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DESIGN OF THE ESCAR INJECTION BEAM LINE

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Abstract

The design features of the elements of the ESCAR (Experimental Superconducting Accelerator Ring) injection beam line are described. The junction of the proton transport system with the ESCAR injection straight section requires the design of mechanical elements compatible with the 10^{-11} torr vacuum requirements of the main ring. These elements include a novel septum magnet whose salient design features include a current-carrying septum of tapered thickness, to reduce the overall power requirements, and total enclosure of the magnet coil in a metal can for vacuum compatibility. Other elements are a wire electro-static septum, and several fast-rise "bump magnets". A transition cryopump is designed to separate the main ring vacuum from the relatively poor 10^{-6} torr vacuum of the conventional beam transport line. A brief description of the conventional beam transport line from the 50 MeV proton linac, recently installed for Bevatron injection, is also included.

Introduction

The beam injected into ESCAR will be provided by the 50 MeV Linac presently operating as a proton source for the Bevatron. The injection line including that part shared for Bevatron injection is approximately 75 meters long and includes 6 bending magnets, 2 solenoids, 11 quadrupoles, 5 vertical and horizontal steering magnets and diagnostic equipment. (Figure 1.) Injection into the ring is in the vertical plane, from underneath, with the radial dispersion of the ring matched by the injected beam. (Figure 3.) Because of the experimental nature of the machine, some flexibility is provided in the beam line to alter the dispersion, beam size, emittance and momentum spread of the injected beam.

Optics

The beam emerging from the linac has the following nominal characteristics:

Energy	51 MeV
Current	75 ma Peak
Energy Spread	+ 200 keV
Pulse Length	30 μsec
Emittance	2.5π cm-mr

The beam from the linac is first focussed and bent 180° by three sector magnets in an achromatic configuration. The use of the three sector magnets is thought to be more economical than two 90° magnets with non-normal end angles with an auxilliary quadrupole.

The elevation of the linac beam is higher than that of the rest of the injection line, so the plane containing the three sector magnets is tilted to lower the beam elevation. Solenoids are used at the ends of the 180° bend to avoid emittance dilution from mixing the x and y planes.

The radial chromaticity of the ring, η_x, is matched as well as the radial β_x, at the injection straight section. The beam is dispersed by a 62° magnet and allowed to drift, where a quadrupole then removes the divergent part of the dispersion. The geometry constraint on the system provides the wrong sign of dispersion at the ring, so a drift space of π radian phase advance is included in the system to reverse the dispersion. The effects of longitudinal chromatic abberations in this section are entirely negligible.

The effect of space charge on the evolution of the beam bunch in the transfer line has been explored with both linear and macro-particle codes. The momentum spread is expected to almost double without a debuncher cavity. As the power required by the r.f. system for a given bunch length in the short-bunch storage ring mode goes as the fourth power of the initial energy spread, careful consideration of this effect is necessary. One, and possibly more debuncher cavities will be included in the transfer line to reduce the energy spread to less than ± 200 keV. Damping of space-charge related instabilities in the circulating beam will be controlled by sextupole and octopole fields in the lattice.

The injection into the ring is in the vertical plane from below. A small vertical achromaticity remains, but is not significant. The pickup during injection is not very sensitive to changes in β_y of the injected beam.

The central orbit of the beam in the ring displaced downward by four bump magnets located asymmetrically around the injection straight section. Approximately 30 turns will be stacked in vertical phase space, with the total accepted charge almost independant of the number of turns over a wide range. However, the power dissipated in the wire septum and other aperture stops must be kept to a minimum, so a small number of turns is preferred.

Bending Elements

The three magnets required for the 180° bend and the 62.9° (M4) bend magnet are fabricated using edge-cooled tape wound coils. The tape-wound geometry, originally developed at the Super Hilac, offers the advantages of compactness, and economy of construction and operation.[1] These four magnets and the first vertical insertion magnet are designed for the same field and radius of curvature. This feature will greatly ease the task of magnetic measruements. M5 is a conventional hollow square copper conductor dipole design. The hollow conductor option was favored for this magnet over the more compact tapewound option since a midplane split was required for access to the transition cryopump inserted through its bore tube.

The septum magnet M6 is a rather more unusual design. (Figure 2.) The conductor is fabricated from .032" thick flat copper sheets insulated, stacked and epoxied together. Inside and outside contours for beam tube regions are machined in this stack, and complete loops in each layer are cut and layer to layer connections are made. The ends of the stack are bent up to form a "saddle" for beam clearance.

The septum is tapered in width along its length resulting in most of the power being dissipated at the thinnest section. Coil cooling is accomplished by flooding the coil with Freon pumped around a circuit

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which includes an external water cooled heat exchanger. The iron yoke, leg and pole assembly welded to the stainless steel beam tube make up the vessel containing the coil and Freon coolant. An attractive feature of this design is the fact that there are only metal surfaces exposed to the high vacuum environment.

The inflector design is similar to wire deflector designs presently in use at CERN, BNL, and Fermilab. The grounded anode is made up of a curved plane of .1 mm Tungsten wires which encloses a cathode operating at 72 kV. The gap, height and length of the septum are 1.2 cm, 7 cm and one meter, respectively. A spring loaded wire extracting mechanism is anticipated. The electrostatic septum and M6 will be mounted as an assembly on an externally adjustable support.

There has been some evidence of the degradation of voltage holding capacity with improved vacuum. We have, therefore, chosen a fairly modest 60 kV/cm operating gradient for the anticipated 10^{-11} to 10^{-12} torr vacuum.

Bump Magnets

Injected beam will be stacked in the vertical phase space. The vertical closed-orbit position of the circulating beam will be moved toward the injection septum by 4 pulsed injection bump magnets with a rise time of approximately 32 μsec. (Figure 3.) The ferrite core magnets will be mounted external to the high vacuum system. A ceramic vacuum tube will be provided with a conductive coating sufficiently thick to provide continuity for the high frequency image currents for a bunched beam, but thin enough to obviate the eddy current effects due to the magnet rise time.

Vacuum

Six ion pumps are distributed along the beam line. Although these pumps are large (~ 500 ℓ/s) the aperture limitation of the beam tube will result in integrated average pressures of not better than low 10^{-8} torr range.

A barrier is needed to separate the 10^{-6} torr vacuum of the injection line with the 10^{-11} to 10^{-12} torr of the ESCAR ring. A 4° K cold bore extends through the last bending magnet and quadrupole in the conventional beam line to intercept gas molecules before they migrate to the main ring. The curvature allows no line of sight communication between the two vacuum systems and the high ℓ/d ratio will support a pressure differential of 5 orders of magnitude with a surface capture fraction of 0.2.[2] (A fairly conservative model for hydrogen gas on a 4° K CO_2 coated surface.)

To protect against the effects of modest temperature excursions which will drastically affect the capture fraction for Hydrogen, sublimation pumping is provided just upstream of the transition cryopump to reduce the hydrogen partial pressure.

Diagnostics

T.V. monitored scintillator screens are positioned along the beam line to aid quadrupole tuning and steering. Other diagnostics include beam transformers and split Faraday cups.

Acknowledgements

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References

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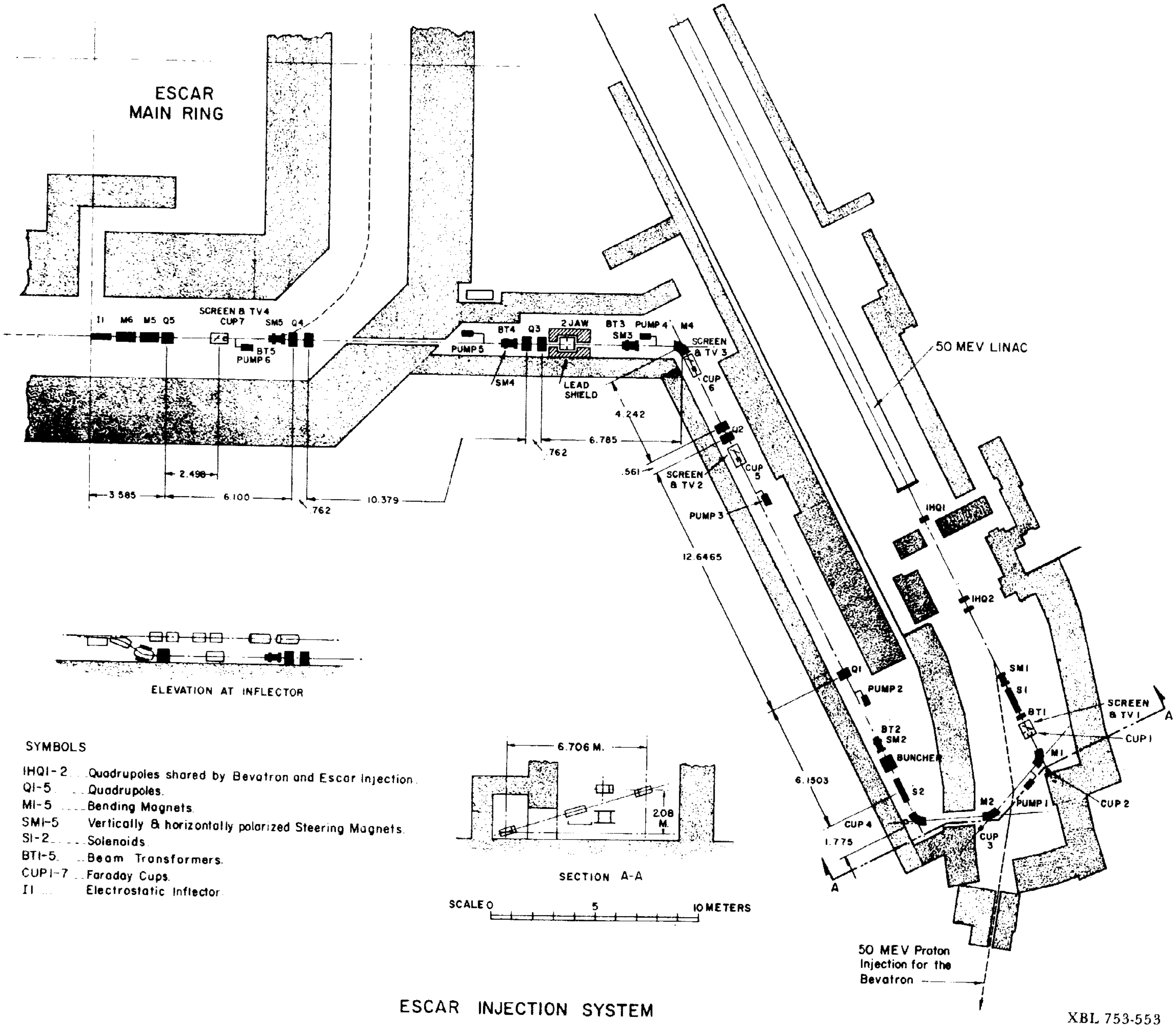
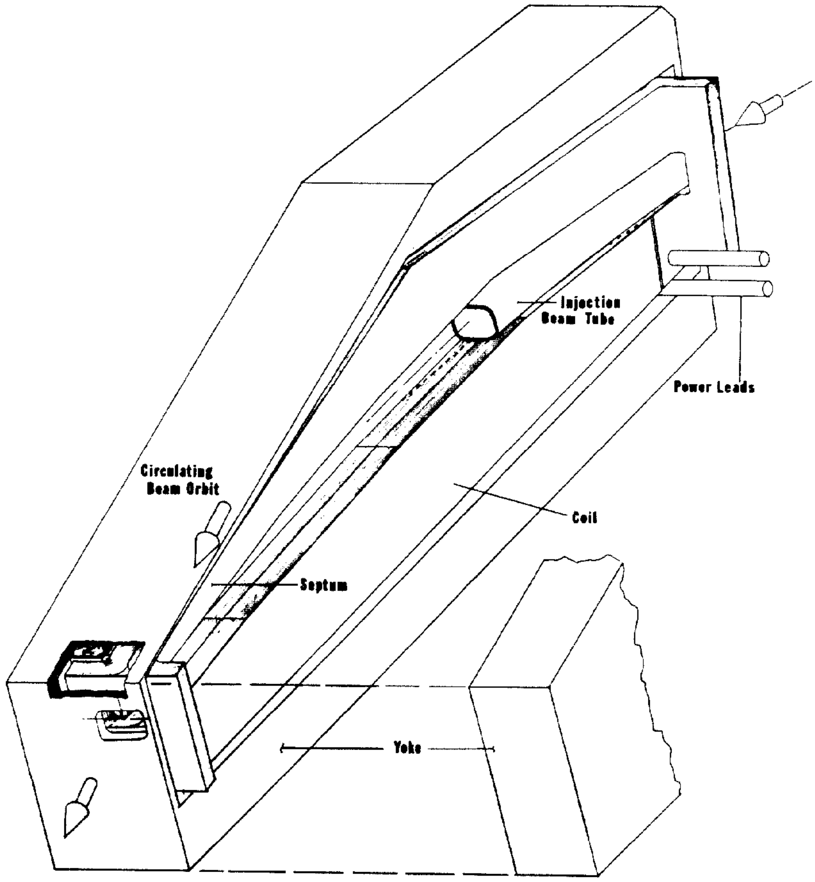
2. R.C. Wolgast, Design of the Cryopumping System for ESCAR, to be presented at this conference, also LBL-3372.



ESCAR INJECTION SYSTEM

Figure 1

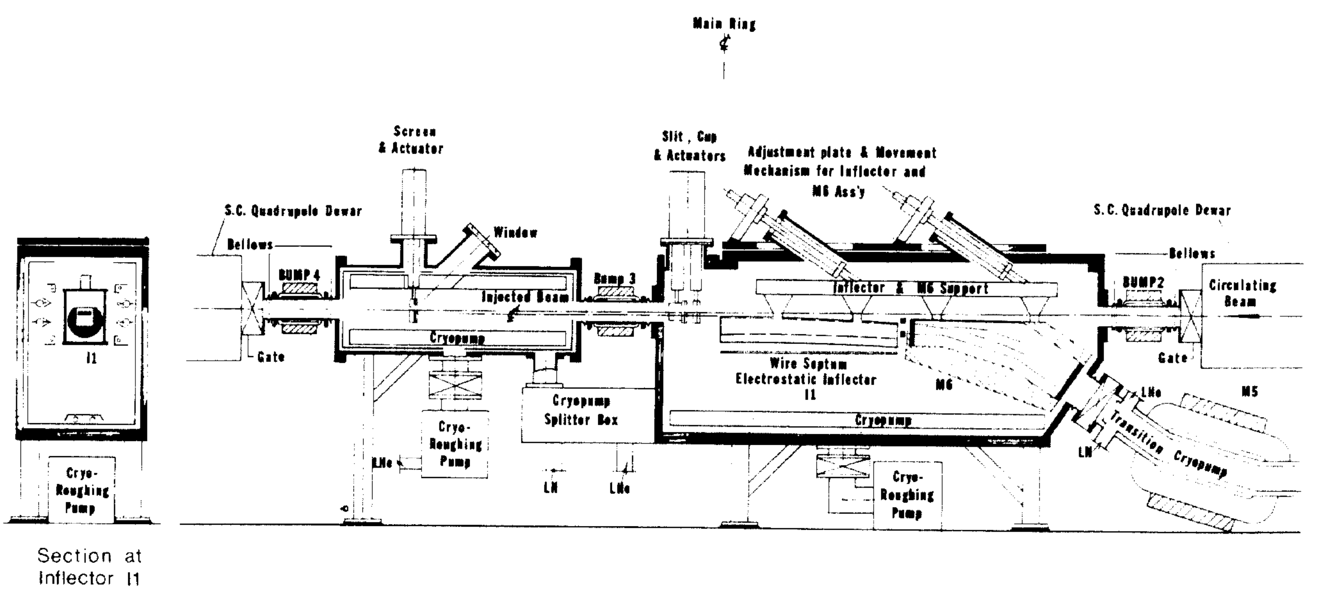


SEPTUM MAGNET

M6

Figure 2

XBL 753-426



INJECTION STRAIGHT SECTION

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Figure 3