RESEARCH ON DRIFT TUBE LINAC MODEL CAVITY FOR CPHS*

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Abstract

The CPHS project in Tsinghua University plans to construct a 13 MeV linear accelerator to deliver a pulsed proton beam having an average beam current of 2.5 mA. A Drift Tube Linac (DTL), following a Radio Frequency Quadrupole accelerator (RFQ), will accelerate protons from 3 to 13MeV. The accelerating field and phase of DTL will be ramped to match the longitudinal restoring forces at the end of the RFQ. Likewise, the transverse focusing forces, provided by permanent-magnet Quadrupole lenses (PMQs) will be programmed to match the transverse restoring forces at the end of the RFQ to avoid mismatch and avoid parametric resonances. We will introduce the main physics design parameters of CPHS DTL shortly. And progress on engineering prototyping cavity is presented also.

INTRODUCTION

Large scale proton-accelerator-driven neutron source have been established world-wide. More and more successful experiments, such as neutron scattering, have achieved wonderful results. For education and development in research and industrial application, flexible and compact neutron sources are more suitable. Tsinghua University has launched CPHS project which is a compact yet expandable neutron complex based on 13 MeV proton accelerator. Initially, CPHS consists of a proton linac (13 MeV, 16 kW, peak current 50 mA, 0.5 ms pulse width at 50 Hz), a neutron target station, a small-angle neutron scattering instrument, a neutron imaging/radiology station, and a proton irradiation station [1, 2].

The 13 MeV accelerator consists of a high-intensity proton source, a 3 MeV radiofrequency quadrupole linac (RFQ), and a 13 MeV drift-tube linac (DTL). The DTL is directly connected after RFQ without Medium-Energy Beam-Transport line (MEBT).

Now proton source has established and under test at IMP in Lanzhou. The mechanical design of RFQ was finished also. And an aluminium test section of RFQ was finished too.

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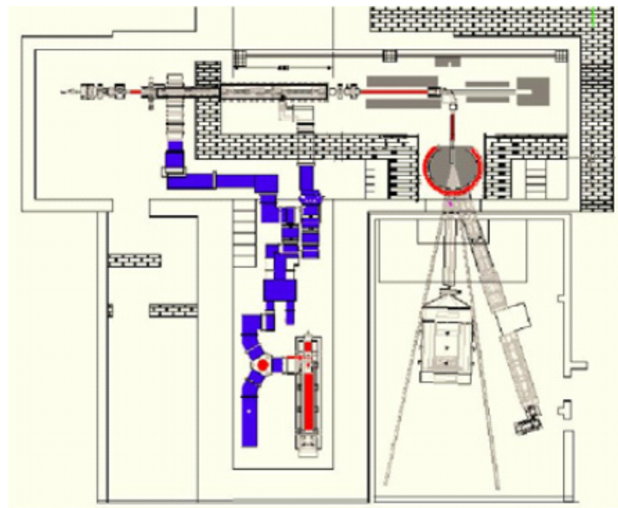

Figure 1: Layout of CPHS project.

The physics design of DTL has finished. And the mechanical design is carrying out. Prototype of drift tube and short cavity with full cross section are under fabrication.

In this paper, the main parameters of the DTL and key point of the physics design is introduced shortly. And progress on engineering prototyping cavity is presented also.

PHYSICS DESIGN OF DTL

The DTL for CPHS accelerates proton beam from 3 MeV to 13 MeV. The DTL is directly connected after RFQ without MEBT.

Based on successful operating of SNS, Permanent Magnet Quadrupoles (PMQs) are adopted in DTL focusing. The magnetic field gradient of the PMQs is programmed to match the transverse restoring forces at the end of the RFQ to avoid mismatch and parametric resonances. The lattice type is FD structure.

The EM field strength and phase are ramped from low to high for match the longitudinal dynamic property at the exit of RFQ.

The main parameters of CPHS DTL are shown as Table 1.

Table 1: CPHS DTL main parameters

Species	proton	
Extraction energy	13	MeV
Extraction peak current	50	mA
RF frequency	325	MHz
RF peak power	1.2	MW
Beam pulse length	0.5	ms
Emittance (norm. rms)	0.2	μm
Entry beam energy	3	MeV
Beam duty factor	2.5	%
Average beam current	1.25	mA
RF duty factor	3	%
Synchronous phase	-30 to -24	degree
Accelerating field	2.2 to 3.8	MV/m
Focusing magnet type	PMQ	
Lattice type	FD	
Quad focusing gradient	6.9~8.9	kG/cm
Cell number	40	
Length	4.4	m

PHYSICS DESIGN

The main goal of the physics design for DTL is capturing proton beam from RFQ exit and accelerating to 13 MeV. At the same time, beam loss should be kept as lower as possible [3]. The principle design was completed by, J. Stovall and others.

Drift Tube Optimization

To ease the fabrication, the bore and outer diameter of drift tubes are chosen to be constant. Phase angle and gap length of the drift tubes is used to optimize for maximum shunt impedance and lower Kilpatrick factor.

The optimized drift tube parameters are shown as table 2.

Table 2: The optimized parameters of DTL drift tube

bore radius	10	mm
inner nose radius	2.1	mm
outer nose radius	6.3	mm
stem diameter	29	mm
drift tube diameter	100	mm
face angle	2.8~16.4	degree
Z*T*T	40~59	MΩ/m

Longitudinal Dynamic Design

Longitudinal focusing strength at the beginning of DTL, K_{0l} is determined by the exit properties of the RFQ. Continuity of K_{0l} helps assure a current independent design.

In addition we match ϕ_s at the end of the RFQ; the target value is -30°. And the objective is to capture entire beam longitudinally. then ϕ_s is ramped to increase acceleration efficiency and without over-focusing the beam longitudinally.

The initial value of E_0 is chosen to meet K_{0l} requirement. Then ramped to maximum value within the sparking limit.

The final design value of ϕ_s is from -30 degree to -24 degree. and the design value of E_0.is from 2.2 MV/m to 3.8 MV/m.

Transverse Dynamic Design

Transverse focusing strength, K_{0t}, in the DTL is chosen to make restoring forces continuous at the RFQ-DTL interface. The continuity of K_{0t} helps assure a current independent design also.

Quadrupole law is chosen to meet a standard design guideline which is to keep the equipartitioning ratio about 1.0 at full current and avoid known parametric resonances.

FD lattice structure is chosen to minimize discontinuity in periodicity and to meet design constraints at all energies.

The length of PMQs is constant. The design magnetic field gradients of the PMQs are from 6.9 to 8.9 kG/cm.

RF Breakdown Analyze

The maximum Kilpatrick factor in DTL design is 1.6 which occurs in the last cell. The Kilpatrick factor of first cell is 0.95 only. The magnetic field at this point is 0.067T when the length of the PMQ is 4 cm. And the value of the electric field at this point is 17 MV/m. This set of data is far below the “Moretti criteria” [4] (Fig. 4).

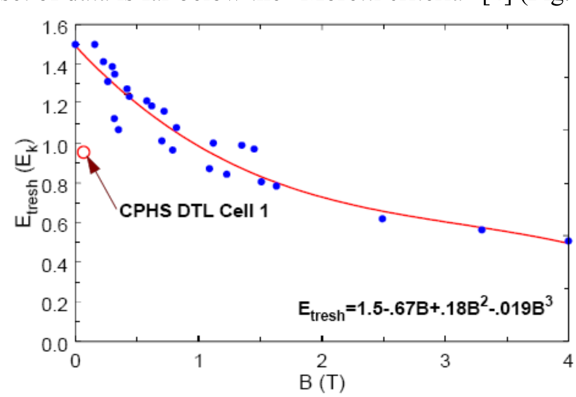

Figure 2: Moretti criteria and CPHS data set.

MECHANICAL DESIGN

The mechanical design of DTL and test parts has been carried out according to physics design. We combined several advantages of SNS and CERN LINAC4 project [5]. The DTL consists of steel cavity, girder support, drift tube and coupler post, etc.

Cavity and Components

The DTL tank consists of two cavities which are made from carbon steel and copper plated inside. The designed thickness of copper plating is 20 μm. 39 drift tubes with stem are hanged on the top of tank. Every third drift tube there is a post coupler for stabilization of the EM field.

9 slug tuners with even distance are used for field and frequency tuning.

A rectangular girder on the top cavity will be used to fix the drift tube.

Model Cavity

A model cavity for test our mechanical design is undertaking now. As shown in Figure 7, it is a short cavity with full cross section same as CPHS DTL design. After fabrication and assembly, we will test vacuum and EM property on it.

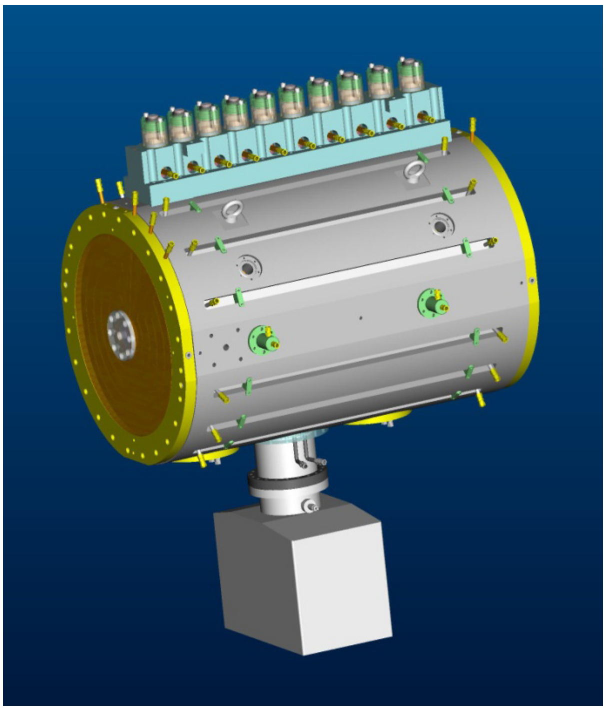

Figure 3: Model cavity of CPHS DTL.

Prototype Drift Tube

Electron beam welding will adopt in drift tube fabrication. But water and vacuum sealing is by normal oven brazing.

Fabrication of drift tubes have been carried out. We have finished oven brazing and EB welding for one prototype drift tube without PMQ in it.

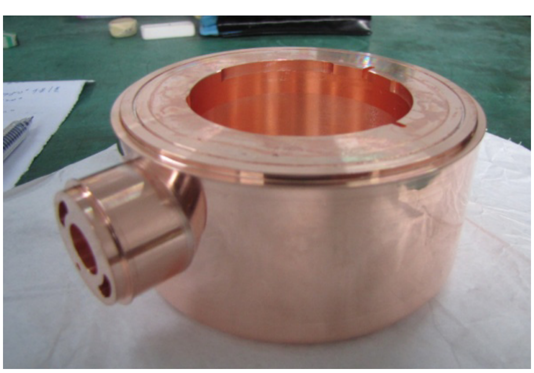

Figure 4: prototype drift tube after brazing.

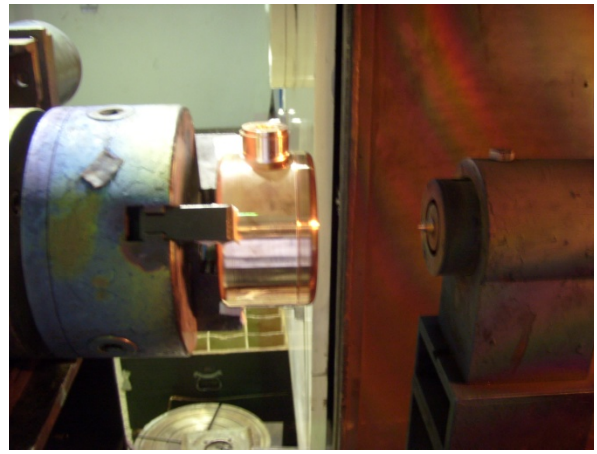

Figure 5: Drift tube on EB welding machine.

CONCLUSION

The physics design of the CPHS DTL has finished. This design meets the requirements of CPHS project well. The transverse and longitudinal matching between RFQ and DTL are good although without MEBT.

The mechanical design for this DTL has been carried out. The design of a model cavity was finished. A prototype drift tube without PMQ inside was fabricated.

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