



LOCO Corrections for Trajectory Optimisation on the ISIS Accelerator

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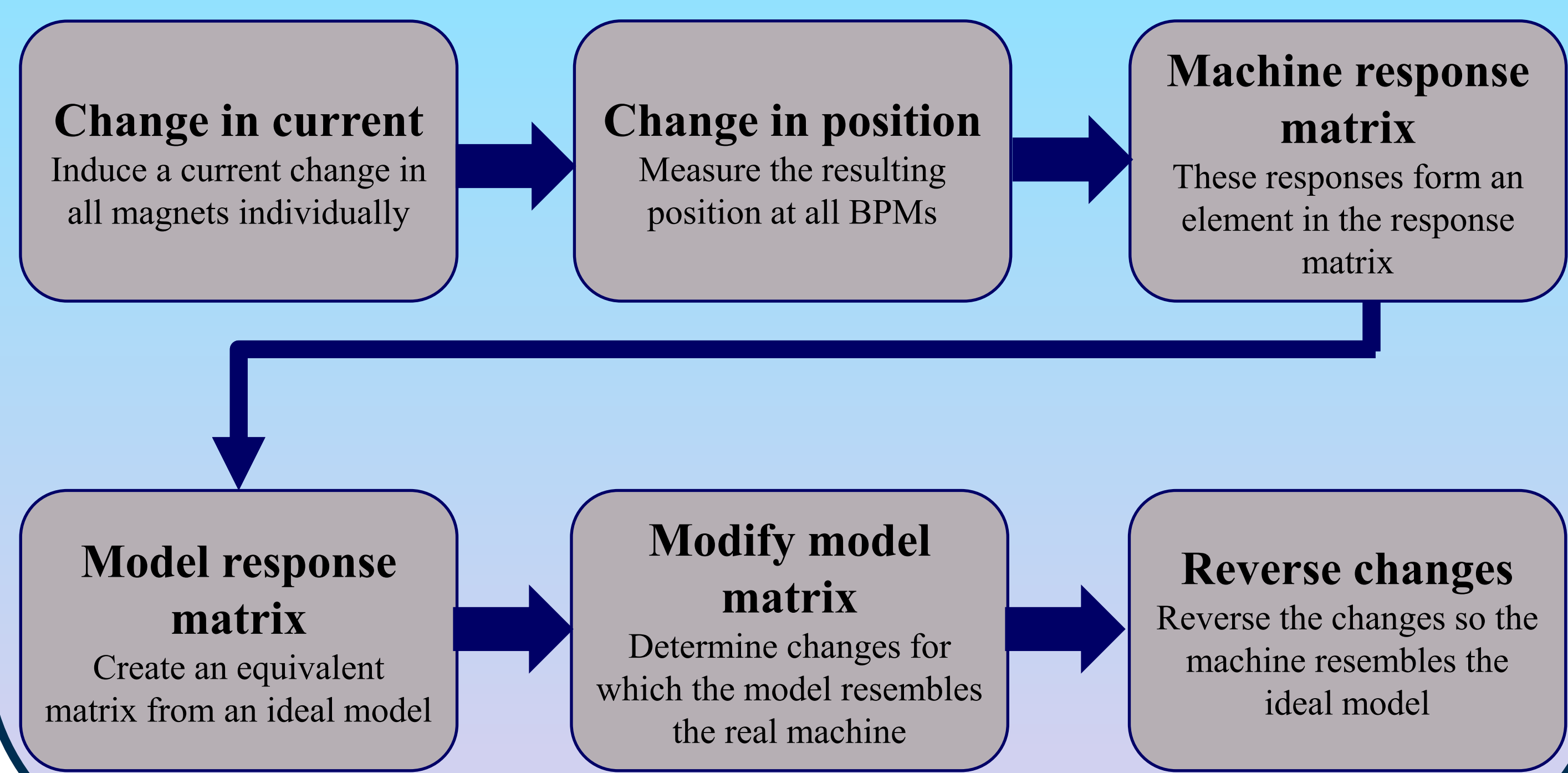
Introduction

The ISIS facility at the Rutherford Appleton Laboratory is a pulsed neutron and muon spallation source. The synchrotron accelerates 3×10^{13} protons per pulse to 800 MeV at 50 Hz and delivers them to two target stations to produce neutrons and muons for condensed matter research. The dynamics of the beam in an acceleration cycle are affected by errors in both the magnets and monitors. Counteracting these errors gives a better understanding of the beam behaviour and can improve control.

This poster describes the recent application of the LOCO method of beam optics correction to the ISIS synchrotron and discusses its initial results.

LOCO

Linear Optics from Closed Orbits (LOCO) is a correction technique which monitors the beam behaviour in response to changes in all lattice elements. To suggest changes to variable parameters (currents, alignments, tilts etc.), LOCO minimises differences between the real machine and an ideal machine model. In this way, real errors can be identified and counteracted on the accelerator.

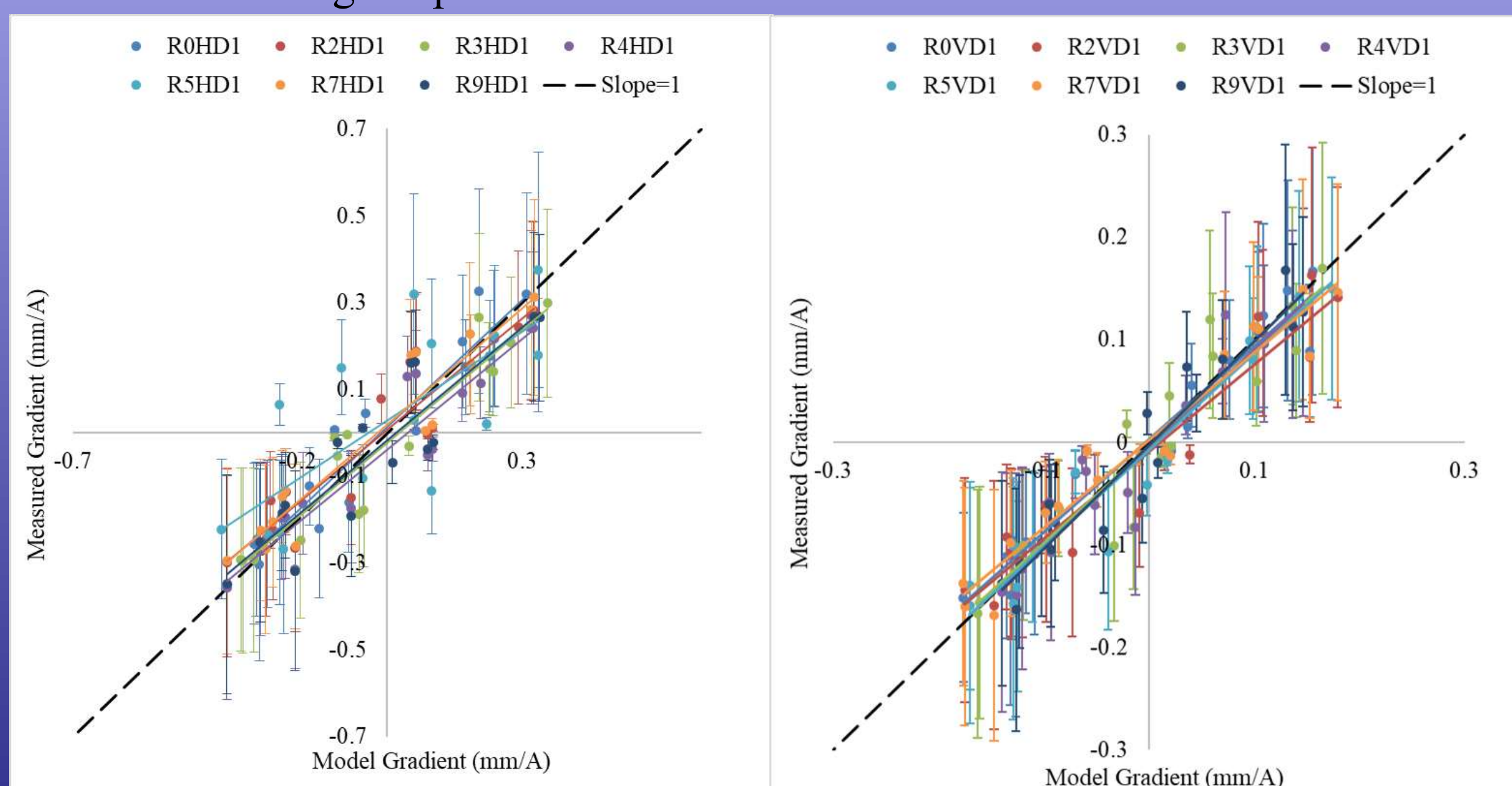


Orbit Response Matrices

There are 17 horizontal and 19 vertical beam position monitors (BPMs) around the ISIS synchrotron. The orbit response to a change in all 14 correction dipoles (7 in each plane) individually is measured at each BPM on a single pulse. These responses take roughly 2 hours to measure and build up an orbit response matrix (ORM). Since this ORM relates to a specific machine setup, it should be remeasured before each correction attempt. An equivalent ORM is then calculated from the MADX ideal machine model

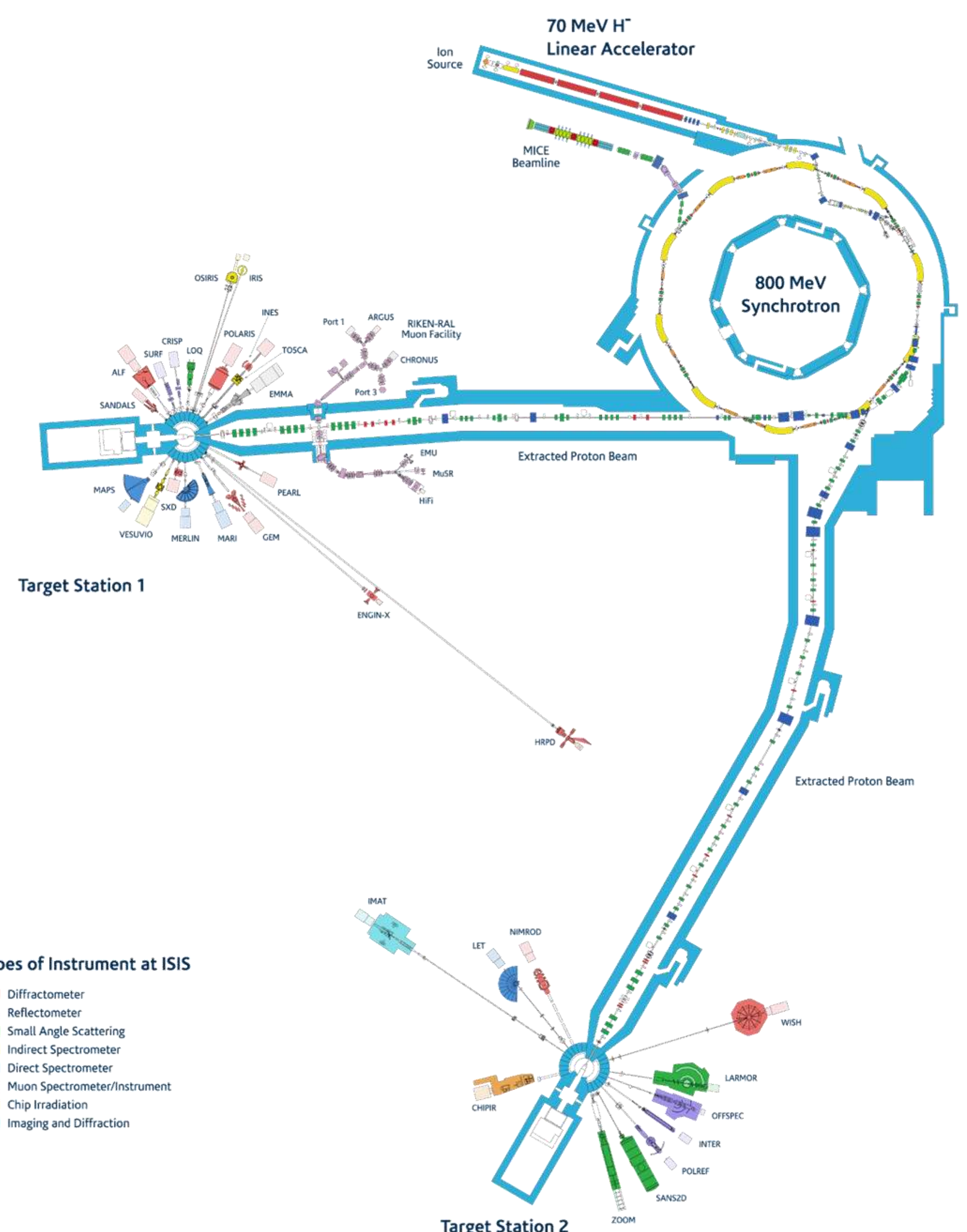
$$\frac{\Delta x_i}{\Delta \theta_j} = \frac{\sqrt{\beta_i \beta_j}}{2 \sin(\pi \nu_x)} \cos(|\psi_i - \psi_j| - \pi \nu_x)$$

Comparison of the machine and model ORMs is shown below, indicating a good agreement. An initial error involving the placement of R5HD1 in the model was identified and corrected.



References

- M. J. McAteer, "Linear optics measurements in the Fermilab booster and the CERN PS booster", Ph.D. thesis, Phys. Dept, The University of Texas at Austin, USA, 2014.
- J. Safranek, "Linear Optics from Closed Orbits (LOCO): an introduction", in *ICFA Beam Dyn. Newsl.*, vol. 44, pp. 43-49, Dec. 2007.

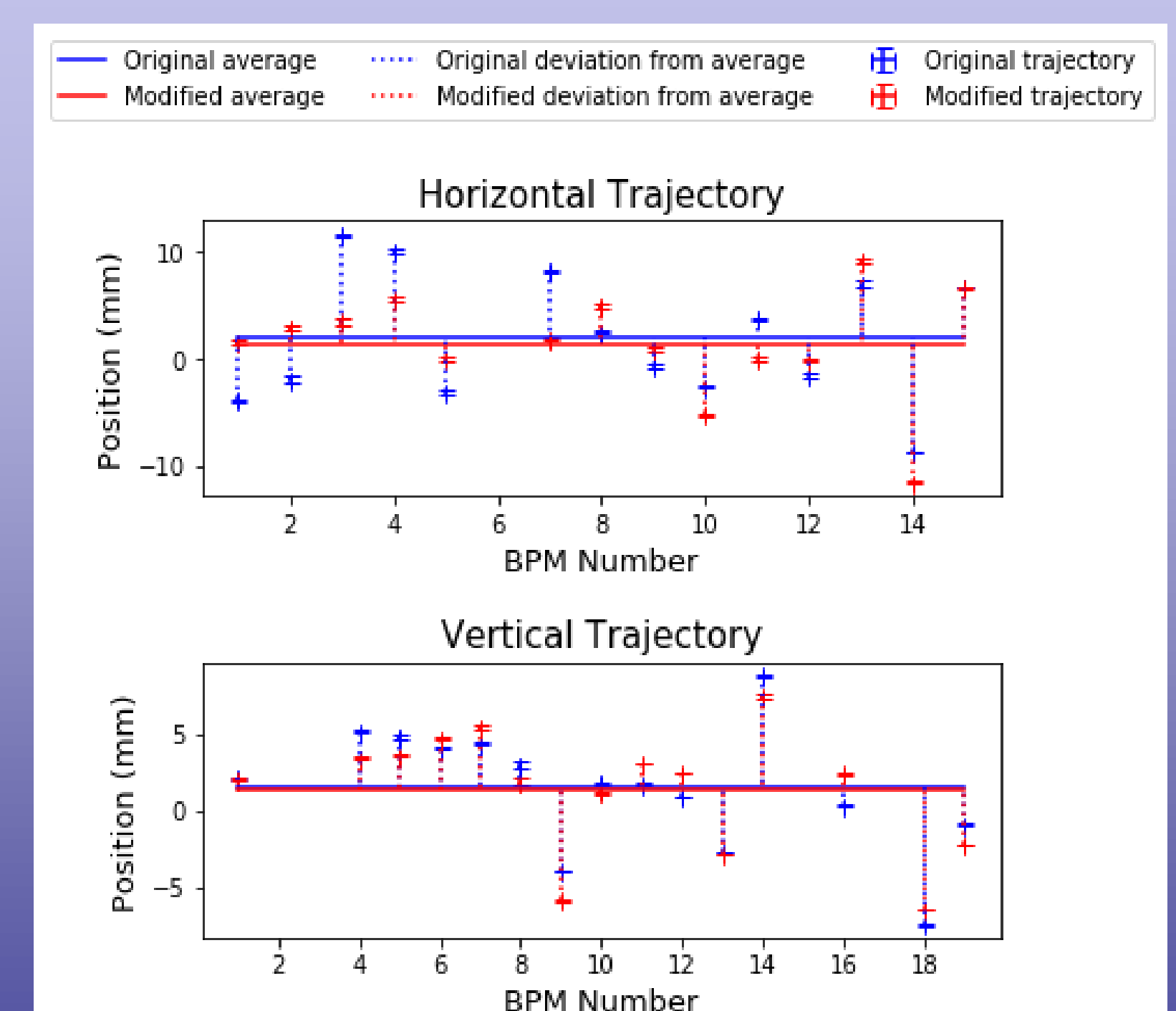


Code Development

A Python code was written to perform the LOCO analysis on the ISIS synchrotron. The CPyMAD package is used to run the machine model directly from the Python environment and reduces the running time to a matter of seconds. This collects the parameters necessary to calculate the model ORM. The measured ORM is loaded into the code from its stored location and the differences between the ORMs are minimised using Singular Value Decomposition. The singular value spectrum doesn't have a clear cut so choice of singular values used is considered carefully. The application discussed here allows the code to determine new settings for the 14 corrector magnets in 3 iterations, using 6 singular values.

Results

The corrections suggested by the Python code should counteract any measurement or field errors and allow for a steadier, more centred beam trajectory. When tested on the machine, corrections were made to a setup already treated by the existing correction technique with small pulse-to-pulse deviations. The LOCO code indicated negligible misalignment errors in both planes, therefore these parameters were removed from future correction attempts.



Resulting trajectory RMS was improved by 17 % horizontally whilst maintaining the well-centred vertical RMS value.

Conclusions

Measuring the ORM takes roughly 2 hours and should be repeated before each correction attempt to account for the specific machine setup. Identification and correction of large errors (such as the position of lattice elements in the model) were demonstrated.

Implementation of the LOCO corrections on the ISIS synchrotron improved the horizontal trajectory RMS by 17 % while maintaining the well-centred vertical trajectory RMS.