Contribution ID: **24** Type: **Oral**

"Accelerating Particle Physics Simulations with Machine Learning using Normalizing Flows and Flow Matching"

Wednesday 13 March 2024 17:50 (20 minutes)

The simulation of high-energy physics collision events is a key element for data analysis at present and future particle accelerators. The comparison of simulation predictions to data allows us to look for rare deviations that can be due to new phenomena not previously observed. We show that novel machine learning algorithms, specifically Normalizing Flows and Flow Matching, can be effectively used to perform accurate simulations with several orders of magnitude of speed-up compared to traditional approaches. The classical simulation chain starts from a physics process of interest, computes energy deposits of particles and electronics response; and finally employs the same reconstruction algorithms used for data. Eventually, the data is reduced to some high-level analysis format. Instead, we propose an end-to-end approach, simulating the final data format directly from physical generator inputs, skipping any intermediate steps. We use particle jets simulation as a benchmark for comparing both *discrete* and *continuous* Normalizing Flows models. The models are validated across a variety of metrics to select the best ones. We discuss the scaling of performance with the increase in training data, as well as the generalization power of these models on physical processes different from the training one. We investigate sampling multiple times from the same inputs, a procedure we name *oversampling*, and we show that it can effectively reduce the statistical uncertainties of a sample. This class of ML algorithms is found to be highly expressive and useful for the task of HEP simulation. Their speed and accuracy, coupled with the stability of the training procedure, make them a compelling tool for the needs of current and future experiments.

Significance

Application of novel machine learning algorithms and training routines to the end-to-end simulation problem in high energy physics. Demonstrated major improvements in simulation speed while retaining a high level of accuracy and fidelity.

References

Experiment context, if any

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