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Accelerator Performance with imperfections

Soft and Hard X-Rays

(Baseline / Upgrade 1 / Upgrade 2)

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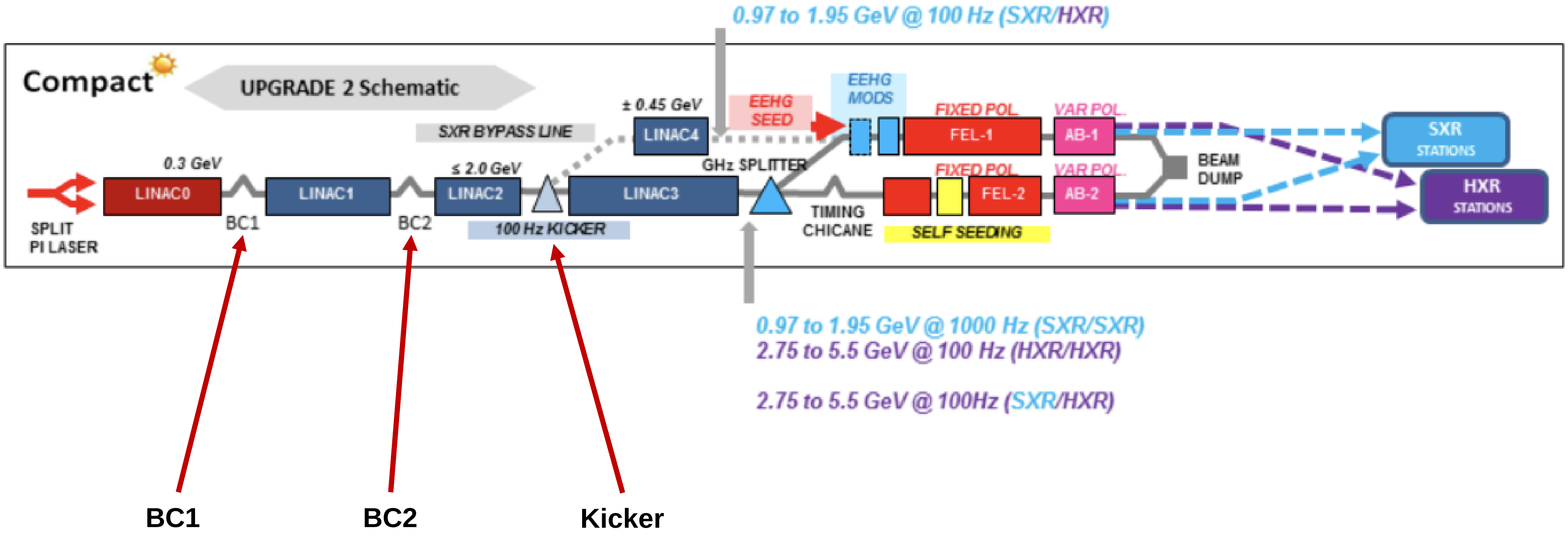
Introduction

XLS simulation from cathode to linac end, using C-band injector at 300 MeV.

Focus on operational modes



Contents of this presentation:

Simulations of realistic static imperfections and beam-based alignment (BBA)

- Hard X-rays mode
- Soft X-rays mode
- Simultaneous Soft + Hard X-rays

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Key beam parameters

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Beam parameters:

- Bunch charge = 75 pC
- C-band injector gun (distribution courtesy of M. Croia – lattice by A. Aksoy)

Target parameters:

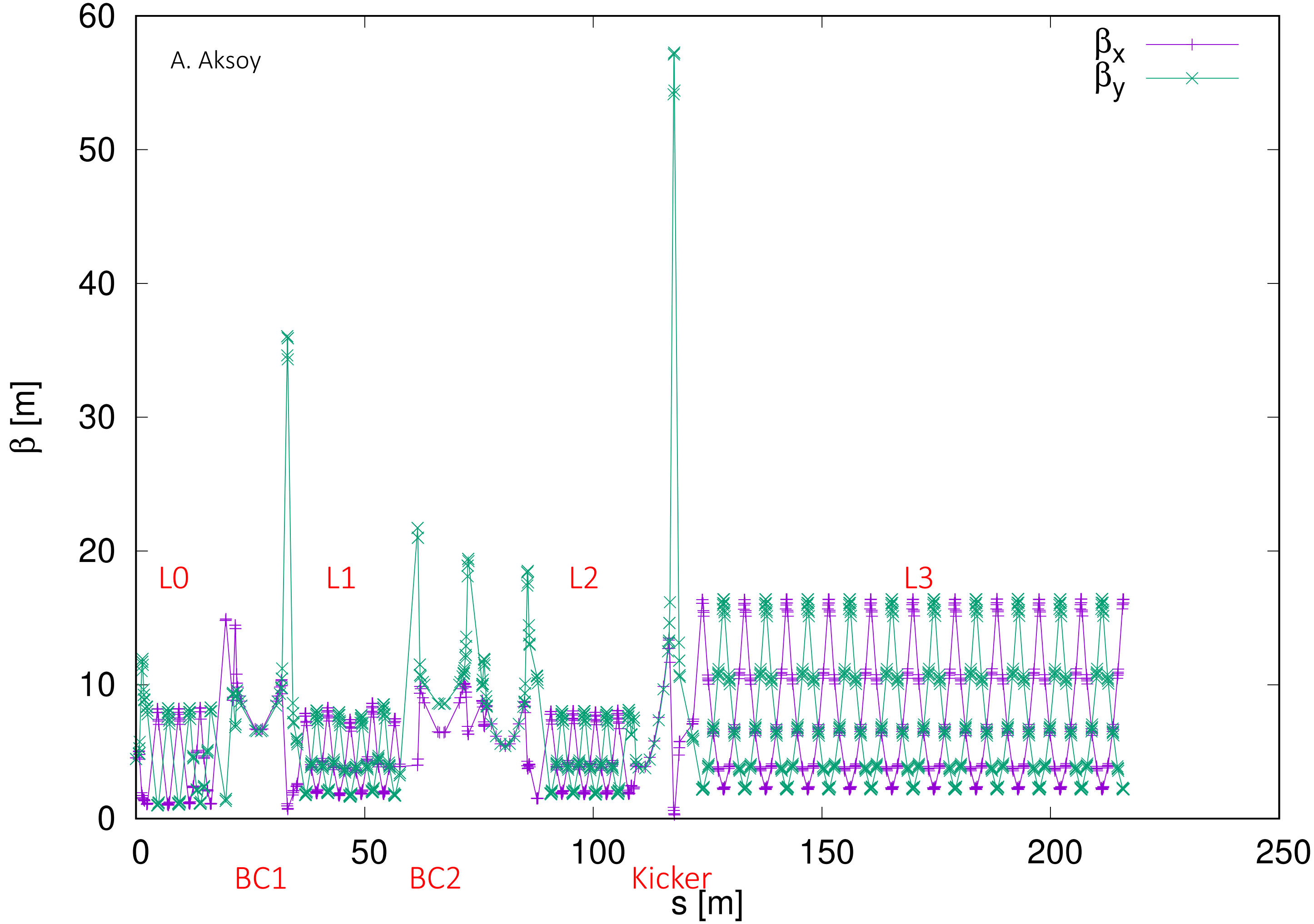
Table 11: Photon energy ranges and electron beam parameters.

Parameter	Unit	|——— SXR	———|		|——— HXR	———|	
Repetition rate	kHz	0.1, 0.25, 1			0.1		
Photon energy range	keV	0.25-0.5	0.5-1	1-2	2-4	4-8	8-16
Electron beam energy	GeV	0.97	1.37	1.95	2.75	3.9	5.5
Minimum peak current	kA	0.35	0.65	0.93	1.5	2.5	5
Slice energy spread (RMS)	%	0.05	0.04	0.03	0.02	0.015	0.01
Normalised slice emittance (RMS)	μm rad	0.2					
Bunch charge	pC	75					

From Deliverable 2.2

Optics functions

For the hard X-rays option.



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All operation modes

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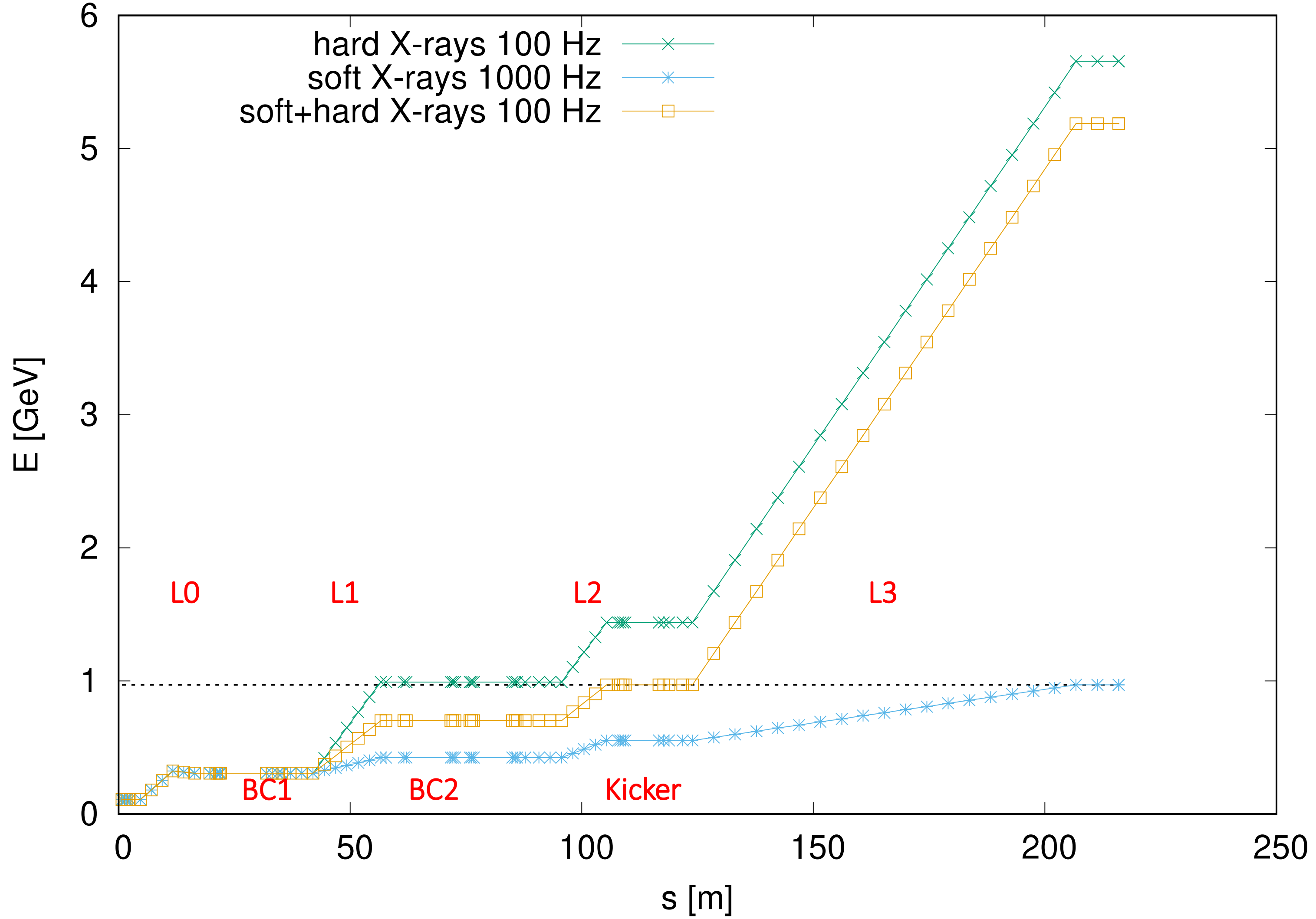
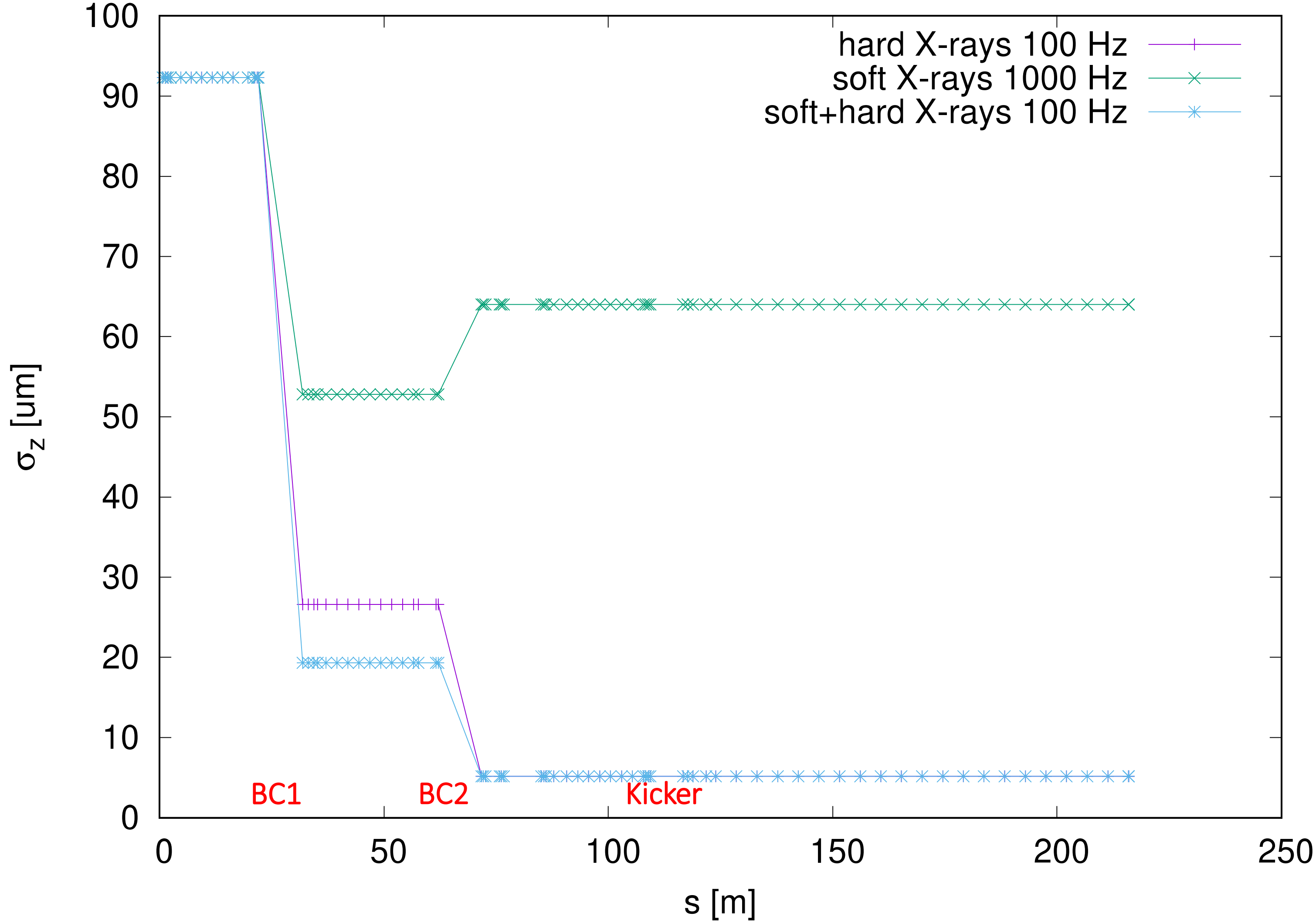
Energy profile



Soft and Hard X-rays

Bunch length profile



Summary of Imperfections

Beam parameters:

- Bunch charge = 75 pC
- C-band injector gun

PLACET simulation considers

- Full 6d tracking
- Coherent synchrotron radiation
- Wakefield in all structures (C-band, X-band, Ka-band)

Elements misalignment:

- Quadrupole = 100 um rms
- C-band accelerating structures = 100 um rms
- X-band accelerating structures = 100 um rms
- Ka-band structure = 100 um rms
- Beam position monitors = 100 um rms

Assumptions

- Each quadrupole is equipped with two dipole correctors (X & Y) and a BPM
- BPM resolution = 5 um

Beam-based correction

Static imperfections are counteracted using beam-based correction.

Beam-based correction procedure consists of three steps:

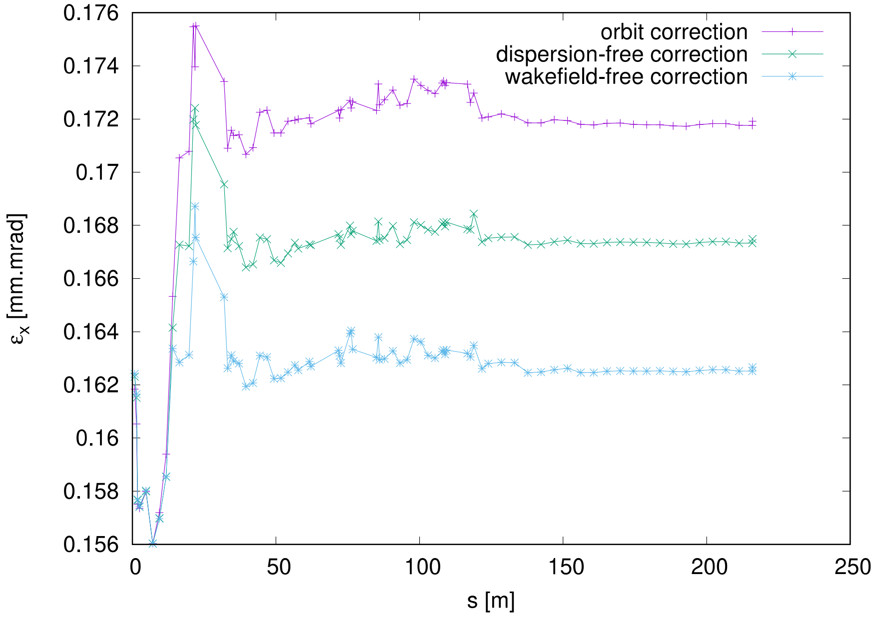
1) Orbit correction
   - Beam is steered to minimize its absolute orbit excursion

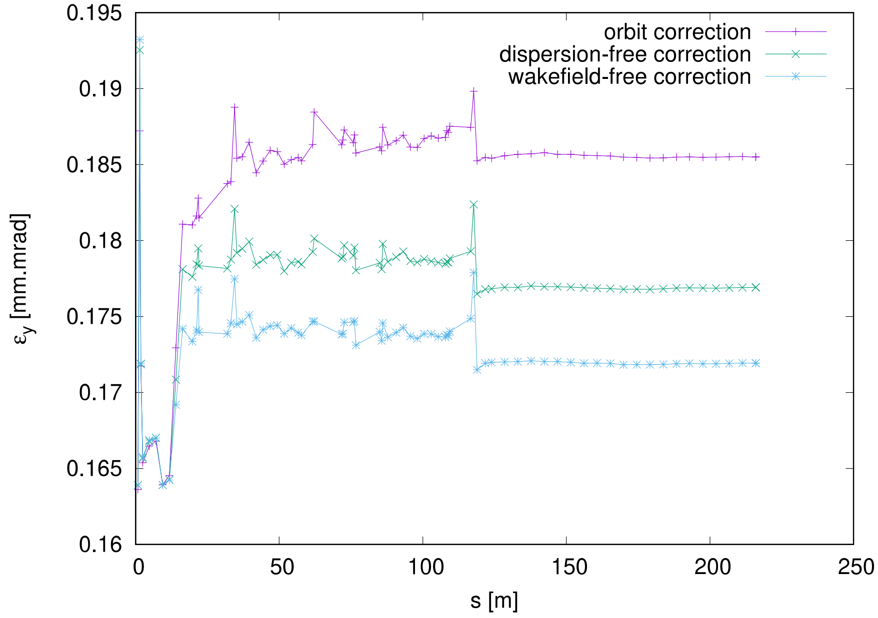
2) Dispersion correction (a.k.a. Dispersion-free steering, or DFS)
   - A test beam with a different energy is transported to measure dispersion
     - Energy difference is obtained with $\Delta\phi_{RF}$ = +10 deg in both LINAC0 and LINAC1
   - Nominal and test beams are steered to achieve design dispersion

3) Wakefield correction (a.k.a. Wakefield-free steering, or WFS)
   - A test beam with a different charge (90% of nominal) is transported to measure the effect of wakefields
   - Nominal and test beams are steered to minimize difference

Hard X-rays (5.5 GeV @ 100 Hz)

Normalized emittances along the accelerator – average of 100 random seeds





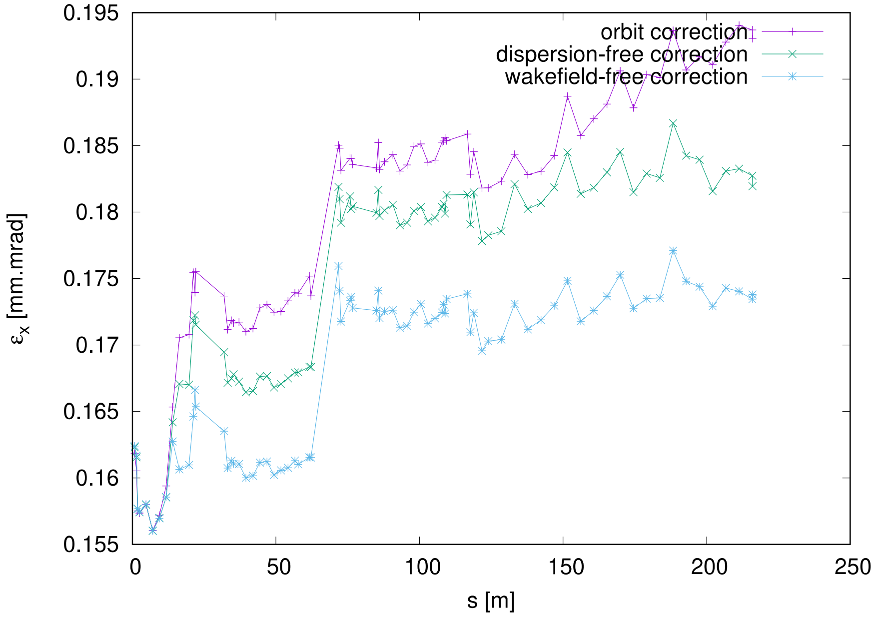
90% of the machines achieve:

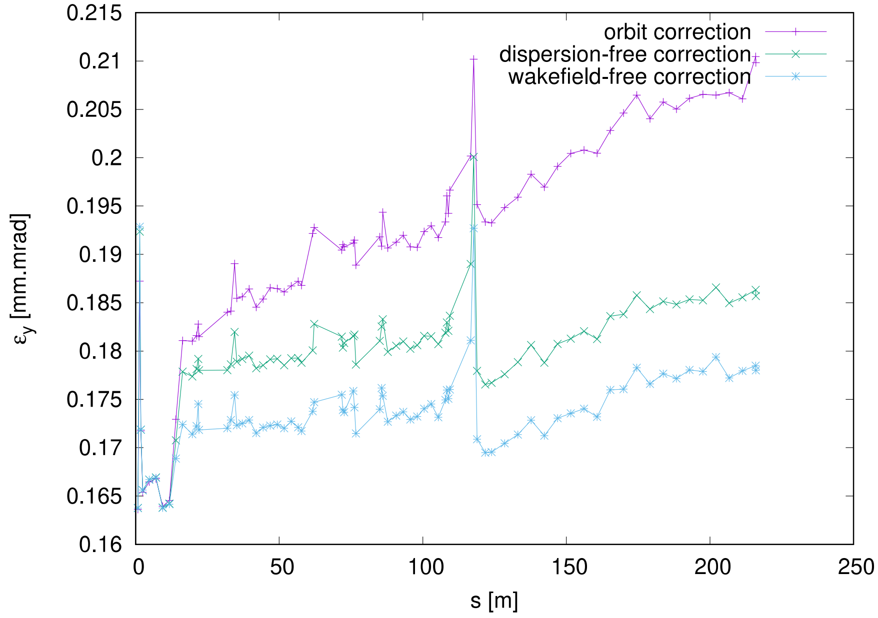
$\varepsilon_{x,\,90\%} < 0.174$ mm.mrad

$\varepsilon_{y,\,90\%} < 0.192$ mm.mrad

Soft X-rays (0.97 GeV @ 1000 Hz) Compact

Normalized emittances along the accelerator – average of 100 random seeds





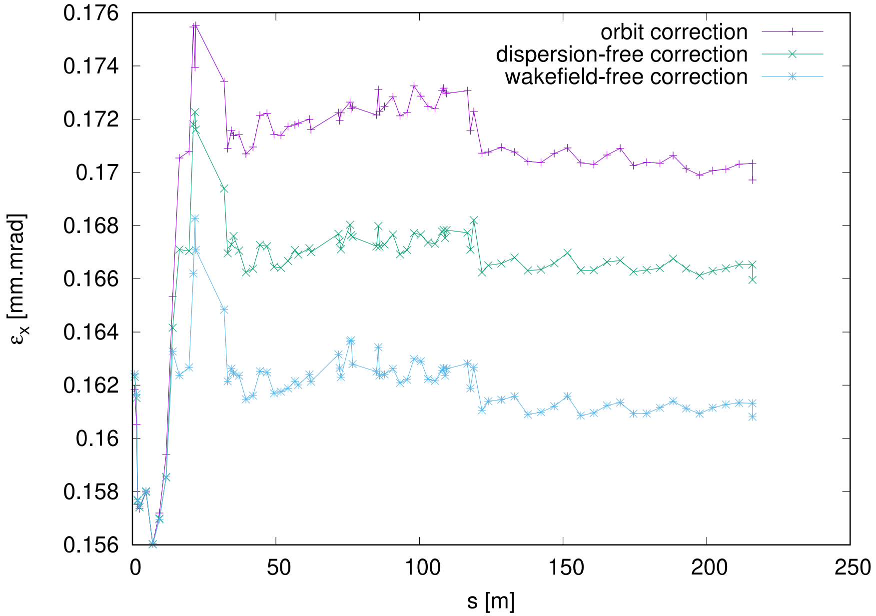
90% of the machines achieve:

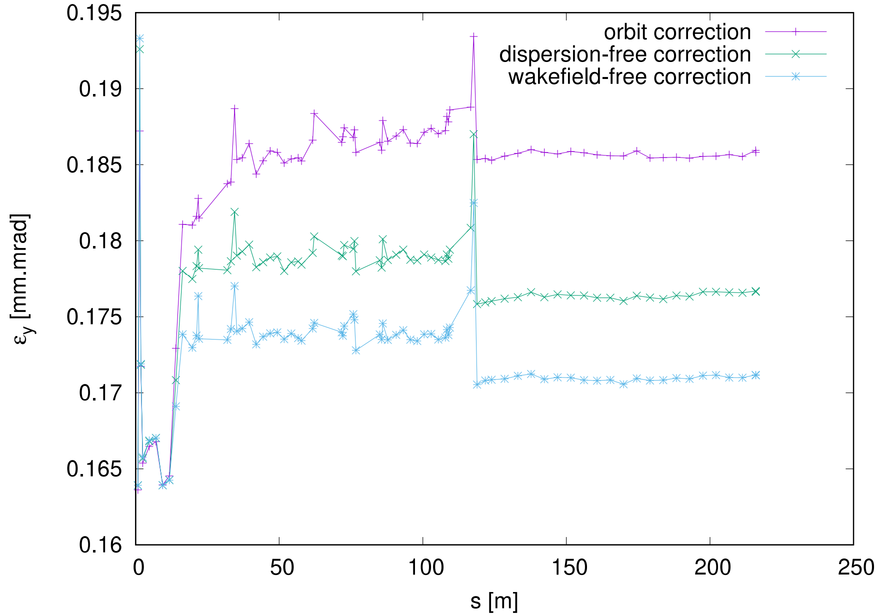
$\varepsilon_{x,\,90\%}$ < 0.195 mm.mrad

$\varepsilon_{y,\,90\%}$ < 0.198 mm.mrad

Soft + Hard X-rays @100 Hz

Normalized emittances along the accelerator – average of 100 random seeds





90% of the machines achieve:

$\varepsilon_{x,\,90\%} < 0.176$ mm.mrad

$\varepsilon_{y,\,90\%} < 0.188$ mm.mrad

Summary

The performance of a Hard X-ray machine run in Soft X-ray mode (with reduced RF gradient, adjusted RF phases, and adjusted chicanes) has been tested

The impact of static imperfections has been evaluated in both Hard and Soft X-rays modes.

Beam-based correction techniques have been applied, achieving very good performance:

- Soft X-rays
- Hard X-rays
- Soft / Hard X-rays

<u>All cases show that 90% of the machies achive ε < 0.2 mm.mrad</u>

Conclusions:

- 2 dipole correctors (X&Y) + 1 BPM per quadrupole seem enough for beam-based correction
- BPM resolution 5 um seems enough for correction

Beam parameters along the accelerator

	Soft X-ray (lowest energy)	Hard X-ray (highest energy)
Bunch charge	75 pC	
Normalised emittance	<0.2 mm.mrad	
No of bunches per train	2	
Bunch spacing	> 0.5 ns	
Rep rate	100 / 250 / 1000 Hz	100 Hz
Transverse size before BC1	~35 um	
Bunch length after BC1	20 - 55 um	
Energy after @ BC1	300 MeV	
Transverse size before BC2	~50 --> 45 um	~35 --> 25 um
Bunch length after BC2	64 um (215 fs)	5 um (17 fs)
Energy after BC2	<0.97 GeV	<5.5 GeV
Transverse size after BC2	~45 --> 35 um	~25 --> 15 um

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Thank you!

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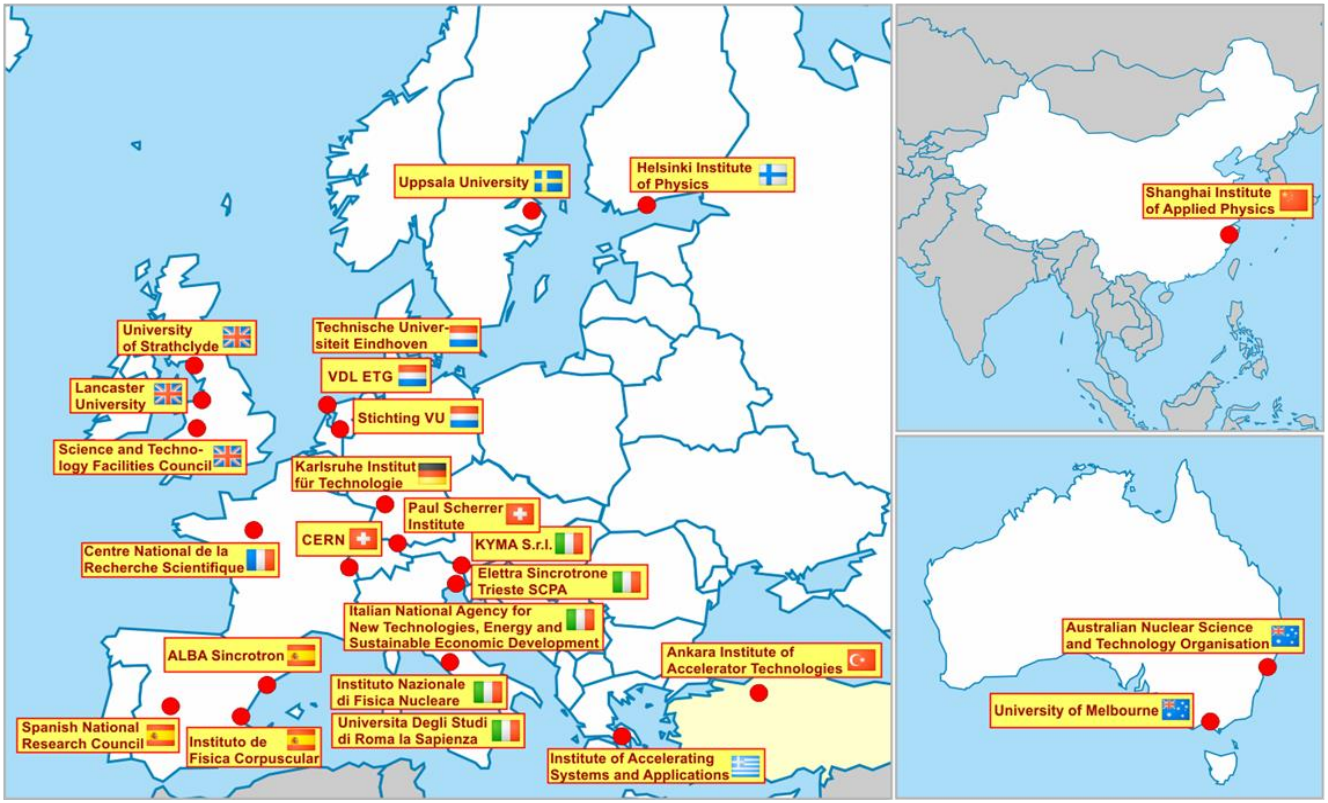

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