Contribution ID : **31**

Type : **Talk**

Deep Generative Models for Particle Simulations at ALICE, CERN

Tuesday, 8 September 2026 14:40 (40)

At the European Organisation for Nuclear Research (CERN), scientists study the fundamental properties of matter by replicating the extreme conditions of the early universe within the Large Hadron Collider (LHC). Understanding particle collisions requires running simulations that mirror the detectors' expected responses within the LHC. With over 50% of CERN's GRID computing power dedicated to High Energy Physics simulations, the need for more efficient simulation methods is critical.

We propose employing generative machine learning to directly simulate detector responses, leveraging advancements in generative adversarial networks (GANs), autoencoders, and diffusion models to tackle simulation challenges. Our contributions include introducing a modified GAN training objective that accommodates varying simulation variance across different conditional inputs, supplemented with additional regularization to increase the simulation fidelity. For autoencoders, we introduce a conditional control mechanism enhancing simulation control by independently manipulating output parameters of the generated samples. With diffusion models, we explore the efficiency of latent diffusion models and the trade-off between inference time and simulation quality.

Our proposed methodologies have the potential to advance particle collision simulations by offering more streamlined, controllable, and faster methods, maintaining the fidelity demanded by modern high-energy physics experiments.

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Session Classification : Machine learning in high energy physics