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O.Tudisco[1], F. Crisanti[1], P.Lomas[2], E.Joffrin[3], F.Rimini[3], A.Becoulet[3], L.Bertalot[1], T.Bolzonella[4], G.Bracco[1], C.Giroud[3], S.Cortes[5], B.Esposito[1], N.Hawkes[2], S.Popovichev[2], E.Rachlew[6], M.Riva[1] and JET EFDA Contributors*

[1]Associazione EURATOM-ENEA sulla Fusione, C.R. Frascati, Frascati, Italy.
[2]EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, U.K.
[3]Association Euratom-CEA, CEA Cadarache, F-13108, St Paul lez Durance, France.
[4]Consorzio RFX, Associazione EURATOM-ENEA sulla Fusione, Padua, Italy.
[5]EURATOM-IST Association, Centro de Fus o Nuclear, Lisboa, Portugal
[6]Association EURATOM-VR, KTH, SE-10044 Stockholm, SWEDEN
** See the appendix of JET EFDA contributors (prepared by J. Paméla and E.R Solano),*
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INTRODUCTION

Many tokamak experiments have been recently performed to study the effect of changes in the magnetic configuration on the plasma transport properties [1,2]. As the shape in the magnetic configuration is rapidly lost going from the edge to the center, these studies have been focused to the transport in H-mode discharges where the transport barrier is located at the plasma edge. However, the plasma shaping should have an effect on the plasma turbulence onset at any radius, in fact the ITG instabilities can be reduced [3] at any aspect ratio increasing the local elongation (κ) or increase the triangularity (δ) beyond the value 0.4. The latter is, however, very difficult to obtained in inner flux surface. Furthermore, the rise of radial electric field is more prompt in highly shaped plasmas as a consequence of the geodesic curvature reduction [4]. In fact, the increase of the flux surfaces elongation reduces the effective inertia of the plasma, and a larger poloidal velocity is expected when the same external momentum source (NBI) is applied to plasma. In order to obtain a larger shaping of the inner surfaces (at fixed boundary shape), it is necessary to modify the plasma current profiles pushing the current to the edge where the shaping is more effective. Fig. 1 shows the profile of the elongation for two discharges having different current profile, the discharge with a hollow current profile have a slower decay of the elongation going through the plasma center, so that inner flux surfaces result to be more shaped. The scientific interest of these kind of current profiles arise from their good confinement properties, for the possibility to produce an internal transport barrier (ITB), which, for similarity to the edge barrier of H-mode discharges, could be affected by the elongation and triangularity of the local flux surfaces. Hence, in such discharges we have the opportunity to study the influence of the shaping on the transport of the plasma core. It is important to warn about the difficulties to separate the contribution of the shaping to the core transport from other effects as the change in q profile and MHD stability of edge (ELM activities). A set of discharges, with reversed magnetic shear, has been dedicated to this study on the JET tokamak. Different plasma boundary elongation and triangularity have been produced leaving the other macroscopic parameters unchanged. Four types of discharges have been considered changing between two values (low and high) the elongation and the triangularity. For each discharge the auxiliary heating timing has been modified to get the best one in terms of confinement.

1. STATISTICAL APPROACH

The possible correlation between the plasma shaping and the plasma core confinement has been searched analysing statistically the latest set of JET discharges with hollow current profile. In Fig. 2 the ion temperature at three different positions (r/a~0, 0.5, 0.9) is plotted versus the upper triangularity for total power ranging between 12 and 16MW. The full marks refer to discharges with high elongation (κ>1.75). Discharges with high triangularity (δ > 0.3) develop a transient ELM free phase, which in certain cases lasts only few hundreds of milliseconds. All points in the plots have been taken in this phase when present. It can be seen from Fig. 2 that the effect of the triangularity is to increase the edge temperature (pedestal) and to decrease the central one giving rise to a broadening of the ion temperature profile. The confinement factor H89 for these discharges increases with the triangularity due to the increase of the pedestal. High-elongated (full marks) and low elongated (open marks) discharges have the same behaviour, so that no dependence from the elongation can be inferred from this plot. It must be remarked that the change in the ELM activity with the shaping has been the main problem for the experiment and the data analysis. Any attempt to control the ELM has been made in this campaign. At high triangularity after the ELM free phase a large ELM usually brought the discharge to a disruption preventing high power operations. Furthermore, the ELM type before the ELM free phase and the duration of this phase changes with triangularity and power, so that any inference about the confinement from the triangularity is affected by the role of ELMs. Anyway, although we do not have an unique explanation for the negative trend of the central ion temperature with the triangularity, it must be pointed out that it is qualitatively in agreement with the prediction of a gyro-fluid code [4] for the linear grow rate of ITG turbulence. In fact, for high aspect ratio (A = 6) as it is in the inner flux surfaces, γ_{ITG} increases when triangularity rises from 0 to 0.4. A beneficial effect can be observed only at triangularity beyond this value. An analogous, but weaker, behaviour is expected for the geodesic curvature with δ, at the aspect ratio of the JET flux surface at ITB radius, while it has a beneficial effect on the pedestal for the higher triangularity and lower aspect ratio [3]. On the other hand, the dependence of the core confinement with the elongation is not in agreement with what is foreseen by the geodesic curvature and by the ITG analysis. A decrease of both the geodesic curvature [3] and of the linear growth rate is expected by increasing the local plasma elongation. However, since there is a stronger dependence of the ITG linear grow rate from other parameters (for instance magnetic shear), than from the flux surfaces shaping, we must be sure that all the key parameters are similar as much as possible when comparing different discharges.

2. THE ELONGATION ROLE: DIRECT COMPARISON OF SIMILAR DISCHARGES.

We tried to work out this point by selecting only discharges with identical time evolution of all macroscopic parameters, so that they, likely, have identical current profile evolution. Of course this procedure reduces quite a lot the number of available shots; however it has been possible to find two couples of Pulse No: (52656/52664 and 52635/52658) where the time evolution of all parameters but the elongation were practically identical. In Fig. 3 it is reported the trace evolution of the main parameters of two of them (52656 full line, 52664 dashed line). In both discharges the triangularity is low and the position of the X-point is almost the same, so that they show the same type of ELM activity [5,6]. The elongation of discharges 52664 is 1.65, while it is 1.76 for the discharge 52656. In these discharges the neutron rate comes mainly from the beam-plasma interaction (80%) so that the higher ion temperature does not correspond to an equivalent increase of the neutron rate. Figure 4 shows the ion temperature and q for the two shots. The ion temperature of the most elongated Pulse No: 52656 remains higher at all radii. The same difference can be found in the central electron temperature The q profiles from MSE (in the limits of the diagnostic capability) are almost equal (Fig.

4). Using the ρ_T^* [7] criterion to detect the internal transport barrier (ITB) on the ion temperature, it can be seen that Pulse No: 52656 develops the barrier earlier (i.e. at a lower power) while less elongated Pulse develops the ITB only during the peak of the auxiliary heating (Fig. 5). These results are confirmed also by the other two discharges, where the less elongated Pulse No: does not develop the ITB at all. The power balance calculation of the two Pulses 52656 and 52664 have been performed and the total confinement time of the Pulse with higher elongation (52656) is, as expected, higher that the other discharge. The evolution of χ_i at R = 3.4 m (Fig. 6) shows that the increase of the gradient is due to a reduction of the energy transport coefficient. The ion thermal conductivity of Pulse No: 52656 is lower at all the radii. Figure 6 also shows the radial electric field evolution as computed in ref 8, which remains higher for the Pulse No: 52656 at almost all radius and times.

CONCLUSIONS

The plasma shape scan of discharges with reversed shear has confirmed a beneficial effect of the triangularity on the pedestal, and has shown a negative effect on the central ion temperature. For discharges with well matched q profiles, ITB formation seems to be more prompt at higher elongation.

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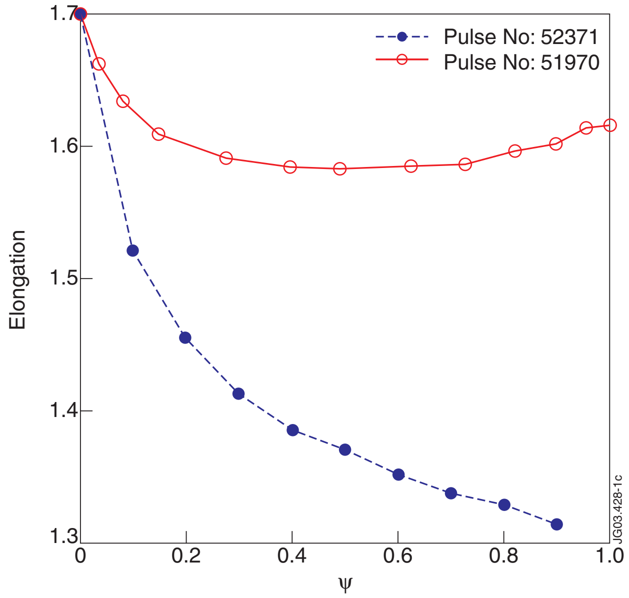


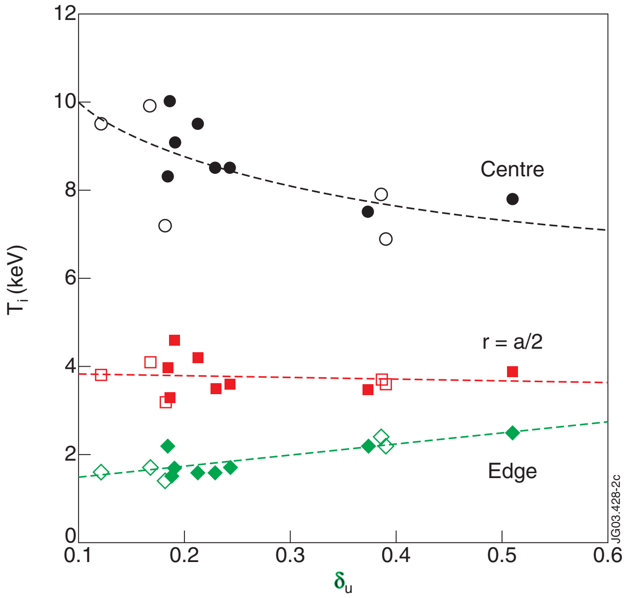
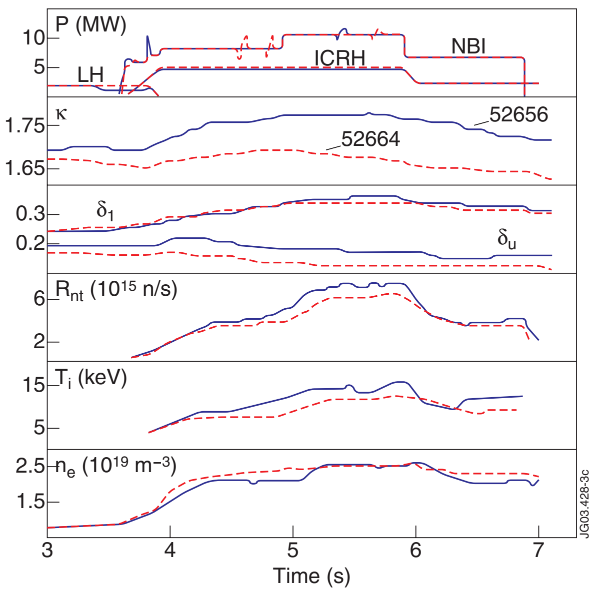


Figure 1: Penetration of the elongation into the plasma, in two Pulse No's: with monotonic (52371) and reversed (51970) q profile.

Figure 2: Ion temperature at 3 different position versus the upper triangularity.



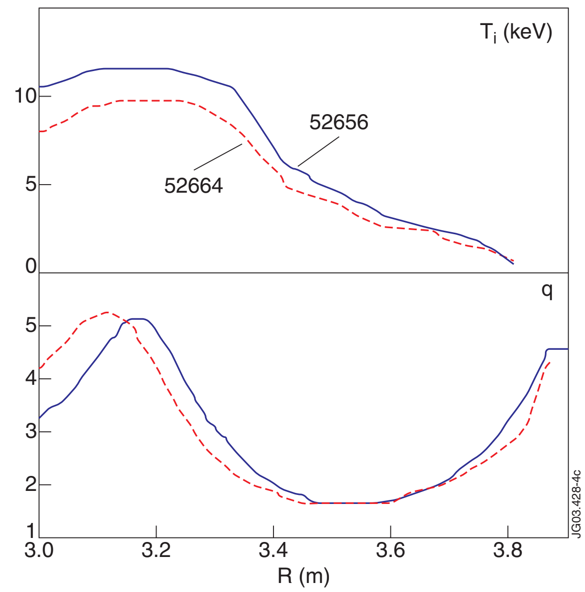


Figure 3: Time evolution of main parameters of the Pulse No: 52656 (high k), and 52664 (low k).

Figure 4: Ion temperature and q profile at t = 5.8s.

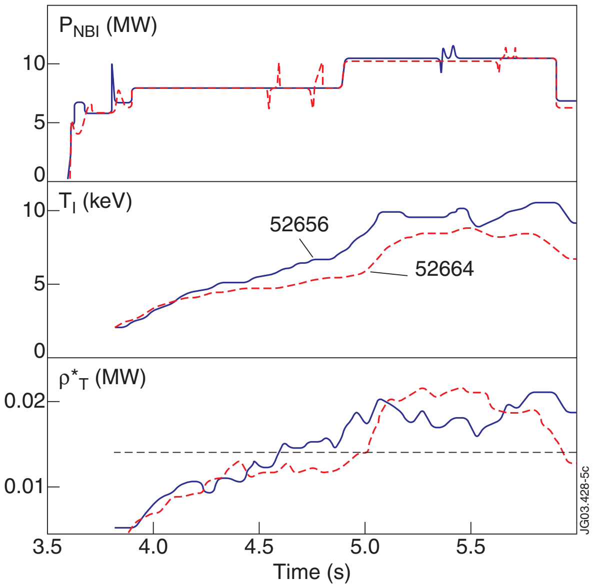


Figure 5: Evolution of the ρ_T^* for the two Pulse No: 52656 and 52664. The horizontal dashed line is the empirical threshold for the ITB.

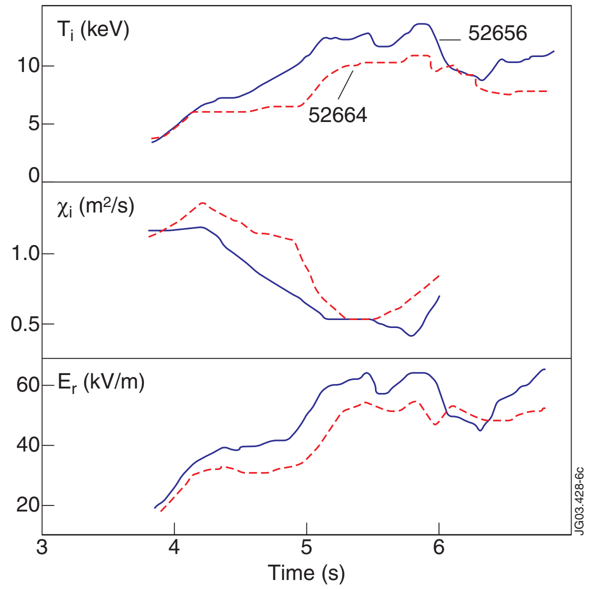


Figure 6: Time evolution of the ion thermal conductivity and the radial electric field at R=3.4m.