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Status of the SuperB project

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Summary. — An international collaboration has been settled to study a high-luminosity e^+e^- collider operating at the $\Upsilon(4S)$ that would deliver a luminosity of the order of $10^{36}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$. This collider, called *SuperB* Factory, would use a combination of linear and storage ring tecniques. Such a collider would produce an integrated luminosity of about $10\,\mathrm{ab}^{-1}$ in a running year at the $\Upsilon(4S)$ resonance. Further possibilities include having longitudinally polarized electrons at the interaction point and operating at the J/ψ beam energy.

PACS `29.20.db` – Storage rings and colliders.
PACS `41.85.-p` – Beam optics.

1. – Introduction

The PEP-II and KEKB asymmetric B-Factories have successfully operated producing world record luminosities, above $10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$, taking our understanding of accelerator physics and engineering demands of asymmetric e^+e^- colliders to a new regime of parameters [1]. This very high luminosity, coupled with the innovation of continuous injection and the high efficiency of accelerators and detectors, has allowed for these machines to produce more than $1.4\,\mathrm{ab}^{-1}$ in total up today.

As a nascent international enterprise and multi-lab effort, *SuperB* aims at the construction of an asymmetric very high luminosity on the Frascati/Tor Vergata Italian area, providing a uniquely sensitive probe of New Physics in the flavour sector of the Standard Model. The luminosity goal of $10^{36}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ can be reached with a new collision scheme with *Large Piwinski Angle* and use of *crab waist* sextupoles [2]. This new interaction region scheme, named *LPA & CW*, has been recently tested at the DAΦNE Φ-Factory

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Table I. – *SuperB main parameters.*

LER/HER	June 2008	January 2009	March 2009
E^+/E^- (GeV)	4/7	4/7	4/7
L (cm^{-2} s^{-1})	$1 \cdot 10^{36}$	$1 \cdot 10^{36}$	$1 \cdot 10^{36}$
I (A)	1.85/1.85	2.00/2.00	2.80/2.80
N_{part} [10^{10}]	5.55/5.55	6/6	4.37/4.37
N_{bunches}	1250	1250	2400
I_{bunch} (mA)	1.48/1.48	1.6/1.6	1.17
$\theta/2$ (mrad)	25	30	30
$\beta^\star_x$ (mm)	35/20	25/20	35/20
$\beta^\star_y$ (mm)	0.22/0.39	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
ξ_x	0.007/0.002	0.005/0.0017	0.004/0.0013
ξ_y	0.14/0.14	0.125/0.126	0.091/0.092
RF AC Power (MW)	16.2	18	25.5

at the LNF-Frascati with very successful results [3]. This novel collision approach allows for very low $\beta^\star$ and for beam currents and bunch length to be comparable to those of PEP-II and KEKB. A unique feature of the *SuperB* collider is the longitudinal polarization close to the Interaction Point (IP) of the electron beam, improving sensitivity for lepton flavor-violating τ decays, for measurement of τ g-2, CP in τ measurements and T violation studies.

After the publication of the Conceptual Design Report last March 2007 [4] the *SuperB* project has started the Technical Design Report (TDR) this Spring 2009, planned to be ready by end 2010. For this purpose lattice design and beam dynamics studies are in progress together with collective effects, R&D studies and parameters assessment [5].

2. – Design key issues

SuperB design consists of two separated rings, asymmetric in energy with electrons in High Energy Ring (HER) at 7 GeV and positrons in Low Energy Ring (LER) at 4 GeV, colliding at a horizontal angle as large as 60 mrad. Each ring has two arcs and two straight sections, one for the IR and the other for diagnostics, radiofrequency (RF) and injection lines. To save on costs the design is based on the reuse of the PEP-II hardware: magnets, beam pipe, RF system and injection components. For this reason the accelerator design is based on keeping wall plug power, beam currents, bunch length and RF requirements comparable to those of PEP-II. Other constraints are based on having parameters as close as possible to those already achieved in the B-Factories, or in other existing machines like ATF ILC-DR test facility, *i.e.* for the very low intrinsic emittance.

Flexibility of *SuperB* design allows different sets of parameters values that would provide the design luminosity of 10^{36} cm^{-2} s^{-1}, as confirmed by beam-beam simulations. Table I summarizes three possible choices of parameters, named as June 2008, January 2009 and March 2009. The vertical beam-beam parameter has decreased since June 2008,

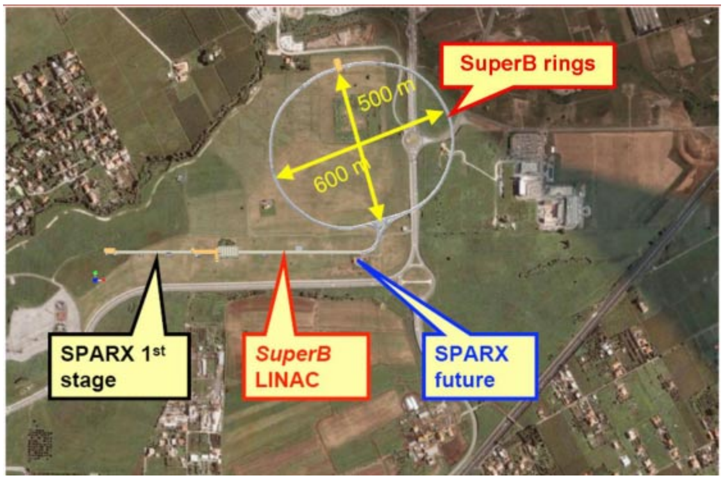

Fig. 1. – Possible *SuperB* location at Tor Vergata University.

at the expenses of the RF Power. Note the extremely low x tune shifts, characteristic of the *LPA* & *CW* scheme. The bunch length is fixed for all the configurations to 5 mm.

Figure 1 shows the possible location at Tor Vergata University near Rome with a ring circumference of about 1.8 km. Lattice studies are improving the layout; a shorter rings solution that provides the same emittance with a lower cells number and a larger arcs phase advance/cell is also being analyzed. The possibility of a more compact collider would have, among others, the advantage of reducing infrastructure costs and opening new scenarios concerning the site.

Standard approach for high luminosity is based on the increase of beam currents and decrease of $\beta^\star$ at the IP. However, $\beta_y^\star$ cannot be lowered below the bunch length σ_z, due to particles in the head and tail of bunches that would excite the *hourglass* effect when experiencing a larger $\beta_y^\star$. Thus, in the classical approach the gain in luminosity due to the $\beta^\star$ decrease is obtained shortening the bunch and accordingly increasing the RF voltage, with the drawback of beam pipe overheating, instabilities excitation and high power costs. Other side effects related to the high currents are the raising High Order Modes (HOM) instabilities and the increase of detector backgrounds.

On the other hand, the new approach for high luminosity given by the *LPA* & *CW* collision scheme overcomes these unwanted effects. In fact, the increase of the Piwinski angle is obtained both with the decrease of the horizontal beam size and the increase of the crossing angle. As a consequence the istantaneous overlap area of the colliding bunches is reduced, being only a portion of the beam sizes. As an important implication $\beta_y^\star$ can be lowered to a value comparable to this smaller overlap area, obtaining an immediate gain in luminosity. Moreover the horizontal tune shift due to the crossing angle is decreased and the parasitic collisions (PC) are automatically overcome, as the beam separation at the PCs is larger in terms of σ_x. A *LPA* itself introduces new beam-beam resonances that may strongly limit the maximum achievable tune shifts. However, the two *CW* sextupoles—the second important ingredient that characterizes this new colliding scheme—overcome this *LPA* side effect. In fact, if they are placed on both sides of the IP with a proper phase advance, they can suppress dangerous betatron and sychro-betatron resonances [6].

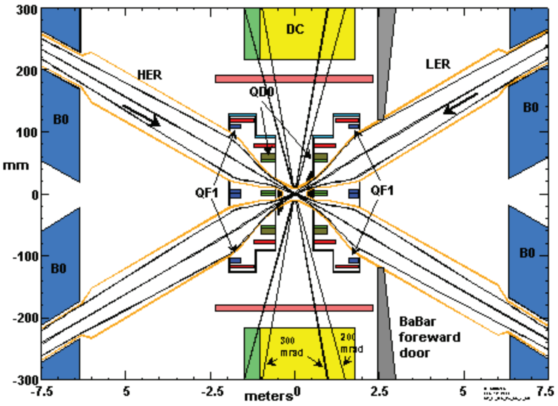

Fig. 2. – *SuperB* interaction region.

The IR final focus design is tight so compact doublet quadrupoles need to be placed very close to the IP. The present IR layout shown in fig. 2 has been optimized in order to ease the engineering design and provide the best performances in terms of beam stay clear and backgrounds [7]. All the magnets inside the detector are either permanent magnets (PM) or superconducting. The requests on the first defocusing quadrupole QD0 demand a challenging and non-conventional design, in fact a gradient larger than 50 T/m is needed separately for each beam line with a space between the two beams as small as about 1 cm. A novel approach based on double-helix coils is under study to fulfill these demanding requirements. To increase the focusing in the LER, where $\beta_y^\star$ is smaller, a small PM is foreseen close to the IP. Designs of IR beam pipe and proper shieldings for preventing physics contamination by backgrounds are underway. Moreover, dedicated backgrounds simulations are in progress; in particular especially for the LER, due to the small beam emittance Touschek and intrabeam scattering are important effects. Beam-gas backgrounds are expected to be comparable to those of PEP-II, nevertheless dedicated simulations are underway. Collimation studies are in progress, as well.

The low horizontal emittance in the *SuperB* rings is obtained by increasing the horizontal betatron phase advance in each arc cell and without the insertion of wiggler magnets. It is possible to reduce the ring circumference, just by increasing in all cells μ_x to 0.75/cell, with $\mu_y = 0.25$/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. Studies for the optimization of the tune working point together with the beam-beam simulations and the luminosity/lifetime optimization are in progress for the present lattice.

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 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.

3. – 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-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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