BNL-104116-2014-TECH

AGS.SN240;BNL-104116-2014-IR

Gamma-Transition, Yet Again

L. Ahrens

May 1988

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

7/1/88

Number 240

AGS Studies Report

Date(s) May 18-19, 1988 Time(s) ____________

Experimenter(s) L.A. Ahrens, P. Yamin (and the inspiration of L. Ratner)

Reported by L.A. Ahrens and P. Yamin

Subject Gamma-Transition, Yet Again

Summary

We repeated and extended the studies originally performed in June, 1987.[1] The "W+" quadrupole configuration was used, with rise times of 30, 50, and 65 ms. In each case, a successful transition jump was achieved, with losses of ~ 1% at an AGS intensity of 1.2×10^{13} protons. Subsequent behavior of the beam showed no excessive blowup or tune shift. Possible instabilities long (> 50 ms) after transition, resulting from the denser beam, were not studied. Radial shifts, induced to simulate momentum dispersion, showed that the aperture was adequate.

The selection of this configuration for implementation at the AGS has been confirmed.

Procedure

The present ring horizontal high field quads were reconnected so as to form three sets of doublets in the "17" straight sections of the [A,C], [E,G], and [I,K] superperiods. (The magnet pairs which comprise doublets are enclosed in brackets.) This is the "W+" configuration.

The power supply applied a constant voltage to the string of magnets (connected in series), limiting the current to a maximum of 450 Amperes. By adjusting the voltage (tap setting), the ramp time could be varied. A crowbar circuit reduced the current to zero, thereby lowering gamma-transition by about two units, in 5 ms.

Figure 1 shows the relationship between $\gamma(t)$,* $_{t}(t)$, and t for the 50% tap setting of the power supply. This arrangement produced satisfactory transition crossing, which is illustrated in Figures 2a-c. Figure 2a shows the pulsed quadrupole excitation, circulating beam intensity, and radial position near transition. The losses are ~ 1%. Figure 2b is a detail of the quadrupole excitation pulse, and Fig. 2c is the wall monitor output in the transition region. Note the absence of large bunch shape oscillations. We performed IPM scans to determine the effect of the transition jump on the beam size and emittance, and these are presented in Figures 3a-f. Figures a-c show data taken with the jump, Figures d-f without the jump. In the first set, the region of quadrupole excitation falls between the vertical lines. In the second set, the same time interval is indicated to facilitate comparison. After transition, both sets of data are virtually indistinguishable, with the exception of a reduced "emittance" after the jump. This presumably reflects the reduced momentum spread with the jump. (The "emittance" plotted includes beam size due to momentum spread as well as that due to transverse emittance.)

Next, using the 75% tap setting, we reproduced the results of June, 1987. Figure 4 shows the initial timing of the relevant pulses, as in Fig. 2a. Here, we also show the timing of the rf phase jump at transition. Figure 5 shows the same pulses on an expanded time scale. Note that the phase jump does not coincide with the most rapidly falling part of the quadrupole pulse. We delayed the start of the pulse by 10 Gauss Clock counts and obtained the results shown in Fig. 6. The phase jump now occurs when gamma-transition is changing most rapidly and the losses were again reduced to ~ 1%.

Finally, we set the power supply to the 100% tap, giving a rise time of 30 ms. Figure 7 displays the pulses, and Fig. 8 the wall monitor output, which shows an interesting effect. The bunches become narrower and then widen before the jump. We concluded that $\gamma(t)$ first approaches $\gamma_t(t)$, narrowing the bunches. The two then diverge and the bunches widen. Finally, the jump is applied and transition crossed. This is illustrated in Fig. 9.

*During this study, the AGS was operating with a longer injection porch than for the study of Ref. 1. Thus, transition (which falls at a given B) occurs later in time relative to t-zero. $\dot{B}$ in the transition region was normal (23 Gauss/ms).

Momentum Aperture of the Gamma-Transition Shifted Machine

We realized after the last jump study (April 25, 1988), that a quantitative estimate of the momentum aperture available in the AGS during the distortion associated with shifting of gamma-transition was possible. The method is as follows. By applying a "radial" shift to the low level rf, the beam momentum can be shifted until beam loss is observed. Equilibrium orbits are taken at the shift values where the loss is first evident both for positive and negative $\Delta p/p$. These orbits show the wild distortions predicted by the MAD simulations. Further, those simulation results can be used to deduce the momentum shift actually obtained at the aperture limits. For the same quad strength in the simulation and in the AGS, $\Delta p/p$ in the simulation can be adjusted until the simulation orbits match the observed distortion. Figure 10a gives the simulation prediction of orbits at a strength "K" = 0.4 and $\Delta p/p = 0.25\%$. Because the jump has three-fold symmetry, only one-third of the ring is shown. Figure 10b gives the orbits (full excitation, 50% tap) corresponding to the apertures for "K_{exp}" = 0.4 ± 0.02. The three-fold symmetry is again visible. From these orbits, averaging over the three-fold symmetry, we extract the result that loss occurs for a shift of the central momentum of $\Delta p/p = \pm 0.25\%$. The data shown were taken near the peak of the quad current pulse on the 50% tap. The limit was nearly the same halfway up the pulse.

To put this result in perspective, we need to know the momentum spread of the beam. For a longitudinal phase space area of 1 eV sec (typical for our current running mode), and for $(\gamma_t - \gamma) \simeq 3$-4 units, $\Delta p/p$ (half-width) is about 0.3% for γ near 9. The above aperture scan then predicts that this could grow by an additional 0.25% or an increase of nearly a factor of two in $\Delta p/p$ before losses would occur. This is equivalent to a factor of four increase in longitudinal phase space area which is the maximum expected to be needed (using the high frequency dilution cavity) to avoid instabilities after transition at Booster intensities.

Conclusion

We have developed a gamma-transition jump for the AGS, using the "W+" configuration, an excitation rise time of 60 ms, and a fall time of 2.5 ms. It has been tested at an intensity of 1.2 x 10^{13} circulating protons. Transition was crossed cleanly, without excessive bunch shape oscillations, and the subsequent size and emittance of the beam were satisfactory.

More details of the proposed implementation of the "W+" configuration are given in the Appendix.

Reference

1. L.A. Ahrens, E.C. Raka, and L.G. Ratner, AGS Studies Report #228, June 5, 1987.

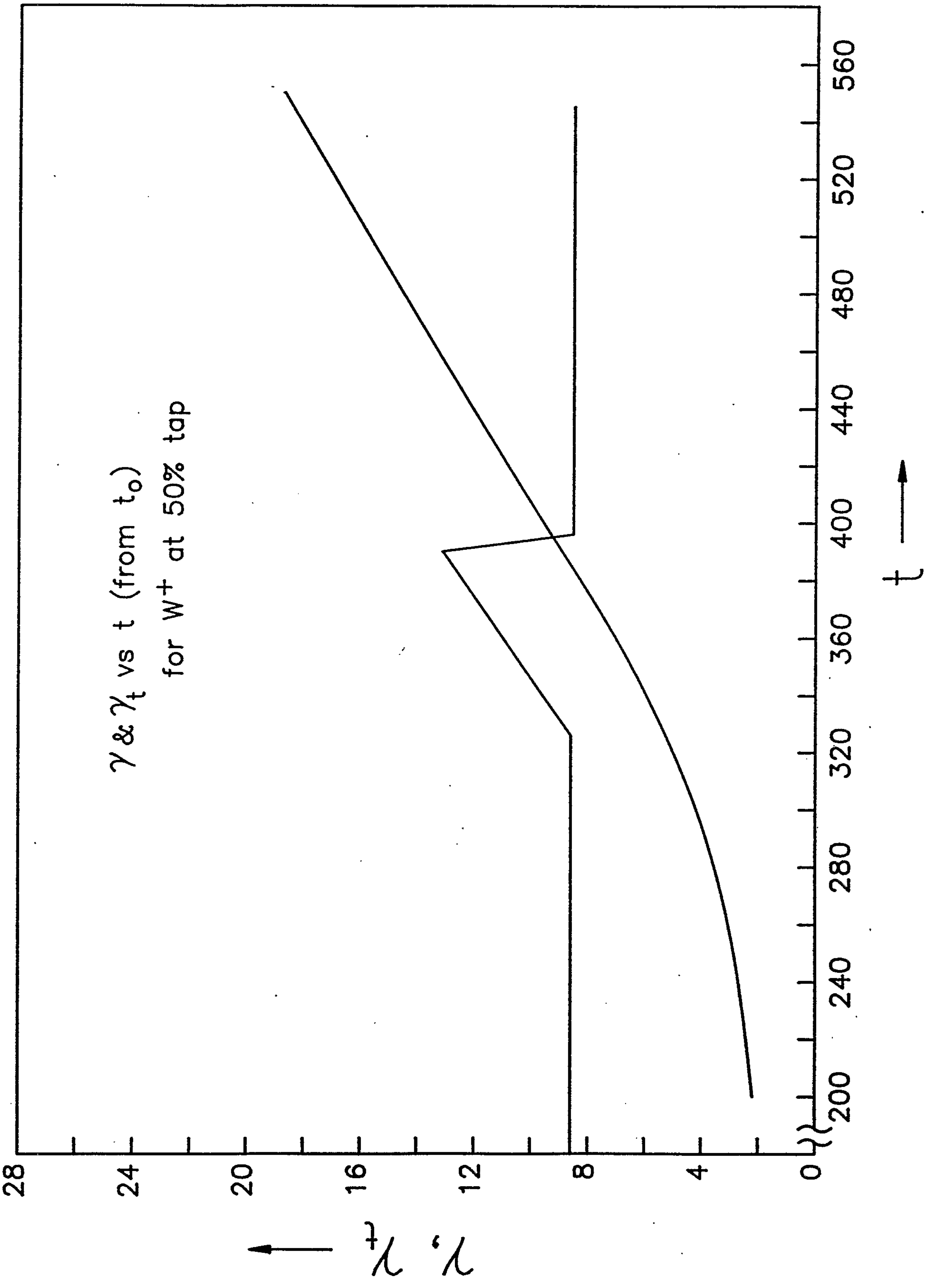

γ & γt vs t (from to)
for W+ at 50% tap
γ, γt
t
0
4
8
12
16
20
24
28
200
240
280
320
360
400
440
480
520
560

Figure 1

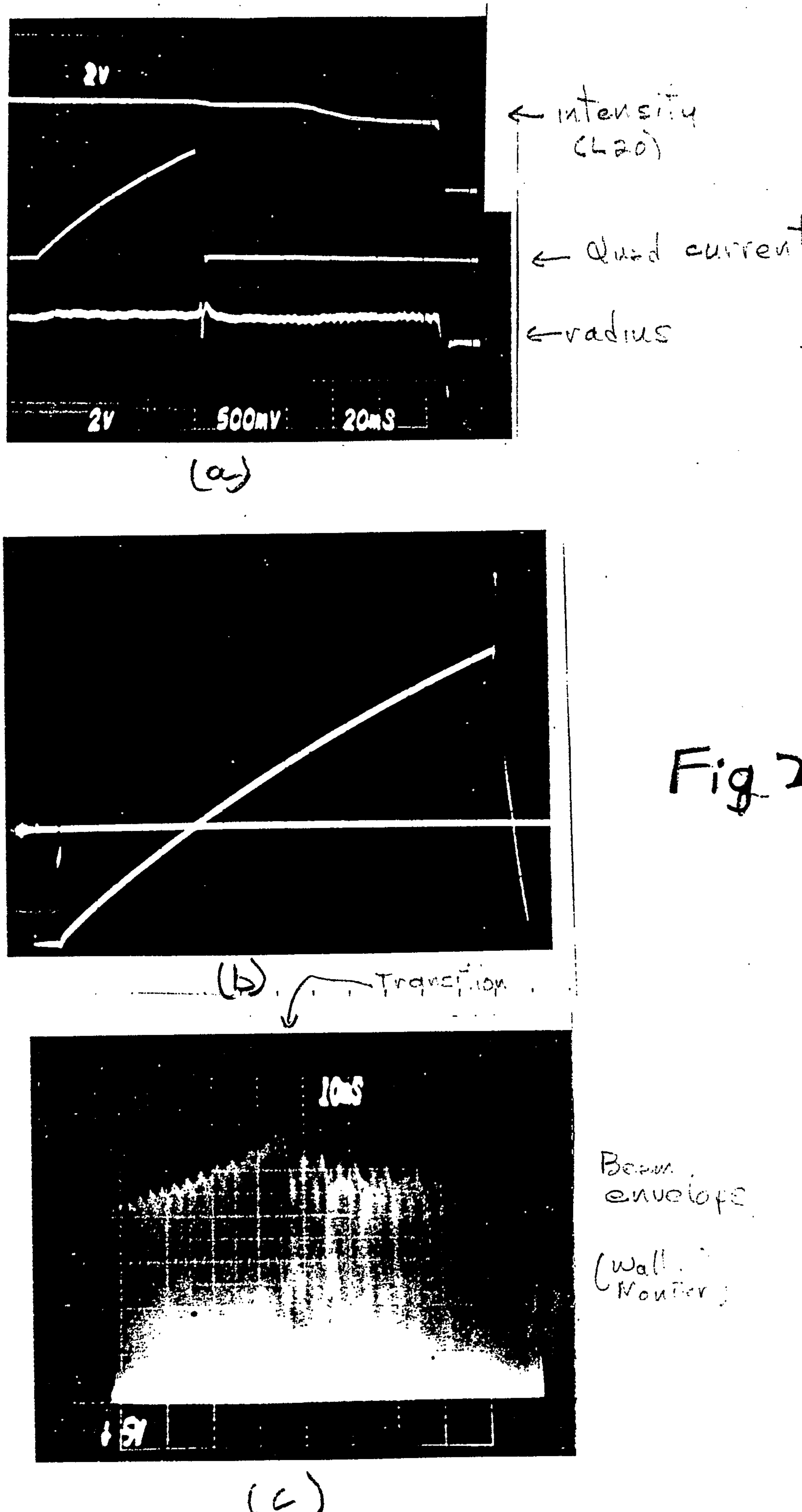

2V
intensity (L20)
Quad current
radius
2V
500mV
20mS
(a)
(b)
Transition
10mS
Beam envelope
(Wall Monitor)
5V
(c)

Fig 2

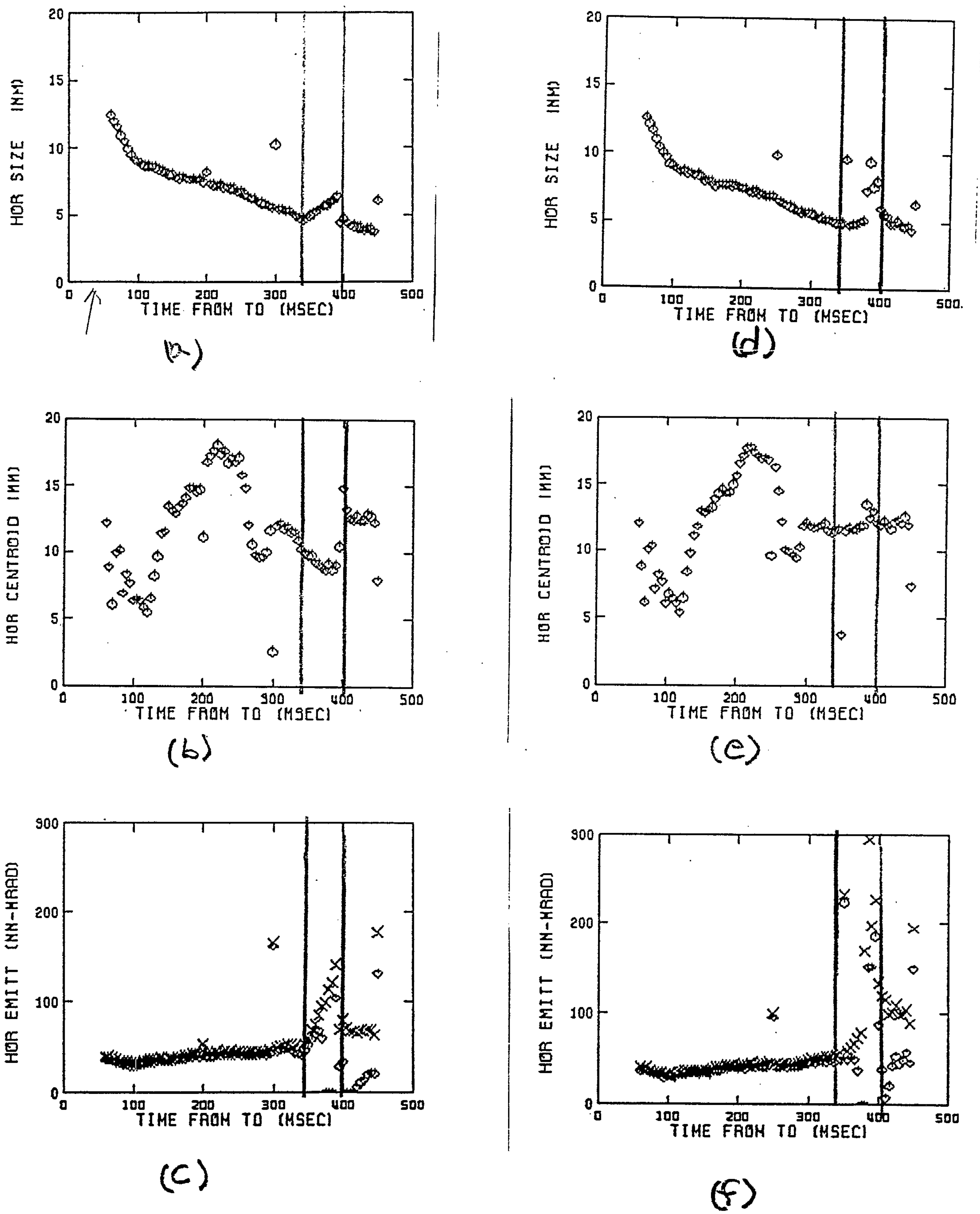

HOR SIZE (MM)
TIME FROM TO (MSEC)
(a)
HOR SIZE (MM)
TIME FROM TO (MSEC)
(d)
HOR CENTROID (MM)
TIME FROM TO (MSEC)
(b)
HOR CENTROID (MM)
TIME FROM TO (MSEC)
(e)
HOR EMITT (MM-MRAD)
TIME FROM TO (MSEC)
(c)
HOR EMITT (MM-MRAD)
TIME FROM TO (MSEC)
(f)

Fig. 3

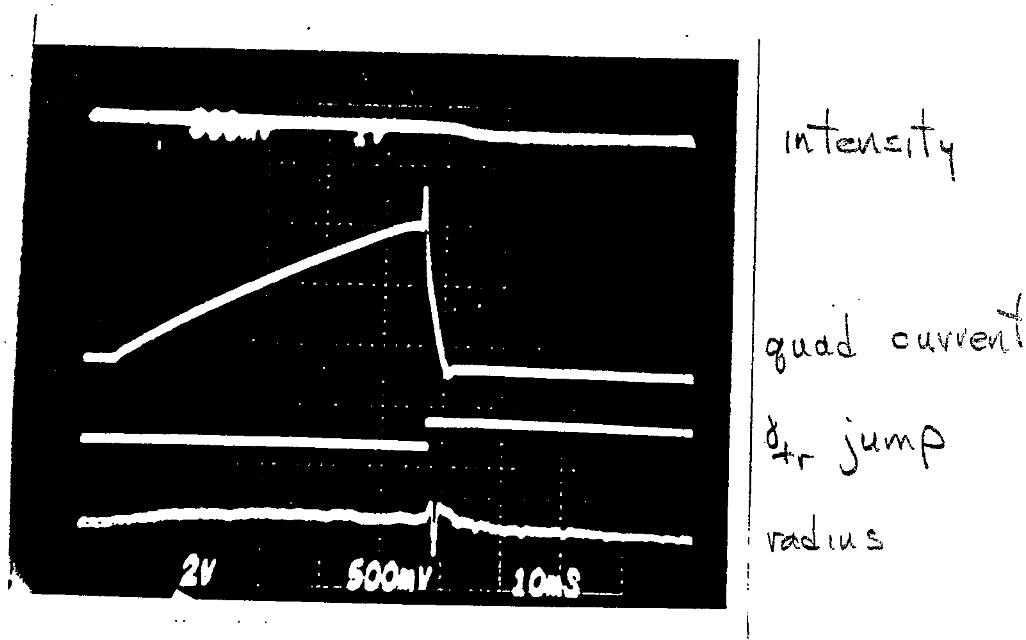


Fig. 4

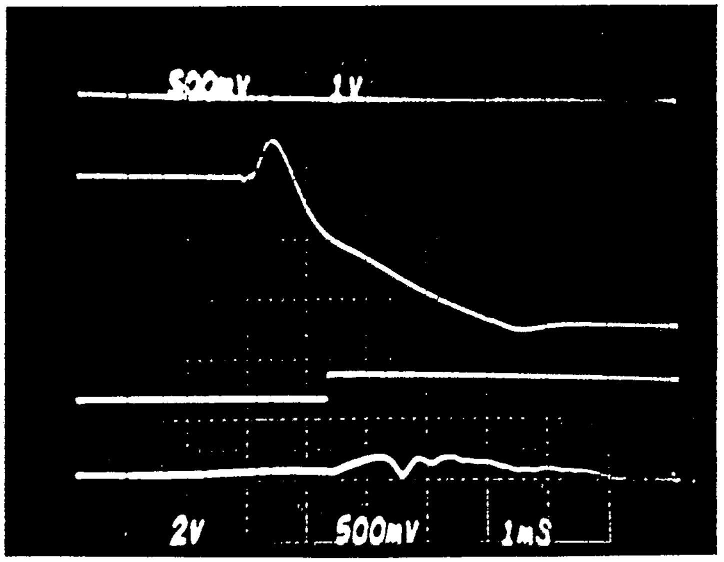


Fig 5

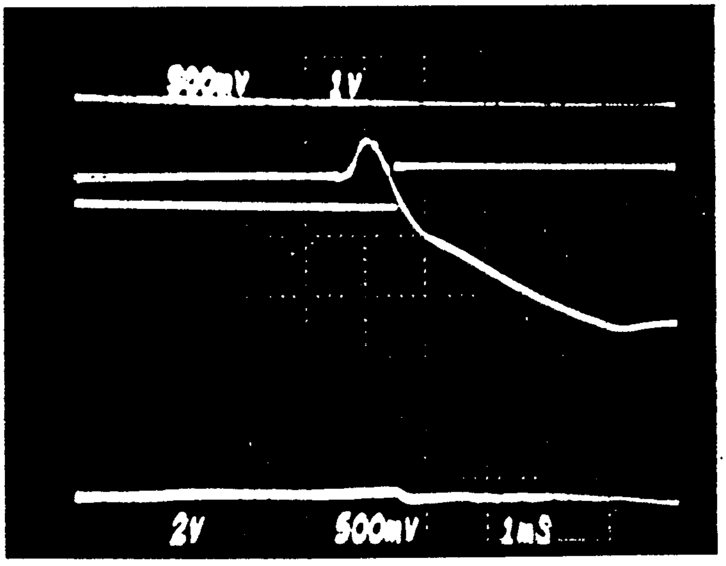


Fig 6

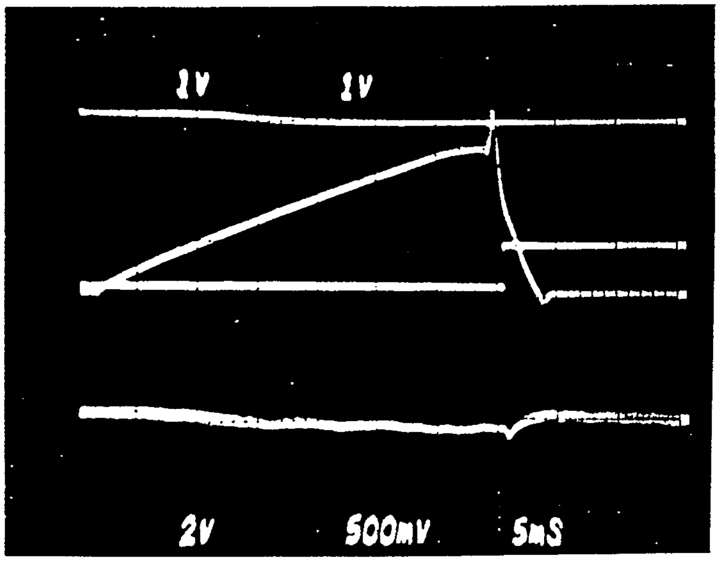
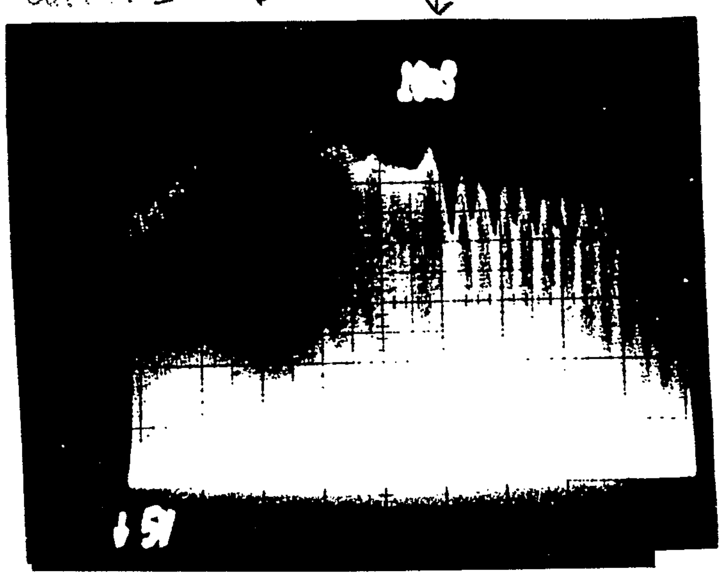


Fig 7

tightest bunches ↓ γ_{tr} jump ↓



Bunch envelope

Fig 8

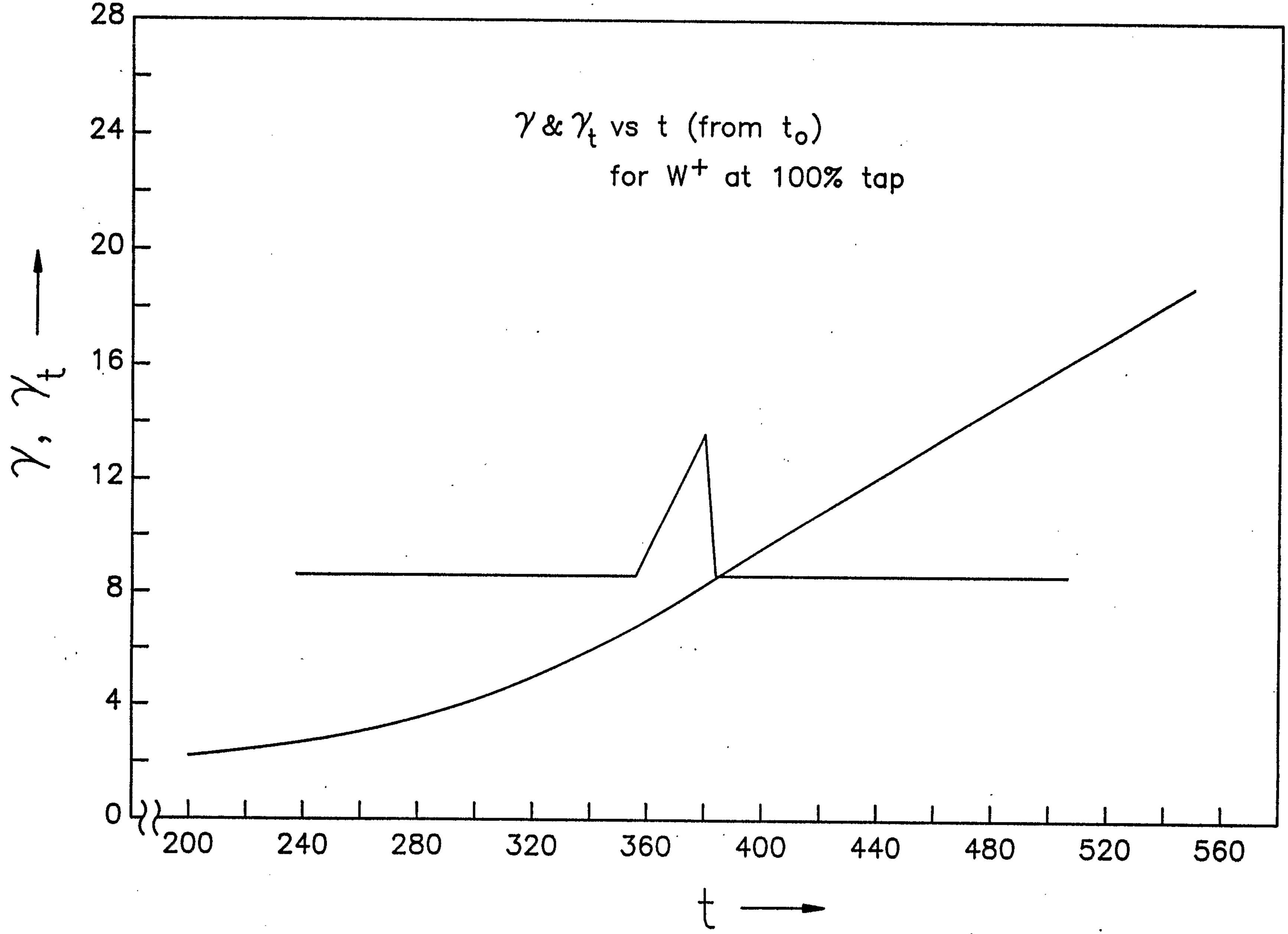

γ & γ_t vs t (from t_o)
for W^+ at 100% tap
28
24
20
16
12
8
4
0
200
240
280
320
360
400
440
480
520
560
γ, γ_t
t

Figure 9

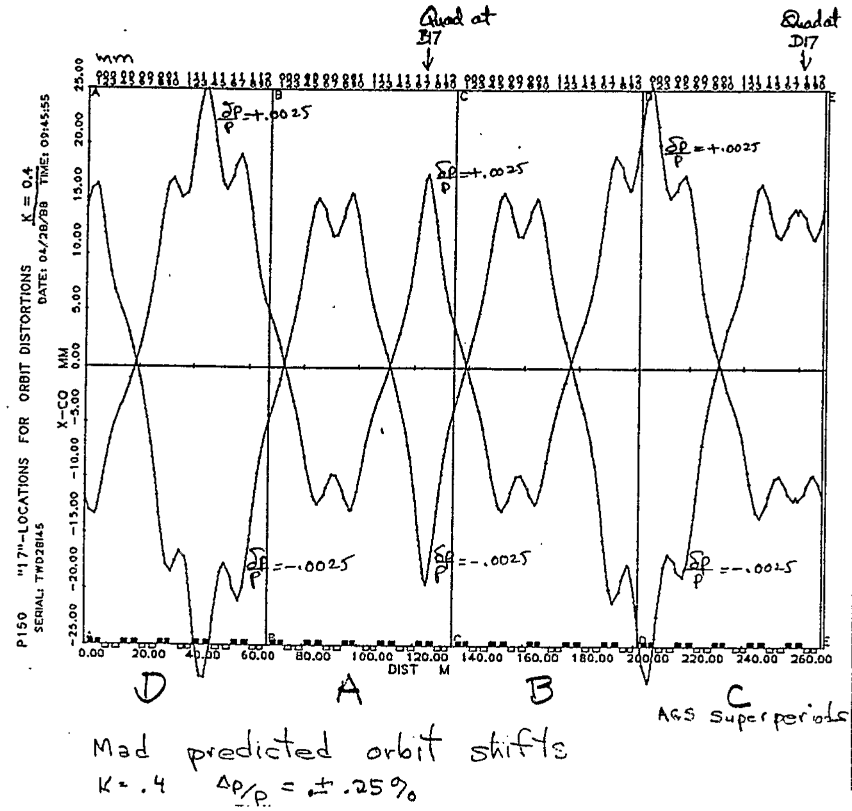


Figure 10a

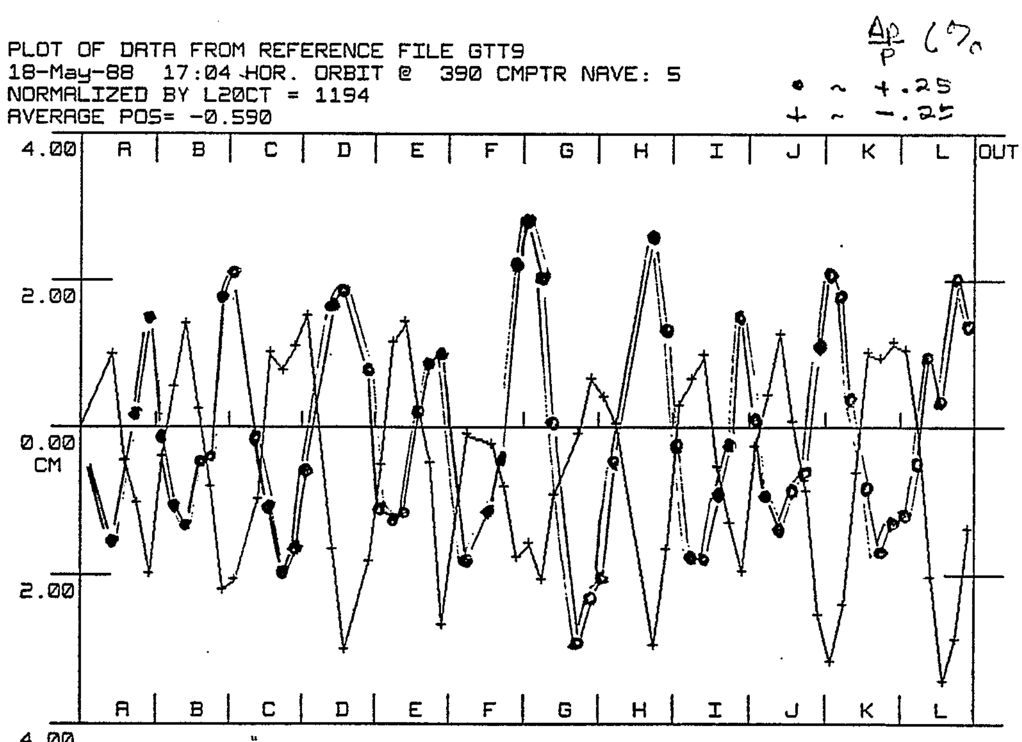


Figure 10b

APPENDIX

The "W+" Configuration

We present here the specifications for the "W+" configuration which will be used for the transition-jump at the AGS.

This configuration requires six quadrupoles in the "17" straight sections of the [A,C], [E,G], and [I,K] superperiods. (The doublet arrangement is indicated by brackets.) It was developed using MAD computer simulations and tested using the high field quads (HFQs) which are presently in these straight sections. Because the experimental results obtained in the studies were within 10% of the values predicted by MAD, we feel confident in the design.

For the actual implementation, we will replace the HFQs with shorter quads based on a design being used for the Booster. This will permit the installation of two magnets per straight section, producing a more versatile AGS. The shorter magnets will be excited to the same focusing strength as the HFQs.

MAD results show that to achieve a gamma jump of two units, we require quadrupoles of strength $KL = G'L/(B \times \rho) = 0.07$. With transition occurring at about 10 GeV, we therefore require $G'L = 2.5$. (Recall that $B \times \rho = p/0.3$.) G. Danby, et al., measured the Booster quads and determined that a 6-turn coil produces $G' = 2.02 \times 10^{-3}$ T/m-Amp. We have chosen a nominal 12" lamination stack for our shorter quads. Taking end-effects into consideration, we get an effective length for this stack, $L = 0.422$ m, or $G'L = 0.847 \times 10^{-3}$. We can therefore attain the required excitation at a current of ≈ 3000 Amperes.

The inductance of these six quads will be 2.5 mH. To reach 3000 Amperes in 60 ms will therefore require 125 V across the magnet string. Shutting off this current in 2 ms will produce 3750 V. However, the electrical design is not yet complete.