SUMMARY OF MY 3 IPAC19 PAPERS

E. Métral

- **1) GALACTIC and GALACLIC: two Vlasov solvers for the transverse and longitudinal planes**
- **2) Longitudinal Mode-Coupling Instability: GALACLIC Vlasov solver vs. macroparticle tracking simulations (with M. Migliorati)**
- **3) A two-mode model to study the effect of space charge on TMCI in the "long-bunch" regime**

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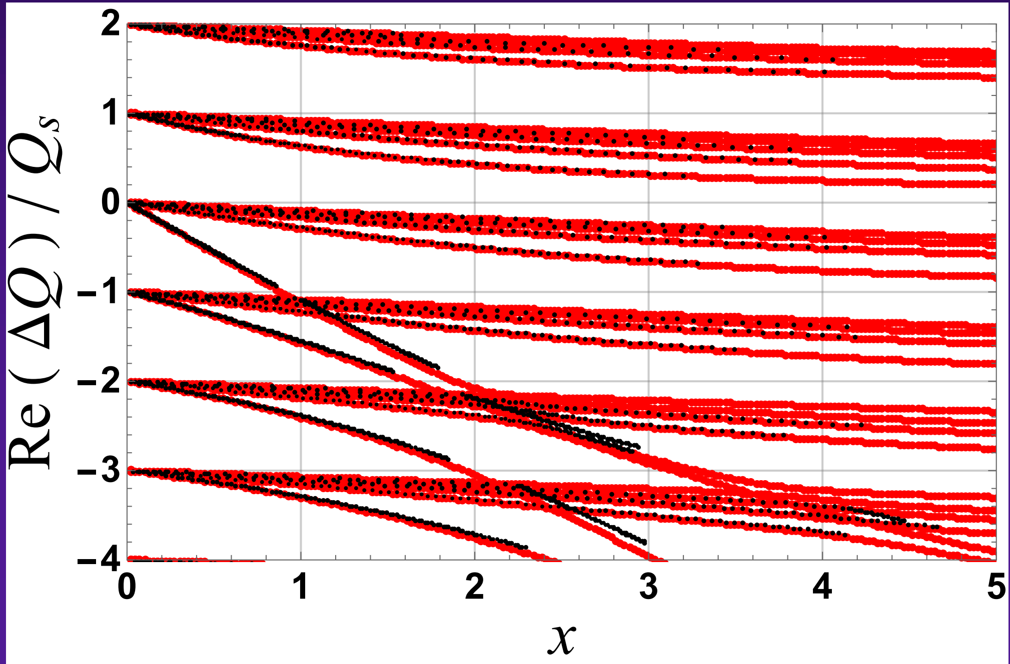
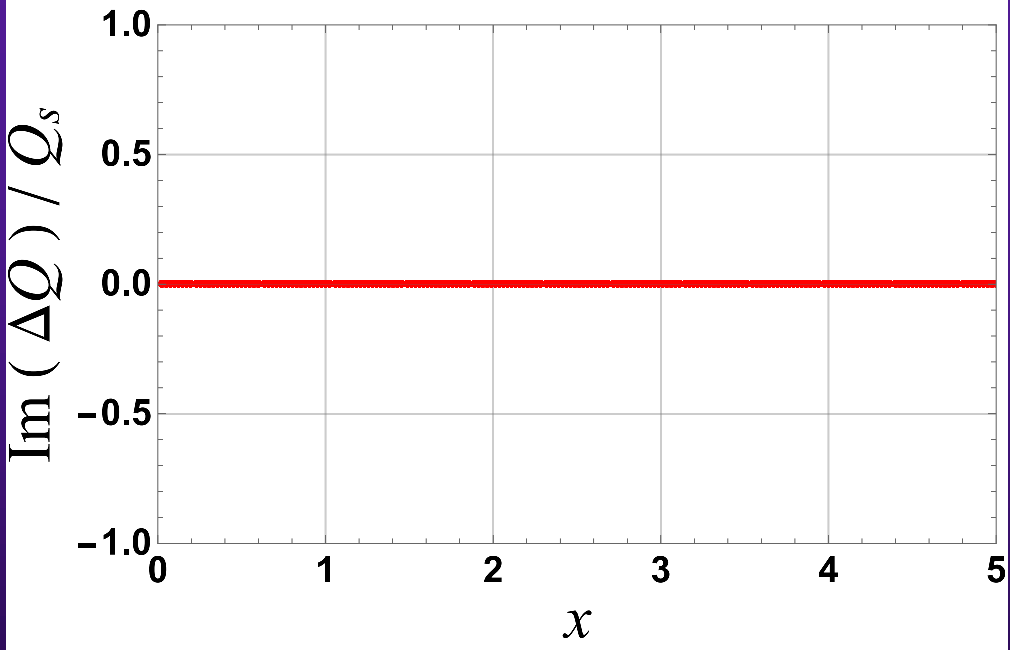
- I followed Garnier's approach and obtained slightly different expressions, which I compared to Laclare => 4 Vlasov solvers discussed here (with Water-Bag for T & Parabolic Amplitude Density for L, but could be any longitudinal distribution)

GALACTIC vs. LACLARE (in black): constant inductive imped.





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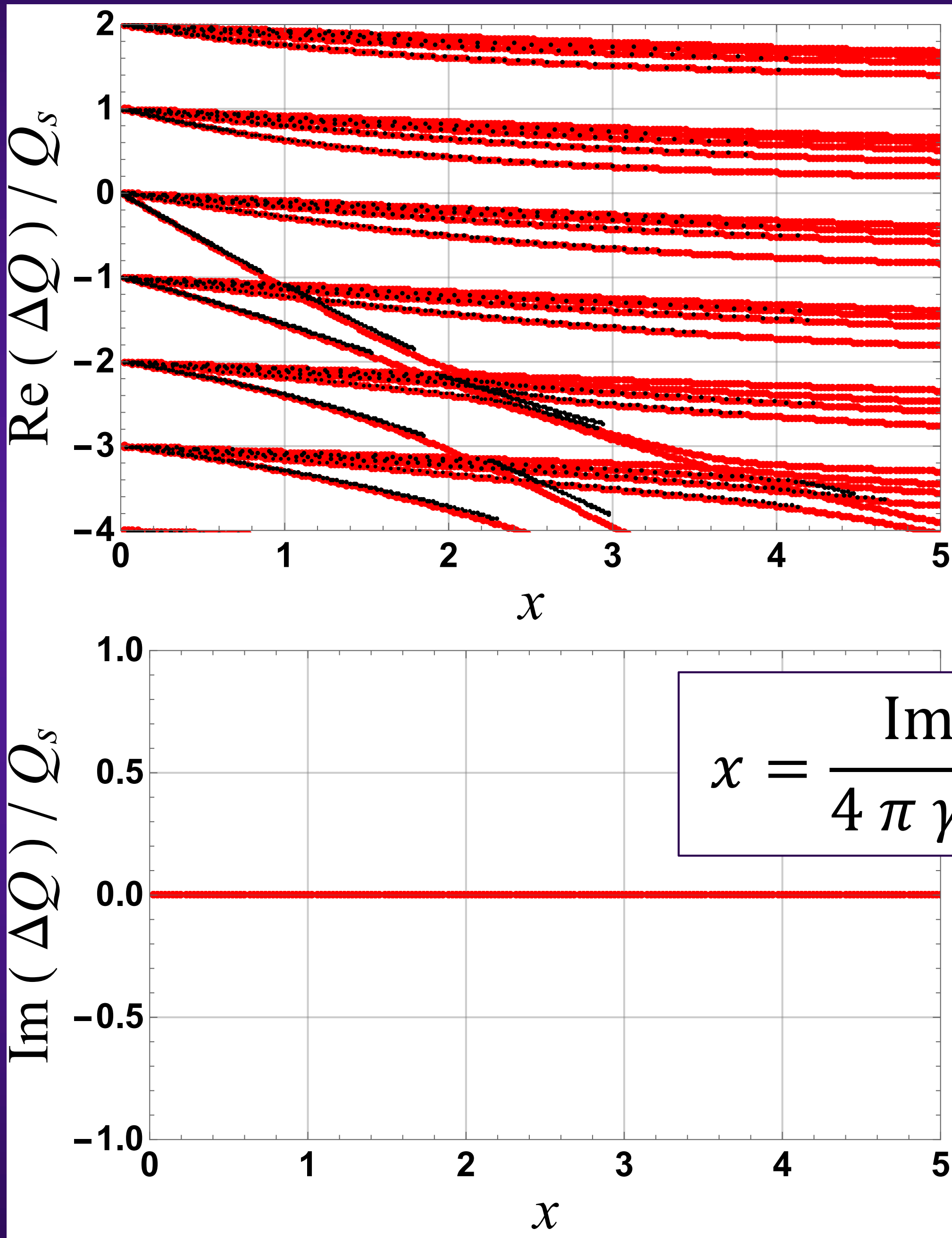

$$x = \frac{\mathrm{Im}[\, Z_x(0)]\, e\, I_b}{4\, \pi\, \gamma\, m_0 c\; Q_{x0} B\; \omega_s}$$

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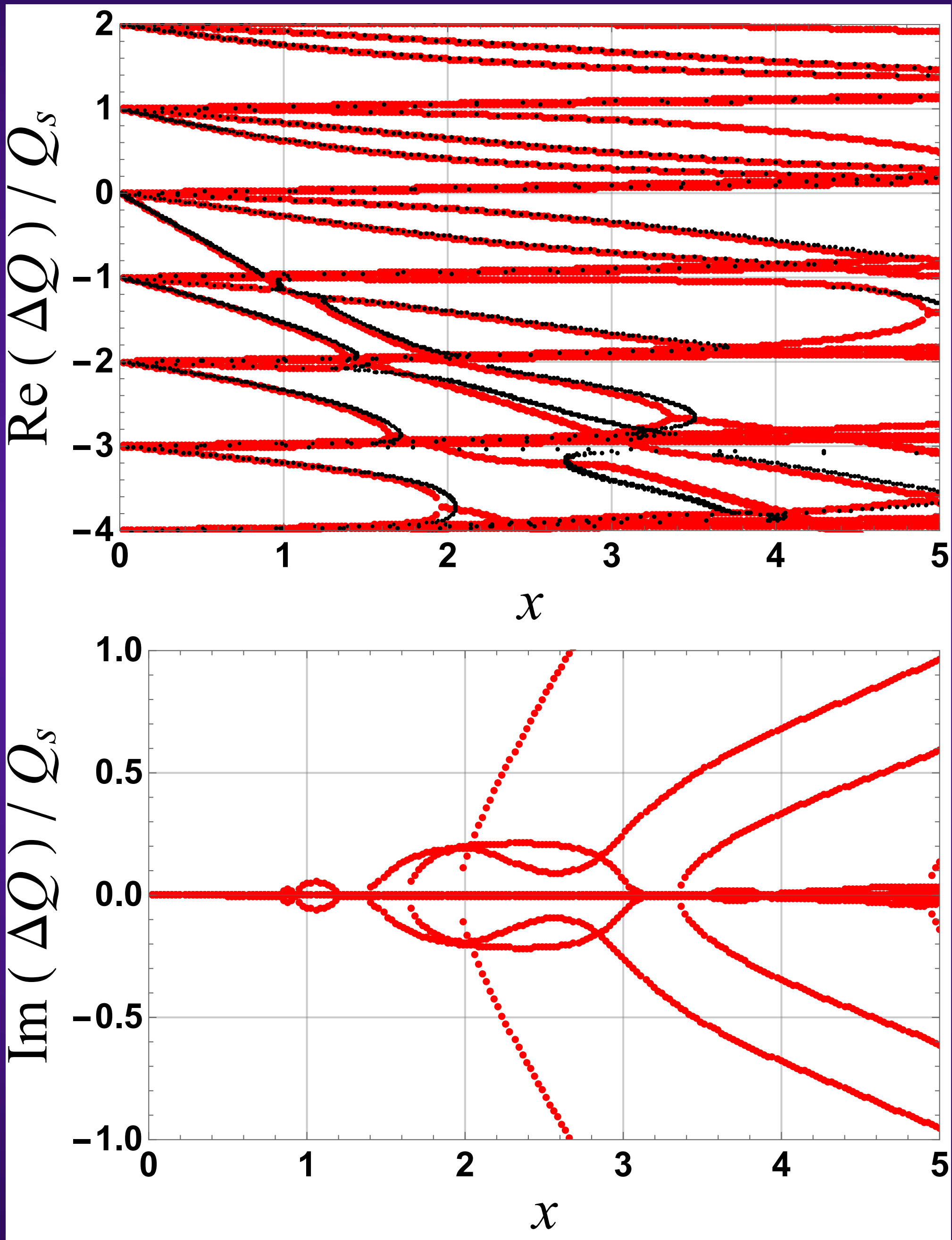

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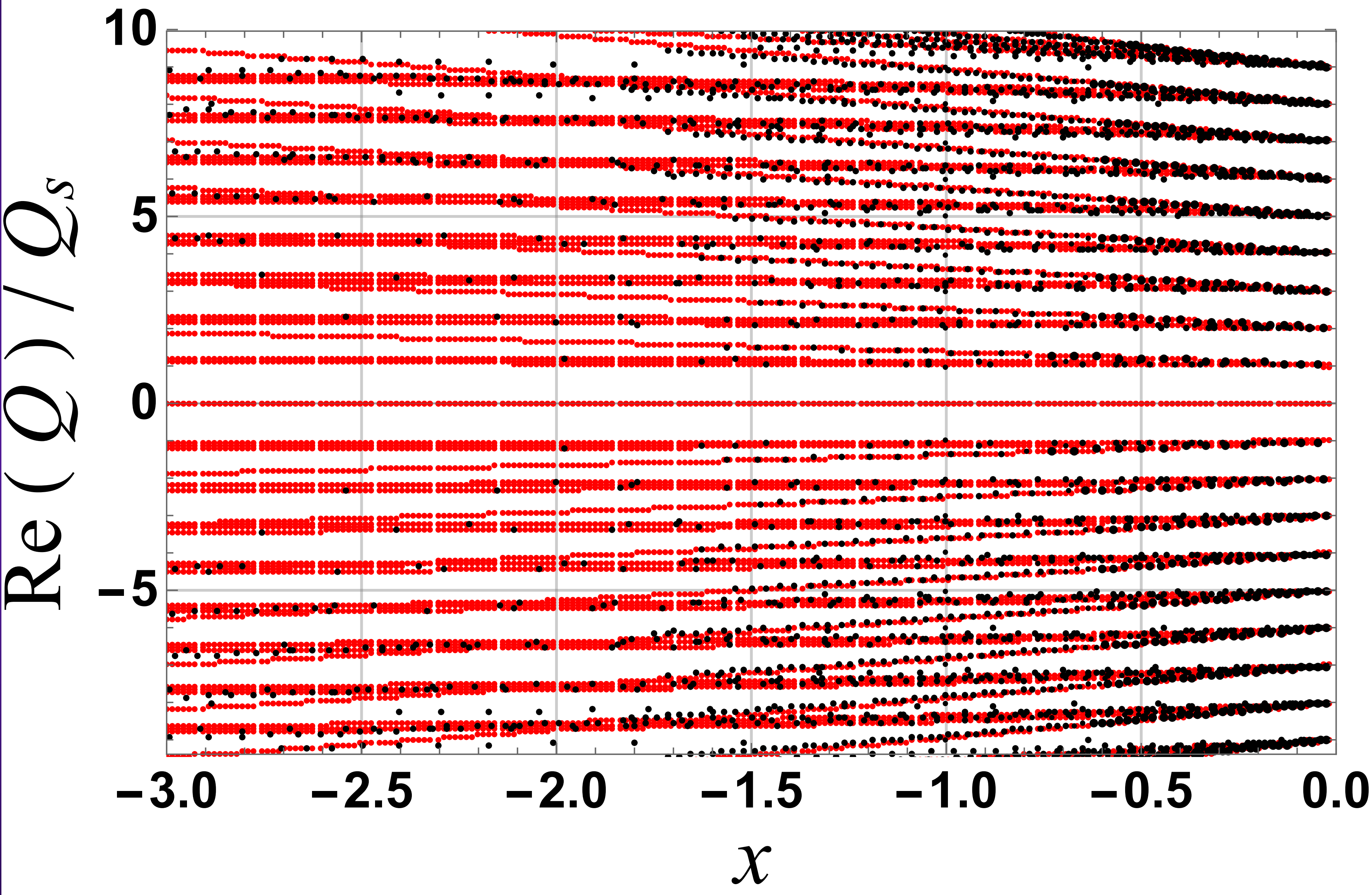

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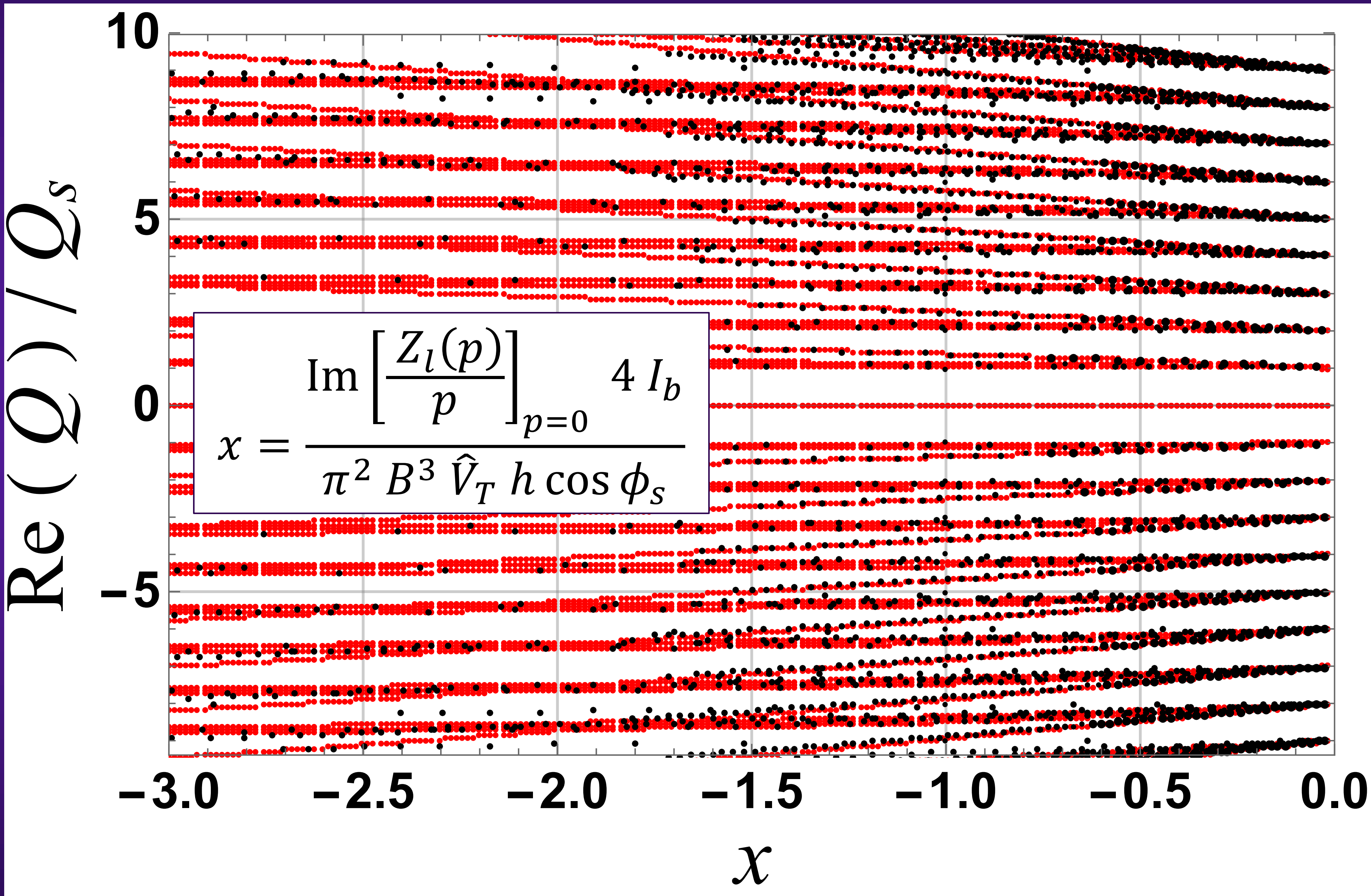

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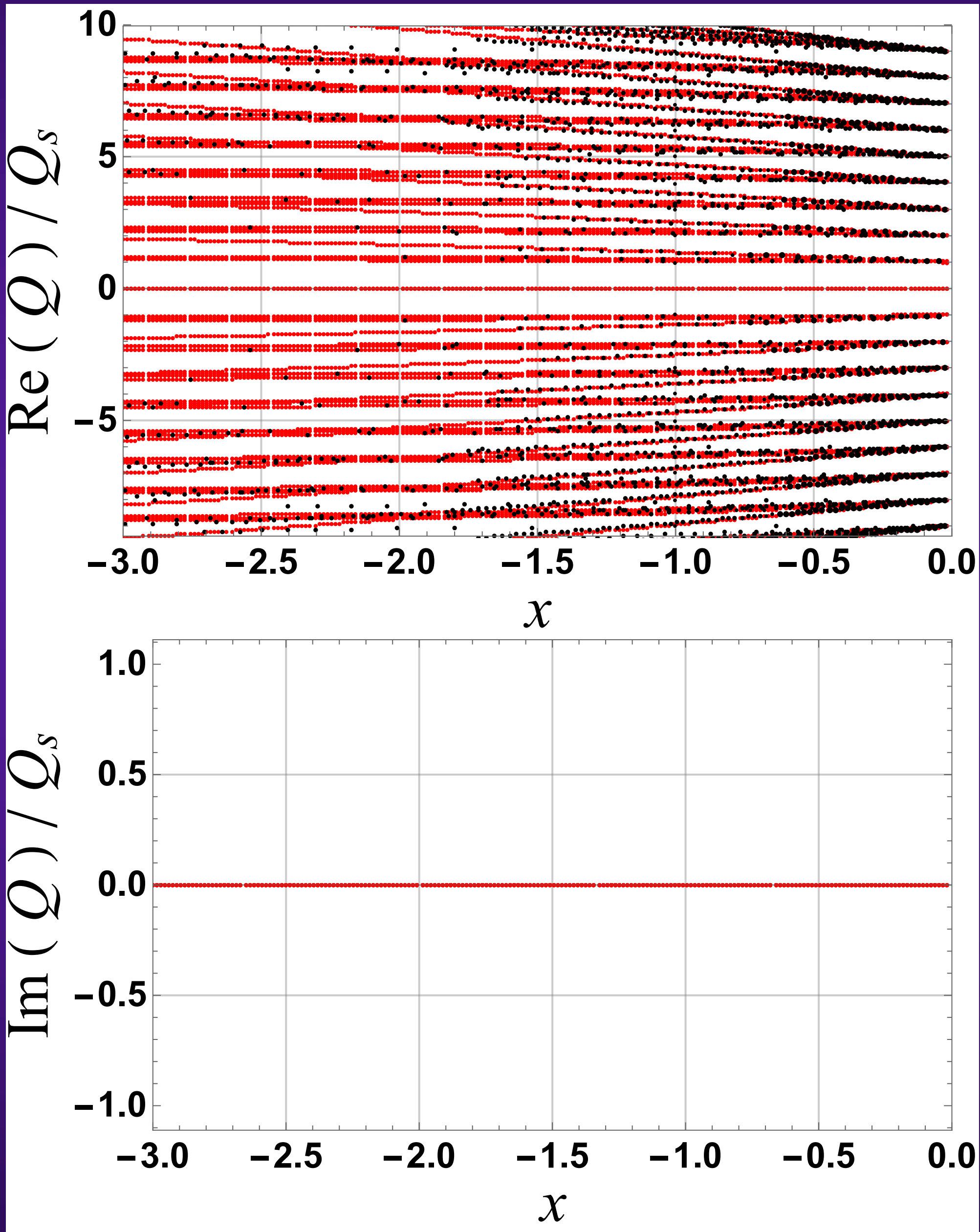

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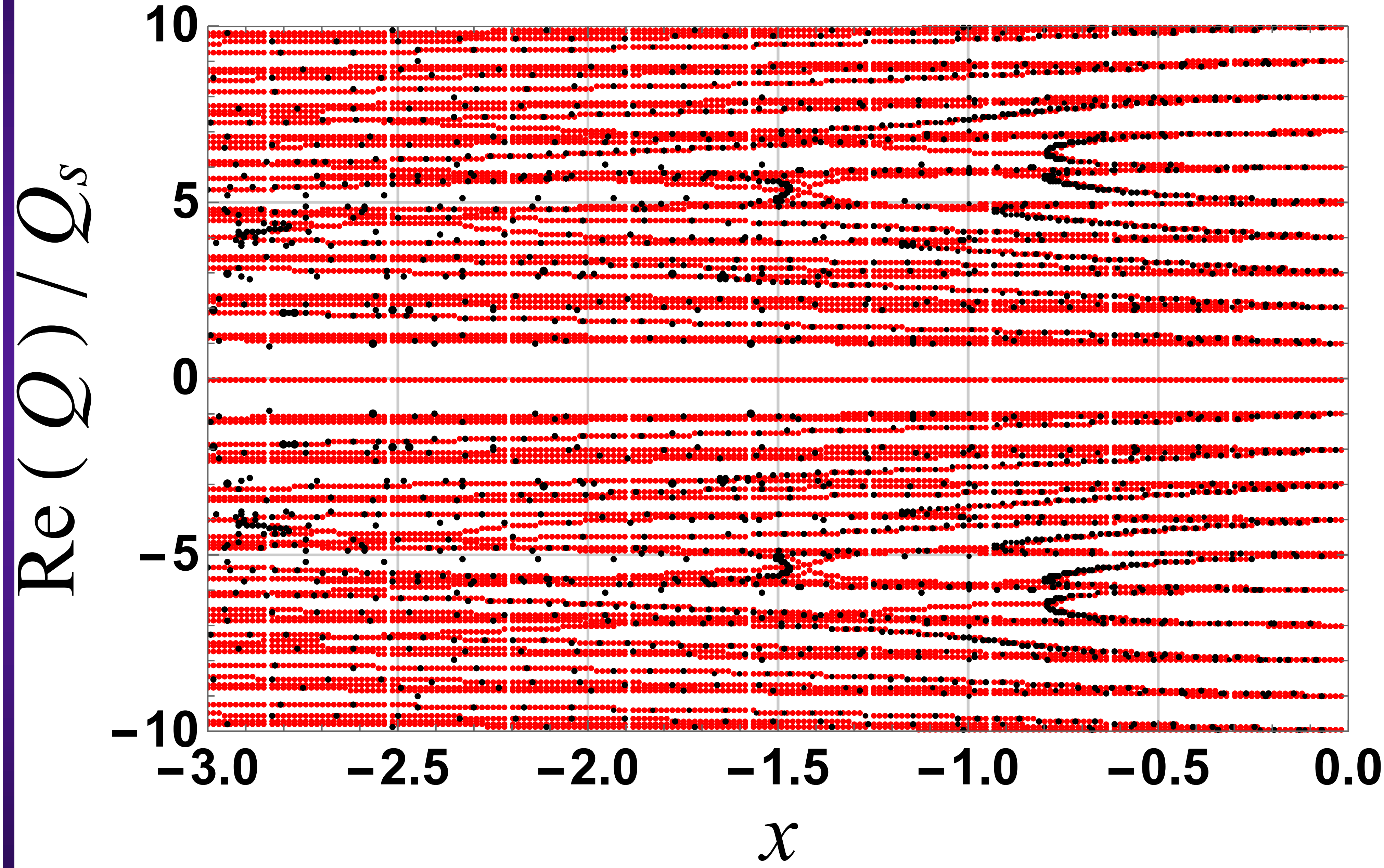

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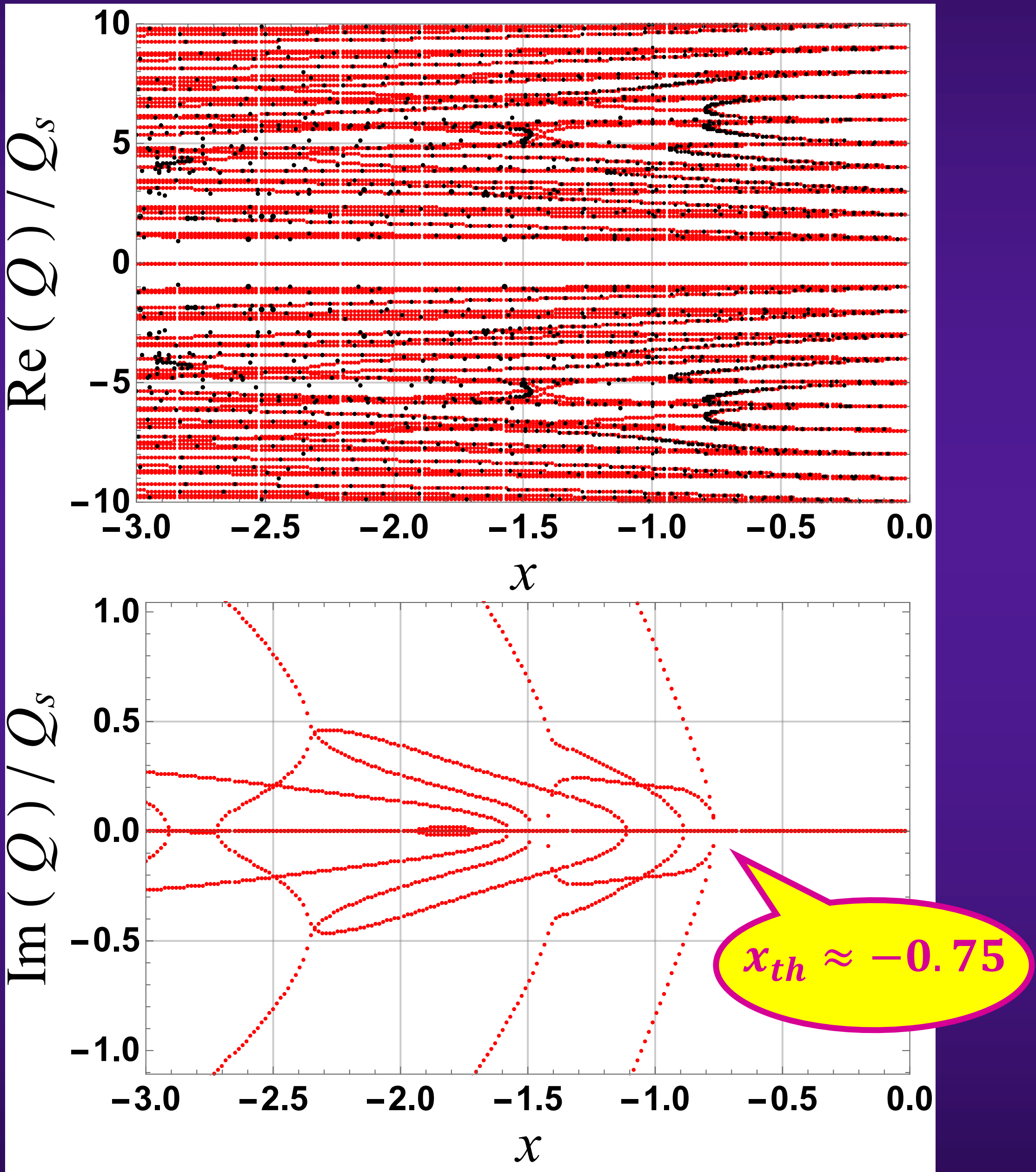

GALACLIC: BB resonator imped. (2.8)
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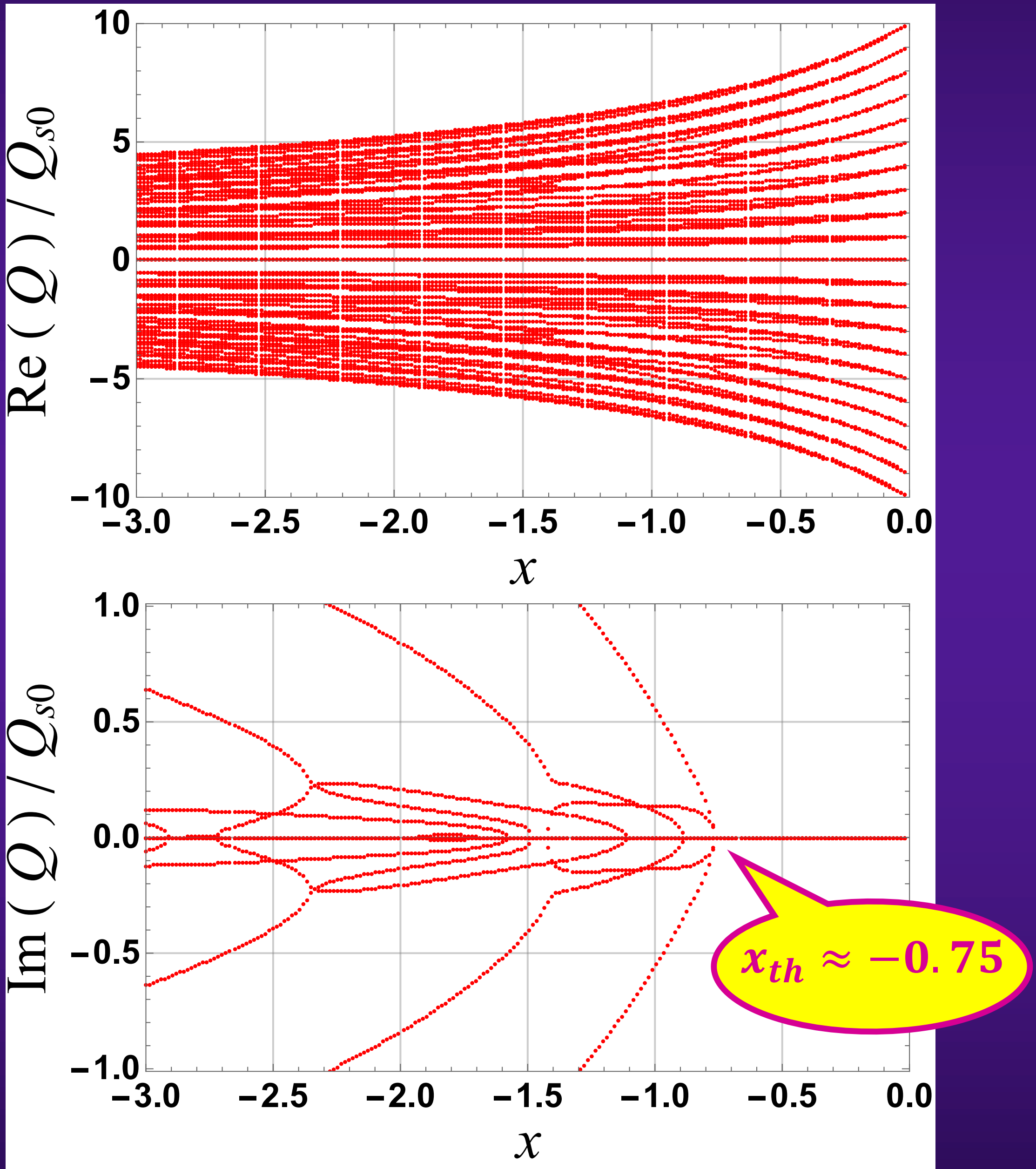

$$\frac{Q}{Q_{s0}} = \frac{Q}{Q_s} \times F_{PWD}$$

$$F_{PWD} = \frac{Q_s}{Q_{s0}} = \frac{1}{\sqrt{1 - \frac{4}{\pi} x}}$$

Assuming here first the simplified case where the shape of the distribution is preserved

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$$f_r\,\tau_b =$$
$$1)\ \mathbf{Inf};\ 2)\ \mathbf{2.7}$$

$$f_0 = 43350.8\ \mathrm{Hz}$$

$$\left[\frac{Z_l}{p}\right]_{p=0} = 8.67\ \Omega$$

$$\omega_{s0} = 889\ \mathrm{rad/s}$$

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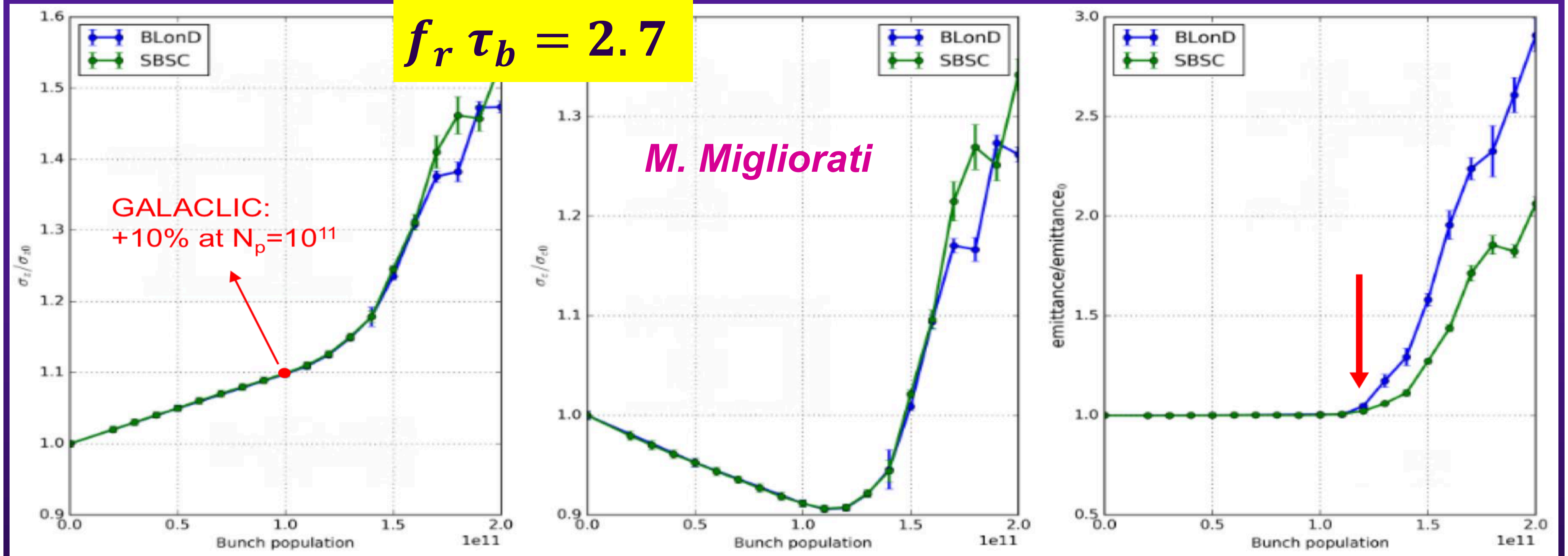
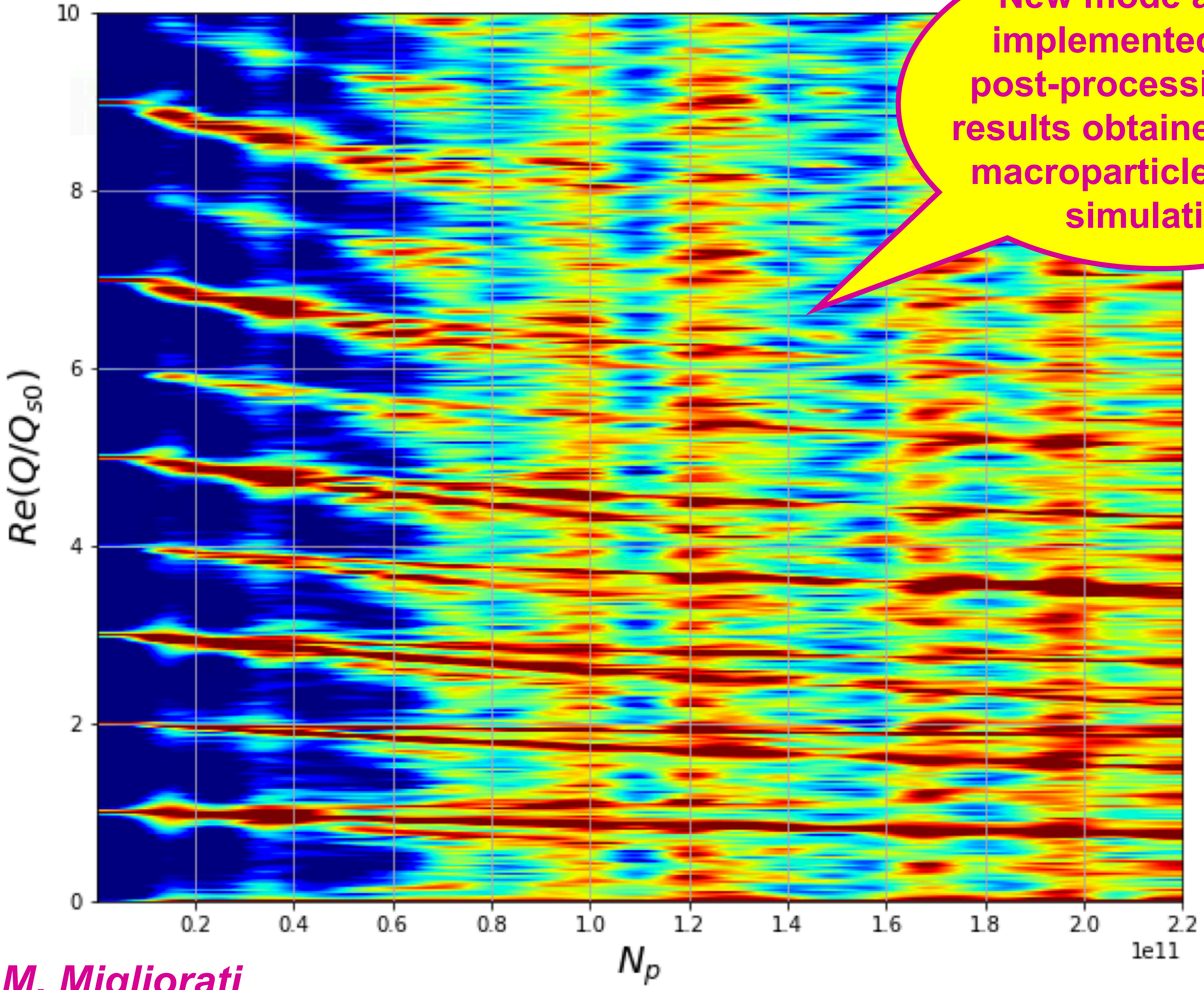


SBSC vs. GALACLIC (in black): constant inductive imped.



New mode analysis implemented for the post-processing of the results obtained through macroparticle tracking simulations

M. Migliorati

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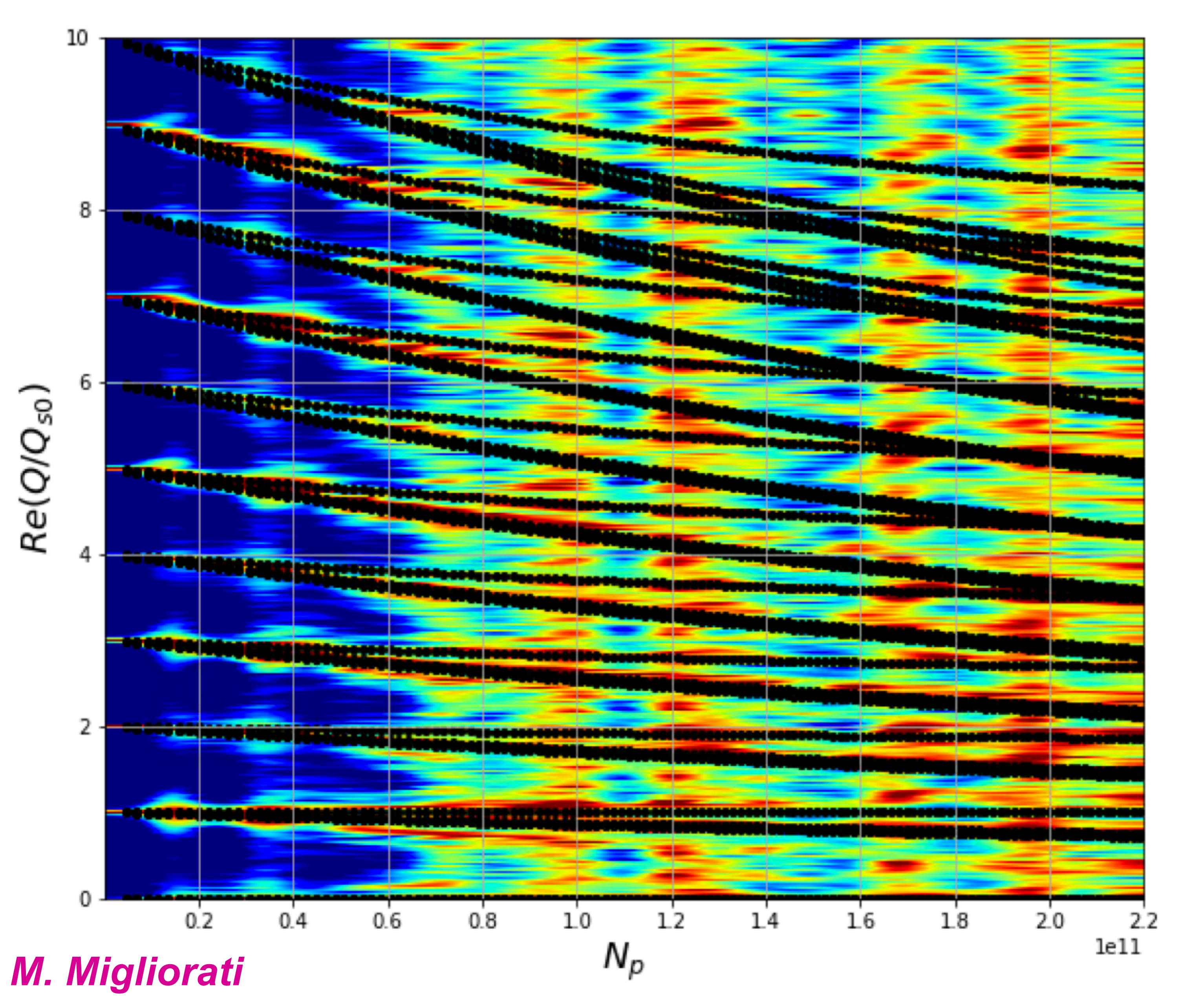

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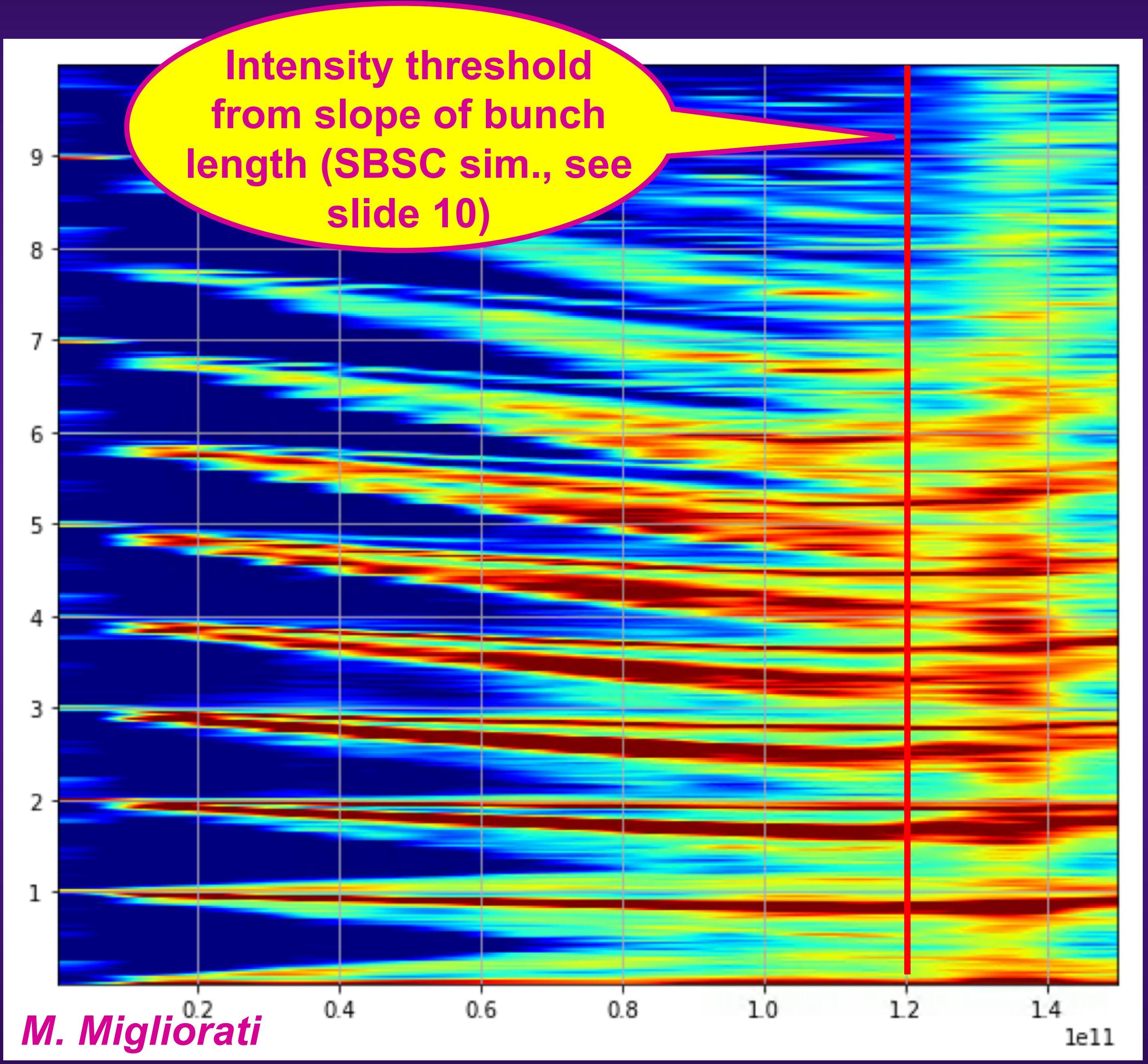

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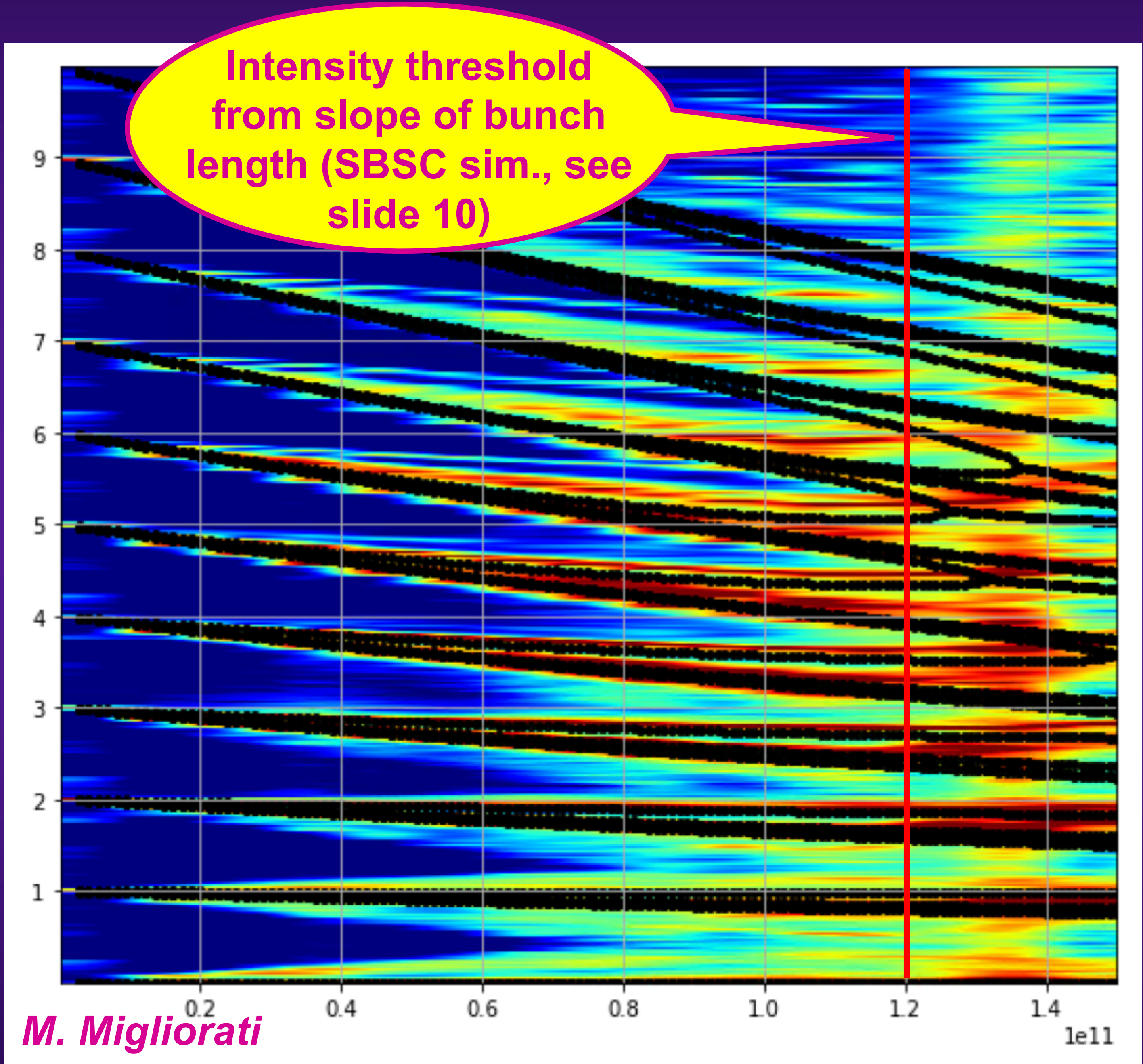

Simple formula

$$\boxed{N_b^{th} = \frac{|x_{th}|\,\pi^2}{4}\,\frac{B_0^3\,V_{RF}\,h}{e\,f_0\left|\frac{Z_l(p)}{p}\right|_{p=0}}\,\frac{B_0}{B}}$$

$$\left(\frac{B_0}{B}\right)_{PLD} = \left(1-\frac{3}{4}\,x_{th}\right)^{-1/4}$$

$$x_{th} \approx -0.75 \Rightarrow \boldsymbol{N_b^{th}} \approx 1.2\times 10^{11}\ \mathrm{p/b}$$

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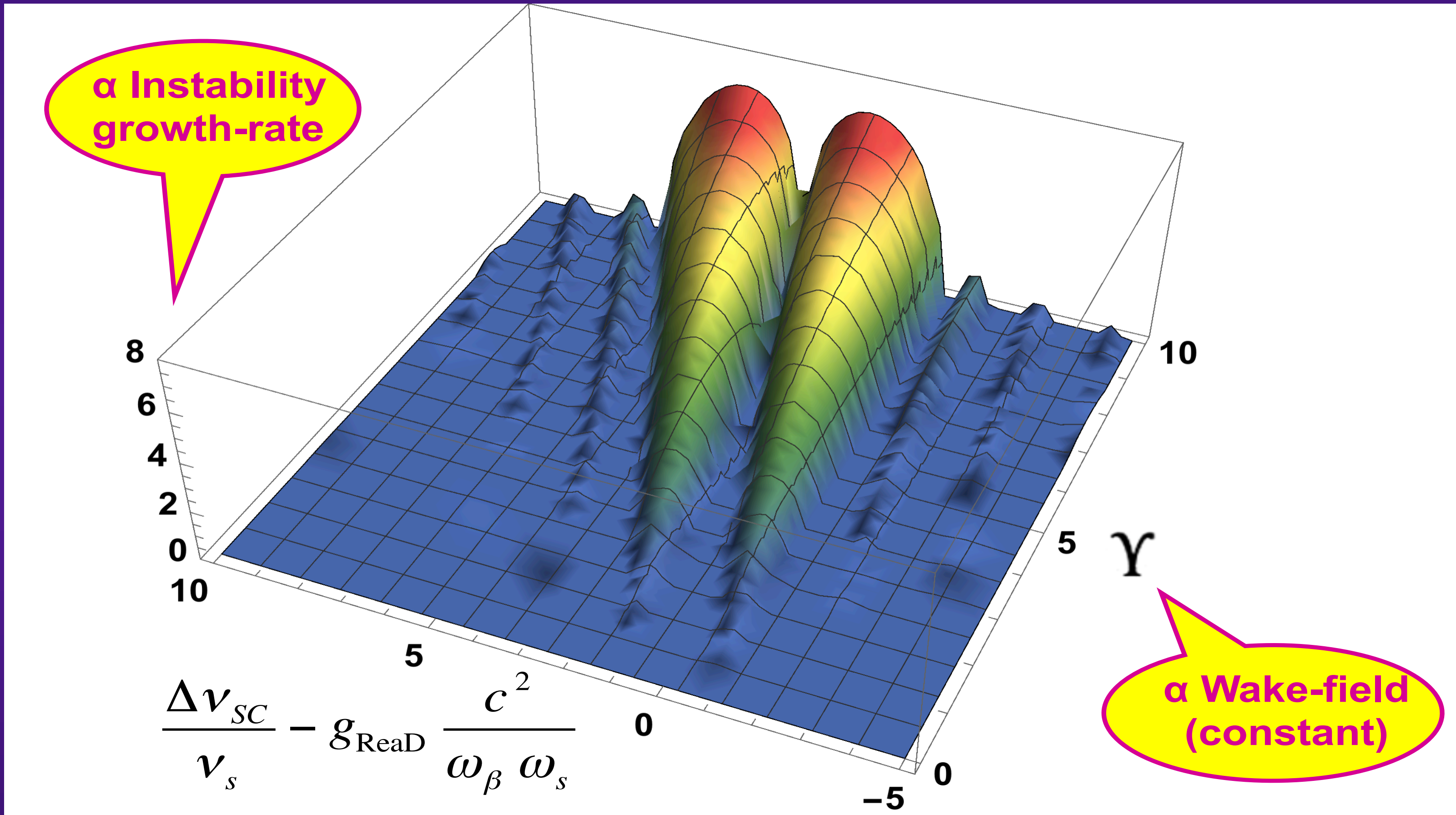
- New simulations were then performed (A. Oeftiger) and analysed in detail (still ongoing), as well as new measurements in the SPS (A. Oeftiger & H. Bartosik) => Confirmed destabilising effect of SC

Reminder on 2-particle model from Y.H. Chin, A.W. Chao and M. Blaskiewicz => Extended to include also a ReaD



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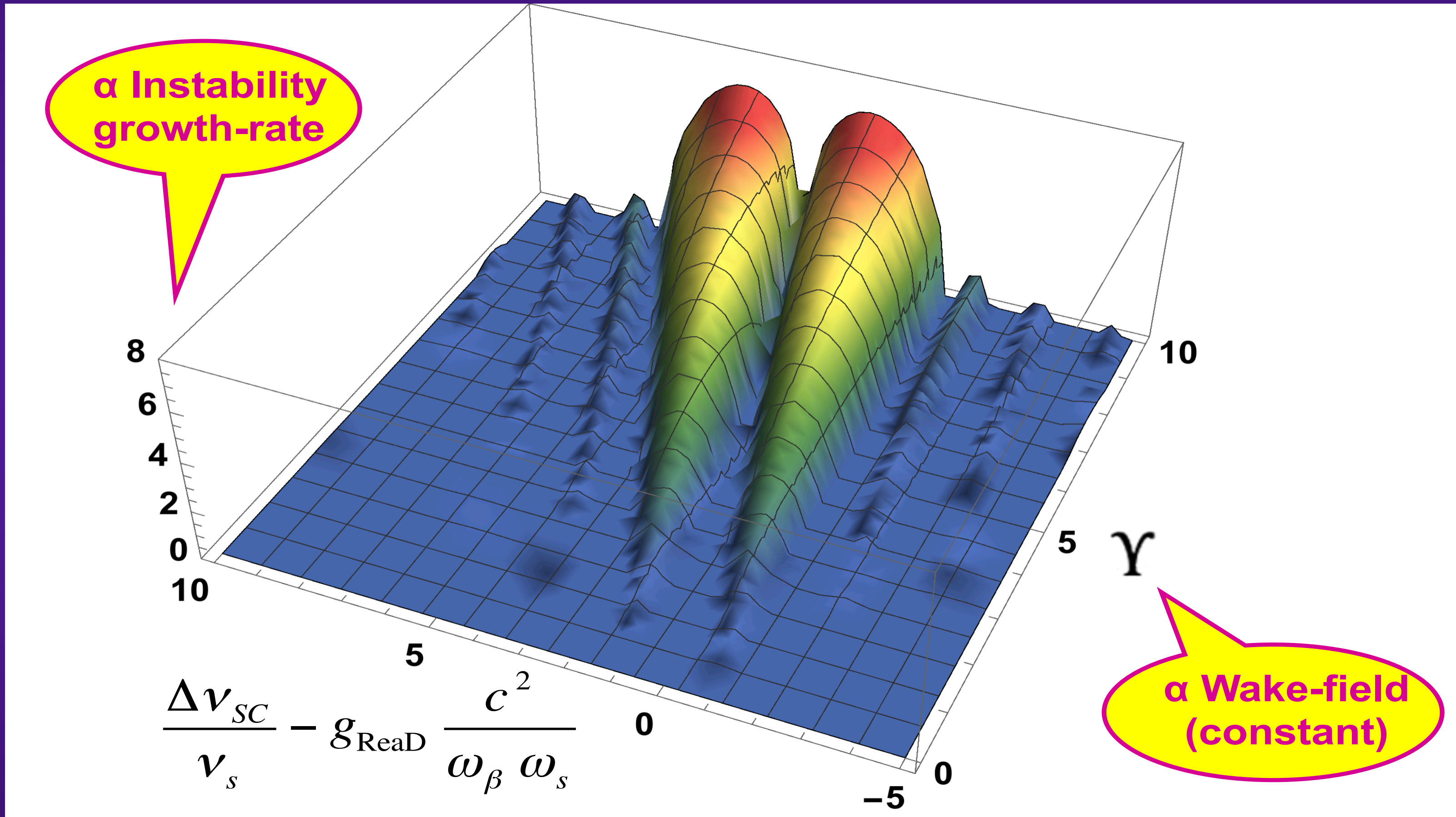
- **Conclusion: both SC and/or a reactive transverse damper (ReaD) would affect TMCI in a similar way and could suppress it**



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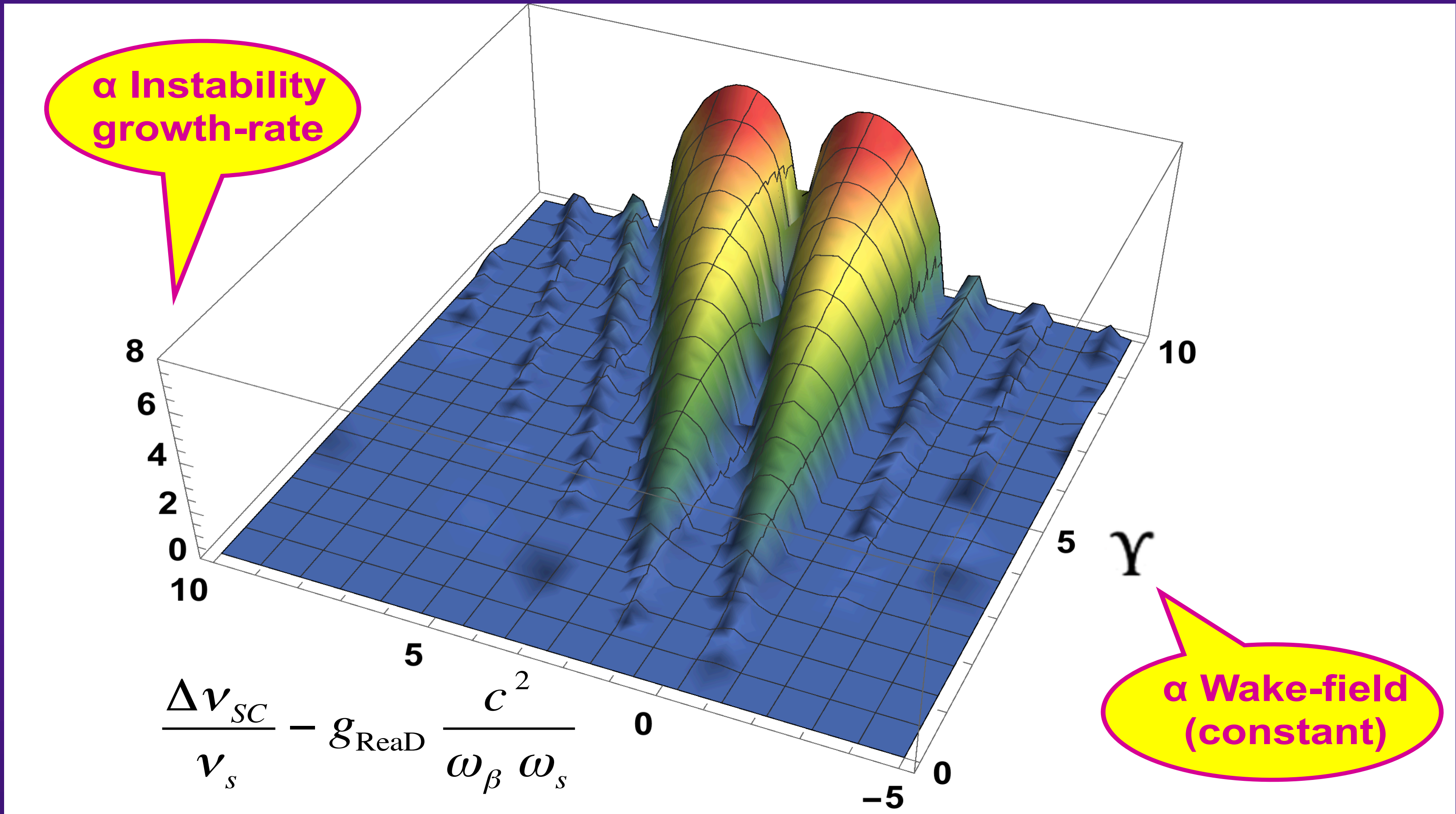

=> Things are more involved with a bunched beam, where the "short-bunch" regime is different from the "long-bunch" regime…

SC only

- **Blaskiewicz1998 (ABS model)**

$$\frac{\Delta Q}{Q_s} = -q_{sc} \pm \sqrt{q_{sc}^2 + m^2} \qquad q_{sc} = \Delta Q_{sc} \,/\, (2\, Q_s)$$

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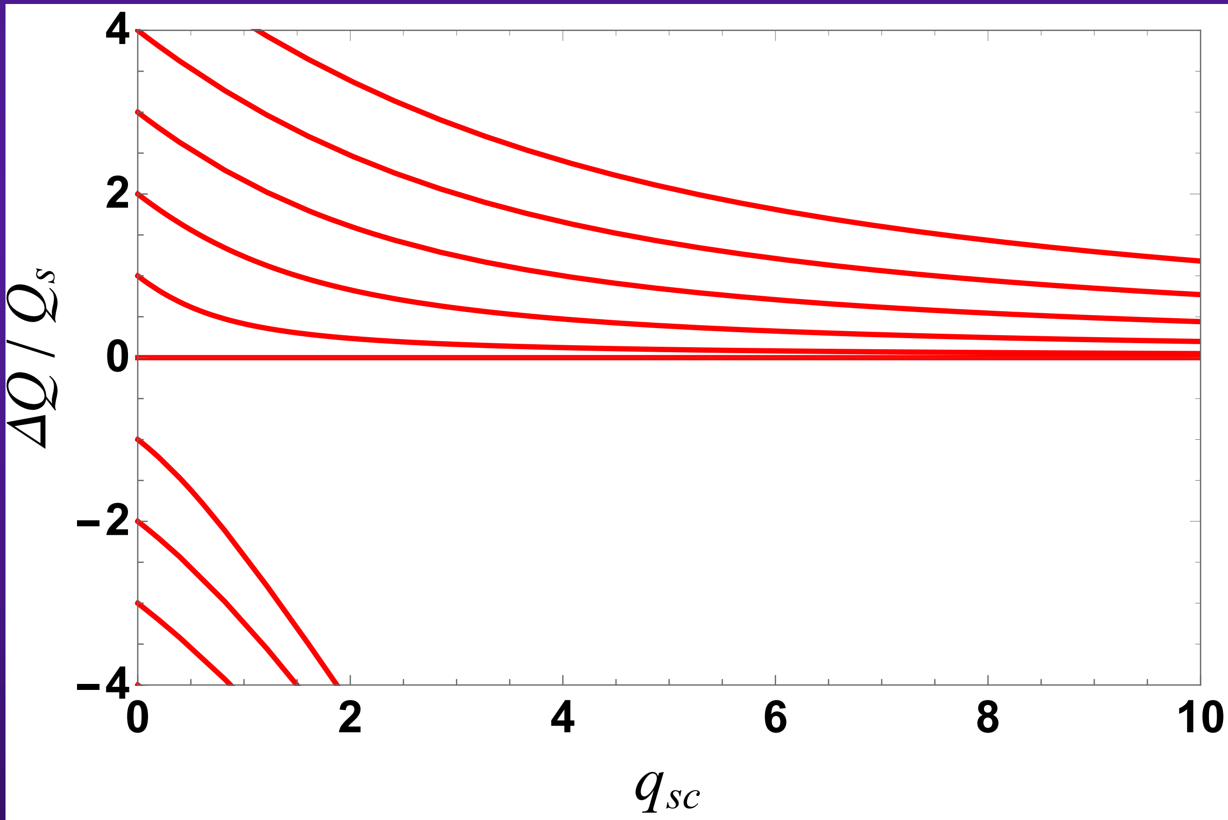

"Short-bunch" regime without and with ReaD or SC

- **Example from my IPAC18 paper on the "Destabilising effect of the LHC transverse damper" => Adding the effect of SC**

$$\begin{pmatrix} F_{sc}\,x - \sqrt{1 + (F_{sc}\,x)^2} & -0.23\,j\,x \\ -0.55\,j\,x & -0.92\,x + F_D \end{pmatrix}$$

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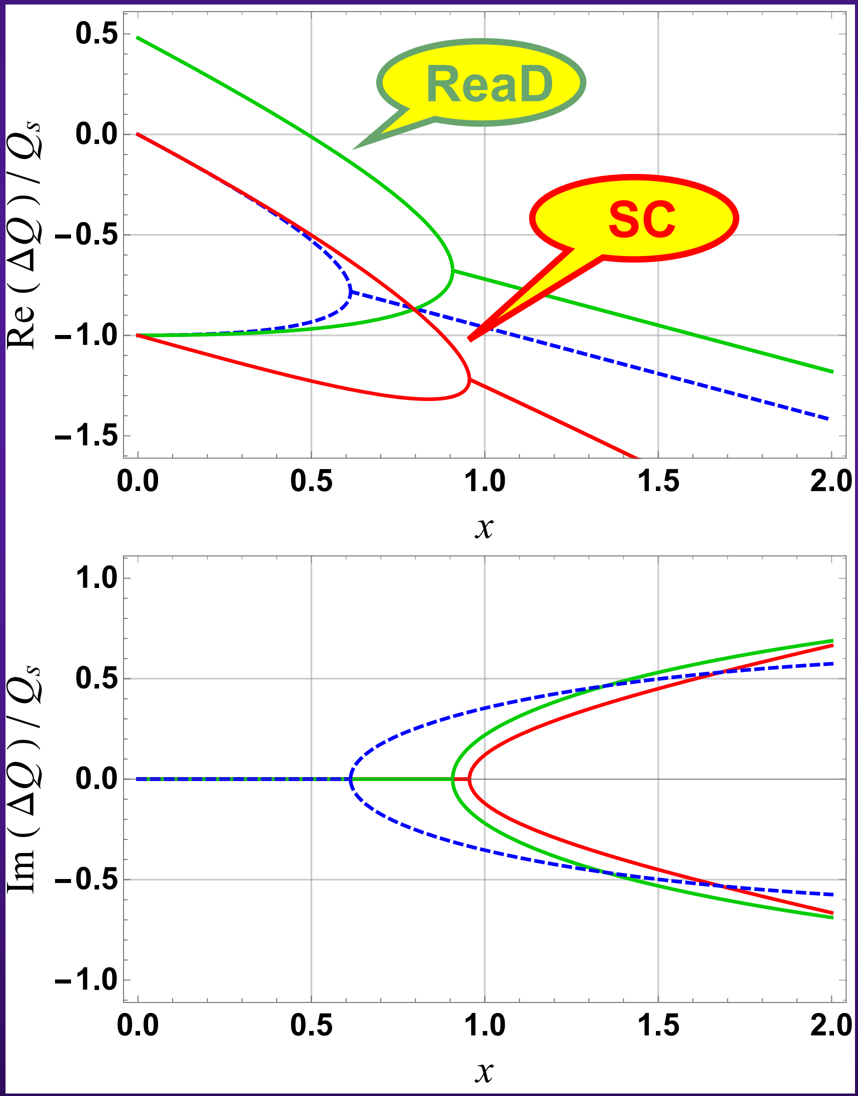
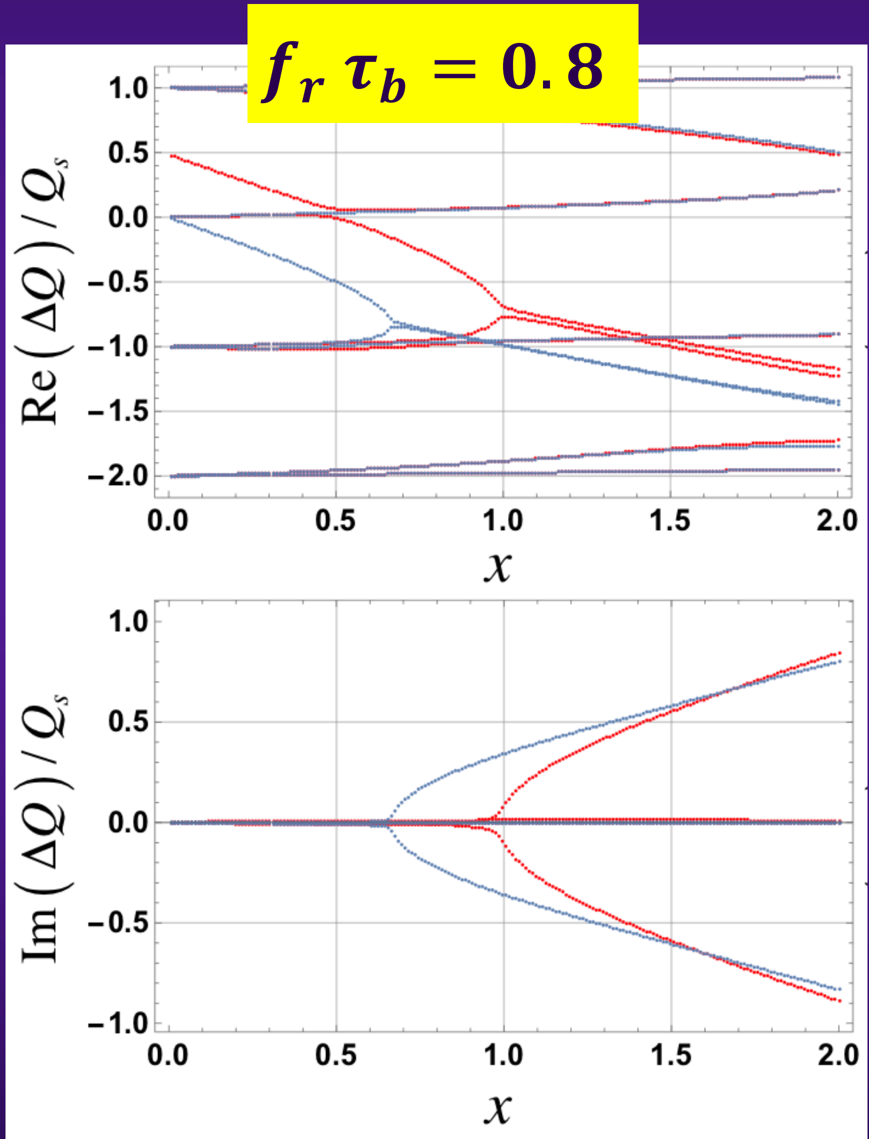
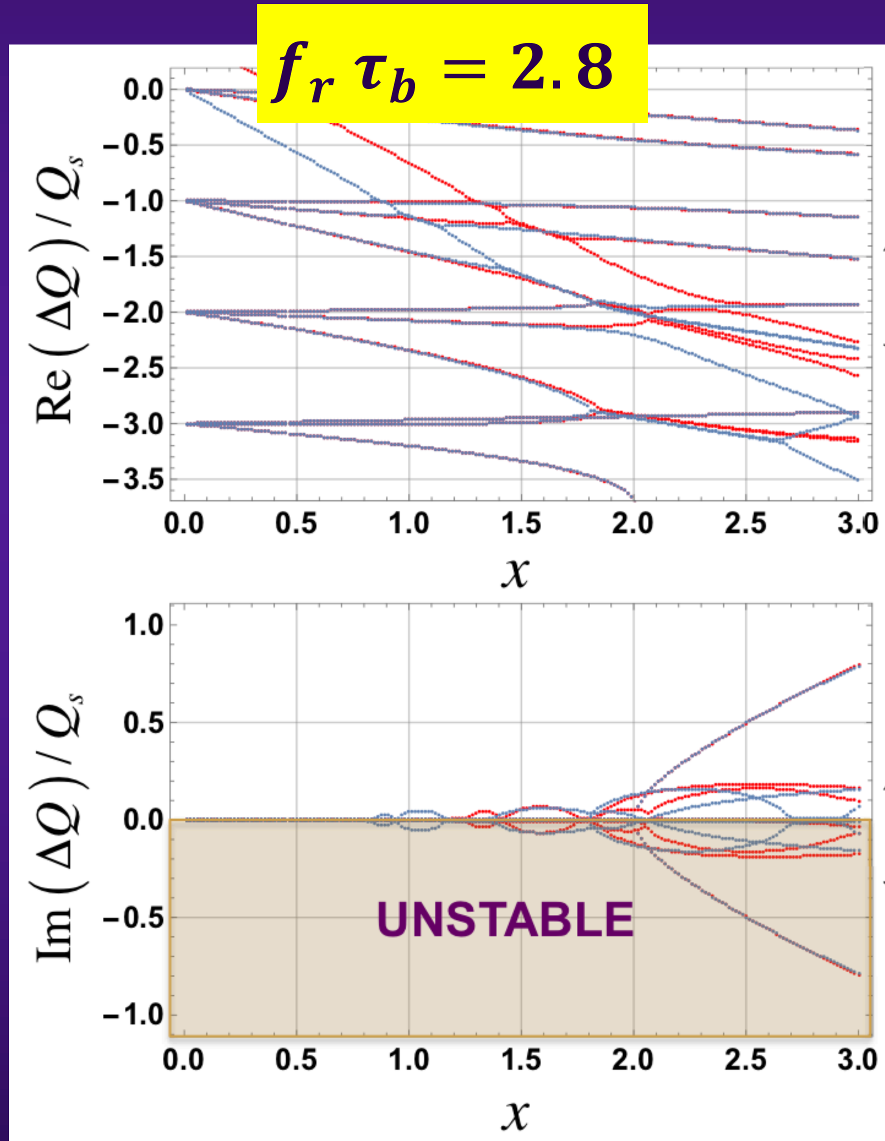


“Long-bunch” regime with neither ReaD nor SC

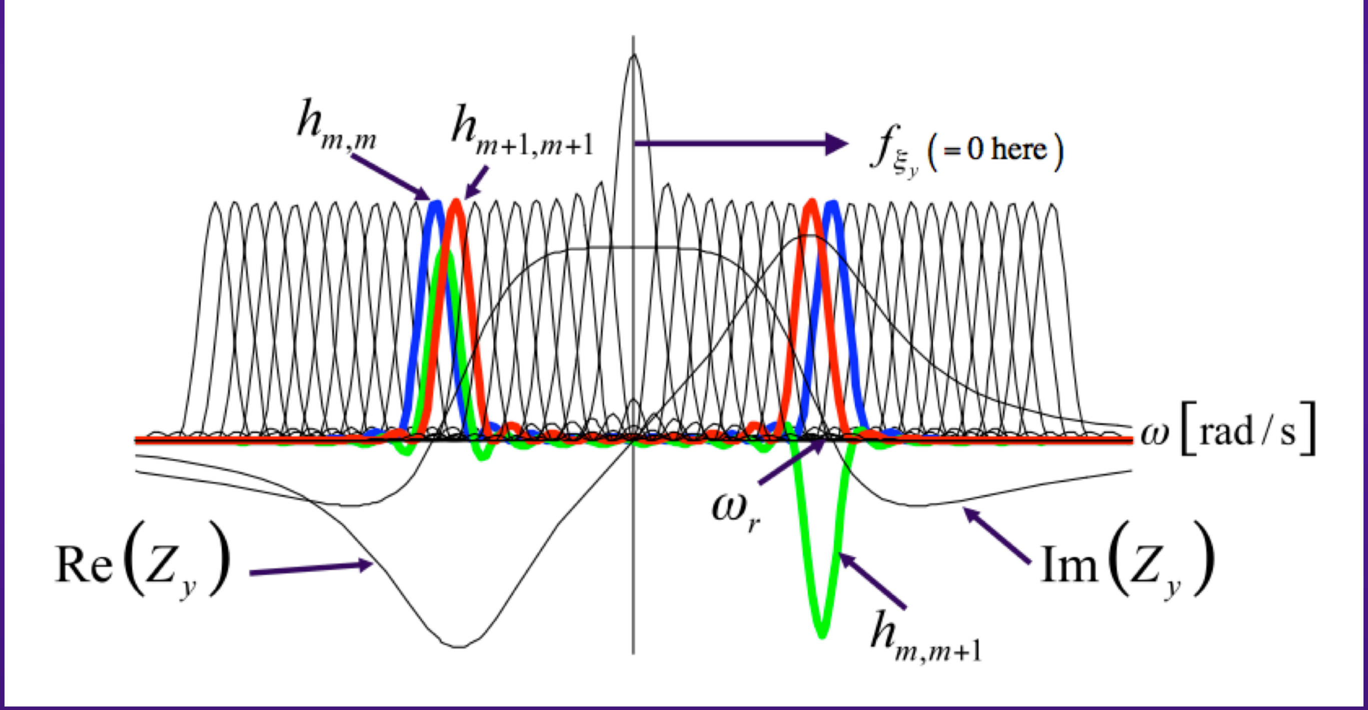
- **See also the previous IPAC18 paper (ReaD in red)**





"Long-bunch" regime with neither ReaD nor SC

- **A simple formula can be obtained by considering only the modes m and $m + 1$ overlapping the peak of the real part of the impedance (note that the eigenvectors / bunch modes are similar for the same radial mode number $q = |m| + 2\,k$)**



$$\begin{pmatrix} Q - Q_y - m\,Q_s - \Delta Q_m & -\Delta Q_{m,m+1} \\ -\Delta Q_{m+1,m} & Q - Q_y - (m+1)\,Q_s - \Delta Q_{m+1} \end{pmatrix}$$

"Long-bunch" regime with neither ReaD nor SC

- **General solution**

$$\left|Q_s + \Delta Q_{m+1} - \Delta Q_m\right| = 2\left|\Delta Q_{m,m+1}\right|$$

- **Approximate solution in our particular case**

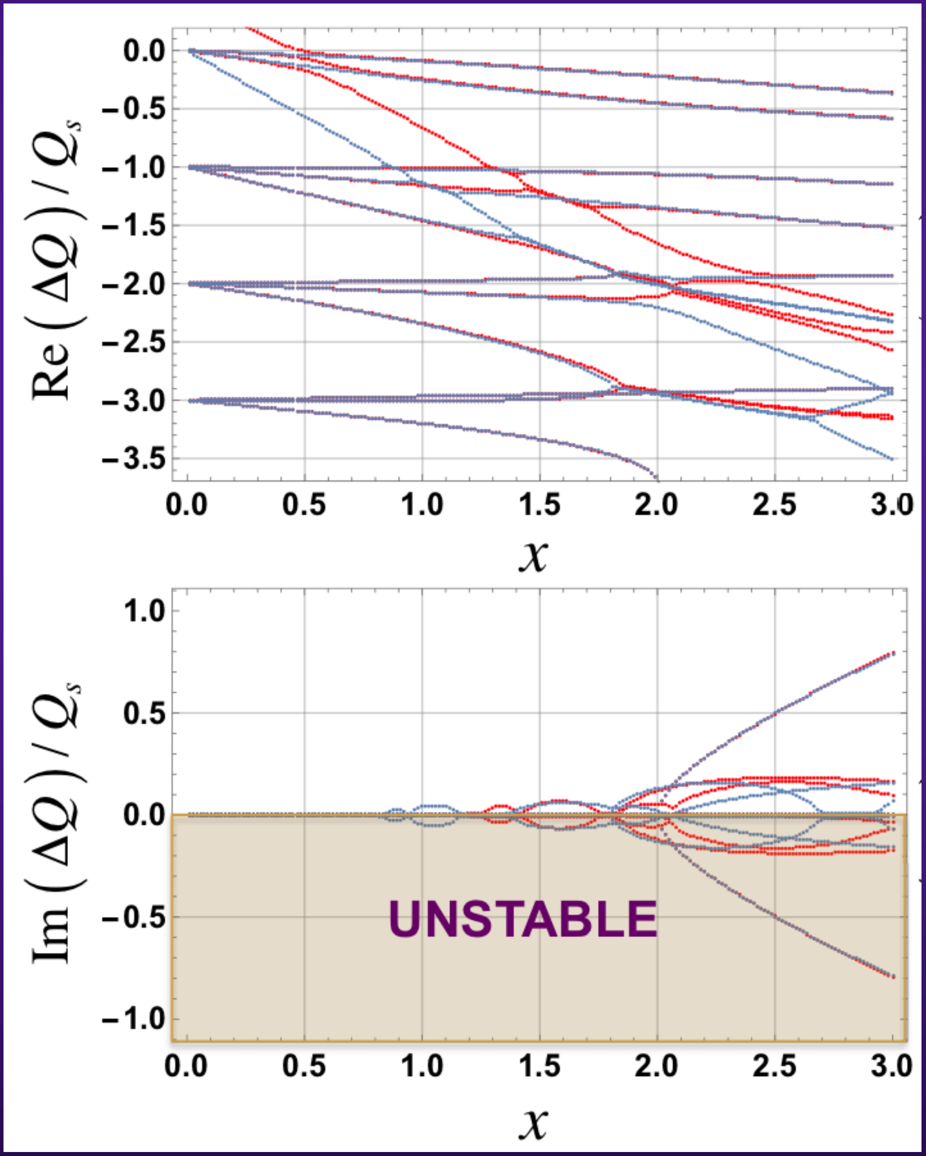
$$Q_s = 2\left|\Delta Q_{m,m+1}\right|$$

$$=> \boxed{N_b^{th} \propto |\eta|\ \varepsilon_l\ Q_y}$$

"Long-bunch" regime with ReaD

- **As a ReaD modifies only the (main) mode 0 and not the others, it is expected to have no effect for the main mode-coupling => Confirmed by GALACTIC**

  (ReaD in red)



"Long-bunch" regime with SC

- **General solution** $\left|Q_s + \Delta Q_{m+1} - \Delta Q_m\right| = 2\left|\Delta Q_{m,m+1}\right|$

$$=> Q_s\, R_{SC} = 2\left|\Delta Q_{m,m+1}\right|$$

$$=> \boxed{N_b^{th} \propto |\eta|\, \varepsilon_l\, Q_y\, R_{SC}}$$

$$\boldsymbol{R_{SC} = \left[\sqrt{q_{SC}^2 + (m+1)^2} - \sqrt{q_{SC}^2 + m^2}\right]}$$

Reduction factor from SC

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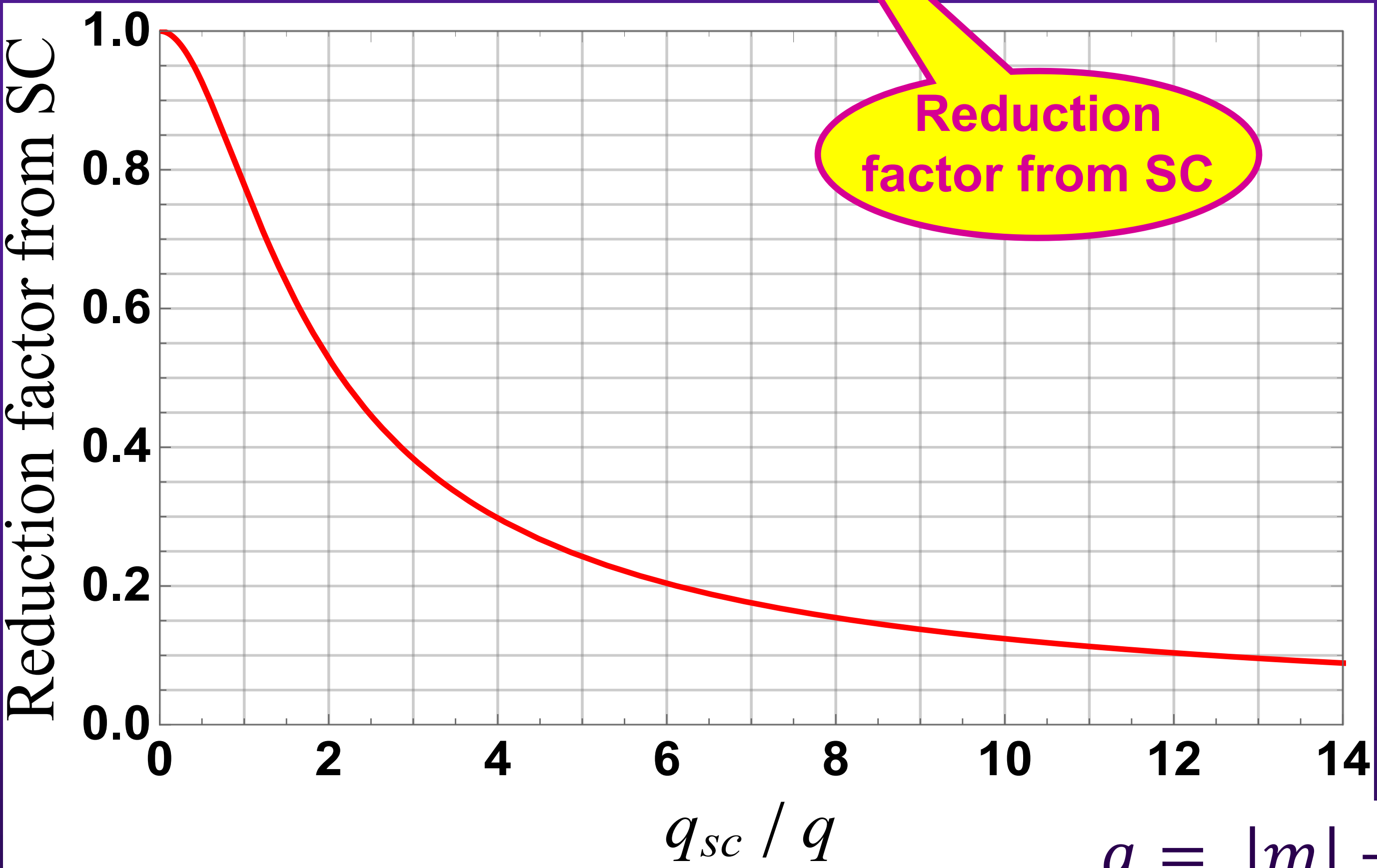

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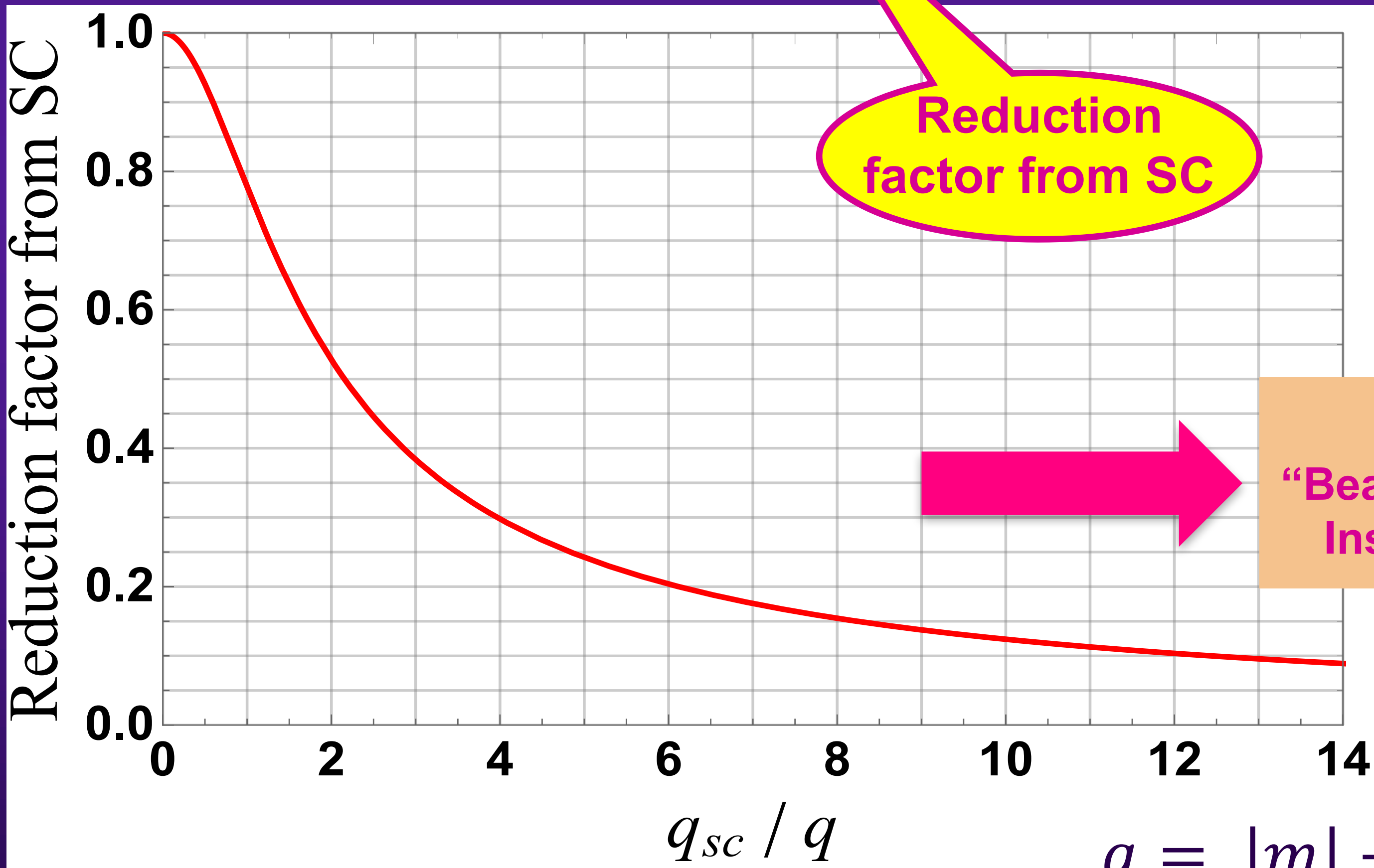

Towards "Beam Break-Up" Instabilities…

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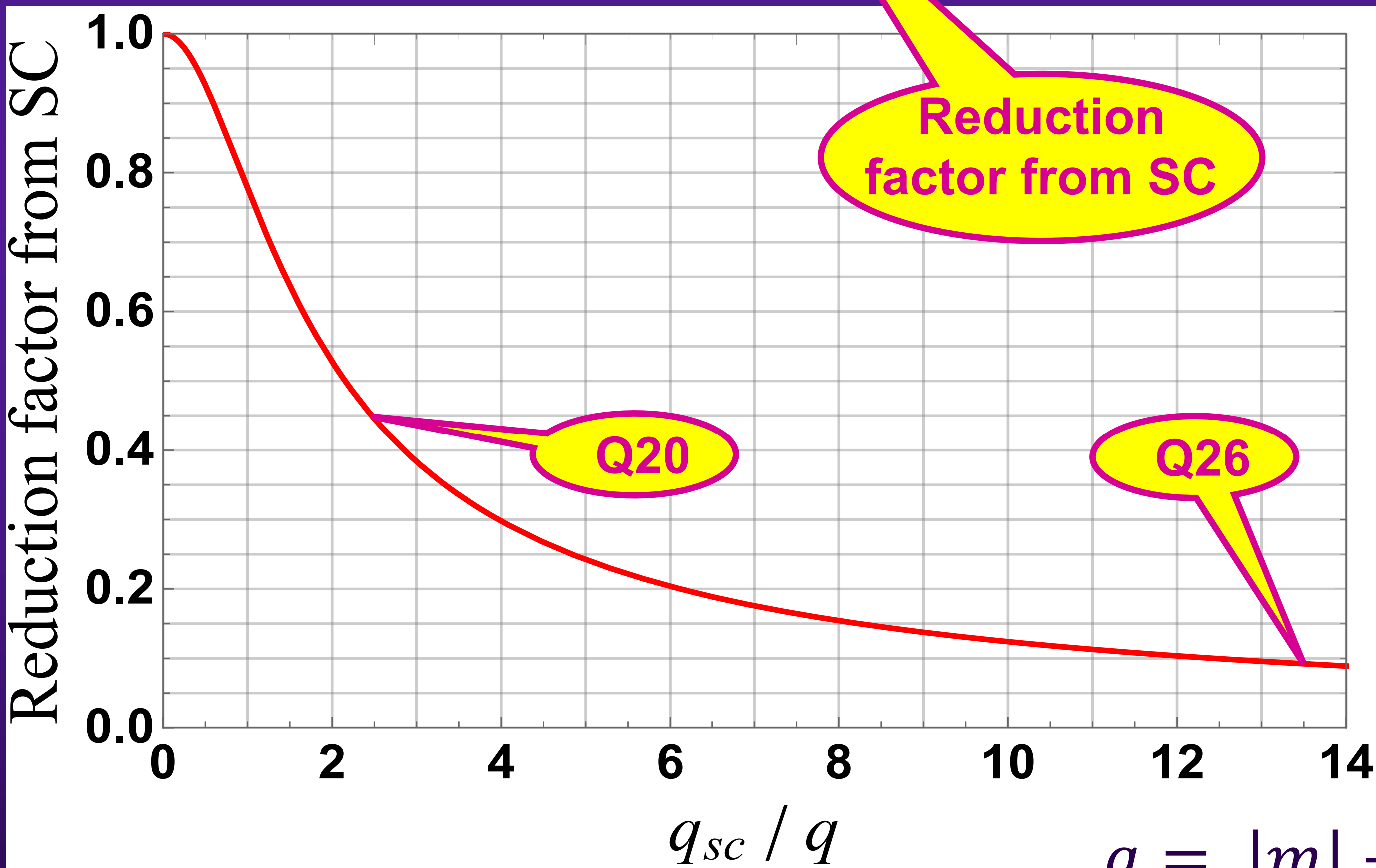

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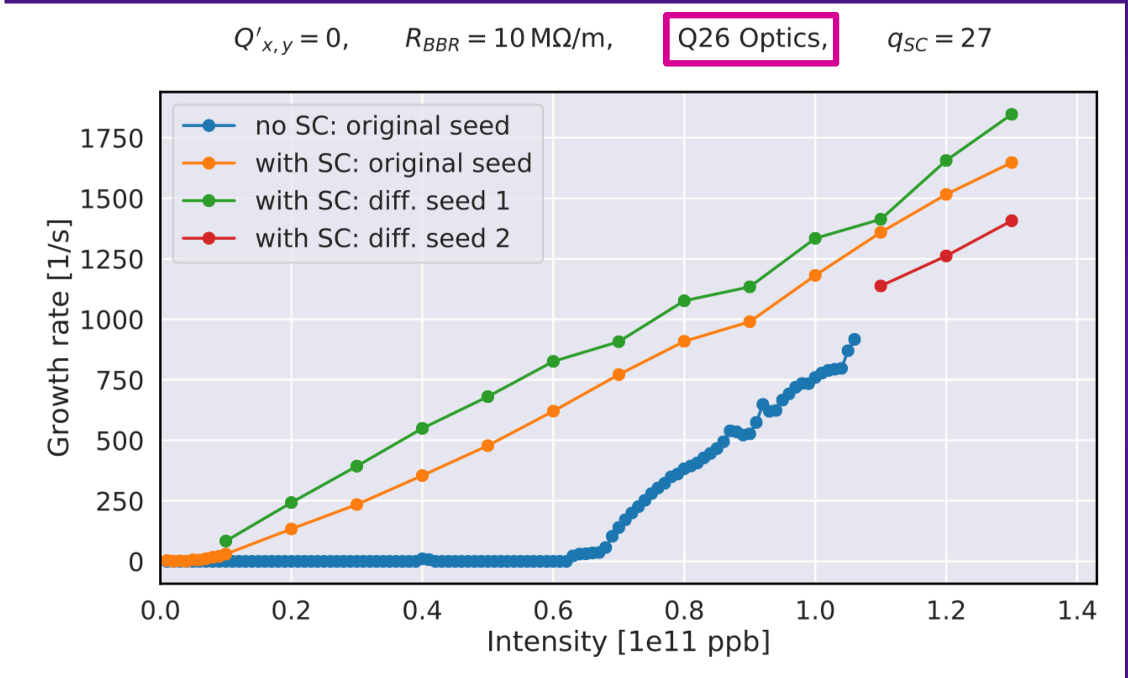
Some simulations from A. Oeftiger with pyHEADTAIL (detailed analyses ongoing)



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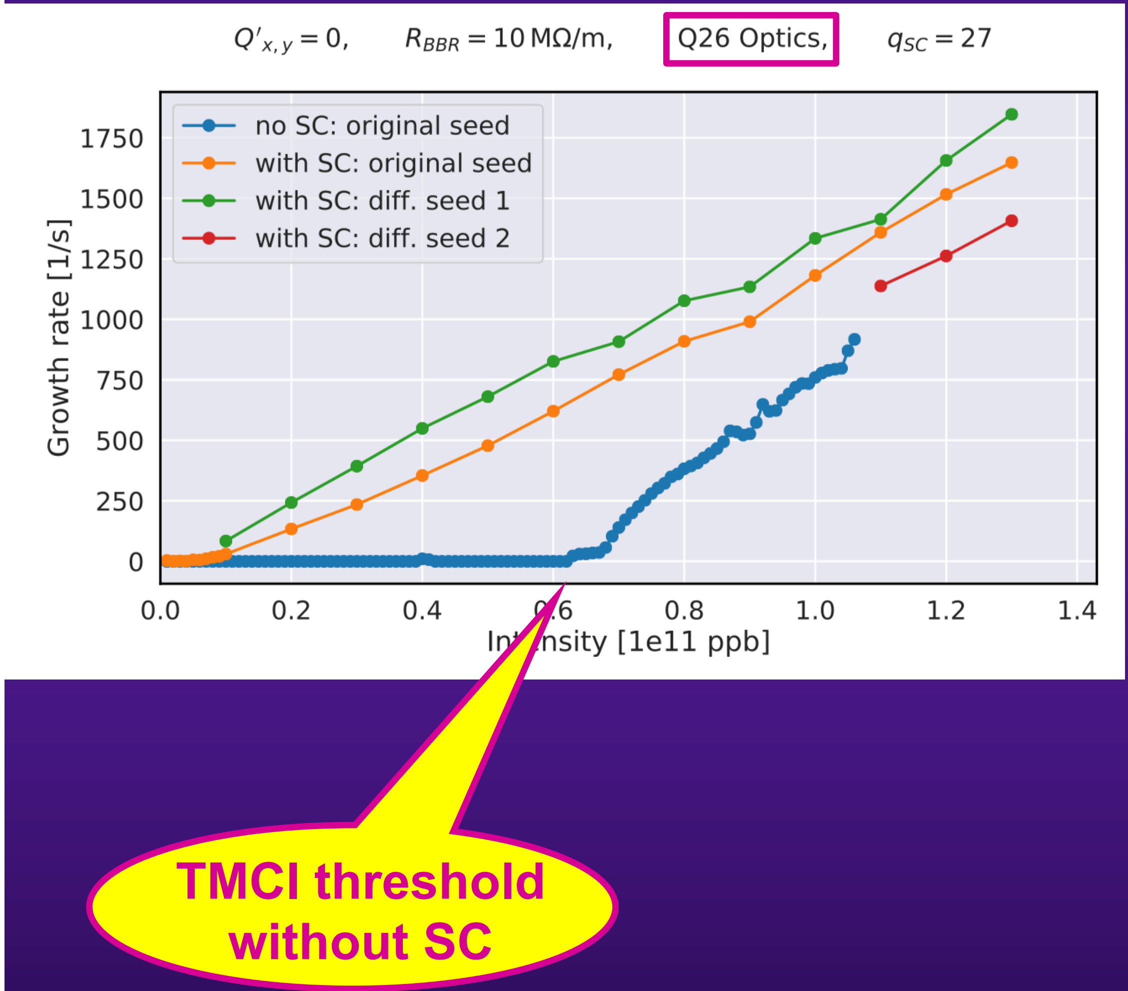
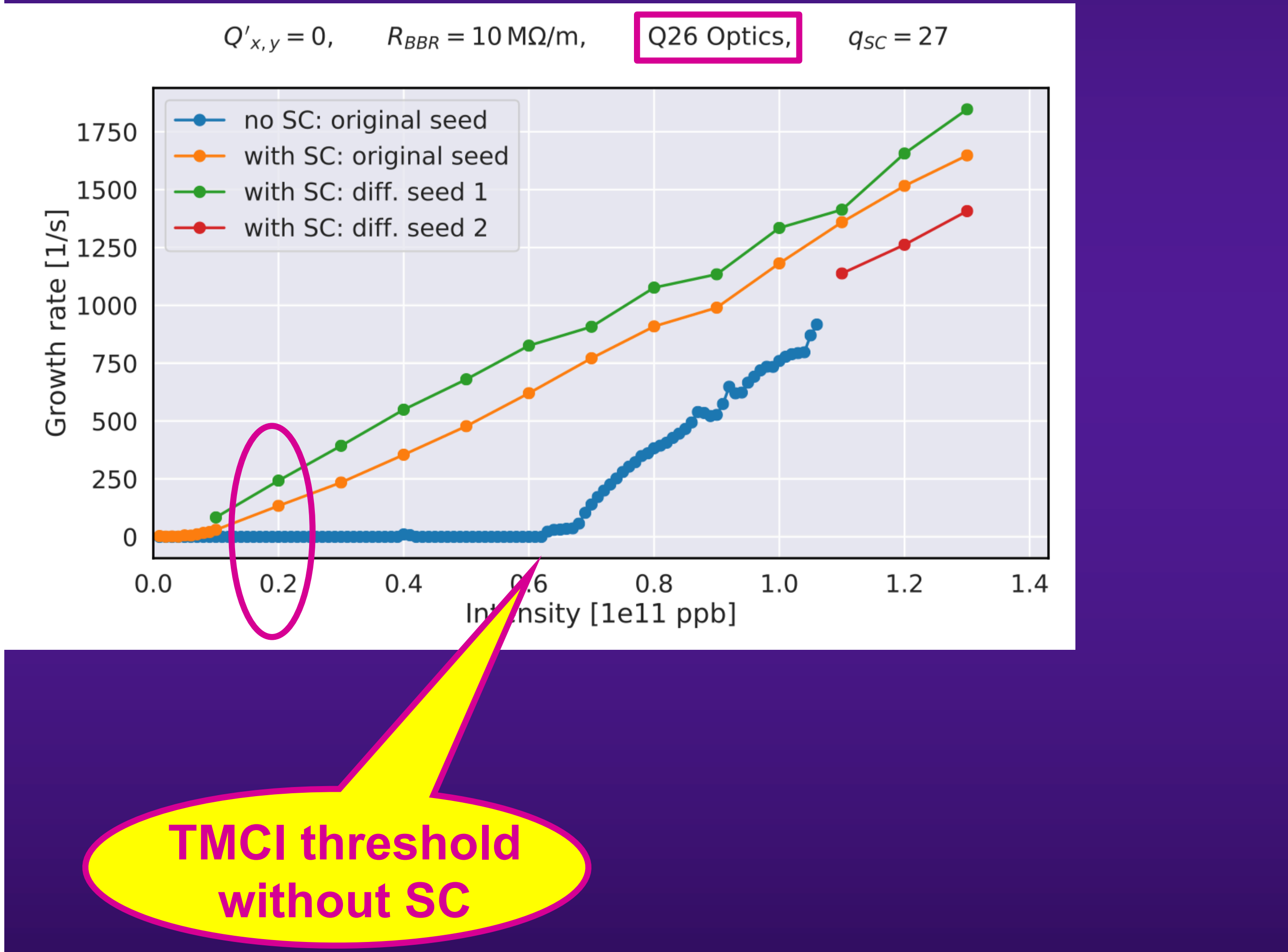
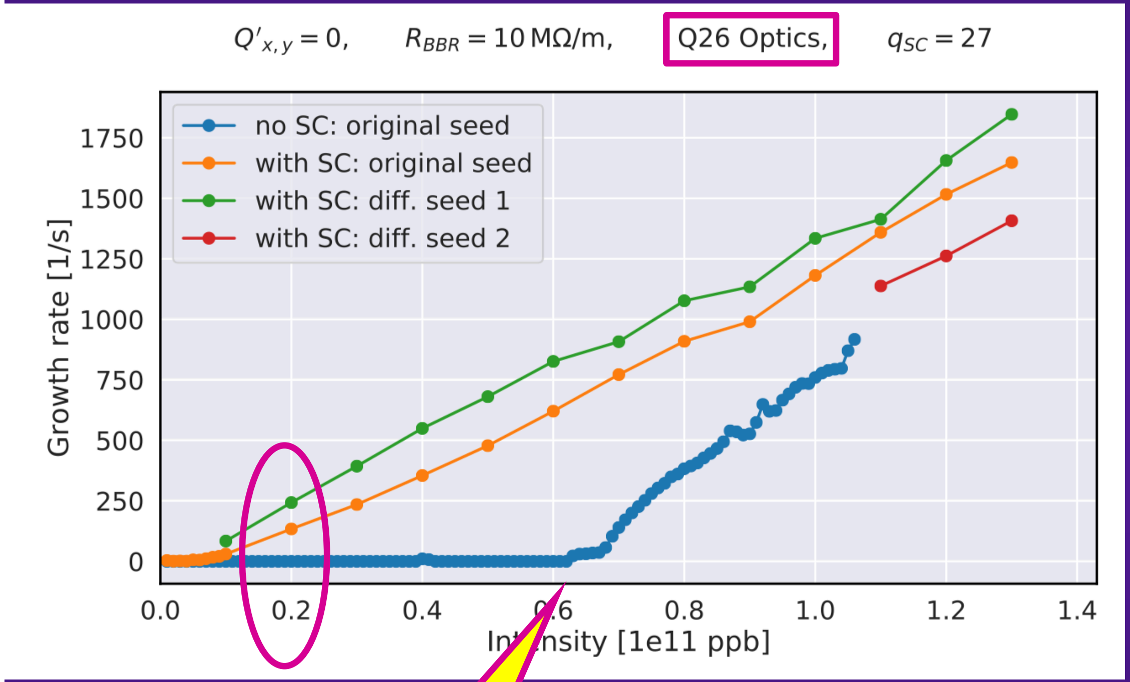


Some simulations from A. Oeftiger with pyHEADTAIL (detailed analyses ongoing)

Q26 case @ 0.2e11 ppb



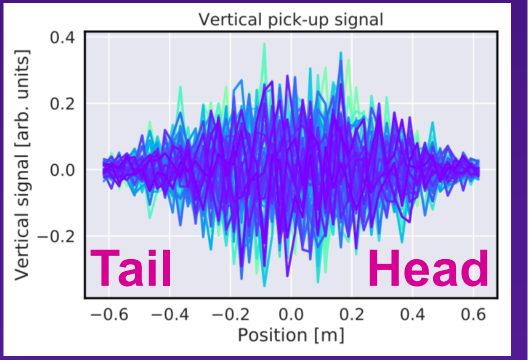
Some simulations from A. Oeftiger with pyHEADTAIL (detailed analyses ongoing)



TMCI threshold without SC

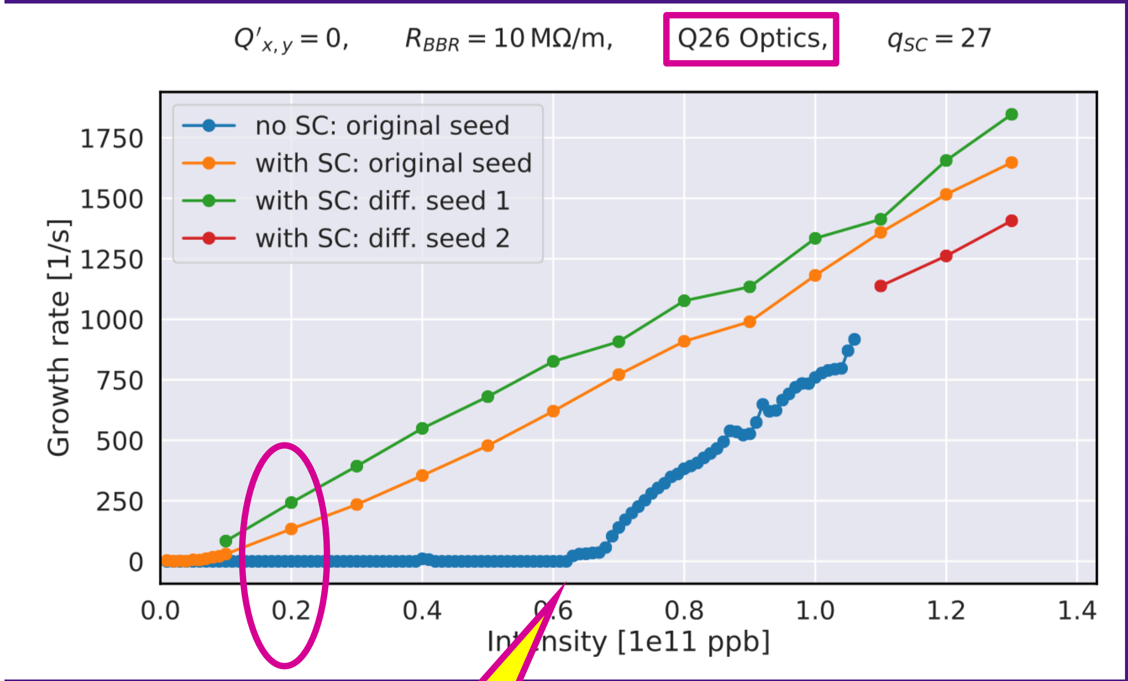
Q26 case @ 0.2e11 ppb

Without SC => STABLE



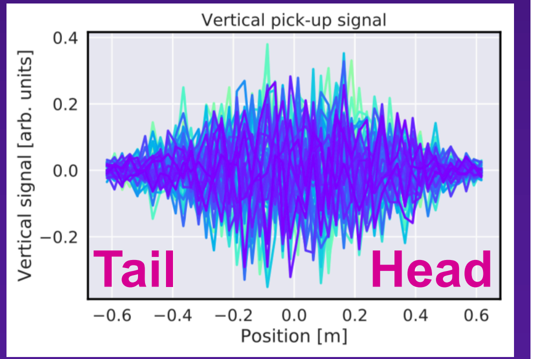
Some simulations from A. Oeftiger with pyHEADTAIL (detailed analyses ongoing)

Q26 case @ 0.2e11 ppb

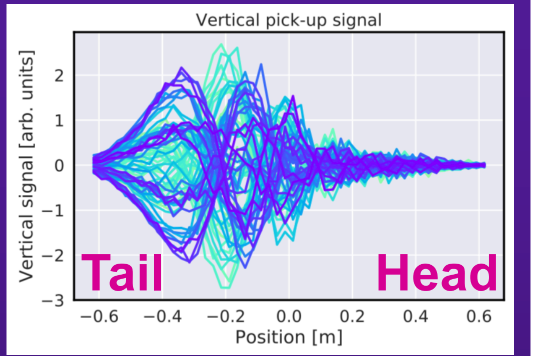


TMCI threshold without SC

Without SC => STABLE

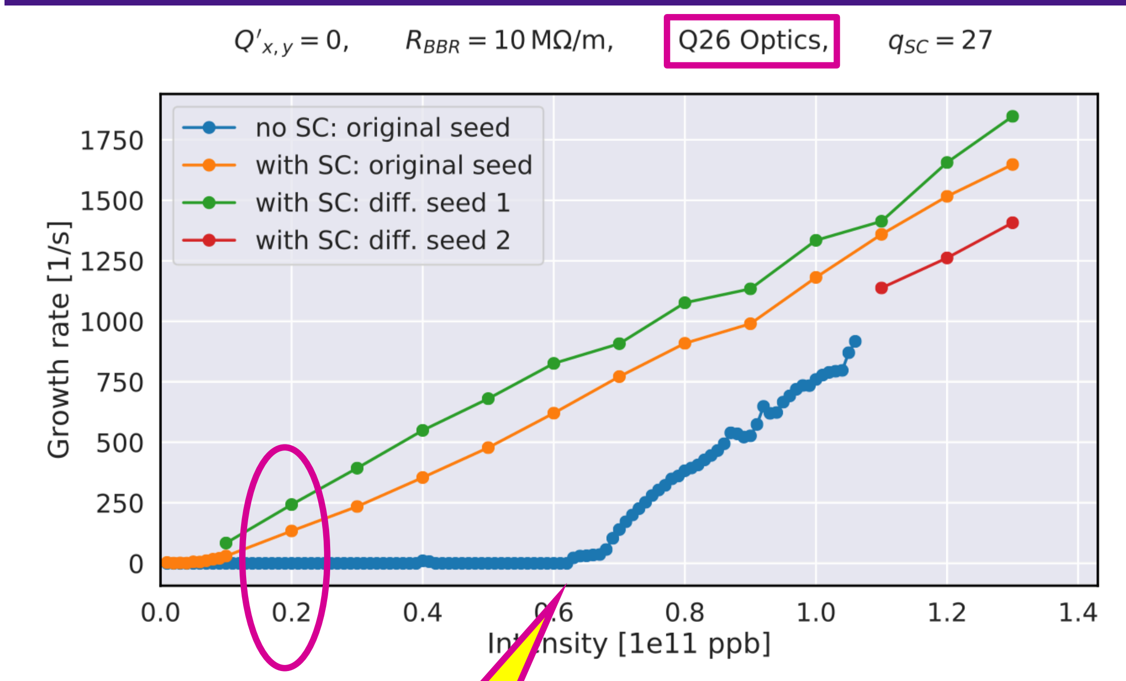


With SC => UNSTABLE

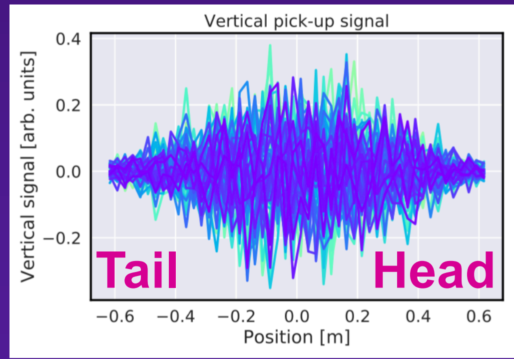


Some simulations from A. Oeftiger with pyHEADTAIL (detailed analyses ongoing)

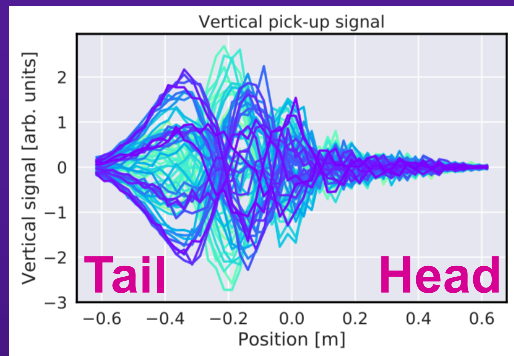
Q26 case @ 0.2e11 ppb



Without SC
=> STABLE



With SC
=> UNSTABLE



TMCI threshold without SC

=> Instability with SC still to be fully characterized… + Understand why ~ no-SC intensity threshold seems to be observed in SPS (effect of nonlinearities, etc.)…