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Impedance Issue of Corrugated Beam Pipe from CDF

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IMPEDANCE ISSUE OF CORRUGATED BEAM PIPE FROM CDF

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I. INTRODUCTION

The CDF collaboration proposed to instal a new corrugated beam pipe at the Tevatron interaction area in order to better monitor the interaction vertex. This note discuss the impedance implication of such a pipe. The drawings of the corrugated pipe are shown in Figs. 1 to 3.

II. CRUDE ESTIMATION

This beam pipe has a radius of $b = 2$ in and of length 128 in only. It therefore will neither influence in any way the resistive-wall impedance of the whole vacuum chamber, nor will it change the space-charge impedance. As a result, the only features that we need to consider are the roughly $N = 222$ corrugations or convolutions, which have a depth of $d - b = 0.546$ cm and a width of $g = 0.183$ cm. Because these convolutions are separated from each other by 1.463 cm, it is not a bad idea to assume that they do not talk to each other. At low frequencies, the longitudinal impedance per unit harmonic is given by

$$\frac{Z_{||}}{n} = j\alpha\beta Z_0 \ln \frac{d}{b} , \quad (2.1)$$

where βc is the velocity of the beam particles, $Z_0 = 377 \Omega$ is the free-space impedance, and α is the fraction of the ring with the corrugations; therefore

$$\alpha = \frac{Ng}{2\pi R} \quad (2.2)$$

where $R = 1$ km is the ring radius. Putting in the numbers, we get

$$\frac{Z_{||}}{n} = j0.0047 \Omega , \quad (2.3)$$

which should be correct when $n \ll \alpha^{-1}$, or $\ll 0.74$ GHz. For higher frequencies, we will meet with resonances inside the convolutions. An estimation is that the depth

of the convolution $d-b = 0.546$ cm will sustain a quarter wavelength. Therefore, the lowest resonant frequency is $f \sim c/4(d-b) = 14$ GHz. Since this is well above cutoff, we expect the resonance to be quite wide.

III. TBCI

TBCI was run for a portion of the beam pipe containing 10 convolutions. The longitudinal impedance is shown in Figs. 4 and 5. We do see a resonance at ~ 10 GHz. For a total of 222 convolutions, we have at low frequencies $Z_{\parallel}/n = j0.0045 \Omega$ (at least up to 5GHz). The lowest resonance has a width of ~ 6 GHz. The maximum shunt impedance is ~ 11 k Ω if the contribution of all convolutions adds constructively; however, this corresponds to a Z/n of 0.05Ω only.

The transverse impedance from TBCI is shown in Figs. 6 and 7. At low frequencies, $Z_{\perp} = j12.9$ k Ω /m for all the convolutions of the beam pipe. The first resonance is again at roughly 10 GHz with a width of ~ 6 GHz. The total maximum shunt impedance is 104 K Ω /m if all convolutions add constructively.

IV. CONCLUSION

The longitudinal and transverse impedances of the corrugated beam pipe turn out to be quite small ($Z_{\parallel}/n \ll 1 \Omega$ and $Z_{\perp} \ll 1$ M Ω /m) both at low frequencies and at the peak of a resonance. As a result, the installation of this pipe will not lead to any instability of the beam.

Bellows:

Material: Stainless Steel $\sigma = 0.135 \times 10^7 (\text{dyn})^{-1}$

O.D. = 2.43

I.D. = 2.0

Pitch of one convolution = 0.144

Pitch of skipping 3 between each conv. = 0.576

Wall = 0.006

of Sections = 2

End connections accomplished by weld bands made as small and thin as possible, max. thick. = 0.016

Mass Spec. checked to leak rate of $< 1.0 \text{ E-9 cc/sec}$

Must be able to withstand pressure internally and externally of up to twice atmospheric.

All dimensions in inches.

Figure 1

DRAWN BY	JEFF MJSUR	DATE	9/3/92
APPROVED BY		DATE
FERMI NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY			
BELLOWS TRANS. SPOOL DESIGN			
SCALE	DRAWING NO.	REV	
NONE			A

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7