EX6/D

EIGHTEENTH FUSION ENERGY CONFERENCE

SESSION EX6

Monday, 9 October 2000, at 10:50 a.m.

Chair: M. NAGAMI (Japan)

SESSION EX6: Transport 2 (provided by A. CARDINALI, Italy)

Paper IAEA-CN77/EX6/1 (presented by G.T. Hoang)

DISCUSSION

K. IDA: The contribution of the pressure gradient is different between ion and electron transport barrier. The ion temperature gradient contributes negative E_r and negative E_r shear, while the electron temperature gradient reduces the negative E_r or E_r shear. Do you have any observation of E_r or E_r shear at the electron transport barrier? This issue would be important to study the role of E_r on transport.

G.T. HOANG: In our experiments, we do not have E_r measurements. However, an estimation of E_r, from the pressure profile and the measurement of $V\phi$ in the center (assuming $V_\theta \sim 0$), does not show any significant change in E_r which is still negative.

A.M. DIMITS: I have two comments/questions:
1) In inferring information for χ_e vs electron-temperature gradient from our χ_i vs S q plots, I should caution that because the zonal-flow dynamics are different in the ITG and ETG cases, the χ_e vs S curves may come out different than χ_i vs S curves.
2) It looks as though some of the χ_e vs $\nabla T_e/T_e$ data that you showed might equally well be fit by a linear ($\chi_e \alpha$ ($\nabla T_e/T_e$ - $L^{-1}_{Te\ crit}$). We have seen such a dependence is many of our ITG simulations. Can you comment?

G.T. HOANG: 1) I think that the dependence of χ_e on S is the same for both ion and electron channels. However the shape of the curves χ vs S should be different.
2) You are perfectly right. Above the critical threshold χ_e vs $\nabla T/T$ can be fitted by a linear fit as well as a power fit. For a linear fit one has to know exactly the threshold value, which depends on local plasma parameters.

Paper IAEA-CN77/EX6/2 (presented by E.J. Doyle)

DISCUSSION

F. RYTER: Do you have any indication of a heat pinch in the electron ITB whit ECH?

E.J. DOYLE: No there is no indication of an inward heat pitch in the electron - ITB plasmas. The inward heat pitch with ECH previously reported on DIII-D occurred in very different plasmas: The results presented here are from plasmas with negative central magnetic shear (NCS) and have a transport barrier. The heat pitch results were observed in conventional L-mode positive shear discharges with no ITB.

R.J. TAYLOR: You have demonstrated that the control parameter for ITB's is the externally imposed rotation. How sure are you that the corresponding variation in fluctuations are electrostatic and not electromagnetic?

E.J. DOYLE: This is an important and interesting question which you have asked repeatedly at this conference. I believe, you yourself are in a better position to determine the relative importance of electrostatic and electromagnetic fluctuations that almost anyone else at this meeting. Your machine, the electric Tokamak (ET), has diagnostic access for such a study. As for DIII-D, we have no measurements of the interior magnetic turbulence. However, over many years we have built up a consistent picture of reduced electrostatic turbulence correlating with improved transport and confinement, in general agreement with theoretical modelling.

S.A. SABBAGH: One motivation for larger ITB radius is to create a larger volume of high performance for greater neutron output. For a given input power, how does neutron output in QDB mode compare to other long pulse operating modes of operation in DIII - D?

E.J. DOYLE: This has not yet been studied systematically, however I believe the neutron rate in the QDB regime is the highest yet achieved on DIII - D with distinct ITBs. Record absolute performance on DIII - D was achieved in discharges in which on ITB an edge H-role barrier merged to give reduced transport across the entire plasma radius, with no distinct ITB. In the QDB regime the core and edge transport barriers remain separate and do not merge.

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Paper IAEA-CN77/EX6/3 (presented by G. Bracco)

DISCUSSION

Y. IKEDA: It is commonly observed that the high peaked T_e plasma is without sawteeth activity. In FTU, was the high T_e plasma terminated by an appearance of and/or disappearance of negative shear in the centre?

G. BRACCO: Both cases can be observed in FTU in the current rump-up scenario! When ECRH is applied on monotonic q-profiles, the high T_e phase is terminated by the onset of sawtooth activity; when ECRH is applied on negative shear configuration, the high T_e phase is terminated by DTM reconnection.

T.R. JARBOE: When ECH is added at the magnetic axis, how is χ_e changed by the extra power?

G. BRACCO: In the current ramp-up scenario, the data shown in the presentation indicates that χ_e values in the plasma core lie between 0.2-0.5 m^2/sec for 0.4 and 0.9 MW of ECRH power.

Paper IAEA-CN77/EX6/4 (presented by Y. Sakamoto)

DISCUSSION

G. STAEBLER: One possible interpretation of your elegant experiments is that the parallel velocity shear can destabilize the ITG mode defeating a complete suppression due to ExB shear. This has been predicted theoretically (Waltz et al., Phys. Plasmas 4 (1991) 2482), but has been verified in experiments. Theory predicts this to occur at high $q_{min} >2$ but not for low q_{min}. Have you observed the weakening of the ITB in experiments with $q_{min} <2$?

Y. SAKAMOTO: Our strong reversed magnetic shear plasmas with strong ITB have been performed at $q_{min} >2$, because the plasmas disrupted when the value of q_{min} was reached 2. Thus our ITB control experiments have been demonstrated only in $q_{min} >2$ regime.

P. DIAMOND: Your statement of proportionality of barrier with + $\rho_{\theta i}$ is interesting, have you considered orbit squeezing effects in your analysis?

Y. SAKAMOTO: We have not considered the orbit squeezing effects. It is difficult to estimate accurately the orbit squeezing effects in the ITB layer because E_r sheer in the ITB layer has strong non-uniformity, where its sign is changed. In our future study, the orbit squeezing effects will be estimated by using orbits following Monte Carlo code.

V. PARAIL: You associate the ITB width with a poloidal ion Larmor radius in case of strong barrier. On the other hand, weak ITB is usually wider. Do you associate its width with poloidal ion Larmor radius as well?

Y. SAKAMOTO: The ITB width became narrow with evolution of ITB. The reached value is scaled by ion poloidal gyroradius, where the ITB is fully developed. The difference between weak ITB and strong ITB is mainly the difference of the dominant term of E_r shear, and also magnetic shear. It is a future study whether the width of weak ITB is scaled by ion poloidal gyroradius or not.

D. MOREAU: You can clearly observe two different time scales in the evolution of the temperature and pressure profiles during the control process. So are you sure that it is simply the effect of rotation rather than the interplay between the q-profile and the ExB rotation which determines the recovery phase? Do you think that this control scheme would apply over larger time scales than presently considered?

Y. SAKAMOTO: In the ITB control experiment, the change of q profile was very small in the ITB recovery phase. I think the time scale of ITB recovery is related to the growth of E_r shear, where the positive feedback process was working.

Current profile control is important in larger time scale ITB control, because the current profile is gradually changed from strong reserved magnetic shear to weak magnetic shear due to decreasing the bootstrap current when the ITB is weakened. The ITB control in larger time scale is our future study.

Paper IAEA-CN77/EX6/5 (presented by G.R. McKee)

DISCUSSION

G. BATEMAN: This was a very clean experimental study of ρ^* scaling. It should be noted that there is another dimensionless parameter which varies from present day experiments to reactors. The atomic scale length divided by the size of the machine. Atomic physics controls neutral penetration which affects the density profile. The density profile shape becomes flatter and broader at higher density. Atomic physics also controls boundary conditions for the temperature profiles.

G.R. McKEE: This is an excellent point regarding atomic physics, edge effects, fueling profile, etc. In fact we do observe a slight difference in the edge density profile in the high and low-ρ^* plasmas, i.e. a slight mismatch in L_{ne} as a result reduced penetration of neutrals in the low-ρ^*, higher density discharge. GLF23 modelling indicated that this mismatch made very little difference in the diffusivity scaling for these discharges (in contrast to the Kinsey, Bateman results with multi-mode (PoP - 1996) analysis for other discharges). There are in fact significant differences in the edge ($\rho \approx 0.96$) turbulence characteristics in these ρ^* discharges, with a second "electron mode" appearing in the high - ρ^* plasma. Likewise, for this point at $\rho \approx 0.96$, the correlation length falls below the ρ_i. scaling, leading to a "Bohm-like" scaling at the edge. Your point on the importance of edge turbulence and the edge transport, pedestal characteristics is well taken, and we do intend to investigate this in more detail. Thank you for your comments.

K, HALLATSCHEK: Can you measure fluctuating zonal flows, and how would D3D$_S$ rotation diagnostics to zonal flow oscillations, such as Geo acoustic modes, at about 10 KHZ?

G.R. McKEE: We are presently investigating the feasibility of measuring velocity (poloidal) fluctuations with the beam emission spectroscopy system. A zonal flow is a uniform electrostatic potential oscillation on a flux surface (m=n=0) and so by measuring the connecting density fluctuations, we may be able to measure $V_\theta = E_r x B/B^2$ and thereby work back to a potential fluctuation. We have evidence that this may work up to 50-100 kHz and so would make zonal flow measurements accessible under the proper plasma conditions. Thank you for your questions.

R. GOLDSTON: It is encouraging that you find absolute correlation times and lengths consistent with simulations. However, these are very challenging measurements, and when you combine correlation times and lengths to get a simple diffusivity, it seems that the value and uncertainity of the scaling is not unambiguosly gyro-Bohm.

G.R. McKEE: This is an excellent point, and it is in fact the magnitude that gives greater confidence in the gyro-Bohm like nature. This is observed in the scaling ($D_{yT}/D_{\perp T}$) case, but does allow for a comparison of power balance simulation (GLF23) and turbulence measurements. Part of the problem lies in only being able to scale ρ^* by 1.6 V due to technical aspects. A larger scan in ρ^*

might lead to a more definitive result. Gyro-Bohm or Bohm differ by ~ 50%, so error bars do make the distinction difficult. Thank you.

P. DIAMOND: It's no surprise that correlation length scales with ρi - Crowley and Mazzucato showed this 20 years ago. It would be interesting to compare both the scaling and magnitude of predicted correlation lengths with the data. This might give a clue as to the need to appeal to streamers, avalanches, etc., as gyro-Bohm breaking mechanism. Have you made such a comparison?

G.R. McKEE: Thank you for bringing the Crowley/Mazzucato results to my attention. I will examine these results, but doubt if those experiments were well-matched "non dimensional" (only in ρ*) discharges, and recall that my conclusions are based on Ò/n, radial correlation length, and decorrelation times, not just radial correlation length. I am working with Rick Sydora and his global, non linear gyro-Kinetic particle code to model these precise discharges, and do thereby plan to directly compare fluctuation characteristics and those predicted by that code with our measurements. Results are not yet ready for presentation. We will consider avalanche/streamer phenomena.

Paper IAEA-CN77/EX6/6 (presented by A. Fujisawa)

DISCUSSION

H. MAASSBERG: At the W7-RS stellarator, quite identical features are experimentally observed. But the interpretation is completely different. The highly localized ECRH leads to suprathermal tails in the electron distribution at low and (in the CHS experiments) extremely low densities. The resulting "convective" fluxes by ripple trapped electrons drive the transition you reported. Consequently, this feature has nothing to do with the ITBs discussed for tokamaks.

A. FUJISAWA: Firstly, we don't deny that high energy electrons should contribute to E_r-formation, the electron current should make the absolute value of E_r higher than that predicted by the neo-classical theory. Secondly, we have observed E_r-shear formation in "the connection layer", where the electron and ion root E_r converges. There, significant E_r-shear is formed and fluctuation reduction is observed. We would like to emphasize that these are the experimental results. The observation contributes to understanding the present E_r-shear paradigm, that is mainly discusses in tokamaks.

P. DIAMOND: Your results are very interesting! What sets the width of the barrier (ITB) in the done regime?

A. FUJISAWA: In order to answer the question, experimentally, we have to perform other experiments to investigate the width dependence on plasma parameters, including magnetic geometrical factor. In the present status, we don't have sufficient data. That is an important future work related to the formation mechanism of transport barriers.

C. HIDALGO: What is the role of ECR heating power in the bifurcation properties of radial electric fields?

A. FUJISAWA: Firstly, an increase in ECR heating power makes realization probabilities of done and bell patterns higher with a fixed density. Second, pulsation behaviour becomes to be more frequently observed as the heating power increases, with a fixed density. The threshold power for pulsation is considered to increase with density.

Paper IAEA-CN77/EX6/7 (presented by H. Yamada)

DISCUSSION

M. MURAKAMI: Bootstrap current is expected to vary with in-out shift. How well does theory predict the variation? What is the magnitude of the current and effect on the currentless operation?

H. YAMADA: The usual pulse length is not sufficient for a precise quantitative argument since the L/R time is several seconds. Certainly it is worth looking into that direction. Observed toroidal currents are a couple of 10's kA in this study and they affect the rotational transport by only a few %. We have not observed a clear effect of currents on confinement to date.

J.H. HARRIS: Can any of the apparent improvement in confinement of the shifted-in configurations be explored by better heat deposition from NBI?

H. YAMADA: The alignment of NBI is optimized for the standard configuration. Therefore the standard configuration has centrally peaked deposition profile, and flattening or broadening of deposition is expected in the inward-shifted configuration. The effect of heat deposition is the opposite direction to what we claim in this study.