

Fast-Ion? Instability in the SPring-8 Storage Ring

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SPring-8 Storage Ring = 3rd Generation Light Source

Particle	electron	
Energy	8	GeV
Stored Current	100	mA
Circumference	1436	m
Number of buckets	2436	(~2ns spacing)
Natural Emittance	6×10^{-9}	m•rad
Radiation Damping Time	$\tau\beta = 8.3\text{ms}$	$\tau E = 4.2\text{ms}$
Chromaticity	$(\xi_x, \xi_y) = (6, 7)$	

to suppress TCI by HOM(x) and ID R.W. (y)

44 Normal Arc Cells + 4 Long Straight Sections

(converted to be Magnet Free with New Chambers,
2000's summer)

Beam Parameters

at a beam size monitor (visible light interferometer $\sim 10\mu\text{m}$)
at small current, normal operation

	Size(rms)	β	Emittance	
Horizontal	150 μm	1.9 m	6×10^{-9}	m•rad
Vertical	20 μm	7.0 m	15×10^{-12}	m•rad
				$\sim 0.3\%$
Horizontal Dispersion			108mm	
Energy spread			1.08×10^{-3}	

After the installation of 30m-long straight sections

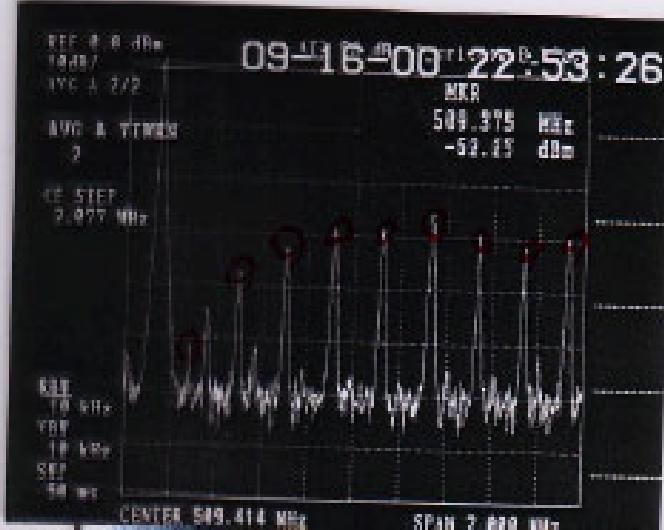
Many Peaks at lower betatron sideband on BPM signal
and Beam size increase

Vertical	horizontal after the suppression of vertical
Slow and Wide	0.2 ~ 10MHz but baseband is suppressed
Filling	long bunch train
Strong	chromaticity ~ -17 was required to suppress 4 times faster than radiation damping
time cures it	vacuum pressure?
Enhances	Vertical Coupled-Bunch Instability driven by Resistive-Wall Impedance of In-Vacuum type IDs at small gap
Not frequency of cavity HOMs	
TM010(Acc.Mode)	508MHz
TM011	$\sim 750\text{MHz}$
TM111	$\sim 1070\text{MHz}$

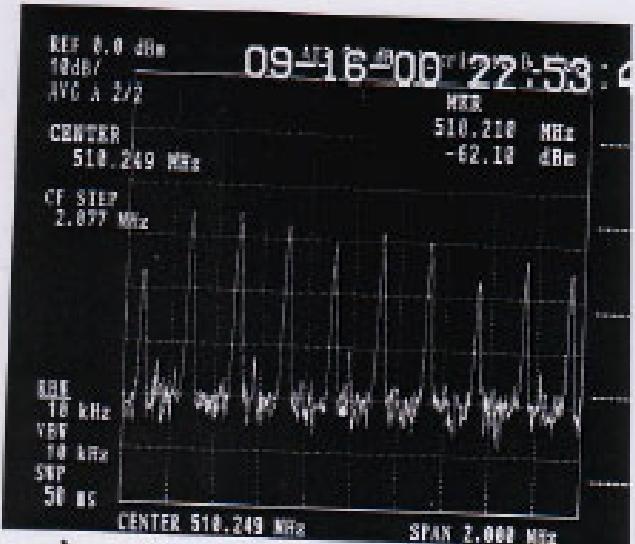
$$\begin{aligned} \text{TM011} &= (508 + 240) \text{ MHz} \\ \text{TM111} &= (2 * 508 + 54) \text{ MHz} \end{aligned}$$

45

-Swallow ~100mV



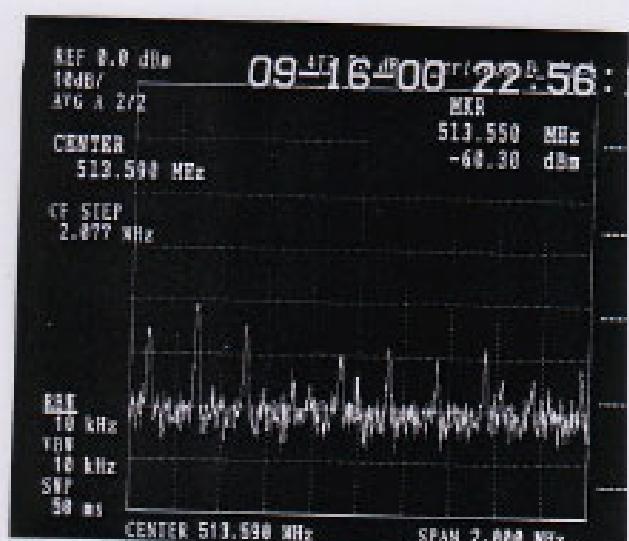
8 PB.6mA h=9



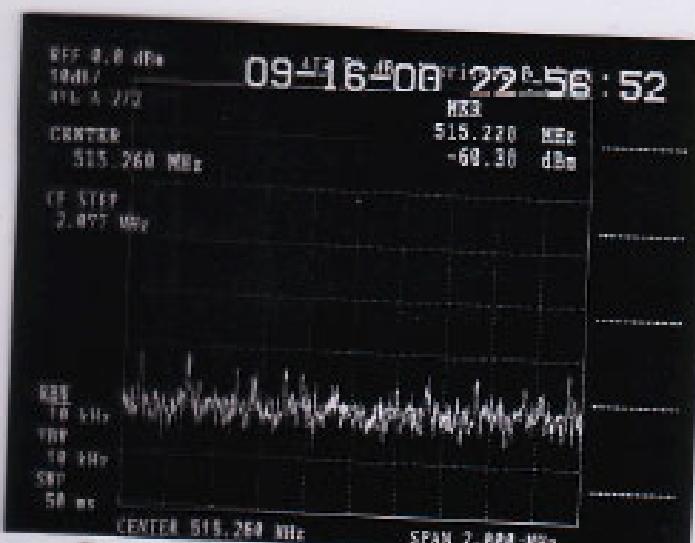
8 PB.6mA h=8



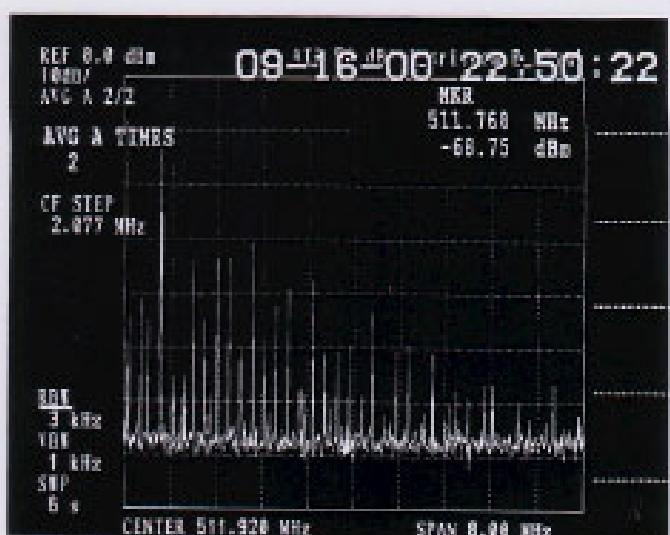
8 h=16



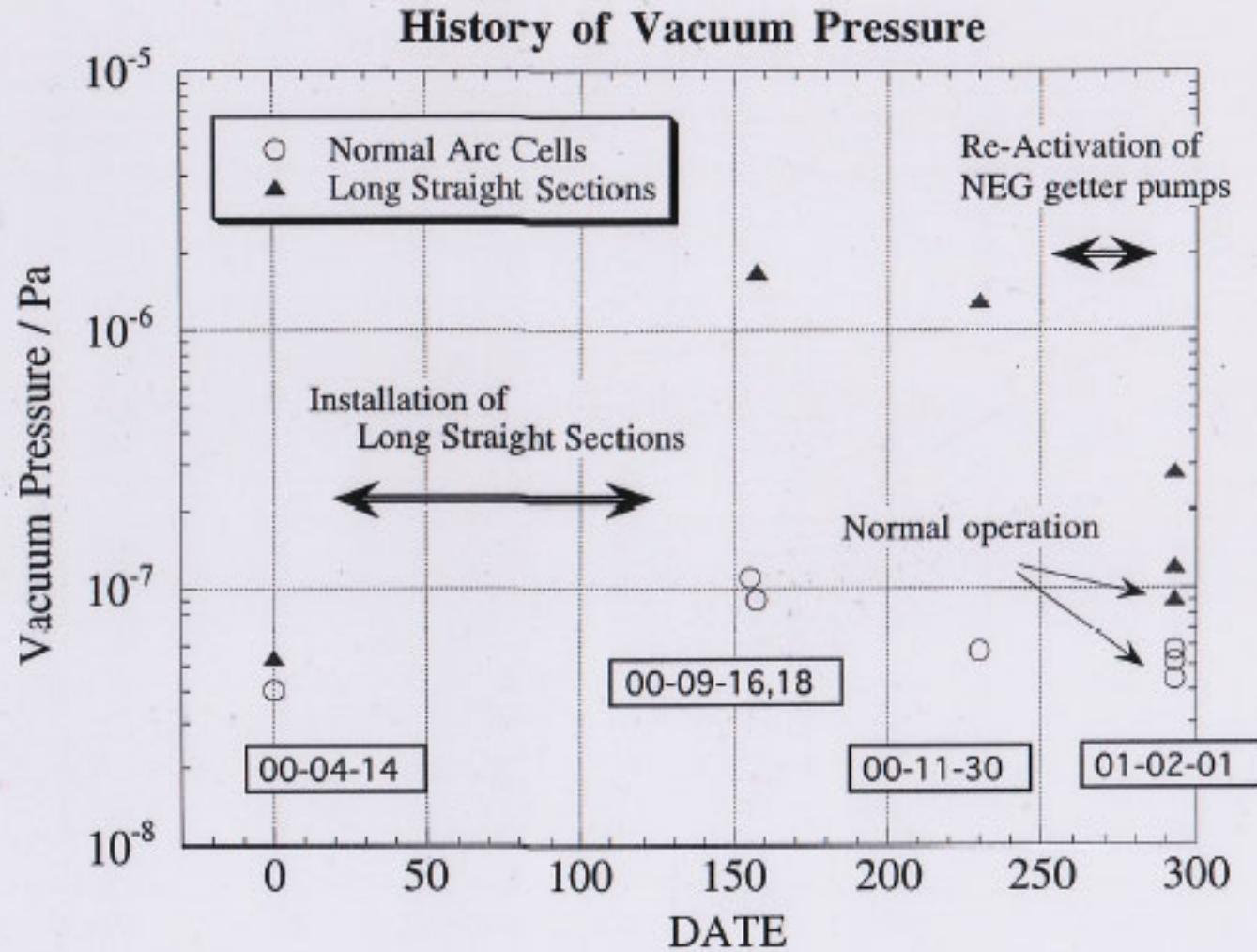
8 h=256



8 PB.5mA h=72



(Y) PB.6mA cf = 16s.

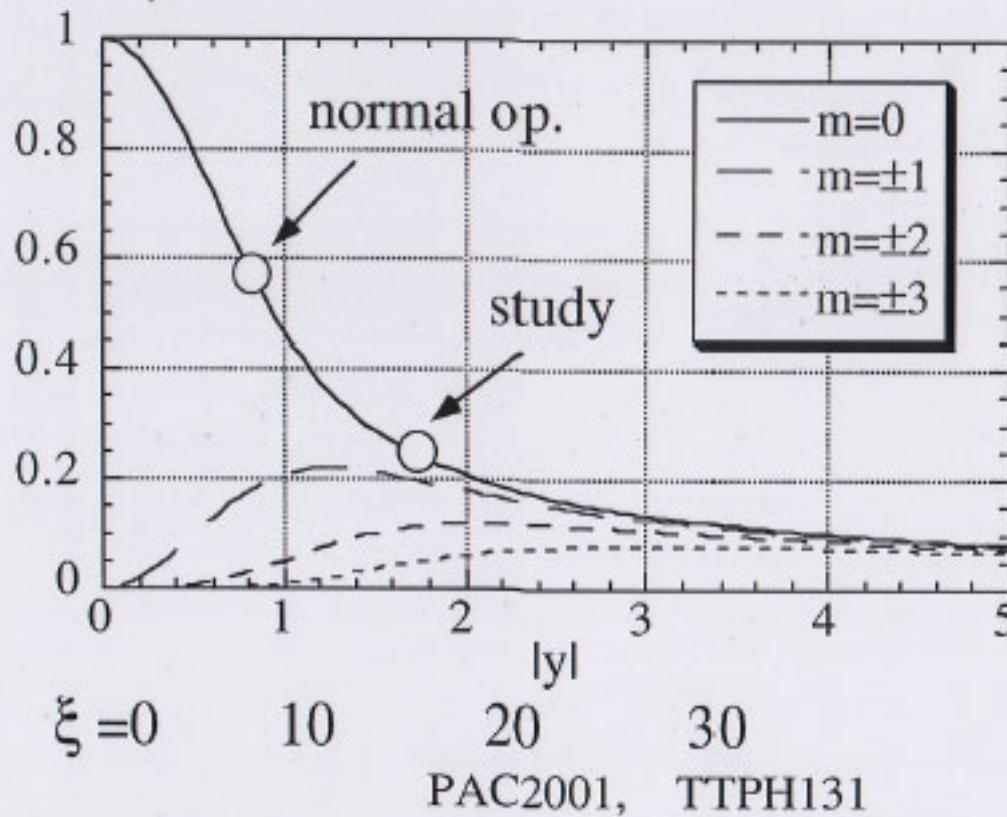


Reduction of the strength of instability

$$R_m(y) = \frac{1}{y^2} \int_0^\infty J_m^2(x) e^{-\frac{x^2}{2y^2}} x dx, \quad y = \left(\alpha \frac{\nu_\beta}{\nu_s} + \frac{\xi}{\nu_s} \right) \sigma_\delta$$

$$\nu_\beta \sim \frac{\text{instability}}{\text{friction}}$$

$$\nu_s = 0.01, \nu_\beta = 21.15, \xi \sim 7, \sigma_\delta \sim 1.1 \times 10^{-3}, \alpha = 1.46 \times 10^{-4}$$



Longer lifetime -> Smaller bunch current
-> Larger bunch number -> Less gap length

But this instability limits the length of bunch trains

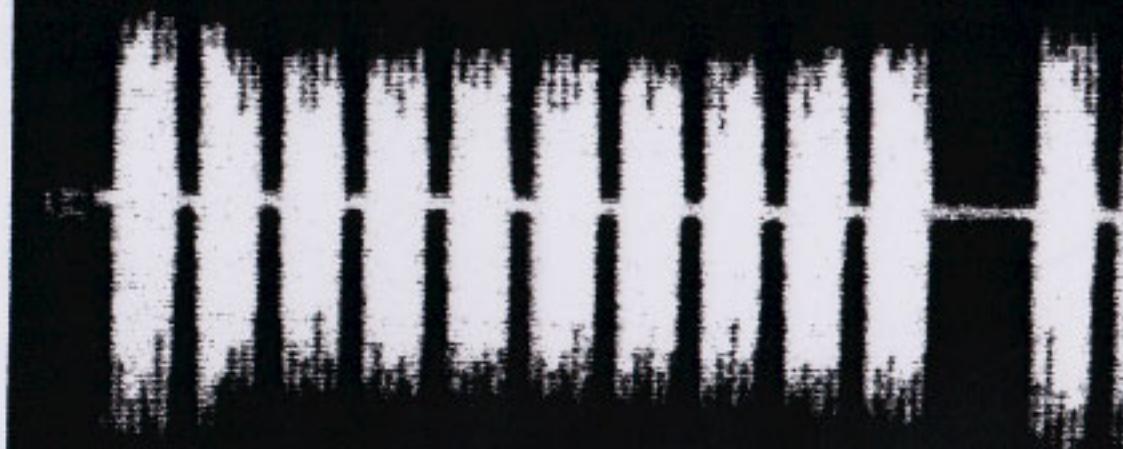
- ? How long bunch train we can obtain without beam size increase?
- ? How long gap we have to put between bunch trains?

Several filling patterns were tested
monitoring betatron oscillation and beam size
1/2 filling, 1/3 filling, 1/6 filling, ... and found

12×(152 bunch + 51 empty buckets) for user operation

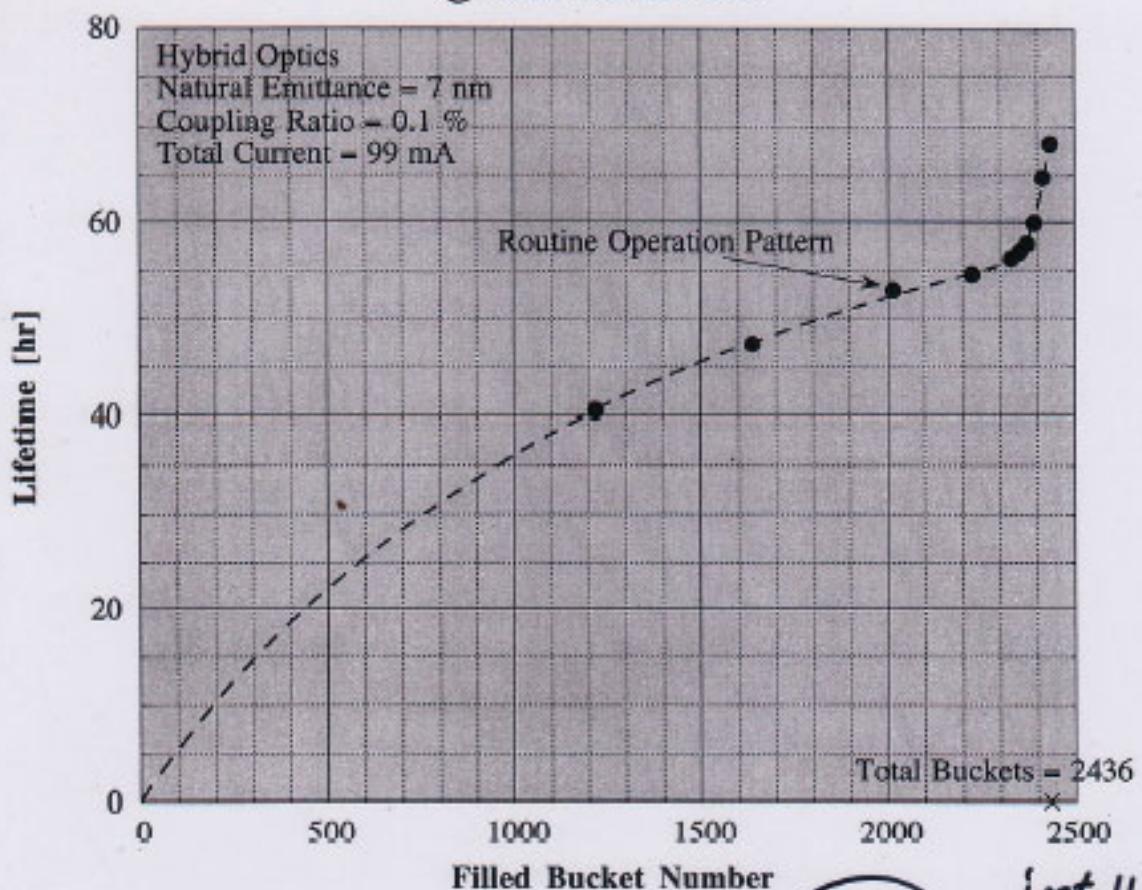
51 empty buckets ~ 100ns
 $v_{\text{thermal}} \sim 200 \text{ m/s}$ $200 \text{ m} \times 100 \text{ ns} = 20 \mu\text{m} \sim \text{vertical beam size}$

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3D 100% 100% 100% 100% 100% 100%

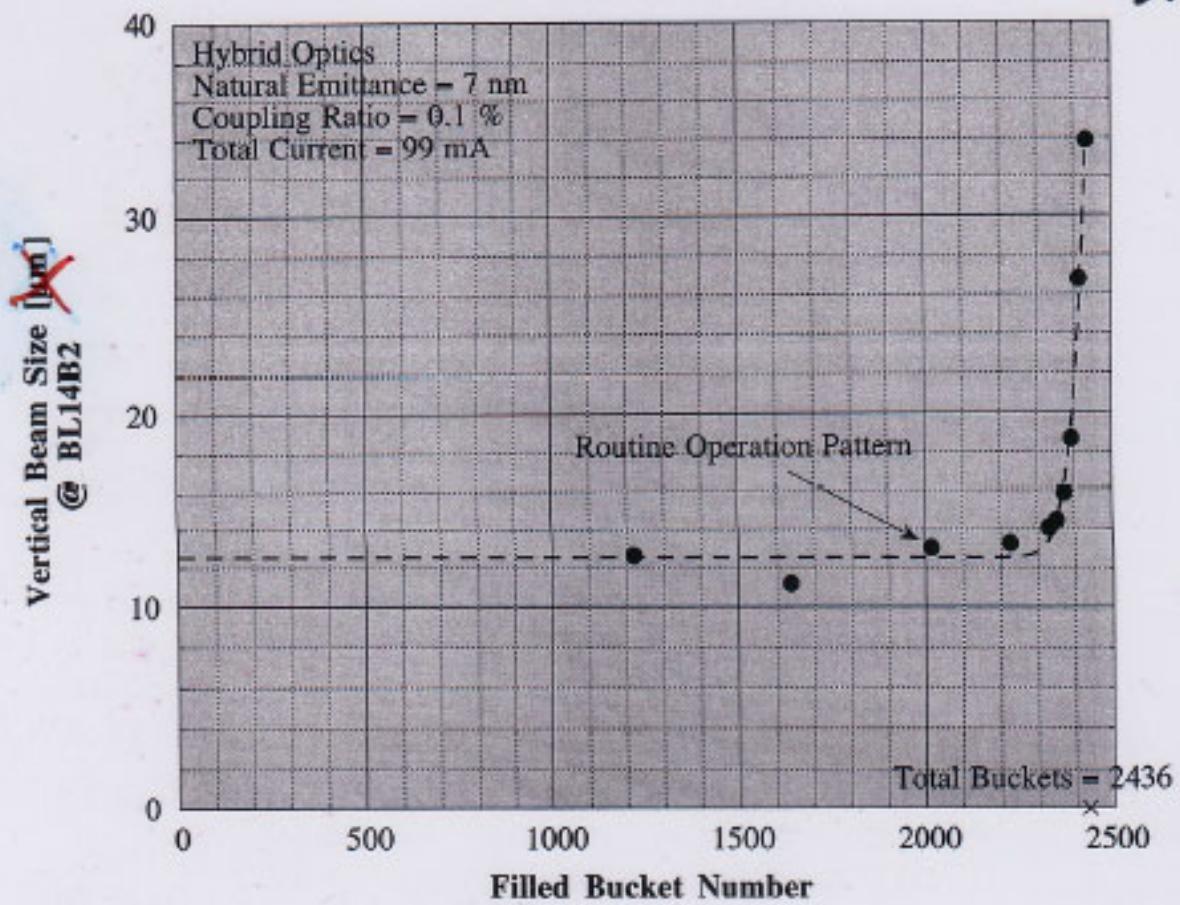
Filling Pattern v.s. Lifetime
@ Multi-bunch Mode



before

installation of
Long
Straight
sections

Filling Pattern v.s. Vertical Beam Size
@ Multi-bunch Mode



old

new

after the installation of Long straight section

2000/9/18

filling dependence

• vertical beam size

○ horizontal beam size

horizontal beam size (μm)

159
158
157
156
155
154
153
152

93mA uniform fill RF=16MV

91mA 1/2 fill RF=16MV

96mA 4*(320 bunch train)

95mA 21*(60 bunch train)

21mA 21 bunch equal spacing

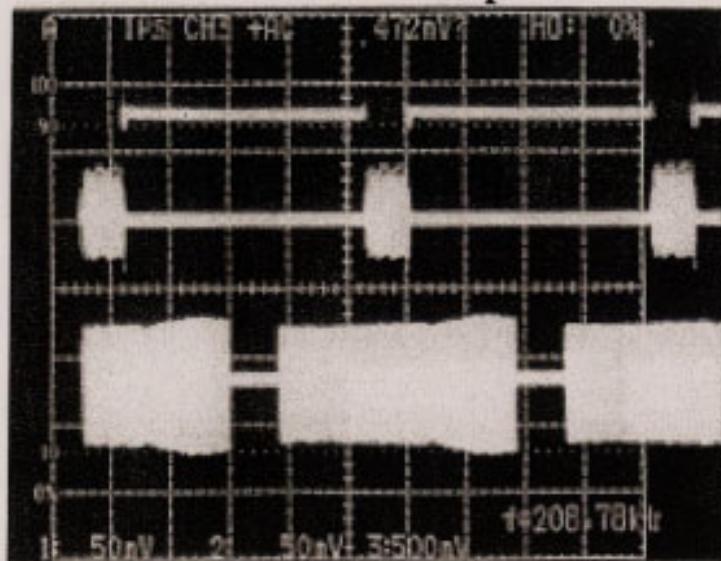
vertical beam size (μm)

140
120
100
80
60
40
20
0

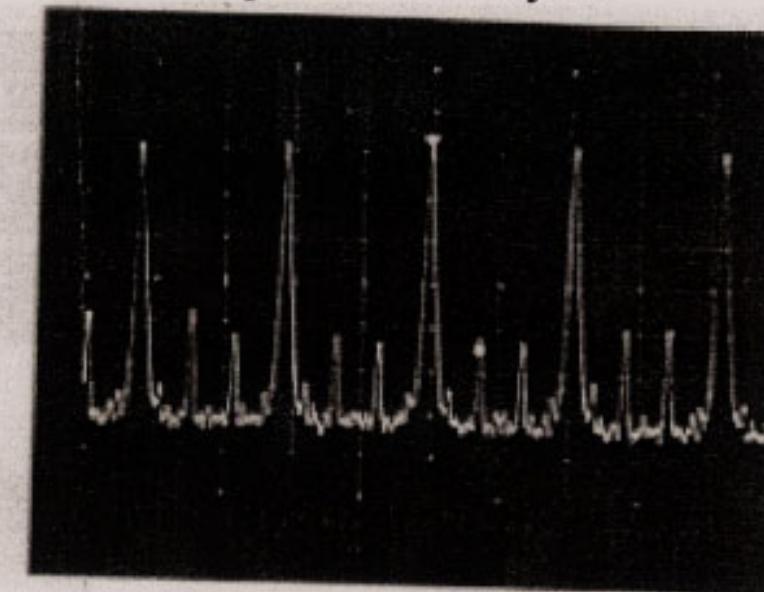
vertical beam size (μm)

Typical Data on Spectrum Analyzer Display

Oscilloscope



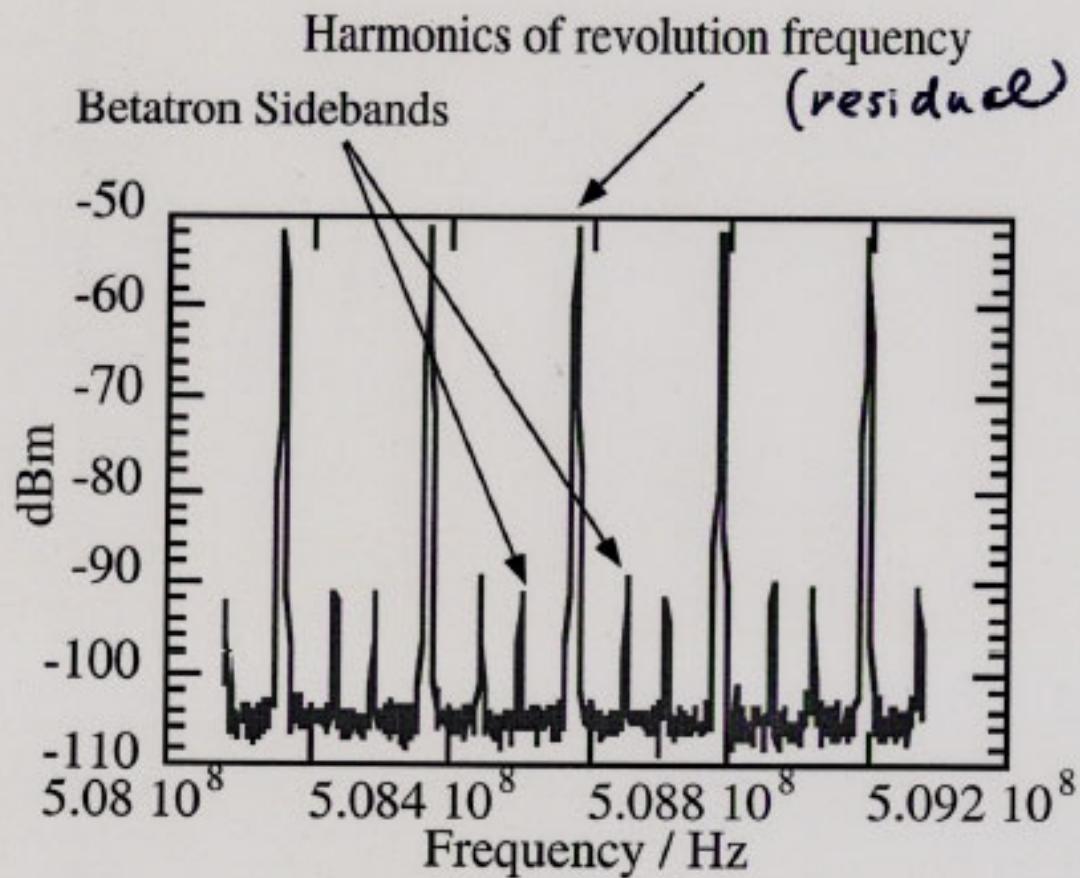
Spectrum Analyzer



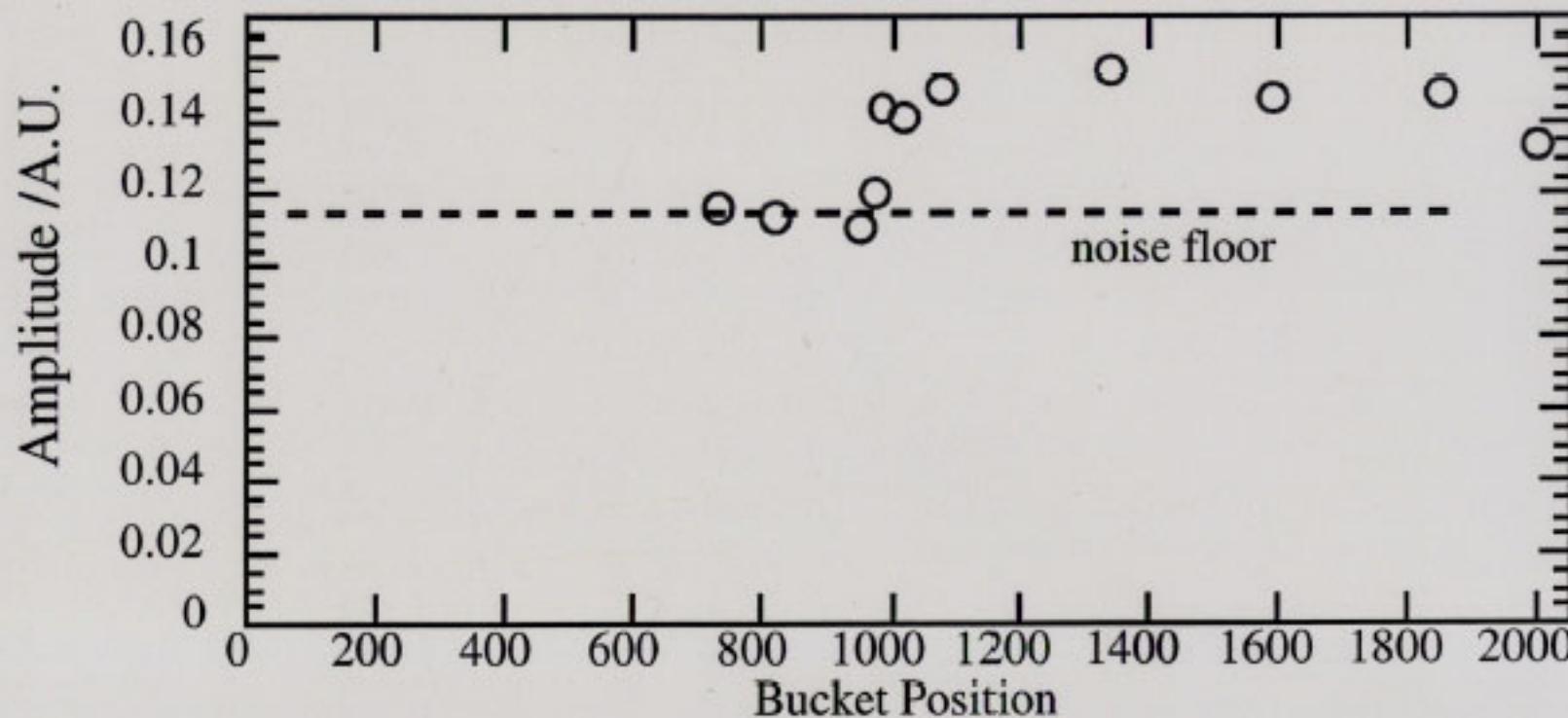
Upper : gate signal
Mid : gated output
Bottom : input signal

Higher Peaks: revolution harmonics
(residual)
Lower Peaks: Betatron sideband

Typical Data on Spectrum Analyzer Display



24/29 filling = 2016 bunches = 96.8 mA



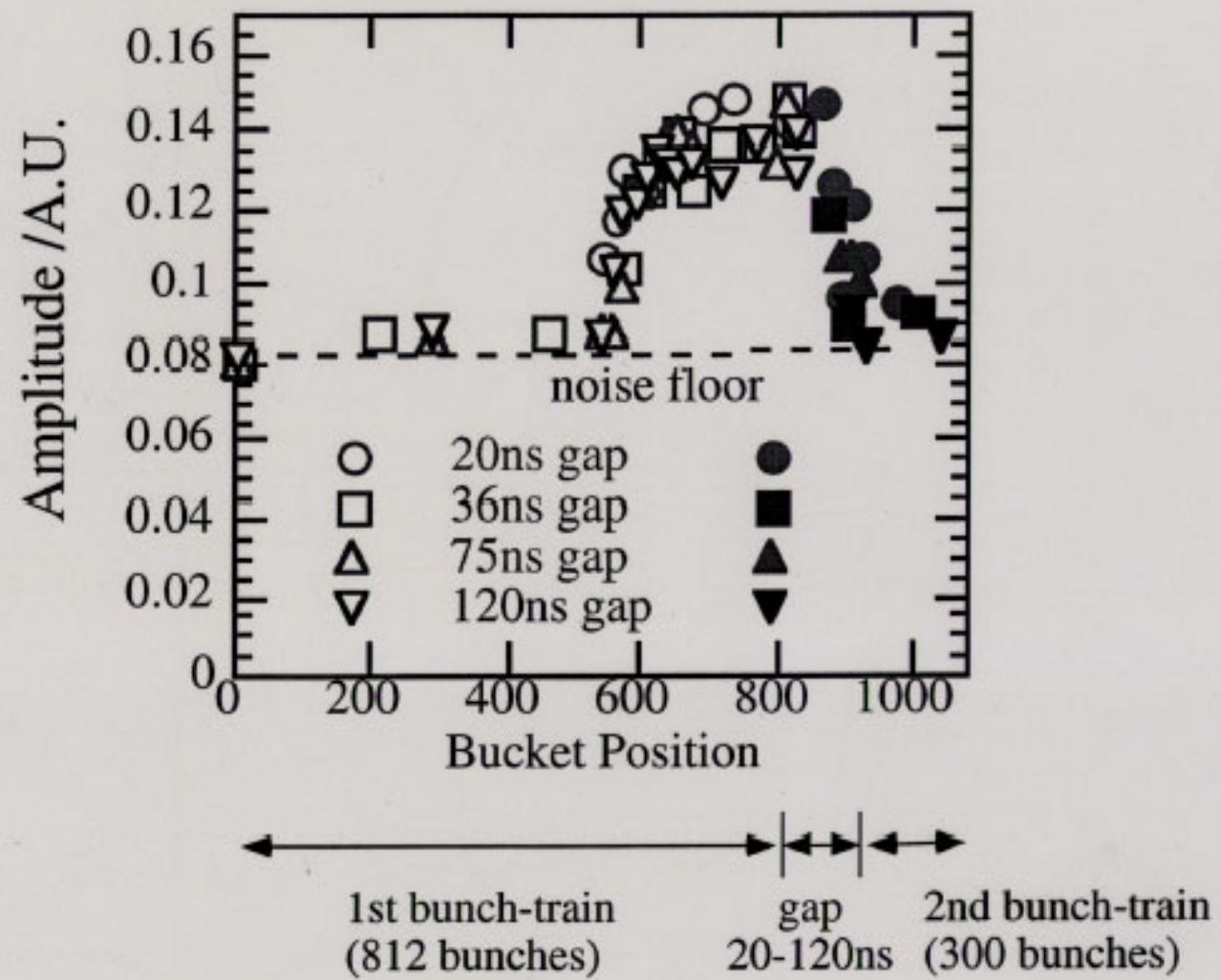
96.8 mA

shown above

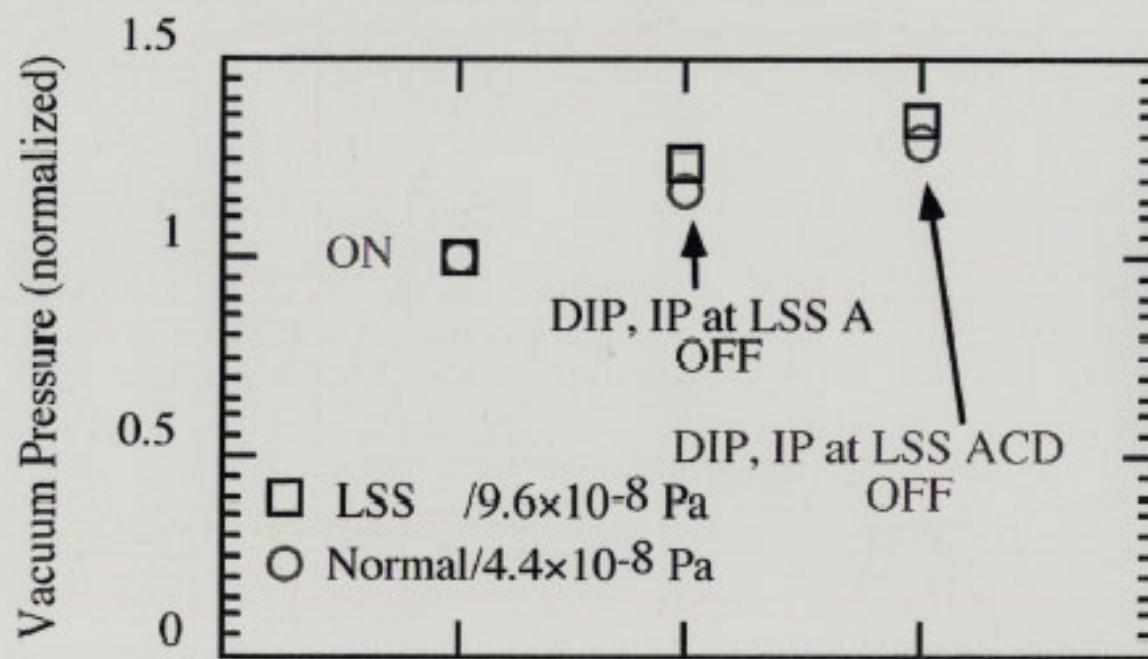
57.4 mA

No betatron sideband \rightarrow No instability

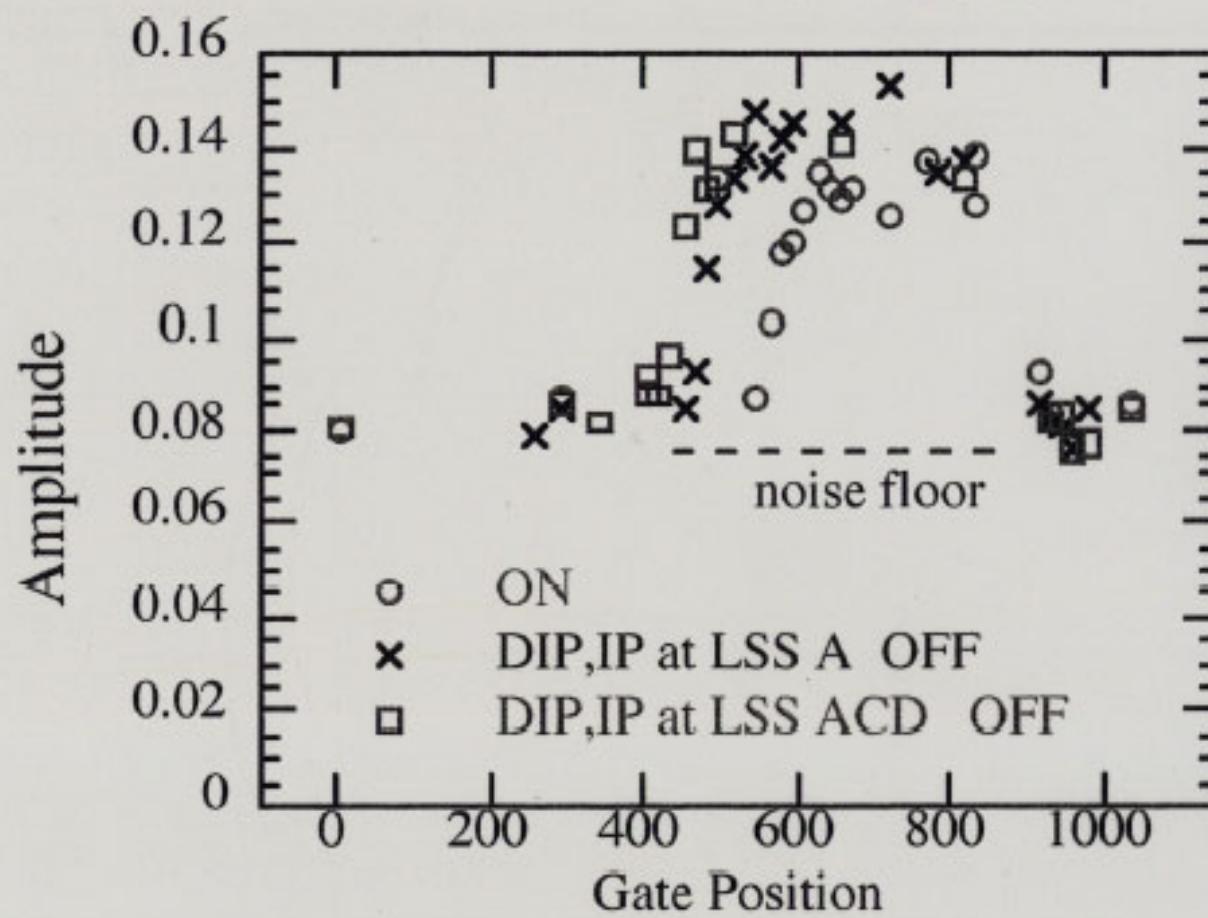
$$812 \text{ bunches} + \text{gap}(20\text{--}120\text{ns}) + 300 \text{ bunches} = 95 \text{ mA}$$



Vacuum Pressure Changed by ON/OFF of IPs

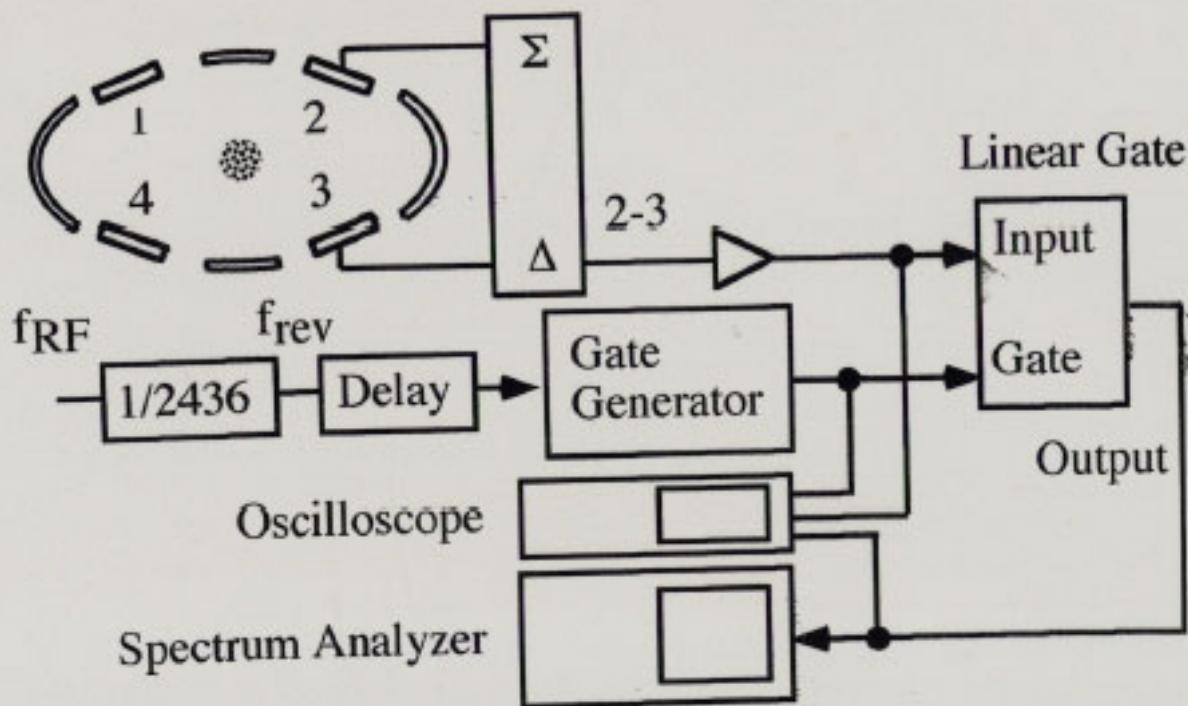


- Circle : at normal sections / 4.4×10^{-8} Pa
Square : at long straight sections / 9.6×10^{-8} Pa.



Vacuum Pressure Dependence
Gap is 120ns

Measurement of Distribution of betatron amplitude in bunch train



Beam signal from pick-up is gated by
external clock of revolution frequency f_{rev}

Gate Width is 30ns

Multibunch instability

It depends

Vaccum Pressure

Length of bunch train

Small Gap cures ($\sim 100\text{ns}$)

In next few months, we expected we can increase
the length of bunch trains.