Design of a 7 MeV/u, 217 MHz Injector Linac for Therapy Facilities

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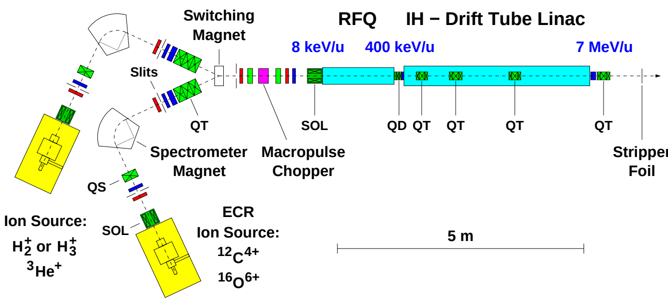

Figure 1: Schematic drawing of the injector linac. SOL $\equiv$ solenoid magnet, QS, QD, QT $\equiv$ magnetic quadrupole singlet, doublet, triplet.

Table 1: Major parameters of the injector linac.

Design ion	$^{12}C^{4+}$	$(A/q = 3)$
Operating frequency	216.816	MHz
Final beam energy	7	MeV/u
Pulse currents after stripper	≈ 100	eμA C^{6+}
	≈ 0.7	mA protons
Beam pulse length	≤ 200	μs @ ≤ 5 Hz
Duty cycle	≤ 0.1	%
Norm. transverse exit beam emittances (95 %) [1]	≈ 0.8	π mm mrad
Exit momentum spread [1]	± 0.15	%
Total injector length [2]	≈ 13	m

[1] Not including emittance growth effects in the stripper foil.
[2] Including the ion sources and up to the foil stripper.

A dedicated clinical synchrotron facility for cancer therapy using energetic proton and ion beams (carbon, helium and oxygen) has been designed at GSI for the Radiologische Universitätsklinik in Heidelberg [1]. A compact injector design is proposed (Fig. 1 and Table 1) [2, 3]. The LEBT allows for switching between two ion sources as well as for beam chopping and for controlled beam current variation. A 4-rod type RFQ of about 1.5 m in length accelerates the ions from 8 keV/u to 400 keV/u. A very compact intertank section has been proposed for matching the beam parameters at the exit of the RFQ to the ones required at the entrance of the subsequent IH-type drift tube linac (Fig. 2). It consists of a two-gap rebuncher integrated into the RFQ tank [3], a pair of steerer magnets, a magnetic quadrupole doublet and a diagnostic box comprising a beam transformer and a phase probe. The total length between the RFQ and IH tanks is about 20 cm only. The IH-DTL for the acceleration to 7 MeV/u has a length of roughly 3.8 m and an expected rf power consumption around 1 MW. It consists of three integrated magnetic quadrupole triplets and 56 accelerating gaps grouped in four KONUS sections. Finally, the beam is focused by another quadrupole triplet following the DTL onto a stripper foil located about 1 m behind of the linac.

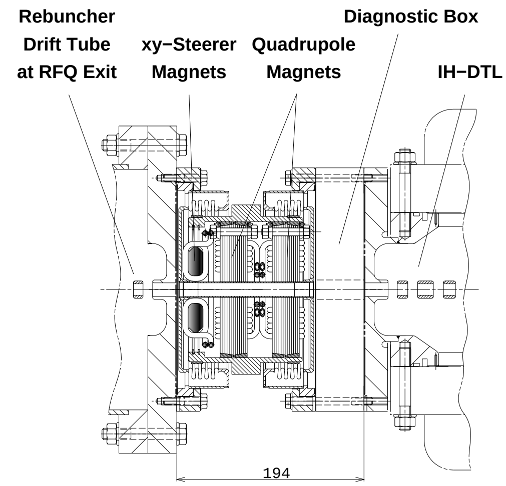

Figure 2: Design of the intertank matching section.

In the last year we focused on the optimization of several details and proceeded in the design of the most challenging critical parts. The integration of two drift tubes into the RFQ tank has been further investigated at the IAP by detailed measurements using rf models and by MAFIA simulations [3, 4]. Realistic field configurations of the transition from the RFQ electrodes to the drift tube geometry have been calculated by 3D simulations and have been integrated into the particle dynamics simulations using a modified PARMTEQ version.

The DTL design has been optimized and a 1:2 scaled rf model is under construction. Due to the comparatively high frequency of 217 MHz the diameter of the IH tank amounts to roughly 30 cm only, requiring very small triplet lenses of around 25 cm in length and about 16 cm in diameter. First 3D design studies of these small quadrupole magnets using the TOSCA code have been performed by B. Langenbeck and C. Mühle, GSI.

To enhance the efficiency of synchrotron injection the momentum spread of the ion beam can be reduced to $\Delta p/p \leq \pm 0.1\,\%$ by an additional debunching cavity installed in the synchrotron injection line. Detailed particle dynamics simulations and a first cavity design study have been performed [5].

References

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