ISBN: 978-3-95450-205-9 doi:10.18429/JACoW-Cyclotrons2019-THA01

PRECISE MODELLING AND LARGE SCALE MULTIOBJECTIVE OPTIMIZATION OF CYCLOTRONS

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SYNOPSIS

This contribution gives a summary of an invited presentation delivered at this conference.

The usage of numerical models to study the evolution of particle beams is an essential step in the design process of particle accelerators. However, uncertainties of input quantities such as beam energy and magnetic field lead to simulation results that do not fully agree with measurements. Hence the machine will behave differently compared to the simulations. In case of cyclotrons such discrepancies affect the overall turn pattern or alter the number of turns. Inaccuracies at the PSI Ring cyclotron that may harm the isochronicity are compensated by 18 trim coils. Trim coils are often absent in simulations or their implementation is simplistic. A realistic trim coil model within the simulation framework OPAL has been investigated. It was used to match the turn pattern of the PSI Ring (see Fig. 1). Due to the high-dimensional search space consisting of 48 simulation input parameters and 182 objectives (i.e. turns) simulation and measurement cannot be matched in a straightforward manner. Instead, an evolutionary multi-objective optimisation with more than 8000 simulations per iteration together with a local search approach was applied that reduced the maximum error to 4.5 mm over all 182 turns (see Table 1 and Figs. 2 and 3).

The results of this study have recently been published in their entirety in [1], to which the reader is further referred.

Table 1: Maximum absolute error (l_∞-norm), mean absolute error (MAE) and the mean squared error (MSE) of the best individual of the optimizer and local search compared to the measurement. In both cases the maximum error is at turn 2.

Method	**l_∞-norm** (mm)	**MAE** (mm)	**MSE** (mm^2)
optimizer	6.4	2.0	6.3
local search	4.5	1.4	3.4

REFERENCES

[1] M. Frey, J. Snuverink, C. Baumgarten, and A. Adelmann, “Matching of turn pattern measurements for cyclotrons using multiobjective optimization”, *Phys. Rev. Accel. Beams*, vol. 22, no. 6, p. 064602, 2019. doi:10.1103/PhysRevAccelBeams.22.064602

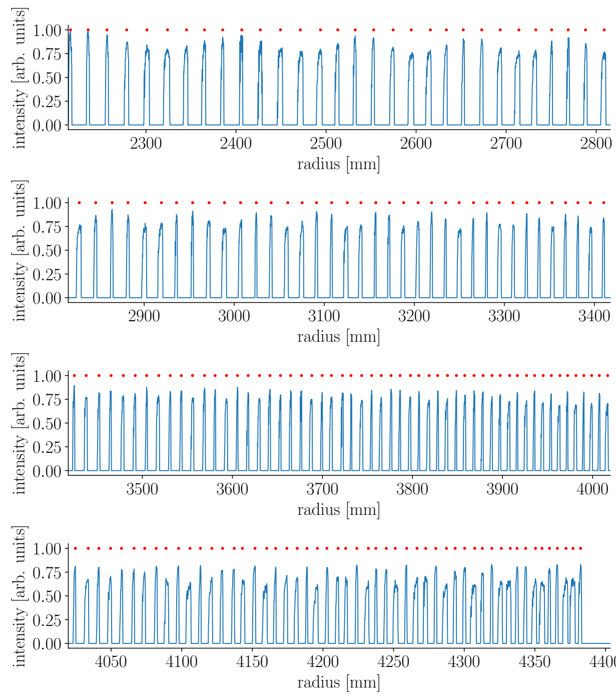

Figure 1: Histogram of the probe RRL measurement. The intensity is normalized. The red dots mark detected peaks.

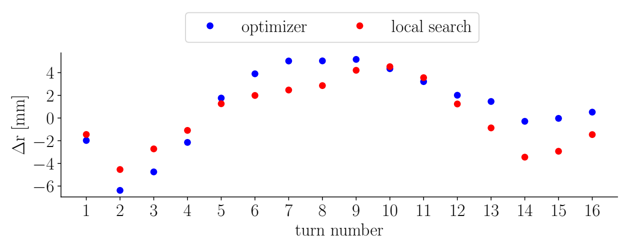

Figure 2: Error of the turn radius at RRI2 between measurement and simulation of the best individual obtained by multi-objective optimization and local search.

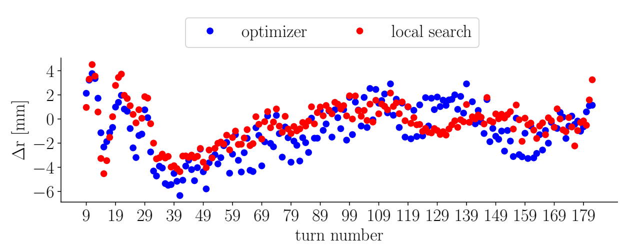

Figure 3: Error of the turn radius at RRL between measurement and simulation of the best individual obtained by multi-objective optimization and local search.

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