The Magnetic Field and the Beam Acceleration of RCNP AVF Cyclotron

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INTRODUCTION

This short report discribes mainly the property of the beam at center region and the emittance of the extracted beam.

THE MAGNETIC FIELD

All the power supplies are current regulated by series transistors with a stability of 1×10^{-5} /h for the main coil, 1×10^{-4} /h for the trim coil, and 1×10^{-3} /h for the valley coil. The magnetic field has been measured mostly by using a large rotating gear system with a Hall probe SIEMENS FC33. The radial and azimuthal positionings have been accurate to 0.1 mm and 10 seconds, respectively. The measurement accuracy of the whole system has been 1×10^{-4} in a few months. The results of the measurement of the magnetic field show good performance. An example of the predicted and measured magnetic field is shown in fig. 1.

OPERATION OF THE CYCLOTRON

The internal beam has been tested with 20 MeV protons, and 60 MeV, 70 MeV and 120 MeV alpha particles. To avoid the problem due to the residual radioactivity, the beam intensity is kept low using the ion source with a small exit slit (2 mm is diameter). For alpha particles the maximum current of 28 μA was obtained at full cyclotron radius of 100 cm. All setting of the trim coils except the center coil (No. 1 coil) are kept at the values given by the computer results through the measurements. So far the operating conditions are so adjusted to give about same number of turns which are expected for full energy protons. The beam is measured using four different direction probes. The vertical motion, beam centering and turn pattern have been observed. The beam is very stable and reproducible. The current stability of internal beam is less than 1 % for 10 minutes.

CENTRAL REGION

The desired isochronous field is produced by the main coil and sixteen trim coils. The example of the central field to accelerate the alpha particles up to 120 MeV is fig. 2. The special rise of the magnetic field near the center is to give a negative field index and to produce vertical (axial) focussing, so in this case the isochronous field begins around 15 cm. The alpha particles could not be accelerated up to full radius by this field. The three finger probe made clear that the beam began to fall at few turns and most of the beam was lost at around 13 cm. The reason of this beam fall was thought to that the vertical focussing was weak or the magnetic median plane was low at the central region. In the central region, the iron shim configuration of upper and lower pole tips are not geometrically symmetric so the median plane of the magnetic field was adjusted within 1 mm by off median plane field measurements. To remedy the median plane, the current of the trim coil No. 1 were 10 % unbalanced. The magnetic median plane is lowered about 3 mm by 10 % unbalance. Then the beam could be accelerated up to full radius but the vertical oscillation became larger. The movement of the ion source exit slit to downward also made the beam accelerate up to full radius. It introduced more vertical oscillation. Next, to increase the vertical focussing force we reduced the current of the trim coil No. 1. (As the trim coil No. 1 is energized negative, the reduction of the current means the increase of the magnetic cone field.) The alpha particles was also accelerated up to full radius as we can see in fig. 3. (lower curve). The current reduction with keeping the 10 % current unbalance are also seen in fig. 2. The result is more effective. It will be seen that only the adjustment of the trim coil No. 1, the beam can be accelerated up to full radius, but the central region is not known completely yet, more careful beam measurements will be needed.

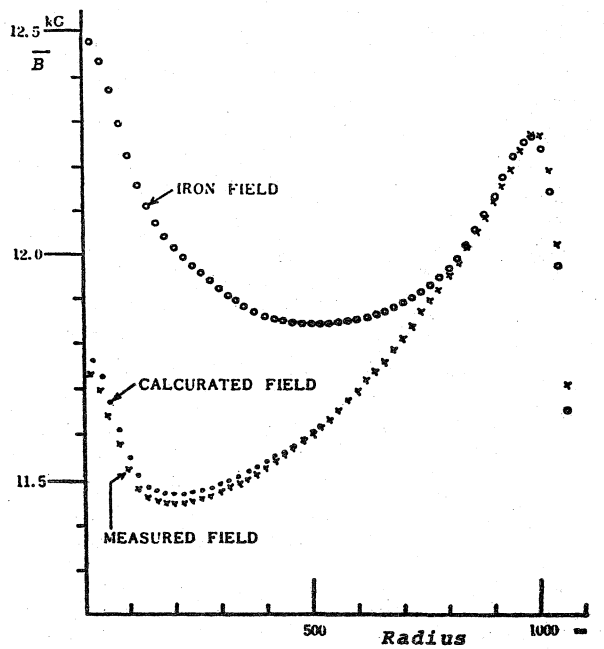

Fig. 1. **Radial profile of the magnetic field. Discrepancy between the calculated and measured fields is caused by ignorance of change of central shim configuration in the calculated field.**

EXTRACTION OF THE BEAM

A 90 MeV alpha beam was extracted and the emittance was measured. The preliminary results show the vartical and horizontal emittance are less than 10 mm-mr and 30 mm-mr, respectively. An example of the measurements is shown in fig. 3.

ACKNOWLEDGEMENTS

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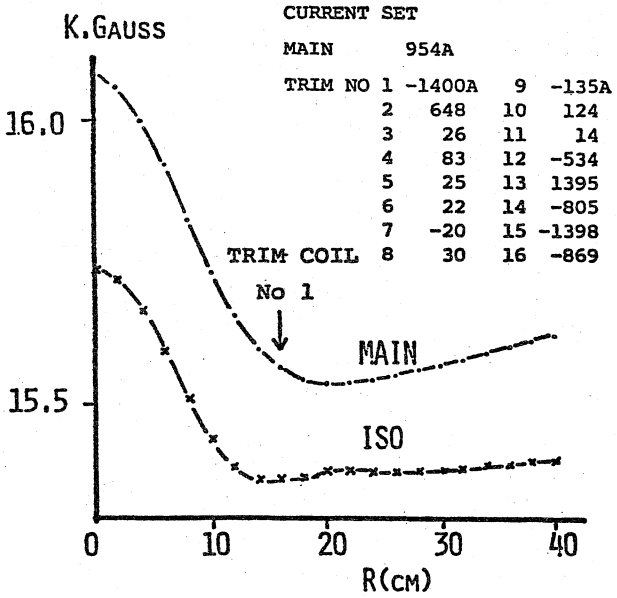

Fig. 2 Radial profile of central region for alpha particle acceleration up to 120 MeV.

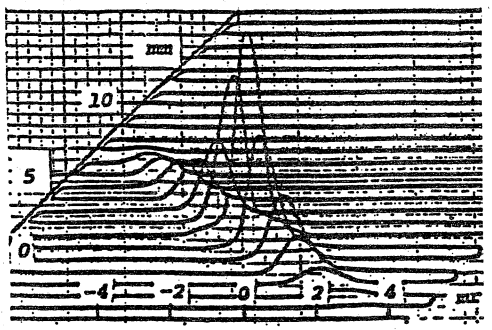

Fig.4 Example of vertical emittance measurements.

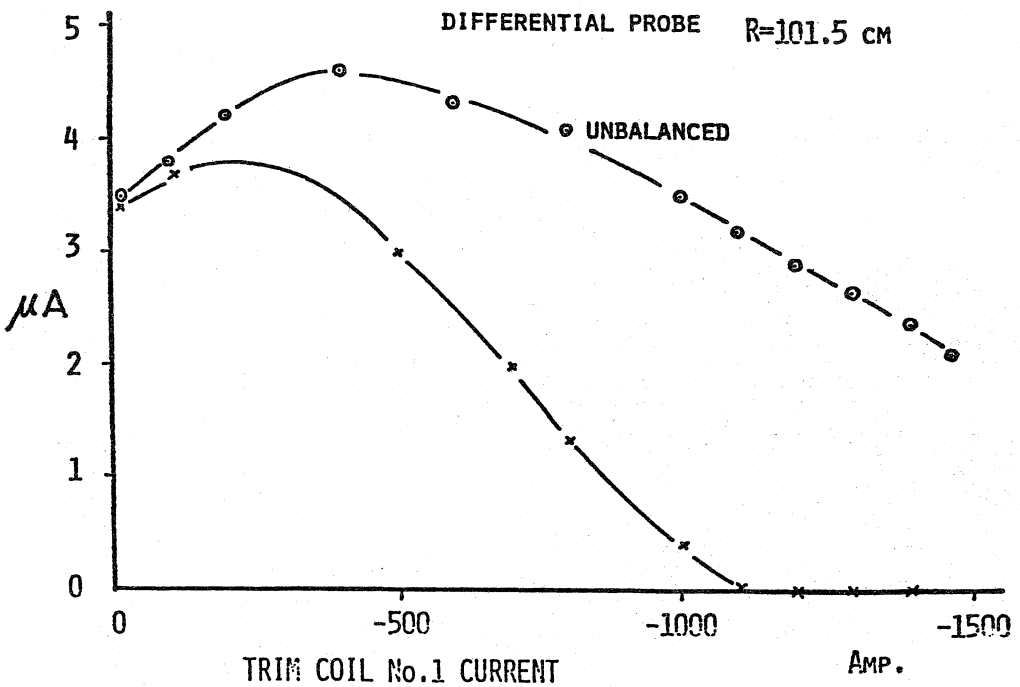

Fig.3 Reduction of the trim coil No.1 current.