SYSTEMATIC STUDY OF THE UNDULATOR BASED ILC POSITRON SOURCE: PRODUCTION AND CAPTURE*

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Abstract

A systematic study of the positron production and capturing yield for the undulatoer-based ILC positron source has been performed. We use undulator parameters of k=0.3 - 1 , λ=0.7 - 1.5 cm as the reference design. The yield is defined as number of positrons captured at the damping ring input by a single electron passing through 100 meter long undulator. Several scenarios for polarizations and capturing schemes are considered here: polarized (60%) and low-polarized positrons, immersed target in magnetic field and non-immersed cases.

INTRODUCTION

An undulator based positron source has been chosen as the baseline configuration design for the International Linear Collider. Concepts of the undulator based e+ source were proposed and studied by many people for different purposes[1-5]. In the past years many ideas and undulator configuration were studied[6-7]. Here we report on a systematic study of the realistic cases for the wide range parameters. First, we discuss in details of the previous standard reference design parameter: k=1 and λ=1 cm and describe the photon spectrum and the e+ yield from each harmonics. A brief description of the OMD system and capturing accelerator is then given. Results on the other undulator parameters are followed. Scenarios for polarized (60%) and low-polarized cases were investigated. Finally, a concise table is given in the summary section. The target we used here is the “standard” 1.4 cm Titanium target.

PHOTON SPECTRUM AND POLARIZATION

The radiation spectrum of an electron produced photons from a helical undulators with K=1 and λu=1cm is shown in the Figure 1. The spectrum contains many harmonics. Photons from any harmonic can have the energy from zero up to the critical energy of the corresponding harmonic. A partition of photons numbers shows that about 49% of the photons were the radiation from the 1st harmonic, about 21% of them were the radiation from the 2nd harmonic and about 12% were from the 3rd harmonic. A similar partition for the new baseline undulator with K=0.92 and λu=1.15cm shows that about 52% of photons numbers were radiation from 1st harmonic, about 22% were from 2nd harmonic, about 11% were from the 3rd harmonic. Figure 2 shows a typical photon polarization spectrum from the helical undulator radiation. Even for photons with the same energy, their radiation angles and polarization are different for different harmonic photons.

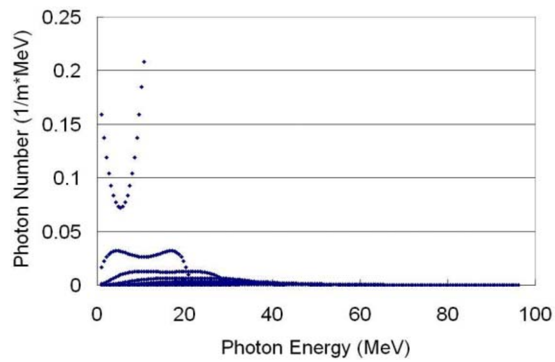

Figure 1: Spectrum of photons produced in undulator with K=1 and λu =1cm.

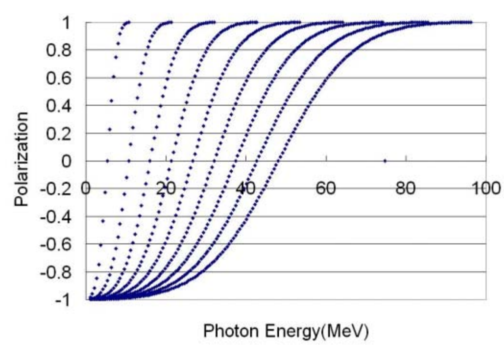

Figure 2: Photon polarization correlation between energy and harmonic index.

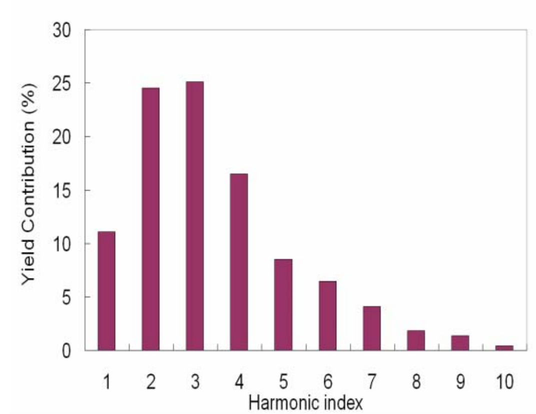

Figure 3: Partition of captured positron yield contribution from the different harmonics.

Due to the high cross section of the positron production from higher energy photons, we found that these higher

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harmonics play dominant role in producing positrons in the target, even though their total number is smaller. A partition of yield contribution from harmonics for polarized positron source using undulator with K=1 λu=1cm is given in figure 3. The 2nd and 3rd harmonics together contribute ~50% of the yield. The 1st harmonic only contributes ~12%.

SYSTEM LAYOUT FOR THE POSITRON PRODUCTION AND CAPTURING

As shown in fig. 4, our simulation model includes helical undulator, drift to a target, a photon collimator, a rotating titanium target, an optical matching device (OMD), a preaccelerator and SC linacs.

We use the helical undulator radiation spectrum with

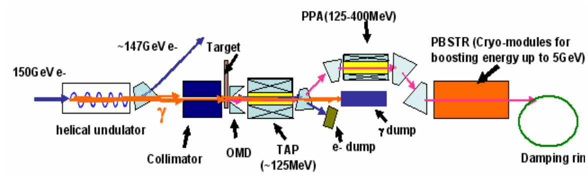

Figure 4: Overall layout of the ILC positron source.

assumed 100m long undulator, 100-500m long drift to the target, a photon collimator in front of the target with various aperture to control the polarization.

Here we use the standard ILC target 1.4 cm thick Titanium for most of our work. In addition we also looked into Tungsten target.

In this study, we first consider that the rotating target immersed in the magnetic field. Here we use 50 cm long OMD, and the field strength is from 5 Tesla at the target to 0.25 Tesla at the linac. For the non-immersed case, the distance of ramping up the OMD field from 0 to 5T also plays an important role in the capture efficiency.

Once beam is captured into the preacelerator, the beam is accelerated to 250 MeV using a conventional copper accelerator. At this point we select the particles meet our criteria (energy, energy spread, and bunch length) and then it is transferred to a standard ILC superconducting Linac to accelerate up to 5 GeV. One of the simulation constraints is not to lose any particles in the SC section.

SIMULATION RESULTS

For the referenced case of 100 meter undulator with K=1 and λu=1cm, immersed target

For polarized positron source, we varied the collimator iris and the drift to target together in order to maximize the yield while maintain a polarization of captured positron beam about 60%. As showing in figure 5, the yield is increasing with drift to target at the beginning and then saturated at about 1.1 when drift to target is about 400m. Also showing in figure 5 is the polarization of captured positron beam. Since we have been varying the iris of collimator together with the drift to maintain the opening angle unchanged, we managed to maintain the polarization of captured positron beam to about 60±2.5%.

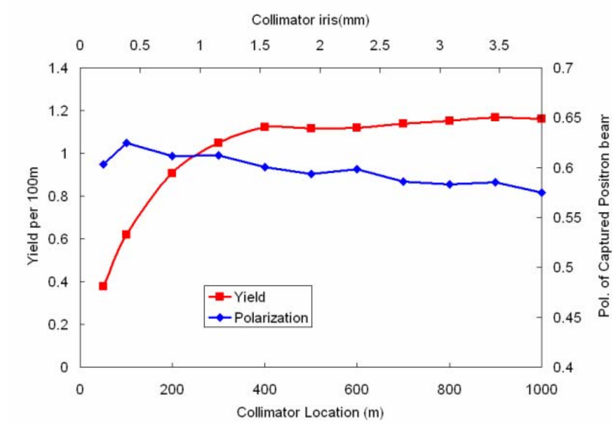

Figure 5: Yield and polarization changing with collimator settings.

For non-polarized positron source, the simulation is done the same way as the polarized case, except there is no photon collimator used here. All the produced photons are used to produce positrons. We maximized the yield as a function of drift distance (although it has a very week dependent). The maximum yield is ~ 2.2 e+/e- for 100m undulator. One interesting result needs to be mentioned here is that even though we did not collimate the photons, but the captured e+ beam in the end still has polarization of ~ 30% due to the fact that higher energy photons produce more positron .

For the new baseline undulator with K=0.92, lu=1.15cm

The same study has also been done for the new baseline undulator parameters, the calculated yield is 0.7 for polarized case with optimization done as before and 1.37 for non polarized case with a drift of about 50m. The yield decreased from about 1.37 down to about 1.29 when drift to target increased from 50m up to 500m. The results of this new baseline undulator is given in figure 6.

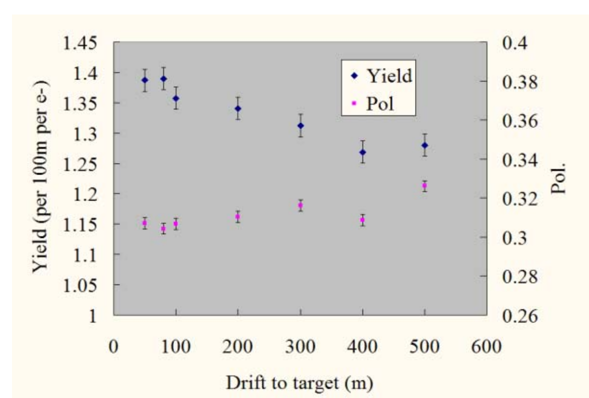

Figure 6: Yield and polarization of captured e+ for new baseline undualtor K=0.92, λu=1.15cm.

For Non-immersed Cases

For non-immersed cases, we assume an OMD field ramps up from 0 at the target up to over 5T in a short

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distance and then decrease adiabatically down to 0.25T in 50cm. We calculated the non-polarized case using the new undulator baseline parameters. For a summary of the results, shorter ramp would give higher yield. A 3cm ramp can reduce the yield by 30%.

For Other Undulator

Following the same process in previous section, we also investigated other undulator parameters. The yield of polarized source as function of K and λu were studied and the overall trends were given in figure 7 and 8. For the same capturing optics described in previous section, the yield goes up with K for a λu fixed undulator as showing in figure 7 and goes down with λu for K fixed ones as shown in figure 8.

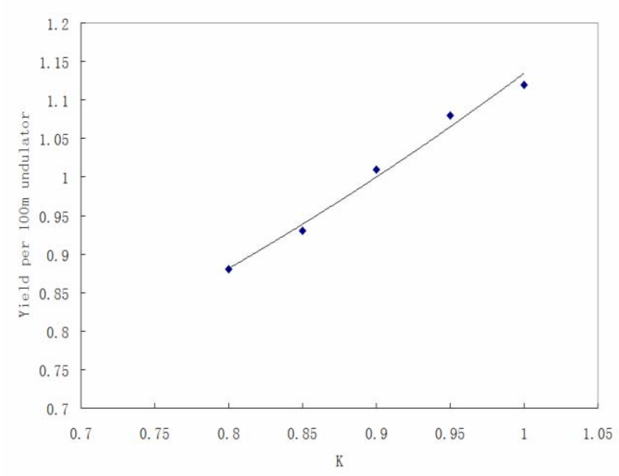

Figure 7: Yield (polarized source) as a function of K for fixed λu=1cm.

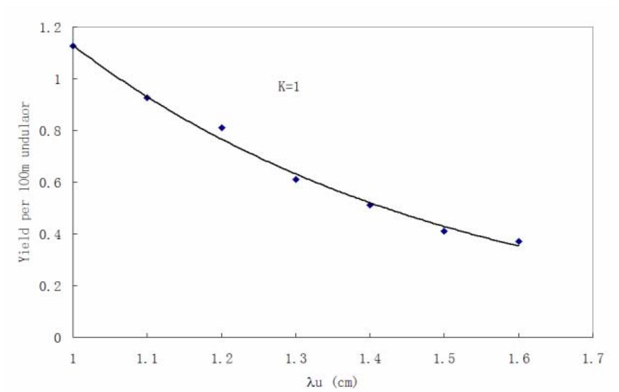

Figure 8: Yield as function of λu for K=1.

Comparison of Proposed Undulators

We also did simulations using the various undulator parameters proposed by the collaborators. The results were given in table 1. For results in table 1, all of them are using 0.4 radiation length Ti target. The capturing optics is the same for all the results in this table. For low K undulators, in order to catch up in yield with high K undulators, special capturing optics and high conversion rate target must be applied if that is possible at all.

Table 1: Yield comparison between different undulator. Yield 1 is the yield of low polarization cases with drift to target of 10m. Yield 2 is also yield of low polarization cases but with a drift to target at 500m. Yield 3 is the yield for 60% polarization cases.

	Old BCD	UK I	UK II	UK III	Corn. I	Corn. II	Corn. III
λu(mm)	10	11.5	11.0	10.5	10.0	12.0	7
K	1	0.92	0.79	0.64	0.42	0.72	0.3
B_0(T)	1.07	0.86	0.77	0.65	0.45	0.64	0.46
E_0(MeV)	10.7	10.1	12.0	14.4	18.2	11.7	28
Yield 1	~2.4	~1.37	~1.12	~0.86	~0.39	~0.75	~0.54
Yield 2	~2.13	~1.28	~1.08	~0.83	~0.39	~0.7	~0.54
Yield 3	~1.1	~0.7	~0.66	~0.53	~0.32	~0.49	~0.44

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