EUROPEAN FUSION DEVELOPMENT AGREEMENT
JET

EFDA–JET–CP(02)02/02

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** See annex of J. Pamela et al, "Overview of Recent JET Results and Future Perspectives", Fusion Energy 2000 (Proc. 18th Int. Conf. Sorrento, 2000), IAEA, Vienna (2001).*

Preprint of Paper to be submitted for publication in
Proceedings of the 29th EPS Conference, (Montreux, Switzerland 17-21 June 2002)

ABSTRACT.
ITBs with high performance in time duration (4 seconds) were produced at JET in plasma discharges operating at the plasma current of 2.4 MA and toroidal magnetic field of 3.45T using Lower Hybrid (LH) radiofrequency power (2.3MW) for heating and current drive (CD) [1]. The coupling of the LH radiofrequency power started during the plasma current ramp-up and was maintained during the main heating phase (neutral beam injection (NBI) and ion cyclotron radiofrequency heating (ICRH) combined). The ITB's feature with longer time duration in shots performed by coupling LH power during the main heating phase was attributed to the low magnetic shear located in the outer half of plasma, as effect of the local LH current drive [2].

1. INTRODUCTION

The first results of the modelling devoted to calculate the LH power deposition and current density profiles for ITB plasmas are presented, considering the same plasma discharges of Ref. 1 and Ref.2. In Pulse No: 53432, the LH power coupled only in the early phase of discharge. In Pulse No: 53429, the LH power coupling i s continued also during the main heating phase. The q-profiles obtained with EFIT-equilibrium code constrained by the polarimetry and the Motional Stark effect (MSE) data are compared with the q-profiles obtained from the JETTO code [4]. The experimental kinetic profiles and the EFIT magnetic reconstruction data of the aforementioned plasma discharges are considered. In the modelling, the LH power deposition and the current density profiles are calculated both by the 1-D LH ray tracing module [5] included in the JETTO code, and by the LH ray-tracing utilising a 2-D relativistic Fokker-Planck solver [6]. The 2-D code can simulate the effect of the non-linear scattering of LH waves by parametric instability driven by ion sound quasi-modes, producing some LH power to be redistributed in a wide spectrum of the refractive index parallel to the toroidal field direction ($n_{//}$) [7]. The LH power deposition and driven current density profiles are calculated considering the magnetic reconstructed equilibrium provided by the EFIT code. The LH power density profile shown in Fig.1 is calculated considering the nominal LH power $n_{//}$ spectrum launched by the antenna ($n_{//0}$=1.84, width 0.43). A substantially centrally deposition (at $\rho \approx 0.3$, ρ is the square root of the normalised toroidal flux) is obtained. Many passes (>10) are necessary for producing a significant fraction of the coupled LH power to be absorbed. Some broadening (20%) of the launched $n_{//}$ power spectrum, simulating the effect of a non-linear wave scattering, is considered for obtaining the LH power density deposition profile shown in Fig. 2. The analysis of the parametric instability (which is beyond the scope of the present contribution) is necessary for calculating the realistic propagating $n_{//}$ power spectrum. The obtained LH power density deposition profile is shown in Fig.2. Most of the LH power is deposited at the first pass, mainly in the outer half of plasma (at $\rho \approx 0.7$). If no broadening is considered (by both the 1-D or the 2-D LH ray tracing modelling), an unrealistic number of passes (>10) is necessary for obtaining significant LH deposition in the outer half of plasma. The LH current density profile is not significantly affected considering the self consistent magnetic equilibrium in the ray-tracing calculation, as a low fraction of the LH driven current occurs in the considered high plasma current discharges. The simulation gives, indeed, a moderate amount (60%) of non-inductive current, including 30% of LHCD fraction..

The q-profiles from polarimetry and from MSE at the beginning of the main heating phase are shown in Fig.3. In Pulse No: 53429 (Fig.3a), at the time t = 4.4s (before the application of the LH power occurring at t=5.8s), the MSE and polarimetry q-profiles have both a reversed shaping. To be noted the different q-minimum in the profiles at that time: q_{min} = 2.8 from MSE and q_{min} = 3.2 from polarimetry. The q-profile simulated by the JETTO code has a good agreement with the EFIT-MSE profile at t = 4.4 s. The simulation is performed considering the LHCD current density profile obtained by the broad $n_{//}$ spectrum.

In Pulse No: 53429, during the ITB phase, the evolution of the q-profile shows a wide region (R≤3.6m) with low magnetic shear, (see Fig. 4a). The q-minimum value is lower than the integer value q=3. The ITB persists during the whole time window considered in the figure. In shot 53432 (see Fig. 4b), a well pronounced reversed shaped q-profile occurs around the time of the ITB collapse (t=6.3s). The collapse may be due to MHD starting as the consequence of the crossing of the q-profile with the integer value q=3.

Both the q-profiles simulated by the JETTO code and those obtained by polarimetry for Pulse No: 53429 show a low magnetic shear in a wide region off-axis and the q minimum lying between the integer values of 3 and 2. For Pulse No: 53432, both profiles show a well-pronounced reversed shape. However, the profile crossing around q=3 is not recovered by the simulation. In a previous work [2], the ITB collapse was related to the inward migration of the layer with negative shear (consistent with the polarimetry q-profile trend), in region dominated by neoclassical transport.

Non-linear plasma edge phenomena allow propagation of some LH power with large $n_{//}$. Such effect should be retained for a realistic LHCD modelling of ITB plasmas. The consequent enhanced off-axis LHCD is consistent with the observed large ITBs and the obtained large region with low magnetic shear. The LH power might provide a powerful tool for controlling the q-profile for ITB at high plasma current, for potential application to the advanced tokamak regimes

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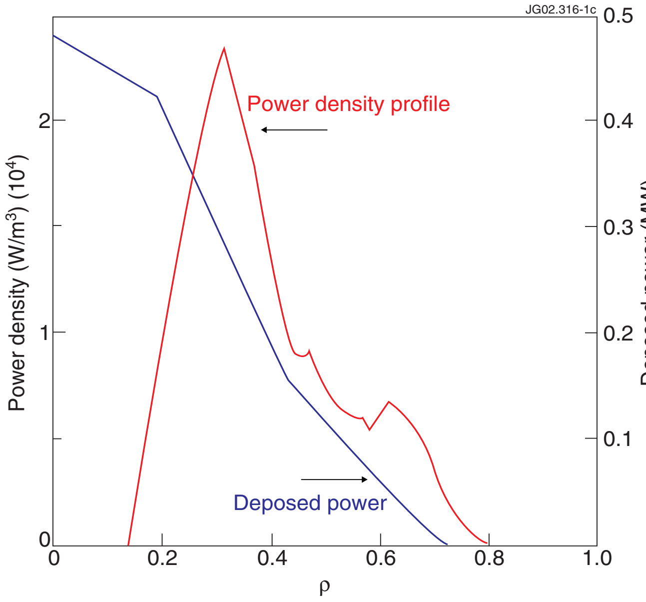


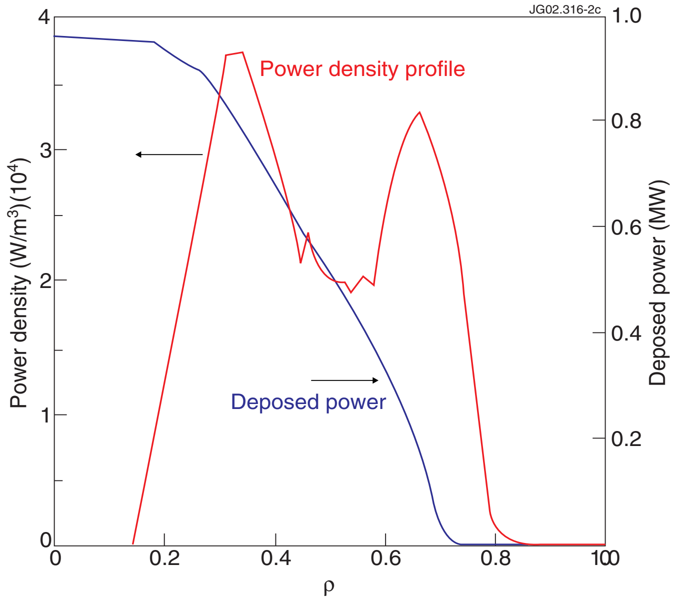
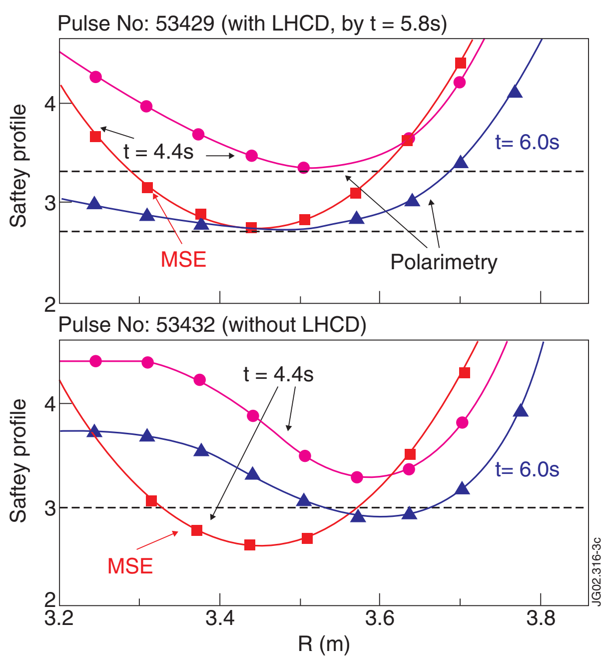


Figure 1: LH deposition profiles with nominal $n_{//}$ power spectrum (see the text)

Figure 2: LH deposition profiles with broad $n_{//}$ power spectrum (see the text)



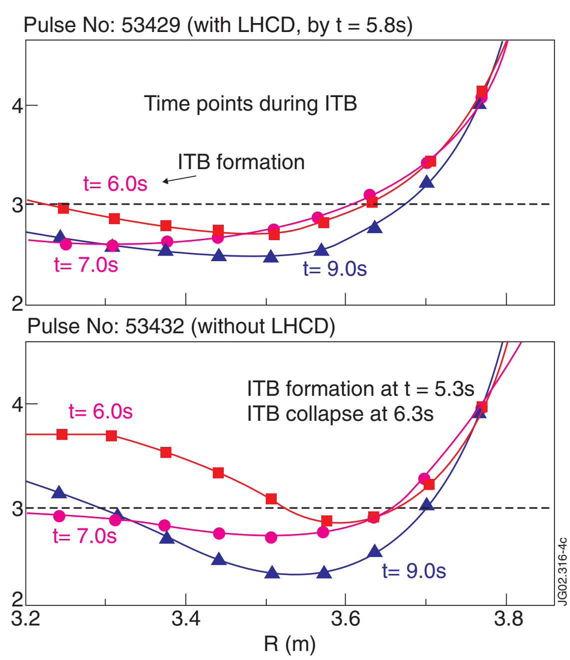


Figure 3: q-profiles at the beginning of the main heating phase

Figure 4: q-profiles during the main heating phase