ON THE POLARIZATION UPGRADE OF ILC UNDULATOR-BASED POSITRON SOURCE*

Wanming Liu, Wei Gai, ANL, Argonne, IL 60439, USA
Sabine Riemann, DESY, Hamburg, Germany
Andriy Ushakov, University of Hamburg, Hamburg, Germany

Abstract

The current nominal polarization for ILC undulator based positron source is 30% without photon collimators. In order to improve the effective luminosity, an upgrade of positron source with higher polarization is required. Some studies on the upgrade options have been done at both DESY and ANL, and the results are presented in this paper.

INTRODUCTION

The ILC SB2009 base line positron source is located at the end of electron main linac and it is still using the RDR undulator with K=0.92 and λu=1.15cm[1]. Without photon collimator, this positron source can generate a positron yield of 1.5 with a polarization of ~30% using its nominal 150GeV drive beam. As the result of relocating the positron source to the end of electron main linac, the drive beam energy of this positron source is now tightly coupled with the CM energies and thus the performance is also tightly coupled with the CM energies. As showing in Fig. 1, the corresponding positron source yield increases with the increase of drive beam energy while the polarization decreases with the increase of the drive beam energy. So in order to produce enough positron beam for lower CM scenarios, a 10 Hz operation scheme has been adapted. In the 10Hz operation mode, a 5Hz 150GeV electron beam for positron production is interlaced with a 5Hz luminosity beam for the given CM energy. On the other side of nominal drive beam energy of ILC RDR undulator, there is no trouble to generate enough flux of positron beam but the polarization of the captured positron beam will be lower than 30% which is the lowest polarization that could have enough impact on the effective luminosity. In order to restore the 30% nominal polarization for higher CM energies, one can either chose to use photon collimator or lower the undulator B field. Both methods can improve the polarization of captured positron beam at the cost of beam intensity. As shown in Fig. 1, the yield of the RDR undulator based positron source are significantly higher than 1.5 and trading positron yield for polarization at higher CM energies is a valid option. But due to the complexity of photon collimators, manipulating the K factor of undulator seems to be more practical and numerical studies were done to choose the operating K factor for higher CM energies. Results of these numerical studies are presented in this paper.

*This work is supported by the US Department of Energy Office of Science under Contract No. DE-AC02-06CH11357

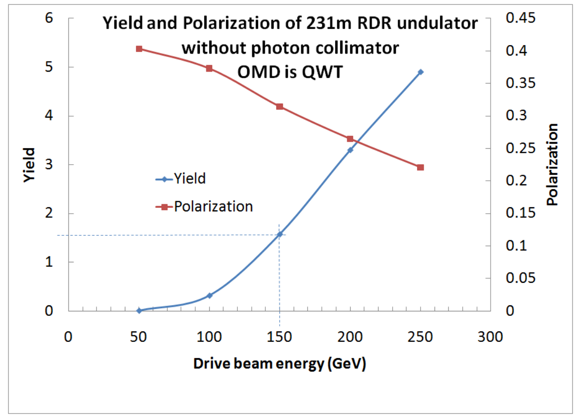

Figure 1: RDR undulator based positron source performance at different drive beam energy.

On the other hand, higher polarization of positron source will further enhance the effective luminosity and thus polarization upgrade of the ILC positron source is always among the most wanted upgrade. Studies on the polarization upgrade options have been done at both DESY and ANL, and the results are presented in this paper.

MAINTAINING THE 30% NOMINAL POLARIZATION AT HIGHER DRIVE BEAM ENERGY

As shown in Fig. 1, the polarization of captured positron beam will be lower than its nominal 30% when drive beam energy goes higher than its nominal 150GeV. In order to restore the 30% nominal polarization for higher CM scenarios, K factor manipulation has been chosen in the soon to be published ILC TDR baseline based on the numerical studies results presented in this paper.

Shown in table 1 are the parameter results of a K scan for undulator based positron source with undulator having a period of 1.15cm and 175GeV and 250GeV drive beam. OMD is a 14cm long FC with ~3T peak Bz field. The other configurations are the same as the ILC SB2009 baseline.

Table 1: Parameters for 350GeV CM and 500GeV CM

Parameter	units	350GeV	500GeV
Electron beam energy (e+ prod.)	GeV	178	253
Photon energy (first harmonic)	MeV	16.2	42.8
Photon openning angle (=1/γ)	μr	2.9	2.0
Undulator length	m	147	147
Required undulator field	T	0.698	0.42
undulator period length	cm	1.15	1.15
undulator *K*		0.75	0.45
Average photon power on target	kW	107	79
Incident photon energy per bunch	J	8.1	6.0
Energy deposition per bunch (e+ prod.)	J	0.59	0.31
Relative energy deposition	%	7.20%	5%
Photon rms spot size on target	mm	1.2	0.8
Peak energy density in target	J/cm^3	295.3	304.3
	J/g	65.6	67.5
Pol. of Captured Positron beam	%	30	30

As shown in table 1, one can operate the RDR undulator at K=0.75 for CM=350GeV and K=0.45 for CM=500GeV to restore the 30% nominal polarization with positron yield of 1.5 without the complication of photon collimators.

TO UPGRADE TO 60% POLARIZATION

As shown in previous section, 30% polarization and 1.5 positron yield can be achieved with manipulating the K parameter of RDR undulator. But for polarization upgrade to higher polarization level, photon collimation has to be applied and is studied in a numerical way here. The practical and engineering aspect of photon collimators are studied at DESY[3] and will not be covered here.

Shown in Fig. 2 is the yield and polarization plot of 231m long RDR undulator with 150GeV drive beam energy as functions of photon collimator iris. In order to make up the lost in yield from polarization upgrade, flux concentrator is always used as OMD in the default configuration. As shown in Fig. 2, 60% of polarization can be achieved using a photon collimator with an iris radius of ~1.65mm. The yield associated with 60% polarization for this case is about 1.2.

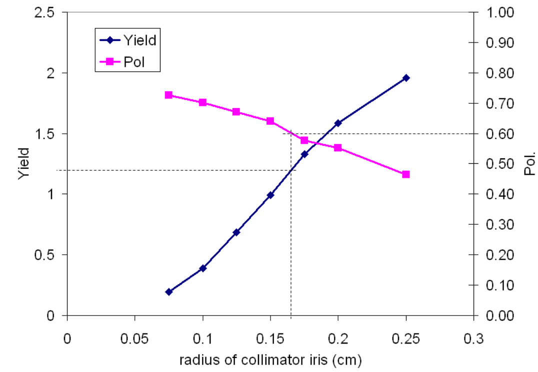

Figure 2: Yield and polarization as functions of photon collimator iris. 231m long RDR undulator driven by 150GeV electron beam. Flux concentrator of 14cm long and with ~3.5T peak field used as OMD.

Shown in Fig. 3 is the yield and polarization of 231 RDR undulator driving with 175GeV drive beam.

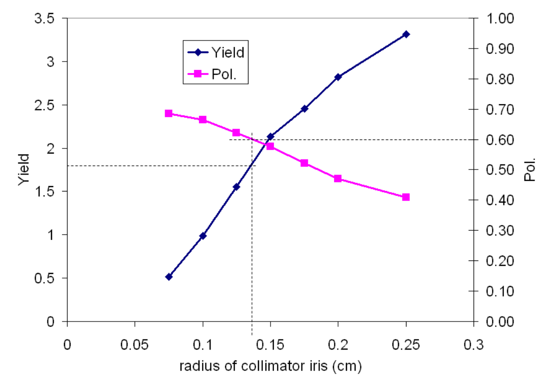

Figure 3: Yield and Polarization of 231m long RDR undulator driving with 175GeV beam. FC is used as OMD.

As shown in Fig. 3, 60% polarization can be achieved for 175GeV drive beam energy with a photon collimator of about 1.4mm in radius. The associated yield for 231m long RDR undulator is about 1.8.

Shown in Fig. 4 is the yield and polarization plot of 231m RDR undulator driving with 250GeV with different photon collimator settings. As shown in Fig. 4, the photon collimator iris associated with 60% polarization is about 0.6mm in radius. The corresponding yield is about 2.0 for this case. Comparing with Fig. 3, the photon collimator iris decreased down from 1.4mm for 175GeV drive beam energy down to 0.6mm for 250GeV drive beam energy. If only one photon collimator will be designed and fabricated, then one would have to sacrifice the polarization of 250GeV drive beam energy and choose the iris to produce enough positron yield at 175GeV drive beam energy.

ISBN 978-3-95450-115-1

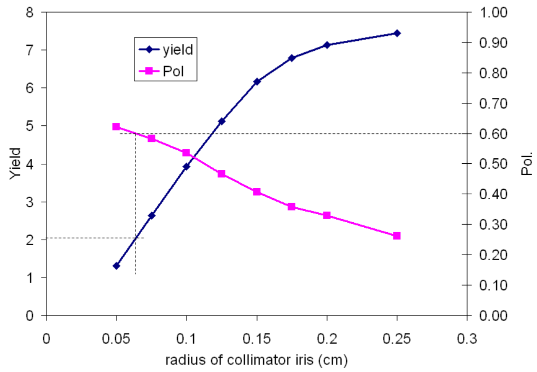

Figure 4: Yield and polarization of 231m long RDR undulator with 250GeV drive electron beam. FC is used as OMD.

Figure 5 shows the yield of 231m long RDR undulator associated with 60% polarization as functions of drive beam energies. For each drive beam energy, the photon collimator iris is independently scanned to obtain the yield associated with 60% polarization.

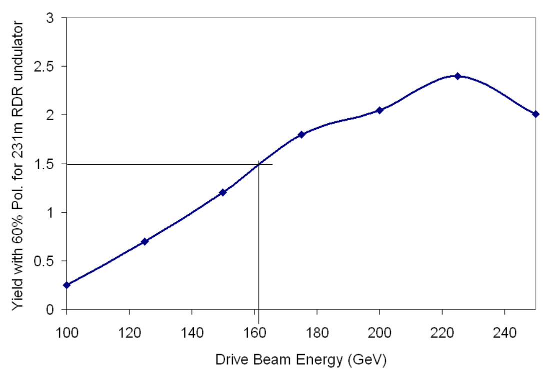

Figure 5: Yield associated with 60% polarization. 231m long RDR undulator with varying drive beam energy. Flux concentrator is used as OMD.

As shown in Fig. 5, 60% and 1.5 positron yield can be achieved for drive beam energy higher than about 163GeV by using 231m long RDR undulator with flux concentrator and a photon collimator in theory. The yield associated with 60% polarization peaks at drive beam energy of 220GeV in Fig 5.

UNDULATOR K PARAMETER AND POSITORN SOURCE POLARIZATION

In order to understand the relation between K and polarization, we scanned K parameter for undulator with period of 1.15cm driving with 250GeV electron beam. For positron source using the above undulator, we varied the photon collimator iris to evaluate the yield and polarization. As shown in Fig. 6, for a fixed drive beam energy, and given requirement on polarization, higher K gives higher yield. Higher K also gives a higher achievable polarization. But higher K also means more high order harmonics, so one should avoid K higher than 1 if possible.

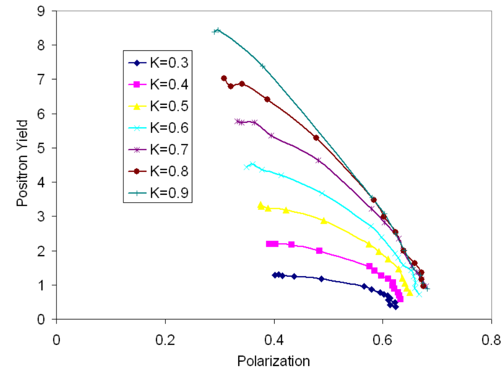

Figure 6: Yield vs polarization for undulator based positron source driving by 250GeV electron beam using undulator with different K and period of 1.15cm.

SUMMARY

Polarization upgrade is always among the most wanted upgrades of ILC positron source. In theory, the polarization of ILC positron source can be upgrade to 60% by using photon collimator to remove photons with low polarization. As a result of relocating positron source to the end of electron main linac, the performance is now tightly coupled with CM energies. A lot of efforts will be involved in order to upgrade the polarization of positron source for all CM scenarios.

REFERENCES

[1] SB2009 proposal document http://lcdev.kek.jp/SB2009/SB20091217B.pdf
[2] Sabine Riemann, Physics applications of polarized positrons. POSIPOL11 proceedings.
[3] F. Staufenbiel et al. Heat Load and Stress Studies for an Design of the Photon Collimator for the ILC Positron Source, POSIPOL11 Proceedings.