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FURTHER PROGRESS ON A DESIGN FOR A SUPER-B INTERACTION REGION*

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Abstract

We present an improved design for a SuperB interaction region. The new design minimizes local bending of the two colliding beams by separating all beam magnetic elements near the Interaction Point (IP). The total crossing angle at the IP is increased from 48 mrad to 60 mrad. The first magnetic element is a six slice Permanent Magnet (PM) quadrupole with an elliptical aperture allowing us to increase the vertical space for the beam. This magnet starts 36 cm from the Interaction Point (IP). This magnet is only seen by the Low-Energy Beam (LEB), the High-Energy Beam (HEB) has a drift space at this location. This allows the preliminary focusing of the LEB which has a smaller beta y* at the IP than the HEB. The rest of the final focusing for both beams is achieved by two super-conducting side-by-side quadrupoles (QD0 and QF1). These sets of magnets are enclosed in a warm bore cryostat located behind the PM quadrupole for the LEB. We describe this design for the interaction region.

INTRODUCTION

Work toward an interaction region (IR) design for an asymmetric-energy B factory with a luminosity of at least 1×10^{36} cm^{-2}s^{-1} has been ongoing for a couple of years now [1,2]. The initial IR design contained a shared vertically focusing quadrupole with the incoming beam close to the magnetic axis of the quadrupole [3,4]. This was done to prevent synchrotron radiation (SR), generated by the incoming beam, from striking and penetrating the 1 cm radius detector beam pipe and making unacceptable detector backgrounds. As a consequence, the two outgoing beams exited through the shared quadrupole considerably off-axis. This, in turn, resulted in the outgoing beams being strongly bent and producing significantly high power SR fans. The strong bending of the outgoing beams also swept the off-energy beam particles produced by the radiative bhabha reaction at the IP, out of the beam pipe and into the detector producing a significant background problem.

In order to ameliorate these drawbacks in the design, efforts since then have concentrated on solutions that have no magnetically shared elements between the beams [5]. This requirement has led to increasing the crossing angle between the beams from 34 mrad, to 48 mrad and finally to the present value of 60 mrad. These increases have allowed the final focus elements to be magnetically separate and yet remain as close as possible to the IP in order to capture the rapidly increasing beta functions and to minimize the chromaticity from these magnetic elements. We have set, as a goal, keeping the maximum beta values from these elements to ~2000 m.

FINAL FOCUS OPTICS

The beta functions at the collision point of the Super-B design are quite small. The HEB β_x^* value is 20 mm and the β_y^* is 0.37 mm while the LEB β_x^* and β_y^* values are 35 mm and 0.21 mm. Table 1 lists the accelerator parameters that are important for the IR design.

The initial IR designs used a beam-stay-clear (BSC) formula developed for PEP-II [6]. PEP-II, had an x BSC value that was defined as 15 uncoupled beam sigmas +2 mm for closed orbit distortion (COD) and the y value was defined as 15 fully coupled beam sigmas +2 mm COD. We recently decided that because of the very small emittance beams for the SuperB this BSC formula was not large enough and have adopted a new definition. The x BSC is now 30 uncoupled beam sigmas +0.5 mm COD and the y BSC is 10 fully coupled beam sigmas +0.5 mm COD. The vertical BSC corresponds to over 140 operational beam sigmas due to the very low coupling requirement for the SuperB (0.25%). PEP-II had a design coupling of 3% corresponding to BSC of about 70 vertical beam sigmas.

Table 1. Accelerator parameters for a Super-B Factory design with L = 1×10^{36} cm^{-2} s^{-1} that influence the IR.

	LER		HER
Energy (GeV)	4.0		7.0
Current (A)	2.00		2.00
No. bunches		1250	
Spacing (m)		1.26	
β_x^* (mm)	35		20
β_y^* (mm)	0.21		0.37
Emittance X (nm-rad)	2.8		1.6
Emittance Y (pm-rad)	7		4
Crossing angle (mrad)		60	

Permanent magnet quadrupole for the LEB

As one can see from the above table, the LEB β_y^* is lower than the HEB β_y^* and therefore one must try to place the first focusing element for the LEB as close as possible to the IP. Keeping in mind that we are adhering to the requirement of separate magnetic elements we have enough room between the beam envelopes at 0.36 m from the IP to place a small PM quadrupole on the LEB beam pipe. The magnet is made up of six slices 2 cm thick and continues out to 0.48 cm from the IP. Each slice has an

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elliptical aperture and is made of 16 wedge shapes designed in the Halbach manner to maximize the central field strength [7]. We have selected a NdFeB magnet material with a remnant field of 13.8 kG. This element uses all of the space between the two beams allowing for a 1 mm thick beam pipe wall for both beam lines. The two beams are far enough apart to go into separate beam pipes 0.35 m from the IP eliminating all but one parasitic crossing just before the entrance to the separate beam pipes in the case of all RF buckets being filled (0.63 cm spacing). Using the elliptical geometry, we are able to increase the vertical space in this magnet by as much as two times the horizontal space which we have specified as a 17 mm diameter throughout the magnet.

QD0

Figure 1 shows a layout of the interaction region. The primary final focus elements for both beams are QD0 and QF1. These magnetic elements are superconducting side-by-side iron free quadrupoles. We have four sets of these elements, two on each side of the IP. The coil windings of these magnets is such as to cancel the external field of the neighboring quadrupole field and is described in more detail in another paper in these proceedings [8]. The cold mass of QD0 is only 4mm thick radially for each single magnet. This leaves us with 5 mm of space between the cold mass and the warm bore beam pipe. Preliminary calculations indicate that this is enough space to effectively shield the cold mass from the warm bore [9]. The z locations of the QD0 and QF1 magnets are 0.58-0.98 m and 1.6-1.9 m respectively from the IP.

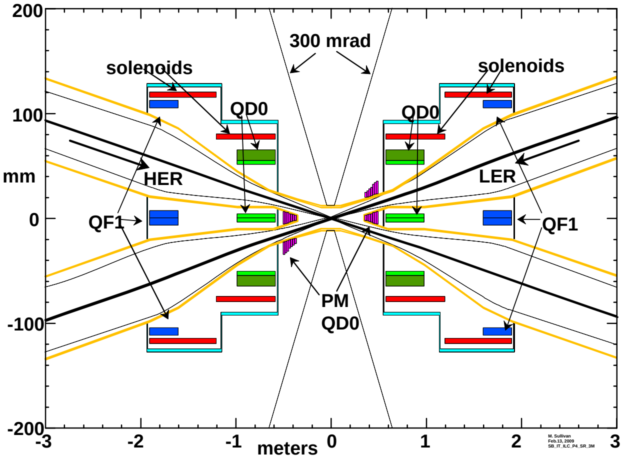

Figure 1. Layout of the SuperB interaction region. Note the exaggerated scale on the left. All of these elements are inside the detector solenoid magnetic field.

We have designed the IR to accommodate upgrade parameters for the IP. We did not want to design out possible machine upgrade parameters. In particular we have designed to lower β_y^* values than those shown in Table 1. We allow for a β_y^* value of 0.16 mm for the LEB and 0.27 mm for the HEB. Using these lower β_y^* values we obtain maximum beta values in the final focus doublet of 580 m for x and 1970 m for y in the HEB and 415 m and 2193 m for the LEB.

DTECTOR BACKGROUNDS

Synchrotron radiation

Detector backgrounds from synchrotron radiation (SR) must be properly controlled. The primary sources of SR background are from the final focus quadrupoles and from the last upstream bend magnets. For the SuperB IR design we have included soft field bend magnets (~10% field strength of the primary bend magnets) about 8 m upstream of the IP in both beam lines. This greatly lowers the synchrotron power and the critical energy of the photons that strike close to the IP. The final focus quadrupoles are the remaining source of SR background and because we have minimized any beam bending in the present design the background rates are now sensitive to the transverse distribution of the beam at large beam sigmas. With this in mind, we have traced the beam particles out to 20 σ in x and 45 σ in y and have verified that no photons generated by beam particles out to these beam sigmas directly strike the one cm radius detector beam pipe physics window which we define as ±4cm from the IP. We do see photons striking within 10 cm of the IP and we will need to study the photon scattering rate from these nearby surfaces in order to be sure we are maintaining the detector background rate from SR at an acceptable level.

Touschek and Beam-gas

The Touschek process has been studied extensively for the SuperB design (especially for the LEB) because the process is a large part of the beam lifetime. In fact, in an earlier design the Touschek lifetime dominated the lifetime of the LEB. The present beam parameters have been chosen to increase the Touschek lifetime for the LEB so that both beam lifetimes are now dominated by the luminosity lifetime of about 10 minutes. In light of this, the detector backgrounds from both Touschek and from beam-gas interactions are under study with preliminary results that look good. We reference another paper in these proceedings that discusses these backgrounds in greater detail [10].

VACUUM AND CRYOSTAT

Cryostat warm bore

As stated above, the beam vacuum chambers in the cryostats are now designed for room temperature operation (warm bore). This is especially important as these chambers intercept a significant amount of SR power from the last upstream bending magnets. Figure 2 displays the power numbers on the various beam pipe surfaces.

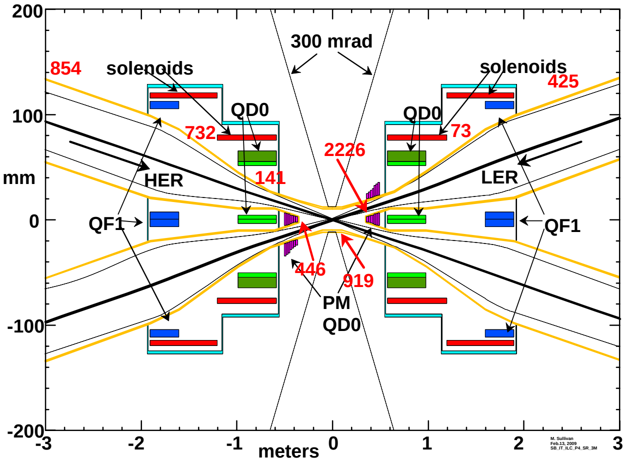

Figure 2. Layout of the interaction region showing synchrotron radiation power numbers on various beam pipe surfaces. The power numbers are in watts and are displayed in red.

As one can see from Fig. 2 some of these power numbers are significant in spite of the soft-bend upstream magnet and a careful study of how we remove this heat load must be undertaken. We do have space in the cryostat in most places to add a water cooled jacket to the beam pipe but there are a few places where space is tight and we will have to ensure we do not add too much of a heat load to the cryogenic system at these locations.

Detector beam pipe

The detector beam pipe is made of Be with a one cm radius. The Be will be coated on the inside with a thin layer of gold several microns thick. We presently plan to water cool this pipe as we expect to have to remove perhaps as much as a kW of power from the beam pipe based on the PEP-II experience. As we design the beam pipes in this area we will be able to perform wake field analysis on the vacuum components which will give us a good estimate of high-order-mode (HOM) power in this region. We expect to have to absorb some amount of HOM power in this area so we will have to include absorbers in the beam pipe design.

SUMMARY

We have developed an improved design for an interaction region for the SuperB accelerator. The new IR design has a larger crossing angle ±30 mrads an increase from the previous design value of ±24 mrads. This allows us to separate all of the magnetic elements so that we have no shared beam elements. In addition, we are able to keep the final focus elements close to the IP. The primary focusing elements start at 0.58 m from the IP with an added element for the LEB starting at 0.36 m. The final focus accelerator elements are now almost all contained in two cryostats; one on either side of the interaction point. There is an additional vertically focusing element for the low-energy beam made from permanent magnet material that is positioned inside the cryostats on either side of the IP and helps to control the low-energy beam vertical beta function. This is necessary because the low-energy beam β_y^* is smaller than the high-energy beam β_y^*. The increased crossing angle has also let us define a new, larger beam-stay-clear envelope to be 30 σ x, an increase from 15 σ x. At the same time, we now enough room to build the cryostat with a warm bore, a significant improvement over previous designs as the beam pipe walls in these cryostats intercept appreciable SR power.

Although we have made good progress toward a feasible design there is still much to do. The SR backgrounds have been checked to first order and look OK but further studies are warranted especially as there is significant SR power striking surfaces near the detector beam pipe. Forward and backscattering of photons from these surfaces needs to be modeled and verified that the SR background is still under control. The cryostat details need to be defined and spelled out and the vacuum chambers for the beams need more detailed study.

Further optimization no doubt will continue as we dig deeper into the design details but this present design looks very promising.

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