RECENT DEVELOPMENTS IN THE DESIGN OF THE NLC POSITRON SOURCE*

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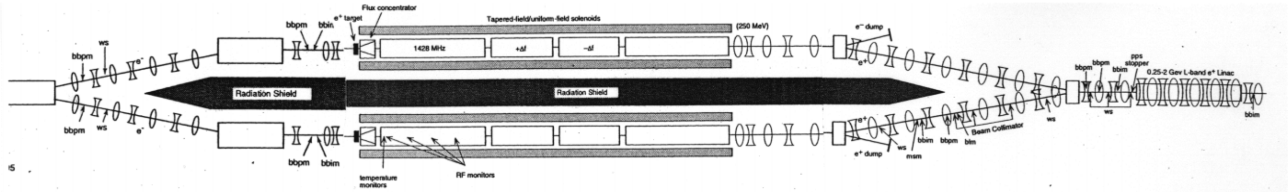

Figure 1. Schematic layout of the positron source. The S-Band electron injector at 6.22 GeV is at the left of the figure (not to scale). There are two positron targets for reliability purposes. The capture and acceleration system is chosen to be to L-Band (at the right of the figure, not to scale)

Abstract

Recent developments in the design of the Next Linear Collider (NLC) positron source based on updated beam parameters are described. The unpolarized NLC positron source [1,2] consists of a dedicated 6.2 GeV S-band electron accelerator, a high-Z positron production target, a capture system and an L-band positron linac. The 1998 failure of the SLC target, which is currently under investigation, may lead to a variation of the target design. Progress towards a polarized positron source is also presented. A moderately polarized positron beam colliding with a highly polarized electron beam results in an effective polarization large enough to explore new physics at NLC. One of the schemes towards a polarized positron source incorporates a polarized electron source, a 50 MeV electron accelerator, a thin target for positron production and a new capture system optimized for high-energy, small angular-divergence positrons. The yield for such a process, checked using the EGS4 code, is of the order of 10^{-3}. The EGS4 code has being enhanced to include the effect of polarization in bremsstrahlung and pair-production process.

1 INTRODUCTION

In the NLC electrons and positrons are generated in separate accelerator complexes. A schematic layout of the positron injector systems is shown in Figure 1. Table 1 lists the parameters of the drive electron beam that creates the positrons and of the positron target and Table 2 lists the positron beam parameters.

Table 1: NLC Injector Positron System Drive Electron Beam and Positron Target Parameters

Parameter	Value
Energy, E (GeV)	6.2
Energy Spread, dE/E (%)	± 1.0
Single Bunch, dEs/E (%)	<0.5
Linac Frequency (MHz)	2856
Emittance (10^{-6} m-rad)	100
Particles/Bunch, N_b (10^{10})	2
Pop. Uniformity dN_b/N_b (%)	<0.5
Number of Bunches N_b	95
Beam radius (mm rms)	1.6
Bunch-length , dt (ps, FWHM)	17.5
Total Beam power/area GeV/mm^2 (10^{12})	1.5
Bunch spacing (ns)	2.8
Repetition rate (Hz)	120
Average Beam Power (kW)	226
Target thickness W-Re (RL)	4
Target power (kW)	23

On the positron side, electrons are produced using a thermionic cathode and accelerated to an energy of 6.22 GeV in an S-band linac before impacting a target to produce positrons. Initial capture and acceleration of positrons to the damping ring energy of 1.98 GeV is done in an L-band (1428 MHz) linac system. The beam-loaded gradients in the L-band and S-band linacs have been chosen to be 13 MV/m and 17 MV/m, respectively (17 MV/m and 21 MV/m unloaded). For a detailed description please see ref. [3]

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Table 2: NLC Injector System Positron Beam Parameters

Parameter	Value
Linac Frequency (MHz)	1428
Energy, E (GeV)	1.98
Energy Spread, dE/E (%)	<1
Single Bunch, dEs/E (%)	<1.2
Emittance, norm.(m-rad)	0.06 (edge)
Bunch-length, dz (mm, sigma)	3.7
Particles/Bunch, nb (10^{10})	1.6
Pop. Uniformity dnb/nb (%)	<1
Number of Bunches Nb	95
Bunch spacing (ns)	2.8
Repetition rate (Hz)	120
Pre-DR acceptance (m-rad) Pre-DR Energy acceptance (%)	0.09 +- 1.5

Redundant e- and e+ sources are incorporated into the design to enhance availability (fig. 1). In the baseline design the positron damping ring and subsequent accelerator systems do not include polarization spin manipulation solenoids or polarimeters. The positron beamlines allow for a later installation of spin preserving solenoids should the NLC be configured for electron-electron collisions or address the issue of polarized positrons. The NLC emittance budget allows for dilution of the beam emittances by 20% in the horizontal and 50% in the vertical between extraction from the damping rings and injection into the main linacs. This budget is used to calculate tolerances. The initial positron rms emittances after the target are $\gamma\varepsilon_{x/y}$ = 0.04 m-rad and reduced to $\gamma\varepsilon_{x/y}$ = $100\mathrm{x}10^{-6}$ m-rad for injection into the positron main damping ring [3].

2 BASELINE DESIGN FOR NLC POSITRON PRODUCTION

Positrons are produced by targeting a 6.22 GeV electron beam into an SLC style positron production system (fig. 1). The target module consists of a water-cooled, 4 r.l. W-Re target followed by a 5.8 T magnetic flux concentrator, a 1.2 T tapered field solenoid, and a 0.5 T uniform field solenoid as seen in fig.2 [1].

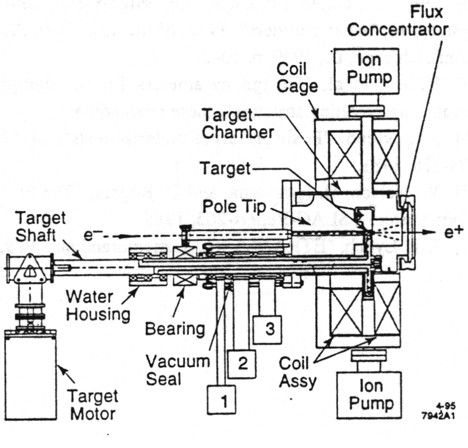

Figure 2. The target module

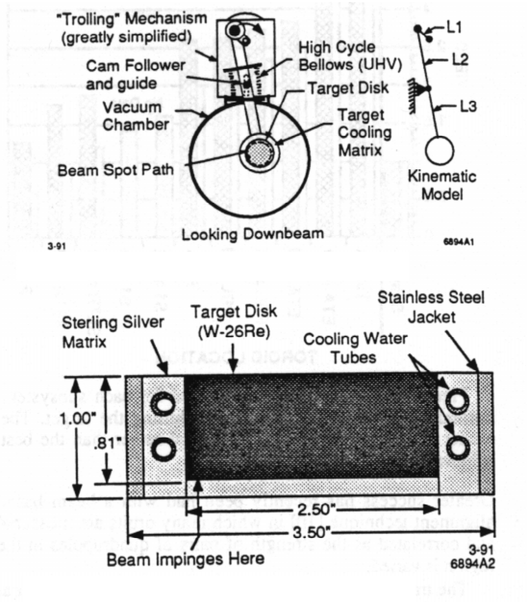

Figure 3. Cross section and detail of the cooling scheme of the SLC and proposed NLC target.

L-band accelerator sections are used in the initial capture region to accelerate the beams to 250 MeV. After separation and removal of the electrons, the positrons are accelerated to the pre-damping ring energy of 1.98 GeV in an L-band linac

A yield of 2 positrons per electron into a phase space edge acceptance of 0.06 m-rad is expected. This yield normalized by the incident electron energy is a factor of 4 improvement over the SLC. L-band has been chosen because of the large transverse aperture and longitudinal acceptance, which are fully utilized in defining the acceptance and subsequent yield calculations. Energy loading in the initial capture regions will be compensated using a ΔF correction scheme but ΔT will be used for the L-band Linac.

3 RECENT DEVELOPMENTS WITH THE SLC TARGET

During the 1998 SLC run the positron target (fig.3) failed, after many years of use, showing a water-to-vacuum leak. When the target system was removed from the beamline, some damage on the downstream side of the target was observed and target material was seen in the flux concentrator immediately downstream of the target.

This has caused significant concern regarding the viability of the NLC positron system design since the NLC design is based on the SLC system. The concern is whether the SLC system failed in an acute manner from exceeding the target damage threshold or from chronic degradation of the target. The former would require a significant redesign of the NLC positron systems whereas the latter would mean that the NLC design is viable albeit the targets will age and require preemptive replacement [3].

Analysis of the SLC target failure is being undertaken as a program that consists of calculations on target cooling and on shock waves from drive beam impact, and of analysis of the damaged SLC target. The calculations are performed in collaboration with LLNL. Material analysis of the target is done with collaboration with LANL. This work is currently concentrating on producing pictures of target details, x-ray and SEM pictures, performing material hardness tests and isotope analysis. This analysis is expected to be completed during the summer of 1999.

4 POLARIZED POSITRONS FOR NLC

There are some advantages for NLC if polarized electrons collide with polarized positrons [4,5]. Although the baseline design of NLC does not include polarized positrons we have started an effort of studying various new methods of polarized positron production. Currently the most promising is the helical undulator approach [6], although new experiments using CO_2 lasers on electron beams may also prove to provide an adequate source of polarized positrons [7]. We have been recently looking into a new idea of using a polarized electron beam on a thin target [8] and efficiently collecting the polarized positrons produced at the peak of the output energy distribution. Here we present a preliminary study of this scheme. We used a modified version of the EGS code that includes polarization for bremsstrahlung, Compton and pair production, with input electron drive beams [5]. The spin flip for input γ's is small for thin targets and can be calculated efficiently using a numerical code [7]. Using a 50 MeV electron drive beam and 0.2 radiation lengths of W-Re target, the yield of polarized positrons with energy higher than 25 MeV is approximately 0.06% with average polarization 85% of the input electron polarization (fig.4). The electron energy has not been optimized yet, but was chosen as a benchmark for the numerical calculations presented in [8]. The low yield suggests that a long pulse drive beam is needed in order to create the number of positrons needed at the IP, which complicates both the drive accelerator and the positron accelerator. Using the above-mentioned parameters, the electron beam power required to produce an NLC type positron beam is approximately 2.4 MW, if the capture system is 100% efficient. A sizable dump should be constructed to collect the electrons after the target, while the radiation issues due to gammas generated on the target create an extra problem. The energy loss in the target is approximately 4% and the power dissipated is 96 kW, which is 4 times that of the baseline NLC design. Assuming an input electron beam with σ =2 mm the energy density of the impinging electron beam is close to the upper experimental limit [2]. Furthermore, in order to recreate the pulsetrain of positron pulses needed at the IP an appropriate accumulator ring has to be designed. The high polarization positrons are concentrated in the forward direction so the capture system will vary from the baseline design (fig.5). We are currently studying the viability of the above-mentioned polarized positron scheme.

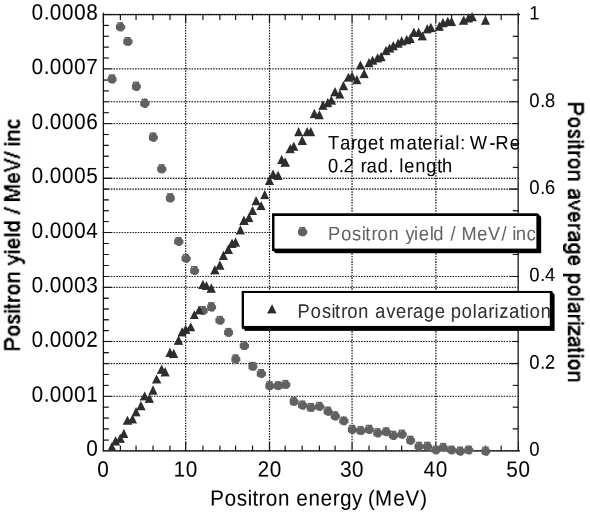

Figure 4. Positron yield and polarization for 50 MeV electron drive beam and 0.2 radiation lengths of W-Re.

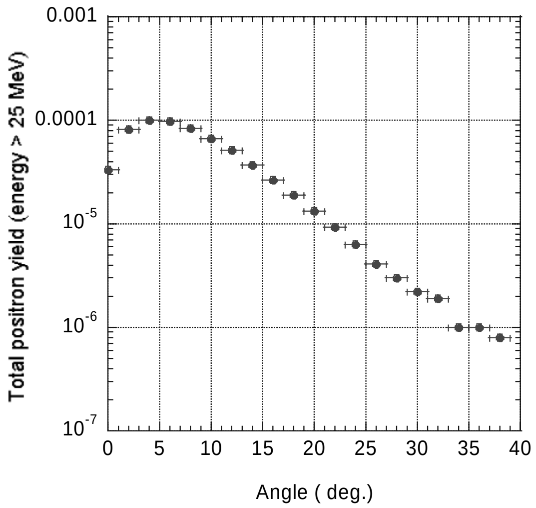

Figure 5. Positron yield vs polar angle of momentum vector.

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