A new mechanism for increasing density peaking in tokamaks: Improvement of inward particle pinch with edge ExB shearing

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The peaking of the electron density has significant consequences for tokamak plasmas. Whereas it can be an important source of bootstrap current, which can reduce the necessity of ohmic or external current drive current for achieving steady-state scenarios, it can also enhance the influx of high Z impurities, like tungsten, which can lead to significant core radiation.

Several mechanisms have been put forward for explaining such peaking. On the one hand, the core particle sources, mainly from the Neutral Beam Injection heating, play a significant role in plasmas from JET [1,2], however, such mechanism is unlikely to be relevant in ITER due to the low source contribution from NBI. On the other hand, the plasma collisionality has been identified as a key parameter from the analyses of experimental results, showing a significant increase of density peaking with lower collisionality [3]. Gyrokinetic analyses made mostly with the quasi-linear approach explain such behavior from the change of outward to inward pinch when the turbulence plasma characteristics change from mostly Trapped Electrons Mode (TEM) to Ion Transport Gradient (ITG) mode with decreasing collisionality [4]. This has significant consequences for future plasmas like the ones expected in ITER which will have very low collisionality and hence high density peaking is expected.

In this paper, a new mechanism contributing to the increase of density peaking has been found from extensive non-linear gyrokinetic simulations performed with the GENE [5] code for a JET hybrid discharge. The thermodiffusion part of the particle pinch becomes more inward with increasing ExB shearing and more outward with Parallel Velocity Gradient (PVG) by, otherwise, preserving the ITG nature of these plasmas. Dedicated analyses of the particle flux show that the ExB shearing reverses the higher ky part of the flux while the lower ky remains unchanged. The PVG has the opposite trend showing that the total pinch direction highly depends on the balance of ExB and PVG mechanisms. This effect becomes stronger the closer to the pedestal top leading to a very strong inward pinch in highly rotating plasmas.

Integrated modelling simulations performed with the CRONOS [6] suite of codes and different quasi-linear models for heat and particle transport show that such models are able to partially capture GENE results. Scans performed on the ExB shearing demonstrate that the density peaking significantly increases with edge ExB through a core-edge effect. This effect breaks the paradigm of density peaking mainly stablished by collisionality and have strong implications for ITER extrapolations as the ExB shearing is expected to be low in such device.