Precision optics measurements in RHIC and future applications

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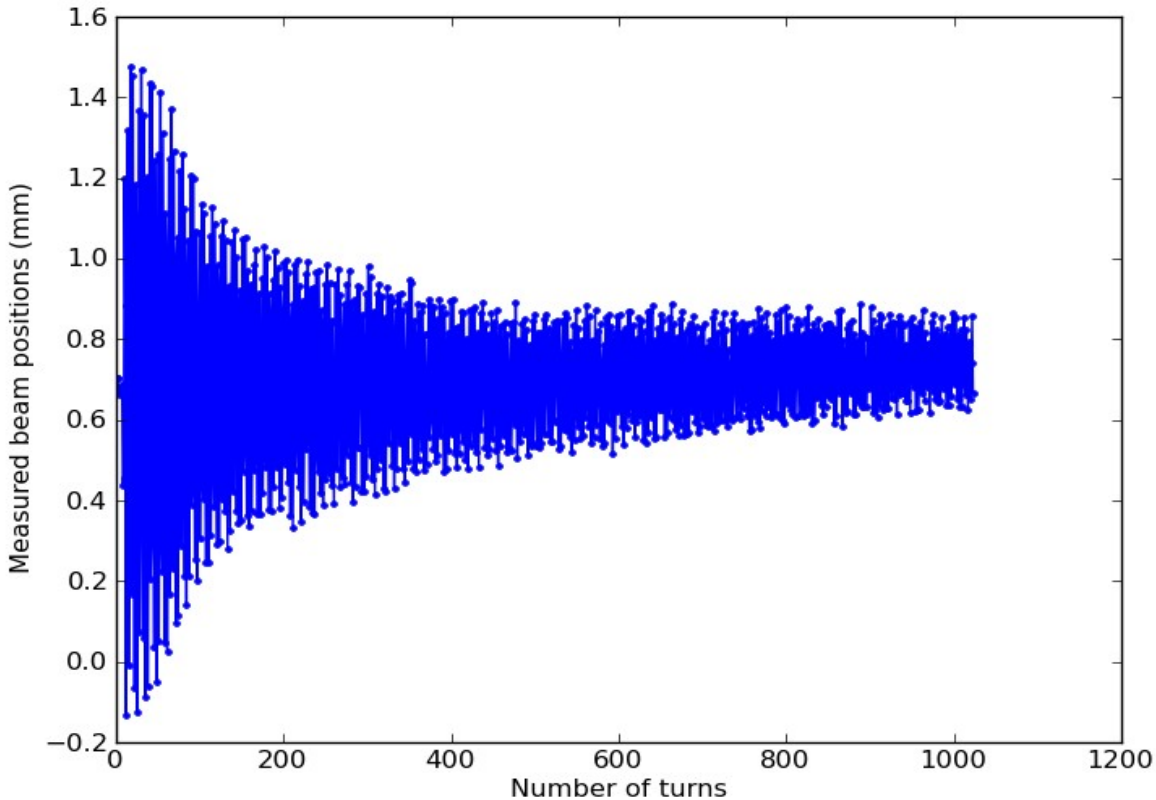
APEX workshop 2012

Outline

1. Overview of new analyses
2. Applications on real data
   a. Kicked beam (Artus data)
   b. Continuously applied excitation (AC dipole data)
3. Measurement resolution
4. Future applications
   a. Artus data at store
   b. Phase correction
   c. Impedance localization
   d. Optics measurement on the ramp
   …...

Overview of new analyses

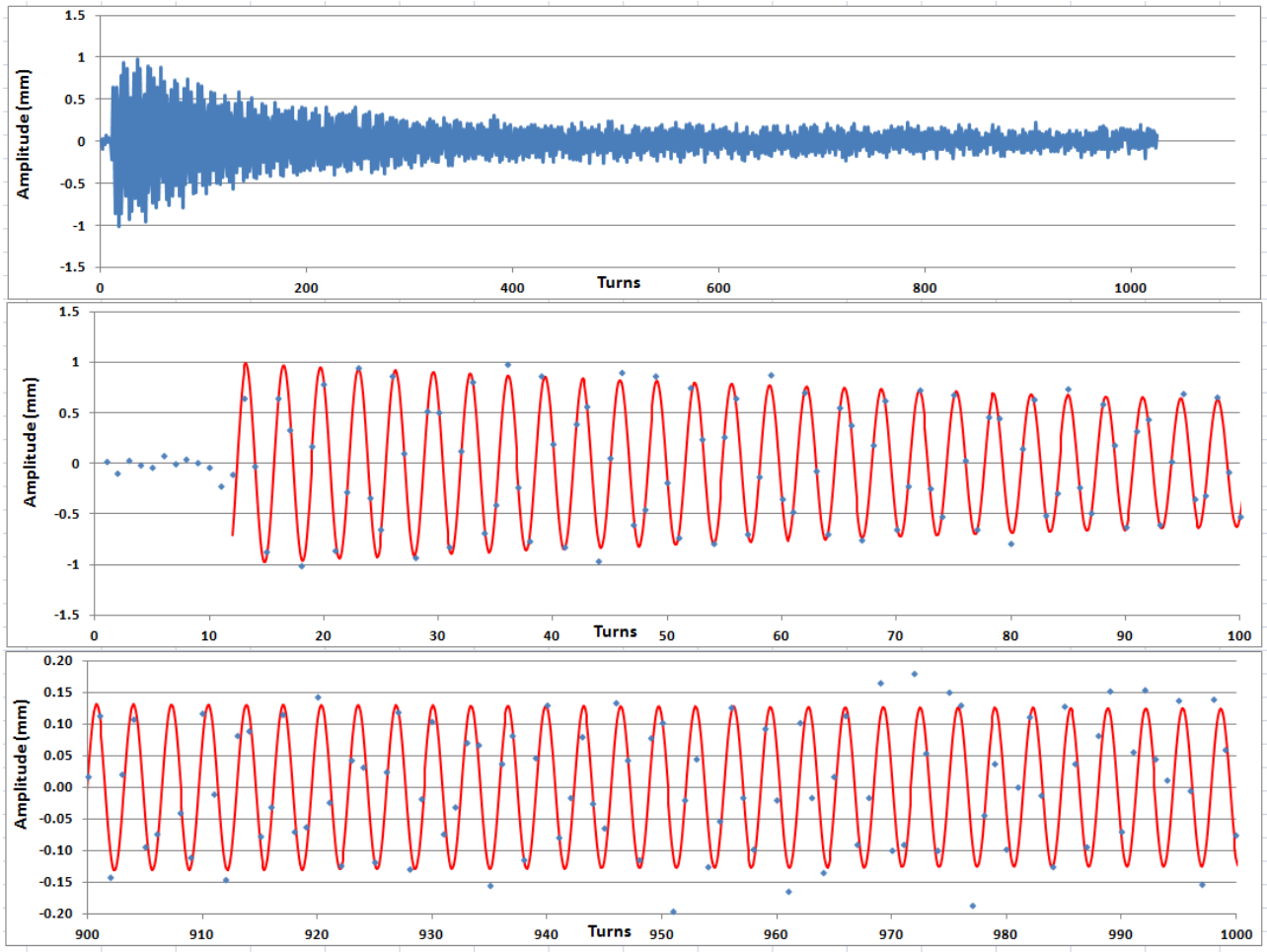
Betatron Oscillation by Artus kick



- In Blue ring, 166 hbpms, 165 vbpms see centroid motion like in the plot
- An oscillation contains information like amp, freq and phase, which relate to beta function, tune and phase advance
- Decay factor relate to nonlinearity and chromaticity, hard to separate the two practically

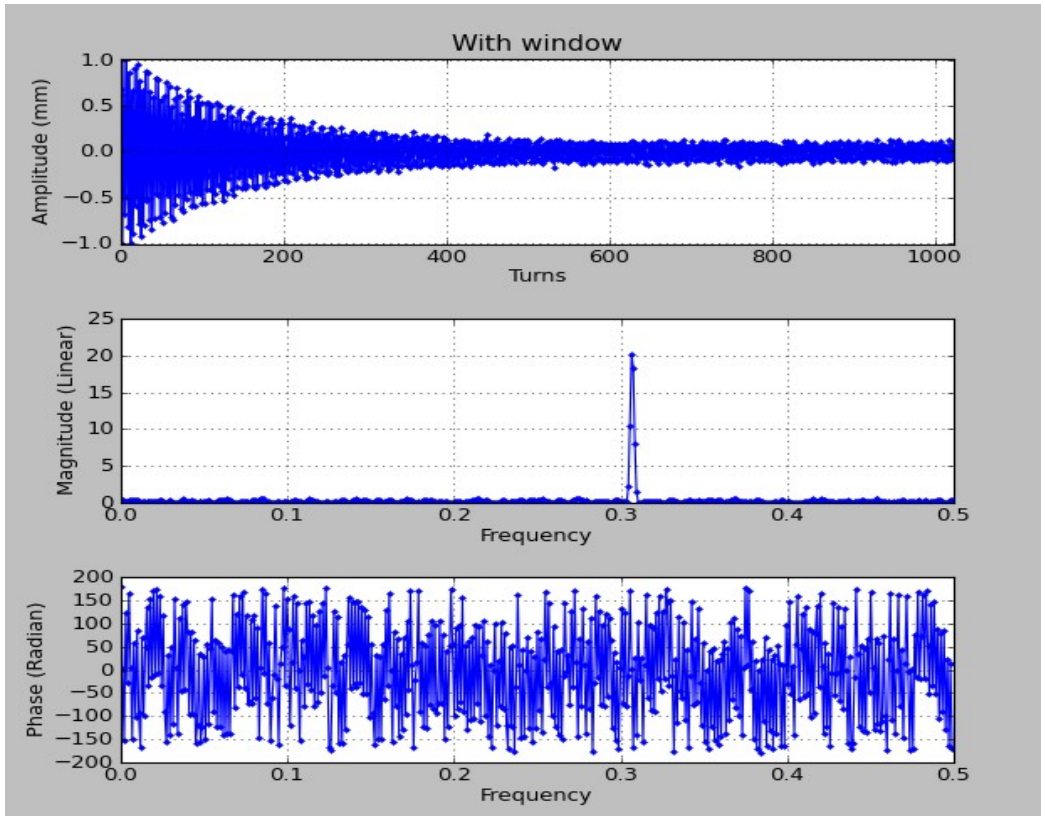
Time-domain analysis

$$x=[A1*\exp(-at)+A2*\exp(-bt)]\cos(2\pi ft+\phi)$$



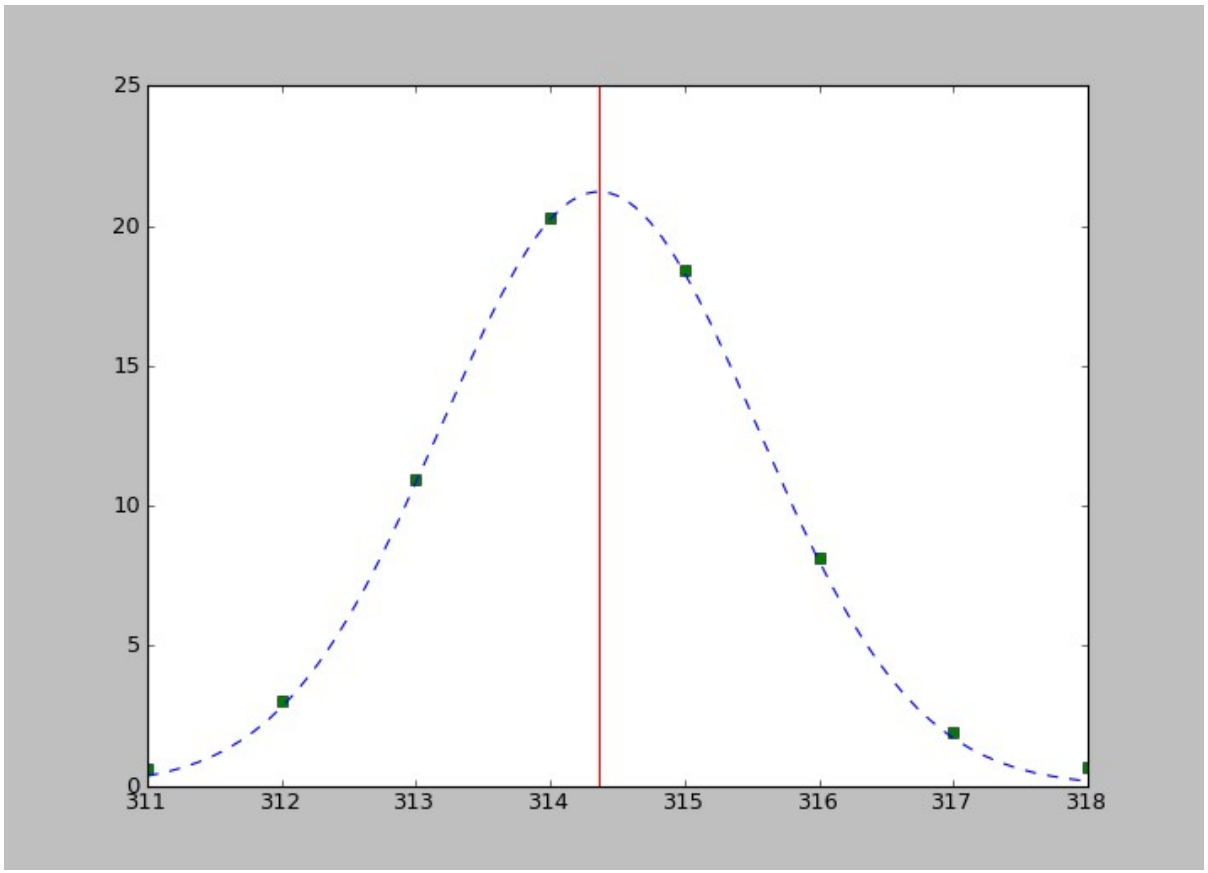
Frequency-domain analysis: step #1

window + FFT:



Frequency-domain analysis: step #2

Interpolation:



M. Gasior, J.L. Gonzalez, “IMPROVING FFT FREQUENCY MEASUREMENT RESOLUTION BY PARABOLIC AND GAUSSIAN INTERPOLATION”, AB-Note-2004-021

Frequency-domain analysis: step #3

CFT, continuous Fourier transform:

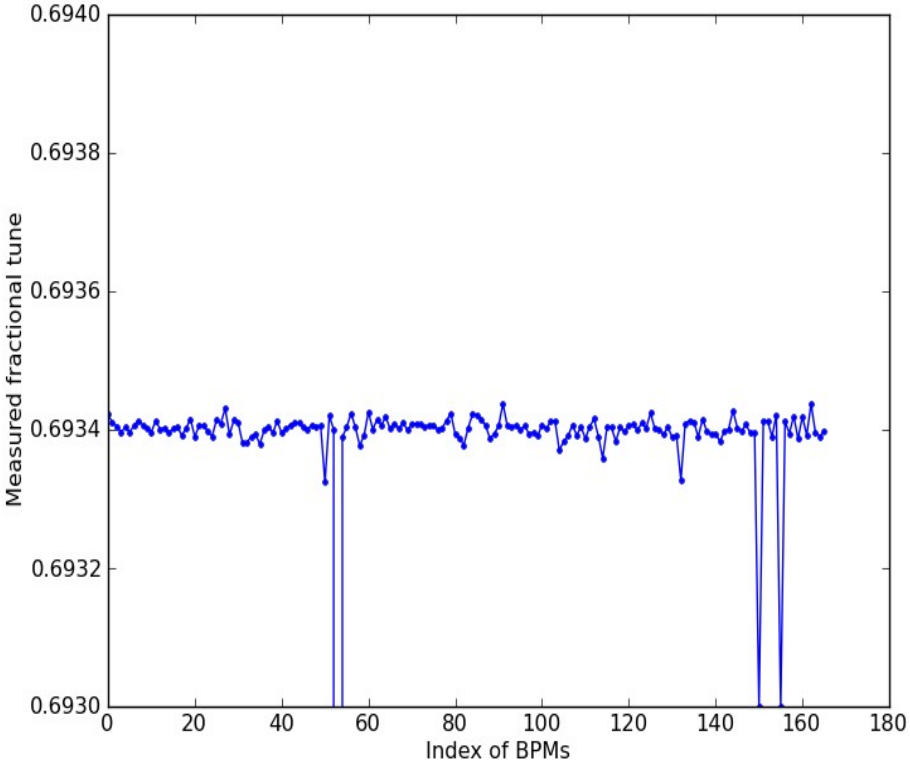
$$X(\nu) = \frac{1}{N}\sum_{n=1}^{N} e^{-2\pi i \nu \cdot n} x_n$$

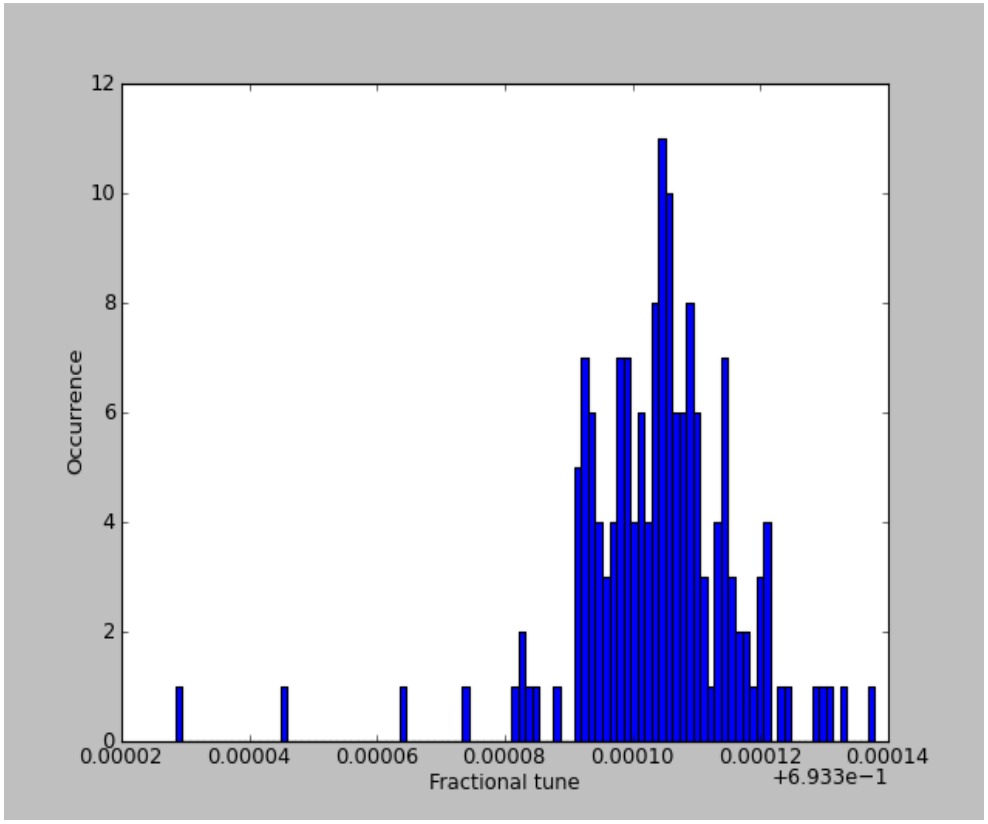
Phase = angle(X)

Applications

Kicked beam (Artus data)_tune measurement

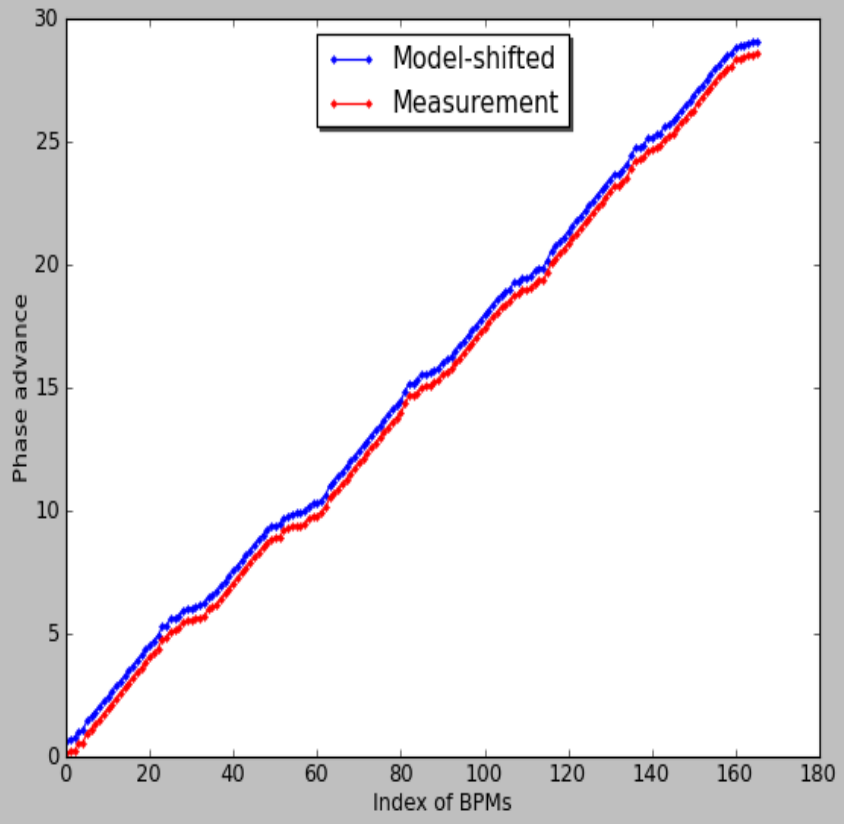
pp12b-v2::injection, blue horizontal, 16681

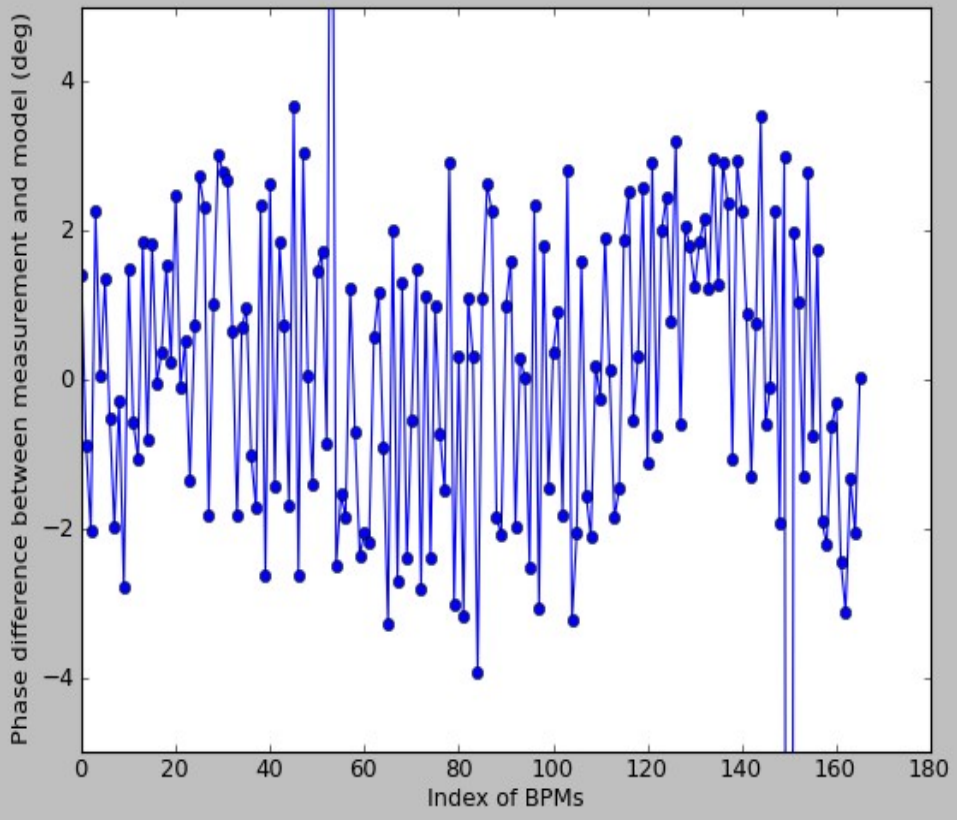




Tune measurement spread across the ring is 1.3E-5.

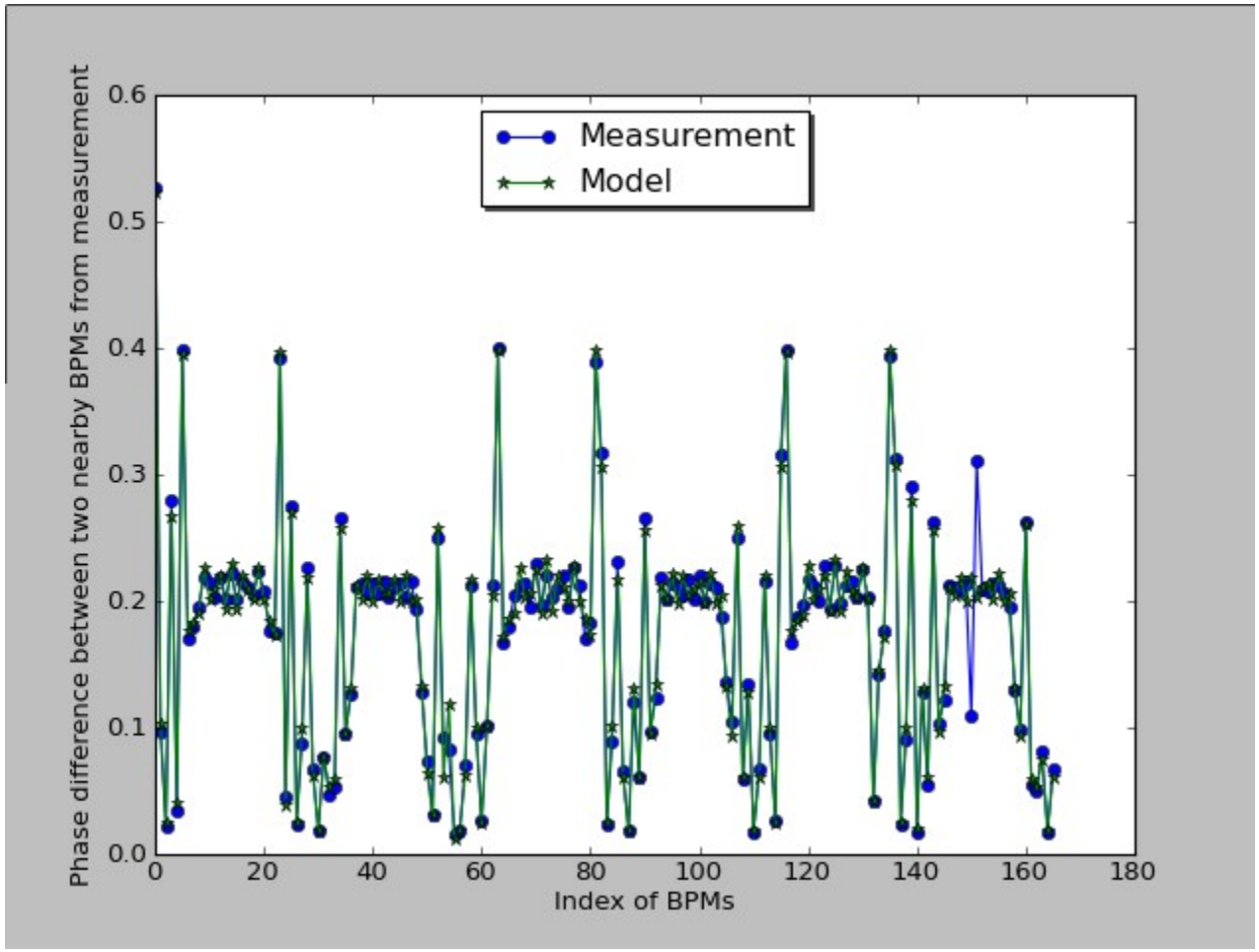
Kicked beam (Artus data)_phase measurement





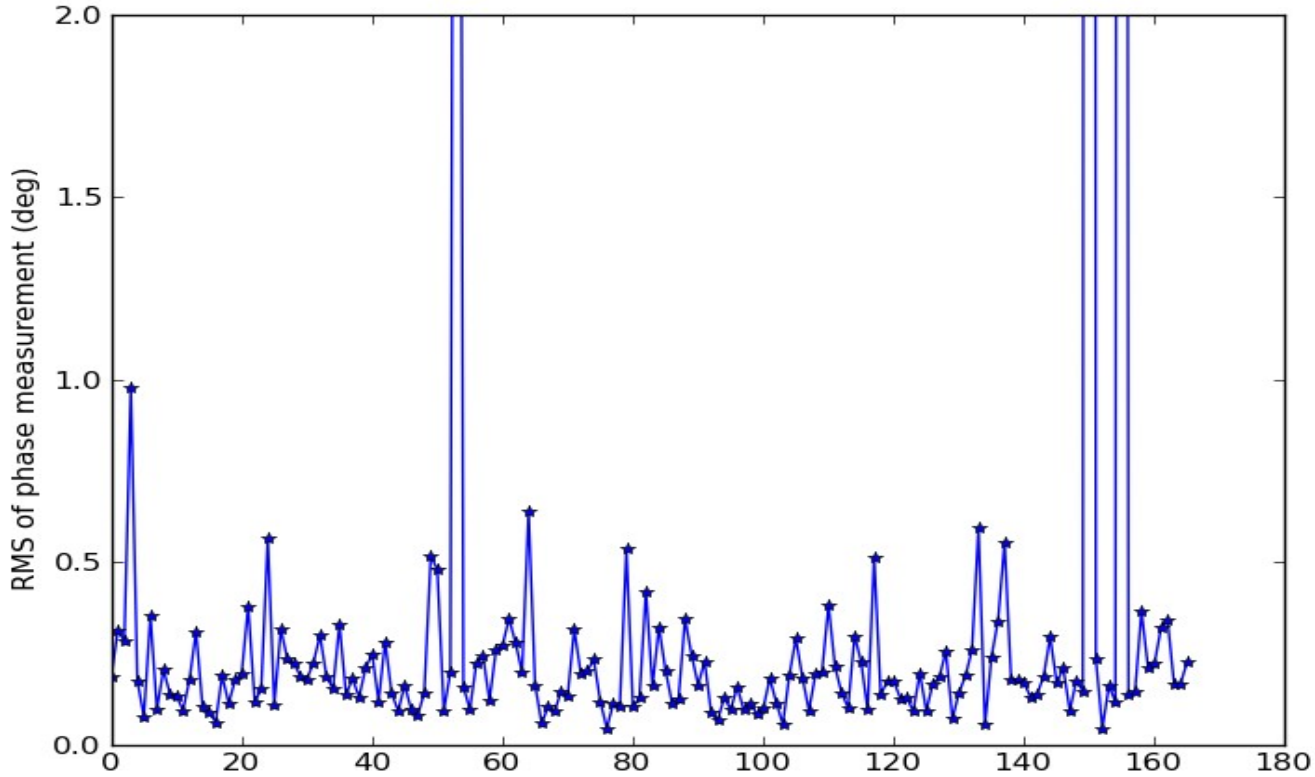
Kicked beam (Artus data)_phase measurement

Phase increment between BPMs:



Kicked beam (Artus data)_phase measurement error

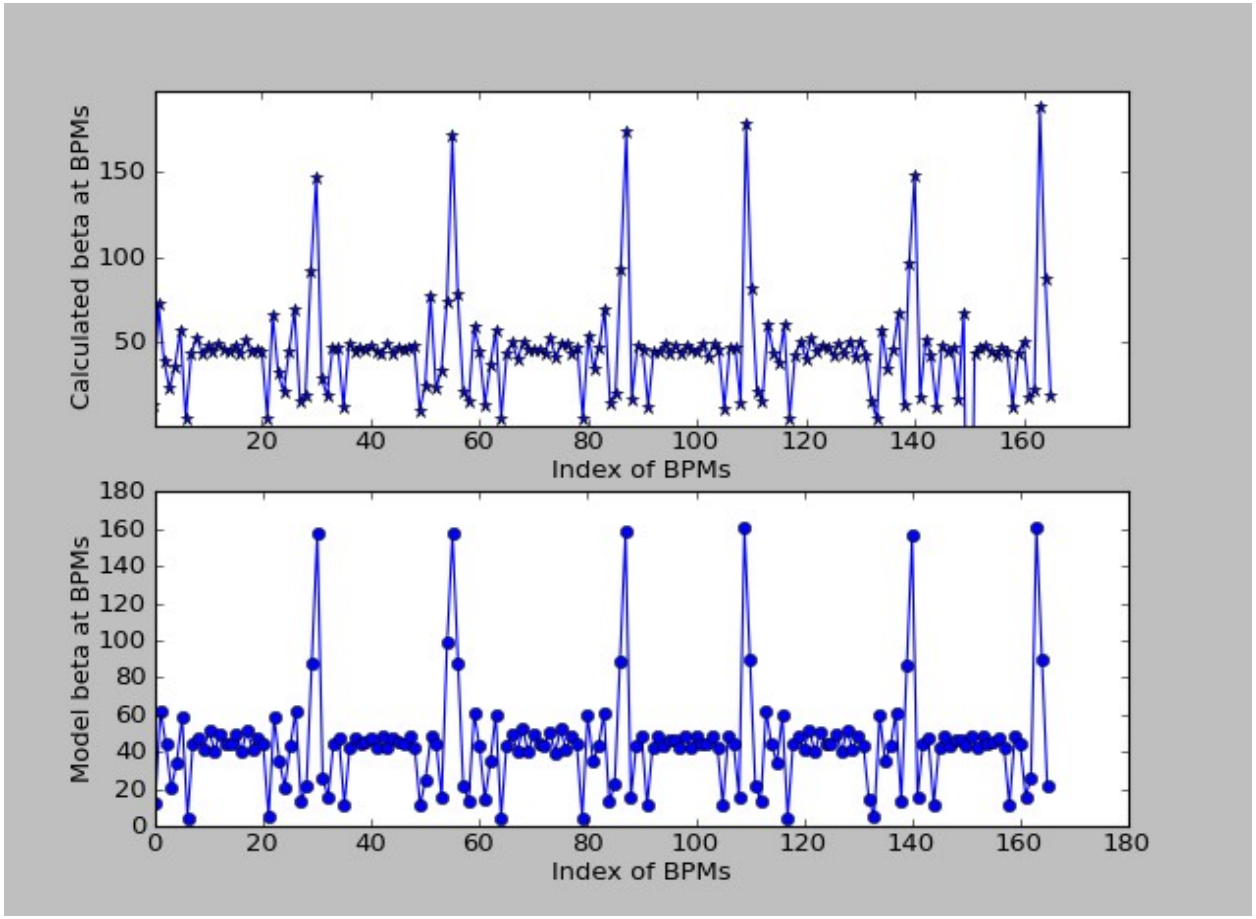
Measurement error (8 sets of Artus data) with new method:



The precision in the above plot was not achieved without struggling.

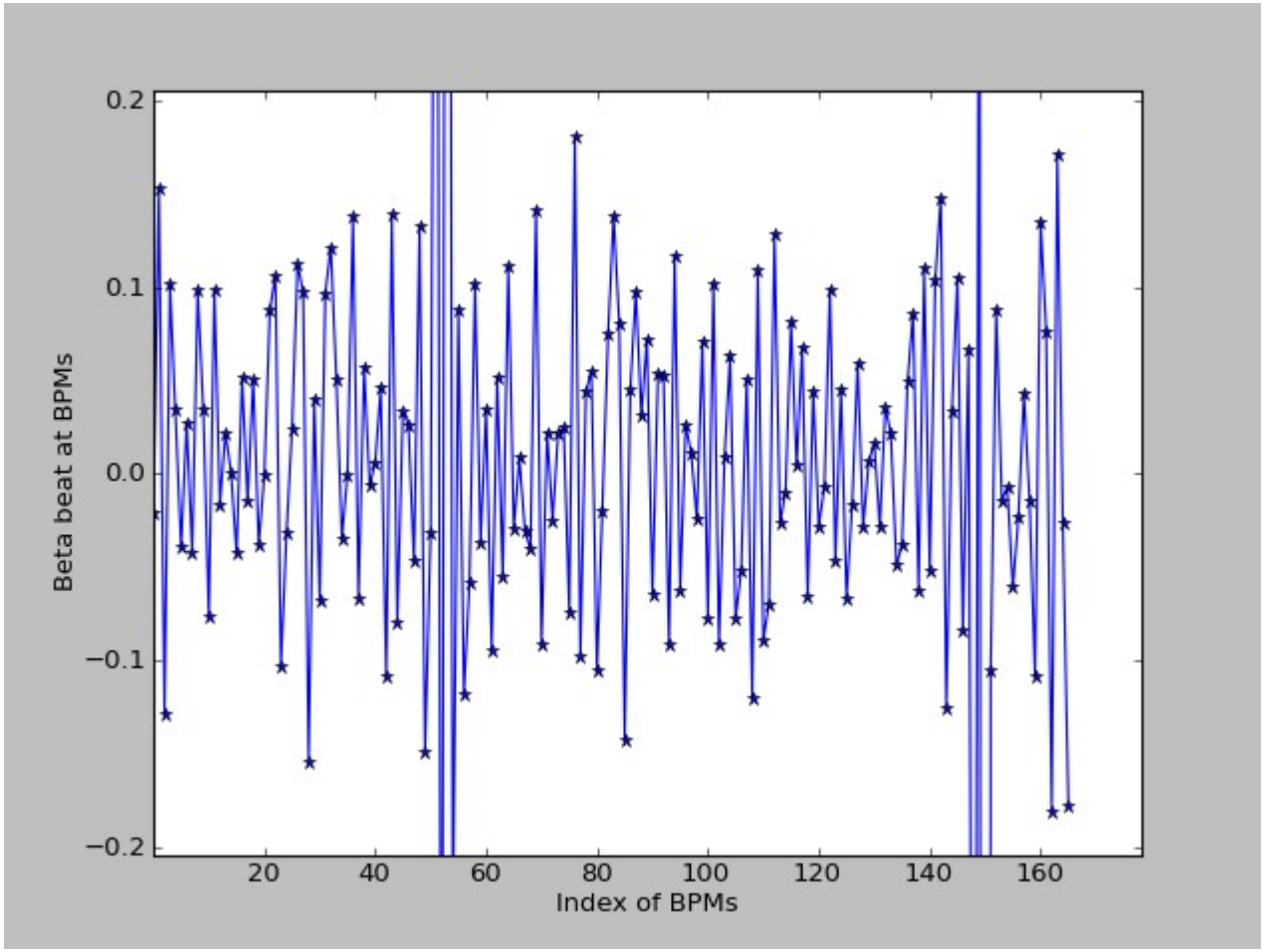
Attention: keep away from simple analytical phase interpolation

Kicked beam (Artus data)_ beta measurement



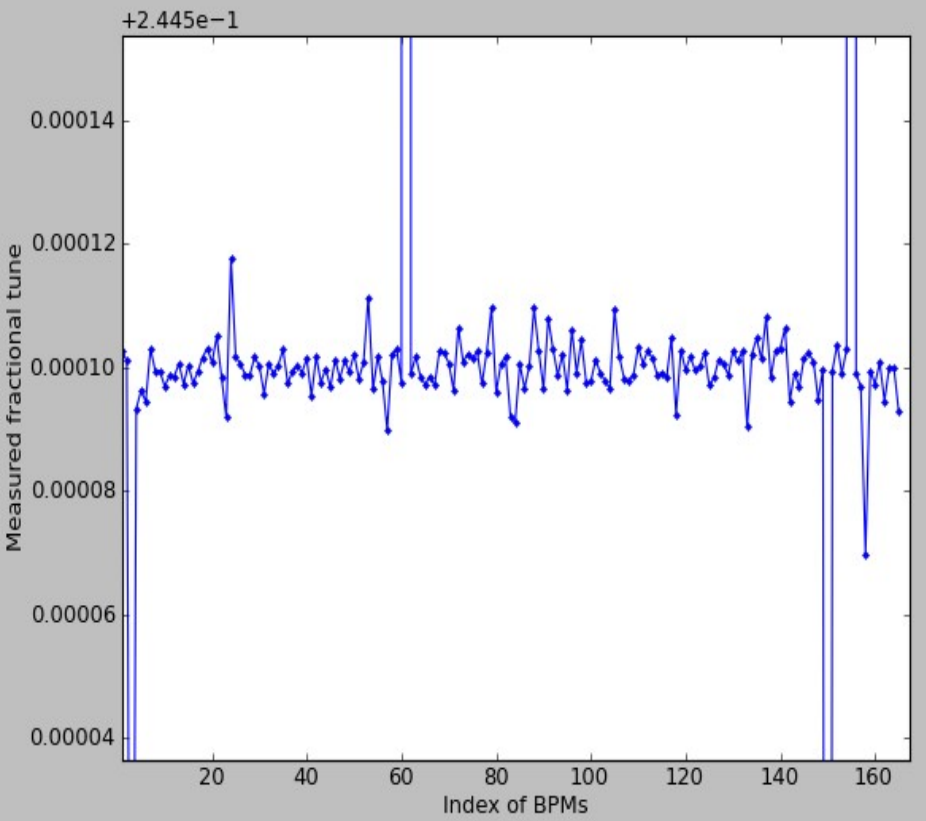
[1] P. Castro, J. Borer, A. Burns, G. Morpurgo, and R. Schmidt, “Betatron function measurement at LEP using the BOM 1000 turns facility,” in Particle Accelerator Conference, 1993., Proceedings of the 1993, 1993, pp. 2103–2105.

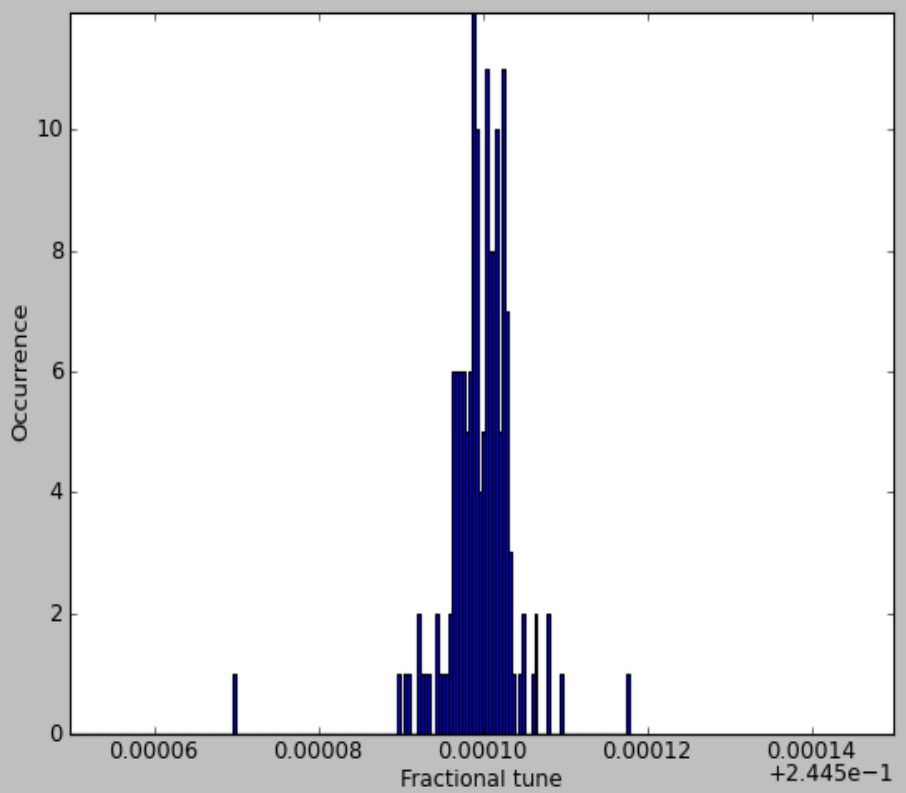
Kicked beam (Artus data)_ beta beat



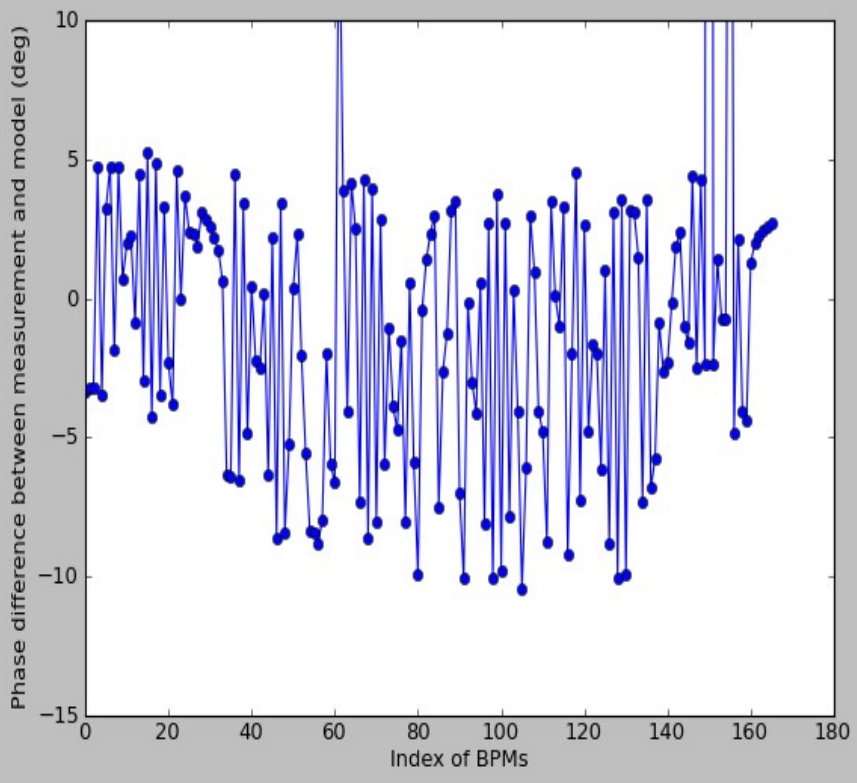
Continuous excitation_frequency measurement

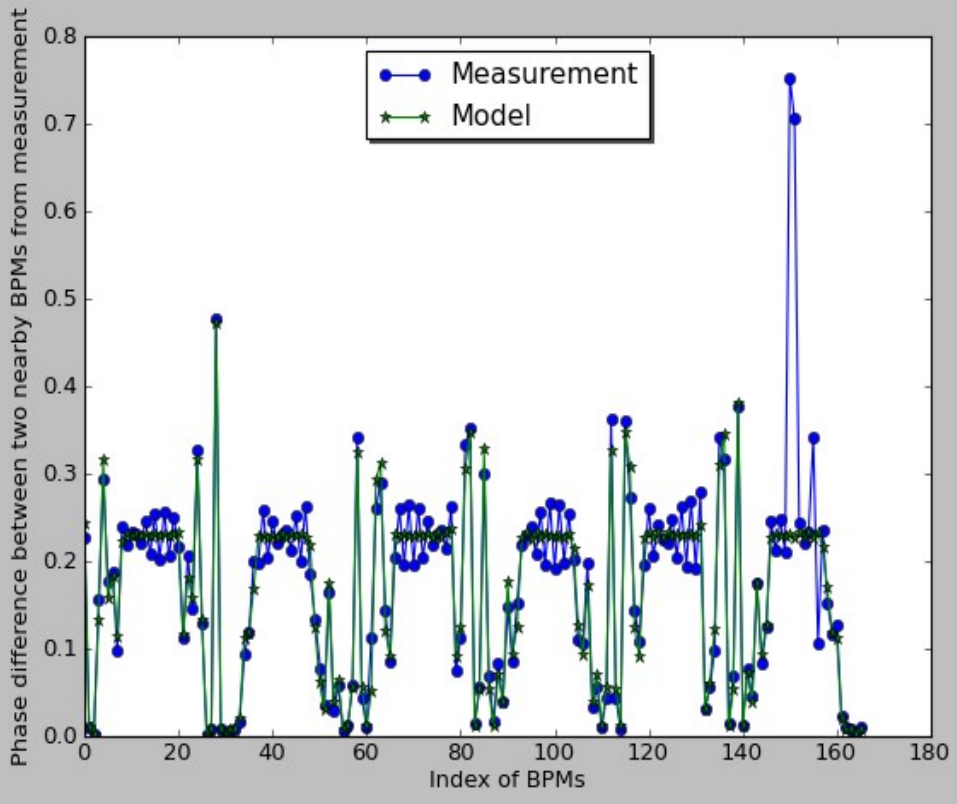
CuAu12-v1, Blue, horizontal, 10A, 16984, data taken during e-lens test of phase shifter





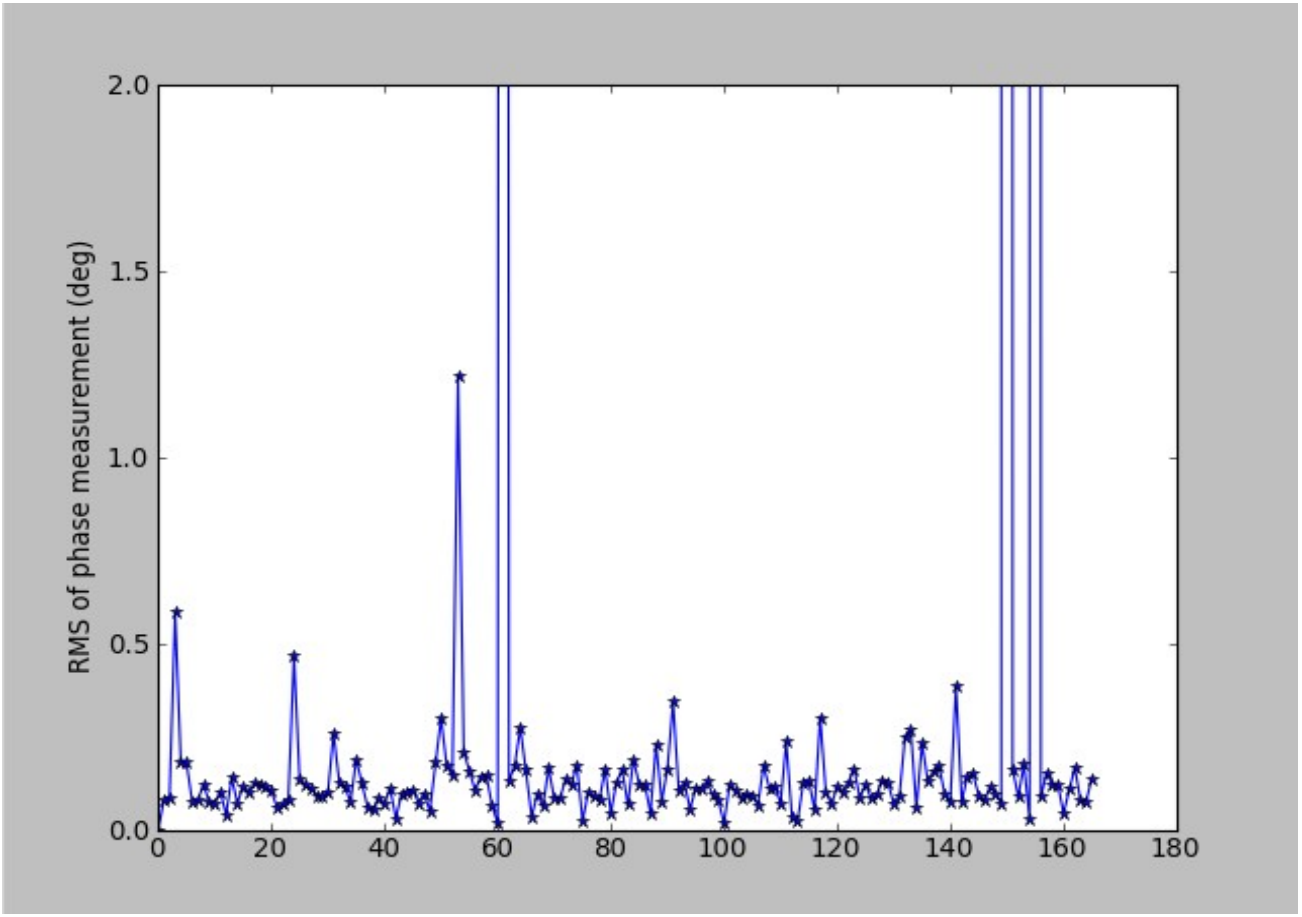
Continuous excitation_phase measurement





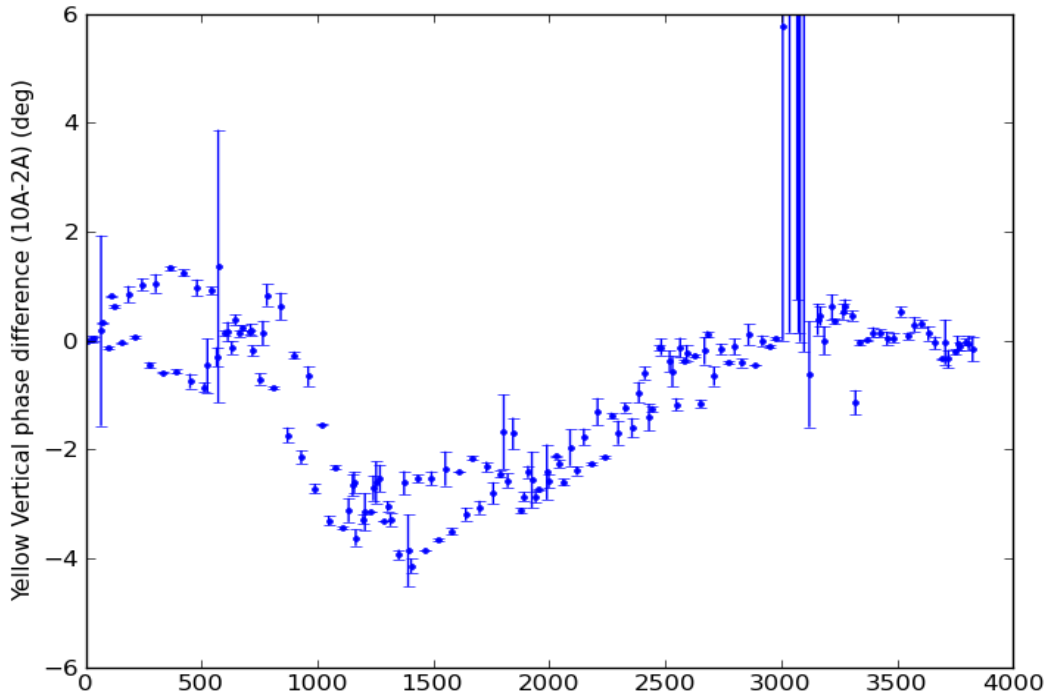
Continuous excitation_phase measurement error

Measurement errors from 4 sets of phase shifter data:

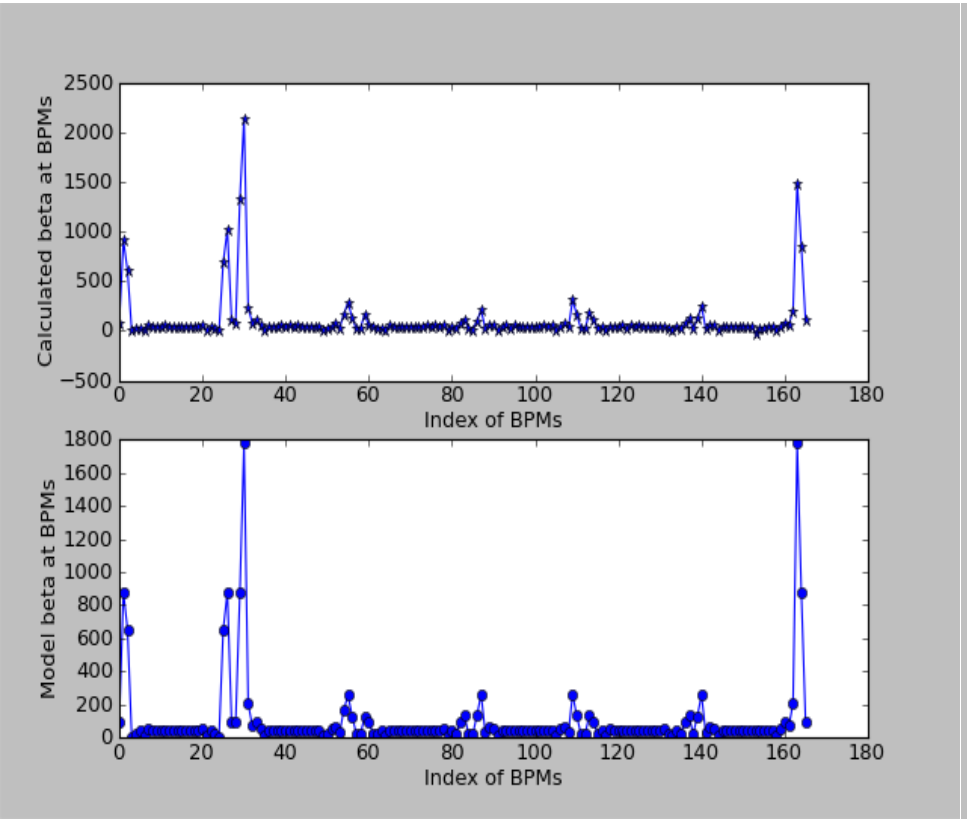


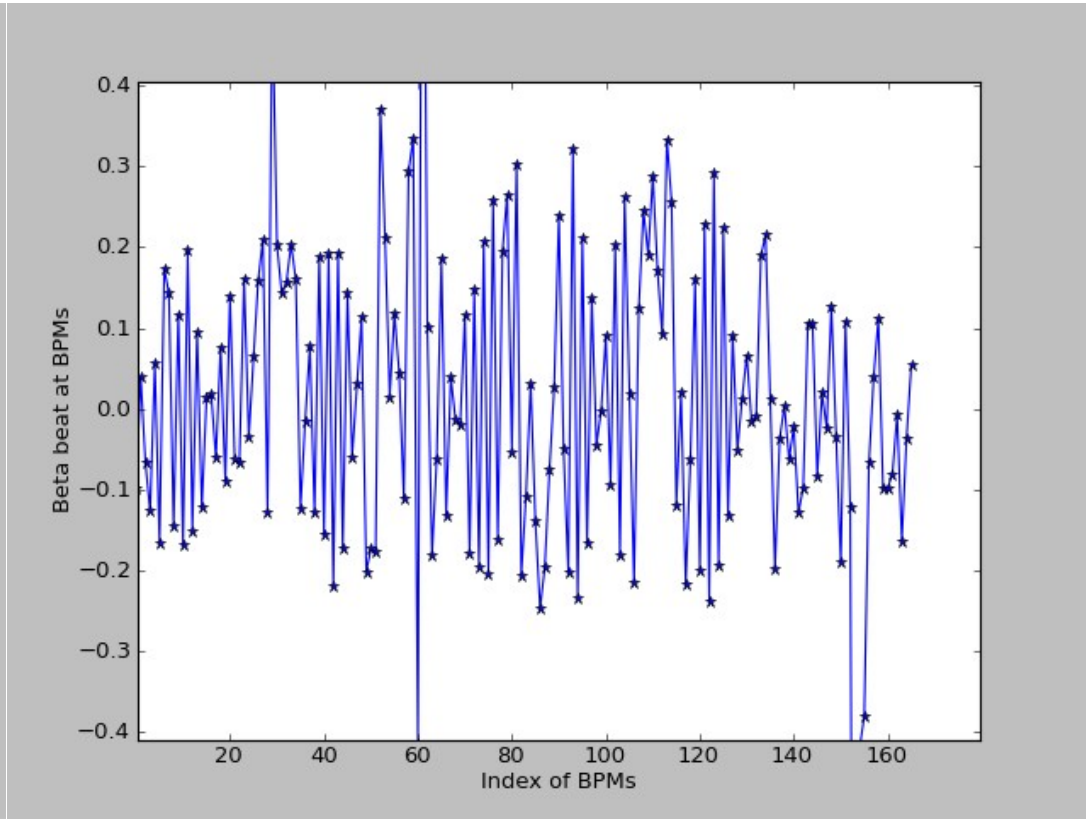
Continuous excitation_phase change

YV phase shifter effect (10A-2A):



Continuous excitation_beta measurement

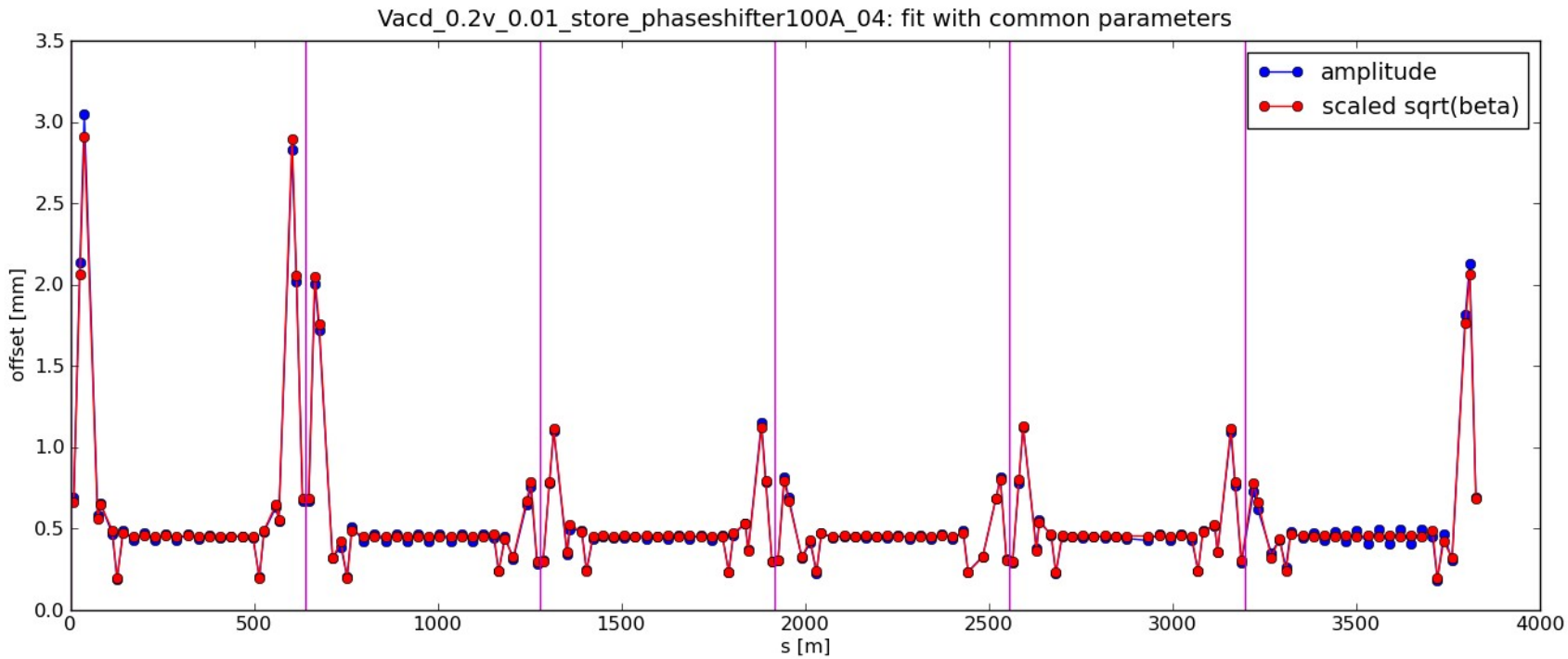




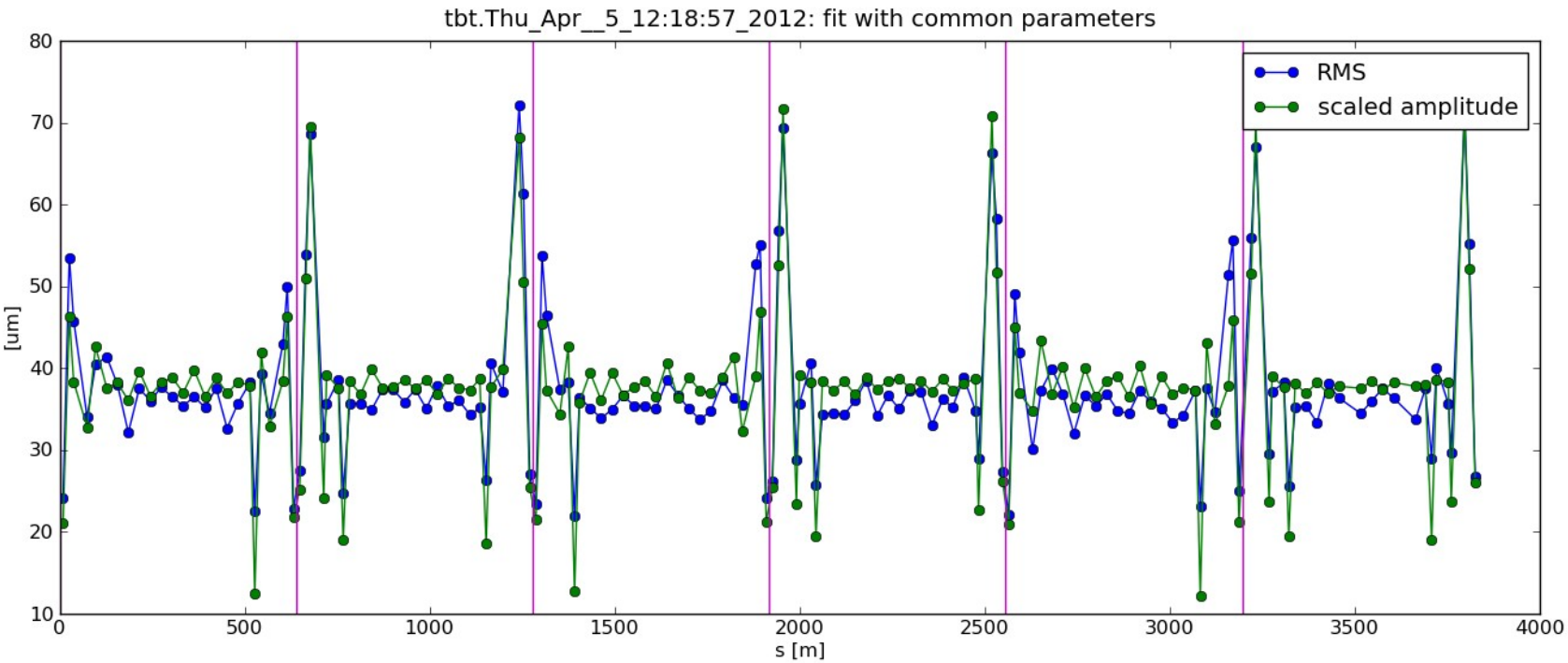
Measurement resolution

	Frequency (tune) resolution	Phase resolution	BPM resolution
Kicked beam (2012 data)	~1.3E-5	~0.2 deg	~ 30 microns horizontal ~ 20 microns vertical
Continuous excitation (2012 data)	~0.6E-5	~0.1 deg	~ 30 microns horizontal ~ 20 microns vertical
Kicked beam at store (Data from 2009)	~1.9E-5	~0.25 deg	

Measurement vs. Model



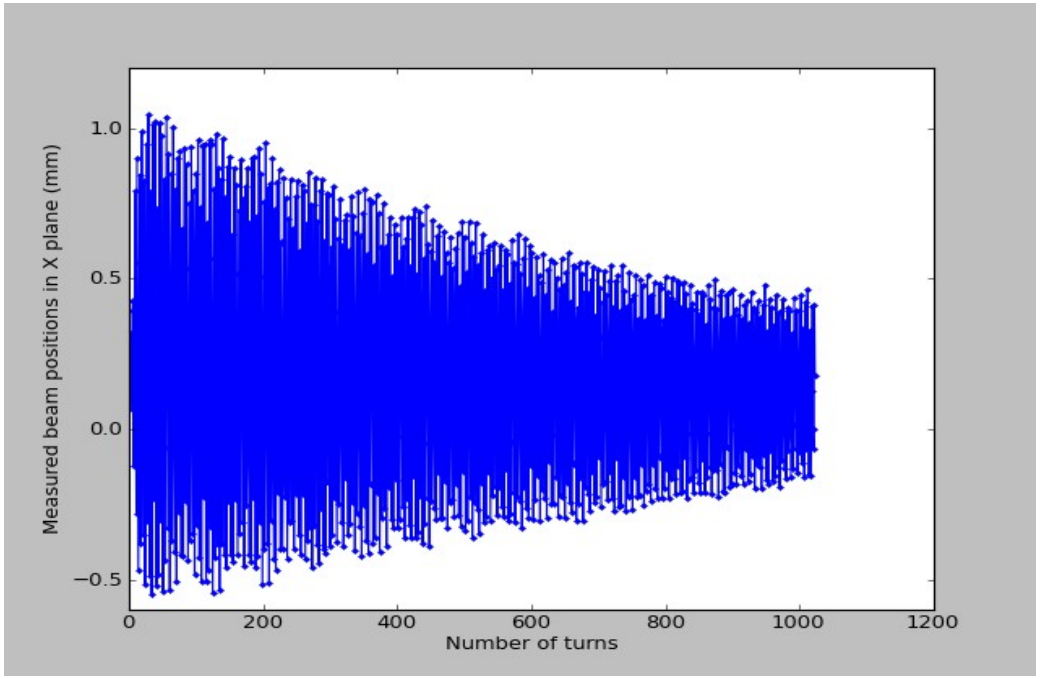
Residuals


tbt.Thu_Apr__5_12:18:57_2012: fit with common parameters
RMS
scaled amplitude
[um]
s [m]
80
70
60
50
40
30
20
10
0
500
1000
1500
2000
2500
3000
3500
4000

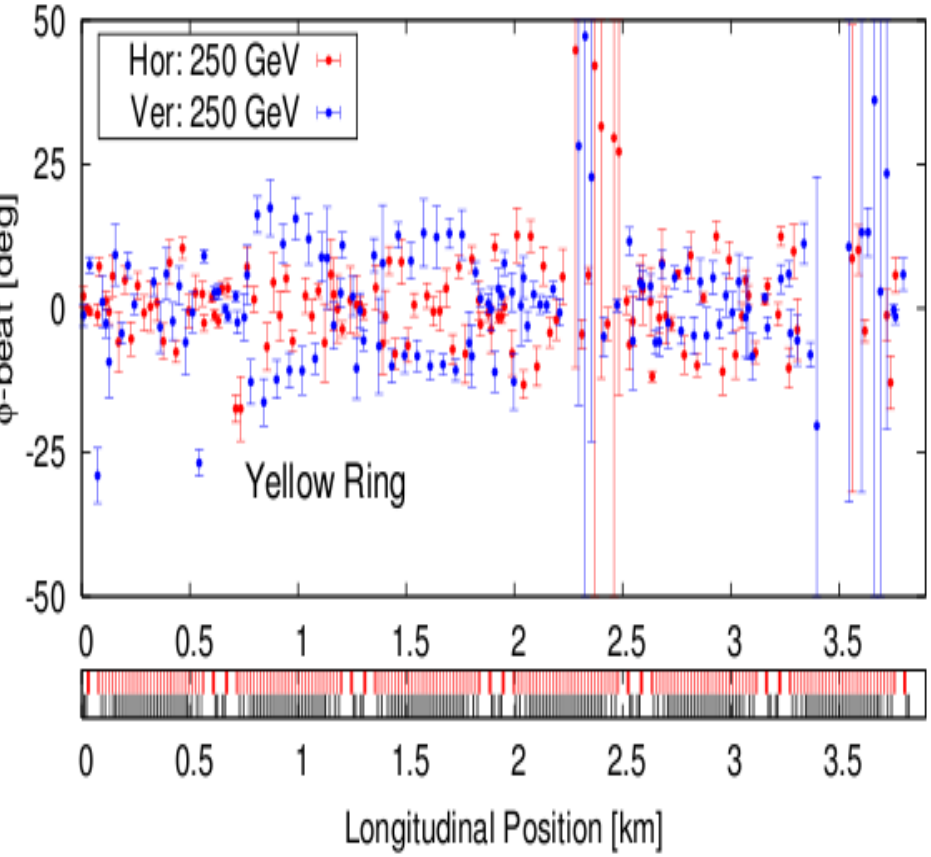
Future applications

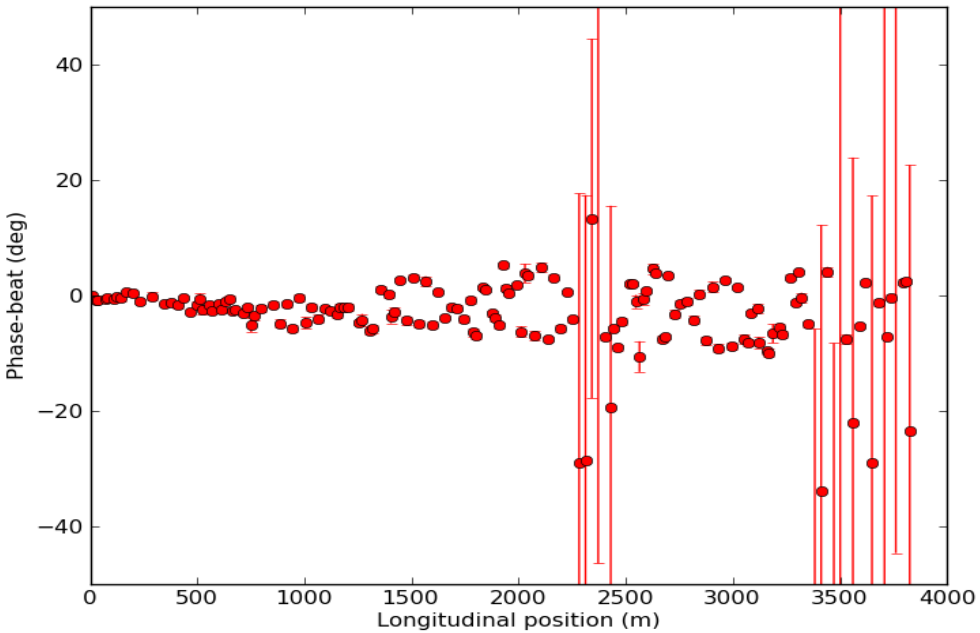
Optics measurement at store using Artus (kicked beam)

- What is the amplitude of the oscillation Artus can excite?
- Is decoherence acceptable?
- What is the precision of phase measurement?
- How good is the precision compared with that from AC dipole if analyzed with the same code?



Comparison of resolution





pp93::store, 10766, Yellow, horizontal

Better agreement between measurement and model observed with improved accuracy

Phase-beating correction

- Compare the measured response of phase increment to quads' strength

- If agreement is acceptable, correct phase increment in both planes simultaneously while maintaining constant tunes (and dispersion)

- Phase-beating correction is equivalent to beta-beating correction

[1] R. Tomás, O. S. Brüning, R. Calaga, S. D. Fartoukh, A. Franchi, M. Giovannozzi, Y. Papaphilippou, S. Peggs, and F. Zimmermann, “Procedures and accuracy estimates for beta-beat correction in the LHC,” 2006.

Impedance localization

Experiment complements C. Montag's high intensity study

(1)Inject 24 equally distributed bunches in the machine at injection, each with different intensity (as suggested by SY)
(2)Take Artus turn-by-turn data for bunches one by one
(3)Fit phase-intensity slope
(4)Calculate localized impedance based on phase increment change

http://impedance.web.cern.ch/impedance/useful_documents.htm#Localization_of_impedance_sources_in_the_SPS

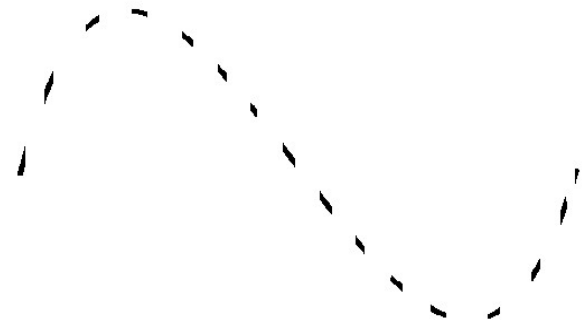
Optics measurement on the ramp

Objective: measure beta function and phase advance at periodic intervals (spaced by 1 or 2 seconds, to be determined) along the energy ramp

Motivation: document continuity of accelerator optics with particular interest at locations of known strong depolarizing resonances

Work in progress:
- document (post shutdown upgrades) measurements of data delivery times with turn-by-turn readout of BPMs (1024 turns, 4096 turns)
- if data delivery for average orbit (for orbit feedback) + turn-by-turn measurements (for optics) < 1 second, configure both acquisitions for a 1 Hz acquisition rate
- if > 1 second, configure for a 0.5 Hz acquisition rate

Sustained oscillation by ARTUS?



Envisioned kick strength from Artus

The motivation would be:

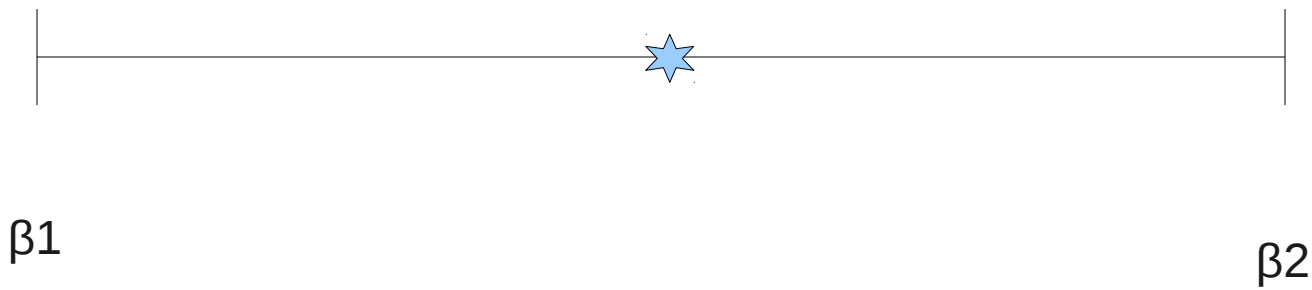
1) Overcome the faster decoherence at store

2) Get larger signals than possible with Artus now.

3) Avoid Artus-induced emittance growth by changing the amplitude adiabatically.

Beta star measurement

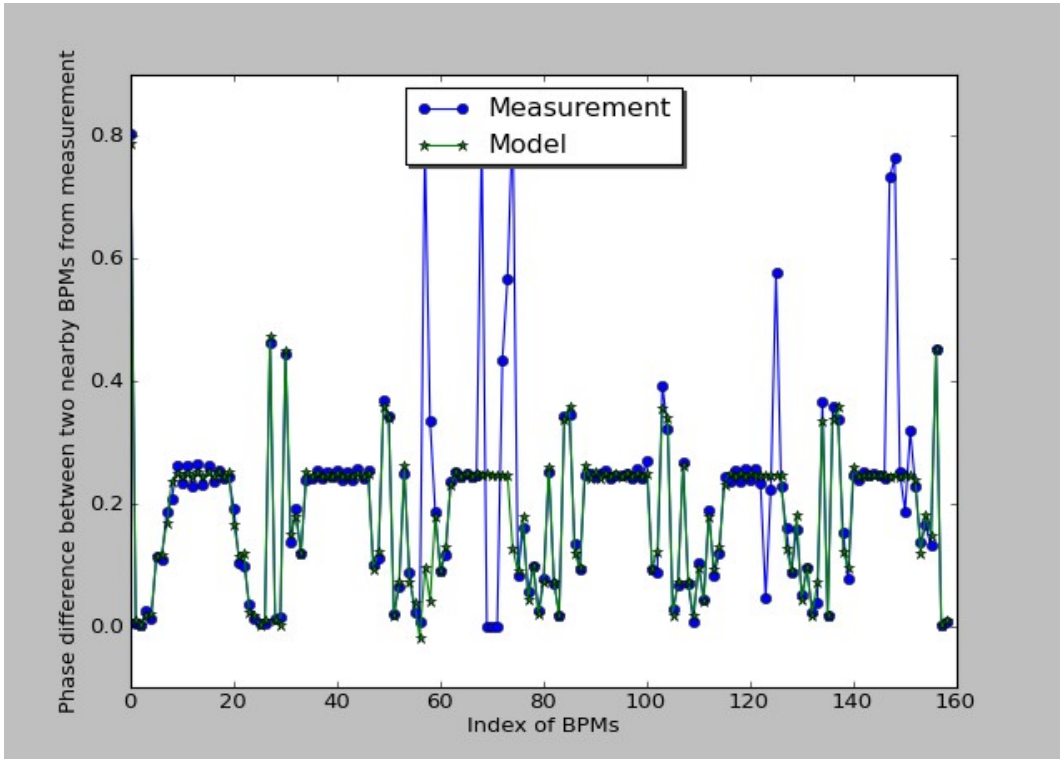
Calculate beta star based on measured beta functions at DX bpms, absolute accuracy of DX bpms do not come into play

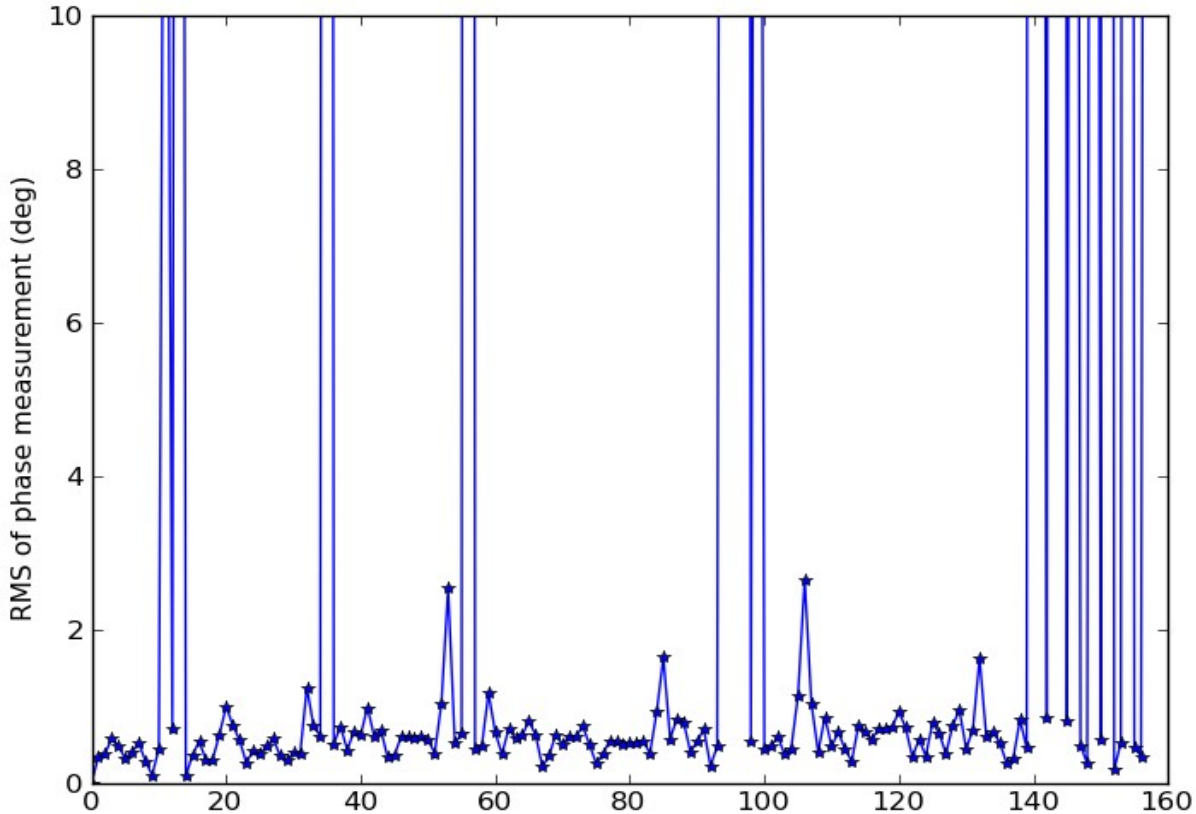


Summary

1. Tune, phase and bpm resolution measured and quantified.
2. BPM performance and "anomalies" related to beam conditions can be distinguished.

List of proposals:
1. Optics measurements with Artus data at store, compared resolution with AC dipole data;
2. Phase-beating (beta-beating) correction
3. Impedance localization
4. Optics measurements on the ramp
5. Beta stars measurements
6. Beta function measurements for IPM calibration
7. Sustained oscillation of one bunch by Artus


Measurement
Model
Phase difference between two nearby BPMs from measurement
Index of BPMs
0.0
0.2
0.4
0.6
0.8
0
20
40
60
80
100
120
140
160


RMS of phase measurement (deg)
0
2
4
6
8
10
0
20
40
60
80
100
120
140
160

Precision tune measurement

- The precision of Artus tune measurement is limited (~2.5E-4) by the data length (4096)
- A similar application is being developed by J. Kewisch with the algorithm in previous slides implemented for high precision tune (~ 1.3E-5) measurement