3.2 km Damping Ring with 6 mm Bunch Length

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AAP Review

7 January 2010

Overview

- Low Power option
  - $N_{bunches}$ 2600 → 1300
  - Circumference 6.4km → 3.2km

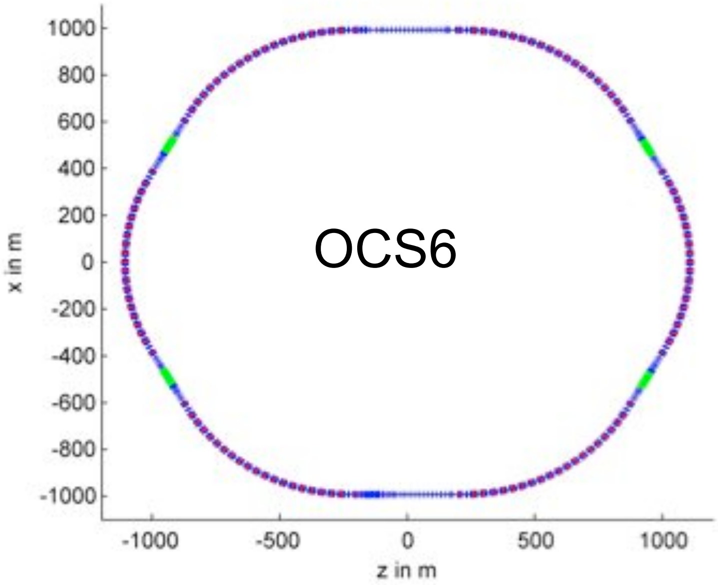
    - The fundamental technical design and implementation of the damping rings remain the same as or similar to previous designs
    - The bunch separation and the number of particles per bunch remain the same, and the beam current in the ring is the same
    - From the view point of beam dynamics and most of the hardware aspects, this change is not expected to cause major performance challenges or technical aggravation, and should provide a firm conceptual basis for more detailed engineering studies during TDP2

Comparison with RDR lattice

- The SB2009 proposal describes the Baseline modifications with respect to RDR
- The DR design has been updated, after the RDR, at TILC08:
  - Layout: hexagonal ⇒ racetrack
  - Bunch length: 9mm ⇒ 6mm
  - Momentum compaction: $4x10^{-4}$ ⇒ $2x10^{-4}$ flexible
- SB2009 lattice has same layout, bunch length and momentum compaction as TILC08

RDR and TILC08 rings layout

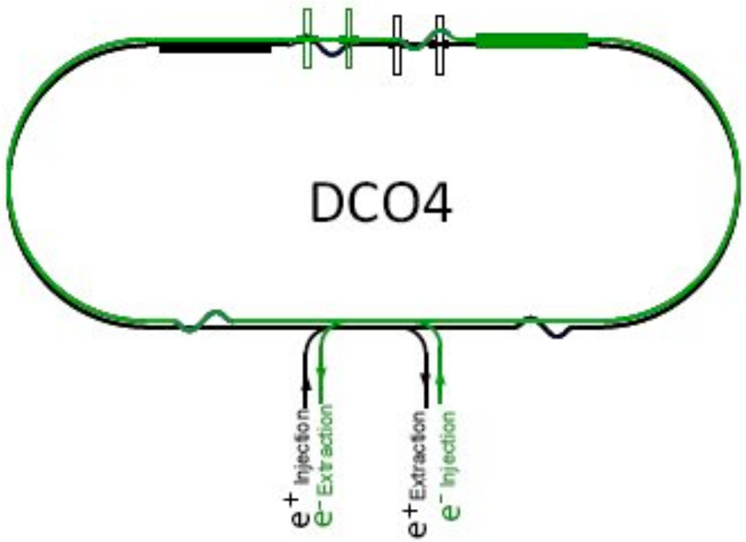
Hexagonal RDR



C = 6.7 km

σ_l = 9 mm

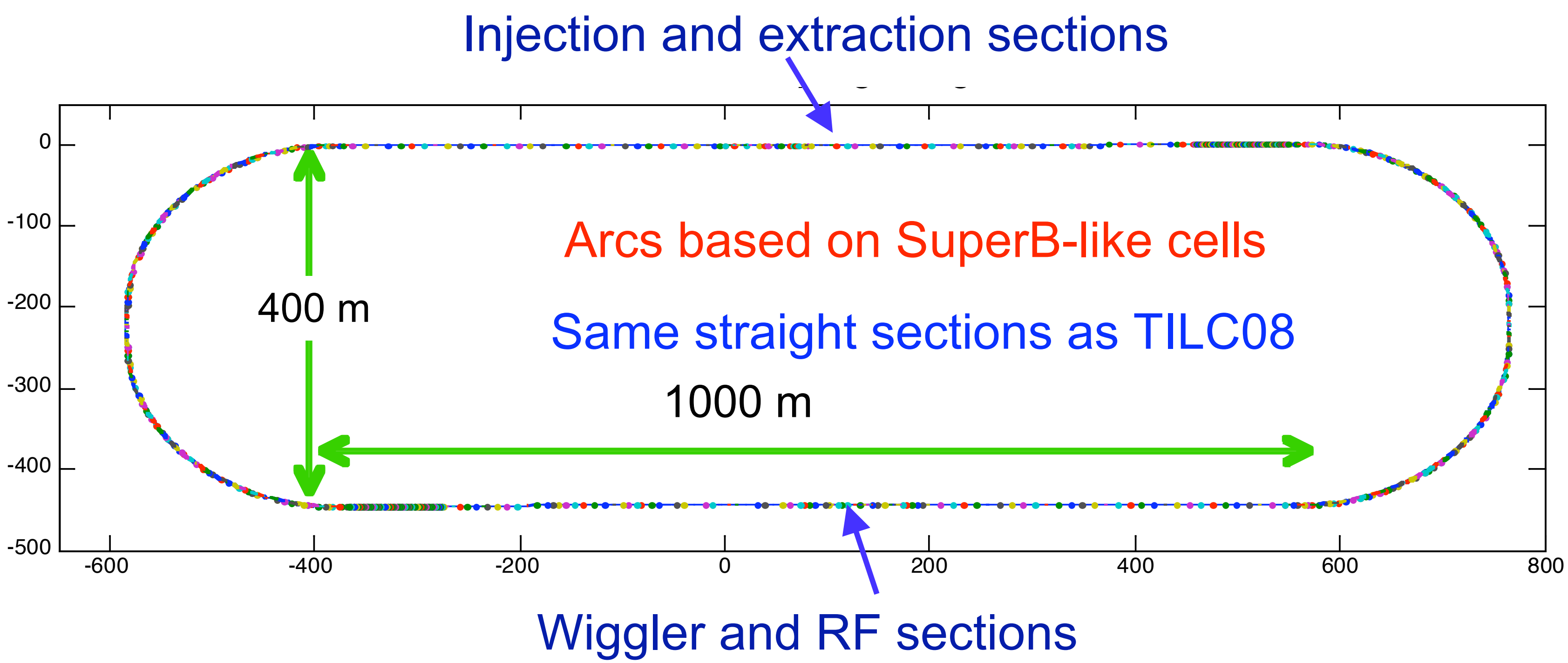
Racetrack TILC08



C = 6.4 km

σ_l = 6 mm

Layout of the 3.2km damping rings



- Injection/extraction lines of the two rings are superimposed
- RF cavities: 18 ⇒ 8
- Wigglers: 80 ⇒ 32

http://ilcagenda.linearcollider.org/materialDisplay.py?contribId=516&sessionId=11&materialId=slides&confId=2628

http://ilcagenda.linearcollider.org/contributionDisplay.py?contribId=119&sessionId=27&confId=3461

Parameter list for the RDR and the TILC08 version of the damping ring compared with the SB2009 3.2 km ring

	RDR	TILC08	SB2009
Circumference (m)	**6695**	**6476**	**3238**
Energy (GeV)	5	5	5
Bunch number	2625	2610	1305
N particles/bunch	2×10^{10}	2×10^{10}	2×10^{10}
Damping time τ_x (ms)	25.7	21	24
Emittance ε_x (nm)	0.51	0.48	0.53
Emittance ε_y (pm)	2	2	2
Momentum compaction	4.2×10^{-4}	1.7×10^{-4}	1.3×10^{-4}
Energy loss/turn (MeV)	8.7	10.3	4.4
Energy spread	1.3×10^{-3}	1.3×10^{-3}	1.2×10^{-3}
Bunch length (mm)	9	6	6
RF Voltage (MV)	24	21	7.5
RF frequency (MHz)	650	650	650
B wiggler (T)	1.67	1.6	1.6
Lwig total	200	216	78
Number of wigglers	80	88	32

Work to Pursue during TDP2

- The main challenges: fast kickers, low emittance tuning, electron cloud and fast ion instability
- Bunch separation and number of particles/bunch remain the same $\Rightarrow$ the magnitude of technical challenges associated with them would remain essentially the same.
- Ongoing R&D programs from the TDP1 period into TDP2 continue as they are (including CesrTA and ATF test facilities)
- An important goal of TDP2 is to evaluate the performance of the SB2009 damping ring design with respect to all the limiting effects, on the basis of these experimental and theoretical efforts.

Work to Pursue during TDP2

- **Kickers**
  - All of the kicker specifications are the same for the short and long rings, except for the repetition frequency within the pulse, which is 1.5 MHz instead of 3 MHz, less demanding for the shorter ring. The required kicker pulse length is given by the bunch separation, 6 ns, for the nominal parameter set (1300 bunches) which is the same as the RDR.
- **Low emittance tuning**
  - For the low emittance tuning we do not expect significant differences between the two rings even though the sensitivity to alignment errors of the new lattice remains to be evaluated.

Work to Pursue during TDP2

- Collective effects
  - Collective effects need to be re-evaluated for the SB2009 design, including the fast ion instability, space charge incoherent tune shifts and intrabeam scattering. We do not expect a big difference from previous evaluations since these effects depend mainly on the ring currents that are the same as for the RDR.
  - The shorter bunch length poses more stringent requirements on the vacuum chamber impedances. First estimates indicate that the nominal operating parameters are below the thresholds for microwave instabilities.
  - Special attention, however, must be paid to the effect of the electron cloud instability.

Work to Pursue during TDP2

- Electron cloud for 1300 bunches (6 ns bunch spacing)
- For the nominal configuration with 1300 bunches and 6ns bunch spacing, electron cloud mitigation techniques are needed both for the RDR and the SB2009 rings.
- R&D is in progress at the dedicated test facility, CesrTA, and at other labs. Results are promising and a range of mitigation methods are being tested.
- We have convened a working group to apply the results of the R&D to the DR design. The findings will be used as input for the ring design that will be chosen for the new baseline.
- Given the same current and bunch distance we expect similar or even higher instability threshold for the shorter ring [M. Pivi presentation at LCWA09].

Luminosity Upgrade

- Electron cloud for 2600 bunches (3ns bunch spacing): luminosity upgrade
- The parameter set for the SB2009 luminosity upgrade has twice the nominal current.
- We expect the electron cloud build-up to be more severe with the shorter bunch spacing.
- Achieving the performance of the SB2009 ring for the luminosity upgrade will require additional simulation studies, improved mitigation techniques, a more expensive vacuum design, etc. Further work on mitigation techniques is needed to significantly increase our level of confidence when dealing with this parameter set. In the event that effective EC mitigations cannot be devised, a back-up option would be to add a second positron damping ring.

Working Group goals

Goals of the LC DR Working Group are:

- To give a recommendation on the feasibility of a shorter damping ring by comparing the electron cloud build-up and instability for the 6.4km and 3.2km rings with a 6 ns bunch spacing by March 2010, then
- Following the CesrTA program or by ECLOUD'10, to give our recommendation on e- cloud mitigations and evaluate the electron cloud in the shorter 3.2 km ring with a 3 ns bunch spacing.
- Furthermore starting late 2010, to fully integrate the CesrTA results into the Damping Ring design.

PROs and CONs

a) **Cost reduction**

b) **RF cavities reduced by 2.3 ⇒ lower impedance**

c) **Wigglers reduced by 2.5 ⇒ lower e-cloud average density per turn**

d) Decreases unscheduled downtime because it has fewer components

e) Space charge incoherent tune shift reduced by a factor 2

a) **The number of bunches that can be stored is half with respect to the 6.4 km ring, for the same bunch spacing**

b) Shorter bunch length implies lower instability thresholds and larger IBS effect, but it is not expected to be an issue

Backup

ECLOUD Working Group

WG Charges:

1. To evaluate the proposal and options to reduce the DR circumference to 3.2 km comparing with the 6.4 km ring and give our recommendation with respect to the electron cloud formation and instability.
   Timeline: early 2010.
2. To evaluate electron cloud mitigation techniques, simulations and code benchmarking for the new baseline. In particular, evaluate the differences between mitigations regarding their feasibility, effectiveness, impact on the vacuum system, on the beam impedance and on costs, for different regions of the ILC DR. Timeline late 2010.

Kickers

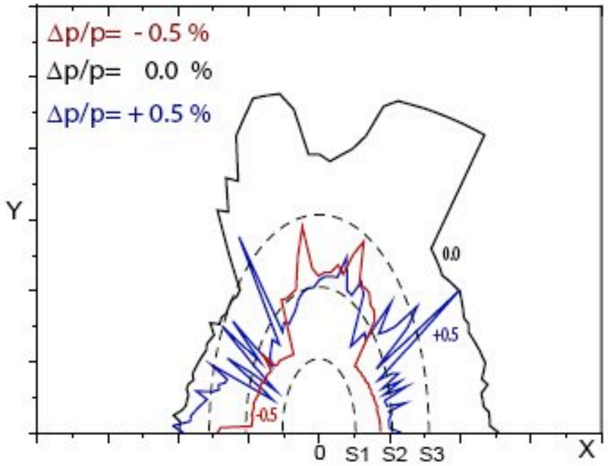
- As for the RDR, injection can be performed by using 22 stripline kickers, each 30 cm long at a voltage of 20 kV, (+10 and -10 kV pulses on opposite electrodes). For the extraction only half the number of kickers is required due to the very small extracted beam size.
- A test of multibunch beam extraction from the ATF damping ring with 5.6 ns bunch distance, slightly shorter than the nominal ILC bunch distance, has been performed in October 2009. This extraction scheme will be used for ATF2 operation in 2010.
- In the RDR the tolerance on horizontal beam jitter of the extracted beam is 0.1 σx which requires the extraction kicker amplitude stability to be 0.1% or better. Present R&D plans aim at this objective. If a tighter limit on the amplitude stability is required, then a further stabilization method, such as adding a feed-forward system in the turnaround, could be considered.
- When considering ~2600 bunches as a possible luminosity upgrade, the bunch distance would be 3ns as in the “low charge” parameter set in the RDR parameter plane. A kicker pulse with rise/fall times shorter than 3 ns has already been measured at KEK ATF [DR5].
- The R&D activity planned for the RDR is continuing to demonstrate kickers satisfying all the DR specifications including repetition rate, amplitude stability, field uniformity, strength and operational reliability.

3.2 km Ring Lattice

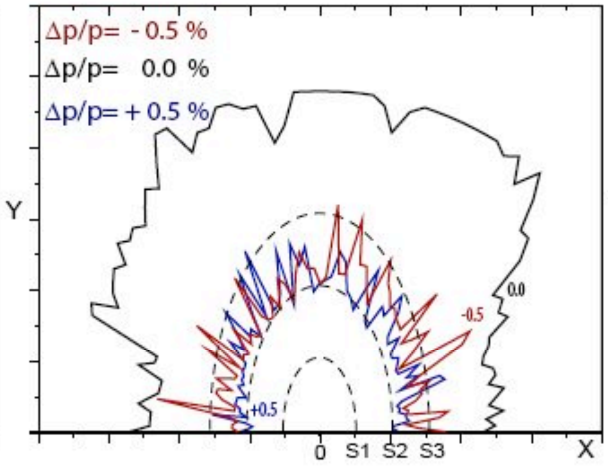
The new lattice is still in a preliminary stage of development and requires further optimization of the dynamic aperture and evaluation of the effects of magnetic errors and alignment errors. Based on the experience gained with the present reference lattice, we are confident that by proper tuning the straight sections, phase advances and the sextupole distribution, an adequate dynamic aperture for the large injected emittance of the positron beam can be achieved. At the same time, work is in progress at IHEP Beijing on an alternative lattice design using FODO cells. The optimal lattice design will be selected similarly to how it was done for the previous longer lattice.

ILC Damping Rings Lattices Evaluation, GDE Meeting TILC08, 3-6 March 2008, Sendai, Japan
http://ilcagenda.linearcollider.org/getFile.py/access?contribId=187&sessionId=63&resId=2&materialId=paper&confId=2432

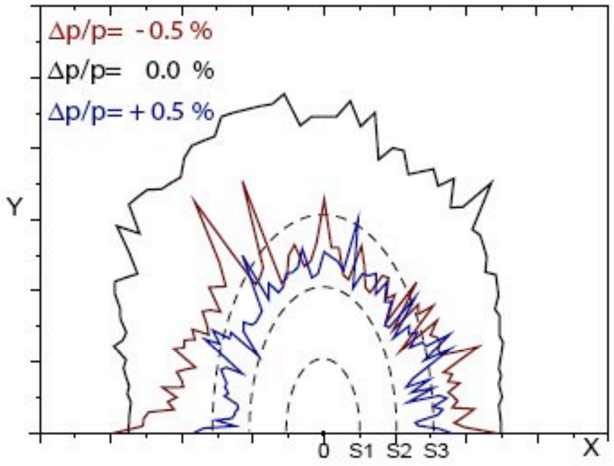
Dynamic aperture of the DCO2, DCO3 and DCO4 lattices at arc cell phase advance close to 72°



DCO2 (nux/nuy=64.12 / 61.41)



DCO3 (nux/nuy=61.12 / 61.41)



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

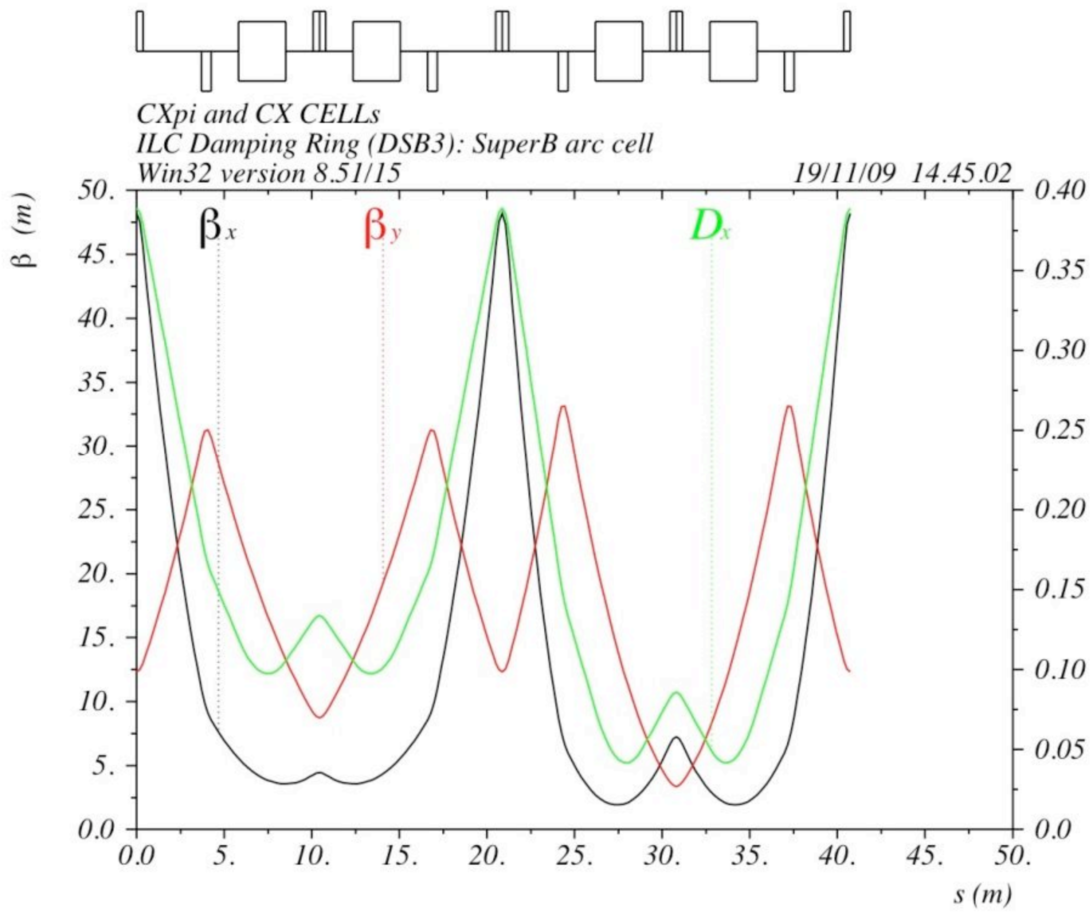
Dashed ellipses show maximum particle coordinates for injected beam size:

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

M. Korostelev

Optical functions of the arc cells

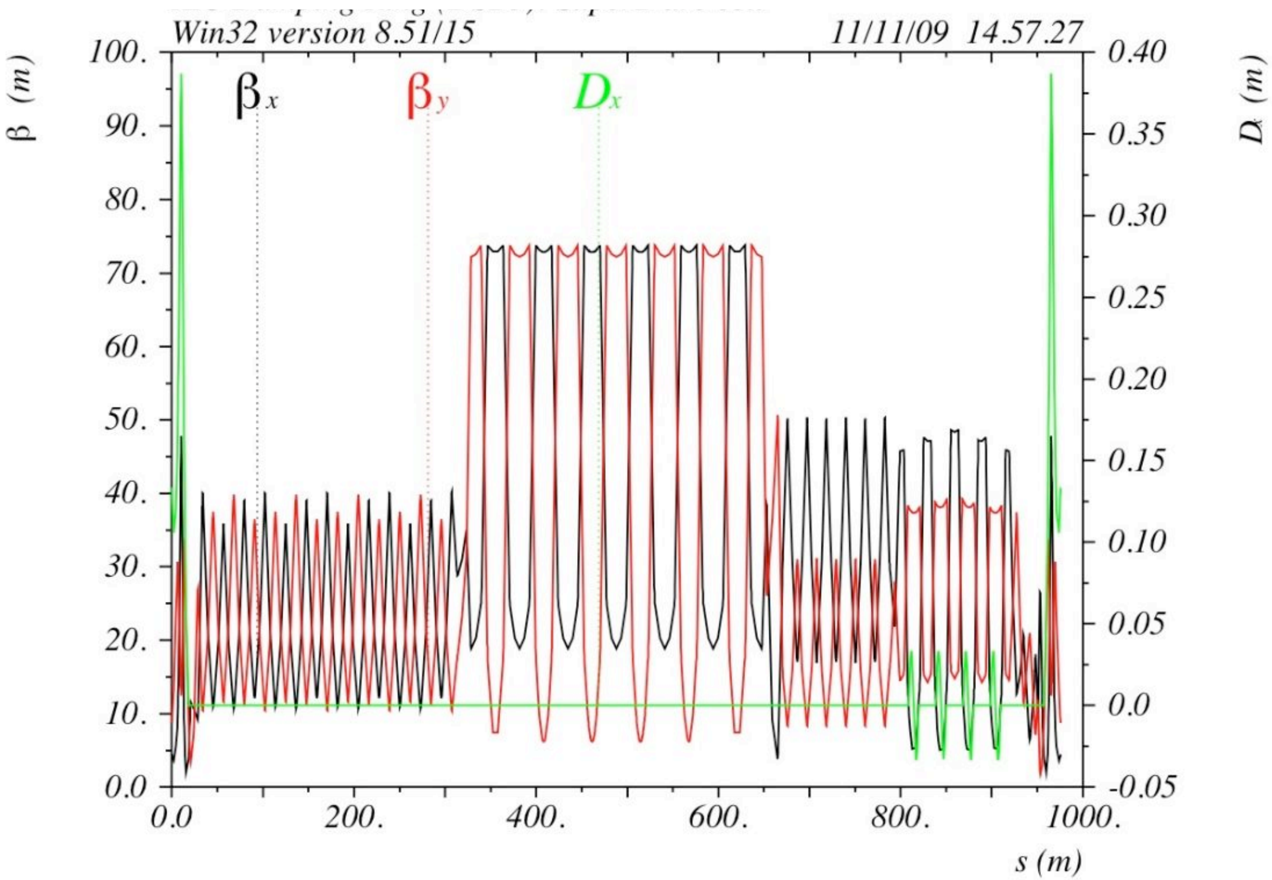


The arc lattice is based on the SuperB arc cells.

2 adjacent cells with very similar but with different phase advance: one is π and the other ~0.75π.

By tuning the phase advance in the second cell, emittance and momentum compaction can be tuned.

Optical functions in the Inj/Extr straight section

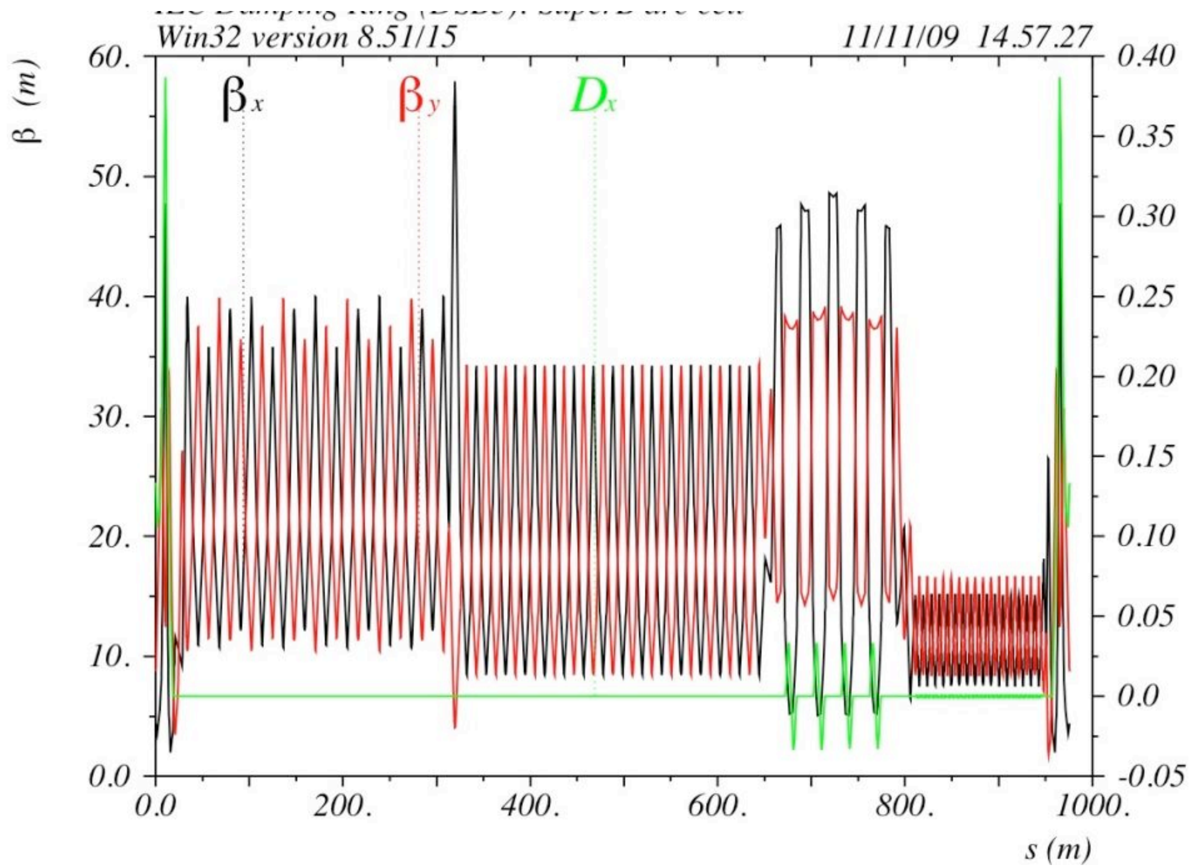


The e^- and e^+ ring are one on top of the other with counter-rotating beams

The injection line entering the electron ring is superimposed on the positron extraction line and vice versa

The lattice of the straight sections is made of the same building blocks as the 6.4km racetrack lattice (TILC08)

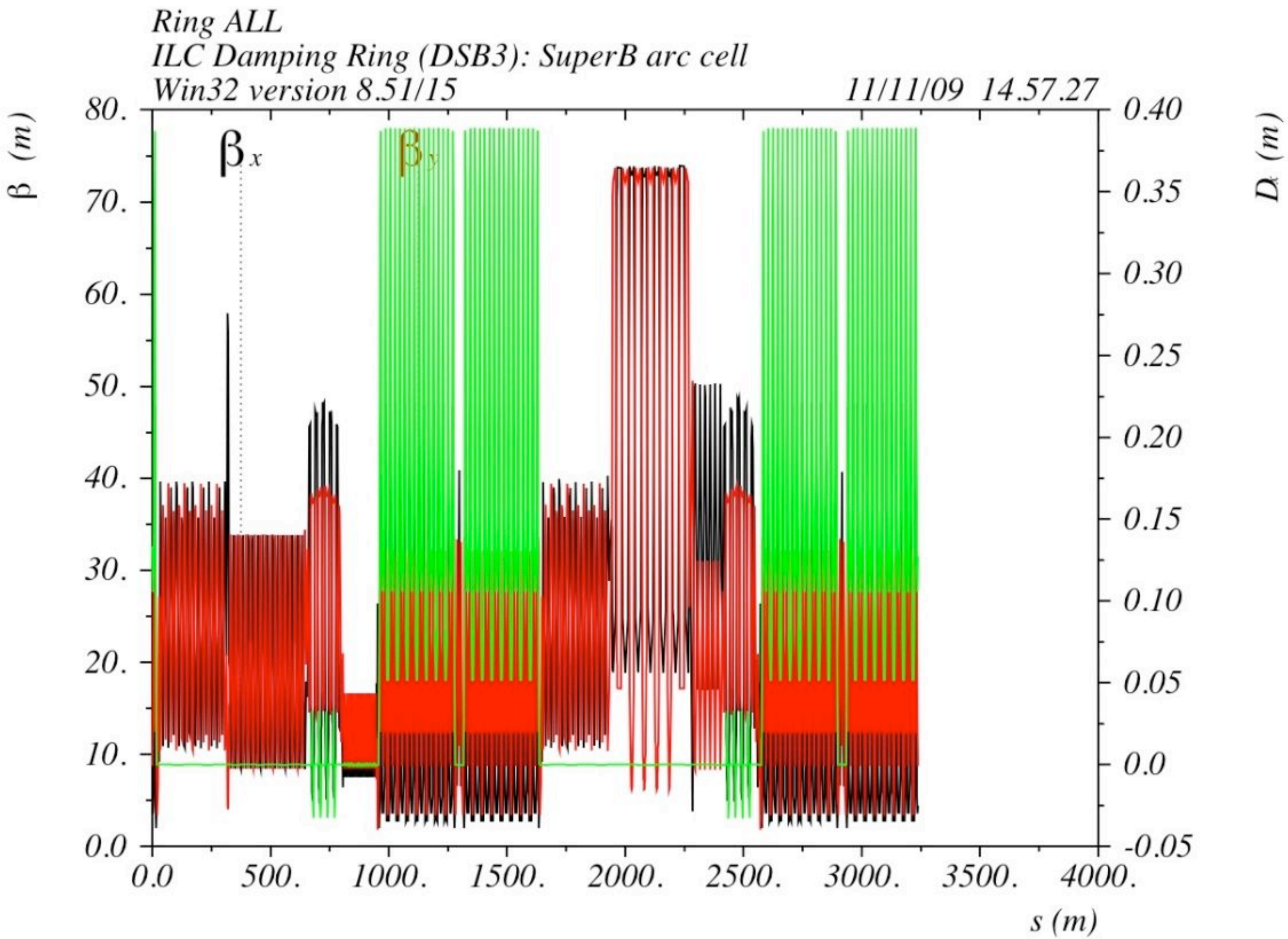
Optical functions in the RF/wiggler straight section



The wiggler straight is located downstream of the RF cavities in order to avoid damage by synchrotron radiation

The RF cavities for each ring are offset from the center of the straight so that they are not superimposed on top of each other

Optical functions of the 3.2km damping ring



M. Biagini