Studies for nonlinear optics measurements from turn-by-turn trajectories in the CERN PSB

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Introduction

- Planned Hi-Luminoisty LHC upgrades will require approximately doubling of intensity in the PS Booster with little emittance increase [1].
- At high intensity, measurement and correction of resonance driving terms will be necessary to maintain beam stability [2].
- Beam position monitor (BPM) upgrades are underway during Long Shutdown 1 (LS1) [3], and then full measurements and correction will proceed in 2014.
- Studies in preparation for resonance driving term measurements are presented here:
  - method of generating beam oscillations
  - choice of optimal working point for measurements
  - results of measurements from three beam position monitors

Methods

Production of coherent transverse oscillations

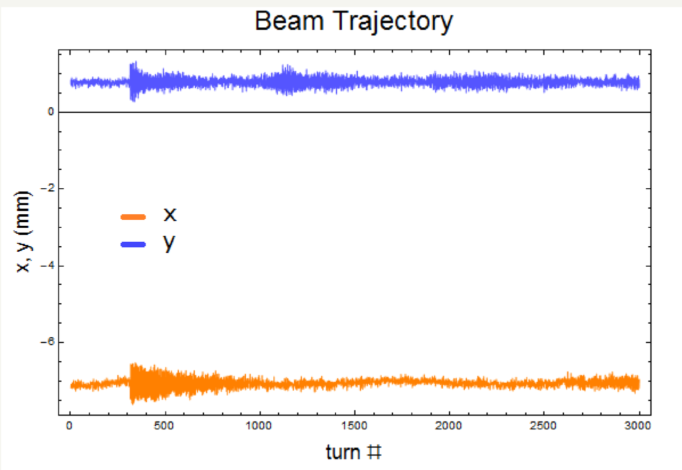

Fig. 1

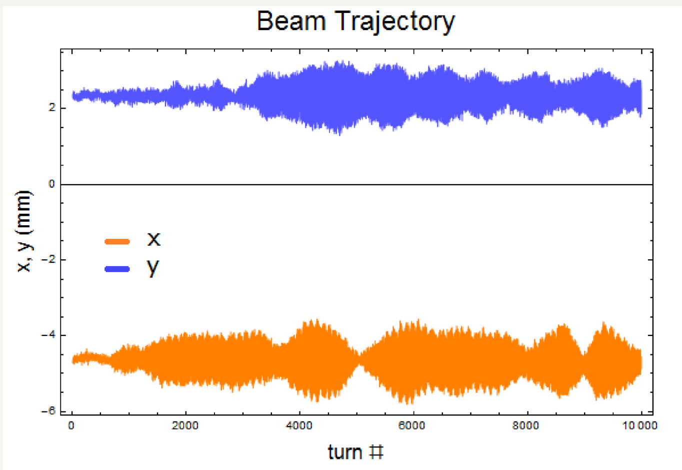

Fig. 2

- Oscillations must be large enough for higher-order spectrum peaks to be visible over BPM noise.
- Figure 1: Free oscillations from fast kicker.
- Figure 2: Driven oscillations with transverse damper.
- Figure 3: Large oscillations due to instabilities with transverse damper deactivated. Source of instability can be localized when turn-by-turn data from all BPMs is available.

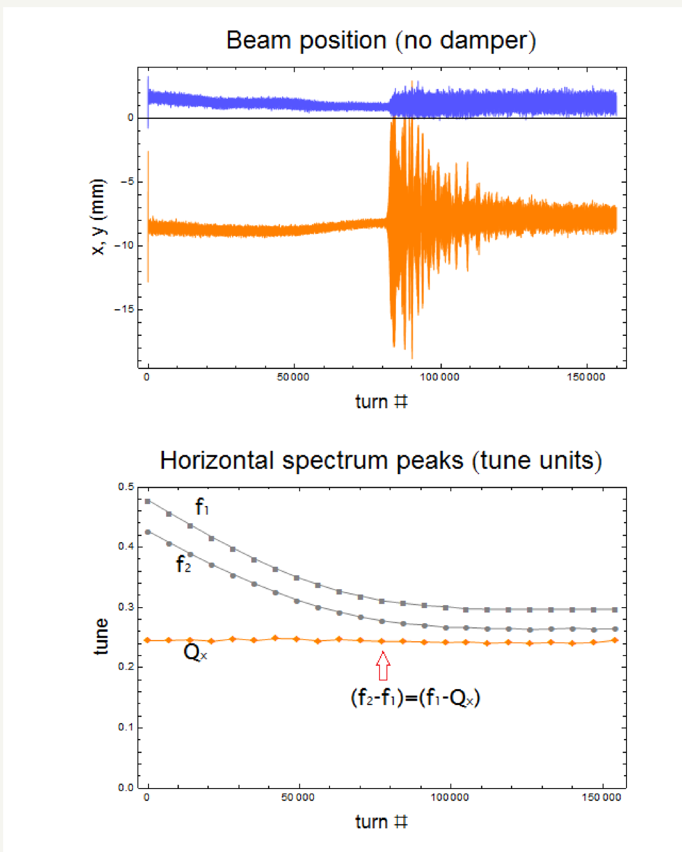

Fig. 3

Effect of working point on measurement precision

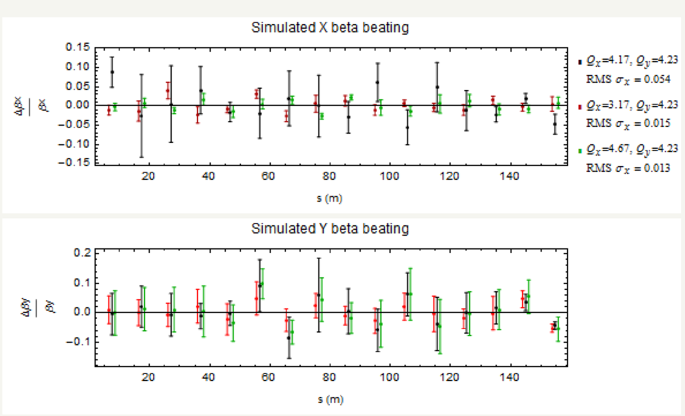

Fig. 4

- $\Delta\psi \approx 90°$ between BPMs at typical working point.
- $\Delta\beta/\beta$ calculated from tracking simulations at three working points shows that the uncertainty in the calculation can be reduced significantly if tune is reduced by 1.0 or increased by 0.5.

First Results

Spectra from measured and simulated trajectories

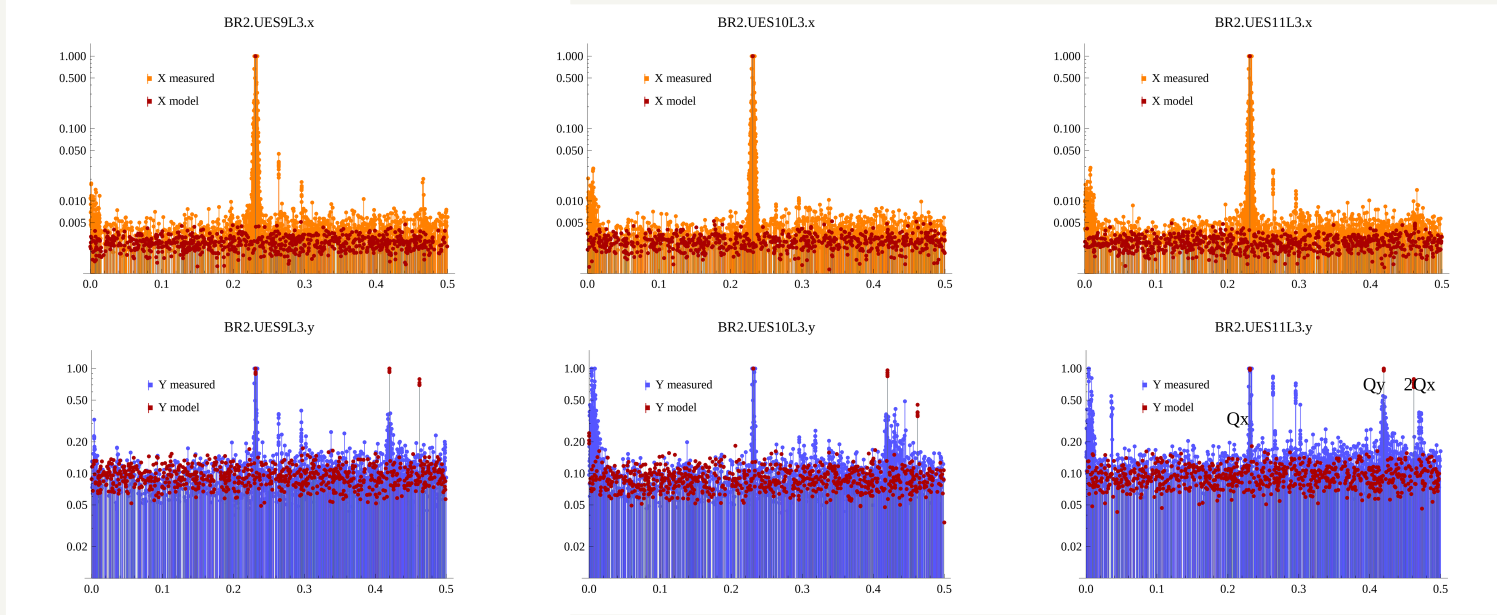

Fig. 5

- Measurements: beam energy 160 MeV, $\xi_x \approx 0$, $\xi_y \approx -14$, oscillations from tune kicker.
- Simulations: normal and skew K2 errors (1‰ at 10 cm) added to bending magnets and 100 μm noise added to the BPMs.

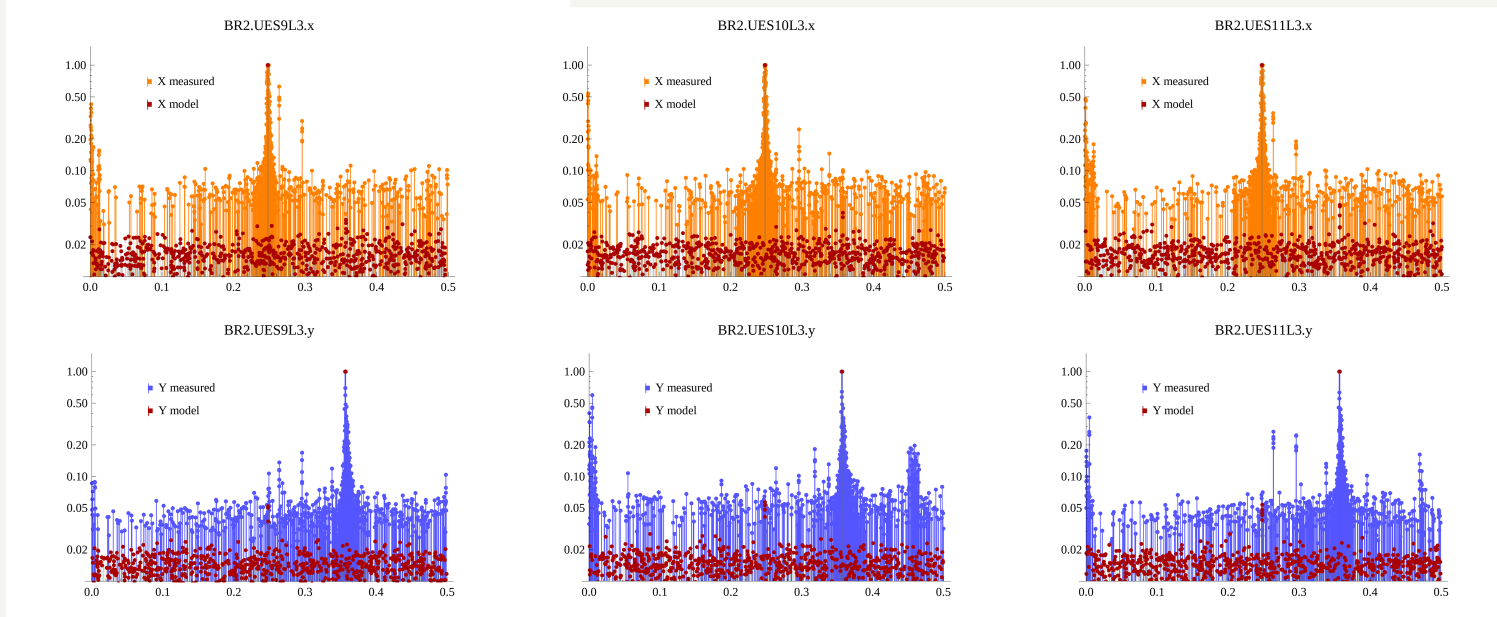

Fig. 6

- Measurements: beam energy 160 MeV, $\xi_x \approx -7$, $\xi_y \approx 0$, oscillations from tune kicker.
- Simulations: normal and skew K2 errors (1‰ at 10 cm) added to bending magnets and 100 μm noise added to the BPMs.

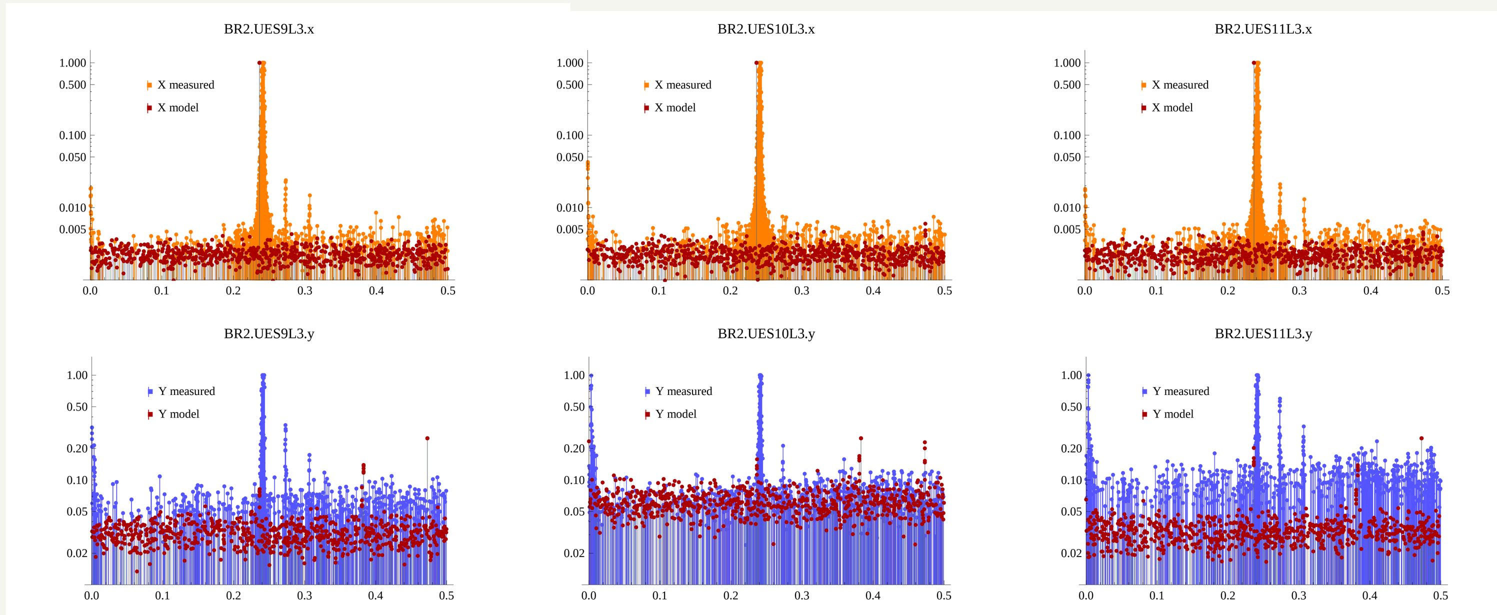

Fig. 7

- Measurements: beam energy 160 MeV, $\xi_x \approx -3.5$, $\xi_y \approx -7$, oscillations from beam instability.
- Simulations: normal and skew K2 errors (1‰ at 10 cm) added to bending magnets and 100 μm noise added to the BPMs.

Conclusions

- Trial trajectory measurements with three BPMs successful, with beam position resolution meeting 100 μm goal.
- Precision of linear optics calculations can be improved by altering tune by 0.5 or 1.0 integer, which is achievable with present magnet power supplies on lower-energy study cycles.
- Analysis of measured data and simulations will allow for specification of beam excitation requirements.
- Preliminary data from three BPMs gives some insight into nonlinear optical properties of the PSB, and these studies will allow for full measurements of resonance driving terms to be completed efficiently as soon as LS1 is over.

Acknowledgments

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References

[1] G. Rumolo et al., "Summary of the LIU Beam Studies Review," CERN-ATS-Note-2012-083 (2012).
[2] R. Tomás, "Direct Measurement of Resonance Driving Terms in the Super proton Synchrotron (SPS) of CERN using Beam Position Monitors," Phd thesis (2003).
[3] J. Belleman, "A proposal for a trajectory measurement system for the PS Booster," CERN-BE-2010-030 (2010).