PARTICLE DYNAMICS INVESTIGATIONS FOR A HIGH CURRENT D^+ DTL

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Abstract

In the framework of the IFMIF (**I**nternational **F**usion **M**aterial **I**rradiation **F**acility) project study particle dynamics calculations have been performed for a 175 MHz, 125 mA deuteron linac. The linac has to provide a 40 MeV beam with low losses and small emittance growth for the homogenous irradiation of a Li target. The linac consists of an RFQ injector followed by a Drift Tube Linac. The complete facility would need in parallel operation two 125 mA linac. In a first attempt the particle dynamics layout of an Alvarez type DTL has been studied aiming for low rf voltages and moderate power losses in the structure due to the required cw operation. In addition first investigations have been started for an H-type DTL to further evaluate the capability of this structure for the acceleration of high intensity beams. Results will be presented and discussed including matching requirements to the DTL.

1 BEAM DYNAMICS IN THE ALVAREZ TYPE DTL

In the IFMIF reference design [1] the main parameters of the linear accelerator facility like frequency, energy and beam current have been fixed (See Table 1).

Table 1: Reference beam parameters for an IFMIF linac.

	Source	RFQ	DTL
I_{out} [mA]	150	140	125
W_{out} [MeV/u]	0.05	2.5	20.0
$\varepsilon^{RMS,N}$ tran. [cm×mrad]	0.02	0.04	0.04
$\varepsilon^{RMS,N}$ long. [cm×mrad]	0.00	0.08	0.08
Frequency [MHz]	175	175	175
Beam Power [MW]	5.0		

Design studies have been performed for the RFQ and for a modular built DTL of the Alvarez type, which demonstrated the suitability of the conceptual design .Since that some critical points have been reconsidered: the transition energy between RFQ and DTL was lowered from initially 8 MeV to 5 MeV, to reduce the RFQ requirements. Beam dynamics calculations showed, that the DTL is capable to handle the high current also at this lower injection energy without losses, but a special matching between RFQ and DTL may be required [2,3].

Another open point is the availability of high power rf amplifiers, to feed the accelerator modules including the very high beam load. In a first choice 1.0 MW input power per tank was assumed for the layout of the Alvarez, leading to 6 tanks with 1 βλ spacing in between the tanks. Rf feeding power reserves are needed when the following aspects are taken into account: The calculated shunt impedances of the rf structure may be too optimistic, some power is needed for phase and amplitude regulation and the required cw operation should avoid sparking , which means lower peak surface fields. Therefore different layouts of the DTL have been studied with reduced shunt impedance (-15%), lower rf input power (0.8 MW per tank), reduced Kilpatrick sparking factor (0.9 instead of 1.0) and rf structure losses limited to 50 kW/m [4].

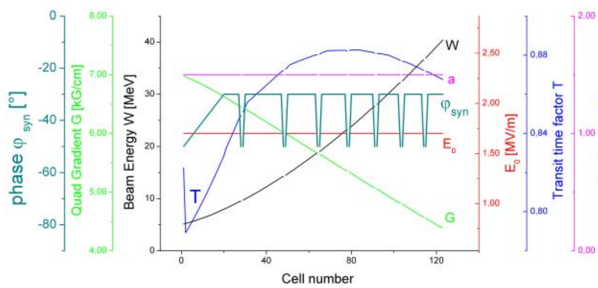

Figure 1: Structure parameter of the DTL as a function of the beam energy.

Fig. 1 shows some of the DTL parameters for the new design: The number of tanks is increasing to 8. Rebunching cells had to be introduced at the input and output of each tank for the preservation of good longitudinal beam emittance. The transverse emittance growth including quadrupole and field errors is sufficiently low, no losses occur along the linac (Fig. 2 and Fig. 3). The calculations have been done with 50,000 particles each.

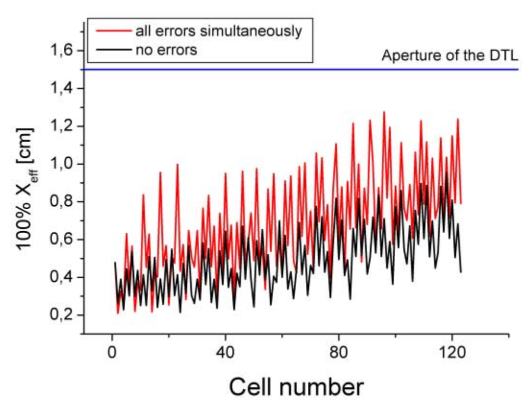

Figure 2: 100% effective beam size in the X-Ncell-plane of the DTL with and without combined quadrupole + rf field errors.

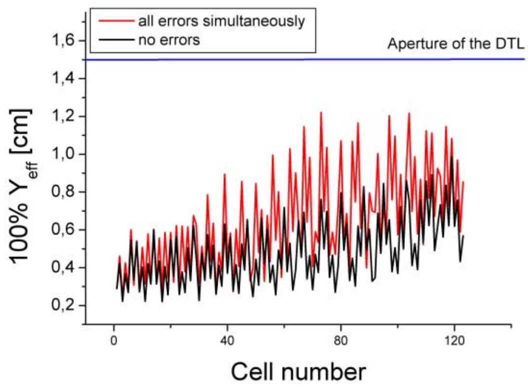

Figure 3: 100% effective beam size in the Y-Ncell-plane of the DTL with and without combined quadrupole + rf field errors.

As a result of this design a certain flexibility in the choice of rf power sources is given now.

2 BEAM DYNAMICS IN AN IH-TYPE DTL

Since several years the IH-type DTL linac has been successfully built and operated for the efficient acceleration of light and heavy ions, e.g. at GSI and CERN [5]. This new type of accelerator combines high acceleration rates with a new focusing scheme called KONUS (**Ko**mbinierte **Nu**ll Grad **S**truktur) and leads to compact accelerators. Therefore this type has been investigated for the use in high intensity machines like IFMIF for the first time. Fig. 4 shows the scheme of an Alvarez- and IH – type DTL for IFMIF in comparison.

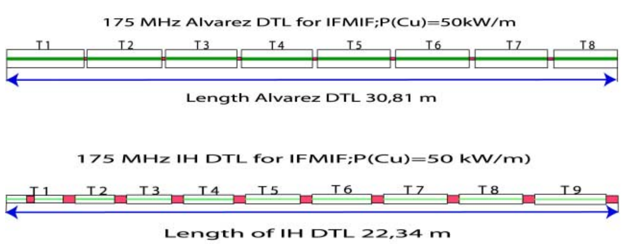

Figure 4: Scaled scheme of the actual Alvarez DTL and IH-type DTL for IFMIF.

Table 2 gives the main parameters of the IH-DTL and Alvarez DTL.

Table 2: Main structure parameters of both DTL's

	ALVAREZ	**IH**
Frequency [MHz]	175	175
Beam Current [mA]	125	125
Transmission [%]	100	100
Number of tanks	8	9
Cell number	123	152
Total length [m]	30.8	22.34
Av. effective E_0 [MV/m]	1.15	1.6
Aperture radius [cm]	1.5	1.5/2.0
B quad [T]	1.0 – 0.6	1.2 – 0.9
$\varepsilon^{N,RMS}$ (x,y) in [cm×mrad]	0.04	0.04
$\varepsilon^{N,RMS}$ (x,y) out [cm×mrad]	0.041	0.070
$\varepsilon^{N,RMS}$ (z) in [cm×mrad]	0.08	0.08
$\varepsilon^{N,RMS}$ (z) out [cm×mrad]	0.083	0.136

In the KONUS scheme the particles are accelerated in a number of gaps with 0 degree bunch center phase which are followed by quadrupole triplet focusing and re-bunching cells with negative phase. In the first tank of the IH-DTL the quadrupole is still integrated in the tank, in the following sections we have intertank quadrupole focusing, which eases the adjustment and maintenance of the quads. Figs. 5-7 show the beam envelopes at full space charge along the DTL calculated with LORASR for the same size of the input emittances as in the Alvarez case. No particle losses were observed with 1,000 macroparticles for a matched input beam, the r.m.s emittance growth is about 75%. More calculations have to be performed with higher particle number and in addition error studies have to be done to investigate the tolerances in detail.

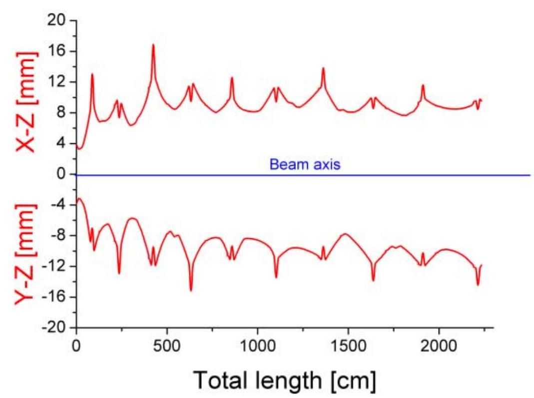

Figure 5: 99% transverse effective beam envelopes of the IH-DTL as a function of the total length.

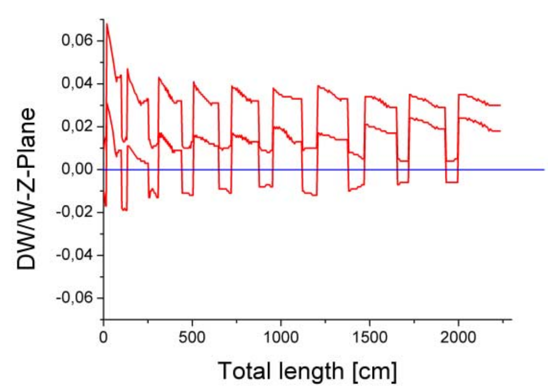

Figure 6: Energy spread of the IH-DTL as a function of the total length.

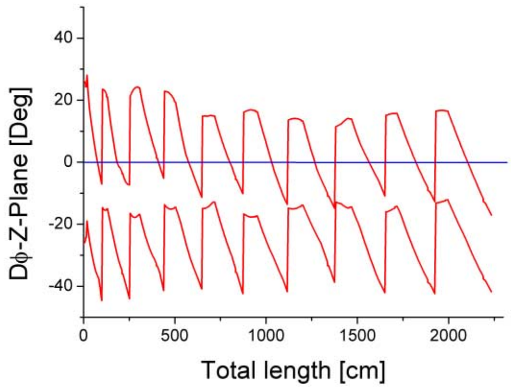

Figure 7: Phase spread of the IH-DTL as a function of the total length.

A possible advantage of the IH-Type DTL could be the lower total power consumption and shorter length of the linac, which can be seen from Figs. 8-10 where the effective shunt impedances, beam energy gain and the sum of copper power losses are plotted along both structures.

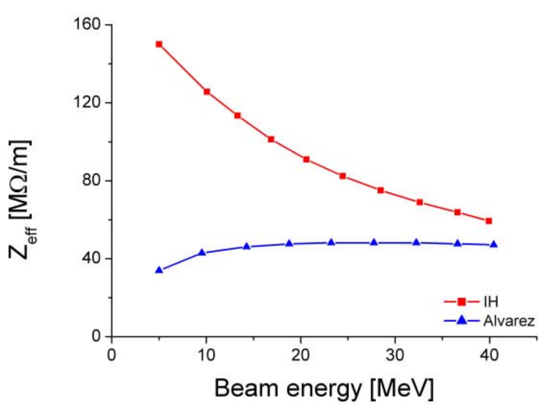

Figure 8: Effective shunt impedances of both structures as a function of the beam energy.

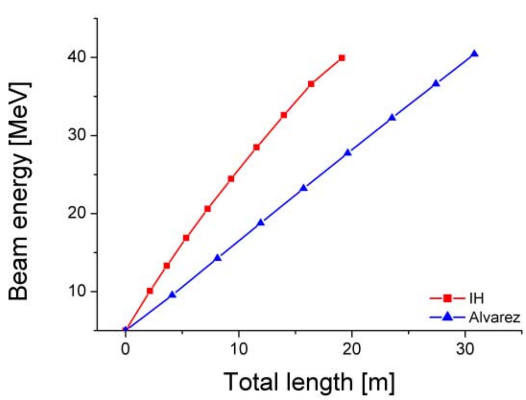

Figure 9: Energy gain of both structures as a function of the total length.

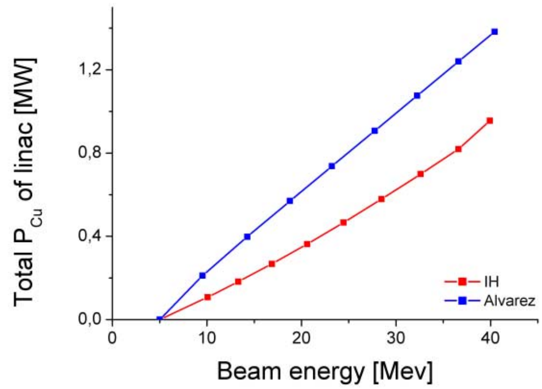

Figure 10: Sum of the rf copper power losses per tank of both structures as a function of the beam energy.

3 SUMMARY AND OUTLOOK

Particle dynamics investigations of the IFMIF DTL showed a rather robust beam behaviour for the Alvarez type DTL of IFMIF. Lower input energy, beam matching and lower input power per tank gave in all cases stable solutions, good emittance conservation and no particle losses even with including standard quadrupole and rf errors and mismatched beams. First beam dynamics studies for the IH-type showed its capability for high intensity acceleration with good power efficiency. Future investigations on stability against matching and field errors have to be done. A further increase in linac efficiency could be gained, if the H-Type structure [6] would be operated at twice the frequency in the second part of the linac.

4 REFERENCES

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[2] N. Pichoff et al., CEA, Saclay, IFMIF Accelerator Team Meeting, Monterey , CA, June 2000, USA.
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