Emittance optimization for SUPERB and experimental results from DIAMOND

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Diamond aerial view

Diamond is a third generation light source open for users since January 2007

100 MeV LINAC; 3 GeV Booster; 3 GeV storage ring

2.7 nm emittance – 300 mA – 18 beamlines in operation (10 in-vacuum small gap IDs)

Courtesy R. Bartolini

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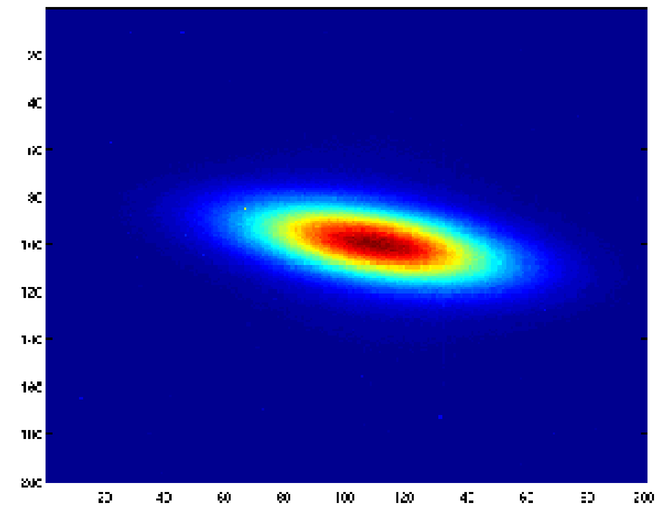
Measured emittances

Coupling without skew quadrupoles off K = 0.9%

(at the pinhole location; numerical simulation gave an average emittance coupling 1.5% ± 1.0 %)



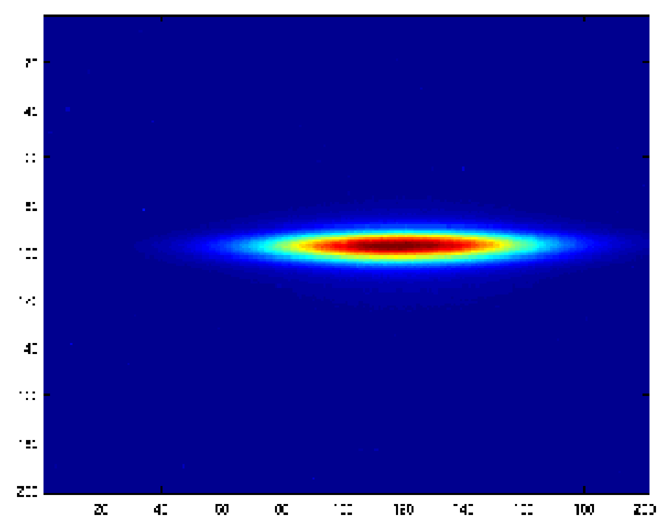
Emittance [2.78 - 2.74] (2.75) nm

Energy spread [1.1e-3 - 1.0-e3] (1.0e-3)

After coupling correction with LOCO (2*3 iterations)

1st correction K = 0.15%

2nd correction K = 0.08%



V beam size at source point 6 μm

Emittance coupling 0.08% → **V emittance 2.2 pm**

Variation of less than 20% over different measurements

SuperB

(Bold: computed values)		V12		V13		V14	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	$cm^{-2}\ s^{-1}$	1.00E+36		1.00E+36		1.01E+36	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18
Circumference	m	1258.4		1263.5		1159.5	
X-Angle (full)	mrad	66		66		66	
b_x @ IP	cm	2.6	3.2	2.6	3.2	2.6	3.2
b_y @ IP	cm	0.03	0.02	0.03	0.02	0.03	0.02
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.25	0.25
Emittance x (without IBS)	nm	1.97	1.82	2.09	1.93	1.90	1.82
Emittance x (with IBS)	nm	2.07	2.37	2.19	2.51	2.00	2.37
Emittance y	pm	5.17	5.92	5.49	6.27	4.99	5.92
Bunch length (zero current)	mm	4.69	4.29	4.8	4.4	4.53	4.29
Bunch length (full current)	mm	5	5	5	5	5	5
Beam current	mA	1892	2447	1930	2470	1892	2447
Buckets distance	#	2		2		2	

Tests in progress at **Diamond Light Source** for the new correction schemes suggested for SuperB in order to achieve the desired vertical emittances.

Short term goal: to compare with LOCO

Long term goal: reduce V emittance below 2.2 pm

Response matrix technique: Orbit Steering

Orbit Response Matrix M is defined as:

$$\vec{y} = M\vec{\theta} \qquad\qquad M_{i,j} = \frac{\Delta y_i}{\Delta \theta_j}$$

Y_i is the vertical orbit measured at BPM & Θ_j is the corrector angle.

$$\vec{y} - M\vec{\theta} = 0$$

Pseudo Inversion with SVD of the matrix M provides a set of correctors Θ that sets to zero all monitor readings.

$$\vec{\theta} = SVD(M)^{-1}\vec{y}$$

Same may be done in the horizontal plane

Response matrix technique:
Dispersions Free Steering

Dispersion Free Steering is as orbit free steering but:

$$\begin{pmatrix} (1-\alpha)\vec{y} \\ \alpha\vec{\eta} \end{pmatrix} = \begin{pmatrix} (1-\alpha)M_{\vec{y}} \\ \alpha M_{\vec{\eta}} \end{pmatrix} \vec{\theta}$$

Y is the vertical orbit measured at bpm, Θ is the corrector angle, η the vertical dispersion as measured at the bpm, α is a relative weight.

Again, pseudo Inversion with SVD of the matrix M provides a set of correctors Θ that sets to zero simultaneously orbit and dispersion.

Same may be done in the horizontal plane, considering the non zero horizontal dispersion in solving the system.

New correction scheme:
Orbit and Dispersion Free Steering + Coupling and Beta-Beating Free Steering

$$m\left\{\begin{pmatrix} (1-\alpha-\omega)\cdot\vec{y} \\ \alpha\cdot\vec{\eta}_y \\ \omega\cdot ORM_{VC\vec{x}} \\ \omega\cdot ORM_{HC\vec{y}} \\ \vdots \end{pmatrix}\right. = M_{m\times n}\left.\begin{pmatrix} \vec{\theta}_y \\ \vec{K}_{skq} \\ \vec{T}_{tilts} \end{pmatrix}\right\}n$$

Measured at BPM

+ 2 (or more) columns of the off diagonal Orbit Response Matrix, being the vertical orbit generated by a Horizontal correctors (HC) and vice versa.
+ Skew quadrupole gradients may be added as correctors.
+ Tilts may be detected from dispersion and coupling vectors measurements adding a diagonal matrix to the system.
+ ALL MATRICES ARE CALCULATED FROM THE MODEL. FAST!

Same is done in horizontal plane with a different matrix sensible to the effect of β-beating (HC x orbit)

Simulations On Diamond Lattice

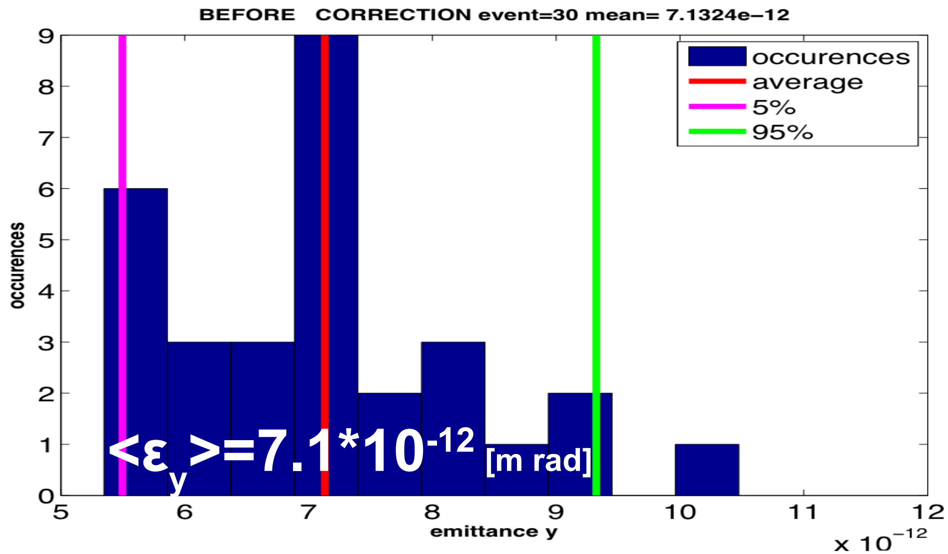
70µm rms horizontal misalignment Quadrupoles and Sextupoles
40µm rms vertical misalignment Quadrupoles and Sextupoles
50 µm rms vertical and horizontal Monitor offsets

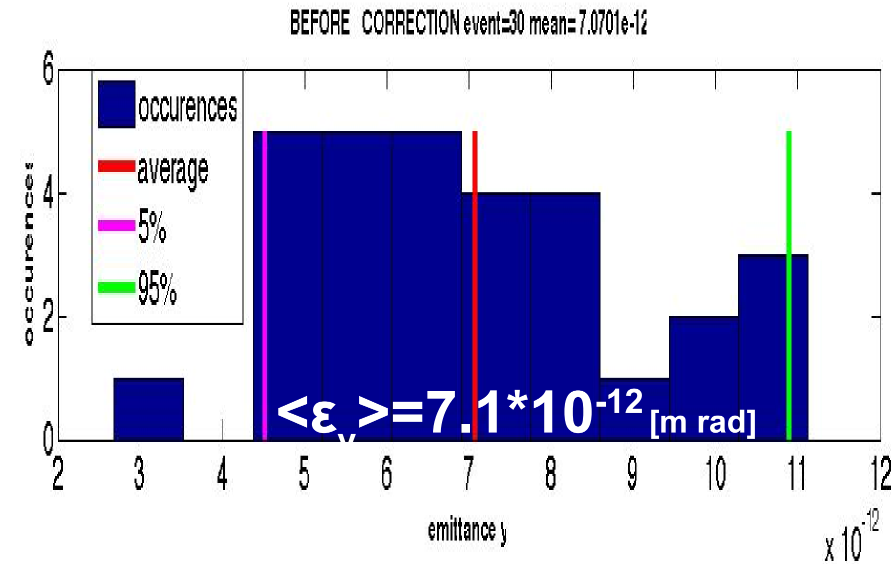
Vertical Emittance [m rad]

DISPERSION FREE STEERING

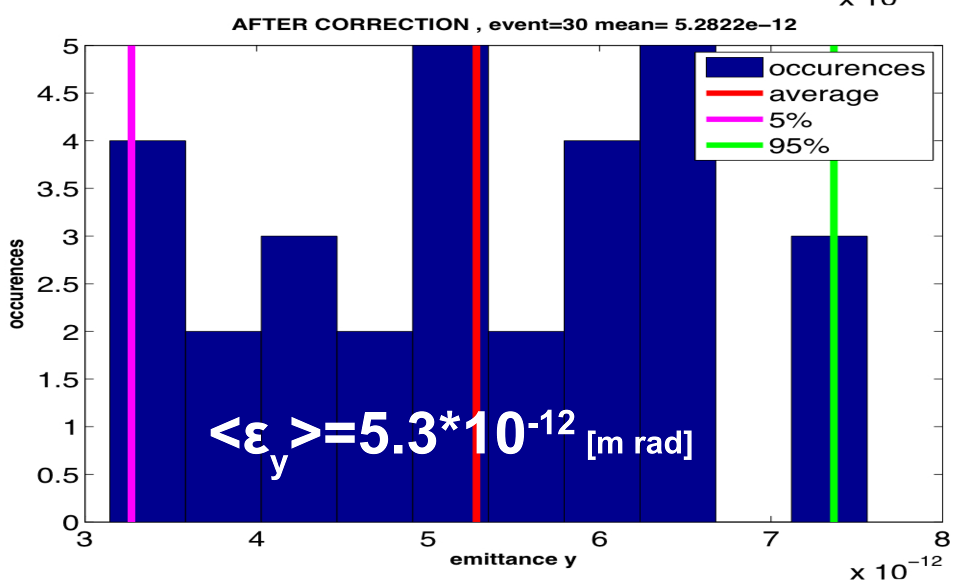
+ Coupling and beta-beating FREE STEERING

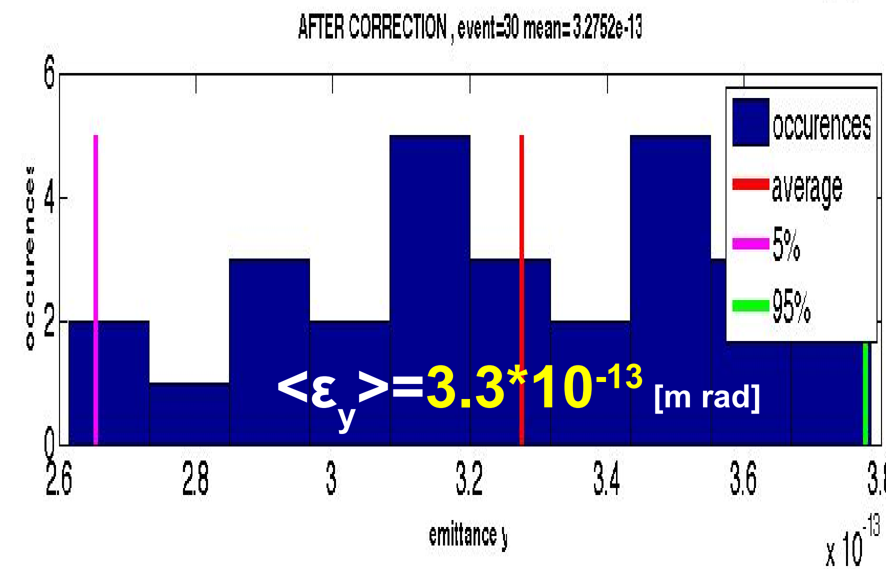
BEFORE





AFTER

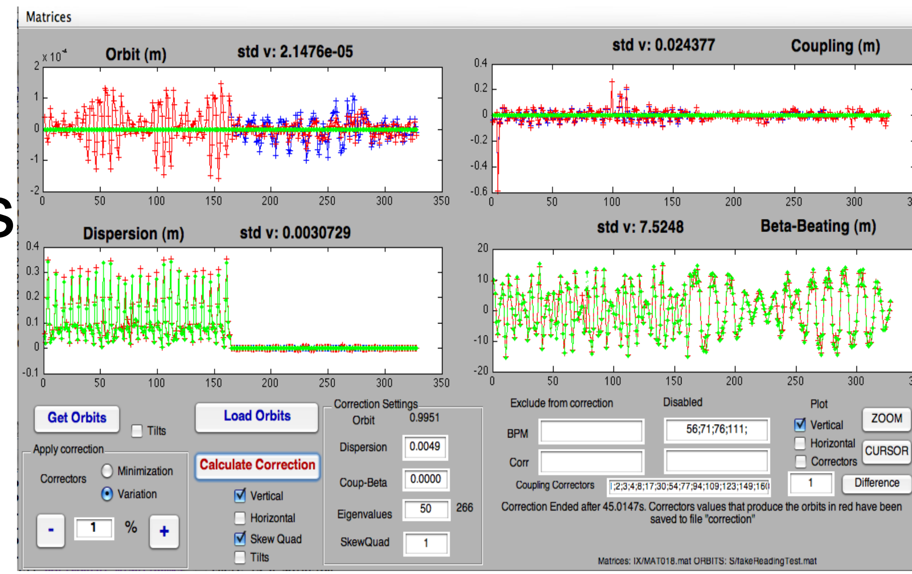




TESTS at Diamond Light Source (UK)

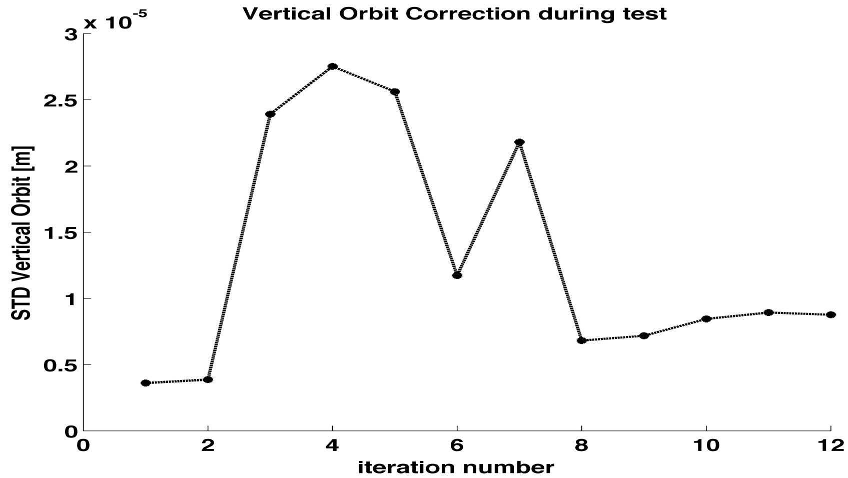
Tested:

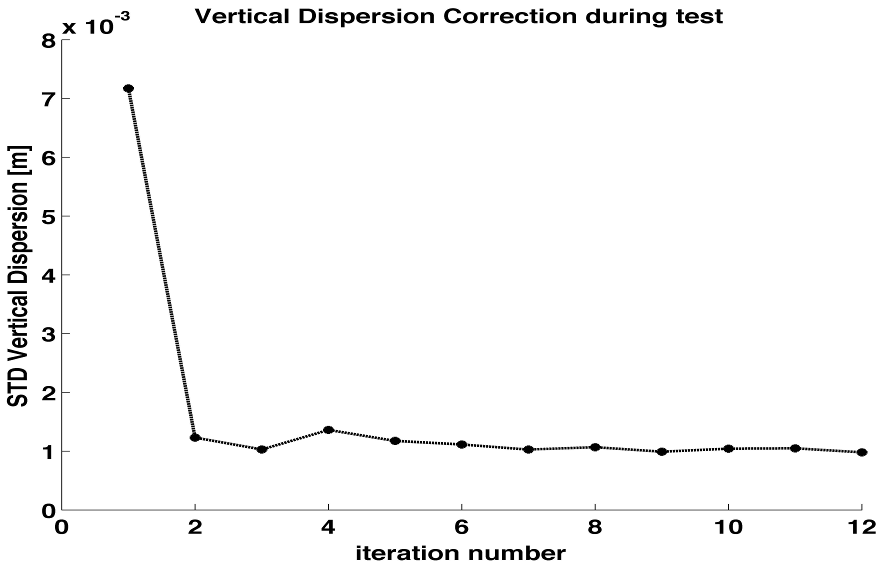
- CFS using vertical steerers
- CFS using skew quadrupoles
- Simultaneous Correction with skew quadrupoles and vertical correctors
- Multiple “coupling vectors”

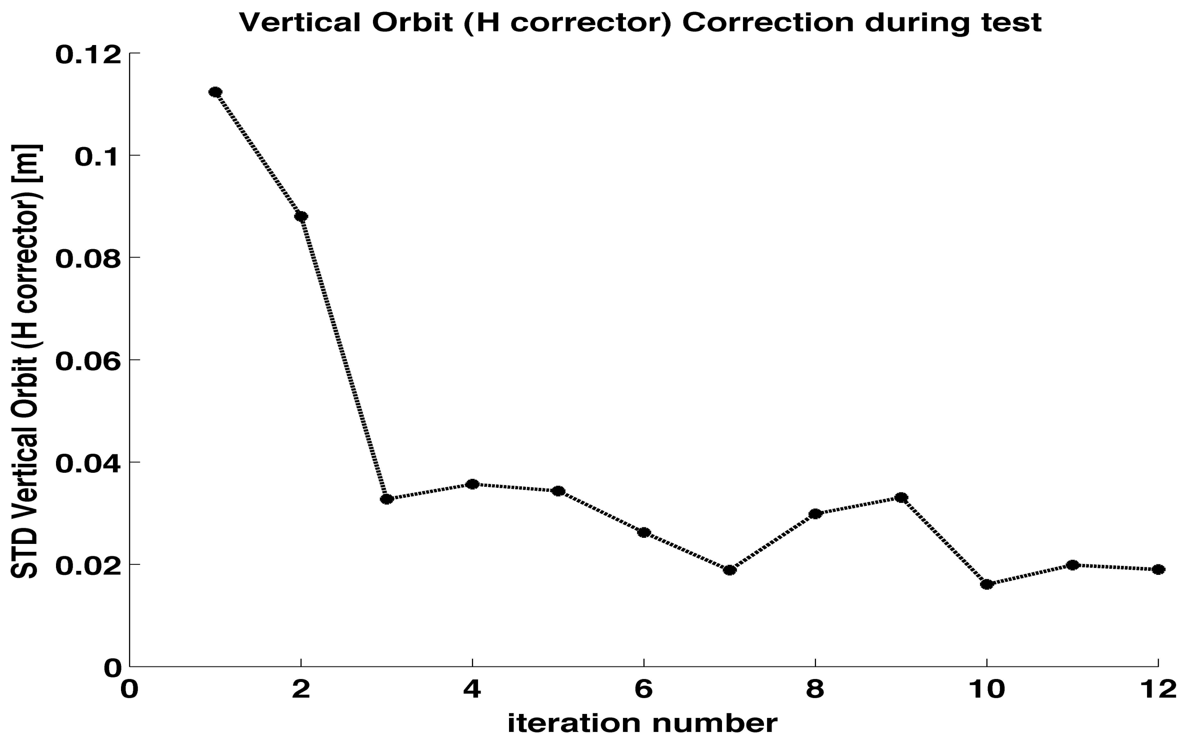


Monitor tilts (previously measured by LOCO) are taken into account in all measurements.

CFS Correction with vertical correctors





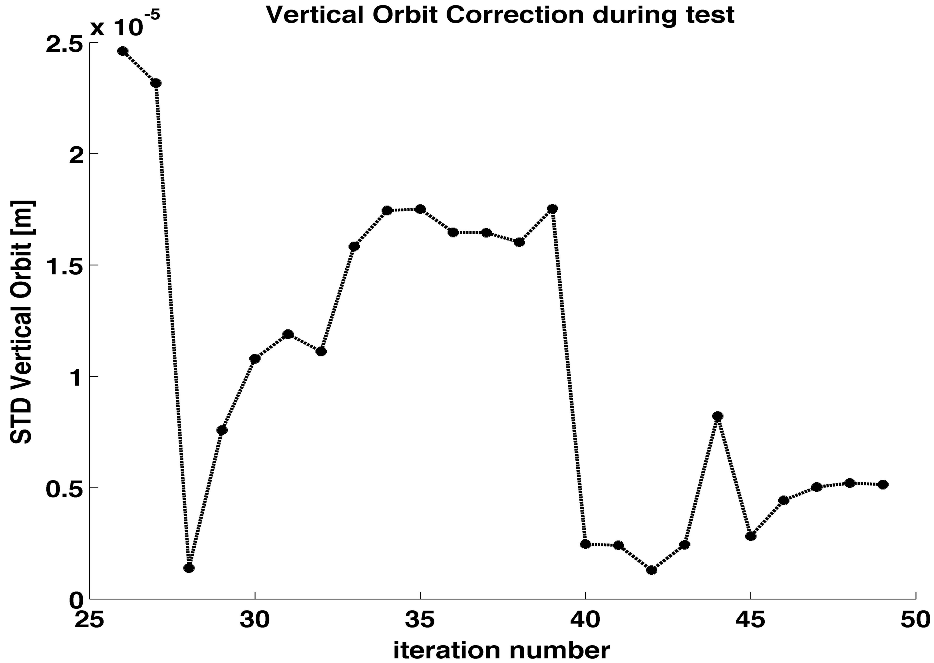


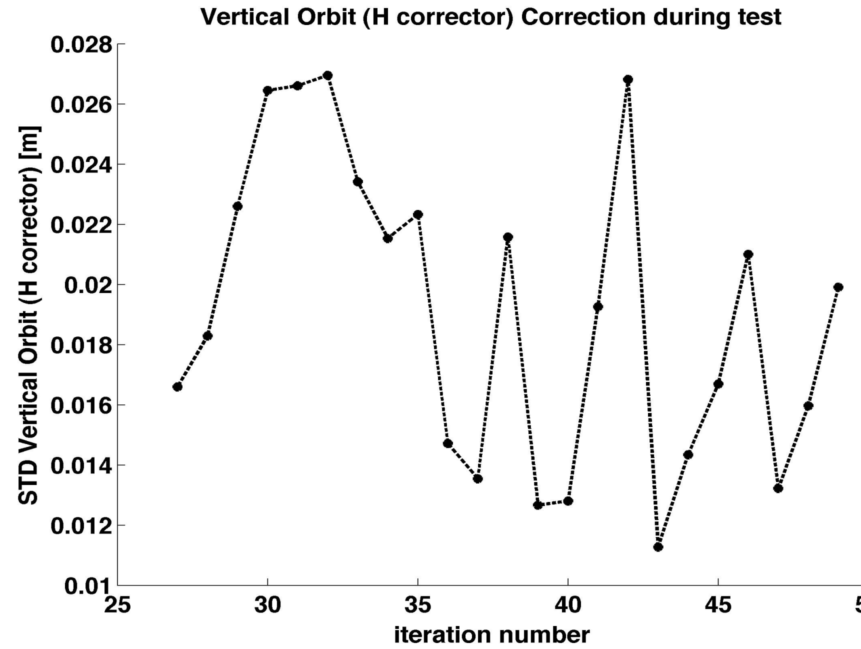
Correction reiteration converges
first for dispersion
then for coupling
and for orbit.

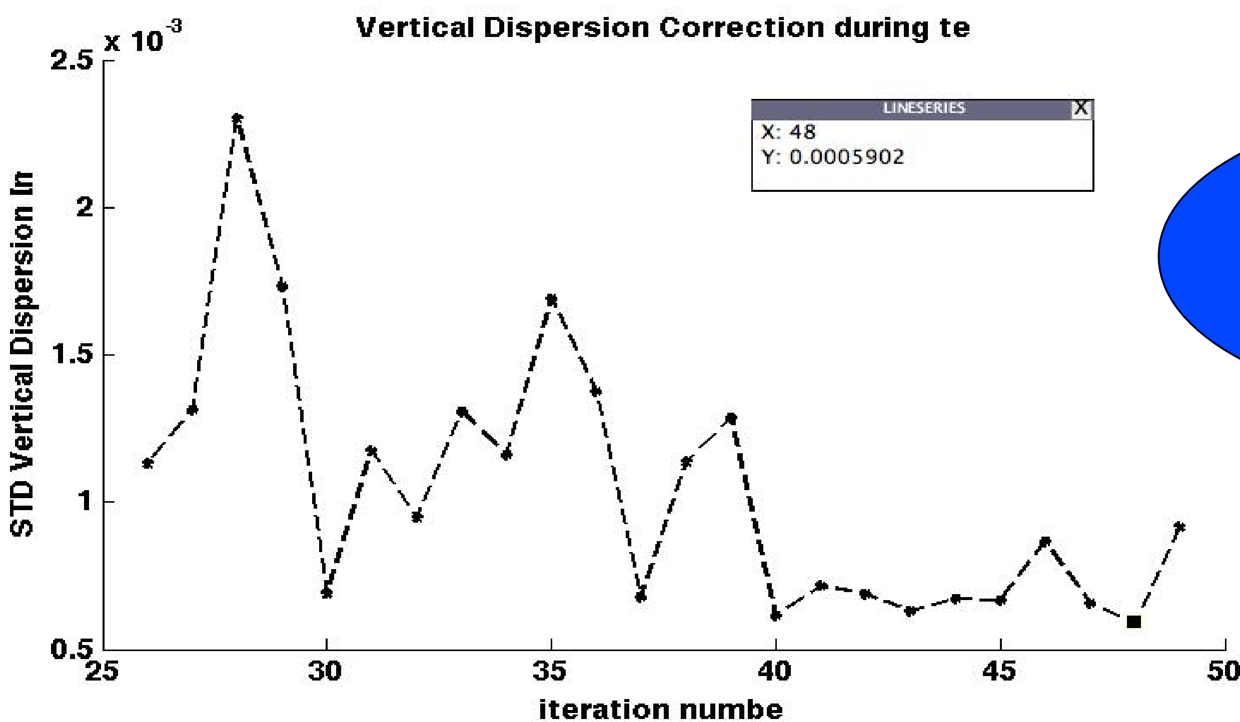
1 mm rms vertical dispersion
10 µm rms vertical orbit

0.24% coupling measured
At end of reiterations

CFS Correction with Skew Quadrupoles







$D_Y \approx 600$ µm

Coupling 0.23%

Beam sizes at the two pinhole cameras

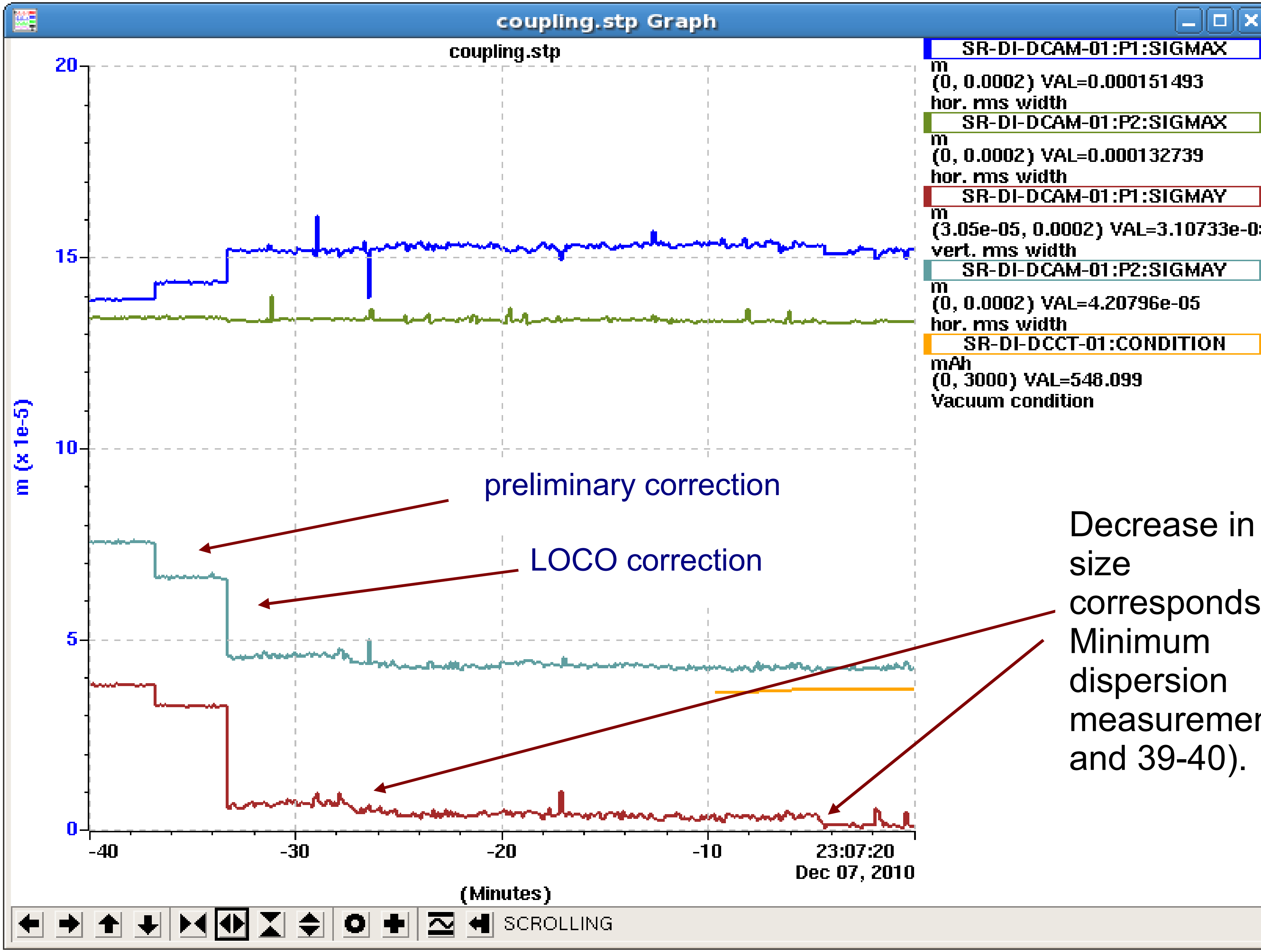
During correction with skew quadrupoles

X1

X2

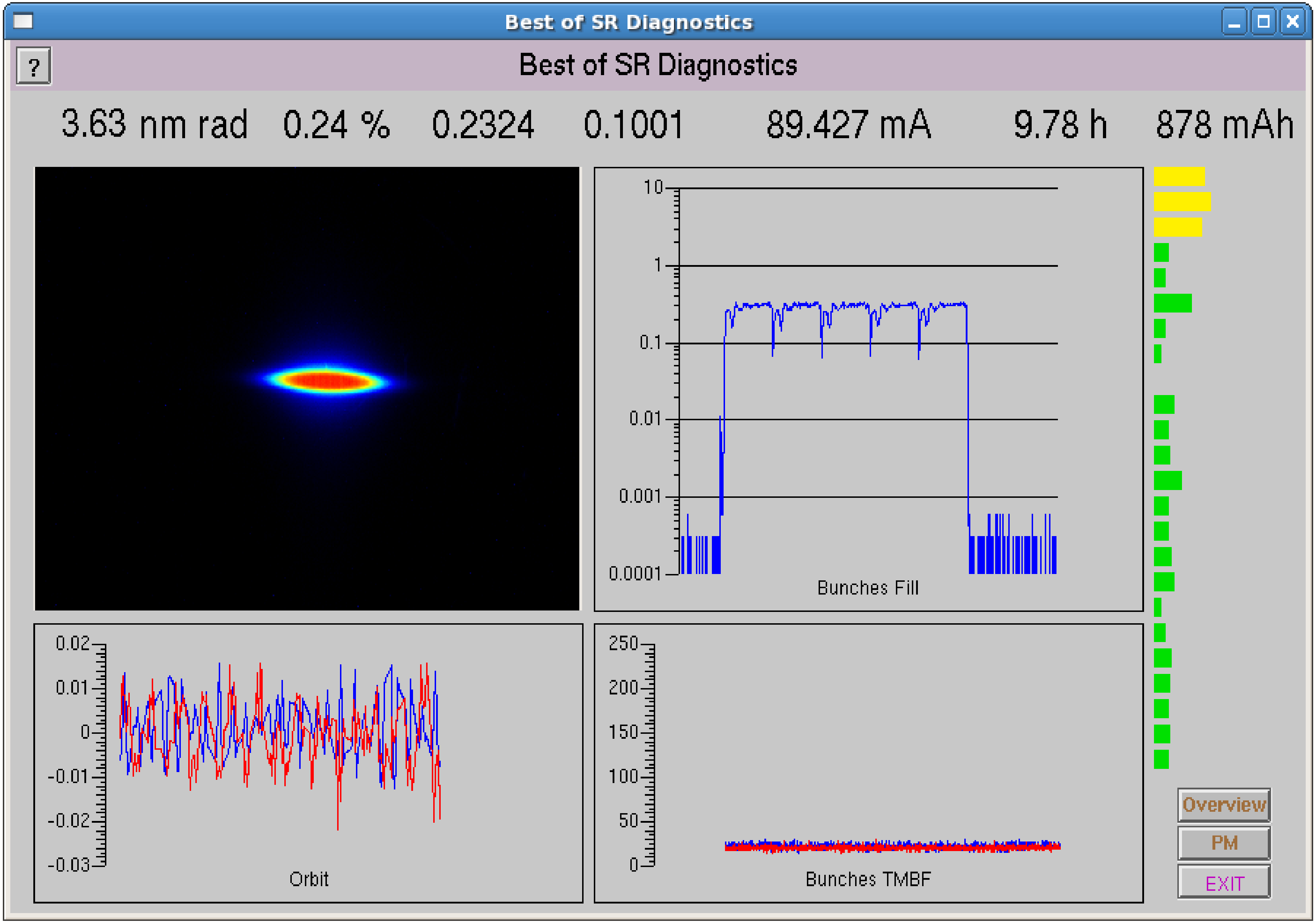
Y1

Y2



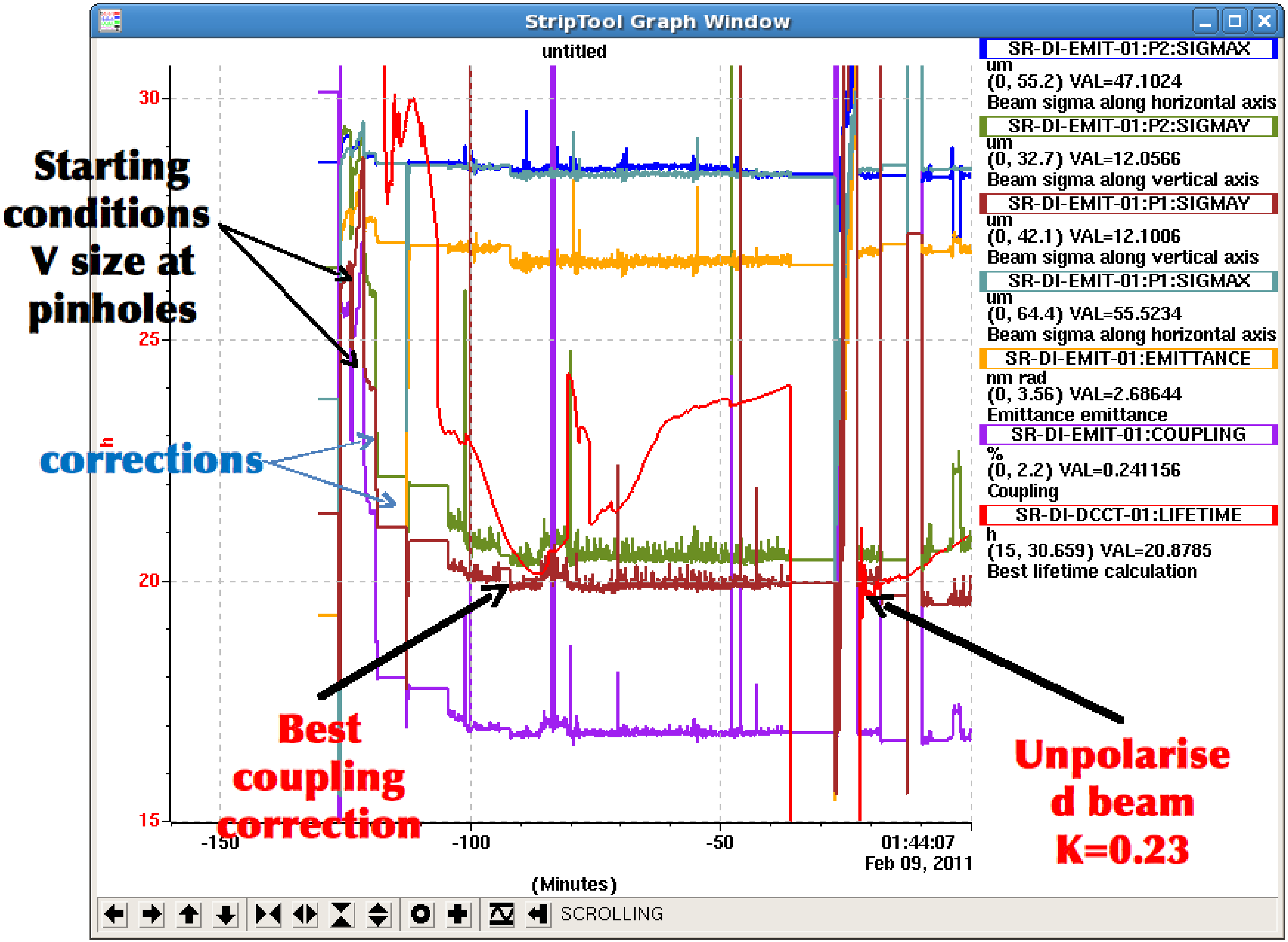
Decrease in beam size corresponds to Minimum dispersion measurements (30 and 39-40).

10 µm orbit and 0.24% coupling.



H Emittance measurement not ok due to change in optics

8 feb 2011- test with vertical and skew simultaneous correction and 10 correctors.



Conclusions

Vertical correction or Skew Quadrupoles correction using Coupling Free Steering provide 0.23%-0.24% emittance coupling and rms vertical Dispersion of 600 μm - 1mm after few reiterations.

Also simultaneous correction with skew quadrupole and vertical correctors have realized the same parameters.

Comparison with LOCO has been performed a few hours ago.

NEXT STEPS

- Test horizontal correction (also beta-beating constrained)
- Try to better exploit coupling correction. Simulation discrepancy.