ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-MOPAB246

DESIGN OF THE MEBT FOR THE JAEA-ADS PROJECT*

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Abstract

The Medium Energy Beam Transport (MEBT) will transport a cw proton beam with a current of 20 mA and energy of 2.5 MeV from the exit of the normal conducting Radiofrequency Quadrupole (RFQ) to the superconducting Half-Wave resonator (HWR) section. The MEBT must provide a good matching between the RFQ and HWR, effective control of the emittance growth and the halo formation, enough space for all the beam diagnostics devices, among others. This work reports the first lattice design and the beam dynamics studies for the MEBT of the JAEA-ADS.

INTRODUCTION

The Japan Atomic Energy Agency (JAEA) is designing a 30 MW cw proton linac for the accelerator-driven subcritical system (ADS) project [1]. Figure 1 shows the linac configuration for the JAEA-ADS project.

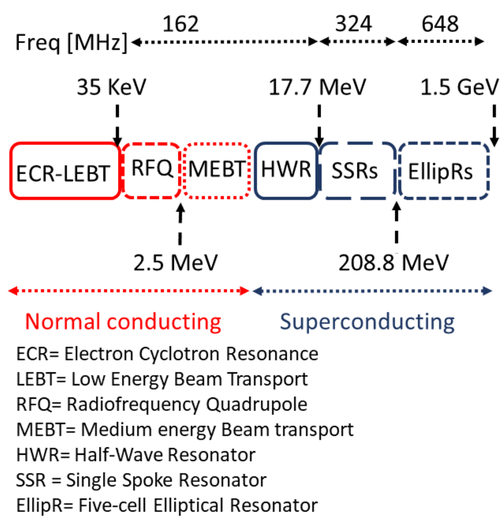

Figure 1: Schematic design of the JAEA-ADS linac.

The Medium Energy Beam Transport is the bridge between the normal conducting and superconducting part of the JAEA-ADS linac. The MEBT matches the Radiofrequency Quadrupole (RFQ) with the Half-Wave Resonator (HWR) section. Besides, the MEBT contains several beam diagnostic used to monitor the beam quality during the operation. Table 1 presents general information about the JAEA-ADS linac, the normalized rms emittance $\varepsilon_{norm,rms}$ at the end of the RFQ [2], and the ideal input $\varepsilon_{norm,rms}$ and twiss parameters for the HWR section. The HWR section uses solenoids for transverse focusing of the beam; thus, the same transverse initial twiss parameters and emittance are required. The ideal values reported in Table 1 were obtained for input matching studies of the main linac. The design and beam dynamics for the JAEA-ADS MEBT are presented.

Table 1: Parameters for the JAEA-ADS MEBT Design

Parameter	**Value**
Energy MeV	2.5
Beam current mA	20
RFQ output $\varepsilon_{norm,rms,x}$ (π mm mrad)	0.20
RFQ output $\varepsilon_{norm,rms,y}$ (π mm mrad)	0.21
RFQ output $\varepsilon_{norm,rms,z}$ (π mm mrad)	0.37
Ideal HWR input $\varepsilon_{norm,rms,x/y}$ (π mm mrad)	0.23
Ideal HWR input $\varepsilon_{norm,rms,z}$ (π mm mrad)	0.38
Ideal HWR input $\alpha_{x/y}$	0.64
Ideal HWR input $\beta_{x/y}$ (mm/πmrad)	0.76
Ideal HWR input α_z	2.05
Ideal HWR input β_z (mm/π mrad)	2.43

MEBT LATTICE DESIGN

In addition to the ideal input parameters presented in Table 1, the MEBT design pursued a compact length to reduce the emittance growth, but requires enough space for the beam matching and diagnostic element. To this end, the MEBT configuration was developed to satisfy the following constraints:

- Beam power lost < 1 W/m, hand-on maintenance criteria.
- $\varepsilon_{norm,rms}$ growth < 20% in all the planes.
- Transverse rms size < 10 mm and maximum transverse beam size < MEBT aperture, to reduce the possibility of beam losses.
- Mismatch factor [3] < 0.1 in all the planes with respect to the ideal twiss parameters in Table 1.
- MEBT length < 3 m.

The models were created using the code TraceWin [4]. We used the J-PARC linac MEBT [5] as a reference, Fig. 2 (a). Our design does not require a chopper or bending magnet; thus, we discarded these elements. The MEBT has a length of 1.92 m and is composed of four normal conducting quadrupoles and two bunchers cavities for the transverse and longitudinal match, respectively. The last matching element at the MEBT is a buncher cavity because the HWR period starts with a solenoid. Figure 2 (b) presents the final design. The parameters of the matching elements and the drift spaces were adjusted using beam envelopes in TraceWin. However, enough space is kept for the diagnostic devices. Table 2 present a summary of the MEBT elements. The envelope study verified some design constraints such as length and

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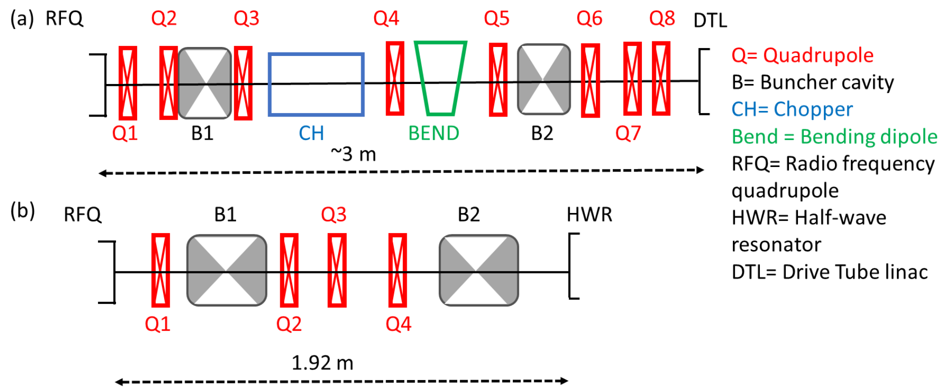

Figure 2: MEBT lattice design for the J-PARC linac (a) and the JAEA-ADS (b).

rms transverse size. For the rest of the conditions, we used multiparticle simulations to evaluate them.

Table 2: Parameters of the MEBT Elements

Element	Length (mm)	Aperture (mm)	Gradient (T/m) / Voltage (kV)
D1	180	40	
Q1	60	70	7.6
D2	105	40	
B1	300	40	64.5
D3	68.9	70	
Q2	60	70	-14.1
D4	156.7	70	
Q3	60	70	18.1
D4	179.6	70	
Q4	60	70	-11.1
D5	193.5	70	
B2	300	40	114.7
D6	200	40	

D stands for drift, Q for quadrupole and B for buncher cavity. The positive sign of Q gradients means that the beam is focusing on the x plane.

MULTIPARTICLE TRACKING STUDIES

The MEBT performance was tested by analyzing the beam loss, normalized rms emittance, transverse beam envelopes, and beam halo. To this end, we tracked a beam distribution of $1x10^7$ macroparticles from the RFQ studies [2]. Figure 3 presents the phase space distributions before and after its transport through the MEBT. Table 3 presents a summary of the design goals from the envelope and multiparticle tracking. Multiparticle tracking shows the maximum transverse sizes did not reach MEBT aperture, as is shown in Fig. 4; consequently, non beam loss was recorded.

Figure 5 presents the normalized rms emittance along the linac. The results show the emittance growth was below 20% on the transverse plane and 5% on the longitudinal one. The mismatch is higher on the transverse plane than the longitudinal one; however, the mismatch was lower than 0.1 on the three planes.

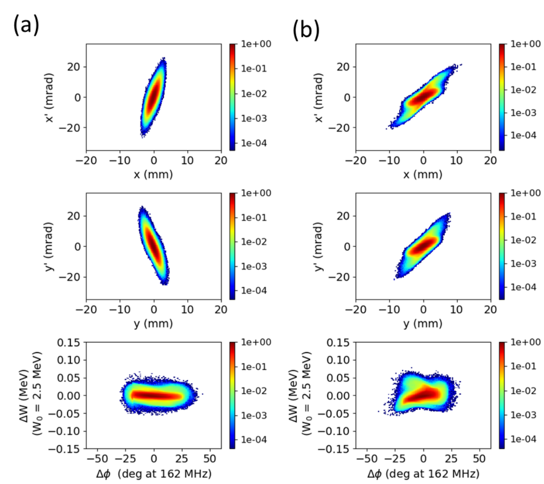

Figure 3: Phase space distribution at the entrance (a) and at the end (b) of the MEBT.

Table 3: Design Goals Values Obtained from Multiparticle and Envelope Simulations in TraceWin

Parameter	Value x / y / z
Beam power lost W/m	0
Length m	1.92
$\varepsilon_{norm,rms}$ growth (%)	17 / 9 / 3
$\varepsilon_{norm,rms,x}$ (π mm mrad)	0.24 / 0.23 / 0.39
Maximum transverse rms size (mm)	7.4 / 3.7
Maximum transverse size (mm)	27.7 / 18.2
Mismatch	0.09 / 0.06 / 0.03

The ε values are at the end of the MEBT. The mismatch is concerning the ideal twiss parameters presented in Table 1

In addition, we analyzed the beam halo behavior by calculated the percentage of halo size (PHS) and halo particles (PHP) introduced by Ngheim [6]. We used the PHS and

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PHP parameters instead of the standard *H* parameter [7] because we were interested in the size and the numbers of particles in the halo along the MEBT. Figure 6 top shows the halo percentage of the particles on the transverse plane was reduced half of the initial value; in contrast, the halo particles on the longitudinal increased by the same proportion. Similar behavior was observed for the halo size, Fig. 6 bottom; however, only 20% of the reduction occurred on the transverse plane.

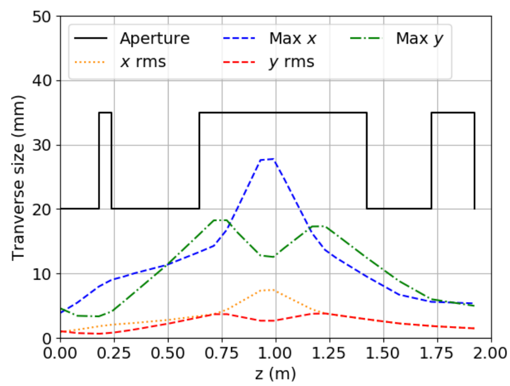

Figure 4: Maximum and rms beam size on the transverse plane in the MEBT. The aperture is the physical radius of the elements that composed the MEBT.

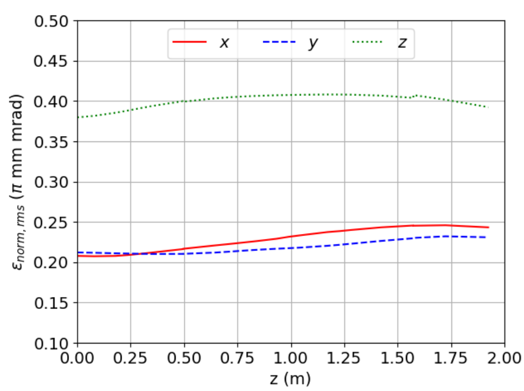

Figure 5: Normalized rms emittance along the MEBT.

CONCLUSION

The MEBT has a length of 1.92 m and contains two cavity bunchers and four normal conducting quadrupoles. The multiparticle tracking showed the normalized rms emittance and twiss parameters are close to the ideal value required for the HWR section. This performance was achieved neither having beam losses higher than the hand-on maintenance limit nor increasing the transverse beam halo. Thus, the JAEA-ADS MEBT is a compact transport line that fulfills the beam optics goals of beam matching, power lost, emittance, and beam halo.

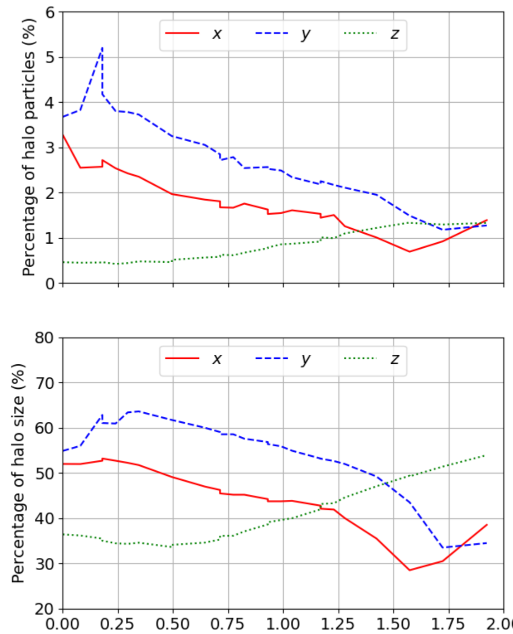

Figure 6: Evolution of the percentage of the halo with respect to the total beam (top) and percentage of the halo size to the total beam size (bottom) in the MEBT.

ACKNOWLEDGMENTS

The authors would like to thank to the members of the JAEA-ADS for their comments and suggestions.

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