RF CAVITIES FOR SUPERCONDUCTING CW LINAC FOR PROJECT-X FACILITY AT FERMILAB*

A. Saini [#], K.Ranjan, University of Delhi, Delhi, India
S. Barbanotti, M.Champion, M.Foley, I.Gonin, C.Grimm, S. Kazakov, T. Khabiboulline, A. Lunin, S. Mishra, L. Ristori, N. Solyak, A.Vostrikov, V.Yakovlev, FNAL, USA

Abstract
Project-X is a proposed high intensity proton facility to be built at Fermilab, US. Project-X facility consists of superconducting Linac which will be operated for 1mA average current with a pulse current of 10mA in continuous wave (CW) mode. The Linac is divided into two sections on the basis of operating frequencies & five sections on the basis of family of RF cavities to be used for the acceleration of beam from 2.5 MeV to 3 GeV. Three families of superconducting spoke resonators (SSR0, SSR1 & SSR2) which will be operated at 325 MHz have been designed for geometrical beta 0.11, 0.22 & 0.4 respectively. These cavities will be used in the low energy section of the linac for the acceleration of beam for the energy range of 2.5 MeV to 160 MeV. Acceleration of the beam from 160 MeV to 3 GeV will be done in the high energy section of the Linac. The high energy part will be operated at 650 MHz & it will use two families of superconducting elliptical cavities which are designed for geometrical beta 0.61 & 0.90. This paper presents description about RF formulation of each family of cavities to be used in CW linac.

INTRODUCTION

Project-X is a proposed high intensity multi MW facility to be built at Fermilab [1], which is based on 3 GeV, 1mA CW superconducting (SC) linac.

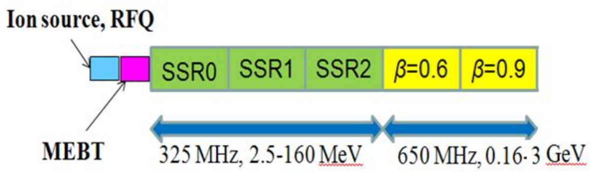

Figure 1: Acceleration scheme

Schematic baseline configuration of CW linac is shown in Fig. 1. The ion source provides 5 mA beam, of H^- ions which is accelerated in the RFQ, and is followed by the Medium Energy Beam Transport (MEBT). The SC linac is segmented into two sections: low energy part and high energy part. The low energy part (2.5-160 MeV) uses three family of SC single spoke resonator i.e. SSR0, SSR1 & SSR2 which are operated at 325 MHz. The high energy part of the linac (160 MeV-3 GeV) uses two families of 5 cell SC elliptical shape cavity, i.e. β=0.61 & β=0.9 which are operated at 650 MHz. Table 1 summarizes the number of beamline elements (RF cavities, solenoids and quadrupoles) and number of cryomodules corresponding to each section along with the transition points between each section.

*Work supported by IUSSTF and US DOE
[#]asaini@fnal.gov

Table 1: No. of Elements along with Transition Energy.

	SSR0	SSR1	SSR2	β=0.6	β=0.9
Cavities	18	20	40	36	152
Solenoids	18	20	20	0	0
Quads	0	0	0	24	38
CM	1	2	4	6	19
Length, m	10.98	16.40	33.20	60.00	292.60
Position, m	0.00	11.38	28.18	62.72	124.69
Period length, m	0.61	0.80	1.60	5.00	15.40
Periods	18	20	20	12	19
Transition energy, MeV	10.18	42.58	160.5	515.4	3028.3

FRONT END CAVITIES

Front end of the linac (2.5-160MeV) uses three families of SC single spoke resonators (SSR). The spoke resonators are preferred over the quarter wave resonator (QWR) due to its high performance, low surface electric field, wider range of beta and no dipole steering. A draw back with spoke design is that it is a bit difficult to tune spoke resonator than QWR.

SSR0: SSR0 cavities will be used for acceleration of the beam energy from 2.5 MeV to 10 MeV. The RF parameters of the SSR0 cavity for β =0.073-0.146 was optimized, and the results are shown in Table 2. HOM analysis, power coupler and mechanical design of SSR0 are underway.

Table 2: SSR0 Cavity Parameters.

Operating frequency	325 MHz
Optimal Beta, β_{opt}	0.114
Qload	$6.5\ 10^6$
E_{peak}/E_{acc}	5.63
B_{peak}/E_{acc}	6.92 mT/(MV/m)
G	50 Ω
R/Q	108 Ω
Cavity effective length, $D_{eff}=2*\beta\lambda/2$	105mm

SSR1: Second family of spoke resonators is SSR1. It will accelerate the beam from 10 MeV to 32 MeV. SSR1

having β =0.21 was originally designed and built for the HINS project [2]. The RF parameters of the cavity are listed in Table 3.

Table 3: SSR1 Cavity Parameters.

Operating frequency	325 MHz
Optimal Beta, β_{opt}	0.215
Qload	6.5 10^6
E_{peak}/E_{acc}	3.84
B_{peak}/E_{acc}	5.81 mT/(MV/m)
G	84 Ω
R/Q	242 Ω
Cavity effective length, D_{eff} =2*βλ/2	198.5mm

SSR2: Third family of spoke resonators, SSR2, will be used for acceleration of the beam energy from 32 MeV to 160 MeV. The RF parameters of the SSR2 cavity for β range of 0.261 - 0.5 are optimized for two different beam pipe diameters, 30 mm and 40 mm. Results of the optimization are shown in Table 4.

Table 4: SSR2 Cavity Parameters.

Operating frequency	325 MHz	325 MHz
Beam pipe diameter	30mm	40mm
Optimal Beta, β_{opt}	0.414	0.419
Qload	1 10^7	1 10^7
E_{peak}/E_{acc}	3.42	3.67
B_{peak}/E_{acc}	6.81 mT/(MV/m)	6.93
G	112 Ω	109
R/Q	304 Ω	292
Cavity effective length, D_{eff} =2*βλ/2	381.9mm	386.5

HIGH ENERGY SECTION CAVITIES

Two families of 5 cell, 650 MHz SC elliptical cavities, designed for β=0.61 and β=0.9, are used for acceleration of beam from 160MeV-3GeV. RF parameters for both cavities are listed in Table 5. Detailed study of these cavities is presented in Ref. [3].

Table 5: RF Parameters of the 650 MHz Cavities.

Beta	0.61	0.9
R/Q, Ohm	378	638
G-factor, Ohm	191	255
Max. gain per cavity, MeV(on crest)	11.7	19.3
Gradient, MeV/m	16.6	18.7
Max. Surface electric field, MV/m	37.5	37.3
E_{pk}/E_{acc}	2.26	2
Max surf magnetic field, mT	70	70
B_{pk}/E_{acc}	4.21	3.75

POWER COUPLER

Requirements of power coupler for CW regime have been formulated for Project-X cavities [3]. The coaxial fundamental power couplers (FPC) are designed for 325 MHz and 650 MHz sections. Fig. 2 shows layout of coaxial FPC for 325 MHz section. All the cavities in 325 MHz section use same FPC. For the sake of simplicity, both the designs are kept similar.

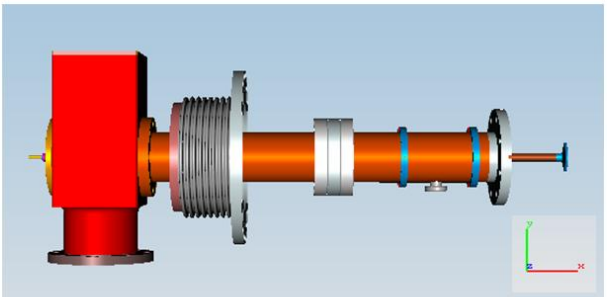

Figure 2: Coaxial Coupler layout for 325 MHz section.

MICROPHONICS

Operation of SC linac at 1 mA average current causes high beam loading for Project-X cavities resulting in narrow operating bandwidth. In present scheme of acceleration, it is found that SC linac uses cavities with bandwidth as low as 18 Hz. At such narrow bandwidth, microphonics effects become dominant, which results in detuning of RF cavities. The source of microphonics in SC linac are: 1) mechanical vibrations transmitted to cavity from the surrounding environment, 2) pressure fluctuation inside the liquid helium and 3) Lorentz force detuning, however its effect is negligible for CW mode of operation. The microphonics effects can be compensated by 1) providing sufficient reserve RF power, 2) reducing pressure sensitivity of cavities, i.e. reduction in frequency shift due to pressure fluctuations (df/dP), and 3) active compensation by using piezoelectric tuner. Studies are in progress to achieve optimal mechanical design which is less sensitive to df/dP

CONCLUSION

This paper presents detail description of the RF formulation of each family of cavity to be used in the CW linac of the proposed Project-X facility. Power coupler, used with RF cavities, and microphonics are also discussed.

REFERENCES

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