# EP-7 The impact of localized ECH on Alfvén Eigenmode activity

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| **TG priority:** High | **Start date:** 2013 | **Status:**  On-going | **Personnel exchange:**  Yes |
| **IO priority:**   | **End date:** 2016  | **Motivation:** Physics Basis  |

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| **Device /****Association** | **Contact****Person** | **2016 TGRequest** | **Activity (from JEX/JA spreadsheets)** |
| **2013** | **2014** | **2015** | **2016** |
| DIII-D  | M. Van Zeeland,W. Heidbrink | Desirable | Not doing | Committed | Analysis |   |
| AUG  | I. Classen,M. Garcia-Munoz | Committed | Committed | Committed | Committed |   |
| TJ-II  | E. Ascasibar,A. Cappa,A.Melnikov | Desirable |   |   | Analysis  |   |
| LHD  | K. Toi,M.Osakabe | Desirable | Committed | Committed |   |   |
| KSTAR  | C.M. Ryu | Desirable | Considering | Considering |   |   |

**Purpose:** Experiments carried out on DIII-D in 2008 show that localized electron cyclotron heating (ECH) can drastically alter beam driven Alfven Eigenmode (AE) activity including, in some cases, the stabilization of RSAEs1,2. Discharges with stabilized or reduced AE activity also exhibited improved fast ion confinement. The exact cause for the observed impact of ECH on the AE activity in these DIII-D discharges remains to be satisfactorily explained. The problem is complicated by the fact that ECH can have a non-negligible impact on AE drive, damping, and the modes themselves.

The overall goal of this joint experiment is to arrive at an understanding of the dominant mechanisms responsible for ECH modification of AEs and to eventually use this understanding to make a prediction for the impact localized ECH can have on AEs in ITER and future devices.

The shorter term goals of the joint experiment are:

1. Test the reproducibility of the DIII-D result on ASDEX-Upgrade and other devices
2. Through experiment and modelling determine dominant effect causing change in mode activity
3. Quantify improvement in fast ion transport

[1] M.A. Van Zeeland, et.al., PPCF 50 (2008) 035009

[2] M.A. Van Zeeland, et.al., Nucl. Fusion 49 (2009) 065003

**Results for 2015**

In 2015, experiments and analyses were carried out worldwide in support of EP-7 on DIII-D, AUG, and TJ-II.

* A DIII-D experiment was performed in hybrid scenario showing the high efficiency of ECCD in affecting Alfvén eigenmodes.
* In parallel, analysis of DIII-D experiments on AE suppression during current ramp-up phase, has been completed. It was found that the original ECH/AE effect in which ECH near qmin was observed to stabilize RSAEs, is caused by the effect of high pressure and high pressure gradient driven by ECH. At the high-q equilibrium, the effect of high pressure shrinks the frequency band between geodesic acoustic modes and TAE, where RSAE exist, similarly to the high-beta effect previously reported from NSTX. The DIII-D results were reported at the IAEA EP TCM in Vienna (1-4 September 2015) and were received well.
* AUG experiments with NBI and an ECH deposition location scan during the current ramp (in successive discharges) were continued. In addition, AUG experiments were also carried out with early NBI heating followed by H minority ion cyclotron heating (ICH) . The goal of these exploratory discharges was to evaluate the impact of ECH on RF tail driven AEs. The data obtained show TAEs are preferentially driven by ICH in these plasmas, and with ECH near qmin, RSAEs were in fact also observed.
* TJ-II experiments showing that AEs can be changed radically by application of ECH, were further analysed. Depending on ECH deposition location, AEs can go from chirping to steady frequency and lower amplitude with lower amplitude corresponding to deposition at or inside of the mode location.

**Plans for 2016**

* The explanation for the ECH impact on RSAE stability is now given in terms of high-beta effect at high-q, and it is consistent with range of available data from DIII-D and AUG. It is proposed that the experiment will be closed in 2016, after the final dedicated set of discharges will be performed on AUG and analysed. Two papers are planned for submission to the Special Issue Nuclear Fusion devoted to the IAEA EP TCM presentations.
* Taking into account a wide variety of observations with ECH/ECCD affecting AEs other, than RSAEs, a possibility of new Joint Experiment will be considered, most likely focused on TAE modes.

**Previous results:** In 2013, extensive work related to EP-7 was carried out on the TJ-II stellarator. In TJ-II experiments, ECH is observed to significantly alter beam driven AE activity. Three of the primary findings from the TJ-II work are: 1) ECH causes steady frequency AEs to decrease in amplitude and begin chirping. Continuous frequency modes are recovered within 2ms when ECH is switched off. 2) At higher density, reduction in mode amplitude is not as large and chirping repetition frequency increases. 3) At higher ECH power, mode amplitudes can be reduced further. Since there is a transition to chirping and back, the TJ-II findings can also obviously contribute to EP-4 “Effect of dynamical friction (drag) at resonance on nonlinear AE evolution”. A portion of the TJ-II work was summarized in K. Nagaoka, et.al. Nucl. Fusion 53 (2013) 072004.

At ASDEX Upgrade, data from 2008 was looked at again and it was found that discharges with ECH inside of, but near qmin, had significant RSAE activity. Additionally, it was found that ECH could alter BAE activity. When ECH was injected, the BAE frequency chirp range was extended and mode amplitudes were enhanced. In 2013, three new discharges, intended to be similar to the original DIII-D experiments, were dedicated to EP-7 in which ECH was injected near qmin or near the magnetic axis during the current ramp phase. These discharges had early beam heating and, without ECH, had robust AE activity including RSAEs and TAEs. The discharge with ECH near the magnetic axis has clear RSAE activity. With ECH near qmin, the AE activity early on is weaker and significantly different than the on-axis case at later times, being more TAE-like as opposed to primarily RSAEs. Unfortunately, the density was not matched well in these two discharges and, although a difference in mode activity was observed, future experiments will be required.

In KSTAR, ECH was injected early during the current ramp portion of a 2T monotonic shear plasma with early beam heating. Without ECH, a combination of n=1 and n=2 EPM-like relatively broadband activity is present. With ECH, the n=2 activity appears to be suppressed.

EP-7 experiments in LHD found a significant change in mode activity with application of ECH near the magnetic axis. Depending on ECH power, RSAE activity was suppressed, with more ECH power being more efficient. It is speculated that the suppression may be due to enhanced EP pressure, i.e. the excitation condition Qgrad > Qhot in K. Toi et.al. PRL (2010) may be violated. It was also observed that ECH destabilizes low frequency n=2 and n=3 modes which may be BAEs.

To take advantage of recent diagnostic upgrades and have improved equilibria as well as mode measurements for modeling, two EP-7 discharges were carried out on DIII-D in 2013. The goal of these discharges was to re-create the ECH on-axis and near-qmin cases. The effect observed in 2008 was reproduced immediately - for ECH near qmin, RSAE suppression was found and for ECH near the magnetic axis, strong RSAE activity was observed. In the same discharges FIDA profiles show ~30% higher central fast ion density for ECH deposition near qmin, in contrast to the classical expectation of lower central fast ion density when compared to discharges ECH near the magnetic axis. These measurements support the idea that EP confinement is improved with reduced RSAE activity. Using these two discharges, modelling using the gyrofluid code TAEFL and gyrokinetic code GTC has begun. Initial results are consistent with a stabilization of RSAEs for ECH deposition near qmin.

In general, there has been a lot of interest both experimentally and theoretically in EP-7. ECH has been clearly established as a useful tool for EP physics capable of impacting AEs and other EP instabilities. LHD, TJ-II, AUG, KSTAR, HL-2A, Heliotron J, and DIII-D have all observed significant modification of AE activity with ECH.