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Design of the SHiP's Muon Shield with Machine Learning

The SHiP experiment is a proposed fixed-target experiment at the CERN SPS aimed at searching for feebly interacting particles beyond the Standard Model. One of its main challenges is reducing the large number of muons produced in the beam dump, which would otherwise create significant background in the detector. The muon shield, a system of magnets designed to deflect muons away from the detector acceptance, must be optimized to achieve the best possible background suppression while keeping costs low. In this work, we extend previous optimization efforts by explicitly incorporating geometric constraints and the on-the-fly simulation of field maps, providing a more realistic evaluation of the shield's performance. This optimization includes both the case of using normal-conducting magnets and the potential for incorporating superconducting magnets, which may offer significant advantages in terms of performance for the muon shielding. We start by re-optimizing the parameters of the magnets through merging Bayesian Optimization (BO) and local optimization with surrogate models. Moreover, to address the computational cost of full-scale simulations, we train the surrogate model on a carefully selected reduced sample, allowing it to predict results for the full sample without sacrificing accuracy. Building upon this, we take a step further by generalizing the problem as a dynamic magnet and veto allocation task. Given the sequential nature of this challenge, we propose to apply reinforcement learning (RL) to iteratively select and arrange magnets in an optimal configuration, offering a more flexible and adaptive solution. We compare both approaches and evaluate their impact on the muon shield's performance and computational efficiency.

AI keywords

Bayesian Optimization, surrogate models, gaussian processes, reinforcement learning

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Track Classification: Simulations & Generative Models