

Constrained collaborative optimization of charged particle tracking with multi-agent reinforcement learning

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Reinforcement learning (RL) offers a promising framework for modeling complex physics-driven systems through end-to-end learning. We present a multi-agent RL approach for particle track reconstruction in pixelated detectors, where tracking is formulated as a heuristic to a multidimensional assignment problem. Agents learn by interacting within shared environments to collaboratively reconstruct particle trajectories by minimizing scattering angles across tracks while satisfying unique hit assignment constraints.

To ensure valid assignments, we incorporate a safety layer, solving a linear assignment problem for every joint action. We further explore the use of cost margins to improve optimization stability and robustness by increasing the distance to decision boundaries of the optimizer mappings. Evaluations on simulated proton imaging detector data show improved reconstruction quality and stability compared to several single-agent and multi-agent baselines.

This work highlights the potential of constrained multi-agent RL for flexible and robust particle tracking in particle physics.