DESIGN OF ACHROMATIC BENDS FOR THE HIGH ENERGY BEAM TRANSPORT SYSTEM OF HCI AT IUAC DELHI

Abanimohan Mandal, Dinakar Kanjilal, Gerald Oscar Rodrigues, Sarvesh Kumar
Inter-University Accelerator Centre, New Delhi, India

Abstract

The high energy beam transport system of the High Current Injector (HCI) being currently developed at IUAC will transport heavy ion beam of maximum energy ~1.8 MeV/u with mass to charge ratio (A/q) of 6 from drift tube linac (DTL) to the superconducting linear accelerator (LINAC) in the zero degree beam line of the existing 15UD Pelletron. The whole transport path (~50 m) consists of four 90 degree bends. Since the beams coming from DTL are expected to have an energy spread of 0.5%, the magnetic bends have to be achromatic. The transport system is designed considering the restrictions imposed by the existing beam hall and the other space constraints. The first three 90 degree achromats have the configuration of Q1Q2Q3MQ4MQ3Q2Q1 and the fourth one has configuration of Q1Q2MQ3Q4Q4Q3MQ2Q1 where Q stands for magnetic quadrupole and M stands for 45 degree bending magnet. Each achromat has been designed so that its total length is restricted to 7 m to fit into the available space. The maximum dispersion occurs at the middle of Q4. Beam dynamics codes like GICOSY and TRACE3D have been used to design the achromats and the detail of optics is presented.

INTRODUCTION

The HCI currently being developed at Inter University Accelerator centre (IUAC) is an alternate injector system based on electron cyclotron resonance (ECR) ion source. The 18 GHz high temperature superconducting based ECR called PKDELIS [1] was designed in collaboration with PANTECHNIK, France. The ions of A/q equal to 6 will be analysed by a large acceptance combined function 90 deg. analyzing magnet [2] placed on a 200 kV high voltage platform. The extracted ions are pre-accelerated to 8 keV/u and bunched using a multi-harmonic buncher to match with the input longitudinal emittance requirement of radio frequency quadrupole (RFQ). The ions of energy 180 keV/u coming out of RFQ will be transported to a room temperature DTL for further acceleration. Several quadrupole magnets and a 48.5 Mhz RF buncher will be used for transverse and longitudinal emittance matching to DTL input. The DTL enhances the energy of the ions to 1.8 MeV/u. This whole injector system will be housed in a beam hall called BH-III. The ions from DTL will be transported to an existing super conducting LINAC approximately 50 m away in a separate beam hall called BH-I. The whole beam transport system of HCI is divided into three sections as follows:

- Low energy beam transport section (LEBT) from ECR to RFQ
- Medium energy beam transport section (MEBT) from RFQ to DTL
- High energy beam transport section (HEBT) from DTL to superconducting LINAC

The HEBT has four 90 deg. bends. Since the ions coming out of DTL are expected to have energy spread ~0.5%, all these bends have been designed to be achromatic using two 45 deg. dipole magnets along with several quadrupole magnets. The present paper describes the design aspects of these achromatic bends.

LAYOUT OF BEAM HALLS

The layout of different beam halls in the accelerator building complex at IUAC is shown in Fig. 1. BH-1 consists of seven beamlines for the existing pelletron. The zero deg. line from the first switching magnet in vault area is used for augmenting energy of the beam coming from 15UD pelletron [3]. The bunched beam having FWHM ~1-2 ns from pelletron is further bunched by a superconducting niobium quarter wave resonator to ~150 ps and then injected into three LINAC cryostats [4] in BH-II. Each cryostat houses eight super conducting quarter wave resonators. The beam from LINAC is switched to four beamlines in BH-II. BH-III is situated on the eastern side of BH-I which is 33 m x 10 m in size housing the HCI. The schematic layout of HCI is shown in Fig. 1.

DESIGN OF ACHROMATIC BENDS

The HEBT has four 90 deg. bends, the first one being in BH-III and the other three are in BH-I. While designing each achromat, besides the input beam characteristics, the stress has been given on the geometrical constraints in the building layout. In BH-III, the major constraints are two pillars near first 90 deg. bend which restrict the overall length of the achromat, as it is necessary to have image point of the achromat before the first pillar to make space for the RF buncher and diagnostic equipment. The overall length available is ~ 7 m. To avoid multiple designs and to reduce cost all the dipoles magnets have been designed to have same specifications. Similarly care has been given on the type of quadrupole magnets used. The first three achromats have been designed identical, called type-I, whereas the last one has different configuration called type-II to accommodate the existing beam lines in BH-I.

Design of Type-I Achromat

This achromat has been designed with the input beam characteristics given in Table 1.

Table 1: Beam Parameters

Transverse and Longitudinal emittances (ε_x and ε_y, ε_z)	9 π mm mrad 350 π deg. keV
Mass to charge Ratio (A/q)	6
Energy of the beam (E)	1.8 MeV/u
Energy spread (ΔE)	0.5%
Phase spread (Δφ)	6.5 deg.

Different simulation codes viz. GICOSY [5] and TRACE 3D [6] have been used for design. Various achromatic configurations have been exercised and the best configuration suited to our geometrical constraints has been chosen. The configuration for type-I is Q1Q2Q3MQ4MQ3Q2Q1 where Q stands for quadrupoles and M stands for 45 deg. bending magnets. The maximum dispersion occurs at the middle of Q4 as shown in Fig. 2. Both spatial and angular dispersion coefficients have been minimized to get achromatic condition. The maximum field and bending radius of the bending magnets have been chosen to satisfy maximum rigidity of 1.28 Tm for the beam coming out of DTL. The lengths of the quadrupoles and drift spaces have been optimized to have total path length within 7 m. The entrance and exit shim angles of the 45 deg. dipole magnets have been optimized to avoid higher order effects due to large shim angles. Quadrupole Q3 and the optimum drift space between Q4 and bending magnet M helps in optimizing shim angles to 24 deg. The specifications of the quadrupoles and the bending magnets are given in Table 2 and 3 respectively. Taking higher order effects into consideration, negligible increase in size is observed. The tolerance in entrance and exit shim angles is found to be 1%. The curvature effects of the entrance and exit boundary have been found to be non-appreciable for radius of curvature greater than 2 m.

The first achromat in BH-III will also be used for momentum resolution to monitor energy of the beam out of DTL. A position sensitive diagnostic system will be placed at the image point to measure energy resolution as well as to tune DTL. In the momentum dispersion mode, the quadrupole Q4 is switched off and the other quadrupoles are used to focus beam at the same image point of the achromat mode. Figure 3 shows the momentum dispersion of the beam which comes out to be 2.6 cm/%Δp at the image plane of the first achromat.

Design of Type-II Achromat

The last 90 deg. bend in BH-I has been designed with slightly different configuration to keep the 15 deg Materials science beam line of pelletron as undisturbed. Type-II achromatic configuration is chosen to be Q1Q2MQ3Q4Q4Q3MQ2Q1. Large drift between Q2 and M is needed due to presence of existing beam line. Figure 4 shows the beam optics simulation for this achromat using GICOSY code.

The transverse and longitudinal optics of the HEBT section using TRACE3D code is shown in Fig. 5.

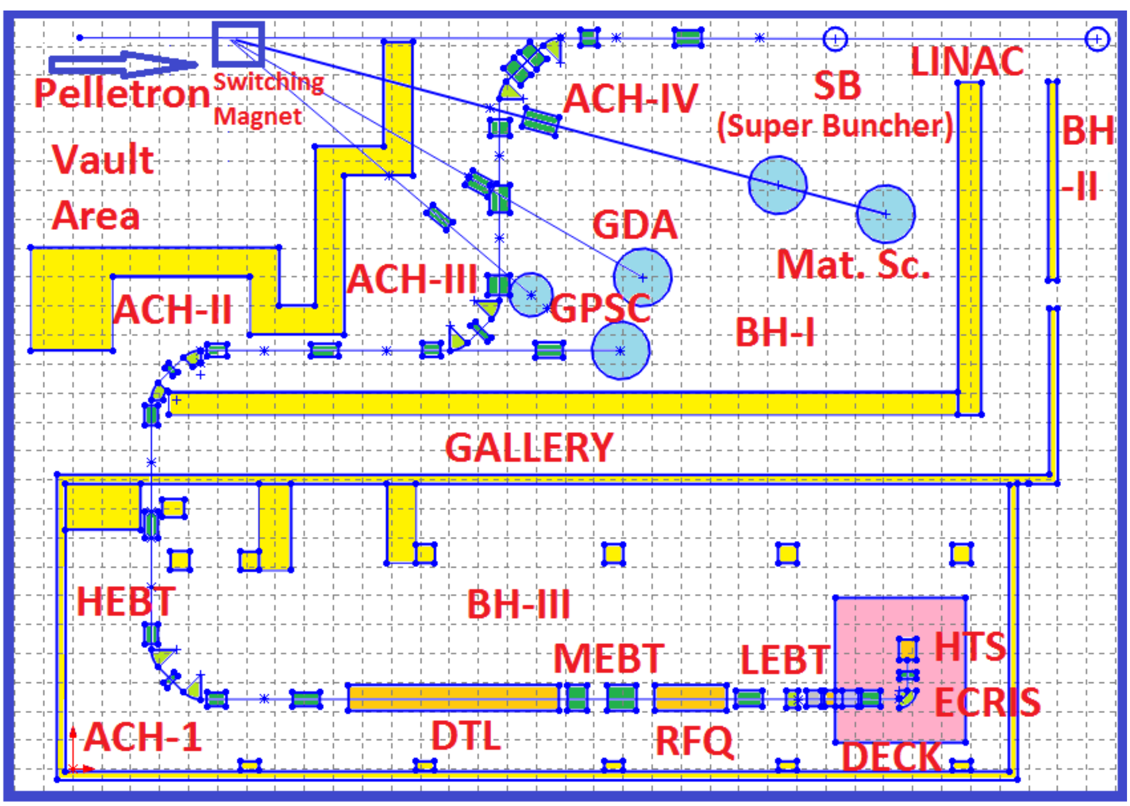

Figure 1: Layout of different beam halls and HCI (1 square box = 1m x 1m).

ISBN 978-3-95450-128-1

Table 2: Specifications of Magnetic Quadrupoles

Magnetic quad-rupoles		Effective length (mm)	Dia. (mm)	Field grad. (T/m)
Type -1	Q1,Q3	106	53	18
	Q2,Q4	212	53	18
Type -2	Q1,Q3,Q4	159	53	18
	Q2	212	53	18

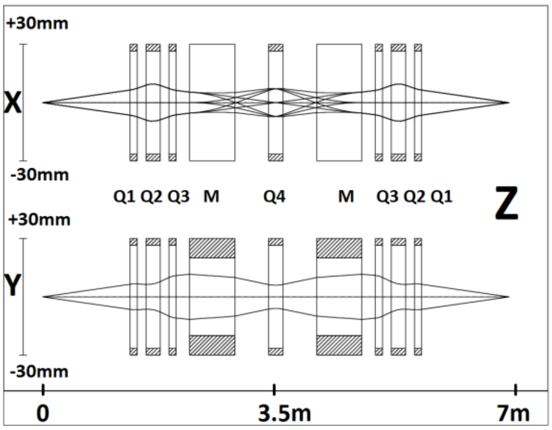

Figure 2: Beam optics of first three achromats.

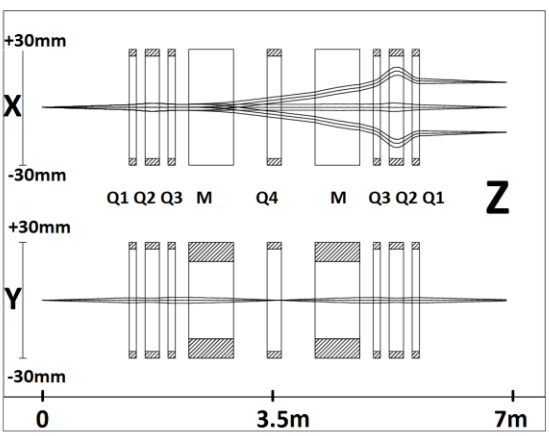

Figure 3: Beam optics of first achromat in energy dispersive mode.

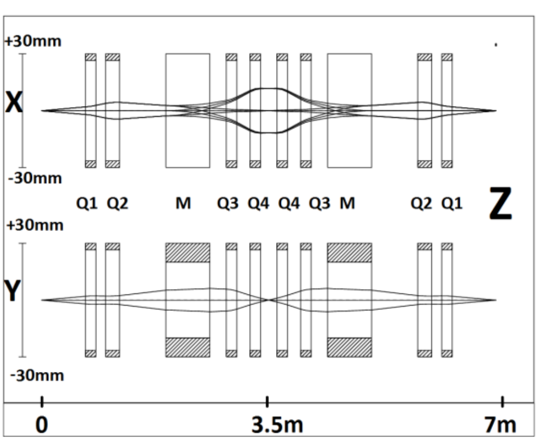

Figure 4: Beam optics of fourth achromat.

Table 3: Specifications of Dipole Magnet

Magnet Type	H-Shaped water cooled
Pole Gap	40 mm
Entrance, Exit Angles	24 deg., 24 deg.
Bending Angle	45 deg.
Bending Radius	850 mm
Maximum Field	1.5 T
Homogeneity	$\leq 10^{-3}$ over ±30 mm of of central trajectory
Radius of curvature of entrance and exit EFB	$\geq$2 m

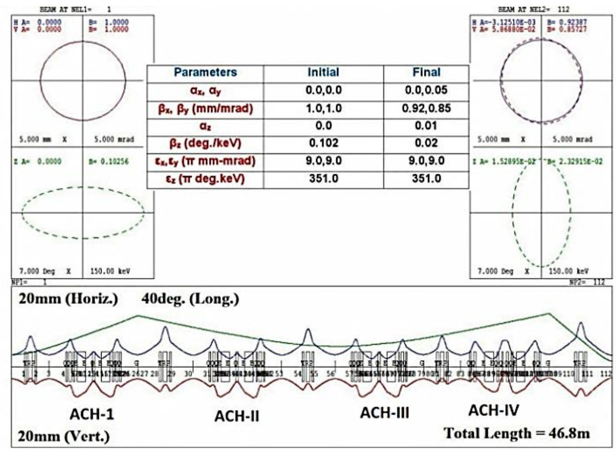

Figure 5: Beam optics of HEBT section using TRACE3D.

CONCLUSION

The design of beam transport system of HCI has been completed and the fabrication of various parts of HCI has started.

ACKNOWLEDGEMENT

The author acknowledges the contribution from A Roy, C.P. Safvan, R. Mehta, S. Ghosh and N. Madhavan for helping in the final design of HCI and for valuable suggestion

REFERENCES

[1] D.Kanjilal et. al. Rev. Sci. Instrum. 77 (2006) 03A317
[2] A.Mandal, G.Rodrigues, D.Kanjilal, Peter Brodt, Franz Bodkar, Nucl. Instr. and Meth. A 583 (2007) 219-227
[3] D. Kanjilal et. al., NIM A 328 (1993) 97.
[4] S. Ghosh et. al. Phys. Rev. ST Accel. Beams 12, 040101 (2009)
[5] http://www.linux.gsi.de/~weick/gicosy
[6] K. R. Crandall, TRACE 3-D Documentation, Report LA-11054-MS, Los Alamos, 1987