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Comparison of the Accelerating Structures for 200 MeV Proton Linac

Hyeok-Jung Kwon*, Han-Sung Kim, Seunghyun Lee, Dong-Hwan Kim
Korea Multipurpose Accelerator Complex, Korea Atomic Energy Research Institute, Gyeongju 38180
**Corresponding author: hjkwon@kaeri.re.kr*

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1. Introduction

An energy upgrade of the existing 100 MeV proton linear accelerator is considered at Korea Multi-purpose Accelerator Complex (KOMAC). The first step of the energy upgrade project is to increase the energy up to 200 MeV. The baseline design is the superconducting linac based on the half-wave resonator (HWR). In addition to the HWR, other accelerating structures are considered for comparison. The high power linac structures in the world are summarized in Figure 1 [1].

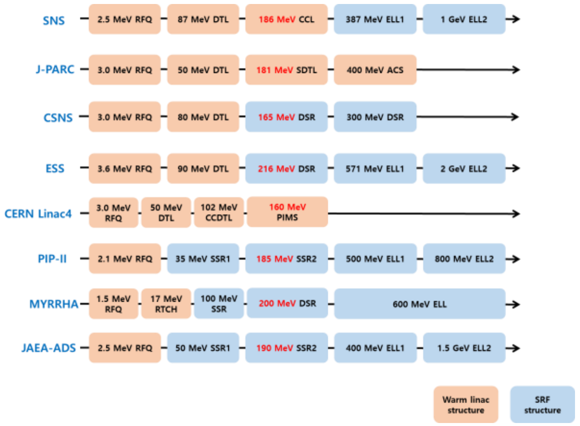

Fig. 1. High power proton linac structure.

Spallation Neutron Source (SNS) at Oak Ridge National Laboratory used a Coupled Cavity Linac (CCL) structure from 87 MeV to 186 MeV, and Japan Proton Accelerator Research Complex (J-PARC) used a Separated type Drift Tube Linac (SDTL) structure from 50 MeV to 181 MeV, both of which are under operation and used warm linac structure. European Spallation Source (ESS), which is now under construction, China Spallation Source (CSNS), Proton Improvement Plan II (PIP II), MYRRHA and JAEA-ADS, which are under design or technology development, use a Single Spoke Resonator (SSR) or Double Spoke Resonator (DSR) based on superconducting technology. KOMAC designed a HWR, which is more simple structure than SSR and is a significant benefit for the new developer, in spite of less acceleration efficiency. In this paper, three structures, a HWR, a SDTL and CCL are compared, which can be used to accelerate proton beam from 100 MeV to 200 MeV at KOMAC with a view point of their number of cavities, length, RF amplifier specification and so on. A design parameters of the KOMAC HWR will be used for comparison whereas the parameters of SDTL and CCL are derived from the scaling of the J-PARC and SNS linac.

2. Accelerating Structure for 200 MeV Proton Linac

2.1 Superconducting HWR

The design parameters of the superconducting HWR is summarized in Table 1 [2].

Table 1: HWR design parameters

Parameter	Values
Frequency	350 MHz
Optimum beta	0.56
Stored energy	23.1 J
Vacc (@ β opt)	3.61 MV
V0	4.14 MV
Eacc (@ β opt)	7.53 MV/m
E0	8.63 MV/m
Ep	29.08 MV/m
Bp	61.66 mT
Ep / Eacc	3.86
Bp / Eacc	8.19 mT/(MV/m)
R/Q (@ β opt)	256.6
G	116.1
Q0 (@ Rs = 20 nΩ)	5.81E+9
Cavity loss (@ Rs = 20 nΩ)	8.75
Aperture	40
Leff (β opt λ)	0.480 m
Cavity inner diameter	0.45 m

The HWR parameters are such that its length and diameter are almost same, therefore we can use the cylindrical cryomodule already developed and used in JLab and SNS. 1 cryomdule contains 4 cavities and it needs 9 cryomodule, 36 cavities to accelerate proton beam from 100 MeV to 200 MeV. The maximum RF power needed to drive the HWR is 60 kW and 120 kW solid state amplifier was selected as a RF amplifier of the HWR. The designed cryomodule is shown in Figure 2. The focusing structure is a doublet and the length between doublet centers is 5.1 m. The heat load equivalent to 4.5 K is 130 W per cryomodule and the total heat load for 9 cyromodules is 1170 W. The accelerator length from 100 MeV to 200 MeV is 46 m.

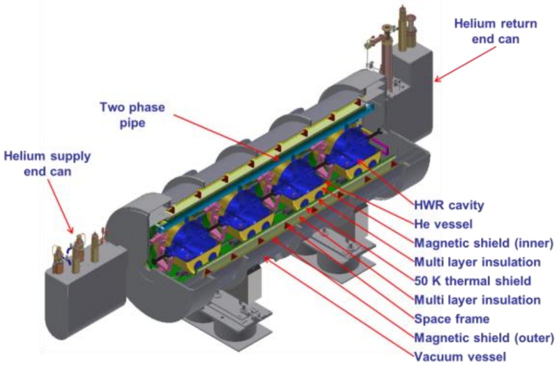

Fig. 2. Cryomodule of the KOMAC HWR.

2.2 Separated type Drift Tube Linac

A Separated type Drift Tube Linac (SDTL) is used at J-PARC in order to accelerate H- beam from 50 MeV to 191 MeV. The parameters of the J-PARC SDTL is summarized in Table 2 [3]. The 32 independent SDTL tanks are used. Each tank has four drift tubes and one klystron drives two SDTL tanks. The distance between tanks is 2βλ. We estimated the parameters of 350 MHz SDTL to accelerate proton beams from 100 MeV to 200 MeV by using J-PARC SDTL parameters. In this case, the maximum RF power including beam is less than 1 MW, therefore the 1.6 MW, 350 MHz used in existing KOMAC linac can be used without further klystron development.

Table 2: J-PARC SDTL parameters

Parameter	Values
Frequency	324 MHz
Input energy	50 MeV
Output energy	191 MeV
Number of tanks	32
Tank inner diameter	520 mm
Tank length	1.5 m ~ 2.5 m
Number of cells	5
Drift tube outer diameter	92 mm
Drift tube inner diameter	36 mm

2.3 Coupled Cavity Linac

A Coupled Cavity Linac is used to accelerate H- beam from 87 MeV to 186 MeV in SNS. The parameters of SNS CCL is summarized in Table. 3 [4]. It uses double frequency of the upstream DTL. Eight accelerating cells and seven coupling cells form a single cavity. And 12 coupled cavities form a single module through the bridge coupler. Four full modules are used in order to accelerate to the final energy of 186 MeV. We estimated the parameters of 700 MHz CCL to accelerate proton beams from 100 MeV to 200 MeV by using SNS CCL parameters. In this case, not only the frequency scaling (including the shunt impedance), but also the peak RF power of the module are considered, because the available klystron in 700 MHz is limited whereas a 5 MW peak power klystron was used to drive one CCL module in SNS.

Table 3: SNS CCL parameters

Parameter	Values
Frequency	805 MHz
Input energy	87 MeV
Output energy	186 MeV
Peak dissipated power	12.1 MW
E0	3.7 MV/m
Synchronous phase	-28 ~ -30 degree
Kilpatrick factor	1.3
Real estate gradient	1.8 MV/m
RF power / energy gain	121 kW / MeV
ZTT	39~50
Total length	55 m

2.4 Comparison

Three accelerating structures are compared in order to accelerate proton beam from 100 MeV to 200 MeV and the results are summarized in Table 4. For SDTL options, we can use the 1.6 MW, 350 MHz klystron as a RF amplifier without further development. For CCL options, we benchmarked a 704 MHz, 1.5 MW klystron for high beta elliptical cavity of ESS [5].

Table 4: Comparison of accelerating structures

Type	HWR	SDTL	CCL
RF frequency [MHz]	350	350	700
Number of module	9	20	16
Total length [m]	46	60	64
RF power per module [MW]	0.12	1.6	1.5
Number of RF amplifier	36	20	16
Modulator power	-	5	5
Number of modulator	-	10	8

3. Conclusions

Three kinds of accelerating structures are compared as a KOMAC linac from 100 MeV to 200 MeV. Detailed cost analysis including not only accelerator itself but also buildings and utilities is planned.

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