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Fabrication and testing of the recoil mass spectrometer at Bombay Pelletron

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Abstract. A recoil mass spectrometer (RMS) has been designed, fabricated and installed at the 15°S beam-line of the Pelletron at TIFR. The RMS consists of a quadrupole doublet just after the target chamber followed by an 'electrostatic deflector', a magnetic dipole and a second electrostatic deflector. The recoils produced in the $^{12}C + {}^{58}Ni$ reaction using 60 MeV ^{12}C beam were focussed with the help of electric and magnetic fields and detected in a strip detector placed at the focal plane of the RMS. Further testing of the spectrometer to obtain mass resolution and efficiency are in progress.

Keywords. Charged particle spectrometers: electric and magnetic; fusion reaction; evaporation residues.

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1. Introduction

The 14UD Pelletron accelerator at TIFR provides the possibility of producing exotic nuclei far off from the β-stability line through heavy ion fusion evaporation reactions. These have a very low reaction cross sections of the order of a few microbarns and the reaction products recoil in the forward direction along with the beam particles. Recoil mass separator enables the study of these reaction products by separating them from the main beam and from each other. This is particularly important for weak reaction channels to avoid any contamination from other products.

2. Design and fabrication

In heavy ion fusion evaporation reaction, the recoils move in the forward direction along with the main beam. Their intensity is 10 to 12 orders of magnitude lower compared to that of the main beam. The recoils and the main beam have the same momenta but different energies. Hence they are first separated in an electric field. Mass dispersion is obtained when the separated recoils pass through the magnetic field. A final passage through a second electric field cancels the energy dispersion produced by the first electric field to a first order and only mass dispersion is obtained at the focal plane of the instrument. The use of a quadrupole doublet just after the target improves the acceptance of the instrument. The bending angles for the electric and the magnetic fields are 20° and 40°, respectively. The design layout was optimized by using the computer codes, 'TRANSPORT' and 'TRIO'.

The electrostatic deflector chambers were designed to have a diameter of 1.875 meters and a height of 0.85 meter each. The fabrication work was carried out in the Central Workshop of BARC. The electrodes were shaped so as to avoid any accumulation of electric field. Fringing field corrections were also applied to the lengths of the electrodes. This reduced the actual lengths of the electrodes from 1.39 meters to 1.27 meters. These were performed with the help of potential calculations routine-'RELAX3D'. Programs were developed to convert the potential calculations into field plots, in order to obtain the fringing field distributions.

In order to minimize the interference due to the main beam in the detection of the reaction products, the main beam is directed to a beam dump, situated on the other side of the electrode, through a cut provided in the electrode. The cut is carefully designed so that the field distortion may be minimum. The fabrication was followed by the electropolishing of these chambers at M/s Godrej and Boyce's w/s, at Vikrohli. A vacuum level of 2×10^{-8} torr was attained in both the chambers, with the help of cryopumps.

The high-voltage, high vacuum feed-through provides the connection of the external power supply to the electrodes in the chamber. The feedthroughs were also designed to take up the weight of the electrode (130 kg for the stainless steel electrode). The length of the ceramic is sufficient to ensure that there is no electrical breakdown in vacuum, along the surface of the feed-throughs. Further, in order to obtain a high vacuum inside the chamber, the ceramic of the feed-through should be nonporous. The feed-throughs were manufactured by M/s FRIATEC AG, Germany.

The coils were fabricated at the Centre for Advanced Technology, Indore. The coils are made of copper tubes of square cross section (12 mm $\times$ 12 mm) with a central bore of 8 mm and 242 turns. It was transported to Bombay with sufficient care so that there is absolutely no damage to the coils. The Yoke was fabricated in the Central Workshop of BARC. The field mapping of the coil was done in the dispersive plane. The results have been presented earlier in ref. [3]. The reproducibility of the field is quite satisfactory. The mass resolution depends on the uniformity of the field which was assured by using a low carbon steel and also by giving a Rogowskii's profile for the edges of the pole faces. The parallelism of the faces was better than 100 microns to provide the uniformity of the field. The power supply for the magnet needs 500 amperes at 75 volts at full load. The power supply has been fabricated at the Technical Prototype Production Division of BARC.

Special gantries were made and assembled on site to handle the bulky and heavy parts of the magnet and the electrostatic deflector chambers. The combined heat load of the dipole magnet, the quadrupole magnet and the pumps amounts to $\sim$70 kW, and a chilled water system has been designed and installed to take care of this.

The deflector chambers needed to be 'conditioned' for the application of high voltage. For this purpose the high voltage is slowly raised in stages for allowing the discharges due to micro-protrusions and other impurities, to pass and become less and less in number so that the applied voltage can be sustained. Thereafter, the voltage can be raised further. Presently a maximum voltage of 96 kV has been applied across the electrodes. The vacuum in the entire system is of the order of 3×10^{-7} millibar. The leak rate is below 5×10^{-9} torr liter per sec, which is satisfactory for the working of the instrument. For some

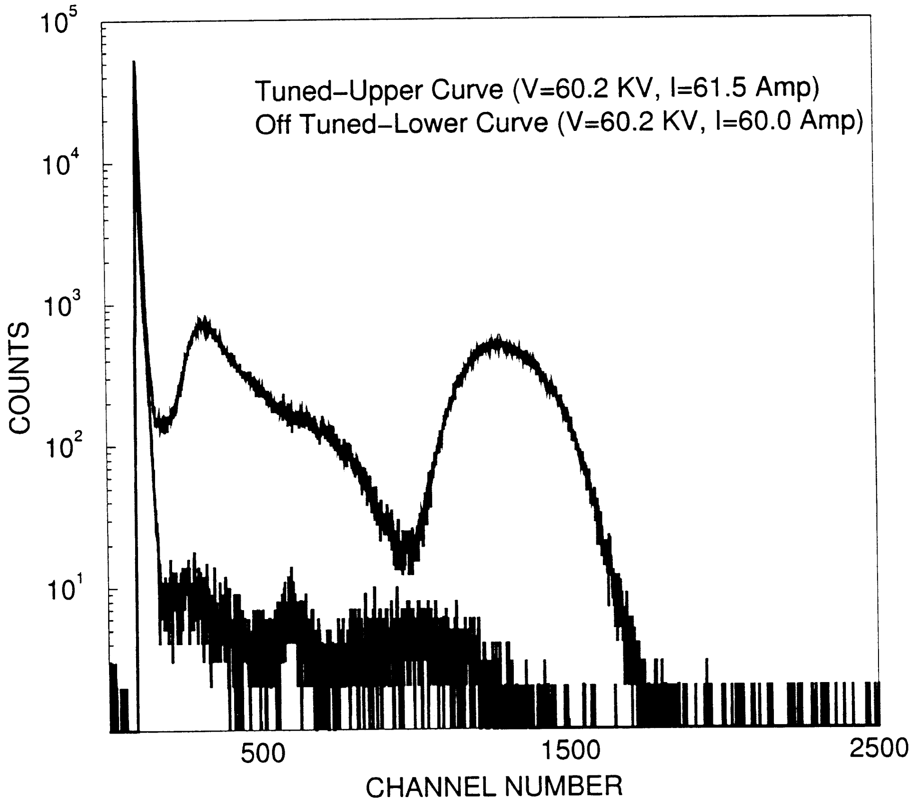

Figure 1. Spectrum of the recoils.

more details, like, the specifications and a typical beam profile through the instrument, the reader is referred to [1] and [2].

3. Test results

The $^{12}C + ^{58}Ni$ reaction with the 60 MeV ^{12}C beam was used to produce recoils with masses ranging between 60 to 70 and recoil energies of the order of 8 MeV and average charge state about 8^+. This gave $E/Q \sim 1$. The electric and magnetic fields were then tuned to obtain the signal in the silicon strip detector placed at the focal plane of the RMS. The signal obtained in the tuned condition is shown in figure 1. The signal nearly disappeared when the current in the magnet was reduced from 61.5 Amps to 60.0 Amps. It should also be stressed that 60 kV applied across the electrodes agrees with the calculated voltage to bend the ions with $E/Q \sim 1$, by 20° in electrostatic chambers. It should also be mentioned that the width of each strip in the detector was of the order of 1 mm [4]. Further experiments are now in progress to characterize the spectrometer, i.e., to measure mass resolution and efficiency. A suitable collimator with a height of 7 cm and width of

3.5 cm has been placed at the entrance of the first electrostatic chamber. This will limit the acceptance of the recoils to 50 mr $\times$ 25 mr and help in improving the mass resolution.

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