

THE SUPER-B PROJECT ACCELERATOR STATUS*

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Abstract

The SuperB project is an international effort aiming at building in Italy a very high luminosity e^+e^- (10^{36} cm⁻² sec⁻¹) asymmetric collider at the Y(4S) energy in the CM. The accelerator design has been extensively studied and changed during the past year. The present design, based on the new collision scheme, with large Piwinski angle and the use of “crab waist” sextupoles already successfully tested at the DAΦNE Φ-Factory at LNF Frascati, provides larger flexibility, better dynamic aperture and spin manipulation sections in the Low Energy Ring (LER) for longitudinal polarization of the electron beam at the Interaction Point (IP). The Interaction Region (IR) has been further optimized in terms of apertures and reduced backgrounds in the detector. The injector complex design has been also updated. A summary of the project status will be presented in this paper.

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on behalf of the SuperB Accelerator Team*

Abstract

The SuperB project [1] is an international effort aiming at building in Italy a very high luminosity e^+e^- ($10^{36} \text{ cm}^{-2} \text{ sec}^{-1}$) asymmetric collider at the $\Upsilon(4S)$ energy in the cm. The accelerator design has been extensively studied and changed during the past year. The present design, based on the new collision scheme, with large Piwinski angle and the use of “crab waist” sextupoles already successfully tested at the DAΦNE Φ -Factory at LNF Frascati [2], provides larger flexibility, better dynamic aperture and spin manipulation sections in the Low Energy Ring (LER) for longitudinal polarization of the electron beam at the Interaction Point (IP). The Interaction Region (IR) has been further optimized in terms of apertures and reduced backgrounds in the detector. The injector complex design has been also updated. A summary of the project status will be presented in this paper.

INTRODUCTION

The SuperB collider can reach a peak luminosity of $10^{36} \text{ cm}^{-2} \text{ s}^{-1}$ with beam currents and bunch lengths similar to those of the past and present e^+e^- Factories, through the use of smaller emittances and new scheme of crossing angle collision. The beams are stored in two rings at 6.7 GeV (HER) and 4.2 GeV (LER). Unique features of the project are the polarization of the electron beam in the LER and the possibility to decrease the energies for running at the τ /charm threshold. The option to reuse the PEP-II B-Factory (SLAC) hardware will allow reducing costs.

The SuperB facility will require a big complex of civil infrastructure. The main construction, which will house the final part of the LINAC, the injection lines, the damping rings, and the storage rings, will be mainly underground. Two sites have been considered: the campus of Tor Vergata University near Frascati, and the INFN Frascati Laboratory. No decision has been made yet. A footprint of the possible SuperB layout on the LNF area is shown in Fig. 1.

SUPERB PARAMETERS FOR 10^{36}

SuperB main parameters have been reviewed in order to assure enough flexibility and the possibility to operate at the design luminosity with different options.

The IP and ring parameters have been optimized based on several constraints. After an intense optimization work, the parameters corresponding to both asymmetric emittances and beam currents for the two rings seem to be more consistent with other requirements. For instance a larger emittance for LER is necessary to keep under control the emittance dilution due to Intra-Beam-Scattering (IBS), at the same time a higher beam current for LER is necessary to minimize the synchronous phase spread difference between the two rings due to the gap transient.

Column 1 of Table 1 shows the baseline parameter set that closely matches these criteria. The most significant are:

- to maintain wall plug power, beam currents, bunch lengths, and RF requirements comparable to present B-Factories, with parameters as close as possible to those achieved or under study for the ILC Damping Ring and at the ATF ILC-DR test facility;
- to reuse as much as possible of the PEP-II hardware;
- to simplify the IR design as much as possible, reducing the synchrotron radiation in the IR, HOM power and increasing the beam stay-clear;
- to eliminate the effects of the parasitic beam crossing, at the same time relaxing as much as possible the requirements on the beam demagnification at the IP;
- to design a Final Focus (FF) system to follow as closely as possible existing systems, and integrating it as much as possible into the ring design.



Figure 1: SuperB footprint at LNF.

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The machine is designed to have flexibility for the parameters choice with respect to the baseline: the horizontal emittance can be decreased by a factor of ~ 2 in both rings by changing the partition number (by changing the RF frequency, as done in LEP, or the orbit in the ARCS) and the natural emittance by readjusting β functions. Moreover the FF system has a built-in capability for decreasing the IP β functions of a factor of ~ 2 , and the RF system will be able to support higher beam currents than the baseline, when all the available PEP RF units will be installed.

Based on these considerations, columns 2 and 3 in Table 1 show different parameters options:

- “Low Emittance” case relaxes RF requirements and problems related to high current operations (including wall-plug power) but puts more strain on the optics and the tuning capabilities;

- “High Current” case relaxes requirements on vertical emittance and IP β functions, but high currents issues are enhanced in terms of instabilities, HOM, synchrotron radiation, wall-plug power, etc.

The cases considered have several parameters kept as much constant as possible (bunch length, IP stay clear etc...), in order to reduce their impact on other unwanted effects (Detector background, HOM heating etc...).

SuperB can also operate at lower cm energy (τ /charm threshold energies near 3.8 GeV) with a somewhat reduced luminosity and minimal modifications to the machine: the beam energies will be scaled, maintaining the nominal energy asymmetry ratio used for operation at the cm energy of the Y (4S). The last column in Table 1 shows preliminary parameters for the run at the τ /charm.

Table 1: SuperB parameters for baseline, low emittance and high current options, and for τ /charm running.

Parameter	Units	Base Line		Low Emittance		High Current		τ -charm	
		HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	cm⁻² s⁻¹	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
Emittance x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
Emittance y	pm	5	6.15	2.5	3.075	10	12.3	13	16
Bunch length (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
RF frequency	MHz	476.		476.		476.		476.	
Number of bunches	#	978		978		1956		1956	
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.097	0.097	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Total RF Wall Plug Power	MW	16.38		12.37		28.83		2.81	

RINGS LATTICE

The SuperB HER and LER ring lattices need to comply with several constraints. First of all extremely low emittances and IP beam sizes, needed for the high luminosity, damping times, beam lifetimes and polarization for the electron beam. The rings can be basically considered as two Damping Rings (similar to ILC and CLIC ones) with the constraint to include a FF section for collisions. So, the challenge is not only how to achieve low emittance beams but how to choose the other beam parameters to be able to reach design luminosity with reasonable lifetimes and small beams degradation. For this purpose a new “Arc cell” design has been

adopted for SuperB [3]. The extremely low- β in the FF system, together with the Crab Waist scheme, requires a special optics that provides the necessary beam demagnification at the IP, corrects its relative chromaticity and provides the necessary conditions and constraints for the “Crab Waist” optics.

Both rings are located in the horizontal plane. The FF is combined with the two ARC in two half-rings (one inner, one outer) and a straight section on the opposite side, which comes naturally to close the ring and readily accommodate the RF system and other necessities (e.g. injection). In this utility region crossing without collisions for the two rings will be provided. More details on the lattice can be found in Ref [3].

INTERACTION REGION

The high luminosity is achieved primarily with the implementation of very small β_x^* and β_y^* values at IP. These conditions are primary driving terms in the design of the IR. The FF doublet (QD0 and QF1) must be as close as possible to the IP in order to minimize chromatic and other higher-order aberrations from these magnet fields. Initial design of the IR incorporated a shared (both beams are inside) quadrupole in order to get this magnet as close as possible to the IP. However, with a non-zero crossing angle, a shared magnet invariably bends one or both of the beams, producing unwanted additional emittance, since the shared magnet is quite strong even when the crossing angle is minimized. In addition, the bending of the outgoing beams generates significant luminosity based backgrounds for the detector.

These issues have led to an IR design with an increased crossing angle (± 33 mrad) in order to use separate focusing elements for each beam. The QD0 magnet is now a twin design of side-by-side super-conducting quadrupoles. The magnet windings are designed so that the fringe field of the neighbouring magnet can be cancelled maintaining high quality quadrupole fields for both beams. Further details about the IR design can be found in the Ref [4]. Fig. 2 shows a detail of the IR near the IP.

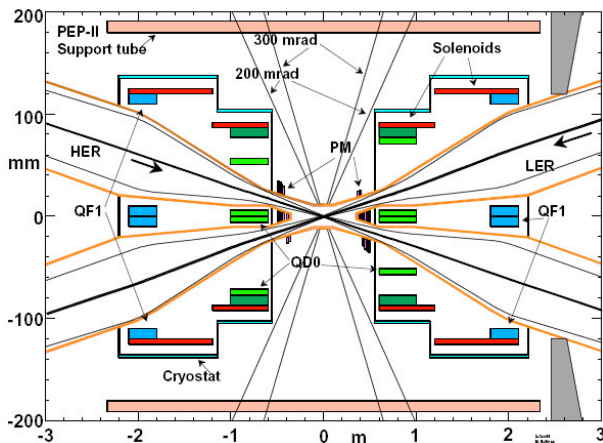


Figure 2: Layout of the IR near IP (-3m to 3m).

POLARIZATION

SuperB will achieve polarized beams by injecting polarized electrons into the LER. We chose the LER rather than the HER because the spin rotators employ solenoids which scale in strength with energy.

In SuperB at high luminosity the beam lifetime will be only 3...5 minutes and continuous-injection (“trickle-charge”) operation is a key component of the proposal. By injecting at a high rate with a polarized beam one can overcome the depolarization in the ring as long as the spin diffusion is not too rapid. In the ring ARC the polarization must be close to vertical to minimize depolarization. In order to obtain longitudinal polarization at the IP, a rotation of the spin by 90° about the radial axis is

required. A rotation of 90° in a solenoid followed by a spin rotation of 90° in the horizontal plane by dipoles also provides the required net rotation about the radial axis without vertical bending and was therefore adopted. The solenoid field integral required is 21.88 Tm for 90° spin rotation, well within the technical capabilities of superconducting solenoids of the required aperture. After the IP, the polarization has to be restored to vertical by a second spin rotator. Due to the low beam lifetime, it turns out that a symmetric spin-rotator scheme is feasible and can achieve 70% polarization or better. More details on these studies can be found in Ref [5].

INJECTION SYSTEM

The injection system for SuperB [6] is capable of injecting electrons and positrons into their respective rings at full energies. The HER requires positrons at 6.7 GeV and the LER 4.18 GeV polarized electrons. At full luminosity and beam currents, up to 4 A, the HER and LER have expected beam lifetimes in the range 3÷5 minutes. Thus, the injection process must be continuous, to keep nearly constant beam current and luminosity. Multiple bunches are injected on each linac pulse into one or the other of the two rings. Electrons from the gun source are longitudinally polarized: the spins are rotated to the vertical plane in a special transport section downstream of the gun. The spins then remain vertical for the rest of the injection system and injected in this vertical state into the LER. Positron bunches are generated by striking a high charge electron bunch onto a positron converter target and collecting the emergent positrons. Electron to positron conversion is done at about 0.6 GeV using a newly designed capture section to produce a yield of more than 10% [7]. The transverse and longitudinal emittances of both beams are larger than the LER and HER acceptances and must be pre-damped. A specially designed Damping Ring at 1 GeV, shared by both beams to reduce costs, is used to reduce the injected beam emittances.

CONCLUSIONS

The SuperB project design is ready for the TDR phase, in view of a possible start of construction already in 2011. Updates in the design and technical aspects will be published soon in a second edition of the Conceptual Design Report.

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