SuperB lattice (& its applications)

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SuperB lattice

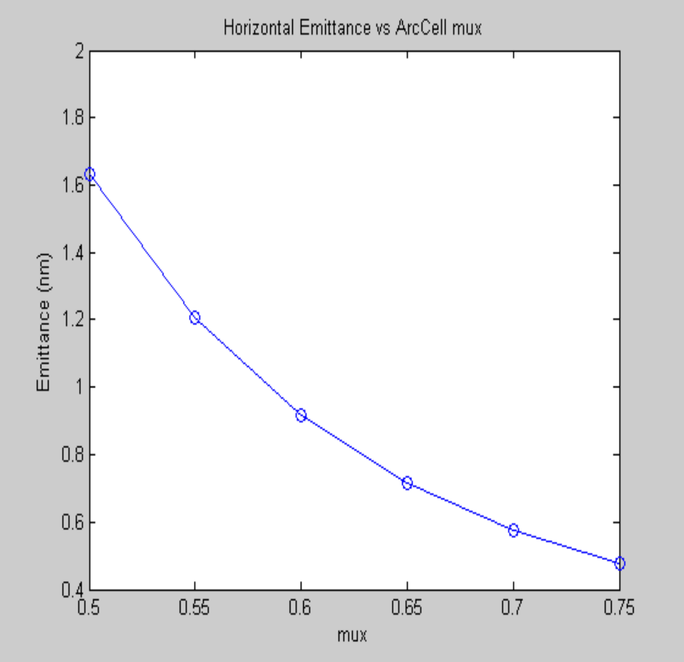
- SuperB ring lattice initially copied from the ILC-DR (TME)
- Adapted to SuperB requirements (similar emittance but longer damping times, and energy 7 and 4 GeV)
- Present Arc lattice has been optimized in order to get the design parameters with the constraint of reusing the PEP as much as possible and minimize ring circumference, power and overall cost
- Present solution is a very good compromise between the different requirements. However we are still analyzing other options that improve some parameter at the expense of others

SuperB Rings

- 2 rings: LER at 4 GeV and HER at 7 GeV
- Two Arcs
  - Provide the necessary bending to close the ring
  - Optimized to generate the design horizontal emittance
  - Correct arc chromaticity and sextupole aberrations
- Interaction Region
  - Provides the necessary focusing for required small beam size at IP
  - Corrects Final Focus chromaticity and sextupole aberrations
  - Provides the necessary optics conditions for Crab Sextupoles
- Dogleg
  - Provides crossing on the opposite to IR side of the ring
- LER Spin Rotator
  - Includes solenoids in matched sections adjacent to the IR
- RF system
  - Up to 24 HER and 12 LER cavities in the long straight section opposite to IP

SuperB Arcs lattice

- Natural emittance decreases by increasing the arc cell μ_x (but dynamic aperture shrinks with larger μ_x)
- The lattice is based on decreasing the natural emittance by increasing μ_x/cell, and simultaneously adding weak dipoles in the drift spaces in the cell to decrease the synchrotron radiation
- Just one type of cell with μ_x=0.75, μ_y=0.25 to reduce the emittance as much as possible
- Sextupoles are missing in some cells (one third) to ensure that they are all paired at –I in both planes to get the best dynamic aperture

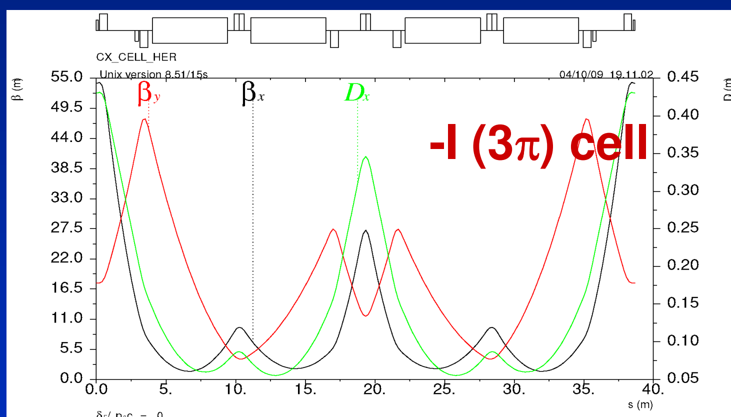


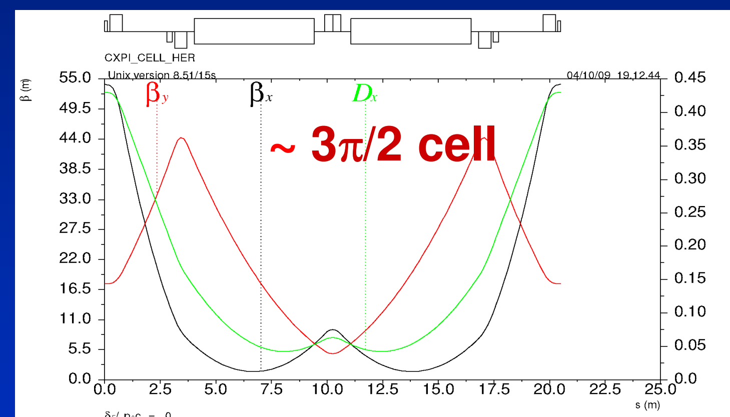
x-emittance vs μ_x/cell

SuperB Arc Cells

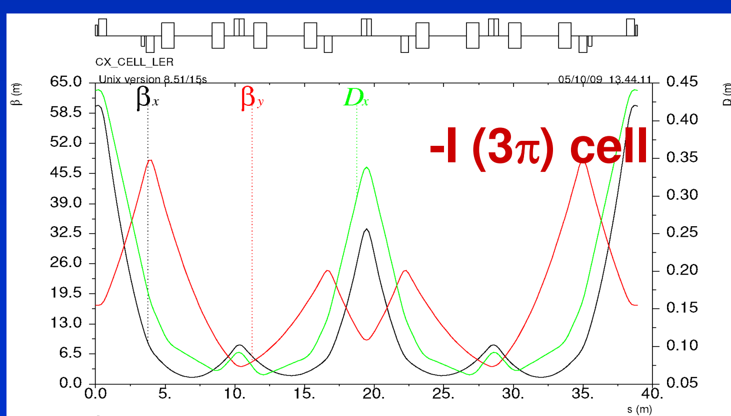
- 2 cell types: -I cell with $\mu/2\pi$ = 1.5 (x)/0.5(y), and a cell with $\mu/2\pi$ ~0.78(x)/0.2 (y)
- Two variations of each type: longer and shorter for outer and inner arcs
- Optimized for low emittance and maximum momentum compaction
- Arc dynamic aperture increased since all sextupoles are at –I in both planes (although x and y sextupoles are nested)
- Emittance smaller and adjustable by varying the betas and etas in the Arc

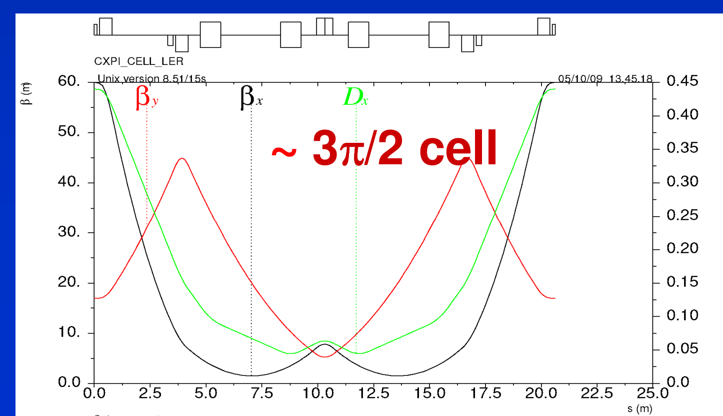
HER





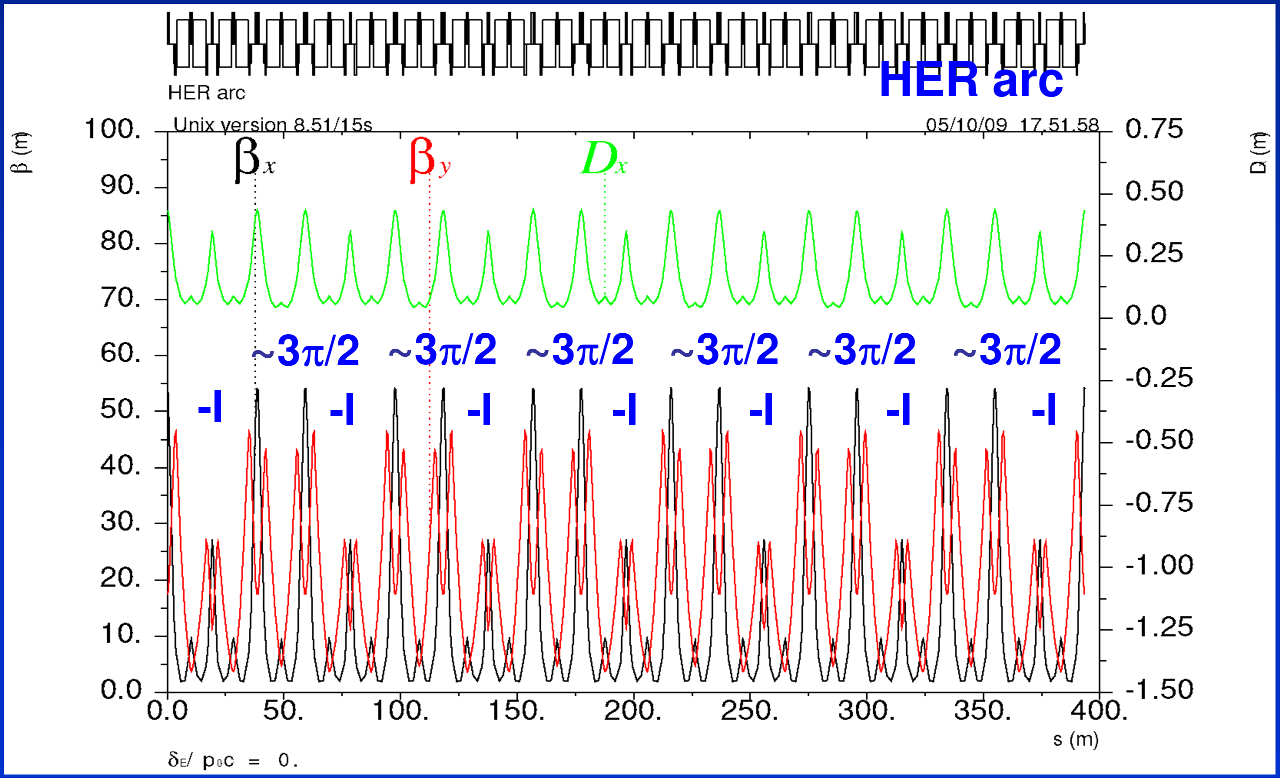
LER



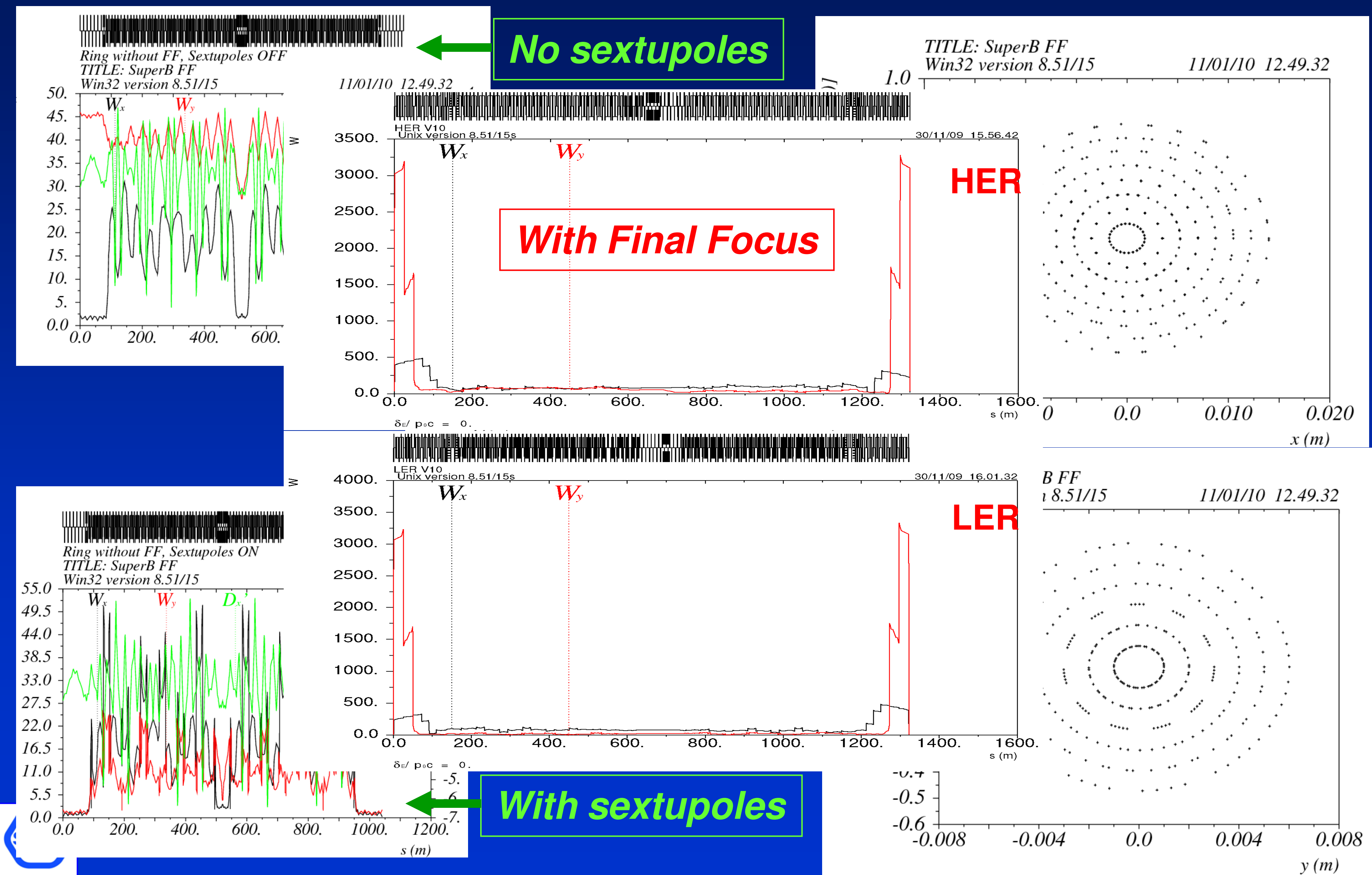


SuperB Arcs

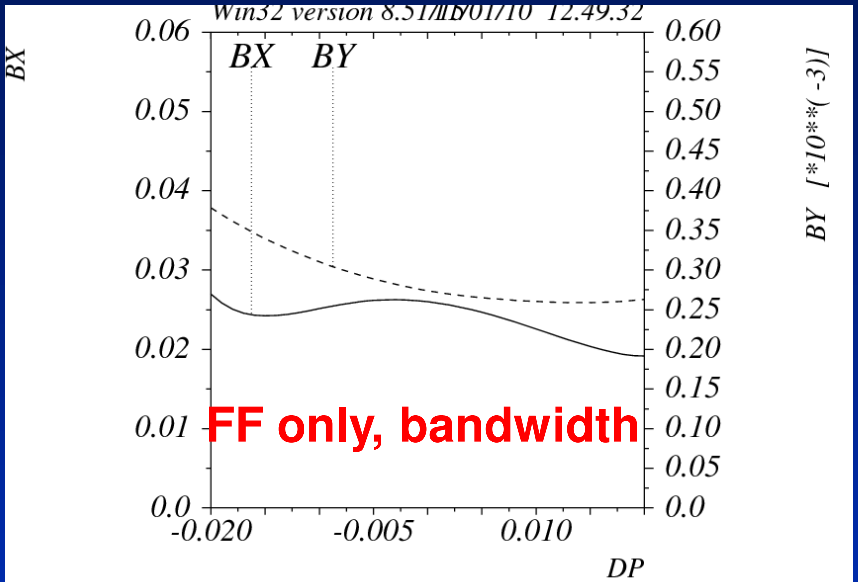
- Each arc contains seven -I cells and six 3π/2 cells
- -I sextupole pairs for local compensation of sextupole geometric aberrations
- Sextupole arrangement: sext-nosext-sext-sext-nosext-sext etc…
- ~π/2 phase between sextupole pairs for local chromatic beta compensation
- One shorter and one longer arc for 2 m separation between HER and LER
- Optimized for large arc transverse acceptance: >100 beam sigma
- Designed to reuse the PEP-II magnets

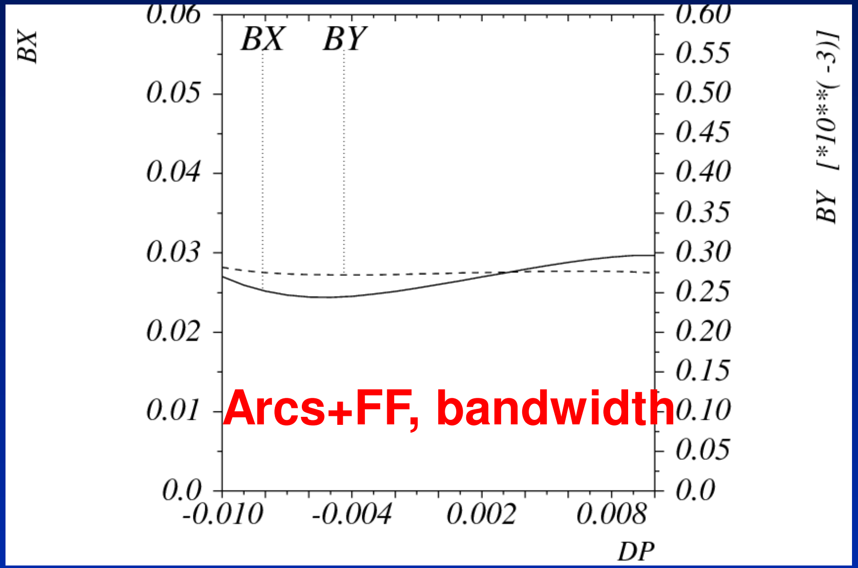


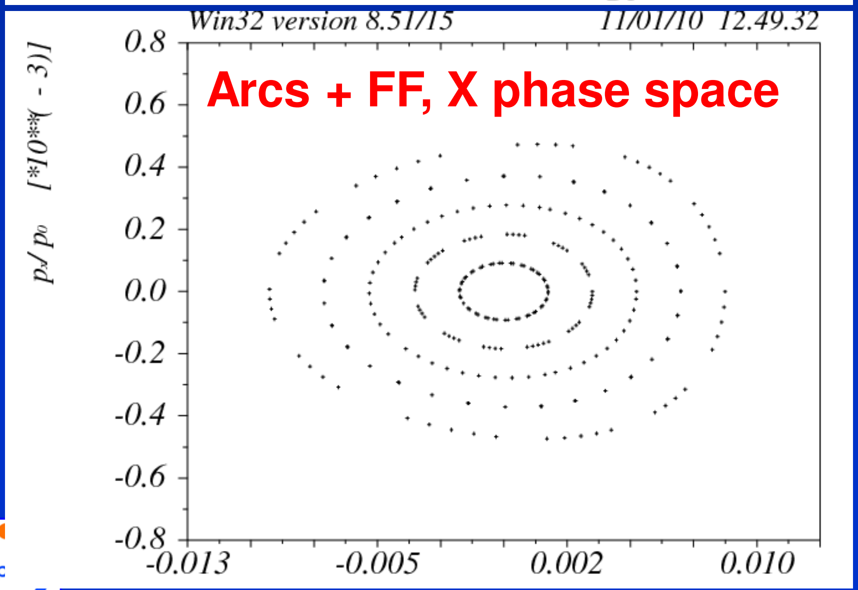
Arcs W-functions and phase space plots

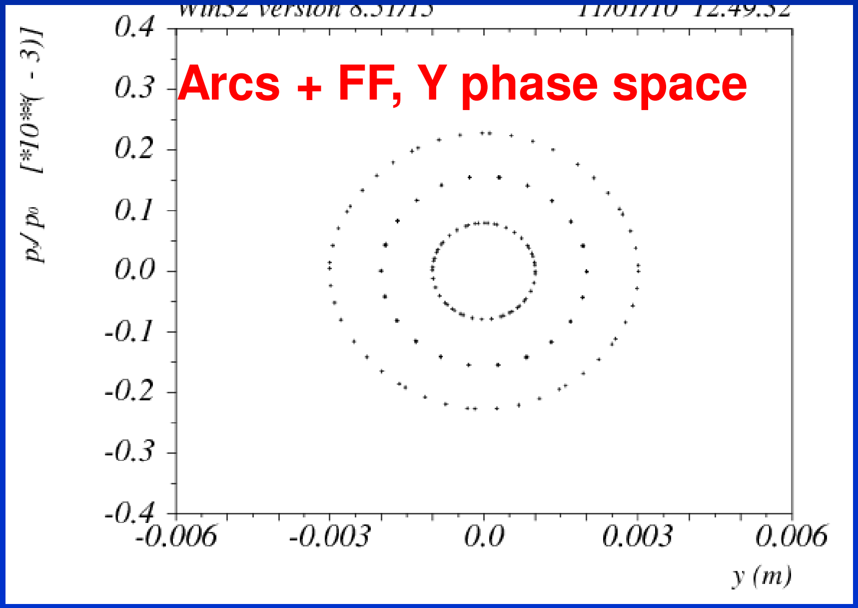


SuperB Arcs + Final Focus



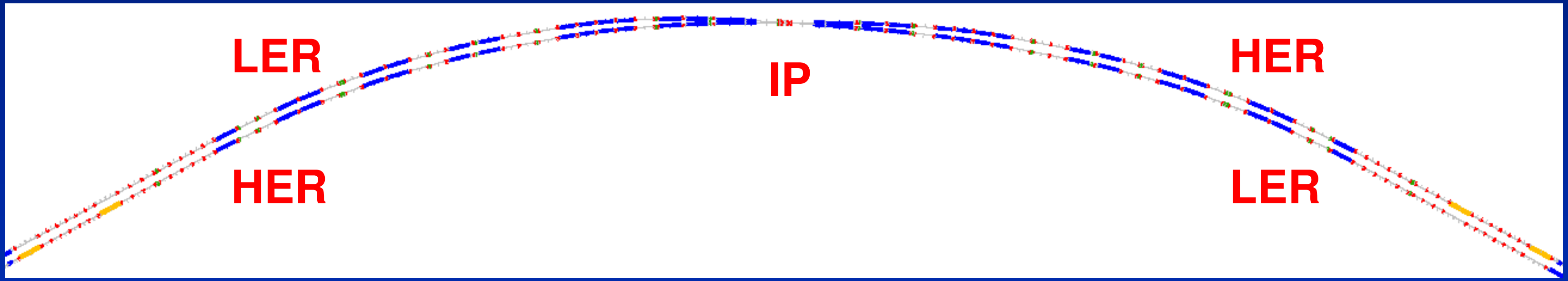


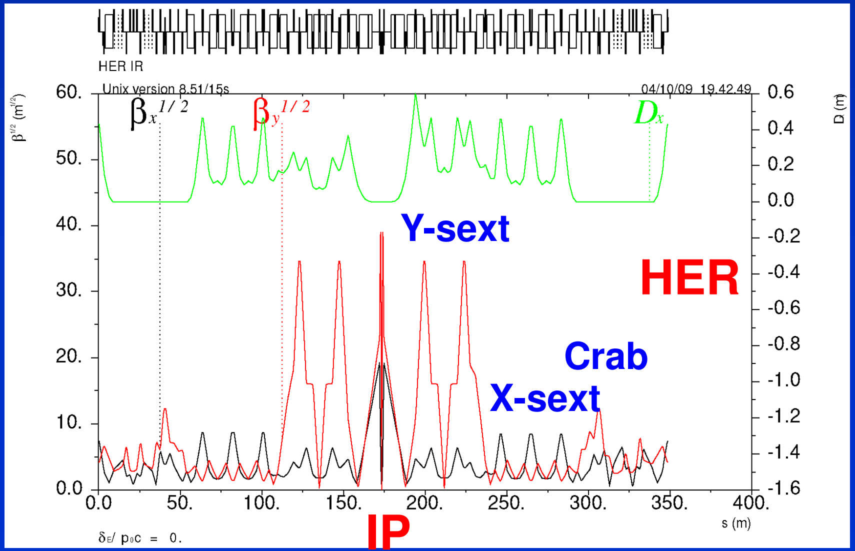


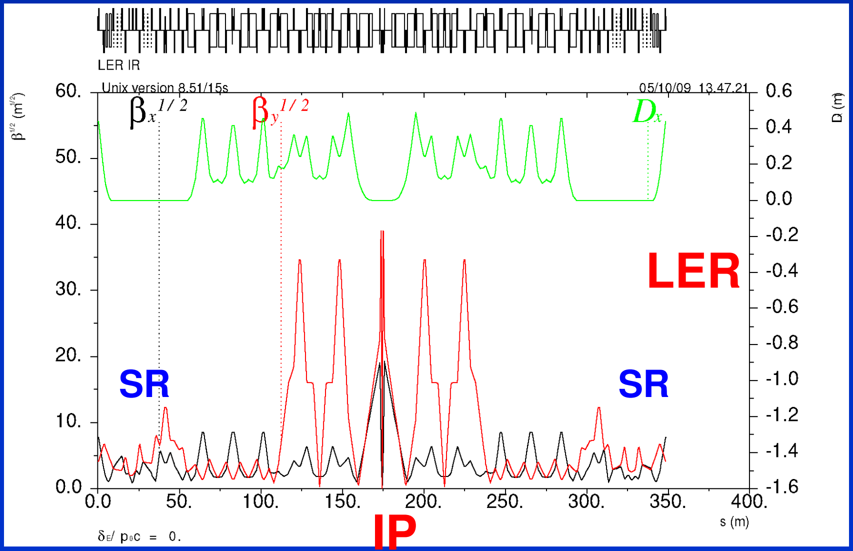


SuperB Interaction Region

- The IR layout is slightly adjusted to match the ring circumference
- The IR bending in LER is mirror symmetric with respect to IP for better match with spin rotators
- The IR bending in HER is asymmetric to provide 60 mrad crossing angle
- Total IR bending angle is 2 x 0.4963 rad = 0.9926 rad

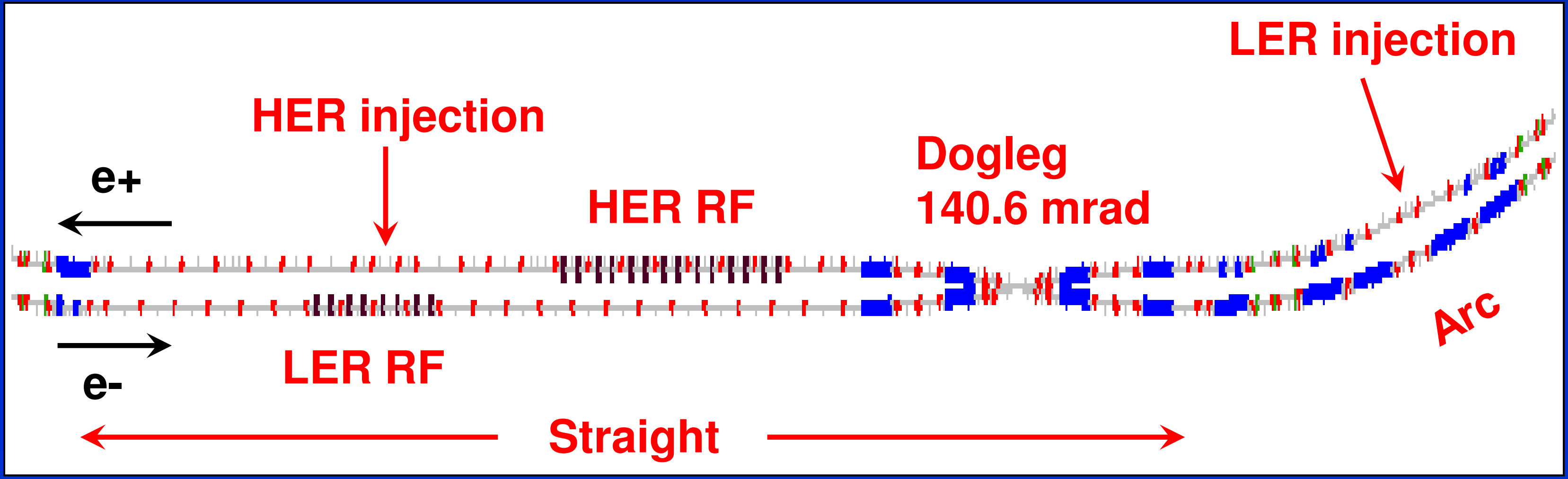




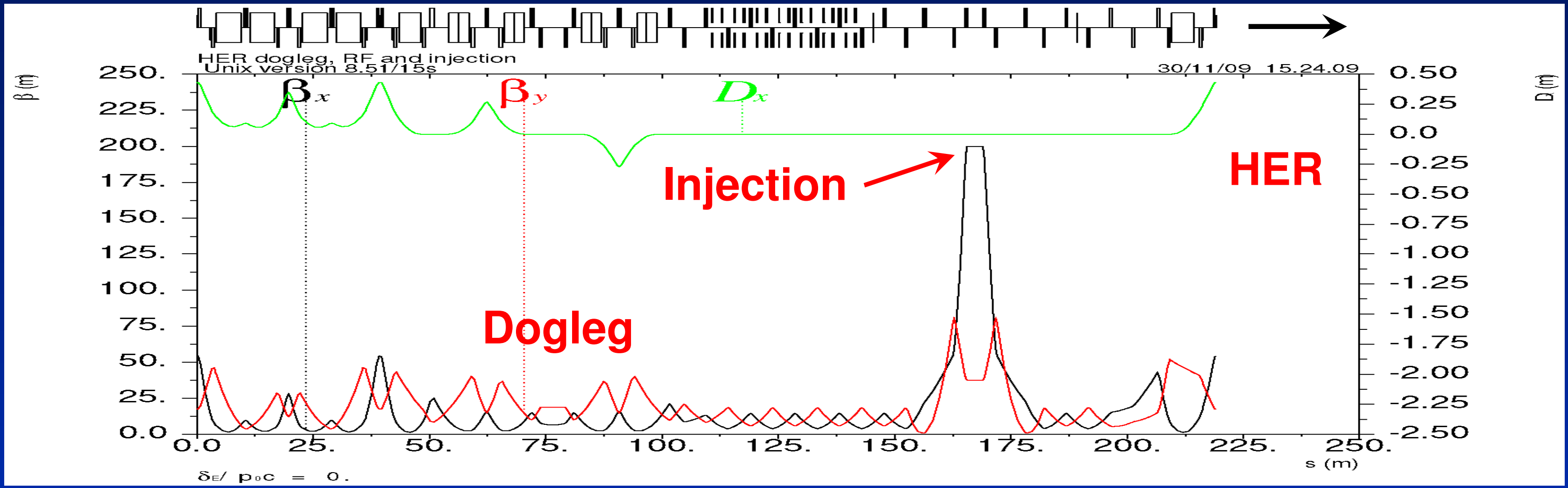


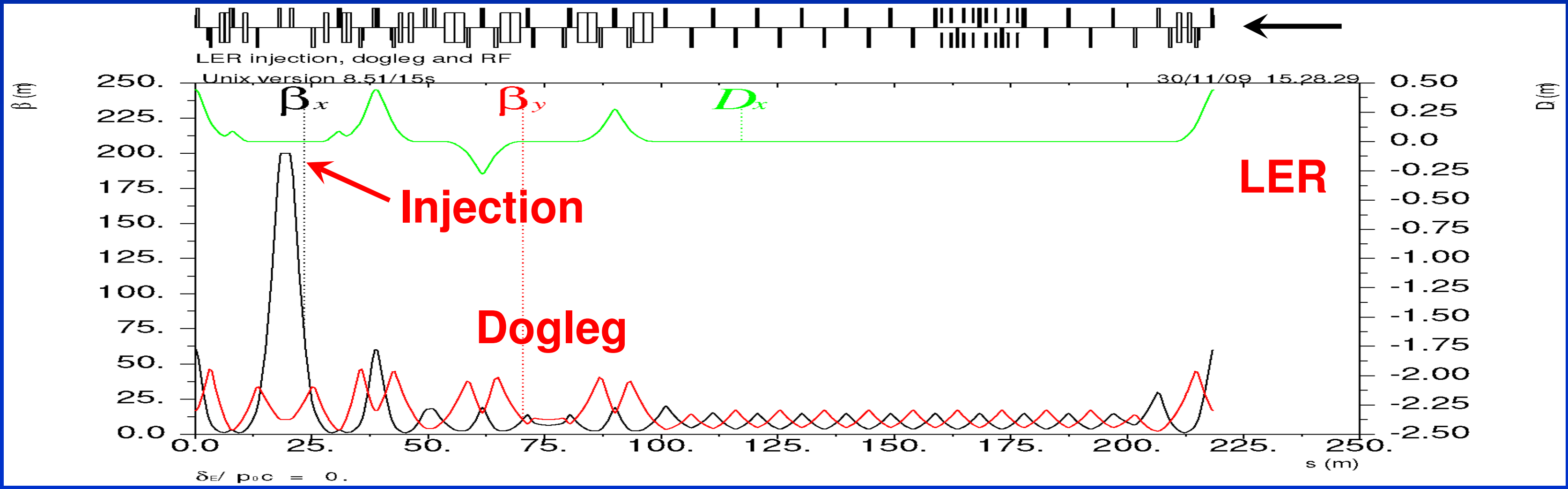
Long straight section with dogleg, injection and RF (opposite to IR)

- Dogleg at one side of the long straight to leave more space for RF and HER injection.
- In HER:
  - 14 RF cavities are inserted into the FODO cells after the HER dogleg.
  - HER injection section is inserted downstream of the RF.
- In LER:
  - 8 RF cavities are inserted at about the same location with the HER injection section.
  - LER injection section is inserted into the arc adjacent to the dogleg. It replaces the nearest -I arc cell.
- FODO cells are used for tune adjustment.



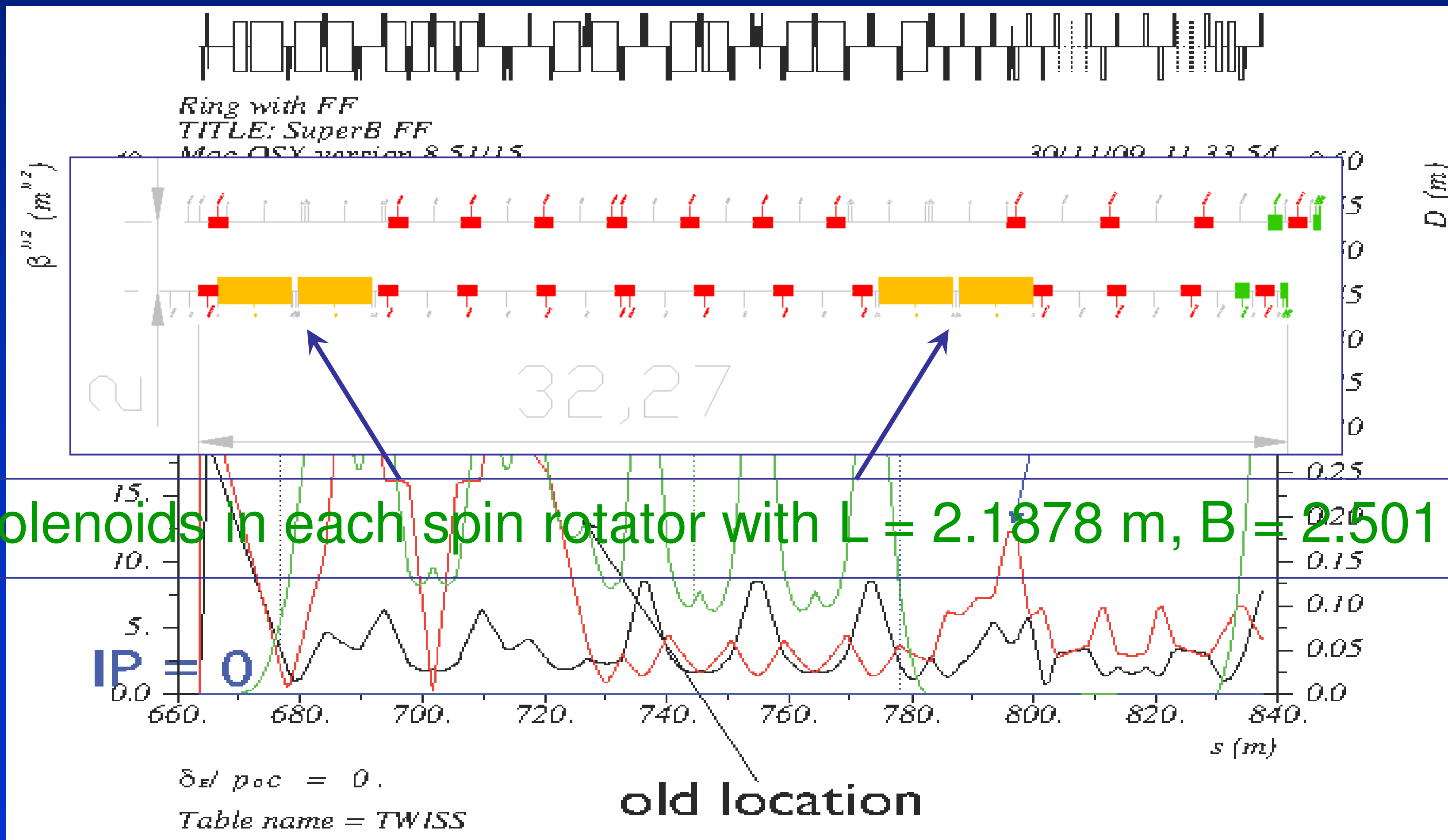
Long straight section optics



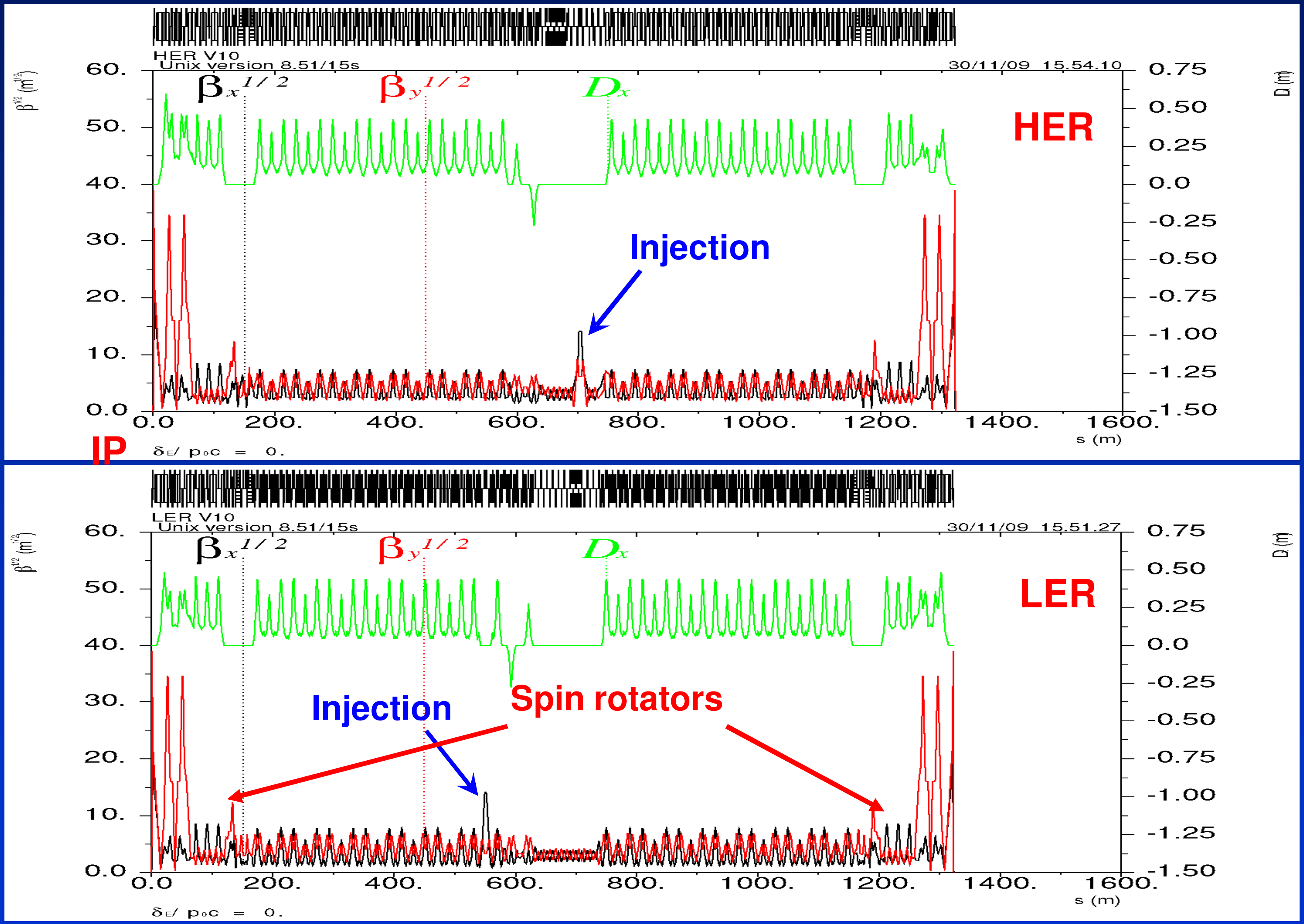


Spin Rotators in LER

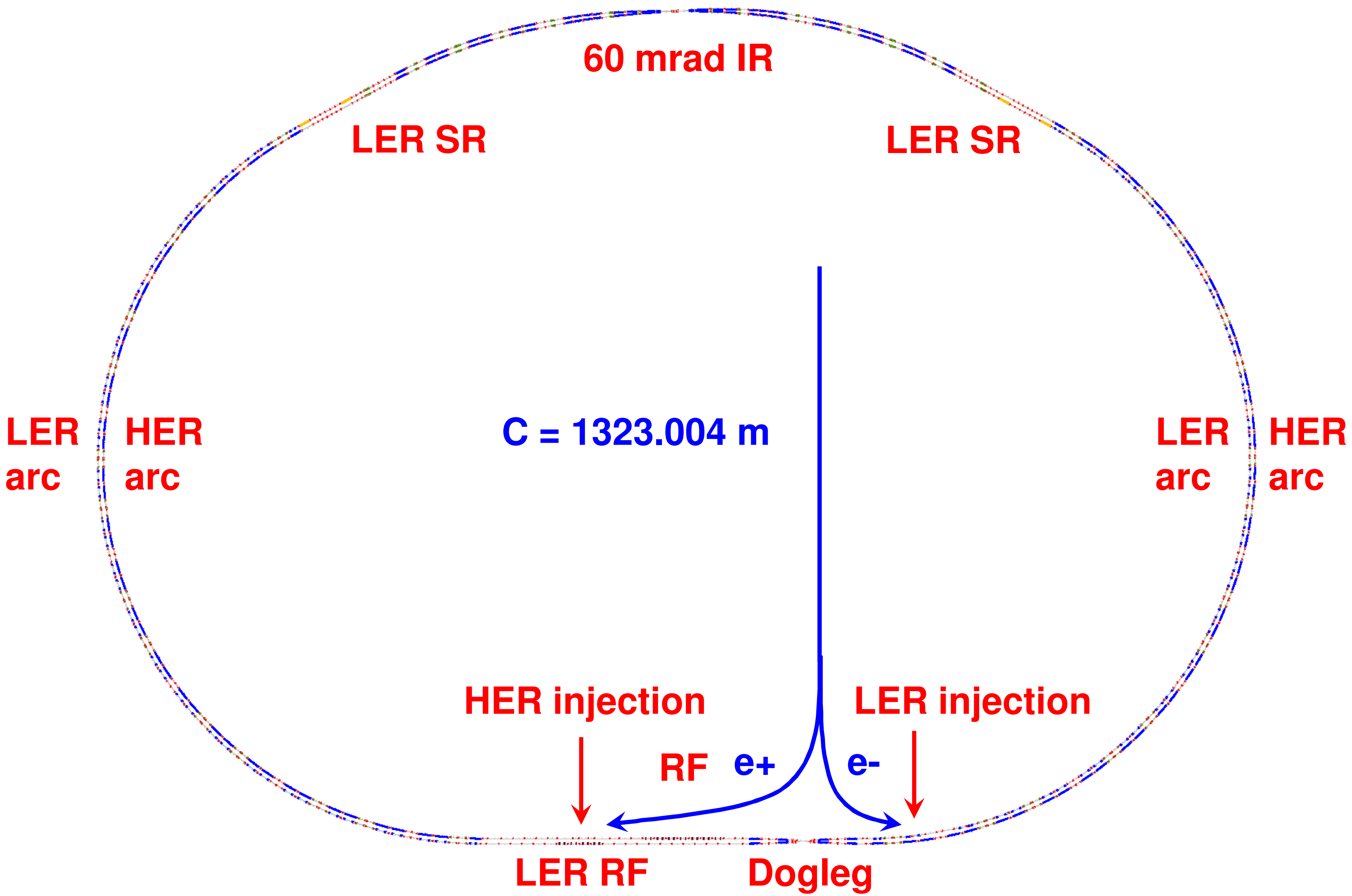
- Spin rotators are needed to rotate the injected transverse spin of electron beam into longitudinal at the IP (needed for Physics studies)
- The LER spin rotator sections are located at each end of the IR
- The spin rotator optics is matched without affecting the LER geometry



Complete ring optics



Layout



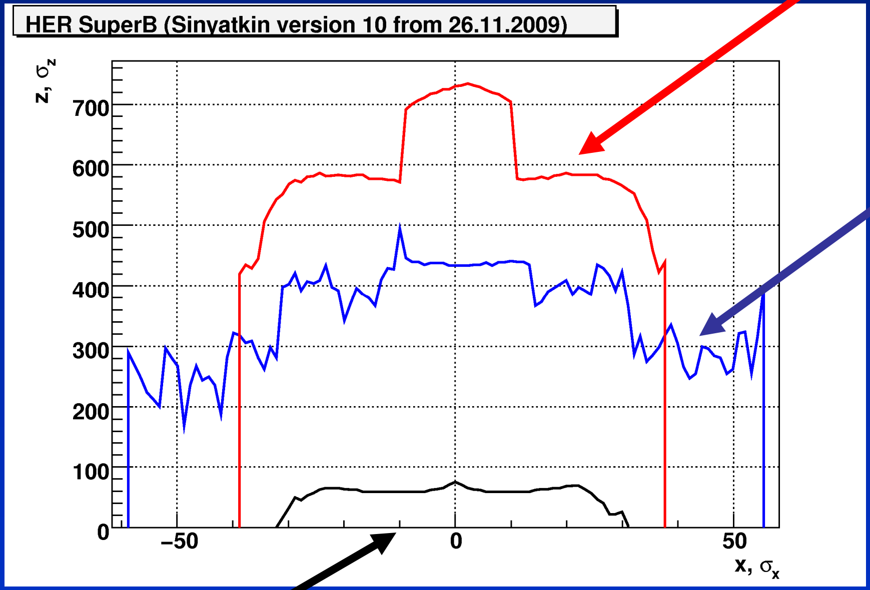
60 mrad IR
LER SR
LER SR
LER arc
HER arc
C = 1323.004 m
LER arc
HER arc
HER injection
LER injection
RF
e+
e-
LER RF
Dogleg

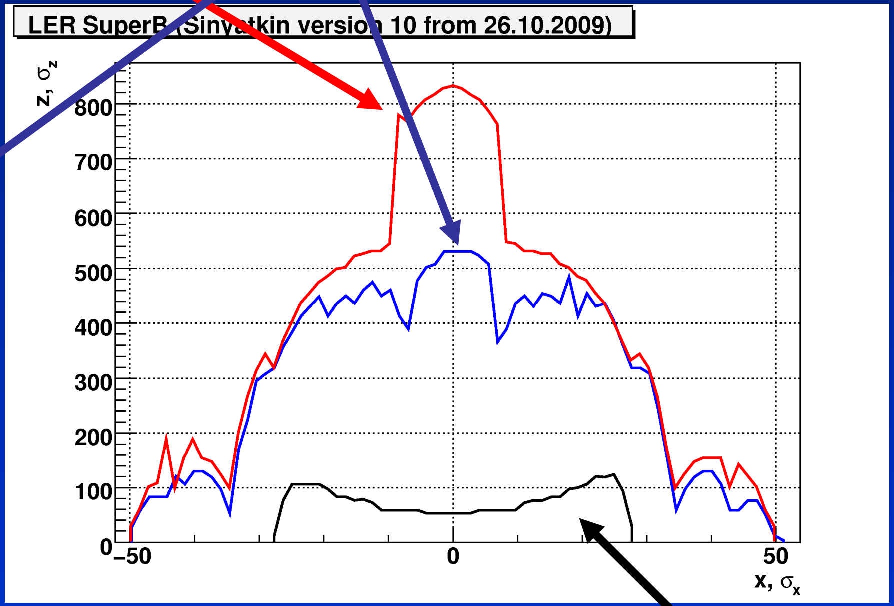
Dynamic aperture optimization (in progress)

Asymmetric lattice of HER IR: sextupoles before and after IP are different

IR Correction

IR + CRAB Correction





Original

HER

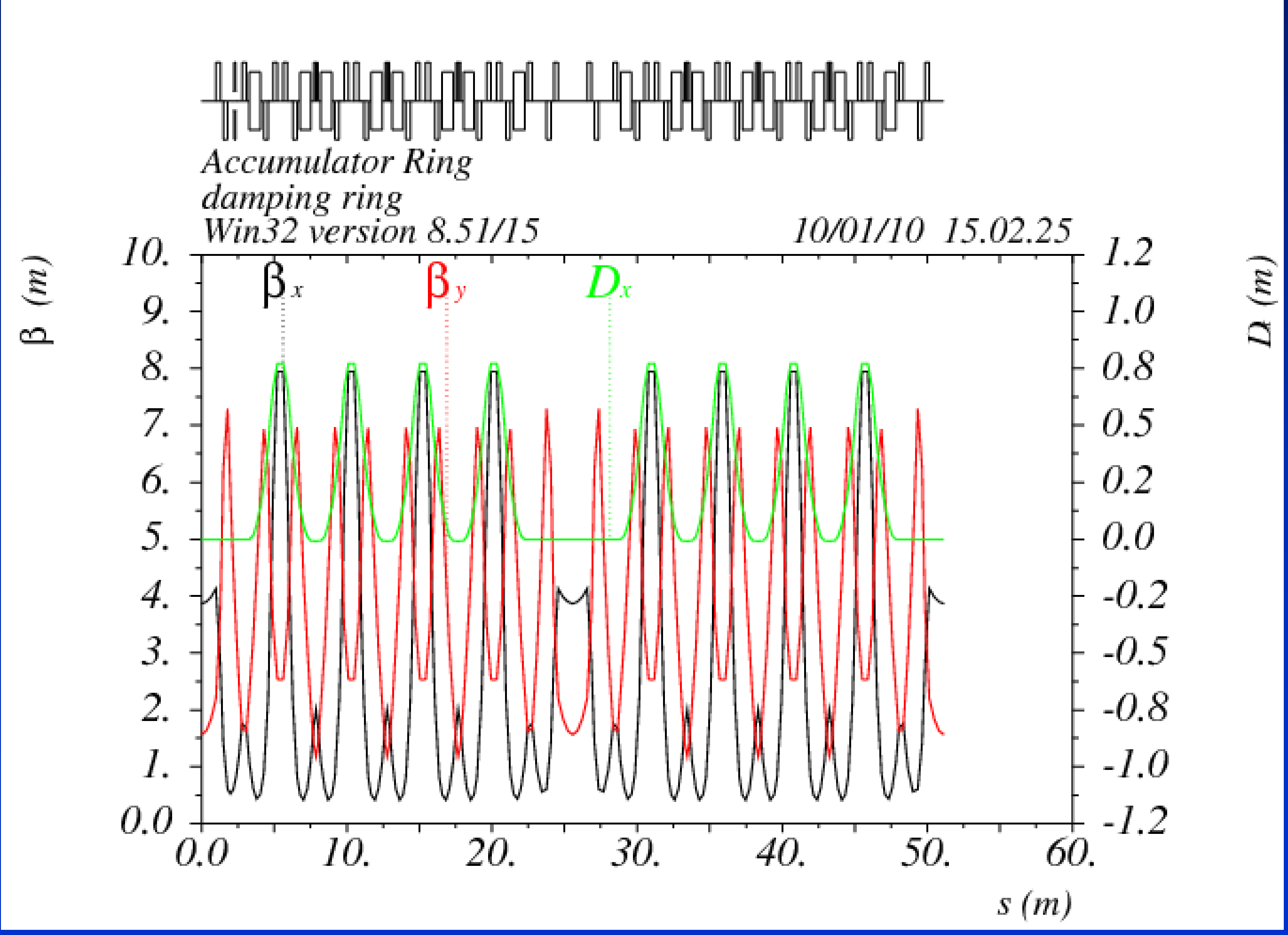
LER

Original

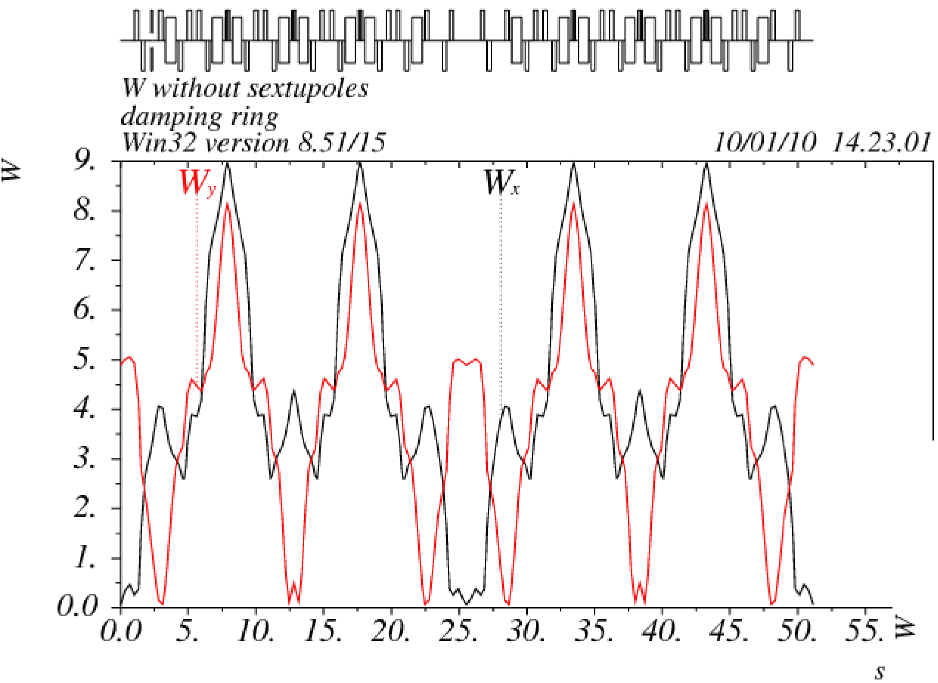
SuperB Damping Ring

- Application of the SuperB cell design, just one type of cell
- Cell has one dipole, split in two parts with a horizontally focusing quadrupole in between, surrounded by two quadrupole doublets
- The phase advance per cell is $0.75*2\pi$ in the horizontal plane and $0.25*2\pi$ in the vertical one, which helps in making the aberrations introduced by the chromaticity correcting sextupoles less harmful
- The ring consists of two identical parts: each one hosts three basic cells, with half dispersion suppressor on each side
- There are two dispersion free long sections for injection and RF. Each one has a 2.0 m straight for the injection septum and two 1.0 m straights, one on each side, for the kickers, with 90° phase advance between kickers and septum

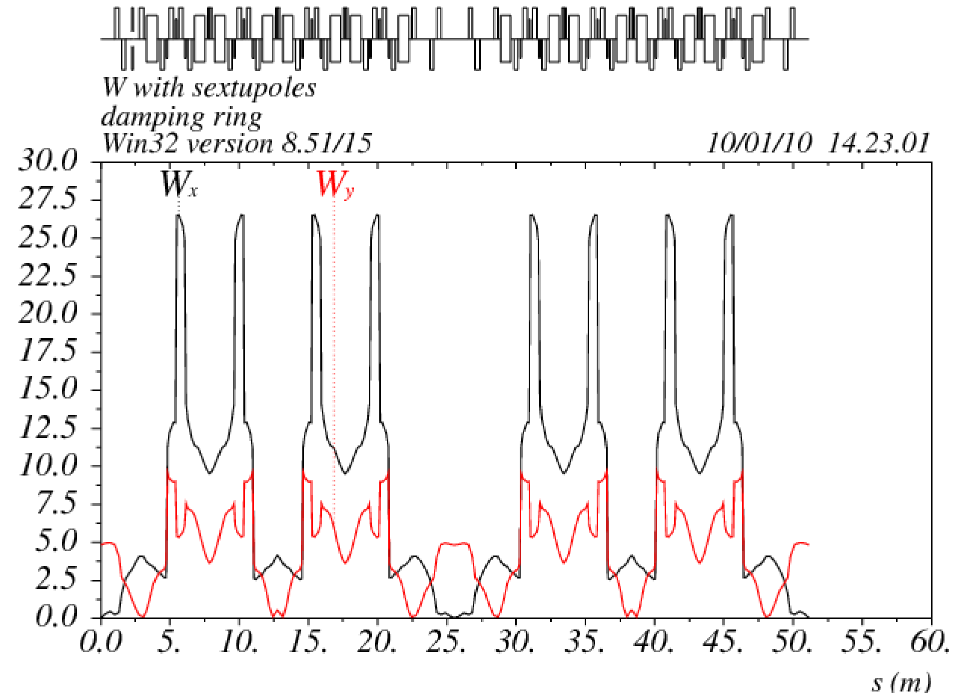
SuperB-DR optics



SuperB-DR chromatic functions

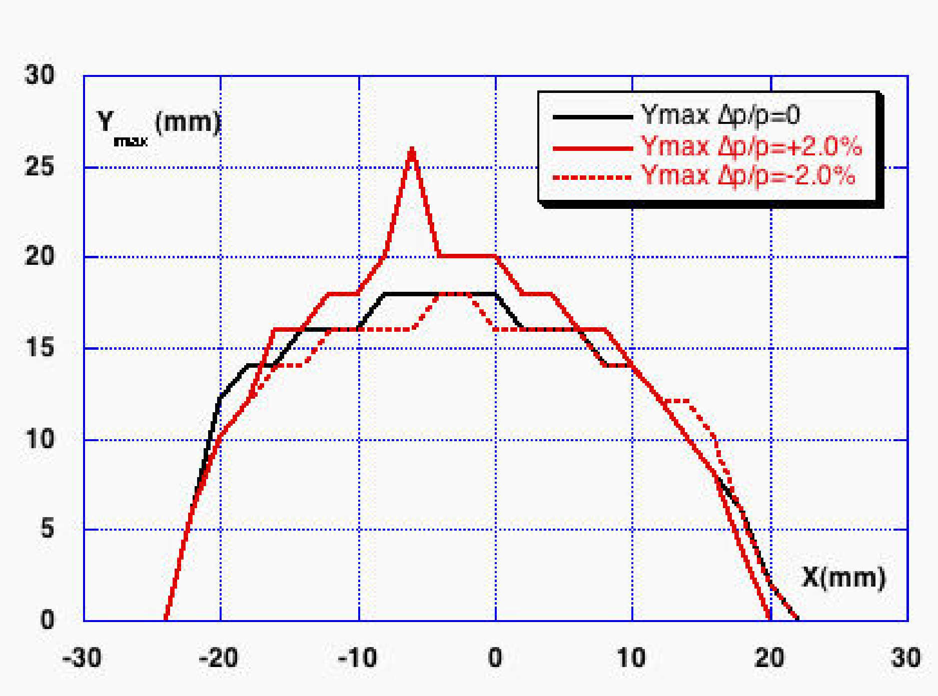


No sextupoles



With sextupoles

SuperB-DR Dynamic aperture

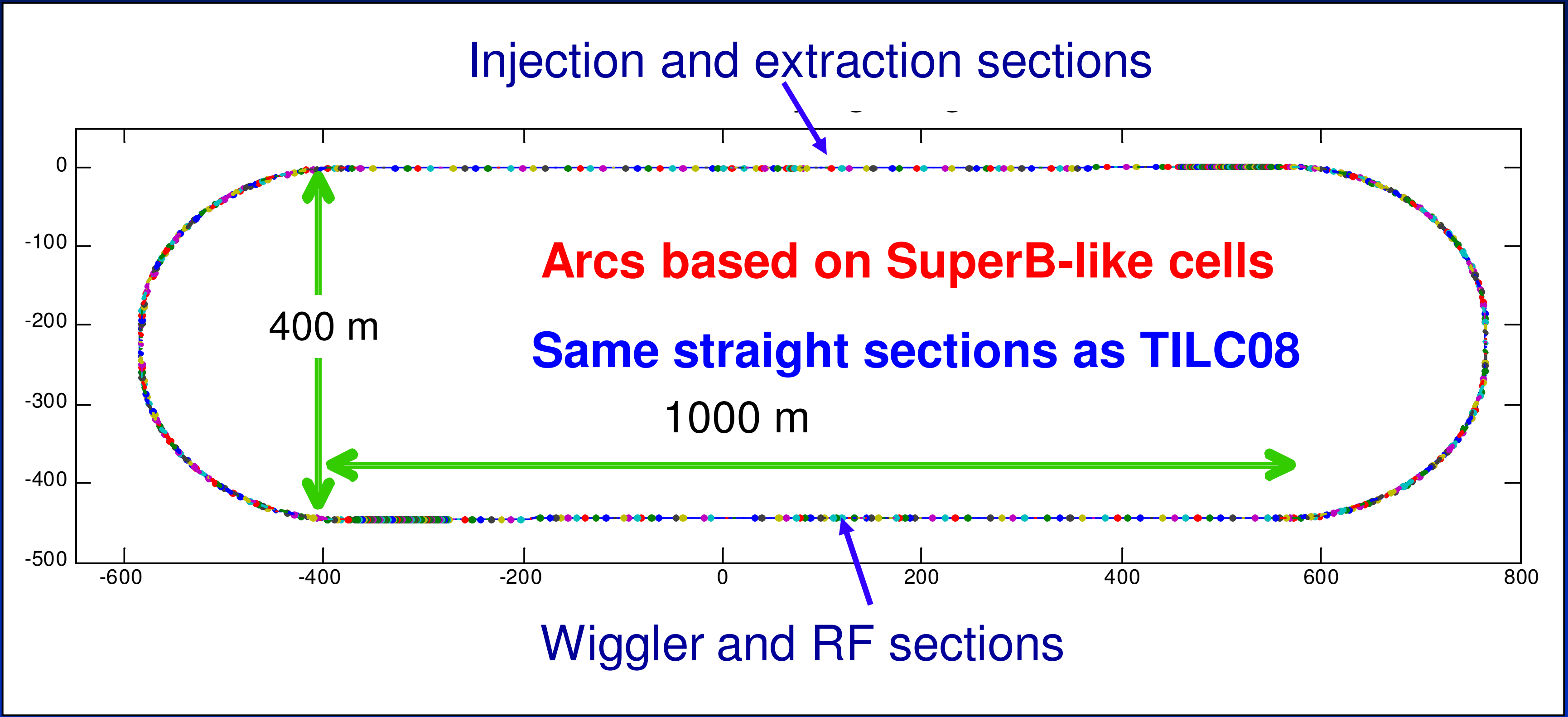


- The phase advance of the basic lattice cell ensures complete cancellation of the aberrations induced by the sextupoles if they are separated by two cells
- Due to the small number of cells (3 in each half ring) only two sextupoles can be used to correct chromaticity in each plane in a non-interleaved scheme, leading to extremely large required gradients
- An interleaved scheme with 8 horizontally focusing sextupoles placed at the boundary of each cell and 16 vertically focusing ones inside each quadrupole doublet in the cell has been adopted, obtaining a smooth distribution of moderate gradient sextupoles

3.2 Km ILC-DR

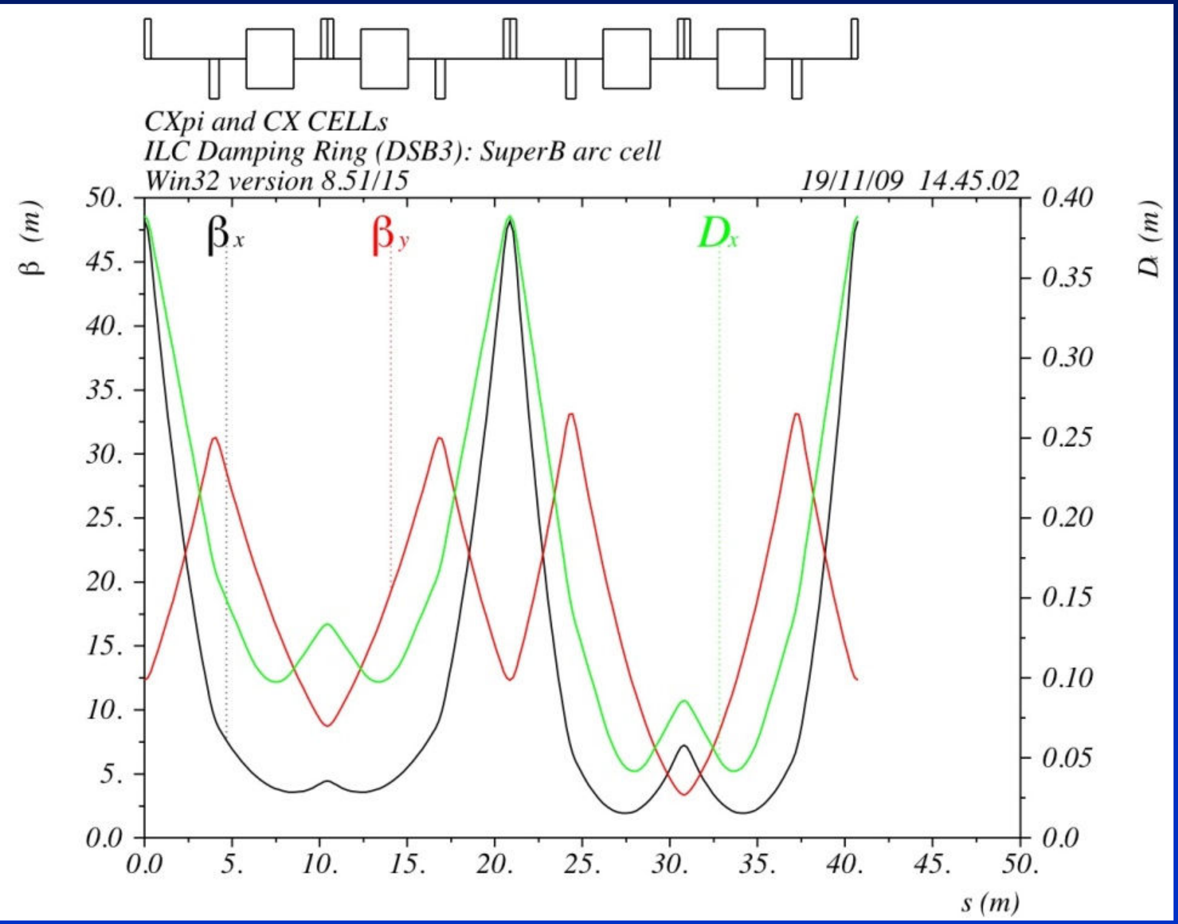
- Application of the SuperB cells to ILC-DR has been considered in order to reduce by a factor of 2 the DR length
- The SuperB cell has an intrinsic lower horizontal emittance (small reduction of wigglers number is possible)
- Flexibility in changing the emittance by changing the phase advance in the cell translates into momentum compaction tunability (requested)
- The 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 longer lattice

3.2 Km layout



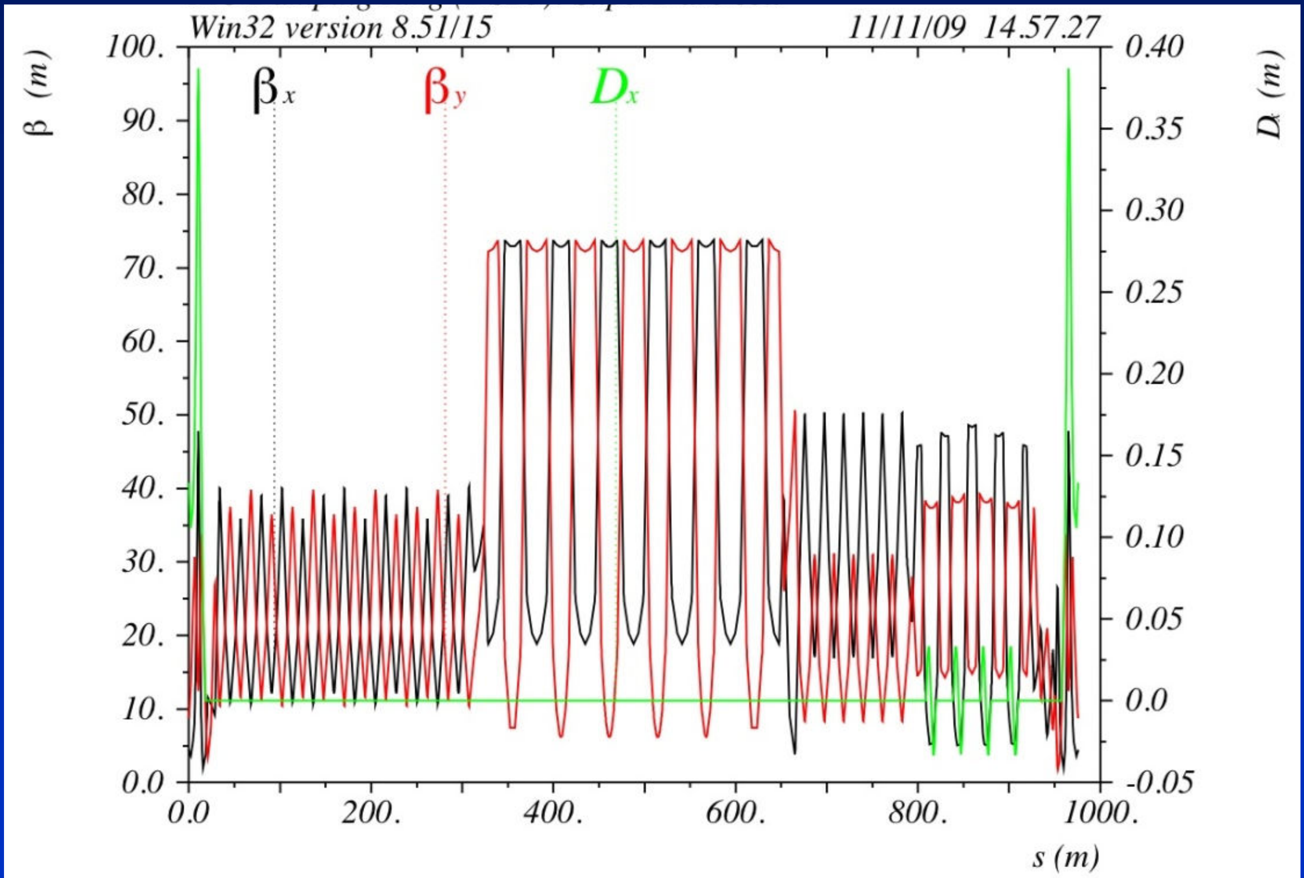
- **Injection/extraction lines of the two rings are superimposed**
- **RF cavities: 18 ⟹ 8**
- **Wigglers: 80 ⟹ 32**

3.2 km Arc cells



- The arc lattice is based on the SuperB arc cells design
- 2 adjacent cells with similar layout but 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

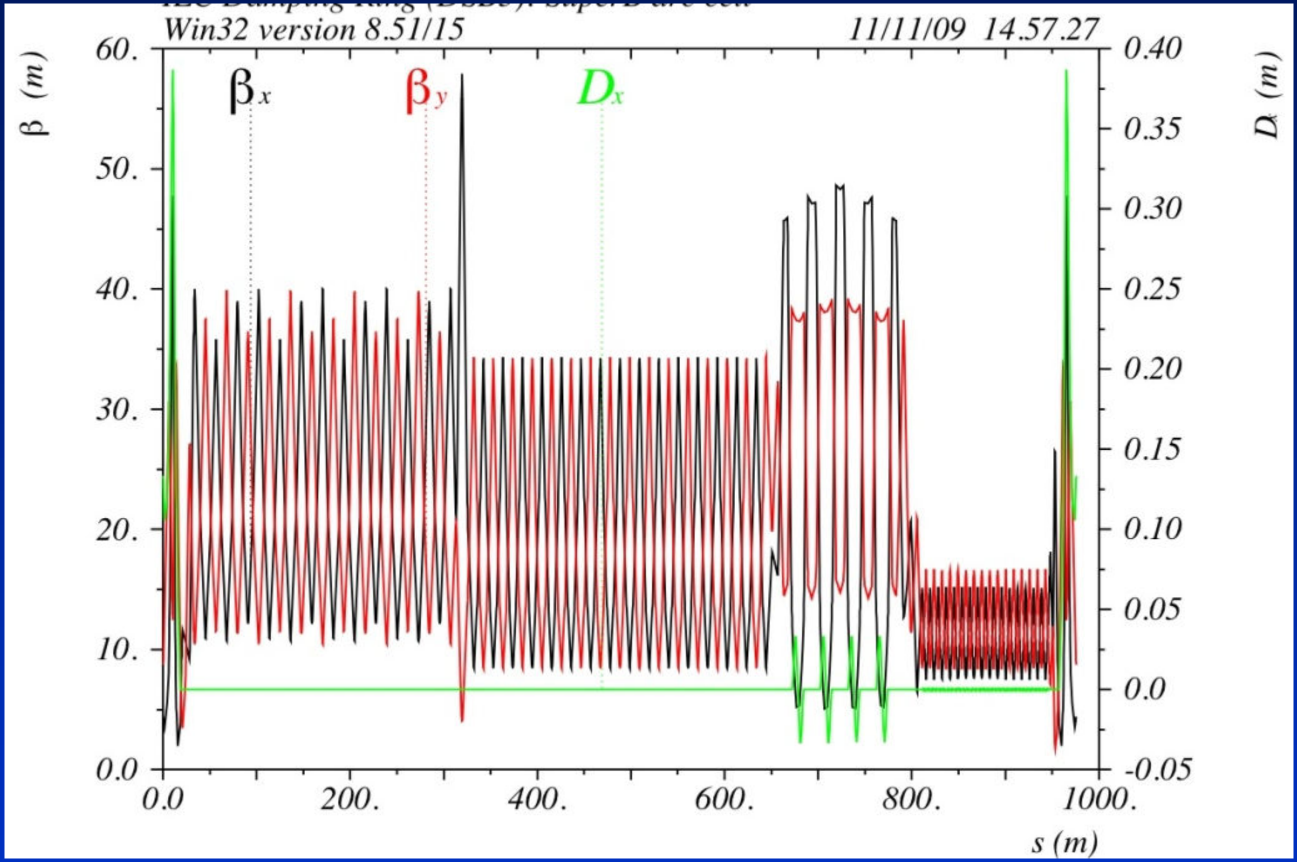
3.2 km Inj/Extr straight section



- 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)

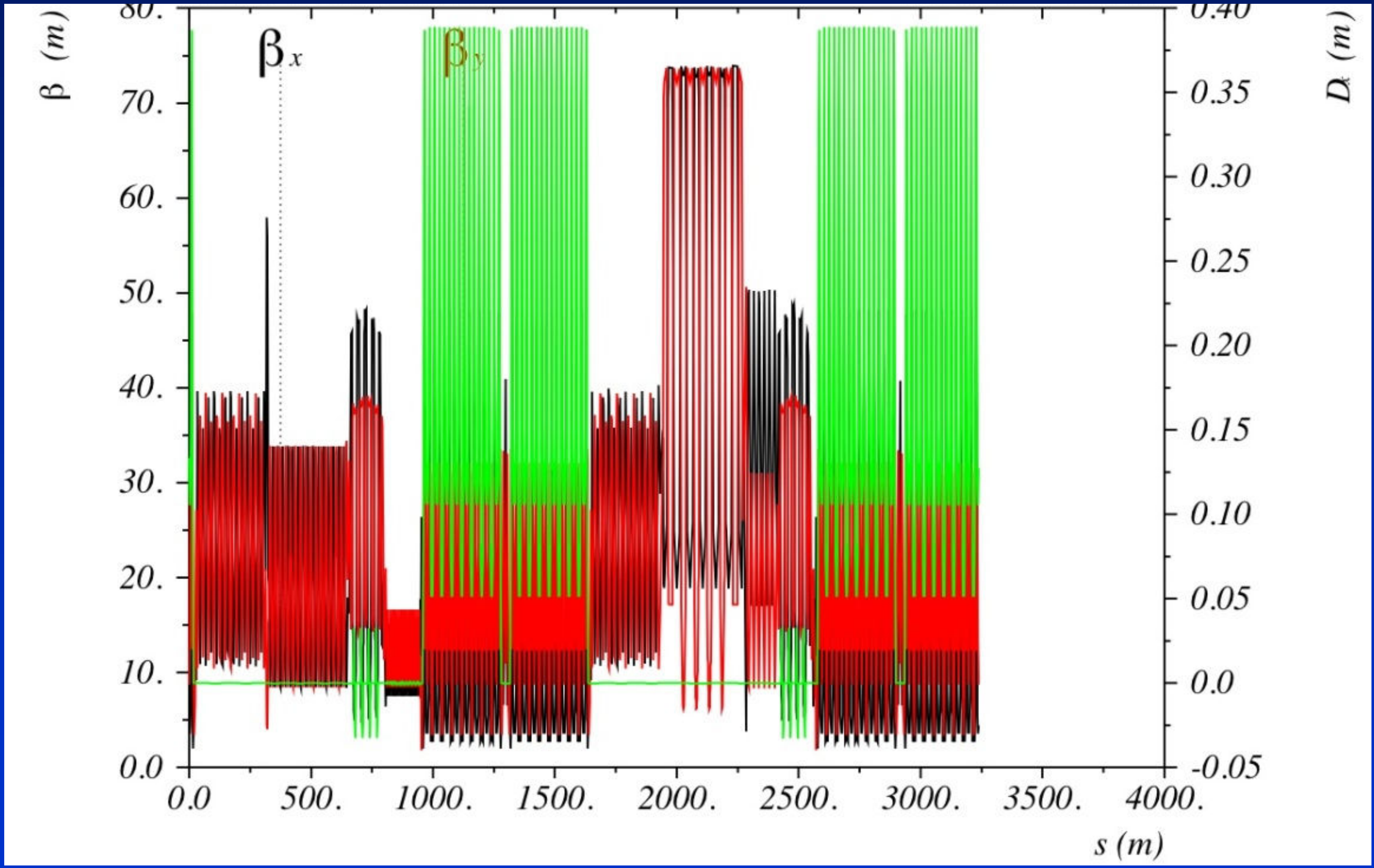
3.2 km RF/wiggler straight section



- 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

Optics of the 3.2 km ILC-DR



ILC-DR Lattice parameters

Circumference (m)	3238.22	RF frequency (MHz)		650	
Energy (GeV)	5	RF voltage (MV)		11	
Bunch length (mm)	6	Harmonic number		7021	
Natural X chromaticity	-102	Natural Y chromaticity		-66	
X phase advance/cell#1	0.72	0.6	0.65	0.75	0.78
Normalized ε_x (μm)	3.4	4.3	3.5	3.9	5.5
Momentum compaction x10^{-4}	1.8	1.4	1.5	2.1	2.7
Transverse damping time (ms)	20.6	21	21	20.2	19.6
Max β_x in cell #1 (m)	50	80	60	45	45
Max D_x in cell #1 (m)	0.4	0.3	0.3	0.5	0.6

Example of emittance and momentum compaction tunability

Conclusions

- The SuperB lattice appears to be very flexible:
  - Allows for reaching low emittances without using wigglers, saving on power
  - Allows for tuning emittance and momentum compaction by changing the phase advance in the acr cells
  - Allows for a similar design, and properties, for 7 and 4 GeV rings
  - The chromatic correction in the arcs is simple and effective
- All the previous in spite of the constraint of reusing the PEP-II magnets
- A straightforward application to the design of the SuperB-DR shows good properties and large dynamic aperture
- For the ILC-DR the presence of the two long straights is a complication, possibly limiting the dynamic aperture, since local correction of the chromaticity there is not possible. Work is in progress to choose the most suitable arc cells layout