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INTERACTION REGION DESIGN AT THE PEP-II *B* FACTORY*

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1 ABSTRACT

We describe the Interaction Region (IR) for the PEP-II project[1], a collaboration of SLAC, LBNL, and LLNL. The near IR region inboard of 3 m from the interaction point (IP) is designed to focus the 3.1 GeV low-energy beam (LEB) and bring it into head-on collision with the 9 GeV high-energy beam (HEB). We describe the overall design parameters of this area and the integration with the detector geometry. Permanent magnet (PM) dipoles and quadrupoles inside the 1.5 T solenoidal field of the detector are described. The beam separation is initiated by a dipole field made from PM blocks in a stepped conical geometry in order to maximize detector solid angle coverage. The beam separation is completed by a hybrid PM quadrupole - dipole. The vacuum chamber is designed to mask synchrotron radiation (SR) away from the beam pipe located around the IP and to absorb the power (70 kW) generated by the SR, image current losses and higher-order-mode (HOM) losses.

2 BEAM SEPARATION SCHEME

The separation of the two beams after the head-on collision is initiated by a horizontally deflecting dipole magnet (B1) located between 21 and 70 cm on either side of the IP. These magnets are tapered in order to maximize the detector angular acceptance and in order to start the beam separation as soon as possible after the collision. The first parasitic crossing (the next place where the beam bunches pass each other) is 0.63 m from the IP and the beams must be separated by at least 7σ (where σ is the largest of the four beam sigmas) in order for the passing to have a negligible tune shift. In PEP-II, the separation at the first parasitic crossing is 10.5σ. The two beams share one more magnetic element (Q1) that completes the beam separation and is located just behind each B1 magnet (from 90 to 210 cm from the IP). Q1 is a hybrid magnet in that it contains a dipole field and a quadrupole field. The quadrupole field supplies vertical focusing to both beams and the dipole field shifts the magnetic center of the quadrupole field 20 mm horizontally so that the HEB essentially goes through the magnetic center of Q1. This configuration produces the maximum amount of horizontal beam separation in Q1 by bending the offset LEB away from the HEB. Both B1 and Q1 are made of PM material. These magnets are immersed in the detector solenoidal field and the need for a compact design led to the choice of PM. The separation of the beams by B1 and Q1 is enough to allow the next machine element (Q2) to start 2.8 m from the IP. Q2 is the horizontal focusing magnet of the final doublet for the LEB and is a septum magnet which has a field-free channel for the HEB. The center of this magnet is tilted (20 mrad) in the horizontal plane and offset (6 mm) horizontally from the LEB in order to maximize the space for the current septum. The next two machine elements are septum quadrupoles Q4 and Q5 (both 1.5 m long) which form the final-focus doublet for the HEB. The HEB goes through Q4 offset from the magnet center by 14 mm. This offset steers the beam and redirects SR generated by the outboard Q5 magnet away from mask surfaces that are near the IP. Q5 is centered on the HEB trajectory. Fig. 1 shows a layout of the IR out to ±7.5 m.

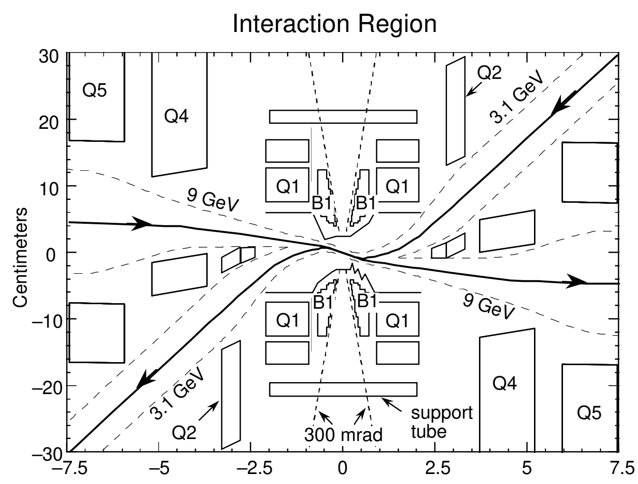

Figure 1. Layout of the interaction region of PEP-II showing the separation of the two beams. The dashed lines marked "300 mrad" define the angular acceptance of the detector. Note the exaggerated vertical scale.

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3 SYNCHROTRON RADIATION

Synchrotron radiation fans are produced when the beams go through the B1 magnets and, in addition, the deflected LEB in Q1 produces a strong fan of radiation. We distinguish SR that is generated by bending the entire beam from that generated by the beam going through a focusing element. The former called "fan" radiation is generally more intense and has power levels that are roughly 100 times higher than SR produced in a focusing element which we designate as "quadrupole" radiation.

As the LEB enters the IR and travels through Q1, it generates a fan of SR that strikes the beam pipe inside the B1 magnet. This pipe has a series of mask surfaces that intercept the 3.5 kW of SR power and prevent the SR from directly hitting the detector beam pipe. In addition, the mask surfaces are sloped so that photons striking a surface can not directly scatter to the detector beam pipe. The LEB then goes through the two B1 magnets, generating two nearly overlapping fans of SR since the B1 magnets have opposite polarity. Nearly two thirds (5.7 kW) of the radiation from these fans travels out of the near IR and is absorbed on two surfaces, one at 9 and the other at 19 m in the incoming HEB beam pipe. About one third of the radiation (3 kW) strikes a mask placed in front of the Q2 septum and the rest is scattered along the outgoing LEB beam pipe inside the Q2 magnet. Fig 2 shows the radiation fans generated by the LEB in the IR.

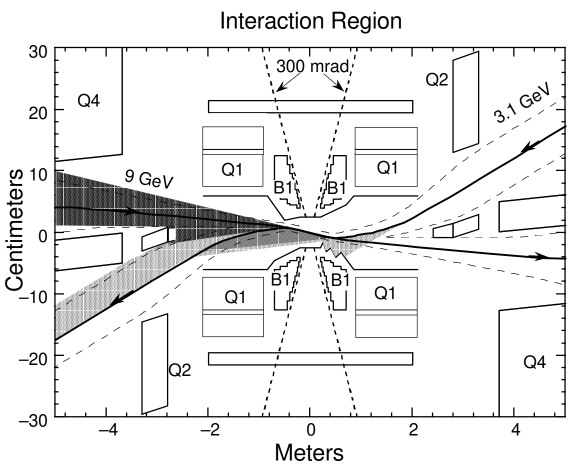

Figure 2. Layout of the IR showing the SR fans from the LEB. The shading indicates the relative power of each fan. The darker shading means higher power density.

The HEB produces a fan of SR when it goes through the Q4 magnet on its way to the IP. This softer, lower power fan (1 kW) strikes a mask located 50 cm from the IP that shields the detector beam pipe. Again, the mask is sloped so that photons striking the mask can not scatter to the detector beam pipe. The rest of the Q4 fan goes past the IP with most of it striking the septum mask positioned in front of the Q2 septum and the remainder following the outgoing HEB and being absorbed on a surface about 20 m from the IP. The two B1 fans generated by the HEB are very intense (50 kW) and do not strike any surfaces until the fans are well outside of the near IR. A special power dump surface inside the outgoing HEB beam pipe starts intercepting these fans at a grazing angle. The dump is located from 15 to 21 m from the IP. Figure 3 shows the HEB fans near the IP.

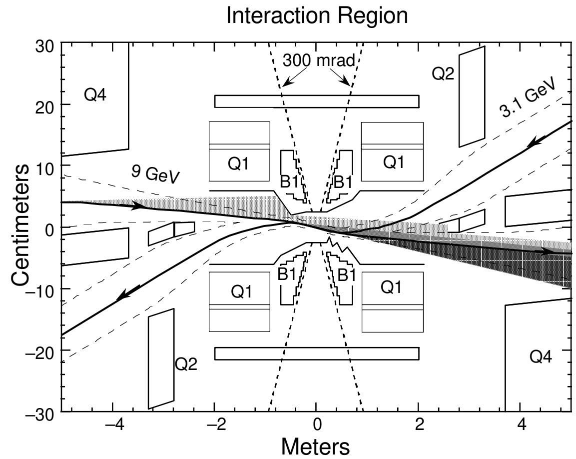

Figure 3. Layout of the IR showing the SR fans from the HEB. The shading indicates the relative power of each fan. The darker shading means higher power density.

4 THE VACUUM CHAMBER

The center part of the vacuum chamber is a double-walled pipe of beryllium. The inside wall is 800 μm thick and the outside is 400 μm thick with a space of 1 mm between the two walls for water cooling adequate for 1000 W and temperature control. Estimates from HOM calculations indicate that there will be about 100 W of power lost in this region.

The beam pipe inside the B1 magnets is complicated. The surfaces of the masks must be precisely machined in order to correctly shield the detector beam pipe. In addition, the SR power that strikes these surfaces must be removed and not heat the PM material. Since the strength of the PM material varies as a function of temperature, a separate water circuit will be used to cool and maintain the temperature of the B1 magnets. The beam pipe will be made of dispersion strengthened copper.

The masks in front of the Q2 septa intercept a significant amount of SR power. Consequently, in order to lower the power density, these mask surfaces are sloped

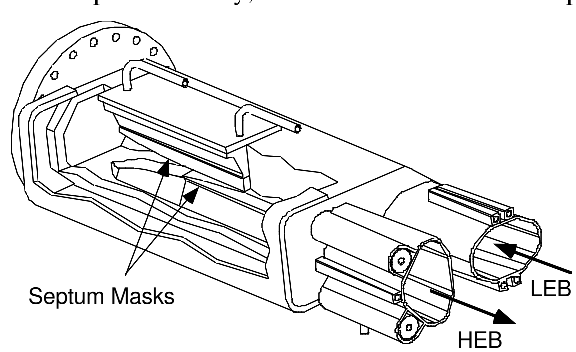

Figure 4. Cut away view of the septum mask vacuum chamber in front of the Q2 magnet.

with respect to the incident photons by a ratio of 50 to 1. These mask surfaces will also be made of dispersion strengthened copper. Figure 4 shows a side view of the septum mask. HOM calculations indicate that in this region about 6 kW of power will be dissipated in the chamber walls. This is primarily the result of one large beam pipe turning into two smaller beam pipes. Extra chamber cooling will be included to absorb this power.

5 PERMANENT MAGNETS B1 AND Q1

The B1 PM is composed of 13 slices of PM material. Each slice has 16 uniformly magnetized blocks with magnetization angles oriented according to the Halbach formulation[2] for making a dipole magnetic field. Figure 5 shows a layout view of B1.

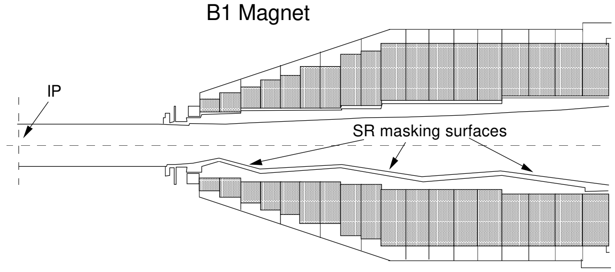

Figure 5. Layout of the B1 magnet. The shaded area is the PM material. The masking surfaces indicated in the drawing are where the SR power is deposited.

The present design of the Q1 magnet is a hybrid with a quadrupole and a dipole component. This is accomplished by constructing a quadrupole field using 32 blocks of PM material and then, outside of these blocks, adding a 16 block ring of PM material that makes a 2.1 kG dipole field. This dipole field effectively offsets the center of the quadrupole field by 20 mm horizontally. Figure 6 shows the block placement for a Q1 slice and also shows the resulting magnetic field.

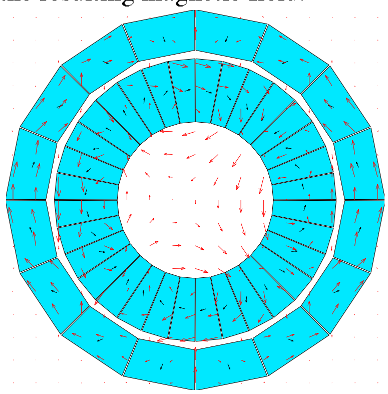

Figure 6. End view of the hybrid Q1 magnet. The offset quadrupole center can been seen in the middle of the magnet.

The Q1 magnet will be made up of 22 slices 5 cm thick. This leaves room for the placement of a harmonic correction ring[3]. The field quality of Q1 must be very good because the LEB is deflected away from the center of the magnet and exits the magnet at a large radius.

6 SUPPORT TUBE

The vacuum chamber, the two B1 magnets and the two Q1 magnets are assembled into a support tube for insertion into the detector. This tube is composed of two outboard pieces of stainless steel and an inner section of carbon fiber composite. The carbon fiber section minimizes the material (1.2% X_0) between the silicon vertex detector which is located around the Be beam pipe and the detector drift chamber which is just outside the support tube. All of the elements inside the support tube will be assembled together as a unit and surveyed into position with the support tube mounted as it will be supported when it is inside the detector. This will insure accurate placement of these critical components.

7 SUMMARY

The interaction region of PEP-II has been described. The beam separation scheme, which dictates much of the interaction region geometry, is explained. The separation is initiated by two horizontal dipole magnets positioned as close to the interaction point as possible and yet still allow for a maximum amount of detector solid angle. The separation is completed through the use of a shared vertical focusing quadrupole in which the high-energy beam is centered and the low-energy beam is further deflected horizontally away from the high-energy beam. Synchrotron radiation generated by this separation scheme strikes the beam pipe inside the dipole magnets, depositing significant power, and must be masked away from the detector Be beam pipe located around the collision point. The SR power is removed through water cooling circuits. The entire assembly of B1 magnets, Q1 magnets, vacuum chamber and vertex detector are contained in a support tube that is inserted into the detector as a unit.

8 REFERENCES

[1] "PEP-II an Asymmetric *B* Factory", Conceptual Design Report, CALT-68-1869, LBL-PUB-5379, SLAC-418, UCRL-ID-114055, UC-IIRPA-93-01, June 1993.

[2] K. Halbach, "Physical and Optical Properties of Rare Earth Cobalt Magnets", Nucl. Inst. and Methods 187, pp. 109-117 (1981).

[3] R. Schlueter, D. Humphries, J. Tanabe, "Pure Permanent Magnet Harmonics Corrector Ring", LBL-38629, to be submitted to Nucl. Inst. and Methods.