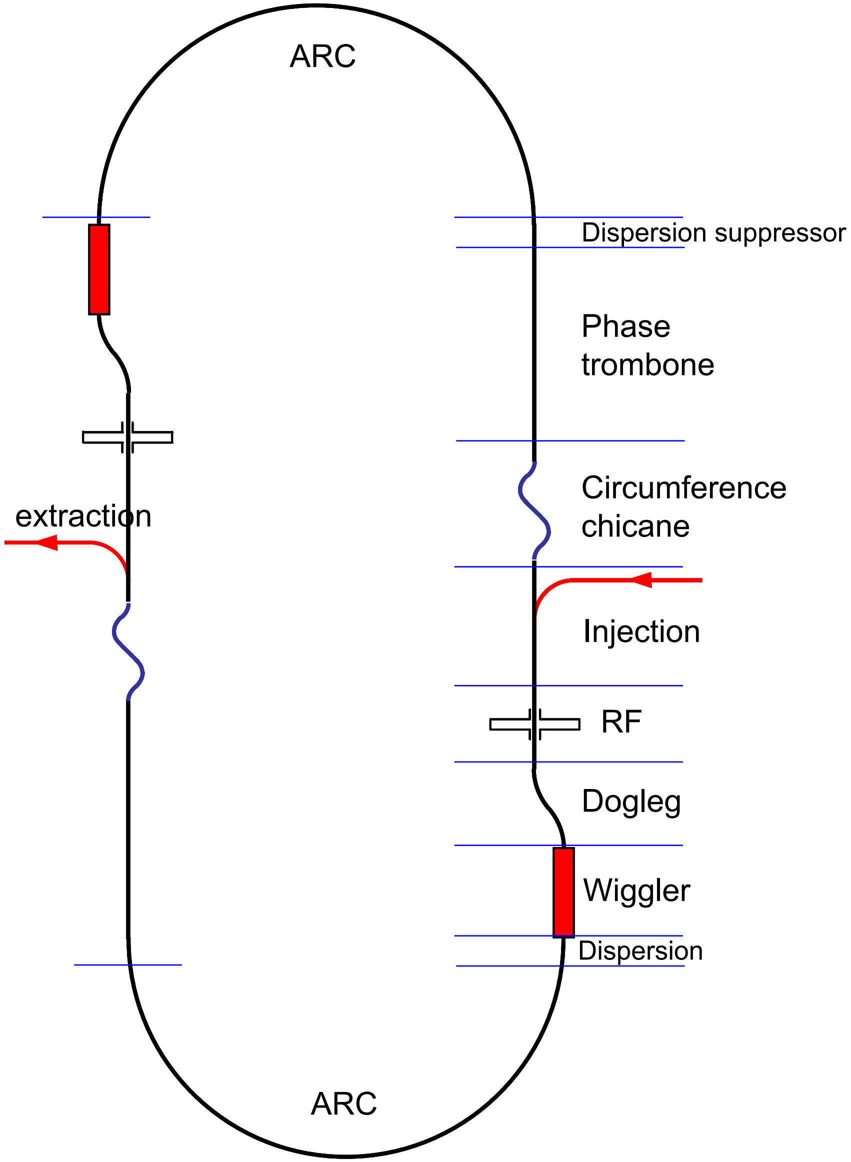
Impedance Model of ILC DR

Damping Ring Layout and Major Parameters



by A. Wolski

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

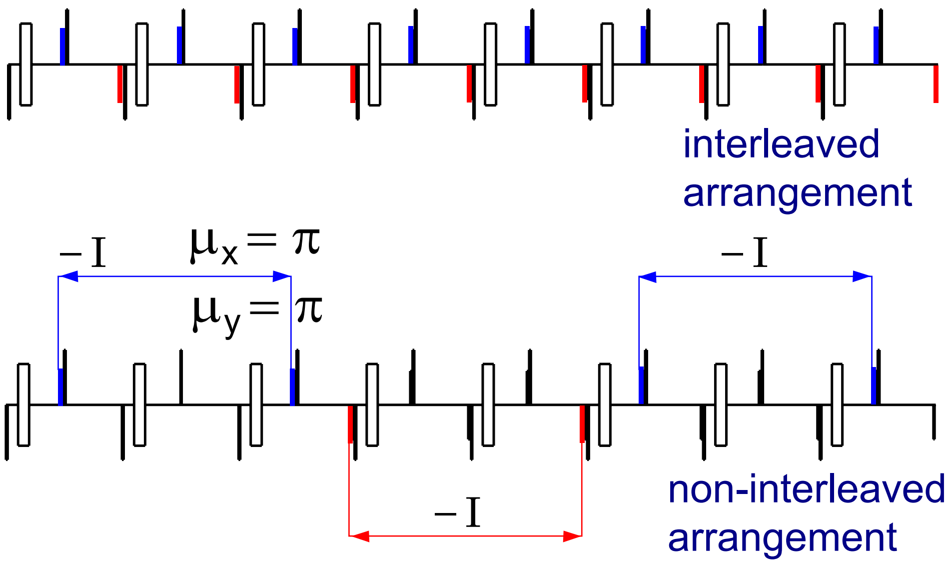
Phase advance per arc cell	72°	90°	100°
Momentum compaction	2.8×10^{-4}	1.7×10^{-4}	1.3×10^{-4}
Normalized horiz. emittance	6.6 μm	4.7 μm	4.3 μm
RMS bunch length	6.0 mm	6.0 mm	6.0 mm
RMS energy spread	1.27×10^{-3}	1.27×10^{-3}	1.27×10^{-3}
RF voltage	31.6 MV	21.1 MV	17.2 MV
RF acceptance	2.35 %	1.99 %	1.72 %
Synchrotron tune	0.061	0.038	0.028
Horizontal betatron tune	64.12	75.12	78.12
Natural horiz. chromaticity	-68.3	-95.1	-105.4
Vertical betatron tune	61.41	71.41	75.41
Natural vert. chromaticity	-67.8	-93.4	-104.0

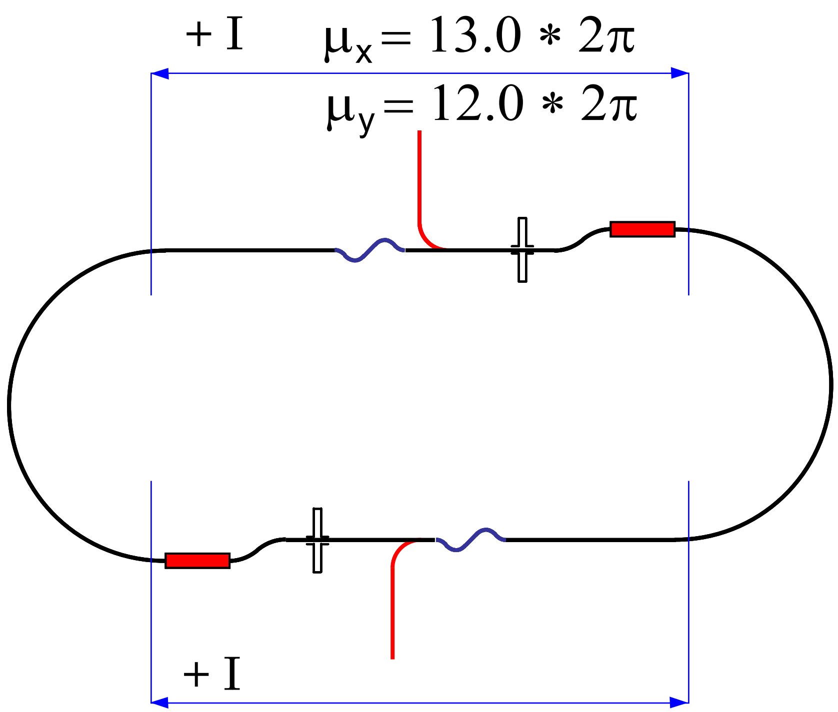
Arrangement of sextupole magnets in the arcs

To compensate the large natural chromaticity, two interleaved sextupole families are arranged in the arcs.

At phase advance close to 90 degree, such interleaved arrangement of the sextupole introduces strong second-order geometric aberrations which limit dynamic aperture to unacceptable value.

So, for this particular phase advance a non-interleaved -I arrangement (minus unity transformation matrix) of the sextupole pairs is applied.



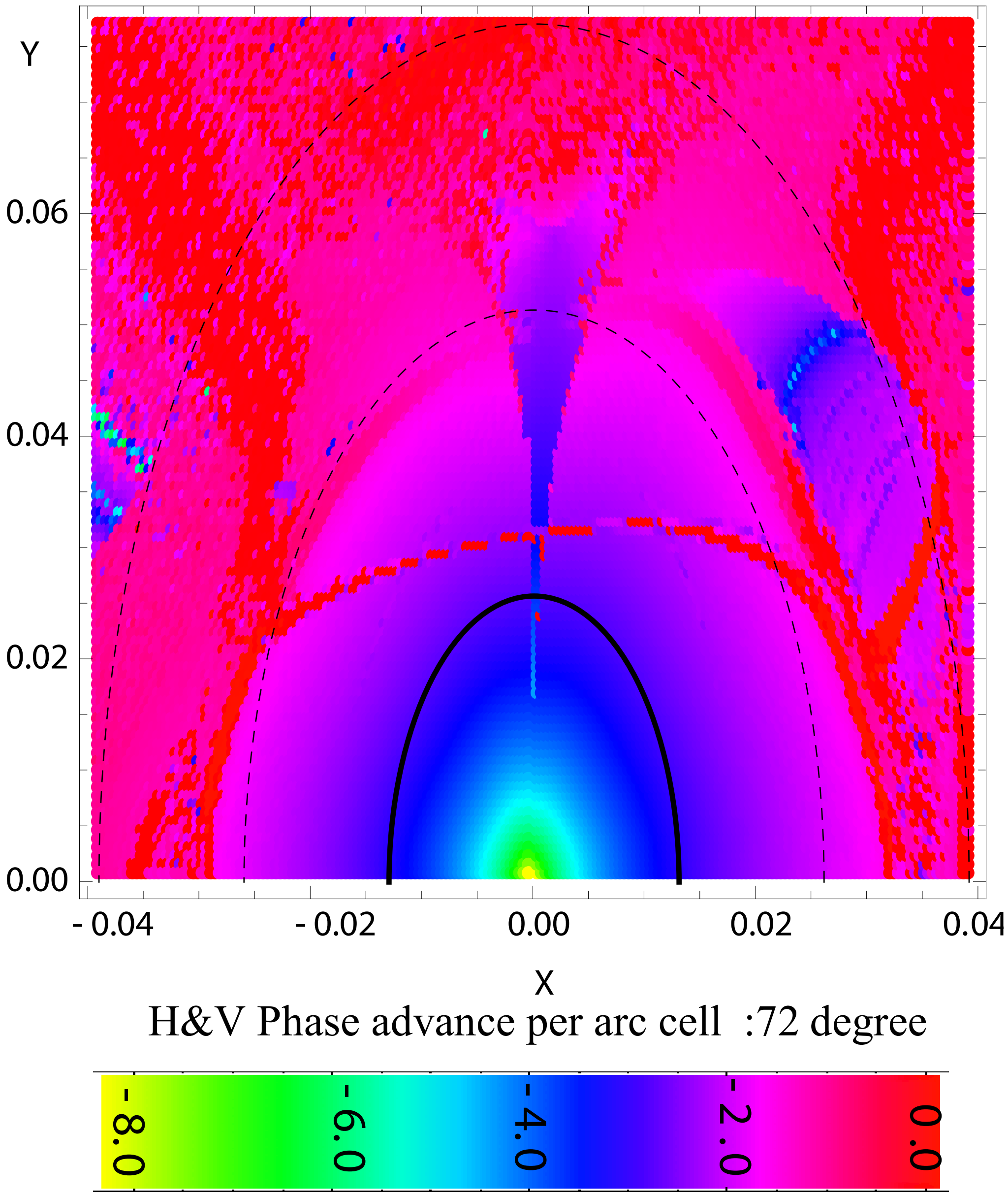


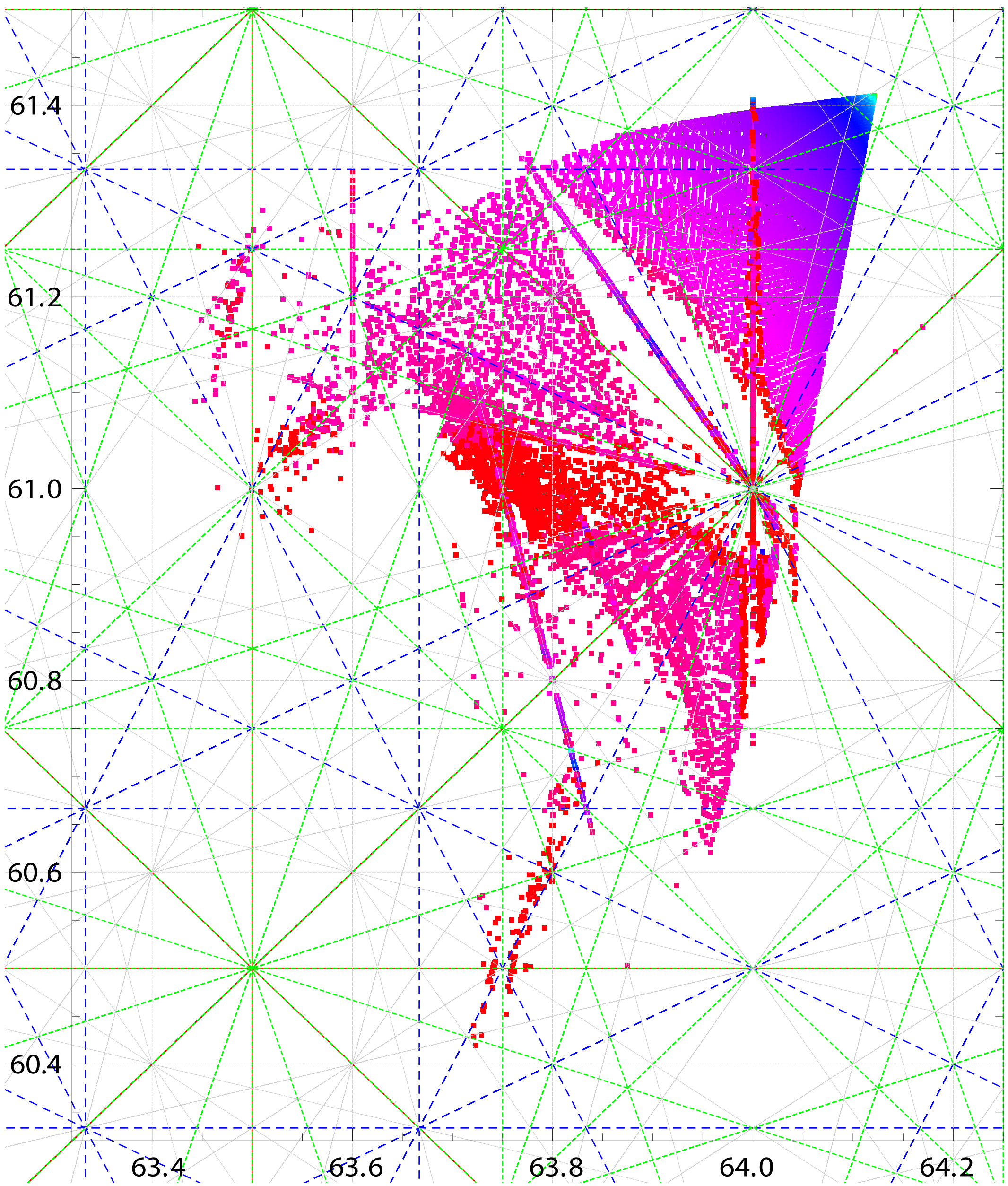
DA looks acceptable for on-momentum particles when +I in the straight sections and H&V phases per arc cell are

Phase advance	72 degree	90 degree	100 degree
ν_x range	64.10 – 64.17	73.10 – 73.17	78.10 – 78.17
ν_y range	61.15 – 61.55	70.15 – 70.45	75.40 – 75.45

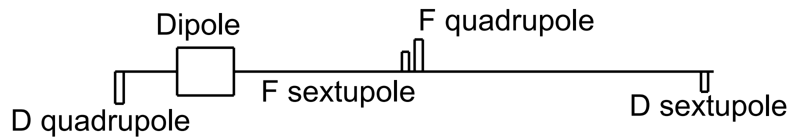
Dynamic aperture of the damping ring

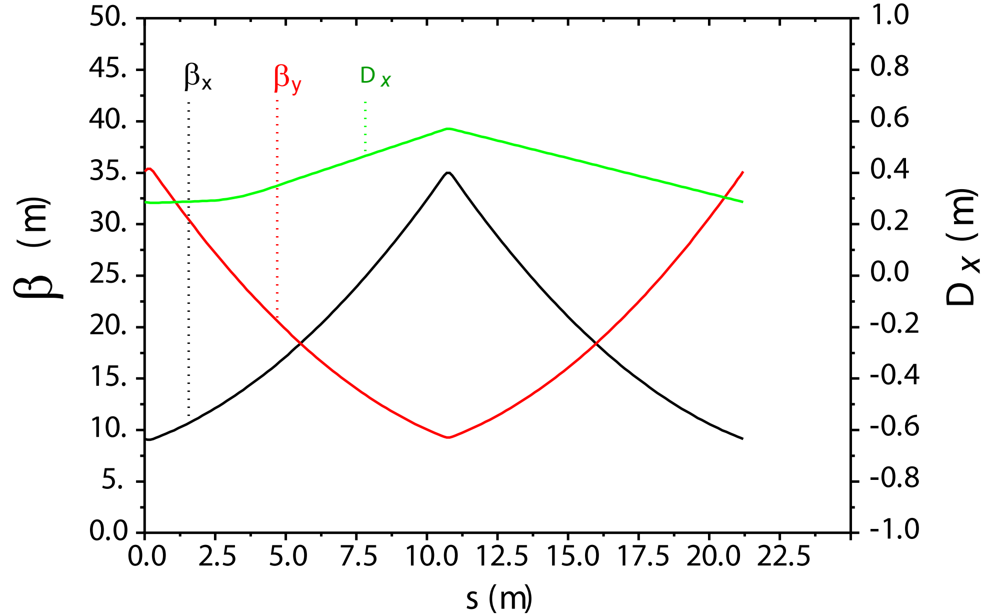
black ellipse shows maximum particle coordinates for injected positron beam that corresponds to $\gamma(A_x + A_y) = 0.09$ m



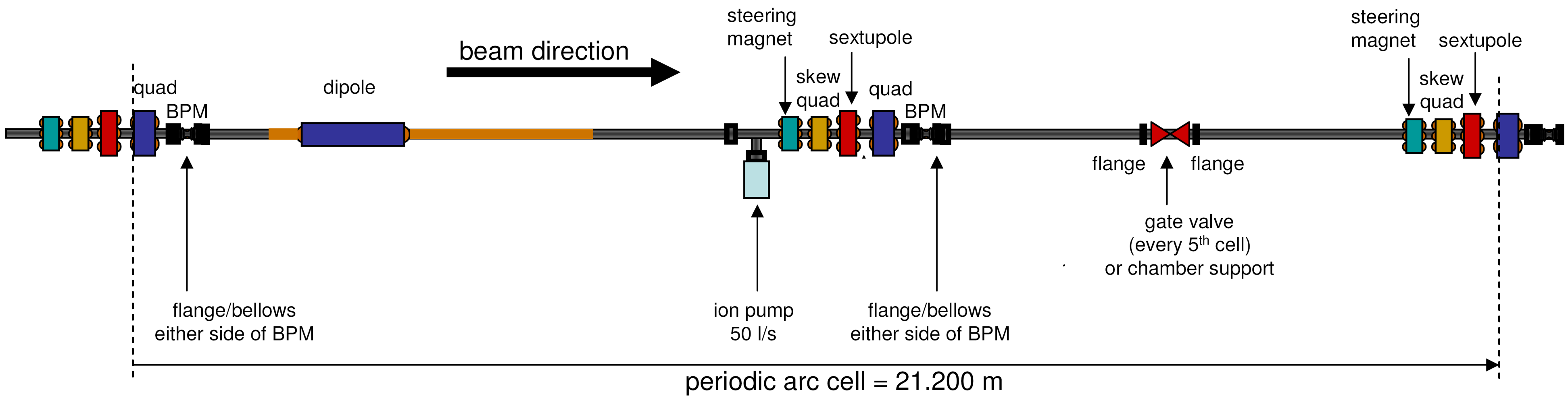


FODO Arc Cell





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

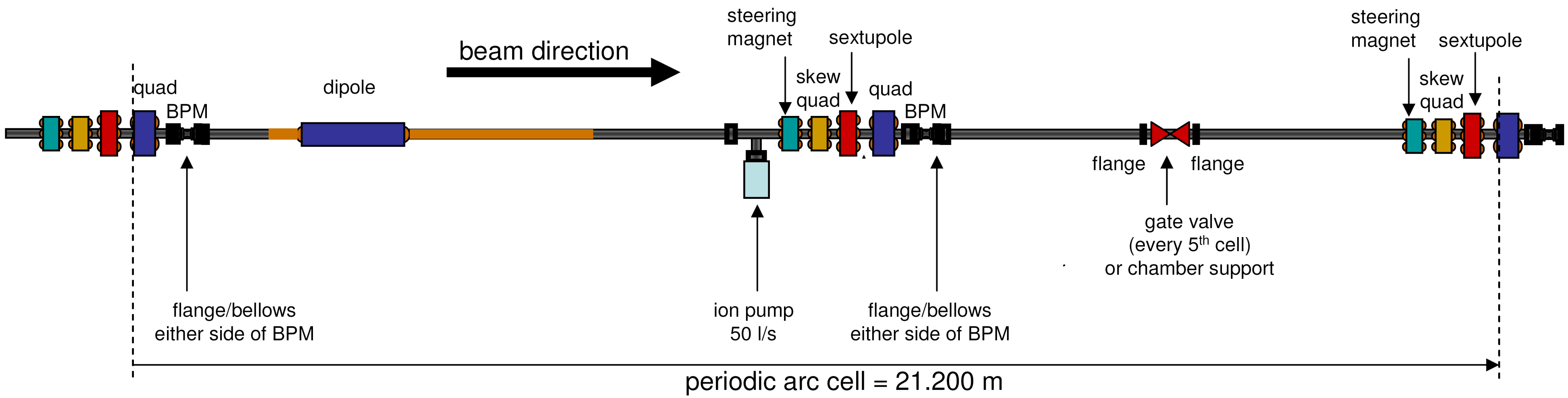


FODO Arc Cell

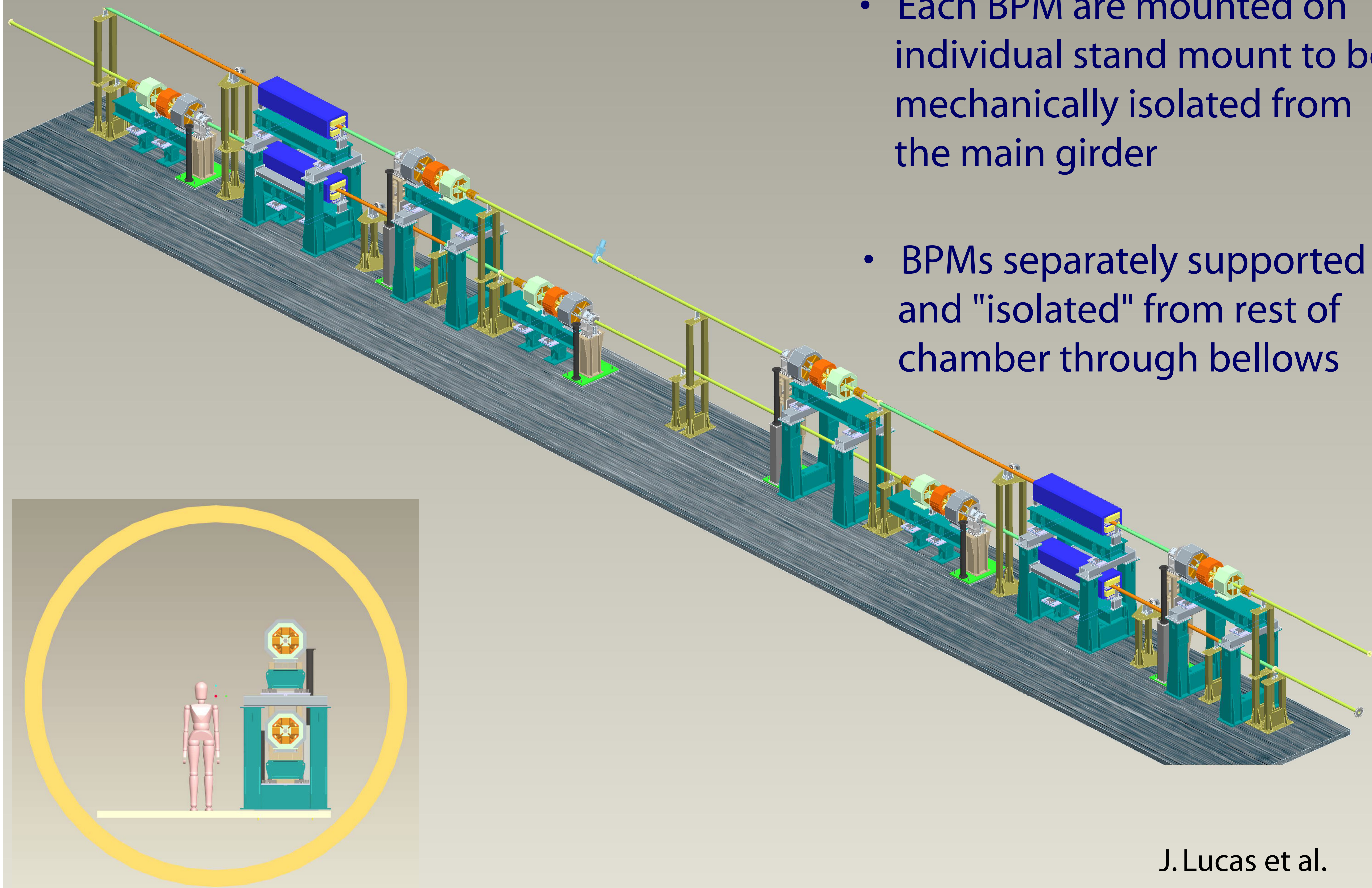
- Large number of high performance beam position monitors (BPMs) are needed to achieve target vertical emittance of 2 pm after the the orbit and coupling correction

- The total number of BPMs may be as large as 690 (assuming one BPM downstream each quadrupole), and they are expected to make a significant contribution to the machine impedance.

- Understanding the impedance of the BPM insertions (that include bellows and flanges) is therefore important for developing a design capable of meeting the overall performance specifications.



FODO Arc Cell



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

- BPMs separately supported and "isolated" from rest of chamber through bellows

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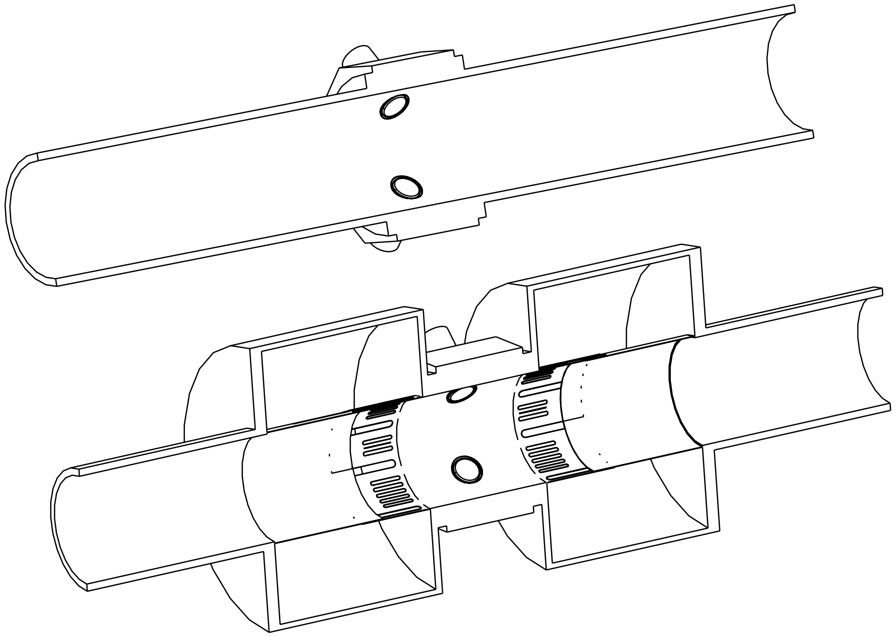
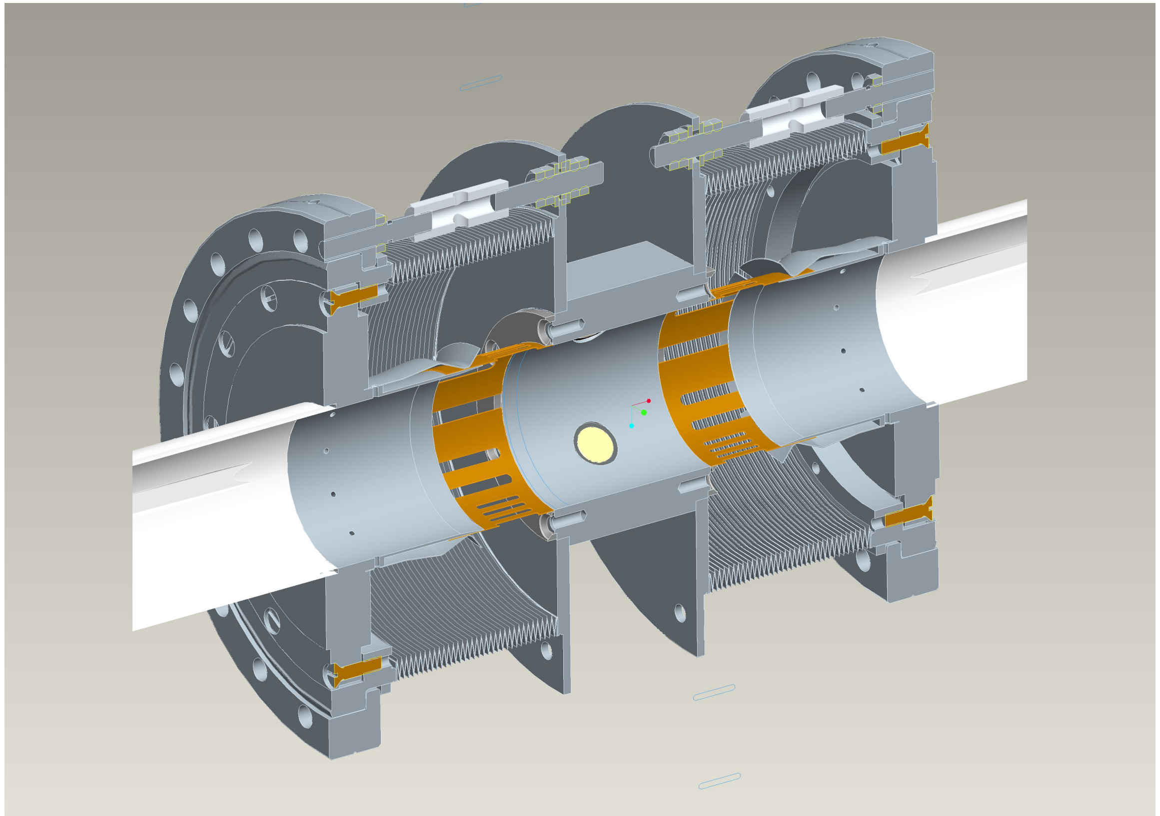
BPM Insertion

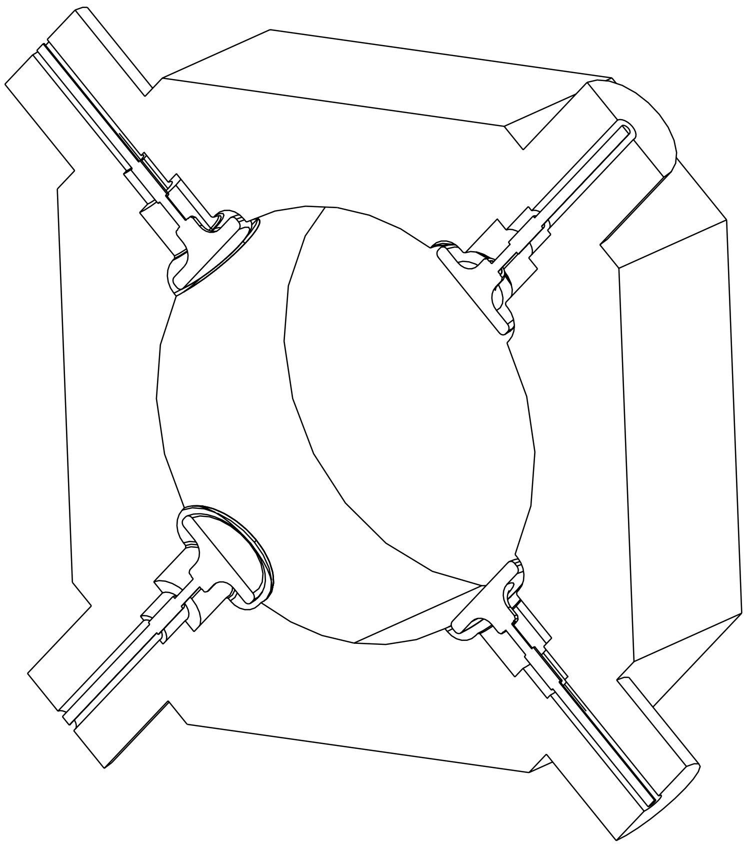


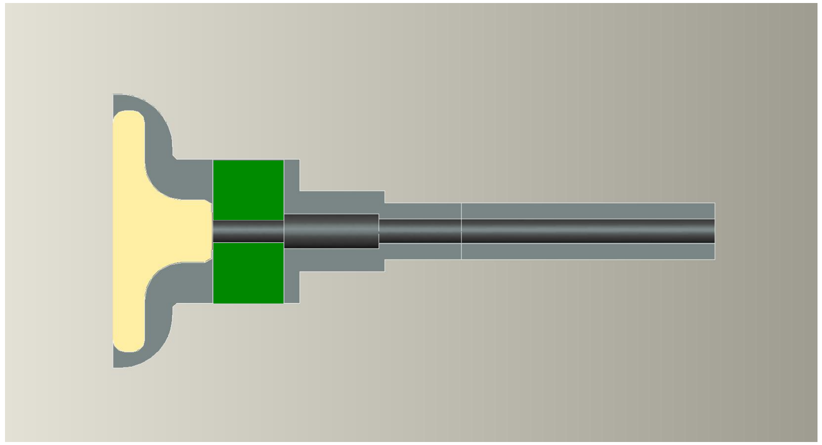


Cut-away section of one BPM insertion, including bellows and flanges .
The bellows provide mechanical isolation of the housing for the BPM buttons from the main vacuum chamber, and are shielded by stainless steel screens to reduce impedance.

To shield the BPMs from synchrotron radiation, the BPM housing has a slightly larger diameter than that in the section of chamber on either side.

BPM Insertion

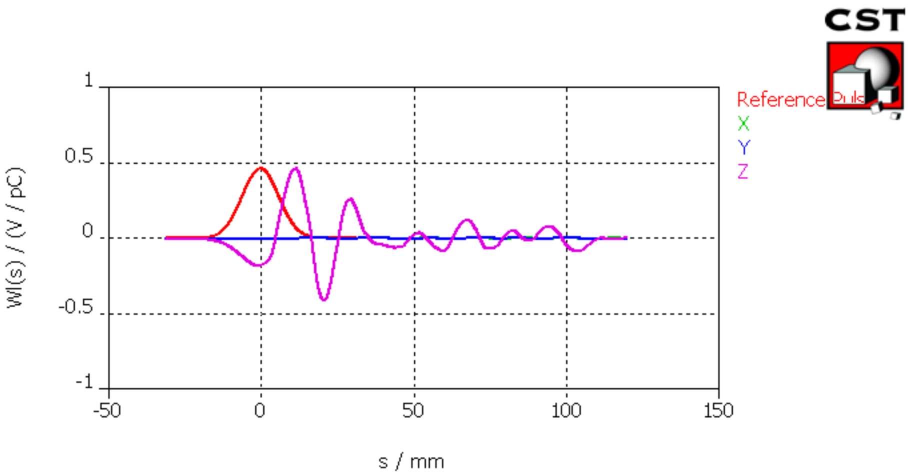


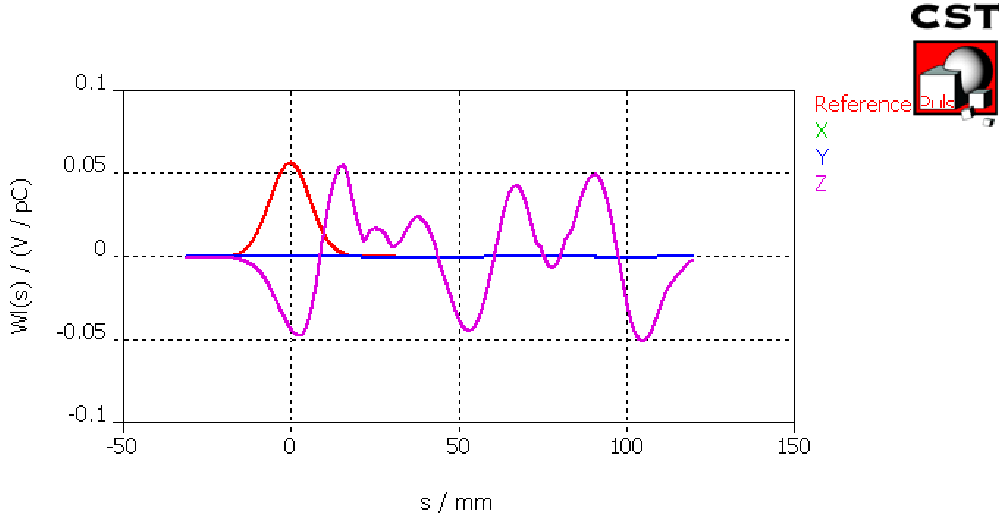


BPM pick-ups consist of four buttons arranged at 45 degree to the horizontal and vertical axes. The buttons are scaled from a model developed for PEP-II. Each button has diameter 8 mm, and there is a gap of 1 mm between the button and its housing. An alumina glass ring is used for vacuum insulation. All pick-ups are terminated by SMA-type (sub-miniature) connector, matched to the impedance of a 50 Ω coaxial line.

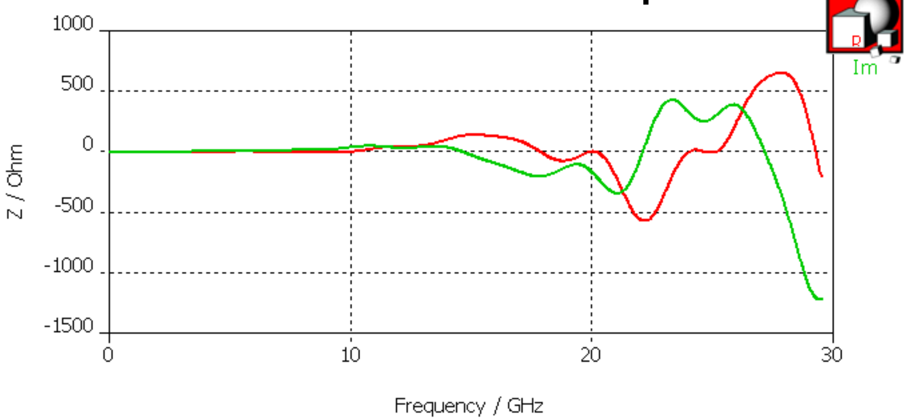
Impedance and wake potential for BPM Insertion with and without bellows/flanges

The wake potential and impedance for given model of the BPM insertion was calculated using the 3D electromagnetic modelling code CST Microwave Studio/Particle Studio.

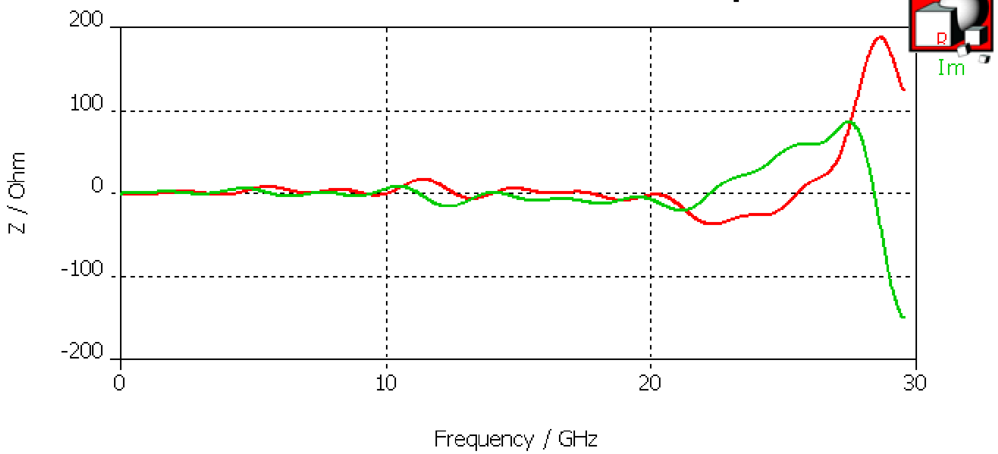




Loss Factor 0.057 V/pC



Loss Factor 0.028 V/pC

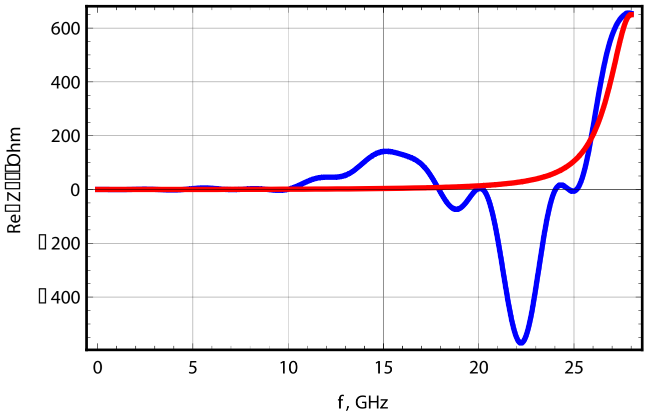


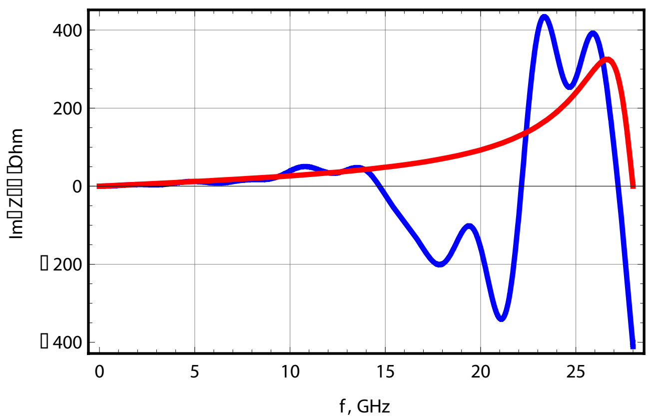
Broad-Band Impedance

The longitudinal impedance of a vacuum chamber component can be approximated, by a single mode cavity (resonant LCR-circuit):

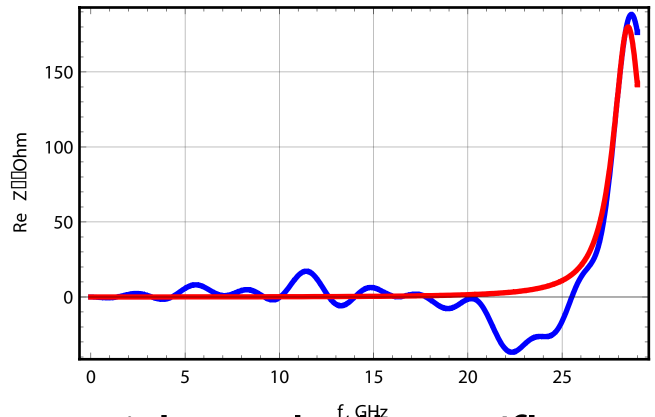
$$Z_{bb}(\omega) = \frac{R_s}{1 + iQ\left(\frac{\omega}{\omega_r} - \frac{\omega_r}{\omega}\right)}$$

Rs=650 [Ohm], fr=28 [Ghz], Q =10

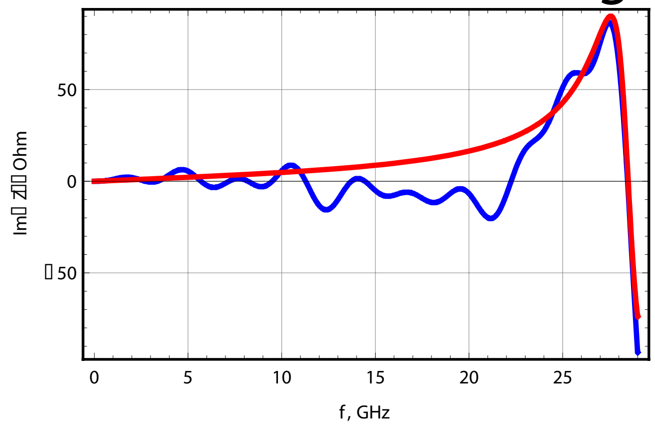




Rs=180 [Ohm], fr=28.5 [Ghz], Q =15



BPM without bellows/flanges



Conclusion

The Keil-Schnell-Boussard criterion gives an instability threshold of around 170 mΩ for present design of the ILC DR.

With the above values for *Rs* and ω_r an effective broad-band impedance of around 0.1 mΩ per BPM insertion. For 690 BPMs, the total broad-band impedance would be around 70 mΩ;

Resolution of the BPM, detail study is needed

More accurate impedance model is needed