CD2-SR LATTICE OPTIMIZATION

NSLS-II Accelerator Systems Advisory Committee

October 8-9, 2007

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for the NSLS-II Design Team

Outline of talk

- Sufficient linear and nonlinear lattice design control
- Overview of lattice changes CDR → CD2
- Proposed CD2 lattice
- CD2 Lattice tuneability range
- Large Positive Linear Chromaticity option
- Summary and Further Work

Linear Lattice Tuneability

Varying Quad Strengths only (no lengths) for Number of Constraints

1. Symmetry at Center of Cell (Alpha X,Y) – 2
2. Symmetry at SID center (Alpha X,Y) & (Beta X,Y) – 4
3. Beta's in LID (Beta X,Y), alpha's come naturally periodic – 2
4. Tunes per cell or ring – 2
5. Dispersion and Slope in either ID – 2
6. Emittance –2 constraints at dipole (BetaX and AlphaX) – 2

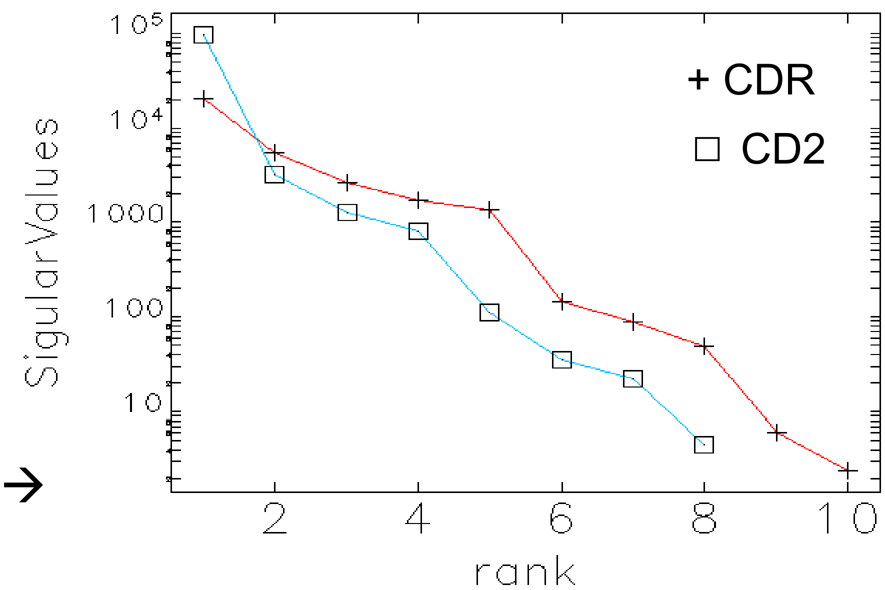
Total constraints = 14

Determine the finite difference response (tuning) matrix, solve with SVD

Sufficient Linear Tuneability

$$\begin{pmatrix} d\alpha_x(m)/dK_1 & \dots & d\alpha_x(m)/dK_q \\ d\alpha_y(m)/dK_1 & \ddots & d\alpha_y(m)/dK_q \\ \vdots & & \vdots \\ d\beta_x(n)/dK_1 & \dots & d\beta_x(n)/dK_q \\ d\alpha_x(n)/dK_1 & & d\alpha_x(n)/dK_q \end{pmatrix} = U\,\Sigma\,V^T$$

Σ diagonal terms give rank of the variables →



For quadrupole tuning

- Conclusion:

Two quadrupole families from CDR lattice have reduced sensitivity for the linear lattice constraints for a given lattice solution, adding trim Quad doesn't increase tuneability.

Optimizing the Chromaticity Tuning

Biggest change CDR→CD2, space for TPW added 0.4m to QD position increasing η_x and β_x at QD, increases η_x' and $\alpha_{y,}$,
peak η_x = 0.45 →0.49m

Normalized Dispersion Amplitude, H_o invariant between dipoles

$$H_o = \frac{(\eta_x^2 + (\beta_x \eta_x' + \alpha_x \eta_x)^2)}{\beta_x}$$

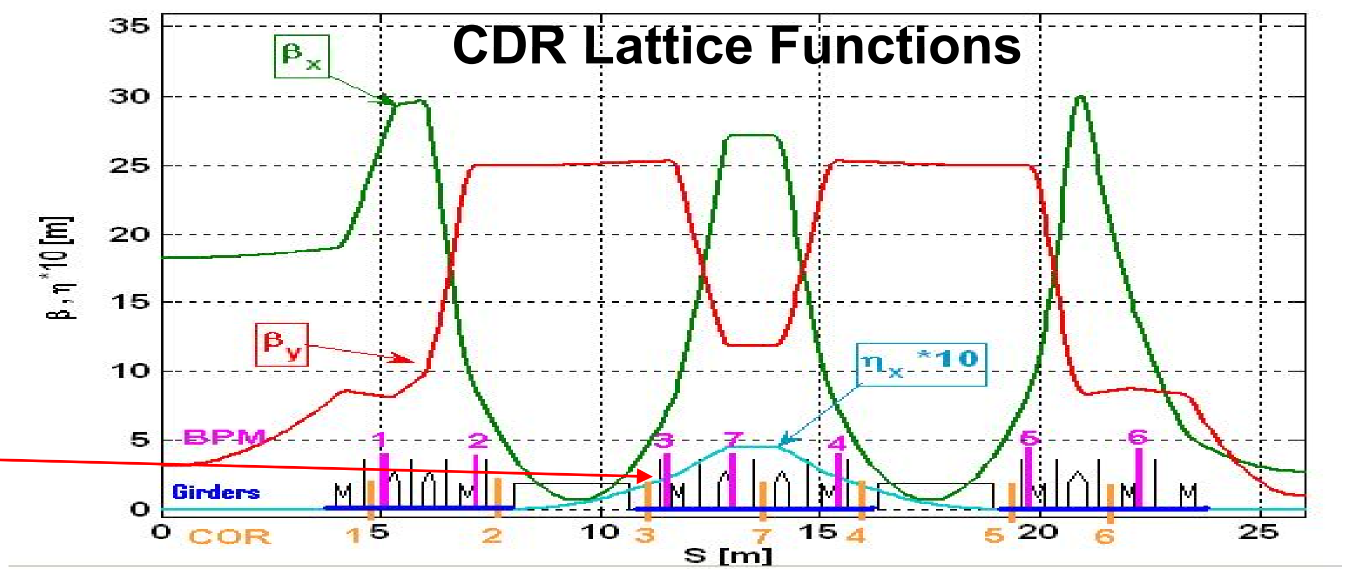
At SF $\alpha_x = \eta_x' = 0$, therefore $H_o = (\eta_x)^2/\beta_x$, or $\beta_x \sim (\eta_x)^2$

Increased η_x could reduce sextupole strengths but increased β_x will enhance nonlinear drive terms faster > $\beta^{3/2}$

Small η_x & β_x means weak QD and less separation $\beta_{x,}$ β_y at SF and SD
which will increase chromatic sextupole strengths

Peak Dispersion Scan

SD1 weak

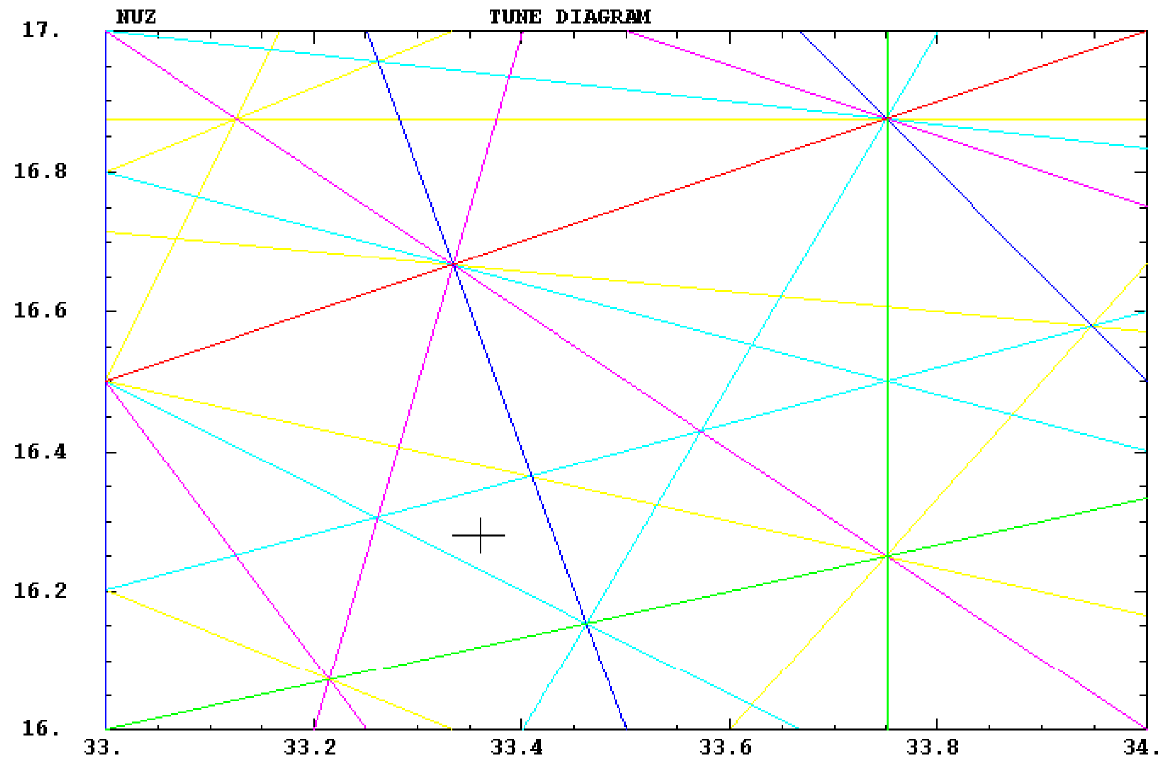


CDR lattice had weak SD1,since SD2 has better $\xi_x^{<2>}$. If SD1 is removed, QD can be shifted to reduce the TPW caused increase of η_x

Fix tunes and scan peak η_x ~ 0.44 to 0.49m for linear lattice constraints and reduced sextupole strength (improved beta function separation at SF& SD2)

Optimum peak η_x ~0.46m with peak β_x ~29 m versus 27 m in CDR

Working Point Selection



SP=15
Syst. Reson.
Order
<----- 8th
<----- 7th
<----- 6th
<----- 5th
<----- 4th
<----- 3rd
<----- 2nd

1/sin(π Q) <1.4 for COAF, Q_y < 0.5 for Head-Tail, Q_y < Q_x for reduced coupling and increased momentum aperture from tune shifts

CDR→CD2 LATTICE CHANGES

- **Reduction in Number of Elements**

Quadruplets in ID straight sections replaced by Triplets: -2 Quads per cell
Chromatic sextupoles reduced 3 to 2 families -2 Sextupole/ cell
Short Straight Section one less geometric sextupole lower β_x -1 Sextupole/ cell
Net per cell:10-Quads (8 families), 10-Sext (9 families) CDR:12-Q(10), 13-S(11)

- **Add Length to ID straight sections**

Vacuum Group better defined transition section to undulators/wigglers
Short ID drift length 5 → 6.6m and Long ID 8 → 9.3m, allow IDs 5 and 7m
Circumference increased for improved harmonic number for RF system

- **Add Three Pole Wigglers in dispersion region**

TPW active length 20cm with 2mradian central bend > 1T plus 20cm free space
Impact on emittance $\Delta\varepsilon_x$ ~ 0.18 to 0.2nm for 15(60) - TPWs

15* (9.3m LIDs + 6.6m SIDs + 4 *0.40m(0.20m) TPWs)= 262.5m
33.1% Circumference= 791.96m (25% CDR 780.3m)

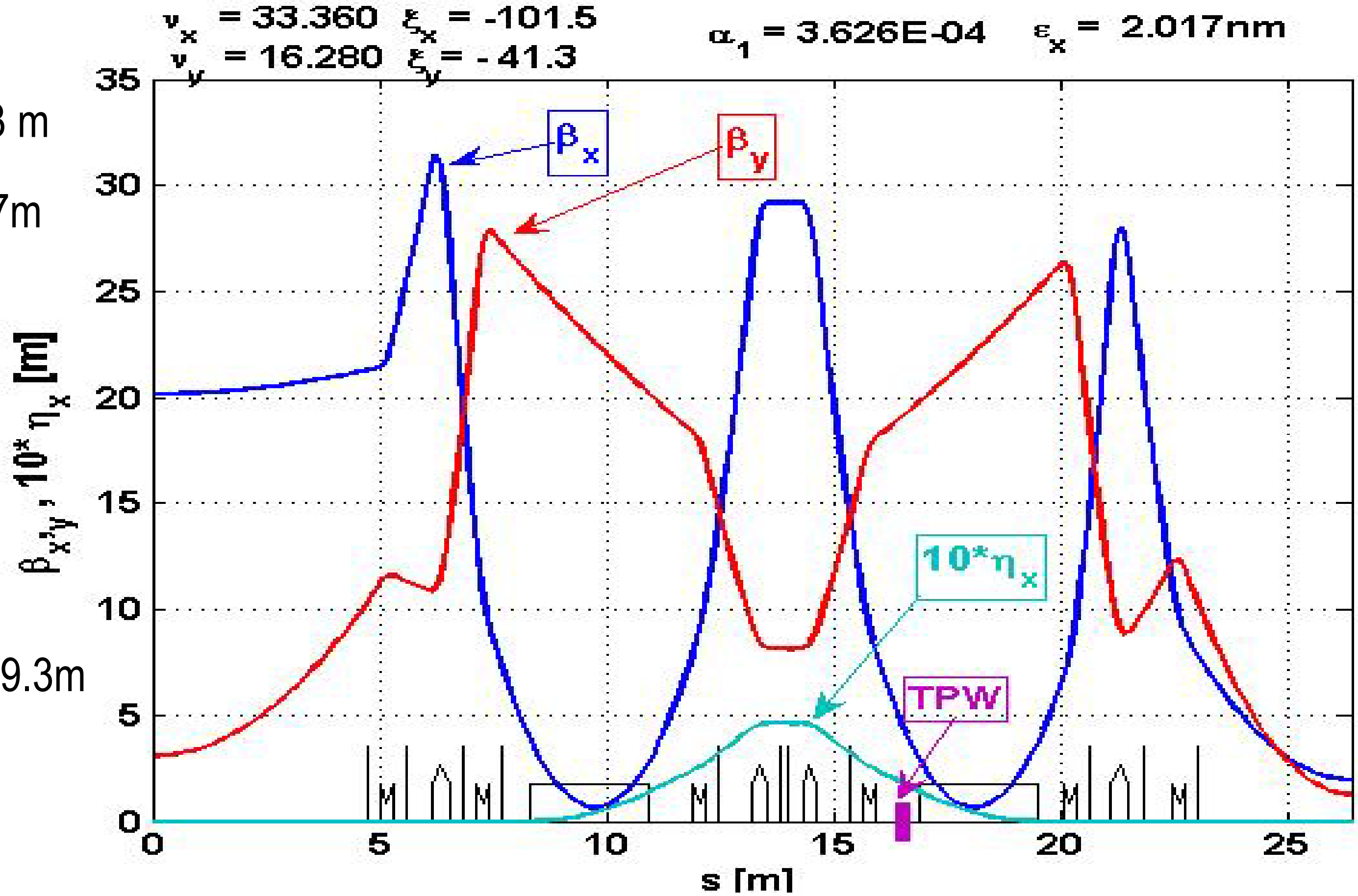
CD2 Lattice Functions one Cell

Quadrupole Triplets in ID Straight sections, 2-Chromatic Sextupole Families, TPW
Circumference =791.96m (780.3m CDR)

β_x = 20.3 m

β_y = 3.07m

Long ID =9.3m



β_x = 1.94 m

β_y = 1.26m

Short ID= 6.6m

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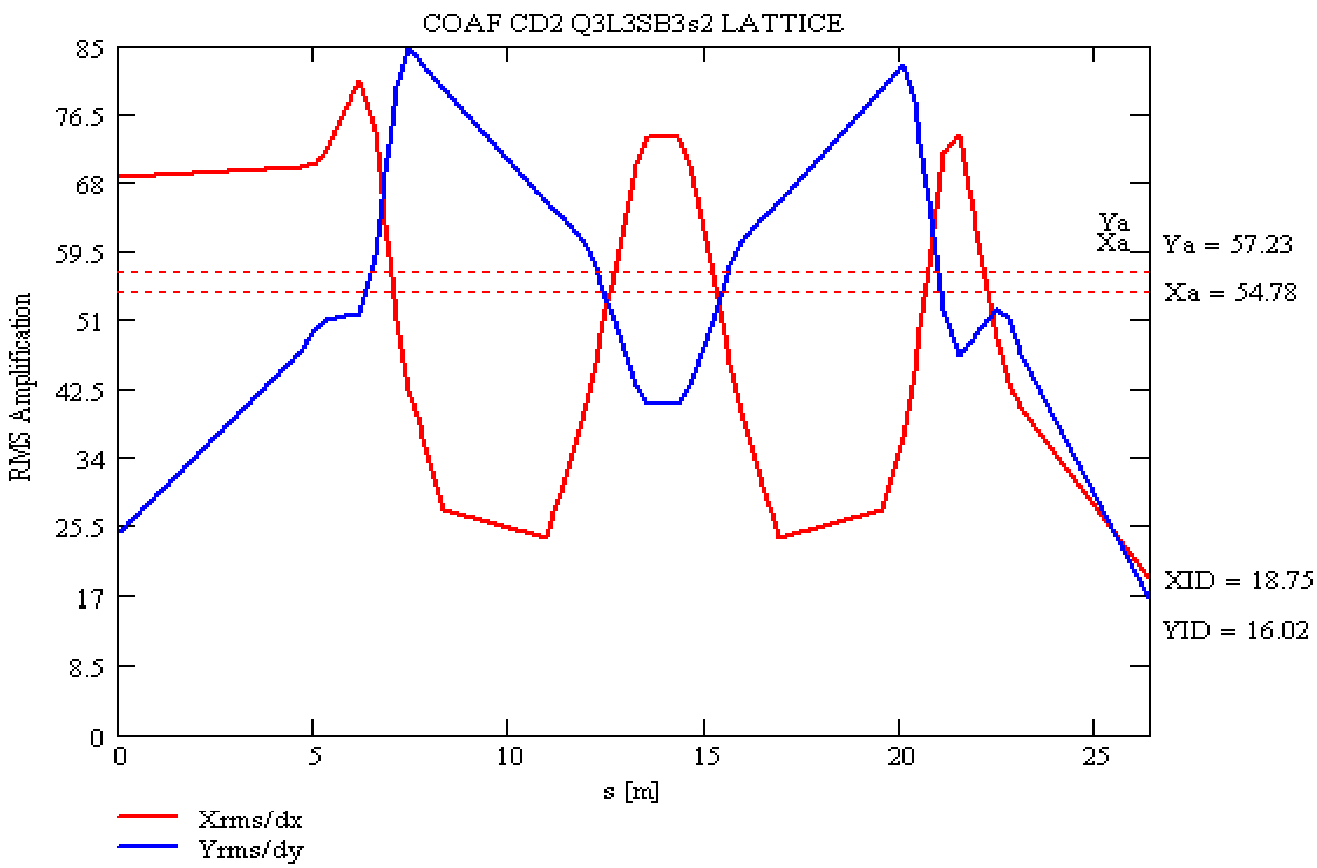
CD2 QUAD Closed Orbit Amp. Factor

Stronger Quadrupole Focusing and Higher Beta functions yields COAFs(X,Y)= (56,52)→(55, 57) Increased in SID Y 12 →16

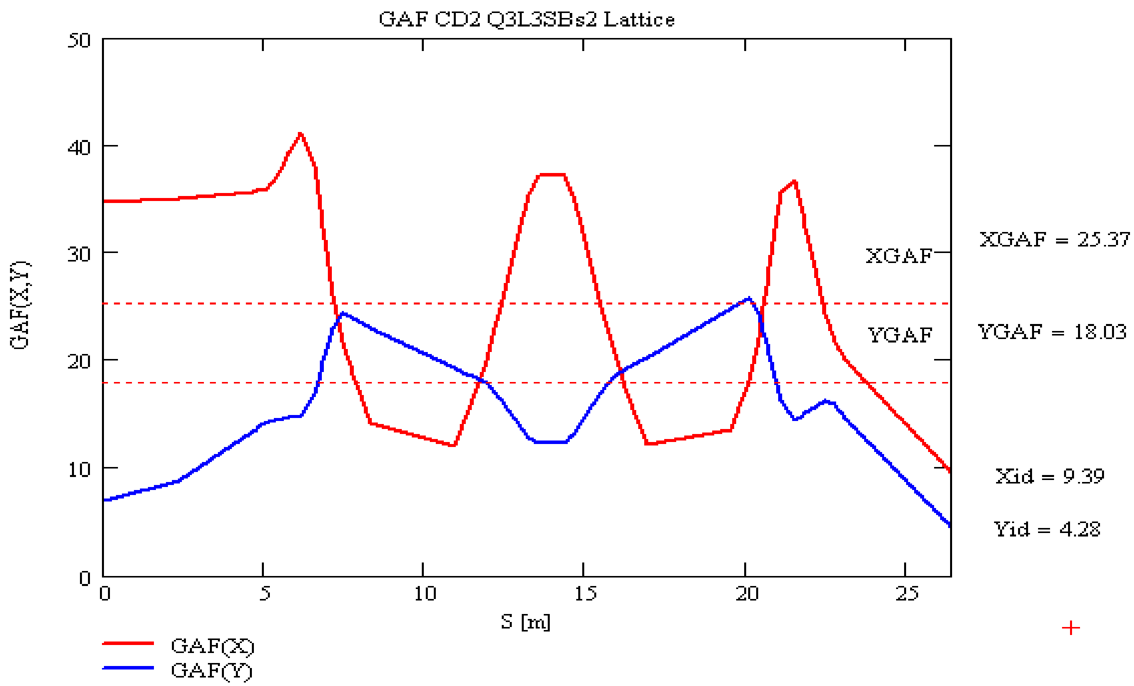


CD2 Magnet Alignment Tolerances

- Quadrupole and Sextupoles have centers measured to a resolution of 10 and 15 μm with vibrating wire technique
- Allow 2X for resolution, alignment Tolerance <u><</u>30μm on girder
- Girder alignment Tolerance in tunnel <u><</u>100μm (as achieved elsewhere)

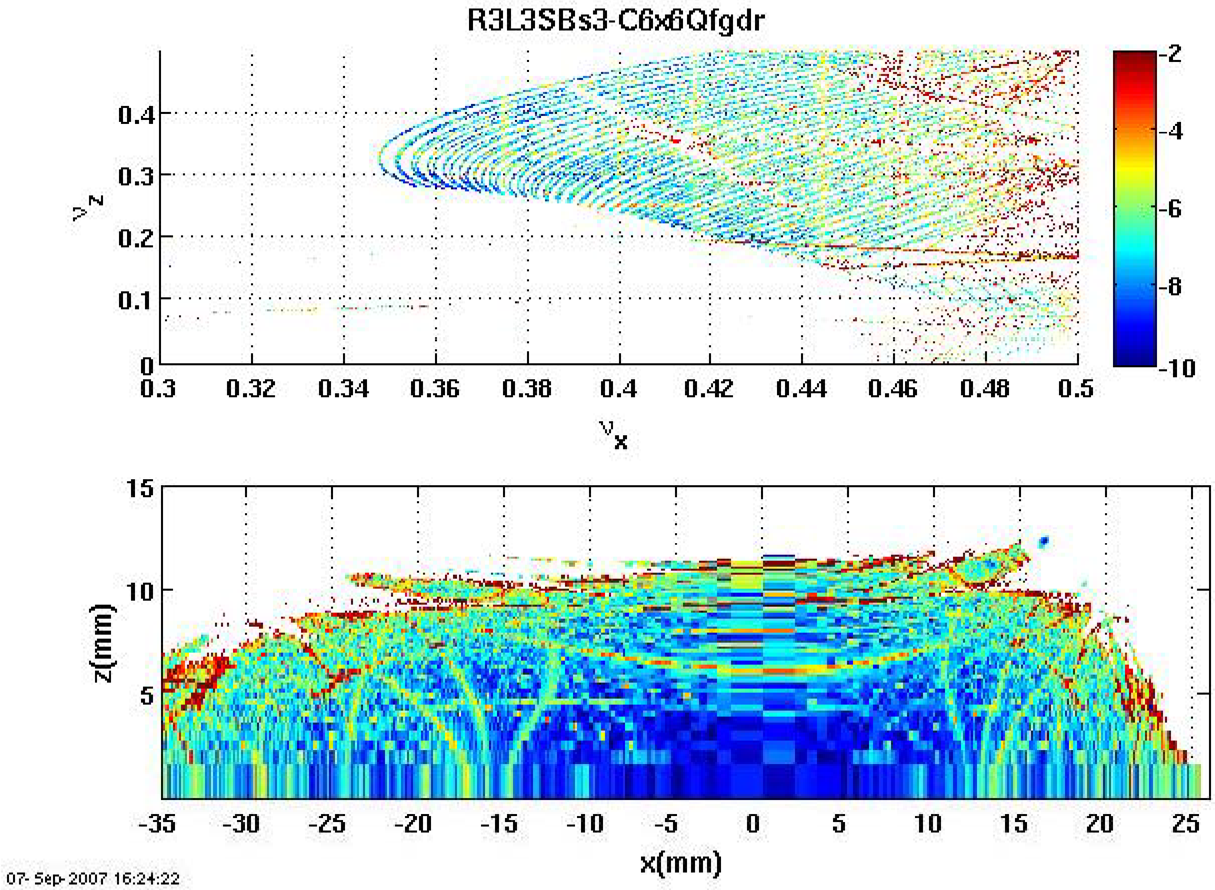
girder amplification factors (9.4,4.3) in SID are ~3 to 4X less than COAF

- Beam based alignment of Quads at ends of girders to 10μm reduces correlated error and random alignment errors impact at lower level



RMS(COD) for 100 seeds with girder alignment $\Delta X, \Delta Y = 10 \mu m$ random at both ends

DA and Diffusion Map CD2



Using 9/9 sextupole families

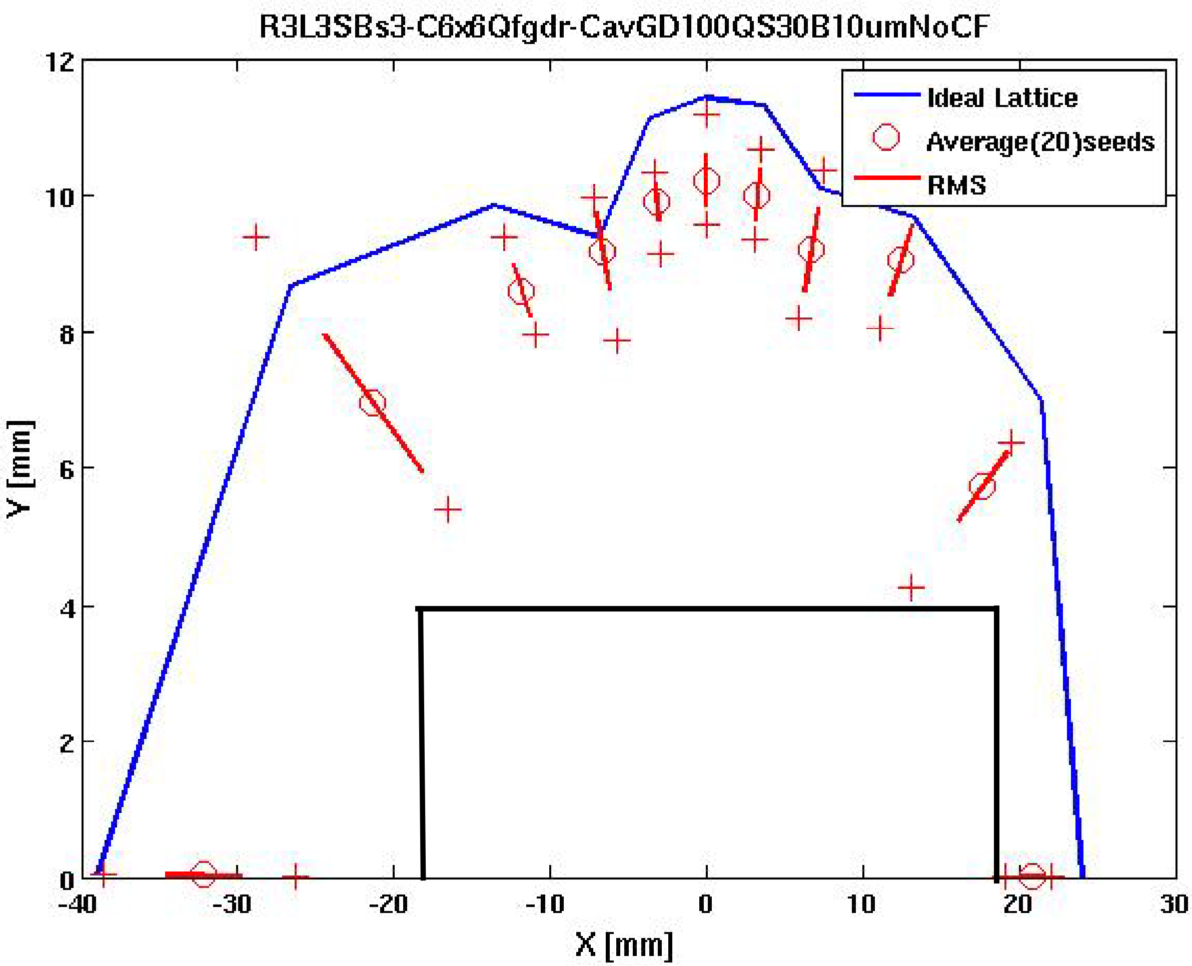
β_x = 20.3 m

β_y = 3.07m

ξ_x = + 2

ξ_y = +1

DA for Corrected Alignment Errors



Alignment Tolers.

Girders & Dipoles

= 100 µm

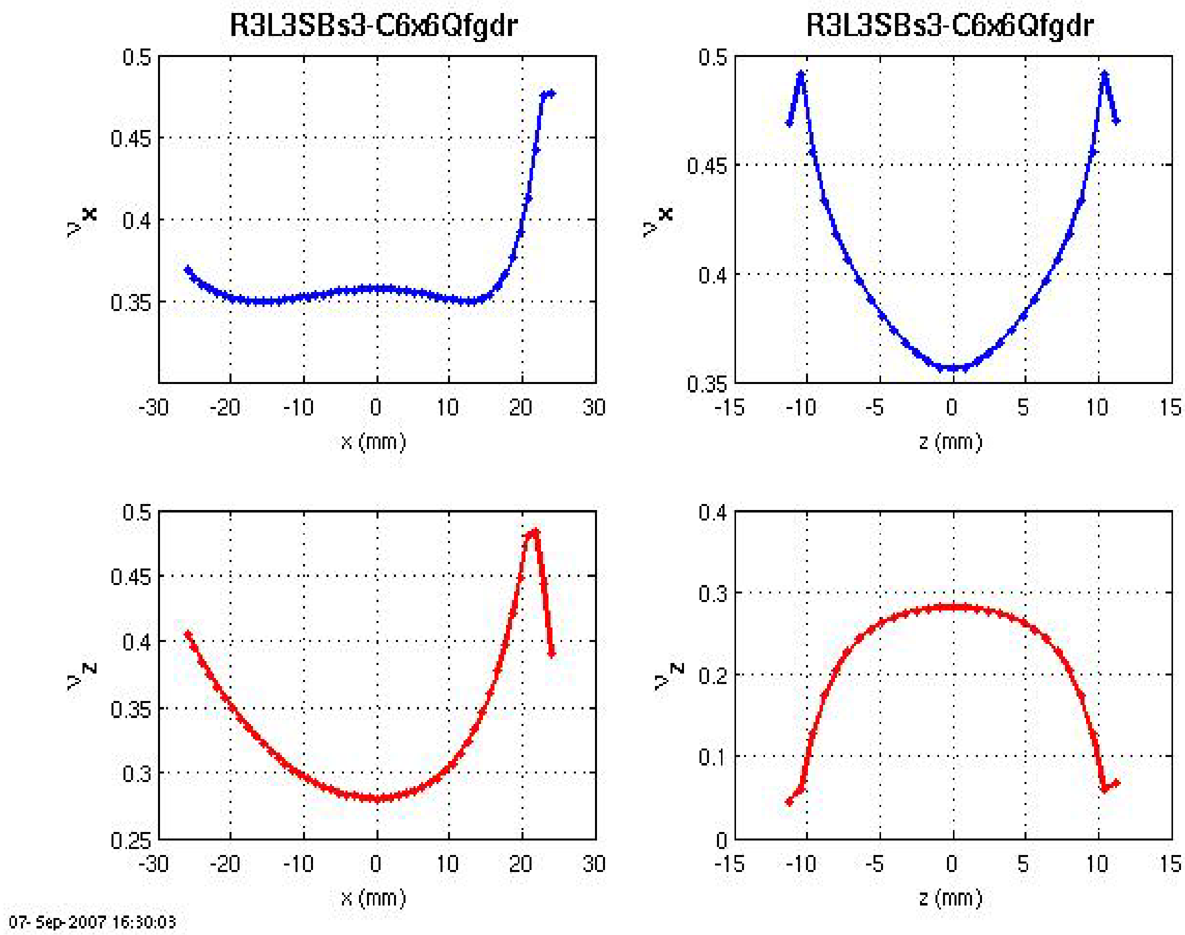
Quads & Sexts.

= 30 µm

BBA BPMs acc.

10 µm

Tune Shift with Amplitude Controlled



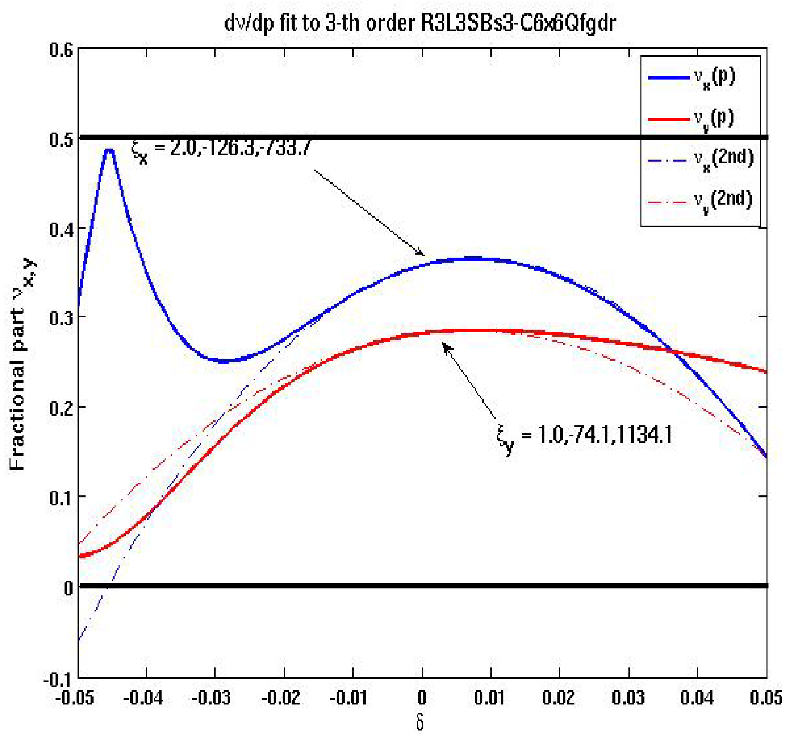
2 Chromatic plus

7 Geometric Sextupoles

Gives adequate control but improvement in dQ_{y}/dJ_{y} being studied

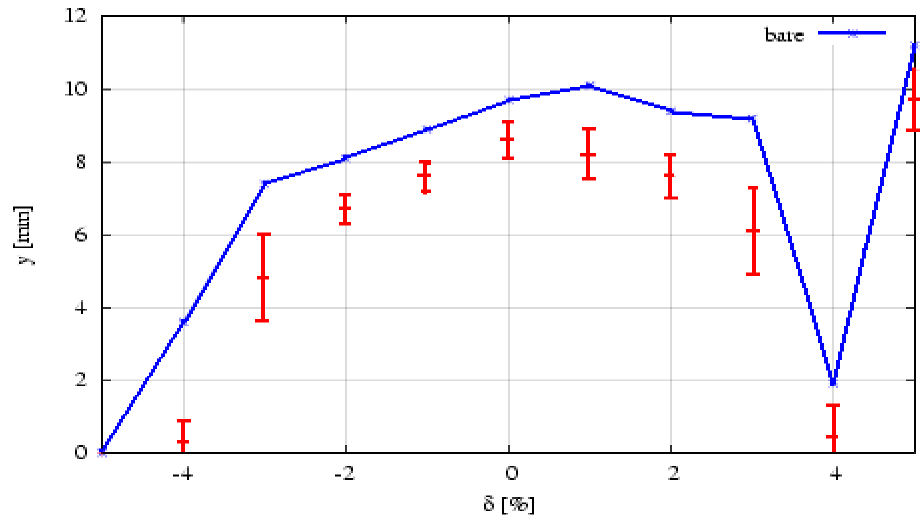
Dynamic Momentum dP/P > 3%

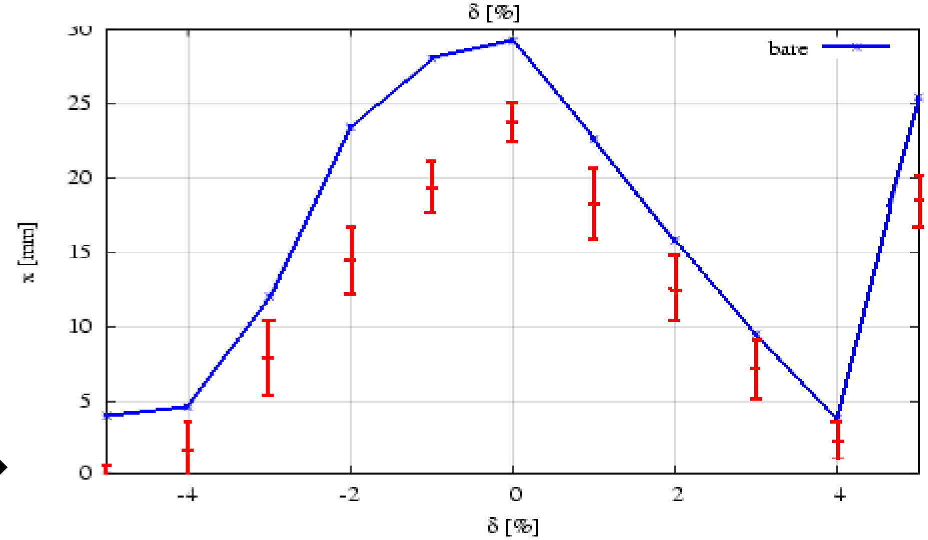
Fractional Tune vs Momentum Offset



$\delta = dp/p$

Including Corrected Alignment Errors →





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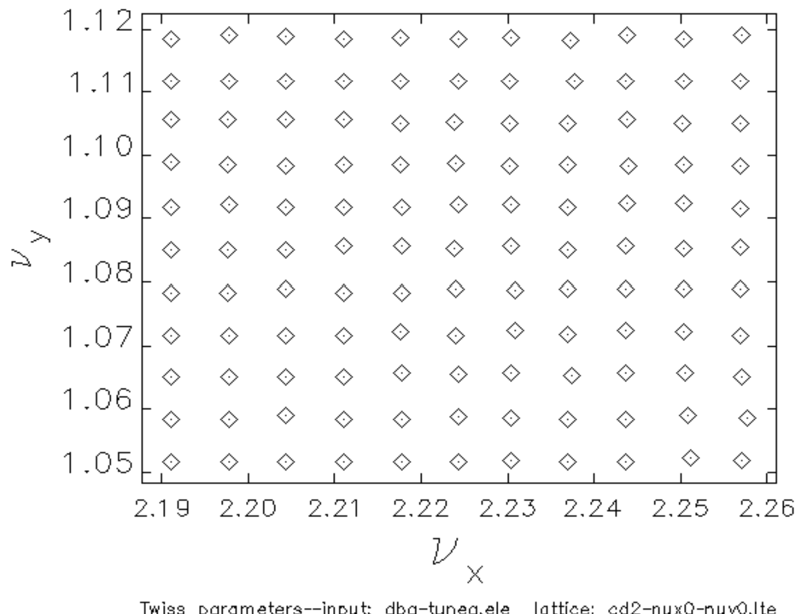
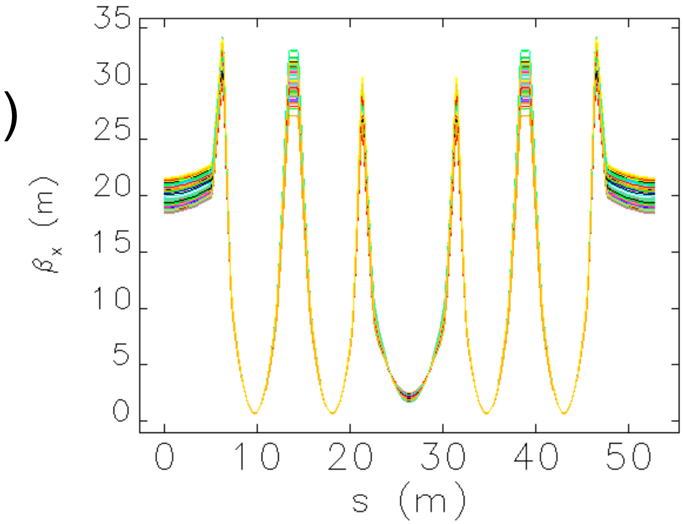
Lattice Tuneability for Nonlinear Optimization

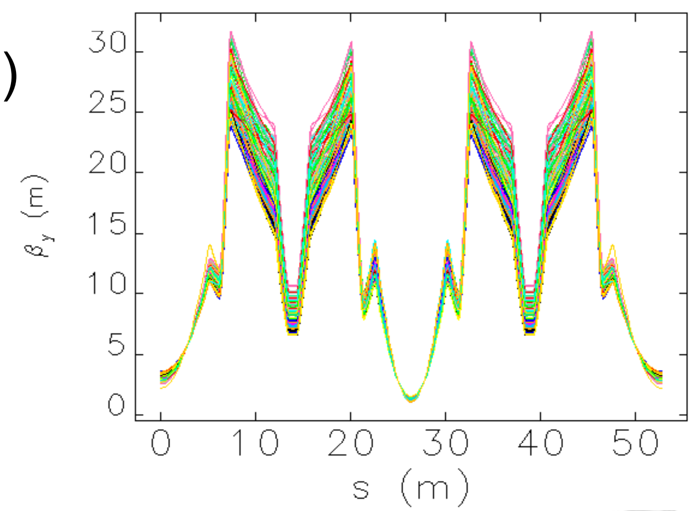
Period Tune Scan



$\beta_x(s)$



$\beta_y(s)$



$\Delta\nu$(period) ~ 0.07 for $\pm$ 0.5 ring tune can be achieved with constraints on β_y in IDs and ε_x but gives β_x (ηx) changes in Long ID and SF, also ratio of beta functions at SD and SF.

Changes in Quad strength < 7% required

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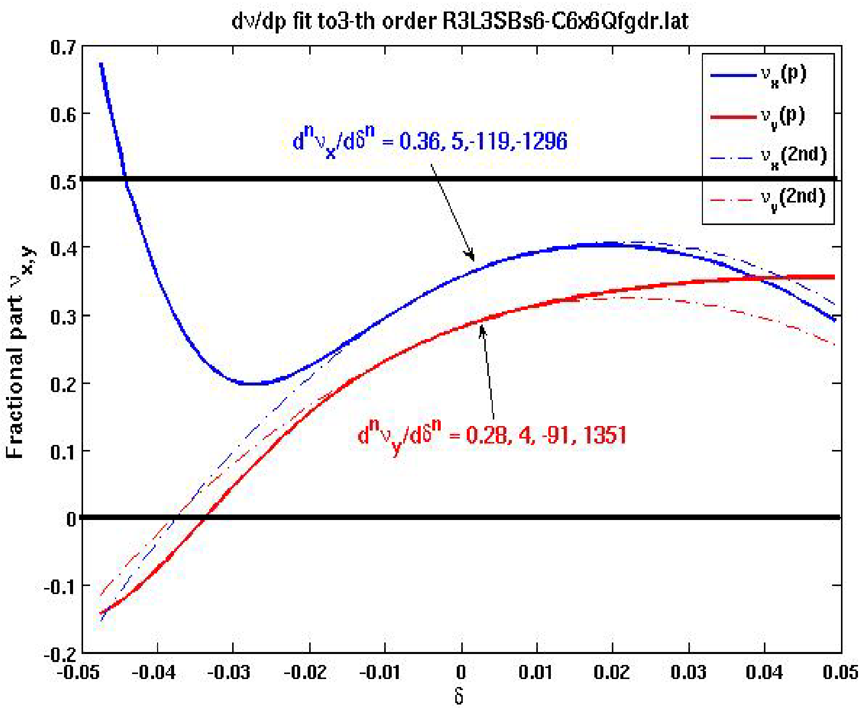
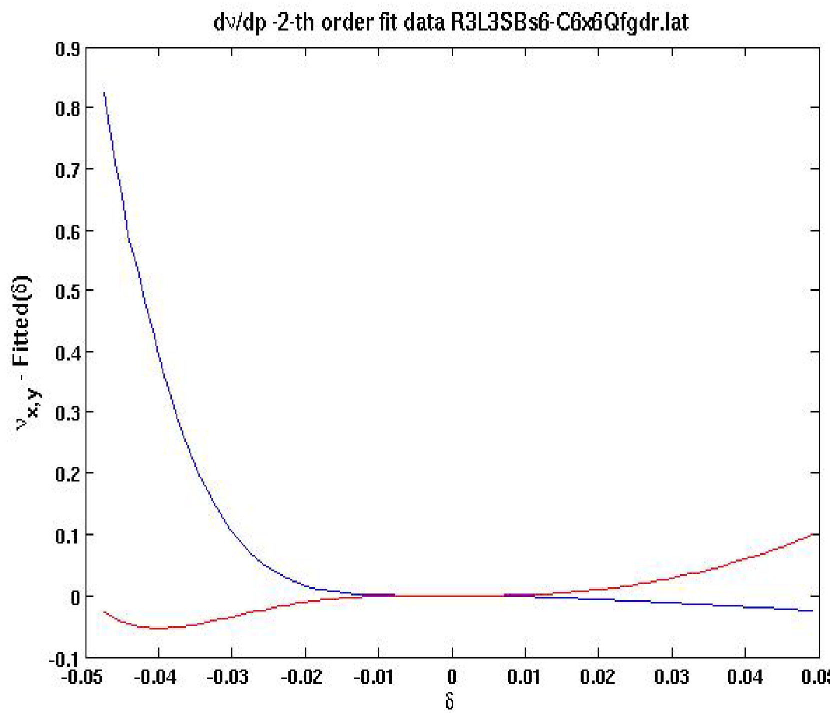
Increased Linear Chromaticity

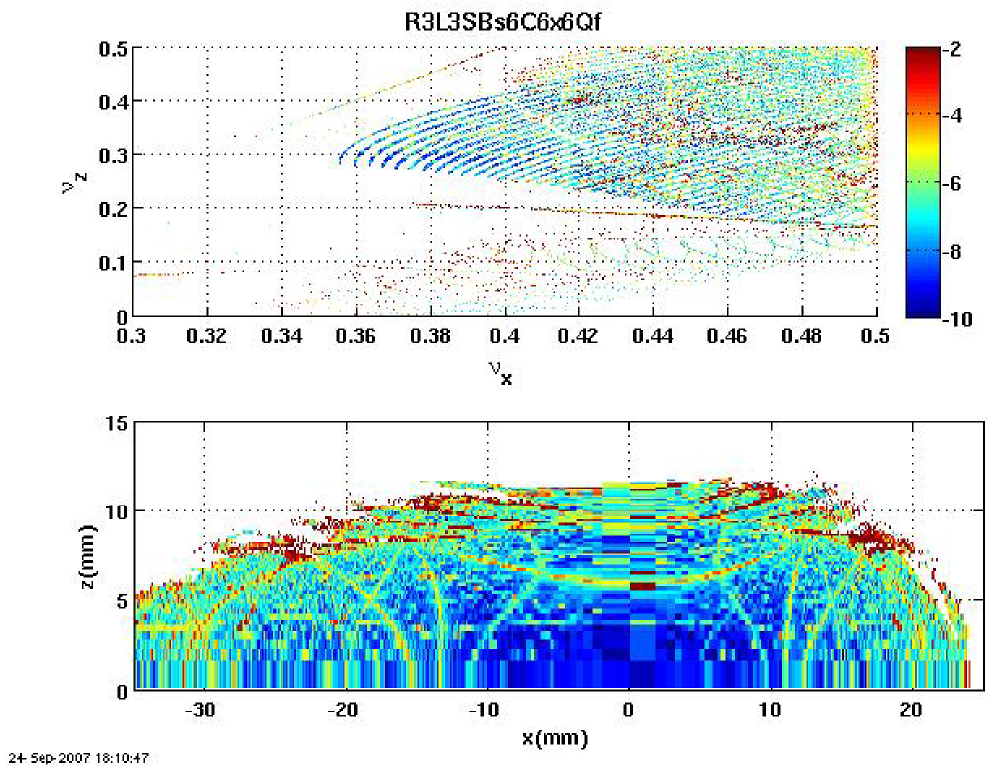
DBA lattice has large high order (odd) chromaticity from achromatic tune

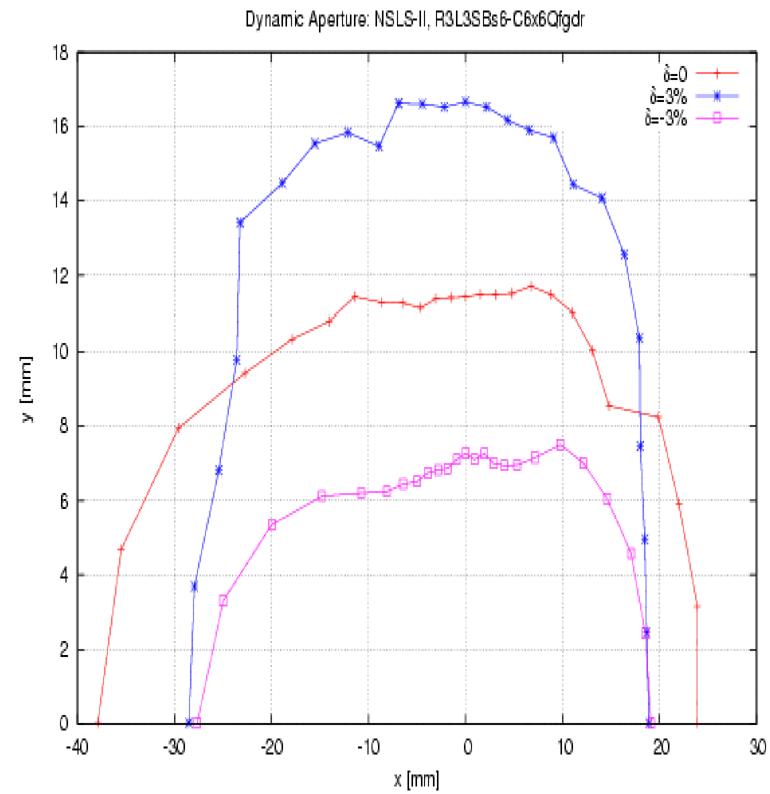
A disadvantage for ξ=0, but advantage for ξ > 0. Example for $\xi_{x,y}$ = +5, +4



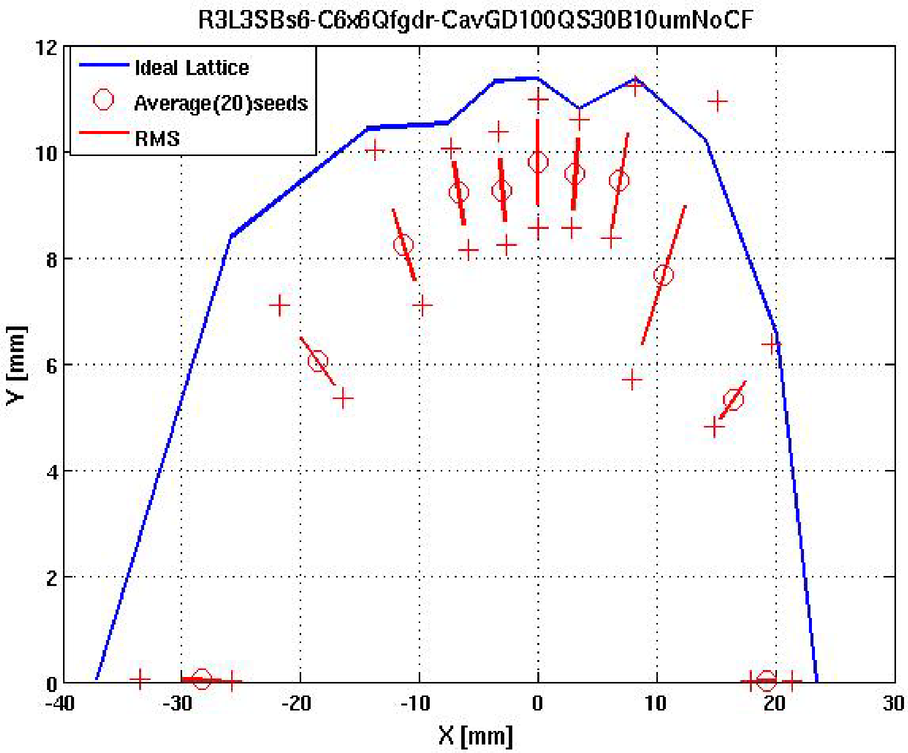


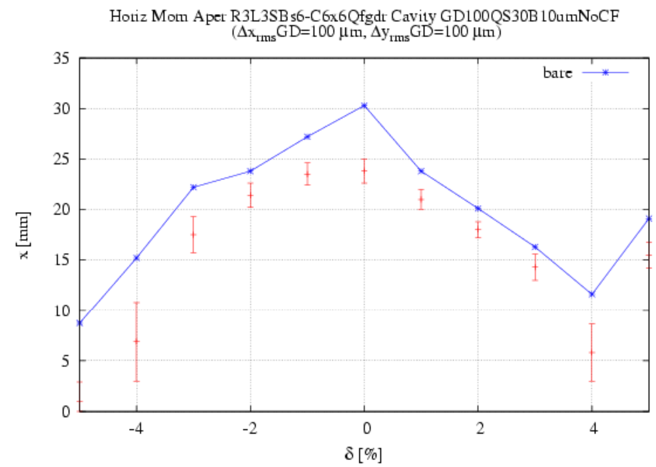
Maintains DA and Momentum Apert.

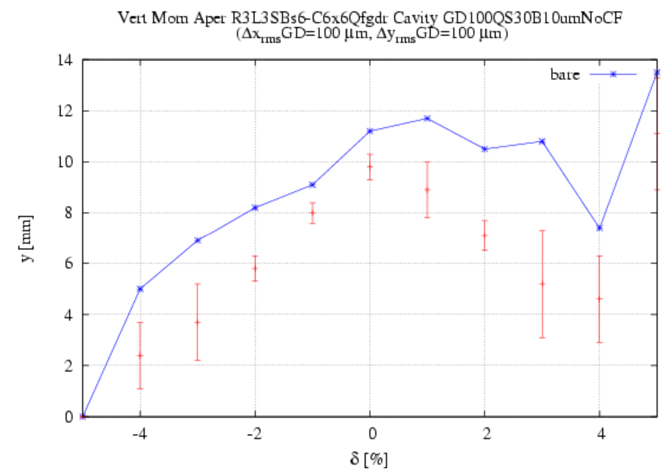




Including Alignment Tolerances







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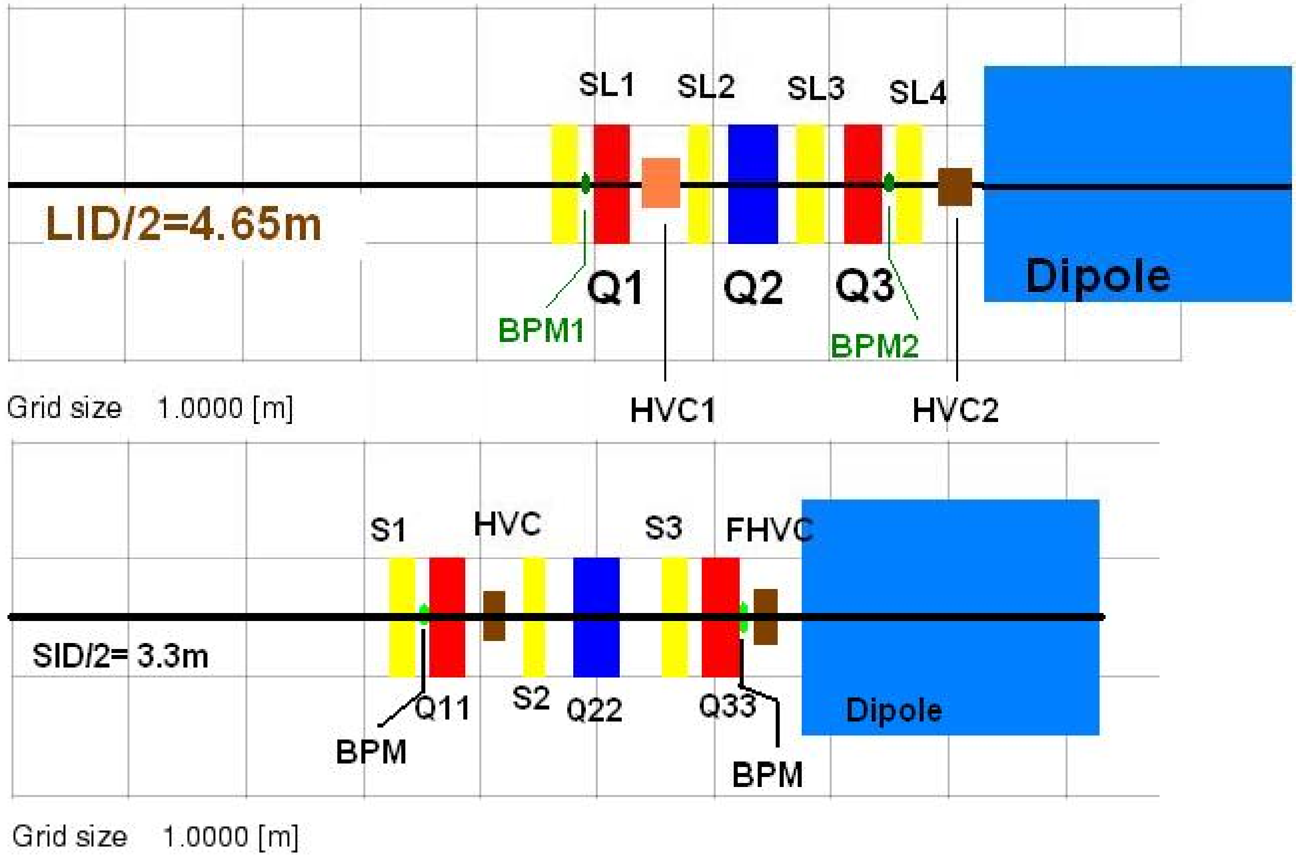
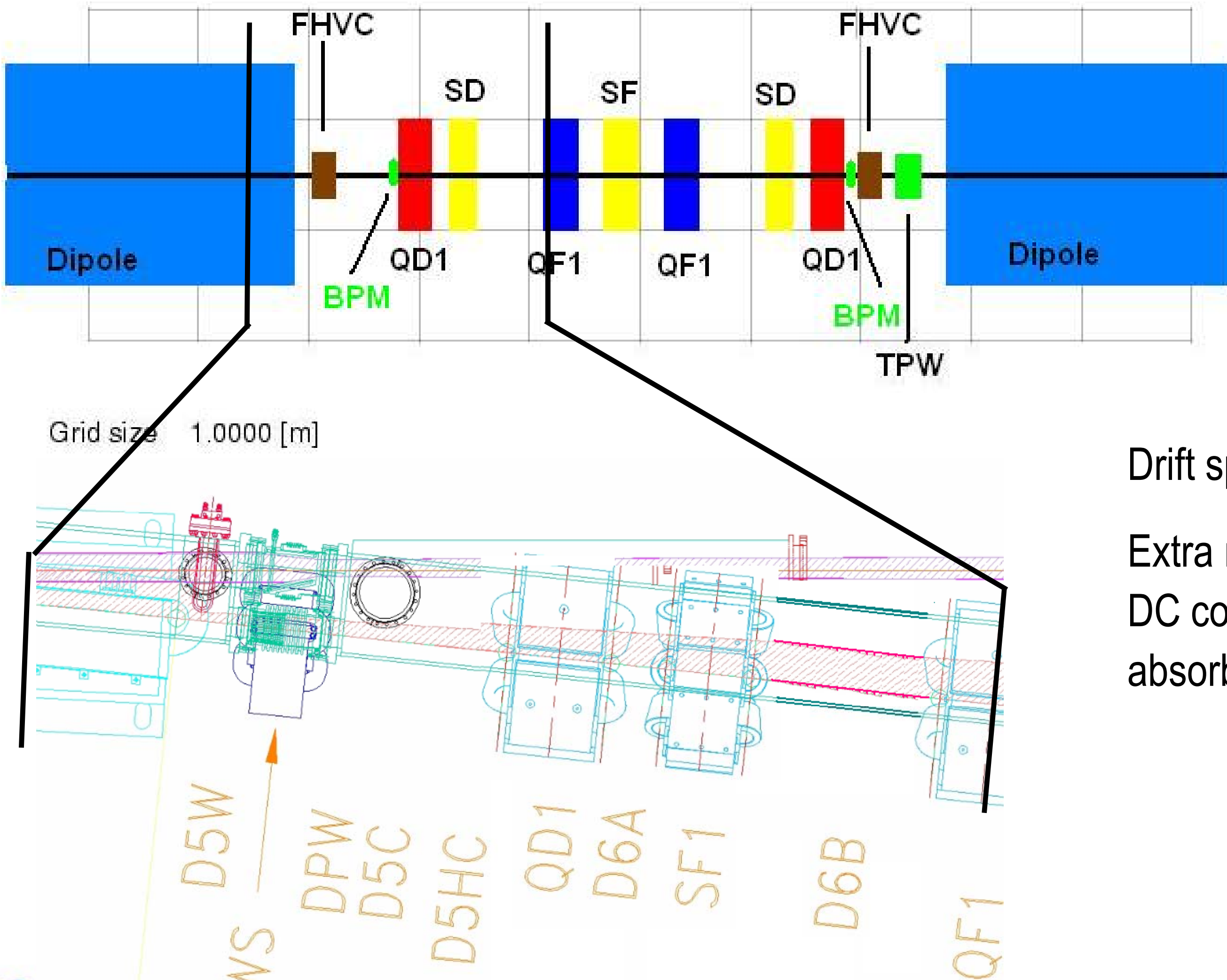
Long & Short ID Layout



Two BPM per girder for BBA of girder, 6 per cell plus 2 user (high precision BPMs) IDs

Discrete H & V Corrector magnets 2/ girder, 6/cell; 4 fast over SS bellows and 2 slow over Aluminum chamber

Dispersion Straight Layout



Drift space for:

Extra multipoles,
DC correctors, or
absorbers, etc.

Changes in Source Parameters

	Length Long ID [m]	Long ID β_x , β_y	Length Short ID [m]	Short ID β_x , β_y	TPW(0.2m) β_x , β_y , η_x
CD2	9.3 (7)	20,3.07	6.6 (5)	1.9 ,1.26	4.1, 19.1 , 0.168
CDR	8 (7)	18.1, 3.1	5 (3)	2.7, 0.95	NA
ε_x=0.5nm ε_y= 8pm	Long ID σ_x , $\sigma_{x'}$ [um, urad]	Long ID σ_y , $\sigma_{y'}$ [um, urad]	Short ID σ_x , $\sigma_{x'}$ [um, urad]	Short ID σ_y , $\sigma_{y'}$ [um, urad]	TPW σ_x , σ_y [um, um]
CD2	107.7,4.64	4.8,1.67	29.6,16.9	3.1,2.58	175,12.4
CDR	95.3,5.25	4.97,1.6	36.9,13.6	2.75,2.9	None

CD2 Lattice Parameters

Circumference	[m]	791.958	Number of cells/SP		30 / 15
Energy	[GeV]	3	RF Frequency	[MHz]	499.68
Uo (8- 7m DW)	[KeV]	286.39 (1320)	Dipole Bend radius [m] Dipole Field	 [T]	25.02 0.399
ε_x dipoles (with 8- 7m DW)	[nm] [nm]	2.017 (0.501)	Energy Spread (8- 7m DW)	[%] [%]	0.051 (0.102)
ε_y	[pm]	8	Bunch length	[ps]	10-20
Tunes Qx,Qy Chrom. ξ_x, ξ_y		33.36,16.28 -101,-41.2	Synchrotron frequency [KHz] $\alpha_c(1)$, $\alpha_c(1)$ (x 10^{-4})		3.1 3.63, -4.64
β_x , β_y LID SID	[m] [m]	20.2,3.07 1.9,1.26	ID length total (active) [m]		9.3 (7) 6.6 (5)

* Changes from CDR in Red

Summary and Additional Work

- Reduction of No. Quads & Sexts in ID & dispersion sections
- Increased ID length for vacuum transitions and components
- Increased Circumference for RF matching and harmonic No.
- Added possibility for 15+ TPWs to provide sources for NSLS beam line migration
- Far IR beams from low field dipoles with increased gap, 4+
- Need further study of sextupole and nonlinear tuning
- Study in progress for field tolerances and IDs effects
- Canted IDs and Decker Distortions were studied to have minimum impact on damped ε_x, but more work to be done