A PROTON ACCELERATOR COMPLEX FOR SPALLATION NUETRON SOURCE AND OTHER APPLICATION

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Abstract

In order to develop frontier sciences in China a proposal for constructing a proton accelerator complex as spallation neutron source is offered. It consists of a 70 MeV normal conducting linac and a 1 GeV rapid cycling synchrotron, which accelerates a pulsed beam of about 2.5×10^{13} protons per pulse at a repetition rate of 25 Hz. Its average power is 100 kW. The facility will also be used for irradiation tests and isotope production and so on. In future it can be upgraded to 2 MW. Its repetition rate can be converted to 12.5 Hz by the addition of an accumulator ring.

1 INTRODUCTION

Recently proton accelerators have become indispensable tools to progress in fundamental and applied research in many disciplines, such as nuclear physics, particle physics, condensed matter physics, material sciences, life sciences, radiotherapy, nuclear energy research and so on. Among them the spallation neutron source occupy an extremely important place [1,2].

The neutron scattering is a particularly important technique to study the structure and dynamics of condensed matter. By this way, scientists can glean details about the nature of materials ranging from liquid crystals to superconducting ceramics, from proteins to plastics, and from metals to micelles to metallic glass magnets.

In the spallation neutron source the short, high current proton beam pulses from a medium energy accelerator are used to bombard the nuclei of a heavy metal target (often Ta or W alloy), from which neutrons evaporate. These fast neutrons are slowed in moderators around the target. The spallation neutron sources are environmentally friendly compared to reactors. The time structure of accelerator beams offers some experiment advantages and peak neutron intensities can exceed those of reactors.

In order to develop these sciences in China a proposal for constructing a proton accelerator complex – Chinese spallation neutron source (CSNS) is offered. Apart from neutron scattering, it will be used for irradiation tests, production of radioactive isotopes for medicine and so on.

2 RAPID CYCLING SYNCHROTRON

Two main schemes are used for the accelerator for spallation neutron source: short linac plus rapid cycling synchrotron (RCS) and long linac plus accumulator ring (LAR). The RCS demands for high energy and low current. It is just *vice versa* for LAR. We select the RCS because it is cheaper than linac. Table 1 lists the major parameters of the RCS ring.

Table 1: Major parameters of RCS ring

Parameter	Value
Circumference (m)	210
Max. Output energy (GeV)	1
Repetition rate (Hz)	25
Beam current (μA)	100
Beam Power (kW)	100
Protons per pulse (10^{13})	2.5
Energy per pulse (kJ)	4
RF harmonic	1
Peak RF voltage (kV)	120
RF synchronous phase (deg)	0-35
Injection energy (MeV)	70
Injection period (μs)	200
Injection turns	105

The RCS ring has three superperiods. A triplet lattice is adopted for the RCS ring. The long dispersion-free straight sections are used for the radio frequency (RF) system, betatron collimation and fast extraction. The high dispersion regions are used for injection and momentum collimation. A RF system of harmonic number h=1 is adopted for future upgrade to 12.5 Hz option (see 4.1).

A thin Al_2O_3 foil strips away the weakly-bound electrons from the negative hydrogen ions to create proton beams. Raising the injection energy can increase the current limit. But at the higher energy the beam losses at trapping can cause serious induced radioactivity and make maintenance difficult. One way to reduce losses is to pre-bunch the beam by chopping at the low energy or medium energy beam transport section with a chopping rate of 55-75%. It is troublesome and not worthwhile. So we would rather select lower injection energy.

The facility can produce a pulsed neutron beam with a peak neutron flux density of 5×10^{15} n/cm^{2}s at a solid W target of $12\times12\times40$ cm^3 [3].

3 LINAC

A negative hydrogen ion linac is adopted as the injector of RCS. It consists of a negative hydrogen ion source (H^- IS), a low energy beam transport section (LEBT), a 2.5 MeV radio-frequency quadrupole (RFQ), a medium energy beam transport section (MEBT), a 35 MeV drift tube linac (DTL) and a 70 MeV separated type drift tube linac (SDTL). The RFQ and DTL operate at 201.25 MHz and the SDTL operates at 402.5 MHz. But if we hope to use permanent quadrupole magnets in drift tubes rather than electromagnets, the RF frequency of 432 MHz can be chosen for all the accelerating structures.

The linac operates at the repetition rate of 25 Hz and pulse length of 200μs, which can be lengthen to 500μs for future upgrade. The RFQ can accelerate a negative hydrogen ion beam of 22mA. After 35 MeV the SDTL has been chosen for its simpler structure and higher shunt impedance. It has a similar structure to a DTL, except for the quadrupole magnets outside the tank.

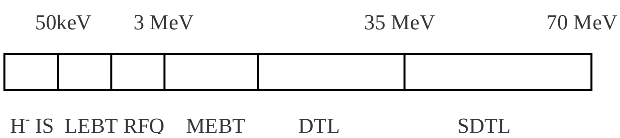

Figure1: The block diagram of the linac

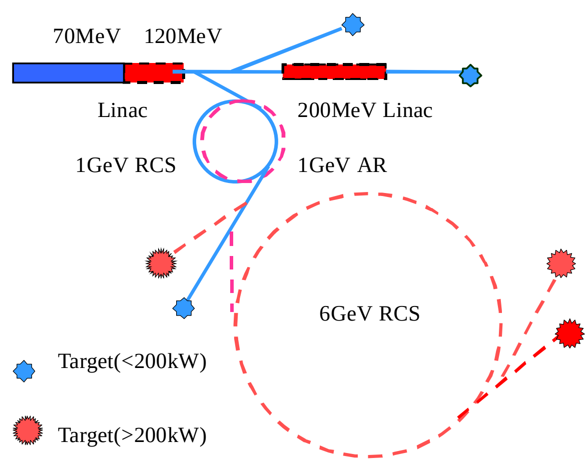

Figure 2: The upgrade options

4 UPGRADE OPTIONS

There are many upgrade options. The following are two examples.

4.1 12.5Hz option

It is similar to AUSTRON 10 Hz[4]. We hope to accelerate more protons per pulse at lower repetition rate. First, the original 1 GeV RCS ring will be upgraded to 50 Hz. For decreasing beam losses a dual harmonic RF system will be installed. In order to increase beam power the linac will be lengthened to 120 MeV and its pulse current will increase to 40 mA. Then an addition of 1 GeV accumulator ring after the RCS ring will convert the beam from 50 Hz to 12.5 Hz. It hold three consecutive RCS pulses in its circumference until a fourth pulse arrives and all the four are sent to the target. It is possible if harmonic number h=1 in the RCS ring. The accumulator ring should have a similar shape and lattice as the original RCS ring in order to be stacked on top of the latter. In this way, a beam power of 340 kW and energy per pulse of 27 kJ can be obtained.

Moreover, the linac can also be lengthened to 200 MeV for proton therapy and other application.

4.2 Upgrade to 2 MW

With the development of science and technology in China, it is necessary to increase beam power of the accelerator complex in future. A 12.5 Hz, 6 GeV RCS ring installed after the accumulator ring can be used to increase beam power to 2 MW and pulse energy to 163 kJ.

The upgrade options are shown in Fig. 2. Their parameters are listed in Table 2.

Table 2: The upgrade options and their parameters

parameters	12.5 Hz option	2 MW option
Max. output energy (GeV)	1	6
Repetition rate (Hz)	12.5	12.5
Beam current (μA)	340	340
Beam Power (kW)	340	2040
Protons per pulse (10^{13})	17	17
Energy per pulse (kJ)	27.2	163.2
Injection energy (MeV)	120	120

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REFERENCES

[1] P. Bryant, Synchrotron-driven spallation sources, Proc. Part. Accel. Conf., 1995, 322.

[2] F. T. Avignone III, T. A. Gabriel (ed), The Savannah river accelerator project and complementary spallation neutron sources, World Scientific, Singapore, 1998.

[3] YAN Qiwei, Internal Report.

[4] P. Bryant et al., A 0.5 MW/10 Hz option of the spallation source AUSTRON, Proc. Part. Accel. Conf., 1999, 2975.