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PROTON BEAM DIAGNOSTICS IN THE FERMILAB ELECTRON COOLING EXPERIMENT

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INTRODUCTION

The goals of the Cooling Ring experiment are to demonstrate electron cooling in a new range of electron beam parameters and to demonstrate the accumulation of small groups of particles by electron cooling. Requirements of radiation physics on the lightly shielded ring have led to single pulse injection intensities of about 10^7 protons. Proper interpretations of electron cooling experiments require a dynamic measurement of beam profile. Correction of closed orbit errors is required to utilize the full aperture of the system. These considerations have led to the present and planned diagnostic systems.

DUMP SYSTEM

The beam dump system is composed of 1) an insulated limiting aperture stop 4.5 inches in horizontal width, 2) slow pulsed magnets located 90° away in betatron phase, and 3) a liquid scintillator detector surrounding the dump. This system is capable of detecting very weak coasting beam and in addition yields information about the local horizontal beam mean position and size distribution. Figure 1 shows the dump magnet current and the dump scintillator signal with the beam lost at the dump.

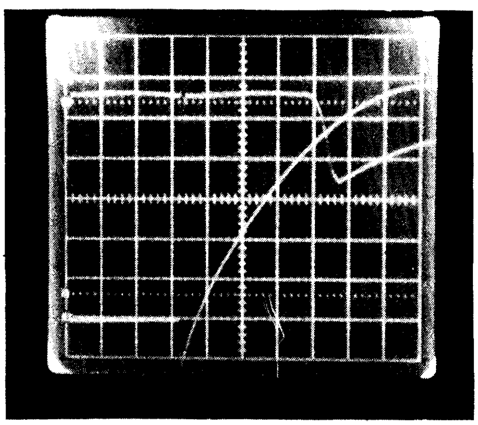

Fig. 1. Dump magnet current and dump scintillator signal.

WIRE SCANNERS

Movable wires[1] are located immediately following the injection septum where they can scan the full horizontal and vertical apertures available for injection and coasting beam. The molybdenum ribbon is .001" x .060" in dimension. The wires have been used to obstruct the coasting beam and infer local beam position and size distributions for the horizontal and vertical planes. It is hoped to develop electronics sufficiently sensitive to detect the injected beam.

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PROFILE MONITOR

In order to measure profiles dynamically during the cooling process, it was decided to employ a device similar to the sodium curtain device in the ISR.[2] A ribbon atomic jet is aimed at 90° to the beam direction with the plane of the ribbon at 45° to the beam direction. The jet atoms are ionized by beam particles producing electrons that drift along magnetic field lines perpendicular to the beam to a position sensitive detector. This provides a two dimensional beam profile. The vacuum properties of magnesium are more favorable than sodium for this purpose in an experimental device where replacement of the jet material does not impose a serious penalty. In order to improve the time resolution in the very low intensity regime, single electrons produced by beam ionization are accelerated to a multichannel plate where they produce a cascade of ~ 10^7 electrons. This cascade is accelerated onto a resistance plate where its position is inferred by making four separate charge readouts (see Figure 2).[3]

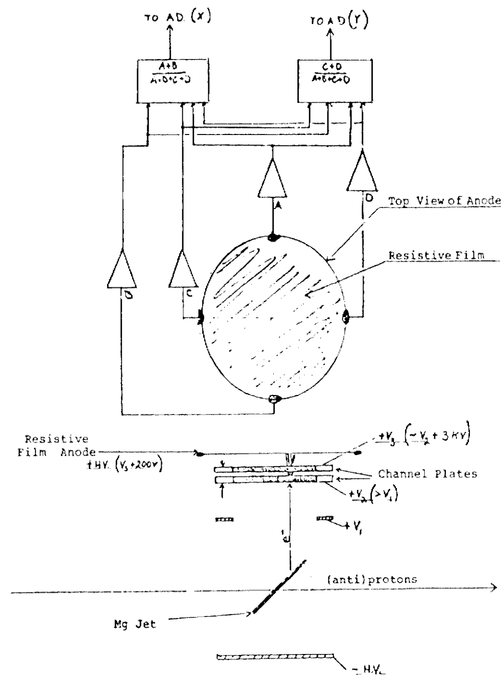

Fig. 2. Magnesium Jet Electron Image Readout System.

Beam profiles are generated as histograms of numbers of electrons versus position of the electron cascade by conventional data processing methods.

The magnesium jet is generated by an oven operating at temperatures near 600°C producing densities of $10^{16}/cm^3$. The atoms effusing from an orifice are collimated by a slit to produce the ribbon jet. Tests have been made of jet densities in an experimental oven (see Figure 3) and slit by measuring the weight of magnesium deposited on a plate behind the slit. These measurements give a rough confirmation of the jet density. The jet is also being used with an electron beam to test the multichannel plate and electron detection system.

The goals for operation of the jet are to achieve a density of $10^{10}/cm^3$ in a 2 mm jet. Then 10^7 200 MeV protons will produce about 10^5 electrons/sec, so that histograms of 10^3 events can be made for 10 msec

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intervals. At this density the contribution to the average pressure in the ring is about 4 x 10^{-12} Torr, less than 10% of the planned ring pressure.

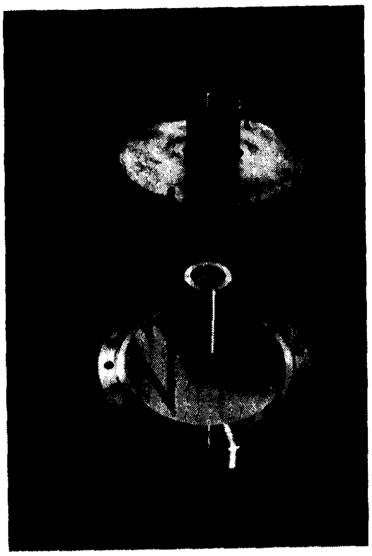

Fig. 3. Photo of magnesium oven and slit assembly.

POSITION ELECTRODES

Position electrodes are installed at each beta max location. The electrodes are 5 inch diameter cylinders 6 inches long cut at 45° to the beam direction (see Figure 4). The capacitance of each half is returned to the control room through a phase matched multiplexed cable system. With 10^7 protons circulating, the mean induced voltage is about 15 micro volt. In order to detect this signal it will be necessary to use high input impedance preamplifiers or use signal averaging techniques. For example with a preamplifier with 1 kΩ input impedance and a resolution bandwidth of 10 kHz at the 7.5 MHz RF frequency, the thermal noise will be of the order of ¼ μV while signal will be 15 μV. The problem will be made more tractable when the beam can be bunched after installation of the RF stacking cavity.

Fig. 4. Position Electrode Assembly.

TUNE MEASUREMENTS

Horizontal and vertical tunes have been measured by radio frequency knock-out methods. Either kicker magnets or position electrodes can be driven with radio frequency power to excite betatron oscillations resonantly against an aperture stop. This method will be replaced by non-destructive electronic methods when power supply ripple and regulation have been sufficiently improved to allow averaging methods.

INTENSITY MONITORS

Relative coasting beam intensity can be monitored by the dump scintillator signal, or by the current on the dump aperture block during the tune-up period. In addition there is a Q electrode 6 inches in length with 100 pf capacitance to the vacuum chamber. This will provide about 15 μV when the beam is bunched at 7.5 MHz.

PORTABLE SCINTILLATORS

A system of movable liquid scintillators (paint cans) and solid scintillators can be moved to any point in the ring. These can be used for beam loss measurements, or for steering the injected beam to specific locations. This method was used to obtain the first coasting beam in the ring.

REFERENCES

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