SLAC-PUB-10546
July 2004

IR UPGRADE PLANS FOR THE PEP-II B-FACTORY*

M. Sullivan[†], S. Ecklund, N. Kurita, A. Ringwall, J.Seeman, U. Wienands, Stanford Linear Accelerator Center, Stanford, CA 94309
M. Biagini, INFN/LNF, Frascati (Roma), Italy

Abstract

PEP-II, the SLAC, LBNL, LLNL B-factory has achieved a peak luminosity of over 9×10^{33} $cm^{-2}s^{-1}$, more than 3 times the design luminosity, and plans to obtain a luminosity of over 1×10^{34} cm^{-2} sec^{-1} in the next year. In order to push the luminosity performance of PEP-II to even higher levels an upgrade to the interaction region (IR) is being designed. In the present design, the interaction point (IP) is a head-on collision with two strong horizontal dipole magnets located between 21-70 cm from the IP that bring the beams together and separate the beams after the collision. The first parasitic crossing (PC) is 63 cm from the IP in the present by2 bunch spacing. Future improvements to PEP-II performance include lowering the β_y^* values of both rings. This will increase the β_y value at the PCs which increases the beam-beam effect at these non-colliding crossings. Introducing a horizontal crossing angle at the IP quickly increases the beam separation at the PCs but recent beam-beam studies indicate that a significant luminosity reduction occurs when a crossing angle is introduced at the IP. We discuss these issues and describe the present interaction region upgrade design.

1 THE INTERACTION REGION

The PEP-II asymmetric-energy electron and positron beams are brought into a head-on collision by strong (~0.8T) horizontal dipole magnets located ±21-70 cm from the IP. The strong dipoles (called B1) are made of permanent magnet material (Sm_2Co_{17}) and are tapered for the first 22.5 cm in order to accommodate the Silicon Vertex Tracker (SVT) of the BaBar detector. Figure 1 is a photograph of the B1 magnets with half of the SVT installed.

The beam separation continues in the next magnet, a shared vertically focusing quadrupole (QD1) with a magnetic axis very close to the High-Energy Beam (HEB) trajectory. This maximizes the horizontal displacement for the Low-Energy Beam (LEB) thereby maximizing the beam separation. The beams are then separated enough to be able to enter individual beam pipes at about 2.5 m from the IP. Figure 2 shows a layout of the PEP-II interaction region. Note the expanded x scale on left of the drawing as compared to the z scale at the bottom.

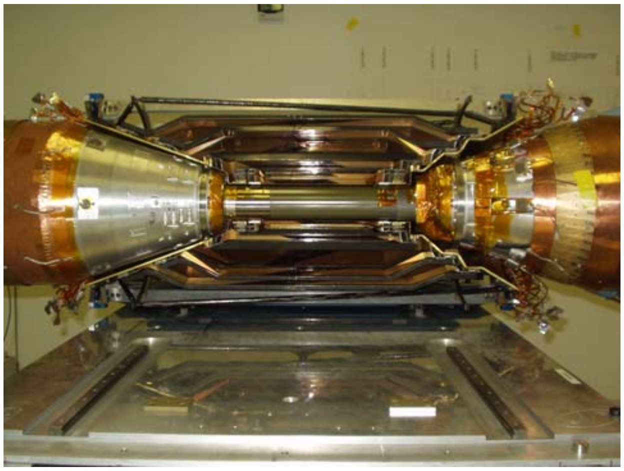

Figure 1. Picture of the tapered sections of the B1 magnets with half of the Silicon Vertex Tracker in place.

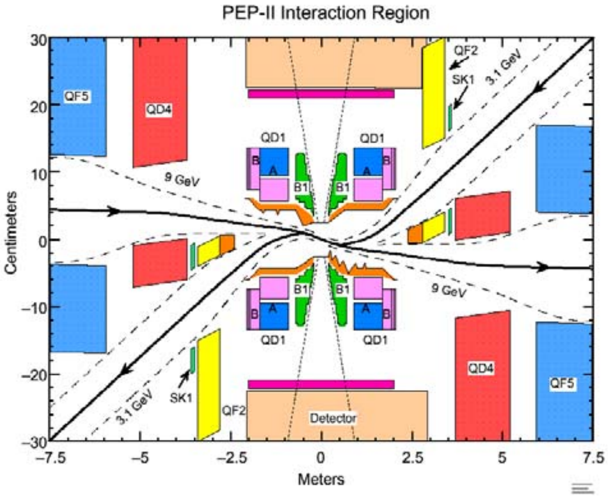

Figure 2. Layout of the PEP-II Interaction Region. The B1 magnets are shown closest to the IP. The 1st parasitic crossing when every other RF bucket is filled with charge is located at the outboard end of the B1 magnets.

2 PARASITIC CROSSINGS AND BEAM-BEAM EFFECTS

---

*work supported by the Department of Energy under contract number DE-AC03-76SF00515.

[†] sullivan@slac.Stanford.edu

Presented at the 9th European Particle Accelerator Conference (EPAC 2004), 7/5/2004 - 7/9/2004, Lucerne, Switzerland

2.1 Beam Bunch Spacing

There are a total of 3492 RF buckets in the PEP-II rings. Of these, about 92 buckets are reserved for the abort kicker ramp up time. This leaves about 3400 RF buckets that can be filled with charge.

Last fall the bunch spacing was changed from 1.89 m (by3 bunch pattern) to 1.26 m (by2 bunch pattern). We had filled up the by3 pattern so, in order to increase the total number of bunches, we moved to a smaller bunch spacing. The change moved the 1st PC from 0.945 m to 0.630 m from the IP. The beam separation at the 1st PC also decreased from 9.7 mm to 3.2 mm. Table 1 shows the design beam separation at all possible PCs.

Table 1. Beam separation at all of the possible parasitic crossings of PEP-II. Beyond 2.5 m the beams enter separate beam pipes. There is virtually no separation at the 0.315 m point because the B1 magnets only begin separating the beams at 0.21 m. This rules out the possibility of filling every RF bucket with charge without introducing a fairly large crossing angle at the IP.

Z (m)	**Beam separation (mm)**	**Notes**
0.315	0.139	1st PC if every bucket is filled (by1)
0.630	3.231	1st PC if every other bucket is filled (by2)
0.945	9.699	1st PC if every third bucket is filled (by3)
1.260	17.780	1st PC if every fourth bucket is filled (by4)
1.575	28.857	1st PC if every fifth bucket is filled (by5)
1.890	43.600	1st PC if every sixth bucket is filled (by6)
2.205	60.549	1st PC if every seventh bucket is filled (by7)
2.520	77.665	1st PC if every eighth bucket is filled (by8)

Increasing the number of bunches from about 1130 to 1580 and lowering the β_y^* of both beams from 12.5 mm to 10.5 mm are two of the reasons the PEP-II accelerator has a peak luminosity of 9.2×10^{33} $\mathrm{cm^{-2}s^{-1}}$ up from the 6.6×10^{33} $\mathrm{cm^{-2}s^{-1}}$ peak we had this past June 2003[1,2].

As seen in Table 1, increasing the number of bunches by moving out of a by3 pattern and going to a by2 bunch pattern has decreased the beam separation at the 1st PC and thereby has increased the beam-beam effects seen at these near-collisions. Indeed, although the amount is difficult to quantify, there was a noticeable drop in luminosity estimated at about 5-10% when we first moved to a by2 bunch pattern. We maintained approximately the same number of total bunches in the machine when the change was made by constructing mini-trains with gaps between the trains. However, after 1-2 weeks it was felt that much of the luminosity decrease had been regained by tuning with an overall loss of still perhaps 3-5% [3].

2.2 Beam-Beam Effect from Parasitic Crossings

The formulas for calculating the beam-beam tune shifts induced by a parasitic crossing are shown below [4,5].

$$\xi_x = -\frac{N\,r_e}{2\pi\gamma}\,\frac{\beta_x\left(x^2-y^2\right)}{\left(x^2+y^2\right)^2} \tag{1}$$

$$\xi_y = +\frac{N\,r_e}{2\pi\gamma}\,\frac{\beta_y\left(x^2-y^2\right)}{\left(x^2+y^2\right)^2} \tag{2}$$

Where x and y are the horiz. and vert. beam separations at the PC.

As seen from the formulas, the tune shift is proportional to the beta function at the PC and inversely proportional to the square of the distance between the two beams. As the β_y^* at the IP is lowered the β_y value at the 1st PC gets larger increasing the PC tune shift.

3 CROSSING ANGLE

We considered the option of introducing a crossing angle at the IP in order to improve the beam separation at the 1st PC. Table 2 shows how much the separation improves with the introduction of a small crossing angle at the IP. However, recent beam-beam studies [6,7] indicate a significant reduction in luminosity for even a small crossing angle.

4 UPGRADE PLANS

We plan to maintain our present head-on collision at the IP but keep open the option of introducing a small crossing angle. In order to improve the beam-beam effect from the 1st PC we plan to upgrade the B1 magnets. The magnets are made up of 12 slices of permanent magnet material; five slices are 25 mm thick and 7 slices are 50 mm thick. By increasing the bending field of the slices closest to the IP we will increase the beam separation at the 1st PC. We will keep the integrated strength of the magnet about the same by removing or weakening some of the slices farthest from the IP. These slices contribute nothing to the beam separation at the 1st PC since they are located either on top of or just after the crossing. Table 2 shows how much more beam separation we should get by increasing the strength of the B1 magnets.

Keeping the integrated strength constant helps minimize the difference between the new beam orbits and the design orbits. We are able to keep the orbit deviations below 2 mm for both beams in both planes until we can match the new orbit to the original design. This eliminates the need for further changes in the IR because of the new orbit. Figure 3 illustrates the changes planned for the IR.

In order to increase the field strength of the inboard slices we need a stronger permanent magnet material. The material we are presently using has a remanent field (Br) of 1.05T. We are looking at material with a Br of ~1.2T. The material must be somewhat radiation hard but the total radiation level this close to the SVT can not be very high. We estimate the material must be rad hard up to about 100 Mrads. This is ten times higher than any number the SVT might encounter.

In addition, we can decrease the inner radius of some of the slices as well as increase the outer radius of some of the slices. We think we can get about a 20% improvement in the field strength.

Table 2. The table shows the beam separation at the 1st PC for the by2 bunch pattern for various crossing angles at the IP. In addition, the table has the separation increase for 2 cases of strengthened B1 magnet slices.

Type of separation	(mm)	% increase
Design (head-on)	3.23	
±0.25 mrad crossing angle	3.54	10
±0.5 mrad crossing angle	3.86	19
±0.75 mrad crossing angle	4.17	29
±1 mrad crossing angle	4.48	39
Head-on with modified B1s		
B1 slices increased +20%	3.46	7
B1 slices increased +30%	3.78	17

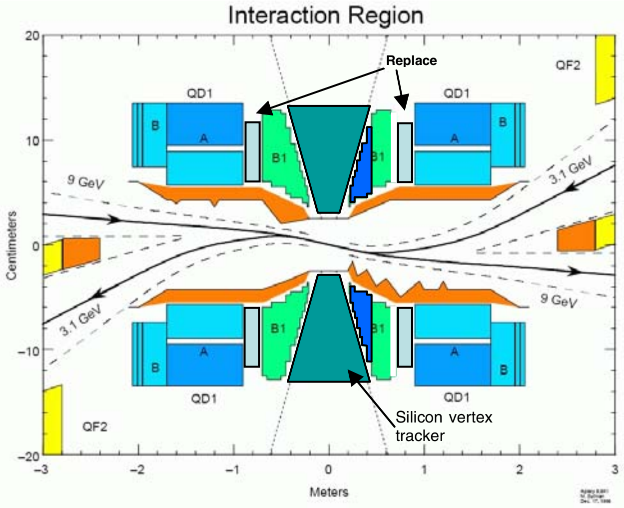

Figure 3. Layout of the Interaction Region showing the upgrade of the B1 magnets. The right hand side of the picture shows the modifications we would make to the B1 magnet. The darker blue slices would be the new stronger slices. For reference, the left hand side of the picture is unmodified and shows what we presently have. The gray boxes between the B1 and QD1 magnets are radial ions pumps that have become inoperable. We would replace these two pumps with new pumps.

5 SUMMARY

PEP-II has made good progress over the last year and has increased the luminosity peak from $6.6\times10^{33}cm^{-2}s^{-1}$ to $9.2\times10^{33}cm^{-2}s^{-1}$. PEP-II is now in a by2 bunch pattern and will remain in that pattern. The by2 pattern has a 1st parasitic crossing at 0.63 m from the IP and a beam separation of 3.2 mm. We have seen some effect on the luminosity of the machine and are looking at ways to improve the beam separation in order to minimize the tune shift from the 1st PC. As we improve the luminosity by lowering the β_y^* values the effect of the 1st PC on the beam will become more pronounced.

One way of improving the separation is to introduce a crossing angle at the IP. However, beam-beam simulations indicate a decrease in luminosity from even a small crossing angle. We have chosen to maintain head-on collisions but leave open the option of introducing a small crossing angle. We plan to increase the bending field of the B1 dipoles on the ends nearest to the IP in order to improve the beam separation at the 1st PC. In order to increase the strength of the B1 magnets we will use higher strength permanent magnet material and increase (slightly) the volume of the material.

6 ACKNOWLEDGEMENTS

We would like to thank the PEP-II team and the operations team who have done so well in getting the performance of PEP-II to where it is. We would also like to thank the general support staff who have worked tirelessly to keep the accelerator running.

7 REFERENCES

[1] J. Seeman, “Results and Plans of the PEP-II B-Factory”, EPAC’04, July 2004, these proceedings.

[2] U. Wienands, “Trickle-Charge: A New Operational Mode for PEP-II”, EPAC’04, July 2004, these proceedings.

[3] F.-J. Decker, “Bunch Pattern with More Bunches in PEP-II”, EPAC’04, July 2004, these proceedings.

[4] M. Biagini, Private communication

[5] J. Jowett, Handbook of Accelerator Physics and Engineering, World Scientific (there is a sign mistake in the formula quoted there).

[6] K. Ohmi, “Study of Beam-Beam Interactions with/without Crossing Angle”, PAC’03, May 2003, pg 353.

[7] I. V. Narsky, “Study of Beam-beam Effects at PEP-II”, EPAC’04, July 2004, these proceedings