DESIGN OF BEAM TRANSPORT LINE FROM RCS TO TARGET FOR CSNS

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Abstract

China Spallation Neutron Source (CSNS) uses the high energy proton beam to strike the Tungsten target to generate neutrons through spallation reaction. The proton beam is extracted from the Rapid Cycling Synchrotron (RCS), whose beam power reaches 100 kW. For the sake of target lifetime, beam distribution at the target surface is required as uniform as possible. Nonlinear beam density redistribution method with two octupole magnets has been studied. Also some simulation and theoretical calculation have been done. According to the simulation result, the beam density at the target is optimized and the beam loss is under control.

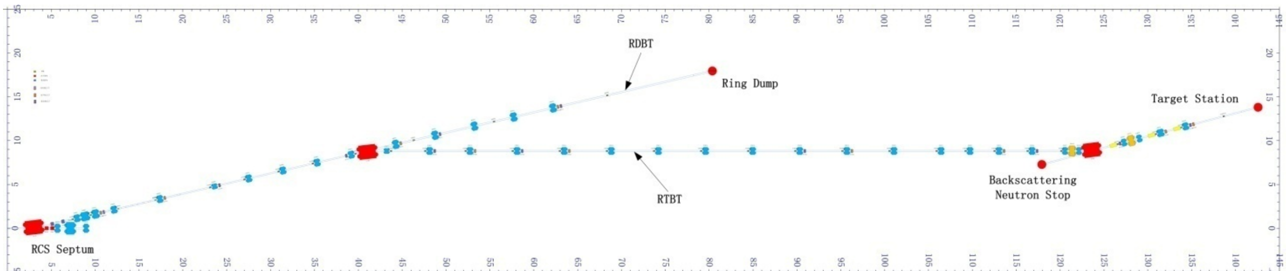

Figure 1: Layout of RTBT and RDBT.

INTRODUCTION

At CSNS the transport line transfers proton beam from the rapid cycling synchrotron (RCS) to the Tungsten target to generate neutrons is named as RTBT (Ring to the Target Beam Transport line). Based on the initial design[1], the design of RTBT is upgrade, and the layout of CSNS was changed a lot. So the RTBT layout and lattice were redesigned. Some detailed simulation and theoretical calculation were studied.

GENERAL LAYOUT

The trunk line of RTBT which transfers the high power proton beam to the target station is about 144 m long (Figure 1). Two horizontal bending magnets (RTB01 and RTB02) divide RTBT into three parts. With the consideration of future arrangements of the second target station and proton application station, two auxiliary branches will attach to RTBT before RTB01, (Figure 2).

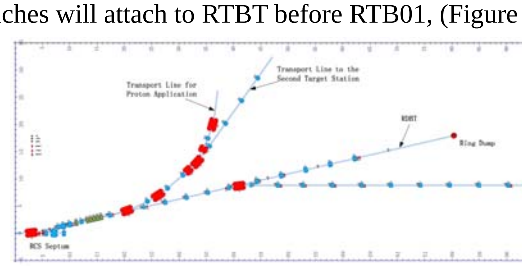

Figure 2: Layout of the transport lines to the second target station and proton application station.

Another auxiliary branch RDBT (Ring to the Dump Beam Transport line) of 41 m long attaches to the trunk line after RTB01, is used for beam commissioning. RTB02 is used to separate the backscattering neutrons from the proton beam line. A backscattering neutron stop will be established at the reverse extension line direction of the final part of RTBT.

LATTICE DESIGN AND SIMULATION

Because of 8 vertical kickers and 1 horizontal lambertson magnet are used for the proton beam extraction from the RCS ring, beam has a 20 mrad vertical angle after the lambertson magnet. Two vertical bending magnets are placed next to the lambertson magnet to cancel the vertical angle. The dispersion produced by the lambertson is cancelled after RTB01 which bending angle is 228 mrad. Enough space is arranged for the future beam extraction to the second target station and proton application station with kicker plus lambertson scheme.

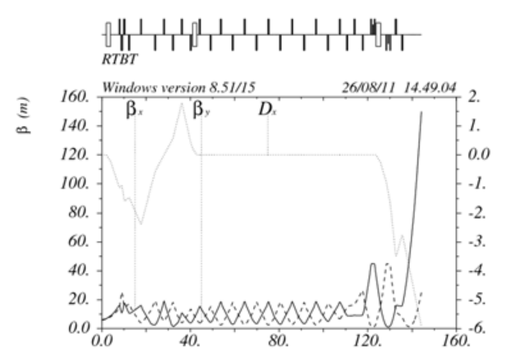

Figure 3: Linear lattice of RTBT.

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The transport line between RTB01 and RTB02 adopts FODO focusing structure (Figure 3). Some quadrupoles in this region are also used for the twiss parameters match which are demanded by the last part of RTBT when practical initial parameters are different from the theoretical design parameters.

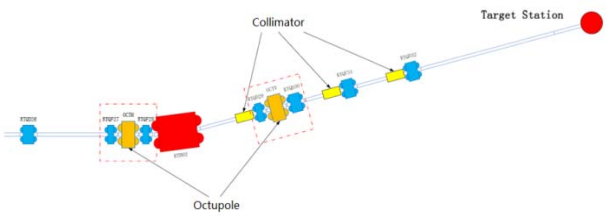


Figure 4: Arrangement of magnets for beam density redistribution.

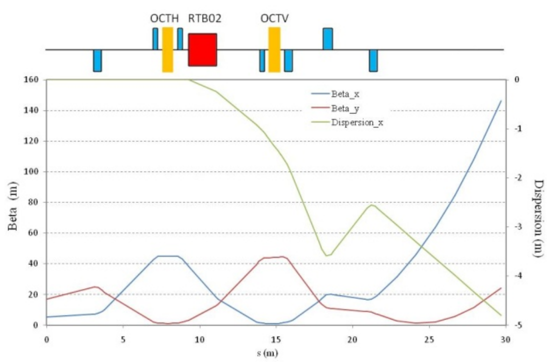


Figure 5: Linear lattice before the target.

The tungsten beam target which is used to produce neutrons is 160 mm (H) × 60 mm (V). Because 100 kW proton beams will bombard on the target, the damage to the and lifetime of target depend on the peak beam density, much uniform is much better. To optimize the beam intensity uniformity at the target surface, a density redistribution scheme with two octupoles is designed (Figure 4). With the consideration of dispersion after RTB02 (~257 mrad), two octupoles are placed at different side of RTB02. The octupole before RTB02 which is named OCTH is used for horizontal beam density redistribution. And the value of β_x/β_y at the position of OCTH is designed as large as possible to minimize the coupling effect between x-x' and y-y' phase space (Figure 5). The other octupole OCTV located after RTB02 is used for vertical beam density redistribution. The value of β_y/β_x at OCTV is also designed as large as possible (Figure 5). β_x/β_y got from linear calculation at the target is over 150/25 m in order to expand the beam size and reduce the beam density at the target centre. The outer particles are fold back to the centre by the octupoles which increase the beam density on the outer of the target and reduce the beam loss. In order to get the best effect, phase advance from the octupoles to the target are chosen carefully. The horizontal and vertical phase advance are about 0.45 π and 0.47 π.

Simulation was done to check the redistribution effect. In the simulation, double Gaussian particle distribution is used as the initial condition to stand for the beam core (97% particles) and beam halo (3% particles)[2]. 10^5 macro particles were used in the simulation. And over 99.5% particles reach to the target. The tracking results at the target are shown in Figure 6, 7, 8. Under the condition of the same beam loss, the peak beam density in the centre of the target was reduced to 50~60% compared with the situation without octupole. Three collimators are used to shield the protons loss because of nonlinear effect brought by the octupoles (Figure 5). And the power produced by the lost protons at each collimator is less than 100 W according to the simulation result.

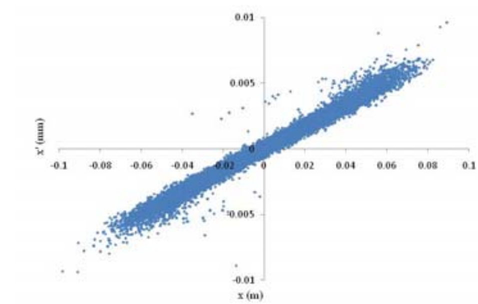


Figure 6: Particle distribution in horizontal phase space at the target.

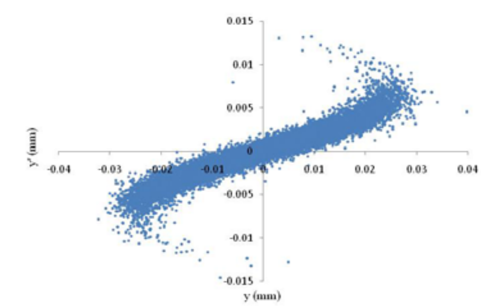


Figure 7: Particle distribution in vertical phase space at the target.

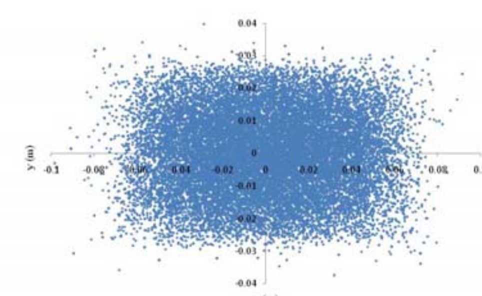


Figure 8: Particle distribution in real space at the target.

KICKER EFFECTS STUDY

8 kickers are used for beam extraction in RCS. The wobble of kickers will arouse the orbit jitter. To restrain the beam position variation at the target, vertical phase advance from the kickers to the target is optimized. Figure 9 gives ten groups of the orbit calculation result induced by random wobble of kickers along RTBT. The wobble amplitude of each kicker is set to 3σ=2%. And the orbits

with ±2% kicker wobble amplitude are also shown in this figure. Normally the maximum orbit variation at the target is less than 1 mm.

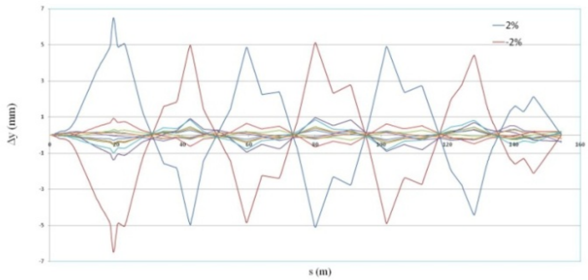


Figure 9: RTBT orbit variation due to extraction kickers wobble.

Each kicker has the probability of malfunction. And the beam orbits are also calculated with different kicker misfire. Most of the beam (>90%) can pass through the whole transport line to get to the target (Figure 10).

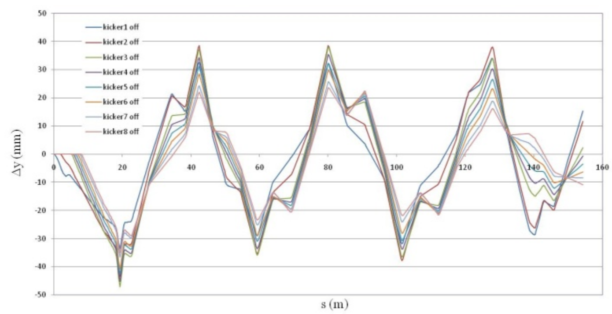
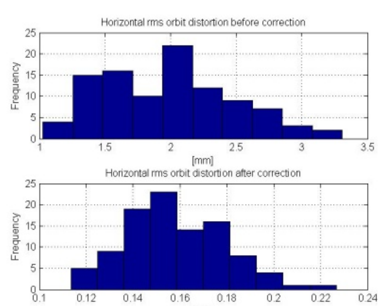


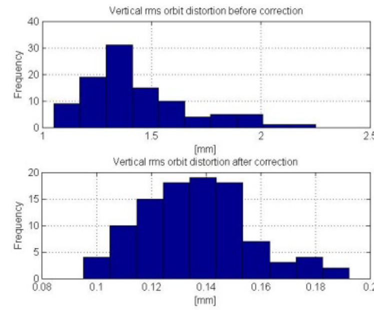
Figure 10: RTBT orbit due to extraction kickers misfire.

BEAM INSTRUMENTATION AND ORBIT CORRECTION

16 BPMs and 8 wire scanners are arranged along RTBT for orbit and beam profile measurement. 4 wire scanners are placed before RTB01 and the others are placed between RTB01 and RTB02. These wire scanners are also used for emittance measure. 8 horizontal and 9 vertical correctors are used for orbit correction. With some assumption of alignment and magnet strength error, we did some orbit correction simulation by using AT program. 100 group simulation results show that the orbit aberration can be corrected significantly (Figure 11).



(a)



(b)

Figure 11: The root mean square of orbit before (a) and after (b) orbit correction (100 groups).

CONCLUSIONS

The beam transport line form RCS to the target is redesigned according to the new requirement of CSNS. To decrease the beam density in the centre of the target, special attentions have been paid to the beam density redistribution. Some works on effects of kicker malfunction, orbit correction have also been done. Special considerations on future upgrading are also reflected in the RTBT lattice design.

ACKNOWLEDGEMENTS

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[1] J.Y. Tang, G.H. Wei, C. Zhang, J. Wei, "Beam Transport Lines for the CSNS", EPAC 2006, Edinburgh, Scotland.

[2] Guohui Wei, Physics Design and Studies of Beam Transport Lines of the CSNS, doctoral dissertation, IHEP, 2007.