AA LONG TERM NOTE No. 23

Summary of the Meeting of November 9, 1982

Present : B. Autin, R. Garoby, W. Hardt, C. Johnson, H. Koziol, J. MacLachlan, W. Pirkl, K. Reich, R. Sherwood, C. Taylor, H.H. Umstätter, S. van der Meer, E.J.N. Wilson

Topics : 1. Military Microwave Conference in London, October 1982, by C. Taylor
2. Visit of the PS Switchyard and Siting in the A.C., by K.H. Reich
3. Bunch Rotation at FERMILAB, by J. MacLachlan

1. Military Microwave Conference and Exhibition (C. Taylor)

The highlights of this conference are :

- The introduction of Traveling Wave Tubes by Thomson Houston in the 2-4, 4.8 GHz range delivering a c.w. power of 400 Watt.
- The use of the 6-port principle for a network analyzer operating in the Q-band (26-110 GHz). The accuracy of phase-amplitude characteristics is better than with other instruments and the method could be applied to lower frequencies. However, there is no alternative to H.P. in our frequency range.
- Super screen flexible cables have now shielding characteristics comparable to semi-rigid copper tubes.
- 400 Watt splitter/combiner by NARDA.
- The ZN tiles used in the AA for damping the wave guide modes can be produced by Emerson and Cunning if the demand is sufficient.

2. Siting the Antiproton Collector (K.H. Reich)

A visit of the PS switchyard and of Lines TT1, TT2 was made on Monday, November 8 by B. Autin, S. Maury, K.H. Reich and R. Sherwood. Boundary conditions for the injection and ejection lines have been fixed. The proton line would be branched right at the exit of the linac at the location of the first beam stopper. It may be necessary to replace the first quadrupole of TT1 by a slim one and to reverse the yoke of the first dipole. The target area would be buried between the elevator of the Y-building and TT2. The ejection line would merge the AA injection line in the DHZ20 element.

3. Bunch rotation at Fermilab (J. MacLachlan)

The general features of the proton bunch rotation in the main ring for antiproton production and the complementary antiproton bunch rotation in the debuncher for momentum spread reduction were described primarily on the basis of material available in Chapters 2 and 4 of the October 1982 version of the Tevatron I Design Report. In addition to a qualitative resume and review of relevent accelerator parameters MacLachlan discussed the kind of particle tracking calculations which have been carried out to optimize parameters of the RF voltage programs etc. Because of the large momentum acceptance of the debuncher, both kinematic and chromatic non-linearities have much more important effects there than in the main ring. Because of this fact, the rectangular distribution of $\bar{p}$'s arriving from the target, and the practical limitations on high level RF hardware the tracking calculations were rather important in arriving at a trustworthy design specification and establishing realistic performance expectations for the debuncher.

B. Autin

Table MAIN RING BEAM PARAMETERS

Proton Beam Kinetic Energy @ Extraction	120 GeV
Relativistic Factors: β	0.99997
γ	128.9318
B ρ, magnetic rigidity	4035.506 kG-m
Momentum, P	120.9347 GeV/c
Number of Booster batches accelerated	one
Number of Proton Bunches	82
Total number of protons per Batch	$<2.0 \times 10^{12}$
Main Ring Cycle Time	2.0 sec
Betatron Emittance, 95% of beam, (H and V)	0.2π µm
Longitudinal Emittance, 95% of beam at 120 GeV	0.3 eV-sec
RF harmonic number (h)	1113
RF Frequency @ 125 GeV	53.1035 Mhz
Revolution Period @ 125 GeV	20.96 µsec
Booster Batch Time Length	1.56 µsec
Transition Energy (γ_t)	18.75
Betatron tune number (H and V)	19.4
$\eta = \gamma^{-2} - \gamma_t^{-2}$	-0.0028
Maximum RF voltage	4.0 MV
Average Radius	1000 m

Table THE DEBUNCHER RING

Kinetic Energy	8.0 GeV
$\eta = \gamma_t^{-2} - \gamma^{-2}$	-0.0047
	12.6
Average Radius	83.1 m
RF Frequency	53.1035 MHz
Maximum RF Voltage	5 MV
Number of $\bar{p}$-bunches injected	80
Harmonic Number	93
Beam Gap for Injection Kicker	230 nsec
Momentum Aperture, $\Delta p/p$	4%
Betatron Acceptance, h and v	20π mm-mrad
Betatron Tunes, h and v	14.28
Natural Chromaticity, h and v	-22
Periodicity	3, each with mirror symmetry
Max β-values, regular cells	19 m
long straight sections	39 m
Max Dispersion Value	1.0 m
Phase Advance Regular Cells, h	120°
v	110°

DIFFERENCE EQUATIONS FOR TRACKING

$\varphi_{i,n}$ IS PHASE OF RF WHEN i^{TH} PARTICLE CROSSES ACCELERATING GAP ON n^{TH} TURN

$\vartheta_{i,n} = \varphi_{i,n}/h$ h IS HARMONIC NUMBER OF RF

$E_{i,n}$ IS TOTAL ENERGY OF i^{TH} PARTICLE AFTER n^{TH} KICK

$$E_{i,n+1} = E_{i,n} + eV_n \sin(h\vartheta_{i,n} + \psi_n) \qquad \text{(FIXED FRAME)}$$

WHERE V_n & ψ_n ARE RESPECTIVELY THE RF AMPLITUDE AND PHASE PROGRAM VALUES

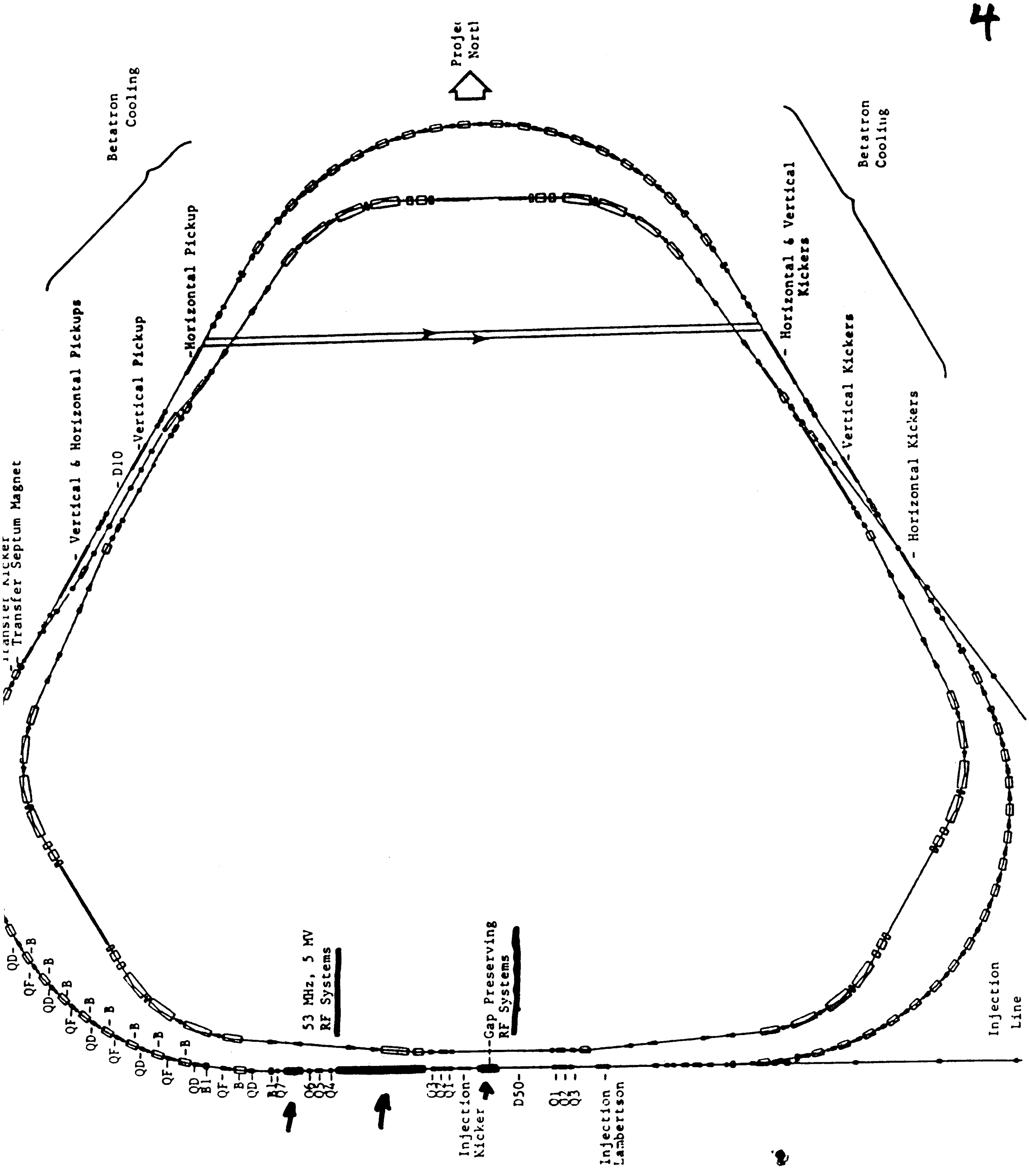
IF $\frac{dp}{dt} \neq 0$ ONE CAN WRITE

$$\varepsilon_{i,n+1} = E_{i,n+1} - \frac{dp}{dt}\tau_\infty \qquad \text{(MOVING FRAME)}$$

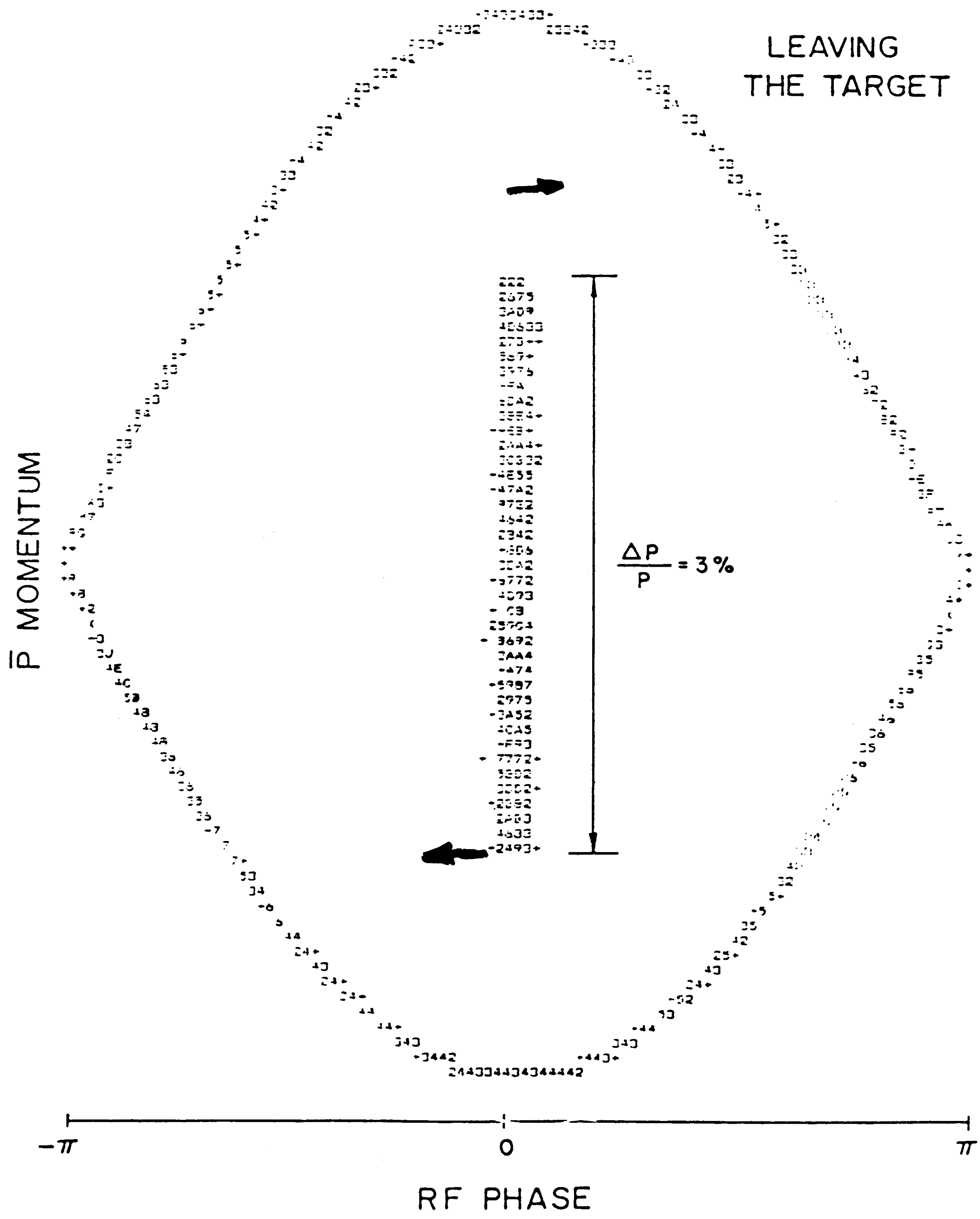
$$\vartheta_{i,n+1} = \vartheta_{i,n} + \Omega\tau_{i,n} - 2\pi$$

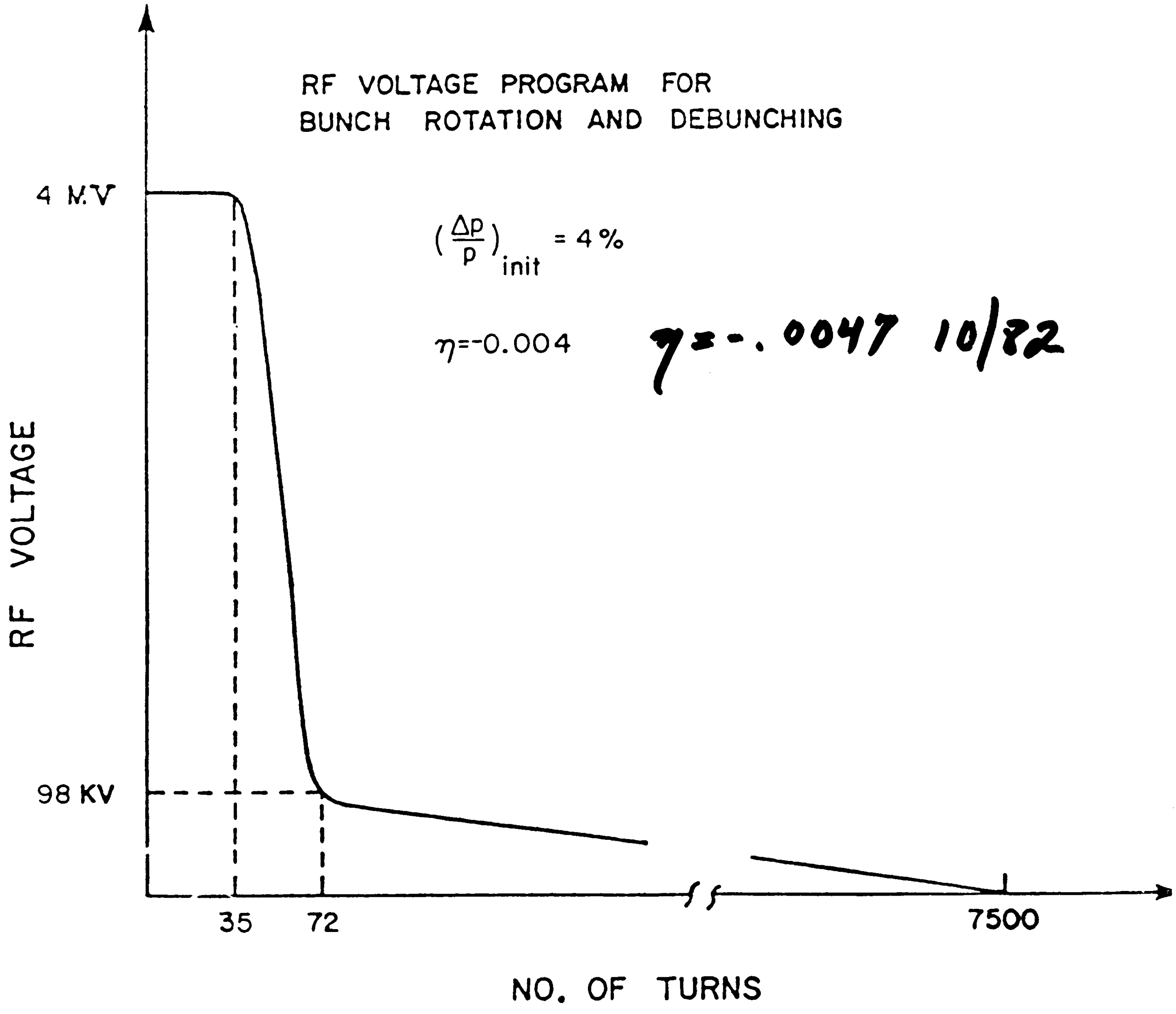
$$= \vartheta_{i,n} + (\beta_{s,n}c/R_0)\left[2\pi R_0(1+\alpha\delta)/(\beta_{i,n}c)\right] - 2\pi$$

$$= \vartheta_{i,n} + 2\pi\left[\frac{\beta_{s,n}}{\beta_{i,n}}(1+\delta(\alpha_0+\delta(\alpha_1+\delta\alpha_2))) - 1\right]$$

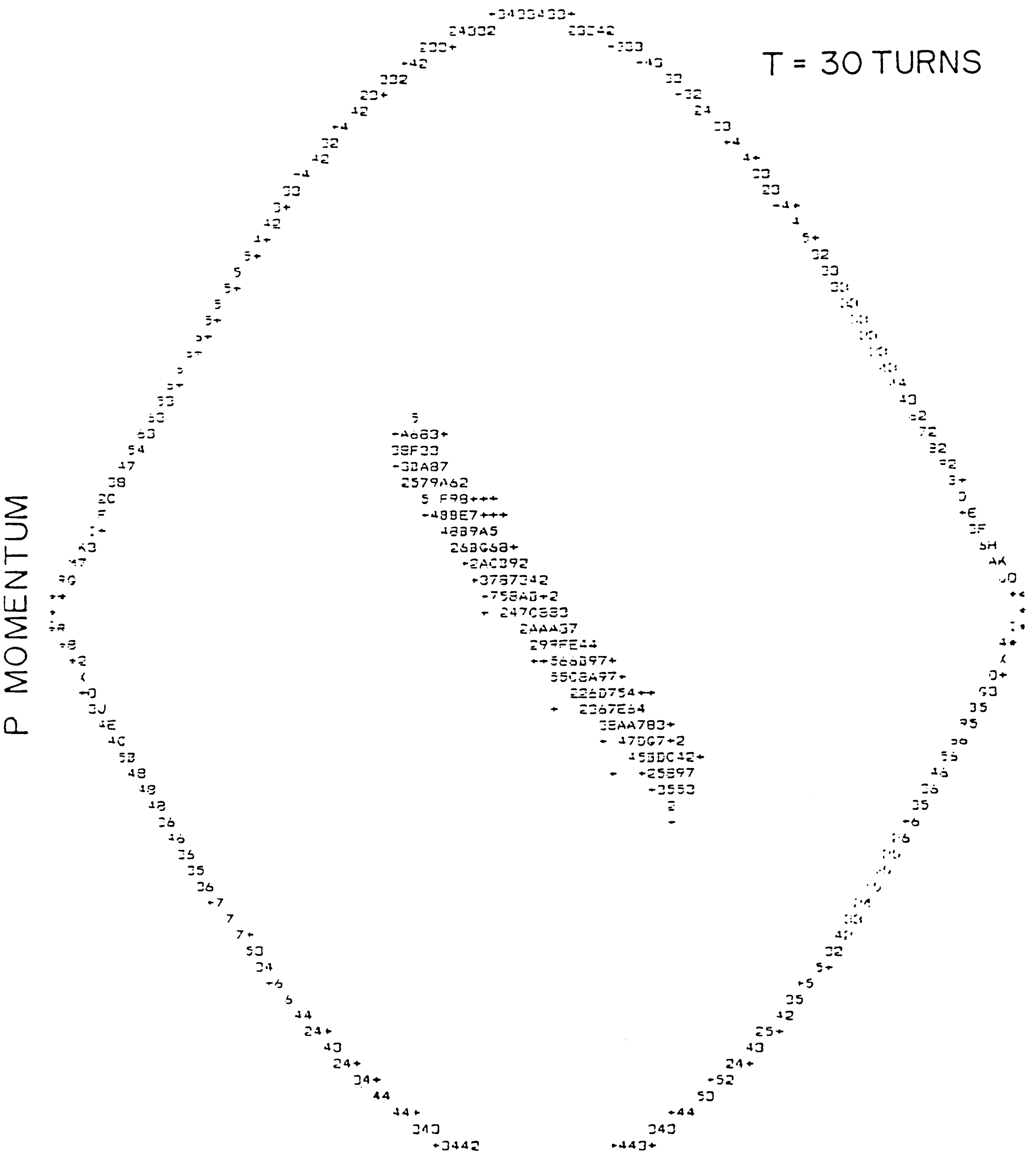


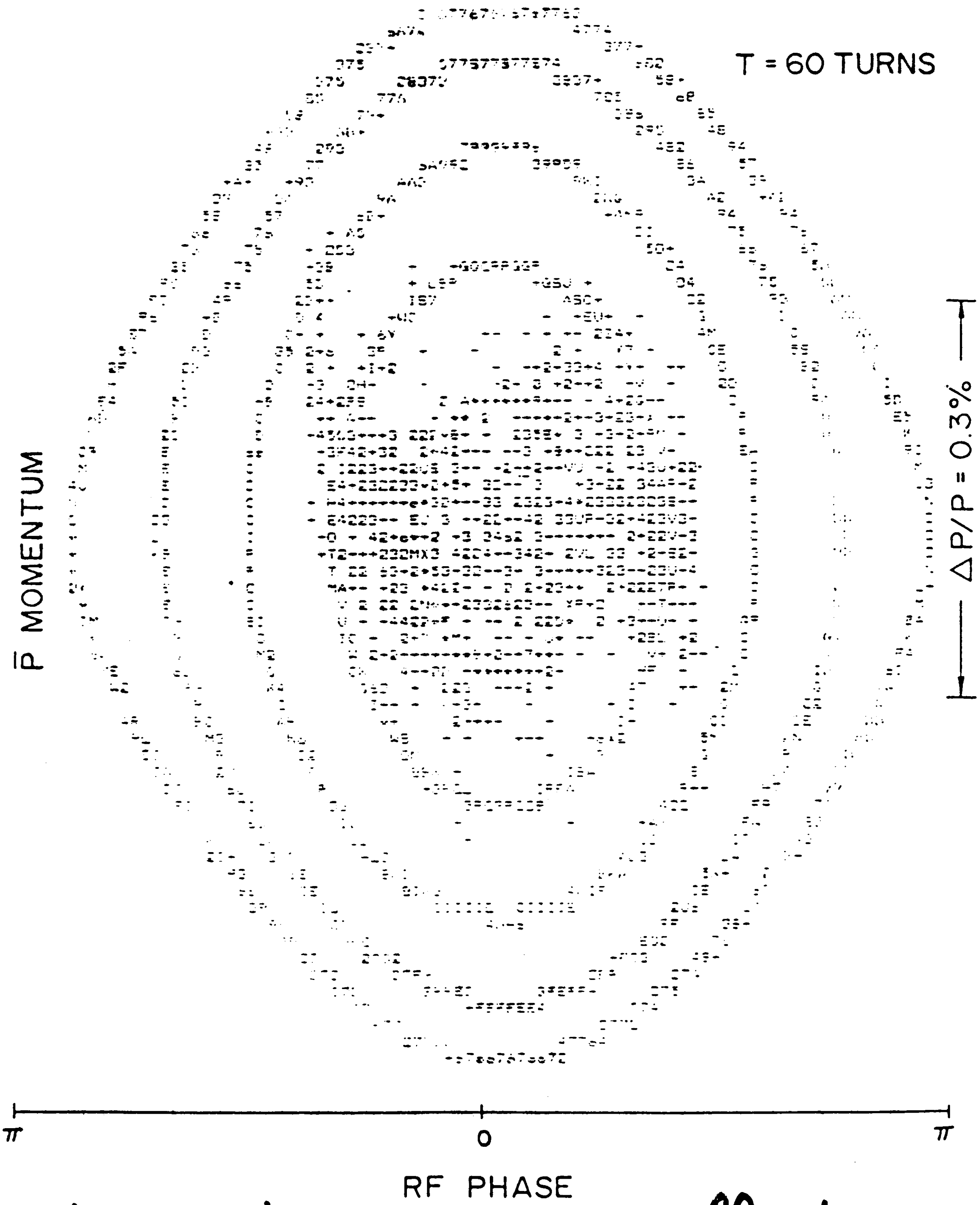
DEBUNCHER (OUTER RING)


LEAVING
THE TARGET
$\Delta P / P$ = 3%
$\bar{P}$ MOMENTUM
$-\pi$
0
π
RF PHASE

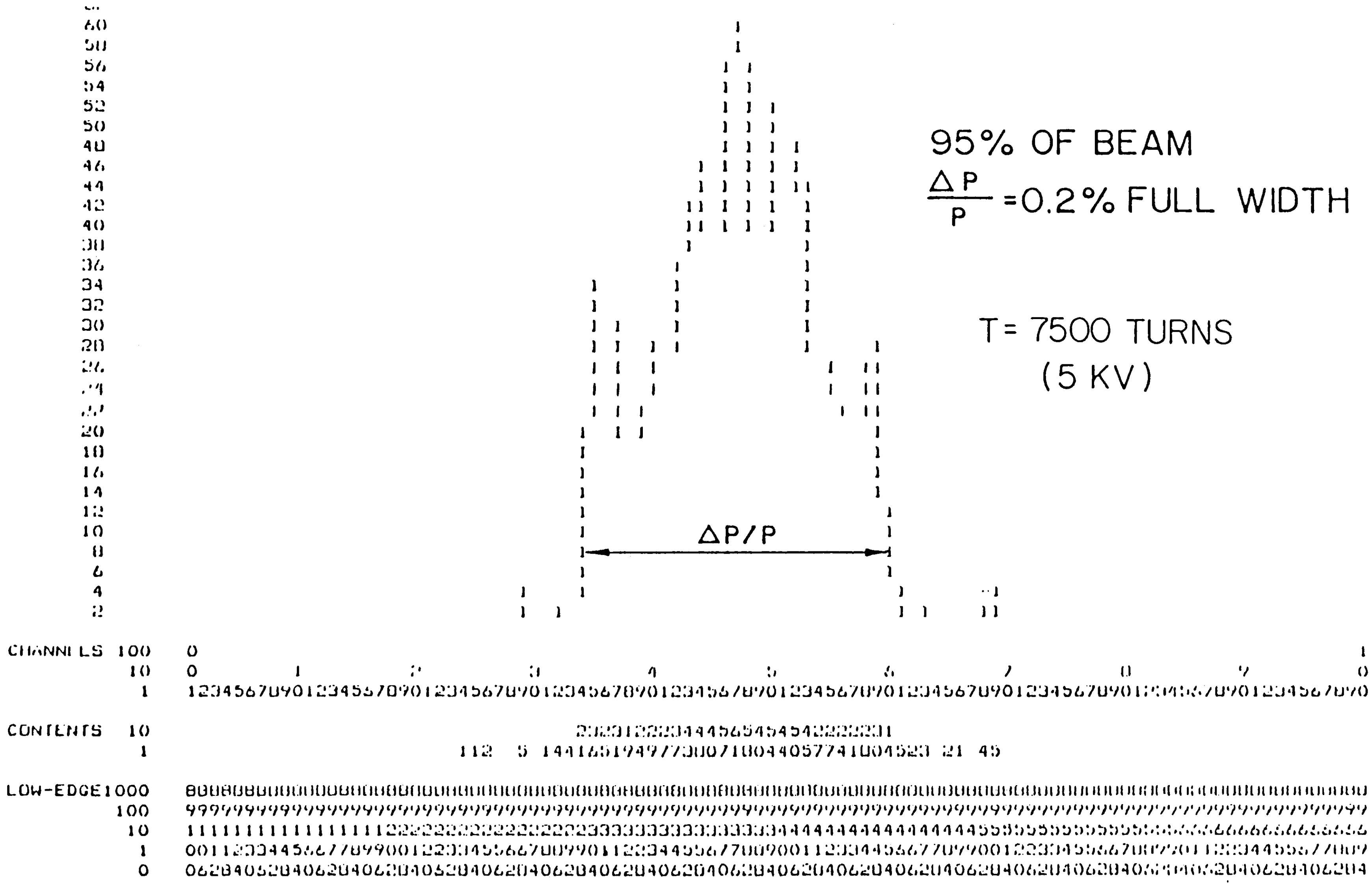


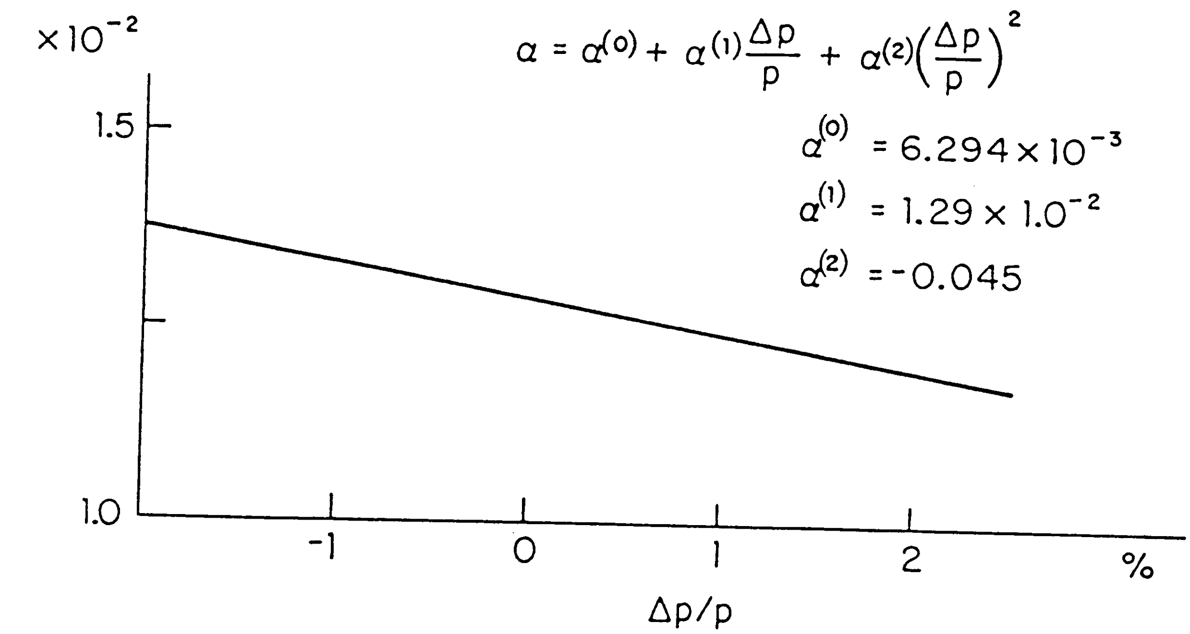
Empirical optimum
constraint: cavity Q & available V


T = 30 TURNS
P̄ MOMENTUM
RF PHASE
−π
0
π



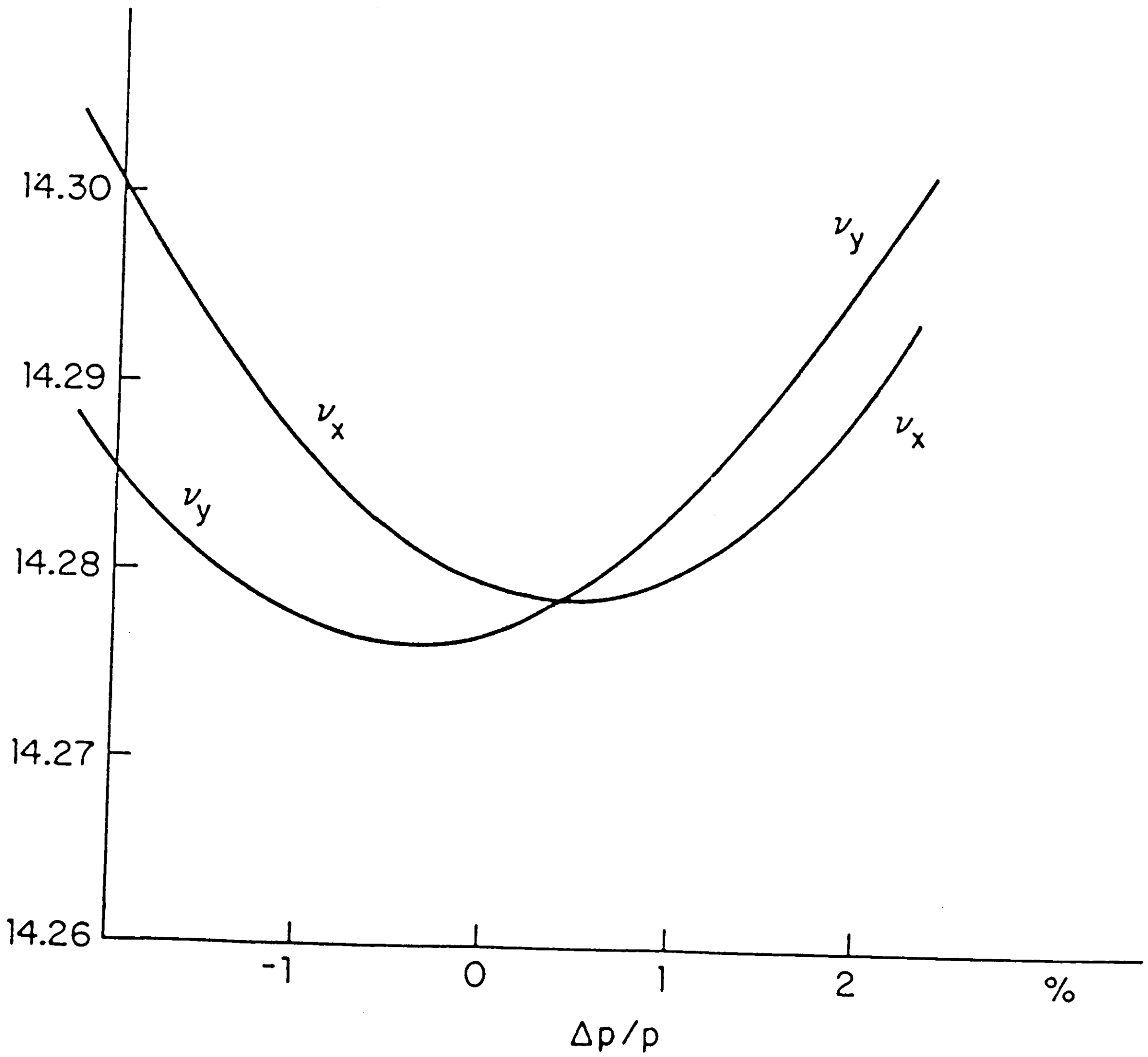
Both kinematic & $\alpha_p(\Delta p/p)$ effects causing dilution


95% OF BEAM
ΔP/P =0.2% FULL WIDTH
T= 7500 TURNS
(5 KV)
ΔP/P
CHANNELS 100
10
1
CONTENTS 10
1
LOW-EDGE1000
100
10
1
0



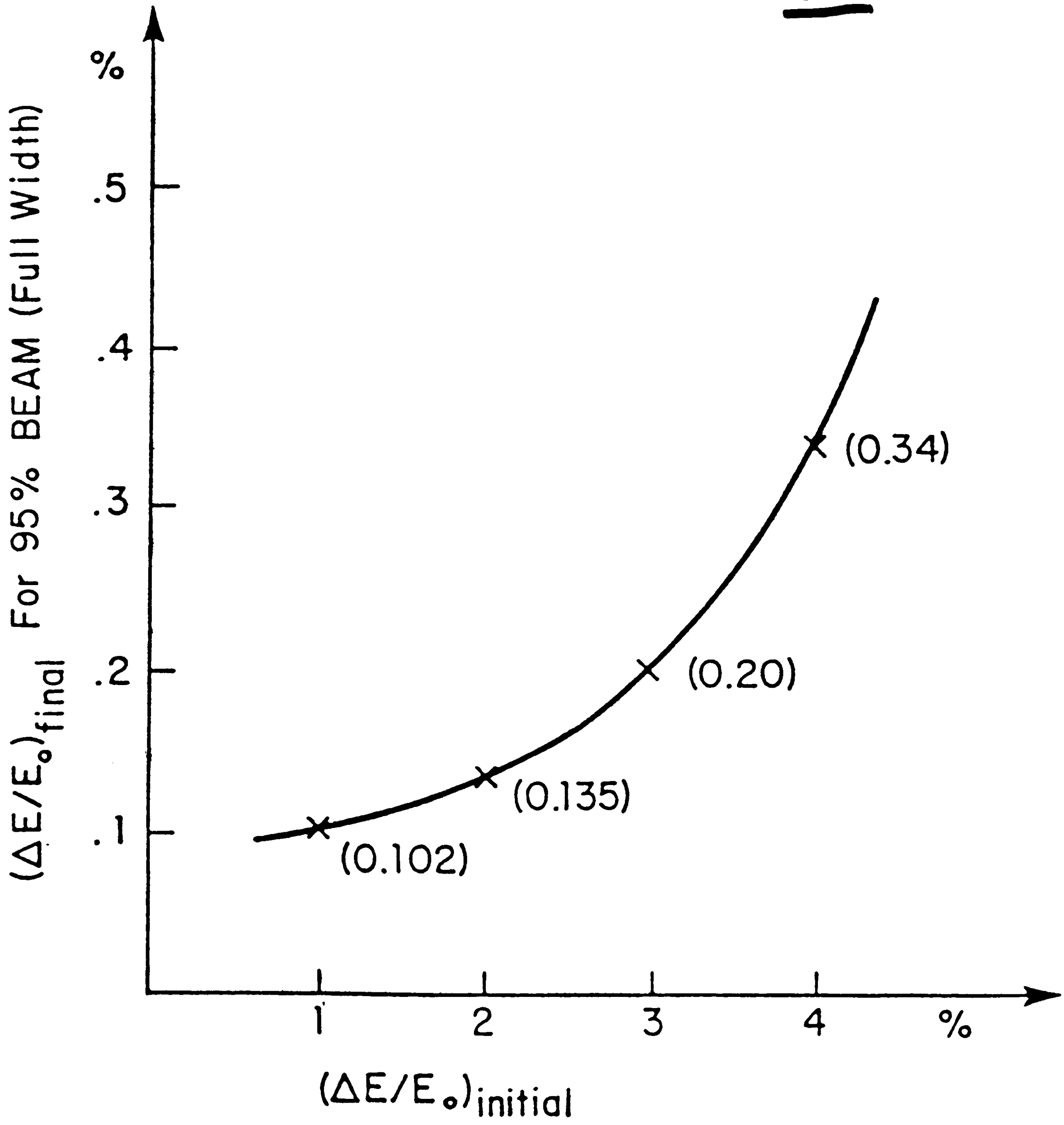
×10⁻²
α = α^(0) + α^(1) Δp/p + α^(2) (Δp/p)^2
α^(0) = 6.294 × 10⁻³
α^(1) = 1.29 × 1.0⁻²
α^(2) = -0.045
1.5
1.0
-1
0
1
2
%
Δp/p

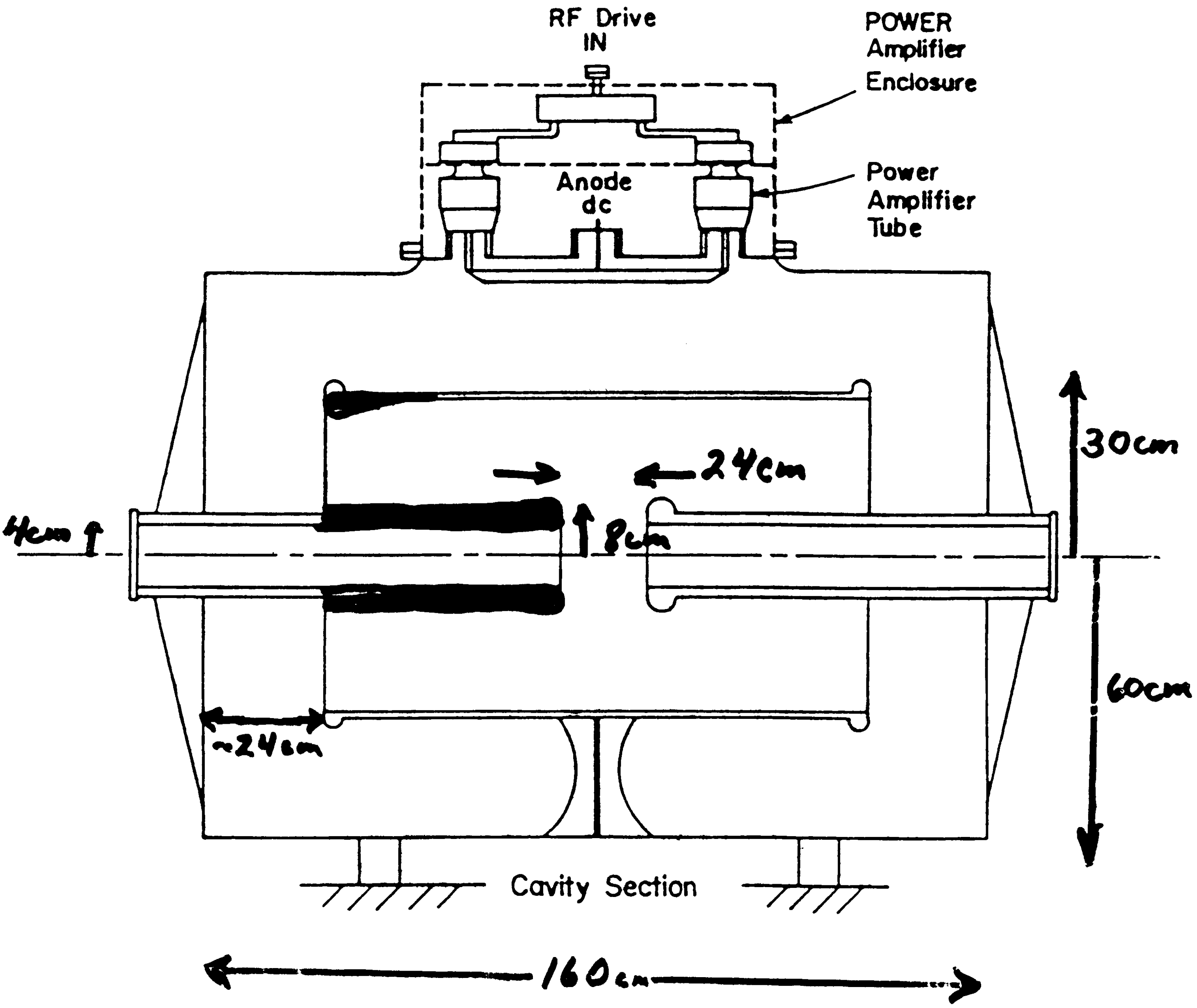
Fig. 4-11



14.30
14.29
14.28
14.27
14.26
ν_y
ν_x
ν_x
ν_y
-1
0
1
2
%
Δp/p

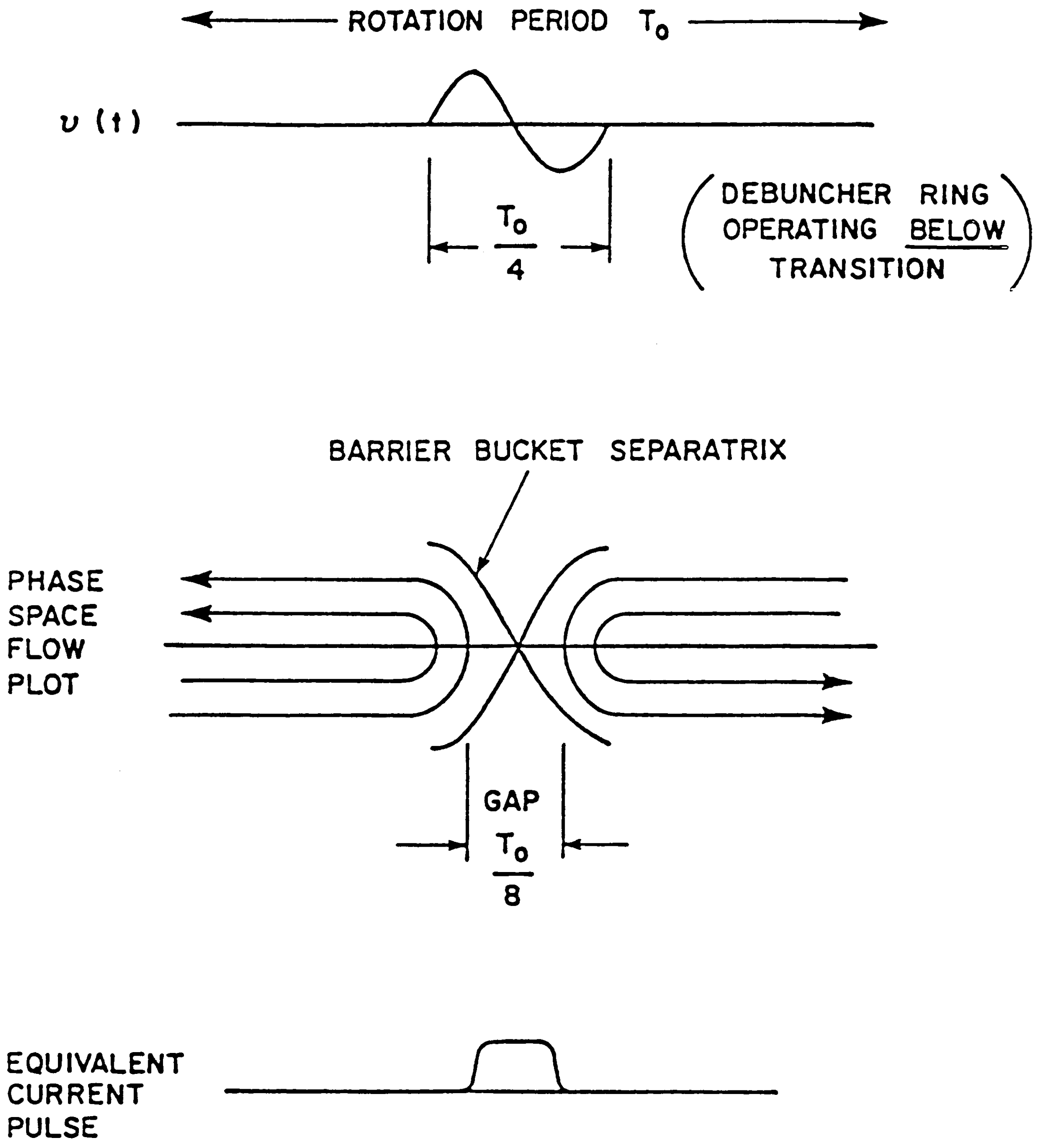
Debunched Beam Spread
vs.
Initial Beam Spread
for V=4MV and a Final V=5KV





$\hat{V} \lesssim 650\,kV$

$Q \sim 1.8 \times 10^4$



$\hat{V} \approx 460V$

Each "cavity" 150V, .5m long, ~300W drive