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

L.I. Malysheva[†], O.S. Adeyemi,V. Kovalenko, G.A. Moortgat-Pick,
A. Ushakov, Hamburg University, Hamburg, Germany
S. Riemann, F. Staufenbiel, DESY, Zeuthen, Germany
A. Hartin, B. List, N.J. Walker, DESY, Hamburg, Germany

April 18, 2013

Abstract

Polarized beams are essential for revealing a full potential of the ILC [1]. The electron and positron beams produced at the source are longitudinally polarized. The results of spin transport study for the ILC [2] suggest that only the vertical component of spin will survive in the damping ring without polarization loss. In order to manipulate polarized beams and to preserve the degree of polarization during beam transport spin rotators are included in the current ILC lattice. Recent update of parameters for the ILC central region provides extra space for a new design of pre-damping ring spin rotator section which is presented below. It consists of two parallel sections for spin rotation with opposite polarities, i.e. setting the spin parallel or antiparallel to the field in the damping ring. The advantage of this new design is in the possibility of quick and random switching between two helicities for the positrons.

1 INTRODUCTION

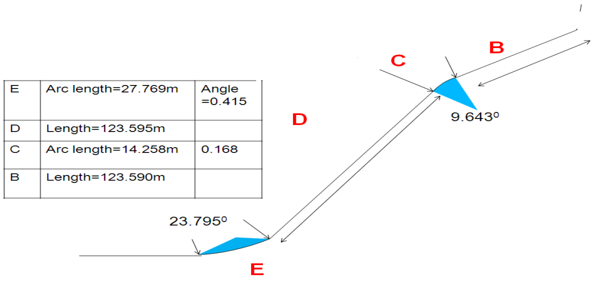
Polarized beams play important role on the experiment. For example, for the ILC scenario the effective luminosity can be increased by approximately 50% in the case of both beams polarized [1]. Furthermore a suitable combinations of polarized electron and positron beams suppress significantly unwanted background processes and enhance signal rates. While the electron polarization can be switched at the source by switching the polarity of the laser beam, the polarization of the positron beam depends on helicity of the undulator and cannot

---

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

[†] larisa.malysheva@desy.de

be switched at the source. Some dedicated helicity flipper for positron beam is required. The "traditional design" version of spin rotator, based on dipole and solenoidal fields, are well established. For the basic theory see the Appendix where these two "classical design" are explained in more details. A few spin rotator designs suggested previously for the ILC can be found in [3, 4]. The disadvantage of all these design is that they cannot provide a fast helicity reversal in the time scale desirable for the ILC, i.e. from train to train. The concept of the spin flipper combined with fast switching between 2 polarities was considered in "general" in [5], but no detailed lattice design was produced. For the RDR parameter set spin flipper design was investigated in [6]. It is based on single pre-damping ring spin rotator followed by a combination of two post-damping ring rotators. In theory, by clever manipulation of latter, any direction of polarization at the IP can be achieved. Nevertheless the manipulation of post-damping ring beams is complicated as the emittance preservation constraints should be fulfilled. The TDR changes in the layout of the Central Region of the ILC design allows spin rotation with quick switch between two helicities be done before DR. 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].



E	Arc length=27.769m	Angle =0.415
D	Length=123.595m	
C	Arc length=14.258m	0.168
B	Length=123.590m	

Figure 1: Schematic layout of new PLTR section

2 THE SPIN FLIPPER-ROTATOR FOR THE ILC

2.1 The ILC Pre-damping Rind Spin Rotator Requirements and Constraints

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 (the Positron Linac To Damping Ring) was allocated to it. The schematic layout of the new PLTR is given in Fig. 1. 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

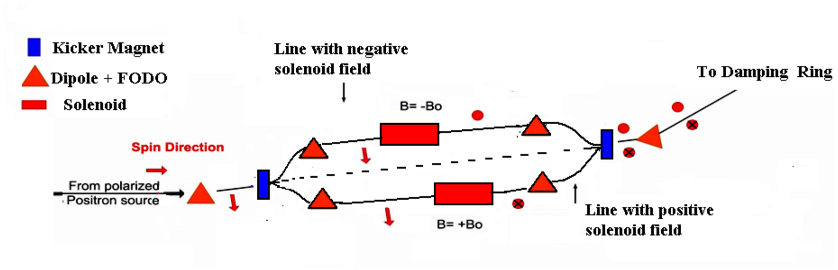


Figure 2: The schematic layout of positron transport to Damping Ring with a two parallel lines spin rotator section.

of $23.795^0 = 3 \times 7.929^0$ which corresponds to the 3π spin rotation around the bending dipole field direction for 5 GeV. The energy compression in section D matches the beam energy spread to the DR acceptance. Previously spin was rotated in section D by solenoid spin rotator from transverse to the vertical direction. The length of new section D was increased from 37.9m to 123.595m. This particular change allows to insert also a splitter for the fast spin flip. Section C and B don't affect the spin direction, as it is already parallel/antiparallel to the field direction of horizontal bending magnets in arc C and in DR.

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

2.2 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.

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 120^0 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

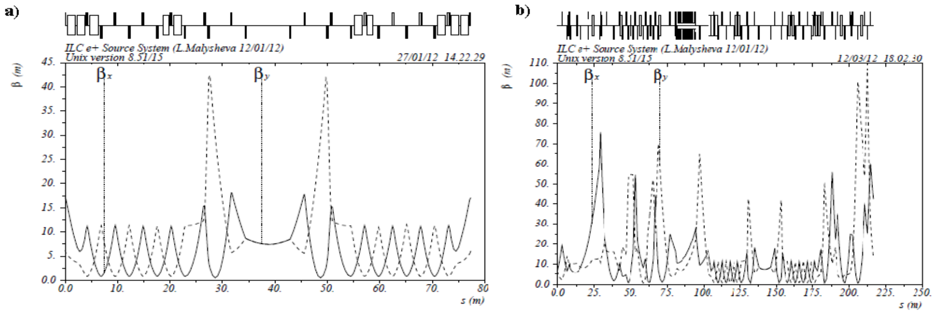


Figure 3: a) Spin rotator branch matched by MAD8. b) Complete PLTR section including one of spin rotator branch matched by MAD8.

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. 3 the results of the optics is given for one branch of such spin rotator.

Similar results were obtained for the 5m long super-conducting 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].

2.3 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

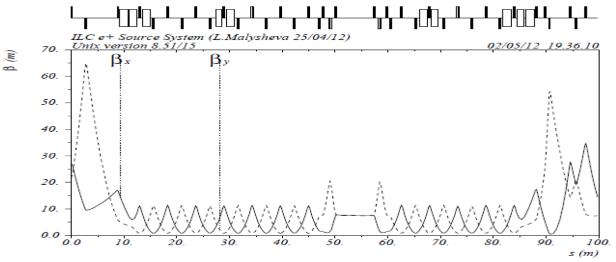


Figure 4: Asymmetric section for one of spin rotator branch matched by MAD8.

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. 4 the design of the new spin rotation section with super-conducting solenoid is given.

3 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.

4 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 (Daresbury) for help and advices concerning ELEGANT running.

A Appendix: Basic Theory

A spin rotator is a device which manipulates polarized beams. Various designs for spin rotators and some examples can be found in [3, 4]. 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. 5:

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 θ_{orbit} as $\theta_{spin} = a\,\gamma\,\theta_{orbit}$, where γ is the Lorentz factor and $a = 0.00115965$ is an anomalous gyromagnetic ratio of

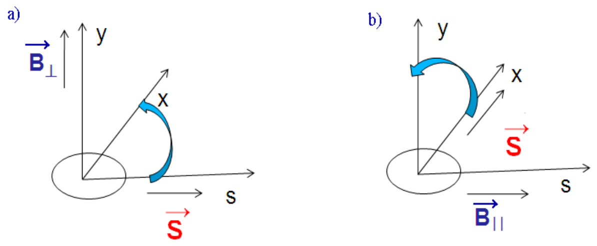


Figure 5: Spin rotation in horizontally bending dipole (a) and solenoidal (b) fields.

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 θ_{spin} which is proportional to the solenoidal field B_z and its length L_{sol} as

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

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.

References

[1] G.Moortgat-Pick et al., Phys.Report.460:131-243,(2008) www.ippp.dur.ac.uk/gudrid/power/.

[2] L.I. Malysheva and D.P. Barber. Depolarisation in the damping rings of the ILC.Proceedings of International Linear Collider Workshop LCWS2007, Hamburg, Germany, June 2007.

[3] P.Emma, A spin rotator system for the NLC, SLAC NLC-Note-07,1994.

[4] P.Schmidt, A spin rotator for the ILC,EUROTev-Report-2005-024-01.

[5] K.Moffeit et al., Spin rotation schemes at the ILC for two interaction regions and positron polarisation with both helicities, SLAC-TN-05-045,2005.

[6] F.Zhou et al.,Start-to-end beam optics development and multiparticle tracking for the ILC undulator based positron source, SLAC-PUB-12239, Jan.2007.

[7] N. Solyak, RTML General Layout and Parameters.; ILC Source/RTML/BDS+MDI Baseline Technical Review, DESY, October 2011

[8] `http://mad.web.cern.ch/mad/`

[9] W.Liu, Private conversation.

[10] M. Borland. elegant: A Flexible SDDS-Comliant Code for Accelerator Simulation, Proceedings of the 6^{th} International Computational Accelerator Physics Conference, ICAP2000, September 2000

[11] www.lepp.cornell.edu/ dcs/bmad

[12] V.Kovalenko et al, Spin Tracking Simulation of a Future International Linear collider, Procceding of the 3rd International Particle Accelerator Conference, New Orlean, 1807 .