

# THE DESIGN OF SPIN-ROTATOR WITH A POSSIBILITY OF HELICITY SWITCHING FOR POLARIZED POSITRON AT THE ILC\*

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## Abstract

The positron beam produced at the ILC positron source is longitudinally polarized. In order to preserve the polarization a spin rotator, which rotates the spin vertically prior to injection in the damping ring, is included in the lattice. A new design of the spin rotator section is presented. This new design gives the possibility of randomly switching between two helicities for the positrons. It is done by inserting two parallel sections for spin rotation with opposite polarities, i.e. setting the spin parallel or antiparallel to the field in the damping ring.

## INTRODUCTION

The use of polarized beams has a significant impact on the experiments. As discussed in [1], the effective luminosity can be substantially enhanced if also the positron beam is polarized. A positron beam polarization of 60% will increase the effective luminosity by approximately 50%. In addition, using the suitable combinations of polarized electron and positron beams allows to suppress significantly unwanted background processes as well as to enhance signal rates. Thus, polarized beams should be used to reveal a full potential of the International Linear Collider (ILC). The electron polarization is achieved at the production and the polarity can be switched there by switching the polarity of the laser beam. The undulator based positron source, which is the current baseline, produces longitudinally polarized beams. The polarization of the positron beam depends on the helicity of the undulator and cannot be switched at the source. Some dedicated helicity flipper for positron beam is required.

It has been confirmed by the previous study [2] that only the vertical component of spin will survive in the damping ring without polarization loss. Thus the pre- and post-damping ring spin rotators are already included in the ILC layout. Various designs for spin rotators and some examples can be found in [3, 4]. Unfortunately, the "classical" version of spin rotator, based on dipole and solenoidal fields, cannot provide a fast helicity reversal in the time scale desirable for the ILC, i.e. from train to train. This additional requirement of fast switching between 2 polarities was con-

sidered in "general" in [5], but no detailed lattice design was produced. The detailed design for the RDR parameter set presented in [6] is based on a pre-damping ring spin rotator and a combination of two post-damping ring rotators. It has the possibility of producing any direction of polarization at the IP. The recent TDR changes in the Central Region of the ILC design include a specially dedicated space before DR for the spin-rotator with two helicities.

## THE SPIN ROTATION AT THE ILC

### Basic Theory

A spin rotator is a device which manipulates polarized beams. The use of spin rotators allows to preserve the degree of polarization during beam transport as well as selecting the desired direction of polarization at the interaction point (IP). According to the design, spin rotators can be divided in two classes which are illustrated in Fig. 1:

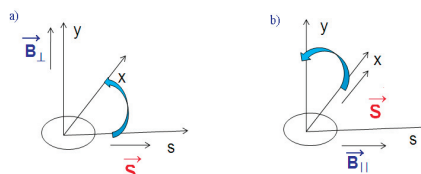


Figure 1: Spin rotation in horizontally bending dipole (a) and solenoidal (b) fields.

The first is based on spin rotation in dipole fields orthogonal to the direction of motion. The precession of spin is around the field direction and proportional to the orbit deflection angle  $\theta_{orbit}$  as  $\theta_{spin} = a\gamma\theta_{orbit}$ , where  $\gamma$  is the Lorentz factor and  $a = 0.00115965$  is an anomalous gyromagnetic ratio of a positron/electron. For example, for positrons at 5 GeV the orbital angle of  $7.929^0$  produce a spin rotation of  $90^0$ . Starting from longitudinal polarization a set of interleaving vertical and horizontal bends can be used for producing the vertical spin direction. The second type is a solenoid based spin rotators where the spin is precessing around the longitudinal direction by the angle  $\theta_{spin}$  which is proportional to the solenoidal field  $B_z$  and its length  $L_{sol}$  as

$$\theta_{spin} \approx \frac{B_z L_{sol}}{B\rho} \quad (1)$$

\*Work supported by the German Federal Ministry of education and research, Joint Research project R&D Accelerator "Spin Management", contract N 05H10CUE

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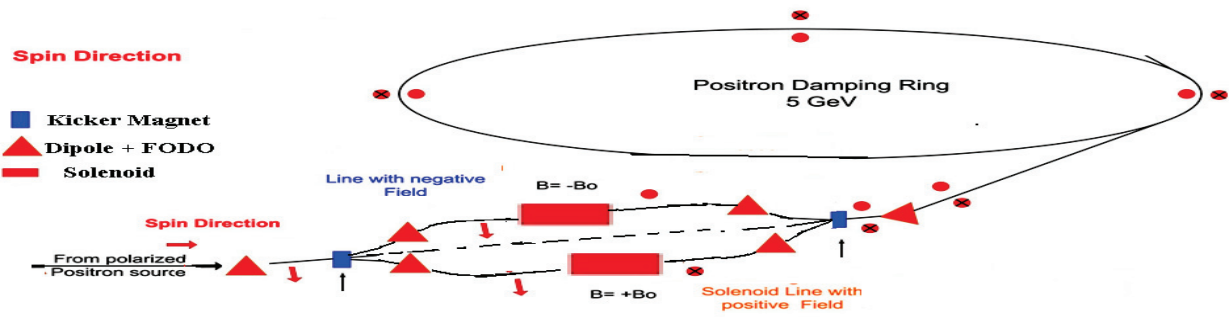


Figure 2: The schematic layout of positron transport to Damping Ring with a two parallel lines spin rotator section.

where  $B\rho$  is the magnetic rigidity. For a 5 GeV positron beam a solenoid with field integral of 26.18 T m is required. This type of spin rotators has a potential of destroying the vertical beam emittance via orbit coupling in solenoid, thus the specially designed so-called Emma rotators [3] with compensating quadrupoles should be used.

### The Spin Rotator Requirements and Constraints

The Positron Linac To Damping Ring (PLTR) is a section of the ILC transport positron beam to the damping ring (DR). Following the recent update of parameters for the ILC central region the possibility of fast helicity switching for the positron beam was considered and a some extra space in PLTR was allocated to it. Fig. 2 gives a possible configuration of the pre-damping ring spin rotator with two parallel beam lines for the spin rotator similar to the one presented in [5]. The schematic layout of the new PLTR is given in Fig. 3. It consists of the following sections: in section E the spin rotation from longitudinal to the horizontal direction is done by means of horizontally bending dipoles with the total orbital rotation angle of  $23.795^\circ = 3 \times 7.929^\circ$ . The energy compression in section D matches the beam energy spread to the DR acceptance. In addition, the increased length of the D section (from 37.9m to 123.595m ) provides enough space to accommodate a splitter for the fast spin flip section.

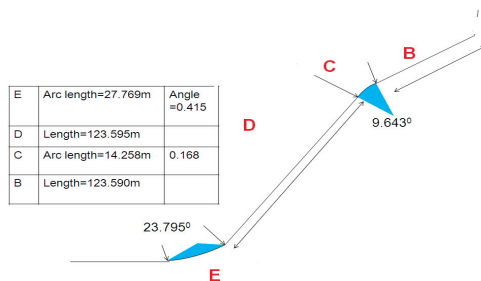


Figure 3: Schematic layout of new PLTR section

The new spin rotator section consists of two parallel spin rotation lines with a solenoidal field of opposite polarity placed symmetrically with respect to design orbit. It con-

sists of a first order achromat FODO dogleg, a solenoid section and another dogleg to recombine the line back to the design orbit as it shown in Fig. 2. The achromat design assures that no dispersion suppressors will be required. The pre-damping ring position of the spin-rotator makes the emittance preservation constraints less severe. Thus, the simple solenoid rotator design, similar to the one used in [6] was applied.

## THE SPIN ROTATOR SECTION

### Symmetric Design

The spin-rotator design is based on the concept of branch splitter/merger used for the post-damping ring positron lines [7] with some modifications: only horizontal bends are used, the length of the splitter section is shortened to approximately 26 m in order to fit the available space, 2m of two horizontal branches separation was taken. The shortening of the section is achieved by using stronger bending magnets as the emittance preservation requirements for the pre-damping ring section are less challenging.

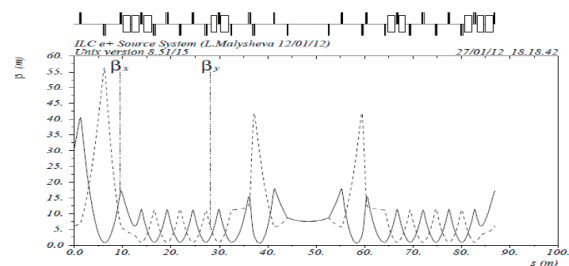


Figure 4: Spin rotator branch matched by MAD8.

The section consists of the first irregular FODO-like cell with 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 8.32 m long solenoid with an integrated field of 26.18  $[T \cdot m]$ . In the solenoid  $\beta_x = \beta_y$  and 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 is 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 [8] to meet the constraints on the length. Then this spin-rotator part of section D was matched to the PLTR lattice developed by W.Liu [9] thus including two extra matching sections. In Fig. 4- Fig. 5 the results of the optics is given for one branch of such spin rotator designed by the MAD8 package [8].

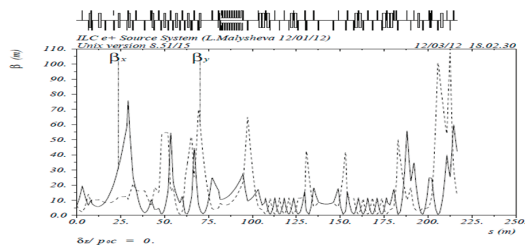


Figure 5: Complete PLTR section including one of spin rotator branch matched by MAD8.

Similar results were obtained for the 5m long superconducting solenoid with a field of  $5.24 [T \cdot m]$ . These matching results were cross-checked by ELEGANT [10] code. Spin tracking with BMAD [11] were done by Kovalenko [12].

### Asymmetric Design

In order to save some transverse space the original design was adjusted in such a way that two solenoid sections in the opposite branches are placed with  $\approx 6 - 11$  m shift, thus leading to a smaller value of horizontal offset for each branch. The horizontal offset of 0.54m was used instead of 1m. The latter could be done adding one or two extra FODO cells before the solenoid section, keeping the lattice unchanged after the solenoid for one branch and adding extra FODO cells after the solenoid section for another branch. As it leads to increase of the length of the whole spin rotator section, some rematching was necessary in order to fit the length of section D (123.595m) and the total PLTR length. In Fig. 6 the design of the new spin rotation section with super-conducting solenoid is given.

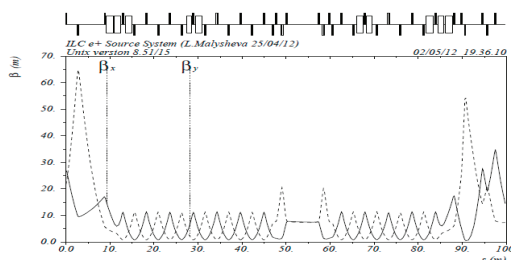


Figure 6: Asymmetric section for one of spin rotator branch matched by MAD8.

## CONCLUSIONS

The suggested spin rotator design confirms that the 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 to the PLTR section requirements.
- An asymmetric design for the solenoid position shifted in two parallel line of spin rotator is produced.
- The optic design is cross-checked with different accelerator design codes
- Depolarization effects in a new lattice are estimated by BMAD [10] and no significant depolarization connected with beam optics is discovered.

## ACKNOWLEDGMENT

The authors are grateful to the all members of the Spin-management group for the fruitful discussions. We are also would like to thank Dr. W. Liu for close collaboration, practical advices and for providing the matching parameters of the PLTR lattice. L.I. Malysheva also thanks Mr. J. Jones and Dr. P. Williams from ASTeC for help and advices concerning ELEGANT running.

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