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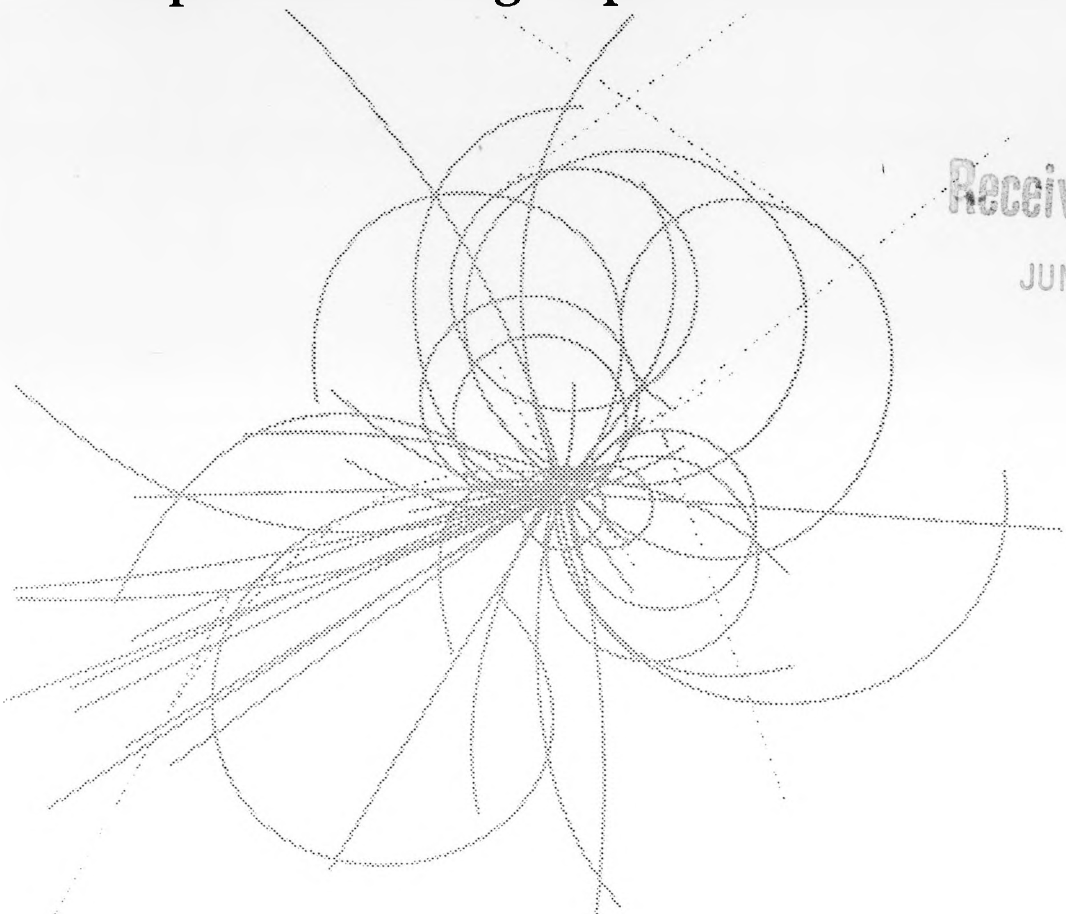
# Superconducting Super Collider Laboratory



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# AN OVERVIEW OF THE SSC SYNCHROTRON RF SYSTEMS

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**Abstract:** The Superconducting Super Collider (SSC) has five synchrotron systems: three booster synchrotrons plus two main synchrotron rings which make up the collider. The three booster synchrotron RF systems will utilize a multiplicity of high-power VHF, 150 KW tetrode amplifiers, whereas the collider RF systems will utilize four 360 MHz, 1-MW cw klystrons. The RF systems include DC power supplies, local control and monitoring systems, and accelerating cavities as well as RF amplifier systems. The system requirements and the conceptual designs for the RF systems for the five SSC synchrotrons are presented. The status of the Low Energy Booster synchrotron accelerating cavity and tuner assembly development programs are specifically addressed. Opportunities for industry to participate in the design and manufacture of RF subsystems and/or major components are also identified and briefly discussed.

## INTRODUCTION

RF systems for the five Superconducting Super Collider (SSC) synchrotrons are addressed in this paper. Synchrotron RF system requirements, initial design concepts, status, and schedules are presented. SSC LINAC RF systems are discussed in a separate paper by J.H. Ferrell.

The five synchrotrons are:

1. One Low Energy Booster (LEB) synchrotron,
2. One Medium Energy Booster (MEB) synchrotron,
3. One High Energy Booster (HEB) synchrotron, and
4. Two main ring SSC Collider synchrotrons.

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The LEB, MEB and HEB RF systems are very similar. Each of these synchrotrons utilizes several RF amplifier systems that operate in the 47.5–60 MHz frequency range. The primary difference is that the tuning range and cavity accelerating gap voltage requirement varies for the three synchrotrons. The final amplifiers for these systems are gridded vacuum tubes delivering approximately 160 kw each.

The main ring RF systems operate at 360 MHz and utilize one megawatt (1 MW) klystrons for the final amplifiers.

## LOW ENERGY BOOSTER RF SYSTEMS

The total accelerating voltage will be provided by six or more ferrite tuned RF cavities, each driven by a gridded vacuum tube amplifier. The vacuum tube amplifier attaches directly to the accelerating cavity, which serves as the resonant tank circuit. The design goal is to achieve the specified ring voltage with eight RF cavities in the normal operating mode, and with six cavities in the extended mode, i.e., when a pair of cavities is not operational. For a ring voltage of 725 kV, operation with only six cavities would require 121 kV per cavity. No operational system to date has cavities that tune 47.5–60 MHz and also produce 121 kV. TRIUMF is in the process of developing a cavity with a slightly larger tuning range and a maximum operating peak voltage of 62.5 kV. The TRIUMF cavity and tuner is shown in Figure 1. Because the desired voltage with such a wide tuning range is much greater than the present state of the art, room is being left in the LEB accelerator lattice for additional cavities.

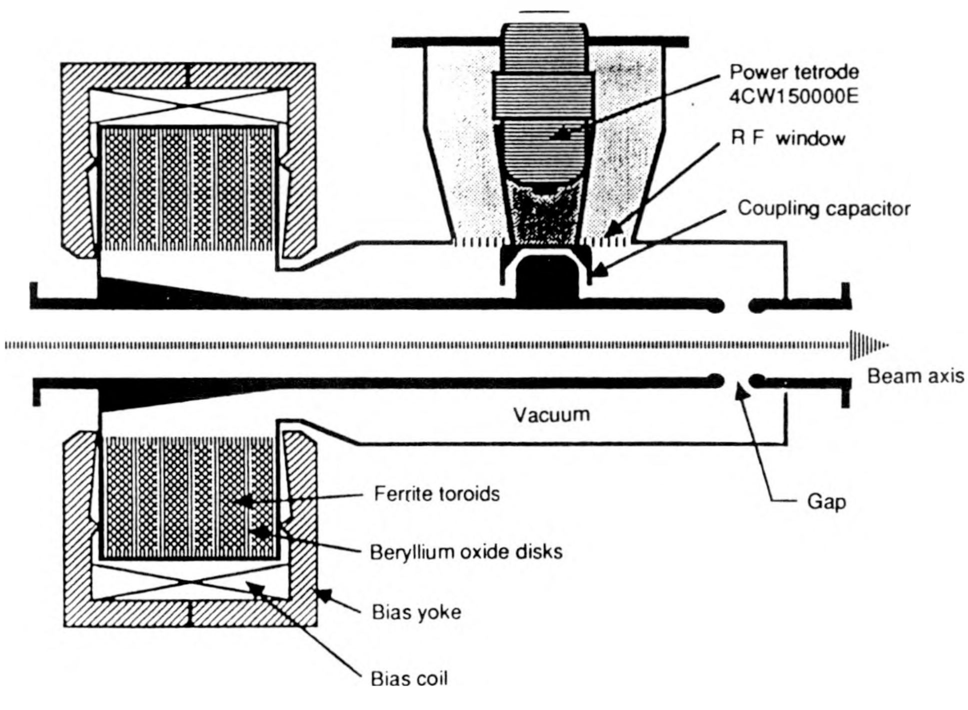


Figure 1. TRIUMF Cavity and Tuner.

The LEB RF System requirements are summarized in Table 1.

Table 1. LEB RF System Requirements.

| | |
|---|---|
| Frequency Tuning Range | 47.5-59.8 MHz |
| Ramp/Reset Time | 50 ms |
| Maximum Tuning Rate | 850 MHz/s |
| Minimum Acceptable Gradient | 40 kV/m |
| Amplitude/Phase Stability | ±0.5%/±1degree |
| Total Peak Circumferential Voltage | 725 kV |

The RF system associated with each LEB cavity is shown in Figure 2. The final amplifier is driven by a solid state RF amplifier. The cavity is tuned by varying the bias current to the ferrite tuner. Depending upon the final tuner design, the bias supply could require voltages in the range of 25–200 volts and currents up to 2000 amperes. It will be required to vary the cavity resonant frequency at rates as high as 850 MHz per second. The ferrite bias current will be controlled by a preprogrammed wave shape and feedback control loops. Likewise, the RF phase and amplitude will be controlled by fast feedback circuits.

Each LEB RF amplifier system will have a local control system that may be utilized for checkout and test. There will also be a local RF control system from which one may operate and troubleshoot all of the LEB RF systems. The control systems will be computer based and will facilitate operation, control, monitoring, and troubleshooting from the SSC main control room. Similar control and monitor systems are used for all the synchrotron RF systems.

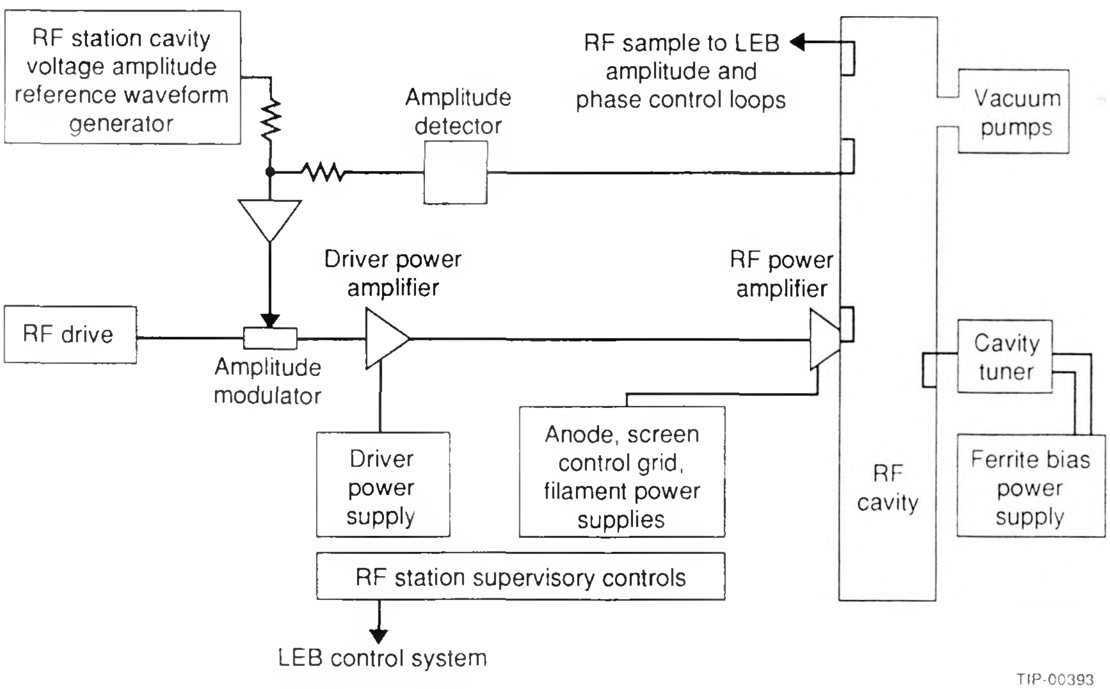


Figure 2. LEB RF System.

## STATUS OF LEB CAVITY AND TUNER DEVELOPMENT PROGRAM

Numerous cavity/tuner design concepts were investigated by SSC personnel and by consultants and personnel from other laboratories. An LEB cavity/tuner design workshop was held at the SSC February 5-8, 1991. Six different designs in varying stages of development were presented for review. The review team, comprised of 10 engineers and physicists from outside the SSC, recommended that highest priority be placed on a design presented by C. C. Friedrichs of LANL and B. M. Campbell. Their design is very similar to the TRIUMF cavity and tuner; the primary difference is that the ferrites are cooled by flowing liquid directly over them instead of sandwiching them between beryllium oxide disks, as is done in the TRIUMF tuner. The liquid design should be capable of higher voltages than the TRIUMF cavity because corona in the tuner is avoided and the cooling system is more efficient. Also under investigation is a design backup approach based on a modification of a FERMI Lab cavity and tuner.

SSC has an RF test stand that will be used for testing the LEB cavity and tuner. At the present time we have a cavity that was developed by LANL which is driven by an EIMAC 4CW 150,000E tetrode. The cavity and tuner is shown in Figure 3. We plan to use the cavity to test tuner concepts.

The LEB schedule milestones are presented in Table 2.

Table 2. LEB Schedule Milestones.

| | |
|---|---|
| Prototype Development | 12/91-7/93 |
| RFP's Issued for Production | 1/93-8/93 |
| Issue Purchase Orders | 10/93 |
| All Subsystems and Components Delivered | 10/94 |
| Assembly, Installation, and Test Complete | 10/95 |

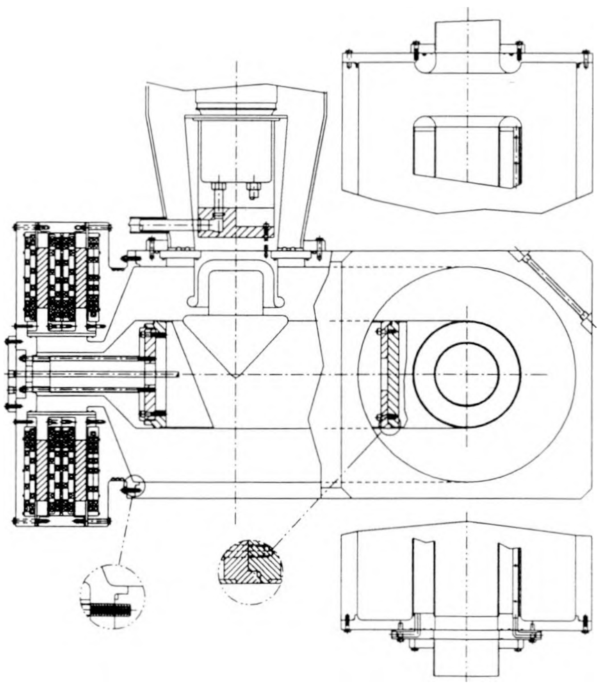

Figure 3. SSC RF Test Stand Cavity and Tuner.

## MEDIUM ENERGY BOOSTER RF SYSTEMS

The MEB RF System requirements are summarized in Table 3.

Table 3. MEB RF System Requirements.

| | |
|---|---|
| Frequency Tuning Range | 59.77-59.96 MHz |
| Pulse Length | 2 sec |
| Duty | 67% |
| Total Peak Circumferential Voltage | 2300 kV |

The total accelerating voltage will be provided by twelve 160 kw RF systems. Each RF system will be very similar to an LEB RF system except for the RF accelerating cavity, tuner and tuner bias supply. The MEB cavities must provide 2300 kV total or 192 kV per cavity when 12 systems are operational. However, the systems will be designed and tested for 230 kV per cavity so that all MEB requirements will be met with only 10 systems operational.

Unlike the LEB, detailed design has not yet begun for the MEB and HEB systems. Preliminary design concepts for the MEB cavity and tuner are based on the Fermilab main ring cavity, shown in Figure 4.

SSC plans to build another test stand, very similar to the LEB test stand, to test the MEB RF system. MEB schedule milestones are presented in Table 4.

Table 4. MEB RF Schedule Milestones.

| | |
|---|---|
| Prototype Development | 2/92-9/93 |
| RFPs Issued for Production | 3/93-10/93 |
| Issue Purchase Orders | 1/94 |
| All Subsystems and Components Delivered | 1/95 |
| Assembly, Install and Test Complete | 6/96 |

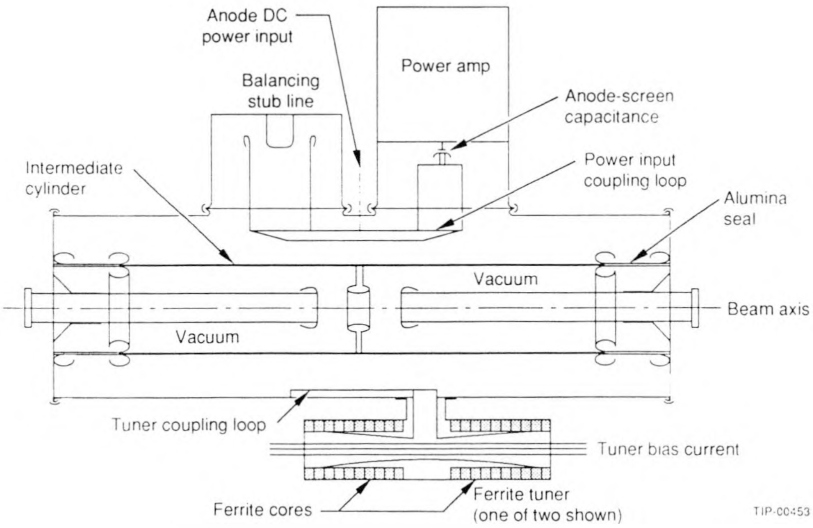


Figure 4. Fermilab Main Ring Cavity.

**HIGH ENERGY BOOSTER RF SYSTEM**

The HEB RF system requirements are summarized in Table 5.

Table 5. HEB RF System Requirements.

| | |
|---|---|
| Frequency Tuning Range | 59.95–60 MHz |
| Pulse Length | 237 sec |
| Duty | 50% |
| Total Peak Circumferential Voltage | 1600 kV |

The total accelerating ring voltage of 1600 kV will be provided by seven 160 kw RF systems very similar to the MEB systems, except that the final RF amplifiers will not be located directly on top of the accelerating cavities. As shown in Figure 5, the amplifiers will be located an integral number of half-wavelengths away, in the RF gallery. This arrangement is possible because the tuning range is almost negligible. Placing the amplifiers in the RF gallery is desirable because they are shielded from radiation and are easily accessible for maintenance.

In normal operation each of the seven systems will be delivering a peak accelerating gap voltage of 229 kV. The systems will be designed to deliver full voltage with any one system inoperable. That is, the systems will be designed and tested to deliver a peak voltage of 267 kV per cavity.

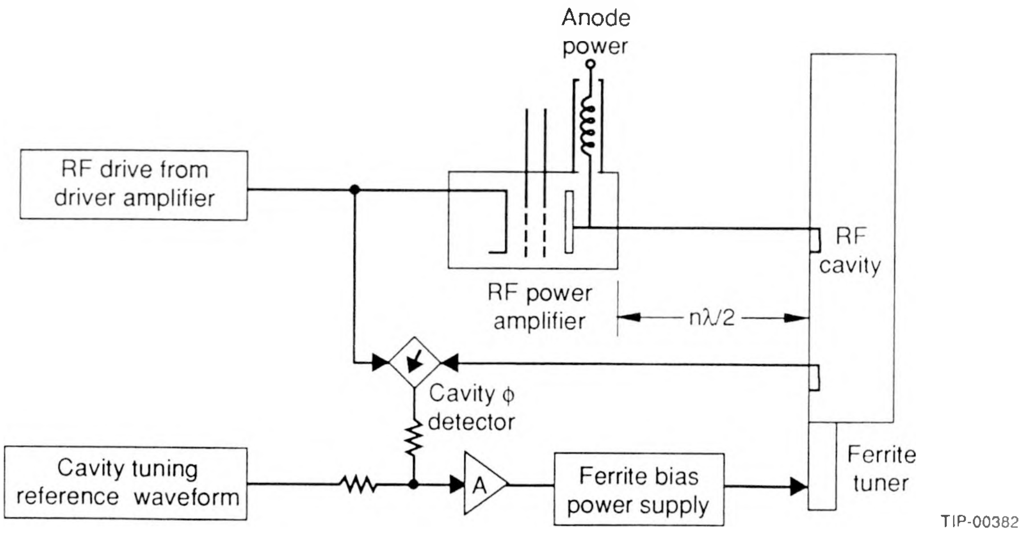


Figure 5. HEB RF Cavity Resonance Control.

The HEB schedule milestones are shown in Table 6.

Table 6. HEB RF Schedule Milestones.

| | |
|---|---|
| Prototype Development | 5/94-12/95 |
| RFPs Issued for Production | 6/95-1/96 |
| Issue Purchase Orders | 4/96 |
| All Subsystems and Components Delivered | 4/97 |
| Assembly, Install and Test Complete | 9/98 |

## COLLIDER RF SYSTEMS

The Collider consists of two synchrotrons with beams traveling in opposite directions. The RF systems for the two Collider synchrotrons are essentially identical. The RF requirements for each of the two synchrotrons are given in Table 7.

Table 7. Collider RF System Requirements.

| | |
|---|---|
| Frequency | 360 MHz |
| Duty | 100% |
| Peak Circumferential Voltage Per Ring | 20 MV |
| Accelerating Voltage Per Turn | 5.3 MV |

The total RF power will be provided by four one megawatt cw 360 MHz klystrons; two per synchrotron. The power from each klystron will be divided by magic-Tees so as to deliver equal power to each of four cavities; eight cavities per synchrotron, sixteen total. The RF system for each synchrotron ring is shown in simplified block diagram form in Figure 6.

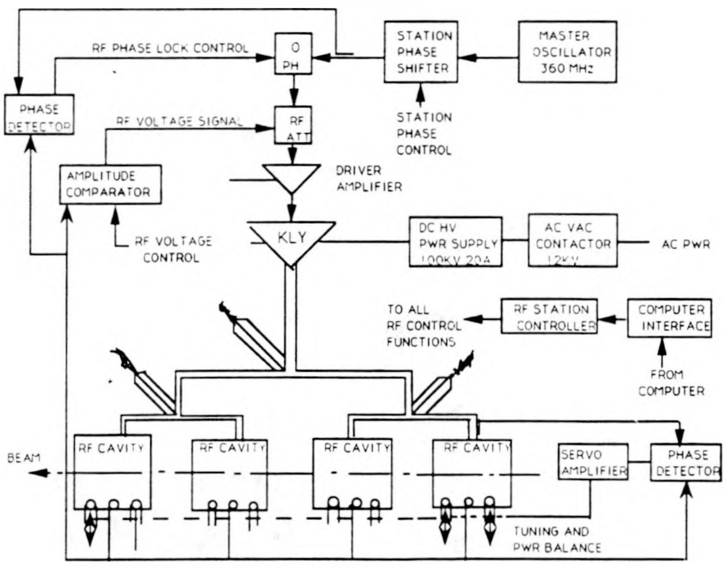


Figure 6. Collider RF System.

The collider cavities have five cells and are tuned with two mechanical slugs. A conceptual diagram is shown in Figure 7.

The klystrons are approximately 16 feet long and will be located in an RF gallery approximately 200 feet under ground along with most of the other RF components. It has not been decided whether to locate the 100 kV 20 ampere HV power supply transformer-rectifier assemblies in the RF gallery or at ground level.

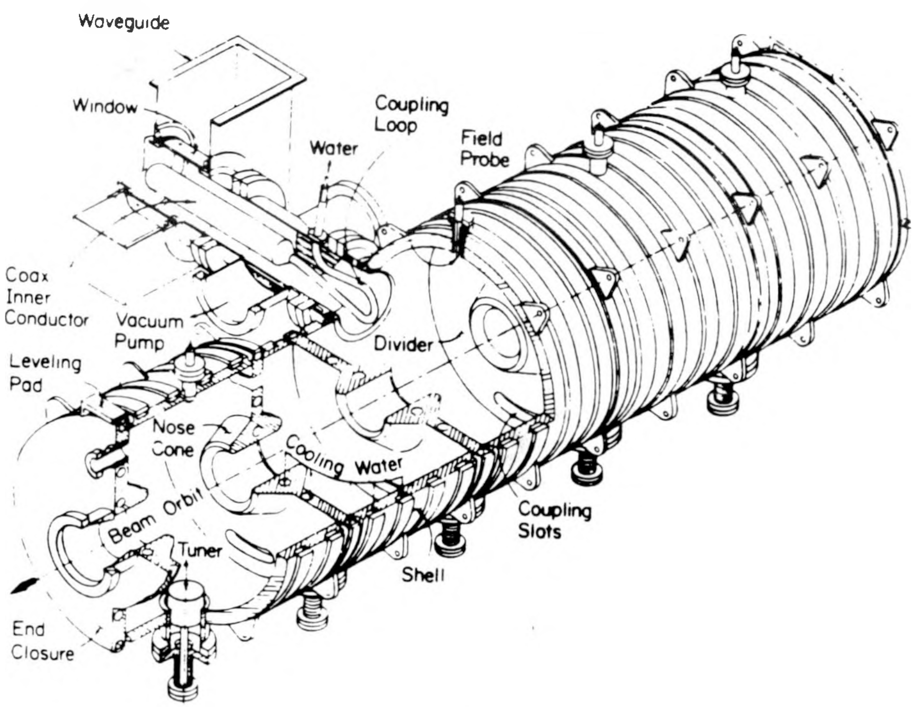


Figure 7. Collider Cavity.

The Collider RF schedule milestones are shown in Table 8.

Table 8. Collider RF Schedule Milestones.

| | |
|---|---|
| RFPs Issued for Production | 2/95 |
| Issue Purchase Orders | 10/95 |
| First System Components and Subsystems Delivered | 4/97 |
| All Subsystems and Components Delivered | 4/98 |
| Assembly, Install and Test Complete | 4/99 |

## POTENTIAL OPPORTUNITIES FOR INDUSTRY PARTICIPATION

Detailed procurement plans have not yet been prepared for the synchrotron RF systems. However, the following provides insight into our preliminary thoughts on procurement.

We plan to design and develop each of the three different booster RF cavity and tuner designs as well as their associated RF amplifiers. The RF amplifiers will then be competitively procured on a fixed-price contract from a design and manufacturing firm with a proven ability to design and manufacture high-power VHF amplifiers. The cavities and tuners will likewise be procured from firms with a proven ability to design and manufacture such equipment. The performance requirements and critical dimensions will be provided, but the manufacturers will have some freedom in how the components are actually produced.

Another critical high-power component is the ferrite bias supplies, which must deliver and control very high, variable DC current to inductive loads. We will develop such a bias supply for our test program, and we plan to utilize what we learn to procure production units from manufacturers who have proven capability to design, manufacture and test such power supplies.

Most of the other high power components will be procured from performance specifications. In some cases, identical components will be required for all three booster systems. In these cases multiyear procurements, or procurements with option quantities, will probably be utilized.

We plan to design and develop the RF supervisory control systems and the high speed low level RF systems. Our procurement plan for the Collider RF system is very similar to that of the booster systems. We plan to design the RF system and procure all components from specifications. We plan to carry out the RF system integration and to be responsible for all RF system tests. We plan to use temporary or contract labor.

High reliability and availability are of prime importance to the SSC. The highest engineering standards will be imposed on all components and subsystems.

## ACKNOWLEDGEMENT

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