The SSC Linear Accelerator

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Abstract

The SSC linear accelerator will generate a 25 mA, 600 MeV, H^- beam with transverse normalized rms emittance less than 0.3 π mm•mrad in 9.6 μs pulses at a 10 Hz repetition rate. The Linac will ultimately have to operate with an availability for Collider filling in excess of 98%. In addition, the Linac will provide beams to service the Test Beams facility and may be delivering beam to a Proton Radiotherapy Facility. This paper presents an overview of the status of design, procurement, fabrication, civil construction, foreign contributions and commissioning plans, and directs the reader to additional details available in other presentations to this Conference.

I. INTRODUCTION

The main parameters of the SSC Linac [1-3] are given in Table 1. Negative hydrogen ions are accelerated so that 4-turn charge changing injection can be used in the Low Energy Booster [4] (LEB) to minimize emittance growth during the injection process. The energy and fundamental rf frequency of 428 MHz are chosen to make emittance growth due to space charge as small as possible in the linac, to make space charge tune shift at the start of the LEB cycle [5] manageable, to maintain the option of bunch-to-bucket transfer into the booster synchrotron by having an integer relationship between the linac rf frequency and that of the LEB at injection, and to allow use of klystrons, rather than gridded tubes in the rf supplies. Sufficient space has been provided in both the tunnel and the rf gallery for the additional equipment needed to increase the linac energy, if that route to higher luminosity is chosen. The transverse emittance and availability specifications are derived from the overall complex requirements of 1 π mm•mrad at the collision point and availability to take data 80% of the time scheduled.

II. GENERAL DESCRIPTION

The linac consists of an rf-driven volume source and electrostatic low energy beam transport (LEBT), a 427.6 MHz radio frequency quadrupole (RFQ), a drift tube linac (DTL) operating at the same frequency as the RFQ and a specialized matching section to match the RFQ output beam into the DTL input acceptance. A coupled-cavity linac (CCL) operating at 1282.8 MHz is preceded by another matching section to take the DTL output beam and transform it into the acceptance of the CCL. Transition energies from one type of accelerator to another have been chosen to produce a cost-optimized high-performance design.

A FODO channel transports the beam to the start of the Linac-LEB transfer line and smoothly matches the CCL transverse optics to that of the transfer line. This space would be occupied by additional CCL modules as part of a linac energy upgrade. At the end of the transport line, an energy compressor cavity reduces the beam energy spread to ≤ 100 keV, as required by the LEB for preparation of beam for the Collider. The transfer line and LEB injection girder match the linac beam into the LEB, place it on the closed orbit and pass it through a stripper foil in an orbit bump.

Specific features have been incorporated in the CCL, the transport/transfer lines and the tunnel, to allow the Linac to provide beam to a proton radiotherapy facility under consideration for the West Campus [6].

Table 1
SSC Linear Accelerator Parameters

	RFQ	DTL	CCL
Frequency (MHz)	427.613	427.613	1282.84
Number of rf systems	1	4	9
Input Energy (MeV)	0.035	2.5	70
Output Energy (MeV)	2.5	70	600
Input Current (mA)	30	27	27
Output Current (mA)	27	27	27
Output Transverse Emittance (n,rms) (π mm•mrad)	≤ 0.20	≤ 0.21	≤ 0.25
Total rf power required/system (MW)	0.345	1.187-2.387	11.98-12.28
Total rf power available/system (MW)	0.6	4.0	20
Structure power/system (MW)	0.280	0.89-1.89	10.37-11.27
Peak surface field (MV/m;* sparking limit)	36; 1.8	28; 1.4	32; 1.0
Total length (m)	2.1863	24.366	112.41

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III.CURRENT STATUS

Both the rf volume source and its cesiated surface source predecessor [7-9] produced beams with greater than specified brightness at the design operating conditions. The volume source is favored because it needs no cesium and is easier to condition. Engineering solutions for the higher gas load and electron contamination have been developed.

Several electrostatic LEBTs are being studied for use in the SSC Linac. Most experimental work has been done on a system comprised of a pair of Einzel lenses [10,11]. High voltages and emittance growth in this device due to its inherent non-linearity are seen as long-term problems which will probably lead to its replacement by an electrostatic quadrupole system [7,12,13], but for initial commissioning of Linac systems, the Einzel lens system will be used.

The RFQ was built for SSCL by Los Alamos National Laboratory, AT Division, and delivered to SSCL on schedule, in August 1992. It has been installed on the Injector Test Stand (Figure 1), integrated with its support systems, rf conditioned and operated [14] with beam. Its performance [15-19] has been excellent, and in agreement with simulation in all respects.

Detailed design of the RFQ-DTL matching section is complete, and construction is advancing on a schedule which will see all components delivered to SSCL in June for assembly and commissioning off-line in July and operation with beam in August [20,21].

Construction activities on the DTL are proceeding at full speed at AccSys Technology, Inc., with scheduled delivery of the first tank in mid-January 1994, and delivery of the fourth and final tank in May 1994. Measured characteristics of the permanent magnet quadrupoles has been significantly better than anticipated. Production of the 4 MW klystrons is complete, and fabrication of the modulator systems is proceeding on schedule [22].

Production of the CCL modulators and klystrons is equally well advanced. Detailed design of the resonant coupled cavity structures, carried out with major assistance from LANL, is now complete, and a close partnership with the Institute for High Energy Physics, Beijing, is being forged for the construction of this primary system [23,24]. The CCL modules will be the longest chains of side-coupled resonators ever operated. This has prompted more detailed studies of beam-loading and other transient effects, which have revealed several interesting phenomena [25,26].

Detailed design of the transport and transfer lines is also complete, and most of the major components have been ordered, or are being prototyped [27]. In addition, considerable progress has been made on the design of the LEB injection girder.

Commissioning of a linac, with its highly serialized configuration, extends over considerable time, and benefits from specialized instrumentation which can be used during commissioning, but which would not fit into the completed machine. Considerable progress has been made in planning for commissioning, including simulation support, and in the construction of special commissioning diagnostic equipment [28-33]. Of particular interest are the developments in the compact bunch shape monitor, being conducted in a collaboration with the Institute for Nuclear Research, Moscow.

Progress with civil construction has also been good. Construction of the tunnel is complete, and SSCL has taken beneficial occupancy. Detailed surveying and installation of beam absorbers is underway. Handover of the surface structures will take place in June, when work on HVAC and installation of a boom crane is complete. Electrical power is available on site, and installation of LCW systems, racks and cable trays will begin in June.

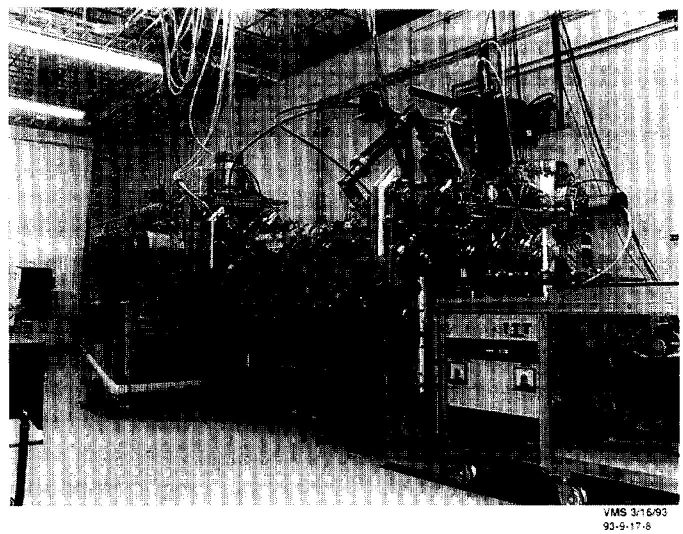

Figure 1. Injector Test Stand, showing ion source cart, RFQ and diagnostic chamber.

IV. FUTURE PLANS

Present plans call for commissioning of all parts of the Linac, up to and including the RFQ/DTL matching section, in the labs of the Central Facility in Waxahatchie during August and September 1993. Preparation of Linac buildings at the Injector Site to receive accelerator components is expected to be complete by October 1993. Transfer of operations to the new buildings is to take place in October and November, and these Injector subsystem are to be made operational during December and the first half of January 1994, in time for the arrival of the first DTL tank in the middle of that month. Rf power systems will begin arriving, at a rate of about one per month, in August of 1993, which should allow sufficient time for commissioning and subsystem integration prior to the need to support cavity conditioning. Completion of DTL commissioning is anticipated in the fourth quarter of calendar 1993.

The first CCL module is expected from IHEP in December 1993. Modules are expected to arrive at an average rate of approximately one every six weeks. This allows a substantial block of time for final module alignment, tuning and rf conditioning before beam will be available for beam commissioning. Transport and transfer line installation is also expected to be complete by the end of calendar 1994.

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