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A PRELIMINARY INTERACTION REGION DESIGN FOR A SUPER B-FACTORY*

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Abstract

The success of the two B-Factories (PEP-II and KEKB) has encouraged us to look at design parameters for a B-Factory with a 30-50 times increase in the luminosity of the present machines to a luminosity of L ~ 1×10^{36} cm^{-2} sec^{-1}. We present an initial design of an interaction region for a "SuperB" accelerator with a crossing angle of ±14 mrad and include a discussion of the constraints, requirements and concerns that go into designing an interaction region for these very high luminosity e^+e^- machines.

1 INTRODUCTION

The PEP-II B-Factory has achieved a luminosity of 9×10^{33} cm^{-2} sec^{-1} and KEKB the B-Factory at KEK has reached a luminosity of 1.5×10^{34} cm^{-2} sec^{-1}. Both B-Factories are performing well over design specifications in both peak and in integrated luminosity. This has sparked an interest into looking at a design for a higher luminosity machine of the order 1×10^{36}. In order to achieve this high luminosity in a PEP-II design, the β_y^* values are reduced from 11 mm to 1.5 mm, the number of bunches is increased from 1725 to 6900 and the bunch currents are increased. Total beam currents are 10 A for the high-energy beam (HEB) and 23 A for the low-energy beam (LEB). Table 1 summarizes the machine parameters for the present PEP-II and for a SuperB PEP-II [1,2].

Table 1. The present PEP-II and a SuperB PEP-II .

Parameter	**PEP-II**	**SuperB**
e^+ energy (GeV)	3.1	8
e^- energy (GeV)	9	3.5
β_x^* (e^+/e^-) (cm)	50/28	15/15
β_y^* (e^+/e^-) (mm)	11/11	1.5/1.5
ε_x (e^+/e^-) (nm-rad)	30/50	40/40
ε_y (e^+/e^-) (nm-rad)	1.25/2.10	0.43/0.43
Bunch length (mm)	11	1.7
Crossing angle (mrad)	0	±14
Number of bunches	1588	6900
Beam current (e^+/e^-) A	2.45/1.55	10.1/23.0
Particles/bunch ($\times10^{10}$)	7.1/4.5	6.7/15.3
Bunch current (e^+/e^-)(mA)	1.54/0.98	1.46/3.33
Lum. ($\times10^{34}$ cm^{-2} sec^{-1})	0.92	100

2 INTERACTION REGION DESIGN

The PEP-II SuperB interaction region design has a ±14 mrad horizontal crossing angle. The crossing angle collision separates the beams enough of 0.155 m, the 1st parasitic crossing for 6900 bunches, to keep the beam-beam effects minimized at this first near miss location. The first magnet from the IP is a shared vertically focusing quadrupole (QD1) located at 0.35 m – 0.85 m from the IP. This horizontally defocusing magnet further separates the two beams horizontally and allows for the placement of the first septum magnet (QF2) to be located at 2.5 m from the IP. The fact that the QD1 magnets are shared and that the two beams have different trajectories through these magnets means that the beams will be bent in these magnets and the bending will generate synchrotron radiation power. At the high beam currents of 10 A and 23 A any amount of bending can generate significant levels of SR power. Bending the beams before the collision can generate backgrounds by sweeping off-energy particles onto the detector beam pipe and bending in the beams after the collision can generate backgrounds proportional to the luminosity by sweeping the off-energy beam particles from radiative bhabhas onto the nearby beam pipe.

In order to try to strike a balance between backgrounds from beam gas events and backgrounds from luminosity terms, the locations of the QD1 magnetic axes with respect to the two beam orbits are considered free parameters. The present design has the QD1 axis for the incoming LEB very nearly centered on the beam orbit while the QD1 on the incoming HEB side is shifted toward the outgoing LEB orbit. This shift decreases the amount of bending the outgoing LEB experiences thereby decreasing the luminosity background term for the LEB at the expense for generating a little more SR power from the HEB by bending the upstream HEB a small amount. For the incoming LEB, shifting the QD1 axis toward the outgoing HEB generates a SR fan that either strikes or comes too close to a detector beam pipe. Figure 1 shows a layout of this initial interaction region design. The QF2 magnets complete the final focusing of the LEB and the two sets of magnets QD4 and QF5 are the primary magnets for the final focusing of the HEB. The axes of these magnets were located on the beam trajectories in this initial design. At this stage, bending radiation from magnets further outboard of the IP is ignored. We believe that soft bends can be placed before any outboard bending magnets so as to minimize the incoming SR.

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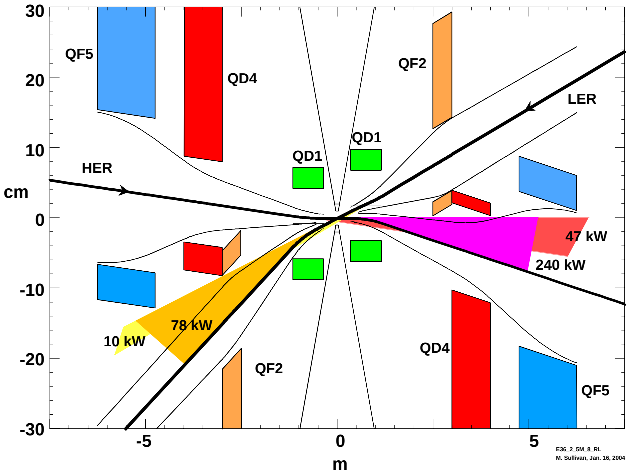

Figure 1. Plan view of the initial Super B-factory IR design. Note the exaggerated vertical scale. The collision angle is ±14 mrads. Some additional bending is introduced into the upstream HEB in order to minimize the total beam bending of both beams. The two small horizontal lines inside the QD1 magnets indicate the centerline of each magnet. The detector acceptance of ±300 mrads is shown in the middle of the picture.

3 SYNCHROTRON RADIATION

The next step in checking the feasibility of the design is to look at synchrotron radiation from the local final focusing quads. In this case, we have QD1 and QF2 for the LEB and QD1, QD4 and QF5 for the HEB. An initial design for the detector beam pipe is a round pipe with a 25 mm inside radius that is ±15 cm long and with masking located at ±15 cm from the IP. The masks are disks that have a smaller radius than the detector beam pipe radius. The assembly is oriented along the HEB collision axis.

The first look at the SR background indicated that there are too many photons directly striking the detector beam pipe from both incoming beams. The physics window of the beam pipe is considered to be ±10 cm from the IP. Closer inspection reveals that the source of the photons striking the beam pipe is from the focusing in the x plane near the outboard end of QF2 for the LEB and focusing in the x plane near the inboard end of QF5 for the HEB. The beam particles that produce the background are between 7 and 10 beam sigmas in x. Table 2 is a summary of the SR backgrounds for various cases and it includes a comparison with the design values for the PEP-II B-factory. The estimated integrated radiation dose from SR for a silicon detector in the PEP-II design was 11 krad/yr. If we scale this dose rate up to the values of the initial baseline for the SuperB we get a dose rate of 650 Mrad/yr from the HEB alone.

In order to ameliorate the SR backgrounds from the HEB, we offset the QD4 magnet from the incoming beam axis by 10 mm. The induced bend in the beam orbit redirects the radiation from 7-10σ particles in the upstream QF5 magnet away from the detector beam pipe. In a similar manner, the QF2 magnetic axis is offset from the LEB orbit by 12 mm and the resulting bend in the beam again redirects the SR from the 7-10σ particles in the outboard part of QF2 away from the detector beam pipe. The background results are shown in table 2.

Table 2. Summary of SR background numbers for various improvements to the initial baseline design. The photon counts are photons that are greater then 4 keV.

Cases	**γ/xing**	**γ/sec**
PEP-II design values	10	2.4×10^{9}
Baseline HER	46500	4.4×10^{13}
Baseline LER	57100	5.4×10^{13}
Offset QD4 10 mm HER	141	1.3×10^{11}
Offset QF2 12 mm LER	244	2.3×10^{11}
Cut at 8σ instead of 10σ HER	140	1.3×10^{11}
Beam tail dist. #1 HER	5.8	5.5×10^{9}
Beam tail dist. #1 LER	9.6	9×10^{9}
Beam tail dist. #2 HER	0.10	9.4×10^{7}
Beam tail dist. #2 LER	0.15	1.4×10^{8}
No beam tail dist. HER	7×10^{-14}	6.5×10^{-5}
No beam tail dist. LER	1×10^{-11}	0.012

Figure 2 shows a plan view of the present SuperB IR design with the offset QD4 and QF2 magnets. The picture also shows the initial beam pipe design. The offset upstream magnets, while generating more total synchrotron radiation, greatly reduce the detector backgrounds from SR. The background values achieved by this method are probably acceptable; they are only about 10-20 times higher than the PEP-II design value. A test was made to verify that the background is dominated by the 7-10s particle distribution by cutting the particle density scan at 8σ instead of 10σ. The result is shown in Table 2 where the backgrounds from the HEB drop to the level of the offset QD4 case. Table 3 summarizes the SR power for the interaction region magnets.

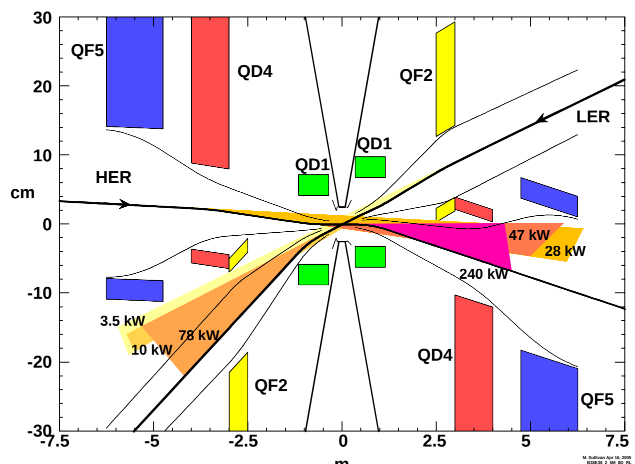

Figure 2. Plan view of the present IR design for a SuperB factory. Note the two extra SR fans generated by the offset QD4 and offset QF2 magnets. The beam pipe design shows a mask present on the incoming HEB side and little or no mask on the incoming LEB side.

Table 3. A summary of the synchrotron radiation power produced from the interaction region magnets. The first column is from the on-axis baseline design and the second column is for the present design with the offset QF2 and QD4 on the incoming beam orbits.

Magnet	Baseline (kW)	Present (kW)
Upstream LER QF2	0.24	**3.48**
Upstream LER QD1	10.21	10.21
Downstream LER QD1	78	78
Downstream LER QF2	0.24	0.24
Upstream HER QF5	1.67	1.67
Upstream HER QD4	1.00	**27.75**
Upstream HER QD1	47.42	47.42
Downstream HER QD1	240	240
Downstream HER QD4	1.00	1.00
Downstream HER QF5	1.67	1.67
Totals	381	411

4 BEAM TAILS

The head-on collision of the PEP-II design together with the beam bending in the shared QD1 magnets and in the offset QD4 magnets generate beam orbits in the PEP-II interaction region that produce SR backgrounds that are dominated by bending radiation and are relatively insensitive to beam-tail distributions. Consequently, we have adopted fairly conservative beam-tail distributions in the present PEP-II design.

In contrast, the SR backgrounds in the SuperB IR design are dominated by the particle density of the beam tails in the 7-10σ area of the x plane. The PEP-II beam-tail distributions were used in the initial baseline background calculations for the SuperB IR. Figure 4 shows plots of various beam tail distributions and Table 2 shows the change in the detector backgrounds based on the different beam-tail distributions seen in the plot. The beam-tail background numbers include the gain in background from the offsets in the QD4 and QF2 magnets. As one can see from Table 2, a reduction in the particle density in the high σ region of the x plane rapidly lowers the detector backgrounds to levels equal to and even below the PEP-II design value. One can also see that the removal of all beam tails (the no tail entries in table 2) completely remove the SR background. It should be noted that the vertical beam tail distribution does not, at present, make any appreciable background even when we use the relatively high beam tail distribution of the PEP-II design. Hence, all background numbers include the PEP-II beam-tail distribution in the y plane except for the no tail entries.

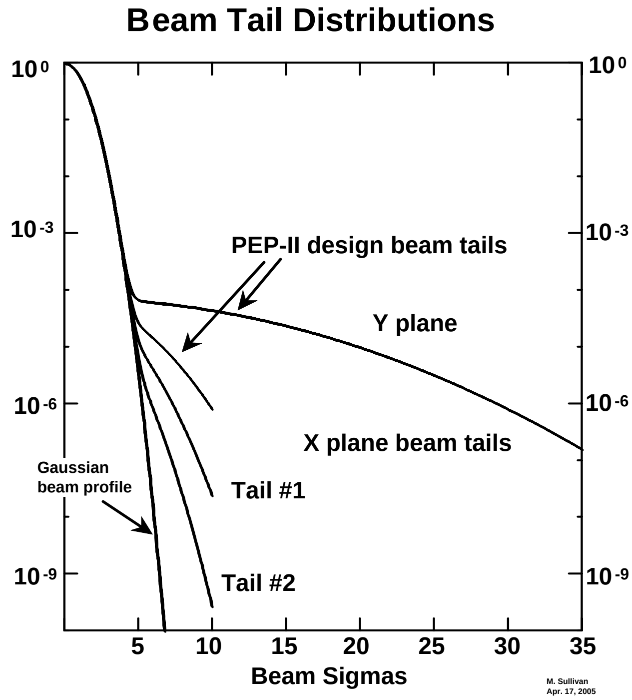

Figure 4. Plot of the various beam-tail distributions used to produce the background numbers in table 2.

5 SUMMARY

We have taken an initial look at an interaction region design for a B-factory with a luminosity of 1×10^{36} cm^{-2} sec^{-1}. The design has a ±14 mrad horizontal crossing angle which separates the two beams quickly enough to permit a bunch spacing of 0.32 m or 6900 bunches in a 2200 m PEP storage ring. Because of the high-current beams there is minimal beam bending in the design. Some beam bending is unavoidable due to the shared QD1 magnet. In addition, some bending of the upstream beam orbits is introduced in order to redirect synchrotron radiation generated by the focusing of the beam away from the detector beam pipe. This reduces detector backgrounds to within an order of magnitude of the PEP-II backgrounds. Further reductions in backgrounds can be achieved by lowering the beam tail distribution in the x plane. Perhaps the present B-factories can shed some light on what the actual particle density is in the beam-tails.

The results from this initial study are encouraging. It looks like synchrotron radiation backgrounds can be controlled. More work needs to be done and further iterations of the design need to include HOM power generated by the SR masking, lost beam particle backgrounds and backgrounds from luminosity as well as magnet and vacuum chamber designs.

6 REFERENCES

[1] J. Seeman, *et.al.*, "Design Studies for a 10^{36} Super-B-factory", EPAC 2004 proceedings.

[2] J. Seeman, et.al., "Parameters of a Super-B-Factory Design", these proceedings.