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# The Beam Orbit Reconstruction in the Linac of CSNS

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## Abstract

In the high current hadron machine, it is essential to reduce the beam loss along the machine for machine maintenance and safety reasons. The linac of Chinese Spallation Neutron Source(CSNS) delivery negative hydrogen bunches with power of 5kW to the RCS which increase the power to 100kW. In the following several years, the power of the linac beam will be increased from 5 kW to 100 kW, therefore it is important to deal the beam loss more carefully. In this paper, we present the reconstruction of the beam orbit along the linac using beam tracking software with the input data measured with BPMs. This kind of reconstruction is expected to provide suggestions for the future machine tuning. The requirements for the BPMs are also presented in this paper.

## Introduction

The China Spallation Neutron Source (CSNS) is hadron accelerator based multidiscipline user facility located at Dongguan, Guangdong, China. The accelerator of CSNS consists of a 80 MeV linac and a 1.6 GeV rapid cycling synchrotron (RCS). The layout of the CSNS is illustrated in Fig.1.

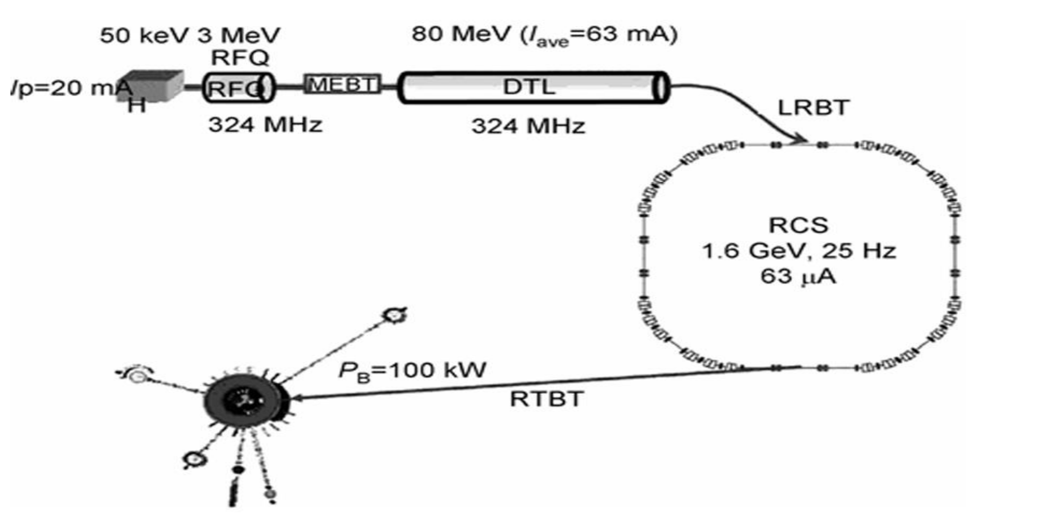


Figure 1: The layout of the CSNS.

The linac of the CSNS aims at delivering high quality negative hydrogen beam to the RCS. Currently the peak current is around 17 mA, and in the next few years, the peak current will be increased to 50 mA which may lead much higher radiation. Therefore, it is important to have good knowledge about the beam along the linac to control the beam loss. The most important information is the beam orbit which is the base for other beam parameters.

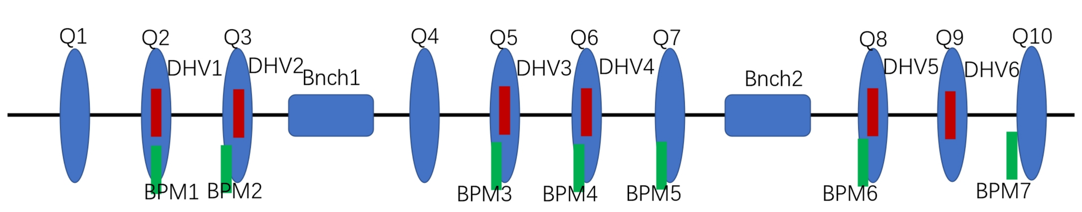


Figure 2: The layout of the MEBT.

## Orbit of MEBT

There are 7 BPMs and 6 correctors along the MEBT. Although there is no operation problem for the orbit, it is still unclear that how looks like the true beam orbit along the MEBT.

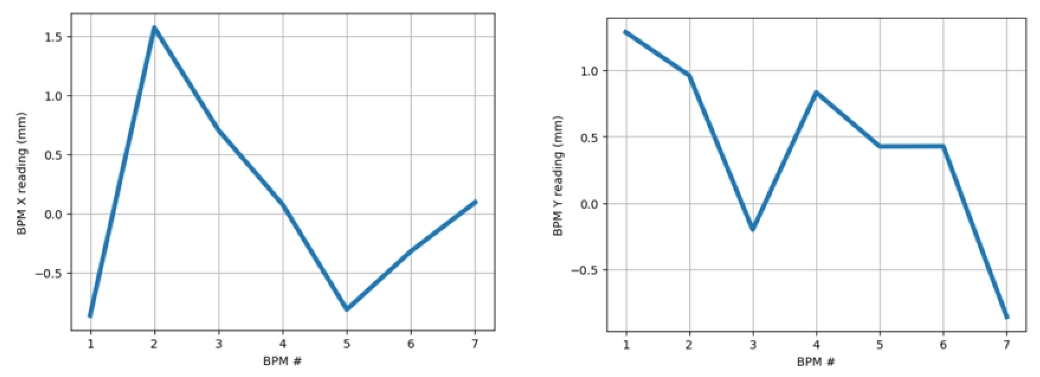

Figure 3: The average measured orbit along MEBT

An optimization method is used to determine all known parameters related to the orbit. TraceWin is used to perform the orbit tracking. The merit function is $f = \sum (x_{sim} - x_{meas})^2$. The BPMs readings are dedicatedly recorded about 1 hour. The average measured orbit are in the range of ±1.6 mm as shown in Fig. 3. The orbit large than 1 mm means that there is a large initial beam offset.

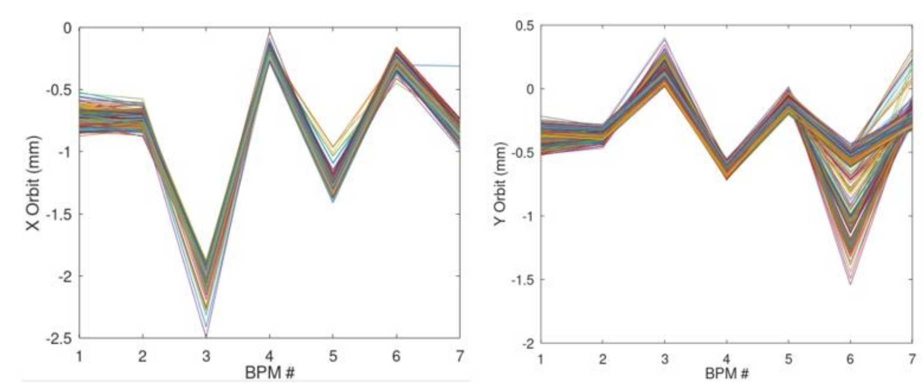

Figure 4: The simulated orbit along MEBT w/o BPM offset

100 orbits are taken to perform optimization. The largest rms of orbit differences is 0.16 mm at BPM3. The simulated orbit with tracewin is shown in Fig. 4. Other orbit datasets have been used to verify the stability of the fitting. The average orbit of the measurements is also checked with fitted offsets as shown in Fig. 5.

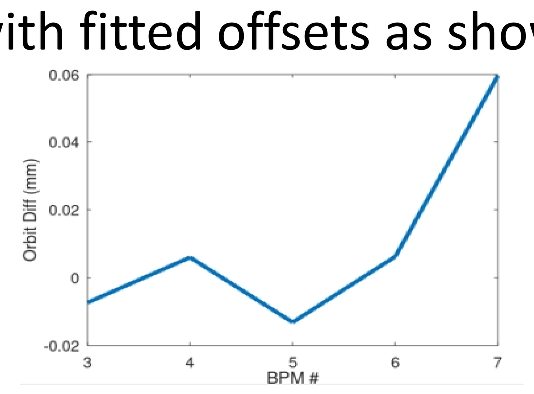

Figure 5. The horizontal orbit diff. between measurement and simulation for average orbit at EMBT

## DTL

The DTL of CSNS consists of 4 independent accelerating tanks and can accelerate H- beam from 3 to 80 MeV. The focusing scheme of the DTL leads to that lack of positions for diagnostic elements as shown in Fig. 6. Therefore, the orbit and shape of beam in the DTL is a black box which is difficult to know.

It would be practical useful to develop beam diagnostic equipment suitable for the 30 m long DTL which can give beam orbit and profiles. For now, the performance of our DTL can only be checked by wire scanners downstream DTL.

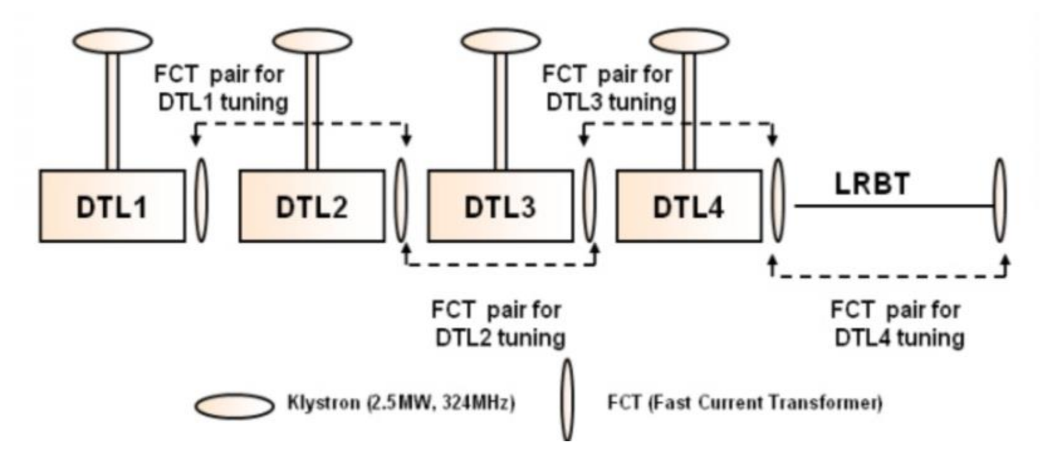


Figure 6. The diagnostic elements in DTL

## Linac to RCS Transfer Line

During the operation, the LRBT works really well with low losses. The orbit measured with BPMs during the operation is shown in Fig. 7. It is noticed that there is an orbit of 4.5 mm at the entrance of LRBT in the vertical plane which can only come from the DTL. In the horizontal plane, the initial is orbit is small which means there is no orbit problem from the DTL

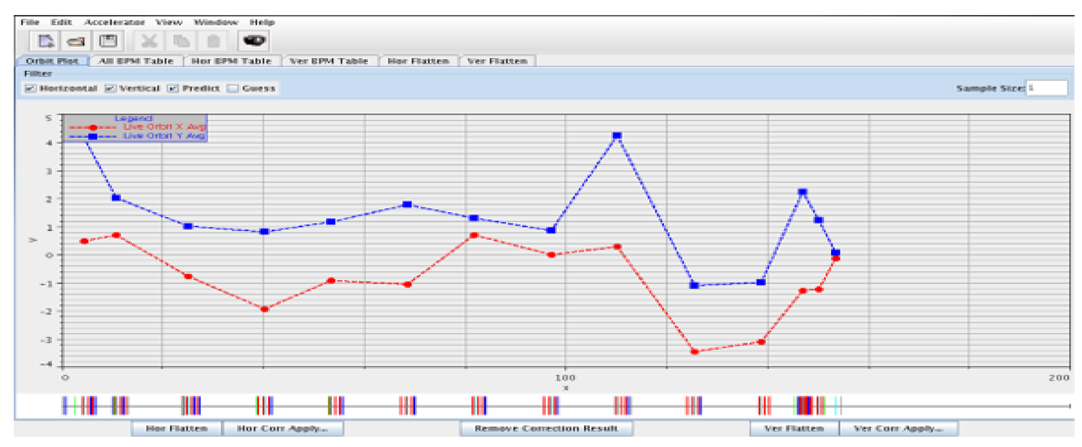

Figure 7. The beam orbit of LRBT during operation

With proper setting the strength of correctors, the initial orbit is determined to be about 1 mm with beam slope of 1.6 mrad.
For the LRBT orbit reconstruction, the large initial vertical orbit make it difficult to measure the offset of first several BPMs offset. Another difficulty comes the grouped power supply of the quadrupole triplet. The fitting method is also challenging. Therefore, it would helpful to improve the BPM reading.

## BPM Considerations

Currently, the reading of BPMs along the linac is the average orbit of one long pulse(520 $\mu s$). It is noticed that there are signal jitters along one pulse which could include the information of bunch jitter due to ion source and other elements. Therefore, it would be useful that bunch-by-bunch orbit can be measured with high signal to noise ratio.

## Conclusion

The beam orbit is an important beam property along the lattice which can significantly affect the beam loss. Therefore, a good knowledge about the orbit with carefully designed and arranged diagnostic elements is necessary to control the beam loss. In the paper, the orbit study about the MEBT and LRBT of the CSNS is presented. The consideration about the DTL and BPM measurements are also discussed.