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OVERALL DESIGN AND PROGRESS OF XiPAF PROJECT

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Abstract

Xi'an Proton Application Facility (XiPAF) which consists of one 230 MeV proton accelerator and irradiation stations, will be constructed in Xi'an city, Shaanxi, China. The facility is composed of a 230 MeV synchrotron, a 7 MeV H- linac injector and two experimental stations. It can provide a flux of 10^5~10^8 p/cm^2/s with the uniformity of better than 90% on the 10 cm×10 cm sample. The overall design of XiPAF accelerator is presented in this paper. And the progress of project is reported also.

INTRODUCTION

To fulfil the need of the experimental simulation of the space radiation environment, especially the investigation of the single event effect, the project of Xi'an Proton Application Facility (XiPAF) is under construction in Xi'an City, Shaanxi China. The facility is mainly composed of a 230 MeV synchrotron with a 7 MeV H^- linac injector and two experimental stations. A proton flux of 10^5~10^8 p/cm^2/s with the uniformity of better than 90% on the 10 cm×10 cm sample is designed [1]. Table 1 shows the main parameters of the synchrotron and linac injector.

Table 1: Main Parameters of the XiPAF

Parameter	Injector	Synchrotron
Ion type	H^-	Proton
Output energy (MeV)	7	60~230
Peak current (mA)	5	
Repetition rate (Hz)	0.1~0.5	0.1~0.5
Beam pulse width	10~40 μs	1~10 s
Max. average current (nA)	100	30
Flux (p/cm^2/s) (10×10cm^2)		10^5~10^8

The schematic layout of the XiPAF Accelerator system is presented in Fig. 1. The H^- beam is produced at the ion source (IS), accelerated to 7 MeV in linac injector, and then transferred to synchrotron through Medium Energy Beam Transport line (MEBT). This H^- beam is stripped into protons by carbon foil in synchrotron and it is accelerated up to 230 MeV. Then the beam is extracted to experimental station through High Energy Beam Transport line (HEBT). The HEBT have two beamlines, where T2 is used for 60 to 230 MeV proton application extracted from synchrotron directly, and the T1 can degrade the proton energy from 60 MeV to 10 MeV for low energy application. The lowest extraction energy from the synchrotron is 60 MeV.

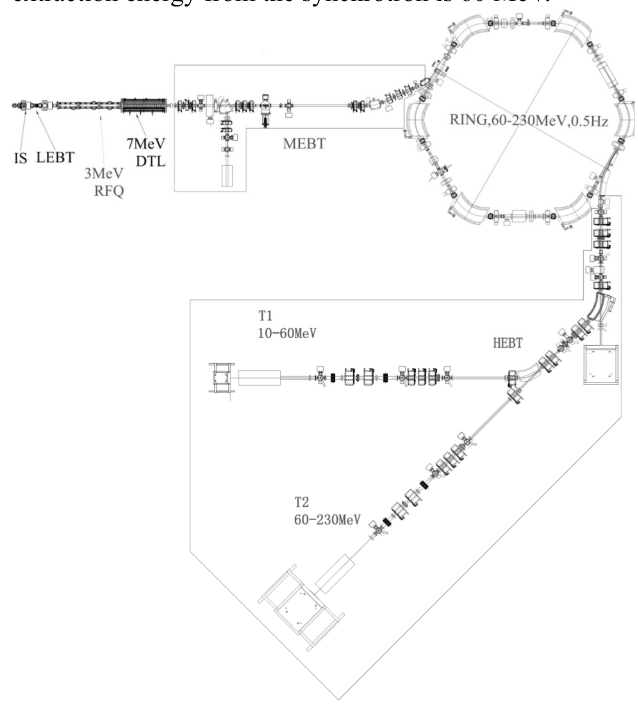

Figure 1: Layout of XiPAF accelerator system.

The main features of this accelerator are listed as follow:

- H^- injection enables transverse space painting flexibility in order to alleviate space charge effects at low energy [2].
- The 6-fold "Missing-dipole" FODO structure simplifies the lattice design and work point tuning. And it supply large space for injecting and extraction.
- The magnet-alloy loaded cavity simplifies the accelerating system and provides wide beam frequency swing.

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- Slow extraction with the 3rd integer resonance can provide stable, uniform and low current for proton irradiation requirement [3].

Synchrotron

Fig. 2 shows layout of synchrotron. The H^- beam is striped into proton beam by carbon foil in injection system of synchrotron, then proton beam is adiabatically captured by RF bucket. The captured 7 MeV proton beam can be accelerated up-to 230 MeV in 0.5 second. The proton beam will be slow-extracted in 1 to 10 s. table 2. List the main parameters of the synchrotron lattice.

Table 2: Main Parameters of the Synchrotron Lattice

Parameter	Value	Unit
Circumference	30.9	m
Dipole effective length	1.6	m
Dipole bending angle	60	degree
Dipole edge angle	30	degree
Maximum beta function(x/y)	5.7/6.0	m
Maximum dispersion	2.6	m
Tune at extraction(x/y)	1.68/1.79	
Chromaticity(x/y)	-0.2/-2.3	
Transition energy	1.64	

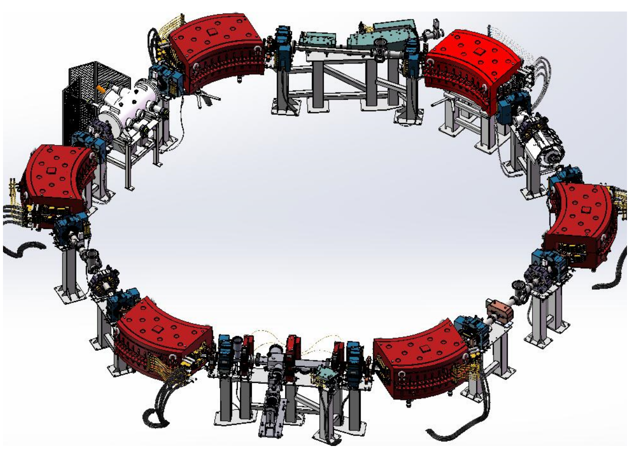

Figure 2: 3-dimension layout of synchrotron.

Injector

The 7 MeV linac injector [4] is composed of the 50 keV H^- ion source, Low Energy Beam Transport line (LEBT), 3 MeV four-vane type Radio Frequency Quadrupole (RFQ) accelerator, 4MeV (from 3 to 7MeV) Alvarez-type Drift Tube Linac (DTL), and the corresponding RF power source system. The designed number of the accumulated protons in each pulse in the synchrotron is 2×10^{11}. We choose the injection energy of 7 MeV for both achievable particle intensity and the cost of the linac injector [4]. Layout of 7 MeV H- injector is shown in Fig. 3.

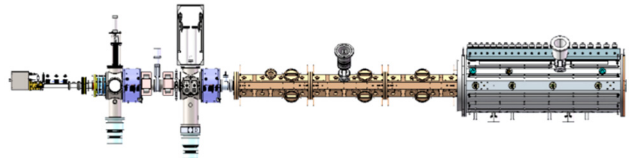

Figure 3: Layout of 7 MeV H- injector.

HEBT and Experimental Stations

The main function of the HEBT is to uniformly irradiate the accelerated proton beam from the synchrotron to the target in experimental station. 2 Step-like field magnets (SFMs) are used for the beam spot homogenization.

PROGRESS

Manufacture of the accelerator equipment were started after Primary Design Review which was held on November 2015. The R&D on key components and technology has been started before the PDR. All components are expected to be finished at the first half year of 2018. Following sections are some examples of project progress.

Permanent Magnetic Quadrupole (PMQ)

PMQs are used in DTL beam focusing. Procedure for high quality and precision PMQ manufacture was established. Special tools are developed for PMQ measurement. HOMs can be controlled under 1%. Fig. 4 is the photo of PMQs.

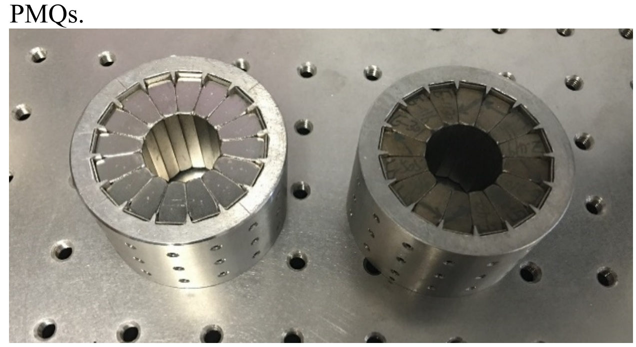

Figure 4: Photo of PMQs.

Magnet-alloy Loaded Cavity

The magnet-alloy (MA) loaded broadband coaxial cavity system is adopted due to its good frequency characteristics and high saturation flux density characteristics.

The main parameters of MA cavity are listed in table 3.. The required accelerating voltage is 800 V.

Table 3: The Main Parameters of MA Cavity

Parameter	Value	Unit
Operation frequency range	1~6	MHz
Acceleration voltage	800	V
Core number	6	
Cavity size		
Length (flange to flange)	630	mm
Outer diameter	550	mm
Inner conductor diameter	120	mm

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Acceleration gap length	30	mm
Core size		
Outer diameter	450	mm
Inner diameter	300	mm
Thickness	25	mm
Electrical parameter (3 MHz)		
Serial inductance (per core)	~1.6	H
Serial impedance (per core)	~57	Ω
Parallel inductance (per core)	~7.3	H
Cavity capacitance	~30	pF
Cavity shunt impedance	~440	Ω
Cavity power consumption	~730	W

The key component of the cavity, large size MA cores, are made in domestic manufacture. Test results show it has good characteristics similar with foreign mature products. The parameters are stable during 3 hour running at 1kV level. And the maximum temperature is stable under 60 degree as shown in Fig5. Fig. 6 is the photo of cavity.

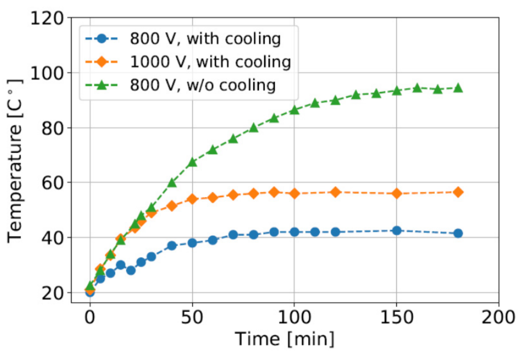

Figure 5: Maximum temperature rising as a function of time with constant gap voltage.

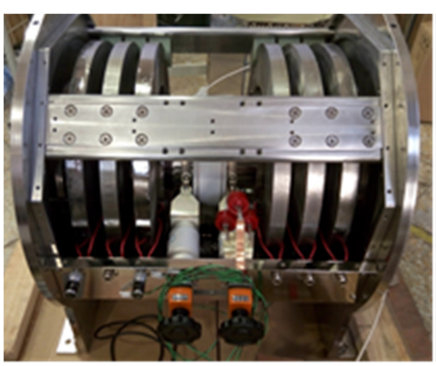

Figure 6: Photo of MA cavity.

Beam Position Monitor (BPM)

Both button type and shoe-box type BPM will be adopted in XiPAF. Fig. 7 are the photos of button and shoe-box BPM.

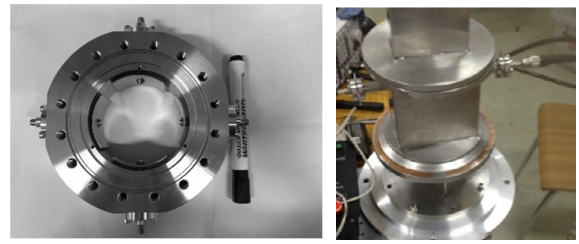

Figure 7: Photos of button (L) and shoe-box (R) BPM.

Button type BPM will be used at MEBT, to measure beam position, energy and current. And prototype has been tested at Compact Pulsed Hadron Source (CPHS) in Tsinghua University. The experimental results show that resolutions of position and phase measurement of XiPAF BPM are better than 60 μm and 0.74°, respectively, and accuracy of absolute position measurement is ±0.34 mm. The prototype satisfies the requirements of XiPAF well.

Shoe-box type BPM will be used in synchrotron. Offline tests show BPM system fulfils all XiPAF requirements.

Slow Extraction at Low Energy

The third resonant slow extraction and RF-Knockout technology was adopted in XiPAF. To fulfil the requirement of irradiation requirement, research on slow extraction at low energy is conducted. Li-tracker, a C++ code for slow extraction was developed. The influence of the quadrupoles/dipoles on extracted spill was investigated in theory and by this code. Some methods other than RF-KO is investigated.

CONCLUSION

The construction of XiPAF is underway after PDR. It is a proton application facility based on 230 MeV synchrotron. The R&D on key components and technology are progressing smoothly. We expect the manufacture of all components can be finished at the first half of next year. And beam commissioning can start at 2018 also.

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