PARAMETER OVERVIEW OF SSC LINAC*

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Abstract

An overview of the parameters of the SSC Linac is presented. The beam parameters, lattice, and longitudinal coordinates through the various sections of the Linac are listed. A synopsis of each section of the Linac is shown, including dimensions, RF power and field requirements, and magnet requirements.

Introduction

The SSC Linac consists of a Linear Accelerator and a Transfer Line. The Linear Accelerator is a cascade of four accelerators with a total length of 142.8 meters that produces a beam of H- ions at an energy of 600 MeV. These are: 1) Ion Source (35 keV), 2) Radio Frequency Quadrupole (2.5 MeV), 3) Drift-Tube Linac (70 MeV), 4) Coupled Cavity Linac (600 MeV). Between the Ion Source and the Radio Frequency Quadrupole (RFQ), there is a Low Energy Beam Transport (LEBT) that matches the beam from the Ion Source to the input to the RFQ. Before the DTL there is a matching section that matches the beam from the RFQ to the input of the DTL. There is another matching section before the CCL, that matches the beam from DTL to input of the CCL. The CCL has an extension of its lattice after the accelerating cavities, the CCL Transport Line, that transports the beam to the Linac Transfer Line. It has a length sufficient to allow expansion of the CCL to an upgraded output energy of 1 GeV.

The predicted performance of the Linac has been enhanced [1]. An overview of the beam parameters, lattice, and longitudinal coordinates through the various sections of the Linac are presented. A brief synopsis of each section of the Linac is shown, including dimensions, RF power and field requirements, and magnet requirements.

Linear Accelerator

The Linear Accelerator has the parameters as listed in Table 1. For future expansion and flexibility, the output current can be upgraded to 50 mA and the output energy can be upgraded to one GeV. Aside from the ion source and LEBT, the Linac is designed for 50 mA.

Ion Source/LEBT

The parameters of the ion source are listed in Table 2. Both the Magnetron and RF Volume source are being studied for use in the SSC Linac [2,3]. A Low Energy Beam Transport matches the beam from the ion source into the RFQ. The parameters of the LEBT are listed in Table 3. Both an Einzel Lens and a Helical Electrostatic Quadrupole (HESQ) are being studied for use in the SSC Linac [2]. The LEBT also chops the beam to the appropriate pulse length with less than 100 ns rise and fall times.

To upgrade the Linac to 50 mA output current, the ion source and LEBT would be upgraded to 70 mA output current.

Table 1
Linear Accelerator Parameters

Ion Type	H^-
Output Energy (Kinetic)	600 MeV
Output Beam Energy Spread	0.10 MeV (rms)
Output Current	25 mA (nominal)
Particles per micro-bunch Collider filling mode	3.8×10^8
Particles per macro-bunch Collider filling mode	1.1×10^{12}
Particles per micro-bunch Test Beam mode	3.8×10^8
Particles per macro-bunch Test Beam mode	5.45×10^{12}
Pulse Length Collider filling mode	7.2 μs
Pulse Length Test Beam mode	36 μs (max)
Repetition Rate	Single Shot to 10 Hz
Output Emittance Transverse Longitudinal	 $<0.3\ \pi$ mm-mrad (rms, normalized) $<0.89 \times 10^6$ eV-s (rms)
Total Length	243.0124 m

Table 2
Ion Source Parameters

Ion Type	H^-
Output Energy (Kinetic)	35 keV
Output Current	30 mA (nominal)
Pulse Length	100 μs (nominal)
Output Transverse Emittance	$<0.18\ \pi$ mm-mrad (rms, normalized)

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Table 3
LEBT Parameters

Input Beam Current	30 mA
Transmission	>99%
Output Pulse Length	2-35 μs
Input Transverse Emittance	<0.18 π mm-mrad (rms, normalized)
Output Transverse Emittance	<0.20 π mm-mrad (rms, normalized)
Bore Radius	15 mm
Length (HESQ)	225 mm

Radio Frequency Quadrupole

A Radio Frequency Quadrupole bunches and accelerates the beam to 2.5 MeV [4]. The parameters are listed in Table 4.

Table 4
RFQ Parameters

Frequency	427.617 MHz
Input Energy (Kinetic)	0.035 MeV
Output Energy (Kinetic)	2.5 MeV
Design Max Input Current	70 mA
Design Output Current	50 mA
Output Transverse Emittance	<0.2 π mm-mrad (rms, normalized)
Output Longitudinal Emittance	0.82 x 10^{-6} eV-s (rms)
Length	2.1863 m
Vane Tip Radius	1.5 - 3.85 mm
Bore Radius (Vane tip to Axis)	2.0 - 3.5 mm
RF Peak Power*	408 kW
RF Pulse Length	100 μs

*RF power includes structure power and 50 mA beam loading

Drift-Tube Linac

A Drift-Tube Linac provides the third stage of acceleration from 2.5 to 70 MeV [5]. The DTL consists of four tanks, with two adjustable permanent magnet quadrupoles between tanks. The parameters of the DTL tanks are listed in Table 5. Each adjustable quadrupole is translatable in both X and Y for beam steering and has a gradient settable from 90 to 130 T/m.

The DTL Input Matching Section matches the beam from the RFQ to the input of the DTL and consists of four variable gradient permanent magnet quadrupoles and two buncher cavities and has a total length of 597.5 mm [6]. The quadrupoles are translatable in X or Y to provide beam steering and are adjustable from 50 to 100 T/m. The parameters of the bunchers are listed in Table 6.

Coupled-Cavity Linac

A Coupled-Cavity Linac provides the fourth stage of acceleration from 70 MeV to 600 MeV [7]. The CCL consists of nine modules of eight tanks each. Each tank has sixteen cells. To provide the space for upgrading the Linac to one GeV output energy, there is an extension of the CCL lattice, called the CCL Transport Line. There is an input matching section to match the beam from the DTL to the input of the CCL. The parameters of the CCL modules are listed in Table 7.

Except for Module #2, the eight quadrupoles of each module are energized by one power supply. Between the second

Table 5
DTL Parameters

Frequency	427.617 MHz
Output Energy (Kinetic)	70 MeV
Design Max Current	50 mA
Output Transverse Emittance	<0.2 π mm-mrad (rms, normalized)
Output Longitudinal Emittance	<1.0 x 10^{-6} eV-s (rms)
Drift-Tube Bore Diameter	16 mm -0, +0.25 mm
Peak RF Field	28 MV/m
RF Pulse Length	100 μs
Cavity Q (unloaded)	>35000
Magnet Type	Permanent Magnet Quad
Gradient	132.7 T/m
Magnet Field Uniformity	-0%, +5% graded
Quad Length	35.0 mm
Quad Inside Diameter	18 mm -0, +0.25 mm
Tank Inside Diameter	420 mm (nominal)
Tank #1-Length	4.515 m ±0.1 mm
Output Energy	13.4080 MeV
Number of Quadrupoles	57
RF Power*	1.5 MW
Tank #2-Length	5.951 m ±0.1 mm
Output Energy	32.8411 MeV
Number of Quadrupoles	41
RF Power*	2.7 MW
Tank #3-Length	6.062 m ±0.1 mm
Output Energy	51.5878 MeV
Number of Quadrupoles	31
RF Power*	2.9 MW
Tank #4-Length	6.226 m ±0.1 mm
Output Energy	70.0010 MeV
Number of Quadrupoles	27
RF Power*	2.9 MW
Total DTL Length	24.3316 m

*RF power includes structure power and 50 mA beam loading

Table 6
DTL Input Matching Buncher Parameters

Frequency	427.617 MHz
RF Pulse Length	100 μs
Design Max Beam Current	50 mA
Bore Radius	8 mm
RF Length	50 mm
RF Power*	30 kW Peak
Cavity Voltage (EoTL)	136/146 kV
Buncher Q (unloaded)	>5000

*RF power includes structure power and 50 mA beam loading

Table 7
CCL Parameters

Frequency	1282.851 MHz
Output Energy (Kinetic)	600±0.08 MeV
Design Max Current	50 mA
Output Transverse Emittance	<0.3 π mm-mrad (rms, normalized)
Output Longitudinal Emittance	<0.9 x 10^{-6} eV-s (rms)
Number of Modules	9
Sections per Module	8
Accelerating Cells per Section	16
Total Number of Magnets	72
Constant Effective Section Accelerating Gradient (E_0T)	7.2-6.5 MV/m
Synchronous Phase	-25 degrees
Magnetic focussing	singlet (FODO)
Quadrupole Gradient	31 T/m (nominal)
Quadrupole Effective Length	70 mm
Bore Radius	10.0 mm
Inner Radius of Accel Cavity	85 mm
Total CCL Length	112.4123 m
Module Peak RF Power*	14 MW
RF Pulse Length	60 µs
Module Q (unloaded)	11700 to 19200

*RF power includes structure power and 50 mA beam loading

and third modules the inter-tank spacing changes from 7/2 $\beta\lambda$ to 5/2 $\beta\lambda$. The last four quadrupoles of Module #2 have different gradients than the other quadrupoles to match the beam at the transition, and consequently each is energized by a separate power supply. The remaining four are energized by one power supply. Beam steering within the CCL is accomplished by combining dipole coils with the quadrupole coils in a single magnet package. Within each module four dipole coils will be energized.

The CCL Transport Line has a length of 100.2331 meters and uses 25 quadrupole magnets identical to those in the CCL operating at a nominal gradient of 28 T/m. The first four quadrupoles and the last two quadrupoles operate at slightly different gradients to match the beam into and out of the Transport Line. These six magnets are energized by separate power supplies and the remainder are connected in two series strings, with each string energized by separate power supplies. Beam steering is eight sets of dipole coils are energized. Four stronger steering magnets are incorporated in the beginning of the line for added steering capability. The Energy Compressor cavity is located in the CCL Transport Line and its parameters are listed in Table 8. The Energy Compressor reduces the energy spread from 0.7 MeV (rms) at its entrance to 0.1 MeV (rms) to match the beam to the input acceptance of the Low Energy Booster, when operated at E_0T = 1.3 MV/m.

The CCL Input Matching Section has a length of 2.9526 meters. It has nine quadrupoles, identical to those of the CCL. The first six quadrupoles are arranged in pairs. Separate power supplies energize each pair and each of the other three magnets. Four sets of dipole coils are energized for beam steering. There are two buncher cavities in the CCL Input Matching Section with parameters as listed in Table 9.

Table 8
Energy Compressor Parameters

Frequency	1282.851 MHz
Design Max Current	50 mA
E_0T	1.55 MV/m max.
Length	1.018 m
Number of Cells	11
Peak RF Power*	77 kW
RF Pulse Length	60 µs
Bore Radius	10 mm
Inside Diameter	172 mm
Cavity Q (unloaded)	15000

*RF power includes structure power and 50 mA beam loading

Table 9
CCL Input Matching Buncher Parameters

Frequency	1282.851 MHz
RF Pulse Length	60 µs
Design Max Beam Current	50 mA
Bore Radius	10 mm
RF Power*	426/657 kW Peak
RF Length	213.6/299.4 mm
Number of Cells	5/7
Inside Diameter	170 mm
Cavity Voltage (E_0TL)	12.0/18.0 MV
Q (unloaded)	15000

*RF power includes structure power and 50 mA beam loading

Conclusion

The 600 MeV Linear Accelerator for the SSC consists of an ion source, RFQ, DTL, and CCL with an output current of 25 mA and pulse length up to 36 µs at up to 10 Hz. It is upgradeable to 50 mA by changing the Ion Source and LEBT. The output energy can be upgraded to one GeV by replacing the CCL Transport Line with four additional CCL modules.

References

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