THAFP02

HB 2023

RESONANCE EXTRACTION RESEARCH BASED ON CHINA SPALLATION NEUTRON SOURCE

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Abstract

Resonance extraction from the RCS ring is a crucial element in beam applications. This article presents a novel design for resonance extraction in the CSNS-RCS ring. Through parameter adjustments, including the skew sextupole magnet, beam working point, RF-Kicker, and more, simulation results highlight the capability to efficiently extract a significant number of protons within a few revolutions. This innovative design offers new insights and approaches towards achieving high-performance proton beam extraction.

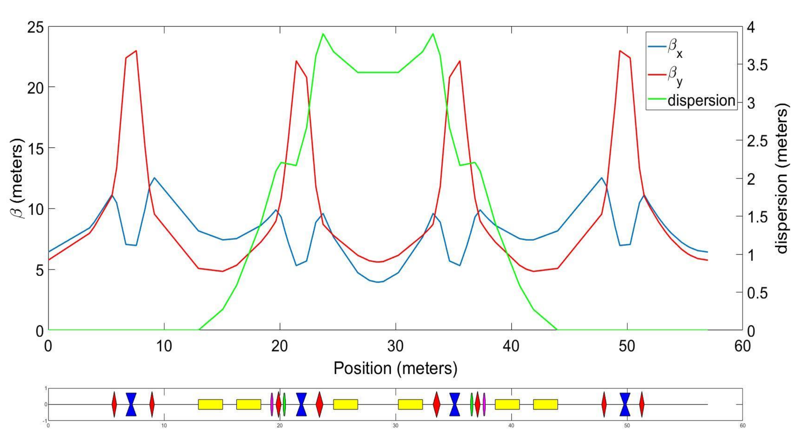
INTRODUCTION

The CSNS accelerator is made up of a linear accelerator (LINAC) and a rapid cycling synchrotron (RCS). In 2020, it achieved stable operation at a power level of 100 kW. CSNSII is a significant upgrade to the accelerator, incorporating a superconducting radiofrequency system to increase the energy of the LINAC to 300 MeV. Additionally, the number of injected particles will be multiplied by five, allowing the accelerator to reach a target power of 500 kW. The increase in power of the neutron scattering source opens up more possibilities for its widespread applications. Proton radiography is one potential application of the neutron scattering source, which requires extraction of beam bunches with strict specifications. For example, the time interval between adjacent beam bunches should be 410 ns, and each beam bunch should contain a high number of particles, such as exceeding 1E11 particles. In the case of CSNSII, the total number of particles in the extracted beam bunches is 7.8E13. If these particles can be extracted through resonant extraction, the requirements can be met.

CSNS/RCS design parameters

Parameters	Values
Circumference	227.92 m
Super periodicity	4
Inj. Energy (MeV)	80
Ext. Energy (GeV)	1.6
Natural chromaticity	-4/-9
Number of ring magnets	
- dipole magnets	24
- quadrupole magnets	48 with 5 families
- trim quadrupole magnets	16
-sextupole magnets	16 with 4 families

Twiss parameters of the CSNS/RCS



Simulation of the resonance extracting

We need to study the necessity of septum magnets.There are two main considerations for the necessity of septum magnets.
First, based on the characteristics of the RCS machine, which has a basic lattice structure of a triplet, it is difficult to design a suitable trajectory that achieves an emittance of 350 pi-mm-mr while maintaining an acceptance of 540 pi-mm-mr at the location of the Lambertson magnet.Second, the deflection angle of the Lambertson magnet is 20 mrad, and it is challenging to achieve such a large angle using resonance-induced sextupole magnets.

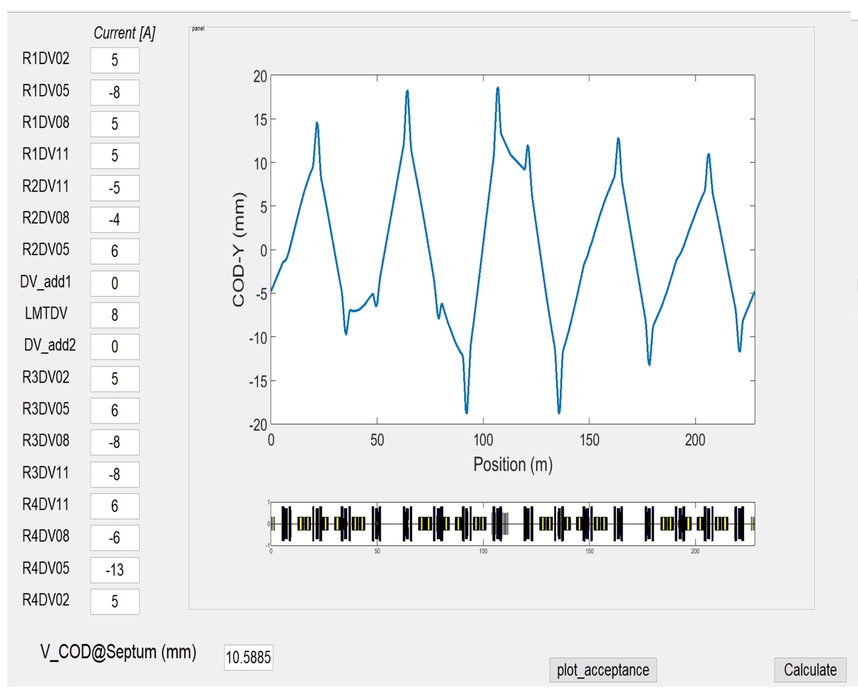


Figure 1: Orbit design in the vertical plane

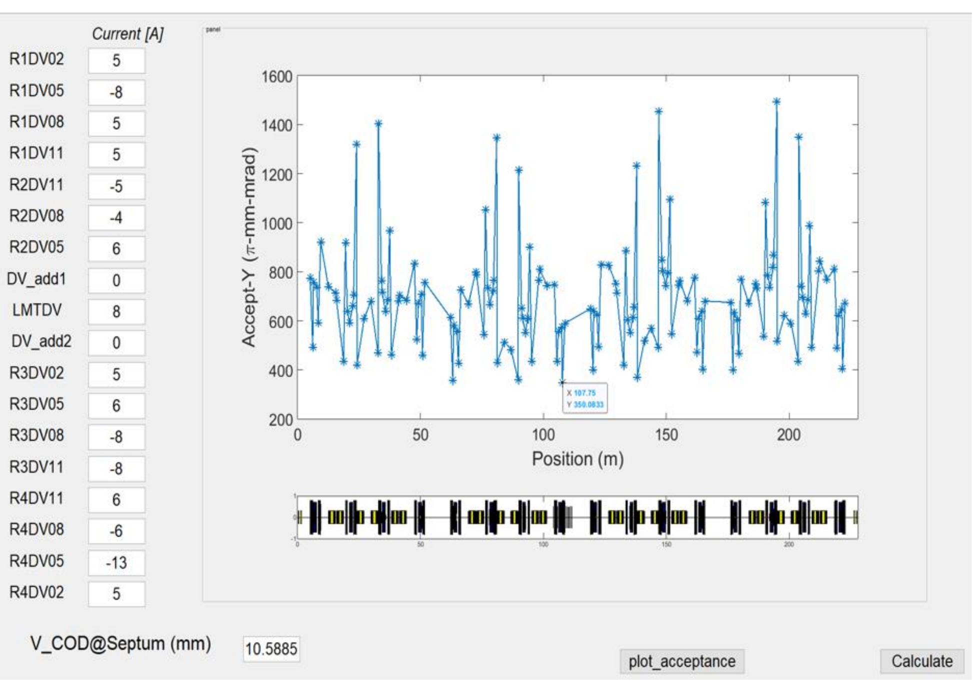
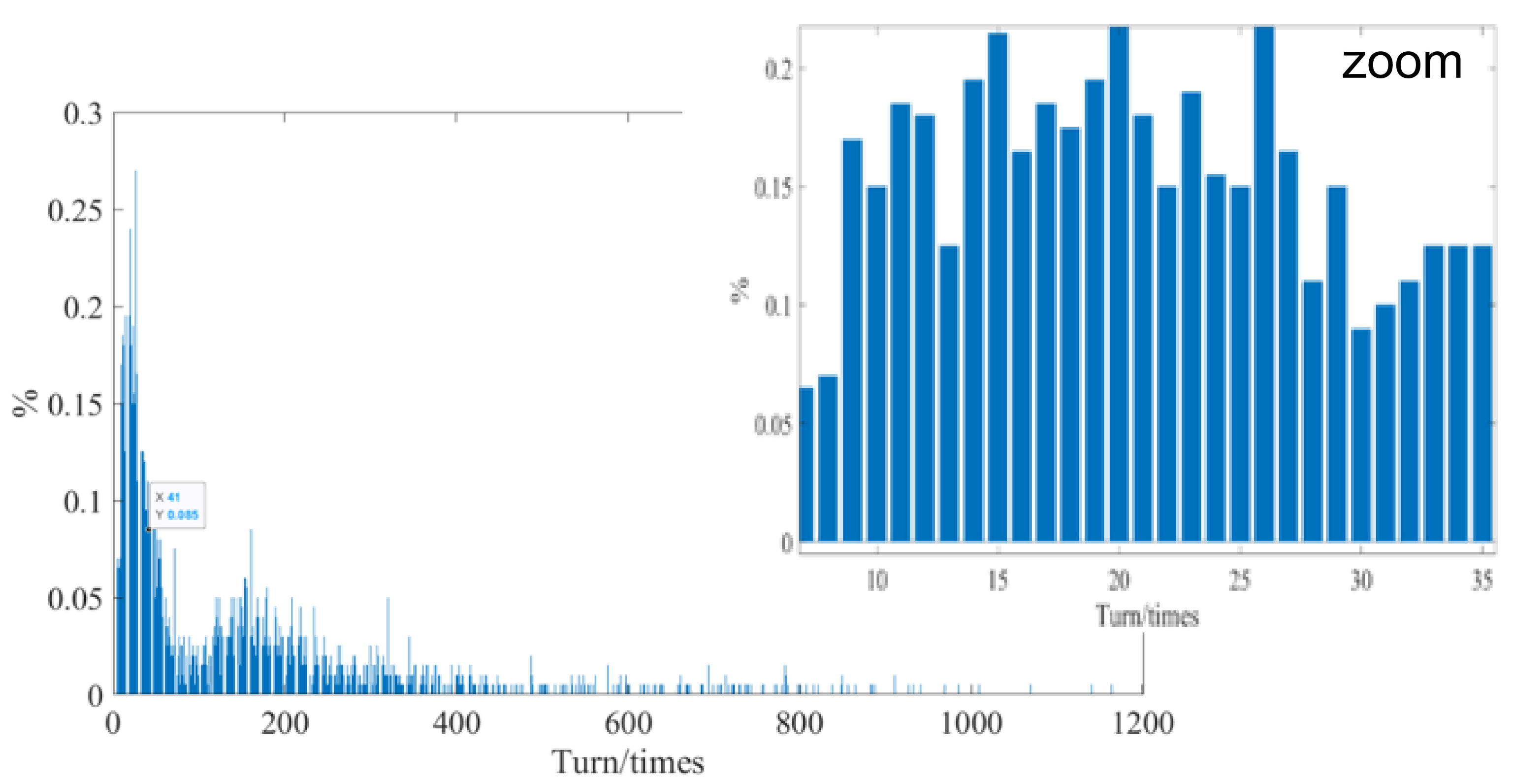
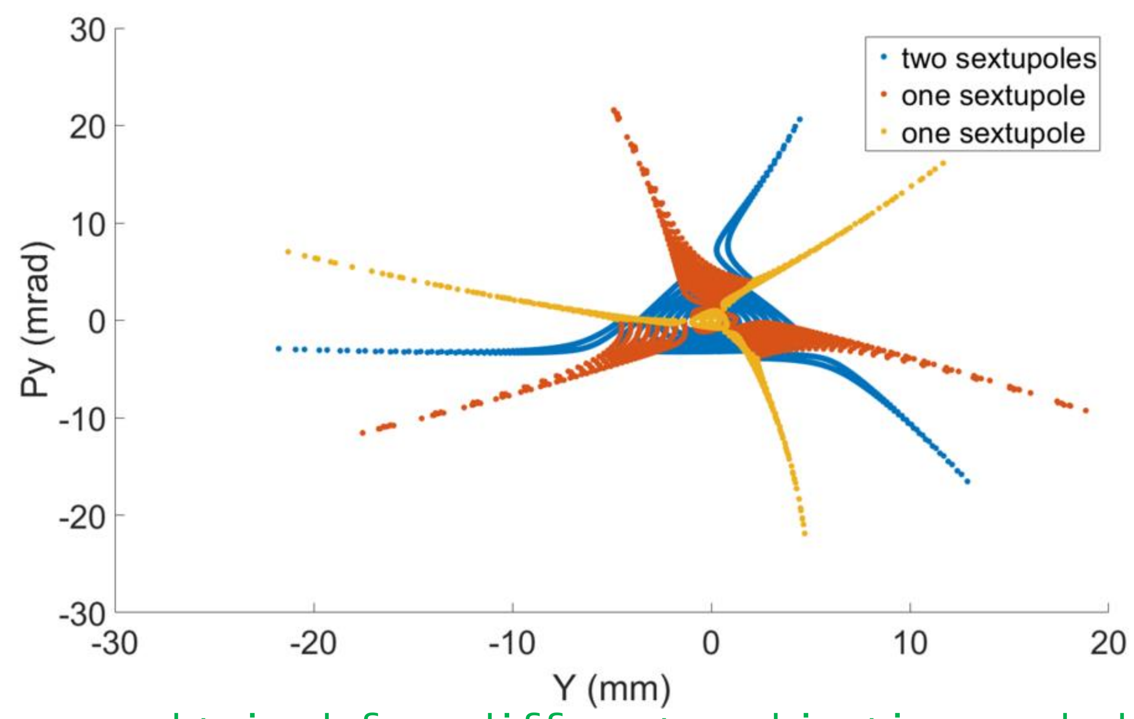


Figure 2: The acceptance shrink due to correctors.



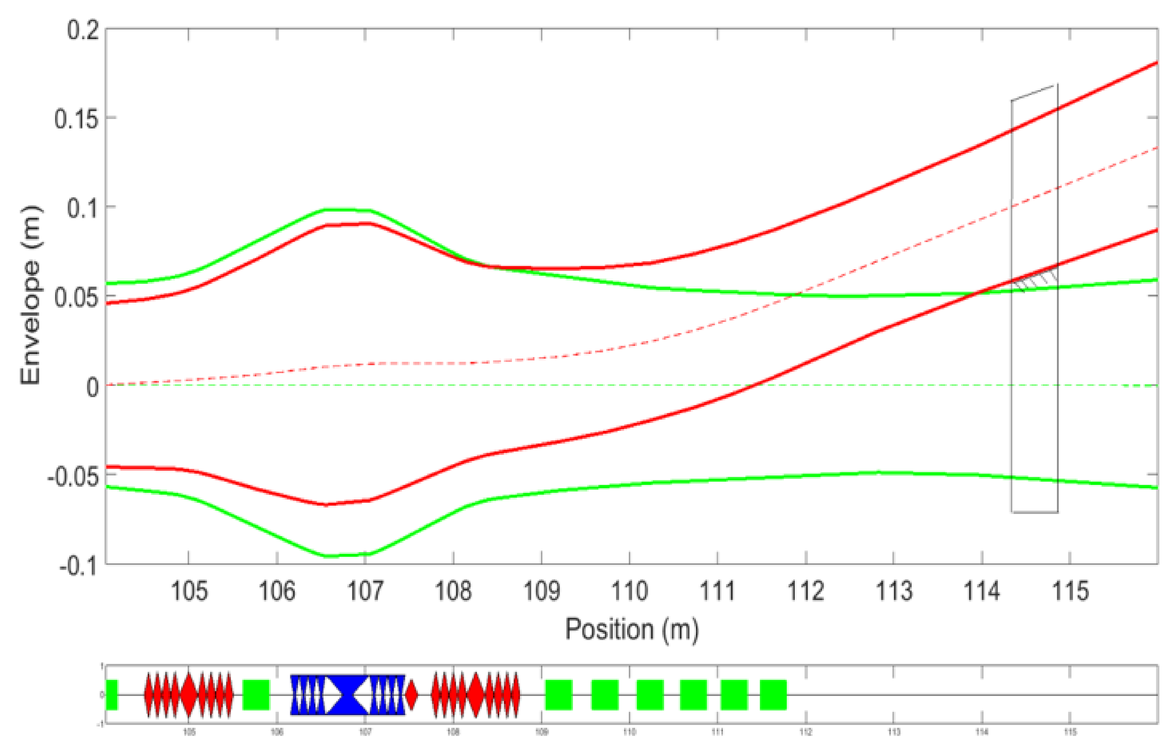
Extraction particles in our simulation

Resonance extraction due to skewsextupoles



The phase space obtained from different combinations and phases of the skew sextupole magnets.

Location of the skew sextupole,septa and RF Kicker



The red line represents the beam with an emittance of 350 pi-mm-mrad being extracted using 8 kicker magnets and directed towards the Lambertson magnet. The green line represents the acceptance of the circular beam pipe, which is 540 pi-mm-mrad. The white box represents the position of the septum. The skew sextupole magnet is located at the straight section of the RCS ring.

The $\beta x/\beta y$ values of the skew sextupole magnet are 6.83m/5.24m indicating that the sextupole magnet has a relatively small aperture. The RF-kicker is in the region 4 of the RCS.

Parameters of the skew sextupole, septa and RF kicker

Devices	Parameters	values
Skew sextupoles	Length (m)	1
	Strength(T/m^2)	80
	Rate of change(T/(m^2*us)	0.1
Septum	Central Field(T)	0.1
	Thickness(mm)	1.5
	Gap(mm)	40
	Leak Field	<0.01
	Length (m)	1
RF Kicker	Max. Kick angle (urad)	4.0
	Frequency of RF kicker(MHz)	0.83

The parameters of the skew sextupole, septum and RF kicker in our simulation

The area of the stable region is mainly determined by the distance of the beam from the resonance line and the strength of the sextupole magnet. In our study, we first varied the strength of the sextupole magnet with a certain rate of change and found that the requirements for resonance extraction could be met. However, due to the high level of factors such as power supply ripple at the operating point of 0.67, we considered changing the lattice through QT in the simulation project. This approach helps to avoid the impact of ripple and beam stability.

SUMMARY

With the increasing power of spallation neutron sources, there is a growing demand for beam-based applications. Techniques such as proton radiography require accelerators to provide beam bunches with large pulse energies and short pulse intervals. In this paper, we investigate the feasibility of achieving this in the RCS ring through resonance extraction. By adjusting parameters such as the skew sextupole magnet, RF kicker, and septum, the simulation results meet the requirements of the users.

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