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BEAM SEPARATION IN AN ASYMMETRIC ENERGY COLLIDER USING A TILTED EXPERIMENTAL SOLENOID

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1 Introduction

A joint working group at CERN and PSI has recently studied the feasibility of a B-Meson Factory in the CERN ISR tunnel (circumference 960 m), using the existing CERN lepton injectors [1]. The proposed machine will have 3.5 on 8 GeV beams colliding at 2 interaction points, with an initial luminosity of $10^{33}\ cm^{-2}\ s^{-1}$ and a potential luminosity increase to $10^{34}\ cm^{-2}\ s^{-1}$. If this machine fails to produce the expected luminosity in asymmetric mode it will have to be converted to symmetric operation at the expense of a modification to the interaction region layout.

The symmetric machine proposed by PSI in 1989 to the Swiss authorities [2] has been used as a starting point, but the energy asymmetry, the geometry of the existing ISR tunnel and the necessity of lowering the energy loss per turn required several modifications to the lattice. The proposed interaction region optics is close to the design of a 4 on 7 GeV variant of the PSI proposal [3]. The CERN - PSI reference machine ($L = 10^{33}\ cm^{-2}\ s^{-1}$) will have 80 bunches, and the ultimate asymmetric machine ($L = 10^{34}\ cm^{-2}\ s^{-1}$) is assumed to have 320 bunches.

The beams collide in the center of two 50 m long straight sections and then traverse 4 common quadrupoles located at distances between 0.85 and 6 m from the IP. The separation scheme will be presented below. The interaction region optics and the arc lattice are described in separate reports [4], [5].

2 Separation using a tilted solenoid

The large number of circulating bunches requires a scheme separating the beams as close as 6 m to the IP initially, and eventually at 1.5 m. This can only be obtained at the expense of adding transverse magnetic fields inside the central detector between the IP and the first quadrupoles. The longitudinal field of 1.5 T, required for particle detection, is produced by a 3 m long superconducting solenoid. Rather than inserting additional dipole magnets we have studied the possibility of rotating the solenoid around the vertical axis by an angle of 4 degrees, which yields a radial field of 0.1 T. This solution has been shown to be compatible with the experimental physics requirements [1].

In the study the solenoid has been provisionally modeled as a pure radial dipole field. The beams enter the first quadrupole with y = 2.5 mm, y' = 6 mrad (3.5 GeV) and y = 1.1 mm, y' = 2.6 mrad (8 GeV). If, contrary to expectation, the separation is significantly reduced by the solenoid end effects, the rotation angle may be somewhat increased without inconvenience for the detector.

3 Quadrupole position offset

After crossing at the IP the beams traverse 4 common quadrupoles. Q1 and Q2 are superconducting quadrupoles mounted in the same cryostat, Q3 and Q4 are normal magnets. The strengths of these quadrupoles have been established [4] by matching the lattice parameters of the two beams simultaneously (table I), imposing $\beta_x = 1.00m$ and $\beta_y = 0.03m$ at the IP for both beams. The radial field of the tilted solenoid is present in the drift space between the IP and Q1, and inside Q1.

element	length [m]	gradient [T/m]
IP	0.00	
drift	0.85	
Q1	0.60	-46.8
drift	0.30	
Q2	0.60	+35.5
drift	0.50	
Q3	1.00	-16.2
drift	1.24	
Q4	1.00	+ 8.1

Table I. Parameters of the common central low-β insertion

In addition to the energy difference the two beams have separate trajectories at the entrance of the first quadrupole and therefore at least one of the two beams is bent in each quadrupole. As the solenoid field extends up to the exit of Q1 the trajectories of both beams are bent in this quadrupole. In order to minimize the amount of synchrotron radiation arriving at the central detector the vertical positions of the 4 quadrupoles have to be determined with great care.

In a first iteration it was attempted to center all quadrupoles around the incoming beam. In this case the majority of the photons would have been emitted towards the arcs, and very few towards the IP. Unfortunately this solution did not provide any separation at 3 m from the IP, a parasitic bunch crossing point in the case of 160 or 320 bunches.

A second solution where all quadrupoles are centered around the low energy beam yields both adequate separation and acceptable synchrotron radiation levels. The vertical geometry of this solution is shown in figure 1.

4 Vertical bending magnets

In the above mentioned quadrupole geometry the beams leave the last of the 4 common quadrupoles at $y = +81.4$ mm (3.5 GeV) and $y = +56.5$ mm (8 GeV), which allows them to enter the separate channels of a double vertical septum magnet VB1.

The septum bending angles must be at least 30 mrad so as to obtain sufficient separation at the next (separate) quadrupole, and to reach the 0.8 m arc separation before the end of the straight section, limited to a length of 50 m because of the circular ISR tunnel geometry. Synchrotron radiation considerations limit their field, which implies a length of about 3 m. The resulting sagitta of 45 mm does not allow the beams to cross over at the exit of the septum, and therefore the low energy beam must always run on top.

A second vertical bend VB2 brings the beams back into the horizontal planes of the arcs. Since the betatron phase advance between VB1 and VB2 is small the two bends must have comparable amplitudes (and opposite signs), so as not to create a too large vertical dispersion. For this reason bending angles of + 33 and -51 mrad at 3.5 GeV and -32 and +22 mrad at 8 GeV for VB1 and VB2 respectively, as shown in figure 1, would be preferable to the geometry presented in the Feasibility Study Report [1].

5 Results and conclusion

With the above described solution the vertical separation of at least 6 σ_x is obtained beyond 3 m from the IP. The values at the first 4 possible parasitic bunch crossings are presented in table II. The width of the wider of the two beams is taken for σ_x. The separation criterion of $5\sigma_x$ is satisfied for bunch numbers up to 160. With 320 bunches the solenoid tilt will have to be increased by a factor of 2.

distance from the IP [m]	vertical separation [sigma_x]
1.5	2.5
3.0	9.5
4.5	6.0
6.0	6.0

Table II. obtained vertical beam separation in numbers of σ_x

The vertical dispersion with the above presented solution is shown in figure 2. Its maximum values in the interaction region straight sections are 0.12 m (3.5 GeV) and 0.18 m (8 GeV). This will have to be compensated at the entrance of the arc, for example in the horizontal dispersion suppressor cell.

References

[1] Feasibility Study for a B-Meson Factory in the CERN-ISR tunnel, CERN 90-02 and PSI PR-90-08, April 1990

[2] Proposal for an Electron Positron Collider for Heavy Flavour Particle Physics and Synchrotron Radiation, PSI PR-88-09, July 1988

[3] K. Wille, Proposal for a High Luminosity Electron Positron Collider at PSI with an option for Symmetric and Asymmetric Collider Mode, XIV International Conference on High Energy Accelerators, August 1989, Tsukuba, Japan

[4] T. Risselada, Asymmetric BFI Low-β matching, CERN-PS/PA Note 90-10

[5] T. Risselada and L. Rivkin, Ring Layout and Lattice Design for a B-Factory in the ISR Tunnel, CERN-PS/PA Note 90-07

Fig. 1 geometry of separation scheme

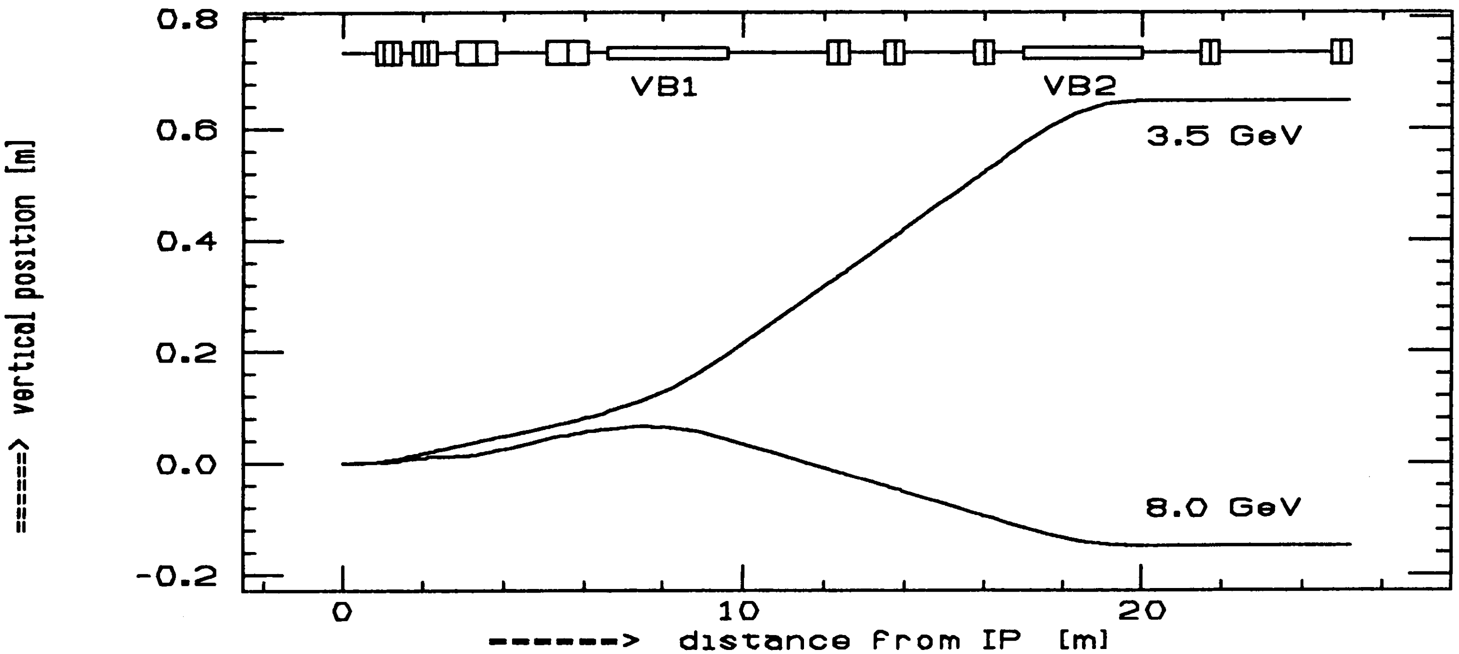

Fig. 2 effect of the separation on Dy