

A COMPARATIVE STUDY BETWEEN SIMULATED AND MEASURED BEAM'S QUALITY OF 30 MeV CYCLOTRON AT KFSHRC

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Abstract

At King Faisal Specialist Hospital and Research Centre (KFSHRC), the C-30 Cyclotron (manufactured by IBA) is used to produce radioisotopes for medical purposes. Working with very expensive machine dedicated for patients needs full attention and understanding of how beam can be controlled safely inside beam transport system. Moreover, knowledge of influence of magnetic lenses on charged particles is desired. Therefore, using off-line source such as PC-based beam simulator allows an operator to immediately see the effect of various magnetic lenses attached to the beam line. Initially, the magnetic field of quadrupoles and steering magnet was recorded using Hall probe Teslameter. The magnetic field values then uploaded into the Beam simulator in which beam quality was recorded and analysed.

INTRODUCTION

Experience gained since the commissioning of the IBA [3] C-30 Cyclotron at the King Faisal Specialist Hospital and Research Centre (KFSHRC) in 2010, has shown this facility to be viable entity. In addition to the C-30 Cyclotron, the facility includes two other Cyclotrons namely; the RDS-111 and the CS30 Cyclotrons. The latter has dual responsibilities; while is kept as a backup for the other Cyclotrons for radioisotopes production, it's used for proton therapy researches and Bragg Peak measurements at that particular energy [1].

Beam transport system is of high importance to carry particles to their final destination, in case of medical Cyclotrons, are isotopes targets. The amount of current that carried out in beamlines could reach up to 250 uA [2]. Hence, working with very expensive machine dedicated for patients needs full attention and understanding of how beam can be controlled safely inside beamlines. Knowledge of influence of magnetic lenses on charged particles is desired.

Therefore, using off -line source such as PC-based beam simulator allows an operator to immediately see the effect of various magnetic lenses attached to the beam line. This would eliminate strike of beam on the internal wall of beamline.

In this paper, a comparison study is conducted between real beam shape and position with simulated beam. During experiment the beam was completely stopped using destructive beam viewer supplied on the line.

DESIGN PARAMETER

Optical Elements

Figure 1 shows the layout of beamline 2.1 which attached to the C-30 Cyclotron. The main elements of beamline 2.1 are explained as follows. Steering magnets: The thickness between coil and support is made with two "Nomex" layers of 0.12 mm thickness. Each coil is assembled with conductor made by enamelled round copper wire of 1.4 mm diameter. Each coil has 962 turns per coil. Quadrupole Magnets: On the beam line, there two Quadrupoles installed; one inside the Cyclotron vault and the other on the PET target vault. They are made by Scanditronix Magnet. Each of which contains 4 layers of 25 turns and 1 cooling plate.

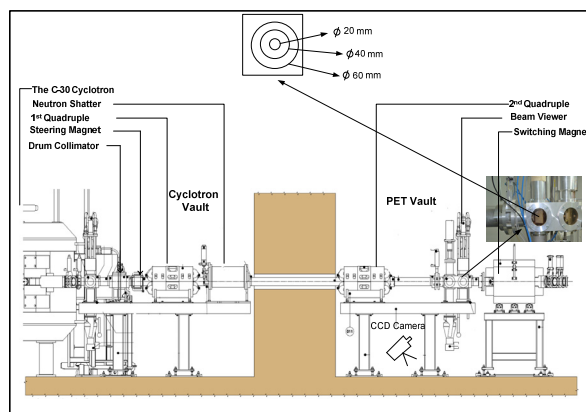


Figure 1: Layout of beamline.

Other Non-magnet elements are installed on the beamline and listed on the figure but outside the scope of simulation of this study.

BEAM MEASUREMENT

On Line Measurement

Real time measurement of beam current was monitored using beam viewer supplied with the C-30 Cyclotron. The Viewer is made of Alumina attached into square piece of copper (the thickness is between 0.2 and 0.3 mm). Within the phosphors screen (figure 1), three indication circles are marked. The diameter of these circles is 20, 40 and 60 mm. A CCD Camera, made by Panasonic, was placed outside the median plane of the Cyclotron. Using very small beam current for short period guarantees the survival of the camera.

Moreover, the beam shape was studied at different beam intensities as shown in Figure 2. The values of the

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magnetic lenses of beamlines were kept unchanged. In some cases and as suggested by figures, changing beam intensity may lead to change the beam distribution horizontally and vertically. This requires varying the values of magnetic lenses, attached to the beam lines, until optimization has been achieved.

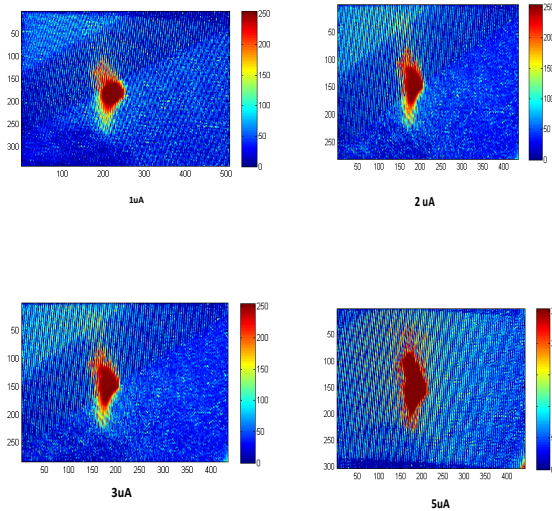


Figure 2: Beam shape at different beam intensities.

Figure 3 shows a beam spot seen on the viewer and its Gaussian shape. This image was used for the comparison study against the simulated beam. The FWHM have been evaluated from the reconstructed images, after normalization, and are plotted with respect to beam width. For image calibration the visible marks seen on the viewer are used.

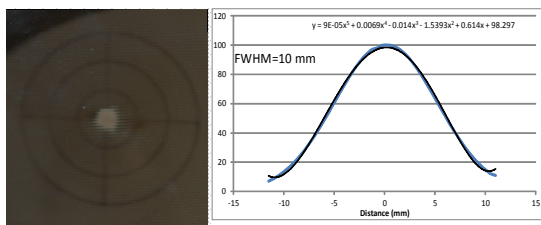


Figure 3: Beam spot on the viewer and its Gaussian shape. The curve describes a polynomial function fit to the experimental data.

SIMULATION ANALYSIS

A beam simulator, ver. 1.4, was used to simulate beamline and its magnetic lenses [4]. Figure 4 shows a snap shot for the developed simulated beam line. The components are explained as follow. Beam Source: It allows for choosing the ion type, its energy and number of particles, as well as ions phase space. Using beam simulator, 10^4 particles were placed in a phase space (X, X', Y, Y'). Drift length it considered as is the region in a beamline where there is no magnetic element. In our design we have three drift lines; one right after the port exit of the cyclotron (0.5 m), second is representing the wall thickness (3 m) and third is just before beam viewer

(0.5 m). Steering magnet: is represented by two dipoles. Two quadrupoles.

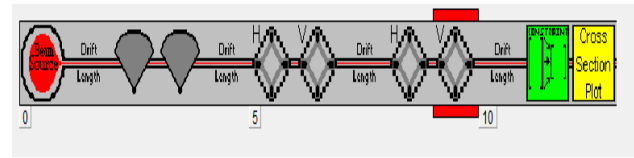


Figure 4: Snap shot of sequential beam icon.

The magnetic field of optical lenses was measured using a Teslometer, Model 3MH5, made by SENIS. The transverse Hall probe can read up to 20 T with a resolution of 100 ppm Fs. Before using the probe, it was calibrated against zero offset using Zero Gauss chamber.

Using the hall probe, linearity curve of quadrupole was measured and plotted as shown in Figure 5. The behaviour of magnetic field as function of power supply current is approximately linear. Temperature of the probe was 22°C.

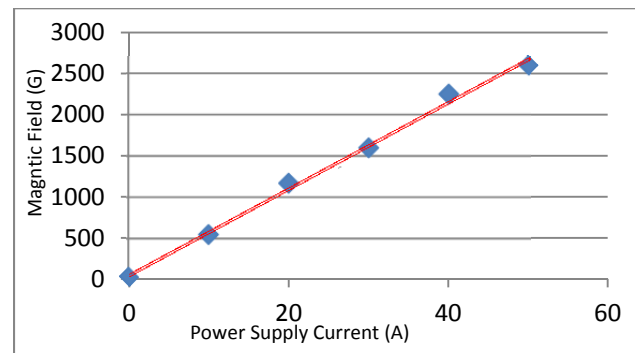


Figure 5: Relation between power supply current and generated field. The curve describes a linear function fit to the experimental data.

The Maximum Beam Half Size (X, X', Y, Y') values for the beam source are, respectively, 1 mm, 0.2mrad, 1mm and 0.2 mrad. The magnetic field values were measured (Table 1) and then uploaded into the Beam Simulator software in which beam shape and position were recorded.

Table 1: Beam Simulator Uploaded Data

Parameter	I_{supplied} (A)	B_{measure} (kG)	L_{effe} (mm)
VQ1	41.9	2.1	0.3
VQ2	45.3	2.3	2.3
HQ1	48.1	2.7	2.7
HQ2	33.7	1.5	1.5
S1*	0.4	0.2	0.2
S2**	41.9	0.3	2.1

*, ** Steering magnets component

Figure 6 illustrates the horizontal (X) and vertical (Y) envelope along the beamline. The divergence of simulated beam was about 2.9 mrad in the horizontal plane and of 1.3 mrad in the vertical plane.

The preliminary comparison shows a larger beam size from the real beam. It has to be brought in mind that the vacuum level inside the beamline was 5×10^{-6} mbar. Such condition and the assumption of the beam phase space at the exit of the beam port could explain the difference between measure and simulated value.

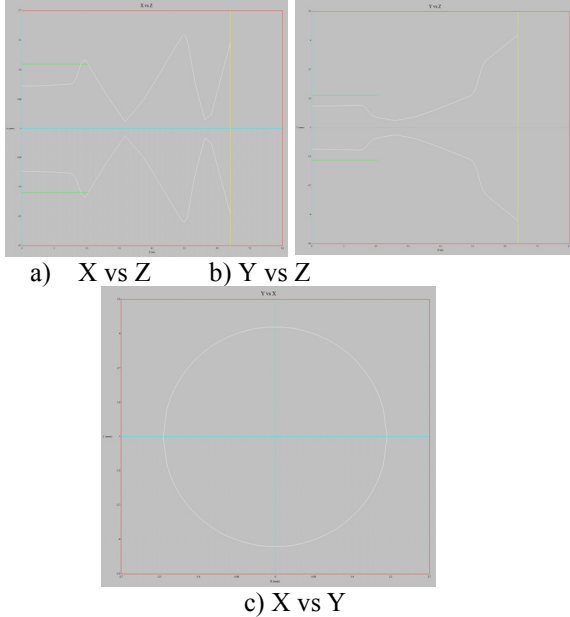


Figure 6: Calculated beam envelopes, A) the vertical Y component of the beam, B) Shows the horizontal X component and C) shows the overall beam spot.

CONCLUSION

We successfully designed and simulated a beam transport system for C-30 Cyclotron based on empirical values obtained from the magnetic lenses attached to the Beamline. The difference in beam profile between measured beams and simulated one was 15%. Considering the fact that ambient temperature will play role in changing slightly the field. Moreover, vacuum inside the beamline can slightly disperse the beam as it continues traveling along the beamline.

All results were obtained under the assumption that the ion beam has the Gaussian distribution, and the beam moves with no placement from the axis of the beam line.

ACKNOWLEDGEMENT.

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