Preliminary results of linear optics from orbit response in the CERN PSB

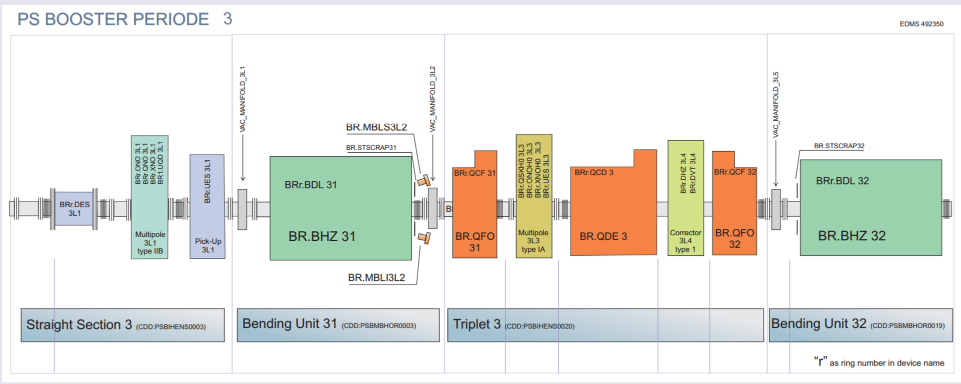
M. McAteer, C. Carli, B. Mikulec, R. Tomás, CERN, Geneva, Switzerland

ABSTRACT

Planned high-luminosity operations at CERN will require the PS Booster to deliver higher intensity beam with little beam loss or emittance increase, and having an accurate knowledge of the machine's lattice imperfections will be necessary to help achieve this. We present preliminary results of the analysis of orbit response measurements in the PS Booster to determine the linear optics and to identify field errors in each of the machine's four rings.

ORM in the PSB

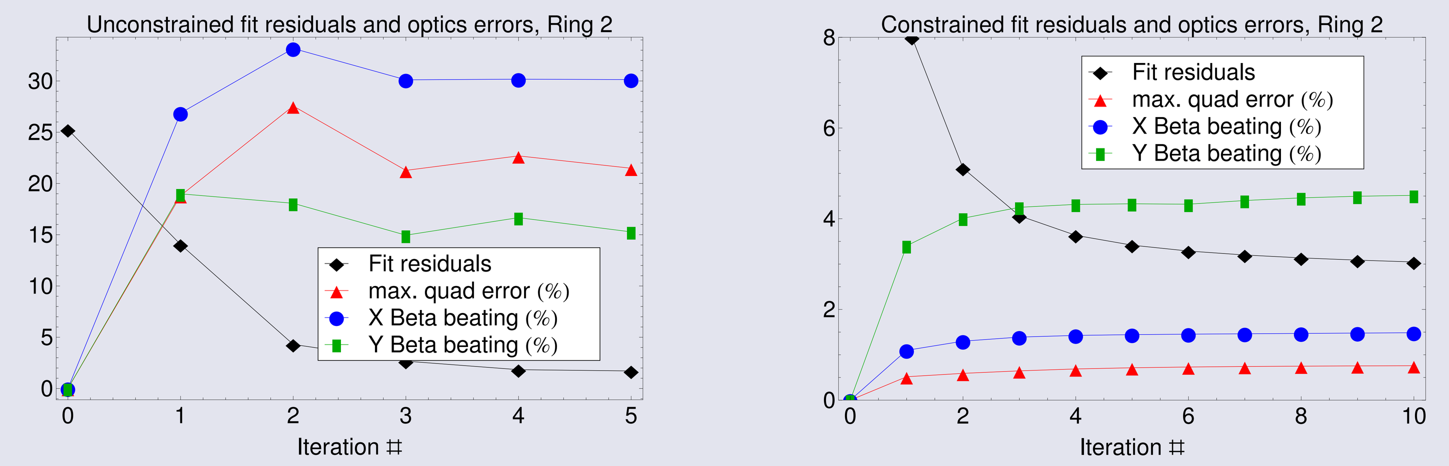
- The PSB accelerate beam from 50 MeV to 1.4 GeV in about 530 milliseconds.
- The machine is composed of four vertically stacked rings each composed of sixteen periods, with an F-D-F triplet and two bending magnets in each period.
- Working point is approximately Qx=4.2 and Qy=4.3 (phase advance between periods $\approx \pi/2$).
- 32 BPMs (16 in each plane) and 26 dipoles (13 in each plane) were used for ORM measurements, for a total of 864 data points in each ring including measured dispersion.
- ORM was measured throughout most of the acceleration cycle; results at future injection energy of 160 MeV are presented here.



Constrained LOCO fitting

- The Linear Optics from Closed Orbits (LOCO) method is used to determine linear optics by adjusting parameters in the lattice model to minimize the discrepancy between model and measured orbit response to dipole perturbations [1].
- The variable model parameters used for LOCO in the PSB were the strengths and tilts of the 48 triplet quadrupoles, calibrations and tilts of the 26 dipoles, and calibrations and tilts of the 32 BPMs (total of 198 parameters in each ring).
- For the PSB, unconstrained optimization gives excessively large values for quadrupole errors due to the large number of quadrupoles relative to BPMs and the $\pi/2$ phase advance between periods.
- The fit can be improved by adding a constraining term to the penalty function (where i is the BPM index, j is the dipole corrector index, σ_{ij} is the standard error of the linear fit, ΔK_q is the change to the q^{th} parameter and w_q is a weighting factor for the q^{th} parameter) [2]:

$$\chi^2 = \sum_{i,j} \frac{1}{\sigma_{ij}^2} \left(\left(\frac{\partial x_i}{\partial \theta_j} \right)_{meas} - \left(\frac{\partial x_i}{\partial \theta_j} \right)_{model} \right)^2 + \sum_q (w_q \Delta K_q)^2 \qquad (1)$$



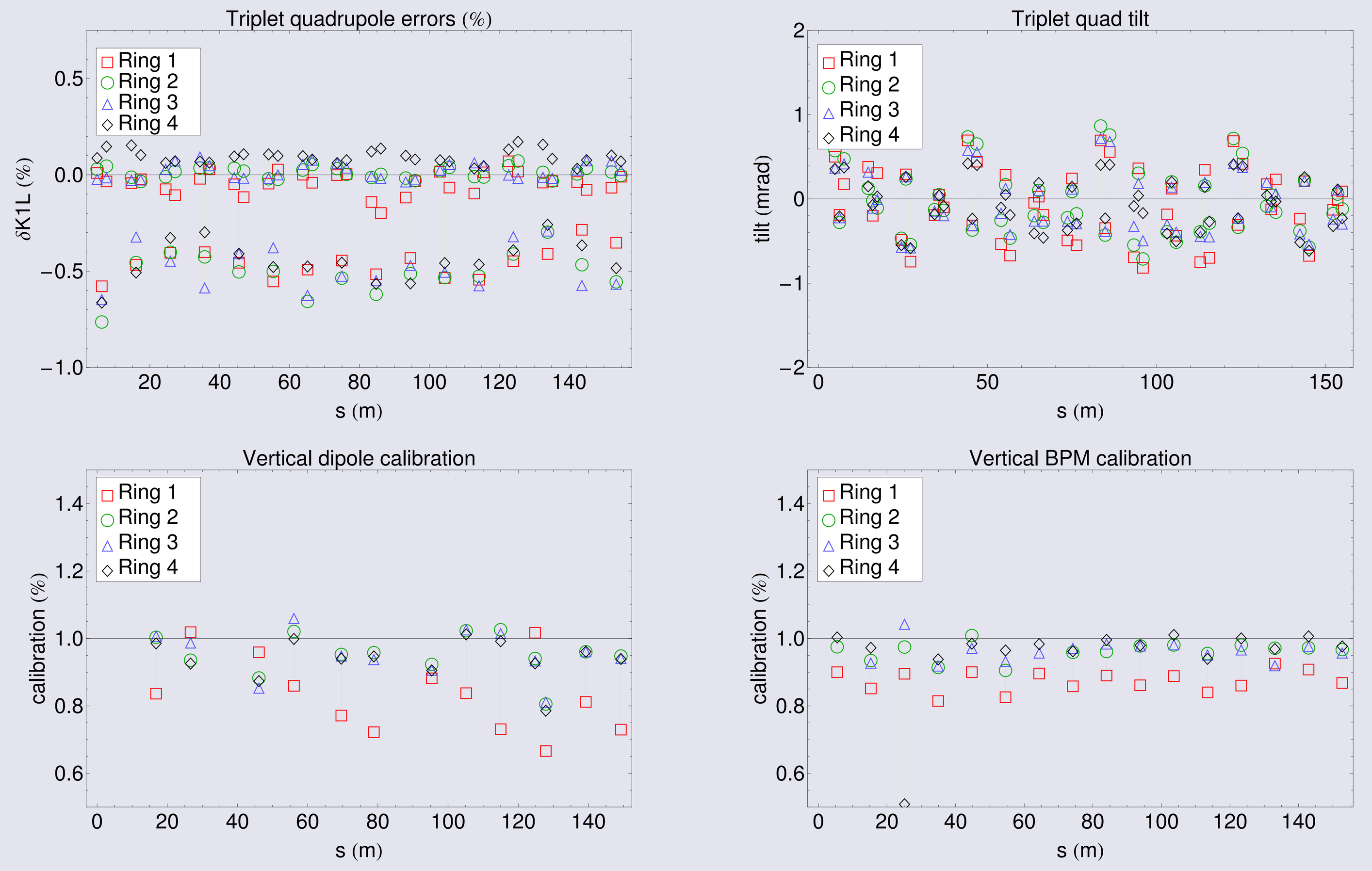
Results of constrained and unconstrained fits. Values of χ^2, the maximum triplet quadrupole error, and the magnitude of beta beating are shown over ten iterations.

Acknowledgments

This research project has been supported by a Marie Curie Early Initial Training Network Fellowship of the European Community's Seventh Framework Programme under the contract number (PITN-GA-2011-289485-OPAC).

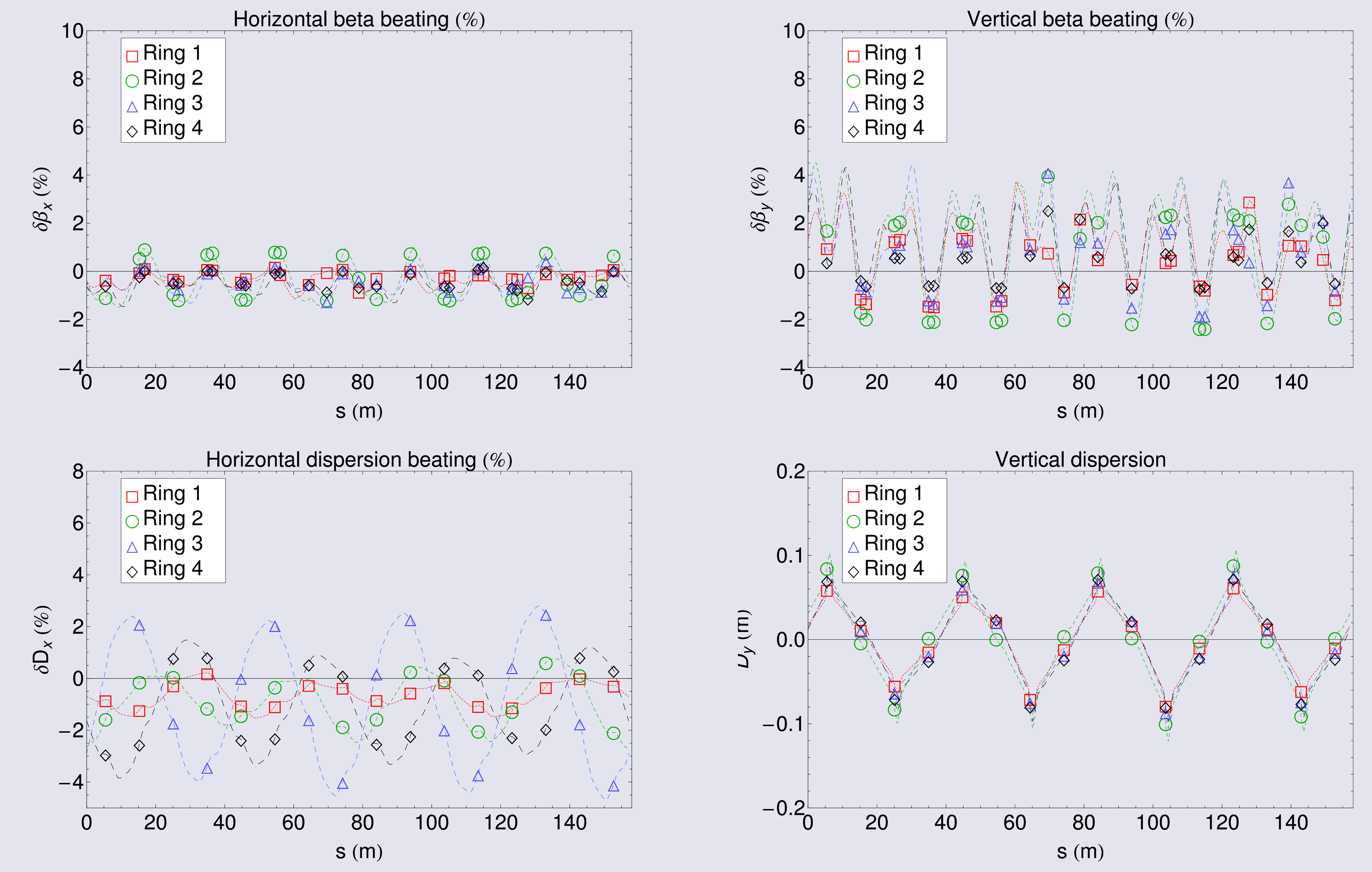
Fit results

Parameter values from constrained LOCO fit



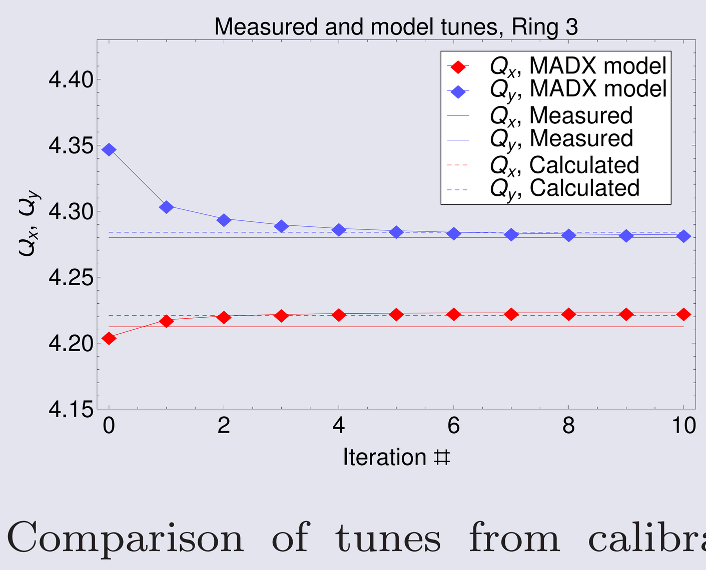
Parameter errors for all four rings from constrained LOCO fit. A heavy penalty weighting factor for quadrupole parameters and a smaller weighting factor for dipole and BPM parameters were chosen to prevent unreasonably large excursions of quadrupole parameter values.

Optics from calibrated MADX model

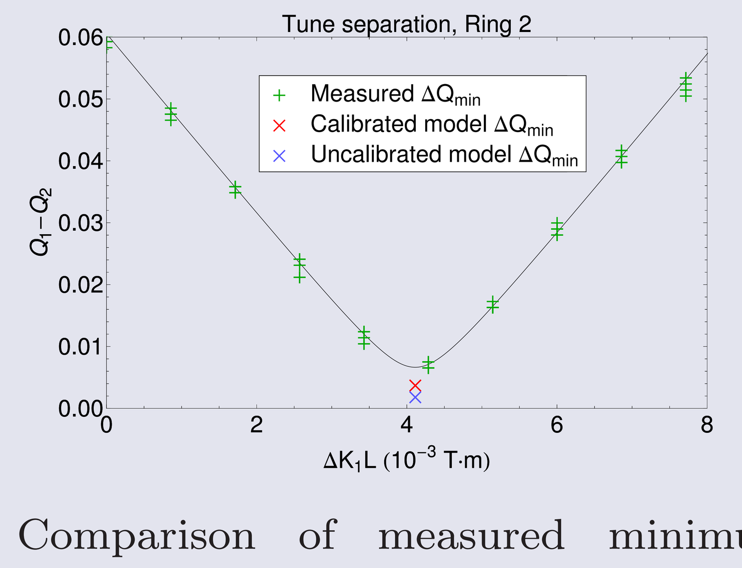


Calibrated MADX model beta beating and dispersion for all four rings. The markers indicate locations of dipoles and BPMs.

Tune and coupling comparison



Comparison of tunes from calibrated MADX model with values calculated by a control system application and measurements. Agreement is significantly improved by the LOCO calibration.



Comparison of measured minimum tune separation with uncalibrated and calibrated MADX predictions. Calibrated model coupling is slightly smaller than measured.

Conclusions

The preliminary analysis of orbit response data in the PS Booster suggests beta beating of only about two percent in the horizontal plane and about six percent in the vertical plane, but the focusing errors and resulting optics found by this fitting method are sensitive to the choice of constraints. These results are not yet conclusive; studies continue in order to fully understand the effects of constraint methods on the solution and to determine the distribution of focusing errors around the ring.

References

[1] J. Safranek, "Linear Optics from Closed Orbits (LOCO)-An Introduction," Beam Dynamics Newsletter No. 44, p.43 (2007).

[2] X. Huang et al., "LOCO with Constraints and Improved Fitting Technique," Beam Dynamics Newsletter No. 44, p.60 (2007).