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LARGE AMPLITUDE ORBITS

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In this report we investigate the dynamics of large amplitude orbits as a function of momentum offset in a Tevatron lattice composed of magnets with the design field harmonics. As one of the primary motivations behind this work concerns the energy deposition problem associated with small-angle scattering, we have chosen to look at negative momentum offsets. The results are expressed in terms of tune as a function of amplitude. The machine tune that we use in this report is the so-called large amplitude tune which determines the turn-to-turn phase-angle rotation. This tune measurement can be made in two different ways: first, one can define a 2×2 matrix which propagates the particles through one turn around the closed orbit. The machine tune is then defined by the trace of this matrix, which can be measured by propagating a single particle around several turns and solving for the individual matrix elements. The validity of this approach rests on the assumption that these matrix elements stay constant during successive turns. While this assumption is generally true, when particles start to experience large orbit amplitudes which begin to sample correspondingly large field deviations from a simple dipole form then the lattice does indeed start to vary from turn-to-turn. Hence we find situations where it is possible to propagate particles around the machine stably but we are not able to analytically measure the tune (small changes in the lattice are sufficient to make an accurate measurement of the tune impossible). In cases such as these we have made a tune measurement by directly looking at the phase-angle rotation for several revolutions as given by a normalized phase-space plot. Examples of these phase-space plots are given in Figs. 1 and 2 which clearly demonstrate the radius vector precessing around the off-momentum closed orbit ($\Delta p/p$ = -0.35%). The quoted oscillation amplitude is given by the magnitude of this radius vector at a standard cell (β = 100 ms). Figure 3 shows a plot of tune versus amplitude for four different momenta. All the data points in this plot were measured with the natural machine chromaticity (-22.5) corrected with sextupoles at each standard half cell quadrupole location to remove the inherent tune shift due to momentum.

From Fig. 3 one can see that the machine aperture does not vary linearly with momentum and also that any particles with a momentum offset $\lesssim$ -0.4% are inherently unstable from the point of view of circulating beam.

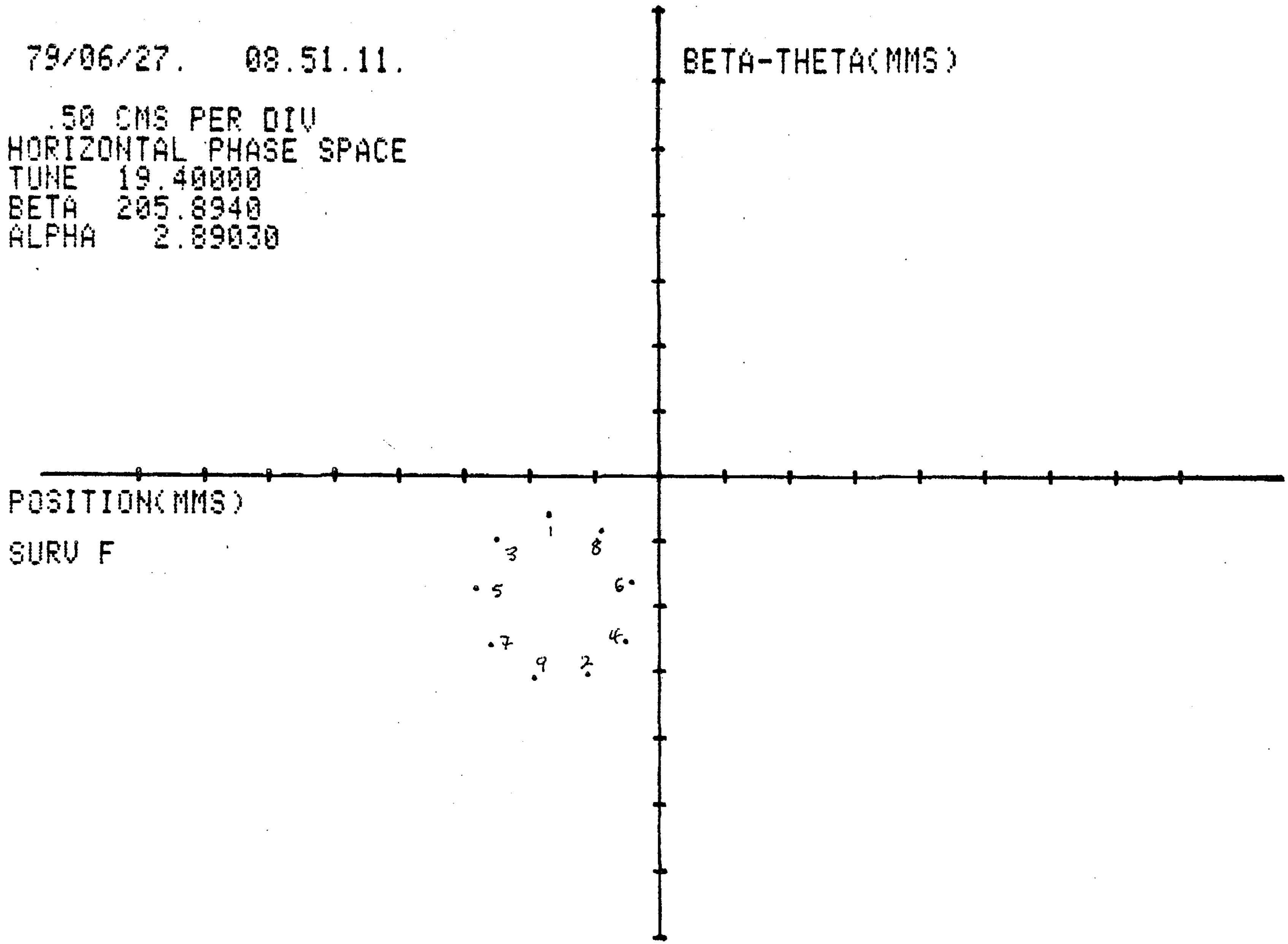

Fig. 1. $\Delta p/p = -0.35\%$.

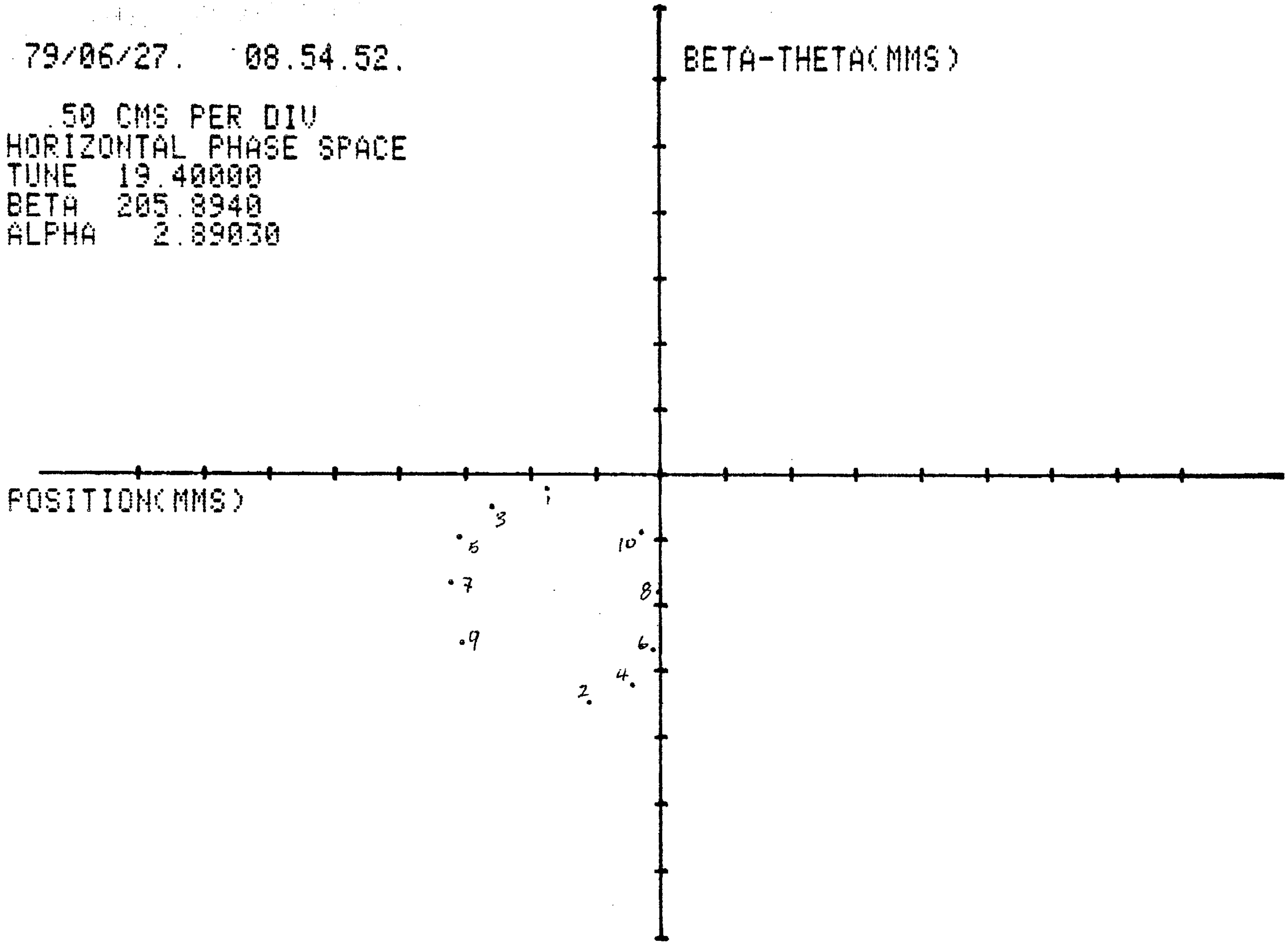

Fig. 2. $\Delta p/p = -0.35\%$.

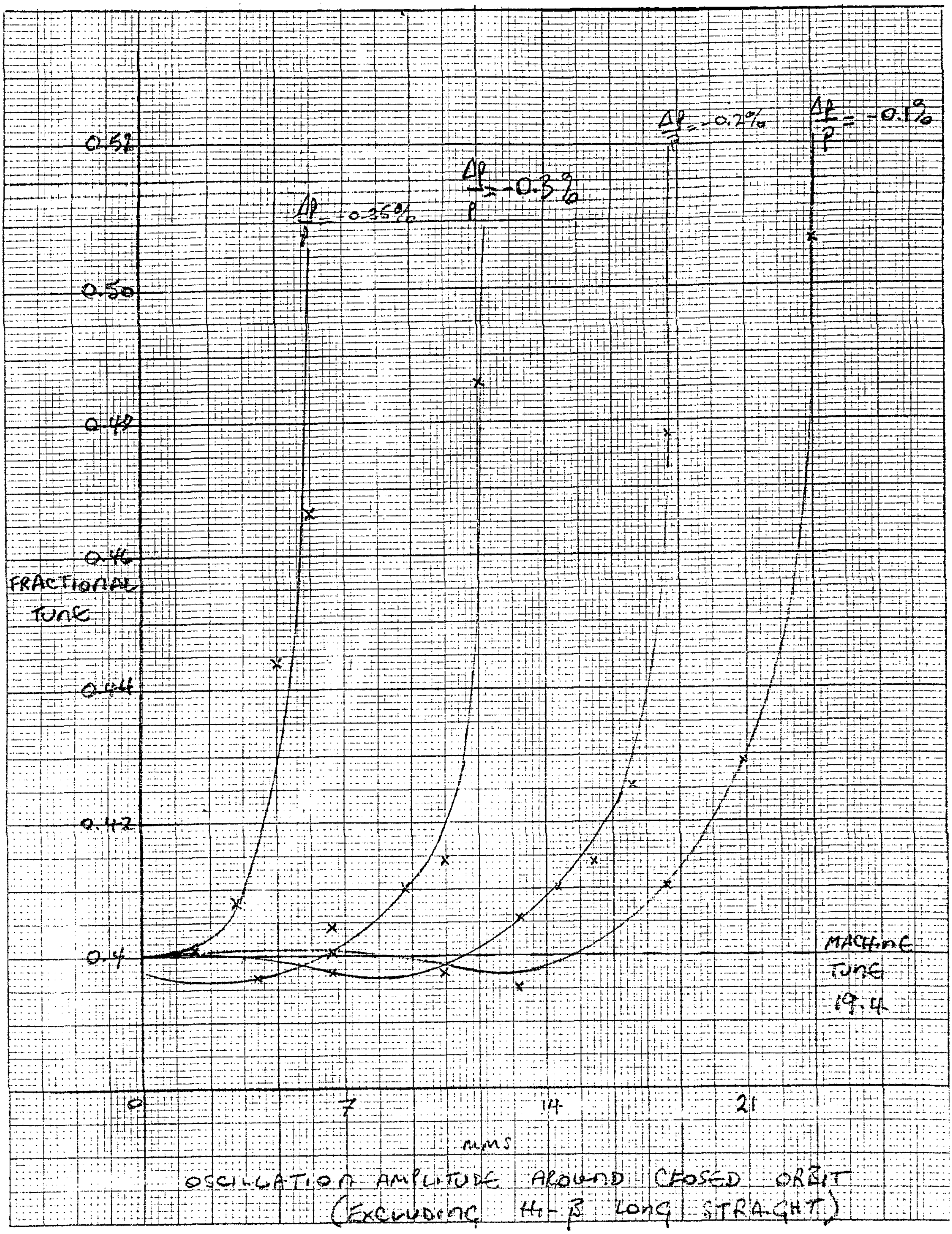

Fig. 3. Large amplitude tune vs. amplitude.