dimensional data combined with the required precision provide a challenging task for modern generative networks. We present solutions with different tradeoffs, including accurate and precise Conditional Flow Matching and faster coupling-based Normalizing Flow networks. Vision transformers, including autoregressive elements, allow us to reliably simulate the energy deposition in the detector phase space starting from the detailed Geant4 detector response. We also study dimension reduction with latent networks and faster flow-matching generation with bespoke samplers. We evaluate the networks using high-level observables, neural network classifiers, and sampling timings, showing minimum deviations from Geant4 while achieving faster generation. Our results use public benchmark datasets for easier reproducibility and further development.

AI keywords

conditional generation; surrogate models; vision transformers; flow matching; point cloud;

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Track Classification: Simulations & Generative Models