A Large High Vacuum Reaction Chamber for Nuclear Physics Research at VECC, Kolkata

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Abstract. A large, segmented, horizontal axis, reaction chamber (SHARC) has recently been fabricated, installed and integrated with the beam line in the VECC superconducting cyclotron (SCC) experimental area. It is a cylindrical, three segment, stainless steel chamber of length 2.2 m, diameter 1 m. Two pairs of parallel rails have been provided internally for placement of the target assembly and detector systems within the chamber. The whole target assembly can be placed anywhere on the rail to facilitate optimum flight path. The nominal vacuum of ~1X10^{-7} mbar has been obtained in ~8 hrs by means of two turbo molecular (1000 l/s) and two cryo pumps (2500 l/s) backed by mechanical pumps. The whole vacuum system as well as the target positioning (vertical and rotational movements) operations are fully automated with manual override option; both are monitored and controlled locally as well as remotely through the local and remote control units providing real time status display.

1. Introduction
The K500 superconducting cyclotron (SCC) at the Variable Energy Cyclotron Centre (VECC), is likely to open up new areas of intermediate energy experimental nuclear physics research and vigorous activities are on to develop new, state-of-the-art experimental setups to facilitate high quality research. Vacuum reaction chamber is an essential component of any accelerator based experimental setup in nuclear physics and the design of the chamber depends upon the experimental programme [1]. It may either be a very specialised chamber for dedicated experimental setup [2, 3, 4], or it may be a versatile general purpose reaction chamber [5] which has sufficient flexibility to incorporate various types of detector systems for different types of experiments. The present chamber belongs to the second category, and the aim here was to design a multipurpose reaction chamber which will cater to the needs of different types of experiments involving large number of charged particle detectors of various kind forming arrays inside the chamber, along with the provision to place gamma and neutron detectors at suitable locations outside the chamber. With this aim, a large, Segmented, Horizontal Axis, Reaction Chamber (SHARC) has recently been fabricated, and then installed and integrated with the beam line in the SCC experimental area. SHARC has been designed in-house at VECC and fabricated by M/s. Vacuum Techniques, Bengaluru. Here we report salient features of SHARC, which will be used mainly for charged particle based experimental studies of intermediate energy heavy-ion collisions, using the accelerated ion beams (~5-80 MeV/A) from SCC.

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2. **Basic design parameters**

SHARC was basically designed as the primary facility to be used for experiments in SCC beam line I. The dimensions of SHARC were optimised to have maximum flexibility for versatile experimental setups; in particular, optimum shape was decided to be cylindrical with its axis coinciding with the beam axis to avail maximum possible flight path for time of flight measurements. Other salient design considerations were,

i. The chamber should be suitably segmented for easy access inside the chamber. Each segment should have independent movement arrangement.

ii. The chamber vacuum control system should have maximum flexibility. The vacuum system should have both auto and manual modes of operation with dynamic display of complete status. There should be facility for remote monitoring of vacuum status with emergency shutdown option.

iii. Target ladder should have the provision to be placed any position inside the chamber along the beam axis. The vertical and rotational movements of the ladder have to be controlled and monitored in auto/manual mode.

iv. Both vertical position and rotational angle of the ladder should be accurately measured. The complete target ladder control and monitoring should also be available at the remote station.

v. The chamber will have a Faraday cup of sufficiently large aperture to stop the beam and measure the beam current.

![Fig. 1. Schematic diagram of SHARC without vacuum pumping system.](image-url)
3. Details of SHARC
A schematic drawing of SHARC is displayed in Fig. 1 and the photograph of the chamber installed in its present position (SCC beam hall – 1) in Fig. 2.

3.1. Mechanical details
SHARC is cylindrical, three segment, stainless steel (SS 304L) chamber of length 2.2 m, diameter 1 m and wall thickness ~10 mm; the front (beam-entry) end is hemispherical in shape of radius 500 mm and the rear end is elliptical dish (2:1) shaped. The segments are mounted on separate support structures which rest on external rails such that each segment can move independently on the rails by automatic gear-motor control mechanism having built-in limit switch locking facility with manual override option. All three segments (and the rear part in particular) may be rolled back on rail to open up the chamber to give accessibility for the installation of users’ equipments inside.
fabricate their own detector stands as per requirement. Two glass windows are kept for viewing the target and detector positions inside.

3.2. Target assembly
The target ladder system has been so designed to take the maximum advantage of the full length of the chamber. The whole assembly is mounted on one pair of internal rails and may be placed at any position within the chamber to optimize the flight path. The target assembly includes a ladder that can hold six targets at a time in a column (see Fig. 3). Target ladder can be rotated with angular precision $0.1^\circ$ and it can be moved vertically with accuracy of 0.1 mm. Ladder movement mechanism is constituted of Programmable Logic Controller (PLC) driven, remote / locally operated, vacuum compatible stepper motors (2 nos.), which are used to execute (i) up/down and (ii) rotational ($360^\circ$, both clockwise and anti-clockwise, along the vertical target ladder axis) movements of the target ladder. Target ladder movements (rotational/vertical) can be measured through PLC.

![Fig. 3. SHARC target assembly.](image)

3.3. Input / Output ports
A number of ports (24 nos., size – 25 cm dia) are provided on different locations of the chamber body (see Fig. 1 & 2) to take the detector and other readout signals out of the chamber. Flanges with standard LEMO connectors as well as indigenously designed and fabricated flanges with Flat Ribbon Connector (FRC) connectors are used for this purpose.

3.4. Faraday cup
A Faraday cup has been fitted with the chamber (not shown in Fig. 1) for the measurement of incident flux. The schematic drawing of the cup is shown in Fig. 4. The Faraday cup has large aperture of...
diameter 75 mm to collect the beam transmitted through the target. A Graphite block has been used to stop the beam. An electron suppressor ring has also been provided to repel back the electrons emitted from target as well as the secondary electrons from Faraday cup.

4. Vacuum pumping system

To achieve optimum vacuum performance, all inside surfaces were given smooth granular finish and were finally electro-polished with bright finish. Clean vacuum $\sim 1 \times 10^{-7}$ mbar is achieved by means of two turbo-molecular (1000 l/s, Varian 1001 Navigator) and two cryo pumps (2500 l/s, CTI-Cryogenics) backed by mechanical pumps (Adixen ACP 40, 37 m$^3$/hr.). The complete vacuum pumping system is shown schematically in Fig. 5. Typically, nominal vacuum $\sim 1 \times 10^{-7}$ mbar is obtained in 8 hrs.

The whole vacuum operation sequence is pre-programmed and fully automated by using a PLC. A typical vacuum pumping sequence is displayed in Fig. 6. The vacuum operation is controlled locally as well as remotely through compact control units, which provide continuous display of the status of the full pumping sequence for monitoring purpose. There is also a provision for slow manual pumping under demanding experimental conditions.
5. Summary
The large multipurpose reaction chamber SHARC, planned for nuclear physics experiments with SCC, has been successfully commissioned and integrated with the 0° beam line in SCC beam hall-1. The fully automated vacuum system and the movable target assembly, which are unique, result in ease of operation and offer more experimental flexibility for the users.

References
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