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Physics Informed and Bayesian Machine Learning for Maximization of Beam Polarization at RHIC

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The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL) provides the world's only high-energy polarized proton beam. It is in the unique position to study from where nuclei obtain their spin, which is ultimately the property responsible for any kind of magnetization. Preserving polarization during particle acceleration is a difficult process that requires tuning many accelerator components. RHIC' s successor, the Electron Ion Collider (EIC) will be one of the most complex scientific instruments ever built, with the capability of colliding polarized proton and electron beams. This increase in instrument complexity will require new, sophisticated tools to optimize accelerator performance thereby maximising the utility of polarized beam experiments.

A collaborative project between BNL, JLab, Cornell, RPI, SLAC, and RadiaSoft is tackling the challenging problem of polarization maximization for RHIC. The polarization benefits from three intermediate objectives: (1) preserve beam density, (2) synchronize accelerator components at depolarizing resonance crossings, and (3) minimize depolarizing resonance strengths. Operational parameters for these objectives can be measured and actuated, making them suitable candidates for optimization. We aim to build a fully Bayesian, physics-informed machine learning (ML) framework to optimize the system and maximize polarization performance. Because the EIC will use the same polarized pre-accelerator chain as RHIC, this methodology will improve future EIC polarization performance as well.

In this presentation, we will describe the project's objectives, initial results, and future plans. Major components of the project include improving physics-based models of the accelerator and learning accurate physics- and data-driven surrogate models by leveraging ML-based model calibration methods. We will use these models in conjunction with Bayesian optimization, reinforcement learning, and fast feed-forward ML-based corrections to achieve optimal polarization performance at RHIC.

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ML-based optimization

Secondary Keyword

digital twins

Tertiary Keyword

AI-based controls

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