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PRELIMINARY STUDY ON THE INJECTION SYSTEM UPGRADE FOR CSNS-II*

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Abstract

The construction of the China Spallation Neutron Source (CSNS-I) had completed the national acceptance in August, 2018, and opened to users. The physics design of the second phase (CSNS-II) has been started. The CSNS-II accelerator upgrade contains three main parts, including the Linac energy upgrade from 80 MeV to 300 MeV, injection system upgrade, and new Magnetic Alloy dual-harmonic cavities. In this paper, a preliminary study on the injection system upgrade had been done. A preliminary upgrade scheme for the injection system is given. Furthermore, some preliminary simulation and calculation for the upgrade injection system had been carried out. The analysis results showed that most injection parameters can preliminarily meet the requirements of accelerator power upgrade.

INTRODUCTION

The China Spallation Neutron Source (CSNS) is a multidisciplinary platform and its construction (CSNS-I) had completed the national acceptance in August, 2018 [1][2]. The accelerator of CSNS-I consists of an 80 MeV H^- Linac and a 1.6 GeV rapid cycling synchrotron (RCS) with a repetition rate of 25 Hz which accumulates an 80 MeV injection beam, accelerates the beam to the designed energy of 1.6 GeV and extracts the high energy beam to the target. The design goal of beam power is 100 kW [3]. Figure 1 shows the layout of CSNS-I.

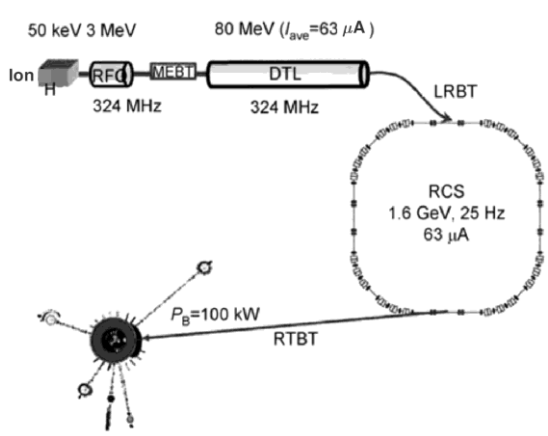

Figure 1: Layout of CSNS-I.

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To improve the beam power on the target from 100 kW to 500 kW, CSNS accelerator needs to be upgraded, including the Linac energy upgrade, injection system upgrade, and new Magnetic Alloy dual-harmonic cavities. Table 1 shows the comparison of the main beam parameters of accelerator between CSNS-I and CSNS-II. It can be found that: the Penning ion source in CSNS-I will be changed to the RF voltage ion source; the Linac energy will increase from 80 MeV to 300 MeV; the average beam current of the Linac will increase from 62.5 μA to 312.5 μA; the protons per pulse will increase from 1.56×10^{13} to 7.8×10^{13}.

Table 1: Comparison of the Main Beam Parameters of Accelerator Between CSNS-I and CSNS-II

Phase	CSNS-I	CSNS-II
Beam power on target /kW	100	500
Linac energy /GeV	0.08	0.3
Extraction beam energy/GeV	1.6	1.6
Average beam current /μA	62.5	312.5
Repetition /Hz	50	50
Protons per pulse /10^{13}	1.56	7.8
Ion Source type	Penning	RF Vol.

With the Linac upgrade, the injection system needs to be to redesign to accommodate the increased injection energy and injection beam current. In the following section, the injection system will be resigned and studied. A preliminary upgrade scheme will be given and discussed.

PRELIMINARY UPGRADE SCHEME OF THE INJECTION SYSTEM

The injection system is the core component of one accelerator and the injection efficiency is an important factor that determines whether the accelerator can operate safely [4]. For the RCS, the injection process determines the initial state of the cyclic beam and has an important influence on the process of beam accumulation and acceleration. The injection beam loss is one of the decisive factors that limit whether the RCS can operate at high power.

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Due to the increased injection energy and injection beam current, the injection system needs to be redesign to reduce the space charge effects and injection beam loss. Based on the injection system design of CSNS-I, refer to the 400 MeV upgrade scheme of J-PARC/RCS injection system [5][6], a preliminary upgrade scheme of the injection system for CSNS-II is given. A lot of new equipments and hardware will be added and replaced in the injection region. Figure 2 shows the preliminary physics layout of the upgrade injection system for CSNS-II. In the Fig. 2, four new dipole magnets BA1-BA4 which can produce a vertical bump will be added to the injection system. With this vertical bump, both correlated and anti-correlated paintings can be achieved at the same time in the position scanning. The vacuum box apertures for the injection channel and I-Dump channel should be increased to reduce the injection beam loss. In order to collect H^- particles which are not stripped by the main stripping foil, the location of the second stripping foil needs to be adjusted and optimized. In addition, a new collimator will be added after the second stripping foil which can control the beam size of the non-stripped particles. An electron collector also needs to be added behind the main stripping foil. Finally, in order to reduce the influence of the edge focusing of BC magnets and BA magnets on the RCS Lattice, BC and BA DC magnets may need to be modified to pulse magnets.

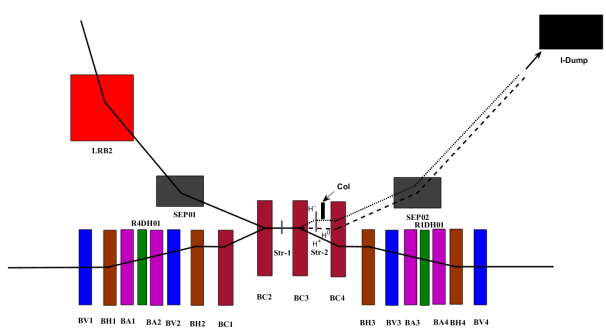

Figure 2: Preliminary physics layout of the upgrade injection system for CSNS-II.

In order to be suitable for the increased injection energy, the physics design parameters of the magnets and power supplies in the injection region needs to be changed. Table 2 shows the comparison of the preliminary physics design parameters of the magnets and power supplies in the injection region between CSNS-I and CSNS-II. It can be found that, compared to CSNS-I, the integrated field strength and current of most magnets and power supplies in the injection region will increase a lot. Therefore, except for the new addition of magnets and power supplies (INBA), other magnets and power supplies (INBH, INBV, SEP1/2, INBC) need to be replaced for the upgrade injection system.

Table 2: Preliminary Physics Design Parameters of the Magnets and Power Supplies in the Injection Region

	BL_{80MeV} (Old)	I_{80MeV} (Old)	BL_{300MeV} (Upgrade)	I_{300MeV} (Upgrade)
INBH	0.0345 T·m	9000A	0.0705 T·m	18500A
INBV	0.0243 T·m	6500A	0.0496 T·m	13500A
SEP1/2	0.3960 T·m	1300A	0.8088 T·m	2700A
INBC	0.0844 T·m	490A	0.1724 T·m	1000A
INBA	----	----	0.08 T·m	----

PRELIMINARY SIMULATION AND CALCULATION FOR THE UPGRADE INJECTION SYSTEM

To further verify the feasibility of the upgraded injection system, by using the codes ORBIT, FLUKA, and ANSYS, some preliminary simulation and calculation have been carried out in this section, including the injection process simulation, the simulation and calculation of the stripping foil scattering [4][7], the calculation of the stripping efficiency and temperature rise for the main stripping foil [8], and so on.

Table 3: Some Results of the Simulation and Calculation for the Upgrade Injection System

Parameters	CSNS-II
Injection turn	430
Injection beam loss	<1%
99% painting emittance (mm·mrad)	250/180
Average traversal number	10
Foil thickness (μg/cm^2)	260
Maximum temperature rise range of the main stripping foil (C)	390～3430
Scattering particles loss of the main stripping foil (W)	4.5

After the preliminary simulation and calculation, some simulation and calculation results for the upgrade injection system can be obtained, as shown in Table 3. It can be found that most injection parameters, such as the injection beam loss, the painting emittance, the average traversal number, the foil temperature rise range and the foil scattering particle loss, can preliminarily meet the requirements of accelerator power upgrade.

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SUMMARY AND DISCUSSION

After the completion of the national acceptance for CSNS-I, the physics design of CSNS-II upgrade needs to start as soon as possible. The injection system upgrade is the core part of CSNS-II accelerator upgrade. In this paper, a preliminary study on the injection system upgrade had been done and a preliminary upgrade scheme had been given. Furthermore, some preliminary simulation and calculation for the upgrade injection system had been carried out. The analysis results showed that most injection parameters can preliminarily meet the requirements of accelerator power upgrade.

It is important to emphasize that the upgrade scheme of the injection system in this paper is just the preliminary study. The scheme needs further study and modification. In addition, the simulation and calculation for the upgrade injection system need to be more in-depth and comprehensive.

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REFERENCES

[1] S. Wang *et al.*, *Chin Phys C*, 33, pp. 1-3, 2009.

[2] CSNS Project Team, *China Spallation Neutron Source Feasibility Research Report*, Chinese Academy of Sciences, 2009 (in Chinese).

[3] J. Wei *et al.*, *Chin Phys C*, 33, pp. 1033-1042, 2009.

[4] M.Y. Huang *et al.*, *Chin Phys C*, 37, pp. 067001, 2013.

[5] N. Hayashi, "*400MeV upgrade of J-PARC RCS injection*", report at CERN, Jul. 2014.

[6] H. Hotchi et al., *Phys. Rev. Acc. Beams*, 12, pp. 040402, 2009.

[7] M.Y. Huang *et al.*, *Atom. Energy Sci. Tech.*, 46, pp. 530-533, 2012 (in Chinese).

[8] P.K. Saha et al., *Nucl. Instrum. Methods Phys. Res. A*, 776, pp. 87-93, 2015.