MODIFIED CENTRE REGION OF K-130 CYCLOTRON FOR LIGHT ION BEAM ACCELERATION

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Abstract

The K-130 Cyclotron at Kolkata after accelerating high charge state light heavy ions for about 10 years was shut down in early 2007 for modernization of cyclotron sub-systems. Since this cyclotron will be used as primary source of beams (alpha and proton) for the radioactive beam facility and also for other experiments in the existing beam lines, the centre region geometry has been modified. This geometry will enable us to operate internal PIG ion source for producing alpha and proton beams. At the same time, making minor change in the geometry, Inflector system can be inserted in the center region, replacing PIG ion source, for high charge state light heavy ion beam acceleration, which will be produced from external ECR ion source. The initial ion orbit of the modified center region was tested using the code 'Pinwheel' and the required electric field was obtained using 'Relax 3D code'. The centre region parameters obtained were very helpful during the beam development.

INTRODUCTION

Presently, K-130 Cyclotron is delivering alpha beam (can also deliver proton beam, if required) through three beam lines to the target for doing nuclear physics experiments, radiochemistry and radiation damage studies etc. and these beams will also be delivered through the feeder line (Channel#4) for producing radio-active atoms. These light ions are produced using internal ion source (PIGIS) as used to in eighties, though the center region at present is quite different. The center region of the cyclotron was first modified in late nineties for high charge state light ion acceleration. The central region was then consisting of a Dee, Dee-insert, Dummy-Dee, Dummy-Dee-insert and a centrally located Inflector. The ions were produced in external ECR ion source and transported through the axial injection line to the centre of the cyclotron where Inflector bends the beam through 90 degrees into the horizontal plane for further acceleration [1]. Since fixing or removing the dummy dee structure, which were incorporated during heavy ion acceleration, is difficult (as the vertical space between upper and lower liner is small) and considering the possibility of heavy ion acceleration in future, a modification has been made in the central region. Since the dummy dee structure is intact in the central region, hence the difficulties of re-fixing the dummy dee structure is avoided and the time needed to change the centre region is minimal.

CENTRE REGION GEOMETRY

The space available for the movement of the ion source is restricted (as compare to eighties) due to the dummy dee structure. Presently, the centre region consisting of a dee, dee insert with puller assembly, dummy dee, dummy dee insert and PIG ion source. The ion source can be rotated about its axis and has radial and azimuthal movement (see Fig.1).

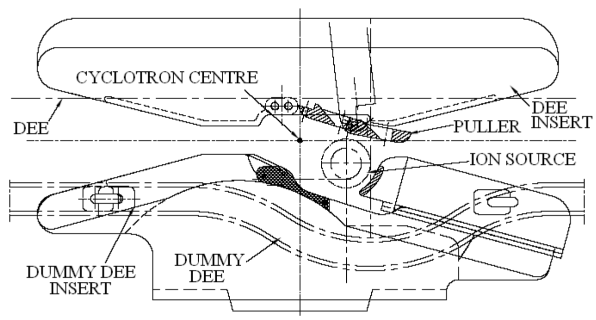

Figure 1: Modified centre region

Region considered for electric field calculation

Relaxation method has been used to evaluate the electric field in a region. With the relaxation method the potential is computed by solving Laplace's equation and the electric field is derived from the potential. A dimension of 7 cm (across the Dee) x 14.0 cm (upper liner to lower liner) x 40 cm(along the Dee) has been considered for the calculation, which consists of Dee, Dee-insert with puller assembly, dummy dee, dummy dee insert and PIG ion source.

Assigning the boundary values

To define the boundary values in the above-specified region, a boundary sub-routine has been written for the code 'Relax3D' [2]. An uniform grid spacing of 2mm has been chosen in each of three dimension. The grid points at dee and dee insert with puller assembly are assigned at high potential (Dee voltage) and the grid points at dummy dee, dummy dee insert and ion source are specified at ground potential. The upper liner and lower liner are usually at ground potential.

After initialisation of grid points, plots are verified in three planes and the checked the values assigned at various points. Then the potential distribution obtained in different plane has been checked and the field has been calculated from the potential.

Fig.2 shows the horizontal section of centre region 14 mm above and below the median plane and Fig.3 shows the equipotential lines in this plane. Fig.4 shows the equipotential lines in the median plane.

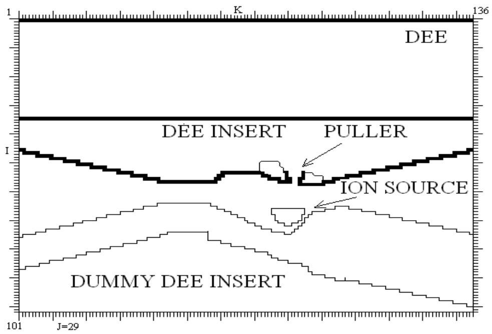

Figure 2: Horizontal section of centre region 14mm above and below the median plane

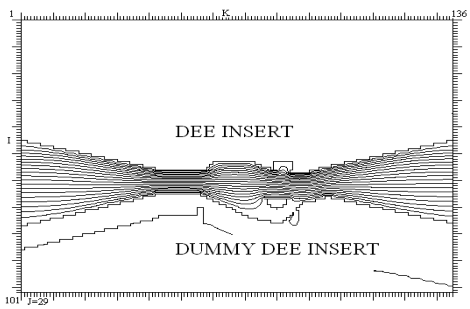

Figure 3: Equipotential lines 14mm above and below the median plane

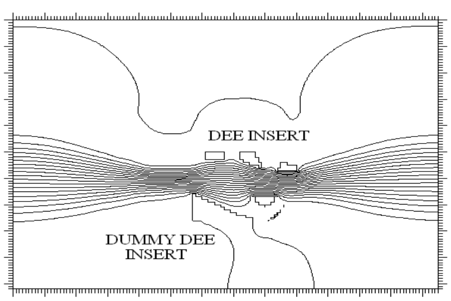

Figure 4: Equipotential lines in median plane

ORBIT CALCULATION

'Pinwheel code' [3] has been used to trace the particle orbit and centring for first few turns. The code has been modified for the internal PIG ion source. The potential distribution obtained by 'Relax3d' code has been utilised in the 'Pinwheel code'. The initial co-ordinates of the ion source position and puller electrode position have been obtained for 30 MeV, 60 MeV, 80 MeV and 100 MeV alpha. Hence the parameters for the intermediate energies come within this. Orbit has been traced for 30 MeV, 60 MeV, 80 MeV and 100 MeV alpha beams. The orbit centre points has been obtained and it is found that the centre converges towards the machine centre and remains around 2.5 mm after few revolutions, which compares well with the coherent oscillation amplitude.

Centre Region parameters obtained

The central region parameters (radial position, azimuthal position of ion source, puller In/Out and left/right position) obtained from the calculation has been used for beam development for different energies (30 to 60 MeV).

Table 1 and Table 2 show the calculated and tuning data of 30 MeV and 60 MeV.

Table 1: Calculated and tuning data for 30 MeV Alpha

Centre Region Parameters	**Calculated data**	**Tuning data**
Radial	X- 20.01 mm Y- 10.03 mm	X- 19.5 mm Y- 09.5 mm
Azimuthal	28.7 degree	26.7 degree
Puller	X- 28 mm (L/R) Y- 11 mm (I/O)	X- 28 mm (L/R) Y- 14 mm (I/O)

Table 2: Calculated and tuning data for 60 MeV Alpha

Centre Region Parameters	**Calculated data**	**Tuning data**
Radial	X- 21.84 mm Y- 10.03 mm	X- 21.0 mm Y- 10.5 mm
Azimuthal	26.32 degree	27.5 degree
Puller In/Out	X- 25.9 mm(L/R) Y-15.2mm(I/O)	X- 28.5 mm (L/R) Y- 14 mm (I/O)

CONCLUSION

It has been found that the central region parameters obtained during beam tuning are very close to the data obtained by calculation. The differences in values arising out may be due to mesh size considered (2mm) in the electric field calculation or the due to the calibration error. The cyclotron is presently delivering alpha beam from 30 MeV to 60 MeV for the experiments, where the above-calculated data has been very useful. Again the central region parameters for proton beam has also been calculated and used for beam tuning. 15 MeV proton beam has been extracted and will be utilised for the experiments. Since alpha will be accelerated beyond 60 MeV and proton beyond 15 MeV, it will give us valuable parameters for cyclotron operation.

REFERENCES

[1] P.S. Chakraborty & other, Indian Journal of Pure & Applied Physics, Vol. 39, Jan-Feb 2001, pp.36-40.
[2] Kost C. J & Jones F. W., RELAX3D code (TRIUMF, Canada).
[3] PINWHEEL Code, (MSU, USA).