Parameters of the SLAC Next Linear Collider[*]

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Abstract

In this paper, we present the parameters and layout of the Next
Linear Collider (NLC). The NLC is the SLAC design of a future
linear collider using X-band RF technology in the main linacs.
The collider would have an initial center-of-mass energy of 0.5
TeV which would be upgraded to 1 TeV and then 1.5 TeV in two
stages. The design luminosity is $> 5 \times 10^{33}$ cm^{-2} sec^{-1} at 0.5
TeV and $> 10^{34}$ cm^{-2} sec^{-1} at 1.0 and 1.5 TeV. We will briefly
describe the components of the collider and the proposed energy
upgrade scenario.

I. INTRODUCTION

A number of groups around the world are creating designs
for a future linear collider. The present state of the designs can
be found in Ref. [1] and a summary of the present status and
the required R&D can be found in Ref. [2]. In this paper, we
describe the SLAC Next Linear Collider (NLC). The NLC would
have an initial center-of-mass energy of 0.5 TeV and would then
be upgraded to 1 TeV and finally 1.5 TeV in the center-of-mass.

The primary parameters for the three stages of the design are
listed in Table 1. The parameters of the 500 GeV collider are
based upon technology that has been demonstrated or is expected
to be demonstrated within the next few years. The upgrade path
to 1 TeV involves a very straightforward extrapolation of the RF
technology, which could be expected to be ready by the time
the collider starts operating at 500 GeV. Specifically, it requires
that each of the 50 MW klystrons be replaced with two 72 MW
klystrons. It also requires increasing the linac and final focus
lengths by roughly 20%. This additional length could be built
into the 500 GeV collider allowing the 1 TeV energy upgrade to
be made adiabatically by simply replacing and adding klystrons
and modulators and replacing spool pieces at the end of the ac-
celerator with accelerating structures.

At this time, there are many possible upgrade paths to 1.5
TeV. The 1.5 TeV design will require further upgrades of the
RF system to limit the AC power consumption. Examples are
a Two Beam Accelerator concept from LBL and LLNL, grid-
switched and cluster klystrons, and binary pulse compressors.
In Table 1, we have listed a set of parameters which assumes a
binary pulse compression system. To ensure both the possibility
of the 1.5 TeV upgrade and to provide operational flexibility, we
are designing the primary components of the collider to allow
for a substantial variation in parameters such as beam charge,
accelerating gradient, *etc*. In the next sections, we will outline
the components of the design and briefly summarize the R&D
status.

Table 1.   Parameters of NLC designs.

CM Energy [TeV]	0.5	1.0	1.5
Luminosity [10^{33}]	7.1	14.5	16.1
Rep. Rate [Hz]	180	120	120
Bunch Charge [10^{10}]	0.7	1.1	1.1
Bunches/RF Pulse	90	75	75
Bunch Sep. [ns]	1.4	1.4	1.4
$\gamma\epsilon_x/\gamma\epsilon_y$ IP [10^{-8} m-rad]	500/5	500/5	500/5
β_x/β_y IP [mm]	10/0.1	25/0.1	37/0.15
σ_x/σ_y IP [nm]	320/3.2	360/2.3	360/2.3
σ_z IP [μm]	100	100	100
Upsilon	0.09	0.27	0.41
Pinch Enhancement	1.3	1.4	1.5
Beamstrahlung δ_B [%]	2.3	7	9
# Photons per e^-/e^+	0.8	1.1	1.1
Loaded Gradient [MV/m]	37	63	63
Active Linac Length [km]	14.2	17.0	25.5
Total Site Length [km]	20.0	25.5	36.2
# of Klystrons	3940	9456	7092
Klyst. Peak Pwr. [MW]	50	72	76
Pulse Comp. Gain	3.6	3.6	6.8
Power/Beam [MW]	4.2	7.9	11.9
AC Power [MW]	103	202	240

II. e^+/e^- SOURCES

The design of the NLC polarized electron source is based
upon the Stanford Linear Collider (SLC) polarized source [3].
The SLC source very reliably delivers highly polarized ($>$80%)
beams to a damping ring at 1.2 GeV with approximately 5×10^{10}
in a single bunch, a beam emittance of roughly $\gamma\epsilon_{x,y} = 1 \times 10^{-4}$ m-rad, and an energy spread of $\pm1\%$. In the NLC design,
the polarized electrons originate at a strained GaAs cathode DC
biased at -120 kV. To create the bunch train, the drive laser is
sinusoidally modulated so that it delivers a pulse train of ninety
700 ps pulses (FWHM) with a repetition rate of 714 MHz. The
electrons are prebunched in two 714 MHz subharmonic bunchers
and then bunched and accelerated in an S-band traveling wave
buncher, an S-band capture section, and a 2 GeV S-band linac.

Because the NLC design requires relatively low single bunch
charge, the important design issues relate to the long bunch trains.
Compensation techniques have been devised to control the tran-
sient beam loading and the long-range transverse wakefields,
which are important in the S-band sections, are reduced by using
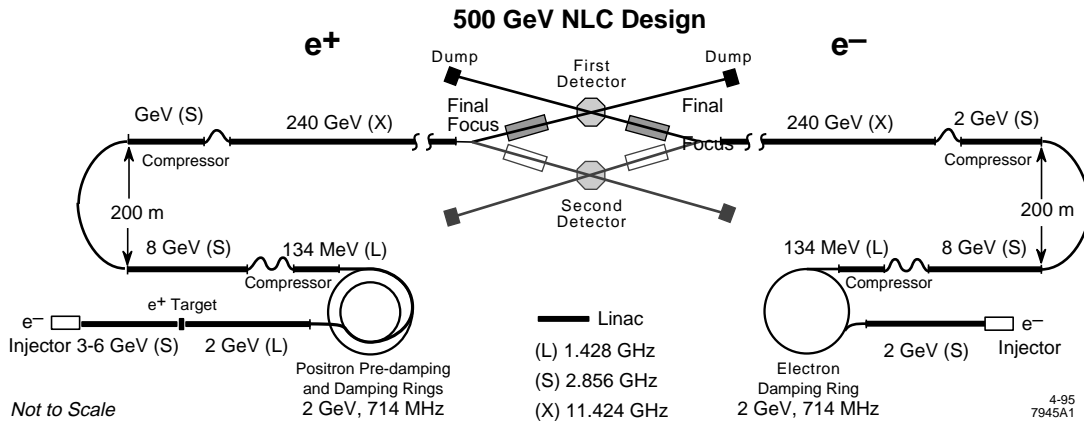scaled versions of the Damped-Detuned Structures discussed in

Figure. 1.   Schematic layout of the SLAC NLC design.

Sect. IV.

The design of the NLC positron source [4] is also based on its SLC counterpart. It is a conventional source which uses an electromagnetic shower generated by colliding a high energy (3~6 GeV) electron beam with a rotating target. Like the SLC design, the target is followed by a flux concentrator and a capture accelerator embedded in a DC solenoid. To reduce the single pulse heating, the beam size at the target is twice that at the SLC target. Because the larger beam size leads to a larger positron emittance and longer bunch length, the NLC design uses L-band (1428 MHz) accelerator structures; the aperture limited emittance is then $\gamma\epsilon_{x,y} = 0.06$ m-rad.

III. DAMPING RINGS AND COMPRESSORS

The damping rings for the NLC [5][6] must produce beams with normalized emittances of $\gamma\epsilon_x = 3 \times 10^{-6}$ m-rad and $\gamma\epsilon_y = 3 \times 10^{-8}$ m-rad. A single damping ring is used to damp the electron beams. It is 220 meters in circumference and damps four trains of 90 bunches simultaneously; the trains are separated by 60 ns, allowing fast kickers to inject and extract individual bunch trains without disturbing the others.

Because the incoming positrons have a much larger emittance, an additional pre-damping ring is used to damp the e^+ beam. The pre-damping ring is half the circumference of the main damping ring and stores two bunch trains at once. It is a relatively simple ring with a large aperture and a large equilibrium emittance. After the pre-damping ring, the positrons are injected into a main damping ring that is identical to the electron damping ring.

The damping ring designs are similar in many ways to the 3rd generation light sources and can benefit from much of the technology that has been developed. Furthermore, the ATF Damping Ring [7], being constructed at KEK, will experimentally verify many of the design concepts.

After the damping rings, the bunch length must be compressed by a factor of 40. This is done in two stages [8]. The first stage, located after the rings at 2 GeV, compresses the rms bunch length from 4 mm to 500 μm. The first stage also contains a spin rotator system, consisting of four solenoids, that provides full control over the orientation of the beam polarization.

Following the first bunch compression, the beam is acceler-

ated to 10 GeV in an S-band linac and then further compressed to a final bunch length of 100 μm. This second stage compressor is a telescope in longitudinal phase space, preventing energy errors from the pre-linac from becoming phase errors in the X-band linac.

IV. X–BAND RF

The NLC X-band RF system is based on the SLAC S-band linac RF, but the frequency has been increased to 11.4 GHz to support the higher gradient. The technology to provide the high gradient at high frequency has been under development at SLAC and KEK for the past 8 years. It will be used to provide acceleration at the NLC Test Accelerator (NLCTA) [9] which is presently under construction.

The 500 GeV NLC requires 50 MW 1.25 μs klystrons [10] as shown in Table 1. For economy and efficiency these are planned to be focussed with a periodic permanent magnet (PPM) lattice. Presently there are two klystrons operating at levels exceeding 50 MW with 1.5 μs pulses. A third klystron has operated at about 60 MW for short pulses and is presently being conditioned for long pulse operation. These three klystrons will be used in the NLCTA to gain operational experience and the NLC PPM klystron is presently undergoing detailed design.

An RF pulse compression system is needed to compress the klystron RF pulse by a factor of 5 while increasing the power by a factor of 3.6. A prototype SLED-II system is presently operating at SLAC. It has achieved pulse compression gain of 4 to 4.4 and has exceeded 200 MW output power. It is presently being used for accelerator structure tests. The three SLED-II systems for the NLCTA are being fabricated.

The accelerator structures for the NLC must control the long-range transverse wakefield to prevent beam-breakup while accelerating beams with an unloaded gradient of 50~100 MV/m. The wakefield is controlled with a Damped-Detuned Structure (DDS) [11] where the transverse modes are *both* detuned and weakly damped, reducing the Q's to roughly 1000. A test of a detuned structure (no damping) in the ASSET facility [12] verified the rapid fall off of the wakefield roughly 1.4 ns behind the driving bunch; the damping in the DDS structure will further decrease the wake over the long bunch train. This detuned structure has also been tested up to 55 MV/m and will be conditioned up to about

65 MV/m with the prototype SLED-II system. Three additional detuned structures for the NLCTA are being brazed. The DDS structure is presently undergoing detailed mechanical design.

V. X–BAND LINAC

The X-band linacs [13] accelerate the beams from 10 GeV to the final beam energy. Each of the linacs includes roughly 700 quadrupoles placed between the accelerator structures in a FODO lattice. To preserve the low emittance beams, very tight tolerances are required on the alignment and RF control. Beam-based techniques are needed to achieve the alignment tolerances. To this end, dipole mode detectors are used in the structures and BPM's are placed in the quadrupoles. In addition, both the structures and the quadrupoles are supported on separate mechanical movers.

Many of the required beam-based alignment techniques are being verified in the SLC. Further tests will be made using AS-SET and the NLCTA. While the alignment concepts are straightforward, experimental verification is necessary to understand the practical limitations and long term stability.

VI. COLLIMATION AND FINAL FOCUS

After the linac and subsequent diagnostics, the beam enters a collimation system [14] which collimates both phases in the horizontal and vertical planes as well as the energy deviation. Although the collimation section is relatively long (1.8 km for the 1 TeV design), it is felt necessary to prevent backgrounds that could overwhelm the detectors.

Following the collimation section, an IP-switch and short arc provide a 10 mrad deflection and direct the beam to one of the two IP's. The design includes two IP's to allow the alternate detector designs and final focus systems that would be required to optimize for γ-γ and γ-e^- collisions as well as e^+-e^- collisions.

Finally, the beam enters the final focus [15]. At the beginning of the final focus, there are coupling control and beta-matching sections along with phase space diagnostics. The remainder of the final focus optics is similar to the Final Focus Test Beam (FFTB) [16] with the addition of two sextupoles [17] to increase the bandwidth and a crab cavity which is needed due to 10 mrad crossing angle. The system parameters were optimized as described in Ref. [18] and the tolerances are described in Ref. [15]. Based on the SLC and FFTB experience, extensive consideration is being given to the tuning techniques and diagnostics requirements, as well as stability issues. Finally, the beam line from the IP to the dump [19] also contains extensive diagnostics to measure the beam centroid, polarization, and disruption, as well as secondary pairs and beamstrahlung.

VII. DISCUSSION

In this paper, we have given the primary parameters and described the layout of the SLAC NLC. We have also described the upgrade path to 1 TeV, which is being explicitly designed into the collider, and possible upgrade paths to 1.5 TeV. Finally, we are designing the collider to operate over a large range of beam parameters to both ensure the feasibility of the upgrades as well as provide operating flexibility. More detailed descriptions of the subsystems and tolerances can be found in the references.

Much of the design is based on the operating experience with the SLC. In addition, many of the novel components of the collider are being or will be tested in specially designed test facilities. In particular, ASSET and the NLCTA will verify the RF system and accelerating structures, the FFTB is studying the final focus designs, and the KEK ATF will study issues for the damping rings.

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