EXTRACTION SYSTEM AND EXTERNAL BEAM HANDLING SYSTEM OF KOLKATA SUPERCONDUCTING CYCLOTRON

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Abstract

The extraction system of the Kolkata Superconducting Cyclotron have all been fabricated. The deflector test stand has been commissioned. Some modifications have been made in the magnetic channels. The characteristics of the extraction path have been studied. The external beam handling system has been designed and is under fabrication. Laminated quadrupole magnets have been used. Four experimental stations have been planned. The first experimental station will be commissioned by the end of this year. The design aspects have been discussed.

INTRODUCTION

The extraction system of the Kolkata Superconducting Cyclotron consists of two electrostatic deflectors, eight passive magnetic channels, one active magnetic channel and two compensating bars. The last active magnetic channel (M9) is located in the yoke hole of the main magnet and maximum current of ± 300 Amp can pass through its coil to suit the steering requirements of different beam species.

E1 & E2 : 1.6×10^6 V/m (maximum electric field)
*M1, M2 & M7** : 1.14 kG field, 0.32 kG/mm gradient
M3,M4,M5 &M6* : 1.04 kG field, 0.52 kG/mm gradient
M8 : 0.96 kG field, 0.45 kG/mm gradient

**M4 & M7 are split into 3 parts and driven by 75 mm long drive ,hence can be totally or partially removed from the beam extraction path when so required. Rest are driven by 25 mm long drive.*

The external beam handling system is designed to transport the extracted beam to four experimental stations located in three different caves. All the lines will be of stainless steel, 100 mm outer-diameter, evacuated by a combination of turbo pumps and cryo-pumps, and use shield wall plugs suitably interlocked so that beams can be sent to the particular cave only when working personals have been evacuated

Electrostatic Deflector

Fig. 1 shows a photograph of one of the electrostatic deflectors. The high voltage electrode is supported by three insulators. The gap between the electrodes and septum is set at 6 mm and its designed to hold 100 kV voltage.

Figure 1: Electrostatic Deflector

Magnetic Channel

The magnetic field along the beam extraction trajectory has been measured/simulated for several main magnet excitations and beam tracking has been performed for several species (Table 2) by computer routines that integrates the equation of motion. It is found that by suitably tuning the M9 coil current, all the beam species could be made to pass through a common point, with less than ± 2° angular deviation. This common point serves as the beam-matching point for the external beam handling system. A focusing effect is evident from the figures, in presence of channel in the yoke hole with relatively small divergence and beam size, which do not pose any problem for the successive beam handling.

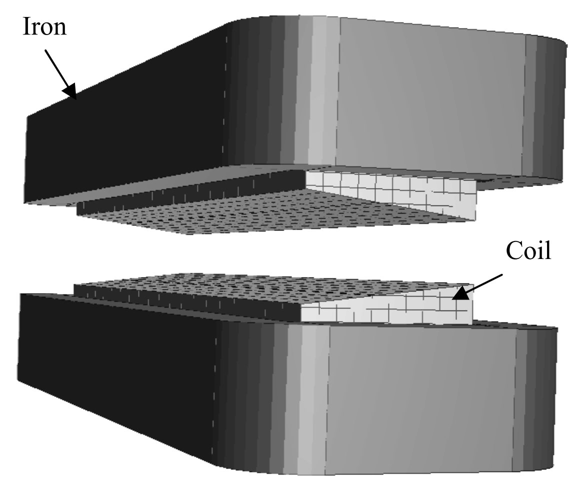


Figure 2: Model of Active Magnetic Channel

Table 1: List of ion species tracked

Z/A	T/A (MeV/A)	B_0 (kG)	B*R (T-m)
0.1	2.05	31	2.068
0.1	5.15	49	3.28
0.25	20	38.35	2.59
0.25	30	46.48	3.188
0.32	49.81	45.5	3.22
0.32	22.15	31	2.12
0.5	56.09	31	2.19
0.5	79.41	36.6	2.62

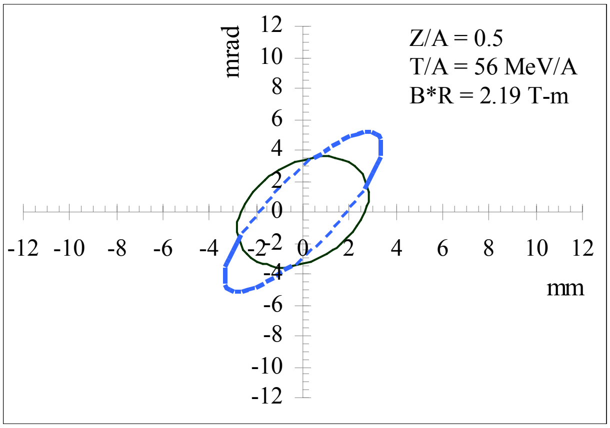


Figure 3. Radial phase space ellipse at the entry of deflector system and at the M9_slit position (solid curve)

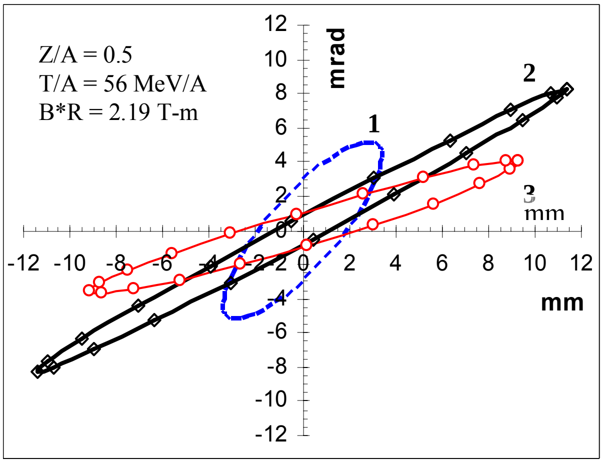


Figure 4. Radial phase space ellipse of same beam at (1) M9_Slit (2) at common point without M9 channel (3) at common point in presence of M9 channel.

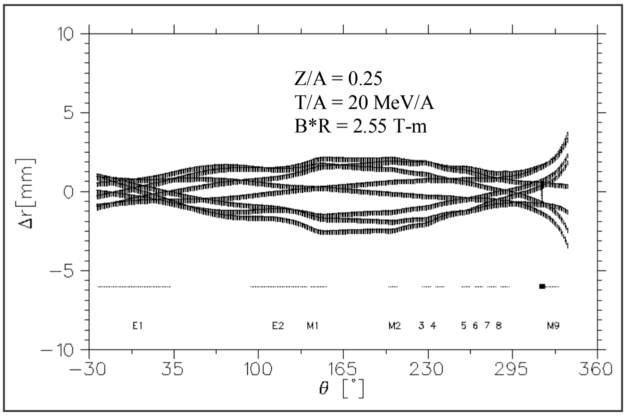


Figure 5. Radial envelope of the mentioned beam as tracked through the extraction path

Quadrupole Magnets

Laminated Quadrupole magnets (triplets,A-B-A) will be placed at various locations in the beam lines for focussing and guiding the beam up to the target. The magnet coils will be made from OFHC copper and water-cooled. The maximum field at the pole tip is 8 kG.

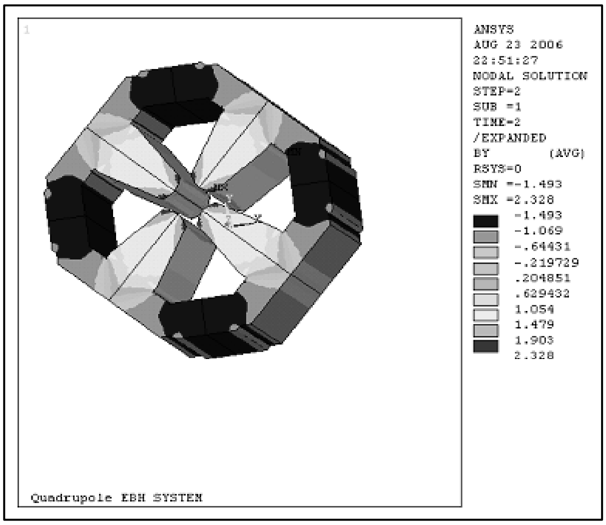


Figure 6: Magnetic Field Contour in ANSYS-3D for B-Type Quadrupole

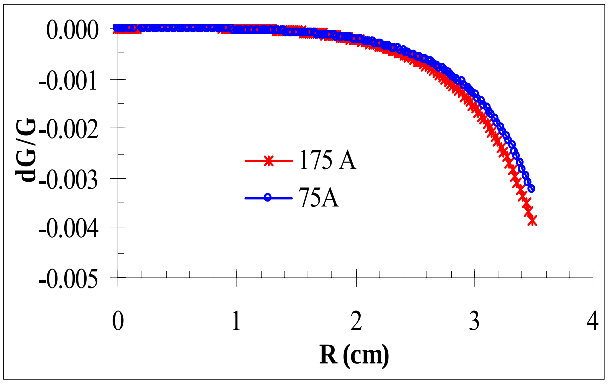


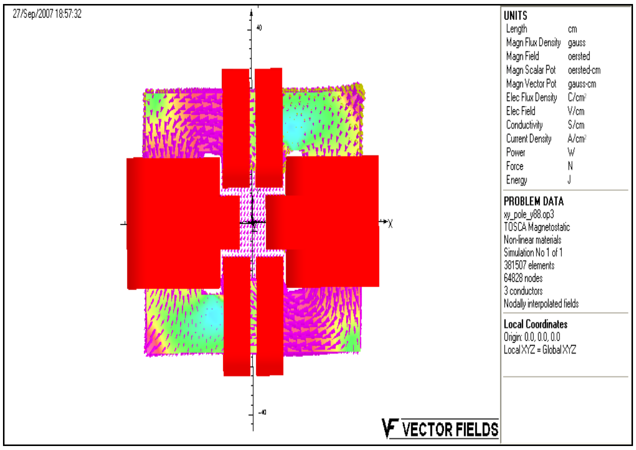
Figure7**:** Field Homogeneity Profile at different ecitations

Table 2: Parameters of Quadrupole Triplet

Parameter	‘A’ type	‘B’ type
Aperture	85 mm	85 mm
Field gradient	18 T/m	18 T/m
Physical length	180 mm	385 mm
Weight	450 kg	850 kg
Core type / Material	Laminated/CRNGO M36 (AISI) grade 0.5 mm thick sheets	Same as ‘A’ type
Conductor section	7× 7× φ5 (mm)	7× 7× φ5 (mm)
Voltage Drop	27.6 V	43 V
Current	200 A	200 A
LCW flow	2.5 LPM @ 9.5 Kg/cm2	2.5 LPM @ 9.5 Kg/cm2
Temperature rise	8 ^{0}C	12 ^{0}C
Quantity	34 nos	17 nos

X-Y Steering Magnet

This magnet (Fig. 4) has been designed to steer the most energetic beam (beam rigidity 3.34 T-m) extracted from the cyclotron by 1.6 degree in horizontal plane and 0.8 degree in vertical plane. To obtain good field uniformity around the centre (Fig.5) an air gap in the each Y coil (i.e., coil for producing steering along horizontal X direction) is introduced. Because of space limitation and in order to produce X (horizontal) and vertical (Y) deflection at the same place, the pancake of horizontal coils are optimised and located in such a way that it contributes to the magnetic field the maximum possible. .



UNITS

Length	cm
Magn Flux Density	gauss
Magn Field	oersted
Magn Scalar Pot	oersted-cm
Magn Vector Pot	gauss-cm
Elec Flux Density	C/cm^2
Elec Field	V/cm
Conductivity	S/cm
Current Density	A/cm^2
Power	W
Force	N
Energy	J

PROBLEM DATA
xy_pole_y88.op3
TOSCA Magnetostatic
Non-linear materials
Simulation No 1 of 1
381507 elements
64828 nodes
3 conductors
Nodally interpolated fields

Local Coordinates
Origin: 0.0, 0.0, 0.0
Local XYZ = Global XYZ

Figure 8: 3D model of X-Y steering magnet by TOSCA.

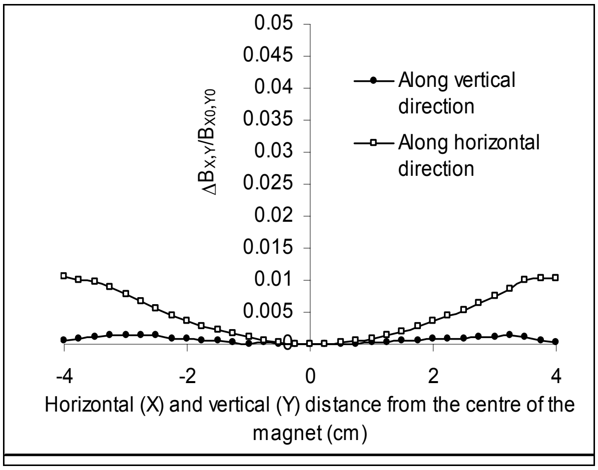


Figure 9: Field uniformity of X-Y steering magnet as obtained from TOSCA model

Bending Magnet

The external beam handling system comprises of three bending magnets. BM-1 will bend the beam by an angle of 18 degree to transport the beam in channel II. BM-2 bends the beam by an angle of 32 degree to transport the beam in channel II and IV. These magnets have uniform field (n=0), normal entry and normal exit, sector shaped dipole magnet. The maximum field that can be produced in these magnets in a gap of 8 cm. is 15 kG. The total weight of the magnet including coils is about 28 tonnes for BM-1 and about 35 tonnes for BM-2. These are all C-type sector shaped dipole magnet.

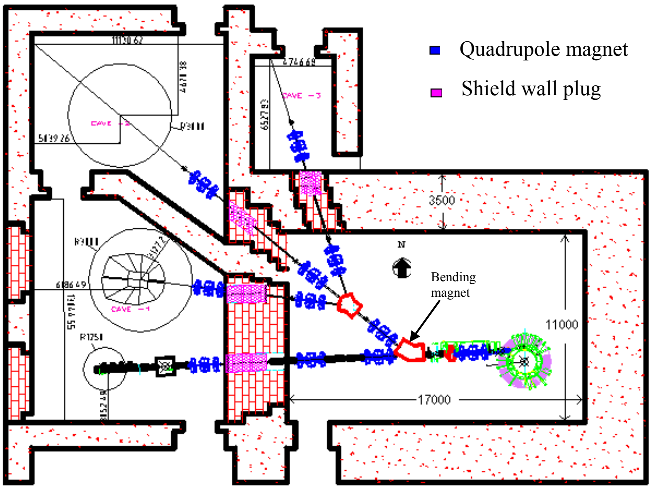


Figure 10: External Beam handling system layout with building

REFERENCES

[1] J.Pradhan et al, “Magnetic Field Simulation using RADIA and TOSCA for Kolkata Superconducting Cyclotron”, presented in this conference

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