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# On the Option of the Single Plane Collimation by Each Collimator in MEBT

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# 1. INTRODUCTION

In the beam physics simulations and the accelerator requirements, it has been assumed that MEBT houses collimator systems at three locations, where the system at each location includes two blades for each transverse plane and four blades in total. Due to limitations in available spaces and costs, it has been considered that the system at each location includes only a pair of blades for one plane, at least during the commissioning and the initial phases of the operation, while maintaining the capability of housing four blades at each location in a later phase of the operation. This document reviews the functions of the MEBT collimators and discuss the implications if the above-mentioned option is actually adopted.

Figure 1 shows the schematic layout of the current baseline MEBT (version 2015.v0d) as well as the beam envelopes and apertures. In the figure, three locations with tight apertures at ~0.86 m, ~2.32 m, and ~3.54 m correspond to the locations of the collimators.

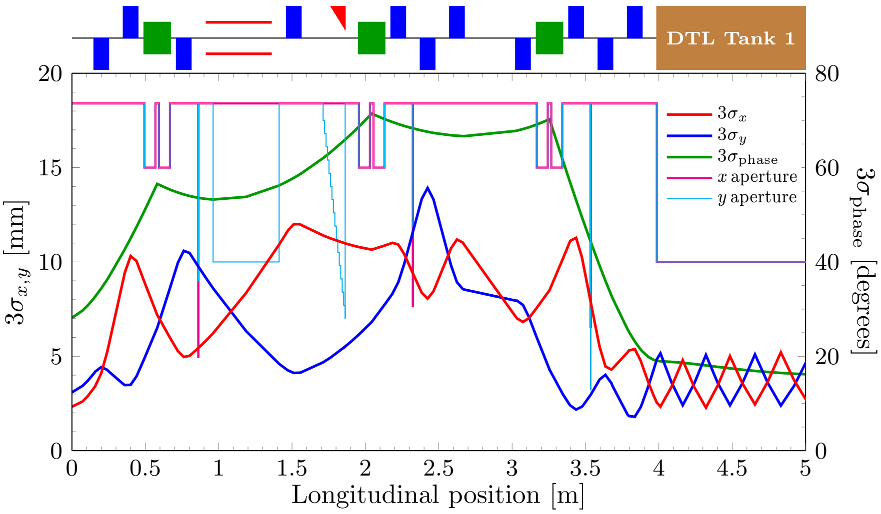

Figure 1: Schematic layout (top) and beam envelopes with apertures (bottom) for MEBT.

# 2. COLLIMATORS FUNCTIONS AND IMPLICATIONS FOR COLLIMATING ONLY ONE PLANE AT EACH LOCATION

As described and discussed below, the collimators in MEBT have four functions. The first function of the collimators is to clean transverse halos in the RFQ output beam, in case there are any. The three collimator locations are separated such as to cover all the direction in the phase space for both plane. This function of the collimators is discussed in detail in page 3 of [1]. If we apply the collimation to only one plane at each location, the phase space of ether plane is no longer covered. On top of that, simulations predict no preferred direction in the phase space or a preferred plane for the transverse plane halos in the RFQ output beam. For example, two likely causes of the halos in the RFQ output beam are a mismatch at the RFQ entrance and a lower level space charge compensation (compared to the nominal 95%) in the LEBT and, for these cases, there is no known mechanism to bias the distribution of the halos over the direction in the phase space or between the planes. Given these conditions, if we adopt this option of applying the collimation to only one plane at each location and thus break the coverage of the phase space, this function of the collimators is heavily compromised and we effectively lose one mitigation scheme of the transverse plane halos in the RFQ output beam.

The second function of the collimators is to compensate the transverse plane halos developed within the MEBT itself. Consisting of independent cavities and quadrupoles, the focusing of the MEBT cannot be as strong as those of the tightly structured RFQ and DTL and thus minor development of halos in a MEBT is hardly avoided when the current is high. The collimators allow to suppress such halo development within the MEBT itself. The optics of the horizontal and vertical planes in the MEBT are not identical since the fast chopping is conducted in the vertical plane. The beam goes through a waist in the vertical plane in the region of the chopper and its dump and the strong space charge force in the vertical plane in this region makes the situation of the halos in the transverse plane much worse in the MEBT (see Fig 4 of [1]). Thus, for this function of the collimators, the vertical plane is more important, especially for the second and third locations which are downstream of the chopper and its dump. Once the beam enters the DTL, the particles are redistributed within the beam and this rapid process evens out the halos in both plane. If evaluated at the end of the DTL, the halos in both plane are mostly originated from the halos in vertical plane developed within the MEBT (assuming no issue in the RFQ output beam). Hence, for this function, applying the collimation only to the vertical plane does not have a significant impact, unlike the case of the first function.

The third function of the collimators is to reduce the intensity of the partially-chopped bunches. The chopper plate of 450 mm is made of a stripline instead of a meander line and also the rise and fall time of the chopper is ~10 ns with respect to the 2.84 ns (352.21 MHz) of the bunch space. Because of these two conditions, several bunches receive kicks with intermediate strengths from the chopper (*partially-chopped*). The locations of the second and third collimators are close to the locations of the first and second maxima of the chopper's deflection. In other words, they are close to 90 and 270 degrees in phase advance from the chopper. This allows for these two collimators to scrape the partially-chopped bunches and reduce their intensities, thus reducing the losses in the DTL. Simulation studies on this subject were reported in [2,3]. Because the chopper deflects the beam in the vertical plane, this function requires vertical blades for the second and third collimator locations. Note the reduction of the intensity is mostly done by the second collimator so the second collimator is more important for this.

The fourth and last function of the collimators is to protect the aperture where the ratio between the beam size and aperture is small. Two critical locations in the MEBT are the chopper entrance, where a square aperture has a much smaller gap of 20 mm in the vertical plane, and the sixth quadrupole. For both case, the ratio becomes small for the vertical plane as seen Fig 1. The first and second collimators are located at these two location (to be precise, in front of the chopper and between the fifth and sixth quads for each) and it has been verified in simulations that these collimators could reduce the losses at these locations. There is no critical location for the horizontal plane so, for this function of the collimators, only the vertical collimation at the first and second locations matter.

# 3. CONCLUSIONS

For each of four functions of the MEBT collimators, we reviewed the impact to have the blades for only one plane at each collimator location and considered the blades for which plane is more important. From the above discussions, the best option is clearly to select the vertical plane for all the three locations. With this option, the first function of cleaning the transverse plane halos in the RFQ output beam is heavily compromised. On the contrary, the second function of suppressing the transverse plane halos generated within the MEBT itself is not likely to have a significant impact since the halos in this case is mostly in the vertical plane. The third and fourth functions are by default only for the vertical plane and so not affected.

If indeed the RFQ output beam includes the transverse plane halos (e.g., due to the lower level space charge compensation level in the LEBT) and we cannot apply the collimation in the horizontal plane, the consequence is a higher risk of losses in the downstream sections. As studied in detail in [4,5], because the aperture in the DTL is much smaller than those in the following sections, it is highly unlikely that the halos in the transverse planes at the DTL entrance cause losses besides inside the DTL. Thus, the risk of the losses in this case only applies to the DTL and no impact is anticipated for more-sensitive-to-the-losses superconducting cavities.

# 4. REFERENCES

[1] R. Miyamoto et al., IPAC14, THPME045; http://accelconf.web.cern.ch/AccelConf/IPAC2014/papers/thpme045.pdf.

[2] R. Miyamoto et al., LINAC14, MOPP039; http://accelconf.web.cern.ch/AccelConf/LINAC2014/papers/mopp039.pdf

[3] R. Miyamoto, ESS-0049826.

[4] R. Miyamoto, HB14, MOPAB18; http://accelconf.web.cern.ch/AccelConf/HB2014/papers/mopab18.pdf.

[5] R. Miyamoto, ESS-0088181.

# DOCUMENT REVISION HISTORY

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