SUPER-B PROJECT OVERVIEW

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Abstract

The *SuperB* project aims at the construction of an asymmetric very high luminosity B-Factory on the Frascati/Tor Vergata (Italy) area, providing a uniquely sensitive probe of New Physics in the flavour sector of the Standard Model. The luminosity goal of 10^{36} cm^{-2} s^{-1} can be reached with a new collision scheme with "large Piwinski angle" (LPA) and the use of "crab waist sextupoles" (CW) [1]. A LPA&CW Interaction Region (IR) has been successfully tested at the DAΦNE Φ-Factory at LNF-Frascati in 2008 [2]. The LPA&CW scheme, together with very low β*, will allow for operation with relatively low beam currents and reasonable bunch length, comparable to those of PEP-II and KEKB. In the High Energy Ring (HER), two spin rotators will bring longitudinally polarized beams into collision at the IP. The lattice has been designed with a very low intrinsic emittance and is quite compact, less than 2 km long. The tight focusing requires the final doublet quadrupoles to be very close to the IP and very compact.

A Conceptual Design Report was published in March 2007 [3], and beam dynamics and collective effects R&D studies are in progress in order to publish a Technical Design Report by the end of 2010.

DESIGN PARAMETERS

SuperB consists of two rings of different energy (electrons in HER, 7 GeV, positrons in LER, 4 GeV) colliding in one IR at a large (60 mrad total) horizontal angle. Spin rotator sections in the HER will provide manipulation of a polarized electron beam. The two rings have two arcs and two long straight sections each. One straight will house the IR, the other will be used for the diagnostics, RF, and injection lines. The crab waist scheme, with a couple of sextupoles per ring in a dispersive section near the IR, and an appropriate betatron phase with respect to the IP, will create a longitudinal waist shift over the width of the beam, so providing suppression of betatron and synchro-betatron resonances arising from the crossing angle geometry. To save on costs the design is based on the reuse of the PEP-II (SLAC) hardware, including magnets, beam pipe, RF system, and injection.

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SuperB parameters need to be flexible in order to achieve the required 10^{36} cm^{-2} s^{-1} luminosity goal. Table 1 presents possible parameter sets, including a shorter circumference version (set #3). All configurations have the same a crossing angle (60 mrad) and bunch length (5 mm). Set #1 presents lower currents and wall plug power, at the expenses of a larger vertical tune shift, while the other two solutions have tune shifts comparable to the highest reached at PEP-II and KEKB. Note the extremely low x tune shifts, characteristic of the LPA&CW scheme. All configurations can be achieved with the same lattice and IR layouts. The shorter rings have a larger phase advance/cell in the arcs and can achieve the same emittance with a lower number of cells.

Table 1: *SuperB* Parameter Possibilities for LER/HER

	Set #1	**Set #2**	**Set #3**
I (Amp)	2/2	2.8/2.8	2.7/2.7
$N_{bunches}$	1250	2400	1740
β_x* (mm)	35/20	35/20	35/20
β_y* (mm)	0.21/0.37	0.21/0.37	0.21/0.37
ε_x (nm)	2.8/1.6	2.8/1.6	2.8/1.6
ε_y (pm)	7/4	7/4	7/4
σ_x* (μm)	9.9/5.7	9.9/5.7	9.9/5.7
σ_y* (nm)	38/38	38/38	38/38
ξ_x	0.005/0.002	0.004/0.001	0.004/0.001
ξ_y	0.125/0.125	0.09/0.09	0.095/0.095
RF stations	5/6	5/8	6/9
RF wall plug power (MW)	18	26	30
Circumference (Km)	1.8	1.8	1.4

Lattice studies

Lattice studies have continued in order to optimize the layout, save power and look for possible alternatives to the Tor Vergata site. The low horizontal emittance in the *SuperB* rings was obtained by increasing the horizontal betatron phase advance in each arc cell [4] and without the insertion of wiggler magnets. It is still possible to reduce the ring circumference by 20%, just by increasing in all cells μ_x to 0.75/cell, with μ_y = 0.25/cell. The arcs number can then be reduced from 4 (with 14 cells each) to 2 (with 21 cells each). With this arrangement the chromaticity correction in the arcs is provided with 30% fewer sextupoles (one sextupole missing each 3 cells) and dynamic aperture is increased since all sextupoles are at –I phase in both planes, although interleaved. The cells have also been optimised in terms of magnet spacing according to the PEP-II hardware needs. Damping times are 5% shorter with respect to the longer rings, with a corresponding increase in needed power. The vertical emittance being at the level of 4 and 7 pm low emittance tuning studies are in progress, in order to establish a table of magnet error tolerances. At a first look it appears that the IR elements, with very high beta values, are critical and will need a special stabilization.

Beam-beam studies

Due to the peculiarity of the interaction scheme, with a large crossing angle but a small beams overlap region, beam-beam simulations for *SuperB* are challenging. Weak-strong simulations have been carried out with the Lifetrac code [5], which can include lattice non linearities. This code has been lately modified to perform "quasi-strong"-weak simulations, where the beams deformed by the bb interaction exchange their role turn after turn. Another important progress was the modification of the BBSS code [6] where the PIC simulation is used for the beam overlap area and the Gaussian approximation for the very long tail slices. With this improvement it has been possible to run a strong-strong bb simulation and preliminary results, in Fig. 1, show that the design luminosity can be reached.

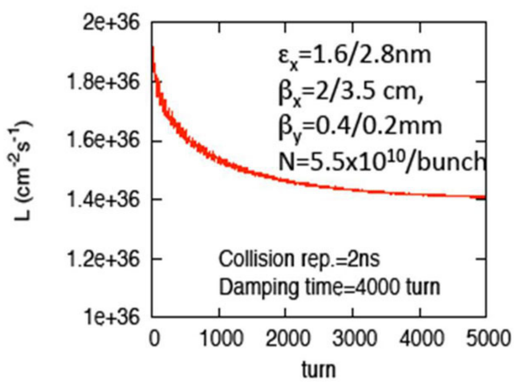

Figure 1: *SuperB* strong-strong simulation (BBSS).

Dynamic Aperture studies

Analysis of the DA limiting sources has been carried out with the Acceleraticum code [7]. This included the effect of non-zero length sextupoles, and of the fringing field in the off-axis trajectory in the IR doublets which may significantly reduce the DA. It was also found that any distortion of the –I transformation in the IR can be recovered by an additional correction sextupole pair (with a 10% strength) placed close to the chromaticity correcting pairs. The arc sextupoles have also been optimised, leading to a DA for on-energy particles of 35x250 (σ_x×σ_y) (σ_x un-coupled, σ_y fully coupled). The tune working point needs still to be optimized together with the bb simulations and the luminosity/lifetime optimization.

Backgrounds studies

Touschek scattering is an important background source in the *SuperB* rings, especially in LER. Simulations have been performed for both rings following the lattice evolution and the dynamic aperture optimization. A first set of horizontal collimators has been studied in order to stop Touschek particles hitting the beam pipe or the detector in the IR. A Touschek lifetime of about 20 min with a strong reduction of the IR losses was found for LER [8]. A study of the distributions of the Touschek particle losses at the IR into the detector with GEANT4 is underway.

INTERACTION REGION DESIGN

The IR design [9] has been optimized in order to ease the engineering design and provide the best performances in terms of beam stay clear and backgrounds. A sketch of the IR is shown in Fig. 2. All the magnets inside the detector are either PM or Superconducting. The challenge for the first defocusing quadrupole QD0 is to provide good quadrupole field with a gradient larger than 50T/m, separately for each beam line. The limited amount of space available in between the two beams (~1cm) together with the required field strength makes difficult to use a conventional design. A novel approach based on double-helix coils [10] has been proposed and is now under development. Both IP quadrupoles QD0 and QF1 will be housed in the same cryostat with a warm bore. To increase the focusing in LER, which has the smallest β_y*, a small PM magnet is installed just in front of the cryostat; its slices have an elliptical aperture to have more vertical space. The large crossing angle means the detector field strongly affects the beams: a first look at the compensation of the Bdl integral with anti-solenoids has started (red lines in Fig. 2).

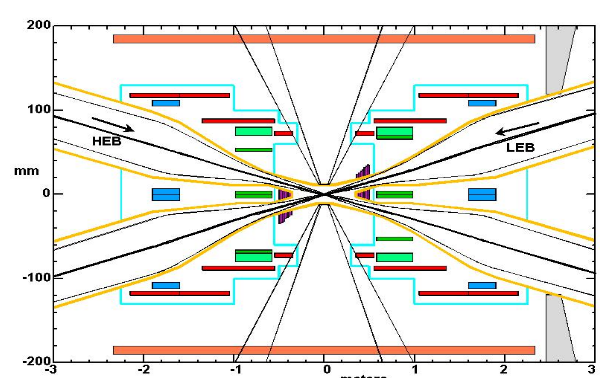

Figure 2*: SuperB* Interaction Region.

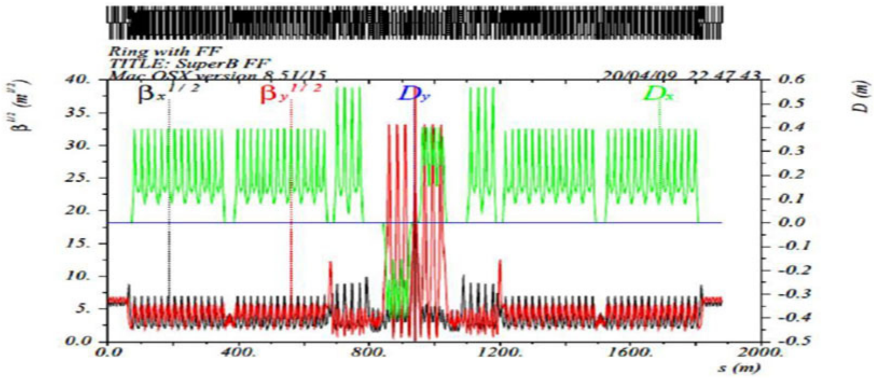

Figure 3: HER optical functions with spin rotator insertions.

ELECTRON BEAM POLARIZATION

The *SuperB* injector will use the SLC polarized gun and will have the necessary spin handling before and after the electron damping ring. At the IP, the desired polarization is longitudinal; this can be provided by 90° spin rotators up and downstream of the IP. The overall spin matching in *SuperB* will be less critical than in facilities like HERA or LEP because of the short beam lifetime. This causes frequent injection of freshly polarized beam, thus reducing the effect of depolarization in the ring, so that maintaining above 90% of the injecting polarization is an achievable goal, provided rotators are spin-matched across the whole energy spread of the beam. The orbital coupling introduced by the solenoids is compensated by inserting a plane twister between two half-solenoids. Particular attention has been paid to the chromaticity correction in the IR, which was perturbed by the spin rotator insertion. Fig. 3 shows the HER optical functions, with the spin rotator matched [11].

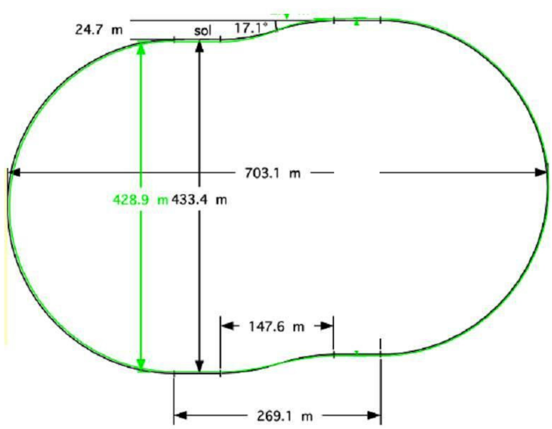

Figure 4: *SuperB* layout with spin rotators.

Solenoid spin rotators need for first-order spin matching to be anti-symmetric about the IP, leading to a horizontal "dog leg" in the IR layout and causing a distortion of the ring geometry. LER will have a similar geometry, even if no spin rotator sections are needed (see Fig. 4).

LAYOUT

The injection system will require to inject in trickle charge mode a 4 GeV positron beam and a 7 GeV polarized electron beam, provided by the SLC polarized electron gun. Damping rings will provide the emittance damping and spin manipulation required before injection into the rings.

A study has been carried out [12] for the Tor Vergata Campus site near Frascati, where the SPARX-FEL project construction is also planned. Although the Tor Vergata site represents the first choice, INFN is seriously investigating the possibility to build *SuperB* and SPARX at the Frascati National Laboratories (LNF) to reuse the civil infrastructures as much as possible after the DAΦNE dismantling foreseen in three or four years from now.

CONCLUSIONS

The SuperB collider, exploiting the new LPA&CW scheme, can reach unprecedented luminosity levels with relatively small rings and beam currents. This collision scheme has been already proved to be very efficient at the DAΦNE Φ-Factory in Frascati, and it is straightforward to be applied to *SuperB*. Beam dynamics and R&D studies are in progress to proceed with the completion of a TDR by the end of 2010.

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