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A deep learning approach for predicting multiple observables in Au+Au collisions at RHIC

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We develop a neural network model, based on the processes of high-energy heavy-ion collisions, to study and predict several experimental observables in Au+Au collisions. We present a data-driven deep learning framework for predicting multiple bulk observables in Au+Au collisions at RHIC energies. A single neural network is trained exclusively on experimental measurements of charged-particle pseudorapidity density distributions, transverse-momentum spectra and elliptic flow coefficients over a broad range of collision energies and centralities. The network architecture is inspired by the stages of a heavy-ion collision, from the quark-gluon plasma to chemical and kinetic freeze-out, and employs locally connected hidden layers and a structured input design that encodes basic geometric and kinematic features of the system. We demonstrate that these physics-motivated choices significantly improve test performance compared to purely fully connected baselines. The trained model is then used to predict the above observables at collision energies not yet explored experimentally at RHIC, and the results are validated using the energy dependence of the total charged-particle multiplicity per participant pair as well as comparisons to a CLVisc hydrodynamic calculation with TRENTo initial conditions. Our findings indicate that such physics-guided neural networks can serve as efficient surrogates to fill critical data gaps at RHIC and to support further phenomenological studies of QGP properties.

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