Using the Sirepo Platform for Beamline Simulations

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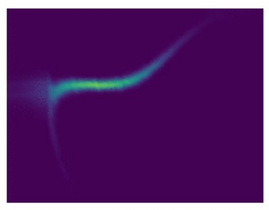
Abstract

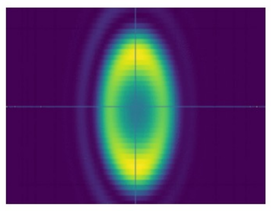
The Sirepo platform is designed to offer GUIs for popular simulation codes used in the accelerator space, along with integration with a JupyterLab Python environment. This includes srw, radia, elegant, and warp, mad-x, opal, and synergia, as well as ongoing development for an online controls and fault detection interface. This open-source platform is available through sirepo.com, as well as a premium solution for deployment on-site. The integrated environment across multiple codes allows for easy optimization, verification, and scripting in custom beamlines, rings, and linacs. Sirepo makes it easier for engineers, students, and scientists alike to build accelerator simulations necessary for better understanding subsystem requirements. Here we provide a general introduction to Sirepo and a tutorial on how to build simple beam-line models using our interface.

What is Sirepo?

Sirepo is an open-source scientific gateway that provides users with access to a broad range of simulation tools. These tools are centered around accelerator technology but are wide reaching in their application spaces. Users have access to traditional particle tracking codes such as Mad-X, elegant, synergia, and Opal. Because we utilize a common mad-x format for lattice definitions users can import or export from each of these tools using mad-x as a base. Sirepo also hosts a range of x-ray optics simulation tools, specialized particle-in-cell applications for electron devices and advanced accelerators in addition to controls applications and machine learning tools. Additionally, users seeking a more flexible sandbox can work out of our Jupyter interface which hosts all the simulation codes in our GUI in addition to stable versions of machine learning libraries and scientific tools that are widely used by the community.



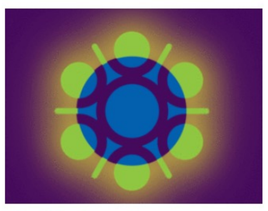
Particle Accelerators
Model beam dynamics for a wide range of particle accelerators.



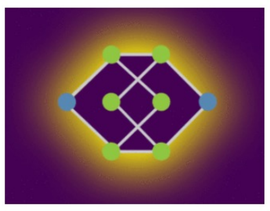
X-ray Beamlines
Simulate synchrotron radiation and design x-ray beamlines.

Particle tracking simulations and x-ray beamline simulations are used to specify the needs for the users and the machine which in turn specifies the requirements for the LLRF system.

Machine learning tools can be used to train models for LLRF systems for "slow controls" our controls application can interface with "slow controls" to provide high level application support.

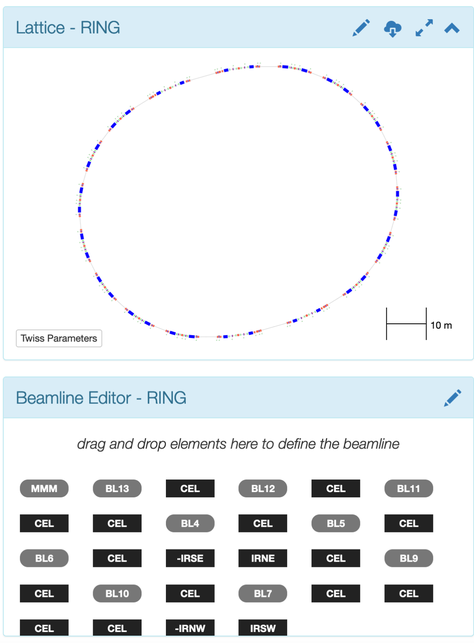


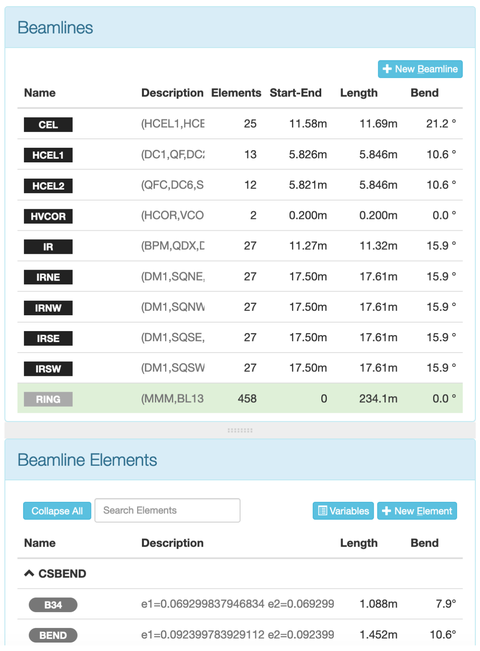
Machine Learning
Analyze complex datasets and develop machine learning algorithms.



Controls
Test automated tuning programs with control-systems codes.

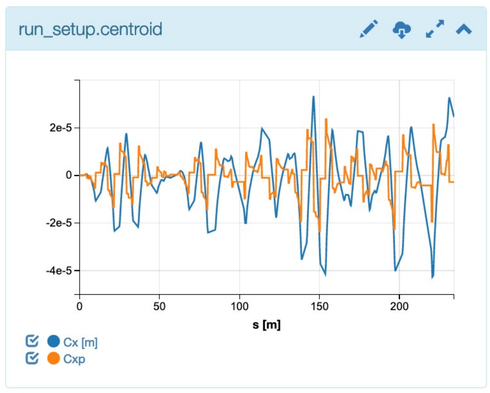
Ring Simulations using Sirepo

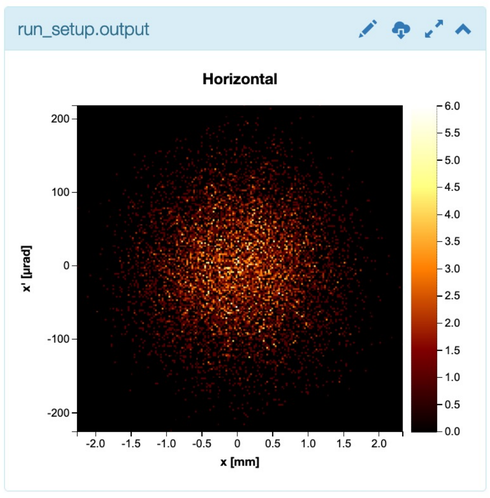


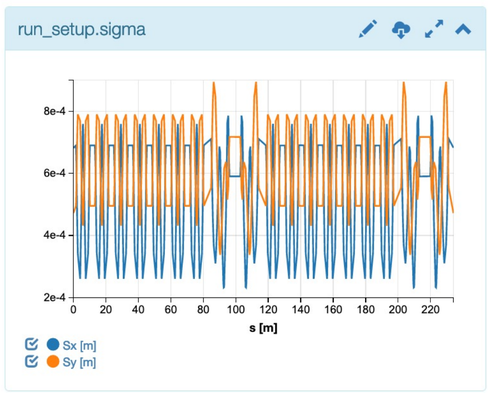


The user has the ability to modify the lattice or import a lattice from a file. Our lattice manipulation tool provides a diverse suite of options for making it easy to build the machine using modular components. When modifying lattices built for studying transverse dynamics it is easy to import RF cavities and study the impact on RF perturbation to the beam.

The users can visualize the output of the simulations in several different ways. They can look at the centroid positions, the beam distribution, and the beam sigma matrix. Users can download plots and raw data for analysis outside of Sirepo.

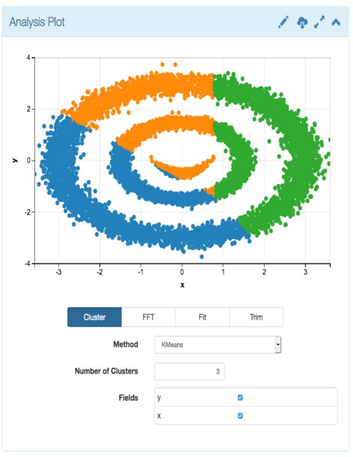


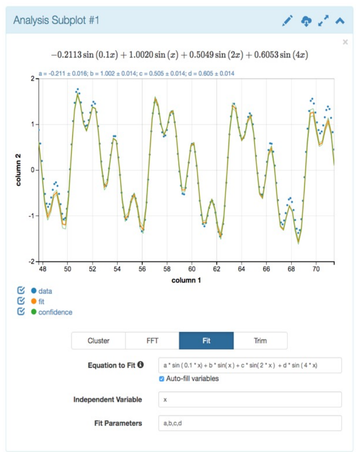


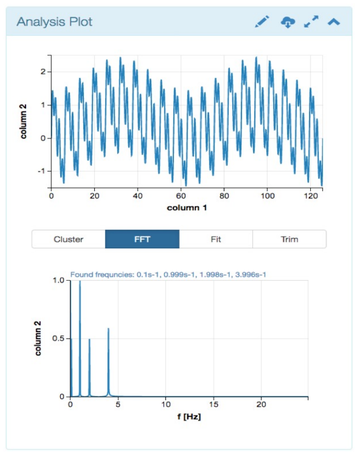


The control panel allows users to modify the various aspects of the simulation. For elegant and mad-x for example, users can preform RF ramp simulations and capture simulations which would be particularly useful for specifying RF control parameters for ring designs. There is also machinery in elegant to preform LLRF feedback simulations. Specialized visualizations for these features could be built into our existing application workflow.

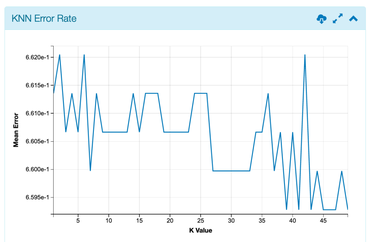
Sirepo for Data Analysis and Controls

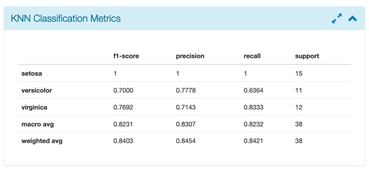


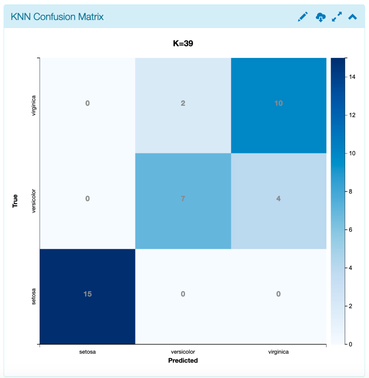


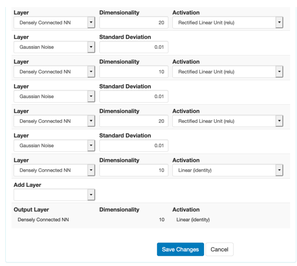


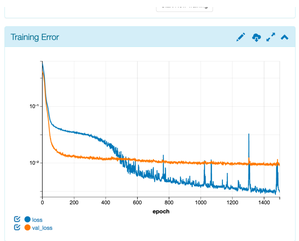
The data analysis pipeline (top) provides access to a range of clustering, curve fitting, and frequency analysis tools. The interface comes with powerful point and click features for data manipulation.

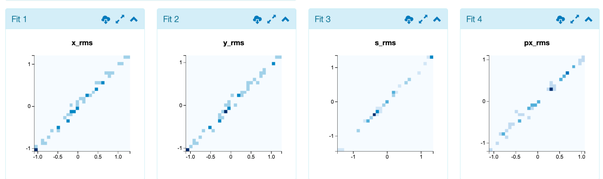












Above: Machine learning classifier tools available in Sirepo Activait. Left: Neual network training tools also available in Sirepo Activait

High level applications are an important part of the LLRF ecosystem. The Sirepo controls application is a powerful tool for automating the generation of high level applications. These displays can be built directly from lattice files or manually depending on the application space. Here we show a beam steering example where measurements are taken from the machine and compared with the model output. A similar thing could be accomplished using RF data in a LINAC for example.

References

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This material is based upon work supported by the U.S. Department of Energy, Office of Science, Award Numbers: DE-SC0021699, DE-SC0018556, DE-SC001871, DE-SC0020593, DE-SC0021555, DE-SC0018719, DE-SC0019682, DE-SC0017162, DESC0011237, DE-SC0011340, DE-SC0019979, DE-SC0017181, DE-SC001512.

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Poster ID 72, Switzerland, 10/2022