# THE CONSTRUCTION OF THE LOW-ENERGY FRONT 60-MeV LINAC FOR THE JAERI/KEK JOINT PROJECT

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*Abstract*

The high-intensity proton accelerator facility project in Japan which comprises a 600-MeV linac, a 3-GeV, 1-MW rapid-cycling synchrotron (RCS), and a 50-GeV synchrotron will promote many important scientific and engineering fields such as life science, materials science, nuclear physics and fundamental particle physics. The construction of the low-energy front 60-MeV linac has been already started. Rationale for the parameters and the unique features of the linac are reported together with the present status of the construction.

## 1 INTRODUCTION

The high-intensity proton accelerator project in Japan [1-4], which is a joint one of Japan Atomic Energy Research Institute (JAERI) and High Energy Accelerator Research Organization (KEK), comprises a 600-MeV linac, a 3-GeV, 1-MW rapid-cycling synchrotron (RCS), and a 50-GeV synchrotron. All the facility will be constructed at the JAERI/Tokai site. The 400-MeV beam accelerated by the normal conducting linac is injected into the RCS, while the beam is further accelerated up to 600 MeV by a superconducting linac for an accelerator-driven nuclear waste transmutation system (ADS). The 3-GeV beam extracted from the RCS is mainly transported to the Life and Materials Science Experimental Area, where the muon-production target and the neutron-production one are, respectively, located in series. Every three second, the beam is injected into the 50-GeV synchrotron. The fast extracted 50-GeV beam is used for neutrino oscillation experiments, which will be conducted by use of the SUPEERKAMIOKANDE detector located 300 km from the Tokai site. The slowly extracted beam is transported to the Nuclear and Fundamental Particle Physics Experimental Area. The details are described in Refs. [1-4].

The construction of the accelerator complex will be started from April, 2001, if funded. On the other hand, the 60-MeV linac has been already funded by the supplementary budget in 1998 for the Japan Hadron Facility (JHF) project of KEK [5-7]. This is now under construction in KEK by the collaboration between KEK and JAERI. After the beam commissioning is finished and the linac building for the Joint Project is completed at the Tokai site, the linac will be shipped there. Since the peak beam current of 30 mA for the JHF linac is different from that of 50 mA for the Joint Project, the ion source and the RFQ linac should be rebuilt for the Joint Project.

In this conference, several papers [9-15] are presented in relation to the 60-MeV linac. These papers are summarized by the present paper.

## 2 RATIONALE FOR THE CHOICE OF PARAMETERS

The scheme and parameters of the 60-MeV linac are shown in Table 1. The accelerating frequency of 324 MHz has been chosen for the following reason. The higher frequency is more preferable for the high-intensity linac for the several reasons, for example, detailed in Ref. [16]. However, if one uses quadrupole electromagnets for a drift-tube linac (DTL) rather than permanent ones, the drift tubes become larger in order to contain electromagnets, resulting in the lower frequency. The chosen frequency is practically the highest value for the electromagnet DTL starting from 3 MeV.

The transition energy from the RFQ linac to the DTL is chosen as follows. Regarding the beam quality, the higher transition energy is more preferable, since the simultaneous, continuous focusing is lost in the medium energy beam transport (MEBT). However, the beam from a linac must be chopped in order to avoid the beam loss indispensable to the adiabatic capture in a ring. The highest energy for the chopper is around 3 MeV, unless a new mechanism is invented. This is the reason why we chose the transition energy of 3 MeV from the RFQ to DTL.

We have chosen the electromagnets for the quadrupole magnets in the DTL rather than permanent magnets for the following reason. Nobody knows the future performance of the ion source, upon which the optimum focusing parameters will be dependent. Also, one has little empirical justification regarding which guideline is most promising for the focusing parameters of the high intensity linac, for example, equipartitioning [17], equal phase advance, or others. Under these circumstances, it is our opinion that a machine should be equipped with the flexible knobs for the focusing parameters.

The frequent focusing, either transversely or longitudinally, which is essential for the high brightness

Table 1: The parameters of the 60-MeV linac. The values within parentheses are for the Joint Project linac.

| | |
|---|---|
| Energy | 60 MeV (600 MeV) |
| Peak Current | 30 mA (50 mA) |
| Beam Pulse Length | 500 µs |
| Repetition | 50 Hz |
| Linac Average Current | 750 µA (1.25 mA) |
| Chopping Rate | 56 % |
| Average Current after Chopping | 420 µA (700 µA) |
| Total Length | 40 m (360 m) |
| **$H^-$ Ion Source** | |
| Type | Volume Production |
| Peak Current | 32 mA (60 mA) |
| Normalized Emittance (90 %) | 0.6 π mm·mrad |
| Extraction Energy | 50 keV |
| **RFQ** | |
| Energy | 3 MeV |
| Frequency | 324 MHz |
| **DTL** | |
| Energy | 50 MeV |
| Frequency | 324 MHz |
| Focusing Quadrupole Magnet | Electromagnet |
| Total Tank Length | 27 m |
| The Number of Tanks | 3 |
| **SDTL** | |
| Energy | 56 MeV (200 MeV) |
| Frequency | 324 MHz |
| Total Tank Length | 3 m (71 m) |
| The Number of Tanks | 2 (34) |
| **RF Source** | |
| The Number of 324-MHz Klystrons (including an RFQ) | 5 (21) |
| Total RF Power | 6 MW (30 MW) |

in the low energy proton linac, is no more necessary around several ten MeV. Then, a separated DTL (SDTL) [18], in which the quadrupole magnets are removed outside from the drift tubes, that is, from the DTL tanks, has some advantages over the conventional DTL as follows. First, the dimensions of the drift tubes can be optimized for the shunt impedance, since the constraint to accommodate the quadrupole magnets is removed. For this reason, the shunt impedance of the SDTL is typically by several ten percent higher than that of the conventional DTL for the structures from several ten MeV to 150 MeV [18]. Up to around 150 MeV, the shunt impedance of the SDTL is higher than that of coupled-cavity linac (CCL) with a frequency of three times as high as that of the SDTL. Second, one can separate the transverse transition from the longitudinal one by inserting the SDTL between the DTL and CCL, obtaining more flexibility for the beam dynamics design. Usually, the frequency of a CCL is several times as high as that of a DTL or an SDTL. In this case, the transition from the DTL to the SDTL is transverse, while that from the SDTL to the CCL is longitudinal. On the other hand, the beam passes through both the longitudinal and transverse transitions at the same time in the conventional transition from the DTL to the CCL. For these reasons we have chosen the SDTL from 50 MeV. We have two tanks between 50 MeV and 60 MeV, in order to do both the high power test and beam test.

## 3 PRESENT STATUS

The design of the $H^-$ ion source, the low energy beam transport (LEBT), and the RFQ linac is based upon the knowledge and experience obtained through the design, the construction, the high-power test, and the beam test of the 5.3 MeV linac for the Japan Hadron Project (JHP), which was proposed in 1987 [19]. The present status of these components is described in detail in Refs. [9,10]. The volume-production type is chosen for the ion source. Since the cesium gas is in general harmful for keeping the high RF voltage in the following RFQ linac, the operation without the cesium will be tried at first. The commissioning of the ion source (see Figure 1) is just started as detailed in Ref. [9]. It seems difficult to obtain a peak current of several ten mA (with a normalized 90% emittance of 1.5 π mm·mrad, typically) without cesium, while an amount of the cesium necessary for the volume-production $H^-$ ion source does not seem so harmful as has been worried. We will probably use the cesium in order to obtain the high peak current. Even so, since the long-term operation of an RFQ linac with an cesium-seeded ion source has not been experienced, the problem related to the cesium is still an issue for the high-intensity $H^-$ linac [16].

Figure 1: The tunnel viewed from the down stream. The ion source being installed can be seen at the far end.

It should be noted that the high-energy, high-frequency, high-duty RFQ linac such as 3-MeV, 432-MHz one was first realized by the invention of the π-mode stabilizing loop (PISL) [20,21]. For this reason, we also install PISL's for the present RFQ. In the same way as the JHP test linac, the main body of the RFQ has neither the vacuum tight sealing or welding in order to avoid the possible deforming. Instead, the main body of the RFQ is contained in a bigger vacuum chamber. The result of the RF measurement is presented in Ref. [10]. The high-power test and the beam test were scheduled in this fall.

It is emphasized that a new type of chopper will be installed in the 3-MeV medium energy beam transport (MEBT) [22]. The MEBT was ordered in this year, for the completion by the end of March, 2001. The prechopper should be developed to be installed to the LEBT in order to avoid the overloading on the scraper in the MEBT.

The DTL contains newly developed coils [11] for the electro-quadrupole magnets. The coils were electroformed with the water cooling channels therein in order to drastically improve the packing factor. The detail of the DTL is described in Refs. [12,13] together with the result of the high-power test of the prototype, the photograph of which is shown in Figure 2.

Figure 2: The prototype of the DTL for the high-power test.

Five klystrons will be installed in total. Full RF power of 3 MW was already achieved with a full rating of 3 percent (600 μs and 50 Hz). A small oscillaion was, however, observed as identified due to the recoil electrons from the collector. The detail is presented in Refs. [14,15].

## 4 CONCLUSION AND FUTURE PLAN

So far the construction of the 60-MeV linac is in progress without any serious trouble. All the accelerating structures will be completed by the end of March, 2001. A full set up to the first tank of DTL (around 20 MeV) will be ready for the beam commissioning by that time. The remaining RF components will be ordered in 2001 together with the prechopper. A full beam commissioning up to 60 MeV will be done in 2002.

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