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Measurement of Coherent Space Charge Tune Shifts in the Booster

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Measurement of Coherent Space Charge Tune Shifts in the Booster
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Participants: W. van Asselt
Reported by: W. van Asselt
Machine: Booster
Beam: Protons
Tools: Tune Meter

The transverse betatron tunes in the Booster have been measured at different proton intensity levels. The chromaticity in both planes was made small for well-defined tune measurements and the measurement was made directly after injection with the rf on. The intensity was varied by changing the number of turns in the chopper program. Figure 1 shows Fourier transforms of the transverse motion for one case with at left the horizontal and at right the vertical tune, while intensity increases from top to bottom. It is seen that the horizontal tune is hardly affected, while there is a significant vertical tune shift (frequency scale corresponds to 0.1 unit in tune). In addition to the shift of the peaks, there is also a widening of the vertical spectra, indicating the tune spread also increases. Figure 2 gives the measured tune shifts as a function of total intensity for two values, 45° and 90°, of the Linac beam chopper width.

The tune shifts have also been calculated using results from the paper of Laslett[1] as summarized by Bryant[2]:

$$\Delta Q_{coh} = -\left(\frac{2r_o}{ec}\right)\left(\frac{RI}{\beta^3\gamma}\right)\sum_i C_i\bar{\beta}_{y,i}\left[\frac{(1-\beta^2)}{B}\frac{\xi_{1,i}}{h_i^2} + \beta^2\frac{\epsilon_{1,i}}{h_i^2} + \beta^2\frac{\epsilon_{2,i}}{g_i^2}\right]$$

where $\xi_{1,i}$, $\epsilon_{1,i}$ *and* $\epsilon_{2,i}$ are geometrical constants, h_i and g_i are the half height of the vacuum chamber and the magnet gap, respectively, and where the other symbols have their usual meaning. It is assumed that in the dipoles a parallel plate geometry can be used (50%) with h = 3 cm and a circular geometry for the rest of the Booster with h = 6 cm. An average β-function of 9 m has been used. Bunching factors (B) of 0.4 and 0.3 for the two chopper settings have been used. These values are based on measurements by Brennan[3], which set a window for the bunching factor (from 0.27 to 0.45) and by the ratio of the tune shifts in Figure 2.

The results from the calculations are shown in the following table, together with the experimental results from Figure 2. The numbers are tune shifts per 10^{12} protons. The numbers in brackets are the contributions of the three terms in the formula.

		Data	Theory	
B=0.4, 90°	Vertical	0.0086	0.00847	(0.0076, 0.00041, 0.00046)
	Horizontal	0.0012	0.00037	(0.00124, -0.00041, -0.00046)
B=0.3, 45°	Vertical	0.0108	0.01102	(0.01015, 0.00041, 0.00046)
	Horizontal	0.0018	0.00080	(0.00167, -0.00041, -0.00046)

The measured vertical tune shifts do agree very well with the calculated results. For comparing the horizontal results, one is reminded that the absolute differences are roughly the same as in the vertical plane.

From these results, it may be concluded that the model used in the calculations reasonably represents the actual Booster machine. The results of this study can advantageously be used to get more accurate estimates for the incoherent tune shifts, which are more difficult to obtain because they depend on the transverse emittance and are much harder to measure.

References

[1] L.J. Laslett, Proc. 1963 Summer Study on Storage Rings, BNL Report, BNL-7534.

[2] P.J. Bryant, CERN Yellow Report 87-10.

[3] J.M. Brennan, private communication.

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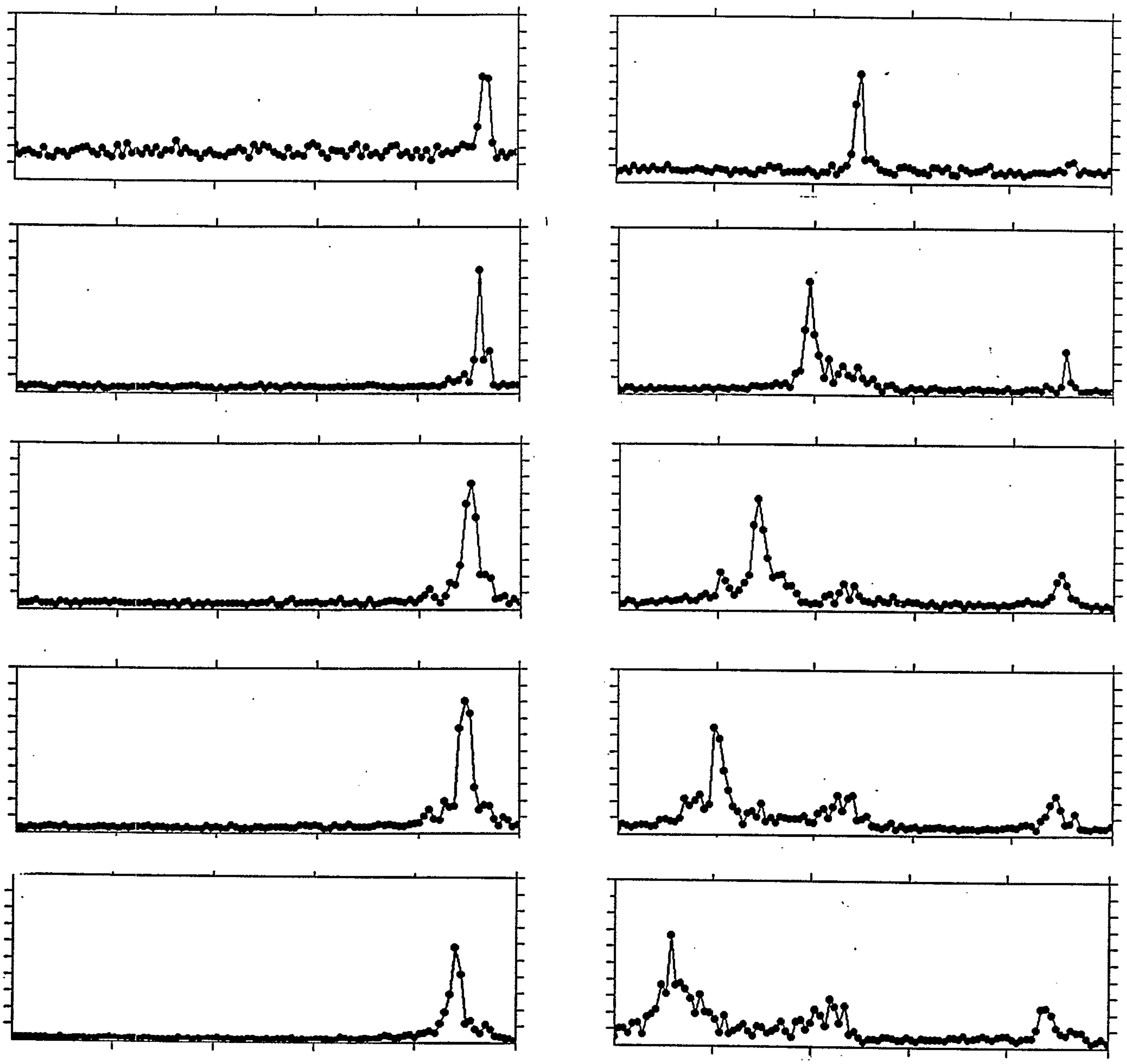
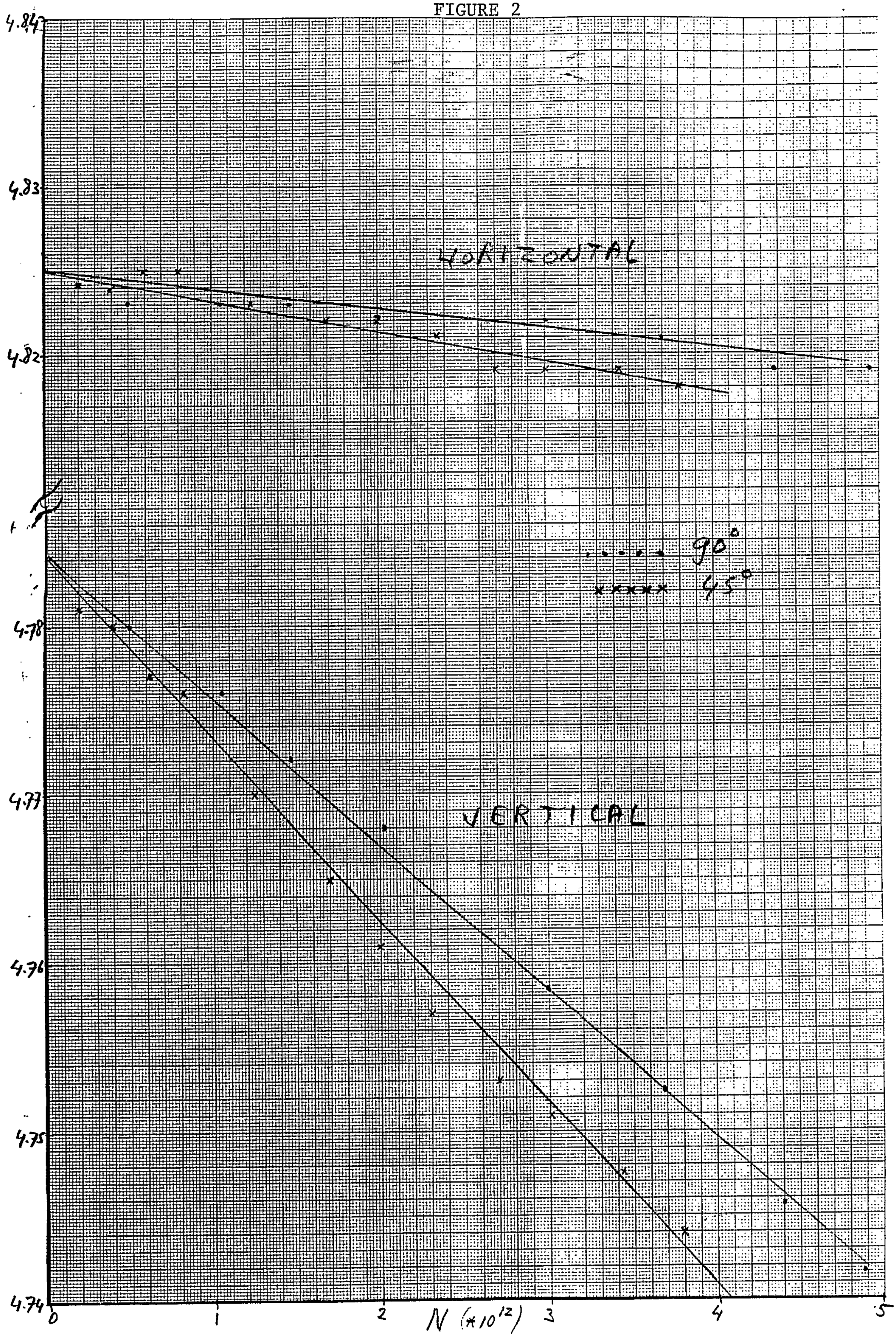


FIGURE 1

FIGURE 2


4.84
4.83
4.82
4.78
4.77
4.76
4.75
4.74
HORIZONTAL
VERTICAL
90°
45°
0
1
2
3
4
5
N (*10^12)