# Lattice update of ILC Damping Ring

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# Plans for TDP-I/Minimum Machine (2009 - start 2010)

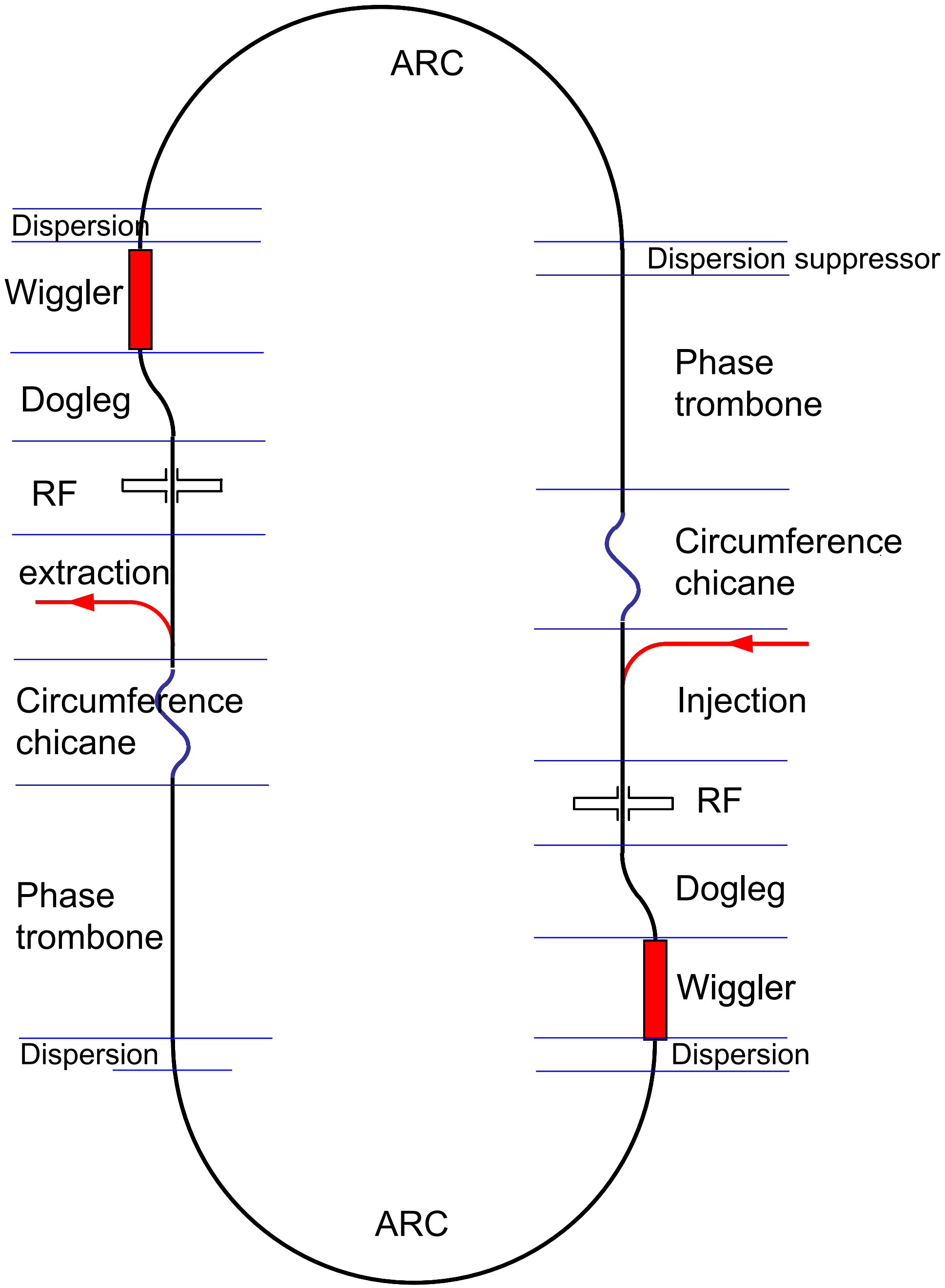
( ILC Workshop, 2008 University of Illinois at Chicago)

1. Demonstrate performance specifications in the critical areas of electron cloud, fast kickers, and low-emittance operation.

2. Produce technical performance and cost comparisons of present baseline (6 km) and possible "minimum machine" (3 km) damping ring configurations by end 2009.

3. Develop design and costs information in support of the Technical Design Report.

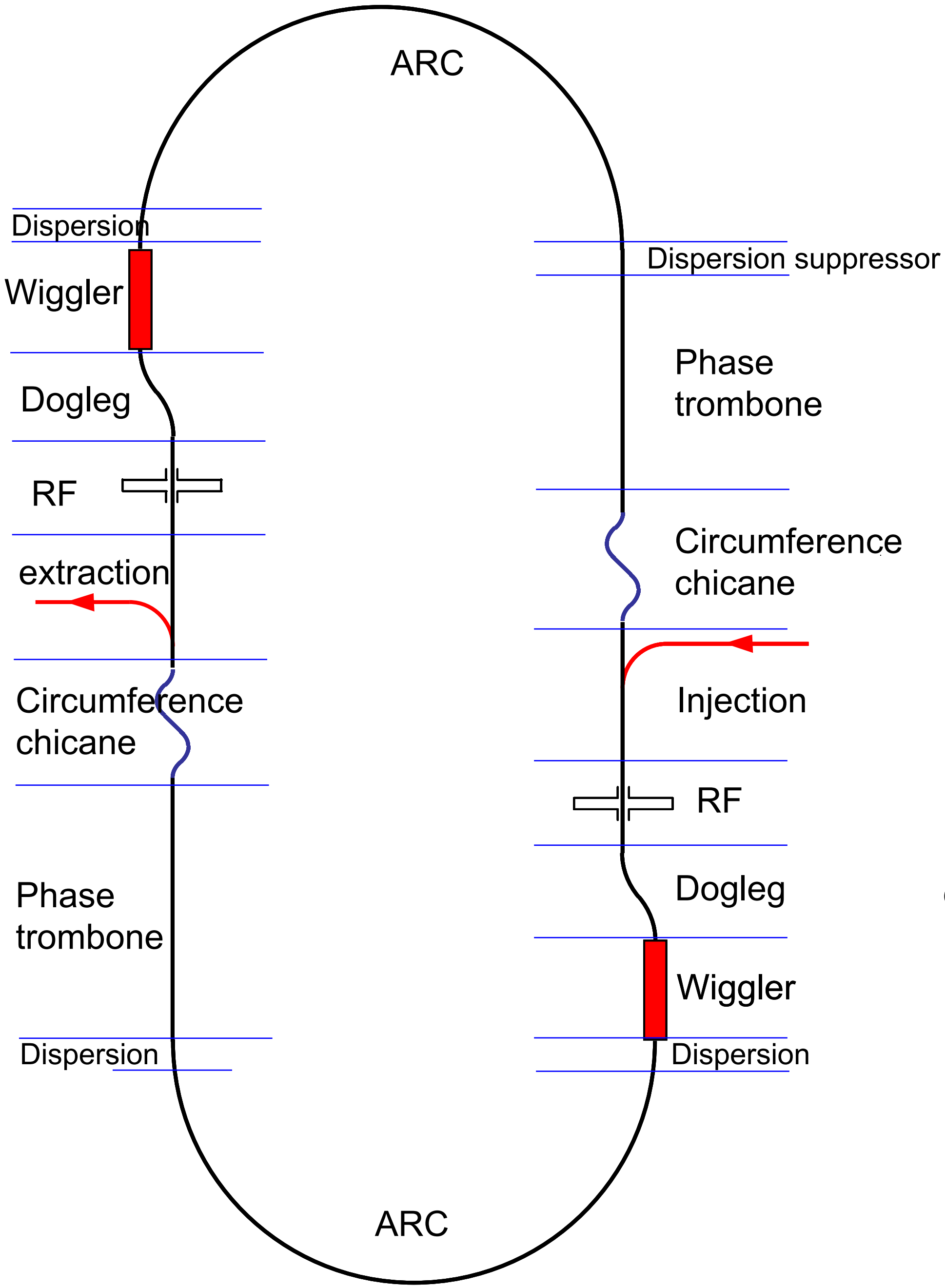
# Original layout and major parameters



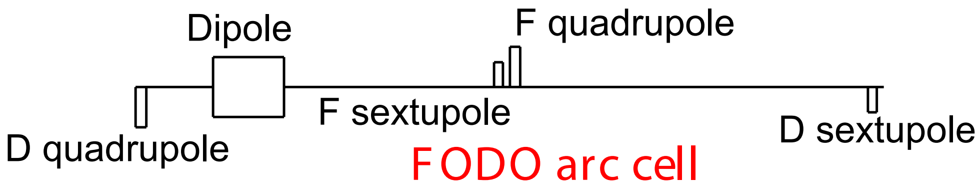

## Major Parameters

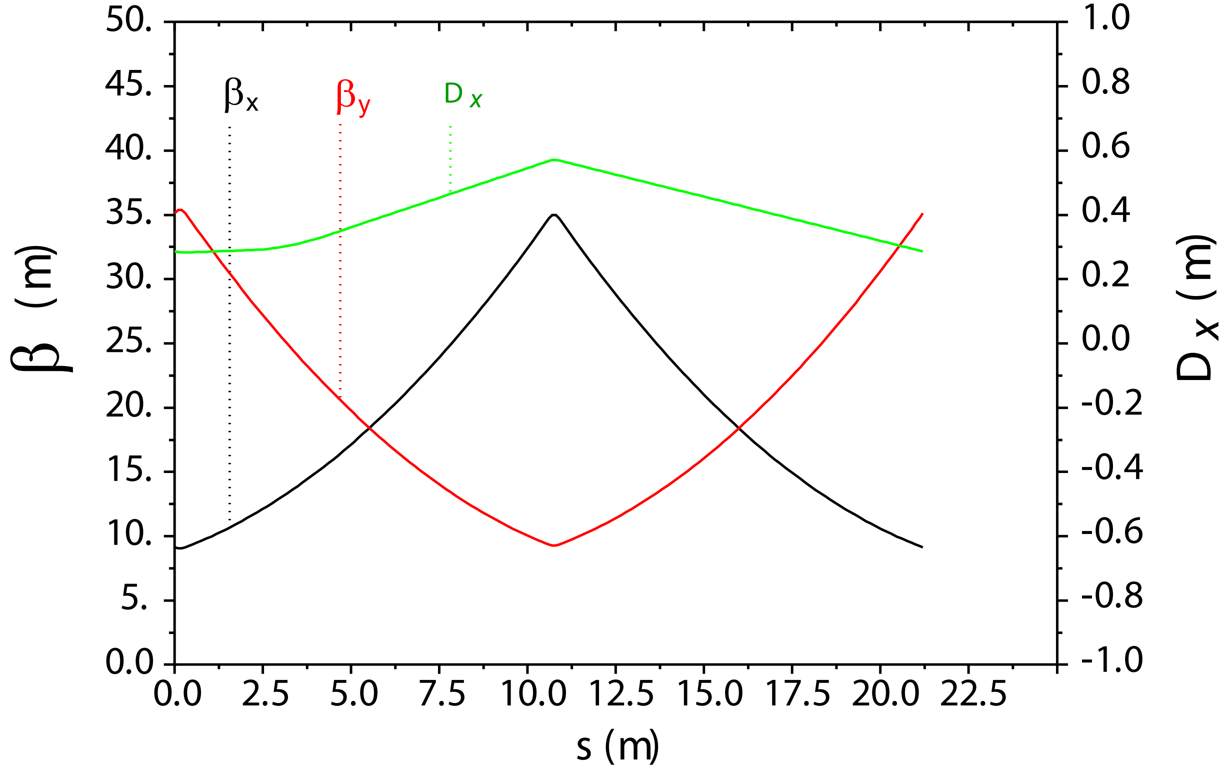
| | |
|---|---|
| Beam energy | 5 GeV |
| Circumference | 6476.44 m |
| Revolution time | 21.6 us |
| RF frequency | 650 MHz |
| Harmonic number | 14042 |
| Type of arc cell | FODO with one dipole |
| Total length of wigglers | 215.6 m |
| Energy loss per turn | 10.3 MeV/turn |
| Relative damping factor | 9.7 |
| Transverse damping time | 21.0 ms |

# Original layout and major parameters




| | |
|---|---|
| Arc FODO cell length | 21.2 m |
| Arc dipole length | 2.0 m |
| Number of FODO cells | 192 |
| Total number of sextupoles | 384 |
| Maximum sextupole gradient | 215 $T/m^2$ |
| Arc dipole field | 0.273 T |



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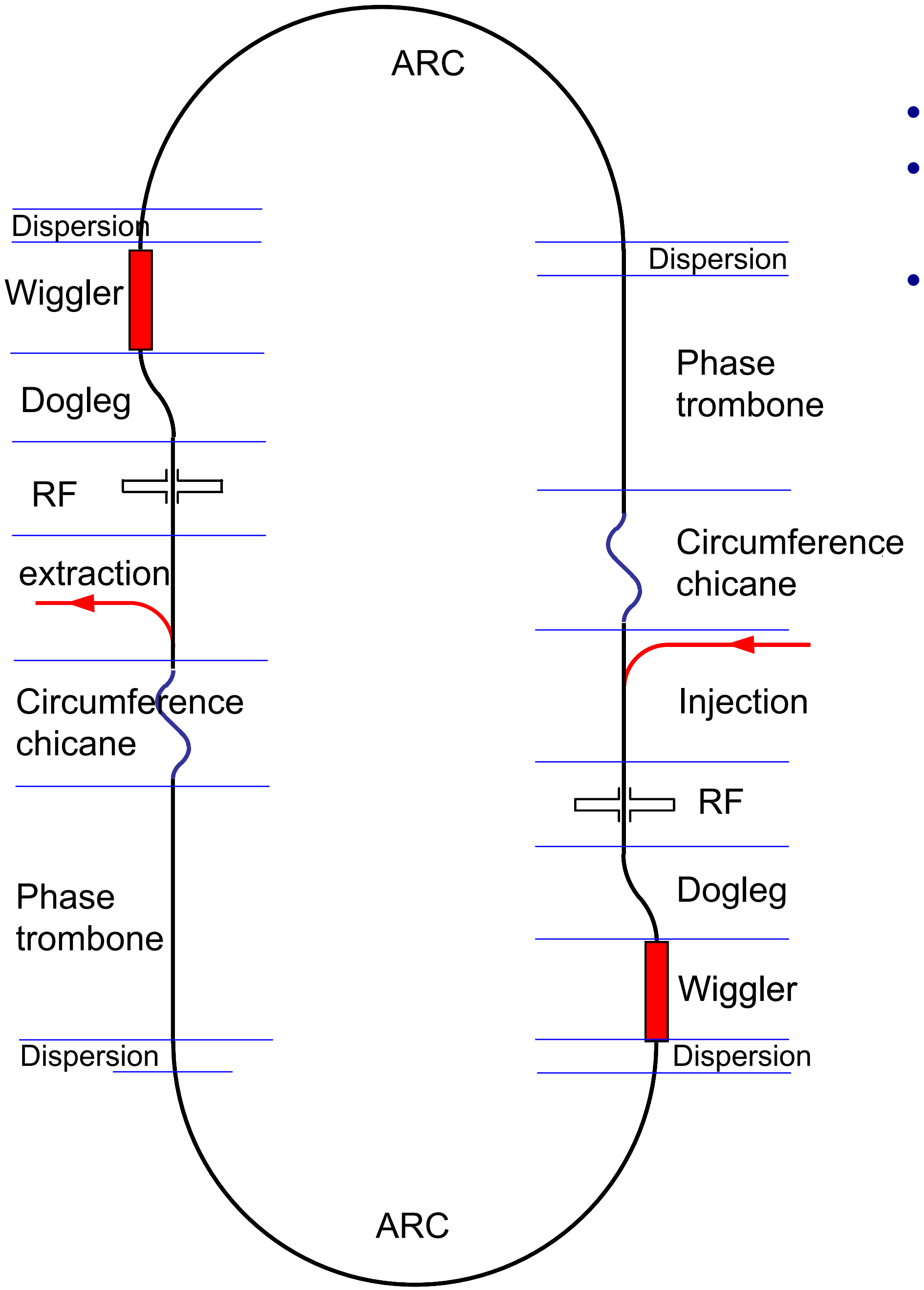
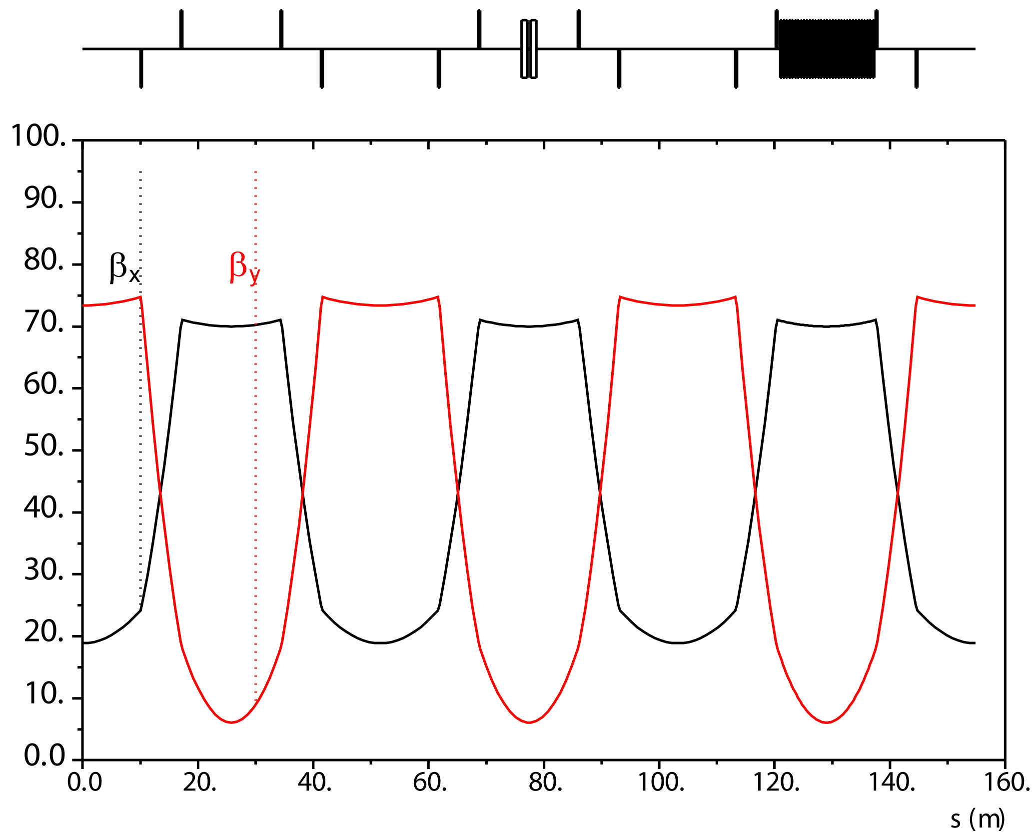



- Injection and extraction optics are similar to each other.
- Symmetry around septum provides possibility for closed orbit bumps.
- High beta function gives low phase advance over kickers, and large beam offset at septum.



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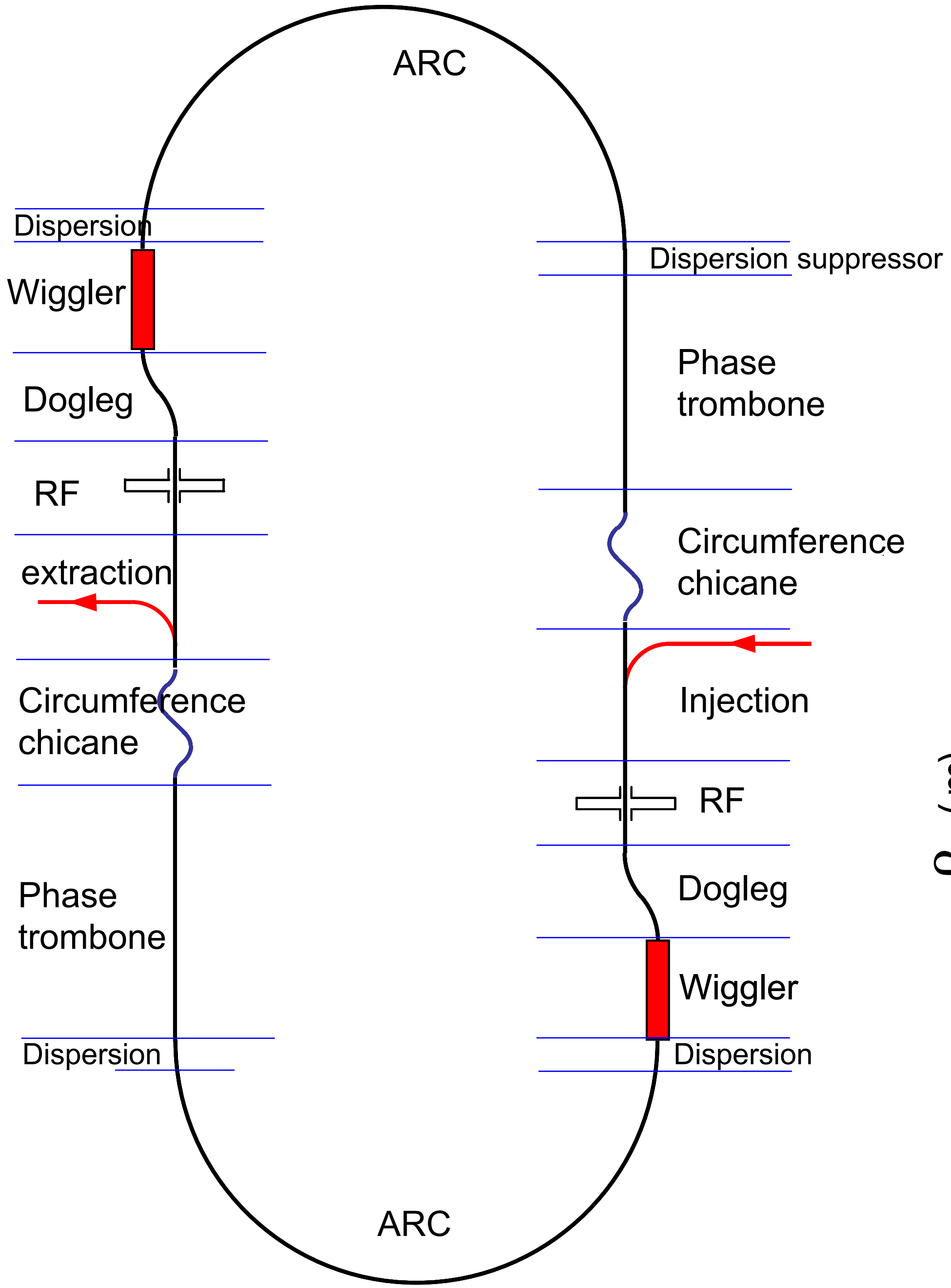
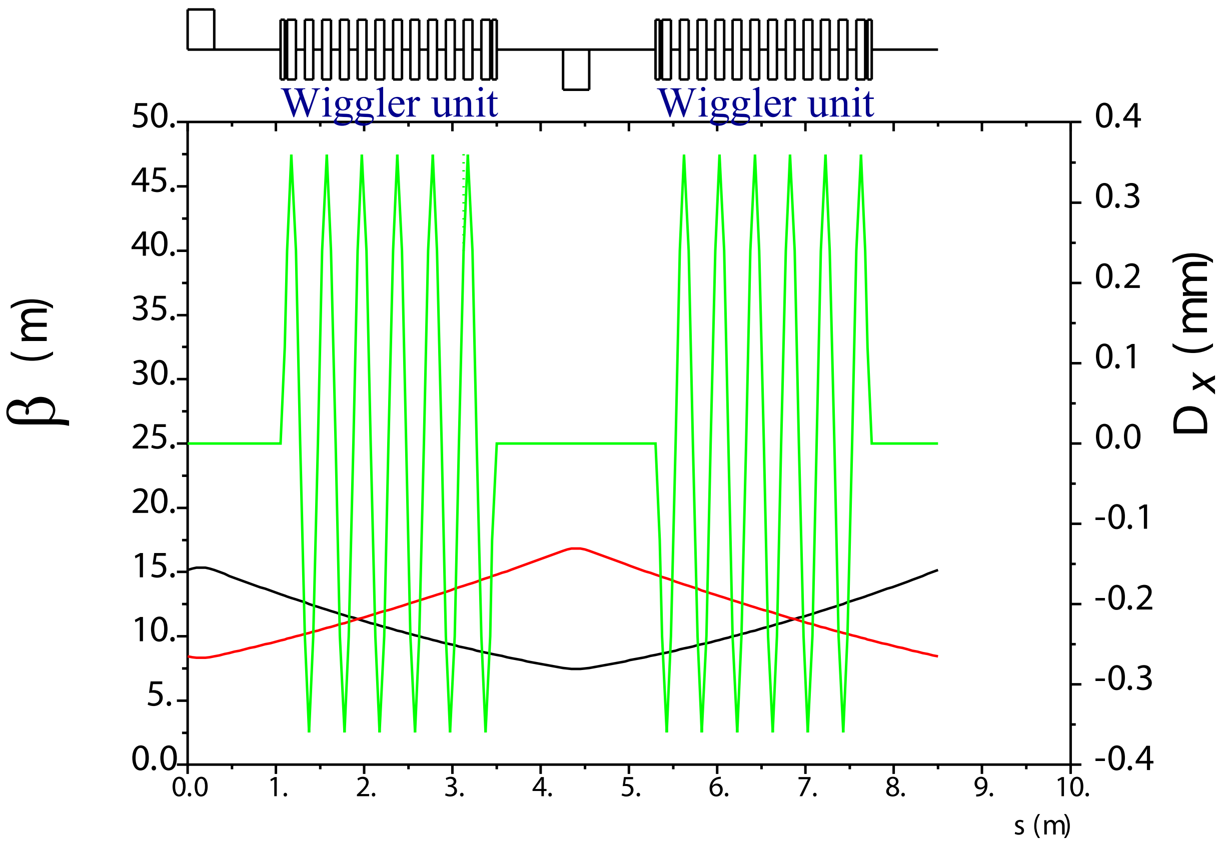
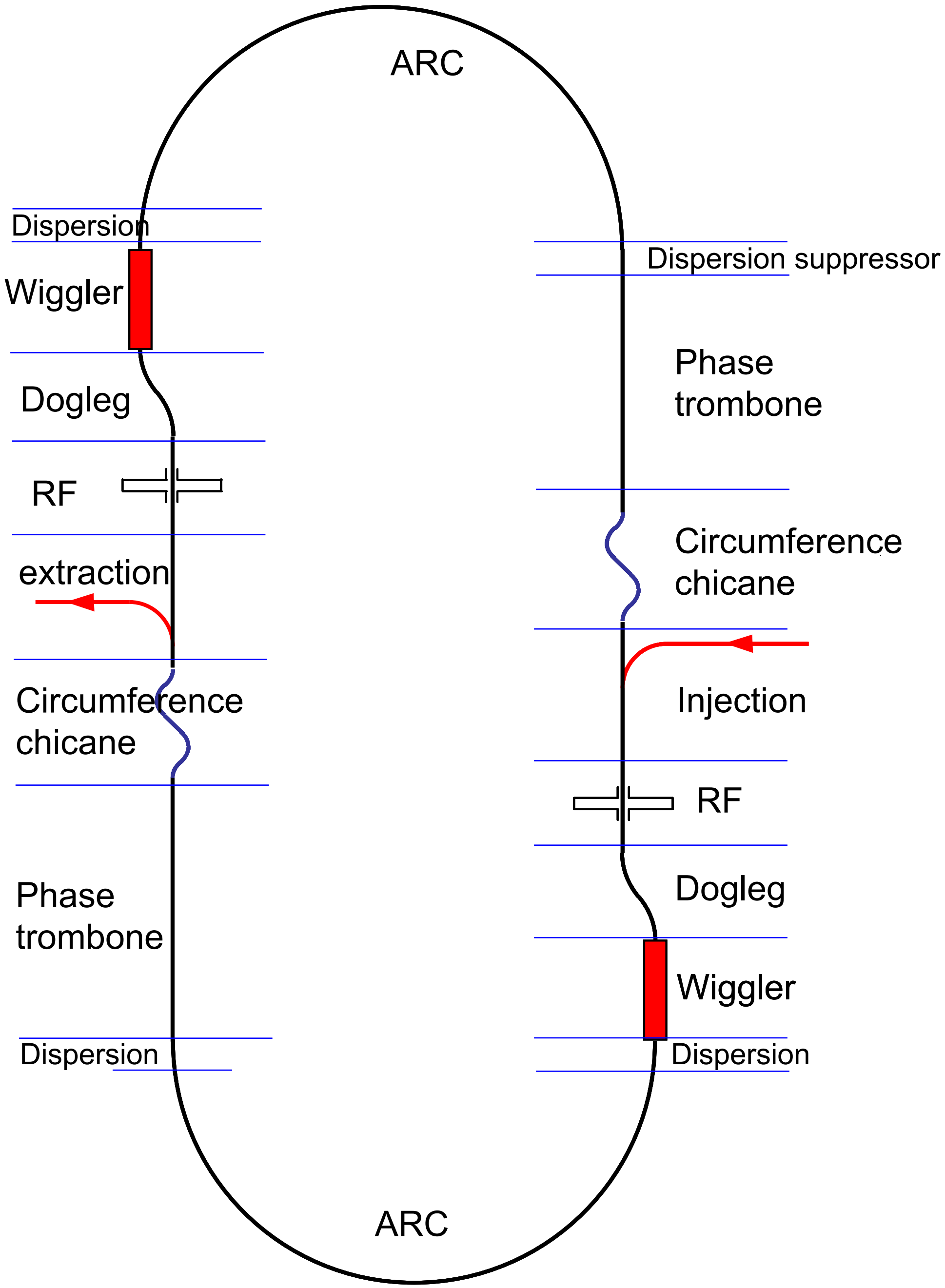



88 superconducting wiggler magnets in the ring

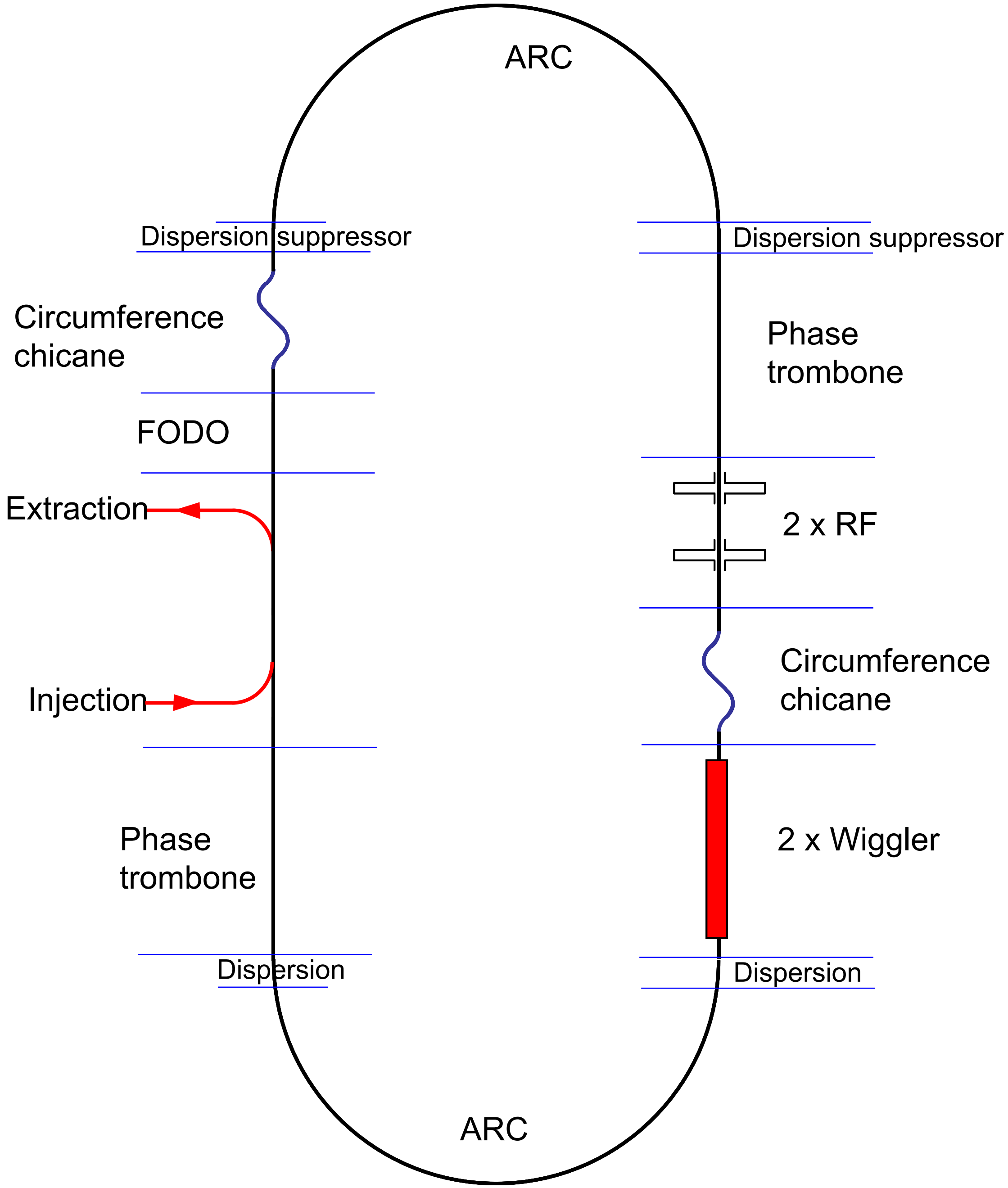
| | |
|---|---|
| Wiggler type | Superconducting |
| Wiggler peak field | 1.6 T |
| Wiggler period | 0.4 m |
| Wiggler unit length | 2.45 m |
| Wiggler total length | 215.6 m |



# Original Desig

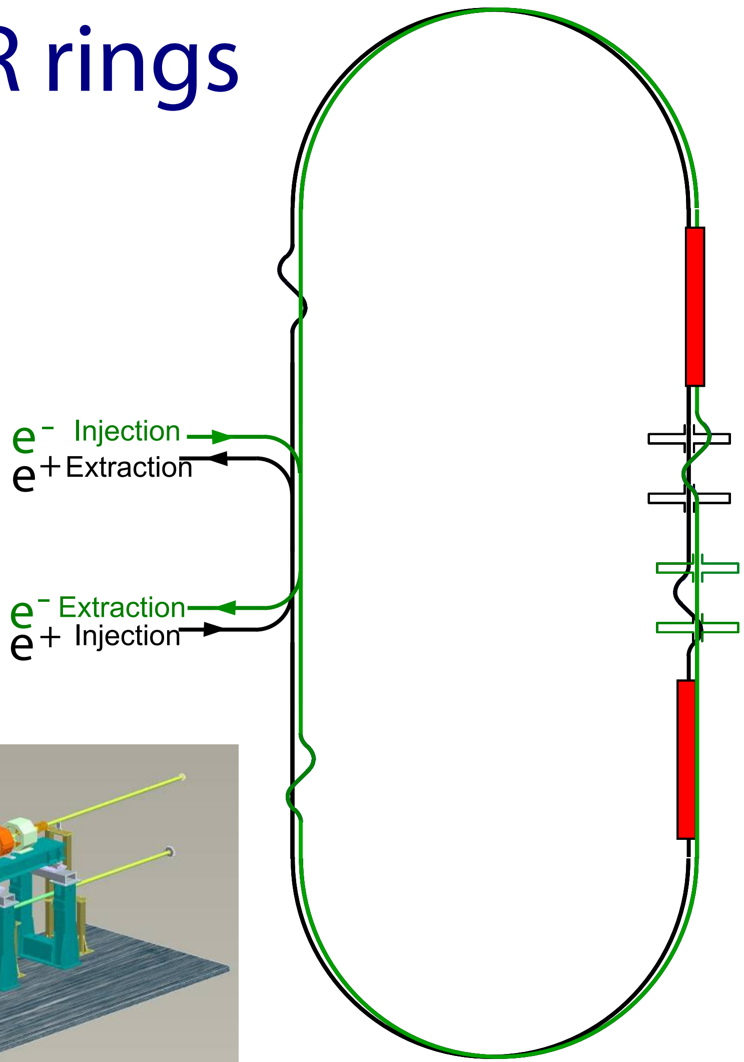



# New design

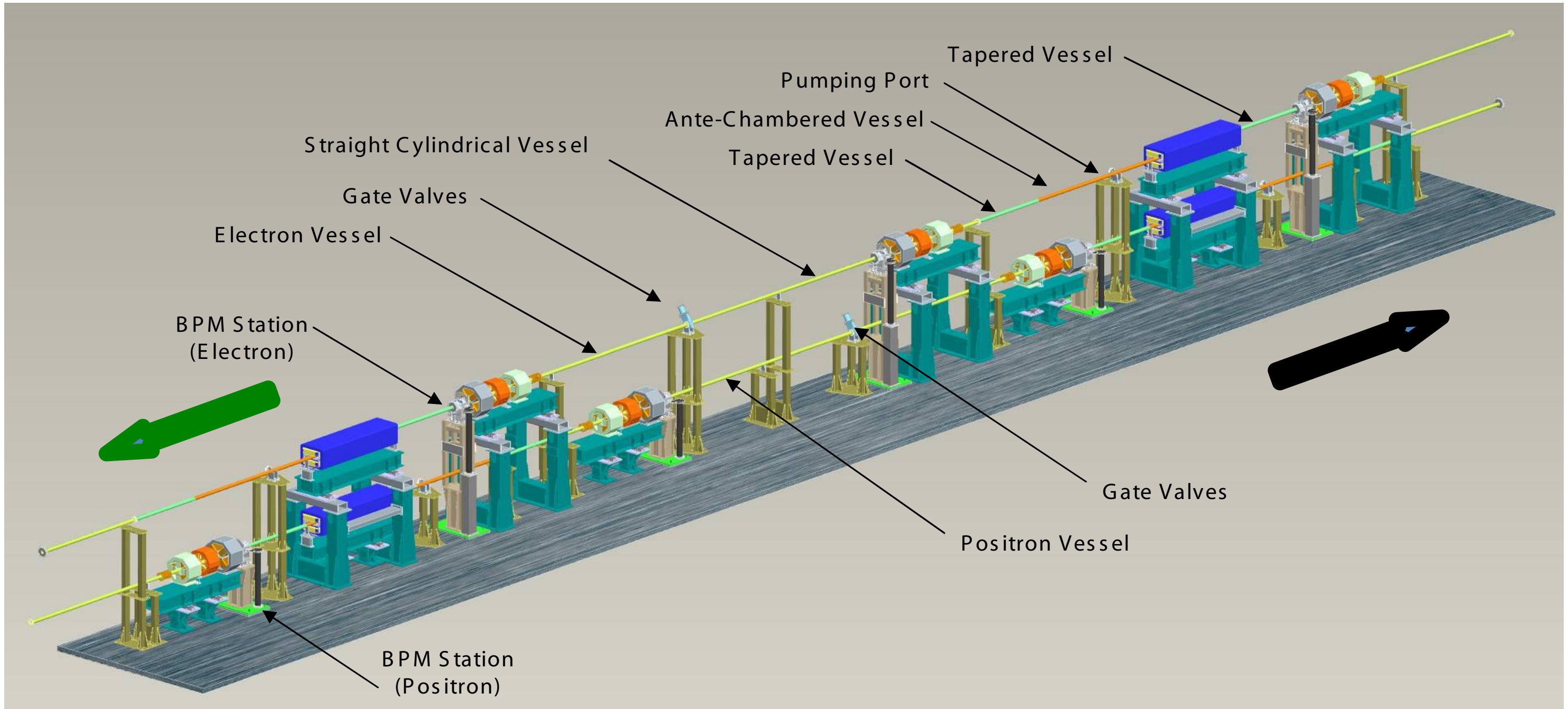


# Positioning of the e+ and e- DR rings

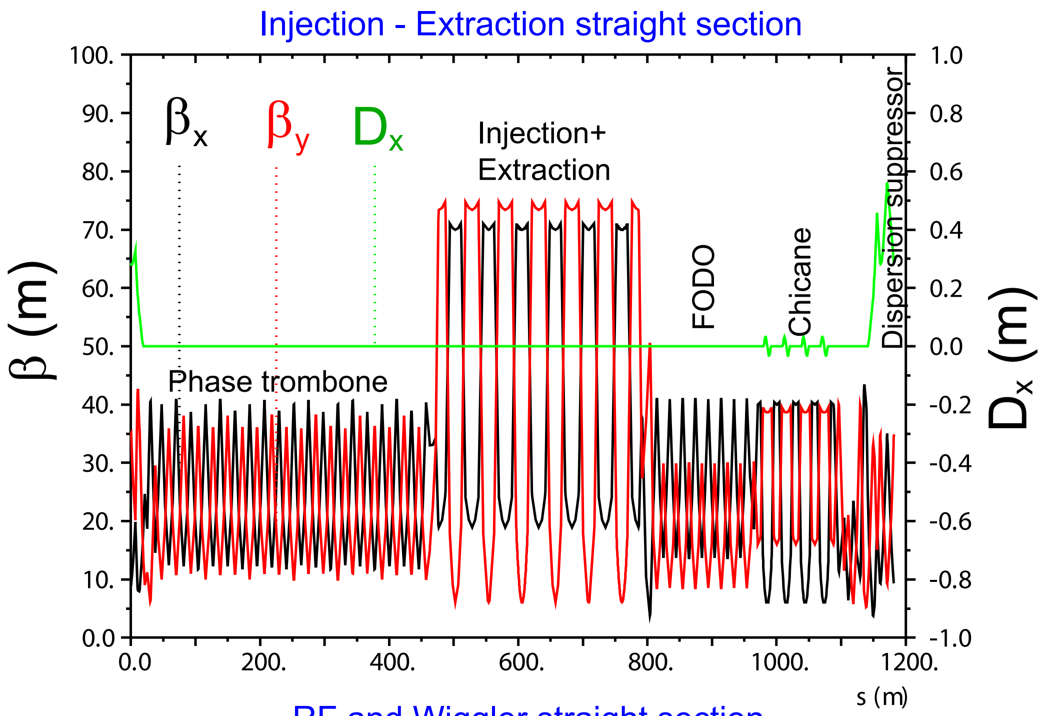
The straight section in the new design is about 100 m shorter than the original one. To restore the ring circumference to the 6476.4 m additional 4 arc cells are inserted to each arc.

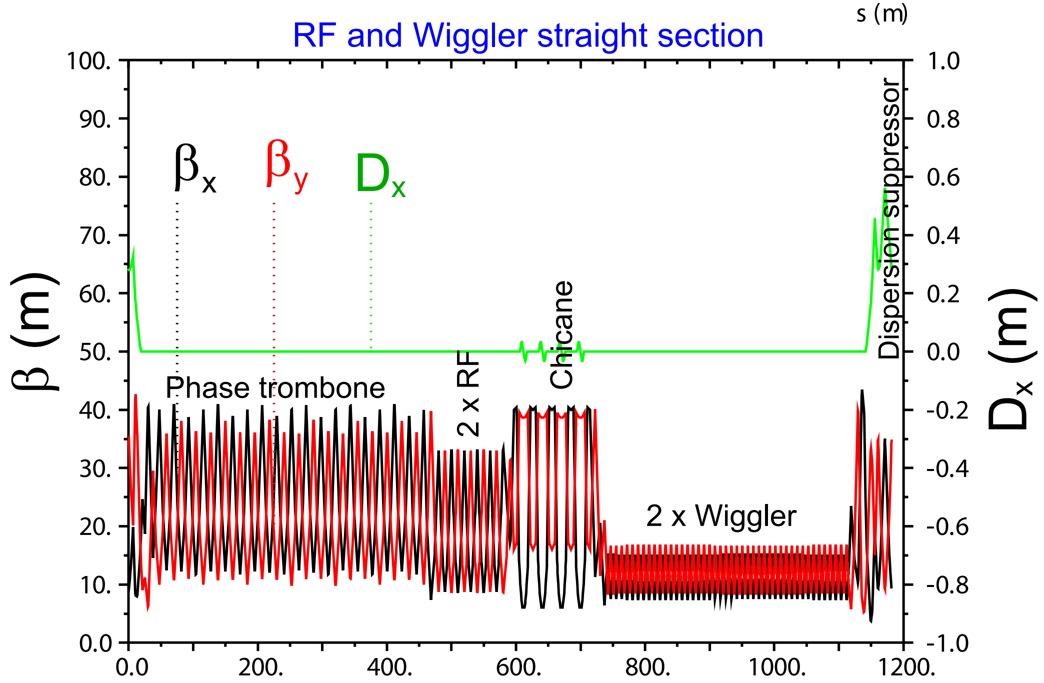



# Design of the arc cells



# Lattice of the new straight sections




Lattice of circumference chicane, FODO RF section, FODO wiggler section, ING/EXT section was not changed.

Number of arc cells is changed from 192 to 200 units to restore the ring circumference but there is no modification of element positioning in the FODO arc cells and the dispersion suppressors.

Total number of quads in the new design and in the original design is the same and equal to 690 units but

in original design 2 x157 quads are in straights and 376 quads in the arcs while

in new design 177 quads - in the RF/WIG straight and 121 quads - in the ING/EXT straight. Arcs contain 392 quads.

Number of sextupole magnets is equal to the number of quads in the arcs

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

# Major Parameters Original/New

| | |
|---|---|
| Beam energy | 5 (the same) GeV |
| Circumference | 6476.4 (the same) m |
| RF frequency | 650 (the same) MHz |
| Harmonic number | 14042 (the same) |
| Transverse damping time | 21.0 / 21.1 ms |
| Type and # of arc cells | FODO with one dipole 192 / 200 |
| Total length of wigglers | 215.6 (the same) m |
| Wiggler peak field | 1.6 (the same) T |
| Relative damping factor | 9.7 / 10.08 |
| Energy loss per turn | 10.3 / 10.23 MeV/turn |

| Phase advance per arc cell | 72° | 90° | 100° | 72° | 90° | 100° |
|---|---|---|---|---|---|---|
| Momentum compaction | $2.8 \times 10^{-4}$ | $1.7 \times 10^{-4}$ | $1.3 \times 10^{-4}$ | $2.9 \times 10^{-4}$ | $1.6 \times 10^{-4}$ | $1.3 \times 10^{-4}$ |
| Normalized horiz. emittance | 6.6 μm | 4.7 μm | 4.3 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 | $1.27 \times 10^{-3}$ | $1.27 \times 10^{-3}$ | $1.27 \times 10^{-3}$ | $1.27 \times 10^{-3}$ | $1.27 \times 10^{-3}$ | $1.27 \times 10^{-3}$ |
| RF voltage | 31.6 MV | 21.1 MV | 17.2 MV | 32.6 MV | 20.4 MV | 17.2 MV |
| RF acceptance | 2.35 % | 1.99 % | 1.72 % | 2.38 % | 1.96 % | 1.74 % |
| Synchrotron tune | 0.061 | 0.038 | 0.028 | 0.063 | 0.036 | 0.028 |
| Horizontal betatron tune | 64.12 | 75.12 | 78.12 | 61.12 | 71.12 | 76.12 |
| Natural horiz. chromaticity | -76.2 | -95.1 | -105.4 | -68.5 | -87.6 | -99.3 |
| Vertical betatron tune | 61.41 | 71.41 | 75.41 | 61.41 | 71.41 | 76.41 |
| Natural vert. chromaticity | -74.7 | -93.4 | -104.0 | -70.2 | -89.2 | -100.7 |

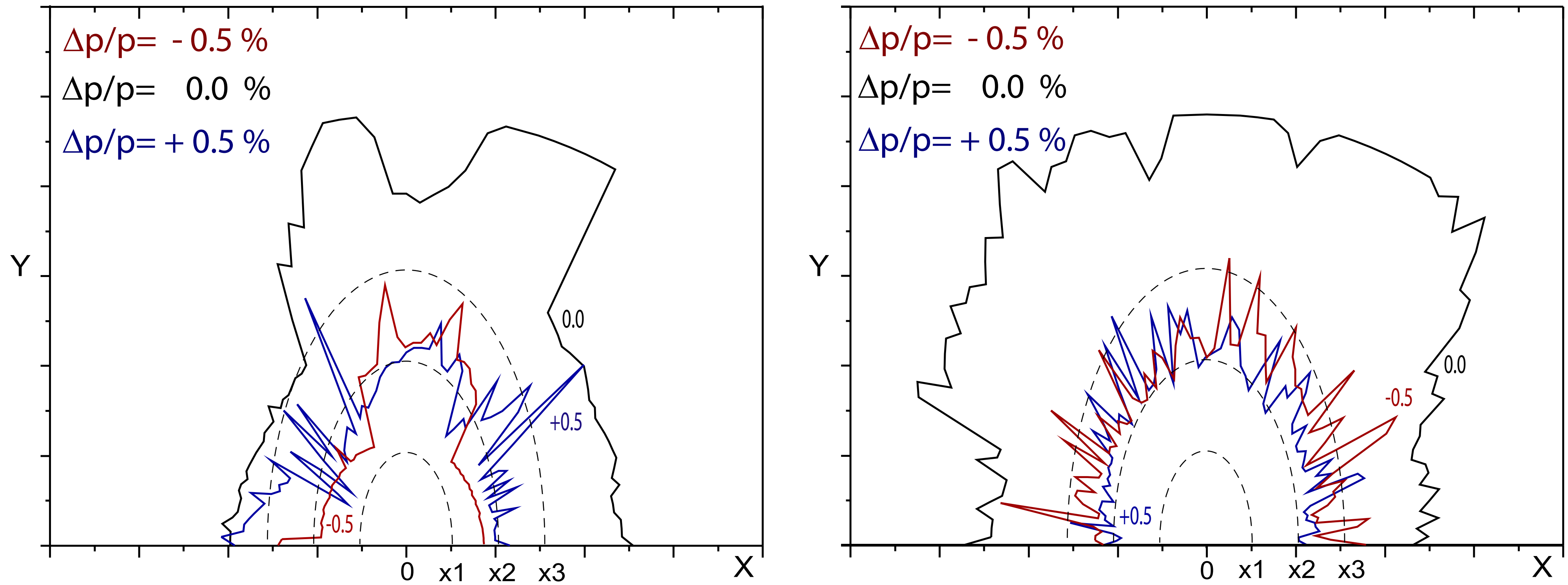
# Dynamic aperture of the DR at arc cell phase advance close to 72°

Two interleaved sextupole families are arranged in the arcs

Dashed ellipses show maximum particle coordinates for injected beam which

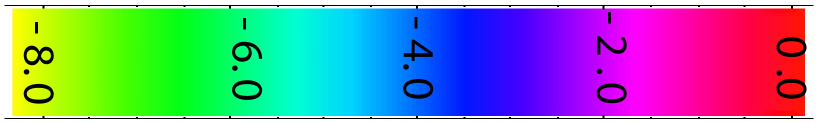
correspond to $x1,\ y1 = \sqrt{\frac{A_{x,y} \cdot \beta_{x,y}(s)}{\gamma}}$ $\quad x2 = 2 \cdot x1, \quad x3 = 3 \cdot x1, \quad y2 = 2 \cdot y1, \quad y3 = 3 \cdot y1$

$$A_x = \gamma_x(s)x^2(s) + 2\alpha_x(s)x(s)x'(s) + \beta_x(s)x'^2(s)\,; \qquad \gamma A_x = \gamma A_y = 0.09\ \mathbf{m}$$

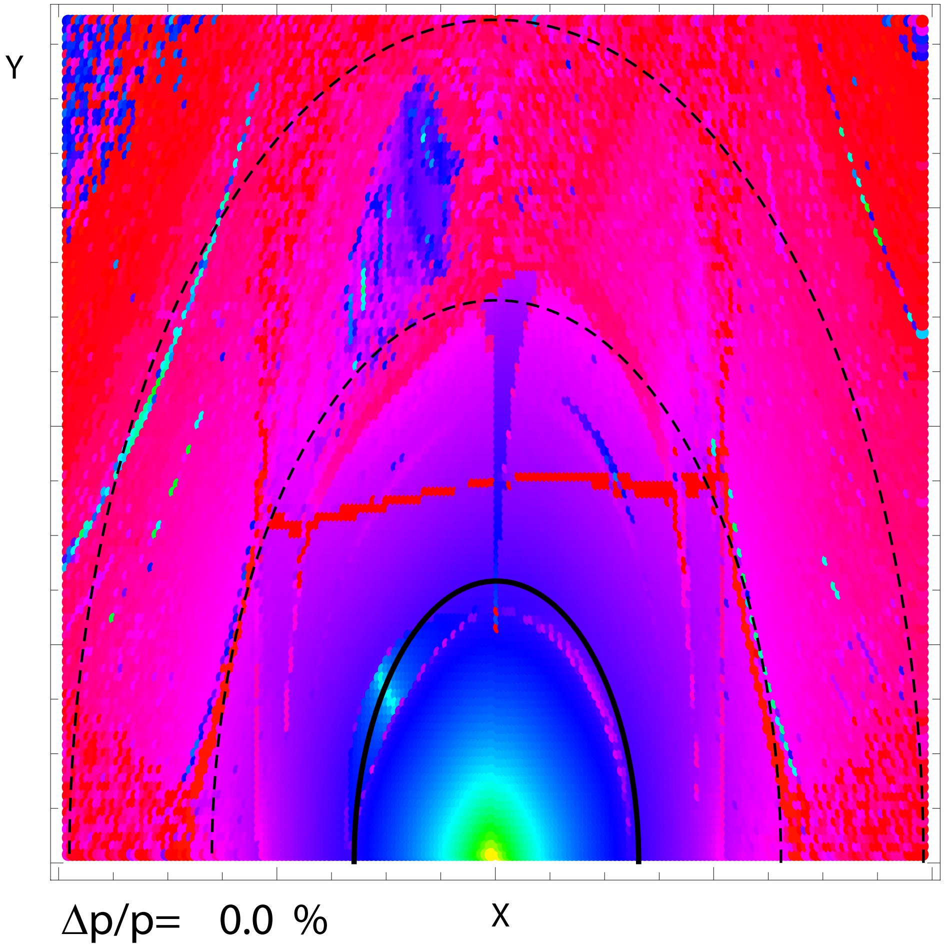


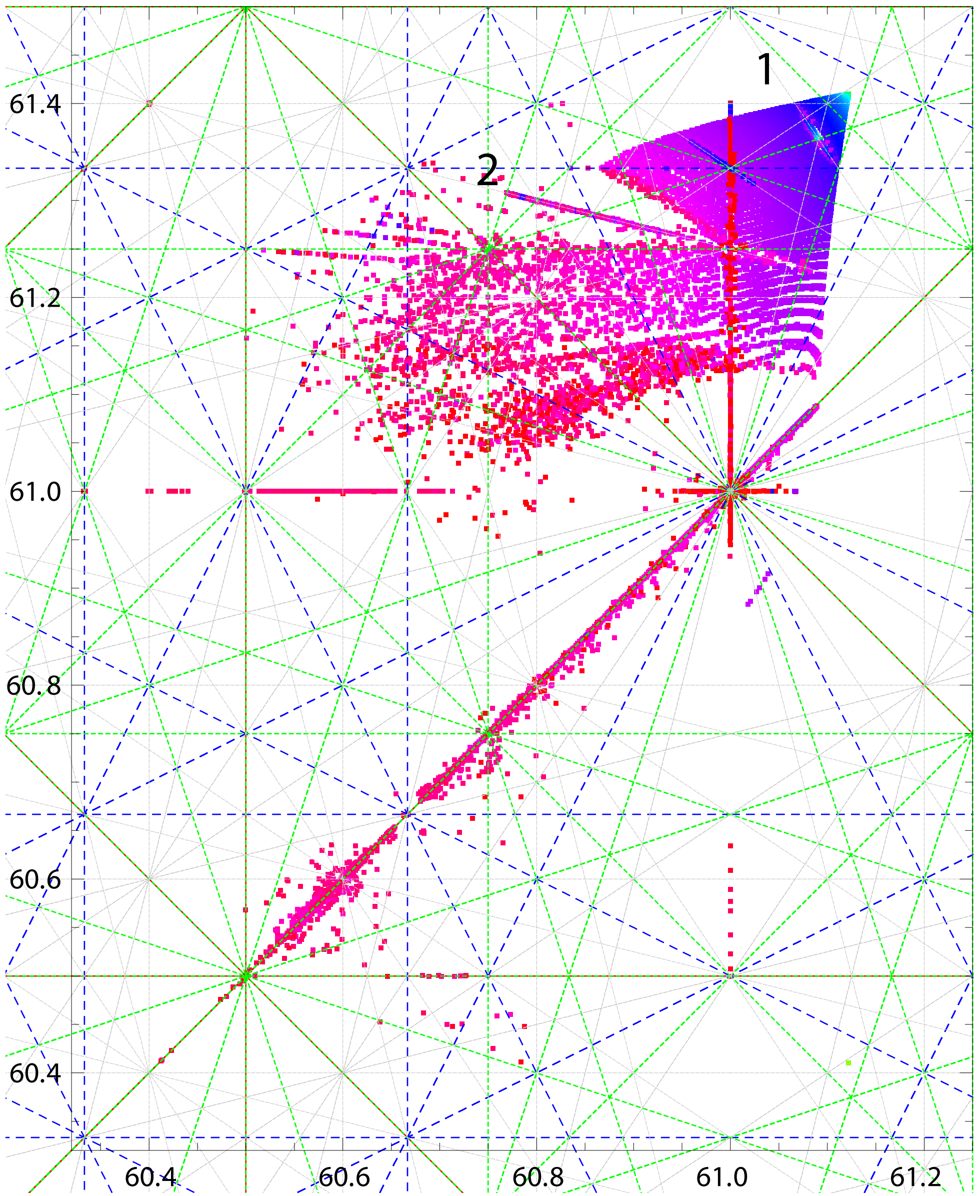

Original lattice (nux/nuy=64.12 / 61.41) New lattice (nux/nuy=61.12 / 61.41)

# Frequency map analysis of the new lattice



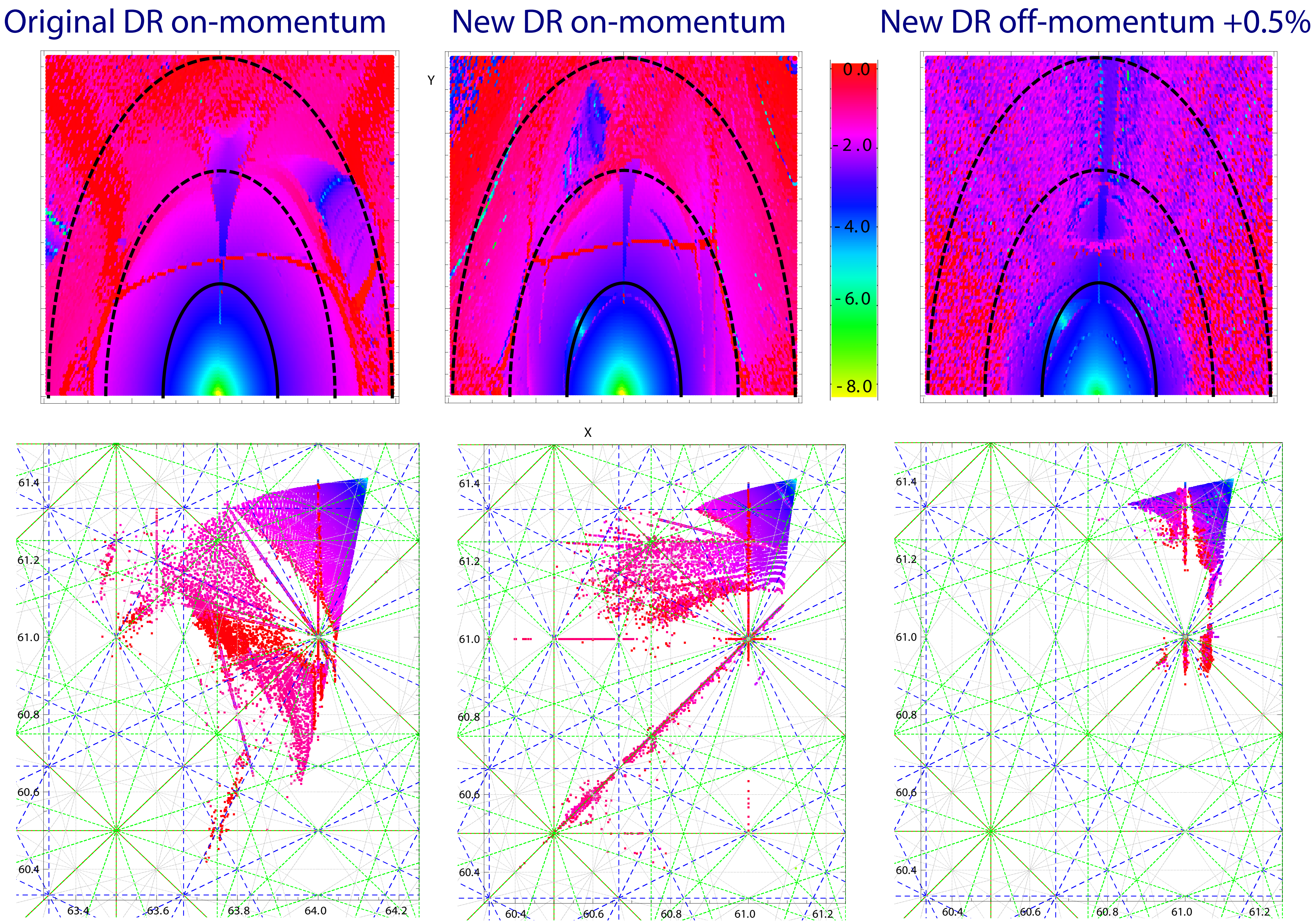

$$\Delta\nu = \log_{10}\sqrt{\left(\nu_x^{1024} - \nu_x^{512}\right)^2 + \left(\nu_y^{1024} - \nu_y^{512}\right)^2}$$




1) $3\nu x + 2\nu y = 306$

2) $\nu x + 4\nu y = 306$


Original DR on-momentum
New DR on-momentum
New DR off-momentum +0.5%
Y
X
0.0
-2.0
-4.0
-6.0
-8.0
61.4
61.2
61.0
60.8
60.6
60.4
63.4
63.6
63.8
64.0
64.2
60.4
60.6
60.8
61.0
61.2

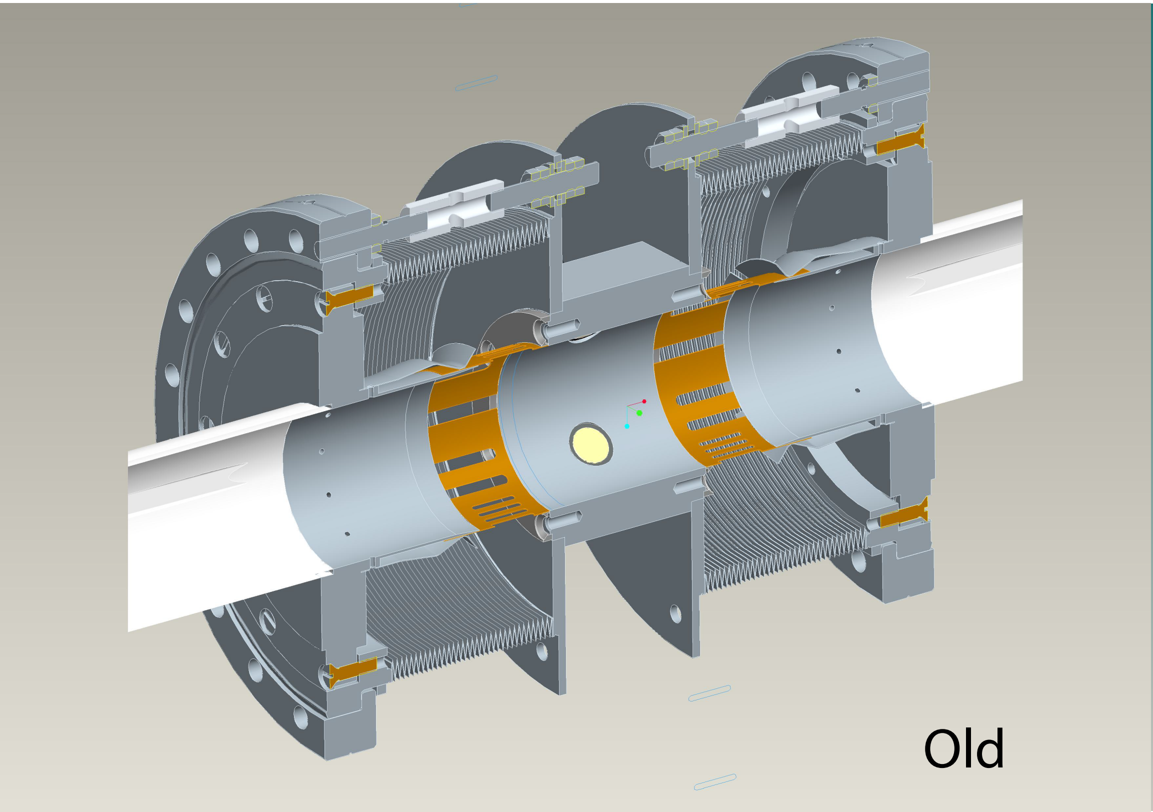
# Vacuum design of the ILC DR BPM

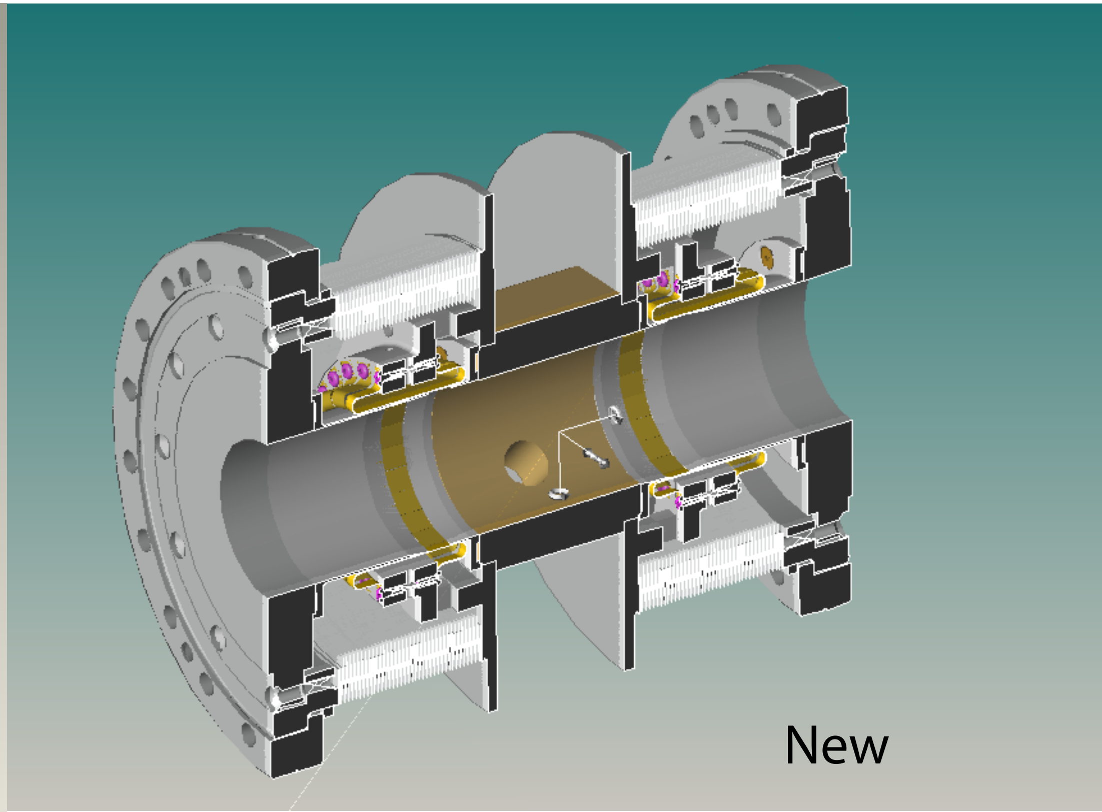
> The total number of BPMs may be as large as 690 (assuming one BPM downstream each quad)

> Each BPM are mounted on individual stand mount to be mechanically isolated from the main girder

> The bellows provide mechanical isolation of the BPM buttons from the main vacuum chamber. They are shielded by rf screens to reduce an impedance.

> A new bellows design with improved rf shielding, based on a design from INFN-LNF, has been implemented in the model



# Evolution of wake field calculation

1) Using 3D electromagnetic code HFSS (frequency domain code).

In our calculation, we used the "improved log formula" to express the impedance of BPM as a function of the S21-transmission parameters. However, in our case this approach gives reliable results in frequency range lower than 3 GHz.

Sweeping frequency across a wide spectrum upto 30 GHz is needed because rms bunch length is 6mm. As alternative, to use some 3D time domain code.

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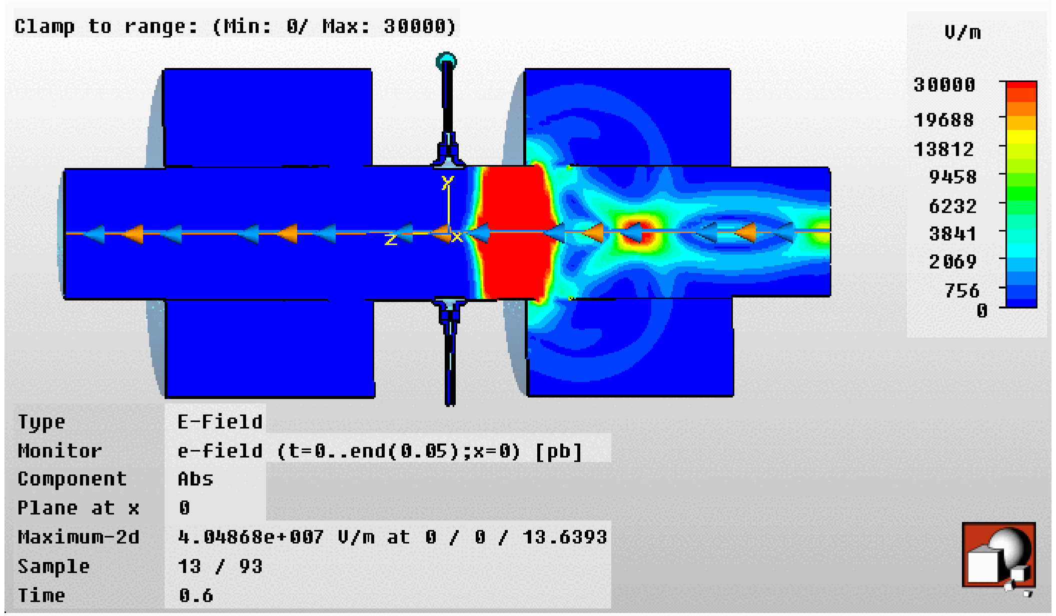
2) Using 3D electromagnetic code CST Microwave Studio/Particle Studio (time domain code)

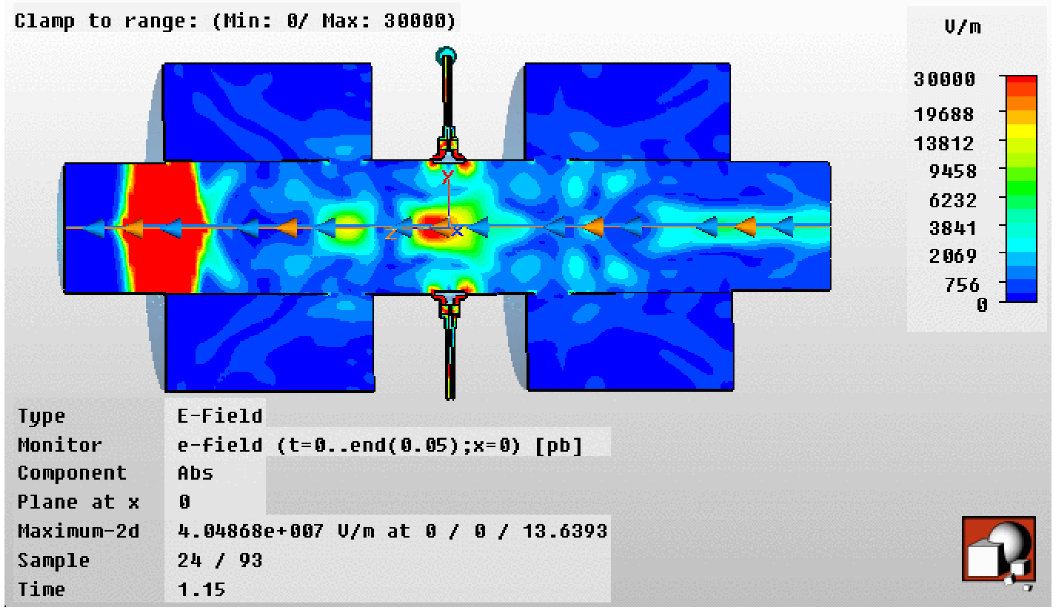
Allow to get wake potential directly from the wake field distribution produced by a bunch. However, due to complicated model geometry and 32bit WinXP that limits maximum memory to 4GB poor mesh is generated (around 11M cells). It is not enough to get good model approximation and results.

64bit WinXP enable to use upto 128 GB of memory.

# Longitudinal wake field of the "old" BPM model

Wake Field



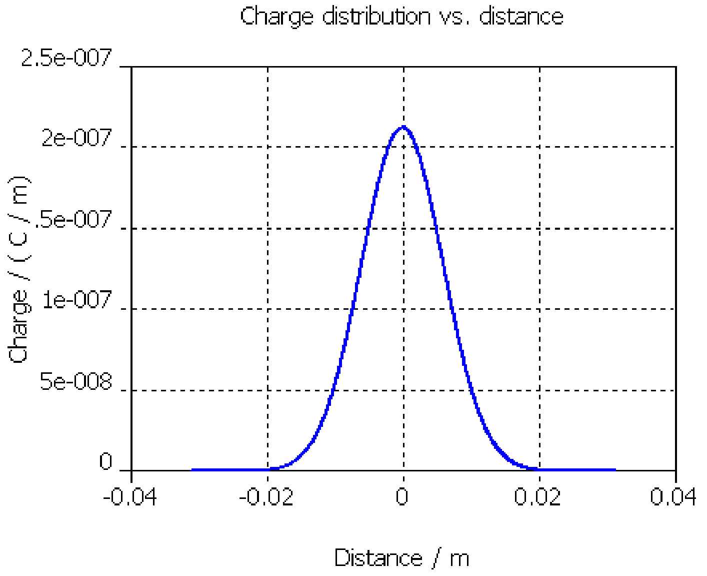



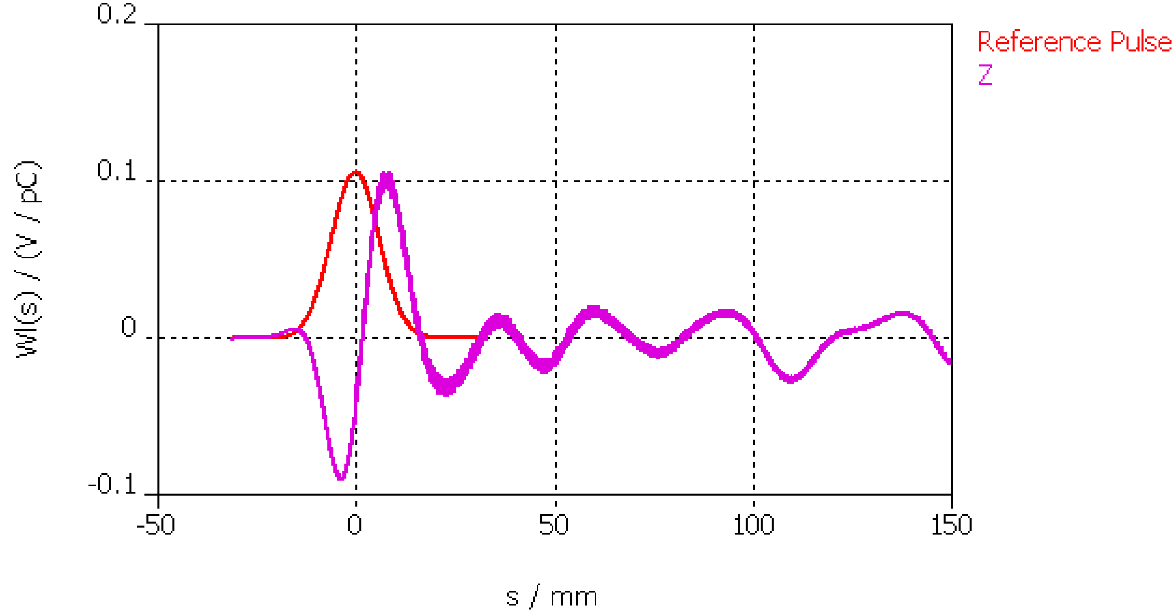

Longitudinal wake potential:

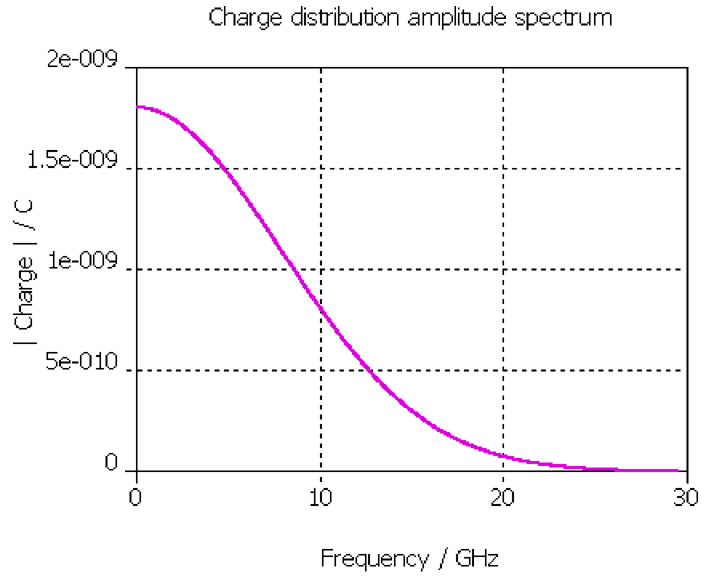
$$W_{\parallel}(\vec{r},s) = -\frac{1}{Q}\int_{-\infty}^{\infty} E_z(\vec{r},z,t(z,s))dz$$

The calculations were done for 173M mesh cells on 64bit Win XP

# Longitudinal wake potential of the "old" BPM model




At rms bunch length 6mm (20 ps), the loss factor per BPM insertion is 0.0104 V/pC. Thus, the average dissipated power per BPM (with $n_e = 2 \times 10^{10}, n_b = 2610$ ) is 13 W.

The calculations were done for 173M mesh cells on 64bit Win XP