Strong safety-factor (q) profile dependence of the linear electromagnetic stabilizing effect and its role in the internal transport barrier formation

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A well-known feature of the internal transport barrier (ITB) is that its formation condition strongly depends on the safety-factor (q) profile. For example, up to now most ITBs (except the hot-ions, super-shot, PEP modes) were obtained only in some specific q-profiles with the reverse or weak-positive shear. The threshold beta for the ITB formation also appears to have a substantial difference, depending on the magnitude of q-min, even with nearly the same magnetic shear (as can be seen from comparison between the optimized-shear [1] and hybrid [2] modes). While numerous theoretical models have been proposed for the ITB trigger mechanism [3], the physics origin of this strong q-profile dependence is still not so clear. Here, as an effort to find a possible model we present a re-assessment of the linear electromagnetic effect on the toroidal ion temperature gradient (ITG) mode, which is widely believed to be the main background turbulence in high temperature core plasmas where the ITB is formed. Noting that the linear electromagnetic stabilization of the toroidal ITG, which arises from the coupling with the shear-Alfven ballooning branch, becomes stronger as plasma beta approaches the ballooning threshold [4], a similar q-profile dependence is first expected between the ITB formation (through the ITG stabilization) and the ballooning threshold. With the well-known ballooning threshold property, which becomes smaller as q increase or magnetic shear (s) decreases through the reduction of the field-line bending force, it is then shown that a strong q-profile dependence can arise in the ITB formation condition. Furthermore, in this case the ITB formation is found to occur through not only the increase of ITG threshold but also the reduction of profile stiffness. With the stabilization of the ITG, the kinetic ballooning mode can be then excited and an estimate is given on its effect in relation to the further development of the ITB. In addition, the effect of trapped elections, which can reduce the electromagnetic stabilization degree, is briefly estimated by using a non-local code in the 1-D ballooning space, which was upgraded from our previous one in Ref. 4 to include trapped electrons.

[1] C. Gormezano *et al.,* 1997 Proc. 16th Int. Conf. on Fusion Energy vol I (Montreal: IAEA) p 487

[2] O. Gruber *et al.,* Phys. Rev. Lett. **83**, 1787 (1999).

[3] for example, see J. Citrin *et al.,* Nucl. Fusion **54**, 023008 (2014).

[4] J.Y. Kim *et al.,* Phys. Fluids **B 5**, 4030 (1993).