PROGRESS OF ONE OF 10 MeV SUPERCONDUCTING PROTON LINEAR INJECTORS FOR C-ADS*

Y. He, Z.J. Wang, B. Zhang, S.H. Zhang, Z. XU, W. Wu, J.X. Wu, Z.M. Zhang, J.H. Zhang, J. Meng, A.M. Shi, Z.Z. Zhou, H.W. Zhao, H.S. Xu, Institute of Modern Physics, Lanzhou, China
D. Li, LBNL, Berkeley, California, USA

Abstract

A 10 MeV superconducting proton linac is being design and constructing at Institute of Modern Physics (IMP) of Chinese Academy of Sciences (CAS). This proton linac is one of two injectors for Chinese ADS project. It is to validate one of concepts technical baseline for C-ADS front end, to demonstrate the low beta acceleration, to minimize the risk of key technologies within the Reference Design. It consists of a 2.1 MeV RFQ and two cryomodules hosting 8 HWR cavities. The basic frequency is 162.5 MHz. The physical design of linac and the progress of prototypes for solid-state amplifiers, superconducting solenoids, superconducting HWRs, ion source, and RFQ are presented in the paper.

INTRODUCTION

The China ADS (C-ADS) project [1] is a strategic plan to solve the nuclear waste problem and the resource problem for nuclear power plants in China. The road map is shown in Figure 1. It is a long-term planning till 2032. In the first five years (phase I), the goal of the project is to do the research of key components. The prototypes of high stability proton source, RFQ [2], superconducting cavities and the relative hardware will be developed. A superconducting linac with ~30 MeV proton beam will be demonstrated. The accelerator for C-ADS is a superconducting proton linac. It consists of two injectors with energy of 10 MeV, and a main linac. The two injectors will be identical and hot spare during operation. It is the redundancy of low energy section of accelerator. Due to the technology on low energy superconducting linac is unqualified, the injectors of C-ADS will follow two concept designs. The injector I bases on spoke cavities and frequency of 325 MHz, and the injector II bases on HWR cavities [3] and the frequency of 162.5 MHz. The two injectors will be constructed in parallel by the Institute of High Energy Physics (IHEP) and Institute of Modern Physics (IMP) separately.

Table 1: Main Specifications of C-ADS

Item	Quantity	Unit
Energy	1.5	GeV
Current	10	mA
Beam power	15	MW
RF frequency	(162.5)/325/650	MHz
Duty factor	100	%
Beam loss	< 1	W/m

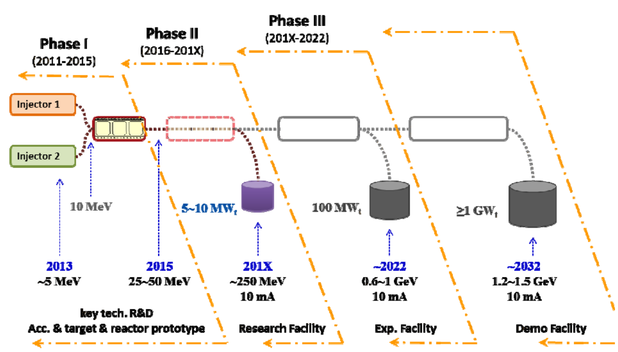

Figure 1: Road map of C-ADS.

PROGRESS OF PROTOTYPES

Conceptual Physics Design

The layout of injector II is shown in Figure 2. The accelerator for C-ADS will operate in CW mode. That is a challenge for RFQ design. Considering the possible thermal-problem of the RFQ, the basic frequency of injector II is selected as 162.5 MHz, the half of frequency of injector I. The main design parameters of injector II for C-ADS proton linear accelerator are listed in Table 2.

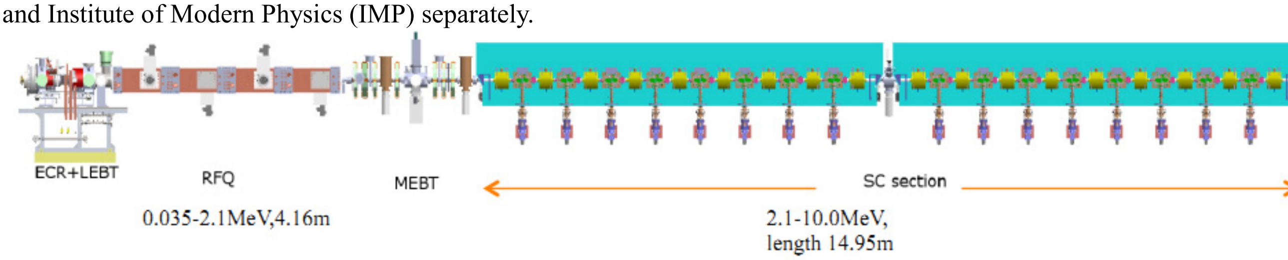

Figure 2: Layout of injector II for C-ADS.

*Work supported by the "Strategic Priority Research Program – Green Nuclear Energy: ADS Transmutation System" of the Chinese Academy of Sciences, Grant No. XDA03020102

ISBN 978-3-95450-122-9

Table 2: Main Specifications of Injector II

	Energy (MeV)	Focusing elements	RF cavity	Length (m)
ECR	0.035	-	-	-
LEBT	0.035	2 r.t. sols	-	1.6
RFQ	0.035~2.1	-	4-vane	4.2
MEBT	2.1	7 r.t. quads	2 r.t. QWRs	2.5
scDTL	2.1~5~10	18 sc sols	16 sc HWRs	14.95

LEBT

The lattice design of LEBT is upgraded for adding a chopper system. This is because beam chopping is very important for the commissioning of the C-ADS linac, when one increases the beam duty factor from very low to 100% step by step. After having studied the very short pulse length operation mode (down to 10 or 20 us) for commissioning the superconducting cavities and the neutralization effect in the LEBT, we found that a chopper at the LEBT end is necessary, significantly better than just using the pulsing of the ion source. The detail layout of the chopping system is shown in Figure 3.

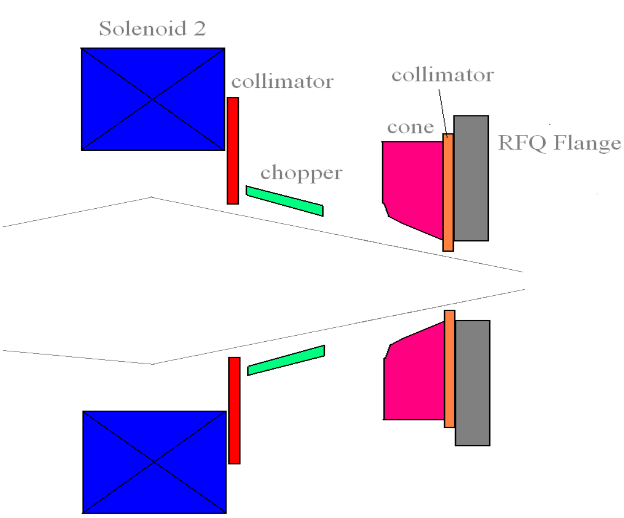

Figure 3: Schematic layout of the fast chopper at LEBT.

The chopping system is located between the second solenoid and the RFQ. The hardware of LEBT has been fabricated. The beam commissioning will be by the end of 2012.

RFQ

The Injector II RFQ is designed to accelerate proton from 0.035MeV to 2.1MeV at 162.5MHz. The main parameters are summarized in Table 3. The mechanical structure is shown in Figure 4.

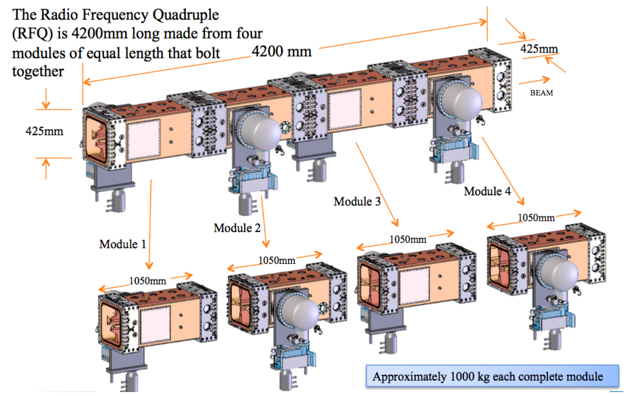

Figure 4: Mechanical structure of RFQ

Table 3: Main Design Parameters for the Injector-II RFQ

Parameter	Value
Inter-vane voltage V (kV)	65
Average bore radius r_0 (cm)	0.5731
Vane tip curvature (cm)	0.4298
ρ / r_0	0.75
Vane length / Total length (cm)	419.2 / 420.8
m_{max}	2.38
Gap1(entrance) (cm)	1.004
Gap2 (exit) (cm)	0.5988
Number of cells	192 (including 2 T cells)
Maximum surface field (MV/m)	15.7791
Synchronous phase	From -90° to -22.7°
a_{min} (cm)	0.3158
Input norm. RMS emittance (x/y, π.mm.mrad)	0.3/0.3
Output norm. RMS emittance (x/y/z, π.mm.mrad, keV.ns)	0.31/0.31/0.92
Overall beam transmission @ 0 /15 mA	99.7% / 99.6%

The RFQ adopts four-vane structure. Considering the dimensions of cavity, four fabrication testing, flying cutter, single vane, 1/4 brazing model, 1/2 full prototype, and an Aluminum model for tuning need to be done in advance. The Al model, 1/4 brazing model, and single vane have been finished. Tuning research on the Al model is on going. The single vane has been machined and the flying cutting tolerance is less than 40 um. 1/4 model brazing has been done in both vacuum and hydrogen finance. The maximum brazing deformation can be controlled less than 100 um. The tolerances are acceptable but still need to be improved. Half size model fabrication is on going. The fabricated testing models are shown in Figure 5. The half model with pi-mode rods, vanes and tuners, also shown in Figure 5, is fabricating in workshops.

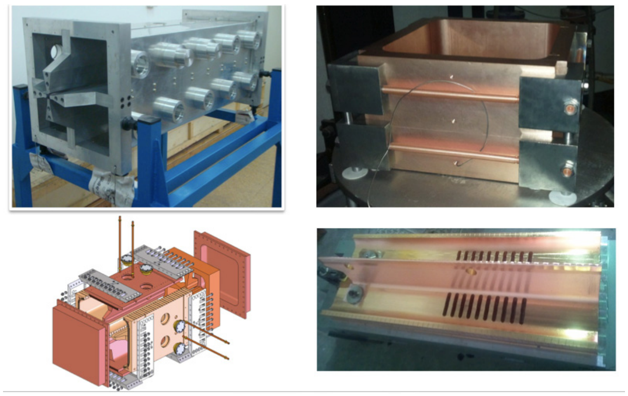

Figure 5: Al and testing models.

Superconducting HWR

The superconducting HWR is designed by IMP. The frequency of cavity is 162.5MHz. The main specifications are shown in Table 4.

Table 4: Main Specifications of HWR

Parameters	Value
F (MHz)	162.0
Gβ	0.09
E_{peak}/E_{acc}	5.34
B_{peak}/E_{acc} (mT/Mv/m)	10.92
R_a/Q_0	148
E_{peak} (MV/m)	25
B_{peak} (mT)	50
E_{acc} (MV/m)	4.7
U_{acc} (MV)	0.78
$G=R_s*Q_0$ (Ω)	28.5
Stored Energy (J)	4
P_{diss} (W)	5.0
Q_0 (4.4K)	1.0E+09

One copper prototype has been fabricated. It was tested in room temperature and liquid nitrogen temperature [2]. The frequency shift 1 atm. and 77 K of liquid nitrogen are 53.59 kHz and 550.6 kHz separately. The tuning sensitive of copper is 150 kHz/mm by calculation and 114 kHz/mm by measurement. The frequency and the field distribution measured by pull-ball are well coincided with the design value. The scissors type tuner works with copper cavity and measured together. The frequency in MHz changes with motor movement in mm is shown in Figure 6.

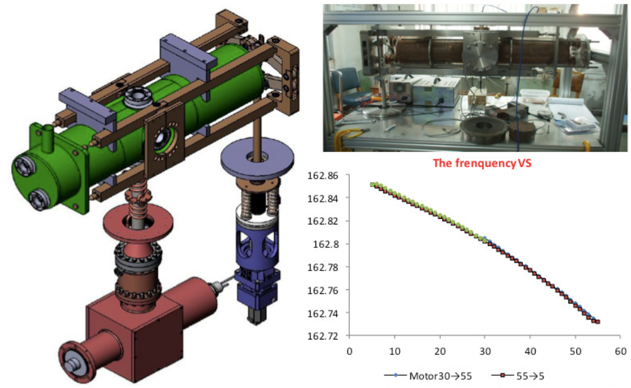

Figure 6: Tuning of copper model.

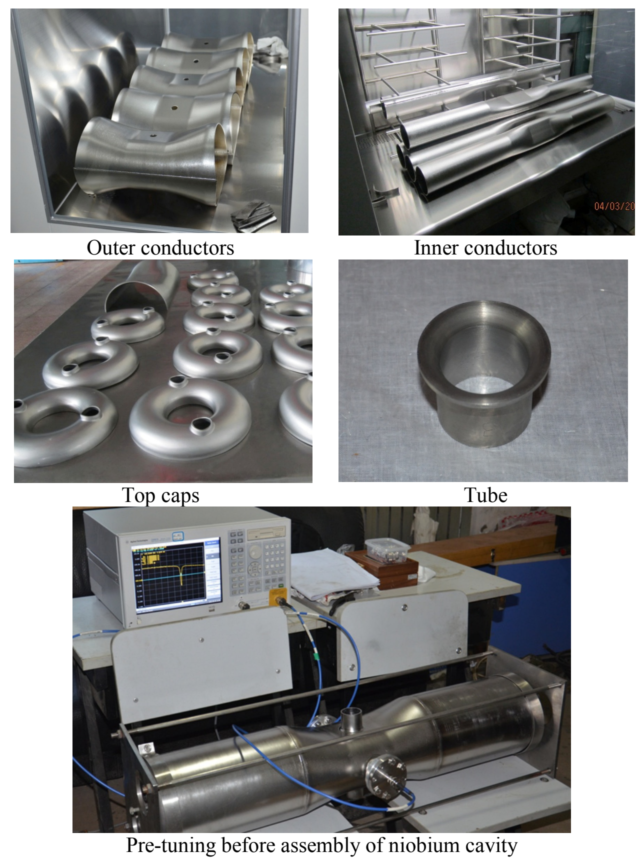

Figure 7: Prototype of niobium cavity.

The progress of niobium prototype is shown in Figure 7. The parts of cavity were prepared. It was pre-tuned to achieve right frequency. The first batch cavities will be welded by the end of the September 2012. Only BCP and HPR are considered during the surface preparation.

REFERENCES

[1] J.Y. Tang, et al., "Conceptual Physics Design on the C-ADS Accelerators", internal report, 2012

[2] B. Zhang, et al., "Fabrication test for IMP 162.5 MHz RFQ", this proceedings.

[3] W.M Yue, et.al., "R&D of IMP Superconducting HWR for China ADS", this proceedings