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(R) Application of generative models for full-detector, whole-event simulated event generation and jet background subtraction

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AI generative models, such as generative adversarial networks (GANs), have been widely used and studied as efficient alternatives to traditional scientific simulations like Geant4. Diffusion models, which have demonstrated great capability in generating high-quality text-to-image translations in industry, have yet to be applied in the high-energy heavy-ion physics.

In this talk, we present the effectiveness of denoising diffusion probabilistic models (DDPMs) as AI-based generative surrogate models for whole-event, full-detector simulations in high-energy heavy-ion experiments [1]. We use HIJING minimum-bias data simulated by Geant4 with the sPHENIX geometry to train the model. We compare its performance with that of a popular alternative—GANs. The results show that DDPMs significantly outperform GANs, providing much faster generation times compared to Geant4 simulations, with a speedup on the order of 100. This suggests the potential for DDPMs in accelerating complex event simulations in high energy collider experiments.

Additionally, unpaired image-to-image translation models can be applied for jet background subtraction techniques. We present that UVCGAN [2], one of the CycleGAN models, demonstrates excellent performance in separating jets from combinatorial background in heavy-ion collisions at both Relativistic Heavy Ion Collider and the Large Hadron Collider.

[1] Y. Go and D. Torbunov et al, Effectiveness of denoising diffusion probabilistic models for fast and high-fidelity whole-event simulation in high-energy heavy-ion experiments, https://link.aps.org/doi/10.1103/PhysRevC.110.034912, https://arxiv.org/abs/2406.01602
[2] D. Torbunov et al, UVCGAN v2: An Improved Cycle-Consistent GAN for Unpaired Image-to-Image Translation, https://arxiv.org/abs/2303.16280

Track

Detector simulation & event generation

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