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MEASUREMENT OF THE INJECTION BEAM PARAMETERS BY THE MULTI-WIRE SCANNER FOR CSNS*

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Abstract

In order to inject the H^- beam to the Rapid Cycling Synchrotron (RCS) with high precision and high transport efficiency, the injection beam parameters need to be measured and then corrected while its eccentric position or direction angle is too large. In this paper, firstly, a method to measure the injection beam parameters by using two of the four multi-wire scanners (MWSs) is presented. The injection commissioning results confirmed that this method works well. Secondly, a method to measure the signals of injection beam and circular beam by the INMWS02 is presented and the method work well during the beam commissioning.

INTRODUCTION

China Spallation Neutron Source (CSNS) is a high power proton accelerator-based facility which used for several subjects [1]. Its accelerator consists of an 80 MeV H^- linac and a 1.6 GeV Rapid Cycling Synchrotron (RCS). With a repetition rate of 25 Hz, the RCS 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 beam power for CSNS is 100 kW and capable of upgrading to 500 kW [2].

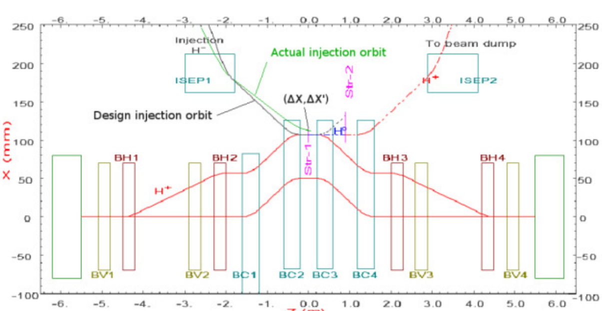

Figure 1: Layout of CSNS injection system.

The beam commissioning of CSNS accelerator started in April 2015. As a key part of CSNS accelerator, the beam commissioning of the injection system started in May 2017. Figure 1 shows the layout of the injection system [3]. In the early stage of the injection system commissioning, in order to inject the H^- beam to the RCS with high precision and high transport efficiency, the injection beam parameters need to be measured [4]. The eccentric position and direction angle of the injection beam need to be corrected while they are too large to affect the injection efficiency. During the beam commissioning, in the I-Dump model, the single of the injection beam can be measured by the four multi-wire scanners (MWSs) in the injection region and the information about the injection beam parameters can be obtained. In the R-Dump model, since the INMWS02 is very close to the injection point, after some technical processing, the singles of the injection beam and circular beam can be measured. The information about the injection orbit matching can be obtained.

MEASUREMENT OF THE INJECTION BEAM PARAMETERS BY USING SEVERAL MWSS IN THE I-DUMP MODEL

While the H^- beam is stripped by the foil, there are large of H^0 that go through the second stripping foil. After the particles of H^0 are stripped to the protons by the second foil, the protons would go into the I-Dump while the beam line is adjusted well. Figure 2 shows the layout of the I-Dump beam line including the four MWSs. During the beam commissioning in the I-Dump model, the injection beam parameters can be measured by using two of the four MWSs.

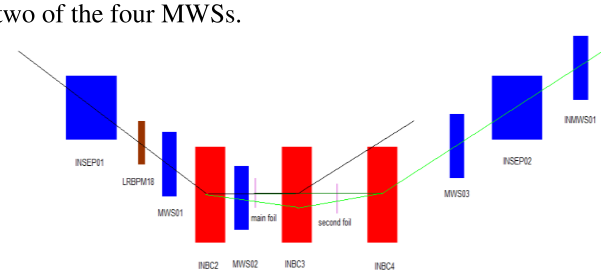

Figure 2: Layout of the I-Dump beam line.

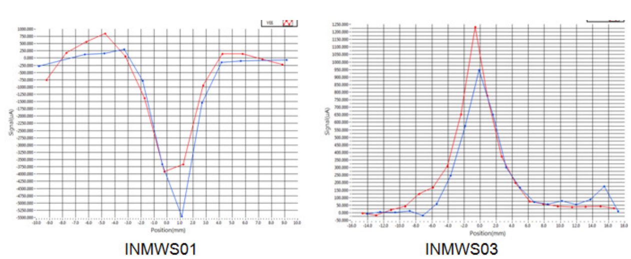

Figure 3: Measured results of INMWS01 and INMWS03.

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By using the transfer matrix, the injection beamparameters can be calculated by the measured results of any two of the four MWSs. Figure 3 shows the measured results of INMWS01 and INMWS03. Define (x_0, x'_0, y_0, y'_0), (x_1, x'_1, y_1, y'_1), (x_3, x'_3, y_3, y'_3) as the eccentric positions and direction angles of the injection beam at injection point, INMWS01 and INMWS03. With Eq. (1),

$$\begin{aligned} x'_0 &= \frac{x_3 - x_1}{L_{13}} \\ x_0 &= x_1 + x'_0 \times L_{10} \\ y'_0 &= \frac{y_3 - y_1}{L_{13}} \\ y_0 &= y_1 + y'_0 \times L_{10} \end{aligned} \tag{1}$$

the eccentric position and direction angle of injection beam can be calculated and the results are given as follow:

$$x_0 = 0.2\text{mm}, \quad x'_0 = 0.05\text{mrad},$$
$$y_0 = 0.4\text{mm}, \quad y'_0 = 0.25\text{mrad}.$$

By using the correctors on the LRBT, the eccentric position and direction angle of the injection beam can be corrected to near zero [5].

A METHOD TO MEASURE THE SINGLES OF THE INJECTION BEAM AND CIRCULAR BEAM BY THE INMWS02 IN THE R-DUMP MODEL

It can be found from Fig. 2 that the INMWS02 is very close to the injection point. While the proton beam injected into the RCS, due to too many traversing turns, the INMWS02 need to be brought up so as not to be broken. However, in order to match the injection beam and circular beam, the method to measure the signals of injection beam and circular beam by the INMWS02 should be studied.

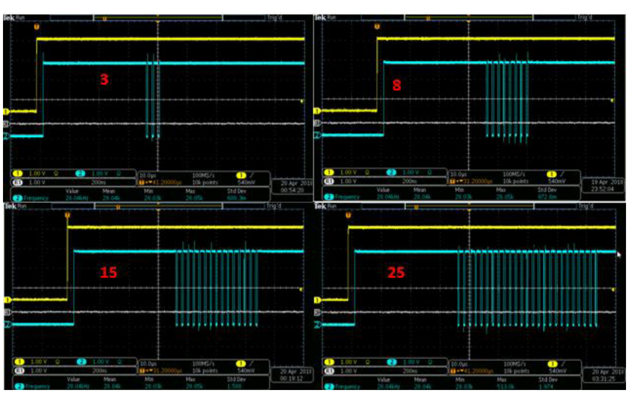

Figure 4: Different chopping situations of the linac beam.

In order to control the particle number that hitting on the INMWS02, the linac beam can be chopped into different amounts of bunches by the chopper. Figure 4 shows different chopping situation of the linac beam. For CSNS, the RCS accelerates the injection beam from 80 MeV to 1.6 GeV within 20000 turns which takes 20 ms. In order to reduce the traversing turns so as not to broken the INMWS02, the injection beam need to be extracted to the R-Dump within 50 turns. Therefore, the timing of the kicker powers should be modified so as to extract the proton beam in time. Figure 5 shows different situations of the accumulation and extraction of the proton beam. It can be known that the injection beam is extracted quickly within the first dozens turns of the 20000 turns.

Figure 5: Different situations of the accumulation and extraction of the proton beam.

During the measurement experiments of the injection beam and circular beam, different situations of the accumulation and extraction of the proton beam were studied. Figure 6 shows the measurement results of the injection beam and circular beam while the injection turn is 3, 8, 15 and 25. It can be seen that the positive single increases as the cumulative beam increases while the negative single is nearly unchanged. Therefore, the positive single represents the proton beam (circular beam) and the negative single represents the H^- beam (injection beam). These two singles can be clearly distinguished.

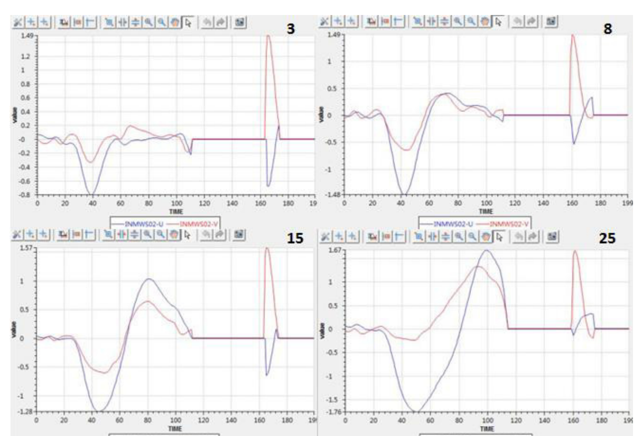

Figure 6: Measured results of the injection beam and circular beam.

By measuring these two singles, the shape and central positions of the injection beam and circular beam can be obtained. After careful calculation and analysis, relative to the circular beam, the injection beam parameters, such as the eccentric position and direction angle, can be

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obtained. Then, by using the correctors on the LRBT, the eccentric position and direction angle of the injection beam can be corrected to near zero.

CONCLUSIONS

In this paper, during the beam commissioning in the I-Dump model, the beam singles can be measured by using the MWSs. With the transfer matrix, the injection beam parameters can be calculated. Then, the eccentric position and direction angle of the injection beam can be corrected by the correctors on the LRBT.

In order to match the injection beam and circular beam, a method to measure the signals of injection beam and circular beam by the INMWS02 was presented. By adjusting the beam structure with the chopper and modifying the timing of the kicker powers, the singles of the injection beam and circular beam can be measured and distinguished clearly. After careful calculation and analysis, relative to the circular beam, the injection beam parameters can be obtained.

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