PROGRESS OF INJECTOR-I AND MAIN LINAC OF CHINESE ADS PROTON ACCELERATOR*

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Abstract

Supported by the "Strategic Priority Research Program" of the Chinese Academy of Sciences (CAS)， The Chinese ADS project is now on-going based on the collaboration of several Chinese institutions. The proton Linac of Chinese ADS is a superconducting CW accelerator. Its energy is 1.5GeV, with beam current of 10mA. Institute of High Energy Physics (IHEP) is responsible for developing one of the two injectors and is the leading institute for the developing of the main Linac. This paper presents the progress of the key hardware R&D work of Chinese ADS proton Linac at IHEP.

INTRODUCTION

The Chinese ADS project is aimed to solve the nuclear waste problem and the resource problem for nuclear power plants in China. With its long-term planning lasting until 2030th, the project will be carried out in 3 phases: Phase I of R&D facility, Phase II of experiment facility and Phase III of industry demonstration facility. The proton Linac for this project is a CW accelerator adopting superconducting technologies except RFQ in injectors. The design specifications for the Chinese ADS proton Linac are shown in Table 1.

Table 1: Specifications of Chinese ADS Proton Linac

Parameters	Value	Units
Energy	1.5	GeV
Current	10	mA
Beam power	15	MW
Frequency	162.5/325/650	MHz
Duty factor	100%	
Beam Loss	<1 (0.3)	W/m
Beam trips/year	<25000 <2500 <25	1s<t<10s 10s<t<5m t>5m

The Strategic Priority Research Program of ADS is financially supported by the central government and administrated by CAS, focusing on the development of key technologies and construction of a CW proton Linac of 50 MeV with maximum beam current 10 mA.

In the past two years, IHEP paid great effort to Chinese ADS Proton Linac, both accelerator physics design and key hardware development, including CW RFQ, SC spoke and elliptical cavity, HP input coupler, SSA RF power source, SC solenoid magnet, CW proton beam diagnostics, digital power supply, cryogenic system etc.

ACCELERATOR LATTICE DESIGN

The Chinese ADS accelerator (Fig. 1) adopts the design with two identical injectors of 10 MeV, so one can be the hot-spare of the other. At present two different injector schemes are under developing and the final solution will be chosen from them based on the R&D results.

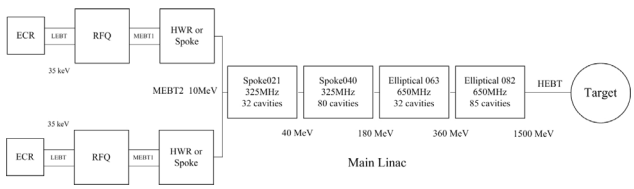

Figure 1: Layout of Chinese ADS Proton Linac.

In the main Linac section, a fully modular superconducting Linac brings the beam up to the final energy with two types of spoke sections (geometry beta=0.21 and 0.40) and two types of elliptical cavity sections (geometry beta=0.63 and 0.82). The main is designed to be intrinsically fault tolerant, which means that an individual cavity or focusing element failure can be handled at all stages without introducing significant beam loss along the Linac by means of local compensation-rematch method. The local compensation-rematch methods for different element failures are studied systematically, it shows that with proper compensation and re-matching, the beam can be accelerated to the final energy without serious beam quality de-rating in the cases of cavity, solenoid and quadrupole failures.

KEY HARDWARE DEVELOPMENT

325MHz RFQ

The RFQ frequency of the injector-I is 325MHz and will operate in CW mode. The design of RFQ and its RF power source has finished and the main parameters of the 325MHz RFQ system are listed in Table 2. Fabrication of the 1st section of the RFQ is finished (Fig. 2) and RF measurement result shows that the design values have been achieved. The fabrication of whole RFQ structure will be completed before the end of June, 2013. According to RF power requirements, Toshiba E37705 600kW 325MHz CW klystron and 80kV PSM power supply are adopted as the RF power source for the RFQ.

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Table 2: Main Parameters of 325MHz RFQ

Parameters	Value	Units
Injection energy	35	keV
Output energy	3.2	MeV
Beam current	10	mA
Beam duty factor	100%	
Total power	320.94	kW
Klystron output	600	kW
PSM output voltage	0-80	kV
PSM output current	18	A

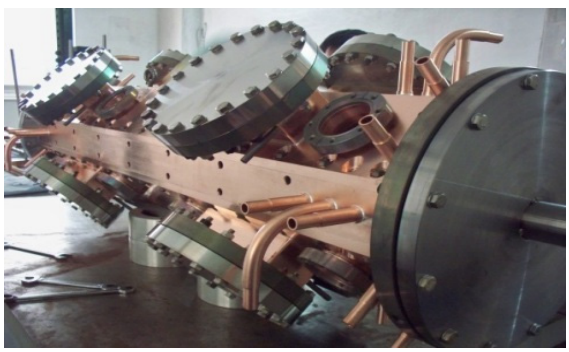

Figure 2: The fabricated 1st section of 325MHz CW RFQ.

Superconducting Cavity

Three types of spoke cavities and two types of elliptical cavities are needed for Chinese ADS accelerator and the main parameters of these cavities are listed in Table 3.

Table 3: Main Parameters of Superconducting Cavities

Parameters	Value					Units
	S012	S021	S040	E063	E082	
Frequency	325	325	325	650	650	MHz
Epeak/Eacc	4.5	325	325	2.6	2.12	
Bpeak/Eacc	6.4	3.78	3.33	4.73	4.05	mT/(MV/m)
R/Q	142	8.07	8.93	304	514	Ω
G	61	193	263	193	235	Ω

Spoke012 Cavity: The 325MHz spoke012 cavity for 3~10MeV injector is the most challenging one, partly because of ambitious technical target and partly because of lack of experience of whole team. Design and fabrication of the first two cavities of Spoke012 (Fig. 3) were completed by IHEP-PKU-HIT joint group. The post-processing and vertical tests of the two prototype cavities finished at the end of 2012. There are no serious multipacting effects observed, and the VT test results are quite promising (Fig. 4).

Figure 3: Two fabricated spoke012 prototype cavities.

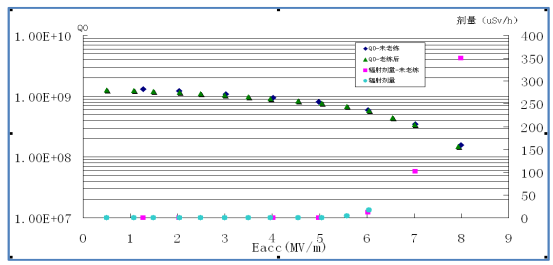

Figure 4: Vertical test result of Spoke012: Q0=5.8x10^8@6MV/m, 4K; Q0=3.4x10^8@7MV/m, 4K

• *Spoke021Cavity:* The 325MHz spoke021 cavity (Fig. 5) has been designed for low energy part of the main Linac, which covers the energy range of 10~40MeV. A set of moderate parameters are adopted, such novel ideas such as simple stiffen ring structure and least welding seam are implanted in the cavity development, and hopes they can help increase the yields on the future mass production. Vertical test is planned in the middle of 2013.

Figure 5: The spoke021 cavities parts.

• *Elliptical082 Cavity:* The 650MHz elliptical082 cavity has been designed for high energy part of the main Linac, which covers the energy range of 367~1500MeV.

Figure 6: Cavity parts for the 650MHz Elliptical082.

Multipacting effect was checked by Track3P and the results show no hard multipacting barrier in the cavity. Figure 6 shows cavity parts for two cavities an EB welding is on-going.

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High Power Input Coupler

Two kinds of high power (HP) input coupler have been fabricated and tested for the 325MHz RFQ cavity and the Spoke012 cavity. The main parameters of input couplers are listed in Table 4. All the couplers feature a Tristan type RF window with one coaxial planar ceramic and choke structures.

Table 4：Main parameters of the HP input couplers

Cavity	Frequency	Power (kW)	Qe
RFQ	325 MHz	80, CW, TW	~5670
Spoke	325 MHz	10, CW, TW	~7.0E+5

Two prototypes of the window and inner conductor assemblies for RFQ input coupler (Fig. 7a) were tested up to 100 kW CW RF power in traveling wave (TW) mode; and two prototype couplers for Spoke012 cavity have been tested up to 10 kW CW RF power in TW mode too. The HP test of Spoke012 cavity input coupler prototype (Fig. 7b) shows good performances and can satisfy the cavity requirements well.

(a) (b)

Figure 7: (a) RFQ input coupler assembly, (b) Spoke012 Cavity input coupler HP test.

Solid State Amplifier

The variable RF power Solid State Amplifier (SSA) is adopted as the RF power source for variable accelerating structures except for RFQ, and main parameters of the amplifier are listed in Table 5.

Table 5: RF power source for the accelerating structures

ACC. Structure	Frequency (MHz)	Power (kW)	Power Source
RFQ	325	600	Klystron
Buncher	325	10	SSA
Spoke012	325	10	SSA
Spoke021	325	20	SSA
Spoke040	325	40	SSA
Elliptical063	650	80	SSA
Elliptical082	650	160	SSA

One 10kW SSA prototype (Fig. 8) has been developed and tested, which is the combination of several 750W base modules. The SSA with higher RF power is going to be manufactured with same topology.

Parameters	Value
frequency	325 ± 3 MHz
Output Power	≥ 10 kW CW
Harmonic	≤ -50 dBc
Random Harmonic	≤ -80 dBc
Amplitude stability	≤ ± 1 %
Phase stability	≤ ± 1 °
Output interface	50 Ù coaxial

Figure 8: Prototype of 10kW SSA.

SC Solenoid Magnet

The superconducting solenoid magnets prototype has been designed and fabricated (Fig. 9). The design current is 210A, and there is no quench occurred up to 400A. The integral field strength, leakage field at the position of neighbouring spoke cavities are all met the design requirements.

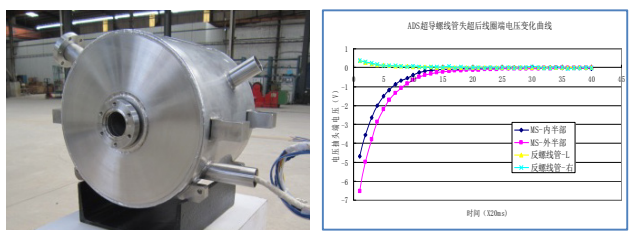

Figure 2: SC solenoid magnet prototype.

SUMMARY

Most of the key technologies for the Chinese ADS Proton Linac key components, such CW RFQ, SC spoke and elliptical cavity, HP input coupler, SSA RF power source, SC solenoid magnet, beam diagnostic devices, digital power supply, cryogenic system etc. are under developing in IHEP and progress well. We are going to construct one 6MeV injector during these two years and CW beam commissioning in 2014.

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