Global & Local Coupling Measurements

@RHIC

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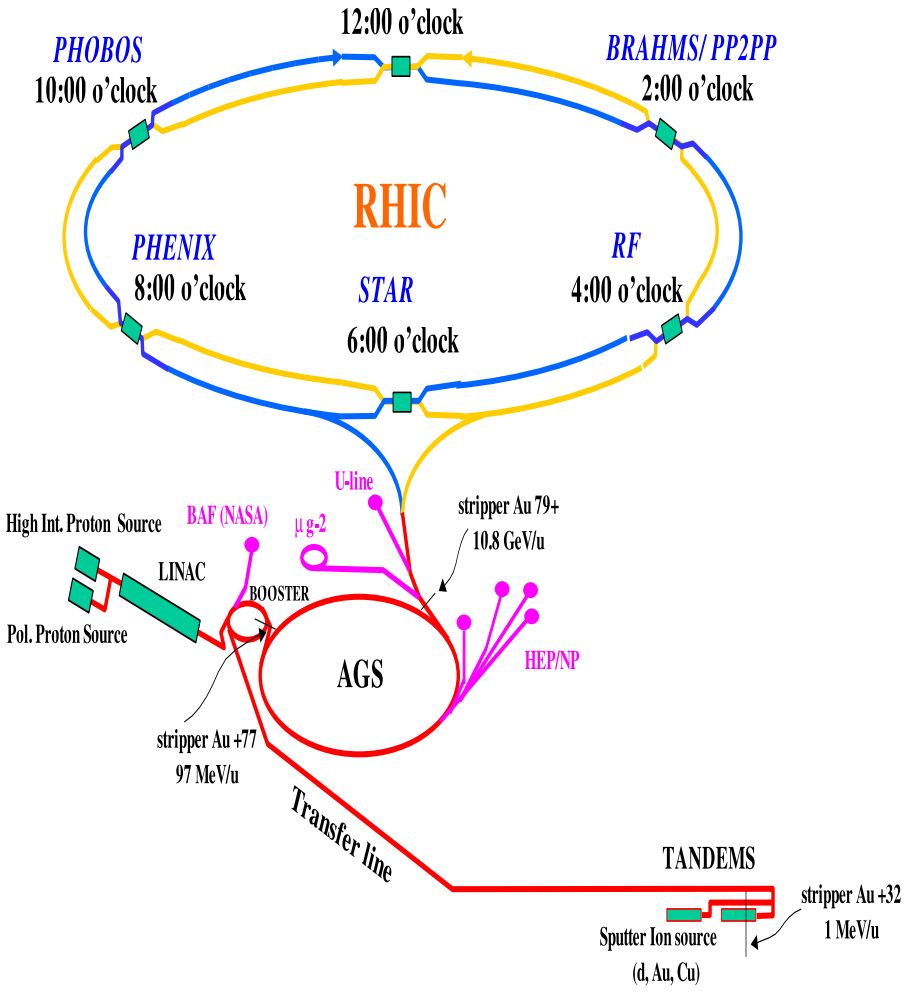
Menu

- Entree:
  - RHIC Intro
  - Existing techniques (Global & Local Correction)
- Main Course:
  - $|\overline{C}|$ & $f_{\substack{1001\\1010}} \rightarrow$ Baseline Measurements
  - IR Scan: Correction Strategy
  - Analysis (Fitting, AC dipole effects, vertical dispersion)
- Dessert:
  - Global Coupling Correction & Optimization
  - Fast Global Correction

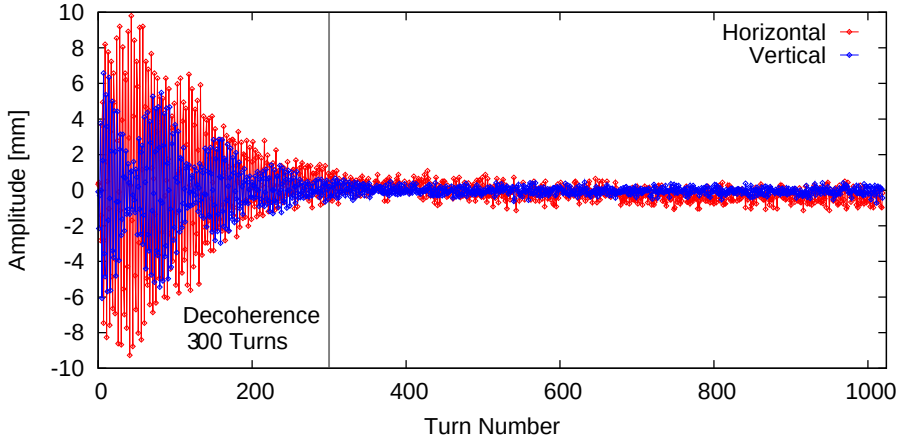
RHIC & BPM System



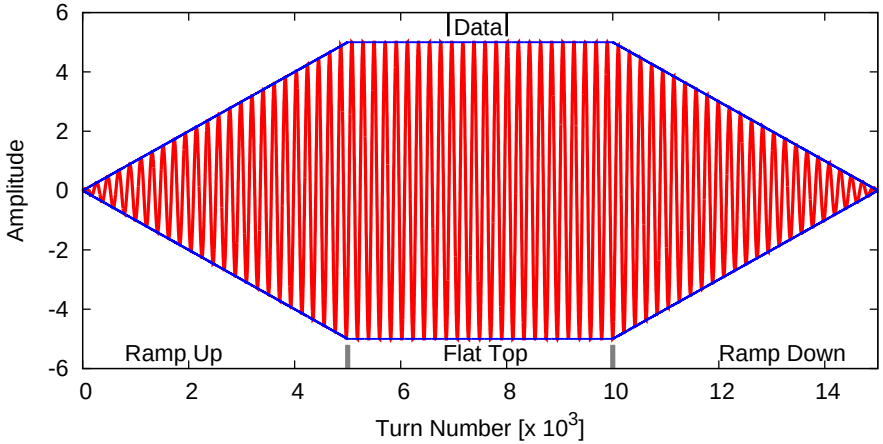
- Collide
  - Au^{+79}-Au^{+79} - 100 GeV/n
  - p^{+}-p^{+} - 100 GeV, 250 GeV
- Beam position monitors
  - 72 dual-plane (IR's)
  - 176 single-plane (Arcs)

Data Acquisition

Transverse Kickers



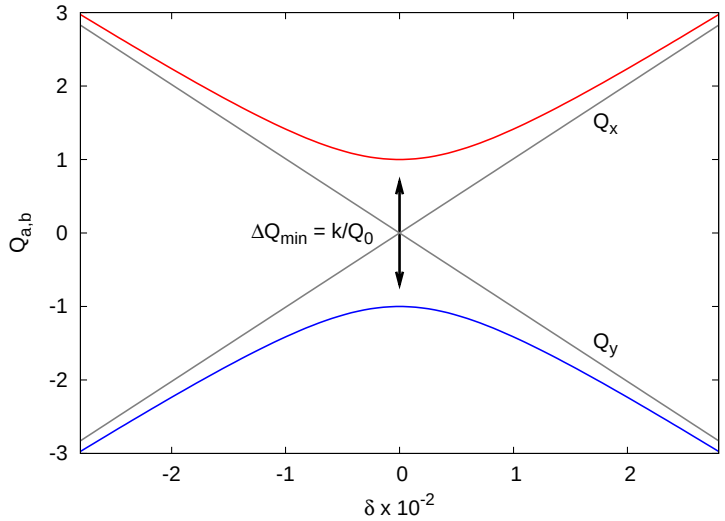
AC Dipoles



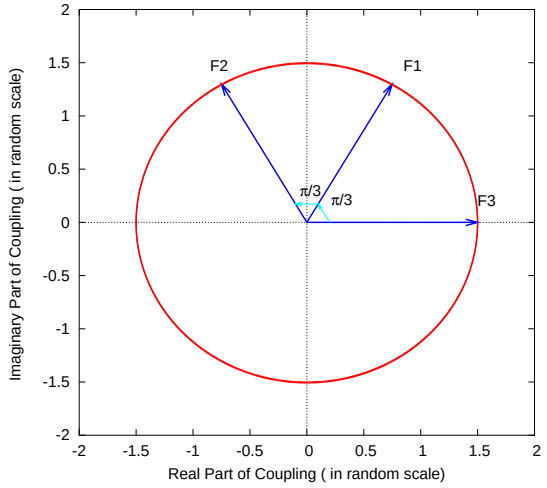
Global Coupling & Correction

Resonance Condition:

$$Q_x \pm Q_y = n$$



- Closest tune approach (manual scan)
- N-Turn Map correction (W. Fischer)
- Amp. and angle modulation (Y. Luo)



Local Coupling

Matrix Approach:

$$\mathbf{T} = \begin{pmatrix} \mathbf{M} & \mathbf{m} \\ \mathbf{n} & \mathbf{N} \end{pmatrix} = \mathbf{V}\mathbf{U}\mathbf{V}^{-1}$$

$$\mathbf{U} = \begin{pmatrix} \mathbf{A} & \mathbf{0} \\ \mathbf{0} & \mathbf{B} \end{pmatrix}, \quad \mathbf{V} = \begin{pmatrix} \gamma\mathbf{I} & \mathbf{C} \\ -\mathbf{C}^{+} & \gamma\mathbf{I} \end{pmatrix}$$

Hamiltonian Perturbation Approach:

$$f(s)_{\substack{1001\\1010}} = -\frac{1}{4\left[1 - e^{2\pi i(Q_x \mp Q_y)}\right]} \sum_l k_l \sqrt{\beta_x^l \beta_y^l} e^{i(\Delta\phi_x^{sl} \mp \Delta\phi_y^{sl})}$$

Equivalence Relations:

$$f_{\substack{1001\\1010}} = \frac{1}{4\gamma}(\pm\overline{C}_{12} - \overline{C}_{21} + i\overline{C}_{11} \pm i\overline{C}_{22})$$

$$\frac{|\overline{C}|}{4\gamma^2} = |f_{1001}|^2 - |f_{1010}|^2$$

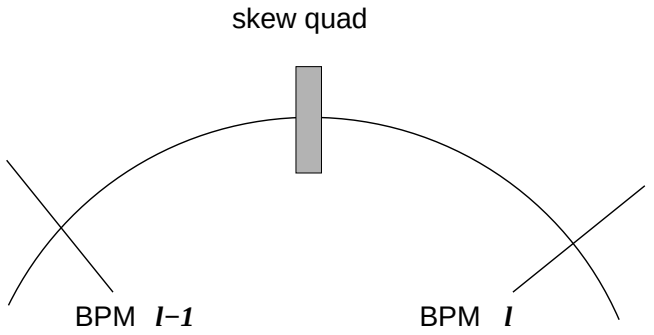
R. Calaga, A. Franchi, R. Tomás, Phys. Rev. ST Accel. Beams 8, 034001 (2005)

Propogation of $|\overline{C}|$

No Skew Quads:

$$\overline{C}_2 = \mathbf{R}_x(\phi_x)\ \overline{C}_1\ \mathbf{R}_y^{-1}(\phi_y)$$

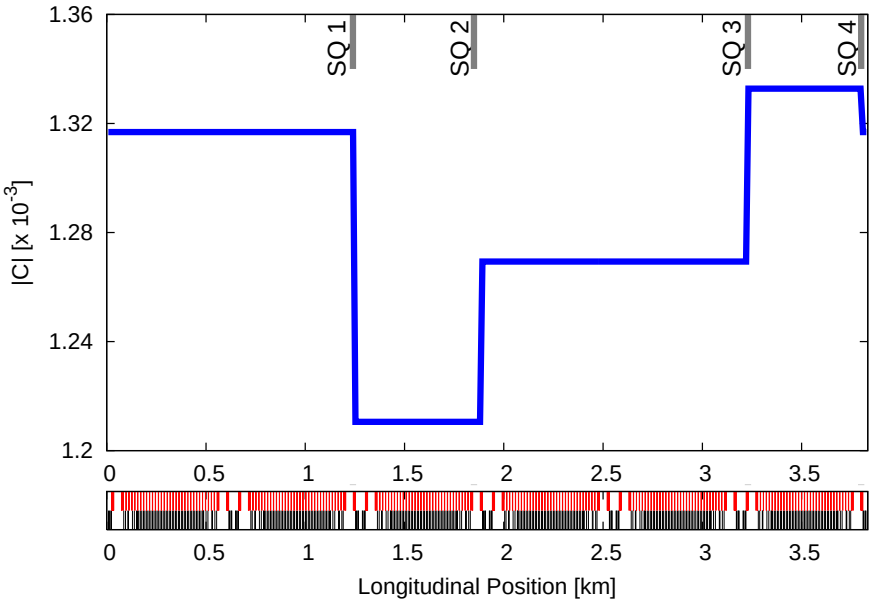
$$|\overline{C}_2| = |\overline{C}_1| \qquad |\mathbf{R}_x| = |\mathbf{R}_y| = 1$$



Thro' Skew Quad:

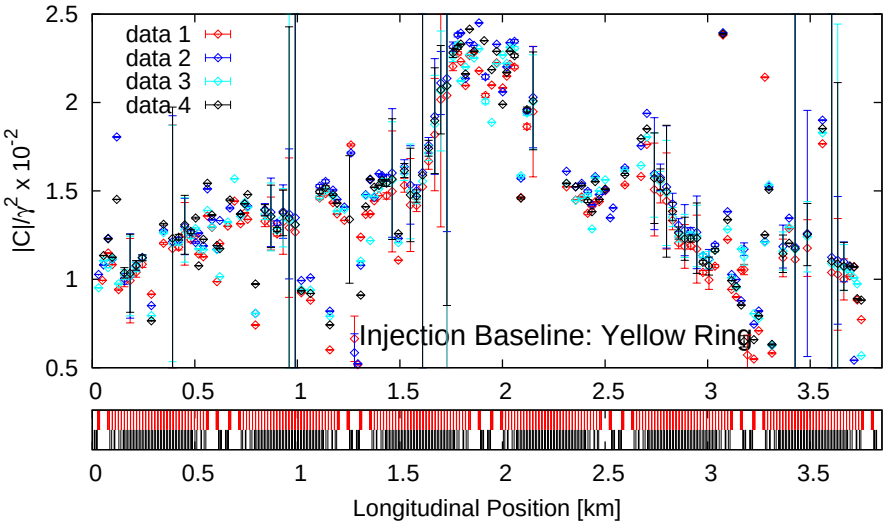
$$\overline{C}_2 = \overline{C}_1 - \overline{k}$$

$$\overline{k} = -\frac{|C^{(2)}| - |C^{(1)}|}{C_{12}^{skew}}$$

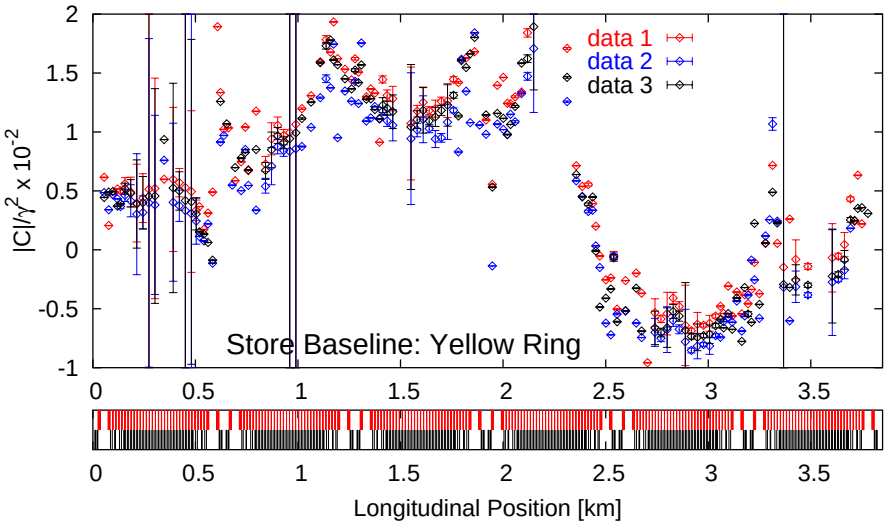


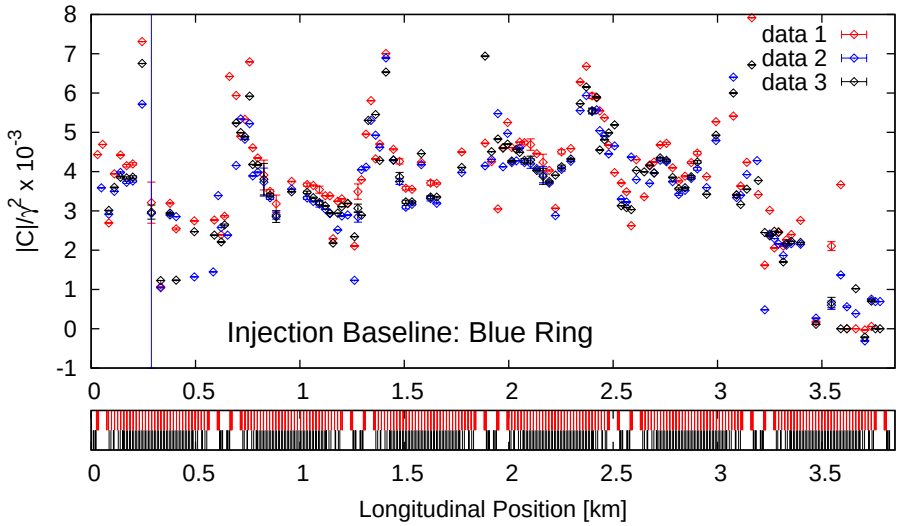
Run 2005: AC Dipole Data

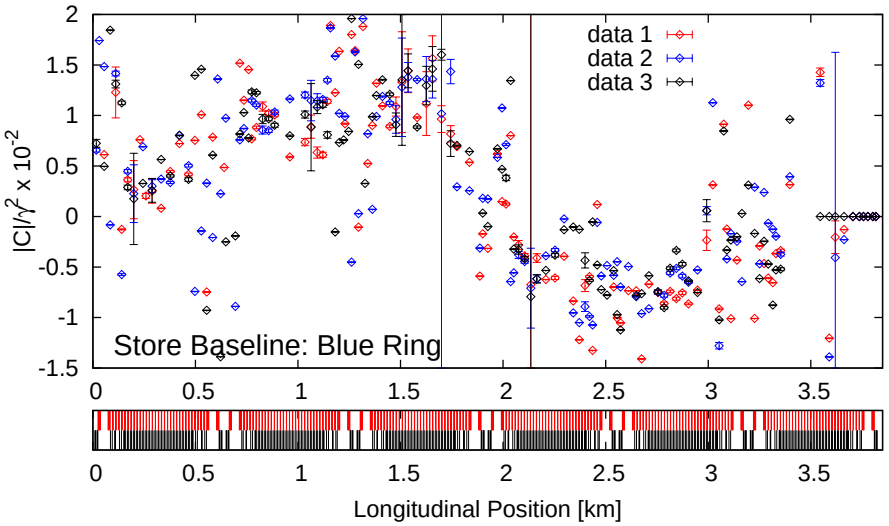
Injection



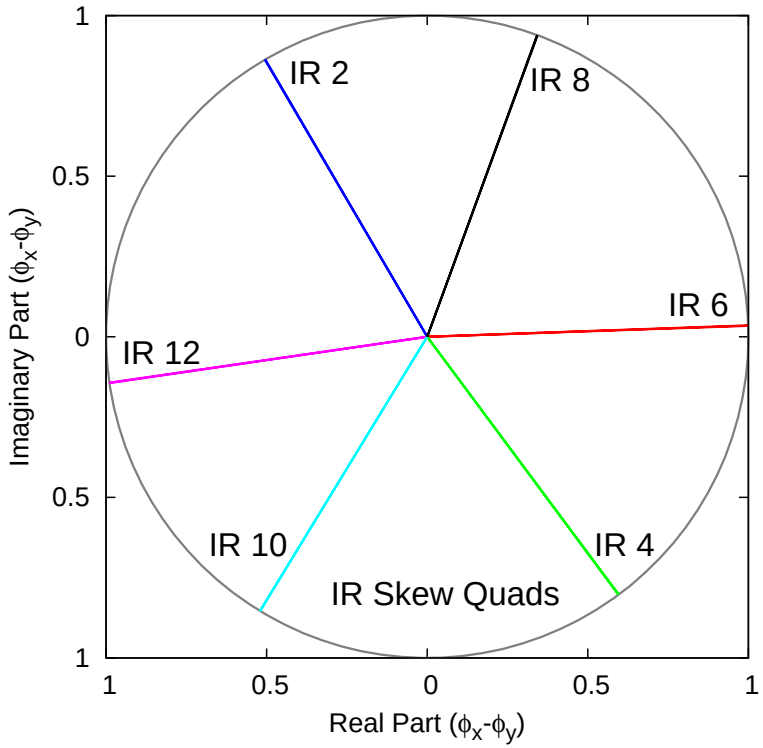
Top Energy





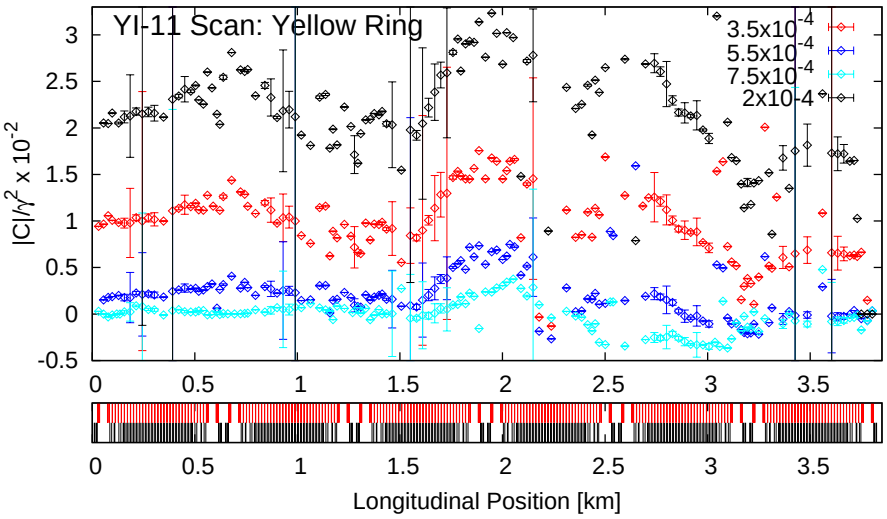


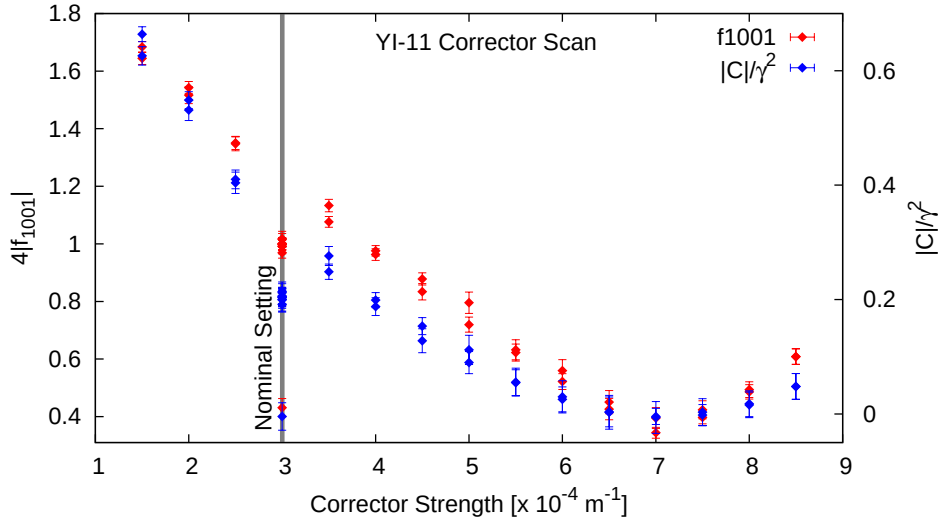
IR Skew Correctors



- Total 12 correctors (3 families - 4 correctors each)
- Correctors in approx. phase with triplets
- Goal: Correct each IR locally

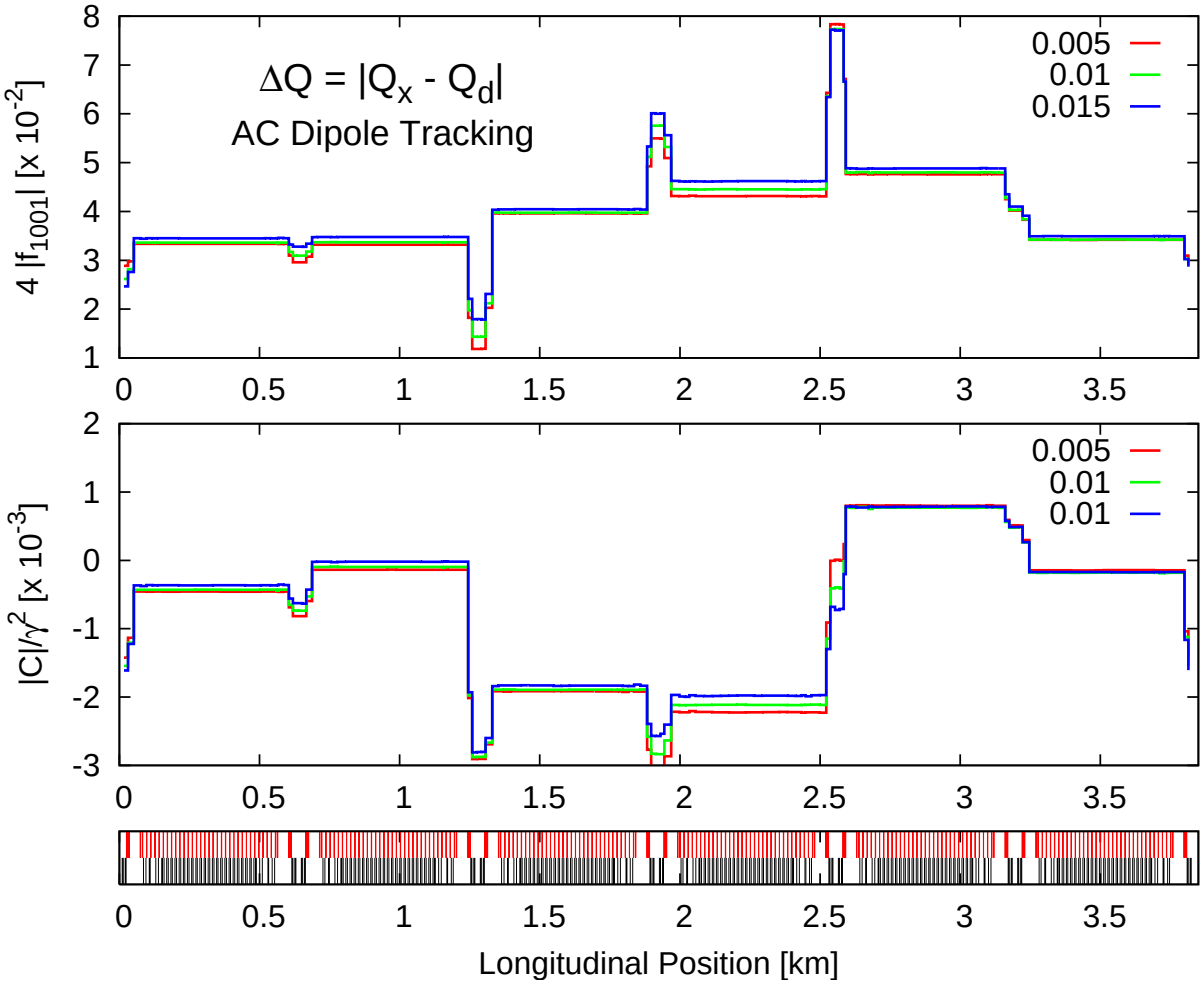
IR Corrector Scan: Injection





- Possible correction strategy by scanning IR skew correctors
- Minimize both local excursions and average value
- Identify slopes
  - AC Dipole artifacts
  - Quadrupole tilts
  - Vertical offsets in sextupoles

AC Dipole Effects (SIXTRACK)

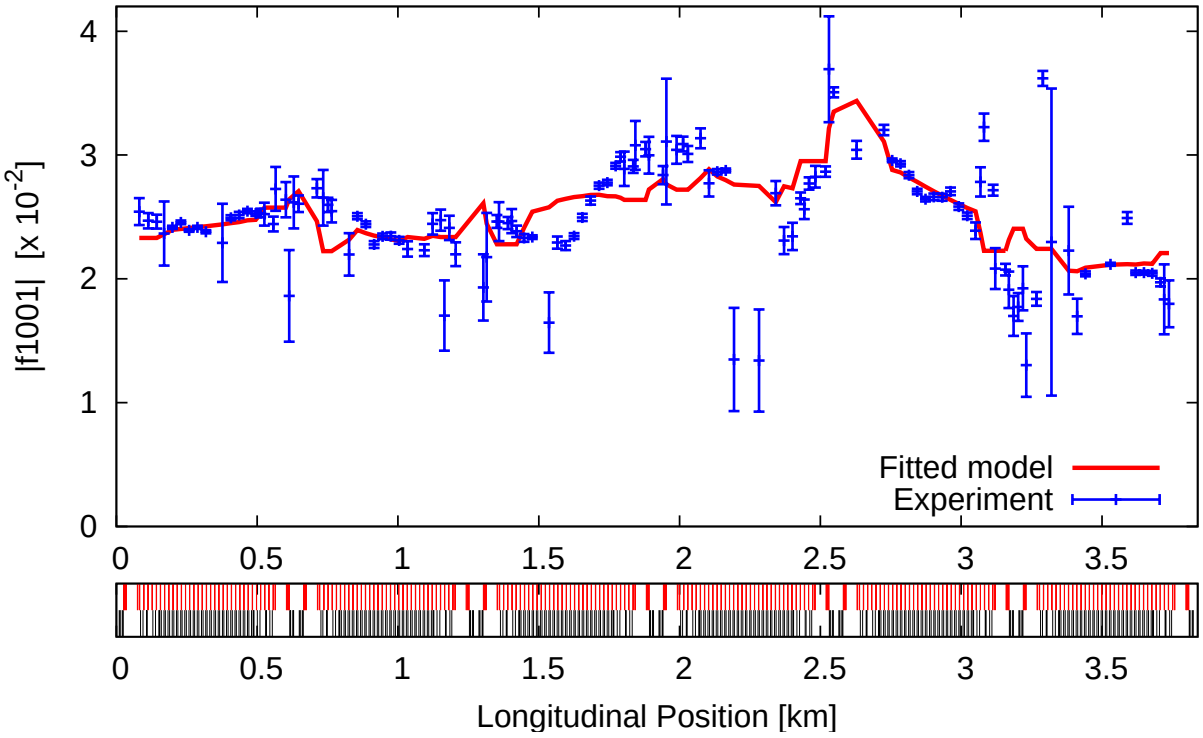


No slopes visible due to large δQ ($\sim$ 0.01) AC dipole artifacts can be excluded !

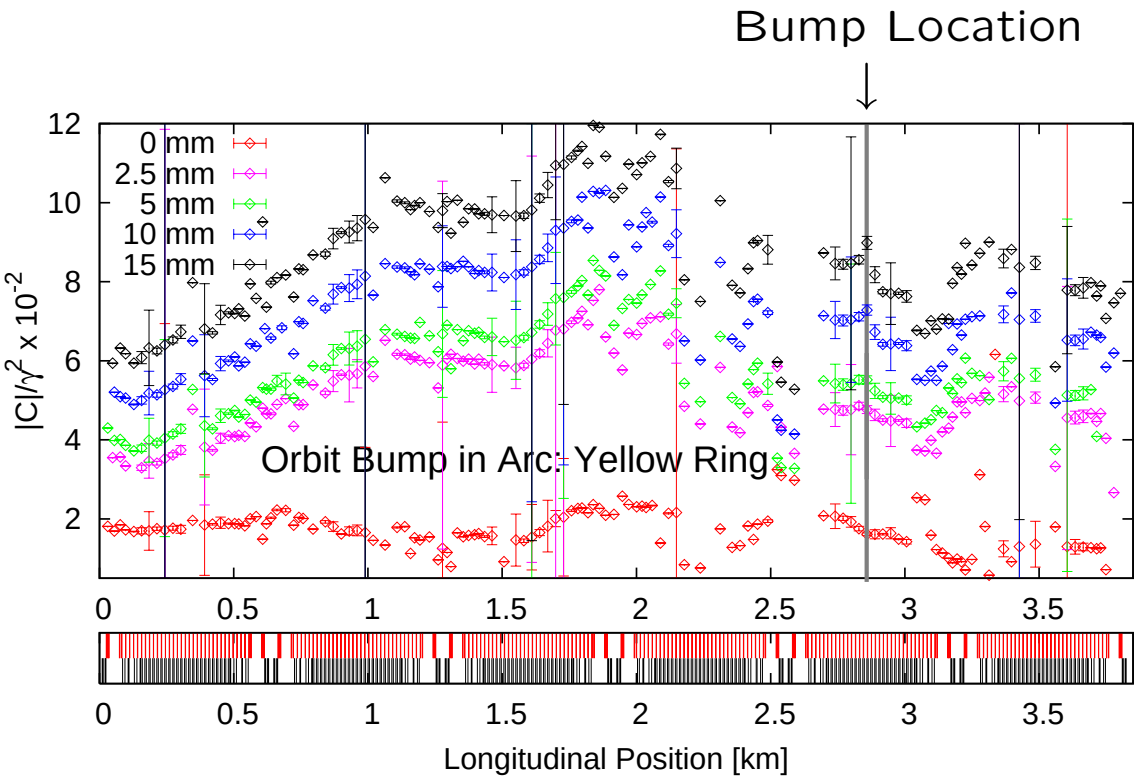
Fitting Model to Data

Fitting Variables:

$$\lim_{\Delta \to 0} \left[\Delta f_{1001}^{(meas-mod)} \right] \rightarrow \left[\begin{array}{c} \text{Arc Quad Tilts (6-families)} \\ \text{IR Skew Correctors} \\ \text{IR Quad Tilts } (Q_1 \text{ - } Q_{10}) \\ \vdots \end{array} \right] \rightarrow \text{MADX Iterate}$$

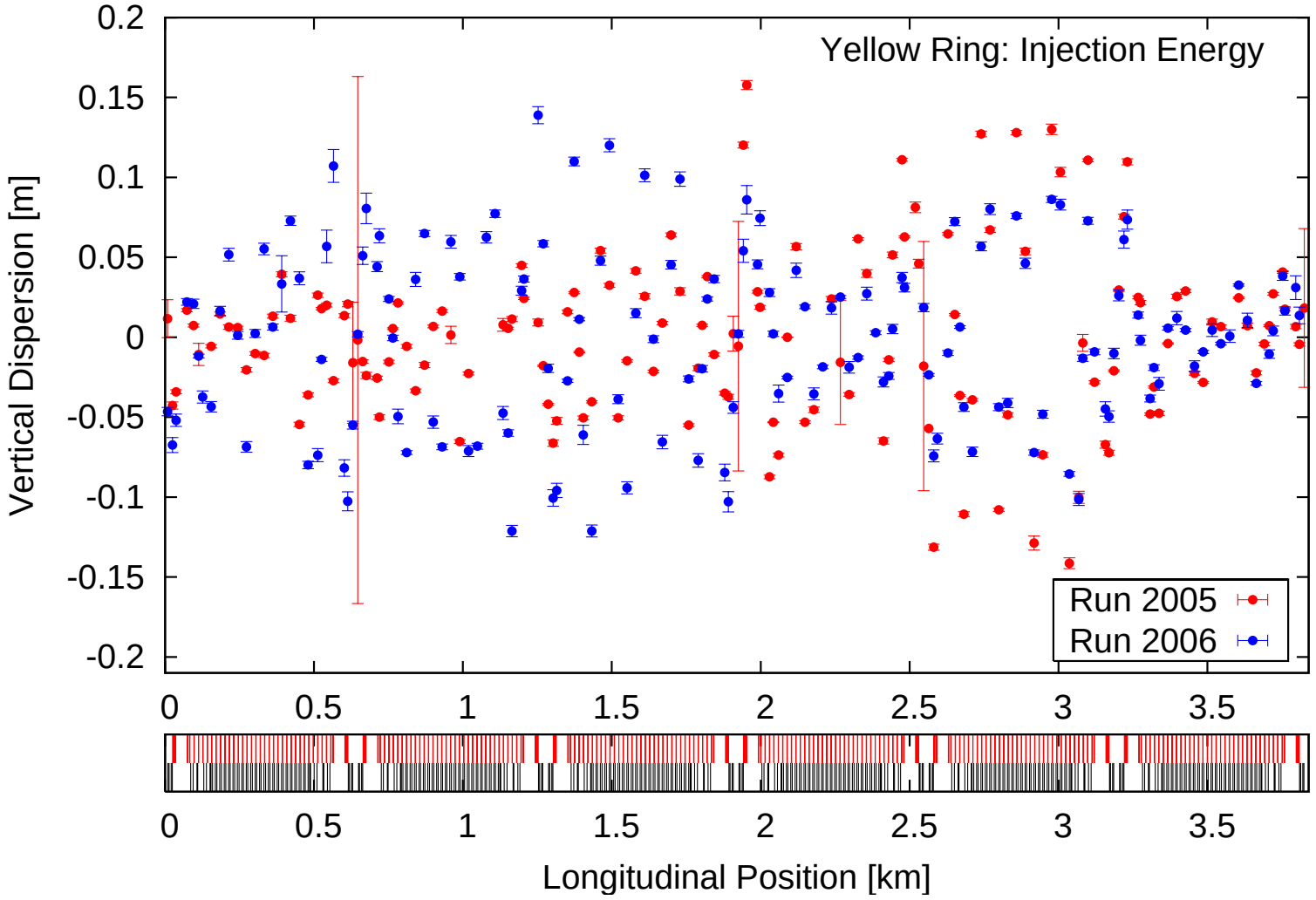


Vertical Offset in Sextupoles



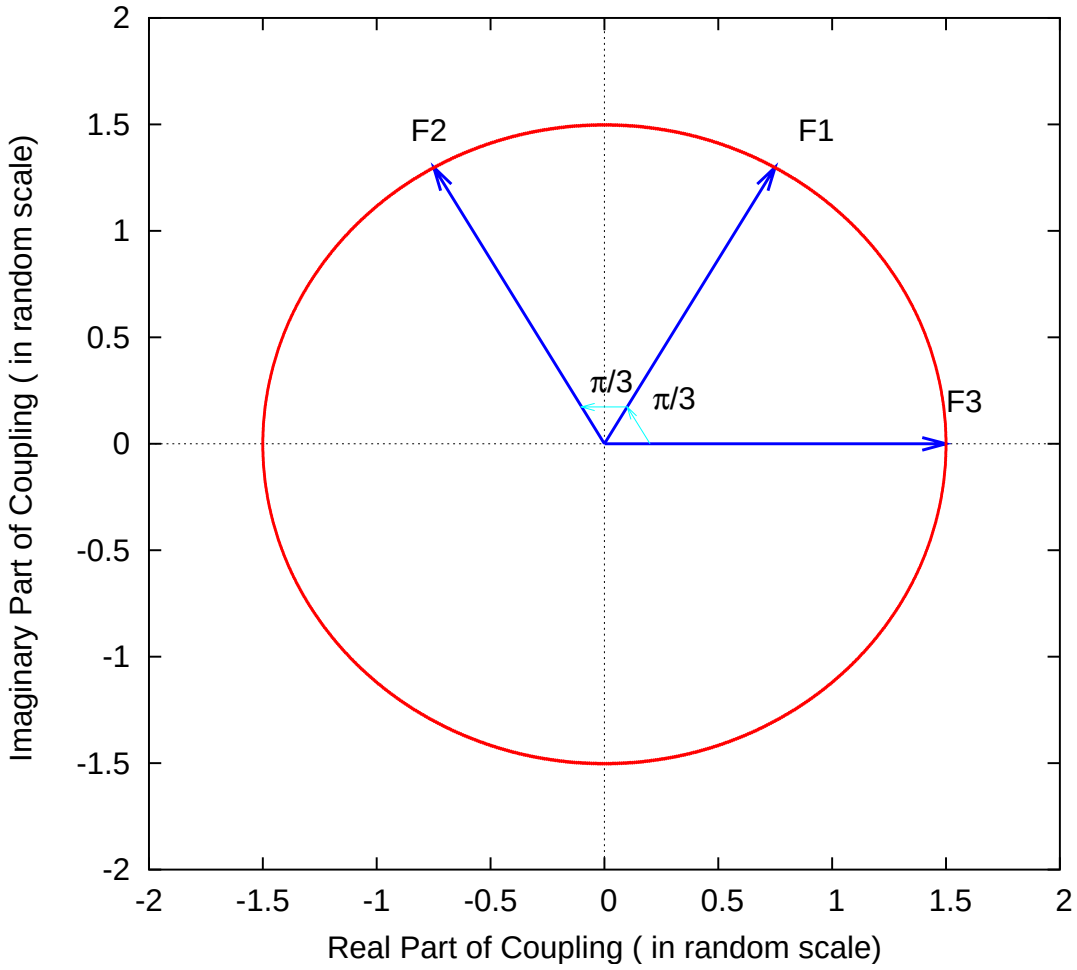
- Discontinuity visible at the bump location
- Slopes AMPLIFY with vertical offset through sextupoles
- Sources of the slopes remain unclear

Vertical Dispersion



*** Fit dispersion to coupling sources or compare for diff. corr. settings

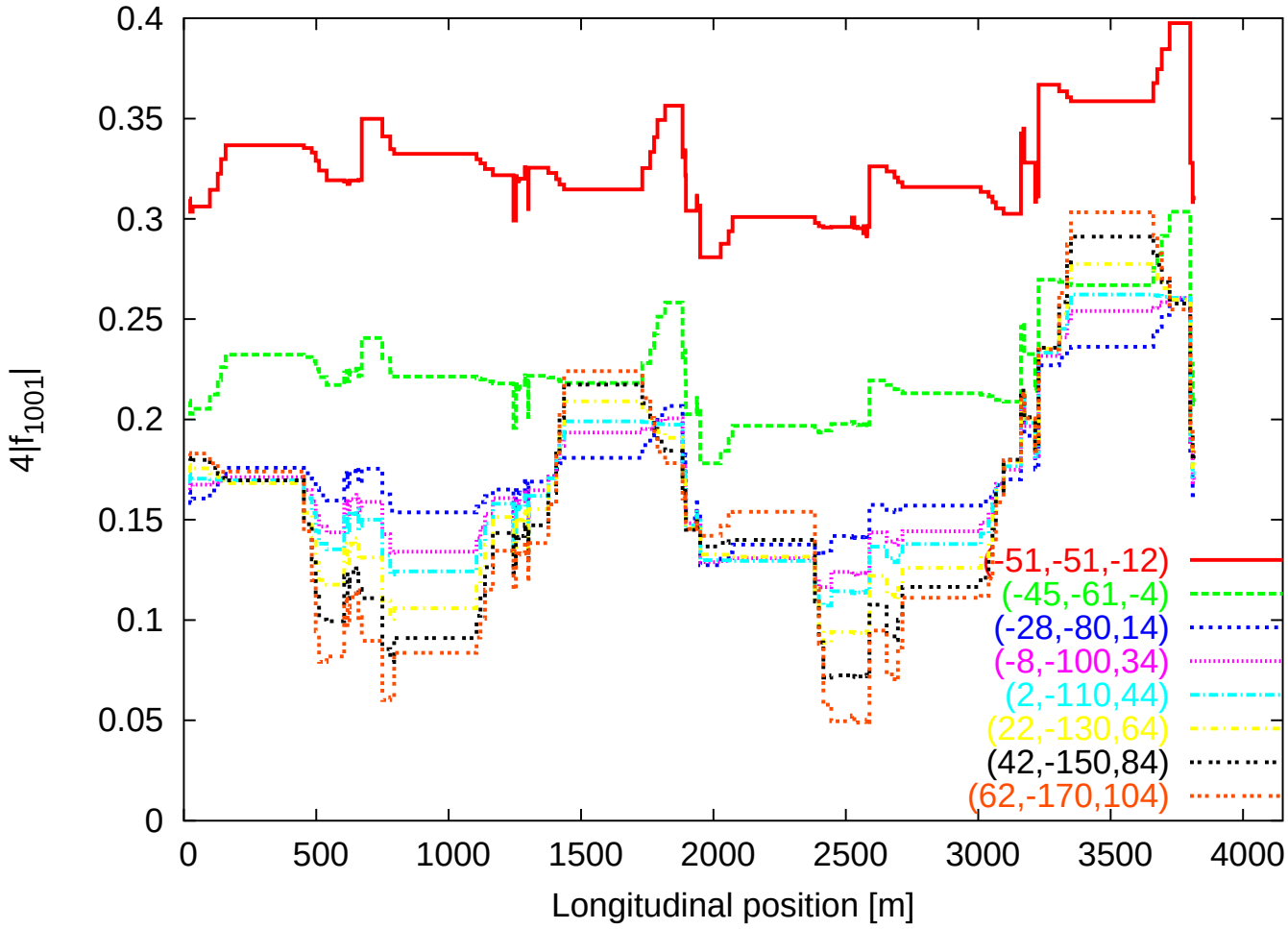
Revisit Global Coupling @RHIC



All settings of the form (F1−Δ,F2+Δ, F3+Δ) have the same ΔQ_{min}

RHIC Model

Global coupling compensated ($\Delta Q_{min} = 1 \times 10^{-3}$)



The numbers in brackets are strengths of the families ($10^{-5} m^{-1}$).

Fast Global Decoupling

Coupling Vector: $\mathbf{C} = |C|e^{i\Theta}$

$$\mathbf{C} = -\frac{1}{2\pi}\oint ds\ k(s)\sqrt{\beta_x(s)\beta_y(s)}e^{-i(\phi_x(s)-\phi_y(s)+\frac{s}{R\Delta})}$$

$\{|C| = \Delta Q_{min},\ \Delta = Q_x - Q_y\}$

$$|C| \simeq 4|\Delta|\langle|f_{1001}|\rangle + O(\Delta)$$
$$\Theta \simeq \frac{1}{N}\sum_i^N [q^i - (\phi_x^i - \phi_y^i) + \pi[1 - \frac{1}{2}sgn(\Delta)]$$

$\{|C| < \Delta \ll 1,\ f_{1001} = |f_{1001}|e^{iq}\}$

$\langle f_{1001}\rangle$	Δ	$\lvert C\rvert_{fast}$	$\lvert C\rvert_{old\ methods}$
0.02 ± 0.008	0.013	1.1 ± 0.4	1.6
0.05 ± 0.009	0.048	10 ± 1.7	10
0.025 ± 0.009	0.039	4 ± 1	3.1
0.03 ± 0.009	0.041	4.9 ± 1	4.4
0.04 ± 0.01	0.03	4.8 ± 1	4.4

Yesterday's Poster WEPCH064 (Andrea Franchi et al.)

Conclusions

- Many formalisms, techniques, and observables exist
- $f_{\substack{1001\\1010}}$ and $|\mathbf{C}|$ are very useful observables
- Extensive measurements of the RHIC during Run 2005
  - Limitation due to faulty and noisy BPMs
  - Slopes observed in arc regions
- Local corrector scan useful to re-optimize current settings
- Fitting model to measurments: Insightful
  - Quadrupole rolls give approx. good result
  - Sextupole offsets and dispersion fitting still in progress
- Also use $f_{\substack{1001\\1010}}$ & $|\mathbf{C}|$
  - Fast global decoupling
  - Re-optimize global coupling

Ack: S. Abeytunge, M. Bai, W. Fischer, T.Satogata, C. X. Wang

Extra Slides

IR Scan Contd.