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OVERVIEW OF ALPHA PARTICLE AND FAST ION STUDIES IN JET DTE2 PLASMAS

J. Garcia

CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France.

JET



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Contributors



¹R. DUMONT, ²Y. KAZAKOV, ³D. KEELING, ³M. FITZGERALD, ⁴P. MANTICA, ⁵M. NOCENTE, ³S. SHARAPOV, ⁶D. ZARZOSO, ⁷P. J. BONOFI GLO, ⁸R. COELHO, ⁹M. DREVAL, ³V. G. KIPTILY, ¹⁰E. de la LUNA, ¹S. MAZZI, ²J. ONGENA, ⁷M. PODESTA, ³Z. STANCAR, ¹¹R. A. TINGUELY, ¹²J. VARELA, ³C. MAGGI, ³J. MAILLOUX and JET CONTRIBUTORS^a

¹CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France.

²Laboratory for Plasma Physics, LPP-ERM/ KMS, TEC Partner, Brussels, Belgium

³UKAEA, Abingdon, United Kingdom

⁴Istituto per la Scienza e Tecnologia Dei Plasmi, Consiglio Nazionale Delle Ricerche, Milano, Italy

⁵Dipartimento di Fisica 'G. Occhialini', Università di Milano-Bicocca, Milano, Italy

⁶Aix-Marseille Université, CNRS, Centrale Marseille, M2P2 UMR 7340, Marseille, France

⁷Princeton Plasma Physics Laboratory, Princeton, NJ, United States

⁸Instituto de Plasmas e Fusao Nuclear, Instituto Superior Técnico, Universidade de Lisboa, 1049-001 Lisboa, Portugal.

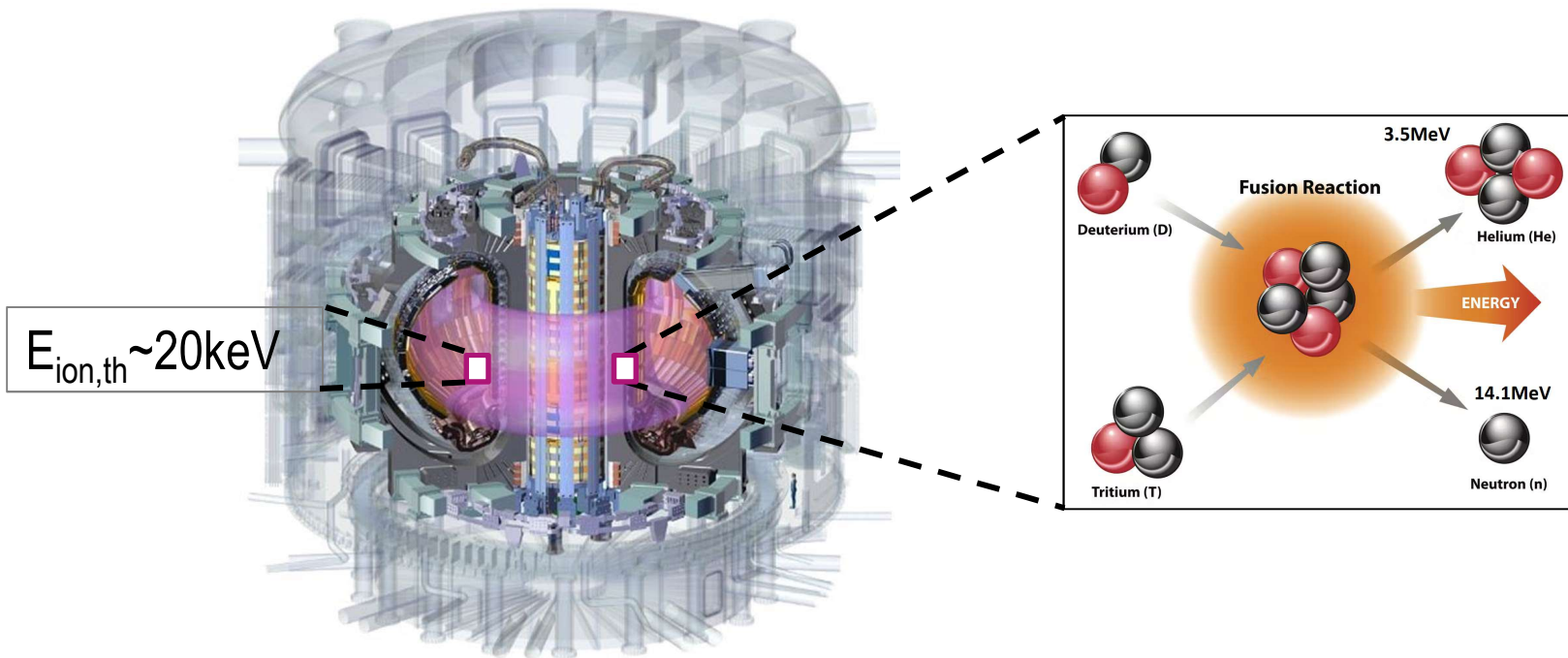
⁹Institute of Plasma Physics, National Science Center, Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine

¹⁰Laboratorio Nacional de Fusion, CIEMAT, 28040 Madrid, Spain

¹¹MIT Plasma Science and Fusion Center, Cambridge, USA

¹²Universidad Carlos III de Madrid, 28911 Leganes, Madrid, Spain

3.5MeV alpha particles: key pillar for fusion energy production by plasmas

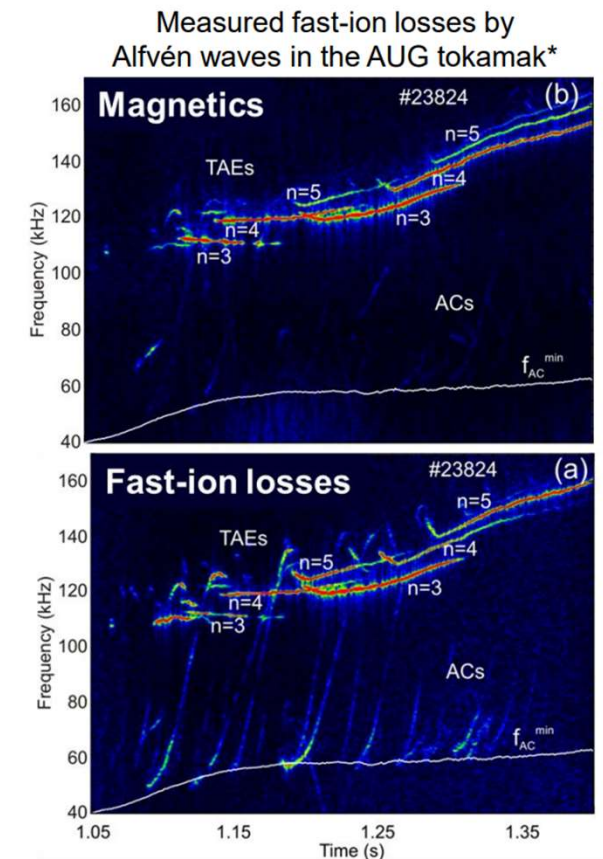


- Fusion produced **3.5MeV alpha particles** → **self heating of plasmas** through collisions
- Presence of T and α particles → Significant differences compared to D plasmas

Impact of α 's in DT burning plasmas



- α 's can interact with Alfvén waves \rightarrow α transport and losses

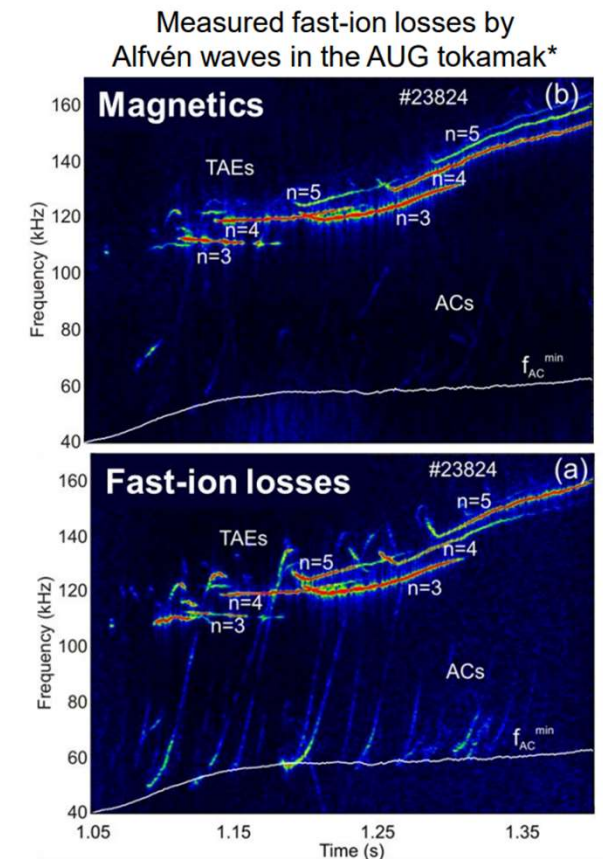


[M. Garcia-Munoz PRL (10)]

Impact of α 's in DT burning plasmas



- α 's can interact with Alfvén waves \rightarrow α transport and losses
- α 's transfer energy mostly to electrons by collisions \rightarrow High electron heating

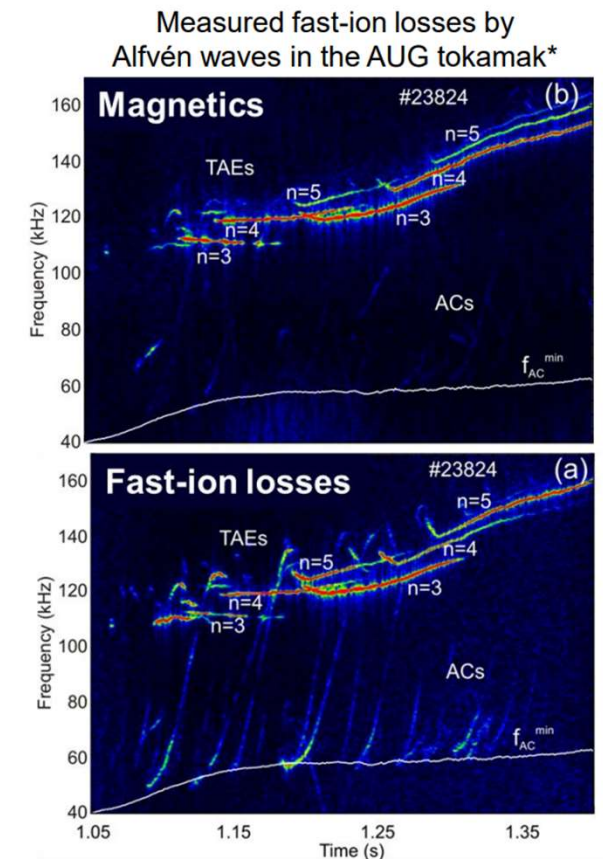


[M. Garcia-Munoz PRL (10)]

Impact of α 's in DT burning plasmas



- α 's can interact with Alfvén waves \rightarrow α transport and losses
- α 's transfer energy mostly to electrons by collisions \rightarrow High electron heating
- α 's do not provide significant torque \rightarrow Low rotation



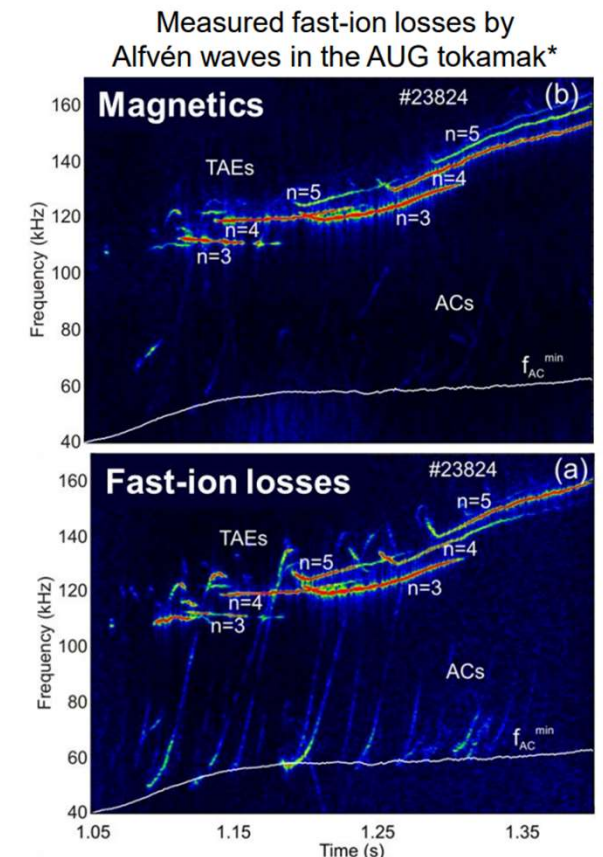
[M. Garcia-Munoz PRL (10)]

Impact of α 's in DT burning plasmas



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Potential negative plasma conditions



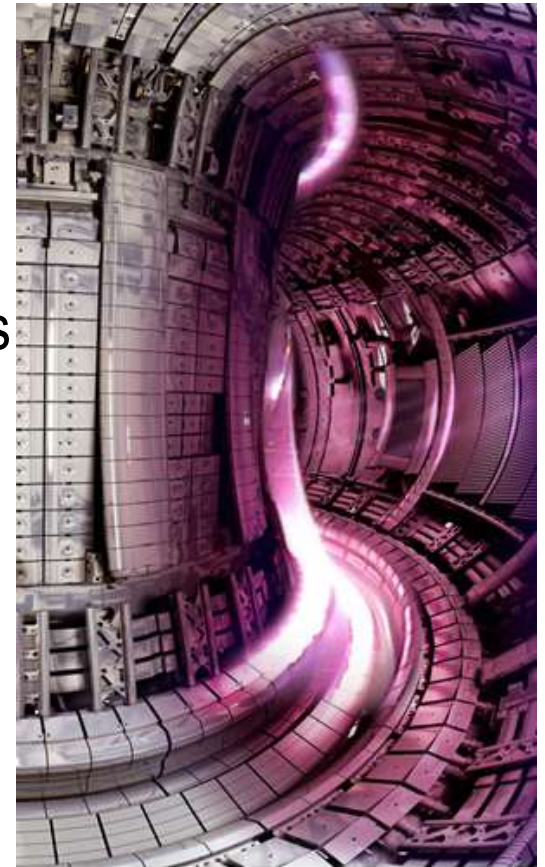
[M. Garcia-Munoz PRL (10)]

JET-DTE2: key α particle and fast ions studies



Exploration of DT key physics towards the tokamak reactor

- Alfvén eigenmodes destabilization
- α particle heating
- Low torque, high electron heated plasmas with MeV ions
- α particle losses



JET-DTE2: key α particle and fast ions studies

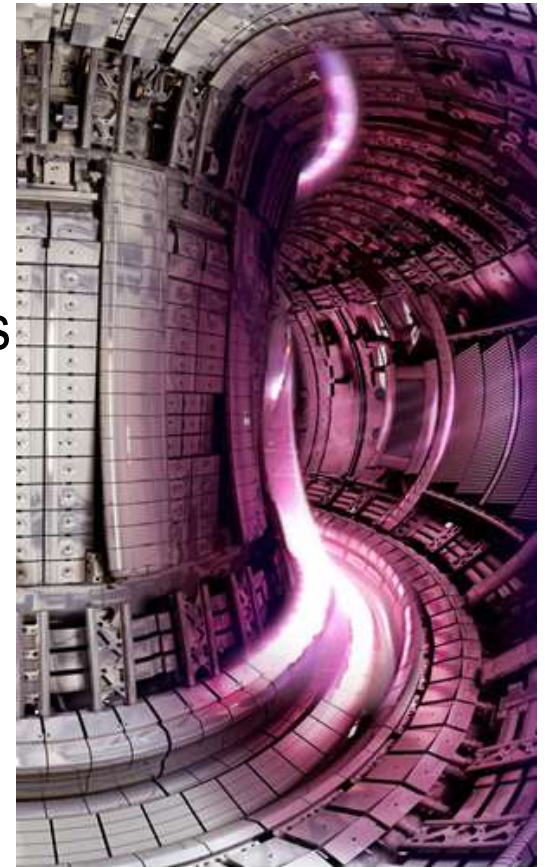


Exploration of DT key physics towards the tokamak reactor

- Alfvén eigenmodes destabilization
- α particle heating
- Low torque, high electron heated plasmas with MeV ions
- α particle losses

Improved capabilities compared to DTE1:

- Better fast ion diagnostics
- More heating power
- Sophisticated Modelling



Outline

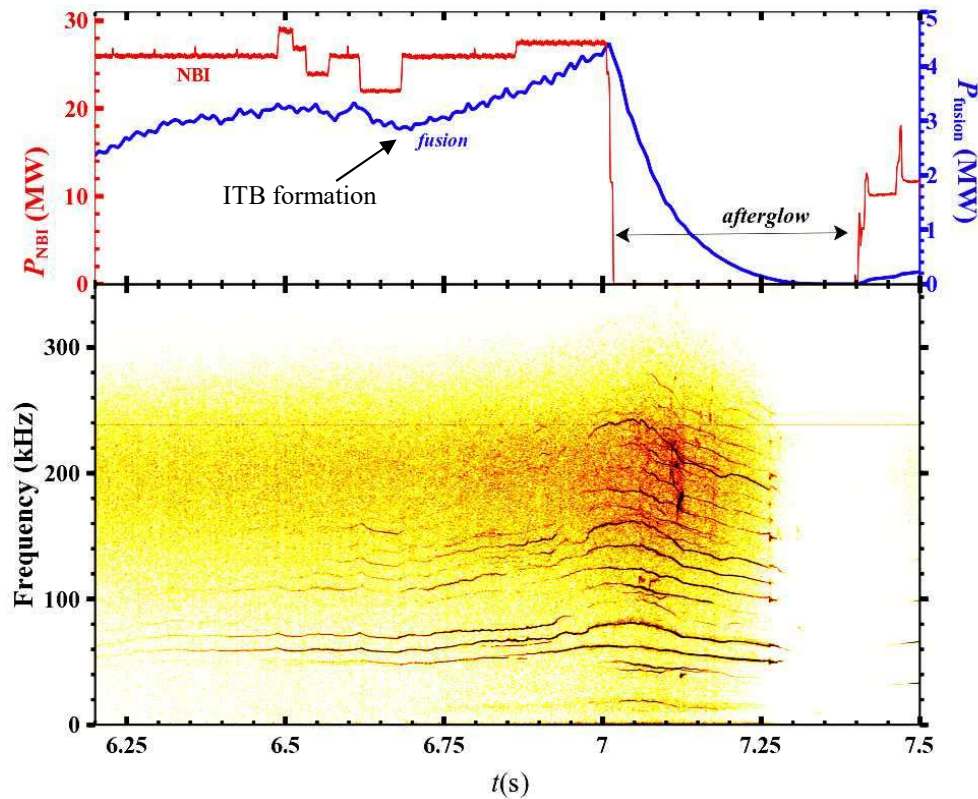


- Alfvén activity destabilized by α particles
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- Conclusions

Afterglow plasmas developed



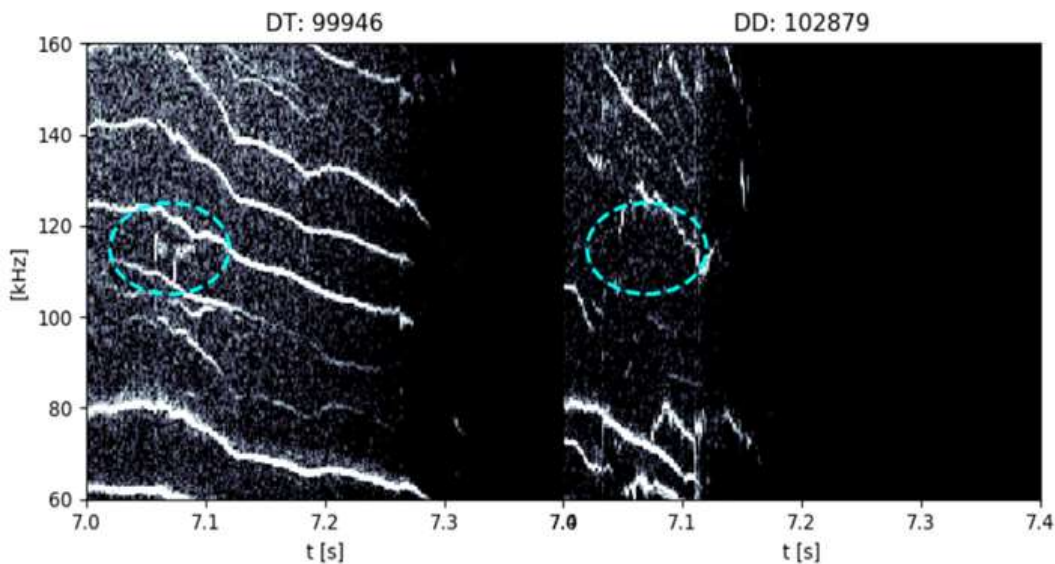
#99946 $I_p=2.9\text{MA}$, $B_t=3.45\text{T}$



[Fitzgerald NF 23]

- TAE generation by α studied in **afterglow scenario**
- Scenario previously performed in TFTR [Nazikian PRL 97]
- ITB developed at $q_0 \sim 2$ before the afterglow

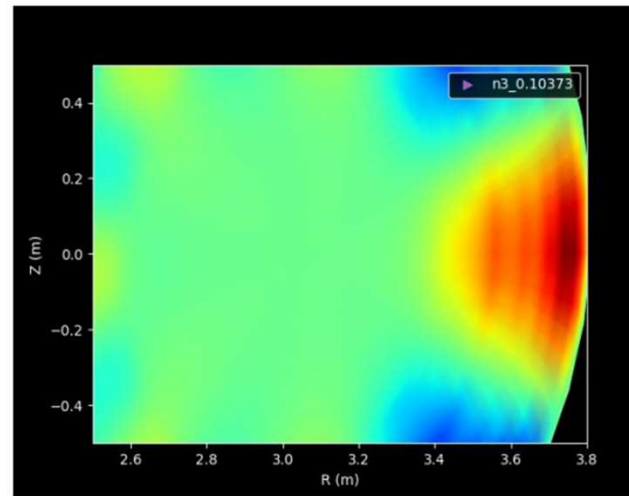
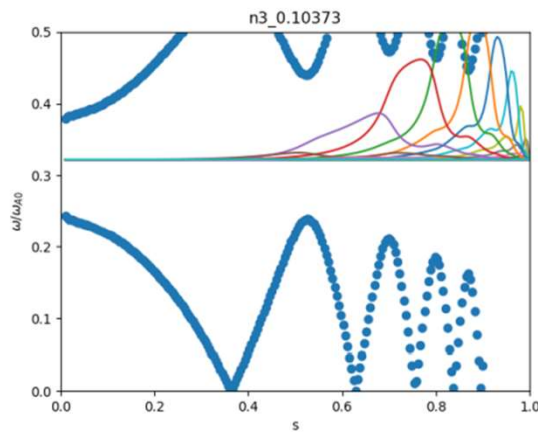
High frequency perturbations in afterglow plasmas



- TAE generation by α studied in **afterglow scenario**
- Scenario previously performed in TFTR [Nazikian PRL 97]
- ITB developed at $q_0 \sim 2$ before the afterglow
- **DT vs D: clear differences in high frequency perturbations**

[Fitzgerald NF 23]

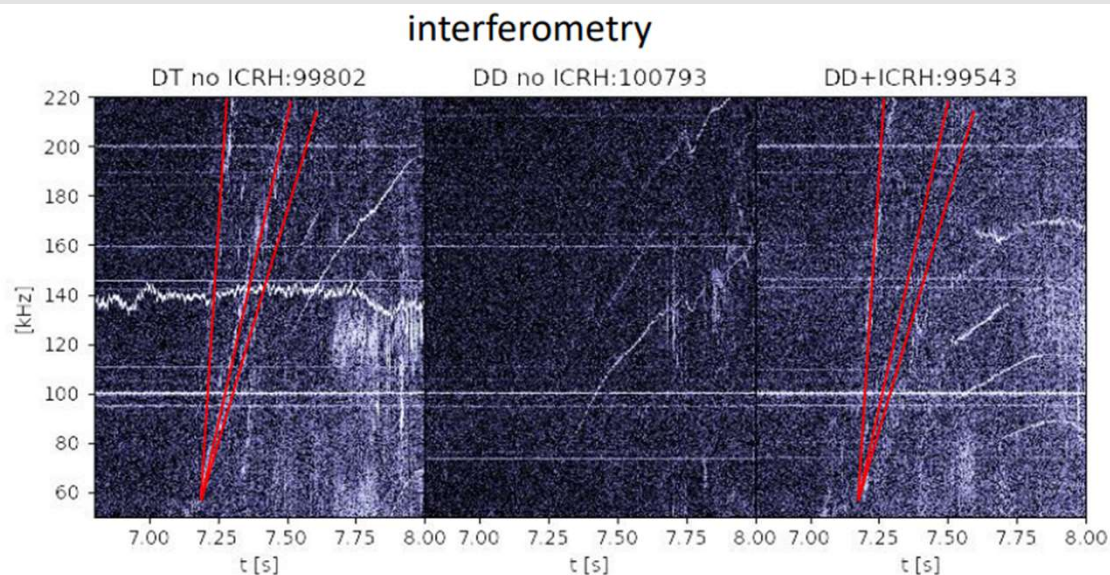
TAE mode identification in afterglow plasmas



[Fitzgerald NF 23]

- Identification of mode performed with MISHKA and HALO codes
- **n=3 TAE destabilized by α 's** compatible with mode observed
- Precessional motion of alphas resonates with the toroidal phase velocity of TAE

Alfvén cascades in afterglow plasmas

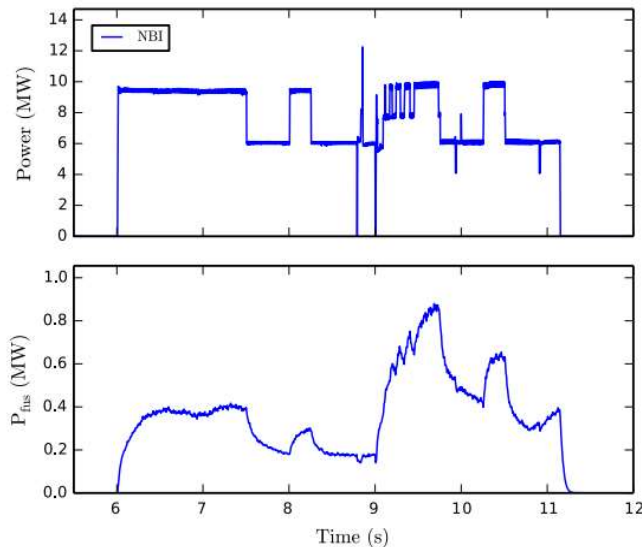


- Afterglow performed in $q_0 \sim 1$ scenario with $P_{fus} \sim 11 \text{ MW}$
- Alfvén cascades in DT (without ICRH) and D (with ICRH)
- Strong indication of α driven instabilities

Alternative route to destabilize α driven modes



#99500 $I_p=2.5\text{MA}$, $B_t=3.7\text{T}$



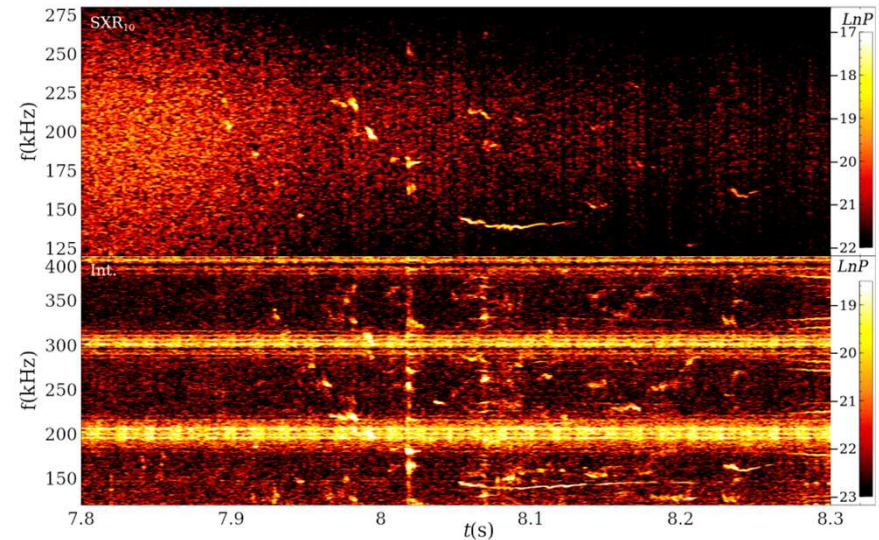
[Sharapov NF 23]

[Oliver NF 23]

[Sharapov this conference

#2305]

- NBI modulation in DT plasmas \rightarrow **Bump-on Tail α distribution** $\frac{\partial f}{\partial E} > 0$
- On axis, $\rho \sim 0.2$, high frequency perturbations not observed in D
- Possible candidates: **kinetic Alfvén waves (KAW)**



Outline

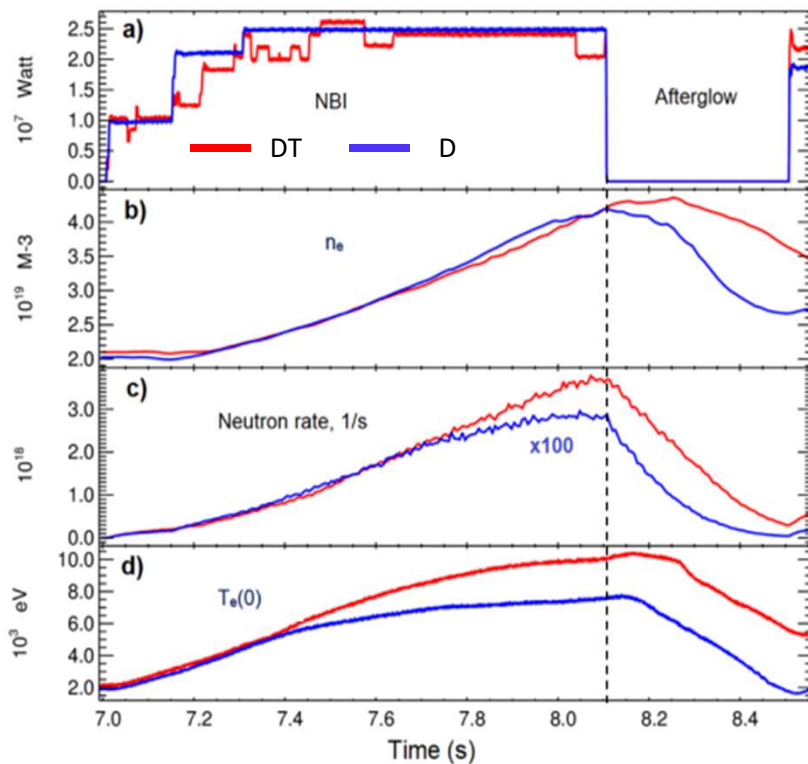


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Afterglow scenario used to demonstrate alpha heating



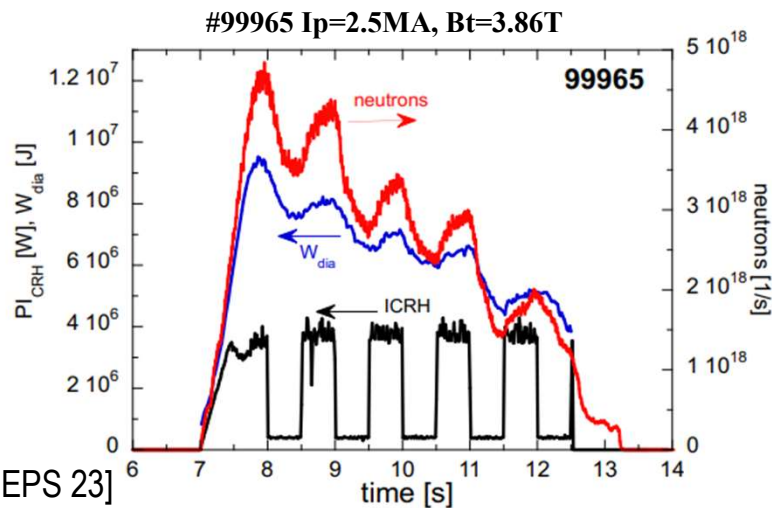
#99801, #100793 $I_p=2.3\text{MA}$, $B_t=3.45\text{T}$



[Kiptily PRL 23] [Kiptily this conference #1836]

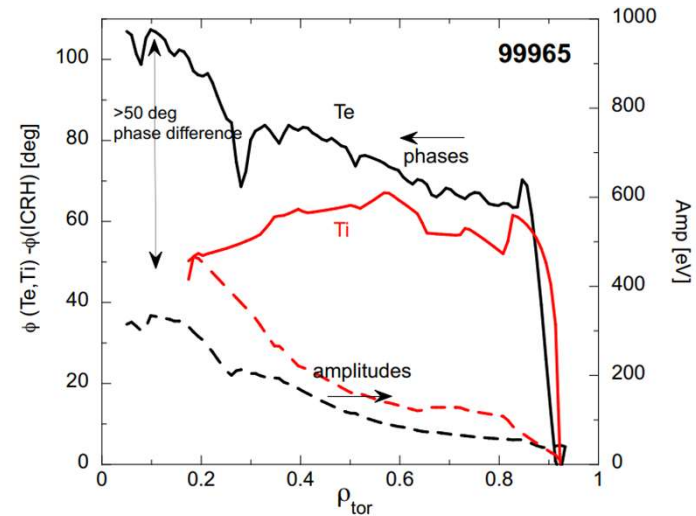
- Afterglow scenario \rightarrow α 's slowing down time longer than NBI ions
- Different T_e evolution in DT and D \rightarrow **α heating**
- Further evidence of α electron heating obtained in gyrokinetic simulations [Disiena this conference #1892]

α power modulation and electron heating



[Casiraghi EPS 23]

[Mantica this conference #1774]



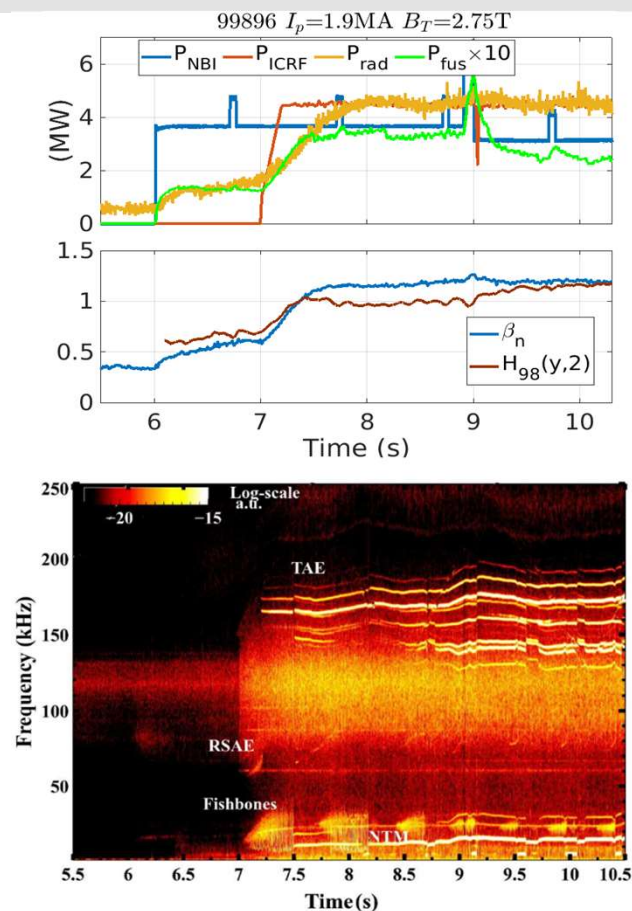
- ICRH modulation performed \rightarrow α modulation
- High phase delay between T_e and T_i time evolution
- Indication of α heating to the electrons

Outline



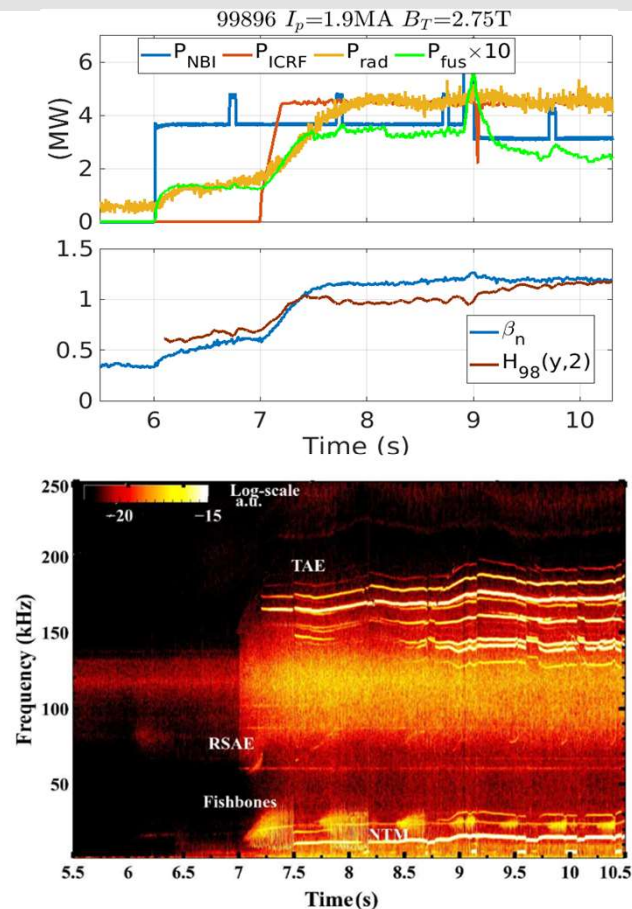
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Exploration of core burning plasmas characteristics



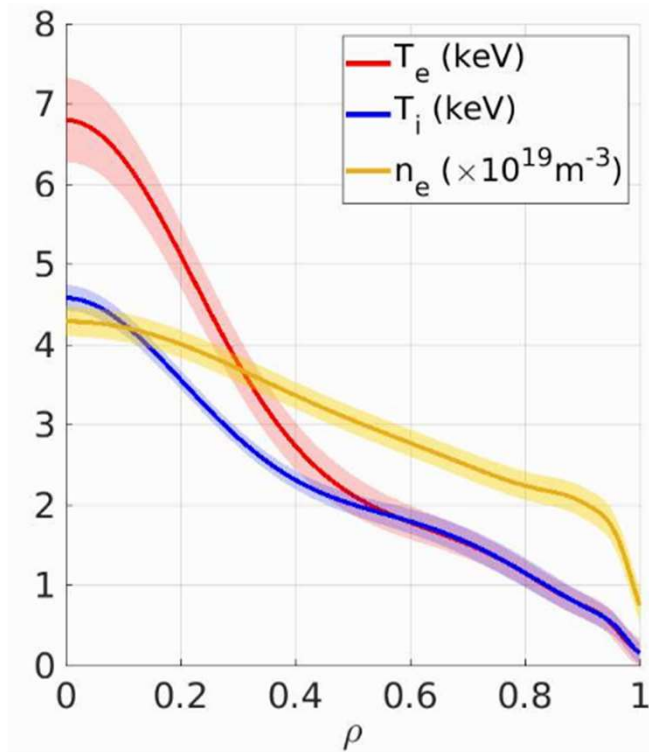
- DT plasmas explored in **core ITER relevant conditions**:
 - High heating fraction to electrons (~60%) (1% H minority)
 - Low input torque
 - Destabilized fast ion modes

Exploration of core burning plasmas characteristics



- DT plasmas explored in **core ITER relevant conditions:**
 - High heating fraction to electrons ($\sim 60\%$) (1% H minority)
 - Low input torque
 - Destabilized fast ion modes
- High confinement obtained: $H_{98}(y,2) \geq 1$
 - Low core transport: $Q_{e,i} \sim 0.5\text{GB}$
 - 15% better confinement in DT than D

High core electron heating with ICRF

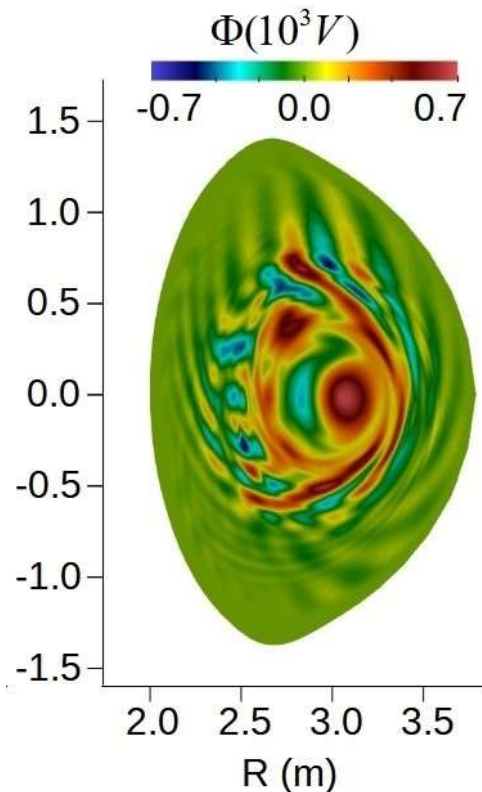


- High electron heating and low torque:
 $T_e/T_i \sim 1.4$, $M_{\text{ach}} = 0.12$

Fast ion perturbations simulated



Non-linear global gyrofluid simulations with
FAR3d code

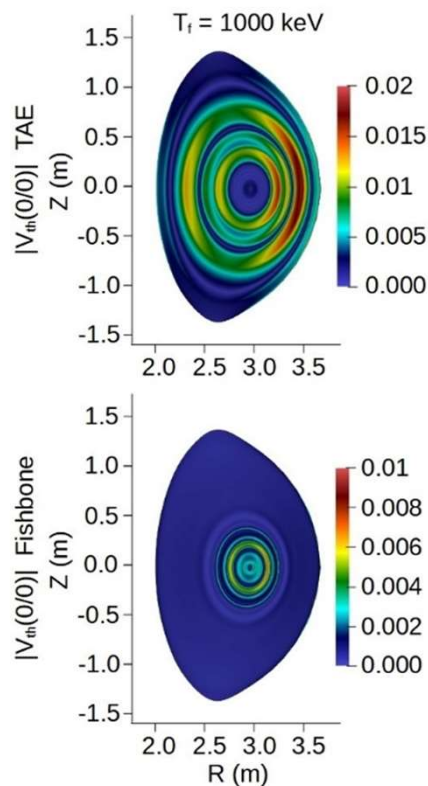


- High electron heating and low torque:
 $T_e/T_i \sim 1.4$, $M_{ach} = 0.12$
- Core fast ions perturbations reproduced considering **ICRF accelerated ions**

Zonal activity induced by perturbations



Non-linear global gyrofluid simulations with FAR3d code

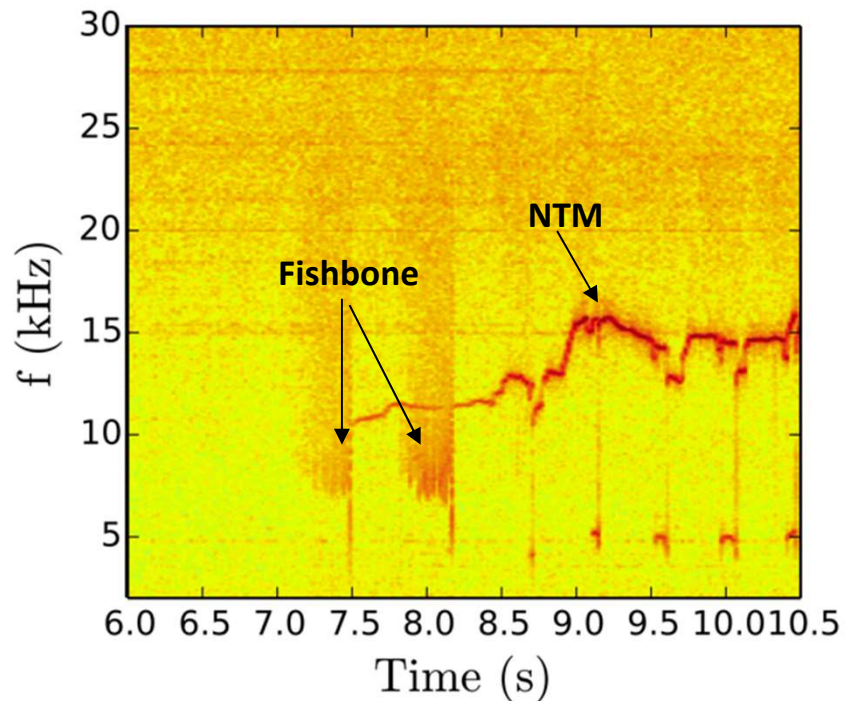


- High electron heating and low torque:
 $T_e/T_i \sim 1.4$, $M_{ach} = 0.12$
- Core fast ions perturbations reproduced considering **ICRF accelerated ions**
- Fishbone and TAE generate zonal structures
- **Zonal activity leads to reduced ion thermal transport**
- No evidence of T_i clamping at 90% of electron heating

α particle losses and transport

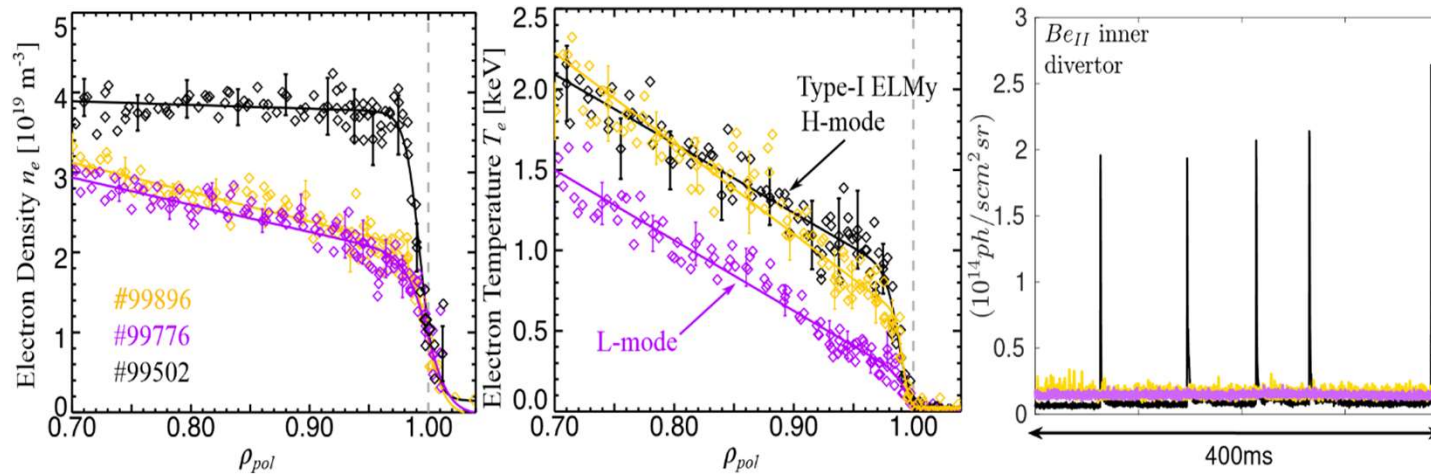


FILD measurements



- **Non-linear coupling**: induced α transport and losses by **fishbone**
- No losses detected from TAE but substantial from NTM
- **Magnetic perturbations optimization is necessary**

I-mode like plasma regime



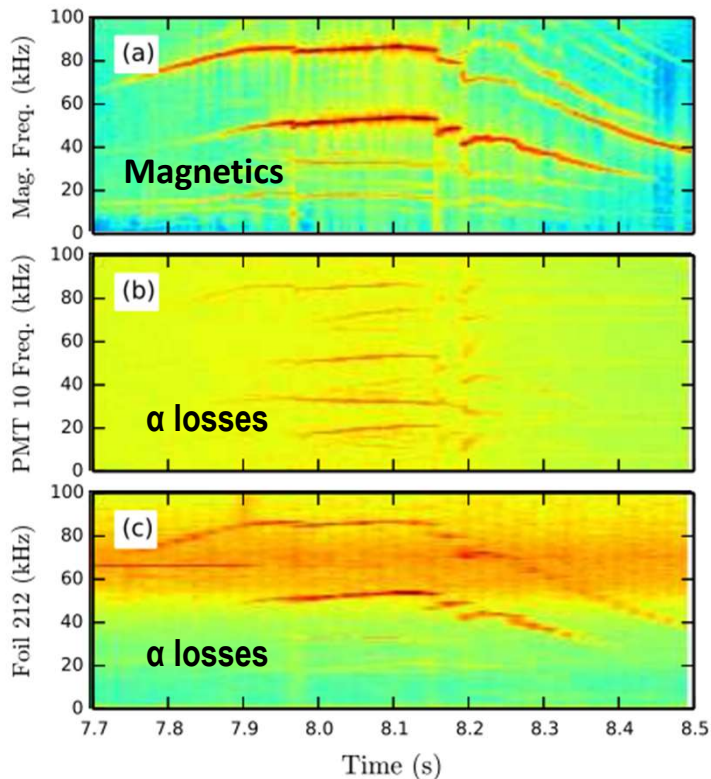
- High confinement regime **similar to I-mode**...
- ...but standard $B \times \nabla B$ used and edge WCM not detected
- Plasma regime close to L-H transition

Outline



- Alfvén activity destabilized by α particles
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α particle losses detection in DTE2



- Detected prompt α losses $\sim 7\%$
- Detected low frequency MHD α losses $\sim 5\%$
 - Fishbone, NTM, Kink
- Overprediction of the neutron rate in TRANSP with no α transport [Stancar this conference #1889]

[Kiptily this conference #1836][Bonfiglio this conference #1991]

Outline



- Alfvén activity destabilized by α particles
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- **Conclusions**

Conclusions



- Several expected α particle effects confirmed in JET-DTE2
 - Alfvén modes destabilization
 - Electron heating
 - Prompt and coherent losses
- High confinement in DT plasmas with ITER core conditions
- DT plasmas show significant differences compared to D → More experiments needed