ERROR ANALYSIS FOR THE C-ADS MEBT2

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Abstract

The driver linac of the China Accelerator Driven Subcritical system (C-ADS) consists of two injectors to ensure its high reliability. The Medium Energy Beam Transport line-2 (MEBT2) is an essential part of the accelerator to transport and match the beam from either injector to the main linac. A local achromatic scheme has been designed for C-ADS MEBT2 based on the injector-I, which is under development in the Institute of High Energy Physics (IHEP). This paper presents the error analysis results for this MEBT2 scheme.The effects of the initial mismatches and displacements of the incoming beam, the magnet and cavity misalignment, as well as the static and dynamic errors of electric and magnetic field will be studied. Beam trajectory correction scheme will also be discussed.

INTRODUCTION

The C-ADS project is composed of two parallel injectors due to its high reliability requirement. Each of the two injectors will be a hot-spare of the other[1, 2]. Although the two injectors that are installed in the final tunnel will be identical, two different design schemes are being pursued in parallel by the Institute of High Energy of Physics (IHEP) and the Institute of Modern Physics (IMP), respectively.

The beam transport line from the end of the injector to the beginning of the main linac is called the second Medium Energy Beam Transport line (or MEBT2). A local achromatic scheme of MEBT2 has been proposed based on injector-I scheme which is under development in IHEP[3]. In this paper, we will show the error analysis results for this MEBT2 scheme. The effects of the initial mismatches and displacement of the incoming beam, magnet and cavity misalignment, as well as static and dynamic errors of electric and magnetic field will be studied. Beam trajectory correction scheme will also be discussed.

MISMATCHES AND DISPLACEMENT OF THE INCOMING BEAM

Betatron mismatch might lead to big emittance dilution[4]. Here we study the emittance growth caused by different input beam mismatches. To characterize a mismatch factor of M in x plane, the TWISS parameters α_x and β_x of the input beam will be multiplied by $(1 + M)^2$ [5]. Here we assume the input beam is mismatched by a factor of up to 20% in each of the three planes, and the resultant beam emitance growth is shown in Fig. 1. The simulated beam distribution from RFQ [6] exit is tracked to the end of the injector and will be used as our input. The number of particles used in the simulation is NGOOD= 99072, and the simulations are carried out with the code TraceWin.

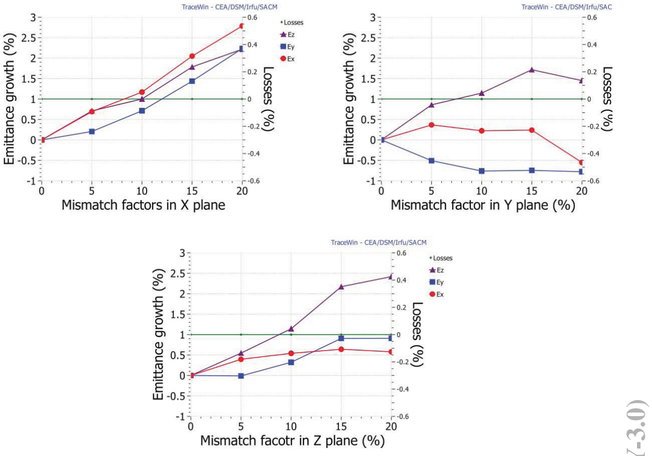

Figure 1: The rms emittance growth caused by different mismatches in each of three planes.

We can see that for a mismatch factor of up to 20% in all three planes, the resulted beam emittance growth is less than 3%, which can be considered small enough for our design.

The displacement effect of the incoming beam on the emittance has also been studied. The results of the displacement in x and $x'$are shown in Fig. 2. It is interesting to note that the emittance growth in all three planes are increasing (or decreasing) linearly as the beam centroid displacement in x and x' increases from -1 mm and -1 mrad to 1 mm and 1 mrad, respectively. The results show that the displacement in x plane has little impact on beam emittance in all three planes.

The emittance growth caused by the displacement in y and y' are shown in Fig. 3. Nonlinearity is shown between the emittance growth and the beam centroid displacement as y and y' increases from -1 mm and -1 mrad to 1 mm and 1 mrad, respectively. A comparable emittance growth is caused by the displacement in y plane as the one in x plane. Thus the displacement in transverse planes has negligible effect on the beam emittance growth.

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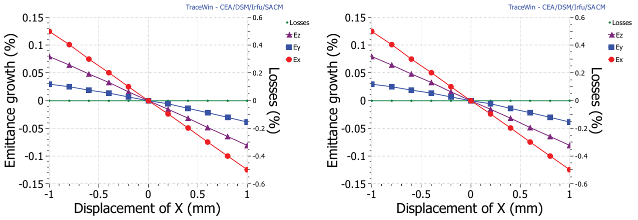

Figure 2: The rms emittance growth caused by displacements of beam centroid in x plane.

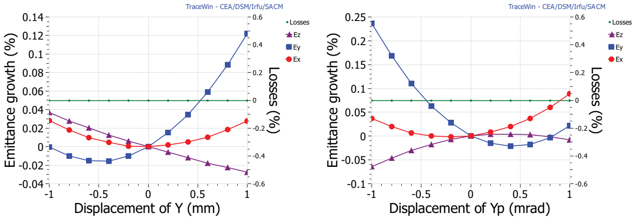

Figure 3: The rms emittance growth caused by displacements of beam centroid in y plane.

For the displacement in longitudinal plane, we only consider the energy displacement effect since the phase can always be adjusted by phase scanning. The beam emittance growth caused by the energy displacement is shown in Fig. 4. We can see that the energy displacement has a much bigger effect on the beam emittance. For an energy offset of up to 0.1 MeV, the transverse emittance growth is 1%, while 6% for the longitudinal emittance.

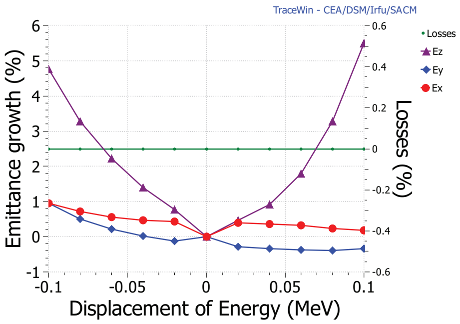

Figure 4: The rms emittance growth caused by beam energy displacements.

STATIC ERROR AND ORBIT CORRECTION

Static errors are mainly the misalignment errors and field errors. The effect of these errors can be detected and corrected with appropriate diagnostic devices and correctors. The amplitude of the static errors used for our error analysis are shown in Table 1. The phasing error of all cavities are 1 degrees. To diagnose the beam centroid distortion caused by static errors, we put one Beam Position Monitor (BPM) next to each bend, each normal conducting cavity and every triplet. One corrector will be located next to every triplet to correct the beam center offset. For the SC spoke-012 and spoke-021 sections, there will be one cold BPM in each cell and one corrector appending to the SC solenoid.

Table 1: Amplitudes of static errors used for the error analysis .

Element	Disp. (mm)	Rot. (mrad)	Field (%)
Quadrupoles	0.1	2	0.5
Bend	0.5	2	0.1
NC cavity	0.1	2	1
SC solenoid	1	2	0.5
SC cavity	1	0.02	1

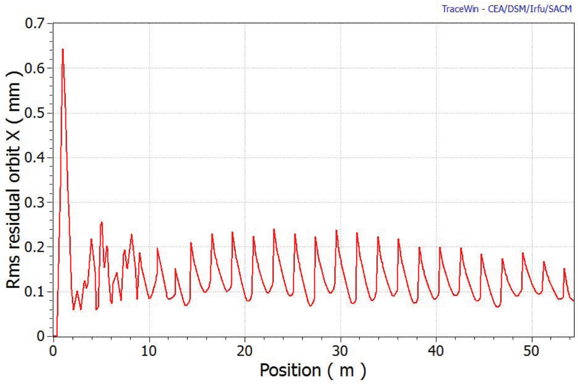

Figure 5: The residual orbit in x plane of MEBT2 and spoke-021 sections.

To better characterize the orbit correction effect, we analyze the correction scheme of the MEBT2 and the following spoke-021 section together. The orbit correction result is shown in Fig. 5. We can see that the residual orbit can be controlled to be less than 0.3 mm.

The first peak in the residual orbit corresponds to a centered incoming beam and the errors of the bending magnet. When the orbit correction is done together with the previous sections of the injector, the peak will disappear.

DYNAMIC ERROR OF MAGNETS AND CAVITIES

Dynamic errors are those errors that can not be measured and then corrected. For the focusing magnet, the dynamic errors are the ripple amplitude from power supplies. For the RF field, the dynamic errors are field amplitude and phasing errors from power source and control systems. Fortunately, most of the dynamic errors are usually much smaller than the static errors with the exception of the dynamic RF errors that are almost simular to the static ones. The amplitude of the dynamic errors for different elements used for error analysis is shown in Table 2. The phasing errors of all cavities are 0.5 degrees.

Table 2: Amplitudes of dynamic errors used for the error analysis .

Element	Disp. (μm)	Rot. (mrad)	Field (%)
Quadrupoles	1	0.02	0.05
Bend	5	0.02	0.01
NC cavity	1	0.02	0.5
SC solenoid	5	0.02	0.05
SC cavity	5	0.02	0.05

With the errors set up as shown in Tables 1 and 2, the orbit correction scheme as described in the previous section, the resulted beam emittance growth is simulated statistically with 1000 runs and 2000 particles in each run. For each run, the errors are randomly generated within the maximum amplitude with an even probability. The simulated results are shown in Fig. 6. We can see that the average emittance growth in x plane is 7% with a rms width of 0.7%. The average emittance growth in z plane is 14% with a rms width of 0.6%.

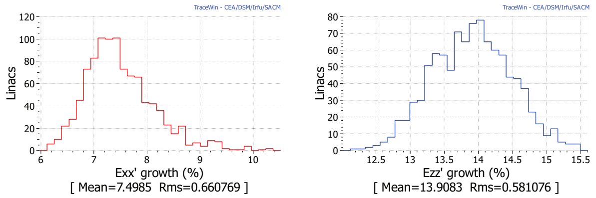

Figure 6: The beam emittance growth in x and z planes with both static and dynamic errors. Beam centroid orbit correction is enabled.

CONCLUSION

In this paper we have studied the error effect on the beam emittance growth for the local achromatic MEBT2 scheme. The effects of the initial mismatches and displacements of the incoming beam, the magnet and cavity misalignment, as well as the static and dynamic errors of electric and magnetic field have been studied. Beam trajectory correction scheme has also been presented.

It is found that the transverse beam centroid displacement has little effect on the rms beam emittance, while the beam energy offset could result in a longitudinal emittance growth of up to 6%. The static errors of different elements have been analyzed, a orbit correction scheme has been presented. The residual orbit could be corrected to be within 0.3 mm based on the proposed correction scheme. When dynamic errors are taken into account, an average emittance growth of 7% and 14% is observed for the transverse and longitudinal planes. All the studies of different errors has encountered no beam losses. The error analysis results show that the local achromatic MEBT2 scheme is a robust design.

ACKNOWLEDGEMENT

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