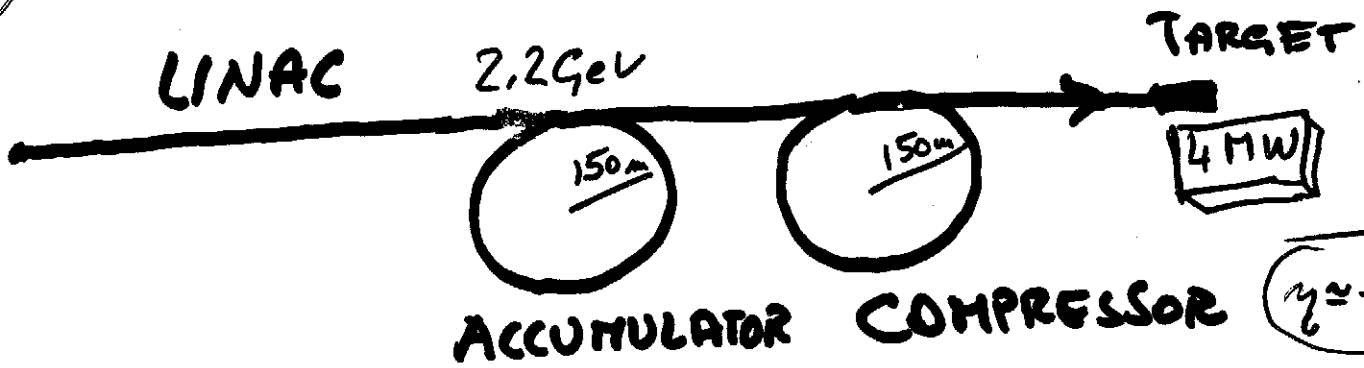
R.Cappi / NuFact 2000

TWO SINGLE BUNCH HIGH INTENSITY PHENOMENA at CPS

- Introduction (2 GeV CERN PDAC)
- An experiment to test beam behavior under extreme space charge conditions during a bunch compression
- Observation of Beam Break Up vertical instabilities nearby transition

INTRODUCTION

PDAC 2



Accum. time = 2ms	Compr. time = 20μs (~8 turns)
$N_b = 1.1 \cdot 10^{12}$ p/b	=
$k_b = 140$	=
$N_t = 1.5 \cdot 10^{14}$ p/p	=
75 Hz	=
$h = 146$ (44 MHz)	=
$V = 300$ kV	2 MV (+0.3 MV 2nd h.)
$\tau_b = 17$ ms	5 ms (1 ms rms)

Remark:

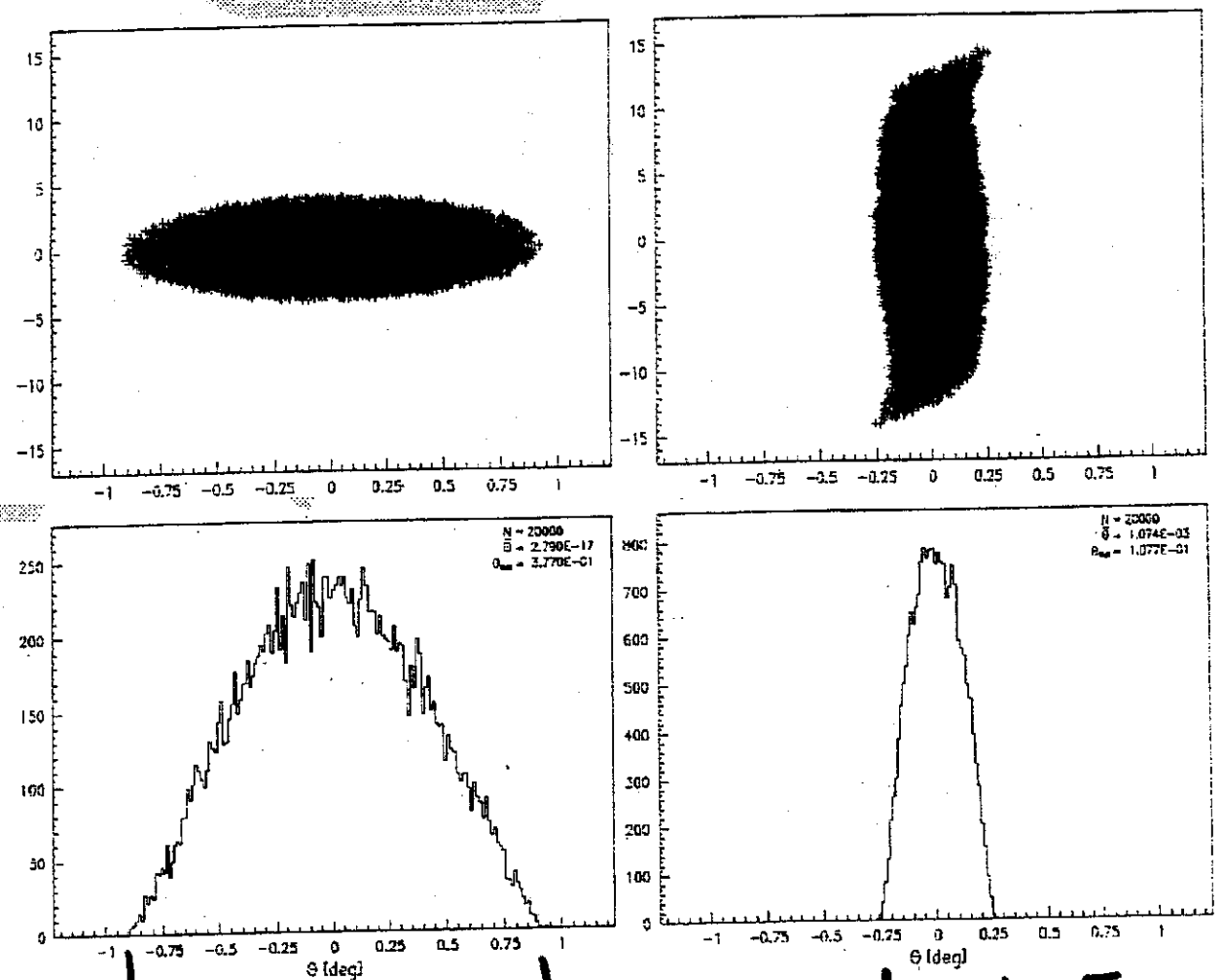
PDAC 1 ~ same as PDAC 2 except:

$k_b = 12$	=
$N_b = 1 \cdot 10^{13}$ p/b	=
$\tau_b = 50$ ms →	5 ms
$V_{RF} = 300$ kV	8 MV

$\Rightarrow \Delta Q_{m,y} = -2$!

uency difference between generator and beam frequencies ($\approx$ 20 kHz at 40 MHz). The compression process rings the bunches from the estimated initial r.m.s. length f 3.5 ns ($\Delta p/p(2\sigma)$ is 1.5×10^{-3}) to the final one of 1 ns $\Delta p/p(2\sigma)$ is 5.0×10^{-3}).

ESME SIMULATIONS



17ns

5ns (≈1ns rms)

Figure 2: Bunch rotation in compressor ring. The phase portraits are shown in the upper part (initial left, final right). The projections along the θ axes are shown in the lower part (1deg = 9.21 ns).

The lattice of the compressor machine, based on doublet cells, has been designed to maximise the free space in the straight section to allow the installation of the RF cavities. To this aim, the dispersion function is zero in the straight

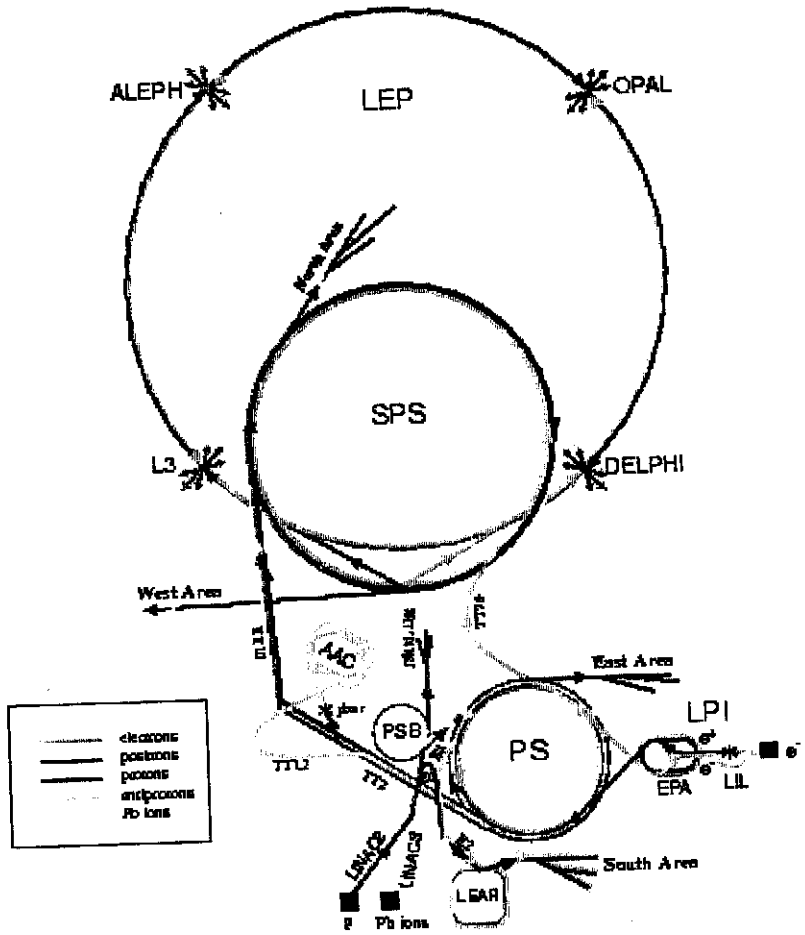
E. Metral ④

Effects	Beams	Impedances	Comments	Limits	
Tr. SC	μbunch	-	ΔQ_{incoh} -0.13, -0.03	> – 0.4	☺
	Mbunch_A	-	-0.28, -0.08	□	☺
	Mbunch_C	-	-2.3, -0.23	□	☹,☺
Long. SC	μbunch	SC Max. voltage /turn(para.)	-j178 Ω, -j146 Ω 108 kV, 24 kV		😐
	Mbunch_A	□	-j88 Ω, -j68 Ω 193 kV, 130 kV		😐
	Mbunch_C	□	-j88 Ω, -j68 Ω 13.3 MV, 1 MV		😐
Tr. HT single-bunch	Mbunch_A	RW (10^{-6} Ωm)	Risetime m = 8, m = 2	~ 110 ms ~ 200 ms	☺
Tr. Coupled-bunch	Mbunch_A	RW (10^{-6} Ωm)	Risetime n = 10, m = 7 n = 133, m = 1	~ 40 ms ~ 5 ms	☺
TMC	μbunch	BB (1Ω)	m = -1, m = 0 m = -1, m = 0	$N_b < 2 \times 10^{12}$ $N_b < 3.3 \times 10^{12}$	☺
	Mbunch_A	BB (1Ω)	m = -1, m = 0 m = -1, m = 0	$N_b < 1.7 \times 10^{14}$ $N_b < 8.8 \times 10^{13}$	☺
BBU single-bunch	μbunch	BB	Y < 10 after 600, 660 turns	$Z_\parallel/n < 674\ \Omega$ $Z_\parallel/n < 1140\ \Omega$	☺
	Mbunch_A	BB	Y < 10 after 300, 330 turns	$Z_\parallel/n < 45\ \Omega$ $Z_\parallel/n < 30\ \Omega$	☺
BBU multi-bunch	μbunch	BB	Y < 10 after 600, 660 turns	$Z_\parallel/n < 8105\ \Omega$ $Z_\parallel/n < 4130\ \Omega$	☺
Long. μwave	Mbunch_A	BB (1Ω) + SC	Risetime	~ 0.25 ms ~ 0.45 ms	☹
Long. coupled-bunch	Mbunch_A	CERN-PS 40 MHz cavity	Risetimes HOMs (without) with dampers 1) n=5, m=12 2) n=53, m=24 3) n=58, m=25	1) 394.367 MHz (~ 0.5) 100 ms 2) 732.224 MHz (~ 3) 20 ms 3) 774.713 MHz (~ 5) 10 ms	☺

+ e-cloud
+ HALO
+ ....

to be done

CERN Accelerators



LEP: Large Electron Positron collider
SPS: Super Proton Synchrotron
AAC: Antiproton Accumulator Complex
ISOLDE: Isotope Separator OnLine DEvice
PSB: Proton Synchrotron Booster
PS: Proton Synchrotron

LPI: Lep Pre-Injector
EPA: Electron Positron Accumulator
LIL: Lep Injector Linac
LINAC: LINear ACcelerator
LEAR: Low Energy Antiproton Ring

Rudolf LEY, PS Division, CERN, 02.09.96

PS synchrotron:
R=100m, E=1-26 GeV, rep.rate: 1pulse /1.2 or 2.4 s
Ip<3E13p/p, Qx ~ Qy ~ 6.25

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Experiment to test beam behavior under extreme space charge conditions

R. GAROBY , D. MÖHL, J.L. VALLET, E. WILDNER , R. CAPPI*(rep.)*

REMINDER

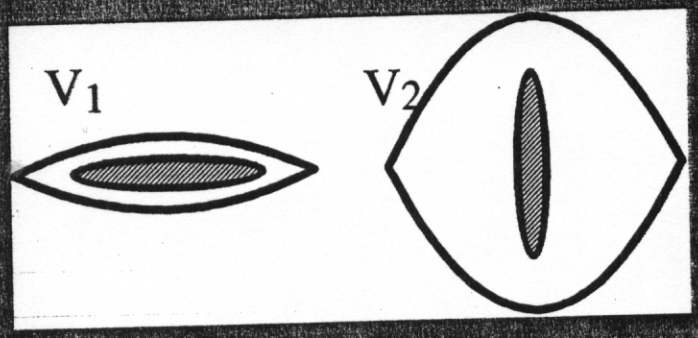
space charge tune depression
(self-field)

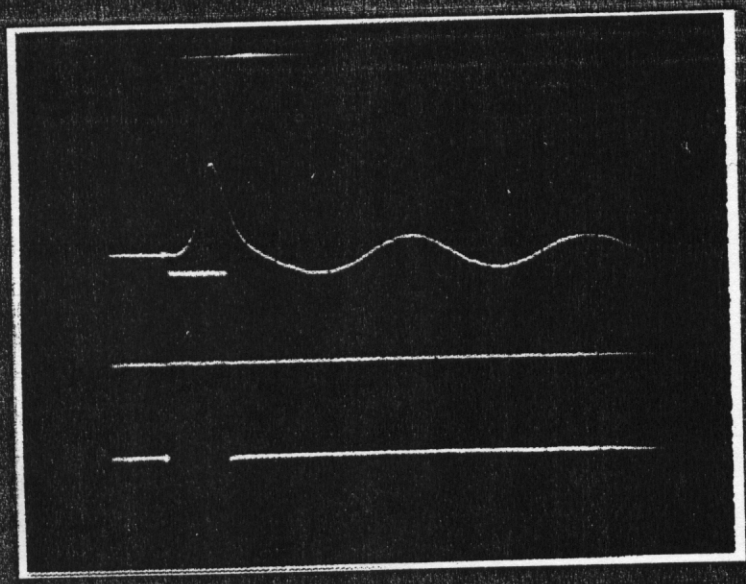
$$\Delta Q_{x,y} \cong -\frac{r_0}{ec} \frac{I_p R^2}{Q_{x,y} (\beta\gamma)^3 \sigma_{x,y} (\sigma_x + \sigma_y)}$$

where for parabolic bunches:

$$I_p = \frac{3eN_b}{2\tau_b}$$

Bunch compression experiment



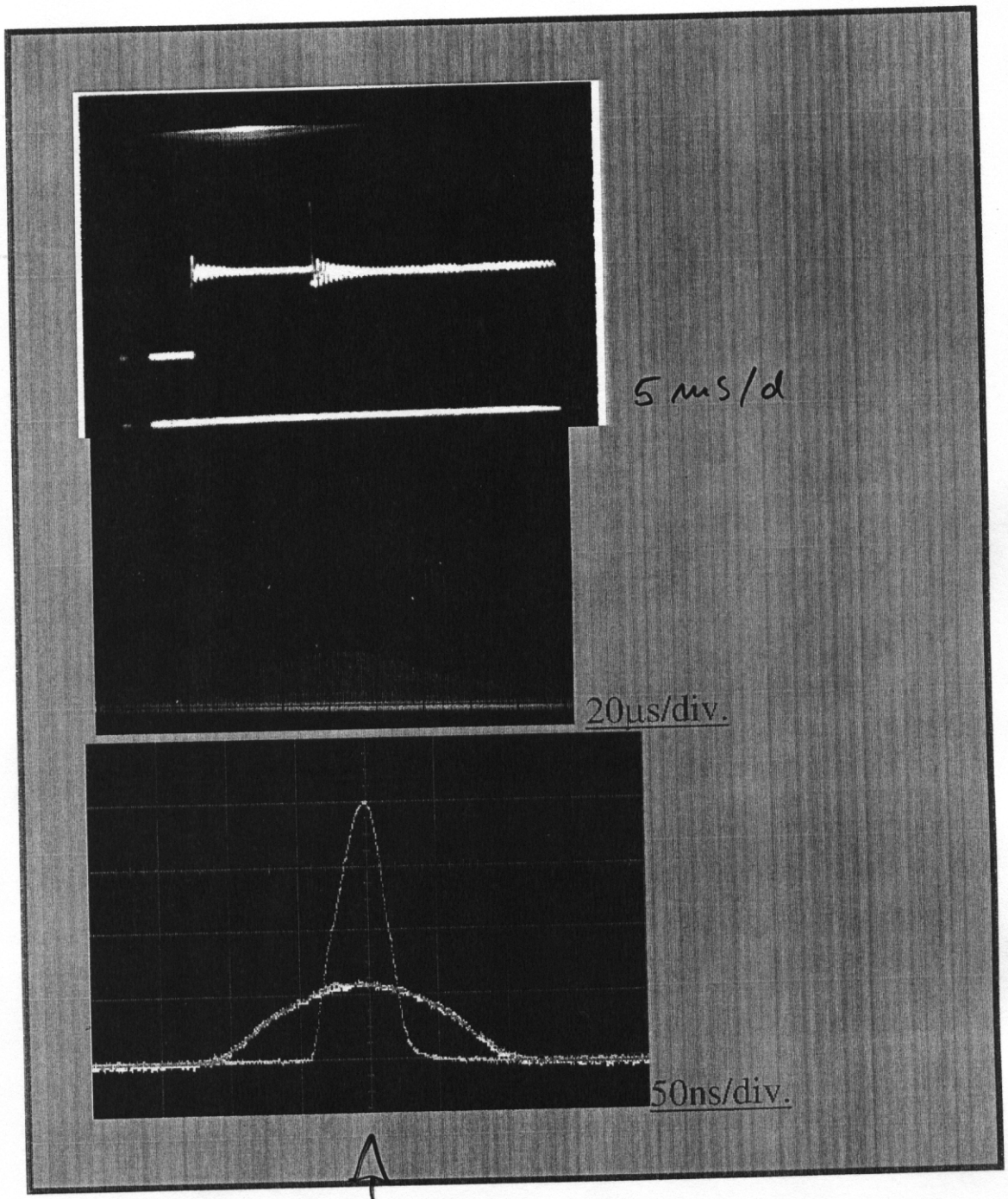


Sample bunch

$T=1$ GeV, $V_{RF}=16\rightarrow200$kV, $h=8$, $N_b=2\ 10^{12}$p/b

$T_s=1270\rightarrow400$µs

bunch compression $=(V_2/V_1)^{1/2}=3.5$



3 traces:

before - during - after B.C.

identical

RESULTS

h=8, ε_l=0.75 eVs, N_b=1.9 10^{12} p/b

	V_{RF}[kV]	τ_b[ns]	$-\Delta Q_{x,y}$	$\varepsilon^*_{x,y}$[μm]
before b.c.	15.6	200	0.34 , 0.38	2.88 , 2.85
during b.c.	200	60	0.54 , 0.95	-
after b.c.	15.6	200	0.23 , 0.27	4.32 , 3.67

measured transv. emitt. blow up 1.50 , 1.28
with wire scanners

NB: no measurable beam losses ... or other

SUMMARY

- $-\Delta Q$: 0.3 → 1 → 0.3 during ~20 turns (i.e. ~ 40μs)

- transv. emittance blow-up:
  50% in x
  30% in y

  ... in the PS

- No other harmful effects *(e.g. losses, instabilities, etc.)*

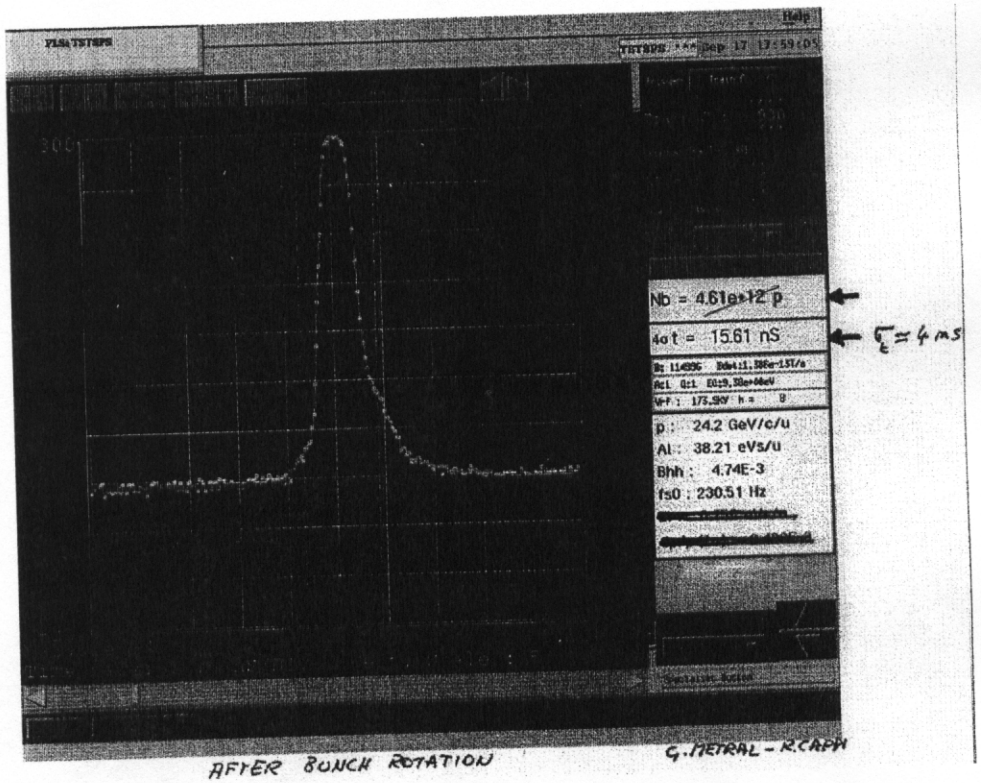
I

(12)

High Intensity single bunch acceleration (for nTOF experiments)

G. Metral, E. Metral, R. Cappi (reporter)

Nb ~ 7E12 p/b *(Ipeak~70A)*



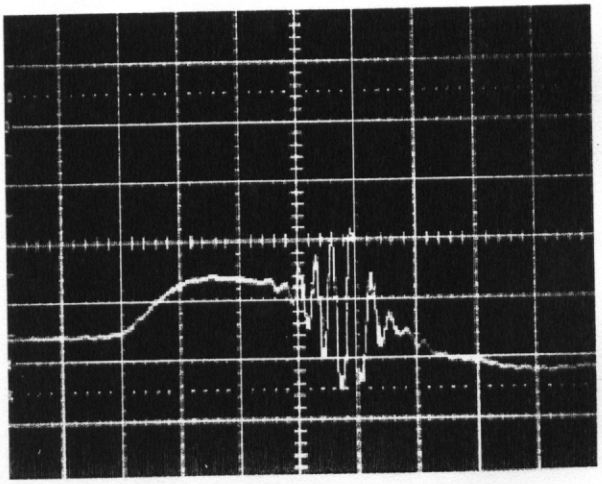
$\tau_b \simeq 4$ ns

AFTER BUNCH ROTATION

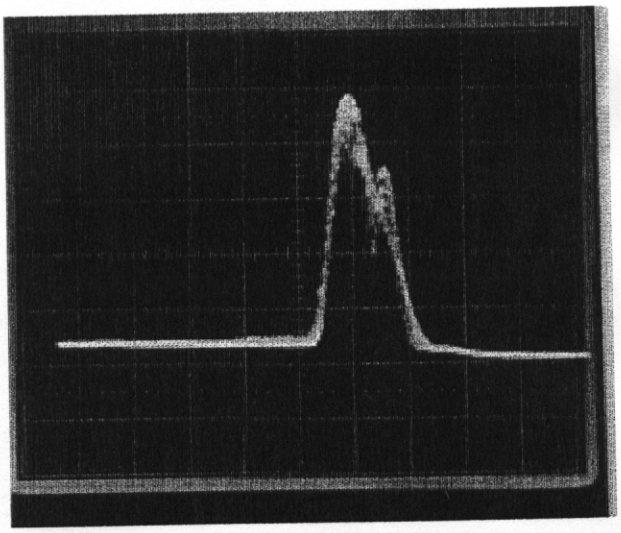
G. METRAL - R. CAPPI

II

Observation of a vertical Beam Break Up instability nearby transition (~6GeV/c)



ΔV bpm signal, 5ns/div



Σ bpm signal (~80 turns), 20ns/div

SUMMARY

- 30% beam loss
- rise time ~ < 1ms~500turns

- theoretical predictions consistent with
  1) η ~**0**

  2) Zl/n = 17Ω , fc = 1.4 GHz, Q = 1 =>

  Z_{TX} ~ 1.1MΩ/m,
  <u>Z_{TY} ~ 2.8MΩ/m</u>

  if y_0=1mm => y_n / y_0 ~ 35mm after ~ 400 turns

see paper by E.Metral et al. @ EPAC2000

- Cured by controlled longitudinal emittance blow-up: 2 => 2.5 eVs