DESIGN OF THE IPHI DTL

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Abstract

The medium energy (about 3 to 20 MeV) part of the new generation of high power, cw proton linacs offers a wide range of choice between different type of machines (separated tank DTL, CCDTL or standard Alvarez). For the IPHI project a 5 to 10 MeV DTL following a 5 MeV RFQ has been chosen. This is a ramped-gradient machine designed to incorporate an intrinsic field ramped without the need of the post-couplers, which are used only for stabilisation purpose. Cell geometry has been first optimised to house realistic quadrupole electromagnets, and then to maximise the effective shunt impedance. An error study using the multiparticle code PARTRAN allowed to choose an aperture for the drift tubes and to define alignment tolerances of the quadrupole magnets. This paper describes the conceptual design of this DTL and its perspectives of evolution. The mechanical and QP magnet aspects of a 3-cells hot model in construction are also described.

1 INTRODUCTION

The IPHI project is a 10-MeV demonstrator for a future high power cw proton linac [1]. It is an injector accelerating 100 mA of protons up to 10 MeV with a 100-keV ECR source [2], a 5-MeV RFQ [3], and a 10-MeV DTL. The source is operational since several years and the RFQ is being built.

The DTL design is in progress, and a 4-cell prototype is being built to test the technological feasibility, quadrupole magnet design and fabrication, vacuum problems, cooling, mechanical aspects, etc.

2 GENERAL DESIGN [4]

Table 1: Main parameters

Current	100 mA CW
Number of cells	53
Length	5.75 m
Copper power losses	306 kW*
Efficiency	71%
Phase law	-45° to -30°
Electric field law	1.08 to 1.75 MV/m
Max. Field (Kilpatrick)	0.9
Output energy	11.6 MeV
Frequency	352.21 MHz

* including 25% SUPERFISH margin.

2.1 General design

The IPHI DTL designed for 1 MW total RF power at 352 MHz is of the ramped-gradient type. Its main features are shown on table 1.

To design the cells and tank, GENWIN2, a DTL generator written in CEA, has been used. It allows to generate a DTL structure according to field and phase laws, quadrupole design and other parameters.

It is intended to obtain the field law by adjusting the local frequency law in each cell; in this case the post-couplers only have a stabilising effect and receive less power [5].

Table 2: Quadrupole tolerances

Misalignment	+/- 51 µm
Transverse rotation	+/- 2.5 deg
Longitudinal rotation	+/- 0.3 deg
Gradient	+/- 0.5 %

Quadrupole error studies have been done using the 100,000 particles distribution coming out of the RFQ. The studies have been done with 1,000 simulations of combined quadrupole errors (misalignment, transverse and longitudinal rotations and gradient error). Table 2 exhibits the tolerances needed to avoid particle losses for a 13 mm diameter drift tube aperture (beams losses in these conditions should be lower than 1nA).

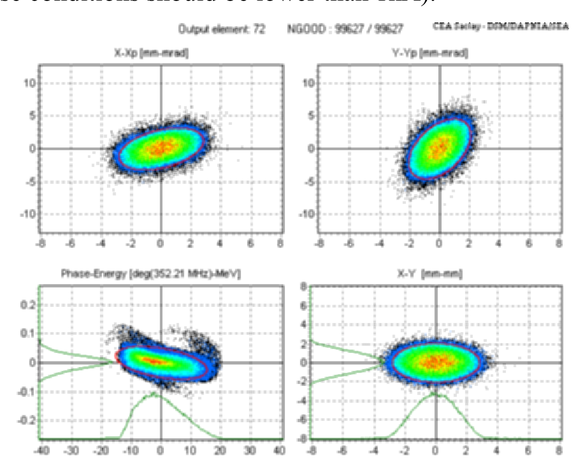

Figure 1: Output beam distributions.

2.2 Beam dynamics

Beam dynamics has been calculated with an output simulation of the RFQ as input distribution in PARTRAN with a 3D space charge routine (PICNIC). A matching line (4 quadrupoles and 2 bunchers) has been included in order to match the beam to the DTL. The output beam

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distribution is shown on figure 1.The emittances are given on table 3.

Table 3: RMS emittances (π.mm.mrad normalized)

Plane	Input	Output
x-x'	0.255	0.257
y-y'	0.255	0.259
z-z'	0.362	0.396

3 QP MAGNET DESIGN

The requirements for the first (shorter) and the 37th (higher gradient) DTL quadrupoles are summarised on the table 4.

Table 4: Quadrupoles data

	1st quad	37th quad
Gradient (T/m)	-64.36	82.39
Gradient x Magnetic length (T)	3.67	4.70
Max length (mm)	48.0	
Max outer diameter (mm)	140.0	
Min aperture (mm)	16.0	

It has been decided that all magnets will be same sized to allow some standardisation and to reduce the size of the drift tubes and then to improve the shunt impedance.

Two types of QP magnets have been designed and built to be tested in the 4-cells hot model. Outer dimensions are the same for both models as the size requirements are the same. The magnets are shown on figure 2.

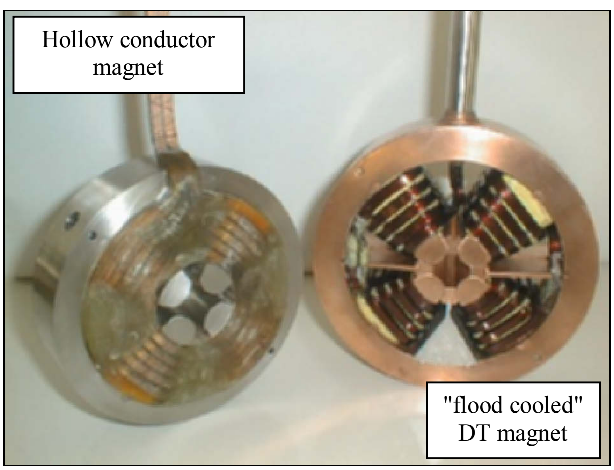

Figure 2: Prototype magnets.

The first one is a standard, hollow conductor QP magnet whose poles and yoke are made up of iron cobalt "Permendur" alloy.

The second QP magnet uses iron poles and yoke and two layers of non-hollow flat conductors. The coolant is external to the conductor and floods the whole inner part of the drift tube.

The advantages of the first design are the well-established reliability and efficiency. The advantages of the "flood cooled" design are:

- compactness and optimisation of the available space;
- optimisation of the conductor section and length for minimising the power consumption;
- single coolant channel for both DT and QP cooling;
- simplification of the drift tube mechanical design leading to a significant cost reduction.

The quality of the magnet cooling has been experimentally verified (without RF power but at full magnet power) using thermocouples and a pyrometer. No hot spots have been found on the magnet conductors. Therefore only the corrosion and erosion resistance of the magnet and relative thin drift tube (2.5-mm) envelope remains a major concern. Poles and yoke are electrolytic copper plated to avoid electrochemical corrosion but the water flow can be damaging over a long period.

4 MECHANICAL DESIGN

4.1 General

The 10-MeV DTL should be 6-meters long and include 51 drift tubes ranging from 62 to 114 millimetres long. Power losses range from an average of 2.3 W/cm^2 on the tank walls up to 10 W/cm^2 on the lower part of the last stem. The total copper losses are 306 kW (147 kW on the stems and drift tubes and 159 kW on the tanks walls and end caps) [4].

As IPHI is intended as a demonstrator for future industrial applications with reliability as a major concern, well established techniques should be preferred over more experimental ones, but cost is also a matter of interest.

A 4-cells hot model is being built to test mechanical features of the future 10-MeV DTL. Three drift tubes of the shortest (5-MeV) type, symmetrical and identical, are included, two of which contain the magnets previously described. The third drift tube contains thermocouples only. RF power will produce the highest axis fields (1.75 MV/m) of the final DTL in both four cells. The vacuum system is also the nominal one with a design vacuum of 5.10^{-6} Pa.

4.2 Drift tube designs

Two kind of drift tubes, externally totally identical, have been designed and built. Both of them are made of massive OFHC copper.

The first one, designed by AES [6], is a conventional drift tube whose stem is made of three coaxial copper tubes: one for the cold water in, the second for the hot water out, and the last for magnet hollow conductors in and out. Only the outer diameter of the drift tube is cooled directly by two counter-flowing water channels. The end caps of the drift tubes are only cooled by heat conduction. An exploded view of this drift tube drift tube is presented on figure 3.

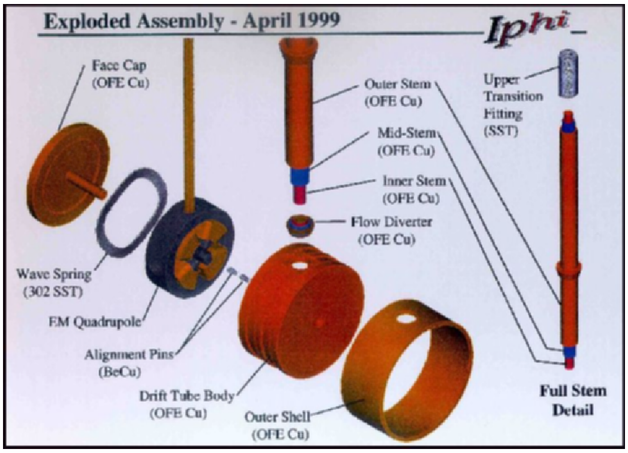

Figure 3: Exploded view of the conventional drift tube.

The second drift tube is more simple. The stem is made of two coaxial tubes (the inner one is made of stainless steel) for the water coolant and magnet conductors. The drift tube itself is made of only two pieces. The coolant circulation around the magnet is shown on figure 4.

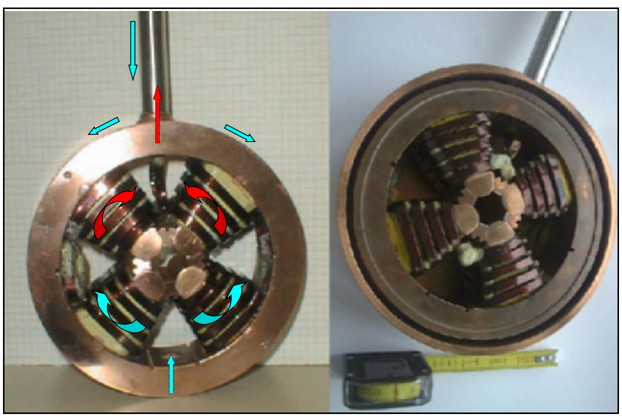

Figure 4: Flood-cooled drift tube. *Left:* coolant circulation around the magnet (blue: cold water in, red: hot water out); *right:* magnet inside the drift tube.

Both models of drift tubes are electron-beam welded. Welding of the flood-cooled type is easier as there are fewer pieces, and as the difficult welding of the "diverter" part (see figure 3) is avoided.

Generally speaking, the flood-cooled drift tube is cheaper, easier to manufacture, and its cooling is better as all inner surfaces are in direct contact with the coolant. Moreover, the stem can be of smaller diameter as the magnet conductors are smaller and there is only one inner stem tube (against two for the standard model).

4.3 Tank design

The tank is designed to minimise thermal expansion and thus to avoid frequency drifts and axis electric field tilts. Cooling is therefore a major concern.

Therefore two major solutions have been considered: full copper tank and copper plated steel tank.

The full copper solution is not considered for now due to the problems associated with the welding of great dimension and relatively thick copper pieces.

The hot model will therefore be made of steel, with internal electrolytic copper plating. Several technologies are studied to enhance cooling: thermally sprayed copper, thick electrolytic copper plating, copper clad steel…

The drift tubes are mounted on a single girder and their position can be adjusted individually. The junction suppleness is provided by OFHC copper bellows. RF *MAFIA* and thermal computations have been made to ensure that the bellows can endure the RF currents and heat flows in this zone.

Helicoflex™ delta vacuum seals will be used. Copper-beryllium spring RF seals will be also used for the end caps and girder to avoid loss of Q factor.

5 PRESENT STATUS

All three drift tubes including the two magnets have been manufactured. Following copper welding unsuccessful tests, the construction of the 4-cell prototype steel tank will begin before the end of June 2001. Low power and high power tests will be made on the hot model from the end of 2001 till the summer of 2002.

6 PERSPECTIVES AND CONCLUSION

Valuable information has been obtained for the realisation of a cw 352 MHz 10-MeV DTL. Magnet and drift tube feasibility has been established, and a new type of magnet drift tube assembly developed. A technology has also been chosen for the prototype tank, while alternative studies are still in progress. The magnetic alignment system is also being studied.

The magnet design is also being improved to increase its aperture and decrease significantly the alignment tolerances.

7 REFERENCES

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