Measurements of Alfvén Eigenmode stability in JET D and T plasmas

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** See author list of J. Mailloux et al "Overview of JET results for optimising ITER operation" to be published in Nuclear Fusion: Overview and Summary Papers from the 28th Fusion Energy Conference*

Goal: Improve prediction of damping/drive of AEs and related fast ion transport in burning plasmas

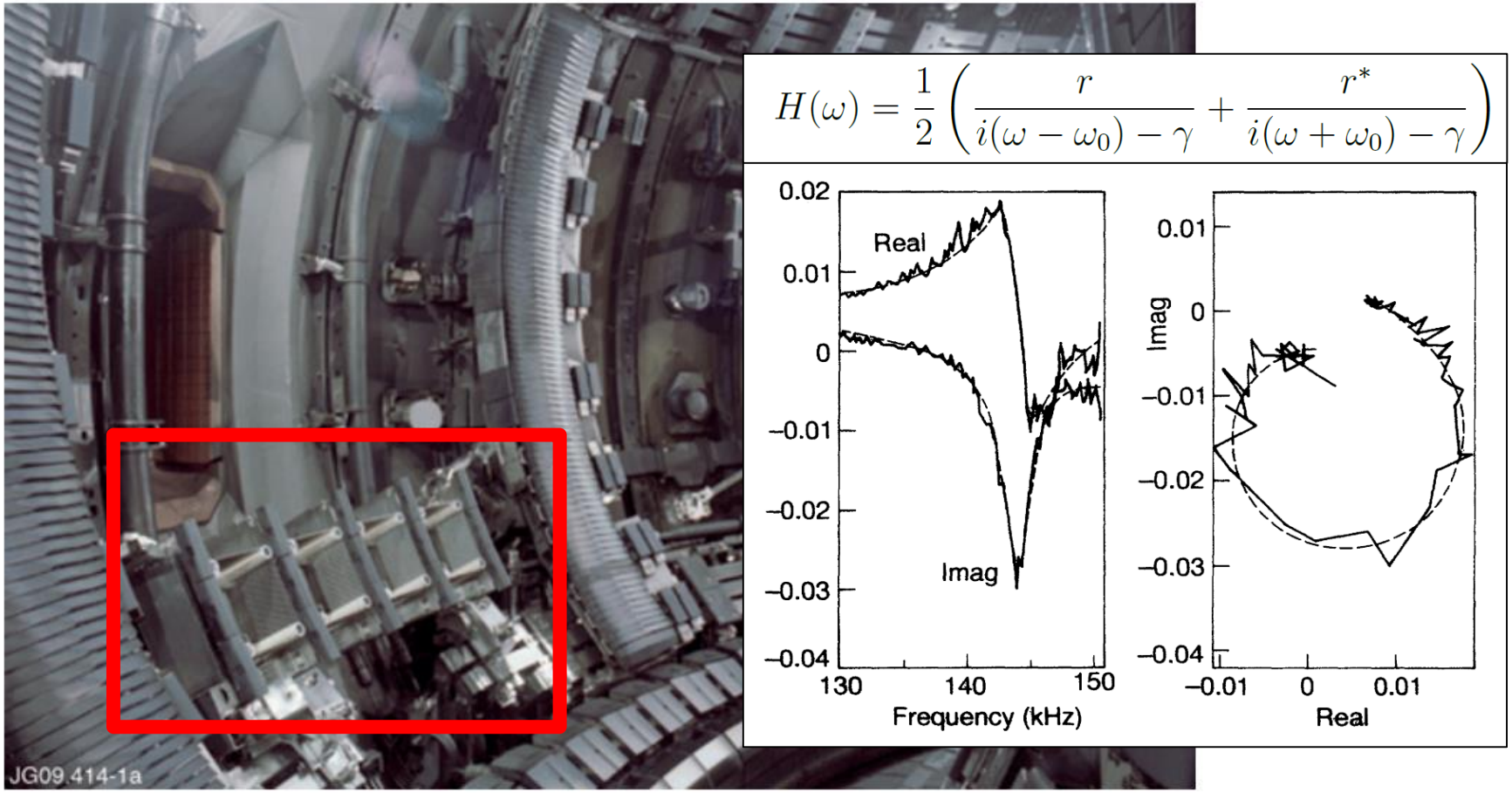
1. **Validate simulations with experimentally measured damping rates**
   Important for ITER Fusion Power Operations (D/T)
   with JET DT campaign ongoing

2. **Compare databases of *stable* AEs (Part 1) with *unstable* AEs (Part 2)**
   Alphas expected to couple most strongly with n ~ 10-12 in ITER
   and intermediate n ~ 5-7 in JET

3. **Explore isotope effects on AE stability**
   Important for ITER Pre-Fusion Power Operations (H/He)
   with JET He campaign planned for 2022

Stable Alfvén Eigenmodes

AE Active Diagnostic (AEAD) actively probes *stable* AEs, with <10 A, |n| < 20, f = 25-250 kHz



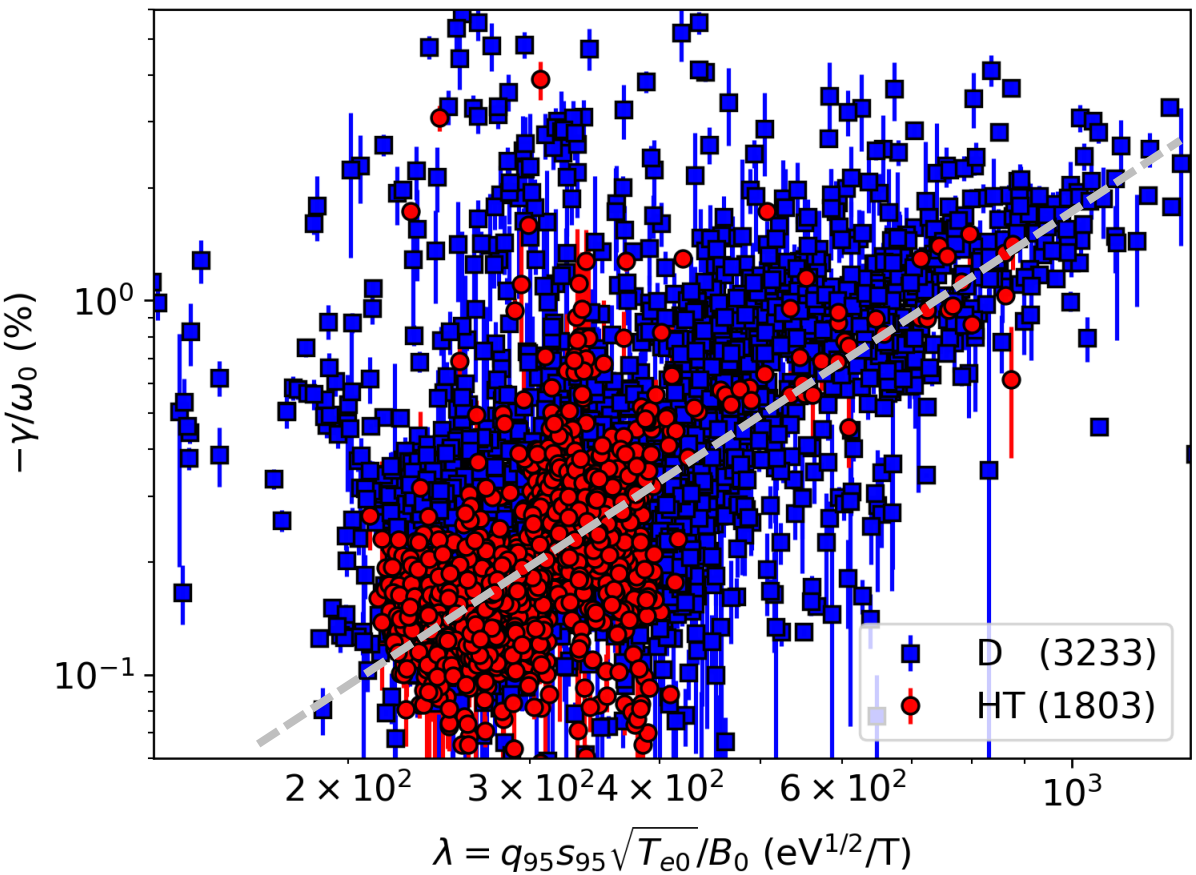
$$H(\omega) = \frac{1}{2}\left(\frac{r}{i(\omega-\omega_0)-\gamma} + \frac{r^*}{i(\omega+\omega_0)-\gamma}\right)$$

Panis 2010 Nucl. Fusion 50
Puglia 2016 Nucl. Fusion 56

Fasoli 1995 Phys. Rev. Lett. 75
Tinguely 2020 Plasma Phys. Control. Fusion 62

JET PSFC EPFL CCFE CULHAM CENTRE FOR FUSION ENERGY

Radiative damping inferred from strong correlation (>0.5) for D, H, and T data



Heidbrink 2008 Phys. of Plasmas 15
Tinguely 2021 Nucl. Fusion (accepted)

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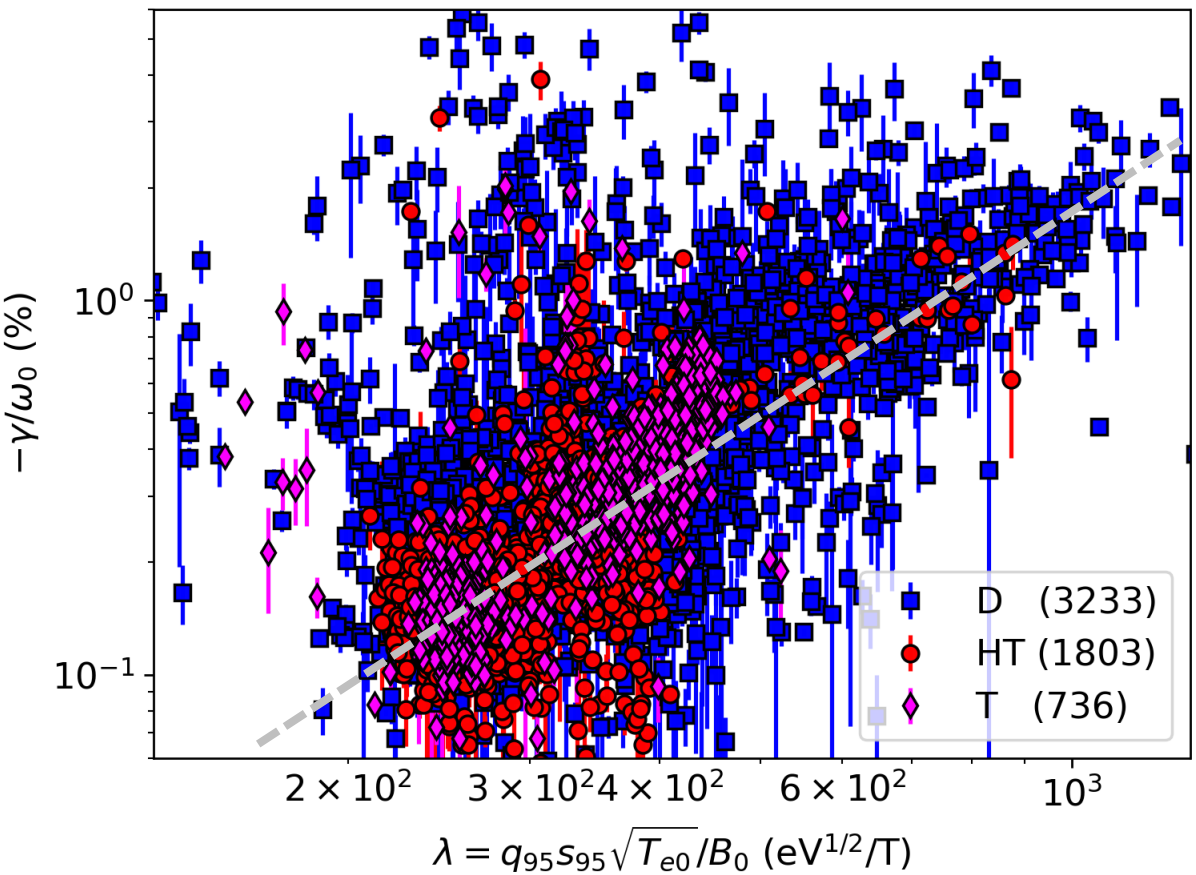

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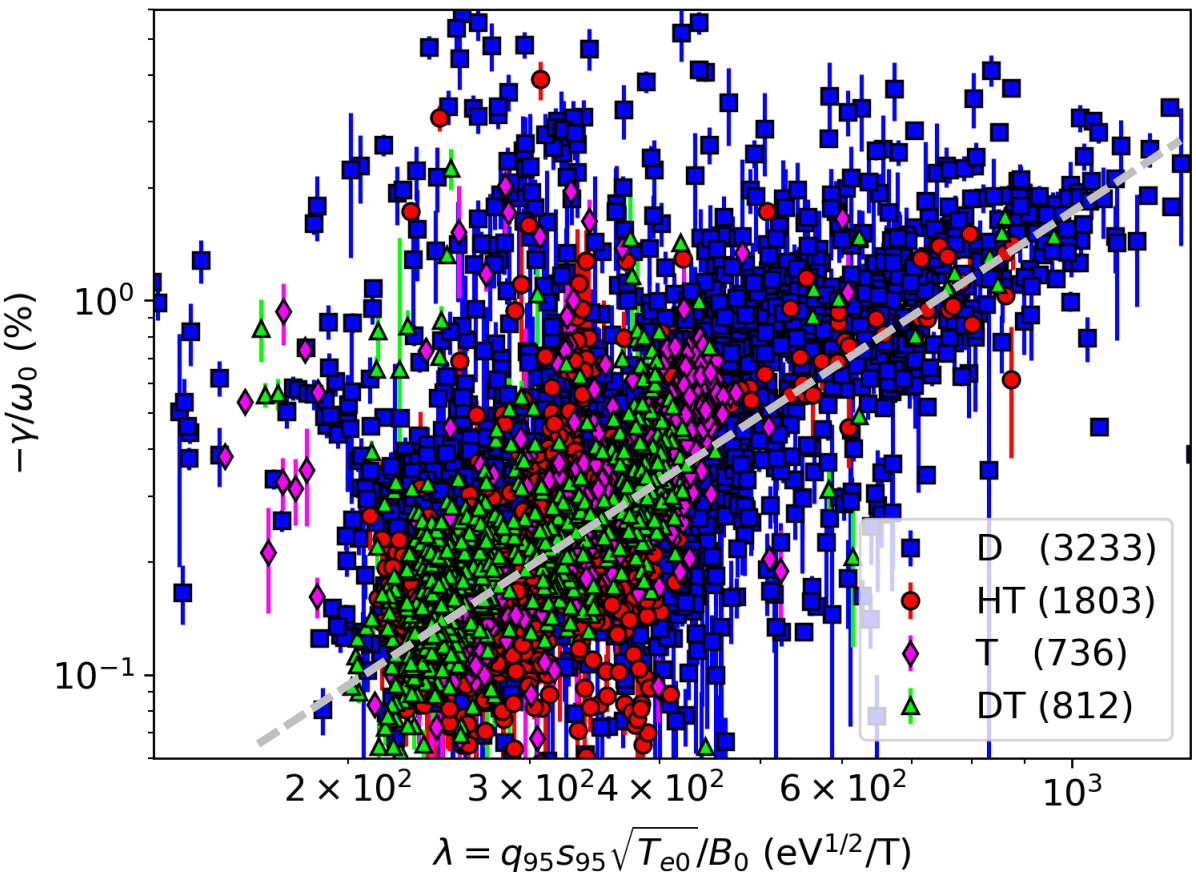
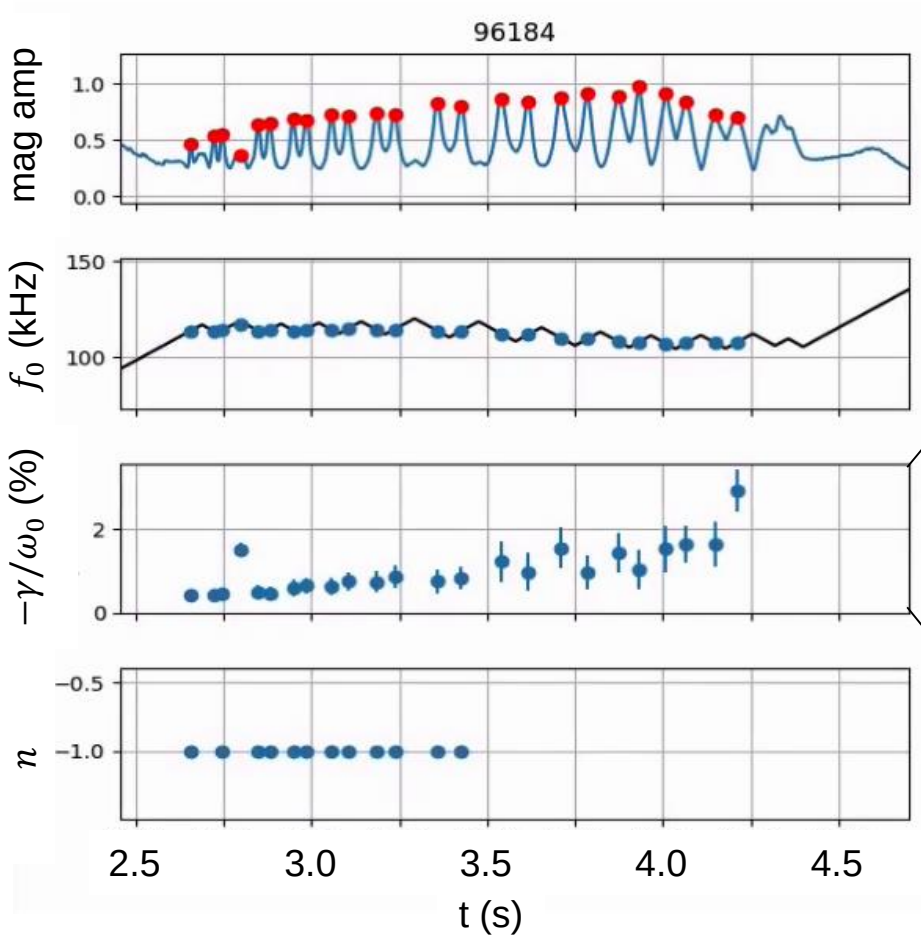


preliminary!

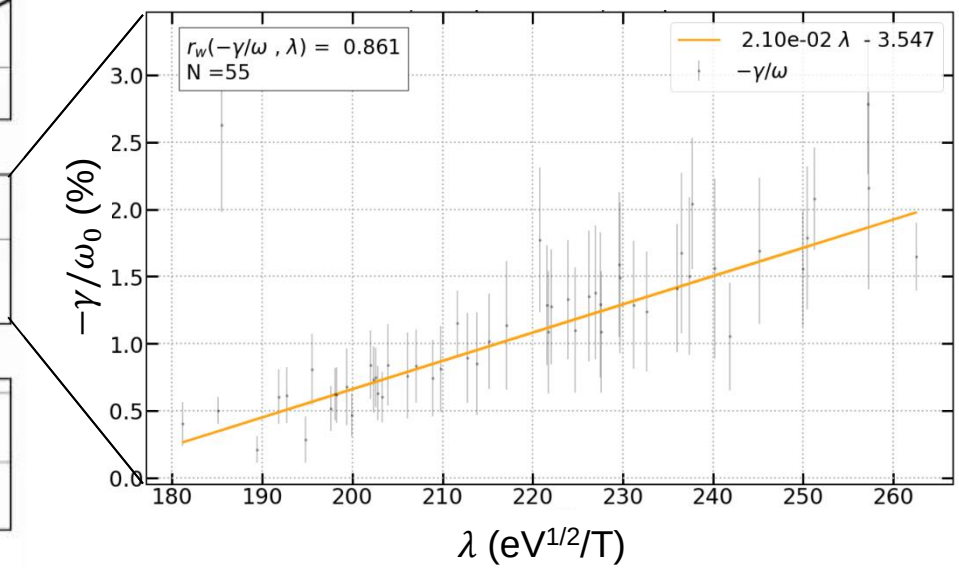
Heidbrink 2008 Phys. of Plasmas 15
Tinguely 2021 Nucl. Fusion (accepted)

JET PSFC EPFL CCFE CULHAM CENTRE FOR FUSION ENERGY

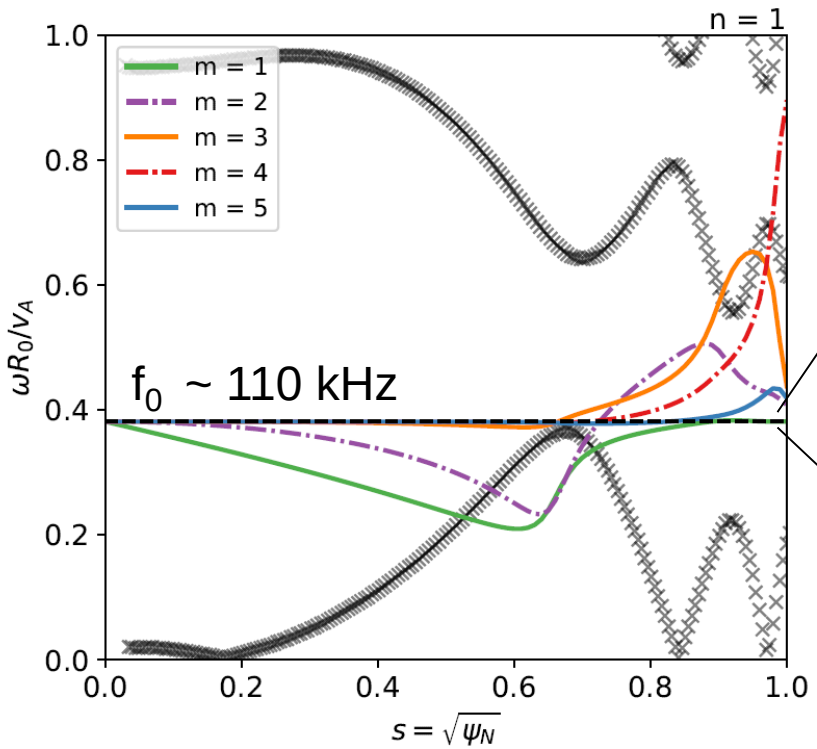
Clear example of radiative damping in an ohmic D plasma

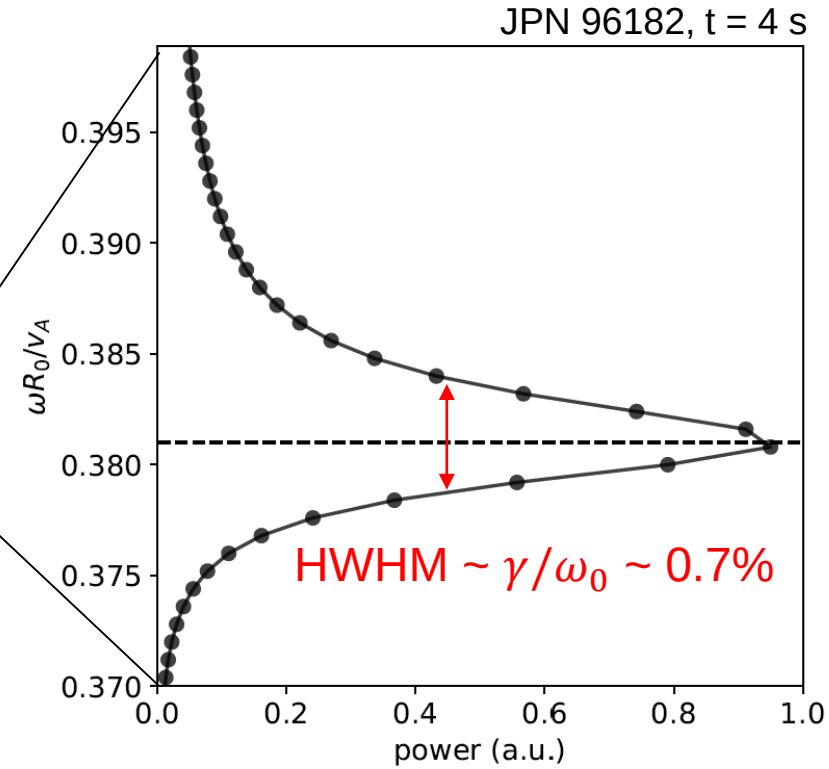


JPN 96182, 96183, 96184



CSCAS and CASTOR modeling confirm n = 1 TAE at f_0 ~ 110 kHz

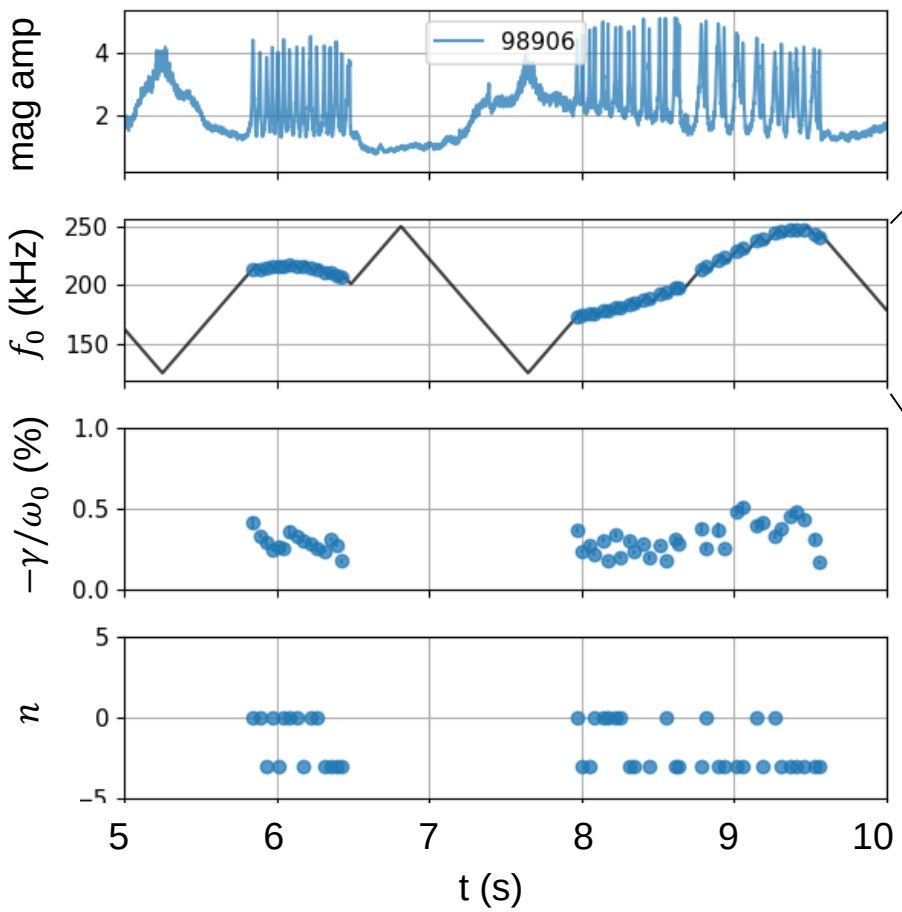


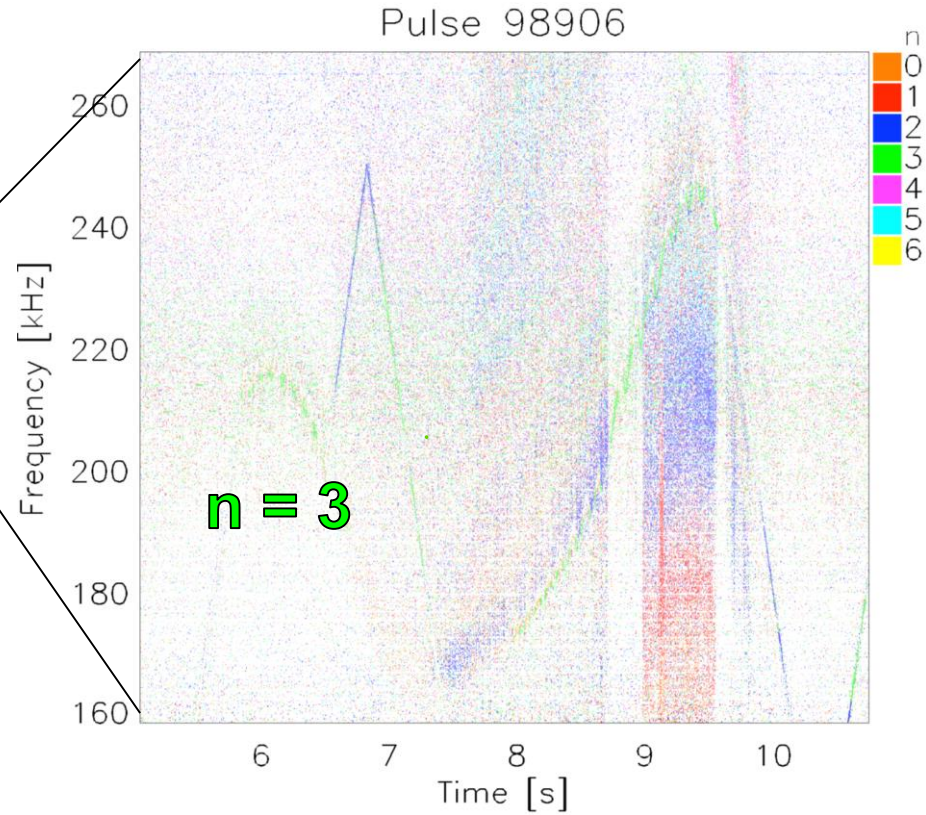


Kerner 1998 J. Computational Physics 142
Huysmans 2001 Phys. Plasmas 8

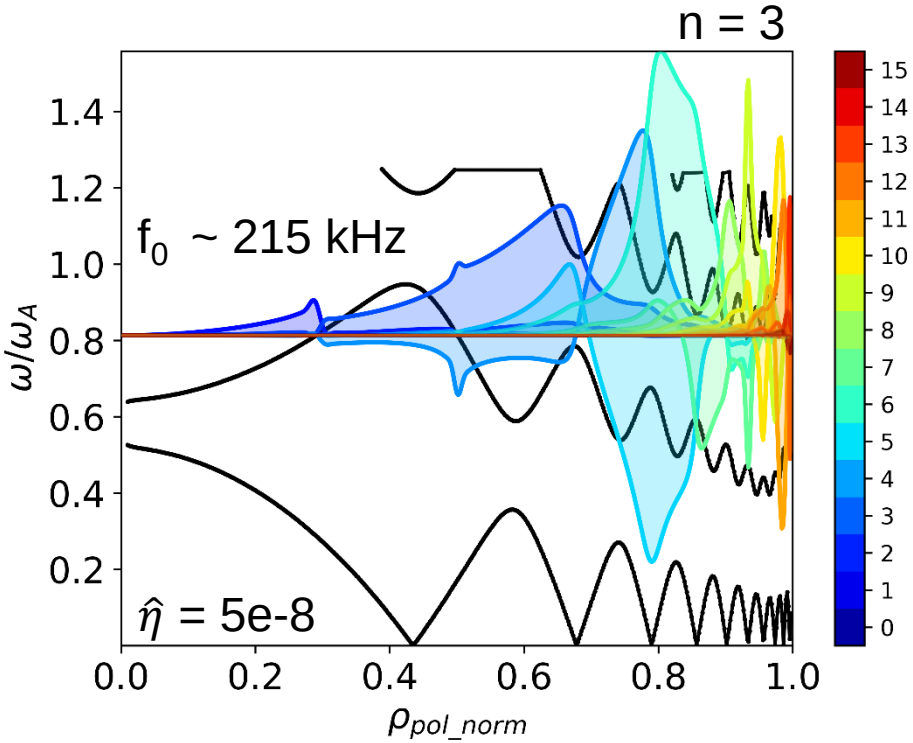
JET PSFC EPFL CCFE CULHAM CENTRE FOR FUSION ENERGY

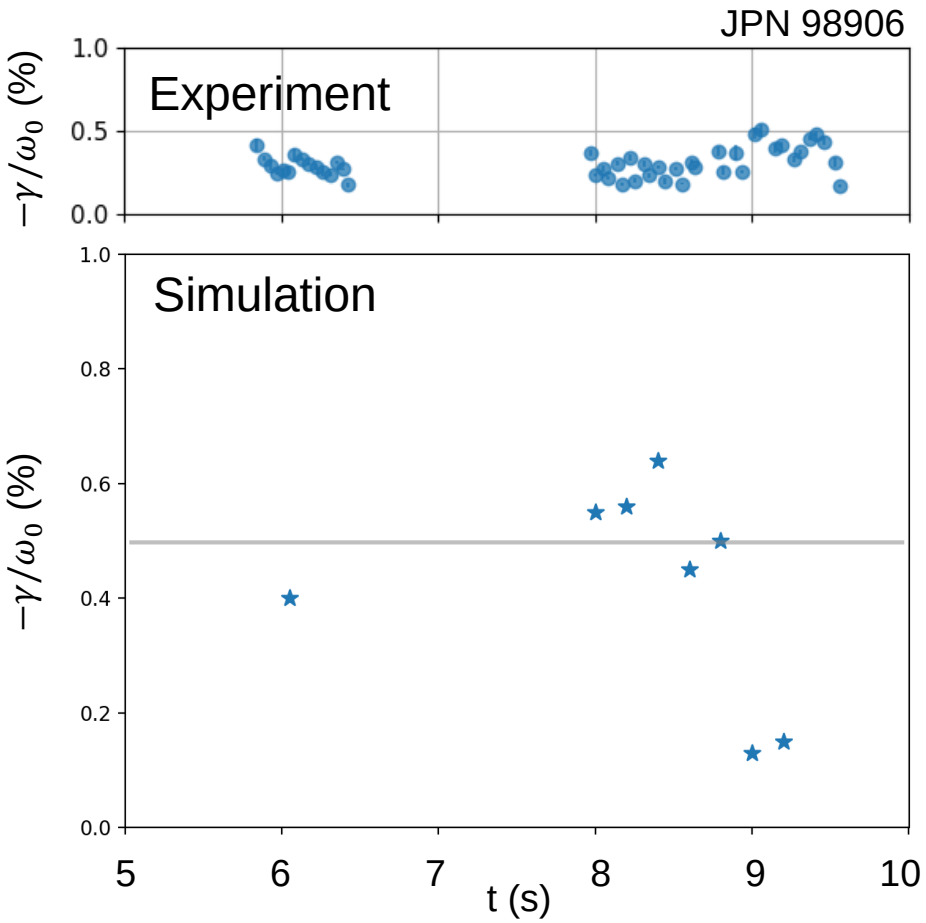
Clear example of collisional damping in an ohmic T plasma





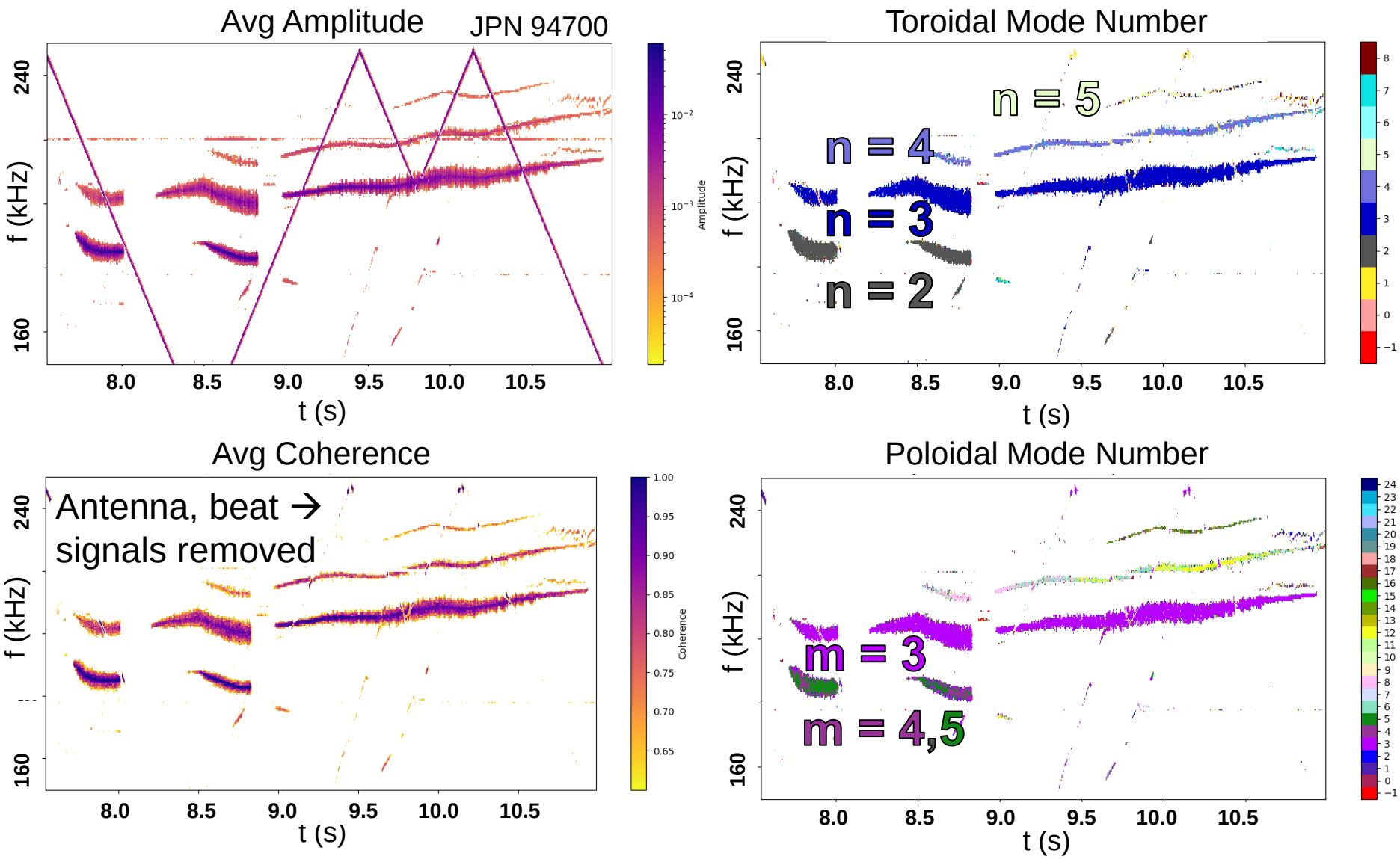
CASTOR finds good agreement in frequency and damping rate at early times





Unstable Alfvén Eigenmodes

Robust identification of unstable MHD



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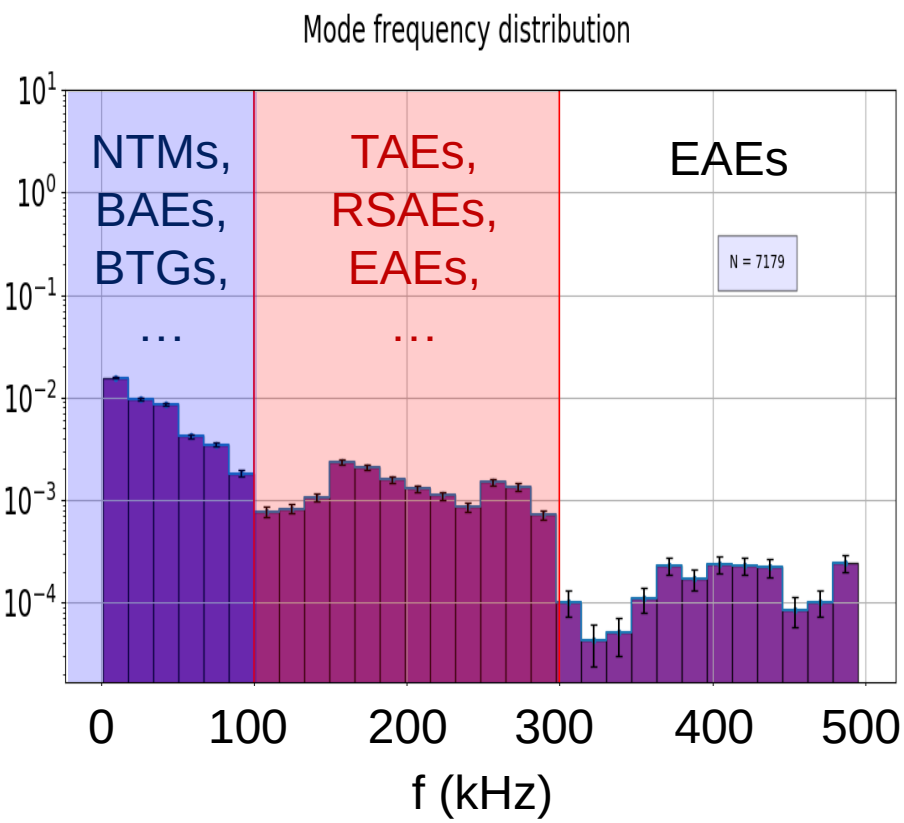
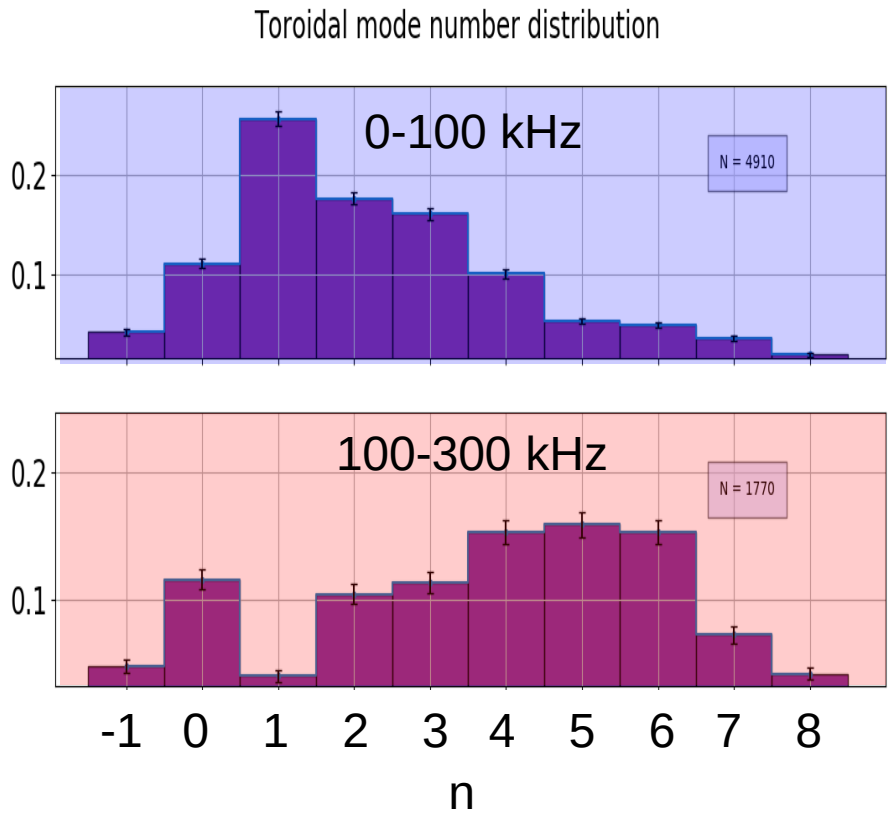
“Most unstable” mode numbers agree with theory, $n = aB_T Z_f e/q\sqrt{8E_f m_f} \sim 5$





Heidbrink 2002 Phys. of Plasmas 9

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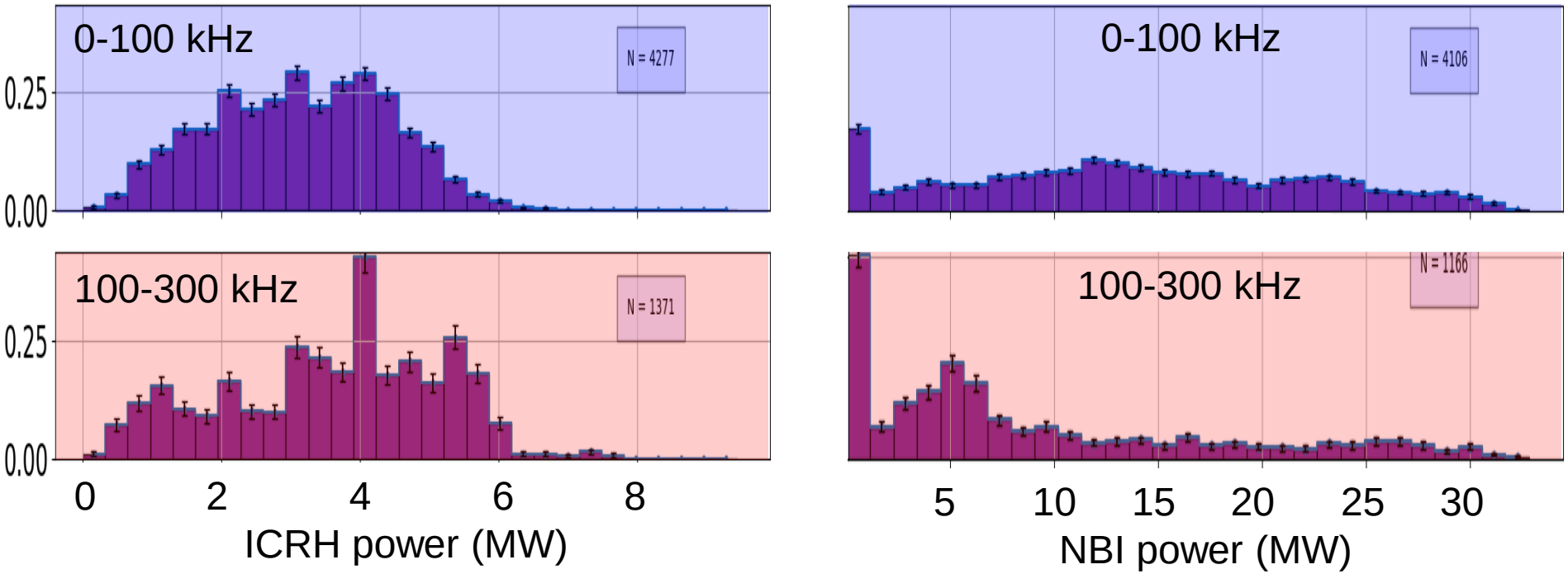
Increasing ICRH/NBI power tends to drive/damp high frequency modes



Summary and outlook

1. *Stable* Alfvén Eigenmodes
   - Databases assembled for H, D, T (and DT) plasmas
   - Radiative damping clearly identified in database and ohmic D plasma
     → Compute γ/ω_0 and compare with experiment
   - Collisional damping dominates in an ohmic T plasma
     → Analyze similar cases in H, D, and DT plasmas

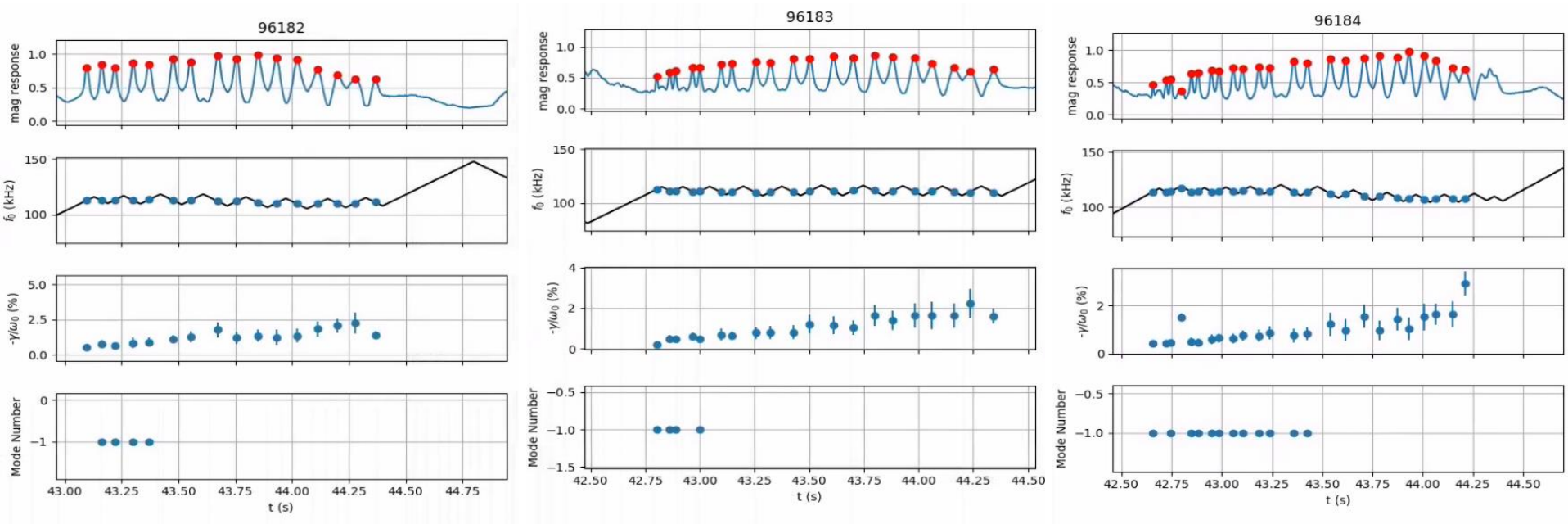
2. *Unstable* Alfvén Eigenmodes
   - Database assembled for D plasmas → Assemble for H, T, DT plasmas
   - Most unstable modes in the TAE frequency range are n ~ 4-6
   - Drive/damping of these modes increases with ICRH/NBI power

   → Much to explore in mode amplitudes, growth rates, fast ion losses,...

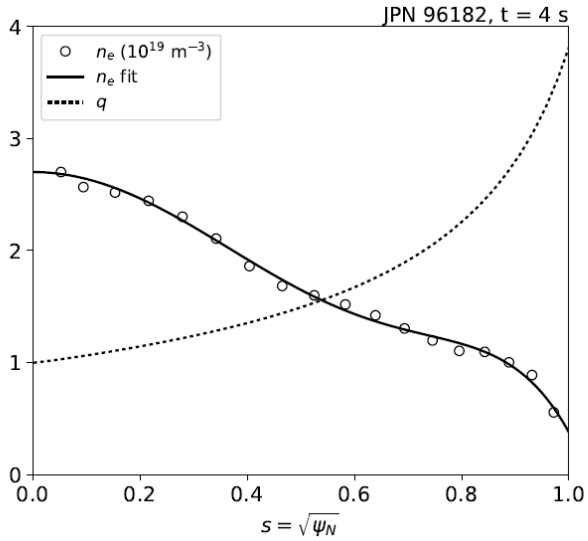
→ In high-performance DT plasmas, assess alpha contribution to drive

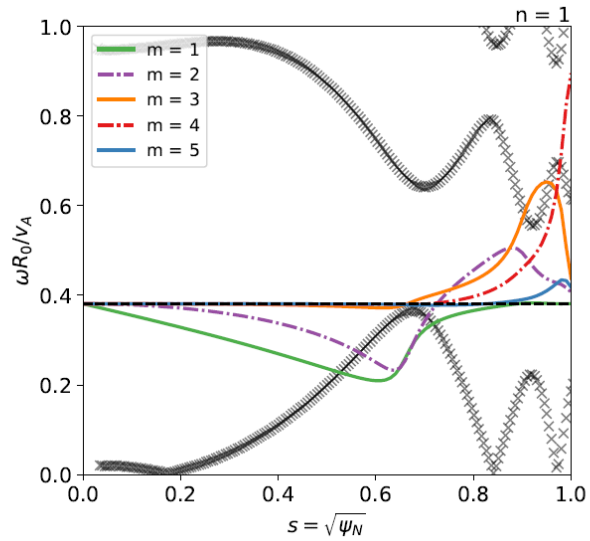
Bonus slides

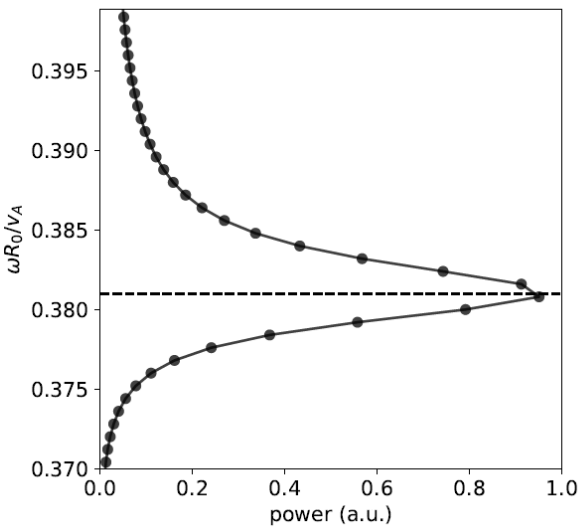
Clear example of radiative damping in JPN 96182-96184



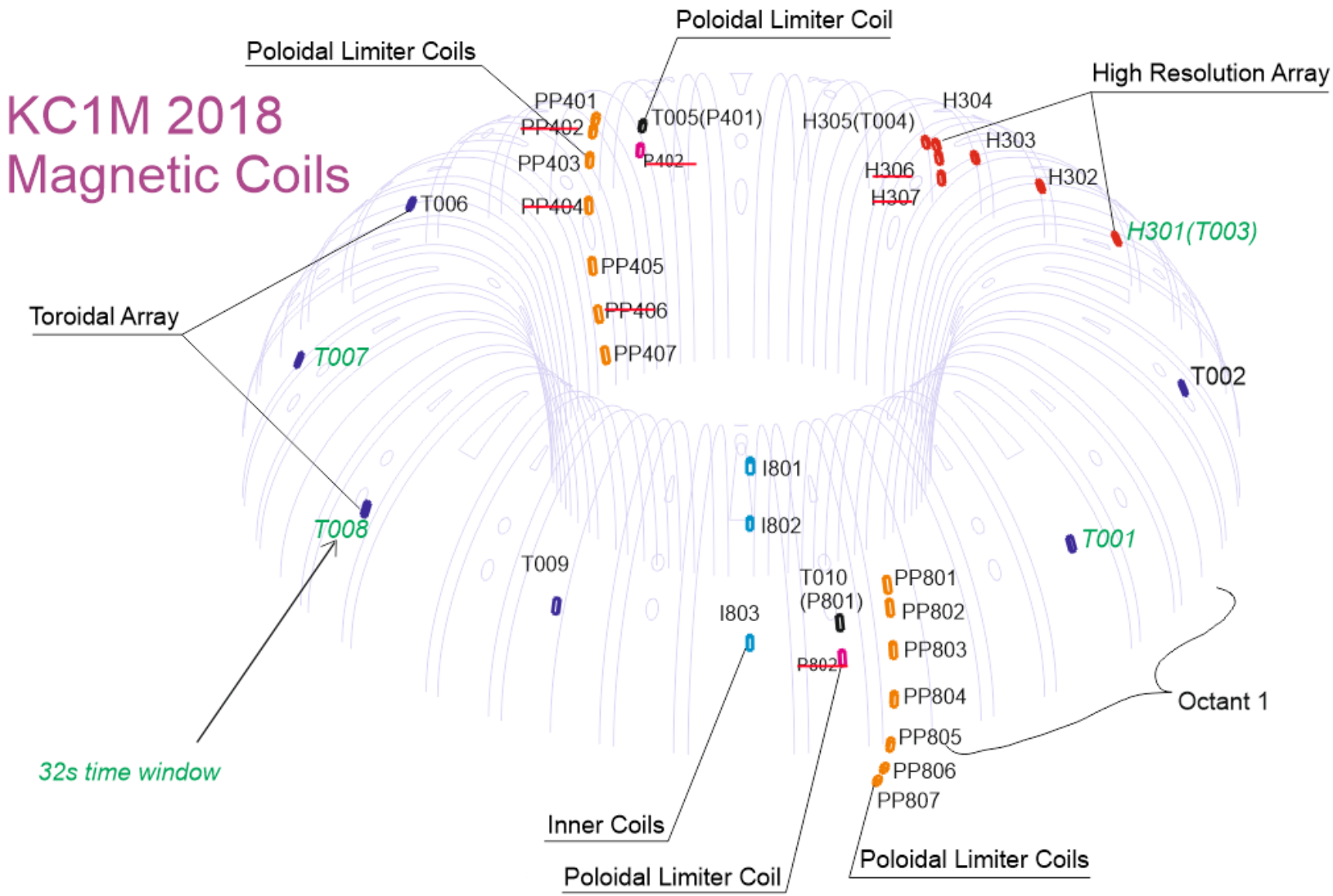
Confirmed by MHD modeling







21 fast magnetic probes used



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