COLOMBIA 200 AÑOS DE IDENTIDAD •1810-2010• COMISIÓN BICENTENARIO INDEPENDENCIA DE COLOMBIA

UNIVERSIDAD NACIONAL DE COLOMBIA SEDE BOGOTÁ FACULTAD DE CIENCIAS

Proposed Procedure to Correct Linear Errors at the LHC IRs using Action and Phase Analysis

J. Cardona and O. Blanco, Universidad Nacional de Colombia

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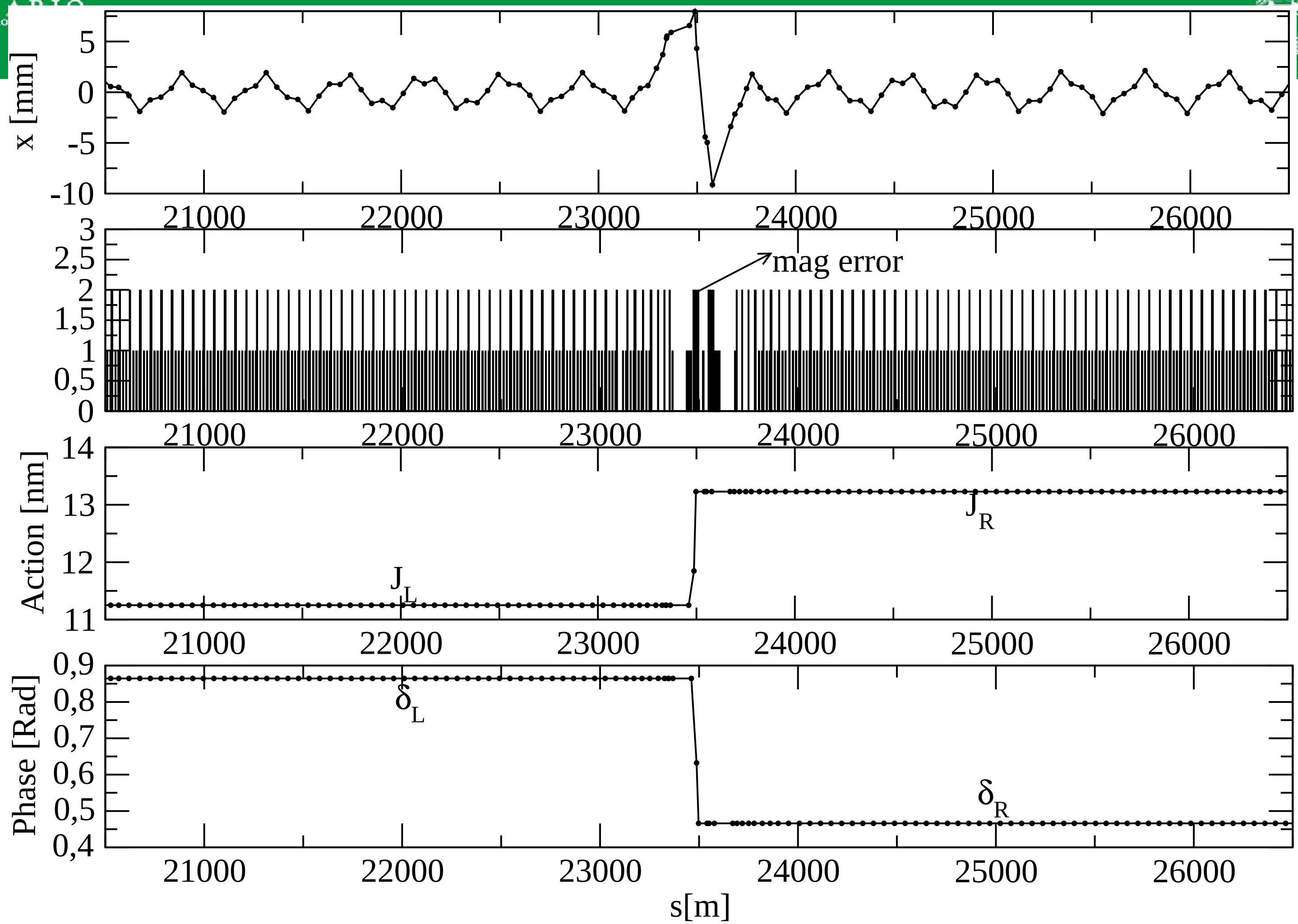
Action and Phase Jump Analysis

- Action and phase jump analysis has been used to estimate strengths of skew quadrupole correctors at RHIC (PAC 01, pg 3132).
- It has been tested using orbit data with known skew and quad errors (EPAC 04, pg 1553).
- It has been used to estimate known Non linear components with SPS data (PAC 2005, pg 2012).
- It will be describe how action and phase jump analysis can be adapted to measure and correct linear error at LHC IRs.

Errors from Action and Phase Analysis



$$\theta_x = \sqrt{\frac{2J_L + 2J_r - 4 * \sqrt{J_L J_R} \cos(\delta_L - \delta_R)}{\beta(s_\theta)}}$$

Linear Components of the Errors

$$\theta_x = -\frac{\Delta B_y l}{B\rho}, \qquad \theta_y = \frac{\Delta B_x l}{B\rho}$$

For one magnet (keeping only linear components):

$$\theta_x = A_1 y - B_1 x$$

$$\theta_y = A_1 x + B_1 y$$

Kick can not be measured for a single magnet.

For a triplet (more realistic):

$$\theta_x^t = A_1^t y - B_1^{tx} x$$

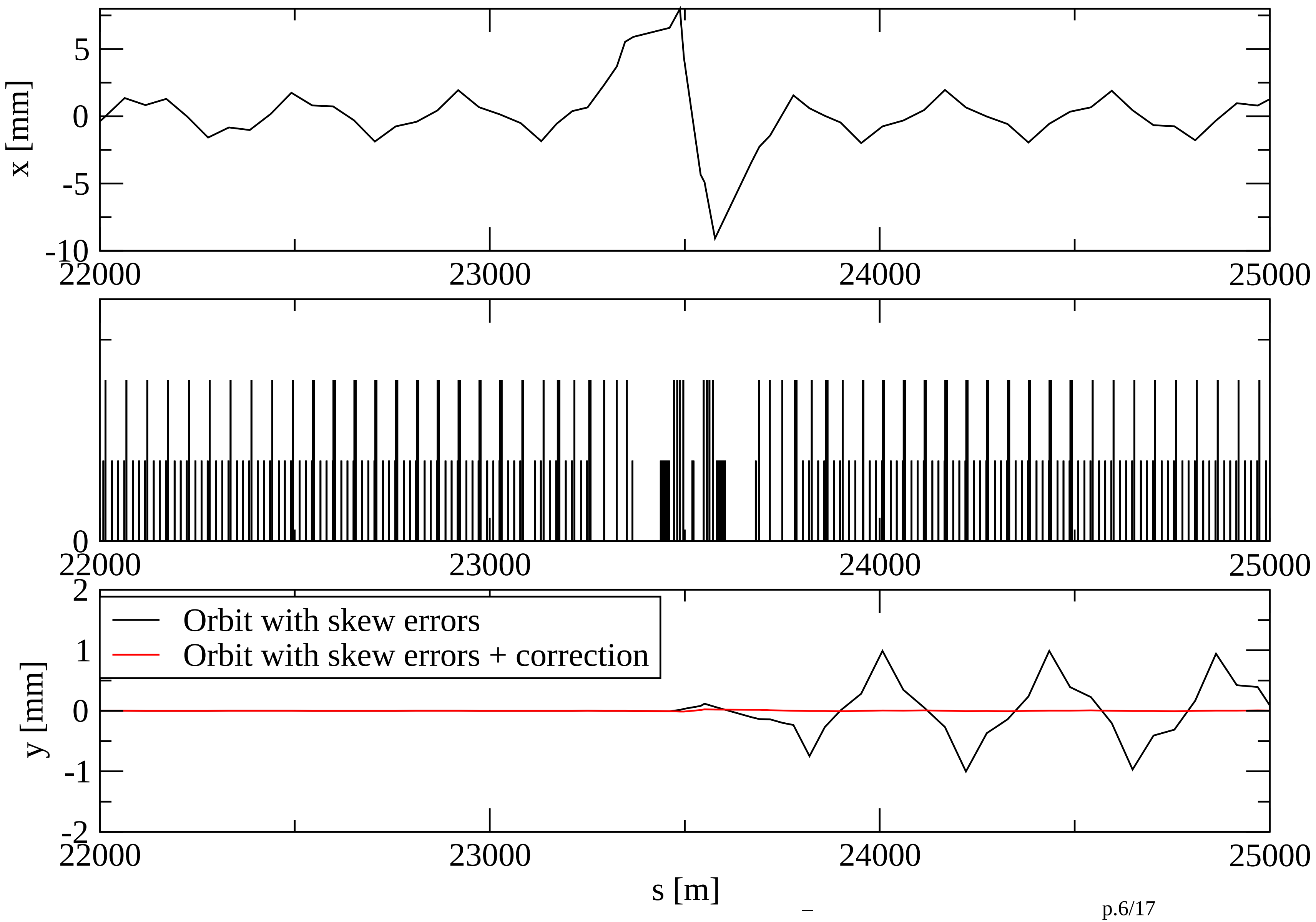
$$\theta_y^t = A_1^t x + B_1^{ty} y$$

A_1^t and B_1^t enough for linear correction.

A_1^t and Coupling Correction

- To correct local coupling use $K1S_c * L_c = -A_1^t$.
- One beam trajectory is simulated in MADX using LHC lattice and the follow. skew errors in IR1: $K1S(Q1) = K1S(Q2) = K1S(Q3) = 10^{-5}m^{-2}$
- Action and phase analysis of the trajectory gives $A_1^t = 1.78 * 10^{-4}m^{-1}$ and $K1S_c = -0.0008m^{-2}$.
- Correction is tested exciting an horizontal trajectory and measuring the coupled orbit in the opposite plane.

Verification of Coupling Correction



B_1^t and Gradient Error Correction

- Since the B_1^t are different for both planes, at least two quads should be tweak to compensate all gradient errors in the triplet.
- The two values for gradient compensation can be found by inverting the equations:

$$B_1^{tx} = \frac{\Delta K1_c(Q1) \int\limits_{Q1} \beta_x ds + \Delta K1_c(Q2) \int\limits_{Q2} \beta_x ds}{\beta_{xe}}$$

$$B_1^{ty} = \frac{\Delta K1_c(Q1) \int\limits_{Q1} \beta_y ds + \Delta K1_c(Q2) \int\limits_{Q2} \beta_y ds}{\beta_{ye}}$$

Simulation of Gradient Error Correction

- One beam trajectory is simulated in MADX using LHC lattice and the follow. grad errors in IR1: $\Delta K1(Q1) = \Delta K1(Q2) = \Delta K1(Q3) = 10^{-5}m^{-2}$.
- Action and phase analysis of the orbit gives $\Delta K1_c(Q1) = 5.47 * 10^{-5}m^{-2}$ and $\Delta K1_c(Q2) = 4.21 * 10^{-5}m^{-2}$.
- Correction is tested looking at the betabeat.

Verification of Gradient Error Correction

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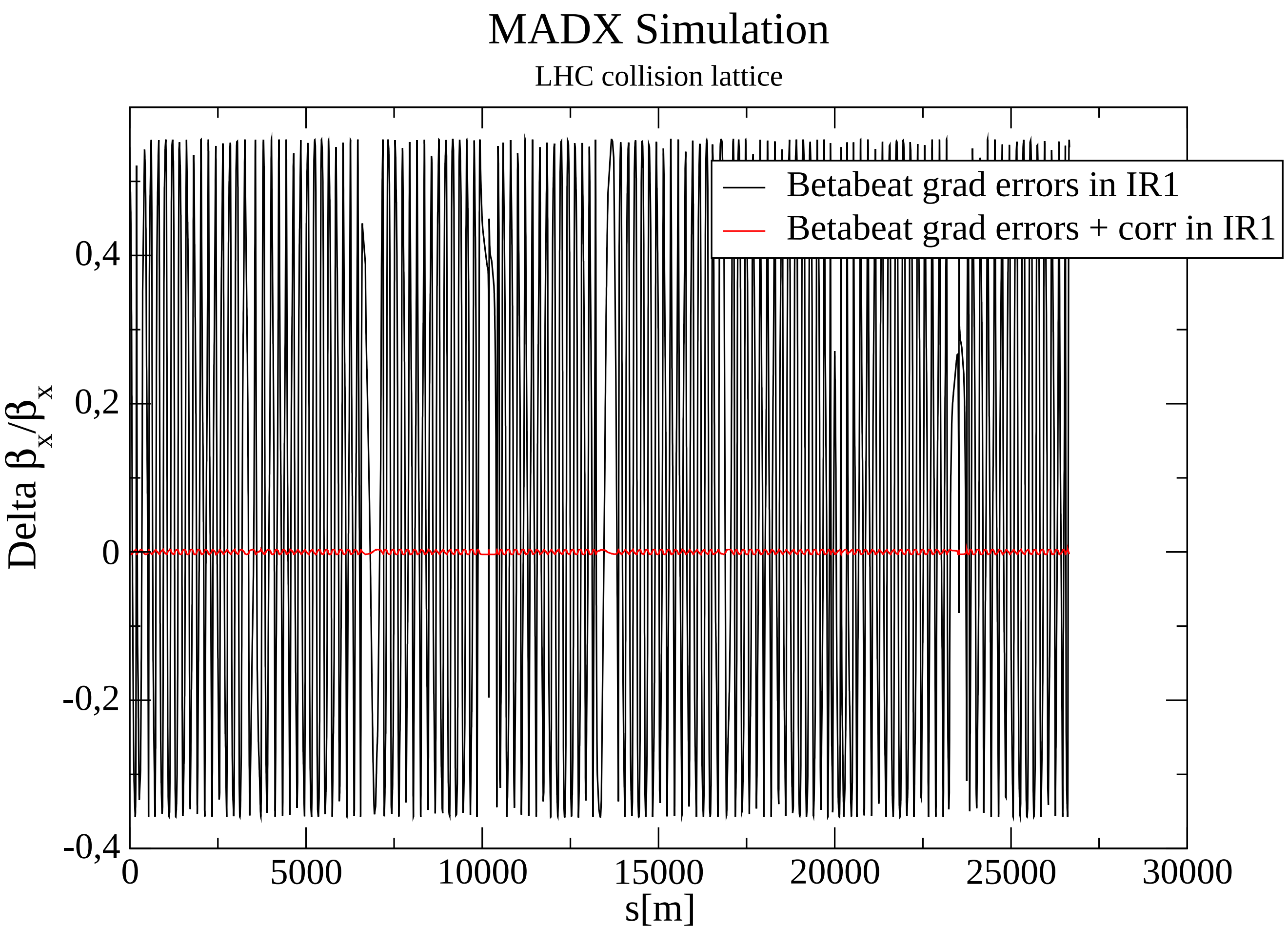


Influence of BPM Noise

- Gaussian errors of 200 μm were introduced in the simulations
- Calculations of correction settings are sensitive to the noise (30% a 45% variation).
- B_1^{tx} and B_1^{ty} are much less sensitive to noise.
- Use as many turns as possible to statistically estimate B_1^{tx} and B_1^{ty} and then calculate de correction settings (1% a 10% variation for 24 orbits).

Skew Quad and Gradient Errors

- Only one beam trajectory has been used for error calculation until now.
- The general case involve skew quad and gradient errors simultaneously and hence at least two orbits (out of phase) are needed.

$$\theta_{x_1} = A_1^t y_1 - B_1^{tx} x_1$$

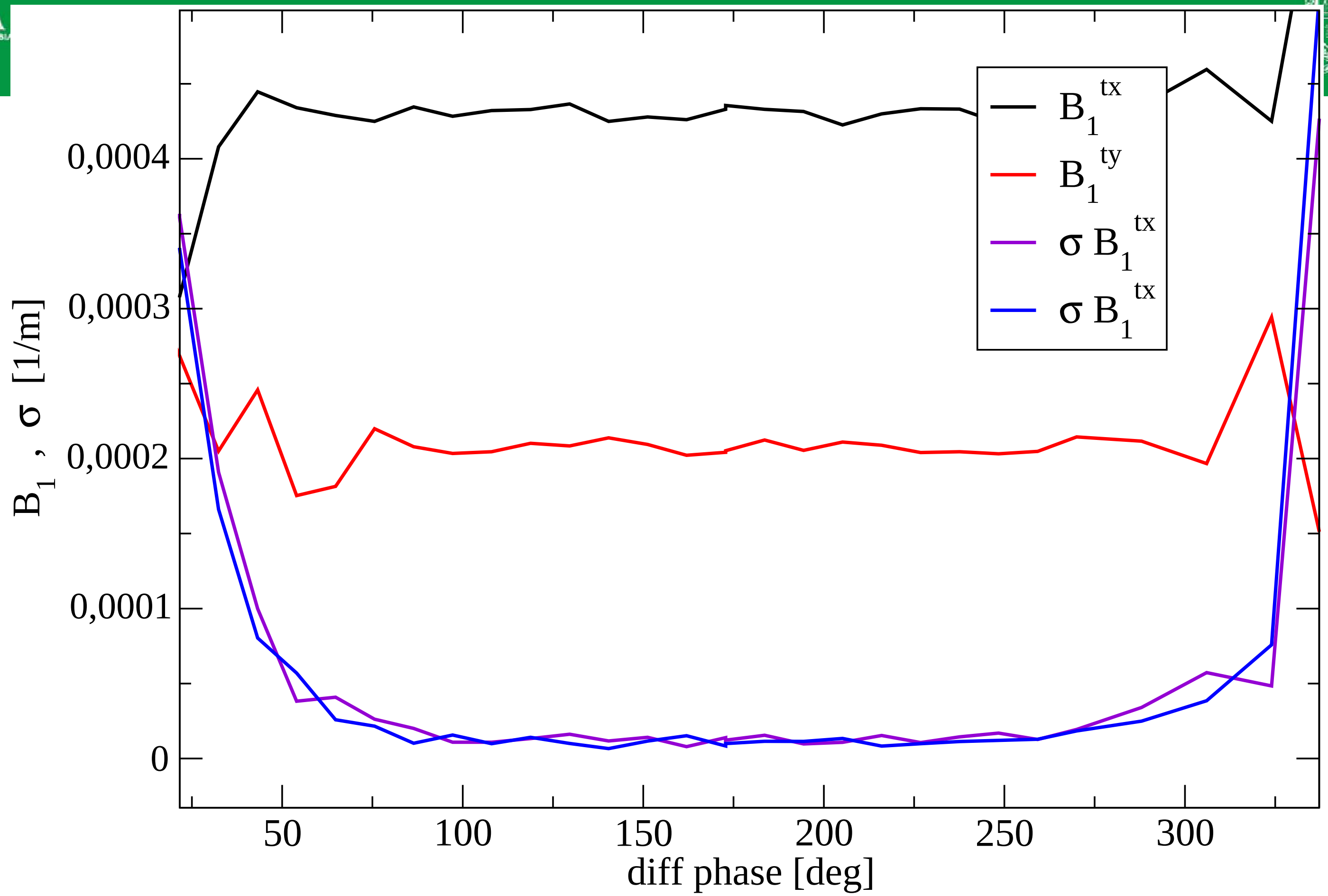
$$\theta_{y_1} = A_1^t x_1 + B_1^{ty} y_1$$

$$\theta_{x_2} = A_1^t y_2 - B_1^{tx} x_2$$

$$\theta_{y_2} = A_1^t x_2 + B_1^{ty} y_2$$

- In practice, four orbits are used.

Influence of Phase Difference



Phase difference between 90 to 270 degrees seems to be optimal for estimation of B_1^{tx} and B_1^{ty}

Conclusions

- It is possible to find the appropriate settings to correct linear errors at IR triplets with action and phase analysis.
- However, the calculated settings are sensitive to the current level of noise present in the LHC BPMs.
- This problem can be overcome using as many trajectories as possible to statistically calculate B_1^{tx} and B_1^{ty} first, and then the corrector settings.
- Still work to do for lattices with high beta* (e.g. injection lattice).

Acknowledgments

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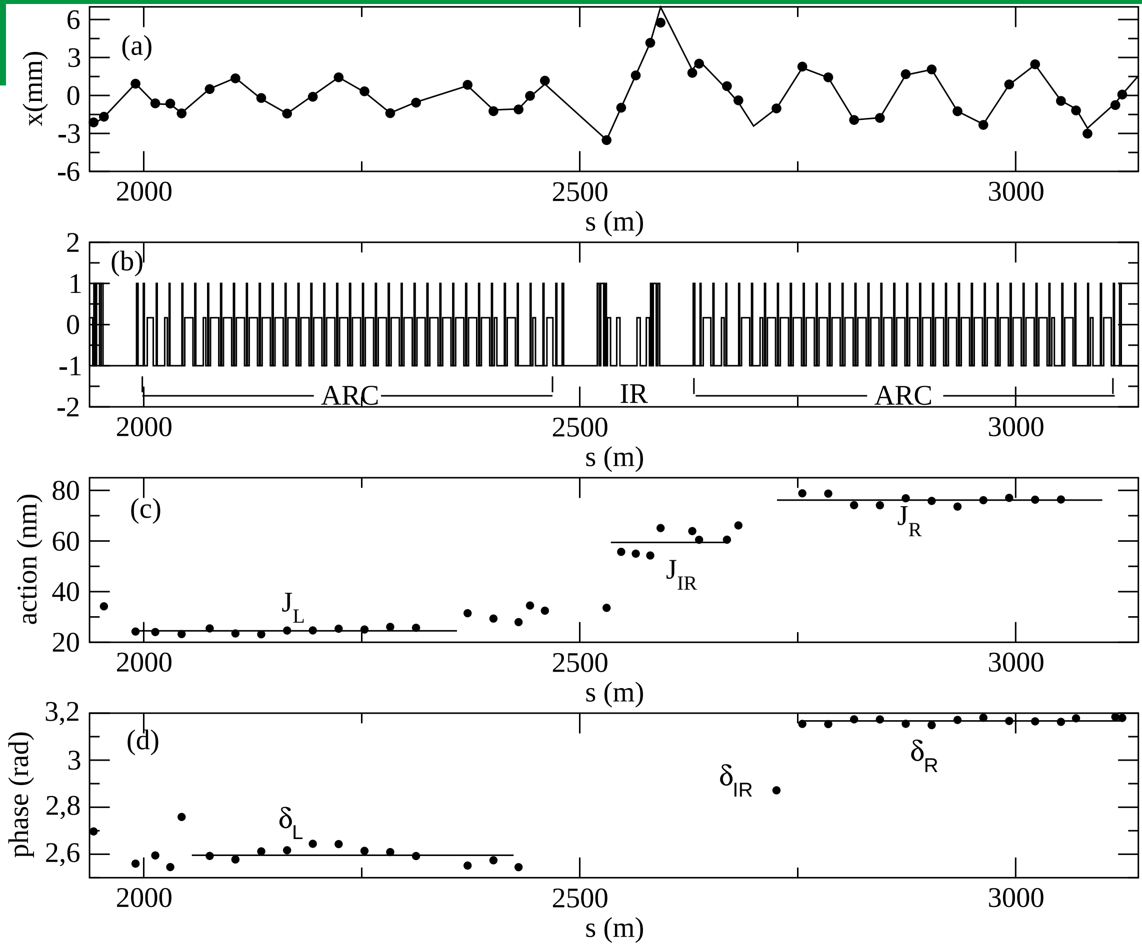
Action and Phase Analysis on a RHIC Trajectory



$$x_i = \sqrt{2J_{i+1}\beta_{xi}}\sin(\psi_{xi} - \delta_{i+1}),$$

$$x_{i+1} = \sqrt{2J_{i+1}\beta_{xi+1}}\sin(\psi_{xi+1} - \delta_{i+1})$$

Action and Phase Jump Analysis in LHC