Super-B Factory

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Collider Retreat 24th Feb. 2010

Jefferson Lab
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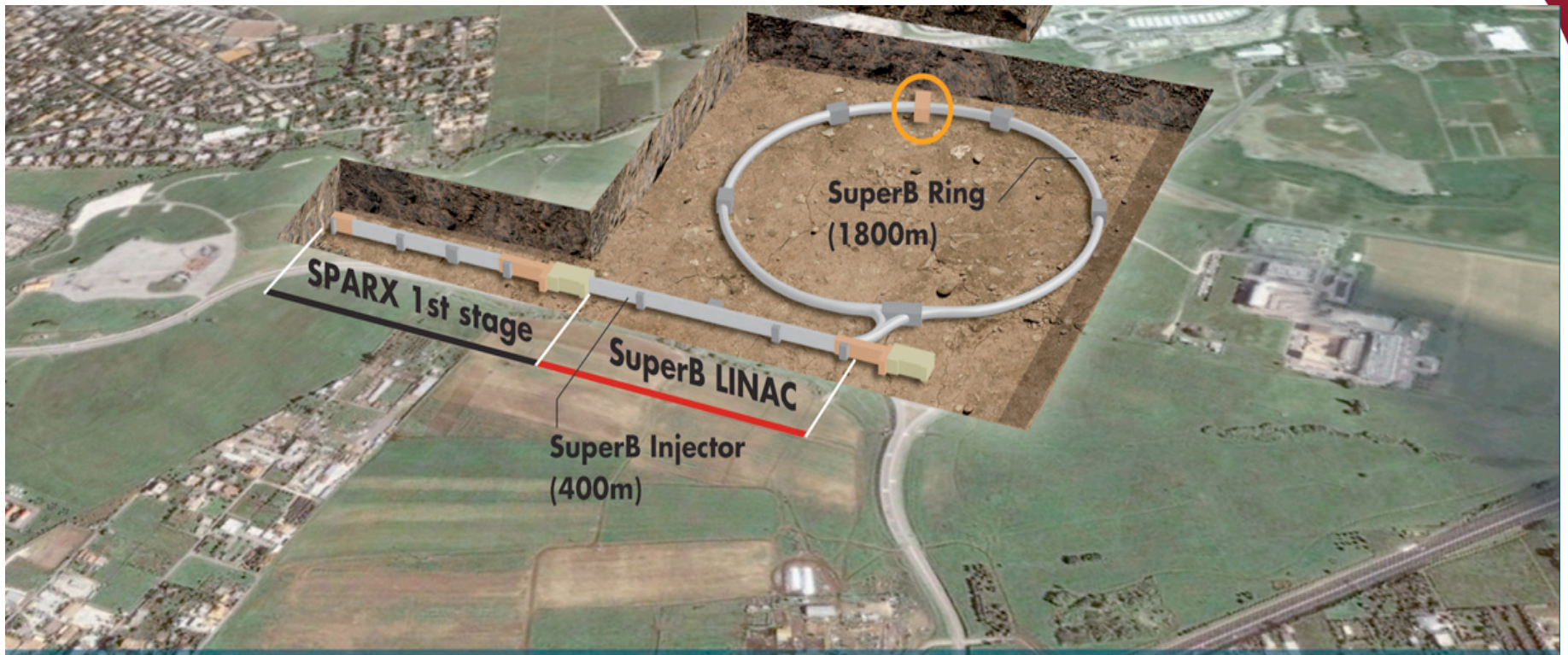


Underground tunnel complex superimposed on the site. Electrons and positrons will circulate in opposite directions in the ring, colliding at the interaction point indicated by the orange circle, where the experimental apparatus will be located. The black line shows the approved SPARX machine for synchrotron radiation, the red line shows the additional linear accelerator for SuperB.

Beam Parameter

Parameter	Nominal Parameters LER	Nominal Parameters HER	Upgrade Parameters LER	Upgrade Parameters HER	Ultimate Parameters LER	Ultimate Parameters HER
Particle type	e^+	e^-	e^+	e^-	e^+	e^-
Energy (GeV)	4	7	4	7	4	7
Luminosity ($cm^{-2}s^{-1}$)	1.0×10^{36}		2.4×10^{36}		3.4×10^{36}	
Circumference (m)	2250		2250		2250	
Revolution freq. (MHz)	0.13		0.13		0.13	
Long. polarization (%)	0	80	0	80	0	80
RF frequency (MHz)	476		476		476	
Harmonic number	3570		3570		3570	
Momentum spread ($\times10^{-4}$)	8.4	9.0	10	10	10	10
Mom. compaction ($\times10^{-4}$)	1.8	3.0	1.8	3.0	1.8	3.0
RF voltage (MV)	6	18	6	18	7.5	18
Energy loss/turn (MeV)	1.9	3.3	2.3	4.1	2.3	4.1
Number of bunches	1733		3466		3466	
Particles/bunch $\times10^{10}$	6.16	3.52	5.34	2.94	6.16	3.52
Beam current (A)	2.28	1.30	3.95	2.17	4.55	2.60

Parameter	Nominal Parameters LER	Nominal Parameters HER	Upgrade Parameters LER	Upgrade Parameters HER	Ultimate Parameters LER	Ultimate Parameters HER
β_y^* (mm)	0.30		0.20		0.20	
β_x^* (mm)	20		20		20	
ε_y (pm-rad)	4		2		2	
ε_x (nm-rad)	1.6		0.8		0.8	
σ_y^* (nm)	35		20		20	
σ_x^* (μm)	5.657		4.000		4.000	
Bunch length (mm)	6		6		6	
Full Crossing angle (mrad)	34		34		34	
Wigglers (#)	4	2	4	4	4	4
τ_{Damping} (trans/long)(ms)	32/16		25/12.5		25/12.5	
Luminosity lifetime (min)	10.3	5.7	7.4	4.1	6.1	3.5
Touschek lifetime (min)	5.5	38	2.9	19	2.3	15
Total beam lifetime (min)	3.6	5.0	2.1	3.4	1.7	2.8
Inj. rate pps (100%) $\times10^{11}$	4.9	2.0	15	5.0	21	7.2
ξ_x (from Eq. 3.5)	0.004		0.007		0.009	
ξ_y (from Eq. 3.4)	0.17		0.16		0.2	
RF Power (MW)	17		35		44	

History

- The initial approach at SLAC & KEK (2001)
  - extrapolations of the very successful B-Factory designs
  - Increase bunch charge
  - Increase number of bunches
  - Reduced β^*_y
  - crab cavities

These proposed designs reached luminosities of 5 - 7 × 10^{35}

Disadvantage → wall plug power of the order of 100MW.

- The new low emittance design reaches the desired luminosity regime with beam currents and wall plug power comparable to those in the current B Factories

The design of the Super$B$ e^+e^- collider combines extensions of the design of the current B Factories with new linear collider concepts to produce an extraordinary leap in B Factory luminosity without increasing beam currents or power consumption.

Target Luminosity

$$\mathcal{L} = \frac{N^+ N^-}{4\,\pi\,\sigma_y \sqrt{(\sigma_z \tan\theta/2)^2 + \sigma_x^2}}\, f_c$$

$$\sigma_{x,y} = \sqrt{\beta_{x,y}\,\varepsilon_{x,y}}\ ,$$

β (in cm) at the collision point

θ crossing angle at the interaction point (IP)

large Piwinski angle scheme will allow for peak luminosity 10^{36} cm^{-2} s^{-1}

without a significant increase in beam currents or shorter bunch lengths

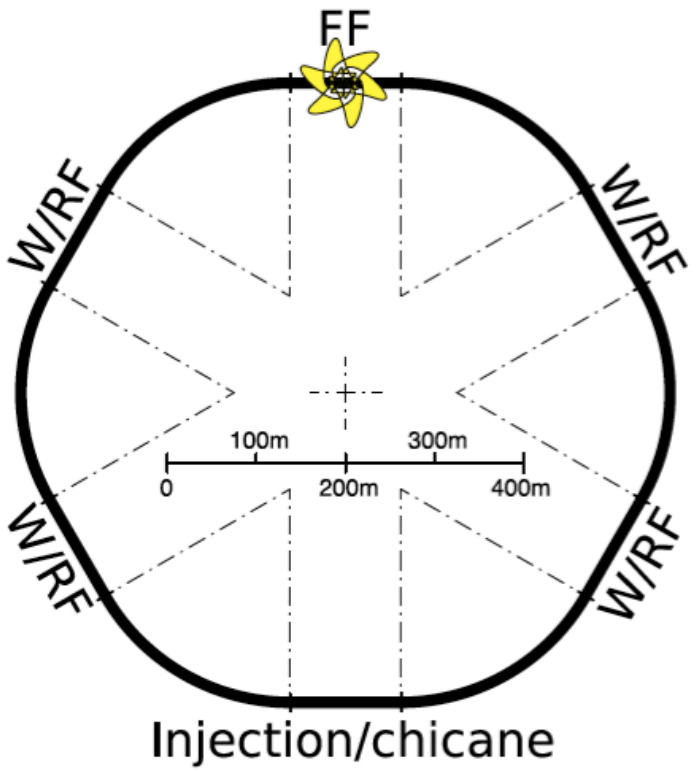
"crab waist" sextupoles used for suppression of dangerous resonances

low currents with reduced detector and background problems, and affordable operating costs

General Strategy

- The IP & ring parameters have been optimized based on several constraints.
  - Maintaining wall plug power, beam currents, bunch lengths, and RF requirements comparable to present B Factories
  - Reuse as much as possible of the PEP-II hardware
  - Requiring ring parameters as close as possible to those already achieved in the B Factories, or under study for the ILC Damping Ring or achieved at the ATF ILC-DR test facility
  - Simplifying the IR Design as much as possible
    - reduce the synchrotron radiation in the IR
    - reduce the HOM power
    - increase the beam stay-clear
    - eliminate the effects of the parasitic beam crossings
    - Relaxing as much as possible the requirements on the beam demagnification at the IP
    - Designing the final focus system to follow as closely as possible already tested systems, and integrating the system as much as possible into the ring design.

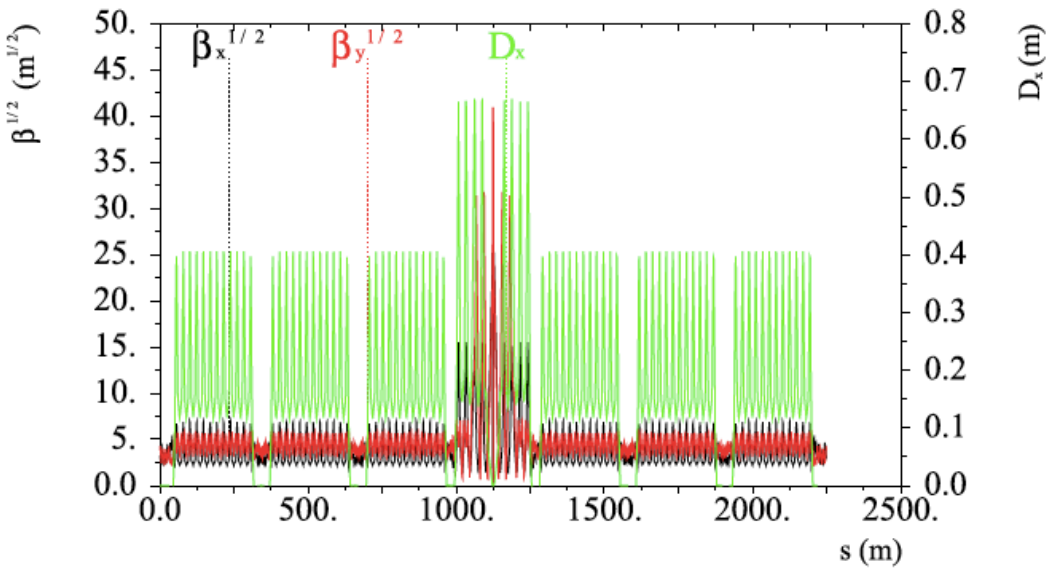
Lattice parameters



	LER	HER
Energy (GeV)	4	7
C (m)	2250	2250
Bw (T)	1.00	0.83
L_{bend} (m) (Arc/FF)	0.45/0.75/5.4	5.4/5.4
Number of Bends (Arc/FF)	120/120/16	120/16
U_0 (MeV/turn)	1.9	3.3
Wiggler sections: Number	4	2
Wiggler sections: L_{tot}(m)	100	50
σ_z (mm)	4.07	5.00
τ_s (ms)	16.00	16.00
ε_x (nm-rad)	0.8	0.8
Emittance ratio	0.25%	0.25%
σ_E	$1.\times10^{-3}$	$1.\times10^{-3}$
Momentum compaction	1.8×10^{-4}	$3.\times10^{-4}$
ν_s	0.011	0.02
V_{RF} (MV),N_{cav}	6, 8	18, 24
N_{part} ($\times10^{10}$)	6.16	3.52
I_{beam} (A)	2.3	1.3
P_{beam} (MW)	4.4	4.3
f_{rf} (MHz)	476	476
N_{bunches}	1733	1733
Ion gap	5%	5%

HER 7 GeV Ring

- Inspired by ILC Damping Rings (DR)
- Uses 120 (PEP-II HER) dipoles(5.4 m) + 16 Final Focus (5.4 m) PEP-II HER dipoles
- Each arc ~ 250 m long
- Six straight sections connect the arcs
  - One contains the final focus (FF) & in the opposite straight section a magnetic chicane is used to keep the beams separated.
  - The other four → house the wiggler magnets & RF cavities



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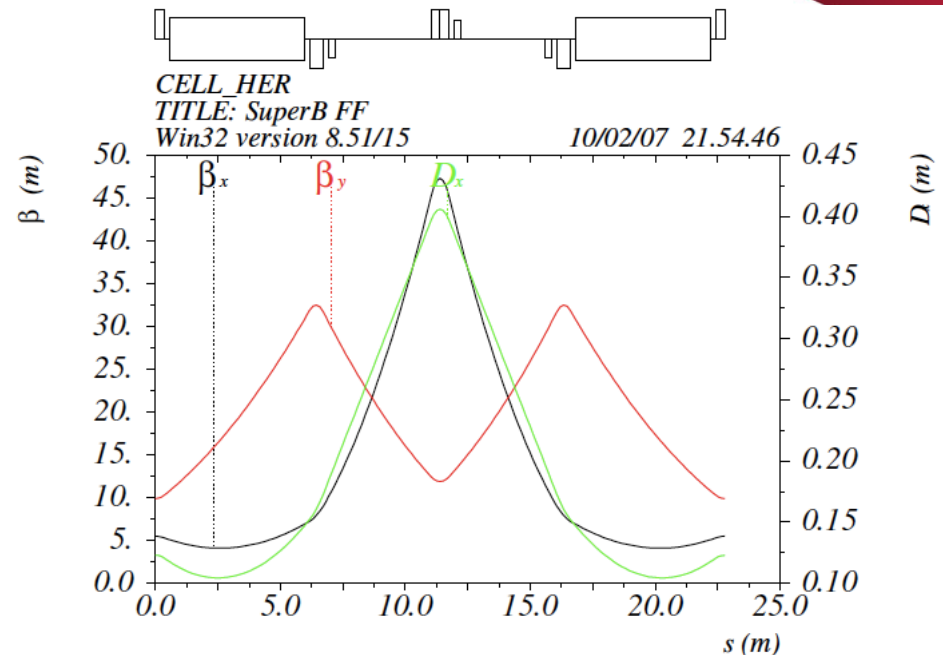
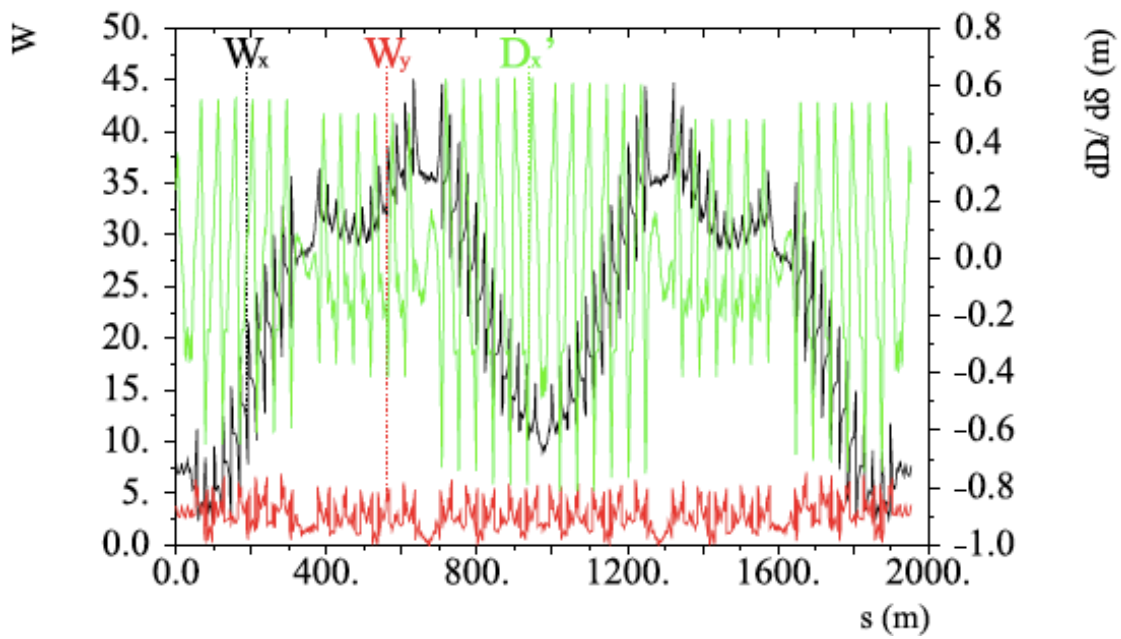
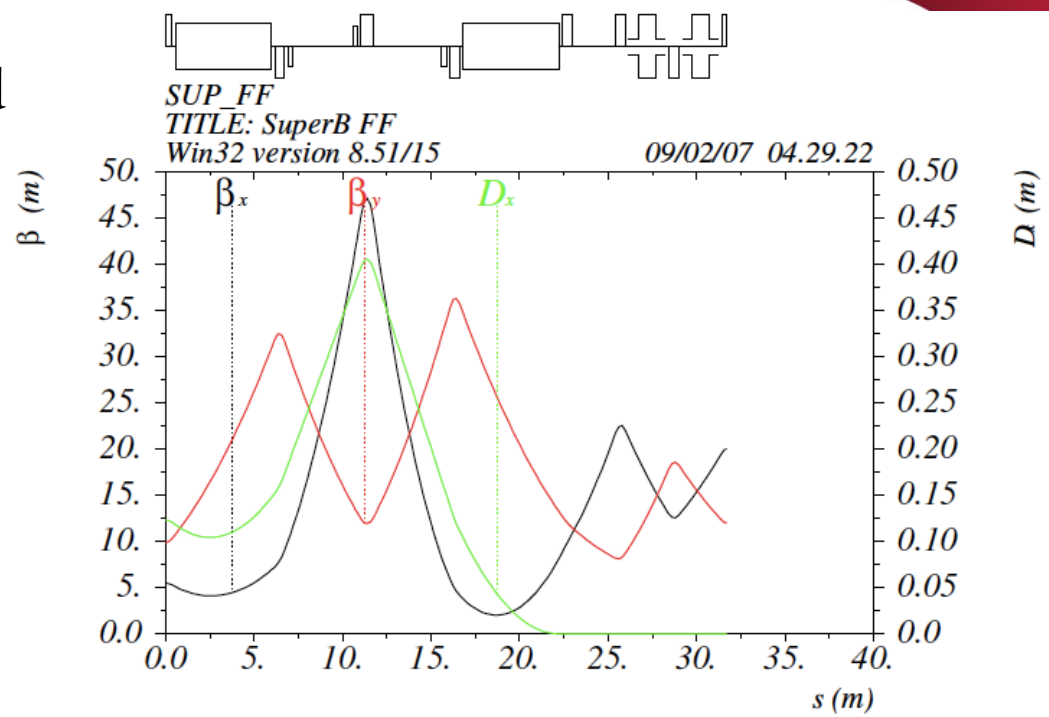
Arc Cells

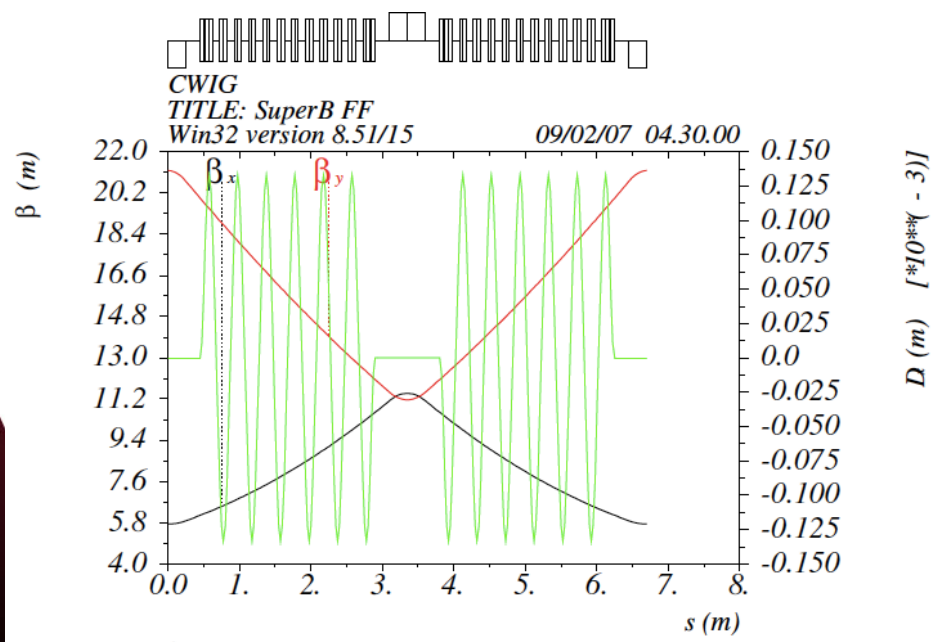
- 2 dipoles/cell
- (π,0.4π) phase advance
- Two sextupole families per cell for chromaticity correction
- Optimized phase advance between arcs (π/3) to get best performances





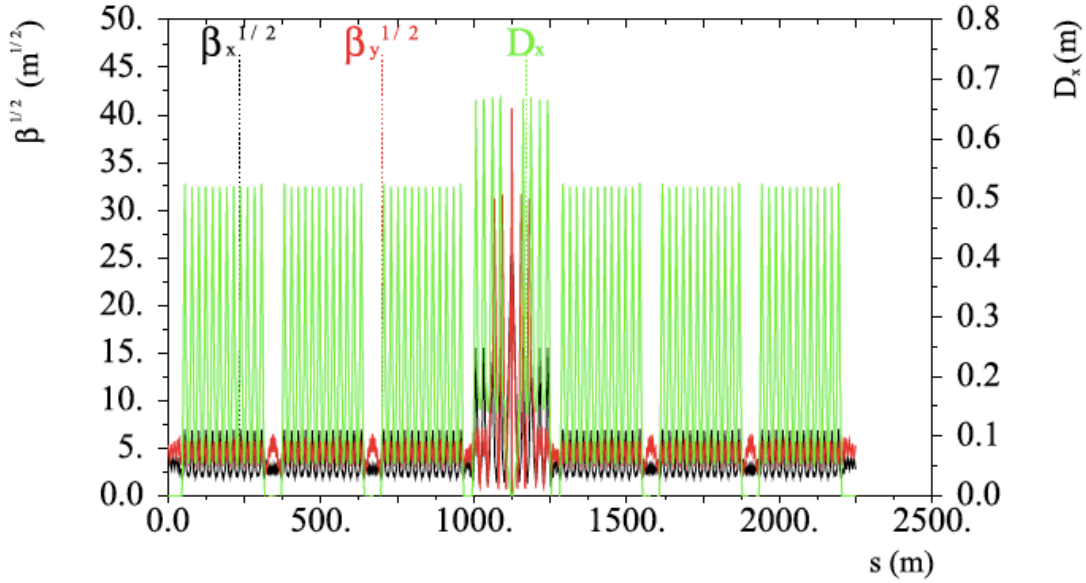
Dispersion suppressors at end of each arc for dispersion free straights (RF & wigglers)

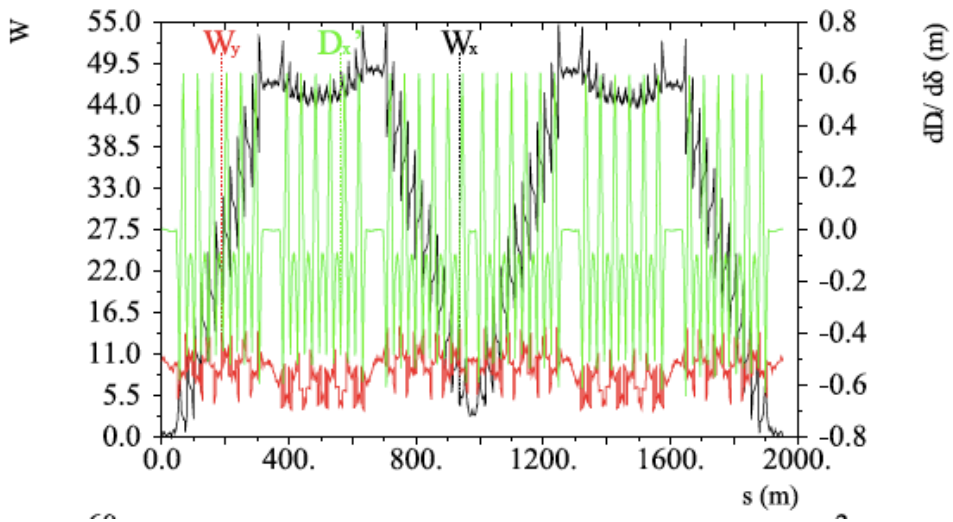


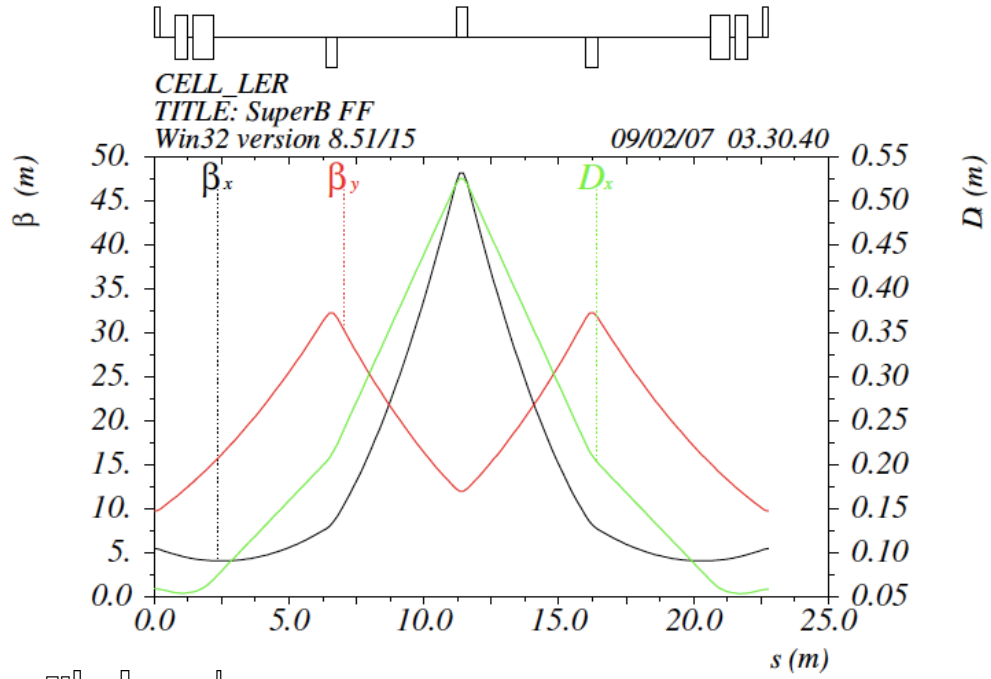


Wiggler Cell

LER 4 Gev Ring



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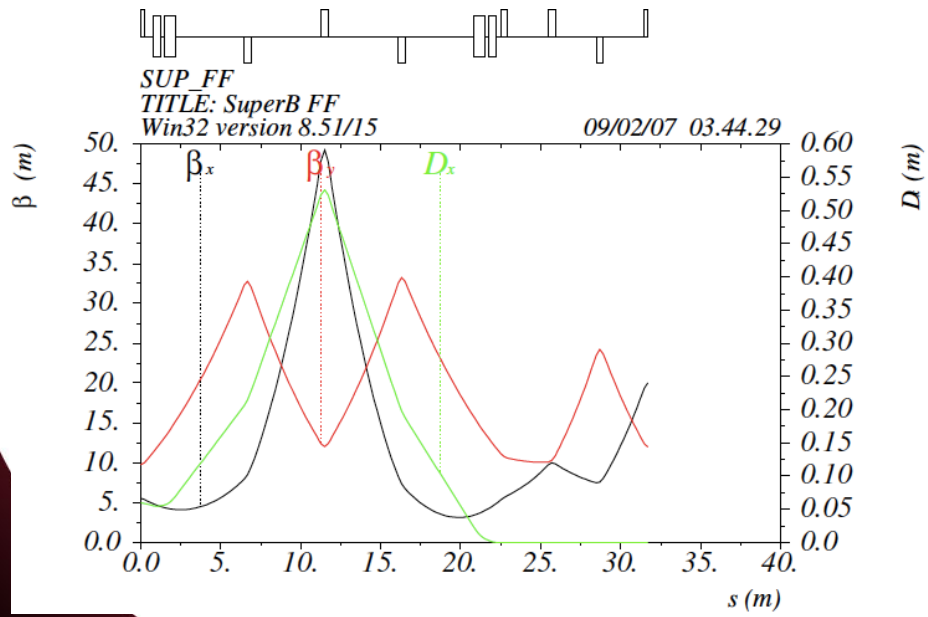
β (m)
D (m)
s (m)
βx
βy
Dx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β (m)
D (m)
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βx
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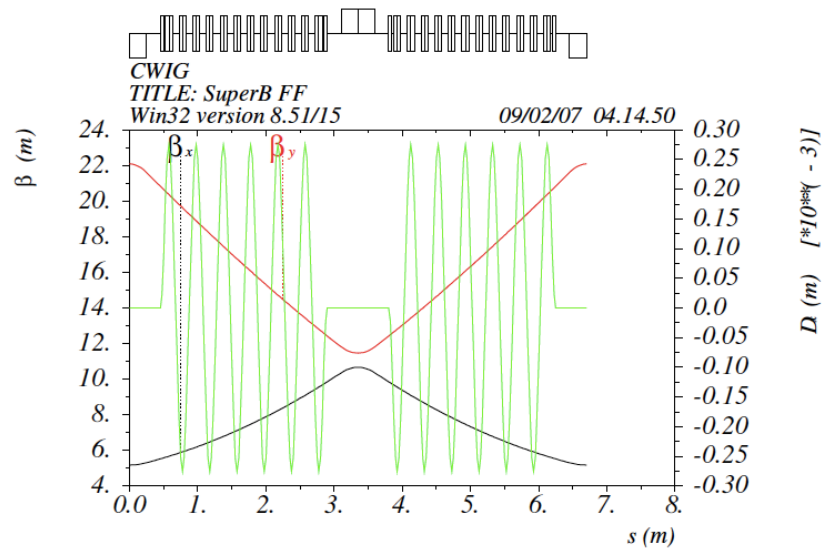
Dx


CWIG
TITLE: SuperB FF
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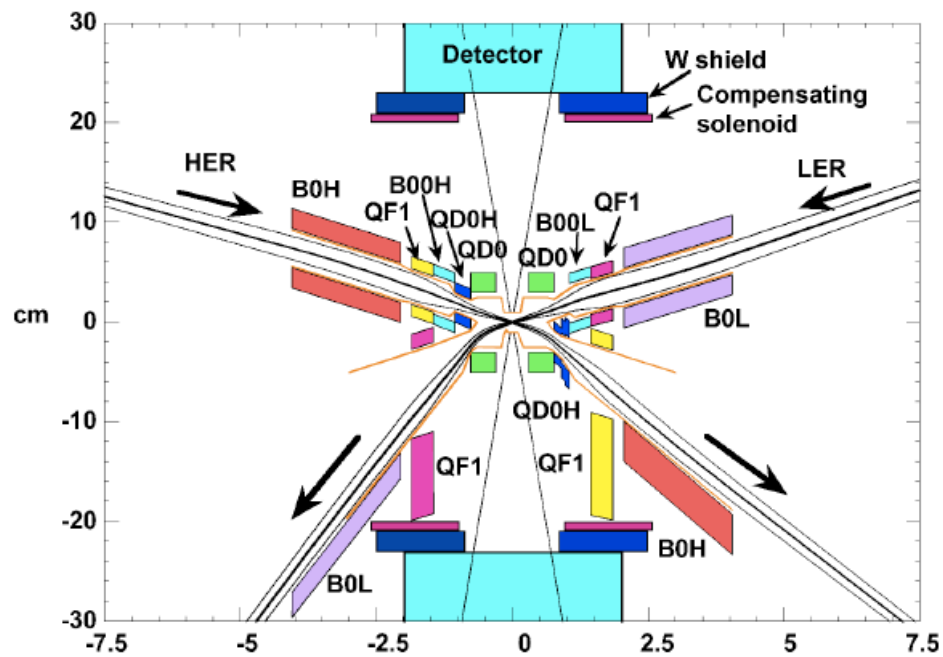
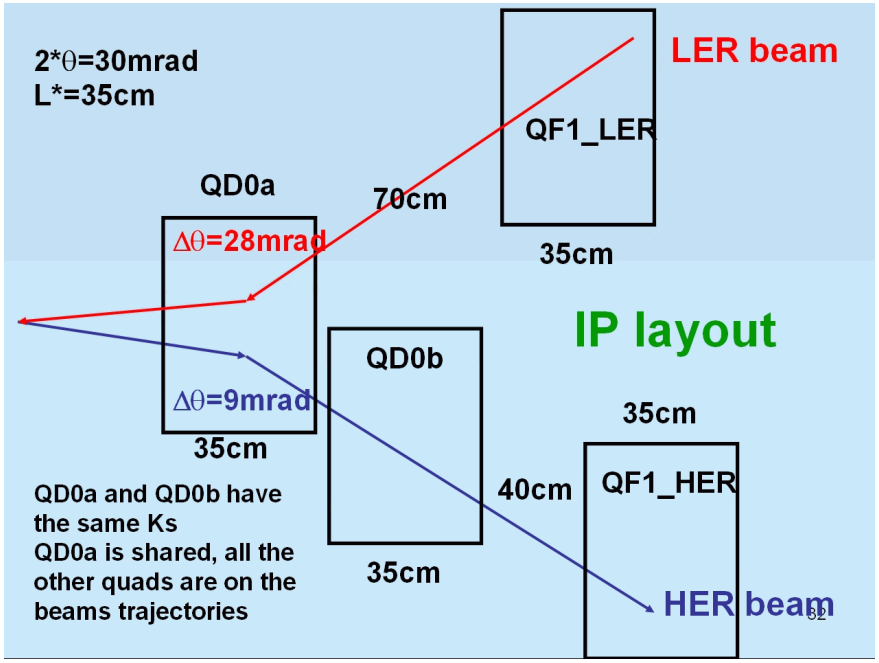
β (m)
D (m) [*10**(- 3)]
s (m)
βx
βy

Final Focus

- Very small spot sizes at the IP
- Chromatic local correction
- Separation of the LER and HER beams as soon as possible
- Preventing synchrotron radiation (SR) production from hitting the beam pipe and the detector
- Compatibility with a beam pipe of minimum radius and thickness
- Maintenance of the largest possible angular acceptance for the detector
- beam-stay-clear (BSC) envelope
  - ➢X → 15 uncoupled beam σ_x +1mm for closed orbit distortion (COD)
  - ➢Y → 15 fully coupled beam σ_y + 1mm COD
- first quadrupole magnet (QD0) to start 0.3m away from the IP

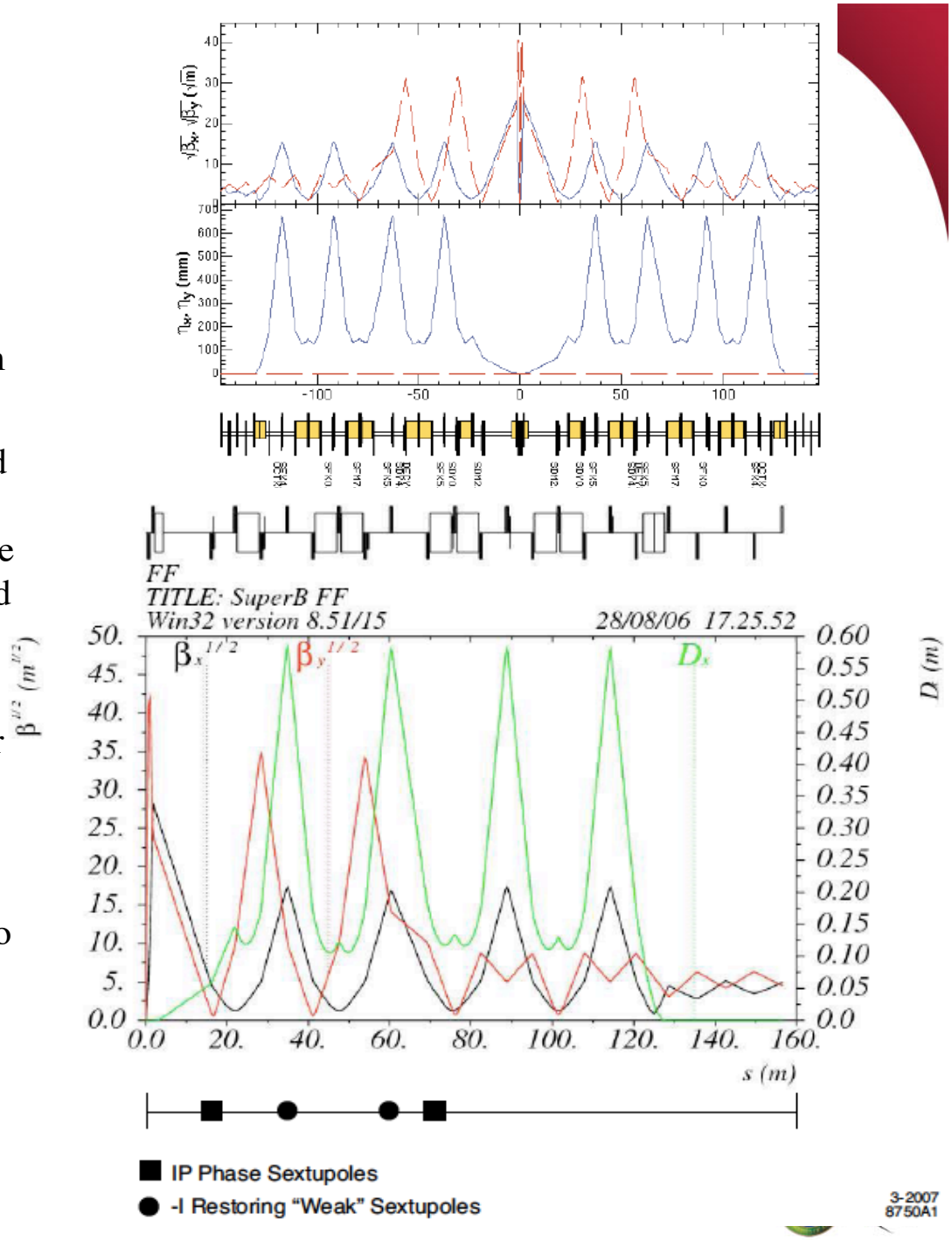
IP horizontal β_x	20 mm
IP vertical β_y	0.2 mm
Horizontal beam size σ_x	4 mm
Horizontal beam divergence $\sigma_{x'}$	200 mrad
Vertical beam size σ_y	20 nm
Vertical beam divergence $\sigma_{y'}$	100 mrad
Bunch length σ_z	7 mm
Crossing angle θ	2×17 mrad




2*θ=30mrad
L*=35cm
LER beam
QF1_LER
QD0a
70cm
Δθ=28mrad
35cm
IP layout
QD0b
Δθ=9mrad
35cm
35cm
40cm
QF1_HER
QD0a and QD0b have the same Ks
QD0a is shared, all the other quads are on the beams trajectories
35cm
HER beam

Local chromaticity correction:

- Two sextupole magnets in each plane
- each pair being at –I transformation matrix
- sextupole pairs reduce nonlinearities for each other in correcting the chromaticity & increasing momentum acceptance
- Dispersion at the sextupoles is created with several bending magnets and matching quadrupole magnets to make the dispersion (η,η`) zero at the IP and localized in the IR
- Additional sextupoles at small β function used to correct the third-order chromaticity (but off-momentum particles see a maximum β). (without reducing the dynamic aperture)
- Two weak octupole magnets are used to correct the chromatic effect for the off-momentum particles

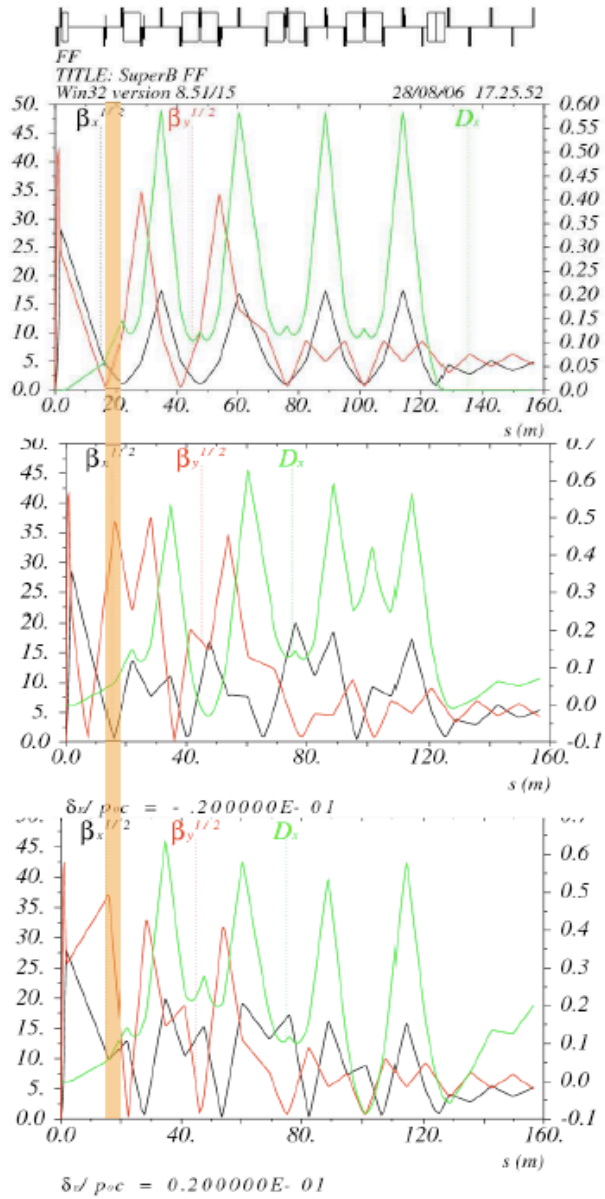


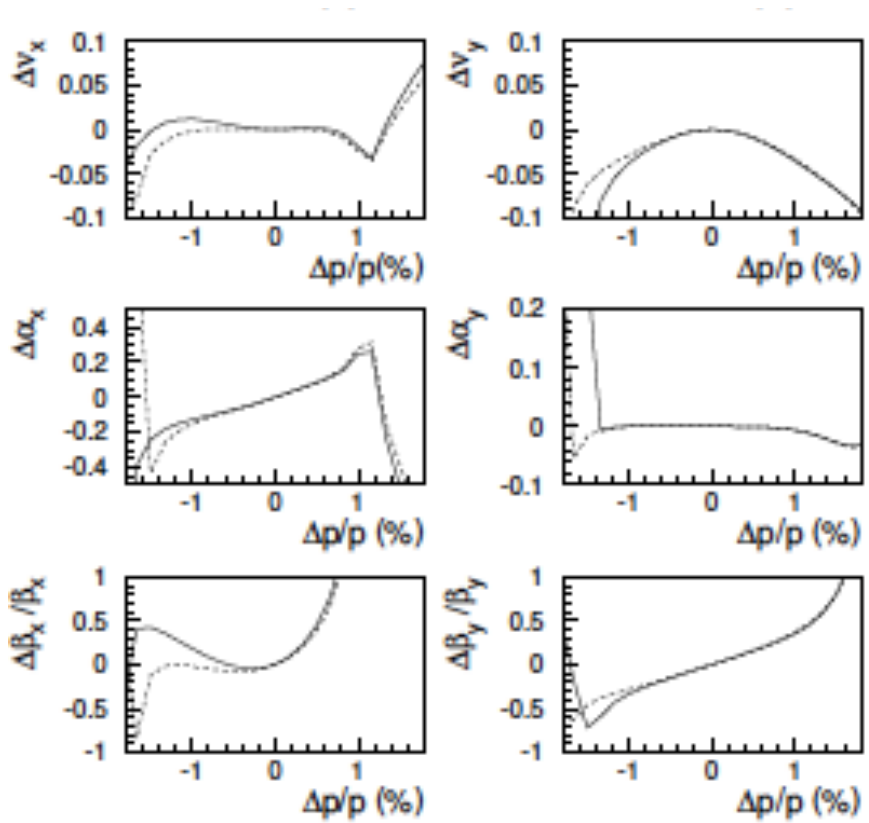
The vertical shaded band indicates minimum β_y for on-momentum particles corresponds to a maximum β_y for ±2% off-momentum particles.

Δp/p=0

Δp/p=-0.02

Δp/p=0.02





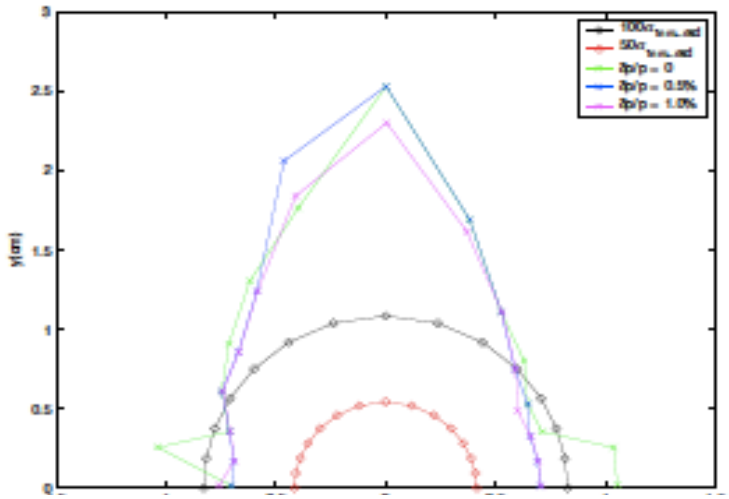
Chromatic effects
dashed lines octupole magnets on
solid lines octupole magnets off

Dynamic Aperture:

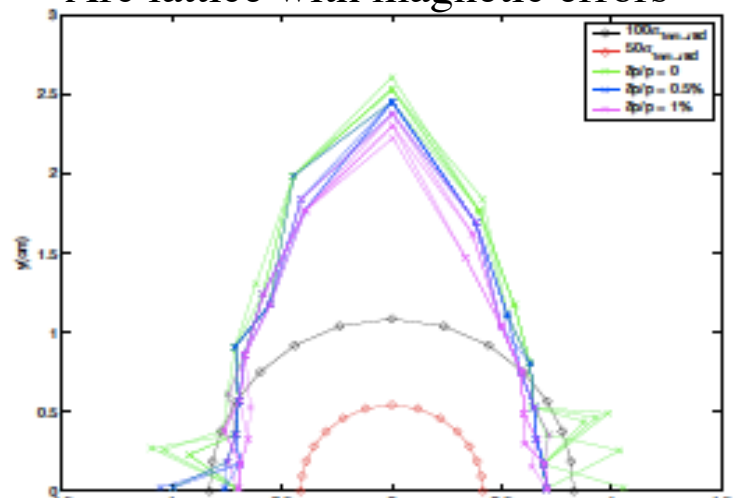
A particle-tracking simulation was performed using SAD

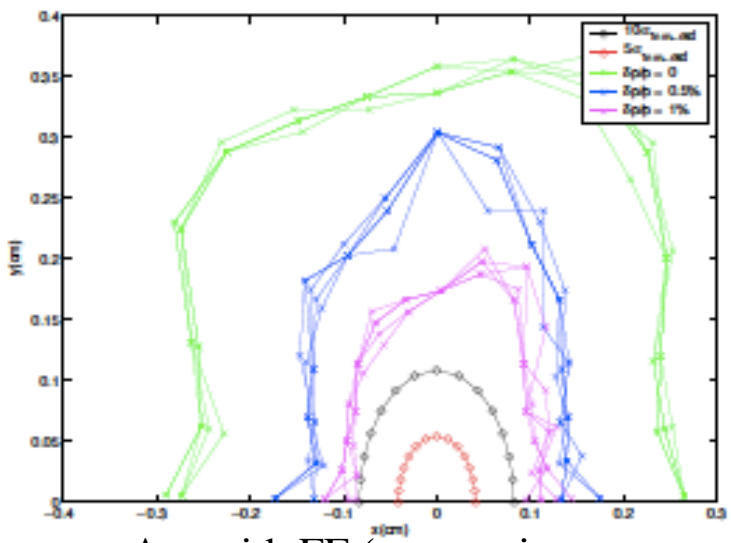
Stability criterion: maximum amplitude ~ 10 cm during one damping time.

"ideal" Arc lattice

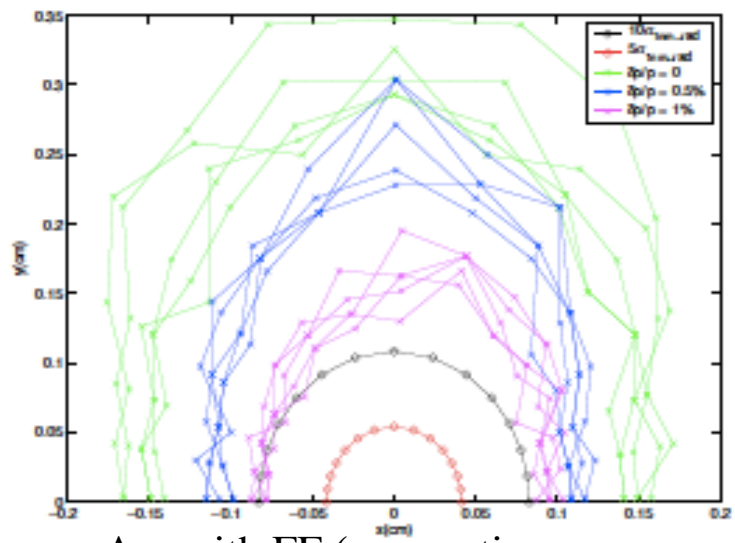


Arc lattice with magnetic errors





Arc with FF (magnetic errors in the arcs only)



Arc with FF (magnetic errors everywher)

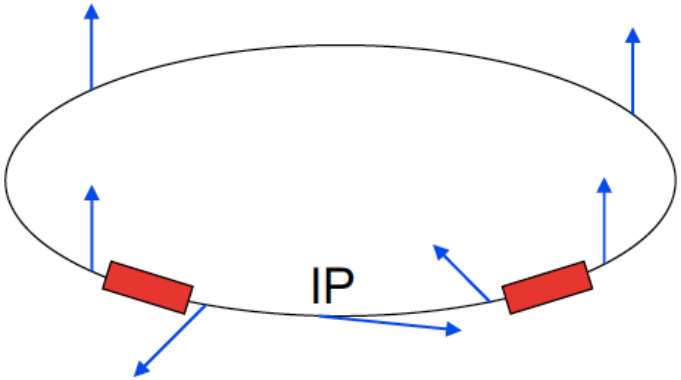
Polarization Schemes for 4GeV and 7GeV

Requirements:

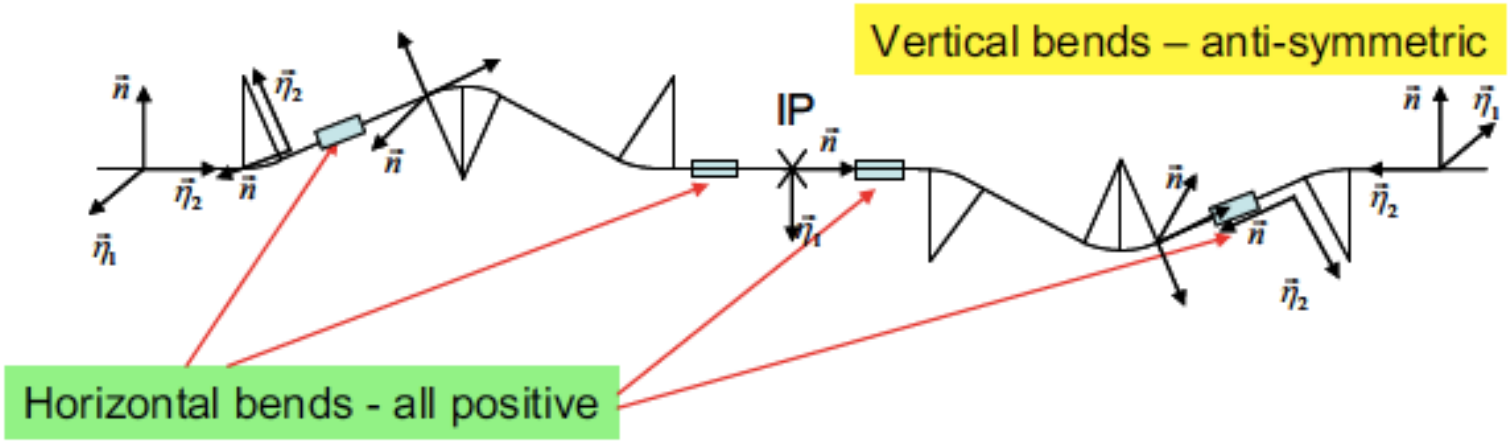
- A stable longitudinal direction for spin at the IP
- A depolarization time longer than one beam lifetime
- Fast switching of the sign of the polarization, within or less one beam lifetime
- High degree of polarization

<u>Siberan Snake Scheme:</u>

1. The first spin rotator (red box) rotates spin by 90◦ around the longitudinal axis
2. 90◦ rotation around the vertical axis brings the spin to a purely longitudinal orientation at the IP.



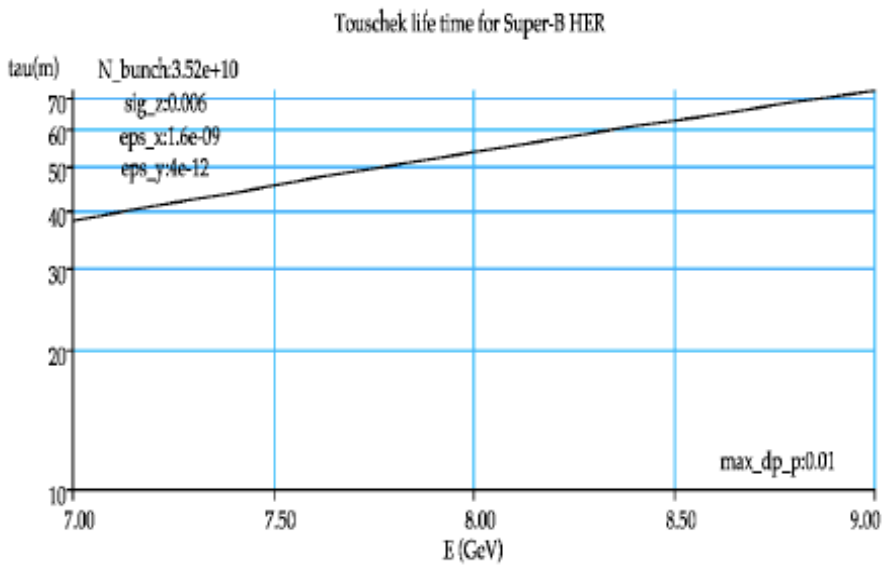
HERA-like solution

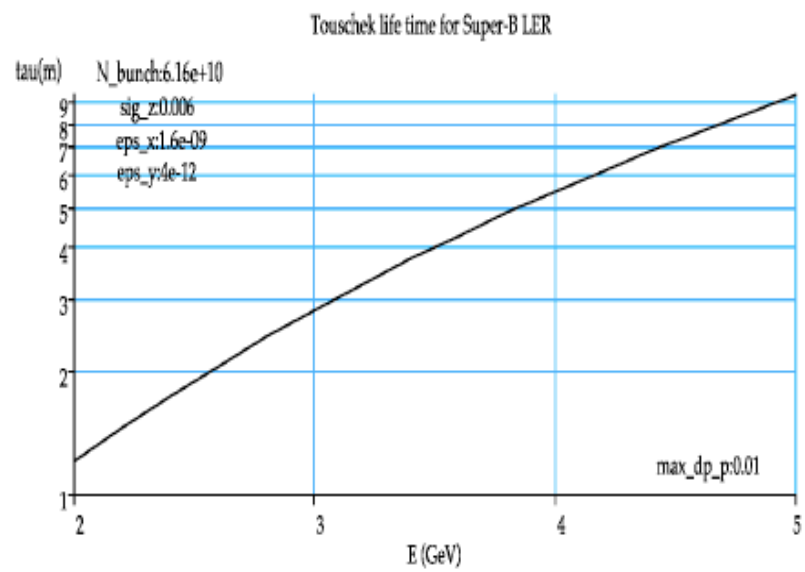


- sequence of vertical and horizontal bends rotate spin by 90◦ transforms initial vertical n into the longitudinal direction at the IP.
- Vertical bends are anti-symmetric relative to IP
- all horizontal bends are positive and symmetric.
- Every vertical bend is made achromatic by being divided in two half-bends and placing some optics in between.
- The two horizontal bends closest to the IP belong to the FF-insertion.

Touschek Lifetime

The total machine acceptance in $\Delta p/p$ is the smaller of the RF acceptance (~ 0.025) and the lattice acceptance (~ 0.01)





Parameter set	Luminosity ($m^{-2}s^{-1}$)	Lifetime HEB (min)	Lifetime LEB (min)
Nominal	1.0×10^{36}	38	5.5
Upgrade	2.44×10^{36}	19	3

Injection System

Requirements: for SuperB must provide

1. electrons and positrons injection rate 10^{12} particles per second due to the short beam lifetimes.
2. small emittance to fit into the restricted phase space volume allocated for the injection(limited dynamic aperture)

First Option

DAΦNE injector

1. 60m-long Linac
2. Accumulator 33m- circumference ring used for longitudinal and transverse phase space damping.

Second Option:

1. polarized electron gun
2. 6GeV linac operating at 2856MHz
3. positron converter at the 5GeV location
4. Two damping rings operating at 1GeV
5. Two beam transport lines (BTL) to the SuperB LER and HER rings
6. spin manipulation solenoids