DESIGN OF PRE-DUMPING RING SPIN ROTATOR WITH A POSSIBILITY OF HELICITY SWITCHING FOR POLARIZED POSITRON AT THE ILC *

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Abstract

The use of polarized beams enhance the possibility of the precision measurements at the International Linear Collider (ILC) [1]. In order to preserve the degree of polarization during beam transport spin rotators are included in the current TDR ILC lattice [2]. In this report some advantages of using a combined spin rotator/spin flipper section are discussed. A few possible lattice designs of spin flipper developed at DESY in 2012 are presented.

1 Introduction

The importance of beam polarization for the ILC experiments can be illustrated by fact that the effective luminosity is increasing by approximately 50% in the case of both beam polarized [1]. Furthermore a suitable combination of polarized electron and positron beams suppresses significantly unwanted background processes and enhances signal rates.

There are two important aspects which should be taken into account for polarized beams. The first one is a delivery of polarized beams from the source to the interaction point. The spin transport for the different areas of the ILC were already studied [3][4] and the installation of spin rotators before and after Damping Ring was recommended. The examples of possible layouts of spin-rotators for the ILC can be found in [3][5]. The second problem arising from

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the presence of polarized beams is the requirement of fast helicity reversal. The helicity pattern of the electron beam can be adjusted by changing the helicity of the laser. For the positron beam this is a non-trivial task, as the polarization of the positron beam depends on helicity of the undulator. The possibility of spin manipulation was considered at [7] where two post-damping ring spin rotators were included. On the other side, the spin manipulation of post damping ring beams is limited by the emittance preservation constraints. In addition the spin rotator used in the TDR design cannot provide a fast helicity reversal in the time scale desirable for the ILC, i.e. from train to train.

The idea of using a pre-damping ring spin rotator section for some beam helicity manipulations has been already suggested in [8], but no detailed lattice was produced. Meanwhile, the layout of the Central Region of the ILC provides enough space before Damping Ring for a combined spin rotation with a possibility of quick switch between two helicities. A possible layout of a pre-damping ring spin rotator/spin flipper section is presented below.

Figure 1: Schematic layout of new PLTR section

2 The ILC Pre-Damping Ring Spin Rotator

The Positron Linac To Damping Ring (PLTR) is a section of the ILC transport positron beam to the Damping Ring (DR). The schematic layout of the PLTR is given in Fig. 1. It serves for the extraction of the positrons from the Positron Linac Booster, energy compression and spin rotation.

In general, the desirable spin rotation can be produced by spin precession around the field direction. In the dipole field the rate of spin precession is directly proportional to the orbit deflection angle $\theta_{\text{orbit}}$ while in the solenoidal field spin precession rate is directly proportional to the field $B_z$ and the length $L_{\text{sol}}$ of solenoid and inversely proportional to the magnetic rigidity $B\rho$. At 5 GeV the orbital deflection angle of $7.929^0$ rotates spins by $90^0$. In section E the spin rotation from the longitudinal to the transversal direction is done by the means of horizontally bending dipoles with the total orbital rotation angle of $23.795^0 = 3 \times 7.929^0$ which corresponds to $\frac{3\pi}{4}$ of spin rotation.

The total length of section D is 123.595 m. The suggested combined spin
The flipper/spin rotator design is only 80 m long. A new modified section D can fulfill two tasks simultaneously, namely spin rotation and train-by-train helicity reversal. The energy compression in section D matches the beam energy spread to the DR acceptance. Then the transversal beam polarization can be rotated to vertical in the solenoid with a field integral of 26.18 [T m]. Two different superconducting solenoids design were considered: 8.32 m long solenoid with an integrated field of 26.18 [T m] (Solenoid 1) and a shorter 5m long superconducting solenoid with integrated field of 26.2 [T m] (Solenoid 2). The pre-damping ring position of the spin-rotator makes the emittance preservation constrains less challenging.

![Figure 2: The schematic layout of the positron transport to Damping Ring with a two parallel lines spin rotator section.](image)

The suggested combined spin flipper/spin rotator consists of two parallel beam lines for spin rotation equipped with two solenoids of opposite polarities, i.e. setting the spin parallel (one beam line) or antiparallel (second beam line) to the field in the Damping Ring, Fig. 2. This spin-flipper design is based on the concept of branch splitter/merger used for the post-damping ring positron lines [9]. The first lattice cell is an irregular FODO cell which include fast kickers and separate the branches horizontally. The total length of the splitter section is approximately 26 m in order to fit the available space, 2m of two horizontal branches separation is taken. The shortening of the splitter section is achieved by using stronger bending magnets.

Each branch consists of a first order achromat FODO dogleg, a solenoid section and another dogleg to recombine the line back to the design orbit. The achromat design assures that no dispersion suppressors would be required. The simple solenoid rotator design is considered, similar to the one used in [7]. The advantage of this design is the possibility of quick and random switching between two helicities for the positrons. In order to save some transversal space an asymmetry can be introduced in the relative position of solenoids at two branches.

### 2.1 Symmetric Design

The section consists of the first irregular FODO-like cell with a pulsed kicker and a combined function defocusing/bending magnet, followed by 4 regular FODO
cells with $120^\circ$ phase advance, forming together an achromat dogleg, a solenoid matching section and a solenoid with an integrated field of 26.18 or 26.2 [T·m]. In the solenoid beta functions $\beta_x = \beta_y$ and they are reaching the minimum in the middle of the solenoid. The rest of the section is a mirror image of the first part with respect to the middle of solenoid. The second branch of the lattice can be obtained by switching the sign of the kick in the pulsed kicker and the bending angles in the following dogleg. The section was optimized by MAD8 package [10] to meet the constraints on the length of total D section. Then this spin-rotator part of section D was inserted to the PLTR lattice developed by W.Liu [11] thus including two extra matching sections. In Fig. 3 Fig. 4 the results of the optics matching using MAD8 package is given for PLRT section. The lattice matching for the section D of the PLRT was done for both versions of superconducting solenoids.

![Figure 3](image1.png) Figure 3: Complete PLTR section including one of spin rotator branch with solenoid 1.

![Figure 4](image2.png) Figure 4: Complete PLTR section including one of spin rotator branch with solenoid 2.

The optics for Solenoid 1 setting is cross-checked with ELEGANT code [12] code. Spin tracking with BMAD code [13] is done by V.Kovalenko [14].

### 2.2 Asymmetric Design

Two solenoid sections in the opposite branches were placed with $\approx 6–11$ m shift producing a horizontal offset of 0.54 m for each branch with respect to design
orbit. One or two extra FODO cells were added in front of the solenoid section for one branch and the same number of extra FODO cells were added after the solenoid section for another branch. These changes lead to an increase of the total length of the whole spin rotator section. Rematching was done in order to fit the total length of section D (123.595m) and the total PLTR length. In Fig. 5 the design of the new spin rotation section for two version of super-conducting solenoids is given.

**Figure 5**: a) Asymmetric section (without energy compressor) for the spin rotator branch with Solenoid 1. b) Asymmetric section with the energy compressor part for the spin rotator branch with Solenoid 2 (b).

### 3 CONCLUSIONS

The suggested spin rotator design confirms that fast helicity switching for the positron beam is possible. The train-to-train polarity selection for electron and positron beams at the IP can be achieved. In particular:

- The suggested optic design for the fast helicity reversal spin rotator section satisfies the PLTR section requirements.
- Both versions of superconducting solenoid for spin rotator are used and two versions of optic files are available for the symmetric lattice
- An asymmetric design for the solenoid position in two parallel lines of spin rotator is produced for two version of superconducting solenoid parameters.
- The optic design is cross-checked with different accelerator design codes
- Depolarization effects in a new lattice are estimated by BMAD and no significant depolarization connected with beam optics is discovered.
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