PS/AA/BA/afm 3 December 1982

AA LONG TERM NOTE No. 24

Summary of the meeting of November 23, 1982

Topic : Bunch rotation in the Antiproton Collector, by H. Koziol and W. Pirkl.

The goal of bunch rotation in the antiproton collector is to decrease the momentum spread of the injected beam from 6% to 1.5%. The attached copies of transparencies describe computations for the contour of the bunch before adiabatic turn-off. Further computations will take lattice non-linearities and more realistic distribution functions into account. The final distributions will serve as an input to mentum cooling computations.

The characteristics of a 1 MVolt cavity are given in page 14.

In the discussion, it was pointed out that an η value of 0.015 would be a good compromise for a lattice with a fixed focusing ; this is a revision of what was contemplated originally when the lattice functions were different for bunch rotation and stochastic cooling. The second point of discussion is the need of a compromise between bunch length and beam intensity or of a special development programme for short bunches in the PS to optimize the production of antiprotons acceptable by the antiproton collector.

B. Autin

Distribution

PS/2 List

BUNCH ROTATION:

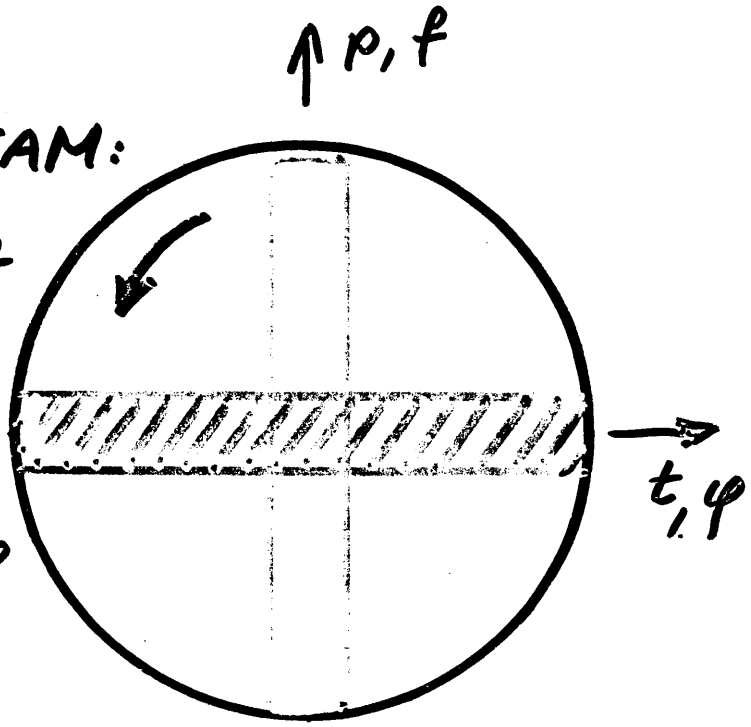
SEQUENCE OF PROCESSES

- PS produces 5 bunches at $h=20$ (as today)
- 5 intense proton bunches hit AC $\bar{p}$ production target
- 5 $\bar{p}$ bunches are accepted in the AC, total $\Delta p/p$ is clipped to 6% (acceptance)
- RF, synchronized to PS-RF, is on full voltage when $\bar{p}$ arrive
- Wait for $\gtrsim 1/4\ \tau_{synchr.}$
- Turn RF off abruptly to zero
- Adiabatic RF turn-off from matched level to zero)
- Fast transverse cooling
- Transfer to AA

A FEW BASIC CONSIDERATIONS

THE BUNCH ROTATORS DREAM:

- a circular (elliptic) bucket
- linear behaviour



$$\frac{\Delta p_{final}}{\Delta p_{initial}} = \frac{\text{initial bunch } L_b}{\text{bucket } L}$$

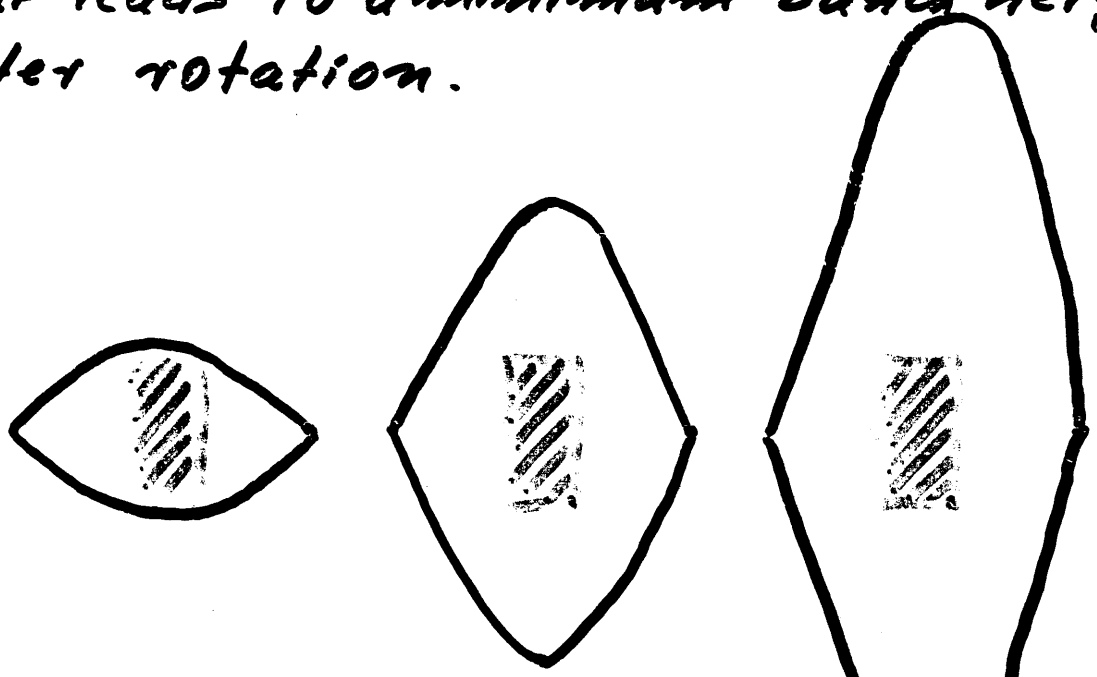
e.g. bucket length = 104 nsec
initial bunch length = 26 nsec * } → factor 4 *

* This gives us already an upper limit:

$$L_b < 26 \text{ nsec}$$

With a real bucket (non-elliptic, motion non-linear), we will need much shorter bunches, in order to obtain a factor 4.

There is an optimum bucket height that leads to a minimum bunch height after rotation.



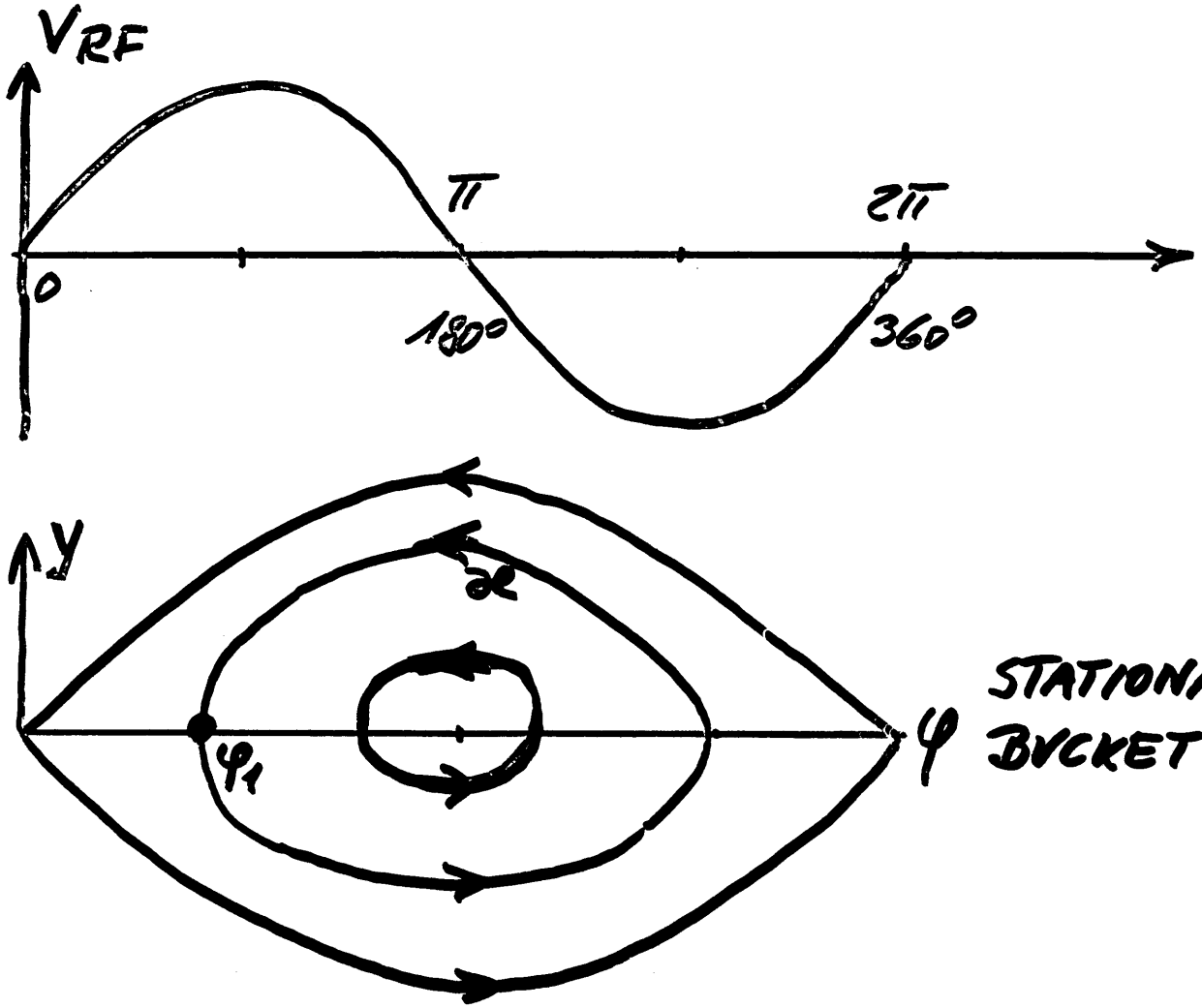
bucket height:	small	"matched"	high
op/p after rotation	Smaller	same	Larger

Conclusion:

We want smallest possible bucket height

Limit: non-linearity of motion

EQUATIONS OF MOTION + TRAJECTORIES



Trajectories: $y = \pm\sqrt{2(\cos\varphi_1 - \cos\varphi)}$

separatrix $y^* = \pm\sqrt{2(1-\cos\varphi)}$

Motion : $\dot{y} = -\sin\varphi$

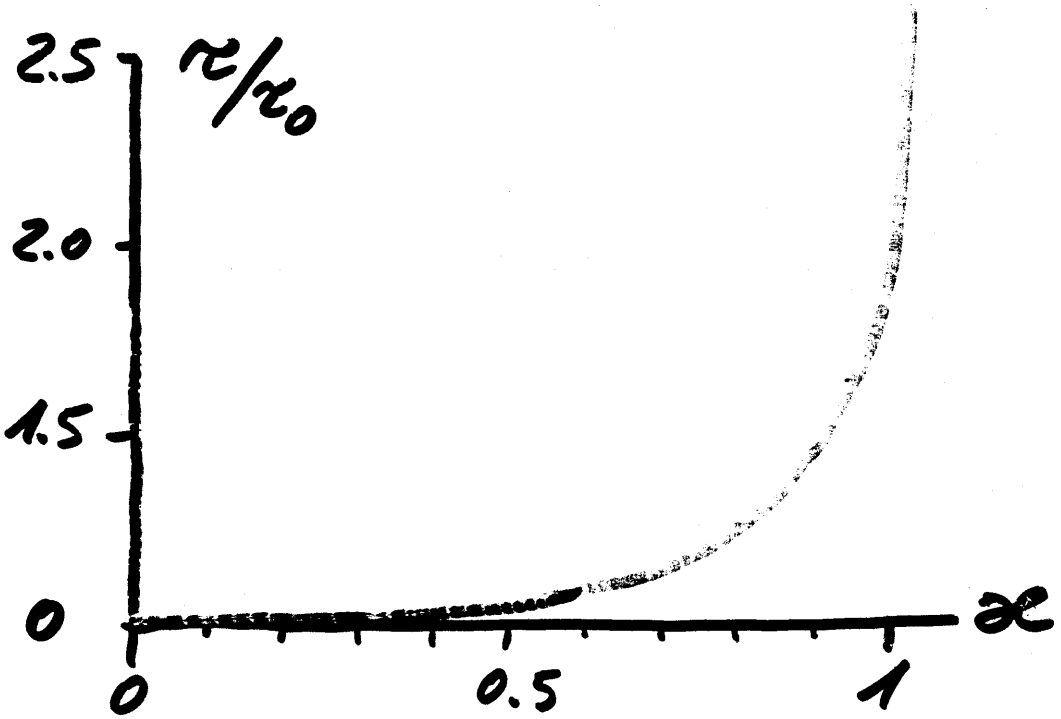
$\dot{\varphi} = -y$

In these scaled coordinates, the revolution period for a small amplitude particle is

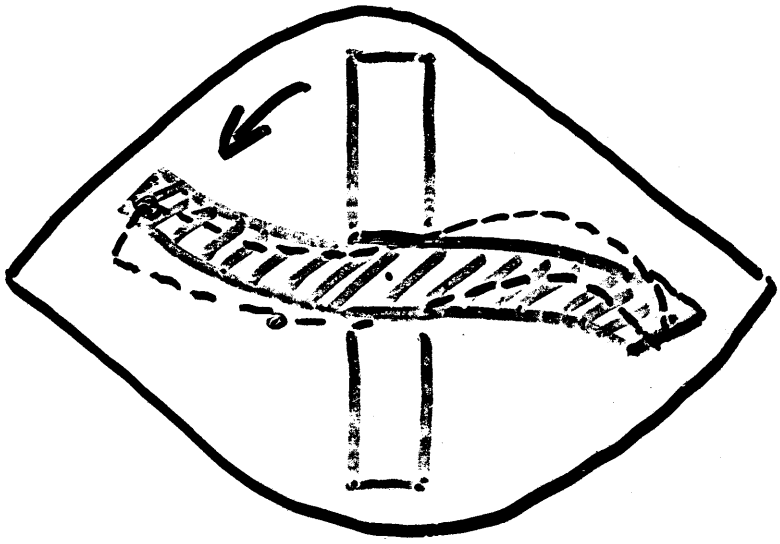
$$\tau_0 = 2\pi$$

The synchrotron oscillation period is a function of amplitude. It becomes ∞ on the separatrix.

For a stationary bucket $\Pi = \sin\varphi_s = 0$:



CONSEQUENCE



We have to rotate for longer than $\tau_0/4$ and find a compromise.

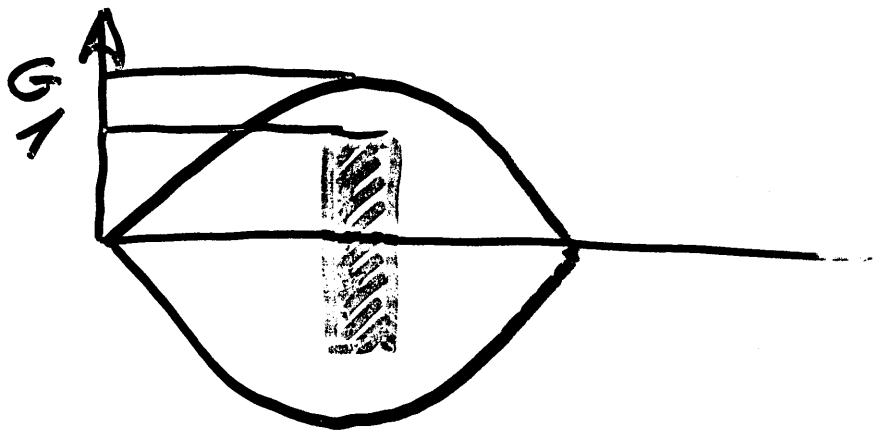
To find that compromise, i.e. the smallest final $\Delta p/p$, we take an HP 9845 and rotate bunches.

Variables: – Total initial bunch length

L_b (nsec)

– Bucket height factor

G



$$G = \frac{\text{Bucket height}}{\text{initial bunch height}}$$

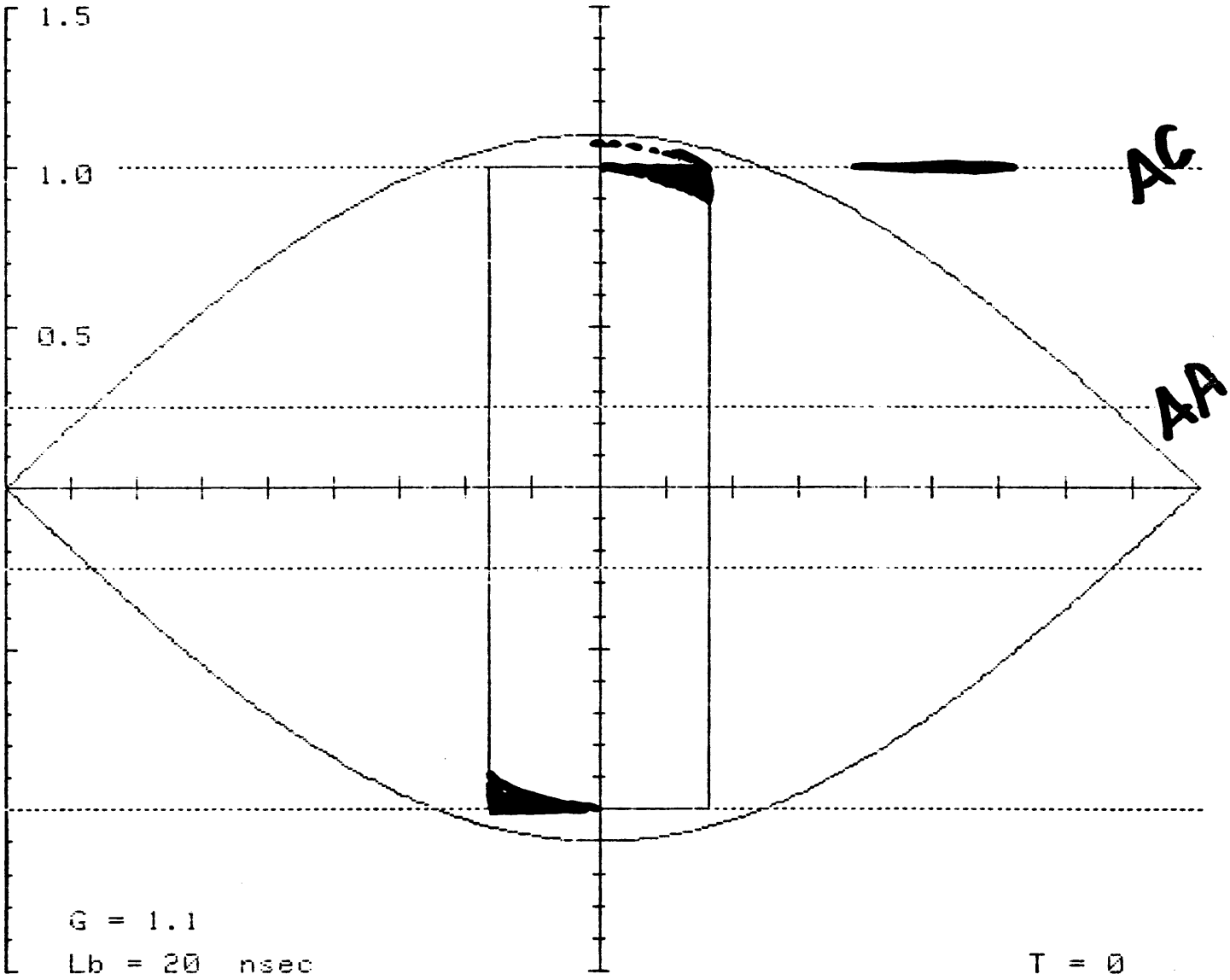
ASSUMPTIONS

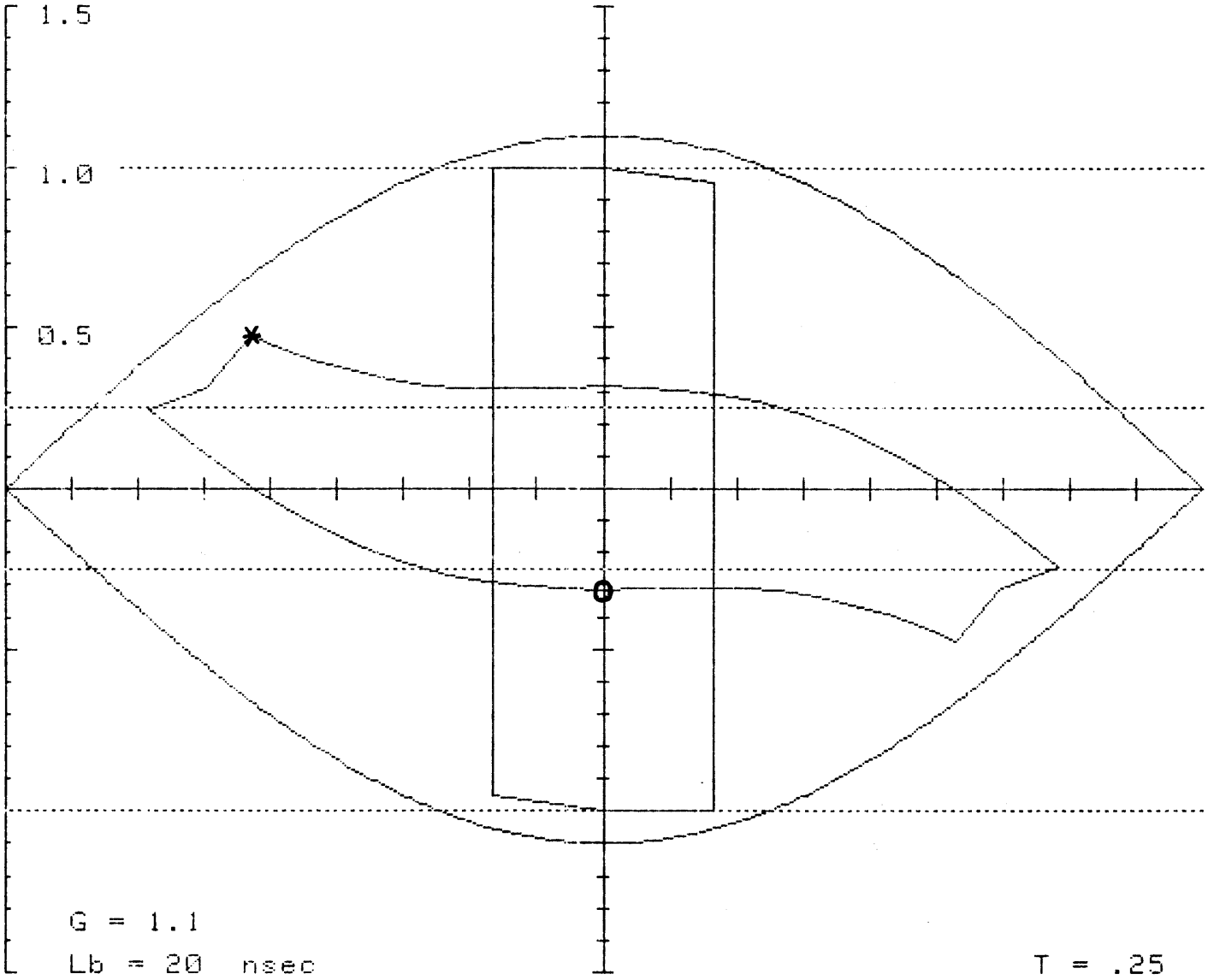
– β, γ are constant over bucket height

– $\eta = \frac{1}{\gamma_{tr}^2} - \frac{1}{\gamma^2}$ is constant –"–

– Only bunch contour is calculated ("hard-edged" model)

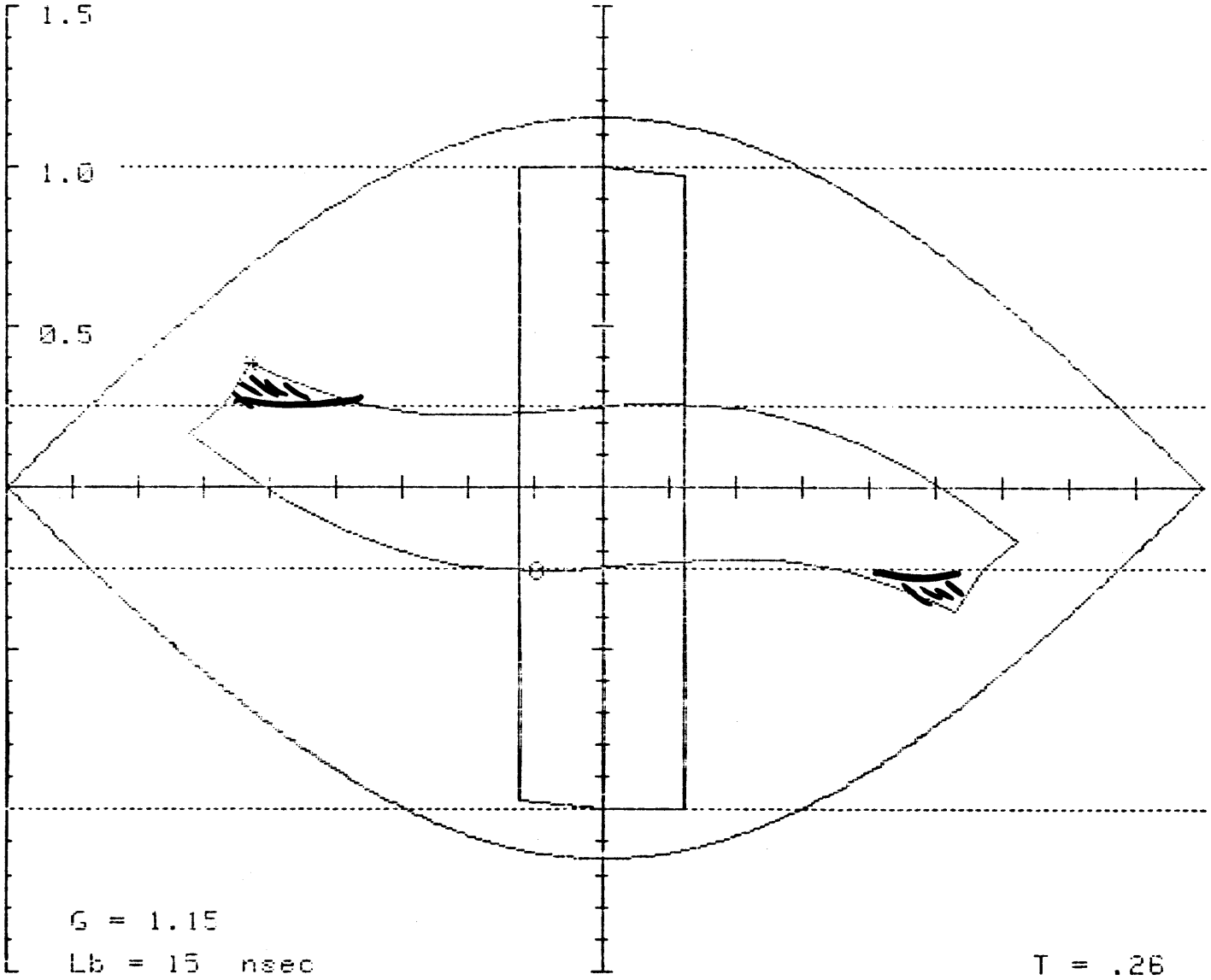
17a





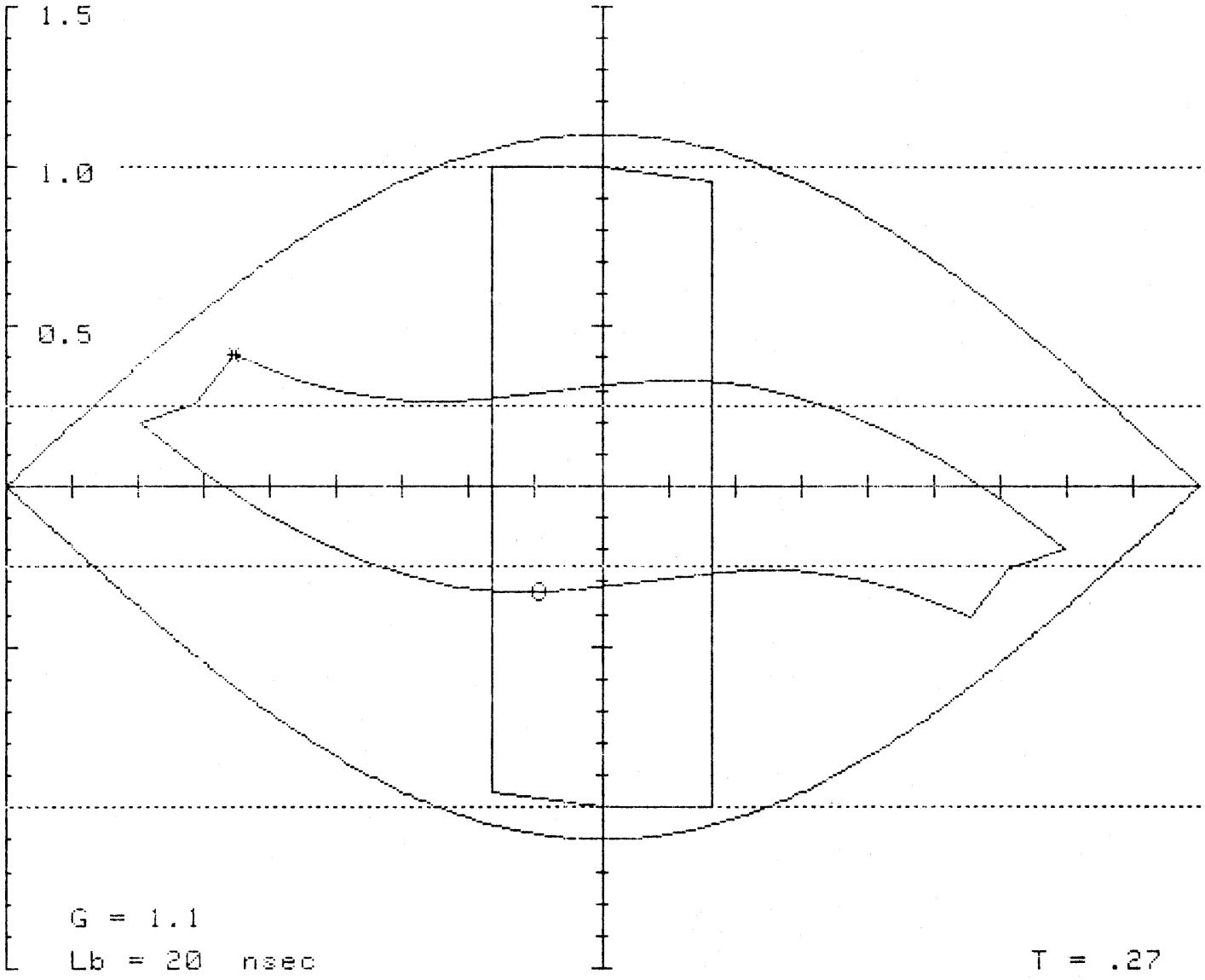
Bunchheight at significant points:

At middle of bunch :	V = .315		
Tip (point No.13):	V = .475	shown by:	*
Lowest (point No. 1):	V =-.315	shown by:	0



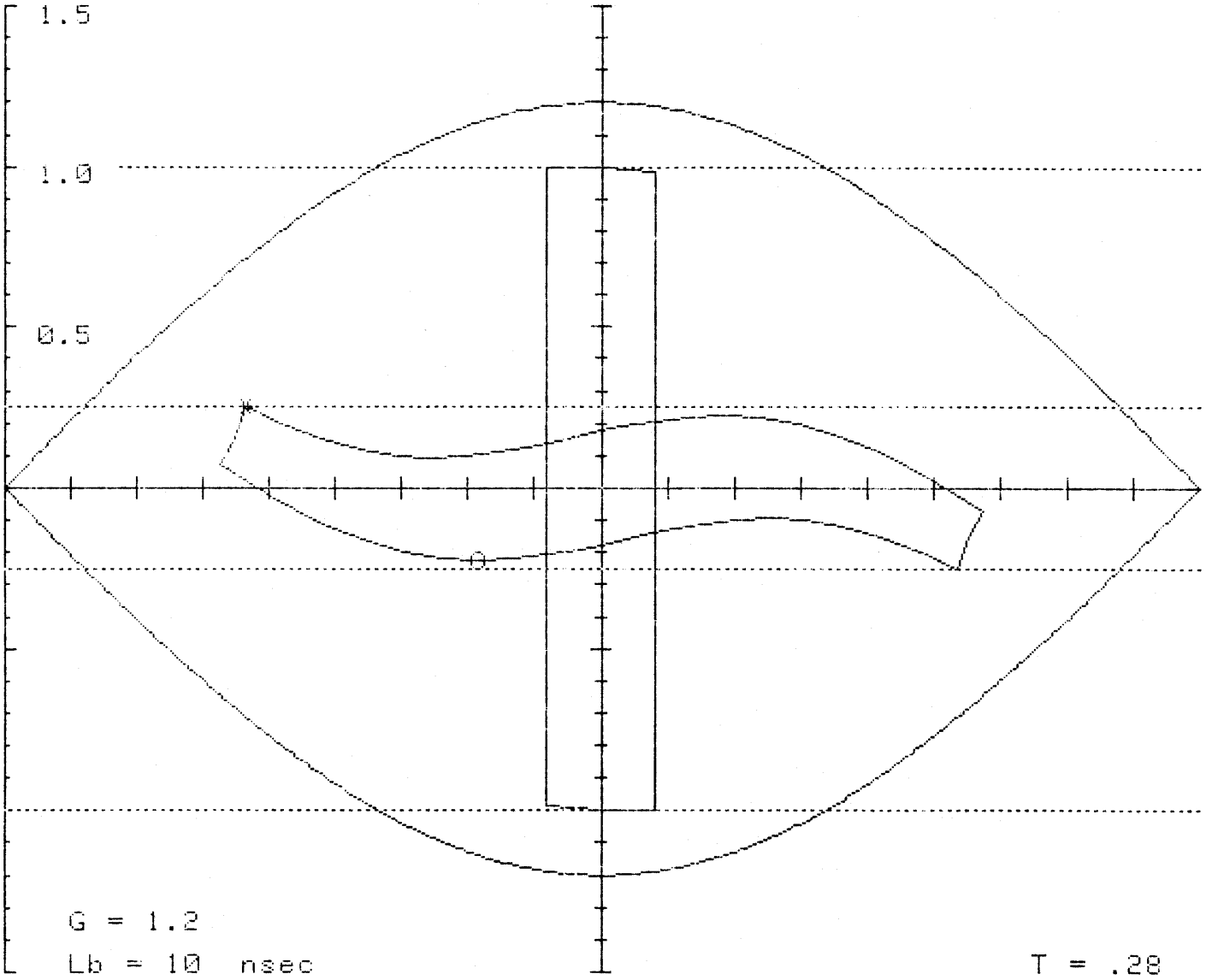
Bunchheight at significant points:

At middle of bunch :	V = .249		
Tip (point No.13):	V = .386	shown by:	*
Lowest (point No. 3):	V =-.257	shown by:	0



Bunchheight at significant points:

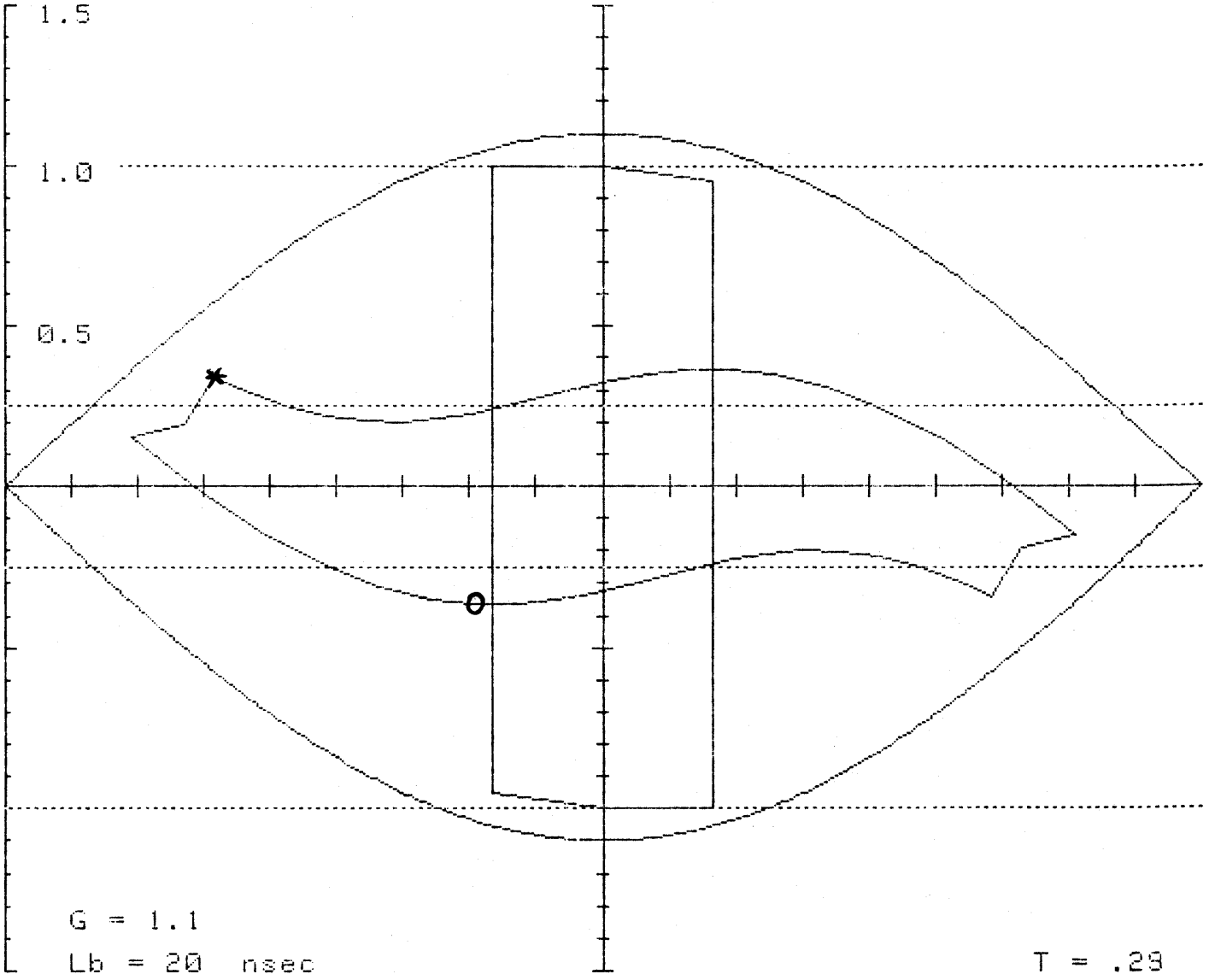
At middle of bunch :	V = .316		
Tip (point No.13):	V = .413	shown by:	*
Lowest (point No. 3):	V =-.330	shown by:	0



Bunchheight at significant points:

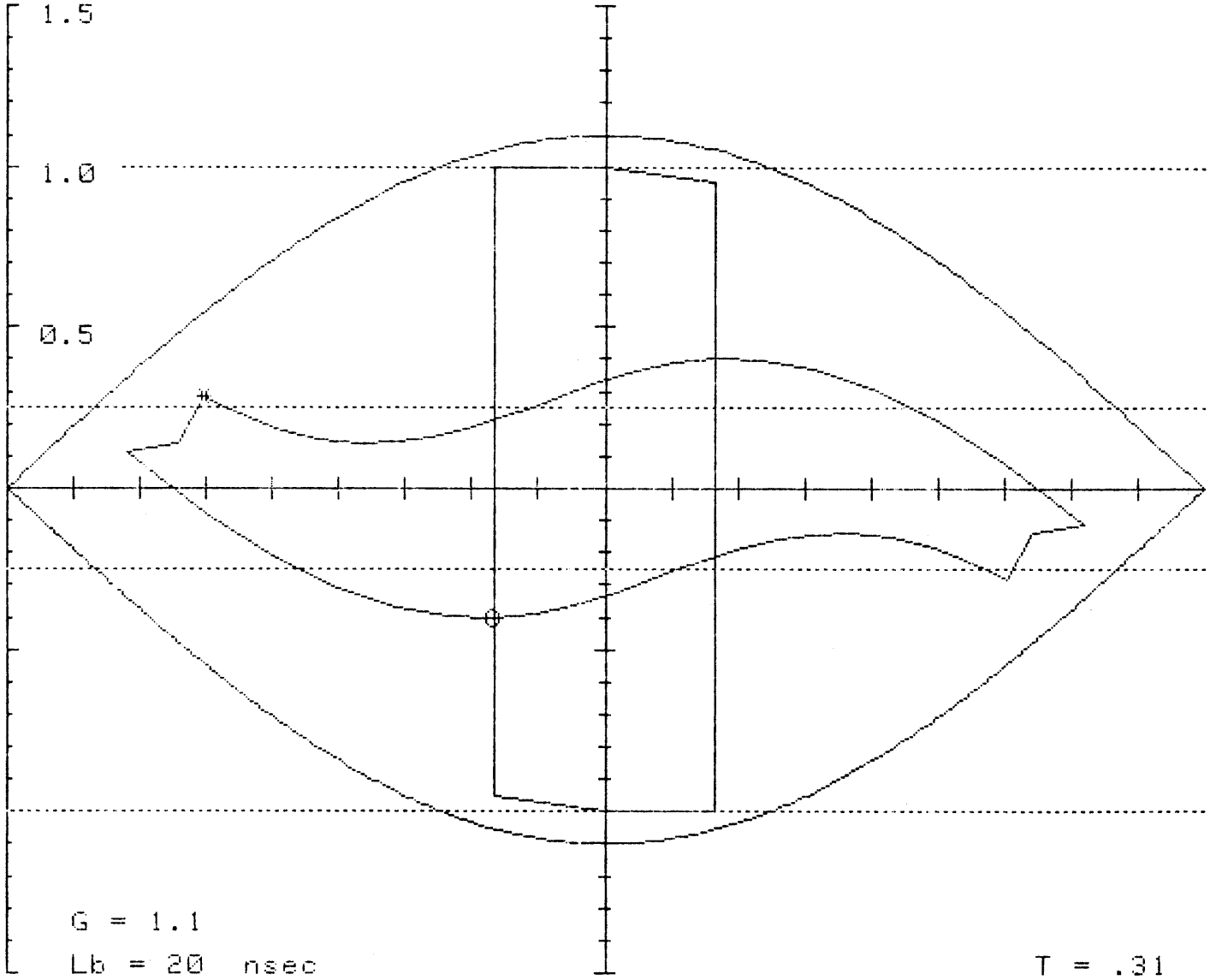
At middle of bunch :	V = .177		
Tip (point No.13):	V = .252	shown by:	*
Lowest (point No. 5):	V =-.223	shown by:	0

* and



Bunchheight at significant points:

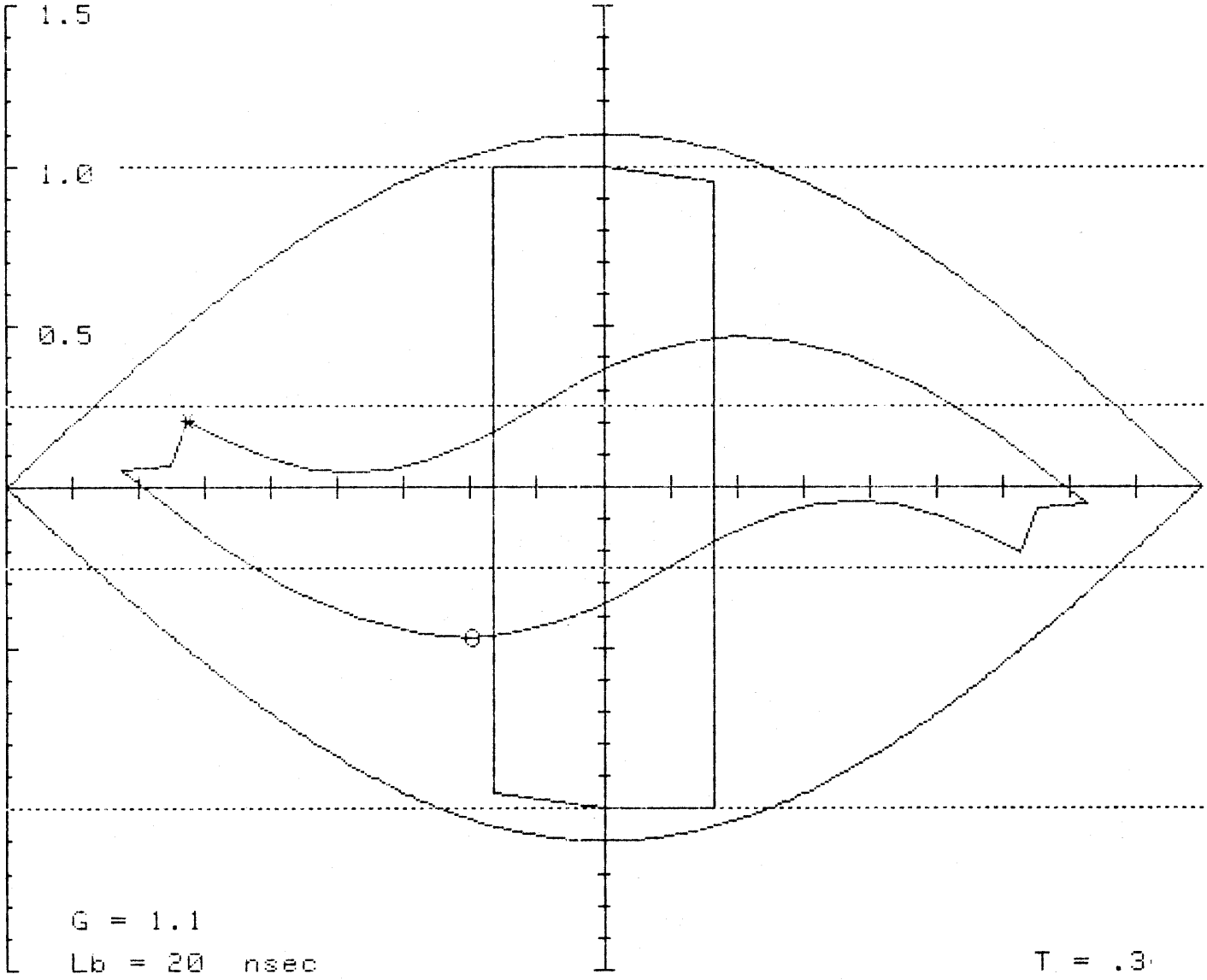
At middle of bunch :	V = .324		
Tip (point No.13):	V = .343	shown by:	*
Lowest (point No. 5):	V =-.364	shown by:	o



Bunchheight at significant points:

At middle of bunch :	V = .336		
Tip (point No.13):	V = .285	shown by:	*
Lowest (point No. 5):	V =-.403	shown by:	0

17h



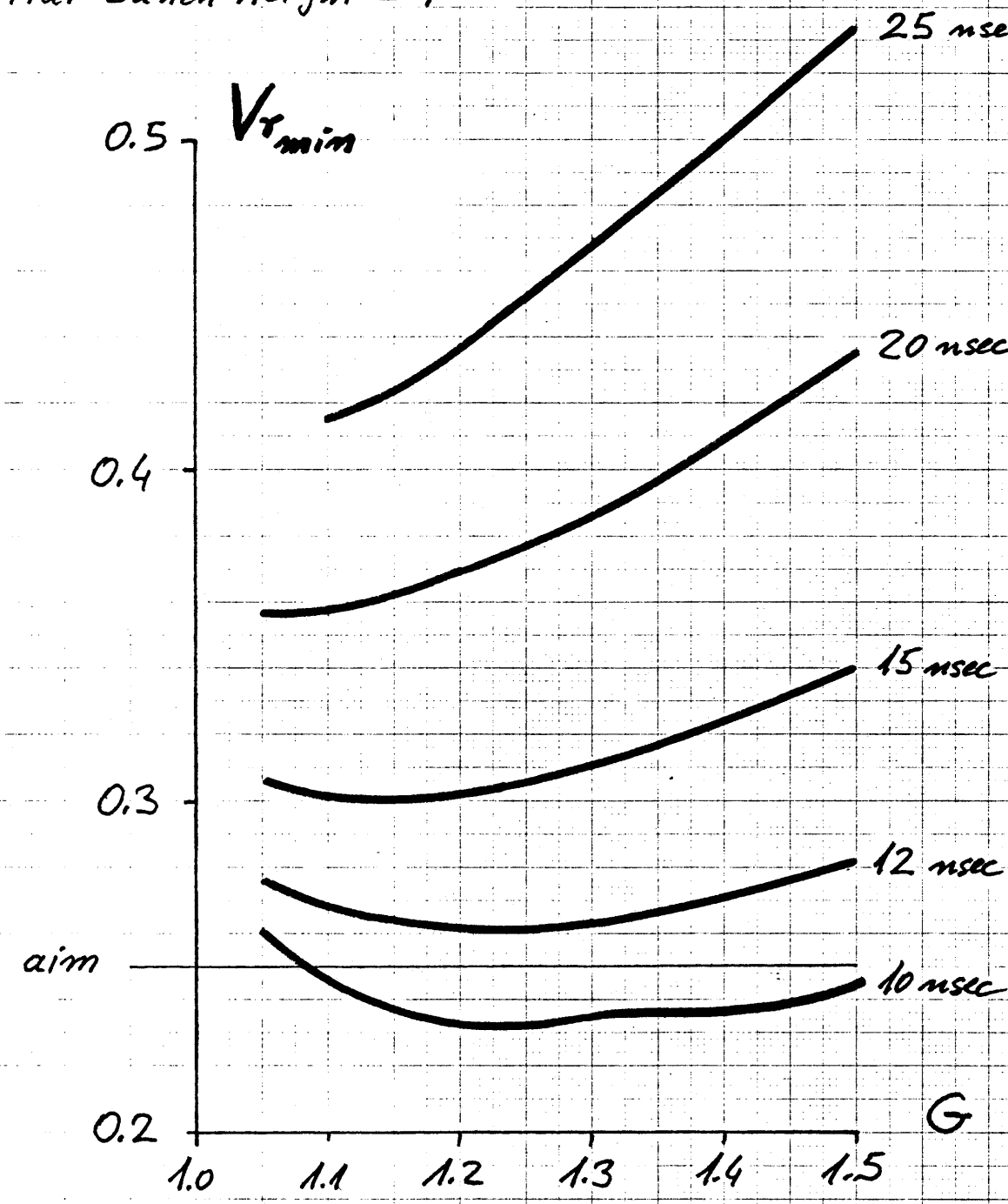
Bunchheight at significant points:

At middle of bunch :	V = .366		
Tip (point No.13):	V = .203	shown by:	*
Lowest (point No. 6):	V =-.466	shown by:	0

Minimum height of rotated bunch

as fct. of bucket height G and initial bunch length L_b (nsec)

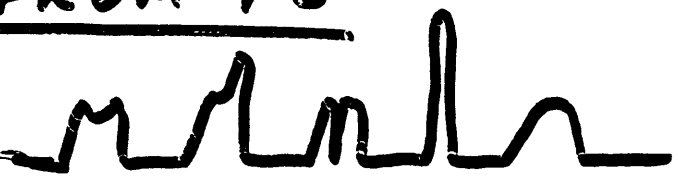
Initial bunch height = 1



AK. 11.82

BUNCH LENGTH FROM PS

Today 35 nsec

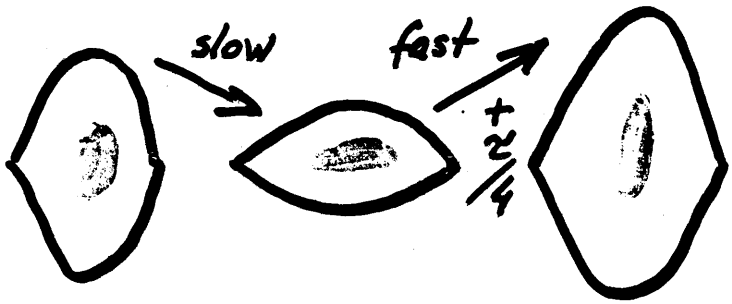


intrinsically 20 nsec + phase differences

Small improvements 30 nsec (less phase diff.)

Double V_{RF} jump 20 nsec

Garoby gymnastics



BUT:

Above values with $1.1 * 10^{13}$ ppp

When AC exists, we hope there will be $2 * 10^{13}$ ppp

and bunch length will increase with $\simeq \sqrt{I}$ (density limitation at PS transition)

CONCLUSION: PS improvement programme to reduce bunch length

We haven't talked about voltages yet

stationary bucket, half-height:

$$H = \sqrt{\frac{2eU}{\pi h \beta^2 E |\eta|}}$$

H in $\Delta p/p$
U in Volts
E in eV

$$\boxed{U = 2716\, H^2 \eta}$$

H in %
U in kV

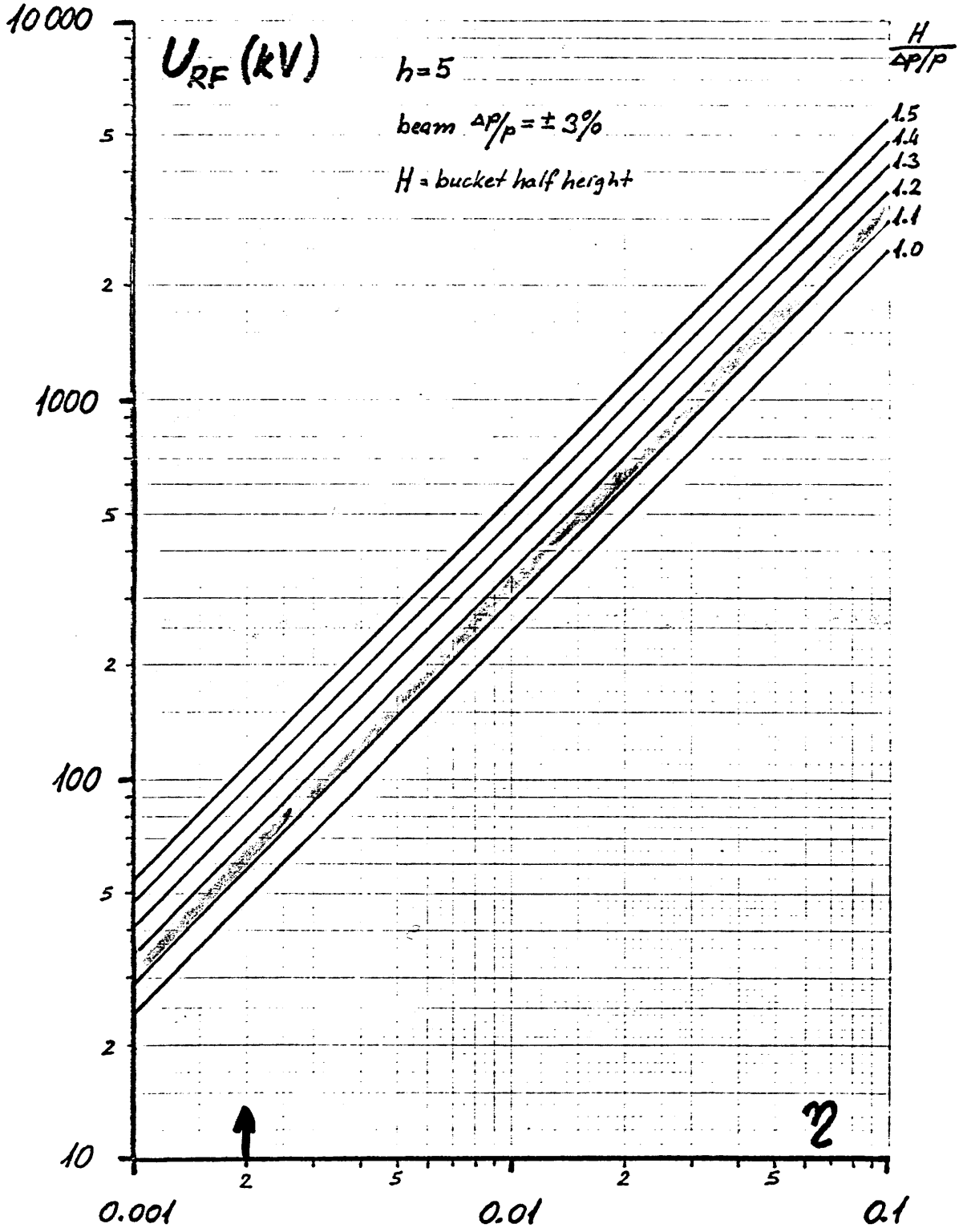
Synchrotron period:

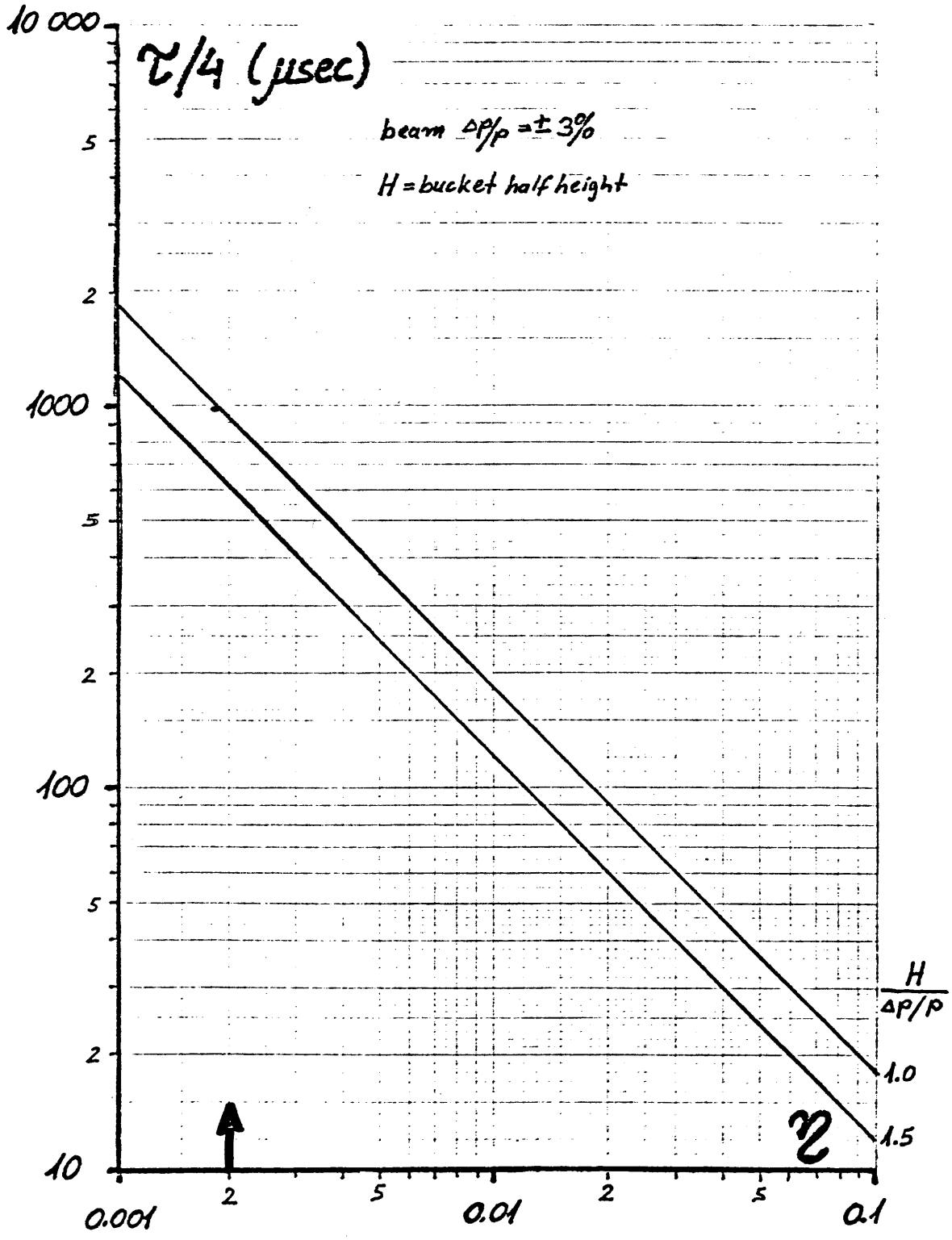
$$\tau = \sqrt{\frac{8\pi^3 E R^2}{h U c^2 |\eta|}}$$

τ in sec
E in eV
R in cm
U in Volts
c in cm/sec

$$\boxed{\tau = \frac{21.66}{H \eta}}$$

τ in μsec
H in %


10 000
5
2
1000
5
2
100
5
2
10
U_{RF} (kV)
h = 5
beam $\Delta p/p = \pm 3\%$
H = bucket half height
$\frac{H}{\Delta p/p}$
1.5
1.4
1.3
1.2
1.1
1.0
2
5
2
5
0.001
0.01
0.1
2


τ/4 (μsec)
beam Δp/p = ± 3%
H = bucket half height
10 000
5
2
1000
5
2
100
5
2
10
0.001
2
5
0.01
2
5
0.1
H/Δp/p
1.0
1.5
τ

CONCLUSIONS

1.) There are two major problems:

i) PS bunch length

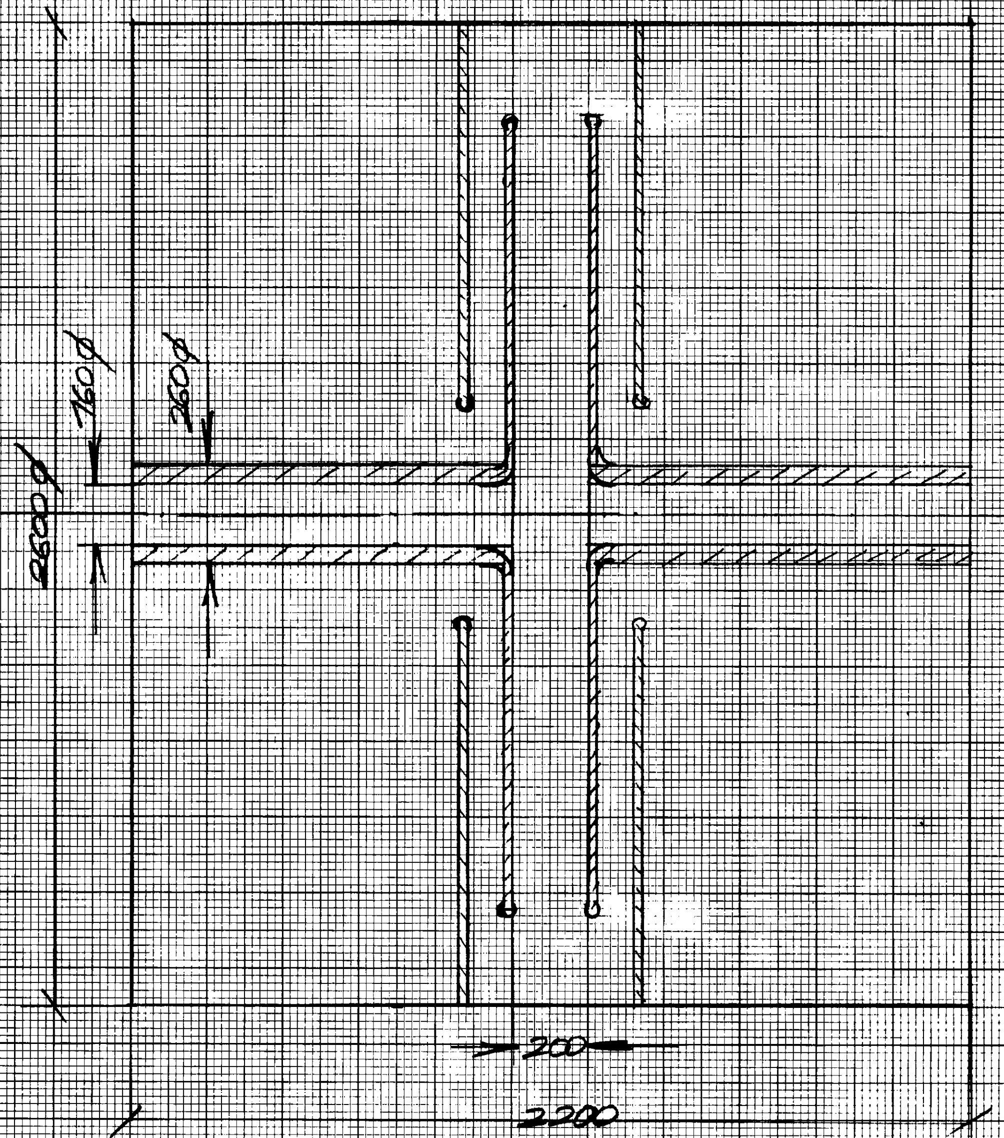
ii) { AC RF voltage
or (and?)
small and ~constant η

2.) Needs further studies:

i) Variation of β, γ, η over bucket height

ii) "linearization" of bucket by adding higher harmonics RF systems

iii) Adiabatic turn-off after rotation



Frequency $f = 9.55$ [MHz]

Voltage $U = 1E6$ [V]

$r/Q = 54,6$ [Ω]

$Q = 13'580$

Shunt impedance $r = 741.6$ [kΩ]

Stored energy $E = 157.5$ [Wsec]

Equivalent capacitance $C = 315$ [pF]

RF - power $P = \frac{U^2}{2r} = 674$ [kW]

Kilpatrick's limit: $\frac{1\,MV}{172\,E\text{-}3} = 5.81$ [MV/m]

Time constant $\tau = \frac{Q}{\pi} T = 452$ [μsec]

Rapid reduction of RF voltage by induced spark (Laser, HV-ignitor)

Pirkl, 22 mar 82