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## Bayesian Optimization for Model-Based Automated Multi-Turn Extraction Tuning at the Proton Synchrotron.

The beam for CERN's North Area proton physics program is produced through a Multi-Turn Extraction (MTE) scheme at the Proton Synchrotron (PS). Using fourth-order resonant excitation, the beam is split into five beamlets in horizontal phase space, with extraction occurring over five consecutive turns. The quality of the splitting is measured by the uniformity of intensities across the beamlets. The process requires precise tuning of several parameters, including the horizontal tune, transverse feedback gain, and excitation frequency. Given the varying conditions in the PS, optimal parameter settings shift frequently, making manual optimization both challenging and inefficient.

This paper focuses on developing and implementing continuous control for the MTE beam using Bayesian optimization (BO) with Gaussian Processes (GP). We discuss experimental studies on various techniques to improve GP convergence and investigate the use of adaptive BO. The experimental results demonstrate the viability of the proposed solution, eliminating the need for manual tuning for MTE beam production.

**Author:** FOLDESI, Levente Alex (University of Zurich (CH))

**Co-authors:** HUSCHAUER, Alexander (CERN); GIOVANNOZZI, Massimo (CERN); SCHENK, Michael (CERN); NAUMENKO, Oleksandr (Hamburg University (DE)); KAIN, Verena (CERN)

**Presenter:** FOLDESI, Levente Alex (University of Zurich (CH))

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