Vertical Effective Impedance Measurements Using Closed Orbit Distortion

Experience carried out by the theory and diagnostics groups of E.S.R.F.

Outline

I Motivations

II General principle and interests of the method

III Measurement of a straight section effective impedance

IV Global measurement of all straight sections effective impedances

V Exotic measurements

VI Conclusion

Motivations

At E.S.R.F. some critical devices, in terms of impedance, are installed (low gap chambers, in vacuum undulators…).

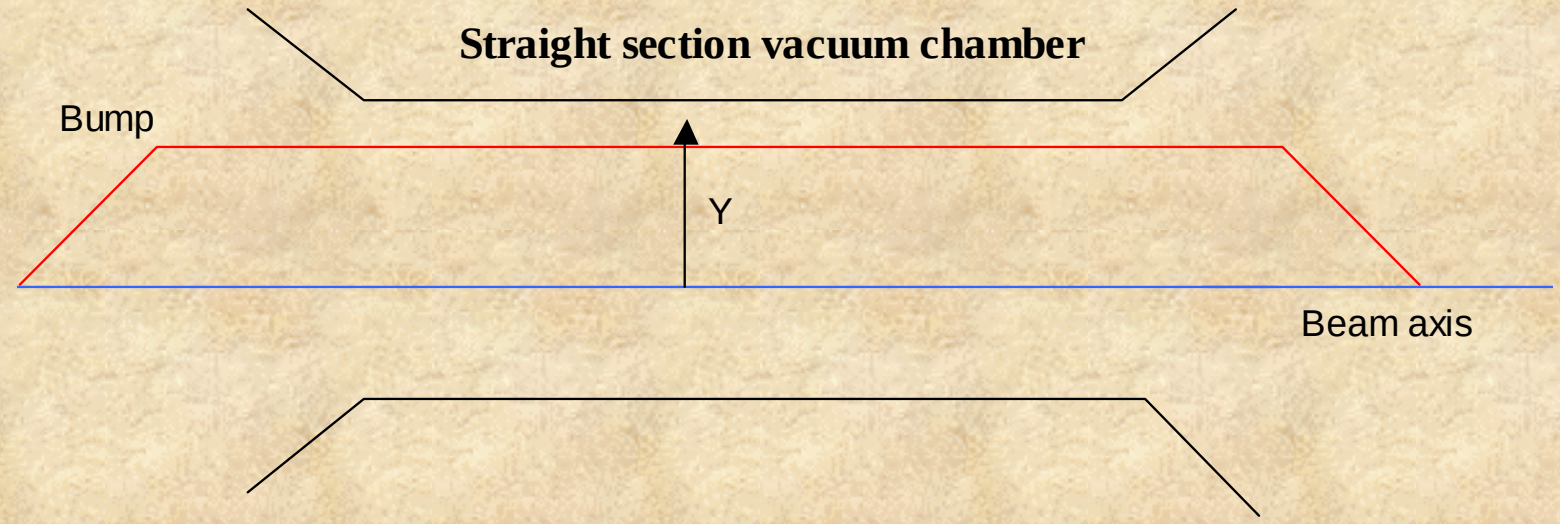
E.S.R.F routinely runs a high current single bunch mode which is limited by tranverse instabilities.

$\Downarrow$

It is an important issue to understand the vertical impedance of those devices in order to keep the global vertical impedance as low as possible.

Principe: Measure on a distorted close orbit, a kick due to impedance.

Introduced by :L.Emery, G.Decker, and J.Galayda at APS and V.Kiselev and V.Zorin BINP



If Y is $\neq 0$ impedance induces a kick to the beam proportional to the displacement Y and the bunch current.

Zero current closed orbit

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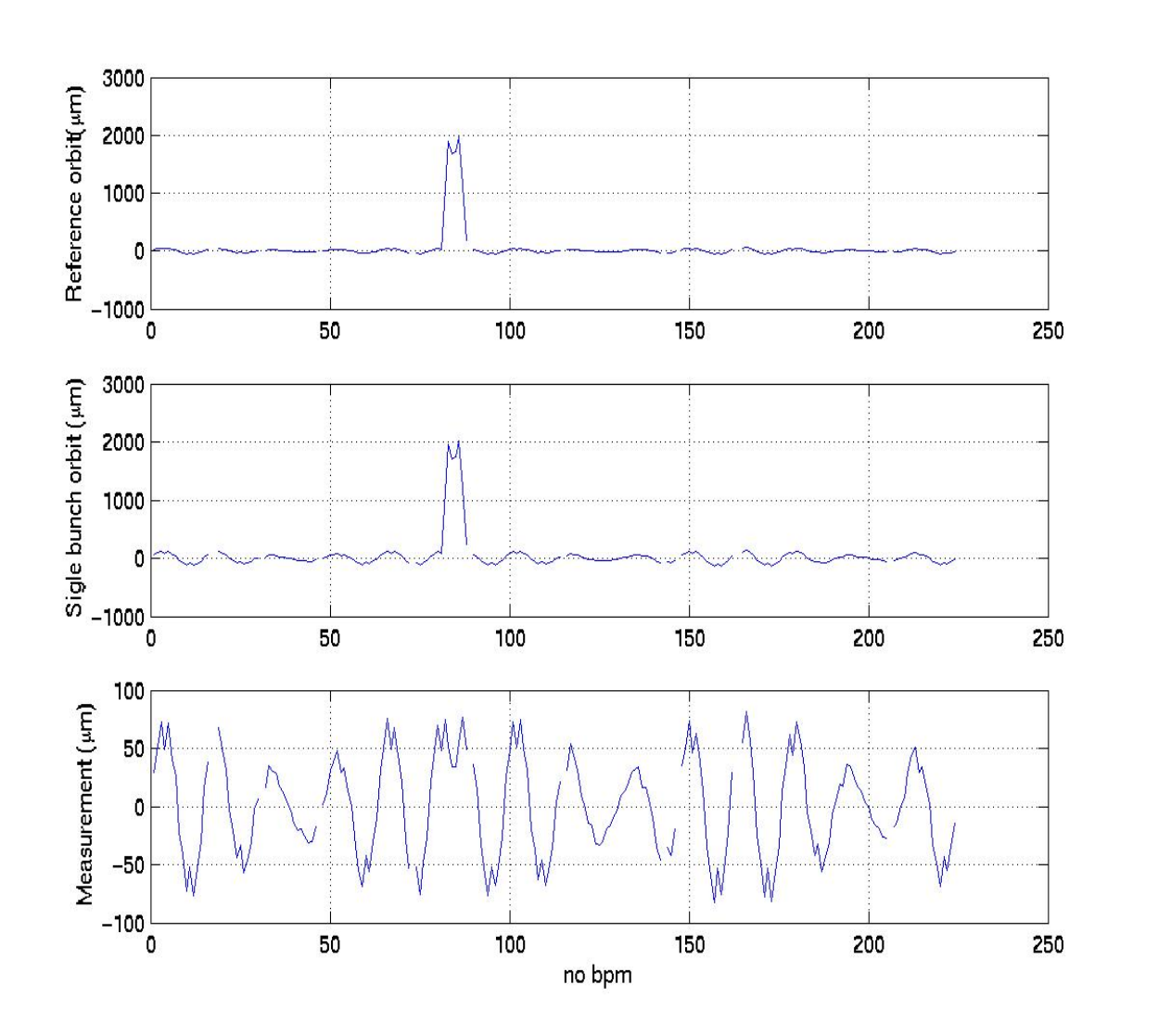
Single bunch high current closed orbit

=

Closed orbit distortion due to impedance kick



$$\theta_{Kick} = \frac{I \times Y_{Bump}}{2\sqrt{\pi} \times f_0 \times \sigma_t \times \left(E/e\right)} \times \Im\left(Z_{\perp eff}\right)$$

For localised impedance

$$d\theta_{Kick(s)} = \frac{I \times Y_{(s)Bump}}{2\sqrt{\pi} \times f_0 \times \sigma_t \times \left(E/e\right)} \times \Im\left(\frac{dZ_{\perp eff(s)}}{ds}\right) \times ds$$

For distributed impedance

Only the imaginary part of the effective impedance can be measured

Effective impedance is an average of impedance over the beam spectrum. Frequential distribution of impedance is not available with a single measurement.

Interests of the method

-Direct measurement of effective impedance

-Local measurement

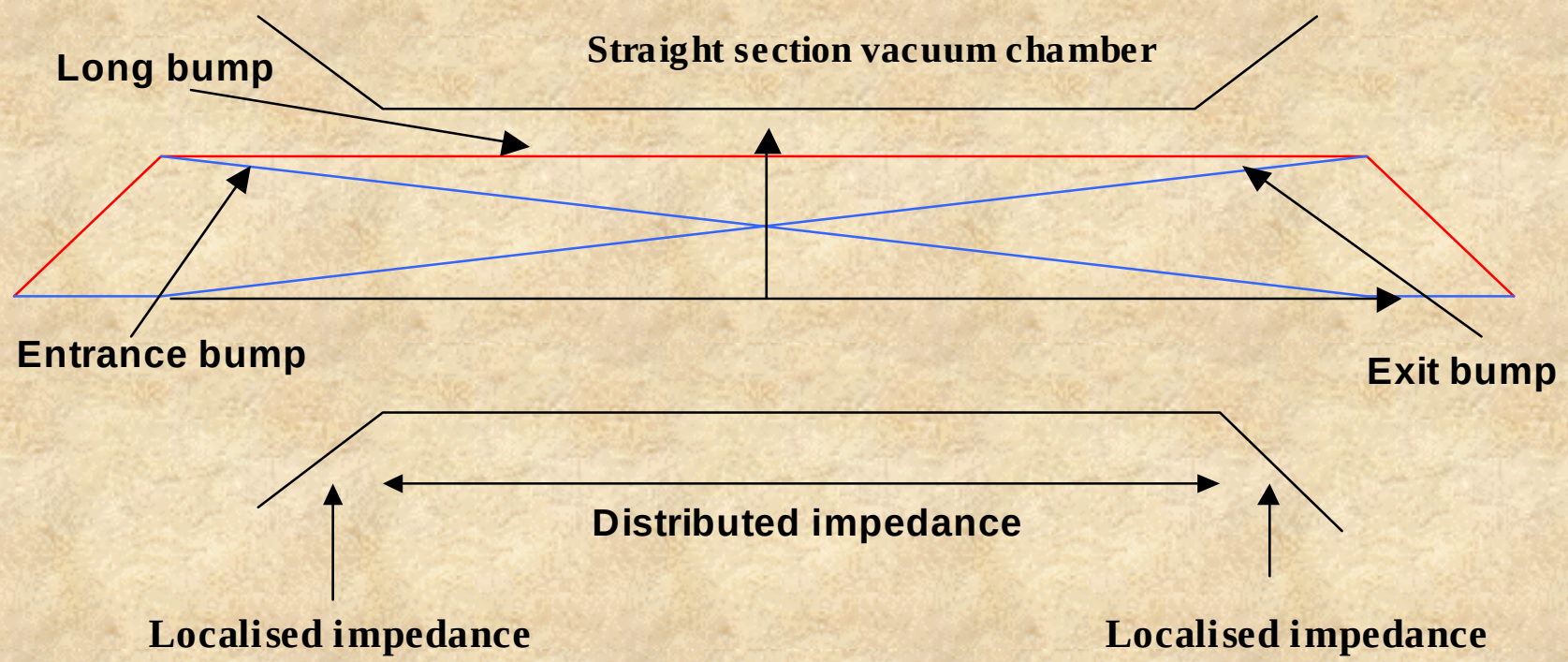
Comments about the precision

-Importance of bump quality.

-Importance of noise in BPM system.

- For 1μm noise in the BPM's, precision is evaluated at 3KΩ/m.

Assumed structure for the impedance: 2 localised impedances, and 1 distributed.



3 bumps $\times$ 2 equations $\Rightarrow$ 6 equations for 3 unknowns

	02/2003 Measurements	05-03 Measurements	06-03 measurements	09-03 measurements
Zid31 taper entrance (Kohms/m)	10,9		41,7	
Zid31taper exit (Kohm/m)	36,55		69,6	
Zid31 RW chamber (KOhm/m)	153,2		78,8	
Zid31 total (Kohms/m)	**200,65**		**190,1**	
Zid31 theory (Kohms/m)	**57,5**		**57,5**	
Zid6 taper entrance		92	62,6	40
Zid6 taper exit		73	51,6	6
Zid6 RW chamber		190,5	-2,33	94
Zid6 total		**355,5**	**111,87**	**140**
Zid6 theory		**57,5**	**58,2**	**58,2**
Zid16 taper entrance			7,6	4,3
Zid16 taper exit			-18	-1,5
Zid16 RW chamber			367,7	382
Zid16 total			**357,3**	**384,8**
Zid16 theory			**57,5**	**57,5**
Zid 26 entrance taper				20
Zid26 exit taper				25
Zid26 RW chamber				20
Zid26 total			**53,37**	**65**
Zid26 theory			**50,4**	**58,2**

Courtesy of Thomas Günzel

Global measurement of effective impedance

Method:

Apply only one kick which will induce an orbit distortion all around the machine.

$\Downarrow$

The beam gets sensitive to impedances all around the machine

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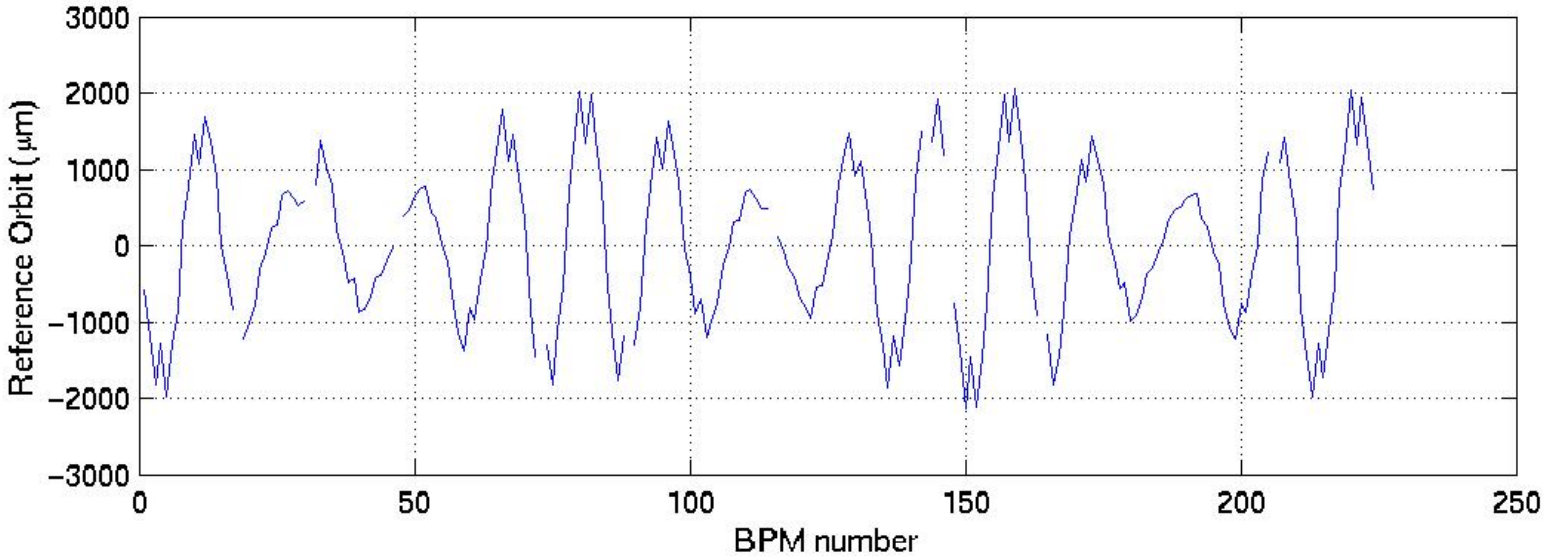
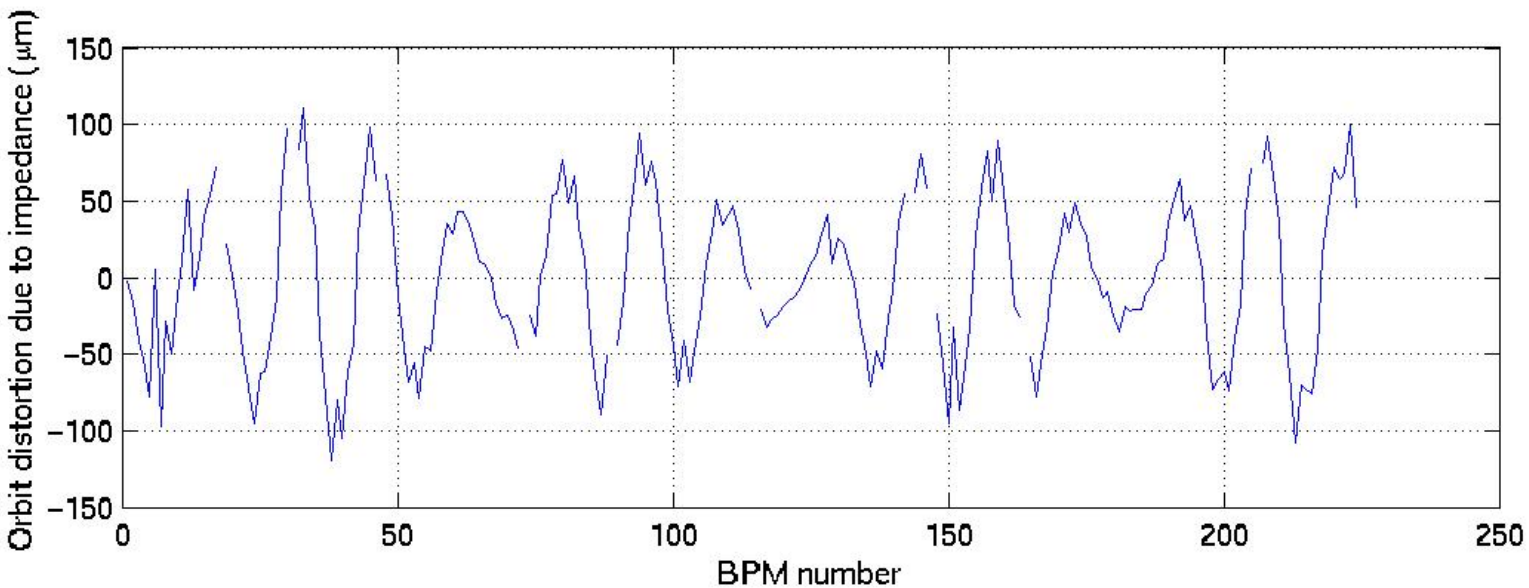
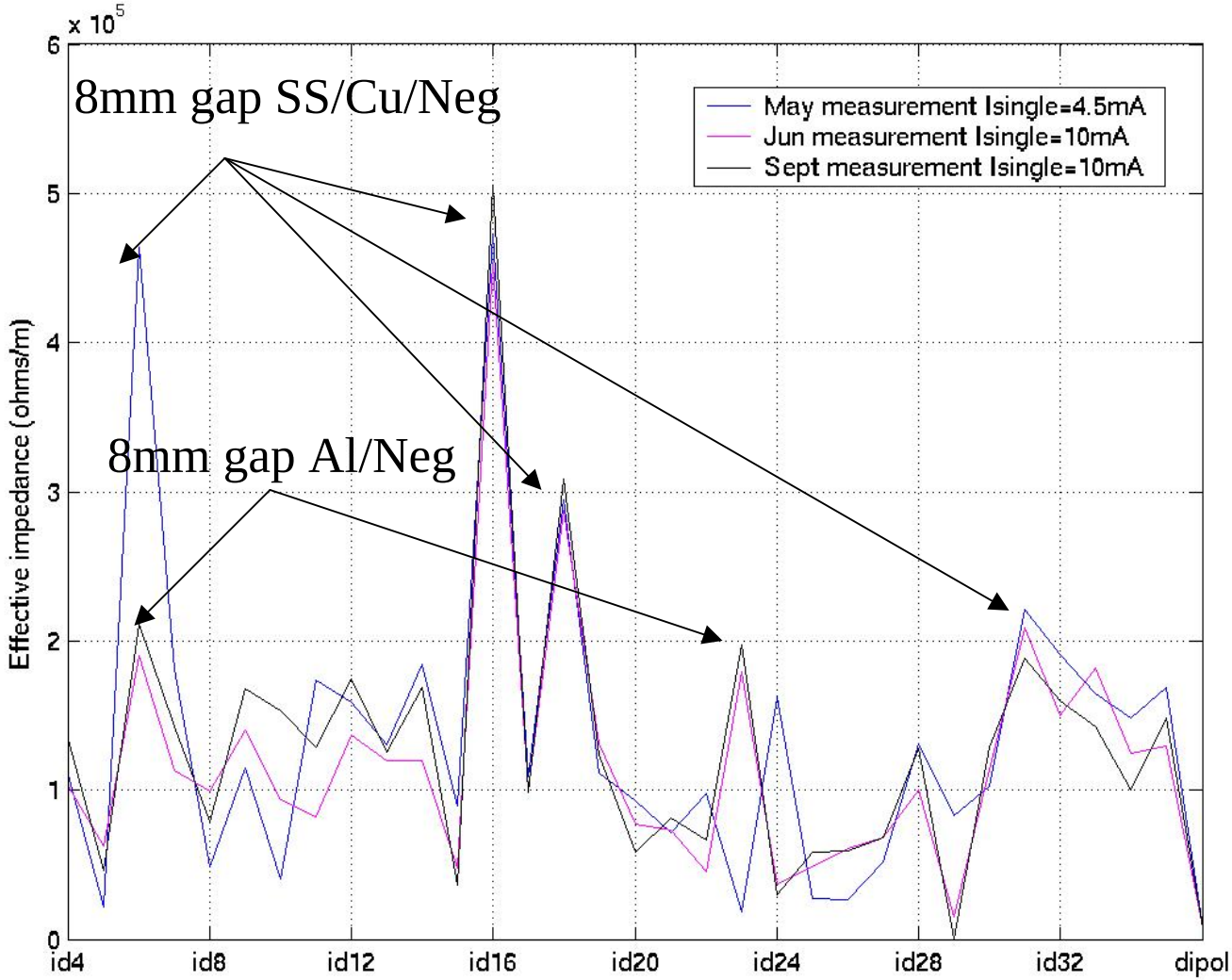
Using the same method of orbit subtraction the distortion due to impedance is fitted using 33 variables:

- 32 independent kicks in the 32 straight sections
- 64 kicks in the dipoles related to the same value of impedance


3000
2000
1000
0
−1000
−2000
−3000
Reference Orbit (μm)
0
50
100
150
200
250
BPM number


150
100
50
0
−50
−100
−150
Orbit distortion due to impedance (μm)
0
50
100
150
200
250
BPM number

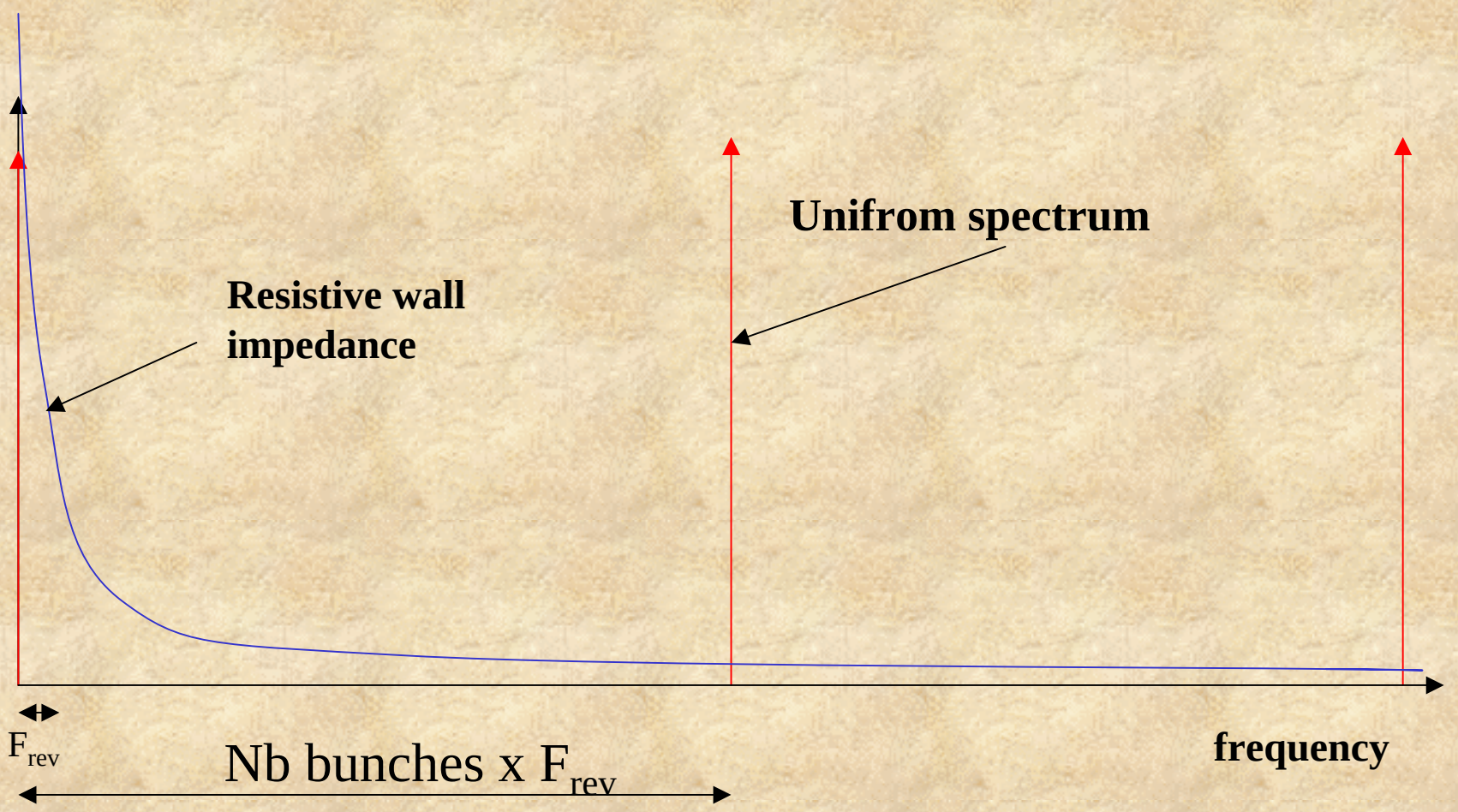


Al mini gap chambers seem to behave much better than SS even without Cu coating.

Exotic experiments

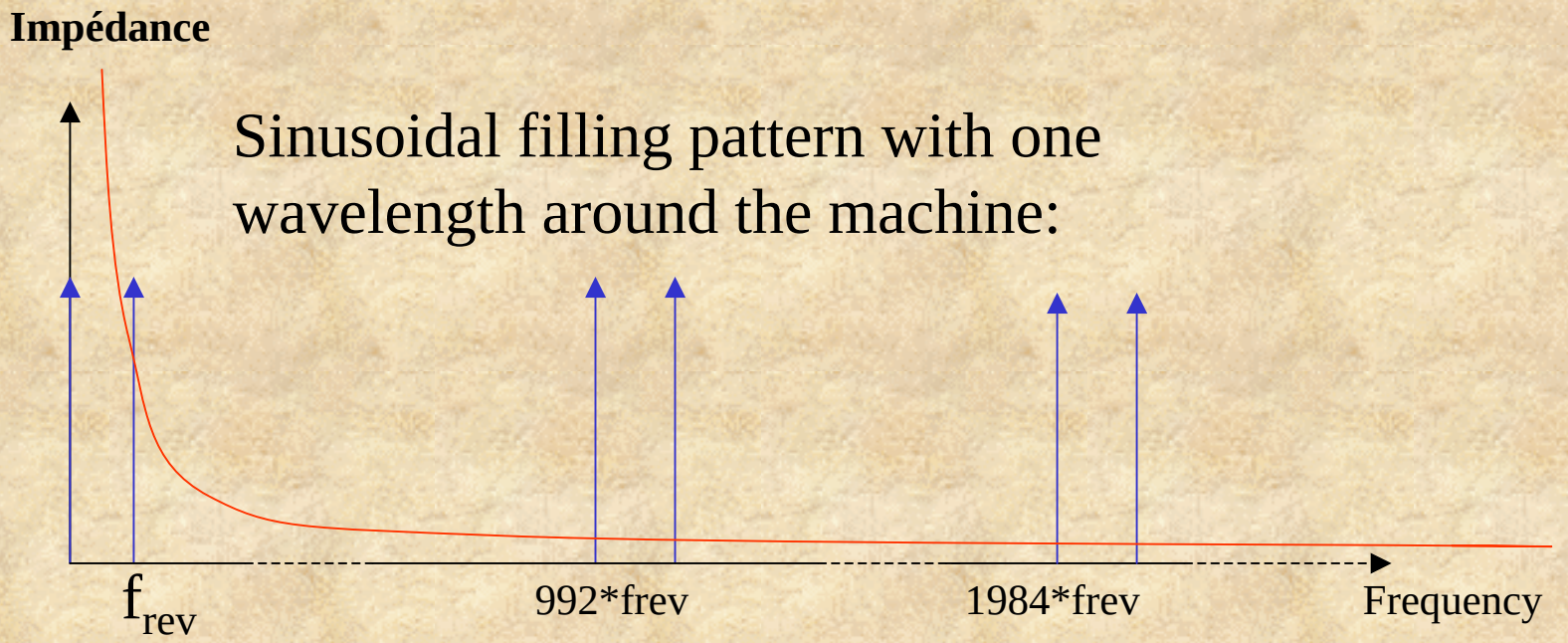
Local zero frequency impedance measurement

For a uniform filling pattern, the interaction between the beam spectrum and impedance will be dominated by the RW impedance at zero frequency.



We get close to the limit of sensibility, but results confirm that at zero frequency, resistive wall impedance only depends on the vacuum chamber geometry, but not on the conductivity of the chamber

Local measurements of impedance at revolution frequency



We reached the limit of sensitivity, no result were found.

Conclusion

The presented method is a simple and precise way to measure effective impedance locally.

The obtained results have shown a valuable comparison between different types of low gap vacuum chambers, and a nice way to locate areas of high impedance in a storage ring.

Efforts are currently focused on decomposition of impedance within a bump.