Rapid Tuning of Synchrotron Surrogate Model at the Recycler Ring

Jason St. John, Fermilab AD

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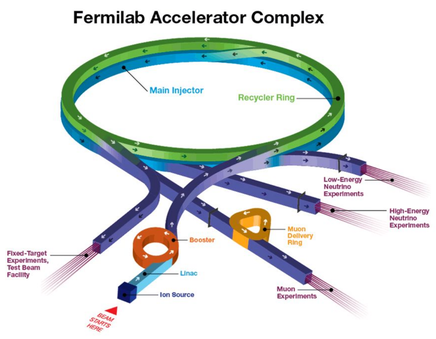
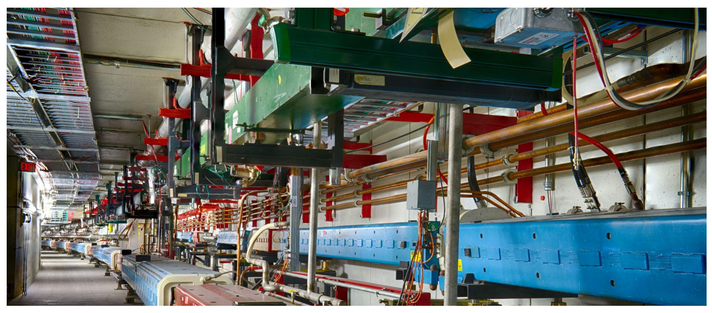
The Recyler Ring is key to world-record neutrino target power



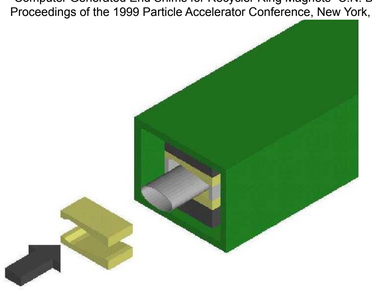


Recycler Ring above, Main Injector below. (Transfer line between.) Obviously the Recycler Ring is green.

The combined-function permanent magnets of the Recycler Ring let it store 8 GeV protons, which are slip-stacked into the Main Injector to double the intensity of proton beams on Fermilab's flagship neutrino targets: NuMI, and soon, DUNE/LBNF.

Magnetic shim plates were meant to correct integrated multipole moments on the 68+66 gradient magents

"Computer Generated End Shims for Recycler Ring Magnets" C.N. Brown, G.W. Foster, G. P. Jackson, J. T. Volk, Proceedings of the 1999 Particle Accelerator Conference, New York, 1999



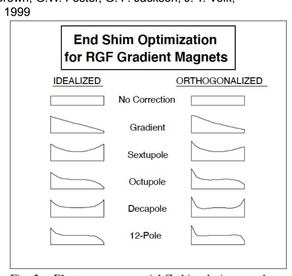


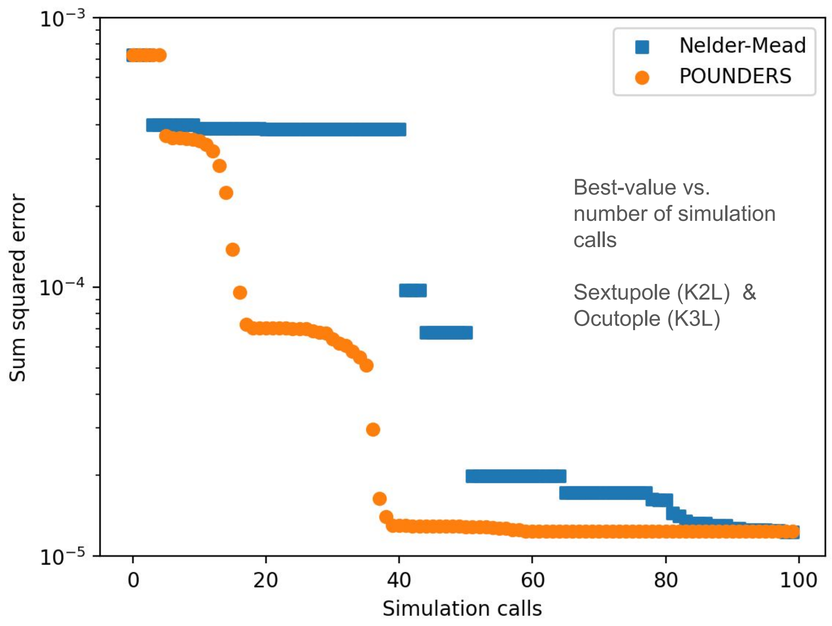
Fig. 2 – Elementary monomial Z-shim designs used as a starting point, and shim designs which were found to produce pure multipole shifts after re-orthogonalizing the multipole contributions from the elementary shims.

Custom magnetic shims extend the pole faces, improving multipole tolerances. Upstream shims were uniform (F or D designs), while downstream shims were individualized. Small, necessary compromises remained (feeddown, etc).

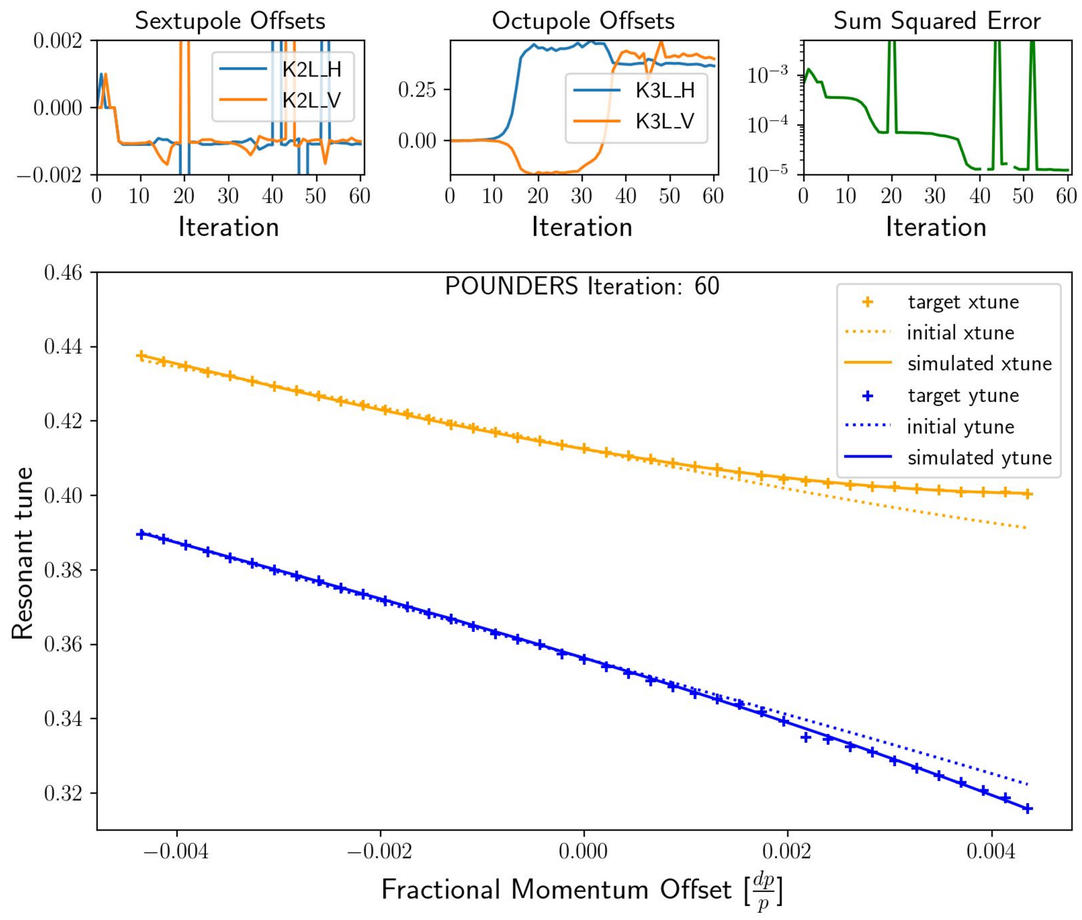
Improving Lattice Parameters with POUNDERS

The **P**ractical **O**ptimization **U**sing **N**o **De**rivatives for sums of **S**quares method is designed to efficiently optimize large-scale least-squares objectives when analytical derivatives are not available or difficult to compute. POUNDERS is a trust-region method that maintains internal models of the simulation outputs around the current iterate. By maintaining such models in a dynamically resizing trust region, POUNDERS often finds high-quality solutions in far fewer simulation evaluations than methods that do not exploit a minimization-of-squares structure.

Best-value history of target (simple sum of squares) POUNDERS and Nelder-Mean downhill simplex methods, varying four simulation parameters: Horizontal and Vertical Sextupole and Octupole moments of upstream magnetic shims.



Rapid convergence to simulation parameters means more realistic models, faster



ABOVE
Top: Iteration histories for POUNDERS adjusting the K2L and K3L (H/V) parameters in the Recycler Ring lattice, and the resulting sum of sq. errors with respect to data
Main: Initial and final simulated tunes for horizontal (upper, yellow) and vertical (lower, blue) planes.

BELOW
Final parameter values for horizontal/vertical sextupole/octupole upstream shim plate moment offsets.

	H sext.	V sext.	H octu.	V octu.
POUNDERS	-0.00107	-0.00099	0.37075	0.40921
NM	-0.00108	-0.00097	0.34959	0.45167

POUNDERS converged faster than the Nelder-Mead simplex method, and to very similar (~%) parameter values. The convergence speed advantage was even greater when decapole and dodecapole terms were added to the parameter space.

Add K4L terms

param	4D result	6D result
K2L_H	-0.00107	-0.00108
K2L_V	-0.00099	-0.00097
K3L_H	0.37075	0.360913
K3L_V	0.40921	0.424178
K4L_H		0.008111
K4L_V		0.0221750

Add K5L terms

param	4D result	8D result
K2L_H	-0.00107	-0.00122
K2L_V	-0.00099	-0.00064
K3L_H	0.37075	0.388951
K3L_V	0.40921	0.362705
K4L_H		0.790581
K4L_V		-1
K5L_H		-1
K5L_V		-0.052298

Pushing against bounds set artificially. If relaxed, could probably improve further.

Best-value histories of target (simple sum of squares) POUNDERS and Nelder-Mean downhill simplex methods, in larger (6D) and larger (8D) multipole shim-plate parameter spaces. The convergence speed advantage of POUNDERS improves as these higher-order multipoles are added.

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