ILC Damping Rings Lattice "DCO"

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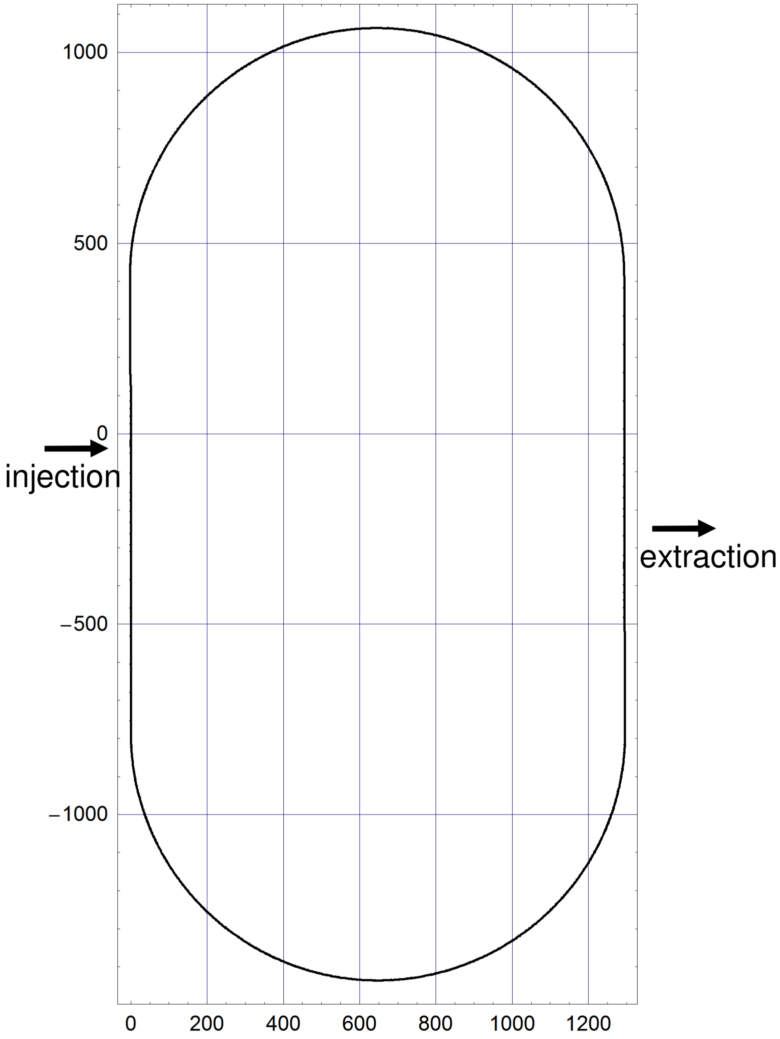
Structure and Layout



- Arcs consist of a total of 192 FODO cells
- Flexibility in tuning momentum compaction factor, given by phase advance per arc cell:
  - **72° phase advance: α_p=2.8×10^{-4}**
  - **90° phase advance: α_p=1.7×10^{-4}**
  - **100° phase advance: α_p=1.3×10^{-4}**
- No changes in dipole strengths needed for different working points.
- Racetrack structure has two similar straights containing:
  - **injection and extraction in opposite straights**
  - **phase trombones**
  - **circumference chicanes**
  - **rf cavities**
  - **"doglegs" to separate wiggler from rf and other systems**
  - **wiggler**

Major Parameters

Beam energy	5 GeV
Circumference	6476.440 m
RF frequency	650 MHz
Harmonic number	14042
Transverse damping time	21.0 ms
Natural rms bunch length	6.00 mm
Natural rms energy spread	1.27×10^{-3}

Phase advance per arc cell (approximate)	72°	90°	100°
Momentum compaction factor	2.80×10^{-4}	1.73×10^{-4}	1.29×10^{-4}
Normalised natural emittance	6.53 μm	4.70 μm	4.27 μm
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 tune	64.750	75.200	80.450
Natural horizontal chromaticity	-76.5	-95.1	-106.9
Vertical tune	61.400	71.400	75.900
Natural vertical chromaticity	-75.6	-93.4	-103.5

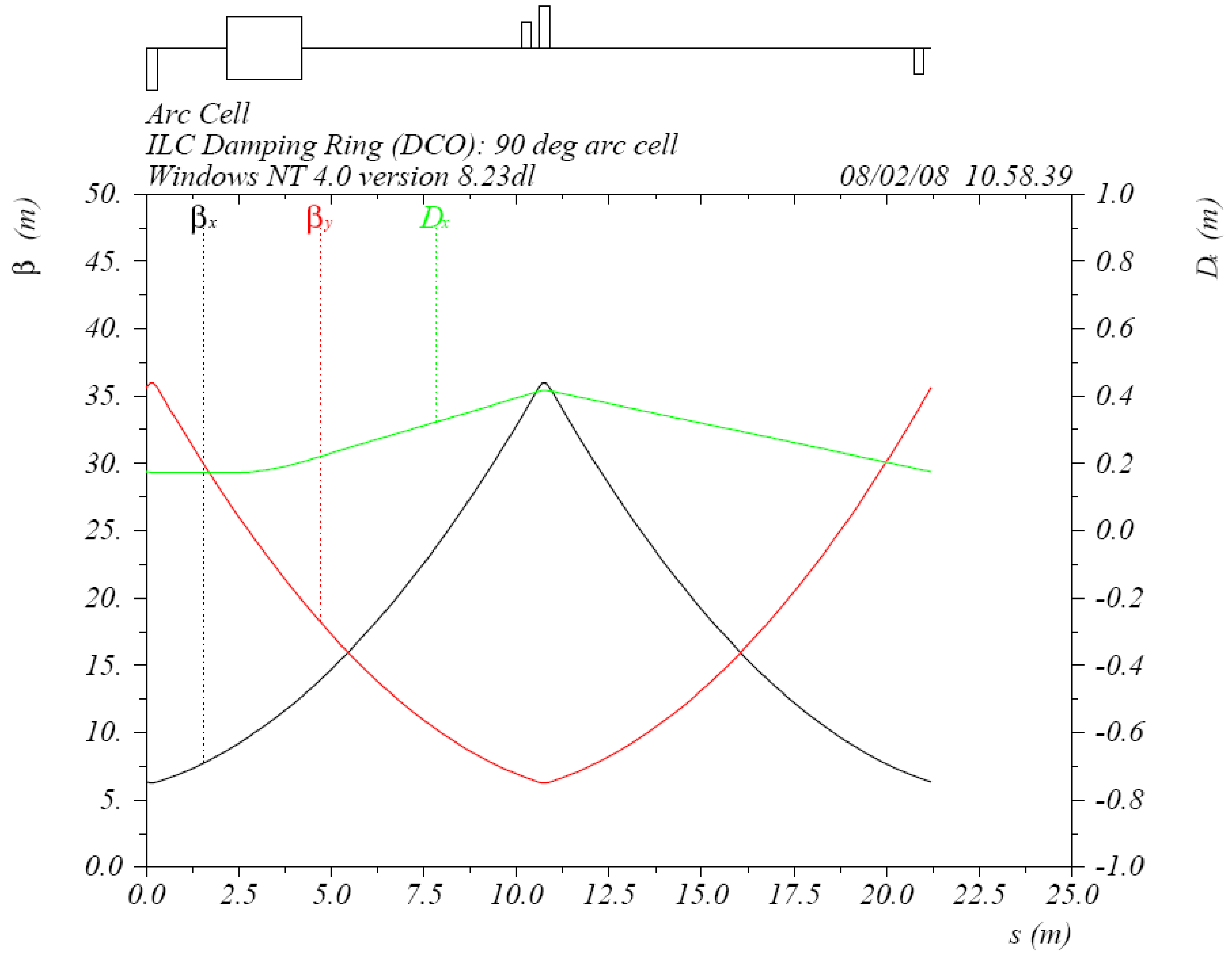
Magnet Counts and Parameters

Arc dipole length	2.00 m
Arc dipole field	0.273 T
Number of arc dipoles	192 (1 per arc cell)
Total number of 2 m dipoles	200
Total number of 1 m dipoles (in chicanes)	48

Total number of quadrupoles	690
Maximum quadrupole gradient	12.0 T/m
Total number of sextupoles	384
Maximum sextupole gradient	215 T/m^2

Wiggler peak field	1.6 T
Wiggler period	0.400 m
Wiggler unit length	2.45 m
Wiggler total length	215.6 m

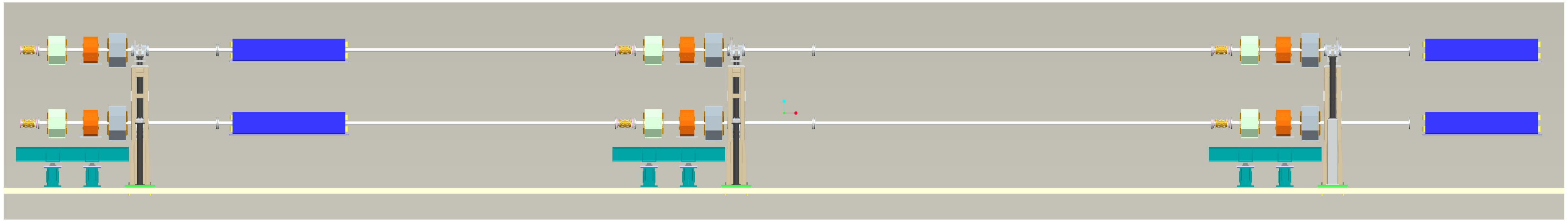
Arc Cell

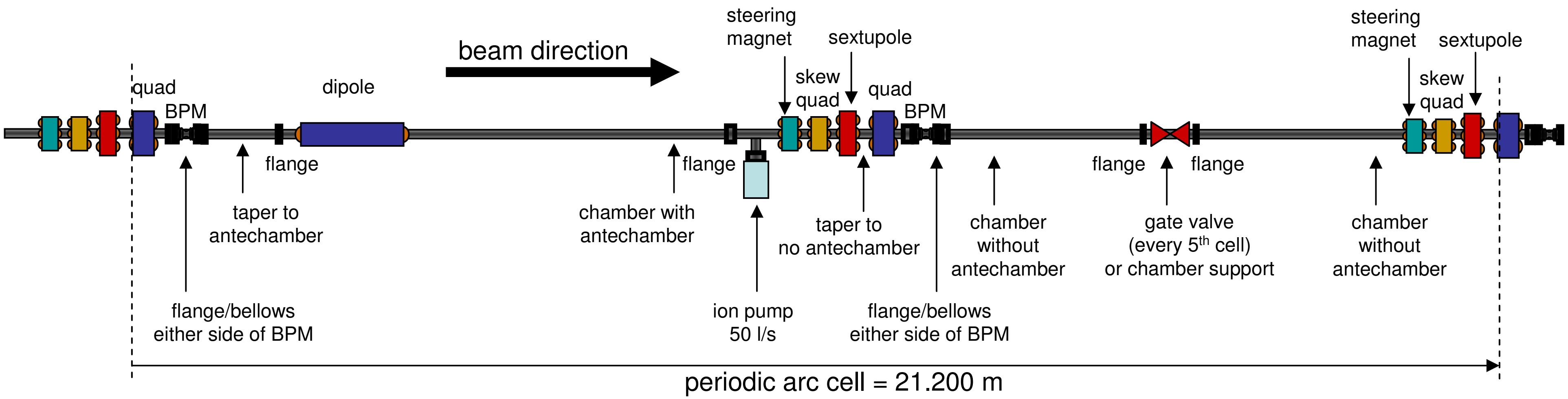


Arc Cell
ILC Damping Ring (DCO): 90 deg arc cell
Windows NT 4.0 version 8.23dl
08/02/08 10.58.39
β (m)
D_x (m)
s (m)
β_x
β_y
D_x
50.
45.
40.
35.
30.
25.
20.
15.
10.
5.
0.0
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0

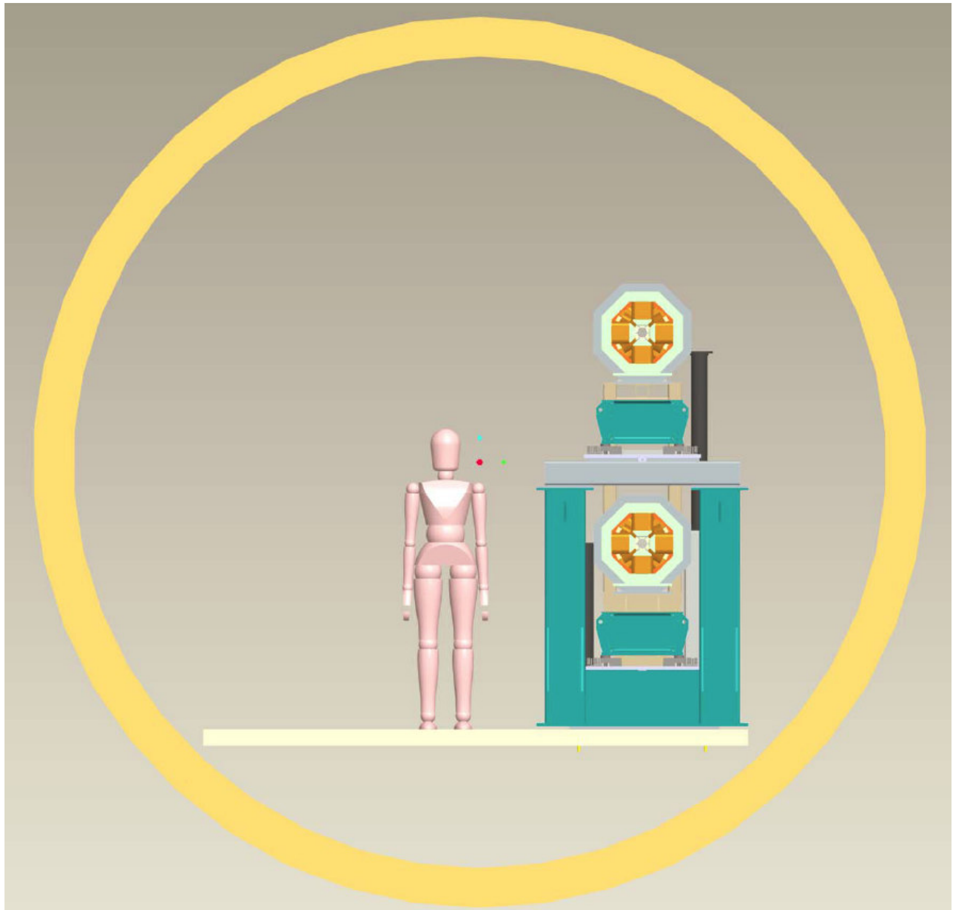
Arc Cell: Vacuum System Concept

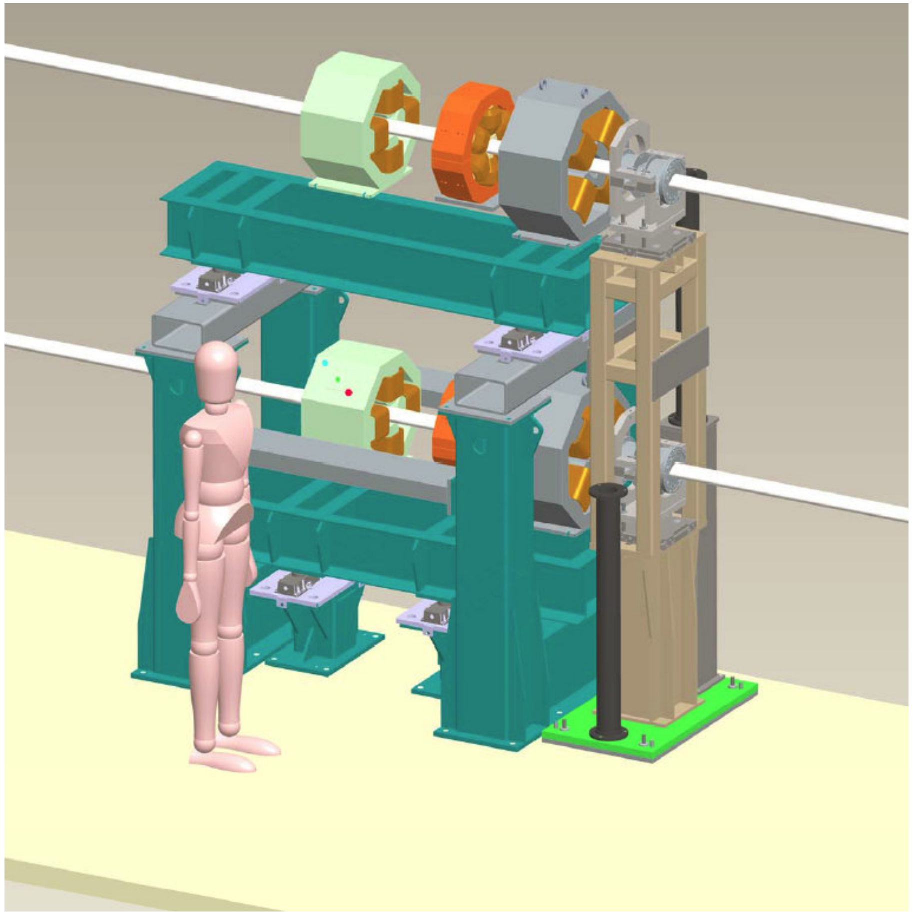
- NEG coating provides most of the pumping.
- Antechamber downstream of dipoles reduces synchrotron radiation in main chamber.
- BPMs shielded from synchrotron radiation by tapers.
- BPMs separately supported and "isolated" from rest of chamber through bellows.
- Bellows occur roughly every 10 m (appropriate for bake-out/activation).
- Single dipole per arc cell simplifies design and reduces cost (minimizes tapers etc.)



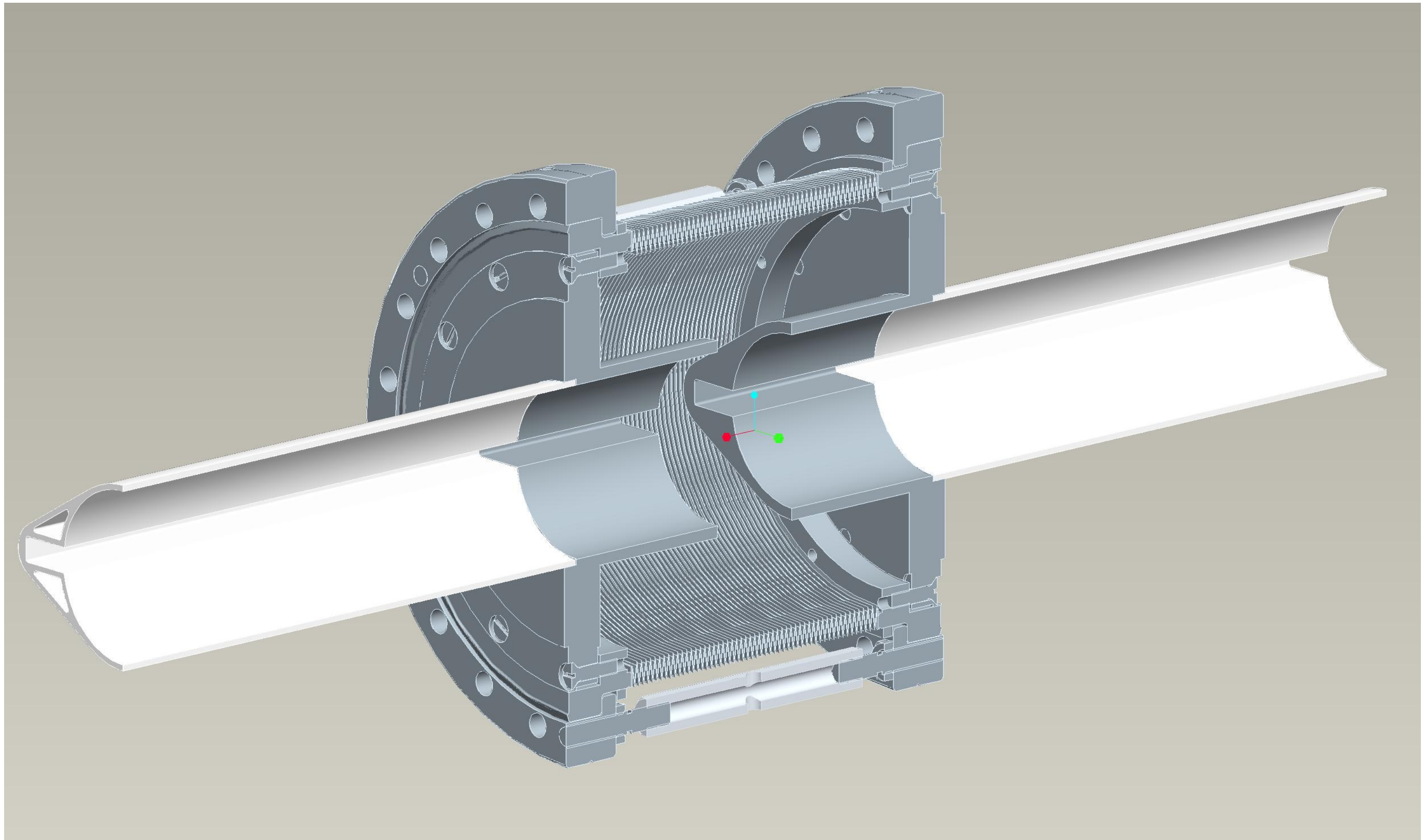


Magnet and BPM Supports

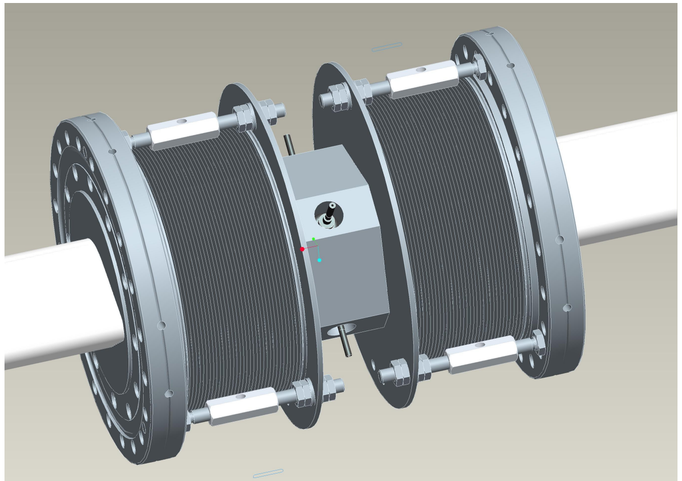




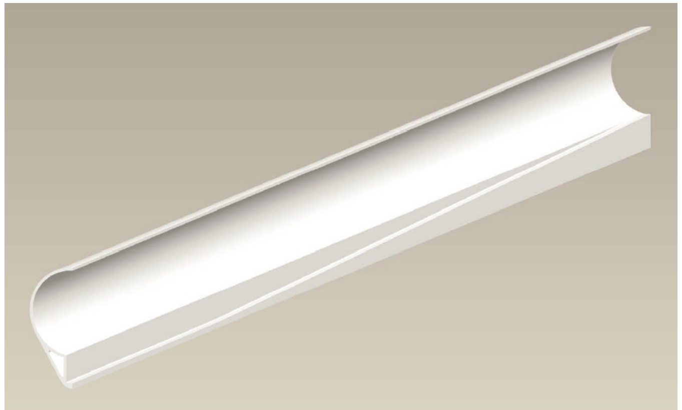
Chamber with Antechamber



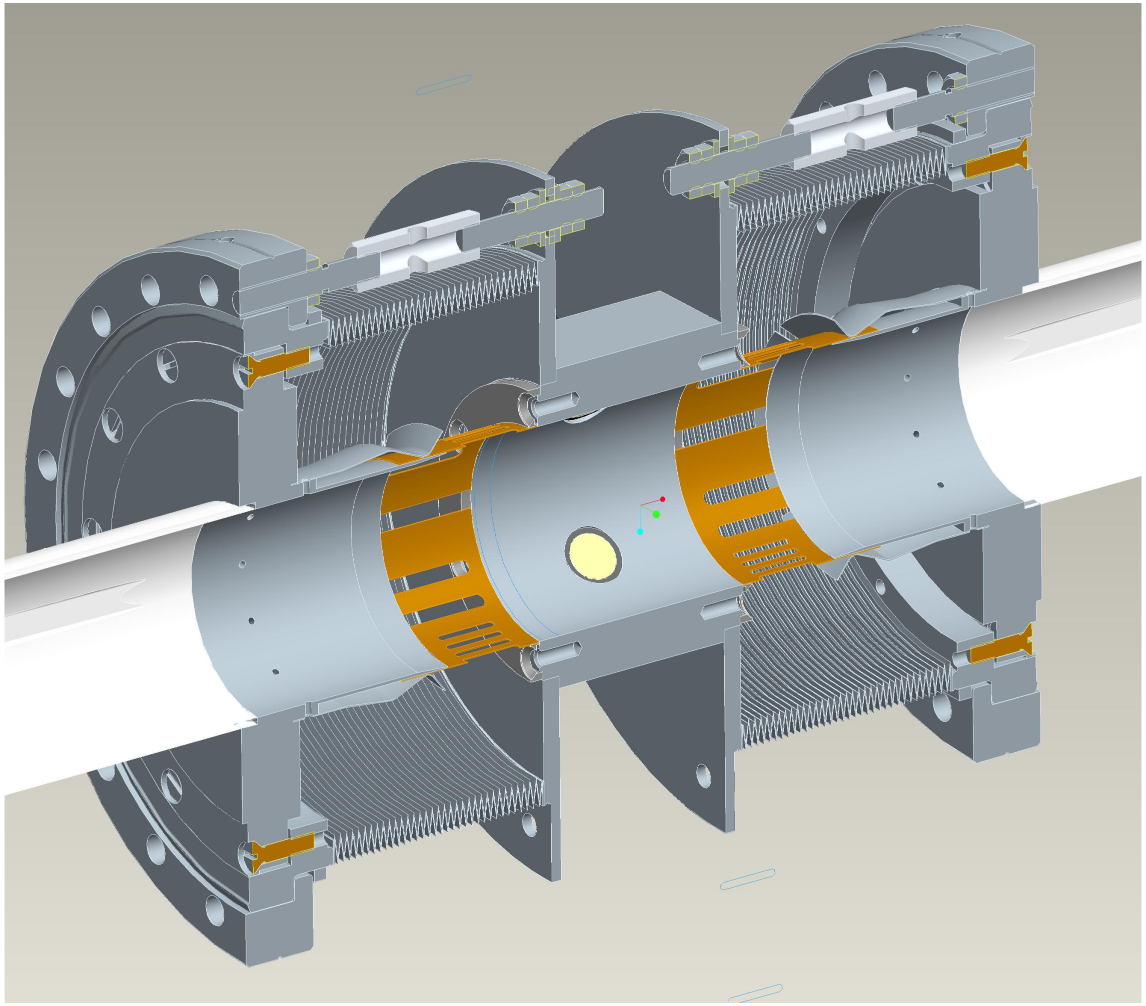
BPM Chambers



Bellows/BPM external view

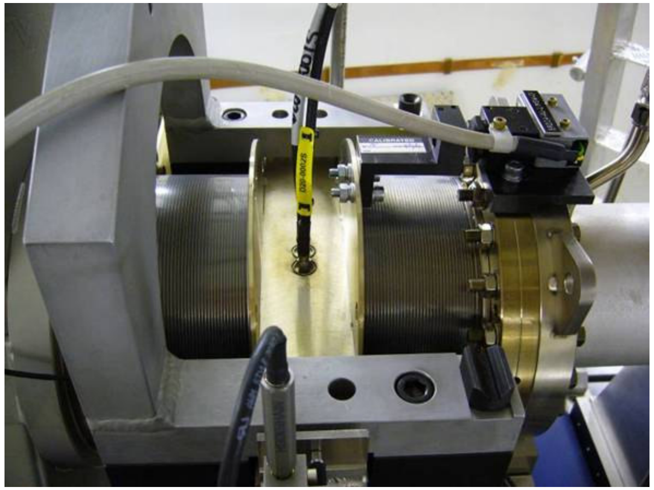


Antechamber taper (into BPM chamber)

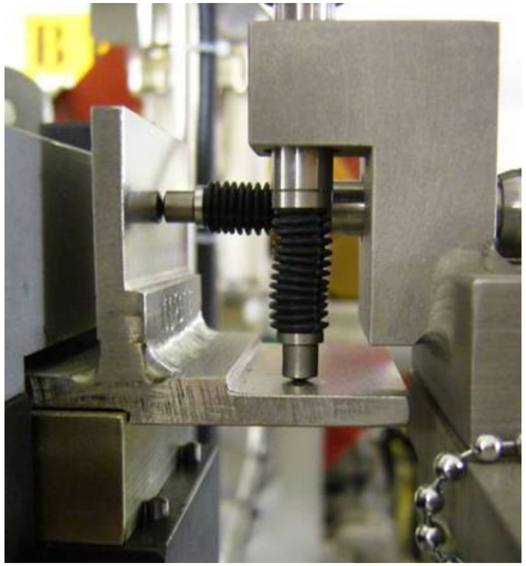


Bellows/BPM internal view

DIAMOND Light Source BPMs



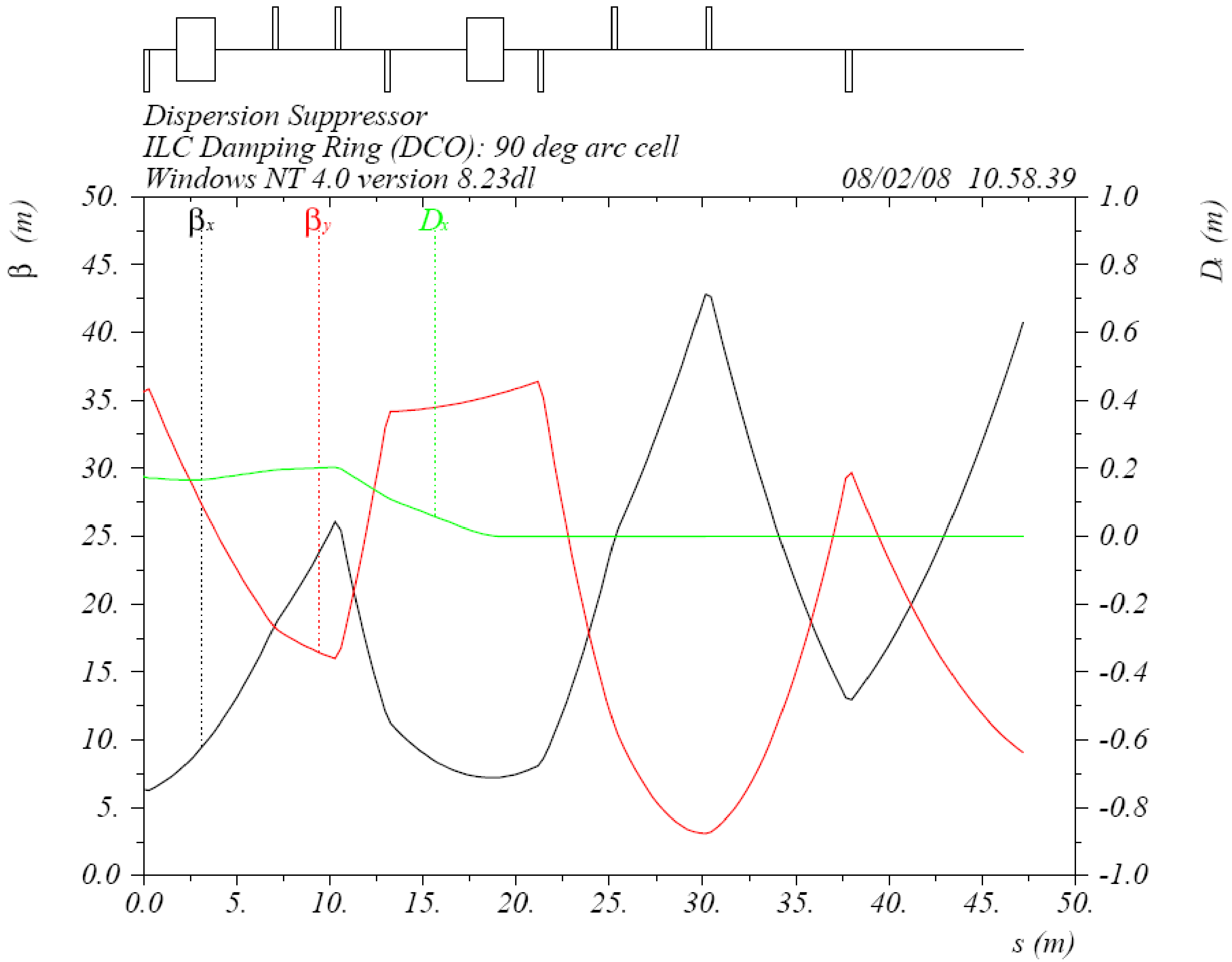
BPM and bellows chamber



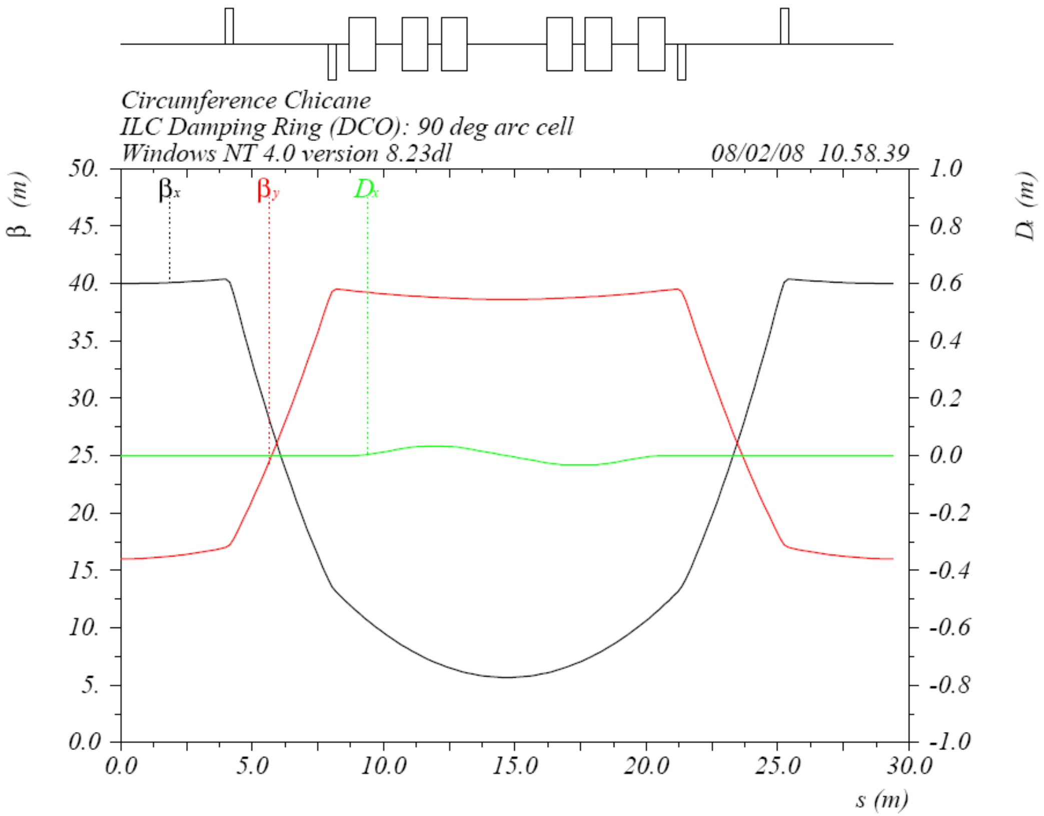
Linear encoders to monitor BPM position with respect to reference pillar

Reference pillar supporting linear encoders

Dispersion Suppressor

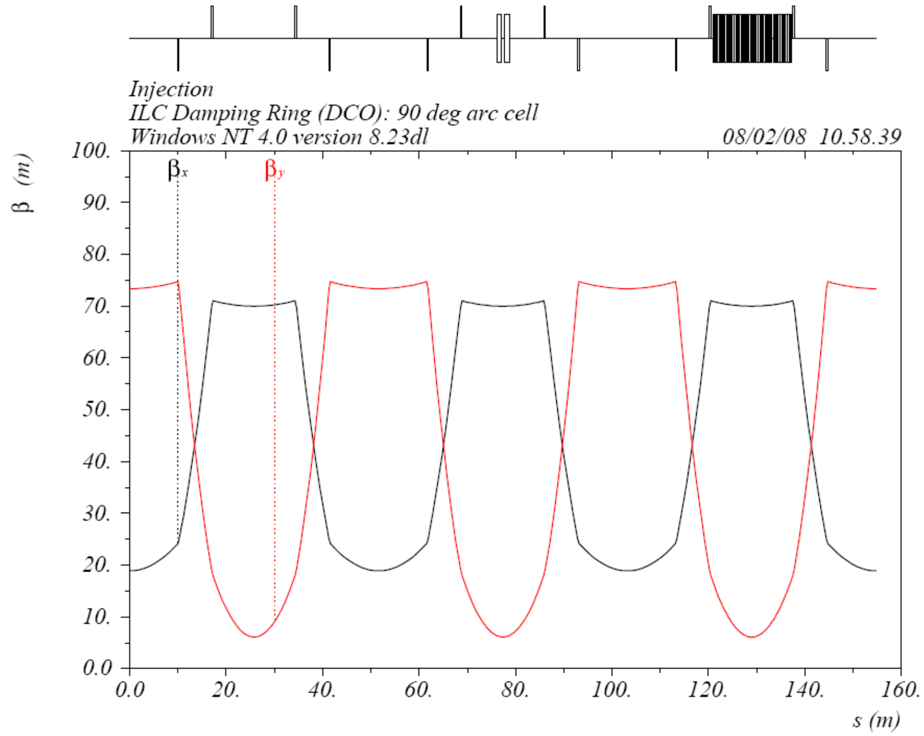


Circumference Adjustment Chicanes



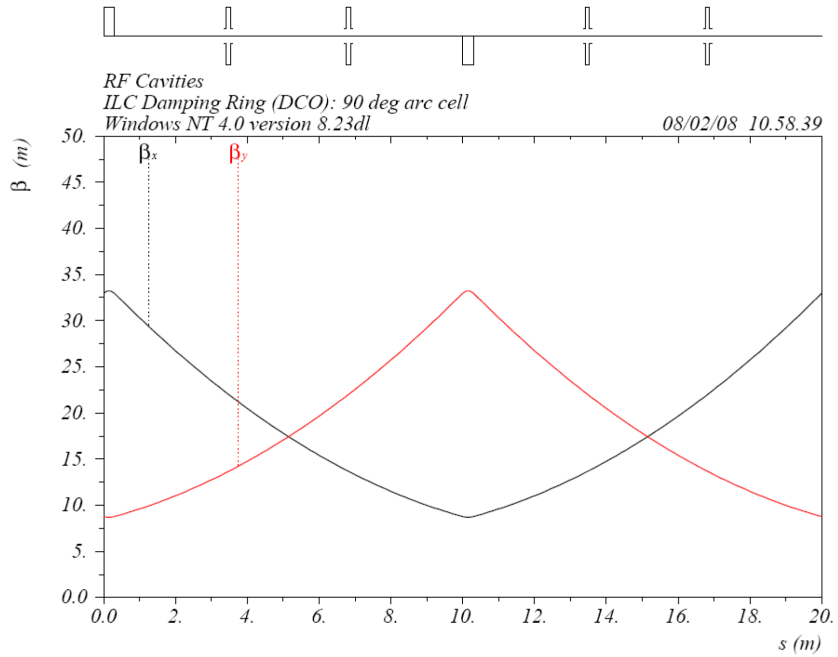
- Each chicane has six dipoles.
- Each dipole is 1 m long with 0.273 T nominal field.
- Total of eight chicanes (four in each straight).
- Total range of circumference adjustability ≈ ±8 mm.

Injection and Extraction Optics



- 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.
- Space for 33 kicker "modules" (assuming 30 cm striplines with 20 cm separation). With 30 kickers operational, pulsers must supply ±7 kV.

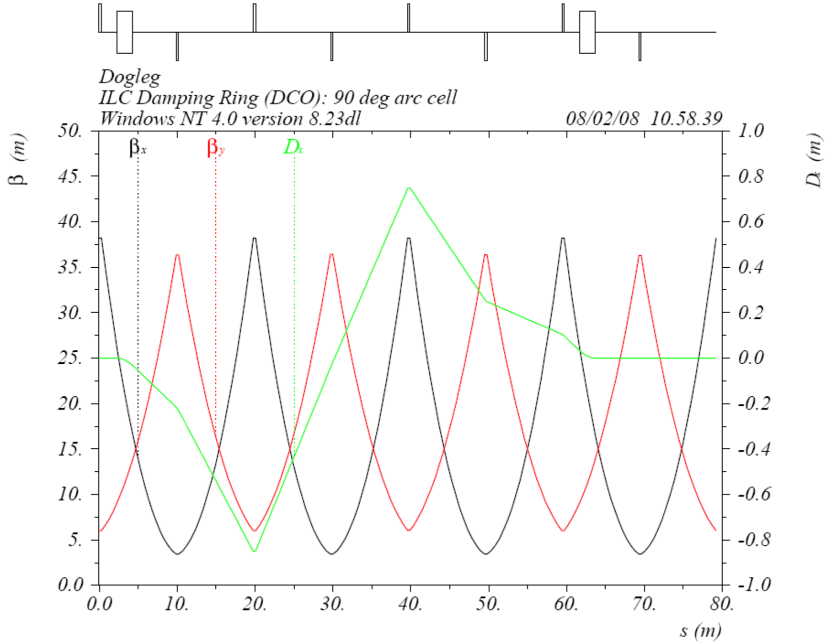
RF Power

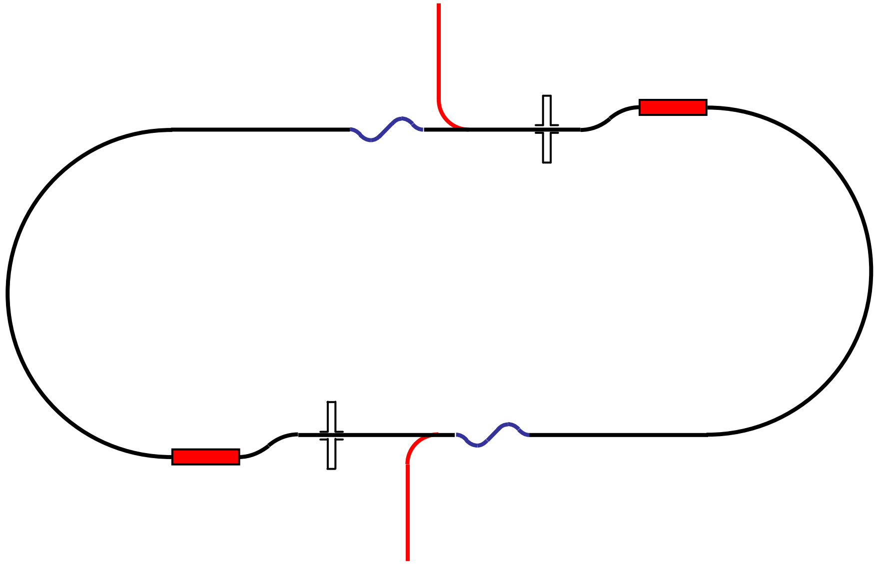


- Space available for 24 rf cavities (12 per straight), assuming one cavity per cryomodule, two cryomodules in 9.7 m space between quadrupoles.
- Assuming maximum accelerating gradient per cavity ≈ 1.7 MV :

Momentum compaction factor	RF voltage for **6 mm** bunch length	Number of rf cavities
2.8×10^{-4}	31.6 MV	19
1.7×10^{-4}	21.1 MV	13
1.3×10^{-4}	17.2 MV	10

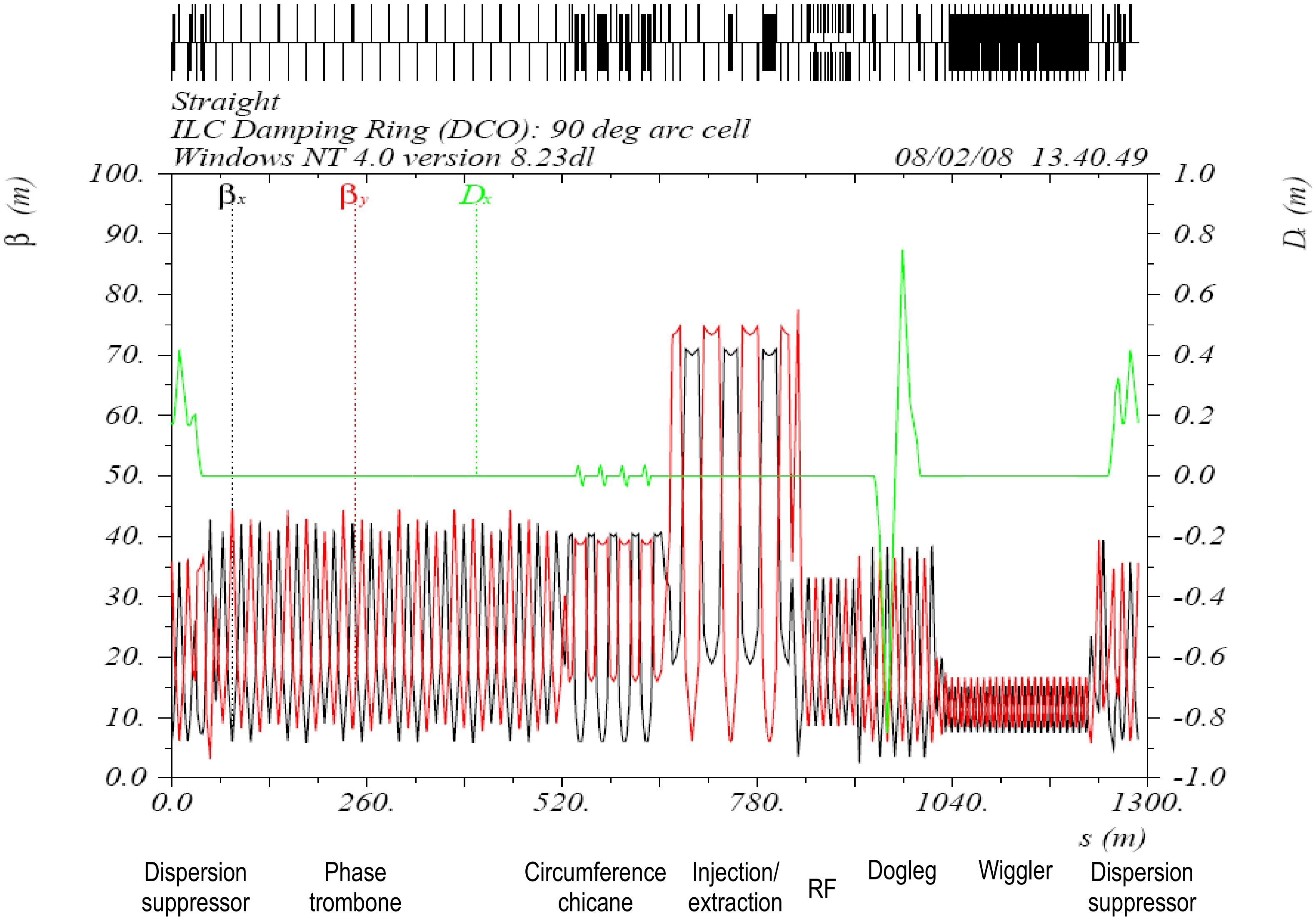
Dogleg



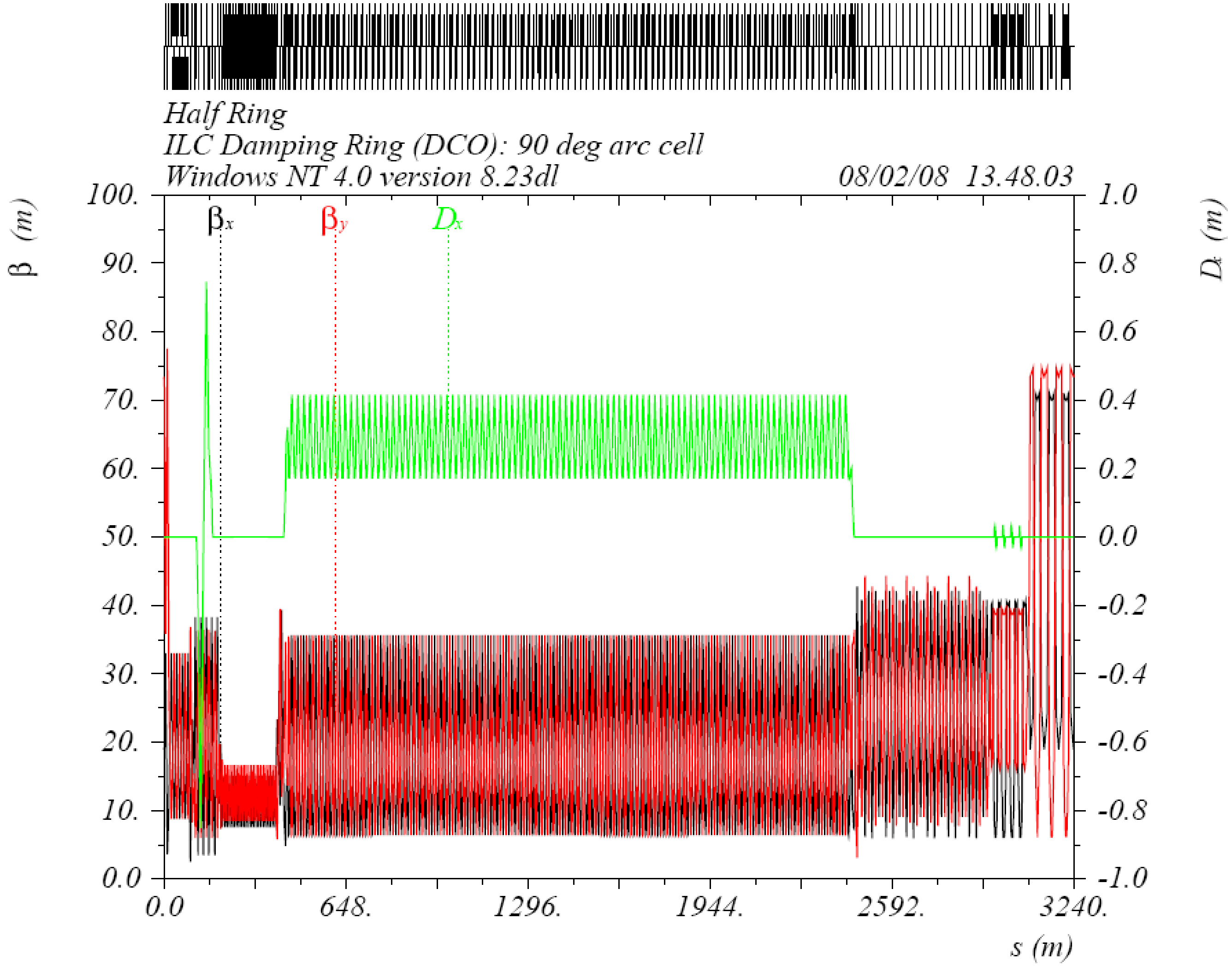


- Dogleg gives transverse (horizontal) separation of roughly 2 m, between the line of the wiggler and the rest of the straight. This provides scope for handling the synchrotron radiation from the wiggler.
- Locating the rf and wiggler near each other should minimise cryogenic transfer lines. In this configuration, if the beams are circulating in opposite directions in the two damping rings, the wiggler will be upstream of the rf in one of the rings: but the dogleg will allow for catching the wiggler radiation.

Straight Section



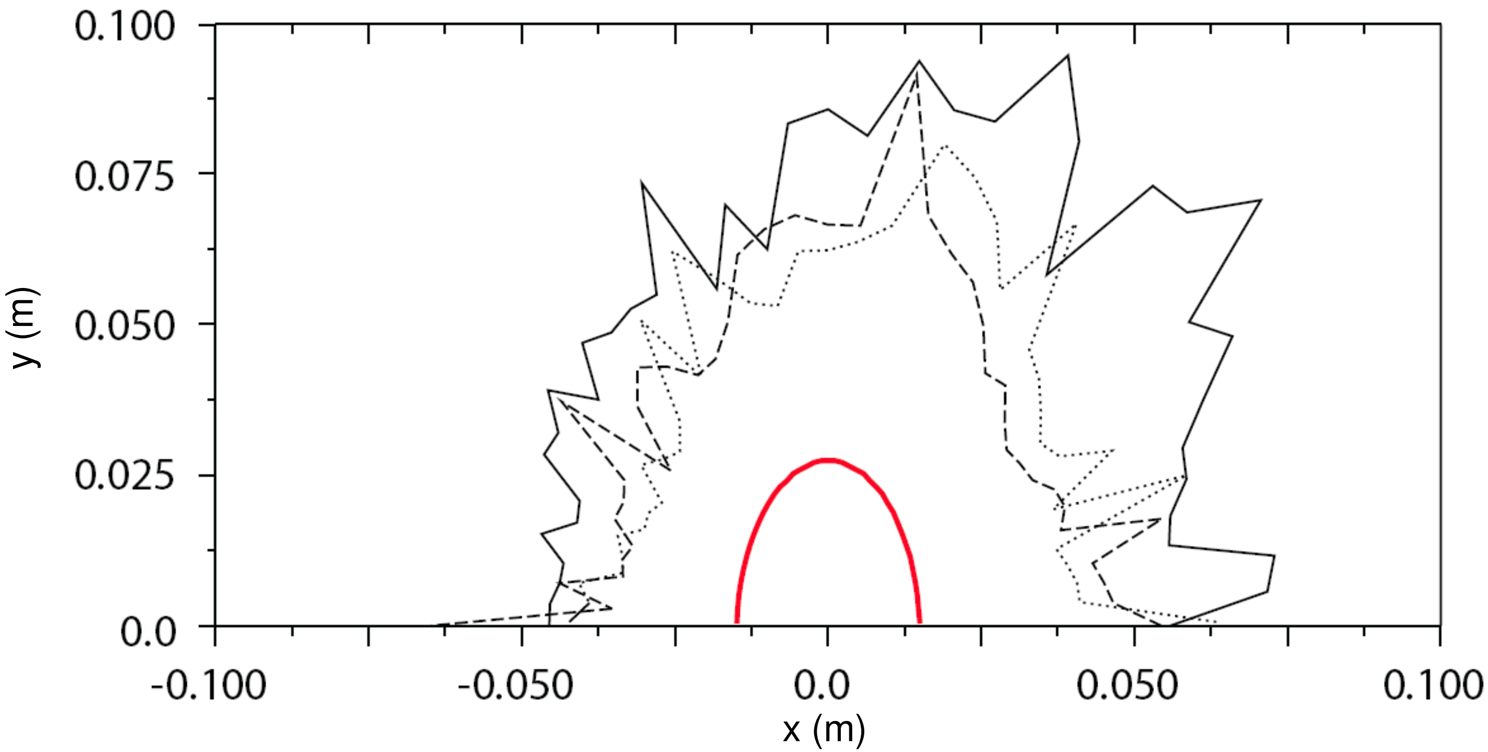
Half Ring (from injection point)



Dynamic Aperture

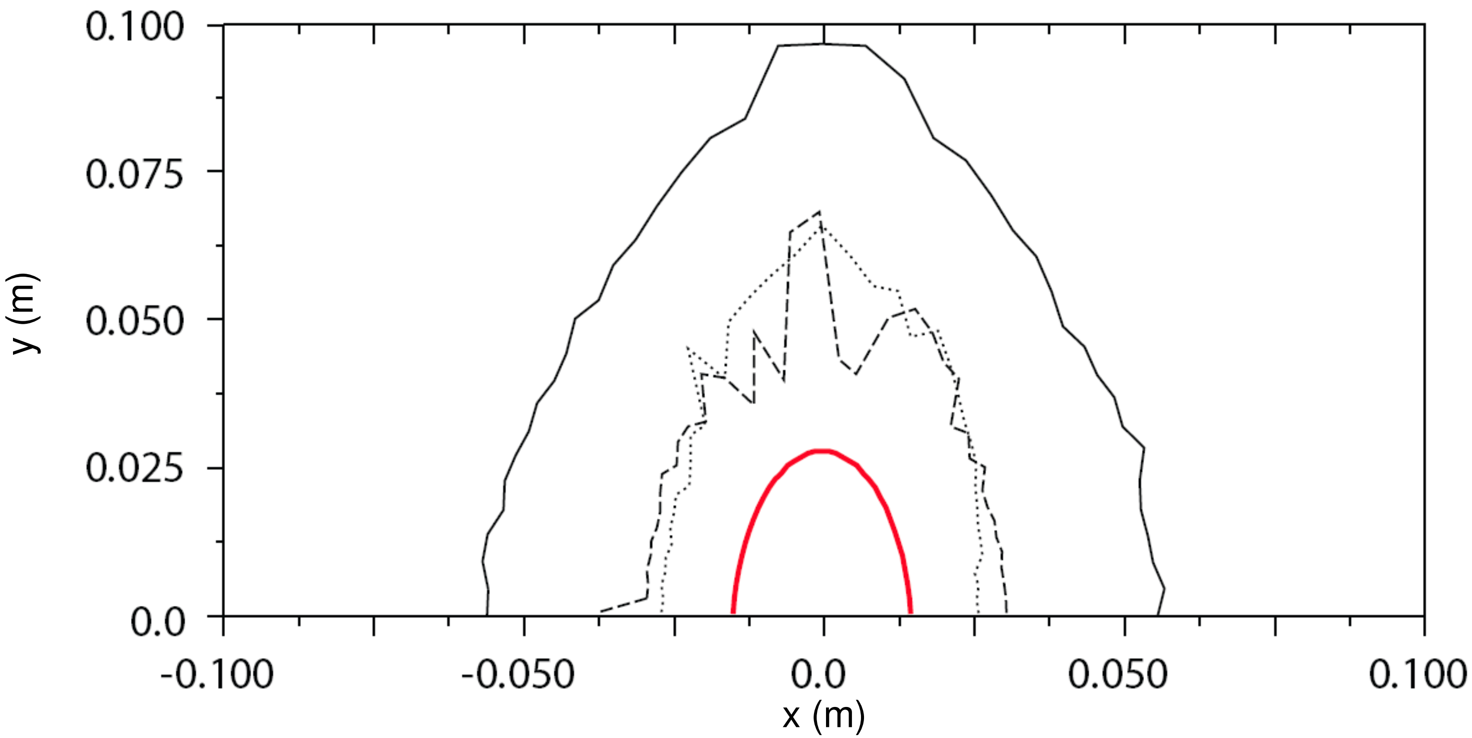
- Dynamic aperture looks reasonable (substantially greater than injected positron beam size up to 0.5% energy deviation) for 72° and 90° arc cells, without errors.
- Lattice with 90° arc cells uses non-interleaved sextupole scheme to improve dynamic aperture.
- For 100° arc cells, dynamic aperture looks insufficient: further tuning and optimisation is needed.
- It should be possible to improve the dynamics in all three cases with further tuning (optimising arc cell and straights phase advance…) Not much work has been done so far.

Dynamic Aperture



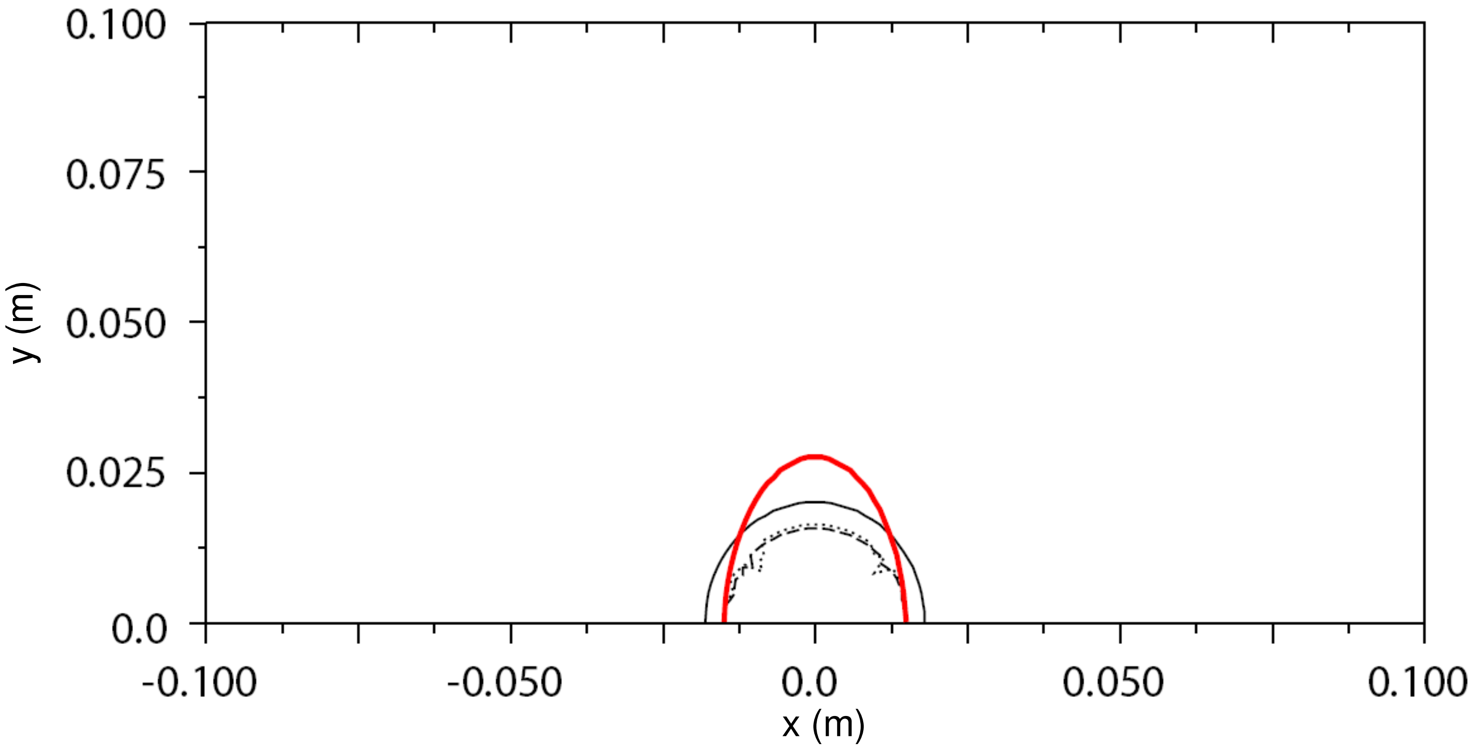
- 72° phase advance per arc cell.
- Red ellipse shows maximum particle coordinates for injected positron beam.
- Solid black line shows on-energy dynamic aperture.
- Dotted and dashed lines show dynamic aperture for 0.5% energy deviation.
- No errors included in the model.

Dynamic Aperture



- 90° phase advance per arc cell.
- Red ellipse shows maximum particle coordinates for injected positron beam.
- Solid black line shows on-energy dynamic aperture.
- Dotted and dashed lines show dynamic aperture for 0.5% energy deviation.
- No errors included in the model.

Dynamic Aperture



- 100° phase advance per arc cell.
- Red ellipse shows maximum particle coordinates for injected positron beam.
- Solid black line shows on-energy dynamic aperture.
- Dotted and dashed lines show dynamic aperture for 0.5% energy deviation.
- No errors included in the model.

Summary

- Lattice design includes all major subsystems…
  - **injection/extraction, wiggler, rf, phase trombone, circumference chicane**
- …and meets specifications for principal parameters
  - **energy, circumference, natural emittance, energy spread**
- Reasonable flexibility in momentum compaction factor
  - **Working points with α_p=1.7×10^{-4} and α_p=2.8×10^{-4} should be possible**
  - **Allows 6 mm rms bunch length with rf voltage 21.1 MV or 31.6 MV**
- Dynamic aperture still needs some work
  - **Looks reasonable for α_p=2.8×10^{-4}**
  - **Becomes more difficult at lower momentum compaction factor, because the dispersion becomes smaller.**
- Magnet quantities and parameters look reasonable
- Promising solution for arcs vacuum system from initial design studies
- Single dipole per arc cell appears to have some advantages:
  - **reduces overall number of dipoles**
  - **allows relatively large downstream distance from dipole to nearest BPM**
  - **reduces number of antechamber tapers, vacuum seals etc.**