Preliminary Simulations of Low Emittance Tuning in the Damping Rings

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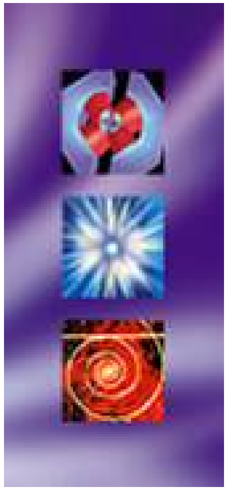


Introduction

- Along with K. Kubo, simulations have begun to investigate the 7 DR lattice designs in terms of their vulnerability to errors and its knock-on effects on the extracted vertical emittance.
- In an effort to provide a basis to the studies it was decided that we would work separately on the method of simulation as well as the code chosen-
  - I use a Mathematica based analysis system based around the MAD code – here given as MAD8.23DL. – as compared to Kubo's choice of the SAD code (see talk).
- We would try to simulate the designs using a variety of random misalignments and provide an assessment in terms of the effectiveness of the various correction stages as well as the resulting extracted vertical emittance.

Method

- I chose to separate the correction of the vertical emittance into 3 separate stages:
    - Correction of the closed orbit
    - Correction of vertical dispersion
    - Correction of horizontal-vertical linear coupling

- The correction method chosen in all 3 cases is through the use of Response Matrices and their inversion using Singular Value Decomposition.

Method – CO Correction

- The correction of the closed orbit is identical in all cases excepting for the varying numbers of correctors and Beam Position Monitors.
- Although a few of the lattices already had designs for correction systems using horizontal and vertically correcting dipole magnets I felt a more direct comparison could be achieved through the use of quadrupole magnets on movers.
    - This avoids the additional difficulties in designing a dipole corrector system, such as BPM vs. corrector positions etc.
- *All Quadrupoles were assumed to have a BPM attached that moved along with the quadrupole*.
- All quadrupoles in the lattice were used within the global correction system.

Method – Dispersion and Coupling Correction

- To correct the dispersion a response matrix of BPM dispersion vs. skew quadrupole field was created.
- Skew quadrupoles were placed at every sextupole in the lattice.
- Only skew quadrupoles at locations of higher dispersion (generally the arc sextupoles) were used for dispersion correction.

- Coupling correction was achieved through the remaining skew quadrupoles and by minimising the vertical response to the orbit induced by 4 horizontally displaced quadrupoles.
- The kickers were generally placed at opposite ends of the lattice an out of phase.

- In theory the correction of dispersion and coupling should then be *mostly* orthogonal.

Simulation

- In all cases the simulation involved applying a set of random errors to the lattice and performing the following steps:
  - **CO Correction:** Apply the CO routine until the vertical emittance no longer decreases. If the starting error set does not produce a real closed orbit, iteratively apply the CO routine with increasing error magnitudes until the desired errors are applied.
  - **Dispersion Correction:** Apply dispersion correction until there is no change seen in the vertical emittance.
  - **Coupling Correction:** Apply coupling correction until there is no longer a decrease in the vertical emittance.
- The applied errors were:

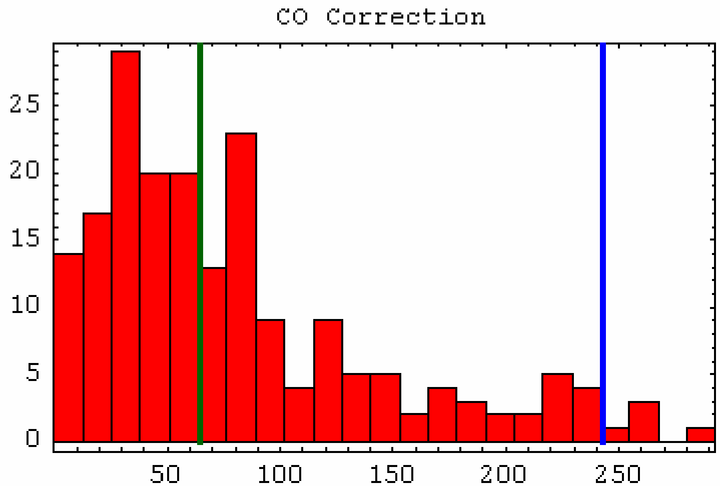
	Δx (3σ)	**Δy (3σ)**	**Δpsi (3σ)**
Quad (+*bpm*)	30μm	30μm	0.3mrad
Sext	30μm	30μm	0.3mrad
Dipole	30μm	30μm	0.3mrad
BPM (*extra*)	100μm	100μm	20mrad

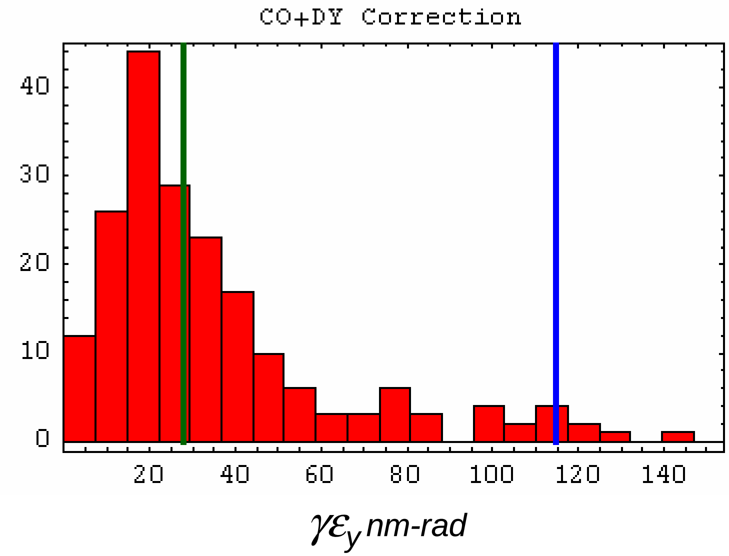
Simulation Components

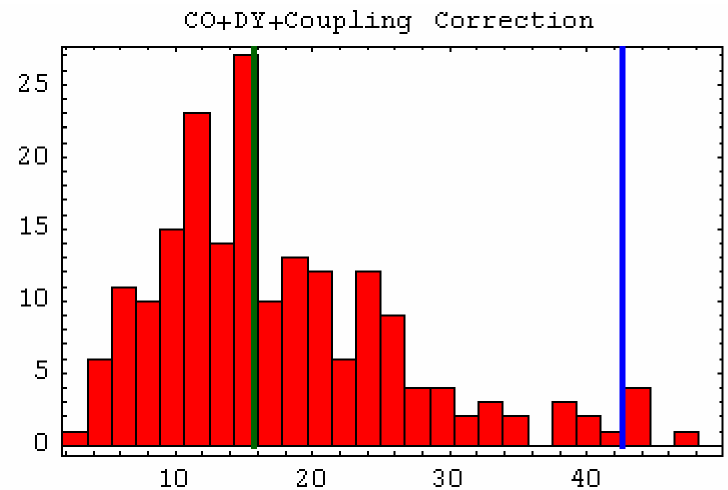
- Simulations have been performed for only 3 lattices over 200 random seeds:

  - **PPA**:
    - *CO*: 396 quadrupoles x 396 BPMs. Drop 205 singular values.
    - DY: 98 Skew quads x 396 BPMs. Drop 41 singular values.
    - XY: 14 Skew quads x 396 BPMs using 4 horizontally displaced quads.
  - **BRU**:
    - *CO*: 858 quadrupoles x 858 BPMs. Drop 410 singular values.
    - DY: 535 Skew quads x 858 BPMs. Drop 279 singular values.
    - XY: 89 Skew quads x 858 BPMs using 4 horizontally displaced quads.
  - **MCH**:
    - *CO*: 1050 quadrupoles x 1050 BPMs. Drop 205 singular values.
    - DY: 488 Skew quads x 1050 BPMs. Drop 370 singular values.
    - XY: 136 Skew quads x 1050 BPMs using 4 horizontally displaced quads.

Results - PPA



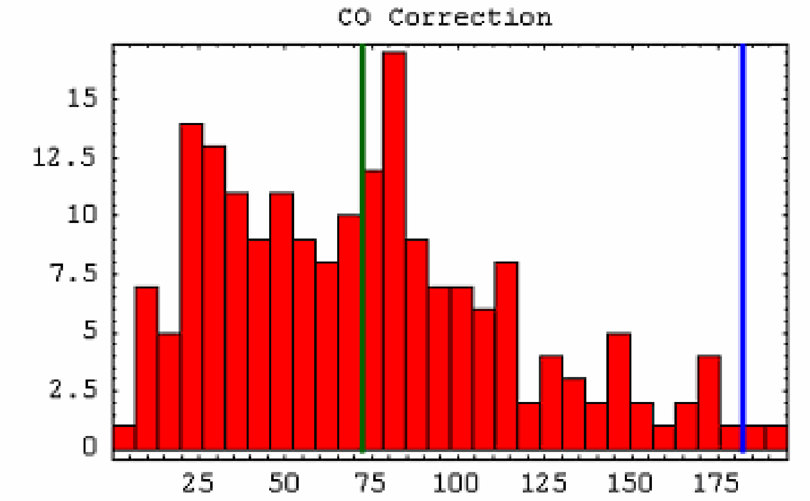


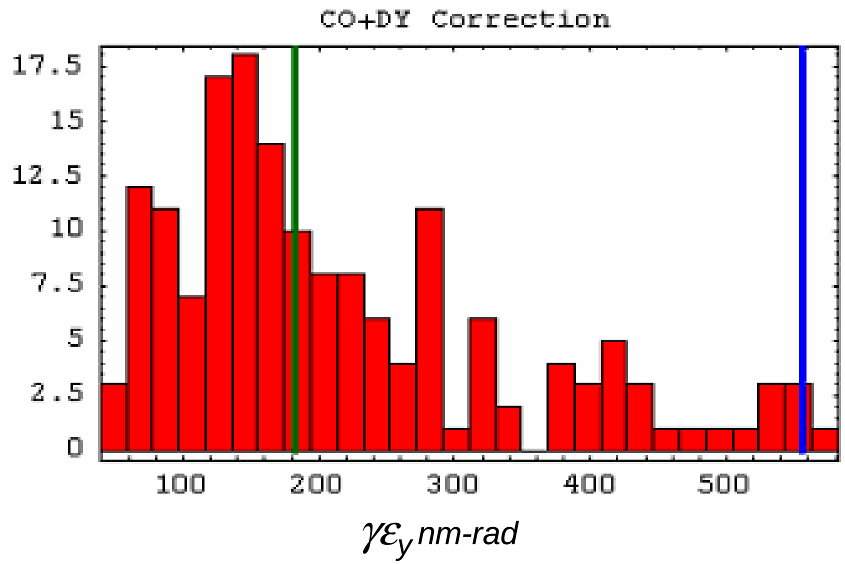


- PPA lattice benefits from all 3 types of correction.
- Median final vertical emittance is ~13nm-rad
- 95% Confidence limit is ~42nm-rad.

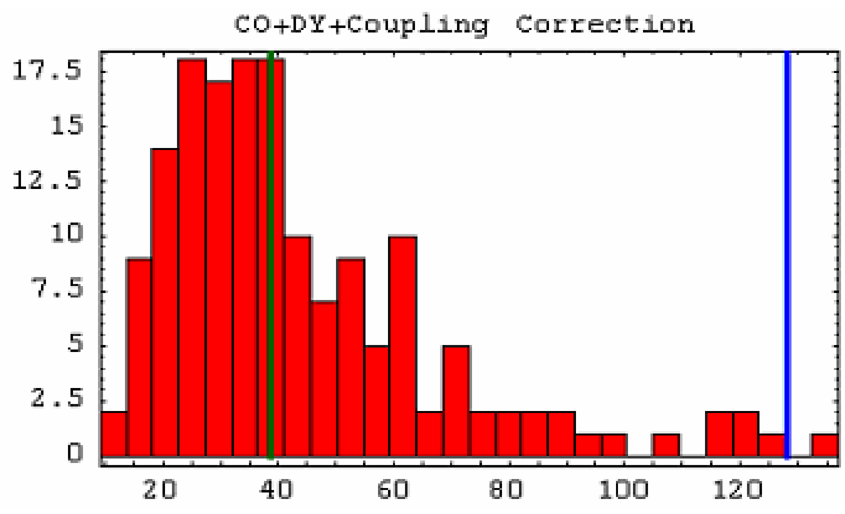
Green = Median; Blue = 95% Confidence

Results - BRU



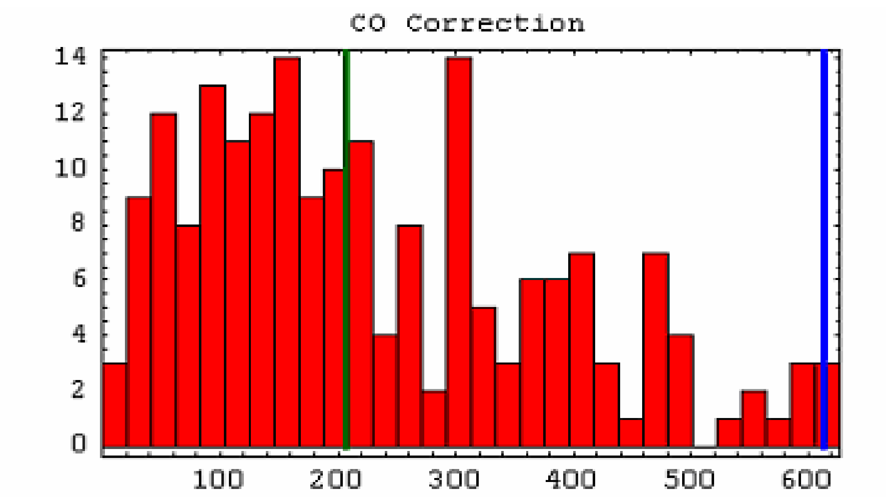


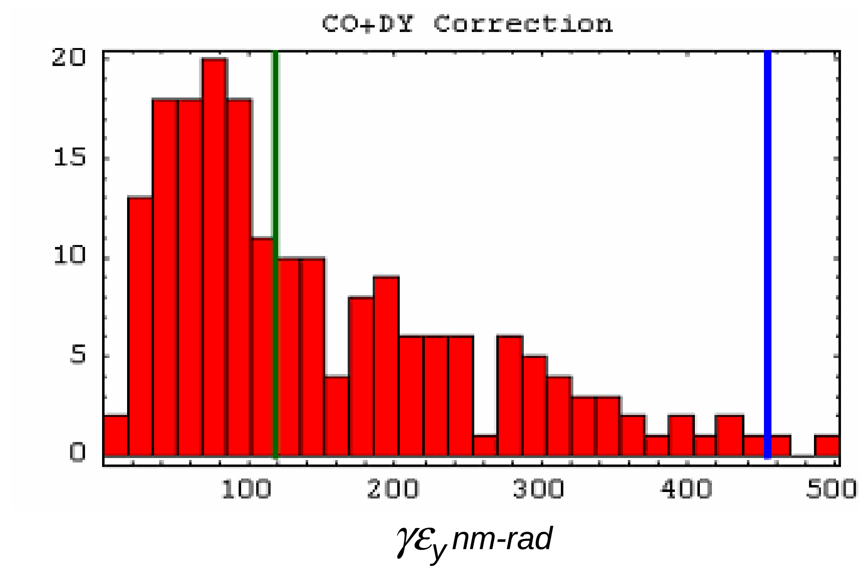
- BRU lattice does not benefit from DY correction!
- Don't yet understand why…DY correction is working but it is blowing up something else in the lattice.
- Emittances are 40nm-rad and 125nm-rad.



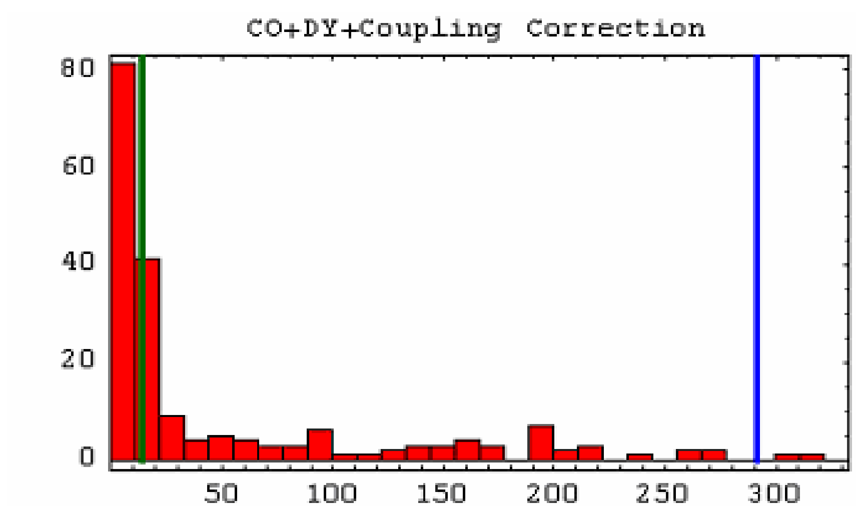
Green = Median; Blue = 95% Confidence

Results - MCH





- All 3 correction routines do work and do provide some benefits.
- Get many outlying points in distribution
- Final Emittances are ~13nm-rad and >300nm-rad!



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Conclusions

- Only looking at the previous three lattices would tend to suggest the PPA is the best lattice overall. It is easiest to tune and the results are reasonable.
- Although the MCH lattice gives the lowest median vertical emittance the distribution of results is terrible.
- The BRU lattice seems to fall down in its dispersion correction. This will need to be investigated further.

- These simulations will also need to be extended to cover the other 4 lattices.

Next Steps

- I t would be nice to compare more directly the methods used by Kubo-san and Myself –
  - Quadrupole/mover correction versus dipole correctors
  - Joint orbit & dispersion correction using dipole correctors versus orbit then dispersion correctors using ? & skew quadrupoles.

- Extensions to the simulations also need to include:
  - Realistic correlated errors such as girders and ground motion effects
  - Field errors
  - Realistic error field distributions
  - …