# PROJECT SUMMARY/ABSTRACT

**Higher RHIC Polarization by Physics-Informed Bayesian Learning**

Georg Hoffstaetter (PI) | Brookhaven National Laboratory & Cornell University

Kevin Brown (Co-PI) | Brookhaven National Laboratory & Stony Brook University

Auralee Edelen (Co-PI) | SLAC National Laboratory

The Relativistic Heavy Ion Collider at Brookhaven National Laboratory provides the world’s only high-energy polarized proton beam and is in the unique position to study wherefrom nuclei obtain their spin, a property ultimately responsible for any kind of magnetization. Preserving polarization during particle acceleration is a difficult process that requires the optimization of many accelerator components. During 25 years of polarized proton operation in RHIC, BNL has become the world expert in these technologies. RHIC’s successor, the Electron Ion Collider is currently being designed to also provide polarized proton beams, colliding with polarized electrons, making it one of the most complex scientific instruments every built.

The technology needed to maximize the scientific power of polarized beam experiments impacts three accelerator science areas in RHIC’s accelerator chain: Beam density preservation, precise timing of all accelerator components, and the minimization of depolarizing forces. Critical beam properties for these optimizations can be measured, and tools are available to influence these. The accelerating chain consists of 4 separate accelerators: Linac, Booster, AGS, and RHIC where critical measurements include the beam’s trajectory, its density, its energy as a function of time, and its polarization. These are optimized by the strengths of steering magnets, phases and amplitudes of radiofrequency accelerating structures, time-dependent pulsers for fast magnet changes, and by the field strengths of polarization-manipulating magnets like Siberian snakes. Many of these optimizations are so complex that only a small group of experienced operators can perform them, and once achieved high performance can quickly deteriorate with time.

We propose to introduce modern Machine Learning optimization tools to increase the polarization performance of RHIC’s accelerator chain, and through automation allow more continuous operation at optimized settings. Polarization is a highly critical parameter, entering in 4th power to some experiments, so that a goal of 5% polarization increase already delivers an accelerator improvement of more than 20%.

*Objectives of the project:* Bring ML tools to (a) better inject into Booster and AGS, (b) correct the charged particle optics of these toward their design by means of the Orbit Response Matrix, (c) time tune-jump quadrupoles by improving energy measurements, (d) minimize horizontal depolarizing resonances driven by the AGS snakes.

*Methods to be employed:* The problems that are faced during polarization maximization are particularly suitable for physics informed Bayesian Optimization, because measurements have significant uncertainties, approximate models for each measurement exist, and a large amount of measured data can be collected, all properties suitable for improving the BO’s acquisition function.

*Potential impact:* This project will not only improve the RHIC accelerator chain but will provide a proof of principle and blueprint of how established, large accelerators can be improved by Machine Learning.