THE COMPACT PULSED HADRON SOURCE CONSTRUCTION STATUS*

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Abstract

This paper reports the design and construction status, technical challenges, and future perspectives of the proton-linac based Compact Pulsed Hadron Source (CPHS) at the Tsinghua University, Beijing, China.

INTRODUCTION

While the 21st century has witnessed outstanding progress in high-power spallation neutron-source projects, noticeably the realization of the SNS (US), J-PARC (Japan), ISIS upgrade (UK) and the ongoing progress of the ESS (EU), and CSNS (China), the development of compact, accelerator-based neutron sources is relatively tardy although their importance, especially in education, user training and R&D of neutronics and instrumentation, has long been recognized. The CPHS project at Tsinghua University started its construction in June 2009 [1]. 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. Currently, fabrication of the accelerator systems has begun. The initial phase of the CPHS construction is scheduled to complete in 2012.

FACILITY LAYOUT

The CPHS main facility is housed in an existing shielded building immediately adjacent to the Tsinghua Thompson-backscattering light source [2] in the main campus of Tsinghua (Fig. 1). The total building area including the main and supporting facilities is about 1,000 m^2. The electrical capacity is 1 MVA. The cooling water capacity is ~2000 l/min. Machine and personnel protection systems are designed to act upon both sudden fault conditions and routine operations. Radiation dosage is limited to 2.5μSv/h at the facility boundary so as to satisfy the 2.5-mSv/yr limit set by the government. Sky-shine and ground water impacts are evaluated accordingly.

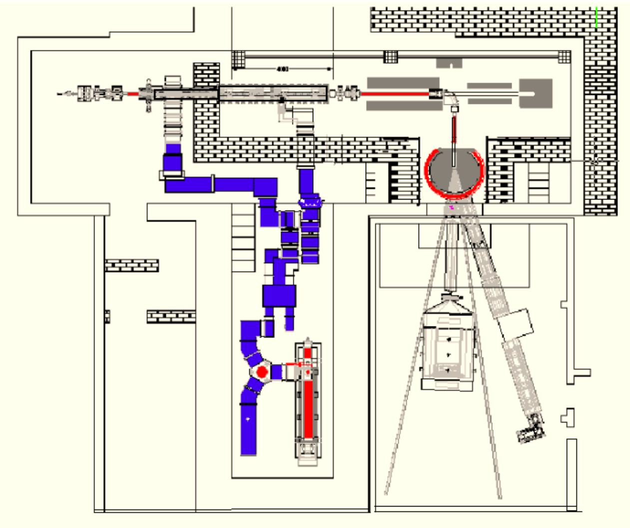

Figure 1: CPHS main facility layout. The building space housing the accelerator and the target station is 6m x 22m. Shaded area shows moveable shielding blocks.

TECHNICAL SYSTEM PROGRESS

Ion Source and Low Energy Beam Transport

The proton beam is produced from the electron cyclotron resonance (ECR) proton source (2.45 GHz, 1.5 kW) and transported through the LEBT (Fig. 2). The H_2 plasma is restricted by an axial magnetic field shaped by the source body of an all-permanent-magnet (NdFeB rings) design. The 50 keV pulsed beam of 0.5 ms length is extracted by a four-electrode system. The 1.3 m long LEBT consists of two solenoid lenses, two sets of steering magnets, and a cone configuration optically matches to the RFQ with the Courant-Snyder parameters of α=1.354 and β=7.731. The design was assisted by Trace-3D [3] and PBGUN [4] simulations for a beam of 97% space-charge neutralization rate reaching the RFQ with 100 mA

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peak current and 0.2 µm rms normalized emittance. This ion source is currently under tests at IMP in Lanzhou.

Radio Frequency Quadrupole (RFQ)

The physical design of the 3 MeV, 50 mA peak-current RFQ was completed revised in late 2009 [5]. With the new design, the length of the RFQ was shortened by about 30%, and the medium-energy-beam-transport (MEBT) was eliminated. The transverse and longitudinal focusing at the high energy end of the RFQ are tailored to match the DTL entry providing continuous restoring forces independent of the beam current. The cavity cross section and vane-tip geometry are tailored longitudinally while limiting the peak surface electric field to 1.8 Kilpatrick. The transmission rate given by the PARMTEQM codes [6] is 97.2%. The transverse emittance increases by ~20% when the beam reaches the RFQ exit. Mechanically, the 3-m long RFQ is separated into three sections of 1 m each to facilitate machining and brazing. Trial fabrication has started at the Kelin Co. Ltd. in Shanghai (Fig. 3).

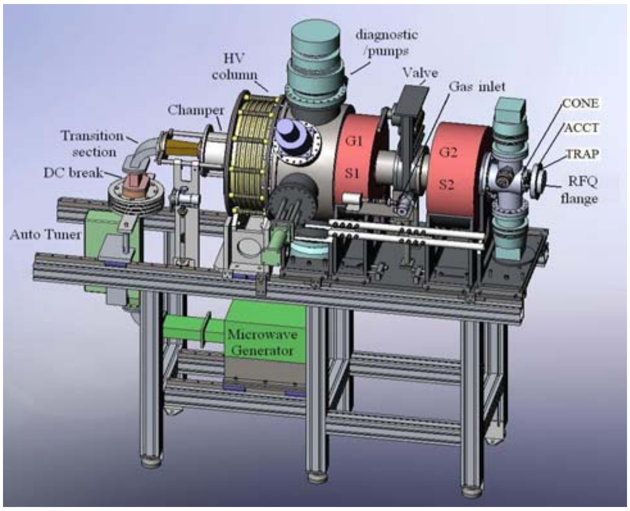

Figure 2: Layout of the ECR ion source and the LEBT.

Drift-tube Linac (DTL)

The physical design of the 13 MeV, 50 mA peak-current DTL was also revised in late 2009 [7] to match the RFQ in the no-MEBT scheme. The 4.4-m long DTL cavity in a FD lattice consists of two sections of totally 40 cells. Permanent-magnet quadrupoles (PMQs) are used for the transverse focusing at the maximum gradient of 0.9 T/cm. The average accelerating field varies from 2.2 to 3.8 MV/m with the maximum surface field up to 1.6 Kilpatrick. Presently, the full cross-section prototype is under construction at the Tsinghua University (Fig. 4).

Radio-frequency System

Both RFQ and DTL share a single RF power source that consists of the signal generator at 325 MHz, amplifier, klystron, high voltage power supply, pulsed modulator, crowbar protection, RF transmission, and control and interlock systems. The RF transmission consists of a power divider with a ratio of 1:2, an isolating attenuator, an isolating phase shifter, and waveguides (Fig. 5). The 2.1 MW peak power from the klystron is split accordingly. The isolating attenuator consists of a 4-port circulator, a Y-junction, a high power load and a sliding short. It can be adjustable for amplitudes from 100 to 80% to meet the 0.6 MW power need of the RFQ. The output of the phase shifter can be adjusted for a range of +/- 45° for the DTL.

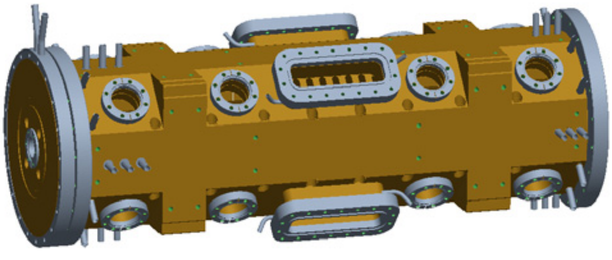

Figure 3: Structure layout of the 1-m long RFQ section 1.

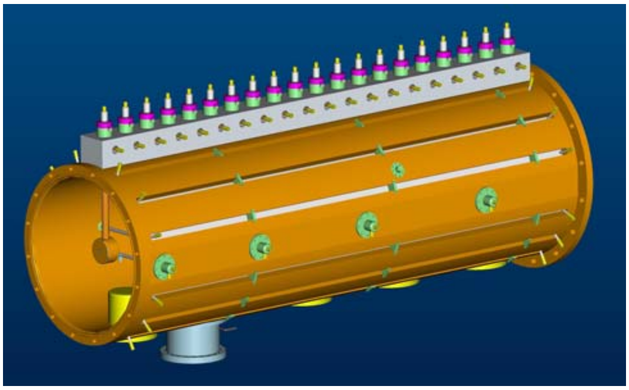

Figure 4: Structure layout of the 2.2m long DTL section 1.

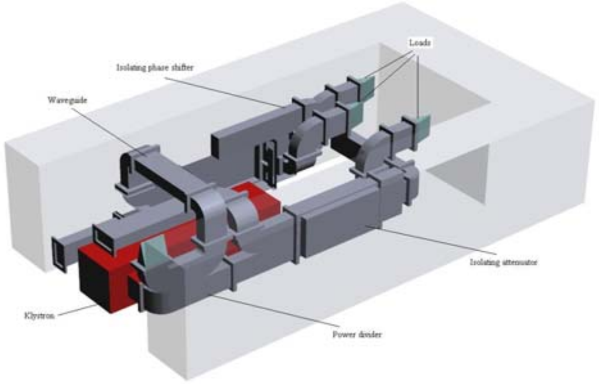

Figure 5: Layout of the RF transmission system.

Neutron Target Station and Instruments

Progresses in the target-moderator-reflector and the cryogenic systems (Fig. 6), the small-angle neutron scattering and the imaging/radiography instruments, the R&D efforts in neutron detectors and choppers have been reported in Ref. [8].

Control System

The CPHS control system consists of the timing/event distribution, EPICS-based distributed run-time database and control, and personnel and machine protections. The timing/event distribution system defines the global system time frame as well as specific events that trigger local devices by an event generator and receiver framework, so that the time delay of each event is controlled in 10 ns resolution, and the timing jitter of trigger signal is below 0.1 ns. The hard-real-time machine protection system is also integrated in the event system so that a fault event is responded within 50 μs. Field control signals like water temperature, vacuum, low level RF phase and amplitude and radiation dose are monitored and controlled via the EPICS database through Ethernet. Currently, system design and prototyping are in full progress.

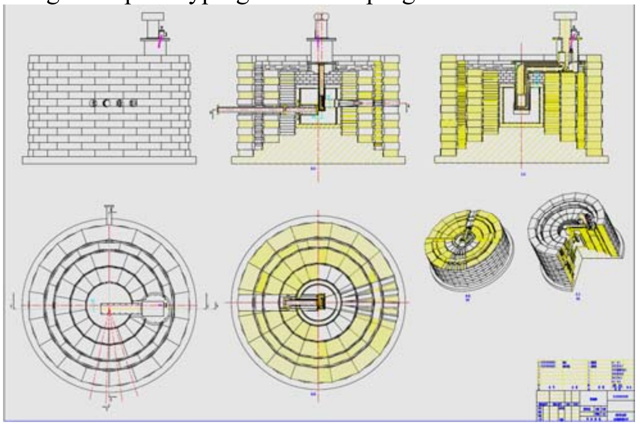

Figure 6: Structure of the Be target station.

FUTURE PERSPECTIVES

In addition to education and academic researches, one of the major goals of developing the Compact Pulsed Hadron Source is to grow the domestic technological expertise and to build-up the team to undertake future related projects and applications. Fig. 7 shows possible extension of a CPHS-like front-end to a multi-purpose hadron accelerator complex, serving one or more application facilities including long-pulse neutron source, short-pulse neutron source, imaging and radiography, irradiation, ion-beam therapy, isotope production, ADS for nuclear-waste transmutation and new nuclear-energy (e.g. thorium) utilization, and rare-isotope research.

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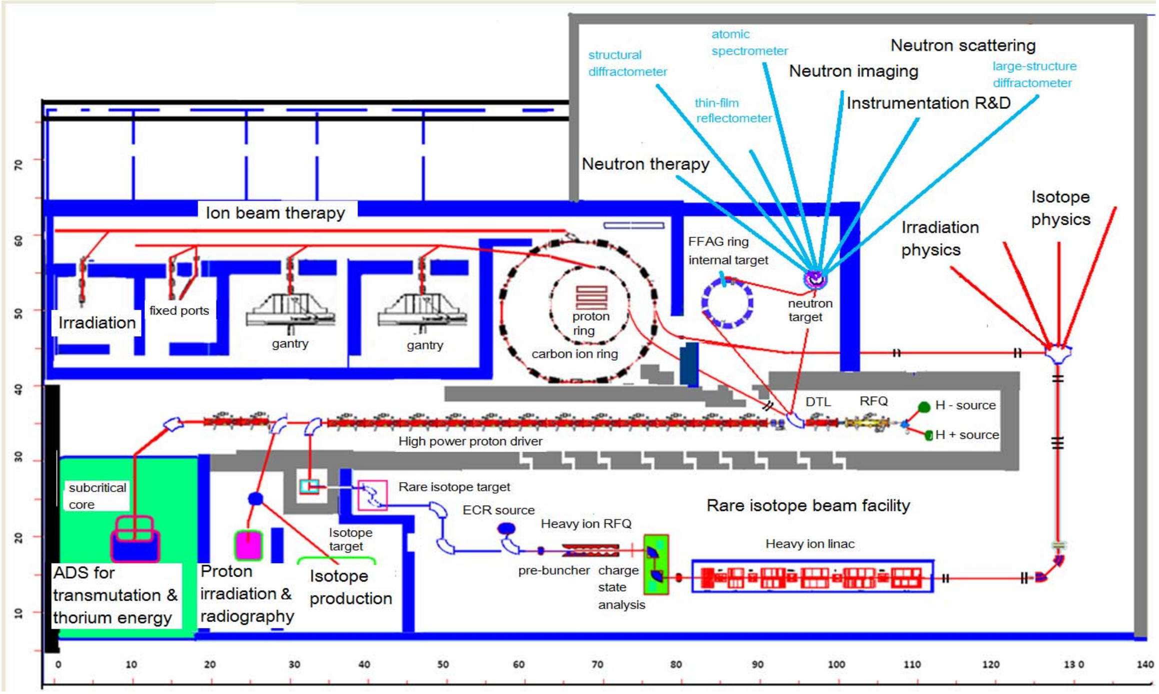

Figure 7: CPHS's possible future extensions including the long- and short-pulse neutron sources, radiography, irradiation, ion-beam therapy, isotope production, ADS applications, and rare-isotope nuclear physics researches.