BNL WS July 99

Collective effects in the CERN-PS

R.Cappi / CERN-PS

- The CPS : *machine, beams, programmes, etc.*
- Longitudinal instabilities
- Transverse instabilities
- Others : space charge, e-ions, …

Thanks to : R.Garoby, E.Metral, G.Metral

The CPS

Machine : AG, comb. fct., R=100 m, E=1.4 =>26 GeV

cycle length = n x 1.2 s (n=1, 2, 3,..)

p, pbars, e+, e-, Pb^{53+}

Ip = 10^9 … 3 10^{13} p/pulse, 200>τ_b>3ns

>26 different RF cav. from 3 to 200 MHz

h= 8, 16, …, 84, 164, 240, 420

8 septa, 4 kickers, >60 p.u.'s, 4 ws's, etc.

….

Many users in PPM :

SPS injector

HEP with SE

pbar prod. for AD

MD's

(see present schedule)

Programmes:

<u>LHC injector chain</u> *(in preparation)*

SPS injector (HEP and ν)

LE Physics (SE)

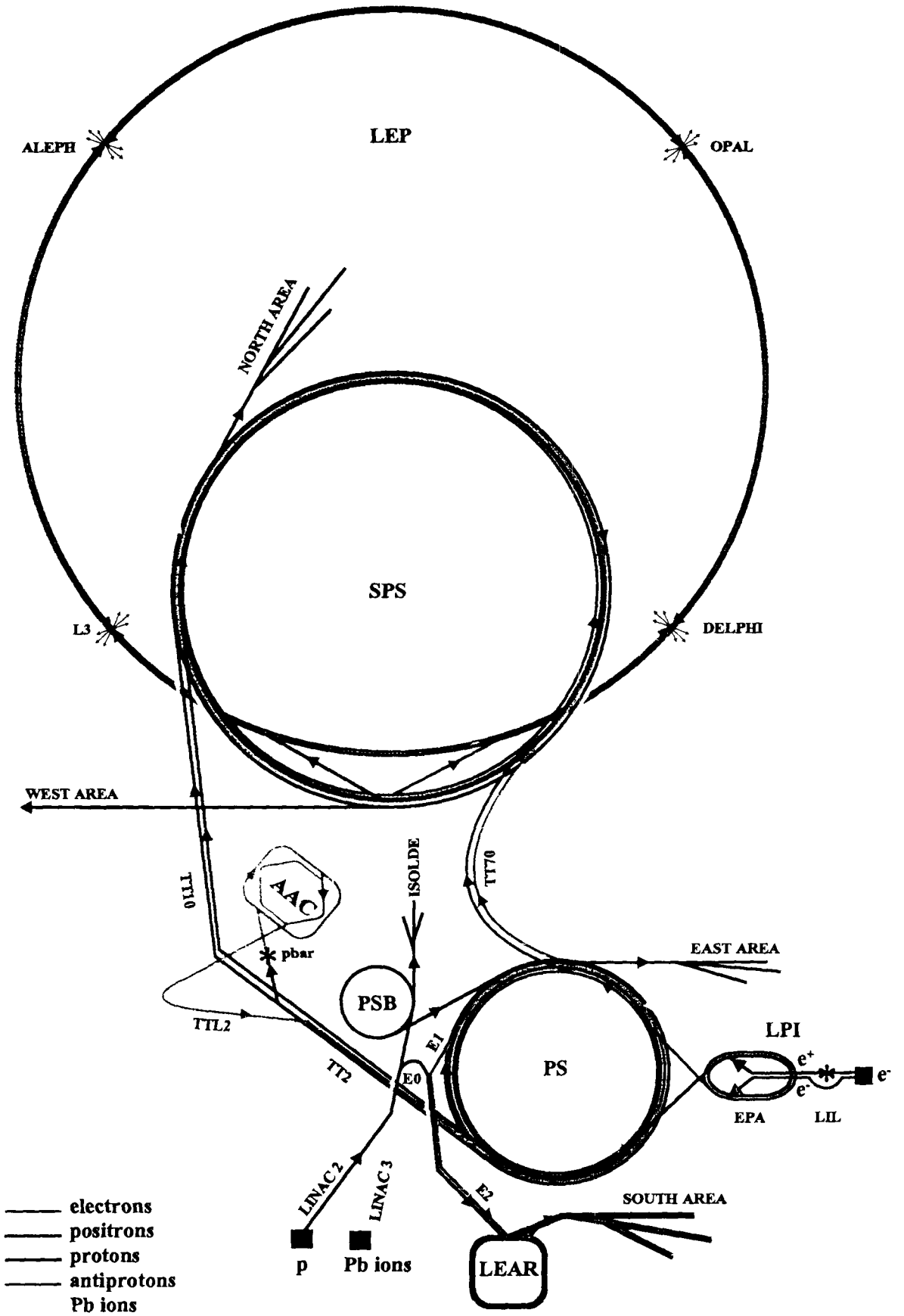
n TOF facility*(in preparation)*

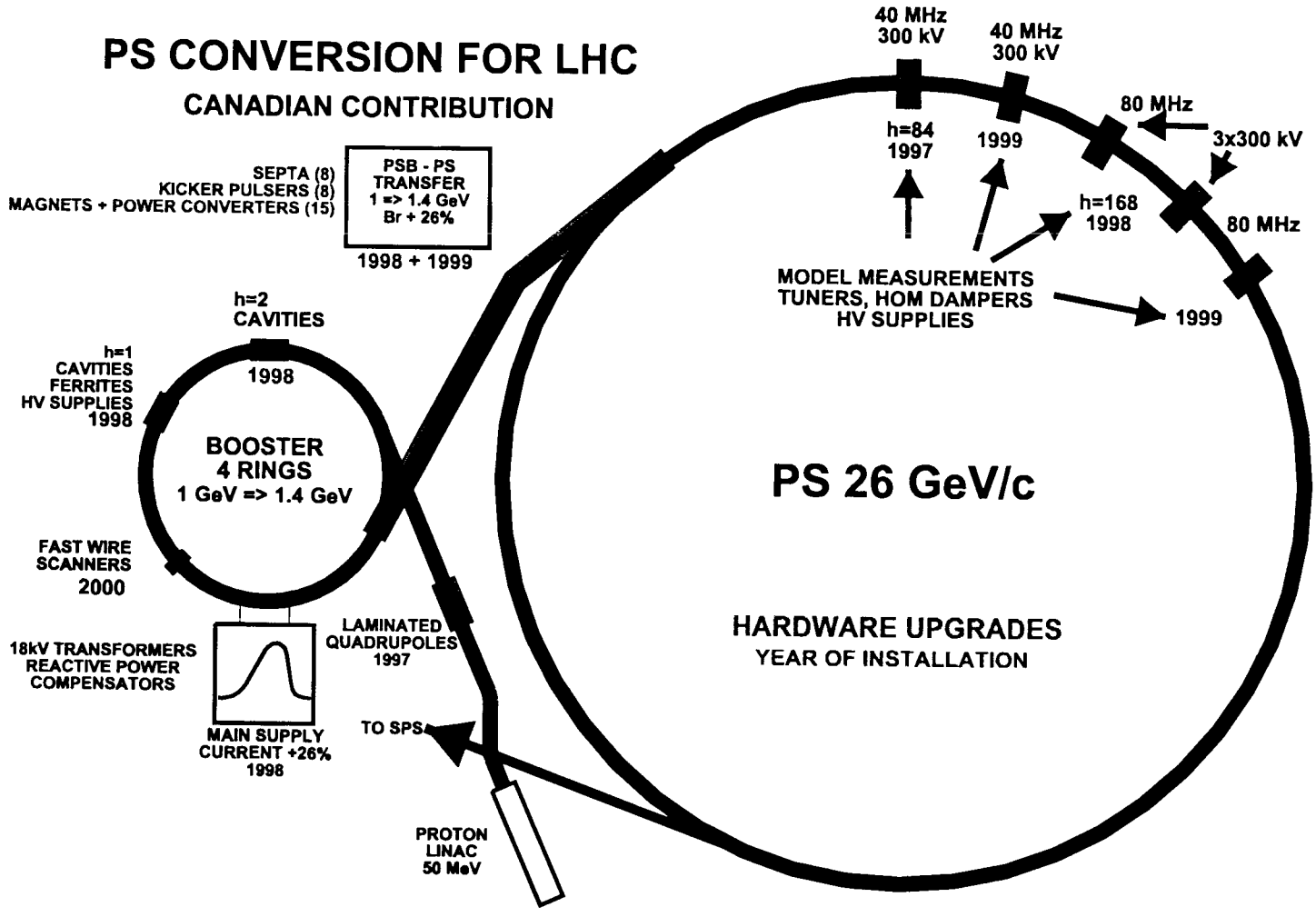
LE ν ?

ISOLDE (for PSB only)

…

Almost all require high intensities (>10^{13} p/p)...but <3 10^{13} p/p


LEP
ALEPH
OPAL
NORTH AREA
SPS
L3
DELPHI
WEST AREA
TT10
AAC
pbar
ISOLDE
TT70
EAST AREA
PSB
TTL2
E1
TT2
E0
PS
LPI
e+
e-
e-
EPA
LIL
LINAC 2
LINAC 3
E2
SOUTH AREA
p
Pb ions
LEAR
electrons
positrons
protons
antiprotons
Pb ions


PS CONVERSION FOR LHC
CANADIAN CONTRIBUTION
SEPTA (8)
KICKER PULSERS (8)
MAGNETS + POWER CONVERTERS (15)
PSB - PS
TRANSFER
1 => 1.4 GeV
Br + 26%
1998 + 1999
h=2
CAVITIES
1998
h=1
CAVITIES
FERRITES
HV SUPPLIES
1998
BOOSTER
4 RINGS
1 GeV => 1.4 GeV
FAST WIRE
SCANNERS
2000
18kV TRANSFORMERS
REACTIVE POWER
COMPENSATORS
MAIN SUPPLY
CURRENT +26%
1998
LAMINATED
QUADRUPOLES
1997
TO SPS
PROTON
LINAC
50 MeV
40 MHz
300 kV
40 MHz
300 kV
h=84
1997
1999
80 MHz
3x300 kV
h=168
1998
80 MHz
MODEL MEASUREMENTS
TUNERS, HOM DAMPERS
HV SUPPLIES
1999
PS 26 GeV/c
HARDWARE UPGRADES
YEAR OF INSTALLATION

Beam ON | Beam OFF | ME Machine Experiment | MD Machine Development | SU Setting up | see overleaf →

)PERATION 1999 PERIOD1: Weeks 24 /25 /26 /27 / 14 JUNE / 11 JULY - PSO1156 - 7.06.99

chedule is definitive at time of publication. For later changes or access conditions, please call the Main Control Room

76677

' July	Wk. 24							Wk. 25							Wk. 26							Wk. 27						
	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su	M	T	W	Th	F	S	Su
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5	6	7	8	9	10	11
	8h	7h	17h					8h	8h	16h			23h		8h		6h	14h		14h			8h	16h				

Tech. Stop

Boillot / S. Baird																	MD							MD				
.. Faugier										MD									MD					* *	▶leptons only			
.. Faugier																												
Baird / L. Rinolfi																	MD											
. Ruf	CMS									CMS																		
. Ruf								NEG														NEG						
CS/PSB C.Hill/M.Lindroos																	ME							ME				
Maury																												
HALL Ruf — t7															LHC Irrad.													
HALL Ruf — t8		SU		SU											DIRAC													
HALL Ruf — t9													PAMELA							NA58-SAT								
HALL Ruf — t10													Muon/RPC											TOF				
HALL Ruf — t11													NA58 SciFi					TOTEM		Spare								
DE/T.Nilsson	IS363,369,349			IS25				staggered beam					IS302, 307, 314, 348, 357, 360					P67										

equidistant pulses

'cycle 4s																												
week-days : 8h—>18h			EASTB		EASTB or MDPS		MDSPS										MDLHC		EASTA		EASTB		MDSPS or MDPS		5 ISOLDE (6 if no AD)			
			MDLHC																TSTAD									
week-days : 18h—>23h + week-ends with AD					TSTAD		MDSPS										EASTA		TSTAD		EASTB		EASTA		6 ISOLDE (7 if no AD)			
			EASTB (optional)																									
week-days : 23h—>8h + week-ends without AD							MDSPS										EASTA				EASTB		EASTA		7 ISOLDE			

special supercycle see MCR

http://www.cern.ch/CERN/Divisions/PS/Schedules/scheds.html

SPS/PS Coordinator : Thomas RUF tel:79237 75090 GSM: 160120

: D. Dagan tel.72901

OK for publication : Jean Boillot tel. 73179 GSM 160234

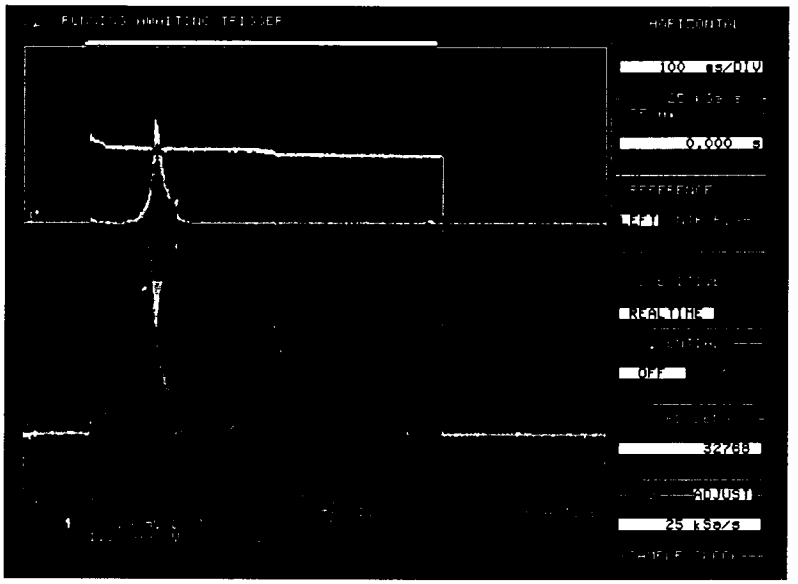
ISOLDE Coordinator : Thomas NILSSON tel:73809 GSM: 160985

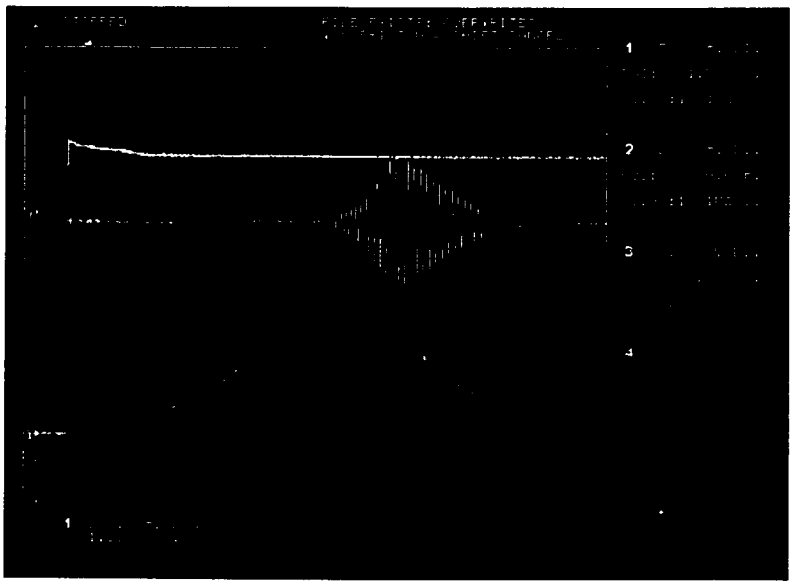
25/6/99

Coupl. bunch Long. Instabilities

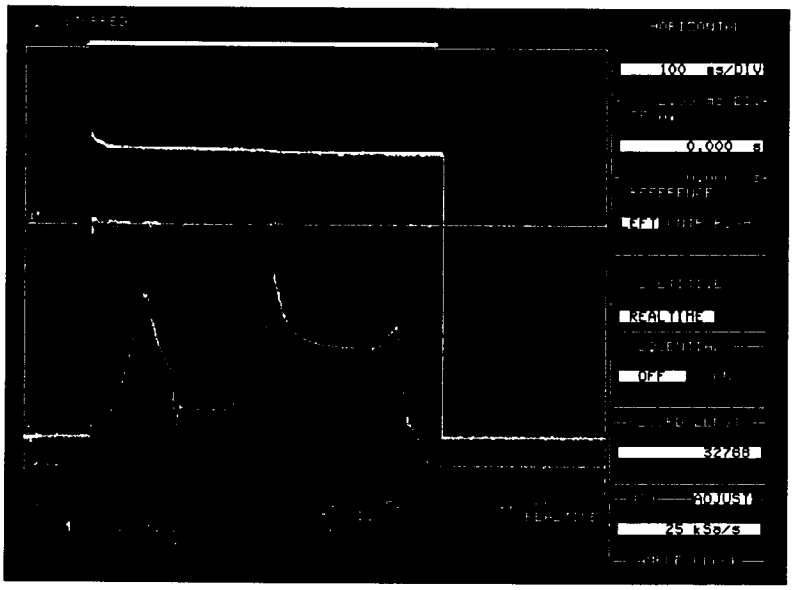
Nearby harmonic 10 (n=2 or 6)

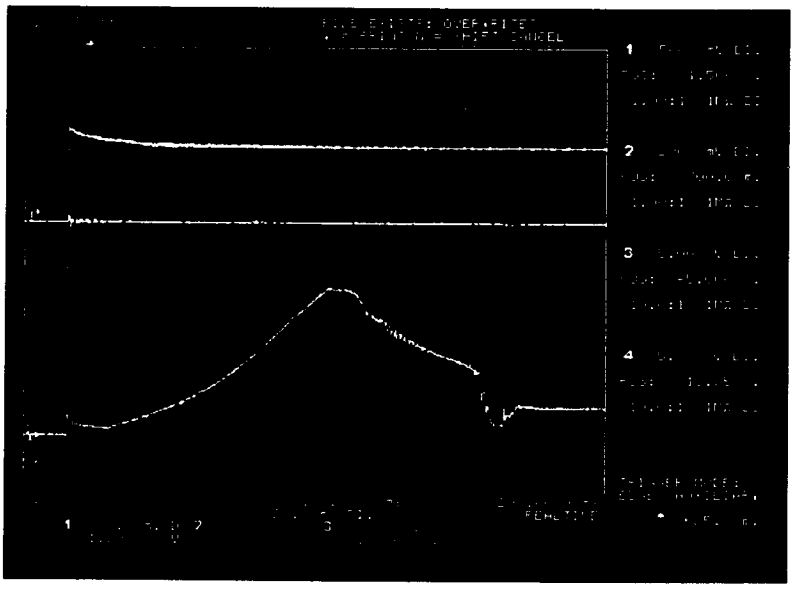
Ip ~ 3 10^{13} p/p, **ε_l ~ 2 eVs/b**, h=8



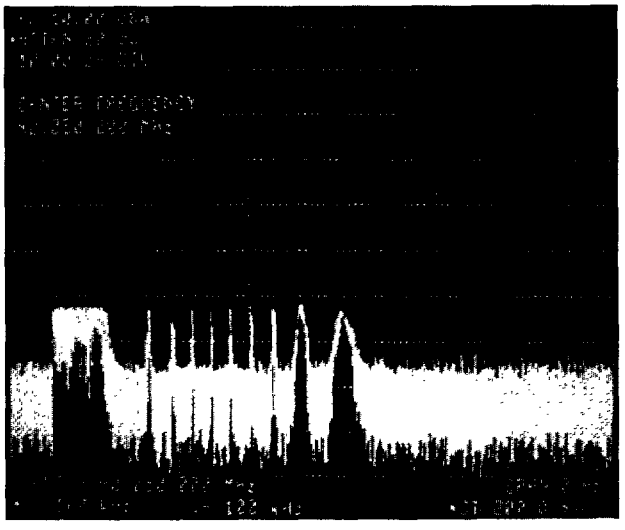


Cured by a feedback nearby harm. 10 (f~ 5MHz).
The signal is injected into the h=8 accel. RF cavities

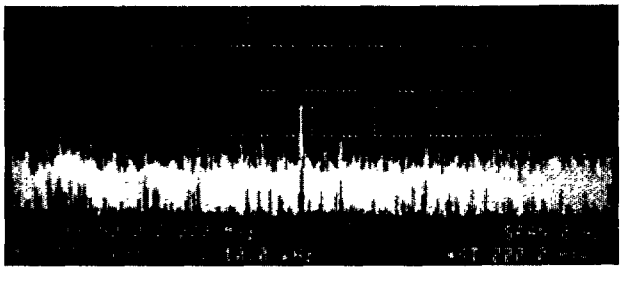




Voltage induced by the beam on one of the 40 MHz cavities *(the beam is practically destroyed)*



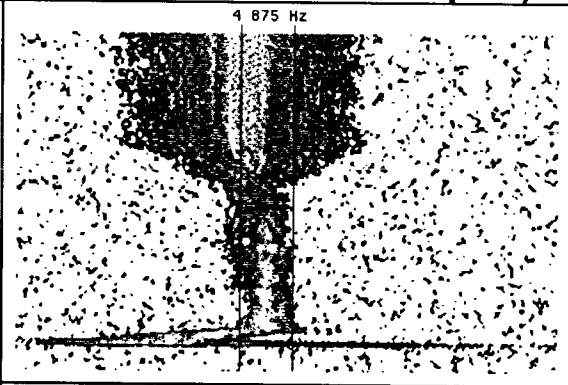
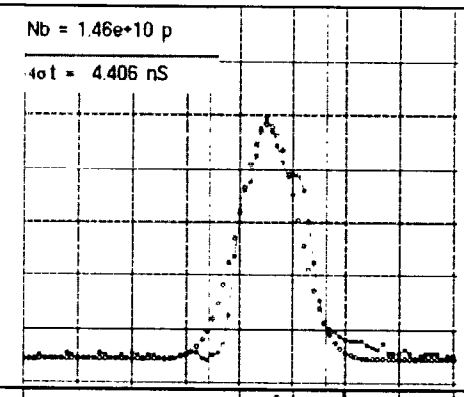
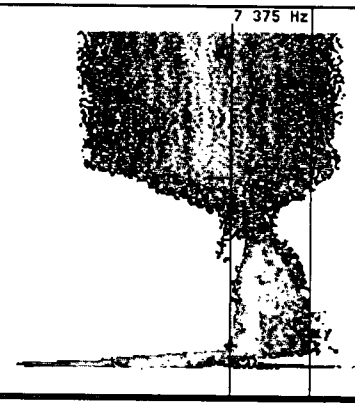
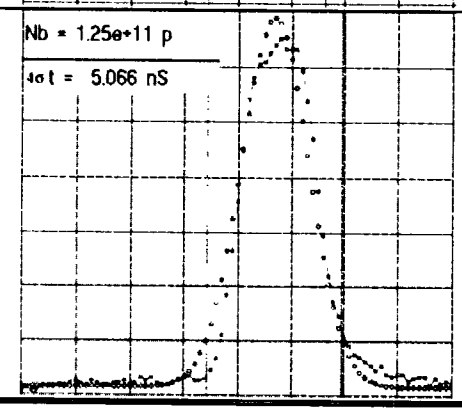
correction by a feedback system



=>All cavities have their proper feedback and are Short-Circuited when not in use.

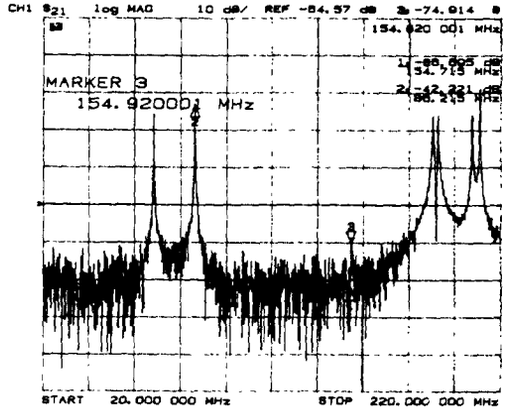
μW instability on debunched beam (LHC):

Z/n~17 Ω , measured by 1) quadr. freq. shift, 2) e- bunch lengthening and 3) transv. tune shift

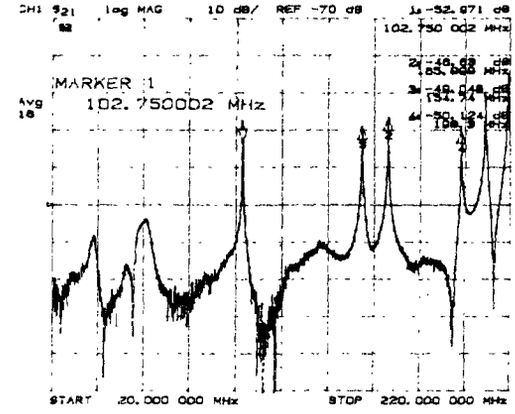
H^+ / bunch	E_L(h=16)	Schottky spec. @ 26 GeV/c (395 MHz – 50 kHz span)	Bunch @ ejection
~ 1×10^{10} H^+ @ ejection	0.85 eVs		
~ 10×10^{10} H^+ @ ejection	1.15 eVs		

Guilty ?

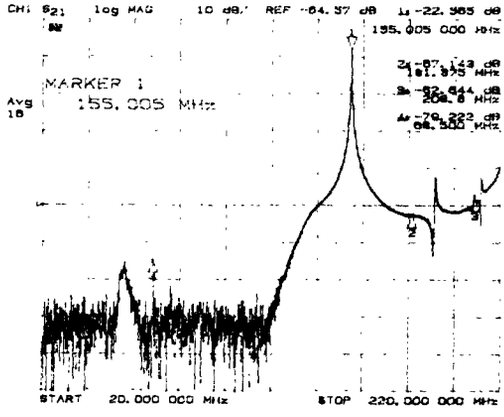
HOM - 114 MHz cavities



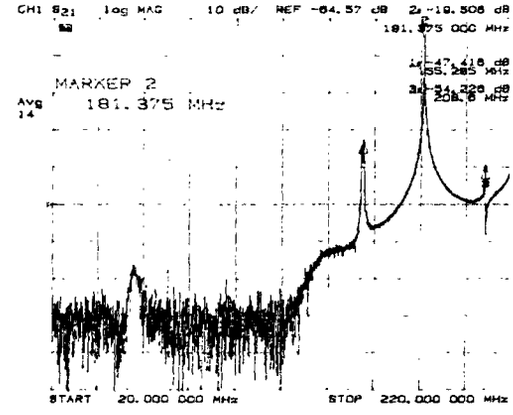
10.1.ac



10.2ac



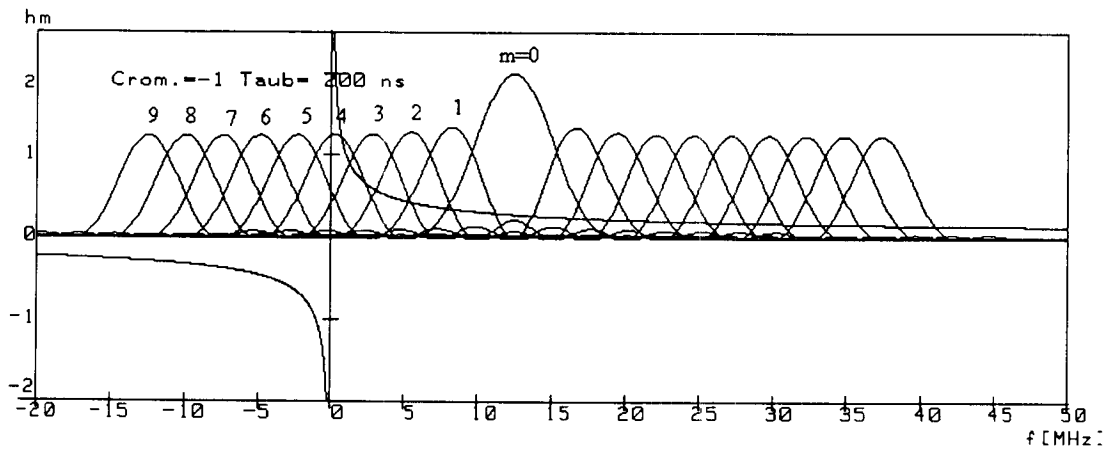
4.1ac



4.2.ac

Transverse instabilities

h-t single bunch hor. inst. driven by Resistive Wall impedance



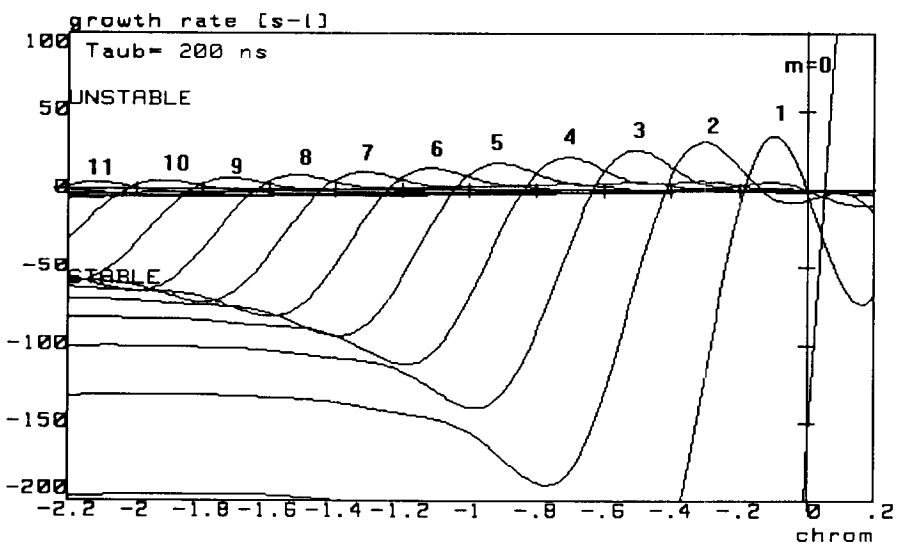
$$Z_{RW\perp} = (\mathrm{sgn}\,\omega - i)\frac{R}{b^3}\sqrt{\frac{2\rho}{\varepsilon_0|\omega|}}$$

$$\Delta\omega_m^{\perp} = -i\frac{1}{(m+1)}\frac{ecN_b}{4\pi Q_x \tau_b E/e}\frac{\sum_{p=-\infty}^{+\infty} Z_{\perp}\left(\omega_p^{\perp}\right) h_m\left(\omega_p^{\perp} - \omega_\xi\right)}{\sum_{p=-\infty}^{+\infty} h_m\left(\omega_p^{\perp} - \omega_\xi\right)}$$

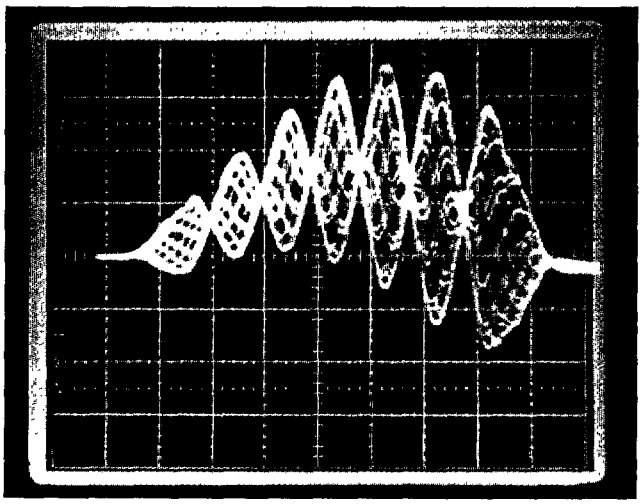
$$\omega_\xi = \frac{\xi Q_x \omega_0}{\eta}$$

The condition for the onset of the instability is:

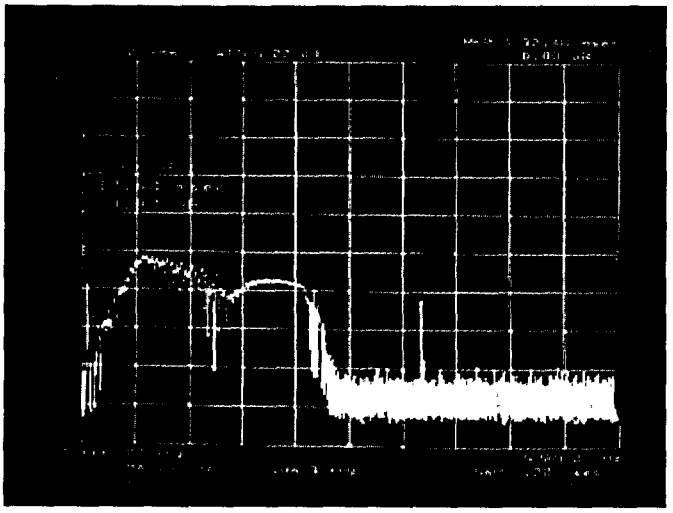
$$\mathrm{Im}\left(\Delta\omega_m^{\perp}\right) = \tau_r^{-1} \propto -\frac{1}{(m+1)}\frac{N_b}{\tau_b E}\sum_{p=-\infty}^{+\infty}\mathrm{Re}\left[Z_{\perp}\left(\omega_p^{\perp}\right)\right]h_m\left(\omega_p^{\perp}-\omega_{\xi}\right) > 0$$



Observation of h-t instabilities at 1.4 GeV/0.6s inj. flat top

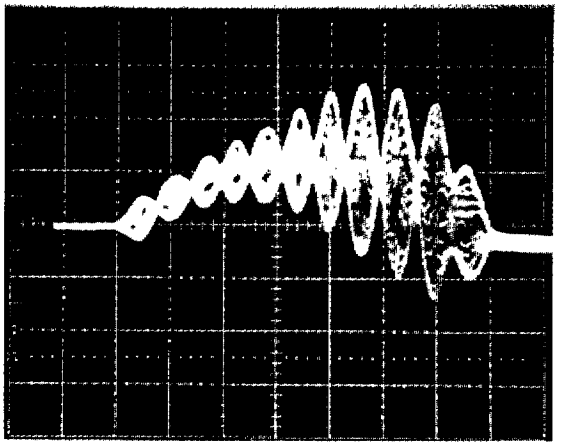


ΔR, I_{oct}=0A, I_{skew}=0.33A 20ns/d, Q_x=6.19, Q_y=6.21, m=6 , $\xi \sim -1$

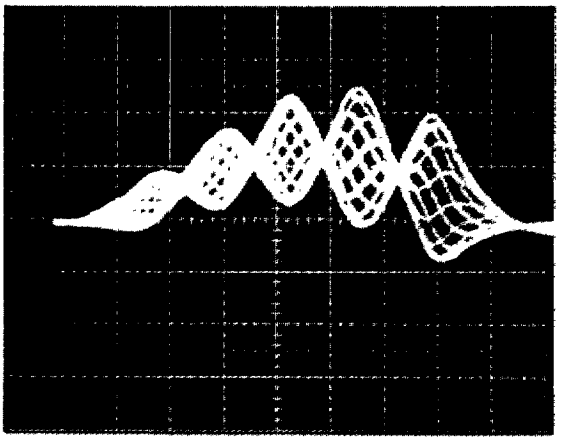


Aplitude of (1-q) betatron line vs time (log scale)

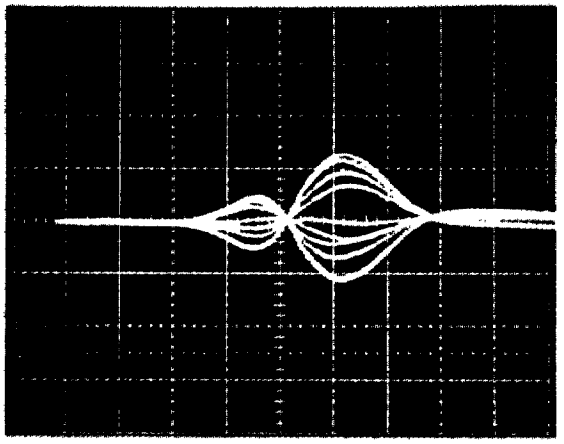
Ip vs time 100ms/d



m=10 , $\xi \sim -2$

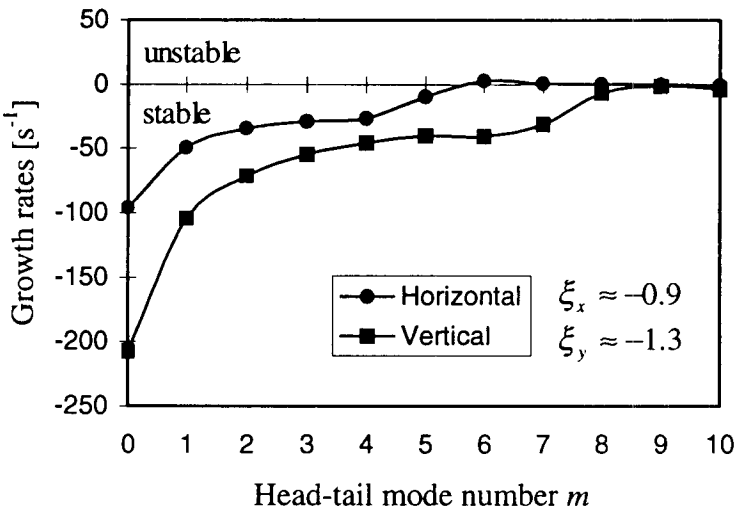


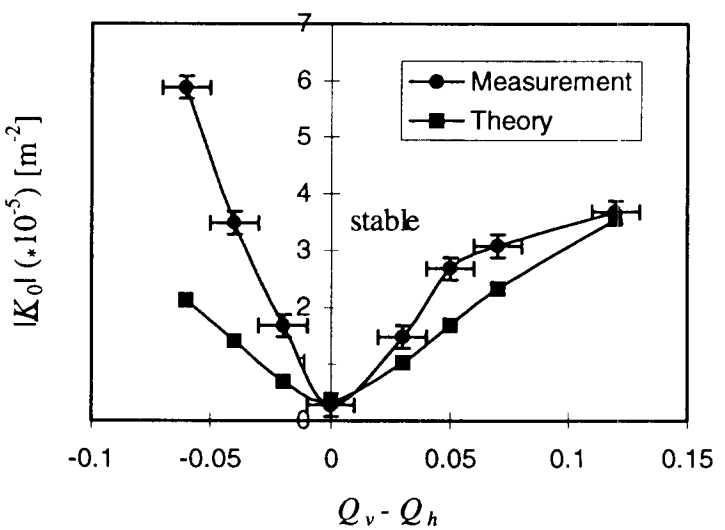
m=4 , $\xi \sim -0.7$



m=1 , $\xi \sim -0.2$

Increasing x-y coupling with Skew Quads the beam is stabilised:





Stability criterion: $|K_0| \geq f(Q_x - Q_y)$

Stabilisation can also be achieved with octupoles

OTHERS

SPACE CHARGE

$$\Delta Q_{x,y} \cong -\frac{3 r_0}{4 c} \frac{R}{\tau_b (\beta\gamma)^2} \frac{N_b}{\varepsilon^*_{x,y}}$$

As far as we stay $|\Delta Q_{x,y}| < 0.25$ no evidence of any transv. emittance blow-up along a 0.5s flat-bottom at 1.4Gev (e.g. LHC 'nominal' beam)

e^- - ions instabilities

Collected ions (CO+) in the e^- pot. well induce coherent vertical instabilities as 'hiccups' on a flat-top at 3.5 GeV at $f_\beta = (1-q)\, f_0 \sim 350$ kHz

They can be cured with a simple transverse feedback

Conclusion

- $I_p = 3\ 10^{13}$ p/p is at present operational.

- We have no requests for much higher intensities… for the time being,

- but we have requests for high beam quality, *e.g.:*

  - ✓ *lowtransv. emittances for LHC (3μm, $I_p \sim 10^{13}$ p/p)*

  - ✓ *short bunches for TOF (25ns, $N_b \sim 0.7\ 10^{13}$ p/b, k_b=1 or 4)*

  - ✓ *low ripple for SE, etc.*

- To preserve the present ~95% machine reliability we want to keep beam losses at $< 5\ 10^{11}$ p/s.