CURRENT STATUS OF THE SUPERCONDUCTING CYCLOTRON PROJECT AT KOLKATA

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Abstract

The commissioning of Kolkata superconducting cyclotron with internal ion beam had been reported in the last cyclotron conference [2]. At that time, there was gradual beam loss due to poor vacuum. After installing a higher capacity liquid helium plant the cryo-panels were made functional leading to a substantial increase in the beam intensity. It was hoped that higher beam intensity would help in extraction of a measurable fraction of the beam, but that did not happen. Detailed investigation of beam behavior with the help of three beam probes, installed temporarily at three sectors, revealed that the beam goes highly off-centered while passing through the resonance zone. A plastic scintillator based phase probe was mounted on the radial probe and beam phase was measured accurately [1]. It was quite clear that large amount of field imperfection was prohibiting the beam to be extracted. So magnetic field measurement has been started again and considerable amount of harmonic and average field errors have been found. In this paper we report the important developments since 2010.

INTRODUCTION

A higher capacity Liquid helium plant was installed in 2010. With the help of this plant we could achieve beam chamber vacuum of the order of $3\text{x}10^{-8}$ mbar from$7\text{x}10^{-7}$ mbar installing 4K-cryo-panels in the valley regions. As a result we got a flat beam profile up to the maximum radius with minimum loss as shown in Fig. 2. The 1st external beam line is ready to take the extracted beam to the experimental hall as shown Fig. 1

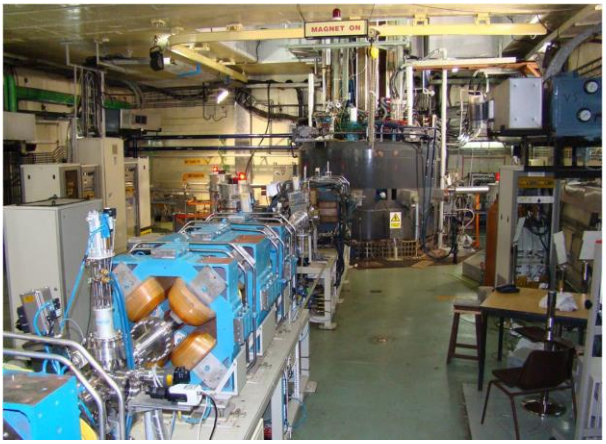

Figure 1: Superconducting cyclotron with beam line.

After getting a good beam profile we carried out the beam extraction trial extensively.

Figure 2: Improvement of beam profile after installing the cryo-panels.

BEAM EXTRACTION TRIAL

In the process of beam extraction trial we have used different diagnostics elements. We have seen the beam profile in the bore-scope monitor at different radii under different settings of magnetic field.

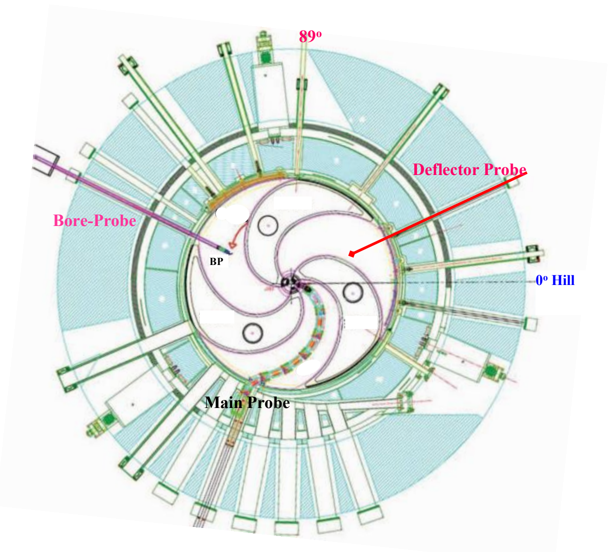

Figure 3: Layout of beam extraction channels and location of the three beam probes.

The schematic of the position of extraction channels and the beam probes are shown in Fig. 3. To get the signature of the extracted beam from the 1st deflector, we put a current reading probe as shown in Fig. 4(b) at the view port at 89°. Then we put an insulated copper plate at the exit of 1st deflector as shown in Fig. 4(c). We could not get any signature of extracted beam from the 1st

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deflector. We put a thin film on the inner edge of the septum of the deflector to get signature of the beam entering into the deflector.

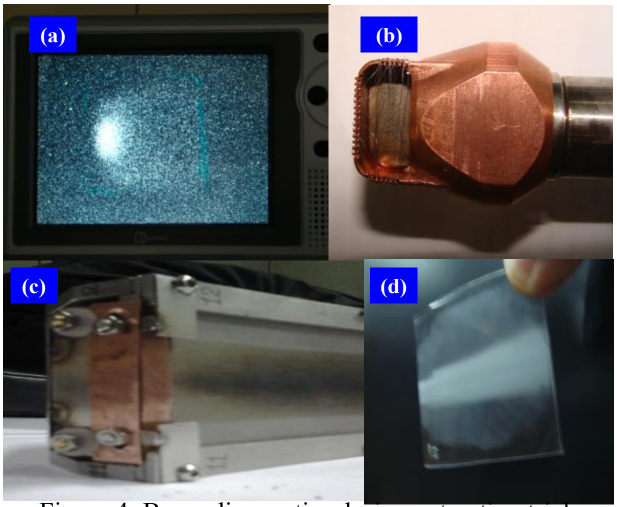

Figure 4: Beam diagnostics during extraction trial.

Beam off-centering Measurement

The superconducting cyclotron has two beam probes [3]. One ‘main-probe’ (MP) running along the spiral central line of a hill measures the beam current. A ‘bore-scope probe’ (BP), running straight across another hill, is sometimes used as a second beam current measuring probe. For quantitative measurement of beam off-centering, three probes are required approximately 120° apart. So, one of the extraction element ports was used temporarily for installing the third beam current measuring device, which we call the ‘deflector probe’ (DP). With these three probes and the beam shadowing technique, beam off-centering were quantified at different radii spanning the acceleration and extraction zone of the cyclotron. The centering behaviour of the beam was also studied by optimizing the trim coil settings and for different beams at different energies.

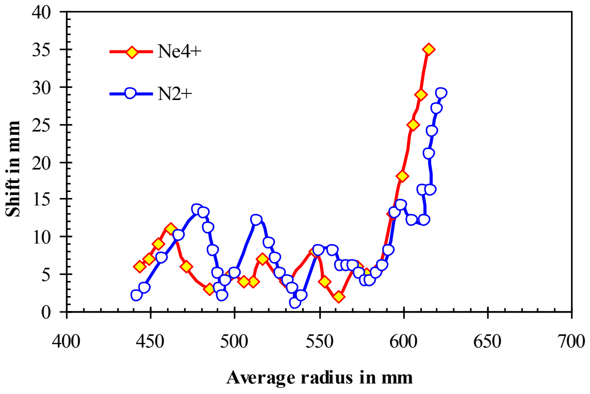

Figure 5: beam centre-shift as a function of radius.

It was observed that the coherent oscillation amplitude of the beam is ~ 5 mm up to radius ~580 mm. Beyond that radius, the beam continuously shifts in one direction and as a result of large off-centering (> 20 mm) it is lost before reaching to the deflector entry (~667 mm). Large first harmonic magnetic field near the resonance crossing zone (~600 mm) is generally responsible for such large beam centre shift in one direction [4]. From the beam shadowing measurements we calculated the average radius of the orbits as a function of radius. It is observed that due to continuous shift of the orbit centre beyond 600mm radius the orbit size does not increase properly beyond ~650 mm. It is to be noted that the deflector is placed at a radius of 670 mm.

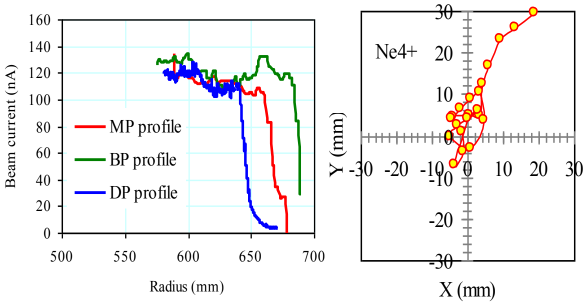

Figure 6: The radial beam profile in the 3 beam-probes and Locus of the beam centre calculated from shadow measurement for Ne4+.

Beam Phase Measurement

The measurement of phase of the ion beam with respect to RF was carried out which includes the development of fast-scintillator based phase measurement system. The measurement system consists of an aluminum target plate, which is hit by the ion-beam and consequently producing the γ rays. These gamma rays are detected by the plastic scintillator detector. A liquid light guide is used to carry the scintillator signal outside the cyclotron where a matching PMT is coupled to the light-guide.

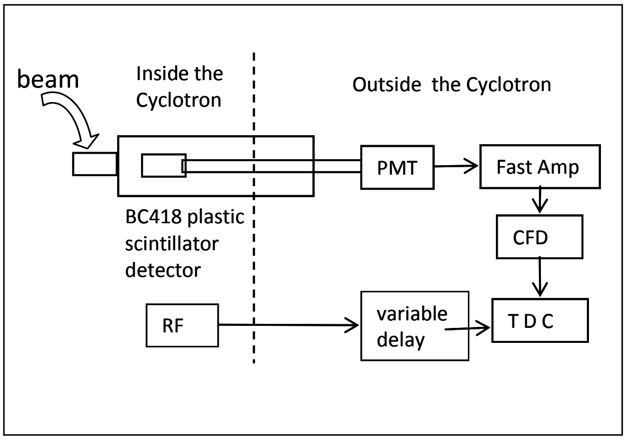

Figure 7: Phase measurement set up.

Phase Probe experiment was carried out with Ne^{4+} beam accelerated in 2nd harmonic mode at 19 MHz RF frequency. The expected beam energy was about 8.2

MeV/A at the extraction radius. The energy of Neon beam was sufficient to overcome the coulomb barrier and induce nuclear reaction in the Al target at 400 mm. The length of the aluminium target was more than the beam size which ensures that the target stops one or at most a few turns. The RF signal was picked up from the DEE, which is adjacent to the phase probe. The circulating beam first crosses the reference DEE and then hits the Aluminium target.

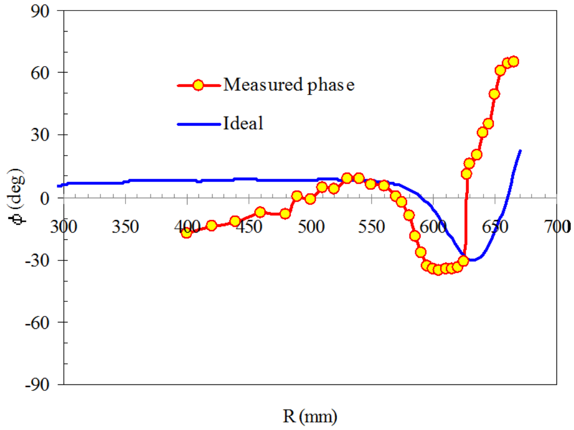

Figure 8: Radial profile of the measured beam phase.

ΔR-Probe Measurement

We have used a ΔR probe to understand the beam centering. The ΔR probe beam current profile is shown in figure 9. Expanded view of ΔR probe current from 150 mm to 350 mm shows the separate turn patterns which is basically a function of energy gain per turn with added effect of orbit centering etc. after crossing 340 mm it shows large coherent oscillation.

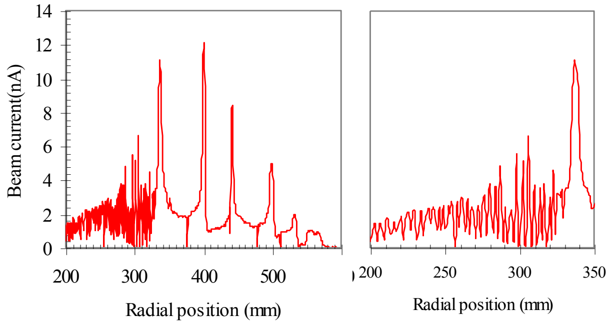

Figure 9: Beam current read by the ΔR-probe.

Magnetic Field Mapping

This year, again the magnetic field mapping has been done to understand and rectify the possible reasons which are preventing the beam to be extracted. It is revealed that there is a large 1st harmonic field present near ν_r=1 resonance and it is rising sharply from 600 mm, peaks at 650 mm (45 Gauss) as shown in figure 10. The Deflector position is 667 mm. This large imperfection field is the main hurdle for beam extraction. The possible source of the large first harmonic filed is the shift of the coil-tank by an amount of only ~ 1.3 mm.

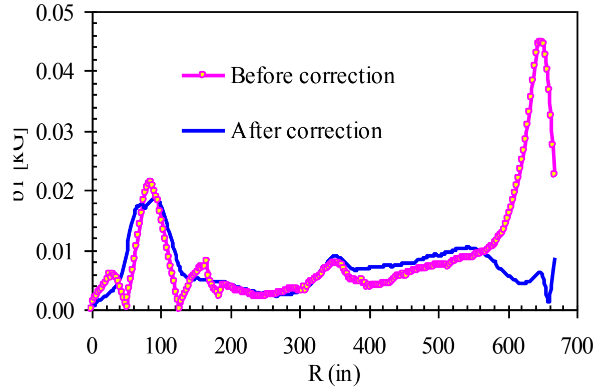

Figure 10: 1st harmonic field profile measured in April 2013 and the corrected one.

CONCLUSION

Though VECC superconducting cyclotron was successfully commissioned with internal beam, but beam extraction has not yet been possible because of large off-centering of the beam beyond 600 mm radius. Magnetic field mapping revealed the presence of a large first harmonic imperfection, which is due to positioning error of the cryostat. Since correction of this error needs dismantling the magnet along with all the subsystems, so an interim beam trial will be done after placing some iron-shims to reduce the 1st harmonic error.

REFERENCES

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