A 100 MEV MULTITANK DRIFT TUBE LINAC FOR PROTON ACCELERATION

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Abstract
Following the demand for a proton beam accelerator capable of accepting protons from a RFQ at about 6 MeV and of accelerating them up to 100 MeV, a new MultiTank Drift Tube Linac (MTDTL) structure has been developed and a detailed theoretical study is being carried out to design such a linear accelerator which already shows some important advantages: technological simplicity, compactness, high efficiency, relative low costs.

1 INTRODUCTION

After the request for a warm pre-injector for the Energy Amplifier [1] was made, a review of the existing possibilities was performed and a modular structure proposed which represented a good compromise between the need to keep the overall efficiency as high as possible and the necessity of a very reliable accelerator, easily aligned and serviced.

A first tentative proposal was presented in Legnaro in the end of October [2] and more detailed calculations were performed for the Preliminar Design Study [3].

The starting point for the proposed MTDTL was that if one looks at the behaviour of the shunt impedance per unit length in a drift tube structure, it is easy to see that its value doesn't change after some meters of RF structure. Having chosen a resonating frequency of 352 MHz, we saw that, with a length per tank between 1 and 2 meters, the shunt impedance per meter already stays over 80% of its maximum value. The possibility of reducing the quadrupole number and of keeping them outside of the tanks allows, on the other hand, an increase in the effective shunt impedance, which contributes to increase the efficiency.

The segmentation as it has been designed follows the decision of limiting the maximum RF power per tank at 200 kW, to allow the adoption of coaxial feedthroughs [4]. The aim of simplifying the RF power distribution system, by means of coaxial components as far as possible, we expect will be justified by a reduction in the whole plant complexity.

A prototype tank has been built to have a comparison between the parameter values calculated by Superfish [5] and the actual ones, to check some technological solutions and to study the gap field stabilization. At present the first measurements performed already seem to support the assumptions made for the calculations.

2 THE ACCELERATING STRUCTURE

The injection energy has been chosen equal to 6 MeV, but it can be lowered to 4.5 or 5 MeV in order to adjust the compromise between good efficiency of the RFQ injector and a reasonable DTL injection energy.

As it is known, the defocusing effect of an RF gap is more effective in the low energy end of the accelerating structure, it is then convenient to increase the beam energy as fast as possible; on the other hand the aim of keeping the focusing quadrupoles outside the accelerating tanks led to a compromise regarding the tank length and the number of RF gaps per tank. Another factor which has been taken into account is the limitation of the longitudinal emittance growth, whilst keeping a smooth variation of the longitudinal phase advance. This has been obtained by modulating in a convenient way the energy gain per gap in the first tanks by acting on the transit time factor according to the $\beta\gamma$ variation of the beam. Since the beam losses have to be kept at the lowest possible value, the influence of so called parametric resonances must be minimized, limiting the large value increase of the beam transverse amplitudes; this has been pursued by matching the 30 mA beam keeping the transverse tune depressions in the range of $0.85 \div 0.9$.

The triplets of quadrupoles have been placed in the intertank space which varies along the Linac from 3 to 2 $\beta\lambda$; in the future optimization of the MTDTL a considerable reduction of this space is foreseen, to gain in compactness.

In the following figure the energy gain per meter is reported as a function of the accelerator length.

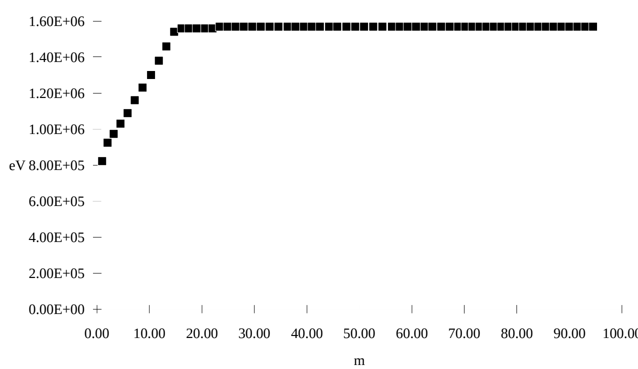

Figure 1: Energy gain per meter vs. MTDTL length.

The whole accelerator is divided into 58 tanks, with a variable number of RF gaps, the tank radius ranges from 0.25 to 0.31 m and it is planned to have not more than three different families of tanks of different diameter, in order to standardize the tank production. Table 1 summarizes the structure parameters, which have been divided in two regions: up to 30 MeV beam energy and from 30 to 100 MeV.

Energy sections (MeV)	6 to 30	30 to 100
Number of tanks	18	40
Tank length (m)	0.7 ÷ 1.2	1.0 ÷ 1.3
Number of gaps / tank	5 ÷ 8	3 ÷ 5
Tank radius (m)	0.31	0.25
Bore radius (mm)	10 ÷ 15	10
Total length (m)	24.9	62.1
Resonating frequency (MHz)	352	352
ZT^2 (MΩ/m)	24 ÷ 32	32 ÷ 33.5

Table 1: RF structure parameters of the MTDTL

Some linear beam dynamics simulations have been performed up to the energy of 30 MeV by means of the code TRACE-3D[5] and in the following table the values of the parameters have been reported, together with the values at 100 MeV, which have been extrapolated.

Energy sections (MeV)	6 to 30	30 to100
Energy in (MeV)	6.0	30.76
Energy out (MeV)	30.76	101.
Synchronous phase (deg)	- 60 ÷ -30	- 30
Field gradient (MV/m)	1.2 ÷ 2.0	2.0
Transit time factor	0.8 ÷ 0.91	0.91
Beam current (mA)	30	30
Input ε_{xy} (π mm mrad) n. RMS	0.35	0.355
Output ε_{xy} (π mm mrad) n. RMS	0.355	0.357
Input ε_z (π deg MeV) n. RMS	0.25	0.4
Output ε_z (π deg MeV) n. RMS	0.4	0.46

Table 2: Beam parameters in the two energy sections.

The estimation of non linear effects is under way by means of the code PARMILA [5]; the beam dynamics through some tanks has already been calculated, confirming the results from TRACE-3D, some more time is needed to complete the simulations.

Some efforts have still to be performed to improve the longitudinal matching between different tanks, especially in the low energy end of the MTDTL; as regards the beam transport, good transverse beam control has been found keeping the quadrupole gradient inside the 30 to 60 T/m range.

3 THE PROTOTYPE TANK

A prototype tank has been built to check the Superfish simulations which have been performed on the first tank of the MTDTL; the TM_{010} field lines are drawn in the following figure, the real tank dimensions are 0.686 m length and 0.312 m radius.

This is a quite simplified tank, lacking the actual RF feedthrough, stems and tuner, but it is consistent with the geometry used in the Superfish calculations, so that the scaling factor can be considered a realistic one.

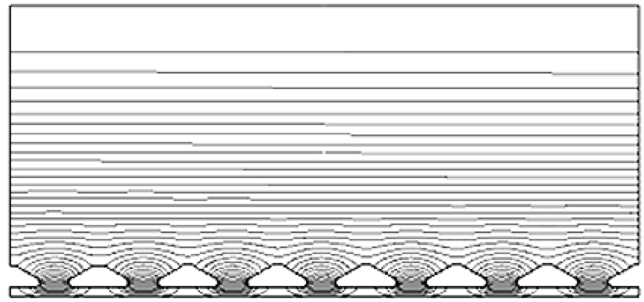

Figure 2: TM_{010} Electric field lines in tank #1

In the following table the calculated parameters are compared with the measured ones, it must be stressed that the 20% of difference in the measurement of the unloaded Q is the expected one with this kind of program.

TANK #1 PARAMETERS	Superfish	measured
Resonating frequency (MHz)	352.04	351.97
Unloaded Q	54263	43883
r (MΩ)	22	17.8
ZT^2 (MΩ/m)	32	25.9

Table 3: Comparison between Superfish and the measured parameters on Tank #1

The value of r, in table 3, is given by the product of ZT^2 times the tank length.

As is pointed out in another contribution in this conference [4], the calculation of the power requirements has been done in a conservative hypotesis and has led to consider for this first tank the value of 16.5 MΩ as the effective shunt impedance.

4 CONCLUSION

The proposal of a Multi Tank Drift Tube Linac which has been presented must be considered a very preliminary one and still a lot of work has to be done. We have verified the simplicity of the alignment procedure, which can be done on bench quickly and with very high accuracy. The modular solution seems to be extremely good as regards technological simplicity and efficiency and we have verified that a reasonable beam dynamics is possible. The crucial point will lie on the RF plant costs which seems to be the conclusive topic in the final choice.

REFERENCES

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