PHYSICS DESIGN OF CSNS RCS INJECTION AND EXTRACTION SYSTEM

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Abstract

In this paper, the development of injection and extraction system design for CSNS RCS are introduced. It is a challenge for the injection system to place all the complicated injection devices in one uninterrupted long drift, such as DC and painting bumper magnets, the carbon stripping foils system, beam monitors, the ceramic vacuum chambers, and beam dump. The beam extraction process from the CSNS RCS is a single turn two step process, requiring a group of kickers and a Lambertson septum magnet.

INTRODUCTION

CSNS-I (Chinese Spallation Neutron Source), which is now under construction, consists of an 80 MeV H^- Linac as the injector and a 1.6 GeV proton rapid cycling synchrotron (RCS) as the main accelerator.

The CSNS RCS lattice is based on triplet cell, with circumference of 227.92 m. And the 4-fold structure is adopted, in the each super period, an 11 m long drift space is left in a triplet cell, and this uninterrupted long space is very good for accommodation of injection, extraction and transverse collimation system[1].

INJECTION SYSTEM

For high intensity circular proton accelerators, such as CSNS which need to inject about 1.56×10^{13} particles of 80 MeV to the RCS. Injection via H^- stripping is actually the only available method. At the same time, because strong space charge effects are main causes for beam loss, it has to increase the beam emittance and beam uniformity in the RCS to control space charge effects, so the phase space painting method is used in CSNS[2].

Layout of Injection System

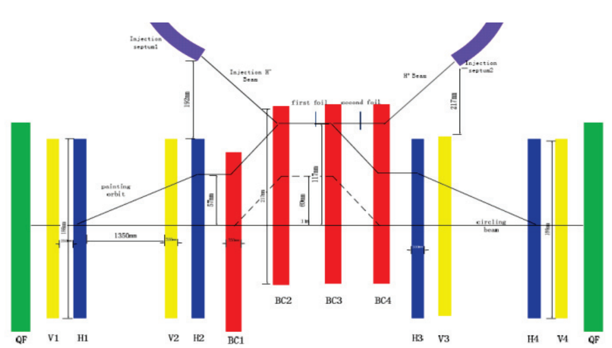

Figure 1: Injection component layout. BC1~BC4: Fixed orbit bump magnets, BH1~BH4: horizontal painting bumpers, BV1~BV4: vertical painting bumpers, ISEP1&2: septum.

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As showed in Figure 1, the whole injection chain is arranged in an 11 m long dispersion free straight section, consisting of four horizontal painting magnets (BH), four vertical painting magnets (BV), and four fixed orbit bump magnets (BC), Two pairs of horizontal bump magnets (BC1-BC4) in the middle are for additional close-orbit shift of 60 mm, which is changed from the early edition for the install of the injection septum. The BC bump magnets will work in DC mode and fall to zero after the beam injection to reduce the proton transversal in the stripping foil[3].

Depending on the 100 μg/cm^2 thickness of stripping foil, a little part of H^- cannot converted, and bulk of them are H^0, a small fraction of them are H^-. To control these particles, the second stripping foil is adopted. The bulk of H^0 are converted into proton and sent to injection dump of 2 kW power through BC4 and the second injection septum.

Transversal Painting

A careful design of the painting scheme is very important to control the emittance blow-up and beam loss. Both correlated and anti-correlated painting schemes are feasible(as shown in Figure 2). In the correlated painting scheme, the beam fills the emittance from inner to outer for both the horizontal and vertical painting, and the beam distribution in the x-y space is nearly rectangular. In the anti-correlated painting scheme, the beam fills the vertical emittance from outer to inner, while fills the horizontal emittance from inner to outer and the beam distribution in x-y space is elliptical.

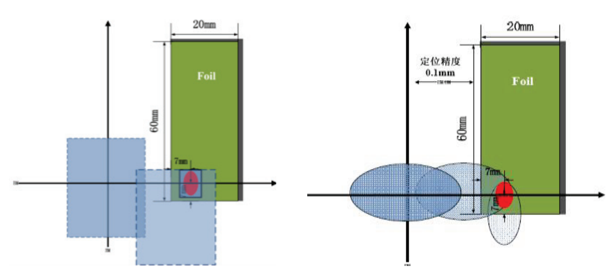

Figure 2: Illustration of correlated painting(left) and anti-correlated painting(right).

The painted emittance is around 240π mm mrad, and at the end of injection, due to the existence of space charge effects, the transverse emittance is around 300π mm mrad. Many works have been done to optimize the painting procedure with the ORBIT code. The results of simulation show that the correlated painting would cause the

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beam distribution susceptible to the transverse coupling and space charge force while the anti-correlated painting would cause beam halo. After all-around comparison, the both painting scheme will be adopted. Figure 3 shows the beam distribution in phase spaces at the injection end with correlated and anti-correlated painting[4].

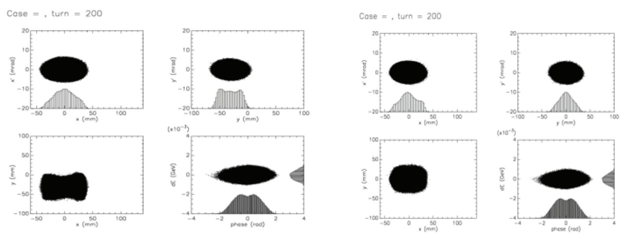

Figure 3: Beam distribution in phase spaces at injection end by an x-y correated(left) and anti-correlated(right) phase space painting.

EXTRACTION SYSTEM

The beam extraction from the CSNS RCS is a single turn two step process. Firstly, the two bunches containing protons at energy of 1.6 GeV is kicked by s set of kickers into the high field region of a septum magnet, and secondly, two bunches are deflected on the outside of the ring by the extraction septum magnet into the RTBT beam transport line to the CSNS target. The bunch length si about 70~100 ns, and the space between two bunches is about 330~360 ns, so the rise time of kickers is required to be less than 250 ns and peak field need to be kept more than 550 ns for high efficiency extraction. The kicked orbit should have a separation large enough to put the septa between the acceptance of circulating beam and extraction beam.

Many extraction schemes have been discussed, such as horizontal kickers and septum magnet, vertical kickers and Lambertson septum magnet and horizontal kickers with bump magnets. This paper will introduce two schemes.

Extraction Layout with Bumper Magnet

A method of using auxiliary bump magnets is adopted to provide additional extraction orbit and ease the kicker requirement. Figure 4 shows extraction scheme with bump magnets[5].

As showed in Figure 4, beside the Lambertson septum magnet, there are four auxiliary bump magnets which work in DC mode. It will produce about 30 mm bump orbit at the injection energy, to keep the acceptance of 540 π mm mrad at the location of septa. With the energy increasing, the beam rigidity is increased, and the bump orbit shrinks and approaches to the septa. At the extraction energy, the acceptance is decreased to 250π mm mrad, and this effectively reduces the requirement to the kicker strength.

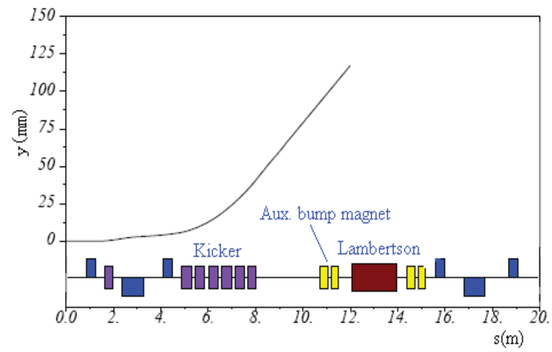

Figure 4: The layout of extraction system with bump magnets.

Final Extraction Scheme

But considering the situation of emittance blow-up, in case of beam loss at the Lambertson septum magnet, after delicate comparison, in the final design, the extraction system don't adopt bump magnet, Figure 5 shows the final extraction scheme.

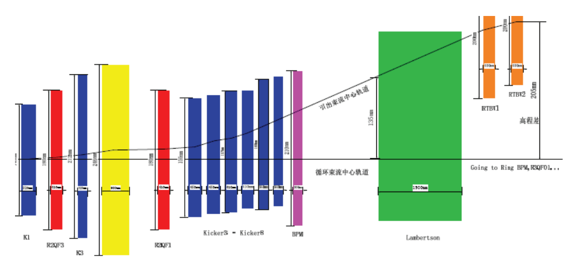

Figure 5: The layout of final extraction scheme.

In this scheme, the kickers are inserted in different straight sections instead of a long uninterrupted straight section. There are 8 kickers in the extraction system and one which is altered from the sample kicker of CSNS is put to the position before the triplet cell, one is put before a defocusing quadrupole in a triplet cell, the other 6 kickers together with Lambertson are placed in the 11 m long straight section. For the extraction acceptance from 250π mm mrad to 350π mm mrad, the kickers can satisfy the kicked deviation at the Lambertson septum magnet. At the same time, this scheme uses the sample kicker to lower the construction cost.

The extraction septum magnet chooses the Lambertson type because of its reliability and high radiation-resistance. In order to maximize the vertical displacement of the extracted beam at the entrance of the Lambertson septum magnet, the Lambertson is placed as far as possible from the kickers. The location of the Lambertson in conjunction with the angle of bend and beam size defines a set of parameters for the magnet. At the same time, the RCS also considers the slow extraction for the future ex-

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periment, so the Lambertson septum magnet design gives attention to the slow extraction scheme. Figure 6 shows the schematic diagram of the septum cross section.

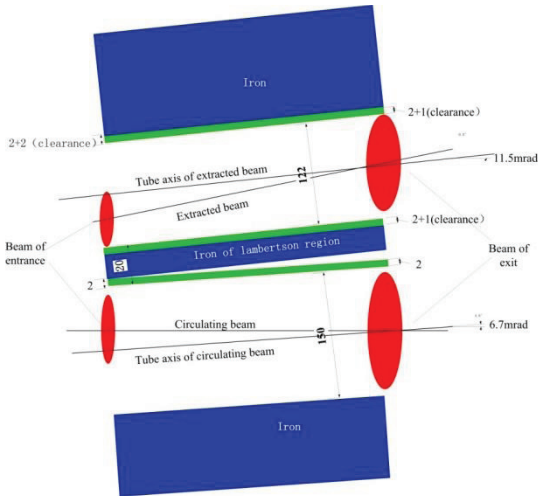

Figure 6: Schematic diagram of the Lambertson septum magnet cross section along the beam.

CONCLUSIONS

The injection system based on one long uninterrupted drift of 11 m has been designed. Lots of simulations have been done to optimize the painting for uniform beam distribution and less proton traversal in the stripping foil.

After many discussions, CSNS RCS adopted the kickers and Lambertson for beam extraction in the end. This scheme has high reliability and used the sample kicker to lower the construction cost.

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