BEAM EXTRACTION SYSTEM AND EXTERNAL BEAM LINE OF KOLKATA SUPERCONDUCTING CYCLOTRON

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Abstract

All the major components of the extraction system of the Kolkata superconducting cyclotron are installed and functional. It includes the Electrostatic deflectors, magnetic channels, M9 slit etc. Internal beam acceleration has already been done successfully and now we are on the verge of extracting and transporting the beam to the cave.

The external beam transport system has been designed comprising of quadrupole magnets, steering magnets, switching magnets, beam diagnostics etc.

One of the four beam lines has been installed, which extends 20 meters up to the experimental cave-1. Control and monitoring system for all these components have been developed and tested. All the beam dynamical and technical aspects of the beam extraction and beam transportation have been discussed.

INTRODUCTION

The extraction system of the Kolkata Superconducting Cyclotron consists of two electrostatic deflectors (the first one is 55o long and the second one is 43o long positioned in the successive hills of the magnet), eight passive magnetic channels, one active magnetic channel and two compensating bars. The active magnetic channel (M9) is located in the yoke hole of the main magnet. Except the active magnetic channel all the other elements are radially moveable as the beam dynamics demands that the extraction components must be moveable to suit extraction conditions of different beams and as the beam traverses almost 330o before being extracted out of the cyclotron. The computer controlled drive system can move the elements precisely.

The extracted beam from the super conducting cyclotron will be transported through four beam lines (channels) to the experimental area. Channel#1 will be at 0 degree. The external beam line layout is shown in figure 6. The beam optics calculation of channel#1 has been carried out. The cyclotron will be operating between 3 Tesla to 5 Tesla average magnetic field. The phase space characteristics of the extracted beam will have wide variations owing to passive magnetic channels being used in the extraction system. So different momentum particle will have different beam characteristics and these wide variations have been considered for beam optics calculation. The optics calculation has been done by Graphic version of Transport code [1].

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Extraction Elements

The extraction system layout is shown in figure 1. All the different parameter of the extraction elements that affects the beam behaviour is listed in Table 1. For the deflectors, the septum to electrode gap is set to 6 mm and the maximum voltage is set at 100 kV. To compensate the field perturbation effects of the magnetic channels on the inner orbits, two compensating bars (C_1 and C_2) are used, C_1 compensates the effect of M_1 while C_2 compensates the overall effect of the remaining magnetic channels.

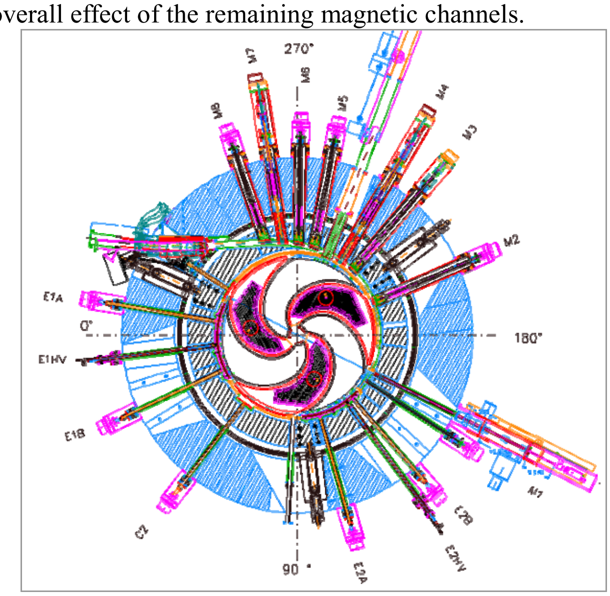

Figure1 Extraction system layout

Table 1: Extraction Element's parameters

	θ_I	θ_F	*R (min)*	*R (max)*	*Rbar (min)*	dR	B	dB/dx
			mm	mm	mm	mm	(kG)	(kG/cm)
E1 A	-23		672.4	678.5	-	6.1		
E1 B	32		678.2	686.4	-	8.2		
E2 A	94		682.2	690.8	-	8.6		
E2 B	137		698	707	-	9.0		
M1	140	153			*702.0*	13.8	1.14	3.46
M2	200	206			*711.0*	17.5	1.14	3.46
M3	226	232			*731.8*	64.0	1.05	5.24
M4	236	242			*730.3*	83.0	1.05	5.24
M5	256	262			*758.8*	18.0	1.05	5.24
M6	266	272			*776.4*	18.0	1.05	5.24
M7	276	282			*800.7*	86.0	1.14	3.46
M8	286	292			*836.4*	17.0	0.97	4.57
C1	320	334			705.5	2.5		
C2	46	58			735.3	6.4		

θ_I , θ_F : Initial and final azimuth of the element listed, Rbar gives the magnetic channel position with respect to cyclotron centre.

Calculations

The beam properties were calculated by the ray tracing method. The radial and axial phase space ellipses of the different beam species obtained by tracking the corresponding eigen ellipses from the deflector entry to the M9 slit passing through the extraction path were investigated as shown in figure 3. The initial ellipse is obtained by running the equilibrium orbit code GENSPEO [2]. The area of the phase space ellipse taken into account is 30 mm mrad.

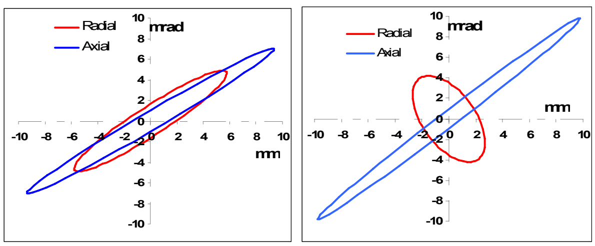

Figure 2. Phase Space Ellipse at (a) Deflector midpoint (b) M9 Slit for Ne3+, E/A=4.5 MeV/A, Bo=30.5 kG

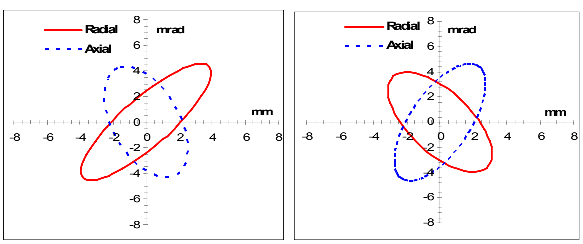

Figure 3. Phase Space Ellipse at (a) Deflector Entry (b) M9 Slit for He1+, E/A=20.1 MeV/A, Bo=38.3 kG

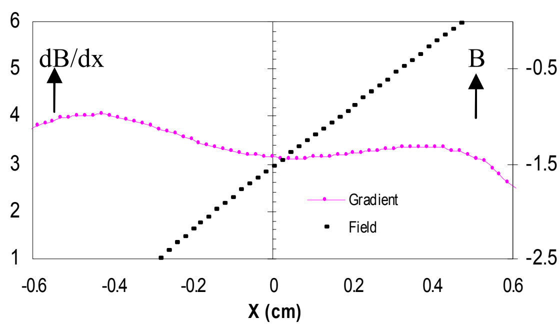

Figure 4. Field gradient (in kG/cm) and Field (in kG) across a magnetic channel.

Beam Transport Calculation

The maximum rigidity of the cyclotron beam is 3.3 Tesla metres hence momentum is about 1GeV/c. The emittance of the beam is considered to be 30 mm mrad. Four different ellipses are considered and the initial ellipses are not upright ellipse as correlation matrix has been introduced. Energy spread is considered to be 0.12%. High rigidity beam is focussed at the first beam viewer and slit size is kept according to the size of the beam to be obtained at the target position. To obtain a particular beam size, first quadrupole triplet may need slight variation in current because of different input beam parameters. The beam optics from first beam viewer to the image point at the second beam viewer in the vault is set as point to point and unity magnification. This is done by two sets of quadrupole triplet. The beam optics from the second beam viewer to the third beam viewer is also set as point to point and unity magnification. A required beam spot can be achieved with this beam optics configuration at the target positions. A beam input parameters is given in the Table 2.

Table 2: Input beam parameters

	Beam 1	Beam 2	Beam 3	Beam 4
X(cm)	0.90	0.89	0.95	0.54
θ (mr)	2.00	1.78	2.68	1.78
Y(cm)	0.94	0.56	1.23	1.13
Φ (mr)	8.94	8.06	1.12	5.58
l (cm)	0.00	0.00	0.00	0.00
δ(percent)	0.03	0.03	0.03	0.03
P(GeV/c)	1.00	1.00	1.00	1.00
R16 cm/(δp/p)%	4.0	-29.6	2.0	-20.0
R26 mrad/ (δp/p)%	40.0	4.0	40.0	4.0

Various beam optics options have been tried to achieve required beam size at the target positions. At the same time it was also kept in mind to handle minimum number of parameters during beam transportation.

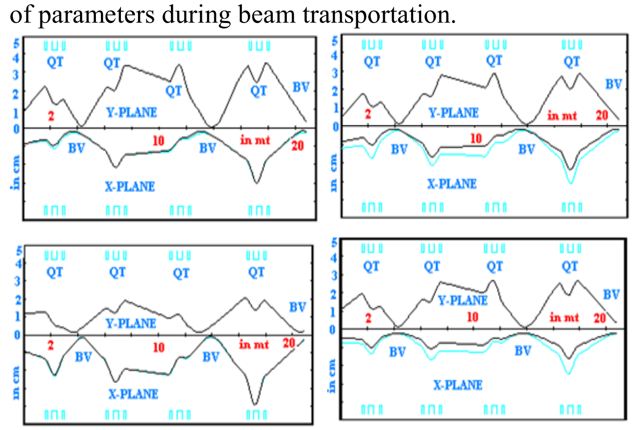

Figure 5. Beam envelopes for 4 types of Beam

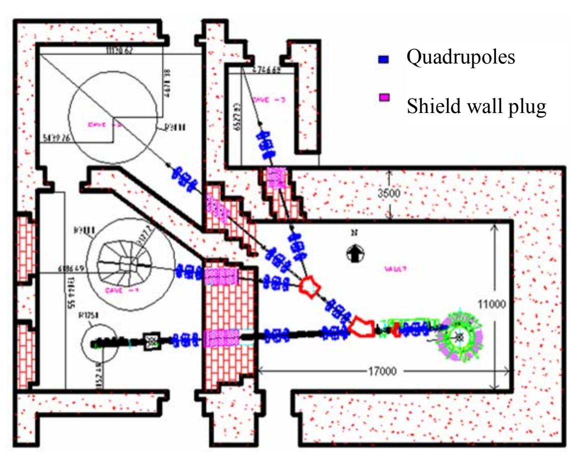

Figure 6: External Beam Handling System Layout

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