Post-Linac Collimation Section of the European XFEL Facility

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XFEL Collimation and Beam Switchyard Review Meeting, 3 December 2007

Detailed description can be found in:
V.Balandin,R.Brinkmann,W.Decking and N.Golubeva, TESLA-FEL 2007-05

Post-Linac Collimation System of the European XFEL

The collimation system should simultaneously fulfill several different requirements:

- In first place, during routine operations, it should remove with high efficiency off-momentum and large amplitude halo particles, which could be lost inside undulator modules and become the source of radiation-induced demagnetization of undulator permanent magnets.

- The system also must protect undulator modules and other downstream equipment against miss-steered and off-energy beams in the case of machine failure without being destroyed in the process.

- From the beam dynamics point of view, the collimation section should be able to accept bunches with different energies (up to ±1.5% from nominal energy) and transport them without any noticeable deterioration of beam parameters.

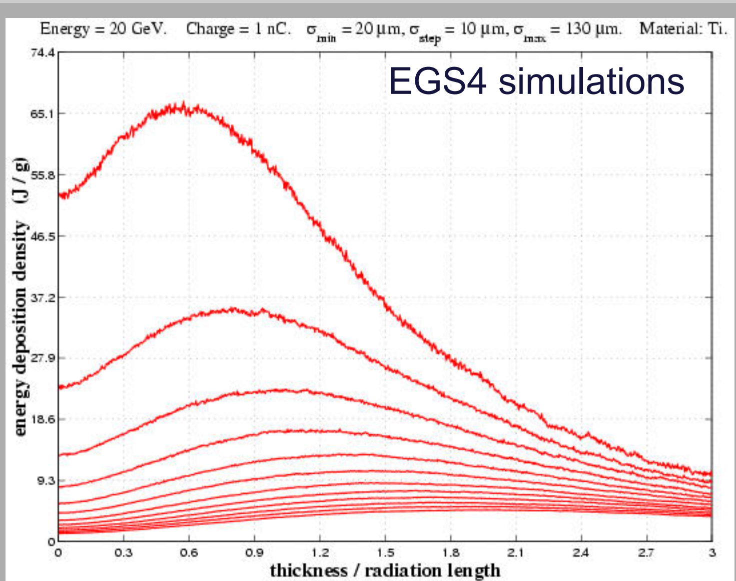
Emergency Scenario:

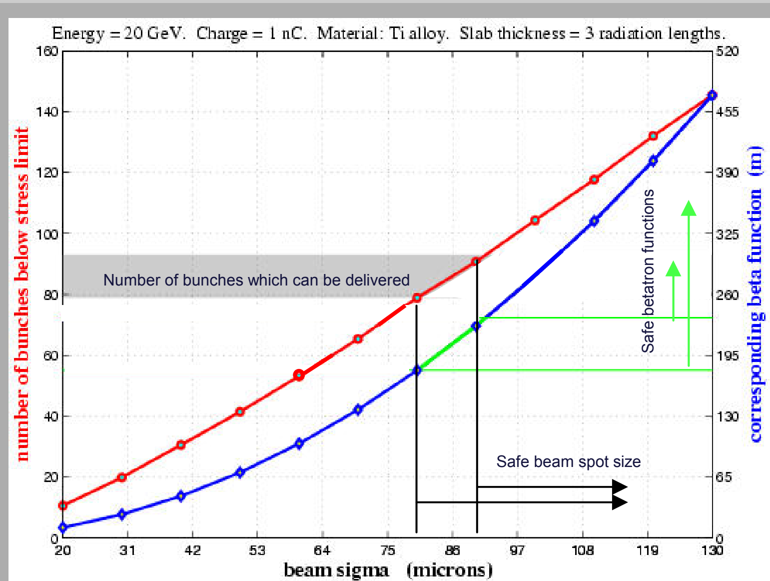
detect a failure and switch the beam production off as quickly as possible

Candidate for Collimator Material: Titanium Alloy

Rough stress analysis shows that to withstand a direct impact of such number of bunches (~100) which can be delivered to collimator location until failure will be detected and the beam production will be switched off, the beam spot size should be not smaller than 80-90 microns

(energy: 20GeV, normalized emittance: 1.4 mm·mrad, bunch charge: 1 nC, bunch spacing: 200 ns).





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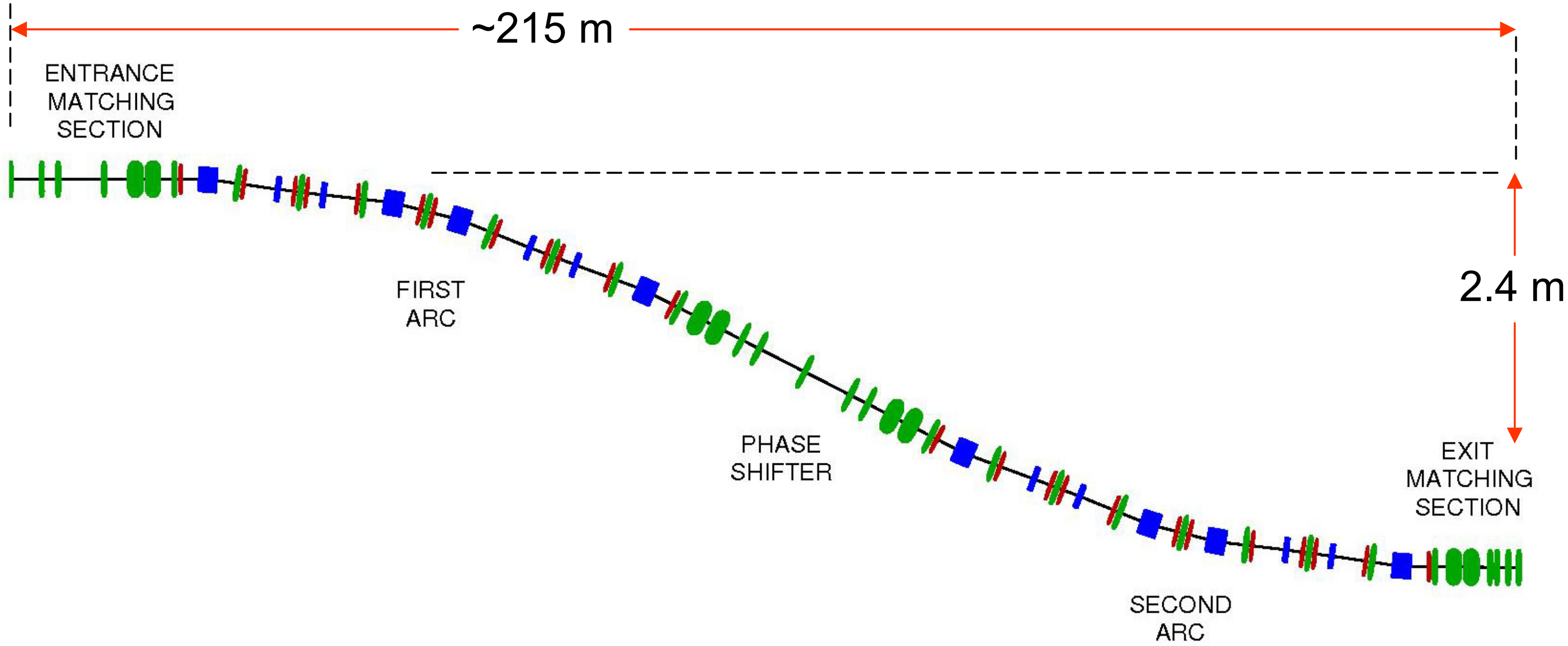
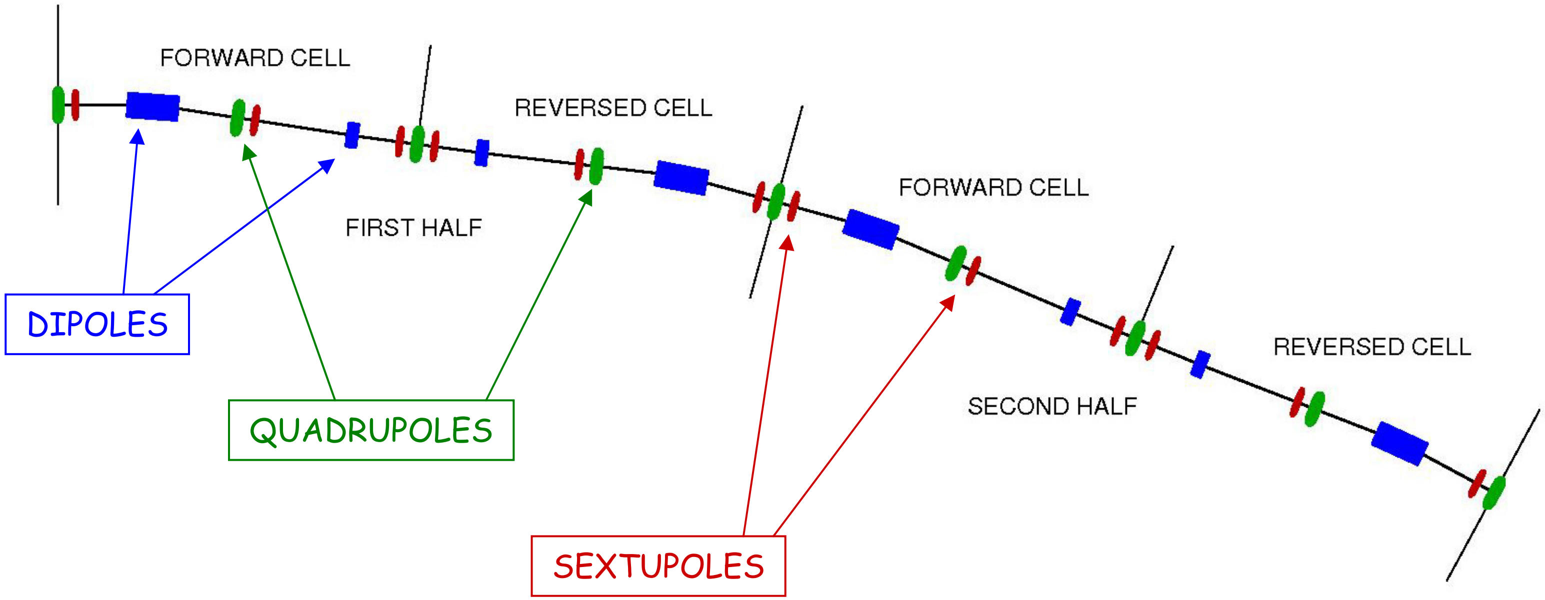
Layout and Structure

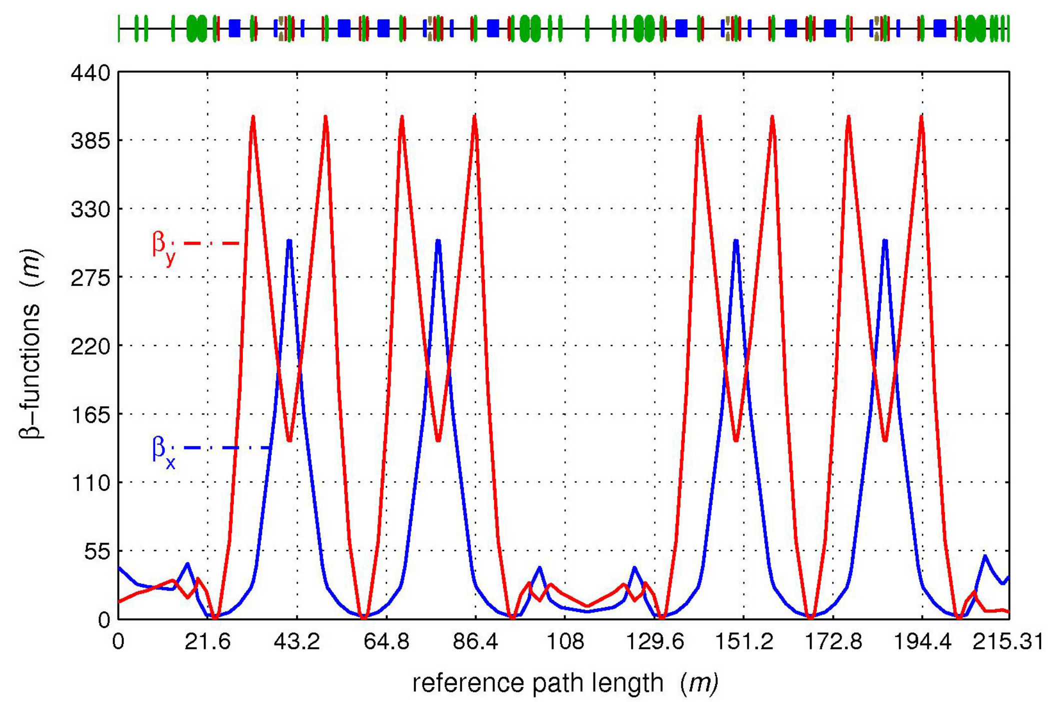


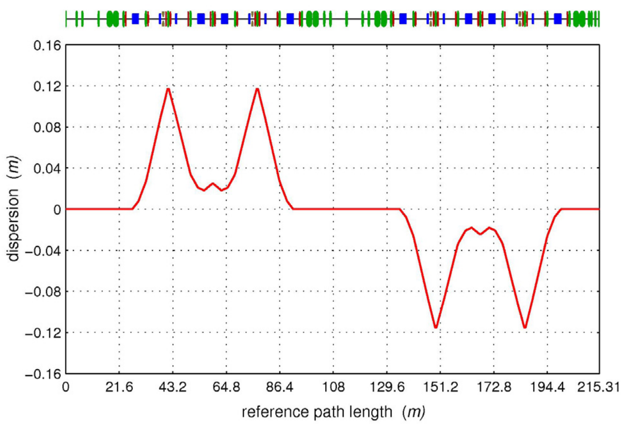
Post-Linac Collimation Section



Each arc consist of four 90° cells, constitutes a second-order achromat and is first-order isochronous

Linear Optics Functions





The energy and the vertical plane collimation will be done simultaneously at the same positions, and therefore the ratio of dispersion to vertical betatron function at collimator locations is properly adjusted.

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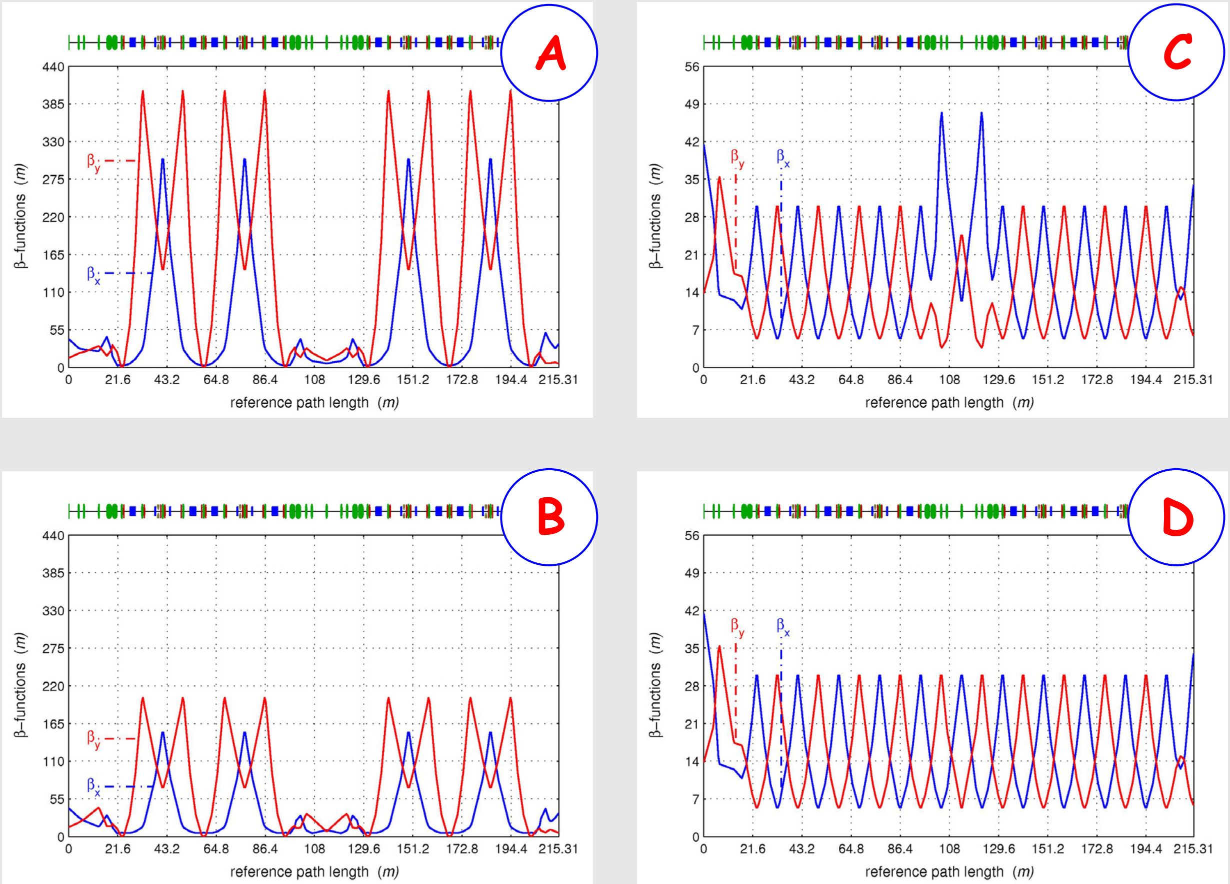
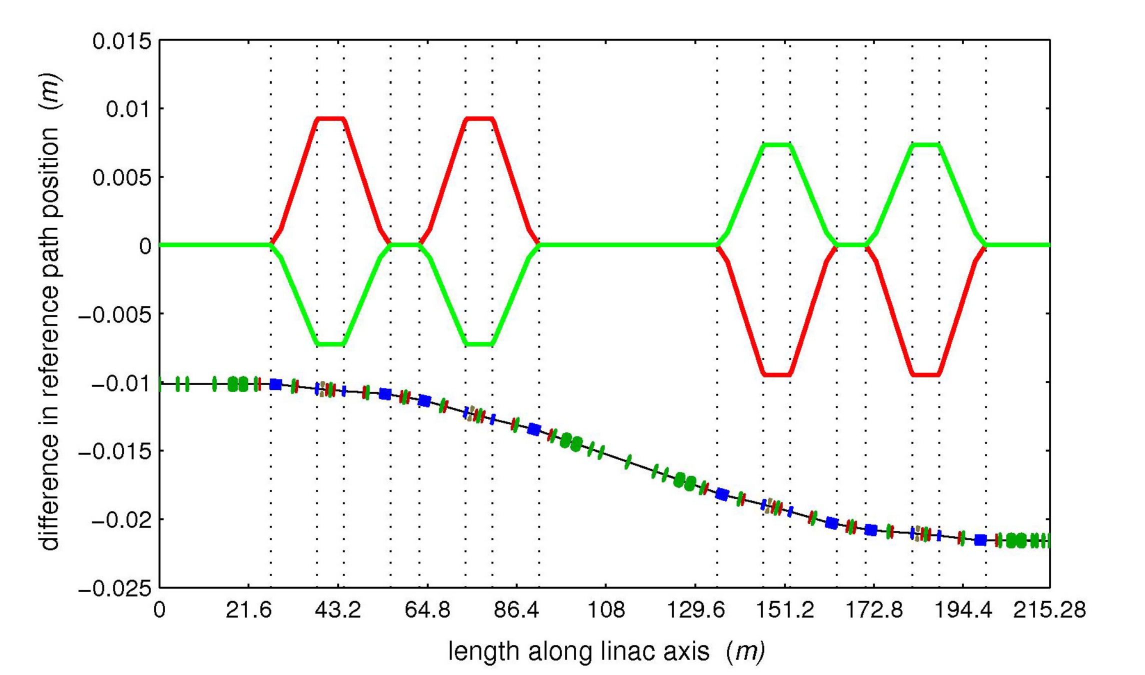
Optics Flexibility



Without touching arc magnets and by tuning only quadrupoles in the matching sections and phase shifter, the maximal values of the betatron functions could be varied. These variations include, for example, possibility of FODO like transport through the whole collimation system. It could be useful feature for commissioning or measurements.

The possibility to vary values of the betatron functions together with usage of collimators having exchangeable apertures allows to adjust energy collimation depth while preserving depth of transverse collimation.

Adjustment of Linear Isochronicity



Changes in the vertical position of the isochronous beam line with r56 = 0, which are required to bring linear momentum compaction of the collimation section to the value r56 = -1 mm (red curve) and to the value r56 = +1 mm (green curve).

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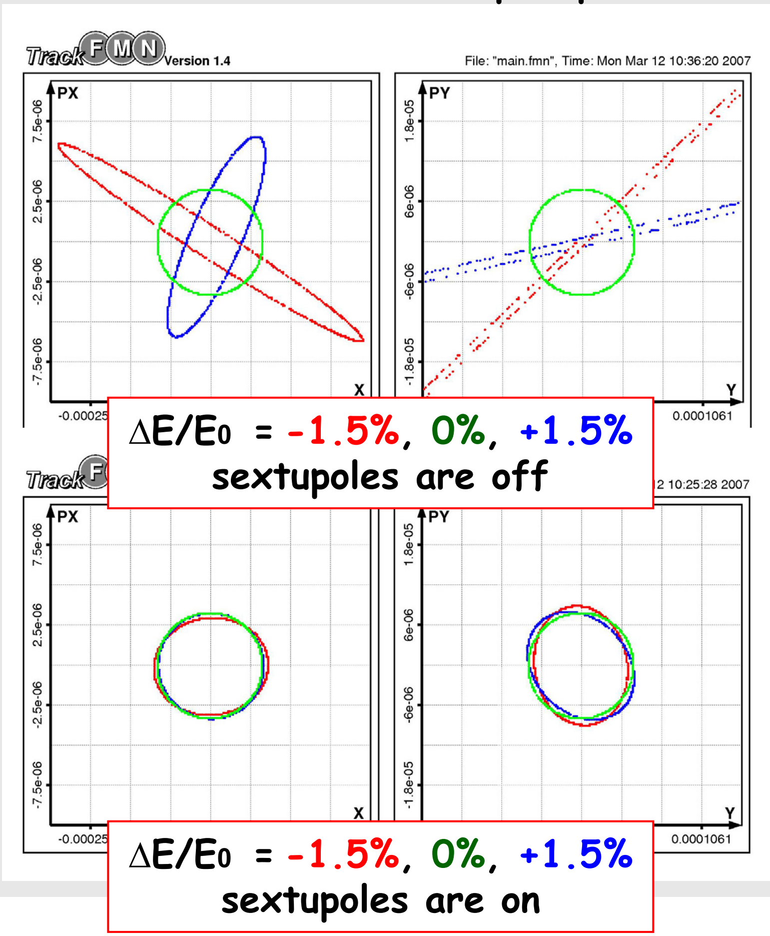
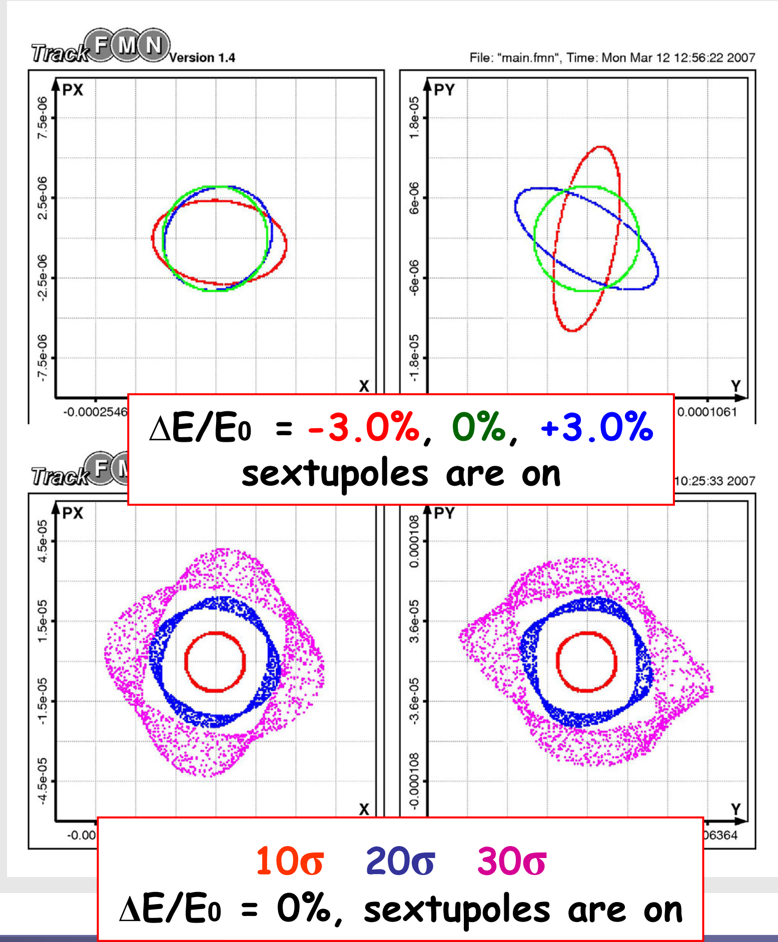
Beam Dynamics: Energy Offset and Nonlinearities

Beam transfer properties of the entire collimation section.





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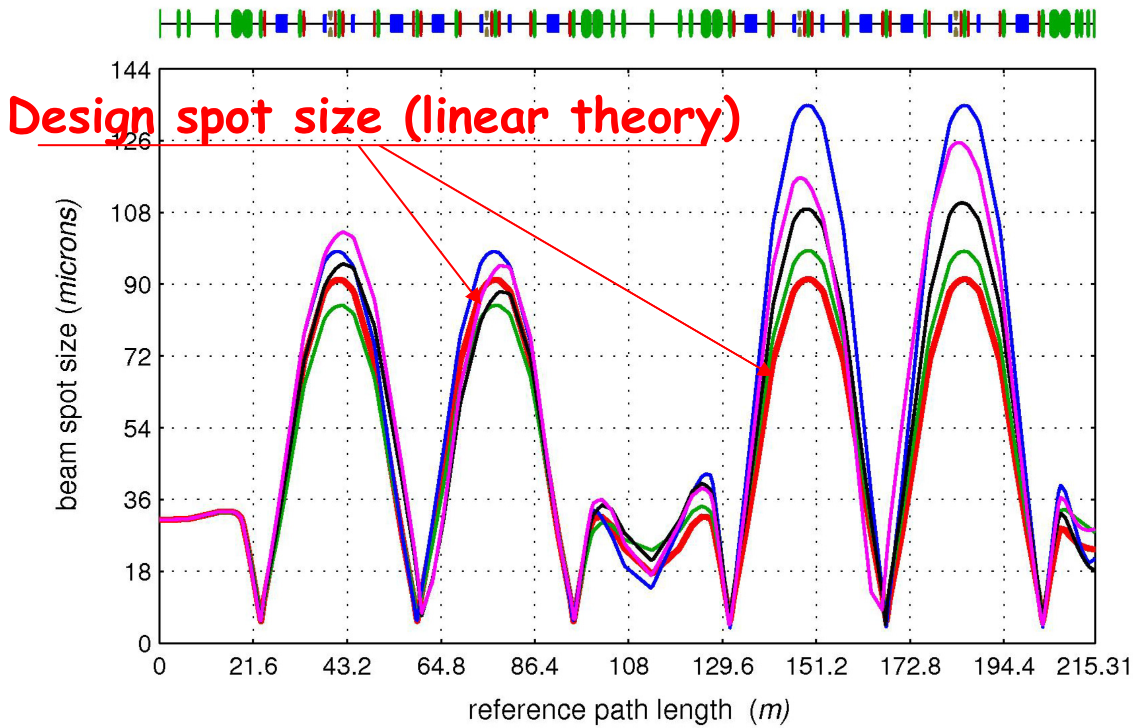
Effect of Energy Offset and Nonlinearities on Evolution of Beam Spot Size Along Collimation Section



Beam spot size (rms) extracted from accurate tracking simulations:

matched Gaussian beam at the entrance with energy offset -3% (blue) , with energy offset +3% (green), with y-offset 40σ (black), with both energy offset -3% and y-offset 40σ (magenta) .

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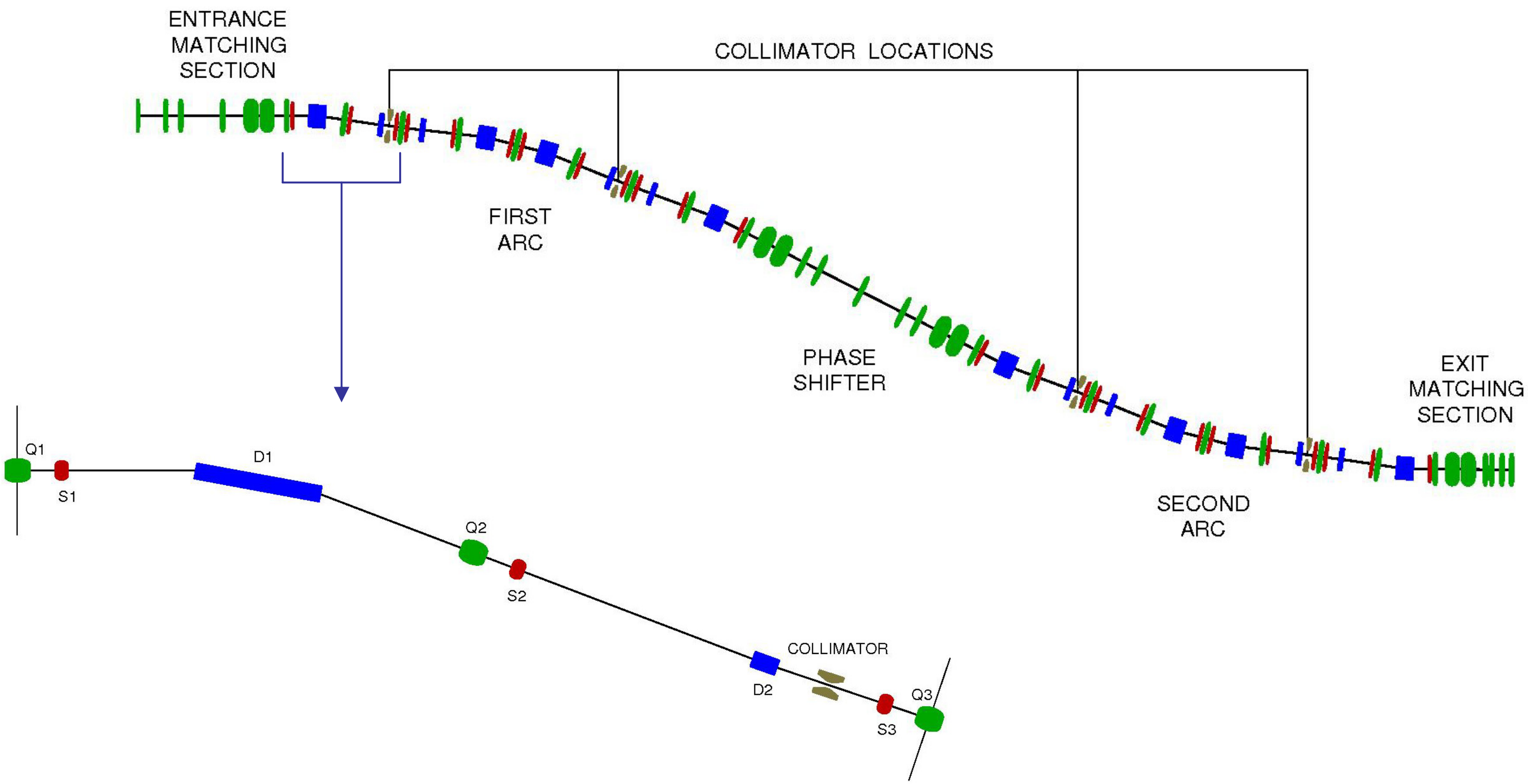
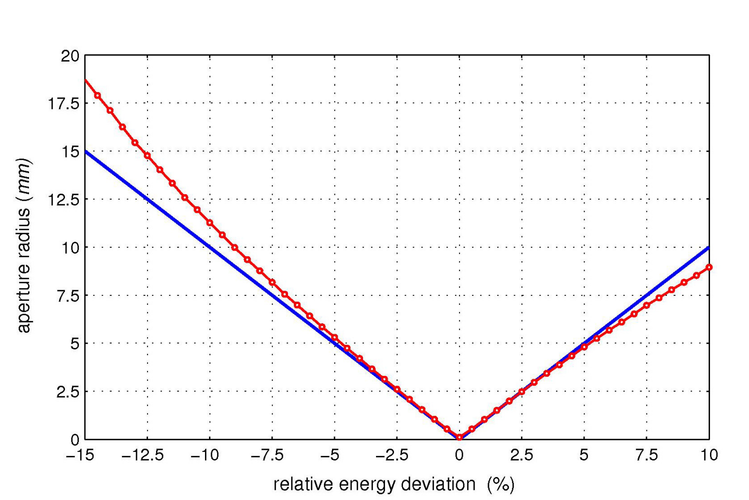
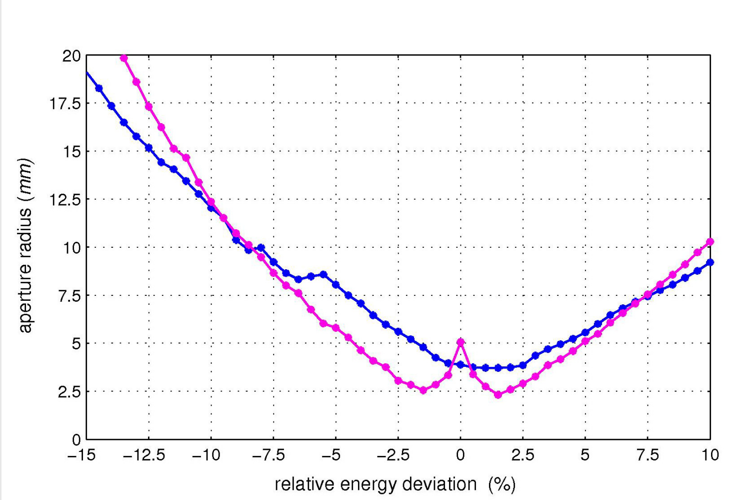
Location of the main primary collimators



Estimate of Required Collimator Apertures



Red curve: aperture radius required to block the corresponding off-energy fraction of incoming particles in the collimation section. Blue curve: analytical estimate for this radius made using linear dispersion at the collimator location. Optics A with sextupoles switched on.



Aperture radius required to protect the undulator vacuum chamber (radius = 4 mm) as a function of the energy deviation. Optics A with sextupoles switched off (magenta curve) and on (blue curve).

Sextupole magnets in the collimator section not only improve beam dynamics, but also allow to use collimators with larger radii.

Because the distribution of the incoming particles, which need to be collimated, is difficult to predict the initial distribution was modeled by mono-energetic 4-dimensional slices, with a transverse extend over the radius of the vacuum chamber at the collimator section entrance (the maximum values for transverse momentums were chosen so as fully populate the acceptance of the transport line), and the results are presented as a function of the energy deviation.

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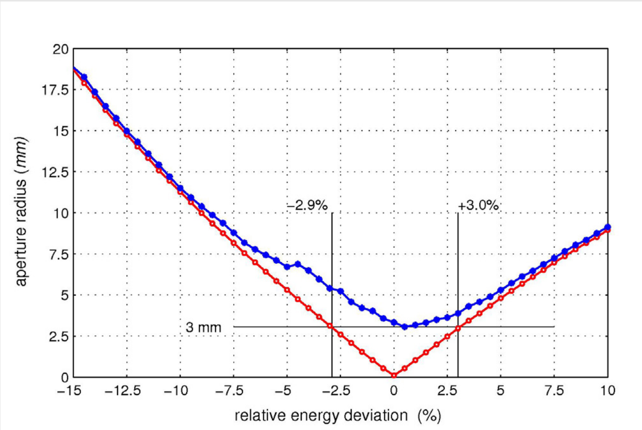
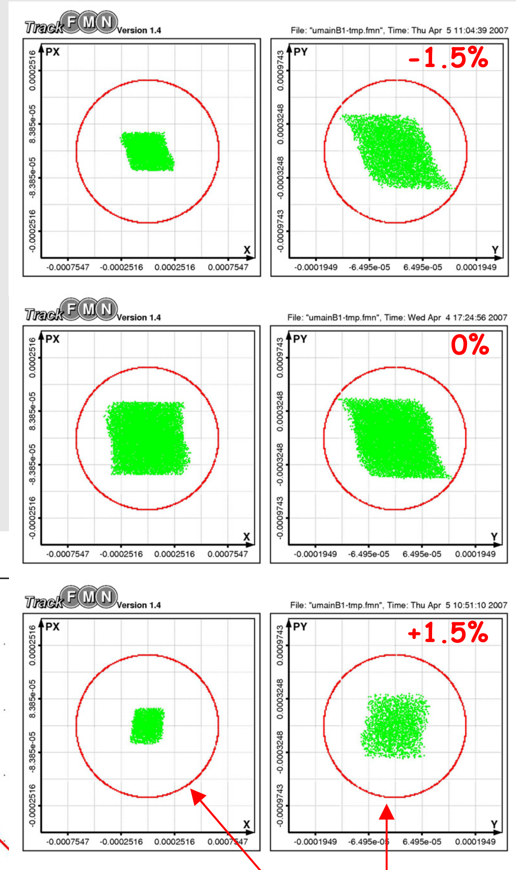
Example: r_{und} = 3 mm

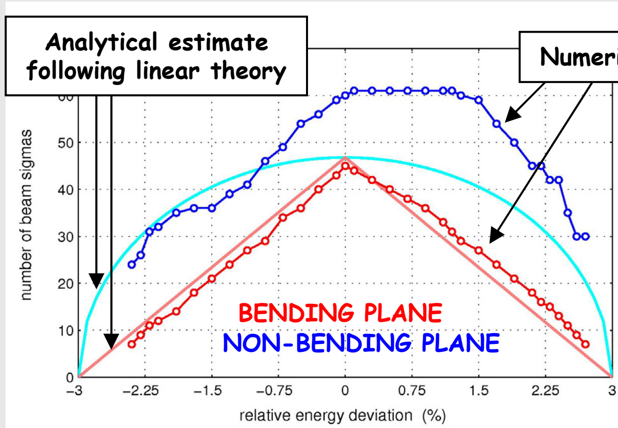


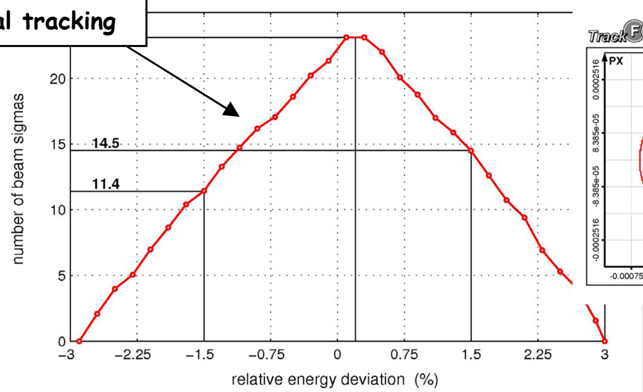
Blue curve: aperture radius required to protect the undulator vacuum chamber (radius = 3mm) as a function of the energy deviation. **Red curve**: aperture radius required to block the corresponding off-energy fraction of incoming particles in the collimation section. Optics A with sextupoles switched on.



WILL BE COLLIMATED

WILL PASS FREELY





TARGET ELLIPSES
(~60σ at 17.5 GeV)

Summary

The optics solution meets all design specification. It is capable of providing simultaneously a large beam spot size at the collimator locations and, in the same time, to transport bunches with different energies (up to ±1.5% from nominal energy) while preserving with good accuracy energy independent input and output matching conditions. These criteria are met by designing a magnetic system whose second-order chromatic and geometric aberrations are controlled by the symmetry of the first-order optics and sextupole fields.

The system uses four main primary collimators and in the next steps the set of exchangeable apertures (2 or 3 apertures) has to be defined, and the question concerning the number and locations of the supplementing primary collimators and secondary collimators has to be considered. Furthermore, the performance of the complete system in the presence of imperfections and with secondary and rescattered particles taken into account has to be studied.