VERTICAL INSTABILITY ANALYSIS AND CURES

(D. Alesini, LNF-INFN, Frascati (Italy))

OUTLINE

1) VERTICAL INSTABILITY IN THE CR:

a) Phenomenology

b) Vertical modes and wakefield model

c) Tracking code results

2) CURES:

a) Mitigate the instability changing the CR parameters

b) Modify the existing RF deflectors

c) New RF deflectors design

VERTICAL INSTABILITY IN THE CR: PHENOMENOLOGY

The ***profile of the vertical oscillation*** as a function of the bunch positions is the ***same shot by shot***
The ***Δ-frequency*** of the oscillation (FFT) with respect to the fundamental one (2.99855 GHz) is ~***48 MHz***.
The instability is ***stronger*** if we increase the ***train length*** for a given bunch current
The instability is ***stronger*** if we increase the ***bunch charges***
Dependence on the ***temperature of the deflectors***: a temperature variation of ***8 ℃ did not change the scenario***
The instability occurs both in the case of a ***single train*** doing different turns than in the case of ***recombination***
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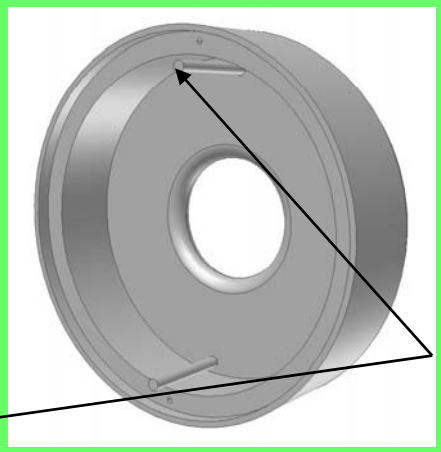
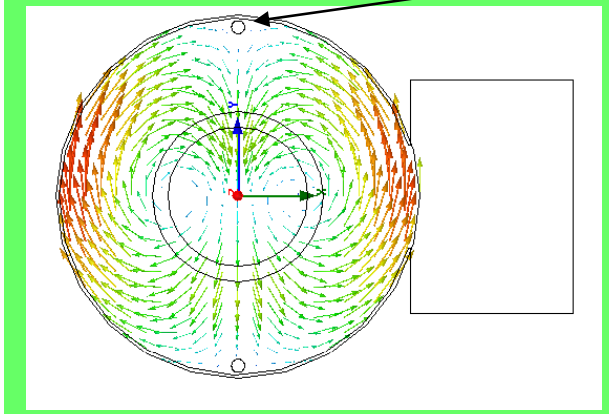
Dependence on the ***vertical orbit*** inside the deflectors: no systematic study but probably a **better steering inside the deflectors gives weaker instability**

VERTICAL MODES IN THE RF DEFLECTORS (1/2)

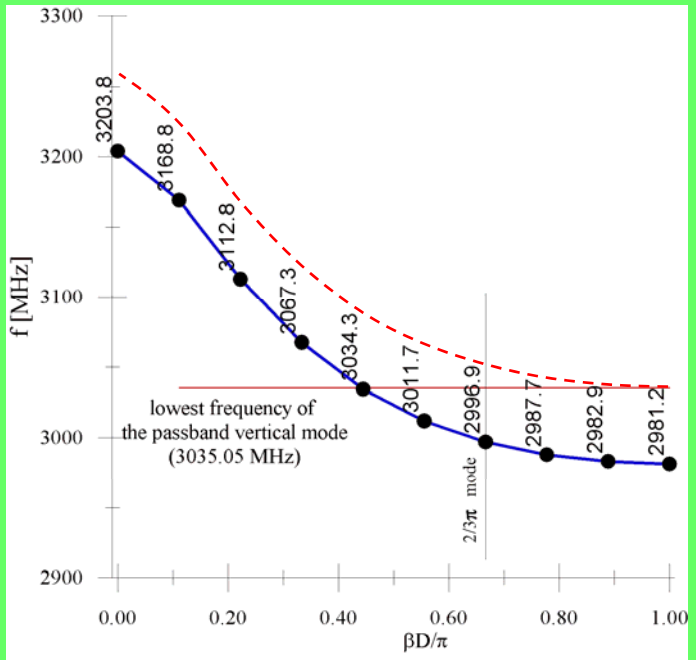




Metallic rods have been inserted to split in frequency the deflecting mode with vertical polarity.

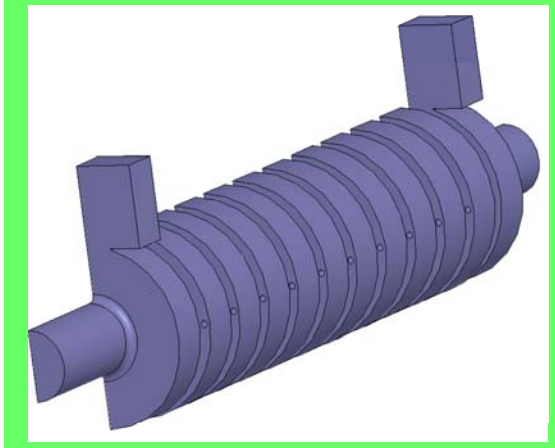
The dimensions and position of the rods have been choosed inorder to avoid the excitation of the vertical modes from the beam power spectrum line at 2.8855GHz and RF generator.

The vertical modes have been measured before the final assembling of the structure and the sampled dispersion curve has been obtained.

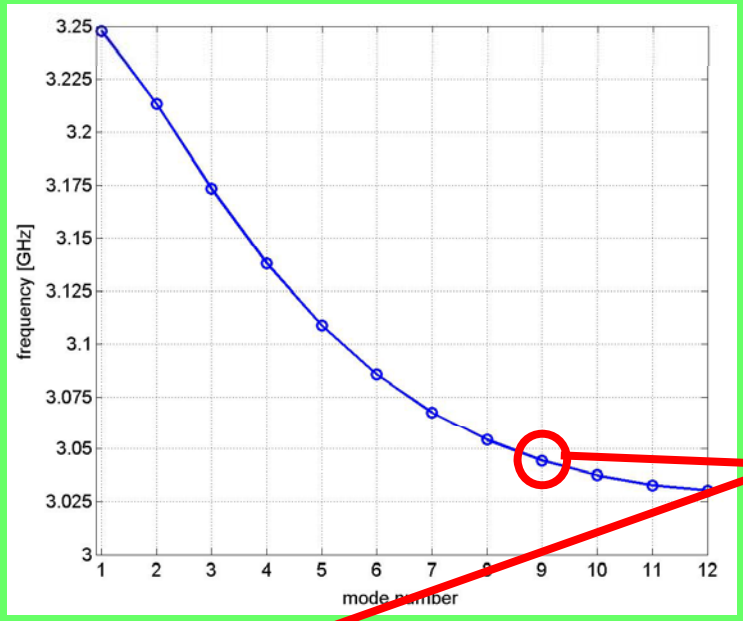


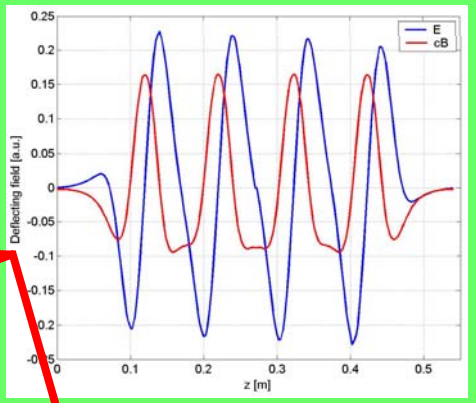
VERTICAL MODES IN THE RF DEFLECTORS (2/2)

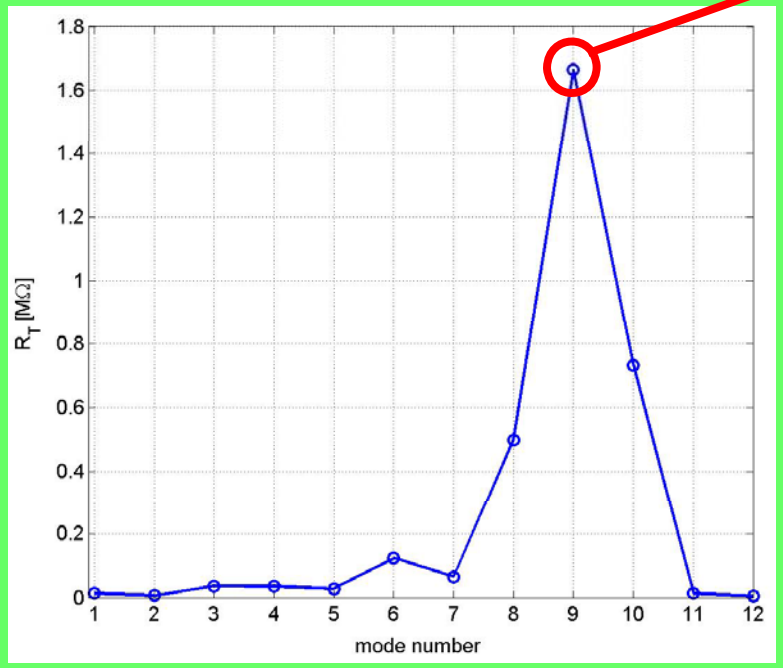
The resonant frequencies, quality factors and transverse shunt impedances of the vertical modes have been calculated by HFSS

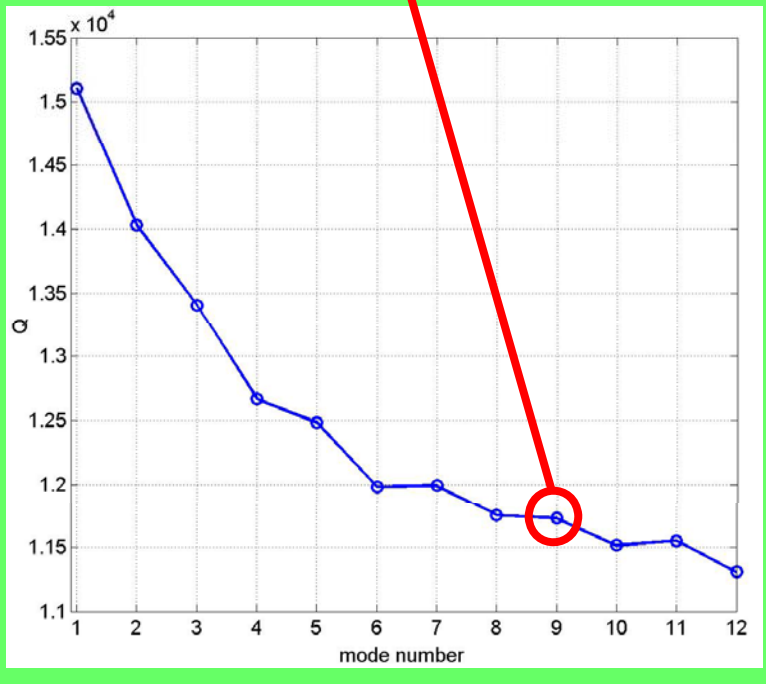


Q	11500
f_{RF}	~ 3.0443 GHz
R_T	~1.6 MΩ

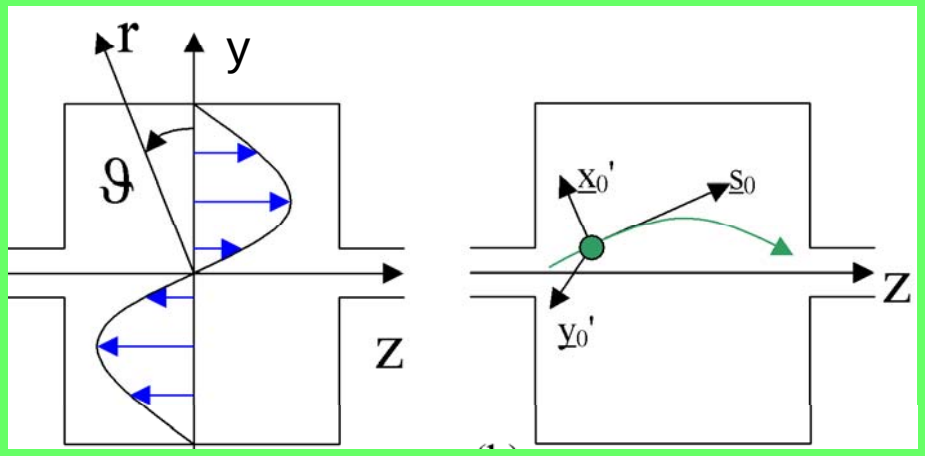


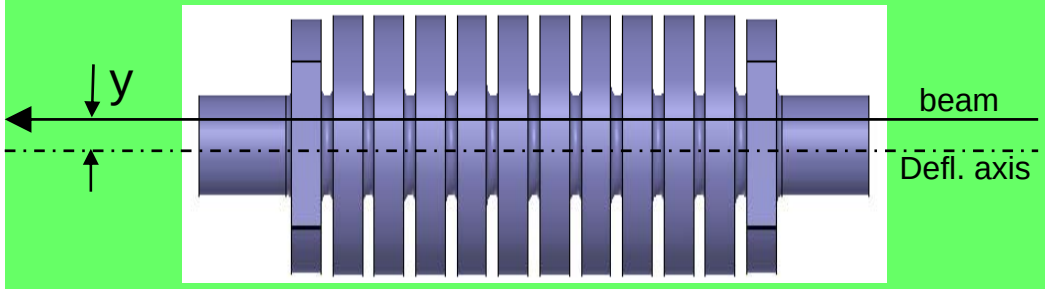






WAKEFIELD INDUCED BY THE VERTICAL MODES (1/3)

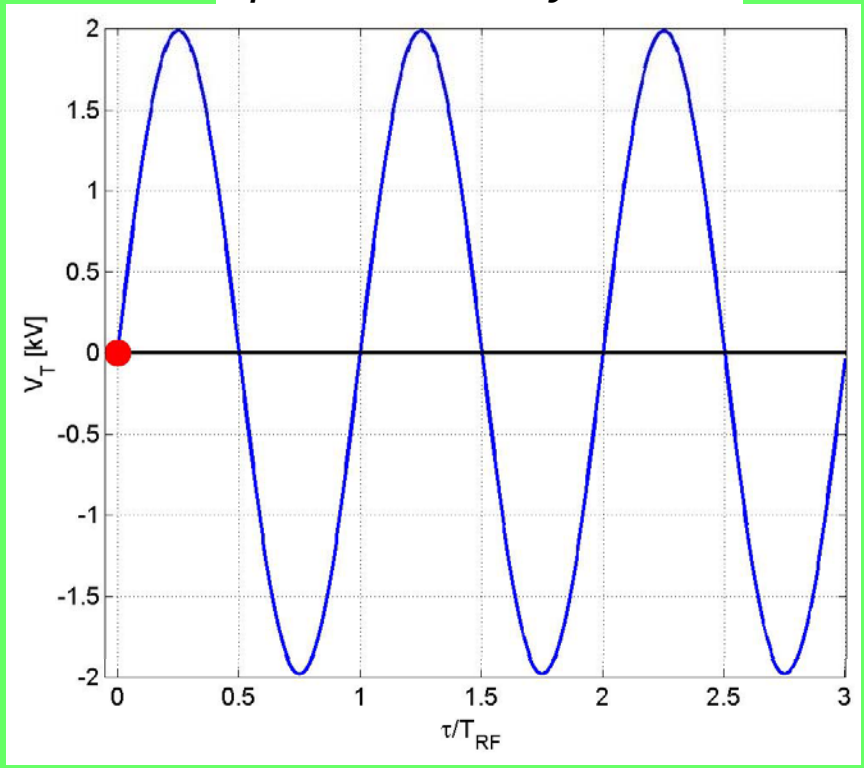




$$V_T(\tau) \cong q \frac{\omega_{RF}^2}{c} \frac{R_T}{Q} y e^{-\frac{\omega_{RF}}{2Q}\tau} \sin(\omega_{RF}\tau)$$

$$R_T = \frac{\left| \int_0^{L_c} \left(E_y + cB_x\right) e^{j\omega_{RF} z/c} dz \right|^2}{2P_{diss}}$$

q=2.33 nC *y=5 mm*



90 deg. out of phase wake

PHENOMENOLOGY VS ANALYTICAL MODEL

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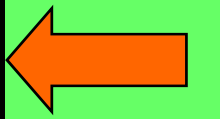
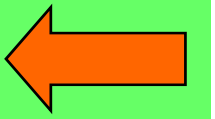
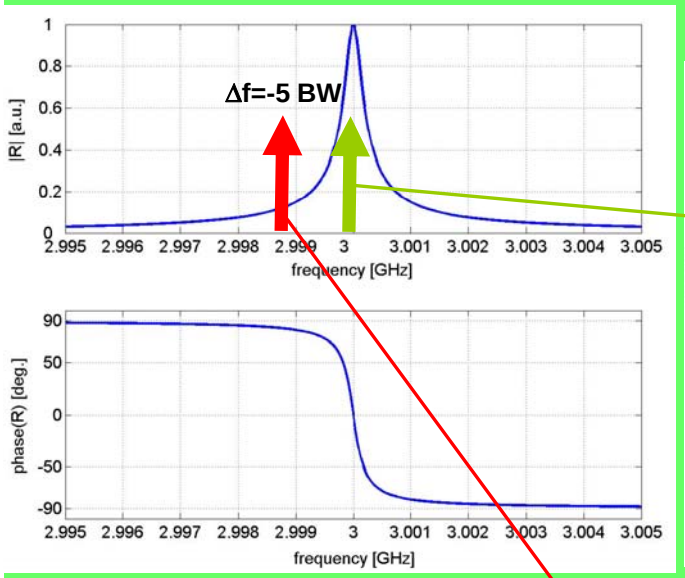
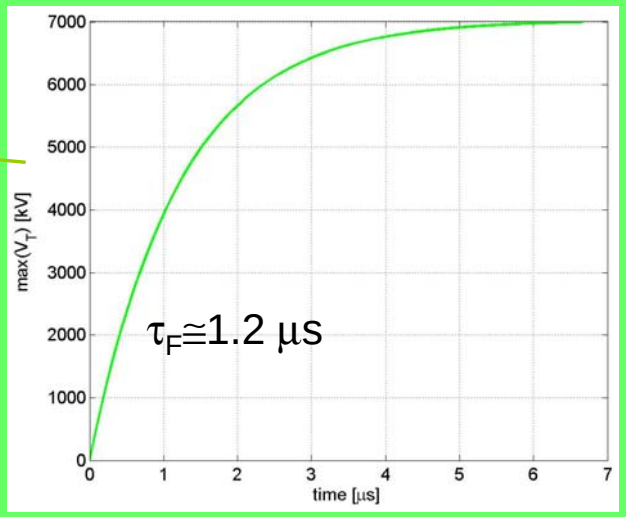


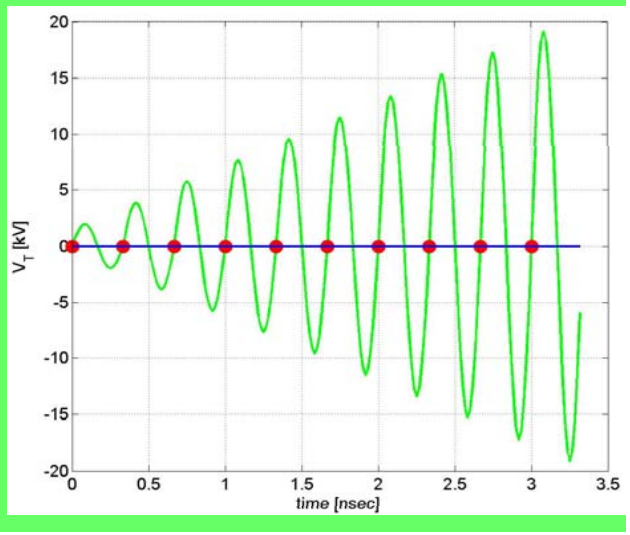


WAKEFIELD INDUCED BY THE VERTICAL MODES (2/3)

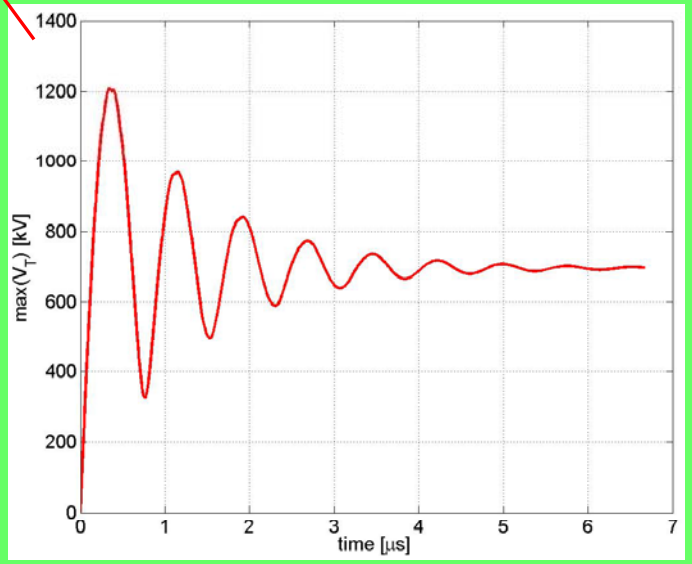
Multi-bunch excitation: q=2.33 nC; y=5 mm

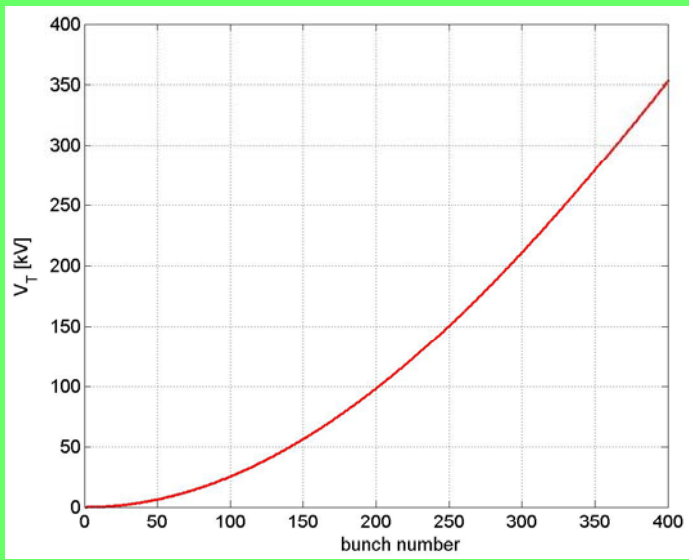






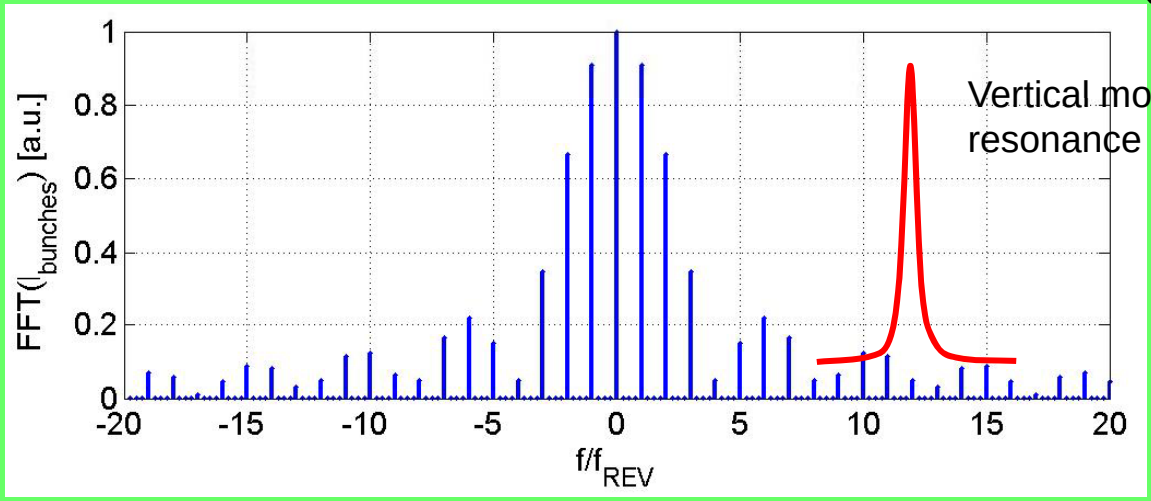
In case of multi-bunch excitation off-resonance the equivalent filling time can be much shorter then the filling time on resonance and the wake can became a cosine wake





WAKEFIELD INDUCED BY THE VERTICAL MODES (3/3)

Spectrum of a 200 bunches in the combiner ring in 4 turns (f_{REV}≅3.56 MHz)



TRACKING CODE

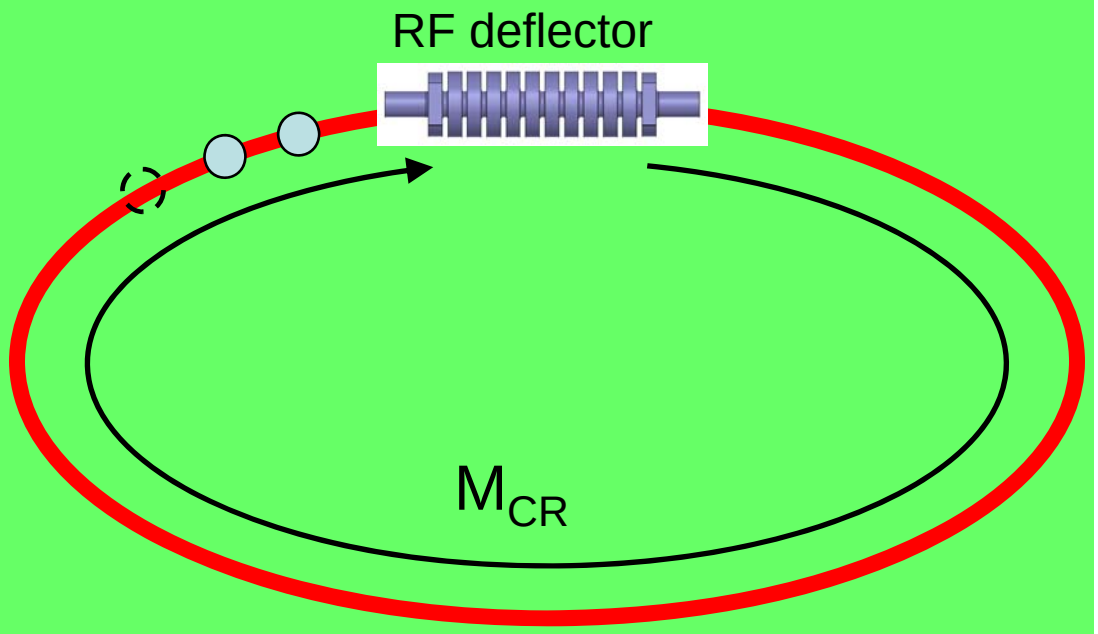
A dedicated tracking code has been written to study the multi-bunch multi- turn effects.

We considered the effect of ***1 RF deflector and 1 mode (dominant)***.

All the ***results*** in term of the oscillation amplitude are ***proportional*** to:

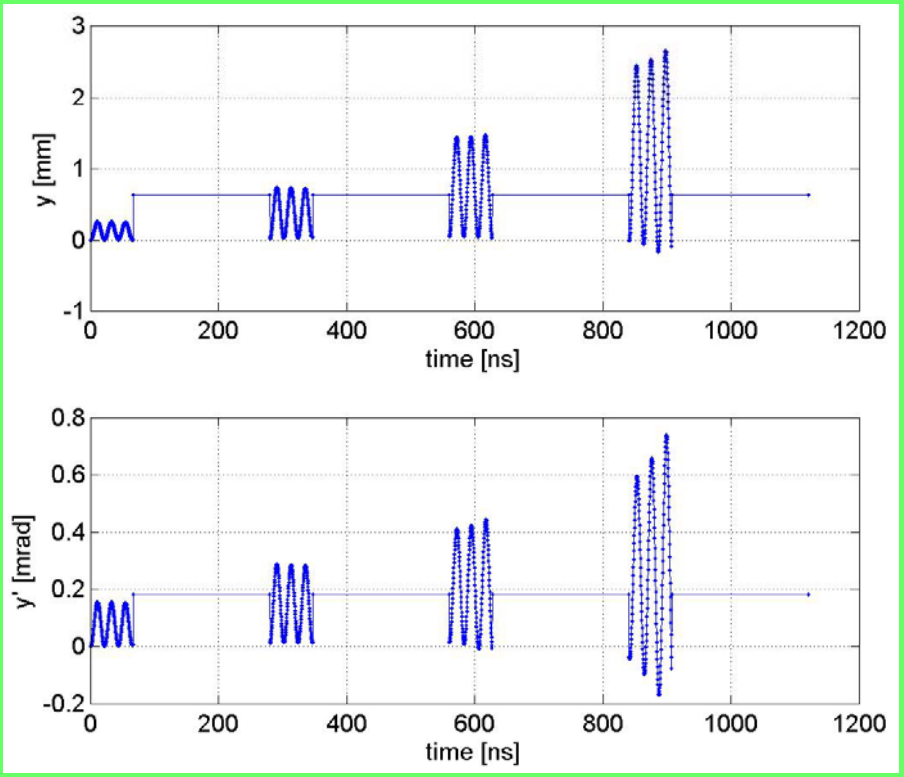
-the ***beam off axis*** ⇒ **y=2 mm** orbit in the deflector has been considered.

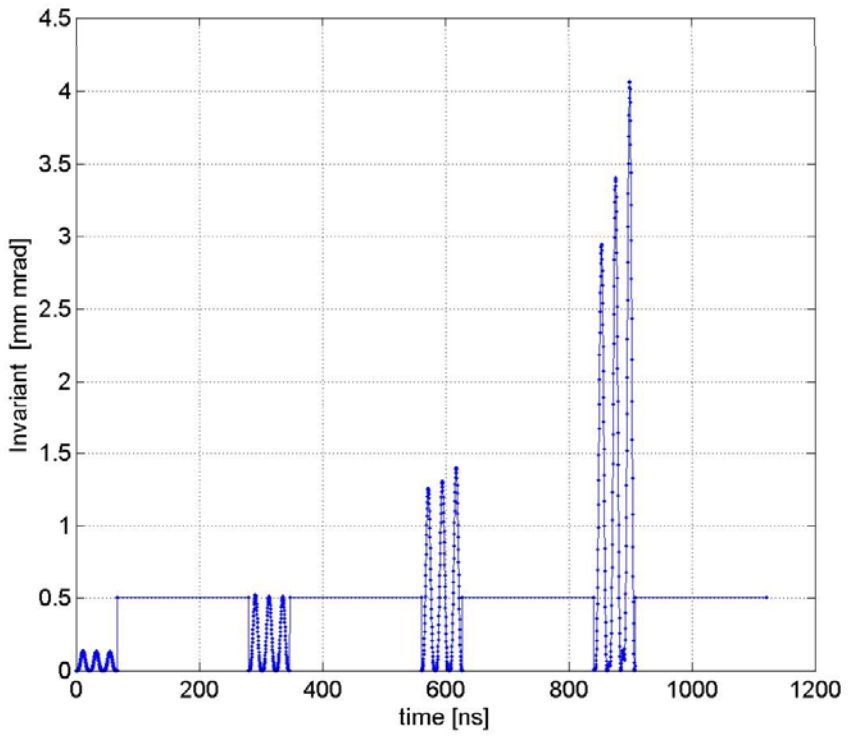
-the ***bunch charge*** ⇒ **q=2.33 nC** bunch charge has been considered



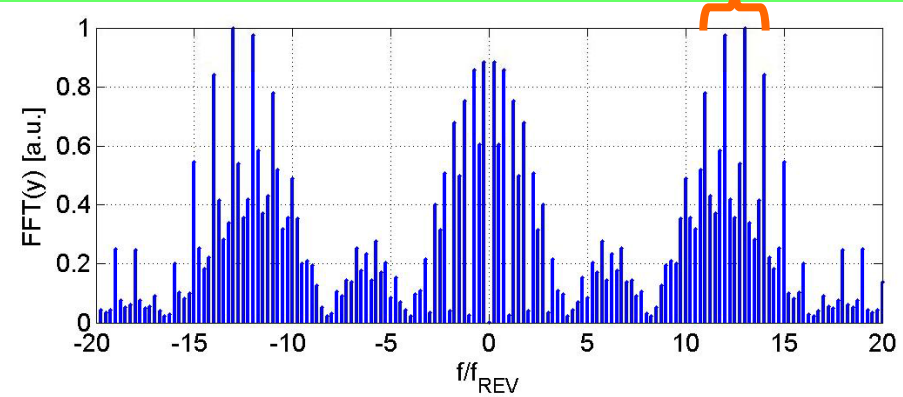
TRACKING CODE RESULTS: Single train

$N_{bunches}$	200
turns	4
E_0	100 MeV
$f_{RF\ vert.}$	3.044300 GHz
Q	11500
$\Delta\phi_{CR}$	18 deg
β_{v_defl}	5 m
α_{v_defl}	0





~45-50 MHz



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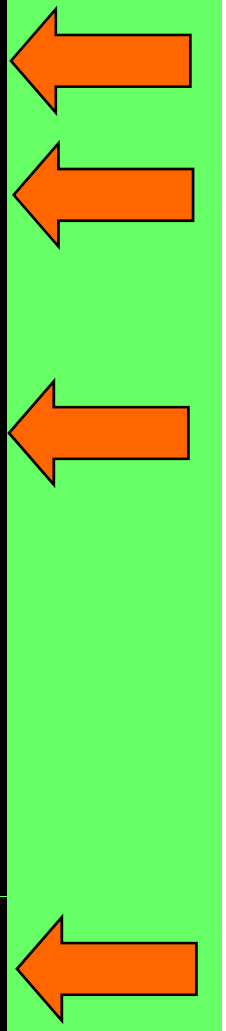

TRACKING CODE RESULTS: Single train and CR phase advance scan

$N_{bunches}$	200
turns	4
E_0	100 MeV
$f_{RF\ v}$	3.044300 GHz
Q	11500
$\Delta\phi_{CR}$	SCAN
β_{v_defl}	5 m
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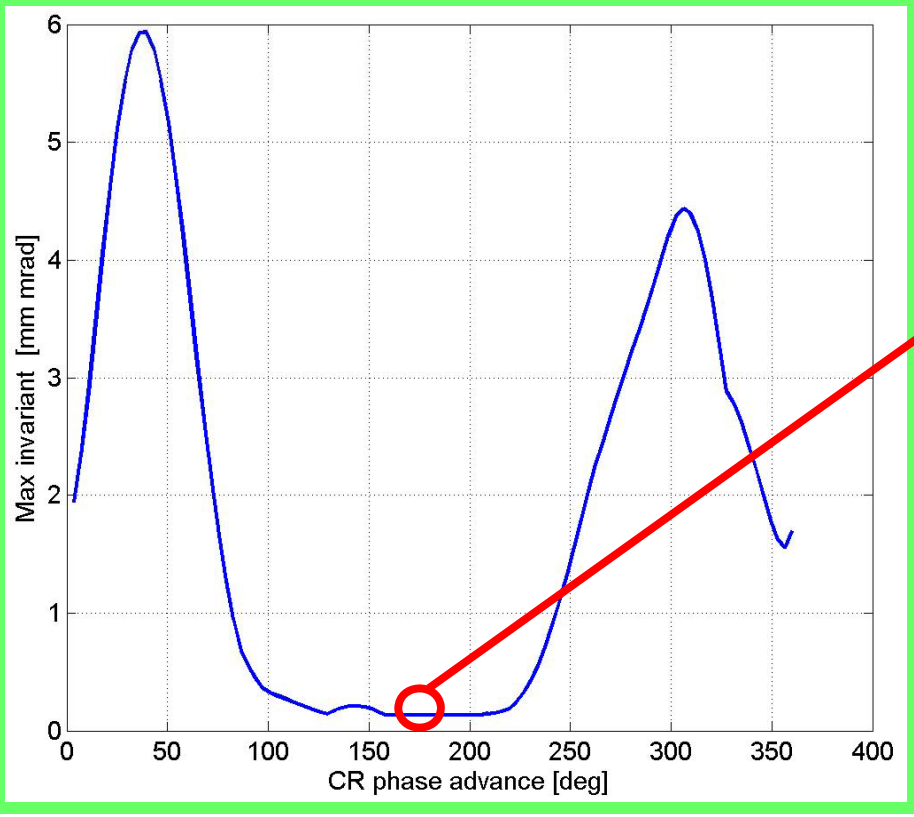
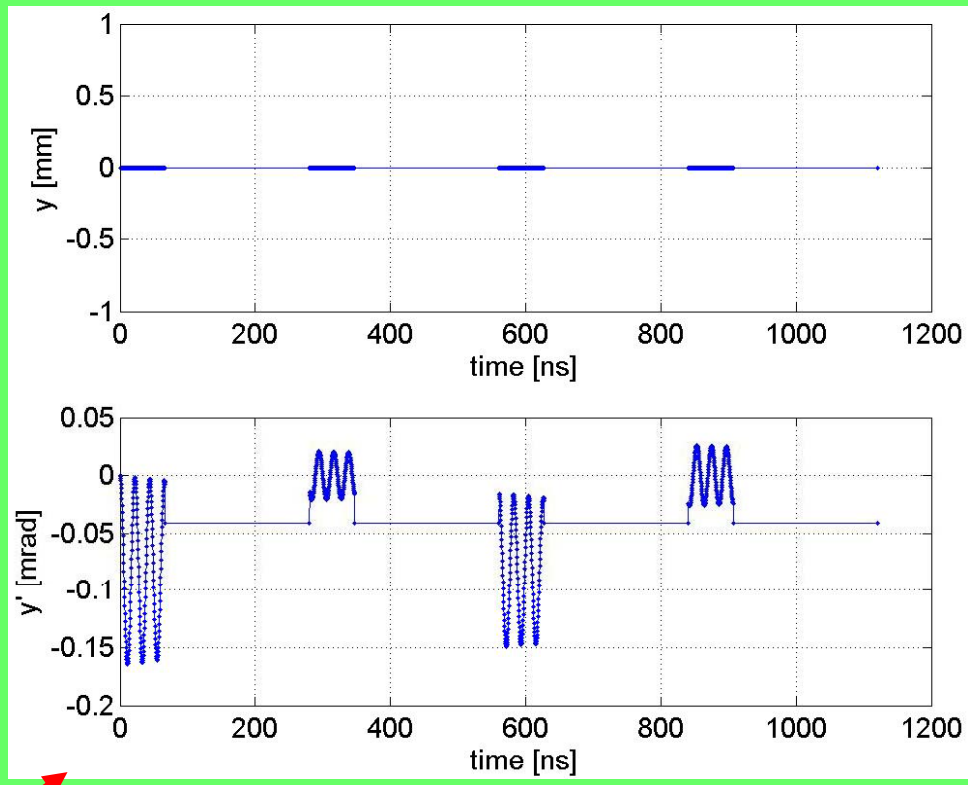
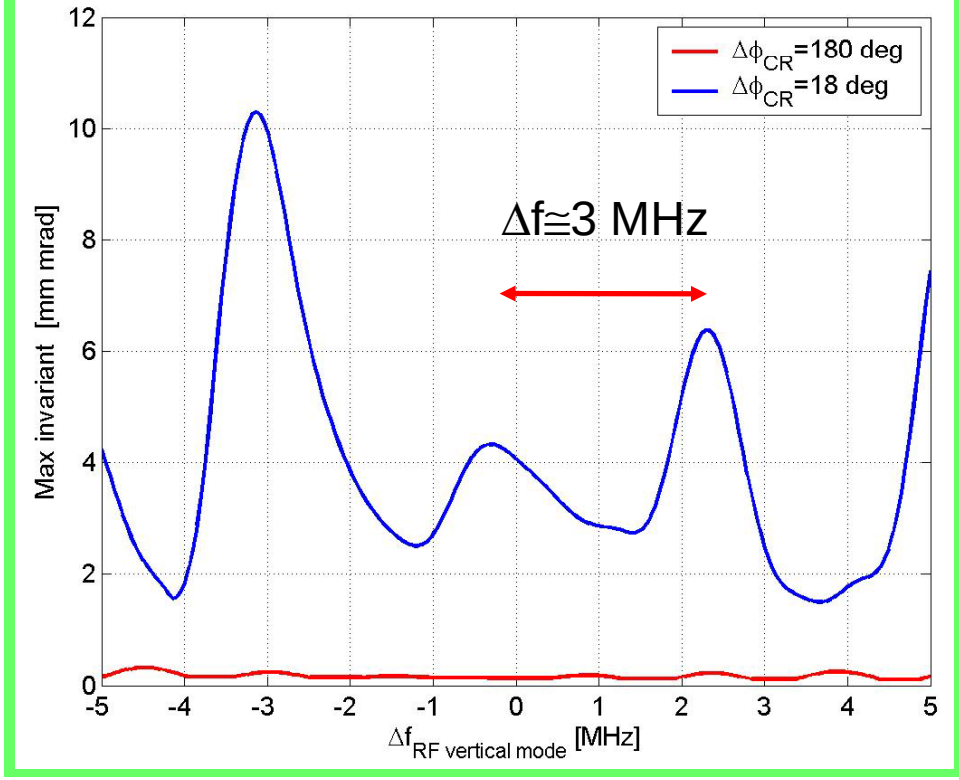


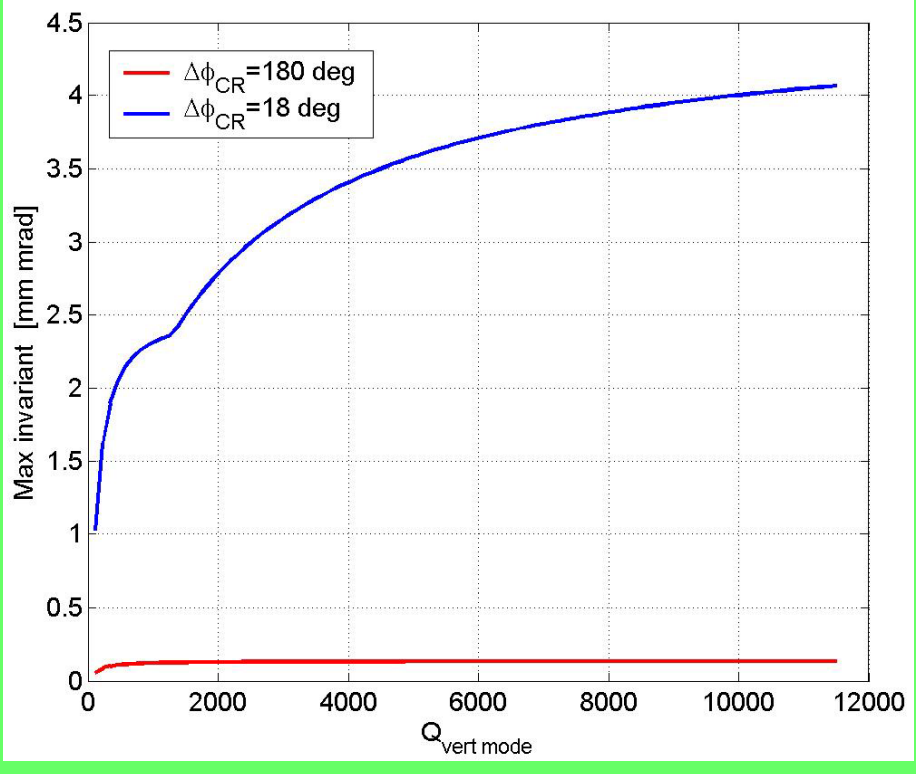


TRACKING CODE RESULTS: Single train, frequency and Q scans

$N_{bunches}$	200
turns	4
E_0	100 MeV
$f_{RF\ v}$	SCAN
Q	11500
$\Delta\phi_{CR}$	180 And 18 deg
β_{v_defl}	5 m
α_{v_defl}	0

$N_{bunches}$	200
turns	4
E_0	100 MeV
$f_{RF\ v}$	3.044300 GHz
Q	SCAN
$\Delta\phi_{CR}$	180 And 18 deg
β_{v_defl}	5 m
α_{v_defl}	0





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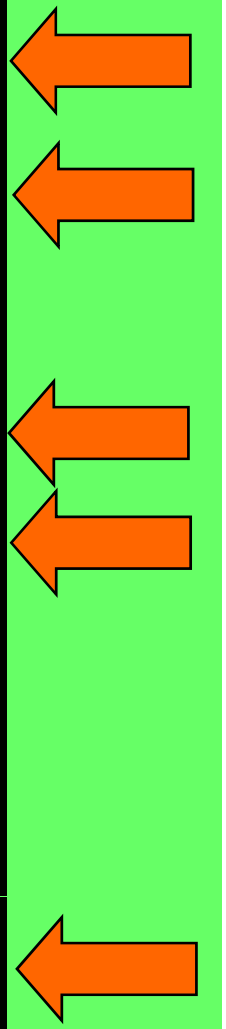

TRACKING CODE RESULTS: Single train, number of bunches and β_v scans

$N_{bunches}$	SCAN
turns	4
E_0	100 MeV
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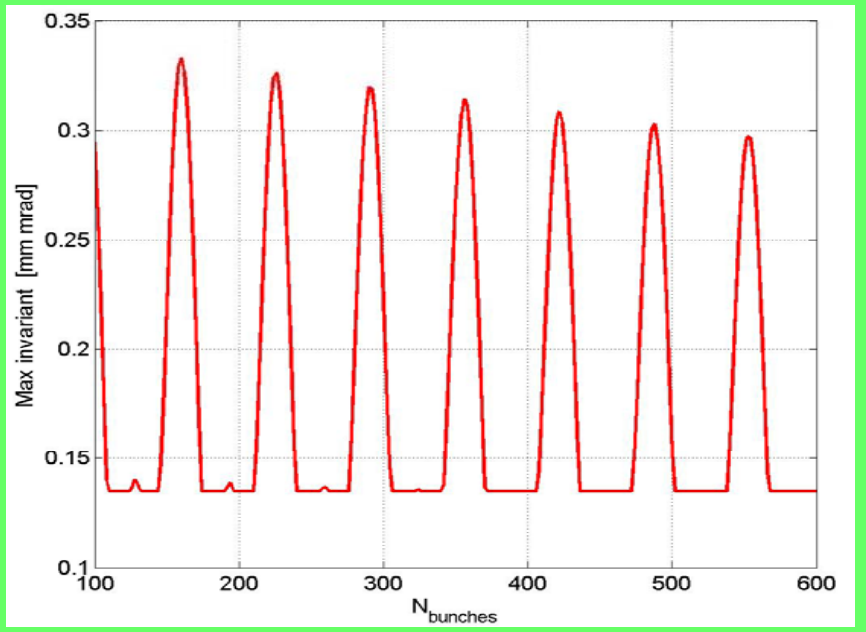
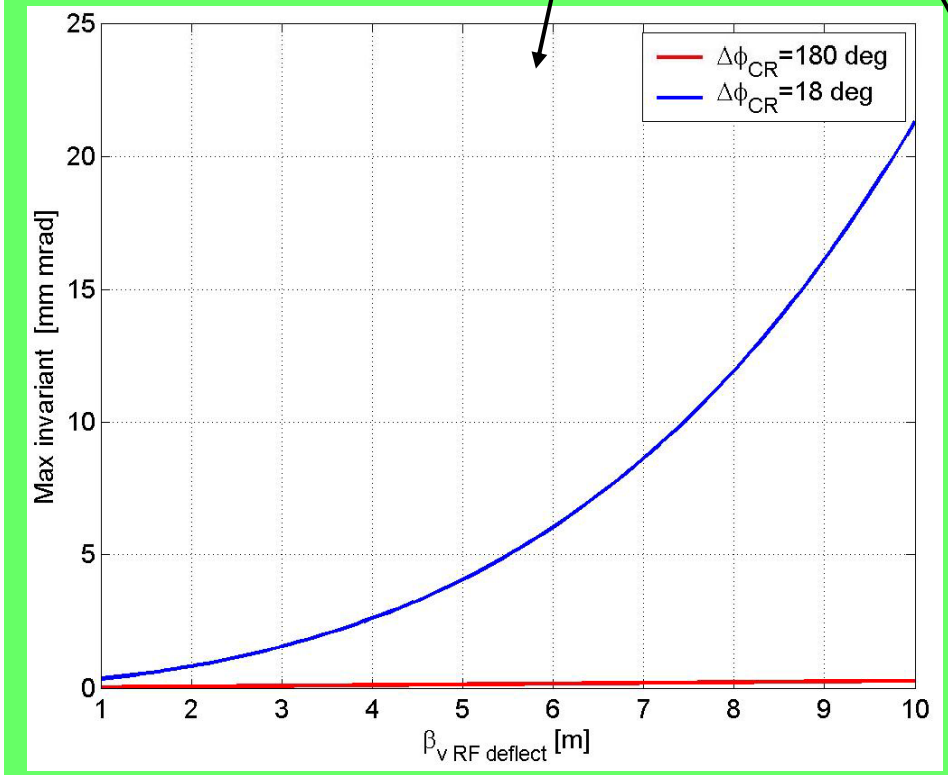
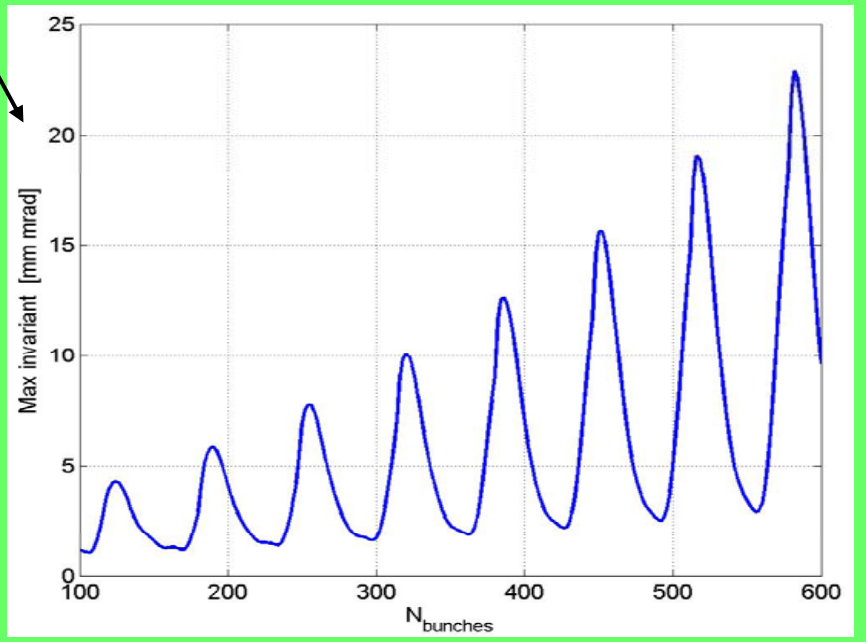
$\Delta\phi_{CR}$	180 And 18 deg
β_{v_defl}	SCAN
α_{v_defl}	0







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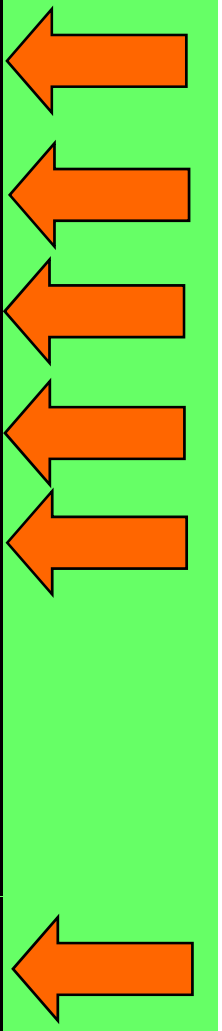
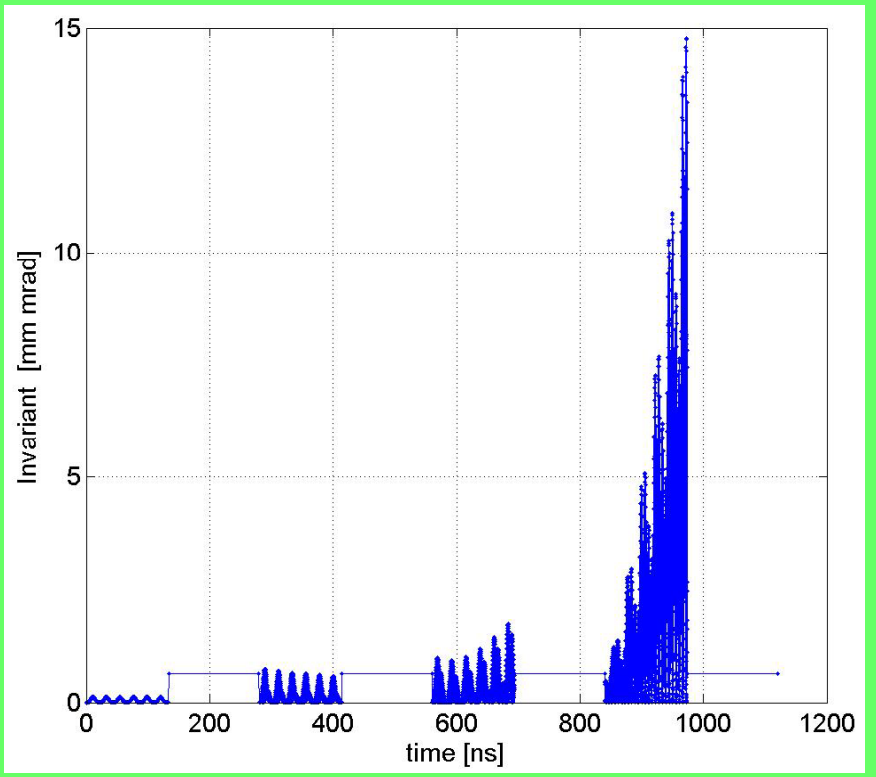
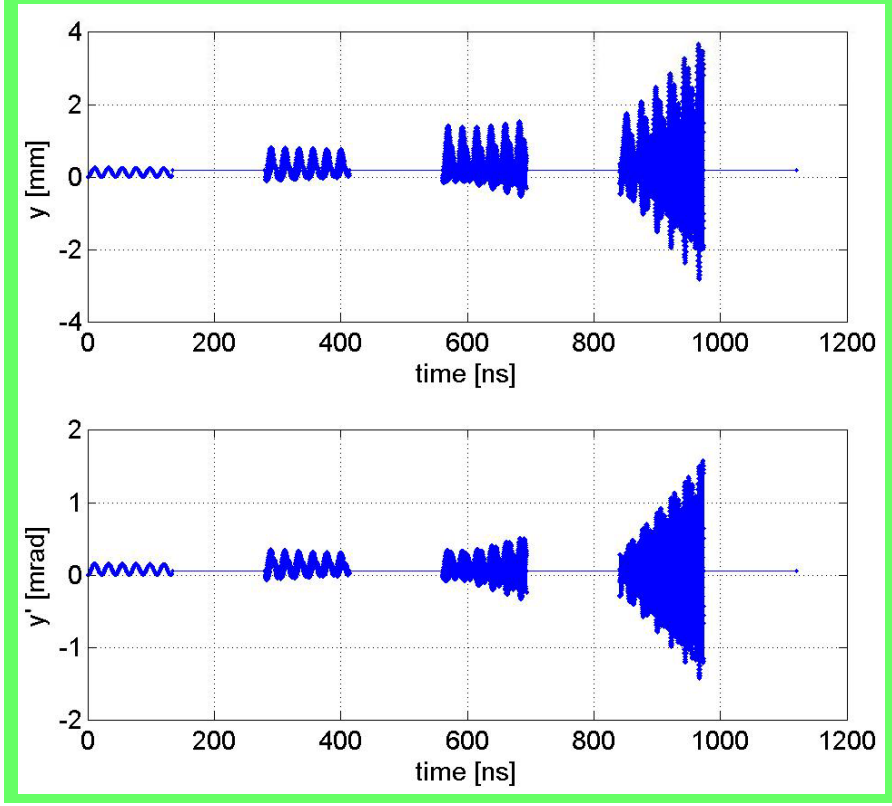


TRACKING CODE RESULTS: Recombination

$N_{bunches}$/train	400
Recomb. factor	4
E_0	100 MeV
$f_{RF\ v}$	3.044300 GHz
Q	11500
$\Delta\phi_{CR}$	18 deg
β_{v_defl}	5 m
α_{v_defl}	0





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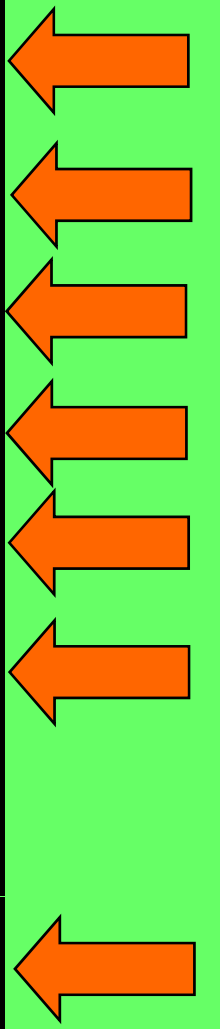
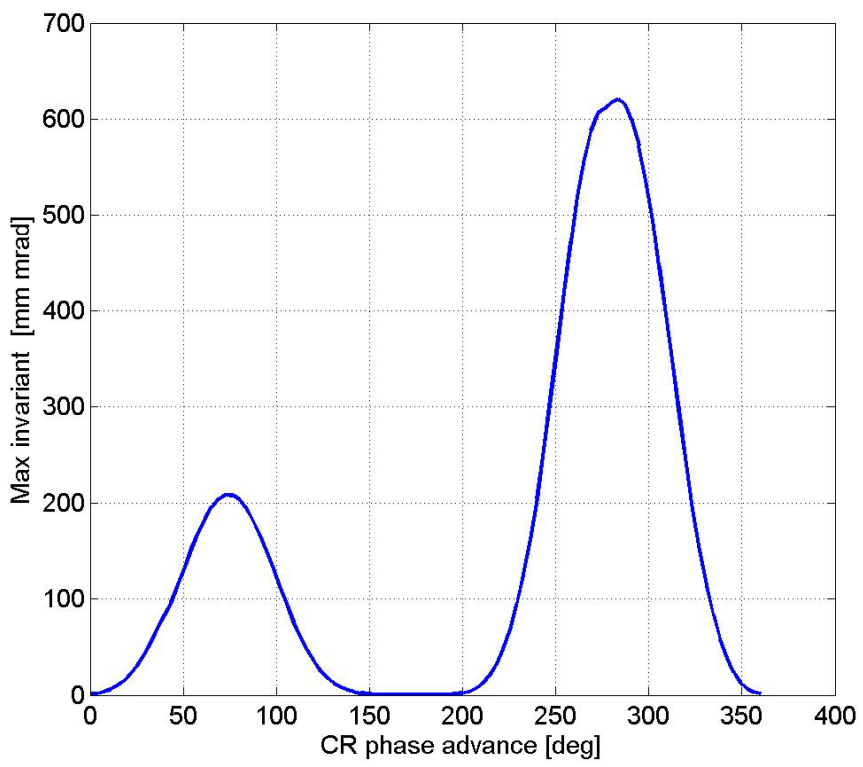
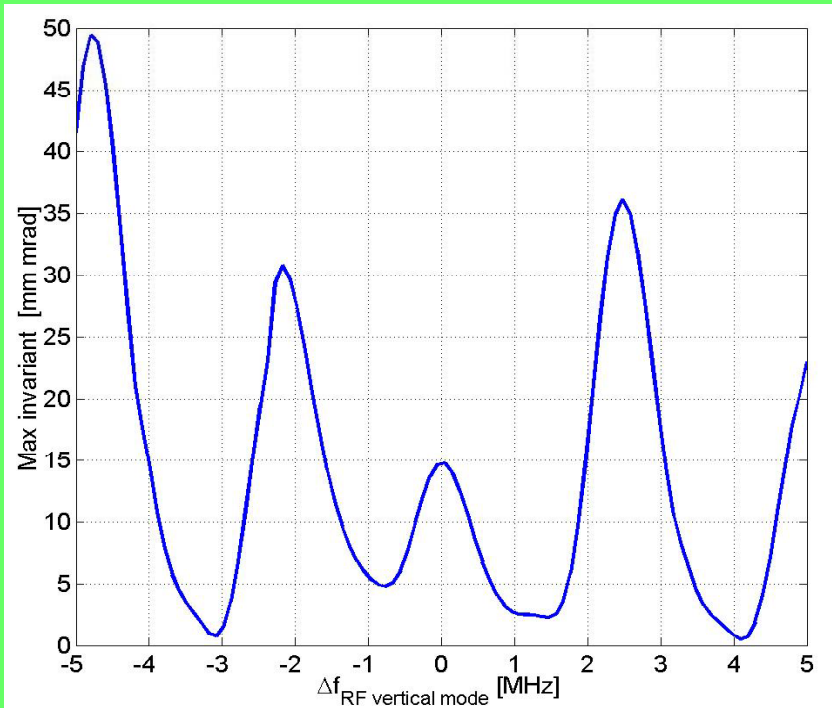
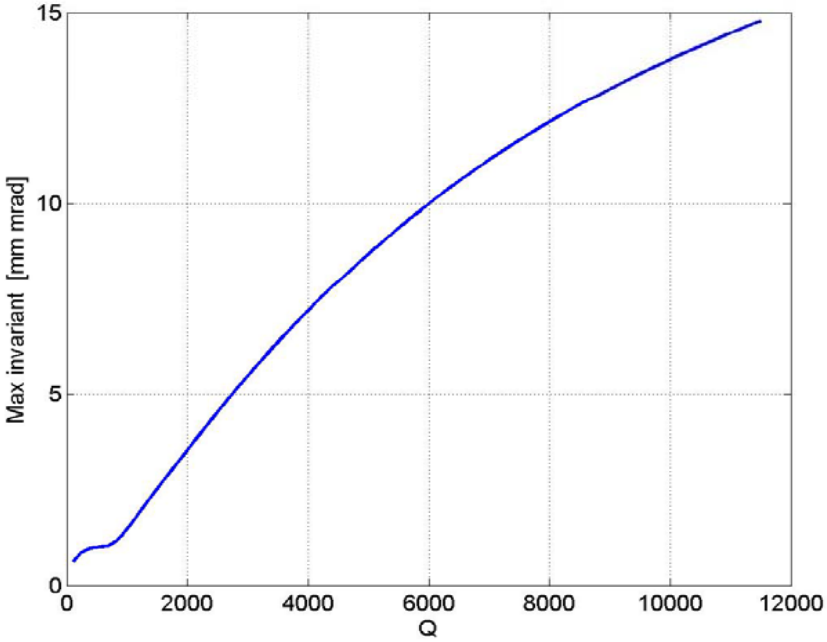


TRACKING CODE RESULTS: Recombination, few scans

$N_{bunches}$/train	400
Recomb. factor	4
E_0	100 MeV
$f_{RF\ v}$	3.044300 GHz
Q	11500
$\Delta\phi_{CR}$	18 deg
β_{v_defl}	5 m
α_{v_defl}	0







SUMMARY OF THE TRACKING CODE RESULTS AND HOW TO MITIGATE THE INSTABILITY BY CHANGING THE CR PARAMETERS

1) **Good agreement** between analytical model/tracking and phenomenology;

2) **Strong instability** driven by **few mm off-axis beam**;

3) **Tuning dependence** study seems suggest that a tune near **half integer** can reduce the effects on beam dynamics;

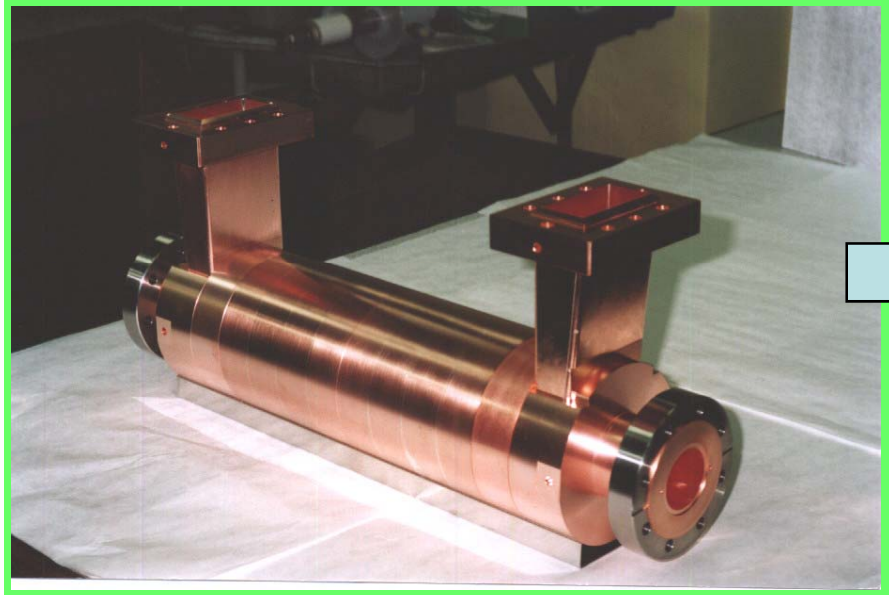
4) **Particular bunch patterns** can also reduce the effects on beam dynamics;

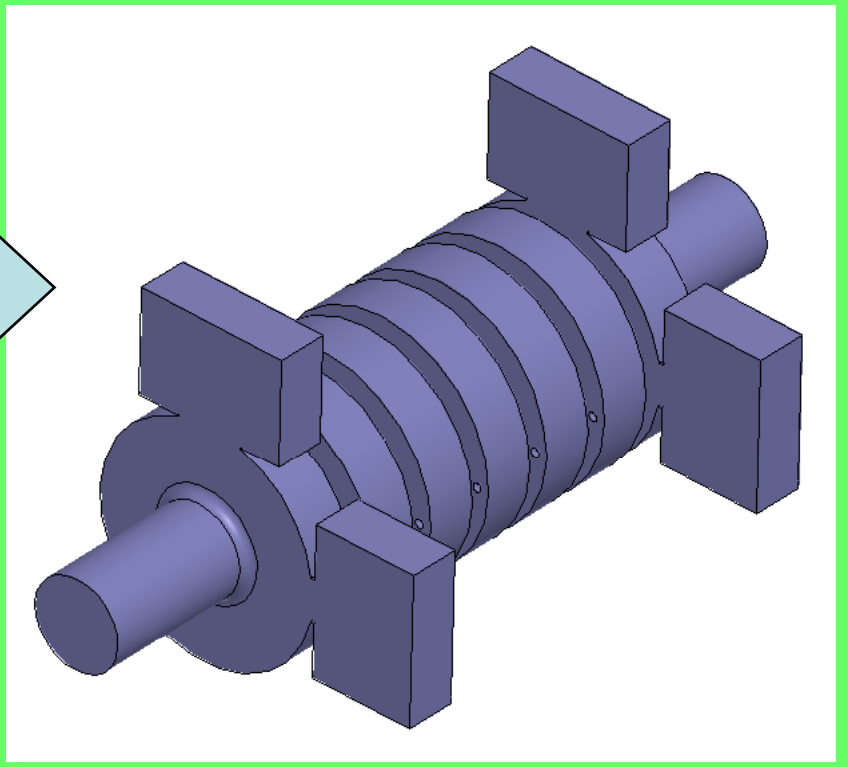
5) The **reduction of the vertical β-function at the deflector** can also help in the control of the instability;

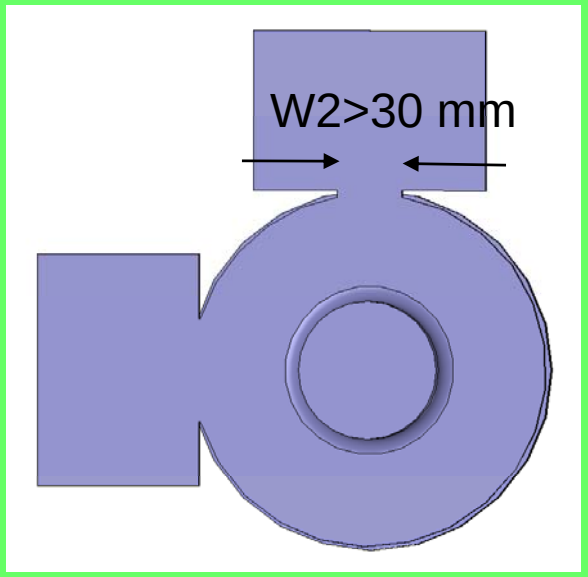
6) **Localized vertical bumps** at the deflectors to minimize the vertical residual orbit can reduce the effects of the trapped modes;

7) **The reduction of the Q-factors** of the modes can reduce the driven force of such vertical modes;

MODIFY THE RF DEFLECTORS







NEW RF DEFLECTORS