Model Calibration for SSRF Storage Ring

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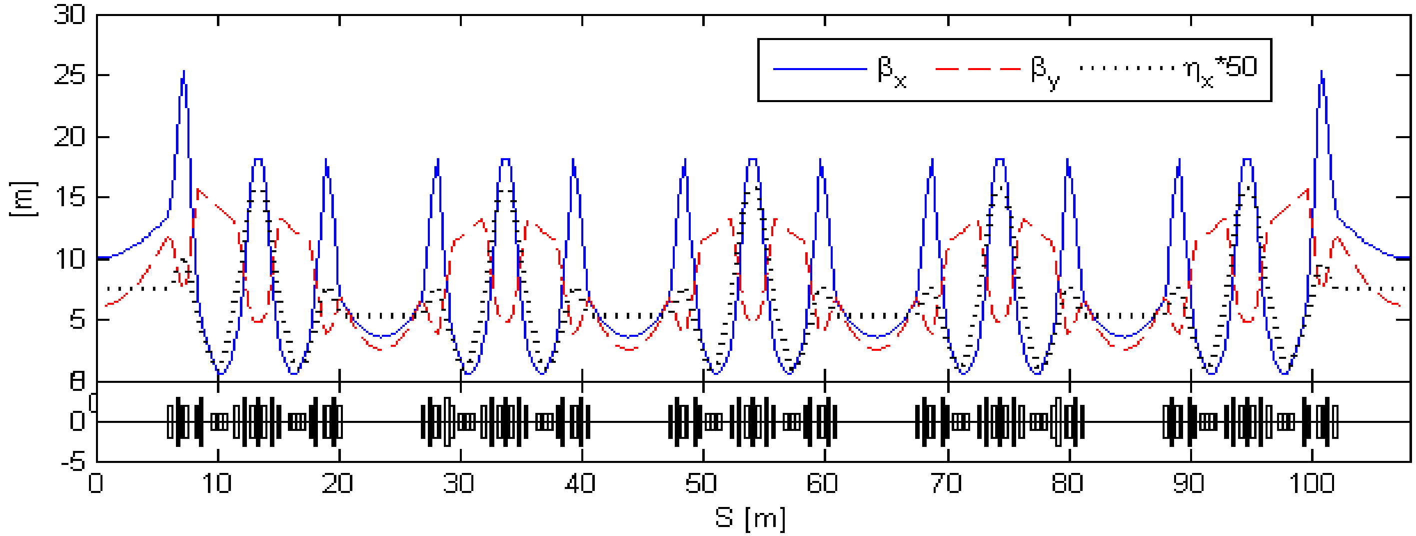
The main design values of the two nominal modes

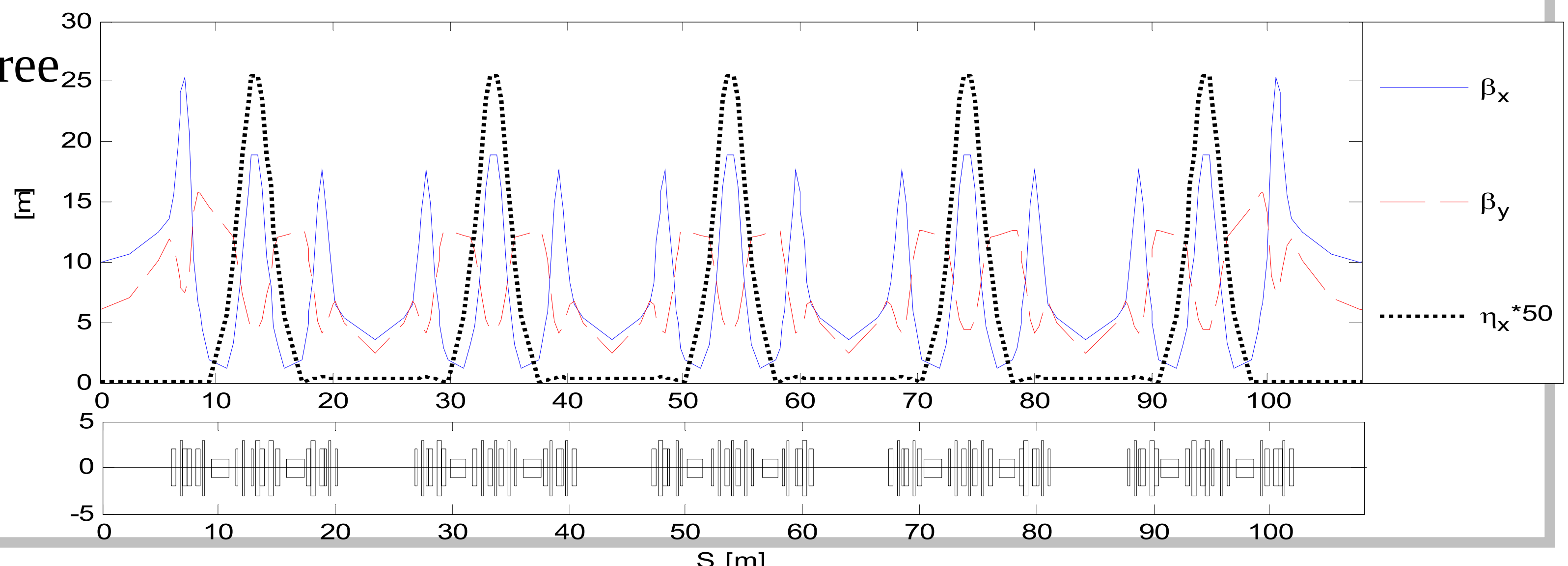
Parameters	Dispersion mode	Dispersion-free mode
Energy (GeV)	(3.0)3.5	(3.0)3.5
Circumference (m)	432	432
Cell	20(DBA)	20(DBA)
Super-period	4	4
Tune Q_x/Q_y	22.22/11.29	22.22/11.29
$\beta_x/\beta_y/\eta_x$(m) in the centers of straight sections	10/6.0/0.15 3.6/2.5/0.10	10/6.0/0 3.6/2.5/0.006
Natural emittance (nm.rad)	3.92 2.86@3.0GeV	11.4 8.4@3.0GeV
Natural chromaticity ξ_x/ξ_y	-55.64/-17.94	-55.56/-18.09
Momentum compactor	4.2118×10^{-4}	5.4249×10^{-4}
Damping partitions $J_x/J_y/J_s$	0.9968/1/2.0032	0.9960/1/2.0040
Natural energy spread (rms)	9.84×10^{-4} 8.44×10^{-4}@3.0GeV	9.84×10^{-4} 8.44×10^{-4}@3.0GeV

The optical functions of the two modes in one fold of the storage ring

Dispersion mode



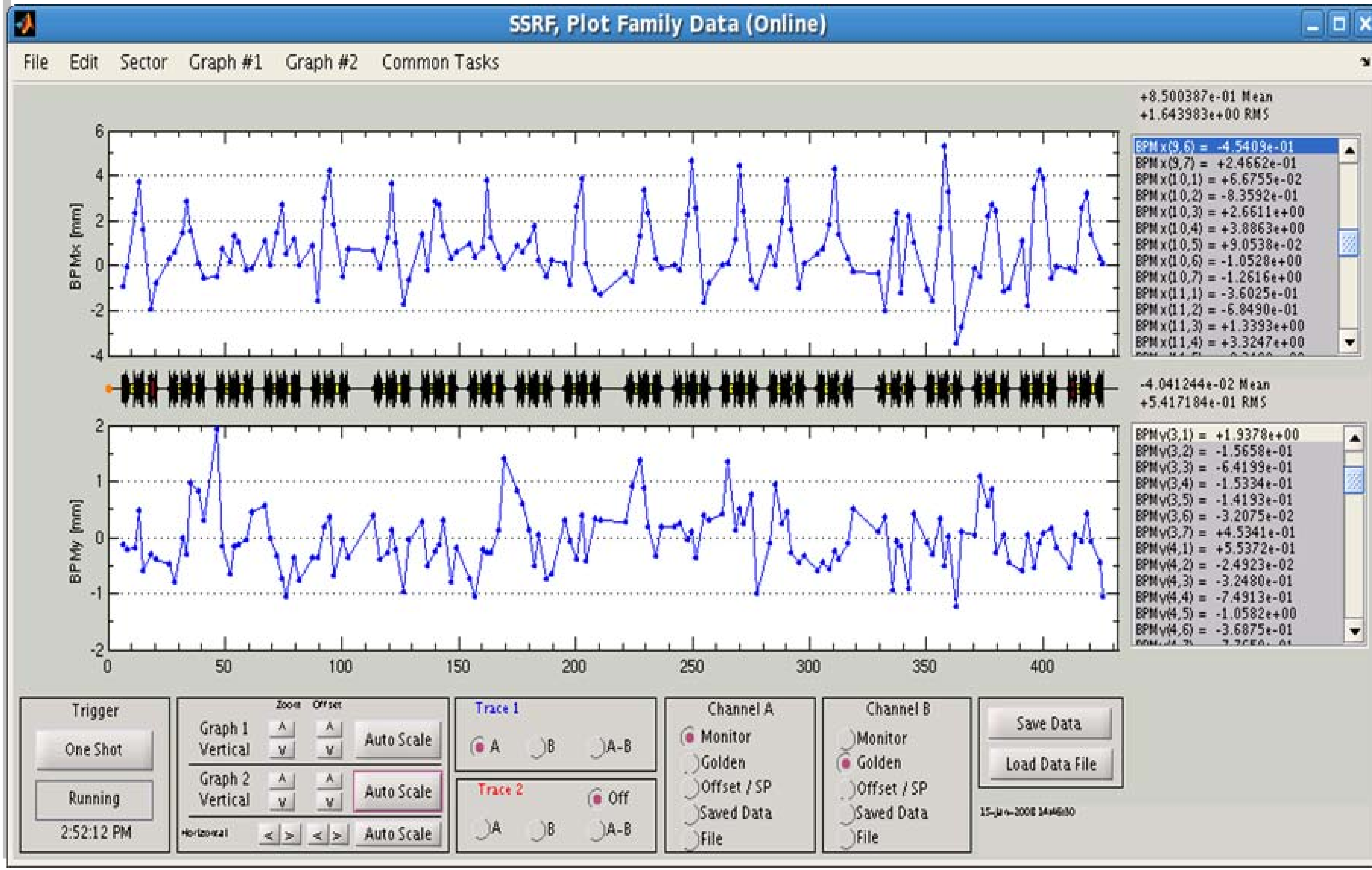
Dispersion-free mode



Calibration the model step by step

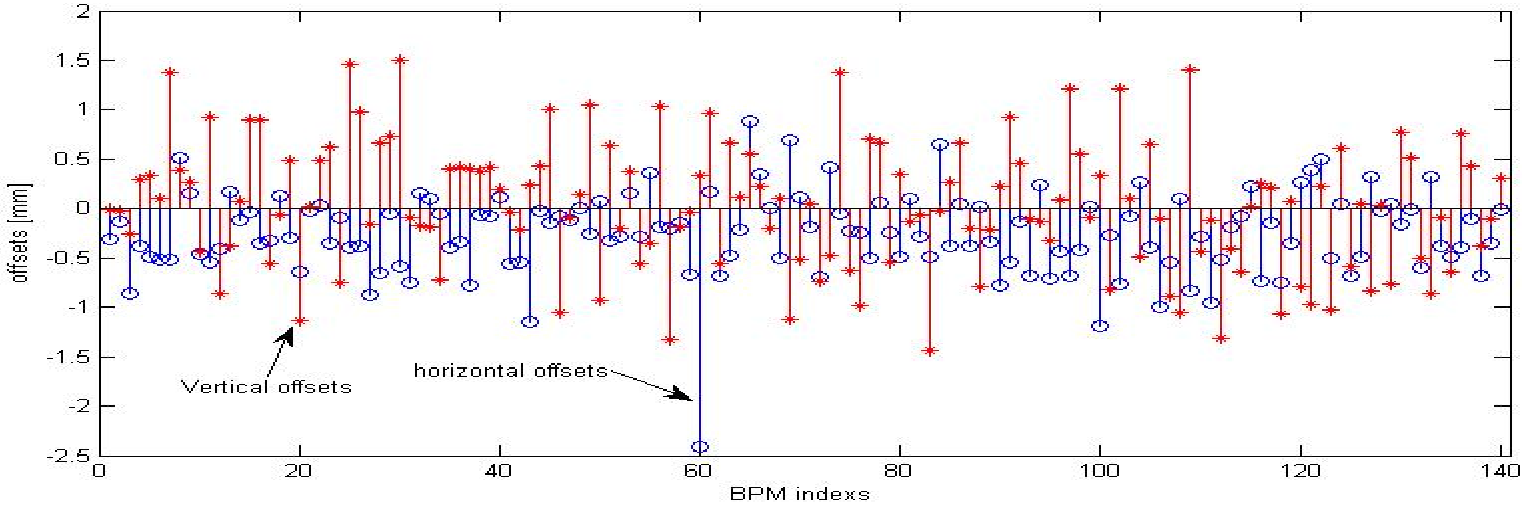
1. First commissioning: dispersion-free mode
   - Tune difference from model: 1.5(H)/0.4(V)
   - rms value of COD is about 1mm in both plane
2. Model calibration after two rounds of BBA
   - Tune difference from model: 0.03(H)/0.07(V)
   - rms value of COD is about 0.08mm in both plane
   - Bad beta function distributions
3. Model calibration with LOCO: by family
   - The measured data are almost same with the model
   - rms value of COD is less than 0.05mm in both plane
   - Working with 100mA beam current
4. Model calibration with LOCO: by magnets
   - Reduce the beta beating caused by the small errors

Step 1: Commissioning mode within the first month



Step 2: Commissioning mode after two rounds of BBA

BPM offsets
Feb. 23 2008



- After two rounds of BBA, the closed orbit can be corrected sufficiently, (x/y(RMS)=0.08mm/0.09mm @2008/2/24). With a simple scaling of magnetic coefficients, the measured optical parameters are close to the ones of the model.
- The measured tunes are 22.196/11.214, and the measured chromaticities are about -58/-16.
- Unfortunately, the measured beta functions show bad periods, and have much difference with the model!

Step 3: Commissioning mode with LOCO (By family)

- Correction of the B-I is done by fitting the quadrupole fields family-by-family with LOCO, and correction the magnetic coefficients.
- The commissioning is changed to dispersion mode after Mar. 5, 2008
- The closed orbit can be corrected to 0.07/0.08 mm (RMS) for horizontal and vertical plane respectively□
- The measured tunes (Qx/Qy) are 22.26/11.28, which is close to the designed value (22.22/11.29) further.
- The measured beta functions have good periods!

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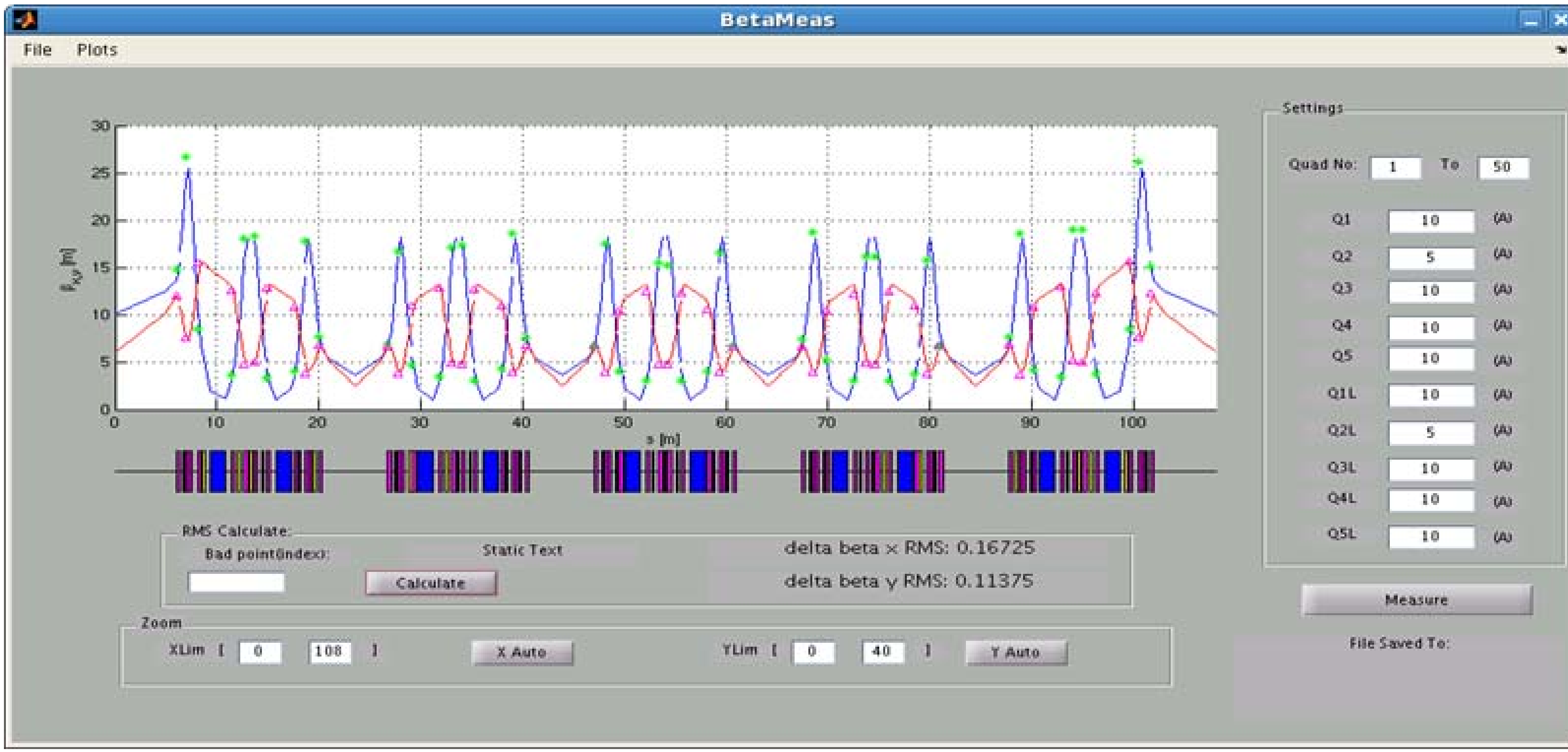
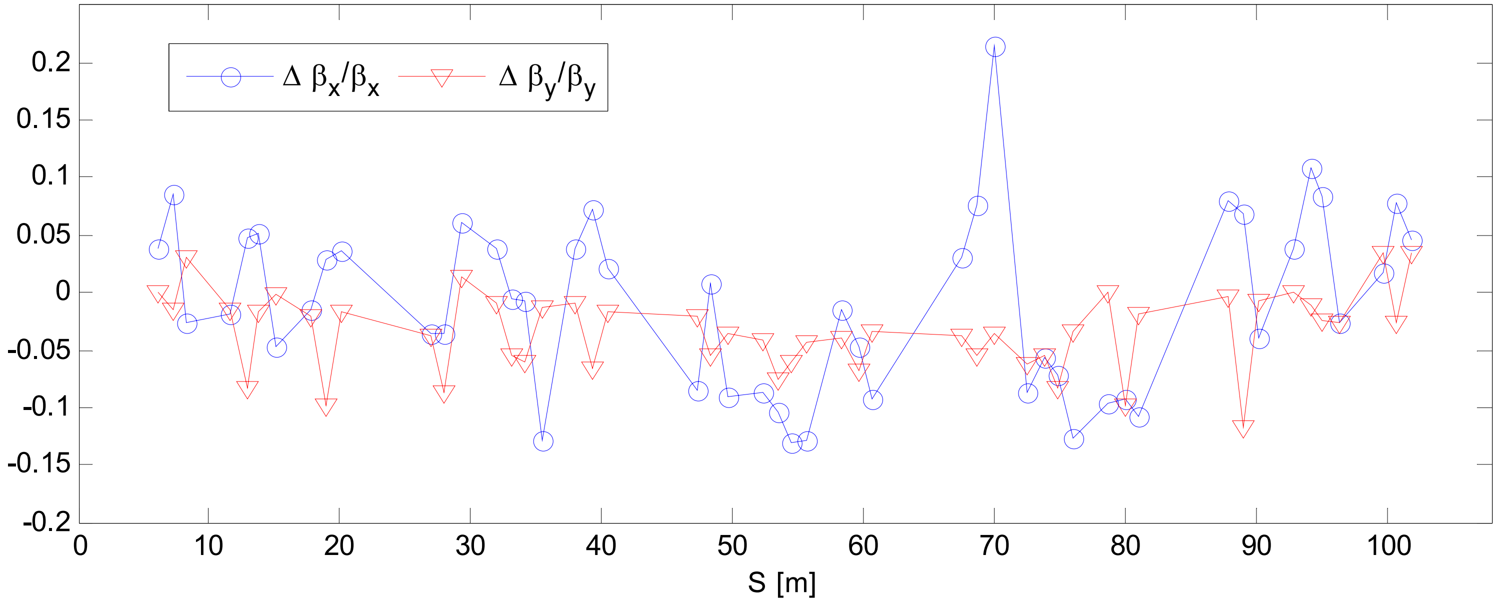
Beta functions



RMS of the beta beating between the designed mode and the measurement are calculated with following formula:

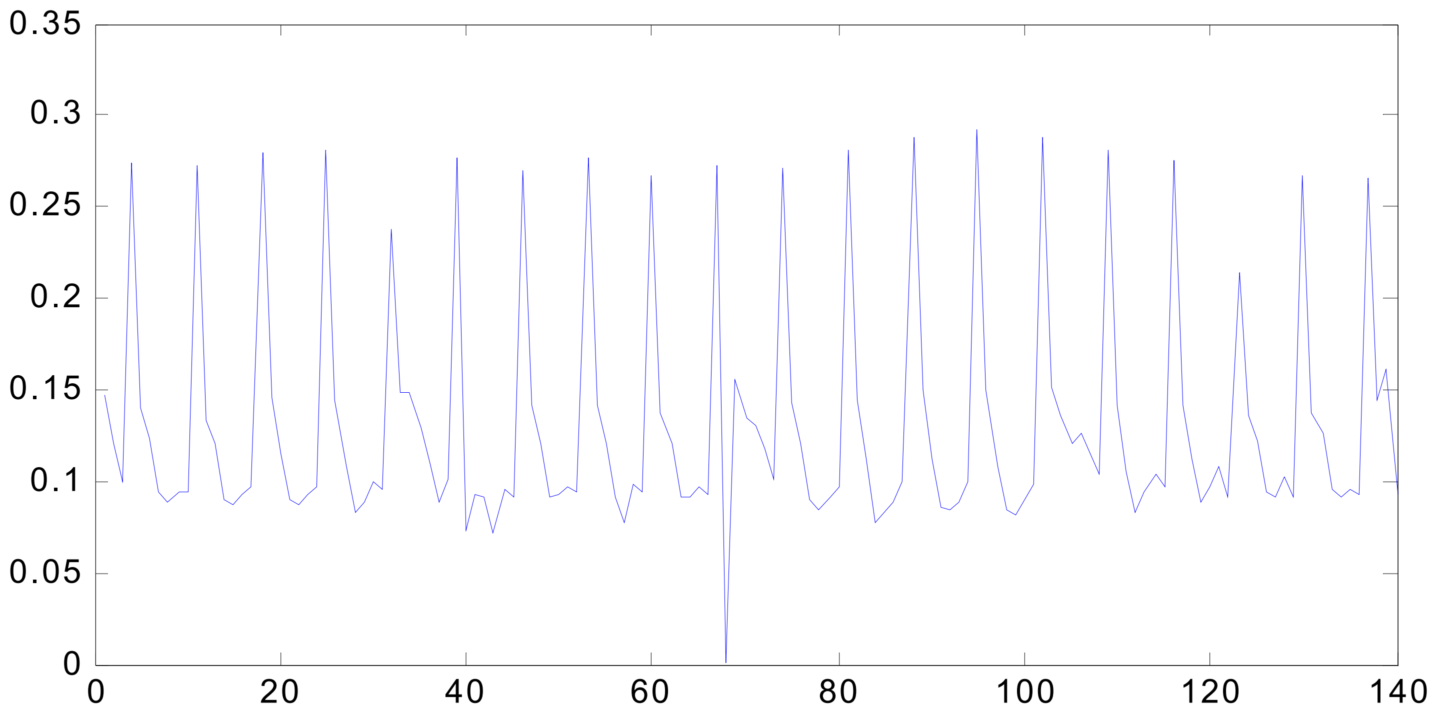
$$RMS. = \sqrt{\frac{1}{N_{Quad.}} \sum_{Quad.} \left(\frac{\Delta\beta_{x,y}^{Meas.-Mod.}}{\beta_{x,y}^{Mod.}} \right)^2}$$

Beta beating at the quadrupoles in one super-period



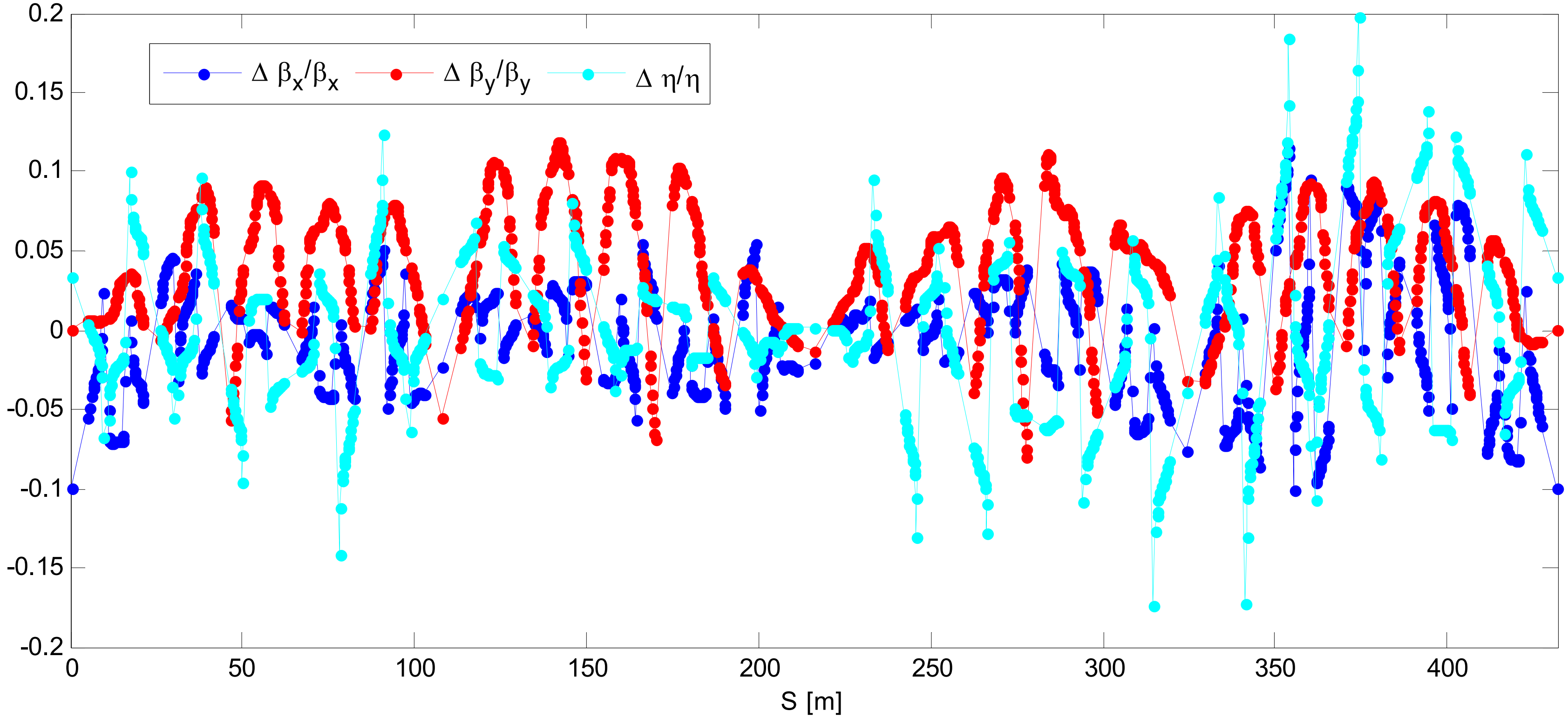
- Beta functions of the designed mode is the average values in quadrupoles.

Dispersion function



The results show that there is still some aberration between the realistic mode and the designed mode.

Beta and dispersion beatings between the LOCO model and the designed mode

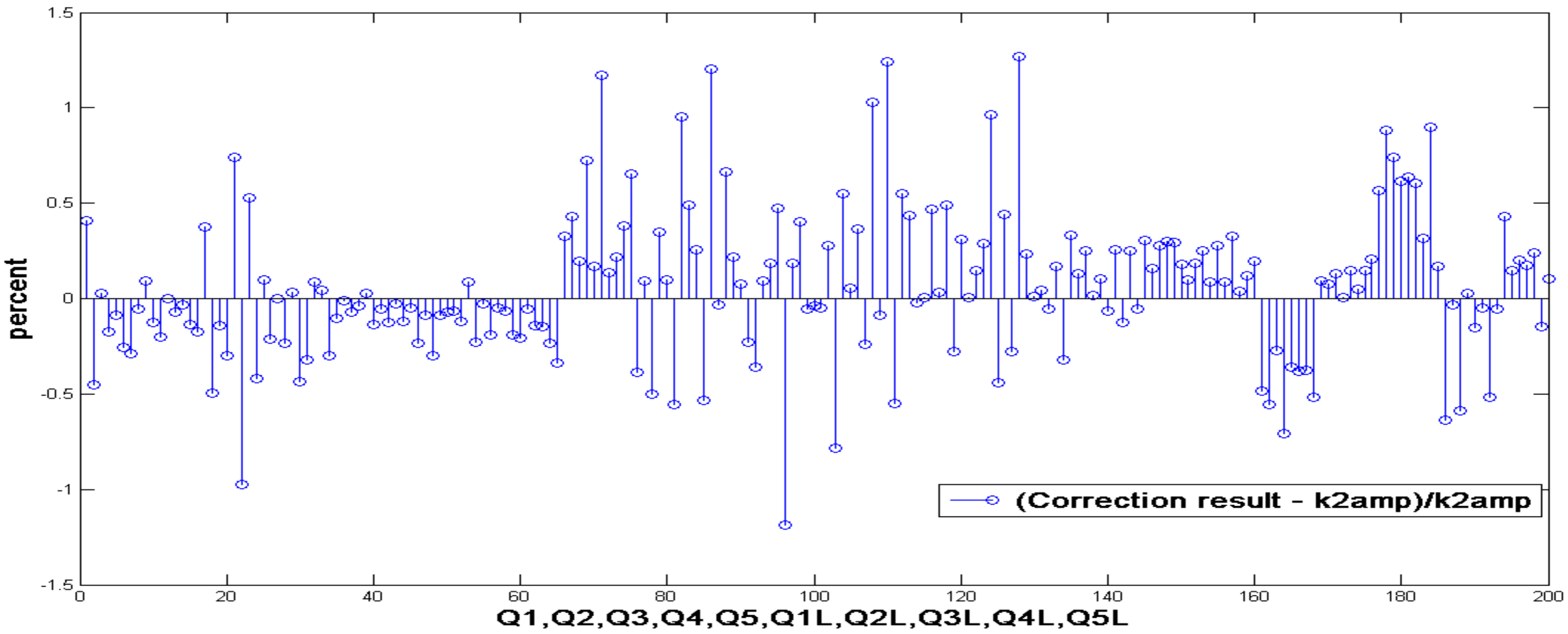


- Aberrations of the optical functions are obvious. The fact can be found both in direct measurements and LOCO measurements.

Step 4: Commissioning mode with LOCO (By magnets)

- With the little difference between model and measurement, one can use LOCO (fitting magnet-by-magnet) to calibrate the realistic mode to be closed to designed mode.
- After calibration of two rounds, the operational mode is tuned to designed mode, and the direct measured parameters are coherent to values resulting from LOCO measurements, and the designed mode.

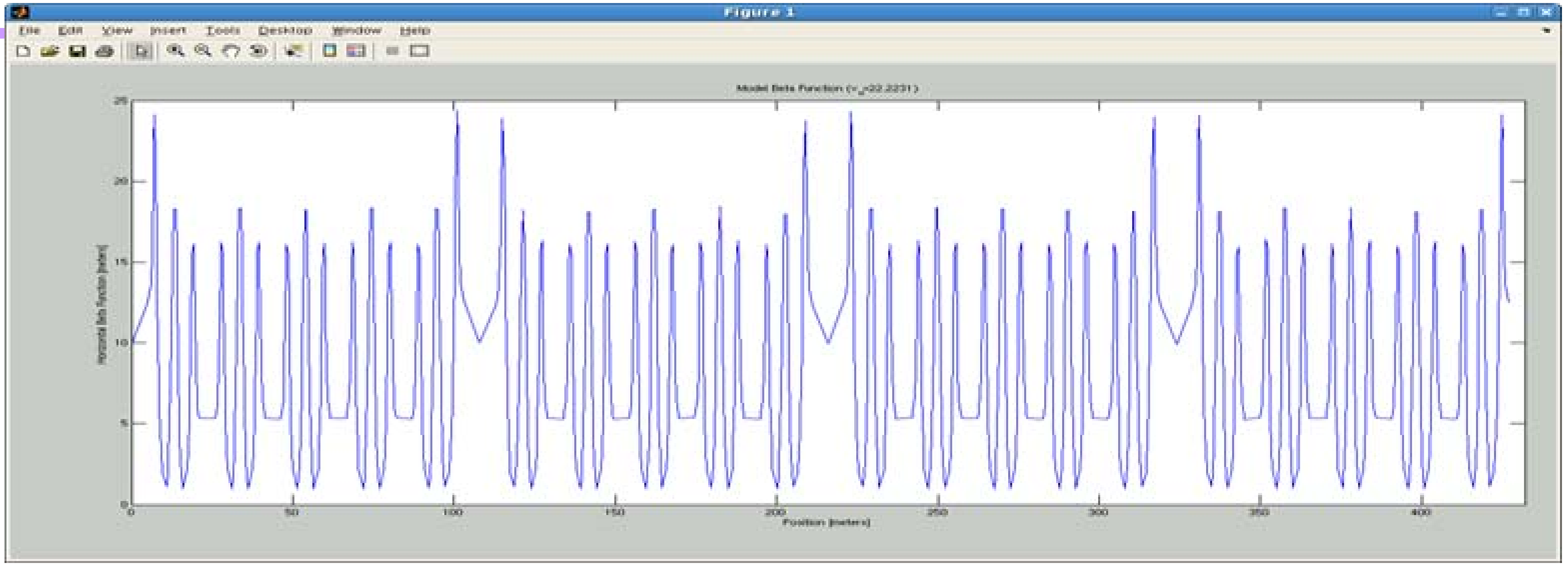
Deviations of the quadrupole gradients



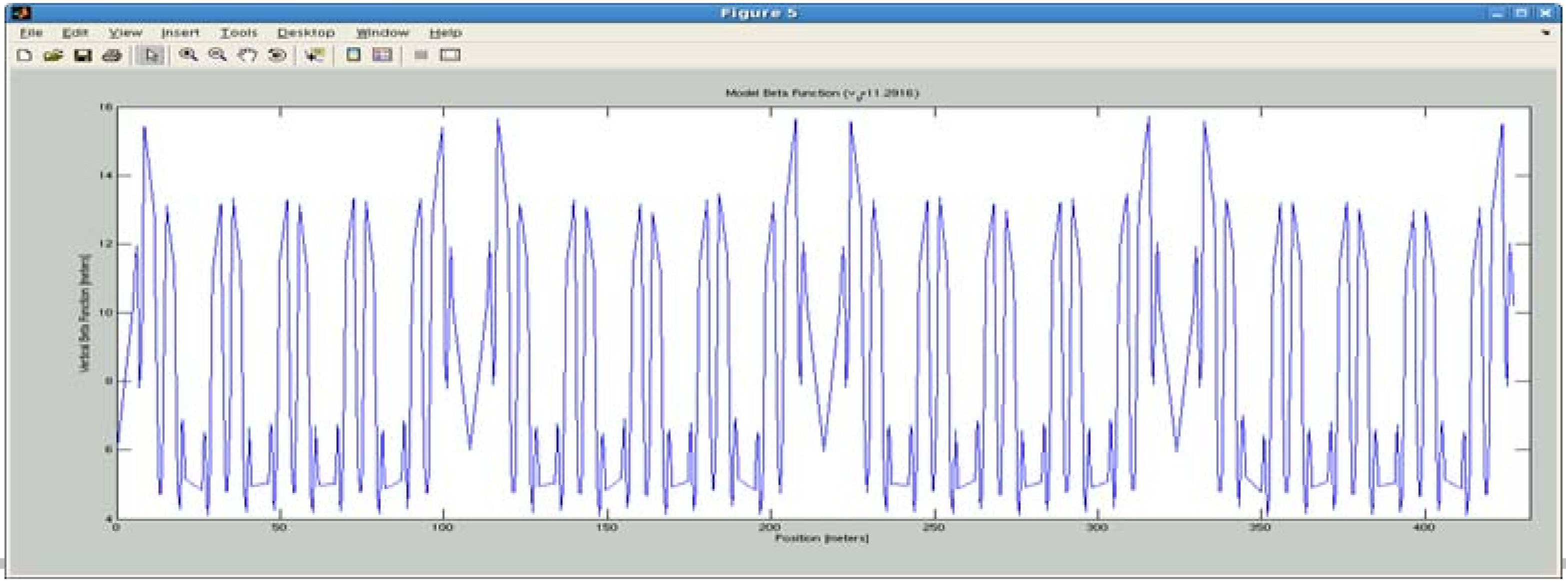
Schematic by families

Optical functions resulting from calibrated model with LOCO

Hori. beta



Vert. beta



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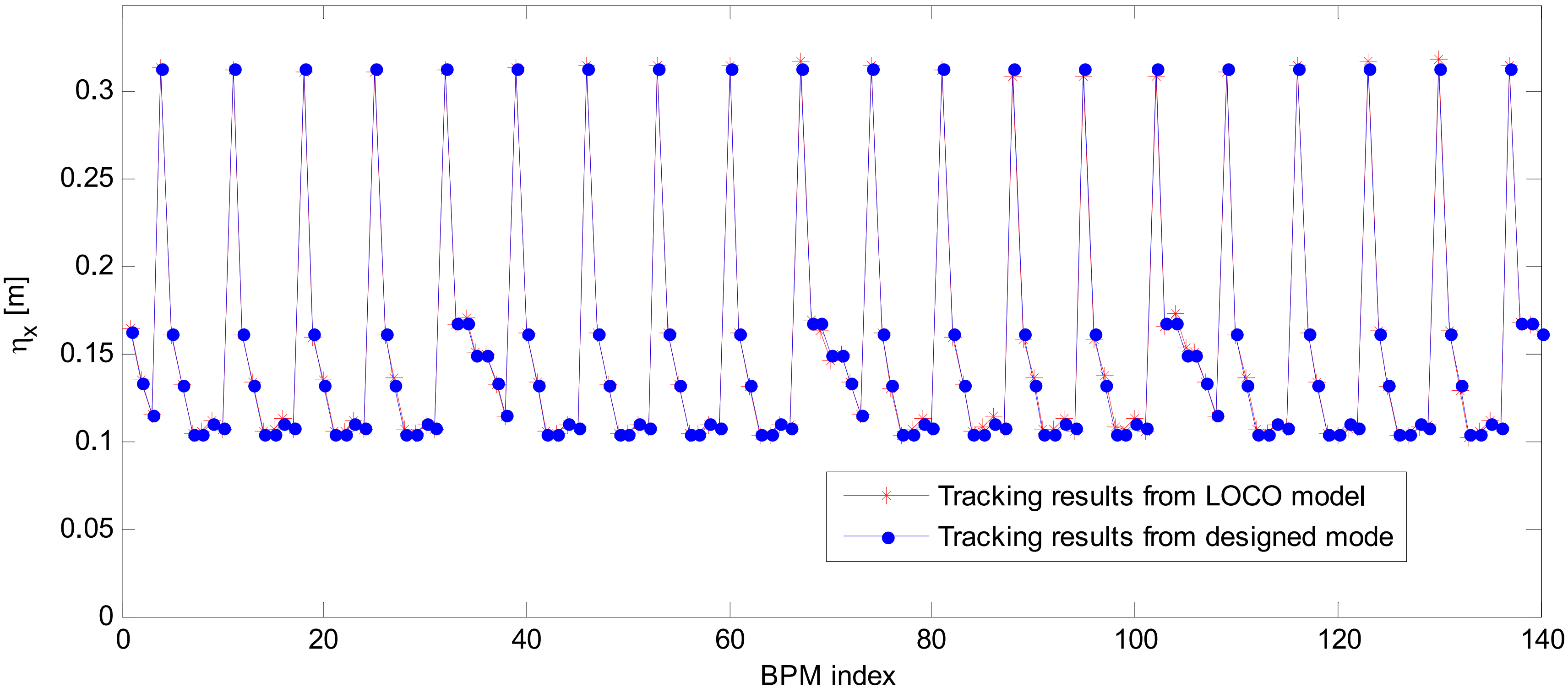
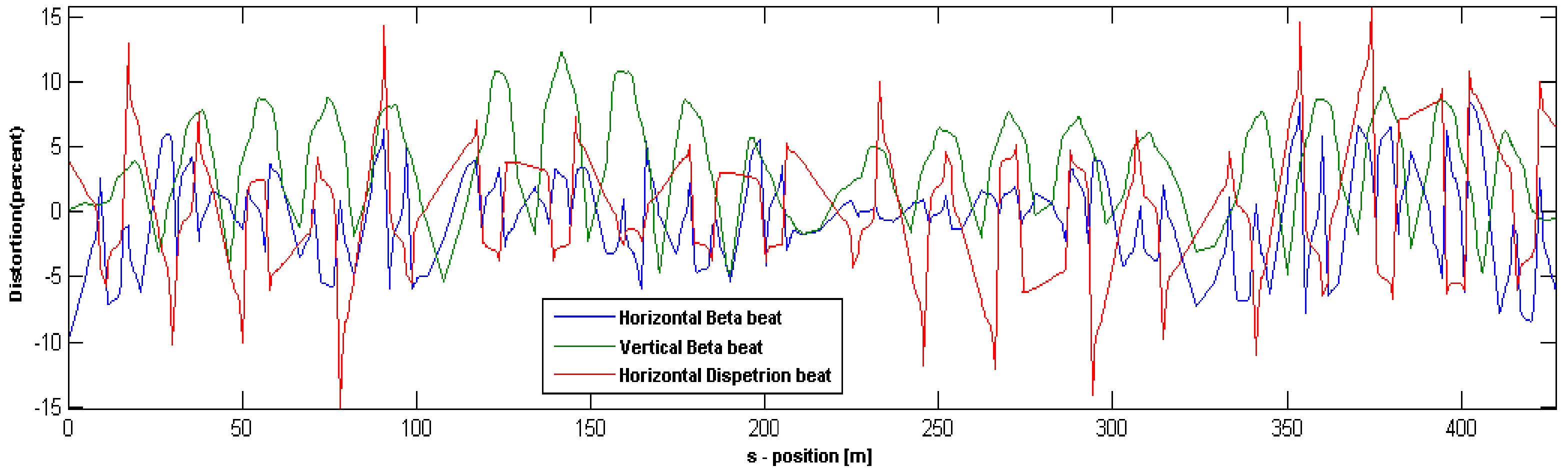
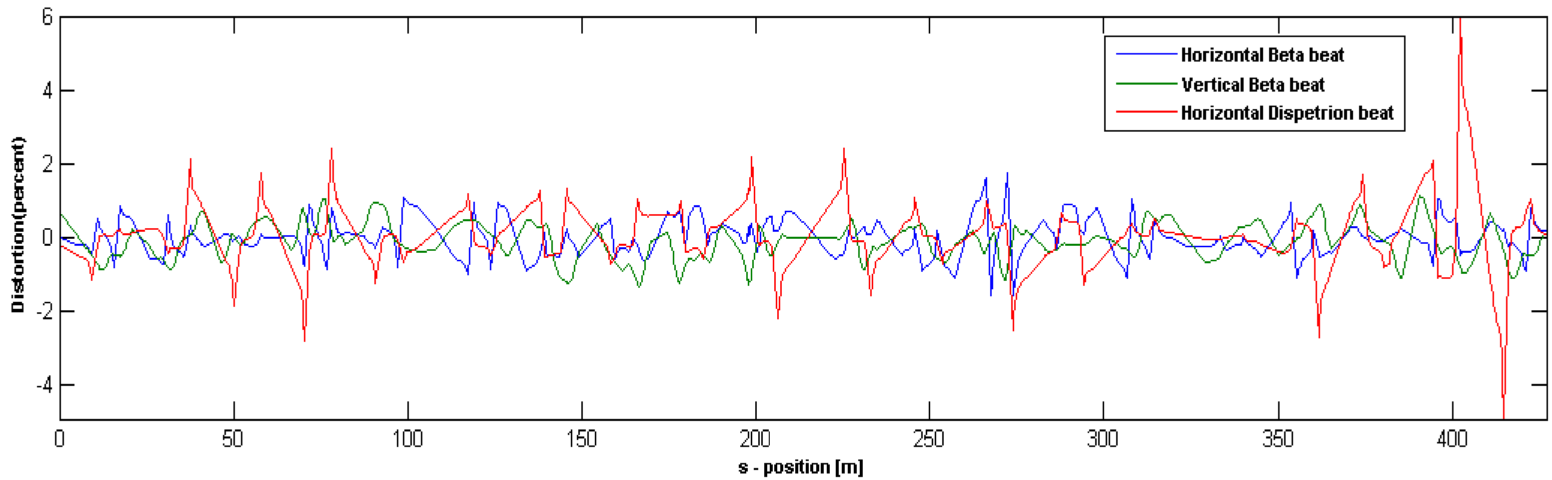
Comparison of the dispersion between the LOCO model and the designed mode tracked with AT code



Beta and dispersion beatings between the LOCO model and the designed mode





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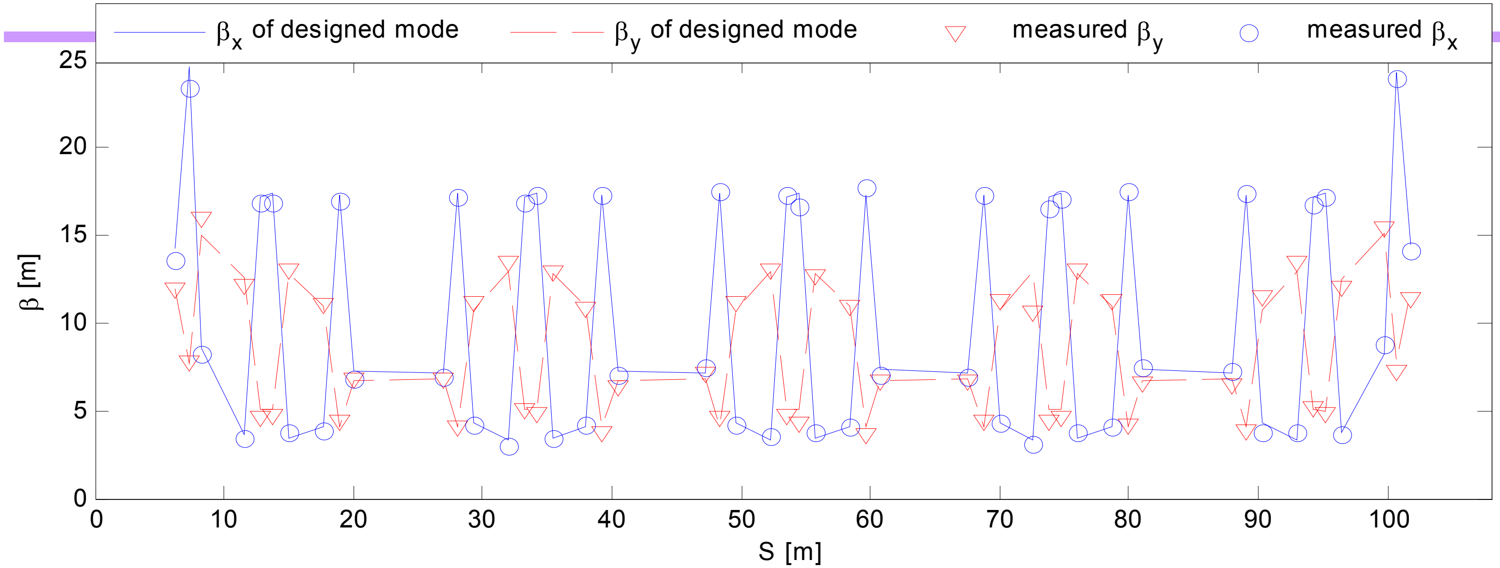
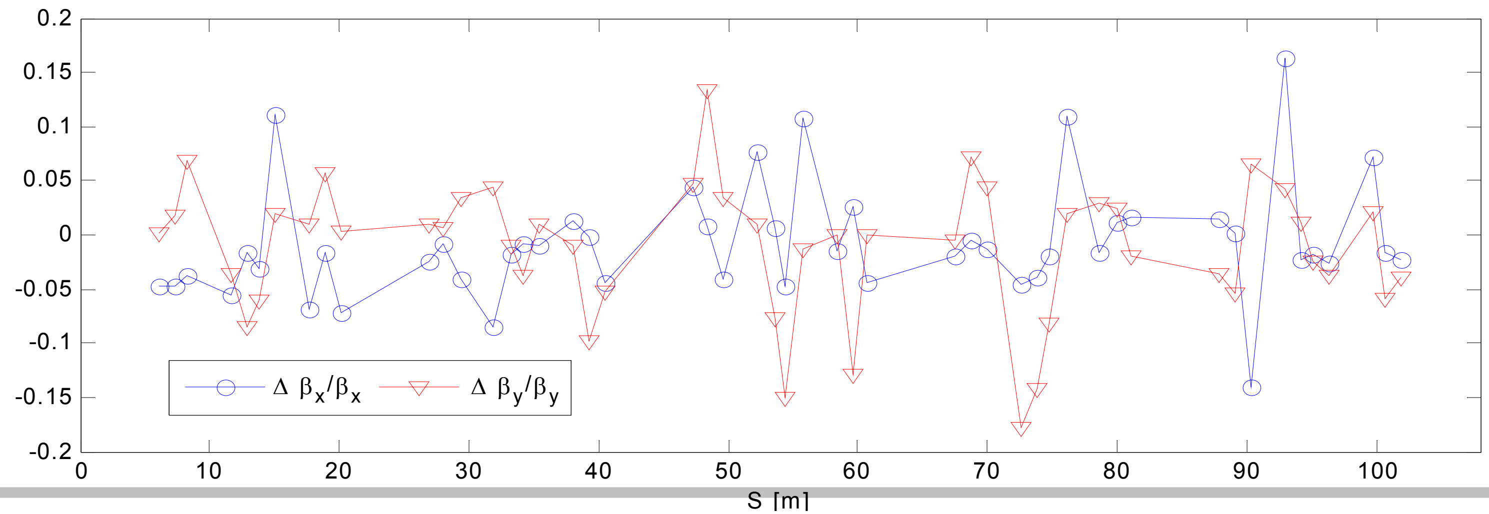
Measured beta functions and the designed values (3/18/2008)



Measured beta beating at the quadrupoles



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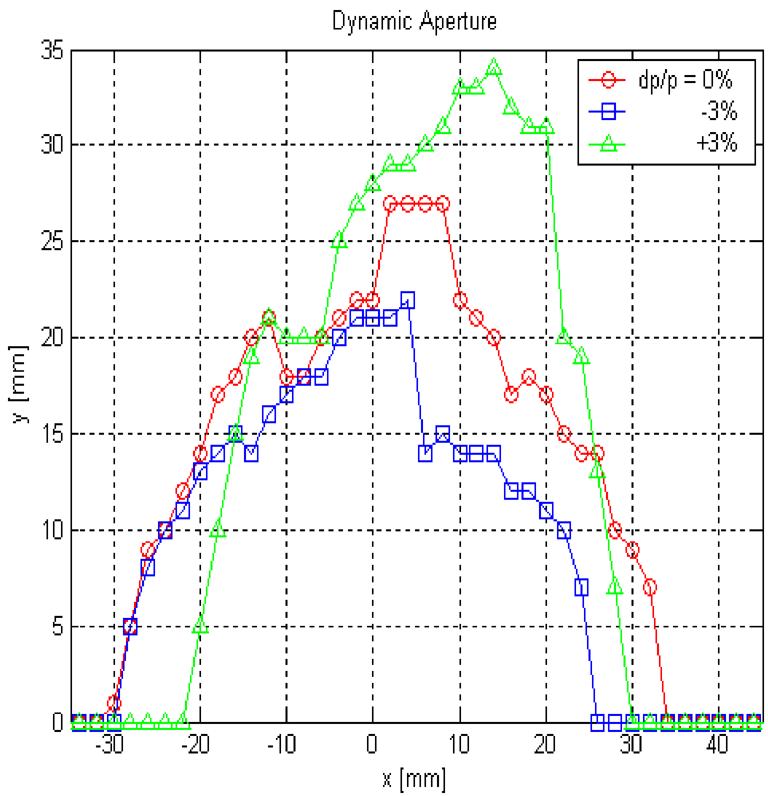
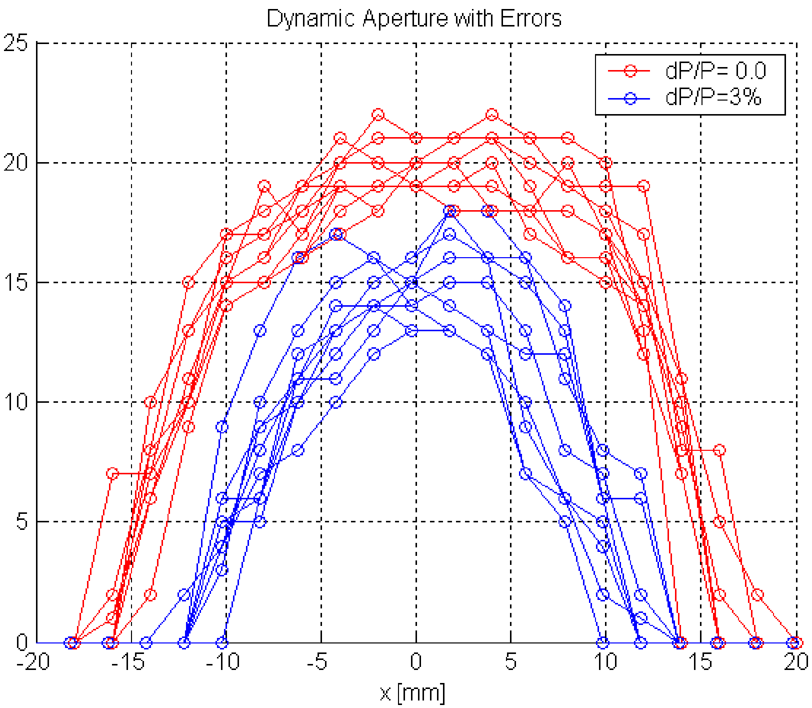
Non-linear study for SSRF

- OPA
- Frequency Map Analysis

Dynamic Aperture after Sextupole Optimization by OPA





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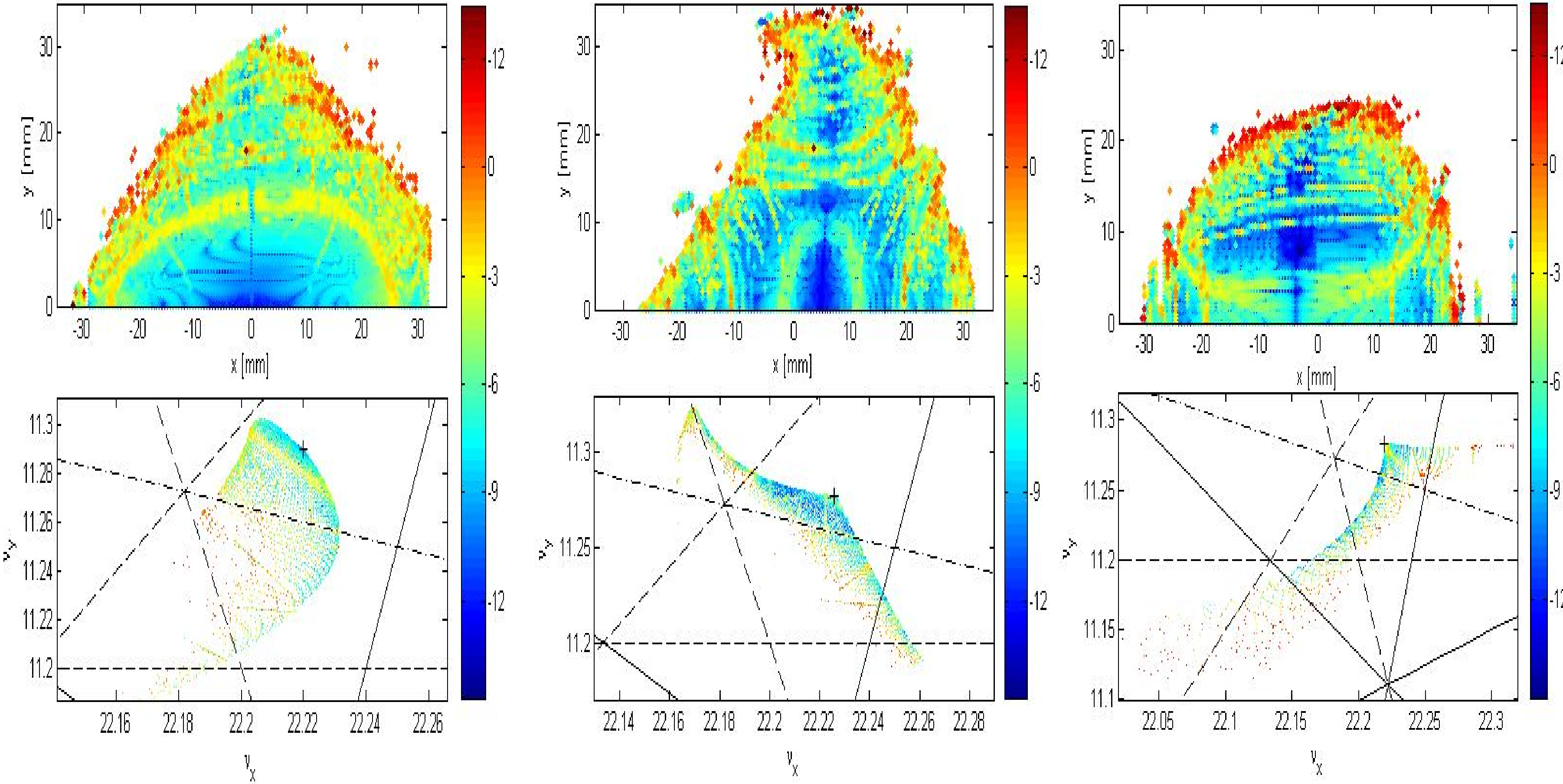
Dynamic apertures and frequency maps at the long straight section center



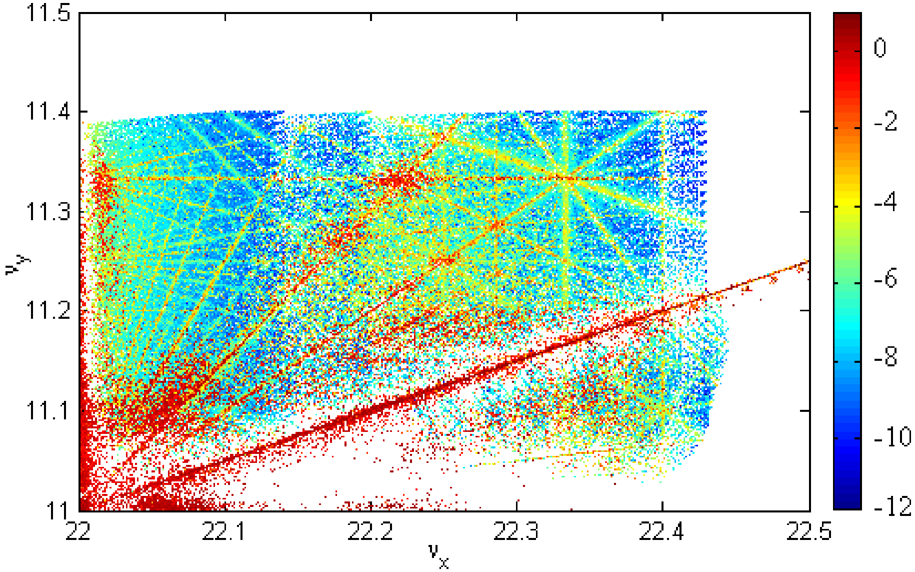
δ= 0

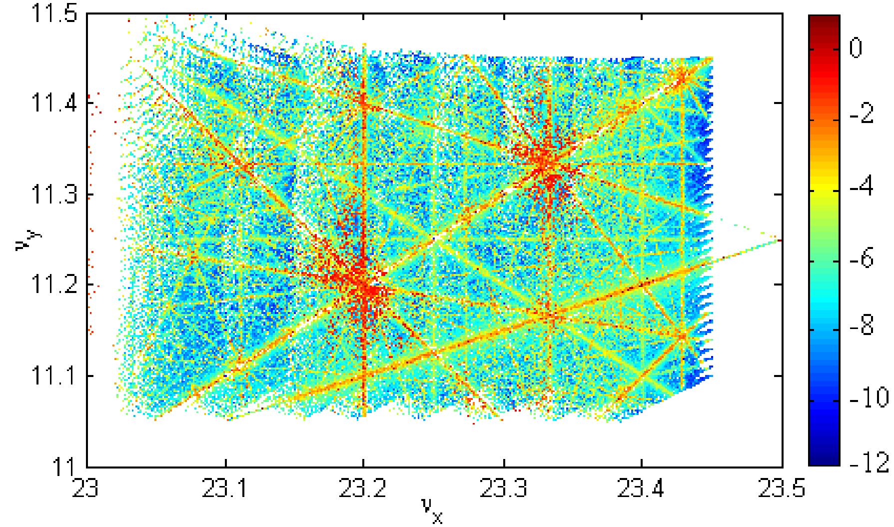
δ= 3%

δ= -3%

All the tracking turns are 1000.

Tune Scan by FMA

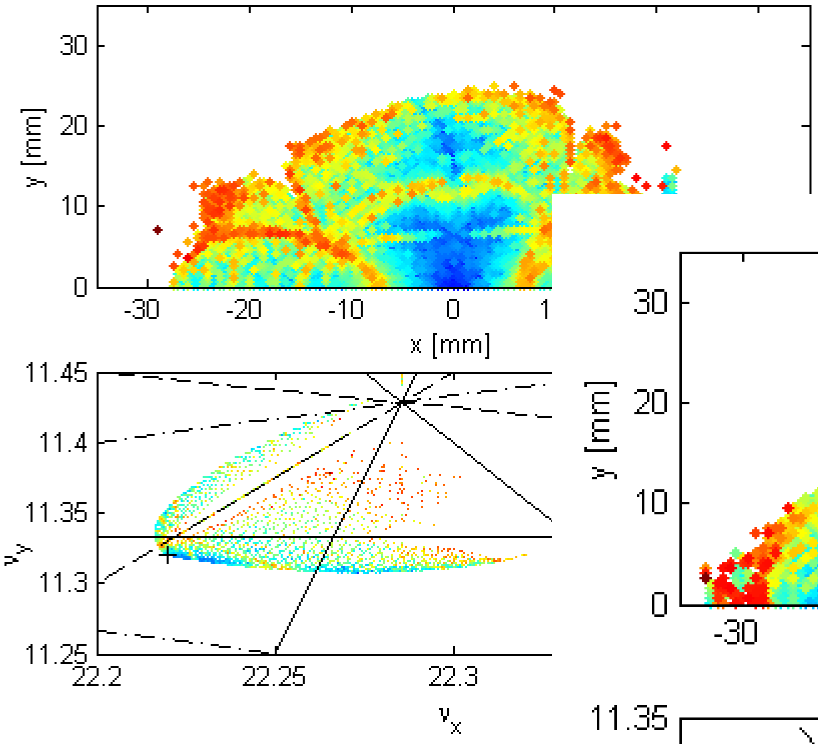


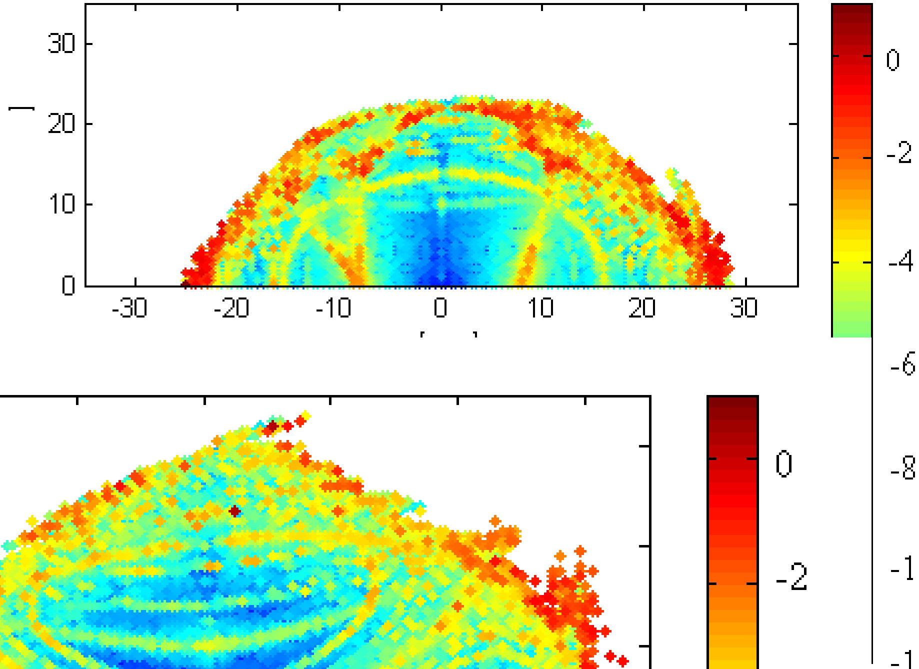


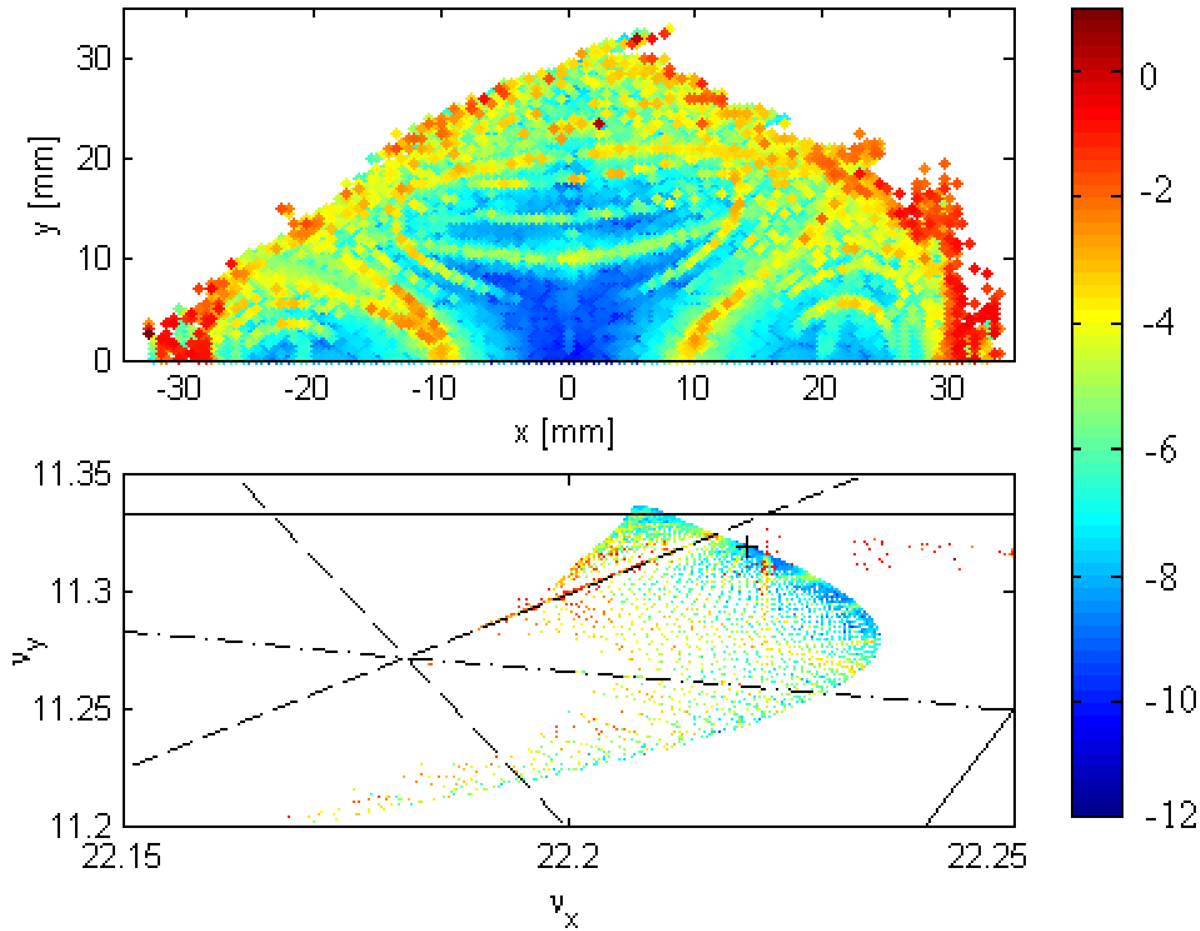
With the above results, it can be realized that some resonance lines have bad effect on the global dynamical property of the lattice, the working point of the SSRF storage ring should be apart from these resonances:

- The second order coupling resonances;
- The third order regular resonances excited by normal sextuples, especially the structural ones;
- The higher order regular structural resonances up to the sixth order.

Sextupole Optimization by FMA







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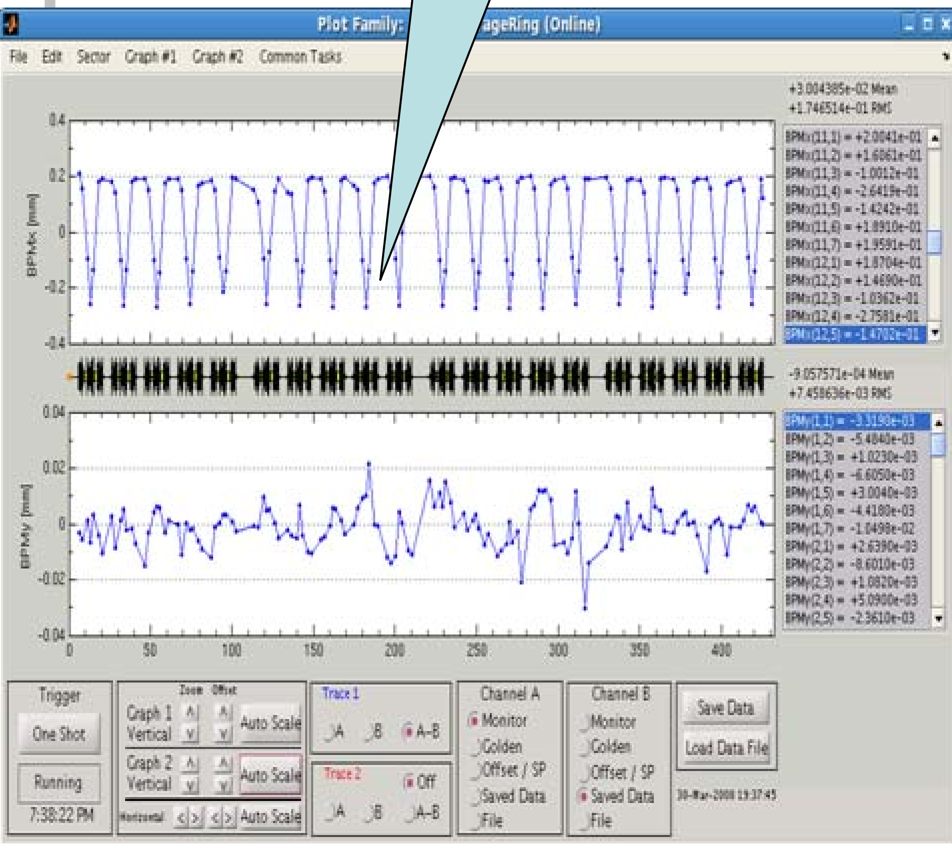
Some phenomena from SSRF commissioning

- Accuracy of the BBA result is depends on the closed orbit distortion, so that we have to make local bump during BBA measurement.
- The closed orbit will change with the sextupole strength, it seems there is an extra dipole field in sextupole, and this will bring us more trouble with the non-linear model calibration for SSRF storage ring.

SF +10%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ageRing (Online)
File Edit Sector Graph #1 Graph #2 Common Tasks
BPMx [mm]
BPMy [mm]
Trigger
One Shot
Running
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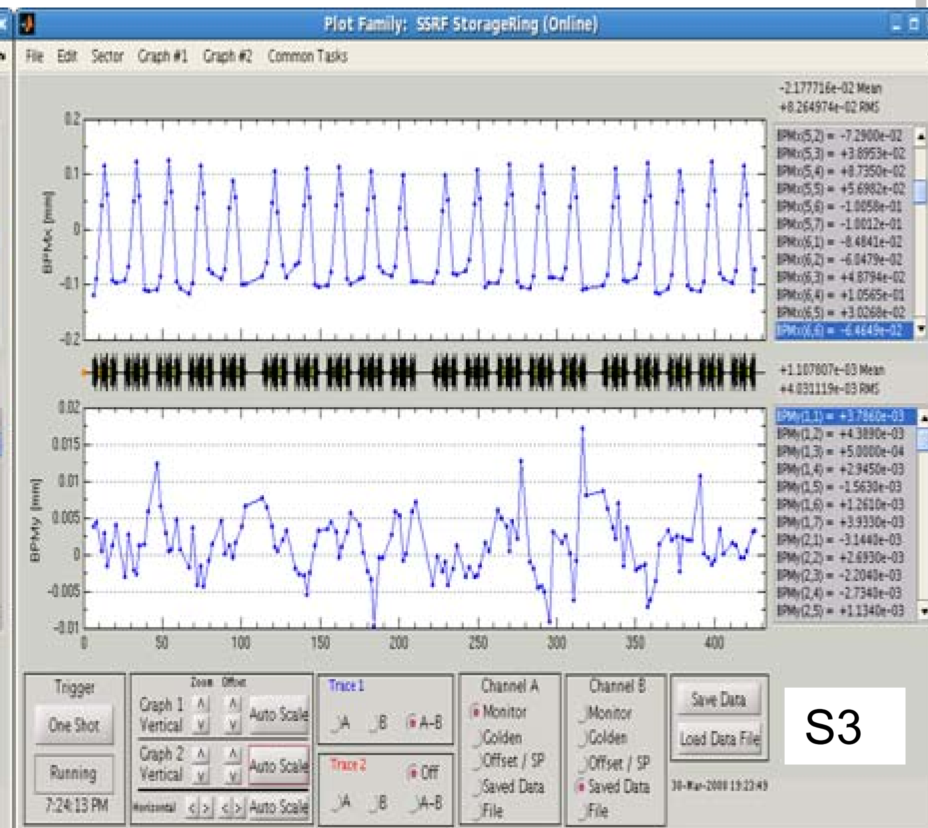
Auto Scale
Trace 1
Trace 2
Channel A
Channel B
Monitor
Golden
Offset / SP
Saved Data
File
Save Data
Load Data File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File Edit Sector Graph #1 Graph #2 Common Tasks
BPMx [mm]
BPMy [mm]
Trigger
One Shot
Running
7:24:13 PM
Auto Scale
Trace 1
Trace 2
Channel A
Channel B
Monitor
Golden
Offset / SP
Saved Data
File
Save Data
Load Data File

S3

conclusions

- The mode has been calibrated efficiently, the beta beating is less than 2%.
- Nonlinearity of the storage ring should be analyzed in the future, such as the dynamic aperture and the appropriate corrected chromaticities. The nonlinear optimization should be well done to improve the injection efficient and beam lifetime.
- Recently, SSRF is running with three normal cavities, the maximum RF voltage is about 1.2MV, and the over-voltage factor is only 1.5.