Summary of 2011 experiments

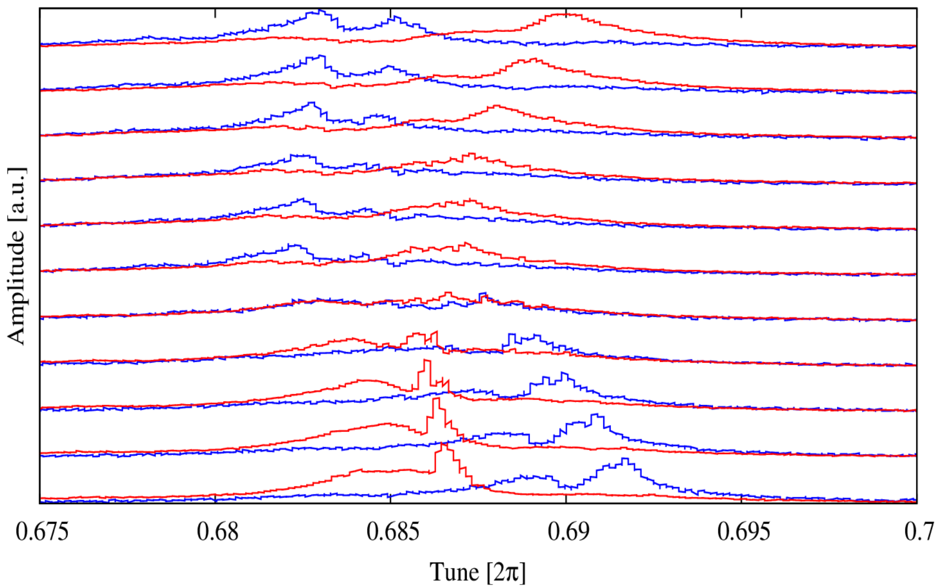
- **Coherent modes suppression:**
  - A tune split was applied to suppress coherent beam-beam modes. Full suppression was observed but resulted in strong emittance blow-up and bad polarization for the beam above 0.7 → not suited for operation
  - The effect of coupling as a possible explanation for the absence of π-mode in horizontal plane was probed by swapping Qx and Qy leading to encouraging results but not fully satisfying due to poor data quality (see following slides)

- **Coherent modes excitation:**
  - Various external excitations (white noise,single frequency,orbit modulation) were applied without detrimental effects on beam stability although lifetime degradation and emittance blow-up were observed in some case

- **Effect of betatron resonances:**
  - The π-mode was put on the 3^{rd} order resonance leading to losses in the beam for which zero amplitude particles approached the resonance, no effect was observed on the other beam → it appears that the 3^{rd} order resonance does not affect coherent stability

- **Results were summarized in two IPAC papers:**
  - S. White et al. “Coherent Beam-Beam Effects Observation and Mitigation at the RHIC Collider”
  - S. White et al. “Simulations of Coherent Beam-Beam Effects with Head-on Compensation”

Coupling and beam-beam



→ Results from last year: BTF data during tune scan

→ As the horizontal (red) and vertical (blue) tunes are exchanged coherent modes appear to be damped

→ Could be explained by an exchange of Landau damping through coupling

→ The beam conditions for this measurement were not optimal

→ Coherent modes not clearly observed even for nominal tunes to start with

→ These preliminary results would require confirmation during a dedicated beam experiment with optimal beam conditions

→ Store energy, few bunches, small beam-beam parameter in order to be able to fully cross the tunes: ~1h at store - could be combined with another experiment

Coherent modes excitation

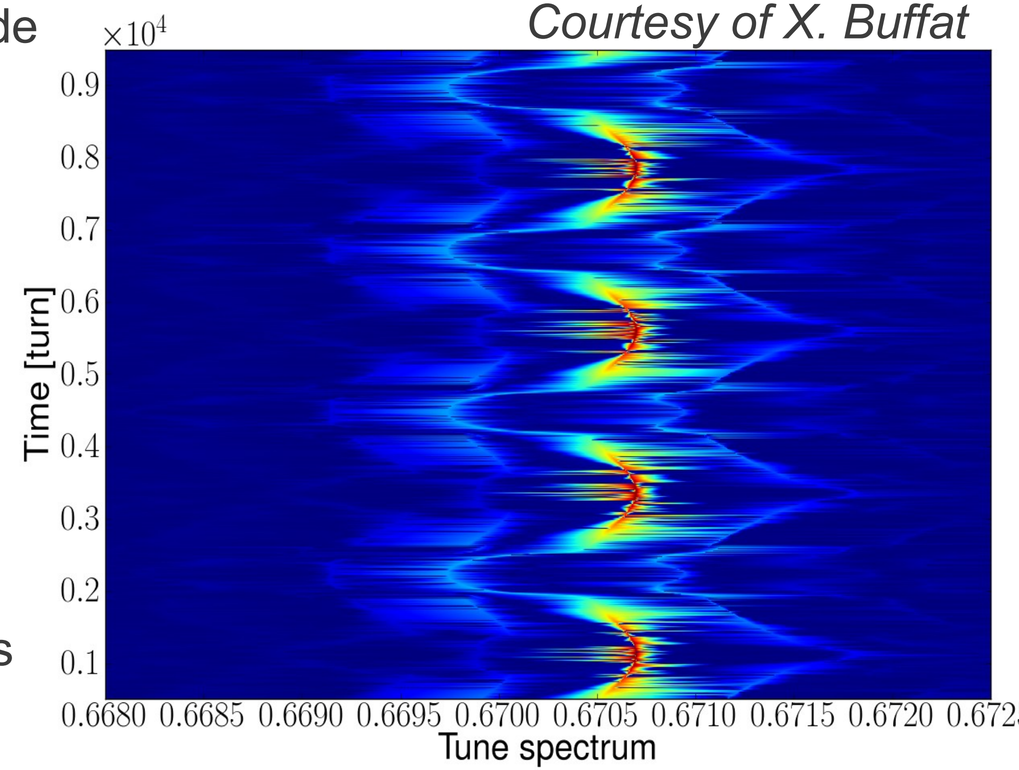
→ Shown here:Excitation close to the π-mode frequency (~0.67)

→ As the π-mode is excited, the amplitude of oscillations is growing, and it goes out of resonance with the excitation frequency

→ No instability can be observed when π-mode is excited with single frequency

→ On the contrary the σ-mode frequency does not depend on amplitude: exciting at its frequency should drive the beam unstable

Courtesy of X. Buffat



→ This was briefly tested last year during the same store as coupling experiment. No instability observed during this test, only losses at large excitation amplitudes

→ Again, the coherent modes were not clearly observed even without excitation making a detailed analysis and conclusions difficult. There was also not enough time to scan frequency and try σ-mode excitation

→ It would be good to confirm these results in a dedicated experiment with more systematic parameter scans. This could be combined with the coupling study for a total of ~3h at store.

AC dipole in collision

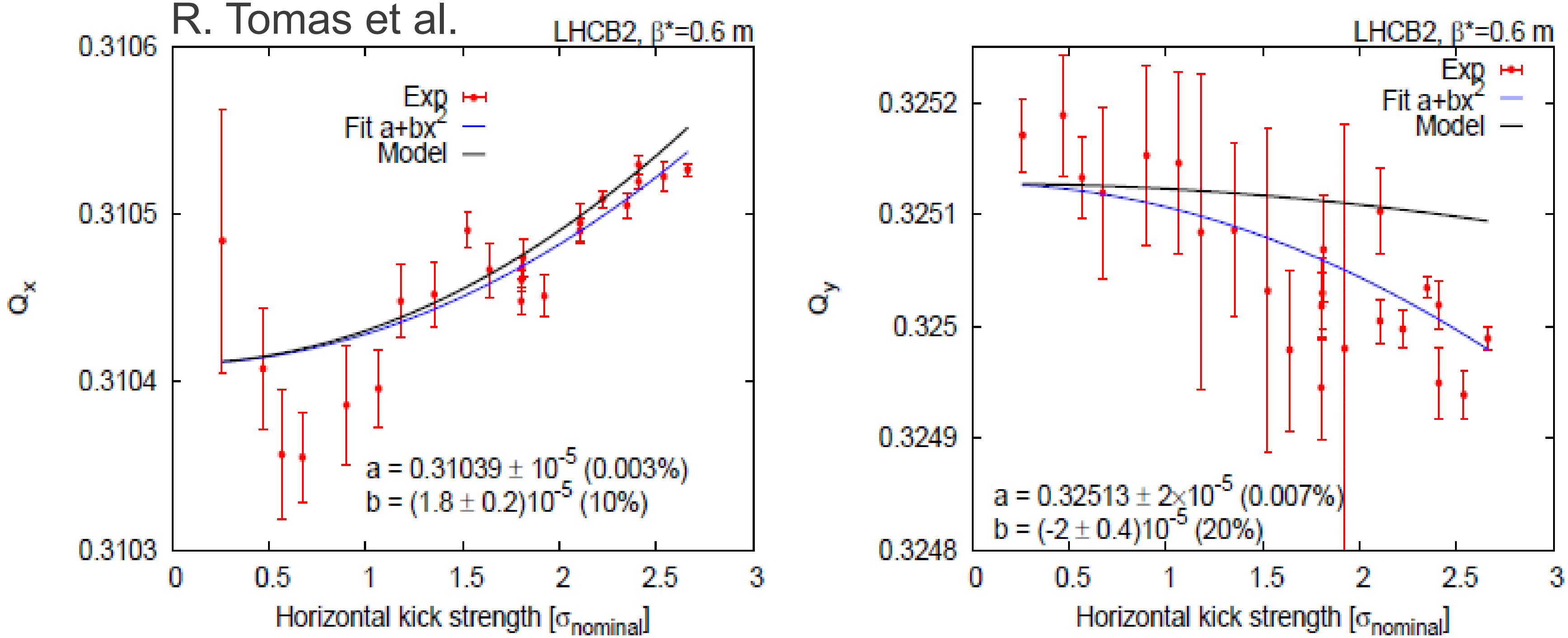
- Feasibility of using AC dipole in collision without emittance blow-up of beam instability was demonstrated during Tevatron end of beam experiments: *A. Valishev et al. "Tevatron End-of-Run Beam Experiments", IPAC 12*.

- In principle this technique would allow to measure:
  - → Coherent and incoherent tune shifts vs. amplitude
  - → Non-linear resonances driven by the beam-beam force
  - → Dynamic beta-beating

- If successful this technique could provide an excellent diagnostic to study the beam-beam dynamics with electron lens compensation

First direct amplitude detuning measurement at the LHC

R. Tomas et al.

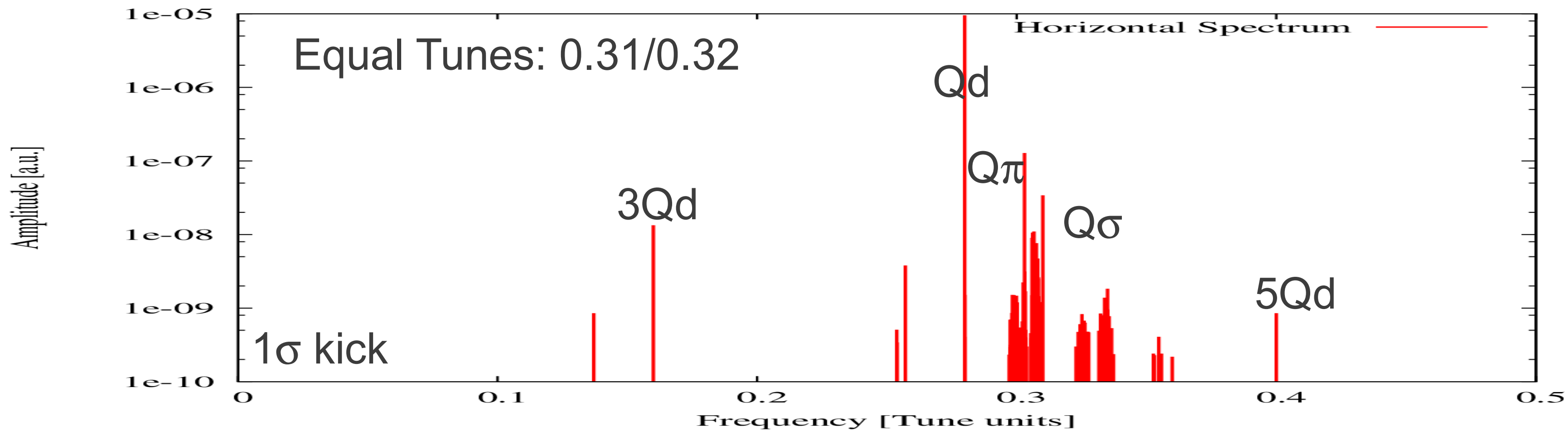


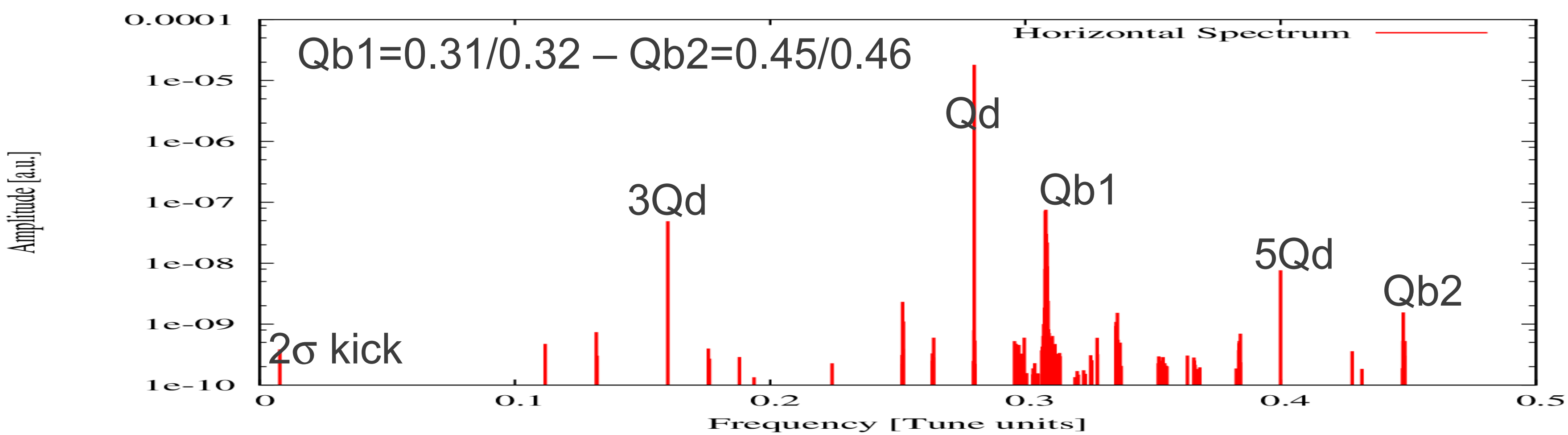
→ Using aggressive cleaning of the noise from the BPM turn-by-turn data and profiting from the imperfections of the AC dipole it was possible to directly measure the natural tune of the machine performing FFT analysis on AC dipole flat top data (in theory only the drive frequency should be observed)

→ Using the same technique at RHIC should be possible (even better BPM resolution) and would allow to extract coherent modes and non-linear resonances frequencies

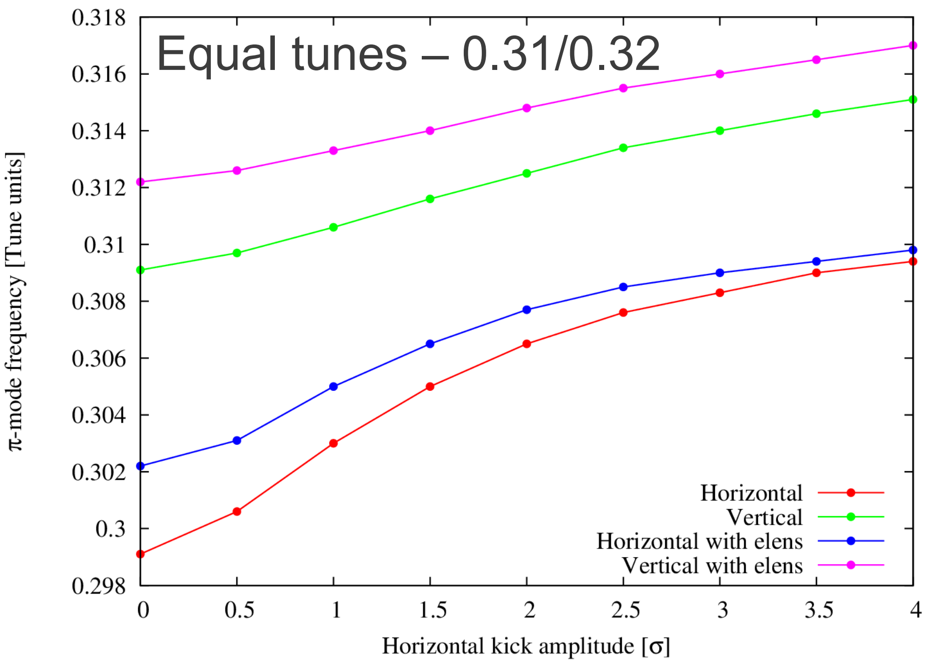
Simulations

→ In order to disentangle coherent and incoherent effects one can look at two configurations:
 → **Equal tunes:** coupled oscillators - coherent effects
 → **Unequal tunes:** one beam oscillating through a fixed lens – incoherent effects – will probably be very difficult to analyze due to the wide tune distribution (see following slide)





Amplitude detuning



→ Excitation close to the π-mode, electron lens at half compensation: $\xi_{el}=\xi/2\sim5.0e\text{-}3$

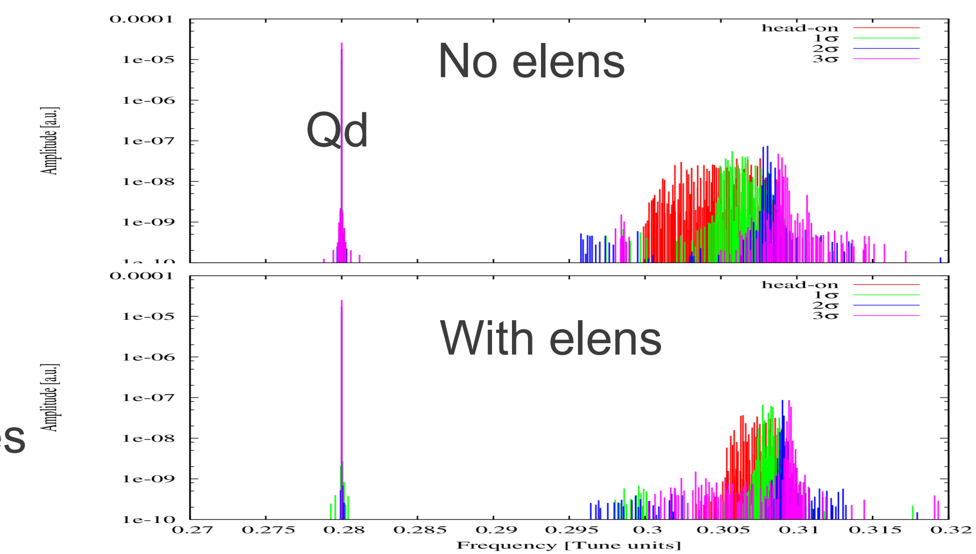
→ At low amplitude the beam samples mostly the linear part of the electron field introducing a tune shift of $\xi_{el}/2\sim2.5e\text{-}3$. This explains the difference in the π-modes frequencies

→ For large amplitudes this is not the case anymore. The electron field decays as 1/r and the π-mode frequencies converge

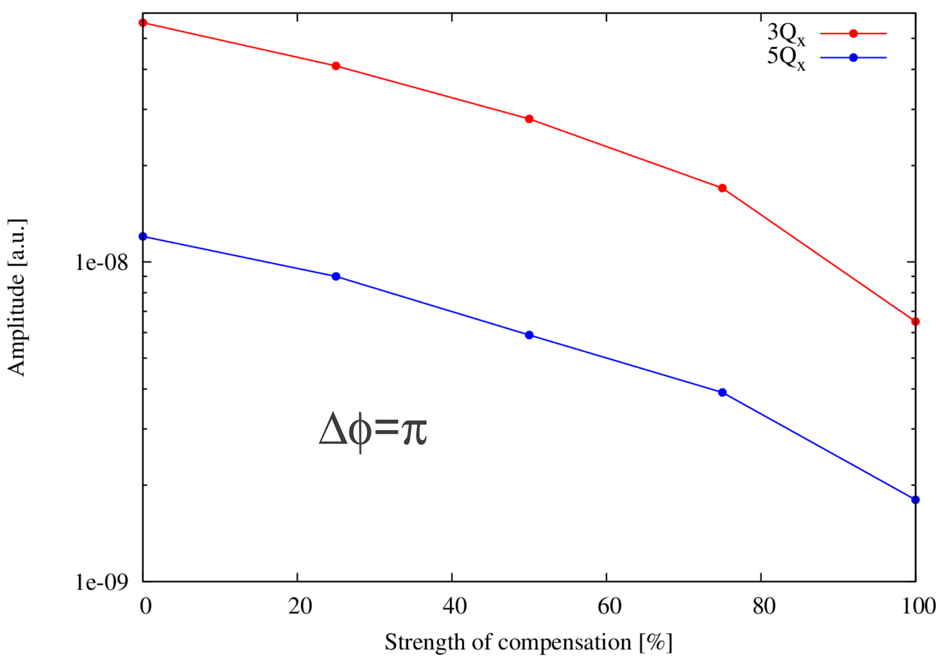
→ Un-equal tunes: coherent modes are removed

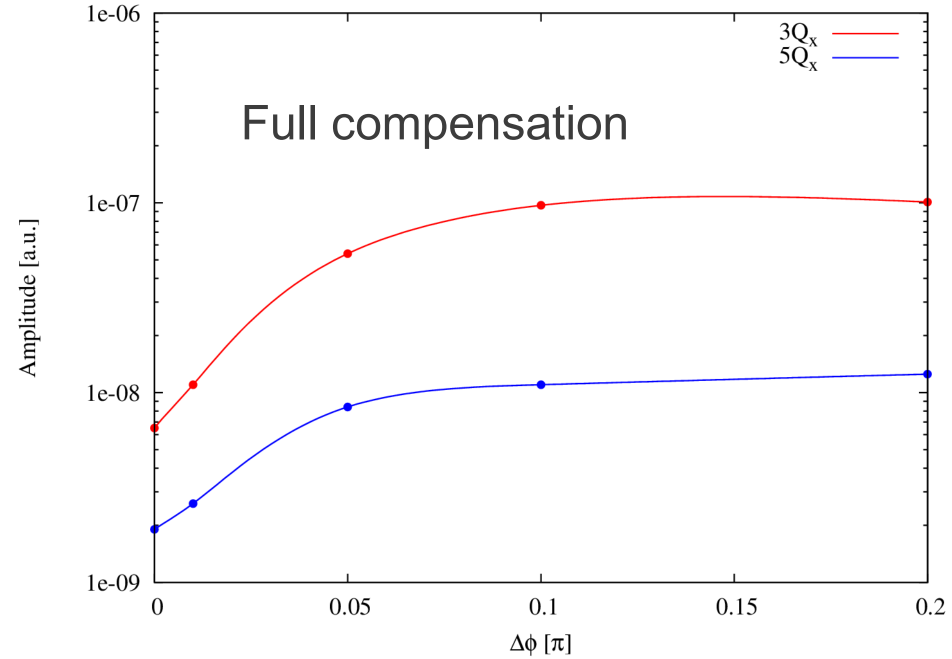
→ Tune distribution starts peaking above 2σ kick but still wide

→ It will be very difficult (impossible?) to see something. Maybe detuning at large amplitudes can be estimated but BTF seems more appropriated to measure tune distribution



Non-linear resonances





→ The electron lens will provide partial compensation of the resonance lines – about an order of magnitude for full compensation

→ Phase errors between the electron lens and the p-p collision can excite the resonance lines to levels higher than the case without electron lenses (worst case $\pi/2$)

→ This cancellation/excitation of the resonances is also true for two p-p collisions, the Cancellation being maximum at $\pi/2$ (equal charges)

Experimental proposal

- Using the AC dipole in collision has a lot of potential but is a very difficult experiment and great care should be taken while setting up the experiment. At RHIC the AC dipole will excite both beams which is not an issue but the frequency of the coherent modes will depend on the phase advance between the IP and the AC dipole

- Reasonable goals for this year:
  - → Show that the AC dipole can be safely operated in the strong-strong regime
  - → Observe coherent modes as a function of amplitude
  - → Try to observe non-linear resonances

- Incoherent effects will be very difficult if not impossible to measure

- This experiment is better done at injection with single bunch/interaction point – this would allow to quickly get fresh beams in case of significant degradation of the beam conditions. 3h hours at injection would be good for a first try

- If time permits one could try to see incoherent effects and measure the effects of phase advance between two consecutive IPs (using the elens phase shifter)