**NAPAC 2022 Abstract:** (1,200 character limit)

**Title:** Optimizing the Discovery of Underlying Nonlinear Beam Dynamics

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**Abstract:**

One of the DOE-HEP Grand Challenges identified by Nagaitsev et al. [1] relates to the use of virtual particle accelerators for beam prediction and optimization. Useful virtual accelerators rely on efficient and effective methodologies grounded in theory, simulation, and experiment. This paper uses an algorithm called Sparse Identification of Nonlinear Dynamical systems (SINDy) [2], which has not previously been applied to beam physics. We believe the SINDy methodology promises to simplify the optimization of accelerator design and commissioning, particularly where space charge is important. We show how SINDy can be used to discover and identify the underlying differential equation system governing the beam moment evolution. We compare discovered differential equations to theoretical predictions and results from the PIC code WARP [3] modeling. We then integrate the discovered differential system forward in time and compare the results to data analyzed in prior work using a Machine Learning paradigm called Reservoir Computing [4]. Finally, we propose extending our methodology, SINDy for Virtual Accelerators (SINDyVA), to the broader community's computational and real experiments.

[1] S. Nagaitsev, Z. Huang, J. Power, J.L. Vay, P. Piot, L. Spentzouris, J. Rosenzweig, Y. Cai, S. Cousineau, M. Conde et al., “Accelerator and Beam Physics Research Goals and Opportunities,” arXiv preprint arXiv:2101.04107, 2021.

[2] S. L. Brunton, J. L. Proctor, and J. N. Kutz, “Discovering governing equations from data by sparse identification of nonlinear dynamical systems,” Proceedings of the National Academy of Sciences, vol. 113, no. 15, pp. 3932–3937, 2016

[3] D. P. Grote, A. Friedman, J.-L. Vay, and I. Haber, “The WARP Code: Modeling High Intensity Ion Beams,” in AIP Conference Proceedings, vol. 749, no. 1. American Institute of Physics, 2005, pp. 55–58

[4] H. Komkov, L. Dovlatyan, A. Perevalov, and D. Lathrop, “Reservoir Computing for Prediction of Beam Evolution in Particle Accelerators,” in NeurIPS Machine Learning for the Physical Sciences Workshop, 2019.

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