DESIGN OF THE MEBT1 FOR C-ADS INJECTOR II

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Abstract

The MEBT1 of Chinese ADS Injector II[1] is described. It transports a 2.1MeV, 10mA CW proton beam through a series of 7 quadrupoles and two buncher cavities from the RFQ to the superconducting (SC) DTL. For emittance preservation, a compact mechanical design is required. Details of the beam dynamics and mechanical design will be given.

INTRODUCTION

The Chinese ADS project is planned to have a 10mA, 1.5GeV CW proton beam for nuclear waste transmutation. Superconducting linac is the major choice in the case. As one of the demonstration of the techniques for C-ADS linac, the Injector II with energy up to about 10MeV is being constructed in IMP independently [1].

A proton ion source provides a 35KeV beam that is matched with a two solenoid LEBT into a 4 meter-long 162.5MHz RFQ and transported by 2.7 meter-long MEBT1 to the first solenoid inside the first cryomodule. The beam will then be accelerated to 10MeV by 16 162.5MHz SC HWR cavities in two cryomodules. The beam will be matched from RFQ into the acceptance of DTL by MEBT1.

In addition, diagnostic devices are supplied to monitor the beam quality during operation and to enable tuning of the MEBT1 itself.

BEAM DYNAMICS

Due to the requirement of CW operation mode at 10mA, MEBT1 obeys the following design principles [2].

a) minimum beam loss
b) avoiding too large or too small envelope
c) phase space matching and emittance control
d) sufficient beam diagnostic devices
e) scraping beam halo
f) performance/cost evaluation

The major consideration in designing MEBT1 is to reduce the emittance growth. In a high current machine, the emittance growth is normally caused by linear and/or nonlinear coupling or strong space charge effects. In MEBT1, 4 quadrupoles (Q1-4) lie upstream to form an approximately symmetric beam. And 3 quadrupoles (Q5-7) lie downstream to form a symmetric waist in front of the SC DTL. The solenoids in crymodules require symmetric input beam to reduce emittance growth due to coupling of horizontal and vertical motion.

Two bunchers are used to match longitudinal twiss parameters. Room temperature quarter-wave-cavity (QWR) is employed as buncher.

Beam diagnostic box lies between Q4 and Q5, measuring the emittance and bunch length. BPM, wire scanner and scraper are distributed between the quadrupoles in MEBT1.The mechanical layout of the MEBT1 is shown in Fig. 1.

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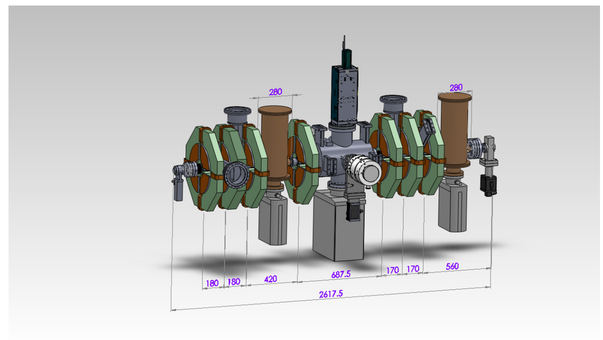

Figure 1: Mechanical layout of the MEBT1.

Figure 2 shows the trace3D simulation of the MEBT1, with beam transversal and phase spread envelopes(1.5cm and 90 degree full scale). The initial emittances are $5\varepsilon_{rms}$ [3].

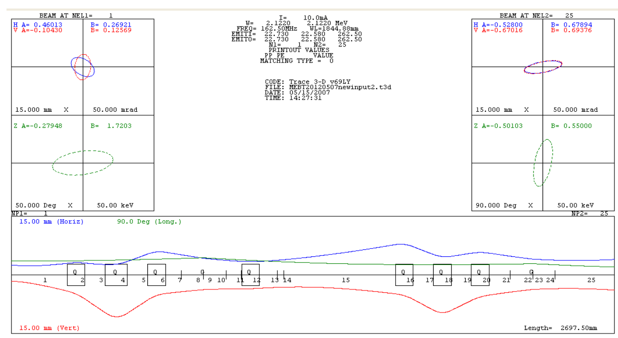

Figure 2: Beam envelopes in MEBT1 by Trace3D.

PIC Simulation

The PIC simulation of MEBT1 with space charge effect is done by Track code, employing the beam distribution from RFQ by Parmteqm, the 3D magnetic field distribution of quadrupoles from Opera and the electro-magnetic RF field of bunchers from CST. For inspection of the field leakage between adjacent quadrupoles, 3 quadrupoles are calculated together. The simulation result is shown in Fig. 3.

The PIC simulation results shows that rms emittance growth in MEBT1 is below 3%. Table 1 shows the normalized rms emittance before and after MEBT1 by Track.

To optimize the matching between MEBT1 and SC DTL, the acceptance of SC DTL section[4] is compared with the emittance at MEBT1 exit. Figure 4 shows that the emittance and acceptance are well matched.

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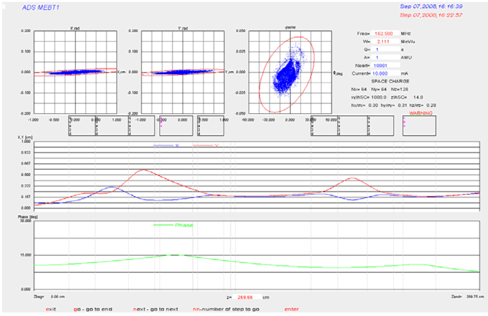

Figure 3: RMS beam envelope in MEBT1 by Track.

Table 1: RMS Emittance at MEBT1

	X (π mmmrad)	Y (π mmmrad)	Z (π mmmrad)
RFQ exit	0.3049	0.3032	0.2870
DTL in	0.3150	0.3096	0.2908

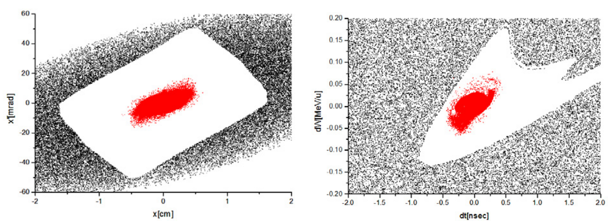

Figure 4: Acceptance(white margin) and emittance(red solid) at MEBT1 exit. Left: transverse phase space. Right: longitudinal phase space.

IMPLEMENTATION

The 2.67m long MEBT1 incorporate 7 quadrupoles, two buncher cavities, a beam stop and numerous beam diagnostic devices.

Quadrupoles

All quadrupoles have an aperture diameter of 54mm, with 50mm beam pipe diameter. Q2 has the effective length of 100mm, while the other six have the effective length of 80mm. Table 2 lists some characteristics of quadrupoles. These quadrupoles also have the dipole coils for orbit correction. Figure 5 shows the quadrupole model in Opera code.

Table 2: Physical Parameters of Quadrupoles

	Type1	Type2
Physical length	80mm	100mm
Pole length	52mm	74mm
Full aperture	54mm	54mm
Maximum pole field	6500Gs	6500Gs
Integral strength of steers	21Gs*m	21Gs*m
Steering angle	10mrad	10mrad
Numbers	6	1

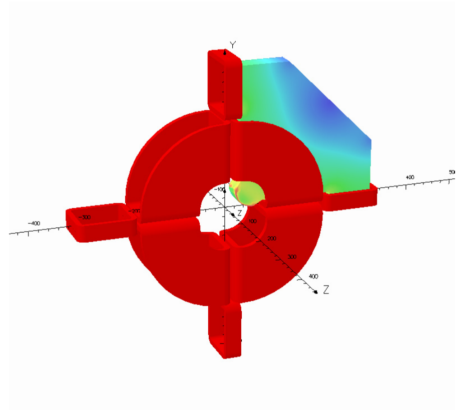

Figure 5: Quadrupole with steering coils.

Buncher Cavities

Two 162.5MHz room temperature buncher cavities focus the beam longitudinally to maintain the bunch length and to match the acceptance of 10MeV SC DTL. Both cavities have 50mm beam pipe diameter. The effective voltage of the two cavities is 100KV and 136KV respectively. Table 3 shows specification of bunchers. Figure 6 shows the cavity model in CST code.

Table 3: Specifications of Bunchers

Cavity type	r.t. QWR
Frequency	162.5MHz
Effective voltage	100, 136 kV
Power	7, 10 kW
Length	<280mm

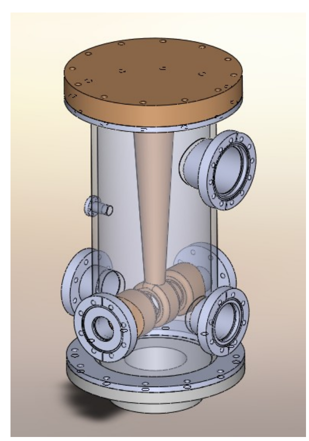

Figure 6: Room temperature(r.t.) QWR buncher cavity.

Diagnostic Devices

FCT and ICT are combined at both ends of MEBT1 to monitor the beam current. BPMs are located inside of the aperture of Q1, Q4, Q5, and Q7 to monitor the position and phase of the beam. They can also be used as the probes for machine protection. When a BPM plate suddenly induces a huge signal or large position error, trigger signal will be sent to the chopper at LEBT to switch off the beam.

A horizontal and a vertical scraper lie between Q1, Q2, and Q3. The un-accelerated particles with energy of

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approximate 35~50keV are scraped due to the larger envelopes at scraper. The third scraper lies between Q5 and Q6, aiming at halo scraping in vertical direction for experimental purpose.

A two-direction wire scanner is located between Q6 and Q7 to measure beam profile. A diagnostic box located between the Q4 and Q5 contains an emittance scanner, a bunch length monitor and a beam stop. The bunch length monitor is a fast faraday cup (FFC). The stop is to avoid beam going downstream to SC section in commissioning procedure.

All the insertion devices, including emittance scanner, wire scanner, fast faraday cup and beam dump, are only used for the shortly pulsed beam (low duty factor) during commissioning.

Magnets, buncher cavities and beam boxes are bolted and shimmed to individual rafts prior to installation of the rafts on the MEBT frame. Each of the two rafts is kinematically supported with an alignment system. Flexible bellows allow each raft to be aligned independently.

ACKNOWLEDGEMENT

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