UPDATE ON ILC POSITRON SOURCE START-TO-END SIMULATION*

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Abstract

As a result of the changes in the new ILC base line, there are many changes in the positron source beamline layouts and thus a new lattice design is required. According to the changes in the ILC baseline, a new lattice design for the ILC positron source has been developed at ANL. In this paper, both the new ILC positron source beamline lattice and the corresponding start to end simulation results are presented.

INTRODUCTION

The helical undulator of ILC positron source used to be located near the middle of electron main linac where the main electron beam reaches 150GeV in energy[1] and starting from SB2009 baseline[2], it is now relocated at the end of electron main linac. This relocation of positron source undulator has reduced the low energy transport line of positron source and also simplified the positron transport line. The new 400MeV transport line is straight line less than 400m.

Another change between the ILC RDR layout and new baseline layout that has impact to positron source beamline lattice is the change of damping designs.

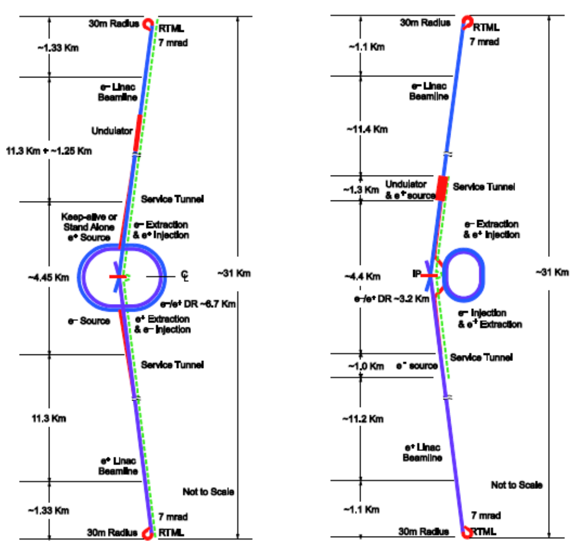

Figure 1: RDR layout (left) and the new baseline layout (right).

As shown in Fig 1, the damping ring in the new baseline is half the size of RDR damping and has been moved to one side of IP. Due to the change in geometrical layout, the PLTR beamline lattice also need to be redesigned to ensure the capture of positron beam. As part of start to end simulation, we also reported our simulation on the main electron beam properties as they passing through the ILC positron source undulator.

THE EMITTANCE AND ENERGY SPREAD OF MAIN ELECTRON BEAM

When electron beam passing though a helical undulator, electrons will lost energy into photon radiation and gama rays will be generated. There exist both quantum excitation and damping effect as results of such photon generation process. Our previous study for RDR undulator based positron source has shown that for RDR undulator and the nominal 150GeV drive electron beam, emittance damping effect is stronger than the quantum excitation effect and thus the emittance of 150GeV drive electron beam will be damping down as it passing though the RDR undulator[3].

Since the photon radiation spectra of a given helical undualtor is depended on the drive electron beam energy, the effect of the same undulator on different drive electron beam could be different and thus the impact of relocating the undulator to the end of electron main linac also need to be revisited.

Table 1: Electron Beam Parameters

CM Energy	GeV	200	230	250	350	500
Effective undulator length	m	147	147	147	147	147
Effective undulator field	T	0.86	0.86	0.86	0.698	0.42
undulator period length	cm	1.15	1.15	1.15	1.15	1.15
Electron energy loss in undulator (e+ prod.)	GeV	3.0	3.0	3.0	2.6	2.0
Electron energy loss in undulator (lumi prod.)	GeV	1.3	1.8	2.1		
Rel. enery spread induced by und.(assumed initial 0.3%)		0.087	0.100	0.112	0.118	0.065
Total energy spread (assumed 0.3% initial)		0.312	0.316	0.320	0.322	0.307
Rel. enery spread induced by und.(assumed initial 0.2%)		0.092	0.112	0.117	0.116	0.082
Total energy spread (assumed 0.2% initial)		0.220	0.229	0.232	0.231	0.216
Rel. enery spread induced by und.(assumed initial 0.1%)		0.098	0.111	0.120	0.120	0.085
Total energy spread (assumed 0.1% initial)		0.140	0.149	0.156	0.156	0.132
Rel. enery spread induced by und.(assumed initial 0%)	%	0.098	0.113	0.123	0.122	0.084
Emittance growth	nm	-0.4	-0.6	-0.7	-0.55	-0.31

Shown in table 1 are the parameters of electron beams passed through the helical undulator for different CM scenarios. As showing in the table, the emittance of electron beam for all CM scenarios are damping down as they passing though the undulator while the energy spreads are growing for electron beam of all CM scenarios.

POSITRON SOURCE BEAMLINE LATTICE DESIGN

As shown in figure 2, conceptual view of positron source, the new positron source beamline is consisted of Positron source Target Area and Pre-Accelerator (PTAPA), Positron CAPture section(PCAP), Positron Pre-Accelerator(PPA), Positron source low energy

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

ISBN 978-3-95450-115-1

transfer line(PTRAN), Positron 5GeV energy Booster(PBSTR), Positron 5GeV transfer line(PTRANH) and Positron Linac To Ring(PLTR.)

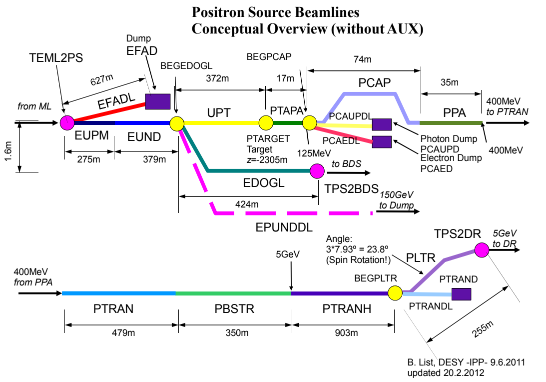

Figure 2: Conceptual layout of the positron source beamline.

The PTAPA beamline is consisted of two standing wave linac and 3 travelling wave linac. This section of beamline is responsible for accelerating the positron beam up to 125GeV. The particle tracking of positron beam through this section is handled by PARMELA and the beamline never change for this section. A typical longitudinal phase distribution of positron beam is given in Fig. 3.

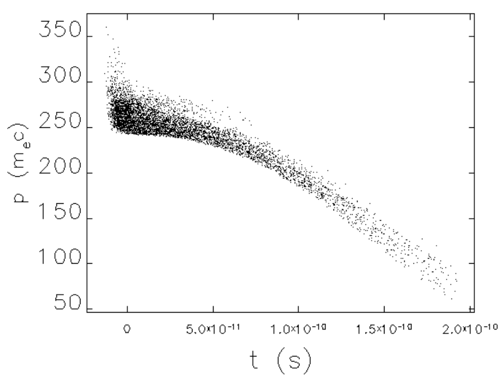

Figure 3: Typical longitudinal distribution at end of PTAPA.

The positrons passing through the capture RF cavities are separated from electrons and photons in the dipole magnet at entrance into the PCAP section. The latter is an achromatic chicane optics which horizontally deflects the positron line by 1.5 m. It includes a set of collimators to scrape the positrons with large incoming angles and large energy errors. As the energy spread of positron beam is big in this stage, one need to minimize both R56 and T566 of this section to minimize the longitudinal phase space dilution of the positron beam. A typical longitudinal phase space distribution of positron is given in Fig. 4.

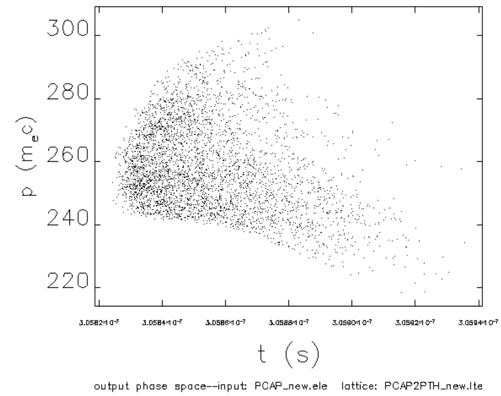

Figure 4: Longitudinal phase distribution of positron beam at the end of PCAP.

Following the PCAP section, PPA is used to accelerate the positron beam up to 400MeV. This beamline section is kept the same as in RDR.

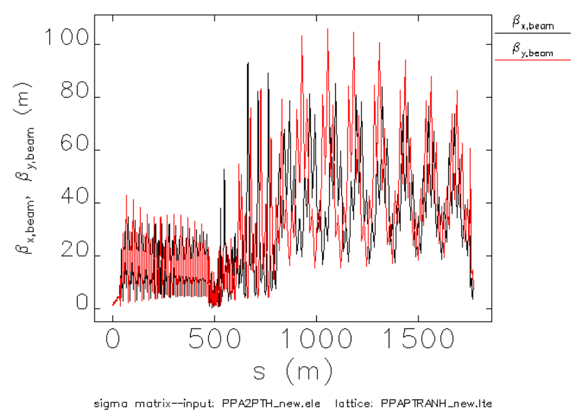

Figure 5: Beta functions from end of PPA to end of PTRANH.

A PTRAN beamline section of about 426m is then used to transport the 400MeV positron beam from PPA downstream to PBSTR, 5GeV positron energy booster beamline. The FODO lattice for PTRAN is borrowed from RDR PTRAN beamline section.

The new PBSTR lattice is now consisted with 6 4 cavities 4 quads(4C4Q) cryomodules for energy from 400 MeV up to ~1082.564MeV, 8 8 cavities 2 quads (8C2Q) cryomodules for beam energy up to ~2507 MeV, and 12 8 cavities 1 quad (8C1Q) cryomodules for beam energy up to 5GeV. The total length of this section including matching in and out is 372.56m.

Following the PBSTR beamline, positron beam will pass through a 934.23m PTRANH transport line before it move down into PLTR beamline. The beta functions of beamline from PTRAN to PTRANH beam line is given in Fig. 5.

The PLTR system which extracts the positrons from the booster linac and injects them into the DR injection line has two main functions: one is to perform spin rotations; and the other to manipulate energy compression to meet the longitudinal DR acceptances.

The longitudinal polarization of the positrons is made at the target and preserved prior to the DR. In the DR, only positron spin directions parallel or anti-parallel to the magnet field – that is, transverse to the plane of the DR – will preserve their polarization. The LTR system consists of bending magnets and solenoids, changing the spin of positrons firstly from the longitudinal to horizontal plane and then from horizontal to vertical, parallel to the magnetic field of the DR (for the magnetic field in DR in the vertical plane). Given $n \cdot 90°$ of spin rotation (n is odd integer) from longitudinal to horizontal plane at 5 GeV, the total bending angle $\theta_{bend} = n \cdot 7.929^{\circ}$ is required. Given 90° of the spin rotation from the horizontal to vertical plane at the energy, the solenoid magnetic field integral of $B_z \times L_{sole}$ = 26.2 T.m is needed. An 8.3-m-long superconducting solenoid with 3.16 T magnetic field is used.

The energy compression is realized by properly manipulating booster linac RF phase using momentum compaction. The chicane at the beginning of PLTR which has a transverse offset of ~1.5m is designed to manipulate the longitudinal phase space of positron source beam for energy compression. The nominal R56 of this chicane is about -0.75m. The first arc of PLTR has a bending angle of $3 \times 7.929°$= 23.787° which is to rotate the spin 90° into transverse from longitudinal. After the 1st arc, an RF voltage of 225 MV provided by a 9 cavities no quads RF cryomodule is implemented to rotate the positrons in the longitudinal phase space to match with longitudinal DR acceptance. The rest of the PLTR system includes: a section with additional 9.626° horizontal bending; a vertical dogleg to raise the elevation up by 1.65m; another vertical dogleg to lower the elevation back down to its final 0.35m; a FODO lattice to transport the beam and a matching section to match twiss parameters at the DR injection line. Its geometry is shown in Fig. 6.

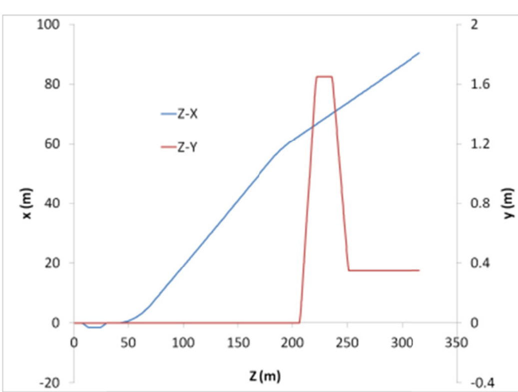

Figure 6: Floor map of PLTR beamline.

A typical longitudinal phase space distribution at the end of PLTR is given in Fig. 7.

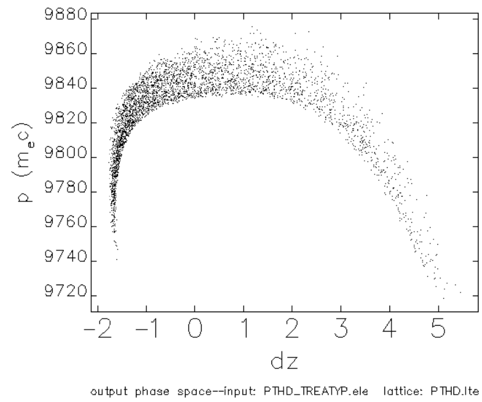

Figure 7: The longitudinal phase space distribution of positron beam at end of PLTR.

SUMMARY

A complete simulation study on the drive electron beam properties passing through positron source undulator were done and reported for all colliding center mass energy scenarios of ILC. Also reported here is a new positron source lattice design based on the up to date geometrical layout of ILC new baseline.

REFERENCE

[1] ILC Reference Design Report.

[2] SB2009 proposal document. http://lcdev.kek.jp/SB2009/SB20091217B.pdf

[3] W. Gai, etc, *Emittance Evolution of the Drive Electron Beam in Helical Undulator for ILC Positron Source*, PAC09-Proceedings, Vancouver, Canada, 2009.

ISBN 978-3-95450-115-1