ILC Curved Linac Simulation

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Fermilab

+

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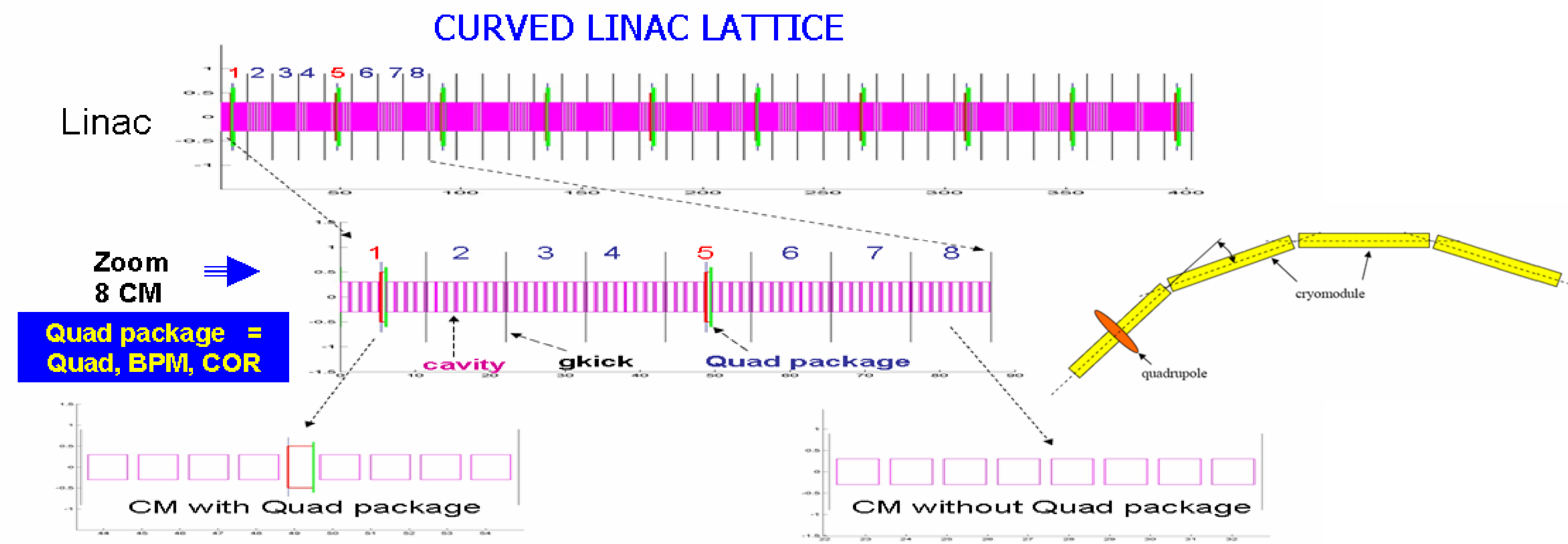
SLAC

Curved ILC-BCD LINAC



- PT’s ILC BCD-like lattice distributed during ILC-LET workshop at CERN.

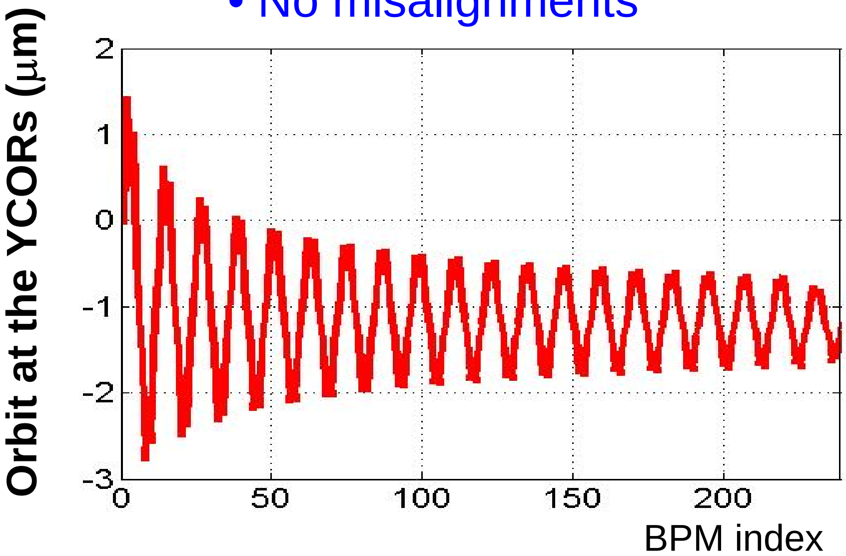
- A constant focusing lattice with a quadrupole spacing of 32 cavities and x/y phase advance of 75/60 per cell (ILC BCD - 1Q / 4CM)

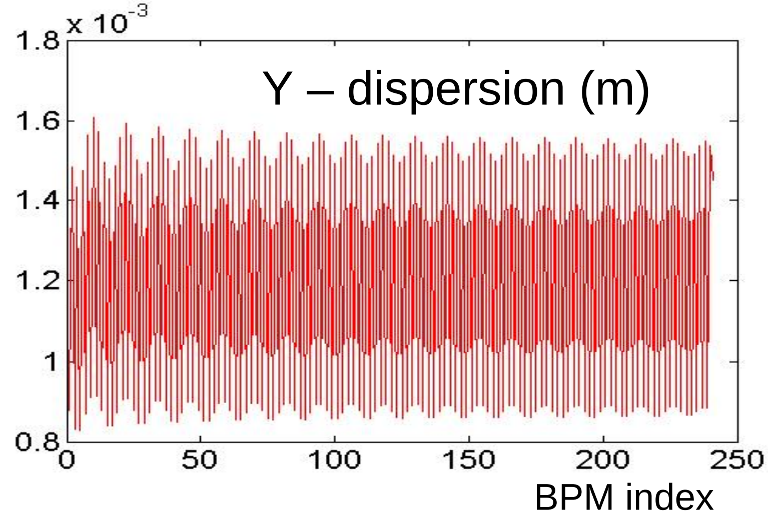
- Modifications in LIAR code to simulate the earth curvature:
  - The curvature is simulated by adding kinks between the cryo-modules - **GKICK**
  - The matched dispersion condition at the beginning of the linac is artificially introduced into the initial beam and is propagated through linac using transfer matrices

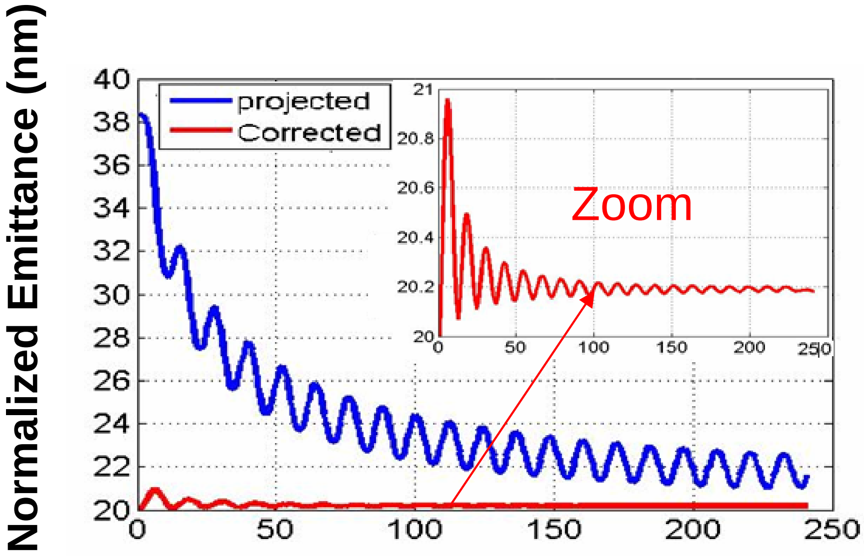
Length (m)	**:**	**10417.2m**
N_quad	**:**	**240**
N_cavity	**:**	**7680**
N_bpms	**:**	**241**
N_Xcor	**:**	**240**
N_Ycor	**:**	**241**
N_gkicks	**:**	**1920**

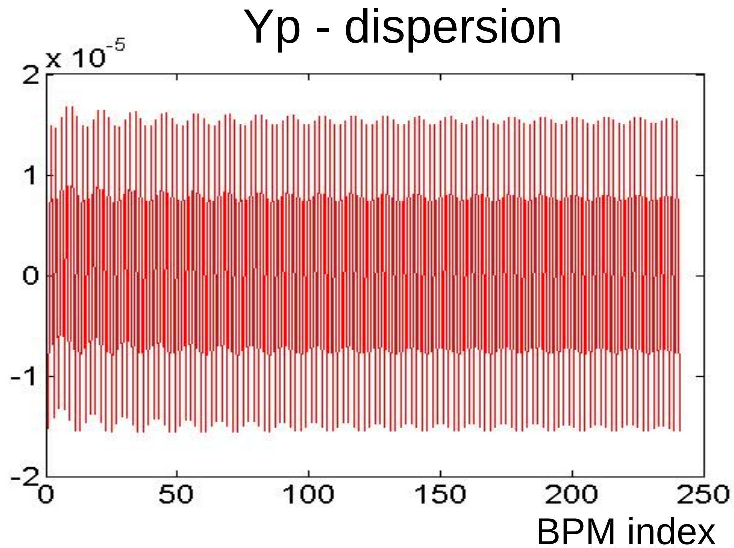
LIAR Simulation: CURVED LINAC

- No misalignments









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

σ_{BPM} = BPM offset

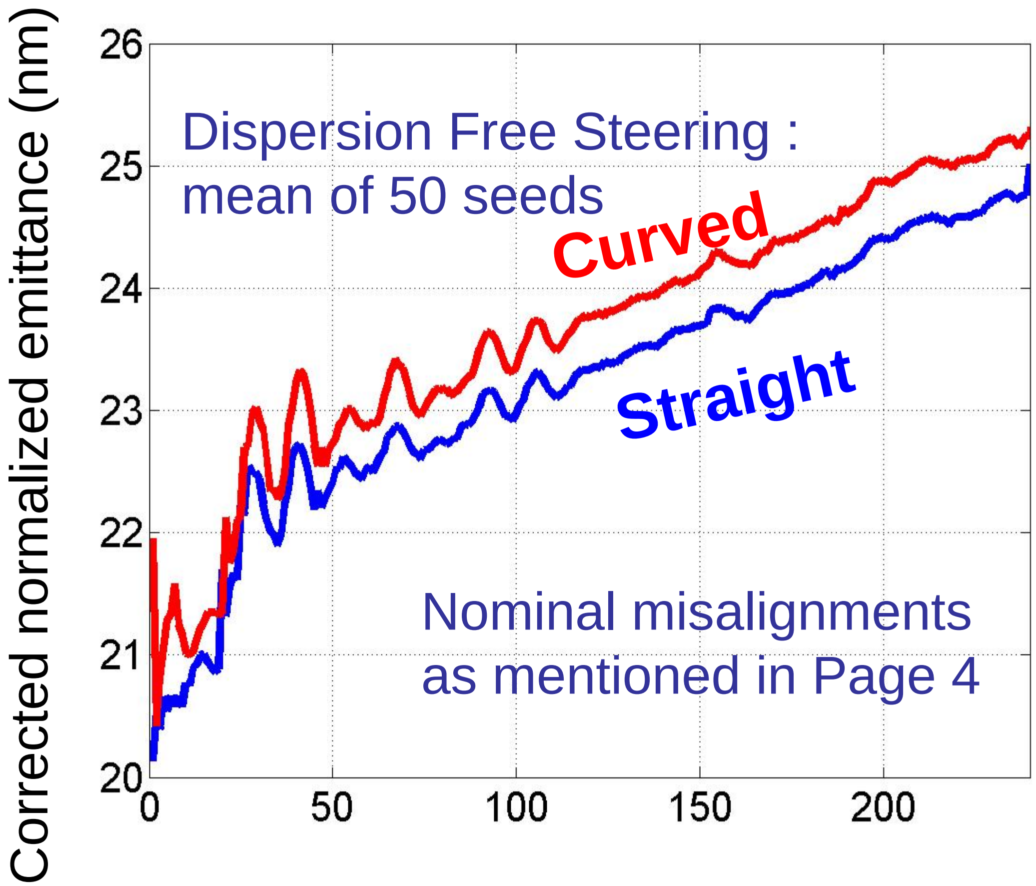
Where $$\Delta\mathbf{y}(\delta) = \mathbf{y}(\delta) - \mathbf{y}(0) - \Delta\mathbf{y}_{nom}(\delta)$$

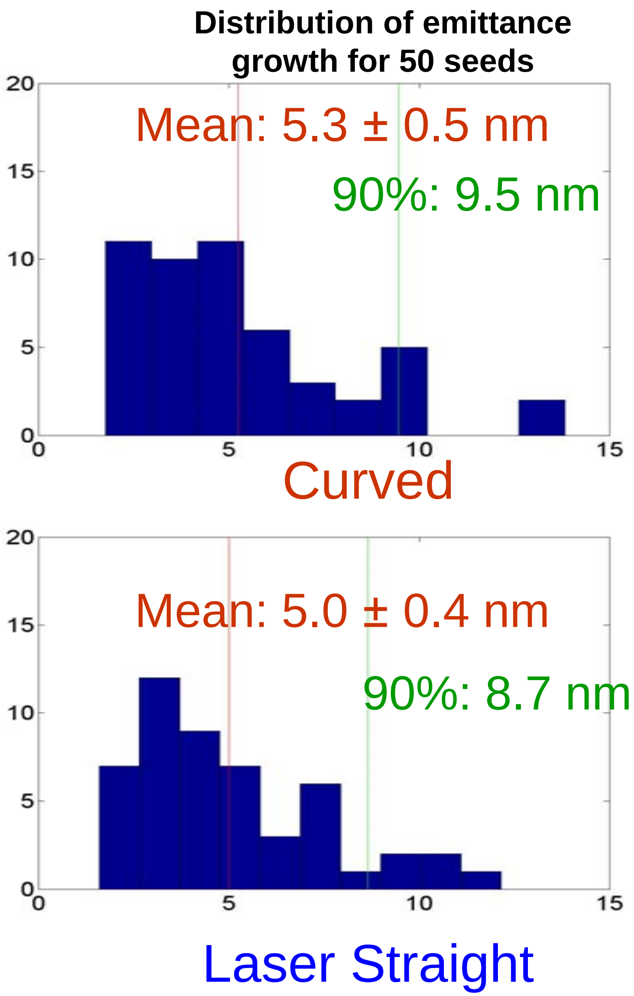
$\Delta\mathbf{y}_{nom}(\delta)$ is the nominal or design difference orbit for the momentum error δ.

Dispersion Free Steering - Results

Misalign the beamline components and perform the DF steering

CURVED vs. STRAIGHT LINAC

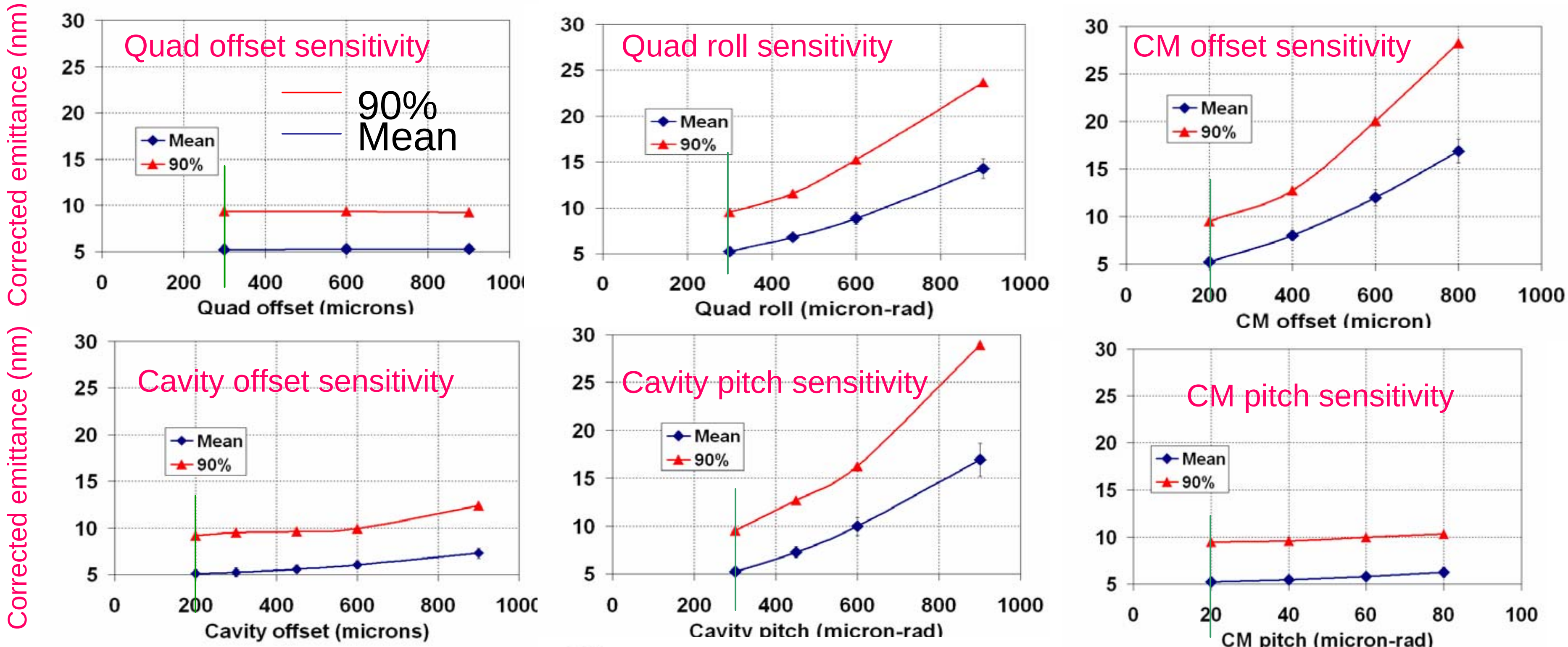


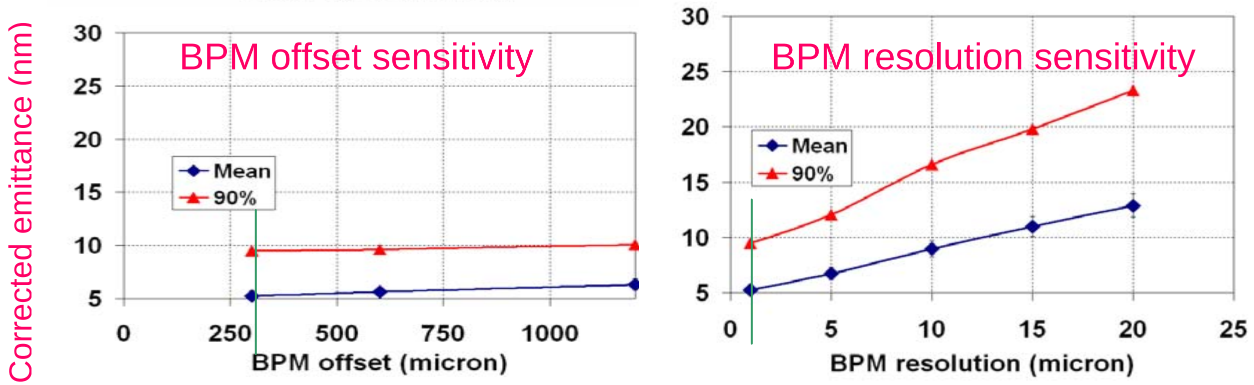


DFS parameters not optimized for Curved Linac

DFS: Sensitivity studies

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

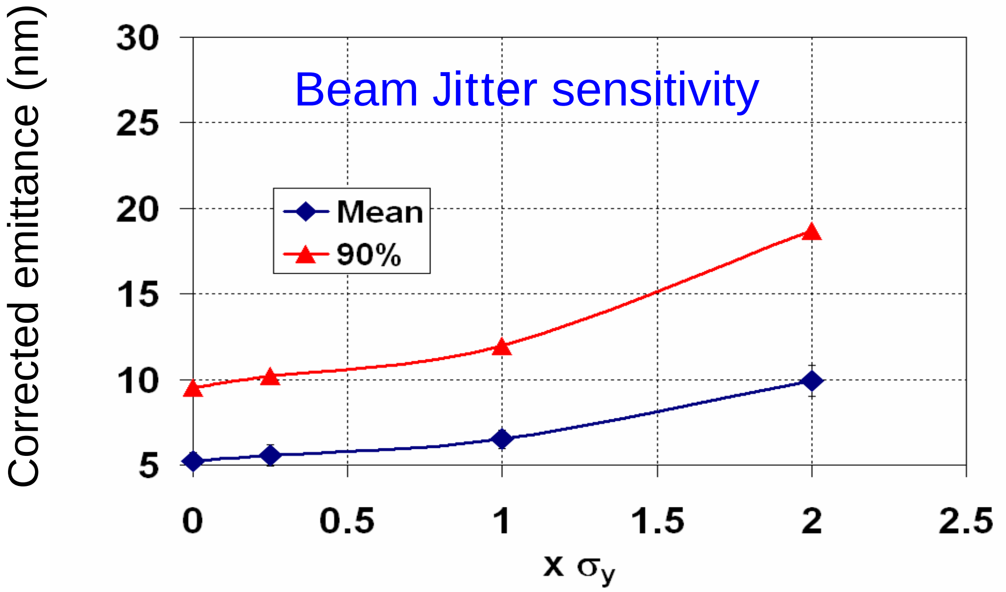


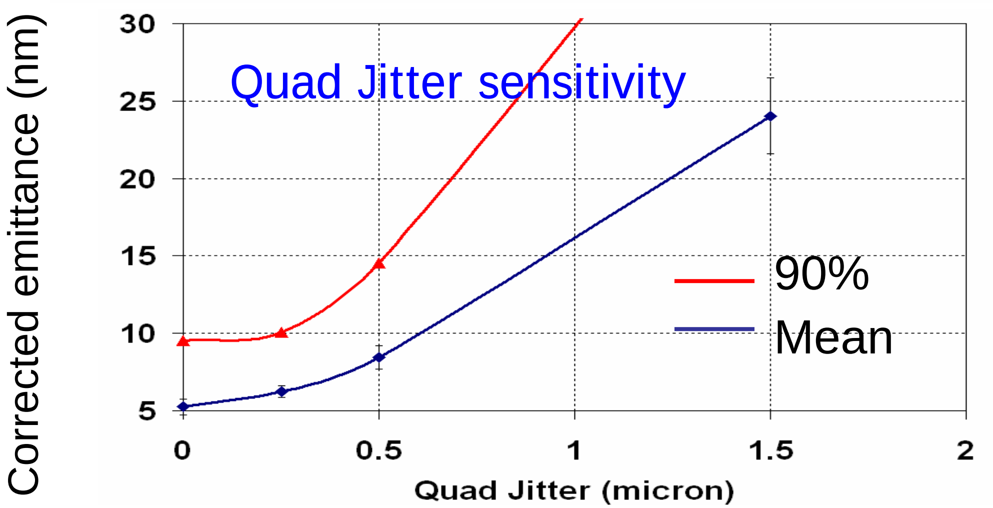


Sensitive to
Cavity pitch*, *BPM resolution*, *CM offset*, *Quad roll

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**

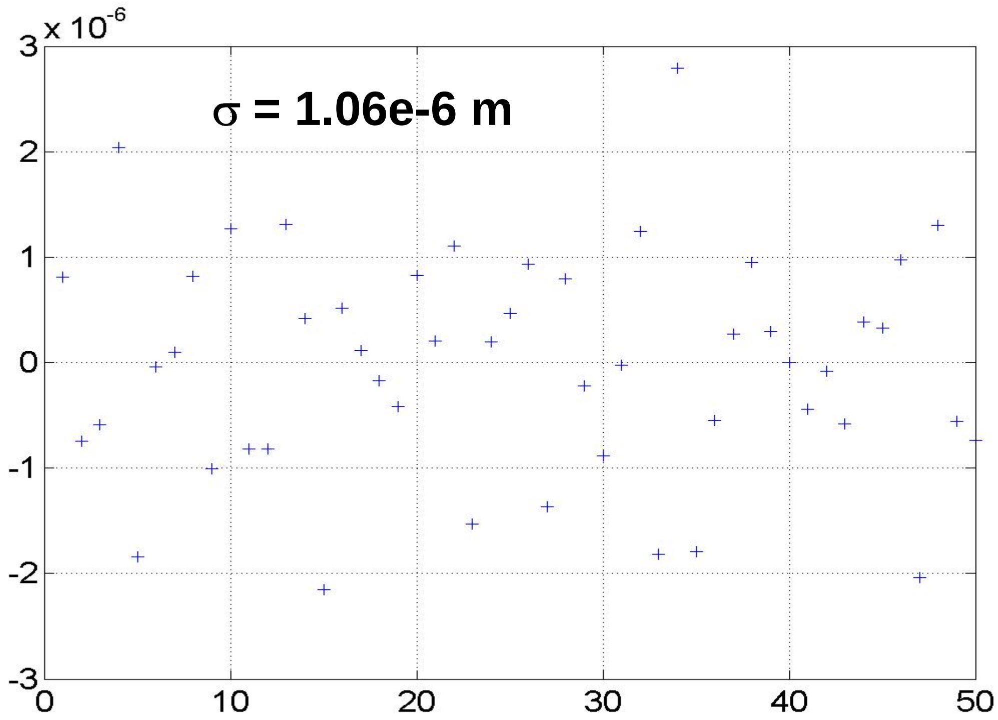
A **systematic contribution** seems to add up in each case, which is added only once when we perform the nominal run

PLAN

- Use RTML to perform DF steering in launch region
- Failure mode analysis – effect of failed BPM, YCOR on DF steering
- Use dispersion + wake bumps in curved linac
- Perform the same in the Final Main Linac Lattice

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