

HIGHER-ORDER HEAD-TAIL MODES IN THE LHC DUE TO THE COLLIMATOR (Part 2)

E. Metral

PARAMETERS USED

◆ Machine and Beam

$$p = 7 \text{ TeV}/c$$

$$M = 3564$$

$$N_b = 1.1 \times 10^{11} \text{ p/b}$$

$$Q_s = 2.12 \times 10^{-3}$$

$$Q_y = 59.32$$

$$\tau_b = 1 \text{ ns}$$

$$\xi_y = 0$$

$$\alpha_1 = 3 \times 10^{-4}$$



$$\gamma_t = 57.7$$

◆ Collimator (graphite)

$$b = 2 \text{ mm}$$

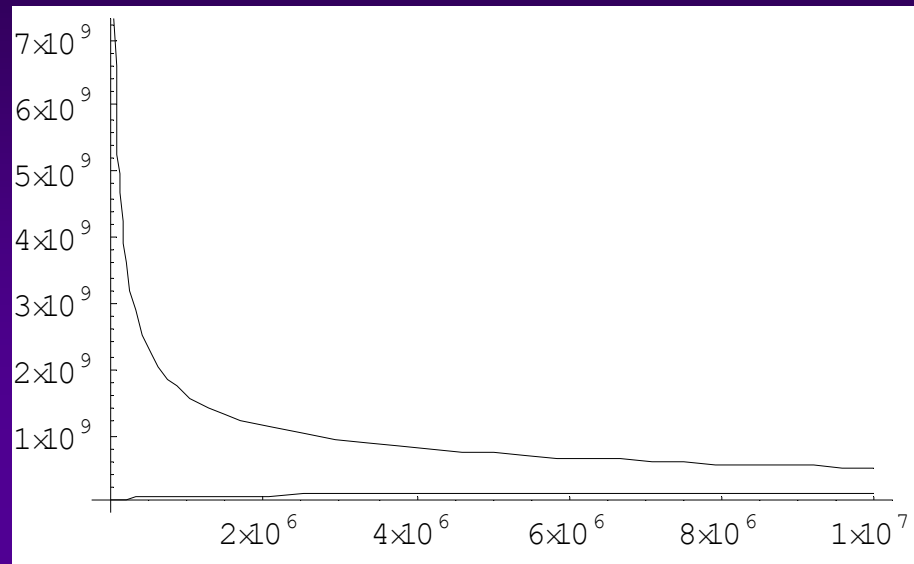
$$l = 20 \text{ m}$$

$$\rho = 18.1818 \times 10^{-6} \text{ } \Omega\text{m}$$

$$\beta_y = 2 \times \beta_{av} = 143 \text{ m}$$

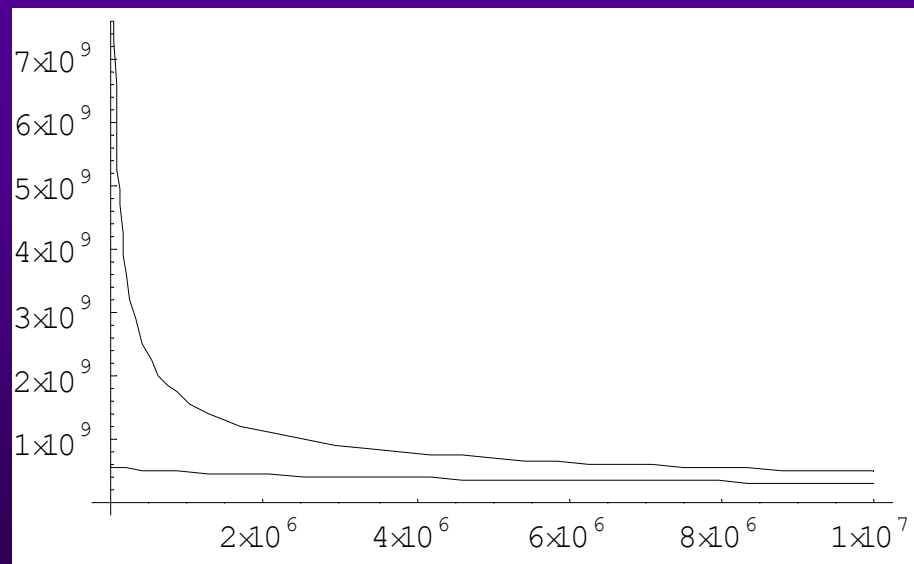
RESISTIVE-WALL IMPEDANCE WITH AND WITHOUT INDUCTIVE BYPASS (1/4)

$\text{Re}(Z_y)$

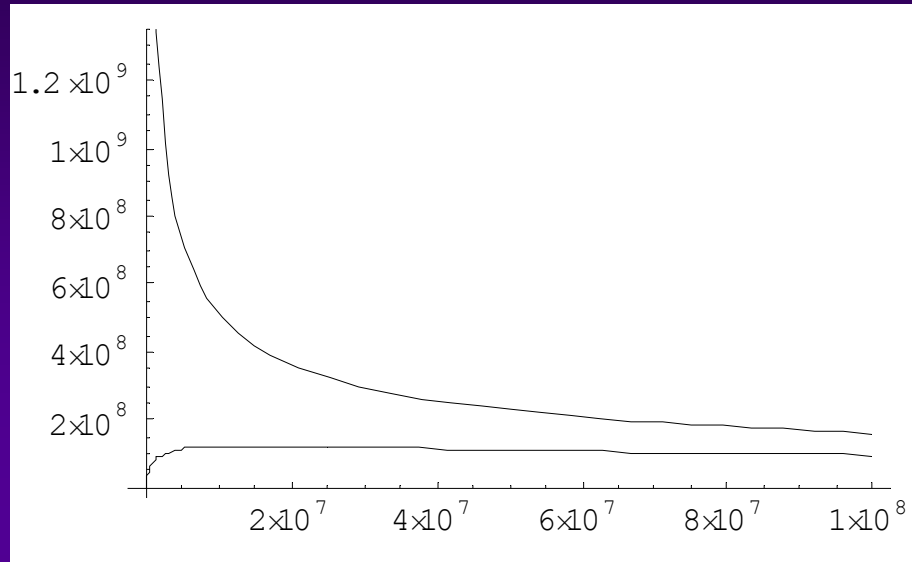


ω [rad/s]

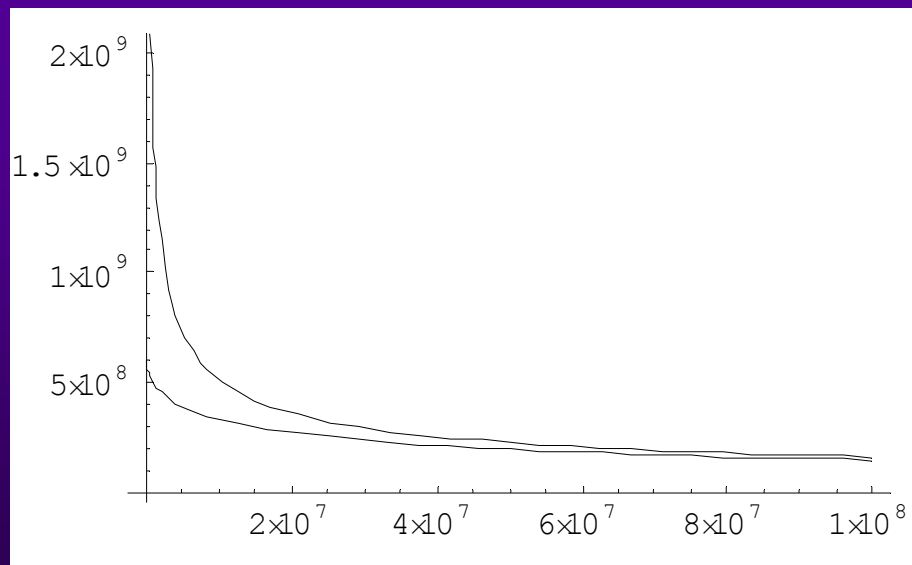
$\text{Im}(Z_y)$



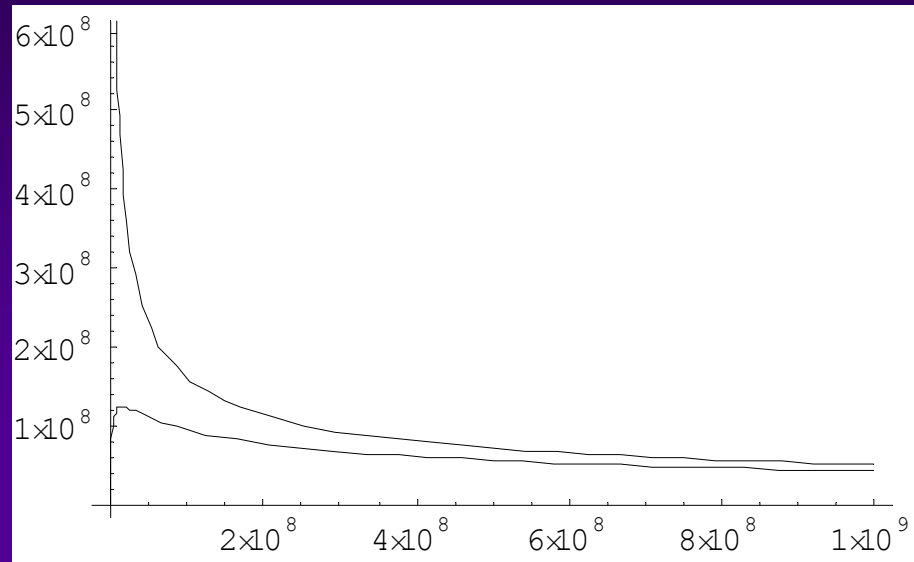
RESISTIVE-WALL IMPEDANCE WITH AND WITHOUT INDUCTIVE BYPASS (2/4)



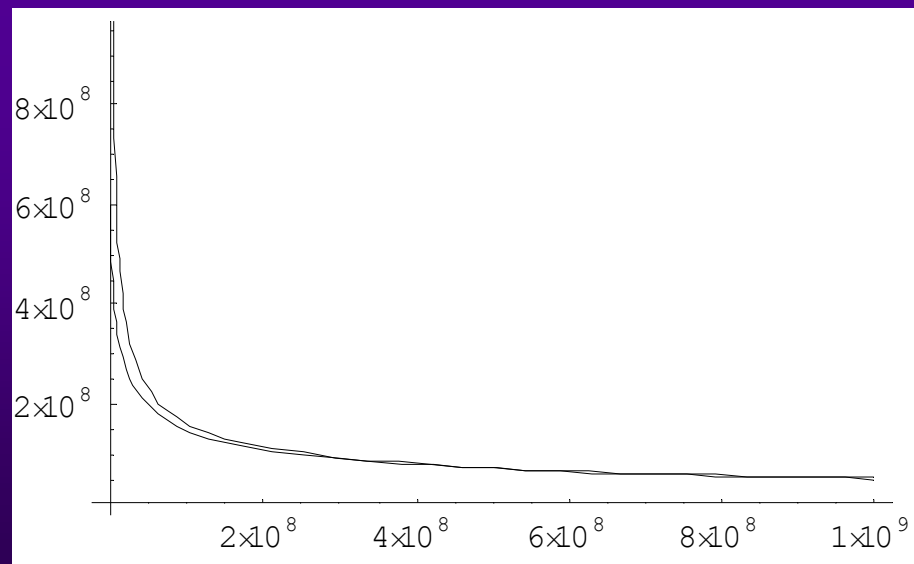
ω [rad/s]



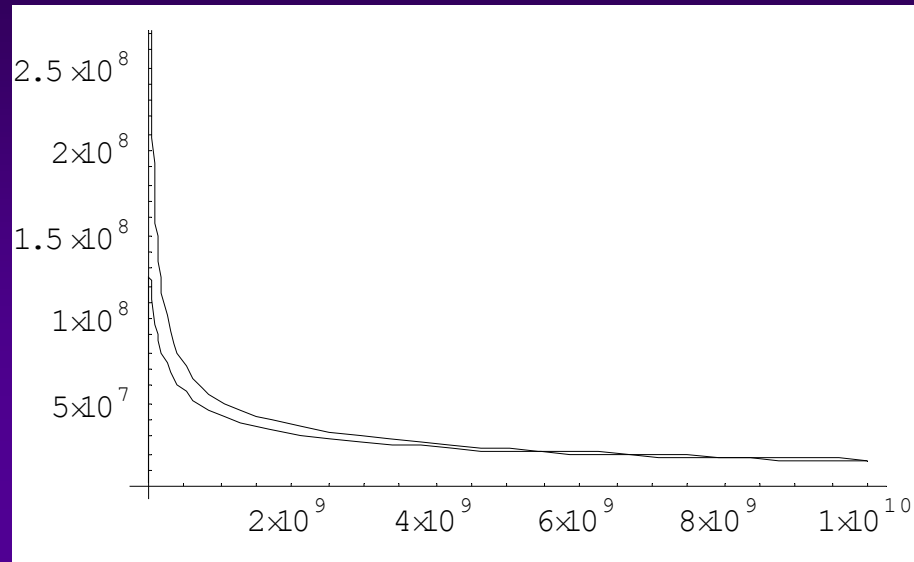
RESISTIVE-WALL IMPEDANCE WITH AND WITHOUT INDUCTIVE BYPASS (3/4)



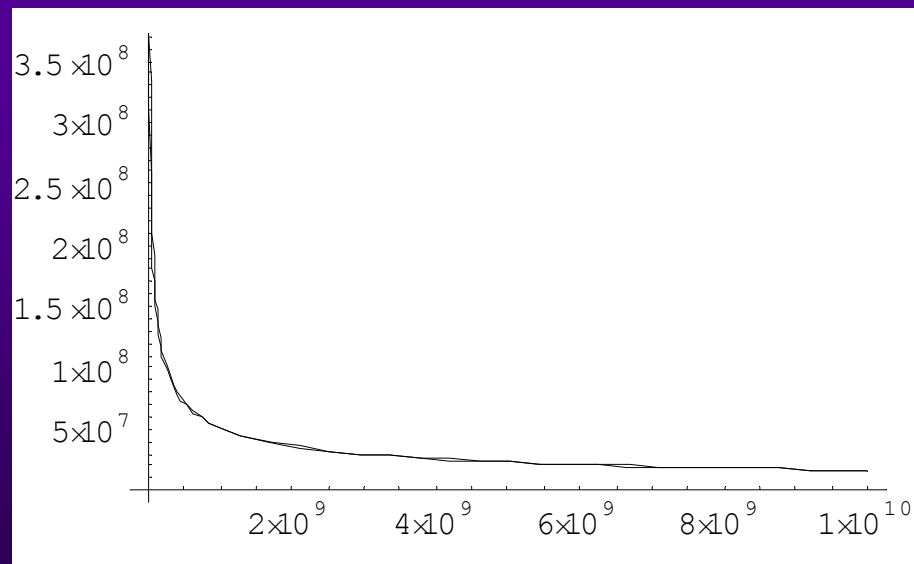
ω [rad/s]



RESISTIVE-WALL IMPEDANCE WITH AND WITHOUT INDUCTIVE BYPASS (4/4)

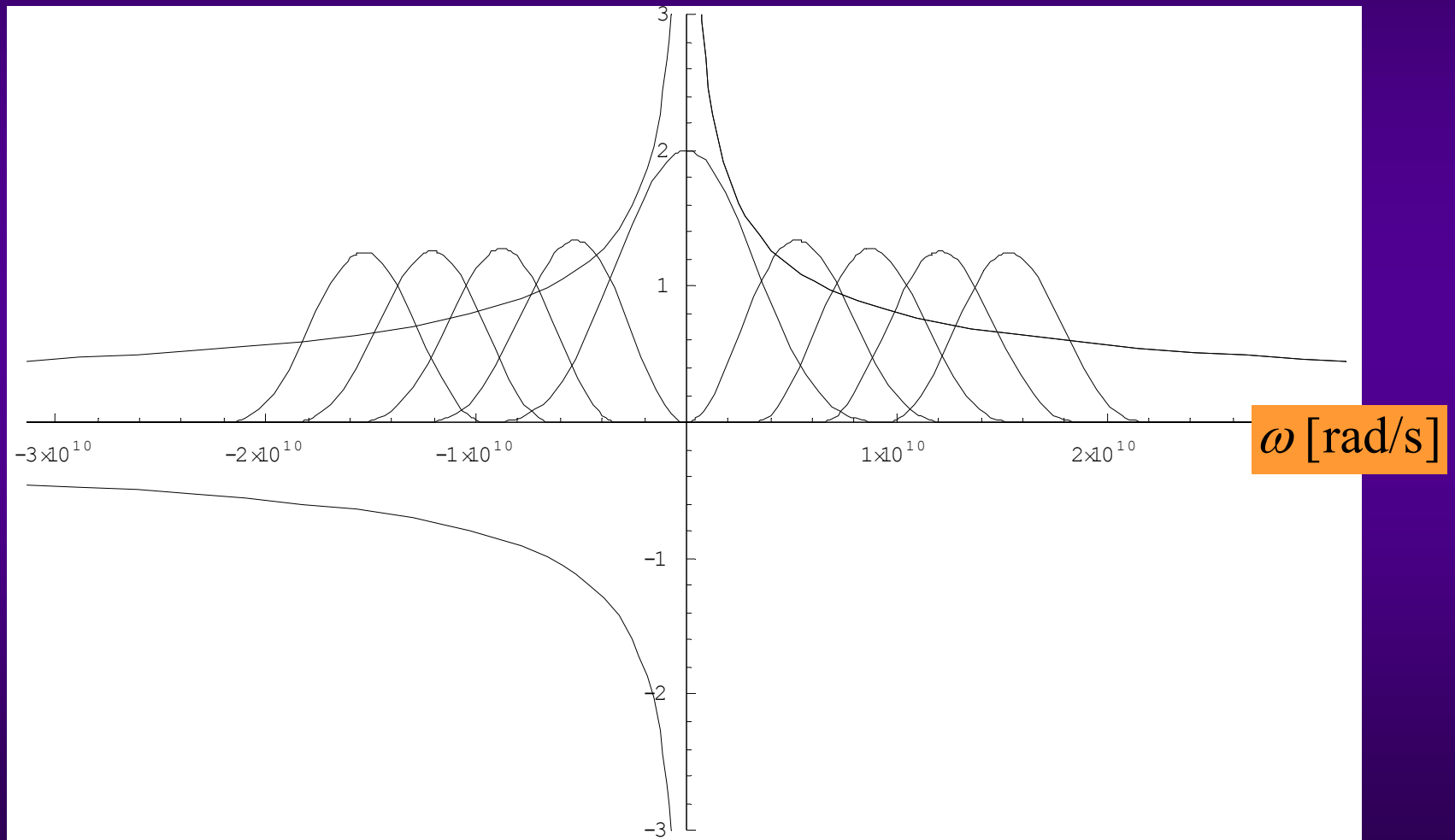


ω [rad/s]



SINUSOIDAL MODES (PARABOLIC BUNCH) WITHOUT LOBES (1/4)

Without Inductive Bypass



SINUSOIDAL MODES (PARABOLIC BUNCH) WITHOUT LOBES (2/4)

- ◆ Most critical coupled-bunch mode number n_y for the real part of the tune shift for modes $m=0$ to 4

{3505, 1723, 3505, 1723, 3505}

- ◆ Most critical coupled-bunch mode number for imaginary part

{3504, 631, 1986, 678, 2451}

- ◆ Real part of the tune shift

{-0.00559576, -0.000166999, -0.0000832749, -0.0000528678, -0.0000374615}

- ◆ Imaginary part of the tune shift

{-0.00344032, -3.55732×10^{-9} , -4.27944×10^{-8} , -1.22389×10^{-10} , -6.62641×10^{-11} }

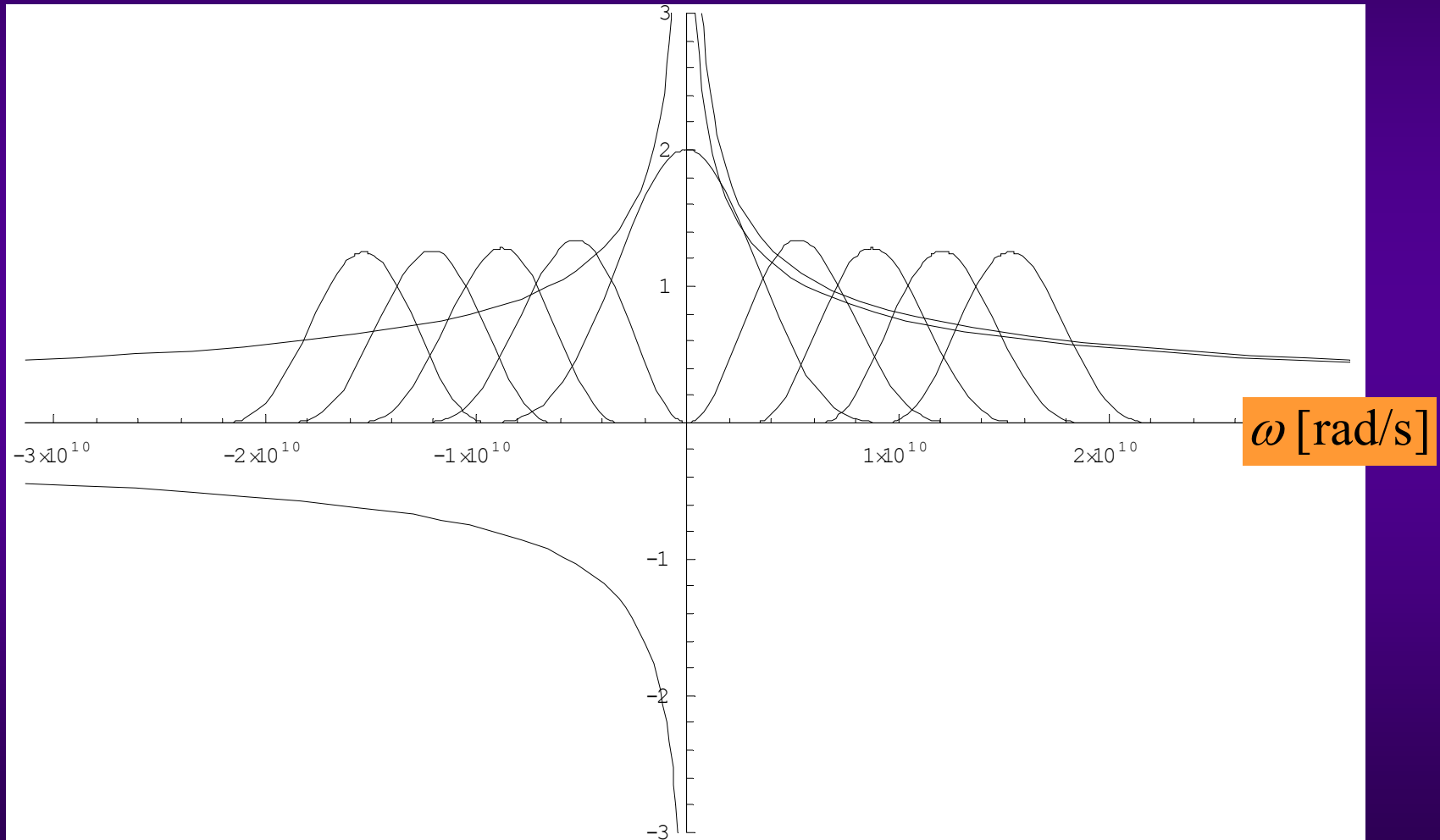
It was -10^{-4} with the lobes

- ◆ Rise-time

{0.00411379, 3978.49, 330.715, 115637., 213581.}

SINUSOIDAL MODES (PARABOLIC BUNCH) WITHOUT LOBES (3/4)

With Inductive Bypass



SINUSOIDAL MODES (PARABOLIC BUNCH) WITHOUT LOBES (4/4)

- ◆ **Most critical coupled-bunch mode number n_y for the real part of the tune shift for modes $m=0$ to 4**

{3505, 1723, 3505, 1723, 3505}

- ◆ **Most critical coupled-bunch mode number for imaginary part**

{3365, 658, 1986, 677, 2449}

- ◆ **Real part of the tune shift**

{-0.000844081, -0.000166346, -0.0000830975, -0.0000527812, -0.0000374098}

- ◆ **Imaginary part of the tune shift**

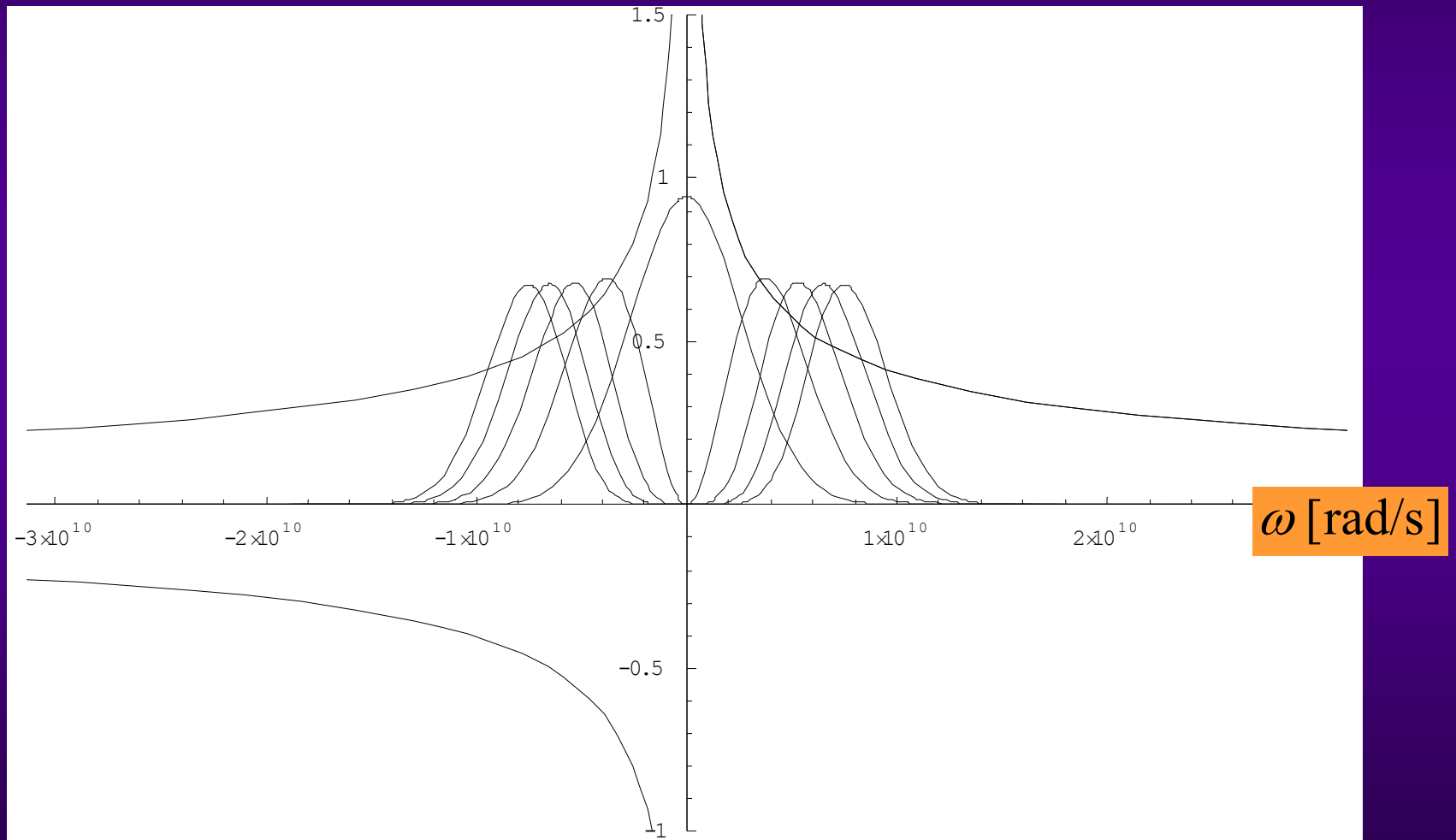
{-0.0000542091, -2.93716×10^{-9} , -4.04619×10^{-8} , -1.13875×10^{-10} , -6.24921×10^{-11} }

- ◆ **Rise-time**

{0.261077, 4818.52, 349.78, 124283., 226473.}

HERMITIAN MODES (GAUSSIAN BUNCH) ⇒ NO LOBES (1/4)

Without Inductive Bypass



HERMITIAN MODES (GAUSSIAN BUNCH)

⇒ NO LOBES (2/4)

- ◆ Most critical coupled-bunch mode number n_y for the real part of the tune shift for modes $m=0$ to 4

{3505, 1723, 3505, 1722, 3531}

- ◆ Most critical coupled-bunch mode number for imaginary part

{3504, 632, 2662, 819, 2631}

- ◆ Real part of the tune shift

{-0.00641366, -0.00019262, -0.000107007, -0.0000722296, -0.0000536562}

- ◆ Imaginary part of the tune shift

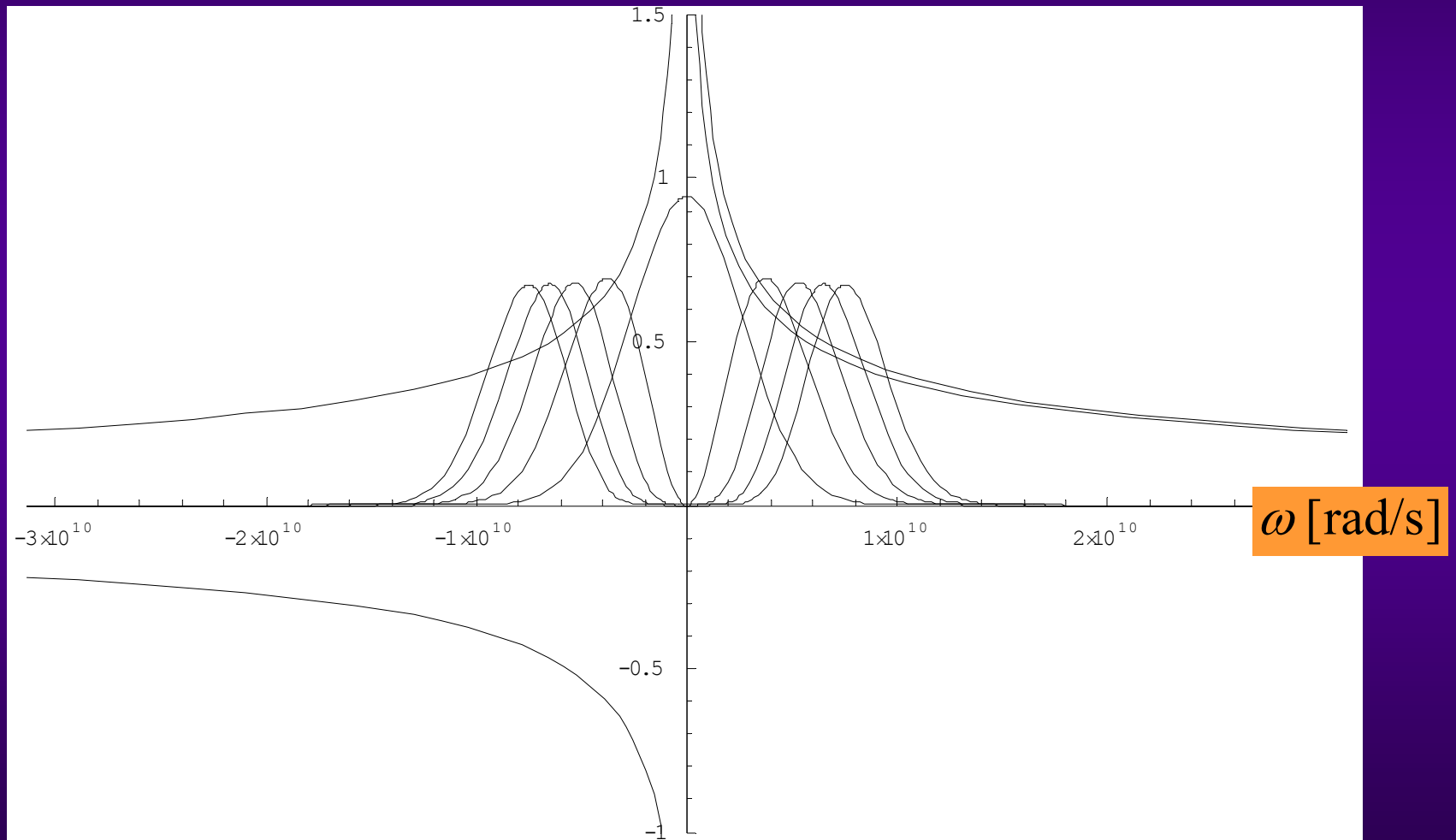
{-0.00398136, -9.36671×10^{-9} , -4.14085×10^{-12} , -3.51179×10^{-15} , -4.48367×10^{-18} }

- ◆ Rise-time

{0.00355476, 1510.96, 3.41784×10^6 , 4.03007×10^9 , 3.15651×10^{12} }

HERMITIAN MODES (GAUSSIAN BUNCH) ⇒ NO LOBES (3/4)

With Inductive Bypass



HERMITIAN MODES (GAUSSIAN BUNCH)

⇒ NO LOBES (4/4)

- ◆ Most critical coupled-bunch mode number n_y for the real part of the tune shift for modes $m=0$ to 4

{3505, 1723, 3505, 1722, 3452}

- ◆ Most critical coupled-bunch mode number for imaginary part

{3365, 659, 2658, 820, 2615}

- ◆ Real part of the tune shift

{-0.000915029, -0.000191646, -0.000106651, -0.0000720335, -0.0000535286}

- ◆ Imaginary part of the tune shift

{-0.0000627354, -7.7475×10^{-9} , -3.76472×10^{-12} , -3.29692×10^{-15} , -4.27565×10^{-18} }

- ◆ Rise-time

{0.225595, 1826.75, 3.75931×10^6 , 4.29272×10^9 , 3.31008×10^{12} }

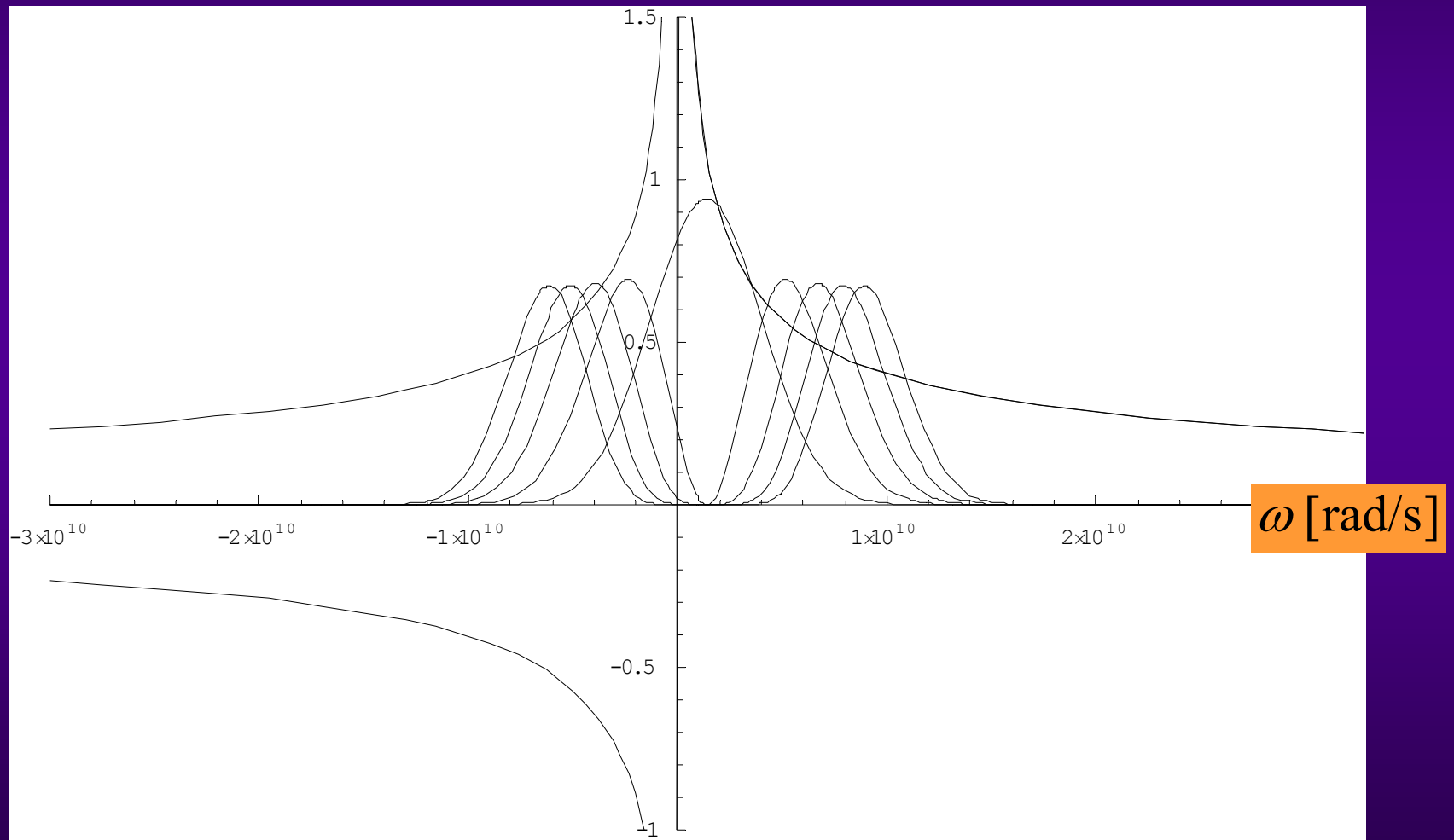
HERMITIAN MODES (GAUSSIAN BUNCH)

⇒ NO LOBES (1/4)

Without Inductive Bypass

$$\xi_y = 0.1$$

$$f_{\xi_y} = 220 \text{ MHz}$$



HERMITIAN MODES (GAUSSIAN BUNCH)

⇒ NO LOBES (2/4)

- ◆ Most critical coupled-bunch mode number n_y for the real part of the tune shift for modes $m=0$ to 4

{3505, 3505, 3505, 3505, 3505}

- ◆ Most critical coupled-bunch mode number for imaginary part

{3504, 3504, 3504, 3504, 3504}

- ◆ Real part of the tune shift

{-0.00563564, -0.000903855, -0.000154333, -0.0000757848, -0.0000546079}

- ◆ Imaginary part of the tune shift

{-0.00328807, -0.000511812, -0.0000466142, -0.0000101348, -5.53855×10^{-6} }

- ◆ Rise-time

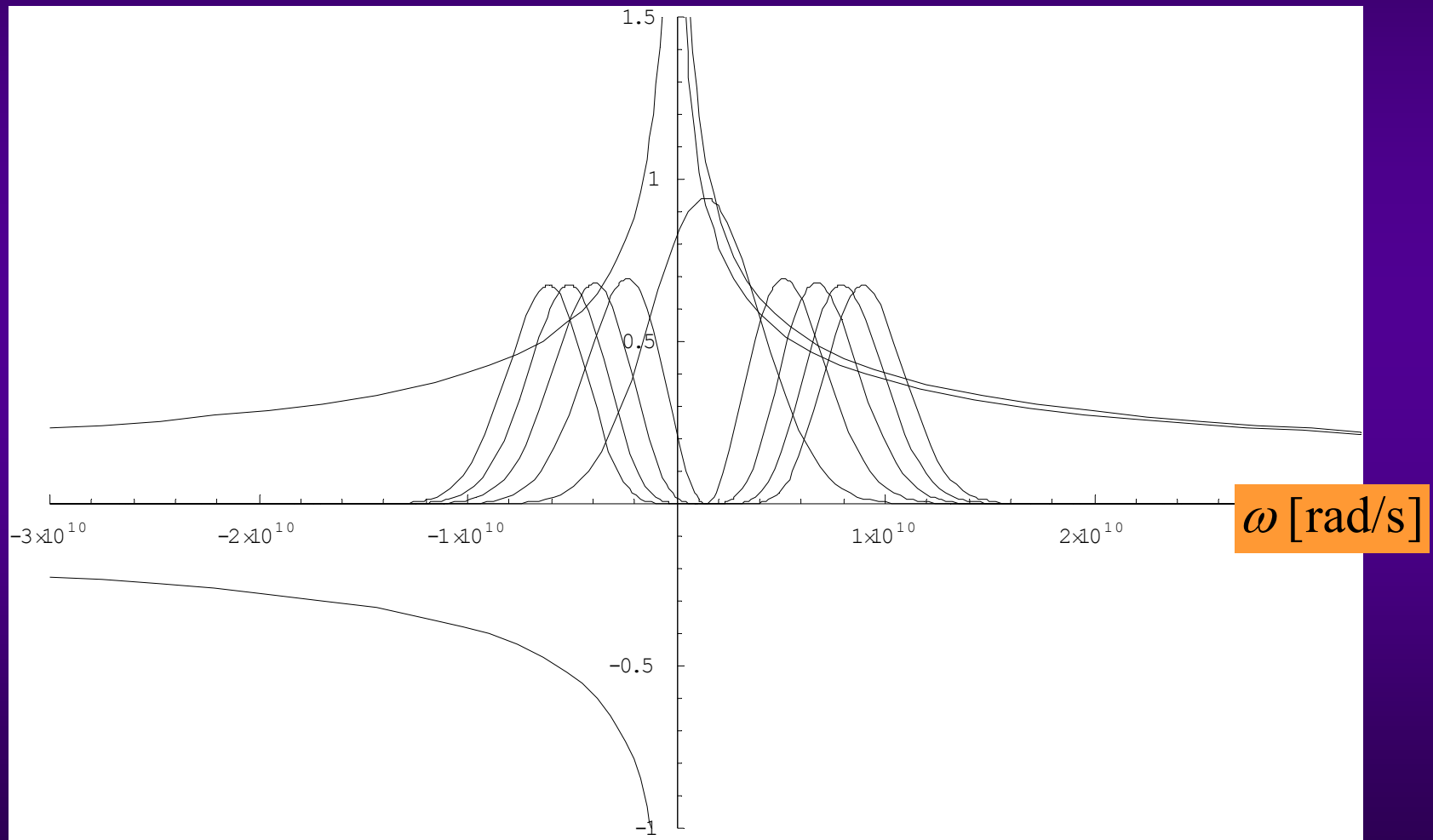
{0.00430428, 0.0276523, 0.303615, 1.39645, 2.55532}

HERMITIAN MODES (GAUSSIAN BUNCH) ⇒ NO LOBES (3/4)

With Inductive Bypass

$$\xi_y = 0.1$$

$$f_{\xi_y} = 220 \text{ MHz}$$



HERMITIAN MODES (GAUSSIAN BUNCH)

⇒ NO LOBES (4/4)

- ◆ Most critical coupled-bunch mode number n_y for the real part of the tune shift for modes $m=0$ to 4

{3505, 3505, 3505, 3505, 3505}

- ◆ Most critical coupled-bunch mode number for imaginary part

{3366, 3355, 3344, 3331, 3317}

- ◆ Real part of the tune shift

{-0.000845886, -0.000244277, -0.000113621, -0.000073899, -0.0000544173}

- ◆ Imaginary part of the tune shift

{0.000105115, -0.0000322337, -0.0000146544, -7.65202×10^{-6} , -4.79264×10^{-6} }

- ◆ Rise-time

{-0.134641, 0.439068, 0.965767, 1.84955, 2.95302}

CONCLUSION

- ◆ The difference between the cases WITH and WITHOUT inductive bypass in Part 1 (for 0 chromaticity and the mode $m=2$) comes from the lobes
- ◆ The Hermitian modes with Gaussian bunches have no lobes
- ◆ Gaussian bunches seem to be a good approximation for the LHC bunches at high energy (synchrotron radiation...)
- ◆ Thanks to the inductive bypass, there should be no problem with the higher-order head-tail modes

for $\xi_y = 0 \rightarrow 0.1$