UPDATE ON ILC POSITRON SOURCE STUDY AT ANL*

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Abstract

As the new ILC baseline has moved the positron production to the end of electron main linac, both the drive beam energy and beamline layouts have also been changed for the positron source. Now the drive beam energy will be varying from 150GeV to 250GeV and 500GeV (for TeV upgrade) as the colliding center of mass (CM) energy changes. Systematic studies on the performance of positron source under different running scenarios have been done at ANL and the results are presented in this paper. We also present results from our recent short period high K undulator parameter study, polarization upgrade, lattice design and TeV upgrade option study.

INTRODUCTION

ILC positron source is an helical undulator based positron source[1,2]. As shown in Fig. 1, electron beam from the main linac will be passing though a hundreds meter long undulator where the electron beam will lose energy into photon radiation. The electron beam will be sent to the Beam Delivery System at the end of undulator while the photon beam will continue drift for about 400m to conversion target to produce positron through EM scattering. The properties of positron beam coming out of the conversion target are related to the properties of photon beam produced from the undulator. The spectra of photon beam coming out of the undulator are determined by both the drive beam energy and the undulator parameters. Thus the performance of ILC positron source will change if the drive beam changed or the undulator changed.

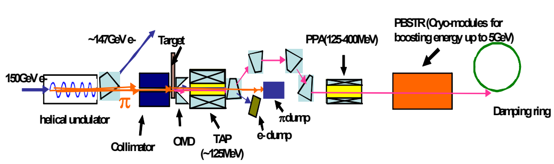

Figure 1: Positron source conceptual layout.

Starting from SB2009 baseline[2], the ILC positron source has been relocated to the end of electron main linac to save the machine cost. As a result of this relocating of positron source, the performance of positron source is now tightly coupled with the CM scenarios of the proposed machine and a systematic study of the positron source performance under different CM scenarios is needed.

The positron source studies at ANL have covered many aspects of ILC positron source such as start to end simulation for comparison of different proposed undulator parameters[3], drive electron beam emittance evolution through RDR undulator[4], optical matching device comparison study and design[5], energy deposition and activation of positron conversion target. In this paper, we report the results from our most recent studies.

YIELD AND POLARIZATION FOR RDR UNDULATOR AT END OF LINAC

The RDR undulator parameters are K=0.92 and λu=1.15cm. For such an undulator, with an effective length of about 230m, using quarter wave transformer as optical matching device(OMD) and a drive beam having 150GeV energy, the ILC positron source will have a positron yield of about 1.5 and polarization of about 30%. As a result of relocating the positron source to end of linac, fixing the drive beam energy becomes very costly and the drive beam energy to the ILC undulator based positron source will be varying. As the 1st attempt to understand the effect of such change, we scanned the drive beam energy of RDR undulator based positron source and the results are presented here in Fig 2.

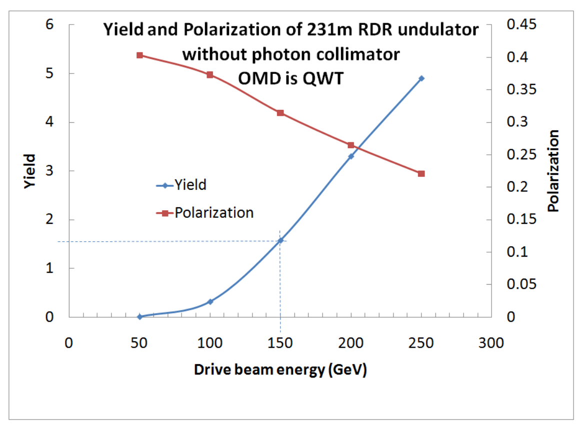

Figure 2: Yield and Polarization of RDR positron source with different drive beam energy.

As showing in Fig. 2, both yield and polarization of the undulator based positron source are a function of drive beam energy. The yield goes higher while the polarization goes lower with the increasing of drive beam energy. The positron yield will be only about 0.3 when drive beam is 100GeV while it can be as high as over 4.8 for drive beam energy at 250GeV. As a result of the above finding, one has to consider a different scheme(10Hz with 5Hz 150GeV drive beam interlaced with 5Hz luminosity production beam) or a different undulator for low energy operation (CM <300GeV). On the other hand when the drive beam energy goes higher than 150GeV, the polarization will be lower than 30% (the minimum polarization can be accepted by physicists). So for ILC CM scenarios where CM=350GeV or

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

500GeV, one need to find a way to increase polarization of captured positron beam while keep the positron yield to be about 1.5.

HIGH K SHORT PERIOD UNDULATOR FOR LOWER DRIVE BEAM ENERGY

As discussed in previous section, for ILC CM scenarios where CM=200GeV, 230GeV and 250GeV, the RDR undulator based positron source won't be able to produce enough positrons to meet the machine requirements unless a 5Hz 150GeV drive beam is provided and interlaced with 5Hz luminosity production beam.

With recent advance in technology, using Nb2Sn superconducting strand, it is possible to make undulators with shorter period while keep K high. With such high K short period undulators, we may be able to produce enough positron for low CM scenarios without using the 10Hz scheme. In order understand the performance of high K short period undulator, we scanned the undulator parameters for ILC undulator based positron source. The results are given in Fig. 3.

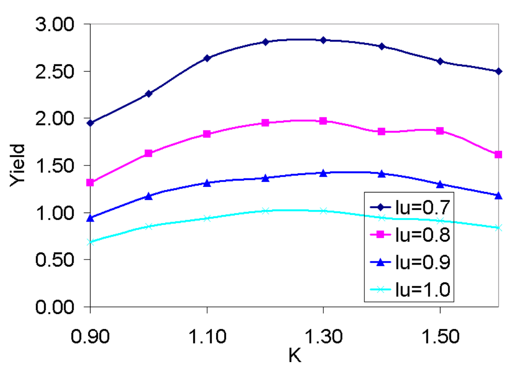

Figure 3: Results of undulator parameter scan for ILC positron source at 100GeV drive beam.

As shown in Fig. 3, the yield increases with the decrease of length of undulator period for a given K. While for a given undulator period length, the positron yield peaks at about K=1.2. For K=0.9 and λu=0.9cm, 100GeV drive beam will give us a yield of about 0.94 for 231m long undulator and quarterwave transformer. With the recent progress in flux concentrator R&D, a flux concentrator with peak field > 3T become feasible and then a positron source for ILC with 100GeV drive beam will be available and one can eliminate the costly 10Hz mode for lower CM scenarios and save a lot on operation cost.

POLARIZATION UPGRADE STUDY

As higher polarization of positron source will enhance the effective luminosity of ILC and thus polarization upgrade is always among the most wanted upgrade. Numerical studies have shown that 30% polarization can be achieved with only manipulating the K parameter of RDR undulator. But in order to achieve 60% polarization, photon collimator has to be applied to remove those photons with lower polarization. In order to find out the photon collimator requirements for polarization upgrade, numerical studies were done and the results are reported here.

In these studies, we used a flux concentrator with 0.5T at target(z=0) and 3.5T at z=2cm decrease adiabatically down to 0.5T at z=14cm as the OMD. The effect length of undulator is 231m. All other configuration is the same as RDR positron source.

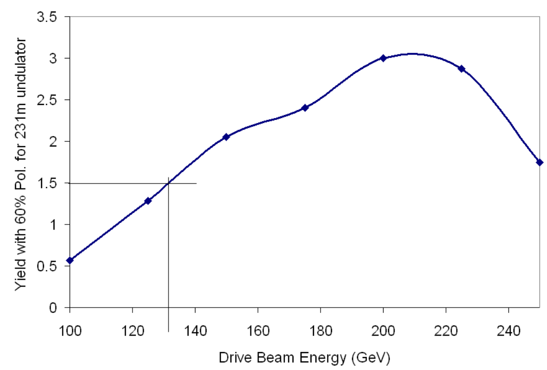

Figure 4: Yield with 60% polarization for undulator with K=0.9 and λu=0.9cm.

Figure 4 shows the achievable yield for 60% polarization using 231m long short period high K undulator which might be available in the near future. We scanned the collimator iris for different drive beam energy to find out the positron yield associated with 60% polarization. As shown in Fig. 4, with 231m long undulator with K=0.9 and λu=0.9cm, 1.5 positron yield and 60% polarization can be achieved with drive beam energy higher than 132GeV.

A similar result for RDR undulator is also obtained in the same way. For RDR undulator, 1.5 positron yield with 60% polarization can be achieved with drive beam energy higher than about 160GeV and the achievable yield for 60% polarization peaks at about 225GeV drive beam energy.

Besides scanning the photon collimator iris to find out the achievable yield associated with 60% polarization, we also studied the photon power collimation ratio required for different level of polarization. The results have shown that for RDR undualtor with 150GeV drive beam energy, 55% of photon power needs to be collimated by the photon collimator in order to achieve 60% polarization while for 250GeV drive beam energy about 80% of photon beam has to be collimated in order to achieve 60% polarization.

POSITRON SOURCE LATTICE

As a result the relocation of positron source to the end of electron main linac and change of ILC site layout, the RDR positron source beam line lattice is no longer valid and a new lattice design is required in order to have a practical beamline conformal with the site layout and provide detail information for the ILC positron source cost estimation.

ISBN 978-3-95450-115-1

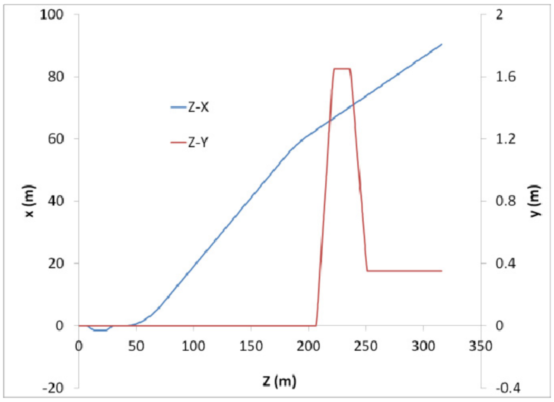

Figure 5: Floor plan of PLTR in zx and zy plane.

Comparing with RDR beamline, the new beamline has a much shorter low energy transport line. The FODO lattice for transport lines are inherited from RDR lattice. We also replaced the RDR 5GeV booster lattice with a more practical one which represents the up to date cryomodule configurations. The new PLTR beamline is also changed a lot from RDR lattice. The new PLTR beamline is much longer than RDR PLTR beamline and the 1st arc is now bending only 23.787^{o} as opposed to the 54.579^{o} bending angle in 1st arc of RDR PLTR beamline which makes achievable R56 from 1st arc too small to yield a proper phase space for energy compressing. As a result of the reduced 1st arc bending angle, we have added a chicane before the 1st arc of PLTR to generate the R56 required for energy compression. The total length of PLTR is now about 330m long including the added chicane. There are also many other changes in PLTR beamline which we will not cover in detail here. The geometry layout of new PLTR is given in Fig. 5.

STUDY OF TEV UPGRADE OPTION

The current ILC machine has CM energy up to 500GeV and there is a possibility that we need to upgrade the collider to 1TeV CM. But starting from SB2009 baseline, the positron source for ILC has been moved to the end of electron main linac and thus the drive beam energy will be tightly coupled with the CM. As the photon radiation opening angle is inversely scaled with γ of drive beam and the 1st harmonic energy is scaling with γ^2, running the current ILC baseline positron source helical undulator with 500GeV drive beam doesn't seem to be an option.

We have investigated options like increase K and undulator period λu; fixed K and increase undulator period. We dropped the increase K with λu option as studies has shown that a lot of photon will be radiated into higher order harmonics and these high order harmonics will cause heating, activation problem and excessive energy lost of drive beam. Based on the results of our studies, we proposed to use undulator with K=1 and λu=4.3cm for TeV upgrade.

SUMMARY

The positron source studies at ANL has covered many aspects of ILC undulator based positron source. We highlighted some of our recent works in this paper. But due to the limited space, we did not discuss them in detail.

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