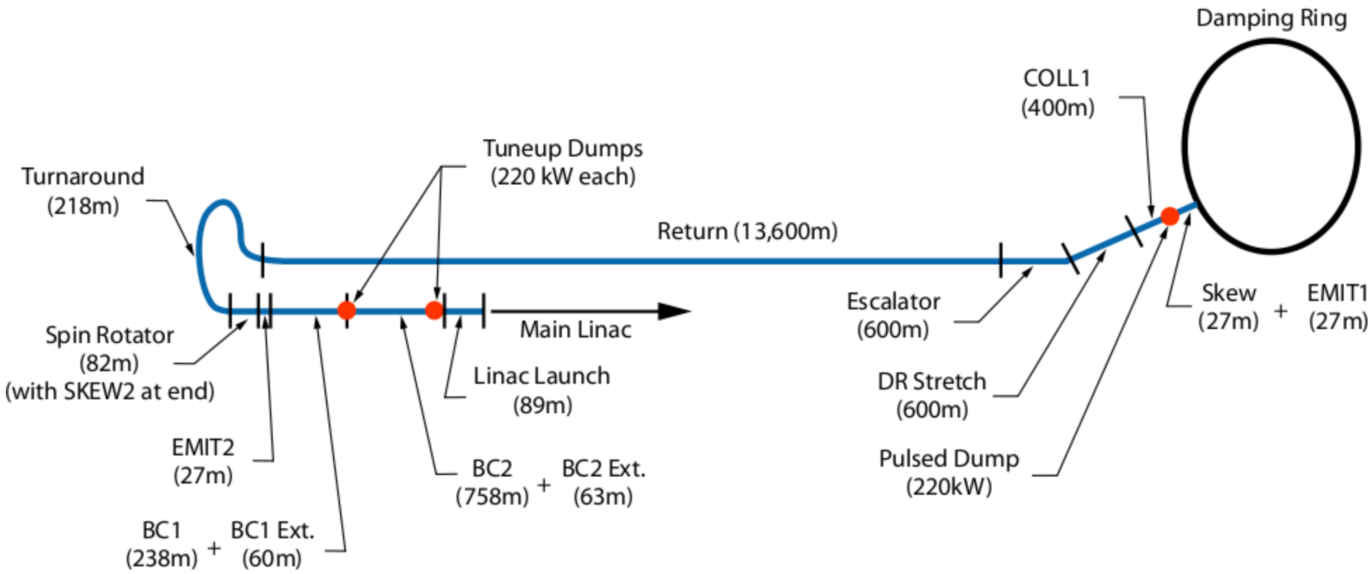
Beam-Based Alignment of the ILC Bunch Compressors

Andrea Latina, FNAL

ILC LET Beam Dynamics Meeting - August 31, 2010

ILC Bunch Compressors



- Two stages of longitudinal bunch compression, from 6/9 mm to about 1 mm, from 1 mm to 300/150 μm
- Both stages are composed by an RF section and a wiggler
- RF of bunch compressor 1 is composed by 3 CM and runs at -104 deg phase (deceleration)
- RF of bunch compressor 2 is composed by 45 CM and runs at -27 deg phase

List of Imperfections Considered

- Alignment Errors

- Standard "COLD" model

$$
\begin{aligned}
\sigma_{\text{quad}} &= 300\ \mu\text{m} && \text{quadrupole position error} \\
\sigma_{\text{quad pitch}} &= 300\ \mu\text{rad} && \text{quadrupole roll error} \\
\sigma_{\text{cav}} &= 300\ \mu\text{m} && \text{cavity position error} \\
\sigma_{\text{cav pitch}} &= 300\ \mu\text{rad} && \text{cavity pitch error} \\
\sigma_{\text{sbend pitch}} &= 300\ \mu\text{rad} && \text{sbend angle error} \\
\sigma_{\text{bpm}} &= 300\ \mu\text{m} && \text{bpm position error}
\end{aligned}
$$

- Bpm resolution error: $\sigma_{\text{bpmres}} = 1\ \mu\text{m}$

- RF-Kick and Wakes due to Couplers of the RF structures

  - See:

    N. Solyak et al., "Final Resultson RF- and Wake- Kicks Caused by the Couplers in the ILC Cavity" presented ICAP 2009

    A. Latina et al., "Emittance Dilution Caused by the Couplers in the Main Linac and in the BC of the ILC", presented PAC 09

Alignment Technique

1) **1-to-1 Correction**

2) **Dispersion Free Steering**

- a phase offset is applied to the RF cavities of the BC1S (BC1) in order to generate the energy difference for the DFS's test beams

  (in BC1S the test beams are synchronized to the PRE-LINAC's RF phase at its entrance)

$$\chi^2 = \sum_{i=1}^{n} y_{0,i}^2 + \sum_{j=1}^{m} \sum_{i=1}^{n} \omega_{1,j} \left(y_{j,i} - y_{0,i}\right)^2$$

$\Rightarrow$ we **scan** the weight $\omega_{1,j}$ to find the optimum

3) **Dispersion Bumps**

- we used two *dispersion* bumps η, η' as global correctors

$$\begin{cases} y_i \Leftarrow y_i + \eta \frac{E_i - E_0}{E_0} \\ y'_i \Leftarrow y'_i + \eta' \frac{E_i - E_0}{E_0} \end{cases}$$

- two dispersion *knobs*: tune dispersion at entrance to minimize the final vertical emittance

4) **Girder Pitch Optimization**

1) BBA: Case with no couplers

- 1-to-1 Correction

- Dispersion Free Steering
  - two test beams
    - $\Delta\phi_1 = \pm 25^o$ phase offset the RF sections of BC1
    - $\Delta\phi_2 = \pm 25^o$ phase offset the RF sections of BC2

- Dispersion bumps optimization
  - minimize the final dispersion-corrected emittance by changing the dispersion at entrance

- Girder Pitch optimization, using
  - 3 CM in BC1
  - 3 CM in BC2, out of 45

  $\Rightarrow$ Angles were limited in the range [-100, 100] μrad

2) BBA: Case with couplers

- 1-to-1 Correction

- Dispersion Free Steering

  - two test beams
    - $\Delta\phi_1 = \pm 25^o$ phase offset the RF sections of BC1
    - $\Delta\phi_2 = 0^o$ phase offset the RF sections of BC2

  $\Rightarrow$ phase synchronization at entrance of BC2 is necessary, otherwise the test beams are blown up by the RF-Kick, due to the large phase difference (10 $\sigma_z \approx 1$ cm)

- Dispersion bumps optimization

  - minimize the final dispersion-corrected emittance by changing the dispersion at entrance

- Girder Pitch optimization, using

  - 3 CM in BC1
  - 3 CM in BC2, out of 45

  $\Rightarrow$ Angles were limited in the range [-100, 100] μrad

Simulation Setup

- A number of simulations were performed with different sets of errors
  - X/Y Misalignments
    - $\sigma_{\text{quad offset}} = 300\ \mu$m RMS w.r.t. design orbit
    - $\sigma_{\text{bpm offset}} = 300\ \mu$m RMS w.r.t. design orbit
    - $\sigma_{\text{bpm res}} = 1\ \mu$m
  - Strength errors
    - $\sigma_{\text{quad strength}} = 0.25\%$ RMS

- Beam of 50000 macro-particles
- ILC2007b lattice
- 6d-tracking along the whole BC

- 100 seeds

- All simulations have been performed using PLACET

Study Cases

1) **Without Couplers**

- X/Y misalignments and angles

⇒ Correction technique:

- 1:1 + DFS
- Duspersion Tuning Knobs

2) **Without Couplers**

- X/Y misalignments and angles
- Quad strength error

⇒ Correction technique:

- 1:1 + DFS
- Duspersion Tuning Knobs

Study Cases

3) **WIth Couplers**

- X/Y misalignments and angles

⇒ Correction technique:

- 1:1 + DFS
- Dispersion Tuning Knobs + Girder Pitch Optimization

4) **WIth Couplers**

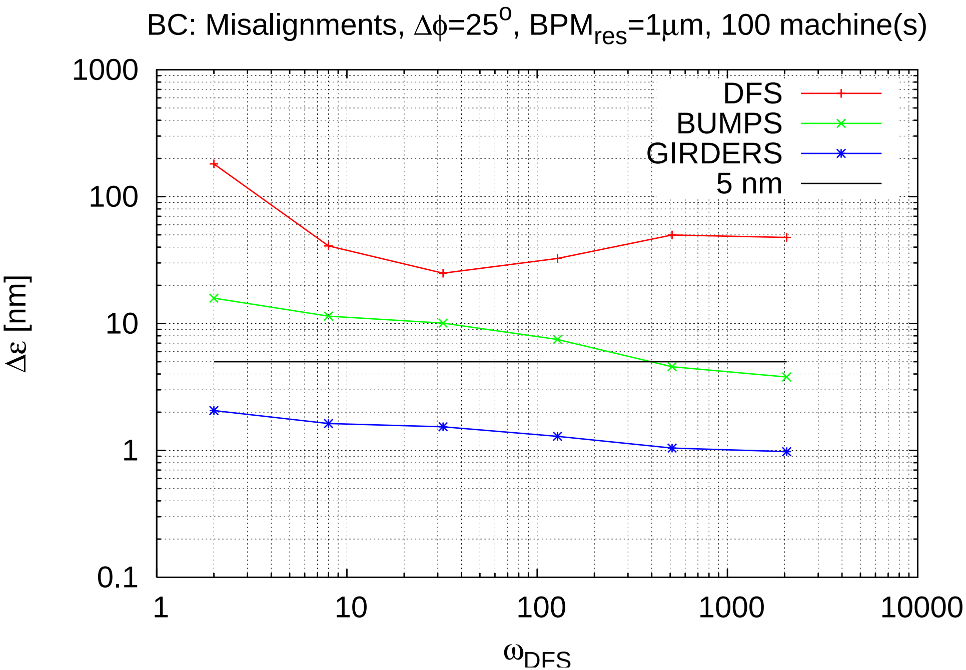
- X/Y misalignments and angles
- Quad strength error

⇒ Correction technique:

- 1:1 + DFS
- Dispersion Tuning Knobs + Girder Pitch Optimization

1) without Couplers

- Correction: 1:1 + DFS + Dispersion Bumps + Girder Optimization
- Emittance growth along the line for 100 seeds:

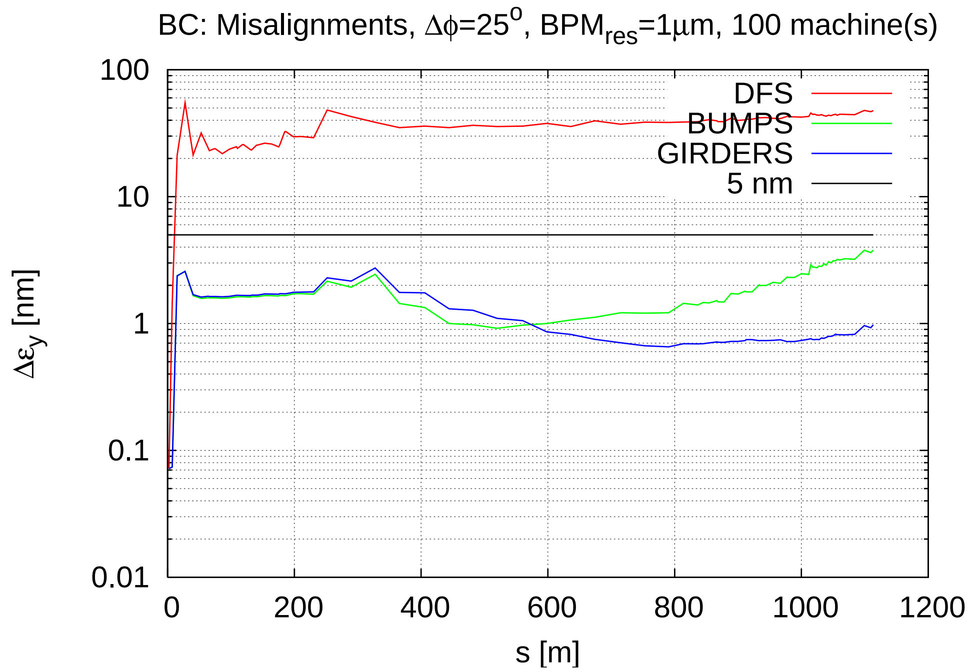


⇒ Minimum of the emittance is at $\omega = 2048$

⇒ Average of final vertical emittance growth is 0.98 nm (1.6 nm 90% c.l.)

1) without Couplers

- Correction: 1:1 + DFS + Dispersion Bumps + Girder Optimization
- Emittance growth along the line for 100 seeds:

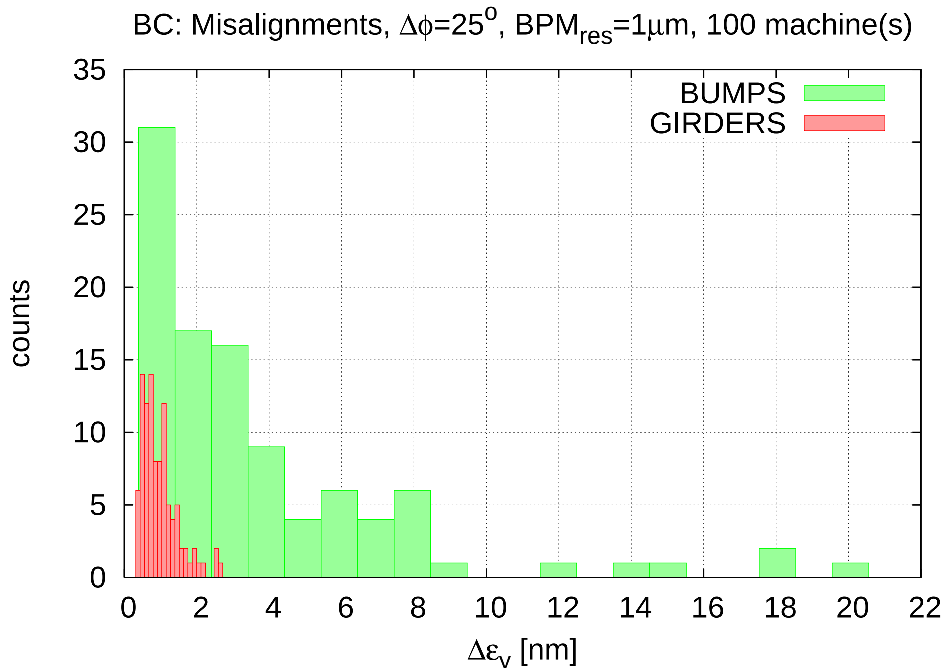


⇒ Minimum of the emittance is at $\omega = 2048$

⇒ Average of final vertical emittance growth is 0.98 nm (1.6 nm 90% c.l.)

1) without Couplers

- Correction: 1:1 + DFS + Dispersion Bumps + Girder Optimization
- Emittance growth along the line for 100 seeds:

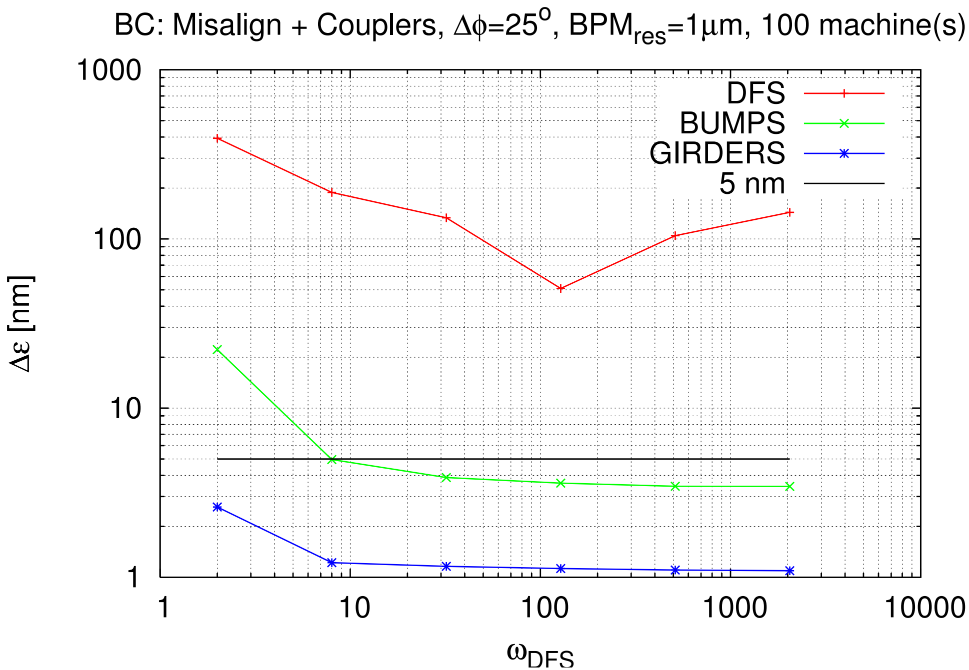


⇒ Minimum of the emittance is at $\omega = 2048$

⇒ Average of final vertical emittance growth is 0.98 nm (1.6 nm 90% c.l.)

2) with Couplers

- Correction: 1:1 + DFS + Dispersion Bumps + Girder Optimization
- Emittance growth along the line for 100 seeds:

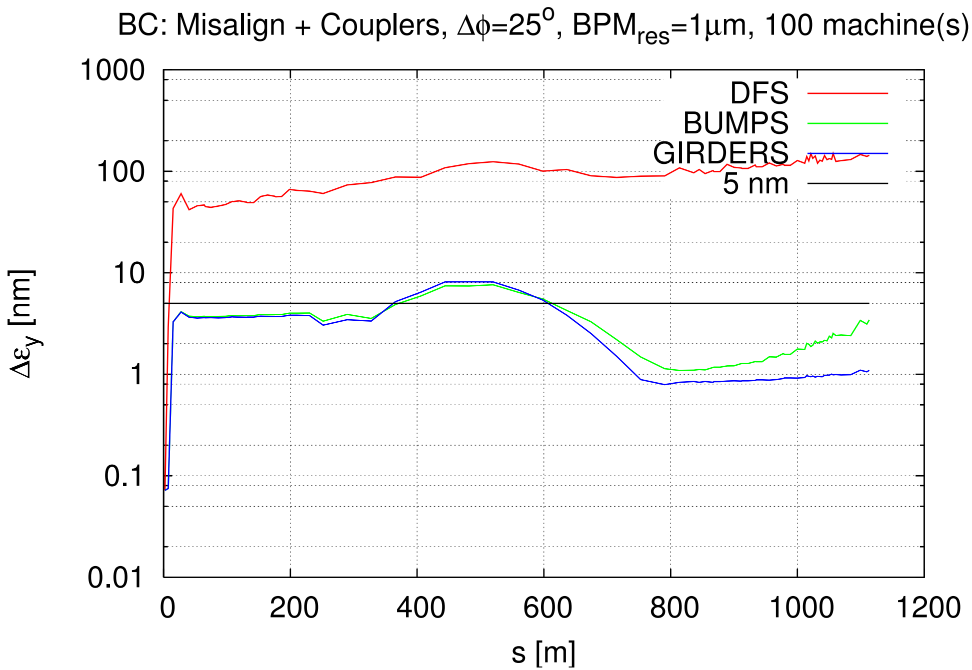


⇒ Minimum of the emittance is at $\omega = 2048$

⇒ Average of final vertical emittance growth is 1.09 nm (1.48 nm 90% c.l.)

2) with Couplers

- Correction: 1:1 + DFS + Dispersion Bumps + Girder Optimization
- Emittance growth along the line for 100 seeds:

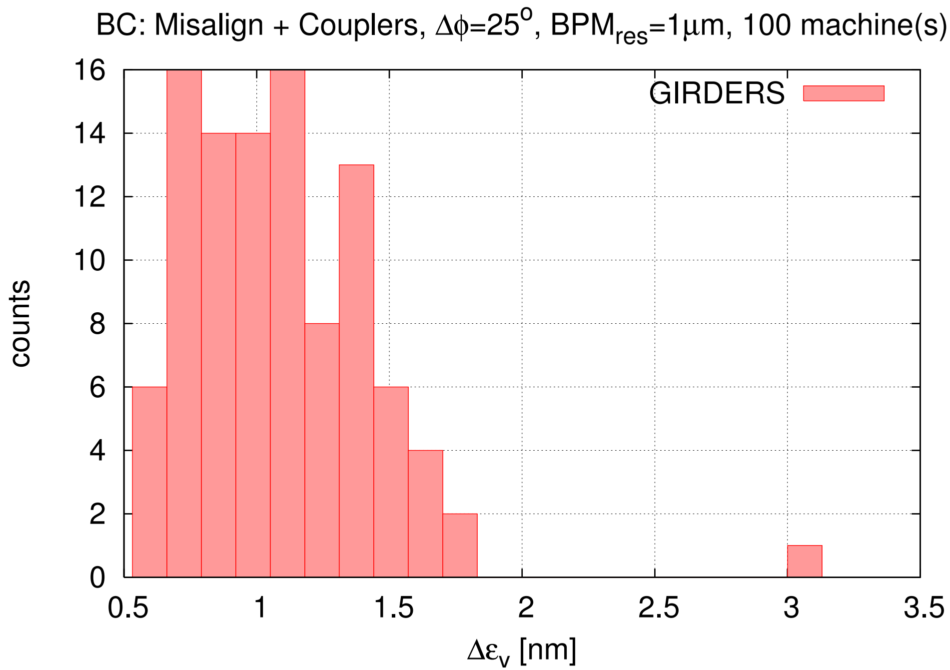


⇒ Minimum of the emittance is at $\omega = 2048$

⇒ Average of final vertical emittance growth is 1.09 nm (1.48 nm 90% c.l.)

2) with Couplers

- Correction: 1:1 + DFS + Dispersion Bumps + Girder Optimization
- Emittance growth along the line for 100 seeds:



⇒ Minimum of the emittance is at $\omega = 2048$

⇒ Average of final vertical emittance growth is 1.09 nm (1.48 nm 90% c.l.)

Summary Tables

- These simulations:

Region	Errors	Emittance Increase (nm)		Correction
		average	90% CL	
BC1+BC2	X/Y/X'/Y' Offsets	0.98	1.6	DFS + knobs + Girders
	+ Quad Strength	-	-	DFS + knobs + Girders
BC1+BC2 w/Couplers	X/Y/X'/Y' Offsets	1.09	1.48	DFS + knobs + Girders
	+ Quad Strength	-	-	DFS + knobs + Girders

Conclusions and Next Steps

- RTML Bunch Compressors have been studied. They seem “almost” under control

- Performances have been evaluated with and without Couplers. Are they satisfactory?

⇒ Integrated simulations of the entire RTML, starting from the damping ring exit, must be performed