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Image processing with ML for automated tuning of the NASA Space Radiation Laboratory beam line

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Research conducted at the NASA Space Radiation Laboratory (NSRL) seeks to increase the safety of space exploration. The NSRL uses beams of heavy ions extracted from Brookhaven's Booster synchrotron to simulate the high-energy cosmic rays found in space. To accomplish this, the source machines provide many potential beam species, ranging in atomic number (Z) from 1, hydrogen/protons, to 83, bismuth and we have gone as high as Uranium. To test large-area samples, beams can be shaped to the user's specifications from a small-format 1-cm radius circular beam up to 20-cm by 20-cm uniform-area rectangular beams. This requires a complex transfer line of 24 magnets, including 9 quadrupole and 2 octupole magnets. Given the wide range of beam rigidity and size possibilities, operators tune the optics by hand while observing the beam profile on a phosphor screen imager. Successful tests have been conducted using a machine learning (ML) workflow for tuning. We capture the beam image, then process and parameterize the beam to assess centroid, shape, tilt, edge thickness, and uniform area size. These parameters are fed to the Badger software stack to avoid re-inventing a UI, using an Xopt-based Bayesian optimization algorithm for iterative tuning. The requirement to start from an image, which can be very noisy, and quantify it, makes the workflow more complex than the standard ML cookie-cutter approach of reading from traditional beam instrumentation fed to an algorithm.

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Footnotes

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