EUROfusion

9th November 2026

RT09 priorities 2027

RTCs: J. Galdon, A. Jensen Van Vuuren, Y. Kazakov, R. Ochoukov

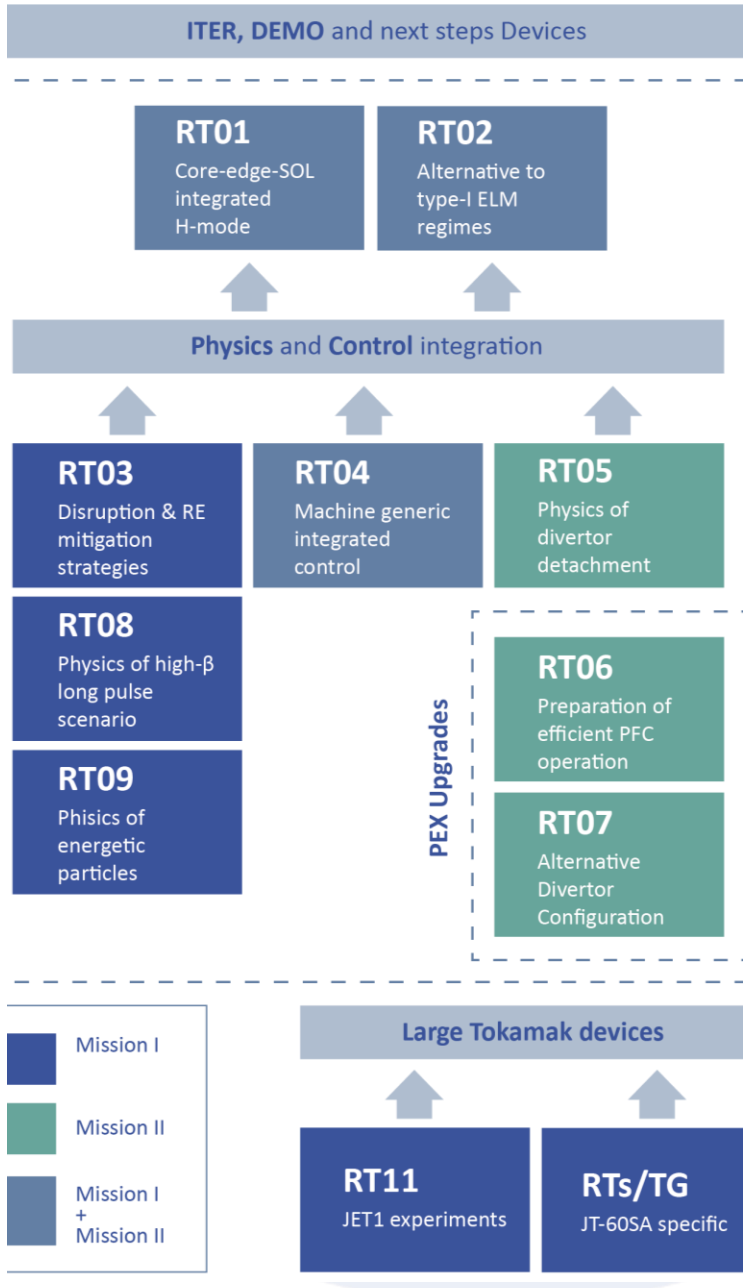
rTFLs: D. Keeling, V. Igochine

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Introduction

- RT-09 is part of mission 1, with a focus on the physics of energetic particles:
  - Transport and loss
  - Drive of, and interaction with MHD modes
  - Beneficial effects (turbulence suppression)

- RT-09 has experimental branches across all TE devices.



Scientific objectives

#	
D1	Provide high quality demonstration of diagnostic techniques for the characterization of confined and lost fast ions with fast ion characteristics relevant for ITER and JT-60SA, qualify further diagnostic techniques required for deployment on JT-60SA
D2	Quantify ion and electron heating and core-turbulence stabilisation by fast ions in view of JT-60SA, ITER and DEMO including tailored FI energy profiles and radial locations relevant to JT-60SA
D3	Quantify the impact of fast ions and fast ion driven MHD instabilities on transport in various scenarios including those relevant to JT-60SA
D4	Integrate the available heating, fast-ion and transport modelling tools for interpretation of experimental results in view of extrapolation of results to ITER and DEMO
D5	Quantify fast-ion losses and associated heat load from edge perturbations (ELMs and RMPs)
D7	Identification of AE control actuators and assessment for ITER and JT-60SA relevant scenarios

Initial proposal prioritisation and grouping

High level topics	Proposal #	Sci. Obj.
3D Fields and ELMs	192, 193, 205	D5 (D1, D3, D4, D7)
Core AE control and suppression	200, 206, 207, 197, 198, 199, 202	D7, D2 (D1, D3, D4)
Core turbulence control	194, 208	D2, D3 (D1)
AUG alpha measurements	195	D1 (D4)
WEST expt. branch	194, 196, 204, 209	D2, D3 (D1, D4)

- RTCs allocated pulses-per-machine to the group.
- Experiments planned principally with P1 proposals in mind but P2 will be included where pulses may be adapted with no risk to P1 or (esp. TCV) where total pulses available not required by P1.

2026 strategy + pulse distribution

		Main proposals (P1 and P1.5)	Integrate P2 and PB studies
MAST-U	**16 pulses** Session #1: 16/02-20/02 (8x) Session #2: 23/02-27/02 (8x)	P192 (Effect of RMPs on FI transport): 2*4x P205 (AE control with RMPs): 2*4x	P193 (Fast-ion losses due to ELMs) P198 (n=0 modes); P199 (Core ICE)
TCV	**50 pulses** Session #1: 30/03-03/04 (13x) Session #2: 06/04-10/04 (13x) Sessions #3, #4: tbd (24x)	P197 (High-frequency AEs and ICE) – sess. 1&2 P200 (AE control with ECRH/ECCD) – sess. 1&2 P194 (Impact of TAEs on turbulence), P199 (Core ICE): in sessions 3,4	P193 (Fast-ion losses due to ELMs) P198 (EGAMs and n=0 modes) P201 (AE control with plasma shape) P202 (Fishbones) P210 (ELM-AE interaction)
AUG	**16 pulses** (D-D plasma) Session #1: 5 pulses Session #2: 5 pulses Session #3: 6 pulses	Proposals share two different ICRF scenarios (3rd harmonic D, 10-11x and H minority, 5-6x) P192 (Effect of RMPs on FI transport): sc.-1 P195 (FI measurements with GRS and neutron spectroscopy): sc.-1 & sc.-2 (PB) P205 (AE control with RMPs): sc.-1 & sc.-2 P208 (FIs and turbulence): sc.-2	P193 (Fast-ion losses due to ELMs) P197 (High-frequency AEs and ICE) P199 (Core ICE) P210 (ELM-AE interaction with off-axis NBI-driven AEs)
WEST	**1 session (2027)** [follow developments in 2026]	P194 (Impact of TAEs on turbulence)	TWA-related: P196, P204, P209

2026 shots executed – tentative 2027 allocation

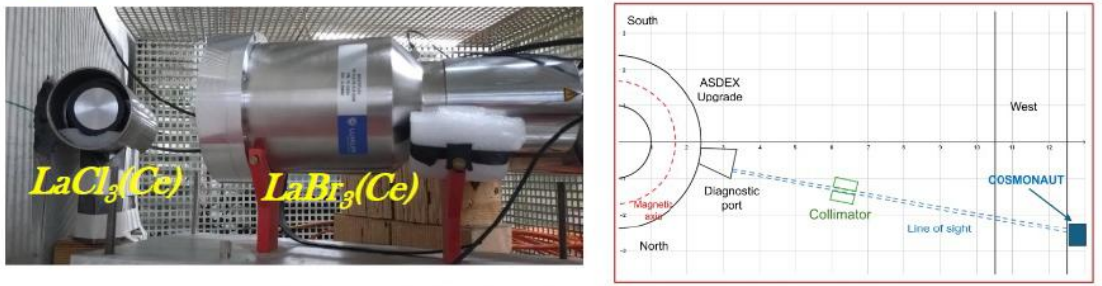
	AUG	TCV	MAST-U	WEST
Shots ’26: allocated/executed	16 / 9	50 / 30	16 / 16	0 / 0
Tentative allocation 2027	18	120	0	15

D1: results 2026 and priorities for 2027

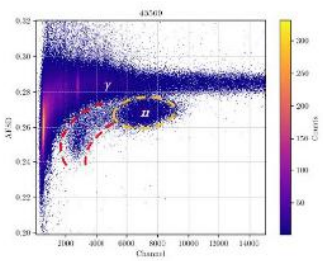
D1: Provide high quality demonstration of diagnostic techniques for the characterization of confined and lost fast ions with fast ion characteristics relevant for ITER and JT-60SA, qualify further diagnostic techniques required for deployment on JT-60SA

- Review presentation showed excellent results from:
  - JET: analysis of data - neutron+gamma-ray analysis applicable to JT-60SA and ITER
  - AUG: New FI diagnostics
    - FILD enhancements
    - "FIRE&GO" project:
      - COSMONAUT+: compact neutron spectrometer
      - A compact gamma-ray spectrometer (GRS)

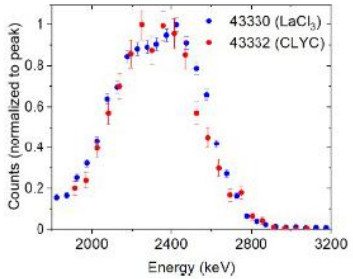
- **COSMONAUT+**, a 1'.5'x1.5'' $LaCl_3(Ce)$ based **compact neutron spectrometer** for **fast deuterium** studies.
- A 3''x3'' $LaBr_3(Ce)$ **gamma-ray spectrometer for proton and alpha particle studies**.



The $LaCl_3(Ce)$ and $LaBr_3(Ce)$ diagnostics at ASDEX Upgrade



Neutron/gamma-ray discrimination (left) and neutron spectrum measurements (right)



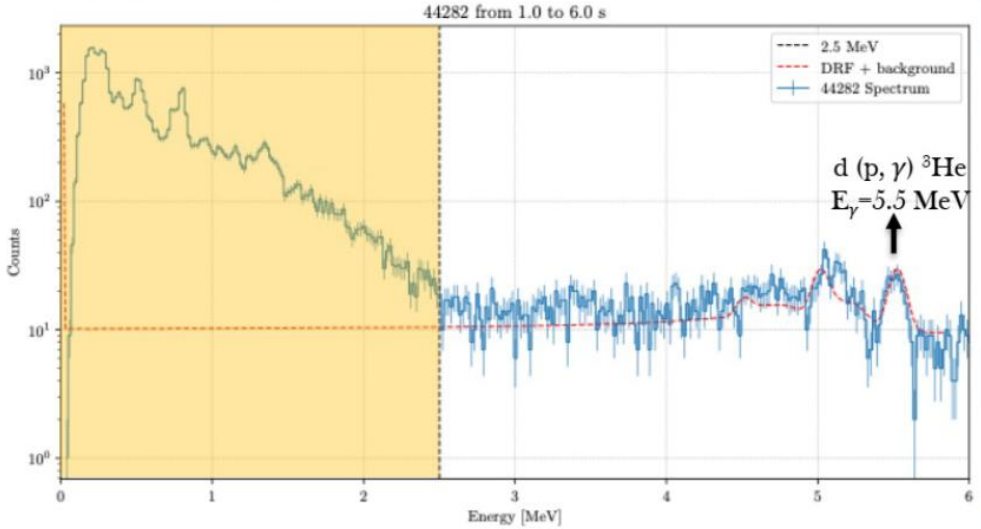
D1: results 2026 and priorities for 2027

- Priority for 2027:
  - AUG: GRS development/exploitation utilising D + ^{11}B and ^{4}He + ^{10}B reactions for critical ITER diagnostic tests (session in Dec 2026 – complete in 2027 if necessary) [P195]
    - Noted that the "workhorse scenario" for RT09/AUG/2027 will depend on remaining 2026 session
  - TCV: Fully exploit ICE capabilities + complete suite of FI diagnostics (FILD, FIDA, magnetics,…) [P192/4/7/200 + Prio2 (see GPM Nov 2025)]

^{4}He + ^{10}B → ^{13}C + *p* + *γ* (E_γ = 3.85MeV/3.68MeV/3.09MeV)

D + ^{11}B → ^{12}C + *n* + *γ* (E_γ = 4.44MeV)

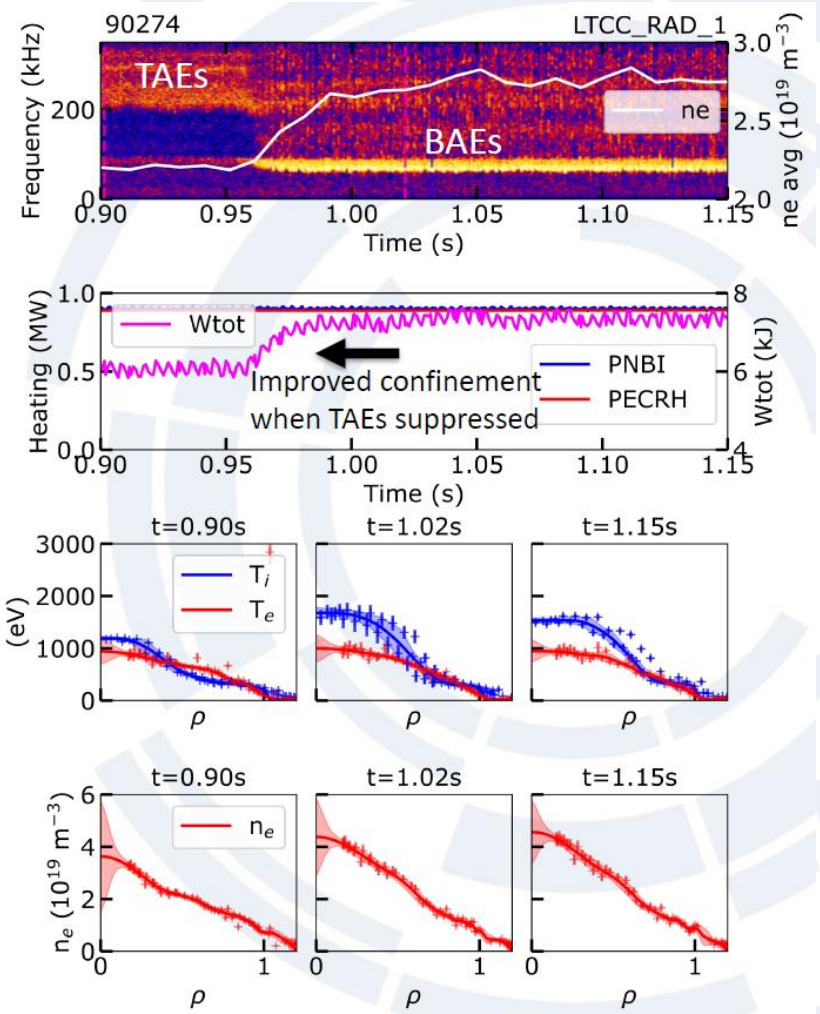
p + D → ^{3}He + γ (E_γ = 5.5MeV)



D2: results 2026 and priorities for 2027

D2: Quantify ion and electron heating and core-turbulence stabilisation by fast ions in view of JT-60SA, ITER and DEMO including tailored FI energy profiles and radial locations relevant to JT-60SA

- Review presentation showed excellent results from:
  - JET: Analysis of FI interaction with turbulence
  - TCV: Interplay between AEs and turbulence shown by modifying ECRH deposition profile and utilising ECE measurements



D2: results 2026 and priorities for 2027

- Priority for 2027:
  - WEST – conduct “flagship” experiment on WEST to determine effect of thermal ion turbulence on core TAEs (ICRH driven) [P194]
  - TCV – complete work to determine effect of thermal ion turbulence on core TAEs (NBI driven + effect of EC) [P194]
  - AUG – In concert with other experiments, determine effect of Pe:Pi ratio effect on turbulence (ICRH+NBI driven) [P208]

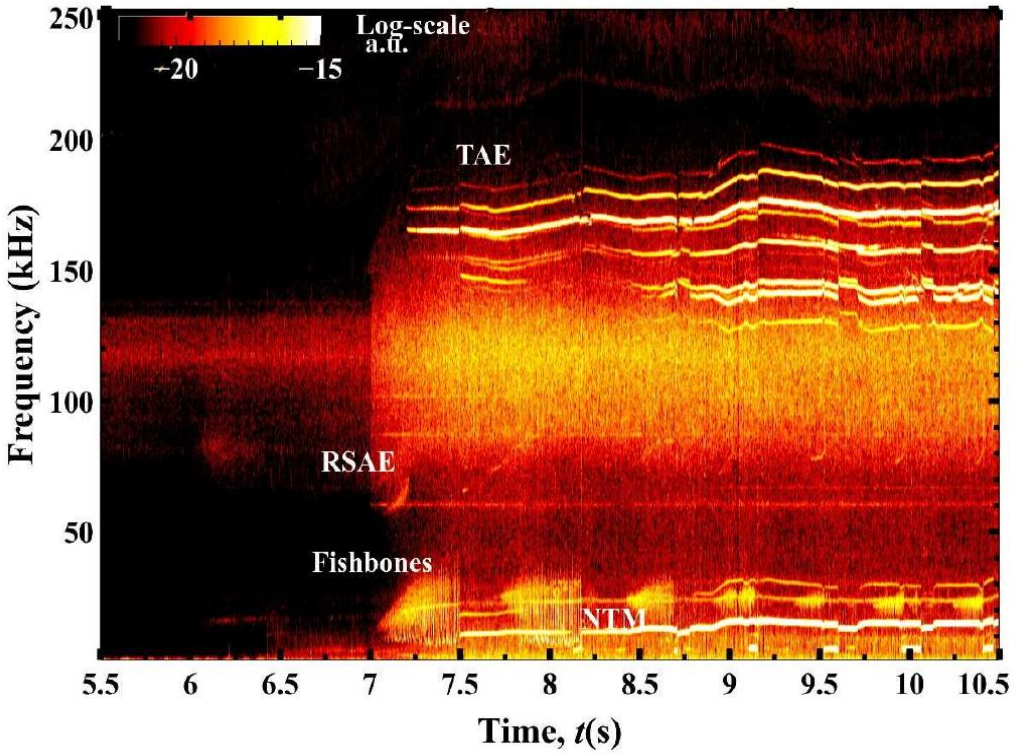
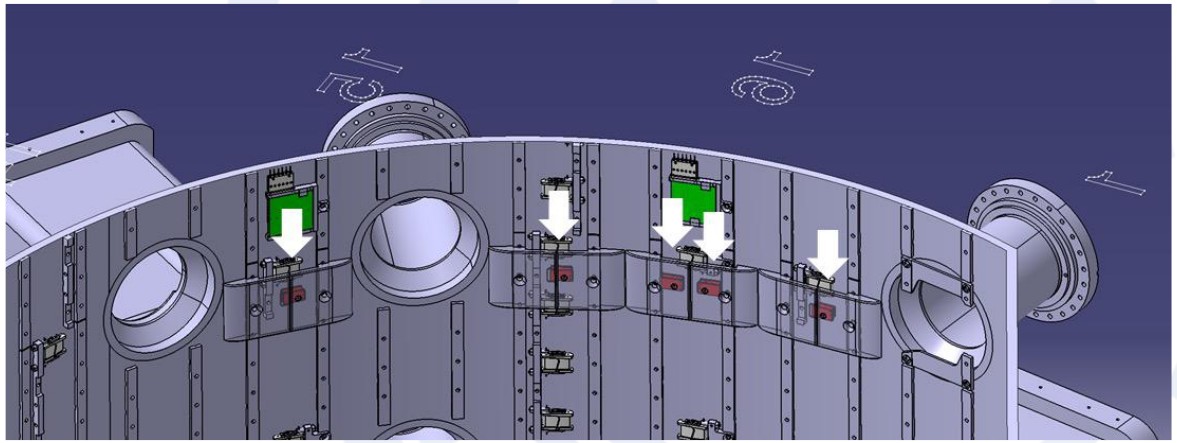


Figure: Magnetic spectrogram of a JET pulse with fast-ion-driven TAEs unstable and confinement improvement

D3: results 2026 and priorities for 2027

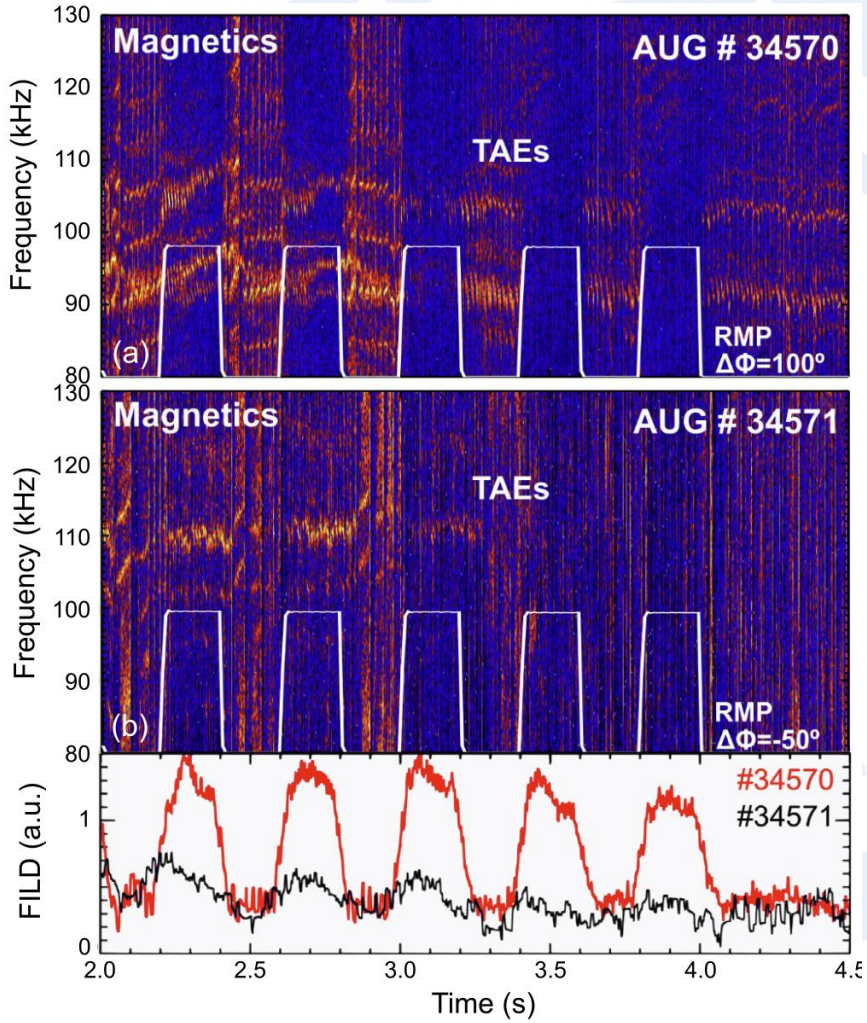
D3: Quantify the impact of fast ions and fast ion driven MHD instabilities on transport in various scenarios including those relevant to JT-60SA

- Review presentation showed excellent results from:
  - MAST-U: GAEs and ICE driven by NB fast ions shown by new high frequency ICE probes supplied by IPP. FI transport also demonstrated by ssNPA & FILD measurements.
  - TCV: Also taking advantage of new ICE probes from IPP.



D3: results 2026 and priorities for 2027

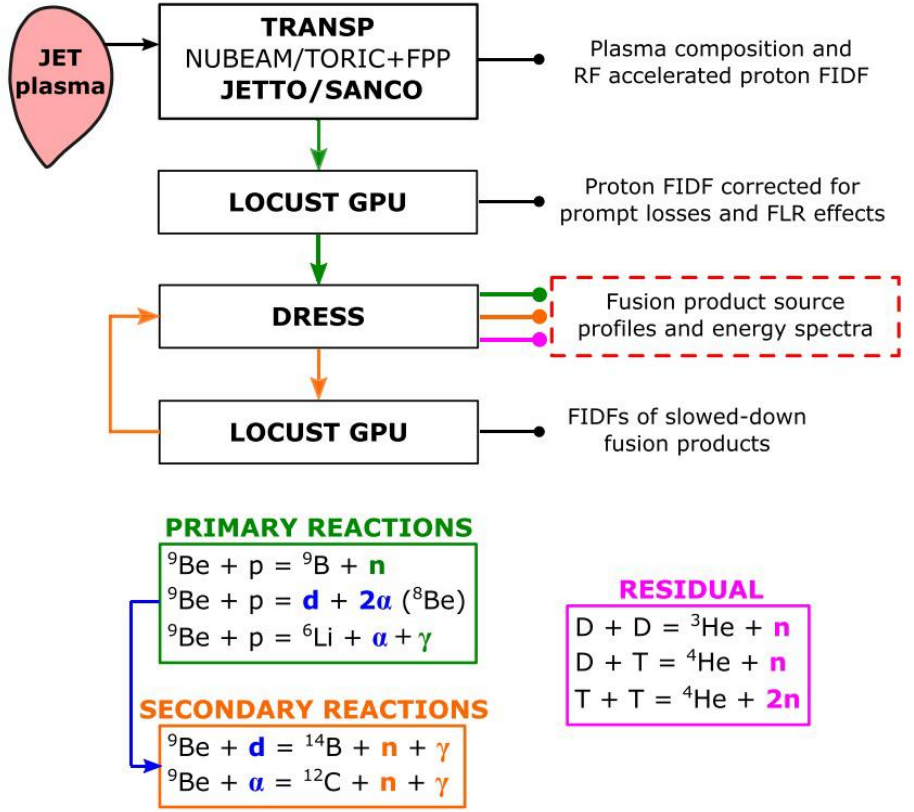
- Priority for 2027:
  - AUG: Complete investigation of 3D applied 3D fields' effects on FI dynamics/losses [P192/205] and utilisation of 3rd harmonic beam ion acceleration with ICRF (in synergy with D1+D5 priorities)
  - TCV: Complete scans of TAE position excitation control utilising appropriate combinations of ECRH/NBI (+ modulation) and gas puffing [P194]



D4: results 2026 and priorities for 2027

D4: Integrate the available heating, fast-ion and transport modelling tools for interpretation of experimental results in view of extrapolation of results to ITER and DEMO

- Review presentation showed excellent results from:
  - JET: Validation of workflow TRANSP→LOCUST→DRESS to model FI distributions of ICRF-accelerated protons and fusion products
  - AUG: Modeling ICRF-heated ^{+}H in response to MPs and comparing to FILD measurements
  - AUG: improvements to ASCOT for mapping wall heat loads from lost FIs



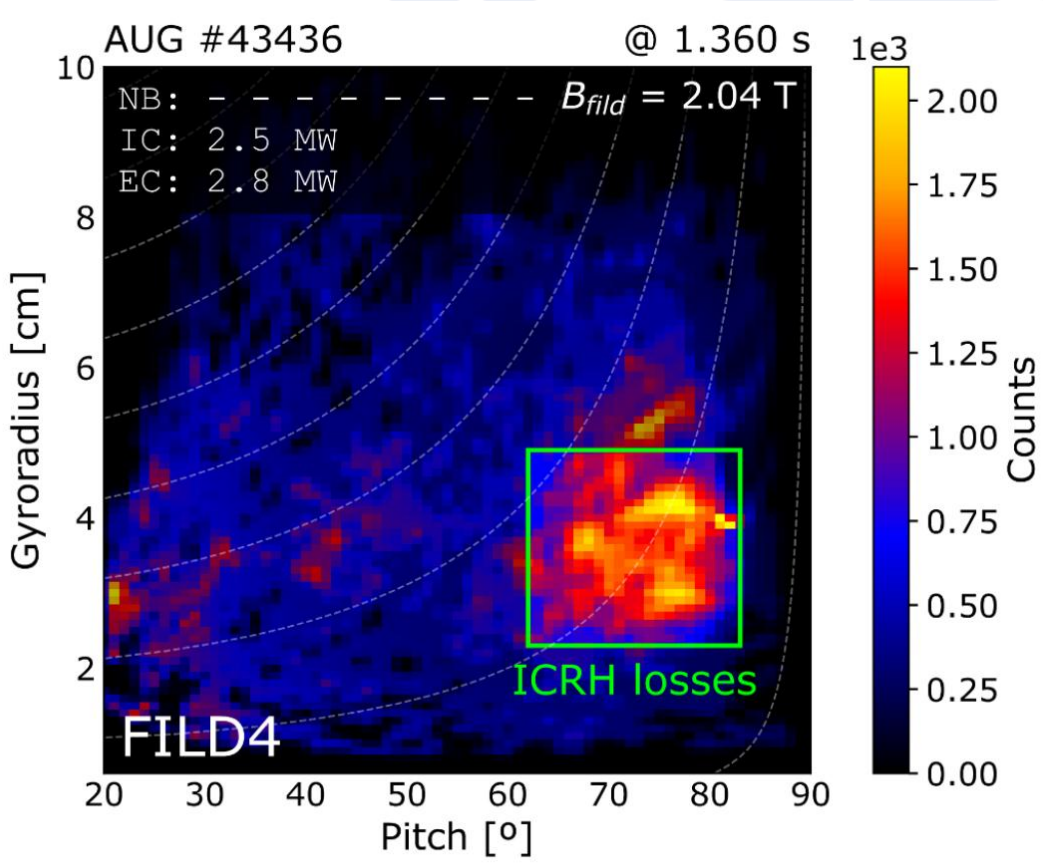
D4: results 2026 and priorities for 2027

- Priority for 2027:
  - D4 depends on analysis of experiments carried out under other Sci. Obj.s – wherever priority for 2027 under other objectives includes analysis, this is an implicit link also to D4.
  - Ensure sufficient effort is included in response to call to fully develop required workflows and complete analysis of experiments.

D5: results 2026 and priorities for 2027

D5: Quantify fast-ion losses and associated heat load from edge perturbations (ELMs and RMPs)

- Review presentation showed excellent results from:
  - AUG: Explore effect of RMPs on FI confinement using unique capabilities – ICRF+MPs+FI diagnostics in 2 scenarios – minority H-heating, 3rd harmonic D heating
  - MAST-U: explore FI losses by coupling between RMPs and EFCC (collaboration also with RT-02 and RT-04)

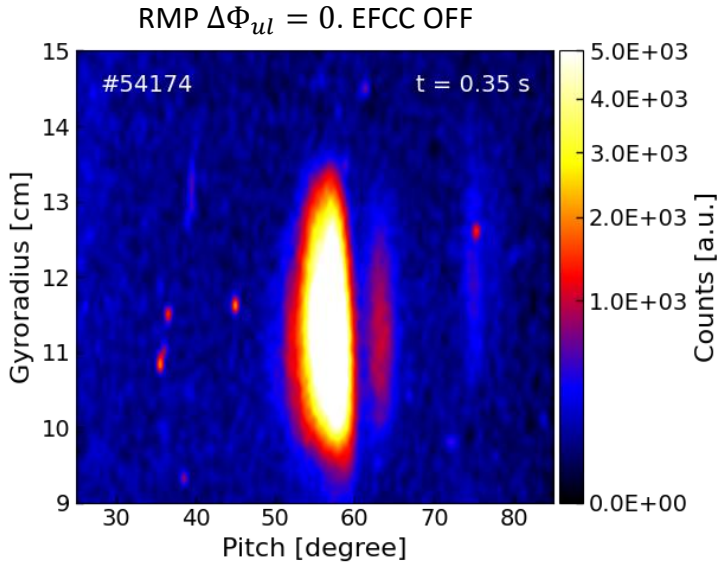


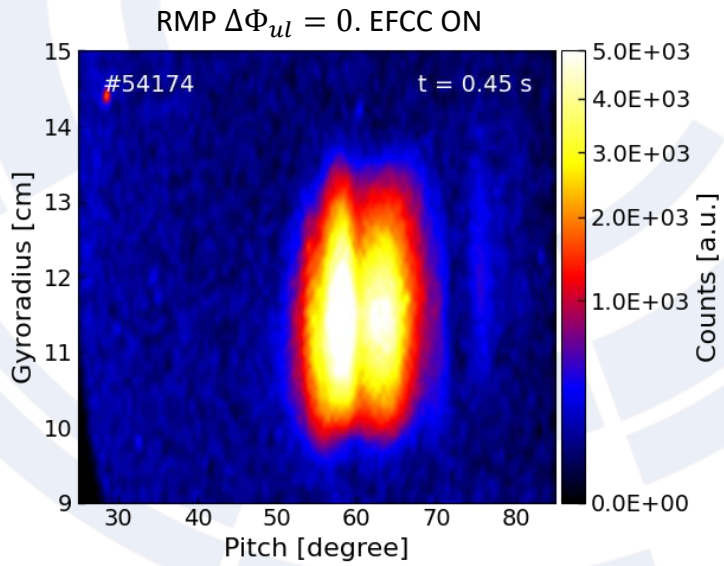
D5: results 2026 and priorities for 2027

- Priority for 2027:
  - AUG: Complete experiments utilising RMPs to perturb FI population exploiting full FI diagnosis suite [P205/192]
  - MAST-U: complete analysis of MU05 experiments and compare with AUG results.

→

- Continue with investigation of MPs on ICRF fast-ion distribution function (3rd harmonic D scheme) → **MPs + ICRF are unique capabilities of AUG!**
- Effect of MPs on NBI confinement in ELM suppressed plasmas (n=2)
- Scans in MP intensity, differential phase and toroidal phase (for 3D effects)



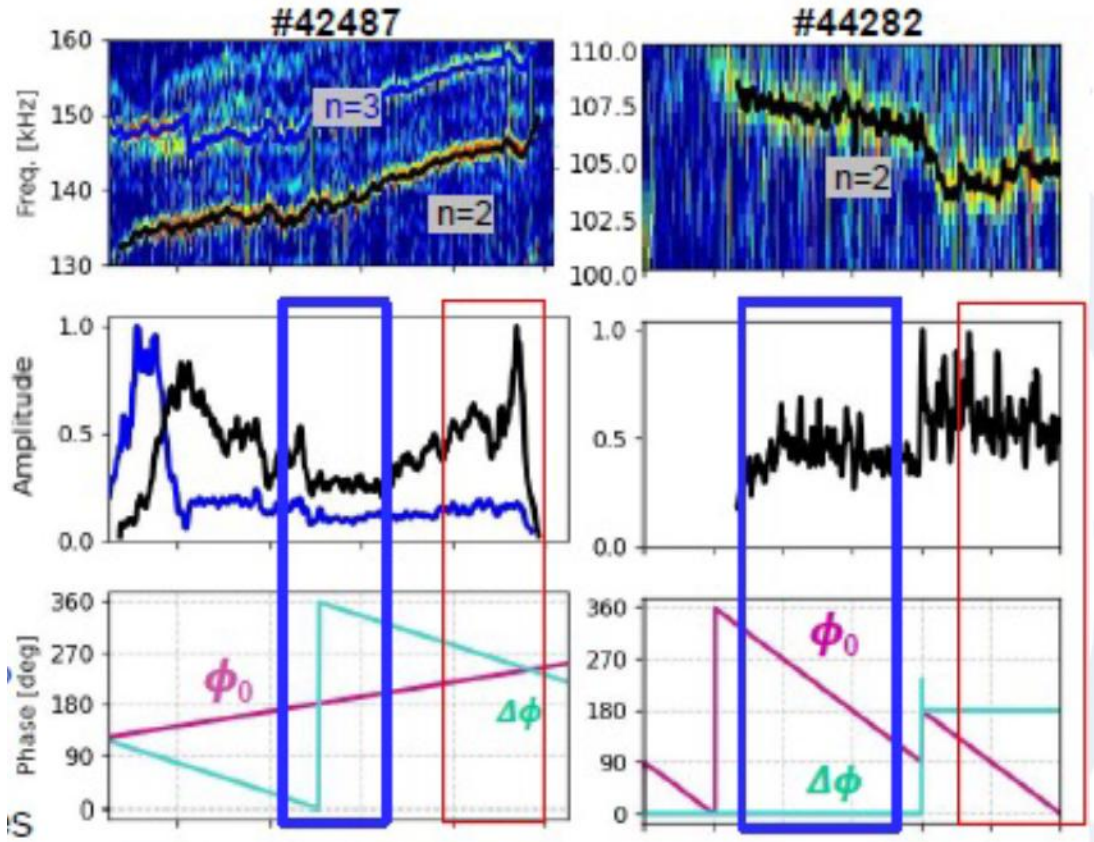


Courtesy of L.Velarde

D7: results 2026 and priorities for 2027

- **D7: Identification of AE control actuators and assessment for ITER and JT-60SA relevant scenarios**

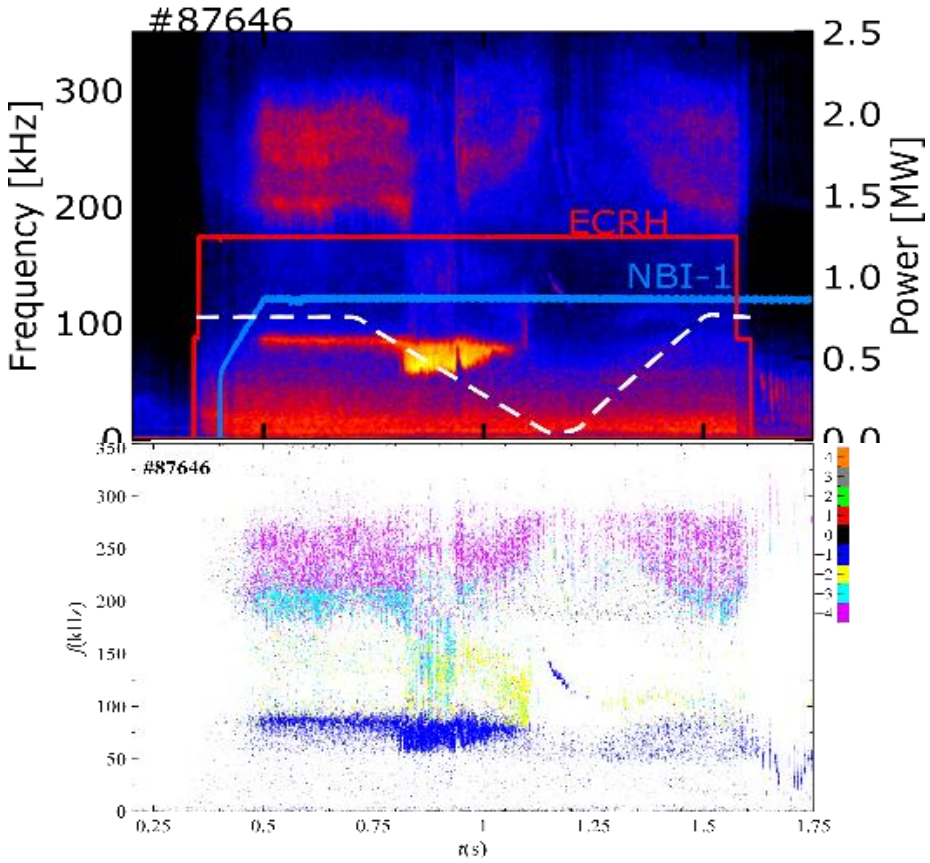
- Review presentation showed excellent results from:
  - AUG: RMP control of ICRF (minority-H) driven TAEs (RMP for AE control)
  - MAST-U: RMP control of high frequency AEs (RMP for AE control)
  - TCV: Reproducible steady-state co-NBI TAE scenario established with off-axis ECRH (ECRH for AE control)
  - WEST(internal prog.): Identification of AE actuators (ICRH for AE control)



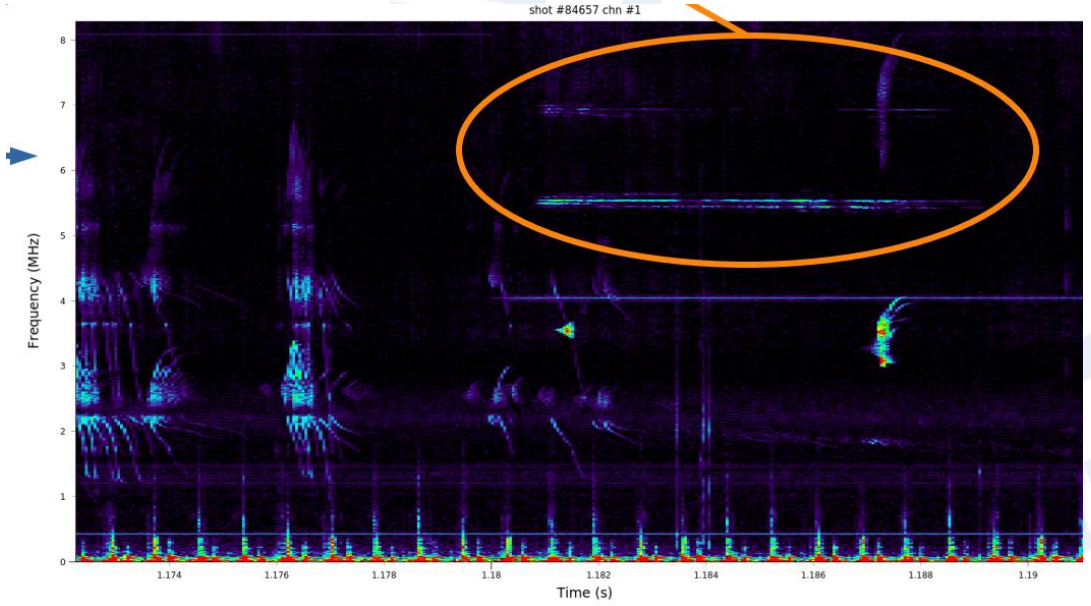
D. Kabirov et al. TMEP 2026 Lausanne

D7: results 2026 and priorities for 2027

- Priority for 2027:
  - TCV: Systematic ECRH deposition scans at full power in previously established AE-active scenario [P200]
  - TCV: Vary plasma parameters (Bt, ne, Te, NBI) around AE active points in previously established scenarios to determine effects on stability [P197]



#84657, with possible GAE on TCV



Summary

- Lots of experimental work still to do across the 3 operating devices in 2027
- Analysis of JET/MAST-U results acquired in previous years will also still require appropriate effort to be bid

Backup

NB: Previous GPM presentation including assessment of all proposals can be found at the Indico page:

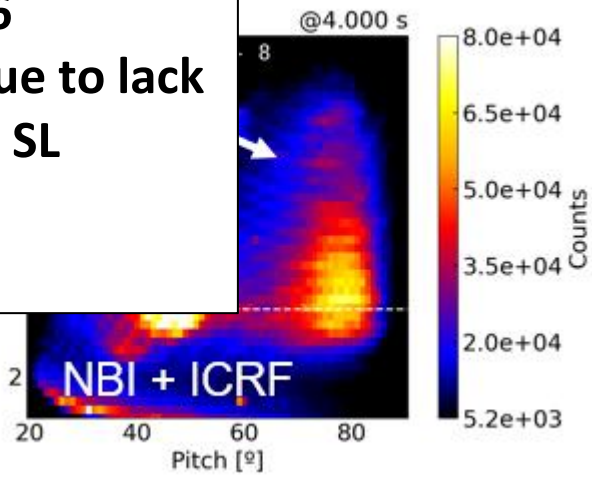
https://indico.euro-fusion.org/event/3646/timetable/#all

Optimization of fast-ion confinement in tokamaks with externally applied 3D fields (#192)

- **Propo**
  - J.G
- **Scien**
  - M
  - M
    EL

- **Continuation of P1 expt begun in previous year(s)**
- **Directly linked to RT Sci. Obj. and ITPA JEX**
- **Important to complete the dataset, especially on MAST-U in 2026**
- **Note that extn. To 1MA on MAST-U may pose some difficulties due to lack of internal prog. Scenario development, to be discussed with ref. SL**
- **Basis of expt. “block” on 3D magnetic fields (combine with #205)**
- **P1-MASTU, P1.5-AUG**

f ICRF (3rd harmonic D) fast-in AUG [July 2025]



In MAS
- Investigate role of coupling to n=2 error field
- Extend to MP ELM suppressed plasmas (n=3)
- Extend to high-beta 1MA scenario

In AUG:
- Continue with investigation of MPs on ICRF fast-ion distribution function (3rd harmonic D scheme) → **MPs + ICRF are unique capabilities of AUG!**
- Effect of MPs on NBI confinement in ELM suppressed plasmas (n=2)
- Scans in MP intensity, differential phase and toroidal phase (for 3D effects)

- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - FILD, FIDA and other fast-ion diagnostics are essential
  - In MU, special settings for IR thermography
  - Scans in MP differential phase and intensity

Proposed pulses

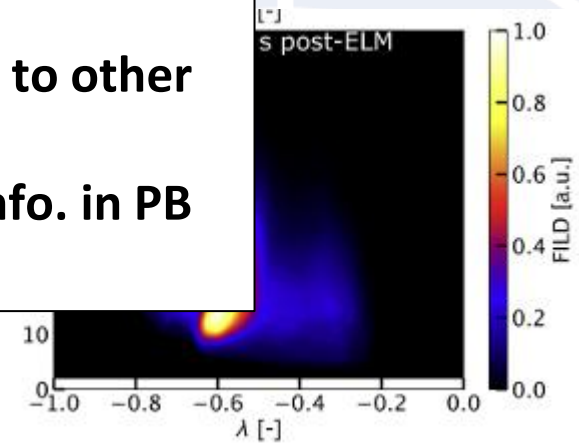
Device	# Pulses/Session	# Development
AUG	14	
MAST-U	24 (3 sessions)	

Fast-ion losses induced by edge instabilities across different confinement regimes (#193)

- **Propon**
  - **J.Gald**
- **Scientif**
  - Backg
  - This p
    regim

- **Continuation of P1 expt begun in previous year(s)**
- **Directly linked to RT Sci. Obj.**
- **Proposed shots include small quantity of dedicated + piggy-back to other studies, principally RT-02 expts but also other RT-09 pulses**
- **Careful planning should be able to gather majority of required info. in PB**
- **PB (P1 but data to be gathered in PB)**

Velocity-space of FI losses induced by type-I ELM in y tail indicative of fast-ion iuan, Nuclear Fusion 2025]



Machine	Already explored	More work needed
AUG	Type-I ELMs, MP mitigated & suppressed ELMs, QCE, I-mode, QH-mode	I-mode (with PREs), MP ELM suppressed
TCV	Type-I ELMs (NBI 1)	Type-I ELMs (NBI2 higher energy); QCE
MAST-U	Type-I and Type-III ELMs (750 kA scen.)	Type-I ELMs (1MA scenario); MP mitigated / suppressed ELMs; QCE

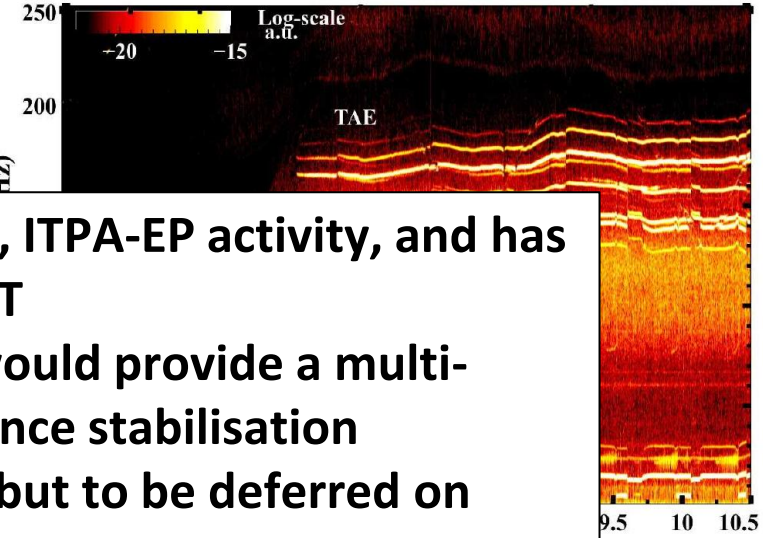
- **Experimental Strategy/Machine Constraints and essential diagnostic**
  - FILD as essential diagnostic
  - Mostly piggyback shots. Only specific dedicated shots for completing scans.

Proposed pulses

Device	# Pulses/Session	# Development
AUG	5 (+ piggyback)	
MAST-U	5 (+ piggyback)	
TCV	10 (+ piggyback)	

Impact of Toroidal Alfvén Eigenmodes on Plasma Core Turbulence and Confinement (#194)

- **Proponents and contact person:**
  - Paulo Puglia (paulo.puglia@cea.fr), Samuele Mazzi (samuele.mazzi@cea.fr), Jesùs Poley (jesus.poley@epfl.ch), Anton Jansen van Vuuren (anton.jansenvanvuuren@epfl.ch)
    - Alexander Karpushov, Rémi D… Colas, Roland Sabot, Philippe … Sharapov, Sergei Sharapov
- **Scientific Backgroun**
  - Goal: Explore effects of Toroidal … microturbulence driven by the t…
  - Based on recent JET results shov… turbulence stabilization by TAEs.
  - Fast ions driven by ICRH waves t…
  - Recent evidence suggests increa… regarding optimal TAE paramete…
- **Scientific Objectives:**
  - Measure the impact of core-TAE…
  - Compare NBI (TCV) vs. ICRH (WE…
  - Assess TAE amplitude and positi…
  - Explore control mechanisms for …
- **Experimental Strate… diagnostic**
  - **TCV:**
    - Use reference scenario with unstable TAEs, move TAE position towards core via ECRH/ECCD.
    - Flip current direction for counter NB2 injection (higher fast ion energy).
    - Optimize density profile with NBI modulation/gas puffing for SPR measurements.
    - Configure plasma for turbulence diagnostics (Correlation-ECE, TPCI).
  - **WEST:**
    - Develop low magnetic field scenario for 2nd harmonic ICRH heating with H-minority.
    - Perform scenario scans with 20 pulses, adjusting H-minority concentration and ICRH power.
    - Use ECE/C-ECE diagnostics to measure core turbulence affected by TAEs.



- **Proposal is well-aligned with RT Sci. Obj.s (D2/3), ITPA-EP activity, and has a sound theoretical background also including JET**
- **Combination of results with previous JET work would provide a multi-machine dataset to demonstrate the ITG turbulence stabilisation**
- **Proposal was recognised previously as high prio but to be deferred on WEST.**
- **Significant investment of shots needed, particularly on WEST cf. available expt. time, careful assessment of what may be achieved in limited expt. time needed – e.g. Can scenario development be carried out in int. prog?**
- **P1-TCV, P1-WEST**

n fast-ion-
ment

Comm. 2024]

opment		
AUG		
MAST-U		
TCV	30 / 2	
WEST	40 / 2	20 (within the 40 proposed)

Development of alpha-particle measurements on AUG in support of JT-60SA and ITER rebaseline (#195)

- **Proponents and contact person**

  Y. Kazakov (LPP-ER
  Full team: see the

- **Scientific Backgr**
  - ITER with the
  - **High-priority** measuremer
  - Essential inp
  - 2025: started **COSMONAU**
  - Synergy with
  - (development

- **Experimental St**
  - Step 1 (e.g. 2
    - ✓ Source **preference: 2.5T/~1MA with core ECRF, if ICRF 55MHz available**)
    - ✓ Source of B impurities: boron dropper (different BD settings tested i
  - Step 2 (e.g. 2027): demonstrate ***α*-particle measurements with GRS**
    - ✓ Source of alphas (#1): D-^{3}He fusion, E_D ~ 500keV with $\omega=3\omega_{ci}$(D) as in step #1, **add 5-10% of ^{3}He**
    - ✓ Source of alphas (#2): p-^{11}B fusion, hydrogen minority ICRF (2.5T/~1MA)
    - ✓ Source of B impurities: boron dropper

Proposed pulses

	Step 1 (e.g. 2026)	Step 2 (e.g. 2027)
	8	10

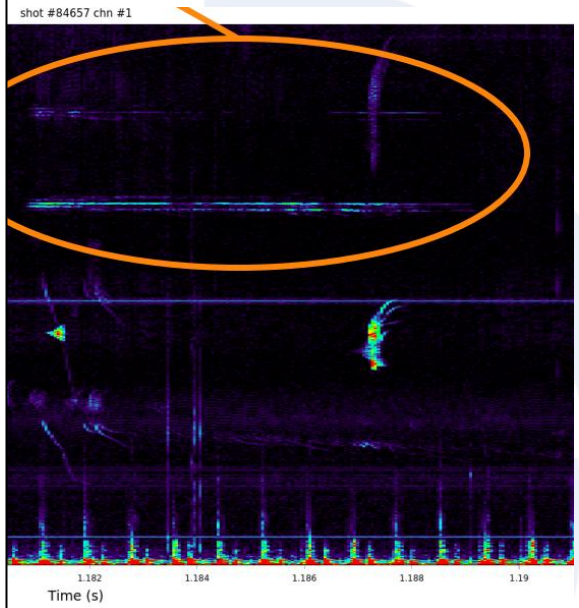
- **Proposal directly linked to a specific open question for ITER (Cat 1 R&D item in ITER re-baselining) which also prompted a new ITPA JEX (EP27)**
- **Follows on from 2025 activity demonstrating COSMONAUT measurements on AUG**
- **Second step (measurements with energetic alphas) requires ^{3}He for 3 of 4 options. Will need careful scheduling within campaign.**
- **Full proposal requires ~half AUG pulse allocation – careful planning to see what other work may be successfully combined without compromising result.**
- **Unlike preliminary work in 2025, pulses need to be in Deuterium (not H) for compatibility with B-dropper.**
- **P1-AUG**

^{4}**He** + ^{10}B → ^{13}C + p + γ (E_γ = 3.85MeV/3.68MeV/3.09MeV)

High frequency Alfvén eigenmode studies with ITER and JT-60SA relevant AE actuators (#197)

- The addition/improvement of ICE diagnostics to all machines has meant a good start to investigation of ICE←→FI interaction during 2025.
- hf AEs are an area less well-documented from previous RT-09 work – diagnostics only available in more recent ops periods
- This proposal therefore has merit from p.o.v. of D1 as well as well as D3/7
- Combines well with #199 – TCV branch may be executed, AUG branch will need careful consideration – a number of required results can be obtained in PB
- TCV part shots can be allocated., AUG part high prio but with reduced allocation of shots cf. request.
- P1-TCV, P2-AUG

#84657 with possible GAE on TCV



Experimental strategy, Machine constraints and essential diagnostic

- For TCV: use 84657 to establish scenario with steady GAE
- Modulate plasma parameters (B_t, n_e, T_e, NBI) to determine GAE stability boundary
- For both AUG and TCV: apply ECCD to discharge with steady GAE (36607 for AUG reference, 84657 for TCV reference), to modulate q-profile
- Rely on iMSE to measure q-profile modifications in presence of ECCD
- Rely on ICE diagnostic to characterize hf AE mode

Proposed pulses

Device	# Pulses/Session	# Development
AUG	15	
MAST-U		
TCV	20	5
WEST		

Systematic Control of Alfvén Eigenmodes in TCV Using Electron Cyclotron Resonance Heating (ECRH) (#200)

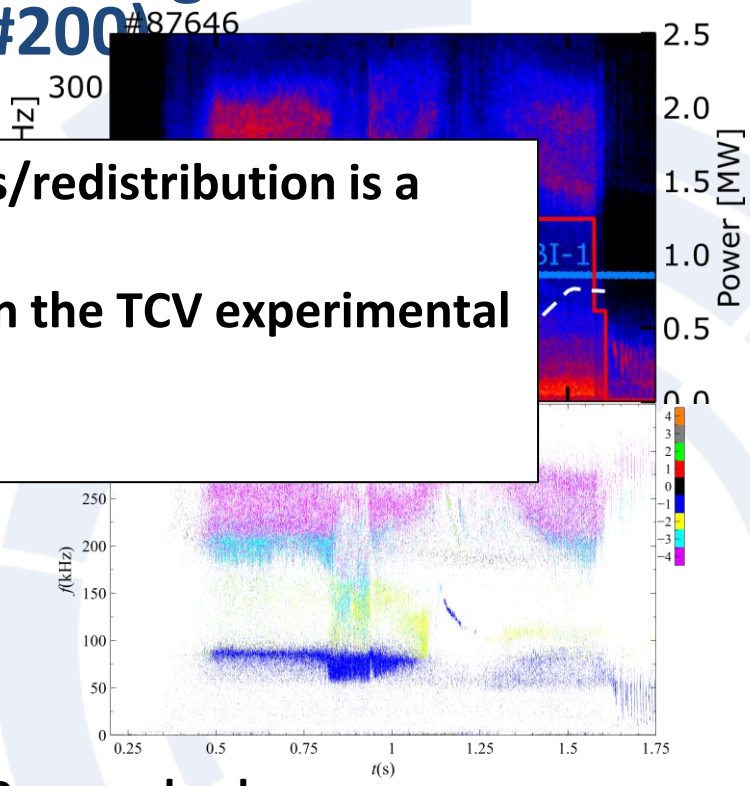
- Anton Jansen van Vuuren (EPFL-SPC)
  Co-proponents: J. Po
  Podestà, D. Testa
- **Scientific Backgr**
  Alfvén Eigenmodes
  heating efficiency,
  experiments demo
  underlying stabiliza
  modification—rem

  Main objectives:
  - Perform **systematic ECRH deposition scans** in an established AE-active TCV scenario.
  - Use the **new Motional Stark Effect (MSE)** diagnostic to measure q-profile and magnetic shear evolution.
  - Correlate AE suppression with local shear changes to identify the dominant control mechanism.
- **Experimental Strategy/Machine Constraints and essential diagnostic**

  Scenario:
  - Established AE-active TCV plasma with NBI drive (I_p = 120 kA, B_t = 1.3–1.5 T, δ ≈ +0.3).
  - Systematic ECRH scans: ρ= 0.2–0.7, multiple power levels.
  - ~20 shots (≈ 10 development).

  Essential diagnostics:
  - Mirnov arrays – AE amplitude and spectra
  - MSE – q-profile & magnetic-shear evolution
  - FILD / FIDA / ICE – fast-ion losses and redistribution
  - Thomson / ECE – Te, ne, and ECRH deposition validation

- **Control/suppression of AEs and the resultant FI loss/redistribution is a primary aim of RT-09**
- **This proposal should therefore feature highly within the TCV experimental branch.**
- **P1-TCV**



Proposed pulses

Device	# Pulses/Session	# Development
AUG		
MAST-U		
TCV	20	10
WEST		

Optimization of active control of Alfvén Eigenmodes with externally applied 3D fields (#205)

Proponents and contact person:

J. Gonzalez-Martin jgonzalez62@us.es

(full list in the wiki)

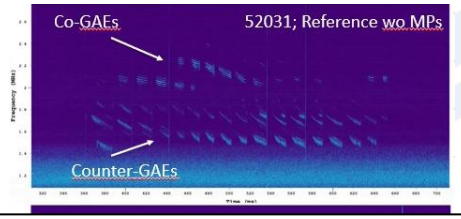
Scientific Backg

- ➢ Expand contr
  AEs
- ➢ Study impact

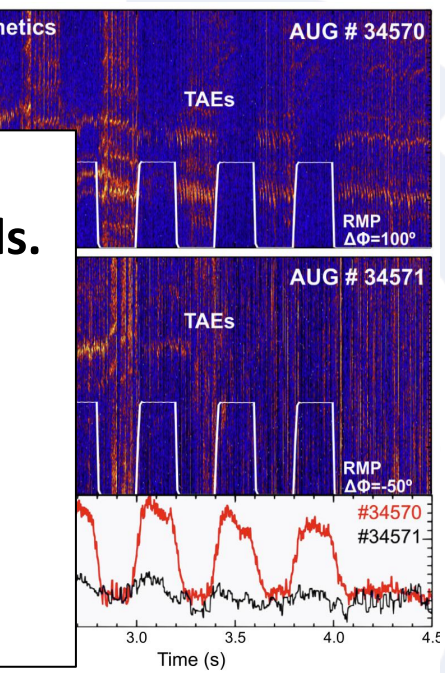
- In AUG:
- ➢ Control of hig
- ➢ Control of ICR
- ➢ Leveraging IN
- In MAST-U:
- ➢ Control of high frequency AEs

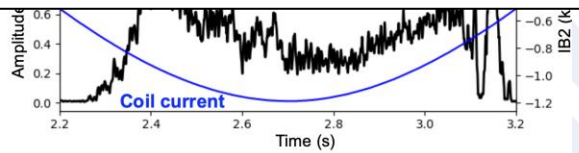
- **This can be added to the RT-09 "3D fields block" of experiments**
- **Spans AUG and MAST-U – both considerably oversubscribed by proposals.**
- **Combine with #192**
- **Some of AUG part may be possible to combine with aspects #195. RTCs/TFLs to consider further together with Proponents.**
- **Similarly with all AUG proposals, careful planning will be needed to see what can be achieved amongst hi Prio. proposals in limited shots**
- **P1-AUG, P1-MASTU**

GAEs Impacted by MPs in MAST-U



AUG: AE active control using n=2 [1]





Proposed pulses

Device	# Pulses/Session	# Development
MAST-U	14	0
AUG	17	4

Experimental Strategy/Machine Constraints and essential diagnostics

- ➢ FILD, FIDA, INPA, and other fast-ion diagnostics are essential
- ➢ In MU, special settings for IR thermography
- ➢ Scans in MP differential phase

[1] J. Gonzalez-Martin et al., Phys. Rev. Lett (2023)

Fast-ion effects on core turbulence at different P_i/P_e on ASDEX Upgrade (#208)

- **Proponents and contact person:**
  - Roberto Bilato *et al* (see full list in wiki)

- **Scientific Background & Objectives**

  The aim is to investigate the effects of NBI/ICRF fast ions (FIs) on core transport for different levels of turbulence (*D2*), which is controlled by changing the Pe/Pi ratio, where Pe and Pi are the auxiliary heating power to electrons and ions, respectively. The ultimate objective is to generate a set of well-diagnosticed discharges (*D1*), which will then be analysed usir
  FI impact on
  (*D3*).

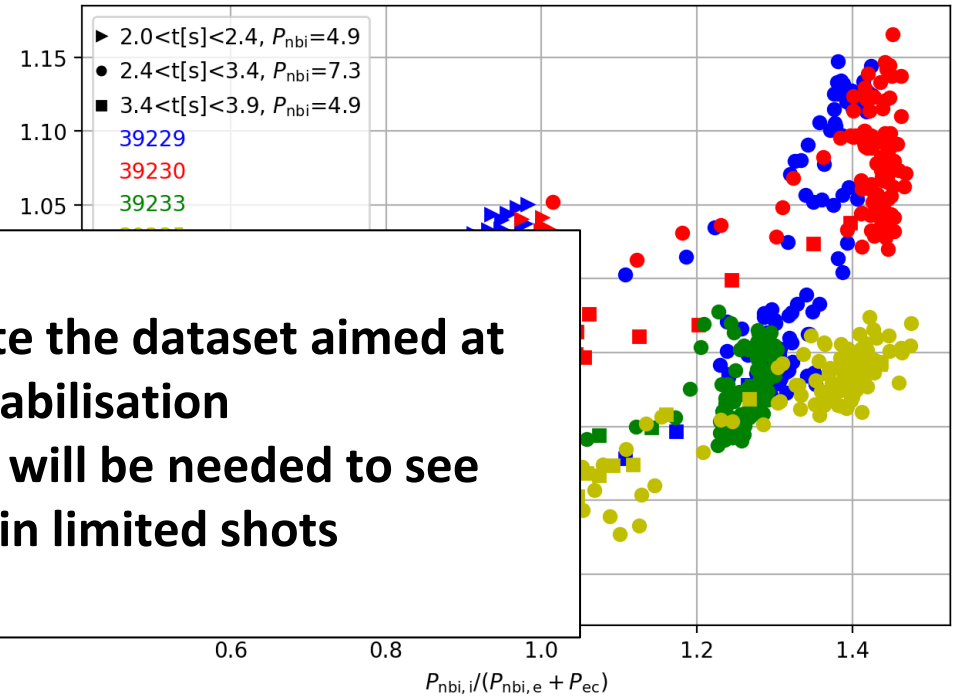
- **Experimenta**

  This study uses
  three heating s
  for analysis.

  - (LSN, 0.
    constar
    power, P_{aux}, is not constant.
  - (LSN, 0.8MA, -2.5T) Impact of P_e/Pi when P_{aux} is the same (P_{icrf} replacing P_{ecrf}) and the FI content unavoidably varies.
  - (USN, 0.8MA, +-2.5T) Impact of the gradB drifts: fav. vs unfav. configuration.
  - (LSN, 0.4MA, -2.5T) Comparison with low-density (low plasma current) discharges where the dilution effect is more important.

  Diagnostics:
  - Characterization the fast-ion population with NPA, FIDA, and FILD diagnostics.
  - Good measurements of plasma profiles for n_e, T_e, T_i, and v_{tor}.
  - Possibly Er measurements (CXRS and DR).

- **Continuation of a successful AUG expt from 2025**
- **Recommend adoption of this proposal to complete the dataset aimed at elucidating the mechanisms of core-turbulence stabilisation**
- **Similarly with all AUG proposals, careful planning will be needed to see what can be achieved amongst hi Prio. proposals in limited shots**
- **P1-AUG**



Proposed pulses

Device	# Pulses/Session	# Development
AUG	10	