Alfvén Eigenmode stability measurements in recent JET H, D, T, and DT plasmas

R.A. Tinguely *et al*

APS DPP, Wednesday, 10 November 2021

NO08: MFE: Research in Support of ITER

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With contributions from

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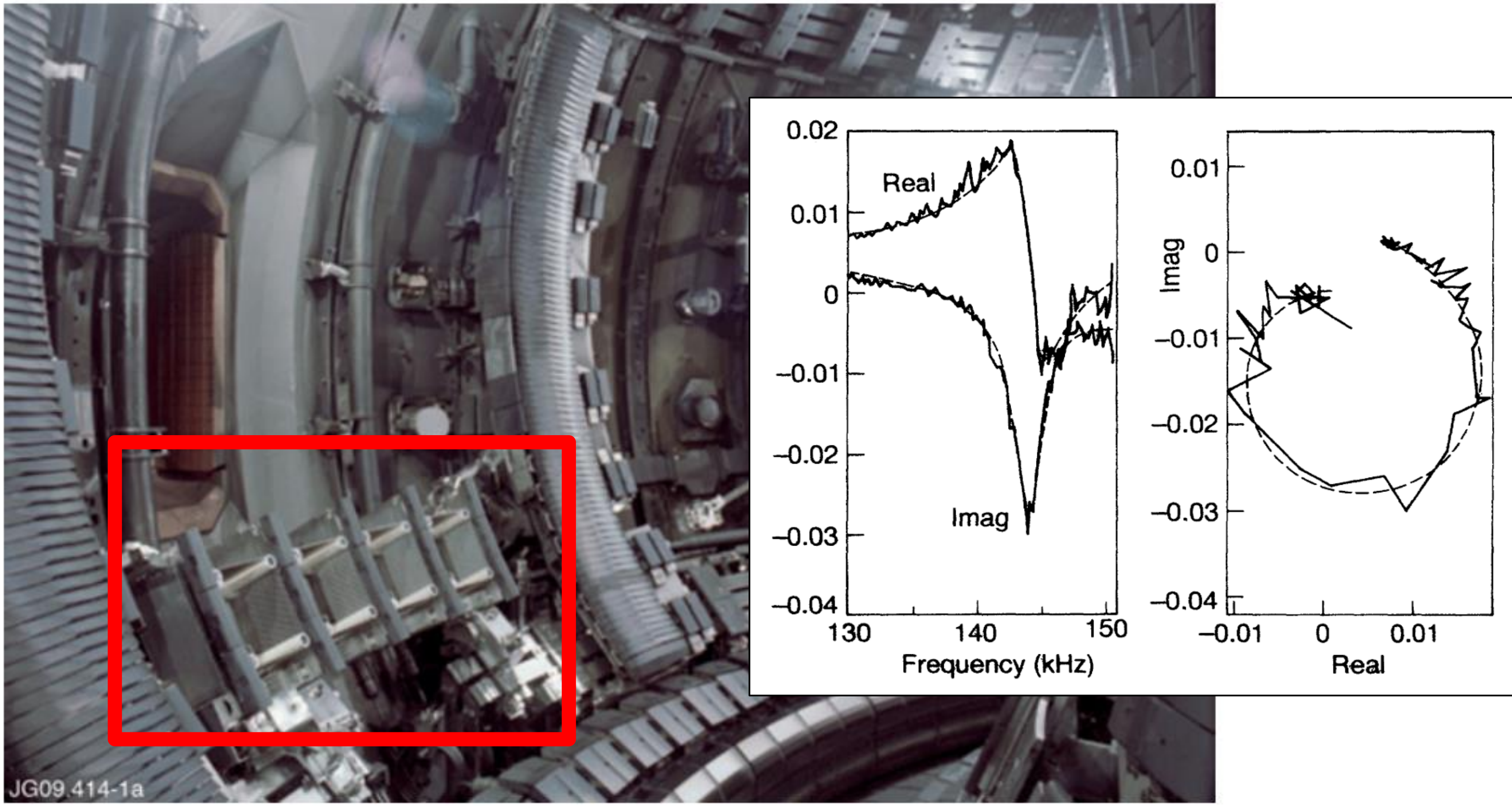
* See author list of J Mailloux et al “Overview of JET results for optimising ITER operation” to be published in Nuclear Fusion: Overview and Summary Papers from the 28th Fusion Energy Conference

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



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

A Fasoli 1995 Phys. Rev. Lett. 75

Goal: Improve predictions of fast ion drive and transport in future burning plasmas

1. **Validate simulations with experimentally measured damping rates**
   - Important for ITER Fusion Power Operations (FPO, D/T) with JET DT campaign ongoing
   - *Part 1: Simultaneous measurements of un/stable AEs in JET*

2. **Explore isotope effects on AE stability**
   - Important for ITER Pre-FPO (H/He) with JET He campaign planned for 2022
   - *Part 2: Big databases of AE stability from H, D, T, and DT plasmas*

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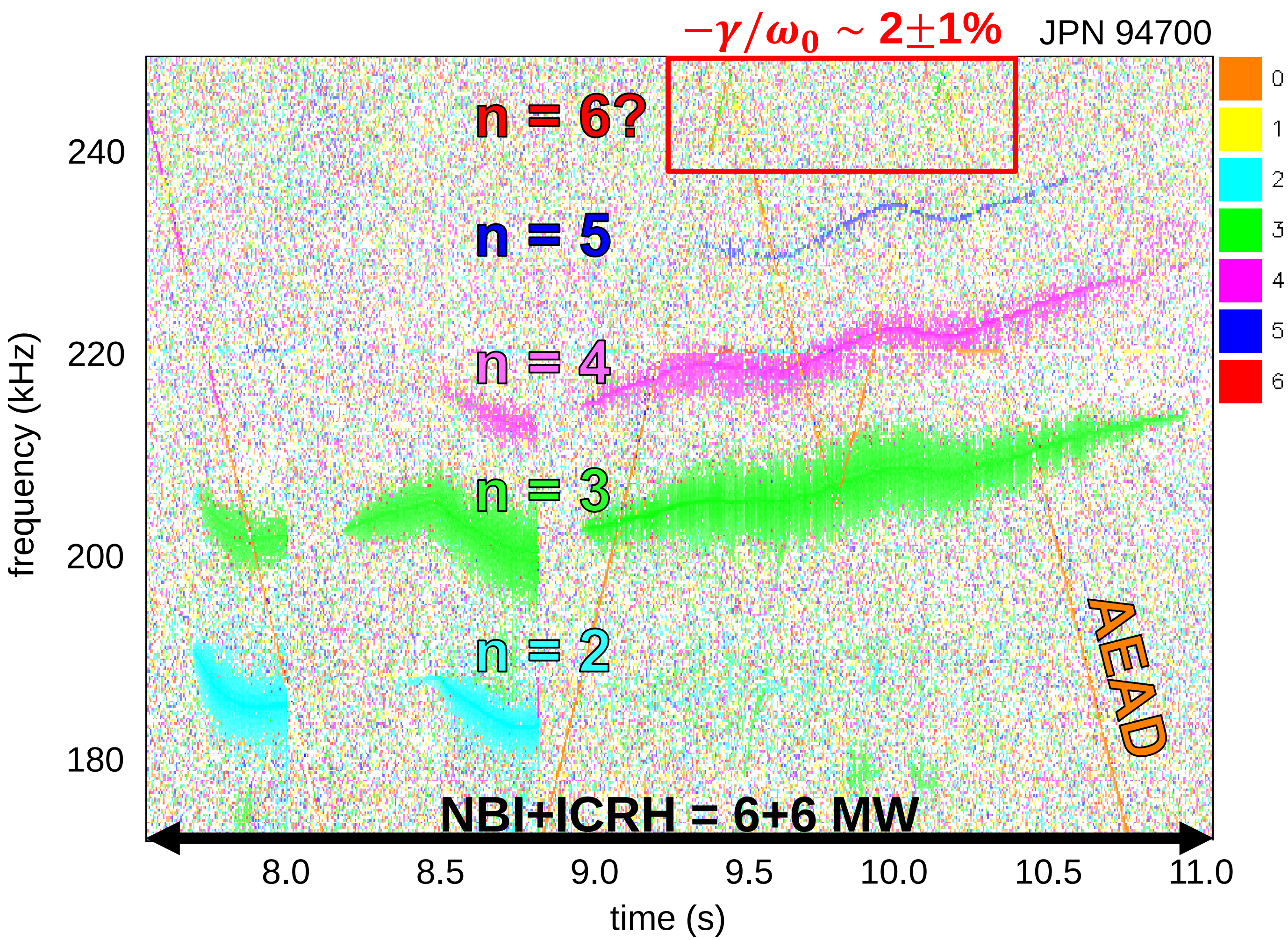
Simultaneously measured un/stable AEs during D-DNBI-^{3}He experiment ($n_{3He}/n_e \sim 27\%$)



Ye O Kazakov et al 2021 Phys. Plasmas 28

Kinetic-MHD code NOVA-K identifies AEs with similar frequencies (df < 10%) and growth rates

n	f_{lab} (kHz)		γ/ω_0 (%)	
	Exp	*Sim*	*Exp*	*Sim*
2	185	180	<0	+2.5
3	205	196	≫0	+1.6
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5	230	215	~0	-2.9
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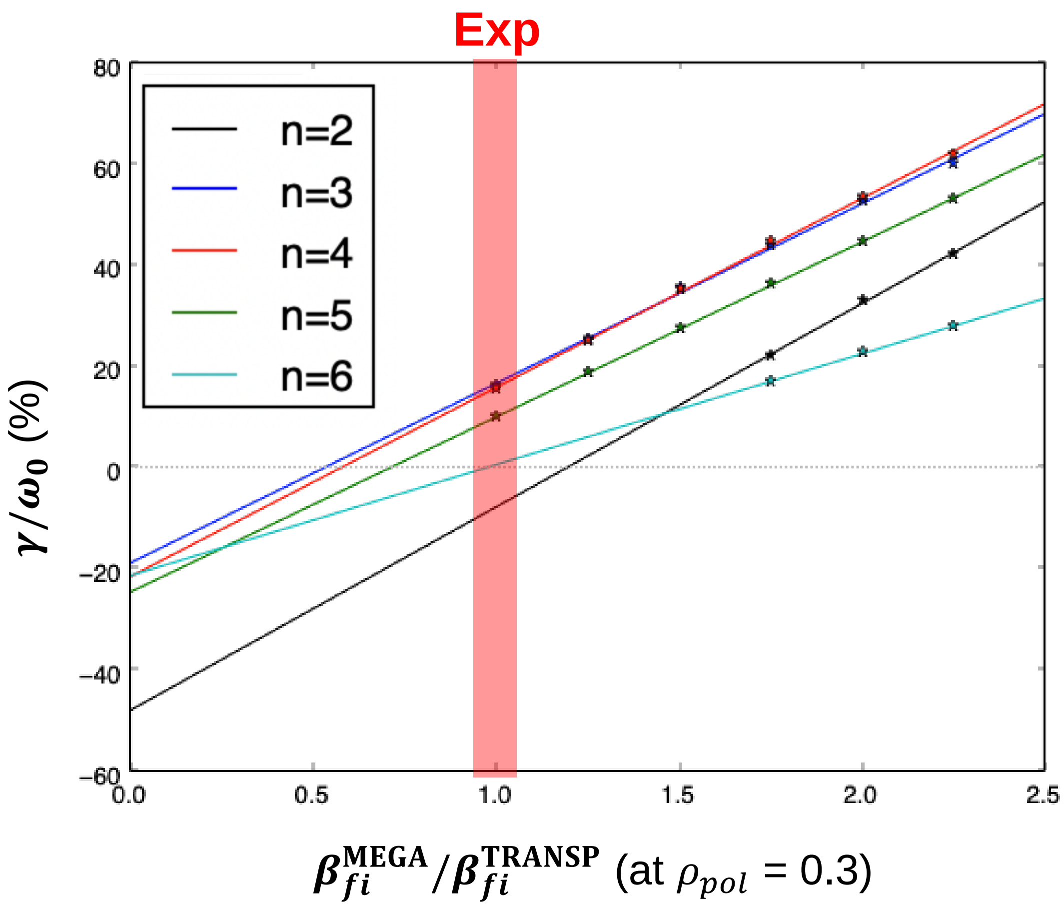
- Effective D-^{3}He density: TRANSP
- Rotation: charge exchange spectroscopy
- q-profile: EFIT + pressure + polarimetry
- Fast D ion distribution: NUBEAM + TORIC
    - NBI: Slowing down distribution
    - ICRH: Effective temperature

CZ Cheng 1992 Phys. Reports 211
GY Fu 1992 Phys. Fluids B: Plasma Phys. 4
NN Gorelenkov 1999 Phys. Plasmas 6

Hybrid MHD-kinetic code MEGA finds similarly driven n = 3-6 TAEs and stable n = 2 TAE



Y Todo 1998 Phys. Plasmas 5

NOTE: Fast ion distribution shifted radially outward

JET PSFC EPFL CCFE CULHAM CENTRE FOR FUSION ENERGY

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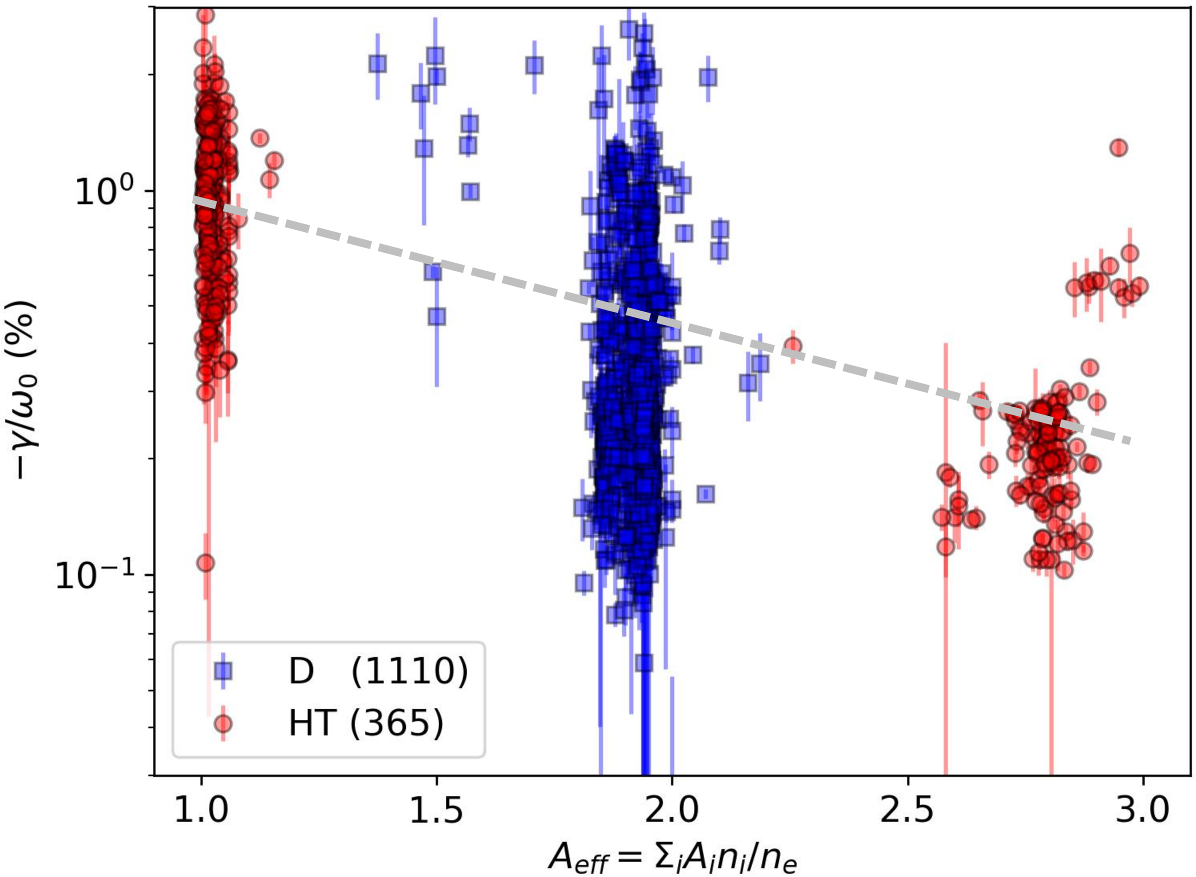
Damping decreases with effective mass → possible mode conversion to kinetic Alfvén waves



B_0	$\in$ [1,2.5] T
I_P	$\in$ [1,3] MA
P_{ICRH}	$\leq$ 1 MW
P_{NBI}	$\leq$ 1 MW

A Fasoli 2000 Phys. Lett. A 265
D Testa 2012 Nucl. Fusion 52
RA Tinguely 2021 EPS P4.1001

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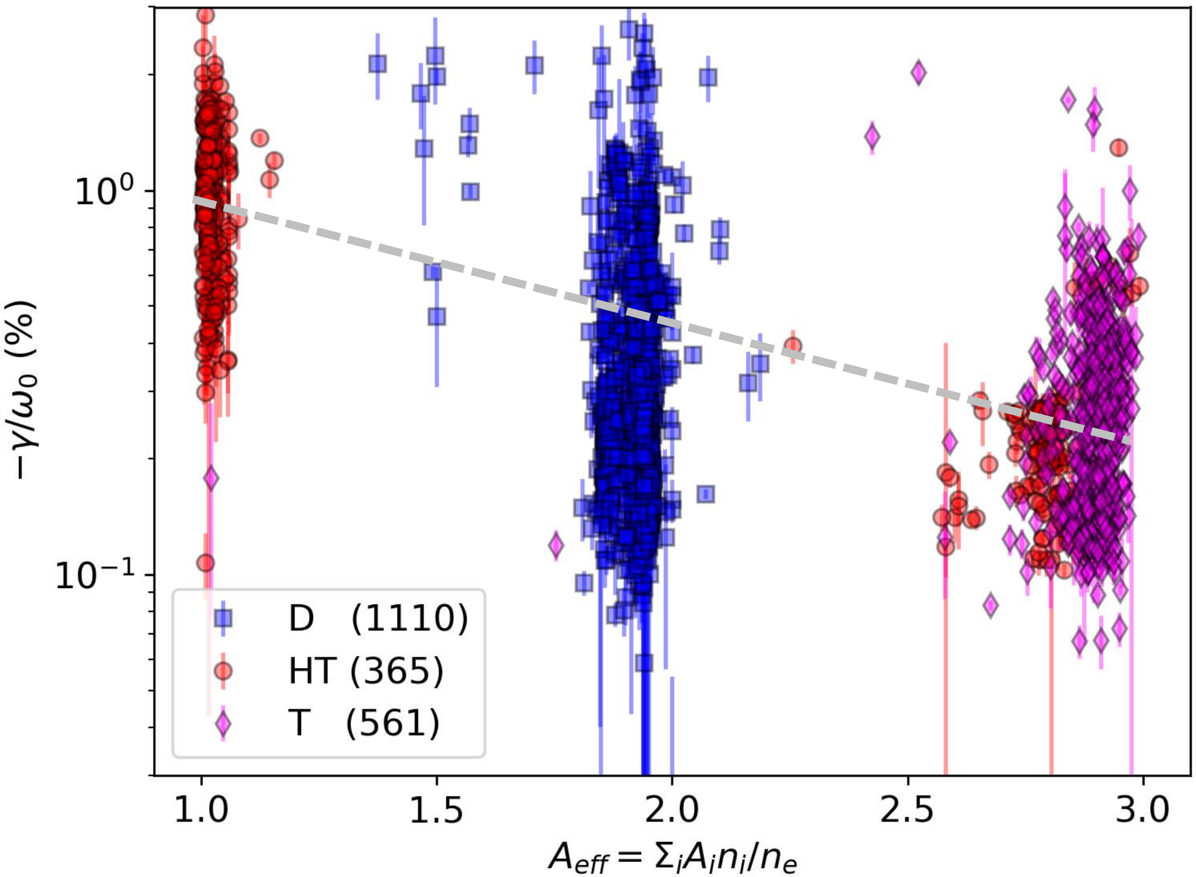

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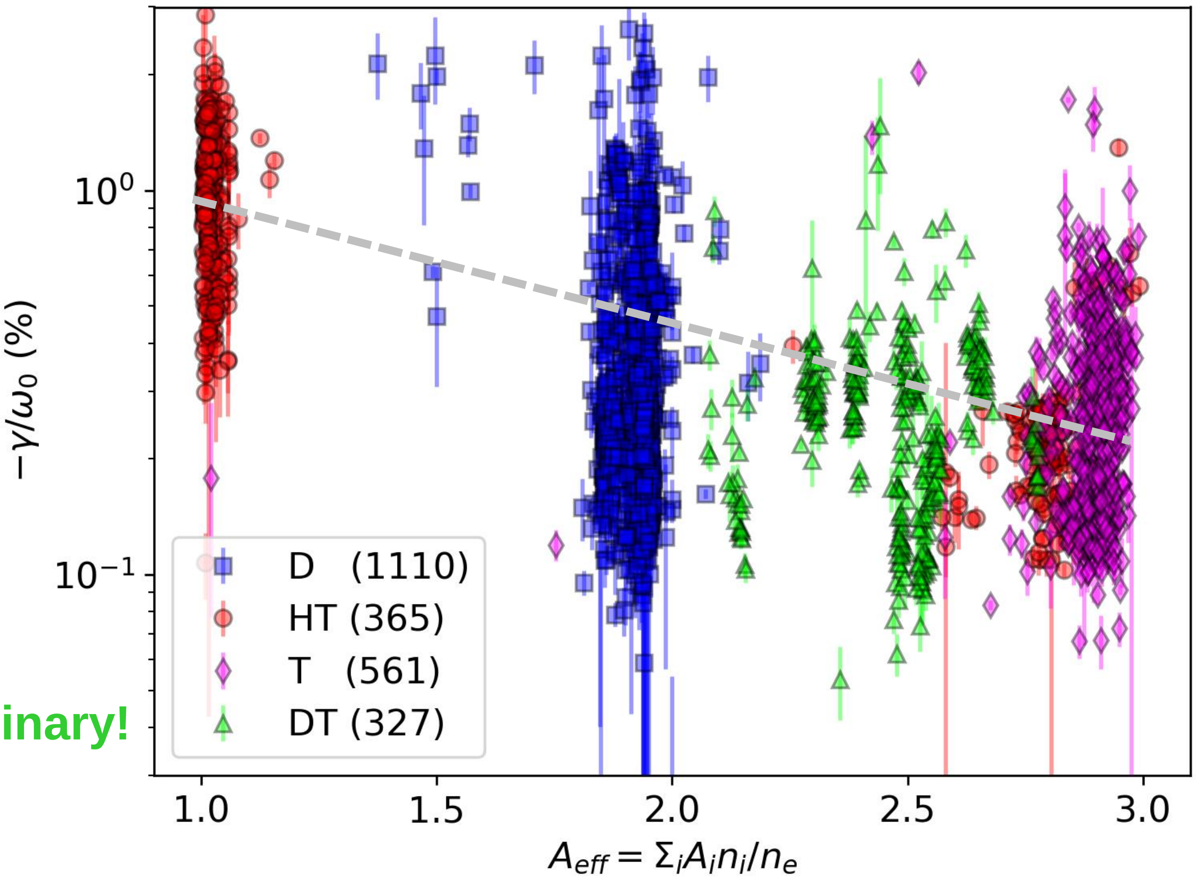

preliminary!

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Summary → outlook

- *Part 1: Simultaneous measurements of un/stable AEs in JET*
  - NOVA-K and MEGA simulations are in relatively good agreement with experimental measurements

  → Better understand competition between drive and damping

  → Explore fast ion-AE-micro/turbulence interactions with ORBIT, GTC

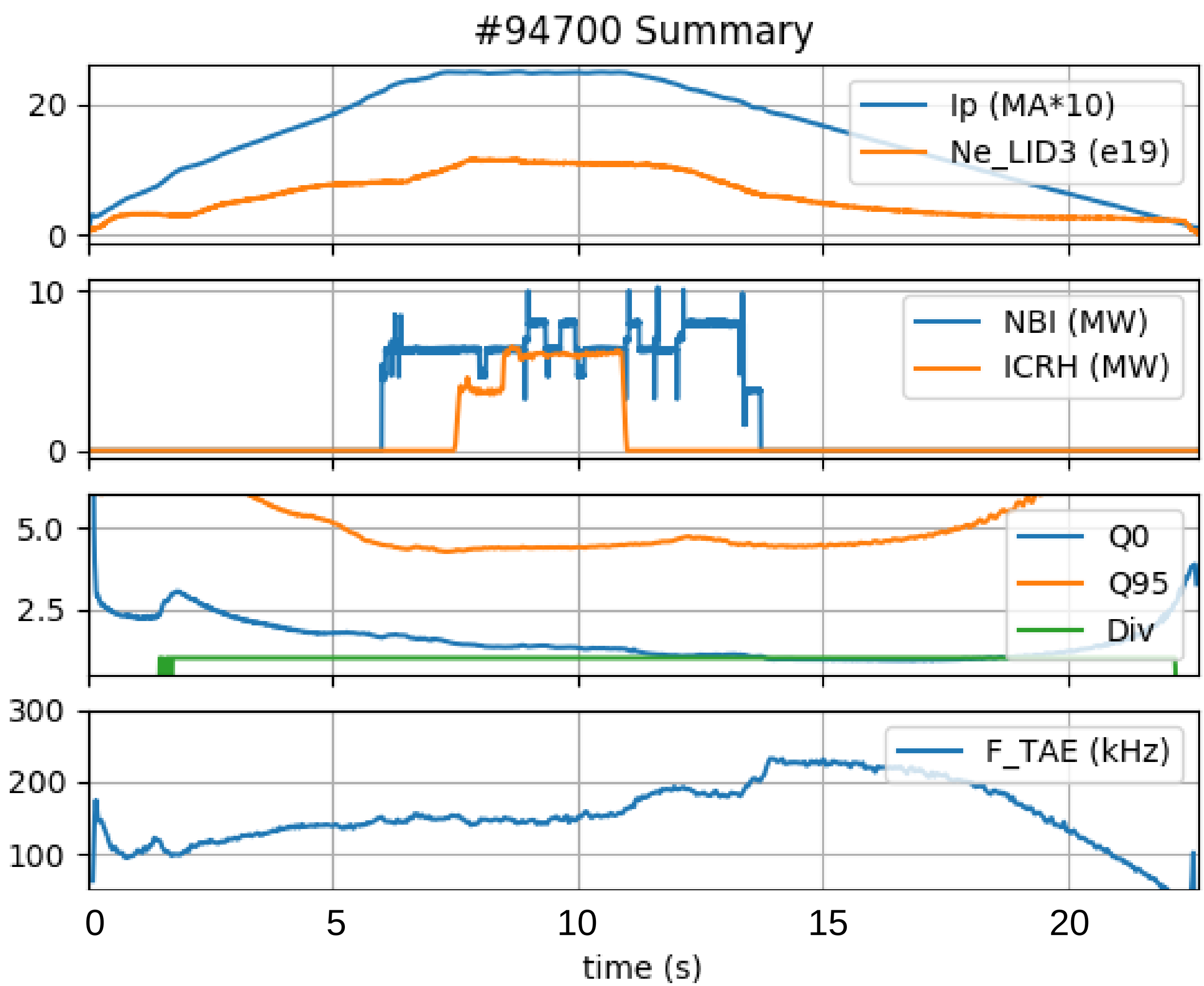
- *Part 2: Big databases of AE stability from H, D, T, and DT plasmas*
  - Hundreds of stable AEs have been detected in the recent T and ongoing DT campaigns
  - Similar trends are observed in the damping rate when considering kinetic and isotope effects

  → Identify and model similar H, D, T, and DT plasmas

ORBIT: RB White 1984 Phys. Fluids 27
GTC: Z Lin 1998 Science 281

Bonus slides

Plasma parameters for JPN 94700



JET PSFC EPFL CCFE CULHAM CENTRE FOR FUSION ENERGY

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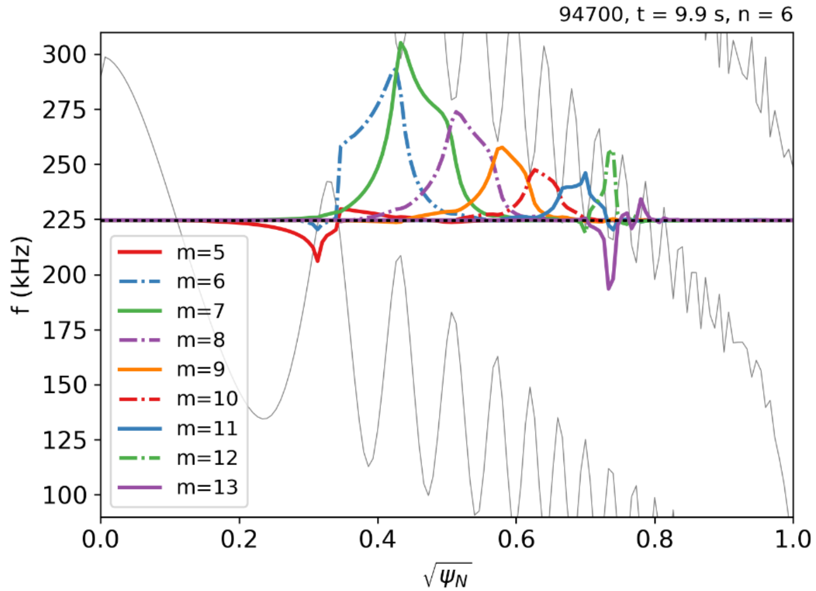

(dominated by radiative damping)

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- Rotation: charge exchange spectroscopy
- q-profile: EFIT + pressure + polarimetry
- Fast D ion distribution: NUBEAM + TORIC
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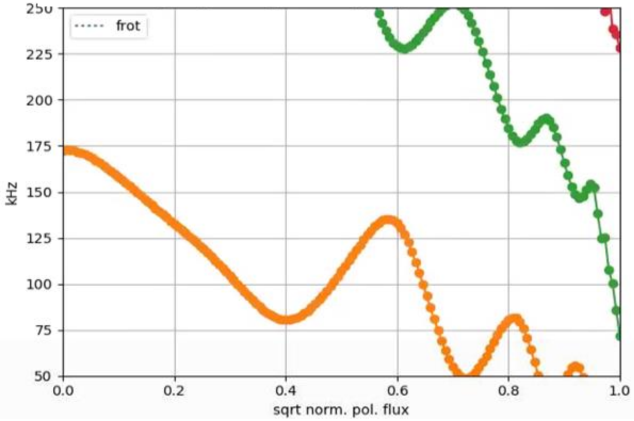
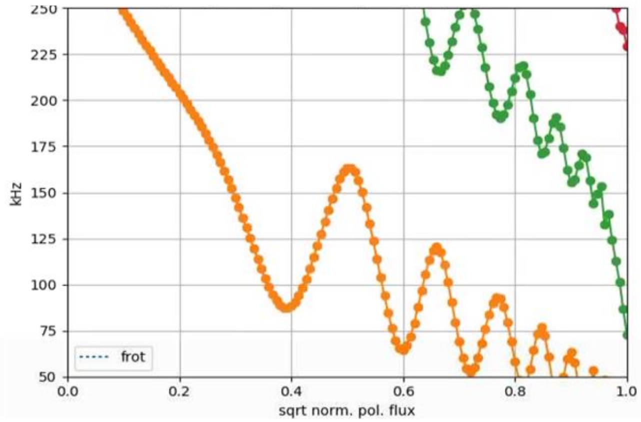
NOVA-K continua, n = 1-6
JPN 94700, t = 9.9 s

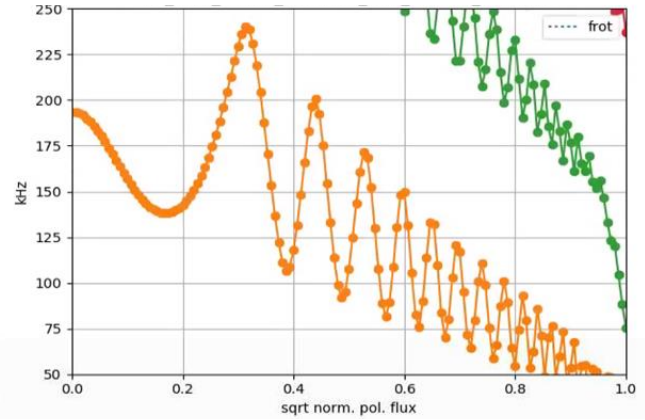
n = 1



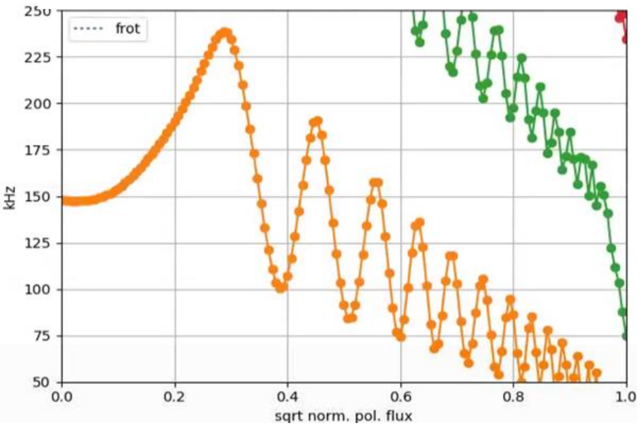
n = 2



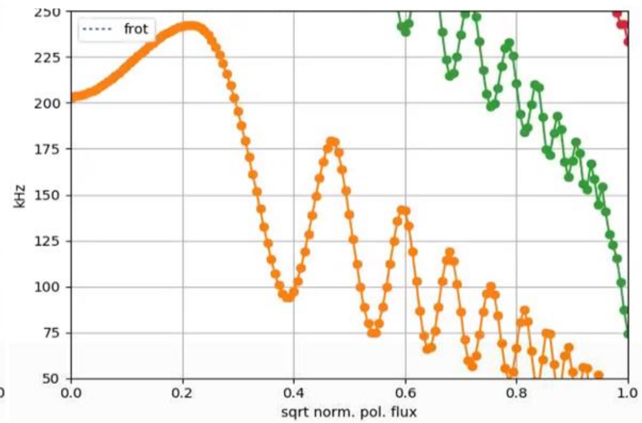
n = 3



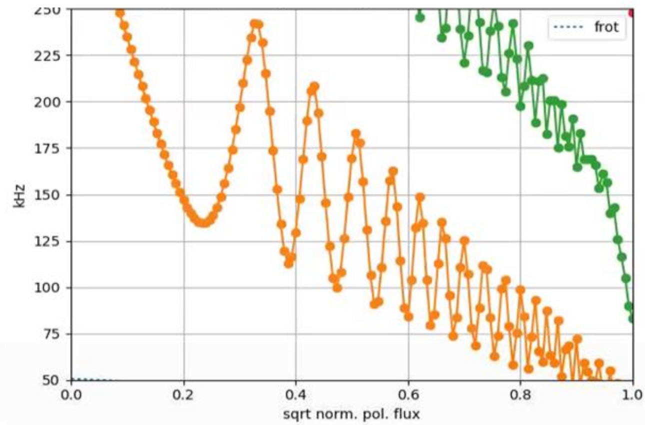
n = 4



n = 5

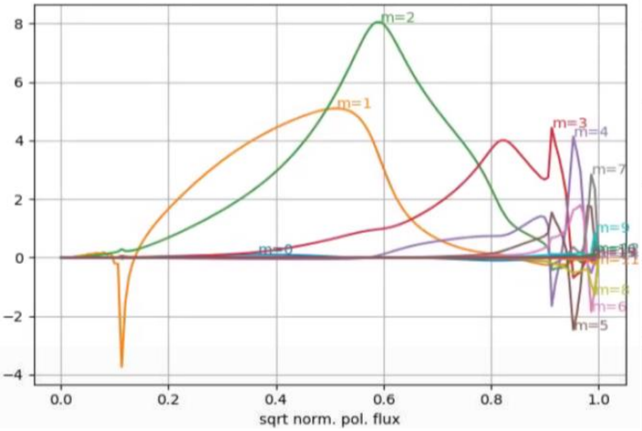


n = 6

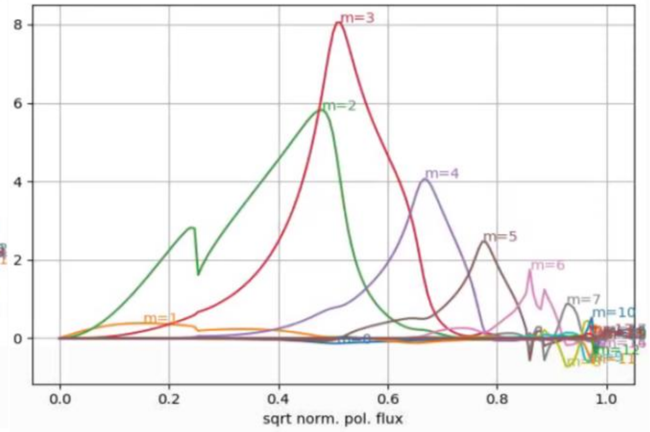


NOVA-K mode structures, n = 1-6
JPN 94700, t = 9.9 s

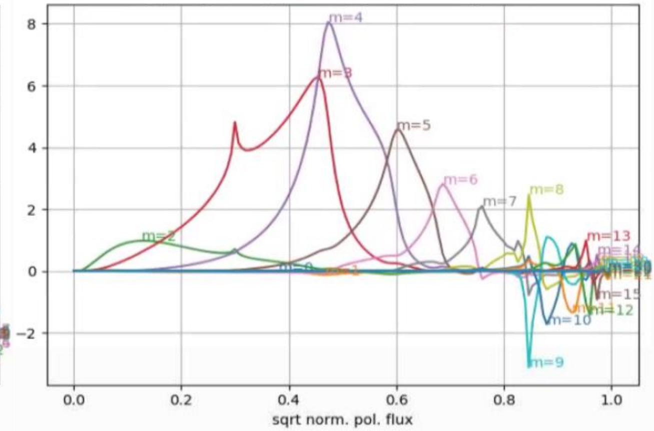
n = 1, f = 155 kHz



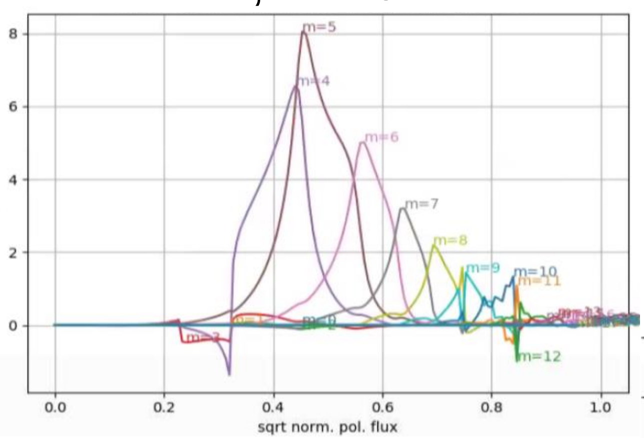
n = 2, f = 180 kHz



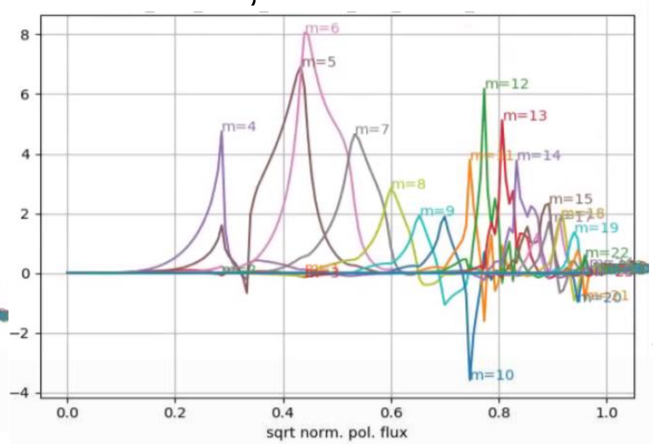
n = 3, f = 196 kHz



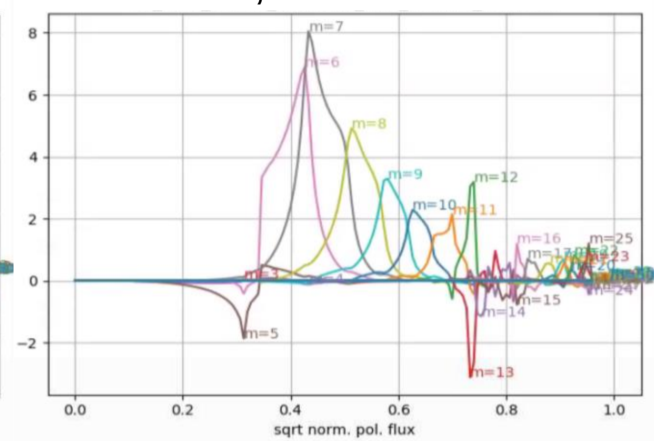
n = 4, f = 207 kHz



n = 5, f = 215 kHz



n = 6, f = 225 kHz



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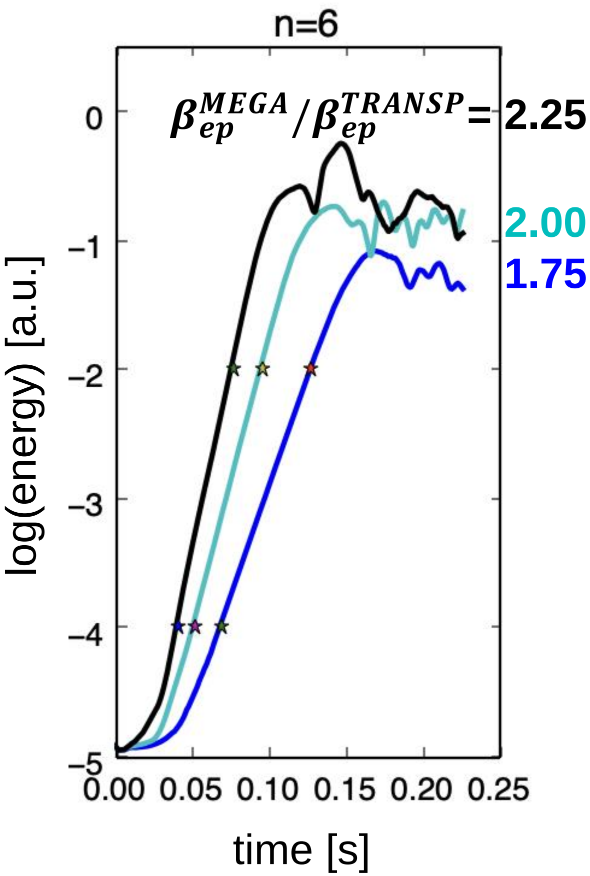
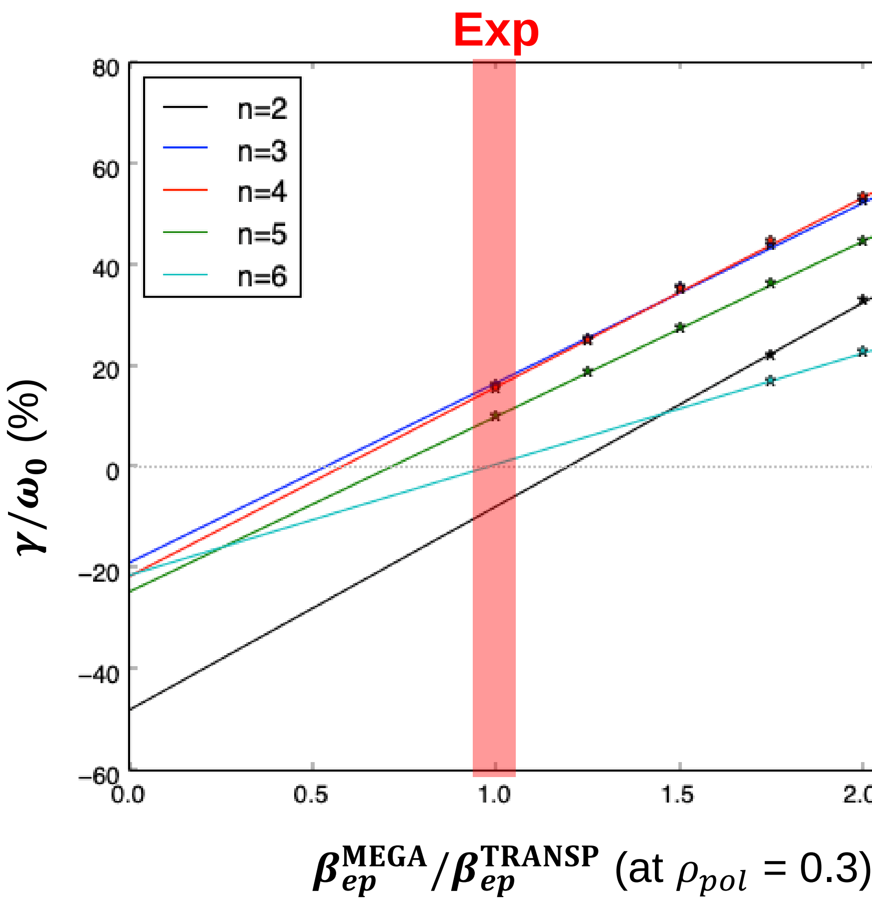


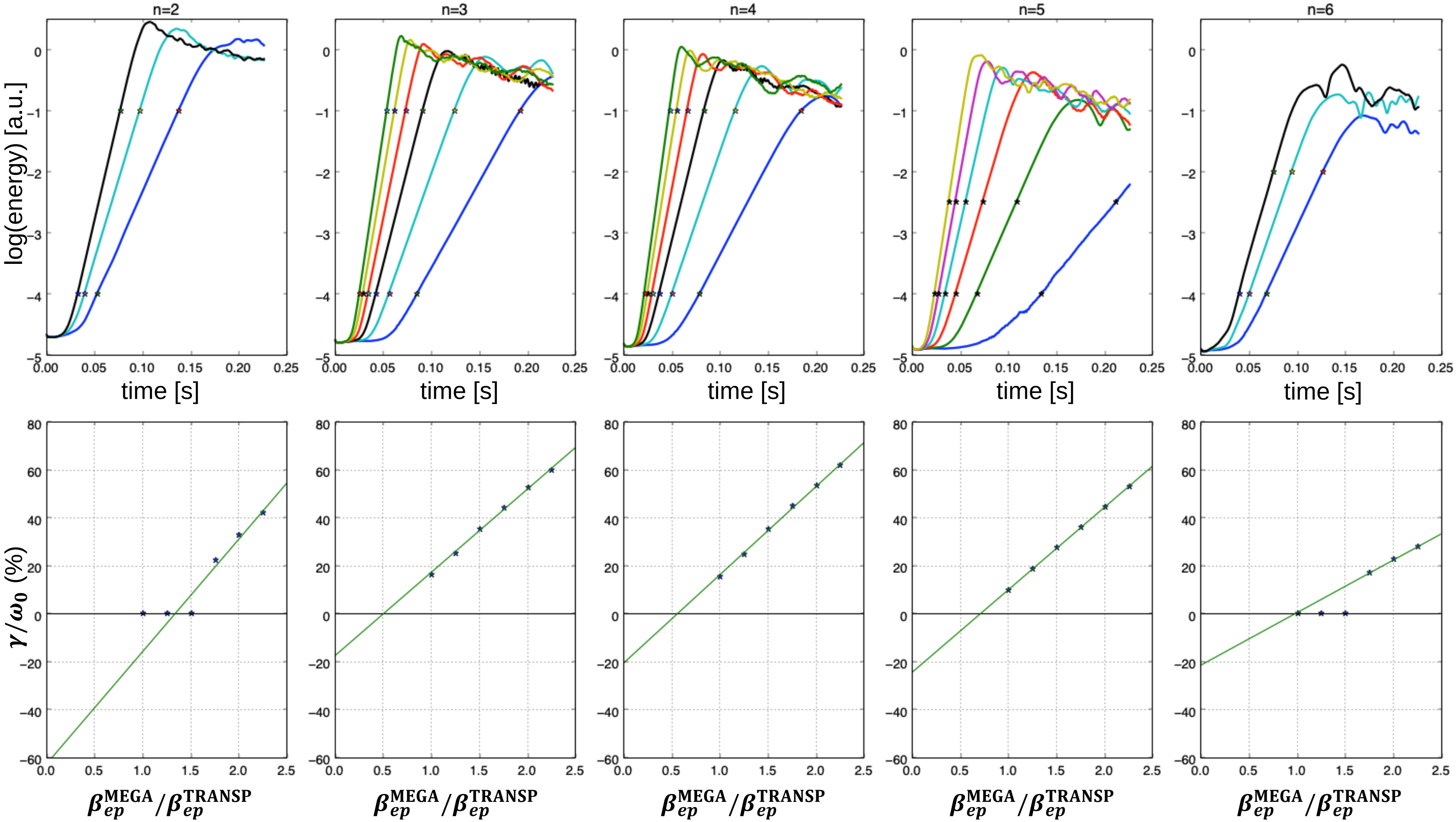


NOTE: Fast ion distribution shifted radially outward

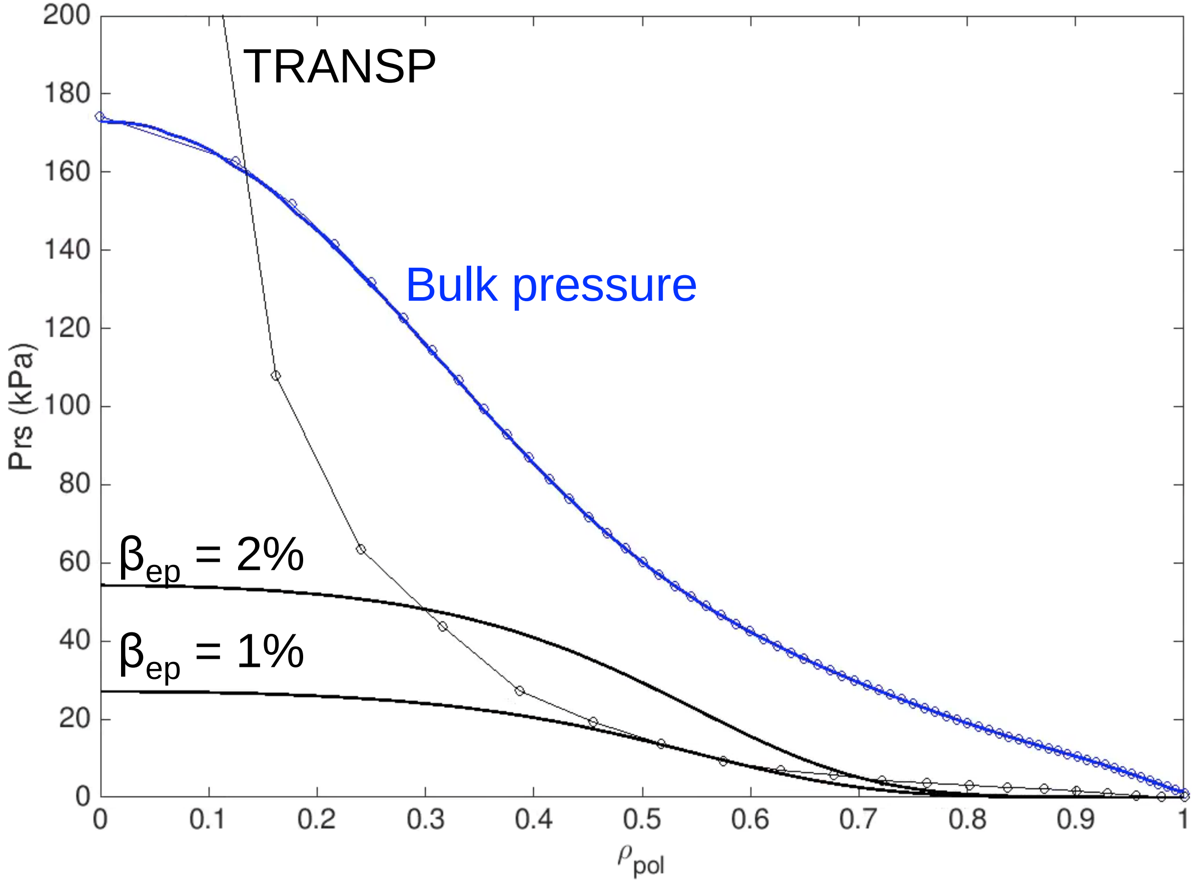
Y Todo 1998 Phys. Plasmas 5

MEGA scans of fast ion beta (norm. at ρ_{pol} = 0.3)

JPN 94700, t = 9.9 s



Fast ion distribution
JPN 94700, t = 9.9 s



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