01-222R1(D) - BEAM DYNAMICS STUDIES FOR MULTIPLE CHARGE STATE LINAC AND FAST SWITCHER

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Purpose: The RIA Facility includes a 1.4 GeV driver linac. In order to provide specified beam power, the driver will accelerate multiple-charge-state heavy ion beams. To avoid problems from beam-induced radioactivation, beam losses must be limited to low values, particularly in the high-energy part of the accelerator, where fractional beam losses must be less than 10^{-4}. Beam dynamics studies are necessary with the goal of identifying all possible sources of effective emittance growth which can result in beam losses. Optimization of the linac structure is necessary to reduce any effective emittance growth of the multiple charge state beams. The dynamics of single- and multiple-charge state beams must be detailed, including the effects of possible errors in rf field parameters and misalignments of transverse focusing elements.

Approach: By simultaneously accelerating several of the multiple-charge states resulting from stripping the beam, a much higher portion of the stripped beam can be utilized. The increase in efficiency not only provides a substantial increase in the available beam current, but also enables the use of multiple strippers, reducing the size of the linac required for 400 MeV/u beams. In addition, it was shown that the front end of the driver linac can be designed for the acceptance of two charge states of uranium beam from the Electron Cyclotron Resonance (ECR) ion source, doubling the available uranium beam power. An important condition for the successful operation of the multiple-charge state linac is the six-dimensional matching of multi-q beams after the stripping. We have developed an iso-path magnetic transport system for this purpose. Beam dynamics of the multiple-charge-state beam is a new field and must be carefully studied in the driver linac. We have developed optimization and simulation computer codes for this purpose.

Technical Progress and Results: The baseline design of the linac contains 9 types of superconducting radio frequency (SRF) accelerating cavities. The layout, configuration, and many details of the RIA driver linac have been published in refereed journals, discussed and presented at several conferences and workshops (the list of publications is attached). The baseline design of the driver linac was described in ref. 1. The latest modifications of the driver linac design include: 1) peak surface electric field in all drifttube superconducting (SC) resonators assumed to be equal to 20 MV/m except for the first seven 4-gap "ATLAS type" resonators; 2) the high-β section of the driver linac contains triple-spoke resonators (TSR) instead of elliptical resonators operating at the same value of peak electric field, 28 MV/m. Except for the first cryostat which contains seven 4-gap resonators and one 2-gap resonator, the linac consists of 6 different types of cryostats filled by five different types of resonators.

Several options for the magnetic transport system (MTS) design have been studied for six-dimensional beam matching in the transition between the strippers and the following SC linac. The options chosen here seem to best satisfy the overall architectural requirements of the linac. For example, after the first stripper, it is convenient to transversely shift the linac beam axis: the MTS incorporates two 90° bends to provide a 7.2 m shift. After the second stripper it is economical to bend the beam through 180°, since such a bend greatly shortens the overall length of the linac tunnel. At the final stage of the MTS design, the higher order terms were included and corrected as necessary.

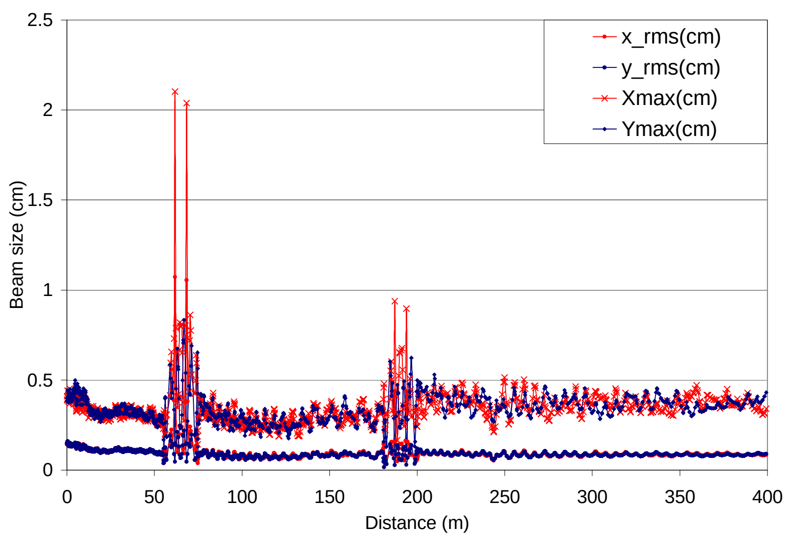

Fig. 1. Beam rms and total envelopes along the driver linac.

Beam dynamics in the SRF linac were numerically simulated using the TRACK code. Beam envelopes along the linac are shown in Fig. 1. The simulation was performed for two-charge state uranium in the low-β section, five charge states in the medium-β and three charge states in the high-β section.

The sensitivity of multi-q beam parameters to various types of random errors and misalignments were studied by the ray-tracing code TRACK. The most essential errors affecting transverse beam motion are the misalignments of transverse position of focusing elements. Due to the strong defocusing of low velocity particles by the SRF cavities, the misalignments of the SRF cavities were taken into account too. Monte Carlo simulations of the dynamics of multi-q beams in the presence of alignment errors have been performed. These studies show that in the worse-case scenario the total emittance growth of the multi-q beam is less than a factor of four in transverse phase space.

Phase and amplitude fluctuations in SRF cavity fields are simulated in order to find their effect on longitudinal effective emittance of the multi-q beam.

Comparison of beam dynamics performance in the high-beta section of the RIA driver linac has been done for two types of accelerating structures: one using elliptical cavities as in the baseline proposal and one based on triple-spoke resonators. The latter provides larger longitudinal acceptance and as expected is much more cost-effective due to the operation at higher helium temperature.

We have completed a design for a driver linac switchyard which can deliver beams to four production targets. Driver beam power of up to 400 kW will be available so that beam sharing between target stations is desirable. Design of the switchyard for the driver beams of RIA is a unique task due to the following features: 1) Distribution of various ion species accelerated to a wide range of energies to four target stations; 2) Delivery of beams to two target stations simultaneously; 3) Providing high quality beam optics with higher order corrections for multiple charge state beams to produce small beam spots at the entrance of the fragment separators. The design of the switchyard has been carried out for the most critical four-charge-state uranium beam with the full momentum and charge spread $\pm(\Delta q/q_0+\delta p/p_0) = \pm 2.1\%$. The multi-q uranium beam can be focused to a spot $x \times y = 1.0 \times 3.0\ mm^2$.

An rf sweeper is used for beam delivery to two targets simultaneously. The rf sweeper will be based on a room temperature H-type resonator operating at 115 MHz. Basic parameters of the rf sweeper have been specified.

Specific Accomplishments: The results of the studies have been published in *Physical Review* and have been reported at the 9th International Heavy Ion Accelerator Technology Conference, at the 2002 Charged Particle Optics Conference (CPO-6), and the LINAC-2002 international conference.

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