RDR Lattice Update

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LC-UK damping rings research goals

Lattice design (Maxim Korostelev)

- Make necessary modifications and improvements to the present 6.4 km baseline lattice.
- Develop designs for the injection/extraction lines.

Vacuum system technical design and costing (Oleg Malyshev/Norbert Collomb/John Lucas)

- Develop technical design for vacuum system and magnet supports.
- Produce costing based on technical design.

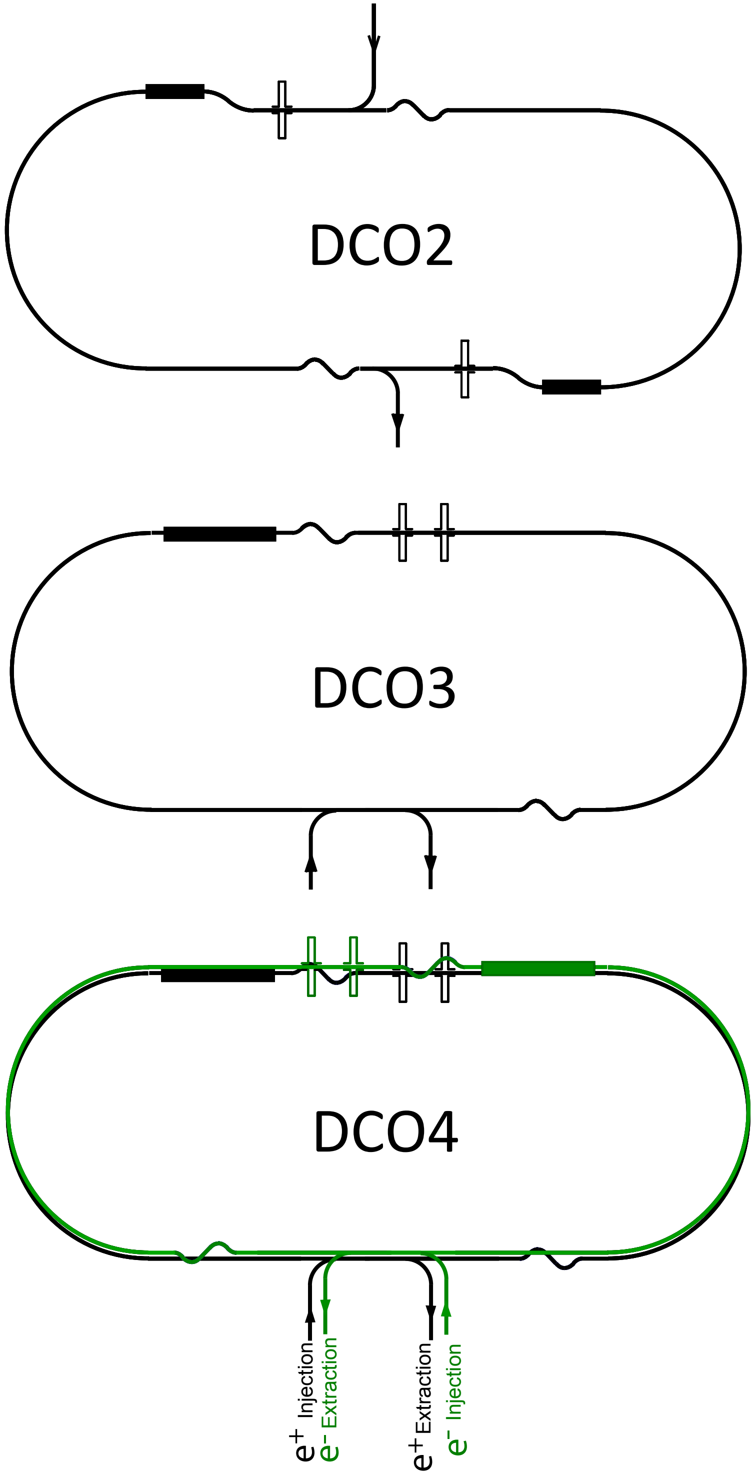
Impedance model and instabilities (Maxim Korostelev)

- Develop impedance model based on technical design of vacuum system.
- Evaluate impact of impedance on beam dynamics.

Low-emittance tuning (Kosmas Panagiotidis)

- Evaluate techniques for low-emittance tuning based on experience at ATF, CesrTA, and other machines.
- Specify requirements for diagnostics and correction systems.

Evolution of the lattice design



Jan 2008: DCO2

- 6.4 km circumference racetrack layout
- FODO - style arc cells
- Injection/extraction in opposite straights
- The left straight section is similar to the write straight section

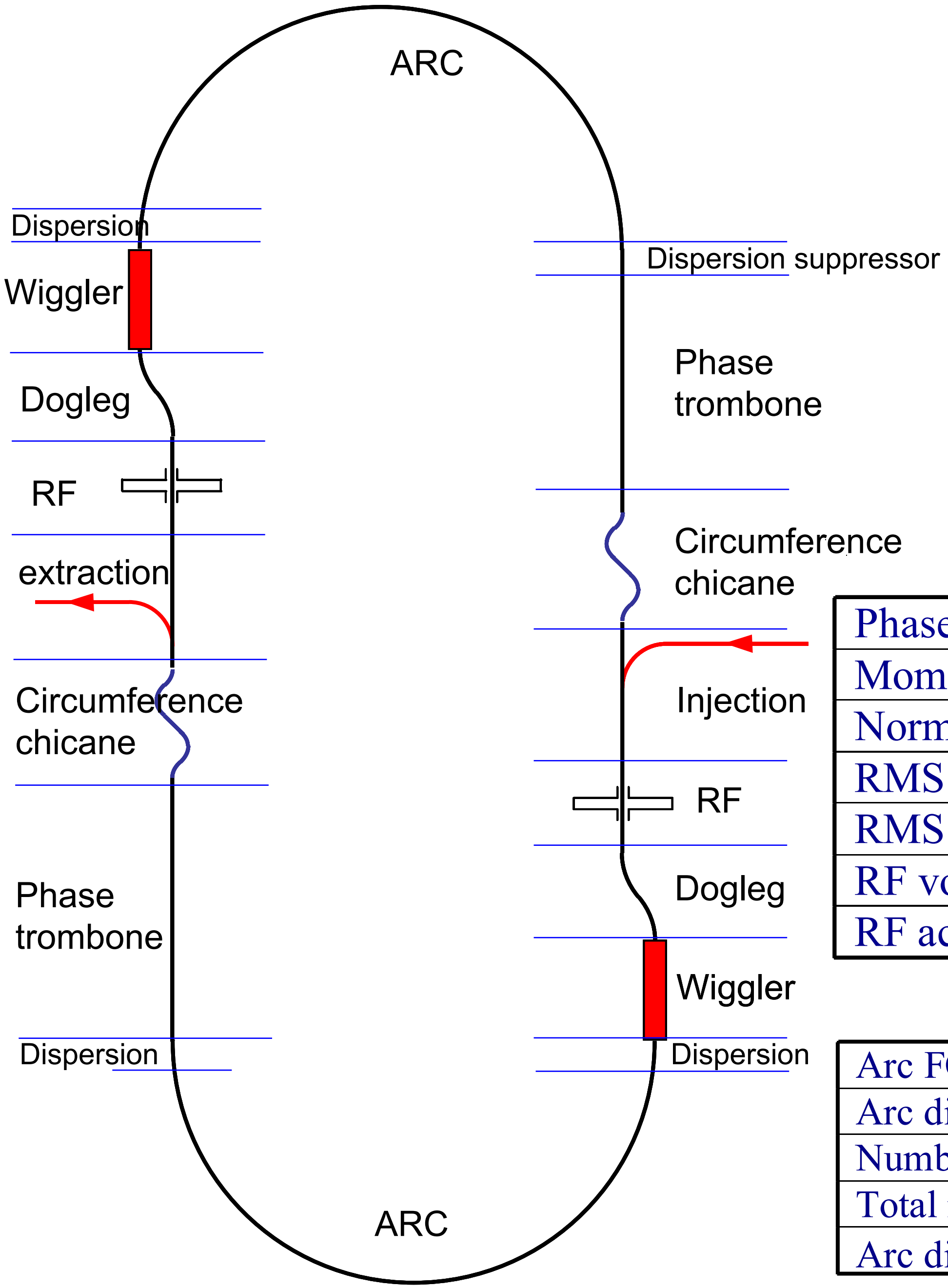
Mar 2009: DCO3

- 6.4 km circumference racetrack layout
- Injection /extraction in one straight
- All wigglers and RF cavities in another straight.

Aug 2009: DCO4

- 6.4 km circumference racetrack layout
- The e+ injection and e- extraction beam lines for both e+ and e- rings are in the same tunnel when two rings are on top of each other.

DCO2 design and major parameters



Major Ring Parameters

Beam energy	5 GeV
Circumference	6476.44 m
RF frequency	650 MHz
Harmonic number	14042
Transverse damping time	21.0 ms
Type of arc cell	FODO with one dipole
Energy loss per turn	10.3 MeV/turn
Relative damping factor	9.7

Phase advance per arc cell	72°	90°	100°
Momentum compaction	2.8×10^{-4}	1.7×10^{-4}	1.3×10^{-4}
Normalized horiz. emittance	6.6 μm	4.7 μm	4.3 μm
RMS bunch length	6.0 mm	6.0 mm	6.0 mm
RMS energy spread	1.27×10^{-3}	1.27×10^{-3}	1.27×10^{-3}
RF voltage	31.6 MV	21.1 MV	17.2 MV
RF acceptance	2.35 %	1.99 %	1.72 %

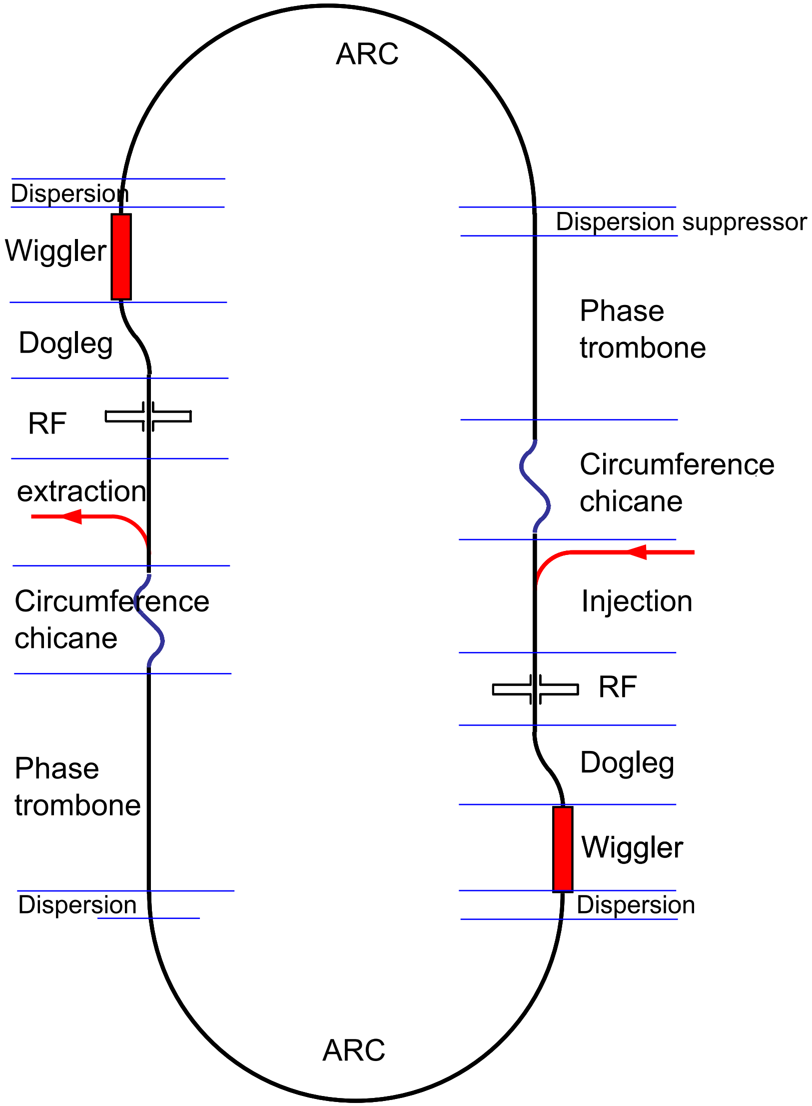
Arc

Arc FODO cell length	21.2 m
Arc dipole length	2.0 m
Number of FODO cells	192
Total number of sextupoles	384
Arc dipole field	0.273 T

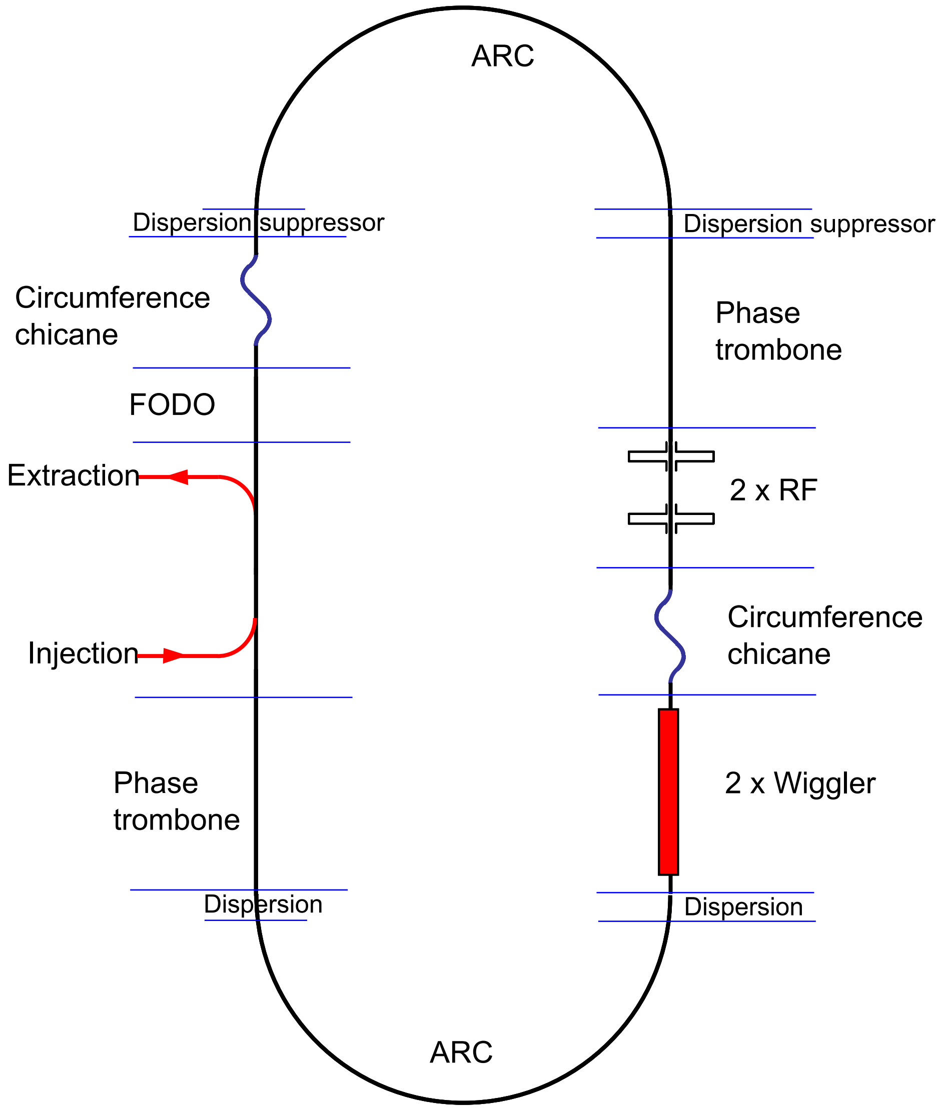
Wigglers

Number and type	88 SC
Peak field	1.6 T
Period	0.4 m
Unit length	2.45 m
Total length	215.6 m

DCO2 design

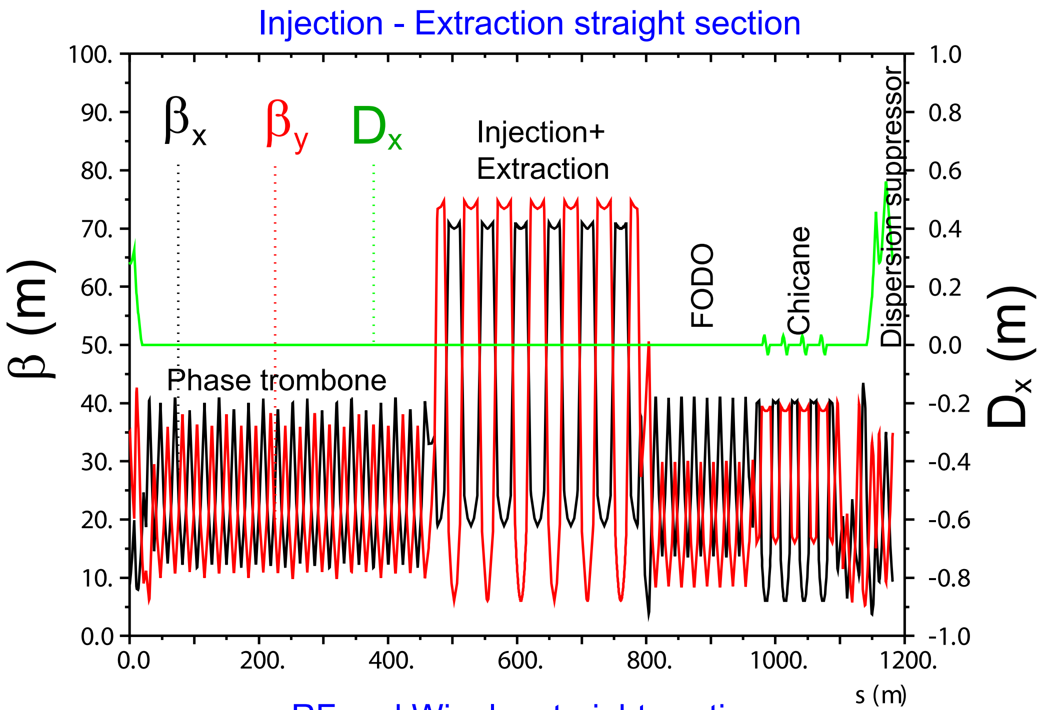


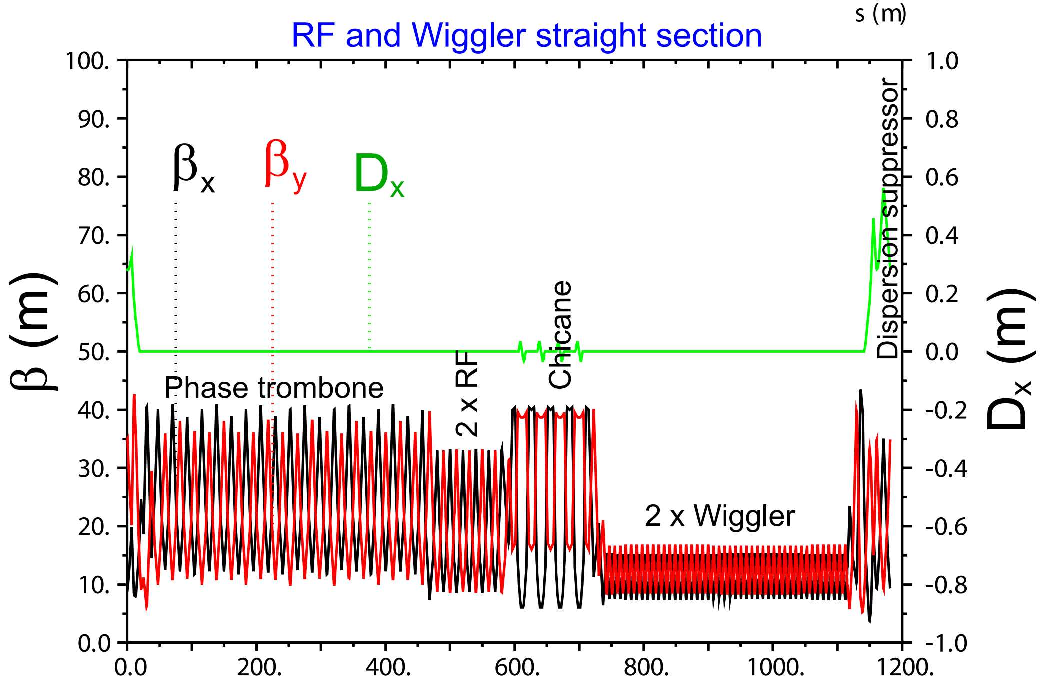
DCO3 design



As first stage of the TDP-I, injection and extraction sections in the DCO2 design have to be arranged into the same straight without change of the ring circumference.

Lattice of the DCO3 straight sections





- In DCO3 design, 4 additional arc cells are inserted to each arc to restore the ring circumference to 6476m

- There is no modification in the arc cell and the dispersion suppressors.

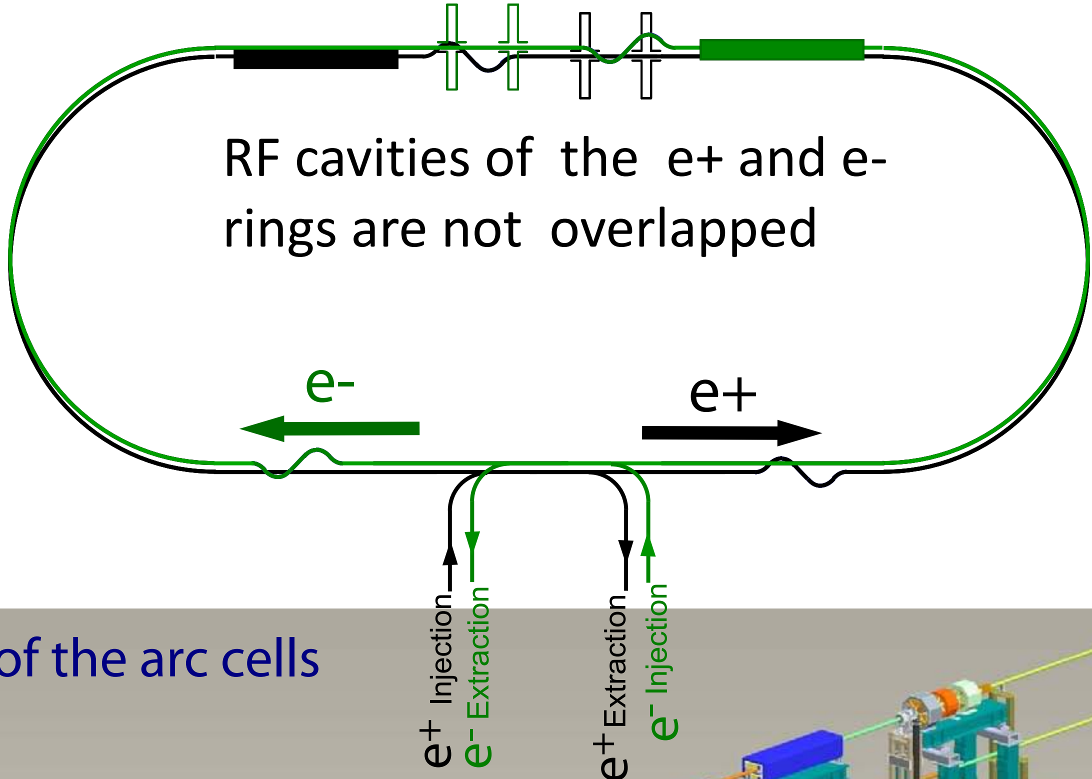
- Lattice of circumference chicane, RF section, wiggler section and ING/EXT sections is not changed.

- Drift between quads in the phase trombone was reduced from 12.04 to 11.09 m to avoid overlapping RF cavities of the e+ and e- rings.

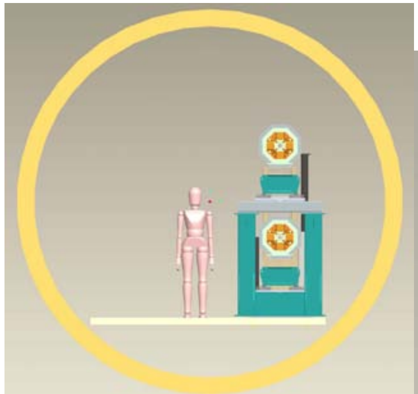
Positioning of the e+ and e- DR rings

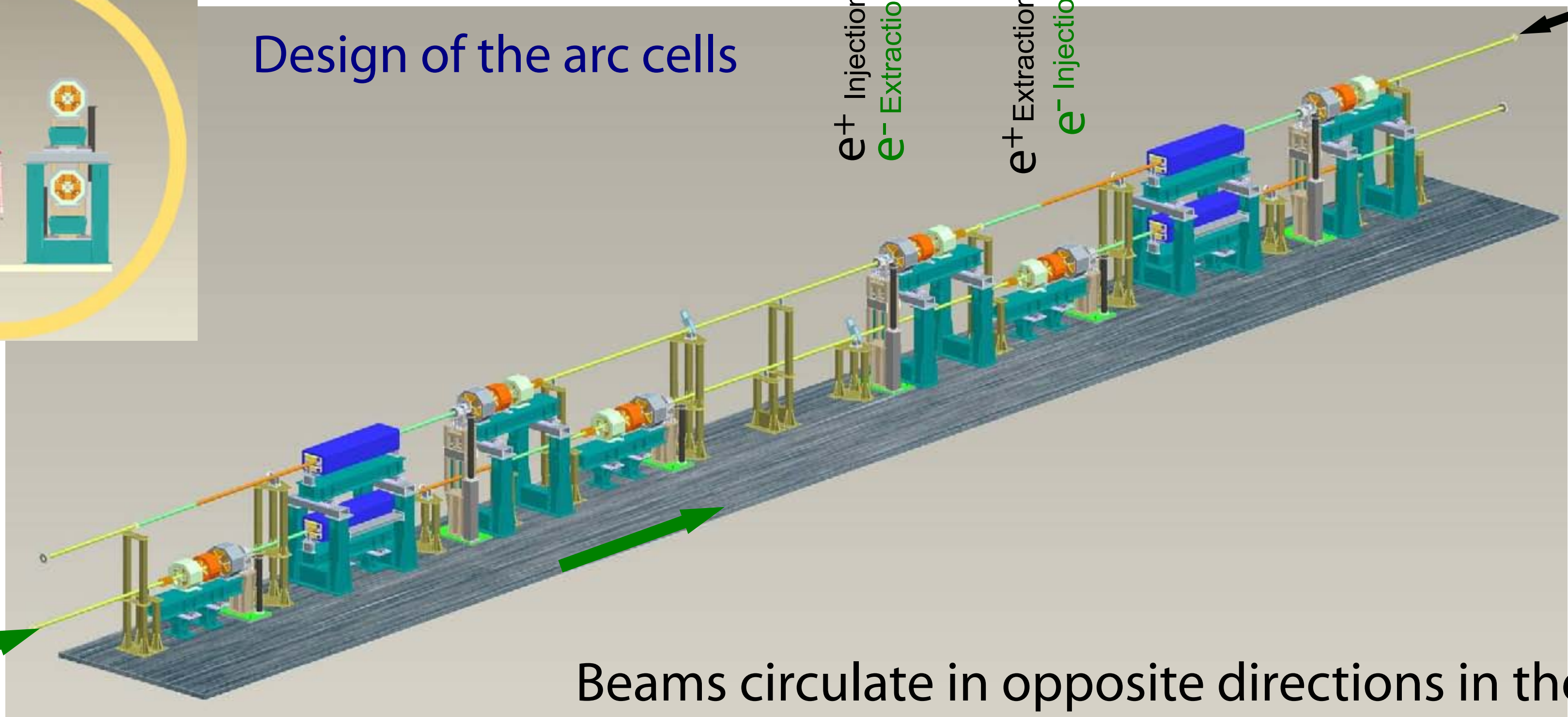
e- Damping Ring
e+ Damping Ring

The lattice of e- DR is identical to the lattice of the e+ DR.



Tunnel





Design of the arc cells

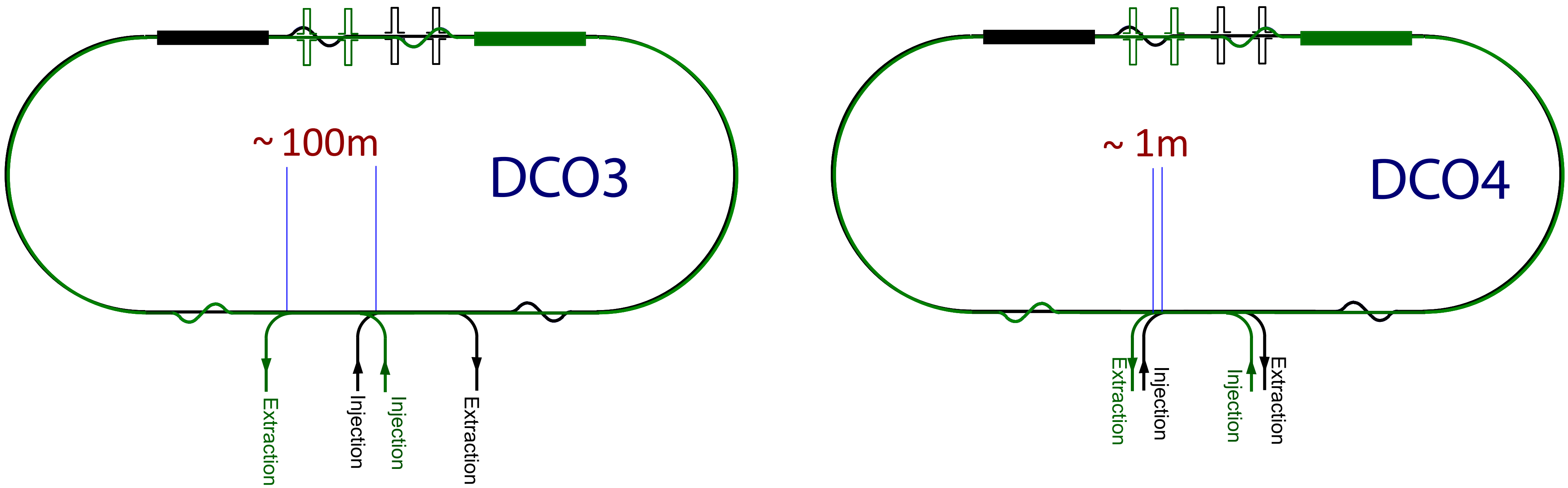
Beams circulate in opposite directions in the two rings.

Main reason of the modifications of the DCO3 design

Injection e+ and extraction e- beam lines have to be in the same tunnel as well as Injection e- and extraction e+ beam lines when the arc bending magnets of the e- and e+ damping rings are put on top of each other

The solution is:

- To move kickers and septums within the inj/ext region by one period towards phase trombone for both e- and e+ rings.
- To modify of the dispersion suppressors and last arc cells



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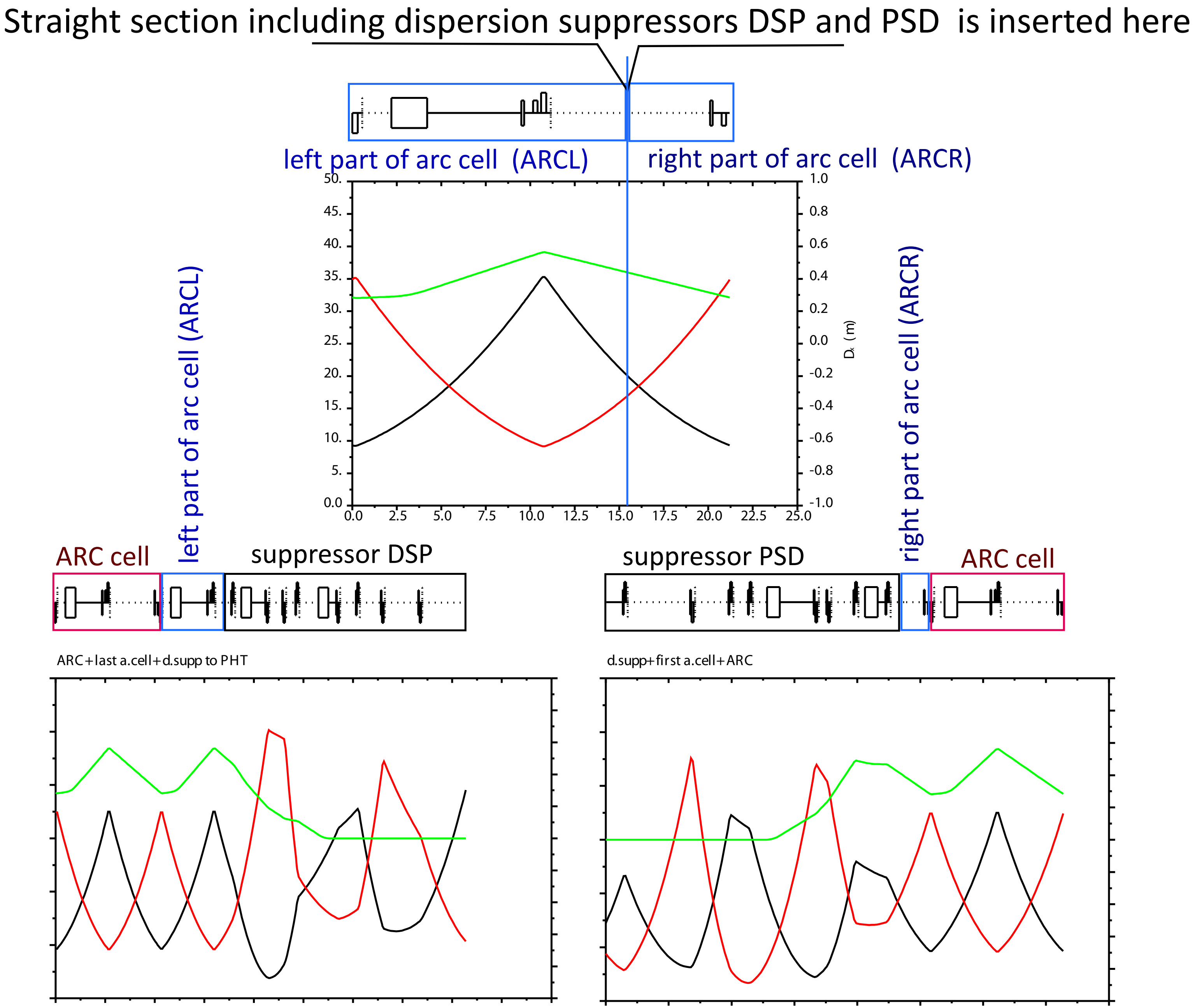
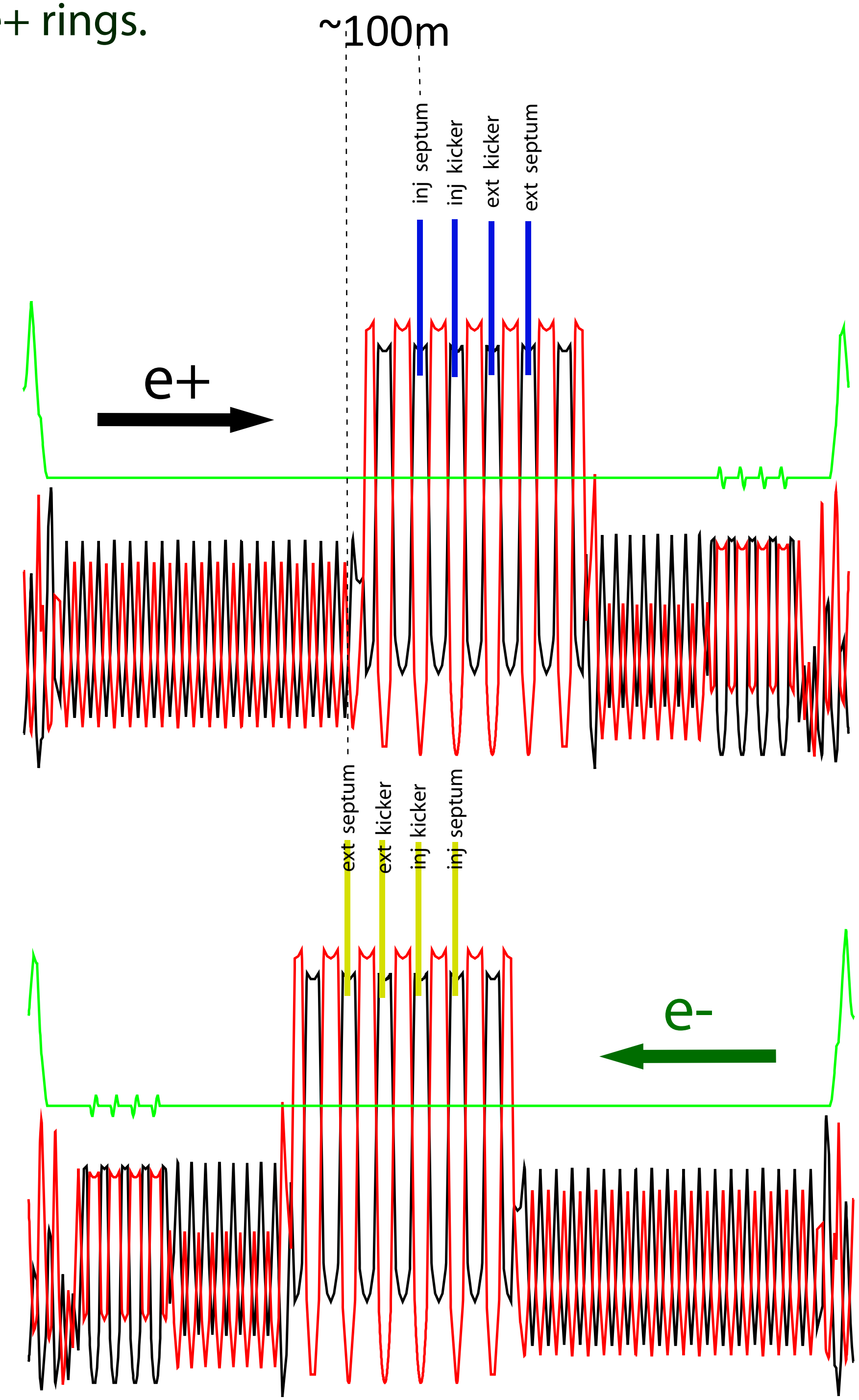


- To move kickers and septums within the inj/ext region by one period towards phase trombone for both e- and e+ rings.



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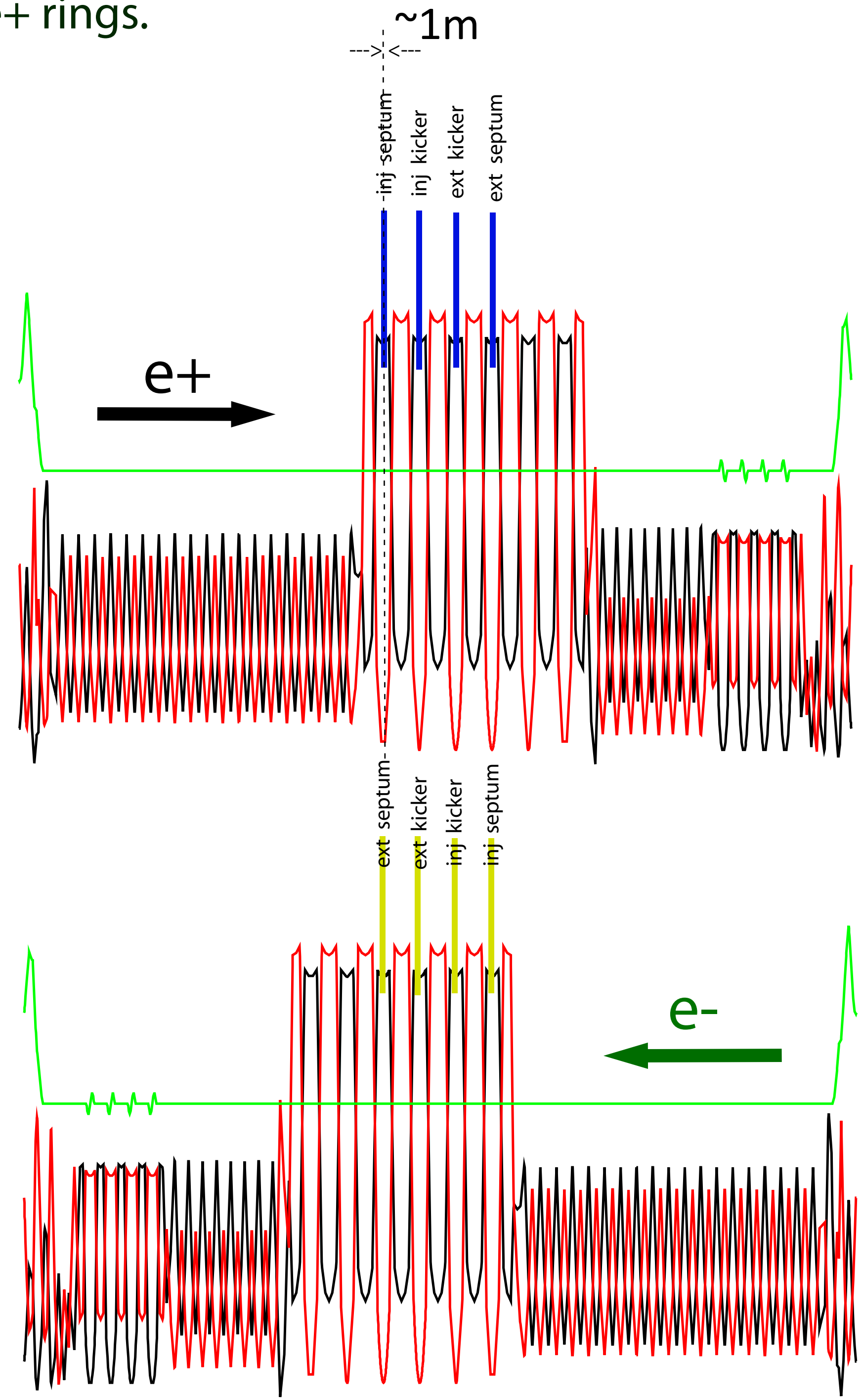


Lattice parameters and beam characteristics

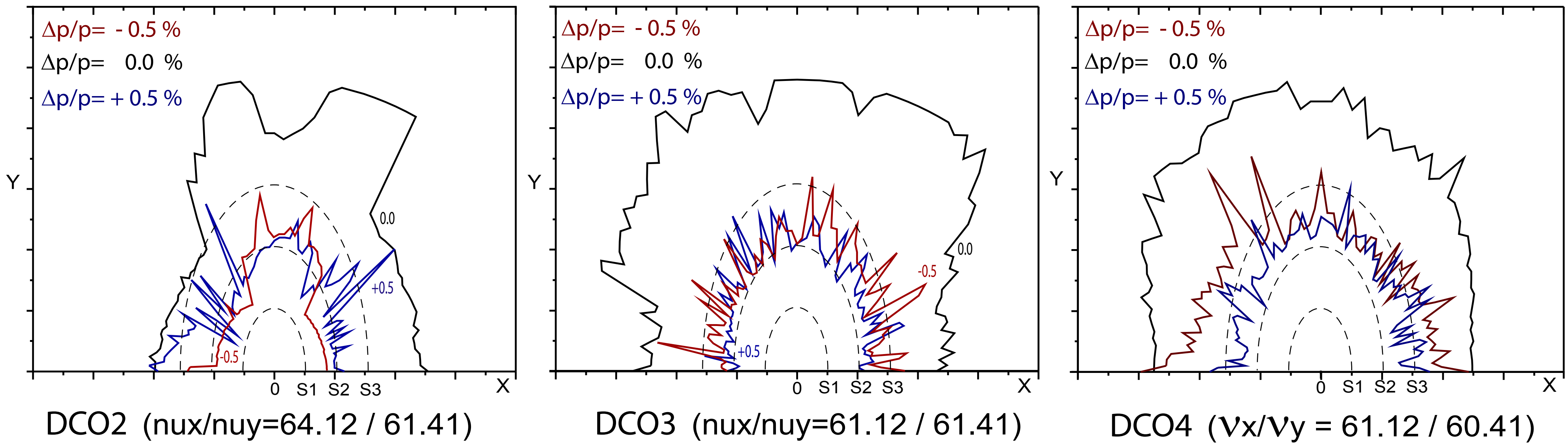
	DCO4	DCO3
Beam energy	5 GeV	5 GeV
Circumference	6476.4 m	6476.4 m
RF frequency	650 MHz	650 MHz
Harmonic number	14042	14042
Transverse damping time	21.1 ms	21.1 ms
Type and # of arc cells	FODO with one dipole 200	FODO with one dipole 200
Total length of wigglers	215.6 m	215.6 m
Wiggler peak field	1.6 T	1.6 T
Relative damping factor	10.08	10.08
Energy loss per turn	10.23 MeV/turn	10.23 MeV/turn

DCO3
690- quads, BPMs, correctors
392- sextupoles, skew quads

DCO4
692- quads, BPMs, correctors
392- sextupoles, skew quads

	DCO4			DCO3		
Phase advance per arc cell	72°	90°	100°	72°	90°	100°
Momentum compaction	2.9×10^{-4}	1.6×10^{-4}	1.3×10^{-4}	2.9×10^{-4}	1.6×10^{-4}	1.3×10^{-4}
Normalized horiz. emittance	6.4 μm	4.4 μm	3.9 μm	6.4 μm	4.4 μm	3.9 μm
RMS bunch length	6.0 mm	6.0 mm	6.0 mm	6.0 mm	6.0 mm	6.0 mm
RMS energy spread	1.27×10^{-3}	1.27×10^{-3}	1.27×10^{-3}	1.27×10^{-3}	1.27×10^{-3}	1.27×10^{-3}
RF voltage	32.6 MV	20.4 MV	17.1 MV	32.6 MV	20.4 MV	17.1 MV
RF acceptance	2.38 %	1.96 %	1.72 %	2.38 %	1.96 %	1.72 %
Synchrotron tune	0.063	0.036	0.028	0.063	0.036	0.028
Horizontal betatron tune	61.12	71.12	76.12	61.12	71.12	76.12
Vertical betatron tune	60.41	71.41	75.41	61.41	71.41	76.41
Natural horiz. chromaticity	-71.0	-89.2	-99.8	-68.5	-87.6	-99.3
Natural vert. chromaticity	-72.6	-91.0	-100.7	-70.2	-89.2	-100.7

Dynamic aperture of the DCO2, DCO3 and DCO4 lattices at arc cell phase advance close to 72°



Dashed ellipses show maximum particle coordinates for injected beam size:

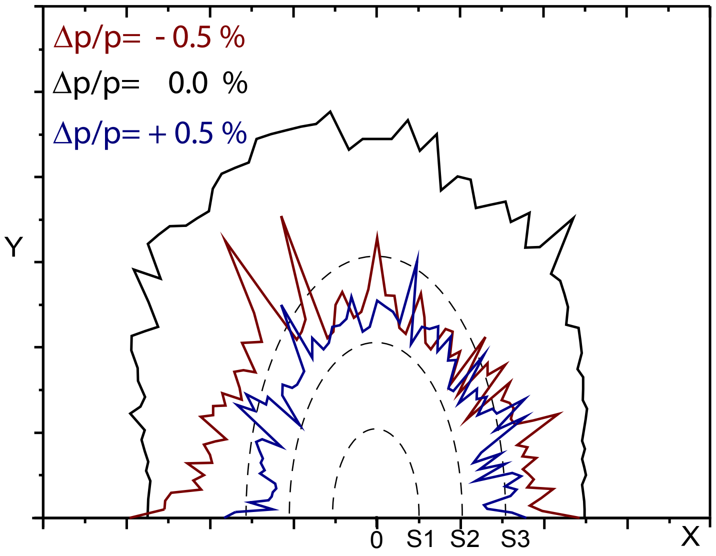
S1 one injected beam size: 25 mm horizontally and 7.4 mm vertically

S1 - one injected beam size
S2 - double injected beam size
S3 - triple injected beam size

Dynamic aperture of the DCO4 lattice at the arc cell phase advance close to:

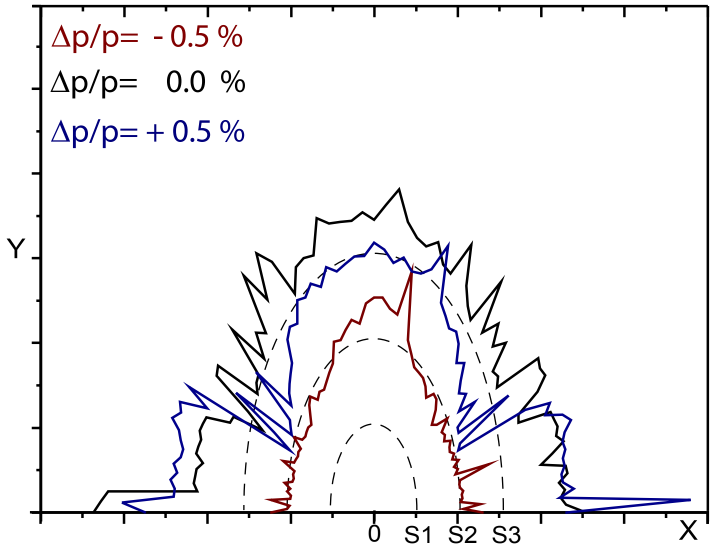
72° | 90° | 100°

DCO4 ($\nu x/\nu y$ = 61.12 / 60.41)



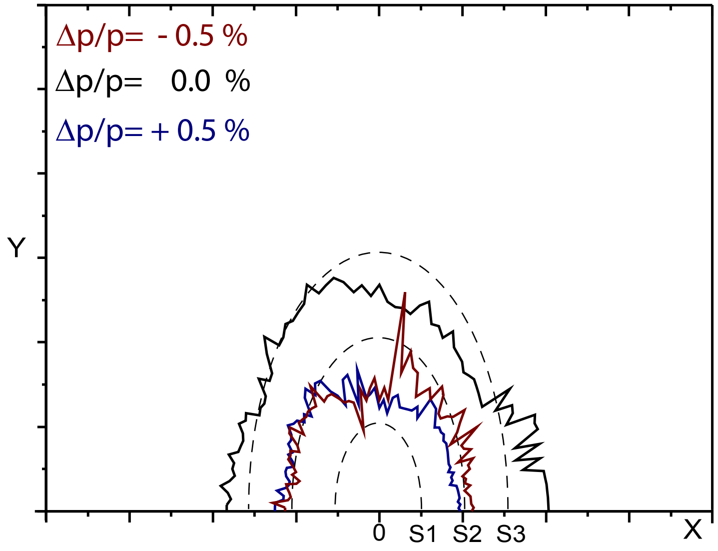
Interleaved arrangement of sextupoles is used

DCO4 ($\nu x/\nu y$ = 71.12 / 71.41)



Non-interleaved arrangement of -I sextupole pairs is used at the 90 degrees phase advance.

DCO4 ($\nu x/\nu y$ = 76.12 / 75.41)



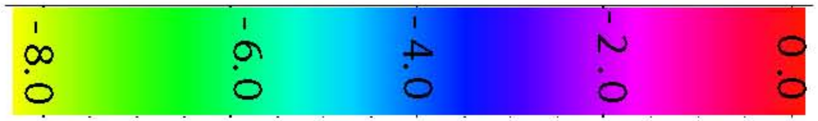
Interleaved arrangement of sextupoles is used

Dashed ellipses show maximum particle coordinates for injected beam size:

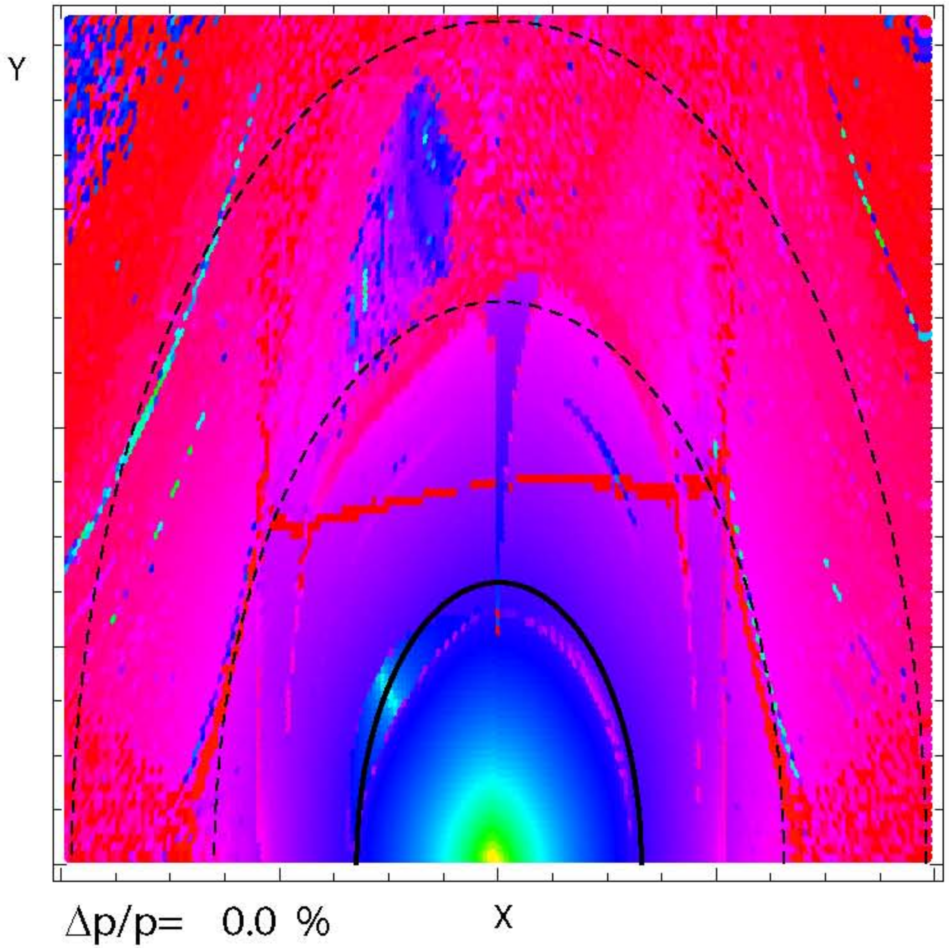
S1 one injected beam size: 25 mm horizontally and 7.4 mm vertically

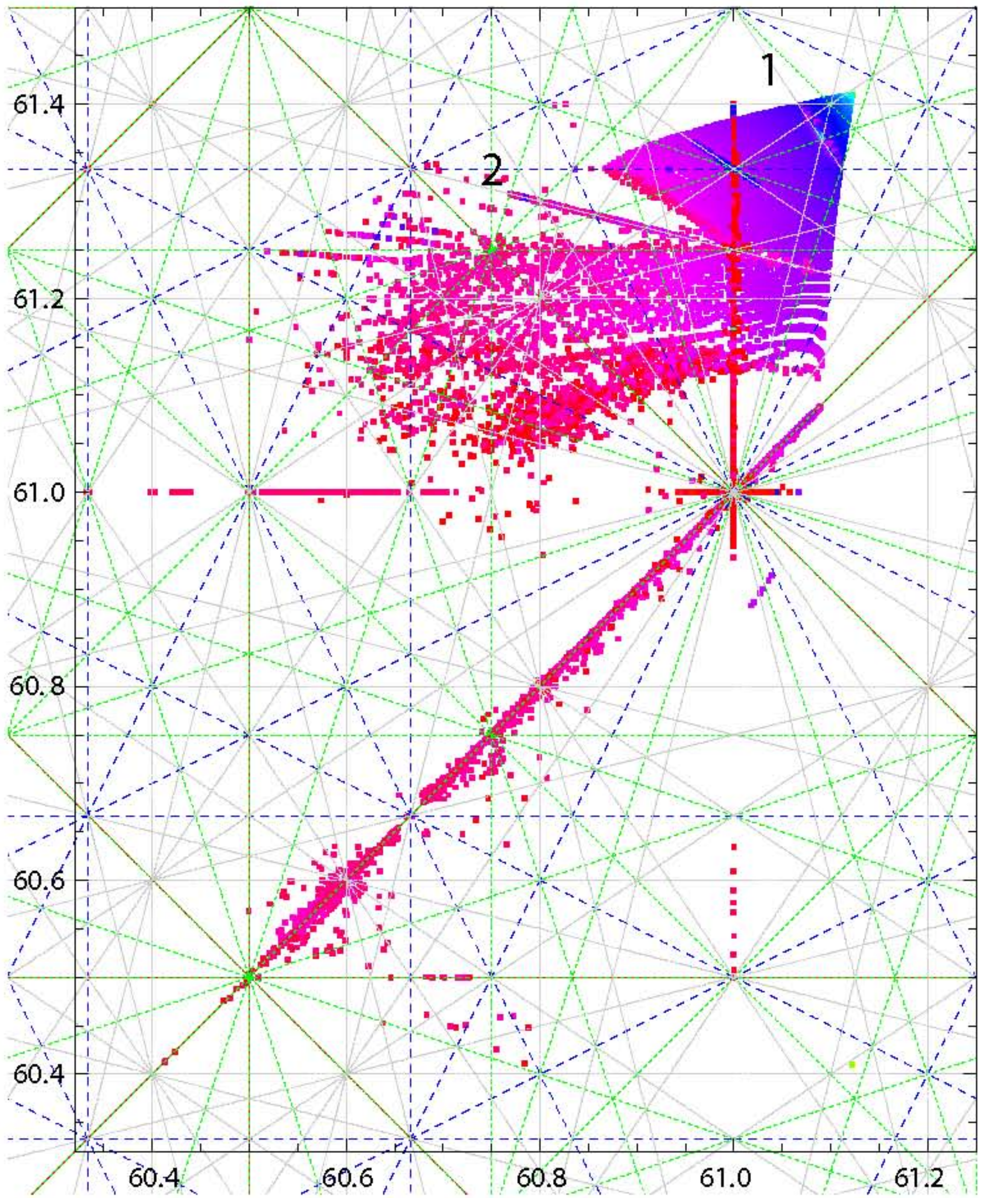
S1 - one injected beam size
S2 - double injected beam size
S3 - triple injected beam size

Frequency map analysis



$$\Delta\nu = \log_{10}\sqrt{\left(\nu_x^{1024}-\nu_x^{512}\right)^2+\left(\nu_y^{1024}-\nu_y^{512}\right)^2}$$



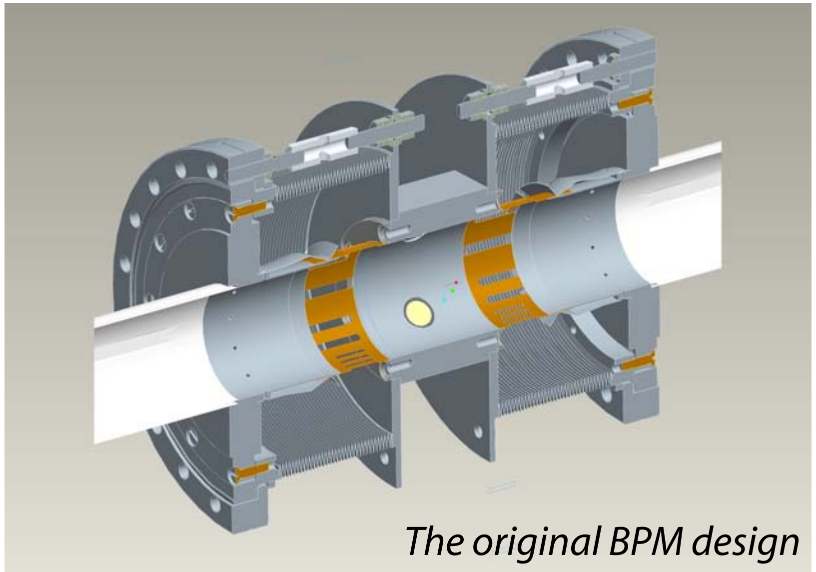


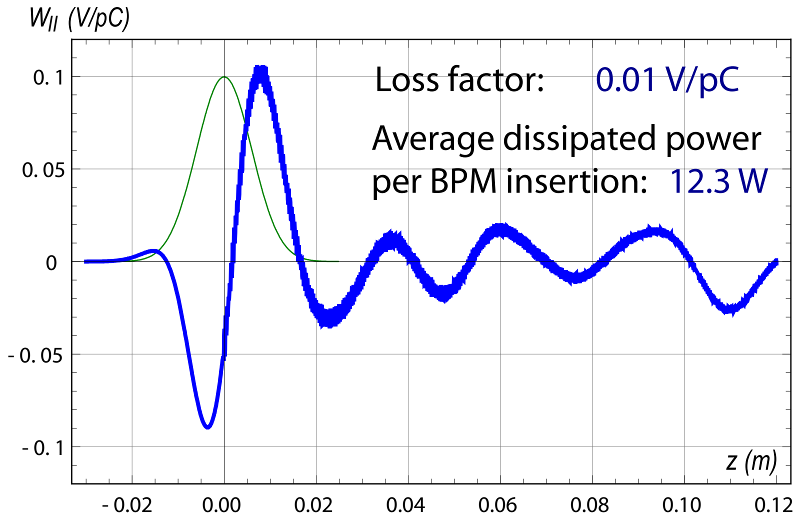
Δp/p= 0.0 %

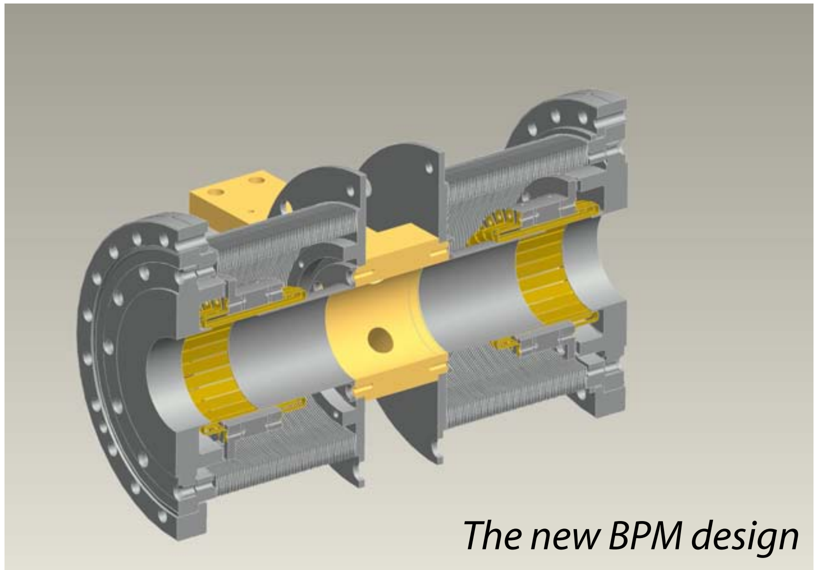
1) 3νx + 2νy = 306

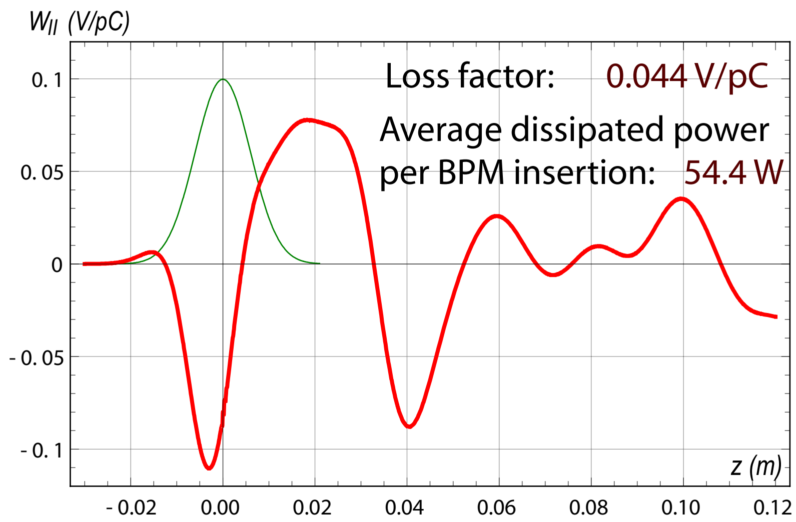
2) νx + 4νy = 306

Longitudinal wake potentials


The original BPM design

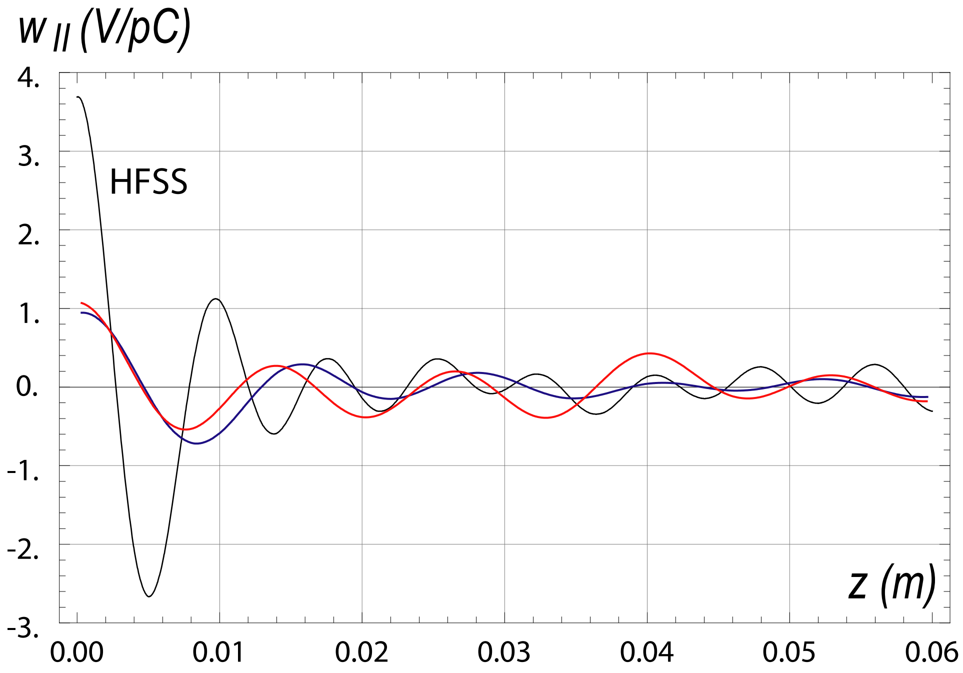



The new BPM design



- CST Particle Studio time-domain simulations
- Gaussian relativistic electron bunch with rms length of 6 mm.

Wake function



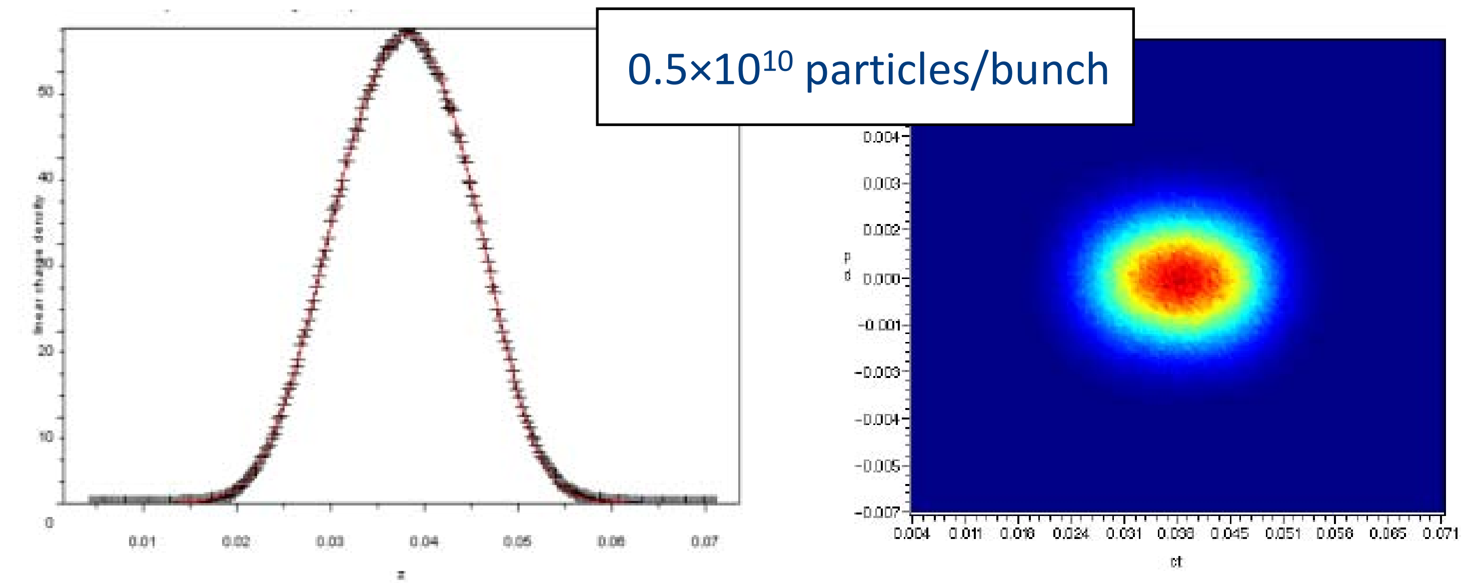
The wake potentials have been computed and integrated over a distance of 1m to provide sufficient resolution for the calculation of the impedance.

Applying an inverse Fourier transform to the impedance with the limits plus/minus 25 GHz, the wake functions have been computed.

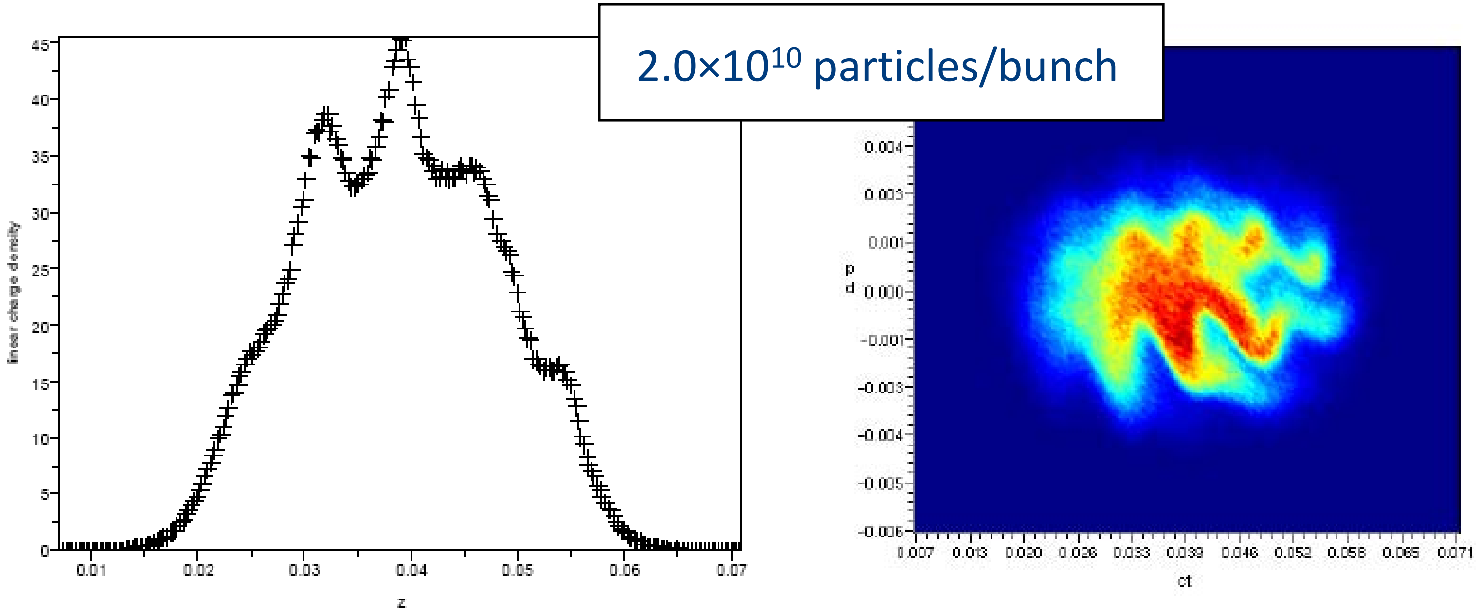
The wake functions of original (blue curve calculated by CST) and new (red curve calculated by CST) BPM models are shown together with the "HFSS wake function" (black curve calculated by HFSS)

"HFSS wake function" is Fourier transformed from the impedance that was calculated from the HFSS S-parameters by the wire method. This indirect approach resulted in the unreliable wake function.

Tracking simulations: beam instability threshold



Alex Thorley,
U. Liverpool.



Tracking simulations done for the "HFSS wake function" show that the instability threshold is around 10^{10} particles per bunch.

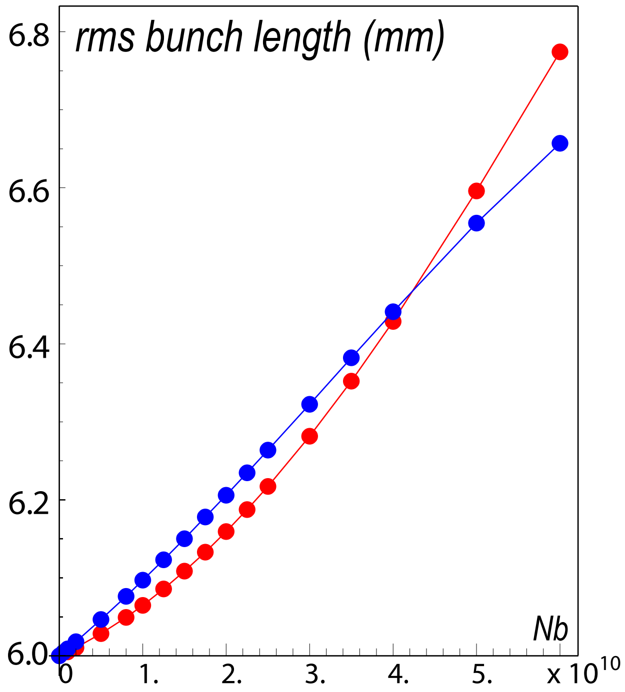
- This instability threshold is overestimated because of unreliable HFSS wake function was used for the tracking simulations.

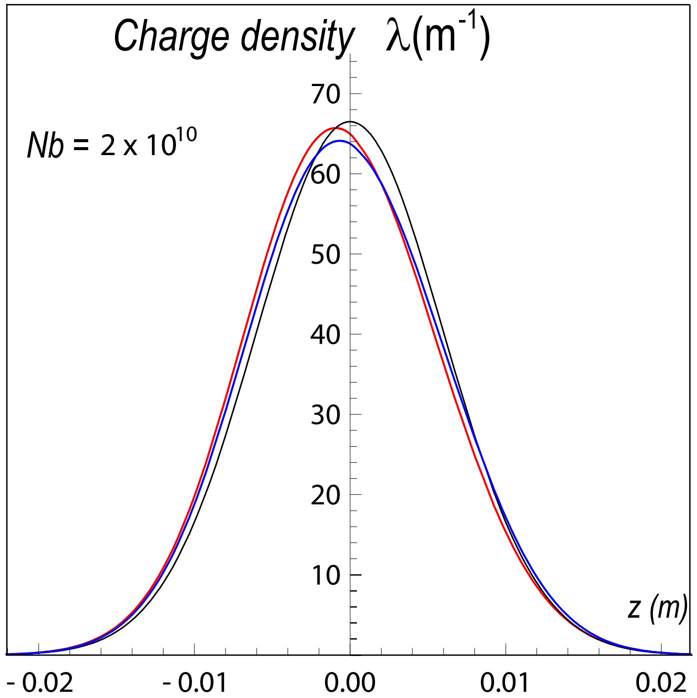
Bunch lengthening

To estimate bunch lengthening for the calculated wake functions, the Haissinski equation have been solved using a numerical iterative technique.

$$\lambda(z) = K\exp\left\{-\frac{z^2}{2\sigma_z^2} - \frac{4\pi\varepsilon_0 r_e N_b}{\alpha_p \gamma C \sigma_\delta^2}\int_0^z W_\parallel(z')dz'\right\}$$

$$\int_{-\infty}^{\infty} \lambda(z)dz = 1;\ W_\parallel(z') = \int_{z'}^{\infty} \lambda(z'')w_\parallel(z'-z'')dz''$$





A Gaussian bunch of rms length 6mm deforms to shapes with rms length of 6.15 mm with the new BPMs (red), and 6.21 mm with the original BPMs (blue)

There is a possible instability threshold just above the nominal bunch population of 2.0×10^{10} particles: this needs more careful study

Summary

Lattice design

- The lattice designs of the positron and electron DRs are identical.
- The injection and extraction beam lines are located in the same tunnel.
- RF sections of the positron and electron damping rings do not overlap each other.
- 6.4 km lattice (DCO4) is now complete, and meets known dynamics and engineering specifications. This lattice provides a stable baseline for the TDR.

Impedance model

- Work on construction of an impedance model, and understanding the impact on the beam dynamics, is on-going.
- New BPM/bellows design has simpler mechanical assembly, and slightly lower inductive wake field; but resistive wake field (and hence power load) is higher.

Vacuum system technical design and costing

– Compilation of the arc cell costing is very near completion.

– Work on the technical design for the wiggler sections is beginning