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BEAM DISTRIBUTION TRANSFORMATION WITH SFMS AT 3MeV C-ADS BEAMLINE*

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Abstract

The C-ADS project is building a test facility at the Institute of High Energy Physics. The design goal of the test facility is 10MeV beam energy with a continuous beam current of 10mA. To sustain the 100kW CW beam power at the beam dump, a beam distribution transform system is designed. The Step Field Magnets (SFMs) are used to transform the beam distribution from Gaussian to uniform. In this test stand, two sets of SFMs will be employed to manipulate the beam distribution. At the first commissioning stage, the bump dump line will be connected to the Medium Energy Beam Transport-1 (MEBT1) to test the beam manipulation scheme. The design and error analysis of this 3MeV beam dump line will be discussed in this paper.

INTRODUCTION

The C-ADS project is to build a 1.5GeV proton linac with a continuous wave beam current of 10mA [1]. To ensure the extremely high reliability, the C-ADS linac will have two identical injectors, which can be the hot-spare of each other. As the first stage of the project, two different schemes of injectors are under study at IHEP and IMP simultaneously.

The test facility of injector-1 is now under construction at the Institute of High Energy Physics. The design goal of the test facility is 10MeV beam energy with a continuous beam current of 10mA. To sustain the 100kW CW beam power at the beam dump, a beam distribution transform system is designed. The Step Field Magnets (SFMs) are used to transform the beam distribution from Gaussian to uniform [2,3]. At the first commissioning stage, the bump dump line will be connected to the Medium Energy Beam Transport-1 (MEBT1) to test the beam manipulation scheme. The design and optimization of this 3MeV beam dump line will be discussed in this paper.

DESIGN OF BEAM DUMP LINE

The test facility is located at the Hall-1 in IHEP. To fit into the hall properly and avaoid the recoil neutrons, the beam dump line is designed to have a bending angle of 15 degrees. The layout of the beam dump line is shown in Fig. 1. The first three quadrupoles before the bending magnet is used to adjust the twiss parameters at the exit of the bending magnet, together with Q4, they create an extreme flat beam at the first pair of SFMs. Q5 and Q6 will then rotate the beam by 90 degrees to form another extreme flat beam with different orientation. The rms beam size from the MEBT1 entrance to the end of the beam dump line is shown in Fig. 2.

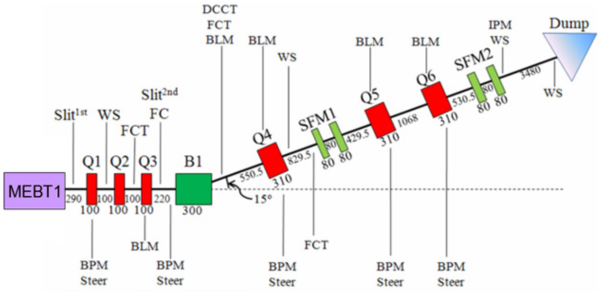

Figure 1: Layout of the 3MeV beam dump line of C-ADS injector-1 test facility.

We can see that the beam sizes from the MEBT1 entrance to the end of the beam dump line has been enlarged by roughly a factor of ten, thus to decrease the maximum power deposition on the dump target. The multi-particle tracking has been done with the code TraceWin using the simulated beam distribution from the RFQ [4]. After tracking, the particle distribution at the real space is shown in Fig. 3.

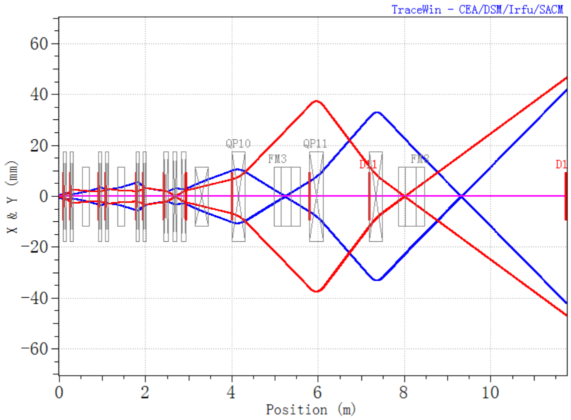

Figure 2: RMS beam sizes from MEBT1 entrance to the end of beam dump line.

From Fig. 3 we can see that, the particle distribution at the end of the beam dump line is pretty uniform, the size of the beam core is about 120mm in both horizontal and vertical plane. The homogeneity of the particle can be measured experimentally using the last wire scanner in the beam dump line. Assuming the resolution of the wire scanner is 1mm, the signal from the measurement can be

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generated from the particle distribution. The emulated signal is shown in Fig. 4.

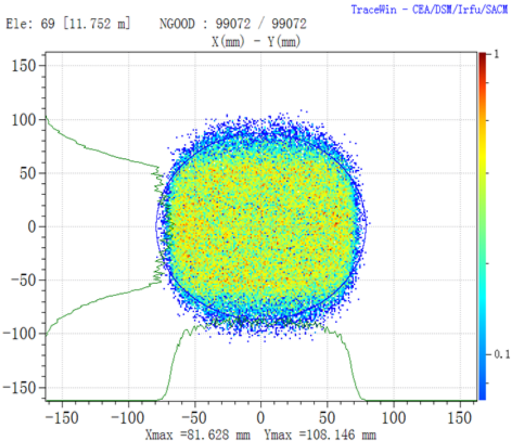

Figure 3: Particle distribution in real space at the target of the beam dump line.

From Fig. 4 we can see that, the variation of particle intensity in the beam core is less than 10%, thus the power deposition. The power density can be calculated assuming each macro particle carries the same power. The resulted power density is 246W/cm^2, which is well below the required maximum power density 585 W/cm^2.

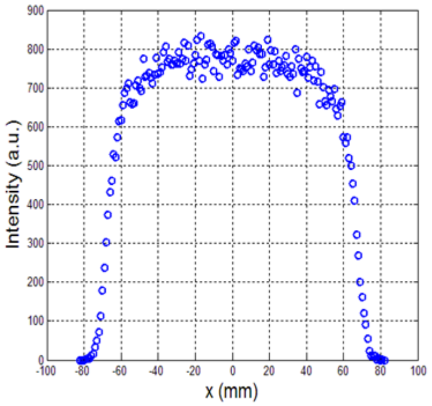

Figure 4: Emulated signal from the last wire scanner at the beam dump line.

ERROR ANALYSIS RESULTS

Since the SFMs has very small aperture at one direction, extensive error analysis has to be carried out to ensure there will be no significant beam loss on the magnets. We used the real field distribution provided by the magnet design group, and divided the field map to three separate parts and insert collimators at the mechanical margin of the SFMs to characterize the beam loss on the magnets.

The specifications of the errors are listed in Table 1. The errors that has been considered are, the displacement error in x and y plane, the rotation error along x, y and z axis and the field gradient error. All the errors have taking into account of the static and dynamic errors. The errors are uniformly distributed between the plus and minus of setting value. The listed value in Table 1 is the maximum range error.

Table 1: Errors (static and dynamic) Used in Beam Dump Line Error Analysis

Error type	**Quadrupole**	**Bending magnet**
Displacement (mm)	0.1/0.002	0.5/0.005
Rotation (mrad)	2/0.02	2/0.02
Gradient (%)	0.5/0.05	0.1/0.01

We simulate 1000 linacs to statistically analyse the error effects. Orbit correction at both x and y direction at each quadrupole is enabled to keep the beam center on orbit. The resulted beam density ratio in x and y planes are shown in Fig. 5.

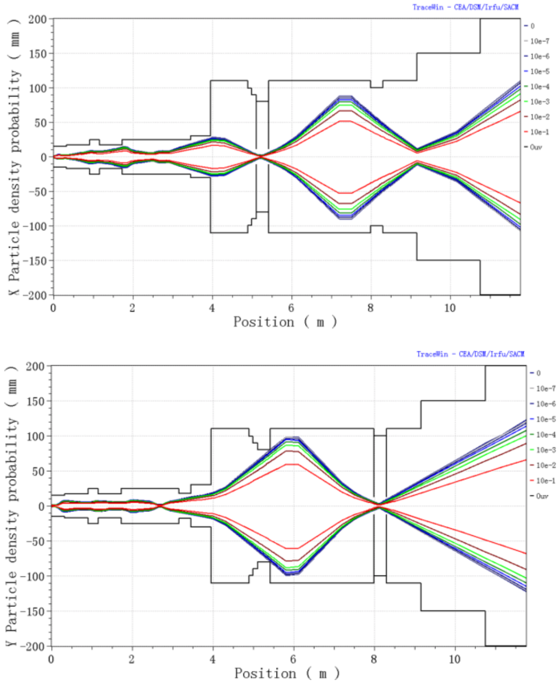

Figure 5: Accumulated beam density in 1000 linacs in x (upper plot) and y plane (lower plot).

The accumulated beam density shows that the 1000 linacs have no particle loss along the beam dump line. The beam sizes are well controlled at the small aperture of the SFMs, while the maximum beam size at the large aperture direction of the first pair of SFMs is getting close to the hard edge. It is worth pointing out that, at the large aperture direction, the beam size is very big, so the outer most particles have very low density, thus we preferred to save more margin at the small aperture direction of the SFMs.

For the orbit correction at the beam dump line, the BPM resolution has been set at 0.4mm due to the big beam size along the beam line. The resulted rms residual orbit is less than 0.4mm.

SUMMARY

We have shown the design and error analysis results of the 3MeV beam dump line for the C-ADS test stand. The SFMs are used to manipulate the beam distribution and decrease the maximum power density at the beam dump target. The design shows the beam core size is about 120mm in both x and y direction. The homogeneity of the beam power distribution is within 10%, and the maximum power density is 246W/cm^2.

Detailed error analysis has been done for the beam dump line, taking into account of static and dynamic element errors. The orbit correction has been enabled, the central orbit was kept below 0.4 mm in rms. The statistical results with 1000 linacs show that there is no beam loss in the beam dump line.

ACKNOWLEDGMENT

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