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Chromaticity Measurements in the AGS Booster

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Subject: Chromaticity Measurements in the AGS Booster

The goal of the study was to demonstrate the absolute centering of the orbit acquisition system and to obtain experimentally the matrix elements that relate the currents in the sextupole strings to the chromaticity.

One way to measure the chromaticity is to vary the radius of the beam (i.e., the momentum at a fixed magnetic field) and simultaneously measure the radius (the average of the PUEs) and the horizontal and vertical tunes. The chromaticity is in this case obtained from the relation

$$\xi = \frac{D}{\nu} \frac{\Delta\nu}{\Delta r} ,$$

where D is the average value of the dispersion at the location of the "live" PUEs in the BPM system and Δr is the radial differences from the BPM system. The matrix elements, which relate the current in the sextupoles to the chromaticity, are obtained from the change in chromaticity caused by powering the horizontal and vertical sextupole strings respectively. A current of 30 A in the horizontal sextupoles and of 40 A in the vertical sextupoles were the maximum values that could be applied for 100% beam survival. The result of these measurements is shown in Figure 1. It is seen that the lines do not all cross at the same location and not at zero radius, which is the expected value, the sextupoles being installed at zero radius. However, an estimated error of 0.25 mm in the radius and 0.001 to 0.003 in the tune (HWHM values of the peak in the FFT spectra) do explain these discrepancies.

A second way to determine the chromaticity is to vary the radius and measure the rf frequency and the transverse tunes. In this case, the chromaticity can be obtained from the relation

$$\xi = \frac{f}{\nu} \cdot \frac{\gamma_{tr}^2 - \gamma^2}{\gamma_{tr}^2 \cdot \gamma^2} \cdot \frac{\Delta\nu}{\Delta f},$$

with γ_{tr} the transition energy in the Booster (4.88) and γ the energy at which the measurements were done. The results of these measurements are shown in Figure 2.

For both cases, the chromaticities have been determined from a linear regression of the data. Table 1 summarizes the results.

TABLE 1				
(I_x, I_y)		(0,0)	(30,0)	(0,40)
Radius	ξ_x	-1.509	-0.376	-1.858
	ξ_y	-0.845	-1.215	0.164
Frequency	ξ_x	-1.497	-0.368	-1.743
	ξ_y	-0.842	-1.185	0.156

The first method gives systematically slightly higher values for the chromaticity than the method based on the frequency measurement, which might be caused by the calibration of the BPM system and/or the accuracy of the dispersion at the PUEs (an average value of 1.983 m that has been used from Luccio's model of the Booster in MAD). The values of the natural horizontal chromaticity agree well with a previous measurement (Studies Report No. 264), the vertical chromaticity, however, was then lower by roughly 25%.

The matrix elements, which relate the sextupole currents to the chromaticity, as defined in the equation

$$\begin{pmatrix} \Delta\xi_x \\ \Delta\xi_y \end{pmatrix} = \begin{pmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{pmatrix} \begin{pmatrix} I_x \\ I_y \end{pmatrix}$$

have been calculated for both cases and the results are summarized in Table 2, together with theoretical predictions, obtained from Luccio's model of the Booster in MAD. The actual current in the sextupole strings as determined from the dial settings were 31 A and 42.5 A, respectively.

TABLE 2				
	C_{11}	C_{12}	C_{21}	C_{22}
Radius	0.0589	-0.0135	-0.0193	0.0385
Frequency	0.0590	-0.0094	-0.0179	0.0380
MAD	0.0625	-0.0153	-0.0239	0.0413

Although there are some mutual differences for the matrix elements, the results from MAD show a good agreement with the experimental results and will therefore be used as the starting point for the chromaticity control program, which is scheduled to be commissioned during the next run.

During the analysis of these results, it was found that the radial positions recorded were averages of the four Booster cycles and that there were small differences between individual cycles, while the frequencies and tunes came from a single fixed cycle. Future measurements should eliminate this possible additional source of error.

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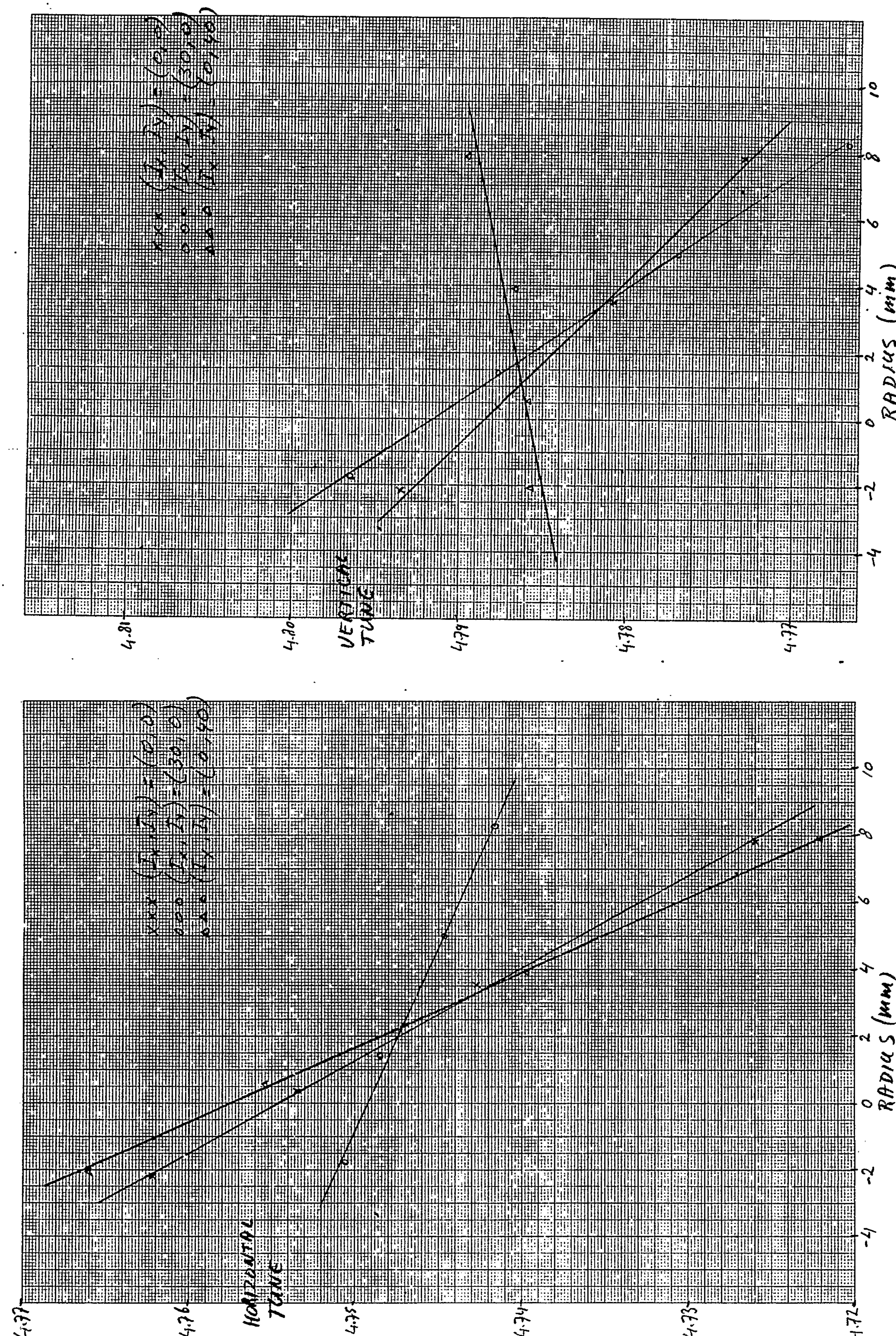
x x x (Ix, Iy) = (0,0)
o o o (Ix, Iy) = (30,0)
Δ Δ Δ (Ix, Iy) = (0,40)
VERTICAL TUNE
4.81
4.80
4.79
4.78
4.77
-4
-2
0
2
4
6
8
10
RADIUS (mm)
x x x (Ix, Iy) = (0,0)
o o o (Ix, Iy) = (30,0)
Δ Δ Δ (Ix, Iy) = (0,40)
HORIZONTAL TUNE
4.77
4.76
4.75
4.74
4.73
4.72
-4
-2
0
2
4
6
8
10
RADIUS (mm)

FIGURE 1

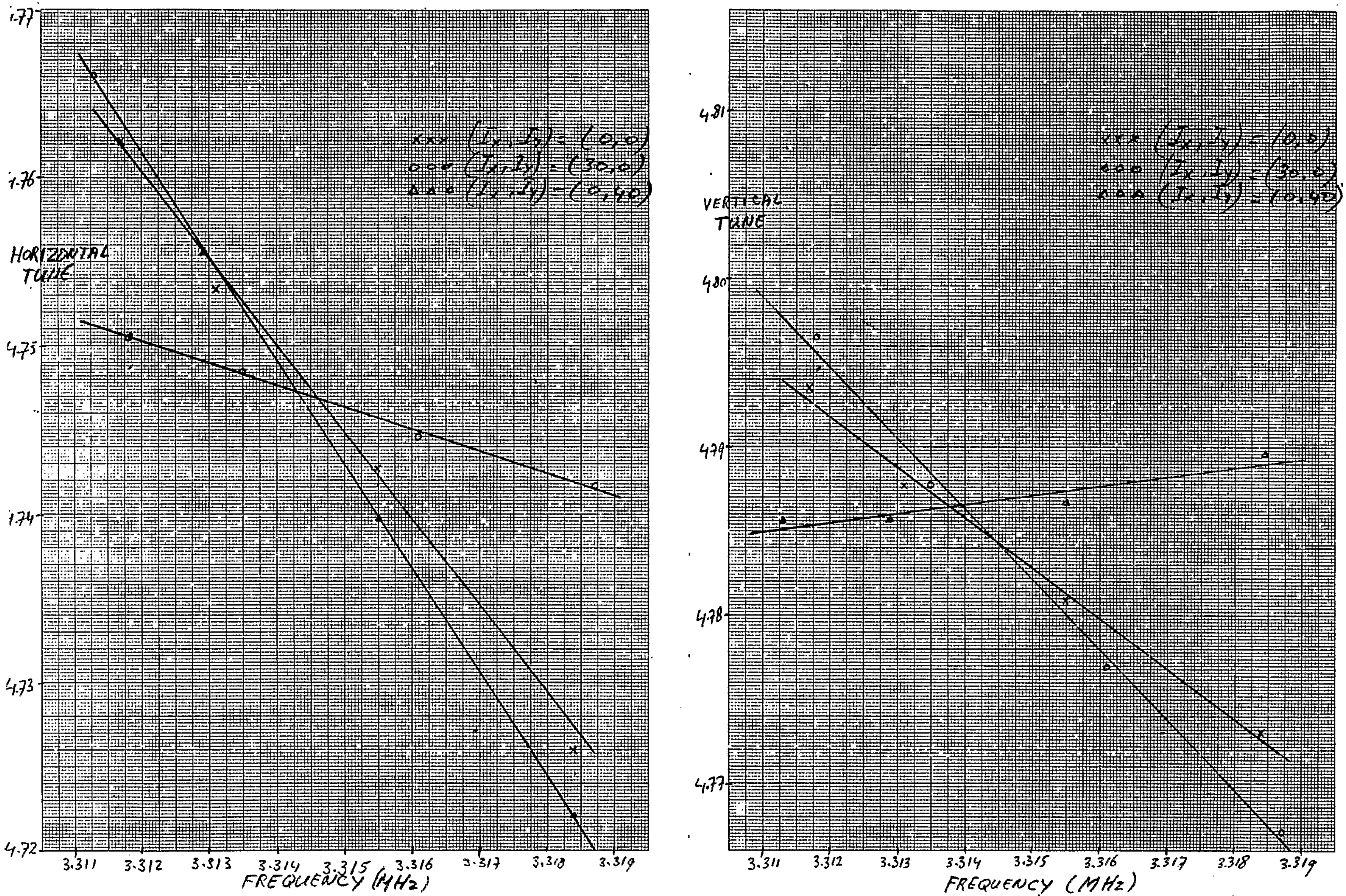
HORIZONTAL TUNE
4.77
4.76
4.75
4.74
4.73
4.72
$\times\times\times$ $(I_x, I_y) = (0,0)$
$\circ\circ\circ$ $(I_x, I_y) = (30,0)$
$\triangle\triangle\triangle$ $(I_x, I_y) = (0,40)$
3.311 3.312 3.313 3.314 3.315 3.316 3.317 3.318 3.319
FREQUENCY (MHz)
VERTICAL TUNE
4.81
4.80
4.79
4.78
4.77
$\times\times\times$ $(I_x, I_y) = (0,0)$
$\circ\circ\circ$ $(I_x, I_y) = (30,0)$
$\triangle\triangle\triangle$ $(I_x, I_y) = (0,40)$
3.311 3.312 3.313 3.314 3.315 3.316 3.317 3.318 3.319
FREQUENCY (MHz)

FIGURE 2