DESIGN AND CONSTRUCTION OF THE AXIAL INJECTION SYSTEM FOR THE 88-INCH CYCLOTRON[*]

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Summary

A new axial injection system for the 88-inch cyclotron has been constructed. It transports beams from external ion sources axially through the magnet yoke to the median plane of the cyclotron. The optical elements include a bending magnet, electric quadrupoles, and the magnetic field of the cyclotron. Beam monitoring is done with scanning wires, phosphor plates and Faraday cups.

Introduction

The old axial line[1] of 1966 used an ion source mounted directly on the line axis, and had electric quadrupole doublet lenses with a 3.0 cm aperture. The new line, Fig. 1, accepts beam from either a polarized ion source on axis, or a duoplasmatron source used with a 90° bending magnet. The aperture has been increased to 7.3 cm and quadrupole triplets are used for greater matching flexibility. This paper describes the system down to the median plane. The new inflector and center region electrodes will be the subject of a future paper.

Design Considerations

Since the polarized source is a complex structure it was placed above the 7 ft thick concrete roof of the cyclotron vault, to allow construction and testing during cyclotron operation. The injection line is required to transport the beam about 15 feet from the sources to the median plane.

The requirements for the injection energy are determined by the center region orbits and geometry as follows:

1) The injected beam must clear the inflector electrode (Fig. 1) on the first turn in the cyclotron median plane, after being inflected into the dummy dee as at Birmingham.[2] This means having a large enough injection voltage, $V_{i,min}$, at the particular cyclotron magnetic field, B, being used, and $V_{i,min} \sim B^2$.

2) The beam must be nearly centered in the cyclotron after several turns of acceleration. This requires the injection voltage to be proportional to dee voltage, $V_i = KV_D$. In the present case of a single dee, on-axis injection and narrow accelerating gaps, $K \simeq .18$. Our normal maximum dee voltage is about 65 kV, so the maximum injection voltage is 12 kV.

Ion Sources

The polarized ion source[3] is of the usual atomic beam type, using a dissociator, sextupole, RF transitions and strong-field ionizer. We expect that it will produce polarized beam for experiments of 100-1000 times the intensity and much better quality than that available with the α-p scattered beam used during the past several years.

The duoplasmatron source[4] produces intensities of over 500 μA of protons, H_2^+, H_3^+ and similar deuteron beams. It is being used to test the transport line performance for efficiency under low and high intensity conditions.

Transport System

The 90 degree bending magnet bring the duoplasmatron beam into the axial line. It gives equal focusing in both planes with a flat field and edges cut at 36 degrees to the beam normal. Edge clamps are used to define the fringing field. Einzel lenses are used just before the magnet on both source lines to produce a waist about 40 cm before the first triplet.

Three quadrupole triplet lenses were chosen to transport the beam efficiently down the column to the median plane.[5] Space between triplets is used for steering plates, scanning wires, phosphor plates and Faraday cups. The scanning wires are motor-driven X-Y double scanners used for recording of beam shape on a storage oscilloscope. The Faraday cups and phosphor plates are remotely controlled by air cylinders. For phosphors we use either quartz or aluminum oxide. A future buncher will be placed in the space between the last two triplets. At present a sine-wave buncher is being planned, rather than the more ideal but more difficult sawtooth buncher suggested previously.[6]

The mechanical structure consists of 6 inch diameter tubes containing the lenses, inside a 12 inch square cross-section evacuated column, as shown in Fig. 1.

The Hole Lens

The beam entering the strong magnetic field of the cyclotron is focused to periodic waists by this half solenoid or "hole lens". Calculations were made on particle trajectories for various phase space shapes and waist positions.[7] They showed that several discrete operating modes produce the desired beam size in the median plane of 2 - 3 mm diameter.

For high energy beams the dotted line in Fig. 2 must be used, so we are between modes. A point on this line was checked on a test of the injection line. Figure 3 shows this case for 10 kV protons going into a 10 kg field with over 50% transmission

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through the line. The spot diameter is about 2 mm FWHM which is quite acceptable. This shows that one can operate efficiently some distance off the mode lines if necessary.

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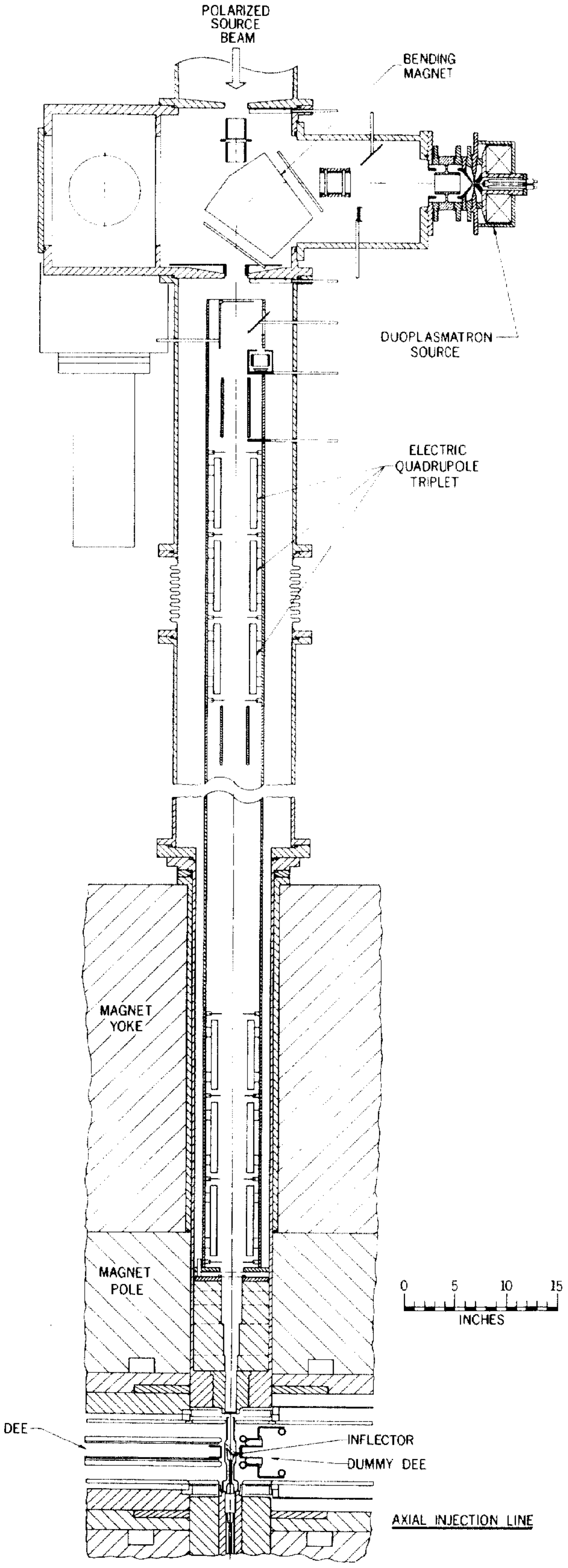

Fig. 1. Schematic drawing of axial injection line for 88-Inch Cyclotron. An additional quadrupole triplet is located in the omitted section above the magnet.

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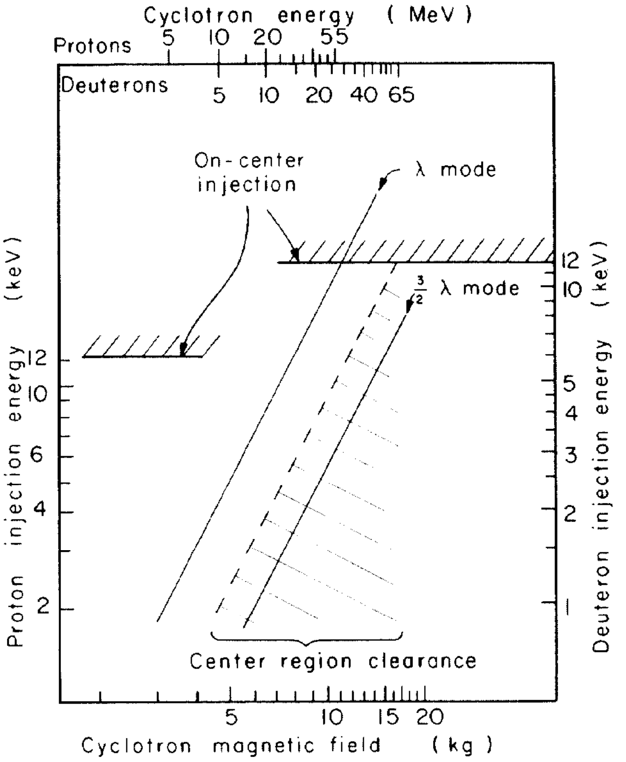

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Fig. 2. Chart of operating parameters for injection line. Forbidden regions are shaded: at the right because of the clearance requirement for inflected beam in the first turn, and at the top because of the orbit centering requirement.

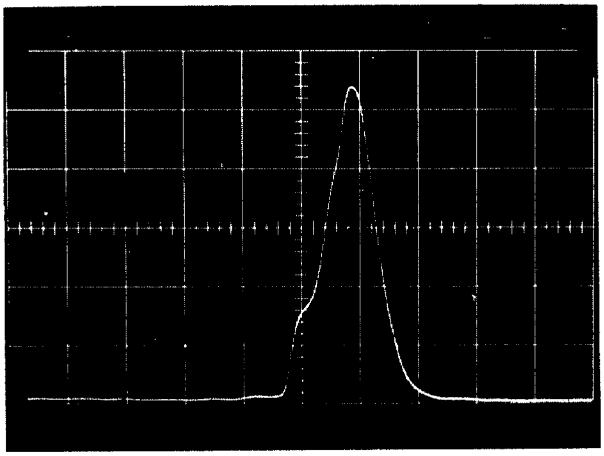

Fig. 3. Photo of scanning wire sweep of beam at the median plane after passing from duoplasmatron source through injection line. Beam was 10 kV protons injected into a cyclotron field of 10 kG, corresponding to a 55 MeV proton cyclotron energy. Horizontal scale is 2 mm per large division.