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DX-D0 Interconnect Shielding

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1 Introduction

The two rings of the RHIC collider merge into a common Interaction Region (IR) between the DX and D0 magnets. Figure 1 prepared by D. Weiss shows the interconnect region. It is designed to reduce the amount of material seen by the calorimeter ZCAL placed between the two beampipes, to detect neutrons close to 0 degree. The two beampipes with 4.8 in ID and .060 in thickness change to perforated pipes about .018 in thick enclosed by a larger 16.5 in ID pipe, at plane MM. The perforated pipes are required to shield the beam from the modes of the 16.5 in cavity. They are made of stainless steel Type 304L, with .25 in holes and .375 in distance between the center of the holes. Starting at plane DD, there is a transition from a racetrack enclosing the two perforated circular pipes to a circular pipe of 11.5 in ID at plane BB. The modes of the 11.5 in pipe were determined using MAFIA [1]. Due to smooth transitions at both ends, the modes from this cavity have a small shunt impedance and hence pose no problem. This interconnect design is agreeable to both the Detector Group and the RAP group, and is mechanically feasible.

2 Power Dissipation

This report gives the power dissipated by the beam image current into the thin .018 in shieldings. It is given by [2]

$$P = 2I_{ave}^2 \sum_{n=1}^{\infty} R_c \left(\frac{n}{n_c}\right)^p exp(-n^2\alpha^2) \tag{1}$$

where n gives the nM harmonic of the revolution frequency, $p = 1/2$, $n < n_c$ and $p = 2/3$, $n > n_c$

$$n_c \simeq \left(\frac{\sigma}{l}\right)^2 (\rho\delta_1)^2 \tag{2}$$

gives the critical frequency above which the anamolous skin depth expression must be used, l is the mean free path, $\sigma = 1/\rho$ is the conductivity of the pipe. The skin depth is

$$\delta = \frac{\delta_1}{\sqrt{n}} \tag{3}$$

where

$$\delta_1 = \sqrt{\frac{2\rho R}{MZ_0}} \tag{4}$$

$Z_0 = 377$ ohm is the impedance of free space and R is the average machine radius. The critical resistance is

$$R_c = \frac{R}{b}\rho^2 \left(\frac{\sigma}{l}\right) \tag{5}$$

where b is the beampipe radius. The average beam current is

$$I_{ave} = \frac{ZN_b e\beta cM}{2\pi R} \tag{6}$$

where Z is the charge state, N_b is the number of particles per bunch and M is the number of bunches.

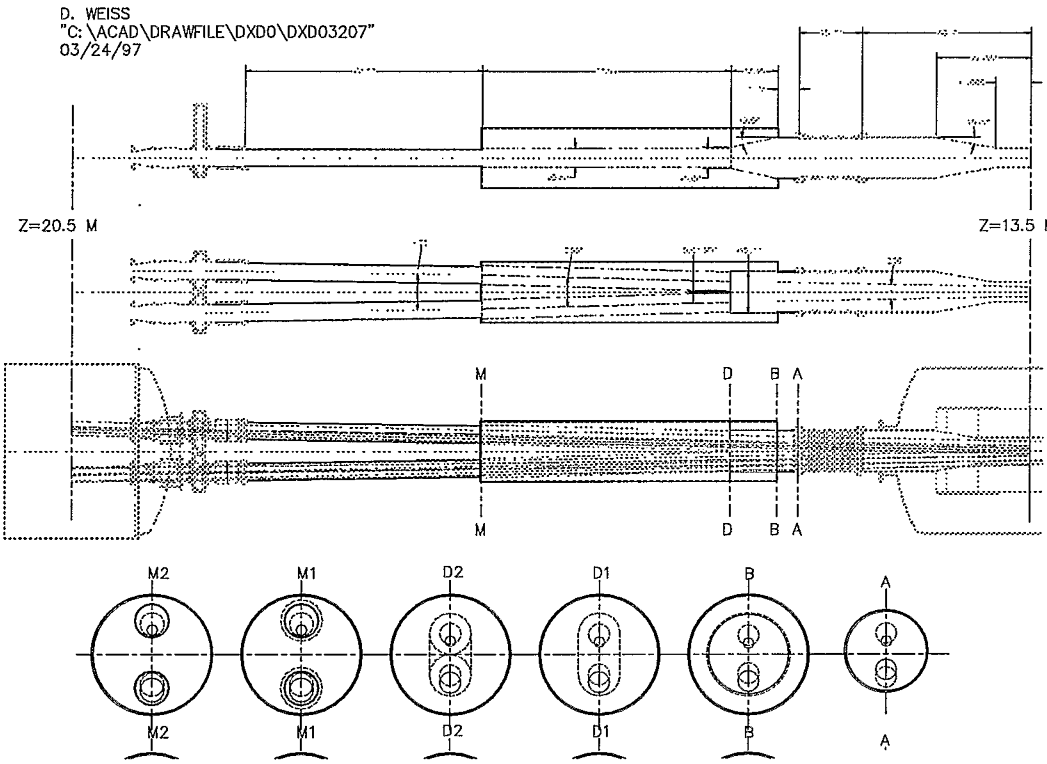

Figure 1: DX-D0 Interconnect

The parameter α is given by

$$\alpha = \frac{M\sigma_L}{R} \tag{7}$$

where σ_L is the rms bunch length.

The conductivity of stainless steel Type 304L is $\sigma = 1.25 \times 10^6 ohm^{-1}m^{-1}$ at room temperature [3]. Due to the perforations in the pipe the cross section area is reduced by 40% and the effective conductivity is decreased by the same amount. Using $\sigma = 0.75 \times 10^6 ohm^{-1}m^{-1}$, $\sigma_L = 7.2$ cm for protons at storage, M = 120 bunches in the upgrade, $N_b = 10^{11}$, b = 2.4 in, $\sigma/l = 1.37 \times 10^{15} ohm^{-1}m^{-2}$ gives $n_c = 12 \times 10^{10}$ and the total power dissipated in the perforated pipe is 0.3 Watt/m. As the total length of the perforated pipe is 71 in, and the interconnect sees 120 bunches from both rings, the total dissipated power is about 1 Watt.

3 Conclusion

The 16.5 in cavity at the DX-D0 interconnect is shielded from the beam with a .018 in thick perforated pipe. It shields freqencies above 1.5 MHz. The total dissipated power of 1 Watt is acceptable.

References

[1] T. Weiland, Particle Accelerators 15 (1984), pp. 245-292.

[2] A. G. Ruggiero, S. Peggs, RHIC/AP/46, Nov 1994.

[3] D. Hseuh, Private Communication.