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ParticleGrow: Event by event simulation of heavy-ion collisions via autoregressive point cloud generation

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The properties of hot and/or dense nuclear matter are studied in the laboratory via Heavy-Ion Collisions (HIC) experiments. Of particular interest are the intermediate energy heavy-ion collisions that create strongly interacting matter of moderate temperatures and high densities where interesting structures in the QCD phase diagram such as a first order phase transition from a gas of hadrons to Quark Gluon Plasma or a critical endpoint are conjectured. Such densities and temperatures are also expected to be found in astrophysical phenomena such as binary neutron star mergers and supernova explosions. The experimental measurements are compared with model predictions to extract the underlying properties of the matter created in the collisions. However, the model calculations are often computationally expensive and extremely slow. Therefore, to exploit the full potential of the upcoming HIC experiments, fast simulation methods are necessary. In this work, we present "ParticleGrow", a novel autoregressive Point cloud generator that can simulate heavy-ion collisions on an event by event basis. Heavy-ion collision events from the microscopic UrQMD model are used to train the generative model. The model built based on the PointGrow algorithm generates the momentum (px,py and pz) and PID (7 different hadronic species) , particle by particle in an autoregressive fashion to create a collision event. The distributions of the generated particles and different observables are compared with the UrQMD distributions. It is shown that the generative model can accurately reproduce different observables and effectively capture several underlying correlations in the training data.

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