ILC Curved Linac Simulation

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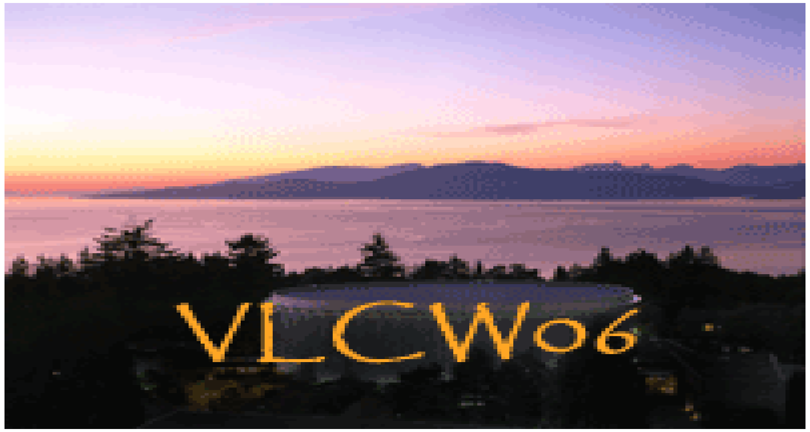
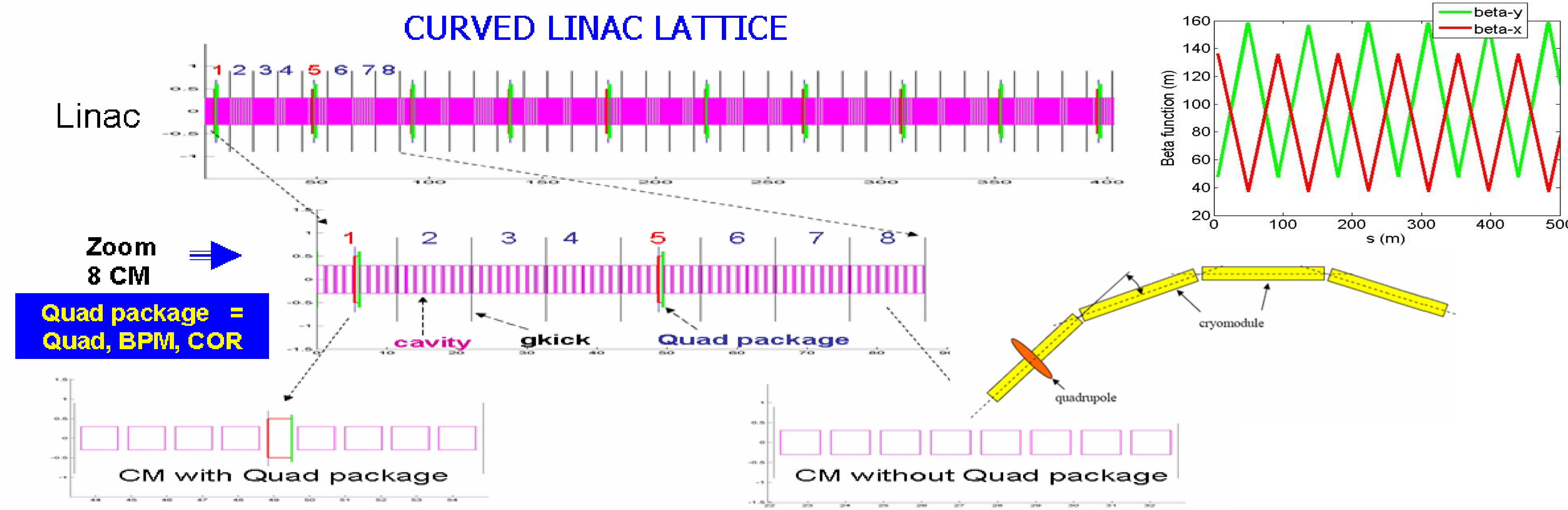
SLAC



OVERVIEW

- ILC BCD Curved LINAC Simulation : Dispersion Free Steering (DFS)
- DFS : Sensitivity studies
- Failure Mode Analysis in DFS: BPM / Corrector Failure
- Different No. of BPMs
- Emittance Bumps

Curved ILC-BCD LINAC

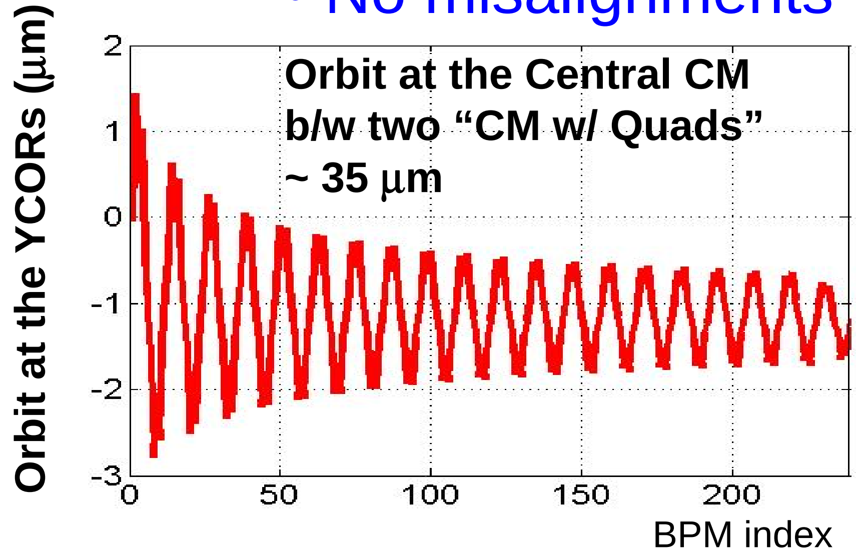


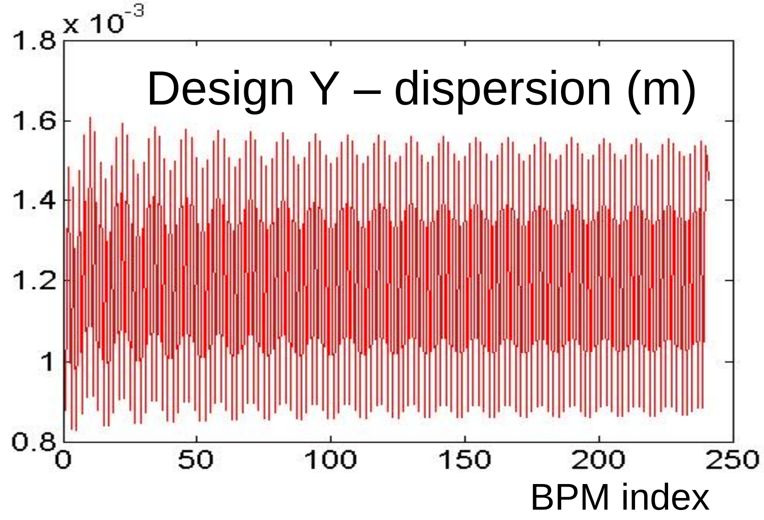
- PT's ILC BCD-like lattice distributed during ILC-LET workshop at CERN (Feb.2006)
- A constant focusing lattice with a quadrupole spacing of 32 cavities and x/y phase advance of 75/60 per cell (ILC BCD - 1Q / 4CM)
- Modifications in LIAR code to simulate the earth curvature:
  - The curvature is simulated by adding kinks between the cryo-modules - ***GKICK***
  - "***Design Dispersion*** (from earth curvature)" : The matched dispersion condition at the beginning of the linac is artificially introduced into the initial beam and is propagated through linac using transfer matrices

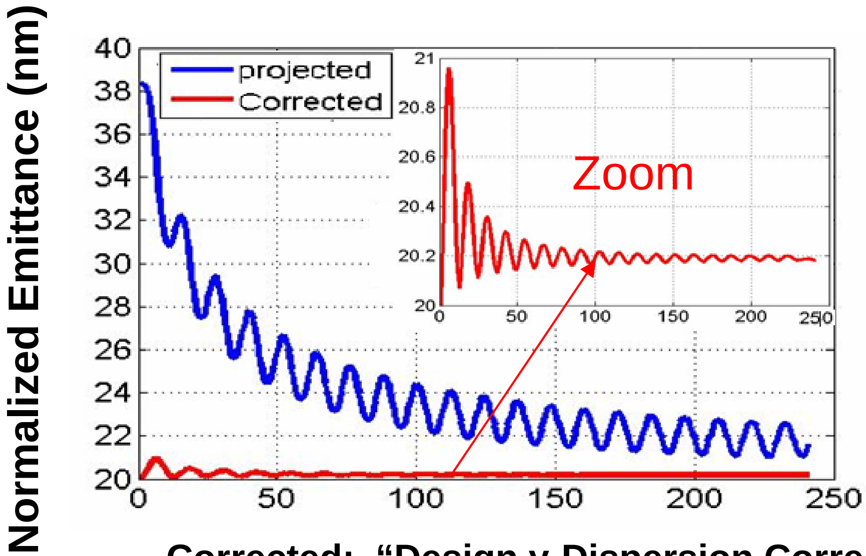
Length (m) :	**10417.2m**
N_quad :	**240**
N_cavity :	**7680**
N_bpms :	**241**
N_Xcor :	**240**
N_Ycor :	**241**
N_gkicks :	**1920**

LIAR Simulation: CURVED LINAC

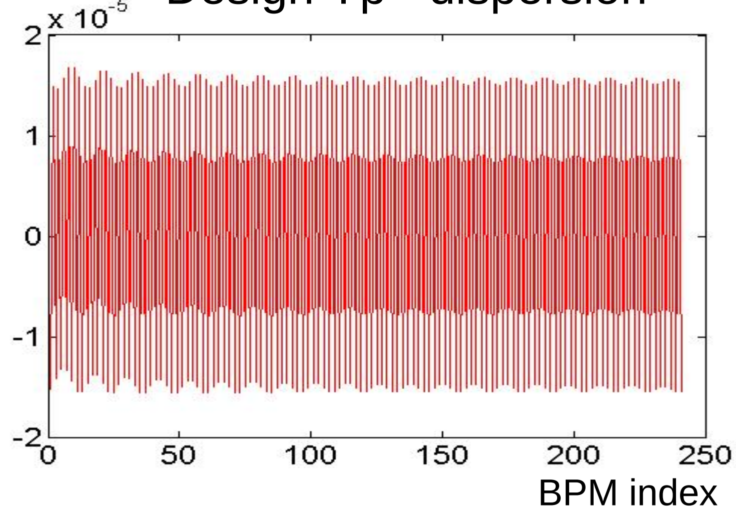
- No misalignments







Corrected: “Design y-Dispersion Corrected”



Nominal Misalignment tolerances

Tolerance	Vertical (y) plane
BPM Offset w.r.t. Cryomodule	300 μm
Quad offset w.r.t. Cryomodule	300 μm
Quad Rotation w.r.t. Cryomodule	300 μrad
Cavity Offset w.r.t. Cryomodule	300 μm
Cryostat Offset w.r.t. Survey Line	200 μm
Cavity Pitch w.r.t. Cryomodule	300 μrad
Cryostat Pitch w.r.t. Survey Line	20 μrad
BPM Resolution	1.0 μm

➔ **1st 7 BPMs have 30 μm RMS offset w.r.t. Cryostat**

- **BPM transverse position is fixed, and the BPM offset is w.r.t. Cryostat**
- **Only Single bunch used**
- **Steering is performed using Dipole Correctors**

Dispersion Free (or Matched) Steering

- 1:1 steering is performed - steer to obtain the nominal, design readings of the BPMs

DFS -

- **Linac is divided into 18 segments (w/ 50% overlap) & 1st DF segment starts from 8th BPM**
- **Measure two orbits –**

  (i) y(0) : one for the nominal energy.

  (ii) y(δ) : other by switching off cavities upstream of the segment (maximum energy change for a given segment is 20% of the nominal energy at the upstream end of the segment, or 18 GeV, whichever is smaller.)

- **In both cases 3 BPMs upstream of each segment (used for fitting the incoming beam trajectory) are included in the measurement.**

- **Simultaneously minimize the Measured dispersion and RMS value of BPM readings**

$$\chi^2 = \frac{\Delta \mathbf{y}(\delta)\cdot\Delta \mathbf{y}(\delta)}{\sigma_{res}^2} + \frac{\mathbf{y}(0)\cdot\mathbf{y}(0)}{\sigma_{BPM}^2}$$

σ_{res} = sqrt(2) * BPM resolution ← **1 μm**

σ_{BPM} = BPM offset ← **300 μm**

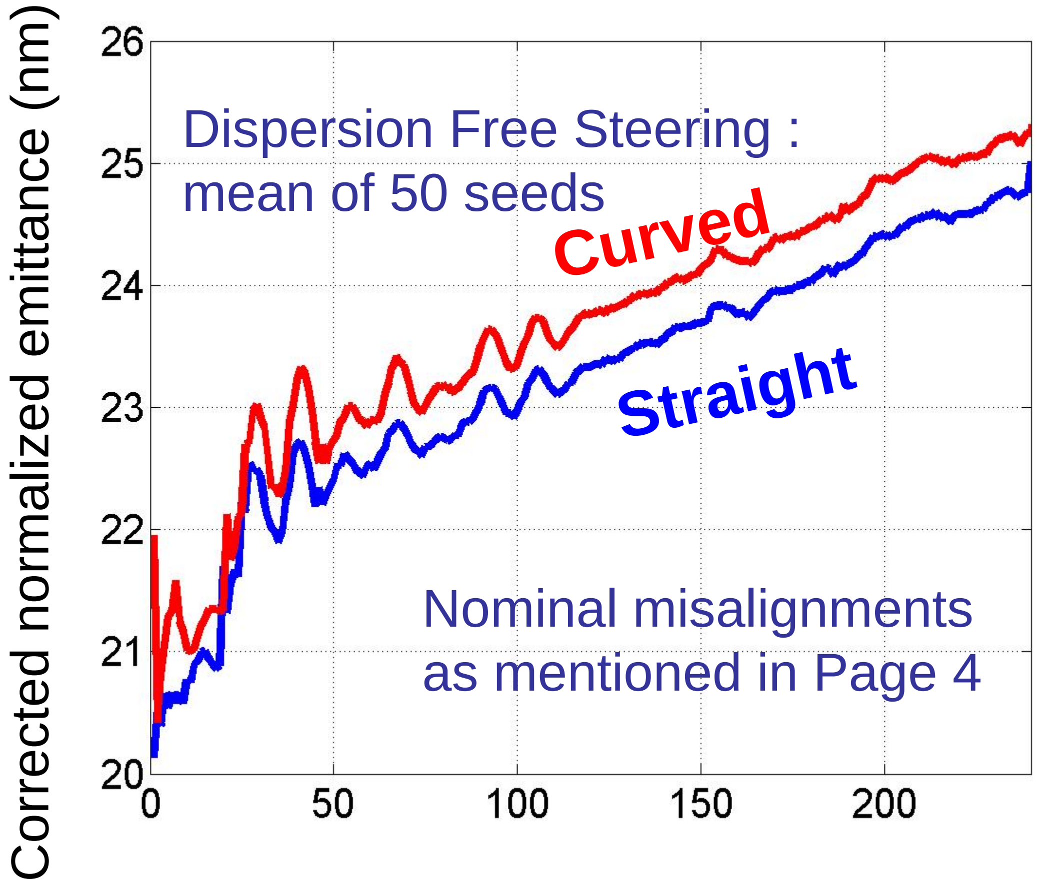
Where $\Delta \mathbf{y}(\delta) = \mathbf{y}(\delta) - \mathbf{y}(0) - \Delta \mathbf{y}_{nom}(\delta)$

$\Delta \mathbf{y}_{nom}(\delta)$ is the nominal or design difference orbit for the momentum error δ.

Dispersion Free Steering - Results

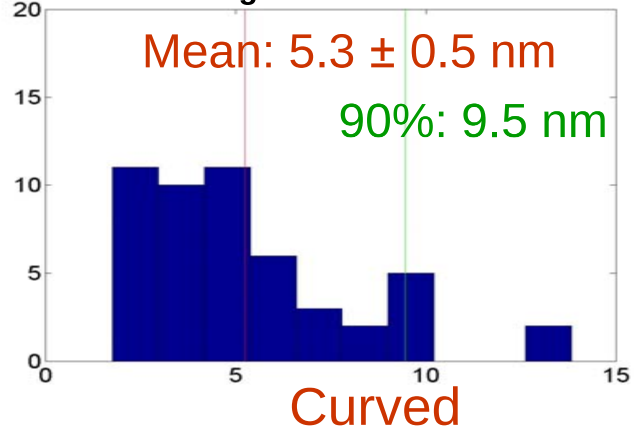
Misalign the beamline components and perform the DF steering

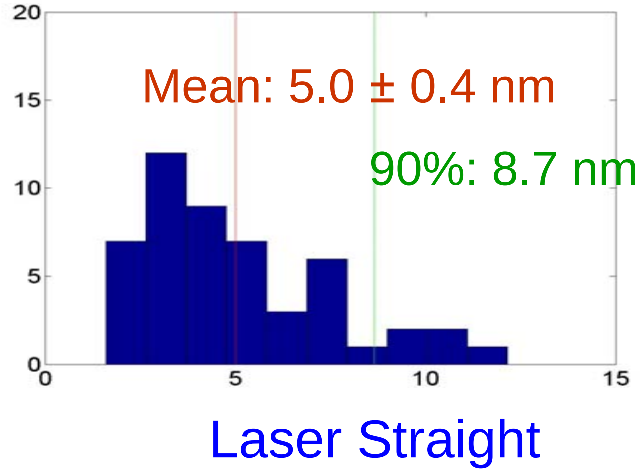
CURVED vs. STRAIGHT LINAC



DFS parameters not optimized for Curved Linac

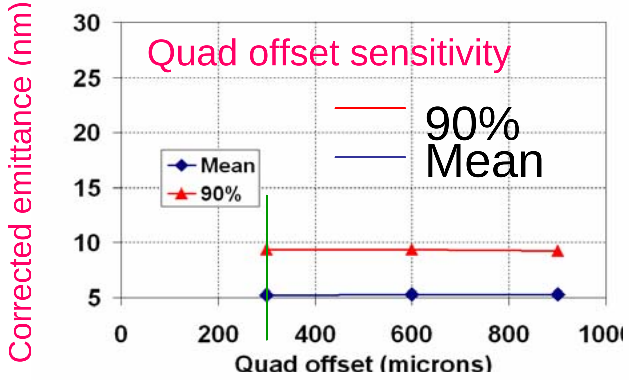
Distribution of emittance growth for 50 seeds

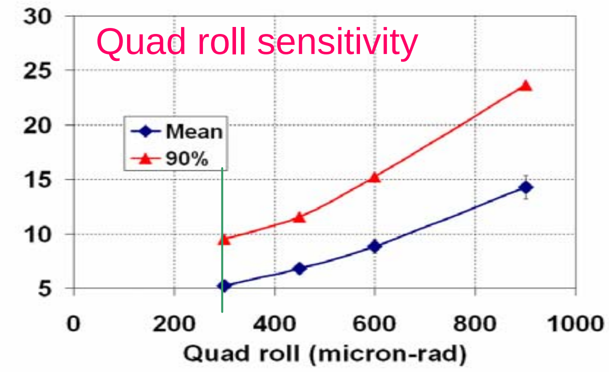


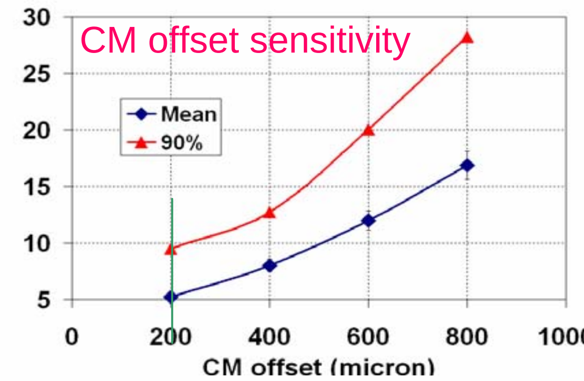


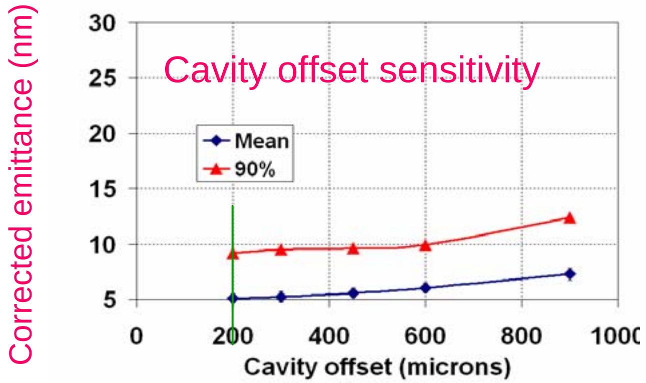
DFS: Sensitivity studies

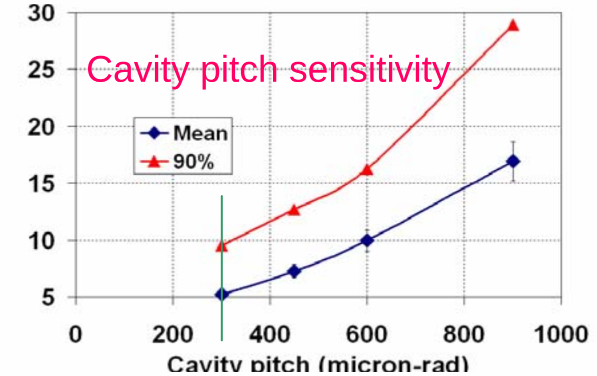
Vary one misalignment from its nominal value - keeping all other misalignments at their nominal value

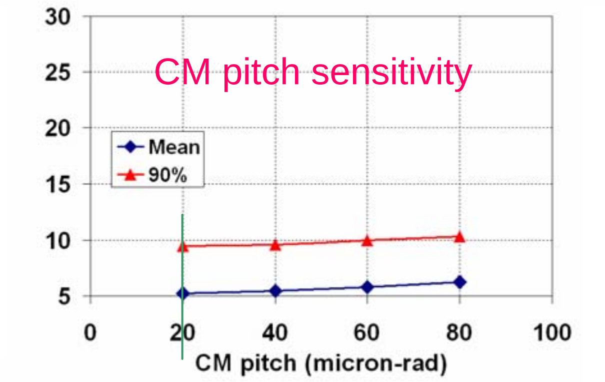


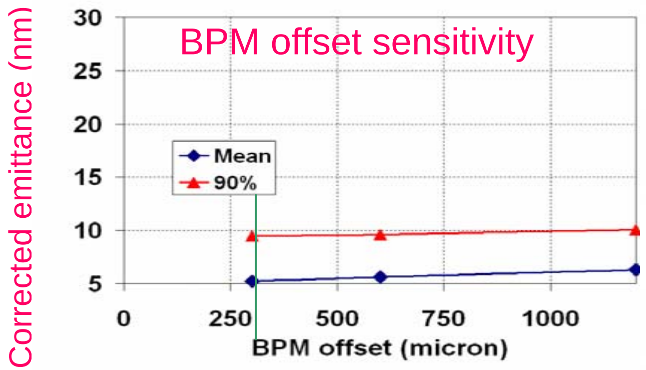


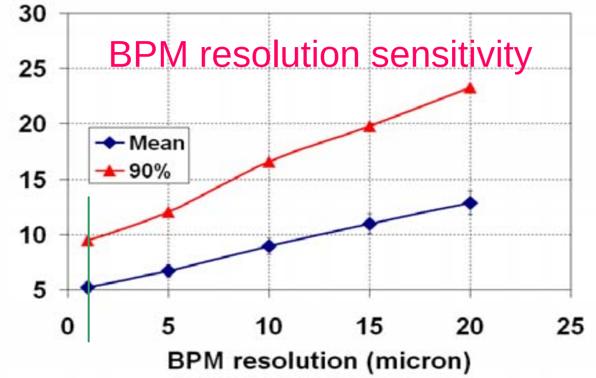








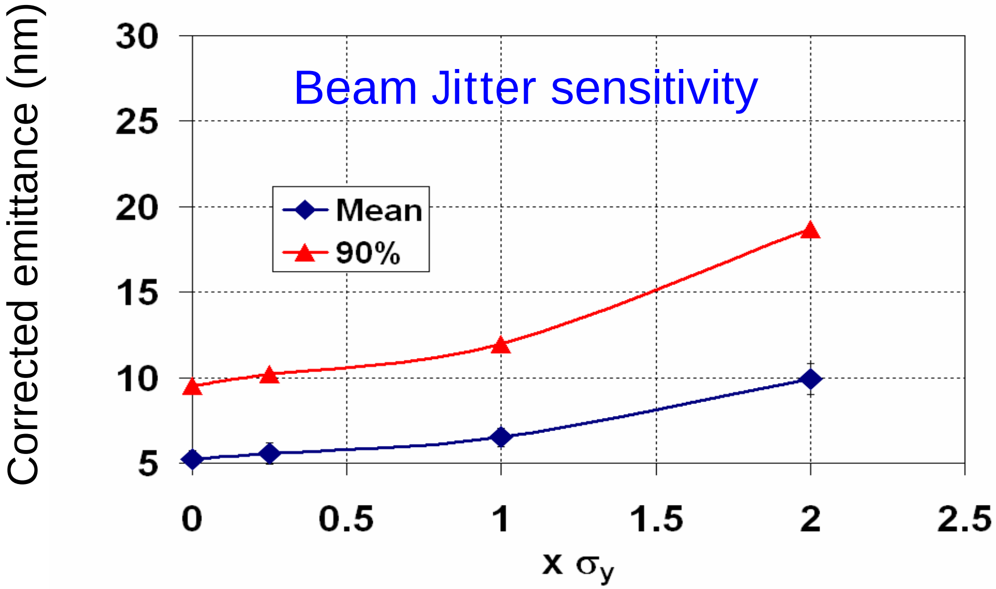


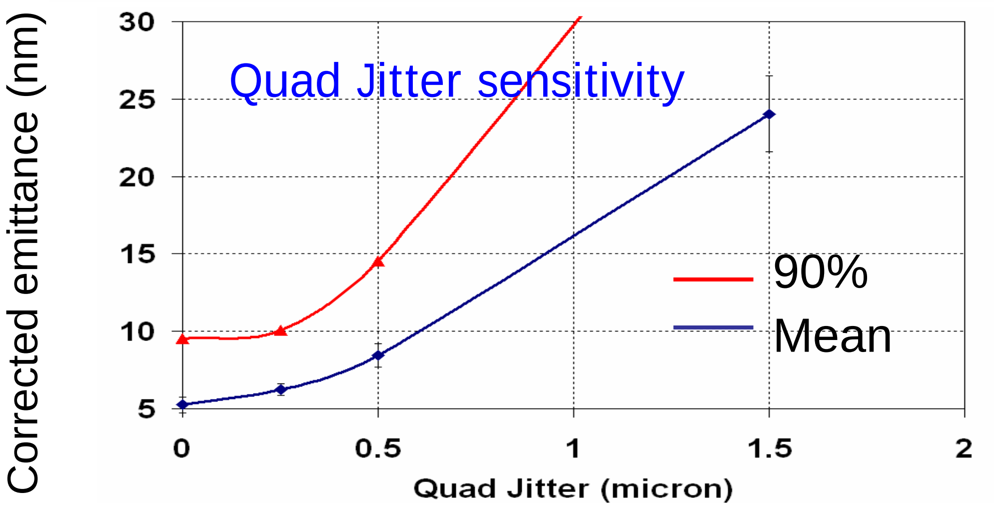


Sensitive to
Cavity pitch**,**
BPM resolution**,**
CM offset**,**
Quad roll

DFS: Sensitivity studies

Beam and Quad Jitter Sensitivity





Quad Strength error

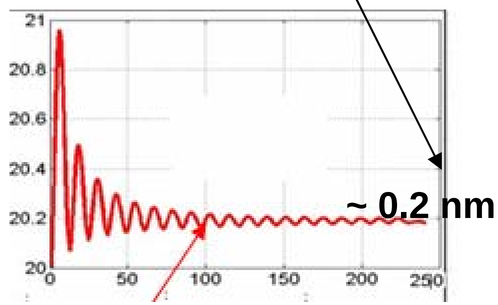
Quad strength error (dK)	Mean	90%
0.5 e-3	7.43±0.46	11.7
1e-3	7.44±0.46	11.5
2.5e-3	7.50±0.46	11.5
5e-3	7.70±0.46	11.9

DFS: Contributions

50 seeds	mean	90%	
Nominal	**5.26 ± 0.38**	**9.47**	
Dispersion only	**1.99 ± 0.24**	**4.22**	**Switch off wakes & quad roll**
Wakes only	**1.8 ± 0.17**	**3**	**Cavity offset & wakes only**
Quad roll only	**1.47 ± 0.13**	**2.83**	**quad roll only**
Total	**5.26**	**10.05**	

Individual misalignment (30 seeds)	mean	err	90%
CM pitch only	**0.25**	0.036	0.56
***Cavity pitch* only**	***2***	*0.35*	*4.3*
Front bpm offset only	**0.41**	0.0493	0.77
Quadroll only	**1.39**	0.13	2.37
***Cavity offset* only**	***1.67***	*0.18*	*2.98*
BPM resolution only	**0.43**	0.0548	0.76
BPM offset only	**0.2**	0.0107	0.28
Quad offset only	**0.17**	0.0026	0.19
Sum	**6.52**		**12.2**

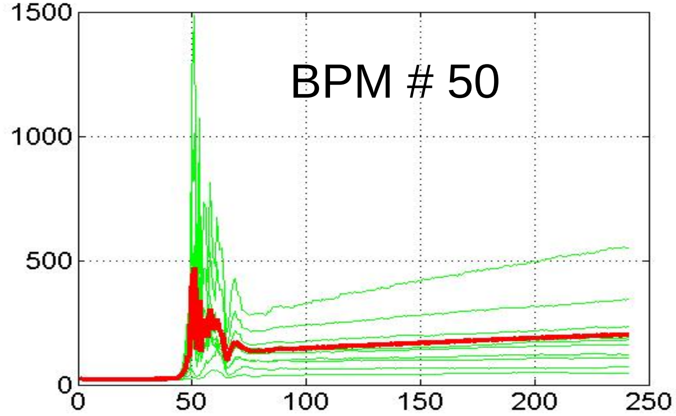
A **systematic contribution** seems to add up in each case, which is added only once when we perform the nominal run

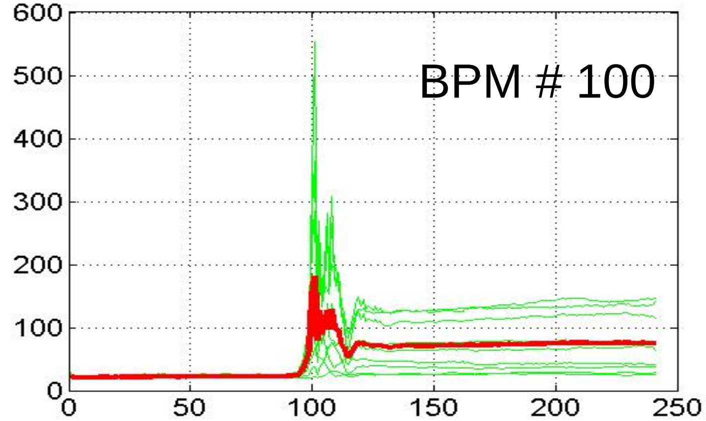


Failure Mode Analysis (ILC BCD Curved Linac)

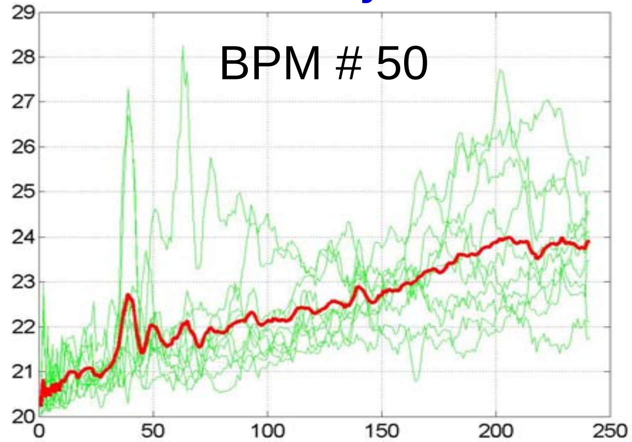
10 seeds; **Curved Linac**; **1 BPM reading = 0 and is used in the DF steering**

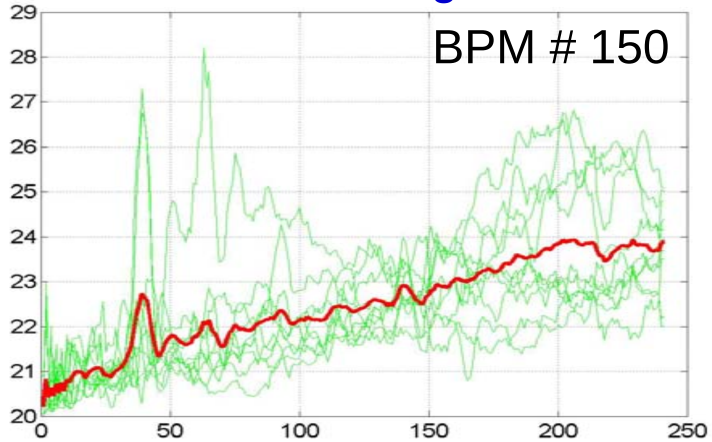
Dispersion corrected emittance growth (nm-rad) vs. BPM index





Case2: Faulty BPM and associated YCOR not used in steering

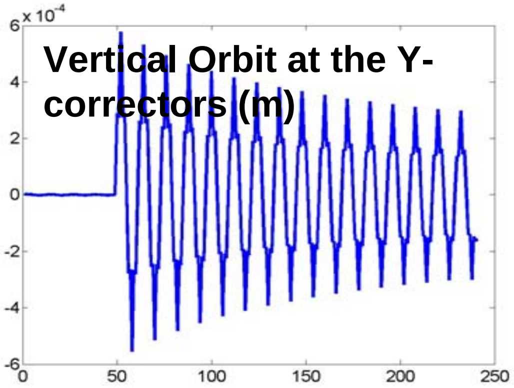


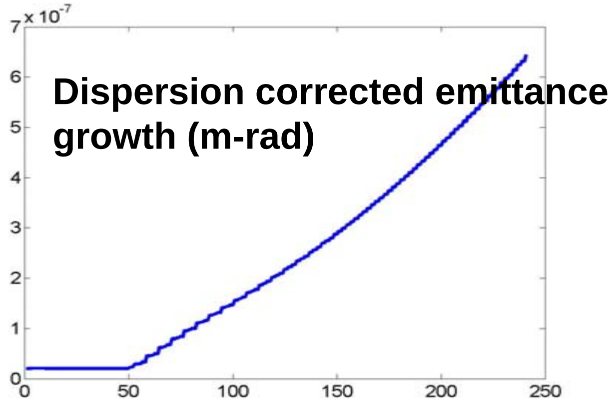


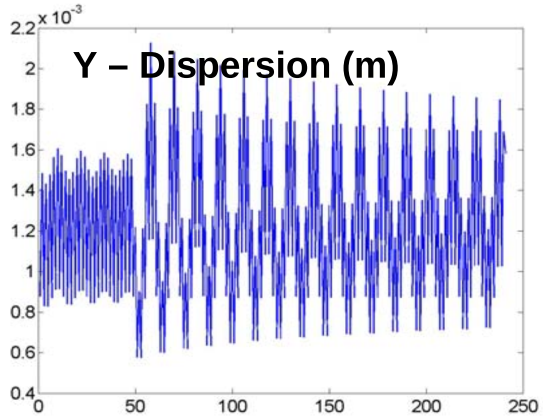
(1) If you know the position of faulty BPM and exclude it from the steering then the results are fine
(2) However, if you use that faulty BPM in finding the corrector settings, then the emittance dilution is significant.

Failure Mode Analysis (ILC BCD Curved Linac)

Case 1: Perfectly straight Linac (1 Y - CORRECTOR NOT WORKING (kick =0) :# 49)



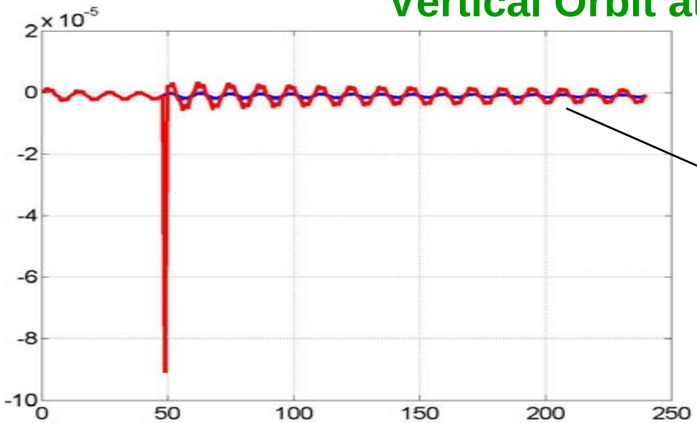


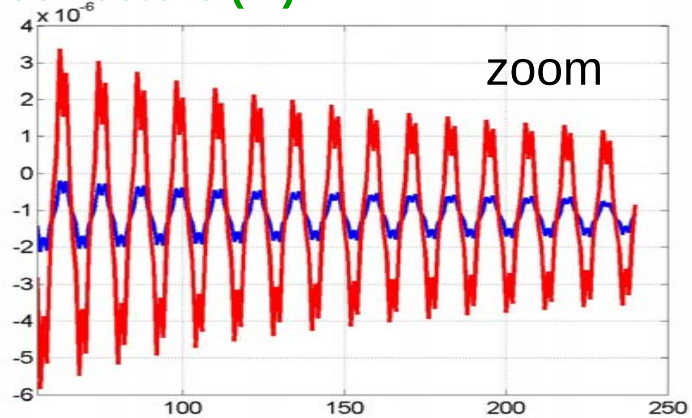


In a perfectly aligned Linac, if one YCOR doesn't work according to it's designed value – then both the trajectory and emittance dilution are significantly worse

- **Adjusted the adjacent two correctors (upstream and downstream) to guide the beam on to the designed orbit – we know which corrector is failed!**

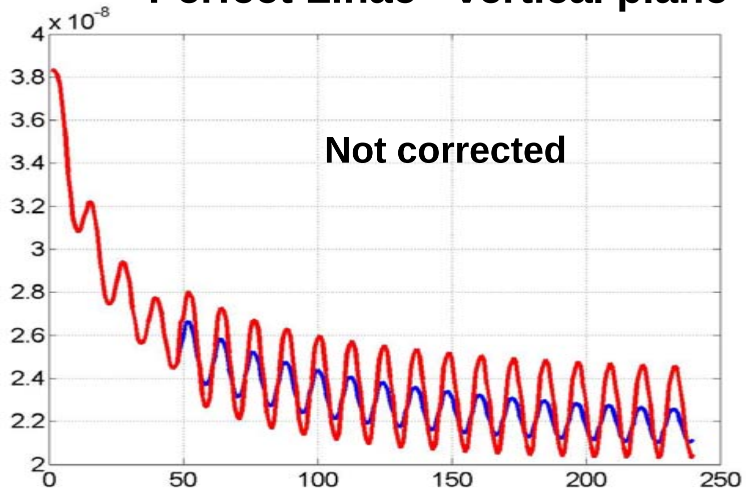
Vertical Orbit at the Y-correctors (m)

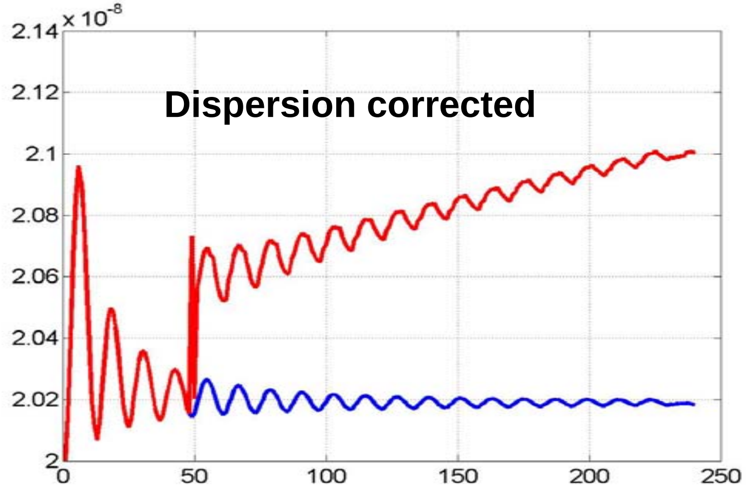




Failure Mode Analysis (ILC BCD Curved Linac)

Perfect Linac - vertical plane - Projected Normalized Emittance (m-rad)

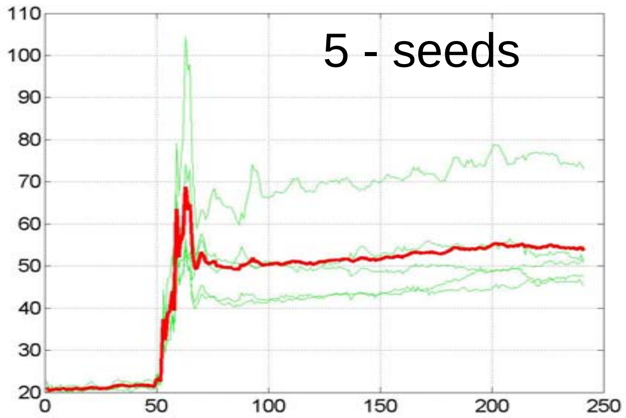




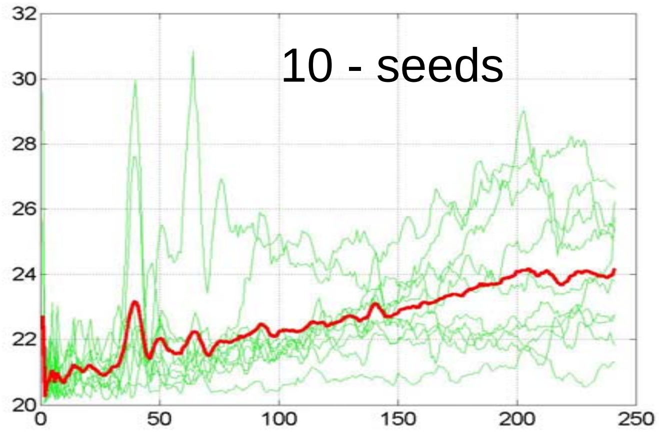
Nominal misalignment ; Dispersion Free Steering;

- **Case 1: Failed Corrector used in finding the correction-settings; but correction is not applied to the failed corrector**

Case 2: Failed Corrector NOT used in finding the correction-settings;



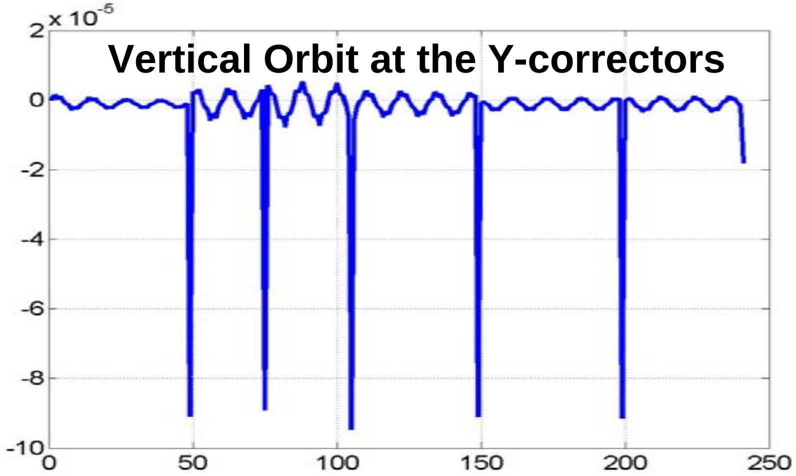
Dispersion corrected – emittance growth (nm-rad)



Failure Mode Analysis (ILC BCD Curved Linac)

5 Y-CORRECTORS NOT WORKING – randomly chosen - CORRECTORS NO. 50,76,106,150,200 (one corrector failure in one DF segment)

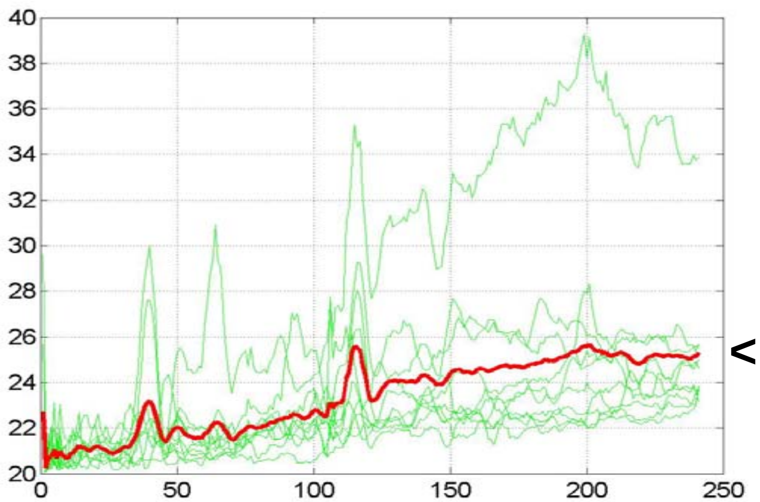
- Adjusted the adjacent two correctors to guide the beam on to the correct orbit



Nominal misalignment ;

Dispersion Free Steering;

Dispersion corrected – emittance growth (nm-rad)

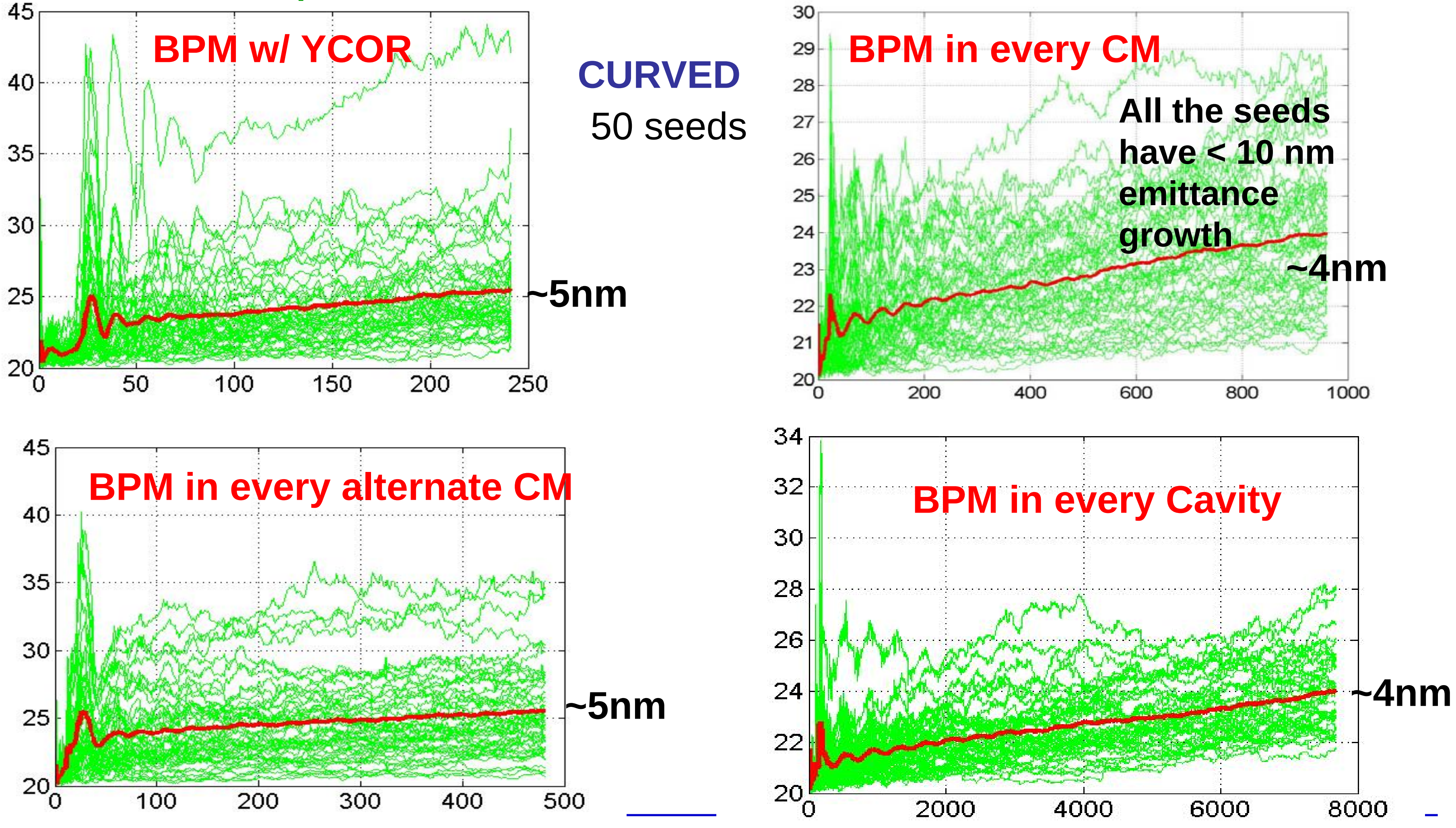


< 6 nm

No. of BPMs

Using BPM in every CM or in every Cavity : Presently we are using BPM in only Quad package along w/ Corrector. (a) What if BPM is there at the centre of every CM? (b) what if each cavity can be read out as BPM – BPM in every cavity?

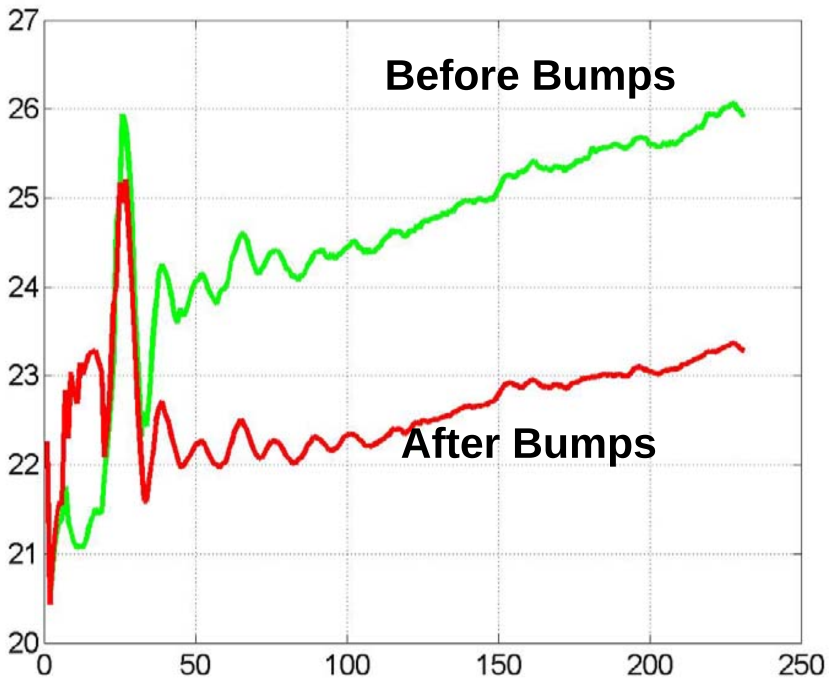
Dispersion Corrected Emittance Growth vs. BPM index



Emittance Bumps

Curved ILC BCD Linac; 50 seeds

Corrected Emittance Growth (nm) vs. BPM Index



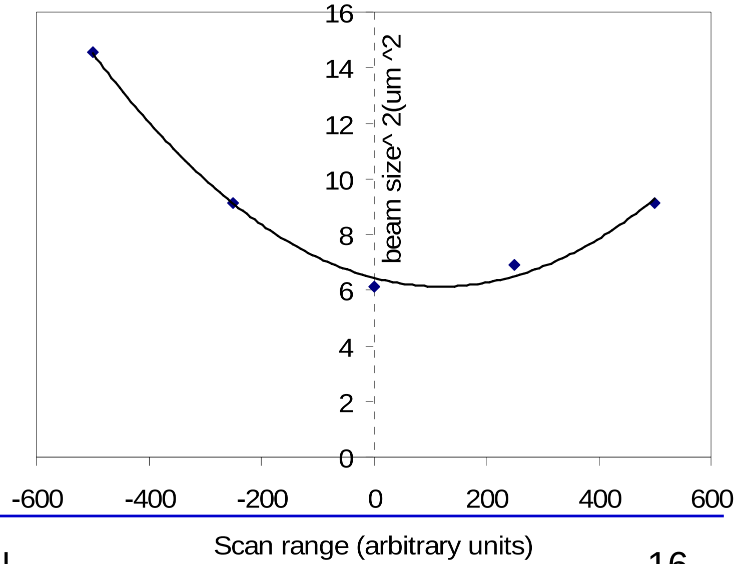
2% error on beam size measurement

One Bump:

Bump (starting at energy = 16.16 GeV)

Cor1:
Coeff= 3.3163e-07
Cor2 (180 deg apart):
Coeff=3.3163e-07*sqrt (energy2 / energy1)

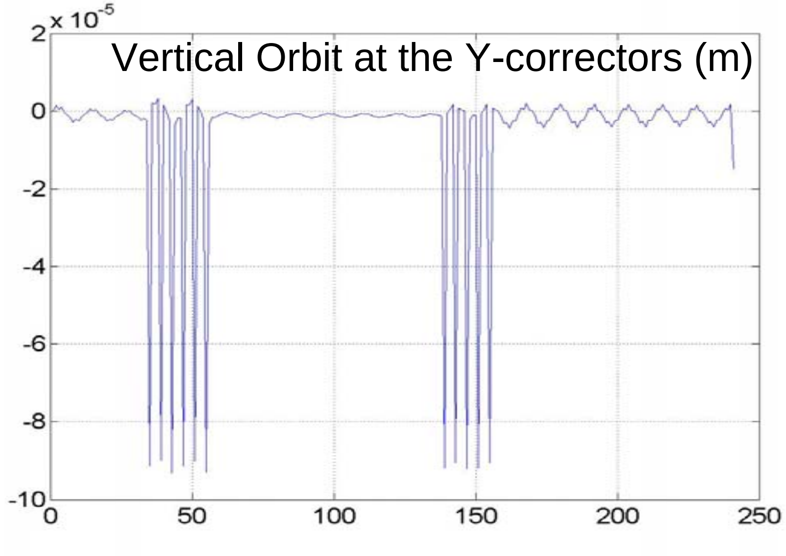
Cor3 (90 deg from 1st Ycor):
Coeff= 4.2299e-07
Cor4:
Coeff=4.2299e-07*sqrt (energy4 / energy3)



PLAN

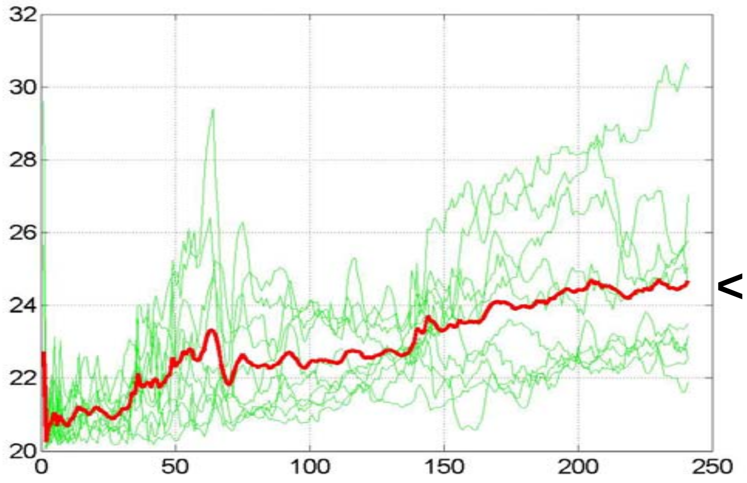
- **Continue w/ dispersion + wake bumps in curved linac**
- **Perform the studies in the Final Main Linac Lattice**

Several Y-CORRECTORS NOT WORKING – randomly chosen
Correctors not used in the steering



Nominal misalignment; DMS

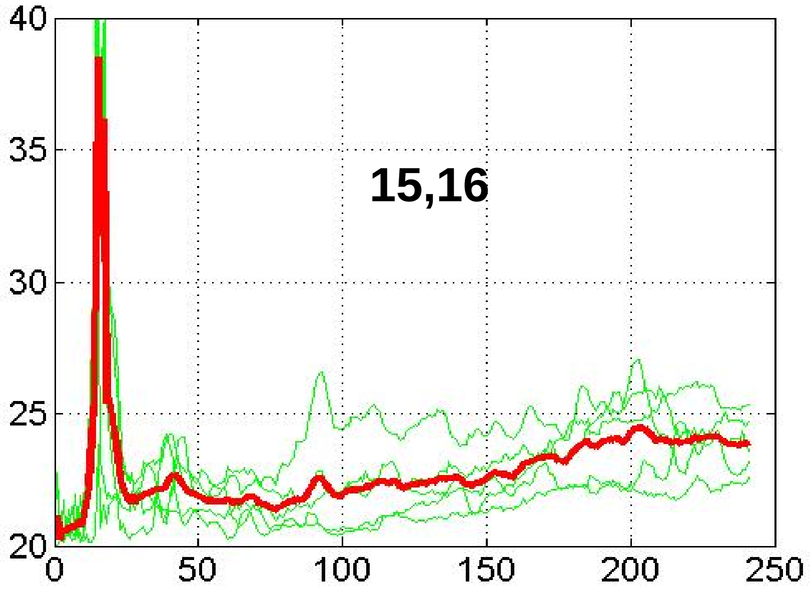
Dispersion corrected emittance dilution (nm-rad);

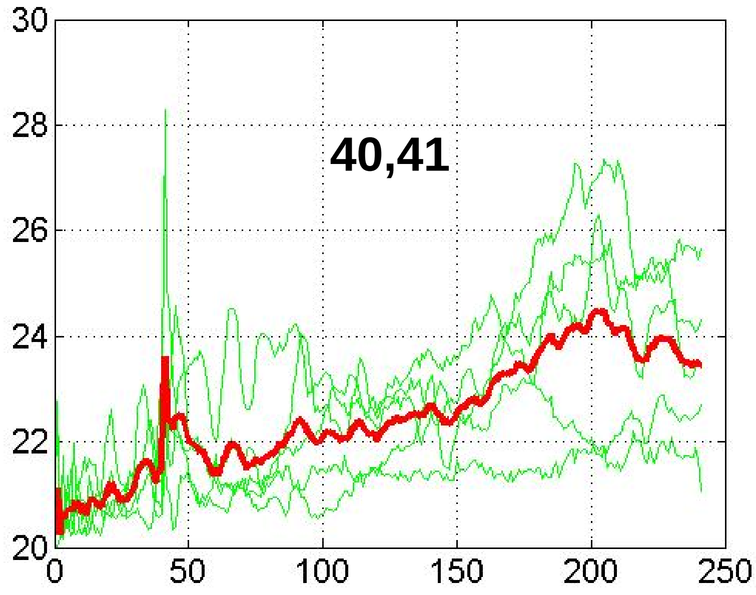


< 6 nm

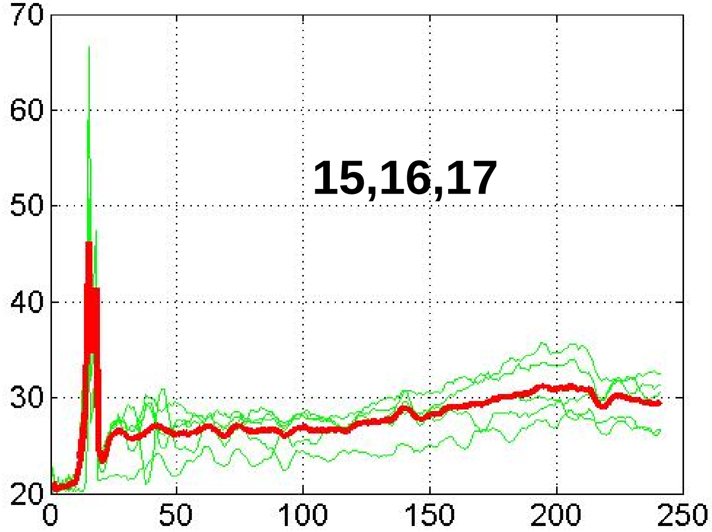
WHAT IF Consecutive BPM / YCORs are not working and not used in finding the corrector settings?

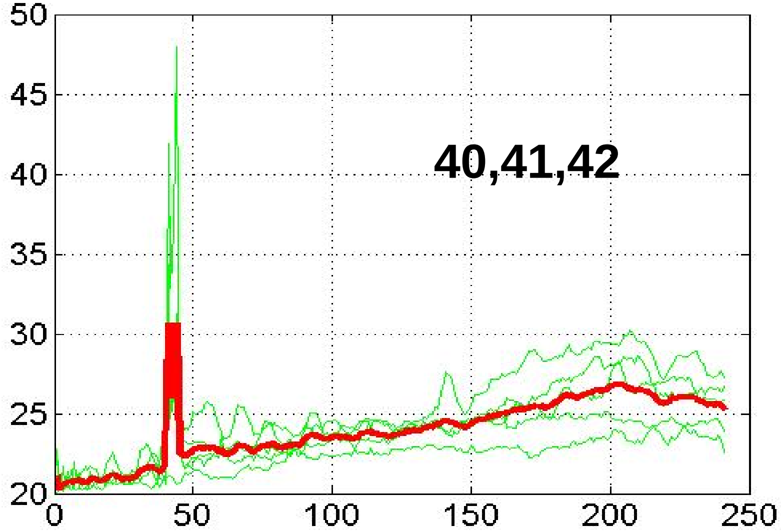
2 consecutive BPM/YCOR removed

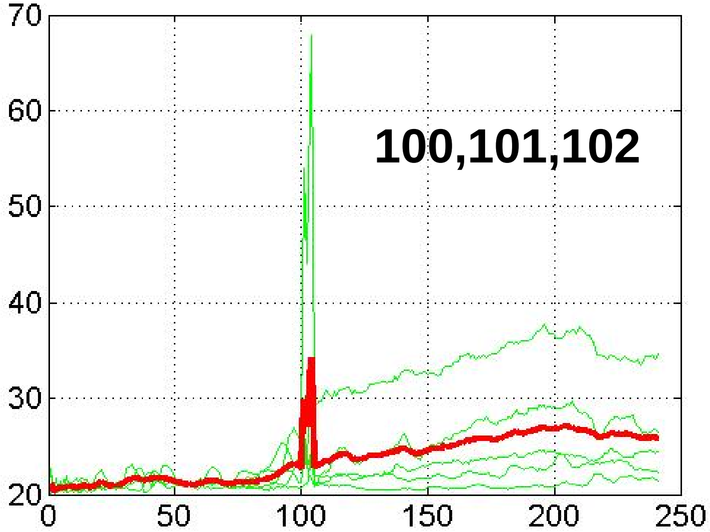




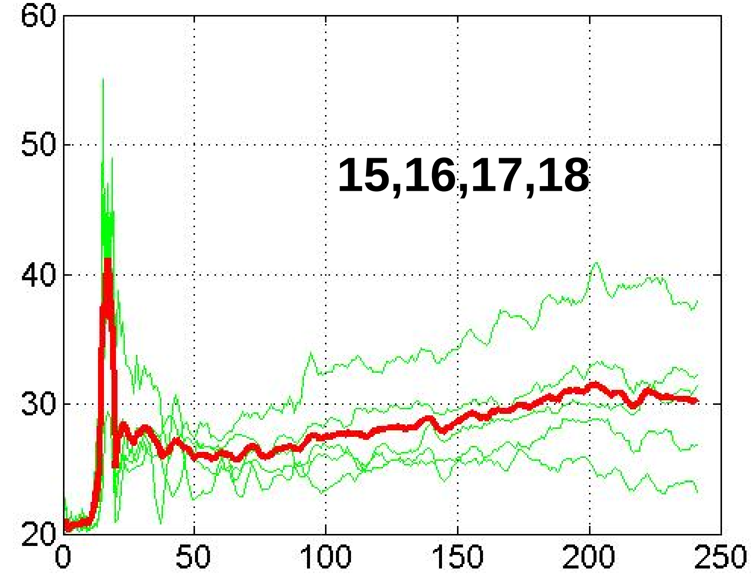
3 consecutive BPM/YCOR removed

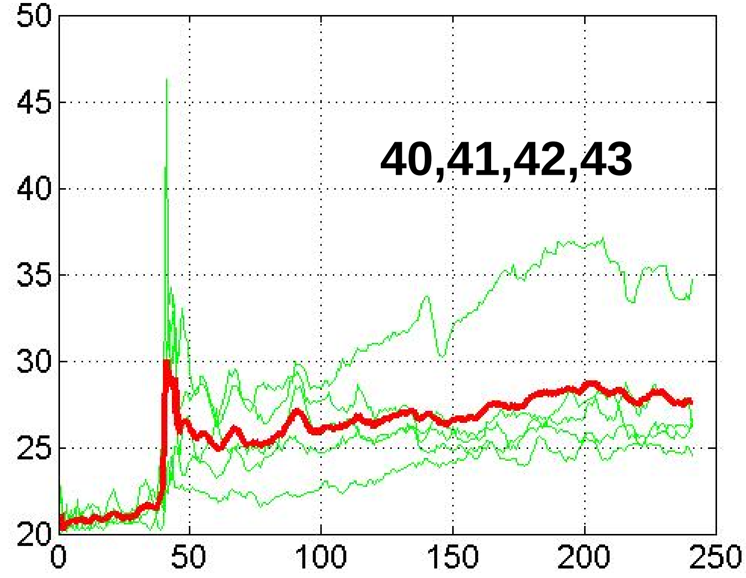


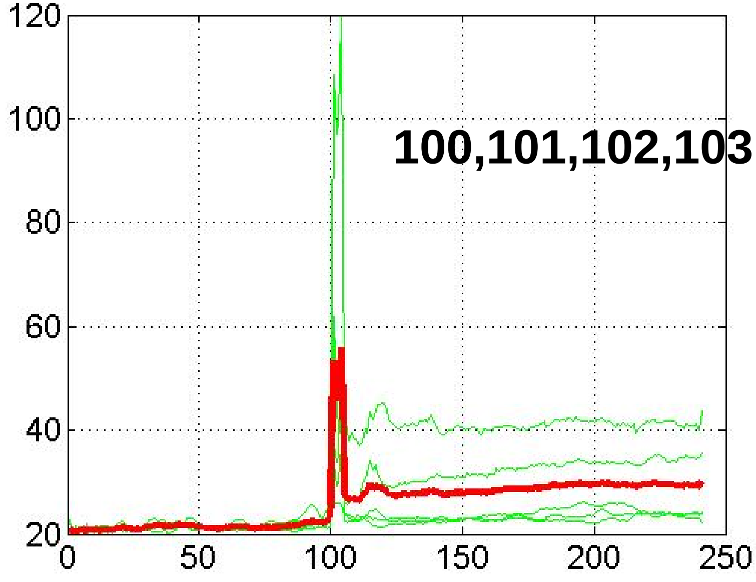




4 consecutive BPM/YCOR removed

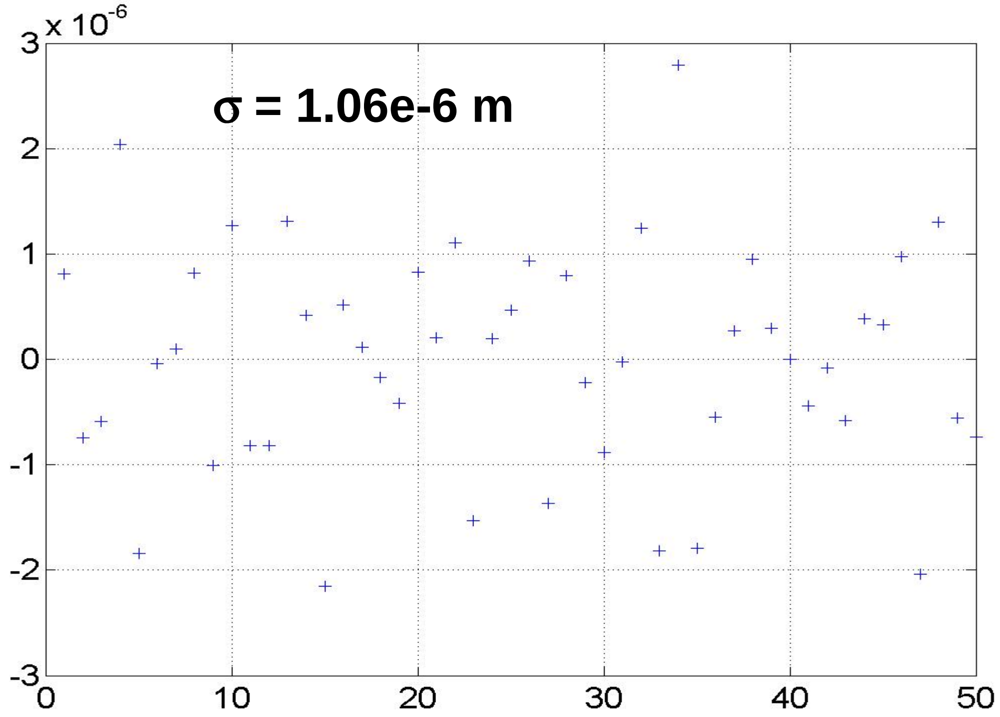






Straight Linac; 30nm RMS (white noise) Quad vibration (no other error); 50 seeds

Ybpm_readings at the end of the linac vs. seed no.



Y_beam_size at the end of the linac= 2.5 e -6 m