Synchrotron motion in TBT data

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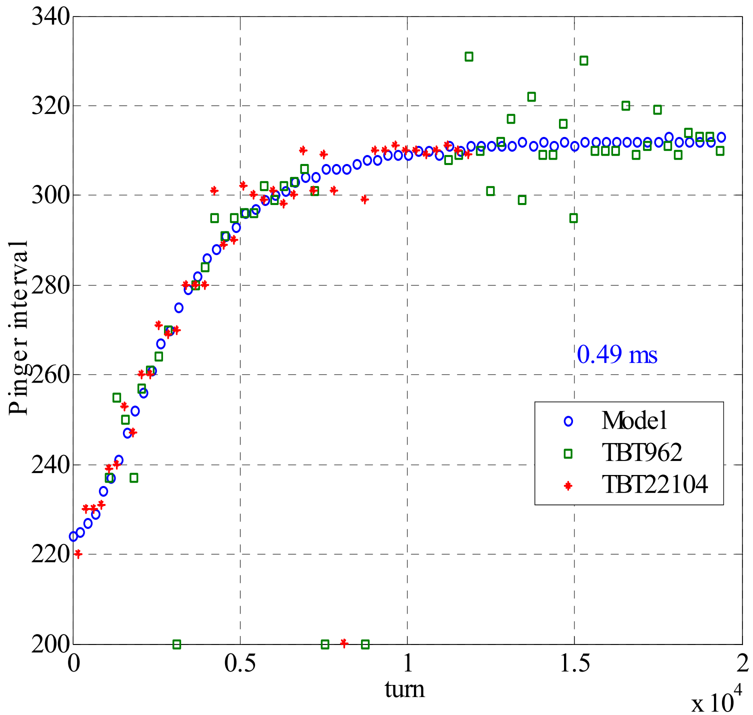
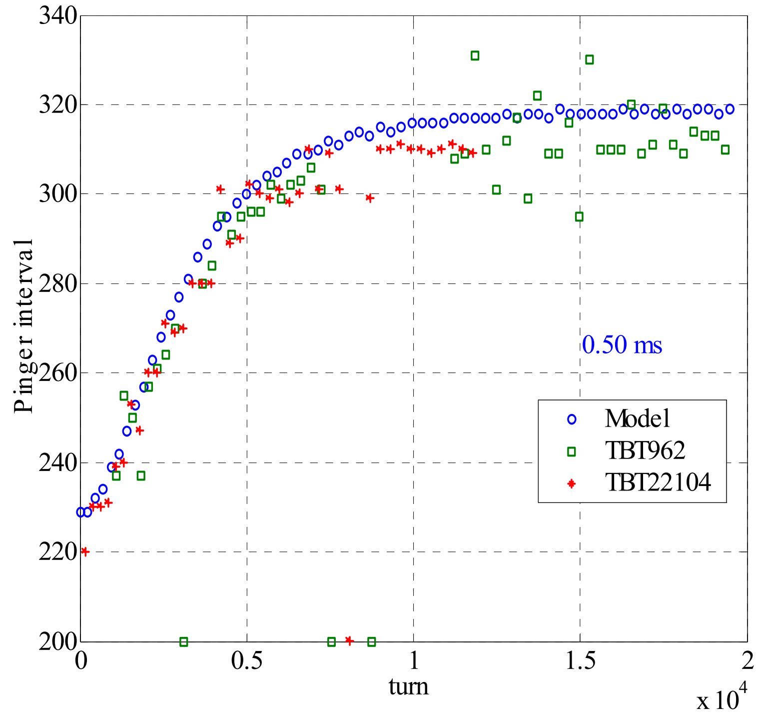
4/29/2004

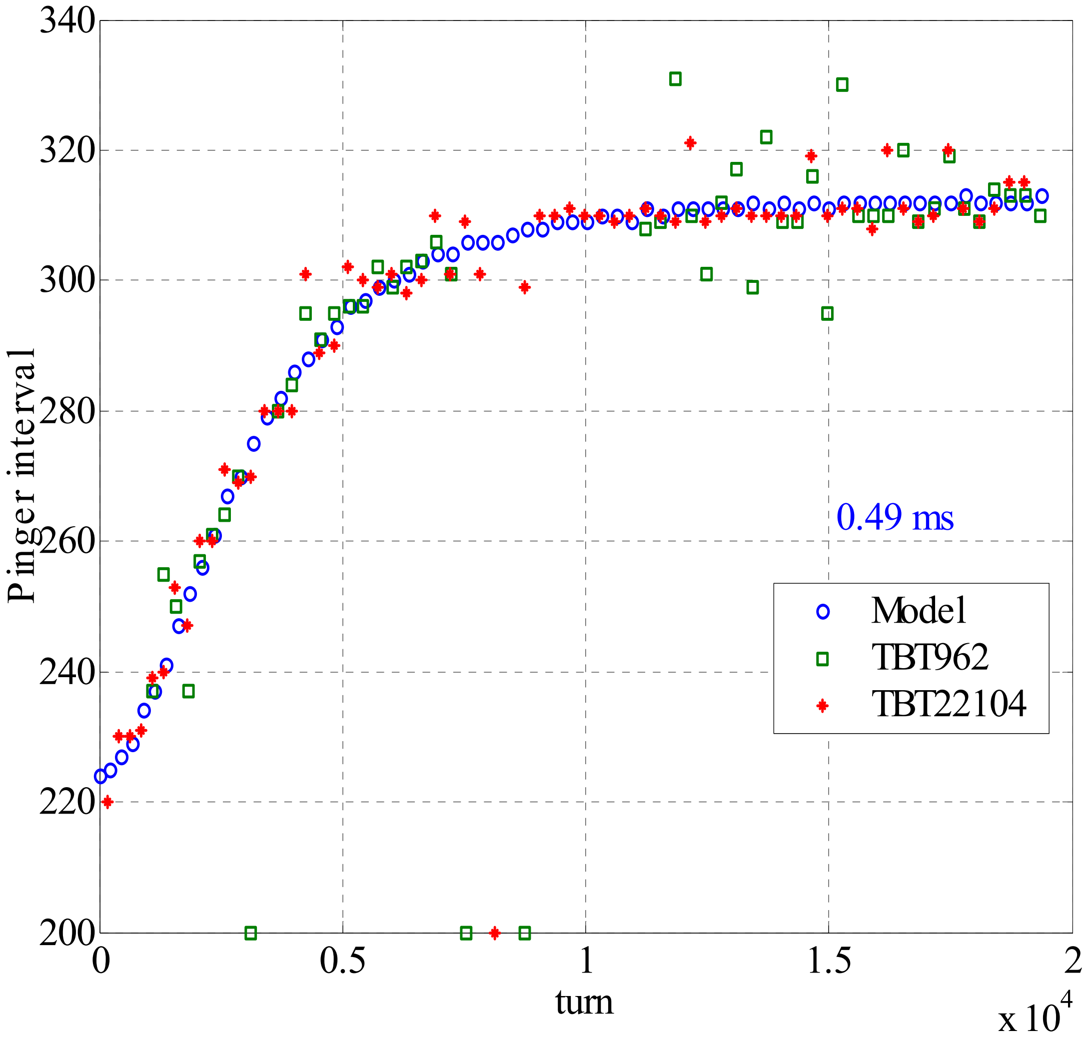
Pinger vs. turns





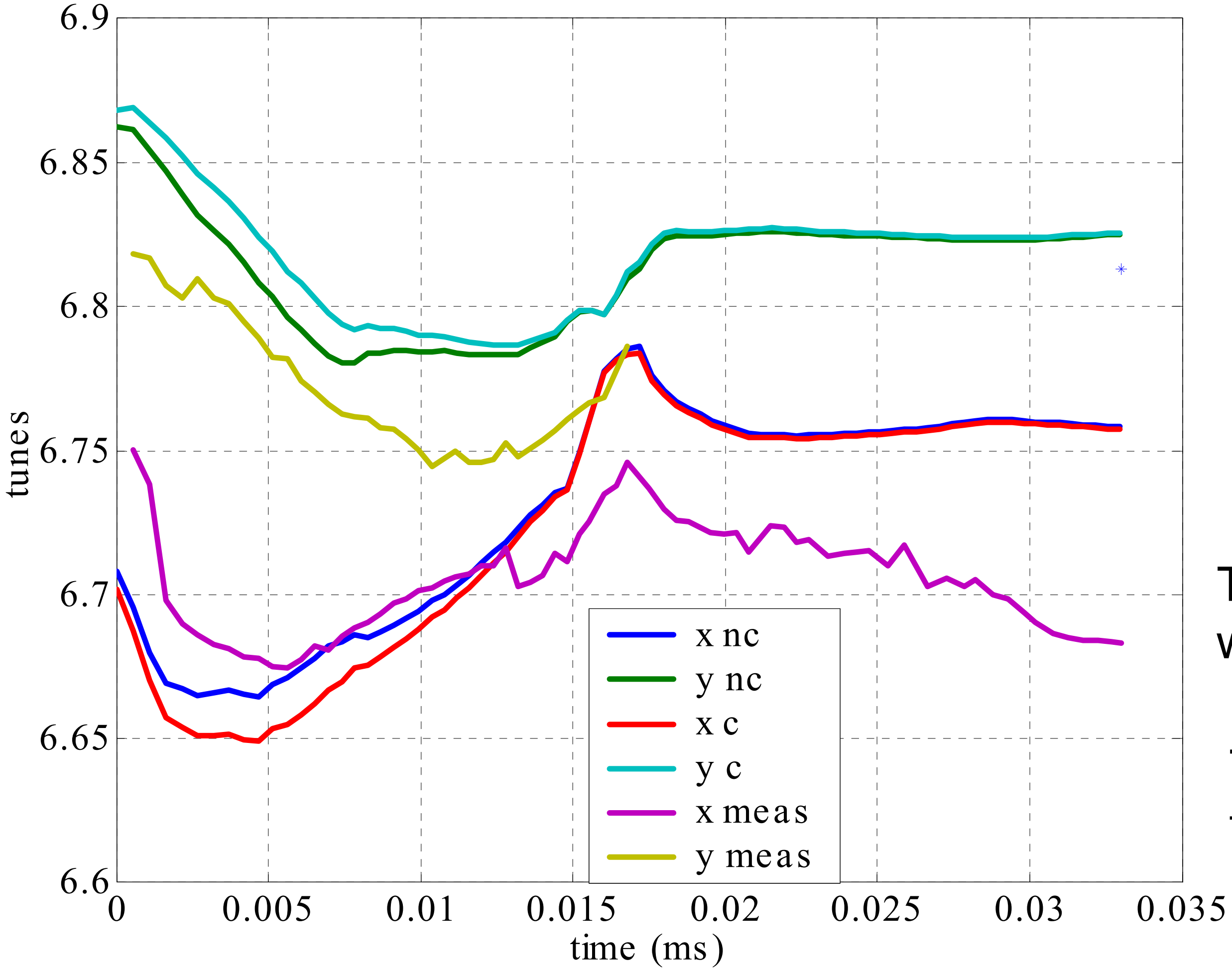
The number of turns between two consecutive pinger shots depends on the revolution period of the beam. It can be predicted with the energy ramp. It can also be seen in the TBT data. Comparison of the model and data indicates that the two agree better if the pinger period is 0.49 ms (instead of 0.50 ms).

Pinger vs. turns



With more data points

Betatron Tunes



Betatron tune vs. time in the cycle.
Model tunes with | without COUPLE option are compared to measurements with turn by turn data.

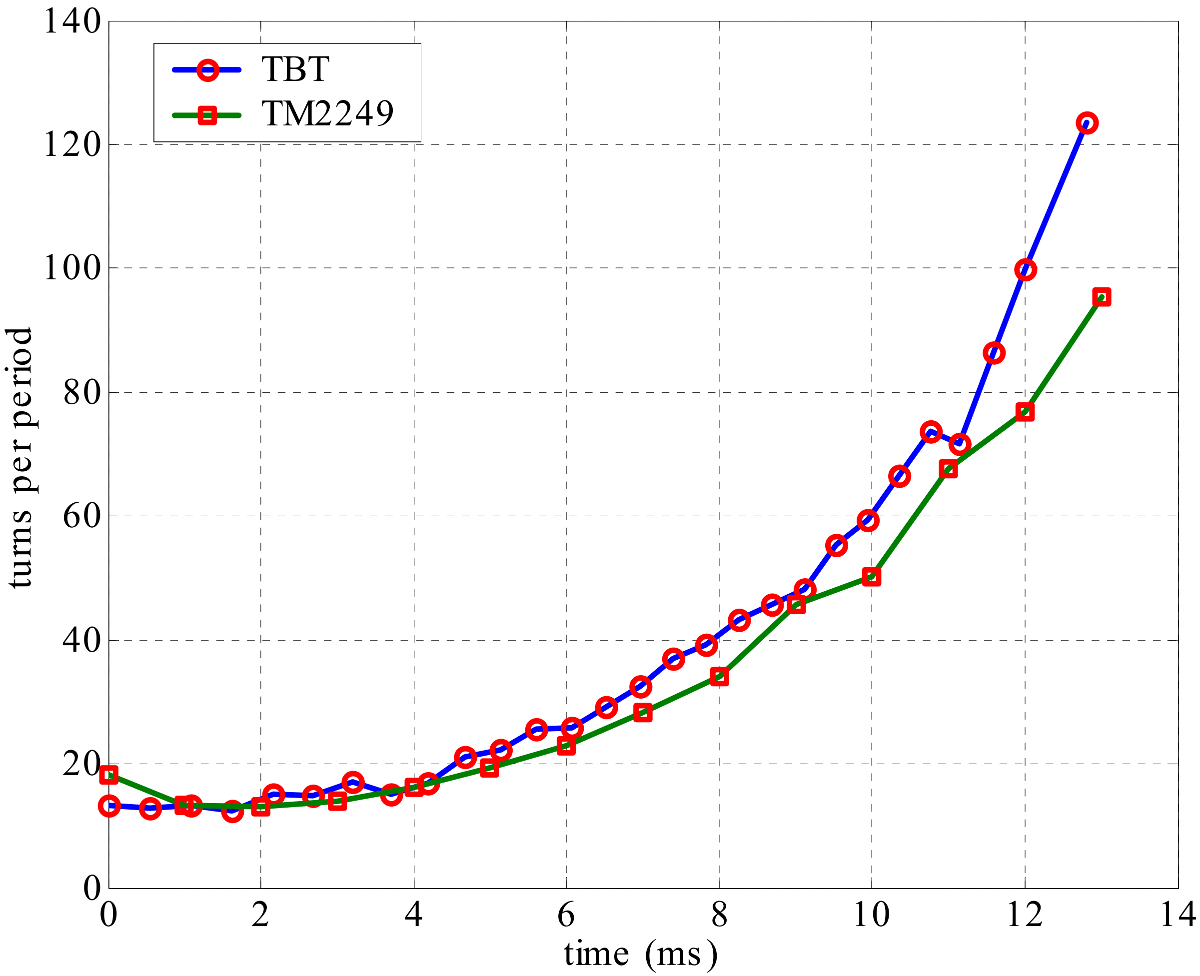
Tunes were measured with every 250 turns

The * is vertical betatron tune at extraction.

Synchrotron Motion

- Synchrotron tunes can be obtained throughout the cycle.
- TM-2239 (X. Yang and J. Maclachlan) helped identify the synchrotron modes
- 2 synchrotron modes are found in most cases, due to unknown reasons. One of them has a spatial pattern that resembles dispersion. The other has opposite signs in locations with RF cavities and elsewhere.

Synchrotron Tune



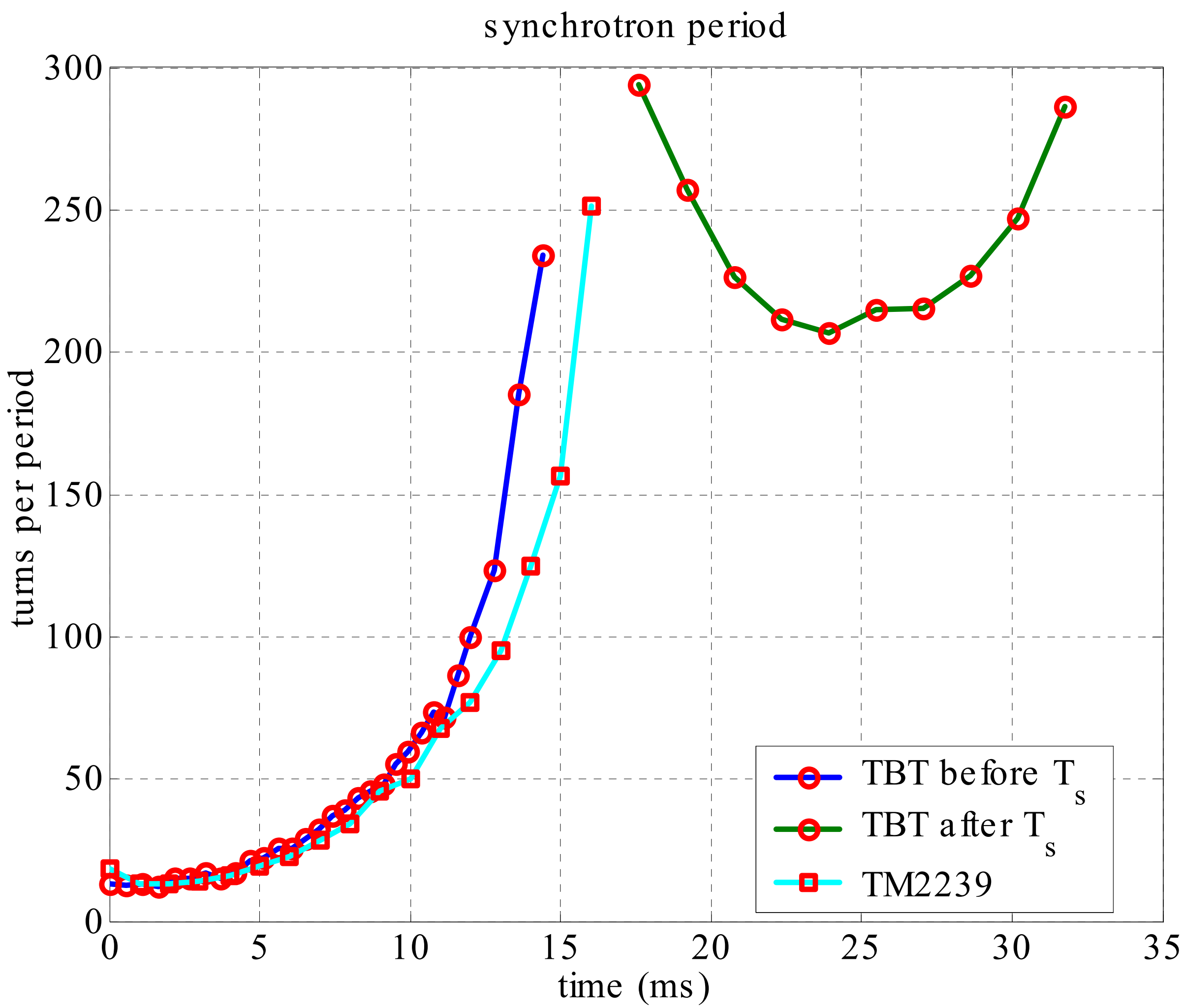
The blue circles are synchrotron period measured from TBT data. The green squares are calculated with synchrotron freq* taken from TM2239 (X. Yang, J. MacLachlan).

Measurements were carried out with every 250 turns.

* Digitized from the Fig. 2 of it

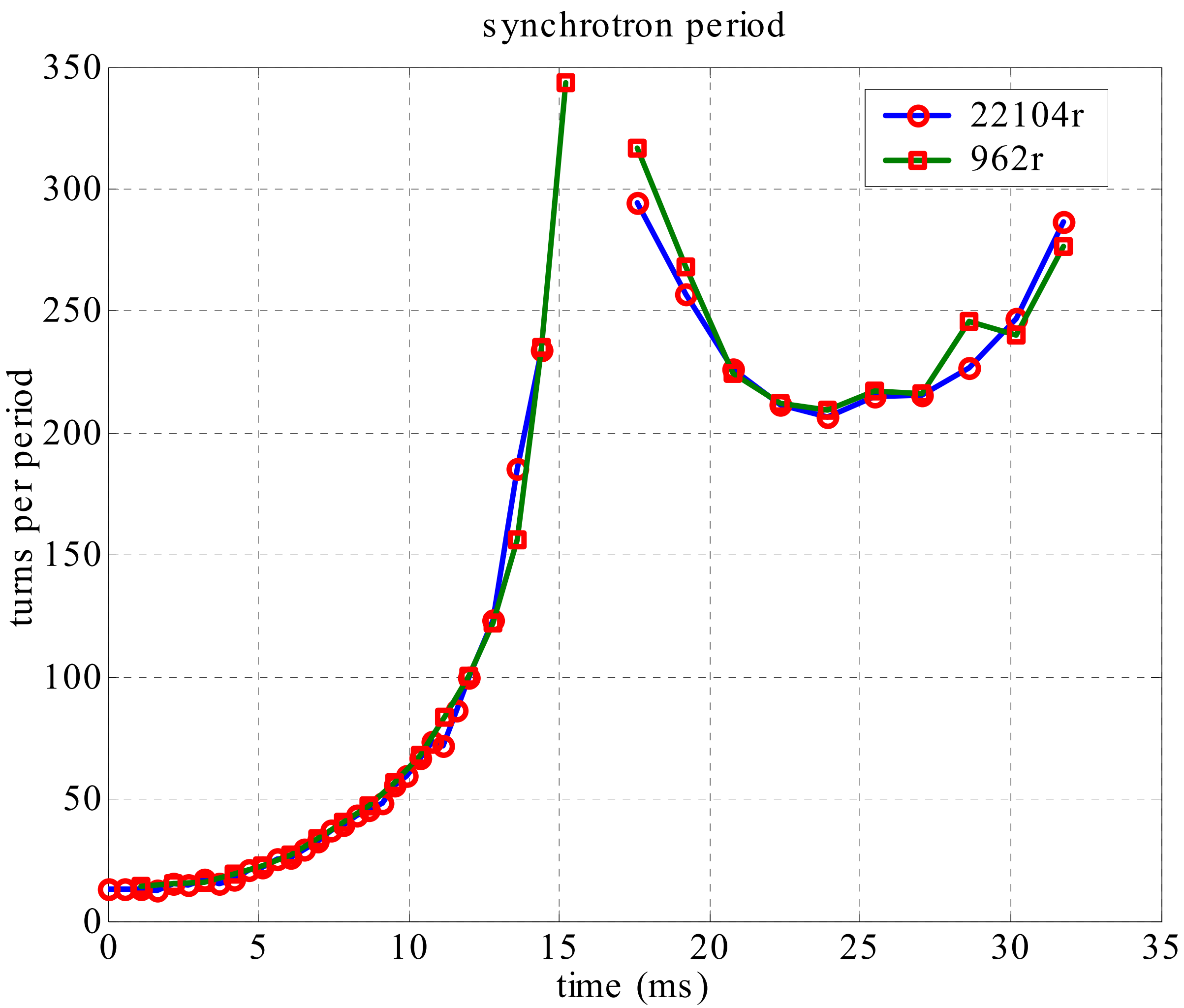
 See synch_tune.xls for data

Synchrotron period



Measurements were carried out with every 1000 turns after transition, every 250 turn before transition.

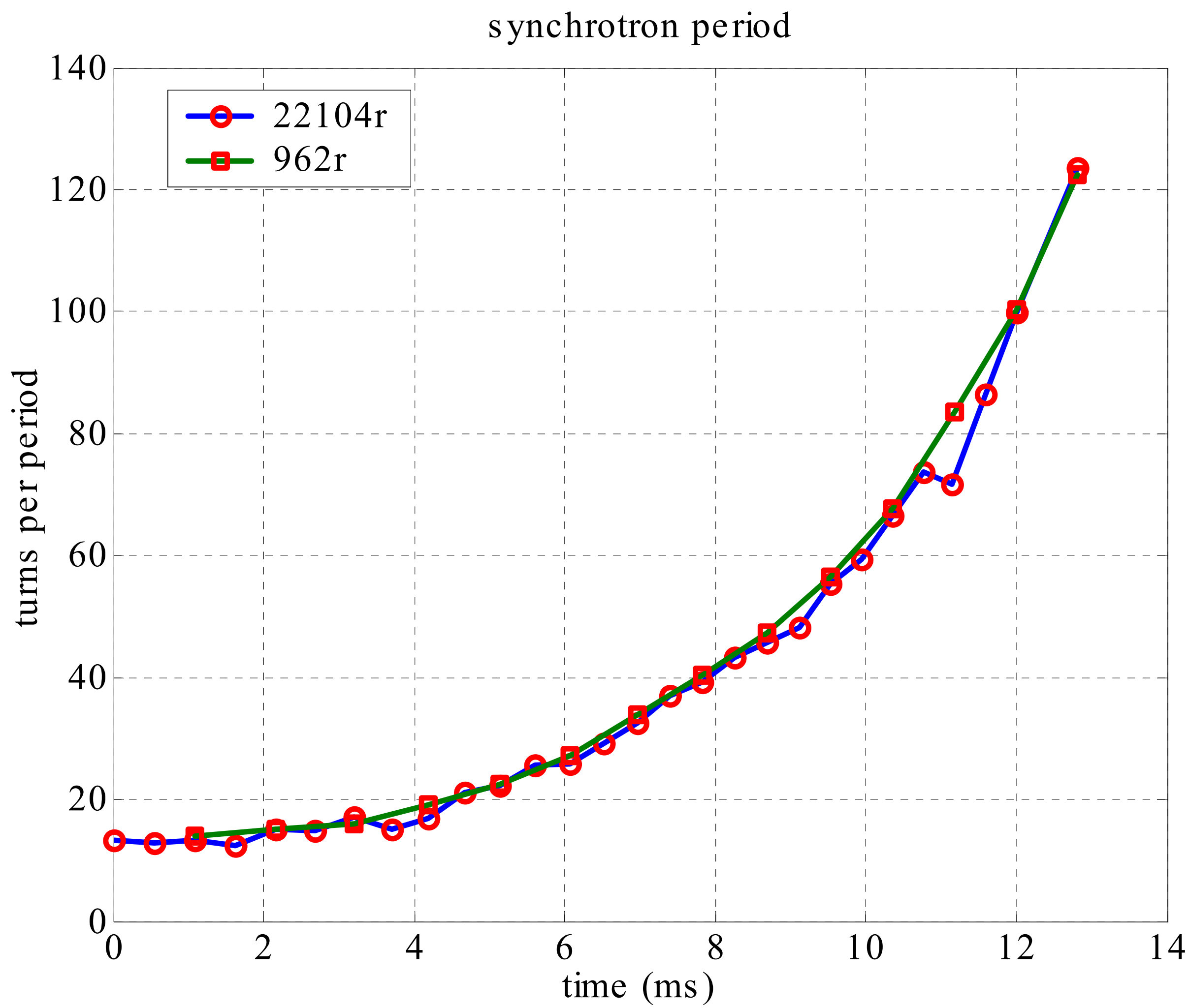
New data vs. Old data (AC)



- 22104r was taken on 4/8/2004
- 962r was taken in September, 2003 before shutdown

For TBT962r, measurements were carried out with every 1000 turns after transition, every 500 turn before transition.

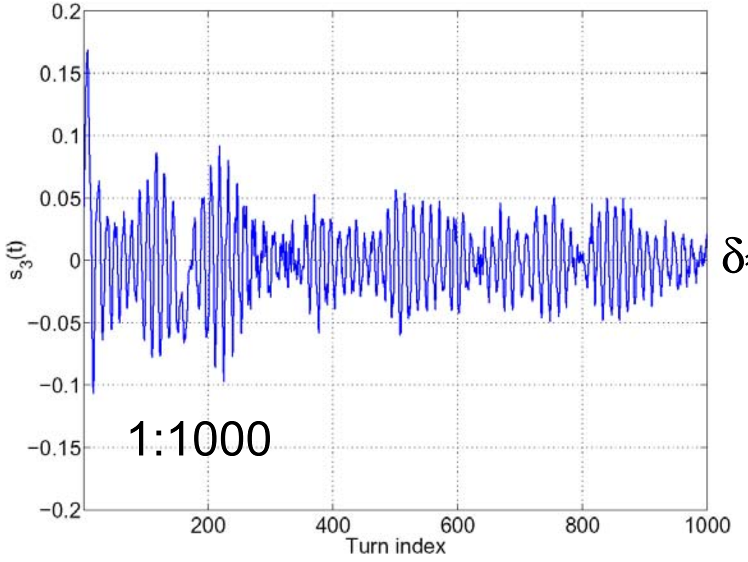
New data vs. Old data (AC)



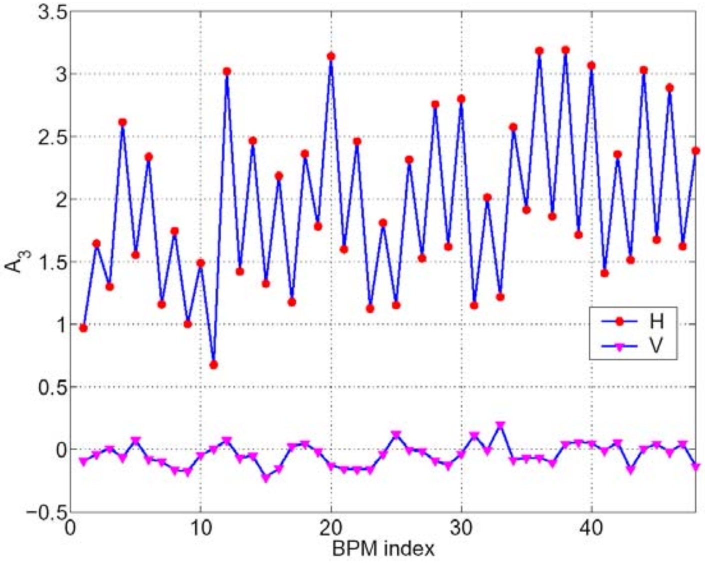
Before transition, with more details

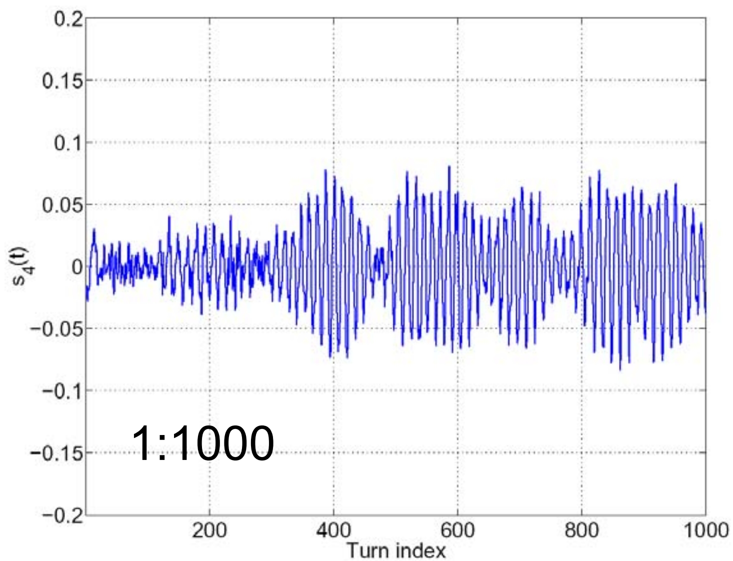
Turn 1 – 1000, M20

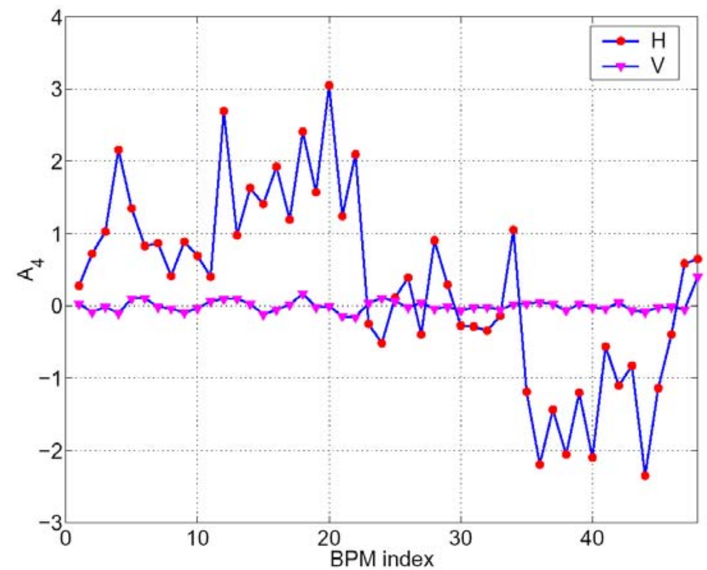
Before transition



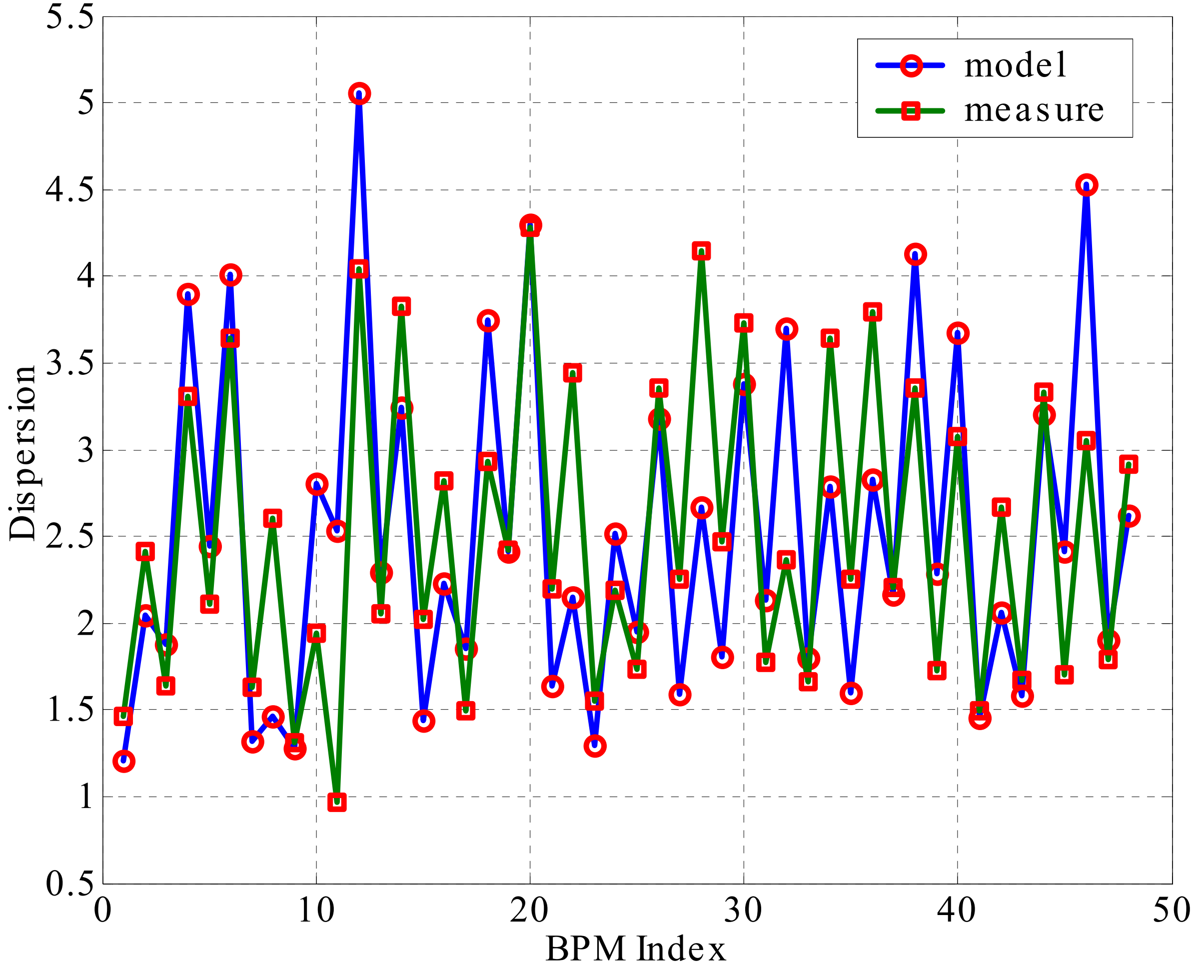
δ≈0.08E-3







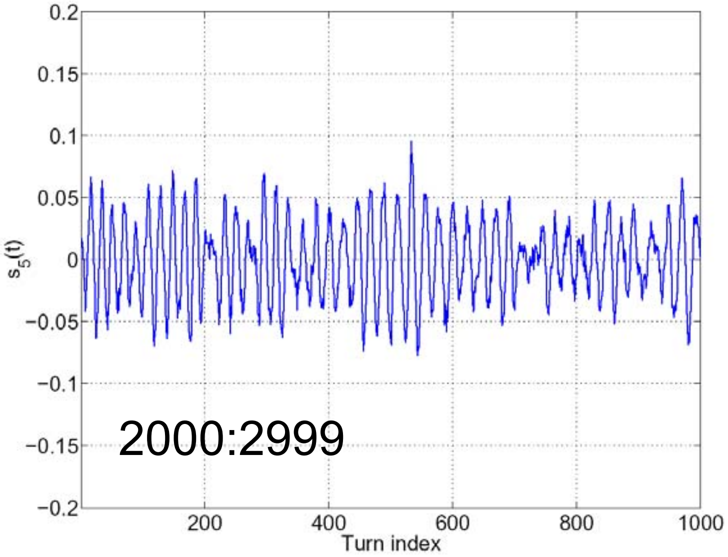
Comparison of dispersion



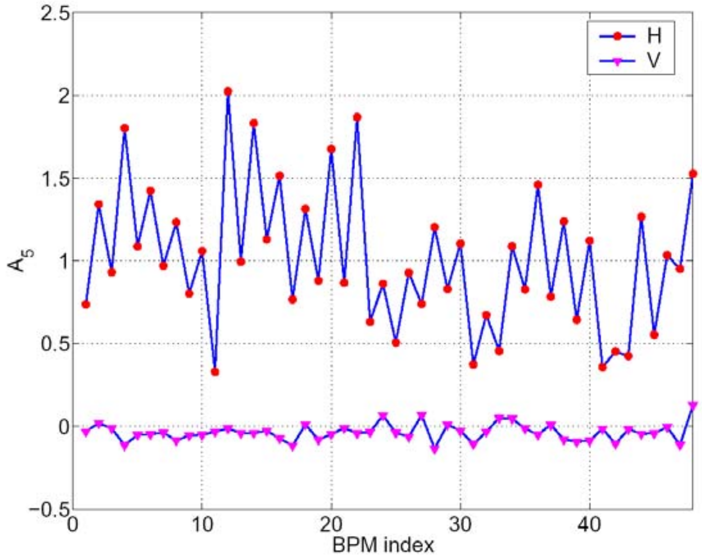
Using spatial pattern of turn 1-1000;
Not in good agreement, because δ is too small.

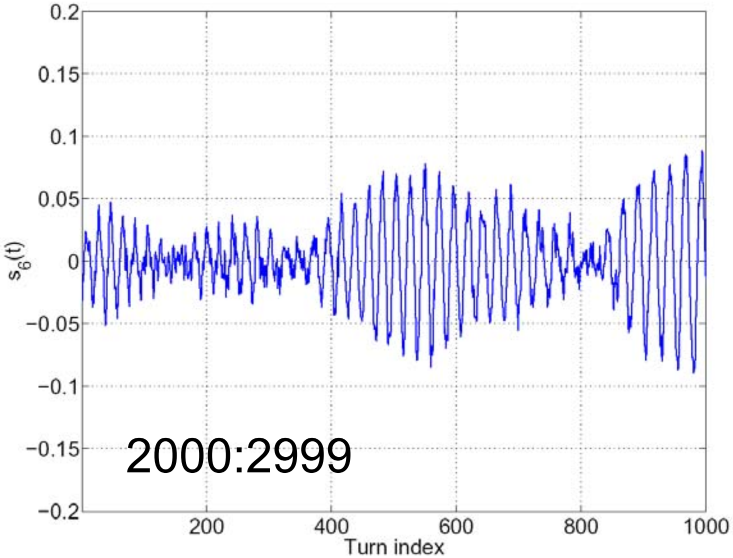
Turn 2000 – 2999, M20

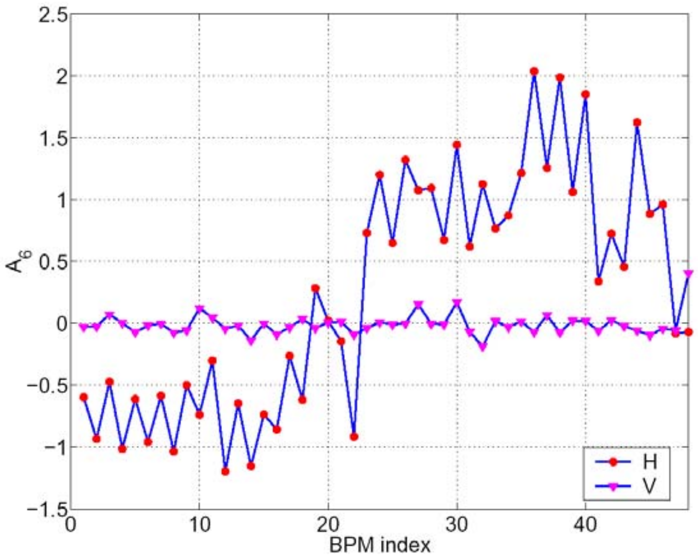
Before transition



δ≈0.05E-3

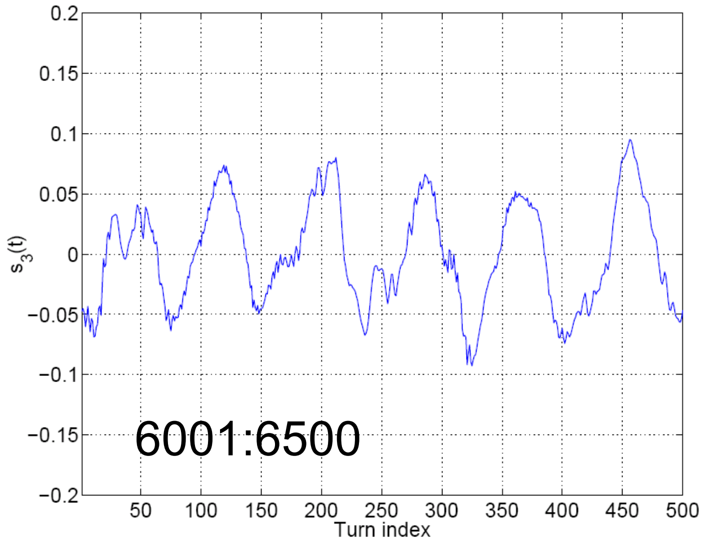


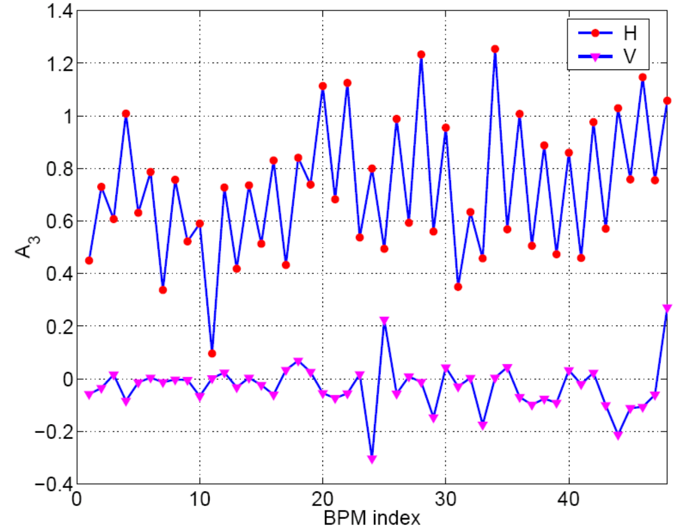




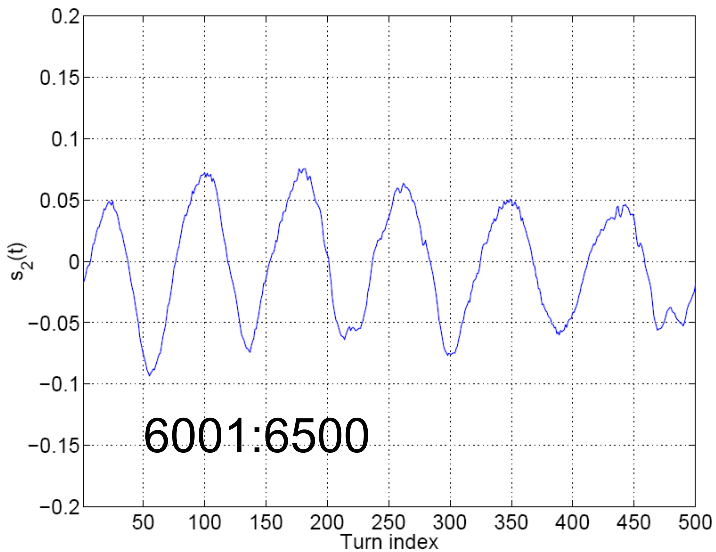
P5, [1 2 3 4]

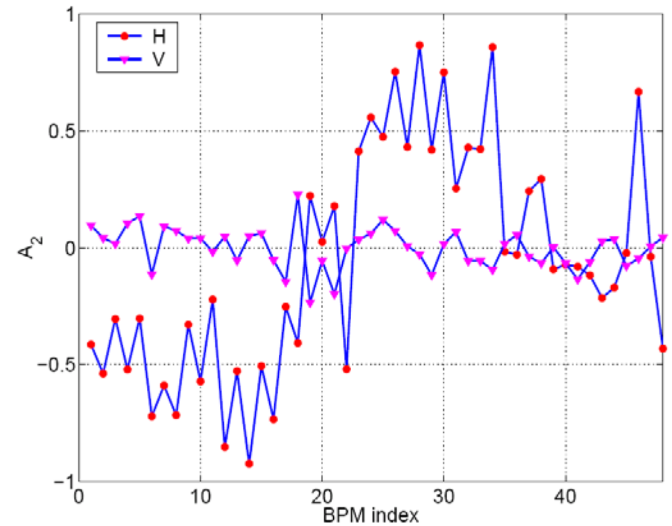
Before transition





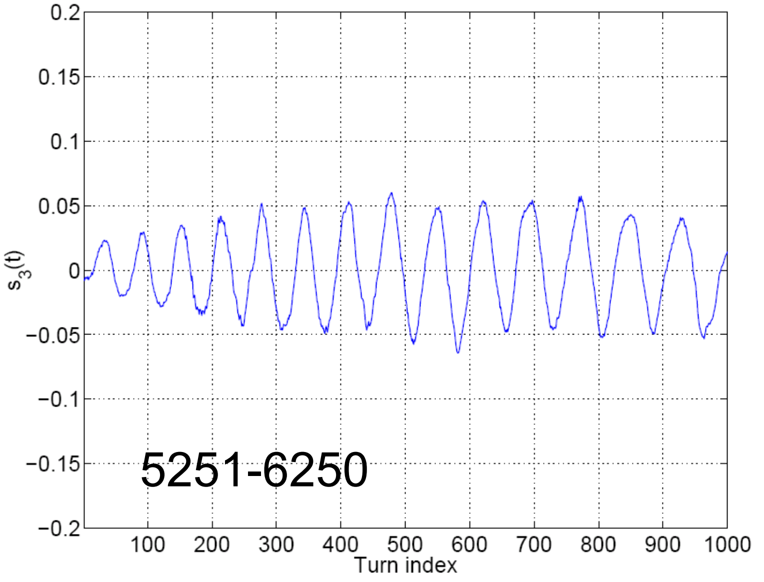
δ≈0.03E-3

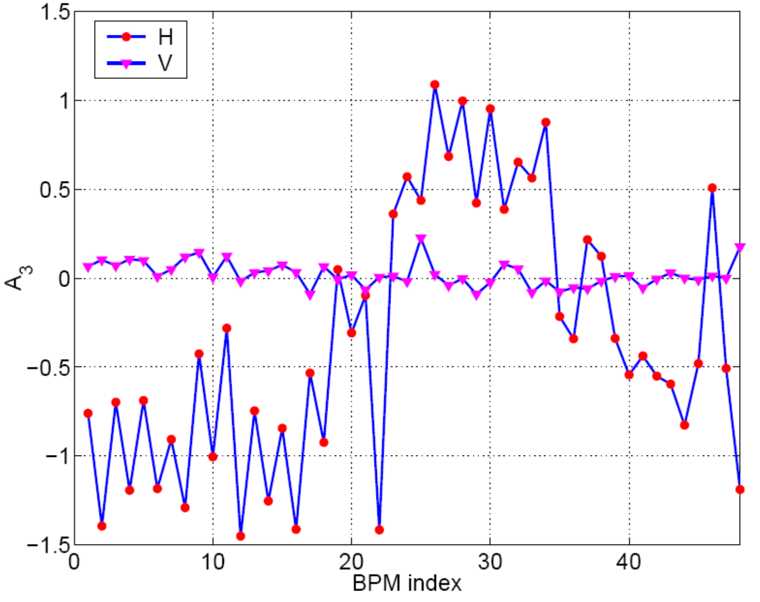


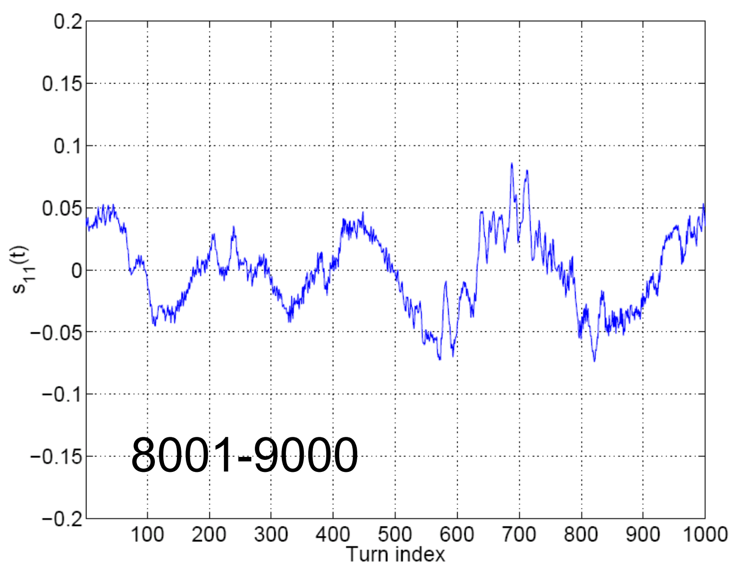


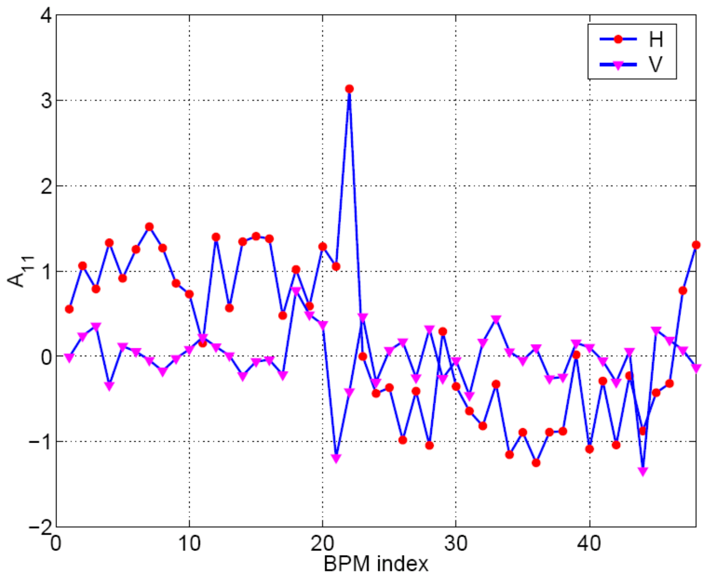
P5, [1 2 3 4]

Before transition

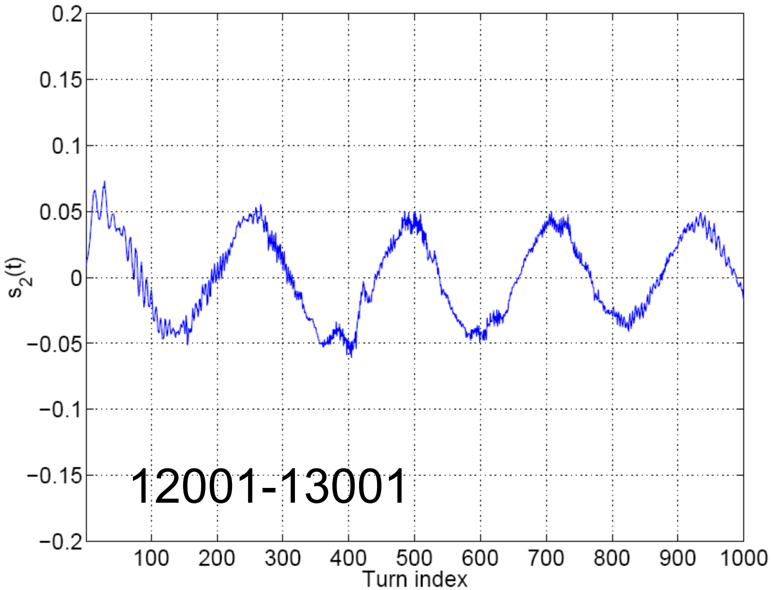


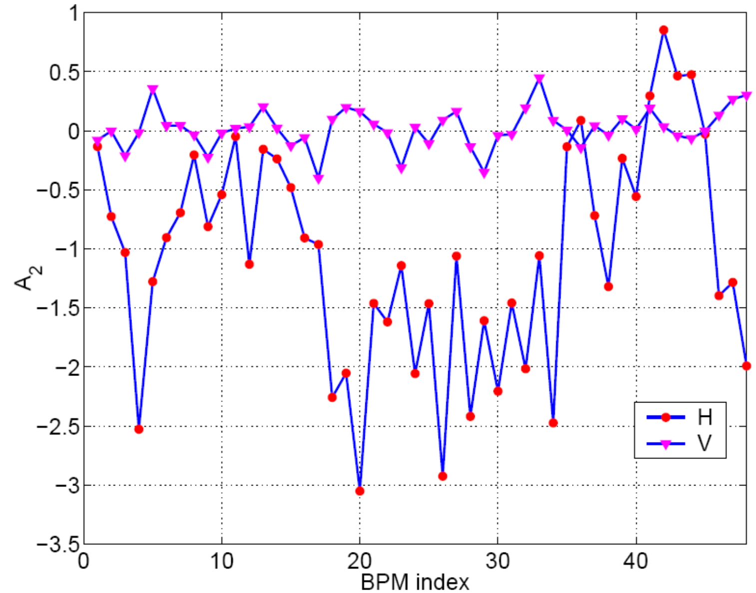


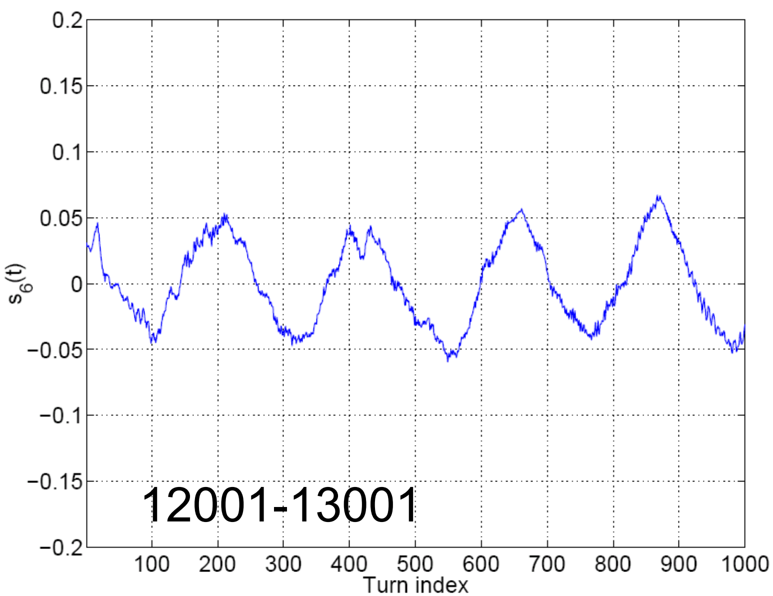


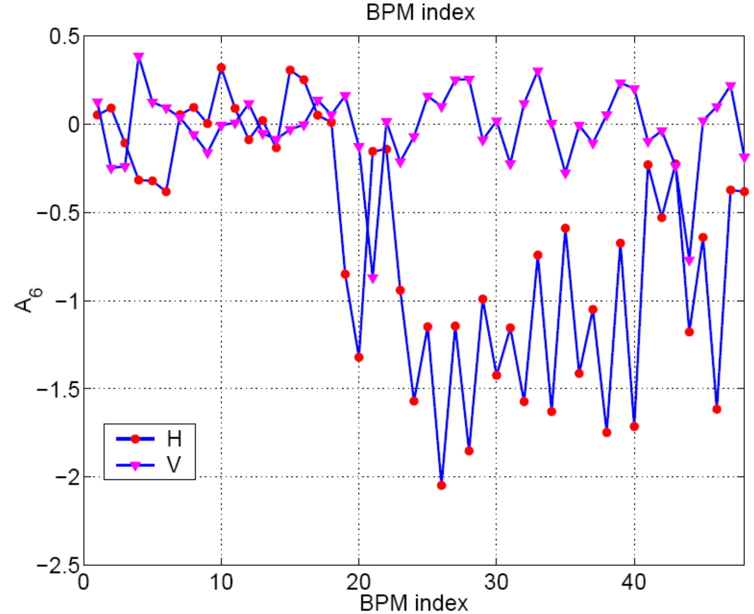


After transition

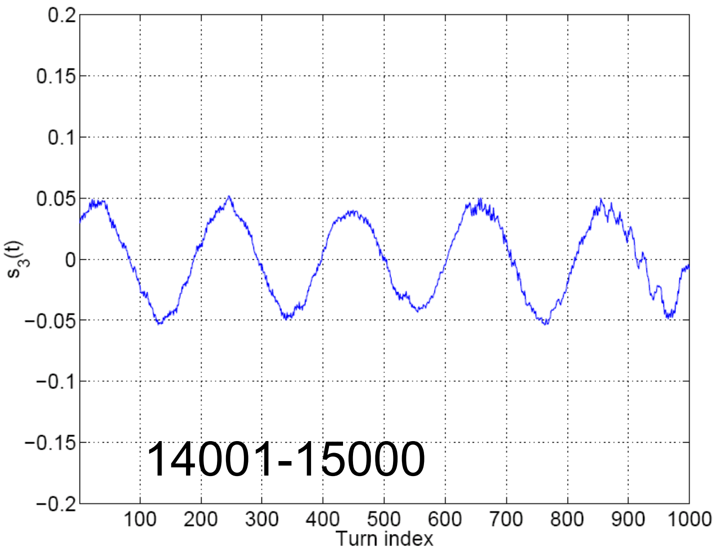


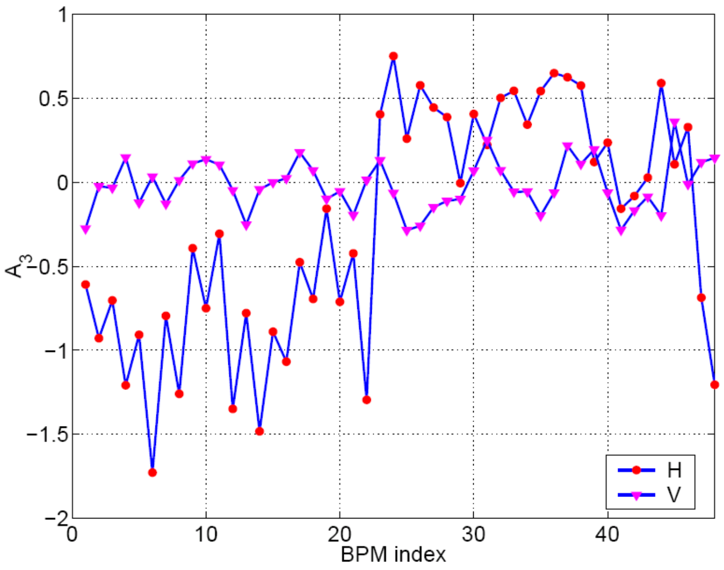


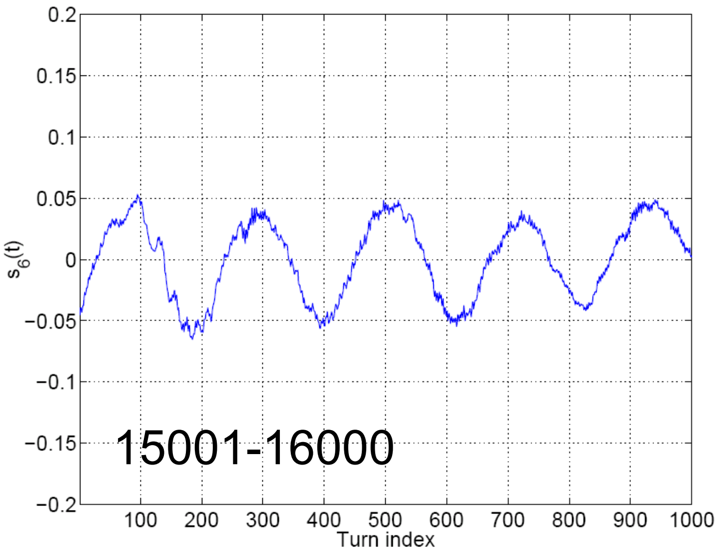


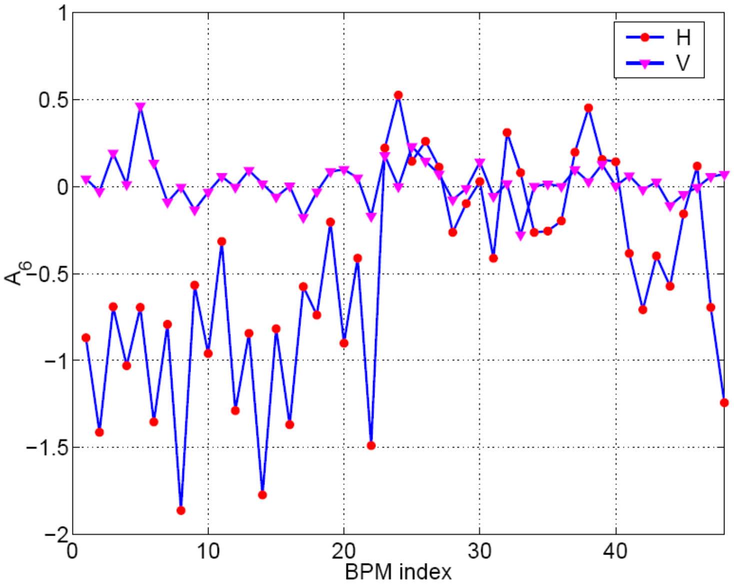


After transition

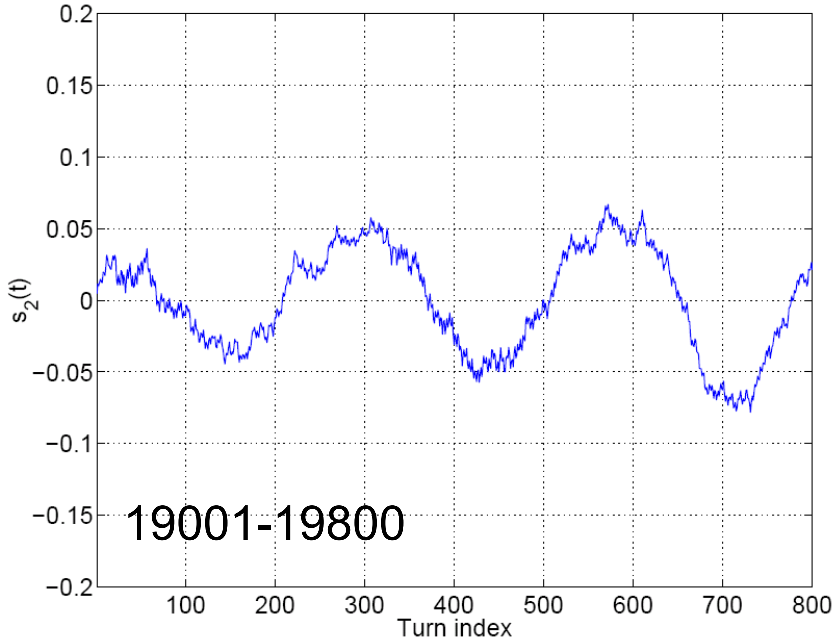


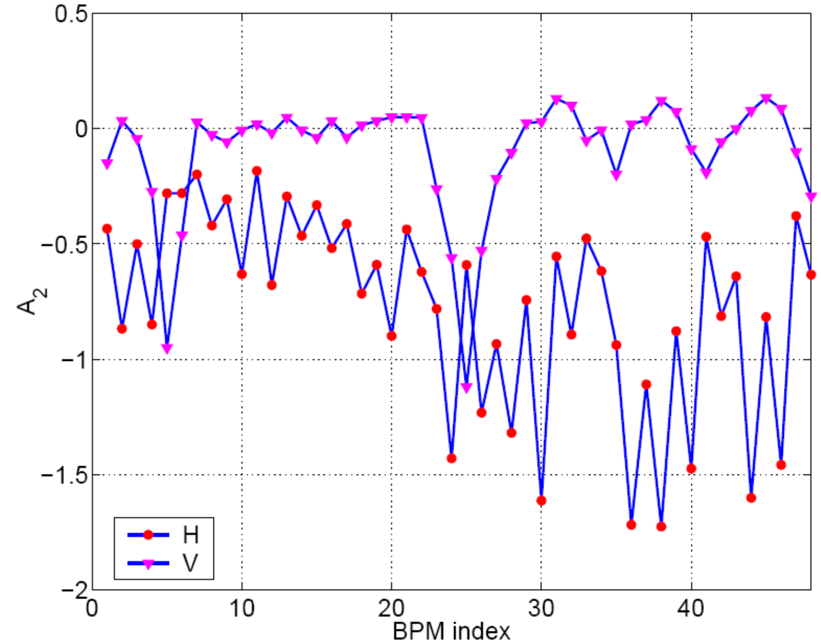






After transition





δ≈0.03E-3

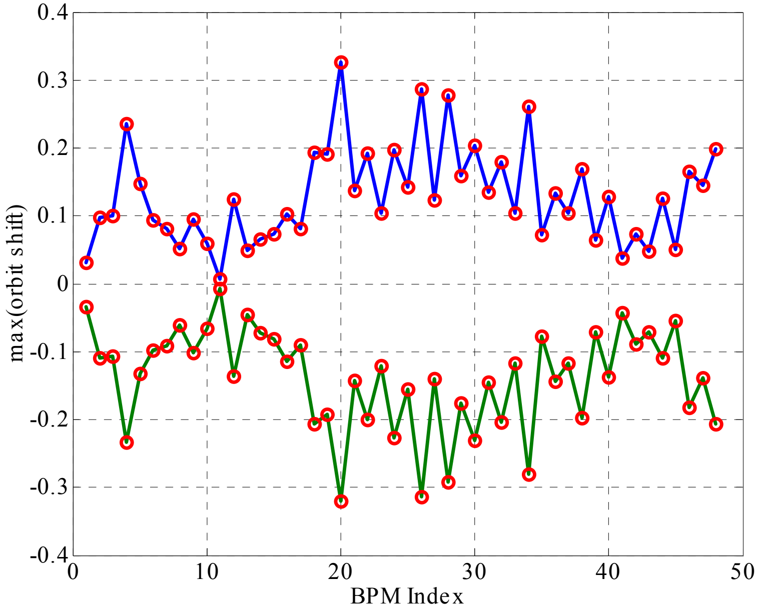
Comments

- The synchrotron tunes can be measured. And the result agrees with direct measurements.
- The feature of the spatial pattern of the synchrotron mode is unexpected.

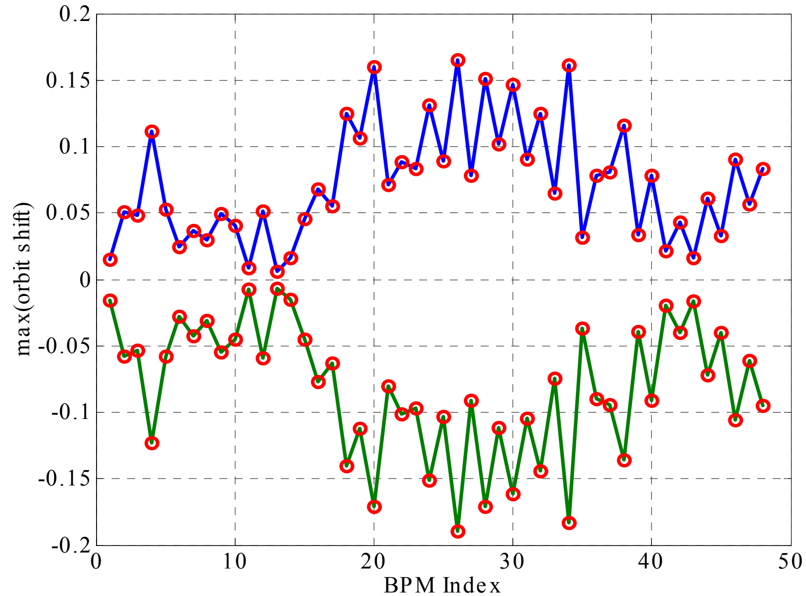
A potential explanation of the spatial pattern:
The momentum deviation δ is very small, only around 0.03E-3, or 0.1 MeV * when p = 4 GeV/c. So the beam energy loss per turn could change a big part of it. If this is true, then δ (in the same turn) seen by the BPMs around the ring is different.
However, the analysis always assumes identical temporal pattern for all BPMs. Consequently, two modes are produced by the analysis.
This is to be verified with simulation.

$$* \quad \Delta E = \delta \frac{p^2 c^2}{E} = (\delta pc) \frac{pc}{\sqrt{m^2 + p^2 c^2}} \approx \delta pc$$

Appendix: Envelope of synchrotron orbit shift



11001:1000



12001:1000

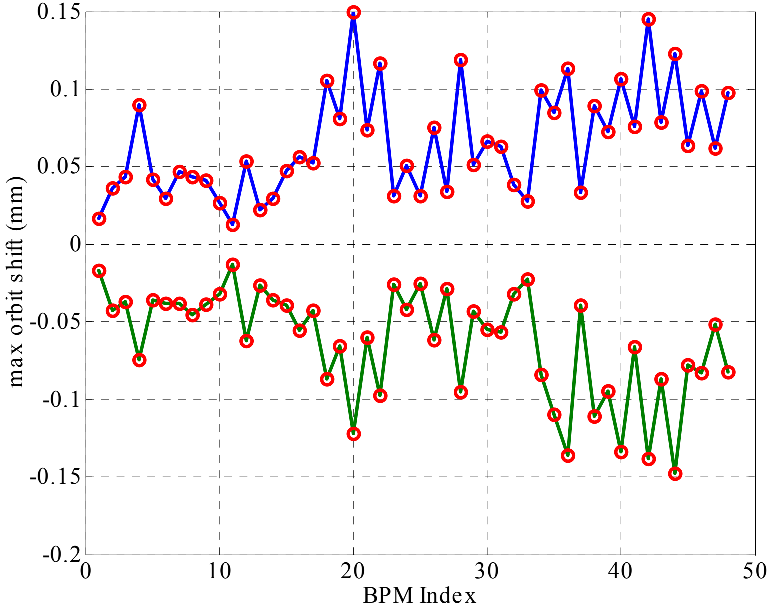
After transition

$$x = a_1 s_1 + a_2 s_2$$

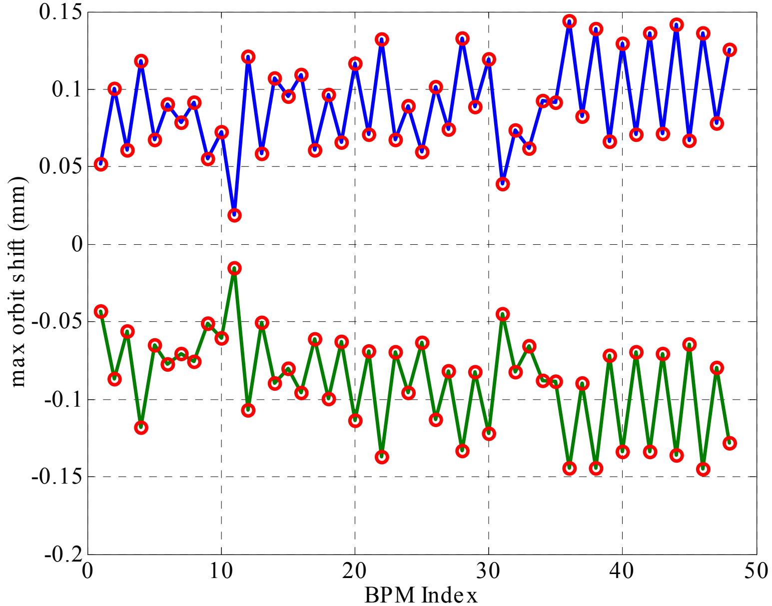
Sum of two synchrotron modes.

The plots show the maximum and minimum of x_i for each BPM.

Appendix: Envelope of synchrotron orbit shift



5001:500



4001:500

Before transition