# AC Dipole Based Diagnostics

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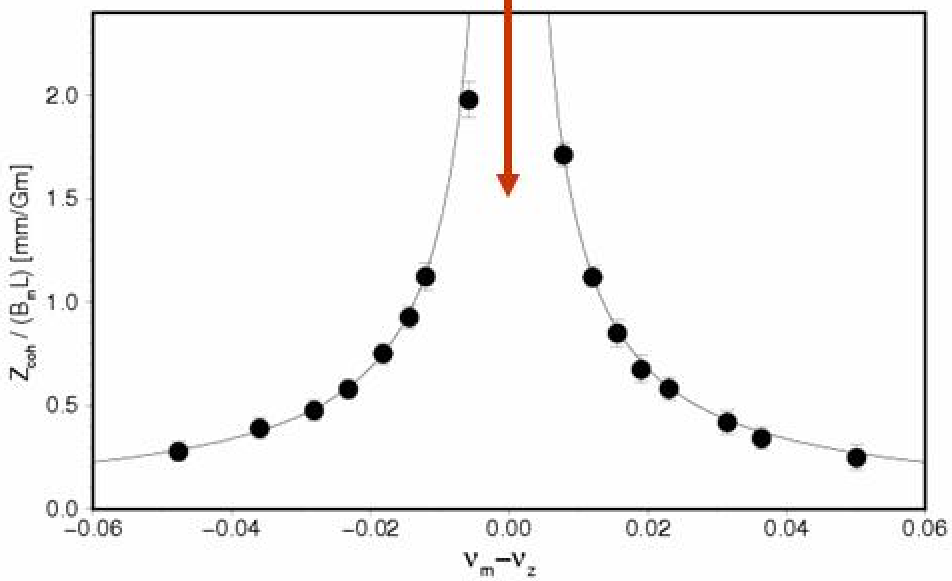
# Outline

- Introduction of ac dipole
- Overview of AC dipole applications in RHIC
  - results & status
- Plan for future
- Summary

# Introduction of ac dipole

- AC dipole: a dipole magnet with oscillating field
- By driving the ac dipole at a frequency at the vicinity of beam betatron frequency, a coherent oscillation can be excited. The size of this excited coherent oscillation is proportional to the strength of the ac dipole. The closer the ac dipole frequency to the beam betatron frequency, th[e] stronger the driven coherent oscillation
- By adiabatically ramping up the a[c] dipole strength, this driven oscillation is well under control and prevent the beam size from being blown up

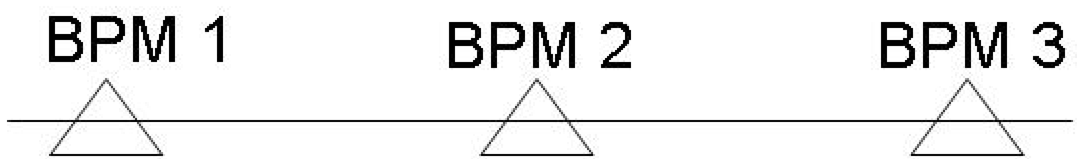
Beam becomes unstable if $\nu_m = \nu_z$




$$Z_{coh}(s) = \frac{\Delta B_m L}{4\pi B\rho |\nu_m - \nu_z|} \sqrt{\beta(s)\beta_m}$$

# Overview of AC dipole based beam experiment in RHIC

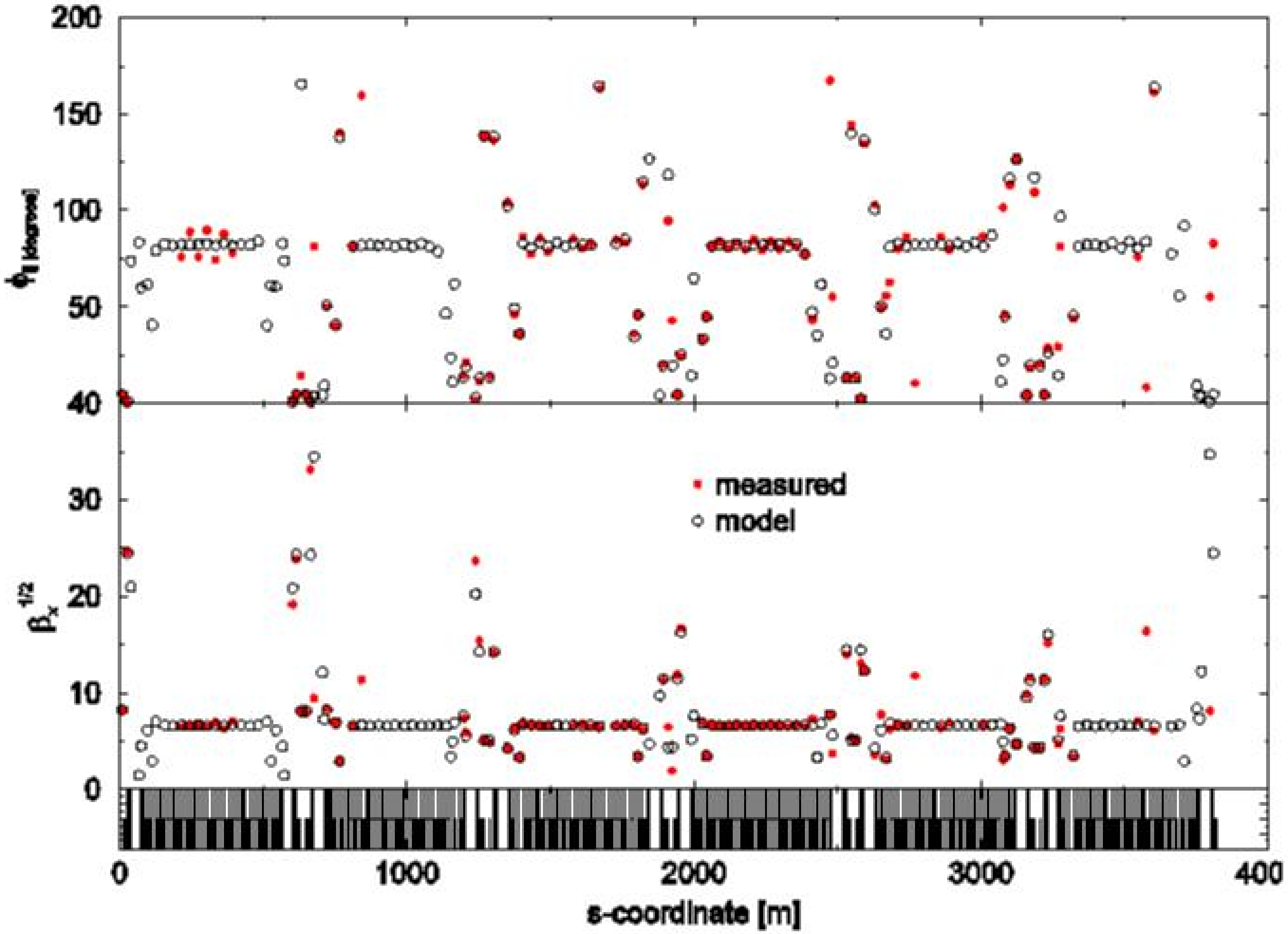
- Linear optics measurement
  - Measure beta functions as well as phase advances
    - Beta function and phase advance ring wide
    - Beta function at interaction point
  - Advantage: quick
  - Key: reliable turn by turn bpm data



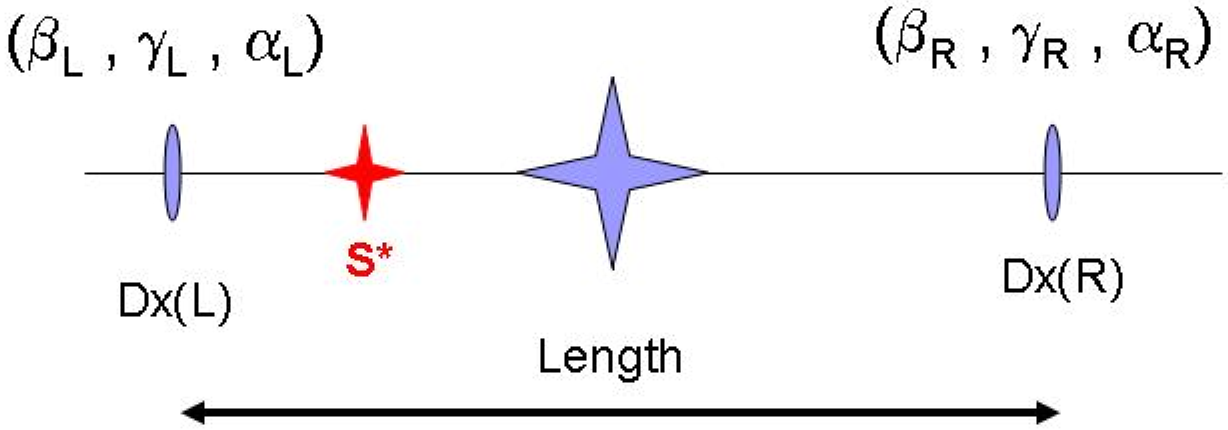

$$\beta_1 \frac{m_{11}^{1,2}}{m_{12}^{1,2}} - \cot\varphi_{12} = \beta_1 \frac{m_{11}^{1,3}}{m_{12}^{1,3}} - \cot\varphi_{13}$$

$$\beta_1 = \beta_1^m \sqrt{\frac{\beta_2/\beta_1}{\beta_2^m/\beta_1^m}} \frac{\sin\varphi_{12}^m}{\sin\varphi_{12}}$$

# Beta function measurement



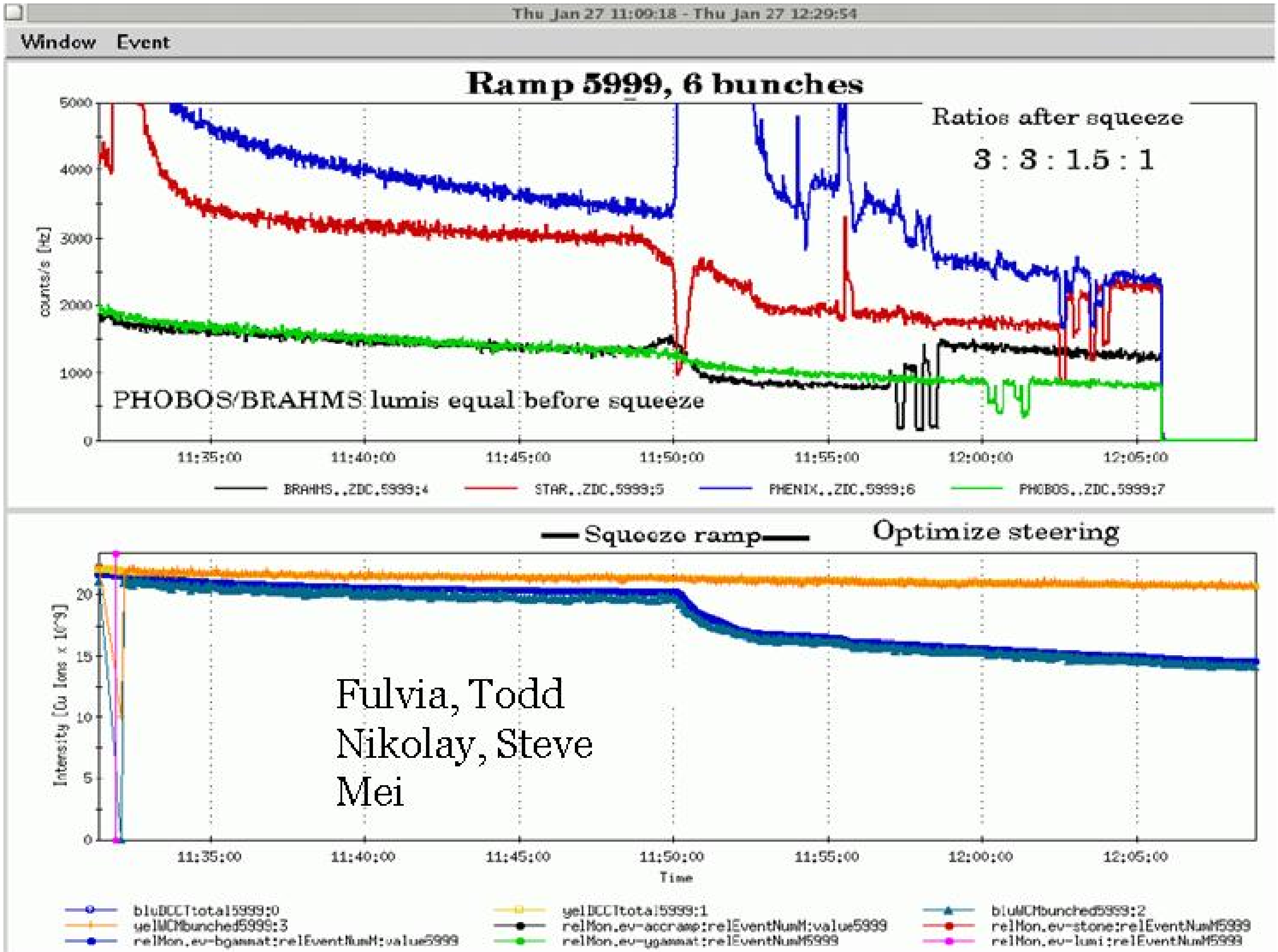
# Measure beta function at interaction point




$$\beta(s) = \beta^* + \frac{(s - s^*)^2}{\beta^*}$$

$$\beta^* = \frac{1}{\gamma_L} = \frac{1}{\gamma_R} \qquad s^* = -\beta^* \frac{\beta_L - \beta_R}{2Length} \beta^*$$

# First test at the end of IP2 Beta Squeeze experiment

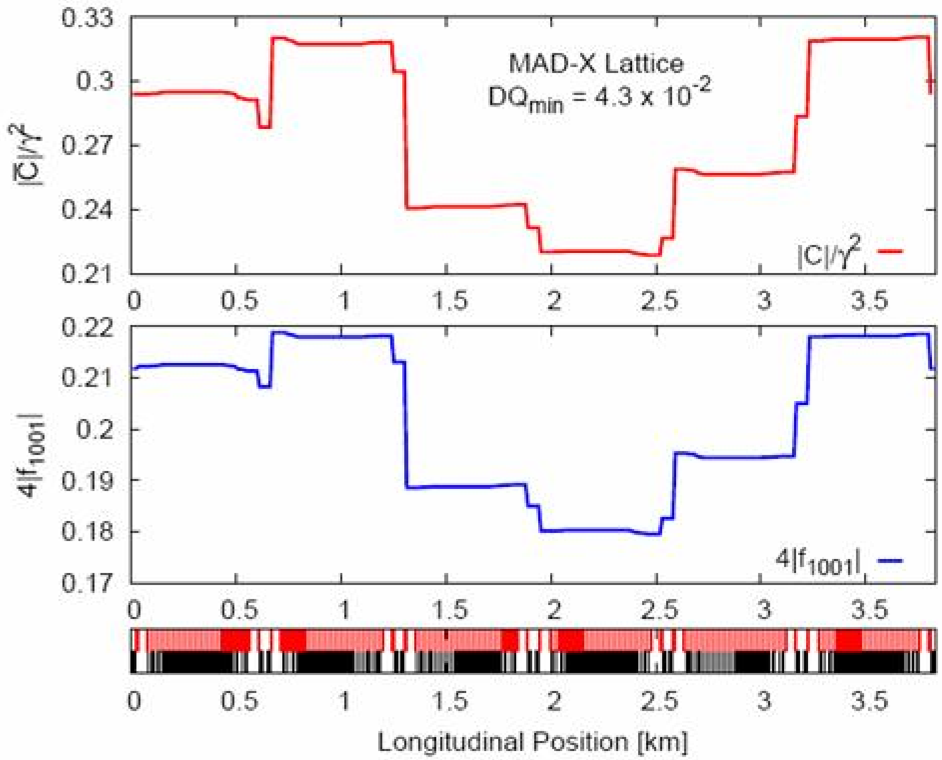


# First test at the end of IP2 Beta Squeeze experiment

| IP | 2 | 4 | 6 | 8 | 10 | 12 |
|---|---|---|---|---|---|---|
| Data 1 | 1.95357 | 4.85838 | 0.89682 | 1.01364 | 2.53181 | 5.85059 |
| Data 2 | 1.83512 | 4.86253 | 0.88635 | 0.99743 | 2.52409 | 5.862 |
| Data 3 | 1.86303 | 4.8547 | 0.87348 | 0.99046 | 2.51453 | 5.87384 |
| Data 4 | 1.88602 | 4.85648 | 0.87407 | 1.00204 | 2.53628 | 6.11184 |
| Average | 1.884 ±0.051 | 4.858 ±0.0034 | 0.883 ±0.011 | 1.000 ±0.0097 | 2.527 ±0.0095 | 5.924 ±0.125 |
| design | 2.0 | 5.0 | 0.85 | 0.85 | 3.0 | 5.0 |

# Local coupling measurement

RHIC Lattice (MAD-X Tracking)




Local IR skew correctors powered to generate coupling sources

Courtesy of Rama

One turn transfer matrix T

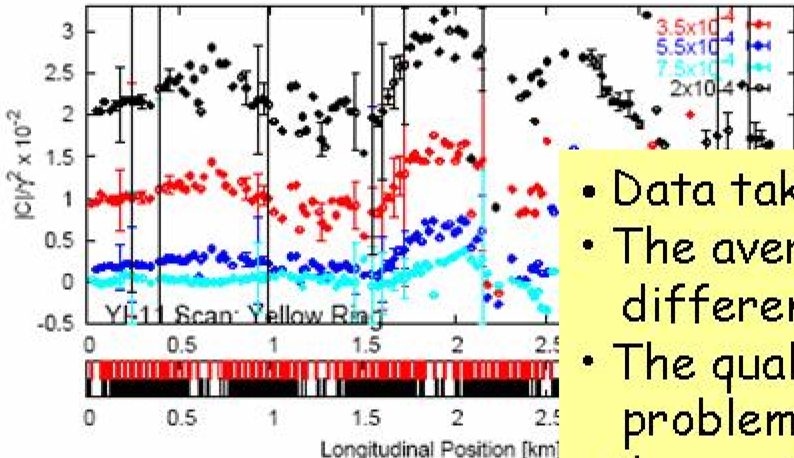
$$T = \begin{pmatrix} M & m \\ n & N \end{pmatrix} = VUV^{-1}$$

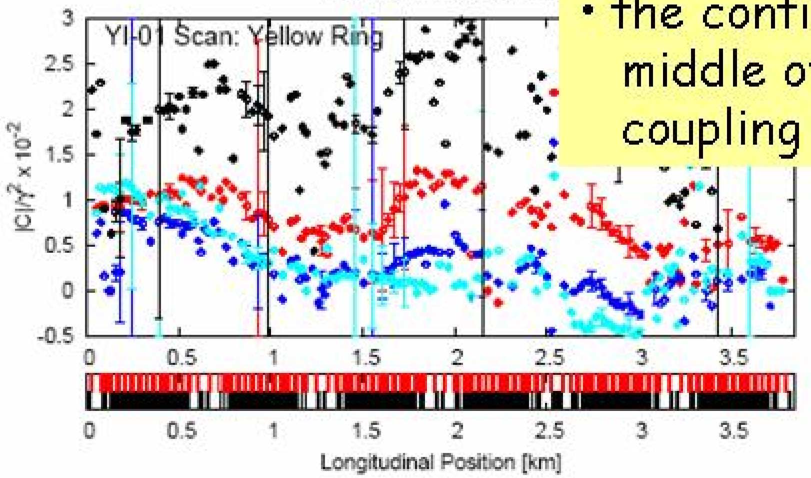
$$U = \begin{pmatrix} A & 0 \\ 0 & B \end{pmatrix} \qquad V = \begin{pmatrix} \gamma I & C \\ -C^{+} & \gamma I \end{pmatrix}$$

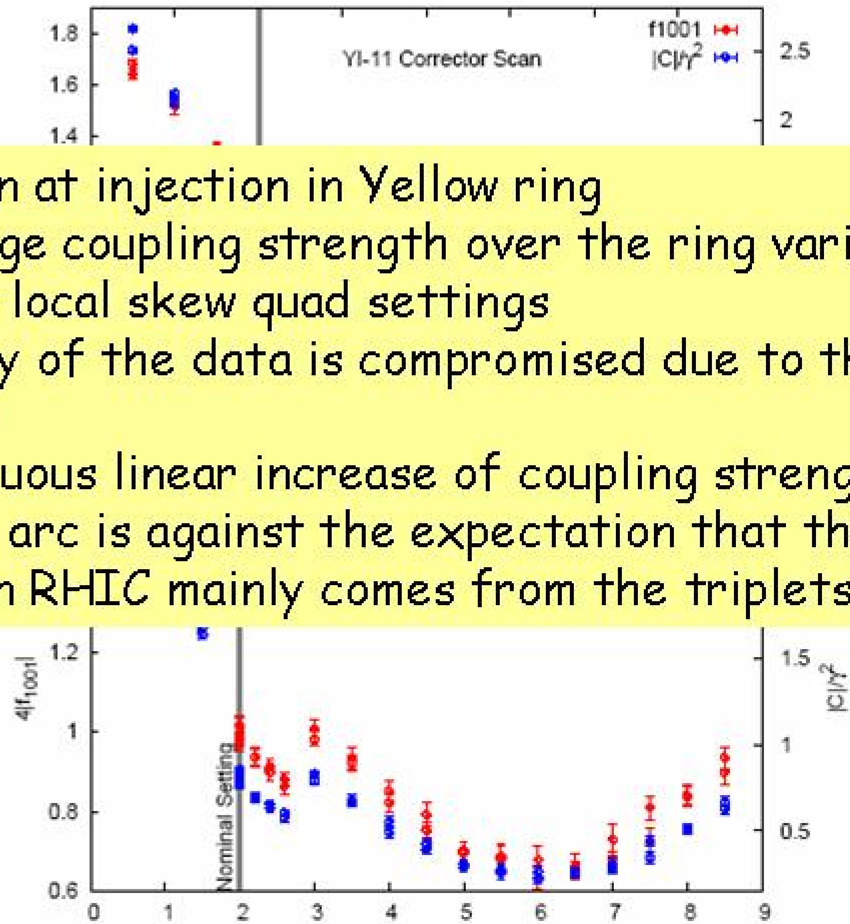
Coupling matrix C changes along the ring and it can be shown that the determinant of C jumps at a coupling source.

# Local coupling measurement

## IR Corrector Scan: Injection



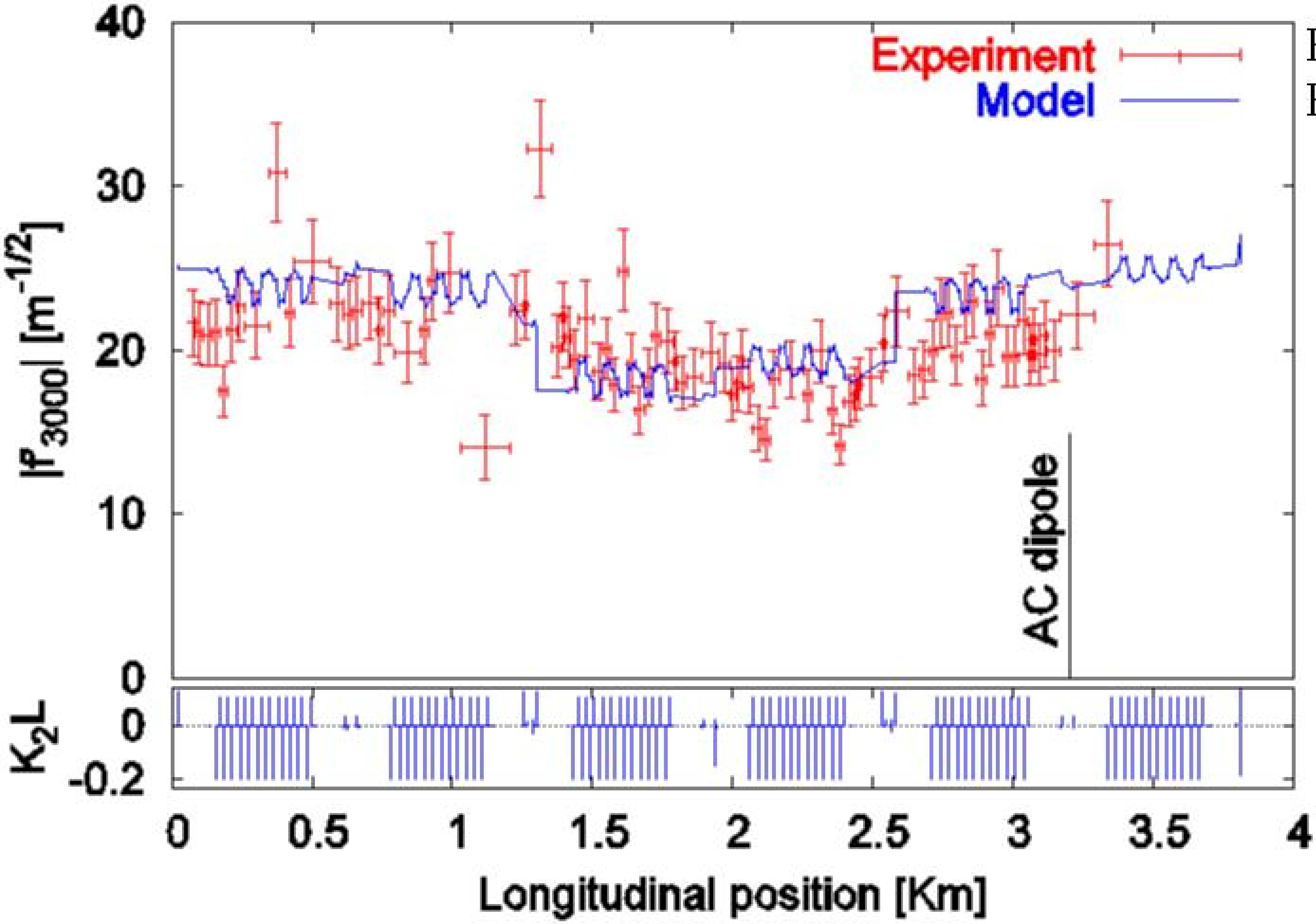




- Data taken at injection in Yellow ring
- The average coupling strength over the ring varied with different local skew quad settings
- The quality of the data is compromised due to the bpm problems
- the continuous linear increase of coupling strength in the middle of arc is against the expectation that the local coupling in RHIC mainly comes from the triplets

Courtesy of Rama

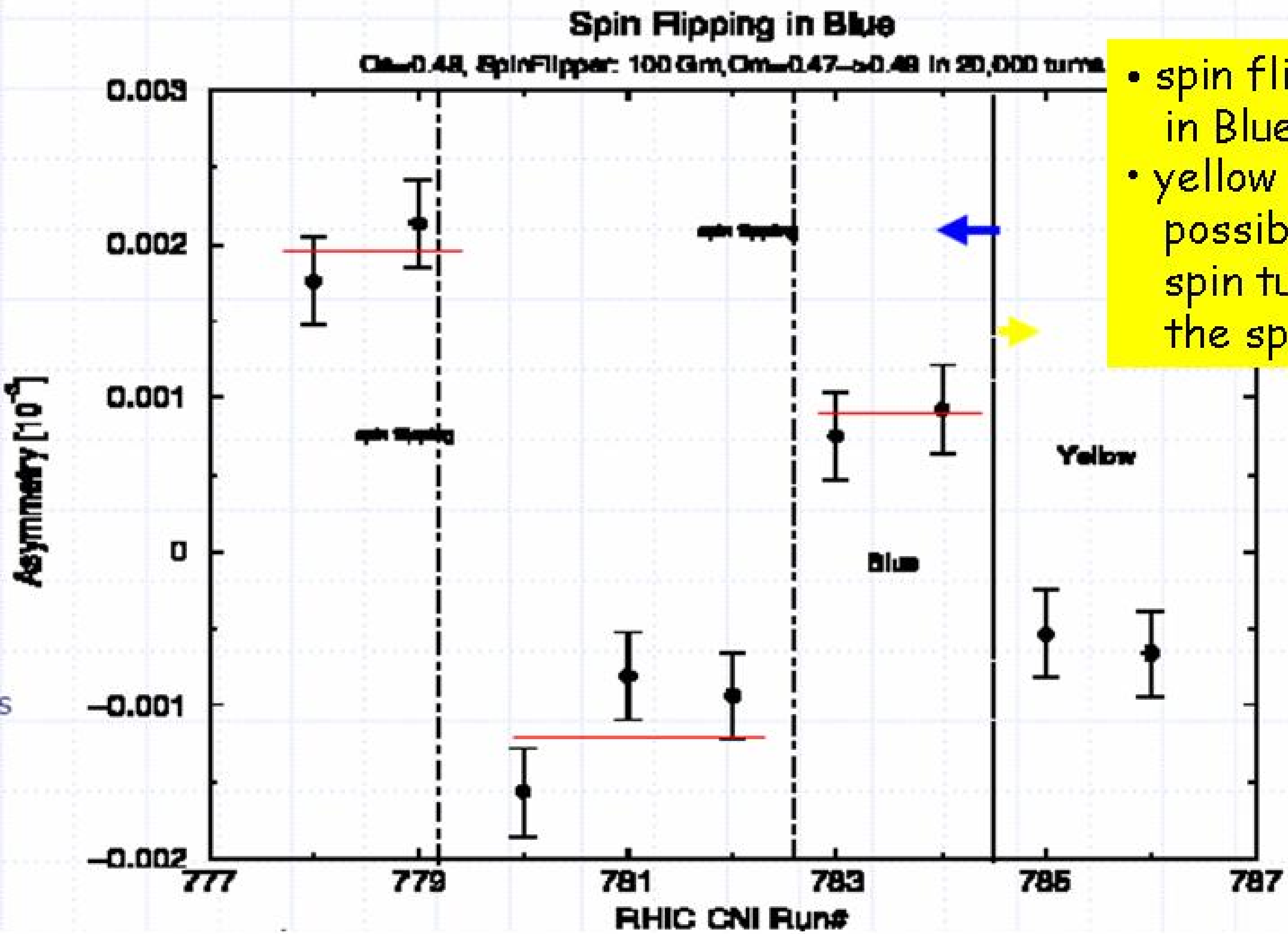
# Non-linear driving term measurement

First 3rd order resonance driving term measurement in RHIC with ac dipole




Rogelio, Wolfram
Rama, Mei, ...

# Spin manipulation -- Spin flipping




- spin flipping efficiency in Blue is 66%
- yellow got depolarized possibly because yellow spin tune is too close to the spin flipper tune

# Summary of AC dipole based beam experiment in RHIC

- Linear optics measurement
  - Status
    - End of experiment phase. Work on making it operational
    - Also, work on algorithms for gradiant error correction based on measured optics
- Local coupling
  - Status:
    - Data look encourage
    - However, limited by the quality of the bpm
    - Need more data especially with improved bpm system
- Non-linear driving term measurement
  - Status:
    - successful data at injection. Needs more time to take data at store
- Spin manipulation
  - Status:
    - very preliminary data. Need more time to fully commission the technique in spin tune measurement as well as spin flipping

# Experience from AC dipole based beam experiments

- Reliable turn by turn data from BPMs are very critical
- Sharing magnets between Blue and Yellow makes it very difficult on using ac dipole independently in the two rings
- The strength of the spin flipper is kind of marginal, esp. for the spin tune measurement. The current RHIC ac dipole only provides a resonance strength of a few units of $10^{-4}$

# What's new for future

- **Dynamic aperture measurement**
  - Limitation of the traditional DA technique is the tune meter kicker strength at store
  - With ac dipole, the idea is to drive the beam with a well controlled ramping strength and record the beam oscillation amplitude. In principle, the amplitude of the coherent oscillation saturates when the DA is reached.
  - One can also extract the frequency spectrum as a function of oscillation amplitude from the million turn bpm data
- **Spin manipulation**
  - Spin tune measurement
    - Very critical for pp operation
  - Spin flipping

# Summary

- For RUN 06
  - Take more data on local coupling as well as non-linearity measurements with ac dipole
  - Measure dynamic aperture with ac dipole
  - Spin tune measurement / spin flipping