Global Coupling and Vertical Dispersion Simultaneous Correction

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Outline

- The motivation
- Source of dispersion
- Dispersion correction
- Impact on coupling
- Dispersion + coupling correction
- Summary

The motivation

- For polarized proton: hopefully save some polarization
- For heavy ions: improve dynamic aperture

Source of dispersion

- Non coupling contribution: vertical offset in quadrupoles..., dipole kicks
- Coupling contribution: all coupling errors (quads roll, solenoid, snakes, offset in sextuple, pitch of main dipole, multipole error...) and skew quadrupoles at horizontal dispersive place
- $D_{quad\ offset} \sim D_{dipole\ kick}$, $D_{coupling\ error} \sim D_{sq}$

Dispersion from correctors' strength in the machine

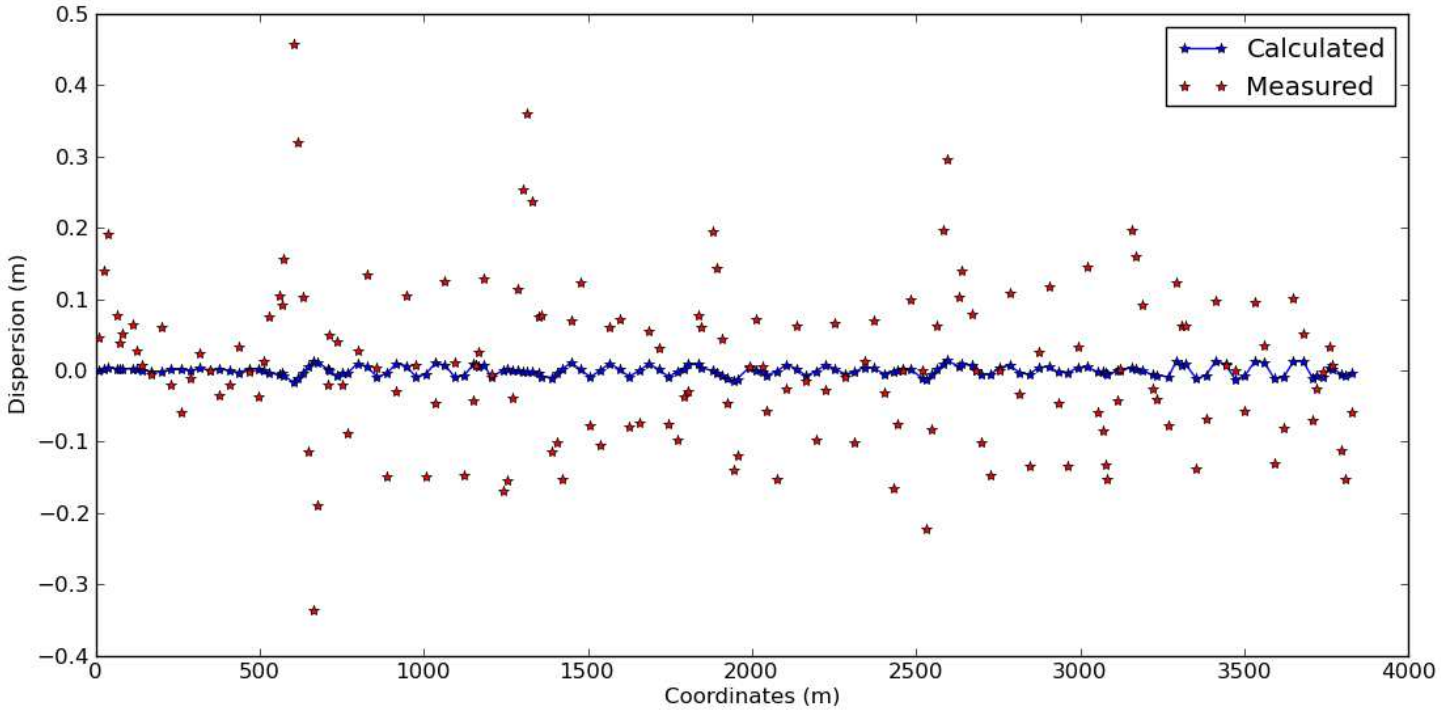

Figure: Measured vertical dispersion vs. dispersion generated by correctors

Task 1

Measure response of Ds to correctors (For later on dispersion-free steering)

- Make a dispersion measurement using RhicChromaticity
- Tweak a corrector, repeat dispersion measurement
- Repeat above for 3 correctors

Dispersion from SQs' strength in the machine

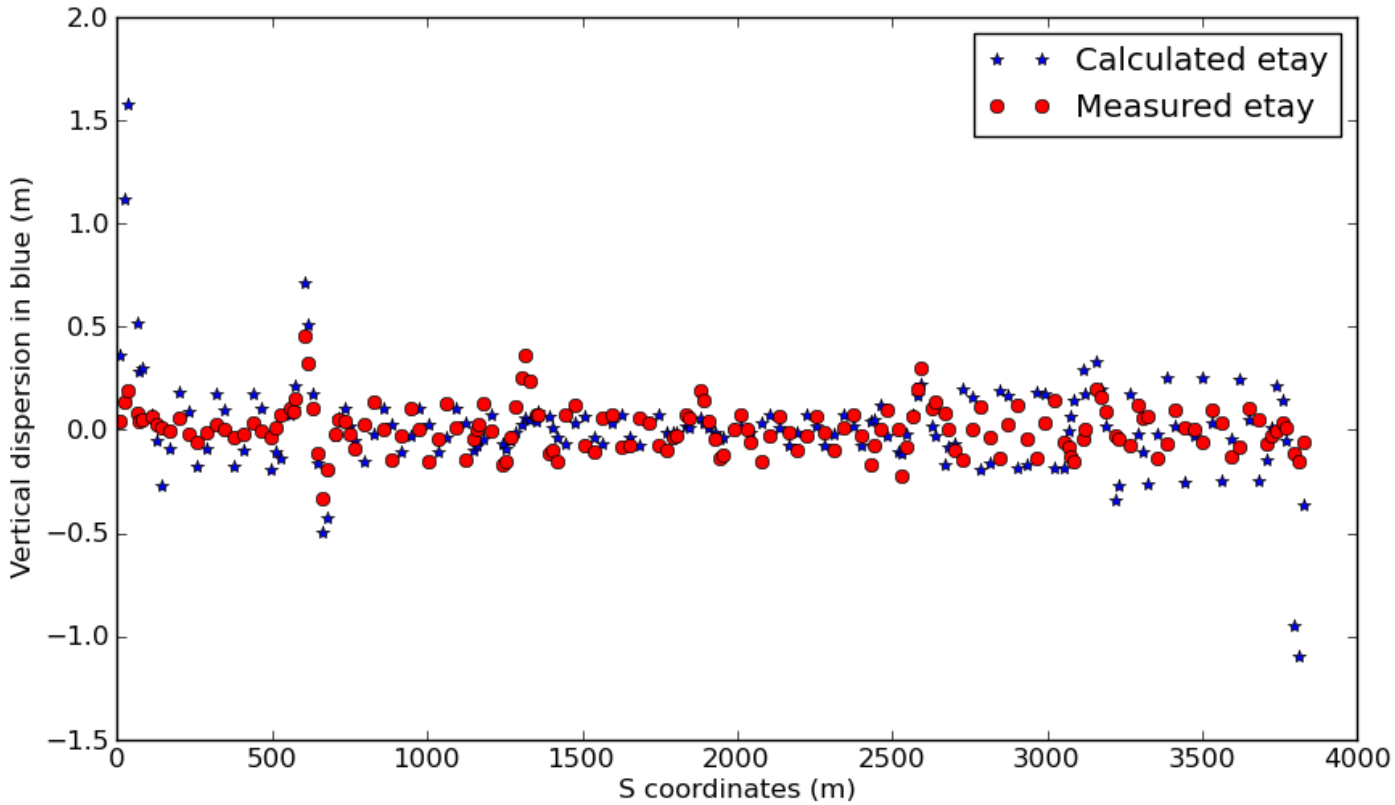

Figure: Measured vertical dispersion vs. dispersion generated by SQs

RHIC SQ families

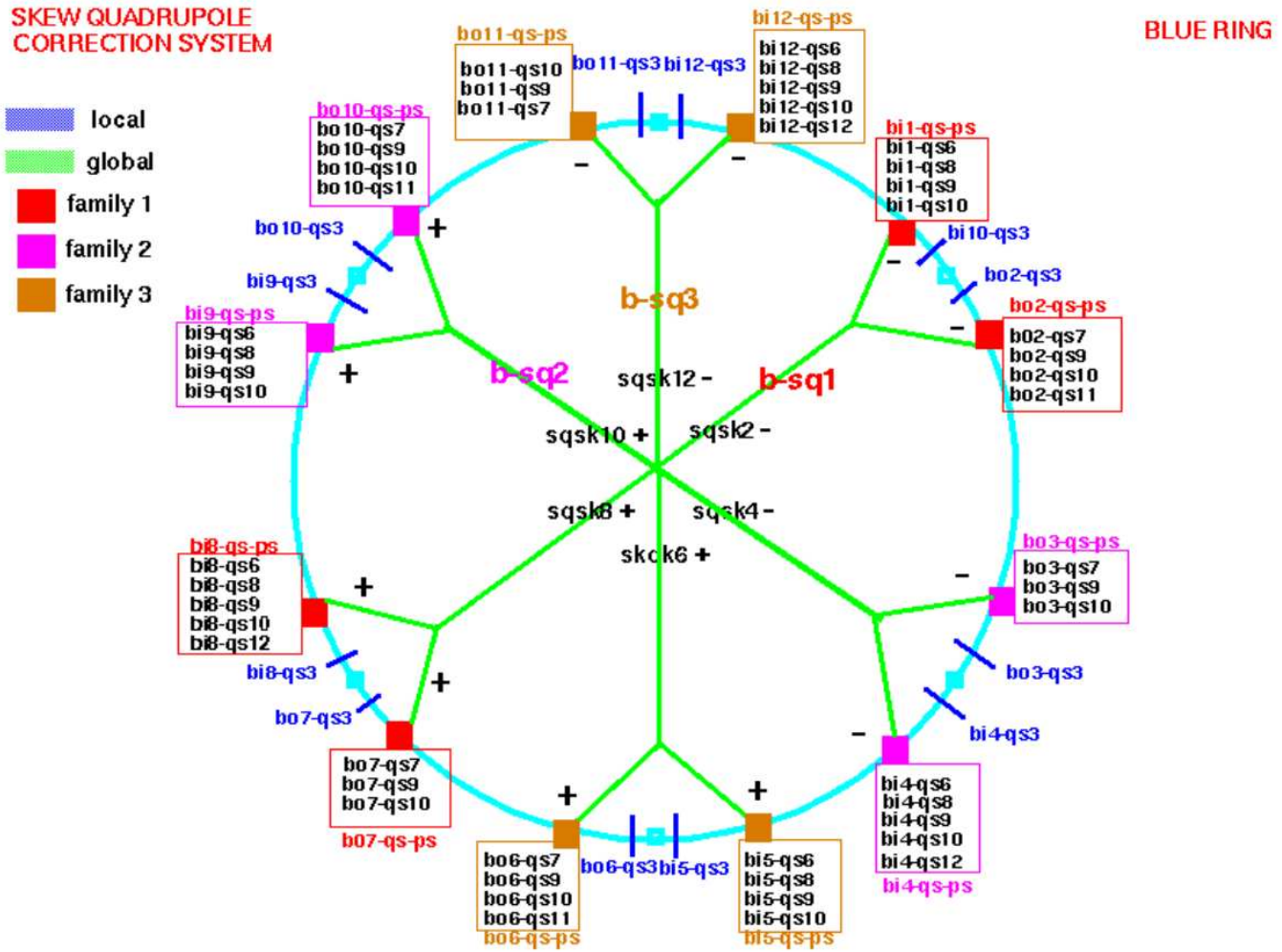

Figure: SQ families configuration in blue ring

Dispersion correction with SQs

General algorithm

$$\begin{pmatrix} D_1 \\ D_2 \\ \vdots \\ D_m \end{pmatrix} = \begin{pmatrix} R_{11} & R_{12} & \cdots & R_{1n} \\ R_{21} & R_{22} & \cdots & R_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ R_{m1} & R_{m2} & \cdots & R_{mn} \end{pmatrix} * \begin{pmatrix} k_1 \\ k_2 \\ \vdots \\ k_n \end{pmatrix}$$

D_i is the dispersion at i th BPM, k_j is the integral strength of the j th SQ

Task 2

Dispersion correction using SQs

Simulation

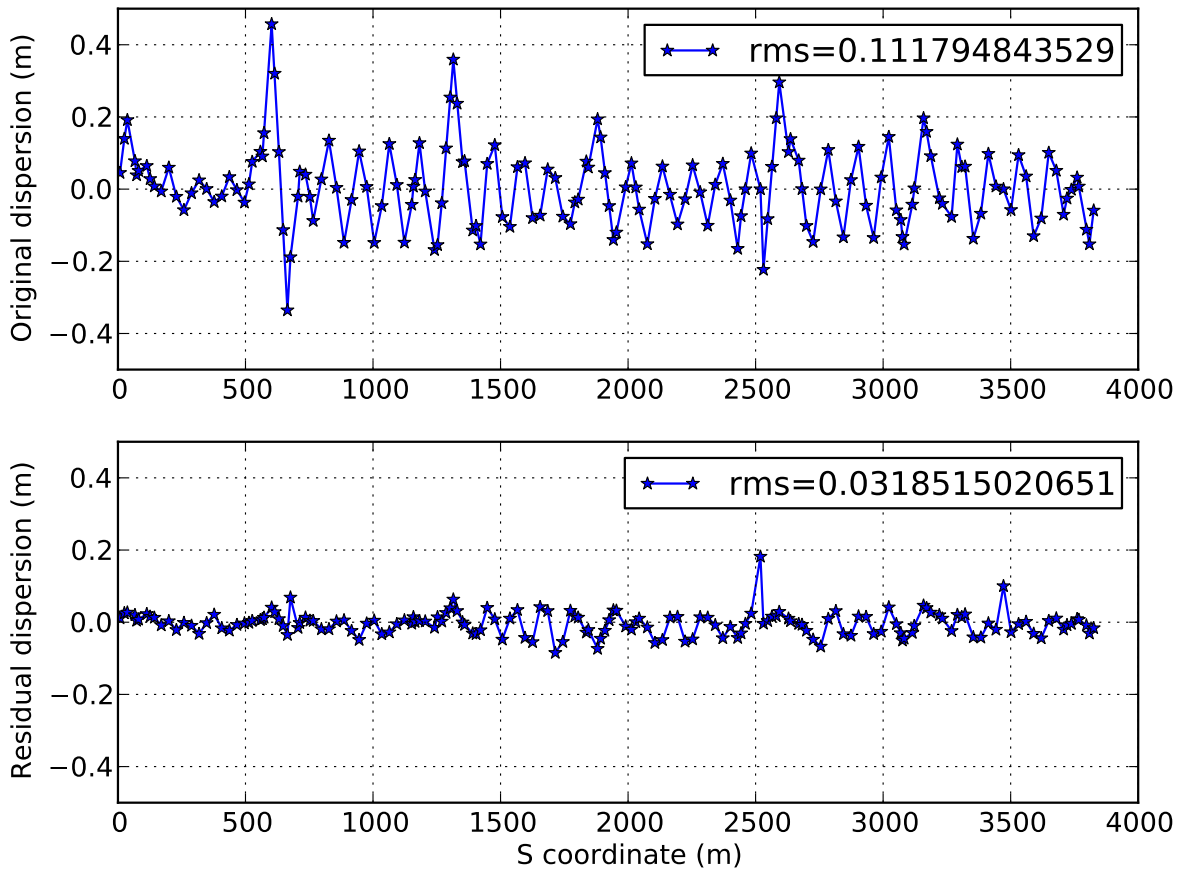

Figure: Dispersion at BPMs before and after correction with 6 SQ families

Impact on coupling

Coupling response to SQs

$$C^- = \frac{1}{2\pi} \sum_i \sqrt{\beta_{ix}\beta_{iy}} k_i l_i \exp(i(\phi_{ix} - \phi_{iy} - 2\pi \triangle \cdot s_i/L))$$

$\beta_{ix,iy}$ are the uncoupled betatron amplitude functions, $\phi_{ix,iy}$ are the uncoupled betatron phase advances, k_i and l_i are individual skew quadrupole strength and length, L is the ring circumference, and s_i is the distance between the skew quadruple and the reference point.

Coupling response matrix

$$\begin{pmatrix} Re(C^-) \\ Im(C^-) \end{pmatrix} = \begin{pmatrix} N_{11} & N_{12} & N_{13} & N_{14} & N_{15} & N_{16} \\ N_{21} & N_{22} & N_{23} & N_{24} & N_{25} & N_{26} \end{pmatrix} * \begin{pmatrix} k_1 \\ k_2 \\ k_3 \\ k_4 \\ k_5 \\ k_6 \end{pmatrix}$$

Task 3

Global coupling correction with new algorithm

Simultaneous correction

Algorithm

$$\begin{pmatrix} f * \begin{pmatrix} Re(C^-) \\ Im(C^-) \end{pmatrix} \\ D_1 \\ D_2 \\ \vdots \\ D_m \end{pmatrix} = \begin{pmatrix} f * \begin{pmatrix} N_{11} & N_{12} & N_{13} & N_{14} & N_{15} & N_{16} \\ N_{21} & N_{22} & N_{23} & N_{24} & N_{25} & N_{26} \end{pmatrix} \\ R_{11} \quad R_{12} \quad R_{13} \quad R_{14} \quad R_{15} \quad R_{16} \\ R_{21} \quad R_{22} \quad R_{23} \quad R_{24} \quad R_{25} \quad R_{26} \\ \vdots \quad \vdots \quad \ddots \quad \vdots \\ R_{m1} \quad R_{m2} \quad R_{m3} \quad R_{m4} \quad R_{m5} \quad R_{m6} \end{pmatrix} * \begin{pmatrix} k_1 \\ k_2 \\ k_3 \\ k_4 \\ k_5 \\ k_6 \end{pmatrix}$$

Task 4

Correct global coupling while minimizing contribution to Dispersion

This could be applied as coupling feedback along the energy ramp without measurement of Dispersion

Simulation

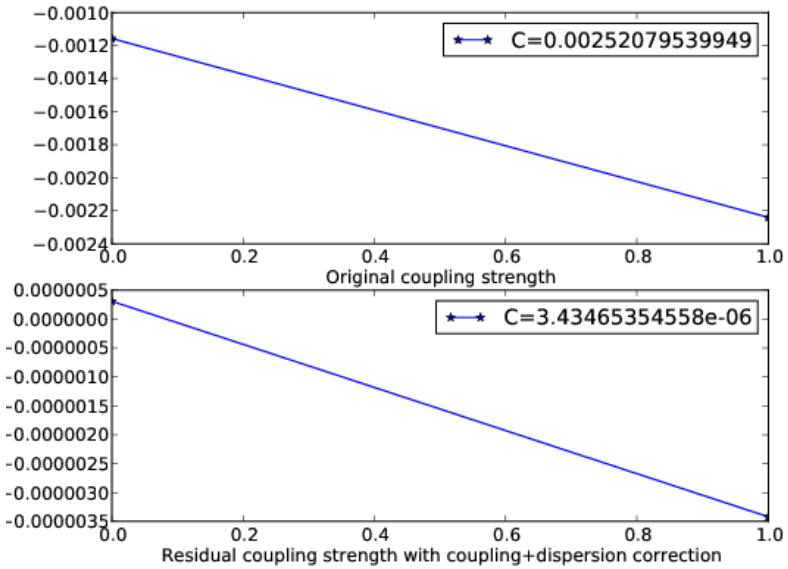

Figure: Coupling before (upper) and after (lower) correction (correcting global coupling with SQs and minimizing dispersion contribution from them) with 6 independent skew quads families

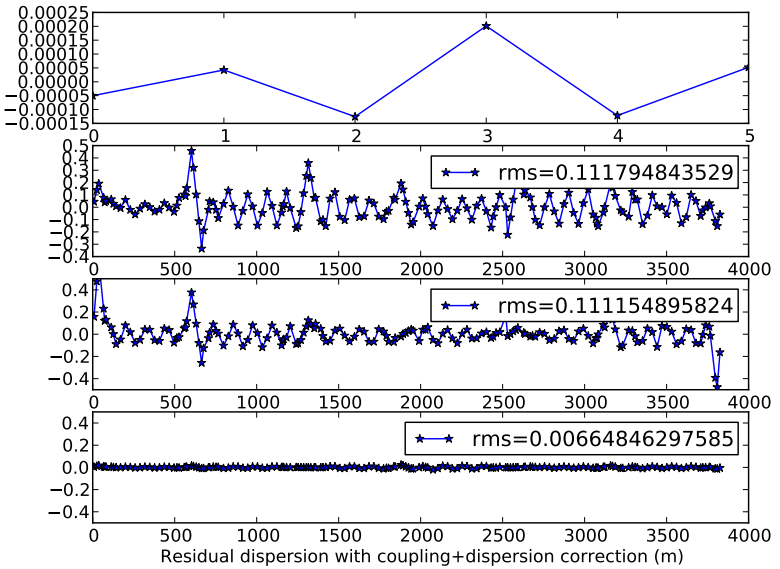

Figure: Required strength (upper), measured dispersion (second), measured dispersion minus skew quads contribution (third) and introduced dispersion (lower) by correction with 6 independent skew quads families

Task 5

Correct global coupling and Dispersion simultaneously

Simulation

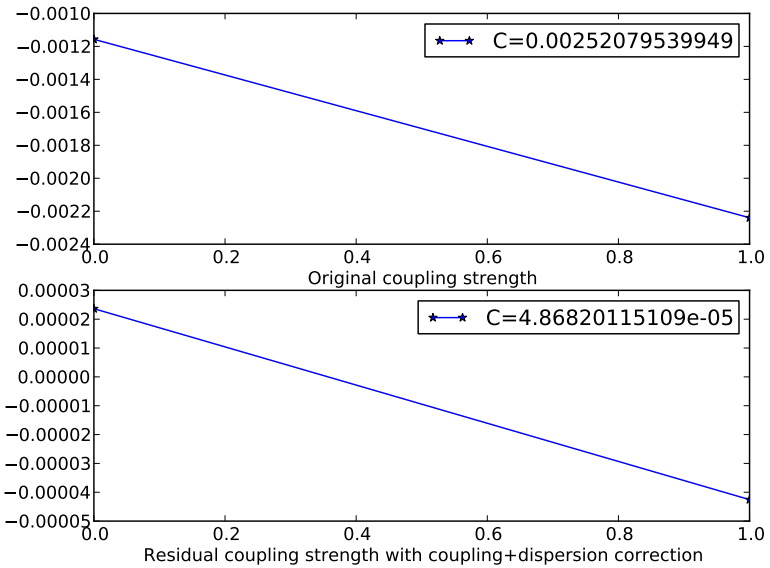

Figure: Coupling before (upper) and after (lower) correction

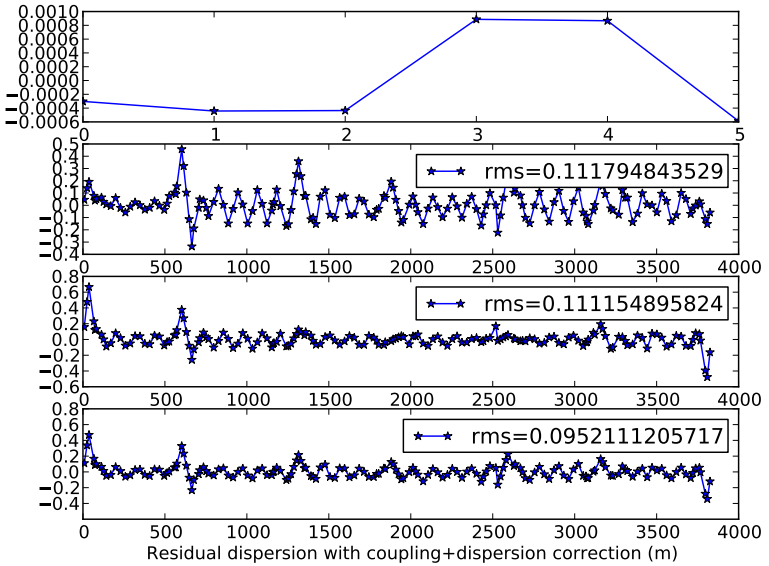

Figure: Required strength (upper), measured dispersion (second), measured dispersion minus skew quads contribution (third) and final dispersion (lower) with 6 independent skew quads families

Correction with 12 families: Coupling

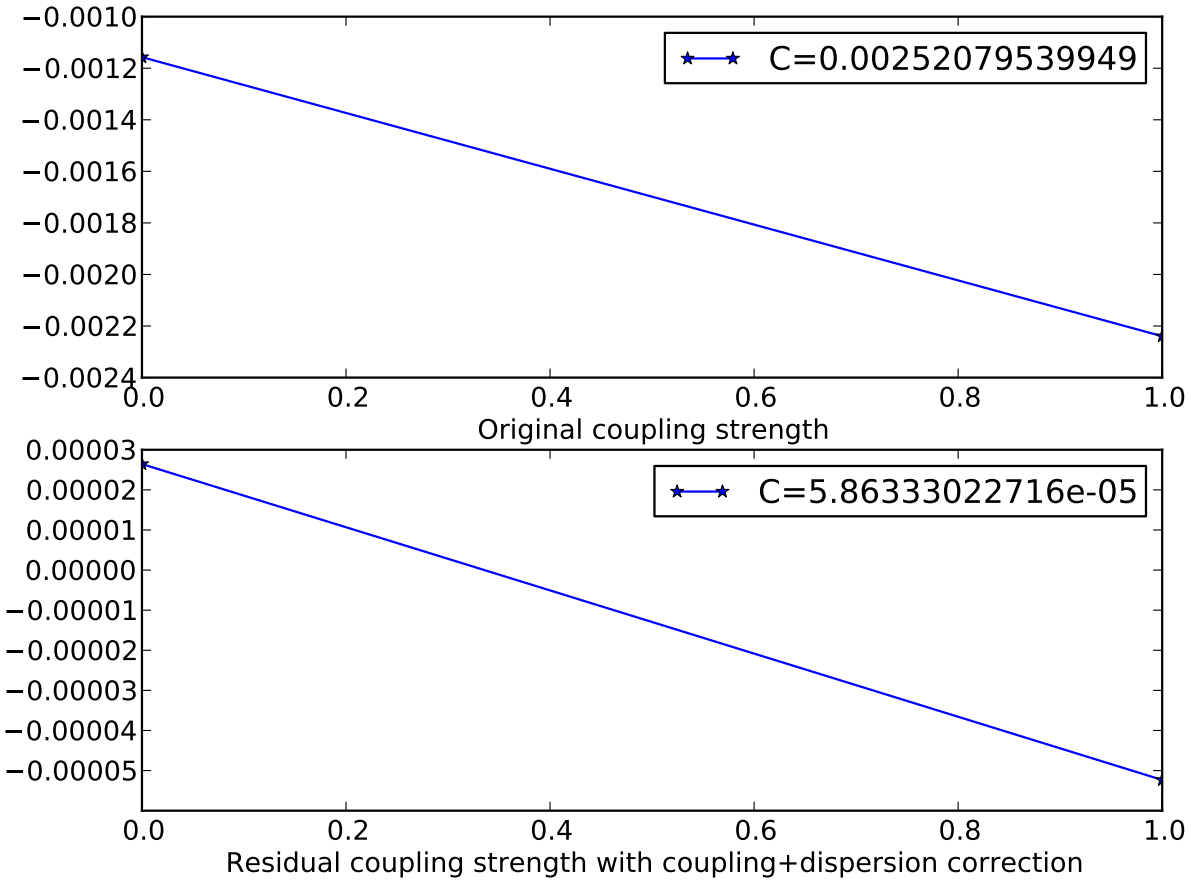

Figure: Coupling (upper) before (lower) and after correction

Correction with 12 families: Dispersion

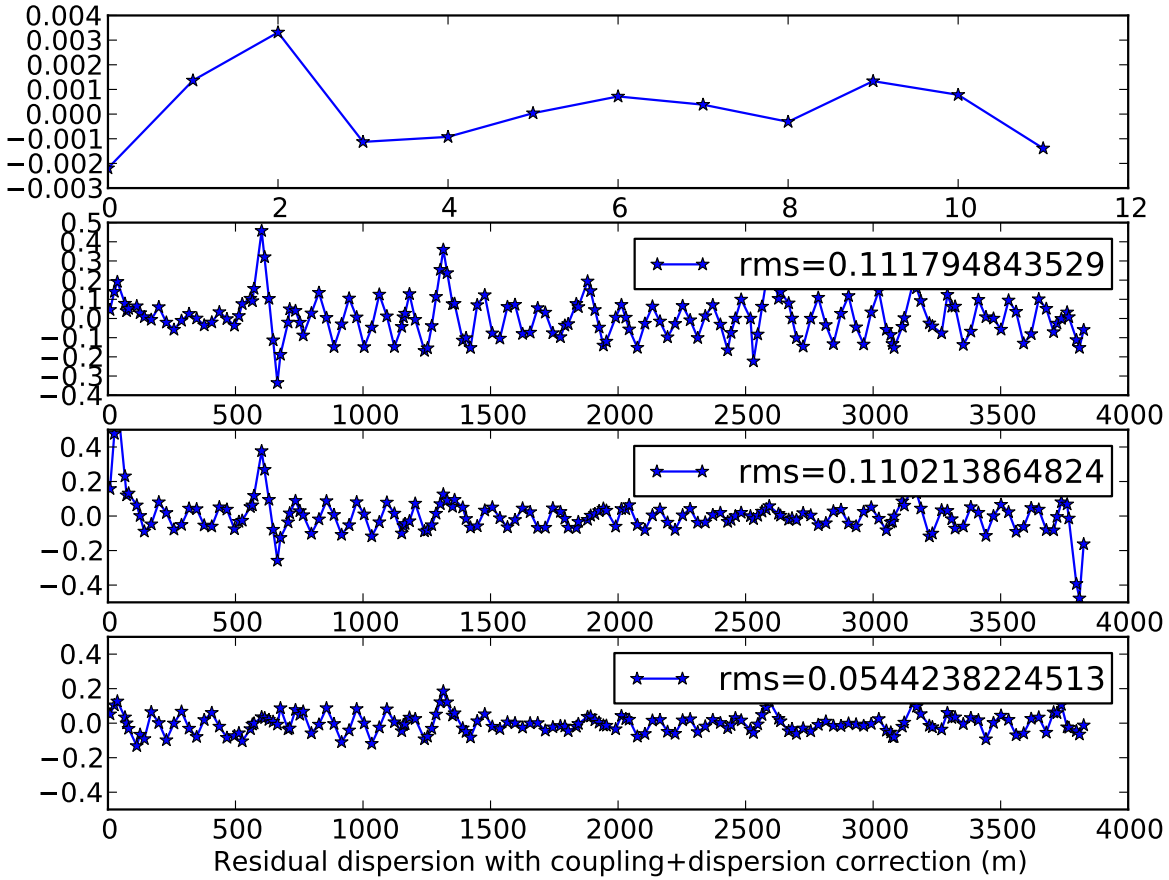

Figure: Required strength (upper), measured dispersion (second), measured dispersion minus skew quads contribution (third) and final dispersion (lower) with correction by 12 skew quads families

Correction with 48 SQs: Coupling

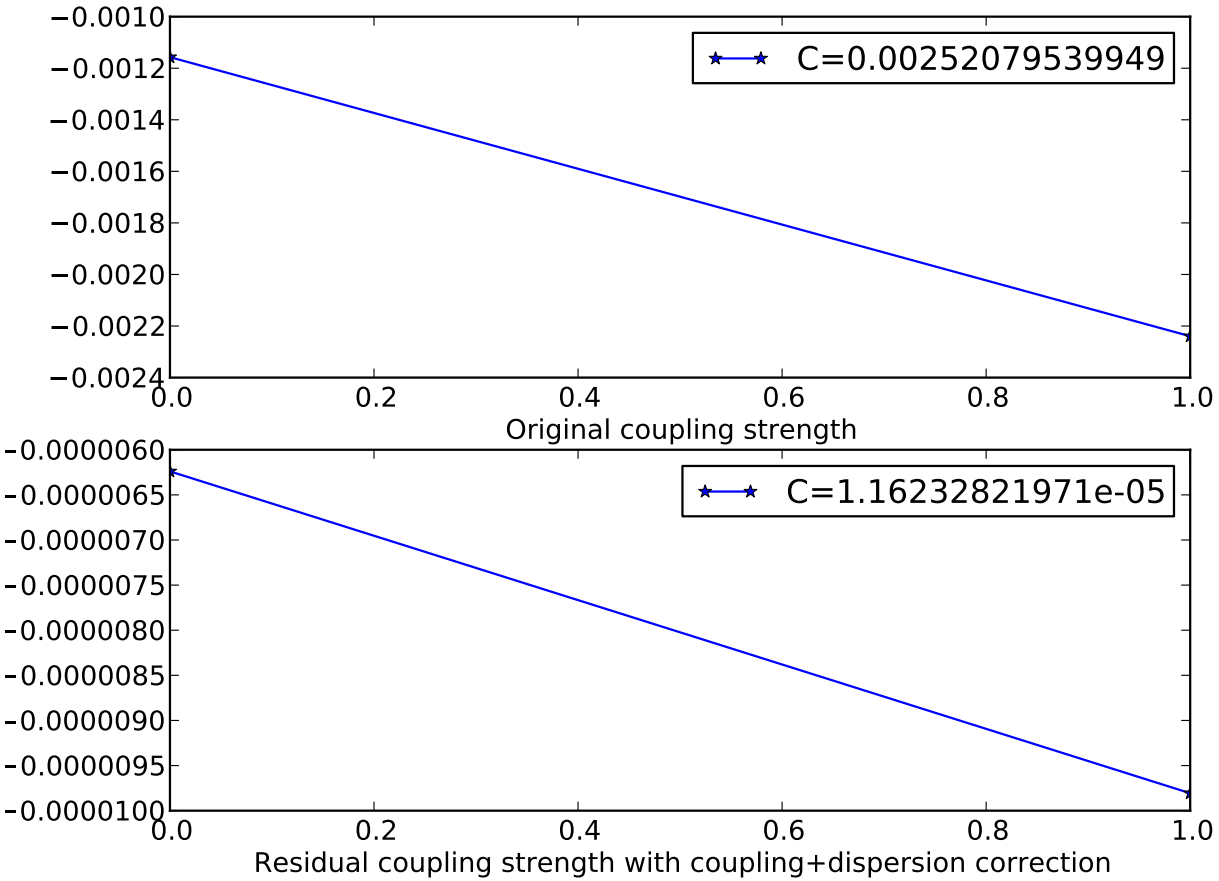

Figure: Coupling before and after correction

Correction with 48 SQs : Dispersion

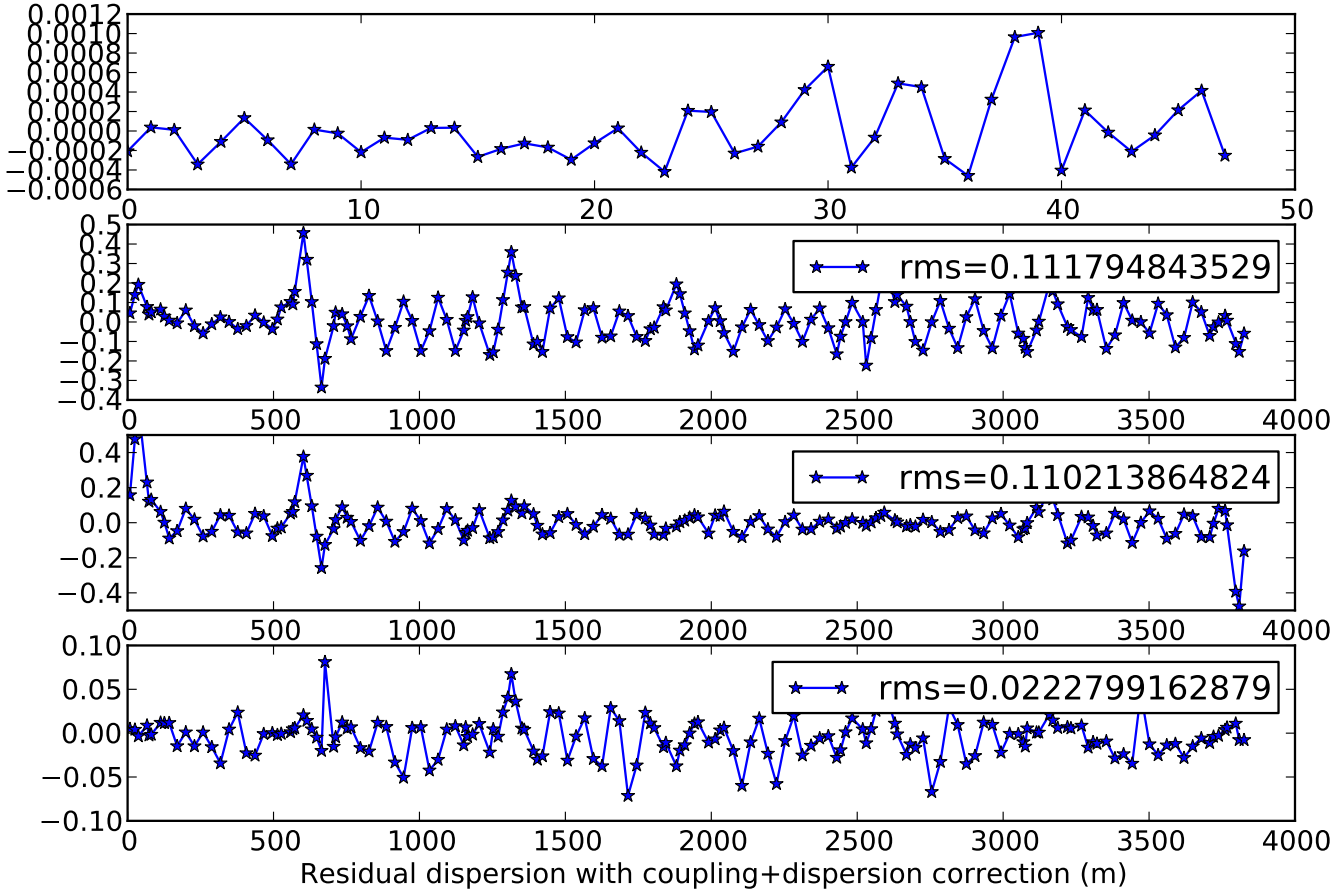

Figure: Required strength (upper), measured dispersion (second), measured dispersion minus skew quads contribution (third) and final dispersion (lower) with correction by 48 skew quads

Summary

- Correction of global coupling or/and dispersion will be done using 12-family SQs with new algorithm
- Task 1: Measure response of Dispersions to correctors
- Task 2: Dispersion correction using 12-family SQs
- Task 3: Global coupling correction using 12-family SQs
- Task 4: Correct global coupling while minimizing contribution to Dispersion
- Task 5: Correct global coupling and Dispersion simultaneously