AN INJECTOR FOR A MULTI ION BEAM DRIVER LINAC

H. Podlech, D. Gorelov, J.-W. Kim, F. Marti, R. York

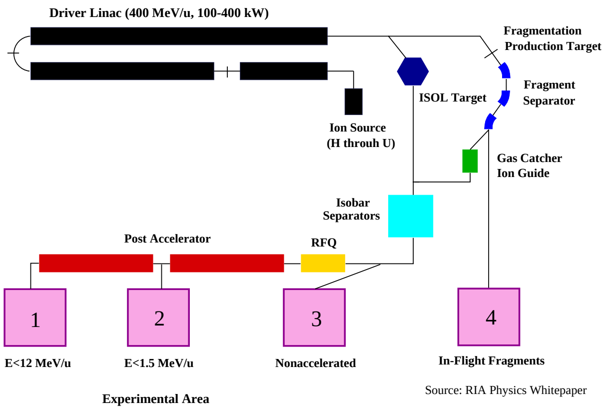

Figure 1: Schematic layout of the Rare Isotope Accelerator (RIA).

1 Introduction

Experiments with radioactive ion beams far from stability is a major frontier in nuclear physics. In the last several years, a concept for a world-class radioactive ion beam facility has been developed [1]. The proposed design for the Rare Isotope Accelerator (RIA) project includes a high power, cw linac. To limit the power consumption, all accelerating structures with β>0.019 are superconducting. The driver linac will provide beams over the whole mass range from hydrogen through uranium with energies between 400 MeV/u (U) and 900 MeV (H) and a beam power between 100 kW and 400 kW.

2 RFQ

The first accelerating structure is a normal conducting radio frequency quadrupole (RFQ) accelerator operated at f=57.5 MHz. RFQ resonators are well established structures for the acceleration of low energy ion beams with simultanious strong transverse focusing [2]. Two possible solutions for RIA have been considered, a 4-vane RFQ and an IH-type RFQ.

2.1 4-vane RFQ The 4-vane RFQ is a cylindrical resonator with four vanes placed symmetrically within the cavity. It is operated in the $TE_{21(0)}$ mode. The low frequency of 57.5 MHz leads to a rather large diameter of about 100 cm. MAFIA simulations have shown a high efficiency (Z_{MAFIA}=680kΩm) because the vane charge current is distributed very uniformly along the whole structure resulting in a high shunt impedance.

2.2 IH-type RFQ A different possibility for RIA is an IH-type RFQ. It is a cylindrical resonator operated in the $TE_{11(0)}$ mode. The resonance structure consists of two ridges carrying the support rings and mini-vane like electrodes. The simulations have shown that the shunt impedance is lower compared with a 4-vane RFQ, but due to the higher capacitance, the strucure is much more compact. The result is a diameter half as large as for the 4-vane RFQ. See table 1. In addition, the IH RFQ is easily tunable and not as sensitive to mechanical perturbations [3].

Figure 3 shows the resonance structure of the IH-RFQ. This RFQ is similar to the RFQ of the new high current injector at GSI which has been successfully commissioned in 1999 [4].

The distance and the width of the support rings have been optimized with MAFIA in order to minimize the dipole component and to maximize the shunt impedance. See fig. 4. A width of 2 cm and a distance of 12 cm

Figure 2: The 57.5 MHz 4-vane RFQ with the characteristic magnetic field of the $TE_{21(0)}$ mode.

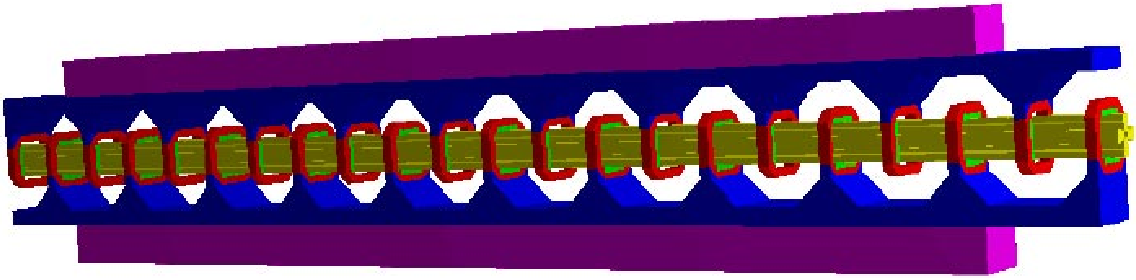

Figure 3: The inner structure of the IH-RFQ consists of two ridges carrying the support rings and the electrodes.

lead to a calculated shunt impedance of 390 kΩm and a dipole component of 0.7%.

Given in Table 2 are the percentage of the power losses for different structure components. Only 7% of the power is dissipated on the electrodes. Therefore, it is possible to cool the electrodes indirectly.

In addition, simulations with the program package Analyst^{TM} Accelerator Edition [5] have been performed as cross-check with the MAFIA simulations. Both programs delivered the same results within two percent.

2.3 RFQ beam dynamic RFQ beam dynamic calculations have been performed using the PARMTEQ code. For uranium, the RFQ must simultaniously accelerate two charge states to meet the beam power requirements.

parameter	**4-vane RFQ**	**IH-RFQ**
f [MHz]	57.5	57.5
Diameter [cm]	100	45
Length [cm]	260	260
Z [kΩm]	680	390
Q_0	20000	12000
U_{vane} [kV]	75	75
E_{in} [keV/u]	13	13
E_{out} [keV/u]	169	169
$\epsilon_{long,out}$ [πkeV/u·ns]	0.14	0.14

Table 1: Comparison between the 4-vane and IH-type RFQ. The shunt impedance and Q-value are the result of MAFIA simulations. The longitudinal emittance is for a single charge state (U^{28+}).

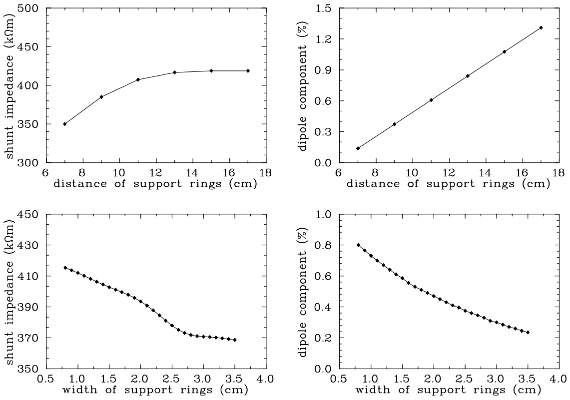

Figure 4: Shunt impedance and dipole component of the IH-RFQ as function of the distance and width of the support rings (MAFIA).

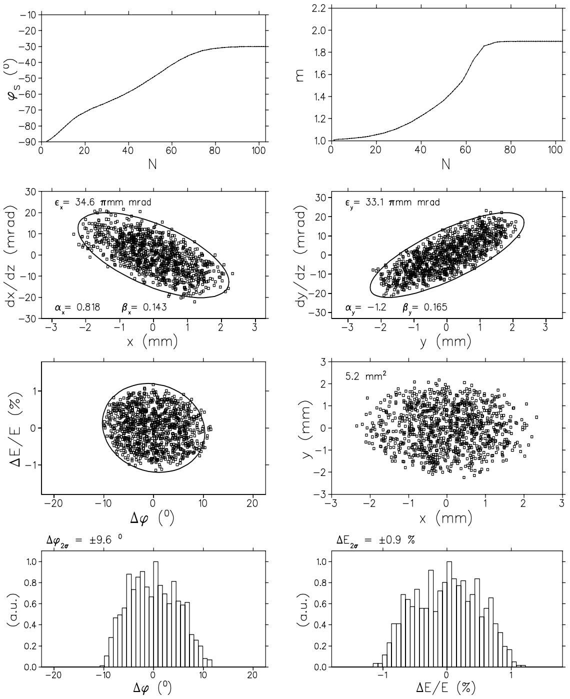

Figure 5: Results of the PARMTEQ simulations. As input a prebunched beam has been used.

Therefore, the longitudinal properties of the beam from the RFQ is of special concern. A program has been developed to optimize the properties of the RFQ and the longitudinal emittance. Fig. 5 shows some results of these simulations. The first two plots show the synchronous phase and the modulation, respectively. The plots in the second row show the transverse phase space and the plots in the third row the phase width and energy width of the beam. The transverse normalized emittance growth is 3% and the longitudinal emittance is 0.14 πkeV/u·ns for a single charge state U^{28+} and prebunched beam. The electrodes have a length of 260 cm and voltage of 75 kV. Table 1 summarizes the parameter of the RFQ.

component	**power losses**
tank	53%
ridges	31%
support rings	9%
vanes	7%
Σ	100%

Table 2: Relative power losses of the IH-RFQ (MAFIA).

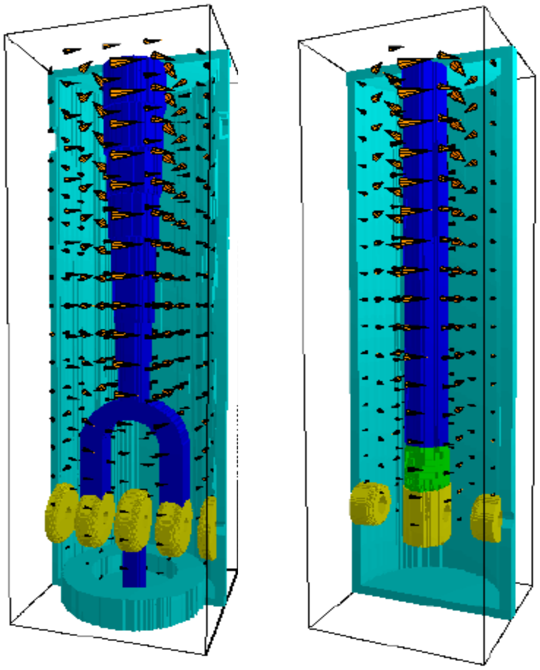

Figure 6: Magnetic field of the β=0.03 fork cavity and of the β=0.06 quarter wave resonator.

3 Superconducting cavities

After the RFQ, the driver linac consists of superconducting cavities. Up to approximately the 85 MeV/u point, drift tube cavities are foreseen whereas elliptical 6-cell cavities are proposed for the remainder of the linac [5].
The injector part could consist of three types of superconducting coaxial-line cavities. The first two types are 4-gap fork resonators very similar to those presented by ANL [6] (see fig. 6, left). They are operated at f=57.5 MHz and designed for a particle beta of 0.02 and 0.03, respectively.
The third type of the drift tube cavities is a 2-gap quarter wave resonator (QWR) operated at f=86.25 MHz and optimized for a beta=0.06 (see fig. 6, right). Due to the broad transit time factor of the QWR, it can accelerate ions efficiently up to β=0.1. The number of required quarter wave resonators is 32 assuming a gradient of E_{acc}=6 MV/m and q/A=29/238. All cavities have been simulated with MAFIA. Table 3 shows some paramter and the most important electromagnetic properties of the cavites.

4 Conclusion

A possible solution of an injector for a cw superconducting high power linac has been presented that would consist of a 57.5 MHz normal conducting RFQ and 39 superconducting coaxial-line resonators operated at fre-

Parameter	**Fork1**	**Fork2**	**QWR**
f [MHz]	57.5	57.5	86.25
β	0.02	0.03	0.06
length$_{total}$ [cm]	109	102	87
G=R$_s$Q$_0$ [Ω]	15.3	19.4	25.2
R$_p$/Q$_0$ [Ω]	1810	2274	718
R$_p$R$_s$ [$10^3\Omega^2$]	27.6	44.3	18.1
E$_{acc}$ [MV/m]	3.27	3.46	6.0
E$_p$/E$_{acc}$	4.9	4.7	5.0
B$_p$/E$_{acc}$ [G/(MV/m)]	77	85	117
W/E$_{acc}$ [mJ/(MV/m)^2]	112	154	161
U$_{eff}$ [MV]	0.72	1.04	1.32
number of cavities	2	5	32

Table 3: Parameters of the first three drift tube cavities.

quencies of 57.5 and 86.25 MHz.

As the first accelerating section, a 4-vane and an IH-type RFQ have been considered. Due to the advantages of the IH-RFQ (more compact, easyly tunable, less sensitive) this structure seems to be more favourable for the low frequency despite the smaller shunt impedance.

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