EUROFUSION CP(15)05/72

J.M. Fontdecaba et al.

The Influence of Alfvén Waves on Fast Ion Confinement in TJ-II Plasmas

(22nd June 2015 – 26th June 2015)
Lisbon, Portugal

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

The influence of Alfvén waves on fast ion confinement in TJ-II plasmas

J.M. Fontdecaba, F. Castejón, E. Ascasíbar, A. Cappa, T. Estrada, M. Liniers, A. Bustos[1],
and TJ-II Team
Laboratorio Nacional de Fusión, Ciemat, 28040 Madrid, Spain
[1]Departamento de Física. Universidad Carlos III, 28911 Leganés (Madrid), Spain

1. Introduction

Fast ion confinement is a key point for fusion devices since alpha particles produced in the fusion reactions must be confined long enough to deposit their energy in the plasma bulk in order to keep the fusion reactions going on[1]. Moreover, the fast ions coming from Neutral Beam Injection (NBI)[2] or Ion Cyclotron Heating must be also well confined in order to increase the heating and current drive efficiencies. Fast ion transport must also be studied in order to find out what are the main escaping points of the ions, since they could damage the vacuum vessel of the device[3]. Fast ions can also develop instabilities[4] that can enhance the transport.

The instabilities caused by fast ions have been previously studied in TJ-II[5], but no direct observation of the dependence of the induced ion transport on the ion energy has been reported so far. In this work, we study the fast ion transport induced by Alfvén wave instabilities, which are themselves driven by fast ions coming from NBI. Several types of Alfvén Eigenmodes (AEs) at different frequencies have been observed in TJ-II and we investigate their effect on the NBI ions confinement properties.

2. Experimental set-up

The stellarator TJ-II heliac flexible is a four period medium size device ($R_0 = 1.5$ m; $a \leq 0.2$ m; $B_0 = 1$ T)[6]. The heating systems are electron cyclotron resonance heating (ECRH) and neutral beam injection (NBI). The ECRH system has two gyrotrons (300 kW each) tuned at the second harmonic of the X-mode (53.2 GHz). The NBI system consists of two injectors of a maximal nominal power of 700 kW each with ion energy of 34 keV in tangential positions (co and counter injectors).

To scan the energy and population of fast ions in the plasma there is a Compact Neutral Particle Analyzer (CNPA)[7]. It can distinguish 16 different energies between 1 and 40 keV with temporal resolution of 1 ms. The line of sight is directed towards the ions coming from the co-injector but it only counts ions coming after a re-neutralization in the plasma because the path between the injector and the CNPA is twisted, so no lost ions from the injector can contaminate the measurements of this diagnostic.

In TJ-II there are three Mirnov coil sets distributed at different poloidal positions of the vacuum vessel. During this work we have used the data of one coil that is located in a set of 12 coils which measures the three components of the magnetic field at four positions located along a vertical line over the plasma column. The sampling frequency of this array of coils is 1 MHz.

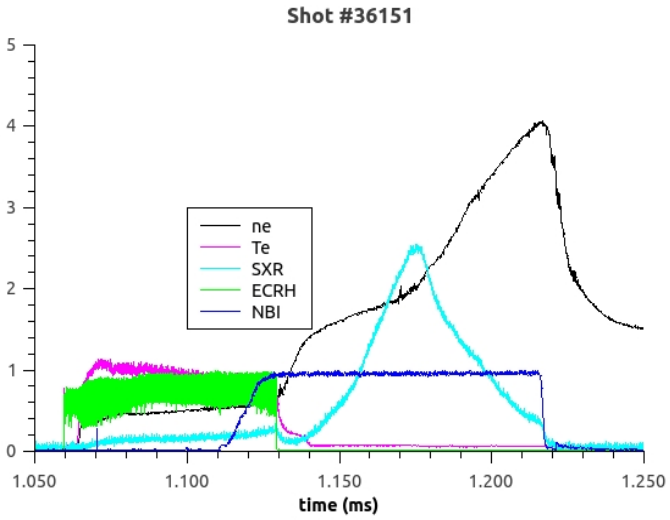

Figure1. Typical NBI heated discharge. It shows the line density (n_e), electron temperature from a central chord measured by ECE (T_e), soft x-rays (SXR) and the heating scheme, ECRH and NBI heating. All the values are arbitrary units except line density in 10^{19} m^{-3}.

In this case the deuterium plasma is started up with the two gyrotrons with 250 kW each focused slightly off-axis. Once the plasma is created the co-injector is fired and the gyrotrons switched off, so the plasma at the second part of the discharge is heated only by NBI, the bulk plasma being deuterium heated by hydrogen beams. During this series of experiments the voltage and current of the injector were scanned. A design of the heating scheme and main signals of a typical discharge for this experiment are plotted in figure 1.

3. Observations

High energy ions are collected by the CNPA and the steady state flux of the neutrals escaping from the plasma after a charge-exchange interaction is measured. We average the spectra in time windows of 10 ms in order to have enough statistics. In the experiments we measure the spectra at two different times of the discharge in order to compare the ion confinement in different conditions. An increase of the steady state flux reflects an increase of the fast ion density and, therefore, an improvement of their confinement.

After the onset of the NBI heating a mode appears at around 150 kHz. At the same time there is a drop of the signal in the high energy channels of the CNPA. This behavior is observed in different configurations and only above a threshold injected NBI power. Figure 2 left shows the signal received by the CNPA at two times of the discharge. Figure 2 at right shows the logarithm of the mean power for a Mirnov coil at the same times. As can be seen there is a clear difference on the signal received by the CNPA, this indicates a difference on the fast ion population inside the plasma. The main difference between the two times represented here is in the power spectra of the Mirnov coil, the decrease of the signal in the CNPA coincides with the on-set of an Alfvén mode at about 150 kHz. So the onset of the Alfvén mode leads to a decrease of the fast ion population in the plasma.

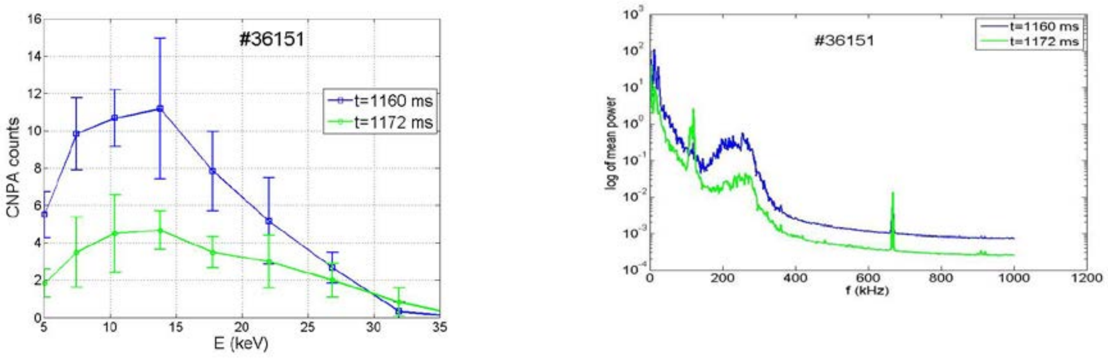

Figure 2. CNPA data (left) and log of power spectrum for a Mirnov coil signal in the same discharge at two different times, before and after the trigger of an Alfvén mode.

The change of configuration has indeed effect on the properties of the Alfvén modes. As expected, differences are observed in the CNPA spectra, showing an influence on the energy distribution of fast ions that arrive to the CNPA detectors. Figure 3 shows the results of the measurements for three different magnetic configurations with similar plasma conditions and same heating power. As can be seen on that figure there is a clear difference on the decrease of the counts on the CNPA depending on the magnetic configuration. The main difference between the

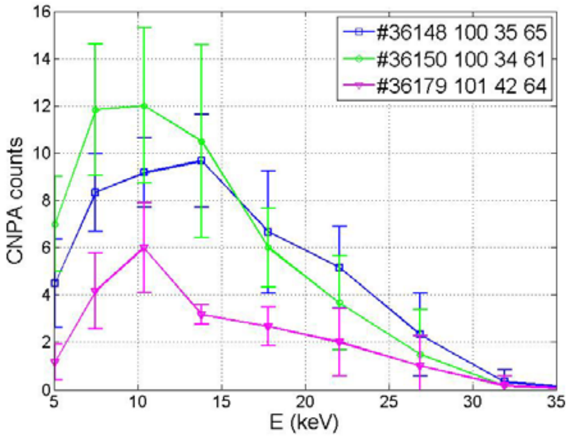

Figure 3. Counts in the CNPA for three different configurations with similar plasma parameters.

configurations studied is the iota profile, being the rest of the plasma parameters very similar, so there is an influence of the iota profiles on the fast ion confinement.

On other set of experiments during the NBI phase of the discharge the gyrotrons were switched on again[8]. The heating by microwaves results on the mitigation of the Alfvén modes. Simultaneously the flux of fast ions measured by the CNPA increased with the mitigation of the Alfvén modes as can be seen on figure 4.

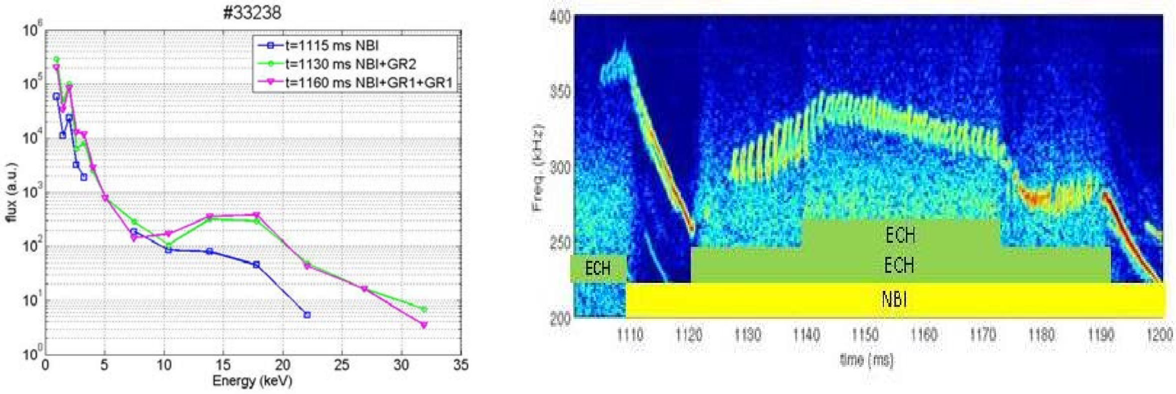

Figure 4. Energy spectra measured by the CNPA (left) and log of power spectra of the Mirnov coil for the same discharge. It is clearly seen the difference on the energy on the ions depending on the excited mode.

4. Conclusions

Different experiments have shown a decrease of the signal collected by the compact neutral particle analyzer when Alfvén modes are triggered. Also an increase of the flux of the fast ions is observed when the Alfvén modes are mitigated when the ECRH is turned on in a pure NBI plasma. These observations indicate that the Alfvén waves interact with the fast ions in the plasma destabilizing them with the consequence of loss of confinement.

Acknowledgements

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission. This work has been partially funded by the Spanish “Ministerio de Economía y Competitividad” under contracts no ENE2013-48109-P and ENE2013-48679-R.

Bibliography

[1] A. Fasoli et al. Nucl. Fusion **47** (2007) S264-S284
[2] T.H. Stix Plasma Physics **14** (1975) 367-384
[3] R.B. White et al. Phys Plasmas **2** (1995) 2871
[4] C. Z. Cheng and M. S. Chance, Physics of Fluids **29** (1986) 3695
[5] R. Jiménez-Gómez et al. Nucl. Fusion **51** (2011) 033001
[6] J. Sánchez et al. Nucl. Fusion **53** (2013) 104116
[7] F.V. Chernyshev et al. Instr. And Exp. Techniques **47** (2004) 214
[8] K. Nagaoka et al. Nucl. Fusion **53** (2013) 072004