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Fast Simulation of Jets with VAEs

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Typically, high-energy physics (HEP) data analysis heavily relies on the production and the storage of large datasets of simulated events. At the LHC, the end-to-end simulation workflow can require up to 50% of the available computing resources of an experiment. Speeding up the simulation process would be crucial to save resources that could be otherwise utilized.

In our study, we investigate the use of Deep Generative Models, and more specifically, of Variational Autoencoders for fast simulation of jets at the LHC. We represent jets as lists of jet constituents (particles) characterized by their momenta. Starting from a simulation of the jet before detector effects, we train a Deep Variational Autoencoder (VAE) to learn a parametric description of the detector response and produce the corresponding list of jet constituents. Doing so, we bypass both the detector simulation and the reconstruction, potentially speeding up significantly the events generation workflow.

For our domain-specific application, we use a permutation-invariant loss function, the Chamfer distance, as the reconstruction loss of the Variational Autoencoder based on the jet constituents. We further modify the reconstruction loss by adding extra penalty terms for the jet mass and the jet transverse momentum p_T to impose physics constraints to the model to learn the jet kinematics. Preliminary results show that jet features like jet pseudorapidity η, jet polar angle in the transverse plane ϕ, or jet cartesian momenta p_x, p_y, p_z are modelled within 10% of accepted accuracy, whereas it is more complicated for the jet mass to be learned.

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