MAX-PLANCK-INSTITUT
FÜR PLASMAPHYSIK

Addressing the impact of fishbones to core microturbulence with gyrokinetic codes

D. Brioschi[1], A. Di Siena[1], R. Bilato[1], A. Bottino[1], A. Mishchenko[2], Thomas Hayward-Schneider[1], E. Poli[1], A. Zocco[2]

[1]Max Planck Institute for Plasma Physics, Boltzmannstr. 2, 85748 Garching, Germany
[2]Max Planck Institute for Plasma Physics, Wendelsteinstr. 1, 17491 Greifswald, Germany

HEPP Introductory Talk

EUROfusion

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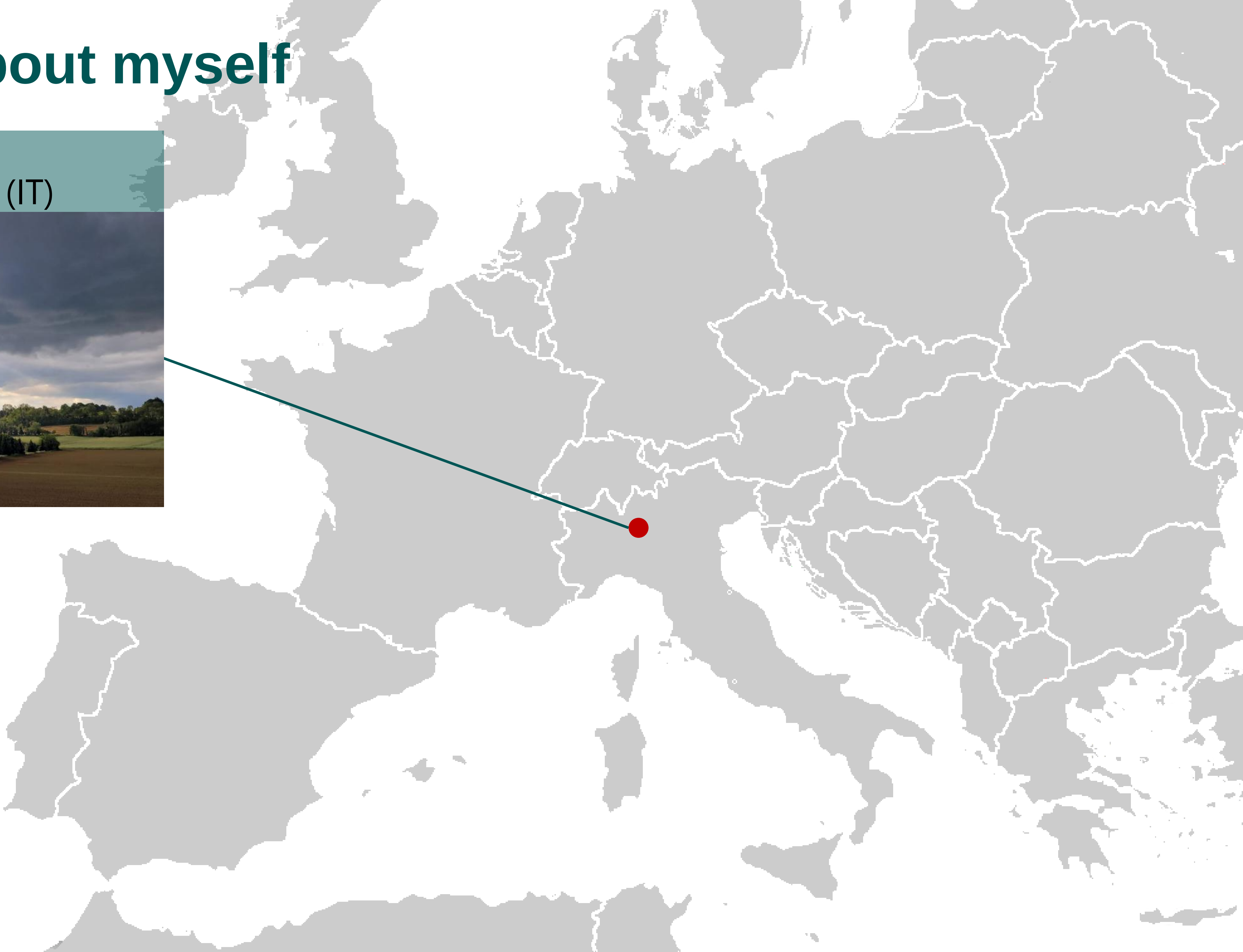
A few words about myself

- Born on 17 May 2000
- Lived in Usmate Velate (IT)



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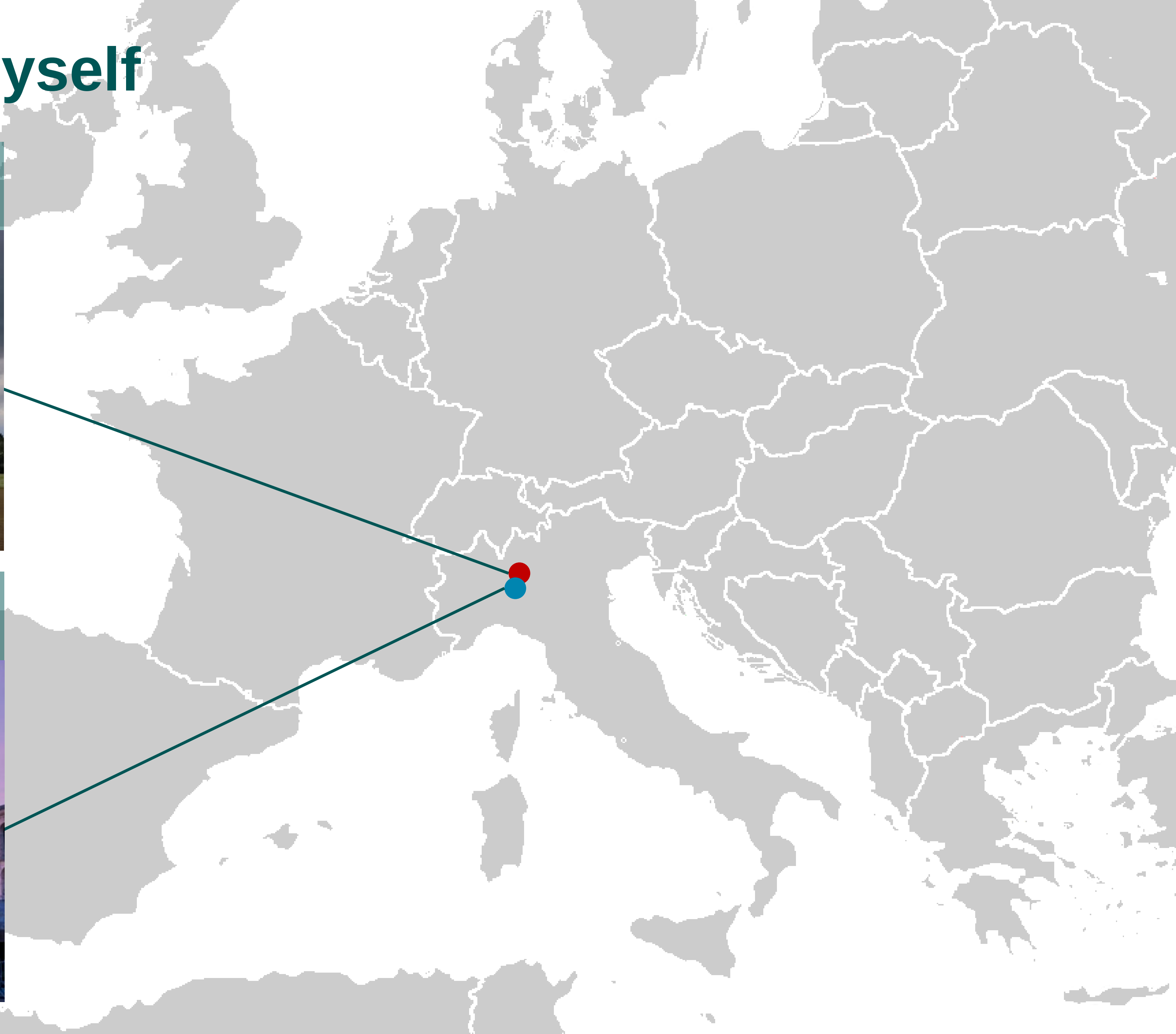

A few words about myself

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- Bachelor and Master thesis in Physics at Bicocca University (MI)

- Moved to Munich on 1 October 2024 to start my PhD at IPP

Bachelor’s thesis (2022)

- Gyrokinetic simulations of the **DTT negative triangularity** (NT) option [1,2].

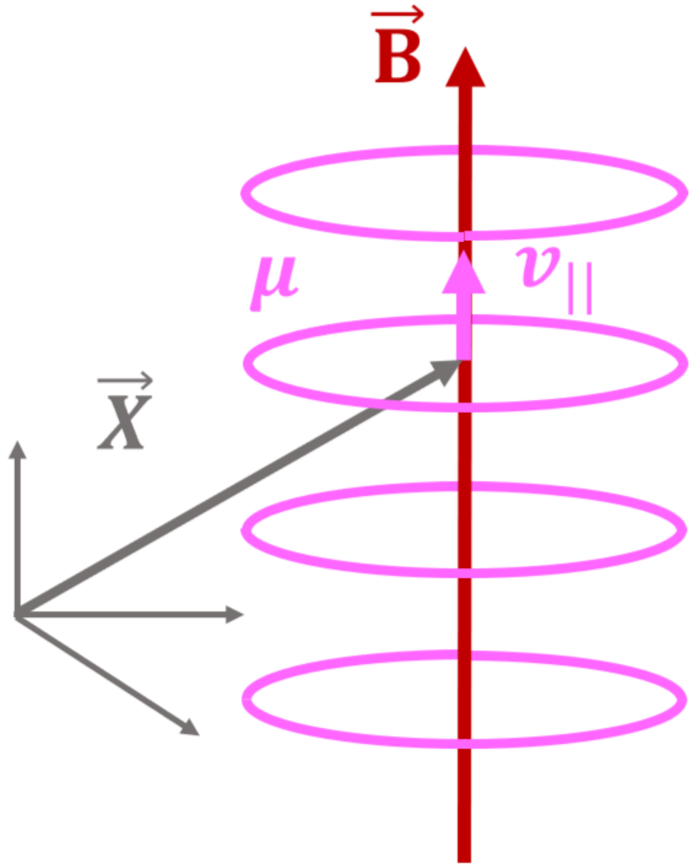
[1] A. Mariani *et al* 2024 *Nucl. Fusion* **64** 106024
[2] A. Mariani *et al* 2024 *Nucl. Fusion* **64** 046018

Bachelor's thesis (2022)

- Gyrokinetic simulations of the **DTT NT** option [1,2].
- Simulations performed with the **GENE code** [3].

Presenting GENE

Full gyrokinetic, eulerian code which solves the Vlasov-Maxwell system in the 5-D **gyrocenter RF** $(x, y, z, v_{||}, \mu)$, with x, y, z f.a.c.



[1] A. Mariani *et al* 2024 *Nucl. Fusion* **64** 106024

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[3] F. Jenko *et al* 2000 *Phys. Plasmas* **7** 1904

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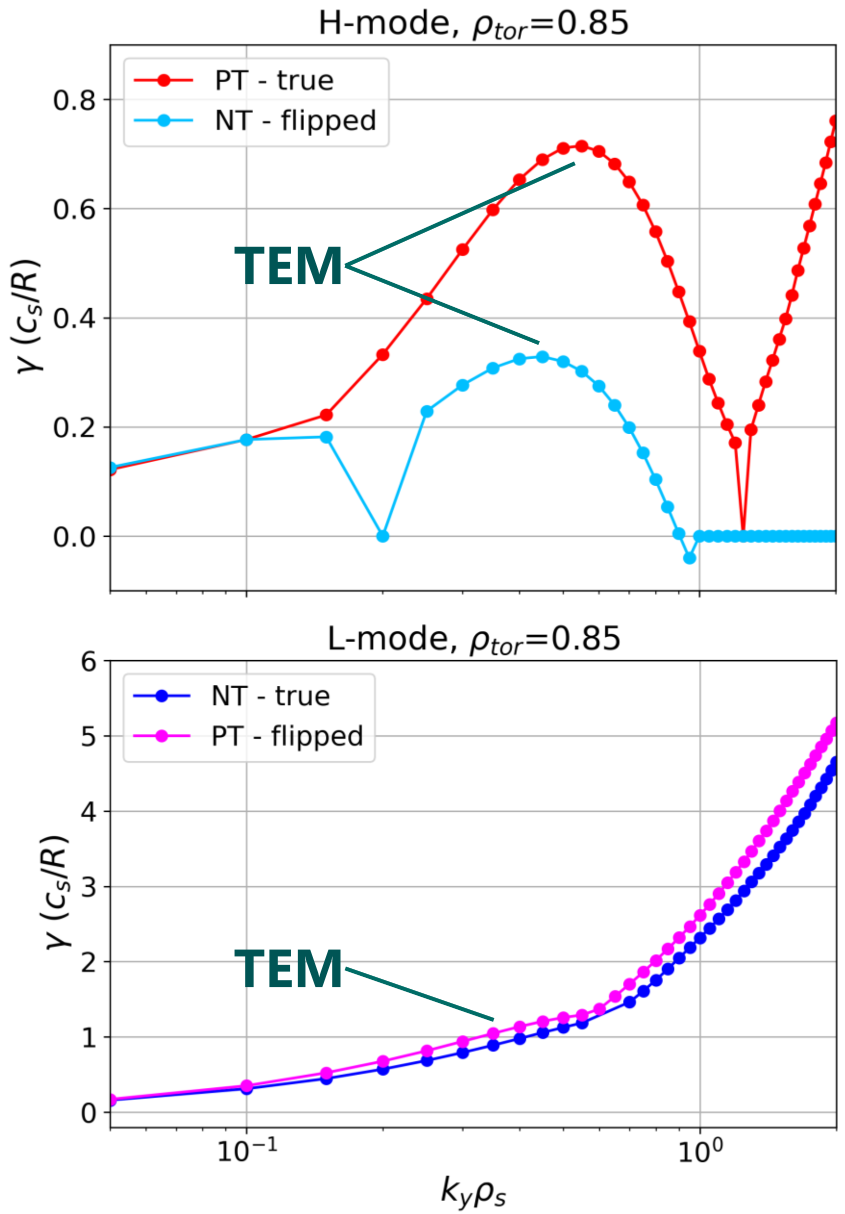
- Scans in different plasma parameters q, $\hat{s}$, ν_{coll} and k_y.

- k_y scans show a **stabilization of TEMs** due to NT.
  NT effect **H-mode** > NT effect **L-mode**.



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Master's thesis (2024)

- Experimental analysis and **GENE** simulations of **JET pure-D** and **pure-T** discharges [4,5].
- How does **ion stiffness** change when:
  a) **H** → **D** → **T**
  b) We include **fast ions** (FI)
  c) We include **electromagnetic effects** (EM)

[4] N. Bonanomi *et al* 2019 *Nucl. Fusion* **59** 096030
[5] D. Brioschi *et al* 2025 *Nucl. Fusion* **65** 026054

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Ion stiffness: how steep $q_{i,gB}$ vs R/L_{T_i} is

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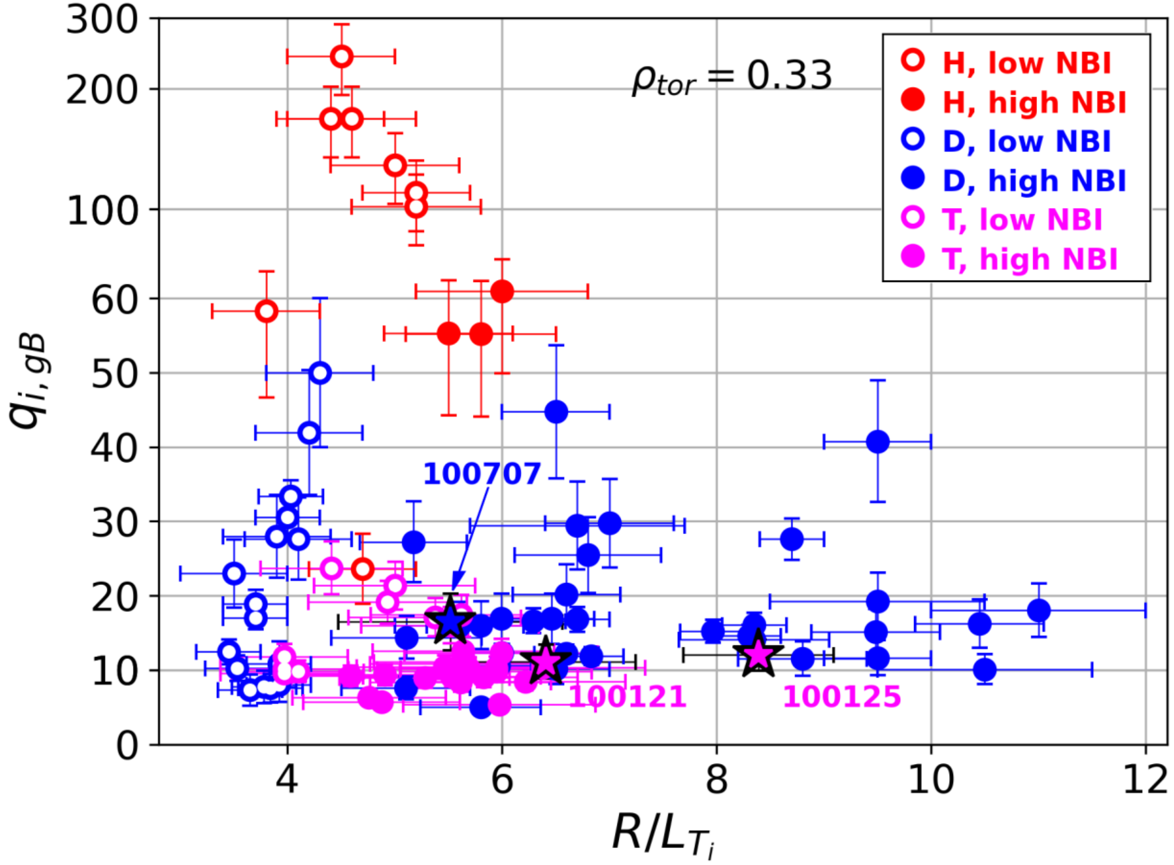
Experimental results

- Destiffening **H** → **D** → **T**
- Destiffening **low NBI** → **high NBI**



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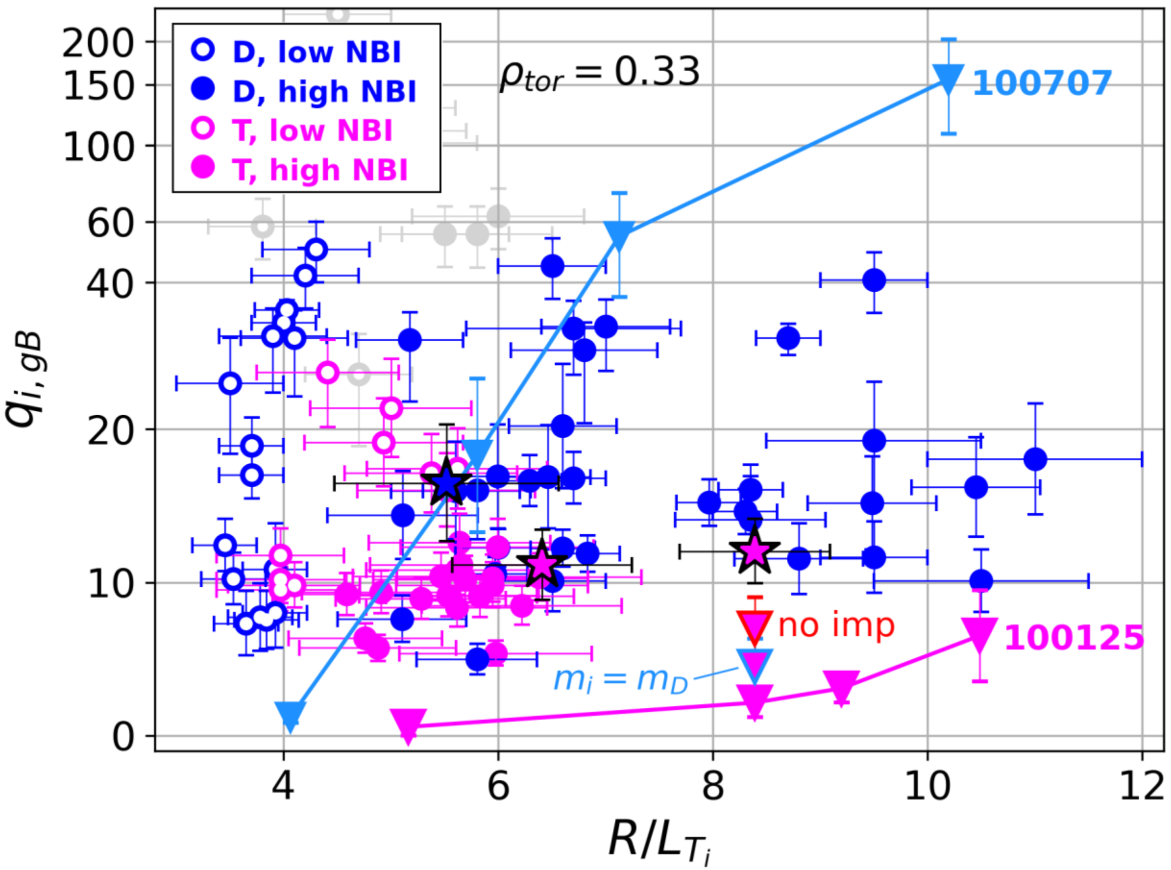

Experimental results

- Destiffening **H** → **D** → **T**
- Destiffening **low NBI** → **high NBI**

Simulations results

- **D** vs **T** with same external heating.
- Destiffening **D** → **T**
- Stabilizing effect of **EM** and **FI only in T**

[4] N. Bonanomi *et al* 2019 *Nucl. Fusion* **59** 096030
[5] D. Brioschi *et al* 2025 *Nucl. Fusion* **65** 026054

PhD project

- **Fishbones** (FB): low frequency MHD modes, $nq=m$.
- FB are linked to the instauration of **ITBs** in tokamaks [6,7].

[6] X. X. He *et al* 2022 *Plasma Phys. Control. Fusion* **64** 015007
[7] G. Brochard *et al* 2024 *Phys. Rev. Lett.* **132** 075101

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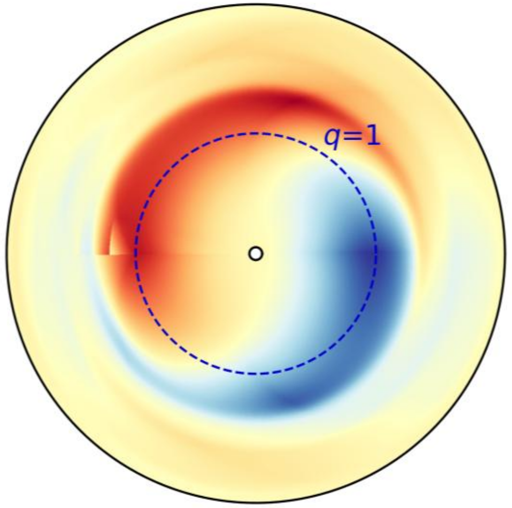
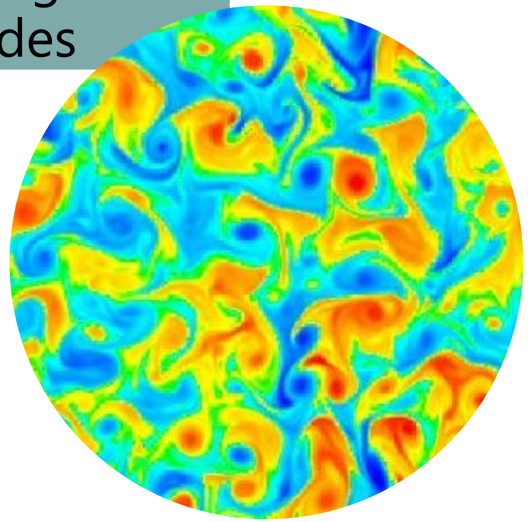
  A description of the **fishbone – microturbulence** interaction is needed.

Fisbones (device scale) ⟷ **Microturbulence** (Larmor scale)

$n=m=q=1$

Ion temperature gradient (**ITG**) modes





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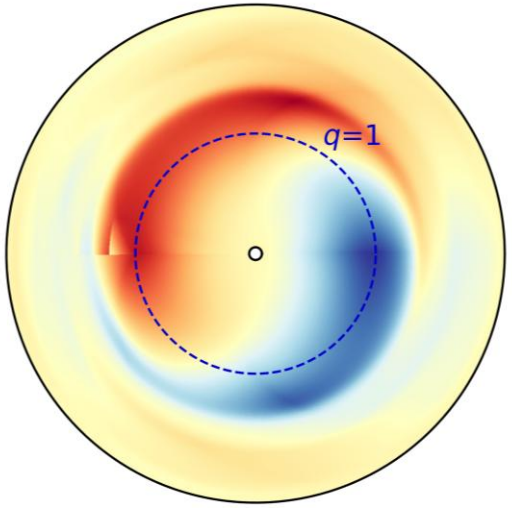

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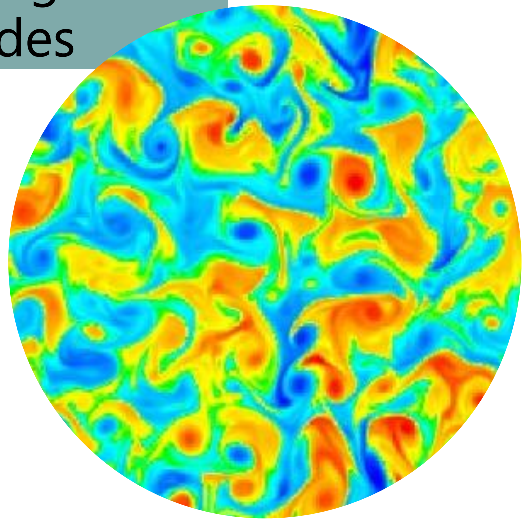

Zonal flows («mesoscale»)

[6] X. X. He *et al* 2022 *Plasma Phys. Control. Fusion* **64** 015007
[7] G. Brochard *et al* 2024 *Phys. Rev. Lett.* **132** 075101

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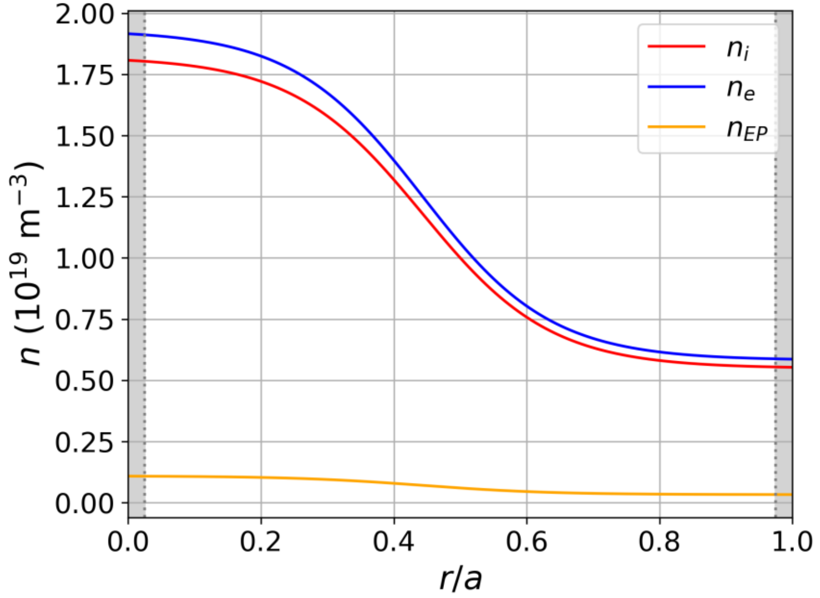
STEP 1 – How good is GENE in simulating FBs?



«Test» setup

- Three species (ions, electrons, EPs)
- Same density gradient for all the species
- Flat $T_i = T_e = 1$ keV and T_{EP} profiles

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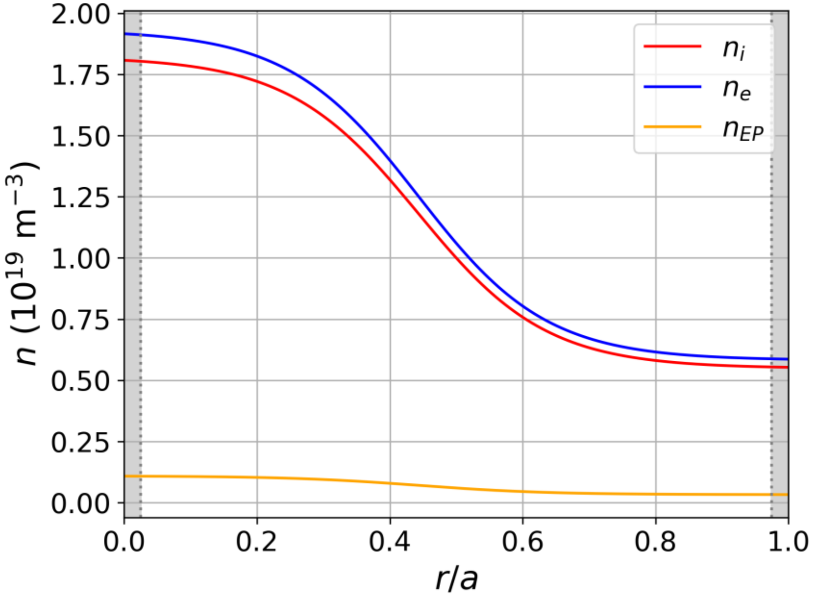
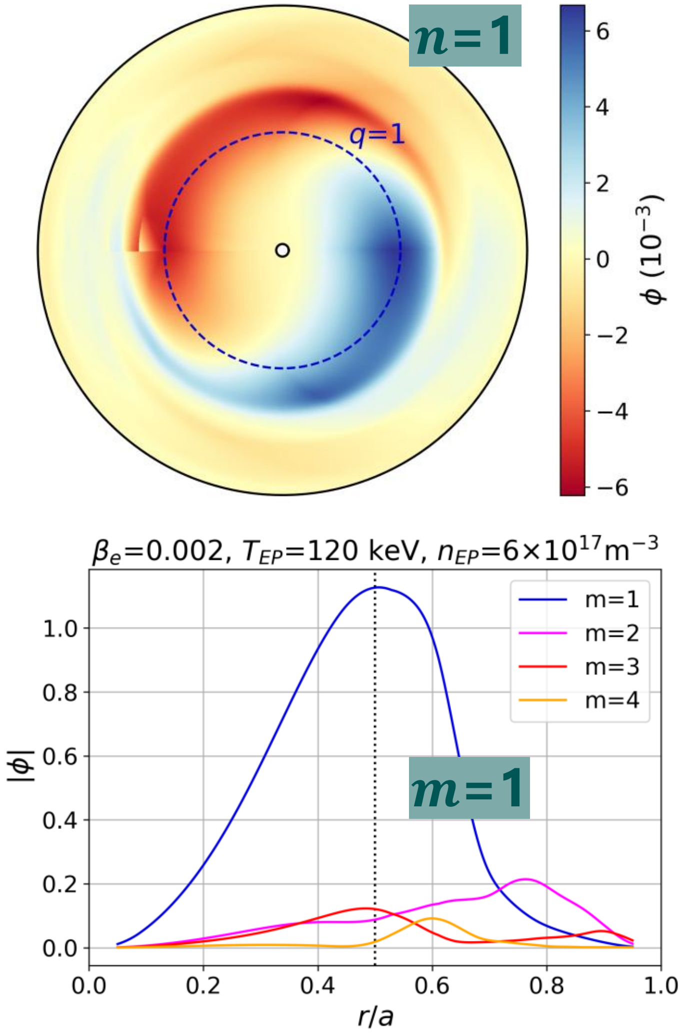


GENE linear, global simulations



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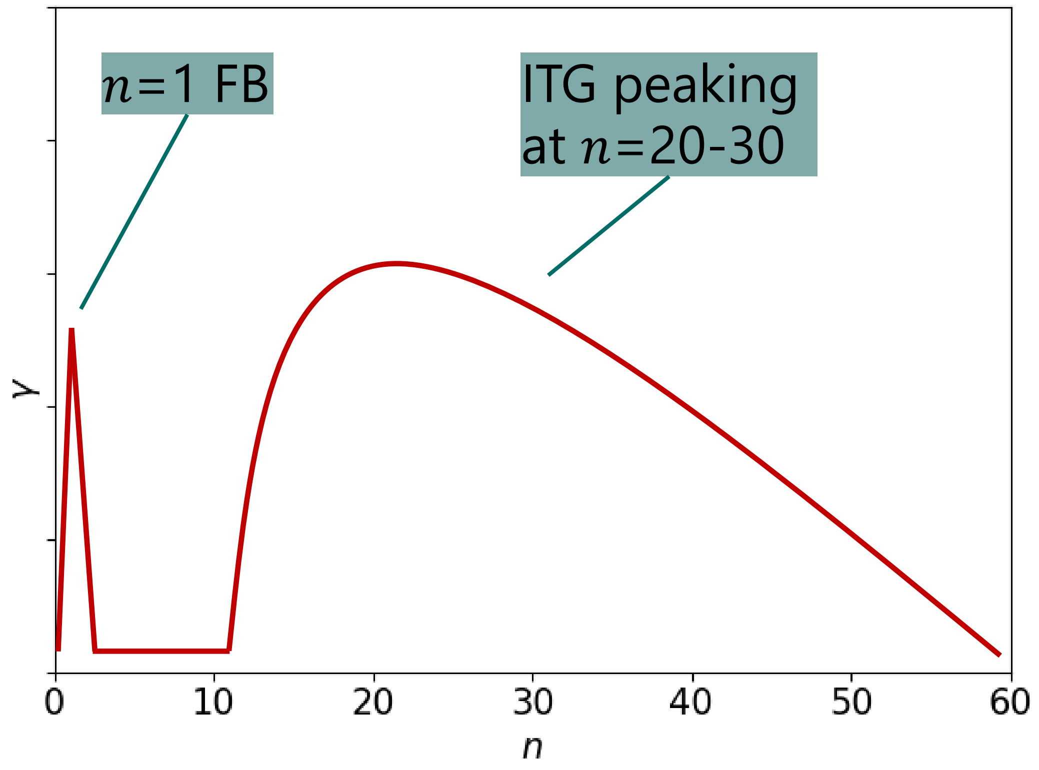
STEP 2 – Searching for a multiscale setup

- *Desiderata* for the multiscale spectrum:



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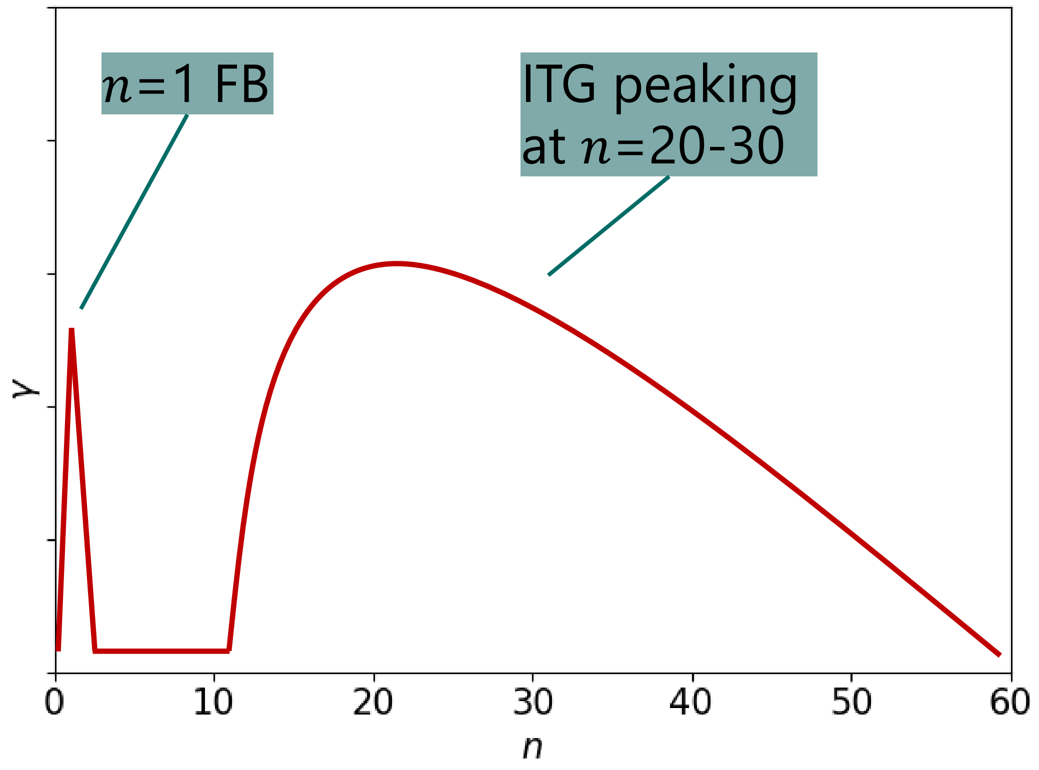

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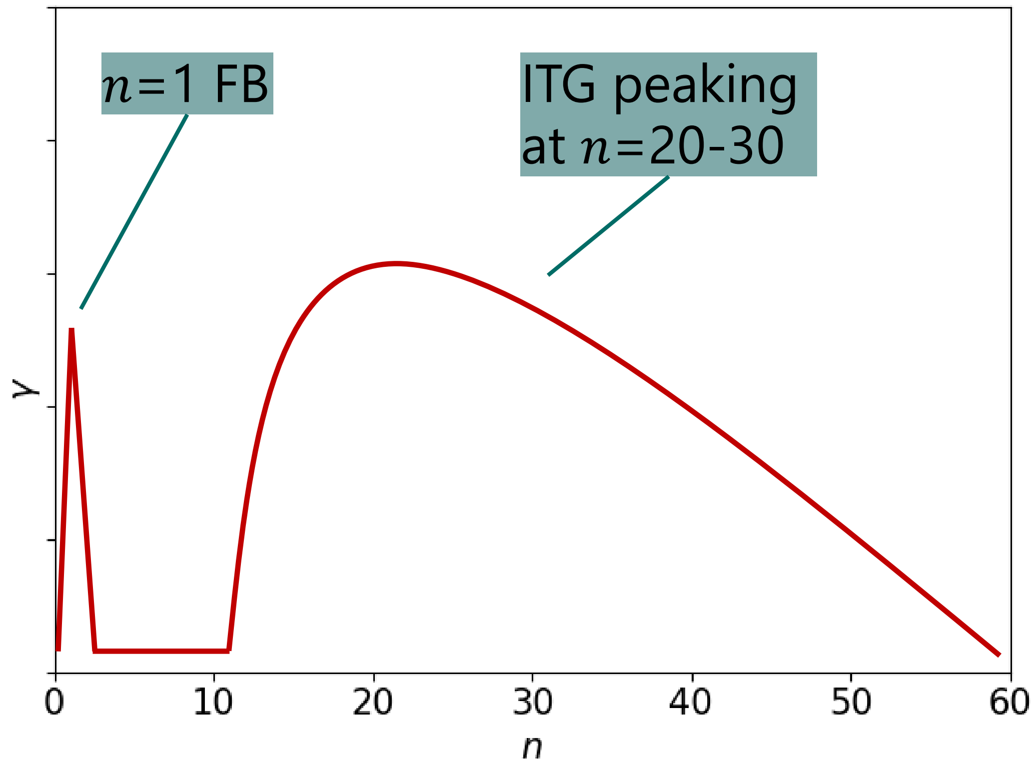

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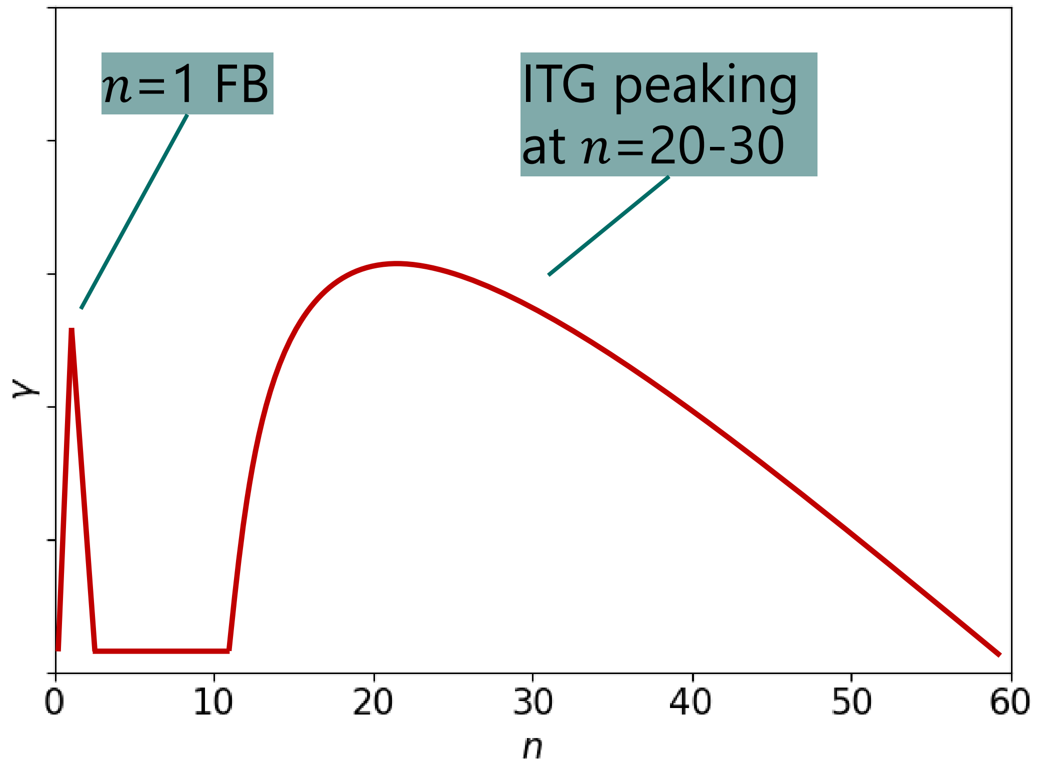
  c) FB and ITG at **same position** to maximize the interaction



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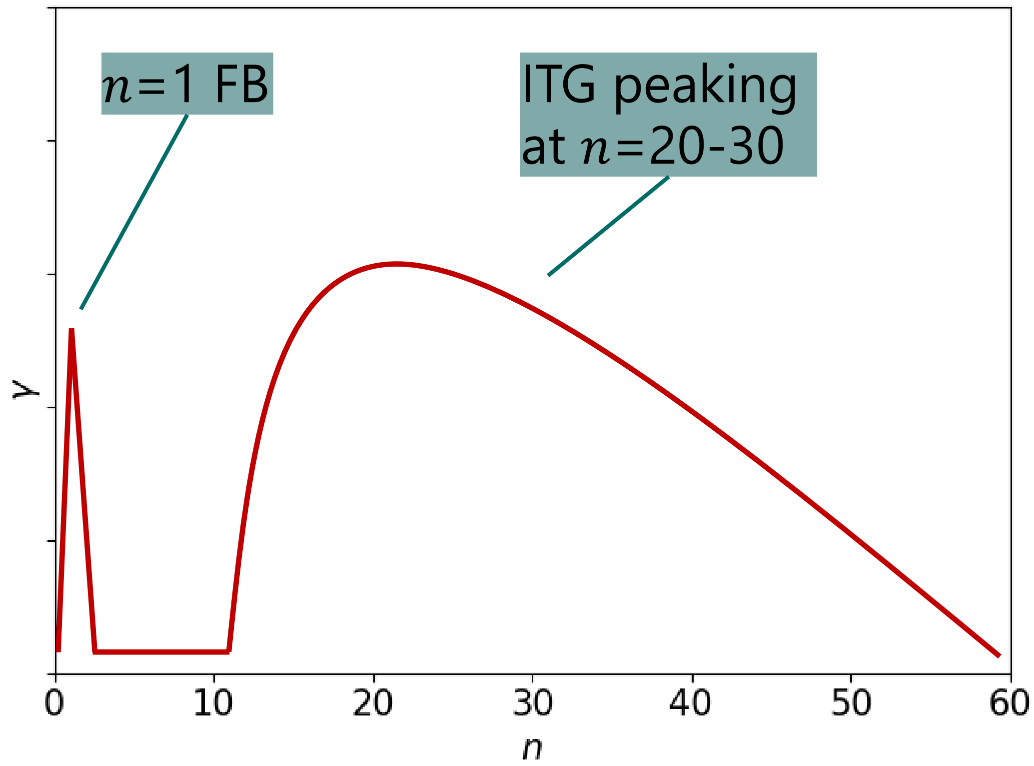
We need a plasma setup that produces this instability spectrum!



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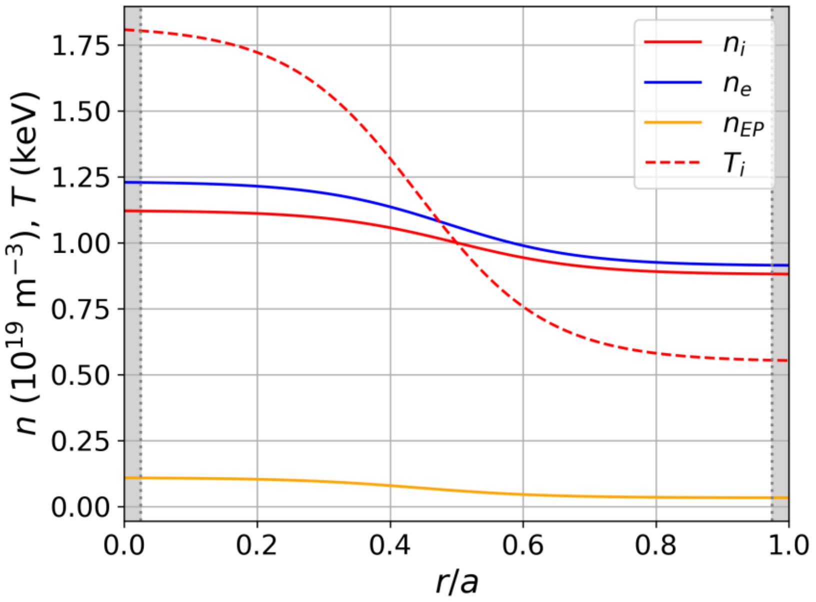

Current setup

- Assigned n_{EP}, variable n_e, n_i=n_e-n_{EP}
- $\nabla T_i \neq 0$, ∇T_e=0, low ∇n_e → **ITG > TEM**
- β_e=0.075% → **n=1 FB** dominant at low-n

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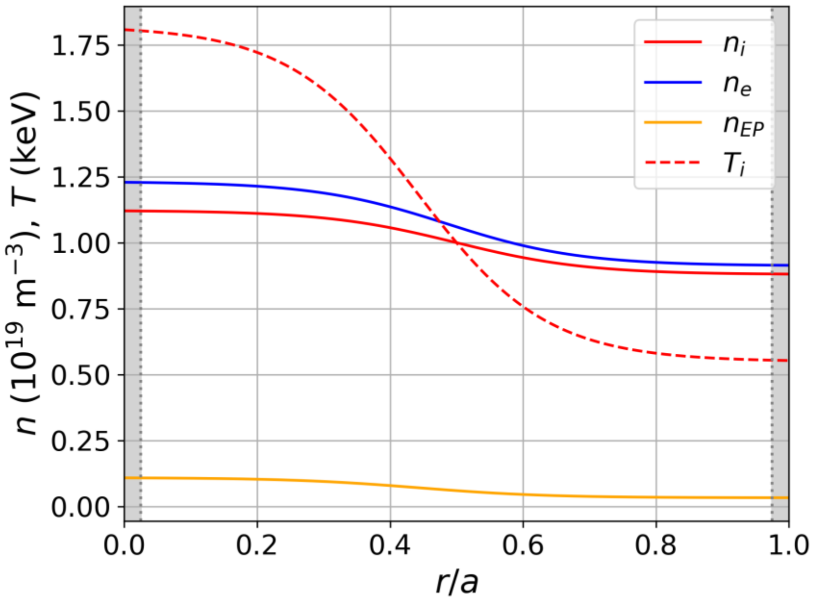

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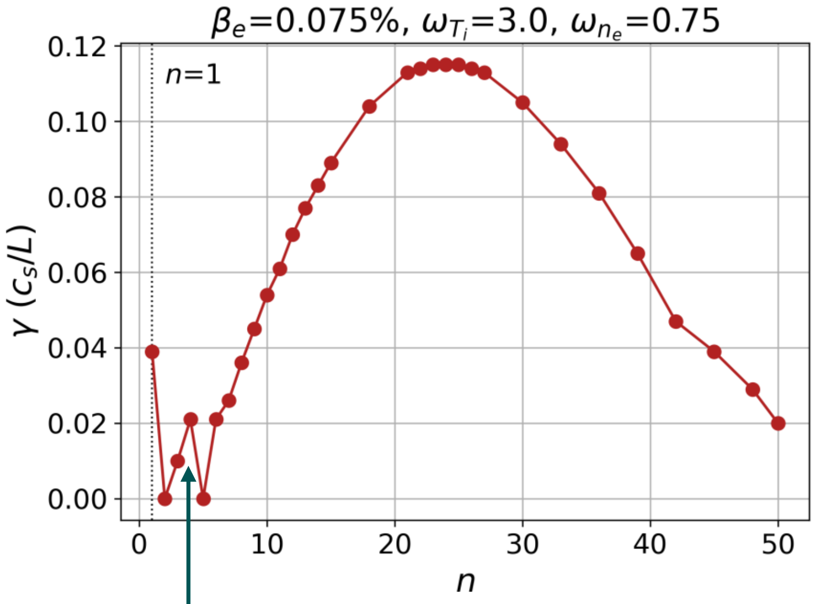

n=3,4 AEs we have to get rid of!

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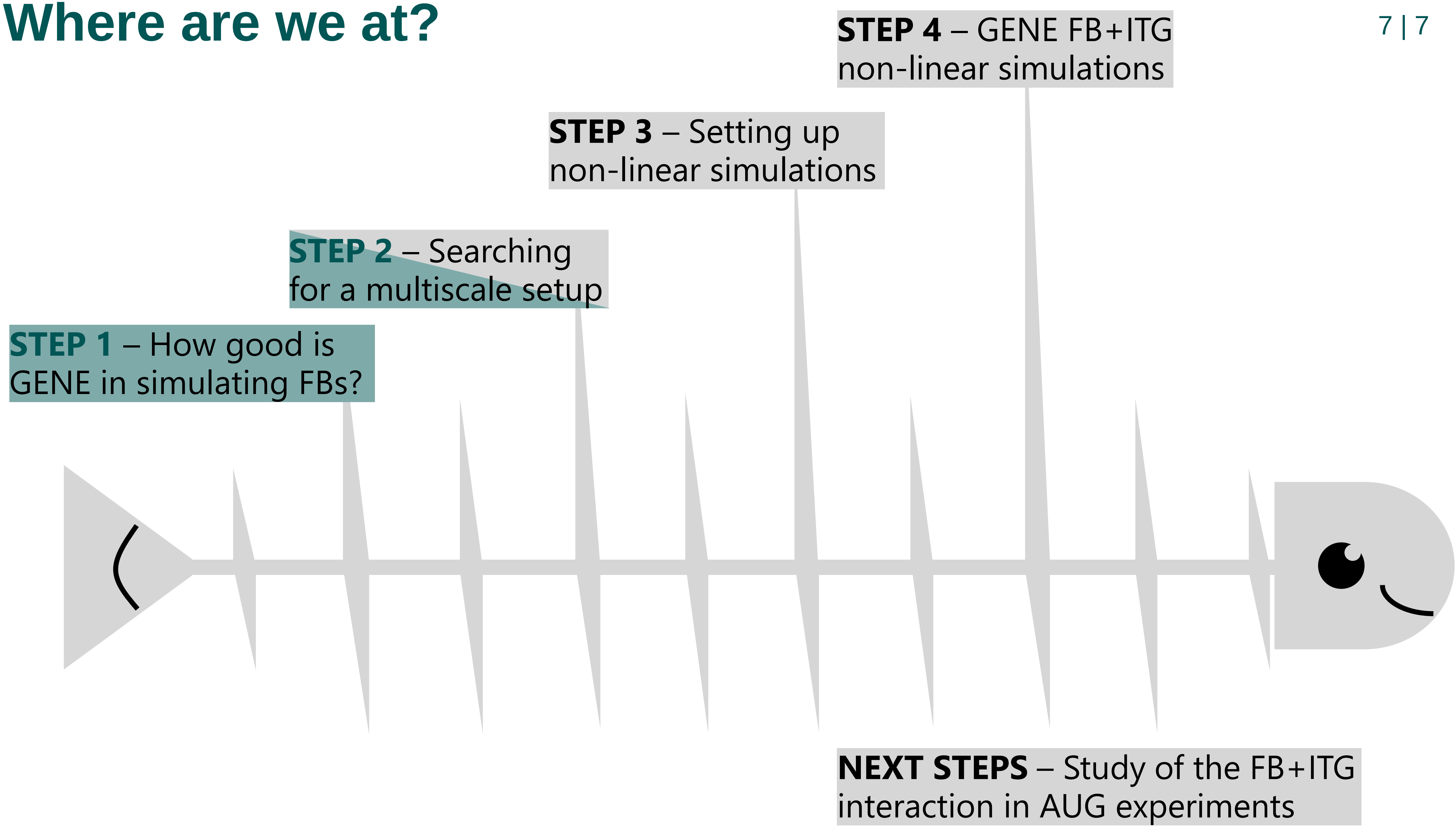
Where are we at?



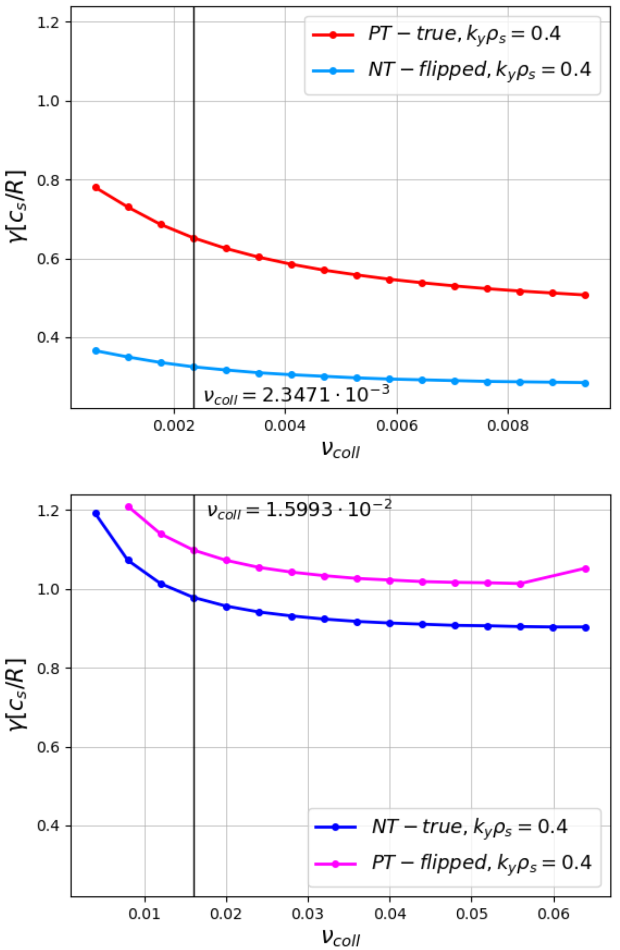
Scan me!

Thank you for your attention!

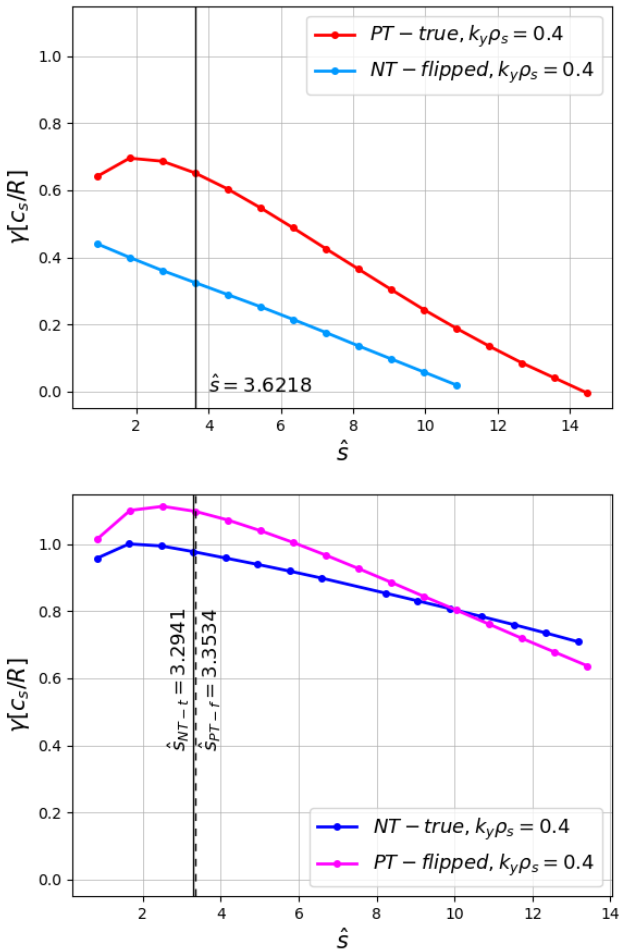
Some other plots from my bachelor’s thesis

- Scans in different parameters comparing **NT** and **PT** were performed.

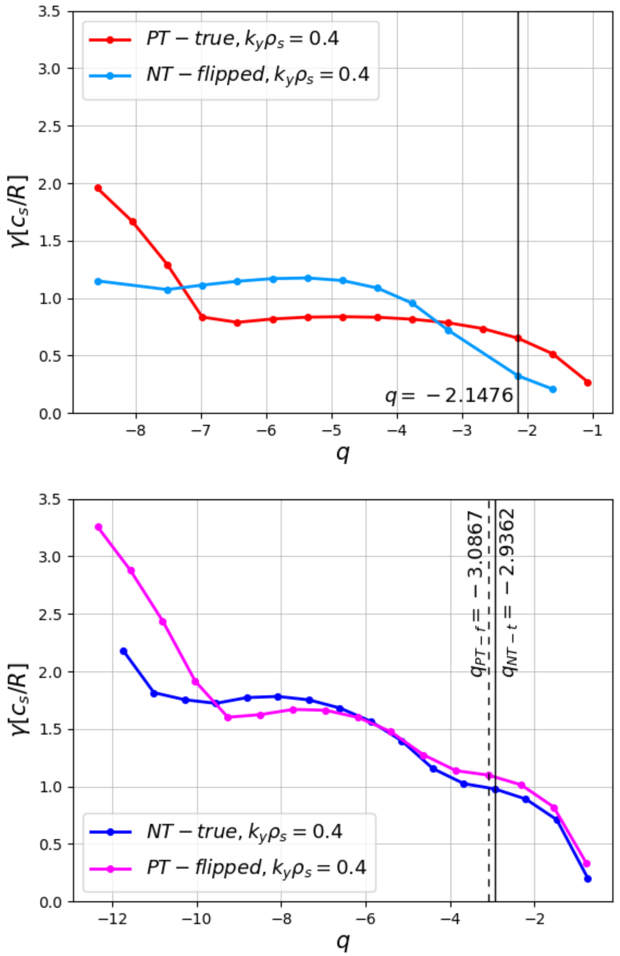
ν_{coll} scans



$\hat{s}$ scans

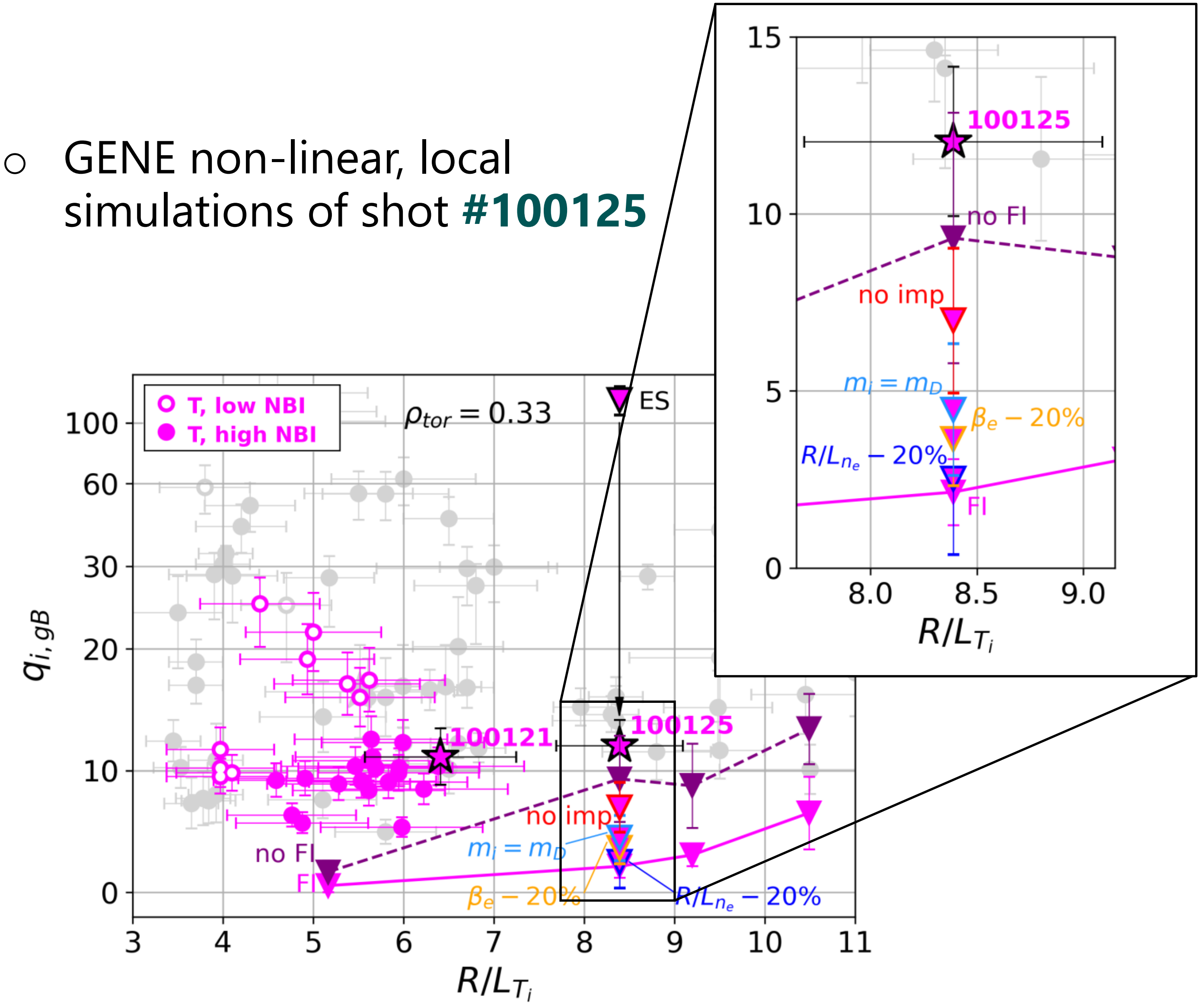


q scans

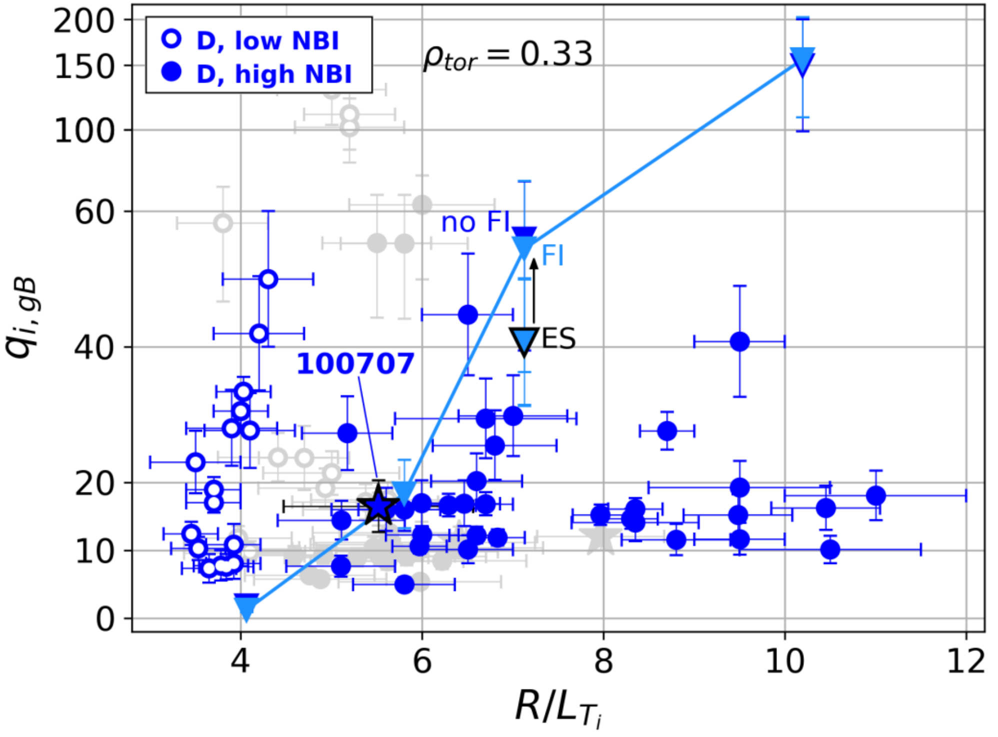


Some other plots from [5]

- GENE non-linear, local simulations of shot **#100125**

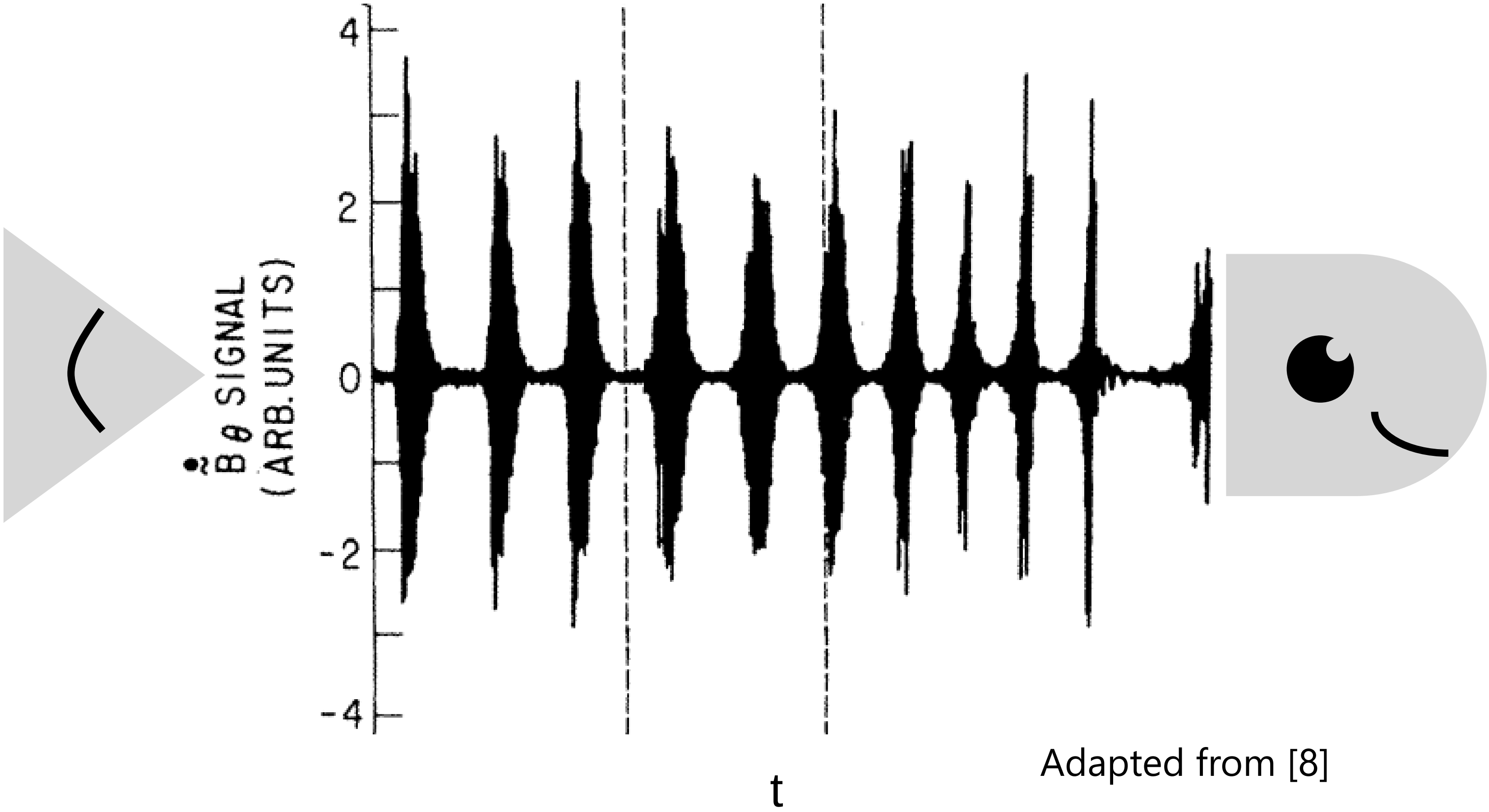


- GENE non-linear, local simulations of shot **#100707**



Why are they called “fishbones”?

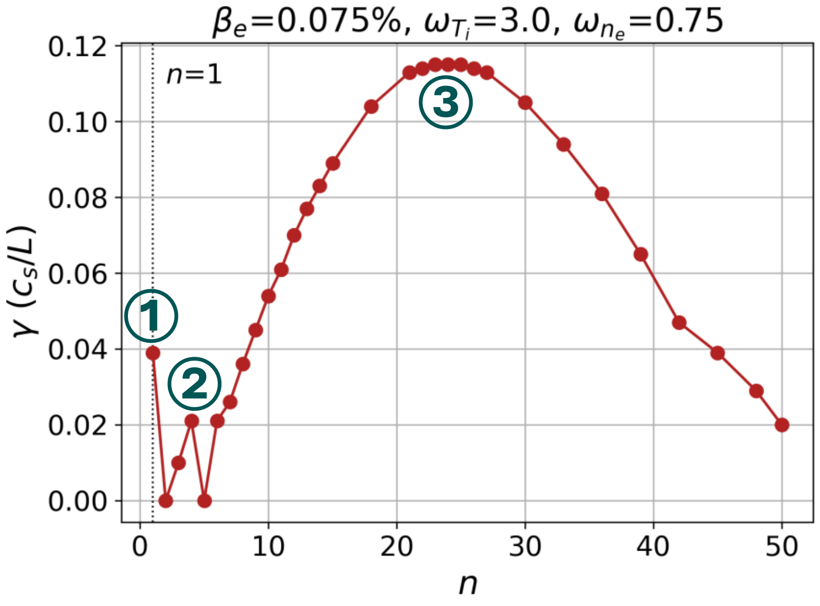
- Because of the shape of the **Mirnov coils signal** during the instability!

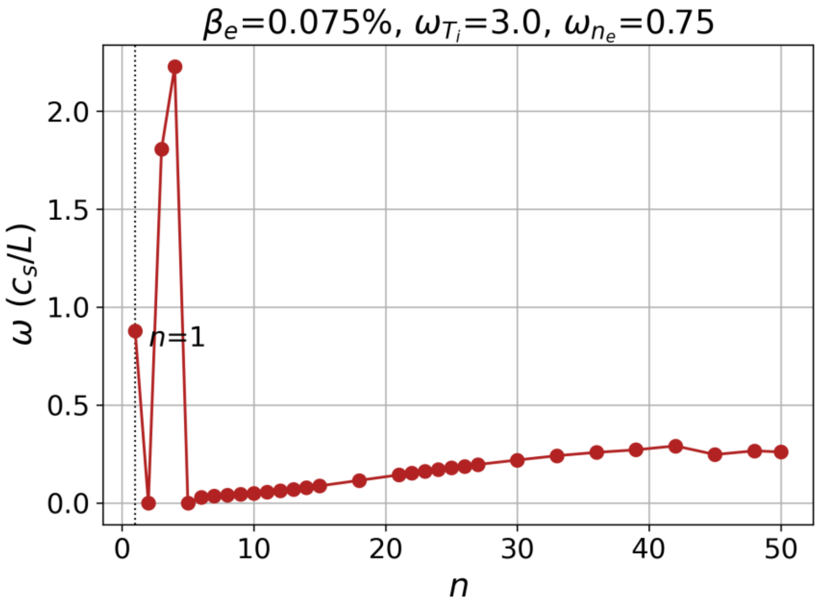


Adapted from [8]

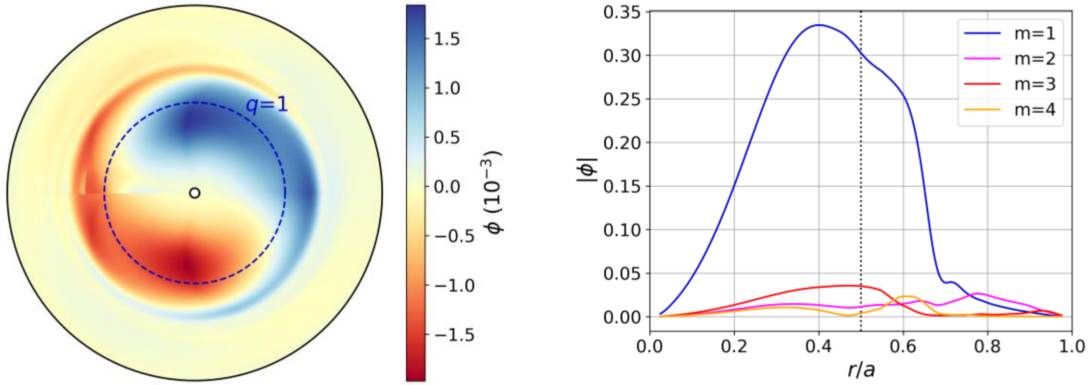
[8] K. McGuire *et al* 1983 *Phys. Rev. Lett.* **50** 12

More about the multiscale spectrum

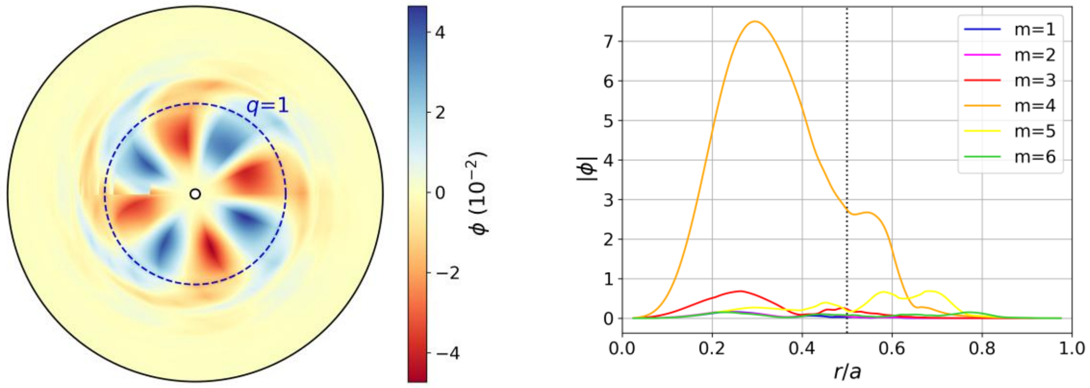




① $n=m=1$ FB



② $n=m=4$ BAE



③ $n=24$ ITG