Review of CTF3 optics

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Outline

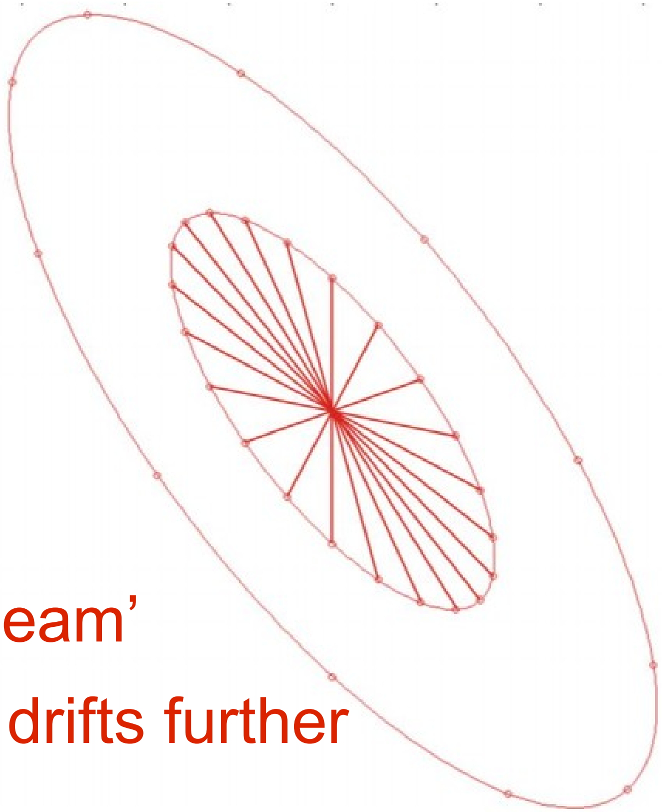
- Maximising CTF3 performance requires good control of optics
- Transverse matching for emittance preservation
- Dispersion control
  - Large energy spread of a few percent
  - Big beams in dispersive regions threaten losses
- Isochronicity to limit energy variation effects on power produced
  - Short bunches
  - Control of beam phase
- Performing campaign of transverse linear optics verification
  - Will describe technique for optics measurements
  - Discuss machine sections in turn

Transverse phase space painting

- CTF3 optics are designed in and referenced against MAD-X
- Pair of corrector magnets used to ‘paint’ a phase space ellipse
  - Ideally, correctors separated by a drift space
- Linear combination of kicks produces orbits with desired x, x’
  - Orbits behave as macroparticles, ensemble simulates beam
  - Orbits uniformly distributed in normalised phase space
- Ellipse is painted to match the design (MAD-X) phase space

Transverse phase space painting

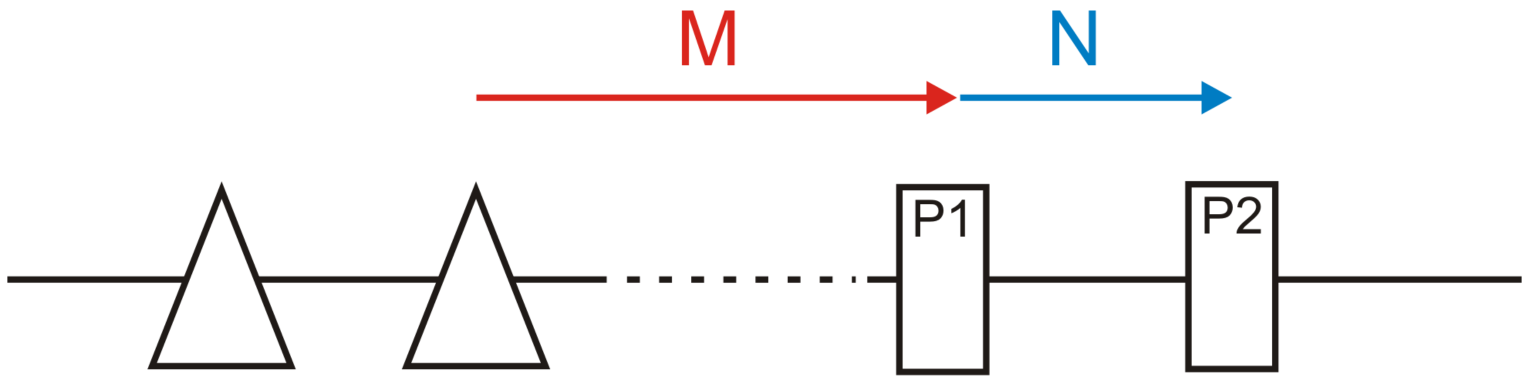
- ‘Star’ pattern painted to maximise signal to noise
  - Difference of two orbits separated by 180 deg. phase adv.
  - Beam drifts thus cancelled
  - Use an average over typically 5 difference orbits



- Repeat measurement with multiple ellipses
  - Increase the ‘emittance’ of the painted ‘beam’
  - Combine ellipses, reducing sensitivity to drifts further

Evolution of painted ellipse

- Aim to measure matrix M
  - Know phase space painted at downstream corrector
  - Want to observe how the ellipse evolves at the BPM P1
  - This requires knowledge of position and angle at P1
  - Assume matrix N from MAD-X, reconstruct using P1 & P2



Reconstruct transfer matrix with symplectic fit

- **MATLAB non-linear fitting code (fmincon). Solve for *M:***

$$\mathbf{x}_{BPM} - \mathrm{M}\mathbf{x}_K = 0$$

- **Where for the *N* difference orbits:**

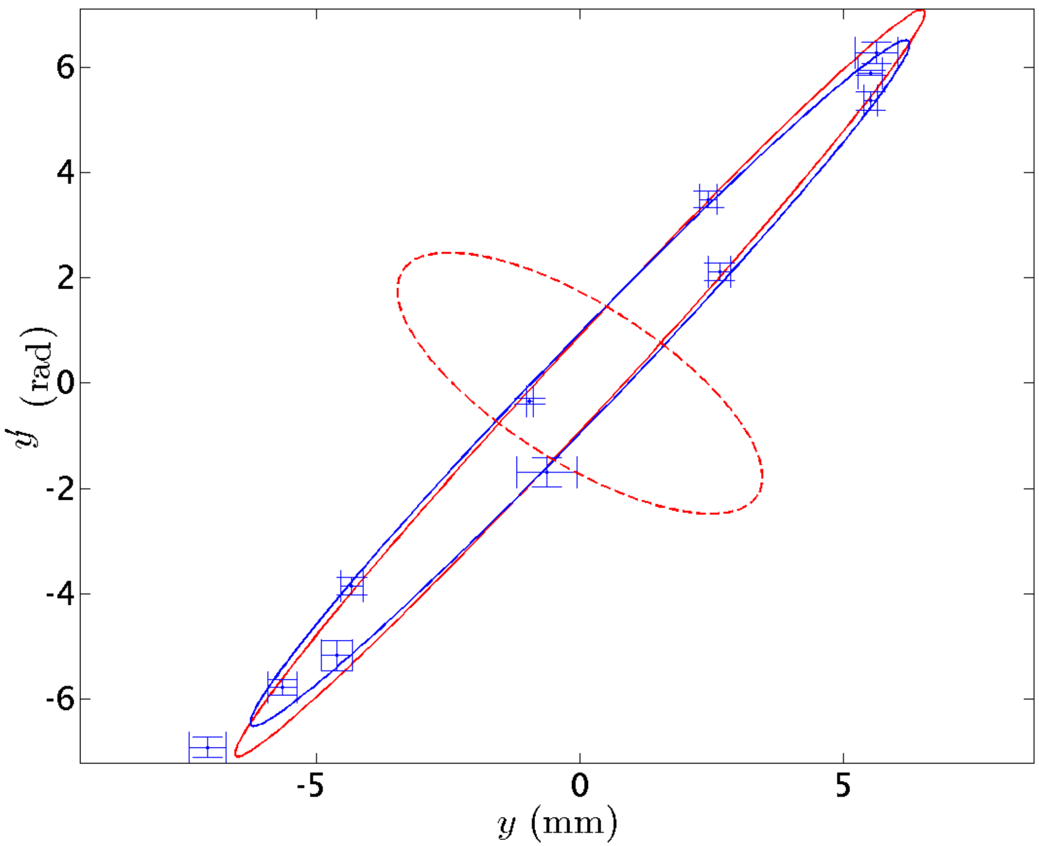
$$\mathbf{x} = \left(\vec{x_1}, \vec{x_2}, \ \ldots \ \vec{x_N}\right)$$

- **And the symplectic constraint is applied:**

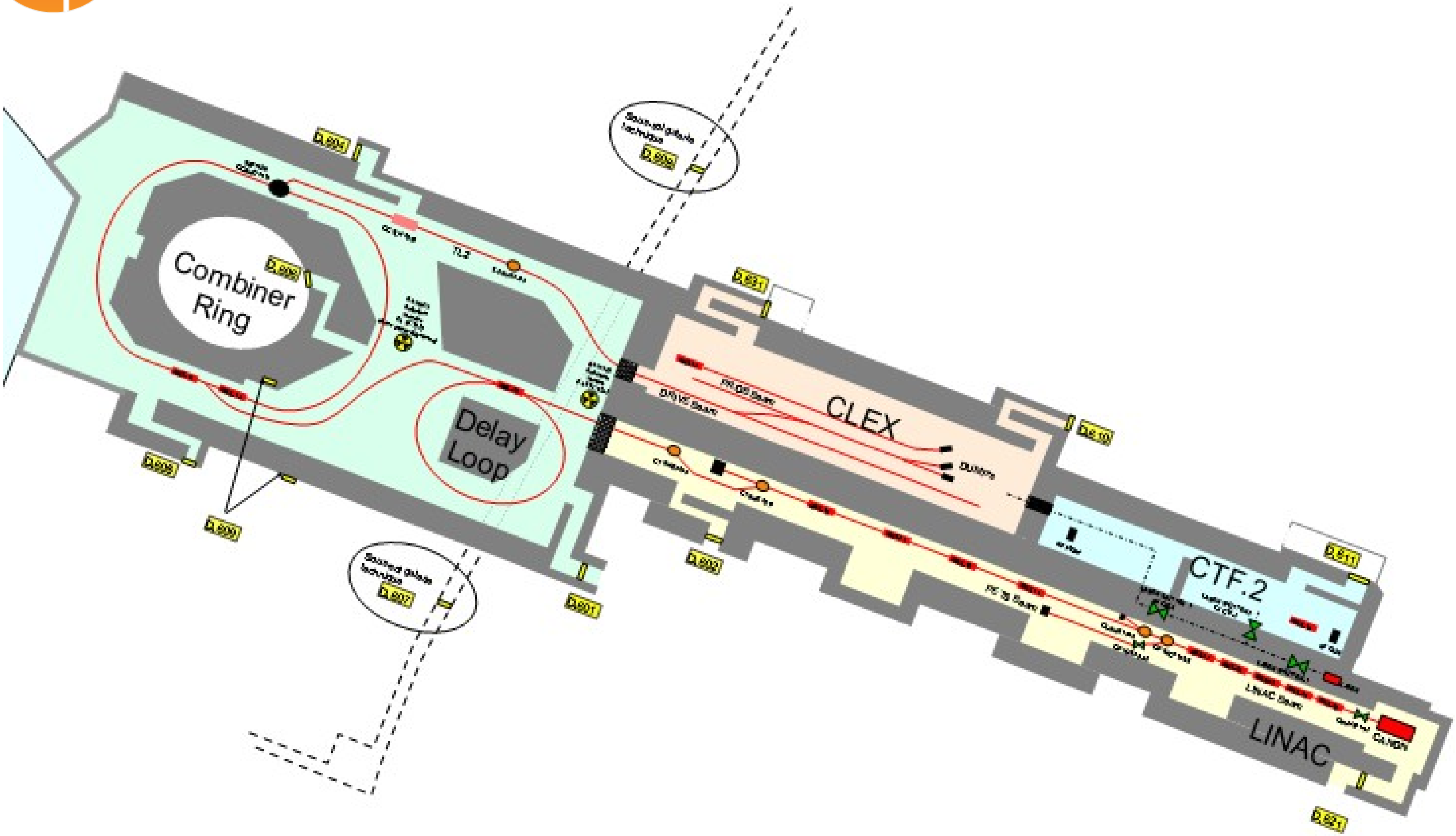
$$\mathrm{M}'\Omega\mathrm{M} - \Omega = 0$$

Example data

- Example of reconstructed ellipse in TL2 BPM
  - Blue – data and symplectic fit
  - Dashed and solid red – original and modified MAD-X



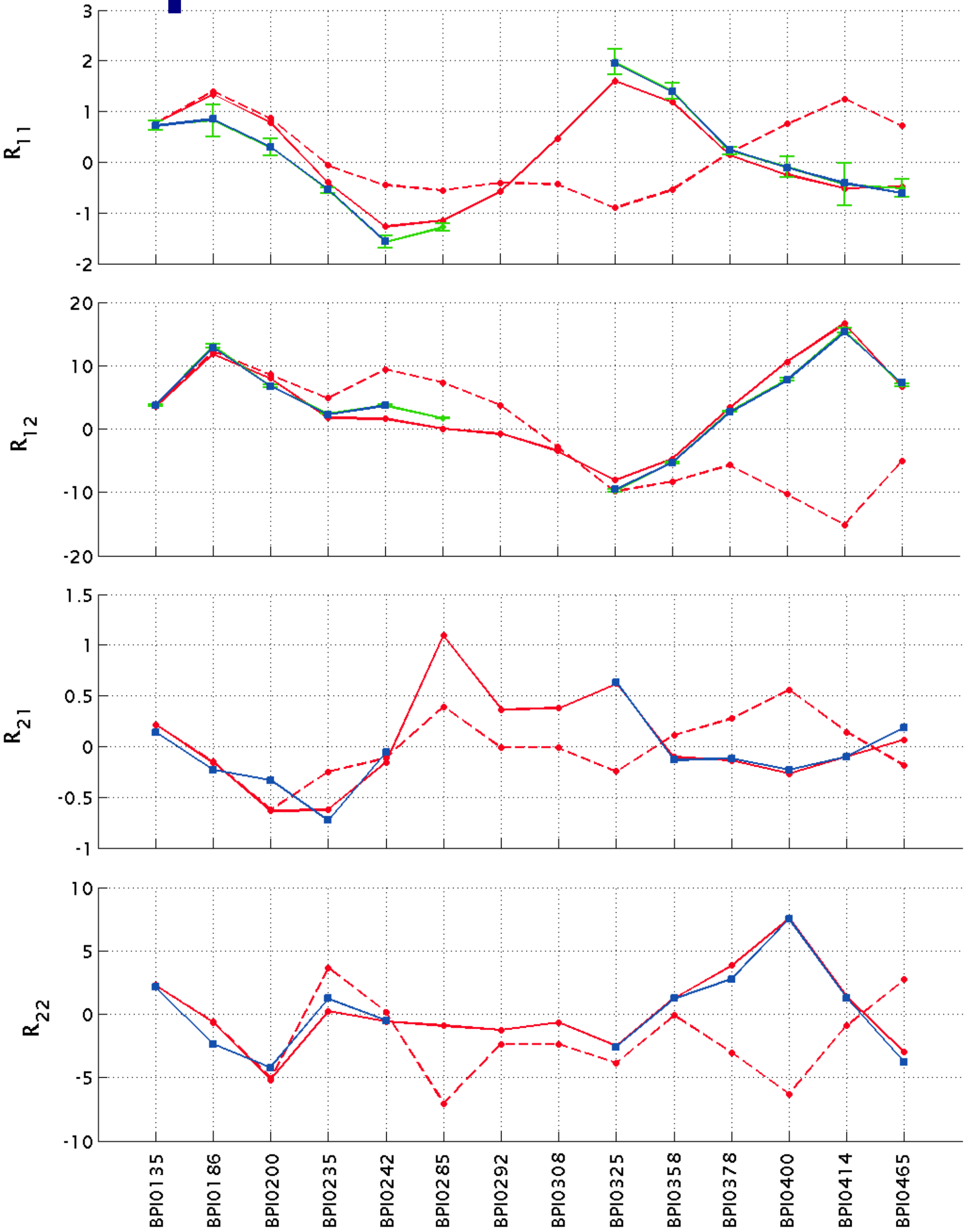
CTF3



Delay loop optics measurements

- Good agreement with MAD-X for horizontal optics
- However, large discrepancy in the vertical plane
  - Lead to suspect modelling of dipole edge focussing
  - Developed an iterative optimisation routine in MATLAB
  - Reconciled with measurements by optimising dipole FINT

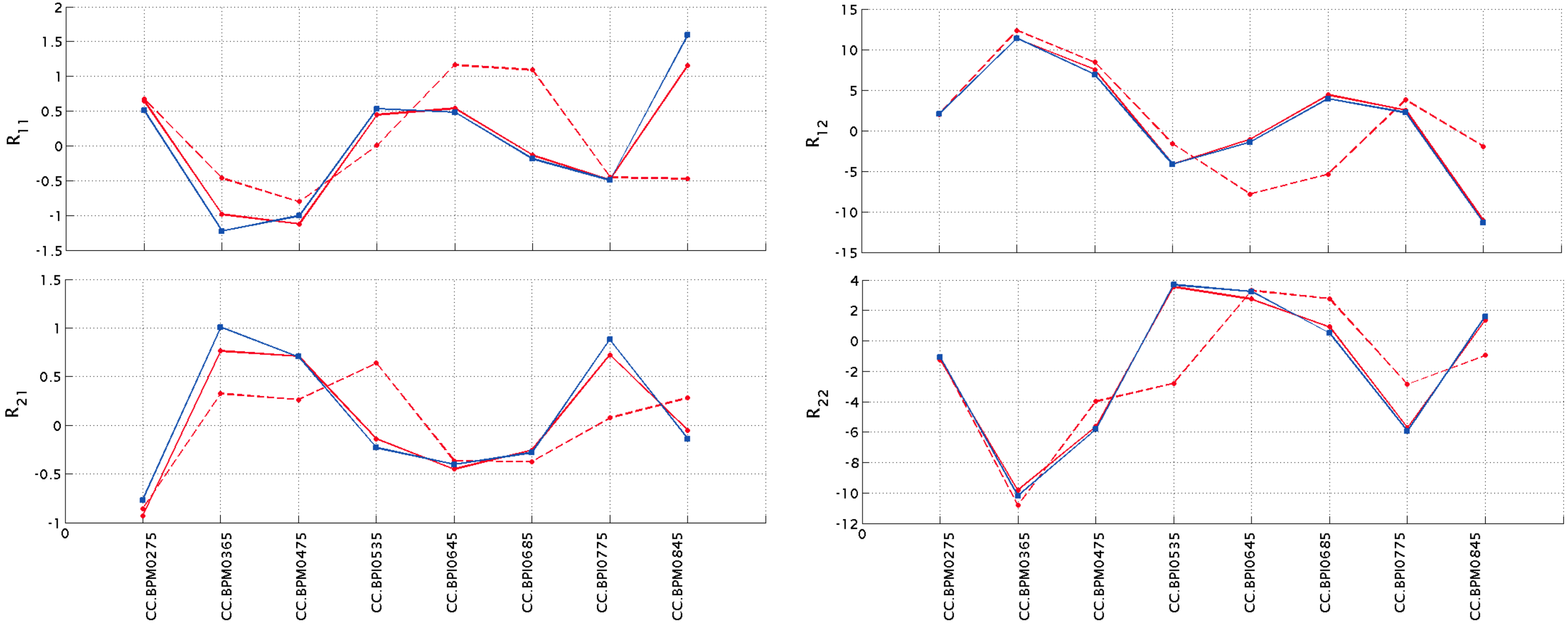
Delay loop vertical measurements



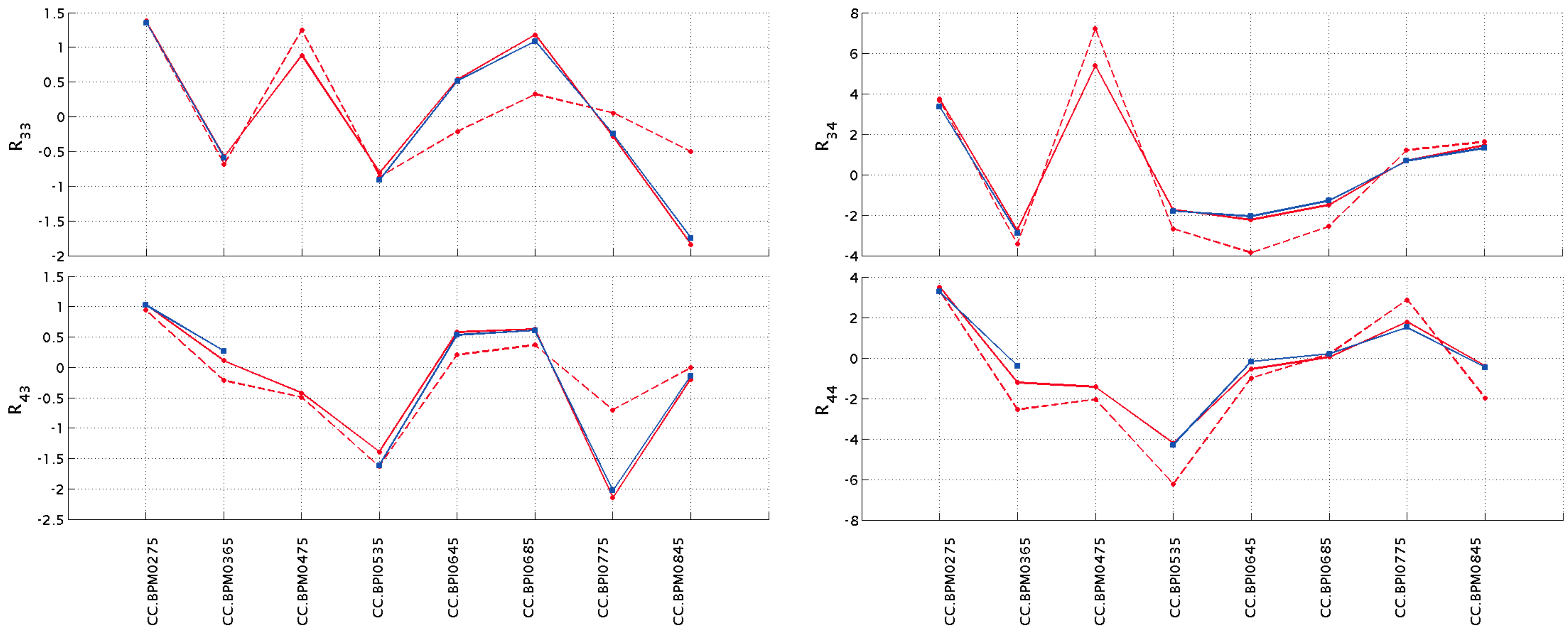
TL2 optics measurements

- Disagreement with MAD-X for both vertical and horizontal optics
- Suggests problem with quadrupole position and/or calibration
  - Confirmed positions are accurate during shutdown
  - Able to reconcile model by fitting selected quadrupole strengths and focussing due to vertical dogleg dipoles
  - Fits agreed to within a few percent for majority of magnets
  - One doublet with 25% error
- Optics to be rematched and exercise repeated after restart

TL2 horizontal measurements



TL2 vertical measurements



Summary

- Optics verification part of consolidation of CTF3 operation
- Confident of linac, TL1 and combiner ring MAD-X models
- Error in model of delay loop dipole edge focussing corrected
- Error in TL2 optics found
  - Model parameters fitted to measurements
  - New model to be confirmed with further data