Increased Understanding of the Dynamics and Transport in ITB Plasmas from Multi-Machine Comparisons*

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The ITPA (International Tokamak Physics Activity) group on Transport and Internal Transport Barrier (ITB) physics was recently formed to address issues relating to transport in tokamaks with an emphasis on future burning plasma devices. This paper will present details of the results from the group's activities. These activities include: (a) examination and compilation of experimental results on transport from the many machines worldwide to better understand the physics of ITB formation and sustainment; (b) the development of an international database on ITB experimental results to determine the requirements for the formation and sustainment of ITBs (for example, results from the database indicate that the E×B shearing rate, $\omega_{E\times B}$, is comparable to the ITG linear growth rate, γ_L, at the time of ITB formation as shown in Fig. 1); (c) determining and performing comprehensive tests of theory-based models and simulations using the experimental ITB database, which is a critical and necessary step in validating models and providing a predictive capability for future burning plasmas. In particular, specific models will be tested using profiles (before and after ITB formation) from several different machines in the database.

The formation and development of the international ITB database [1] is an important step towards determining and unifying the underlying physics of ITB formation and sustainment from results obtained from many different tokamaks (ASDEX Upgrade, DIII–D, FTU, JET, EFDA-JET, JT-60U, RTP, T10, Tore Supra). The database variables consist of 126 global and local parameters together with 2-D profile data (e.g. $T_i(r)$, $T_e(r)$, $n_e(r)$, v(r), q(r), $P_{abs}(r)$). Presently the emphasis is on the formation conditions for ITBs in the ion and electron channels. Although there is a dependence of the formation of the ion ITB on electron density

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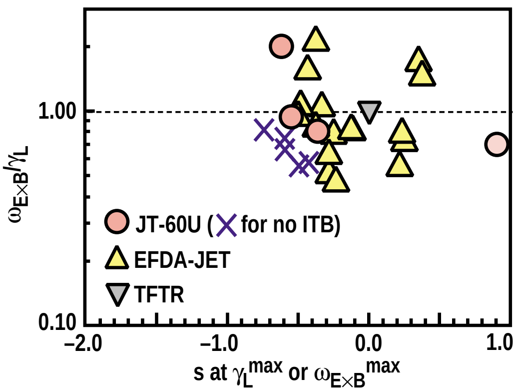

Fig. 1. Influence of the sheared ExB flow on the ITB formation in terms of $\omega_{E\times B}/\gamma_L$, using data from the international ITB database.

and minor radius, the power dependence on toroidal magnetic field, B_T, is very weak [2,3]. Presently, the database contains less data on electron ITBs. For electron ITBs, the power for formation also exhibits a dependence on the minor radius, a, and a lack of dependence on the toroidal field, B_T. However, for similar parameters, the power required to form electron ITBs with predominant electron heating is approximately a factor of 4 lower than for ion ITBs [2]. The large variation in formation conditions for the ITBs observed across many devices indicates that local parameters are important. Consequently, there is increased emphasis on placing more profile data (and more time dependent profile data) into the database. The profile data will aid in resolving the issues of local parameters and will be used to check the validity of scaling relationships determined from 0-D quantities. The profile data will also provide essential data for modeling the barriers and for performing tests of transport models and theories, which will be carried out in collaboration with the ITPA Modeling Group. Results will be presented on modeling of profile data fom DIII–D, JT-60U, TFTR, ASDEX Upgrade and JET, for which profile data presently exists in or is in the process of being added to the database. Particular emphasis will be placed on using various models, such as GLF23, to determine the the key physics of ITB formation for cases of low and high negative central magnetic shear.

This paper will further present the status of research on critical issues in ITB physics including barrier formation and access conditions, particle and impurity transport, fueling, core-edge integration, profile control and stability as well as issues of accessibility in reactor scale devices such as barriers with $T_e=T_i$, barriers with low toroidal rotation and flat density profiles. The critical issues for a reactor or burning plasma can be different than those for present devices and so attention needs to be paid to relevant conditions in future devices. Results will be presented from many devices that provide a clearer understanding of transport and ITB physics in present plasmas and how this understanding can be applied to increase the performance of plasmas in future devices. In particular, there is now greater emphasis on determining impurity transport in ITB plasmas because of the potential for performance degradation due to impurity buildup in the plasma core.

Another objective of the group is to take results obtained on some present devices (such as barriers with $T_e=T_i$ obtained on JT-60U [4] and ASDEX Upgrade [5]) and model and replicate them on other machines to obtain a better understanding of the above issues. A further objective is to understand the variation in barrier formation characteristics from the large variety of approaches pursued in different devices.

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