Observation of coherent instability in the CERN PS Booster

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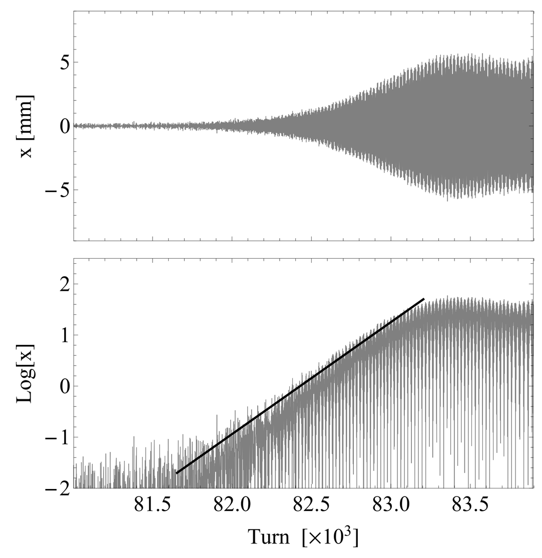
1. Introduction

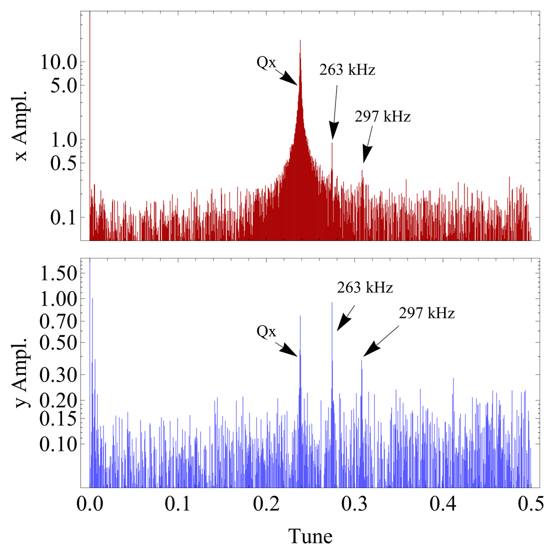
At high intensities and at certain working points, an instability develops in the CERN PS Booster and large coherent transverse oscillations and beam loss occur [1]. The coherent oscillations and beam loss can be effectively controlled with the transverse damper system, but the origin of the instability is not well understood. First tests with the PSB's new trajectory measurement system give some new insight into the nature of this transverse instability.

2. Trajectory measurements with transverse instability

- With high beam intensity and no transverse feedback, instability occurs near 120 ms into the acceleration cycle ($c \sim 395$ms); $\sim 2/3$ of beam is lost
- At certain working points, instability occurs even with transverse feedback
- Trajectory spectra show unexpected lines at 263.5 and 296 kHz

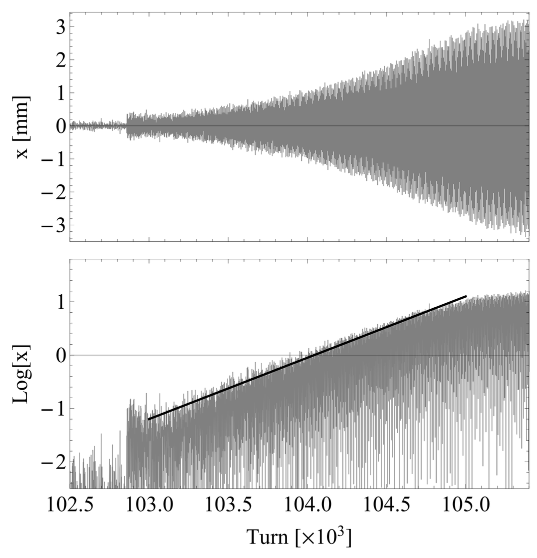
Horizontal trajectory at $c = 390$ ms, with no transverse feedback. Growth time $\tau \approx 0.45$ ms.

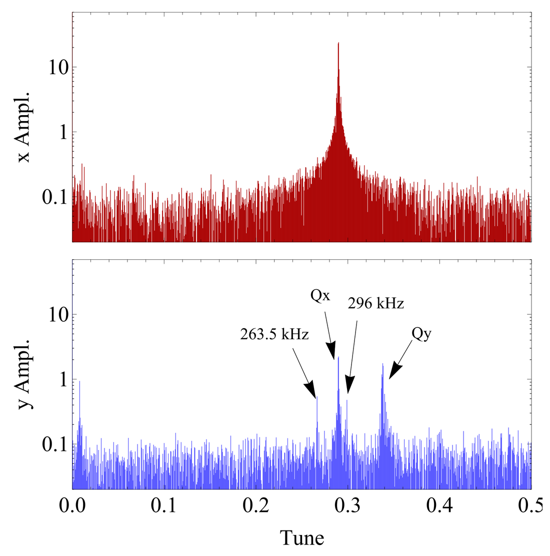




Fourier spectra of x and y trajectories during instability at $c = 390$ ms. Peaks at 263.5 kHz at 296 kHz are visible throughout acceleration cycle.

Horizontal trajectory at $c = 415$ ms, with transverse feedback. Growth is slowed but not suppressed; $\tau \approx 0.85$ ms.

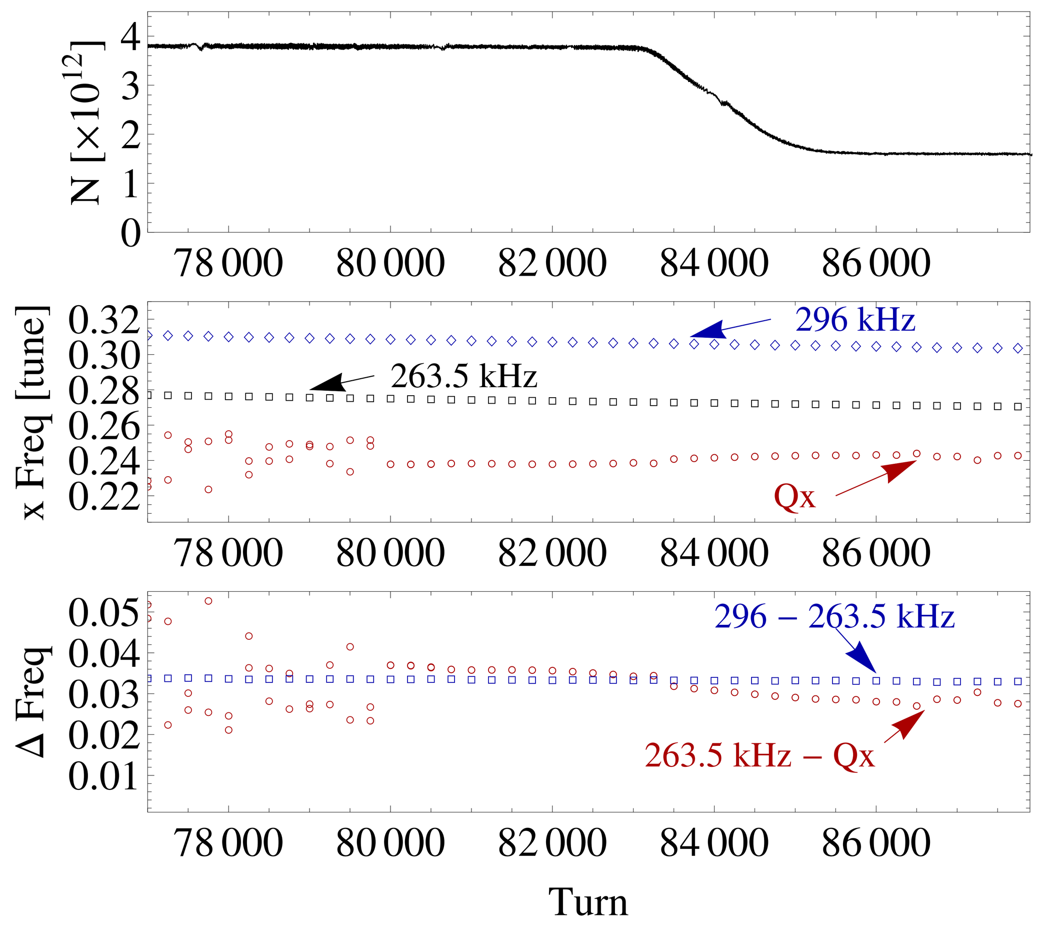




Fourier spectra of x and y trajectories during instability at $c = 415$ ms. Peaks at 263.5 kHz at 296 kHz are still visible.

3. 263.5 and 296 kHz spectral lines

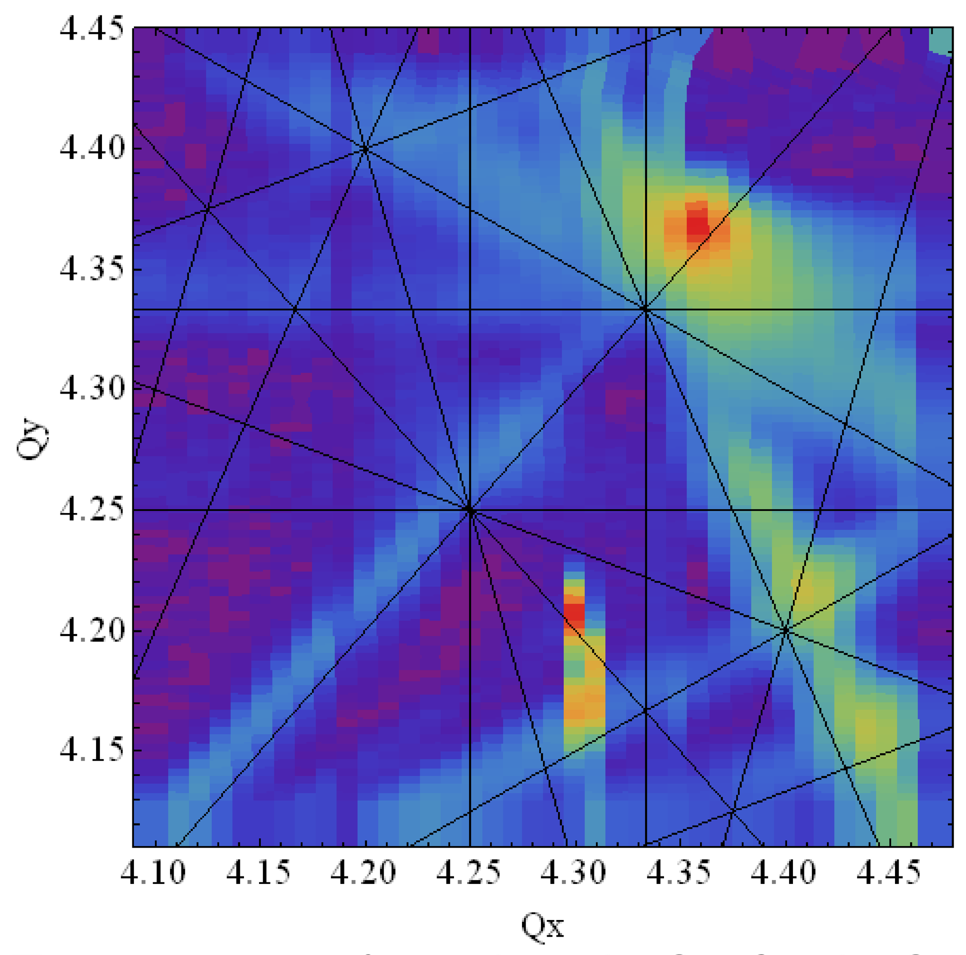
- Lines are always visible at 263.5 and 296 kHz, regardless of beam revolution frequency
- Instability occurs precisely when Q_x and 263.5 and 296 kHz tunes are all equidistant; instability is avoided if damper is left active until just after this point



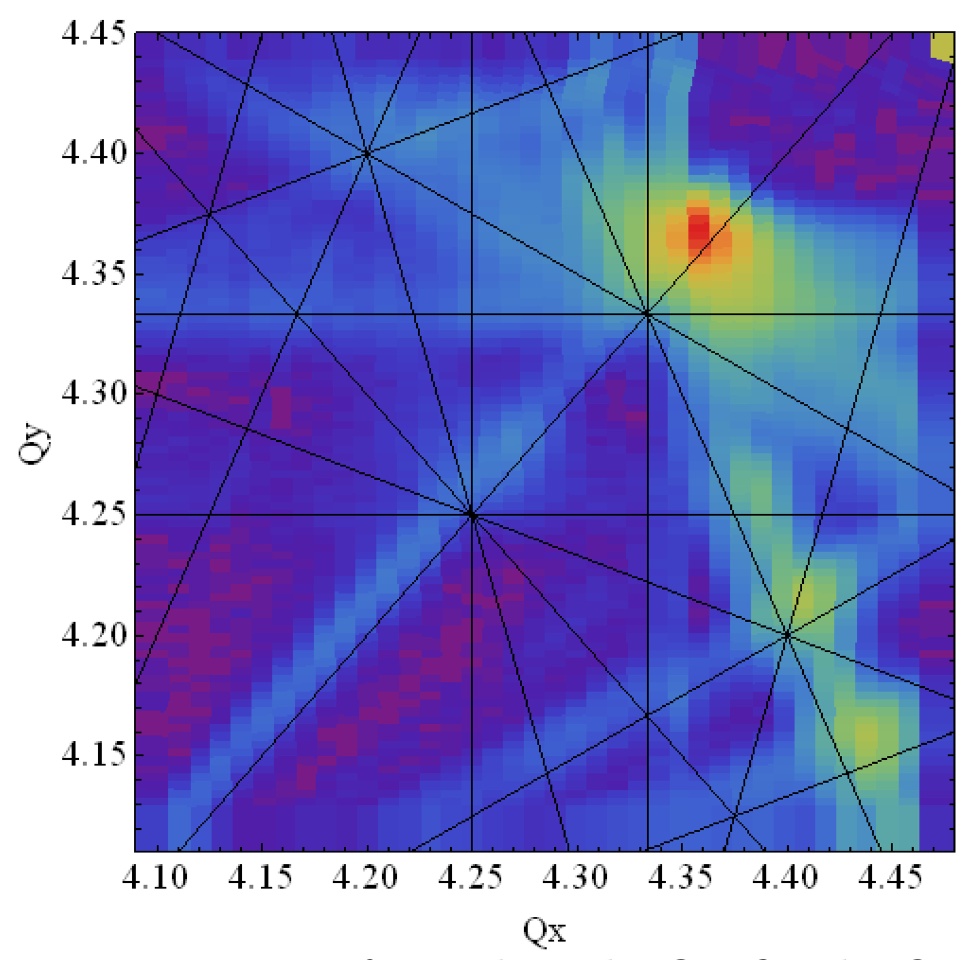
Top: Beam intensity near instability at $c = 390$ ms.
Center: Q_x and tunes of 265.5 and 296 kHz lines. Revolution frequency is increasing, so tunes of fixed-frequency lines are changing.
Bottom: Difference between tune of 263.5 kHz line and Q_x, and between tunes of 296 and 263.5 kHz lines. Beam loss begins precisely when the differences between all three spectral lines are equal.

4. Instability seen in tune scans

- Tune scans [2] show loss pattern not expected from lower-order resonances
- Losses occur along $Q_x \approx 4.30$ line when closed orbit is uncorrected, but disappear when closed orbit distortion is corrected (suggesting quadrupolar nature)



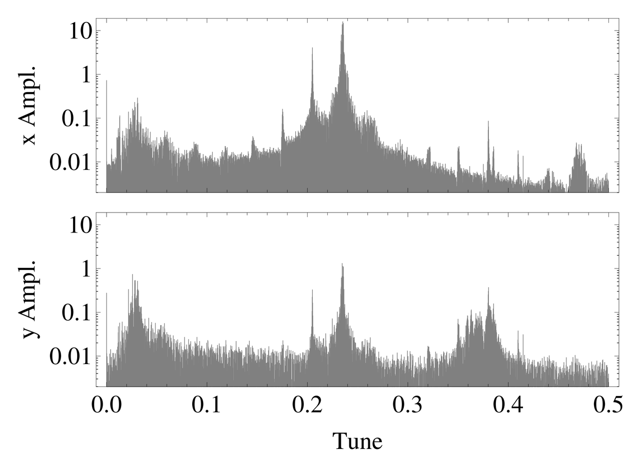
Tune scans performed with Q_x fixed, Q_y varied from 4.45 to 4.10. Closed orbit distortion is not corrected. Losses occur along $Q_x \approx 4.30$ line.



Tune scans performed with Q_x fixed, Q_y varied from 4.45 to 4.10. Unexpected loss pattern disappears when closed orbit distortion is corrected.

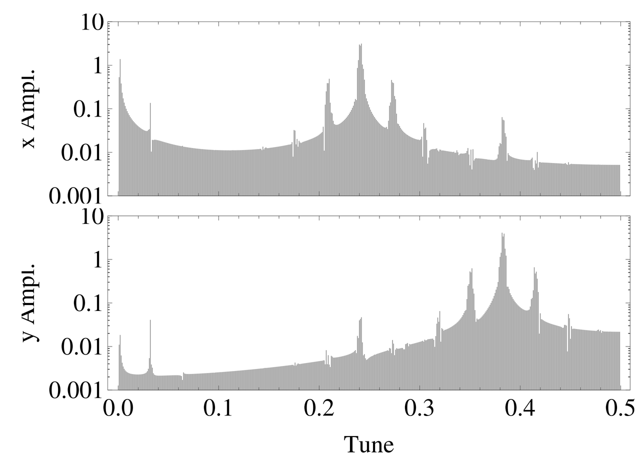
5. Simulations with quad noise

- Quadrupole noise at 296 kHz and 32.5 kHz produces spectra similar to that observed with tune meter pickup [3]



Spectrum from PSB tune meter pickup, which has greater sensitivity to small oscillations than other BPMs.

Spectra from tracking simulation with quadrupole noise at 296 kHz and 32.5 kHz.



6. Conclusions

Measurements made with a prototype trajectory measurement system have provided some interesting new clues about a transverse instability that has long been observed in the PSB. The behavior of the instability seems consistent with a quadrupolar perturbation, so it may be related to a large ripple in the focusing quadrupole magnets' power supply which was observed before LS1. After LS1, we will attempt to identify the source of the perturbation by measuring the trajectory with many BPMs and locating any unexpected phase jump between adjacent pickups.

Acknowledgments

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References

[1] V. Kornilov et al., "MD on Head-Tail Instability in the PS Booster," CERN-ACC-NOTE-2014-0025, 2013.

[2] V. Forte et al., "Space charge studies in the PSB - MD report," CERN-ACC-NOTE (to be published), 2014.

[3] M. Gasior, "High sensitivity tune measurement using direct diode detection," Proc. of BIWâĂŹ12, Virginia, U.S.A (2012).