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AN IMPROVED DESIGN FOR A SUPER-B INTERACTION REGION *

M. Sullivan†, J. Seeman, U. Wienands, SLAC, Menlo Park, CA 94025, S. Bettoni, CERN, Geneva, Switzerland, M. Biagini, P. Raimondi, INFN, Frascati, Italy, E. Paloni, INFN, Pisa, Italy.

Abstract

We present an improved design for a Super-B interaction region. The new design attempts to minimize the bending of the two colliding beams which results from shared magnetic elements near the Interaction Point (IP). The total crossing angle at the IP is increased from 34 mrad to 50 mrad and the distance from the IP to the first quadrupole is increased. Although the two beams still travel through this shared magnet, these changes allow for a new magnetic field design with a septum which gives the magnet two magnetic centers. This greatly reduces the beam bending from this shared quadrupole and thereby reduces the radiative bhabha background for the detector as well as any beam emittance growth from the bending. We describe the new design for the interaction region.

INTRODUCTION

The success of the two B-factories has encouraged the study of yet higher luminosity machines. The physics community has expressed the desire to have a B-factory with a hundred-fold increase in luminosity from present day B-factories (PEP-II and KEKB). With this increase in luminosity and the acquisition of at least 75 ab^{-1} (5 yrs of running at 1×10^{36} $cm^{-2}s^{-1}$) they argue that the sensitivity to very rare decays becomes high enough to enable the possible observation, in some cases, of new physics up to the 10 TeV mass scale [1-3]. With this incentive, some of us have started looking at ways to increase luminosity at the Upsilon 4S center-of-mass energy. KEK has studied the possibility of increasing the number of bunches and beam currents (up to 5000 bunches and 9.4A on 4.1A) while shortening the beam bunch length down to 3 mm and crabbing the beam bunches so they collide head-on. They have a plan to upgrade their present B-factory to obtain these parameters and obtain a luminosity of 5×10^{35} $cm^{-2}s^{-1}$.

A small PEP-II team has also considered this approach (short beam bunches and high beam currents) but found difficulties with the design. The experience of the present B-factories with damaged vacuum components due to increased beam currents and/or attempts to shorten the beam bunch as well as increased power usage argued that this was a difficult path for a luminosity upgrade [4-6]. A new accelerator design, pioneered by P. Raimondi, that uses very low emittance beams and very small β_y^* values in a large crossing angle scheme with a way of crabbing the magnetic waist, has design parameters that achieve a luminosity of over 1×10^{36} cm^2s^{-1} with beam currents and bunch lengths similar to those found in today's B-factories [2,7,8]. This interesting design is currently being tested at the DAFNE accelerator in Frascati, Italy [9]. A Conceptual Design Report for a new Super-B factory accelerator was written up in the fall of 2007 [2]. It describes the older Interaction Region (IR) design mentioned below.

INTERACTION REGION DESIGN

In table 1, we list some of the machine parameters important for the IR design. The extremely low β^* values mean the final focusing elements need to be close to the IP.

Table 1: The most recent accelerator design values for a Super-B that are important for an interaction region design

	Nominal	Upgrade
Parameter	HER/LER	HER/LER
Luminosity ($\times10^{36}cm^{-2}s^{-1}$)	1	2
Beam Energy (GeV)	7/4	7/4
Beam Current (A)	1.85/1.85	1.85/1.85
β_x* (mm)	20/35	20/35
β_y* (mm)	0.39/0.22	0.27/0.16
Emittance x (nm-rad)	1.6/2.8	0.8/1.4
Emittance y (pm-rad)	4/7	2/3.5
Bunch spacing (m)	1.26	0.63
Crossing angle (mrad)	±25	±25

Previous IR design

The previous IR design described in the CDR had the final vertically focusing quadrupole (called QD0) as a magnetic element shared by both beams. The magnet is located 0.3 m from the IP and is 0.45 m long. The quadrupole center is aligned with the detector magnetic field and is horizontally displaced so that, on average, the incoming beam is centered in this quad. The smaller opening angle of the CDR design (±17 mrad) then minimizes the beam separation in this quad thereby minimizing the horizontal bending of the outgoing beam while producing enough separation to get the beams into separate beam pipes just outboard of QD0. Figure 1 shows a layout of this design. Although the bending of the off-axis beam was minimized in this design, the bending is still significant and causes several concerns. The radiative bhabha beam particles which now have too low an energy are swept out of the beam by this off-axis bending in QD0 and cause a significant background in the detector. In addition, the bending creates high power synchrotron radiation (SR) fans that can be managed but do cause more exotic magnet designs for the outgoing beam magnets. The final concern was emittance growth from the high field bending in these shared quads. More information about this design can be found in the following references [2, 10].

*Supported by US DOE contract DE-AC02-76SF00515.
†sullivan@slac.stanford.edu

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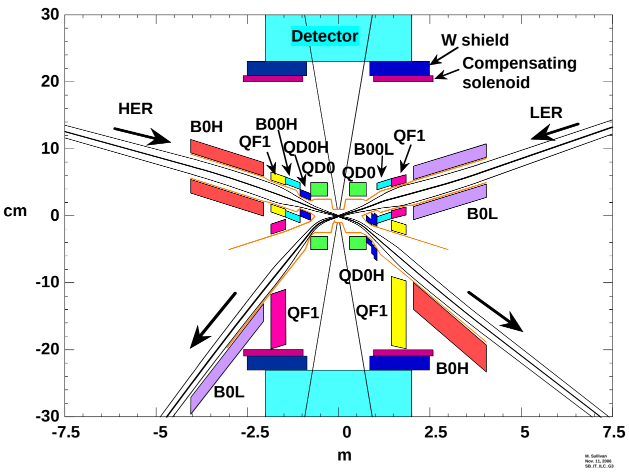

Figure 1. Layout of the IR design in the CDR. Note the large bending angles for the outgoing beams. The outgoing magnet apertures have to be quite large to accommodate the outgoing SR fans.

New IR design

In order to eliminate some of these concerns and further improve the IR design, a new layout and a new kind of QD0 magnet is envisioned. The new QD0 is a double quadrupole in that it has two magnetic centers with a septum of super-conducting coils. The magnet bores are cold in order to minimize the material between the two beams thereby maximizing the beam-stay-clear (BSC). In addition, the crossing angle has increased to ±25 mrad and the QD0 magnet face has moved back from the IP. The magnet is now located 0.4 m from the IP and is 0.25 m long. The two coil windings of QD0 are assumed to be equally energized. In a like fashion to the CDR design, the High-Energy Beam (HEB) needs more vertical focusing and hence we add an additional small vertical focusing quadrupole to the HEB beam line just outboard of QD0 called QD0H. The following two magnets are, respectively, the horizontal final focusing magnets for the Low-Energy Beam (LEB) and for the HEB. Figure 3 shows a layout of the new IR design.

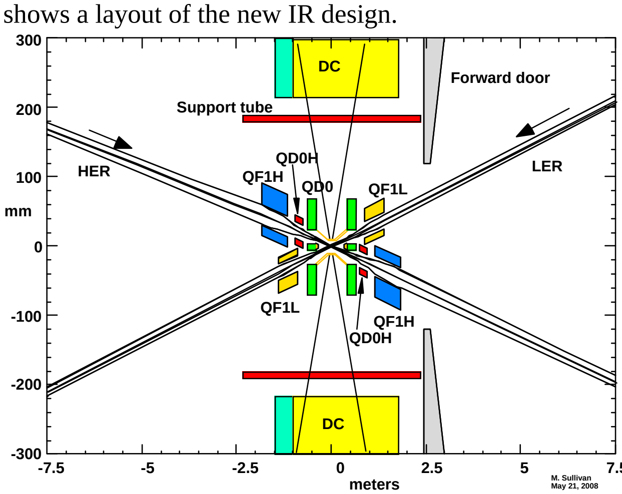

Figure 3. Layout of the new IR design. The QD0 is now a septum magnet with super-conducting windings in the septum.

RADIATIVE BHABHAS

One can see that the outgoing beams in the new design are essentially straight with very little bending. Figs 3 and 4 show the difference between the designs of the radiative bhabha energy spectrum. The energy of beam particles that can escape from the beam envelope is much lower in the new design. Clearly the detector backgrounds from this source are greatly reduced. The lack of bending also eliminates the concern of emittance growth.

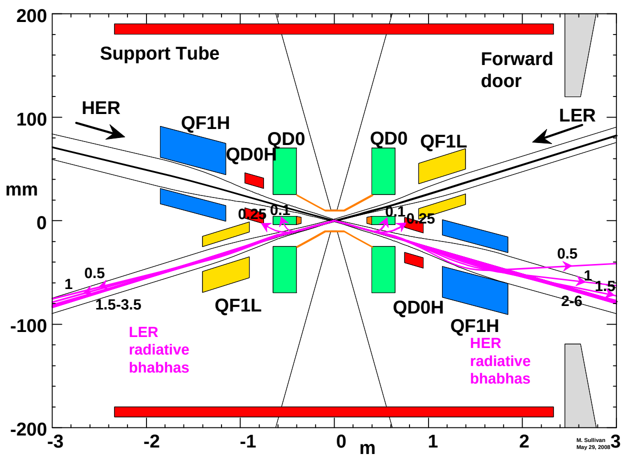

Figure 3. Plot of the trajectories of the off-energy beam particles for the radiative bhabha events for the new design. Figure 4 below is the same plot for the previous design. Only the lowest energy beam particles now have a chance of escaping from the beam envelope and hitting the beam pipe near the detector. The reason even these low energy beam particles escape is because there is still a little bending in the new QD0.

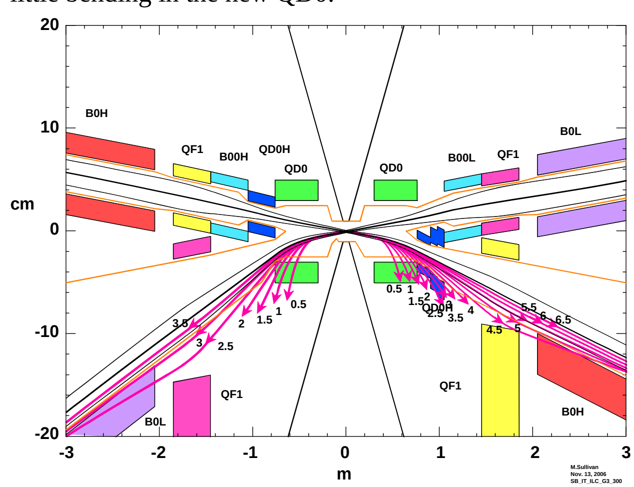

Figure 4. Plot of the radiative bhabha trajectories from the CDR design. Many more higher-energy particles are swept out of the beam envelope due to the strong bending in the shared QD0 magnet.

SYNCHROTRON RADIATION

Synchrotron radiation (SR) from the beam as it goes through the final bend magnet and through the final focus quadrupoles on its way to the IP can be a source of detector backgrounds. The final bend magnet is nearly 10 m from the IP so very little of the total bending power from this magnet reaches the area near the IP. The low emittance beams are a help in reducing backgrounds from SR. However, an added constraint is that very little power from SR is allowed to strike the cold bore surfaces of QD0. A careful first order study has been done for both of these designs and both designs do produce SR backgrounds in the detector but for both cases the level is acceptable. In both designs one of the upstream final focus magnets has been slightly displaced horizontally in order to steer the SR generated by the beam in the QF1 magnet away from the detector beam pipe. The detector beam pipe is a 20 cm long cylinder 1 cm in radius. The actual physics window is a cylinder that is about ±4 cm long for a detector aperture of ±300 mrad. Figure 5 shows the power in Watts from SR on various surfaces near the detector beam pipe.

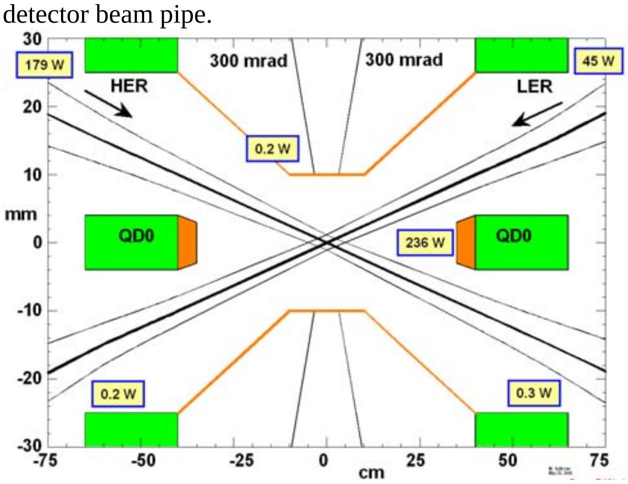

Figure 5. Diagram of the power incident on nearby surfaces from synchrotron radiation.

There are small amounts of power on the downstream cold bore surfaces of QD0. The amount of power (<1 W) is considered acceptable. There are no SR photons that strike the upstream cold bore surfaces and there are no photons that strike directly on the detector beam pipe. There is still a significant amount of SR power that strikes the mask in front of the downstream HER QD0 (236 W in this case). This is a high enough number to warrant further investigation, which we did, and a first order solid angle calculation reveals that the backscatter rate from this septum surface to the detector beam pipe is acceptably low.

SUMMARY

The success of the two B-factories has prompted interest in a Super-B factory design. An interaction region design is an important aspect of any collider design where detector background concerns and machine performance are interrelated. The present design is an improvement on the first design in that we have avoided bending the outgoing beams by using a more sophisticated design for the focusing magnet closest to the IP, QD0. Instead of sharing the quadrupole field with both beams we make QD0 into a septum quad with each beam being centered on a separate quadrupole field. This eliminates the strong bending of the outgoing beams that we had in the previous design. This reduces detector backgrounds from off-energy beam particles created by the radiative bhabha interaction at the IP and also eliminates the beam emittance growth seen in the older design. The new design has increased the distance of the first focusing element and the IP thereby increasing the beta function peaks. The new design also increases the crossing angle.

CONCLUSIONS AND OUTLOOK

We have come up with an improved IR design for a Super-B accelerator. There is still much to do. The new QD0 magnet is a challenging design in that we have presently only 8 mm of space in the septum between the two beams to make the super-conducting magnet. We are already exploring modifications to the design to improve the septum space. We are also looking at reducing the SR power from the upstream bending magnets in order to minimize the total amount of SR in the area around the IP. Many more iterations on the design are needed as well as more cross-checks, but it is beginning to look like a creditable design for a Super-B interaction region can be made.

REFERENCES

[1] "The Discovery Potential of a Super B Factory", Proceedings of the 2003 SLAC workshops, SLAC-R-709, December 2004.

[2] "Super-B a High-Luminosity Heavy Flavour Factory", Conceptual Design Report, INFN/AE-07/2, SLAC-R-856, LAL 07-15,March 2007.

[3] A. Stocchi, "The Super Flavour Factory Physics Case", Presentation at Super-B meeting, La Biodola**,** Isola d'Elba, May 31st - June 3rd, 2008, http://www.pi.infn.it/bfactory/SuperB_elba2008/index.html

[4] U. Wienands, *et. al.*, "High-Intensity Effects in PEP-II", These Proceedings, WEPP041.

[5] A. Novokhatski, *et. al.*, "A model of an Electrical Discharge in the Contacts with Omega Seals at High Currents in PEP-II", These Proceedings, TUPP054.

[6] A. Novokhatski, *et. al.*, "Loss Factor of the PEP-II Rings", These Proceedings, TUPP055.

[7] J. Seeman, *et. al.*, "Design of a 10^36/cm^2/s Super B-factory", These Proceedings, WEPP039.

[8] M. E. Biagini, *et. al.*, "New Low Emittance Lattices for the Super-B Accelerator Project", These proceedings, WEPP040.

[9] P. Raimondi, "Crabbed Waist Collisions in DAFNE and SuperB Design", These proceedings, WEXG02.

[10] M. K. Sullivan, *et. al.*, "Interaction Region for a Super-B Factory", Proceedings of PAC07, 2007, TUPAS066, pg. 1085.