STUDY OF DIFFERENT MODELS ON DTL FOR CSNS

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Abstract

China Spallation Neutron Source (CSNS) is a high intensity accelerator based facility. Its accelerator consists of an H- injector and a proton Rapid Cycling Synchrotron (RCS). The injector includes the front end and linac. The RFQ accelerates the beam to 3MeV, and then the Drift Tube Linac (DTL) accelerates it to 80MeV[1]. A Medium Energy Beam Transport (MEBT) matches RFQ and DTL, and the DTL consists of four tanks (DTL1, 2, 3, 4). A Linac to Ring Beam Transport (LRBT) matches DTL and RCS, also decreases beam energy spread. Commissioning of the first three DTL tank and LRBT straight section have been almost accomplished in this run. This paper takes a beam dynamics simulation on beam transport in MEBT and DTL at different DTL accelerate models. Meanwhile, beam's central orbit deviation at DTL and LRBT straight section due to DTL mechanical cavity's alignment errors is studied with IMPACT-Z code[2].

INTRODUCTION

During the linac beam commissioning, four energy models are successively taken corresponding to beam energy of 3MeV, 21MeV, 41MeV, 61MeV at DTL exit. The beam energy can be measured with FCT by Time of Flight method and checked with a bent magnet on LRBT. And the peak current of beam is 10mA. In order to compare beam quality at different models, the PARMILA code is taken to study. Due to the alignment error of DTL's mechanical cavity, beam's central orbit deviation may increase in DTL and LRBT, therefor some simulation study is necessarily to do for evaluating the size of the orbit change. This paper gives beam's orbit variation along linac and LRBT straight section.

SIMULATION STUDY OF BEAM DYNAMICS ON DIFFERENT DTL MODELS

CSNS/DTL consists of four accelerating cavities, the length among the cavities is designed to maintain longitudinal continuity. Figure 1 shows the layout of the front end and linac, inside the red box is MEBT and DTL. Now, the beam commissioning includes MEBT, DTL and LRBT straight section. Correspondingly, in this paper, the simulation study has been taken on these sections. Beam is matched from RFQ exit to DTL1 entry by MEBT, then matched from DTL4 exit to LRBT entry by LRBT. When

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no RF cavity of DTL is on, theoretical beam energy is 3MeV at DTL exit, similarly the DTL1 cavtity is on, beam energy is 21MeV at DTL exit. Correspondingly, 41MeV beam in DTL2, 61MeV beam in DTL3. Unfortunately, the power supply of DTL4 still doesn't work, so there is no 80MeV beam in this beam commissioning, the simulation also excludes 80MeV beam in the paper.
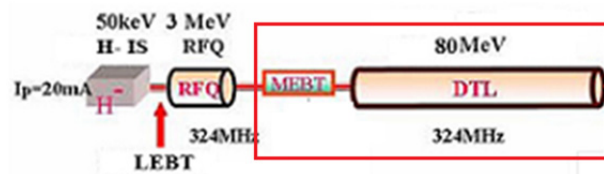

Figure 1: Layout of the front end and linac.

Emittance Growth with Different DTL Models

In the simulation, the initial distribution of particles is 6D water bag, the number of macro particles is 100,000, the peak currents of beams is 10mA, the normalized RMS emittance of beam at RFQ exit is about 0.2 π mm.mrad. Figure 2 is a comparison of the horizontal emittance evolution of beam along linac. Figure 3 is a comparison of the vertical emittance evolution of beam along linac.
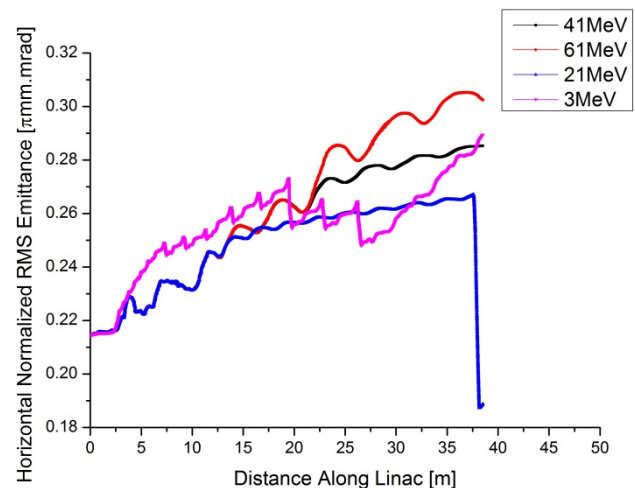

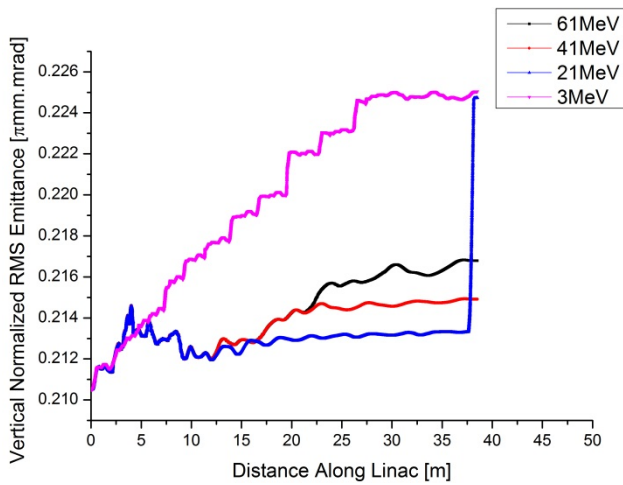Figure 2: Beam horizontal RMS emittance growth along linac.

Figure 3: Beam vertical RMS emittance growth along linac.

21MeV model, 41MeV model and 61MeV model have the same magnet lattice of MEBT and DTL, but the 3MeV model has a new different lattice in order to avoid obvious beam loss, the significant space charge effect has also been taken into consideration. However, beam loss is still large in 21MeV model, so this model still need to improve.

As can be seen from the Figure 2, when the 3MeV model and 21MeV model are taken, there are obvious decline in beam's horizontal RMS emittance growth curve. In the emittance's significant decrease section, there is a large number of beam loss. However, Figure 3 shows that the difference of beam's vertical emittance is quite small. It seems beam is well matched in vertical direction, and there is a mismatch in beam's horizontal direction. Through comparing Figure 2 to Figure 3, a conclusion can be gotten that differences between 41 MeV model and 61MeV model is small, and there is strong coupling of beam between the horizontal emittance and vertical emittance in 21MeV model. In this circumstance, large envelop oscillation may occur, thus lead beam loss.

Simulation Study of Beam Central Orbit Deviation with Alignment Error of DTL Cavities

In the simulation, the initial distribution of particles is also 6D water bag, the number of macro particles is still 100,000, the currents of beams is 10mA, the normalized RMS emittance of beam at RFQ exit is still 0.2 π mm.mrad, and 61MeV model is taken corresponding to realistic beam commissioning. In this simulation, there are no assumed quadruple magnet alignment error, gradient error and RF amplitude error, only alignment errors of DTL's vertical mechanical cavities is taken account.

Figure 4 is the beam loss rate along linac and LRBT straight section. Figure 5 is a linear fit curve with measured alignment error of mechanical cavities. To ignore the magnet location error and drift tube location error relative to mechanical cavity，every quadruple

magnet's alignment error indue to cavity can be obtained by linear fit equation in Figure 5.
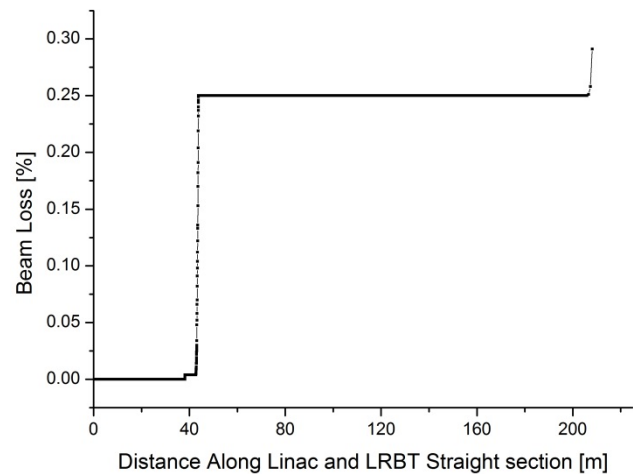

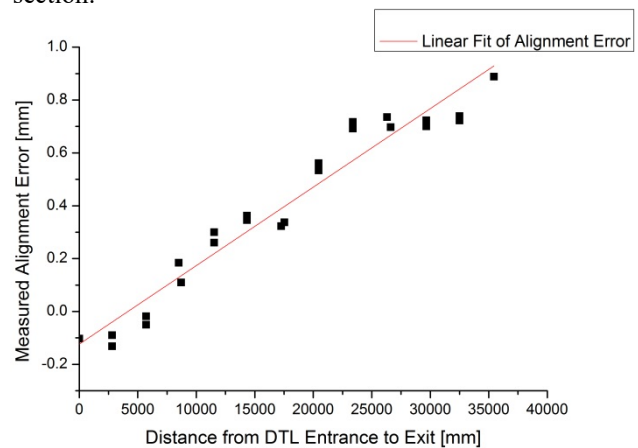Figure 4: Beam loss rate along linac and LRBT straight section.

Figure 5: Linear fit of DTL cavity's vertical alignment error with measured data.

As can be seen from the Figure 4, it starts to appear beam loss at DTL exit, all the beam loss rate is about 0.3% which is not quite large, and the Figure 5 shows that linear fit is quite similar to measured alignment data.
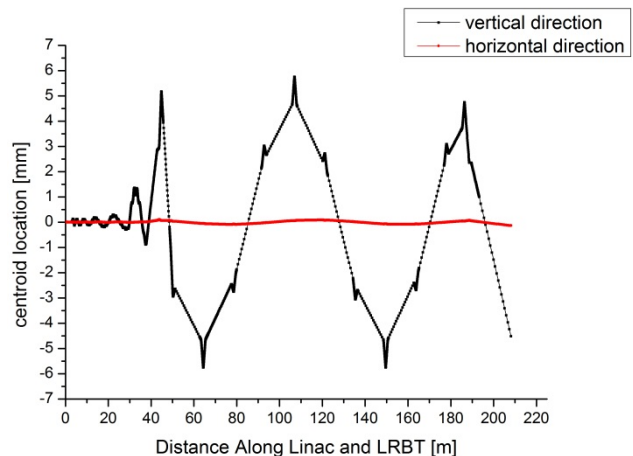

Figure 6: Centroid location along Linac and LRBT straight section.

Figure 6 is the beam central orbit variation along Linac and LRBT straight section. It shows that beam's veritical orbit is quite small in DTL, and significantly enlarge in LRBT. The largest vertical central orbit deviation is about 6mm due to DTL's vertical alignment error, and horizontal orbit is nearly 0. Therefore, beam's orbit in DTL entrance must be corrected quit well, and better LRBT model need to be considered.

CONCLUSION

In this paper, different DTL model is compared by simulation code IMPACT-Z, 41MeV model and 61MeV is closer to theoretical model. And beam need to be matched better in horizontal direction due to the large emittance growth. DTL mechanical cavity's vertical alignment error accordingly affects beam's vertical central orbit deviation. Beam's centroid location varies more obvious in DTL than LRBT straight section. In order to decrease beam orbit in LRBT, beam's orbit at DTL entrance must be corrected quit well.

ACKNOWLEDGEMENTS

REFERENCES

[1] S. Wang, S. X. Fang, S. N. Fu *et al.*, "Introduction to the overall physics design of CSNS accelerators", Chinese Physics C, 2009, 33(S2): 1-3.

[2] J. Qiang, R. Ryne, S. Habib, V. Decyk, "An Object-Oriented Parallel Particle-in-Cell Code for Beam Dynamics Simulation in Linear Accelerators", Journal of Computational Physics, 2001, 163: 434.