$\bar{p}$ note 481

NEUTRALISATION EXPERIMENTS WITH PROTON AND ANTIPROTON STACKS - ION SHAKING.

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AND A. PONCET (CERN)

MARCH 12TH TO 25TH, 1989

NEUTRALISATION (ELECTRONS)

EXPERIMENTS WITH A PROTON STACK IN THE ACCUMULATOR

(15 - 16 March 1989)

(A. PONCET / CERN)

(A) EXCITATION OF NON LINEAR RESONANCES 3/15/89

$\phi = 1.6 \cdot 10^{11}$

A TUNE SCAN WAS MADE AROUND THE 15TH AND 18 TH ORDER RESONANCES DURING WHICH THE EMITTANCES GROWTH WAS RECORDED. NO SIGN OF NEUTRALISATION INDUCED EXCITATION OF RESONANCES. THEE EMITTANCES GROWTH RATES WERE*

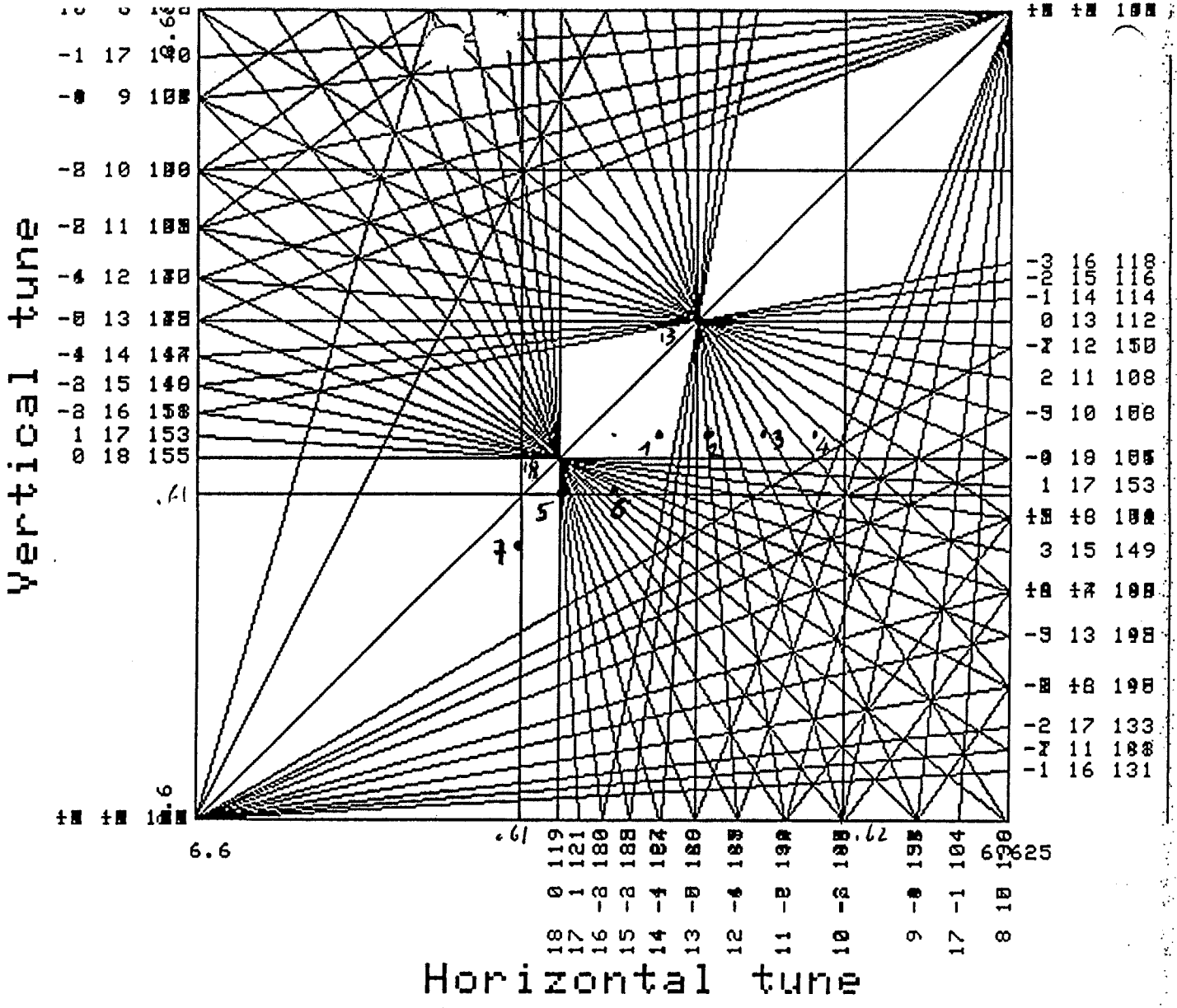
$$dE_H/dt \simeq 1.8 \text{ to } 2\ \pi/hr$$

$$dE_V/dt \simeq 1.3 \text{ to } 1.5\ \pi/hr$$

THIS DESPITE THE FACT THAT THE CLEARING ELECTRODES HAD THE WRONG POLARITY.

FURTHERMORE, WE FAILED TO MEASURE ANY INCOHERENT TUNE SHIFT DUE TO NEUTRALISATION.

*: Note: ALL COOLING SYSTEMS WERE OFF. THE VERTICAL RATE SUGGESTS THAT IT IS NOT ONLY DUE TO INTRABEAM SCATTERING AND THAT THE RESIDUAL GAS IS INFLUENT (TO BE CHECKED BY CALCULATION).

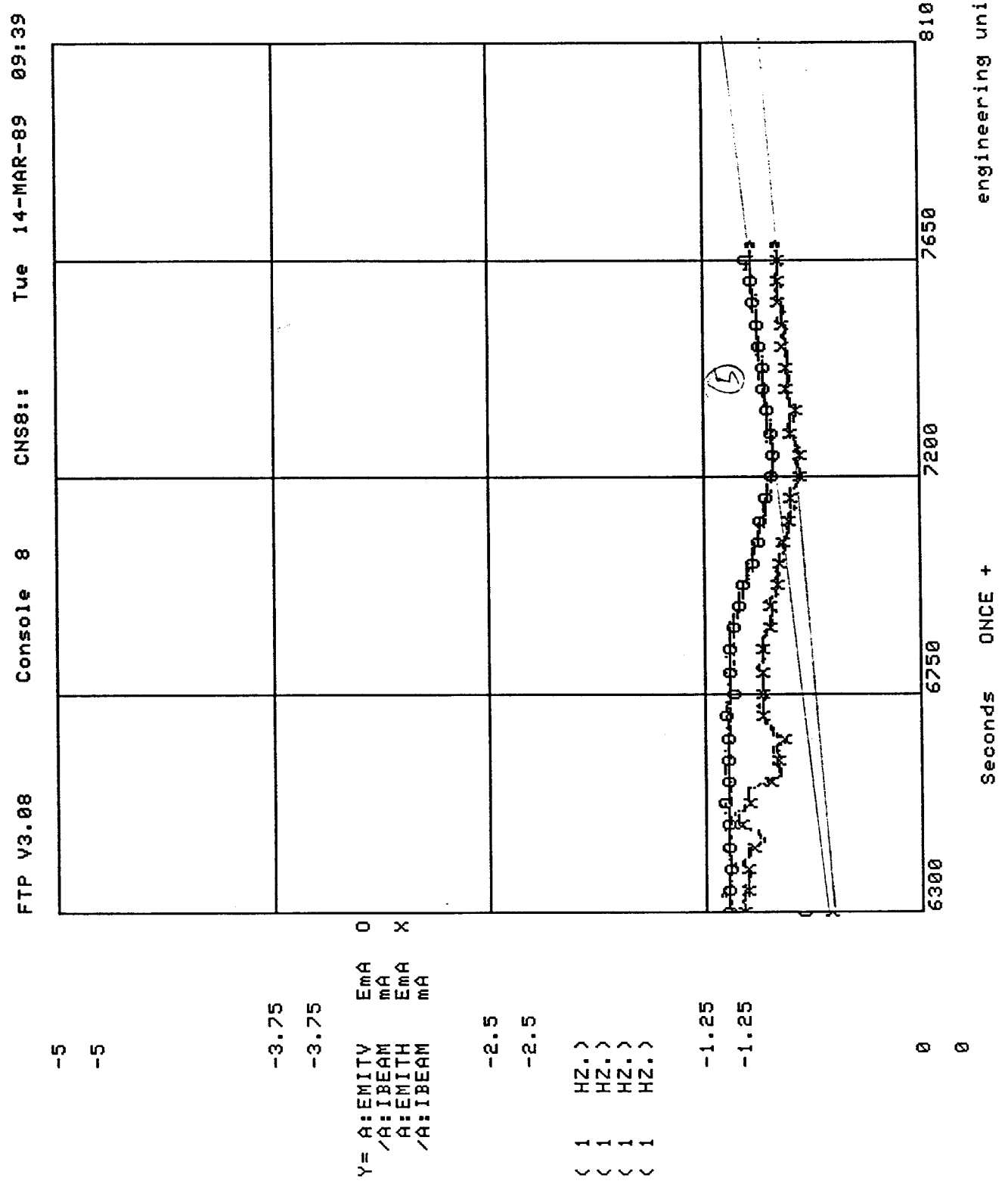


Resonances from order 1 to 19

CONSOLE LOCATION 08; AP10 14-MAR-1989 11:47
Fast Time Plot

Proton S

Tune Scan around 13th and 18th order resonances and heating rates



(B) ELECTRON NEUTRALISATION AT HIGH BEAM INTENSITY

16th March 1989

PROTON STACK $\simeq 10^{12}$

THE CLEARING ELECTRODES POLARITY HAS BEEN INVERSED TO PERMIT EFFICIENT CLEARING.

1. MEASUREMENT OF THE SPACE CHARGE TUNE SHIFT.

WE MEASURED THE INCOHERENT SPACE CHARGE TUNE SHIFT BY BLOWING UP A COOL BEAM (ν 1π) BY TURNING OFF THE DAMPER (γ_t (>4π)) ON THE $125 - Q_{H,V}$ LINE AT 79 MHz.

WE MEASURED A SHIFT OF +250 Hz

$$\Delta\omega_n = 250\ \text{Hz} \Rightarrow \Delta Q_{H,V} = \frac{-250}{629\times10^3} = 3.9\times10^{-4}$$

(629 kHz, revolution frequency)

WHICH FITS WITH 0.8π – 1π EMITTANCES.

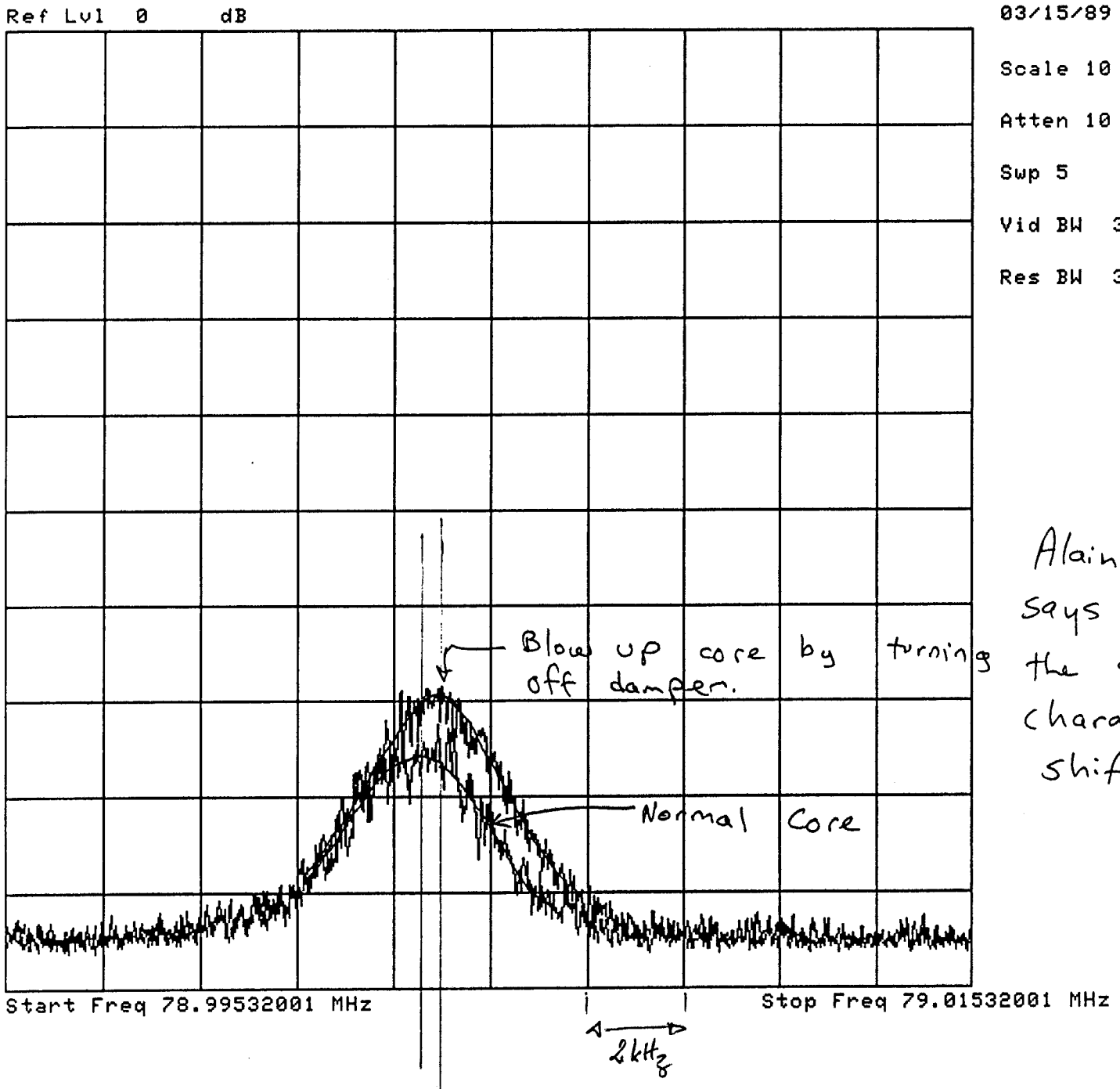
INCOHERENT SPACE CHARGE TUNE SHIFT:

$$\Delta Q_{H,V} = -\frac{r_p\ N}{E_{H,V}\left(1+\sqrt{E_{V,H}/E_{H,V}}\right)\gamma^3}$$

$$= -3\times10^{-4} \quad \text{WITH } 1\pi$$

$$\left(3.9\times10^{-4} \quad \text{WITH } .8\pi\right)$$

NOTE THAT DUE TO THE γ^{-3} DEPENDENCE, THIS IS MUCH LESS ($2.5^3 \simeq 16$ times) THAN THE AA, AND THIS HAS TO DO WITH LANDAU DAMPING OF INSTABILITIES!



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hor=20, hor=30, acc dampers

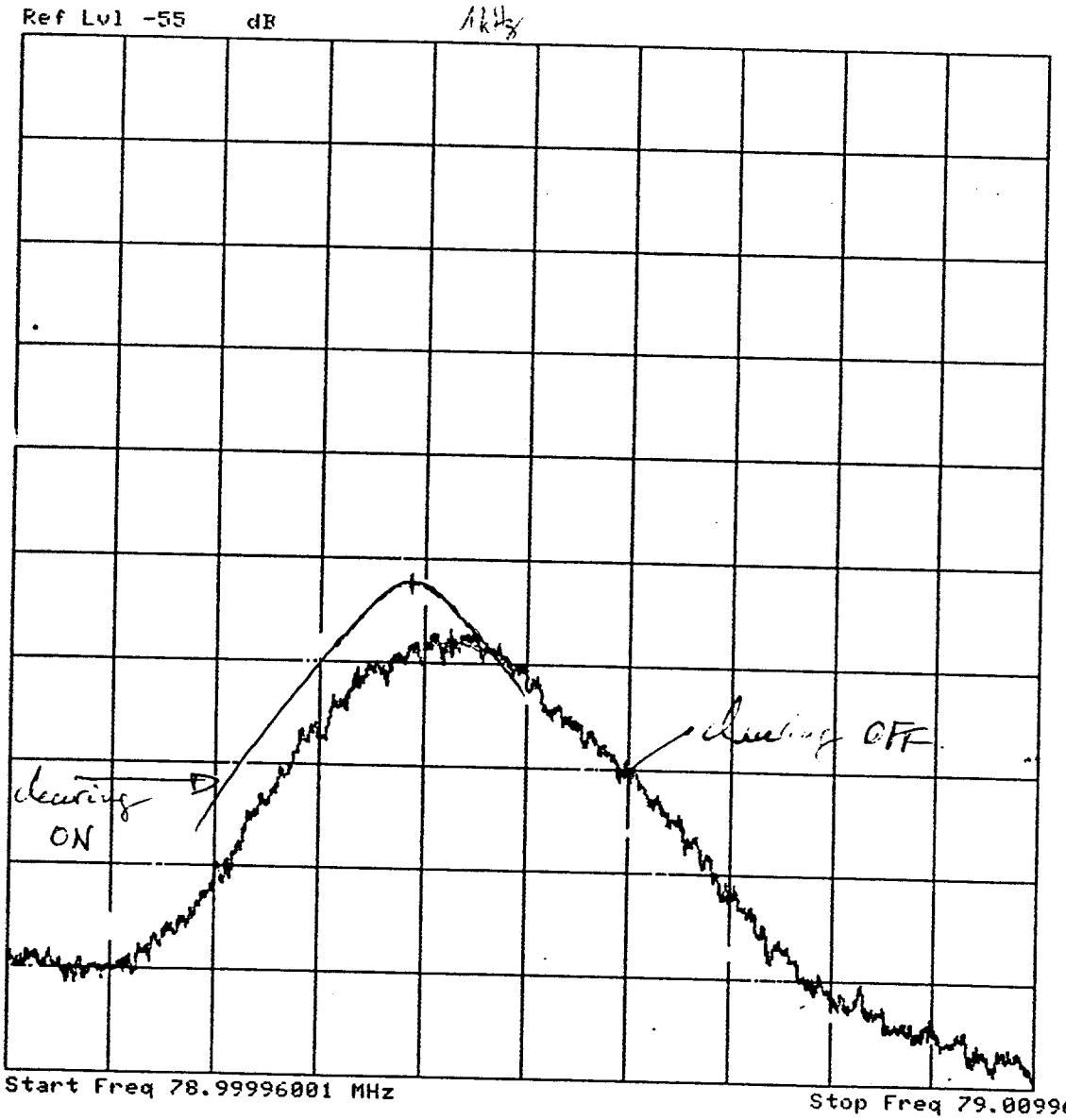
Alain Poncet says this is the space charge tune shift.

SVDH

Clearing ON with positive polarity +100 V.

CONSOLE 08 15-MAR-1989 20:23
P28 GRAPHICS DISPLAY
ERSE blue/yellow

(A)

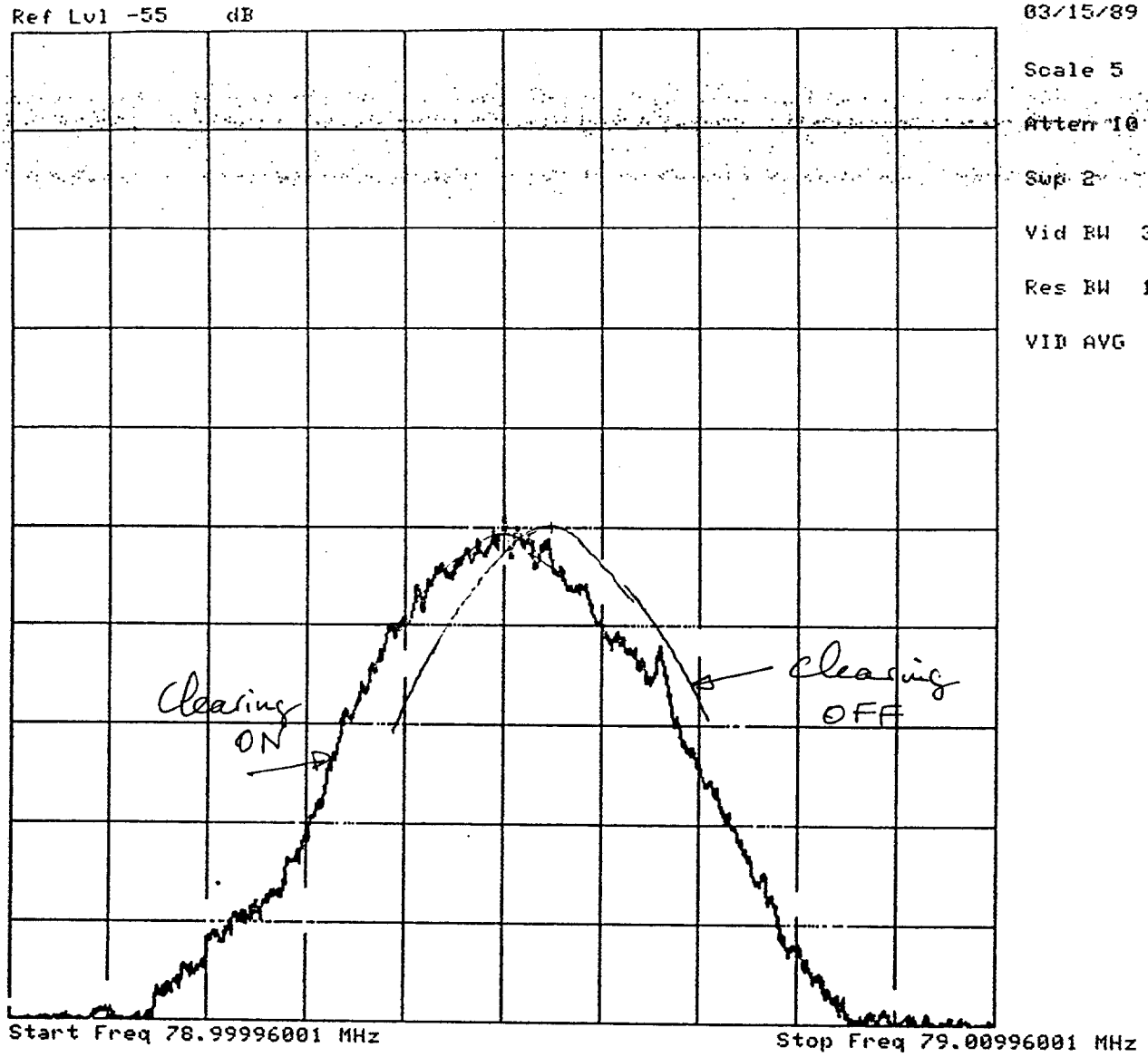


Vertical schottky band

$$\omega_m = (125 + Q_v) f_r$$

$$\Delta\omega_m = \Delta Q f_r$$

$\Delta\omega_m = 400 Hz \Rightarrow \Delta Q_v = 6.3 \times 10^{-4}$



Horizontal Schottky band

$\omega_n = (125 + Q_H) f_r$

$\Delta\omega_n = 500\,Hz$; $\Delta Q_V = 7 \times 10^{-4}$

if emittances $\leq 2\pi$

this means* 5.4 % neutralisation

(if 1π → 2.7 % neutralisation)

* assuming no neutralisation with clearing ON

CONSOLE 08 15-MAR-1989 20:47
P28 GRAPHICS DISPLAY
REVERSE blue/yellow

2. MEASUREMENT OF THE NEUTRALISATION TUNE SHIFT

TURNING ON/OFF THE CLEARING ELECTRODES, THE ELECTRON INDUCED POSITIVE TUNE SHIFT WAS MEASURED AND FOUND TO BE

$$\Delta Q_{H,V} = \frac{r_p N \eta}{E_{H,N}\left(1+\sqrt{E_{V,H}/E_{H,V}}\right)\gamma} = .013\,\eta = 7\times10^{-4}$$

[$(.25 - Q_{H,V})$ shift of $\sim$ 450 kHz electrodes ON/OFF]

ASSUMING NEGLIGIBLE NEUTRALISATION WITH ELECTRODES ON, THIS GIVES

$$\eta \sim 5.4\,\%.$$

WITH CLEARING OFF

IS THIS CONSISTENT WITH THE VACUUM?

$$\sigma_{H,V} = \sqrt{\frac{E_{H,V}\beta}{\pi}} \sim 3.4 \text{ MM}$$; ROUND BEAM OF UNIFORM DENSITY:

$$r_b = \sqrt{2}\,\sigma \sim 5 \text{ MM}$$

BEAM POTENTIAL $$V = \frac{I}{4\pi\varepsilon_0\beta c}\left(1+2\ln\frac{r_b}{a}\right)$$

a chamber radius $\sim$ 50 MM

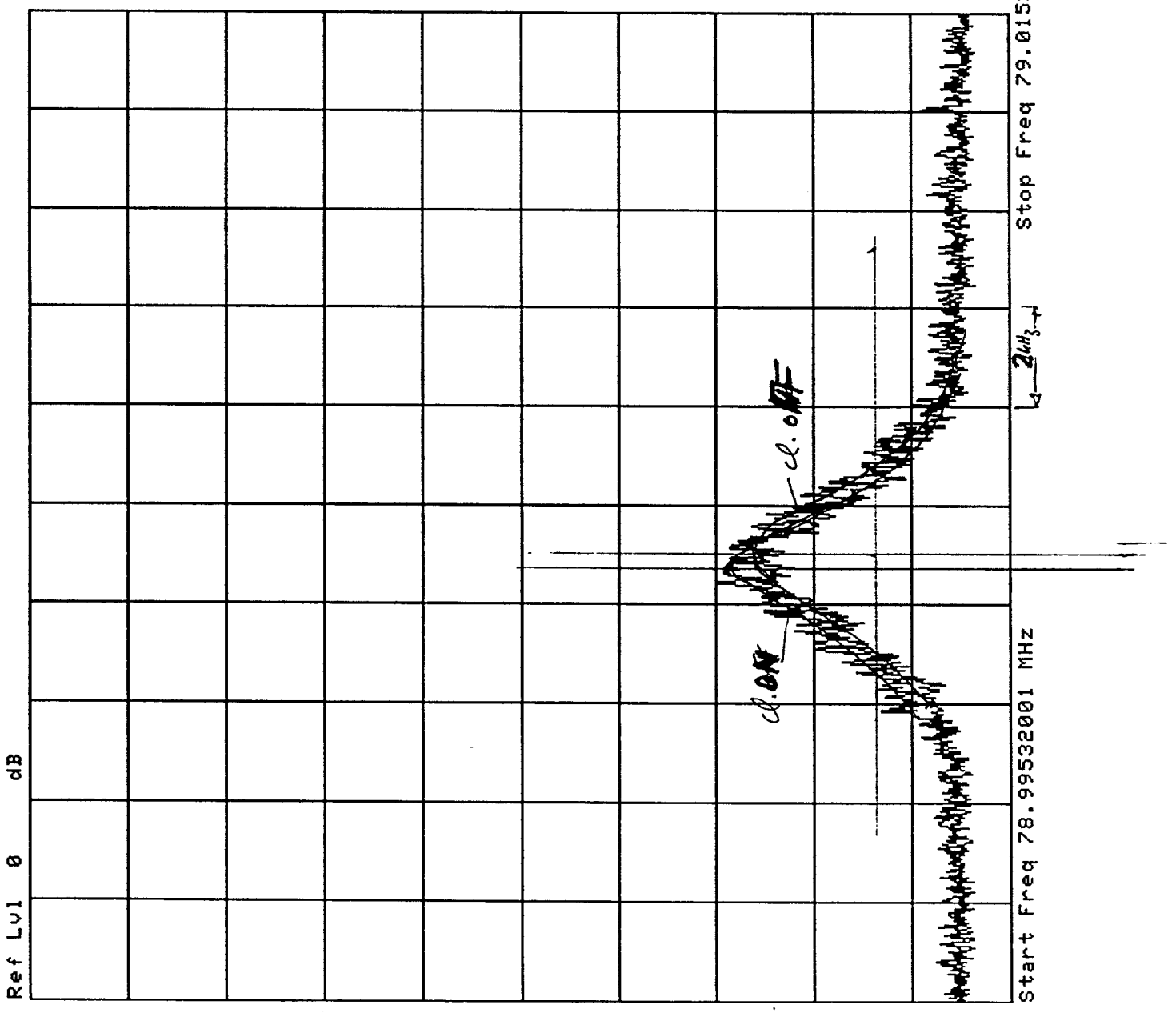
$$V_0 \sim 16{,}8 \text{ VOLTS}$$

THE PRODUCTION RATE OF TRAPPABLE ELECTRONS (BORN WITH SUFFICIENTLY LOW ENERGY) CAN BE SHOWN TO BE

$$R_p\,[\text{sec}^{-1}] = \frac{2\pi m_e c^2 r_e^2 c}{\beta}\,\frac{NZ}{V_0}\,\ln\left(\frac{b_{max}}{b_{min}}\right)^2$$

WHERE b_{max} AND b_{min} ARE THE MAXIMUM AND MINIMUM THAM — PARAMETERS OF THE IONIZING COLLISION

CONSOLE LOCATION 14; AP10 15-MAR-1989 13:33
electron induced tune shift



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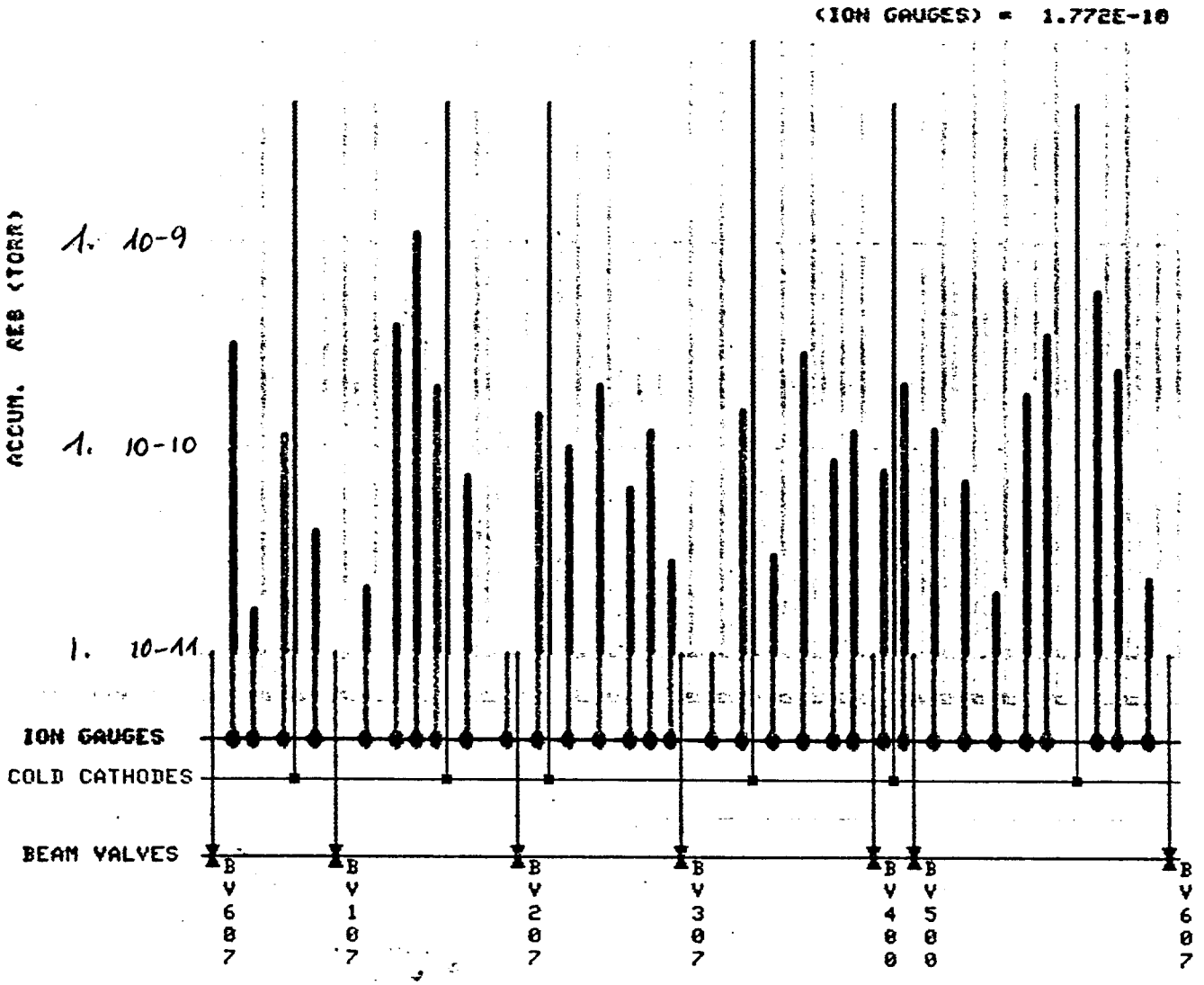
8

REVERSE blue/yellow

ACCUMULATOR PRESSURE PROFILE



$$\ln\left(\frac{b_{max}}{b_{min}}\right)^2 = \ln\left(\gamma^2 \beta^4 \frac{m_e c^2}{2 E_I^2 \alpha^2} V_0\right)$$

$\frac{m_e c^2}{\alpha^2} = \frac{c\hbar}{r_e} = 7 \cdot 10^{-11}$; E_I (MINIMUM IONIZING ENERGY) $\simeq 13.5\, Z$ ($Z = 1$ FOR HYDROGEN, 14 FOR CO)

ONE FINDS A PRODUCTION RATE OF

$$H_2: \quad R_p \simeq 4 \cdot 10^8 \, P\,[\text{TORR}] \quad [\text{sec}^{-1}]$$

$$CO: \quad R_p \simeq 2.4 \times 10^9 \, P\,[\text{TORR}] \quad [\text{sec}^{-1}]$$

"CLEAN" SECTORS:

$$P_T \simeq 10^{-10} \text{ TORR} \qquad 90\%\ H_2, \quad 10\%\ CO$$

$$\Rightarrow \begin{cases} P_{H_2} \simeq 1.8 \times 10^{-10} \text{ TORR} \ * \\ P_{N_2} \simeq 2 \times 10^{-11} \text{ TORR} \end{cases}$$

(* DUE TO RELATIVE SENSITIVITY OF ION GAUGES)

$$\Rightarrow R_p \simeq 0.1 \ [\text{sec}^{-1}]$$

"DIRTY" SECTORS:

$$P_T \simeq 10^{-9} \text{ TORR} \qquad 50\%\ H_2, \quad 50\%\ CO$$

$$\begin{cases} P_{H_2} \simeq 5 \times 10^{-10} \\ P_{CO} \simeq 5 \times 10^{-10} \end{cases}$$

$$\Rightarrow R_p \simeq 1.4 \ [\text{sec}^{-1}]$$

MULTIPLE COULOMB SCATTERING IS THE ONLY CLEARING MECHANISM WITH ELECTRODES OFF:

CLEARING RATE BY ELECTRON HEATING:

$$R_c\ [sec^{-1}] = \frac{1}{V_0}\frac{dE}{dt}$$

RATE OF ENERGY CHANGE $\frac{dE}{dt} = 2 m_e c^2 r_e^2 \frac{I}{\beta^2 e a^2} \ln\left(\frac{\beta^2 \gamma a}{r_e}\right)$

ISR Beam $\begin{cases} I = 10\ A \\ a = 5\cdot 10^{-3}\ m \\ \gamma = 28 \end{cases} \Rightarrow \frac{dE}{dt} = 1580\ eV/s$

(Note that ION HEATING WOULD BE $\frac{m_p Z}{m_e}$ WEAKER!)

WEAK ($\ln$) DEPENDENCE ON γ, SAME BEAM SIZE, YIELDS FOR 100 mA:

$$\frac{dE}{dt} \simeq 15.8\ eV/sec$$

FOR THE ACCUMULATOR - THEREFORE, WITH $V_0 = 16.8\ V$

$$R_c = \frac{1}{V_0}\frac{dE}{dt} \simeq 1\ [sec^{-1}]$$

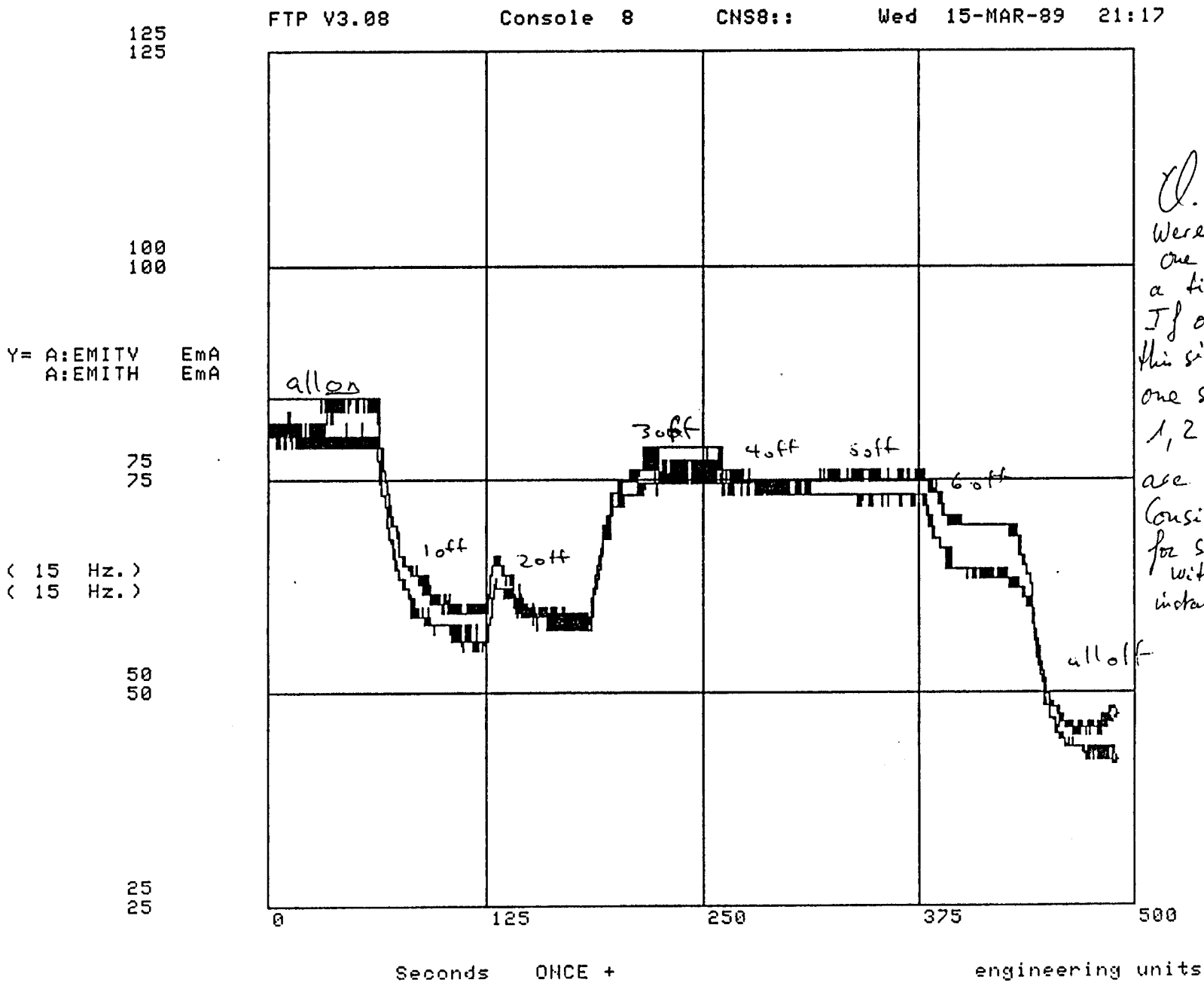
AND THE NEUTRALISATION WITH "CLEAN" VACUUM

$$\eta = \frac{R_p}{R_c} = \frac{.1}{1} \simeq 10\%$$

"DIRTY" SECTOR: $\eta \simeq 1$

ON THE AVERAGE WE MEASURE $\sim 5.4\%$ FROM TUNE SHIFTS, BUT THE PRESSURE IN THE "CLEAN" PART OF THE MACHINE IS PROBABLY $< 10^{-10}$ TORR ...

CONSOLE LOCATION 08; AP10 15-MAR-1989 21:25
Fast Time Plot



Cl. electrodes were switched one sector at a time. If one interprets this signal as a time shift one sees that sectors 1, 2 and 6 (to a lesser extent) are worse consistent (but for sector 2) with triggered instabilities.

($P = 10^{12}$ protons)

3 - ELECTRON INDUCED TRANSVERSE COHERENT INSTABILITIES

WITH CLEARING OFF, MANY UNSTABLE BANDS $n - Q$ WERE OBSERVED ON TRANSVERSE SCHOTTKY SPECTRA MEASURED WITH THE WIDE BAND DAMPER PICKUP, AT FREQUENCIES RANGING FROM $\sim$20 MHZ TO $\sim$50 MHZ, IN BOTH PLANES.

THIS IS DUE TO ELECTRON INDUCED DIPOLE COHERENT INSTABILITIES.

IN ADDITION A COOL STACK WAS SEEN TO BLOW UP (EMITTANCES) IN BOTH PLANES, WITH CLEARING OFF.

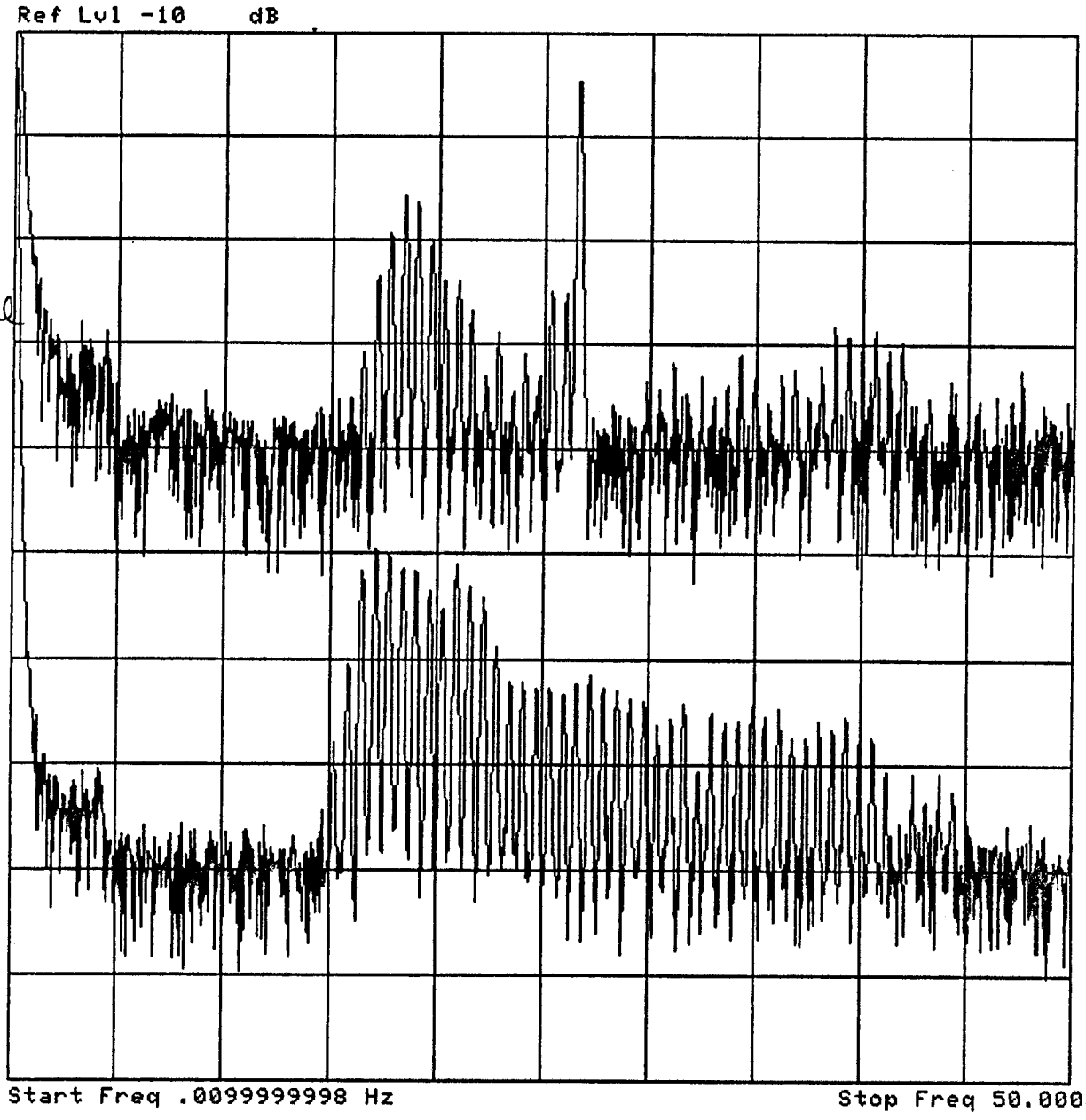
TURNING OFF THE ELECTRODES SECTOR BY SECTOR REVEALED THAT THE "DIRTY" SECTOR 1 WAS BY FAR THE MOST OFFENDING (MANY MORE LINES):

CL. OFF	SECTOR 1 :	SEVERAL LINES UNSTABLE
	2 :	NO LINES
	3 :	"
	4 :	"
	5 :	1 LINE AT 30 MHZ
	6 :	NO LINE

THIS IS (MORE OR LESS) CONSISTENT WITH THE PRESSURE DISTRIBUTION.

IN ADDITION, THE NEUTRALISATION TUNE SHIFT AS RECORDED BY "EMITTANCE" CHANGE DUE TO THE NARROW (OR NON FLAT RESPONSE) BAND OF THE TUNE RECEIVERS CONFIRMED THAT SECTOR 1 WAS THE WORSE, NEUTRALISATION - WISE.

CONSOLE LOCATION 14, AP10 15-MAR-1989 11:48
hor=20, hor=30, acc dampers



03/15/89 1100
Scale 10 dB/div
Atten 0 dB
Swp .03 sec
Vid BW 30 KHz
Res BW 100 KHz

Horizontal

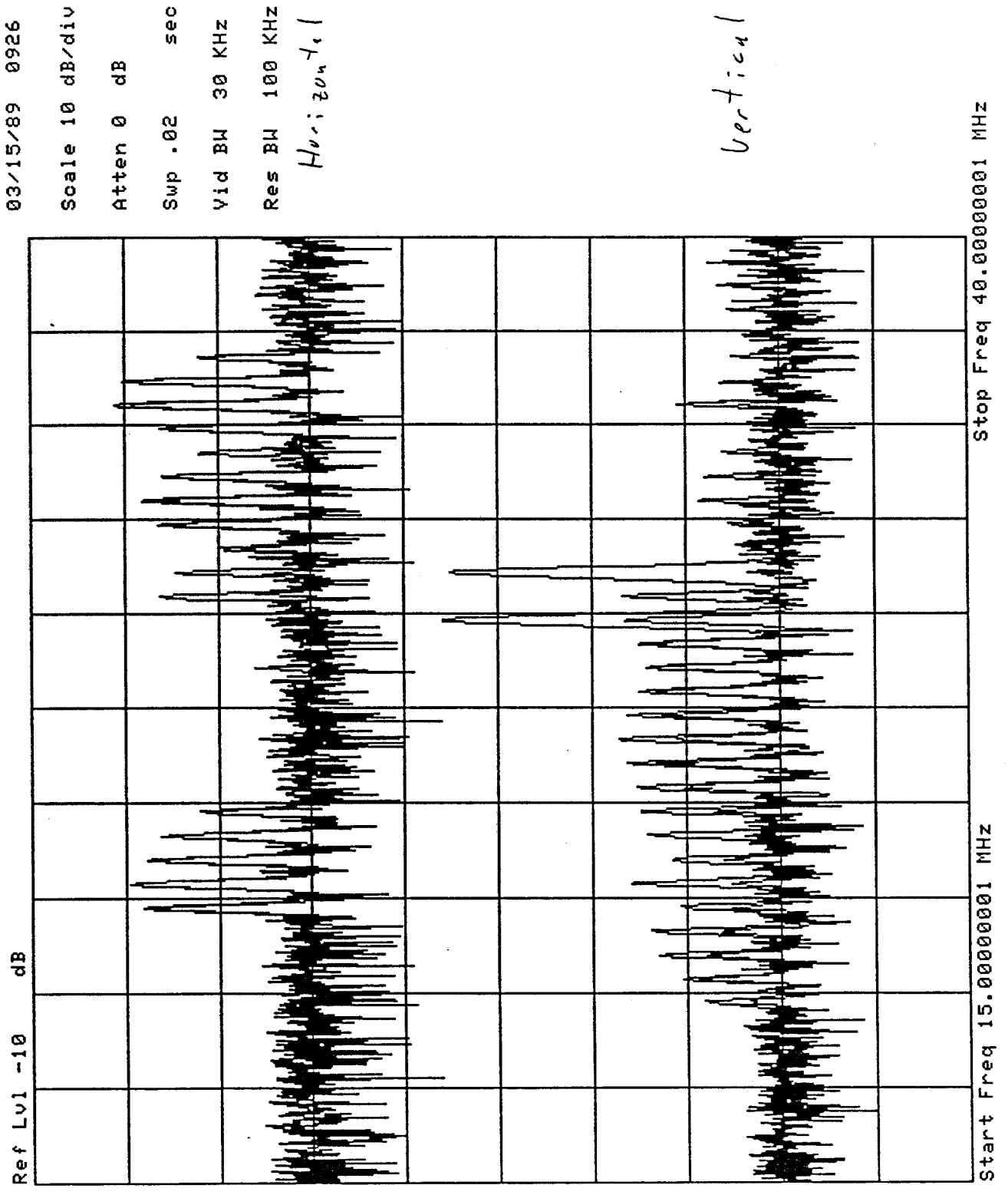
Vertical

electron induced coherent instabilities

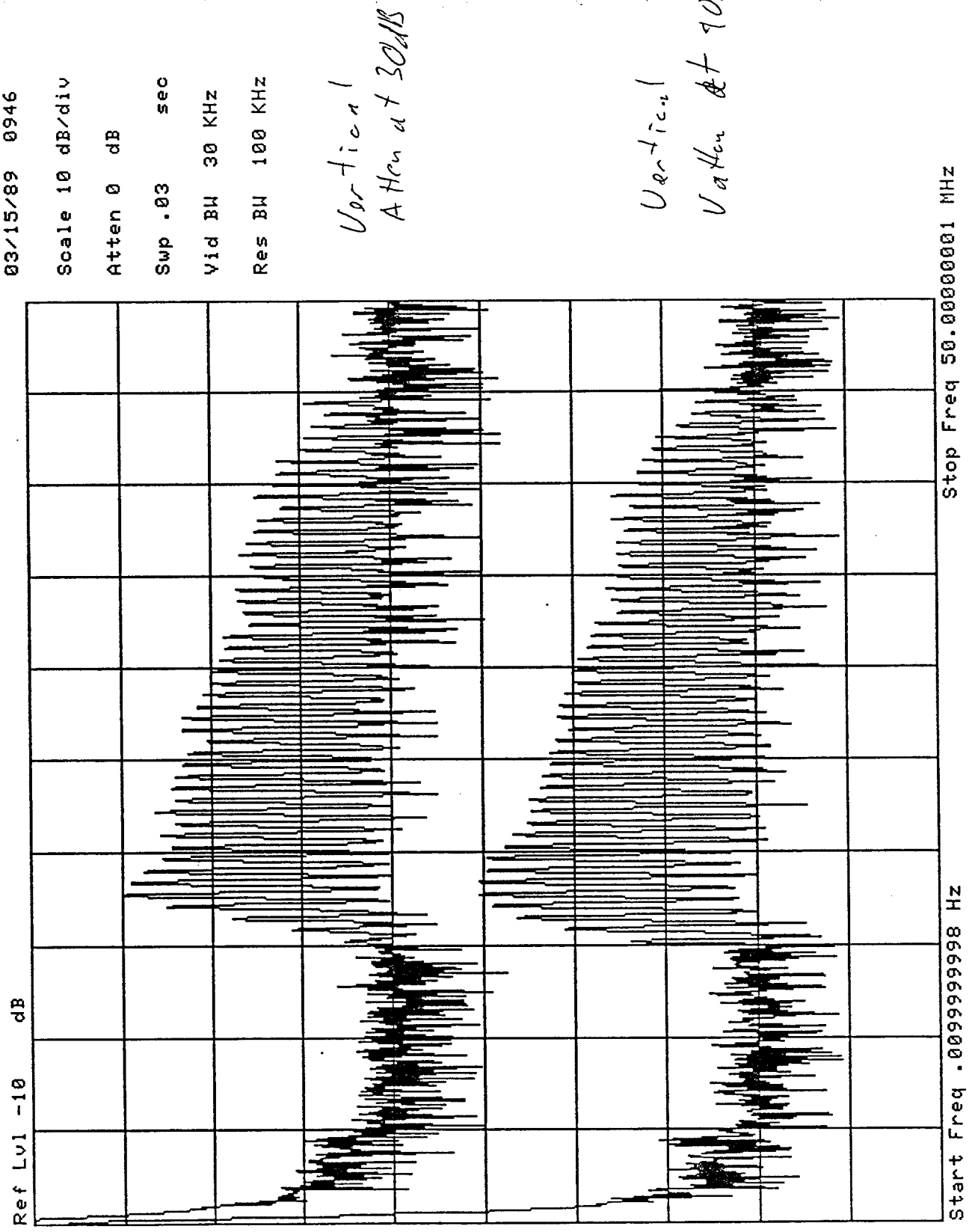
(clearing off)

(proton stack = 10^{12})

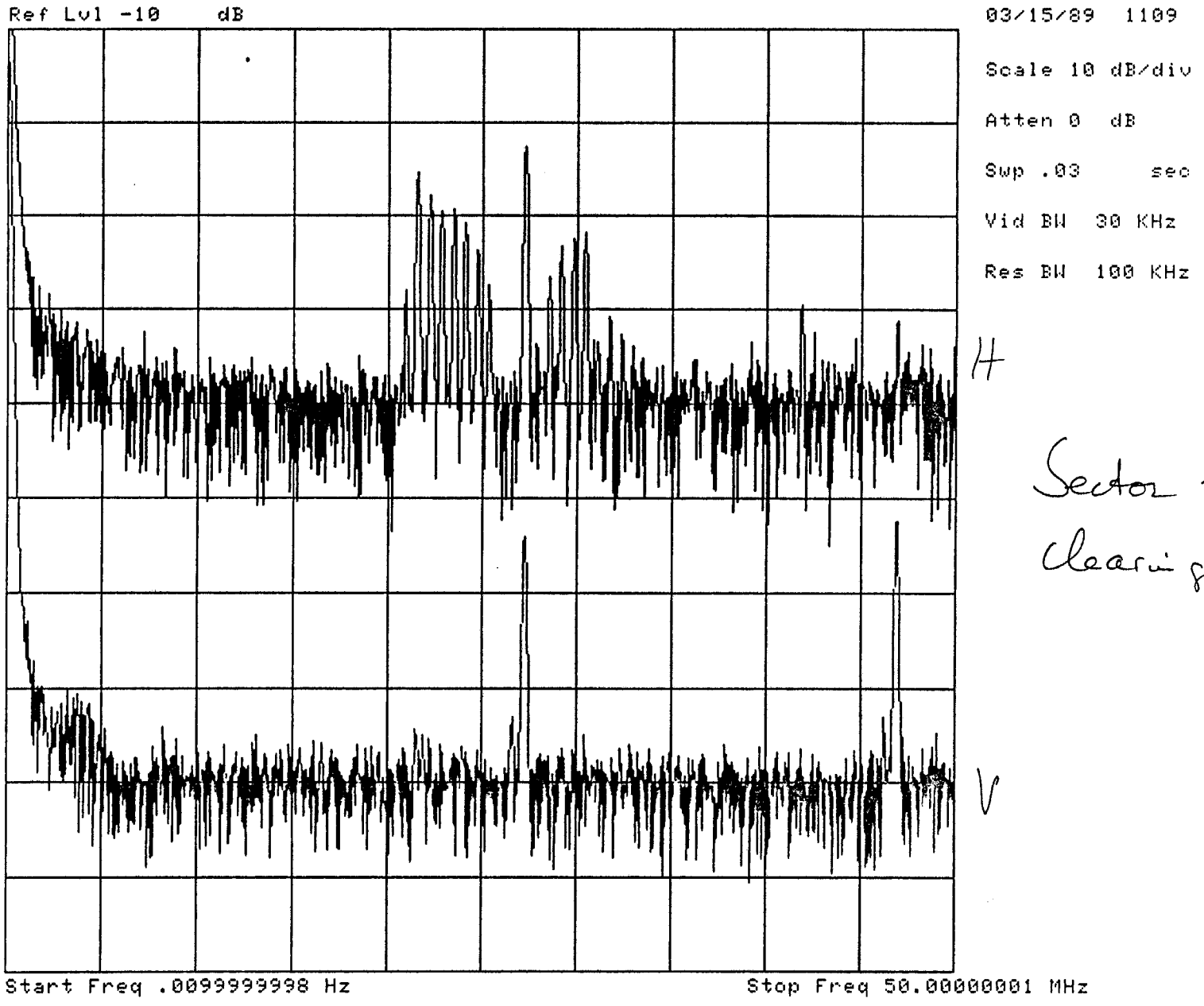
CONSOLE LOCATION 15; AP10 15-MAR-1989 09:30
P40 GRAPHICS DISPLAY ©



CONSOLE LOCATION 15; AP10 15-MAR-1989 09:48
P40 GRAPHICS DISPLAY

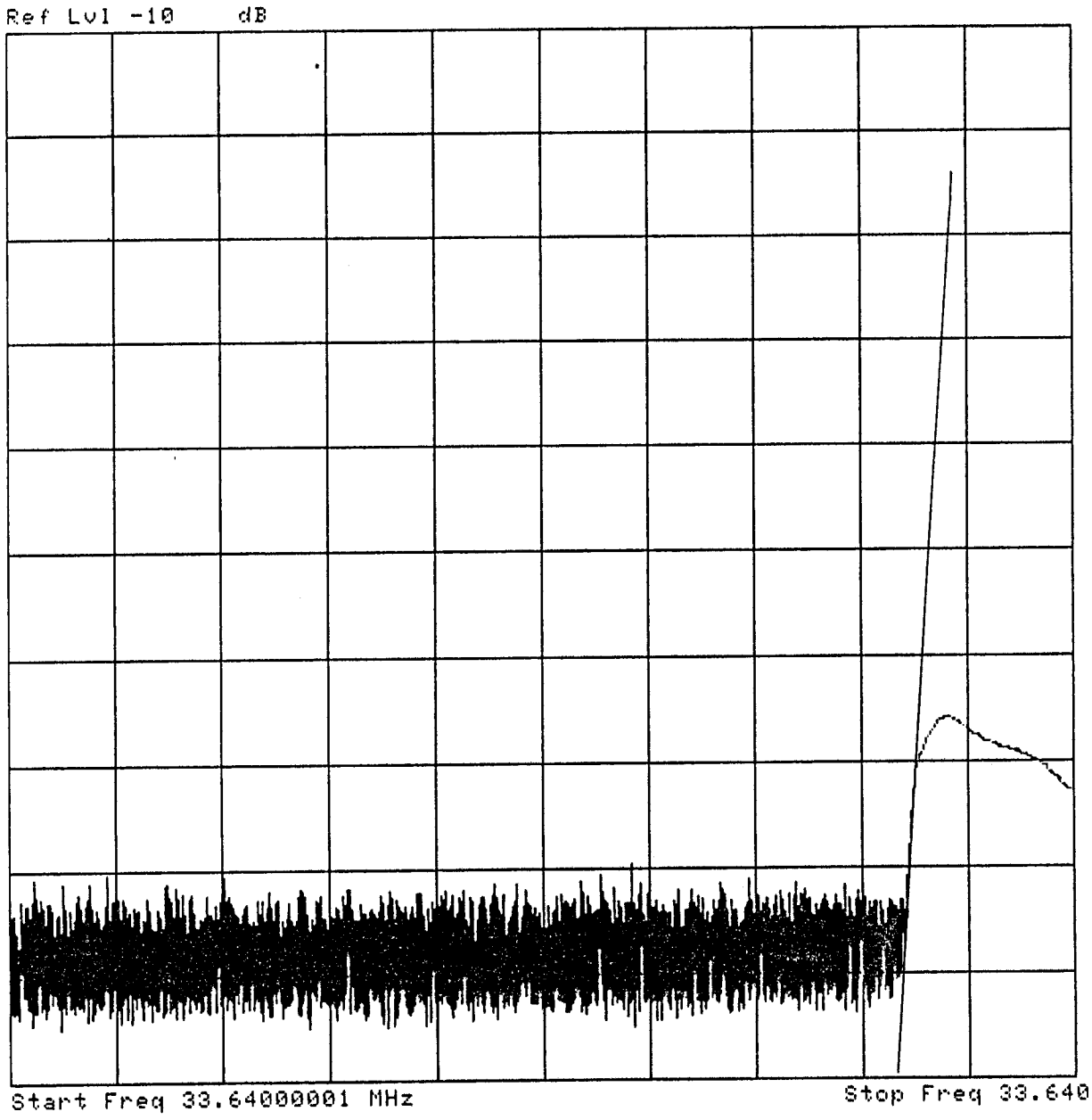


CONSOLE LOCATION 15, AP10 15-MAR-1989 11:50
hor=20, ver=10 acc dampers



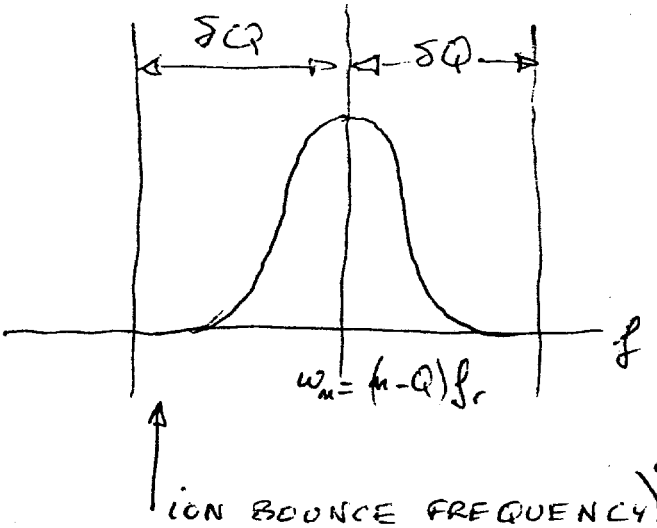
Sector 1
Clear & OFF

CONSOLE LOCATION 14, AP10 15-MAR-1989 11:43
hor=20, hor=30, acc dampers



rise time
$\frac{1}{\nu}$ 1 ms

TRANSVERSE COHERENT ELECTRON-PROTON OSCILLATIONS ARE POSSIBLE WHEN THE ELECTRON BOUNCE (PLASMA) FREQUENCY LIES IN A BAND $\pm \delta Q$ AROUND THE TRANSVERSE UNSTABLE MODE



$$\delta Q = \frac{q_c Q_c}{\sqrt{q_c Q_0}}$$

EQUATIONS OF MOTION FOR INDIVIDUAL PARTICLES

$$\text{protons}: \quad \frac{1}{\Omega_0^2}\ddot{y} + Q_0^2 y - Q_{sc}^2 (y - \bar{y}) + Q_c^2 (y - \bar{y}_i) = 0 \qquad (1)$$

$$\text{electrons}: \quad \frac{1}{\Omega_0^2}\ddot{y}_i - q_{sc}^2 (y_i - \bar{y}_i) + q_c^2 (y_i - \bar{y}) = 0$$

WHERE $\bar{y}$, $\bar{y}_i$ ARE THE BEAMS CENTER DISPLACEMENTS

Q_0 THE PROTON UNPERTURBED TUNE

Q_{sc} THE PROTON SPACE CHARGE TUNE SHIFT

Q_c THE PROTON BOUNCE NUMBER IN THE ELECTRON SPACE CHARGE

q_{sc} THE ELECTRON SPACECHARGE TUNE SHIFT ($q_{sc} \simeq$ [illegible] FOR LOW NEUTRALISATION)

q_c THE ELECTRON BOUNCE NUMBER IN THE PROTON SPACE CHARGE

THE INCOHERENT TUNE IS $Q^2 = Q_0^2 + Q_c^2 - Q_{sc}^2$

$q^2 = q_c^2 - q_{sc}^2$

δQ IS OBTAINED BY SOLVING EQUATIONS (1) WITHOUT FREQUENCY SPREADS, i.e. $y = \bar{y}$, $y_i = \bar{y_i}$

THE CHARACTERISTIC EQUATION IN THAT CASE WRITES

$$\left(Q^2 - (x-n)^2\right)\left(q_c^2 - x^2\right) - q_c^2 Q_c^2 = 0 \quad (2)$$

WITH $Q^2 = Q_0^2 + Q_c^2$

QUARTIC, SIMPLIFIED TO QUADRATIC, (2) HAS 2 COMPLEX (THUS ONE UNSTABLE) CONJUGUATE SOLUTIONS FOR THE COHERENT FREQUENCY $x = \frac{\omega}{\Omega}$ WHEN THE ELECTRON BOUNCE NUMBER q_c IS CLOSER TO ONE OF THE p SIDEBAND UNSTABLE MODE $n - Q$ THAN:

$$|q_c - (n-Q)| \leq \frac{q_c Q_c}{\sqrt{q_c Q_0}} = \delta Q$$

$$\left.\begin{aligned} Q_c^2 &= \frac{4 N_i r_p R}{2\pi a (a+b) \beta^2 \gamma} \\ q_c^2 &= \frac{4 N_p r_e R}{2\pi a (a+b) \beta^2} = 4 \end{aligned}\right\} \quad (3)$$

FOR OUR CASE

$$q_c^2 = \frac{4 \times 10^{12} \cdot 2.8 \cdot 10^{-15} \cdot 64}{2\pi \cdot 50 \cdot 10^{-6}} = 2'282$$

$$q_c \simeq 48$$

ELECTRON BOUNCE FREQUENCIES AROUND

$$48 \times .629 \simeq 30 \text{ MHz}$$

WHICH CORRESPONDS TO OBSERVATIONS.

FROM (3) $Q_c = \sqrt{\frac{\eta}{\gamma}} \sqrt{\frac{r_p}{r_e}}\, q_c$ WITH $\eta = \frac{N_i}{N} = 5.4\,\%$

$$Q_c \simeq 0.8$$

WITH THE VALUES OF Q_c, q_c, Q_0 WE FIND THAT THE WIDTH OF THE BAND WHERE WE CAN HAVE DIPOLAR INSTABILITIES IS

$$\Delta Q \simeq 1.9$$

(i.e. $\nu \pm 1.1$ MHz !)

LANDAU DAMPING INSIDE THIS BAND WOULD REQUIRE (INCLUSIVE!):

(a) $\Delta \bar{p} > \left| \frac{\Delta Q_{sc}^2}{Q} \right|$; $\Delta i > \left| \frac{\Delta q_{sc}^2}{q} \right|$ (b)

AND $\Delta \bar{p}\, \Delta i > \frac{q_c^2 Q_c^2}{q Q}$ (c)

WHERE ΔQ_{sc}^2 IS THE SPACE CHARGE TUNE SHIFT FOR THE PROTONS MEASURED TO BE

$$\Delta Q_{sc}^2 \simeq (4 \times 10^{-4})^2 \; ; \; Q \simeq Q_0$$

AROUND THE UNSTABLE BAND WE MEASURE AN HWHM FREQUENCY SPREAD OF $\Delta \bar{p} \simeq \frac{10\ kHz}{30000} \simeq 3.4 \times 10^{-4}$

WE SEE THEREFORE THAT THE FIRST CONDITION IS EASILY SATISFIED. $\Delta q_{sc}^2 \simeq 0$ WITH LOW NEUTRALISATION, $q \simeq q_c$, $\Delta i \gtrsim 2$ (PROBABLY!), THUS THE SECOND CONDITION (b) IS CERTAINLY ALSO SATISFIED.

REMAINS CONDITION (c) $\Delta_{\bar{p}}\, \Delta_i > \frac{q_c^2 Q_c^2}{9Q}$

WITH OUR NUMBERS, THIS MEANS

$$\Delta_{\bar{p}}\, \Delta_i \gtrsim 3.6$$

WE SEE THEREFORE THAT WITH CLEARING OFF AND $\Delta_{\bar{p}}\, \Delta_i \simeq 10^{-3}$, WE ARE VERY FAR FROM THE STABILITY CONDITION FOR LANDAU DAMPING!

SINCE

$$Q_c = \sqrt{\frac{\eta}{\gamma}}\ \sqrt{\frac{\bar{p}}{r_e}}\ q_c$$

WE SEE THAT IN ORDER TO HAVE STABILITY

i.e. $$\delta Q = \frac{q_c^2 Q_c^2}{9Q} = \Delta_{\bar{p}}\, \Delta_i = 10^{-3}$$

THE NEUTRALISATION OUGHT TO BE

$$\eta \simeq 1.5 \times 10^{-4}$$

CONDITION WHICH WE PROBABLY MEET WITH CLEARING ON.

THE FASTEST GROWTH RATE OCCURS IN THE BAND CENTER AND IS:

$$\frac{1}{\tau} \simeq \left(\frac{\Omega}{2}\right) \delta Q \simeq \left(\frac{\Omega}{2}\right) \frac{q_c Q_c}{\sqrt{q_c Q_0}}$$

WE MEASURED $\tau \lesssim 1$ ms, THEREFORE $\delta Q \simeq 5 \times 10^{-4}$, WHICH MEANS THAT ONLY A SMALL PART OF THE ELECTRONS WERE FEEDING THE INSTABILITY.

19/3/89 NEUTRALISATION AND ION SHAKING STUDIES WITH PBARS

(A) 19/3/89 - ION SPACE CHARGE INDUCED TUNE SHIFT WITH ELECTRODES ON/OFF

STACK COOLED FOR $\sim\frac{1}{2}$ HOUR OF 52.6×10^{10} $\bar{p}$

TUNES MEASURED AT $Q_H = .61331$, $Q_V = .6113$ $\quad E_{H,V} = 1\pi$ (?)

MEASURED SHIFT CLEARING ON/OFF:

$$\Delta Q_H = \frac{2.75}{629}\,(kHz) = 4.4 \times 10^{-3}$$

$$\Delta Q_V = \frac{3}{629} = 4.8 \times 10^{-3}$$

$$\Delta Q_V = \frac{r_p N \eta}{E_V\,(1 + E_H/E_V)\,\gamma} = .013\,\eta$$

$$\Rightarrow \eta = 37\% \quad \text{with } 1\pi \text{ emittances}$$

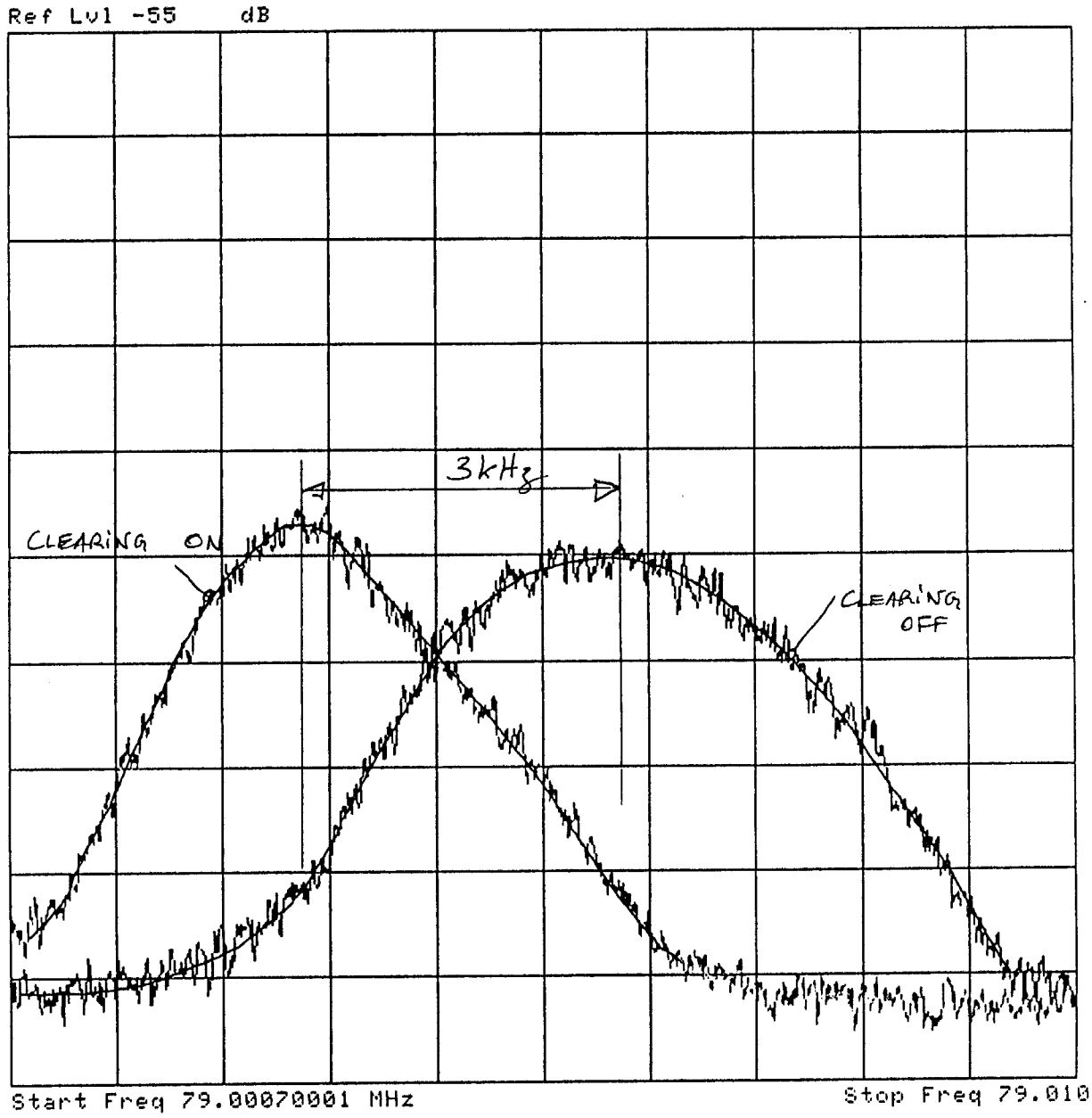
EXPERIENCE WITH THE AA IS THAT WE SHOULD HAVE $\sim$ 98% NEUTRALISATION WITH ELECTRODES OFF.

TO FIT THE TUNE SHIFT, EMITTANCES OUGHT TO BE $E_{H,V} = 2.7\,\pi$ ...

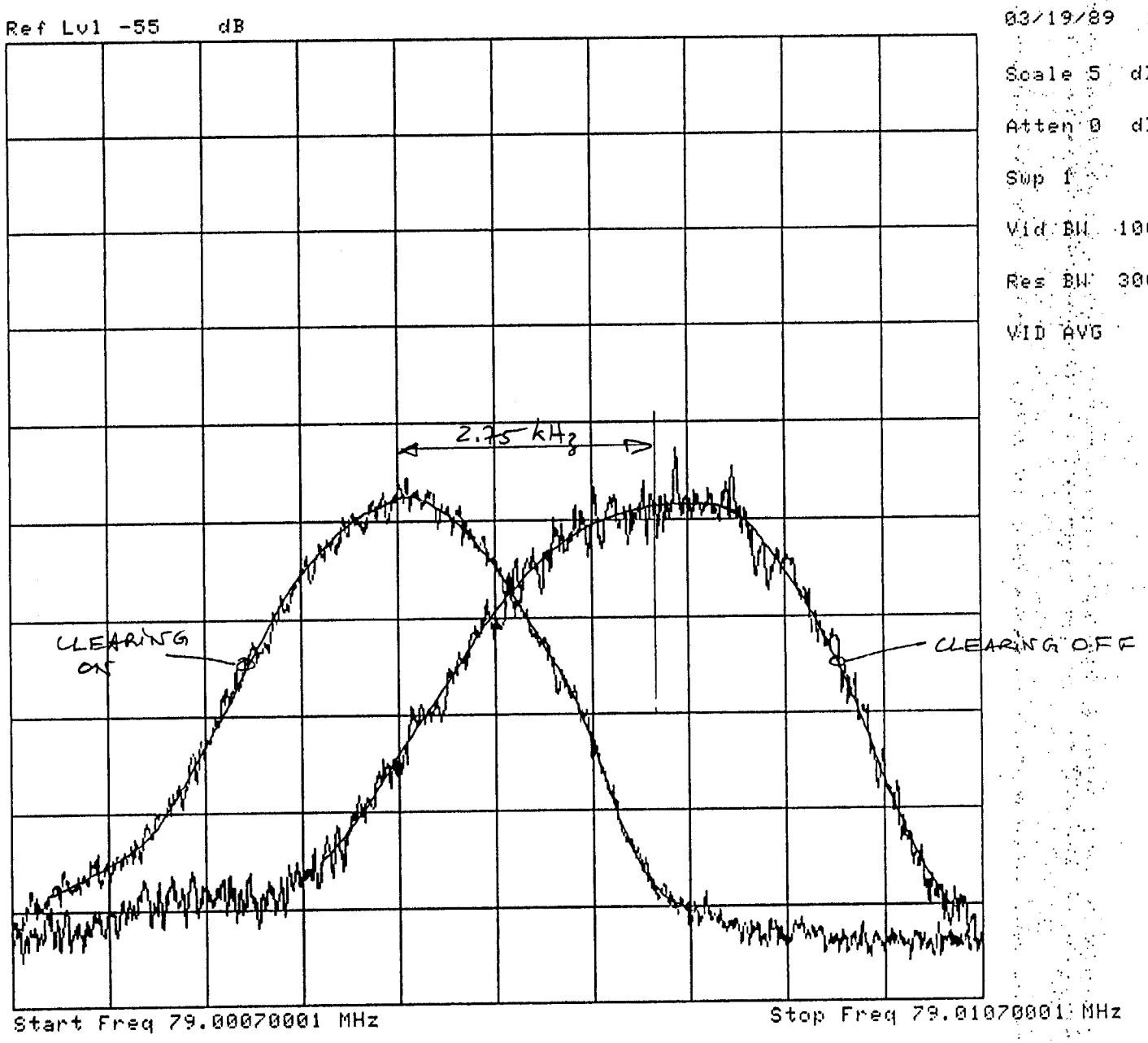
ARE THESE EMITTANCES FEASIBLE? MAY BE ...

TURNING CLEARING OFF SECTOR AFTER SECTOR SHOWED THAT, UNLIKE WITH PROTONS, ALL SECTORS CONTRIBUTE MORE OR LESS EQUALLY. (TO BE EXPECTED SINCE R_c (CLEARING RATE) $<< R_p$ WITH IONS. (and $\eta = \frac{R_p}{R_c}$)

CONSOLE LOCATION 14, AP10 19-MAR-1989 17:41
vertical ion induced tune shift



CONSOLE LOCATION 14, AP10 19-MAR-1989 17:03
horizontal ion induced tune shift



(6) - ION NEUTRALISATION FROM TUNE MEASUREMENTS (WITH CLEARING ON)

SPACE CHARGE : $$\Delta Q_{V,H} = \frac{r_p N_{\bar{p}}}{E_V (1 + E_H/E_V)\gamma} \left(\eta - \frac{1}{\gamma^2}\right)$$

SEVERAL TUNE MEASUREMENTS WERE MADE FOR VARIOUS STACK INTENSITIES & EMITTANCES

SHAKING OFF

52.6×10^{10} $\bar{p}$ $Q_H = .61331$ (1/2 hour cooling)
$Q_V = .6113$

42.4×10^{10} $Q_H = .61305$ (stacking)
$Q_V = .61067$

49.55×10^{10} $Q_H = .61330$ (stacking)
$Q_V = .611111$

THEN, 400 kHz VERTICAL SHAKING ON :

64.3×10^{10} $Q_H = .613115$ (stacking)
$Q_V = .610634$

THEREFORE ONE SEES - FOR SHAKING OFF - THAT THE TUNE GOES UP WITH INTENSITY. SO DO PROBABLY THE EMITTANCES. THIS MEANS FROM THE ABOVE FORMULA THAT $\eta > \frac{1}{\gamma^2}$ i.e. $> 1.1\%$
(MY GUESS IS A FEW PERCENT)
IT SEEMS ALSO THAT SHAKING REDUCES THE TUNE - AS EXPECTED -

THESE MEASUREMENTS OUGT TO BE REPEATED, FOR INSTANCE BY BLOWING UP THE BEAM.

(C) ION SHAKING

EXPERIENCE WITH THE CERN AA AND THEORY PREDICT ION SHAKING TO BE EFFICIENT (AT LEAST FOR THE POWERS AVAILABLE):

- # CLOSE TO ION(S) BOUNCE FREQ.
- # CLOSE TO A BETATRON SIDEBAND
- # ABOVE IF $m+q$
- # BELOW IF $m-q$

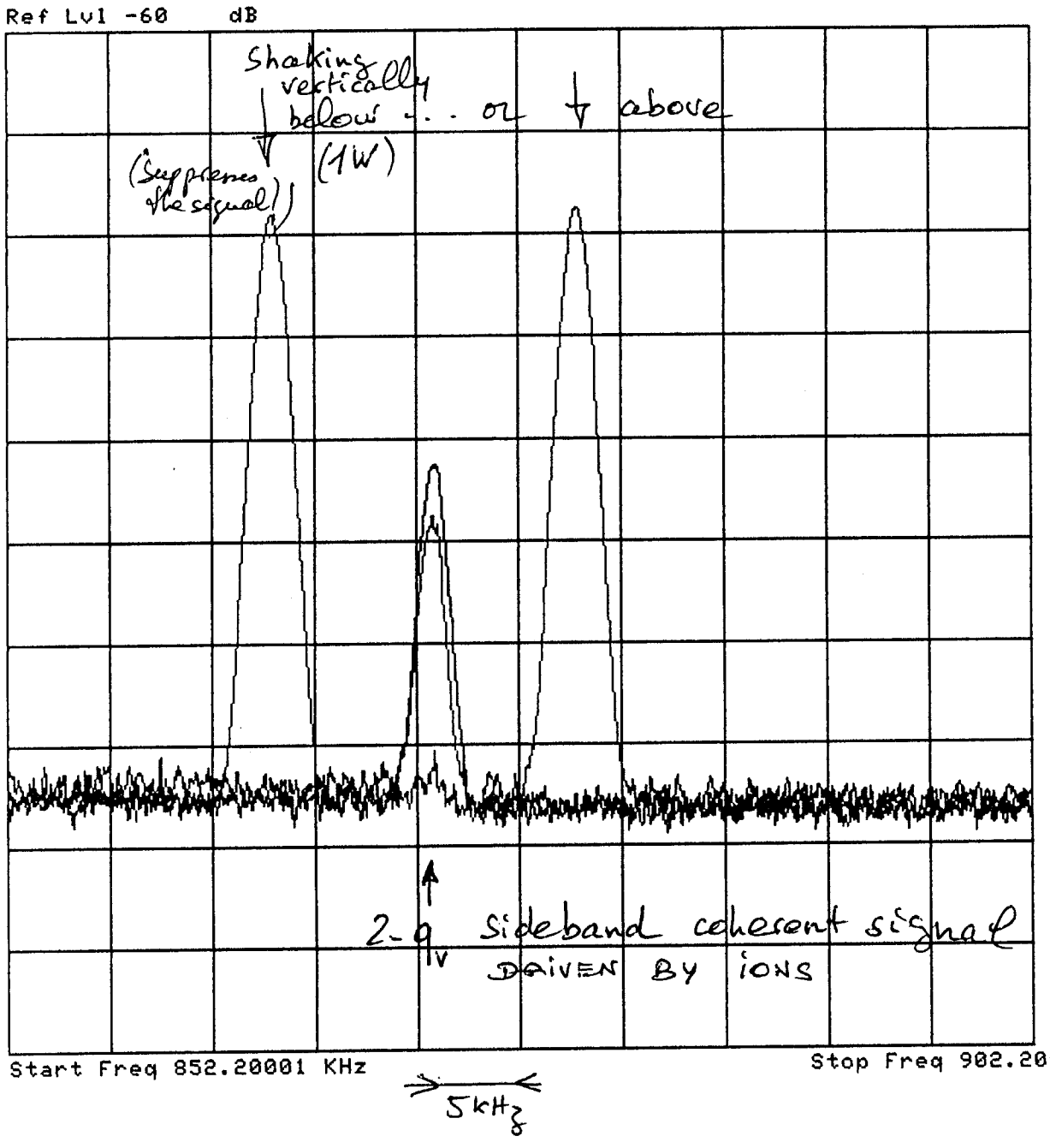
1. ION INDUCED DIPOLE INSTABILITY AT 872 kHz

ABOVE $\sim 5\times10^{-11}$ pbars, A COHERENT LINE AT 872 kHz ($2-q_{H,V}$) IS MOST OF THE TIME VISIBLE. THIS IS MOST LIKELY DUE TO IONS (H_2^+ OR H^+ ?). THE COHERENT AMPLITUDE IS CERTAINLY VERY SMALL (< 1 MM?), AND IS STABILIZED BY THE GIVEN ION PRODUCTION RATE WHICH FEEDS IT (STANDING WAVE). (AN INTERESTING EXPERIMENT WOULD BE TO RAISE THE PRESSURE BY TURNING OFF ION PUMPS: THE AMPLITUDE SHOULD GROW).

WE THEN APPLIED A VERTICAL SHAKING FREQUENCY ± 8 kHz OFF THIS SIDEBAND. THE INSTABILITY WAS SUPPRESSED ONLY BELOW THE SIDEBAND! THIS IS A BEAUTIFUL VERIFICATION OF THE ION SHAKING THEORY CONCERNING ASSYMETRY!

(SEE RELEVANT PAPER AT PAC 89, CHICAGO). BY D. MÖHL et al

CONS .E LOCATION 02, MCR-N2 19-MAR-1989 18:38
beam shaking - no instability



03/19/89 1802
Scale 5 dB/div
Atten 0 dB
Swp .3 sec
Vid BW 300 Hz
Res BW 1 KHz
VID AVG

$55 \cdot 10^{10}$ pbars

IT WAS ALSO FOUND THAT SHAKING AT 865 kHz HAD A BENEFICIAL EFFECT BOTH ON EMITTANCES AND STACKING RATE

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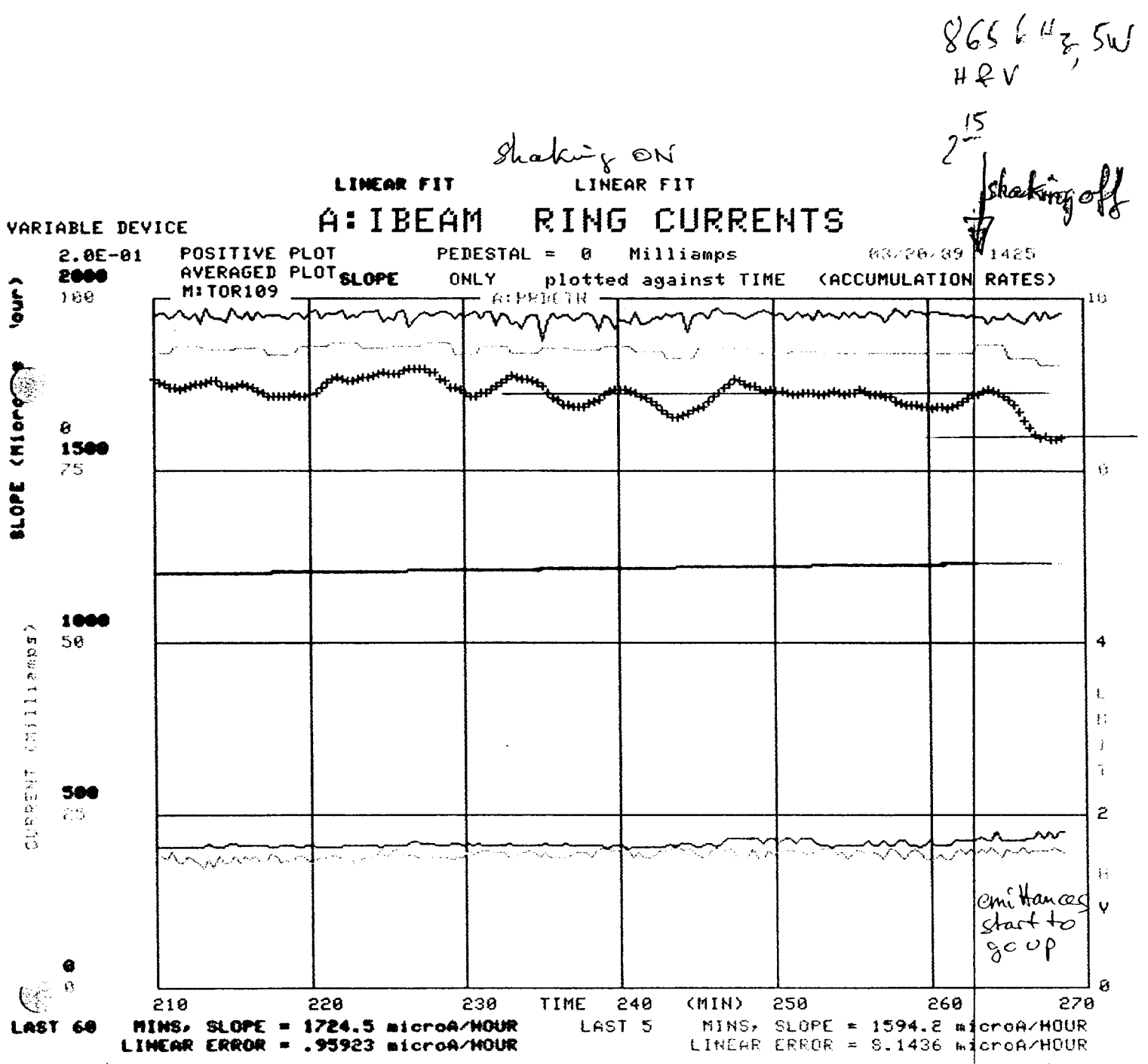
REVERSE blue/yellow



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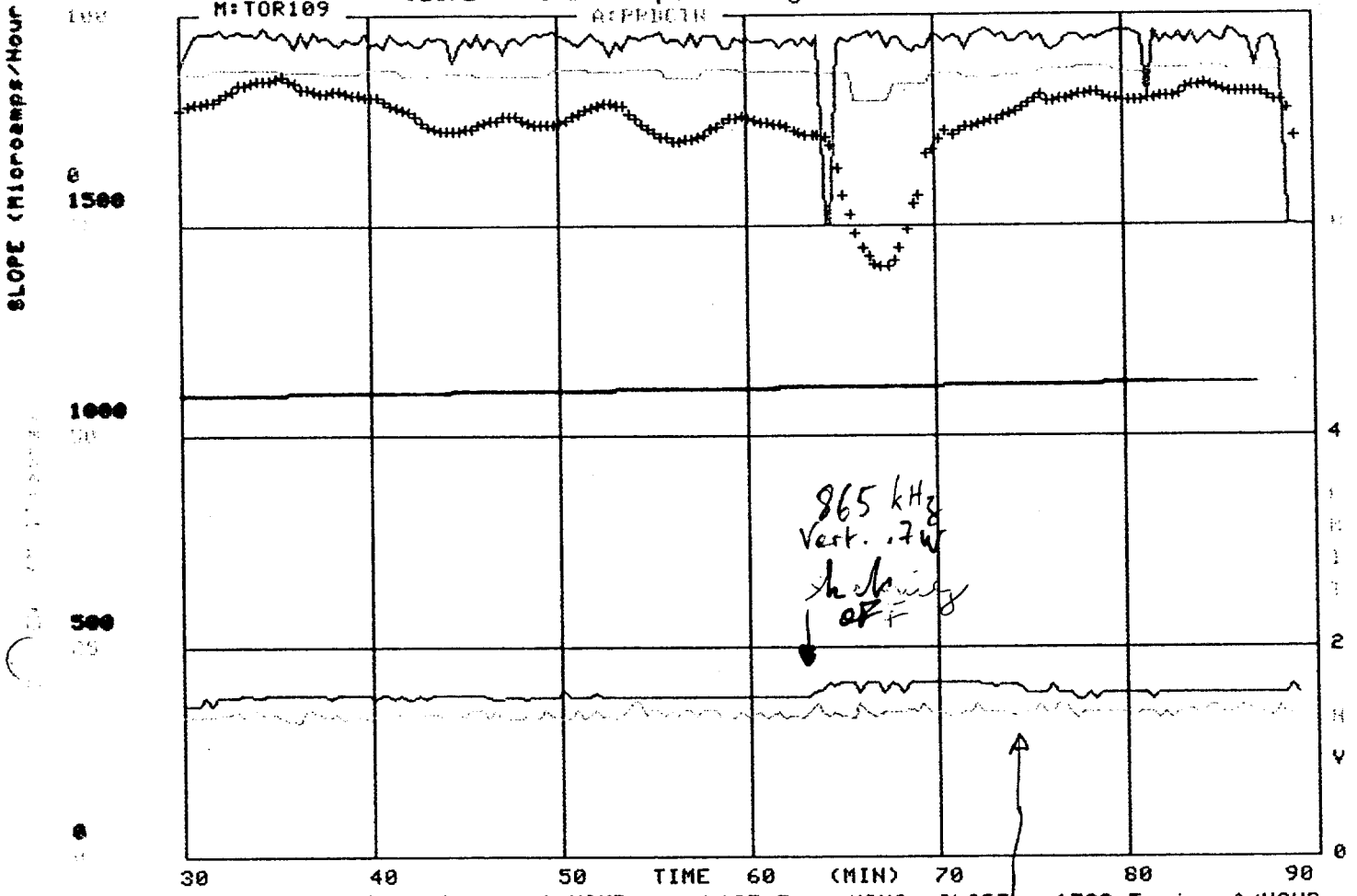
LINEAR FIT LINEAR FIT

VARIABLE DEVICE

A:IBEAM RING CURRENTS

2.0E-01 POSITIVE PLOT PEDESTAL = 0 Milliamps 03/20/89 1125
2000 AVERAGED PLOT SLOPE ONLY plotted against TIME (ACCUMULATION RATES)
M:TOR109 A:PRDCTN



LAST 60 MINS, SLOPE = 1728.9 microA/HOUR
LINEAR ERROR = 1.8718 microA/HOUR

LAST 5 MINS, SLOPE = 1708.5 microA/HOUR
LINEAR ERROR = 38.24 microA/HOUR

2 - TESTS ON VARIOUS SHAKING FREQUENCIES

AS SAID, IT IS MOST USEFUL TO SHAKE CLOSE TO A BEAM'S TRANSVERSE MODE FREQUENCY:

$$\begin{cases} Q_H = .61331 \\ Q_V = .6113 \end{cases} \qquad f_r = 628.952 \text{ kHz}$$

MODES:

$1 - q_V = 244.47$ [kHz]	$1 - q_H = 243.21$ [kHz]
$2 - q_V = 873.42$	$2 - q_H = 859.65$
$3 - q_V = 1'502.377$	$3 - q_H = 1'488.6$
$4 - q_V = 2'131.33$	$4 - q_H = 2'117.55$
$0 + q_V = 384.48$	$0 + q_H = 398.25$
$1 + q_V = 1'013.43$	$1 + q_H = 1'014.70$
$2 + q_V = 1'642.38$	$2 + q_H = 1'643.64$
$3 + q_V = 2'271.33$	$3 + q_H = 2'272.6$

HIGHER MODES ARE OF LITTLE INTEREST AS ION BOUNCE FREQUENCIES SHOULD LIE IN THE LOWER PART OF THIS RANGE ($\sim 5 \cdot 10^{11}$ pbars & $E_{H,V} = 1\pi$)

SHAKING WAS (RATHER) SYSTEMATICALLY STUDIED UP & ABOVE

244 kHz $(1 - q_{V,H})$

400 kHz $(0 + q_{V,H})$ (12 hours!)

873 kHz $(2 - q_{V,H})$

BY RECORDING OF EMITTANCES AND STACKING RATES (TUNE VARIATIONS WERE FOUND TOO SMALL TO BE RELIABLE)

IT WAS FOUND THAT:

SHAKING WORKS BEST AT 400 kHz, 8 W. (−25 dB)

i.e., ABOVE THE SIDE BAND AS INDICATED BY THEORY.

ALTHOUGH SMALLER, THE EFFECT AS PREVIOUSLY NOTED EXISTS AT 865 kHz

SHAKING HAS NO EFFECT NOTICEABLE AT 4.10^{11} pbars

AT 5.5×10^{11} pbars THE GAIN IN STACKING RATE IS ~7,8% (~20% ON EMITTANCES)

THE GAIN RISES WITH STACK INTENSITY, AND WAS ~20% IN ST. RATE AT $6.5.10^{11}$ (30-40% ON EMITTANCES)

AS FOR THE CERN AA, SHAKING HORIZONTALLY DOES NOT IMPROVE ST. RATE & EMITTANCES

THESE RESULTS ARE VERY SIMILAR TO THE CERN AA!

SIGNED: THE GHOST BUSTERS!

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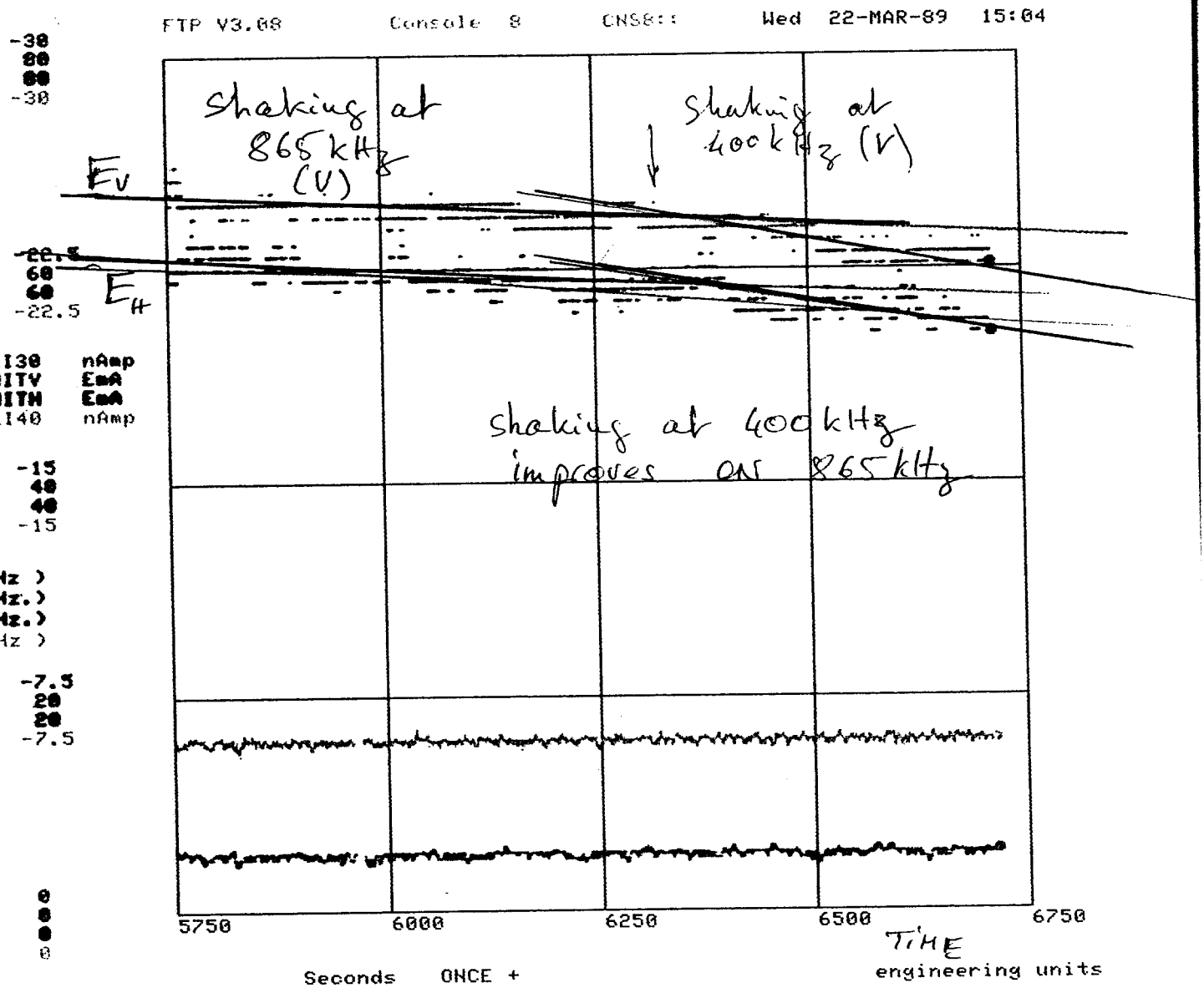
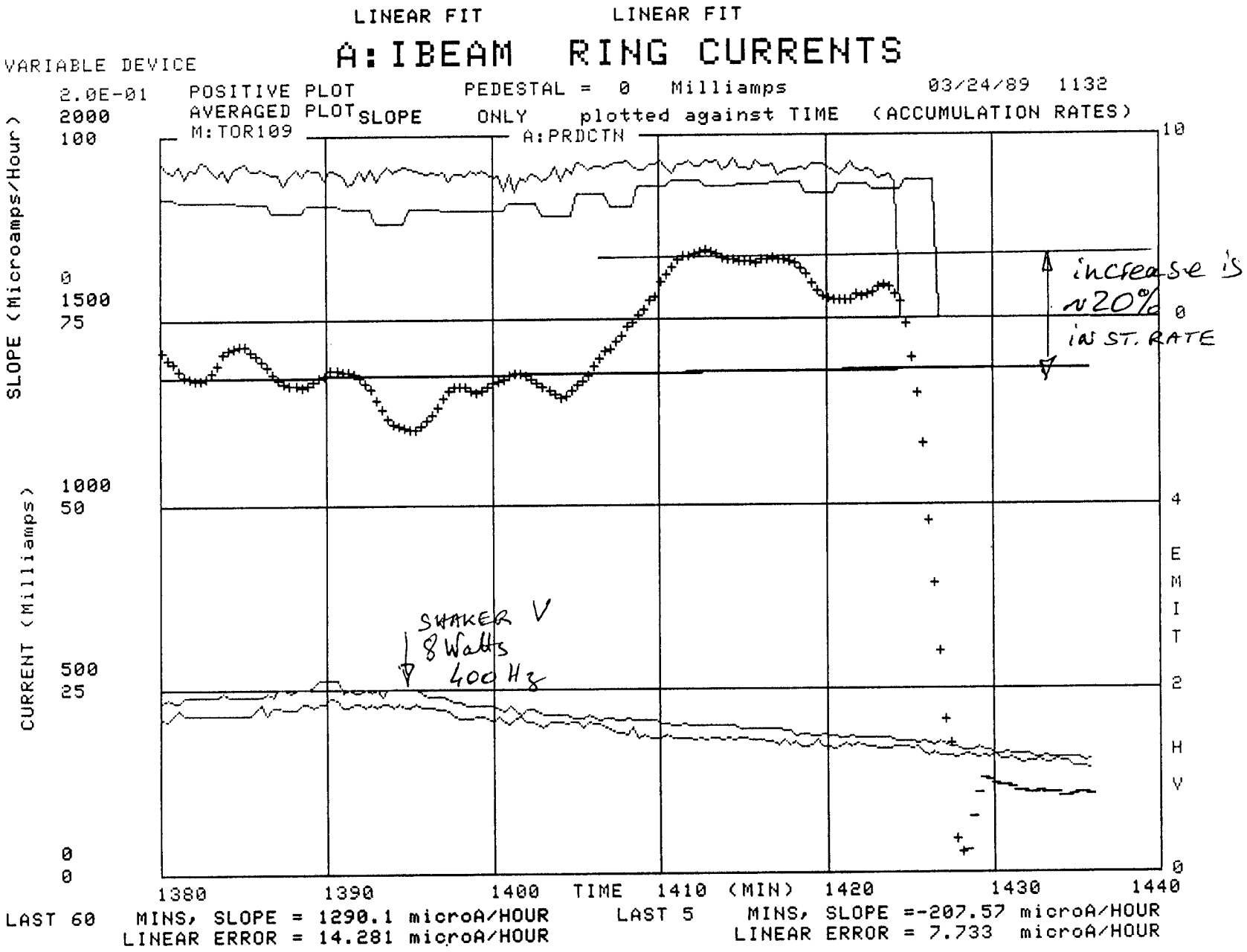
Fast Time Plot
REVERSE blue/yellow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