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AIDO: An End-to-end Detector Optimization Framework using Diffusion Models

The design of modern high-energy physics detectors is a highly intricate process, aiming to maximize their physics potential while balancing various manufacturing constraints. As detectors become larger and more sophisticated, it becomes increasingly difficult to maintain a comprehensive understanding of the entire system. To address this challenge, we aim to translate the design process into an optimization task suitable for Machine Learning by treating the parameters of the simulation as hyper-parameters of the model.
The AIDO framework is a generalized tool for the optimization of continuous and discrete detector parameters. We train a diffusion-based surrogate model on parallel Geant4 simulations with varying detector geometries, enabling the model to interpolate the expected performance across different configurations. This allows for gradient descent on the generated parameter space and identification of the optimal combination of parameters that maximizes a specific physics goal. As a demonstration, we show how this approach can be applied to generate an optimal sampling calorimeter by maximizing its energy resolution starting from a random initial composition.

Significance

We show the results from our submitted paper which includes the optimization of a sampling calorimeter from scratch.

References

We attach the link to the corresponding arxiv submission https://arxiv.org/abs/2502.02152

Experiment context, if any

Experiment agnostic

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