EE

CERN - PS 90-09 PA

9

2 MAI 1990

**EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE**

CERN LIBRARIES, GENEVA

CM-P00059374

CERN/PS 90-09 (PA)

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

T. Risselada

Talk presented at "Workshop on Beam Dynamic Issues of High-Luminosity Asymmetric
Collider Rings" held on 12-16th February, 1990
at Lawrence Berkeley Laboratory, CA, United States of America

Geneva, April 18th, 1990

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

T. Risselada
CERN, Geneva, Switzerland

ABSTRACT

The CERN - PSI feasibility study of a B-Meson Factory in the ISR tunnel has resulted in the proposal of a 3.5 on 8.0 GeV machine with a bunch spacing of 12 m, to be reduced eventually to 3 m. The beams will be vertically separated by the radial field component of the 1.5 T experimental solenoids, rotated for this purpose by 4 degrees, and by the fields acting on the off-centered beams in the central interaction region quadrupoles. Vertical separations of $6 \sigma_x$ are obtained at 3 m from IP, and of $2.5 \sigma_x$ at 1.5 m. The solenoid tilt and the amount of synchrotron radiation arriving in the central detector are compatible with the requirements of the experiments. The geometry and the performance of the proposed separation scheme are presented.

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 injectors¹. The proposed machine will have 3.5 on 8 GeV beams colliding at 2 interaction points, with an initial luminosity of $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ and a potential luminosity increase to $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$. 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 authorities² 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 proposal³. The CERN-PSI reference machine ($L = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$) will have 80 bunches, and the ultimate asymmetric machine ($L = 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$) is assumed to have 320 bunches. The beams collide in the center of two 50 m long straight sections and then traverse four common quadrupoles before being separated by a vertical septum. Five matching quadrupoles in each ring match the interaction region lattice functions to those of the arcs, which are superimposed with a distance of 0.8 m. Two additional 50 m long dispersionless straight sections are foreseen for the r.f.system. The interaction region optics and the arc lattice are described in separate reports^{5,6}.

SEPARATION USING A TILTED SOLENOID

The large number of circulating bunches requires a scheme separating the beams as close as 6 m to 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 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 T⁴. This

solution has been shown to be compatible with the experimental physics requirements¹.

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 it turns out that the separation is too much reduced by the solenoid end effects, the rotation angle may be further increased without inconvenience for the detector.

QUADRUPOLE POSITION OFFSET

After crossing at 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 established⁵ by matching the lattice parameters of the two beams simultaneously (table I), imposing $\beta_x = 1.00$ m and $\beta_y = 0.03$ m at IP for both beams. The radial field of the tilted solenoid is present in the drift space between IP and Q1, and inside Q1.

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

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

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 IP. Unfortunately this solution did not provide any separation at 3 m from 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.

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, as shown in figure 1, will have to be used for VB1 and VB2 respectively, rather than the geometry presented in the Feasibility Study Report ¹.

RESULTS AND CONCLUSION.

With the above described solution a vertical separation of at least $6\sigma_x$ is obtained beyond 3 m from 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.

Table II. obtained vertical beam separation in numbers of σ_x

Distance from IP [m]	Vertical separation [σ_x]
1.5	2.5
3.0	9.5
4.5	6.0
6.0	6.0

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.

ACKNOWLEDGEMENTS

This report presents the result of contributions by several subgroups of the CERN - PSI working group. The author would like to acknowledge particularly the constant support of working group chairman Y. Baconnier who initiated this study, and of T. Taylor who proposed the idea of a tilted solenoid.

REFERENCES

1. Feasibility Study for a B-Meson Factory in the CERN-ISR tunnel, CERN 90-02, and PSI 90-08, April 1990. See also L. Rivkin, these Proceedings and references 4, 5 and 6 mentioned below.

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 and T. Taylor, Interaction Region Optics and Separation for an Asymmetric Energy Beauty Factory in the ISR Tunnel, CERN-PS/PA Note 90-06.
5. T. Risselada, Asymmetric BFI Low-Beta matching, CERN-PS/PA Note 90-10.
6. 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 D_y