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Electron distribution function and radial electric fields in the TJ-II stellarator

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Introduction

The transport in a device with high magnetic field ripple even in the plasma core, as is the case of TJ-II, is strongly dominated by the behaviour of trapped particles. Then, the shape of the effective absorption profile, that depends primarily on the electron distribution function in the absorption region, would be significantly modified by the off-axis reheating produced by the detrapping of trapped electrons along their drifts [1].

Applying to the plasma high and localized ECR heating power densities would lead to strong deformations of the electron distribution function, favouring the direct ripple trapped particle losses. As a result, the expected electron density profiles would be hollow and the electron temperature profile narrow and peaked in the plasma center.

In other stellarator devices, the ECRH driven convective flux of ripple-trapped suprathermal electrons in low-density plasmas has been mentioned as being related to various features and phenomena: the suprathermal feature and the burst-like phenomena in the ECE emissions [1], the electron-root feature [2] and the phenomenon of electric pulsation [3]. In TJ-II low-density plasmas heated with ECR, a considerable particle pump-out is usually detected, but depending on the magnetic configuration, regimes of reduced convective losses can be observed [4], and recent measurements with the HIBP are consistent with these different pump-out scenarios [5]. In the present work we try to relate the electron distribution function and the radial profile of plasma potential.

Experimental set up

The TJ-II stellarator is equipped with a Heavy Ion Beam diagnostic [6] which allows to measure both with time and spatial resolution plasma and density potential profiles in the whole TJ-II plasma radius. The secondary (Cs^{++}) ion current profile, directly reflects the plasma density.

The suprathermal electron tail is monitored with an intrinsic Ge detector (2 - 15 keV) working in PHA mode, with an energy resolution of about 200 eV, and a CdZnTe detector also working in PHA mode (20 - 200 keV) [7]. .

Experiments were carried out in steady state plasmas as well as in plasmas with low-frequency input power modulations. For the latter case, series of reproducible discharges were used to obtain both, the radial profile of plasma potential and the time evolution of this magnitude in discrete radial positions.

Experimental results.

There are several experimental evidences that qualitatively indicate the intensity of the particle pump-out in TJ-II. In a previous work [4], the observation of toroidal asymmetries in radiation allowed for the detection of different confinement regimes, associated with the level of ECRH driven convective flux of ripple-trapped particles. Fig. 1 shows the Hα signals from detectors located at two toroidal positions for consecutive shots. The differences observed were interpreted in terms of changes in the local flux of trapped particles reaching the wall in the vicinity of the gyrotron injection port (see Fig. 1 caption).

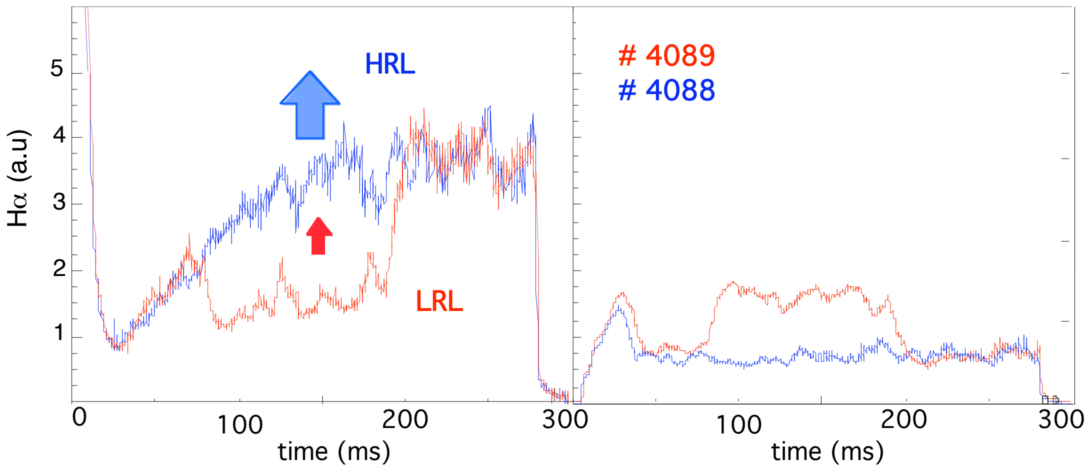

Fig. 1. *Hα signals for to consecutive shots at two toroidal positions. In blue is depicted a shot with high ripple losses (HRL) during all the discharge. In red, a shot with a transition to a low ripple losses (LRL) regime.*

Depending on the input power density, the ECRH on axis heating may cause a pronounced deformation of the electron distribution function that can be characterized through the soft x ray emission spectra. Even though this deformation is strongly non-symmetric in the velocity space, it can be detected far from the gyrotron port. In Fig. 2 the radial profile of the mean energy of suprathermal electrons generated in series of reproducible discharges with an average electron density of about 0.5×10^{19} m^{-3} is shown. Thomson scattering electron density and temperature profiles are also displayed. The observed radial evolution of the suprathermal electrons energy can be explained in terms of particle orbit change from helically trapped to passing.

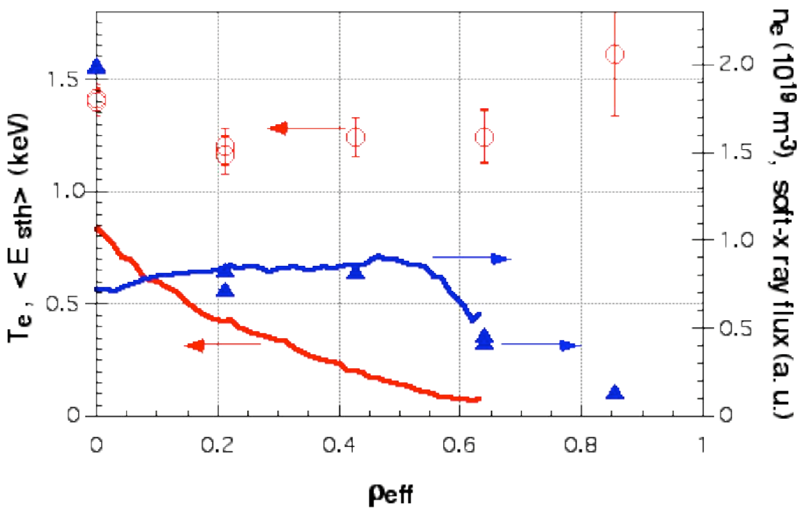

Fig. 2. *Radial profiles of Thomson Te (red line) and ne (blue line) and suprathermal mean energy (open circles). Blue triangles are the measured Bremsstrahlung intensity in the energy range between 4 and 10 keV.*

The variation of the ECR input power density also affects the plasma potential profile. The effect of input power modulation on plasma potential at the core region is shown in Fig. 3, together with the change of the characteristic energy of the suprathermal electron tail. When the ECRH power is suddenly increased the plasma potential becomes more positive, the soft-x ray energy spectra (in the range of 4 to 10 keV), show an increase of the characteristic energy of the suprathermal electron tail and the chord averaged electron density slightly decreases.

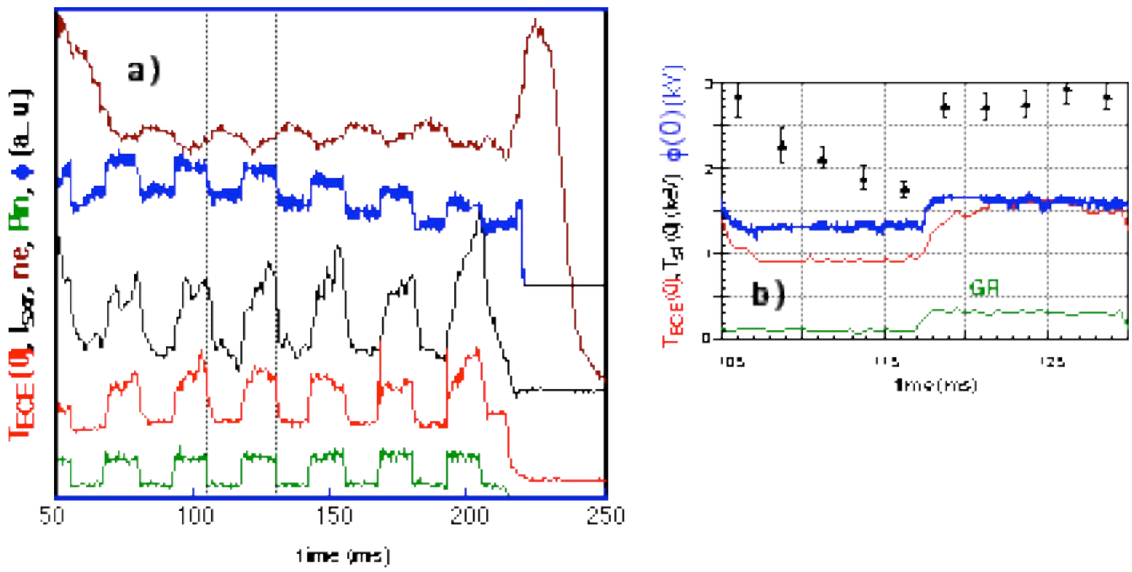

Fig. 3. *Signals from an input power modulated discharge. a) temporal evolution of line density, central plasma potential, soft x rays intensity and central electron temperature. b) time evolution of characteristic suprathermal energy (black triangles).*

The change of the radial profile of secondary Cs^{++} ion current, represented in Fig. 4 as the ratio Itot (500kW)/Itot (250 kW), evidences that the density profiles become more hollow when input power density increases.

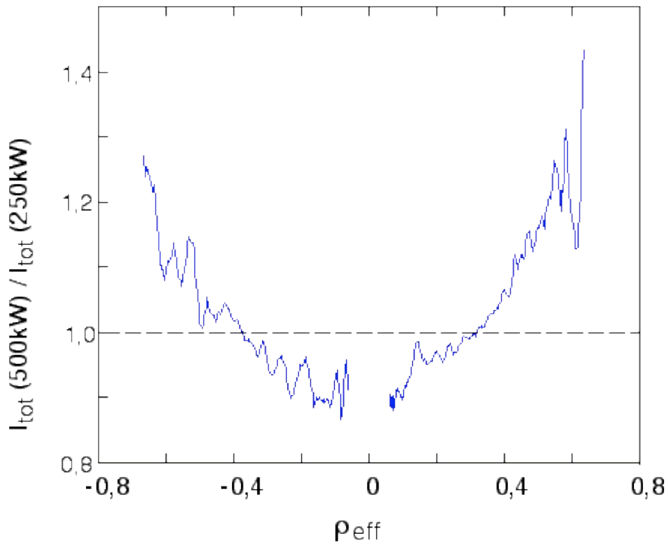

Fig. 4. *Ratio of secondary Cs++ ion current for the two different input power of Fig 3.*

Conclusions

There are three parameters deeply coupled: the input power density, the plasma potential and the energy of the suprathermal electron tail. The above described observations indicate that in TJ-II plasmas, ECRH produces strong deformations of the electron distribution function and that the higher the energy of the electron suprathermal tail the higher plasma core potential. Also, the obtained hollow density profiles are in qualitative agreement with a high direct ripple losses scenario. Next step will be the simultaneous measurement of the electron distribution function deformation near de gyrotron port to try to estimate the energy sink due to the direct losses. Calculations of the ECRH driven convective flux based on Langevin equations are in progress [8].

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