Impact of non-axisymmetric magnetic perturbation fields on plasma density in the JET tokamak

Y. Wei[1, 2], Y. Liang[1], L. Zeng[3], S. Jachmich[4, 5], J. Cai[3], H. R. Koslowski[1] and JET Contributors*

EUROfusion Consortium, JET, Culham Science Center, Abingdon, OX14 3DB, UK

[1] *Forschungszentrum Jülich GmbH, Institut für Energie– und Klimaforschung–Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany*

[2] *Southwestern Institute of Physics, Chengdu 610041, China*

[3] *Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China*

[4] *LPP, Ecole Royale Militaire/Koninklijke Militaire School, TEC partner, Brussels, Belgium*

[5] *EUROfusion PMU, JET, Culham Science Centre, Abingdon, UK*

Introduction Non-axisymmetric magnetic perturbation fields (NAMP) have been considered as an attractive method for active control of the large edge localized mode (ELM) on ITER. Drop in plasma density, so called density pump-out effect, has been often observed in many NAMP ELM control / suppression experiments. Study of the density pump-out effect is important for understanding the physical mechanism of ELM control.

On JET, a low n (n = 1, 2) field can be produced by adjusting both the orientation and the amplitude of the currents flowing in four external error field correction coils (EFCCs). Active control of the frequency and the size of the type-I ELMs has been achieved with either n = 1 or n = 2 NAMP fields [1, 2]. While applying the EFCCs, reduction in the plasma density has been observed in wide range of plasma operational domain. The multiple resonance of ELM frequency as a function of the edge safety factor, q_{95}, has been reported in previous studies [3, 4]. Significant increases of ELM frequency can be seen at various q_{95} values [3, 4]. The ideal external peeling mode/relaxation model [5] can be used as a possible explanation of the multi-resonance effect [4, 6].

In this paper, the dependences of density pump-out effect on q_{95} and the edge pedestal electron collisionality, $\nu^*_{e,ped}$, have been investigated with an application of low n NAMP fields on JET. The experimental results show that the density pump-out effect is strong ($\Delta n_e/n_e$ ~ 40%) in low collisionality plasma ($\nu^*_{e,ped}$ ~ 0.1). The plasma density can be

*See the author list of "Litaudon et al, Overview of the JET results in support to ITER, accepted for publication in Nuclear Fusion" compensated when $\nu^*_{e,\,ped}$ increases with additional fueling. Furthermore, the amplitude of the density change has been analyzed for the plasmas with different q_{95} in low collisionality regime.

Dependencies of density pump-out effect on $\nu^*_{e,\,ped}$ On JET, active control of type I ELMs has been achieved by using EFCCs to produce n = 1 or n = 2 field. Data analysis shows that the edge electron collisionality decreases while plasma electron density drops during the application of EFCCs. Fig. 1 shows the correlation between edge electron collisionality and plasma density and temperature. In low collisionality plasma ($\nu^*_{e,\,ped} \sim 0.1$), the drop of the central line-integrated density $\Delta n_e l$ (normalized to the $n_e l$ before EFCCs) is up to 40%. The density drop decreases as $\nu^*_{e,\,ped}$ increases. Higher collisionality is achieved with additional fueling, and the density pump-out is compensated, as shown in fig. 1(a). The density change at pedestal region show the same tendency as the overall line-integrated density change but slightly larger. The pedestal temperature increases for the low

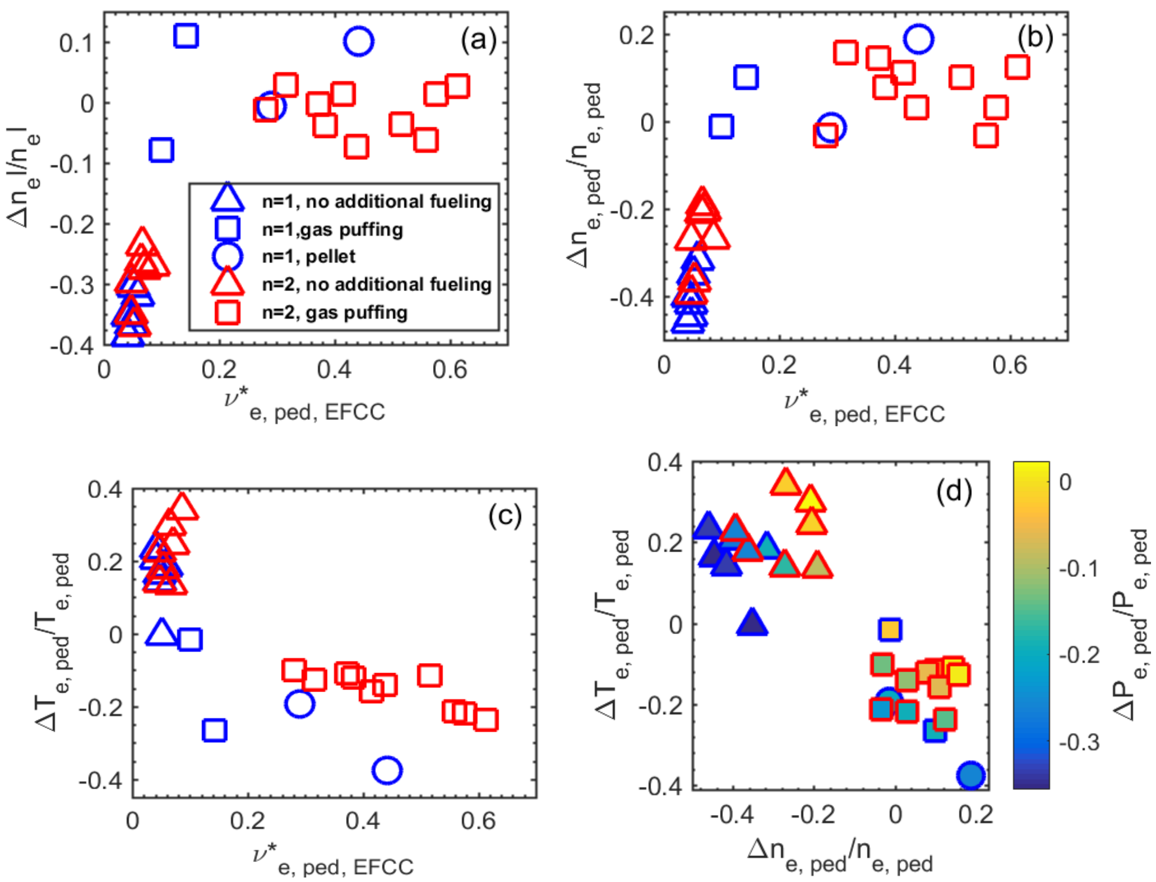

FIG.1 Normalized line-integated density change (a), normalized pedestal density change (b) and normailized pedestal temperature change (c) as function of pedestal electron collisionality during EFCCs. (d) is the normalized pedestal temperature change versus normailized pedestal density change and the colormap shows the normalized pedestal pressure change.

collisionality plasma without additional fueling, as the heating power remains the same while less particles need to be heated up due to the strong density pump-out effect. When additional fueling is employed to compensate the density pump-out effect, the collisionality increases not only because the density increases but also due to the decrease of temperature, as shown in fig. 1(c). It can be seen in fig. 1(d) that for the case without additional fueling during EFCCs, the pedestal pressure drop is mainly due to strong density pump-out effect. While for the case with additional fueling, confinement could become worse if over-compensation cause strong pedestal temperature decrease.

Dependencies of density pump-out effect on q_{95} In previous studies, the multiple resonance effect of the dependence of NAMP ELM control on the edge safety factor, q_{95}, has been observed. Significant increases of ELM frequency can be seen at various q_{95} values [3, 4]. The amplitude of the density drop has been analysed for the plasmas with different q_{95} in low collisionality regime. Fig. 2 (left) shows the q_{95} scan experiments with n = 1 field. All five discharges was applied with the same amount of perturbation field, and strong density drop and edge electron collisionality drop can be seen. In fig. 2 (right), the top figure shows the ELM frequency during EFCCs flattop as a function of q_{95}. Multiple peaks can be seen at several q_{95} values [4]. The density change normalized to the number of ELMs occurred in every 200 ms time slice is analysed and shown in the bottom figure. Both f_{ELM} and $\Delta n_e/N_{ELM}$ show strong dependencies on q_{95}. While ELM frequency peaks, the density pump-out effect

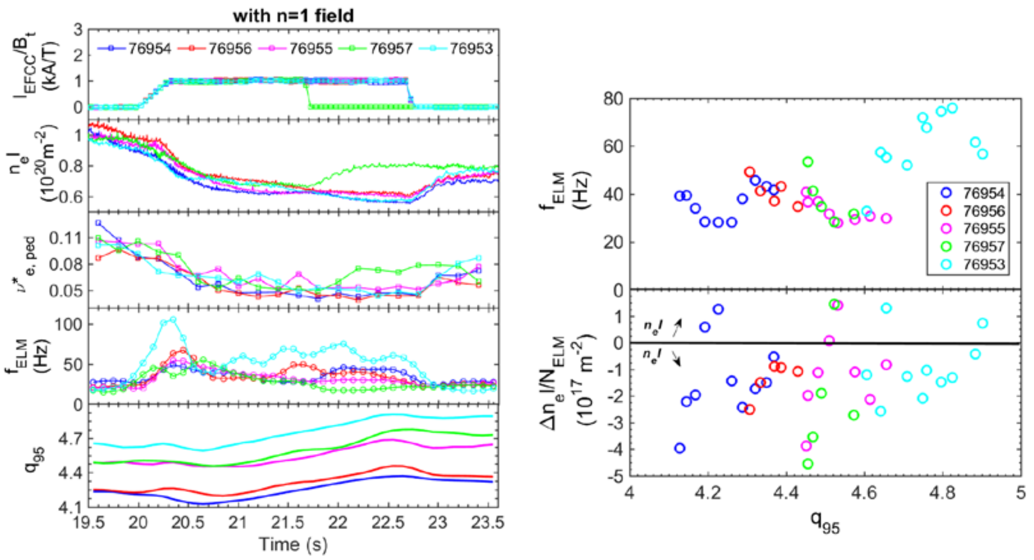

FIG. 2 q_{95} scan with n = 1 field. The time trace from top to bottom in the left figure are the EFCC current normalized to the toroidal field, central line-integrated plasma density, the pedestal electron collisionality, the ELM frequency and the edge safety factor q_{95}. The right figure shows the ELM frequency and plasma density change normalized to ELM number in 200 ms time slice as function of edge safety factor q_{95}.

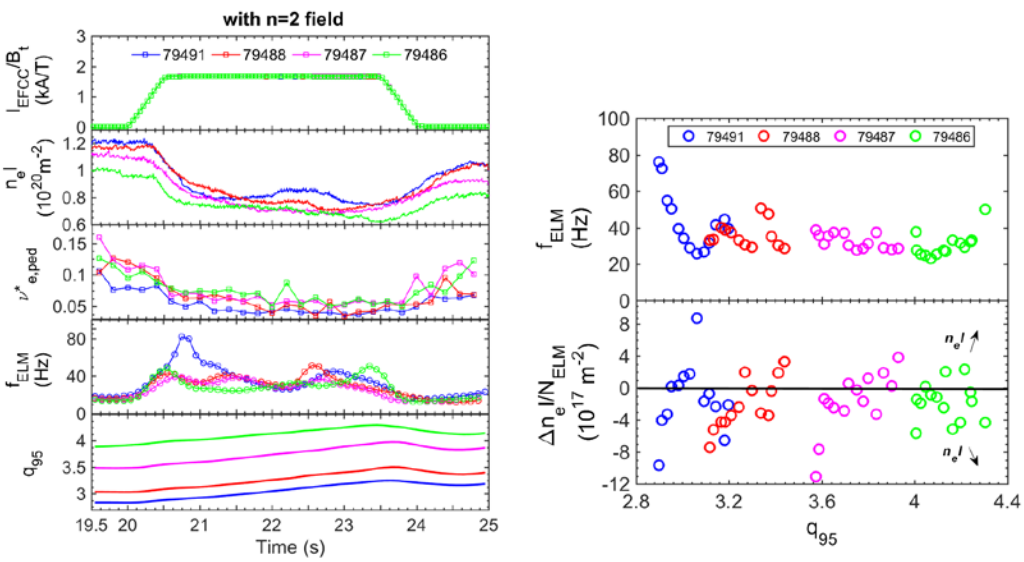

FIG. 3 q_{95} scan with n = 2 field. The time trace from top to bottom in the left figure are the EFCC current normalized to the toroidal field, central line-integrated plasma density, the pedestal electron collisionality, the ELM frequency and the edge safety factor q_{95}. The right figure shows the ELM frequency and plasma density change normalized to ELM number in 200 ms time slice as function of edge safety factor q_{95}.

is enhanced. Density recovery can be seen when f_{ELM} is low. The q_{95} scan with n = 2 field also has been investigated, as shown in fig. 3. The q_{95} is varied from 2.8 to 4.4 during the application of n = 2 field. The density pump-out effect also show strongly dependence on q_{95}.

Summary The experimental results show that the density pump-out effect is strong ($\Delta n_e l/n_e l$ ~ 40%) in low collisionality plasma ($\nu^*_{e,\,ped}$ ~ 0.1). The plasma density can be compensated when $\nu^*_{e,\,ped}$ increases with additional fueling. The amplitude of the density change has been analysed for the plasmas with different q_{95} in low collisionality regime. The density pump-out effect show strong dependencies on q_{95}. The density drop is enhanced while ELM frequency peaks.

Acknowledgement 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.

Reference

[1] Y. Liang *et al.* Plasma Phys. Control. Fusion 49 (2007) B581–B589.

[2] Y. Liang *et al.* Nucl. Fusion 50 (2010) 025013.

[3] Y. Liang *et al.* Phys. Rev. Lett. 105 (2010) 065001.

[4] Y. Liang *et al.* Nucl. Fusion 51 (2011) 073001.

[5] C.G. Gimblett, R.J. Hastie and P. Helander. Phys. Rev. Lett. 96 (2006) 035006.

[6] J. Pearson *et al.* Nucl. Fusion 52 (2012) 074011.