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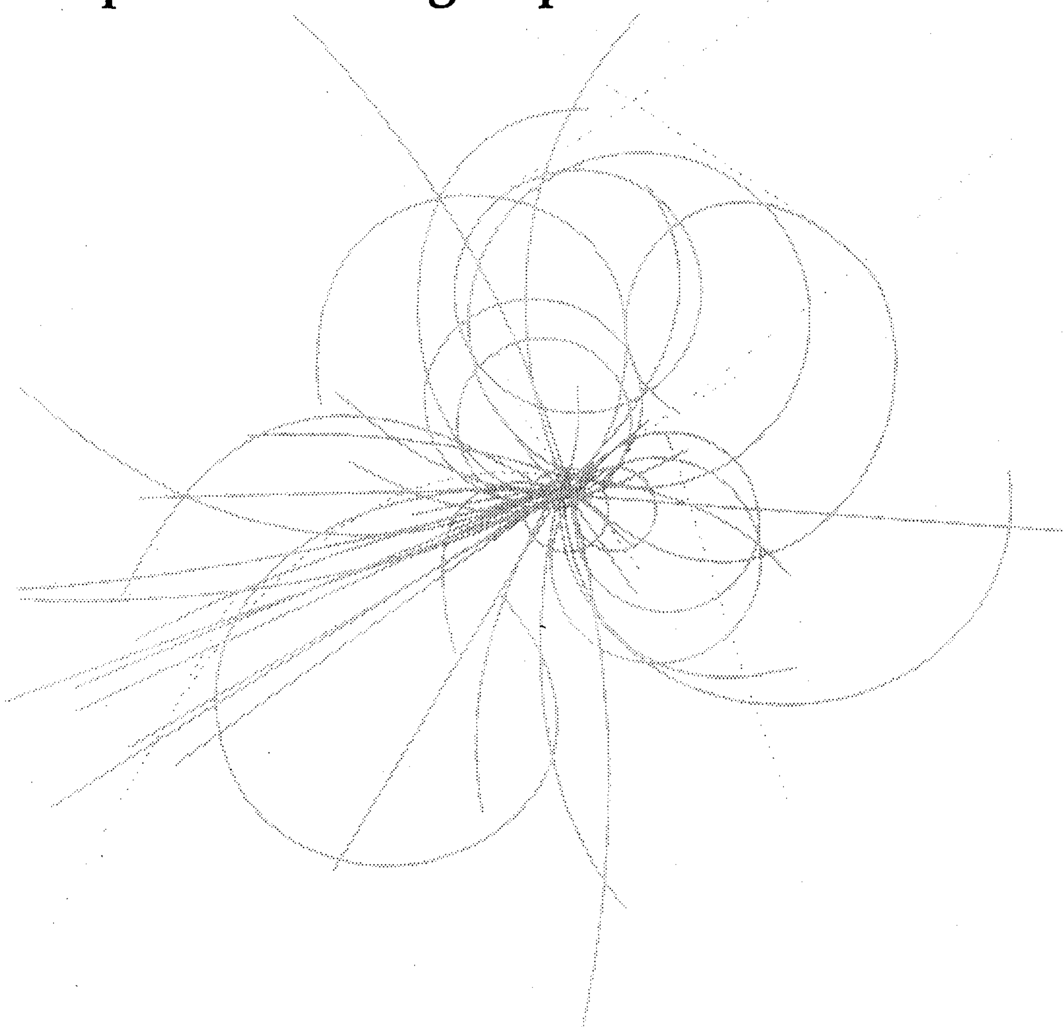

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COMMISSIONING PLANS FOR SSC LINAC

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Abstract

Presented are the general description of the SSC linac and the plans for commissioning. Sections of the linac are installed, tested, and beam commissioned in a serial approach. A specialized set of diagnostics is used to characterize the beam through each section. In addition to the standard diagnostic set, plans call for the use of a bunch shape monitor and x-ray spectrometer. Streak camera and digital imaging diagnostics will be developed. The commissioning plan is folded into the general linac project schedule to show the relation between delivery, staging, installation, conditioning, and actual commissioning with beam. These plans form the basis for coordination between the various organizations responsible for different elements of the linac including the technical components, infrastructure, and temporary staging and operation facilities.

Introduction

The SSC linac accelerates H^- ions to an energy of 600 MeV and delivers them to the Low Energy Booster, a 11.1 GeV synchrotron. A cascade of two more synchrotrons into the two main, counter rotating collider rings bring the protons to an energy of 20 TeV for collisions in the interaction regions. The SSC accelerator complex is described in the Conceptual Design report [1]. The major elements of the linac are an ion source, a 428 MHz Radio Frequency Quadrupole (RFQ), a 428 MHz Drift-Tube Linac (DTL), and a 1283 MHz Coupled-Cavity Linac (CCL). Fig. 1 shows a simple representation of the linac. Besides providing beam for the collider, the linac will also provide test beams and protons for the cancer therapy center.

The linac design current is 25 mA H^- with a pulse structure of up to 10 Hz and a variable length from 2 μsec to 35 μsec, depending on the intended use. Additional variations in energy and average intensity will be required for the proposed cancer therapy facility. The normalized, RMS, transverse emittance of the beam will be less than 0.3 π mm-mrad. The longitudinal emittance is expected to be $\approx 7.0 \times 10^{-7}$ eV-sec. One of the greatest challenges for the SSC linac is the goal of better than 98.9% reliability. Details of the linac are described in several papers and poster sessions presented at this conference [2-8].

The commissioning of the SSC linac starts with the commissioning of each major subsystem of the linac, then integrates the subsystems, and finally brings beam through the accelerator sections. Commissioning must be coordinated with installation and rf conditioning activities to meet schedule requirements. Acceptance Test Plans are used as a method to define the commissioning process. In addition an experimental plan of linac measurements and parameterizations will be generated to define the beam commissioning phase of turning-on the linac.

Process of Commissioning

Plans call for commissioning the linac in sections. A section typically consists of a major rf structure or ion source, and its downstream transport. The sections are:
1) ion source and low energy transport,
2) RFQ,
3) RFQ-DTL matching section,
4) DTL tank 1,
5) DTL tank 2,
6) DTL tank 3,
7) DTL tank 4 and DTL-CCL matching section,
8) CCL module 1, and
9) CCL modules 2-9 and transports to the LEB.

To facilitate installation, a shield wall is located in the region where CCL module 2 will eventually be placed. Upstream of the wall, the ion source, RFQ, DTL tanks 1-4, and CCL module 1 are each installed, RF conditioned, and commissioned with beam. Simultaneously, downstream of the wall, CCL modules 3-9 and the transport lines to the LEB are installed and RF conditioned. After CCL module 1 is commissioned, the wall is removed and CCL module 2 is installed and RF conditioned. Then the remainder of the linac, from CCL module 2 to the LEB, is commissioned with beam. The schedule for commissioning is shown in Fig. 2.

There is a general order for the installation and commissioning of each section. Once commissioning of an upstream section of linac has been complete, installation and alignment of the next section begin. After the major rf, vacuum, controls, and diagnostics systems are installed they are tested. Tests include interlock checks, controls test, leak checks, and functional tests. In the testing process, the subsystems are turned on for the first time and operated. Once the subsystem is operated in a stand alone configuration it is integrated into the system and the computer controls tested. A major part of the process is conditioning rf systems to hold voltage. This process is described for the RFQ at this conference [9]. After the rf conditioning is complete, the section is ready for first beam.

Beam commissioning is done in a two pass process. In the first pass the gross features of the linac section are investigated with the beam. Transmission is measured and optimized at low currents. Magnet polarities are checked by changing the strength and observing the behavior of the beam. Beam instrumentation and display codes are checked with beam and investigated for reproducibility. After the first pass,

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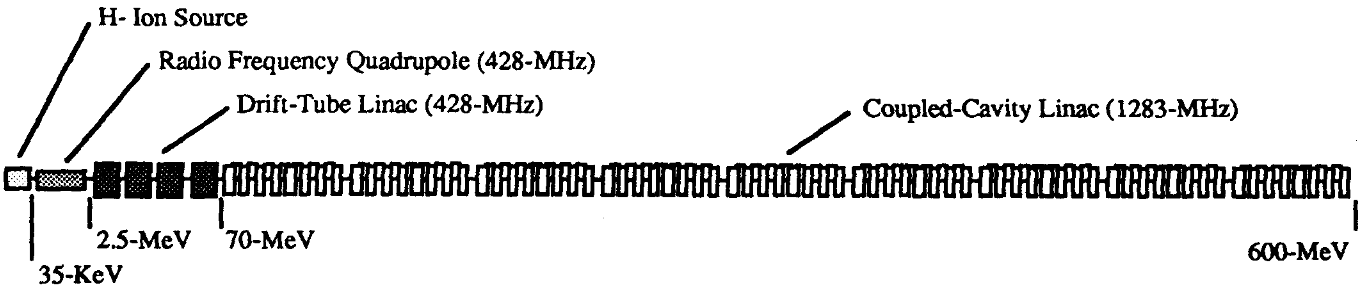

Fig. 1 Representation of SSCL linac: The Radio Frequency Quadrupole, 4 Drift-Tube Linac modules, and 9 Coupled-Cavity Linac modules are each powered by one Klystron. Coupled-Cavity Linac Modules are 8 tanks connected by bridge couplers.

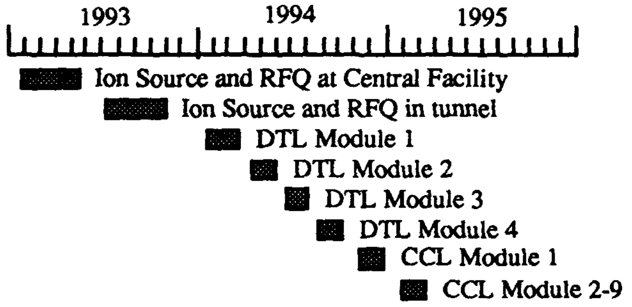

Fig. 2 Commissioning schedule for SSC linac Commissioning begins at the Central Facility in Waxahachie where the ion source, low energy transport, RFQ, and RFQ to DTL matching section are commissioned. Commissioning continues in the tunnel after it is ready for occupancy in July, 1993. Commissioning is complete and the linac is ready to deliver beam to the LEB in April, 1995.

corrections are made to the system as needed. At this point the section of linac has been proven to work.

The second pass of beam commissioning begins to address the fine details of reliability and beam parameterization of the linac section. The transmission of the section is mapped out as a function of the variable input parameters to determine the acceptance or at least establish lower limits on the acceptance. Steering studies are done to determine the strength and range of the steering elements and to confirm the transformation between the steering elements and measuring device. The transverse tune is measured as a function of lens strengths. Time dependence, sensitivity, and tune optimization are studied. Both longitudinal and transverse phase space are investigated. These studies are used to confirm that the design parameters of the linac can be met and to indicate the direction for further development.

Commissioning is the first part of the process to develop reliability. The first effort is to get all equipment on-line and working. Some beam can be delivered in the first pass through the section. The system is then developed to the point where stable beam can be delivered for periods long enough to complete beam physics studies. As the operating period of the linac section is increased, system life-time studies can be done in parallel with beam physics studies. A standard set of set points and measurements is developed for reproducibility studies and the beam is often measured at these set-points to establish the degree of reproducibility. Reliability to some minimum level must be established in any one section before proceeding to commission the next section of linac.

Diagnostics

To commission the sections of the linac as they are installed, a diagnostic cart is used at the end of each section. The general concept is similar to the diagnostic plate used at Los Alamos to commission the Ground Test Accelerator [10]. The diagnostic cart is on wheels and can easily be moved along the linac tunnel as the linac is assembled. The cart consists of a stand, alignment adjustments, vacuum vessel, ports, and diagnostics. The system is designed to support a large number of varied beam measurement activities. It is large, portable, and has its own vacuum system.

The set of commissioning diagnostics comprises an emittance measurement unit, wire scanners, position monitors, current monitors, harps, and Faraday cups. Similar components to be permanently installed in the beam line are being designed to fit into a standard size beam box. The emittance measurement unit is a slit and collector type. The harp and emittance measurement unit collector both have 128 wires for high resolution. The position monitor is a micro-strip giving longitudinal phase as well as transverse position information. The wire scanner has three wires, one x, one y, and one wire diagonal to x and y. The third wire is used to detect cross coupling and is only used in areas where cross coupling might be expected to occur. Three wire scanners in series along the beam line can be used to reconstruct the RMS emittance and Courant-Snyder parameters and compare them to slit and collector results. Diagnostics are specified to have a bandwidth to 10 MHz where possible such that time dependent transients can be observed [11].

Basic longitudinal information is determined by phase measurements along the beam line using the micro-strip beam position monitors. The change in the phase of the beam at two points along the beam line is measured as a function of the rf phase, rf amplitude, and input energy. The resulting dependence is compared to theory. These measurements are used in either the Δt [12] or least squares [13] procedures to set the phase and amplitude of the rf structures. A third technique [14] is used where the phase information cannot be accurately measured with capacitive pick-up monitors. This method uses an absorber that stops low energy particles. Transmission through the absorber is measured as a function of rf phase of the upstream rf structure. Results are compared with PARMILA [15] simulations to determine phase and amplitude of the rf tanks and input bunchers. This method also gives rough information about longitudinal phase spread of the beam.

In addition to the standard set of diagnostics, a suite of special diagnostics is used during the commissioning stage. This includes a spectrometer, an x-ray detector, and optical diagnostics. The spectrometer is used at the end of the RFQ to separate full-energy transmission from transmission of off-energy beam. The spectrometer can also be used to measure the energy spectrum of the beam out of the RFQ. An elastic scattering experiment is planned to determine the absolute energy of the beam out of the RFQ and to calibrate the spectrometer. The energy of elastically scattered protons are measured at a well defined angle using a Si detector. The kinematics of the scattering process from the thin foil determines the energy of the input particles. A high purity Ge detector is used to measure x-rays produced by the rf structures. The x-ray detector is used as an indirect vane voltage and gap voltage measurement for the RFQ and bunchers respectively.

Optical diagnostics will be developed as a non-intercepting method of measuring the transverse phase space of the beam. Streak cameras also may be used to measure time dependent and longitudinal beam characteristics. The digitized output is analyzed to reconstruct the beam phase space distribution. This activity is in the research and development phase and will be carried out as time permits during commissioning. The optical diagnostic techniques developed for the linac have important applications in the higher energy synchrotrons.

A bunch shape monitor [16,17] has been procured from the Institute for Nuclear Research in Moscow. The first model is a copy of their original design modified for 428 MHz operation. Three other units will be designed to fit in a standard size beam box and to operate at 1283 MHz. The bunch shape monitors are expected to have better than 9 psec resolution. They can be used to derive the RMS longitudinal properties of the beam in a manner analogous to wire scanners in the transverse plane.

The commissioning diagnostics will not be available after commissioning. The short transport sections between accelerator sections preclude installation of a full set of diagnostics between each module. The short transport is important to minimize emittance growth for low energy, space charge dominated beams. The results of the full set of commissioning diagnostics must be correlated with the limited set of standard diagnostics. The reproducibility of the standard diagnostics is also to be determined. Given particular results from the standard diagnostics, one should be able to predict the beam as measured on the full set of commissioning diagnostics over the full operating range of the linac.

During the initial stages of commissioning, plans call for control of the diagnostics with a VXI located processor. This processor drives the hardware and takes data at the lowest level. The data is then shipped to a higher level control processor for analysis and display. Once the system moves to the tunnel, the higher level processor will be associated with control from a temporary control room. Applications codes, data bases, and analysis codes must be written for all the diagnostics systems before they can efficiently be used in commissioning.

Conclusion

After commissioning of each section, the section will have passed the acceptance test plan. To be accepted, each module must meet a minimum performance level in terms of transmission, emittance, stability, and reliability. The minimum performance level is sufficient to achieve the necessary level of acceptance for commissioning of the next section of the accelerator. These parameters are measured by a sophisticated set of transverse and longitudinal diagnostics.

When the linac commissioning is complete, the output beam should be sufficiently bright and reliable to commission the LEB. As the LEB and subsequent accelerators of the SSC complex are being commissioned, work on the linac will continue to develop it to full design specifications. It is important during the commissioning stage to gain enough information with the full set of commissioning diagnostics to be able to develop the machine after commissioning.

References

[1] *Site-Specific Conceptual Design of the Superconducting Super Collider*, ed. J. R. Sanford, and D. M. Matthews, SSCL-SR-1056, July 1990.

[2] L. W. Funk, "The SSC Linac", these Proceedings.

[3] J. F. Tooker, *et. al.*, "Parameter Overview of SSC Linac", these Proceedings.

[4] K. Saadatmand, *et. al.*, "Performance of the SSC Magnetron Ion Source and LEBTS", these Proceedings.

[5] K. Saadatmand and N. C. Okay "Performance of the SSC RF-Driven Volume Source", these Proceedings.

[6] R. C. Sethi, *et. al.*, "Design of the RFQ-DTL Matching Section for the SSCL Linac", these Proceedings.

[7] D. Raparia, *et. al.*, "SSC Drift-Tube Linac Design", these Proceedings.

[8] D. Raparia, *et. al.*, "Design Improvements for the SSC CCL", these Proceedings.

[9] R. I. Cutler, *et. al.*, "SSC Linac RFQ Amplifier Progress and Commissioning", these Proceedings.

[10] K. F. Johnson, *et. al.*, "GTA Commissioning Progress", these Proceedings.

[11] J. W Hurd, "Solution to the Transverse Phase Space Time Dependence Problem with LAMPF's High Intensity H+ Beam", Proceedings of the 1983 Particle Accelerator Conference, Santa Fe, NM , (1983).

[12] K. R. Crandall, *et. al.*, "The Δt Turn-On Procedure", Proceedings of 1972 Proton Linear Accelerator Conference, Los Alamos, NM, (1972).

[13] F. W. Guy and J. W. Hurd, "Procedure for Setting RF Phase and Amplitude in the SSC DTL Tanks", these Proceedings.

[14] D. A. Swenson, "Phase Scan Experiment on the Drift Tube Linac", internal MP-9 memo, Los Alamos National Laboratory, June 22, 1973.

[15] D. A. Swenson and J. E. Stovall, "PARMILA + Appendix A", MP-9, Los Alamos, private communication.

[16] A. V. Feschenko and P. N. Ostroumov, "Bunch Shape Measuring Technique and Its Application for an Ion Linac Tuning", Proceedings of Linear Accelerator Conference, SLAC, (1986).

[17] A. V. Feschenko, *et. al.*, "Precise Energy Measurement of the Continuous Proton Beam", Proceedings of the 1989 Particle Accelerator Conference, Chicago, IL, (1989).