TRIUMF CENTRAL REGION CYCLOTRON PROGRESS REPORT

E.W. Blackmore, G. Dutto, M. Zach
TRIUMF, Vancouver 8, B.C., Canada

L. Root
University of British Columbia, Vancouver 8, B.C., Canada

ABSTRACT

The central region cyclotron has been built to investigate beam behaviour through the axial injection system and the first five turns of acceleration. A brief description of the resonator structure and the design of the electrostatic inflector is given. Preliminary results of beam tests are discussed.

INTRODUCTION

Early in the TRIUMF project it was decided to combine a number of full-scale prototype tests which had been proposed during the design study and to build a central region cyclotron. The two major testing programs which had been planned were the development of an external H^- ion source and injection system and the mechanical and electrical testing of the resonator structures. To complete the cyclotron so that a beam could be accelerated to five or six turns required the addition of a magnet to simulate the field of the main magnet in the region out to a radius of 40 in.

Fig. 1 shows the major components in the central region model. The magnet has the same 6-pole geometry and the same gap 20.8 in. as the main magnet. The average magnetic field at the centre is 3000 G and the magnetic ν_z^2 is 0.01 at a radius of 30 in. Five trim coils and one set of six harmonic coils are provided for precise field shaping.

The H^- ions are injected vertically along the magnet axis at an energy of 300 keV and guided into the median plane by a spiral electrostatic inflector. A description of the ion source and injection system is given in these proceedings.[1]

The accelerating structure for TRIUMF is a two-dee system made up of 20 widths of quarter wave length resonators. These resonators are described in more detail in another paper.[2] The sections are identical except for those at the centre which are modified for the axial injection. Only these central resonator sections are included in the central region cyclotron, resulting in the rectangular shape of the stainless steel vacuum tank. The resonators are powered through a tuned transmission line and coupling loop by a 200 kW tetrode amplifier operating at 23 MHz. The nominal dee gap voltage is 200 kV. A third harmonic amplifier for flat-topping the RF wave is also available.

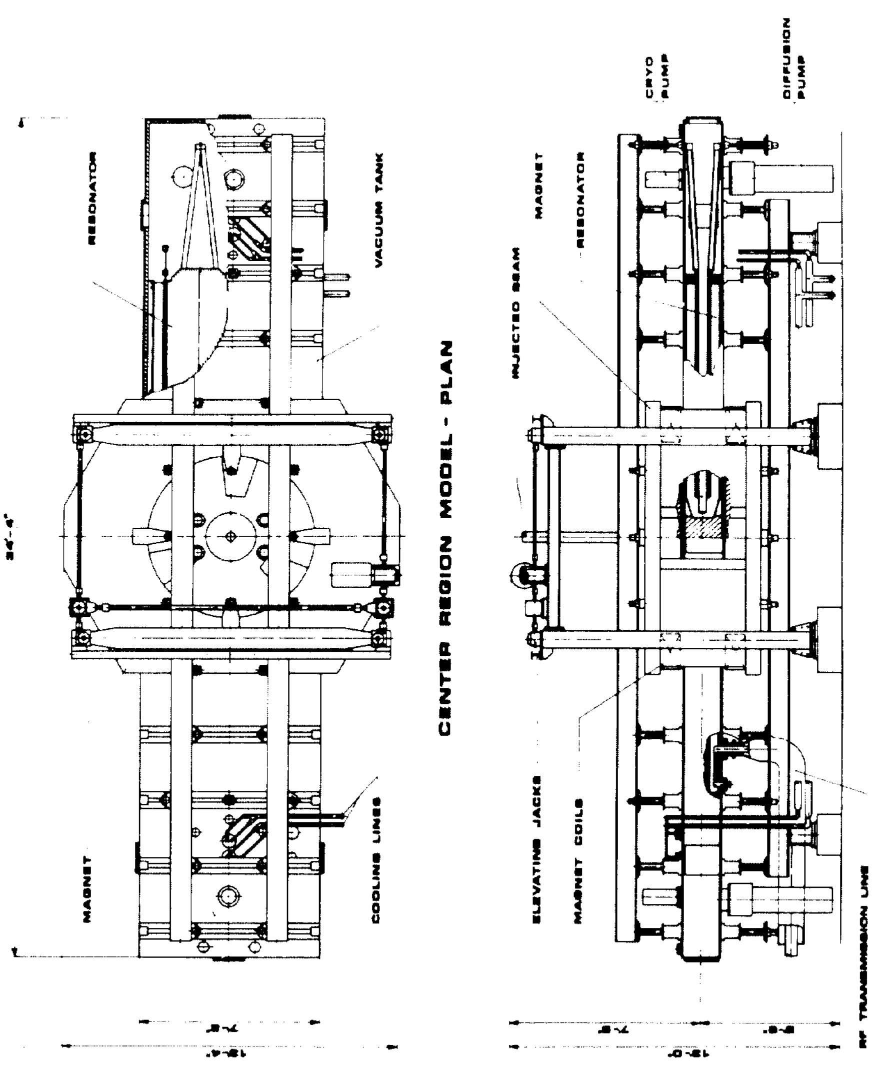

Fig. 1. Assembly of the central region cyclotron. The lid of the vacuum tank can be used to permit access.

Considerable work has been done on the standard resonator sections mounted in the vacuum tank to establish their mechanical and electrical characteristics. These tests showed that the quality factor and voltage holding of the resonators are satisfactory and that good electrical contacts at the resonator root and between adjacent sections are necessary. The stability of the RF voltage and frequency was found to be seriously affected by mechanical vibrations and thermal distortions in the resonator structure. The first problem was eliminated using mechanical dampers and the second by attaching the RF surface to the support structures by a more flexible mounting.

This paper will be concerned mainly with the status of the axial injection system and the central region geometry of the resonators.

AXIAL INJECTION

A vertical view of the axial injection system, together with the magnetic field profile along the magnet axis, is shown in Fig. 2. The inflector system is designed to satisfy a number of requirements: the beam at the inflector exit must be positioned for proper centring of the orbits at large radii, the optics of the system must match the acceptance of the cyclotron, and the inflector must fit into the available space. There is a severe space limitation for the inflector as it is mounted inside the centre post, an important structural member in the main cyclotron. This led to the choice of a combination of a spiral inflector together with a cylindrical deflector in the median plane. The spiral inflector has the property that the electric field vector along the central trajectory is always perpendicular to the velocity vector of the ion. The variable parameters in the design are the height of the inflector and the slant of the electrodes. The additional deflector electrodes are used to reduce the height of the inflector and to provide more flexibility in centring the beam for injection.

Fig. 3 shows the inflector system. The electric fields required are 55 kV/in. on the inflector and 34 kV/in. on the deflector. The gap for both electrodes is 1 in. × 2 in. The inflector electrode surfaces have been machined from an aluminum casting using a numerically controlled milling machine.

The optical properties of the inflector system have been calculated using both a semi-analytical and relaxation technique to determine the electric fields. Fig. 4 shows the overlap between the calculated radial and vertical beam ellipses at the exit of the inflector system and the cyclotron acceptance for a good quality beam (A_r = 0.15 in. at 20 MeV and 30 deg phase width). The required beam ellipses at the inflector entrance are shown as well. A number of improvements to increase this overlap are envisaged.

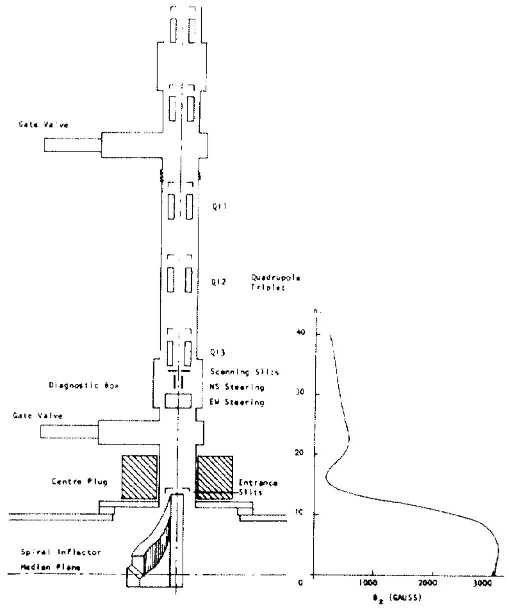

Fig. 2. Vertical view of the axial injection line.

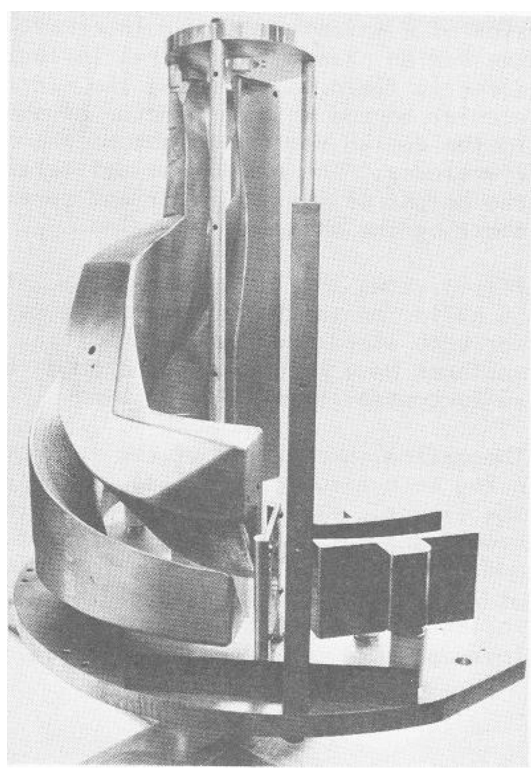

Fig. 3. Photograph of inflector and deflector.

CENTRAL REGION GEOMETRY

The present design of the central region is shown in Fig. 5. After being bent into the median plane the beam enters the dee structure through a 100 kV injection gap and is then accelerated every half-turn by the 200 kV dee gap. This location of the injection gap gives near-perfect centring of ions for all RF phases of interest if distortions produced by transverse electric field components and first harmonic magnetic field errors are avoided or compensated for.[3,4] The dee gap is tapered from the standard 6 in. separation at 30 in. radius (2.5 MeV) to 2 in. at a 16 in. radius to increase the energy gain at low energies.

Vertical focusing out to a radius of 30 in. is determined primarily by the RF electric forces at the dee gaps. One important result of this and of the fact that our orbits are about 5 times larger than in other cyclotrons is that the vertical alignment of the resonators at the centre becomes crucial. A misalignment of $\geq$1 mm would lead to a vertical coherent oscillation of $\gtrsim$1 mm and eventual loss of the beam. To increase the tolerances required on the alignment, vertical electrostatic correction plates are provided to correct for any geometric misalignment effects.[4]

FIRST BEAM MEASUREMENTS

Fixed beam diagnostic probes are provided at the entrance and exit of the inflector system, and radial scan probes are mounted in the cyclotron median plane at 0 deg (injection gap), 90 deg and 270 deg. Several types of probe heads are used, differential, multi-wire profile probes as well as glass scintillators. The 90 deg and 270 deg probes produce a current readout and can be used with a scanning wire on the 0 deg probe for centring measurements. The control of power supplies and probe drives and the monitoring of all analog signals are done using CAMAC.

The beam current has been kept intentionally low (20 μA) for the preliminary measurements. The measured central trajectory through the inflector system agrees with that calculated. The transmission is at least 80% and probably higher. The optical properties of the inflector have not been measured in detail as yet, but the full emittance beam from the ion source can be focused to a 0.3 in. diam spot at 90 deg after the injection gap. The measured entrance beam profiles to produce this output agrees with those predicted by TRANSPORT calculations using the calculated inflector transfer matrix.

During the first accelerated beam measurements, injecting a DC beam, the beam was observed out to four turns but a large percentage was lost vertically after the second turn. By observing the beam profiles on a glass scintillator at successive turns it could be seen that the loss was due to a phase-dependent vertical deflection of the beam. Possible causes of this vertical loss are a misalignment of

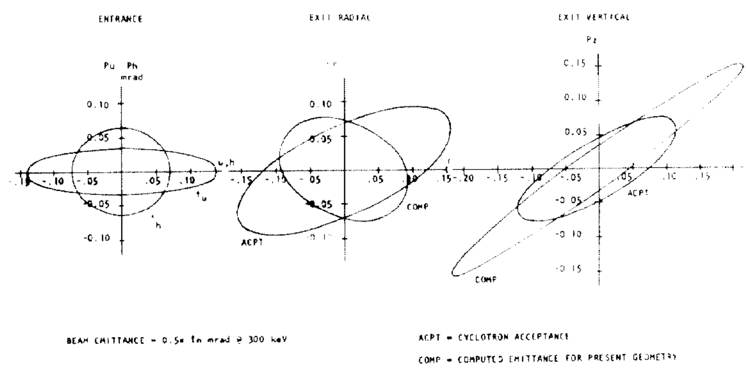

Fig. 4. Comparison of calculated injected beam ellipses with cyclotron acceptance for present geometry

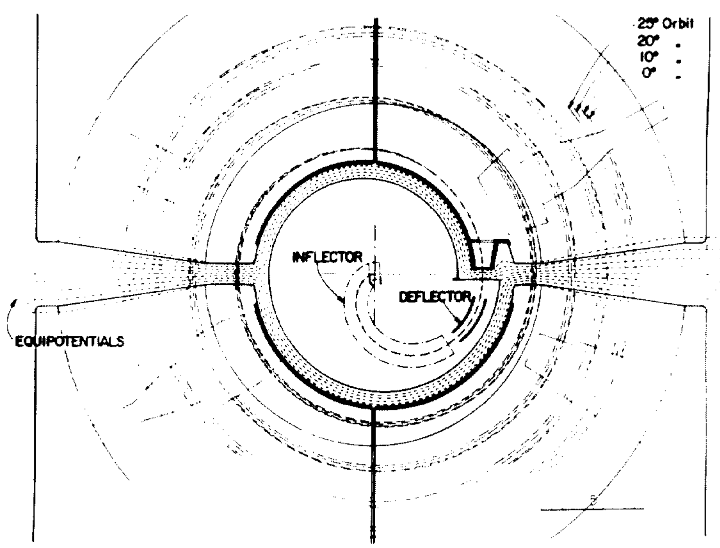

Fig. 5. Plan view of central region showing correction plates

the resonator dees or injection gap, as mentioned previously, or an up-down voltage asymmetry in the resonators. A magnetic field median plane shift has been ruled out as a cause.

Further measurements showed that the electrostatic correction plates on the first two turns could successfully compensate for the vertical deflection and remove its phase dependence. The present beam at 1.2 MeV is 6-8% of the DC beam before injection but little effort has been made to improve the phase acceptance.

At present the RF chopper and buncher in the injection line are being commissioned. The chopper will provide a phase width of 10-20 deg to simplify the problems of studying the phase-dependent effects.

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