SuperB: NEXT-GENERATION e^+e^- B-FACTORY COLLIDER *

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Abstract

The SuperB international team continues to optimize the design of an electron-positron collider, which will allow the enhanced study of the origins of flavor physics. The project combines the best features of a linear collider (high single-collision luminosity) and a storage-ring collider (high repetition rate), bringing together all accelerator physics aspects to make a very high luminosity of 10^{36} cm^{-2} sec^{-1}. This asymmetric-energy collider with a polarized electron beam will produce hundreds of millions of B-mesons at the Υ(4S) resonance. The present design is based on extremely low emittance beams colliding at a large Piwinski angle to allow very low $\beta_y^\star$ without the need for ultra short bunches. Use of crab-waist sextupoles will enhance the luminosity, suppressing dangerous resonances and allowing for a higher beam-beam parameter. The project has flexible beam parameters, improved dynamic aperture, and spin-rotators in the Low Energy Ring for longitudinal polarization of the electron beam at the Interaction Point. Optimized for best colliding-beam performance, the facility may also provide high-brightness photon beams for synchrotron radiation applications.

INTRODUCTION

To achieve the design luminosity of 10^{36} in operation an ongoing effort of improvement is necessary. As part of this process new design options are explored and their effect on the design parameters studied. No individual option improves every single aspect of the machine and therefore all solutions have to be carefully compared and the solution with the overall best performance chosen. Part of this work is the study of unwanted effects, developing methods to compensate these and possibly test them in operating facilities. Based on these results design specifications and tolerances are developed. We report on the latest results of these efforts.

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PROJECT STATUS

In December 2010 the Italian Ministry for Education, University and Research approved the SuperB project [1]. With this decision the project enters a new stage. The current conceptual design has been published in [2]. The next goal is to deliver the engineering design report within the next year. Design construction has started.

LATEST DESIGN FEATURES

Design Parameters All calculations discussed in this paper and [2] are based on the design parameters as summarized in table 1.

Table 1: Super-B Parameters

Parameter	HER	LER
Luminosity $[cm^{-2}s^{-1}]$	1.00E36	
Energy [GeV]	6.7	4.18
X-Angle (full) [mrad]	66	
$\beta_x^\star$ [cm]	2.6	3.2
$\beta_y^\star$ [cm]	0.0253	0.0205
ϵ_x (with IBS) [nm]	2.07	2.37
ϵ_y [pm]	5.17	5.92
Bunch length @ I=0 [mm]	4.69	4.29
Beam current [mA]	1892	2447
Tune shift x	0.0021	0.0033
Tune shift y	0.0989	0.0955
δ @ I_{max} $[\frac{\Delta E}{E}]$	6.43E-4	7.34E-4
Lifetime [min]	4.20	4.48

IR Layout There are currently two designs under consideration for the interaction region layout. One bases its design on vanadium permendur Panofsky quadrupoles for QD0 and QF1 for both rings (”Russian” design) as shown in fig. 1. The second utilizes superconducting air coils for QD0 and QF1 (”Italian” design). In addition a portion of the HER QD0 is laid out as vanadium permendur Panofsky quadrupole. Both solutions show good behavior for synchrotron radiation backgrounds and beam aper-

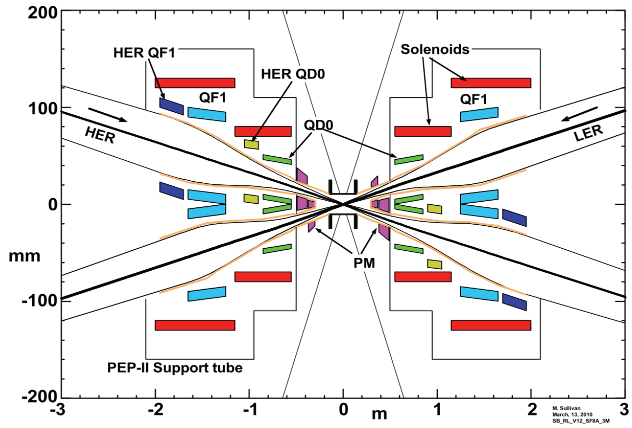

Figure 1: Vanadium Permendur “Russian” Design.

tures. With respect to the detector solenoid compensation the latter option provides better compensation possibilities for both rings as different angles for QD0 and QF1 of HER and LER is the optimum solution.

QD0 prototype For the QD0 design a prototype of the superconducting ”Italian” design is being built. The quadrupole will have a magnetic length of 30 cm and a gradient of 96 T/m and an inner bore radius of 2 cm. Critical aspects are the small space available for the SC wire and the thermal stabilization material (Cu+Al), and the small margin to quench. The prototype will help in determining the maximum gradient achievable at 4.2K and the field quality at room temperature. See Fig. 2 for a sketch of the magnet.

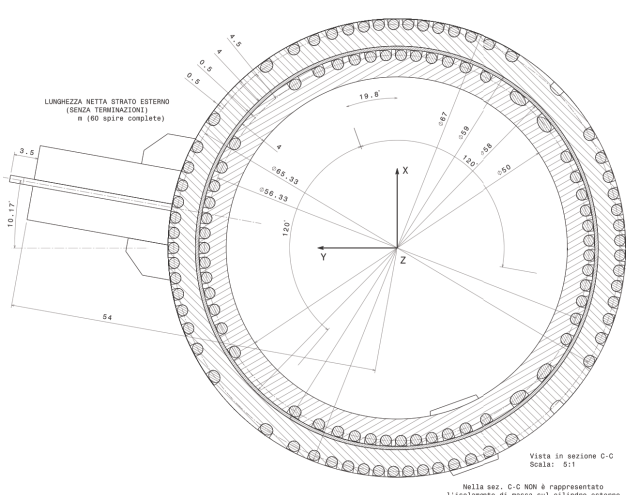

Figure 2: Construction drawing for QD0 prototype “Italien” style.

Arc Cell Design Over the past year two alternative arc cells have been developed. Three different versions for the HER arc cell were designed: V12 is the current version, V13 was modified to improve chromatic behavior and V14 to reduce the ring circumference. The major driver were the optimization of emittance, dynamic aperture, reduction of chromaticity for version 13 and reduction of ring circumference for version 14. The parameters for these new lattices are summarized in [3]. A detailed description for both solutions is given in [4].

Synchrotron Light Option Recently the possibility of using the HER and LER storage rings as third generation light source have been investigated. As an initial step the performance of both rings were compared to state of the art facilities in operation, construction and design [5]. Both HER and LER compare favorable in this study. As a result the synchrotron light option has been made integral part of the Super-B project. A preliminary analysis was performed of the ring geometry locating synchrotron light beam lines on the LNF site at Frascati. This is work in progress. Adding the functionality of a light source to the project will have influence on the final site decision.

Compensation of Detector Solenoid The detector solenoid has a strong 1.5 T field in the IR area, and its tails extend over the range of several meters. The coupling of the horizontal and vertical betatron motion needs to be corrected in order to preserve the small design beam size at the Interaction Point. Additional complications are: (1) The solenoid is not parallel to either of the two beams due to the crossing angle leading to orbit and dispersion perturbations. (2) The solenoid overlaps the innermost IR permanent quadrupoles causing additional coupling effects. The proposed correction system provides local compensation of the solenoid effects independently for each side of the IR. It includes bucking solenoids to remove the unwanted longitudinal solenoid field tails and a set of skew quadrupoles, dipole correctors and ante-solenoids to cancel all linear perturbations to the optics. The details of the correction system design are presented in [6].

Low Emittance Tuning The ultra low vertical emittances in SuperB rings need a very careful procedure of emittance tuning, including the study of the maximum tolerable magnet errors (such as misalignments, tilts, BPM errors). To minimize the vertical emittance an orbit and dispersion as well as coupling and β-beating free steering routine has been developed. The efficiency of this routine has been studied for the SuperB lattices with MADX. The results were presented in [7]. The SuperB final focus (FF) introduces stringent restrictions on alignment of both FF and arcs. To test the applicability of this method beam studies were conducted in late 2010 at the Diamond Light Source. In this test the vertical emittance correction was compared to the standard method using LOCO. These studies are still ongoing and preliminary results were presented in [8].

Vibration Study To establish a “vibration budget” an ongoing study investigates the effects of on beam sensitivity to dynamic misalignments. The major sources for these are expected to be the vibration of the IR cryostat. To confirm this the effects of ground motion as measured at LNF and the vibration of arc quadrupoles have been compared to the first. For this investigation ground motion measurement at LNF site at Frascati, vibration measurement at the SLD detector at SLAC are combined with theoretical modeling. To establish the budget a maximum allowed orbit displacement at the interaction point reducing the luminosity is defined. The preliminary results are summarized in table 2. These results are based on the assumption that the

Table 2: Super-B Proposed Vibration Budget

Element	RMS motion	Xfer Fn	IP motion no FB	with FB
Linear Cryostat	$1\,\mu m$	0.035	$35\,nm$	$3.5\,nm$
Cryostat rotation	$1\,\mu rad$	$0.03\,\frac{m}{rad}$	$28\,nm$	$2.8\,nm$
Rest FF			$30\,nm$	$3.0\,nm$
Arc	$0.5\,\mu m$	0.03	$15\,nm$	$1.5\,nm$
Total x2			$79\,nm$	$7.9\,nm$

beam feedback achieves a 10 times reduction of motion at IP. Also the integrated RMS motion is larger than 1 Hertz. By achieving these values the relative beam motion at the IP will be within 8 nm and the luminosity loss below one percent. This work has been presented in [9].

Effect of Second Order Momentum Compaction A longitudinal head-tail instability can appear when the momentum compaction shows a strong nonlinear energy dependency [10]. The momentum compaction can be developed as a function of energy spread δ as follows: $\alpha = \alpha_1 + \alpha_2\,\delta + \alpha_3\,\delta^2$. This particular instability is affected by the combination of nonlinear momentum compaction and beam impedance. To better understand its effect it was studied using the code described in [11]. It showed the behavior of an saw tooth instability as depicted in fig. 3. The following preliminary results were obtained: (1) Second order term of momentum compaction may play important role in the longitudinal beam dynamics for low compaction machines. (2) There is no instability threshold for a positive value of $\frac{\alpha_2}{\alpha_1}$. (3) It is necessary to check that the second part of the momentum compaction of the Super-B lattice has the right sign, or at least is less than 0.05, if it is positive. During operation of the DAΦNE collider this behavior has been observed in the past. With this study the effects could be understood and, more important, provide the knowledge on how to avoid it.

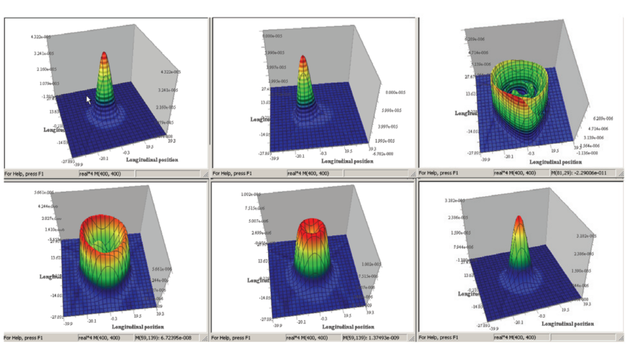

Figure 3: Simulation of head tail instability caused by nonlinear momentum compaction and wake fields. The instability manifests itself in an saw tooth behavior.

CONCLUSIONS

With the approval by the Italian government the project is moving from the conceptual to the technical design phase. The site choice will be the first official step. The collaboration with other funding agencies, through MOU, will soon be established. Construction plans will follow soon.

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