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PROPOSED MAIN RING EXTRACTION UPGRADE

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Introduction

In this report we shall present a brief description of the layout and operational characteristics of the Main Ring extraction system modified by the installation of a second pair of electrostatic septa location in the D0 straight section of the Main Ring. The introduction of this pair of septa will move a substantial amount of the extracted beam loss away from the transfer hall to the lesser used D0 straight section. Besides lowering the radiation levels in the transfer hall the extra septa should improve the overall extraction efficiency somewhat by providing a more cleanly separated beam at the magnetic septa. A dual system of electrostatic septa will also add an element of redundancy to the overall system as extraction will be possible with either pair (F48 or D0) of septa running individually.

Half-Integer Resonant Extraction in the Main Ring

For the purposes of this report we shall restrict ourselves to considering half-integer resonant extraction; the extraction mode used in the day-to-day running of the machine. Half-integer extraction basically consists of using a suitable mixture of quadrupoles and octupoles to slowly raise the machine tune from its operating value of 19.4 towards the unstable value of 19.5. As the beam becomes unstable the particles begin to leave the stable phase space region along paths called separatrices. The position, shape and turn-to-turn step size of the particles on these separatrices are controlled by the position and strength of the extraction quadrupoles and octupoles. The final extraction from the Main Ring is accomplished by placing electrostatic and magnetic septa at suitable places in the ring to provide an extra kick to the outermost particles causing them to enter the extraction channel. Extraction from the machine is currently accomplished by using quadrupoles located at F24 and A34. The electrostatic septa in the F48 half cell, two magnetic septa at A0 (Lambertson magnets) and the residual (zeroth harmonic) octupole component of the Main Ring, which fortunately has the correct sign. Figure 1 shows an actual beam profile taken downstream of the electrostatic septum during resonant extraction. From this data one can see the beam intensity falling away with radial position and the extracted beam physically separated from the circulating beam by the electostatic septum.

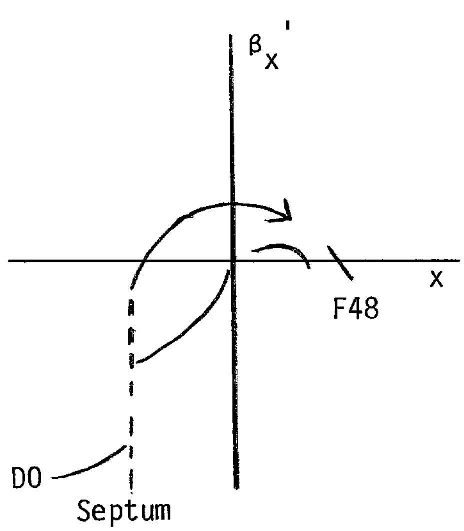
The first step in trying to make any calculations on the extraction process involves determining the inherent octupole moment of the Main Ring. Figure 2 summarizes the results obtained by measuring the tune shift of the machine for variou large amplitude orbits created by turning on a single bump magnet in the ring. A one parameter fit to this data was made by giving each quadrupole in the ring a small octupole moment which was then varied to obtain the fit shown in Fig. 2. If we made the simple octupole parameterization $\Delta x' = Zx^3$ then the fit gives a value of $Z = 0.1$ where x is in inches. The effect of this zeroth harmonic octupole on the half-integer separatrices is demonstrated in Fig. 3, which shows the transverse phase space position of the separatrices at the F48 septa for two different octupole strengths. The change in position and slope of the orbit becomes quite apparent in the large amplitude orbits (the important ones for extraction).

Using this type of input data we are able to compute a beam profile for the current Main Ring extraction system and compare it with data such as that shown in Fig. 1. Figure 4 shows a comparison of Fig. 1 with a calculated profile, the results have been arbitrarily normalized to the same intensity. The reasonably good agreement between the calculated and measured profile gives us some confidence that we are able to make a sensible prediction on the major characteristics of the new system.

Extraction System Upgrade

The proposed extension to the Main Ring extraction system consists of installing two more 10' electrostatic septa together with the appropriate local bump magnets. The septa are centered approximately 12 meters downstream from D0. The D0 septa have identical gap sizes (1 cm) and operation voltage ranges to those currently used at F48.

Figure 5 shows the phase space plot of the separatrices at the onset of extraction at both septa positions. The relative phase advance between the two points is $\sim\frac{4\pi}{3}$. An electrostatic septum changes the direction but not the position of a particle (zero length approximation). In a plot such as Fig. 5 this effect would look like a break in the separatrix, with the size of the break proportional to the applied septum voltage.



Continuing the orbit around to F48 the break in angle is transformer into a displacment in position by the $\frac{4\pi}{3}$ phase angle rotation. The DO septa will then produce a spatially separated beam at F48. The F48 septa will then add an additional kick to that portion of the beam to be extracted which will increase further the beam separation at the Lambertson magnets. Figure 6 shows the effect of the DO septum on the separatrices shown in Fig. 5. The beam separation at F48 is $\sim$3.3 mms. With the DO septa offset 1.3 cms radially inwards from the Main Ring center line with a 65 kV applied voltage. With this setup the amount of beam striking the septum would be $\sim$1%.

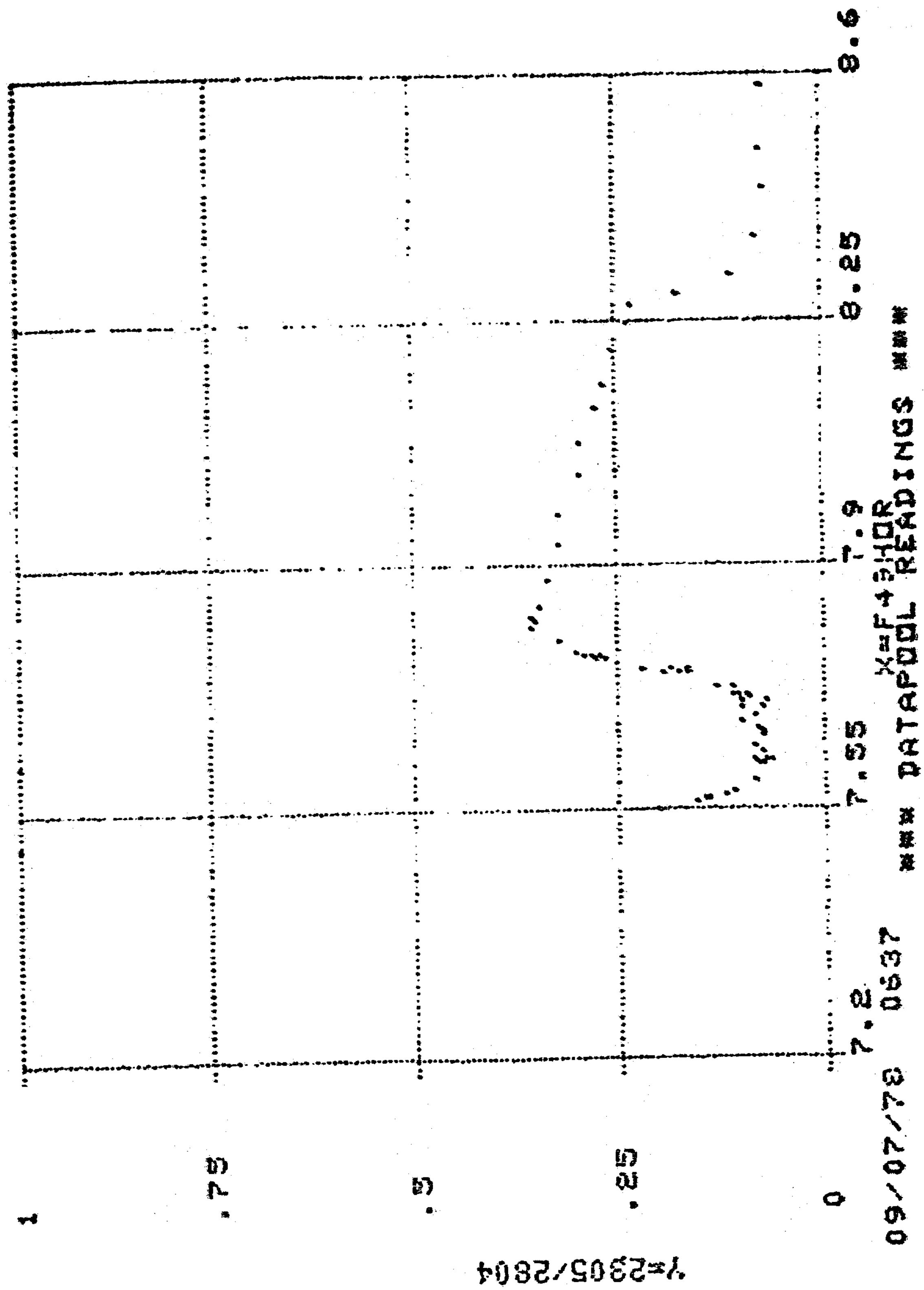
The position of the beam at the upstream end of the Lambertson magnets is shown in Fig. 7. The spatial separation between the extracted and circulating beam is $\sim$6 mms. These data were obtained by taking the results shown in Fig. 6, inserting the F48 septa with a 2.0 cms offset and a 45 kV applied field and then tracing the resultant separatrix through the lattice to the AO Lambertson position. This 6-mm beam split at the Lambertson magnets is approximately twice as large as that obtained in the present extraction system and may serve to reduce extraction losses in this region.

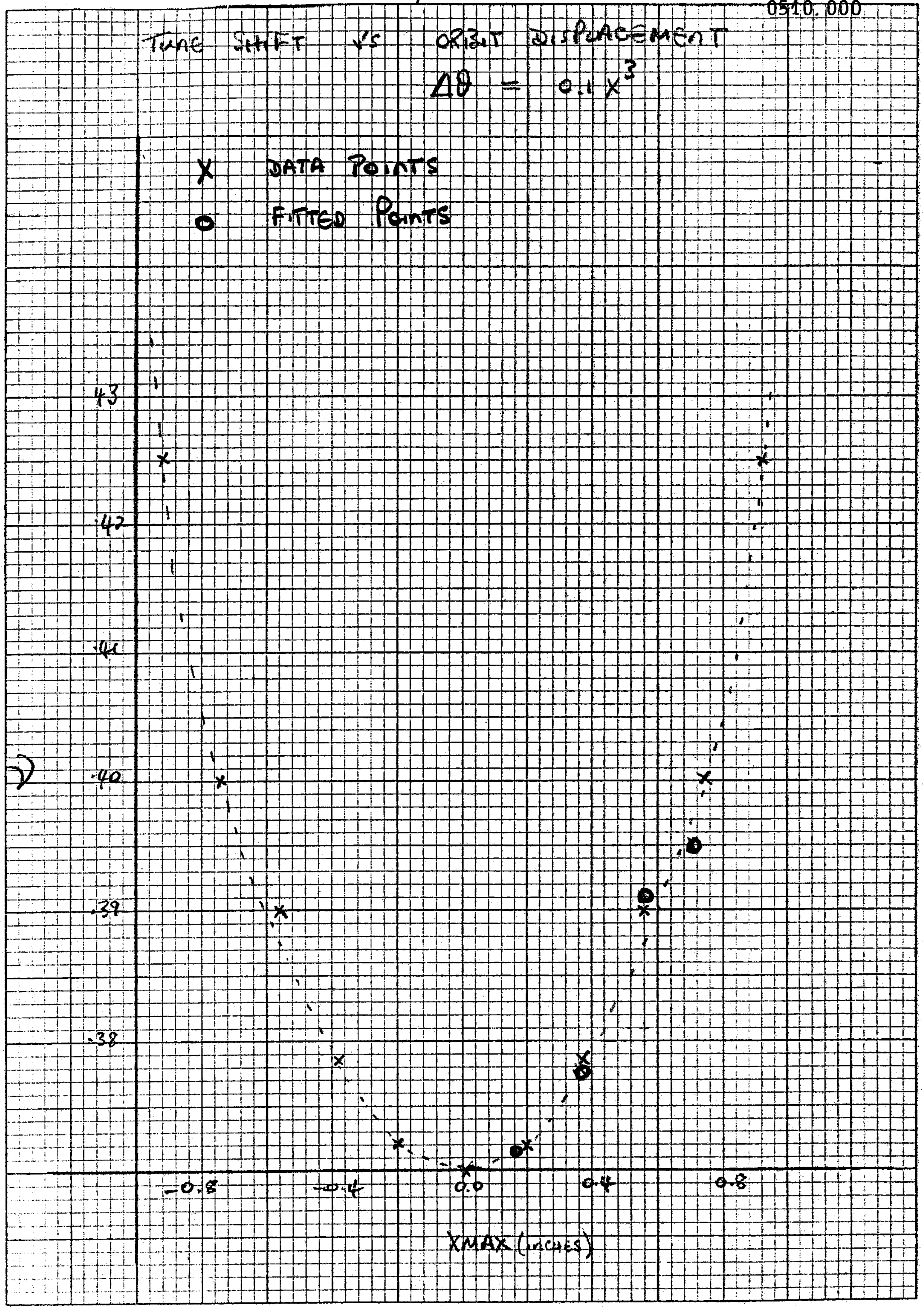
The data shown thus far can be considered ideal in the sense that we have only considered the behavior of a mono-energetic beam at the onset of the extraction process. The two major effects that we have ignored so far are that of momentum dispersion, and the fact that during extraction as the area of the stable phase space shrinks to zero the position of the separatrices changes somewhat. Figure 8 shows the "smearing" of the separatrix at the Lambertsons during extraction due to these two effects ($\frac{\Delta p}{p} = \pm.1\%$), the split between the circulating and extracted beams has been reduced to $\sim$4 mm, still ample separation to clear the 1-1/2 mm Lambertson septum. The maximum amplitude beam oscillation during extraction under these conditions is ∿3.2 cms.

Local Orbit Bumps

In an analogous fashion to the present extraction system, localized beam steering in the D0 straight section will be provided by three sets of bump magnets: vertical position (C47-D18), horizontal position (C34-D13), and horizontal angle (C44-D15). The local orbit bumps from each pair of magnets are shown in Figs. 9, 10, and 11. With these magnets as shown and a 80 A maximum current, horizontal displacements with a constant angle of up to 2.0 cms are possible.

Fig 1
MAIN Ring HORIZONTAL BEAM PROFILE




TUNE SHIFT VS ORBIT DISPLACEMENT
Δθ = 0.1 X³
X DATA POINTS
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43
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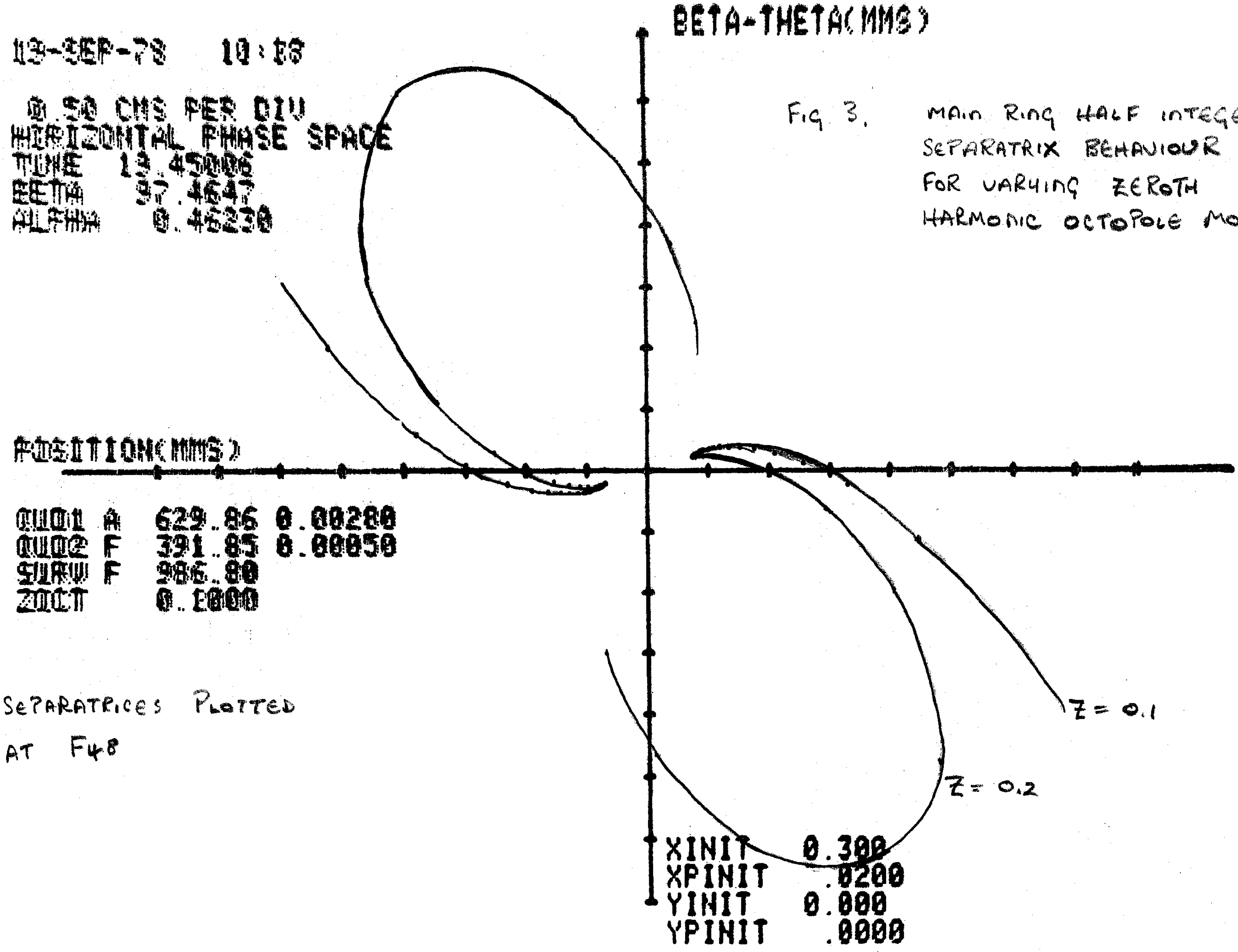
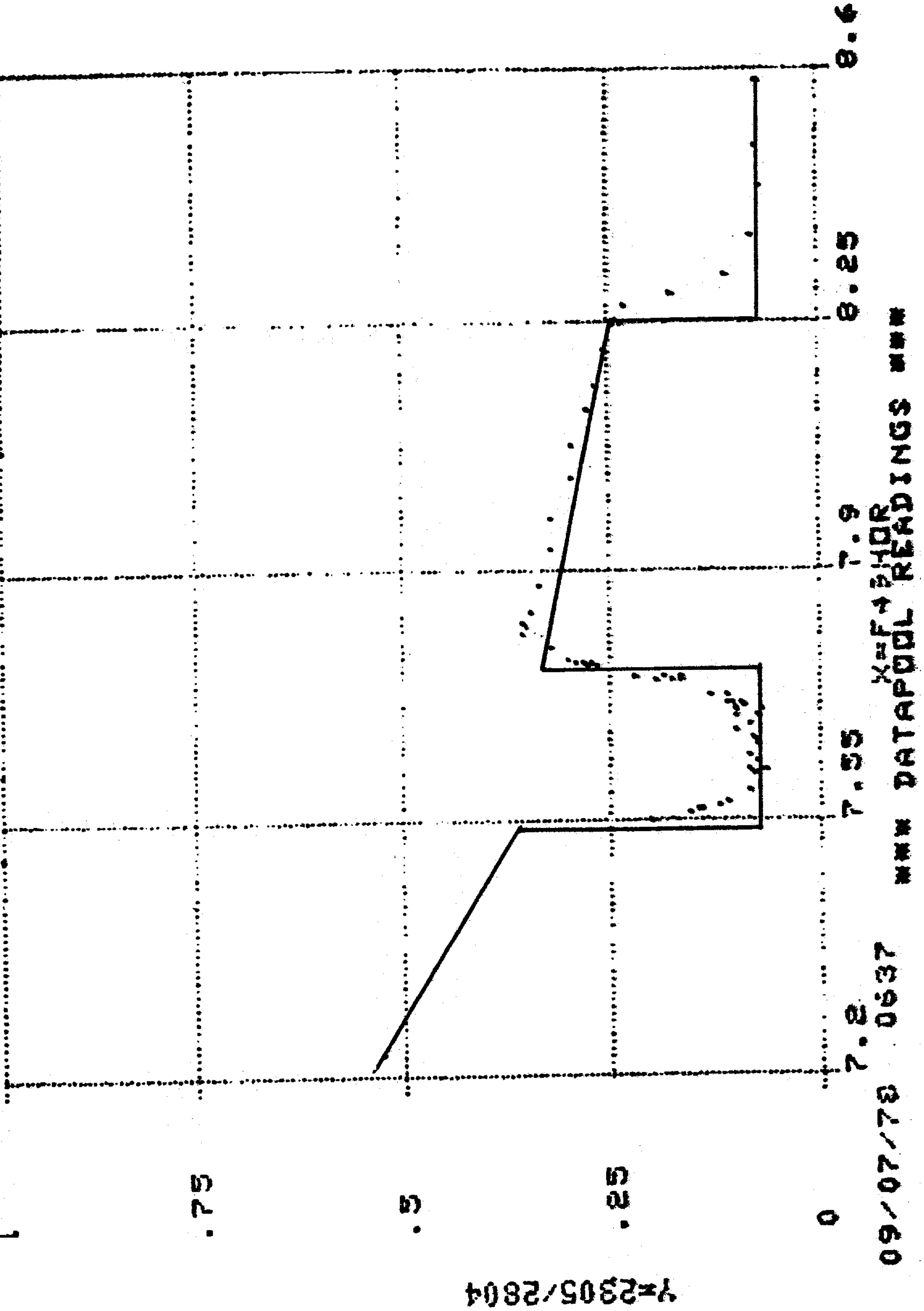


Fig. 3. Main Ring half integer separatrix behaviour for varying zeroth harmonic octopole moment

Fig 4 Main Ring Beam Profile
Measured and Calculated



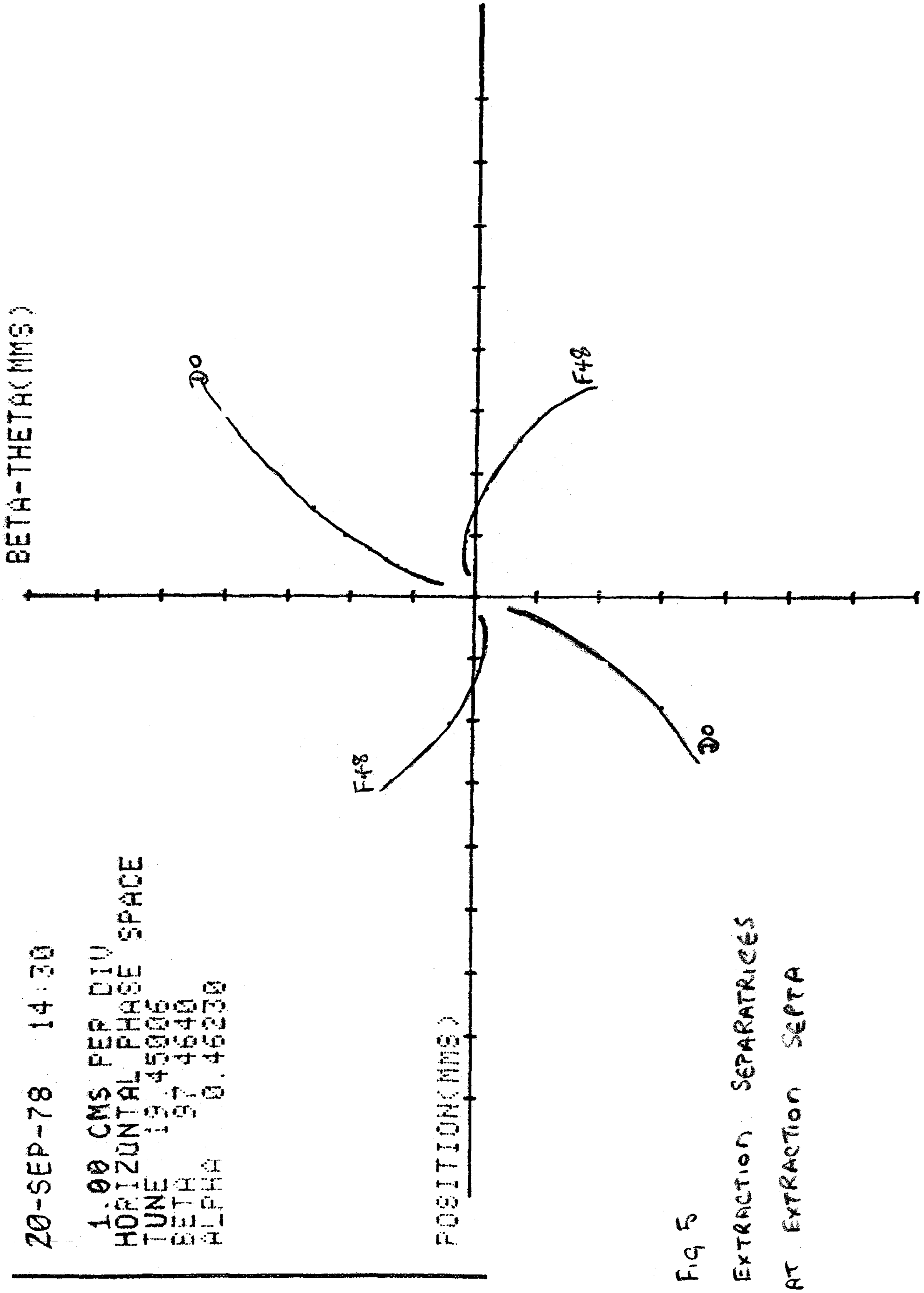


Fig 5
Extraction Separatrices
at Extraction Septa

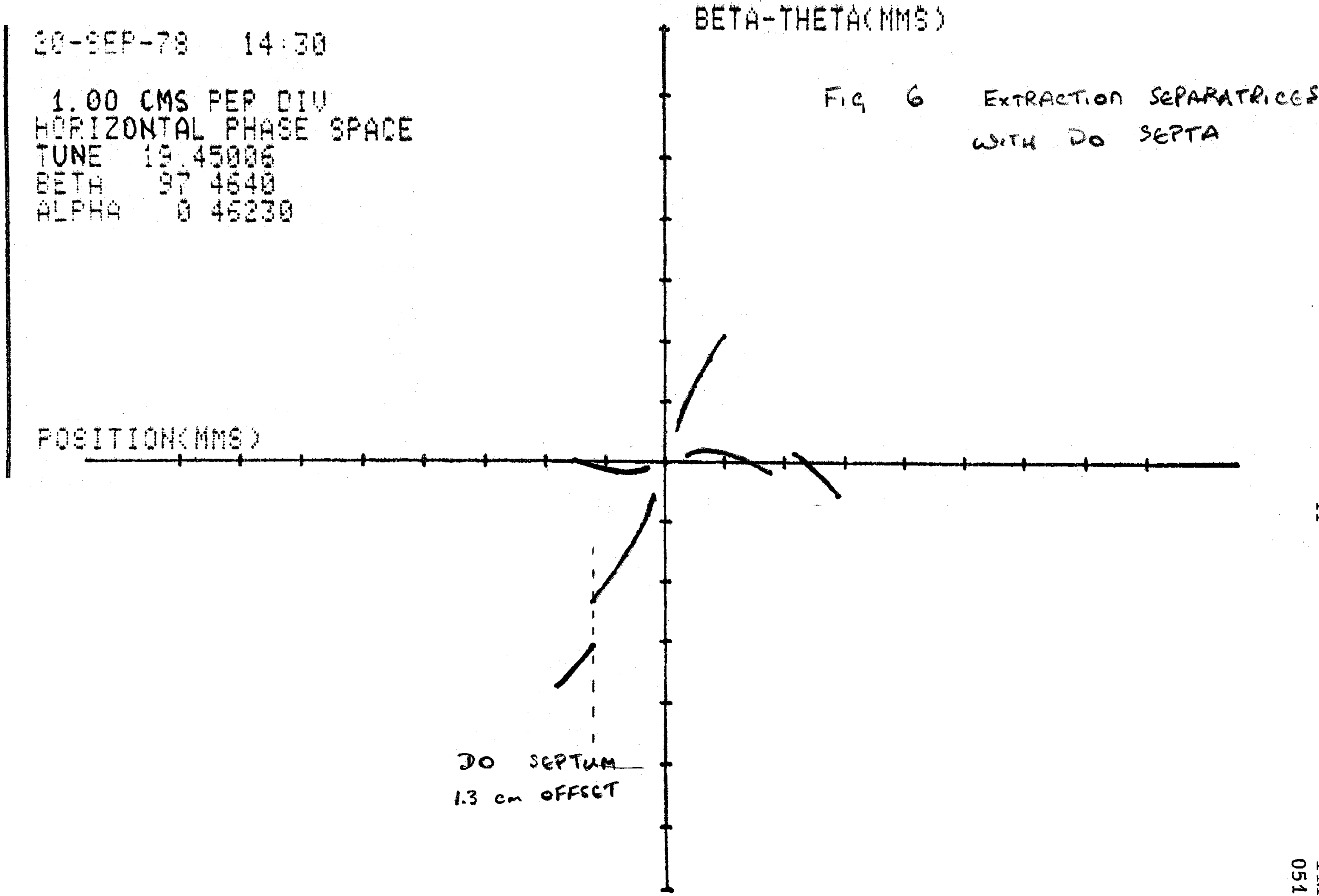


Fig 6 EXTRACTION SEPARATRICES WITH DO SEPTA

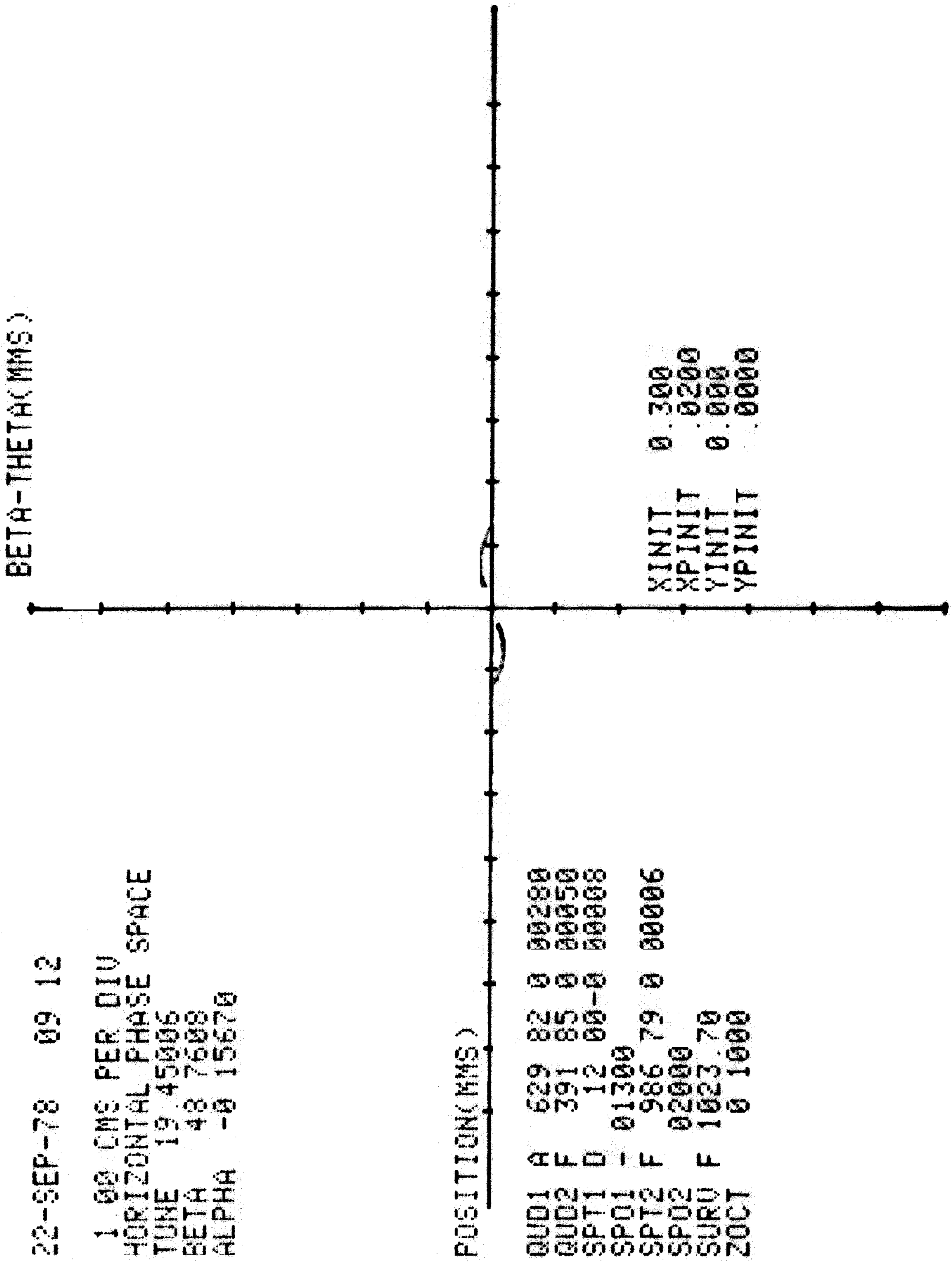


Fig. 7 Separatrix at AO Lambertson Magnets

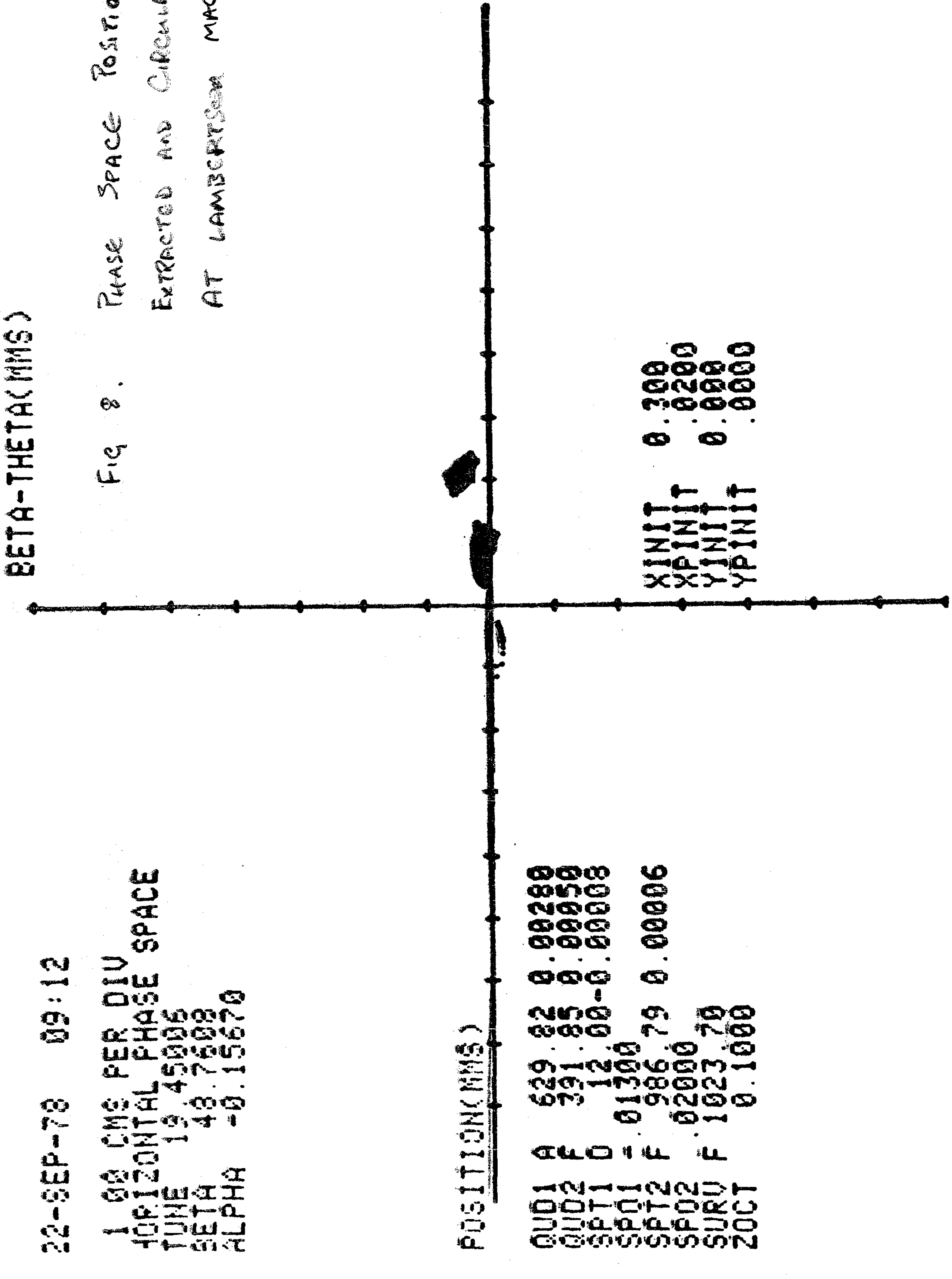


Fig 8. Phase Space Positions Extracted and Circulating Beam at Lambertson Magnets.

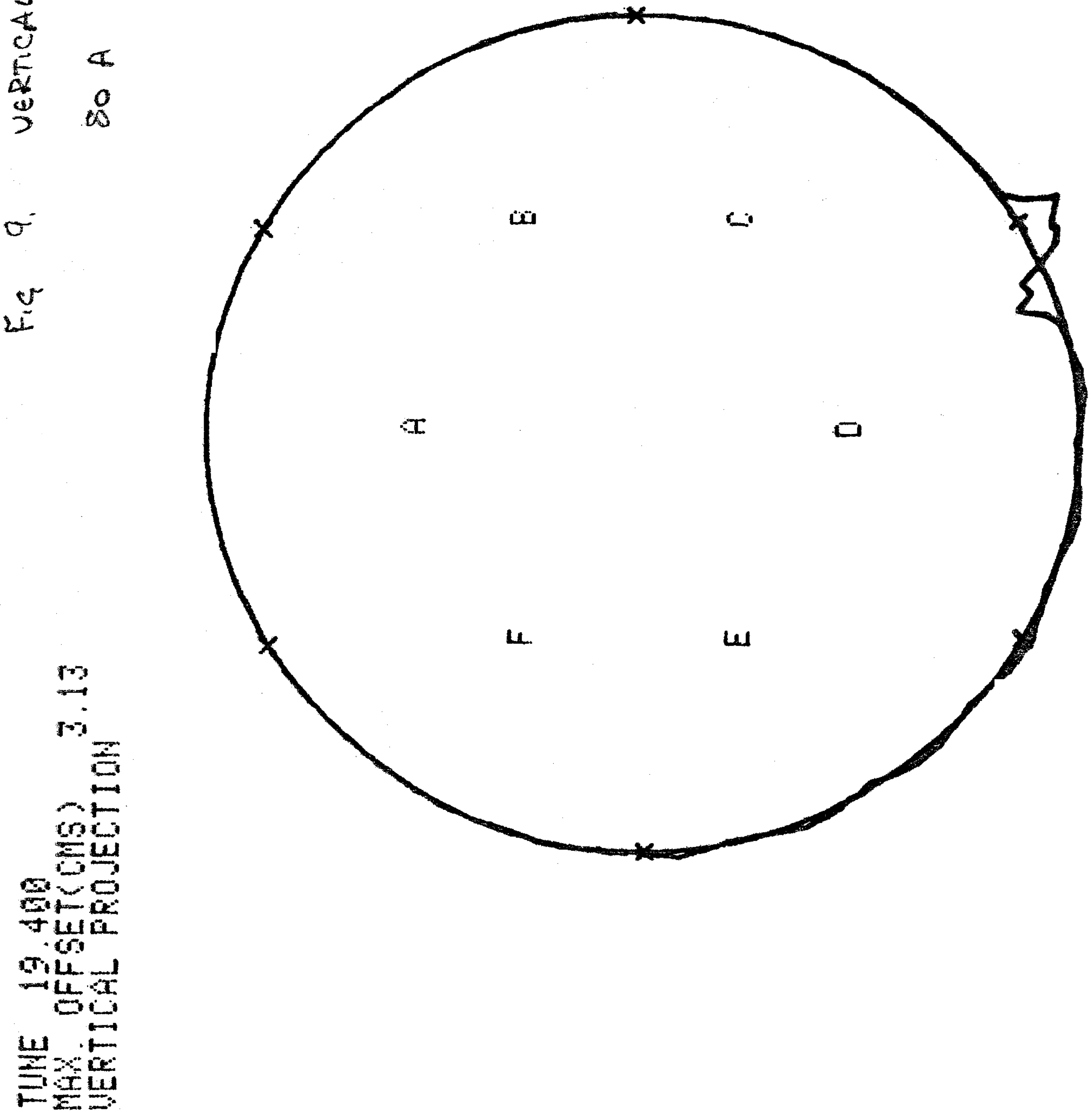


Fig 9. Vertical Position Bump
80 A Current

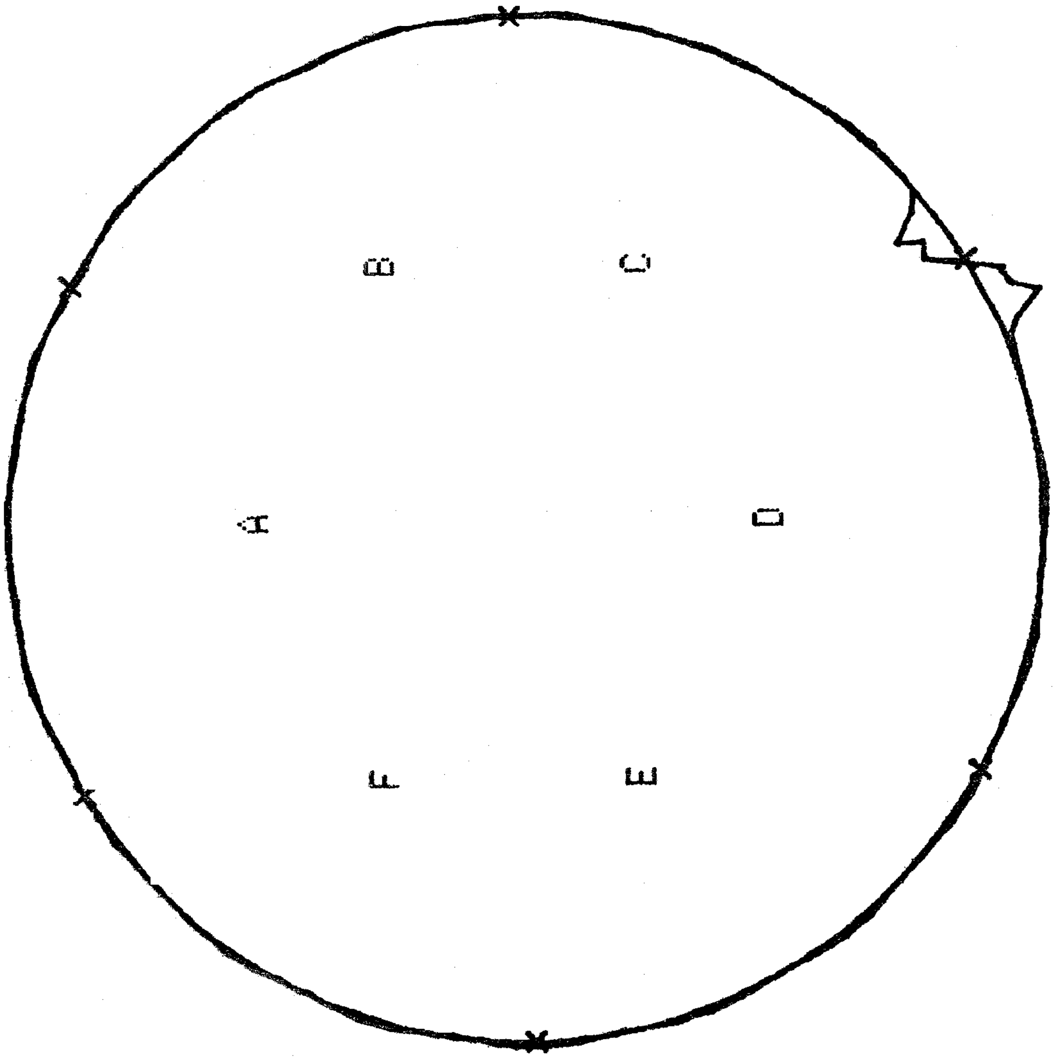


Fig. 11 Horizontal Angle Bump
80A Current