Prise en compte de l'amortissement non linéaire dans le dimensionnement d'un NES

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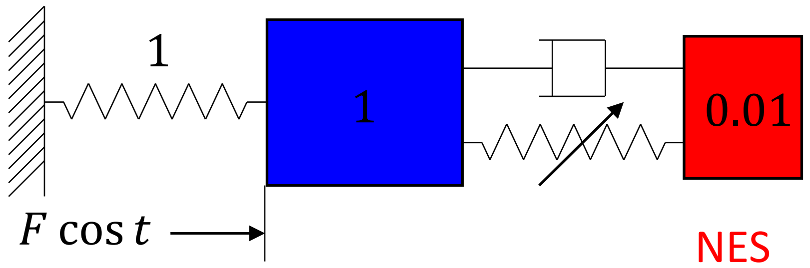
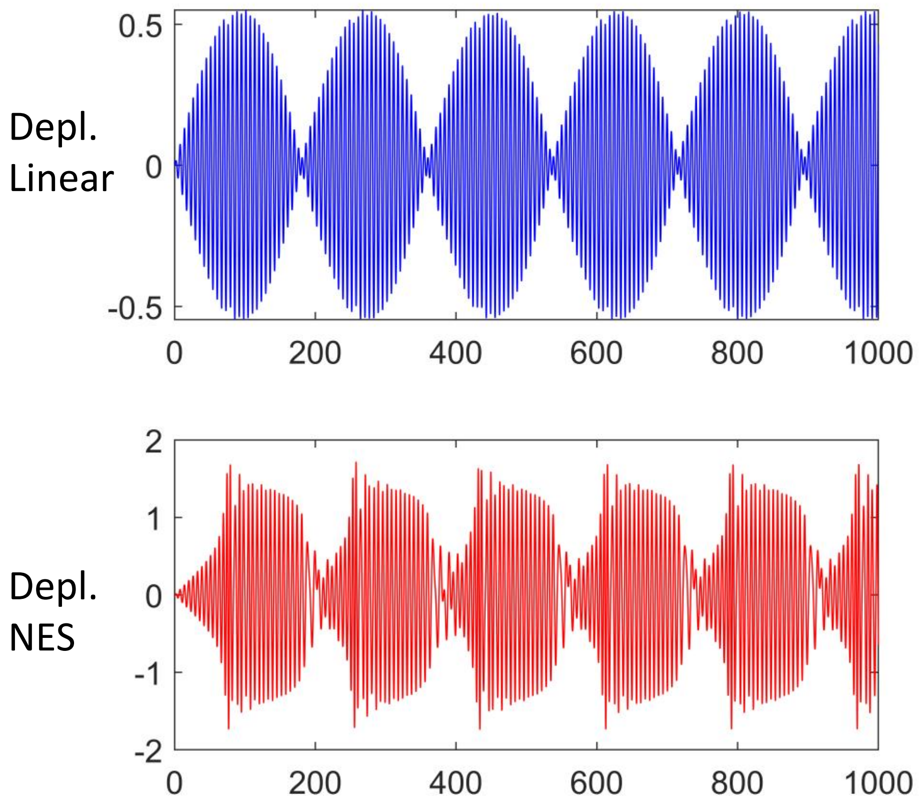
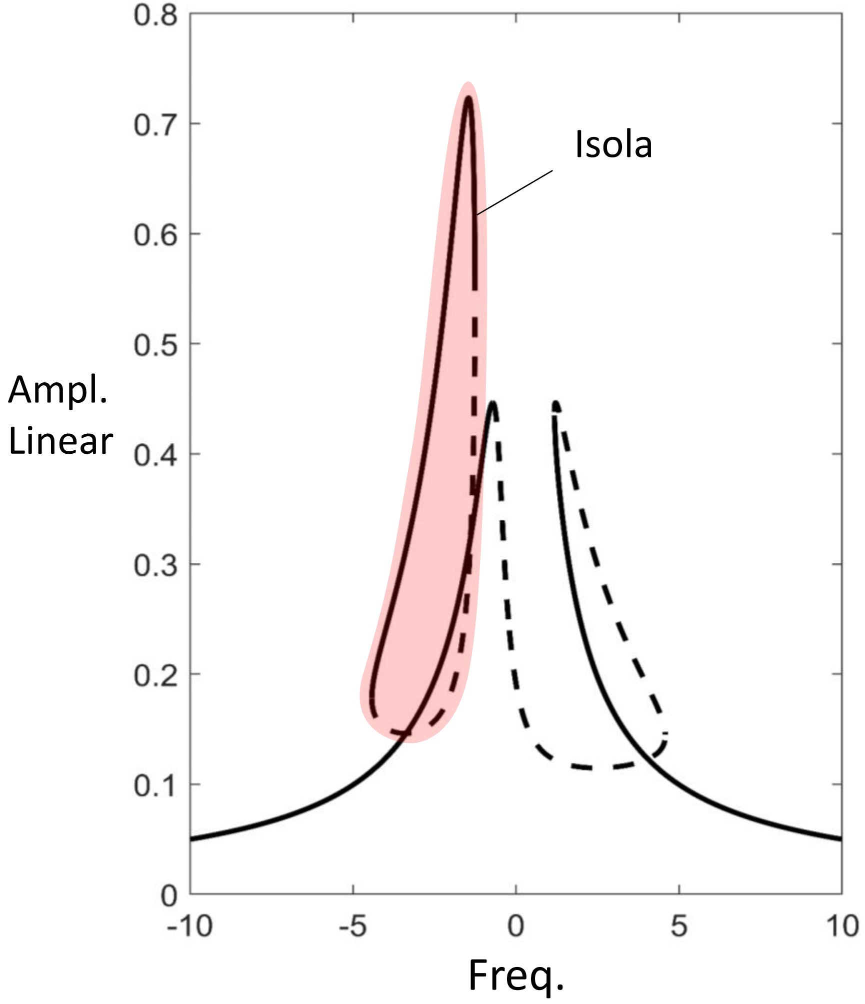
Working principle under harmonic excitation



Passive control through relaxation oscillations



High amplitude Isola limits the performance of NES



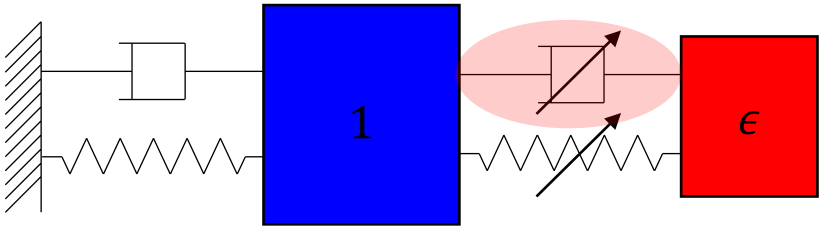
A nonlinear energy sink with nonlinear damping

Adimensional equation of motion

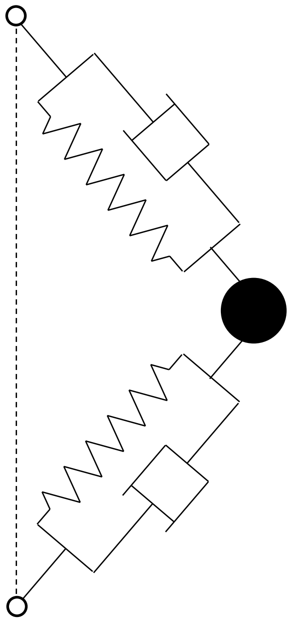
$$\ddot{x} + x + 2\zeta\dot{x} + \epsilon(\mu\dot{w} + \kappa w^3 + \lambda w^2\dot{w}) = G\cos(\omega t)$$

$$\epsilon(\ddot{x} - \ddot{w} - \mu\dot{w} - \kappa w^3 - \lambda w^2\dot{w})$$

Nonlinear damping



ϵ : mass ratio $\ll 1$



Objectives :

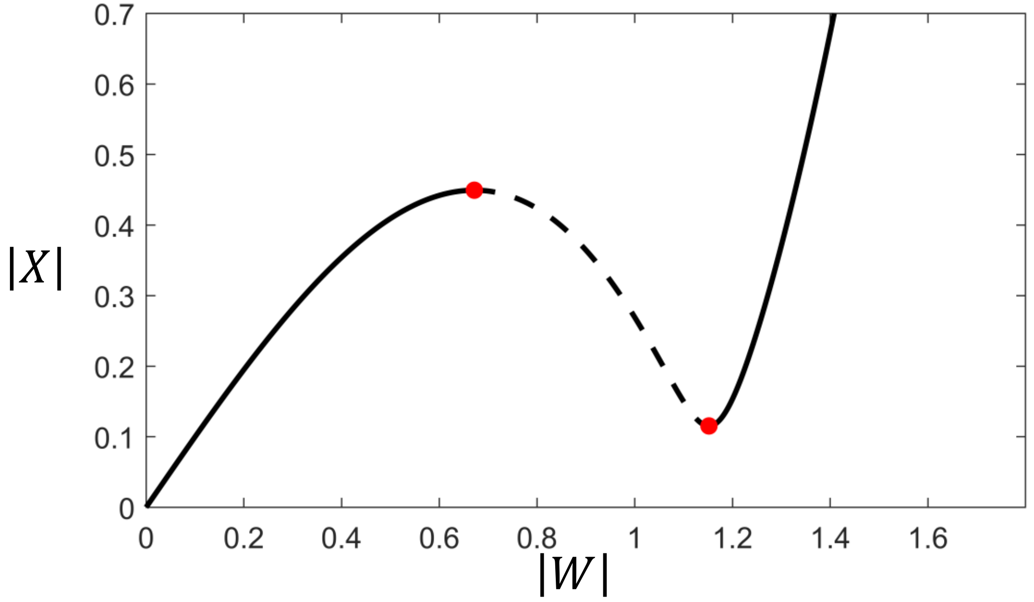
- Describe the dynamical behavior
- Propose a tuning methodology
- Quantify the effect of nonlinear damping

Theoretical analysis using MS/HBM[1]

order $\mathcal{O}(\epsilon^0)$

The Slow Invariant Manifold

$$X = (1 - i\mu)W - \frac{1}{4}(3\kappa + i\lambda)W^2\overline{W}$$



[1] Luongo, A., Zulli, D. (2012). *Dynamic analysis of externally excited NES-controlled systems via a mixed Multiple Scale/Harmonic Balance algorithm. Nonlinear Dynamics*

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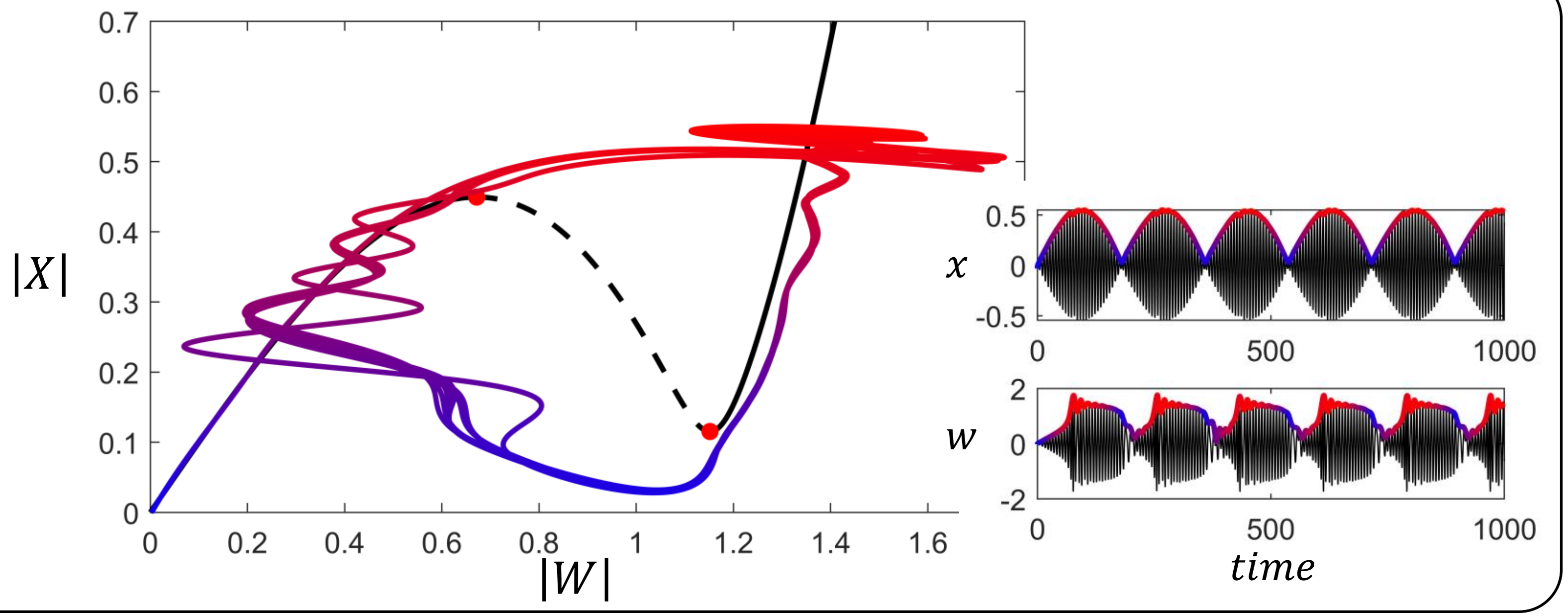

Theoretical analysis using MS/HBM[1]

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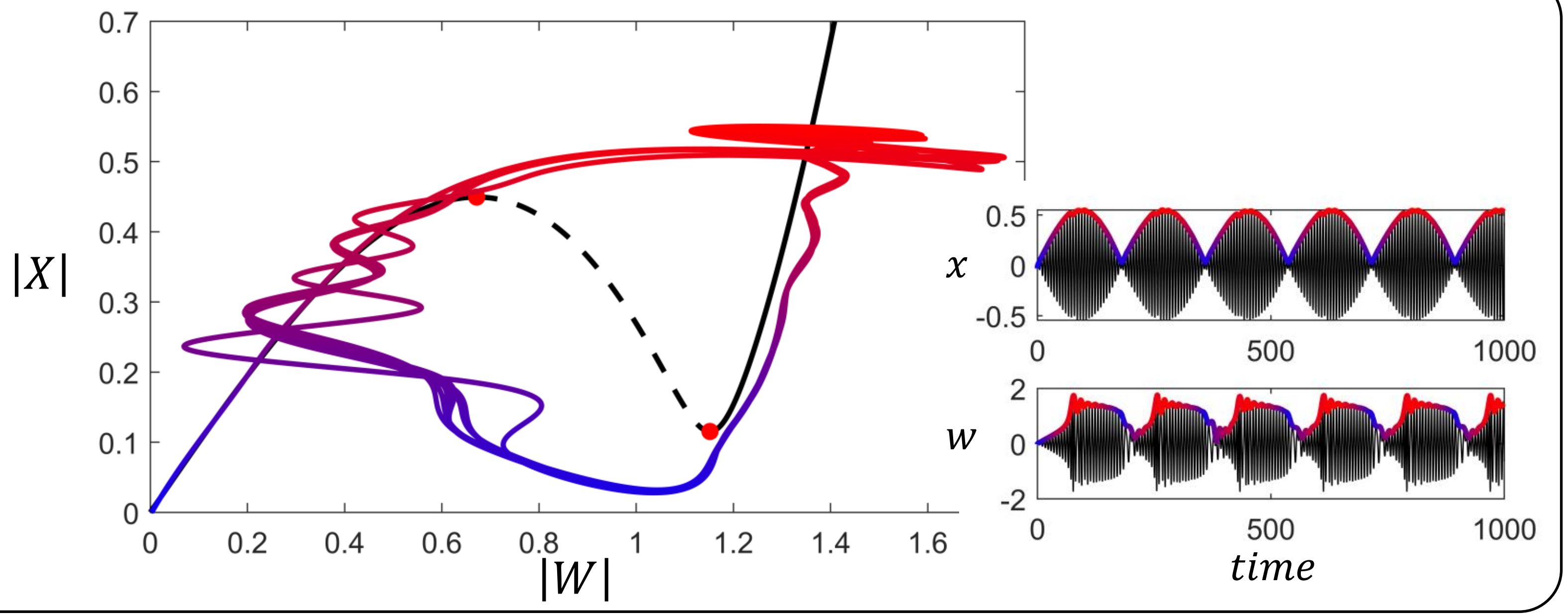
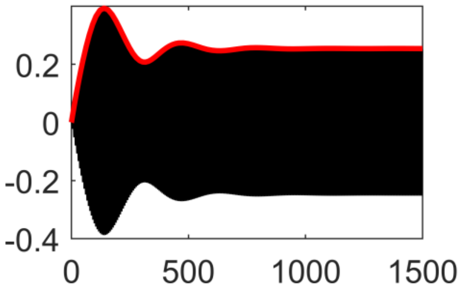


order $\mathcal{O}(\epsilon^1)$

Modulation equation

$$|\dot{W}| = \frac{f_1(W)}{g(W)}$$

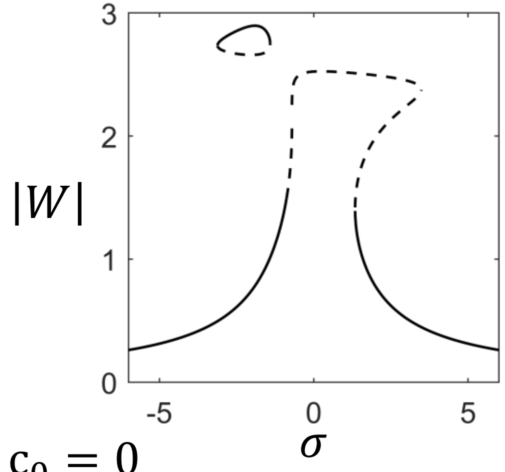
$$\arg \dot{W} = \frac{f_2(W,\sigma)}{g(W)}$$



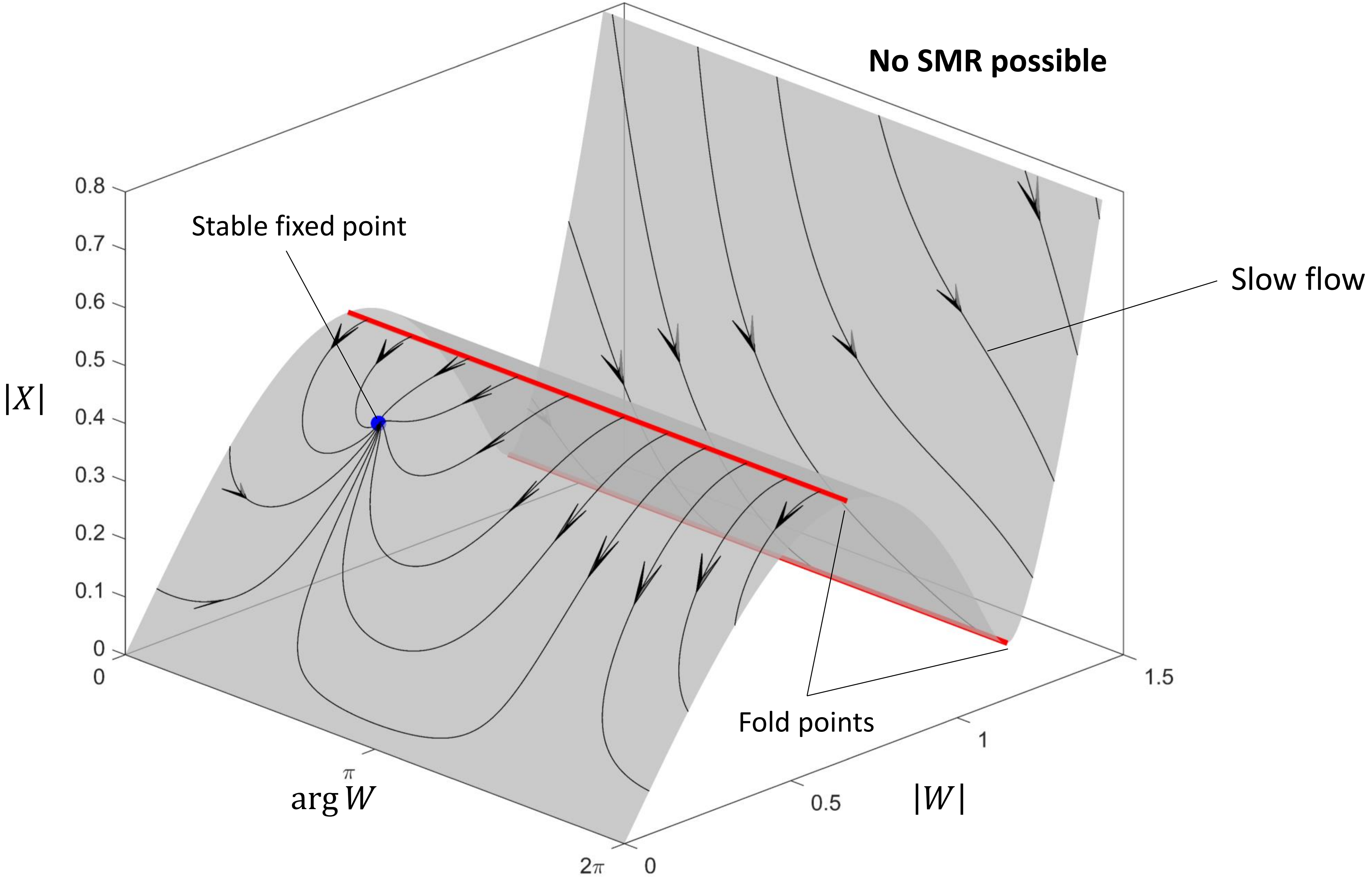
Fixed points

$$\begin{cases} f_1(W) = 0 \\ f_2(W,\sigma) = 0 \end{cases}$$

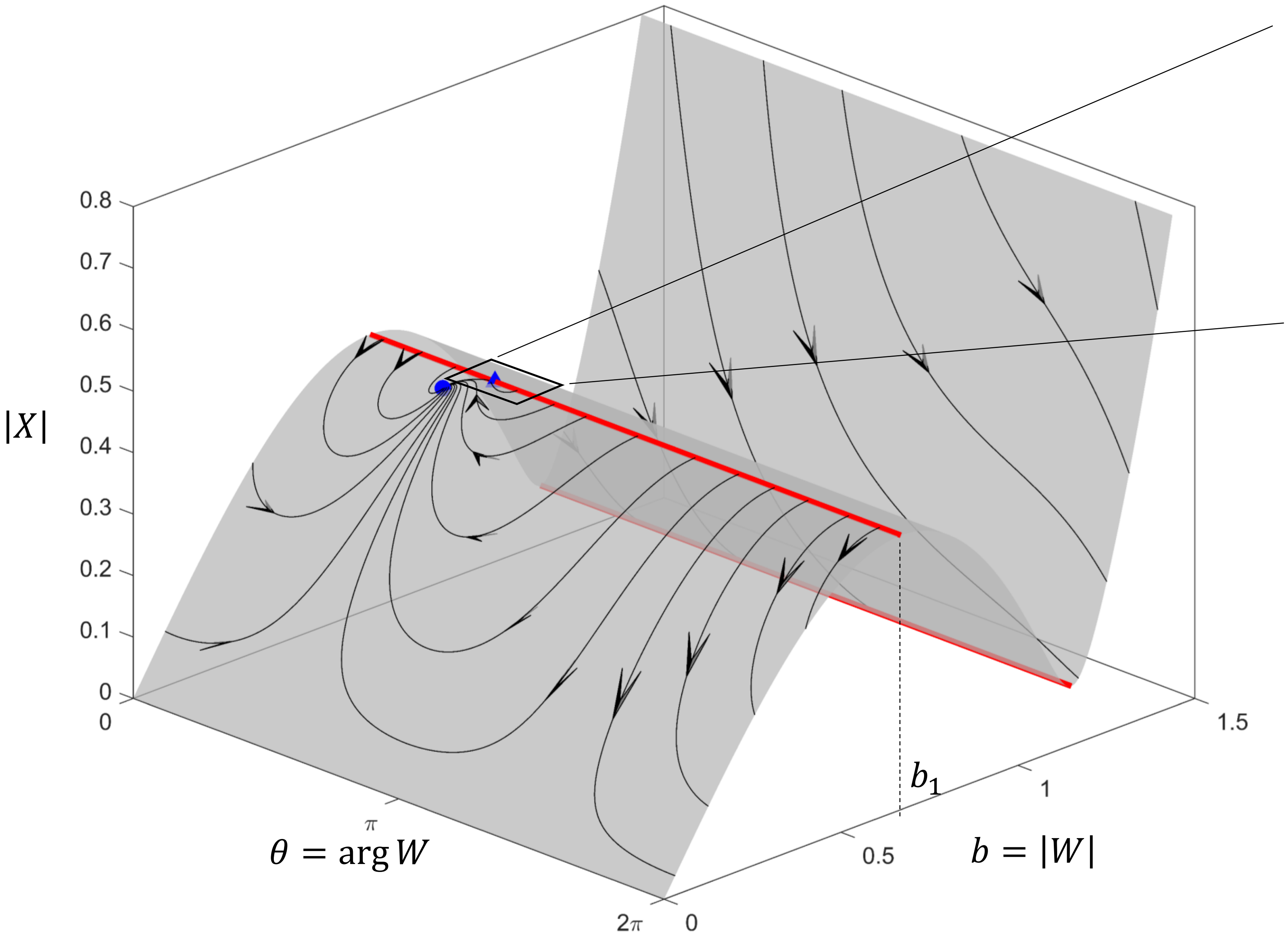
$$f_3(W,\sigma) \equiv c_3|W|^6 + c_3|W|^4 + c_3|W|^2 + c_0 = 0$$

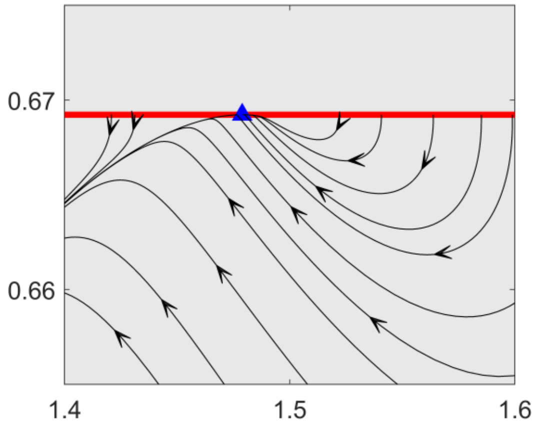


Activation threshold of SMR



SMR triggered by grazing flow



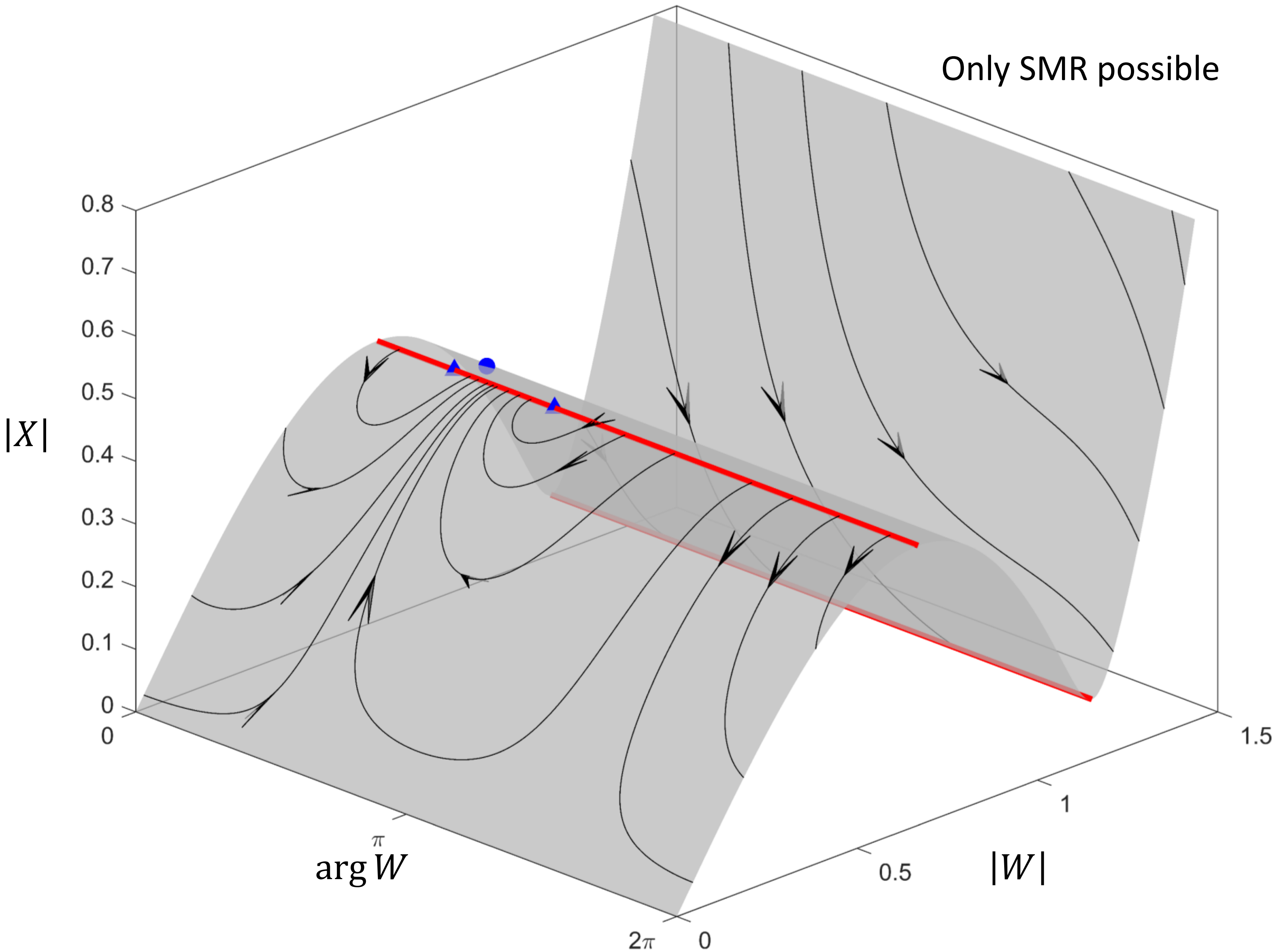


Grazing flow

$$\left.\frac{db}{d\theta}\right|_{b=b_1} = \left.\frac{\frac{db}{dt}}{\frac{d\theta}{dt}}\right|_{b=b_1} = \left.\frac{f_1}{f_2}\right|_{b=b_1} = 0$$

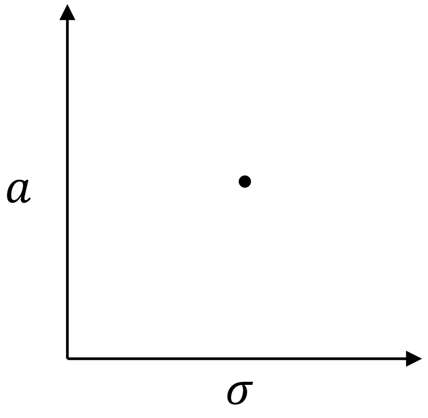
Critical forcing amplitude G_{SMR}

SMR triggered by grazing flow

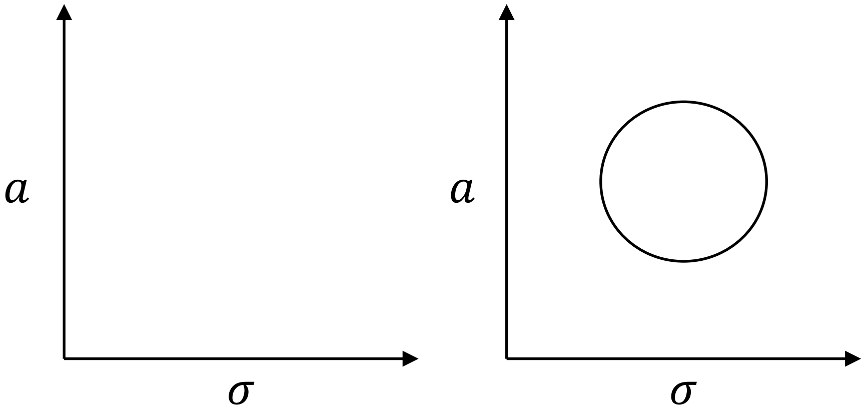


Singularity theory[2,3] : a usefull tool to detect DRC

The isola singularity



Unperturbed diagram



Perturbed diagram

$$f_3(|W|,\sigma) = 0, \qquad \frac{\partial f_3}{\partial \sigma} = \frac{\partial f_3}{\partial |W|} = 0, \qquad \frac{f_3}{\partial |W|^2} \neq 0, \det(d^2 f_3) > 0$$

Fixed points expression

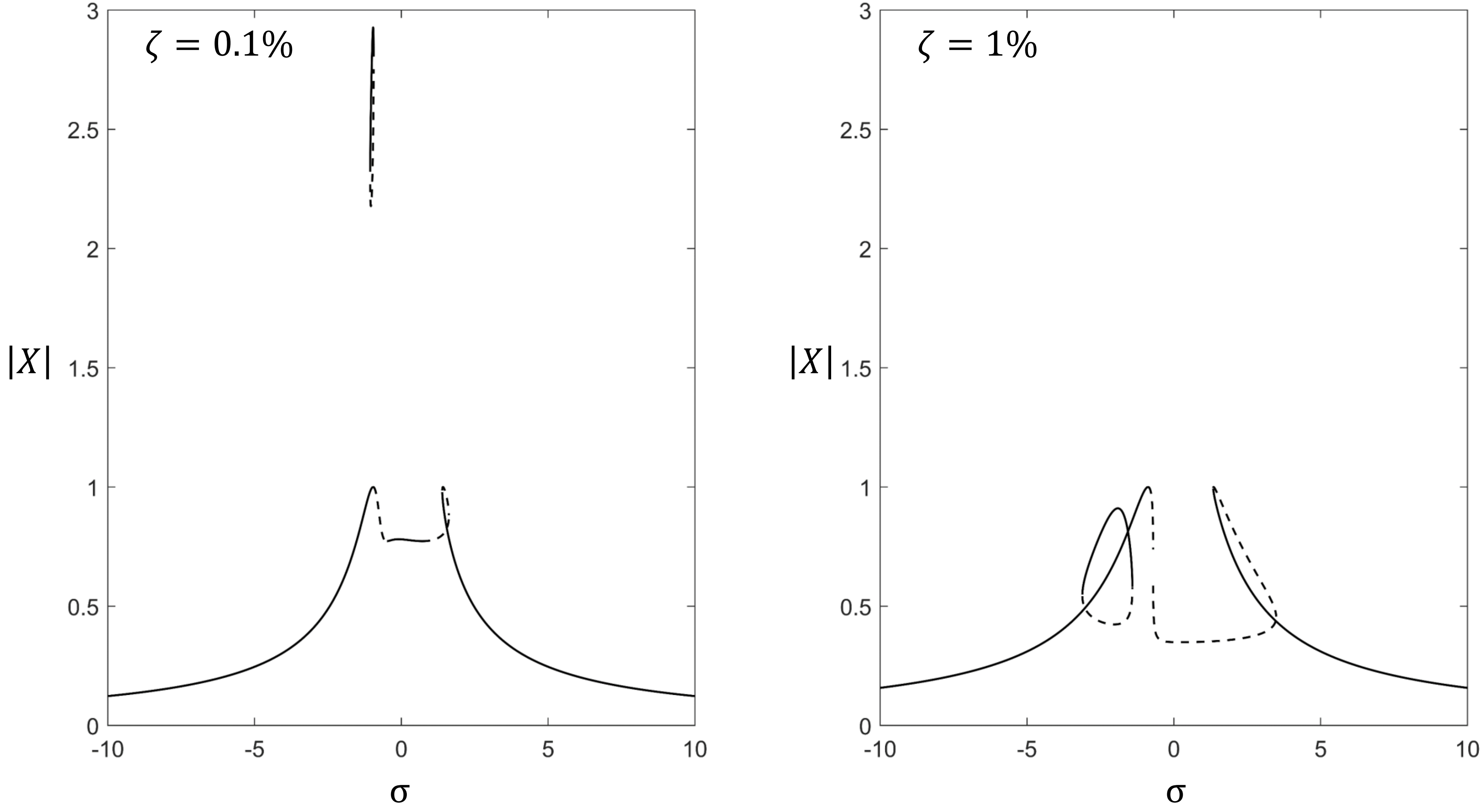
Isola singularity defining conditions

Non-degeneracy conditions

Critical forcing amplitude G_{DRC}

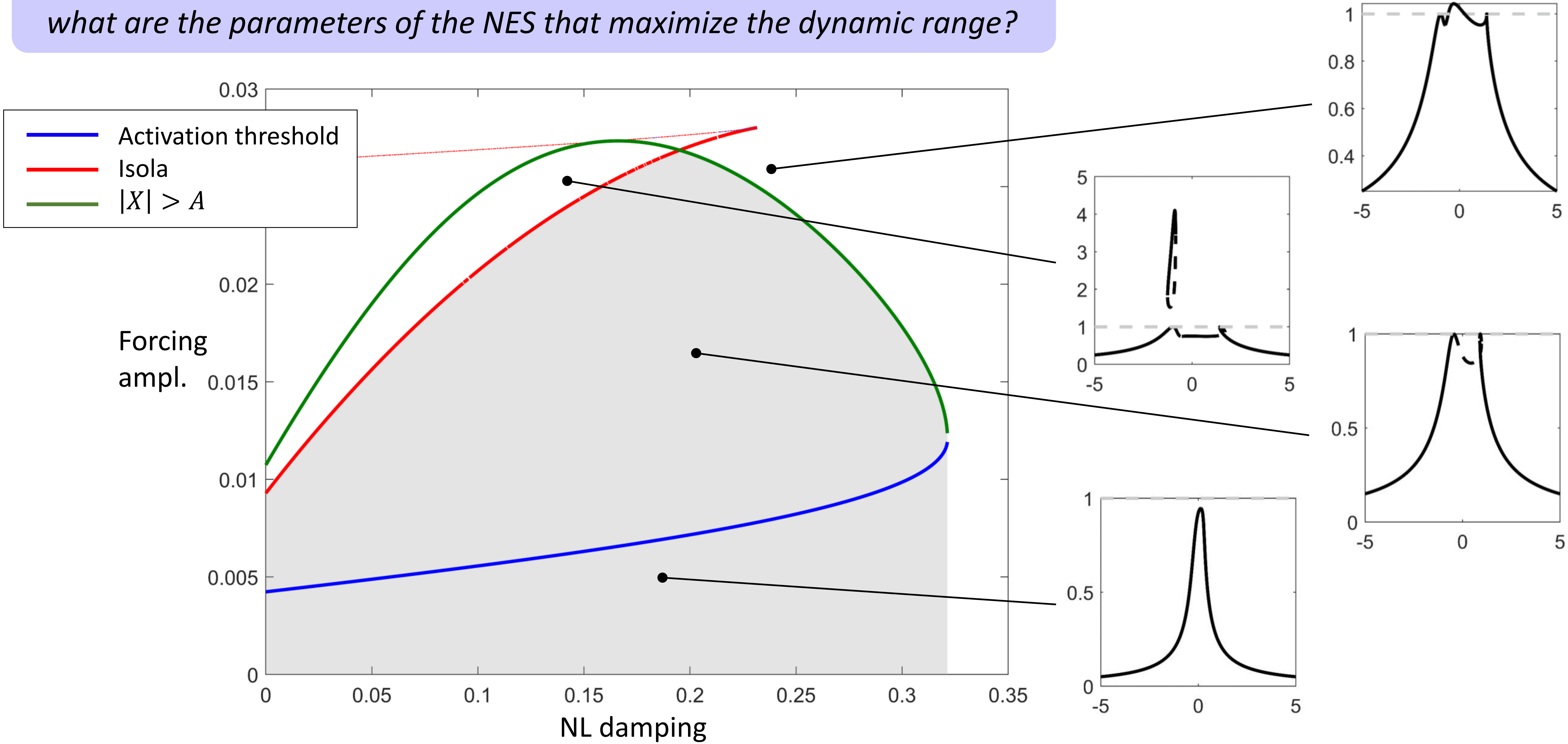
[2] M. Golubitsky, D. Schaeffer, Singularities and groups in bifurcation theory
[3] I. Cirillo, G. Habbib, K. Kerschen, R. Sepulchre, Analysis and design of nonlinear resonances via singularity theory

All DRC are not problematic!

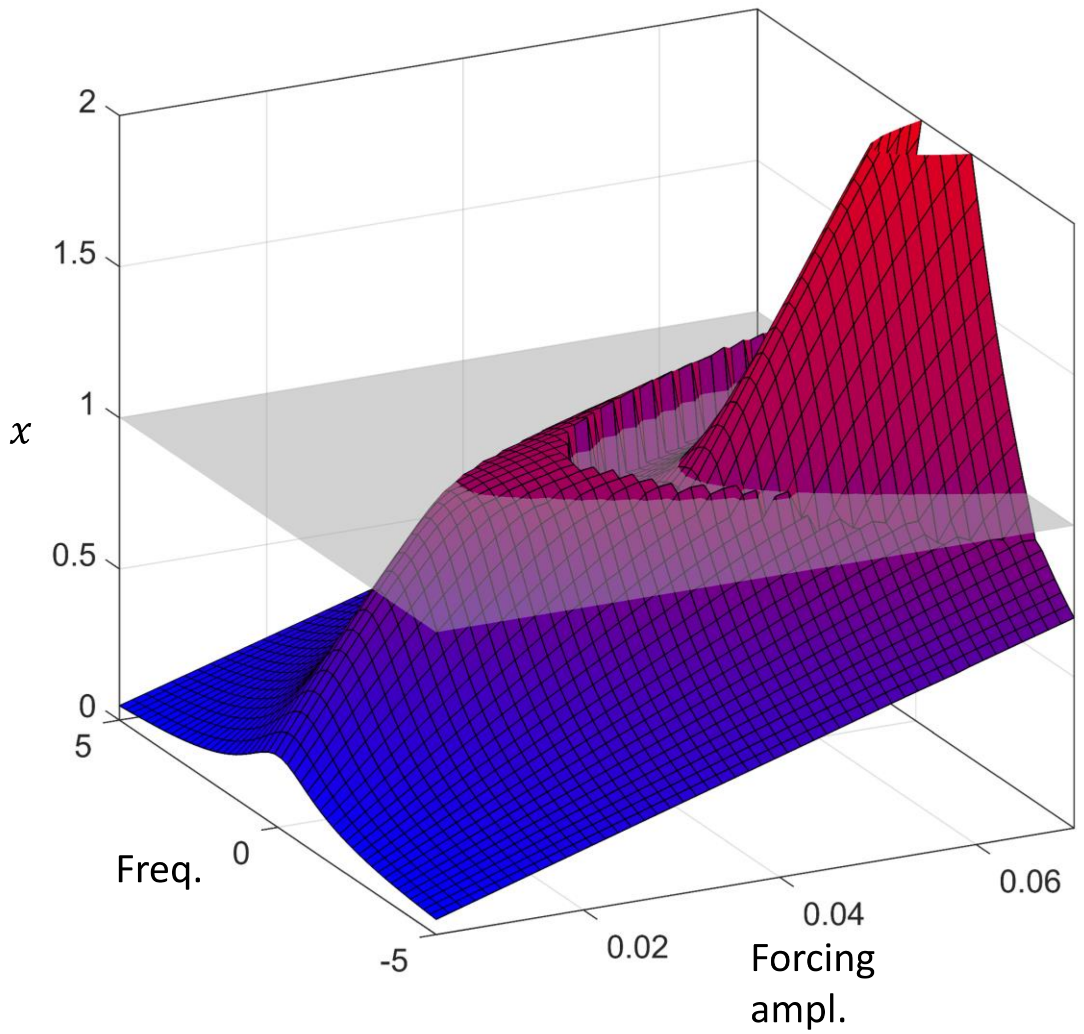


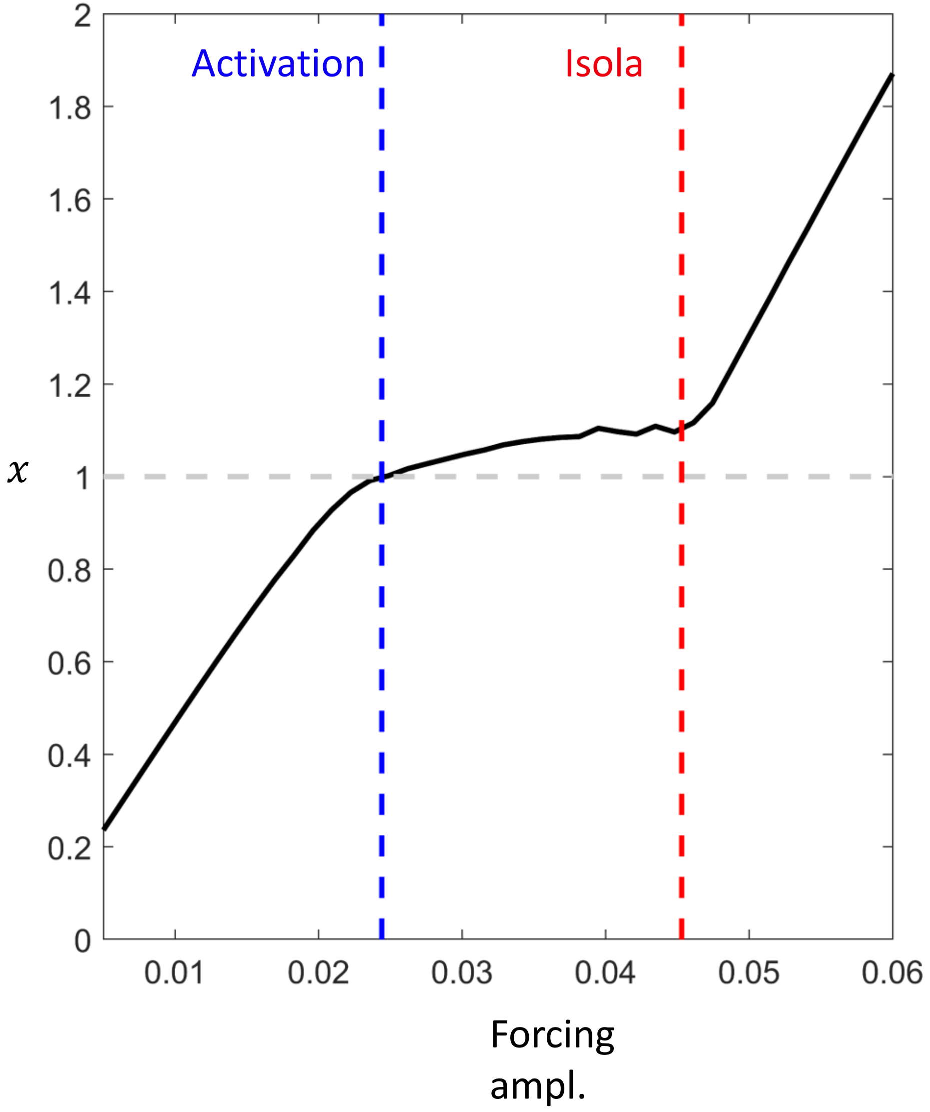
A simple design procedure

Given a maximal allowed vibration amplitude A of the primary system, what are the parameters of the NES that maximize the dynamic range?

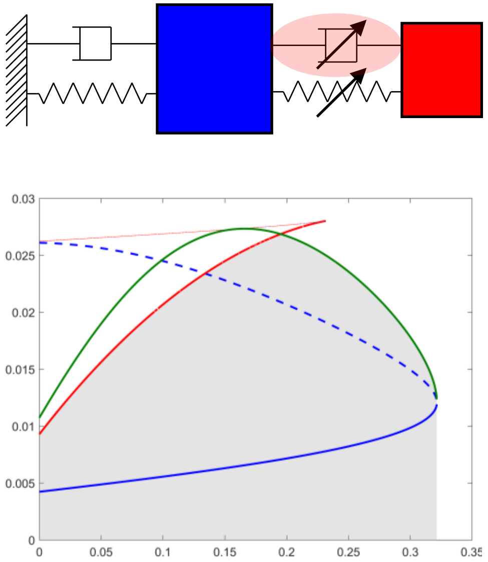


Numerical validation of the design procedure





Conclusion



A Nonlinear Energy Sink with nonlinear damping

Tuning procedure based on theoretical developments

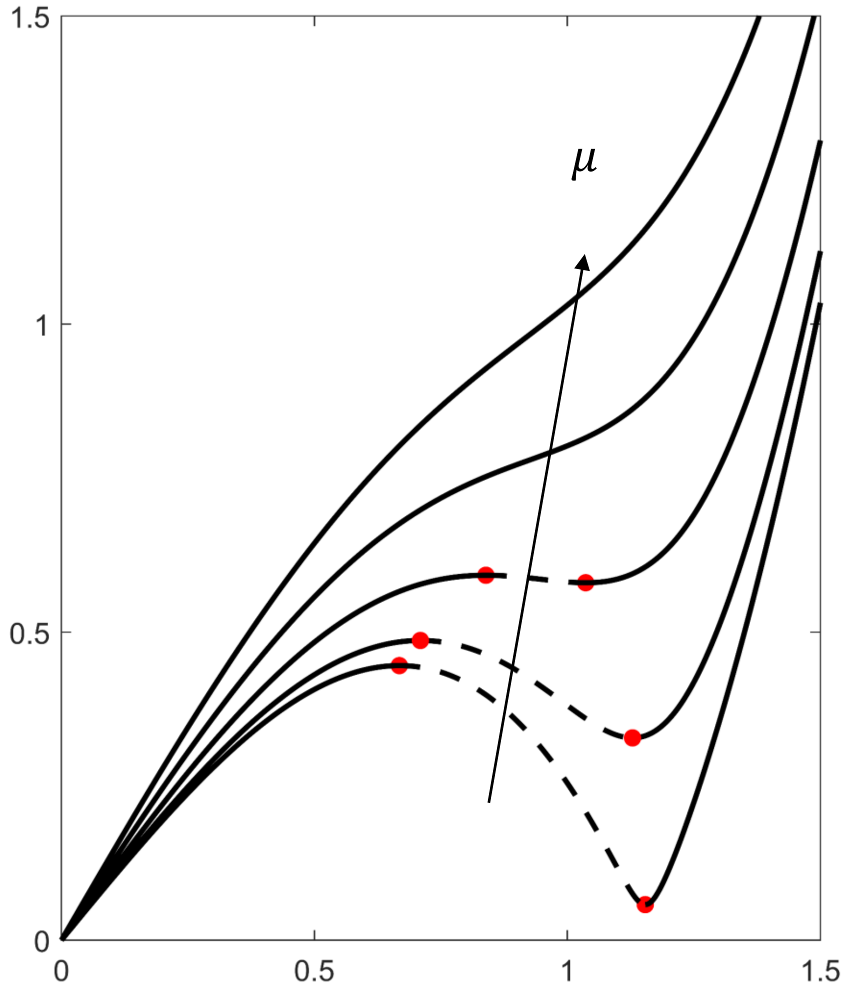
Perspectives

Experimental validation

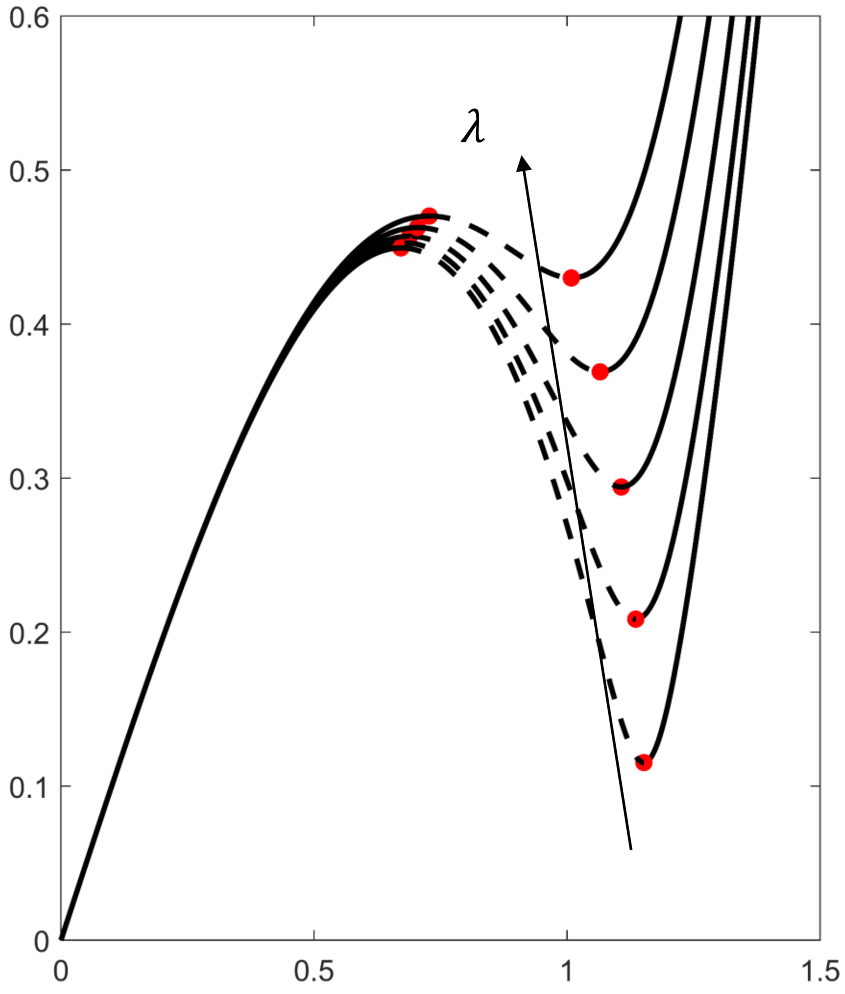
More realistic model of FOWT

How does the parameters of the NES affects the SIM?

Linear damping



Nonlinear damping



Too high damping → NO TET